David A. Christian
Senior Vice President
Nuclear Operations and Chief Nuclear Officer

Dominion Nuclear North Anna, LLC
5000 Dominion Boulevard, Glen Allen, VA 23060



September 25, 2003

10 CFR Part 52, Subpart A

James E. Dyer, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Serial No. 03-457
NRC Project No. 719
ESP/JDH

Dear Mr. Dyer:

NORTH ANNA EARLY SITE PERMIT APPLICATION

Pursuant to Part 52, Subpart A of Title 10 of the Code of Federal Regulations, Dominion Nuclear North Anna, LLC ("Dominion") applies to the U.S. Nuclear Regulatory Commission (NRC) for an Early Site Permit (ESP) for a location in central Virginia identified as the North Anna ESP site. The location is described and characterized in the enclosed application. Dominion requests that the NRC issue an ESP with a duration of twenty years.

Pursuant to 10 CFR 52.15(b), 50.30(a)(6), and 50.4(b)(3), Dominion hereby submits this application for acceptance review and determination of sufficiency for docketing.

The North Anna ESP application is submitted in the form of a CD-ROM, consistent with NRC Regulatory Issues Summary 2001-05, *Guidance on Submitting Documents to the NRC by Electronic Information Exchange or on CD-ROM*. The enclosed CD-ROM contains the North Anna ESP application organized as follows:

- **Transmittal Letter.** This transmittal letter replicated on the CD-ROM.

- **Part 1—Administrative Information**. This part contains general corporate information about Dominion and an overview of the application format and content.

- **Part 2—Site Safety Analysis Report**. This part contains information about site safety, emergency preparedness, and quality assurance. The site safety analysis information includes a description of the site and proposed facilities, an assessment of the site features affecting the facility design, and the meteorological, hydrologic, geologic, and seismic characteristics of the ESP site.

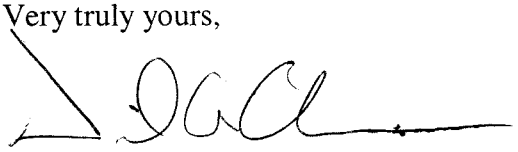
- **Part 3—Environmental Report**. This part contains information about site environmental issues sufficient to support a NRC evaluation culminating in the issuance of an Environmental Impact Statement.

- **Part 4—Programs and Plans**. This part contains information about site redress.

Service upon the applicants of comments, hearing requests, intervention petitions or other pleadings related to this application should be made to counsel for Dominion as follows: Lillian M. Cuoco, Senior Counsel, Dominion Resources Services, Inc., Rope Ferry Road, Waterford, CT 06385 (phone: 860-444-5316; e-mail: lillian_cuoco@dom.com; fax: 860-444-4278) and David R. Lewis at Shaw Pittman, 300 N. Street, N.W., Washington D.C. 20037 (phone: 202-663-8474; e-mail: david.lewis@shawpittman.com; fax: 202-663-8007).

Any written correspondence to Dominion regarding this application should be sent to me at the address shown above. If any additional information concerning this application is needed, please contact Mr. Joseph D. Hegner (phone: 804-273-2770 or e-mail: joseph_hegner@dom.com).

Very truly yours,



David A. Christian

Enclosures: 1. Affirmation Statement
2. CD-ROM containing North Anna ESP Application

C w/encls: Mr. L. Reyes, NRC Region II Administrator
Mr. M. Morgan, NRC North Anna Senior Resident Inspector
Mr. M. Scott, NRC North Anna ESP Project Manager
Dr. R. Simard, Nuclear Energy Institute
Ms. M. Parkhurst, Battelle, DOE

I, David A. Christian, being duly sworn according to law, state that I am Senior Vice President-Nuclear Operations and Chief Nuclear Officer of Dominion Nuclear North Anna, LLC, that I am authorized to sign and file this application on behalf of Dominion Nuclear North Anna, LLC, and that the application is true and correct to the best of my knowledge, information and belief.

Dominion Nuclear North Anna, LLC

David A. Christian
Senior Vice President-Nuclear Operations and
Chief Nuclear Officer

STATE OF Virginia

COUNTY OF Henrico

Subscribed and sworn to before me, a Notary Public, in and for the County and State above named, this 18th day of September, 2003.

Maggie McClure

My commission expires 3-31-04

Eugene S. Grecheck
Vice President-Nuclear Support Services

Dominion Nuclear North Anna, LLC
5000 Dominion Boulevard, Glen Allen, VA 23060

Dominion

October 2, 2003

10 CFR Part 52, Subpart A

James E. Dyer, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Serial No. 03-457A
NRC Project No. 719
ESP/JDH

Dear Mr. Dyer:

NORTH ANNA EARLY SITE PERMIT APPLICATION—REVISION 1

On September 25, 2003, Dominion Nuclear North Anna, LLC (Dominion) submitted its North Anna Early Site Permit application, Revision 0, to the NRC pursuant to 10 CFR 52, Subpart A. As a result of subsequent discussions between M. L. Scott, North Anna ESP Project Manager, and J. D. Hegner of my staff, it was determined that unnecessary detail had been included in Revision 0 of the application. That information has since been removed and Revision 1 of the North Anna Early Site Permit application in CD-ROM format is enclosed. A set of affected pages is also enclosed for convenience.

If you have any questions or require additional information, please contact Mr. Hegner at 804-273-2770 or joseph_hegner@dom.com.

Very truly yours,

Eugene S. Grecheck

Enclosures: 1. Affirmation Statement
2. CD-ROM containing North Anna ESP Application, Revision 1
3. Revision 1 Affected Pages

C w/encls 1&2: Mr. L. Reyes, NRC Region II Administrator
Mr. M. Morgan, NRC North Anna Senior Resident Inspector
Mr. M. Scott, NRC North Anna ESP Project Manager
Dr. R. Simard, Nuclear Energy Institute
Ms. M. Parkhurst, Battelle, DOE

Serial No. 03-0457A
Enclosure 1

I, Eugene S. Grecheck, being duly sworn according to law, state that I am Vice President-Nuclear Support Services of Dominion Nuclear North Anna, LLC, that I am authorized to sign and file this document on behalf of Dominion Nuclear North Anna, LLC, and that the information is true and correct to the best of my knowledge, information and belief.

Dominion Nuclear North Anna, LLC

Eugene S. Grecheck
Vice President – Nuclear Support Services

STATE OF Virginia

COUNTY OF Henrico

Subscribed and sworn to before me, a Notary Public, in and for the County and State above named, this 2nd day of October, 2003.

Maggie McClure

My commission expires 3-31-04

Dominion Nuclear North Anna, LLC
5000 Dominion Boulevard, Glen Allen, VA 23060

Dominion®

July 15, 2004

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 04-434
ESP/JDH
Docket No. 52-008

DOMINION NUCLEAR NORTH ANNA, LLC
NORTH ANNA EARLY SITE PERMIT APPLICATION
REVISION 2

Enclosed is Revision 2 to the North Anna Early Site Permit application. The application consists of four parts: Part 1, Administrative Information, Part 2, Site Safety Analysis Report, Part 3, Environmental Report, and Part 4, Programs and Plans. Revision 2 primarily updates the Environmental Report to support the NRC staff's ongoing environmental review and planned issuance of a draft environmental impact statement. Revision 2 incorporates Dominion's responses to NRC requests for additional environmental information, Dominion's letter to the NRC responding to Virginia Department of Environmental Quality comments, and other information discussed with the NRC.

Certain information in the North Anna ESP application is common to both the Environmental Report and the Site Safety Analysis Report. Because only information in the Environmental Report is being changed by Revision 2, the corresponding common information in the Site Safety Analysis Report will require separate revision. That revision will occur in the next update, Revision 3, of the ESP application. Revision 3 is intended to be a comprehensive update.

A summary of the changes is provided in Enclosure 1. A CD containing Revision 2 of the ESP application is provided in Enclosure 2.

If you have any questions or require additional information, please contact us.

Very truly yours,

Eugene S. Grecheck
Vice President-Nuclear Support Services

Enclosures: 1. Description of Changes in Revision 2.
2. One CD-ROM labeled "North Anna Early Site Permit Application, Docket No. 52-008, September 2003; Revision 2, July 2004, NRC ADAMS Edition," containing the following 9 files:

001 North Anna ESP Application R2 (1 of 9).pdf; 2,989 KB; publicly available
002 North Anna ESP Application R2 (2 of 9).pdf;19,202,736 bytes, publicly available
003 North Anna ESP Application R2 (3 of 9).pdf; 49,572,480 bytes, publicly available
004 North Anna ESP Application R2 (4 of 9).pdf; 40,897,951 bytes, publicly available
005 North Anna ESP Application R2 (5 of 9.pdf; 37,328,818 bytes, publicly available
006 North Anna ESP Application R2 (6 of 9).pdf; 26,629,982 bytes, publicly available
007 North Anna ESP Application R2 (7 of 9).pdf; 1,153,004 bytes, publicly available
008 North Anna ESP Application R2 (8 of 9).pdf; 44,908,018 bytes, publicly available
009 North Anna ESP Application R2 (9 of 9).pdf; 24,746,868 bytes, publicly available

Commitments made in this letter: None.

cc: U.S. Nuclear Regulatory Commission, Region II
Sam Nunn Atlanta Federal Center
61 Forsyth Street, SW
Suite 23T85
Atlanta, Georgia 30303

Mr. Andy Kugler
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Mr. Michael Scott
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Mr. M. T. Widmann
NRC Senior Resident Inspector
North Anna Power Station

Ms. Ellie L. Irons, Program Manager
Office of Environmental Impact Review
Virginia Department of Environmental Quality

Mr. Adrian Heymer
Nuclear Energy Institute
1776 I Street, N.W.
Washington, D.C. 20013

COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President, Nuclear Support Services, of Dominion Nuclear North Anna, LLC. He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of Dominion Nuclear North Anna, LLC, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 15th day of July, 2004.

My Commission expires: 3/31/08

Maggie McClure
Notary Public

(SEAL)

Enclosure 1

Description of Changes in Revision 2
North Anna Early Site Permit Application

North Anna Early Site Permit Application Description of Changes in Revision 2	
Affected Section, Table, or Figure	Reason for Change
Acronyms/Abbreviations/Initialisms	
▪ New entries	Added new entries for changes made in Revision 2
Part 1, Administrative Information	
▪ Section 1.2.2.5	Added section describing notation of changes.
Part 3, Environmental Report (ER) Chapter 1	
▪ Section 1.1.4	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
Part 3, ER Chapter 2	
▪ Sections 2.3.1.1, 2.3.3.1	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
▪ Sections 2.5.1.2, 2.5.1.3.1 ▪ Tables 2.5-5, 2.5-8, 2.5-10, 2.5-13, 2.5-15, 2.5-16 ▪ Figures 2.5-3, 2.5-4, 2.5-5, 2.5-6, 2.5-7, 2.5-9, 2.5-10, 2.5-11, 2.5-12	Corrected and updated population figures. Reference May 13, 2004 telecon advising NRC of population figure errors and of intent to correct with next revision.
▪ Section 2.7.5.2 ▪ Tables 2.7-9, 2.7-10, 2.7-11, 2.7-12	Response to RAI 2.3.4-1; Reference Dominion's 7/12/04 Letter to NRC, Serial No. 04-170A.
Part 3, ER Chapter 3	
▪ Sections 3.1.2.2, 3.1.5	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
▪ Table 3.1-1, Section 9.1	Response to RAI E3.1-1; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Sections 3.2.3, 3.3, 3.3.1 ▪ Table 3.3-2 ▪ Figure 3.3-2 ▪ Sections 3.4.1.1, 3.4.1.3.1, 3.4.1.3.3, 3.4.1.3.4, 3.4.2.1, 3.4.2.2, 3.4.2.3 ▪ Figures 3.4-3, 3.4-4	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
▪ Section 3.8.2.3	Response to Follow-up Environmental RAI

North Anna Early Site Permit Application Description of Changes in Revision 2	
Affected Section, Table, or Figure	Reason for Change
	2 and revised response to RAI E3.8-7; Reference Dominion's 7/12/04 Letter to NRC, Serial No. 04-170A.
▪ Section 3.8.2.5 ▪ Table 3.8-2	Response to Follow-up Environmental RAI 2; Reference Dominion's 7/12/04 Letter to NRC, Serial No. 04-170A.
Part 3, ER Chapter 4	
▪ Section 4.2.1.1	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
▪ Section 4.2.3 ▪ Section 4.2 References	Response to RAI E4.2.2-2; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Section 4.3.2	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
▪ Section 4.5.3.1	Response to RAI E4.5-4; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Section 4.5.3.2	Response to RAI E4.5-7; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Section 4.5.4.1	Response to RAI E4.5-4; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Section 4.5.4.2	Response to RAI E4.5-7; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Section 4.5.4.4	Response to RAI E4.5-4; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Table 4.5-1	Response to RAI E4.5-3; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Tables 4.5-2, 4.5-3, 4.5-4	Response to RAI E4.5-4; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Table 4.5-5	Response to RAI E4.5-7; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.

North Anna Early Site Permit Application Description of Changes in Revision 2	
Affected Section, Table, or Figure	Reason for Change
Part 3, ER Chapter 5	
▪ Sections 5.1.1, 5.1.1.2, 5.2.1, 5.2.1.1, 5.2.1.2, 5.2.1.3, 5.2.1.4 ▪ Table 5.2-1 ▪ Sections 5.2.1.5, 5.2.2, 5.2.2.1.2, 5.2.2.1.3	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
▪ Section 5.2.2.2	Response to VDEQ Comment AA1; Reference Dominion's 6/28/04 Letter to NRC, Serial No. 04-364.
▪ Sections 5.2.2.3, 5.2.2.4	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
▪ Section 5.2 References ▪ Tables 5.2-5, 5.2-6, 5.2-7, and 5.2-8	Response to VDEQ Comment AA1; Reference Dominion's 6/28/04 Letter to NRC, Serial No. 04-364.
▪ Sections 5.3, 5.3.1, 5.3.1.1, 5.3.1.1.2, 5.3.1.2.1.b ▪ Table 5.3-4 (Deleted) ▪ Sections 5.3.1.2.2, 5.3.1.2.3.a, 5.3.1.2.3.b ▪ Table 5.3-8 (Deleted) ▪ Sections 5.3.1.2.4, 5.3.2.1, 5.3.2.1.2, 5.3.2.1.3, 5.3.2.2.3, 5.3.3, 5.3.3.1, 5.3.3.2, 5.3.3.2.1, 5.3.3.2.2, 5.3.3.2.3, 5.3.3.2.4, 5.3.4, 5.3.4.1, ▪ Section 5.3 References ▪ Tables 5.3-14, 5.3-15, 5.3-16 ▪ Figure 5.3-4	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
▪ Section 5.4.2	Response to RAI E5.4.2-1; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Section 5.4.4.2	Response to RAI E5.4.4-1; Reference Dominion's 5/17/04 Letter to NRC, Serial No. 04-170.
▪ Section 5.4 References ▪ Table 5.4-12	Response to Follow-up Environmental RAI 6; Reference Dominion's 7/12/04 Letter to NRC, Serial No. 04-170A.
▪ Section 5.5.13, 5.8.1.2, 5.8.1.3, 5.8.1.4, 5.8.1.5, 5.8.1.6, 5.8.2.3	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
▪ Table 5.10-1	Change in Unit 4 cooling approach from wet towers to dry towers; Reference

North Anna Early Site Permit Application Description of Changes in Revision 2	
Affected Section, Table, or Figure	Reason for Change
	Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
Part 3, ER Chapter 7	
▪ Section 7.1.4 ▪ Tables 7.1-1, 7.1-2, 7.1-4, 7.1-6, 7.1-8, 7.1-10, 7.1-11, 7.1-13, 7.1-15, 7.1-17, 7.1-19, 7.1-20, 7.1-22, 7.1-24, 7.1-26, 7.1-28	Response to RAI E7.1-1; Reference Dominion's 7/12/04 Letter to NRC, Serial No. 04-170A.
▪ Section 7.2.2.1	Response to RAI E7.2-1; Reference Dominion's 7/12/04 Letter to NRC, Serial No. 04-170A.
Part 3, ER Chapter 9	
▪ Section 9.1	Added description of "No-Action Alternative" in response to June 21-22, 2004 ASLB pre-hearing conference.
▪ Sections 9.4.1, 9.4.1.1, 9.4.1.1.1, 9.4.1.1.2, 9.4.1.2, 9.4.1.2.1, 9.4.1.2.2, 9.4.2, 9.4.2.1, 9.4.2.3, 9.4.2.4, 9.4.2.5 ▪ Section 9.4 References ▪ Tables 9.4-1, 9.4-2, 9.4-3, 9.4-4, 9.4-5, 9.4-6	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.
Part 3, ER Chapter 10	
▪ Section 10.1.3 ▪ Table 10.1-2 ▪ Sections 10.2.1.2, 10.2.1.6, 10.3.2	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194.

Dominion Nuclear North Anna, LLC
5000 Dominion Boulevard, Glen Allen, VA 23060

Dominion®

September 7, 2004

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 04-537
ESP/JDH
Docket No. 52-008

DOMINION NUCLEAR NORTH ANNA, LLC
NORTH ANNA EARLY SITE PERMIT APPLICATION
REVISION 3

Enclosed is Revision 3 to the North Anna Early Site Permit (ESP) application. Revision 3 updates the application to incorporate Dominion's responses to NRC's requests for additional information and other information discussed with the NRC staff.

Note that Revision 2, submitted July 15, 2004 (Serial No. 04-434) only updated information in the Environmental Report. Revision 3 updates the corresponding common information in the Site Safety Analysis Report.

A summary of the Revision 3 changes is provided in Enclosure 1. A CD containing the North Anna ESP application, Revision 3, is provided in Enclosure 2.

If you have any questions or require additional information, please contact Mr. Joseph D. Hegner at 804-273-2770.

Very truly yours,



Eugene S. Grecheck
Vice President-Nuclear Support Services

Enclosures:

1. Description of Changes in Revision 3.

2. One CD-ROM labeled "North Anna Early Site Permit Application, Docket No. 52-008, September 2003; Revision 3, September 2004, NRC ADAMS Edition," containing the following files:

001 North Anna ESP Application R3 (1 of 9).pdf; 2,989 KB; publicly available
002 North Anna ESP Application R3 (2 of 9).pdf;19,202,736 bytes, publicly available
003 North Anna ESP Application R3 (3 of 9).pdf; 49,572,480 bytes, publicly available
004 North Anna ESP Application R3 (4 of 9).pdf; 40,897,951 bytes, publicly available
005 North Anna ESP Application R3 (5 of 9.pdf; 37,328,818 bytes, publicly available
006 North Anna ESP Application R3 (6 of 9).pdf; 26,629,982 bytes, publicly available
007 North Anna ESP Application R3 (7 of 9).pdf; 1,153,004 bytes, publicly available
008 North Anna ESP Application R3 (8 of 9).pdf; 44,908,018 bytes, publicly available
009 North Anna ESP Application R3 (9 of 9).pdf; 24,746,868 bytes, publicly available

Commitments made in this letter: None

cc: U.S. Nuclear Regulatory Commission, Region II
Sam Nunn Atlanta Federal Center
61 Forsyth Street, SW
Suite 23T85
Atlanta, Georgia 30303

Administrative Judge
Alex S. Karlin, Chair
Atomic Safety and Licensing Board
Mail Stop T-3 F23
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Administrative Judge
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Administrative Judge
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Mr. Michael Scott
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Mr. M. T. Widmann
NRC Senior Resident Inspector
North Anna Power Station

Ms. Ellie L. Irons, Program Manager
Office of Environmental Impact Review
Virginia Department of Environmental Quality
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Richmond, Virginia 23240

Mr. Adrian Heymer
Nuclear Energy Institute
1776 I Street, N.W.
Suite 400
Washington, D.C. 20006-3708

COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President-Nuclear Support Services, of Dominion Nuclear North Anna, LLC. He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of Dominion Nuclear North Anna, LLC, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 7TH day of September, 2004.

My Commission expires: May 31, 2006

Vicki L. Hull
Notary Public

(SEAL)

Enclosure 1

Description of Changes in Revision 3
North Anna Early Site Permit Application

North Anna Early Site Permit Application Description of Changes in Revision 3	
Affected Section, Table, or Figure	**Reason for Change**
Acronyms/Abbreviations/Initialisms	
▪ New entries	Added new entries for changes made in Revision 3.
Part 2 Chapter 1	
▪ Table 1.3-1	Response to RAI E3.1-1; Reference Dominion's 5/17/04 Letter, Serial No. 04-170.
▪ Table 1.3-1	Response to RAI 1.3-2; Reference Dominion's 8/10/04 Letter, Serial No. 04-348.
▪ Section 1.8	Response to RAI 1.8-1; Reference Dominion's 8/20/04 Letter, Serial No. 04-354.
▪ Sections 1.8.1, 1.8.2, 1.8.3	Response to RAI 2.3.5-2; Reference Dominion's 8/20/04 Letter, Serial No. 04-354.
▪ Section 1.8.2	Response to RAI 2.5.2-9 and July 9, 2004 RAI; Reference Dominion's 8/19/04 Letter, Serial No. 04-438.
▪ Section 1.9 (new) ▪ Section 1.9 References ▪ Tables 1.3-1, 1.9-1(new)	Response to RAI 1.3-1; Reference Dominion's 8/19/04 Letter, Serial No. 04-318A.
Part 2 Chapter 2	
▪ Sections 2.1.3.1, 2.1.3.2, 2.1.3.3.1, 2.1.3.3.2, 2.1.3.4, 2.1.3.5, 2.1.3.6 ▪ Section 2.1 References ▪ Figures 2.1-4, 2.1-5, 2.1-6, 2.1-7, 2.1-8, 2.1-8A (new), 2.1-10, 2.1-11, 2.1-12, 2.1-13, 2.1-13A (new), 2.1-14	Response to RAI 2.1.3-1; Reference Dominion's 8/10/04 Letter, Serial No. 04-348.
▪ Section 2.1 References	Response to RAI 1.8-1; Reference Dominion's 8/20/04 Letter, Serial No. 04-354.
▪ Section 2.2.3.1.2	Response to RAI 2.2.2-3; Reference Dominion's 8/2/04 Letter, Serial No. 04-318.
▪ Sections 2.3.1.1, 2.3.1.2, 2.3.1.3.1, 2.3.1.3.2, 2.3.1.3.3, 2.3.1.3.4, 2.3.1.3.5, 2.3.1.3.6, 2.3.1.3.8, 2.3.2.1, 2.3.2.2.1, 2.3.2.3, 2.3.2.4, 2.3.2.5 ▪ Section 2.3 References ▪ Tables 2.3-1, 2.3-2, 2.3-4, 2.3-5, 2.3-6, 2.3-7, 2.3-18 (new) ▪ Figure 2.3-24	Response to RAIs 2.3.1-1 (revised), 2.3.1-2, 2.3.1-3, 2.3.1-4, 2.3.1-5, 2.3.1-6, 2.3.2-1, 2.3.2-2; Reference Dominion's 8/2/04 Letter, Serial No. 04-318.
▪ Section 2.3.4.2 ▪ Tables 2.3-3, 2.3-13, 2.3-14	Response to RAI 2.3.4-1; Reference Dominion's 7/12/04 Letter, Serial No. 04-170A.

North Anna Early Site Permit Application Description of Changes in Revision 3	
Affected Section, Table, or Figure	**Reason for Change**
▪ Section 2.3 References	Response to RAI 1.8-1; Reference Dominion's 8/20/04 Letter, Serial No. 04-354.
▪ Section 2.4.1.1 ▪ Sections 2.4.7.2, 2.4.7.4 ▪ Section 2.4.8 ▪ Sections 2.4.11.3, 2.4.11.4 ▪ Table 2.4-6	Change in Unit 4 cooling approach from wet towers to dry towers; Reference Dominion's 3/31/04 Letter to NRC, Serial No. 04-194. Response to RAIs 2.4.1-2, 2.4.1-4; Reference Dominion's 8/2/04 Letter, Serial No. 04-318.
▪ Section 2.4.7.6	Response to RAI 2.4.7-5; Reference Dominion's 8/2/04 Letter, Serial No. 04-318.
▪ Section 2.4.9	Response to RAI 2.4.9-1; Reference Dominion's 8/2/04 Letter, Serial No. 04-318.
▪ Sections 2.4.12.1.2, 2.4.12.3, 2.4.12.4 ▪ Table 2.4-15 ▪ Figure 2.4-15	Response to RAI 2.4.12-1; Reference Dominion's 8/2/04 Letter, Serial No. 04-318.
▪ Section 2.4.12.2 ▪ Section 2.4 References ▪ Table 2.4-19	Follow-up response to RAI 17.1-1; Reference Dominion's 8/20/04 Letter, Serial No. 04-354.
▪ Section 2.5.1.1.4, 2.5.2.2.8	Response to RAI 2.5.1-1; Reference Dominion's 7/8/04 Letter, Serial No. 04-270.
▪ Section 2.5.1.1.4	Response to RAI 2.5.1-2; Reference Dominion's 7/8/04 Letter, Serial No. 04-270.
▪ Section 2.5.1.1.4	Response to RAI 2.5.1-3; Reference Dominion's 7/8/04 Letter, Serial No. 04-270.
▪ Section 2.5.1.1.4	Response to RAI 2.5.1-4; Reference Dominion's 7/8/04 Letter, Serial No. 04-270.
▪ Section 2.5.1.2.6	Response to RAI 2.5.4-7; Reference Dominion's 8/5/04 Letter, Serial No. 04-347.
▪ Section 2.5.2.6.2 ▪ Section 2.5 References	Response to RAI 2.5.2-4; Reference Dominion's 7/8/04 Letter, Serial No. 04-270.
▪ Sections 2.5.2, 2.5.2.6.5, 2.5.2.6.6, 2.5.2.6.7, 2.5.2.6.8, 2.5.2.6.9, 2.5.2.6.10, 2.5.2.7 ▪ Section 2.5 References ▪ Tables 2.5-24, 25, 26, 27, 28 ▪ Figures 2.5-44A, 44B, 46, 48, 49, 50, 51, 52, 53, 54A, 54B, 54C, 55	Response to RAI 2.5.2-9 and July 9, 2004 RAI; Reference Dominion's 8/19/04 Letter, Serial No. 04-438.
▪ Sections 2.5.4.7.3, 2.5.4.7.4 ▪ Table 2.5-46	Response to RAI 2.5.4-9; Reference Dominion's 8/19/04 Letter, Serial No. 04-347A.
▪ Sections 2.5.4.8, 2.5.4.8.2, 2.5.4.8.4, 2.5.4.8.5	Response to RAI 2.5.4-10; Reference Dominion's 8/19/04 Letter, Serial No. 04-347A.
▪ Sections 2.5.5.1.2, 2.5.5.2.3, 2.5.5.5, 2.5.5.6	Response to RAI 2.5.5-1; Reference Dominion's 8/19/04 Letter, Serial No. 04-347A.

North Anna Early Site Permit Application Description of Changes in Revision 3	
Affected Section, Table, or Figure	**Reason for Change**
▪ Tables 2.5-20, 2.5-23	Correction of controlling earthquake calculation; Reference Dominion's 8/19/04 Letter, Serial No. 04-347A.
▪ Table 2.5-45	Response to RAI 2.5.4-5; Reference Dominion's 8/5/04 Letter, Serial No. 04-347.
▪ Table 2.5-47	Response to RAI 2.5.4-11; Reference Dominion's 8/5/04 Letter, Serial No. 04-347.
Part 2 Chapter 15	
▪ Section 15.2 ▪ Section 15.4 ▪ Tables 15.4-1, 15.4-3, 15.4-5, 15.4-7, 15.4-9, 15.4-10, 15.4-12, 15.4-14, 15.4-16, 15.4-18, 15.4-19, 15.4-21, 15.4-23, 15.4-25, 15.4-27	Response to RAIs 15.4-2, 15.4-3, 15.4-5, 15.4-6; Reference Dominion's 8/10/04 Letter, Serial No. 04-348.
▪ Section 15.2 References	Response to RAI 1.8-1; Reference Dominion's 8/20/04 Letter, Serial No. 04-354.
▪ Section 15.3 References	Response to RAI 1.8-1; Reference Dominion's 8/20/04 Letter, Serial No. 04-354.
Part 3 Chapter 2	
▪ Section 2.3.2.2.1 ▪ Table 2.3-11 ▪ Section 2.3 References	Follow-up response to RAI 17.1-1; Reference Dominion's 8/20/04 Letter, Serial No. 04-354.
▪ Section 2.5.1, 2.5.1.1, 2.5.1.2, 2.5.1.3.1, 2.5.1.3.2, 2.5.1.5 ▪ Section 2.5 References ▪ Table 2.5-12 ▪ Table 2.5-15 ▪ Figures 2.5-7A (new), 2.5.12A (new) ▪ Figure 2.5-10 ▪ Figure 2.5-13	Response to RAI 2.1.3-1; Reference Dominion's 8/10/04 Letter, Serial No. 04-348.
▪ Section 2.5.2	Response to RAI 1.3-1; Reference Dominion's 8/19/04 Letter, Serial No. 04-318A.
▪ Sections 2.7.1, 2.7.1.1, 2.7.1.2, 2.7.1.3, 2.7.1.4, 2.7.1.5, 2.7.2.1, 2.7.3.1, 2.7.3.2, 2.7.3.3, 2.7.3.4, 2.7.4, 2.7.4.1.1, 2.7.4.1.2, 2.7.4.1.3, 2.7.4.1.4, 2.7.4.1.5, 2.7.4.1.7 ▪ Section 2.7 References ▪ Tables 2.7-1, 2.7-2, 2.7-3 ▪ Figure 2.7-2	Response to RAIs 2.3.1-1 (revised), 2.3.1-2, 2.3.1-3, 2.3.1-4, 2.3.1-5, 2.3.1-6, 2.3.2-1, 2.3.2-2; Reference Dominion's 8/2/04 Letter, Serial No. 04-318.

North Anna Early Site Permit Application Description of Changes in Revision 3	
Affected Section, Table, or Figure	**Reason for Change**
Part 3 Chapter 3	
▪ Section 3.1.6 (new) ▪ Section 3.1 References ▪ Tables 3.1-1, 3.1-9 (new)	Response to RAI 1.3-1; Reference Dominion's 8/19/04 Letter, Serial No. 04-318A.
▪ Sections 3.2.1, 3.8.1, 3.8.2.2	Response to RAI 1.3-1; Reference Dominion's 8/19/04 Letter, Serial No. 04-318A.
▪ Table 3.1-1	Response to RAI 1.3-2; Reference Dominion's 8/10/04 Letter, Serial No. 04-348.
Part 3 Chapter 5	
▪ Sections 5.4.3, 5.8.2.1.2	Response to RAI 1.3-1; Reference Dominion's 8/19/04 Letter, Serial No. 04-318A.
Part 3 Chapter 6	
▪ Section 6.4.1	Response to RAIs 2.3.1-1 (revised), 2.3.1-2, 2.3.1-3, 2.3.1-4, 2.3.1-5, 2.3.1-6, 2.3.2-1, 2.3.2-2; Reference Dominion's 8/2/04 Letter, Serial No. 04-318.
Part 3 Chapter 7	
▪ Section 7.1 References	Response to RAI 1.8-1; Reference Dominion's 8/20/04 Letter, Serial No. 04-354.

Dominion Nuclear North Anna, LLC
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Dominion®

May 12, 2005

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 05-305
ESP/JDH
Docket No. 52-008

DOMINION NUCLEAR NORTH ANNA, LLC
NORTH ANNA EARLY SITE PERMIT APPLICATION
REVISION 4

Enclosed is Revision 4 to the North Anna Early Site Permit (ESP) application. Revision 4 updates the application to incorporate Dominion's responses to NRC's requests for additional information, our responses to the open items in the December 2004 draft Safety Evaluation Report, and other information discussed with the NRC staff.

A summary of the Revision 4 changes is provided in Enclosure 1. A CD containing the North Anna ESP application, Revision 4, is provided in Enclosure 2.

If you have any questions or require additional information, please contact Mr. Joseph D. Hegner at 804-273-2770.

Very truly yours,

Eugene S. Grecheck
Vice President-Nuclear Support Services

Enclosures:

1. Description of Changes in Revision 4.

2. One CD-ROM labeled "North Anna Early Site Permit Application, Docket No. 52-008, September 2003; Revision 4, May 2005, NRC ADAMS Edition," containing the following files:

1. North Anna ESP Application R4 (1 of 8).pdf; 4664 KB; publicly available
2. North Anna ESP Application R4 (2 of 8).pdf; 28,064,970 bytes, publicly available
3. North Anna ESP Application R4 (3 of 8).pdf; 49,772,368 bytes, publicly available
4. North Anna ESP Application R4 (4 of 8).pdf; 47,298,189 bytes, publicly available
5. North Anna ESP Application R4 (5 of 8).pdf; 43,676,749 bytes, publicly available
6. North Anna ESP Application R4 (6 of 8).pdf; 34,149,855 bytes, publicly available
7. North Anna ESP Application R4 (7 of 8).pdf; 51,103,672 bytes, publicly available
8. North Anna ESP Application R4 (8 of 8).pdf; 31,311,890 bytes, publicly available

Commitments made in this letter: None

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COMMONWEALTH OF VIRGINIA

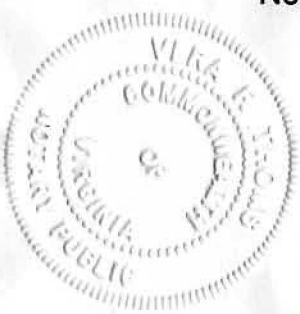
COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President-Nuclear Support Services, of Dominion Nuclear North Anna, LLC. He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of Dominion Nuclear North Anna, LLC, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 12th day of May, 2005.

My Commission expires: My Commission Expires July 31, 2007

Vera F. Thoms
Notary Public



(SEAL)

Enclosure 1

Description of Changes in Revision 4
North Anna Early Site Permit Application

North Anna Early Site Permit Application Description of Changes in Revision 4	
Affected Section, Table, or Figure	**Reason for Change**
Part 2 Chapter 1	
▪ Section 1.8.1	Editorial change to clarify conformance with requirements of 10 CFR 100.21(c)(1).
▪ Section 1.8.2	Revision 3 format error. Added electronic link to RG 1.76 and DG 1105.
▪ Table 1.9-1	Response to DSER Open Items 2.3-1, 2.3-2, 2.3-3, 2.4-5, 2.4-8, 2.4-10, 2.4-11; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
Part 2 Chapter 2	
▪ Section 2.1.2.1	Response to DSER Open Item 2.1-1; Reference Dominion's May 2, 2005 Letter, Serial No. 05-194A.
▪ Section 2.3.1.3.1 ▪ Table 2.3-4 (deleted)	Response to DSER Open Item 2.3-1; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
▪ Section 2.3.1.3.8	Response to DSER Open Item 2.3-3; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
▪ Section 2.3.2.3	Response to DSER Open Item 2.3-4; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
▪ Section 2.3.5.1	Editorial change to clarify conformance with requirements of 10 CFR 100.21(c)(1).
▪ Section 2.4.7.5 ▪ Section 2.4 References ▪ Table 2.4-13 (deleted)	Response to DSER Open Item 2.3-3; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
▪ Sections 2.4.11.1, 2.4.11.4 ▪ Section 2.4 References	Response to DSER Open Item 2.4-3; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
▪ Section 2.4.13 ▪ Section 2.4 References ▪ Table 2.4-20 (new)	Response to DSER Open Item 2.4-11; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
▪ Sections 2.4.12.1.2, 2.4.12.3, 2.4.12.4 ▪ Table 2.4-15 ▪ Figure 2.4-15	Response to DSER Open Item 2.4-7; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
▪ Sections 2.5.2.5, 2.5.2.6.7, 2.5.2.6.7.c, 2.5.2.6.7.d, 2.5.2.7, 2.5.4.7.1, 2.5.4.7.3, 2.5.4.7.4, 2.5.4.8.2, 2.5.4.8.4.a, 2.5.4.8.4.b, 2.5.4.8.4.c, 2.5.4.8.5, 2.5.5.2.3.a, 2.5.5.2.3.b ▪ Section 2.5 References ▪ Tables 2.5-27A (new), 2.5-45, 2.5-46	Response to DSER Open Item 2.5-2; Reference Dominion's March 30, 2005 Letter, Serial No. 05-194.

North Anna Early Site Permit Application Description of Changes in Revision 4	
Affected Section, Table, or Figure	**Reason for Change**
▪ Figures 2.5-48, 2.5-48A (new) 2.5-51, 2.5-53, 2.5-54A, 2.5-54B, 2.5-54B(1) (new), 2.5-54B(2) (new), 2.5-54B(3) (new), 2.5-55A (new)	
Part 2 Chapter 13	
▪ Section 13.3.2.2.2.h	Response to DSER Open Item 13.3-3; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
Part 2 Chapter 15	
▪ Table 15.4-26	Revision 3 typographical errors. Corrected isotope designations.
Part 3 Chapter 2	
▪ Table 3.1-1 ▪ Table 3.1-9	Response to Supplemental RAIs 1.a and 1.c; Reference Dominion's April13, 2005 Letter, Serial No. 05-209A.
▪ Table 3.1-9 ▪ Table 3.3-1 ▪ Figure 3.3-1	Response to Supplemental RAI 1.b; Reference Dominion's April13, 2005 Letter, Serial No. 05-209A.
Part 3 Chapter 3	
▪ Section 3.4.1.3.3	Response to DSER Open Item 2.4-3; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
▪ Section 3.8	Revision 3 typographical error. CFR citation should be 10 CFR 51.52.
▪ Section 4.2 References	Revision 3 format error. Reference 13 text should be black versus blue.
Part 3 Chapter 5	
▪ Sections 5.2.2.1.3, 5.2.2.2 ▪ Section 5.2 References	Response to DSER Open Item 2.4-3; Reference Dominion's March 3, 2005 Letter, Serial No. 05-785B.
▪ Section 5.7.1	Response to October 29, 2004 RAI on Uranium Fuel Cycle Impacts; Reference Dominion's November 18, 2004 Letter, Serial No. 04-705.
Part 3 Chapter 7	
▪ Section 7.1.2 ▪ Table 7.1-27	Revision 3 typographical errors. Corrected EAB and LPZ χ/Q values (Section 7.1.2) and isotope designations (Table 7.1-27).

Dominion Nuclear North Anna, LLC
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Dominion®

July 25, 2005

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 05-457
ESP/JDH
Docket No. 52-008

DOMINION NUCLEAR NORTH ANNA, LLC
NORTH ANNA EARLY SITE PERMIT APPLICATION
FINAL SAFETY EVALUATION REPORT REVIEW ITEMS AND REVISION 5 TO THE NORTH ANNA ESP APPLICATION

On June 16, 2005, the NRC issued its Final Safety Evaluation Report (FSER) for the North Anna Early Site Permit Application. As part of our review of the FSER, we identified several corrections that must be made to documents Dominion previously submitted to the NRC. Enclosure 1 to this letter describes those corrections.

The North Anna ESP Application has been updated to reflect the corrections. A summary of the changes in Revision 5 of the ESP Application is provided in Enclosure 2. A CD containing Revision 5 of the ESP Application is provided as Enclosure 3.

If you have any questions or require additional information, please contact Mr. Joseph Hegner at 804-273-2770.

Very truly yours,

Eugene S. Grecheck
Vice President-Nuclear Support Services

Enclosures:

1. Final Safety Evaluation Report Review Items
2. Description of Changes in Revision 5
3. One CD-ROM labeled "North Anna Early Site Permit Application, Docket No. 52-008, September 2003; Revision 5, July 2005, NRC ADAMS Edition," containing the following files:

- North Anna ESP Application R5 (1 of 8).pdf; 9355 KB; publicly available
- North Anna ESP Application R5 (2 of 8).pdf; 28,064,970 bytes, publicly available
- North Anna ESP Application R5 (3 of 8).pdf; 49,772,302 bytes, publicly available
- North Anna ESP Application R5 (4 of 8).pdf; 47,578,761 bytes, publicly available
- North Anna ESP Application R5 (5 of 8).pdf; 43,787,240 bytes, publicly available
- North Anna ESP Application R5 (6 of 8).pdf; 34,327,107 bytes, publicly available
- North Anna ESP Application R5 (7 of 8).pdf; 51,600,526 bytes, publicly available
- North Anna ESP Application R5 (8 of 8).pdf; 32,215,787 bytes, publicly available

Commitments made in this letter: None

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COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President, Nuclear Support Services, of Dominion Nuclear North Anna, LLC. He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of Dominion Nuclear North Anna, LLC, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 25TH day of July, 2005

My Commission expires: May 31, 2006

Vicki L. Hull

Notary Public

(SEAL)

Enclosure 1

Final Safety Evaluation Report Review Items

Correction of Coordinates for ESP Site Footprint

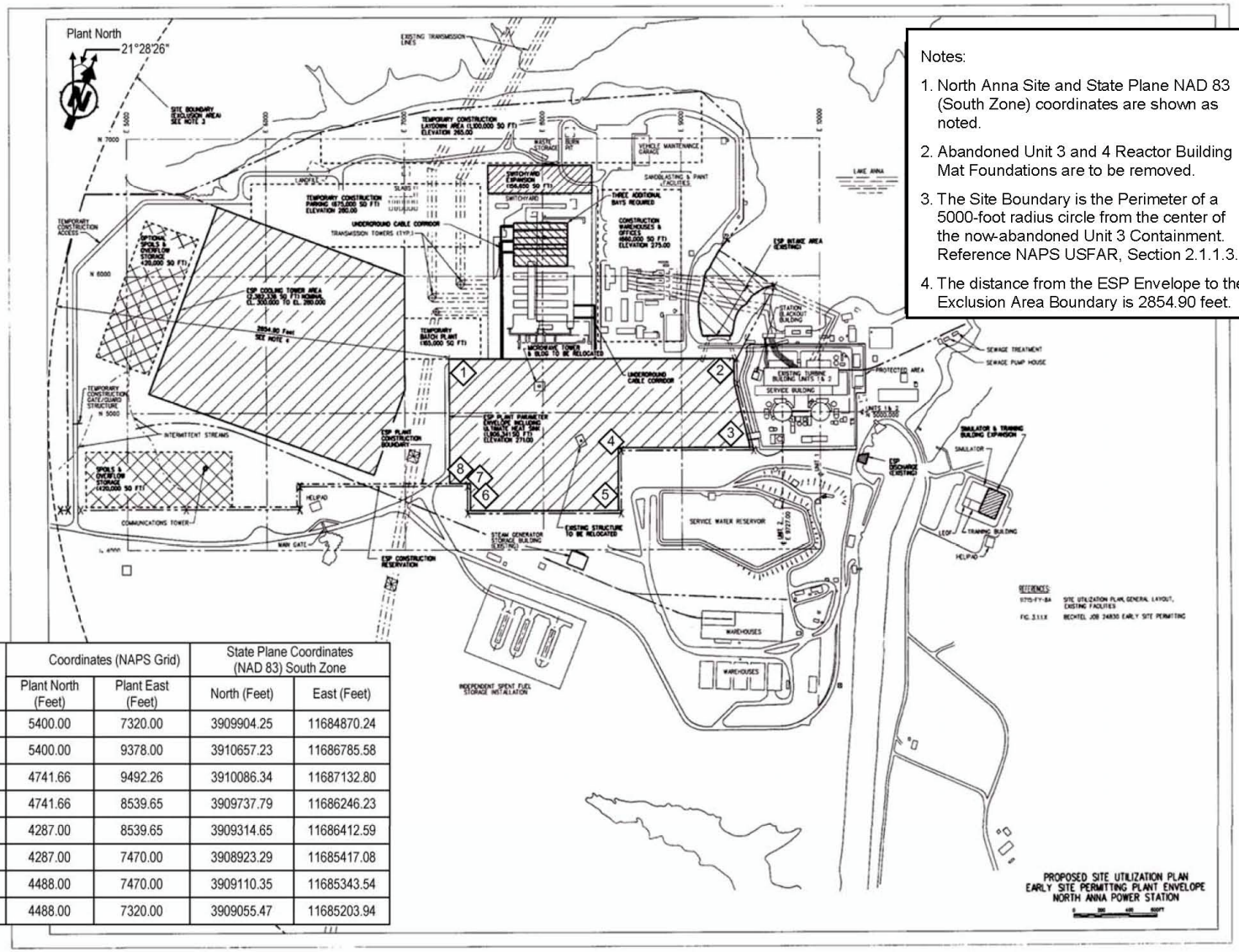
Coordinates for the ESP site footprint were submitted to the NRC in response to Draft Safety Evaluation Report (DSER) Open Item 2.4-1 (Dominion Letter 05-785B dated March 3, 2005).

As discussed in a July 5, 2005 conference call with NRC Staff, upon further review, it has been determined that the coordinates identified in Figure 1 of the DSER Open Item 2.4-1 response contained errors.

A corrected version of Figure 1 is provided on the next page.

Application Revision

None. Figure 1 on the next page is not included in the North Anna ESP Application.



Point	Coordinates (NAPS Grid)		State Plane Coordinates (NAD 83) South Zone	
	Plant North (Feet)	Plant East (Feet)	North (Feet)	East (Feet)
1	5400.00	7320.00	3909904.25	11684870.24
2	5400.00	9378.00	3910657.23	11686785.58
3	4741.66	9492.26	3910086.34	11687132.80
4	4741.66	8539.65	3909737.79	11686246.23
5	4287.00	8539.65	3909314.65	11686412.59
6	4287.00	7470.00	3908923.29	11685417.08
7	4488.00	7470.00	3909110.35	11685343.54
8	4488.00	7320.00	3909055.47	11685203.94

Incorrect Version of SSAR Figure 2.5-55A

In Dominion's response to DSER Open Item 2.5-2 (Dominion Letter 05-194 dated March 30, 2005), a new SSAR figure, Figure 2.5-55A, was included titled:

Figure 2.5-55A	Selected Horizontal and Vertical OBE and SSE Spectra for the Hypothetical Rock Outcrop Control Point at the Top of Zone III-IV Material (Representative Elevation 250 ft, 3300 ft/sec Shear Wave Velocity)

Revision 4 of the North Anna ESP Application included an incorrect version of SSAR Figure 2.5-55A. (A duplicate copy of SSAR Figure 2.5-55 was inadvertently included as SSAR Figure 2.5-55A.)

The correct version of SSAR Figure 2.5-55A has been incorporated in Revision 5 of the ESP Application.

Application Revision

In Revision 5 of the ESP Application, SSAR Figure 2.5-55A has been replaced with the correct version shown on the next page.

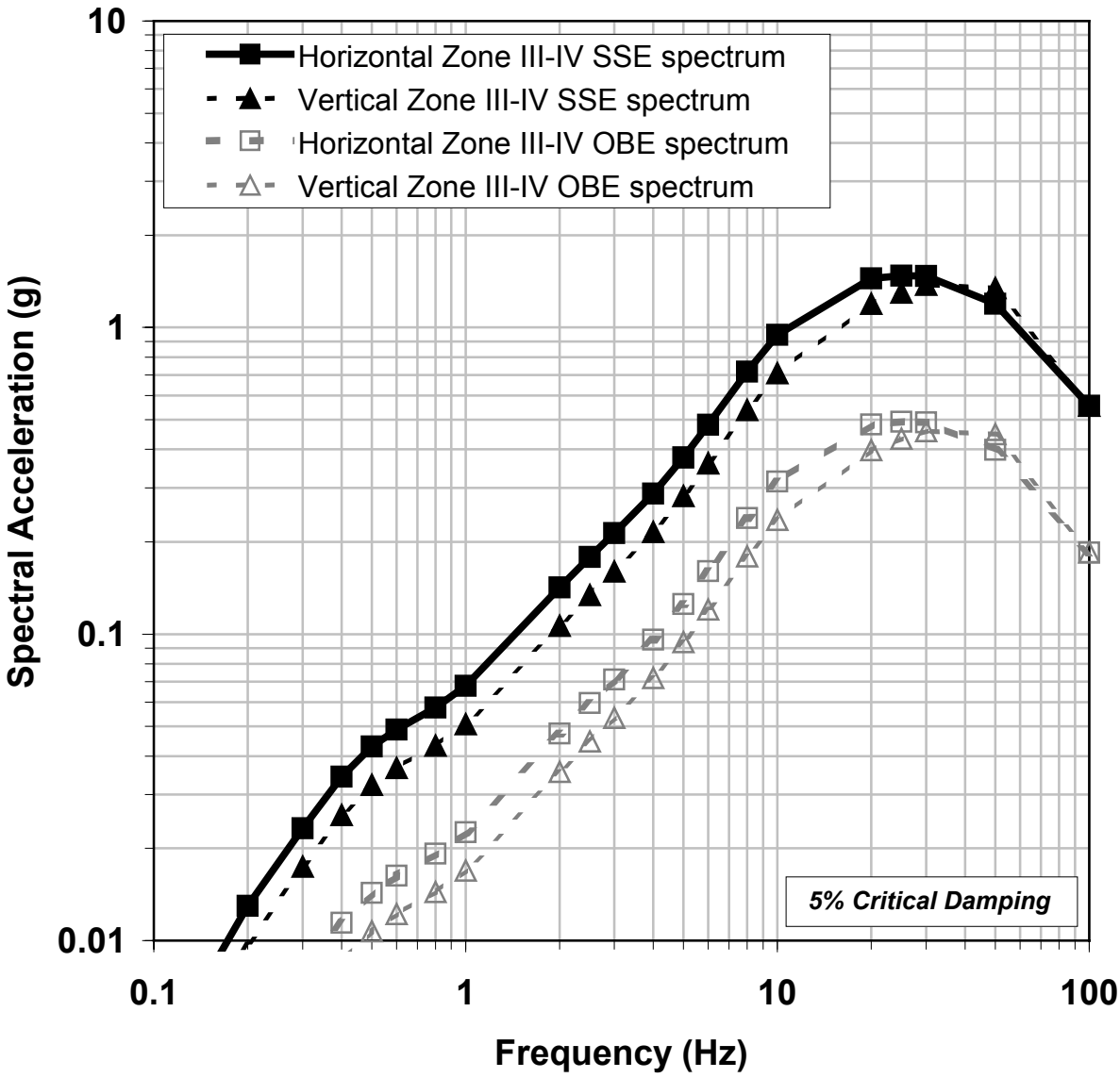


Figure 2.5-55A **Selected Horizontal and Vertical OBE and SSE Spectra for the Hypothetical Rock Outcrop Control Point at the Top of Zone III-IV Material (Representative Elevation 250 ft, 3300 ft/sec Shear Wave Velocity)**

Confirmatory Analysis of V/H Ratios for Zone III-IV Hypothetical Rock Outcrop Control Point SSE Spectrum

In Revision 4 of the North Anna ESP Site Safety Analysis Report (SSAR), the site horizontal and vertical safe shutdown earthquake (SSE) spectra were estimated at a control point at the top of a hypothetical outcrop of Zone III-IV material having a best estimate shear wave velocity of 3,300 ft/sec. The vertical SSE was determined using V/H ratios from NUREG/CR-6728 (Reference 171 of SSAR Section 2.5) and are listed in SSAR Table 2.5-27A. These V/H ratios are identical to those used for hard rock conditions (see SSAR Table 2.5-27).

As discussed in a July 14, 2005 conference call with NRC Staff, upon further evaluation, it has been determined that the NUREG/CR-6728 V/H ratios apply explicitly to hard rock conditions with a shear wave velocity of 9,200 ft/sec. The NUREG/CR-6728 V/H ratios are not explicitly appropriate for the site-specific shear wave velocity profile and controlling earthquake magnitude and distance for the North Anna ESP site.

A site-specific analysis has been performed to investigate the appropriateness of the V/H ratios listed in SSAR Table 2.5-27A for the characteristics of the North Anna ESP site. A description of the site-specific analysis is provided in the following section.

Site-Specific Analysis of V/H Ratios

1. Description of Site-Specific Analysis

A site-specific vertical to horizontal (V/H) spectral ratios analysis has been performed following a methodology similar to that used in NUREG/CR-6728 (Reference 171 of SSAR Section 2.5), which is the source of the V/H spectral ratios in SSAR Table 2.5-27A. For the analysis, site-specific shear and compressional wave (S- and P-wave) profile data were used along with the high frequency deaggregation results from the PSHA. The stochastic point source ground motion model was used with an implementation of random vibration theory to generate the horizontal and vertical ground motions and subsequent V/H spectral ratios.

To maintain a consistency between the S- and P-wave profiles, the P-wave profile was developed from a model of Poisson's ratio with depth rather than the P-wave velocity data for the site. This application of the Poisson's ratio model to the previously developed S-wave profile maintains the consistency between the S- and P-wave profiles developed for the site. The Poisson's ratio values were derived from the site S- and P-wave data. Based on the distribution of observed Poisson's ratio data, two models were developed which, when applied to the single S-wave profile, resulted in

two P-wave profiles for the analysis. The first model was based on the older subsurface data from the Units 1 and 2 investigation, using the profiles from borings B-20 and B-104, and Well #1. The more recent ESP investigation data from boring B-802 were used to develop the second model. Preferred relative weights of 0.25 and 0.75 were used in the analysis for the P-wave Models 1 and 2, respectively; these weights were assigned based on the quality of the recently recorded ESP site investigation data compared to the older North Anna site data. The two Poisson's ratio models used in the analysis are shown in Figure 1 along with the site-specific data. The corresponding two P-wave velocity profiles are listed in Table 1 along with the S-wave and two Poisson's ratio models.

Four pairs of magnitude and distance values (weighted average magnitudes for given distance bins of the high-frequency PSHA deaggregation, shown in SSAR Figure 2.5-50) were used in the analysis. These same magnitude and distance pairs were used for both the horizontal and vertical ground motions. Associated deaggregation weights for these paired values, below, were used to combine the results.

Magnitude (M)	Distance (km)[1]	Weight[2]
5.1	7.5	0.34
5.3	22.5	0.33
5.7	37.5	0.25
6.1	75.0	0.08

[1] value used for the given distance bin
[2] contribution of the hazard for the given distance bin

Horizontal and vertical ground motions spectra, based on the magnitude-distance values and corresponding profiles listed in Table 1, were computed using a stochastic point source model and an implementation of random vibration theory. For each case, a total of 100 realizations were performed to provide a stable statistical estimate of the ground motions and corresponding V/H spectral ratios. Ground motions were computed based on a linear response at low strain material damping levels of 0.5, 1.0, 2.0, and 5.0%. The 2.0% damping level was chosen as the base case level and the additional three damping levels were used for a sensitivity analysis of the site-specific V/H ratios.

Statistical 16th, 50th, mean, and 84th percentile V/H spectral ratio values as a function of frequency were developed based on the relative weighting between the two P-wave profiles and four magnitude-distance cases from the high-frequency deaggregation results. These results were computed for the four damping levels.

2. Results

The statistical results of the V/H spectral ratios for the 0.5% damping level are shown in Figure 2. For comparison purposes, the V/H ratio for the 0.2g<PGA<0.5g bin from NUREG/CR-6728, which was used in SSAR Table 2.5-27A, is shown in Figure 2.

Similar plots for the additional damping levels of 1.0, 2.0, and 5.0% are shown in Figures 3, 4, and 5. The results for the base case damping level of 2.0% are tabulated in Table 2 for the 21 frequencies used in SSAR Table 2.5-27A.

3. Summary and Conclusions

A site-specific analysis of vertical to horizontal (V/H) spectral ratios for the North Anna ESP site was performed. Two P-wave profiles were developed which are consistent with the base case S-wave profile used in the PSHA. The results from these two models were assigned relative weights of 0.25 and 0.75 for P-wave Model 1 and 2, respectively. The higher weight of 0.75 was based on P-wave Model 2 being developed from the more recently recorded ESP site investigation data. Horizontal and vertical ground motion spectra were computed for four magnitude and distance values based on the 5-10 Hz PSHA deaggregation. The associated weights from the PSHA deaggregation for these four magnitude-distance values were combined with the assigned weights for the two P-wave models. The base case was run for a damping level of 2.0%. In addition, damping levels of 0.5, 1.0, and 5.0% were analyzed. These other damping values did not produce significantly different results (i.e., comparison of the results presented in Figures 2 through 5).

The 16th, 50th, and 84th percentiles and mean V/H ratios are shown in Figure 4 for the 2.0% damping case and listed in Table 2. For comparison, the V/H ratios from NUREG/CR-6728 for the 0.2g<PGA<0.5g case, which was used for SSAR Table 2.5-27A, are also shown in Figure 4 and listed in Table 2. On average, the mean V/H ratios from the site-specific analysis are approximately 30% lower (ranging from 18-35% lower) over the complete frequency range of 100 Hz to 0.1 Hz than the V/H ratios used in SSAR Table 2.5-27A. At the 84th percentile, the site-specific V/H ratio values are on average 8% lower (ranging from 19% lower to 5% higher) over the entire frequency range than the SSAR Table 2.5-27A V/H ratio values.

The comparison results provide justification that the V/H ratios given in NUREG/CR-6728 and used in SSAR Table 2.5-27A are appropriate for the North Anna ESP site. To maintain a hazard-consistent level in scaling the horizontal ground motions, the fractile level needed for the V/H ratio is between the 50th and 84th percentile. The exact percentile level would depend on frequency, site, design considerations, and judgment.

The site-specific analysis included the deaggregation information from the high frequency (i.e., 5-10 Hz) controlling earthquake only. If a more detailed analysis were performed, the deaggregation events from the low-frequency (i.e., 1-2.5 Hz) deaggregation would be included. In addition, the 5-10 Hz deaggregation events for distances greater than 75 km were included in the 75 km case. These factors would lead to a more conservative V/H ratio (shown in Figure 4) for the lower frequency range than for the higher frequency range.

Table 1. S-wave profile, Poisson's ratio models, and corresponding P-wave profiles.

Thickness (m)	Base Case Vs (m/sec)	Model 1 Poisson's Ratio	Model 2 Poisson's Ratio	Model 1 P wave (m/sec)	Model 2 P wave (m/sec)
2.286	1102	0.3340	0.4267	2207.4	3082.2
2.286	1199	0.3326	0.4253	2394.3	3326.5
2.286	1295	0.3313	0.4240	2578.1	3564.5
2.286	1391	0.3299	0.4226	2760.9	3799.2
2.286	1488	0.3285	0.4212	2944.6	4033.4
2.286	1584	0.3272	0.4199	3125.3	4261.8
2.286	1680	0.3258	0.4161	3305.0	4431.2
2.286	1777	0.3244	0.4062	3485.6	4471.7
2.286	1873	0.3230	0.3964	3663.4	4521.1
2.286	1969	0.3217	0.3866	3840.2	4579.0
2.286	2066	0.3203	0.3767	4018.0	4645.8
2.286	2162	0.3189	0.3669	4193.0	4715.5
2.286	2258	0.3176	0.3571	4367.1	4789.2
2.286	2355	0.3162	0.3473	4542.2	4868.4
2.286	2451	0.3108	0.3341	4678.2	4911.0
2.286	2547	0.2930	0.3097	4707.1	4850.8
2.286	2644	0.2752	0.2852	4747.4	4823.4
2.286	2740	0.2573	0.2608	4793.4	4816.5
2.286	2830	0.2500	0.2500	4901.7	4901.7

Table 2. V/H Spectral Ratios[1]					
Frequency (Hz)	**16th Percentile**	**50th Percentile**	**Mean**	**84th Percentile**	**SSAR Table 2.5-27A**
.1000	.4066	.5161	.5315	.6552	0.75
.2000	.4164	.5129	.5245	.6317	0.75
.3000	.4081	.5005	.5113	.6138	0.75
.4000	.3936	.4906	.5030	.6114	0.75
.5000	.3881	.4965	.5125	.6350	0.75
.6000	.3926	.5170	.5381	.6808	0.75
.8000	.4162	.5654	.5935	.7682	0.75
1.0000	.4325	.5848	.6119	.7907	0.75
2.0000	.3850	.5281	.5533	.7246	0.75
2.5000	.3787	.5300	.5583	.7418	0.75
3.0000	.3772	.5268	.5545	.7359	0.75
4.0000	.3838	.5013	.5192	.6547	0.75
5.0000	.3808	.4887	.5045	.6273	0.75
6.0000	.3748	.4912	.5094	.6439	0.75
8.0000	.3346	.4712	.4969	.6635	0.75
10.0000	.3046	.4569	.4913	.6855	0.75
20.0000	.3393	.5263	.5726	.8162	0.83
25.0000	.3593	.5475	.5919	.8343	0.88
30.0000	.3777	.5727	.6185	.8682	0.94
50.0000	.4176	.6693	.7380	1.0725	1.12
100.0000	.4276	.6329	.6788	.9366	1.00

[1]V/H spectral ratios for the 16th, 50th, and 84th percentiles, and mean from the site specific analysis and the V/H ratio values used in SSAR Table 2.5-27A at the 21 frequency points used in SSAR Table 2.5-27A. The site-specific results are based on the relative weights from the PSHA deaggregation and a weighting of 0.25 for P-wave Model 1 and 0.75 for P-wave Model 2.

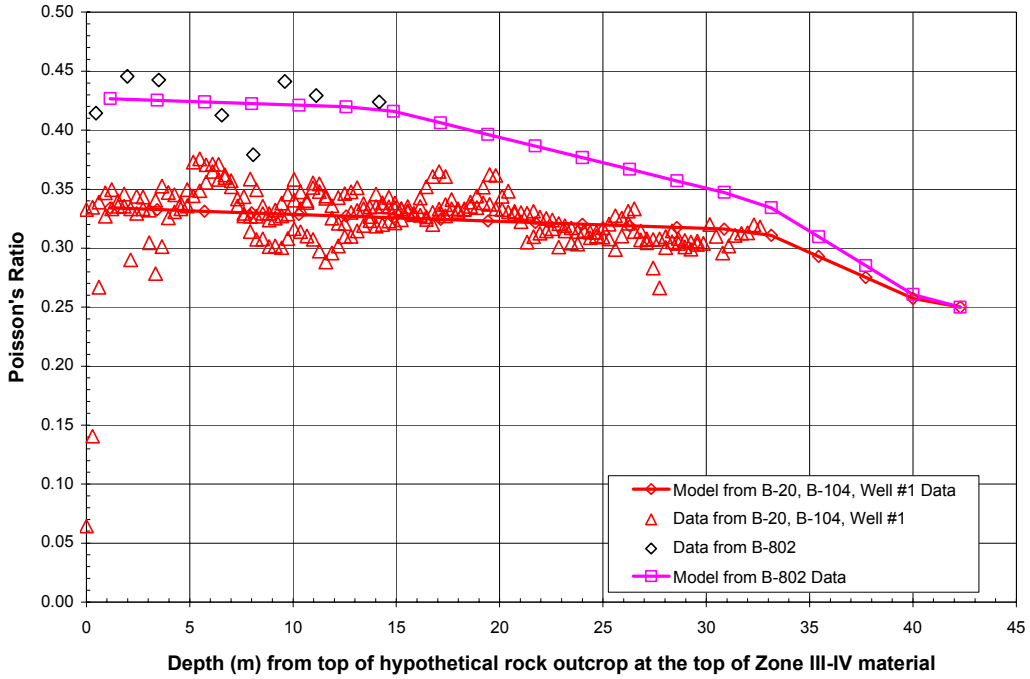


Figure 1. Poisson's ratio data and fitting models, used to develop P-wave velocity models.

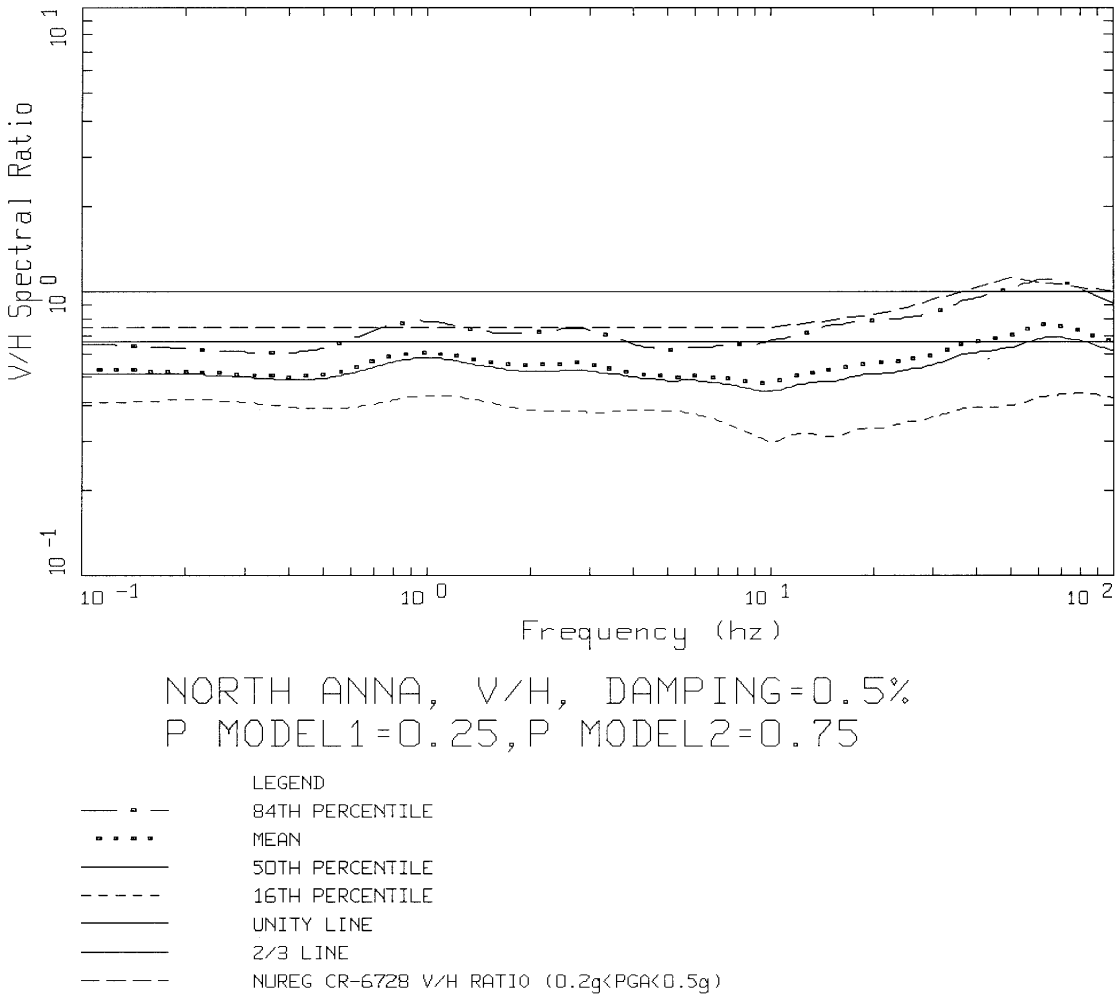


Figure 2. V/H spectral ratios for the base damping level of 0.5% with a combined weighting of 0.25 and 0.75 for the P-wave Model 1 and 2, respectively. Median, mean, and plus and minus one-sigma (84th and 16th percentile) curves are shown. The NUREG/CR-6728 V/H ratio used in SSAR Table 2.5-27A is shown as a long dashed line for comparison.

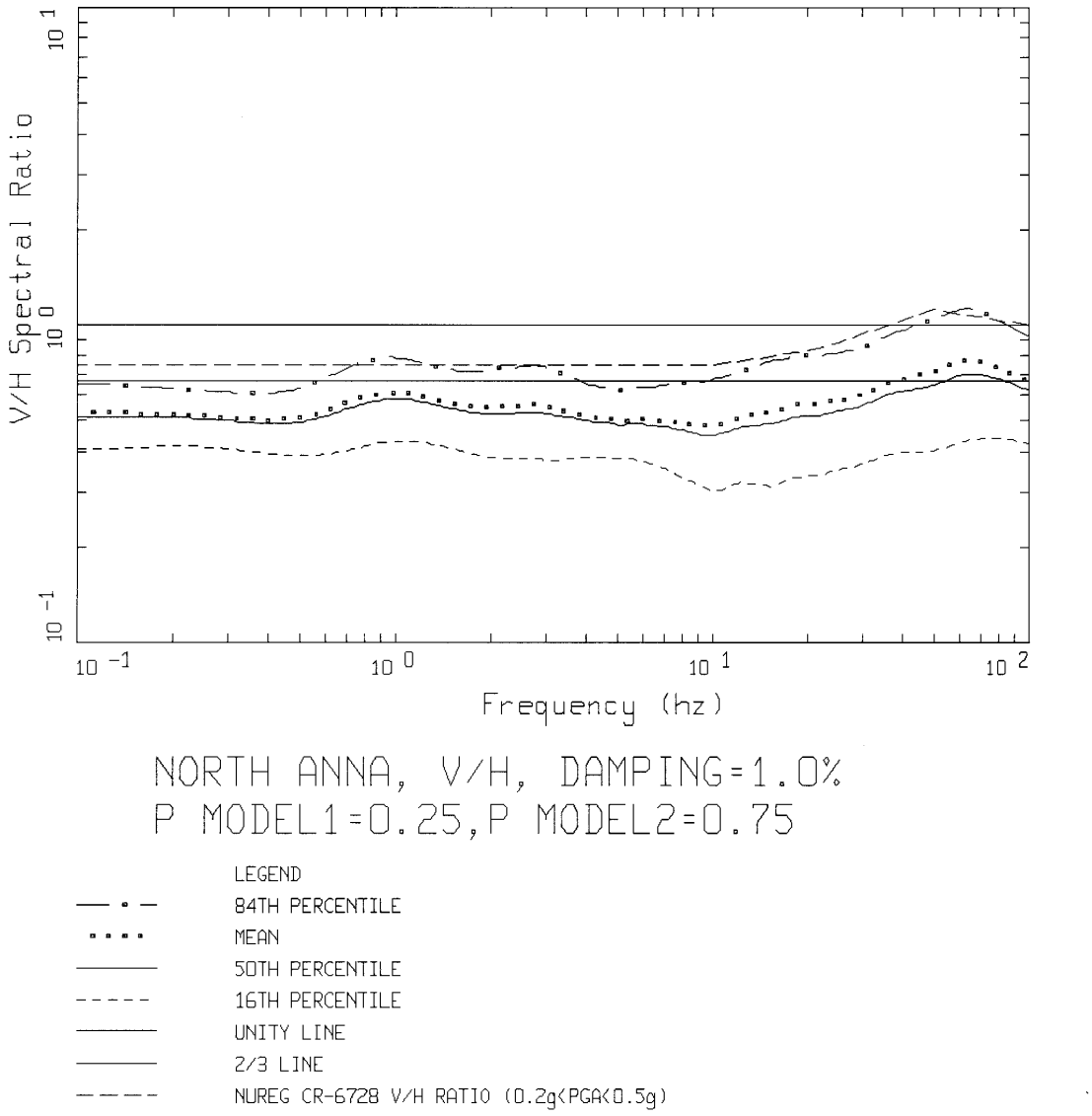


Figure 3. V/H spectral ratios for the base damping level of 1.0% with a combined weighting of 0.25 and 0.75 for the P-wave Model 1 and 2, respectively. Median, mean, and plus and minus one-sigma (84th and 16th percentile) curves are shown. The NUREG/CR-6728 V/H ratio used in SSAR Table 2.5-27A is shown as a long dashed line for comparison.

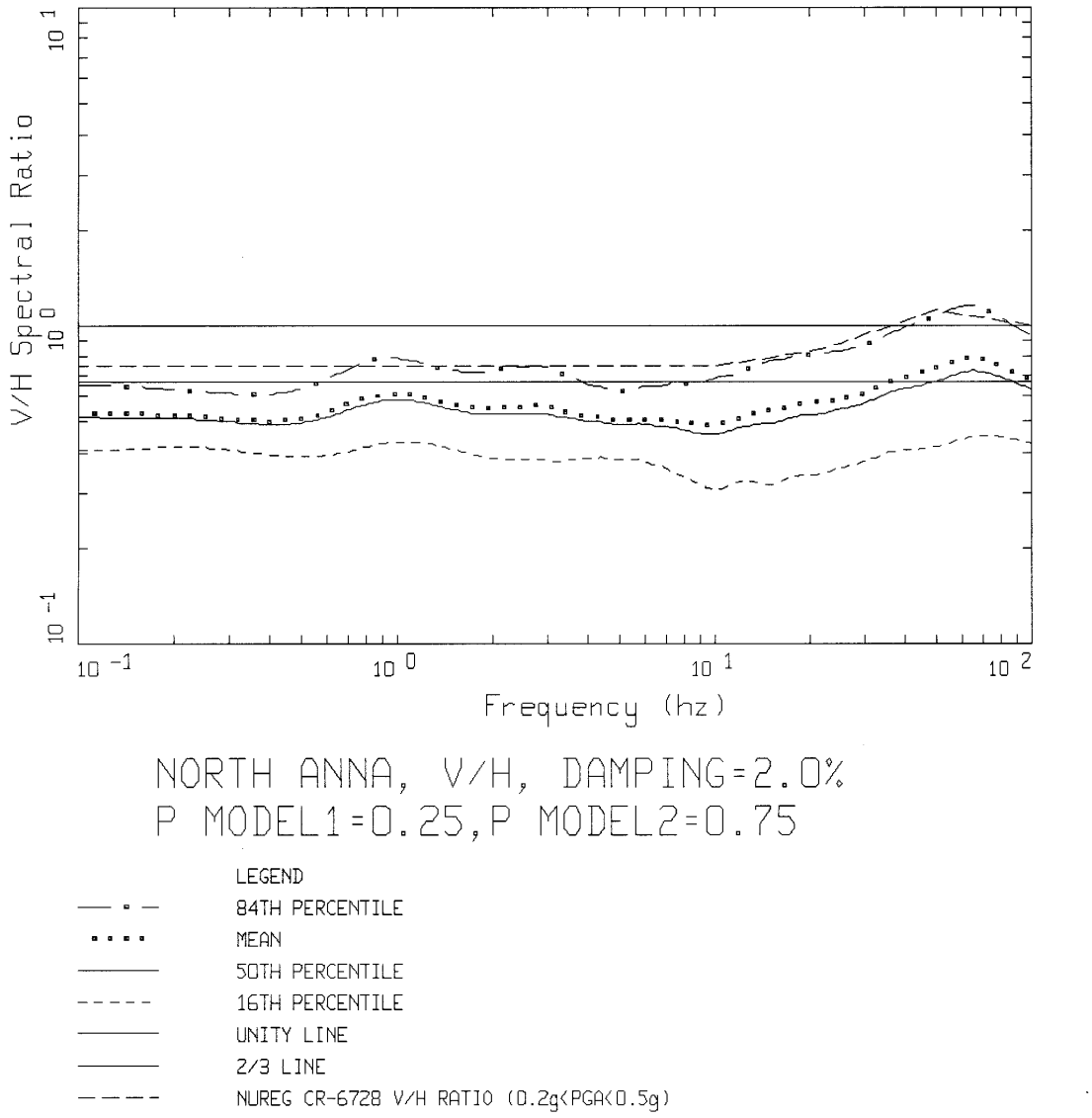


Figure 4. V/H spectral ratios for the base damping level of 2.0% with a combined weighting of 0.25 and 0.75 for the P-wave Model 1 and 2, respectively. Median, mean, and plus and minus one-sigma (84th and 16th percentile) curves are shown. The NUREG/CR-6728 V/H ratio used in SSAR Table 2.5-27A is shown as a long dashed line for comparison.

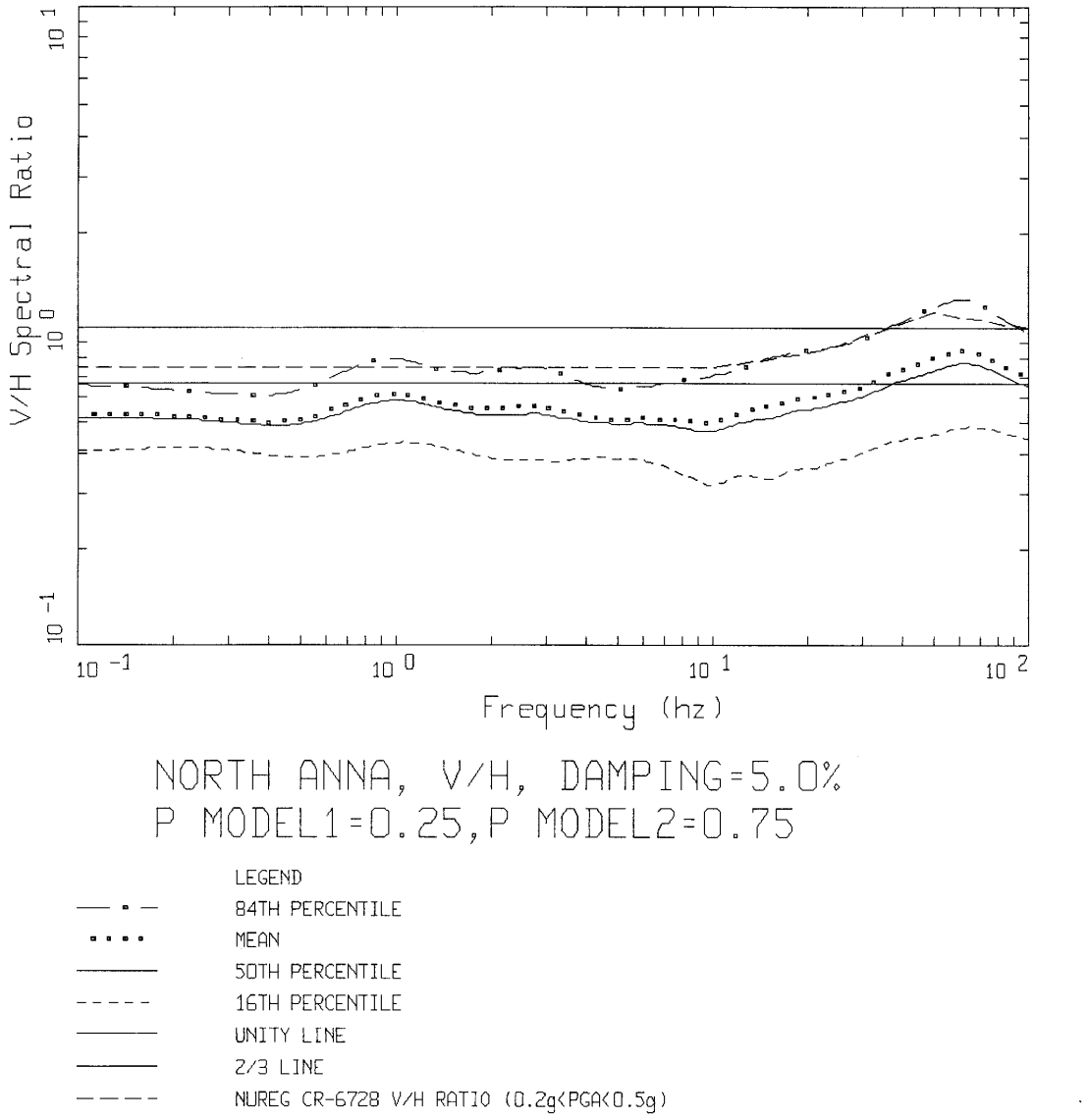


Figure 5. V/H spectral ratios for the base damping level of 5.0% with a combined weighting of 0.25 and 0.75 for the P-wave Model 1 and 2, respectively. Median, mean, and plus and minus one-sigma (84th and 16th percentile) curves are shown. The NUREG/CR-6728 V/H ratio used in SSAR Table 2.5-27A is shown as a long dashed line for comparison.

Application Revision

In Revision 5 of the ESP Application, SSAR Section 2.5.2.6.7.d has been revised to read as follows:

d. Development of Vertical SSE Spectra

Hard Rock SSE Spectrum

The applicable V/H ratios used to develop the selected vertical hard rock SSE spectrum (5 percent of critical damping) are listed in Table 2.5-27. The vertical SSE spectrum is calculated by multiplying the selected horizontal SSE spectral amplitude at each frequency by the applicable V/H ratio for that frequency. The selected horizontal and vertical spectra are plotted in Figure 2.5-48 for the hard rock SSE.

Zone III-IV Hypothetical Rock Outcrop Control Point SSE Spectrum

The horizontal SSE spectral accelerations, V/H ratios, and vertical SSE spectral accelerations for the Zone III-IV hypothetical rock outcrop control point are listed in Table 2.5-27A. The vertical SSE spectrum is calculated by multiplying the selected horizontal SSE spectral amplitude at each frequency by the applicable V/H ratio for that frequency. The selected horizontal and vertical spectra are plotted in Figure 2.5-48A.

To confirm the appropriateness of the V/H ratios listed in Table 2.5-27A, a site-specific analysis was performed. For the site-specific analysis, the stochastic point source model was used with an implementation of random vibration theory to model both horizontal and vertical spectra. The vertical ground motion was extended to consider P-SV waves. This approach has been used to develop the recommended V/H ratios in Reference 171 and has been shown to predict general trends in V/H ratios for earthquakes recorded in the Western United States. The model has been validated against empirical V/H ratio data from the 1989 Loma Prieta earthquake for rock site conditions.

Two site-specific P-wave profiles were developed that are consistent with the base shear wave profile used in the site analysis. These two P-wave profiles were developed by applying two Poisson's ratio models as a function of depth to the base shear wave profile. These two Poisson's ratio models are based on measured shear and compression wave data for the North Anna site, with the more recent data from the ESP investigation being assigned a larger weight of 0.75 and the older data from the investigation for Units 1 and 2 having a weight of 0.25 in the analysis. Both the horizontal and vertical ground motions were

computed assuming a linear response. Four magnitude-distance values and associated weights based on the 5-10 Hz PSHA deaggregation were used in the analysis to develop the horizontal and vertical ground motions. Relative weights for each of the four cases were used in combining the spectral ratios. A constant damping level of 2.0% was used. For each case, a total of 100 realizations were performed for both the horizontal and vertical ground motions. Statistics were computed for the suite of V/H spectral ratios. Additional damping levels of 0.5%, 1.0, and 5.0% were computed in a sensitivity study.

The results of the site-specific analysis confirm the appropriateness of the V/H ratios listed in Table 2.5-27A. Compared with the Table 2.5-27A values, the mean V/H ratios from the site-specific analysis are, on average, approximately 30% lower (ranging from 18-35% lower) over the complete frequency range of 100 Hz to 0.1 Hz. At the 84th percentile, the site-specific V/H ratio values are on average 8% lower (ranging from 19% lower to 5% higher) over the entire frequency range than the Table 2.5-27A V/H ratio values.

The comparison results provide justification that the V/H ratios given in Reference 171 and used in Table 2.5-27A are appropriate for the North Anna ESP site. To maintain a hazard-consistent level in scaling the horizontal ground motions, the fractile level needed for the V/H ratio is between the 50th and 84th percentile. The exact percentile level would depend on frequency, site, design considerations, and judgment.

Enclosure 2

Description of Changes in Revision 5
North Anna Early Site Permit Application

North Anna Early Site Permit Application Description of Changes in Revision 5	
Affected Section, Table, or Figure	**Reason for Change**
Part 2 Chapter 2	
• Section 2.5.2.6.7.d	Confirmatory analysis for V/H ratios; Reference Dominion's 7/20/05 Letter; Serial No. 05-457.
• Figure 2.5-55A	Replaced incorrect figure; Reference Dominion's 7/20/05 Letter; Serial No. 05-457.

Dominion Nuclear North Anna, LLC
5000 Dominion Boulevard, Glen Allen, VA 23060

Dominion®

April 13, 2006

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 06-273
ESP/JDH
Docket No. 52-008

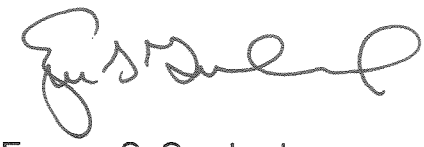
DOMINION NUCLEAR NORTH ANNA, LLC
NORTH ANNA EARLY SITE PERMIT APPLICATION
RESPONSE TO NRC QUESTIONS AND REVISION 6 TO THE NORTH ANNA ESP APPLICATION

On February 10, 2006, NRC informed Dominion that it was conducting a review of the North Anna ESP Application Supplement submitted January 13, 2006. In its letter, the NRC noted that several key areas had been identified for which additional information was needed. On March 2, 2006, NRC documented the results of that review and identified specific information needs. Separately, on March 13, 2006, NRC requested information related to possible bald eagle nests reportedly in the vicinity of North Anna and requested that Dominion investigate the matter and provide the results when it submitted the next revision of the North Anna ESP application.

Dominion's response to the March 2, 2006 NRC questions and the separate March 13, 2006 request are provided in Enclosure 1. As described in Enclosure 1 the North Anna ESP Application has been revised, where appropriate, to incorporate changes resulting from both the January 13, 2006 supplement and subsequent NRC questions. A summary of the changes is provided as Enclosure 2. A CD containing Revision 6 of the application is provided as Enclosure 3. A CD containing MACCS2 computer code files (in response to NRC Question 14b) is provided as Enclosure 4.

If you have any questions or require additional information, please contact Tony Banks at 804-273-2170 or Joe Hegner at 804-273-2770.

Very truly yours,



Eugene S. Grecheck
Vice President-Nuclear Support Services

Enclosures:

1. Response to March 2 and March 13, 2006 NRC questions.
2. Summary of North Anna ESP Application Revision 6 changes.
3. One CD-ROM labeled, “North Anna Early Site Permit Application, Docket No. 52-008, September 2003; Revision 6, April 2006, NRC ADAMS Edition,” containing the following files:

001 North Anna ESP Application R6 (1 of 9).pdf; 8,450,087 bytes; publicly available
002 North Anna ESP Application R6 (2 of 9).pdf; 29,537,825 bytes; publicly available
003 North Anna ESP Application R6 (3 of 9).pdf; 49,775,907 bytes; publicly available
004 North Anna ESP Application R6 (4 of 9).pdf; 49,721,570 bytes; publicly available
005 North Anna ESP Application R6 (5 of 9).pdf; 46,242,534 bytes; publicly available
006 North Anna ESP Application R6 (6 of 9).pdf; 36,568,346 bytes; publicly available
007 North Anna ESP Application R6 (7 of 9).pdf; 41,520,610 bytes; publicly available
008 North Anna ESP Application R6 (8 of 9).pdf; 39,890,330 bytes; publicly available
009 North Anna ESP Application R6 (9 of 9).pdf; 33,186,644 bytes; publicly available

4. One CD-ROM labeled, “Title of Record: SM-1526 Rev 0, Add. N/A, dated 4-12-06,” containing multiple MACCS2 code input and output files.

Commitments made in this letter:

1. Provide NRC with a copy of information prepared by the U.S. Army Corps of Engineers (Question 4 response).
2. Inform NRC of stakeholder meeting results (Question 6a response).

Cc: (with Enclosures 1-3 except as noted)

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COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President, Nuclear Support Services, of Dominion Nuclear North Anna, LLC. He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of Dominion Nuclear North Anna, LLC, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 13TH day of April, 2006.

My Commission expires: May 31, 2006

Vicki L. Hull
Notary Public

(SEAL)

Enclosure 1
Dominion Response to March 2 and
March 13, 2006 NRC Questions

1. Drift (NRC 3/2/06 Letter)

a. ER Table 3.1-9 — Include a plant parameter envelope (PPE) value related to cooling tower drift for the Unit 3 wet cooling tower.

b. ER Table 3.3-1 — Include drift estimates for the cooling towers.

c. ER Sections 3.4.1.1, 3.6.1 — Drift needs to be discussed in these sections.

d. ER Section 5.1.1 — Drift should be included in the bullet list.

e. ER Section 5.3.3.2.1 — Provide an evaluation of cooling tower drift and visible plumes.

1a Response

A drift rate, based on a percent of cooling water flow has been added to the Design Parameters portion of ER Table 3.1-9

Application Revision

ER Table 3.1-9 is revised to reflect the above response

1b Response

Drift estimates, based on a percent of cooling water flow, have been added, as appropriate, to the tabulation of water use in ER Tables 3.3-1 and 3.3-2 for Units 3 and 4, respectively.

Application Revision

ER Tables 3.3-1 and 3.3-2 are revised to reflect the above response.

1c Response

For ER Section 3.4.1.1, the discussion has been revised to include the description that the make-up water is required in order to compensate for water lost from the closed-cycle cooling system due to evaporation, blowdown, and drift. In the energy conservation (EC) mode[1], these losses would be no greater than 1.67 E4 gpm for evaporation, 5.57 E3 gpm for blowdown, and 8 gpm for drift. In the maximum water conservation (MWC)

[1] EC and MWC modes are described in response to Question 3.

mode, these losses would be no greater than 1.15 E4 gpm for evaporation, 3.84 E3 gpm for blowdown, and 8 gpm for drift.

ER Section 3.6.1 discusses liquid plant effluents. The section indicates that discharges would occur due to the cooling tower treatment. In that context, the existing discussion is appropriate to describe the discharge from the cooling tower. Since the small drift loss is not a liquid effluent per se, it is more appropriately addressed in the air quality section of the ER (Section 5.3.3) and no changes to ER Section 3.6.1 are necessary. The response to Question 13 addresses the impact of drift loss.

Application Revision

ER Section 3.4.1.1 is revised to reflect the above response.

1d Response

The bulleted list in ER Section 5.1.1 has been updated to include both salt deposition and an explicit description of moisture dissipation (indicating that this is from evaporation and drift). In addition, the description of moisture dissipation in ER Section 5.1.1.2 has been modified to indicate that this is from evaporation and drift. ER Section 5.1.1.2 provides a reference to a more detailed description of the effects of the cooling towers in ER Section 5.3.3.

Application Revision

ER Sections 5.1.1 and 5.1.1.2 are revised to reflect the above response.

1e Response

An evaluation has been performed to quantify the fogging, icing, moisture and salt deposition, and visible plume which could be present as a result of the operation of the wet cooling towers. This evaluation was performed using the SACTI computer program, a tool first developed at Argonne National Laboratories to predict cooling tower plume behavior and effects. The evaluation, including methodology, significant assumptions, and results, is discussed in ER Section 5.3.3.2.1.

Application Revision

ER Section 5.3.3.2.1 is revised to include the description of the cooling tower impact evaluation. ER Tables 5.3-22 through 5.3-41 have been added to provide the results of the evaluation.

2. Noise (NRC 3/2/06 Letter)

ER Section 5.8.1.2

This section concluded that the noise associated with the new cooling design would not cause adverse offsite impacts and that a noise study would be described in a future COL application. Make reasonable assumptions about the design and analyze the environmental impact, if the final design of the cooling system and the associated noise level is not known at ESP stage.

a. ER Section 3.1.5 states that operation of the cooling fans would produce noise below 60–65 dbA at the exclusion area boundary (EAB). Table 3.1-9 lists this noise level for the Unit 4 dry towers, but does not provide values for the Unit 3 or the Ultimate Heat Sink (UHS) towers. If all of the towers are running (Unit 3 dry and wet, Unit 4 dry, and the UHS towers), would the total noise level still be below 65 dbA at the EAB?

b. Provide the calculations and assumptions used to estimate noise levels at the EAB and the closest residence. Include initial sound levels (background and cooling towers), the number of sources, distances, and attenuation factors considered in reaching a conclusion but not included in the calculations.

2a Response

ER Table 3.1-9 has been revised to reflect noise information for the Unit 3 wet and dry cooling towers. The values presented in this table for both Units 3 and 4 are not sound levels for an individual source. Rather, the values reflect the results of the evaluation which shows that the sound level at the nearest point on the EAB would be less than 65 dBA, which the NRC has defined as the significance level. The evaluation (which is described in ER Section 5.8.1.2) shows that the total sound level from the cooling towers is less than or equal to 65 dBA at the EAB with the Unit 4 dry cooling towers operating and either the Unit 3 dry and wet cooling towers operating (in the case of the MWC mode of operation) or the Unit 3 wet cooling towers operating (in the case of the EC mode of operation). The UHS (or service water) towers are considered operating in all conditions.

Application Revision

ER Table 3.1-9 and ER Section 5.8.1.2 are revised to reflect noise information for the Unit 3 wet and dry cooling towers.

2b Response

ER Section 5.8.1.2 has been revised to include the description of the methodology, the significant inputs and assumptions, and the results of the evaluation. The description includes the sound levels at the source due to cascading water, fans and fan motors. Since the sound levels at the EAB at the closest point to the cooling tower area will be dominated by the sound from the cooling towers, there is no background noise included in the evaluation. Also, no credit has been taken for attenuation (other than due to distance) from structures, vegetation, or the slight changes in terrain between the cooling towers and the EAB. Sound levels beyond the EAB were not evaluated since the evaluation showed that at the EAB the sound level was below the level characterized by the NRC as significant (65 dBA).

Application Revision

ER Section 5.8.1.2 is revised to include the description of the methodology, the significant inputs and assumptions, and the results of the evaluation. In addition, ER Section 5.3.4.2 is revised to provide details of the analysis program used for the noise impact evaluation.

3. ER Section 3.4.1.1 (NRC 3/2/06 Letter)

Explain the statement: "The wet towers would incorporate water savings features to reduce evaporative water losses." Describe the associated design features and how they affect the amount of water used by the cooling towers.

3 Response

The normal plant cooling system is a closed cycle system combining dry and wet cooling towers to provide the capability to reduce water consumption during drought conditions. The process flow diagram for the system is shown in the attached Figure. In the Maximum Water Conservation (MWC) mode of operation, heated cooling water leaving the plant main condenser would be cooled in a dry cooling tower section where a minimum of one-third of the heat would be rejected. The cooling water passes through the tubes of the dry cooler while fans move air across the outside of the tubes to transfer the heat to the air. After passing though the dry coolers, the water then passes through a wet cooling tower section, where the remaining heat is dissipated by spraying the water into an air stream, achieving the majority of the heat transfer by evaporation of a portion of the water. The cooled water then returns to the plant condenser to condense the steam leaving the turbines. When the system is in the Energy Conservation (EC) mode of operation, the dry tower fans are turned off with 100% of the cooling then provided using the wet tower section.

Several features are available for conserving water in wet cooling towers. A hybrid tower can be used that incorporates a dry cooling section into the top of the wet cooling tower. A portion of the water entering the tower passes through the tube side of a heat exchanger while air is drawn or forced over the tubes before mixing with the air that has passed through the wet section. This configuration increases the heat transfer due to convection and conduction and reduces the amount of evaporation required to achieve the desired return temperature to the condenser.

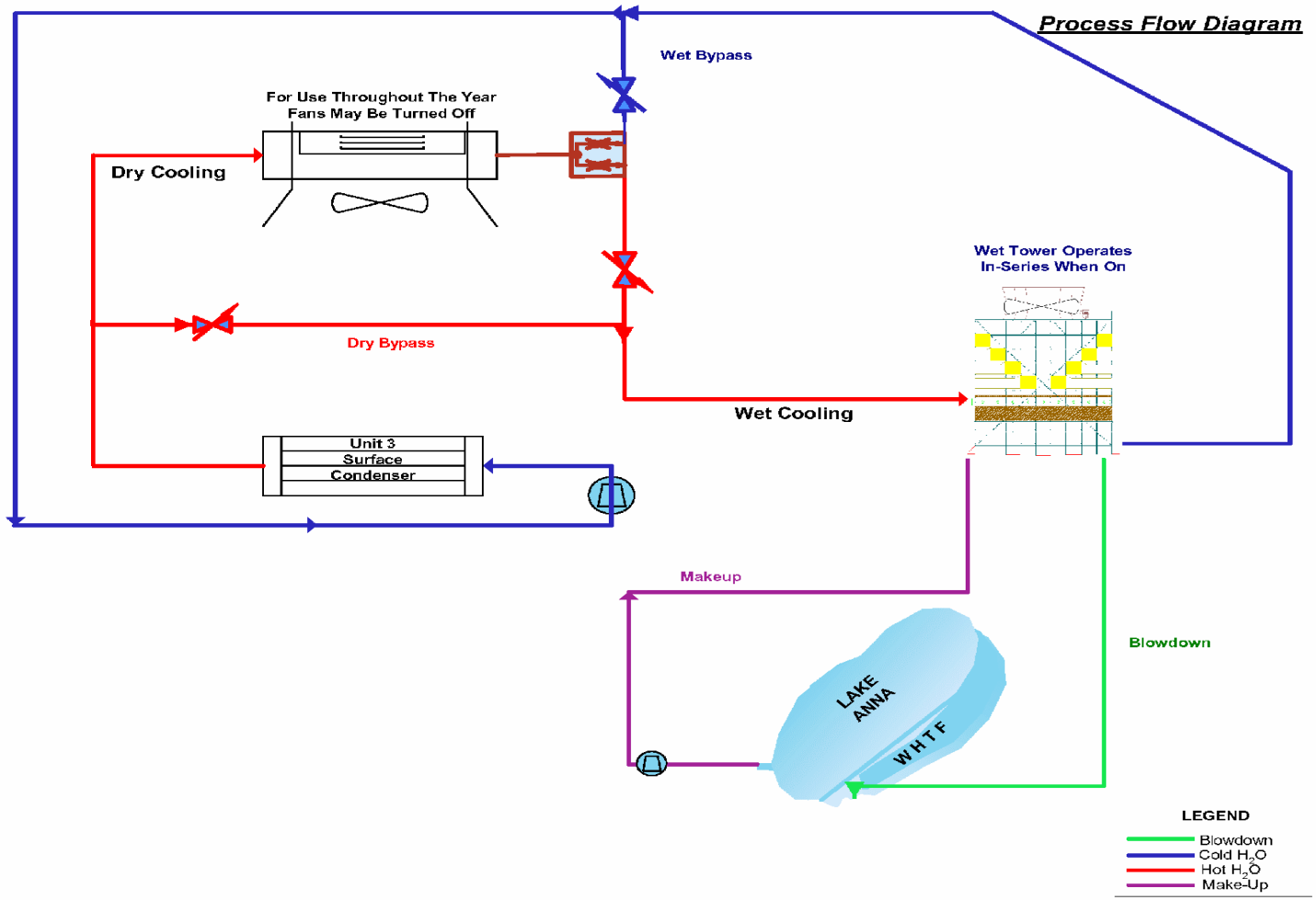
A variation of the hybrid tower uses a dry section above the wet tower section where cooler outside air is drawn in through ducts while the warm moist air from the wet section exhaust passes over the outside of the ducts. Water from the wet section exhaust condenses on the cooler dry section duct surfaces and falls back into the process stream before leaving the cooling tower, thereby reducing the water loss due to evaporation.

Additional means for saving water include using variable speed fans and pumps and adjustable louver settings to more accurately control air and water flow. These methods provide for controlling the heat rejection capacity of the tower and matching the load and ambient conditions without over-cooling at the expense of higher than required evaporation rates.

The performance characteristics of the cooling towers analyzed for Unit 3 are based on consideration of a model that incorporates such features.

Application Revision

ER Section 3.4.1.1 is revised to include the diagram of the cooling system shown in the attached Figure and to describe examples of the water saving features that could be used in the wet towers. The figure in the ER Section also includes a plant service water system described in the section.



NORTH ANNA UNIT 3 CLOSED CYCLE CIRCULATING WATER SYSTEM DIAGRAM

4. Terrestrial Ecosystems (NRC 3/2/06 Letter)

ER Section 2.4.1.8, Wetlands

Are there any areas identified by Army Corp of Engineers (ACE) as jurisdictional wetlands under the Clean Water Act? If so, what protection or mitigation measures have been proposed or agreed to?

4 Response

Wetlands delineation for the potentially affected areas was obtained by Dominion in November 2005. This information was presented to ACE [Army Corp of Engineers], and additional information was requested. Dominion is currently in the process of finalizing the survey information requested, and expects to present this to ACE by the end of April 2006 with a subsequent request for ACE confirmation. Following that, mitigation measures would be addressed as necessary. Dominion will provide a copy of the required delineation and survey documentation to NRC.

Application Revision

ER Section 2.4.1.8 is revised to reflect the above response.

5. Aesthetic (NRC 3/2/06 Letter)

ER Section 5.8.1.5

Provide an evaluation of the aesthetic impacts of the moisture plumes from the cooling towers. Estimate by season (summer, fall, winter, spring) the approximate percentage of the time that the plume would be visible above the containment building and would extend more than 0.5 miles. Provide this information for two cases: 1) with the wet cooling towers operating 100% of the time in energy conservation (EC) mode and 2) with the wet cooling towers operating 100% of the time in maximum water conservation (MWC) mode.

5 Response

The visible plume from the wet cooling towers has been evaluated for the Energy Conservation (EC) mode (i.e., only wet cooling towers operating) using the SACTI suite of computer programs. A description of the SACTI evaluation is provided in ER Section 5.3.3.2.1. In that section, frequency tables are provided of the predicted height and length of the visible plume as functions of wind direction and season of the year. Only the EC mode was evaluated because it represents the bounding case for the plume evaluation and, as long as there is adequate water supply to Lake Anna, it is the mode in which the plant would commonly be operated. Further, the visible plume is most probable and would be most pronounced in the late autumn through early spring; times when the plant is more likely to be operated in the EC mode.

A description of visual intrusion due to visible plume from the wet cooling towers has been included in ER Section 5.8.1.5 and a reference made to the evaluation description in ER Section 5.3.3.2.1.

Application Revision

ER Section 5.8.1.5 is revised to include the visual impact of the cooling tower plumes and to refer to the evaluation description in ER Section 5.3.3.2.1.

6. Human Health (NRC 3/2/06 Letter)

ER Section 5.3.4.1

Recent correspondence with Virginia Department of Health (VDH, September 2005) addressed the health risks associated with exposure to Naegleria fowleri. Dominion stated in its supplement that it is working with State agencies to communicate the information related to risk that was provided in the VDH correspondence to residents around the waste heat treatment facility (WHTF).

a. Provide the details of the plan for communication regarding the risk from thermophilic organisms to the residents around the WHTF.

b. Provide an evaluation of the thermophilic micro-organisms in the basins below the wet cooling towers.

c. In view of the fact that the WHTF, although regulated as a private pond with a point of compliance at Dike 3, is also used for water-based recreation (especially swimming), specifically include an analysis of any health impacts of swimming in the WHTF. Include in your analysis the impacts related to the cooling water blowdown from the wet cooling towers that will be regulated as an internal source in accordance with 40 CFR 423.10.

6a Response

With the changed cooling system, Unit 3 does not contribute to the risk of exposure to thermophilic organisms. Dominion, in concert with VDEQ and VDH, is exploring options to communicate to local residents information related to existing risks. The option(s) will be discussed at a stakeholder meeting to be scheduled in mid-2006. Dominion will inform NRC of the results of the meeting.

Application Revision

ER Section 5.3.4.1 is revised to reflect the above response.

6b Response

The makeup water to the plant cooling towers would be treated with a biocide (such as sodium hypochlorite). With this treatment, there would be no potential for growth of thermophilic micro-organisms in the plant cooling towers or water collection basin.

Application Revision

ER Section 5.3.4.1 is revised to reflect the above response.

6c Response

The chemistry of the circulating water in wet cooling towers is typically controlled through the use of additives. For example, typical treatment includes biocides to prevent fouling of heat exchanger surfaces by algae and other macroscopic organisms. Cooling tower water pH is adjusted with acid to discourage corrosion and the formation of scale. Other organic and inorganic corrosion inhibitors may be used in combination with an acid for pH control. Dispersants are commonly used to prevent the formation of deposits on the heat exchange surfaces.

Dominion would use treatment chemicals that have been tested for toxicity and determined to be protective of the environment and human health. The chemicals are added to the cooling tower water circulation system in concentrations in accordance with manufacturer's recommendations to ensure that they are below toxicity thresholds as defined by each chemical's Material Safety Data Sheet. Discharge limits are administratively controlled through the National Pollutant Discharge Elimination System (NPDES) permitting process which prescribes the concentrations that can be released to surface waters.

Although Dominion has not selected which chemicals would be added to the proposed cooling towers to control water chemistry, the following are common additives which are typically used:

Biocides-

- Sodium Hypochlorite
- Sodium Bromide (in combination with Sodium Hypochlorite)
- Bromonated Hydantoins (typically 1-bromo-3-chloro-5,5,-dimethylhydantoin, but others may be used)
- Isothiazolin (typically 5-chloro-2-methyl-4-isothiazoline, but others may also be used)

Corrosion Inhibitors-

- Organic and Inorganic Phosphates
- Tolytriazole (and potentially other azoles)
- Zinc Chloride or Zinc Sulfate

Dispersants-

- Polyelectrolytes & Organophosphates

Acid-

- Sulfuric Acid

The chemicals in these potential additives would be modeled against applicable EPA human health and aquatic life criteria to demonstrate that the concentrations of these chemicals in the WHTF would not exceed the criteria, and thus would not pose any risks to human health or the environment. None of the listed additives are identified priority pollutants defined in 40CFR423 with the exception of chlorine. The Total Residual Chlorine concentration of the cooling tower blowdown would be maintained to meet permit limits. Dominion would maintain adequate flow from the lake through the discharge canal (even if the existing units are not operating) to ensure that the water quality in the WHTF would not differ significantly from water quality of the North Anna Reservoir.

Application Revision

ER Section 5.3.4 is revised to reflect this text. ER Section 5.2.2.5 is revised to provide reference to the ER Section 5.3.4 discussion.

7. Meteorology (NRC 3/2/06 Letter)

a. SSAR Section 2.3.2 and ER Section 2.7.4.1

Describe how potential increases in atmospheric moisture resulting from the operation of a wet cooling tower for proposed Unit 3 would impact onsite humidity data and provide a quantitative analysis for the potential for increased fog formation.

b. SSAR Section 2.3.2.3

Describe how potential increases in atmospheric temperature and moisture resulting from the operation of a closed-cycle dry and wet cooling tower system for proposed Unit 3 would impact plant design and operation.

c. ER Section 5.3.3.1

(1) What is the basis for the statement that "Salt deposition rates would be below the threshold value of 1 kg/ha/month beyond the site boundary at ground levels"?

(2) The supplement states: "In a COL application, when a specific reactor design is selected, a more detailed evaluation would be made of the fogging and salt deposition, and specific design consideration would be given to mitigate the effects of these phenomena or to eliminate them from occurring." Provide the detailed evaluation of fogging and salt deposition, including any assumptions necessary to perform the analysis, so that the staff can reach its conclusion on the impacts of fogging and salt deposition. Include a discussion of mitigation if necessary.

(3) What are the "industry standard techniques for limiting fogging?"

(4) What is a "reasonable level" for fogging?

d. ER Section 5.3.3.2.1

The first sentence Section 5.3.3.2.1 states: "As concluded in Section 5.3.3.1, steam fog formation, drift and steam-fog-

induced icing conditions resulting from operation of the WHTF are very localized and infrequent at the NAPS site." Provide the justification for the above statement.

7a Response

The normal atmospheric moisture content, as reflected by the relative humidity, is discussed in SSAR Section 2.3.2.2 and ER Section 2.7.4.1.4. The relative humidity that is reported is from the National Weather Service first order station at Richmond. The appropriateness of the use of Richmond data has been confirmed in a comparison of dewpoint temperatures from the North Anna site and Richmond. Over a 10 year period, the annual average dewpoint temperatures from the two locations were found to be very comparable, with the dry bulb and dewpoint temperatures for North Anna typically 1 – 2 degrees lower than the corresponding Richmond temperatures.

The operation of the wet cooling towers for Unit 3 may result in moisture deposition in the immediate vicinity of the towers due to drift and condensation of vapor near the discharge at the top of the towers. In addition, periodic fogging may occur around the towers when atmospheric conditions are so conducive. ER Section 5.3.3.2.1 provides a description of the environmental impact of the cooling towers. That evaluation includes a determination of the cooling tower induced fogging as a function of both distance from the towers and season of the year. The evaluation shows that the cooling tower induced fogging is predicted to occur an average of 70 hours per year (in addition to the naturally occurring atmospheric fog), with nearly all occurrences during the cooler seasons of the year, from late autumn through early spring. Therefore, the impact of the cooling tower induced fogging would be small.

Application Revision

SSAR Section 2.3.2.2.1 is revised to include a description of the normal relative humidity at the NAPS site. SSAR Section 2.3.2.3 has been revised to include a discussion of the impact of the operation of the wet cooling towers on the onsite atmospheric moisture.

7b Response

The warm moist air-water vapor mixture (from the wet cooling towers) and the warm dry air (from the dry towers), would tend to rise as it exits from the cooling towers. Although the prevailing winds at the site are generally not in the direction from the cooling tower area toward the plant (as contained in the ESP PPE area), there may be occasions when the wind would direct the warm air or air/vapor mixture towards the plant. Under low velocity wind conditions, the air or air/vapor mixture would tend to rise above the elevation of the plant structures as it moves

the distance from the cooling tower area to the PPE area. Under higher velocity conditions, when the air or air/vapor plume would be forced directly toward the plant, the velocity-induced turbulence would typically cause the plume to dissipate before reaching the plant. Since the specific design of the cooling towers and their exact location within the land designated for the towers has not been determined, and because the specifics of the plant design (including such details as HVAC intake locations) can not be finalized until the reactor technology has been selected and the placement and orientation of the plant(s) within the PPE has been decided, the potential impact on the design or operation of the new units will be considered as part of detailed engineering.

Application Revision

SSAR Section 2.3.2.3 is revised to clarify that the commitment to consider potential impact on the design or operation of the new units is applicable to both Unit 3 and Unit 4 cooling towers as appropriate.

7c(1) Response

The statement concerning the salt deposition rates is based on an analysis of the wet cooling towers using parameters that are bounding and fairly representative of the performance of types of tower that could be used for the new Unit 3. A full description of the analysis is provided in ER Section 5.3.3.2.1. Since the results of the analysis are more appropriately included with the discussion of the bases and methodology of the analysis, the above referenced statement concerning salt deposition rates has been deleted from Section 5.3.3.1.

Application Revision

ER Section 5.3.3.1 is revised to reflect the above response.

7c(2) Response

A full description of the analysis is provided in ER Section 5.3.3.2.1. A statement has been added to ER Section 5.3.3.1 to refer to ER Section 5.3.3.2.1.

Application Revision

ER Section 5.3.3.1 is revised to reflect the above response.

7c(3) Response

While the design of the cooling towers may include features that will limit drift and plume, specific cooling tower design selection has not yet been made. The analysis of fogging, icing, salt deposition, and plume formation, as described in

ER Section 5.3.3.2.1 is based on a bounding set of parameters. The sentence in ER Section 5.3.3.1 which says: "Industry standard techniques would be employed during final design to limit fogging to be within reasonable limits" has been deleted.

Application Revision

ER Section 5.3.3.1 is revised to reflect the above response.

7c(4) Response

See response to 7c(3).

Application Revision

ER Section 5.3.3.1 is revised to reflect the above response.

7d Response

The statement concerning steam fog formation, drift, and steam-fog-induced icing is based on general observations by plant personnel at the North Anna site under current conditions (with Units 1 and 2 operating). The above referenced statement in ER Section 5.3.3.2.1 has been retained. The statement in ER Section 5.3.3.1 has been revised to clarify that:

1. the conclusions of the infrequent and localized nature of the conditions are based on general observations, and
2. the additional heat to the WHTF from the blowdown from the Unit 3 cooling towers is negligible compared to the heat dissipation from the existing units and, therefore, would not contribute to fogging, drift, or icing conditions on and around the WHTF.

Application Revision

ER Section 5.3.3.1 is revised to reflect the above response.

8. Land Use (NRC 3/2/06 Letter)

a. SSAR Section 2.3.2.4 and ER Section 2.7.4.1.7

A sentence in the last paragraph of SSAR Section 2.3.2.4 and ER Section 2.7.4.1.7 states: "No large-scale cut and fill activities would be needed to accommodate the new units since a large portion of the area to be developed is already relatively level." Given the additional land area that the wet and dry towers for Unit 3 will use in comparison to a once through cooling system, confirm or revise the above statement.

b. ER Section 4.1

Given the change in cooling system for Unit 3, is the total land area to be used shown in Section 4.1.1.4 and Table 4.1-2 of the ESP environmental report still the same? Will the overall footprint of the cooling towers, including areas that will be cleared to support construction and laydown areas, etc., fit within the 55 acres previously identified as the cooling tower area. If not then, provide updated land use figures.

c. ER Section 5.3.3.2.2

What is the expected atmospheric temperature rise at the vegetation level at the NAPS site boundary?

8a Response

The defined ESP Plant Parameter Envelope area is relatively level and undulating surfaces in the area of the planned cooling towers would be leveled to accommodate the towers.

Application Revision

SSAR Section 2.3.2.4 and ER Section 2.7.4.1.7 are revised to better define the topography in these two areas and the necessary cut and fill activities in the cooling tower area.

8b Response

The ESP Cooling Tower area as depicted in SSAR Figure 1.2-4 and ER Figure 3.1-3 in Revision 5 of the ESP has not changed as a result of the changes described in the Supplement.

The depicted Cooling Tower area is highly dependent on the selected cooling tower design, e.g., conventional tower rows vs. a round arrangement, and each unit's cooling tower duty. For purposes of evaluating the potential environmental impacts from Unit 3 cooling, Dominion has used an upper bound estimate of land-use assuming the bounding PPE condenser duty and a conservative design consisting of single row wet type towers with full capacity cooling and horizontal, flat panel dry fin-fan towers with 1/3 capacity cooling (both towers were sized for design summer conditions). The depicted cooling tower area accommodates the bounding land use estimate. Utilization of taller alternate tower designs would allow more cooling capacity within a smaller area of the defined cooling tower area and would be considered during development of the site plan at the time of the COL application. In evaluating the environmental impacts that are affected by tower height, Dominion has used the height of the taller alternatives to ensure that the impacts are bounded.

Application Revision

None.

8c Response

The statement previously made concerning the small temperature increase around the tower was based on engineering judgment and general industry experience (as relayed by various cooling tower vendors). The statement in Section 5.3.3.2.2 has been revised to clarify that the conclusion of small and localized temperature increase is based on industry experience. In addition, the statement concerning the potential beneficial effect on vegetation in the immediate vicinity of the towers has been deleted.

Application Revision

ER Section 5.3.3.2.2 is revised to reflect the above response.

9. Construction (NRC 3/2/06 Letter)

ER Table 3.1-1 and Table 3.1-9

Confirm that the number of construction personnel (combined maximum of 5000 for two units) is the same as originally stated, the number of operating personnel is still 720 for the two new units, and that the number of additional outage personnel is still 700-1000. If these numbers have changed, provide the new values, and make adjustments to the corresponding values in all of the sections of the ER that depend on these values.

9 Response

The original estimates as reflected in ER Tables 3.1-1 and 3.1-9 have been based on a conservative set of assumptions for construction and operation of the new units (e.g., simultaneous construction activity on Units 3 and 4, no credit for offsite modular construction, full operating staffs for each of the new units in independent and simultaneous operation). The potential change in the size and complexity of the plant (at a higher power level and with cooling towers instead of once-through cooling) does not cause a change in the construction and operation personnel estimates. No changes are required to the tables in the Application.

Application Revision

None.

10. Hydrology/Water Use and Quality (NRC 3/2/06 Letter)

a. PPE Table 3.1-1 includes cooling water temperature rise. Explain why this value is relevant as a PPE value for a cooling tower design.

b. In Site Characteristics and Design Parameters Table 3.1-9, a 96 percent plant capacity factor was used to define the average evaporation rate. Explain how the average was estimated. What would be the average at 100% load factor? Justify why a load factor of 96% (and 93% for existing units) would be appropriate during critical periods (e.g. dry summers, droughts).

c. Provide a copy of Dominion's response to the questions regarding water use and quality and aquatic impacts in the Commonwealth of Virginia's January 31, 2006, letter.

d. Provide a water quality analysis in sufficient detail for the staff to establish the magnitude of potential water quality impacts and weigh the environmental effects of degradation, if any, in water quality as a result of the new cooling systems.

e. Dominion established 250 mean sea level (MSL) as the lake level setpoint for shifting between energy conservation and water conservation modes. Provide documentation of the basis for selecting this setpoint and the 7 day lag before the shift in modes is implemented. If any studies were conducted to assess the impact of increasing or decreasing this setpoint, provide a description of the studies.

f. The volume of water in Lake Anna could be reduced due to evaporation from Unit 3's wet tower. This reduction in lake volume could result in less water volume in the lake to disperse the heat from Units 1 and 2 and therefore some increase in lake temperature. This indirect increase in lake temperature would cause some increased evaporation from the lake. Provide documentation demonstrating that this indirect increase in lake temperature and evaporation is insignificant or quantify the increase in temperature and evaporation.

g. Provide an electronic copy of the analysis spreadsheet used to estimate the lake level and downstream flow impacts.

h. Quantitatively define the relationship between meteorological conditions and the percent of heat load being dissipated via dry towers in the water conservation mode.

i. SSAR Section 2.4.11.3 discusses consumption of additional water and outflow from the dam. Provide an analysis of the number of additional days of reduced downstream flow that might result from operation of Unit 3.

j. Define when the cooling system would be placed into the MWC mode (an example of the time period, "e.g., 7 days," is not sufficient).

k. Provide the maximum amount of water Unit 3 would consume when operating at the following lake levels: above 250 MSL, between 248 and 250 MSL, and below 248 MSL. Based on the above water use, evaluate the impact on lake level and downstream users.

l. Provide further analysis on Unit 3 alternative 6 (dry cooling) in light of the proposed wet and dry hybrid cooling system. Include in your analysis the environmental impacts of the efficiency penalty of dry cooling (increased fuel consumption) versus the base case of combination wet and dry cooling towers.

m. With respect to SSAR Section 2.4, the ESP application supplement changed the normal plant cooling system for proposed Unit 3 from a once-through system to a wet and dry hybrid cooling tower system.

(1) Provide a conceptual description of the hybrid cooling tower system, its interaction with safety-related components, and an assessment of the reliability of this system.

(2) Describe how the hybrid cooling towers function for the normal cooling system (NCS) for the plant, and whether or not the NCS draws water from the ultimate heat sink (UHS) underground reservoir. If so, show how the remaining volume of water in the UHS reservoir will be adequate for a 30 day cooling water supply for safety system cooling.

(3) In order to show that there is no abrupt or frequent reliance on the UHS, provide an estimate of the frequency of reliance on the UHS due to various failure modes of the hybrid NCS.

(4) Any increase of the required lake water surface elevation above 250 ft MSL would necessitate staff re-evaluation of the probable maximum flood elevation at the proposed ESP site. If the lake water surface elevation is increased above 250 ft MSL, identify the increase and provide an analysis of the probable maximum flood (PMF) for the new and increased lake level.

10a Response

The referenced PPE item, "Cooling Water Temperature Rise," is a vendor-supplied PPE value defined in the Once-Through Cooling section of PPE Table 3.3-1. It is not relevant to a plant with a cooling tower design. This section in the ESP Supplement was revised only to remove the once-through cooling operational clarification previously added (when once-through cooling was the planned method of cooling for Unit 3) and to return the description to its original PPE Table wording.

Application Revision

None.

10b Response

The average evaporation rate from the wet towers is based on the long term average water consumption for the described cooling tower operating plan and a bounding 96% plant capacity factor from the reactor vendors' input to the PPE Table. The average evaporation rate at a 100% capacity factor would be the 96% value divided by 0.96.

The average evaporation rate reflecting the bounding PPE capacity factor is the appropriate value to use in the water budget model to evaluate the long term water use impact of Unit 3. While the plant capacity factor is indicative of long term average operation, the plant would likely operate at 100% capacity on any given day when it is in operation.

Apart from the above response, it should be noted that, in order to reflect the evaporation rate contribution of 404 gpm from the Service Water System cooling tower, the average evaporation rate from all normal plant cooling wet towers is

revised from 8303 gpm to 8707 gpm. The 100% value discussed above would be 9070 gpm.

Application Revision

"Evaporation Rate" average value in "Normal Plant Heat Sink" section of ER Table 3.1-9 is revised.

10c Response

A response to the Commonwealth of Virginia's January 31, 2006 letter was provided to VDEQ on March 31, 2006. A copy of the information submitted to VDEQ was sent to the NRC on April 3, 2006.

Application Revision

None.

10d Response

Refer to Question 6c response. As noted in response to Question 6c, chemicals would be applied in small amounts to ensure that they are below toxicity thresholds as they enter the discharge canal. Further, as noted in the response provided for RAI 6c, Dominion would maintain adequate flow from the lake through the discharge canal (even if the existing units are not operating) to ensure the water quality in the WHTF would not differ significantly from water quality of the North Anna Reservoir.

Application Revision

None.

10e Response

The basis for selection of a lake level of 250 ft. MSL as the setpoint for shifting between Energy Conservation (EC) and Maximum Water Conservation (MWC) modes is that this level is the normal lake level. The normal lake level of 250 ft. MSL has been in place since Lake Anna was originally formed more than two decades ago and has been the basis for innumerable lake-related decisions (e.g., home and dock locations, as well as other improvements).

If the level of the lake can be maintained at the normal 250 ft. MSL with the higher evaporative loss from using 100% wet towers and no dry cooling, while maintaining at least 40 cfs downstream flow, then water is available to operate in the EC mode. When the level of the lake decreases below 250 ft. MSL, the

downstream discharge flow from the dam is reduced to a minimum of 40 cfs. The decrease in lake level below the 250 ft. elevation indicates that water needs to be conserved.

The seven day waiting period before switching from EC to MWC mode is an assumption of the water budget model that allows time to restore the level of the lake to 250 ft. MSL before realigning equipment for the MWC mode. A reasonable time period is necessary to allow for short term level variations that may be corrected through an intervening event (e.g., rain) or reduction of downstream discharge to a minimum of 40 cfs. This period also minimizes changes in equipment alignments and impacts on operating staff and provides planning and coordination time for communications with the transmission entity. Although a seven day waiting period was assumed for the analysis, the actual timeframe would be established with the Virginia Department of Environmental Quality (VDEQ) at the time of permitting by the Commonwealth of Virginia.

The VDEQ requested Dominion to perform additional analyses to assess the effect of changing the normal lake level and the Contingency Plan level. The Contingency Plan is initiated if the lake level is less than 248 ft. MSL, below which the minimum flow is reduced from 40 cfs to 20 cfs in 5 cfs increments per approximately 24 hours. The objective of the VDEQ staff request was to determine what variance in normal or Contingency Plan level would fully mitigate the impact of the additional consumption from a proposed Unit 3. The impact considered was the duration of time (expressed in percent) the lake was projected to be below the Contingency Plan level, and thus the downstream flow at the minimum 20 cfs. The results indicate that the normal lake level would need to be raised approximately 7 inches or the Contingency Plan level reduced about 6.5 inches to maintain the frequency at which the 20 cfs downstream flowrate occurs no more than is currently experienced with Units 1 and 2. The results of these studies were contained in a March 31, 2006 letter to the VDEQ and were provided to the NRC at the same time.

Application Revision

References to a reasonable time period before the cooling system is placed in the MWC mode as “e.g., 7 days” are deleted. The text is revised to indicate that 7 days was assumed for analysis; however, the actual timeframe will be established with VDEQ at the time of permitting. ER Sections 3.4.1.1, 5.2.1.3, and 5.2.2.4 are revised to reflect the above response.

10f Response

The reduction in lake level and lake volume due to the water consumption of the wet towers of Unit 3 would have a very small impact on the lake temperature and lake evaporation. The impact has been evaluated by considering the heat

balance of incoming energy and outgoing energy in the lake. Incoming energy includes the waste heat loading from Units 1 and 2, solar shortwave and atmospheric longwave radiation. Outgoing energy is in the form of evaporative heat loss, back radiation and conductive heat loss. The average drop in lake level due to Unit 3 has been estimated to be 0.11 ft according to the water budget model, which would result in a reduction in the lake surface area of about 40 acres. For the same meteorological condition, the incoming radiation fluxes (both shortwave and longwave) per unit lake area would remain unchanged. With a lower lake level, there would be less effective lake surface area to dissipate the same heat loading from the two existing units leading to a potential increase in the water temperature. The outgoing heat fluxes would increase in response to the water temperature increase as well. From a long-term heat balance basis, the overall impact on the lake temperature and the evaporation rate is small. The average increase in water temperature of the cooling lake due to the reduced lake level from Unit 3 has been estimated to be less than 0.1 ^{o}F. The corresponding increase in the evaporation flux from the lake has been estimated to be less than 0.2-0.4% over the effective cooling lake area. However, when considering that the effective lake area would be reduced by 40 acres, the result would be a small savings of the order of 0.1 cfs in the evaporation due to the reduction in natural evaporation loss.

Application Revision

ER Section 5.2.2.1.3 of the application is revised to state that the impact on lake temperature and evaporation due to Unit 3 would be negligible.

10g Response

An electronic copy of the water budget spreadsheet calculation was provided to NRC on March 8, 2006.

Application Revision

None.

10h Response

In the Maximum Water Conservation (MWC) mode, the dry tower would have the capacity to remove 33 percent of the design condenser heat duty at a design dry bulb temperature (DBT) of 95°F (the 0.4% exceedance DBT for the site). As the DBT decreases, the percentage of heat which can be removed by the dry tower would increase proportionately, until at some lower DBT, the dry tower will have the capability of removing the entire condenser heat duty.

Application Revision

ER Section 3.4.1.1 is revised to provide this additional detail.

10i Response

Table 5.2-3 of the ER reports the outflow frequency (percent of time) for the existing 2-unit operation and the future operating condition with the new Unit 3. Outflow frequency (versus additional days) is a more appropriate measure of the reduced downstream flow that might result from operation of Unit 3.

Application Revision

The last paragraph of SSAR Section 2.4.11.4 is revised to include a reference to ER Table 5.2-3.

10j Response

See response to question 10e.

Application Revision

References to a reasonable time period before the cooling system is placed in the MWC mode as “e.g., 7 days” are deleted. The text is revised to indicate that 7 days was assumed for analysis; however, the actual timeframe will be established with VDEQ at the time of permitting. ER Sections 3.4.1.1, 5.2.1.3, and 5.2.2.4 are revised to reflect this response.

10k Response

When the lake level is at or above 250 ft msl, Unit 3 would be operated in the Energy Conservation (EC) mode. The maximum instantaneous evaporation rate for a new unit running in EC mode would be 16,695 gpm (37.2 cfs) (ER Table 3.1-9). When lake levels fall below 250 ft msl, Unit 3 would be operated in the Maximum Water Conservation (MWC) mode. The maximum instantaneous evaporation rate for a new unit running in MWC mode would be 11,532 gpm (25.7 cfs) (ER Table 3.1-9). These maximum instantaneous evaporation rates are design values based on the maximum site ambient condition (0.4% annual exceedance). These are not appropriate values for use to represent the long-term water use in evaluating lake level and downstream flow impact as they would not be sustainable over even a short duration of time such as a day for the ESP site meteorological conditions.

Based on site meteorological data and water budget modeling, the maximum weekly evaporation rate from Unit 3 when lake level is at or above 250 ft MSL would be 34.2 cfs. When lake level is below 250 ft msl, the maximum weekly average evaporation rate from Unit 3 is estimated to be 23.4 cfs.

Application Revision

None.

10l Response

The analysis of cooling system alternatives has been revised to properly reflect the environmental impacts of the dry cooling tower system compared to the wet and dry cooling tower system. The evaluation considers the increased power consumption required to operate the dry towers, the reduction in plant efficiency, especially during periods of high ambient dry bulb temperatures, and the increased land requirement associated with the dry tower system. The revision to the analysis does not change the conclusions that, for Unit 3, the combination wet and dry cooling tower system is the preferred cooling alternative.

Application Revision

ER Section 9.4.1.1.2 and Tables 9.4-2, 9.4-3, and 9.4-6 are revised to reflect this response.

10m(1) Response

A conceptual description of the cooling system and its function as the normal cooling system is provided in the response to question 3.

The system consists of dry and wet cooling tower sections with the required piping, valves, fans, and pumps to meet the design objective of heat rejection from the station main condenser and auxiliary cooling heat exchangers. There is no interaction of the system with any safety-related system, component or structure. There are no interconnections with or reliance on any safety-related systems, including emergency cooling systems or the Ultimate Heat Sink (UHS), if a UHS is required. The cooling towers would be located such that the separation distance from safety-related structures is sufficient to preclude any physical interaction resulting from a postulated collapse of the cooling tower structure. The cooling tower system is typical for steam power plants and would be designed with sufficient margin of capacity to provide a level of reliability consistent with the requirements of power generation.

Application Revision

SSAR Section 2.4.1.1 is revised to reference the cooling system description in ER Section 3.4.1.1. SSAR Section 2.4.7.2 is revised to provide a clarifying statement that there is no system interconnection or reliance between normal and emergency cooling.

10m(2) Response

A conceptual description of the cooling system and its function as the normal cooling system is provided in the response to question 3. The source of makeup to the system is provided from Lake Anna. The system blowdown is routed to the Waste Heat Treatment Facility (WHTF) via the discharge canal. There is no reliance of the normal cooling system on the UHS, if a UHS is required, and therefore no effect on the 30 day cooling water supply for safety system cooling.

Application Revision

SSAR Section 2.4.1.1 is revised to reference the cooling system description in ER Section 3.4.1.1. SSAR Section 2.4.7.2 is revised to provide a clarifying statement that there is no system interconnection or reliance between normal and emergency cooling.

10 m(3) Response

The normal cooling system is a non-safety system for which typical failure modes for system components would include such events as fan failures and tube leaks. These types of failures affect incremental capacity of the system but would not result in a complete loss of condenser cooling or any reliance on safety systems. Additionally, adequate capacity margins in the system would ensure that these failures do not significantly affect the reliable generation of electric power. Therefore, a complete loss of normal cooling is highly unlikely, and thus there is no abrupt or frequent reliance on the UHS, if a UHS is required.

Application Revision

SSAR Section 2.4.1.1 is revised to reference the cooling system description in ER Section 3.4.1.1. SSAR Section 2.4.7.2 is revised to provide a clarifying statement that there is no system interconnection or reliance between normal and emergency cooling.

10m(4) Response

An increase of the lake water surface elevation above 250 ft. MSL is not being proposed at this time. As stated in the response to question 10e, VDEQ requested additional analyses, including raising the normal lake level to eliminate the effects of water consumption by a proposed Unit 3. Dominion does not believe that raising the normal lake level is a desirable means of fully mitigating the increase in frequency of times when the downstream flow is at a minimum of 20 cfs. The additional impacts of this solution are discussed in the response to question 16f.

Application Revision

SSAR Section 2.4.1.1 is revised to reference the cooling system description in ER Section 3.4.1.1. SSAR Section 2.4.7.2 is revised to provide a clarifying statement that there is no system interconnection or reliance between normal and emergency cooling.

11. ER-Aquatic Impacts (NRC 3/2/06 Letter)

a. Section 5.2.2.2 states that the frequency of reduced flow from the dam would increase. Provide an analysis of the impact on fish and other aquatic communities in the North Anna River downstream of the dam. Specifically, address how the reduced water flow rates would affect environmental conditions at known striped bass spawning habitat areas during the striped bass spawning season.

b. Dominion's RAI response dated April 12, 2005, stated that Dominion planned to provide assistance to aid the Virginia Department of Game and Inland Fisheries (VDGIF) in development and stocking of a more thermally tolerate species, such as a sterile white bass/striped bass hybrid. Given the change to the cooling system, does Dominion still plan to provide this assistance?

11a Response

Flow Analysis

From the perspective of potential impacts on aquatic life in the North Anna and Pamunkey rivers, the flow changes can be viewed over two time periods. The first is on an annual basis for the general aquatic communities of the rivers. The second is specifically during the period of striped bass spawning and early development, primarily in April and May, but extending through the summer for juveniles.

Dominion's flow analysis focused on two points in the river system: (1) at the dam, which is representative of the lower North Anna River, and (2) at the Hanover USGS gauging station on the Pamunkey River about 46 miles downstream from the dam and about 25 miles upstream of the Hwy 360 Bridge (which is upstream of tidal influence and representative of freshwater flows into the downstream striped bass spawning areas, although it does not include added fresh water flow from small tributaries downstream of Hanover).

The change in flow at the dam due to Unit 3 operation was calculated using the estimated weekly-average flows over the dam for two and three units for the period from October 1978 to April 2003. The period 1978-to-2003 was considered representative of flows expected in the future, including both wet and dry years. Flows in the Pamunkey River for the 3-unit operation were obtained by subtracting from the recorded flow at the Hanover gauge the estimated flow change at the dam between the existing condition and the expected future condition with Unit 3 operation. The flow values were calculated using a "running"

7-day average recorded as daily averages at the Hanover gauge, while allowing a 2 day travel time for the flow from the North Anna Dam to reach the Hanover gauge. This assumes a velocity of about 1.5 fps (feet per second) in the free-flowing North Anna River. This approach is physically reasonable and it accounts for the travel time from the dam to the gauging station, which is not accounted for by simply subtracting a daily North Anna flow change from the daily flow at the Hanover gauge.

Certain characteristics of the changes in flow at the dam between 2-unit and 3-unit operation are apparent from these calculations as illustrated in Figure 1:

- Typical reductions in North Anna River flow are in the 25 to 35 cfs (cubic feet per second) range, which is expected due to the water consumption by the wet cooling towers that reduces the amount of water being passed through the reservoir and dam;

- There are periods of zero differences between flows under two-unit and three-unit operation, which represent periods when the reservoir level is at or below elevation 250 ft, and either 20 or 40 cfs minimum-flow releases are mandated (this would have occurred approximately 35 times in the 1978-2003 period, with durations of one week to more than one year);

- There are short periods with a difference of 20 cfs, e.g., when 2-unit operation is releasing 40 cfs minimum flow, but 3-unit operation, with a lower lake level, would release 20 cfs, which would have occurred seven times in the 1978-to-2003 period, lasting one week to 3 months;

- There are periods when the 2-unit dam release is much larger (up to 550 cfs, but mostly 100 to 350 cfs) than the 3-unit release, due to the fact that runoff after a dry period fills the reservoir level to elevation 250 ft more rapidly for the 2-unit case and nearly all the river inflow is passed over the dam for a short period before the reservoir would have filled under the 3-unit scenario. Flow differences above 100 cfs would have occurred approximately 25 times in the 1978-to-2003 period, with each episode lasting a few days to two weeks.

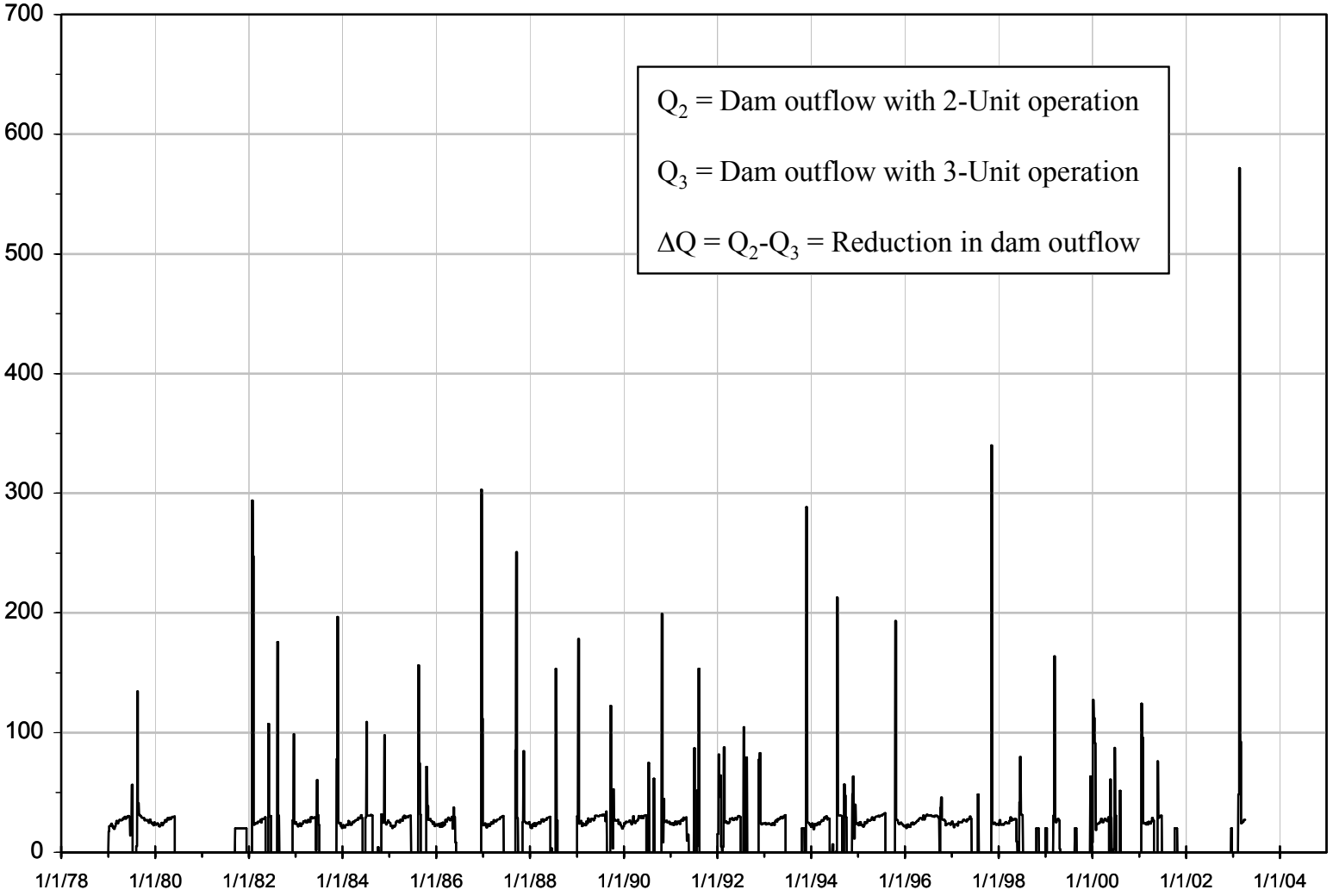


Figure 1: Flow Reduction ($\Delta Q = Q_2 - Q_3$) over Dam (from October 1978 to April 2003)

The number of days when these changed flows occur varies among years depending on the amount of rainfall or other runoff (e.g., snowmelt). For dry years, such as occurred in recent years, there is generally no change because the dam is passing the minimum flow of either 20 or 40 cfs most of the time under each scenario.

These changes in flow were compared to the actual flows from the dam with two units during the period 1978-to-2003. With many North Anna River flows in the 300-500 cfs range and peaks above 2,000 cfs, a lowered flow by 25 to 35 cfs is hardly noticeable under average to high flows.

Although there would be the same 25 to 35 cfs change in flow due to Unit 3 at the Hanover flow gauge on the Pamunkey River downstream of the confluence of the North Anna and South Anna rivers, this change is set against the Pamunkey's flows that are considerably higher than for the North Anna River. Many Pamunkey River flows are in the 1,000 to 3,000 cfs range, and peak flows rise over 6,000 cfs. Median flows in the Pamunkey at the Hanover gage are in the 500 cfs range, versus 130 cfs for the North Anna River at the Hart Corner gage about 30 miles below the Dam.

Dominion calculated the Pamunkey River flows at Hanover occurring at specific frequencies during the period of study (late 1978 to early 2003) with 2- and 3-unit operation. The results given in Tables 1 and 2 show that:

- The low frequency, low flows are affected very little at Hanover, e.g., the 5% flow drops from 80 cfs to 79 cfs, and the 10% flow from 104 cfs to 103 cfs. The 50% (median) flow drops from 535 cfs to 510 cfs, in line with the expected cooling tower consumption for the combined wet/dry towers. At higher flows the change is slightly higher, 30-35 cfs, roughly equivalent to the wet tower consumption.

- The occurrence (frequency) of low flows in the 50-150 cfs range (i.e., % of time the flow is below 50-150 cfs) is increased by 0.2 to 0.4%, while the frequency of flows below the moderate range of 200-500 cfs is increased by 0.4 to 1.3 %.

The number of days when flows would be set at the minimum flow release of 40 and 20 cfs at the Dam would increase with a third unit. Over the period October 1978 to March 2003, the minimum flow of 40 cfs would increase on average from 163 days per year to 181, an increase from about 45% of the year to about 50%. Minimum flow of 20 cfs would increase on average from 19 to 27 days per year, an increase from about 5% of the year to about 7%.

Because of interest in striped bass spawning and early life stage rearing, the Pamunkey River flows in April and May at the Hanover gauge were also analyzed for 2-unit and 3-unit operation. The results are given in Tables 3 and 4. The low flow (5% occurrence frequency, as 7-day running average) was diminished from 207 to 206 cfs (0.5 % difference), while the median flow was reduced from 851 cfs to 824 cfs (3% difference). Across all flows, the reduction in cfs ranged from 0.5 % to 5%. Mandated minimum flows of 40 or 20 cfs would be highly unlikely in April and May.

Table 1
Flows in Pamunkey River at Hanover for "Annual" Time Period

Percentiles (Non Exceedance)	Flows with 2-Unit Operation (cfs)	Flows with 3-Unit Operation (cfs)
5	80	79
10	104	103
15	131	129
20	160	157
25	196	192
30	244	236
40	353	337
50	535	510
60	729	705
70	1009	982
80	1440	1404
90	2365	2337

Table 2
Percentiles of Flows in Pamunkey River at Hanover for "Annual" Time Period

Flow (cfs)	Percentile (Non Exceedance) with 2-Unit Operation	Percentile (Non Exceedance) with 3-Unit Operation
50	0.6	0.8
75	3.8	4.1
100	9.0	9.2
150	18.4	18.8
200	25.5	25.9
300	35.4	36.5
400	42.9	44.0
500	48.1	49.4
750	60.8	61.9
1000	69.7	70.6
1500	81.0	81.4
2000	87.0	87.2

Table 3
Flows in Pamunkey River at Hanover for "April-May" Time Period

Percentiles (Non Exceedance)	Flows with 2-Unit Operation (cfs)	Flows with 3-Unit Operation (cfs)
5	207	206
10	291	276
15	355	339
20	429	408
25	493	471
30	568	545
40	699	673
50	851	824
60	1043	1014
70	1298	1262
80	1834	1806
90	2903	2874

Table 4
Percentiles of Flows in Pamunkey River at Hanover for "April-May" Time Period

Flow (cfs)	Percentile (Non Exceedance) with 2-Unit Operation	Percentile (Non Exceedance) with 3-Unit Operation
50		
75	<0.01	<0.01
100	0.38	0.40
150	2.1	2.2
200	4.5	4.7
300	10.4	11.4
400	18.2	19.2
500	25.4	26.4
750	43.7	46.2
1000	57.7	59.2
1500	74.3	74.7
2000	82.3	82.7

Biological Assessment

North Anna River

The biological communities of the North Anna River downstream of the dam are accustomed to wide variations in flows, as the patterns of flow from 1978 to 2003 show. Typically, there are high and irregular flows in spring and early summer that spill from North Anna Dam, with summer and fall periods of lower flows often sustained by releases from the dam of 40 cfs, or during extreme drought releases of 20 cfs, by the existing mandated minimum-flow releases from the dam. The spring and early summer periods of moderate to moderately high flows are often when most important biological productivity occurs (e.g., growth of benthic algae, maturation and emergence of aquatic insects, reproduction and growth of many fishes). The reductions of 25 to 35 cfs at the dam during times when more than 40 cfs is released (mostly late winter and spring, but occasionally at other times of year when runoff is high from storms) are likely of little consequence to the aquatic life of the downstream river.

The low flows of late summer and fall are often the most critical for sustaining aquatic life, when very low flows in Piedmont and Coastal Plain rivers reduce the availability of habitat for many fish and invertebrates. The mandated minimum flows from the dam at these times would continue with Unit 3 operation although their frequency would be increased somewhat (from approximately 5% to approximately 7% of the time for the 20 cfs flow, and from approximately 45% to 50% for the 40 cfs condition). The sustained flows of 40 or 20 cfs under dry conditions should continue to benefit aquatic life under Unit 3 operation. Based on USGS data for the North Anna River at Doswell, about 15 miles downstream from the dam, flows less than the 20 cfs minimum flow occurred approximately 3% of the time before the dam was built (1929-1971). Flows as low as 1cfs were measured, whereas now flows less than 20 cfs would no longer occur. Although the VDEQ notes that a summer flow in the range of 74 to 111 cfs is needed for resource protection according to the Tennant Method (letter of February 10, 2004 from E. L. Irons of VDEQ to P. Faggert of Dominion), the pre-dam river did not always attain this ideal flow during low-flow periods.

In a river as biologically diverse as the North Anna River, it is difficult to assess the effects of relatively infrequent flow reductions, as are expected under Unit 3 operation. Dominion (2005) reported 50 species of fishes collected from the North Anna River during biological surveys conducted from 1981 to 2004. A variety of habitat use specialists were represented, some of which may be expected to temporarily benefit from reductions in flow, and some temporarily disadvantaged. The Virginia Department of Game and Inland Fisheries (VDGIF) periodically surveys the North Anna River with emphasis on recreationally important largemouth and smallmouth bass populations, which it has judged to be healthy despite limited forage (Dominion 2004). Dominion's monitoring since

1987 has also focused on documenting the largemouth and smallmouth bass populations (Dominion 2004).

Intensive studies of smallmouth bass and redbreast sunfish in the North Anna River were conducted by graduate students from Virginia Polytechnic Institute and State University (Virginia Tech) during the 1990s. Studies of habitat use by the smallmouth bass population in the North Anna River downstream of the dam indicated low-velocity microhabitats found at lower flows in summer were important to the early life stages (Sabo and Orth 1994). Larvae occupied low-velocity areas with large substrate or cover after dispersal from brood sites. During the first 4-6 weeks after dispersal, juveniles continued to use relatively deep, low-velocity microhabitats. Thereafter, juveniles occupied shallower microhabitats with greater focal-point velocities. Net rate of energy gained by juvenile smallmouth bass increased as water depths decreased and average water column velocities increased (Sabo et al. 1996). In a study of diet overlap between redbreast sunfish and smallmouth bass in the North Anna River, Pert (1997) found food acquisition was not a serious problem for either species during the summers of low, stable flow. Pert (1997) also noted that the typically relatively stable streamflow and temperatures in the North Anna River (because of the minimum flow releases) create conditions considered optimal for smallmouth bass growth. Lukas (1993) found spawning habitat for smallmouth bass in the spring was not expected to be limited by flows less than 10 m^3/s (353 cfs), and the temporal pattern of stream flow fluctuations was the most important abiotic factor affecting smallmouth bass reproductive success in the North Anna River. High flows occurring during spawning caused nest abandonment, whereas stable flows promoted reproductive success. The temporal pattern of spring streamflow is determined largely by seasonal runoff from the watershed.

Given the amount of relevant, available fisheries data, the changes in hydrology expected to occur with Unit 3 operation are not expected to negatively affect the North Anna River's fish populations.

Pamunkey River at Striped Bass Spawning Sites

Striped bass spawn in the lower Pamunkey River generally from York/Pamunkey River Mile (RM) 27 (West Point) to about RM 53 (just downstream of a railroad crossing) (Grant and Olney 1991; Bilkovic et al. 2002). This is tidal fresh water, in which spawning and egg/larval development takes place at salinities of 1 part per thousand or less and in tidally alternating flows. This spawning area is downstream from the Hanover USGS gage by about 50 miles. Egg stage and larval development generally occur in the same area. Grant and Olney (1991) found larvae distributed a few miles upstream of the peak egg densities in only one year. All other studies show eggs and larvae being distributed similarly to spawning.

Spawning takes place between early April and mid May each year, apparently cued by water temperature of 12 to 19°C with peaks near 16 to 18°C as in other Chesapeake Bay tributaries (Setzler-Hamilton et al. 1980, 1981; Grant and Olney 1991; McGovern and Olney 1996). Spawning occurs upstream of the 1 part per thousand salinity level, even though this salinity moves upstream or downstream somewhat from year to year (McGovern and Olney 1996), probably in response to major changes in freshwater inflow. The location of peak spawning varied somewhat in studies by Grant and Olney 1991, McGovern and Olney 1996, and Bilkovic et al. 2002). Thus, the adult striped bass are adaptable in finding spawning locations within a general area that match environmental conditions. They likely would easily adapt to changes in freshwater inflow of 1-5%. Larval development is generally complete by the end of May (Grant and Olney 1991). The spawning and larval development periods are typically periods of spring freshet flows rather than drought conditions.

Flow velocities for maintaining striped bass eggs and larvae in suspension are generated primarily by tidal currents and not simply by freshwater inflow. The complex mixing dynamics of saline and fresh water in an estuary, often referred to as the “conveyor belt”, move eggs and larvae that settle toward the bottom in an upstream direction while freshwater inflows tend to move surface drifters downstream. Mixing of the upper and lower layers by tidal flow and ebb keeps eggs and larvae in suspension during the several days of development when only passive movements are possible. Tidal ebb and flow volumes are typically greater than freshwater inflow volumes at the striped bass spawning zones. The over-riding importance of tidal flows and well-known estuarine mixing patterns, coupled with the fact that the relative inflow reduction from a third unit is very small in April and May when striped bass eggs and larvae are suspended, indicate that water velocities would be maintained. Thus, a third unit should have no effect on egg and larvae suspension and development.

Juvenile striped bass generally rear in the estuary for their first two years, with gradual movement into Chesapeake Bay (Setzler-Hamilton et al. 1981). Juveniles typically disperse from the spawning areas into both freshwater and brackish tidal reaches of estuaries in the Chesapeake Bay region. There are anecdotal records of juvenile striped bass being caught by anglers occasionally in the non-tidal Pamunkey River upstream of the North Anna confluence (VDGIF, personal communication to W. Bolin of Dominion), but not in the North Anna River itself. Local biologists consider it highly unlikely that striped bass from the lower Pamunkey spawning grounds ascend the Fall Line (about 2 miles upstream of the confluence) to the rest of the North Anna River below the dam. With most juvenile striped bass spawned in the Pamunkey River occupying the freshwater tidal and brackish zones of the Pamunkey, Mattaponi, and York rivers, it is unlikely that small decreases in freshwater inflow from a third unit at the North Anna Power Station (1-5%) could alter their survival and well-being.

The timing and success of striped bass reproduction in the Pamunkey, as in other Chesapeake Bay tributaries, varies with environmental conditions. There was better year-class survival in the Pamunkey River when spawning temperatures were higher than when the year was cool; when the season was cool, most surviving juveniles were spawned late in the season when temperatures were warmer (McGovern and Olney 1996). The advantage was attributed to better food production. Investigators on the Pamunkey River have not considered freshwater inflow rates during striped bass spawning to be important enough to report for their surveys, although Bilkovic et al. (2002) noted that the Pamunkey River had an average discharge rate of 1,678 cfs during spawning periods. In the extreme, the amount of runoff can affect success of year classes of striped bass, for Uphoff (1989) found better striped bass recruitment in the Choptank River, Maryland when rainfall was high in April and May than when it was about half in the same period.

The Pamunkey River in the vicinity of striped bass spawning is also accustomed to wide variations of freshwater inflow during April and May, as shown by the Hanover gage data. The variations of freshwater inflow in the spawning areas are attenuated, however, by the tidal flows in the freshwater tidal reach. There are wide temperature variations and considerable variation in timing of spawning episodes in the Pamunkey River (Olney et al. 1991). Thus, it would seem reasonable that the spawning fish or their developing eggs, larvae and early juveniles would not detect the small changes in freshwater inflow caused by 25 to 35 cfs lowering of North Anna flows. The adjacent Mattaponi River, with a considerably lower springtime average flow of 961 cfs, also has excellent striped bass spawning and early life rearing (Bilkovic et al. 2002).

Food availability, among other environmental factors, has been linked in the scientific literature to striped bass survival through early life stages (Rothschild 1986; McGovern and Olney 1996). Starvation has long been considered a source of larval mortality in fishes (Cushing 1975). However, striped bass larvae are extremely voracious feeders on planktonic organisms like cladocerans and calanoid copepods (Setzler-Hamilton et al. 1981) and have been found to be highly resistant to food deprivation in the laboratory (Martin et al. 1985). McGovern and Olney (1996) state that “although some evidence of poor nutritional condition was determined for larvae collected by Setzler-Hamilton et al. (1987) in the Potomac and Choptank rivers, most studies [they cite ten references] indicated that starvation alone was not a significant mortality factor for striped bass.” In their own study, McGovern and Olney (1996) found abundant food for first-feeding larvae (12 invertebrate taxa) but that timing of microzooplankton abundance and striped bass hatch was not always in synchrony. This asynchrony was not linked to freshwater inflow (they did not consider it), but to temperature (in which warmer temperatures produced more food, faster growth, and more rapid growth beyond sizes preferred by predators).

It seems unlikely that the differences in freshwater inflow calculated during April and May due to a third unit would disrupt the food chain for striped bass larvae in a freshwater tidal system dominated by tidal flows.

Similarly, juvenile striped bass in the freshwater and brackish tidal estuary are unlikely to be food limited. Striped bass prey on early life stages of bay anchovy and Atlantic menhaden, which are abundant in the Pamunkey. The abundance of these species is of concern for predation on early life stages of striped bass (McGovern and Olney 1996). Their abundance in rearing areas for juvenile striped bass is unlikely to be influenced by the changes in freshwater inflow on the order of 1-5%, especially when the dynamics of the estuary are largely governed by tidal flows. This conclusion is bolstered by recognition that the adjacent Mattaponi River, with much lower freshwater flow than the Pamunkey, is also a major striped bass spawning river.

Conclusions

Dominion concludes that there will be indistinguishable biological impacts to the general aquatic community of the North Anna River and the striped bass spawning and early rearing areas of the Pamunkey River from changes in flows from the additional evaporative water loss from a new Unit 3 that uses evaporative wet-dry cooling towers.

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Application Revision

ER Section 5.2.2.2 is revised to reflect the above response.

11b Response

The elimination of any additional thermal impact to Lake Anna and downstream from proposed Unit 3 with a closed-cycle cooling system eliminates the need to develop and stock a more thermally tolerant species. However, Dominion remains committed to work with the state to maintain a viable and healthy habitat.

Application Revision

None.

12. ER-State Permits (NRC 3/2/06 Letter)

a. Please confirm that the concerns raised by State agencies have been resolved and that permits for consumptive water use can be obtained.

b. What is your schedule for obtaining the Coastal Zone Management Act consistency certification?

c. The Virginia Pollution Discharge Elimination System (VPDES) permits for the existing Units 1 and 2 are undergoing renewal. Because the operating limits in these permits factor into the analysis for proposed Unit 3, as necessary, update the analysis to account for any changes in the permit. Provide within 30 days of issuance of the renewed VPDES permits the updated analysis to the NRC or a justification for why the analysis is not affected.

d. Provide Clean Water Act (CWA) Section 401 certification or documentation from the Commonwealth of Virginia that Section 401 certification is not needed because Dominion will request a permit condition that will prohibit any activities that could result in discharges to navigable waters until a Section 401 certification is obtained or waived by the Commonwealth of Virginia.

12a Response

In a February 2006 conference call, VDEQ confirmed to the NRC that Dominion's cooling water approach addresses their concerns. The state's concurrence with the CZMA consistency certification would provide reasonable assurance that consumptive water use permits can be obtained. A response to the Commonwealth of Virginia's January 31, 2006 letter was provided to VDEQ on March 31, 2006. A copy of the information submitted to VDEQ was sent to the NRC on April 3, 2006.

Application Revision

None.

12b Response

A response to the Commonwealth of Virginia's January 31, 2006 letter was provided to VDEQ on March 31, 2006. A NOAA "stay of review" for the CZMA consistency concurrence review was removed March 31, 2006, with Dominion's submittal of additional analyses to VDEQ. A copy of the information submitted to VDEQ was sent to the NRC on April 3, 2006. In communications with VDEQ,

Dominion has been told that the CZMA consistency review would be scheduled for spring-to-summer 2006. See also NRC question number 10c.

Application Revision

None.

12c Response

Dominion's review of the draft renewed VPDES permit conditions for existing Units 1 & 2 has not identified any effect on the analysis for a proposed Unit 3. There are increased monitoring frequencies for some parameters at some previously included discharge points, and there are decreased monitoring frequencies for others. A copy of the final permit will be provided to the NRC when it is issued.

Application Revision

None.

12d Response

In a letter dated October 6, 2005 responding to an RAI, Dominion stated:

> A certification under section 401 of the Federal Water Pollution Control Act (FWPCA) is not appropriate at this time, because a specific scope and schedule for preconstruction activities and determination of specific activities that would result in a discharge have not been established. To address the timing of this certification, the ESP should include a condition prohibiting Dominion from conducting any pre-construction activity that would result in a discharge into navigable waters without first submitting to the NRC a Virginia Water Protection Permit (which under Virginia's State Water Control Law at Va. Code § 62.1-44.15:5(A) constitutes the certification required under FWPCA § 401) or a determination by the Virginia DEQ that no certification is required.

The Commonwealth of Virginia has agreed to provide a letter to the NRC within 30 days after Dominion submits its revised application concurring with this approach.

Application Revision

ER Section 1.2, Table 1.2-1 Federal, State, and Local Authorizations is revised to reflect the above response.

13. SSAR and ER Section 7.1 (NRC 3/2/06 Letter)

Address the following source term related issues for the ESBWR design demonstrating the reactor accident source term PPE values specified in SSAR are still appropriate and that the radiological consequence doses at the proposed ESP site would meet the requirements of 10 CFR 50.34:

a. Provide ESBWR source terms for a power level at 4590 MWt (102% of requested power level to account for uncertainty). The source terms are expressed as the timing and release rate of fission products to the environment from the proposed ESP site.

b. Describe your analysis of selected design basis accidents based on the proposed version of the ESBWR design to demonstrate compliance of the proposed ESP site with the dose consequence evaluation factors specified in 10 CFR 50.34(a)(1).

c. Provide ESBWR design-specific χ/Q values used in the ESBWR design and compare them with the site-specific χ/Q values at the proposed ESP site.

13a Response

SSAR Section 15 and ER Section 7.1 have been revised to show ESBWR source terms for all accidents having radiological consequences. The source terms at 4590 MWt are obtained from ESBWR DCD Revision 1 and increased by 25%. This margin is added because the DCD is still being reviewed by the NRC and source terms may change by the time the design is certified.

Application Revision

SSAR Section 15 and ER Section 7.1 are revised to show ESBWR source terms.

13b Response

SSAR Section 15 and ER Section 7.1 have been revised to show ESBWR doses for all accidents having radiological consequences. Reference doses are obtained from ESBWR DCD Revision 1 and adjusted to reflect site-specific χ/Q

values. Furthermore, the doses are increased by 25% as the DCD is still being reviewed by the NRC and doses may change by the time the design is certified.

Application Revision

SSAR Section 15 and ER Section 7.1 are revised to show ESBWR doses.

13c Response

SSAR Section 15 and ER Section 7.1 have been revised to show ESBWR design-specific χ/Q values from ESBWR DCD Revision 1. These design-specific χ/Q values are compared to site-specific χ/Q values to demonstrate that the site-specific χ/Q values are bounded by the design-specific χ/Q values.

Application Revision

SSAR Section 15 and ER Section 7.1 are revised to show ESBWR χ/Q values and ratios of site χ/Q values to ESBWR χ/Q values.

14. ER Section 7.2 Severe Accidents (NRC 3/2/06 Letter)

a. Include the results of a site-specific assessment of the consequences of severe accidents for air and surface water pathways based on the results of the MACCS2 computer code.

b. Provide electronic copies of input and output files for the MACCS2 code for an ESBWR at 4500 MWt.

c. For an ESBWR, provide and justify the accident release categories and the core damage frequency for each release category.

14a Response

A site-specific assessment of severe accident consequences has been calculated using the MACCS2 computer code. GE provided accident source term release fractions and their corresponding frequencies for the ESBWR. Population dose and economic cost out to a 50-mile radius from the site is provided for all severe accident categories. Analysis results for the ESBWR are included as a part of this RAI response. Analyses results for the ABWR and AP1000 were provided to NRC in Dominion letters 04-170 and 04-170A, dated May 17, 2004 and July 12, 2004, respectively.

ESBWR MACCS2 Results

The ESBWR consequences in terms of dose in sieverts and US dollars are provided below in Tables 11-1 and 11-2 for all eleven source term categories that were evaluated.

Application Revision

ER Section 7.2 is revised to reflect the above response.

Table 11-1: ESBWR Population Dose, Sieverts						Category Frequency
STC	**CASE1A 98MET**	**CASE2A 97MET**	**CASE3A 96MET**	**CASE4A 5500MWt**	**CASE5B Plume=1.0E 6W**	**Prob/yr**
BOC	9.33E+04	8.55E+04	8.77E+04	9.79E+04	8.84E+04	<1E-12
BYP	8.68E+04	7.96E+04	8.22E+04	9.11E+04	8.28E+04	4E-12
CCID	7.17E+04	6.48E+04	6.65E+04	7.16E+04	6.71E+04	2.9E-11
CCIW	1.24E+04	1.09E+04	1.18E+04	1.30E+04	1.20E+04	2.9E-10
DCH	6.29E+04	5.74E+04	5.73E+04	6.41E+04	5.76E+04	<1E-12
EVE	7.72E+04	6.90E+04	7.18E+04	7.70E+04	7.27E+04	2.5E-10
FR	3.15E+02	2.64E+02	2.98E+02	3.60E+02	3.02E+02	2.3E-10
OPVB	3.12E+04	2.83E+04	2.91E+04	3.30E+04	2.93E+04	<1E-12
OPW1	5.52E+04	5.13E+04	5.21E+04	5.73E+04	5.27E+04	<1E-12
OPW2	2.87E+04	2.68E+04	2.76E+04	2.96E+04	2.78E+04	1.4E-11
TSL	2.43E+02	2.02E+02	2.29E+02	2.73E+02	2.32E+02	2.8E-8

Table 11-2: ESBWR Offsite Cost, $						Category Frequency
STC	**CASE1A 98MET**	**CASE2A 97MET**	**CASE3A 96MET**	**CASE4A 5500MWt**	**CASE5B Plume=1.0E 6W**	**Prob/yr**
BOC	1.36E+10	1.27E+10	1.41E+10	1.63E+10	1.43E+10	<1E-12
BYP	1.34E+10	1.25E+10	1.38E+10	1.58E+10	1.41E+10	4E-12
CCID	1.51E+10	1.36E+10	1.42E+10	1.62E+10	1.44E+10	2.9E-11
CCIW	8.19E+08	6.24E+08	7.54E+08	1.06E+09	7.80E+08	2.9E-10
DCH	9.46E+09	8.50E+09	9.20E+09	1.01E+10	9.37E+09	<1E-12
EVE	1.59E+10	1.44E+10	1.50E+10	1.70E+10	1.52E+10	2.5E-10
FR	2.48E+06	1.93E+06	2.51E+06	3.25E+06	2.47E+06	2.3E-10
OPVB	4.15E+09	3.45E+09	3.95E+09	4.38E+09	4.04E+09	<1E-12
OPW1	9.13E+09	8.11E+09	8.63E+09	9.63E+09	8.74E+09	<1E-12
OPW2	4.58E+09	3.84E+09	4.25E+09	4.93E+09	4.35E+09	1.4E-11
TSL	1.64E+06	1.47E+06	1.74E+06	2.60E+06	1.68E+06	2.8E-8

14b Response

The site specific MACCS2 input and output files using the source term inventory for a ESBWR design thermal power level of 4500 MWt, and the analysis results are provided on the enclosed CD.

Application Revision

None.

14c Response

A description of the ESBWR accident release categories and their corresponding release frequencies as provided to Dominion by GE is included as part of this response.

Accident Release Categories / Release Frequencies

Shown below in Table 6-1 are descriptions of the accident release categories and their corresponding frequencies.

Application Revision

None.

Table 6-1: ESBWR Source Term Category Frequencies		
Release Category	**Summary Description**	**Release Frequency (reactor year^{-1})**
BYP	Containment is bypassed because of CIS failure with large (>12" diameter hole) opening in containment. Lower drywell debris bed covered.	<1E-12
BOC	Break outside of containment.	4E-12
CCID	Containment fails due to core concrete interaction; lower drywell debris bed uncovered.	2.9E-11
CCIW	Containment fails due to core concrete interaction; lower drywell debris bed covered.	2.9E-10
DCH	Direct containment heating (high pressure RPV failure) event damages containment	<1E-12
EVE	Ex-vessel steam explosion fails containment	2.5E-10
FR	Release through controlled (filtered) venting from suppression chamber	2.3E-10
OPVB	Containment fails due to failure of vapor suppression (vacuum breaker) function.	<1E-12
OPW1	Containment fails due to early (<24 hours) loss of containment heat removal.	<1E-12
OPW2	Containment fails due to late (>24 hours) loss of containment heat removal.	1.4E-11
TSL	Containment leakage at Technical Specification limit.	2.8E-8

15. ER-Fuel Transportation (NRC 3/2/06 Letter)

Provide an assessment of the impacts of the revised power levels on the numbers of shipments of unirradiated fuel, spent fuel, and radioactive waste and the radionuclide inventories of spent fuel assemblies.

15 Response

There were no changes to the power levels for the majority of the reactor designs used to bound the site. The only change was to the ESBWR. The power level increase, from 4000 MWth to 4500 MWth, had a small impact on the fuel transportation assessment.

The fuel assemblies for the ESBWR are similar to the assemblies for the ABWR in construction, but slightly shorter and lighter. Truck loading for shipment is constrained by the weight of the load. With the ESBWR assemblies being lighter, this allows an additional 28% of unirradiated fuel assemblies to be added to each truckload. Since the ESBWR contains approximately 30% more assemblies compared to the ABWR, the total number of unirradiated fuel shipments would increase slightly (1-2%).

The same analysis applies to spent fuel. Although the shipping cask design for the ESBWR is not yet available, it is expected that the reduced weight of the assemblies would allow additional assemblies to be loaded in each cask. The increase in total cask shipments would be expected to increase in the same amount as for unirradiated fuel.

No change is anticipated in the volume of radioactive waste produced. The level of waste generated is largely controlled by the operational practices of the licensee. The changes in the reactor design from the ABWR to the ESBWR are not anticipated to produce additional quantities of radioactive waste. In addition, the power level increase would have little impact on the amount of waste generated.

Since there is a slight additional increase in the amount of fuel loaded into the ESBWR and based on estimated inventories and activity of the spent fuel, a change in reactor power for the ESBWR would produce only a small increase in the radionuclide inventory of the spent fuel.

Application Revision

ER Section 3.8 is revised to reflect the higher ESBWR power output, a small change in the amount of uranium loaded into the core, and the change in burnup.

16. (NRC 3/2/06 Letter)

Provide justification for the sections identified as unaffected by the change to the cooling system and the increase in power level. For example, why is ER Section 7.2, Severe Accidents, not affected by the increase in power from 4300 - 4500 MWt? Examples of the sections that appear to be affected, (which are not exhaustive) are given below.

a. ER Section 1.2

ER Section 1.2 and the associated table state that a Coastal Zone Management Act (CZMA) consistency determination is not applicable. Given that Dominion has submitted its project to the Commonwealth of Virginia for a consistency determination, justify or revise the first sentence of the first paragraph, the next to last sentence of the third paragraph, and the entry in Table 1.2-1 which lists the CZMA as N/A.

b. ER Sections 2.7.4.1.4 and 2.7.4.1.6

Provide a detail discussion of onsite humidity data as a baseline input for evaluating fogging and increased humidity due to the addition of a wet cooling tower.

c. ER Section 3.6.3.3

Include a discussion of any scale or other waste from the wet cooling tower and potential wastes from cleaning the dry towers.

d. ER Section 5.3.3.1

Because of the addition of a wet cooling tower, include a discussion of humidity on site at the level of the cooling tower exit.

e. ER Section 5.8.1.2

Provide an estimate of the maximum height of trees on the site that may help block the view of new facilities from offsite locations. The location of the cooling towers needs to be clearly identified in Figure 5.8-1.

f. ER Section 5.8.2.3

Discuss the potential impacts of operating Lake Anna above the 250 MSL level.

g. ER Section 6.4.1 and SSAR Section 2.3.3

Section 6.4 of the Environmental Standard Review Plan (NUREG-1555) states that in order to provide an adequate meteorological database for evaluating the effects of plant operation, basic onsite meteorological instrumentation should include atmospheric moisture measurements at a height(s) representative of water-vapor release at sites at which large quantities of water vapor are emitted during plant operation. Likewise, SSAR Section 1.8.2 states that the SSAR conforms to Proposed Revision 1 to Regulatory Guide (RG) 1.23, "Onsite Meteorological Programs." Section C.2 of Proposed Revision 1 to RG 1.23 states "ambient moisture should be monitored at approximately 10 meters and also at a height where the measurements will represent the resultant atmospheric moisture content if cooling towers are to be used for heat dissipation." Provide the additional onsite humidity meteorological information at a height where the measurements will represent the resultant atmospheric moisture content if wet cooling towers are to be used for heat dissipation for Unit 3.

h. ER Sections 7.1.1 and 7.2

Revise these sections of the ER to make them consistent with responses to the questions 13 and 14 of this letter.

i. ER Section 7.1.2

The increase in power level for the ESBWR should result in a revision to the calculated DBA doses. The time-dependent ratios of the LPZ site-to-design certification (site/DC) X/Q values presented in ER Table 7.1-1 are based on (1) four DC 50% X/Q values that are a function of time and (2) one site 50% X/Q value that is time-independent. The ER DBA LPZ dose calculations should be based on 50% LPZ X/Q values that vary throughout the course of each design basis accident in accordance with NRC guidance (e.g., Environmental Standard Review Plan 7.1 and Regulatory Guide 1.145) and the approach used in the SSAR Chapter 15 accident analyses. Therefore, (1)

provide 50% LPZ X/Q values that vary as a function of time for AP1000, ABWR and ESBWR, (2) replace the LPZ site/DC X/Q ratios presented in Table 7.1-1 by LPZ site/DC X/Q ratios where both the DC and site LPZ X/Q values are a function of time, and (3) revise Table 7.1-2 accordingly.

j. ER Section 9.3

Justify not reevaluating the North Anna site versus the alternative sites in the light of the changes to the cooling system. Discuss the differences that the cooling system change would have on the North Anna site rating.

16a Response

ER Section 1.2 will be revised to indicate its CZMA consistency certification submittal to the Commonwealth of Virginia for concurrence review.

Application Revision

ER Section 1.2 is revised to reflect the above response.

16b Response

As noted in response to Question 7a, the normal atmospheric moisture content, as reflected by the relative humidity, is discussed in ER Section 2.7.4.1.4. The relative humidity that is reported is from the National Weather Service first order station at Richmond. The appropriateness of the use of Richmond data has been confirmed in a comparison of dewpoint temperatures from the North Anna site and Richmond. Over a 10 year period, the annual average dewpoint temperatures from the two locations were found to be very comparable, with the dry bulb and dewpoint temperatures from North Anna typically 1 – 2 degrees lower than the corresponding Richmond temperatures. ER Section 2.7.4.1.6 provides a discussion of local fogging. The closest location for which fog data is maintained is the NWS station in Richmond. The discussion in Section 2.7.4.1.6 points out that the frequency of fog conditions would be expected to be slightly different due to the proximity of the site to Lake Anna.

To further the characterization of the ESP site humidity under the current conditions, an evaluation of dewpoint depression has been performed and is reported below. The evaluation is based on NAPS site data for 3 years (1998 – 2000). The evaluation compiles the average number of hours per year that the dry bulb temperature is within 5 degrees of the dewpoint temperature as a function of season, time of day, and wind direction. This data may be useful in

providing a preliminary indication of conditions conducive to the formation of an extended visible plume or fog when wet cooling towers are in operation. The results of the dewpoint depression evaluation are presented in the following tables.

The prediction of plume and fog formation has been evaluated using the SACTI suite of programs as described in ER Section 5.3.3.2.1.

Table 1a Dewpoint Depression for NAPS site

Winter (Dec/Jan/Feb)

Number of Winter Hours Per Year that Dew-Point Depression <= 5F: 793.3

Percentage of Hours Per Winter that Dew-Point Depression <= 5F: 37%

Time of Day	Wind From → DPD <= 5 ↓	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0100	37.7	3.3	2.0	1.3	0.3	1.7	0.3	0.3	0.7	2.0	3.7	1.7	1.7	2.3	9.0	4.0	3.3
0200	43.3	4.0	3.3	2.0	0.7	0.0	1.0	1.3	2.0	2.7	1.0	4.3	2.0	4.7	8.0	2.3	4.0
0300	46.0	7.0	2.0	1.3	1.0	1.0	0.7	0.3	1.0	3.7	3.0	3.0	1.0	4.3	11.0	2.7	3.0
0400	47.0	5.7	3.0	0.3	0.7	1.0	0.3	1.0	1.3	2.7	3.7	3.0	1.3	5.0	6.3	8.7	3.0
0500	49.3	5.7	1.3	1.3	0.3	1.0	0.7	2.0	1.0	1.7	4.0	2.0	2.7	6.7	9.0	6.7	3.3
0600	52.3	4.3	4.0	2.7	0.7	1.0	0.0	2.0	0.3	3.7	4.3	2.0	2.7	7.3	10.3	4.7	2.3
0700	54.3	3.7	2.3	2.7	0.3	2.0	1.0	2.0	0.7	4.7	5.7	2.0	3.0	4.7	9.0	7.0	3.7
0800	54.0	6.0	2.0	1.3	1.3	1.7	0.0	1.3	1.7	5.0	5.0	2.0	2.3	7.0	7.0	5.7	4.7
0900	46.0	6.0	2.3	2.3	1.0	0.7	0.3	1.0	0.3	4.0	4.7	2.3	2.7	3.7	3.7	7.7	3.3
1000	33.0	5.7	2.7	2.7	1.3	1.0	1.3	0.3	1.0	4.0	2.3	2.3	1.0	0.3	1.7	3.0	2.3
1100	25.7	4.0	2.7	1.7	0.7	0.7	1.0	0.3	1.3	1.7	3.3	2.3	1.0	0.0	0.0	1.3	3.7
1200	21.0	2.0	4.3	1.0	0.7	1.3	1.0	0.7	0.0	1.3	2.0	1.0	1.3	0.0	0.7	1.7	2.0
1300	19.7	3.7	1.7	0.7	1.0	1.3	0.0	0.0	0.3	1.3	2.0	2.0	0.3	0.7	0.7	1.3	2.7
1400	17.7	3.7	1.3	1.0	1.3	0.3	0.0	0.7	0.0	0.7	2.3	1.3	0.7	0.3	0.7	1.7	1.7
1500	17.3	2.7	2.3	0.3	1.0	0.0	0.3	1.0	0.3	1.0	2.3	1.3	0.0	0.3	1.0	1.3	2.0
1600	16.3	4.0	1.7	0.7	0.3	0.3	0.7	0.3	0.3	1.0	1.3	2.0	0.3	0.0	1.7	0.7	1.0
1700	16.7	1.3	1.7	1.3	1.0	0.0	0.7	0.7	0.3	1.0	2.0	1.3	0.3	0.7	0.3	1.3	2.7
1800	18.7	2.3	2.7	1.3	0.7	0.3	0.0	1.7	0.3	1.0	2.0	1.3	0.7	1.0	0.0	1.7	1.7
1900	21.7	2.7	2.0	1.3	1.7	0.3	0.7	1.3	1.0	0.7	0.7	2.3	2.0	0.0	1.7	1.0	2.3
2000	26.3	3.0	3.0	1.3	0.7	1.7	0.3	1.0	1.0	0.7	1.7	3.0	0.7	0.7	2.0	2.7	3.0
2100	31.0	2.3	2.7	2.7	0.7	1.0	1.3	0.0	1.0	2.0	2.7	2.7	0.7	2.0	4.0	3.3	2.0
2200	31.3	3.0	2.0	1.7	1.0	1.3	0.7	1.0	0.0	1.3	3.0	2.3	1.3	1.3	6.0	2.0	3.3
2300	32.0	3.7	1.7	0.7	0.3	0.3	0.7	0.7	0.3	2.0	1.7	3.7	0.3	1.3	8.0	4.7	2.0
2400	35.0	3.7	1.0	2.3	1.0	0.3	0.0	1.3	0.0	1.7	2.7	2.3	1.7	3.3	6.0	6.0	1.7
Total	793.3	93.3	55.7	36.0	19.7	20.3	13.0	22.3	16.3	51.3	67.0	53.7	31.7	57.7	107.7	83.0	64.7

Table 1b Dewpoint Depression for NAPS site

Spring (March/April/May)

Number of Spring Hours Per Year that Dew-Point Depression <= 5F: 613.7

Percentage of Hours Per Spring that Dew-Point Depression <= 5F: 28%

Time of Day	Wind From → DPD <= 5 ↓	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0100	36.3	3.7	1.3	2.7	1.0	2.0	1.7	0.7	1.3	0.7	2.0	1.7	0.7	2.0	9.3	3.3	2.3
0200	39.3	2.7	2.0	1.7	0.7	0.7	1.3	2.3	1.0	1.7	0.7	2.0	1.3	3.0	9.3	5.7	3.3
0300	42.0	2.7	4.0	2.0	0.7	1.7	1.3	1.0	1.7	2.3	1.7	2.7	0.7	3.3	9.0	4.7	2.7
0400	46.7	1.7	4.3	2.0	1.7	0.3	2.0	1.0	1.0	3.0	3.0	2.0	1.7	4.3	8.7	7.0	3.0
0500	48.7	3.3	3.7	0.7	2.3	1.3	1.3	0.3	1.3	3.0	2.0	4.0	2.3	6.3	11.0	3.0	2.7
0600	50.3	5.3	2.3	2.0	2.0	2.7	0.7	1.0	1.0	2.0	3.0	3.0	2.0	4.7	10.7	5.3	2.7
0700	48.7	5.7	3.0	1.7	3.0	1.7	1.7	1.7	0.7	3.3	2.3	2.3	1.0	3.0	7.7	5.3	4.7
0800	37.7	5.0	3.3	0.3	3.3	2.0	2.0	0.3	0.3	2.3	2.7	1.3	0.7	1.3	2.0	6.0	4.7
0900	23.3	4.3	2.3	2.0	1.7	2.0	1.0	0.0	1.0	1.0	1.0	1.0	0.3	0.3	1.3	1.7	2.3
1000	19.3	3.3	2.0	2.0	2.0	2.7	1.0	0.3	0.0	1.0	1.3	1.0	0.0	0.0	0.0	0.7	2.0
1100	13.0	2.3	1.3	1.3	1.3	1.3	0.7	0.3	0.3	1.0	0.7	0.7	0.0	0.0	0.3	0.3	1.0
1200	12.0	2.7	2.3	1.3	1.0	1.0	0.7	1.0	0.3	0.0	0.3	0.0	0.3	0.0	0.0	0.3	0.7
1300	11.7	1.7	1.0	1.3	1.7	1.0	1.3	0.7	0.0	0.3	0.7	0.0	0.0	0.0	0.3	0.7	1.0
1400	9.7	1.7	1.3	1.3	0.3	1.0	1.3	0.7	0.0	0.0	0.3	0.3	0.0	0.0	0.3	0.3	0.7
1500	9.7	1.7	1.7	1.0	1.3	0.3	1.3	0.0	0.0	0.0	1.0	0.3	0.0	0.0	0.0	0.7	0.3
1600	10.7	2.0	1.0	2.0	0.7	1.7	0.3	0.3	0.0	0.0	0.7	0.7	0.3	0.0	0.7	0.0	0.3
1700	11.7	2.7	1.7	1.0	2.3	0.3	0.0	0.3	0.7	0.3	0.3	0.7	0.0	0.3	0.0	0.3	0.7
1800	12.3	1.7	2.0	1.7	1.7	1.0	0.0	1.0	0.3	0.0	0.3	0.3	0.3	0.3	0.7	0.0	1.0
1900	14.0	1.7	1.3	2.7	1.0	1.7	0.7	0.3	0.3	0.0	0.3	0.3	0.3	0.3	0.0	1.3	1.7
2000	15.7	1.3	2.7	2.3	1.3	1.3	1.3	0.3	0.7	0.3	0.3	0.3	0.0	0.7	0.3	0.7	1.7
2100	19.7	3.0	3.7	1.7	1.7	0.3	2.0	1.3	0.3	1.0	0.7	0.0	0.3	0.0	0.7	1.3	1.7
2200	23.7	4.0	1.3	2.3	2.3	0.7	2.3	0.7	0.3	1.3	1.0	0.3	0.7	0.0	1.0	3.0	2.3
2300	26.3	3.3	1.7	2.7	1.0	0.7	2.3	2.0	0.7	1.0	0.3	1.0	0.3	0.3	3.3	2.7	3.0
2400	31.3	4.3	1.3	2.7	1.0	1.0	0.7	1.3	1.3	1.3	1.0	0.7	1.0	0.7	6.7	3.3	3.0
Total	613.7	71.7	52.7	42.3	37.0	30.3	29.0	19.0	14.7	27.0	27.7	26.7	14.3	31.0	83.3	57.7	49.3

Table 1c Dewpoint Depression for NAPS site

Summer (Jun/Jul/Aug)

Number of Summer Hours Per Year that Dew-Point Depression <=5F: 720.3

Percentage of Hours Per Summer that Dew-Point Depression <= 5F: 33%

Time of Day	Wind From → DPD <= 5 ↓	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0100	48.0	3.3	2.0	1.3	1.0	1.3	1.0	2.3	2.7	2.3	4.7	5.7	2.7	6.0	7.3	2.7	1.7
0200	54.3	4.0	2.3	1.3	1.0	2.0	0.7	2.0	1.3	4.7	5.7	8.0	1.0	7.7	8.3	2.0	2.3
0300	59.0	4.7	3.7	2.0	1.0	1.7	0.7	0.7	1.7	7.3	5.0	7.3	2.7	8.0	7.7	1.7	3.3
0400	63.3	5.7	3.7	2.0	1.3	2.0	1.3	0.3	1.7	6.3	3.7	10.3	2.7	6.3	8.7	2.7	4.7
0500	67.7	6.7	2.7	1.7	4.3	2.0	0.3	0.3	1.0	6.3	8.3	8.0	3.7	6.7	8.0	4.7	3.0
0600	66.0	5.7	3.3	1.3	3.0	2.3	0.3	0.0	1.0	7.3	8.7	7.7	2.0	9.0	6.3	2.7	5.3
0700	54.3	6.3	3.7	1.3	3.0	2.3	0.7	1.0	0.0	6.3	6.0	8.7	2.3	3.3	3.3	2.0	4.0
0800	34.0	3.3	4.7	2.7	2.0	2.3	0.3	1.3	1.0	1.7	4.3	4.0	0.7	1.0	2.3	0.3	2.0
0900	20.7	2.0	2.0	2.7	2.3	1.3	0.3	0.3	2.0	0.3	3.7	1.0	0.3	0.7	0.3	1.0	0.3
1000	13.3	1.0	1.3	2.0	1.7	1.0	0.7	0.3	0.3	1.0	1.0	1.3	0.3	0.3	0.3	0.0	0.7
1100	8.3	0.7	2.0	0.0	0.3	1.0	1.3	0.7	0.3	0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.7
1200	7.7	1.3	1.0	0.7	0.0	1.0	0.7	1.0	0.0	0.0	0.3	0.7	0.3	0.3	0.0	0.0	0.3
1300	6.3	0.7	1.3	0.7	0.7	0.7	1.3	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.3
1400	5.0	1.3	0.3	0.0	0.3	1.3	0.3	0.7	0.0	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0
1500	5.7	1.0	1.0	0.0	0.7	1.3	0.3	0.3	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.3	0.0
1600	7.7	1.0	0.7	1.0	0.3	1.0	0.7	0.0	0.0	0.3	0.0	0.7	0.0	0.7	0.0	1.0	0.3
1700	6.7	1.0	1.0	0.3	0.7	0.7	0.7	0.0	0.7	0.0	0.7	0.3	0.0	0.0	0.3	0.0	0.3
1800	10.0	1.0	1.0	0.3	1.7	1.3	1.3	0.3	0.7	0.3	0.3	0.0	0.0	0.7	0.7	0.3	0.0
1900	12.0	0.7	1.0	1.0	1.0	2.0	0.7	1.0	0.0	0.3	1.3	0.0	1.0	0.0	0.3	0.7	1.0
2000	18.3	2.3	1.7	1.0	2.0	2.0	2.0	0.0	0.7	1.0	1.3	1.7	0.3	0.7	0.0	1.0	0.7
2100	28.7	2.7	1.7	2.3	2.3	3.3	2.0	2.0	0.7	2.0	1.3	2.0	2.0	0.7	1.7	1.0	1.0
2200	36.7	2.3	0.7	2.7	2.0	2.7	2.3	1.7	2.7	1.0	3.3	3.3	2.3	1.7	4.3	2.0	1.7
2300	41.7	2.0	2.0	3.0	0.7	1.7	2.7	1.7	0.7	3.7	3.3	5.3	1.7	4.0	4.3	4.0	1.0
2400	45.0	3.0	0.3	3.3	1.7	3.0	0.7	2.3	1.7	1.7	5.0	6.3	2.3	3.3	6.3	2.0	2.0
Total	720.3	63.7	45.0	34.7	35.0	41.3	23.3	20.3	20.7	54.7	68.0	84.0	29.0	61.0	71.0	32.0	36.7

Table 1d Dewpoint Depression for NAPS site

Fall (Sep/Oct/Nov)

Number of Fall Hours Per Year that Dew-Point Depression <= 5F: 742.3

Percentage of Hours Per Fall that Dew-Point Depression <= 5F: 34%

Time of Day	Wind From → DPD <= 5 ↓	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0100	46.0	4.3	0.7	0.3	1.0	1.7	1.3	2.0	0.7	3.0	4.7	5.3	2.7	6.0	6.0	3.0	3.3
0200	49.7	4.0	1.7	0.7	0.7	1.3	1.7	2.0	1.0	4.7	3.3	5.7	1.3	7.3	7.7	4.3	2.3
0300	53.7	4.3	1.0	1.0	1.0	1.0	1.3	2.7	1.0	3.7	5.0	5.3	2.7	11.0	5.3	4.3	3.0
0400	56.3	5.0	1.7	0.7	1.3	0.7	0.7	3.0	0.7	4.7	3.3	5.7	3.7	10.3	8.0	4.7	2.3
0500	61.0	6.7	1.0	2.3	1.3	0.7	1.0	2.7	1.0	4.3	6.0	6.0	4.7	12.0	4.3	4.3	2.7
0600	64.3	5.3	2.3	2.3	1.0	0.3	1.7	1.7	1.7	4.7	5.0	7.0	2.7	14.7	6.7	2.3	5.0
0700	62.3	4.0	3.3	0.7	2.3	0.7	1.0	1.7	2.0	4.0	7.0	6.0	2.3	13.0	7.0	3.3	4.0
0800	53.7	5.7	2.0	3.3	0.3	1.0	0.7	2.0	0.7	4.0	4.7	4.7	2.0	8.0	6.3	4.3	4.0
0900	34.3	2.0	4.3	1.3	1.7	1.3	1.7	1.7	0.7	1.7	2.7	3.0	1.3	0.7	2.7	5.0	2.7
1000	19.3	1.7	3.0	1.7	1.7	1.0	1.3	1.3	0.7	1.0	1.7	1.7	0.0	0.0	0.3	1.3	1.0
1100	13.3	1.0	2.0	0.7	1.0	1.7	0.7	1.0	0.7	1.3	0.7	0.3	0.0	0.3	0.0	0.3	1.7
1200	10.7	2.7	1.3	0.7	0.0	0.7	2.0	0.3	0.3	0.3	0.7	0.7	0.0	0.0	0.0	0.7	0.3
1300	9.7	3.0	1.3	0.3	0.3	0.0	0.7	1.3	0.3	0.3	0.7	0.3	0.0	0.0	0.0	1.0	0.0
1400	7.7	2.0	1.3	0.0	0.0	0.3	0.7	1.3	0.0	0.3	0.0	0.3	0.0	0.0	0.3	0.3	0.7
1500	7.7	2.3	1.7	0.3	0.0	0.3	1.0	0.3	0.3	0.3	0.0	0.3	0.0	0.0	0.3	0.3	0.0
1600	8.0	1.3	1.3	0.7	0.3	0.7	0.7	1.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.7	0.7
1700	8.3	1.7	1.0	0.3	0.7	0.3	0.3	1.3	0.0	0.3	0.7	0.0	0.0	0.3	0.3	0.0	1.0
1800	10.0	2.0	0.7	1.7	0.0	0.0	0.3	0.7	0.7	1.0	1.0	0.0	0.0	0.0	0.3	0.0	1.7
1900	13.3	3.3	1.0	0.7	0.0	0.7	1.0	1.7	0.3	0.7	0.7	0.3	0.7	0.3	0.7	0.7	0.7
2000	23.0	3.7	1.3	0.3	0.7	1.3	1.0	2.3	0.3	0.3	1.7	1.3	0.3	1.3	5.3	0.7	1.0
2100	29.0	3.0	2.0	0.7	1.3	1.3	1.0	1.3	0.7	1.0	1.7	2.3	0.7	3.0	5.0	1.7	2.3
2200	30.7	4.3	1.0	0.7	0.7	2.3	0.7	1.7	1.3	1.3	2.3	3.0	0.7	2.3	5.7	1.3	1.3
2300	33.7	3.0	1.3	1.0	1.3	1.7	0.0	3.0	2.0	0.7	1.7	3.0	1.3	4.0	6.7	1.3	1.7
2400	36.7	2.7	0.3	2.0	0.3	2.0	0.7	2.3	1.0	2.0	4.0	4.3	1.3	4.3	4.7	2.3	2.3
Total	742.3	79.0	38.7	24.3	19.0	23.0	23.0	40.3	18.0	45.7	59.7	66.7	28.3	99.0	83.7	48.3	45.7

Application Revision

None.

16c Response

As noted in ER Sections 3.3.2.1 and 3.4.1.3.4, chemical treatment would be provided as necessary to prevent scaling. At the time of COL application development, the water quality data defined in ER Table 2.3-13 and from additional sampling, as required, would be used in the evaluation to determine the need for antiscalants. Over a period of time, suspended solids in the cooling tower make-up water would silt in the cooling tower basin. Further, any larger debris entering the basin would be blocked by screens at the intakes for the circulating pumps. Collected solids would be handled in accordance with appropriate local regulation under "truck and haul" permitting addressed in ER Section 3.6.3.3. No other wastes are expected from the wet cooling towers. Tower construction would use material that would not have the potential for leaching of hazardous chemicals.

Periodic cleaning of the dry cooling tower heat exchangers may be required to remove any air entrained solids (e.g. dust and dirt) that are trapped within the coil array as they pass through the radiator panels. A low volume, high pressure wash, utilizing no added cleaning agents, is typically used to remove the expected minor debris. The area under the dry tower would be designed to prevent runoff of wash water to storm drains. Collected solids would be handled in accordance with appropriate local regulation under "truck and haul" permitting addressed in ER Section 3.6.3.3.

Application Revision

ER Section 5.5.1.1 is revised to address potential waste constituents in the blowdown stream. ER Section 3.6.1 is revised to clarify the possible chemical constituents of effluents.

16d Response

With the use of wet cooling towers, warm, moist air will be discharged from the top of the towers. This would tend to cause the atmosphere to be saturated in the immediate vicinity of the tower discharge. As the vapor plume mixes with the cooler surrounding air, some of the water vapor would condense and fall to the ground in the area close to the towers. The remaining water vapor would dissipate into the atmosphere. Due to the buoyancy of water vapor and the

natural movement of air (e.g., currents and breezes), the mixing of the water vapor in the plume with the atmosphere would cause any increase in the overall humidity due to the towers to be transient and very localized. The environmental impacts of the operation of the wet cooling towers (specifically, fogging, icing, salt deposition, and visible plume height and length) were evaluated using the SACTI suite of computer programs. The evaluation, including methodology, assumptions, major inputs, and results, is discussed in ER Section 5.3.3.2.1.

Application Revision

ER Section 5.3.3.1 is revised to expand the discussion of the effect of the cooling towers on the local environment and to refer to the description of the evaluation in ER Section 5.3.3.2.1.

16e Response

ER Section 5.8.1.2 addresses noise. The comment 16e is understood to be in reference to ER Section 5.8.1.5.

As noted in ER Section 5.8.1.5, except for recreational users on Lake Anna and some residents along the lake shore, the ESP site is shielded by forested land. Forested areas are composed of both deciduous and coniferous trees. In particular, the area around the cooling tower area (as defined on ER Figure 5.8-1) is shielded by mostly coniferous trees to the north in the undeveloped area north of the lake finger shown on the Figure, and a mix of coniferous and deciduous trees to the northwest, west, south, and southeast. ER Section 2.4.1, Terrestrial Ecology, provides a description of the tree varieties on the North Anna site. Note, that as defined in Table 10.1-1 of ER, a 50-100 ft band of trees will be maintained along southern edge of the construction zone. In addition to these trees, a minimum band of trees along the western EAB boundary and the coniferous trees on the northern shore of the reservoir finger directly north of the defined construction area would be maintained.

In addition to the visual shielding provided by trees, it is noted that the site grade elevation of the ESP area and cooling tower area will be lower than the terrain surrounding the site to the north, west and south. This will provide additional visual shielding.

The height of the Unit 3 wet and dry cooling towers will vary depending on the design selected for the site. Tower height could vary from approximately 45 feet for a stand-alone dry tower capable of rejecting a minimum of 1/3 of the Unit 3 condenser heat duty up to 180 feet for a hybrid wet/dry tower capable of rejecting all condenser heat during EC operation while having the capability of rejecting heat via dry cooling as well. See response to RAI Item 3 for further detail.

The cooling towers would be within the defined cooling tower area shown in ER Figures 1.2-4 and 5.8-1 and SSAR Figure 1.2-4. As the cooling tower design has not yet been defined, their specific location cannot be defined at this time.

Application Revision

ER Sections 3.1.2.2, 5.3.3.2.4 and 5.8.1.5 are revised to recognize the potential height of Unit 3 cooling towers may be up to 180 feet, depending on the cooling tower design selected.

16f Response

Dominion evaluated shoreline areas in an effort to assess, in general, various impacts of potentially raising normal operating lake level 6 inches to 12 inches above 250 ft. MSL, in the event a Virginia permitting agency process determined the need for such an action. [Note: Raising normal operating lake level is not being proposed to demonstrate site suitability. And though not currently proposed, Virginia DEQ could require an increase in lake level to mitigate impacts on down-river flows. Increasing the lake level by approximately 7 inches would eliminate changes in the frequency and duration of the 20 cfs minimum instream flow.]

Dominion's evaluations included:

- a review of the US FWS National Wetlands Inventory, and various Lake Anna topographical maps;
- a physical survey by boat of the best estimate of areas that could be impacted; and
- an aerial survey of uplake, low gradient tributaries
- select interaction with local residents

The conclusion is that a rise in water level of 6 inches to 12 inches, because of the generally steep shoreline topography, would result in minimal changes to the types and amounts of wetlands other than to shift the prevailing vegetation in gradually sloping tributaries in an upland direction.

The review of the US FWS National Wetlands inventory indicated the presence of broader wetland areas uplake, particularly in the tributary headwaters above the Route 208 Bridge.

The physical boat survey included Freshwater Creek, Contrary Creek, and the main lake channel toward the dam. The survey began below the Route 208 Bridge in Freshwater Creek. Typical vegetation included rushes and sedges with river birch grading to yellow poplar with increases in elevation. This area

represents one in which increased lake level would be most evident due to the more gradually sloping shoreline. In many of the headwater lake tributaries, a successional shift, or movement in wetland vegetation in an upland direction with forest shrub/scrub transitioning to emergents, and emergents to submersed, would be expected. These shifts would likely develop over several years and depend on conditions such as soil type, water clarity and extent of canopy cover.

Contrary Creek, although a gently sloping tributary, also had same shoreline areas with more abrupt channel bank elevations. Rushes were observed intermittently in these areas. Due to the altered shoreline in some areas, the lateral extent of flooding and resulting changes to the types and amounts of wetlands appear to be less than in the neighboring headwater, Freshwater Creek.

Additional boat surveying of the main lake channel toward the dam, both upstream and downstream, showed shoreline topography of relatively steep banks. Some of these banks were nearly vertical gradients due to the effect of wind and wave action undercutting the banks. Several points and coves on either shoreline toward the dam confirmed that a lake level rise would likely result in little lateral or upland change within these areas. Much of the main lake shoreline is more exposed to wind and wave action and would unlikely contain rooted vegetation.

Uplake, near the southern shore about one mile above the Route 208 Bridge, there is an area of cleared and gently sloping land which would not be flooded by the postulated water level increase. There appeared to be dormant water willow in a protected area adjacent to this land.

A helicopter survey of the upper lake followed the boat survey, specifically to view the low gradient tributaries in both the North Anna and Pamunkey arms. The survey confirmed that changes associated with an increased water level would be most evident in these areas and result in the likely shift of wetland vegetation in an upland direction. Beaver activity was observed throughout these upper tributaries, with their dams already acting to flood and alter the wetland landscape. A direct result of the aerial survey was an identification of about 15 areas, ranging in size of approximately one-half acre to 25 acres, which could be impacted as described.

As a result of the evaluations described above, including ground-truthing points around the lake, the conclusion is that a 6 inches to 12 inches water level increase above the normal 250 ft. MSL, depending on seasonal variation in precipitation and lake management, over time, would most likely result in little to no net loss of wetland areas impacted, with many areas remaining largely unchanged. Other areas, most notably the gradually sloping headwater

tributaries, would exhibit an upland shift in the vegetation community concurrent with any sustained increase in normal water level.

In addition to wetland impacts, raising the lake level would likely affect usage of some residential and marina boat ramps and docks, including Lake Anna State Park. These might need some modification to avoid impacting the year-round and seasonal recreational usage of the lake. Raising the lake level could also increase the potential for localized flooding with higher downstream flows.

Application Revision

ER Section 5.8.2.3 is revised to reflect the above response.

16g Response

The NAPS onsite meteorology instrumentation measures the dewpoint temperature at an elevation of 10 meters from the ground. This data was converted to relative humidity and that data was used in the evaluation of environmental impact of the operation of the wet cooling towers as described in ER Section 5.3.3.2.1. The effect of elevation on relative humidity was evaluated and it has been shown that for the small difference in height considered here (approximately 23 meters for the towers used in the evaluation vs. the 10 meter data measurement point), the difference in relative humidity is insignificant. Therefore, the data collected at 10 meters is considered to be representative of that at the height of the water vapor release with the use of wet cooling towers and no exception to Section 6.4 of NUREG 1555 or Proposed Revision 1 to Regulatory Guide 1.23 is required.

Application Revision

None.

16h Response

As indicated in the response to Question 13, ER Section 7.1 has been revised to show source terms, X/Q values, and doses specific to the ESBWR design.

As indicated in the response to Question 14, ER Section 7.2 has been revised to show severe accident consequences specific to the ESBWR design.

Application Revision

ER Sections 7.1 and 7.2 have been revised to show ESBWR-specific data.

16i Response

The increase in power level does result in a change to the calculated design basis accident doses. These changes have been reflected in revisions to Chapter 15 of the SSAR and Chapter 7.1 of the ER. However, the change in power level does not affect the methodology for calculating the X/Q. Since the X/Q values decrease with time (short-term values being greater than long-term values), it is conservative to use the highest X/Q for the duration of each accident. The 50% probability X/Q value for 0 – 2 hours post-accident, is already a small fraction of the conservative value used in the SSAR analysis. Thus, the use of this single value over the duration of the accident, while it is conservative, is not excessively conservative and provides a reasonable basis to assess the environmental impacts of the unlikely events.

Application Revision

None.

16j Response

The North Anna site was selected as the preferred ESP site based on an evaluation performed that reviewed previous nuclear industry siting information and current power plant siting approaches. The results of this evaluation are documented in a report prepared by Dominion Energy, Inc. and Bechtel Power Corporation entitled, Study of Potential Sites for the Deployment of New Nuclear Plants in the United States, dated September 2002 [North Anna Early Site Permit Application, Part 3 – Environmental Report, Section 9.3, Reference 2]. For this evaluation, four candidate sites: North Anna, Surry, Savannah River, and Portsmouth were identified as potential sites. Each site was evaluated against 45 suitability criteria that were grouped into the following four major categories: Environmental, Sociological, Engineering, and Economic (see North Anna Early Site Permit Application, Part 3 – Environmental Report, Table 9.3-2). A ranking or score was assigned for each criterion based on a common ranking scale of 1 to 5, where 1 is the lowest ranking and 5 is the highest. In addition, the relative importance of each criterion was assigned a weighting factor to reflect its importance in the calculation of a site ranking within each category. The results of the evaluation showed a narrow total score spread (i.e., ranging from 351 to 377) with the North Anna ESP site ranking highest. In addition, the evaluation results showed that all four sites were considered to be environmentally acceptable locations for additional nuclear generating units.

The revised approach for Unit 3 cooling is to utilize a closed-cycle circulating water system with a combination of wet mechanical draft and dry cooling towers. To determine if there would be any differences in the alternative site evaluation due to a change in the cooling system design, a review of the 45 suitability criteria was conducted to first identify which criteria would be affected by such a change. From this review it was determined that the rankings assigned to the affected suitability criteria were not strictly based on the use of a once-through cooling system for Unit 3 and cooling towers for Unit 4. Although Lake Anna was considered to be a viable option as a cooling water source for one unit, the study recognized that further evaluations would be needed to assess the full impact of use of the lake for additional units; thus, other cooling system design options were considered as part of the ranking assignments, including the use of wet or dry cooling towers for both units. Therefore, the possible use of cooling system options other than the once-through cooling system approach was already considered in developing the ranking assignments for the North Anna site.

The primary environmental issues raised regarding use of a once-through cooling system for Unit 3 involved water consumption from Lake Anna, and potential thermal impacts to Lake Anna, in particular to aquatic life (including the striped bass population) due to higher temperatures in the North Anna reservoir. Under the revised approach for Unit 3 cooling, there would be less water consumption from Lake Anna and significantly reduced thermal effluent discharge to the Lake. That would, in turn, lead to less thermal impacts to the striped bass population or other aquatic life, when compared to the once-through cooling option. Other environmental considerations, such as terrestrial impacts on the surrounding area from cooling tower construction (e.g., habitat relocation) and from cooling tower operation (e.g., drift, noise, and aesthetic impacts due to occasional visible plumes) were taken into consideration when developing ranking assignments for these criteria; thus, there would be no additional impacts than those previously considered due to the revised cooling system approach. Since use of alternative approaches for the cooling system design was already considered in the alternative site evaluation performed, the impact of changes to the rankings assigned is considered to be minimal. Therefore, the cooling system design change would either have no impact or would result in a slightly higher ranking assignment for some of the affected suitability criteria, such as the aquatic habitat/organisms criterion, that were evaluated to determine site suitability.

In summary, based on a review of the site study, the changes in the cooling system design would have minimal impact on the North Anna site ranking versus the alternative sites. Therefore, this design change would not affect the overall conclusion reached in the site study that there are no obviously superior sites to the North Anna ESP site.

Application Revision

ER Section 9.3.4.2 is revised to include a discussion that the cooling system design change has minimal impact on the North Anna site rankings and the conclusions reached in the alternative site evaluation.

Question 16 General Response

A comprehensive review of the application was performed to identify any additional sections that might be affected by the cooling system design or power level increase. Two sections were identified. SSAR Section 3.1.4, "Plant Appearance" and ER Section 5.8.2.3, "Impacts on Lake Anna Recreational Area" were modified to acknowledge the location of the cooling towers and the potential for visual impact.

Application Revision

SSAR Section 3.1.4 and ER Section 5.8.2.3 are revised to reflect the above response.

17. Possible Bald Eagle Nesting (NRC 3/13/06 letter)

During the course of our review, the Friends of North Anna, by letter dated August 31, 2005, gave the locations of what might be two bald eagle nesting areas within three miles of the North Anna discharge canal. Please determine whether or not these are bald eagle nesting areas in the vicinity of the North Anna site, the locations of any nests, and the effect of plant construction and operation on these nests.

17 Response

In response to a NRC follow-up inquiry about potential eagle nests sited or located around the shoreline of the plant discharge canal or the Waste Heat Treatment Facility (WHTF)(March 13, 2006), Dominion conducted both an aerial and ground-truthing survey of the area based on two sets of GPS coordinates reported from local residents. The surveyors had extensive field experience and knowledge in raptor biology. Results of the helicopter survey confirmed the presence of one nest belonging to a red-tailed hawk, not a bald eagle.

The nest was located on a point of residentially developed land along the first lagoon of the WHTF, southeast of the ESP site and with coordinates slightly different than those reported. The second set of coordinates suggested the possible presence of a second nest located in proximity to the first. However, due to the active presence of the hawk in the vicinity of the coordinates, the second set was not verified. The surveyors concluded that no active eagle nests currently exist within a few miles of the North Anna Power Station and ESP site, based in part on the confirmed sighting of the red-tailed hawk. This conclusion is supported by no known recent report of eagle nests around Lake Anna by the Virginia Department of Game & Inland Fisheries, working with the noted Center for Conservation Biology of the College of William and Mary.

From a more historic perspective, an active eagle nest was last reported in the northwest region of Lake Anna in 2002, west of Route 522. It would not be unusual to visually "spot" a bald eagle around Lake Anna's 200 plus miles of shoreline because the habitat is generally conducive to support feeding and nesting. Although nests were not seen from this survey or from recent state surveys, it is likely that the nesting location of any bald eagles being reported would be outside the primary and secondary noise buffer zones, approximately 750 feet and 1300 feet, respectively. The red-tailed hawk nest was located outside these zones. In conclusion, noise impacts to the avian habitat from construction activities at the North Anna Power Station or the ESP site would be small.

Application Revision

None.

Enclosure 2
Description of Changes in Revision 6
North Anna Early Site Permit Application

North Anna Early Site Permit Application Description of Changes in Revision 6	
Affected Section, Table, or Figure	**Reason for Change**
Part 2 Chapter 1	
▪ SSAR Section 1.2.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ SSAR 1.3.2.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ SSAR Table 1.3-1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ SSAR Table 1.9-1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
Part 2 Chapter 2	
▪ SSAR Section 2.3.2.2.1	▪ Response to question 7a of March 2, 2006 NRC letter
▪ SSAR Section 2.3.2.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 7a and 7b of March 2, 2006 NRC letter
▪ SSAR Section 2.3.2.4	▪ Response to question 8a and 8b of March 2, 2006 NRC letter
▪ SSAR Section 2.4.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 10m(1), 10m(2), 10m(3), and 10m(4) of March 2, 2006 NRC letter
▪ SSAR Section 2.4.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ SSAR Section 2.4.7.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 10m(1), 10m(2), 10m(3), and 10m(4) of March 2, 2006 NRC letter
▪ SSAR Section 2.4.7.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ SSAR Section 2.4.7.5	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ SSAR Section 2.4.8	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ SSAR Section 2.4.10	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ SSAR Section 2.4.11.1	▪ ESP Supplement Serial No. 06-010

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▪ SSAR Section 2.4.11.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ SSAR Section 2.4.11.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 10i of March 2, 2006 NRC letter
▪ SSAR Table 2.4-6	▪ ESP Supplement Serial No. 06-010 January 13, 2006
Part 2 Chapter 15	
▪ SSAR Sections 15.1, 15.2, 15.3, 15.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 131, 13b, and 13c of March 2, 2006 NRC letter
▪ SSAR Table 15.4-1	▪ Response to question 131, 13b, and 13c of March 2, 2006 NRC letter
▪ SSAR Tables 15.4-5a to 15.4-5d	▪ Response to question 13a, 13b, and 13c of March 2, 2006 NRC letter
▪ SSAR Tables 15.4-12a to 15.4-12b	▪ Response to question 13a, 13b, and 13c of March 2, 2006 NRC letter
▪ SSAR Tables 15.4-19a to 15.4-19c	▪ Response to question 13a, 13b, and 13c of March 2, 2006 NRC letter
▪ SSAR Tables 15.4-23a to 15.4-23b	▪ Response to question 13a, 13b, and 13c of March 2, 2006 NRC letter
▪ SSAR Tables 15.4-28 to 15.4-31	▪ Response to question 13a, 13b, and 13c of March 2, 2006 NRC letter
▪ SSAR Table 15.4-17	▪ Minor correction
▪ SSAR Table 15.4-19	▪ Minor correction
Part 3 Chapter 1	
▪ ER Section 1.1.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 1.1.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 1.2-1	▪ Response to question 12d of March 2, 2006 NRC letter
▪ ER Section 1.2	▪ Response to questions 12d and 16a of March 2, 2006 NRC letter

Part 3 Chapter 2	
▪ ER Section 2.3.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Figure 2.3-2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 2.3.3.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 2.4.1.8	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 4 of March 2, 2006 NRC letter
▪ ER Section 2.4 References	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 2.7.1.4	▪ Corrected number of days of fogging
▪ ER Section 2.7.4.1.6	▪ Corrected number of days of fogging
▪ ER Section 2.7.4.1.7	▪ Response to question 8a and 8b of March 2, 2006 NRC letter
Part 3 Chapter 3	
▪ ER Tables 3.3-1 and 3.3-2	▪ Response to question 1b of March 2, 2006 NRC letter
▪ ER Section 3.1.2.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.1.4	▪ Clarification for cooling towers
▪ ER Section 3.1.5	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Consistency with ER Section 5.8.1.2
▪ ER Table 3.1-1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Addition of ESBWR values ▪ Typographical error
▪ ER Table 3.1-9	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 1a of March 2, 2006 NRC letter ▪ Response to question 2a of March 2, 2006 NRC letter ▪ Response to question 10b of March 2, 2006 NRC letter ▪ Added Unit 3 Cooling Tower height
▪ ER Tables 3.1-2, 3.1-7, 3.1-8	▪ Addition of ESBWR values
▪ ER Section 3.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006

▪ ER Section 3.2.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.2.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 16e of March 2, 2006 NRC letter
▪ ER Section 3.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.3.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.3.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.3.2.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.3.2.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 3.3-1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 1b of March 2, 2006 NRC letter
▪ ER Table 3.3-2	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 1b of March 2, 2006 NRC letter
▪ ER Figure 3.3-1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Minor numerical revision
▪ ER Figure 3.3-2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.4.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 1c, 3, 10e, 10h, and 10j of March 2, 2006 NRC letter
▪ ER Section 3.4.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.4.1.3.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.4.1.3.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.4.1.3.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.4.2.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006

▪ ER Section 3.4.2.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.4.2.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Figure 3.4-3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Figure 3.4-4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Figure 3.4-7	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Figure 3.4-11 (New)	▪ Response to question 3 of March 2, 2006 NRC letter
▪ ER Section 3.6.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question16c of March 2, 2006 NRC letter
▪ ER Section 3.7.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.7.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 3.8.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 3.8-1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 15 of March 2, 2006 NRC letter
Part 3 Chapter 4	
▪ ER Section 4.1.1.6.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER 4.2.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER 4.3.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER 4.3.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER 4.3.2.1 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
Part 3 Chapter 5	
▪ ER Section 5.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 1d of March 2, 2006 NRC letter
▪ ER Section 5.1.1.1	▪ ESP Supplement Serial No. 06-010

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▪ ER Section 5.1.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 1d of March 2, 2006 NRC letter
▪ ER Section 5.2.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.2.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.2.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.2.1.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 10e and 10j of March 2, 2006 NRC letter
▪ ER Section 5.2.1.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.2-1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.2.2.1	▪ Response to question 10f of March 2, 2006 NRC letter
▪ ER Section 5.2.2.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.2.2.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.2.2.1.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 10f of March 2, 2006 NRC letter
▪ ER Table 5.2-2	▪ Minor numeric change
▪ ER Tables 5.2-3 and 5.2.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.2.2.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 11a of March 2, 2006 NRC letter
▪ ER Section 5.2.2.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.2.2.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 10e and 10j of March 2, 2006 NRC letter
▪ ER Section 5.2.2.5	▪ Response to question 6c of March 2,

	2006 NRC letter
▪ ER Section 5.2 References	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 11a of March 2, 2006 NRC letter
▪ ER Table 5.2-5	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.2-6	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.2-7	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.2-8	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Figure 5.2-2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Figure 5.2-3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.1.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.1.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.1.2.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-4 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.1.2.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.1.2.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-6	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-7	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-8 (Deleted)	▪ ESP Supplement Serial No. 06-010

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▪ ER Section 5.3.1.2.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.1.2.5 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.2.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.2.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.2.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.2.1.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.2.1.4 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.2.2.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.2.2.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.2.2.4 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.3.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 7c(1), 7c(2), 7c(3), 7c(4), 7d, and 16d of March 2, 2006 NRC letter
▪ ER Section 5.3.3.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.3.3.2.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 1e of March 2, 2006 NRC letter
▪ ER Section 5.3.3.2.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 8c of March 2, 2006 NRC letter
▪ ER Section 5.3.3.2.3	▪ Consistency with ER Section 5.8.1.2
▪ ER Section 5.3.3.2.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 16e March 2,

	2006 NRC letter
▪ ER Section 5.3.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 6c of March 2, 2006 NRC letter
▪ ER Section 5.3.4.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 6a and 6b of March 2, 2006 NRC letter
▪ ER Section 5.3.4.2	▪ Response to question 2b of March 2, 2006 NRC letter
▪ ER Section 5.3 References	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-14 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-15 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-16 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-17 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-18 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-19 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-20 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-21 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 5.3-22 through 5.3.-41 (New)	▪ Added by response to question 1e of March 2, 2006 NRC letter
▪ ER Figure 5.3-2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Figures 5.3-5 through 5.3-16 (Deleted)	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.4.2.1	▪ Addition of ESBWR values
▪ ER Section 5.4.2.1 References	▪ Minor correction
▪ ER Table 5.4-1	▪ Minor correction
▪ ER Table 5.4-3	▪ Minor correction
▪ ER Table 5.4-6	▪ Addition of ESBWR values
▪ ER Table 5.4-7	▪ Addition of ESBWR values
▪ ER Table 5.4-8	▪ Addition of ESBWR values
▪ ER Table 5.4-9	▪ Addition of ESBWR values
▪ ER Table 5.4-10	▪ Addition of ESBWR values

▪ ER Table 5.4-11	▪ Addition of ESBWR values
▪ ER Table 5.4-12	▪ Addition of ESBWR values
▪ ER Table 5.4-16	▪ Addition of ESBWR values
▪ ER Section 5.5.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.5.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 16c of March 2, 2006 NRC letter
▪ ER Section 5.5.1.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.6.1	▪ Typographical error
▪ ER Section 5.7.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.8.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 2a and 2b of March 2, 2006 NRC letter
▪ ER Section 5.8.1.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.8.1.5	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 5 and 16e of March 2, 2006 NRC letter
▪ ER Section 5.8.1.6	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 5.8.2.3	▪ Response to question 16f of March 2, 2006 NRC letter ▪ Clarification regarding cooling towers
▪ ER Table 5.10-1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Consistency with ER Section 5.3.3.1
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▪ ER Section 6.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 6.3.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 6.5.2.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 6.5.2.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
Part 3 Chapter 7	
▪ ER Section 7.1	▪ Response to question 13a, 13b,

	13c, and 16h of March 2, 2006 NRC letter
▪ ER Section 7.1.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 7.1.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 7.1 References	▪ Minor correction
▪ ER Table 7.1-1 and 7.1-2	▪ Response to question 13a, 13b, 13c, and 16h of March 2, 2006 NRC letter
▪ ER Table 7.1-6a to 7.1-6d	▪ Response to question 13a, 13b, 13c, and 16h of March 2, 2006 NRC letter
▪ ER Tables 7.1-13a to 7.1-13b	▪ Response to question 13a, 13b, 13c, and 16h of March 2, 2006 NRC letter
▪ ER Table 7.1-201 to 7.1-20c	▪ Response to question 13a, 13b, 13c, and 16h of March 2, 2006 NRC letter
▪ ER Table 7.1-24a to 7.1-24b	▪ Response to question 13a, 13b, 13c, and 16h of March 2, 2006 NRC letter
▪ ER Table 7.1-2 to 7.1-32	▪ Response to question 13a, 13b, 13c, and 16h of March 2, 2006 NRC letter
▪ ER Table 7.1-18	▪ Minor correction
▪ ER Table 7.1-20	▪ Minor correction
▪ ER Section 7.2	▪ Response to question 14a and 16h of March 2, 2006 NRC letter
Part 3 Chapter 9	
▪ ER Section 9.3.4.2	▪ Response to question 16j of March 2, 2006 NRC letter
▪ ER Section 9.4.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 9.4.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 9.4.1.1.1	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 9.4.1.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 10l of March 2, 2006 NRC letter
▪ ER Section 9.4.1.1.3	▪ ESP Supplement Serial No. 06-010

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▪ ER Section 9.4.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 9.4.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
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▪ ER Section 9.4.2.3	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 9.4.2.4	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 9.4.2.5	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 9.4-1	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Consistency with ER Section 5.8.1.2
▪ ER Table 9.4-2	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 10l of March 2, 2006 NRC letter ▪ Consistency with ER Section 5.8.1.2
▪ ER Table 9.4-3	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 10l of March 2, 2006 NRC letter
▪ ER Table 9.4-4	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Consistency with ER Section 5.8.1.2
▪ ER Table 9.4-5	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Consistency with ER Section 5.8.1.2
▪ ER Table 9.4-6	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Response to question 10l of March 2, 2006 NRC letter
▪ ER Table 9.4-9	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 9.4-10	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Table 9.4-11	▪ ESP Supplement Serial No. 06-010

	January 13, 2006
Part 3 Chapter 10	
▪ ER Table 10.1-2	▪ ESP Supplement Serial No. 06-010 January 13, 2006 ▪ Consistency with ER Section 5.3.3.1
▪ ER Section 10.2.1.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 10.2.1.6	▪ ESP Supplement Serial No. 06-010 January 13, 2006
▪ ER Section 10.3.2	▪ ESP Supplement Serial No. 06-010 January 13, 2006

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June 21, 2006

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 06-507
ESP/JDH
Docket No. 52-008

DOMINION NUCLEAR NORTH ANNA, LLC
NORTH ANNA EARLY SITE PERMIT APPLICATION
RESPONSE TO NRC QUESTIONS AND REVISION 7 TO THE NORTH ANNA ESP APPLICATION

In a May 24, 2006 letter (Serial No. 06-440), Dominion Nuclear North Anna, LLC (Dominion) submitted its responses to a May 10, 2006 NRC request for additional information, NRC comments in a May 12, 2006 site audit summary report, and follow-up telephone questions from the NRC environmental project manager related to the site audit. Those responses have been incorporated in the enclosed Revision 7 of the North Anna Early Site Permit (ESP) application.

On June 2 and 5, 2006, NRC conducted additional telephone conference calls with Dominion to further discuss the application. As a result, in a June 7, 2006 letter, NRC requested that Dominion provide information in response to five additional questions. Dominion's responses to those five questions are provided in Enclosure 1 and have also been incorporated in Revision 7 of the North Anna ESP application.

A summary of the changes in Revision 7 of the North Anna ESP application is provided as Enclosure 2. A CD containing Revision 7 of the North Anna ESP application is provided as Enclosure 3.

If you have any questions or require additional information, please contact Tony Banks at 804-273-2170 or Joe Hegner at 804-273-2770.

Very truly yours,

Eugene S. Grecheck
Vice President-Nuclear Support Services

Enclosures:

1. Response to June 7, 2006 NRC questions.
2. Summary of Changes to North Anna ESP Application Revision 7.
3. One CD-ROM labeled “North Anna Early Site Permit Application, Docket No. 52-008, September 2003; Revision 7, June 2006, NRC ADAMS Edition,” containing the following files:

001 North Anna ESP Application R7 (1 of 6).pdf; 13.5MB; publicly available
002 North Anna ESP Application R7 (2 of 6).pdf; 20,333,587 bytes, publicly available
003 North Anna ESP Application R7 (3 of 6).pdf; 49,720,156 bytes, publicly available
004 North Anna ESP Application R7 (4 of 6).pdf; 36,955,037 bytes, publicly available
005 North Anna ESP Application R7 (5 of 6.pdf; 38,933,988 bytes, publicly available
006 North Anna ESP Application R7 (6 of 6).pdf; 28,420,032 bytes, publicly available

Commitments made in this letter: None

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COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President, Nuclear Support Services, of Dominion Nuclear North Anna, LLC. He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of Dominion Nuclear North Anna, LLC, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 21st day of June, 2006.

My Commission expires: My Commission Expires July 31, 2007

Vera F. Thomas
Notary Public

(SEAL)

Enclosure 1

Response to June 7, 2006 NRC Questions

June 7, 2006 NRC Letter (General Comment)

The staff has reviewed revision 06 of the ESP application and it has discovered apparent discrepancies in the application.

It is our understanding the ER Table 3.1-1 indicates various reactor designs that were used to develop the bounding site specific plant parameter envelope (PPE) values contained in ER Table 3.1-9. The values in ER Table 3.1-1 are generic values not site specific values. Therefore, the site specific values in ER Table 3.1-9 differ from the values in ER Table 3.1-1. Likewise, ER Tables 3.1-7 and 3.1-8 provide radionuclide activity values for various designs whereas, ER Tables 5.4-6 and 5.4-7 provide bounding values for radionuclide activity.

Based on the above observations, the staff is requesting that Dominion provide responses to the following questions:

NRC Question 1 (June 7, 2006)

Clarify the purpose of the ER Tables 3.1-1, 3.1-9, 5.4-6, and 5.4-7 in ER section 3.1-3 and 3.1-6. Make consistent changes to the corresponding tables in the SSAR.

Response

The staff's understanding of the purposes of ER Tables 3.1-1 and 3.1-9 is correct. For clarification, ER Table 3.1-1 has been renamed "Generic Plant Parameters Envelope" and ER Table 3.1-9 has been renamed "Bounding Site-Specific Plant Parameters Envelope." Similarly, SSAR Table 1.3-1 has been renamed "Generic Plant Parameters Envelope" and SSAR Table 1.9-1 has been renamed "Bounding Site-Specific Plant Parameters Envelope." The text in ER Section 3.1 and SSAR Section 1.3 has been revised to further clarify the purpose of the two tables.

The radionuclide activity releases in ER Tables 5.4-6 and 5.4-7 are composite, bounding values based on multiple reactor designs. To eliminate inconsistencies, ER Tables 3.1-7 and 3.1-8 have been deleted and any references to these tables have been changed to ER Tables 5.4-6 and 5.4-7. SSAR Tables 1.3-7 and 1.3-8 have been revised to be identical to ER Tables 5.4-6 and 5.4-7.

Application Revision

The application has been revised as indicated.

NRC Question 2 (June 7, 2006)

The reference of ER Table 3.1-1 in Table 3.1-9 should be removed due to differences between the site specific and generic PPE values.

Response

The references to ER Table 3.1-1 have been removed from ER Table 3.1-9. Similarly, all references to SSAR Table 1.3-1 have been removed from SSAR Table 1.9-1.

Application Revision

The application has been revised as indicated.

NRC Question 3 (June 7, 2006)

The footnote in ER Tables 5.4-6 and 5.4-7 is misleading. Please clarify the footnote to indicate that the radionuclide values in ER Tables 5.4-6 and 5.4-7 are the bounding values for the application.

Response

The footnotes explained the differences between ER Tables 5.4-6 and 5.4-7 and corresponding ER Tables 3.1-7 and 3.1-8. Since the latter tables have been deleted (see Question 1 response), the footnotes have also been deleted. Footnotes were added to explain how ABWR and ESBWR activities were adjusted in arriving at the composite values. The only place in the ER that radionuclide release values are now presented is in Tables 5.4-6 and 5.4-7. Further, SSAR Tables 1.3-7 and 1.3-8 have been revised to be identical to ER Tables 5.4-6 and 5.4-7.

Application Revision

The application has been revised as indicated.

NRC Question 4 (June 7, 2006)

The staff has identified the following discrepancies in SSAR tables 1.3-1, 1.3-2, 1.3-7, 1.3-8, 1.9-1 and ER tables 3.1-1, 3.1-2, 3.1-7, 3.1-8, 3.1-9, 5.4-6, and 5.4-7, and the bounding notes of various tables:

a. SSAR Table 1.3-1 (Item 10) indicates that the source term is based on "Bounding Notes" or "Bound Notes" 1, 3, 4, 5 and 13 out of SSAR Table 1.3-2. SSAR Table 1.3-2 indicates that notes 1, 3, 4 and 5 reflect the designs of the AP1000, ABWR/ESBWR, PBMR, and the ACR-700, while note 13 cites the ABWR, AP1000, ACR-700 as the basis, but it excludes the PBMR design. However, ER Table 3.1-2 redefines note 13 as being comprised of the ABWR, AP1000, ACR-700, and the ESBWR designs.

b. SSAR Table 1.3-7 indicates that its footnotes refer to the ACR-700, ABWR, and AP1000 designs. However, ER Table 3.1-7 indicates that the basis for the source term is different as it refers to the ACR-700, ESBWR with a 25% margin, ABWR, and the AP1000 designs.

c. ER Table 3.1-9 indicates that the basis of the liquid effluent source term is ER Table 3.1-1 (Item 10) and ER Table 5.4-6. However, the source term in ER Table 5.4-6 has been maximized and is higher than that given in SSAR Table 1.3-7 and ER Table 3.1-7 supporting the use of the PPE concept.

d. There are inconsistent values of liquid effluent source term radioactivity levels (by radionuclides and as totals) among SSAR and ER Tables 1.3-7, 3.1-7, and 5.4-6, with some radionuclides being excluded, e.g., Zn-69m, Br-83, Ru-105, Ba-139, and La-142 from SSAR Table 1.3-7. Also, some activity levels cited in SSAR Table 1.3-7 and ER Table 3.1-7 seems to be inconsistent with those given in Tables 1.3-1 and 3.1-1.

e. ER Table 3.1-1 provides a link to the various reactor designs from which the bounding values in ER Table 3.1-9 are derived. ER Table 3.1-9 contains the site specific bounding values (or PPE values) that the reactor design selected at the COL stage must fit within. Please explain this discrepancy or clarify the titles of ER Table 3.1-1 and ER Table 3.1-9 to remove the confusion.

The above examples are based on using ER Table 5.4-6 for liquid effluents, similar discrepancies were also noted using ER Table 5.4-7 for gaseous effluents. Dominion should review the application for inconsistencies/discrepancies elsewhere in the application and provide the corrected information in revision 07 of the application.

Response

Changes have been made to SSAR Section 1.3 and ER Section 3.1 to remove inconsistencies. Specific comments are addressed below.

a. Bounding Notes 12 and 13 in SSAR Table 1.3-2 have been revised to include the ESBWR in the list of designs considered for source terms, consistent with Notes 12 and 13 of ER Table 3.1-2.
b. ER Tables 3.1-7 and 3.1-8 have been deleted (see Question 1 response) with the references to these tables replaced by references to ER Tables 5.4-6 and 5.4-7. SSAR Tables 1.3-7 and 1.3-8 have been revised to be identical to ER Tables 5.4-6 and 5.4-7, thereby eliminating inconsistencies.
c. The references to ER Table 3.1-1 have been deleted from ER Table 3.1-9. Now ER Tables 3.1-1 and 3.1-9 refer to ER Table 5.4-6 for the liquid source terms. The section on gaseous source terms has been similarly revised.
d. See Response b above.
e. ER Table 3.1-1 has been renamed “Generic Plant Parameters Envelope” and ER Table 3.1-9 has been renamed “Bounding Site-Specific Plant Parameters Envelope.” The text in ER Section 3.1 has been revised to further clarify the purposes of the two tables. The SSAR has been similarly revised.

The application has been reviewed for inconsistencies/discrepancies. This resulted in a change in text from a prior revision, eliminating differences in tables, and correcting a typographical and a grammatical error. A summary of the changes is provided in Enclosure 2 which identifies where a response to the June 7, 2006 RAIs has resulted in a change to the application.

Application Revision

The application has been revised as indicated.

NRC Question 5 (June 7, 2006)

Provide a conversion for liquid and gaseous effluents releases (from Ci/yr to µCi/ml) that meets the requirements of 10CFR Part 20, Appendix B, Table 2, Columns 1 and 2 (e.g., refer to ESBWR DCD Revision 1, Tier 2, Table 12.2-17 and 12.2-19b). The derivation of effluent concentrations (µCi/ml) should be based on the source terms (Ci/yr) presented in ER Tables 5.4-6 and 5.4-7 using North Anna specific data. Dominion should include this information in the SSAR.

Response

ER Tables 5.4-6 and 5.4-7 have been revised to show five columns of information: (1) isotope name, (2) activity release (Ci/yr), (3) effluent concentration (µCi/ml), (4) 10 CFR 20 effluent concentration limit (ECL) (µCi/ml), and (5) fraction of ECL. ER Section 5.4.2 has been revised to briefly explain how the effluent concentrations are calculated. SSAR Tables 1.3-7 and 1.3-8 have been revised to be identical to ER Tables 5.4-6 and 5.4-7. SSAR Section 1.3.1 has been revised to briefly explain how the effluent concentrations are calculated.

Application Revision

The application has been revised as indicated.

Enclosure 2

Summary of Changes to North Anna ESP Application Revision 7

Summary of Changes to North Anna ESP Application Revision 7	
Affected Section, Table, or Figure	**Reason for Change**
Part 2 Chapter 1	
▪ Section 1.3.1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 1.3.3	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 1.3 References	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 1.3-1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 1.3-2	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 1.3-7	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 1.3-8	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 1.9	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 1.9-1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
Part 2 Chapter 2	
▪ Section 2.5.4.2.2	▪ Corrected typographical error
Part 2 Chapter 15	
• Section 15.4	• Dominion letter (Serial No. 06-440), dated May 24, 2006
• Table 15.4-1	• Dominion letter (Serial No. 06-440), dated May 24, 2006
• Table 15.4-5a	• Dominion letter (Serial No. 06-440), dated May 24, 2006
• Table 15.4-5b	• Dominion letter (Serial No. 06-440), dated May 24, 2006
• Table 15.4-5d	• Dominion letter (Serial No. 06-440), dated May 24, 2006
• Table 15.4-12b	• Dominion letter (Serial No. 06-440), dated May 24, 2006

• Table 15.4-19b	• Dominion letter (Serial No. 06-440), dated May 24, 2006
• Table 15.4-19c	• Dominion letter (Serial No. 06-440), dated May 24, 2006
• Table 15.4-23b	• Dominion letter (Serial No. 06-440), dated May 24, 2006
• Table 15.4-28	• Dominion letter (Serial No. 06-440), dated May 24, 2006
• Table 15.4-29	• Dominion letter (Serial No. 06-440), dated May 24, 2006
• Table 15.4-31	• Dominion letter (Serial No. 06-440), dated May 24, 2006
Part 3 Chapter 2	
▪ Section 2.7.5.1	▪ Corrected grammatical error
▪ Table 2.7-20	▪ Removed text leftover from previous revision
Part 3 Chapter 3	
▪ Section 3.1.3	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 3.1.6	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 3.1-1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 3.1-2	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 3.1-7	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 3.1-8	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 3.1-9	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 3.2	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 3.3	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 3.3.1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 3.3-1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 3.3-2	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006

▪ Section 3.4.1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 3.4.1.1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 3.4.1.2	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 3.4.2	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Section 3.5	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
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▪ Section 5.3.3.2.4	▪ Dominion letter (Serial No. 06-440), dated May 24, 2006
▪ Section 5.4.2.1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
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▪ Table 5.4.7	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
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▪ Section 5.8.1.2	▪ Dominion letter (Serial No. 06-440), dated May 24, 2006

▪ Section 5.8.1.5	▪ Dominion letter (Serial No. 06-440), dated May 24, 2006
Part 3 Chapter 6	
▪ Section 6.4.1.1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
Part 3 Chapter 7	
▪ Section 7.1.4	▪ Dominion letter (Serial No. 06-440), dated May 24, 2006
▪ Table 7.1-2	▪ Dominion letter (Serial No. 06-440), dated May 24, 2006
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Part 3 Chapter 9	
▪ Section 9.3.3.4.1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 9.4-1	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006
▪ Table 9.4-5	▪ Dominion letter (Serial No. 06-507), dated June 21, 2006



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North Anna Early Site Permit Application

June 2006

Revision 7

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Part 4: Programs and Plans

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Acronyms/Abbreviations/Initialisms

ABWR	Advanced BWR
ANS	Alert and Notification System
ANSI	American National Standards Institute
AQCR	Air Quality Control Region
ASCE	American Society of Civil Engineers
BWR	Boiling Water Reactor
CDWMDCT	Combination Dry and Wet Mechanical Draft Cooling Tower
CEDE	Committed Effective Dose Equivalent
CEQ	Council of Environmental Quality
CEUS	Central and Eastern United States
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
Ci	Curies
cm	Centimeter
COL	Combined License
CVSZ	Central Virginia Seismic Zone
CWA	Clean Water Act
CWIS	Cooling Water Intake System
dBA	decibels (A scale)
DBA	Design Basis Accident
DBT	Dry Bulb Temperature
DDE	Deep Dose Equivalent
DEI	Dominion Energy, Inc.
DEM	Virginia Department of Emergency Management
DHS	United States Department of Homeland Security
DNAG	Decade of North American Geology
DNP	Dominion Nuclear Projects, Inc.
DOE	United States Department of Energy
DRI	Dominion Resources, Inc.
EAB	Exclusion Area Boundary
EAC	Evacuation Assembly Center
EAL	Emergency Action Level
EAS	Emergency Alert System
EC	Energy Conservation
ECL	Effluent Concentration Limit
ECFS	East Coast Fault System
EDS	Engineering Design Spectrum
EI	Exposure Index
EMI	Emergency Management Institute
EOC	Emergency Operations Center
EOF	Emergency Operations Facility
EPA	United States Environmental Protection Agency
EPRI	Electric Power Research Institute

Acronyms/Abbreviations/Initialisms

EPZ	Emergency Planning Zone
ERDS	Emergency Response Data System
ERO	Emergency Response Organization
ESBWR	Economic Simplified BWR
ESF	Engineered Safety Features
ESP	Early Site Permit
ETE	Evacuation time estimate
FCO	Federal Coordinating Officer
FES	Final Environmental Statements
FOSID	Frequency of Onset of Significant Inelastic Deformation
fps	Feet per Second
FRERP	Federal Radiological Emergency Response Plan
FRMAC	Federal Radiological Monitoring and Assessment Center
FRP	Federal Response Plan
GEIS	Generic Impact Environmental Statement
gpd	Gallons per Day
gpm	Gallons per Minute
GSA	Geological Society of America
GT-MHR	Gas Turbine Modular Helium Reactor
HMR	Hydro-Meteorological Report
IHA	Indicators of Hydrologic Alteration
INPO	Institute of Nuclear Power Operations
IPZ	Ingestion Exposure Pathway Emergency Planning Zone
IRIS	International Reactor Innovative and Secure
ISFSI	Independent Spent Fuel Storage Installation
LCD	Local Climatological Data
LOCA	Loss-of-Coolant Accident
LOS	Level of Service
LPGS	Liquid Pathway Generic Study
LPZ	Low Population Zone
LV5	Landview 5
LWR	Light-Water-Cooled Reactor
MCV	Medical College of Virginia
MDCT	Mechanical Draft Wet Cooling Tower
MEI	Maximally Exposed Individual
mg/kg	Milligrams Per Kilogram
mgpd	Million Gallons per Day
MMMD	Mean Maximum Mixing Height Depth
mph	Miles per Hour
MSA	Metropolitan Statistical Area
msl	Mean Sea Level
MT	Metric Tons
MTU	Metric Tons Uranium

Acronyms/Abbreviations/Initialisms

MW	Megawatts
MWC	Maximum Water Conservation
MWd	Megawatt Days
NAAQS	National Ambient Air Quality Standards
NAEP	North Anna Power Station Emergency Plan
NANIC	North Anna Nuclear Information Center
NAPS	North Anna Power Station
NCDC	National Climatic Data Center
NDCT	Natural Draft Cooling Tower
NEI	Nuclear Energy Institute
NEP	Nuclear Emergency Preparedness
NEPA	National Environmental Policy Act
NESDIS	National Environmental Satellite, Data and Information Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPSEPT	Nuclear Power Station Emergency Preparedness Training
NRC	United States Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NRP	National Response Plan
NWS	National Weather Service
OBE	Operating Basis Earthquake
ODEC	Old Dominion Electric Cooperative
OOM	Order-of-Magnitude
OSC	Operational Support Center (Onsite Operations Assembly Area)
OT	Once-Through
OTHT	Once-Through and Helper Tower
PAZ	Protective Action Zone
PBMR	Pebble Bed Modular Reactor
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PPE	Plant Parameter Envelope
ppm	Parts Per Million
PSHA	Probabilistic Seismic Hazards Analysis
PWR	Pressurized Water Reactor
RAA	Remote Assembly Area
RAP	Radiological Assistance Program
RERP	Radiological Emergency Response Plan
RG	Regulatory Guide
ROI	Region of Interest
RP	Reference Probability
RVA	Range of Variability Approach
SAMA	Severe Accident Mitigation Alternatives
SCC	State Corporation Commission

Acronyms/Abbreviations/Initialisms

SCDF	Seismic Core Damage Frequency
SCR	Stable Continental Regions
SDS	Seismological Design Spectra
SDWIS	Safe Drinking Water Information System
SEIS	Supplemental Environmental Impact Statement
SF	Scale Factor
SHPO	State Historic Preservation Officer
SIR	Settlement Improvement Ratio
SPRA	Seismic Probabilistic Risk Assessment
SRP	Standard Review Plan
SSAR	Site Safety Analysis Report
SSCs	Structures, Systems, and Components
SSE	Safe Shutdown Earthquake
SWPPP	Storm Water Pollution Prevention Plan
SWR	Service Water Reservoir
SWU	Separative Work Units
TEDE	Total Effective Dose Equivalent
TSC	Technical Support Center
UFSAR	Updated Final Safety Analysis Report
UHS	Ultimate Heat Sink
UHS	Uniform Hazard Spectrum
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VCU	Virginia Commonwealth University
VDCR	Virginia Department of Conservation and Recreation
VDEQ	Virginia Department of Environmental Quality
VDGIF	Virginia Department of Game and Inland Fisheries
VDH	Virginia Department of Health
VDHR	Virginia Division of Historic Resources
VDOT	Virginia Department of Transportation
VEC	Virginia Employment Commission
V/H	Vertical-to-Horizontal
VMRC	Virginia Marine Resource Commission
VPDES	Virginia Pollutant Discharge Elimination System
VSP	Commonwealth of Virginia State Police
WHTF	Waste Heat Treatment Facility

Changed Pages

Pages changed/added after initial publication (Revision 0) are listed here.

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1	October 2003	Cover, xxiii-xxxii, xxxvii, 2-2-114, 2-2-171, 3-2-21, 3-2-55
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PART 1 - ADMINISTRATIVE INFORMATION
Contents

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PART 1: ADMINISTRATIVE INFORMATION

Chapter 1 Introduction

Dominion Nuclear North Anna, LLC ("Dominion") submits this application for an early site permit (ESP) to the U.S. Nuclear Regulatory Commission (NRC) in accordance with the requirements of Title 10 of the Code of Federal Regulations, Part 52, (10 CFR 52) Subpart A, Early Site Permits. Dominion requests that the NRC issue an ESP to Dominion having a duration of twenty years for the site described herein. The information in this application has been developed to support the issuance of that permit.

The site selected for the ESP is a parcel of land on the North Anna Power Station (NAPS) site in Louisa County, Virginia, approximately 40 miles north-northwest of Richmond, Virginia. Other, existing nuclear facilities licensed by the NRC are located on the NAPS site. Those other facilities are NAPS Units 1 and 2 (Docket Nos. 50-338/339; NRC Facility Operating License Nos. NPF-4/7) and the North Anna Independent Spent Fuel Storage Installation (ISFSI) (NRC Docket No. 72-16; Materials License No. SNM-2507). NAPS Units 1 and 2 have been producing electricity for customers since 1978 and 1980, respectively. The site selected for the ESP, called the ESP site, is located within the NAPS site. It is adjacent to and generally west of the existing units and is illustrated in Figure 1.0-1.

The NAPS site, which includes the existing facilities and the ESP site, is owned by Virginia Electric and Power Company (Virginia Power) and Old Dominion Electric Cooperative (ODEC), as tenants in common. Virginia Power is the licensed operator of the existing facilities, with control of the existing facilities and the authority to act as ODEC's agent. Virginia Power supports this application.

Both Virginia Power and Dominion are direct and indirect wholly-owned subsidiaries, respectively, of Dominion Resources, Inc. (DRI). If Dominion decides to proceed with the development of new nuclear units on the ESP site, it would enter into and obtain, to the extent necessary, appropriate state public utility commission approval(s) of an agreement to purchase or lease the ESP site. Similarly, if Dominion decides to conduct any pre-construction activities authorized by the ESP pursuant to 10 CFR 52.17(c), it would enter into and obtain, to the extent necessary, appropriate state public utility commission approval(s) of site redress or related agreement(s) with Virginia Power, before conducting the activities. The agreement would authorize Dominion to conduct the pre-construction activities and confirm Dominion's obligation to perform any site redress as may be required pursuant to the site redress plan approved by the NRC. Dominion's site redress obligation would be supported by a guaranty provided by its ultimate parent, DRI (see Part 4, Programs and Plans).

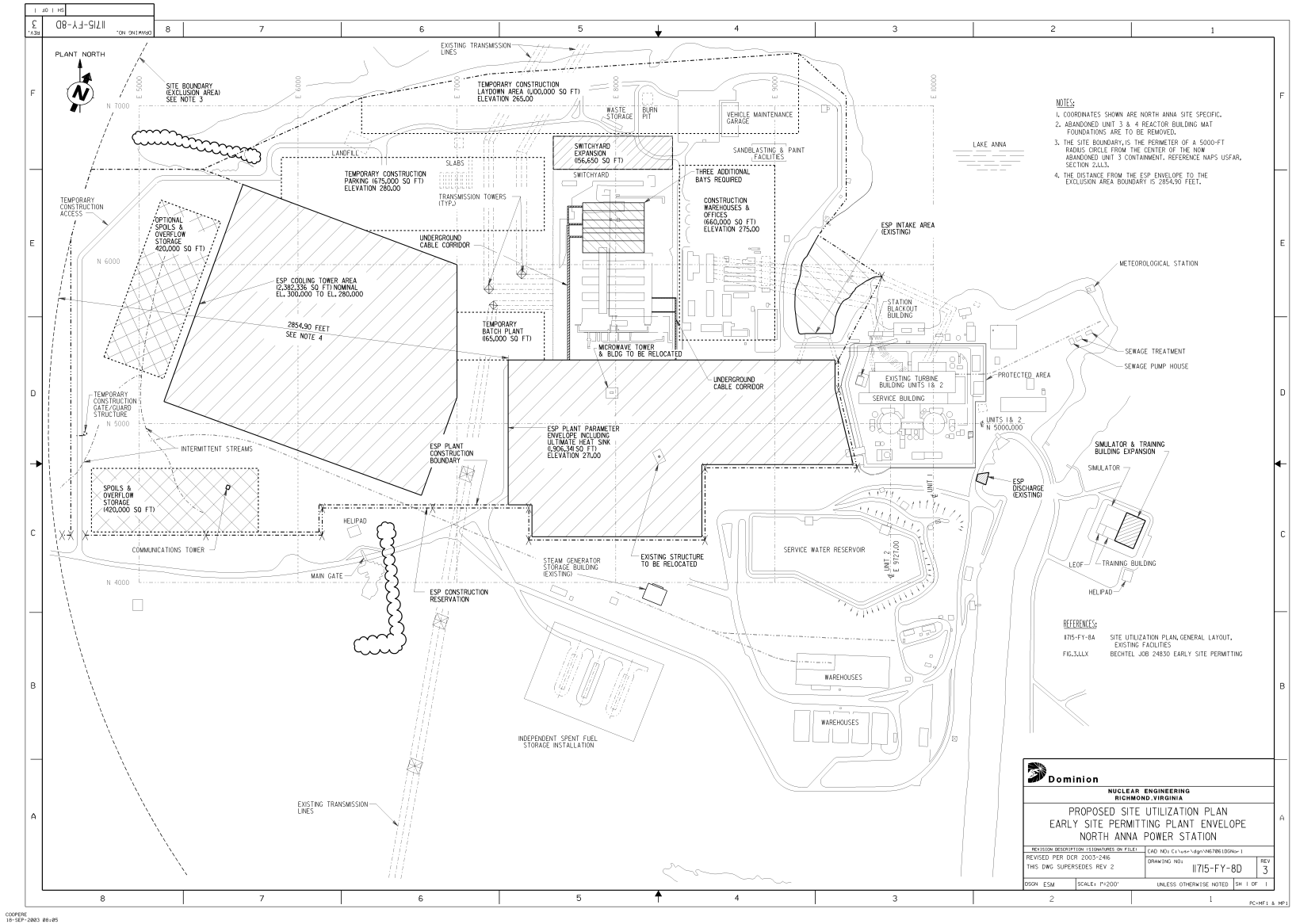

Figure 1.0-1 ESP Site Layout

1.1 Purpose of an Early Site Permit Application

For a commercial nuclear power plant to operate in the United States, it has to obtain a license from the NRC. Over the decades, the NRC and its predecessor agency, the Atomic Energy Commission, have issued more than a hundred operating licenses.

In the past, nuclear power plants were licensed under a two-step licensing process set forth in Part 50 of NRC's regulations. That process required the NRC to first issue a construction permit and later, an operating license. In 1989, the NRC established an alternative licensing process, designated Part 52, that essentially combined the construction permit and operating license processes, with certain conditions, into a single "combined license (COL)." Other licensing actions governed by Part 52 include the ESP, which allows an applicant to obtain approval for a site and "bank" it for future use, and the certified standard plant design, which can be used by an interested applicant as an "off-the-shelf" design already approved by the NRC.

Under Part 52, the NRC can issue an ESP approving one or more sites separate from any other licensing action contained in NRC's regulations. Such permits are valid for ten to twenty years and can be renewed for an additional ten to twenty years.

Site safety issues, environmental issues, and certain aspects of emergency preparedness are addressed as part of the ESP process. Those issues are addressed independent from NRC's review of any specific reactor design. Licensing issues are resolved with finality under the ESP process and are not re-examined in any subsequent licensing action involving the permitted site, absent information meeting certain standards established by the NRC (Reference 1).

Section 1.1 References

1. 10 CFR 52.39, Finality of Early Site Permit Determinations.

1.2 Early Site Permit Application Format and Content

1.2.1 Format and Content

This application contains the information required by NRC regulations (Reference 1) for an ESP application. The application has been submitted to the NRC in accordance with NRC guidance (Reference 2).

The application is organized as follows:

- **Part 1 – Administrative Information.** This part contains general corporate information about Dominion and an overview of the application format and content.
- **Part 2 – Site Safety Analysis Report (SSAR).** This part contains information about site safety, emergency preparedness, and quality assurance. The site safety section includes a description of the ESP site and proposed facilities, an assessment of the site features affecting the facility design, and meteorological, hydrologic, geologic, and seismic characteristics of the site.

  Regarding the description of the facilities for which the proposed site may be used, Dominion has not selected a particular reactor design to be constructed at the ESP site. Thus, in order to provide sufficient design information to enable the NRC to determine that the proposed site is suitable for new units, a surrogate design has been provided as part of the application. The surrogate plant is in the form of a set of bounding plant parameters termed the “plant parameters envelope (PPE).” The PPE approach has been accepted by the NRC (Reference 3). The combination of PPE values and site characteristics that would form the licensing basis for NRC’s issuance of an ESP are identified in the application.

  This part also discusses the capability of the facilities to withstand the natural and man-made environmental hazards of the site. The emergency preparedness information includes an assessment of any impediments to implementing an emergency plan at the ESP site and describes the major features of an emergency plan. The quality assurance program under which ESP-related activities have been performed is provided.

  Where possible, the SSAR section numbers correspond to the section numbers identified in draft NRC Part 52 guidance (Reference 4). Consistent with that guidance, there are some gaps in the numbering sequence. This is intentional. Also, in a few instances, information has been located elsewhere in the application because it was deemed more appropriate for ESP purposes. However, to the extent practical, the numbering sequence in this ESP application has been maintained consistent with NRC guidance. This approach is intended to facilitate any subsequent integration of the information in this ESP application with a design certification and/or COL activity in which the complete numbering sequence would be used.
- **Part 3 – Environmental Report.** This part contains information about site environmental issues. It focuses on the environmental impacts to the ESP site from the construction and operation of one or more reactors having characteristics that fall within the plant parameters envelope.

- **Part 4 – Programs and Plans.** This part contains information about site redress. Site redress describes the actions that would be taken by Dominion to ensure that the ESP site is restored to an environmentally stable and aesthetically acceptable condition if certain limited pre-construction activities are conducted and the ESP expires before it is referenced in an application for a COL.

Each part is intended to stand alone to the extent practical. That is, information appearing within one part may be referenced elsewhere within the same part to minimize duplication. However, if the same information is used in more than one part, that information may be replicated so that each part may be used without reliance on another part. In the electronic format, references between parts may be “hyperlinked.”

1.2.2 Labeling Conventions

Each page of this application, except Appendix 2.5.4B (a third-party report), has a header that indicates the Part of this application to which it belongs. Other content identity is established as follows.

1.2.2.1 Pagination

Content pages are numbered to indicate their Part, Chapter, and page within a chapter. For example, page 3-2-36 is the 36th page in Part 3, Chapter 2.

Page numbers on part-level supporting pages, such as tables of contents, indicate the associated part number and sequential page number (in lower-case roman numerals). Page numbers on overall supporting pages, such as the table of contents for the entire application, consist only of lower-case roman numerals.

1.2.2.2 Paragraph Numbering

Within each Part, chapters are numbered sequentially. Subtier content is numbered based on the chapter number. For example, Chapter 2, Section 2.1, Section 2.1.1, etc. References to sections are within a Part unless otherwise specified.

1.2.2.3 References

Reference lists appear at the end of each Section, i.e., the first subdivision within chapters. For example, the References list for Part 3, Section 2.5 appears at the end of Section 2.5.

1.2.2.4 Tables and Figures

Table and figure numbers consist of the Section number, and a sequential number. For example, Figure 2.3-10 is the 10th figure for Section 2.3. See the lists of Tables and Figures at the beginning of this application for a complete inventory.

1.2.2.5 Change Notation

In accordance with the NRC Final Rule on Electronic Maintenance and Submission of Information, effective January 1, 2004, Appendix A, United States Nuclear Regulatory Commission (NRC) Guidance for Electronic Submissions to the Commission, this application is considered a living document. Accordingly, updates are submitted as total replacements, a list of changed pages is provided (Changed Pages), and the location of changed content is denoted with a bold line in the right margin. All pages display the current revision number and issue date.

1.2.3 Industry Coordination

As part of the activities undertaken in the preparation of this application, another DRI subsidiary, Dominion Energy, Inc. (DEI), participated in the Nuclear Energy Institute's (NEI) Early Site Permit Task Force. The task force included the other lead applicants involved in demonstrating the Part 52 ESP process. The task force met periodically with the NRC staff over a two-year period. A number of generic issues related to the ESP process were identified and resolved through those interactions. In addition, DEI worked in concert with the other lead applicants to optimize commonality among the lead applicants. The results of those issue resolutions and the common approaches are reflected in this application.

Section 1.2 References

1. 10 CFR 52.17, Content of Applications.

2. NRC Regulatory Issues Summary 2001-05, "Guidance on Submitting Documents to the NRC by Electronic Information Exchange or on CD-ROM," January 25, 2001.

3. NRC letter to NEI, J. E. Lyons to R. L. Simard, titled "Resolution of Early Site Permit Topic 6 (ESP-6), Use of Plant Parameter Envelope (PPE) Approach," February 5, 2003.

4. NRC Review Standard RS-002, Processing Applications for Early Site Permits: Draft for Interim Use and Public Comment, December 23, 2002, as supplemented.

1.3 Information Required by 10 CFR 50.33(a) through (d)

Dominion Nuclear North Anna, LLC (Dominion) is the applicant for this ESP. Dominion Nuclear North Anna, LLC is an indirect wholly-owned subsidiary of DRI. DRI is one of the nation's leading energy companies, serving five million retail energy customers in nine states. DRI is the largest fully-integrated natural gas and electric provider in the United States, with over $37 billion in assets, over $10 billion in annual revenue, and over $2 billion in annual cash flow. DRI's energy base includes 24,000 megawatts (MW) of electric generation, 6.1 trillion cubic feet equivalent of proved gas and oil reserves, and nearly 7,900 miles of natural gas transmission pipeline. Virginia Electric and Power Company (Virginia Power), a subsidiary of DRI, is the NRC-licensed operator of NAPS, the Surry Power Station, and their associated ISFSIs. Dominion Nuclear Connecticut, Inc., also an indirect, wholly-owned subsidiary of DRI, is the licensed operator of the Millstone Power Station.

NRC regulations (Reference 1) require that an ESP application contain certain corporate information about the applicant. The required information is provided in Table 1.3-1.

Section 1.3 References

1. 10 CFR 50.33(a) through (d), Contents of Applications, general information.

Table 1.3-1 Dominion Nuclear North Anna, LLC, Officers and Directors

Name of Applicant	Dominion Nuclear North Anna, LLC, a Virginia limited liability company
Address	120 Tredegar Street Richmond, Virginia 23219
Description of Business	Entity seeking to obtain an early site permit for new nuclear generation at the North Anna site
Principal business location	120 Tredegar Street, Richmond, Virginia 23219

Names, addresses, and citizenship of member:			
Name	**Title**	**Address**	**Citizenship**
Dominion Nuclear Projects, Inc.	Sole Member	120 Tredegar Street Richmond, VA 23219	USA

Names, addresses, and citizenship of directors and officers:			
Name	**Title**	**Address**	**Citizenship**
Mark F. McGettrick	President and Chief Executive Officer – Generation	120 Tredegar Street Third Floor Richmond, VA 23219	USA
David A. Christian	Senior Vice President - Nuclear Operations and Chief Nuclear Officer	Innsbrook Technical Center - 2SW 5000 Dominion Boulevard Glen Allen, VA 23060	USA
G. Scott Hetzer	Senior Vice President and Treasurer	100 Tredegar Street Third Floor Richmond, VA 23219	USA
William R. Matthews	Senior Vice President - Nuclear Operations	Millstone Power Station Rope Ferry Road Waterford, CT 06385	USA
Martin L. Bowling, Jr.	Vice President - Technical Services	Innsbrook Technical Center, 1NE 5000 Dominion Boulevard Glen Allen, VA 23060	USA
Pamela F. Faggert	Vice President - Chief Environmental Officer	Innsbrook Technical Center, 1SE 5000 Dominion Boulevard Glen Allen, VA 23060	USA
Eugene S. Grecheck	Vice President - Nuclear Support Services	Innsbrook Technical Center, 2SE 5000 Dominion Boulevard Glen Allen, VA 23060	USA
Leslie N. Hartz	Vice President - Nuclear Engineering	Innsbrook Technical Center, 2SE 5000 Dominion Boulevard Glen Allen, VA 23060	USA

Table 1.3-1 Dominion Nuclear North Anna, LLC, Officers and Directors

James K. Martin	Vice President - Business Development	120 Tredegar Street Third Floor Richmond, VA 23219	USA
Patricia A. Wilkerson	Vice President and Corporate Secretary	100 Tredegar Street Third Floor Richmond, VA 23219	USA
Lee D. Katz	Controller	120 Tredegar Street Third Floor Richmond, VA 23219	USA
James P. Carney	Assistant Treasurer	100 Tredegar Street Second Floor Richmond, VA 23219	USA
E. J. Marks, III	Assistant Secretary	100 Tredegar Street Second Floor Richmond, VA 23219	USA
Jerry G. Overman	Assistant Treasurer	100 Tredegar Street Third Floor Richmond, VA 23219	USA

No Foreign Ownership, Control or Influence:
Dominion Nuclear North Anna, LLC, is wholly-owned by Dominion Nuclear Projects, Inc. (DNP). DNP is a wholly-owned subsidiary of Dominion Energy, Inc., which in turn is wholly-owned by Dominion Resources, Inc. (DRI). None of the aforementioned entities is owned, controlled, or dominated by an alien, foreign corporation, or foreign government.

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PART 2: SITE SAFETY ANALYSIS REPORT

Chapter 1 Introduction and General Description

1.1 Introduction

This Site Safety Analysis Report (SSAR) supports Dominion's application for its ESP site. The SSAR addresses site suitability issues and complies with the applicable portions of 10 CFR 52, Subpart A, Early Site Permits.

The site selected for the Early Site Permit (ESP) is a parcel of land on the North Anna Power Station (NAPS) site in Louisa County, Virginia, approximately 40 miles north-northwest of Richmond, Virginia. Other, existing nuclear facilities licensed by the U. S. Nuclear Regulatory Commission (NRC) are located on the NAPS site. Those other facilities are NAPS Units 1 and 2 (Docket Nos. 50-338/339; NRC Facility Operating License Nos. NPF-4/7) and the North Anna Independent Spent Fuel Storage Installation (ISFSI) (NRC Docket No. 72-16; Materials License No. SNM-2507). NAPS Units 1 and 2 have been producing electricity for customers since 1978 and 1980, respectively. The site selected for the ESP, called the ESP site, is located within the NAPS site. It is adjacent to and generally west of the existing units and is illustrated in Figure 1.2-4.

The NAPS site, which includes the existing facilities and the ESP site, is owned by Virginia Electric and Power Company (Virginia Power) and Old Dominion Electric Cooperative (ODEC), as tenants in common. Virginia Power is the licensed operator of the existing facilities, with control of the existing facilities and the authority to act as ODEC's agent. Virginia Power supports this application.

Dominion has not selected a particular reactor design to be constructed at the ESP site. Thus, in order to provide sufficient design information to enable the NRC to determine that the site is suitable for new units, a surrogate design has been provided. The surrogate design is in the form of a set of bounding plant parameters termed the "plant parameters envelope (PPE)." The PPE approach has been accepted by the NRC (Reference 1). The combination of PPE values and site characteristics that would form the permit basis for NRC's issuance of an ESP are identified in this SSAR.

The SSAR contains information about site safety, emergency preparedness, and quality assurance. The following paragraphs briefly describe the contents of the SSAR:

Chapter 1, Introduction and General Description, includes a general site description, an overview of reactor types, and the PPE approach.

Chapter 2, Site Characteristics, includes geography and demography, nearby industrial installations, transportation and military facilities, and meteorologic, hydrologic, geologic, and seismic characteristics of the site, including information about aircraft hazards. It also includes descriptions of effluents, thermal discharges, and conformance with 10 CFR 100, Reactor Site

Criteria, requirements. This chapter provides the anticipated maximum levels of radiological and thermal effluents the new units would produce.

Chapter 3, Design of Structures, Components, Equipment, and Systems contains a pointer to information on air craft hazards located in Chapter 2.

Chapter 13, Conduct of Operations, includes the major features of the emergency plan and other emergency preparedness information.

Chapter 15, Accident Analyses, includes accident and dose consequence analyses required by 10 CFR 52.17(a)(1), 50.34(a)(1) and 100.21(c)(2), applying the PPE approach.

Chapter 17, Quality Assurance, includes the Quality Assurance Program under which the ESP application has been prepared.

Where possible, the SSAR section numbers correspond to the section numbers identified in draft NRC Part 52 guidance (Reference 2). Consistent with that guidance, there are some gaps in the numbering sequence. This is intentional. Also, in a few instances, information has been located elsewhere in the application because it was deemed more appropriate for ESP purposes. However, to the extent practical, the numbering sequence in this ESP application has been maintained consistent with NRC guidance. This approach is intended to facilitate any subsequent integration of the information in this ESP application with a design certification and/or combined license (COL) activity in which the complete numbering sequence would be used.

Section 1.1 References

1. February 5, 2003 NRC letter to NEI, J. E. Lyons to R. L. Simard, titled “Resolution of Early Site Permit Topic 6 (ESP-6), Use of Plant Parameter Envelope (PPE) Approach.”

2. NRC Review Standard RS-002, Processing Applications for Early Site Permits: Draft for Interim Use and Public Comment, December 23, 2002, as supplemented.

1.2 General Site Description

1.2.1 Site Location

The ESP site is situated on a peninsula on the south shore of Lake Anna, at the end of State Route 700 in Louisa County, in northeastern Virginia (see Figure 1.2-2). The ESP site is approximately 40 miles north-northwest of Richmond, Virginia; 36 miles east of Charlottesville, Virginia; and 22 miles southwest of Fredericksburg, Virginia. Interstates 95 and 64 pass within 16 miles to the east and 18 miles to the south of the ESP site, respectively.

The NAPS site comprises 1803 acres, of which about 760 acres are covered by water. The NAPS site is laid out according to the site plan as shown in Figure 1.2-3. Virginia Power and ODEC own, and Virginia Power controls, all of the land within the NAPS site boundary, including those portions of the North Anna Reservoir and Waste Heat Treatment Facility (WHTF) that lie within the site boundary. These companies also own all land outside the NAPS site boundary that forms Lake Anna, up to the expected high-water marks. The NAPS site and all supporting facilities, including the North Anna Reservoir, the WHTF, the earth dam, dikes, railroad spur, and roads constitute approximately 18,643 acres. Lake Anna, which includes the North Anna Reservoir and the WHTF, was created to serve the needs of the power station.

A more detailed description of the site can be found in Section 2.2.

1.2.2 Site Development

The NAPS site currently has two Westinghouse pressurized water reactors (PWR), rated at 2893 MWth and their supporting structures. These structures include a circulating water pumphouse and discharge structure, water treatment building, switchyard, and training center. In addition, an ISFSI is located on the site. Figure 1.2-3 shows the current NAPS site development.

The site selected for the ESP is a parcel of land on the NAPS site. The ESP site is adjacent to and generally to the west of the existing units, and is illustrated in Figure 1.2-4.

No specific plant design has been chosen for the ESP site within the NAPS site. Instead, a set of bounding plant parameters is presented to envelop future ESP site development. This PPE is based on the addition of power generation from two distinct units, to be designated North Anna Units 3 and 4. (The PPE is described in Section 1.3.) Each unit represents a portion of the total generation capacity to be added and would consist of one or more reactors or reactor modules. These multiple reactors or modules (the number of which may vary depending on the reactor type selected) would be grouped into distinct operating units. Each unit would consist of a plant of one or more modules that would not exceed 4500 MWth of nuclear generating capacity. Because a specific design has not been selected, boundaries have been established for the placement of the new units. The boundaries are shown in Figure 1.2-4.

Section 1.2 References

None

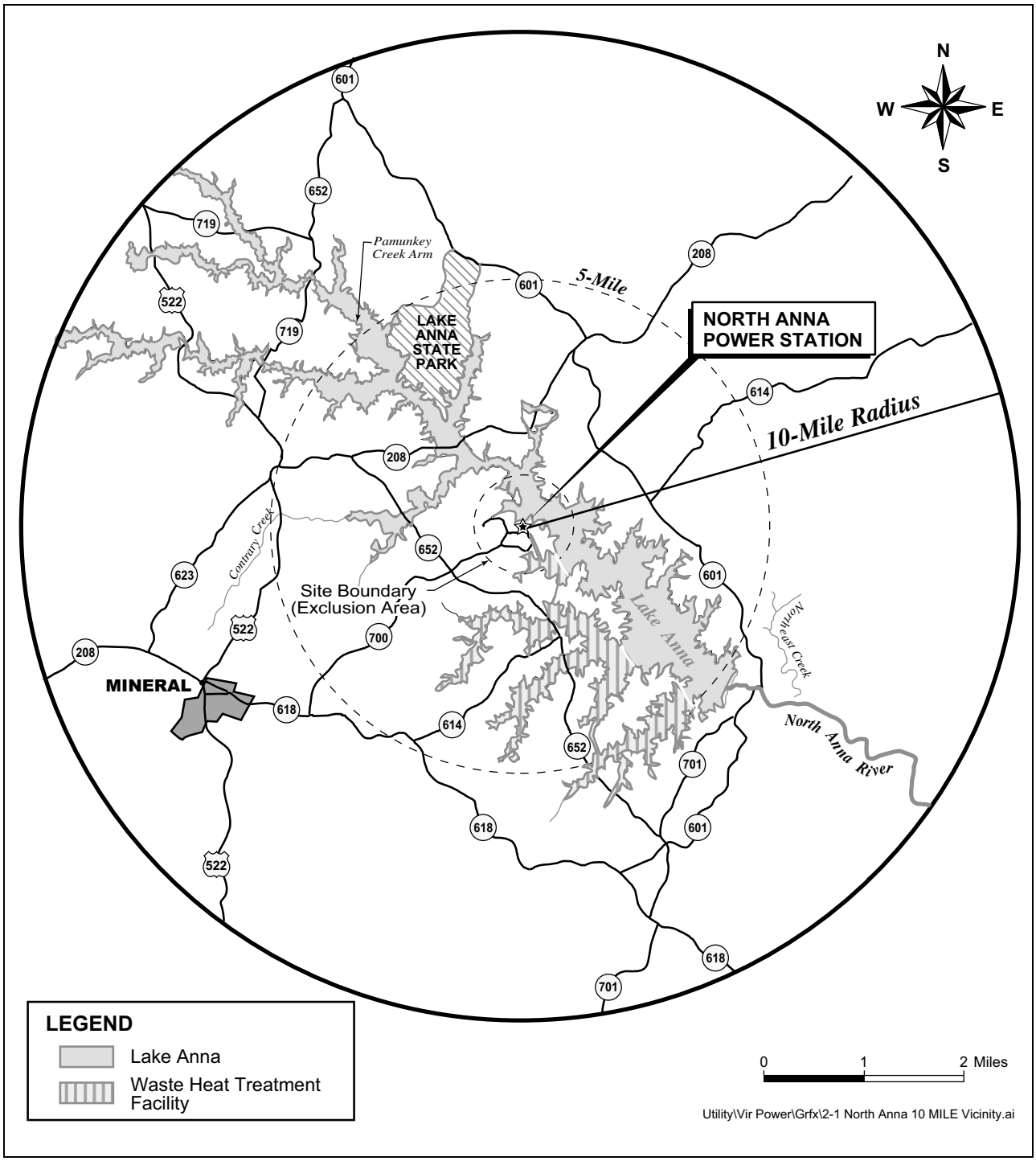


Figure 1.2-1 Site Location – 10 Mile Radius

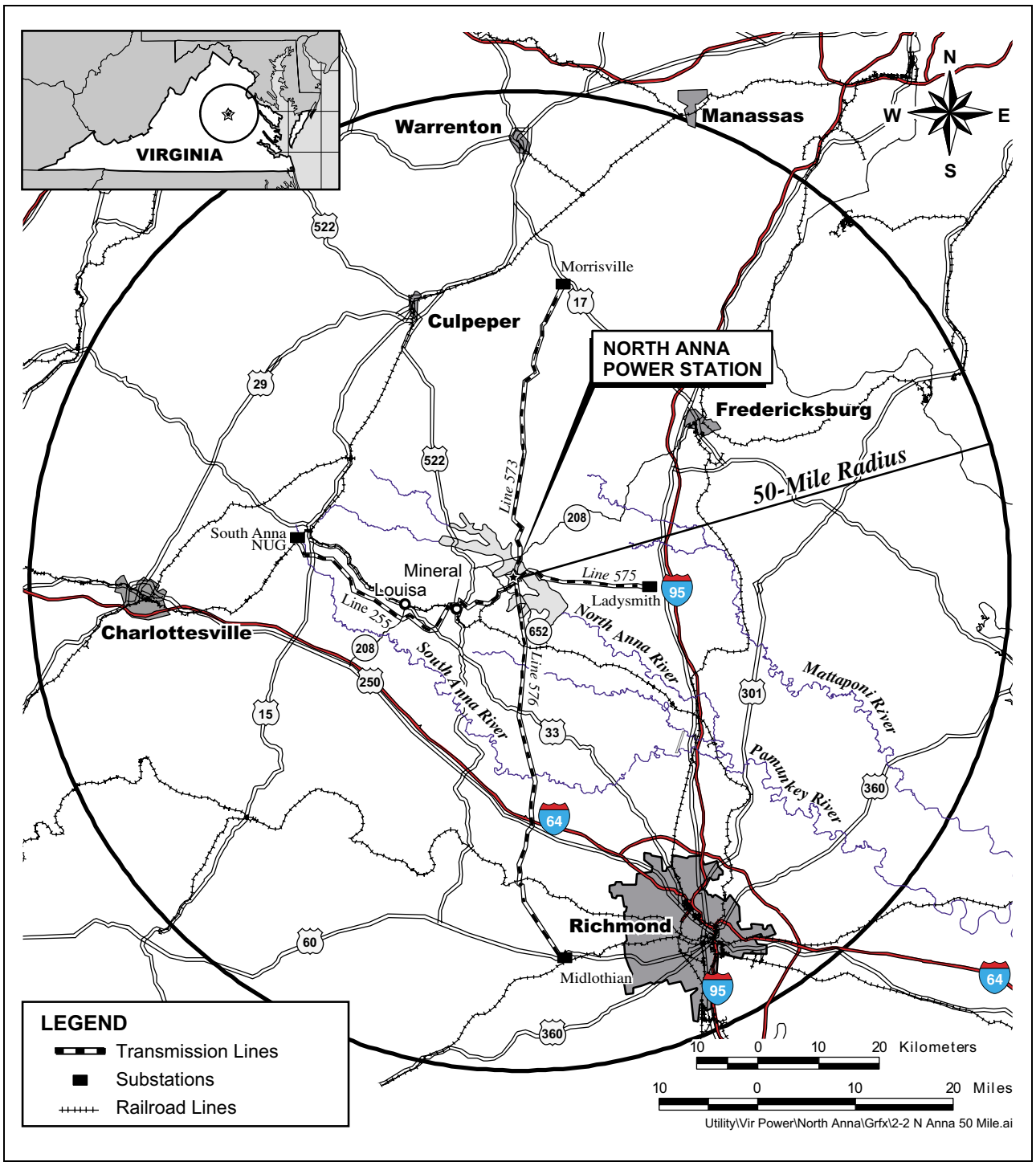


Figure 1.2-2 Site Location – 50 Mile Radius

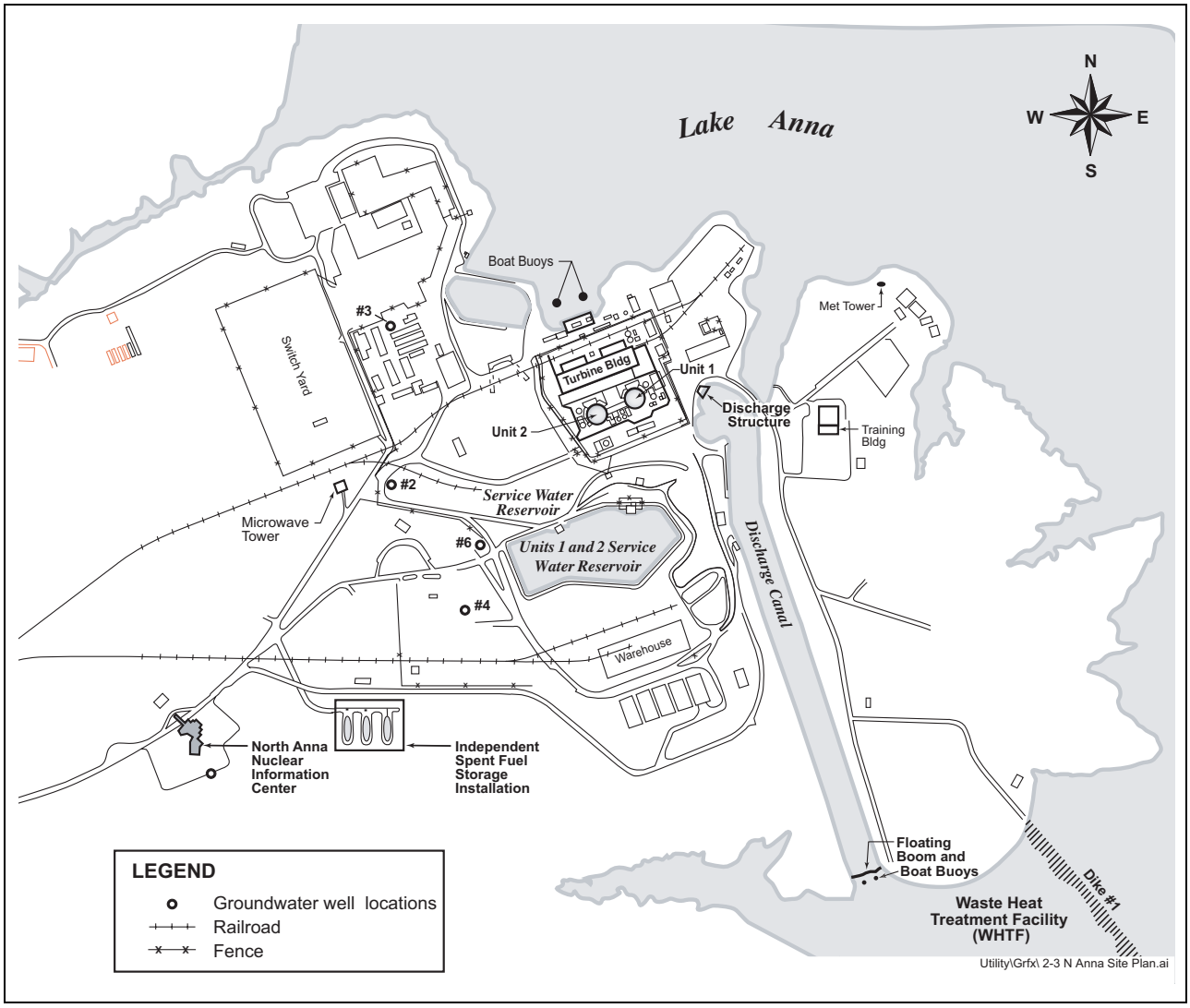


Figure 1.2-3 Site Layout – Current Development

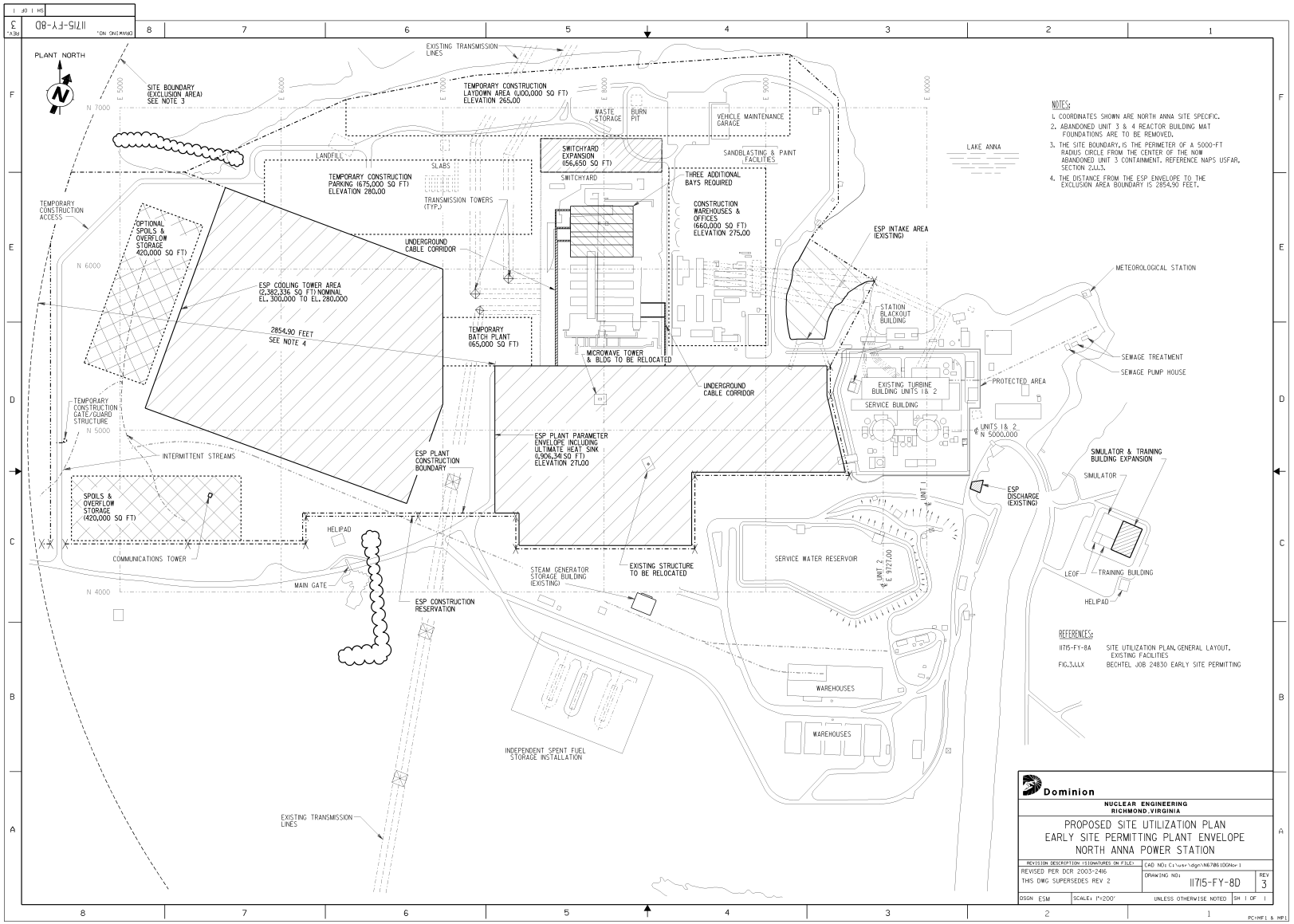


Figure 1.2-4 Site Layout – New Development

1.3 Plant Parameters Envelope

The required contents of an ESP application are specified in 10 CFR 52.17. The application should specify the number, type and thermal power level of the facilities for which the ESP site may be used [10 CFR 52.17(a)(1)(I)]. The concept of a PPE to describe the bounding plant for which the ESP site is suitable has been accepted by the NRC (Reference 1). The PPE, its development, and its use in this application is presented in the following sections. This PPE approach provides sufficient design details to support NRC review of the ESP application while also recognizing that technological developments may result in new reactor technologies becoming available that may not have been envisioned at the time of ESP application submittal. The actual design selected would be reviewed at the time of a COL application to ensure that the design fits within the PPE envelope. Any differences would be addressed in the COL application.

1.3.1 Plant Parameters Envelope Approach

The listing of plant parameters necessary to define the plant-site interface – the PPE – was developed in the early 1990s based on work sponsored by the U.S. Department of Energy (DOE) and the nuclear industry, which included reactor vendors and utilities. The effort was intended to provide a comprehensive list of plant parameters to accurately characterize a plant at a site. Over time, this list has evolved to encompass information needed to support development of an ESP application, including the SSAR and the Environmental Report.

The PPE was developed based on data from selected reactor designs of two types (light-water-cooled reactors (LWRs) and helium-cooled reactors). To ensure that the resulting PPE has the flexibility to bound multiple reactor designs, these designs were selected to provide a broad cross section of available reactors. Brief descriptions of each of these reactor types are included in Section 1.3.2.

The resulting Generic PPE table, Table 1.3-1, lists both the single and two unit values for each parameter. The bounding parameters are the single largest (or smallest) value for each category, using engineering, safety and environmental conservatism to select the appropriate value. As noted in Section 1.3.2, a single unit may consist of more than one reactor for purposes of developing the PPE. Definitions for each PPE parameter are supplied on this table. Additional supporting information to support this table is included in Table 1.3-3 through Table 1.3-8.

The liquid and gaseous activity releases (source terms) during normal plant operation are shown in Table 1.3-7 and Table 1.3-8, respectively, for a single new unit. These are bounding, composite activities, obtained by taking the maximum activity for each isotope from multiple reactor designs. The liquid effluent concentrations for the new units are calculated using the composite activity releases with the methodology presented in the NAPS Updated Final Safety Analysis Report (UFSAR) (Reference 2, Section 11.2.5.1). The concentrations from the existing units are obtained from UFSAR Table 11.2-14. Table 1.3-7 shows the total effluent concentrations from the new and existing units and compares them to the effluent concentration limits (ECLs) in 10 CFR 20,

Appendix B, Table 2, Column 2. Table 1.3-8 shows the maximum airborne activity concentrations at the site boundary from the new and existing units and compares them to the ECLs in 10 CFR 20, Appendix B, Table 2, Column 1. The gaseous effluent concentrations are calculated based on the composite activity releases for the new units and the activity releases from the existing units from UFSAR Table 11.3-2 and the respective atmospheric dispersion factors at the site boundary. In both tables the sum of the fractions of ECLs is within unity, in conformance with 10 CFR 20.

The Generic PPE is not intended to be limited to the designs selected to create the envelope, but rather to provide a broad overall outline of a design concept and to include other potential designs if they can be demonstrated to fall within the parameter values provided in the Generic PPE.

The SSAR Bounding Site-Specific PPE table, Table 1.9-1, which contains the bounding site characteristics and design parameters for evaluating the ESP site, is described in Section 1.9.

1.3.2 Overview of Reactor Types Used for PPE Development

Seven reactor designs have been used to develop the PPE bounding values.

- ACR-700, LWR, developed by Atomic Energy Canada Limited
- Advanced Boiling Water Reactor, developed by General Electric (ABWR)
- AP1000, PWR, developed by Westinghouse Electric Company
- Economic Simplified Boiling Water Reactor, developed by General Electric (ESBWR)
- Gas Turbine Modular Helium Reactor (GT-MHR), developed by General Atomics.
- International Reactor Innovative and Secure (IRIS) next generation PWR, developed by a consortium led by Westinghouse Electric Company
- Pebble Bed Modular Reactor (PBMR), developed by PBMR (Pty) Ltd.

1.3.2.1 ACR-700

The ACR-700 is designed by Atomic Energy Canada Limited (AECL) and is based on the CANDU 6 design. The ACR-700 is a 1983 MWth light-water-cooled, heavy-water-moderated reactor. It uses four heat transport pumps circulating light water through two steam generators to remove the heat from the horizontal reactor vessel, called a calandria. This light water primary coolant circulates through individual pressurized fuel channels in the calandria. On the other side of these fuel channels, the calandria contains a heavy water moderator at low temperature and pressure, which allows increased neutron efficiency.

The CANDU 6 design is a natural uranium fueled reactor; a design attained by using heavy water as the primary heat removal fluid. For ACR-700, the primary coolant has been changed to light water, reducing the cost and complexity of the plant. The resulting reduction in neutron efficiency requires that the fuel be slightly enriched, to approximately 2 percent U^{235}. The fuel elements,

however, are similar to those used in CANDU 6 with minor improvements to increase thermal efficiency.

Unlike the ABWR and AP1000, the use of individual pressurized fuel channels in the ACR-700 allows the ACR-700 to be continuously refueled on power. Fueling machines are designed to isolate an individual fuel channel, remove a selected number of fuel assemblies (which are only about 20 inches long) and return the channel to service. Electrical power generation would be through the use of a standard steam turbine cycle.

The CANDU reactor design has been inservice in a variety of countries. Thirty-four CANDU units have been constructed worldwide. The ACR-700 design is configured in a two-reactor block, with shared systems between the two reactors. This two-reactor block makes up one unit for purposes of developing the PPE.

1.3.2.2 **Advanced Boiling Water Reactor**

The ABWR is an evolutionary design of the boiling water reactor (BWR) design developed by the General Electric Company. The ABWR design has been certified by the NRC (under 10 CFR 52, Appendix A). The certified design is rated at 3926 MWth and is a single cycle, forced circulation BWR. The design is based on existing BWR designs, similar to the ones operating in the United States at Clinton and Grand Gulf, but incorporates several advanced features, including vessel-mounted recirculation pumps, fine motion control rod drives and an advanced digital and multiplexed instrumentation and control system. Additional changes have added a third division of safety-related equipment and improved the containment design.

Studies performed by General Electric indicate that this design has sufficient operating margins to allow uprate of the core thermal power. Based on this analysis, the PPE data supplied for this design is based on the uprated, 4300 MWth design of this plant. Other than a thermal power uprate, no other significant design changes are required. Electrical power generation is through the use of a standard steam turbine cycle.

To date, two ABWR units have been constructed and are currently in operation in Japan. Additional units are under construction in Taiwan (two) and Japan (two), with six others in various stages of design in Japan. The ABWR is designed as a single-unit, stand-alone configuration.

1.3.2.3 **AP1000**

The Westinghouse AP1000 is a 3400 MWth PWR. Its design is based on the NRC design certified AP600 (under 10 CFR 52, Appendix C), with design changes to accommodate the increase in power output. The AP1000 is a two-loop, four-reactor-coolant-pump design that uses fuel, reactor vessel, and internals similar to those in service today at South Texas. The reactor coolant pumps are canned-type pumps to reduce the probability of leakage and to improve reliability. The design is functionally similar to that of the AP600, with the containment building, reactor vessel, steam

generators, reactor coolant pumps and pressurizer increased in size to accommodate the increase in thermal power.

The AP1000 is designed to use passive features for accident mitigation. An externally cooled steel containment building, in-containment refueling water storage tank, rapid depressurizing capability and other design features allow the elimination of all safety-related alternating current powered equipment. Electrical power generation would be through the use of a standard steam turbine cycle.

The AP1000 is designed in a single-unit, stand-alone configuration.

1.3.2.4 **Economic Simplified Boiling Water Reactor**

The ESBWR is a further evolution from the ABWR and is designed by the General Electric Company. The ESBWR is a 4500 MWth single cycle BWR with an estimated electrical output of 1520 MWe. The ESBWR relies on the use of natural circulation and passive safety features to enhance plant performance and simplify the design. The use of natural circulation has allowed the elimination of several BWR systems. This has also increased plant accident reliability by eliminating active safety systems for emergency plant cooling.

The ESBWR has achieved its plant simplification by using innovative adaptations of operating plant systems, for example combining shutdown cooling and reactor water cleanup systems. The only major new concept or system is the passive containment cooling system (PCCS). In other cases, key components such as depressurization valves and isolation condensers are new, but utilize proven concepts.

The ESBWR is designed as a single, stand-alone unit.

1.3.2.5 **Gas Turbine – Modular Helium Reactor**

The Gas Turbine – Modular Helium Reactor (GT-MHR) is under development by General Atomics Corporation. The GT-MHR is a modular, medium sized helium cooled graphite moderated reactor using helium as the coolant. Each 600 MWth module includes a reactor and gas turbine, operating in a high temperature (900°C) Brayton cycle. The fuel for the GT-MHR consists of triple coated small uranium spheres formed into compacts and inserted into hexagonal graphite blocks. These blocks, along with those without fuel, are assembled inside the reactor to form a reactor core. The helium removes the heat from the reactor and is expanded across a gas turbine to generate electricity. Low and high pressure turbines, located on the same shaft as the power turbine, compress the gas and return it to the reactor.

Four GT-MHR modules are grouped together to make one unit for purposes of developing the PPE.

1.3.2.6 **International Reactor Innovative and Secure**

The IRIS is being designed by a consortium lead by Westinghouse Electric Company. The IRIS design is a modular, medium-power, light-water reactor under development to meet DOE

Generation IV reactor design criteria. Using light water for both a coolant and moderator, the IRIS design eliminates all loss of coolant accidents by placing the entire reactor coolant system within a single reactor vessel. The components used for the design of IRIS are not new technology but some of them are employed in nuclear power for the first time. The steam generators are of a helical tube design, the reactor coolant pumps are spool type and require eight pumps per reactor, and the pressurizer is located in the upper head of the vessel.

The reactor core is designed for long burns between refueling outages, with outages planned for 4-year to 6-year intervals. The fuel assemblies are similar to that used by Westinghouse in U.S. and European reactors. Electrical power generation would be through the use of a standard steam turbine cycle.

Individual IRIS modules are rated at 1000 MWth and are grouped two or three modules to each power block. Three IRIS reactors make up one unit for purposes of developing the PPE.

1.3.2.7 **Pebble Bed Modular Reactor**

The PBMR is designed as a small modular graphite moderated helium cooled gas turbine reactor. PBMR (Pty) Ltd. of South Africa is developing the design. Each module is designed as a 400 MWth reactor and gas turbine assembly. The reactor uses low enriched uranium fuel encased in small triple coated spheres and then assembled into spheres, or pebbles. These pebbles are then loaded into a graphite shielded and moderated reactor vessel. Heat generated in the reactor is removed using the helium coolant and converted to electricity through a gas turbine operating on a high temperature (900°C) Brayton cycle. Individual low-pressure and high-pressure gas turbines compress the gas and return it to the reactor.

Specialized systems remove the pebbles one at a time, assay them to determine burnup, and then replace or return the pebble to the reactor. This design allows on power refueling with the fuel continuously replaced as needed. The PBMR design also stores all of its spent fuel (for its 40-year operating life) on site in specially designed tanks.

The design of the PBMR groups one or more of these modules together using a common service building. Eight PBMR modules are grouped together to make one unit for purposes of developing the PPE.

1.3.3 **Use of the Generic PPE Tables**

The Generic PPE tables are based on information supplied by the reactor vendors for the plant designs listed above. Site dependant PPE data was based on a typical site (not a specific site and not the ESP site) and chosen to bound approximately 85 percent of all existing sites. Site-specific information is not listed on these tables.

The data included in this table is not to be taken as final design specific information. In some cases, where designs are not mature, the data supplied is based on engineering judgement, prior

experience, or a calculation based on non-site specific assumptions. The data is reasonable and would bound most applications. An example of this is in the design of the circulating water system, which is based on site-specific water supplies and temperature. Additionally, site-specific environmental data is used to design the condenser and circulating water heat removal systems. The listed circulating water designs, which include once through cooling and both mechanical and natural draft towers, are based on a bounding plant design and location and would be modified to meet site characteristics when required. However, the data provided is reasonable and can be used until site-specific design data is available.

Section 1.3 References

1. Letter from James E. Lyons of USNRC to Dr. Ronald L. Simard of NEI, dated February 5, 2003.

2. North Anna Power Station Updated Final Safety Analysis Report, Revision 38.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments [c]	Definition
1. Structures				
1.1 Building Characteristics				
1.1.1 Height	234 ft-0 in. [Same for 2nd unit/group]	1		The height from finished grade to the top of the tallest power block structure, excluding cooling towers.
1.1.2 Foundation Embedment	140 ft [Same for 2nd unit/group]	2		The depth from finished grade to the bottom of the basemat for the most deeply embedded power block structure.
1.2 Precipitation (for Roof Design)				
1.2.1 Maximum Rainfall Rate	19.4 in/hr (6.2 in/5 min) [Same for 2nd unit/group]	2, 3, 4, 5		The probable maximum precipitation (PMP) value that can be accommodated by a plant design. Expressed as maximum precipitation for 1 hour in 1 square mile with a ratio for five minutes to the 1 hour PMP of 0.32 as found in National Weather Service Publication HMR No. 52.
1.2.2 Snow and Ice Load	50 lb/sq ft [Same for 2nd unit/group]	2, 3, 4		The maximum load on structure roofs due to the accumulation of snow and ice that can be accommodated by a plant design.
1.3 Safe Shutdown Earthquake (SSE)				
1.3.1 Design Response Spectra	RG 1.60 [Same for 2nd unit/group]	6		The assumed design response spectra used to establish a plant's seismic design.
1.3.2 Peak Ground Acceleration	0.30g [Same for 2nd unit/group]	6		The maximum earthquake ground acceleration for which a plant is designed; this is defined as the acceleration which corresponds to the zero period in the response spectra taken in the free field at plant grade elevation.
1.3.3 Time History	Envelope SSE Response Spectra [Same for 2nd unit/group]	6		The plot of earthquake ground motion as a function of time used to establish a plant's seismic design.
1.3.4 Capable Tectonic Structures or Sources	No fault displacement potential within the investigative area [Same for 2nd unit/group]	1		The assumption made in a plant design about the presence of capable faults or earthquake sources in the vicinity of the plant site (e.g., no fault displacement potential within the investigative area).

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
1.4 Site Water Level (Allowable)				
1.4.1 Maximum Flood (or Tsunami)	1 ft below plant grade [Same for 2nd unit/group]	2, 3, 4		Design assumption regarding the difference in elevation between finished plant grade and the water level due to the probable maximum flood (PMF) and PMP (defined in ANSI/ANS 2.8-1992) used in the plant design.
1.4.2 Maximum Ground Water	1 meter below grade (i.e., 3.3 feet below grade) [Same for 2nd unit/group]	7		Design assumption regarding the difference in elevation between finished plant grade and the maximum site ground water level used in the plant design.
1.5 Soil Properties Design Bases				
1.5.1 Liquefaction	None at Site-Specific SSE [Same for 2nd unit/group]	6		Design assumption regarding the presence of potentially liquefying soils at a site (e.g., none at Site-Specific SSE).
1.5.2 Minimum Bearing Capacity (Static)	15 ksf [Same for 2nd unit/group]	2, 3		Design assumption regarding the capacity of the competent load-bearing layer required to support the loads exerted by plant structures used in the plant design.
1.5.3 Minimum Shear Wave Velocity	≥3,500 fps [Same for 2nd unit/group.]	1		The assumed limiting propagation velocity of shear waves through the foundation materials used in the plant design.
1.6 Tornado (Design Bases)				
1.6.1 Maximum Pressure Drop	2.0 psi [Same for 2nd unit/group]	6		The design assumption for the decrease in ambient pressure from normal atmospheric pressure due to the passage of the tornado.
1.6.2 Maximum Rotational Speed	240 mph [Same for 2nd unit/group]	6		The design assumption for the component of tornado wind speed due to the rotation within the tornado.
1.6.3 Maximum Translational Speed	60 mph [Same for 2nd unit/group]	6		The design assumption for the component of tornado wind speed due to the movement of the tornado over the ground.
1.6.4 Maximum Wind Speed	300 MPH [Same for 2nd unit/group]	6		The design assumption for the sum of maximum rotational and maximum translational wind speed components.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
1.6.5 Missile Spectra	Spectrum II from NUREG-0800 SRP Section 3.5.1.4 [Same for 2nd unit/group]	4, 8		The design assumptions regarding missiles that could be ejected either horizontally or vertically from a tornado. The spectra identify mass, dimensions and velocity of credible missiles.
1.6.6 Radius of Maximum Rotational Speed	150 ft [Same for 2nd unit/group]	6		The design assumption for distance from the center of the tornado at which the maximum rotational wind speed occurs.
1.6.7 Rate of Pressure Drop	1.2 psi/sec [Same for 2nd unit/group]	6		The assumed design rate at which the pressure drops due to the passage of the tornado.
1.7 Wind				
1.7.1 Basic Wind Speed	110 mph [Same for 2nd unit/group]	2, 3, 4		The design wind, or “fastest mile of wind” with a 100-year return period (NUREG-0800, Sections 2.3.1 and 3.3.1) for which the facility is designed.
1.7.2 Importance Factors	1.0 (non-safety related)/ 1.11 (safety related) [Same for 2nd unit/group]	2, 3		Multiplication factors (as defined in ANSI A58.1-1982) applied to basic wind speed to develop the plant design.
2. Normal Plant Heat Sink				
2.1 Ambient Air Requirements				
2.1.1 Normal Shutdown Max Ambient Temp (1% Exceed)	100°F db / 77°F wb coincident [Same for 2nd unit/group]	6		Assumption used for the maximum ambient temperature that will be exceeded no more than 1% of the time, to design plant systems capable of effecting normal shutdown under the assumed temperature condition.
2.1.2 Normal Shutdown Max Wet Bulb Temp (1% Exceed)	80°F wb non-coincident [Same for 2nd unit/group]	6		Assumption used for the maximum wet bulb temperature that will be exceeded no more than 1% of the time – used in design of plant systems that must be capable of effecting normal shutdown under the assumed temperature condition.
2.1.3 Normal Shutdown Min Ambient Temp (1% Exceed)	-10°F [Same for 2nd unit/group]	6		Assumption used for the minimum ambient temperature that will be exceeded no more than 1% of the time to design of plant systems that must be capable of effecting normal shutdown under the assumed temperature condition.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
2.1.4 Rx Thermal Power Max Ambient Temp (0% Exceed)	115°F db/80°F wb coincident [Same for 2nd unit/group]	6		Assumption used for the maximum ambient temperature that will never be exceeded – used in design of plant systems that must be capable of supporting full power operation under the assumed temperature condition.
2.1.5 Rx Thermal Power Max Wet Bulb Temp (0% Exceed)	81°F wb non-coincident [Same for 2nd unit/group]	6		Assumption used for the maximum wet bulb temperature that will never be exceeded – used in design of plant systems that must be capable of supporting full power operation under the assumed temperature condition.
2.1.6 Rx Thermal Power Min Ambient Temp (0% Exceed)	–40°F [Same for 2nd unit/group]	6		Assumption used for the minimum ambient temperature that will never be exceeded – used in design of plant systems that must be capable of supporting full power operation under the assumed temperature condition.
2.2 Condenser				
2.2.1 Max Inlet Temp Condenser/Heat Exchanger	100°F [Same for 2nd unit/group]	2, 3, 4		Design assumption for the maximum acceptable circulating water temperature at the inlet to the condenser or cooling water system heat exchangers.
2.2.2 Condenser/Heat Exchanger Duty	1.03 E10 Btu/hr [Additional 1.03 E10 Btu/hr for 2nd unit/group]	11		Design value for the waste heat rejected to the circulating water and service water systems.
2.3 Mechanical Draft Cooling Towers			[d]	
2.3.1 Acreage	50 acres [100 acres]	3, 5	[e]	The land required for cooling towers or ponds, including support facilities such as equipment sheds, basins, canals, or shoreline buffer areas.
2.3.2 Approach Temperature	10°F [Same for 2nd unit/group]	1, 4, 7		The difference between the cold water temperature and the ambient wet bulb temperature.
2.3.3 Blowdown Constituents and Concentrations	See Table 1.3-3 [Twice that shown in table]		[f]	The maximum expected concentrations for anticipated constituents in the cooling water systems blowdown to the receiving water body.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section		Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
2.3.4	Blowdown Flow Rate	6400 gpm expected (24,500 gpm max) [12,800 gpm expected (49,000 gpm max)]	1, 5	g	The normal (and maximum) flow rate of the blowdown stream from the cooling water systems to the receiving water body for closed system designs.
2.3.5	Blowdown Temperature	100°F [Same for 2nd unit/group]	1, 2, 3, 4, 5	g	The maximum expected blowdown temperature at the point of discharge to the receiving water body.
2.3.6	Cycles of Concentration	4 [Same for 2nd unit/group]	6	f	The ratio of total dissolved solids in the cooling water blowdown streams to the total dissolved solids in the make-up water streams.
2.3.7	Evaporation Rate	17,550 gpm expected (19,500 gpm max) [35,100 gpm expected (39,000 gpm max)]	3	h	The expected (and maximum) rate at which water is lost by evaporation from the cooling water systems.
2.3.8	Height	60 ft [Same for 2nd unit/group]	1, 3, 4, 5, 7	c	The vertical height above finished grade of either natural draft or mechanical draft cooling towers associated with the cooling water systems.
2.3.9	Make-up Flow Rate	23,950 gpm expected (44,000 gpm max) [47,900 gpm expected (88,000 gpm max)]	9	g	The expected (and maximum) rate of removal of water from a natural source to replace water losses from closed cooling water system.
2.3.10	Noise	55 dBA at 1000 ft [Same for 2nd unit/group]	6	i	The maximum expected sound level produced by operation of cooling towers, measured at 1000 feet from the noise source.
2.3.11	Cooling Tower Temperature Range	23°F [Same for 2nd unit/group]	7		The temperature difference between the cooling water entering and leaving the towers or ponds.
2.3.12	Cooling Water Flow Rate	800,000 gpm [1,600,000 gpm]	5		The total cooling water flow rate through the condenser/heat exchangers.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
2.3.13 Heat Rejection Rate (Blowdown)	6,400 gpm expected (19,500 gpm max) @100°F [12,800 gpm expected (39,000 gpm max)]	3, 5		The expected heat rejection rate to a receiving water body, expressed as flow rate in gallons per minute at a temperature in degrees Fahrenheit.
2.3.14 Maximum Consumption of Raw Water	30,000 gpm [60,000 gpm]	1		The expected maximum short-term consumptive use of water by the cooling water systems (evaporation and drift losses).
2.3.15 Monthly Average Consumption of Raw Water	23,000 gpm [46,000 gpm]	10		The expected normal operating consumption of water by the cooling water systems (evaporation and drift losses).
2.3.16 Stored Water Volume	11,800,000 gal [23,600,000 gal]	5		The quantity of water stored in cooling water system impoundments, basins, tanks and/or ponds.
2.4 Natural Draft Cooling Towers			[d]	
2.4.1 Acreage	34.5 acres [69 acres]	7		The land required for cooling towers or ponds, including support facilities such as equipment sheds, basins, canals, or shoreline buffer areas.
2.4.2 Approach Temperature	10°F [Same for 2nd unit/group.]	1, 4, 7		The difference between the cold water temperature and the ambient wet bulb temperature.
2.4.3 Blowdown Constituents and Concentrations	See Table 1.3-3 [Twice that shown in table]		[f]	The maximum expected concentrations for anticipated constituents in the cooling water systems blowdown to the receiving water body.
2.4.4 Blowdown Flow Rate	6,400 gpm expected (24,500 gpm max) [12,800 gpm expected (49,000 gpm max)]	1, 5	[g]	The normal (and maximum) flow rate of the blowdown stream from the cooling water systems to the receiving water body for closed system designs.
2.4.5 Blowdown Temperature	100°F [Same for 2nd unit/group]	1, 3, 4, 5	[g]	The maximum expected blowdown temperature at the point of discharge to the receiving water body.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section		Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
2.4.6	Cycles of Concentration	4 [Same for 2nd unit/group]	1, 3, 4, 5, 7	[f]	The ratio of total dissolved solids in the cooling water blowdown streams to the total dissolved solids in the make-up water streams.
2.4.7	Evaporation Rate	17,550 gpm expected (19,500 gpm max) [35,100 gpm expected (39,000 gpm max)]	3	[h]	The expected (and maximum) rate at which water is lost by evaporation from the cooling water systems.
2.4.8	Height	550 ft [Same for 2nd unit/group]	3, 5, 7	[j]	The vertical height above finished grade of either natural draft or mechanical draft cooling towers associated with the cooling water systems.
2.4.9	Make-up Flow Rate	23,950 gpm expected (44,000 gpm max) [47,900 gpm expected (88,000 gpm max)]	9	[g]	The expected (and maximum) rate of removal of water from a natural source to replace water losses from closed cooling water systems.
2.4.10	Noise	55 dBA at 1000 ft [Same for 2nd unit/group]	1, 3, 4, 5, 7	[i]	The maximum expected sound level produced by operation of cooling towers, measured at 1000 feet from the noise source.
2.4.11	Cooling Tower Temperature Range	23°F [Same for 2nd unit/group]	7		The temperature difference between the cooling water entering and leaving the towers or ponds.
2.4.12	Cooling Water Flow Rate	800,000 gpm [1,600,000 gpm]	5		The total cooling water flow rate through the condenser/heat exchangers.
2.4.13	Heat Rejection Rate (Blowdown)	6,400 gpm expected (19,500 gpm max) @100°F [12,800 gpm expected (39,000 gpm max) @100°F	3, 5		The expected heat rejection rate to a receiving water body, expressed as flow rate in gallons per minute at a temperature in degrees Fahrenheit.
2.4.14	Maximum Consumption of Raw Water	33,720 gpm [67,440 gpm]	4		The expected maximum short-term consumptive use of water by the cooling water systems (evaporation and drift losses).

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
2.4.15 Monthly Average Consumption of Raw Water	23,000 gpm [46,000 gpm]	10		The expected normal operating consumption of water by the cooling water systems (evaporation and drift losses).
2.4.16 Stored Water Volume	11,800,000 gal [23,600,000 gal]	5		The quantity of water stored in cooling water system impoundments, basins, tanks and/or ponds.
2.5 Once-Through Cooling			d	
2.5.1 Cooling Water Discharge Temperature	127°F [Same for 2nd unit/group.]	2	g	Expected temperature of the cooling water at the exit of the condenser/heat exchangers.
2.5.2 Cooling Water Flow Rate	1,140,000 gpm [2,280,000 gpm]	5	g	Total cooling water flow rate through the condenser (also the rate of withdrawal from and return to the water source).
2.5.3 Cooling Water Temperature Rise	18°F [Same for 2nd unit/group.]	1, 3, 5	g	Temperature rise across the condenser (temperature of water out minus temperature of water in).
2.5.4 Evaporation Rate	10,550 gpm expected (11,700 gpm max) [21,100 gpm expected (23,400 gpm max)]	3	h	The expected (and maximum) rate at which water is lost by evaporation from the receiving water body as a result of heating in the condenser.
2.5.5 Heat Rejection Rate	1.03 E10 Btu/hr [2.06 E10 Btu/hr]	11		The expected heat rejection rate.
3. Ultimate Heat Sink			k	
3.1 Ambient Air Requirements				
3.1.1 Maximum Ambient Temp (0% Exceedance)	115°F db/80°F wb coincident [Same for 2nd unit/group]	2, 3, 5, 7		Assumption used for the maximum ambient temperature in designing the UHS system to provide heat rejection for 30 days under the assumed temperature condition.
3.1.2 Maximum Wet Bulb Temp (0% Exceedance)	81°F wb (non-coincident) [Same for 2nd unit/group]	2, 3, 5, 7		Assumption used for the maximum wet bulb temperature in designing the UHS system to provide heat rejection for 30 days under the assumed temperature condition.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
3.1.3 Minimum Ambient Temp (0% Exceedance)	-40°F [Same for 2nd unit/group]	2, 3, 5, 7		Assumption used for the minimum ambient temperature in designing the UHS system to provide heat rejection for 30 days under the assumed temperature condition.
3.2 CCW Heat Exchanger				
3.2.1 Maximum Inlet Temp to CCW Heat Exchanger	95°F [Same for 2nd unit/group]	3, 5, 7		The maximum temperature of safety-related service water at the inlet of the UHS component cooling water heat exchanger.
3.2.2 CCW Heat Exchanger Duty	420 E6 Btu/hr (shutdown) [Additional 420 E6 Btu/hr (shutdown) for 2nd unit]	3		The heat transferred to the safety-related service water system for rejection to the environment in UHS heat removal devices.
3.3 Mech Draft Cooling Towers				
3.3.1 Acreage	0.5 acre [1.0 acre]	3, 5	k	The land required for UHS cooling towers or ponds, including support facilities such as equipment sheds, basins, canals, or shoreline buffer areas.
3.3.2 Approach Temperature	15°F [Same for 2nd unit/group]	3, 5		The difference between the cold water temperature and the ambient wet bulb temperature.
3.3.3 Blowdown Constituents and Concentrations	See Table 1.3-3 [Twice that shown in table]		k	The maximum expected concentrations for anticipated constituents in the UHS blowdown to the receiving water body.
3.3.4 Blowdown Flow Rate	144 gpm expected (850 gpm max) [288 gpm expected (1700 gpm max)]	3, 7	k	The normal (and maximum) flow rate of the blowdown stream from the UHS system to receiving water body for closed system designs.
3.3.5 Blowdown Temperature	95°F [Same for 2nd unit/group]	3, 5	k	The maximum expected UHS blowdown temperature at the point of discharge to the receiving water body.
3.3.6 Cycles of Concentration	4 (2 Minimum) [Same for 2nd unit/group]	3, 5, 7	k	The ratio of total dissolved solids in the UHS system blowdown streams to the total dissolved solids in the make-up water streams.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
3.3.7 Evaporation Rate	411 gpm normal 850 gpm shutdown [822 gpm normal 1700 gpm shutdown]	3, 7	k	The expected (and maximum) rate at which water is lost by evaporation from the UHS system.
3.3.8 Height	60 ft [Same for 2nd unit/group]	3, 5, 7	k	The vertical height above finished grade of mechanical draft cooling towers associated with the UHS system.
3.3.9 Make-up Flow Rate	555 gpm 1700 gpm max [1,110 gpm, 3,400 gpm max]	3, 7, 9	k	The expected (and maximum) rate of removal of water from a natural source to replace water losses from the UHS system.
3.3.10 Noise	55 dBA at 1000 ft [Same for 2nd unit/group]	2, 3, 5, 7	k	The maximum expected sound level produced by operation of mechanical draft UHS cooling towers, measured at 1000 feet from the noise source.
3.3.11 Cooling Tower Temperature Range	16°F [Same for 2nd unit/group]	5		The temperature difference between the cooling water entering and leaving the UHS system.
3.3.12 Cooling Water Flow Rate	26,125 gpm (normal) 52,250 gpm (shutdown/ accident) [52,250 gpm (normal), 104,500 (shutdown/ accident)]	3		The total cooling water flow rate through the UHS system.
3.3.13 Heat Rejection Rate (Blowdown)	100 gpm expected (850 gpm max) @95°F [200 gpm expected (1,700 gpm max) @95°F]	3		The expected heat rejection rate to a receiving water body, expressed as flow rate in gallons per minute at a temperature in degrees Fahrenheit.
3.3.14 Maximum Consumption of Raw Water	900 gpm [1800 gpm]	7		The expected maximum short-term consumptive use of water by the UHS system (evaporation and drift losses).
3.3.15 Monthly Average Consumption of Raw Water	533 gpm [1066 gpm]	10		The expected normal operating consumption of water by the UHS system (evaporation and drift losses).

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
3.3.16 Stored Water Volume	30,600,000 gal [61,200,000 gal]	3		The quantity of water stored in UHS impoundments, basins, tanks and/or ponds.
4. Containment Heat Removal System (Post-Accident)				
4.1 Ambient Air Requirements				
4.1.1 Maximum Ambient Air Temperature (0% Exceedance)	115°F db/80°F wb coincident [Same for 2nd unit/group]	1, 7		Assumed maximum ambient temperature used in designing the containment heat removal system.
4.1.2 Minimum Ambient Temperature (0% Exceedance)	-40°F [Same for 2nd unit/group]	1, 7		Assumed minimum ambient temperature used in designing the containment heat removal system.
5. Potable Water/Sanitary Waste System				
5.1 Discharge to Site Water Bodies				
5.1.1 Flow Rate	60 gpm expected (105 gpm max) [120 gpm expected (210 gpm max)]	7	I	The expected (and maximum) effluent flow rate from the potable and sanitary waste water systems to the receiving water body.
5.2 Raw Water Requirements				
5.2.1 Maximum Use	120 gpm [240 gpm]	5	I	The maximum short-term rate of withdrawal from the water source for the potable and sanitary waste water systems.
5.2.2 Monthly Average Use	90 gpm [180 gpm]	5	I	The average rate of withdrawal from the water source for the potable and sanitary waste water systems.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
6. Demineralized Water System				
6.1 Discharge to Site Water Bodies				
6.1.1 Flow Rate	110 gpm expected (150 gpm max) [220 gpm expected (300 gpm max)]	5, 7	I	The expected (and maximum) effluent flow rate from the demineralized system to the receiving water body.
6.2 Raw Water Requirements				
6.2.1 Maximum Use	720 gpm [1440 gpm]	5	I	The maximum short-term rate of withdrawal from the water source for the demineralized water system.
6.2.2 Monthly Average Use	550 gpm [1100 gpm]	5	I	The average rate of withdrawal from the water source for the demineralized water system.
7. Fire Protection System				
7.1 Raw Water Requirements				
7.1.1 Maximum Use	2,500 gpm [5,000 gpm]	11	I	The maximum short-term rate of withdrawal from the water source for the fire protection water system.
7.1.2 Monthly Average Use	675,000 gal/mo [1,350,000 gal/mo]	7	I	The average rate of withdrawal from the water source for the fire protection water system.
7.1.3 Stored Water Volume	2,325,000 gallons [4,650,000 gallons]	7		The quantity of water stored in fire protection system impoundments, basins or tanks.
8. Miscellaneous Drain				
8.1 Discharge to Site Water Bodies				
8.1.1 Flow Rate	100 gpm expected (150 gpm max) [200 gpm expected (300 gpm max)]	3, 7	I	The expected (and maximum) effluent flow rate from miscellaneous drains to the receiving water body.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
9. Unit Vent/Airborne Effluent Release Point				
9.1 Atmospheric Dispersion (CHI/Q) (Accident)			[m]	The atmospheric dispersion coefficients used in the design safety analysis to estimate dose consequences of accident airborne releases.
9.1.1 0-2 hr @EAB	0.61 E-3 sec/m^3 [Same for 2nd unit/group]	1		
9.1.2 0-8 hr @ Low Population Zone (LPZ)	1.30 E-4 sec/m^3 [Same for 2nd unit/group]	5		
9.1.3 8-24 hr @LPZ	1.0 E-4 sec/m^3 [Same for 2nd unit/group]	1, 5		
9.1.4 1-4 day @LPZ	3.36 E-5 sec/m^3 [Same for 2nd unit/group]	3		
9.1.5 4-30 day @LPZ	7.42 E-6 sec/m^3 [Same for 2nd unit/group]	3		
9.2 Atmospheric Dispersion (χ/Q) (Annual Average)	1.17 E-6 sec/m^3 [Same for 2nd unit/group]	3	[m]	The atmospheric dispersion coefficients used in the safety analysis for the dose consequences of normal airborne releases.
9.3 Dose Consequences			[n]	
9.3.1 Normal	10 CFR 20, 10 CFR 50 App I [Same for 2nd unit/group]	6		The estimated design radiological dose consequences due to gaseous releases from normal operation of the plant.
9.3.2 Post-Accident	10 CFR 100 [Same for 2nd unit/group]	1, 3, 4, 5, 7		The estimated design radiological dose consequences due to gaseous releases from postulated accidents.
9.3.3 Severe Accidents	25 rem wb in 24 hr 0.5 mi <1E-6/rx-yr [Same for 2nd unit/group]	1, 3, 7		

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
9.4 Release Point			o	
9.4.1 Configuration (Horiz vs. Vert)	Horizontal	2		The orientation of the release point discharge flow.
9.4.2 Elevation (Normal)	95.5 ft [Same for 2nd unit/group]	2		The elevation above finished grade of the release point for routine operational releases.
9.4.3 Elevation (Post Accident)	Ground level [Same for 2nd unit/group]	1, 2, 3, 5, 7		The elevation above finished grade of the release point for accident sequence releases.
9.4.4 Minimum Distance to Site Boundary	0.5 mi exclusion area [Same for 2nd unit/group]	1, 3, 7		The minimum lateral distance from the release point to the site boundary.
9.4.5 Temperature	No value bounds, overall range is 35-120°F [Same for 2nd unit/group]			The temperature of the airborne effluent stream at the release point.
9.4.6 Volumetric Flow Rate	118,000 scfm for 2 units (normal operation) [for 2 units]	5		The volumetric flow rate of the airborne effluent stream at the release point.
9.5 Source Term			p	
9.5.1 Gaseous (Normal)	15,000 Ci/yr [30,000 Ci/yr] See Table 1.3-8 for isotopic breakdown	12		The annual activity, by isotope, contained in routine plant airborne effluent streams.
9.5.2 Gaseous (Post-Accident)	See Chap 15 Tables RG 1.70 [Same for 2nd unit/group]	1, 3	q	The activity, by isotope, contained in post-accident airborne effluents.
9.5.3 Tritium	3500 Ci/yr [7000 Ci/yr]	5		The annual activity of tritium contained in routine plant airborne effluent streams.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
10. Liquid Radwaste System				
10.1 Dose Consequences			r	
10.1.1 Normal	10 CFR 50, Appendix I, 10 CFR 20	1, 3, 4, 5		The estimated design radiological dose consequences due to liquid effluent releases from normal operation of the plant.
10.1.2 Post-Accident	10 CFR 20, 10 CFR 100 [Same for 2nd unit/group]	1, 3, 4, 5		The estimated design radiological dose consequences due to liquid effluent releases from postulated accidents.
10.2 Release Point			s	
10.2.1 Flow Rate	100 gpm + 10,000 gpm dilution [200 gpm + 20,000 gpm dilution]	3		The discharge (including minimum dilution flow, if any) of liquid potentially radioactive effluent streams from plant systems to the receiving water body.
10.3 Source Term			t	
10.3.1 Liquid	0.37 Ci/yr [0.74 Ci/yr] See Table 1.3-7 for isotopic breakdown	13		The annual activity, by isotope, contained in routine plant liquid effluent streams.
10.3.2 Tritium	3100 Ci/yr [6200 Ci/yr]	5		The annual activity of tritium contained in routine plant liquid effluent streams.
11. Solid Radwaste System			u	
11.1 Acreage				
11.1.1 Low Level Radwaste Storage	2 years in radwaste building @ expected generation rate [Same for 2nd unit/group]	1		The land usage required to provide onsite storage of low level radioactive wastes.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
11.2 Solid Radwaste				
11.2.1 Activity	2700 Ci/yr [5400 Ci/yr]	3		The annual activity contained in solid radioactive wastes generated during routine plant operations.
11.2.2 Volume	9041 cu ft/yr [18,646 cu ft/yr]	4		The expected volume of solid radioactive wastes generated during routine plant operations.
12. Auxiliary Boiler System				
12.1 Exhaust Elevation	110 ft above plant grade [Same for 2nd unit/group]	5	V	The height above finished plant grade at which the flue gas effluents are released to the environment.
12.2 Flue Gas Effluents	See Table 1.3-4 [Twice that shown in table]		V	The expected combustion products and anticipated quantities released to the environment due to operation of the auxiliary boilers, diesel engines and gas turbines.
12.3 Fuel Type	No. 2 [Same for 2nd unit/group]	1, 3, 5, 7	V	The type of fuel oil required for proper operation of the auxiliary boilers, diesel engines and gas turbines.
12.4 Heat Input Rate (btu/hr)	156,000,000 Btu/hr [312,000,000 Btu/hr]	1		The average heat input rate due to the periodic operation of the auxiliary boilers.
13. Heating, Ventilation and Air Conditioning System				
13.1 Ambient Air Requirements				
13.1.1 Non-safety HVAC max ambient temp (1% Exceed)	100°F db/77°F wb coincident [Same for 2nd unit/group]	6		Assumption used for the maximum ambient temperature that will be exceeded no more than 1% of the time, to design the non-safety HVAC systems.
13.1.2 Non-safety HVAC min ambient temp (1% Exceed)	-10°F [Same for 2nd unit/group]	6		Assumption used for the minimum ambient temperature that will be exceeded no more than 1% of the time, to design the non-safety HVAC systems.
13.1.3 Safety HVAC max ambient temp (0% Exceed)	115°F db/80°F wb coincident [Same for 2nd unit/group]	1, 3, 5, 7		Assumption used for the maximum ambient temperature that will never be exceeded, to design the safety-related HVAC systems.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section		Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
13.1.4	Safety HVAC min ambient temp (0% Exceed)	-40°F [Same for 2nd unit/group]	1, 3, 5, 7		Assumption used for the minimum ambient temperature that will never be exceeded, to design the safety-related HVAC systems.
13.1.5	Vent System max ambient temp (5% Exceed)	95°F dry bulb/ 77°F wb coincident), 79°F wb (non-coincident) [Same for 2nd unit/group]	3, 5		Assumption used for the maximum ambient temperature that will be exceeded no more than 5% of the time to design the non-HVAC ventilation systems.
13.1.6	Vent System min ambient temp (5% Exceed)	- 5°F [Same for 2nd unit/group]	3		Assumption used for the minimum ambient temperature that will be exceeded no more than 5% of the time to design the non-HVAC ventilation systems.
14. Onsite/Offsite Electrical Power System					
14.1 Acreage					
14.1.1	Switchyard	15 acres [30 acres]	7	e	The land usage required for the high voltage switchyard used to connect the plant to the transmission grid.
15. Standby Power System					
15.1 Diesels					
15.1.1	Diesel Capacity	2 × 15,000 kw [4 × 15,000 kw]	11		The capacity of diesel engines used for generation of standby electrical power.
15.1.2	Diesel Exhaust Elevation	30 ft [Same for 2nd unit/group]	4	v	The elevation above finished grade of the release point for standby diesel exhaust releases.
15.1.3	Diesel Flue Gas Effluents	See Table 1.3-5 [Twice that shown in table]		v	The expected combustion products and anticipated quantities released to the environment due to operation of the emergency standby diesel generators.
15.1.4	Diesel Noise	55 dBA at 1000 ft [Same for 2nd unit/group]	1, 3, 4, 5, 7	i	The maximum expected sound level produced by operation of diesel engines turbines, measured at 1000 feet from the noise source.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
15.1.5 Diesel Fuel Type	No. 2 per ASTM D975-1974 [Same for 2nd unit/group]	1, 3, 4, 5, 7		The type of fuel oil required for proper operation of the diesel engines.
15.2 Gas Turbines				
15.2.1 Gas Turbine Capacity (kw)	20 MWe at limiting site conditions [40 MWe at limiting site conditions]	3		The capacity of gas turbines used for generation of standby electrical power.
15.2.2 Gas Turbine Exhaust Elevation	60 ft [Same for 2nd unit/group]	3	v	The elevation above finished grade of the release point for standby gas turbine exhaust releases.
15.2.3 Gas Turbine Flue Gas Effluents	See Table 1.3-6 [Twice that shown in table]		v	The expected combustion products and anticipated quantities released to the environment due to operation of the emergency standby gas-turbine generators.
15.2.4 Gas Turbine Noise	55 dBA at 1000 ft [Same for 2nd unit/group]	2, 3	i	The maximum expected sound level produced by operation of gas turbines, measured at 1000 feet from the noise source.
15.2.5 Gas Turbine Fuel Type	Distillate [Same for 2nd unit/group]	2, 3	v	The type of fuel oil required for proper operation of the gas turbines.
16. Plant Characteristics				
16.1 Access Routes				
16.1.1 Heavy Haul Routes	7 acres [Same for 2nd unit/group]	3, 7	e	The land usage required for permanent heavy haul routes to support normal operations and refueling.
16.1.2 Spent Fuel Cask Weight	150 tons [Same for 2nd unit/group]	3	w	The weight of the heaviest expected shipment during normal plant operations and refueling.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
16.2 Acreage	87 acres [174 acres]	2	x	The land area required to provide space for plant facilities.
16.2.1 Office Facilities	1.8 acres [2.18 acre (95,200 sq ft)]	2		
16.2.2 Parking Lots	3.86 acres [7.72 acres]	3		
16.2.3 Permanent Support Facilities	12 acres [8.4 acres]	2		
16.2.4 Power Block	11.64 acres [23.3 acres]	7		
16.2.5 Protected Area	40 acres [80 acres]	7		
16.3 Megawatts Thermal	4500 MWt [9000 MWt]	11		The thermal power generated by one unit (may be the total of several modules).
16.4 Plant Design Life	60 years [Same for 2nd unit/group]	1, 2, 3, 5, 7	y	The operational life for which the plant is designed.
16.5 Plant Population				
16.5.1 Operation	580 people [1160 people]	5	y	The number of people required to operate and maintain the plant.
16.5.2 Refueling / Major Maintenance	1000 people [Same for 2nd unit/group]	1	y	The additional number of temporary staff required to conduct refueling and major maintenance activities.
16.6 Station Capacity Factor	96% [Same for 2nd unit/group]	2		The percentage of time that a plant is capable of providing power to the grid.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition
17. Construction				
17.1 Access Routes				
17.1.1 Construction Module Dimensions	90' (H) x 82' (W) x 93' (L) or 130' (Dia) x 51' (H) [Same for 2nd unit/group]	1, 7	w	The maximum expected length, width, and height of the largest construction modules or components and delivery vehicles to be transported to the site during construction.
17.1.2 Heaviest Construction Shipment	2,200,00 lb. [Same for 2nd unit/group]	2	w	The maximum expected weight of the heaviest construction shipment to the site.
17.2 Acreage				The land area required to provide space for construction support facilities.
17.2.1 Laydown Area	29 acres [58 acres]	3	e	
17.2.2 Temporary Construction Facilities	52 acres [104 acres]	3	e	
17.3 Construction				
17.3.1 Noise	76-101 db @ 50 ft [Same for 2nd unit/group]	1, 3, 4, 5, 7	i	The maximum expected sound level due to construction activities, measured at 50 feet from the noise source.
17.4 Plant Population				
17.4.1 Construction	3150 people max [5,355 for unit simultaneous construction]	3, 14	y	Peak employment during plant construction.
17.5 Site Preparation Duration	18 months [Same for 2nd unit/group]	1, 3, 7	y	Length of time required to prepare the site for construction.

Table 1.3-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 1.3-2	Comments	Definition

Comments:

a. PPE values should be based on plant designs being considered. The Bounding PPE values provide an envelope (most restrictive values selected) for the ABWR, ESBWR, AP1000, IRIS, GT-MHR, PBMR and ACR-700 designs. A composite PPE should be used for the actual set of plant designs under consideration for the site.

b. The values in brackets reflects the values corresponding to a plant that is twice the vendor's specified standard size plant, i.e., two ABWR units, two ESBWR units, two AP1000 units, six IRIS units, two sets of four GT-MHR modules, two sets of eight PBMR modules and two ACR-700 twin unit plants.

c. Visual resources impacts.

d. Applicants must identify main condenser cooling system alternatives (e.g., mechanical or natural draft cooling towers, cooling ponds, or once-through cooling). To maintain multiple options, the most restrictive value for each cooling system PPE section should be used in the ESP application (e.g., 550-foot cooling tower height selected if both mechanical and natural draft towers are being considered).

e. Construction impacts on ecological resources.

f. Operational impacts on water quality and ecological resources.

g. Operational impacts on water quality and ecological resources. A National Pollutant Discharge Elimination System (NPDES) permit must be obtained for this blowdown rate, blowdown temperature, withdrawal rate or temperature rise.

h. Operational impacts on water quality and local climatology.

i. Noise impacts.

j. Visual impacts.

k. Impacts of the main condenser cooling system will usually bound impacts from operation of the Ultimate Heat Sink.

l. Operational impacts on water quality and aquatic ecological resources.

m. The atmospheric dispersion values presented in PPE Sections 9.1 and 9.2 represent typical site parameter values assumed by reactor vendors.

n. Values listed for Section 9.3 are regulatory standards for effluent concentrations, doses from routine operations, and doses from postulated accidents. The applicant must demonstrate that the plant is capable of meeting these standards considering the plant design and, for the dose standards, dilution and dispersion conditions at the site.

o. Release point characteristics (Section 9.4.1 - Section 9.4.6) are used to calculate atmospheric dispersion factors used: S - In the Site SAR to demonstrate compliance with requirements listed in Section 9.3, and, E - In the ER to estimate impacts from routine and accident-scenario atmospheric releases.

p. Source term data (Section 9.5.1 -Section 9.5.3) are used to calculate dose consequences used: S - In the Site SAR to demonstrate compliance with requirements listed in Section 9.3, and, E - In the ER to estimate impacts from routine and accident-scenario atmospheric releases.

q. See Section 9.5. Tables in Chapter 15 of RG 1.70 list the design and accident sequence parameters necessary to derive these source terms. Applicants must obtain calculated release values from the vendor/A-E for designs under consideration.

r. Values listed for Section 10.1 are regulatory standards for effluent concentrations, doses from routine operations, and doses from postulated accidents. The applicant must demonstrate that the plant is capable of meeting these standards considering the plant design and, for the dose standards, dilution and dispersion conditions at the site.

s. Flow rate and dilution characteristics (Section 10.2) are used to calculate dilution factors used: S - In the Site SAR to demonstrate compliance with requirements listed in Section 10.1, and, E - In the ER to estimate impacts from liquid effluents.

t. Liquid discharge data (Section 10.3.1 - Section 10.3.2) are used to calculate dose consequences used: S - In the Site SAR to demonstrate compliance with requirements listed in Section 10.1, and, E - In the ER to estimate impacts from liquid effluents.

u. Environmental effects of the uranium fuel cycle, including solid waste management, are set forth in Table S-3 of 10 CFR 51.20. Reference to this Table is made in the applicant's ER.

v. Operational impacts of non-radiological atmospheric emissions.

w. Transport requirements for component delivery.

x. Total acreage footprint for site facilities is used to estimate construction impacts on ecological resources.

y. Socio-economic impacts of plant construction and operation.

Table 1.3-2 Bounding Value Notes for Table 1.3-1

1. Bounding value from AP1000 criteria.
2. Bounding value from GT-MHR criteria.
3. Bounding value from ABWR/ESBWR criteria.
4. Bounding value from PBMR criteria.
5. Bounding value from ACR-700 criteria.
6. Bounding value common for the seven designs.
7. Bounding value from IRIS criteria.
8. The Spectrum A missiles were for plants that used the November 24, 1975 version of the SRP; for all plants since, the Spectrum I or II of the July 1981 version of the SRP was to be used.
9. The bounding Make-up Flow Rate is a calculated value based on the sum of the bounding Evaporation rate plus the bounding Blowdown Flow Rate.
10. The bounding value for the Monthly Average Consumption of Raw Water is a calculated value based on the maximum bounding make-up flow rate times the bounding capacity factor (PPE Section 16.6).
11. Bounding value from ESBWR criteria.
12. The Gaseous (Normal) source term bounding value is the sum of the bounding values of the yearly released activity for each nuclide type for each reactor (ABWR, AP1000, ACR-700, ESBWR). These were the only reactor types with adequate information available. See Table 1.3-8.
13. The liquid waste source term bounding value is the sum of the bounding values of the yearly released activity for each nuclide type for each reactor (ABWR, AP1000, ACR-700, ESBWR). These were the only reactor types with adequate information available. The PBMR value was not supported by isotopic data and was not used in the evaluation. See Table 1.3-7.
14. Two-unit simultaneous construction staffing is based on 170% of single unit build. This assumes optimum timing between units and is based on rough estimates by Bechtel. Refined information will be contingent upon type of plant built, and plant location.

Table 1.3-3 Blowdown Constituents and Concentrations[a]

Constituent	Bounding Value			
	Concentration (ppm)[b]			
	River Source	Well/ Treated Water	Envelope	Notes
Chlorine demand	10.1	--	10.1	c, d, e
Free available chlorine	0.5	--	0.5	f
Chromium	--	--	--	
Copper	--	6	6	f
Iron	0.9	3.5	3.5	f
Zinc	--	0.6	0.6	f
Phosphate	--	7.2	7.2	c,d,e
Sulfate	599	3500	3500	f
Oil and grease	--	--	--	
Total dissolved solids	--	17,000	--	c,d,e
Total suspended solids	49.5	150	150	f
BOD, 5-day	--	--	--	

a. See PPE Section 2.3.3, 2.4.3, and 3.3.3.
b. Assumed cycles of concentration equals 4.
c. Bounding value from ABWR/ESBWR criteria.
d. Bounding value from AP1000 criteria.
e. Bounding value from PBMR criteria.
f. Bounding value common for the seven designs.

Table 1.3-4 Yearly Emissions Auxiliary Boilers[a]

	Bounding Value	
Pollutant Discharged[b]	**Quantity (lb.)**	**Notes**
Particulates	9,900	c
Sulfur oxides	31,703	d
Carbon monoxide	1749	d
Hydrocarbons	50,100	e
Nitrogen oxides	19,022	d

a. See PPE Section 12.2.
b. Emissions are based on 30 days/yr operation for each of the generators.
c. Bounding value from ABWR/ESBWR criteria.
d. Bounding value from ACR-700 criteria.
e. Bounding value from AP1000 criteria.

Table 1.3-5 Yearly Emissions From Standby Diesel Generators[a]

	Bounding Value	
Pollutant Discharged[b]	**Quantity (lb.)**	**Notes**
Particulates	<1,230	c
Sulfur oxides	4,608	d
Carbon monoxide	4,600	e
Hydrocarbons	3,070	e
Nitrogen oxides	28,968	d

a. See PPE Section 15.1.
b. Emissions are based on 4 hrs/month operation for each of the generators.
c. Bounding value from IRIS criteria.
d. Bounding value from ABWR/ESBWR criteria.
e. Bounding value from ACR-700 criteria.

Table 1.3-6 Standby Power System Gas Turbine Flue Gas Effluents[a]

Fuel: Distillate 20°F Ambient
9,890 Btu/kWH (LHV)
10,480 Btu/kWH (HHV)

Bounding Value		
Fuel Consumption Rate	**121,200 lb/hr [b]**	
Effluent	**Quantity[c] (lb.)**	**Notes**
NO_X (PPMVD @15% O_2)	42	d
NO_x as NO_2	2016	d
CO (PPMVD)	31	d
CO	912	d
UHC (PPMVD)	3	d
UHC	48	d
VOC	10	b
SO_2	1882	d
$S0_3$	30	b
Sulfur Mist	50	b
Particulates	22	b
Exhaust Analysis	**% Vol**	
Argon	0.87	d
Nitrogen	72.56	b
Oxygen	12.52	d
Carbon Dioxide	5.19	b
Water	9.87	b

a. See PPE Section 15.2.
b. Bounding value from GT-MHR criteria.
c. Emissions are based on 4 hrs/month operation for each of the generators.
d. Bounding value from ABWR criteria.

Table 1.3-7 Release of Activities in Liquid Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
H-3	3.1E+03	5.8E-05	1.0E-03	5.8E-02
C-14	4.4E-04	7.7E-12	3.0E-05	2.6E-07
Na-24	3.5E-03	3.5E-11	5.0E-05	7.1E-07
P-32	6.6E-04	6.7E-12	9.0E-06	7.4E-07
Cr-51	2.1E-02	2.4E-10	5.0E-04	4.8E-07
Mn-54	2.8E-03	7.6E-11	3.0E-05	2.5E-06
Mn-56	4.2E-03	4.2E-11	7.0E-05	6.0E-07
Fe-55	6.4E-03	9.6E-11	1.0E-04	9.6E-07
Fe-59	2.0E-04	2.8E-11	1.0E-05	2.8E-06
Co-56	5.7E-03	6.1E-11	6.0E-06	1.0E-05
Co-57	7.9E-05	9.9E-13	6.0E-05	1.7E-08
Co-58	3.4E-03	7.8E-10	2.0E-05	3.9E-05
Co-60	1.0E-02	2.2E-10	3.0E-06	7.4E-05
Ni-63	1.5E-04	2.7E-12	1.0E-04	2.7E-08
Cu-64	8.2E-03	8.3E-11	2.0E-04	4.1E-07
Zn-65	7.5E-04	9.3E-12	5.0E-06	1.9E-06
Zn-69m	6.0E-04	6.0E-12	6.0E-05	1.0E-07
Br-83	7.5E-05	7.5E-13	9.0E-04	8.4E-10
Br-84	2.0E-05	2.0E-13	4.0E-04	5.0E-10
Rb-88	2.7E-04	2.7E-12	4.0E-04	6.8E-09
Rb-89	4.8E-05	4.8E-13	9.0E-04	5.4E-10
Sr-89	3.6E-04	1.1E-10	8.0E-06	1.4E-05
Sr-90	3.8E-05	1.3E-11	5.0E-07	2.5E-05
Sr-91	9.8E-04	2.9E-11	2.0E-05	1.4E-06
Sr-92	8.8E-04	8.8E-12	4.0E-05	2.2E-07
Y-90	3.4E-06	1.3E-11	7.0E-06	1.9E-06
Y-91m	1.0E-05	1.0E-13	2.0E-03	5.0E-11
Y-91	2.4E-04	1.3E-10	8.0E-06	1.7E-05

Table 1.3-7 Release of Activities in Liquid Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
Y-92	6.6E-04	6.6E-12	4.0E-05	1.6E-07
Y-93	9.8E-04	9.9E-12	2.0E-05	4.9E-07
Zr-95	1.0E-03	3.2E-11	2.0E-05	1.6E-06
Nb-95	1.9E-03	4.2E-11	3.0E-05	1.4E-06
Mo-99	3.9E-03	9.9E-08	2.0E-05	5.0E-03
Tc-99m	5.1E-03	8.5E-08	1.0E-03	8.5E-05
Ru-103	4.9E-03	5.1E-11	3.0E-05	1.7E-06
Ru-105	1.0E-04	1.0E-12	7.0E-05	1.4E-08
Ru-106	7.4E-02	9.7E-10	3.0E-06	3.2E-04
Rh-103m	4.9E-03	5.0E-11	6.0E-03	8.3E-09
Rh-106	7.4E-02	7.4E-10	—	—
Ag-110m	1.1E-03	1.3E-11	6.0E-06	2.2E-06
Ag-110	1.4E-04	1.4E-12	—	—
Sb-124	6.8E-04	7.2E-12	7.0E-06	1.0E-06
Te-129m	1.4E-04	1.4E-12	7.0E-06	2.0E-07
Te-129	1.5E-04	1.5E-12	4.0E-04	3.8E-09
Te-131m	1.0E-04	1.0E-12	8.0E-06	1.3E-07
Te-131	3.0E-05	3.0E-13	8.0E-05	3.8E-09
Te-132	2.4E-04	4.8E-09	9.0E-06	5.3E-04
I-131	1.4E-02	5.6E-08	1.0E-06	5.6E-02
I-132	2.8E-03	8.5E-09	1.0E-04	8.5E-05
I-133	2.4E-02	6.2E-08	7.0E-06	8.9E-03
I-134	1.9E-03	1.2E-09	4.0E-04	3.0E-06
I-135	8.2E-03	3.7E-09	3.0E-05	1.2E-04
Cs-134	9.9E-03	1.8E-08	9.0E-07	2.0E-02
Cs-136	1.2E-03	2.6E-09	6.0E-06	4.4E-04
Cs-137	1.3E-02	1.2E-07	1.0E-06	1.2E-01
Cs-138	2.1E-04	2.1E-12	4.0E-04	5.2E-09

Table 1.3-7 Release of Activities in Liquid Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
Ba-137m	1.2E-02	1.3E-10	—	—
Ba-139	2.5E-05	2.5E-13	2.0E-04	1.3E-09
Ba-140	5.5E-03	1.5E-10	8.0E-06	1.8E-05
La-140	7.4E-03	1.2E-10	9.0E-06	1.4E-05
La-142	2.5E-05	2.5E-13	1.0E-04	2.5E-09
Ce-141	1.3E-04	1.3E-12	3.0E-05	4.5E-08
Ce-143	1.9E-04	1.9E-12	2.0E-05	9.5E-08
Ce-144	3.2E-03	5.8E-11	3.0E-06	1.9E-05
Pr-143	1.4E-04	1.4E-12	2.0E-05	6.9E-08
Pr-144	3.2E-03	3.2E-11	6.0E-04	5.3E-08
W-187	2.1E-04	2.1E-12	3.0E-05	7.1E-08
Np-239	1.4E-02	1.4E-10	2.0E-05	6.9E-06
Total w/o H-3	3.7E-01	4.7E-07		2.1E-01
Total w/ H-3	3.1E+03	5.8E-05		2.7E-01

Note: The releases are composite, bounding values for a new single unit based on multiple reactor designs. In determining the composite values, ABWR activities were scaled up to 4300 MWt and ESBWR activities were increased by 25 percent. The concentrations are the total liquid effluents from the two new units and the two existing units. No ECLs are provided in 10 CFR 20 for Rh-106, Ag-110, and Ba-137m.

Table 1.3-8 Release of Activities in Gaseous Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
H-3	3.5E+03	8.3E-10	1.0E-07	8.3E-03
C-14	1.2E+01	2.8E-12	3.0E-09	9.3E-04
Na-24	4.4E-03	1.0E-15	7.0E-09	1.5E-07
P-32	1.0E-03	2.4E-16	5.0E-10	4.7E-07
Ar-41	3.0E+02	7.1E-11	1.0E-08	7.1E-03
Cr-51	3.8E-02	9.0E-15	3.0E-08	3.0E-07
Mn-54	5.9E-03	1.4E-15	1.0E-09	1.4E-06
Mn-56	3.8E-03	9.0E-16	2.0E-08	4.5E-08
Fe-55	7.1E-03	1.7E-15	3.0E-09	5.6E-07
Fe-59	8.9E-04	2.1E-16	5.0E-10	4.2E-07
Co-57	8.2E-06	1.9E-18	9.0E-10	2.1E-09
Co-58	2.3E-02	5.4E-15	1.0E-09	5.4E-06
Co-60	1.4E-02	3.3E-15	5.0E-11	6.7E-05
Ni-63	7.1E-06	1.7E-18	1.0E-09	1.7E-09
Cu-64	1.1E-02	2.6E-15	3.0E-08	8.6E-08
Zn-65	1.2E-02	2.8E-15	4.0E-10	7.1E-06
Kr-83m	1.3E-03	3.0E-16	5.0E-05	5.9E-12
Kr-85m	3.6E+01	7.9E-11	1.0E-07	7.9E-04
Kr-85	4.1E+03	2.2E-09	7.0E-07	3.2E-03
Kr-87	4.9E+01	5.1E-11	2.0E-08	2.6E-03
Kr-88	7.4E+01	1.4E-10	9.0E-09	1.6E-02
Kr-89	4.7E+02	1.1E-10	1.0E-09	1.1E-01
Kr-90	4.2E-04	9.9E-17	1.0E-09	9.9E-08
Rb-89	4.7E-05	1.1E-17	2.0E-07	5.6E-11
Sr-89	6.2E-03	1.5E-15	2.0E-10	7.3E-06
Sr-90	1.2E-03	2.8E-16	6.0E-12	4.7E-05
Sr-91	1.1E-03	2.6E-16	5.0E-09	5.1E-08
Sr-92	8.6E-04	2.0E-16	9.0E-09	2.2E-08

Table 1.3-8 Release of Activities in Gaseous Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
Y-90	5.0E-05	1.2E-17	9.0E-10	1.3E-08
Y-91	2.6E-04	6.2E-17	2.0E-10	3.1E-07
Y-92	6.8E-04	1.6E-16	1.0E-08	1.6E-08
Y-93	1.2E-03	2.8E-16	3.0E-09	9.5E-08
Zr-95	1.7E-03	4.1E-16	4.0E-10	1.0E-06
Nb-95	9.2E-03	2.2E-15	2.0E-09	1.1E-06
Mo-99	6.5E-02	1.5E-14	2.0E-09	7.6E-06
Tc-99m	3.3E-04	7.6E-17	2.0E-07	3.8E-10
Ru-103	3.8E-03	9.0E-16	9.0E-10	1.0E-06
Ru-106	7.8E-05	1.8E-17	2.0E-11	9.2E-07
Rh-103m	1.2E-04	2.8E-17	2.0E-06	1.4E-11
Rh-106	2.1E-05	4.9E-18	1.0E-09	4.9E-09
Ag-110m	2.2E-06	5.1E-19	1.0E-10	5.1E-09
Sb-124	2.0E-04	4.6E-17	3.0E-10	1.5E-07
Sb-125	6.1E-05	1.4E-17	7.0E-10	2.0E-08
Te-129m	2.4E-04	5.6E-17	3.0E-10	1.9E-07
Te-131m	8.3E-05	1.9E-17	1.0E-09	1.9E-08
Te-132	2.1E-05	4.9E-18	9.0E-10	5.4E-09
I-131	5.1E-01	3.5E-13	2.0E-10	1.7E-03
I-132	2.4E+00	6.1E-13	2.0E-08	3.0E-05
I-133	1.9E+00	7.2E-13	1.0E-09	7.2E-04
I-134	4.1E+00	9.9E-13	6.0E-08	1.6E-05
I-135	2.6E+00	7.3E-13	6.0E-09	1.2E-04
Xe-131m	1.8E+03	4.2E-10	2.0E-06	2.1E-04
Xe-133m	8.7E+01	1.2E-10	6.0E-07	2.0E-04
Xe-133	4.6E+03	1.0E-08	5.0E-07	2.1E-02
Xe-135m	7.7E+02	1.9E-10	4.0E-08	4.7E-03
Xe-135	8.2E+02	4.0E-10	7.0E-08	5.7E-03

Table 1.3-8 Release of Activities in Gaseous Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
Xe-137	9.8E+02	2.3E-10	1.0E-09	2.3E-01
Xe-138	7.8E+02	2.1E-10	2.0E-08	1.0E-02
Xe-139	5.3E-04	1.2E-16	1.0E-09	1.2E-07
Cs-134	6.8E-03	1.6E-15	2.0E-10	8.0E-06
Cs-136	6.5E-04	1.5E-16	9.0E-10	1.7E-07
Cs-137	1.0E-02	2.4E-15	2.0E-10	1.2E-05
Cs-138	1.9E-04	4.4E-17	8.0E-08	5.5E-10
Ba-140	3.0E-02	6.9E-15	2.0E-09	3.5E-06
La-140	2.0E-03	4.6E-16	2.0E-09	2.3E-07
Ce-141	1.0E-02	2.4E-15	8.0E-10	2.9E-06
Ce-144	2.1E-05	4.9E-18	2.0E-11	2.4E-07
Pr-144	2.1E-05	4.9E-18	2.0E-07	2.4E-11
W-187	2.1E-04	4.9E-17	1.0E-08	4.9E-09
Np-239	1.3E-02	3.1E-15	3.0E-09	1.0E-06
Total w/o H-3	1.5E+04	1.5E-08		4.2E-01
Total w/ H-3	1.8E+04	1.5E-08		4.2E-01

Note: The releases are composite, bounding values for a single new unit based on multiple reactor designs. In determining the composite values, ABWR activities were scaled up to 4300 MWt and ESBWR activities were increased by 25 percent. The concentrations are the total at the site boundary from the new units and the two existing units.

1.4 Identification of Agents and Contractors

Dominion selected Bechtel Power Corporation (Bechtel) as its primary contractor to assist with the preparation of the ESP application. In this role, Bechtel supplied personnel, systems, project management, and resources to work on an integrated team with Dominion.

1.4.1 Bechtel Power Corporation

Bechtel is the nation's largest power contractor, headquartered in San Francisco. Bechtel has a history of supporting the nuclear power industry, beginning with the construction in 1950 of the EBR-1 reactor. Since then, Bechtel has engineered and constructed more than 60,000 MWe of nuclear power capacity worldwide. Currently, Bechtel has 50,000 employees working on 1,100 projects in 66 different countries around the globe.

1.4.2 Other Contractors

In addition to Bechtel, contractual relationships were established with several specialized consultants to assist in developing the ESP application.

1.4.2.1 Tetra Tech NUS, Inc.

Tetra Tech NUS, Inc. performed data collection and analysis, and prepared several sections of the Environmental Report, including the ecological description of the site and vicinity, environmental impacts of construction, and plant cooling system impacts on terrestrial and aquatic ecosystems.

1.4.2.2 MACTEC Engineering and Consulting, Inc.

MACTEC Engineering and Consulting, Inc. performed geotechnical field investigations and laboratory testing in support of SSAR Section 2.5, Geology, Seismology, and Geotechnical Engineering. That effort included performing standard penetration tests; obtaining core samples and rock cores; performing cone penetrometer tests, cross-hole seismic tests, and laboratory tests of soil and rock samples; installing ground water observation wells; and preparing a data report.

1.4.2.3 William Lettis & Associates, Inc.

William Lettis & Associates, Inc. performed geologic mapping and the characterization of seismic sources in support of SSAR Section 2.5, including literature review, geologic field reconnaissance, review and evaluation of existing seismic source characterization models, identification and characterization of any new or different sources, and preparation of the related SSAR sections.

1.4.2.4 Risk Engineering, Inc.

Risk Engineering, Inc. performed probabilistic seismic hazard assessments and related sensitivity analyses in support of SSAR Section 2.5. These assignments included sensitivity analyses of seismic source parameters and updated ground motion attenuation relationships, development of

updated Safe Shutdown Earthquake (SSE) ground motion values, and preparation of the related SSAR sections.

Section 1.4 References

None

1.5 Requirements for Further Technical Information

There are no technical information development programs remaining to be performed to support this application.

Section 1.5 References

None

1.6 Material Incorporated by Reference

No material has been incorporated by reference in this application.

Section 1.6 References

None

1.7 Drawings and Other Detailed Information

No such information has been submitted separately as part of this application.

Section 1.7 References

None

1.8 Conformance to NRC Regulations and Regulatory Guidance

This section discusses the conformance of the ESP application SSAR with applicable NRC regulations and guidance. NRC regulations are contained in Title 10 of the Code of Federal Regulations. NRC guidance is contained in NRC Regulatory Guides (RGs) and the draft NRC review standard for ESP applications (Reference 1). Exemptions, exceptions, and clarifications to the requirements and guidance are described below.

NRC regulations are legally binding requirements. If a legally binding requirement applicable to ESP can not be met, an *exemption* from the applicable regulation is needed. No *exemptions* to NRC regulations are required to support this ESP application. In certain instances, a regulation is listed because it could have applied under certain conditions. If the conditions are not met, conformance is specified as “not required” or “not applicable” and an explanation provided.

Exceptions are identified when the guidance can not be met as stated, but the intent or objective can be achieved by acceptable alternatives.

Clarifications are identified when guidance is met, but additional information is needed to provide complete understanding of the method of conformance.

Conformance with NRC regulations is described in Section 1.8.1, conformance with NRC RGs is described in Section 1.8.2, and conformance with NRC Review Standard RS-002 is described in Section 1.8.3.

1.8.1 Conformance with NRC Regulations

This section describes conformance with the applicable requirements of NRC regulations. Conformance with the regulation was determined using the acceptance criteria sections of NUREG-0800, as modified by draft RS-002 (Reference 1, Attachment 2). The NRC regulation number, title, description of applicable requirements, affected SSAR sections, and statement of conformance are provided. Exceptions and clarifications to conformance with the regulation are noted, as appropriate.

Regulation	**10 CFR 20**
Title	Standards for Protection Against Radiation
Description	2.1.1 - Describe the restricted area boundaries in order to determine whether releases in excess of limits may occur. 13.3.2 - Establishes occupational dose limits for emergencies
Affected Sections	2.1.1, 13.3.2
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 20, Appendix B, Table 2**
Title	Annual Limits on Intake and Derived Air Concentrations of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage
Description	Provides radionuclide-specific concentration limits for ingestion of water.
Affected Section	2.4.13
Conformance	Conforms
Exceptions	None
Clarifications	Defer to the COL application. The types of facilities that would be used to store radioactive liquids and any associated inventory are unique to each design. Therefore, it is not feasible to complete this evaluation until a reactor design is selected.

Regulation	**10 CFR 50.34(a)(1)**
Title	Contents of Applications; Technical Information
Description	Requires that reactors reflect an extremely low probability for accidents that could result in the release of significant quantities of radioactive fission products. Section (a)(1)(ii)(D) further states that EAB and LPZ accident doses should be within 25 Rem TEDE.
Affected Sections	2.1.3, Chapter 15
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 50.34(a)(12) [referenced in 52.17]**
Title	Contents of Applications; Technical Information
Description	Requires conformance to current (i.e., probabilistic) NRC seismic criteria
Affected Section	2.5.2
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 50.34(b)(10) [referenced in 52.17]**
Title	Contents of Applications; Technical Information
Description	This section of the regulation requires conformance to current (i.e., probabilistic) NRC seismic criteria
Affected Section	2.5.2
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 50.47**
Title	Emergency Plans
Description	Describe additional meteorological measurements taken for emergency preparedness planning.
Affected Section	2.3.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 50.47(b)(4)**
Title	Emergency Plans
Description	Provides requirement for standard emergency classification and action level scheme.
Affected Section	13.3.2
Conformance	Conforms
Exceptions	None
Clarifications	Following initial approval, any necessary updates in the emergency planning information would be handled in a COL application.

Regulation	**10 CFR 50.55a**
Title	Codes and Standards
Description	Requires structures, systems, and components to be designed and constructed to quality standards commensurate with the importance of the safety function to be provided.
Affected Sections	2.4.8, 2.4.10, 2.5.5
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 50, Appendix A, GDC 2**
Title	Design Bases for Protection Against Natural Phenomena
Description	Requires structures, systems, and components important to safety to be designed to withstand the effects of natural phenomena.
Affected Sections	2.3.1, 2.3.2, 2.4.1, 2.4.8, 2.4.10, 2.4.11, 2.5.1, 2.5.3
Conformance	Conforms
Exceptions	None
Clarifications	Section 2.5.3 – This section evaluates the potential for surface deformation only.

Regulation	**10 CFR 50, Appendix A, GDC 4**
Title	Environmental and Dynamic Effects Design Bases
Description	Provide information on tornadoes that could generate missiles.
Affected Section	2.3.1
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 50, Appendix A, GDC 44**
Title	Cooling Water
Description	Requires an ultimate heat sink capable of accepting the plant's heat load under normal and accident conditions.
Affected Sections	2.4.8, 2.4.9, 2.4.11, 2.5.4, 2.5.5
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 50, Appendix B**
Title	Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants
Description	Provide a description of the Quality Assurance Program/Plan
Affected Section	17.1
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 50, Appendix E**
Title	Emergency Planning and Preparedness for Production and Utilization Facilities
Description	Section 2.3.3 - Describe additional meteorological measurements taken for emergency preparedness planning. Section 13.3.2 - Provide a discussion of plans for coping with emergencies.
Affected Sections	2.3.3, 13.3.2
Conformance	Conforms
Exceptions	None
Clarifications	Section 13.3.2 - Following initial approval, any necessary updates in the emergency planning information would be handled in a COL application.

Regulation	**10 CFR 50, Appendix I**
Title	Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low As Reasonably Achievable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents
Description	Section 2.1.1 - Provides guidelines for radiation exposures to meet ALARA criterion at the 5000 ft radius Exclusion Area Boundary. Section 2.3.3 – Describe meteorological data used in the compliance with the numerical guides for doses to meet the criterion of ALARA. Section 2.3.5 – Demonstrate compliance by characterizing atmospheric transport and diffusion conditions in order to estimate the radiological consequences of routine releases of materials to the atmosphere.
Affected Sections	2.1.1, 2.3.3, 2.3.5
Conformance	Conforms
Exceptions	None
Clarifications	Section 2.3.5 - Actual values for venting locations, structural dimensions, and layout would be established during detailed engineering for the selected reactor design. The COL application would provide confirmation that the actual values are acceptable with respect to the evaluation in the ESP SSAR

Regulation	**10 CFR 50, Appendix S IV(a)**
Title	Earthquake Engineering Criteria for Nuclear Power Plants
Description	The SSE ground motion must be characterized by free-field ground motion response spectra at the free ground surface. The OBE must be characterized by response spectra.
Affected Section	2.5.2
Conformance	Conforms
Exceptions	None
Clarifications	Surface rock conditions are assumed. The OBE has been defined as one third of the SSE ground motion design response spectra.

Regulation	**10 CFR 50, Appendix S IV(b)**
Title	Earthquake Engineering Criteria for Nuclear Power Plants
Description	The potential for surface deformation must be taken into account in the design of the nuclear power plant by providing reasonable assurance that in the event of deformation, certain structures, systems, and components will remain functional.
Affected Section	2.5.3
Conformance	Conforms
Exceptions	None
Clarifications	This section evaluates the potential for surface deformation only.

Regulation	**10 CFR 50, Appendix S IV(c)**
Title	Earthquake Engineering Criteria for Nuclear Power Plants
Description	Account for seismically induced floods and water waves from either locally or distantly generated seismic activity and other design conditions.
Affected Sections	2.4.2, 2.4.5
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 52, Subpart A**
Title	Early Site Permits
Description	Section 1.1 - Provides requirements for Early Site Permit application. Sections 2.5.1, 2.5.2 - Describe the seismic and geologic characteristics of the proposed site.
Affected Sections	1.1, 2.5.1, 2.5.2
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 52.17(a)**
Title	Contents of Applications
Description	Sections 2.4.1, 2.4.2, 2.4.5, 2.4.6, 2.4.10, 2.4.12 – Describe the hydrologic characteristics of the site. Section 2.4.7 – Provide a description of any icing phenomena with the potential to result in adverse effects to the intake structure or other safety-related facilities for a nuclear power plant or plants of specified type that might be constructed on the proposed site. Section 2.4.9 – Requires that physical characteristics of the site are taken into account to determine acceptability of site for nuclear power plants.
Affected Sections	2.4.1, 2.4.2, 2.4.5, 2.4.6, 2.4.7, 2.4.9, 2.4.10, 2.4.12
Conformance	Conforms
Exceptions	None
Clarifications	Section 2.4.6 – The North Anna Site is not located in a coastal region and not subject to tsunami flooding.

Regulation	**10 CFR 52.17(a)(1)**
Title	Contents of Applications
Description	Provide an analysis and evaluation of the major structures, systems, and components of the facility that bear significantly on the acceptability of the site under the radiological consequence evaluation factors identified in 10 CFR 50.34(a)(1).
Affected Section	Chapter 15
Conformance	Conforms
Exceptions	None
Clarifications	The PPE provides this information. Results conform to 50.34(a)(1).

Regulation	**10 CFR 52.17(a)(1)(i)**
Title	Contents of Applications
Description	Specify the number, type and thermal power level of the facilities for which the ESP site may be used.
Affected Section	1.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 52.17(a)(1)(ii)**
Title	Contents of Applications
Description	Provide the site boundaries
Affected Section	2.1.1
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 52.17(a)(1)(vi)**
Title	Contents of Applications
Description	Describe the hydrologic characteristics of the proposed site.
Affected Sections	2.4.3, 2.4.4
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 52.17(a)(1)(vii)**
Title	Contents of Applications
Description	Provide the location and description of any nearby industrial, military, or transportation facilities and routes.
Affected Sections	2.2.1, 2.2.2
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 52.17(a)(1)(viii)**
Title	Contents of Applications
Description	Provide the existing and projected population profiles for the area around the site.
Affected Section	2.1.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 52.17(b)(1)**
Title	Contents of Applications
Description	This section of the regulation requires that certain emergency preparedness information be submitted. The application must identify physical characteristics unique to the proposed site that could pose a significant implement to the development of emergency plans.
Affected Section	13.3
Conformance:	Conforms
Exceptions:	None
Clarifications:	None

Regulation	**10 CFR 52.17(b)(2)**
Title	Contents of Applications
Description	Provides an option in the regulation to submit a major features emergency plan as part of an ESP application.
Affected Section	13.3
Conformance	Conforms
Exceptions	Certain EP criteria are not implementable at the ESP stage. See Section 4.0 of the Major Features Emergency Plan
Clarifications	The applicant has the option to submit the Major Features of an Emergency Plan or a complete and integrated Emergency Plan. Dominion has elected to exercise the major features option and has included the required information.

Regulation	**10 CFR 52.17(b)(3)**
Title	Contents of Applications
Description	Requires the applicant to identify contacts and arrangements with local, state and federal agencies with emergency preparedness responsibilities.
Affected Section	13.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 73.55**
Title	Requirements for Physical Protection of Licensed Activities in Nuclear Power Reactors Against Radiological Sabotage
Description	Specifies requirements for physical protection of licensed activities against radiological sabotage.
Affected Section	13.6
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100**
Title	Reactor Site Criteria
Description	All Sections Not Listed Below – Evaluate the hydrologic characteristics of the site. Sections 2.5.1, 2.5.2, 2.5.4, 2.5.5 – Provides general criteria that guide the evaluation of the suitability of the site for nuclear power reactors. Sections 15.2, 15.4 – Provide requirements that radiological dose consequences meet site acceptance criteria.
Affected Sections	2.4.1, 2.4.5, 2.4.6, 2.4.7, 2.4.8, 2.4.9, 2.4.11, 2.4.13, 2.5.1, 2.5.2, 2.5.4, 2.5.5, 15.2, 15.4
Conformance	Conforms
Exceptions	None
Clarifications	Section 2.4.13 – Defer to the COL application. The types of facilities that would be used to store radioactive liquids and any associated inventory are unique to each design. Therefore, it is not feasible to complete this evaluation until a reactor design is selected.

Regulation	**10 CFR 100.3**
Title	Definitions
Description	Defines exclusion area, low population zone, and population center distance as they apply to 10 CFR 100.
Affected Sections	2.1.2, 2.1.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100, Subpart B**
Title	Evaluation Factors for Stationary Power Reactor Site Applications on of After January 10, 1997
Description	Provide information on the exclusion area, low population zone, and population center distance to the site.
Affected Sections	2.1.2, 2.1.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100.20**
Title	Reactor Site Criteria
Description	Sections 2.2.1, 2.2.2 - Provide details of the use characteristics of the site environs. Section 2.2.3 - The nature and proximity of man-made hazards must be evaluated to establish site parameters for use in determining whether a plant design can accommodate commonly occurring hazards, and whether the risk of others hazards is low.
Affected Sections	2.2.1, 2.2.2, 2.2.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100.20(c)**
Title	Reactor Site Criteria
Description	Sections 2.3.1, 2.3.2 – Describe the consideration that has been given the meteorological characteristics of the site. Section 2.3.3 – Describe meteorological data collected for use in characterizing the meteorological conditions of the site. Sections 2.4.1, 2.4.2, 2.4.3, 2.4.5, 2.4.6, 2.4.10 – Describe the hydrologic characteristics of the proposed site. Section 2.4.4 – Requires that the physical characteristics of the site, including hydrology, be taken into account when determining site acceptability. 2.4.5 – Provide a description of the surface and subsurface hydrologic characteristics of the region and an analysis of the potential for flooding due to surges and seiches. 2.4.6 – Provide a description of the hydrologic characteristics of the coastal region in which the proposed site is located and an analysis of severe seismically induced waves. Section 2.4.7 – Provide a description of any icing phenomena with the potential to result in adverse effects to the intake structure or other safety-related facilities for a nuclear power plant or plants of specified type that might be constructed on the proposed site. Section 2.4.9, 2.4.12 – Requires that physical characteristics of the site be taken into account to determine acceptability of site for nuclear power plants.
Affected Sections	2.3.1, 2.3.2, 2.3.3, 2.4.1, 2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, 2.4.7, 2.4.9, 2.4.10, 2.4.12
Conformance	Conforms
Exceptions	None
Clarifications	Section 2.4.6 – The North Anna Site is not located in a coastal region and, therefore, not subject to tsunami flooding.

Regulation	**10 CFR 100.21**
Title	Non-seismic Siting Criteria
Description	Discuss meteorological considerations used in the evaluation to determine an acceptable EA and LPZ.
Affected Section	2.3.4
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100.21(c)(1)**
Title	Non-seismic Siting Criteria
Description	Radiological effluent release limits associated with normal operation can be met for any individual located offsite.
Affected Sections	2.3.5.1
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100.21(c)(2)**
Title	Non-seismic Siting Criteria
Description	Radiological dose consequences of postulated accidents shall meet the criteria in 10 CFR 50.34(a)(1).
Affected Sections	2.1.3, Chapter 15
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100.21(d)**
Title	Non-seismic Siting Criteria
Description	Sections 2.3.1, 2.3.2 – Describe the consideration that has been given the meteorological characteristics of the site. Section 2.3.3 – Describe meteorological data collected for use in characterizing the meteorological conditions of the site.
Affected Sections	2.3.1, 2.3.2, 2.3.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100.21(f)**
Title	Non-Seismic Siting Criteria
Description	Describe the security-related characteristics of the site.
Affected Section	13.6
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100.23**
Title	Geologic and Seismic Siting Criteria
Description	Section 2.4.12 - Sets forth the criteria to determine the suitability of design bases with respect to seismic characteristics of the site. Section 2.5.1, 2.5.3, 2.5.5 - Obtain the seismic and geologic data necessary to address site suitability and identify seismic and geologic factors to be taken into account in the siting and design of the nuclear power plant.
Affected Sections	2.4.12, 2.5.1, 2.5.3, 2.5.5
Conformance	Conforms
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100.23(c)**
Title	Geologic and Seismic Siting Criteria
Description	Section 2.4.4 – Requires an investigation to obtain geologic and seismic data for evaluating seismically induced floods, including failure of an upstream dam during an earthquake or low water levels from failure of a downsteam dam. Section 2.4.6 – Investigate distantly and locally generated waves or tsunami that have affected or could affect the proposed site, including available evidence regarding the runup or drawdown associated with historic tsunami in the same coastal region and local features of coastal topography that might modify runup or drawdown. Section 2.4.7 – Provide a description of any icing phenomena with the potential to result in adverse effects to the intake structure or other safety-related facilities for a nuclear power plant or plants of specified type that might be constructed on the proposed site. Section 2.4.11, 2.4.12 – Requires that physical characteristics of the site be taken into account to determine acceptability of site for nuclear power plants. Sections 2.5.1, 2.5.2, 2.5.3 – Determine the SSE and its uncertainty, the potential for surface tectonic and nontectonic deformations, the design bases for seismically induced floods and water waves, and other design conditions. Section 2.5.4, 2.5.5 – Consider the geologic and seismic conditions at the site during the siting and design of the nuclear plant. Investigate the geological and seismological characteristics of the site in sufficient scope and detail to permit an adequate evaluation of the proposed site.
Affected Sections	2.4.4, 2.4.6, 2.4.7, 2.4.11, 2.4.12, 2.5.1, 2.5.2, 2.5.3, 2.5.4, 2.5.5
Conformance	Conforms
Exceptions	None
Clarifications	Section 2.4.6 – Since the site is inland and not subject to tsunami flooding, no wave analysis was performed or investigated. The site is protected from tsunami flooding.

Regulation	**10 CFR 100.23(d)(4)**
Title	Geologic and seismic siting factors
Description	Section 2.4.12 – Requires that the physical properties of materials underlying the site be considered when designing a system to supply cooling water for emergency and long-term shutdown decay heat removal.
Affected Section	2.4.12
Exceptions	None
Clarifications	None

Regulation	**10 CFR 100, Appendix A**
Title	Seismic and Geologic Siting Criteria for Nuclear Power Plants
Description	Investigate the seismic and geologic data necessary to determine site suitability and identify seismic and geologic factors to be taken into account in the siting and design of the nuclear power plant.
Affected Sections	2.5.1, 2.5.3, 2.5.5
Conformance	Conforms
Exceptions	None
Clarifications	None

1.8.2 Conformance to NRC Regulatory Guides

This section describes conformance with the applicable guidance in published NRC RGs, as specified in the acceptance criteria sections of NUREG-0800, as modified by draft RS-002 Reference 1, Attachment 2. The RG title, description of applicable guidance, revision number, date, affected SSAR sections, and statement of conformance are provided. Exceptions and clarifications to conformance with the guidance in the RG are noted, as appropriate.

Document	**Regulatory Guide 1.3**
Title	Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors
Description	Identifies acceptable methods for implementing AST.
Revision	Rev. 2
Date	June 1974
Affected Section	15.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.5**
Title	Assumptions Used for Evaluating the Potential Radiological Consequences of a Steam Line Break Accident for Boiling Water Reactors
Description	Provides information, recommendations, and guidance and in general describes an acceptable basis to implement the requirements of 10 CFR 100.
Revision	[Initial issue]
Date	March 1971
Affected Section	2.3.4
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.23**
Title	Onsite Meteorological Programs
Description	Provides the criteria for an acceptable onsite meteorological measurements program.
Revision	[Initial Issue]/ Proposed Revision 1
Date	1972/1980
Affected Sections	2.3.2, 2.3.3, 2.3.4
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.24**
Title	Assumptions Used for Evaluating the Potential Radiological Consequences of a Pressurized Water Reactor Radioactive Gas Storage Tank Failure
Description	Provides information, recommendations, and guidance and in general describes an acceptable basis to implement the requirements of 10 CFR 100.
Revision	[Initial Issue]
Date	March 1972
Affected Section	2.3.4
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.25**
Title	Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors
Description	Provides information, recommendations, and guidance and in general describes an acceptable basis to implement the requirements of 10 CFR 100.
Revision	[Initial Issue]
Date	March 1972
Affected Sections	2.3.4, 15.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.27**
Title	Ultimate Heat Sink for Nuclear Power Plants
Description	Section 2.3.1 – The ultimate heat sink meteorological data should be based on long-term regional records that represent site conditions. Section 2.4.7 – Describes the ultimate heat sink capabilities that apply. Section 2.4.8 – Use as a basis for the adequacy of design criteria and provisions where canals or reservoirs comprise a part of the ultimate heat sink. Sections 2.4.9, 2.4.11, 2.4.12, 2.4.13, 2.5.4, 2.5.5 – Provides guidance on acceptable criteria for the ultimate heat sink.
Revision	Rev. 2
Date	January 1976
Affected Sections	2.3.1, 2.4.7, 2.4.8, 2.4.9, 2.4.11, 2.4.12, 2.4.13, 2.5.4, 2.5.5
Conformance	Conforms (all sections except as noted below) Not Required (Sections 2.4.8, 2.4.11, 2.4.13) Not Applicable (Section 2.4.12)
Exceptions	Section 2.4.8 – Canals or reservoirs do not comprise a part of the ultimate heat sink. Sections 2.4.11, 2.4.13 - The design of the ultimate heat sink would be provided in the COL application. Section 2.4.12 – Groundwater will not be used as part of any safety-related function.
Clarifications	None

Document	**Regulatory Guide 1.29**
Title	Seismic Design Classification
Description	Identifies the seismic design classification of structures, systems, and components.
Revision	Rev. 3
Date	September 1978
Affected Sections	2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, 2.4.7, 2.4.8, 2.4.10, 2.4.12
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.58**
Title	Qualification of Nuclear Power Plant Inspection, Examination, and Testing Personnel
Description	Provides qualification requirements for inspection, examination and testing personnel.
Revision	Rev. 1
Date	September 1980
Affected Section	17.1
Conformance	Conforms
Exceptions	None
Clarifications	Some of the activities described in this section are included in the operational QA program and may not be needed for ESP application development.

Document	**Regulatory Guide 1.59**
Title	Flood Design Basis for Nuclear Power Plants
Description	Provides guidance for estimating the design basis for flooding, considering the worst single phenomenon and combinations for less severe phenomena.
Revision	Rev. 2
Date	August 1977
Affected Sections	2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, 2.4.7, 2.4.8, 2.4.10
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.60**
Title	Design Response for Seismic Design of Nuclear Power Plants
Description	Smoothed response spectra are generally used for design purposes, for example, a standard spectral shape that has been used in the past is presented in RG 1.60. These smoothed spectra are still acceptable when the smoothed design spectra compare favorably with site-specific response spectra.
Revision	Rev. 1
Date	December 1973
Affected Section	2.5.2
Conformance	Not Required
Exceptions	Site-specific response spectra are lower than RG 1.60 for low frequencies and exceed RG 1.60 spectra for high frequencies.
Clarifications	None

Document	**Regulatory Guide 1.70**
Title	Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants – LWR Edition
Description	Section 2.0 – Provide information on the geological, seismological, hydrological and meteorological characteristics of the site and vicinity, in conjunction with present and projected population distribution and land use and site activities and controls. Section 2.1.1 – Specify the location of each reactor at the site. Provide a site area map that shows property lines, site boundary, principal plant structures, other structures within the site area, exclusion area boundary, and highways, railways, and waterways that traverse the site. Describe the boundaries of the restricted area (per 10 CFR 20) and how access to this area will be controlled. Section 2.1.2 – Address ownership of all lands within the exclusion area. Describe any activities unrelated to plant operation that may be permitted within the exclusion area. Describe how traffic on any highways, railways, or waterways that traverse the exclusion area will be controlled in the event of an emergency. Section 2.1.3 – Describe the population distributions within 50 miles of the site, including any seasonal or transient populations. Specify the low population zone. Identify the nearest population center and the projected cumulative population density. Section 2.2.1 – Provide maps showing the location and distance from the nuclear plant of all significant industrial facilities, military installations, oil and gas pipelines, etc. Also show any nearby air traffic patterns or transportation routes. Section 2.2.2 – Describe all significant industrial facilities, military installations, oil and gas pipelines, etc. Detail products manufactured and shipped of a hazardous nature, relationship of shipping to the intake structure, and airport operations. Also provide a project of future growth of existing and new types of activities in the vicinity of the plant. Section 2.2.3 – Determine the design basis external events considering explosions, flammable vapor clouds, toxic chemical, fires, collisions with the intake structure, and liquid spills and evaluate the effects of these events on safety-related SSCs. Section 2.3.1 – Describe the: 1) general climate of the region, 2) seasonal and annual frequencies of severe weather phenomena, 3) meteorological data used for evaluating the performance of the ultimate heat sink, 4) design basis tornado, and 5) all other regional meteorological and air quality conditions used for design and operating basis considerations.

(continued)

Regulatory Guide 1.70 (continued)

Description (continued)

Section 2.3.2 – Provide monthly and annual summaries of: 1) wind roses and wind persistence, 2) air/dewpoint temperatures, 3) extremes of atmospheric water vapor, 4) precipitation, 5) fog and smog, and 6) atmospheric stability, 7) monthly mixing height data, 8) and hourly averages of wind speed and direction. Discuss and evaluate the potential impact of the plant on the meteorological parameters. Provide all local meteorological and air quality conditions used for design and operating basis considerations.

Section 2.3.3 – Describe the preoperational and operational programs for meteorological measurements at the site. Provide joint frequency distributions of wind speed and direction by atmospheric stability class.

Section 2.3.4 – Provide conservative and realistic estimates of atmospheric diffusion (χ/Q) at the EA and LPZ. Base diffusion estimates on the most representative meteorological data. Discuss any impacts due to local topography.

Section 2.3.5 – Provide realistic estimates of annual average atmospheric transport and diffusion characteristic to a distance of 50 miles from the plant. Provide a detailed description of the model used to calculate realistic annual average χ/Q values. Provide a calculation of the maximum annual average χ/Q at or beyond the site boundary for each venting location.

Section 2.4.1 – Describe the site and all safety-related elevations, structures, exterior accesses, equipment, and systems from the standpoint of hydrologic considerations. Describe the location, size, shape, and other hydrologic characteristics of streams, lakes, shore regions, and ground water environments influencing plant siting. Include a description of existing and proposed water control structures, both upstream and downstream, that may influence conditions at the site.

Section 2.4.2 – Provide date, level, peak discharge, and related information for major historical flood events in the site region. The considerations taken to determine the design basis flood elevation, as well as the elevation itself should be discussed. The effects of local intense precipitation at the site should be discussed.

Section 2.4.3 – Indicate the methodology and approach used to determine the PMF level. Include discussion on development of PMP, precipitation losses, runoff models, PMF flow hydrograph, water level determination, and coincident wave activity.

Section 2.4.4 – Discuss the investigation of seismically induced floods including results for seismically induced dam failures and antecedent flood flows coincident with the flood peak.

Section 2.4.5 – Discuss the maximum water levels associated with the probable maximum surge and seiche flooding at the site. Areas to be considered include the probable maximum hurricane or other probable maximum wind, antecedent water levels, coincident wave action and run-up and resonance.

Section 2.4.6 – Discuss historical tsunami, either recorded or translated and inferred, that provide information for use in determining the probable maximum water levels and the geoseismic generating mechanisms available.

Section 2.4.7 – Describe potential icing effects and design criteria for protecting safety-related facilities from the most severe ice jam flood, wind-driven ice ridges, or other ice-produced effects and forces that are reasonably possible and could affect safety-related facilities with respect to adjacent streams, lakes, etc., for both high and low water levels.

Section 2.4.8 – Present the design basis for the capacity and operating plan for safety-related cooling water canals and reservoirs.

Section 2.4.9 – Discuss the potential for upstream diversion or rerouting of the source of cooling water.

Section 2.4.10 – Describe the static and dynamic consequences of all types of flooding on each pertinent safety-related facility. Present the design bases required to ensure that the safety-related facilities will be capable of surviving all design flood conditions.

(continued)

Regulatory Guide 1.70 (continued)

Description (continued)

Section 2.4.11 – Discuss the impact of low water conditions on safety-related facilities as well as cooling water and service water systems. For safety-related structures demonstrate ability to perform adequately with probable minimum flow rate and level. For non-safety-related water supplies, demonstrate that the supply will be adequate during a 100-year drought.

Section 2.4.12 – Describe ability of the surface water environment to disperse, dilute, or concentrate accidental liquid releases of radioactive effluents as related to existing or potential future water users.

Section 2.4.13 (except 2.4.13.3) – Describe the regional and local groundwater aquifers, formations, sources and sinks and onsite groundwater use, including present and projected future use. Describe the effects of present and projected groundwater use on gradients and groundwater or piezometric levels beneath the site. Note any potential groundwater recharge areas. Indicate the range of values and method of determination for vertical and horizontal permeability and total and effective porosity (specific yield). Discuss the potential for reversibility of groundwater flow resulting from local areas of pumping for both plant and non-plant use. Discuss plans, procedures, safeguards, and monitoring programs to be used to protect present and projected groundwater use. Identify existing groundwater users. Discuss the history of groundwater or piezometric level fluctuations beneath and in the vicinity of the site. Provide groundwater or piezometric contour maps of aquifers beneath and in the vicinity of the site.

Section 2.4.13.3 – Provide a conservative analysis of a postulated accidental release of liquid radioactive material at the site.

Section 2.5.1 – Discuss the regional and site geology including:

All geologic and man-made hazards within the site region and relate them to the regional tectonic structures and tectonic provinces, and geomorphology.

Identify and describe tectonic structures underlying the region surrounding the site and discuss their geologic history.

Detailed discussions of regional tectonic structures of significance to the site.

Structural geology in the vicinity of the site.

The relationship of the site structure to regional tectonics, with particular attention to specific structural units such as folds, faults, anticlines, synclines, domes, and basins.

Section 2.5.2 – Determine the SSE and OBE design ground motion based on identification of tectonic provinces or active geologic structures with which earthquake activity in the region can be associated.

Section 2.5.3 – Information should be provided to describe whether there exists a potential for surface faulting at the site.

Section 2.5.4 – Present information that thoroughly defines the conditions and engineering properties of both soil and/or rock supporting nuclear power plants. The stability of the soils and rock under plant structures should be evaluated both for static and dynamic loading conditions. Both the operating and safe shutdown earthquakes should be used in the dynamic stability evaluation.

Section 2.5.5 – Present information concerning the static and dynamic stability of all soil or rock slopes, both natural and man-made. Evaluate the stability of the slopes using classic and contemporary methods of analyses. Include in the evaluation, comparative field performance of similar slopes. Include in the stability evaluation of man-made slopes summary data and a discussion of construction procedures, record testing, and instrumentation monitoring.

Section 2.5.6 – Include information related to the investigation, engineering design, proposed construction, and performance of all earth, rock, or earth and rock fill embankments used for plant flood protection or for impounding cooling water required for the operation of the nuclear power plant.

(continued)

	Regulatory Guide 1.70 (continued)
Description (continued)	Chapter 15 – Evaluate the response of the plant to postulated disturbances in process variables, malfunctions, or failures of equipment. Examine the effects of anticipated process disturbances and postulated component failures to determine their consequences and to evaluate the capability of the plant to control or accommodate such failures and situations.
Revision	Rev. 3
Date	November 1, 1978
Affected Sections	1.1, 1.4, 1.5, 1.6, 1.7, 1.8, 2, 2.1.1, 2.1.2, 2.1.3, 2.2.1, 2.2.2, 2.2.3, 2.3.1, 2.3.2, 2.3.3, 2.3.4, 2.3.5, 2.4.1, 2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, 2.4.7, 2.4.8, 2.4.9, 2.4.10, 2.4.11, 2.4.12, 2.4.13, 2.5.1, 2.5.2, 2.5.3, 2.5.4, 2.5.5, 2.5.6, Chapter 15
Conformance	Conforms (all except those listed below) Partial Conformance (Sections 2.3.5, 2.4.11, 2.5.4, Chapter 15) Not Required (Section 2.4.13.3) Not Applicable (Sections 2.4.8, 2.5.6)
Exceptions	Specific design information is not provided. Section 2.3.5 – Actual values for venting locations, structural dimensions, and layout would be established during detailed engineering for the selected reactor design. The COL application would provide confirmation that the actual values are acceptable with respect to the evaluation in the ESP SSAR. Section 2.4.11 – Since the Lake Anna water level during drought conditions is determined by many factors in addition to inflow rate (i.e. air temperature and rejected heat load) the 100-year drought condition does not directly apply to Lake Anna and has not been determined. Historic and predicted low water levels and durations are presented. Section 2.4.13.3 – Defer to the COL application. The types of facilities that would be used to store radioactive liquids and any associated inventory are unique to each design. Therefore, it is not feasible to complete this evaluation until a reactor design is selected. Section 2.5.4 – Discussed excavation and backfill in general terms – specific locations, quantities etc. would be addressed in the COL application when details are known. A brief summary of the derivation of the SSE and OBE is provided. Discussed subsurface instrumentation in overall terms – specific locations, types of instrumentation, reading schedule would be addressed in the COL application when details are known. Chapter 15 – Most but not all the accidents listed in RG 1.70 are analyzed (e.g., waste gas decay tank failure not analyzed). The main criteria for selecting the accidents are RG 1.183 and NUREG-0800, as suggested in Chapter 15 of RS-002.
Clarifications	The guidance is written for Part 50 applicants with a known plant design. It is followed to the extent feasible for an ESP application submitted in accordance with Part 52 using the PPE approach. Section 2.4.8 – The cooling water canals and reservoirs at the ESP site are not safety-related. Section 2.5.2 – Per RG 1.165, EPRI 1989, evaluated for any needed updating, provides an acceptable basis for source model description. Section 2.5.6 – No embankments or dams for plant flood protection or cooling water will be constructed.

Document	**Regulatory Guide 1.76, Including March 25, 1988 Interim Staff Position, ALWR Design Basis Tornado**
Title	Design Basis Tornado for Nuclear Power Plants
Description	Defines the design basis tornado.
Revision	[Initial Issue]
Date	April 1974
Affected Section	2.3.1
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.77**
Title	Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release
Description	Provides information, recommendations, and guidance and in general describes an acceptable basis to implement the requirements of 10 CFR 100.
Revision	[Initial Issue]
Date	May 1974
Affected Section	2.3.4
Conformance	Not Required
Exceptions	Control room impacts would be evaluated in the COL application.
Clarifications	None

Document	**Regulatory Guide 1.78**
Title	Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release
Description	Sections 2.2.1, 2.2.2, 2.2.3 – Provides guidance for evaluating the habitability of the control room during a postulated hazardous chemical release. Section 2.3.4 – Provides information, recommendations, and guidance and in general describes an acceptable basis to implement the requirements of 10 CFR 100.
Revision	Rev. 1
Date	December 2001
Affected Sections	2.2.1, 2.2.2, 2.2.3, 2.3.4
Conformance	Not Required
Exceptions	Section 2.2.3 - The locations and quantities of chemicals that would be stored for the new units at the ESP site have not been determined, and no detailed control room design parameters are available at this time. The impact on the new units from chemicals stored onsite or nearby would be evaluated in the COL application.
Clarifications	None

Document	**Regulatory Guide 1.91**
Title	Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants
Description	Describes methods for ensuring that the risk of damage due to an explosion on a nearby transportation route is sufficiently low.
Revision	Rev. 1
Date	February 1978
Affected Sections	2.2.1, 2.2.2, 2.2.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.101**
Title	Emergency Planning and Preparedness for Nuclear Power Reactors
Description	Provides guidance on methods acceptable for complying with regulations for emergency response plans and preparedness at nuclear power reactors.
Revision	Rev. 3
Date	August 1992
Affected Sections	13.3.2, 13.3.4
Conformance	Conforms
Exceptions	Site-specific EALs would be proposed in the COL application.
Clarifications	Revision 4 provides for use of an EAL scheme not referenced in NUREG-0654, Supplement 2. The yet-to-be-selected design may dictate use of another EAL scheme, or a site-specific model may be needed. (See Section 13.3.4.)

Document	**Regulatory Guide 1.102**
Title	Flood Protection for Nuclear Power Plants
Description	Provides guidance on flood protection measures.
Revision	Rev. 1
Date	September 1976
Affected Sections	2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, 2.4.7, 2.4.8, 2.4.10
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.111**
Title	Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors
Description	Provides criteria for characterizing atmospheric transport and diffusion conditions for evaluating the consequences of routine releases.
Revision	Rev. 1
Date	July 1977
Affected Sections	2.3.4, 2.3.5
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.113**
Title	Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I
Description	Provides guidance in selecting and using surface water models.
Revision	Rev. 1
Date	April 1977
Affected Section	2.4.13
Conformance	Not Required
Exceptions	Defer to the COL application. The types of facilities that would be used to store radioactive liquids and any associated inventory are unique to each design. Therefore, it is not feasible to complete this evaluation until a reactor design is selected.
Clarifications	None

Document	**Regulatory Guide 1.125**
Title	Physical Models for Design and Operation of Hydraulic Structures and Systems for Nuclear Power Plants
Description	Provides guidance on the use of physical models of hydraulic structures and systems.
Revision	Rev. 1
Date	October 1978
Affected Sections	2.4.5, 2.4.6, 2.4.8, 2.4.10
Conformance	Not Required
Exceptions	None
Clarifications	Physical modeling of hydraulic structures is not necessary for the ESP.

Document	**Regulatory Guide 1.132**
Title	Site Investigations for Foundations of Nuclear Power Plants
Description	Provides guidance for site investigation programs.
Revision	Rev. 1/Proposed Rev. 2 (Draft RG DG-1101)
Date	March 1979/February 2001
Affected Sections	2.5.1, 2.5.2, 2.5.3, 2.5.4, 2.5.5
Conformance	Conforms (all except those listed below) Partial (Section 2.5.4, 2.5.5)
Exceptions	Section 2.5.4 – Only borings used for cross-hole seismic tests were surveyed for deviation. Only split-spoon and rock core samples were taken. Soil sampling was continuous to 5 m depth and rock coring was continuous in all borings. Appendix D Borings were spaced farther apart than recommended because of the general nature of the investigation. Section 2.5.5 – Only borings used for cross-hole seismic tests were surveyed for deviation (DG Section 4.3.1.2); Only split-spoon and rock core samples were taken (DG Section 4.3.2); Soil sampling was continuous to 5 m depth and rock coring was continuous in all borings. Appendix D Borings were spaced further apart than recommended because of general nature of investigation (DG Section 4.3.2.2).
Clarifications	None

Document	**Regulatory Guide 1.138**
Title	Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants
Description	Describes laboratory investigations and testing practices acceptable for determining soil and rock properties and characteristics needed for engineering analysis and design for foundations and earthwork.
Revision	[Initial Issue]/Proposed Rev. 1 (Draft RG DG-1109)
Date	April 1978/August 2001
Affected Sections	2.5.4, 2.5.5
Conformance	Partial Conformance
Exceptions	No new cyclic triaxial tests were performed since a large number of high quality cyclic triaxial tests had been performed previously. No resonant column tests were performed.
Clarifications	None

Document	**Regulatory Guide 1.145**
Title	Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants
Description	Identifies acceptable methods for choosing χ/Q values for evaluations.
Revision	Rev. 1
Date	November 1982
Affected Sections	2.3.4, 15.2
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 1.165**
Title	Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion
Description	Describes acceptable methods to: 1) conduct geological seismological, and geophysical investigations of the site and region around the site, 2) identify and characterize seismic sources, 3) perform PSHA, and 4) determine the SSE for the site.
Revision	[Initial Issue]
Date	March 1997
Affected Sections	2.5.1, 2.5.2, 2.5.3
Conformance	Conforms
Exceptions	None
Clarifications	Section 2.5.2 – The evaluation of vibratory ground motion in Section 2.5.2 includes the development of a conservative SSE ground motion based on two alternate approaches: a RG 1.165 reference probability approach and a "performance-based" approach. See Section 2.5.2.6.7. The RG 1.165 approach uses a revised reference probability of mean 5×10^{-5}. Section B.3 of RG 1.165, Appendix B recognizes that there are situations in which it is appropriate to establish a new reference probability on which design-basis ground motions should be calculated, including, "…if general revisions to PSHA methods or data bases result in significant changes in hazard predictions for the selected plant sites in Table B.1." As discussed in Section 2.5.2.6.7, the PSHA and related analyses performed for the North Anna ESP site indicate that a new reference probability is appropriate.

Document	**Regulatory Guide 1.183**
Title	Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Plants
Description	Identifies acceptable evaluation methods and dose acceptance criteria for various design basis accidents using AST.
Revision	[Initial Issue]
Date	July 2000
Affected Sections	15.1, 15.2, 15.3, 15.4
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Draft Regulatory Guide DG-1105**
Title	Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites
Description	Provides guidance for evaluation of the behavior of soils subjected to earthquake shaking.
Revision	[Initial Issue]
Date	March 2001
Affected Sections	2.5.2, 2.5.4, 2.5.5
Conformance	Conforms (Section 2.5.2) Partial Conformance (Sections 2.5.4, 2.5.5)
Exceptions	Sections 2.5.4, 2.5.5 – For updated analysis for ESP, SPT and CPT values were used. The original analyses using cyclic triaxial test results were modified using newly generated peak accelerations.
Clarifications	None

Document	**Regulatory Guide 4.2**
Title	Preparation of Environmental Reports for Nuclear Power Stations
Description	Provide at least one annual cycle of onsite meteorological data.
Revision	Rev. 2
Date	July 1976
Affected Section	2.3.3
Conformance	Conforms
Exceptions	None
Clarifications	None

Document	**Regulatory Guide 4.4**
Title	Reporting Procedure for Mathematical Models Selected To Predict Heated Effluent Dispersion in Natural Water Bodies
Description	Provides reporting procedure for mathematical models selected to predict heated effluent dispersion in natural water bodies
Revision	[Initial Issue]
Date	May 1974
Affected Section	2.4.13
Conformance	Not Required
Exceptions	Defer to the COL application. The types of facilities that would be used to store radioactive liquids and any associated inventory are unique to each design. Therefore, it is not feasible to complete this evaluation until a reactor design is selected.
Clarifications	None

Document	**Regulatory Guide 4.7**
Title	General Site Suitability Criteria for Nuclear Power Stations
Description	Discusses the major site characteristics related to public health and safety that the NRC considers in determining the suitability of the site.
Revision	Rev. 2
Date	April 1998
Affected Sections	2.1.3, 2.3.4, 2.5.1, 2.5.2, 2.5.3, 2.5.4, 13.6
Conformance	Conforms
Exceptions	None
Clarifications	None

1.8.3 Conformance to NRC Review Standard

This section describes conformance to the published draft NRC review standard RS-002 (Reference 1). Draft RS-002, Attachment 2 incorporates and clarifies NRC guidance from the Standard Review Plan (SRP). For each applicable SRP section listed, the corresponding SSAR section(s), and a statement of conformance are provided. Exceptions and clarifications are noted, as appropriate.

RS-002 Section and Title	**2.1.1 Site Location and Description**
Section	2.1.1
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.1.2 Exclusion Area Authority and Control**
Section	2.1.2
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.1.3 Population Distribution**
Section	2.1.3
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.2.1–2.2.2 Identification of Potential Hazards in Site Vicinity**
Sections	2.2.1, 2.2.2
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.2.3 Evaluation of Potential Accidents**
Section	2.2.3
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.3.1 Regional Climatology**
Section	2.3.1
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.3.2 Local Meteorology**
Section	2.3.2
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.3.3 Onsite Meteorological Measurements Program**
Section	2.3.3
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.3.4 Short-Term Dispersion Estimates for Accidental Atmospheric Releases**
Section	2.3.4
Conformance	Conforms (except as noted below)
Exceptions	Atmospheric dispersion estimates for the Control Room from radiological and onsite hazardous material releases would be evaluated in the COL application.
Clarifications	None

RS-002 Section and Title	**2.3.5 Long-Term Diffusion Estimates**
Section	2.3.5
Conformance	Conforms
Exceptions	None
Clarifications	Section 2.3.5 - Actual values for venting locations, structural dimensions, and layout would be established during detailed engineering for the selected reactor design. The COL application would provide confirmation that the actual values are acceptable with respect to the evaluation in the ESP SSAR.

RS-002 Section and Title	**2.4.1 Hydrologic Description**
Section	2.4.1
Conformance	Conforms
Exceptions:	None
Clarifications	None

RS-002 Section and Title	**2.4.2 Floods**
Section	2.4.2
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.4.3 Probable Maximum Flood (PMF) on Streams and Rivers**
Section	2.4.3
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.4.4 Potential Dam Failures**
Section	2.4.4
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.4.5 Probable Maximum Surge and Seiche Flooding**
Section	2.4.5
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.4.6 Probable Maximum Tsunami Flooding**
Section	2.4.6
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.4.7 Ice Effects**
Section	2.4.7
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.4.9 Channel Diversions**
Section	2.4.9
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.4.11 Low Water Considerations**
Section	2.4.11
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.4.12 Groundwater**
Section	2.4.12
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.4.13 Accidental Releases of Liquid Effluents in Ground and Surface Waters**
Section	2.4.13
Conformance	Not Required
Exceptions	Defer to the COL application. The types of facilities that would be used to store radioactive liquids and any associated inventory are unique to each design. Therefore, it is not feasible to complete this evaluation until a reactor design is selected.
Clarifications	None

RS-002 Section and Title	**2.5.4 Stability of Subsurface Materials and Foundations**
Section	2.5.4
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**2.5.5 Stability of Slopes**
Section	2.5.5
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**3.5.1.6 Aircraft Hazards**
Section	3.5.1.6
Conformance	Conforms
Exceptions	None
Clarifications	None

RS-002 Section and Title	**13.3 Emergency Planning**
Section	13.3
Conformance	Conforms
Exceptions	See Section 13.3.4.
Clarifications	See Section 13.3.4.

RS-002 Section and Title	**15.0 Radiological Consequences of Design Basis Accidents**
Section	Chapter 15
Conformance	Conforms
Exceptions	None
Clarifications	The PPE approach in RS-002 was used for the evaluation.

RS-002 Section and Title	**17.1.1 Early Site Permit Quality Assurance Controls**
SSAR Section	Chapter 17
Conformance	Conforms
Exceptions	See Section 17.1, QA Manual, Appendix B
Clarifications	None

Section 1.8 References

1. NRC Draft Review Standard RS-002, *Processing Applications for Early Site Permits*, December 23, 2002, as supplemented.

1.9 Bounding Site-Specific Plant Parameters Envelope

Table 1.9-1, Bounding Site-Specific Plant Parameters Envelope, provides a summary listing of site characteristics that have been established by analyses presented throughout the SSAR. This list provides a summary of bounding important site characteristics necessary to establish the findings required by 10 CFR Parts 52 and 100 on the suitability of the proposed ESP site. This listing is intended to support development of Table 2, “Site Characteristics and Plant Design Parameters for the Early Site Permit,” as defined by Reference 1. Table 1.9-1 also provides a listing of design parameters and assumptions about the design of a nuclear power plant that might in the future be constructed on the ESP site. It was necessary to assume certain design parameters in order to assess site characteristics.

Section 1.9 References

1. NRC letter to Dominion, J. E. Lyons to D. A. Christian, “Early Site Permit Template,” June 22, 2004.

2. Draft Regulatory Guide DG-1105, *Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites*, NRC, March 2001.

Table 1.9-1 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Part 1 - Site Characteristics		
Maximum Rainfall Rate	18.3 inches in one hour (6.1 inches in 5 minutes) [Same for 2nd unit/group]	• PMP for 1-hour and 5-minute durations of precipitation at the site • Refer to Section 2.4.2.3; Table 2.4-3.
Winter Precipitation		
• 100-year Snowpack	30.5 lb/sq ft [Same for 2nd unit/group]	• Weight, per unit area, of the 100-year return period snowpack at the site • Refer to Section 2.3.1.3.4 & Section 2.4.7.6.
• 100-year Snowpack plus 48-hour Maximum Snowfall	45.5 lb/sq ft [Same for 2nd unit/group]	• 48-hour maximum snowfall (28.5 inches, [a]15 lb/sq ft) on top of a 100-year return snowpack (30.5 lb/sq ft) • Refer to Section 2.3.1.3.4 & Section 2.4.7.6.
• 48-hour Winter PMP	20.75 inches [Same for 2nd unit/group]	• Maximum probable winter rainfall in 48-hour period • Refer to Section 2.3.1.3.4 & Section 2.4.7.6.
Design Response Spectra	Values specified and illustrated in Section 2.5.2.6 [Same for 2nd unit/group]	• Site-specific response spectra • Refer to Section 2.5.2.6.
Capable Tectonic Structures or Sources	No fault displacement potential within the investigative area [Same for 2nd unit/group]	• Conclusion on presence of capable faults or earthquake sources in the vicinity of the site • Refer to Section 2.5.1.2.4 & Section 2.5.3.2.2.
Maximum Flood (or Tsunami)	267.39 ft msl [Same for 2nd unit/group]	• Water level in the power block area due to the probable maximum flood (PMF) • Refer to Section 2.4.2.2 & Section 2.4.3.
Maximum Ground Water	<270 ft msl (maximum groundwater elevations range from 265 to 270 ft msl) [Same for 2nd unit/group]	• Site basis for subsurface hydrostatic loading due to difference in elevation between the site grade elevation in the power block area and the maximum site ground water level • Refer to Section 2.4.12.4.
Maximum Hydraulic Conductivity	3.4 ft/day [Same for 2nd unit/group]	• Hydraulic conductivity used to assess the accidental release of liquid effluent to the groundwater • Refer to Section 2.4.12.1.2
Hydraulic Gradient	0.03 ft/ft [Same for 2nd unit/group]	• Hydraulic gradient used to assess groundwater flow across the ESP site to Lake Anna • Refer to Section 2.4.12.1.2

Table 1.9-1 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Distribution Coefficients (Kd)		• Distribution coefficients used to assess subsurface hydrological radionuclide transport • Refer to Section 2.4.13
• Mn-54	50 cm^3/g [Same for 2nd unit/group]	
• Fe-55	165 cm^3/g [Same for 2nd unit/group]	
• Co-60	60 cm^3/g [Same for 2nd unit/group]	
• Zn-65	200 cm^3/g [Same for 2nd unit/group]	
• Sr-90	15 cm^3/g [Same for 2nd unit/group]	
• Ru-106	55 cm^3/g [Same for 2nd unit/group]	
• Cs-134	30 cm^3/g [Same for 2nd unit/group]	
• Cs-137	30 cm^3/g [Same for 2nd unit/group]	
Subsurface Material Properties		
• Liquefaction	None at site-specific SSE (see Note 1) [Same for 2nd unit/group]	• Liquefaction potential at the site • Refer to Section 2.5.4.8.
• Minimum Bearing Capacity (Static)	Values in Table 2.5-47 [Same for 2nd unit/group]	• Allowable load-bearing capacity of layer supporting plant structures • Refer to Sections 2.5.4.10.1 & 2.5.4.11; Table 2.5-47.
• Minimum Shear Wave Velocity	Values in Table 2.5-45 [Same for 2nd unit/group.]	• Propagation velocity of shear waves through foundation materials • Refer to Section 2.5.4.7.1; Table 2.5-45.

Table 1.9-1 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Tornado		
• Maximum Pressure Drop	1.5 psi [Same for 2nd unit/group]	• Decrease in ambient pressure from normal atmospheric pressure at the site, due to passage of a tornado having a probability of occurrence of 10^{-7} per year • Refer to Section 2.3.1.3.2.
• Maximum Rotational Speed	208 mph [Same for 2nd unit/group]	• Rotation component of maximum wind speed at the site, due to passage of a tornado having a probability of occurrence of 10^{-7} per year • Refer to Section 2.3.1.3.2.
• Maximum Translational Speed	52 mph [Same for 2nd unit/group]	• Translation component of maximum wind speed at the site, due to the movement across ground of a tornado having a probability of occurrence of 10^{-7} per year • Refer to Section 2.3.1.3.2.
• Maximum Wind Speed	260 mph [Same for 2nd unit/group]	• Sum of the maximum rotational and maximum translational wind speed components at the site, due to passage of a tornado having a probability of occurrence of 10^{-7} per year • Refer to Section 2.3.1.3.2.
• Radius of Maximum Rotational Speed	150 ft [Same for 2nd unit/group]	• Distance from the center of the tornado at which the maximum rotational wind speed occurs at the site, due to passage of a tornado having a probability of occurrence of 10^{-7} per year • Refer to Section 2.3.1.3.2.
• Maximum Rate of Pressure Drop	0.76 psi/sec [Same for 2nd unit/group]	• Maximum rate of pressure drop at the site, due to passage of a tornado having a probability of occurrence of 10^{-7} per year • Refer to Section 2.3.1.3.2.
Basic Wind Speed	96 mph [Same for 2nd unit/group]	• 3-second gust wind velocity, associated with a 100-year return period, at 33 feet (10 meters) above ground level in the site area • Refer to Section 2.3.1.3.1.
Intake Structure Ice Formation	Potential for formation of frazil and anchor ice [Same for 2nd unit/group]	• Refer to Section 2.4.7.4.

Table 1.9-1 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Ultimate Heat Sink Ambient Air Controlling Parameters (for reactor designs requiring an external UHS system to reach safe shutdown)		• Refer to Section 2.3.1.3.8.
• Worst 30-day daily average of wet-bulb temperatures and coincident dry-bulb temperatures	76.3°F wb/79.5°F db coincident [Same for 2nd unit/group]	• Meteorological conditions resulting in the maximum evaporation and drift loss during any consecutive 30 days.
• Worst 1-day daily average of wet-bulb temperatures and coincident dry-bulb temperatures	78.9°F wb/87.7°F db coincident [Same for 2nd unit/group]	• Meteorological conditions resulting in the minimum water cooling during any one day.
• Worst 5-day daily average of wet-bulb temperatures and coincident dry-bulb temperatures	77.6°F wb/80.9°F db coincident [Same for 2nd unit/group]	• Meteorological conditions resulting in the minimum water cooling during any consecutive 5 days.
• Maximum-Cumulative-Degree-Days-Below-Freezing	322 degree (F)-days [Same for 2nd unit/group]	• Meteorological condition resulting in the maximum formation of surface ice in the UHS basin • Refer to Section 2.3.1.3.8
Atmospheric Dispersion (CHI/Q) (Accident)		• Atmospheric dispersion coefficients used in the design safety analysis to estimate dose consequences of accident airborne releases • Refer to Sections 2.3.4 & 15.2; Tables 2.3-3, 2.3-13, & 2.3-14.
▪ 0–2 hr @EAB	2.26 E-4 sec/m^3 [Same for 2nd unit/group]	
▪ 0–8 hr @LPZ	2.05 E-5 sec/m^3 [Same for 2nd unit/group]	
▪ 8–24 hr @LPZ	1.36 E-5 sec/m^3 [Same for 2nd unit/group]	
▪ 1–4 day @LPZ	5.58E-6 sec/m^3 [Same for 2nd unit/group]	
▪ 4–30 day @LPZ	1.55E-6 sec/m^3 [Same for 2nd unit/group]	
Dose Consequences		
• Post-Accident	10 CFR 50.34(a)(1) and 10 CFR 100 dose limits [Same for 2nd unit/group]	• Radiological dose consequences due to gaseous releases from postulated plant accidents • Refer to Sections 15.2 & 15.4.

Table 1.9-1 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Release Point		
• Minimum Distance to Site Boundary	2854.9 ft [Same for 2nd unit/group]	• Minimum lateral distance from the ESP Plant Parameter Envelope (PPE) boundaries to the Exclusion Area Boundary (EAB) • Refer to Figure 2.1-1.
Selected Site Characteristic Ambient Air Temperatures	Site characteristic wet bulb and dry bulb temperatures	• Site characteristic wet bulb and dry bulb temperatures associated with the listed exceedance values and the 100-year return period • Refer to Section 2.3.1.2; Table 2.3-18
• Maximum Dry Bulb		
2% annual exceedance	90°F db/75°F wb coincident [Same for 2nd unit/group]	
0.4% annual exceedance	95°F db/77°F wb coincident [Same for 2nd unit/group]	
0% exceedance	104.9°F db/79°F wb coincident [Same for 2nd unit/group]	
100-year return period	109°F db [Same for 2nd unit/group]	
• Minimum Dry Bulb		
1% annual exceedance	18°F db [Same for 2nd unit/group]	
0.4% annual exceedance	14°F db [Same for 2nd unit/group]	
100-year return period	–19°F db [Same for 2nd unit/group]	
• Maximum Wet Bulb		
0.4% annual exceedance	79°F wb [Same for 2nd unit/group]	
0% exceedance	84.9°F wb [Same for 2nd unit/group]	
100-year return period	88°F wb [Same for 2nd unit/group]	

Table 1.9-1 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Population Density		
• Population density at the time of initial site approval and within about 5 years thereafter	Population density meets the guidance of RS-002, Section 2.1.3 for RG 4.7, Regulatory Position C.4 [Both units/groups]	• At the time of initial site approval and within about 5 years hereafter, the population densities, including weighted transient population, averaged over any radial distance out to 20 miles (cumulative population at a distance divided by the circular area at that distance), would not exceed 500 persons per square mile. • Refer to Section 2.1.3.6; Figure 2.1-14.
• Population density at the time of initial operation	Population density meets the guidance of RS-002, Section 2.1.3 [Both units/groups]	• The population densities, including weighted transient population, averaged over any radial distance out to 30 miles (cumulative population at a distance divided by the area at that distance), would not exceed 500 persons per square mile at the time of initial operation. • Refer to Section 2.1.3.6; Figure 2.1-14.
• Population density over the lifetime of the new units until 2065	Population density meets the guidance of RS-002, Section 2.1.3 [Both units/groups]	• The population densities, including weighted transient population, averaged over any radial distance out to 30 miles (cumulative population at a distance divided by the area at that distance), would not exceed 1000 persons per square mile over the lifetime of new units. • Refer to Section 2.1.3.6; Figure 2.1-14.
• Site Is Away From Very Densely Populated Centers	10 CFR 100.21(h) Meets requirement [Both units/groups]	• Reactor sites should be located away from very densely populated centers. Areas of low population density are, generally, preferred. However, in determining the acceptability of a particular site located away from a very densely populated center but not in an area of low density, consideration will be given to safety, environmental, economic, or other factors, which may result in the site being found acceptable. • Refer to Section 2.1.3.5.
Population Center Distance	10 CFR 100.21(b) Meets requirement [Both units/groups]	• The distance from the ESP plant parameter envelope to the nearest boundary of a densely populated center containing more than about 25,000 residents is not less than one and one-third times the distance from the ESP plant parameter envelope to the outer boundary of the LPZ. • Refer to Sections 2.1.3.5 & 2.3.4.
Exclusion Area Boundary	10 CFR 100.21(a) Meets requirement [Both units/groups]	• The exclusion area boundary is the perimeter of a 5000-ft-radius circle from the center of the abandoned Unit 3 containment. • Refer to Sections 2.1.1.3, 2.1.2.2, 2.2.2.1,2.3.4, 2.3.5, 15.2, & 15.4; Tables 2.3-3, 2.3-13, 2.3-16, 15.4-1, 15.4-3, 15.4-5, 15.4-7, 15.4-9, 15.4-10, 15.4-12, 15.4-14, 15.4-16, 15.4-18, 15.4-19, 15.4-21, 15.4-23, 15.4-25, & 15.4-27; Figure 2.1-1.

Table 1.9-1 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Low Population Zone (LPZ)	10 CFR 100.21(a) Meets requirement [Both units/groups]	• The low population zone is a 6-mile-radius circle centered at the Unit 1 containment building. • Refer to Sections 2.1.3.1, 2.1.3.4, 2.3.4, 2.3.5, 15.2, & 15.4; Tables 2.3-3, 2.3-14, 15.4-1, 15.4-3, 15.4-5, 15.4-7, 15.4-9, 15.4-10, 15.4-12, 15.4-14, 15.4-16, 15.4-18, 15.4-19, 15.4-21, 15.4-23, 15.4-25, & 15.4-27; Figure 2.1-2.
Part 2 - Design Parameters		
Structure Height	≤ 234 ft [Same for 2nd unit/group]	• The height from finished grade to the top of the tallest power block structure, excluding cooling towers • Refer to Sections 2.2.3.2.2, 2.3.3.1.2, & 2.3.4.
Structure Foundation Embedment	≤ 140 ft [Same for 2nd unit/group]	• The depth from finished grade to the bottom of the basemat for the most deeply embedded power block structure • Refer to Section 2.5.4; Figures 2.5-57 & 2.5-58.
Normal Plant Heat Sink		
• Unit 3 Closed-Cycle, Dry and Wet Tower Cooling		
Make-Up Flow Rate	22,269 gpm, maximum (EC mode)	• Maximum rate of removal of water from Lake Anna to replace water losses from the closed-cycle cooling water system • Refer to Sections 2.4.1.1 and 2.4.8.
Blowdown Flow Rate	5565 gpm, maximum (EC mode)	• Maximum flow rate of the blowdown stream from the closed cooling water system to Lake Anna • Refer to Sections 2.4.1.1 and 2.4.8.
Unit 4 Dry Cooling Towers		
• Evaporation Rate	None or negligible (on the order of 1 gpm, average)	• The expected rate at which water is lost by evaporation from the cooling water system • Refer to Sections 2.4.1.1, 2.4.7.2, and 2.4.11.3.
• Make-Up Flow Rate	None or negligible (on the order of 1 gpm, average)	• The expected rate of removal of water from Lake Anna to replace evaporative water losses from the cooling water system • Refer to Sections 2.4.1.1, 2.4.7.2, 2.4.11.3, & 2.4.11.4.
Release Point		
• Elevation (Post Accident)	Ground level	• The elevation above finished grade of the release point for accident sequence releases
Source Term		
• Gaseous (Post Accident)	Values in Section 15.4 tables (maximum values) [Same for 2nd unit/group]	• The activity, by isotope, contained in post-accident airborne effluents • Refer to Section 15.4; Tables 15.4-2, 15.4-4, 15.4-6, 15.4-8, 15.4-11, 15.4-13, 15.4-15, 15.4-17, 15.4-20, 15.4-22, 15.4-24, & 15.4-26.

Table 1.9-1 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Plant Characteristics		
• Megawatts Thermal	≤4500 MWt [≤9000 MWt]	• The thermal power generated by one unit (may be the total of several modules) • Refer to Sections 1.2.2, 1.3.2.4, 15.3 & 15.4.

Notes: 1. Safety-related structures would be founded on rock with no liquefaction potential, or on soil with a factor of safety against liquefaction equal to or greater than 1.1 (Reference 2), at the SSE ground motion.

Chapter 2 Site Characteristics

Chapter 2 describes the characteristics of the ESP site.

This section is divided into the following subsections:

- Geography and demography
- Nearby industrial, transportation, and military facilities
- Meteorology
- Hydrology
- Geology and seismology

2.1 Introduction

2.1.1 Site Location and Description

2.1.1.1 Site Location

The ESP site is located within the existing NAPS site. The location of the new units would be confined to the plant envelope area shown in Figure 2.1-1 and Figure 1.2-4. The eastern boundary of the plant envelope area is approximately 570 feet west of the center of the existing Unit 1 containment building.

The ESP site is located in the northeastern portion of Virginia in rural Louisa County. The site is on a peninsula on the southern shore of Lake Anna at the end of State Route 700. The earth dam that creates Lake Anna is about 5 miles southeast of the site. The North Anna River flows southeasterly, joining the South Anna River to form the Pamunkey River about 27 miles southeast of the site.

Louisa County includes two incorporated towns, Louisa and Mineral. According to the 2000 Census survey, the Town of Mineral, which has a population of 424 located within about 1 square mile (incorporated), is the largest community within 10 miles of the ESP site (Reference 1). Figure 2.1-2 shows the general location of the ESP site and localities surrounding the site within 10 miles.

Regionally, as indicated in Figure 2.1-3, the site is about 40 miles north-northwest of Richmond, Virginia; 36 miles east of Charlottesville, Virginia; and 22 miles southwest of Fredericksburg, Virginia. Highways U.S. Route 1 and I-95, the two principal eastern corridor highways passing through Richmond, pass within 15 and 16 miles, respectively, east of the site.

2.1.1.2 Site Description

The topography surrounding the ESP site is characteristic of the central Piedmont Plateau with a gently rolling surface varying from 200 to 500 feet above sea level.

Lake Anna was created to serve the needs of the power station. It is about 17 miles long and has 272 miles of irregular shoreline with various contour and scenic views (Reference 2, Section 2.1).

The ESP site lies along the lake shoreline. The land adjacent to Lake Anna is becoming increasingly residential as the area is developed.

Lake Anna is divided into two separate impoundments: the North Anna Reservoir and the WHTF. The North Anna Reservoir covers 9600 acres and functions as a storage impoundment for plant cooling. The smaller 3400-acre WHTF, consisting of three cooling ponds, is separated from the North Anna Reservoir by a series of dikes.

The NAPS property comprises 1803 acres, of which about 760 acres are covered by water. NAPS is laid out according to the site plan shown in Figure 2.1-1. Virginia Power and ODEC own, and Virginia Power controls, all of the land within the NAPS site boundary, including those portions of the North Anna Reservoir and WHTF that lie within the site boundary. These companies also own all land outside the NAPS site boundary that forms Lake Anna up to the expected high-water marks. The NAPS site and all supporting facilities, including the North Anna Reservoir, the WHTF, the earth dam, dikes, railroad spur, and roads constitute approximately 18,643 acres (Reference 3, Section 2.1.1.2).

If Dominion decides to proceed with the development of new units at the ESP site, it would first enter into and obtain appropriate regulatory approvals of an agreement with the NAPS owners to purchase or lease the ESP site. The agreement or conveyance documents would provide for mutual use of the NAPS site as a single exclusion area and single restricted area for all nuclear units within the NAPS property including the new units located within the ESP site.

2.1.1.3 Boundary For Establishing Effluent Release Limits

The ESP exclusion area, shown in Figure 2.1-1, is the perimeter of a 5000-ft-radius circle from the center of the abandoned Unit 3 containment. This is the same as the exclusion area for the existing units. There are no residents in this exclusion area. The new units would be located within the ESP plant envelope area west of the existing units protected area and would be well within the exclusion area.

Consistent with the licenses for the existing units, the gaseous effluent release limits for the new units would apply at or beyond the ESP exclusion area, as shown in Figure 2.1-1. The liquid effluent release limits for the new units would apply at the end of the discharge canal, which is designated as the release point to unrestricted areas.

All areas outside the exclusion area would be unrestricted areas in the context of 10 CFR 20. Additionally, the guidelines provided in 10 CFR 50, Appendix I for radiation exposures to meet the criterion “as low as is reasonable achievable” would be applied at the 5000-ft-radius exclusion area boundary (EAB).

2.1.2 Exclusion Area Authority and Control

2.1.2.1 Authority

As presented in Section 2.1.1.2, if Dominion decides to proceed with the development of new units, it would enter into and obtain appropriate regulatory approvals to purchase or lease the ESP site from Virginia Power and ODEC. Under the Virginia Electric Utility Restructuring Act, a certificate issued by the Virginia State Corporation Commission ("SCC") will be required before DNNA may construct and operate additional nuclear units at North Anna. Virginia Code, § 56-580 D. That section provides that the SCC will permit the construction and operation of electrical generating facilities upon a finding that such generating facility and associated facilities: 1) will have no material adverse effect upon the reliability of electric energy service provided by any regulated public utility and 2) are not otherwise contrary to the public interest.

DNNA and Virginia Electric Power Company ("Virginia Power") are "affiliated interests" as defined in the Virginia Affiliates Act, Va. Code §§ 56-76 et seq. As a result, the SCC must also grant prior approval of any agreements to purchase or lease the ESP site and to provide for joint control of the exclusion area before DNNA will have access to the site to commence construction. Under Virginia law, no contract or "arrangement" between a public utility and an affiliate for, among other things, the purchase, sale, lease or exchange of any property, right or thing is effective unless and until approved by the SCC. Va. Code § 56-77. (A similar approval may be required in North Carolina, in which a portion of Virginia Power's utility service territory is located.)

Under this statutory framework, if DNNA decides to proceed with the construction of new nuclear units at North Anna, it will negotiate an appropriate agreement to purchase or lease the ESP site and to provide joint control of the NAPS exclusion area. It is reasonable to presume that if the site owners are willing to sell or lease the ESP site to allow DNNA to construct and operate new nuclear units, they will be willing to allow the necessary joint control of the exclusion area. After this agreement is negotiated, DNNA and Virginia Power will apply to the SCC (and any other public utility commissions if required) for approval to make the agreement effective. DNNA would also apply to the SCC for a certificate of public convenience and necessity to allow construction and operation of the new units. If these approvals–both of which are prerequisites to construction–are granted, DNNA will have the requisite authority over the exclusion area before construction begins, consistent with Section 2.1.2 of the Standard Review Plan. If these approvals are not granted, construction cannot occur.

The agreement or conveyance documents would provide for the mutual use of the NAPS site as a single exclusion area. As part of this arrangement, each party would agree to immediately notify the other in the event of an emergency and to abide by the reasonable requests of the party declaring an emergency to exclude non-plant personnel and property from the exclusion area. The parties would also agree to work cooperatively to control third party activity that might otherwise present an unacceptable hazard to nuclear operations. Because the appropriate regulatory approvals of the

conveyance and agreement (pursuant to Virginia Code, 56-77 and 56-580) would be a prerequisite to Dominion's development of the new units, such arrangements would be in place before issuance of a COL for the new units.

The perimeter of the existing NAPS EAB on land is adequately posted with "No Trespassing" signs. Also, floating bottom-moored buoys supporting the "No Trespassing" signs have been implanted, with suitable spacing, across the entrance to the small inlet of the North Anna Reservoir immediately north of the existing units. All markers conform to Virginia state standards. Also, a log-type boom arrangement and a small number of bottom-moored floating buoys supporting "No Trespassing" signs have been placed across the entrance to the main cooling water canal (Canal C). No additional posting would be necessary for the new units.

Along Lake Anna, outside the exclusion area, Virginia Power has granted each land owner an easement to use a portion of Virginia Power's property above the fluctuating water line for the erection of piers, jetties, or other recreational structures for access to the lake. Such structures require Virginia Power approval as to type and location and are permitted only to the extent that they would not be detrimental to the development, operation, and maintenance of the electric generating facilities, the dam, the reservoir, the dikes, and the cooling lagoons. With respect to the land bordering the cooling lagoons, Virginia Power has granted each land owner a permit to use the Virginia Power-owned land above the fluctuating water level; however, this permission is expressly revocable by Virginia Power to the extent necessary to preserve the character and maintain the operation of the WHTF (cooling lagoons) as a private water treatment facility. A limited number of landowners have been granted permissions to erect docks on the shoreline within the exclusion area. Since the ESP plant envelope (as shown in Figure 2.1-1) is located close to the existing units, Dominion intends to maintain the above practices for the new units in order to safeguard the proper use of the lake and the cooling lagoons.

2.1.2.2 Control of Activities Unrelated to Plant Operation

A portion of the smallest cooling lagoon, where recreational use is primarily for fishing, lies within the EAB. Water skiing and recreational boating are more prevalent in the other two, much larger cooling lagoons, which are entirely outside the exclusion area. Access to the cooling lagoons is restricted to property owners and their guests, as there is no means of access by boat from the North Anna Reservoir to any of the cooling lagoons.

Boaters on the North Anna Reservoir also have access to the portion of the lake within the exclusion area. Such use is largely transient as boaters from the marinas and boat ramps north and west of the NAPS site access the area between the existing units and the dam.

Should an event that necessitates implementing boating and water use restrictions on Lake Anna occur, the restrictions would be under the direction and authority of the Virginia Department of Game and Inland Fisheries (VDGIF), and the Sheriffs' Departments of Louisa, Spotsylvania, and Orange Counties. Such arrangements would be documented in the new units' emergency plan. In

parallel, the appropriate portions of the emergency plan would be implemented in support of those state and local actions.

2.1.2.3 Arrangements for Traffic Control

No state or county roads, railways or waterways traverse the ESP exclusion area; therefore, no traffic control would be required. State Routes 700 and 652 provide access for NAPS staff and access by the general public to the North Anna Visitor Center. These same routes would provide similar access to the ESP site.

2.1.3 Population Distribution

The population distribution surrounding the ESP site, up to an 80-kilometer (50-mile) radius, has been estimated, based on the most recent United States Census Bureau decennial census data (Reference 4). The population distribution encompasses 9 concentric rings at 2 km (1.2 mi.), 4 km (2.5 mi.), 6 km (3.7 mi.), 8 km (5.0 mi.), 10 km (6.2 mi.), 16 km (10 mi.), 40 km (24.9 mi.), 60 km (37.3 mi.), and 80 km (50 mi.), and 16 directional sectors. The projected population estimates for Years 2010, 2020, 2030, 2040, and 2065 have been calculated with a formula adopted from the Weldon Cooper Center for Public Service (Reference 6) using the 1990 Census and 2000 Census data as the base.

2.1.3.1 Resident Population Within 10 Miles

Figure 2.1-2 shows the general locations of the municipalities and other features within 10 miles (16 kilometers) of the ESP site. According to the 2000 Census survey, Mineral, which has a population of 424 located within about 1 square mile (incorporated), is the largest community within 10 miles of the site (Reference 4). As reported in NAPS Updated Final Safety Analysis Report (UFSAR) (Reference 3, Section 2.1.3.1), the population in 1990 was 452. Therefore, the population of Mineral has remained constant during the past decade.

The population distribution within 10 miles of the site has been computed by overlaying the 2000 Census block points data (the smallest unit of census data) (Reference 4) on the grid shown on Figure 2.1-2, and summing the population of the census block points falling in each of the polar sectors comprising the grid. The census block-point summation and allocation has been accomplished using the Landview 5 (LV5) software, operating directly on census data, and the MARPLOT mapping software (Reference 5). The system can display Census 2000 demographic data, jurisdictional entities, and many statistical entities of the U.S. Census Bureau. It can also calculate Census 2000 population, racial distribution, census block count, and housing unit count within a user-defined radius. Using MARPLOT, the grid system was created as shown on Figure 2.1-2. LV5 was designed to summarize the population distribution and other information once the user selected an area of interest within the grid system. The entire grid system is evenly divided into sixteen directions, each direction consisting of 22.5 degrees.

The population distributions and related information were collected and the results tabulated in all distances of interest for all sixteen directions. In order to generate more accurate counts, census block points were used in LV5 to calculate population distributions. The LV5 results show that the Year 2000 resident population within 10 km (6 miles) and 16 km (10 miles) of the ESP site were 5890 and 15,511 persons, respectively.

Population projections for the area within 10 miles of the ESP site up to 65 years from the 2000 census were developed. The formula used for average annual growth (percentage of growth) is adopted from Reference 6. The Weldon Cooper Center for Public Service group has performed the 2001 provisional population estimates for the Commonwealth of Virginia.

$$\text{Annual Average Growth} = \frac{\text{Log}_{10}(\text{Population}_{2000} / \text{Population}_{1990})}{(2000 - 1990) \times 0.4342945}$$

The 1990 population distributions within each county and city considered in Virginia and Maryland were also obtained from the U.S. Census Bureau (Reference 12). The same formula also is used for projection of the transient population up to the Year 2065. The 16-km (10-mile) resident and transient population for Year 2000 is shown on Figure 2.1-4. The resident and transient 16-km (10-mile) population projections for the years 2010, 2020, 2030, 2040, and 2065 are given in Figure 2.1-5 through Figure 2.1-8A.

2.1.3.2 Resident Population Between 10 and 50 Miles

The 50-mile (80-km) radius centered at the ESP site covers thirty counties and four cities in Virginia and one county in Maryland. The Town of Louisa is approximately 12 miles to the west of the ESP site. The population of the town has increased from 1088 (Reference 12) to 1401 (Reference 2, Section 2.2.8.5) between 1990 and 2000. Estimates of the Year 2000 resident population from within 10 miles to 50 miles from the ESP site were computed using the same methodology used to develop the 10-mile population distribution.

The population grid from 10 to 50 miles is shown on Figure 2.1-3 and the 50-mile population distribution for Year 2000 is shown on Figure 2.1-9.

Population projections for the area between 10 and 50 miles for the years 2010, 2020, 2030, 2040, and 2065 are based on the same methodology as the 10-mile projections. These population projections are given in Figure 2.1-10 through Figure 2.1-13A, respectively.

Besides the thirty counties within Virginia, the 50-mile radius from the ESP site also encompasses a portion of Charles County, Maryland. The population portion within that 50-mile radius for Charles County, which at its closest point is 37 miles northeast of the site, is 9270 based on the 2000 Census data.

2.1.3.3 Transient Population

2.1.3.3.1 Transient Population Within 10 miles

Information concerning transient population for the area has been collected from several sources, because this information is not available from the 2000 Census data. The area within 10 miles of the ESP site is predominantly rural and characterized by farmland and wooded tracts of land. Since there are no significant industrial or commercial facilities in the area, and none are anticipated (Reference 3, Section 2.1.3.3), the transient employment population is likely to move out of, rather than into, the area.

Recreational use of Lake Anna, including Lake Anna State Park, is the greatest contributor to transient population in the area. The usage of the lake has been estimated from a number of contributing factors including the number of boat ramps, wet slips, campsites, picnic areas, etc. These contributing factors are listed in Table 2.1-1.

An estimate of lake usage on a peak weekend day in the peak summer season has been developed based on representative use of recreational facilities (e.g., boating, picnicking, camping) provided by the Virginia Department of Conservation and Recreation (Reference 3, Section 2.1.3.3) and the Lake Anna facilities listed in Table 2.1-1. This estimate does not include lake use by local residents with their own docks. However, residents should be included in the census data. In addition, many residents without docks keep their boats in marina wet slips or use the boat ramps and are, therefore, included in the lake usage.

There are six marinas in the vicinity of the ESP site. The closest one is 1.4 miles north-northeast of the site. The remaining marinas are from 2 to 2.5 miles distant. A survey of several of the marina owners indicates that their actual boat launches per ramp range from 15 to 40 per ramp per peak day, which is significantly lower than the number of 80 per day provided by the Virginia Department of Conservation and Recreation as an upper limit for ramp usage. The usage per ramp has dropped as new ramps are added. This has been attributed to parking space limitations and the fact that the lake usage by recreational boaters may be approaching saturation. A rate of 50 launches per ramp per day has been selected as being representative of Lake Anna conditions.

Based on 50 launches per ramp per day, these marinas and other boat ramps, including those at Lake Anna State Park, could provide access for up to 1450 pleasure crafts on the North Anna Reservoir. Peak day usage estimates of boats moored in wet slips have ranged from 30 to 50 percent. Assuming that all slips are rented, 150 additional boats would be added, bringing the total (excluding boats from private docks) to 1600. The resulting transient population at three persons per boat would be 4800 (Reference 3, Section 2.1.3.3).

The two commercial campgrounds, with a combined total of more than 200 campsites, are estimated by the Virginia Department of Conservation and Recreation to contribute about 650 persons to the transient population, assuming three persons per campsite. The number of

picnickers has been estimated at 450. Since both campsites have boat ramps, significant double counting is likely (Reference 3, Section 2.1.3.3).

Lake Anna State Park, which provides facilities for picnicking, fishing, boat launching, swimming, and biking, has increased in popularity each year. The Park Manager has estimated a peak daily attendance at 4372 from June through August 2002, and an annual attendance of 187,302 between July 1, 2001 and June 30, 2002 based on traffic counters. Double counting is likely, as boaters are included in the traffic count.

The resulting estimated total peak daily transient population on Lake Anna (including the WHTF and Lake Anna State Park) is less than 11,270 (Table 2.1-2). Given these assumptions and the potential for double counting, this number is conservative.

Since use of the WHTF is limited to residents and their quests, there are no public boat ramps. The transient population, estimated at less than 1000, is based on one guest for each resident in the polar sectors encompassing the WHTF.

Annual transient population is uncertain because of the dramatic drop in boating on weekdays and non-summer months. Based on Lake Anna State Park data, assuming 180 days of operation, the average daily attendance is less than one quarter of the peak daily attendance. Conservatively assuming that the average attendance, excluding the park, is one half the peak daily figure, the total annual attendance would be about 807,300, based on a 180-day season.

Transient population within 10 miles of the ESP site when combined with the resident population in that same area for Year 2000 and for projected years 2010, 2020, 2030, 2040, and 2065 are presented in Figure 2.1-4 through Figure 2.1-8A.

2.1.3.3.2 Transient Population Between 10 and 50 Miles

It is difficult to provide an accurate count of the transient population between 10-mile and 50-mile concentric circles from the ESP site. There are colleges, schools and hospitals within the 50-mile radius of the site. However, compared to the resident population within the same 50-mile radius area, transient population use of these facilities is expected to be insignificant.

Between 10 and 50 miles of the ESP site, Paramount's Kings Dominion Amusement Park is a major recreational facility that induces a significant amount of transient population. Paramount's Kings Dominion is located 35 miles southeast of the ESP site. The park opens from March to November and hosts about 2 to 2.5 million visitors annually. According to the park's public relations manager, the park could experience slow growth in the future until it reaches its current maximum capacity of 2.875 million visitors per year (i.e., an additional 15 percent above the current attendance). On average, the park opens to the public about 138 days per year (Reference 7). Using the maximum capacity of the park and the average number of days open, the average daily park visitor count is estimated to be 20,830.

There is no official count of visitors that come from areas outside the 50-mile radius from the ESP site. However, the majority of the park visitors are expected to come from the Richmond and Fredericksburg areas due to their proximity to the park. It is conservatively assumed that 40 percent of the daily park visitors come from areas outside the 50-mile radius. The 8350 park visitors from further than 50 miles are considered transient population and that number is included in the population distribution estimates.

Transient population between 10 and 50 miles of the ESP site when combined with the resident population in that area for Year 2000 and for projected years 2010, 2020, 2030, 2040, and 2065 are presented in Figure 2.1-9 through Figure 2.1-13A.

2.1.3.4 Low Population Zone

The Low Population Zone (LPZ) for the ESP site is the same as the LPZ for the existing units. As shown in Figure 2.1-2, a 6-mile-radius circle centered at the Unit 1 containment building defines the LPZ. Design basis accidents (DBAs) are evaluated in Chapter 15 to demonstrate that doses at the LPZ are within the dose limits of 10 CFR 100.21(c). Exposure of individuals to radiation in the LPZ would be within the limits established in 10 CFR 50.34(a)(1)(ii).

The resident and transient population distribution within the LPZ is indicated in Figure 2.1-4 through Figure 2.1-8A, based on the 2000 Census and projections through Year 2065. These figures use an increment of 2 km for distances within a 10-km radius of the ESP site. The 6-mile radius LPZ falls within the 8–10 km (5–6.2 mile) range. For reporting purposes, the LPZ population is represented by the population enclosed within the 10-km distance circle.

In summary, the LPZ population for Year 2000 and the projected population through Year 2065 are as follows:

Year	Population
2000	16,705
2010	22,841
2020	28,978
2030	35,112
2040	41,247
2065	56,588

The only school in the LPZ is Livingston Elementary, which is in Spotsylvania County, 5.7 miles to the north-northeast of the ESP site. Schools within 10 miles of the ESP site are listed in Table 2.1-3 (Reference 8) (Reference 9).

As demonstrated in the previous section, the only significant source of transient population within 10 miles is recreational use of Lake Anna. Since most of the lake area falls within the LPZ, almost the entire estimated peak transient population within 10 miles could be in the LPZ.

Considering the available road network leading from the LPZ, together with the availability of private as well as public vehicles, there is reasonable assurance that these populations could be evacuated in a timely manner in the event of a DBA.

2.1.3.5 Population Center

The nearest population center to the ESP site with more than 25,000 residents is the City of Charlottesville, with a 2000 Census population of 45,049 (Reference 4). The closest point of Charlottesville to the site is 36 miles west. The next closest population center is Fredericksburg, which is 22 miles northeast of the ESP site. Fredericksburg has a projected Year 2065 population of about 20,950. The distance to Fredericksburg is well in excess of the minimum population center distance required by 10 CFR 100.

2.1.3.6 Population Density

Given an approved ESP period of 20 years and an assumed ESP approval date of 2005, the startup date of new units is conservatively assumed to be 2025. Assuming an operational period of 40 years for new units, new unit operations could extend until 2065.

Figure 2.1-14 shows the actual cumulative populations in Year 2000 and projected cumulative population in Year 2065 as a function of 10-mile to 50-mile radial distances from the site. On the same figure, population density curves, spanning the same radial distances, are shown for 500 persons per square mile, and 1000 persons per square mile.

By inspection of the curves for actual population densities of Year 2000 and Year 2065 projections, it is concluded that at the time of initial site approval and within about 5 years thereafter, the population densities, including weighted transient population, averaged over any radial distance out to 20 miles (cumulative population at a distance divided by the circular area at that distance), would not exceed 500 persons per square mile. The results conform to the guidance in RG 4.7, Regulatory Position C.4 (Reference 10).

Similarly, by inspection and projection of the same curves to account for trends over the lifetime of new units, it is concluded that the expected population densities, including weighted transient population, averaged over any radial distance out to 30 miles (cumulative population at a distance divided by the area at that distance), would not exceed: 1) 500 persons per square mile at the time of initial operation, and 2) 1000 persons per square mile over the lifetime of new units (Reference 11, Section 2.1-3).

Section 2.1 References

1. Town of Mineral, Website, www.louisa.net/mineral/, accessed October 14, 2002.

2. NUREG-1437, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 7, Regarding North Anna Power Station, Units 1 and 2, U.S. Nuclear Regulatory Commission, November 2002.

3. North Anna Updated Final Safety Analysis Report, Rev. 38, Dominion Virginia Power.

4. U.S. Department of Commerce, Bureau of the Census, 2000 Census of Population, Website, www.census.gov/main/www/cen2000.html, accessed October 1, 2002.

5. LandView 5, U.S. Census Bureau, U.S. Environmental Protection Agency (EPA), U.S. Geological Survey, National Oceanic and Atmospheric Administration, June 2002.

6. Weldon Cooper Center for Public Service, Website www.ccps.virginia.edu/demographics/estimates/city-co/2001estimates.pdf, accessed September 22, 2003.

7. Paramount's Kings Dominion, Website, www.kingsdominion.com/visit_calendar.jsp, accessed August 15, 2003.

8. Louisa County High School, Website, www.greatschools.net/modperl/browse_school/va/1016, accessed October 11, 2002.

9. Louisa County Middle School, Website, www.greatschools.net/modperl/browse_school/va/1018, accessed October 11, 2002.

10. Regulatory Guide 4.7, Rev. 2, General Site Suitability Criteria for Nuclear Power Plants, U.S. Nuclear Regulatory Commission, April 1998.

11. NRC Review Standard RS-002, *Processing Applications of Early Site Permits: Draft for Interim Use and Public Comment*, NRC, Office of Nuclear Reactor Regulation, December 23, 2002, as supplemented.

12. U.S. Department of Commerce, Bureau of the Census, 1990 Census of Population, website, www.census.gov/main/www/cen1990.html, accessed October 1, 2002.

Table 2.1-1 Lake Anna Recreational Facilities

Facility	Distance	Number of Wet Slips	Number of Ramps	Camp Sites
Marinas				
Anna Point	2.3 miles NNW	25	1	—
Dukes Creek	2.2 miles E	55	5	—
High Point	2.3 miles NNW	50	4	—
Lake Anna	1.4 miles NNE	160	2	—
Rocky Branch	2.3 miles NNE	—	4	—
Sturgeon Creek	2 miles N	36	5	—
Public Landings				
Christopher Run Campground	6 miles WNW	—	1	152
Hunters Landing	6.6 miles NW	—	1	—
Lake Anna Campground	2.5 miles NW	—	1	61
Lake Anna Landing	9 miles NW	—	1	—
Lake Anna State Park	4.3 miles NNW	—	2	—
Pleasants Landing	5.6 miles SE	—	1	—
Sullivan's Landing	8 miles NW	—	1	—
Total		326	29	213

Source: Reference 3, Table 2.1-1
Note: "—" means no data was reported in source

Table 2.1-2 Tourist Attractions, Parks and Recreational Areas

Facility	Location	Annual Usage	Peak Daily Usage *	Comments
Lake Anna Recreational Usage	1.4 mi, NNE	530,000	5900 **	Annual usage based on 180 days at 2950 people per day.
Waste Heat Treatment Facility	—	90,000	<1000	Peak daily usage based on doubling the resident population in cooling lagoon sectors (one guest per resident). Annual usage based on 180 days at 500 people per day.
Lake Anna State Park	2.8 mi, NNW	187,300	4370	Annual use was 187,300 between July 1, 2001 and June 2002. Park closed in winter. Use includes occupants of boats launched at the park.
Paramount's Kings Dominion Amusement Park	35 mi, SE	2,875,000	20,830	Annual use was 2 to 2.5 million between March and November. Add 15% to calculate maximum capacity. Park closed in winter.

* Peak daily usage is based on a peak weekend day during the summer.

** This number is based on an average of 3 persons per boat, campsite and picnic area.

Table 2.1-3 Schools Within 10 Miles of ESP Site

School	Number of Students (2002)	Distance (miles)	Direction from Plant
Louisa County			
Louisa County High School	1232[a]	7	WSW
Louisa County Middle School	1.035[b]	7	WSW
Spotsylvania County			
Livingston Elementary	477	6	NE

a. Source: Reference 8

b. Source: Reference 9

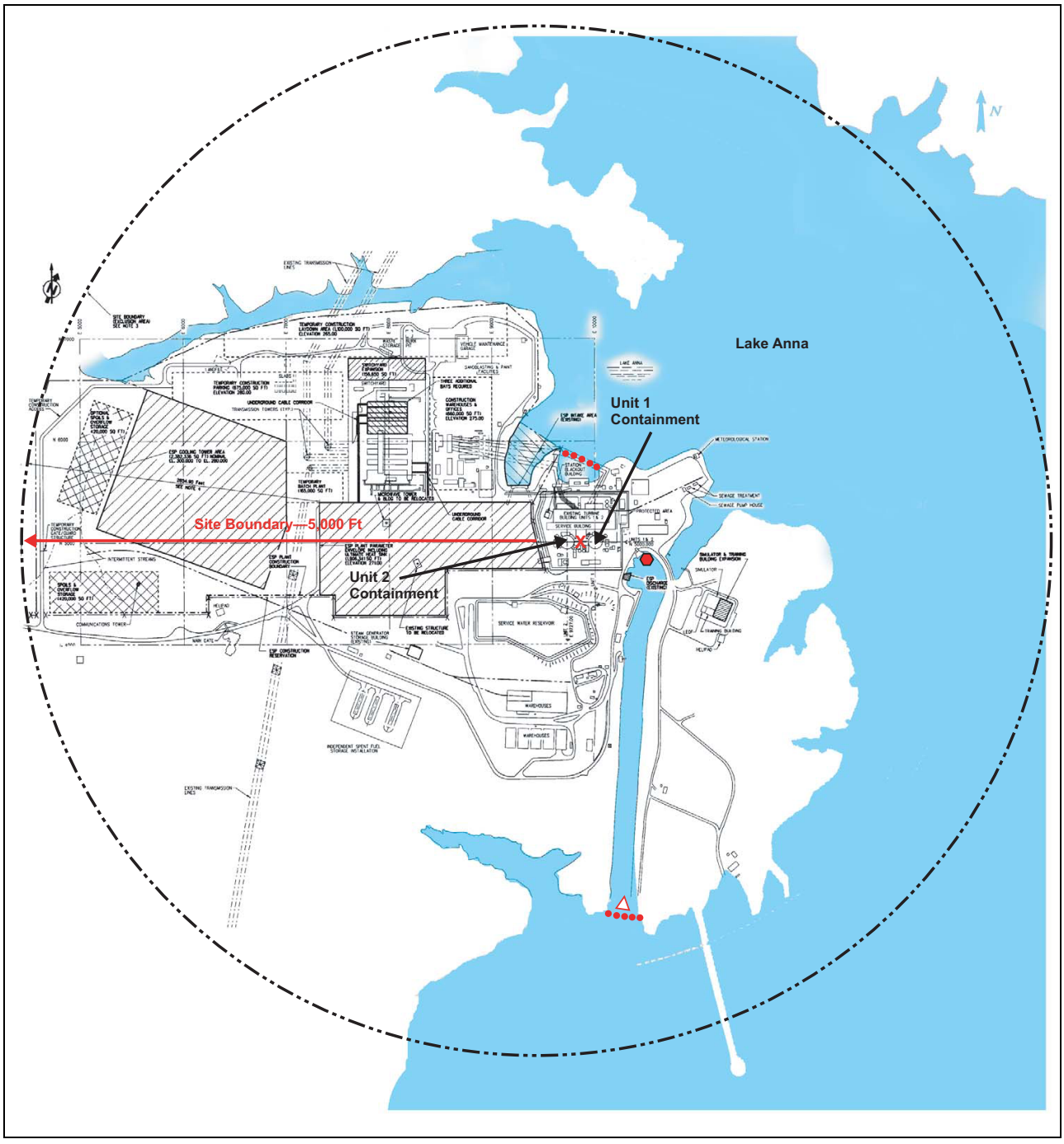


Figure 2.1-1 Site Boundary

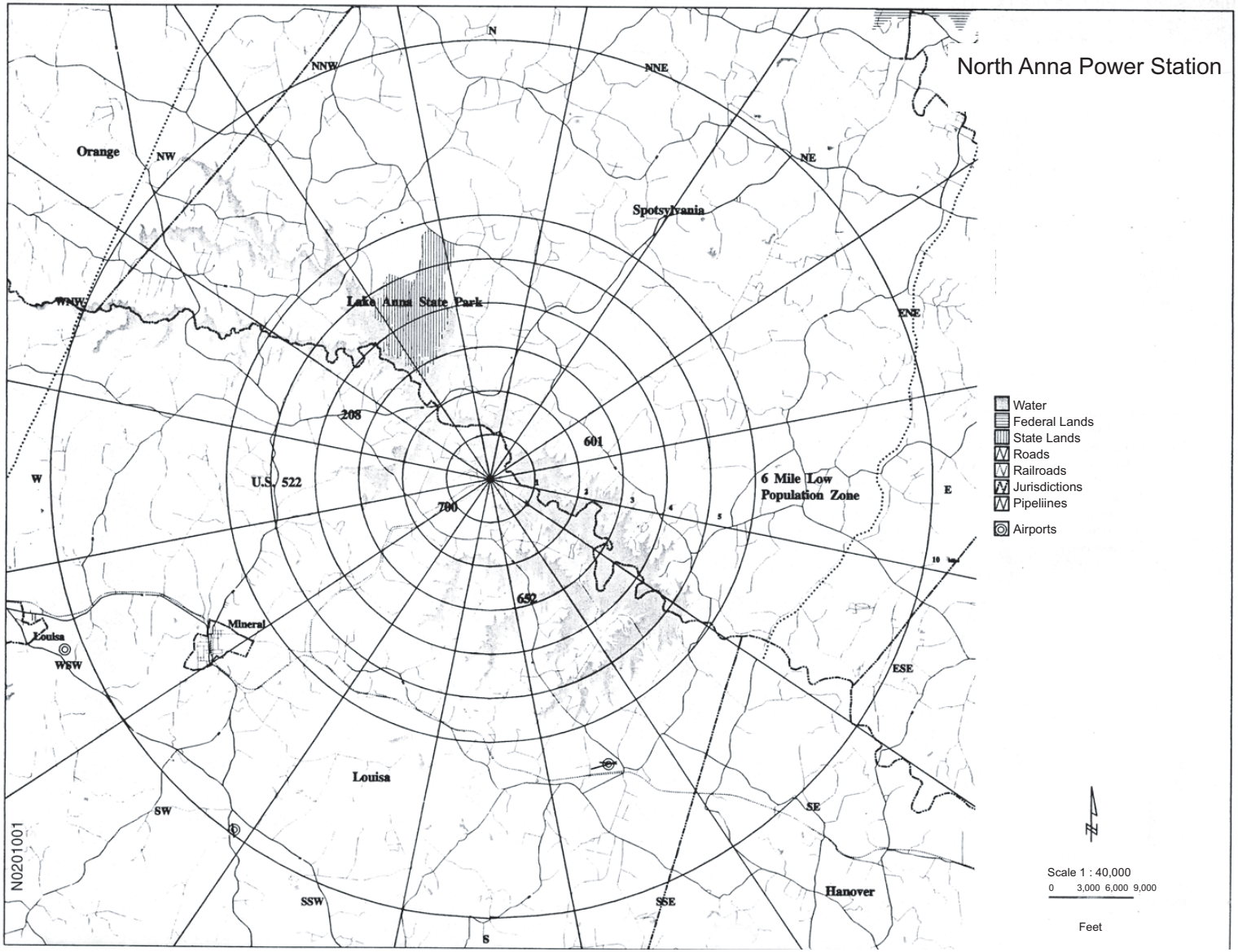


Figure 2.1-2 Ten-Mile Surrounding Area

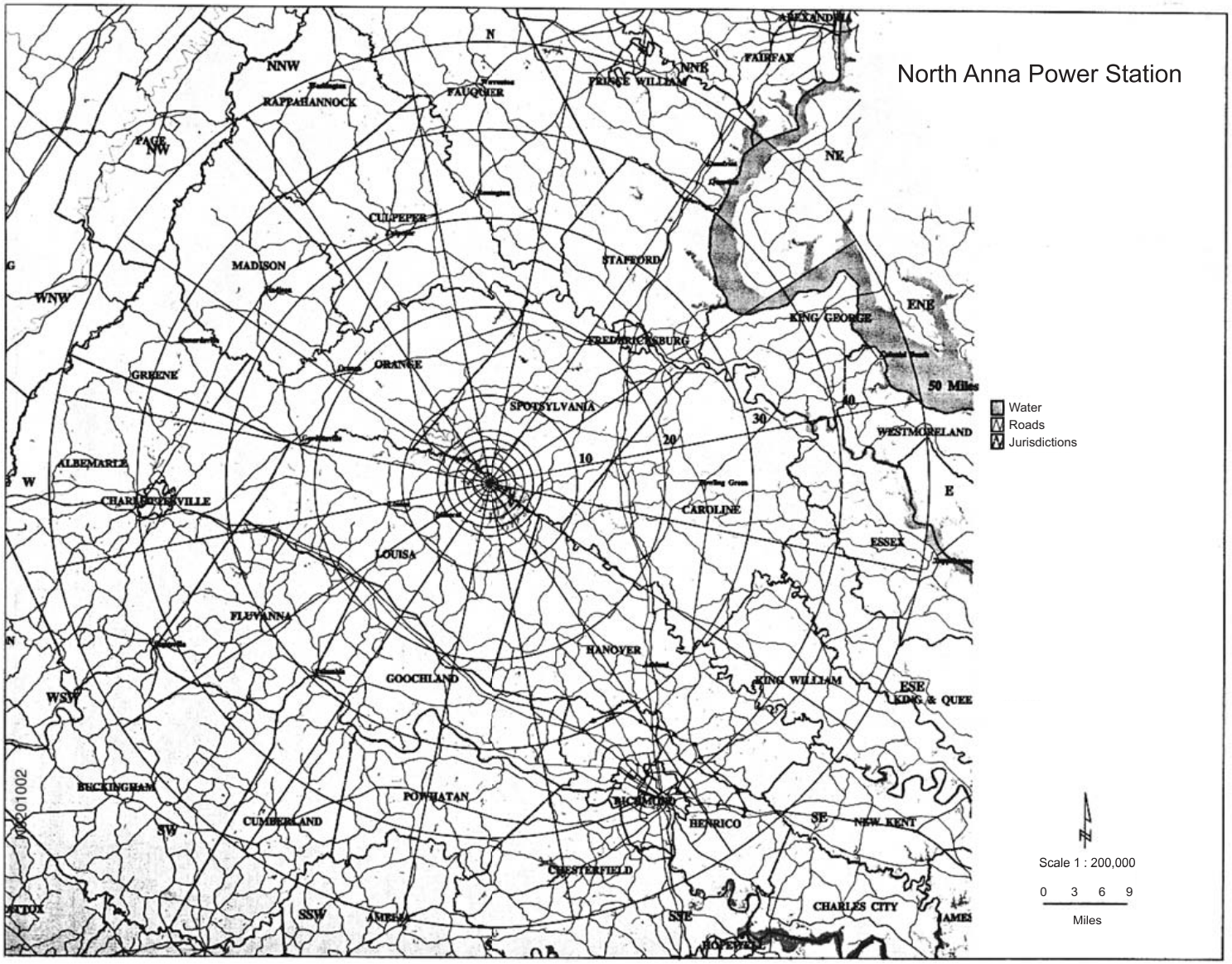
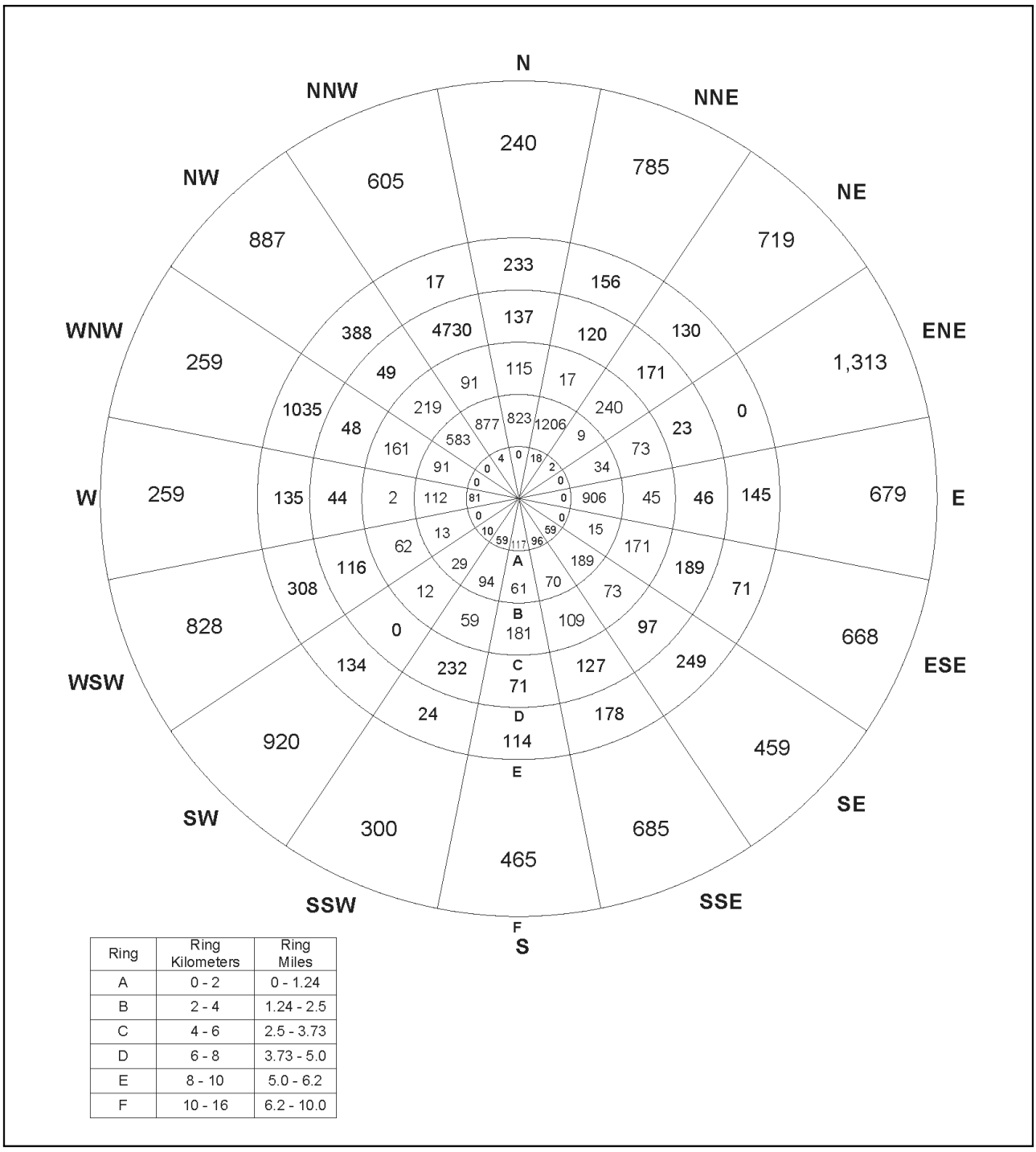


Figure 2.1-3 Fifty-Mile Surrounding Area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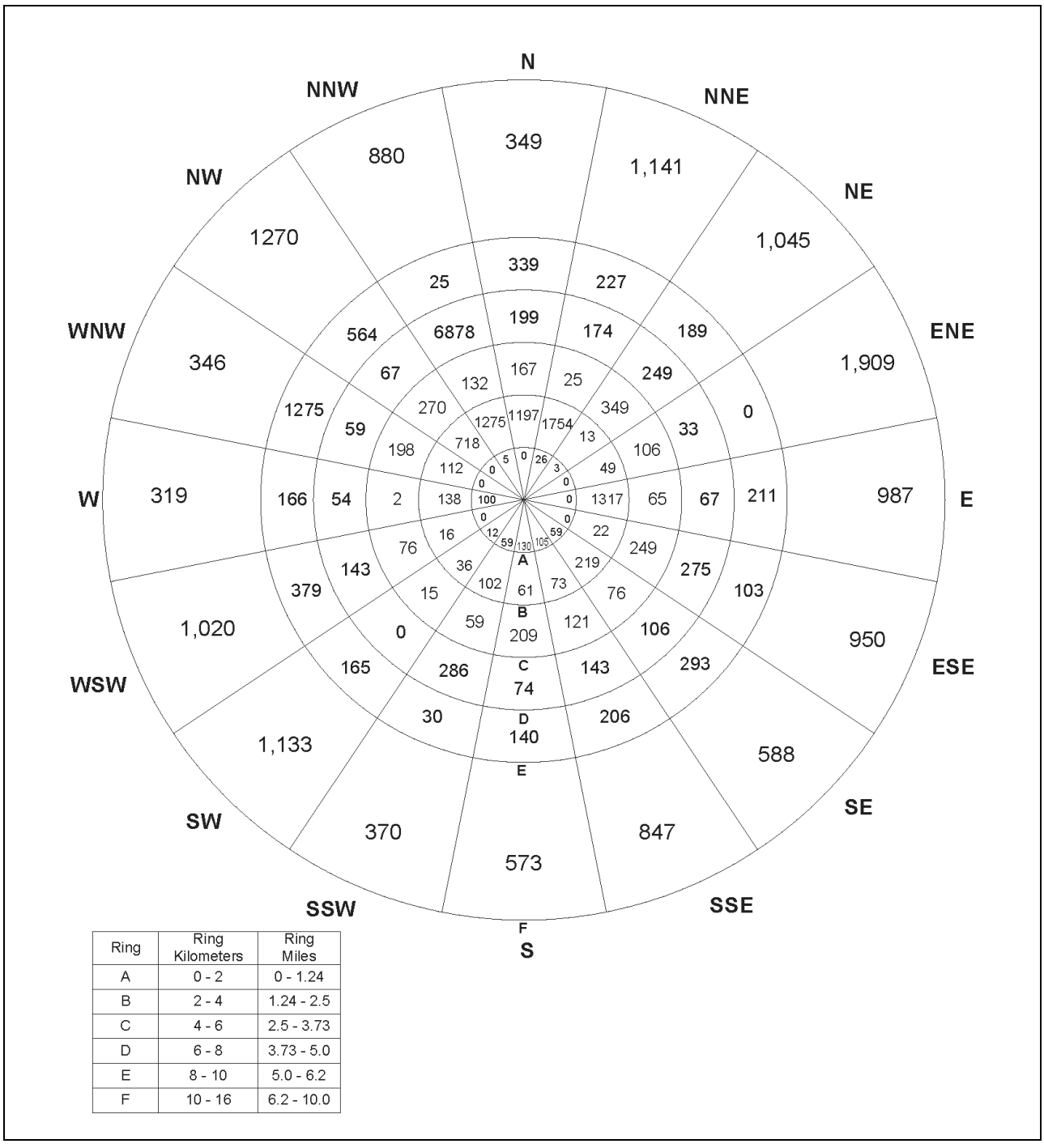
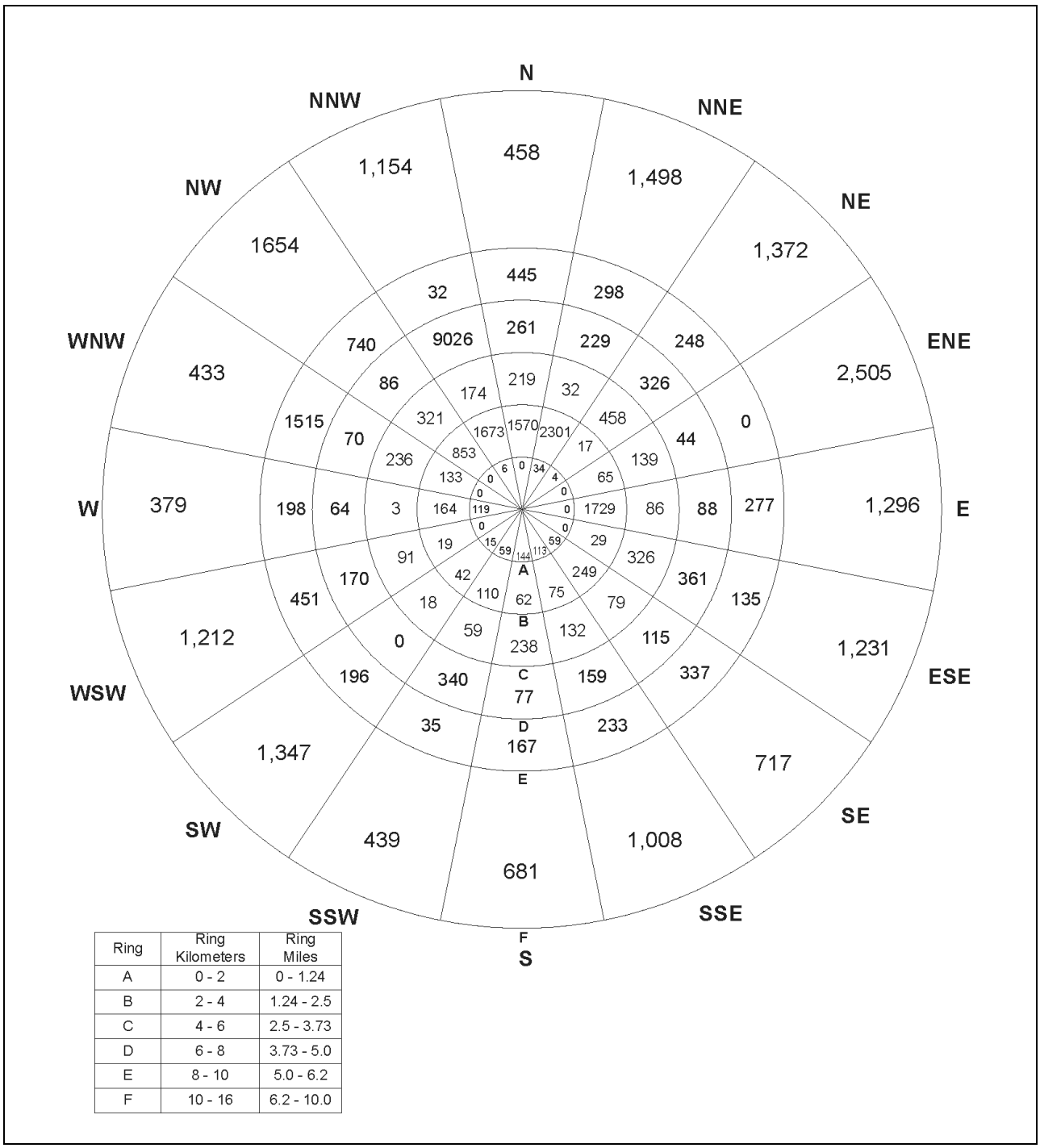


Ring	Ring Kilometers	Ring Miles
A	0 - 2	0 - 1.24
B	2 - 4	1.24 - 2.5
C	4 - 6	2.5 - 3.73
D	6 - 8	3.73 - 5.0
E	8 - 10	5.0 - 6.2
F	10 - 16	6.2 - 10.0

Figure 2.1-5 16-Kilometer (10-Mile) Resident and Transient Population Distribution–2010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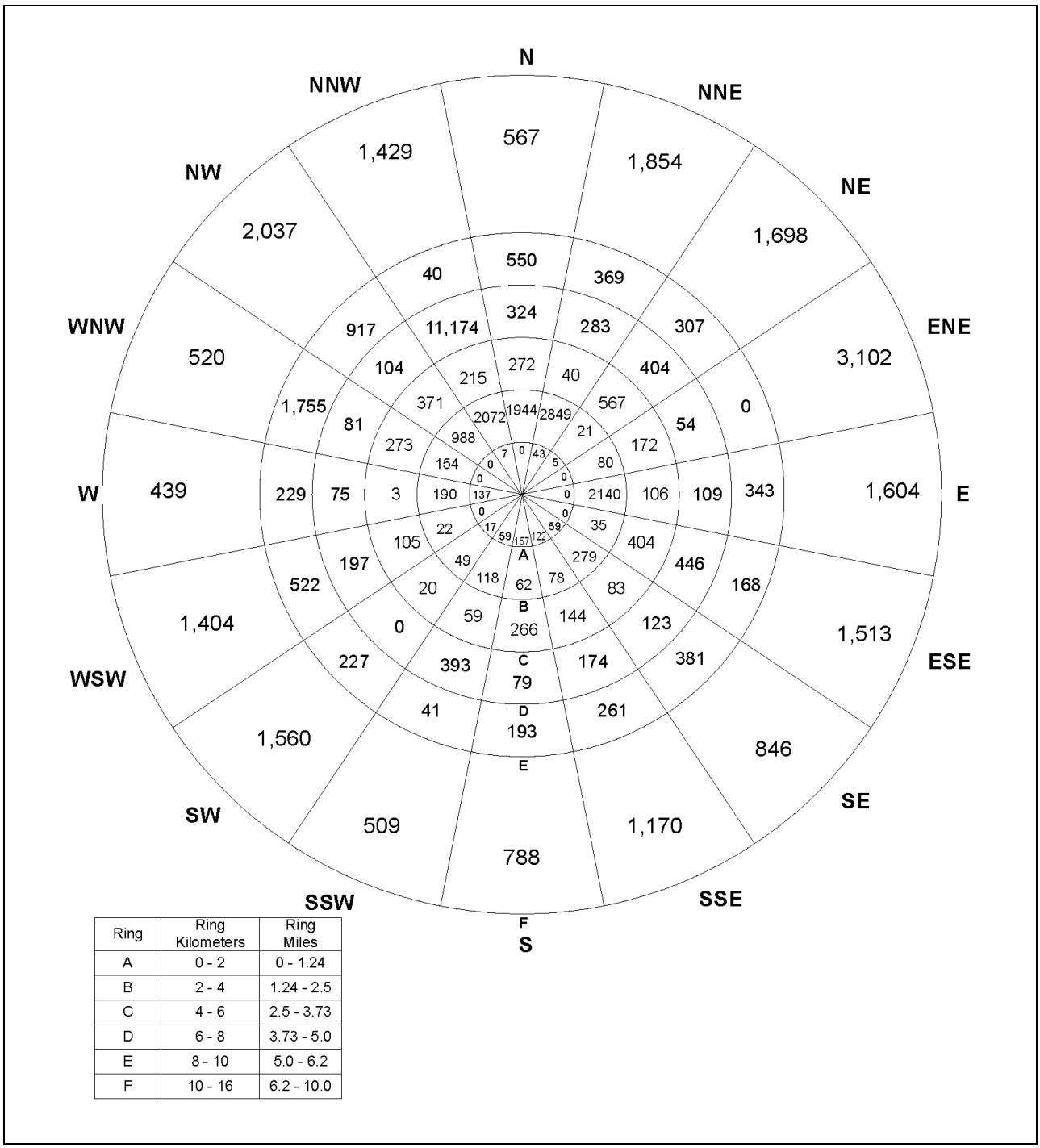


Ring	Ring Kilometers	Ring Miles
A	0 - 2	0 - 1.24
B	2 - 4	1.24 - 2.5
C	4 - 6	2.5 - 3.73
D	6 - 8	3.73 - 5.0
E	8 - 10	5.0 - 6.2
F	10 - 16	6.2 - 10.0

Figure 2.1-7 16-Kilometer (10-Mile) Resident and Transient Population Distribution–2030

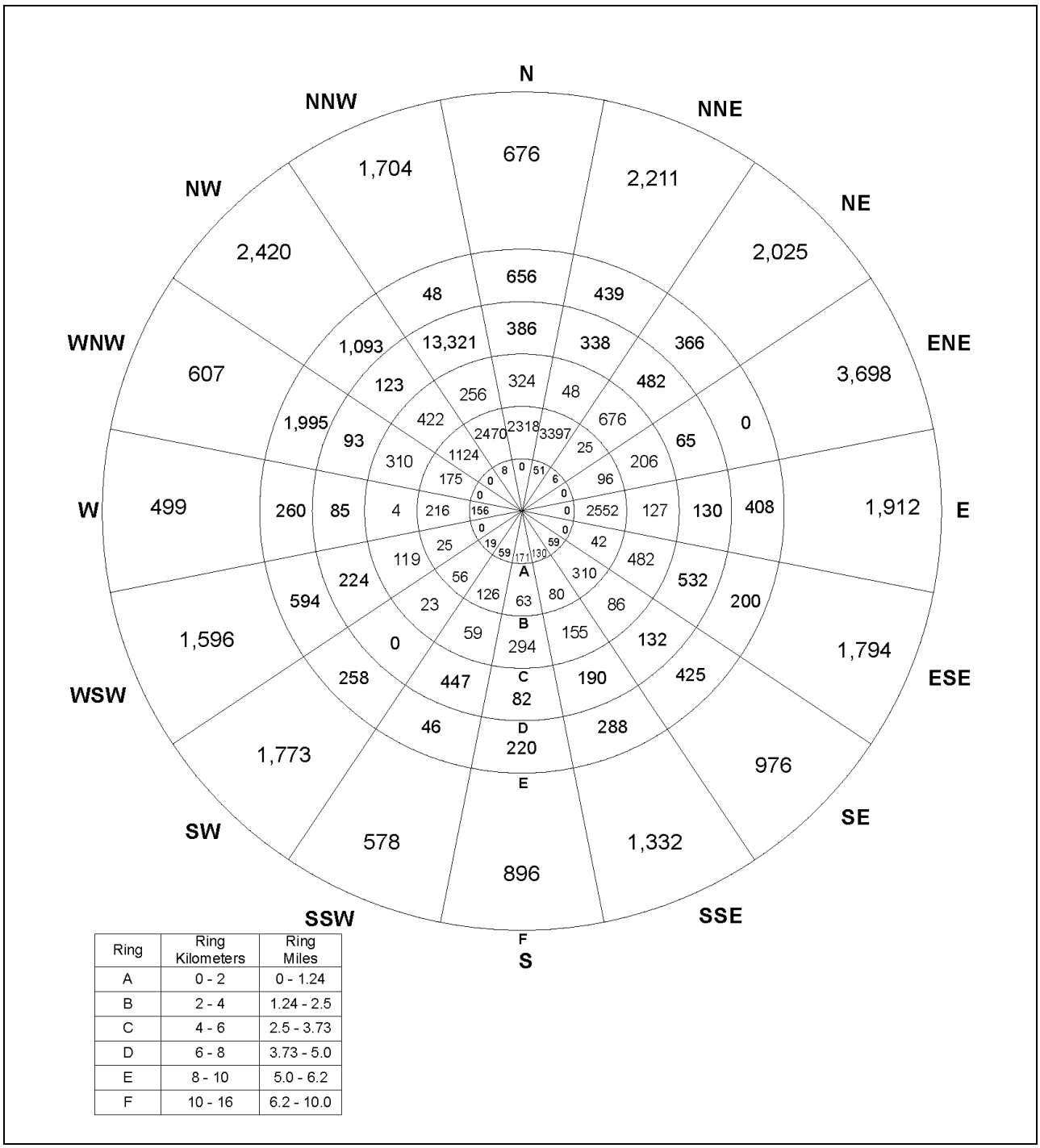
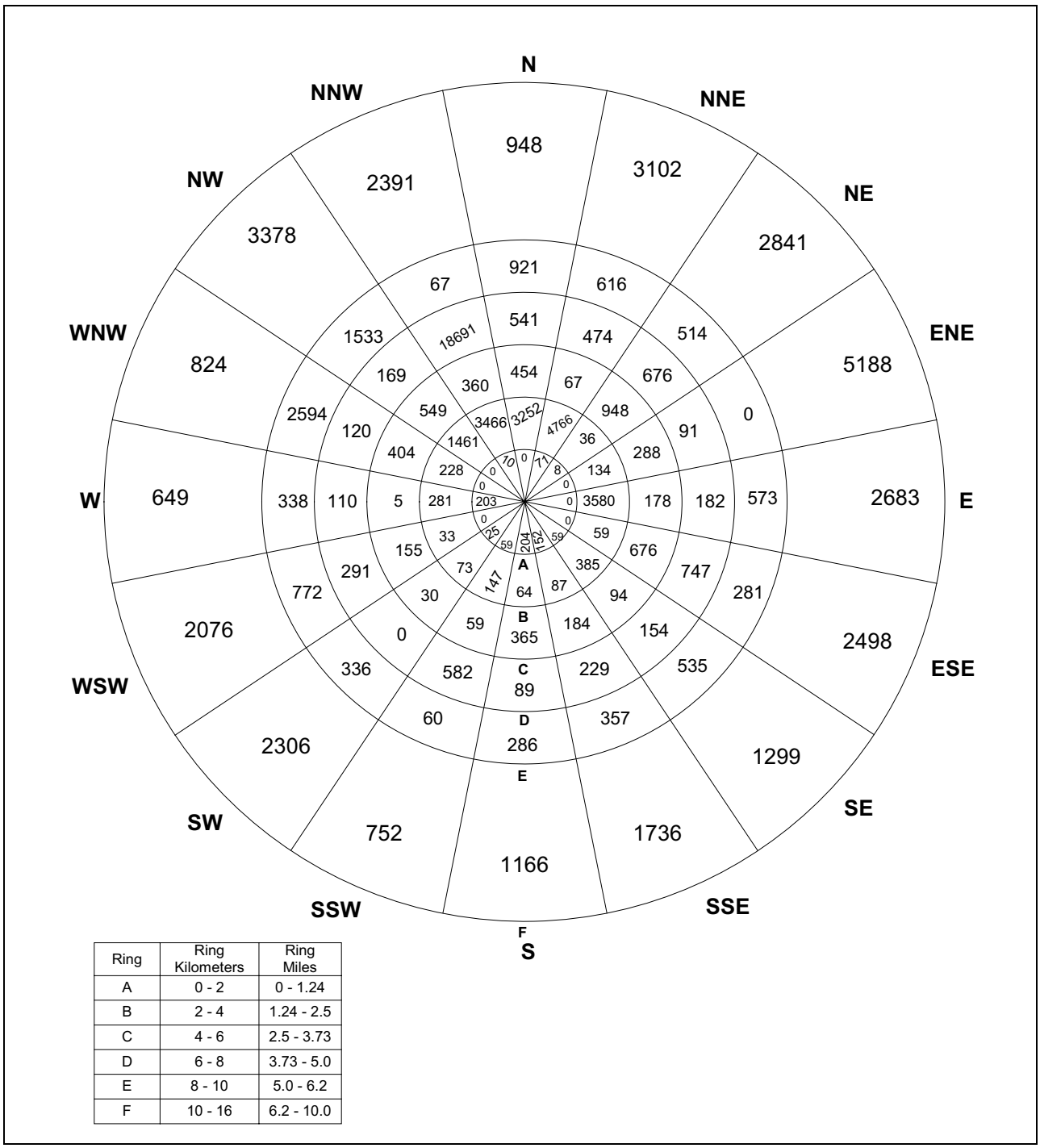


Figure 2.1-8 16-Kilometer (10-Mile) Resident and Transient Population Distribution–2040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2306
2076
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824
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541
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514
454
67
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948
91
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573
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178
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59
676
747
281
535
357
286
229
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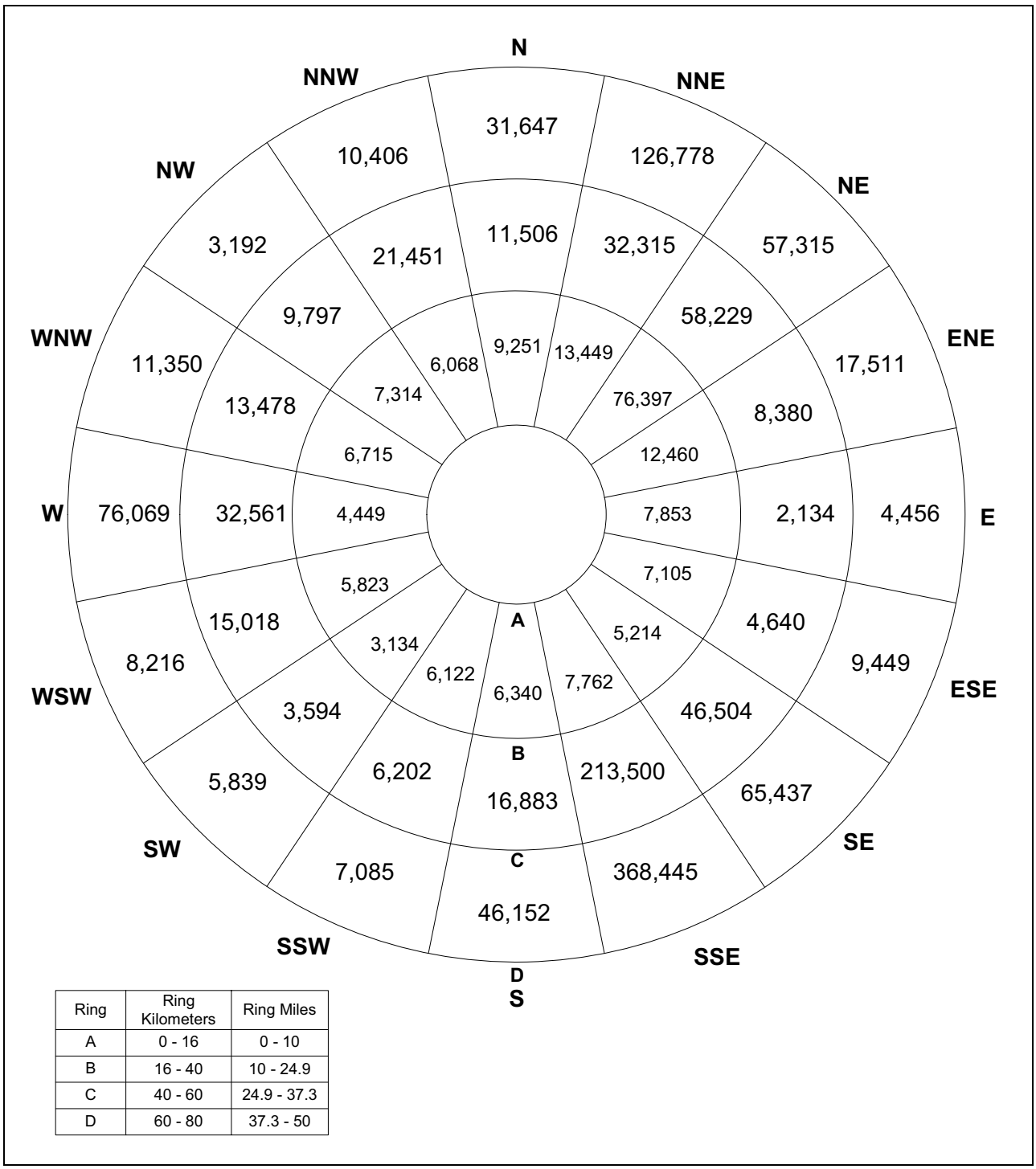
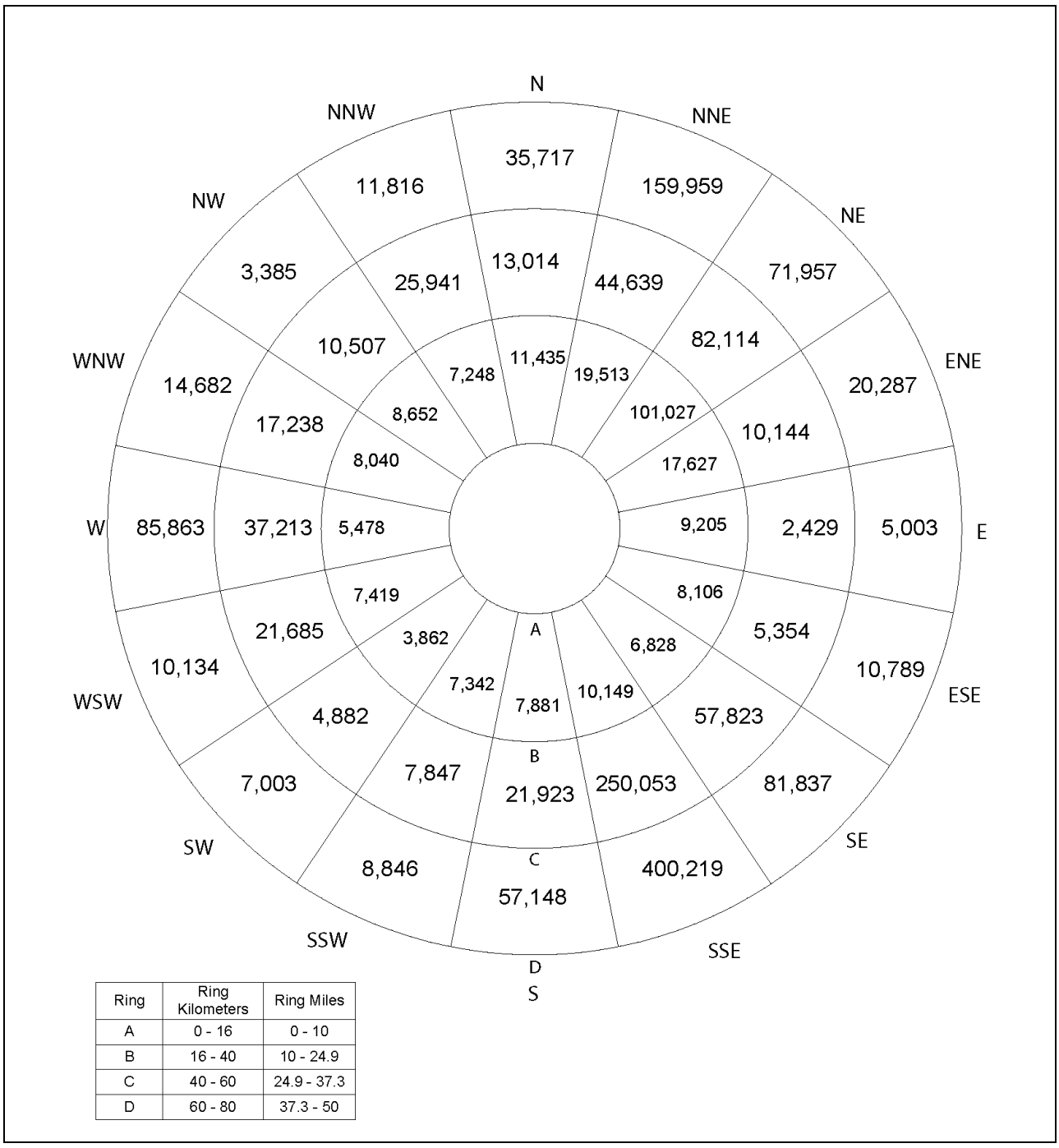


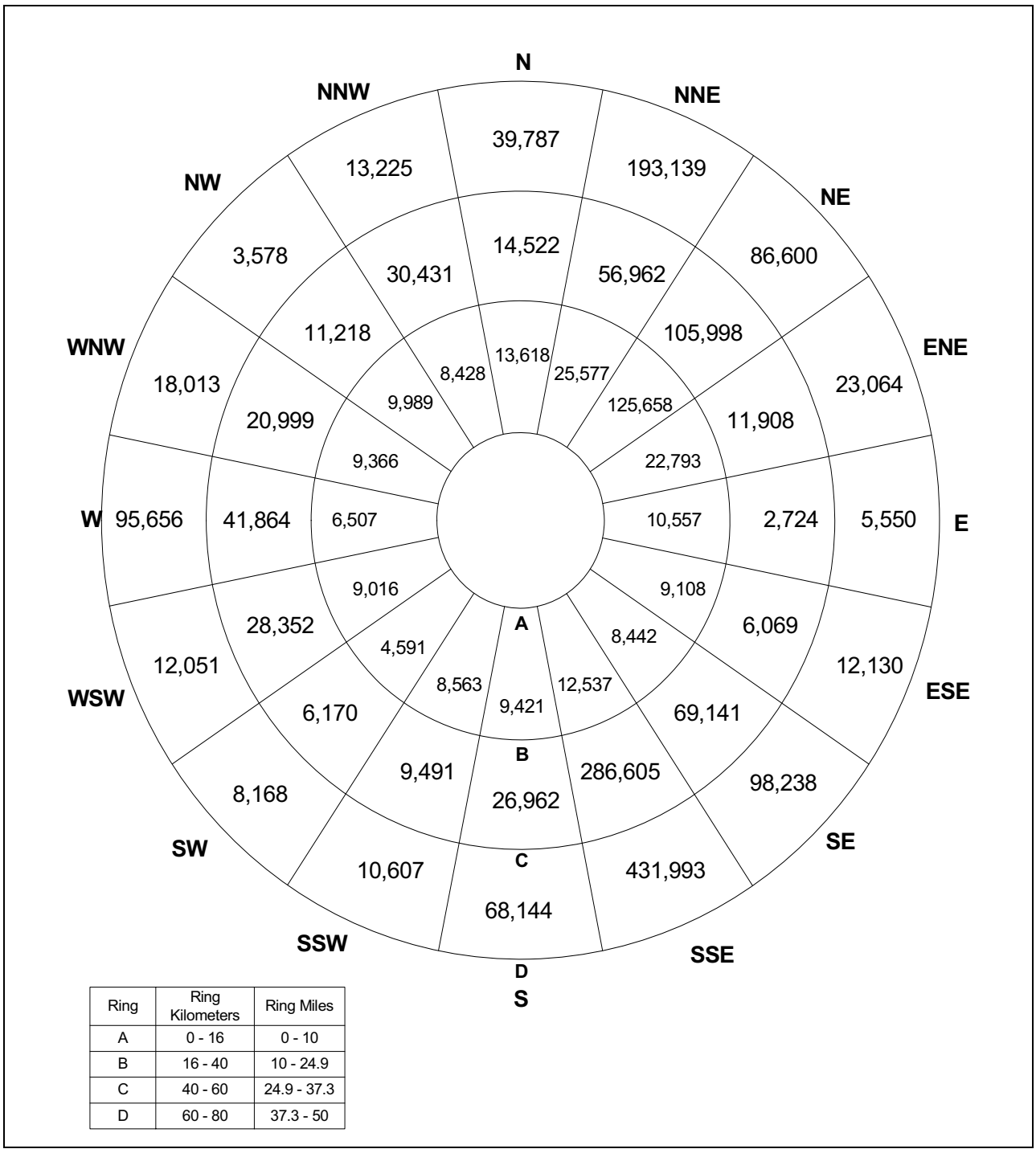
Ring	Ring Kilometers	Ring Miles
A	0 - 16	0 - 10
B	16 - 40	10 - 24.9
C	40 - 60	24.9 - 37.3
D	60 - 80	37.3 - 50

Figure 2.1-9 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2000



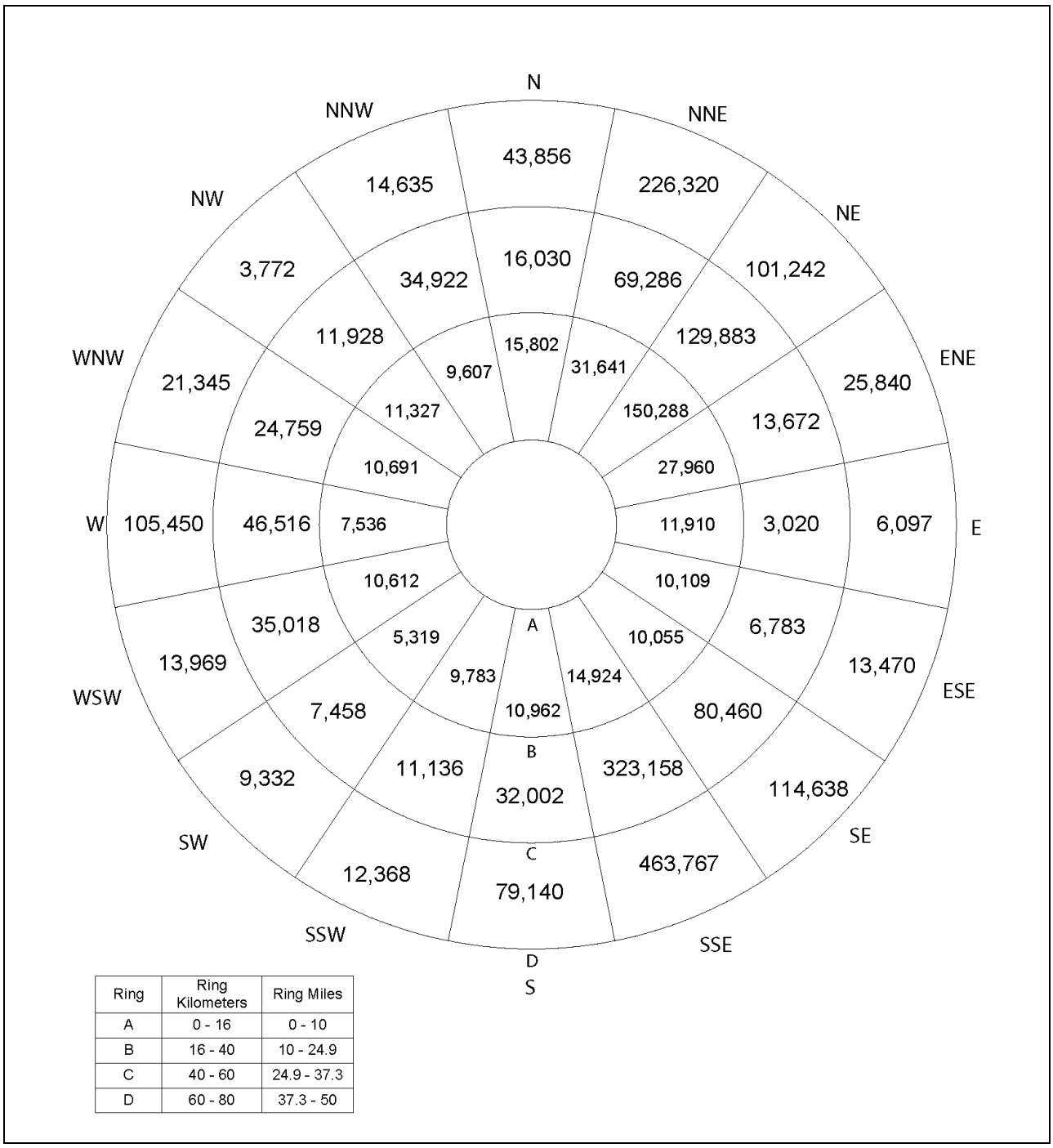
Ring	Ring Kilometers	Ring Miles
A	0 - 16	0 - 10
B	16 - 40	10 - 24.9
C	40 - 60	24.9 - 37.3
D	60 - 80	37.3 - 50

Figure 2.1-10 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2010



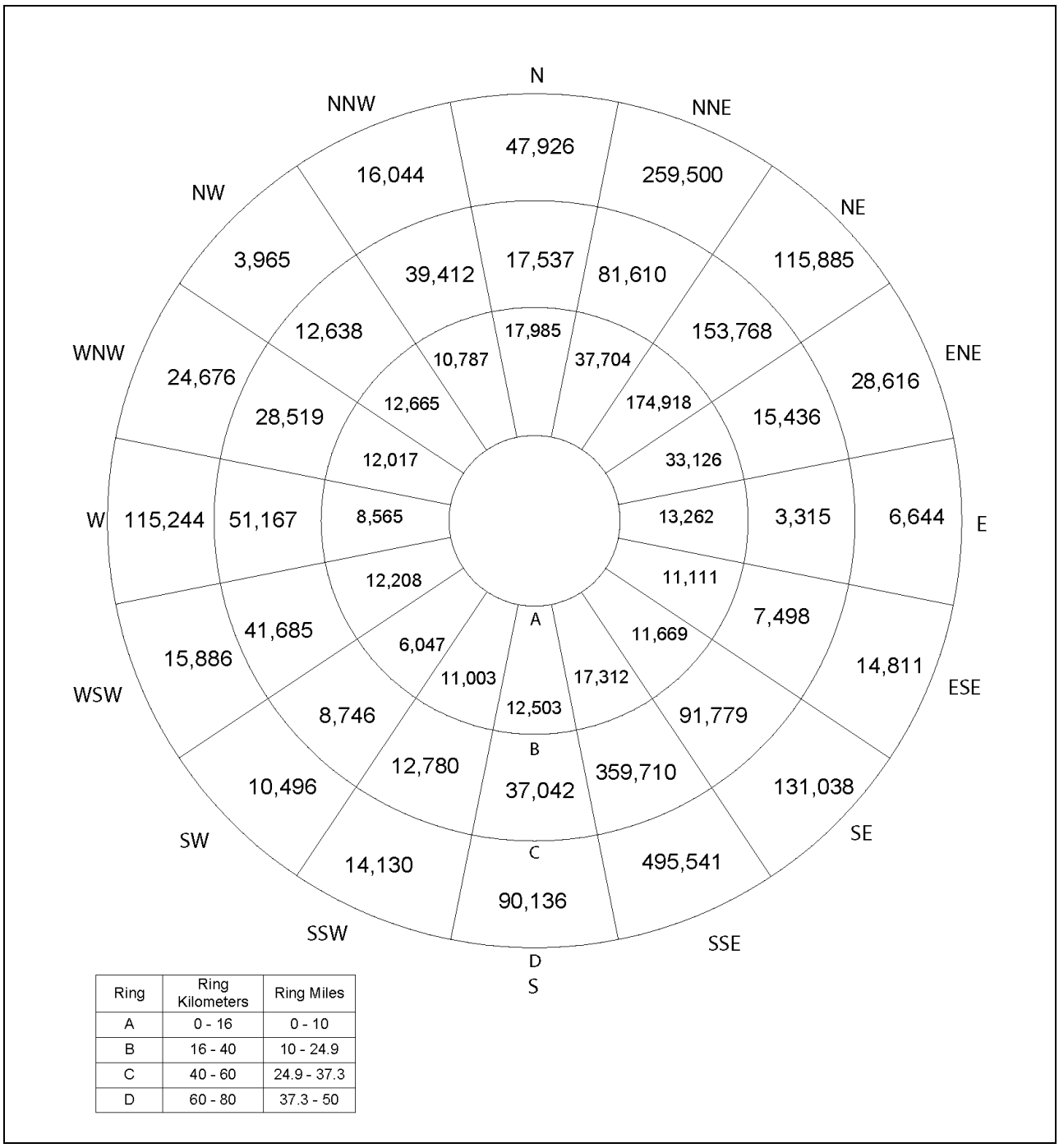
Ring	Ring Kilometers	Ring Miles
A	0 - 16	0 - 10
B	16 - 40	10 - 24.9
C	40 - 60	24.9 - 37.3
D	60 - 80	37.3 - 50

Figure 2.1-11 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2020



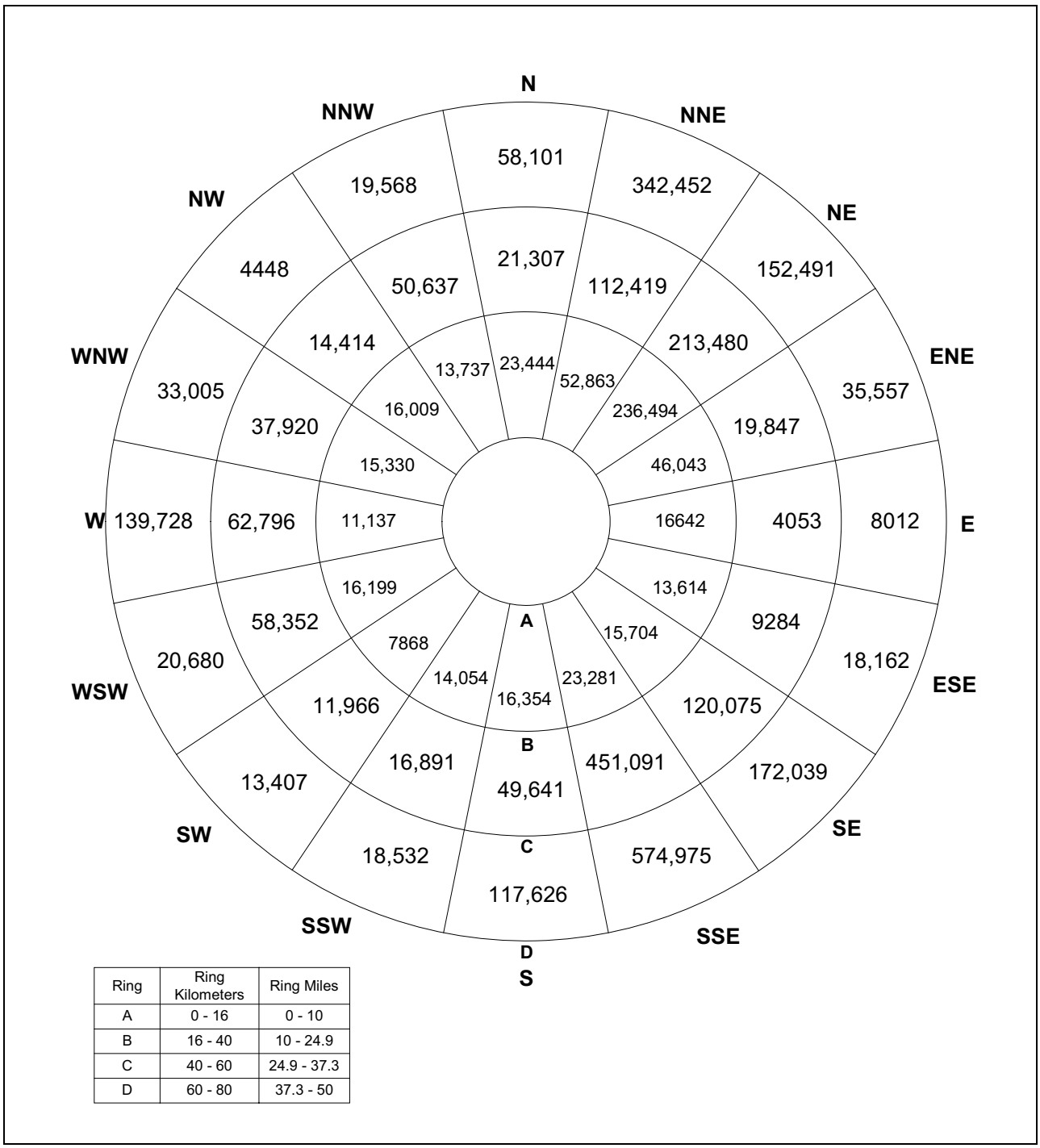
Ring	Ring Kilometers	Ring Miles
A	0 - 16	0 - 10
B	16 - 40	10 - 24.9
C	40 - 60	24.9 - 37.3
D	60 - 80	37.3 - 50

Figure 2.1-12 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2030



Ring	Ring Kilometers	Ring Miles
A	0 - 16	0 - 10
B	16 - 40	10 - 24.9
C	40 - 60	24.9 - 37.3
D	60 - 80	37.3 - 50

Figure 2.1-13 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2040



Ring	Ring Kilometers	Ring Miles
A	0 - 16	0 - 10
B	16 - 40	10 - 24.9
C	40 - 60	24.9 - 37.3
D	60 - 80	37.3 - 50

Figure 2.1-13A 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2065

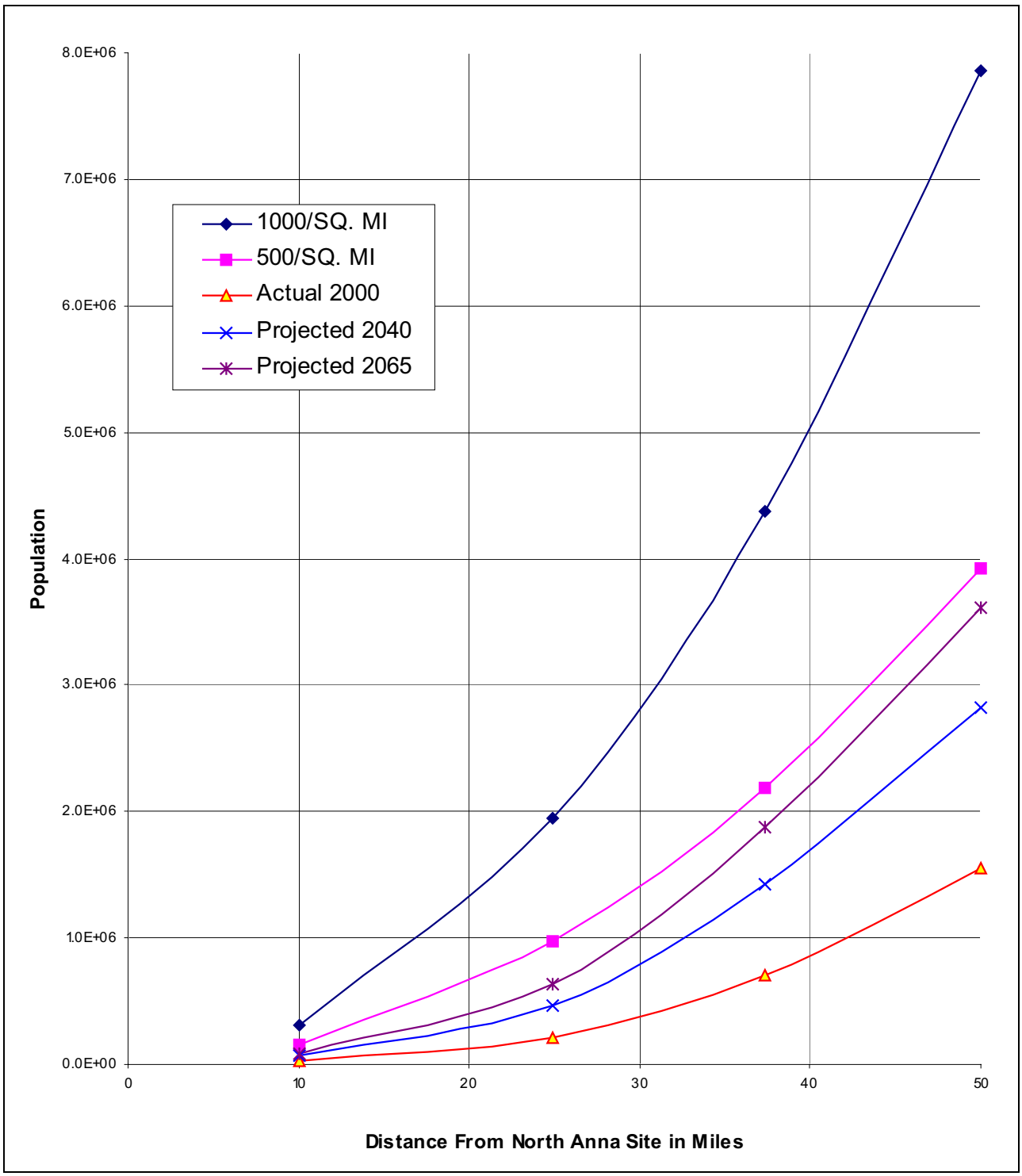


Figure 2.1-14 Population Density

2.2 Nearby Industrial, Transportation, and Military Facilities

2.2.1 Location and Routes

Based on the NAPS UFSAR, Section 2.2.1(Reference 1)), no military bases, missile sites, manufacturing plants, chemical plants, chemical or other storage facilities, airports, major railroad lines, major water transportation, or oil and gas pipelines are located within 5 miles of the ESP site.

Major highways, such as Interstates 95 and 64, are located more than 16 miles away from the site. Nearby U.S. Route 522, is located about 5 miles west of the site. The closest point of Virginia Route 652 is 1.5 miles to the south of the site. The only road that provides access to the site is State Route 700, coming from the southwest to within about half a mile of the site. No public or commercial highways, railroads, or waterways traverse the site.

2.2.2 Descriptions

2.2.2.1 Industrial Facilities

Louisa County is a rural and residential area. There are no substantial industrial activities within 5 miles of the ESP site. Any major industrial expansion in the area is subject to the approval from the local county planning commission. The Louisa County Board of Supervisors has approved a zoning ordinance allowing industrial development of approximately 620 acres near the site EAB. Within 10 miles of the site, there are several other areas zoned for industrial development, the largest one being 150 acres near Pendleton, Virginia. However, there are no plans for development in this area (Reference 1, Section 2.2.1.1).

Population projections provided in Section 2.1 indicate that among all the neighboring counties, Spotsylvania County is one of the largest and fastest growing counties in Virginia. The development in the county is concentrated in the City of Fredericksburg, 22 miles northeast of the ESP site, and along the I-95 corridor, which is about 16 miles away from the proposed site (Reference 2). In addition, nearly half of the county residents commute to the DC area or to Richmond. Therefore, future major industrial developments are more likely to be concentrated along the I-95 corridor rather than within 5 miles of the site.

2.2.2.2 Mining Activities

There are no mining activities within 5 miles of the ESP site.

2.2.2.3 Roads

The roads within 10 miles of the ESP site are shown in Figure 2.1-1. Virginia State Route 700 provides access to the site and State Routes 601 and 652, which run parallel to the Lake Anna shoreline, pass about 2.2 miles northeast and 1.5 miles south of the site, respectively. Primary State Route 208 crosses Lake Anna at a point about 2 miles northwest of the site and joins U.S. Route 522 about 5 miles west of the site.

2.2.2.4 Railroads

The closest railroad line to the ESP site is the main line of the Chesapeake and Ohio Railway, which runs from Newport News to Chicago. It passes through the towns of Louisa, Mineral, Fredericks Hall, and Bumpass; its closest approach to the site is about 5.5 miles southwest. A spur line connects the ESP site with this line.

2.2.2.5 Marine Transportation

There are six marinas in the vicinity of the ESP site (Reference 1, Table 2.1-1). These marinas, including wet slips and other boat ramps, provide access for up to 1600 pleasure craft on Lake Anna on a peak day. The closest marina is 1.4 miles north-northeast of the site. The remaining marinas are from 2 to 2.3 miles distant. The nearest marina stores gasoline in amounts up to about 4000 gallons. There are no large boats or barges on Lake Anna.

2.2.2.6 Airports and Airways

2.2.2.6.1 Airports

Airports within 15 miles of the ESP site as of 2002 are listed in Table 2.2-1; their locations are presented in Figure 2.2-1. None of the airports are expected to grow substantially in the foreseeable future (Reference 1, Section 2.2.1.6.1). Only two of the airports are within 10 miles of the site: Lake Anna Airport and Cub Field.

The Louisa County Airport (Freeman Field), located 11 miles west-southwest of the site, began operation in 1987 after NAPS was licensed. The airport has a 4300-foot east-west-oriented asphalt runway, and a shorter 2000-foot turf runway. Operations involve single-engine light aircraft, primarily. Thirty-two aircraft are based at this airport: 25 single-engine airplanes, 6 multi-engine airplanes, and one jet. It is a modern well-maintained facility with 120 aircraft operations per week. (Reference 3)

The Lake Anna Airport, near Bumpass, is 7 miles south-southeast of the site. The airport has limited facilities. A flight instructor at the Louisa County Airport stated that traffic at the Lake Anna Airport was very light and consisted primarily of practice landings (Reference 1, Section 2.2.1.6.1). Landing facilities consist of a 2560-foot asphalt runway. Only two single-engine airplanes are based at this airport, and on average there are about 70 landings per week (Reference 4).

Cub Field, a private landing strip with an unlighted 1400-foot turf runway, is 10 miles southwest of the site. It is not licensed and the reported volume of traffic is very light. No aircraft are based at this field. (Reference 1, Section 2.2.1.6.1)

Data on these airports are provided in Table 2.2-1.

2.2.2.6.2 Airways

One civil airway – V223 – and three military training routes – IR714, IR760, and VR1754 – pass near the ESP site as shown in Figure 2.2-1, which is extracted from the Washington Sectional Aeronautical Chart issued in 2003 (Reference 5). The centerline of V223 is 5.5 miles west of the ESP site, and the corridor width is 4 miles on either side of the centerline. No data are kept on traffic in this airway. The Federal Aviation Administration (FAA) stationed at Richmond International Airport has characterized the airway as "not heavily used" and estimates traffic at no more than 200 aircraft per day. (Reference 1, Section 2.2.1.6.2)

The centerlines of the military training routes, which are 10 miles across, lie within 1 mile south of the ESP site. The Oceana Naval Air Station in Virginia Beach, Virginia, which provided data on their use, controls these routes. Pilots are directed to avoid the NAPS site by flying at the edge of the air corridor. An officer at Oceana has stated that the aircraft pass no closer than 3 to 4 miles from the NAPS site. The combined number of flights using these three routes has remained fairly constant. Flights typically consist of 1 or 2 aircraft, rarely 4 aircraft in a flight. (Reference 1, Section 2.2.1.6.2)

2.2.2.7 Natural Gas or Petroleum Pipelines

There are no oil or gas pipelines within 5 miles of the ESP site.

2.2.2.8 Military Facilities

There are no military facilities within 5 miles of the ESP site.

2.2.3 Evaluation of Potential Accidents

2.2.3.1 Explosions and Flammable Vapor Clouds

The effects of explosion and formation of flammable vapor clouds from the nearby sources are evaluated below.

2.2.3.1.1 Truck Traffic

The largest explosive load routinely transported by truck on Virginia highways contains 8500 gallons of gasoline. The explosive force of this quantity of gasoline is estimated to be equivalent to 50,700 pounds of TNT, using a simple TNT-equivalent yield formula. (Reference 1, Section 2.2.2.1.1)

According to NRC RG 1.91 (Reference 6), if this amount of gasoline were to explode, a peak overpressure of 1 pound per square inch (psi) would be experienced as far as 1900 feet away from the point of explosion. The closest point of Virginia Route 652 to the ESP site is 1.5 miles (6420 feet). RG 1.91 cites 1 psi as a conservative value of peak positive incident overpressure, below which no significant damage would be expected. Thus, no significant damage would occur in the event of an explosion resulting from a gasoline truck traffic accident.

2.2.3.1.2 Pipelines

No natural gas pipeline or mining facilities are located within 10 miles of the ESP site. There are no pipelines carrying potentially hazardous materials within 5 miles of the ESP site. Therefore, the potential for hazards from these sources that could adversely affect safe operation of the plant is minimal.

2.2.3.2 Aircraft Crashes

In accordance with NUREG-0800, Section 3.5.1.6 (Reference 8), a review of aircraft hazards was performed because the ESP site lies within 5 miles of the edge of a military route and within 2 miles of the edge of a federal airway.

2.2.3.2.1 Airports

None of the airports within 10 miles of the ESP site, as described in Section 2.2.2.6.1 and Table 2.2-1, supports operations in excess of the threshold criteria specified in RG 1.70 (Reference 7, Section 2.2.2.5).

2.2.3.2.2 Airways

The probabilities (P_{FA}) per year of an aircraft flying on the nearby airways crashing into a new unit at the ESP site were estimated using the following relationship, as specified in NUREG-0800 (Reference 8, Section 3.5.1.6).

$$P_{FA} = C \times N \times A/W$$

Where:

C = crash rate per mile of flight
N = number of flights per year
A = effective plant area in square miles
W = width of airway (plus twice the distance from the airway edge to the site when the site is outside the airway) in miles

The PPE indicates that the tallest reactor height is 234 feet above grade. Including consideration of the nearby safety-related structures (i.e., control building, service building, and auxiliary building) (Reference 9, Figures 1.2-13, 1.2-15, 1.2-17, 1.2-21, 1.2-23, 1.2-26, 1.2-28, 1.2-29, and 1.2-30), a total effective plant area of 0.013 square miles was conservatively used in the evaluation.

For Civil Airway V223:

$C = 4 \times 10^{-10}$ (Reference 8)

$W = 8 + (2 \times 1.5) = 11$ miles

$N = 200 \times 365 = 73{,}000$ aircraft/year

$P_{FA} = 3.45 \times 10^{-8}$

For the military routes:

C = 0.2 x 10^{-8} (Reference 1, Section 2.2.2.2.2)

W = 10 miles

N = 3000 flights/year x 2 aircraft/flight = 6000 aircraft/year

P_{FA} = 1.56 x 10^{-8}

These accident probabilities are within the NUREG-0800 guideline of less than 10^{-7} per year.

2.2.3.3 Toxic Chemicals

RG 1.78 (Reference 10) requires evaluation of control room habitability for a postulated release of chemicals stored within 5 miles of the control room. As described in Section 2.2.2, there are no manufacturing plants, chemical plants, storage facilities, major water transportation routes, and oil or gas pipelines within 5 miles of the ESP site. Therefore, as described in RG 1.78, only two scenarios were evaluated:

1. Chemicals transported on routes within a 5-mile radius of the site, at a frequency of 10 or more per year, and with weights outlined in the RG.

2. Chemicals stored within 0.3 miles of the control room in a quantity greater than 100 pounds.

Four roads (State Roads 652, 601, and 208, and U.S. Route 522) pass within 5 miles of the ESP site. U.S. Route 522 passes about 5 miles to the west-northwest; the other three routes pass the site at closer distances.

The NAPS UFSAR (Reference 1, Section 6.4.1.3.3) states that due to lack of chemicals and industrial facilities along these state routes, and considering the longer distance between Route 522 and the site, no chemicals are transported along these routes at a frequency and weight sufficient to require evaluation in accordance with the RG. Therefore, the UFSAR concludes that no significant control room habitability impact on the existing units is expected due to chemicals being shipped along these routes. Because of the close proximity of the new units to the existing units, no significant impact would be expected on those persons inhabiting future control rooms for the new units due to chemical accidents on these routes.

Reported toxic chemicals stored at the NAPS site, which could impact control room habitability for the existing units, are listed in Table 2.2-2. The list is comparable to that used for the toxic release evaluation reported in Reference 1, Section 6.4.1.3.3. These chemicals have been evaluated for the worst-case accidental release of each type of chemical. The results of the evaluation indicate that the worst-case concentration inside the control room of the existing units for each chemical analyzed is less than the toxicity limit that could cause a health hazard to the control room operators. (Reference 1, Section 6.4.1.3.3)

The locations and quantities of chemicals that would be stored for the new units at the ESP site have not been determined, and no detailed control room design parameters are available at this time. The impact on the new units from chemicals stored onsite or nearby would be evaluated in the COL application.

Section 2.2 References

1. Updated Final Safety Analysis Report, North Anna Power Station, Revision 38.

2. Web Page: Spotsylvania County, Virginia, www.simplyfredericksburg.com/spotsylvania/spotsylvania.shtml, accessed June 27, 2003.

3. Web Page: Louisa County Airport/Freeman Field, Louisa, Virginia, www.airnav.com/airport/LKU/, accessed June 23, 2003.

4. Web Page: Lake Anna Airport, Bumpass, Virginia, www.airnav.com/airport/7W4, accessed June 23, 2003.

5. Washington Aeronautical Chart, 73rd Edition, published by the U.S. Department of Transportation, Federal Aviation Administration, National Aeronautical Chart Office, February 20, 2003.

6. Regulatory Guide 1.91, Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants, Revision 1, U.S. Nuclear Regulatory Commission, February 1978.

7. Regulatory Guide 1.70, Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition, Revision 3, U.S. Nuclear Regulatory Commission, November 1978.

8. NUREG-0800, Standard Review Plan, U.S. Nuclear Regulatory Commission, July 1981.

9. AP1000 Design Control Document, Rev. 1, Tier 2 Material, Westinghouse Electric Company, 2002.

10. Regulatory Guide 1.78, Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release, Revision 1, U.S. Nuclear Regulatory Commission, December 2001.

Table 2.2-1 Airports Within 15 Miles of the ESP Site

	Number of Flight Operations						Longest Runway		
Airport	**Type**	**Distance**	**Sector**	**Commercial**	**Total[a]**	**kd^2 [b]**	**Orientation**	**Length**	**Comments**
Lake Anna	Civil	6 miles	SSE	None	3640	12,500	WSW-ENE	2560 ft	Occasional use for practice landings. Planes based there.
Cub Field	Private	10 miles	WSW	None	Few	100,000	SSW-NNE	1400 ft	Unpaved strip, no facilities, no planes based there.
Louisa County	Civil	11 miles	WSW	None	6240	121,000	W-E	4300 ft	32 planes based there.

Source: Reference 1, Table 2.2-1.

a. Year 2002

b. RG 1.70: d < 10 miles, k = 500; d >10 miles, k = 1000; where d is the distance in miles from the site, and k is a constant.

Table 2.2-2 Toxic Chemicals– Largest Single Container Stored at the NAPS Site

Chemical	**Quantity**
Ammonium Hydroxide	55 gallons
Carbon Dioxide	17 gallons
Hydrazine	300 gallons
Sodium Hydroxide	700 gallons

Source: Reference 1, Table 2.2-3.



Figure 2.2-1 Location of Airports And Airways

Source: Reference 5

2.3 Meteorology

2.3.1 Regional Climatology

2.3.1.1 Data Sources

Data acquired by the National Weather Service (NWS) at its Richmond, Virginia first-order station and from its network of cooperative observer stations, as compiled and summarized by the National Climatic Data Center (NCDC) and its predecessor agencies, have been used to characterize the regional climatology pertinent to the ESP site.

Normals (i.e., 30-year averages), means and extremes of temperature, rainfall, and snowfall are based on:

- The 2003 Local Climatological Data (LCD) Annual Summary with Comparative Data for Richmond, Virginia (Reference 1),
- Climatography of the United States No. 20 (CLIM 20) summaries for the cooperative network stations of Louisa (Reference 10), Piedmont Research Station (Reference 11) and Charlottesville 2W, Virginia (Reference 8),
- Climatography of the United States No. 20-44 summary for Partlow 3WNW, Virginia (Reference 12),
- Climatography of the United States No. 81 (CLIM 81), U.S. Daily Climate Normals (1971–2000) summaries for Fredericksburg National Park and Gordonsville 3S, Virginia (Reference 39), and
- Cooperative Summaries of the Day (TD3200) for Charlottesville 2W, Fredericksburg National Park, Gordonsville 3S, Louisa, Partlow 3WNW, Piedmont Research Station, Bremo Bluff PWR and Free Union, Virginia (Reference 40).

First-order NWS stations record observations of other weather elements including winds and relative humidity (typically on an hourly basis), as well as fog and thunderstorms (when those events occur). LCD summaries for the Richmond NWS station have been used to describe these characteristics. Several databases containing hourly temperature measurements (dry- and wet-bulb) made at this station between 1961 and 2003, or summaries based on portions of that period of record, have been used to represent various frequencies of occurrence for these parameters and to evaluate characteristics associated with the ultimate heat sink (Reference 41) (Reference 42) (Reference 43) (Reference 44).

Design basis extreme wind conditions are characterized based on information in the American National Standards Institute's (ANSI) publication "Minimum Design Loads for Buildings and Other Structures" (Reference 45) and its current version by the American Society for Civil Engineers and the Structural Engineering Institute (Reference 46). In addition, since the NWS changed the averaging interval for collecting maximum wind speeds in 1990, the 1989 LCD for Richmond has been used to report observed fastest-mile-wind information on a long-term basis for the ESP site

area (Reference 6). Similarly, design basis snow load conditions are characterized based on the weights of probabilistic snow pack and winter PMP amounts derived from (Reference 46) and (Reference 47), respectively.

Information on severe weather has been collected from a variety of sources. Severe storm, tornado and hurricane data have been obtained from the NCDC's Storm Events database for Virginia (Reference 3) (Reference 48), Thom (Reference 4), the historical tropical cyclone tracks database available through the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center (Reference 49), and Virginia Tropical Cyclone Climatology (Reference 7).

The frequency and magnitude of hailstorms, snowstorms and ice storms have been characterized by information available in the Climate Atlas of the United States (Reference 50), measurements from NWS cooperative observation network stations in the ESP site area (Reference 40), and entries from the NCDC publication "Storm Data" (Reference 51).

Information regarding the climatology of restrictive dilution conditions has been obtained from a variety of sources dealing with the potential for stagnating conditions and atmospheric mixing heights in the United States (Reference 14) (Reference 15) (Reference 16).

2.3.1.2 General Climate

The climate in the Piedmont region of Virginia, where the ESP site is located, is classified as modified continental. Summers are warm and humid, and winters are generally mild. The Blue Ridge Mountains to the west act as a partial barrier to outbreaks of cold, continental air in winter. The mountains also tend to channel winds along a general north-south orientation.

Temperatures in the site region rarely exceed 100°F or fall below 0°F (Reference 1). Site-characteristic dry- and wet-bulb temperatures associated with various exceedance values and a 100-year return period are listed in Table 2.3-18. The exceedance values were obtained directly from the NCDC's Engineering Weather Data summary for Richmond, Virginia covering the 1973 to 1996 period of record (Reference 41). The 100-year return period maximum and minimum dry-bulb temperatures and wet-bulb temperature are extrapolations of several databases for Richmond covering the 30-year period from 1973 to 2002 (Reference 42) (Reference 43) (Reference 44).

Based on the latest 30-year normal period from 1971–2000 at Richmond, the area around the site receives an annual average rainfall of approximately 44 inches. Rainfall is fairly well distributed over the entire year, with the exception of July and August, when thunderstorm activity raises monthly totals to between about 4.2 and 4.7 inches (Reference 1). Tropical cyclones can also contribute significantly to precipitation (rainfall) totals.

Based on the latest 30-year normal period at Richmond, monthly snowfall is greatest during January and February, averaging 4.3 and 4.8 inches, respectively, with an annual average total of 12.4 inches. The long-term period of record for this station (62 years) is similar: 4.7 and 3.8 inches in January and February, with a slightly higher annual total of 13.5 inches (Reference 1). Snow

generally remains on the ground for only 1 or 2 days (Reference 1) although durations of a week or more have occurred following heavy snowfall events and/or cold air outbreaks after the storm's passage (Reference 40).

2.3.1.2.1 Interaction Between Synoptic Scale Processes and Local Conditions

Synoptic scale processes are commonly examined with respect to the general circulation and general climatological characteristics of a region. Therefore, synoptic scale processes generally involve examination of gross meteorological conditions, such as prevailing wind patterns, temperature variability, precipitation patterns, and the occurrence of meteorological phenomena (e.g., fog, severe storms) in the site region. The analysis of the micrometeorology (local conditions) of a region usually encompasses the examination of the gross climatic characteristics of the region with respect to how local conditions can alter or influence a change in the general climatology of the region at a specific location. There are times when certain meteorological variables would deviate from the expected normal due to topographic effects or man-made interference.

In general, during light wind conditions, the local environmental conditions predominate, resulting in a channeling effect of winds such that the airflow patterns follow the contour lines of the region. Lake Anna has a moderating effect with respect to extreme temperatures in the immediate vicinity of the site region. For the most part, the general synoptic conditions predominate in regard to climatic characteristics of the site region; however, during periods of extreme temperatures or light wind conditions, the local conditions have an influence on the micrometeorology.

2.3.1.3 Severe Weather

2.3.1.3.1 Extreme Winds

According to American National Standard, ANSI A58.1-1982, the operating basis wind velocity at 33 feet (10 meters) above ground level in the ESP site area associated with a 100-year return period is 64 miles per hour (mph) (Reference 45). The fastest-mile-wind speed is defined as the passage of one mile of wind with the highest speed for the day. The actual observed fastest-mile-wind speed at Richmond (68 miles per hour) was recorded at that station in October 1954 (Reference 6). The 3-second gust wind speed that represents a 100-year return period is 96 mph at 10 meters above ground. This wind speed was determined in accordance with the guidance in Reference 46, and is selected as a conservative basic wind speed site characteristic.

2.3.1.3.2 Tornados

During the period of January 1950 through December 2003, a total of 235 tornadoes were reported within a 2-degree square area around the ESP site (Reference 3). The 2-degree square is the area enclosed by two degrees of longitude and latitude lines centered on the ESP site. (Reference 18). This averages 4.35 tornadoes per year within this area, which includes counties in Virginia, three counties (Charles, Prince Georges, and Montgomery) in Maryland, one county in West Virginia

(Hardy), and Washington, D.C. Among those 235 tornadoes, 204 occurred in Virginia, 29 in Maryland, 2 in Washington, D.C., and none in West Virginia.

Tornado strength is classified according to the Fujita-Pearson scale, ranking from F0 (gale) to F5 (incredible). During the 54-year period, no F3 or higher tornadoes were reported in Louisa or Spotsylvania counties. The most intense tornadoes outside of these counties, and within the 2-degree square area, were three classified as F4. The wind speeds of an F3 tornado range from 158 mph to 206 mph; the wind speeds of an F4 tornado range from 207 mph to 260 mph (Reference 18).

According to statistical methods proposed by Thom, the probability of a tornado striking a point within a given area may be estimated as follows (Reference 4) (Reference 18):

$$P = \frac{z \times t}{A}$$

Where

P = the mean probability per year

z = the mean path area of a tornado

t = the mean number of tornadoes per year

A = the area of concern

The Event Record Details provided in the Storm Events Report list path length and path width for specific tornadoes (Reference 3). For tornado events within the 2-degree square area around the ESP site, according to the available recorded data, the calculated mean tornado path length is 3.1 miles and the calculated mean path width is 116.7 yards. These values yield a z value of 0.2056 square mile. Using a 2-degree square area as a basis for A and a value of 4.35 tornadoes per year yields an annual strike probability of 5.94×10^{-5}, or a recurrence interval of 16,835 years. The strike probability, multiplied by the intensity probability yields the total probability that a tornado of a certain strength will strike a certain area. Table 2.3-1 describes the tornado with a total annual strike probability equal to 10^{-7} of striking the ESP site.

The tornado maximum wind speed consists of two components, a rotational wind speed and a translational wind speed. Using methods provided in Reference 18, Reference 38, and Reference 52, and an assumed radius of maximum rotational wind speed of 150 feet, other tornado parameters have been calculated and are provided in Table 2.3-1. The radius of maximum rotational wind speed of 150 feet was suggested in Reference 18 for intense tornadoes.

Table 2.3-1 ESP Site Tornado Parameters

Criteria	Unit of Measure	Site Tornado (10-7 per year occurrence)
Max. Wind Speed	mph	260
Max. Rotational Velocity	mph	208
Max. Translation Velocity	mph	52
Radius of Max. Rotational Velocity	ft	150
Pressure Drop	psi	1.5
Rate of Pressure Drop	psi/sec	0.76

In 1988, the NRC developed an interim position (Reference 38) to replace the criteria for design basis tornadoes as specified in the 1974-issued RG 1.76 (Reference 17). Because a considerable quantity of tornado data is now available that was not available when RG 1.76 was developed, the Interim Position has concluded that regional maximum wind speeds, as reported in RG 1.76, were too conservative and that the contiguous United States is better represented by four tornado regions instead of three. The ESP site is in Region II, as designated in the Interim Position, which has a maximum wind speed of 300 mph.

2.3.1.3.3 Tropical Cyclones

On average, a tropical cyclone, or its remnants, can be expected to impact some part of the Commonwealth of Virginia each year (Reference 7). Tropical cyclones include not only hurricanes and tropical storms, but systems classified as tropical depressions, sub-tropical depressions, and extra-tropical storms, among others.

This characterization considers all “tropical cyclones” (rather than systems classified only as hurricanes or tropical storms) because storm classifications are generally downgraded once landfall occurs and the system weakens although it may still result in significant rainfall events as it travels through the site region.

A comprehensive database of historical tropical cyclone tracks (i.e., currently extending from 1851 through 2003), available through the NOAA’s Coastal Services Center and based on information compiled by the National Hurricane Center (Reference 49), indicates that a total of 55 tropical cyclone centers or storm tracks have passed within a 100-nautical mile radius of the North Anna ESP site. Storm classifications and respective frequencies of occurrence over this period of record are as follows:

- Hurricanes - Category 3 (1), Category 2 (1), and Category 1 (5)
- Tropical Storms - 27

- Tropical Depressions - 13
- Subtropical Depressions - 1
- Extra-Tropical Storms - 7

Tropical cyclones are responsible for at least two separate record rainfall events in the North Anna ESP site area. In August 1969, Hurricane Camille, a tropical depression by the time it passed through the area within 100 nautical miles of the site, resulted in a record 24-hour (daily) rainfall total of 11.18 inches at the nearby Louisa observation station (see Table 2.3-5). The Louisa station is part of the NWS's cooperative climatological network.

In August 1955, Hurricane Connie passed within about 120 nautical miles of the site at its closest approach. Although not included in the count of tropical cyclones above, Connie, then classified as a tropical storm, was responsible for the current record 24-hour (daily) rainfall total at Richmond International Airport (i.e., 8.79 inches) (see also Table 2.3-5).

2.3.1.3.4 Precipitation Extremes

Historical precipitation extremes (rainfall and snowfall) are listed in Table 2.3-5 along with climatological extremes of temperature for the available periods of record at selected NWS and cooperative observing stations in the ESP site area.

As noted in the preceding section, the remnants of Hurricane Camille passed through the site area in August 1969 and resulted in the overall highest 24-hour (daily) rainfall total recorded at any station to date in the ESP site area—11.18 inches at the nearby Louisa cooperative observation station (Reference 10) (Reference 49). Similarly, record 24-hour (daily) rainfall totals for other nearby stations listed in Table 2.3-5 were attributable to tropical cyclones that passed beyond 100 nautical miles of the ESP site, including:

- Piedmont Research Station (7.85 inches) in June 1972 due to Tropical Storm Agnes (Reference 40) (Reference 51),
- Richmond (8.79 inches) and Partlow 3WNW (5.45 inches) in August 1955 due to Tropical Storm Connie (Reference 1) (Reference 12) (Reference 49).

The other 24-hour (daily) rainfall records in Table 2.3-5 are due to both synoptic-scale (e.g., stalled frontal boundaries) and regional-scale events (i.e., thunderstorms) (Reference 51). For several of these observing stations (i.e., Louisa, Gordonsville 3S and Charlottesville 2W), record monthly rainfall totals coincide with these 24-hour (daily) station records.

Table 2.3-5 also summarizes 24-hour (daily) and monthly record snowfall totals for selected stations in the ESP site area. For the available periods of record, Richmond has logged the highest 24-hour (daily) amount measuring 21.6 inches in January 1940 (Reference 1). Comparable maxima have been observed at the other stations ranging from 16.0 to 20.7 inches, many associated with the same snowstorm (e.g., March 1962).

Similarly, record monthly totals coincide with several of these 24-hour (daily) station records (e.g., at Richmond and Partlow 3WNW) or have occurred at multiple stations in the site area during the same month, including the overall highest and second-highest monthly totals of 41.0 and 32.2 inches at Partlow 3WNW and Louisa, respectively (Reference 12) (Reference 10) as well as the records at Piedmont Research Station, Gordonsville 3S and Fredericksburg National Park.

Overall, then, in terms of extreme precipitation events, these station histories indicate that rainfall and snowfall maxima over the ESP site area, when they occur, are fairly similar.

The weight of the estimated 100-year return period snow pack for the ESP site area is 30.5 pounds per square foot (lb/ft^2), as determined in accordance with Figure 7-1 and Table C7-3 in the snow load guidance of Reference 46. The 48-hour winter PMP is 20.75 inches. This estimated precipitation was linearly interpolated from the 24-hour and 72-hour, 10-square-mile area, values shown in Figures 35 and 45, respectively, for December (Reference 47). The highest winter PMP values for the site area occur in December (Reference 47).

As Section 2.4.7.6 indicates, the design features that demonstrate acceptable roof structure performance for the selected reactor design would be described in the COL application.

2.3.1.3.5 Hail, Snowstorms, and Ice Storms

Frozen precipitation typically occurs in the form of hail, snow, sleet and freezing rain. The frequency of occurrence of these types of weather events in the ESP site area are based on the latest version of the Climate Atlas of the United States (Reference 50), published by the NCDC in 2002, which has been developed from observations made over the 30-year period of record from 1961 to 1990.

Hail can occur at any time of the year and is associated with well-developed thunderstorms, but has been observed primarily during the spring and summer months. The data indicate that Louisa and Spotsylvania Counties can expect, on average, hail with diameters greater than or equal to 0.75 inch about one day per year. The occurrence of hailstorms with hail greater than or equal to 1.0 inch in diameter averages less than one day per year.

However, the annual mean number of days with hail 0.75 inch or greater is slightly higher in nearby southern and eastern Hanover County (just to the southeast of the ESP site), eastern Goochland County (south of the ESP site) and Henrico County (also southeast of the ESP site), ranging from one to two days per year. Similarly, hailstorms with hail 1.0 inch or greater occur about one day per year on average. NCDC cautions that hailstorm events are point observations and somewhat dependent on population density.

While no hailstorms of note have been recorded in some years, multiple events have been observed in other years, including four in Louisa County during 1998 and three in Spotsylvania County during 1993, both with diameters up to 1.75 inches (Reference 48). Therefore, the slightly higher annual mean number of hail days may be a more representative frequency for the relatively less-populated ESP site area.

In terms of extreme hailstorm events, softball size hail (about 4.5 inches in diameter) has been observed in recent years at two locations in the general ESP site area (Reference 48) - on June 4, 2002 at Free Union, just northwest of Charlottesville in Albemarle County (about 42 miles west of the ESP site) and on May 4, 1996 at Lignum in central Culpeper County (about 28 miles north-northwest of the ESP site).

The Climate Atlas (Reference 50) indicates that the occurrence of snowfalls greater than or equal to 1 inch in the ESP site area ranges from about three to five days per year. However, the frequency of such snow events increases to the west and northwest of the ESP site in far western Louisa County, north-central Fluvanna County, and much of Albemarle and Orange Counties, ranging between 6 and 10 days per year. In general, these differences can be attributed to topographic effects.

On the other hand, the frequency of snowstorms of greater magnitude is similar over the ESP site area because the weather systems that produce such events often affect fairly large areas. On average, the data indicate that daily snowfall totals greater than or equal to thresholds of 5 and 10 inches occur less than one day per year.

Nevertheless, daily snowfall totals greater than these threshold values have occasionally occurred in the site area on more than one day during a given year, e.g., the winters of 1962, 1966, 1987, and more recently 1996 and 2003 at Louisa and other NWS cooperative observation network stations in the ESP site area (Reference 40) (Reference 51) - some of the events during these years appear as daily or monthly total snowfall extremes in Table 2.3-5.

2.3.1.3.6 **Thunderstorms**

Based on a 67-year period of record, Richmond averages 36 thunderstorm-days per year. July has the highest frequency of occurrence—about 8 days, on average (Reference 1).

The mean frequency of lightning strikes to earth can be estimated using a method reported by the Electric Power Research Institute (EPRI) (Reference 53). The EPRI formula assumes a relationship between the average number of thunderstorm-days per year (T) and the number of lightning strikes to earth per square mile per year (N).

$$N = 0.31T$$

As indicated previously, there are 36 thunderstorm-days per year, on average, at Richmond. Consequently, the number of lightning strokes to earth per square mile is about 11.2 per year. The ESP site plant envelope area is approximately 0.068 mi^2. Using this area as the potential reactor area, the annual average number of lightning strokes in the reactor area can be calculated as follows:

$$11.2/mi^2/year \times 0.068\ mi^2 = 0.76 \text{ lightning strokes per year at the reactor area}$$

2.3.1.3.7 Restrictive Dilution Conditions

In the ESP site region, the annual frequency of low-level inversions or isothermal layers based at or below a 500-foot elevation is approximately 30 percent according to Hosler (Reference 14). Seasonally, the greatest frequencies of inversions occur during the fall and winter (34 and 33 percent, respectively). Spring and summer have the lowest inversion frequencies (about 28 percent of the time for each season). Most of these inversions are nocturnal in nature, generated through nighttime cooling.

The mean maximum mixing height depth (MMMD) is another indication of the restriction to atmospheric dilution at a site. The mixing depth is the distance above the ground to which relatively free vertical mixing occurs in the atmosphere (Reference 15). According to Holzworth, the annual afternoon MMMD value for the ESP site, is about 4900 feet (Reference 16). The seasonal afternoon MMMD values for fall and winter are about 4600 feet and 3300 feet, respectively. Shallow mixing depths have a greater frequency of occurrence during the fall and winter seasons: fall and winter have a higher frequency of inversions. The actual effect of the mixing height on pollutants emitted within the mixing depth is determined by the actual hourly mixing heights.

2.3.1.3.8 Meteorological Data for Evaluating the Ultimate Heat Sink

The evaluation for determining the meteorological conditions resulting in the maximum evaporation and drift loss of water from and the minimum cooling by the ultimate heat sink (UHS) is in accordance with the guidance of RG 1.27 (Reference 54) and uses data from Reference 42, Reference 43, and Reference 44. The controlling parameters for the type of UHS selected for the ESP application (i.e., mechanical draft cooling tower over a buried water storage basin or other passive water storage facility, as required by the reactor design) are the wet-bulb temperature and coincident dry-bulb temperature.

The meteorological conditions resulting in the maximum evaporation and drift loss of water from the UHS are the worst 30-day average combination of the controlling atmospheric parameters. Calculating “running, 30-day,” daily averages and selecting the 30-day period with the highest daily average wet-bulb temperature, determined the worst 30-day period. The worst 30-day daily average of wet-bulb temperatures and coincident dry-bulb temperatures is 76.3°F and 79.5°F, respectively, based on the referenced data encompassing a 25-year period of record from 1978 to 2003.

The meteorological conditions resulting in minimum water cooling are the worst combination of controlling atmospheric parameters, including diurnal variations where appropriate, for the critical time periods unique to the UHS design. The worst 1-day and the worst 5-day daily average of wet-bulb temperatures and coincident dry-bulb temperatures are considered to conservatively represent these conditions.

The worst 1-day is the day having the highest daily average wet-bulb temperature. Calculating “running, 5-day,” daily averages and selecting the 5-day period with the highest daily average

wet-bulb temperature determined the worst 5-day period. Both the worst 1-day and the worst 5-day temperatures were determined using the same reference data over the same period of record as the worst 30-day temperatures.

The worst 1-day wet-bulb temperature and coincident dry-bulb temperature is 78.9°F and 87.7°F, respectively. The worst 5-day daily average of the wet-bulb temperatures and coincident dry-bulb temperatures is 77.6°F and 80.9°F, respectively.

The meteorological conditions resulting in the maximum formation of surface ice (and therefore the minimum initial volume of liquid water available for cooling) is the cumulative dry bulb temperature depression below freezing, measured in degree-days. This is determined by integrating over time, from December 1st of any given year through the following March 31st, the depression below freezing of the daily mean dry bulb temperature using the meteorological data for the Piedmont Research Station (Reference 40). The maximum-cumulative-degree-days-below-freezing was determined to be approximately 322 degree (F)-days, and it occurred in the December 1976–March 1977 period.

2.3.2 Local Meteorology

2.3.2.1 Data Sources

Data acquired by the NWS at its Richmond, Virginia first-order station and from six nearby locations in its network of cooperative observer stations, as compiled and summarized by the NCDC, have been used to characterize normals (i.e., 30-year averages), means and extremes of temperature, rainfall and snowfall in the ESP site area. Section 2.3.1.1 lists the sources of these climatological summaries and data resources. The approximate distance and direction of these climatological observing stations relative to the ESP site are listed in Table 2.3-2.

First-order NWS stations also record observations of other weather elements including winds and relative humidity (typically on an hourly basis), as well as fog when those conditions occur, among others. The 2003 Local Climatological Data summary for the Richmond NWS station has been used to describe the characteristics of these parameters (Reference 1).

Table 2.3-2 NWS and Cooperative Observing Stations Near the ESP Site

Station	Distance (miles)	Direction
Partlow 3WNW	5	East
Louisa	12	West
Piedmont Research Station	21	Northwest
Gordonsville 3S	22	West
Fredericksburg Nat'l Park	26	Northeast

Table 2.3-2 NWS and Cooperative Observing Stations Near the ESP Site

Charlottesville 2W	40	West
Richmond	46	Southeast

The closest station to the ESP site, Partlow 3WNW, was decommissioned on December 31, 1976 (Reference 20). Nevertheless, a climatological summary of means and extremes of temperature and precipitation covering a 20-year period of record from 1952 through 1971 was prepared by the NCDC (Reference 12). With the exception of temperature measurements from Gordonsville 3S, longer-term periods of record for the other stations listed in Table 2.3-2, as well as summaries of the latest 30-year station normals (averages) from 1971 through 2000, are available from NCDC and have been taken into consideration.

Besides using data from these nearby climatological observing stations, data collected from the meteorological monitoring system at the existing units was also used to characterize local meteorological conditions. The onsite primary meteorological tower is about 1750 feet east-northeast of the Unit 1 containment building (see Figure 2.3-23 and Figure 2.3-24). Based on proximity, the meteorological parameters (i.e., wind speed and wind direction) collected by this tower are representative of the ESP site. Consequently, they are appropriate for use in describing local meteorological conditions.

2.3.2.2 Normal and Extreme Values of Meteorological Parameters

2.3.2.2.1 Local Climatological Data

Historical extremes of temperature, rainfall and snowfall are presented in Table 2.3-5 for the seven nearby NWS and cooperative observing stations in the ESP site area that are listed in Table 2.3-2. The normals, means, and extremes of the more extensive set of measurements and observations made at the Richmond, Virginia first-order NWS station are provided in Table 2.3-6 (Reference 1). Table 2.3-7 compares the annual normal (i.e., 30-year average) daily maximum, daily minimum and daily mean temperatures, as well as the normal annual rainfall and snowfall totals for these stations. The precipitation extremes have been discussed previously in Section 2.3.1.3.4.

Extreme maximum temperatures have ranged from 100°F to 107°F with the highest reading observed at Charlottesville 2W in September 1954 (Reference 8). As seen for the extreme rainfall and snowfall events, the synoptic-scale conditions responsible for periods of excessive heat affect the overall ESP site area. For example, the record high temperature at Charlottesville 2W was coincident with the station maxima at Louisa and Piedmont Research Station. Similarly, the 106°F record maxima at Partlow 3WNW at the end of August and the beginning of September 1953 occurred at the same time that the station records were tied at Louisa and set at Fredericksburg National Park.

Extreme minimum temperatures have ranged from –10°F to –21°F, with the lowest reading observed at Louisa (about 12 miles west of the ESP site) in February 1996 (Reference 10). Like the extreme maximum temperatures discussed above, excessive cold air outbreaks affect the overall ESP site area considering that comparable low temperature records were also set at the same time at Gordonsville 3S and Bremo Bluff PWR (i.e., –18°F) (Reference 40) and Piedmont Research Station. The slightly higher record minimum temperatures for Richmond and to some extent Fredericksburg National Park (i.e., –12°F) (Reference 1) (Reference 40) are probably moderated somewhat by urban heat-island effects.

Daily mean temperatures for the NWS and cooperative observing stations in Table 2.3-7 are fairly similar ranging from a low of 54.2°F at Louisa (Reference 10) to a high of 57.6°F at Richmond (Reference 1). In general, the diurnal (day-to-night) temperature ranges, as indicated by the differences between the daily maximum and minimum temperatures, are slightly greater at the more rural stations closest to the ESP site (i.e., Louisa and Partlow 3WNW) than at those stations within or adjacent to urban areas (i.e., Richmond, Fredericksburg National Park and Charlottesville 2W). These rural settings typically allow for greater radiational cooling at night.

The annual average relative humidity in Richmond is 70 percent, as shown in Table 2.3-6. The early morning relative humidity is highest during August and September, with an average of 90 percent. Heavy fog conditions, with visibility less than 0.25 mile are infrequent, on average occurring 27.2 days per year. These data are typical of the mid-Atlantic region of the United States and are representative of the ESP site.

Normal annual precipitation totals are fairly comparable for these stations ranging from 42.24 to 48.87 inches of rainfall, and from 12.4 to 18.8 inches of snowfall. Notwithstanding the record 24-hour (daily) snowfall total for the site area, the lowest of the range of annual average snowfall totals (i.e., at Richmond) is considered to be another consequence of urban heating.

On balance then, the more extensive meteorological data available for the Richmond NWS station are fairly representative of conditions in the ESP site area although slight differences are noted with respect to minimum temperature extremes, diurnal temperature ranges, and annual average total snowfall.

The closest station to the ESP site at which observations of fog are made and routinely recorded is the NWS station at Richmond Byrd International Airport. The 2003 LCD summary for Richmond (Reference 1) indicates an average of 27.2 days per year of heavy fog conditions based on a 75-year period of record. The NWS defines heavy fog as fog that reduces visibility to one-quarter of a mile or less.

The frequency of fog conditions at the ESP site would be expected to be somewhat different than for Richmond. The ESP site is characterized by gentle rolling terrain that rises to an average height of 50 to 150 feet above Lake Anna's level. Low regions at the site and in the vicinity of the lake would be expected to have a higher frequency of fog occurrences attributed to the accumulation of

relatively cool surface air due to drainage flows from higher elevations when compared to the relatively flat region of the Richmond airport.

a. **Average Wind Direction and Speed**

The distribution of wind direction and speed is an important consideration when evaluating transport conditions relevant to site diffusion climatology. The topographic features of the site region and/or the general circulation to the atmosphere (i.e., movement of pressure systems and location of semi-permanent zones) are factors in influencing the wind direction within the site region. For the ESP site, the prevailing wind is from the south-southwest during the summer season and from the northwest and north during the winter season. These wind directions are due primarily to the location of the Bermuda High off the eastern coast of the United States during the summer season and the development of a cold, high-pressure zone over the eastern portion of the United States during the winter season.

However, the topographic features of the ESP site region, in conjunction with the movement of pressure systems and the location of the semi-permanent pressure zones, have a definite influence on the wind direction distribution. The Blue Ridge Mountains, which are oriented in a south-southwest to north-northeast direction, are approximately 40 to 50 miles northwest of the ESP site. Consequently, the prevailing winds during the summer season are from the south and south-southwest because of the channeling effect created by the presence of the Blue Ridge Mountains. Additionally, the Blue Ridge Mountains act as a barrier to the prevailing westerly winds at the surface; but even more so, they act as a barrier to the movement of low-pressure cells from the Gulf of Mexico region to the northeast portion of the United States. Consequently, low-pressure cells that are generated in the Gulf are frequently forced to move toward the east on the back (west) side of the Blue Ridge Mountains, therefore resulting in a southerly flow of air in the ESP site region instead of a southeast or easterly wind.

Topographic features also influence the wind direction distribution during light winds. Usually, during episodes of near calm, the pressure gradient is weak and there is no organization in the general circulation. However, due to topographic effects such as the presence of Lake Anna, the airflow would typically follow the contour lines of the land. Air is channeled along Lake Anna and the North Anna River Valley during light wind conditions. If there is a sufficient temperature gradient between the ambient air over the lake and surrounding land, a weak lake breeze could form. However, the lake breeze would affect only the area in the immediate vicinity of the lake (less than 1 mile) (Reference 13, Section 2.3.2.2.1.1).

The seasonal and annual average distributions of wind direction based on site data are presented in Figure 2.3-1 through Figure 2.3-10 for the lower (33 ft) and upper (159 ft) tower levels (Reference 13). Winds occur on an annual basis along a north-south orientation with a general westerly component. Wind direction distributions based on the lower level data are similar to those based on the upper level data. However, the upper level data indicate a more

distinct north-south orientation of wind flows. Richmond wind data show a south-southwest/north orientation (Reference 1) that is similar to the general wind flow at the ESP site.

Wind direction distributions show seasonal variations. The frequencies of northerly and southerly winds are generally equivalent during the fall season. Winds from the northwest and south-southwest sectors characterize wind flows during the winter. During the spring season, the wind flow is predominantly from the northwest at the lower level. During the summer months, the predominant wind is from the south-southwest.

Atmospheric dilution is directly proportional to the wind speed (other factors remaining constant). The seasonal and annual median wind speeds at the ESP site are presented in Table 2.3-8. As indicated in the table, mean wind speeds show seasonal variations.

The mean annual wind speeds at the ESP site are 6.3 mph and 8.6 mph at the lower and upper tower level, respectively. The annual frequencies of calm are 0.37 and 0.75 percent for the lower and upper tower levels, respectively (Reference 13, Section 2.3.2.2.1.1).

b. **Wind Direction Persistence**

Wind persistence is important when considering potential effects of radiological release. It is defined as a continuous flow from a given direction or range of directions. Wind persistence roses for meteorological data collected at the NAPS site are presented in Figure 2.3-11 through Figure 2.3-20. The maximum 22.5-degree range direction persistence episodes recorded at NAPS during the period of record from the data for the lower level was a 26-hour wind from the north. The maximum persistence period at the upper level was 33 hours from the west-northwest. In general, extreme persistence periods (greater than 18 hours) at the ESP site are associated with moderately high winds and relatively low or moderate turbulence (Reference 13, Section 2.3.2.2.1.2).

c. **Atmospheric Stability**

Atmospheric stability, as applied in this report, is determined by the ΔT method as defined by the NRC (Reference 13, Section 2.3.3.2).

The seasonal and annual frequencies of stability classes and associated wind speeds for the ESP site are presented in Table 2.3-9. The vertical stability data, based on ΔT site measurements, indicate the predominance of neutral and slightly stable conditions (Reference 13, Section 2.3.2.2.1.1).

Extremely unstable conditions (Stability Class A) are more frequent and extremely stable conditions (Stability Class G) are less frequent during the summer than during the winter. This situation is attributed to the greater solar heating of the surface during the summer and the large-scale restrictive dilution conditions that generally occur during the winter. Also, ground snow cover is conducive to the formation of stable (or inversion) conditions.

Instrumentation is available in the main control room of the existing units by which personnel can identify atmospheric stability. This instrumentation is presented in Section 2.3.3.1.5. From the temperature recorder presented in Section 2.3.3.1.3, a ΔT can be ascertained. The existing units' Emergency Plan Implementing Procedures identify station-specific instructions and appropriate temperature values for determining RG 1.23, Table 2 (Reference 21) atmospheric stability classifications. This stability classification method allows for the rapid assessment of pertinent meteorological parameters by control room personnel in the event of an accidental release of radioactive material to the atmosphere.

2.3.2.3 Potential Influence of the Plant and the Facilities on Local Meteorology

Lake Anna, comprising the North Anna Reservoir and the WHTF, has some effects on diffusion climatology, with those effects mainly confined to the immediate area of the lake. Slade (Reference 22) has documented that on average, a 50 percent reduction of horizontal wind direction fluctuation values and a 25 percent increase in wind speeds occurs after over-water trajectories of 7 miles. Because of the complex configuration of the lake, over-water trajectories would generally be less than 2.5 miles. Since the average water temperature in the reservoir is higher at the outfall and immediate surroundings within the WHTF than the average air temperature is, enhanced low-level atmospheric turbulent vertical mixing would occur. Although it is difficult to extrapolate Slade's results to other distances, the reduction of horizontal wind direction fluctuation values and the increase in wind speeds would be smaller than those reported by Slade due to the shorter over-water trajectories near the ESP site. Therefore, the offsite impact due to the effect of the lake on local diffusion climatology would be minimal.

The dimensions of the new nuclear plant structures and the associated paved, concrete, or other improved surfaces are insufficient to generate discernible impacts to local and regional meteorological conditions. While wind conditions may be altered in areas immediately adjacent to the larger site structures, these impacts will likely dissipate within ten-structure heights downwind of the intervening structure. Likewise, the daytime ambient atmospheric temperatures immediately above any newly improved surfaces could increase. However, these localized temperature influences are too limited in their vertical profile and coverage area to alter local ambient or regional temperature patterns.

As discussed in Part 3: Section 5.3.2.1.2, the increase in maximum daily surface water temperature on the Lake resulting from operation of the Unit 3 cooling system would be negligible and would not impact the ongoing moderation of temperature extremes and alterations of wind patterns by the lake. Under extreme humidity conditions during cooler seasons, the increase in cooling lake induced-fog formation resulting from the operation of Unit 3 and Unit 4 would be negligible.

The convective and conductive heat losses to the atmosphere resulting from the operation of the Unit 3 closed-cycle, dry and wet cooling tower system would dissipate rapidly through continuous mixing with the surrounding moving air mass. Therefore, any increase in overall ambient

temperature would be very localized to the NAPS site and would not affect the ambient atmospheric and ground temperature beyond the NAPS site.

The operation of the wet cooling towers for Unit 3 may result in moisture deposition in the immediate vicinity of the towers due to drift and condensation of vapor near the discharge at the top of the towers. In addition, periodic fogging may occur around the towers when atmospheric conditions are so conducive. Part 3: Section 5.3.3.2.1 provides a description of the environmental impact of the cooling towers. That evaluation includes a determination of the cooling tower induced fogging as a function of both distance from the towers and season of the year. The evaluation shows that the cooling tower induced fogging is predicted to occur an average of 70 hours per year (in addition to the naturally occurring atmospheric fog), with nearly all occurrences during the cooler seasons of the year, from late autumn through early spring. Therefore the impact of the cooling tower induced fogging would be small.

Similarly, the convective and conductive heat losses to the atmosphere resulting from operation of the Unit 4 closed-loop dry tower system would dissipate rapidly through continuous mixing and entrainment with the surrounding moving air mass. Therefore, any increases in overall ambient temperature would be very localized to the NAPS site and would not affect the ambient atmospheric and ground temperatures beyond the NAPS site boundary, or otherwise significantly alter local temperature patterns.

The potential impact on the design or operation of the new unit(s) from any cooling-tower-induced increase in the local ambient air temperature or moisture content would be considered as part of detailed engineering.

2.3.2.4 Topographic Description

The ESP site and exclusion area (approximately 1803 acres) is located in the northeastern portion of Virginia in Louisa County along the North Anna River. The site region is characterized by gently rolling terrain that rises to an average height of 50 to 150 feet above Lake Anna's level and is divided by the North Anna River. The topography in the site region is characteristic of the Central Piedmont Plateau, which has a gently undulating surface that varies from 200 to 500 feet above sea level. Figure 2.3-21 and Figure 2.3-22 present the topographic features of the site. Section 2.3.2.2.1 discusses how the topographic features of the site influence wind direction distribution.

Lake Anna, which extends approximately 17 miles along the old North Anna riverbed, was formed by damming up the North Anna River about 5 miles southeast of the site. The lake comprises the North Anna Reservoir and WHTF, which together cover a surface area of about 13,000 acres and contain approximately 100×10^9 gallons of water (Reference 13, Section 2.1.1.2).

Because of the gently rolling terrain, cold air drains into low-lying areas at night. Some wind channeling along Lake Anna is expected during low wind speed conditions. This same effect also occurred in the natural lowland area before the lake was developed.

The ESP site for the new Units 3 and 4 is immediately west of the existing units. The primary topographic influences on local meteorological conditions at the ESP site are Lake Anna and the North Anna River Valley. During construction of the new units, a portion of the currently undeveloped area of the ESP site would be cleared of existing vegetation and subsequently graded to accommodate the new units and their ancillary structures. No large-scale cut and fill activities would be needed in the area of the defined ESP Plant Parameter Envelope to accommodate the new units since a large portion of the area to be developed is already relatively level. Undulating surfaces in the area of the planned cooling towers would be leveled to accommodate the towers. Therefore, the expected terrain modifications associated with development of the new nuclear power plant(s) at the ESP site would be limited to the existing NAPS site and would not significantly impact terrain features around the Lake and/or Valley, nor significantly alter the site's existing gently undulating surface that is characteristic of its location in the Piedmont region of Virginia.

2.3.2.5 Current and Projected Site Air Quality Conditions

The ESP site is located within the Northeastern Virginia Intrastate Air Quality Control Region (AQCR). The region is designated as being in attainment or unclassified for all criteria pollutants (40 CFR 81.347) (Reference 55). Attainment areas are areas where the ambient air quality levels are better than the EPA-designated (national) ambient air quality standards. Criteria pollutants are those for which National Ambient Air Quality Standards (NAAQS) have been established (i.e., sulfur dioxide (SO_2), fine particulate matter (PM_{10}), carbon monoxide (CO), nitrogen dioxide (NO_2), Ozone (O_3), and Lead (Pb)) (Reference 56).

The Commonwealth of Virginia is also subject to the revised 8-hour O_3 standard and the new standard for $PM_{2.5}$ (fine particulate matter with an aerodynamic diameter of less than or equal to 2.5 microns), both promulgated by the EPA in July 1997 (Reference 56). Currently, Louisa County is designated as attainment for the ozone 8-hour standard (Reference 55). The attainment status for $PM_{2.5}$ standards has not been determined for the Northeastern Virginia Intrastate AQCR or resident ESP site. However, both the Virginia Department of Environmental Quality (VDEQ) recommendations and the EPA response as provided in a "Comparison of state and EPA recommendations" conclude that the entire Northeastern Virginia Intrastate AQCR should be designated attainment for the fine particulate matter ($PM_{2.5}$) standards (Reference 58). Attainment status designations for this pollutant are expected to be finalized in December 2004.

The ESP site development could be influenced by its relative proximity to two pristine regions referred to as Class I areas (the James River Face Wilderness and the Shenandoah National Park). Maintenance and restoration of visibility is the primary focus in these sensitive areas.

These air quality characteristics are not expected to be a significant factor in the design and operating bases of the new nuclear plant(s). The new nuclear steam supply system and other related radiological systems are not sources of criteria pollutants or other air toxics. The addition of supporting auxiliary boilers, emergency diesel generators, station blackout generators (and other non-radiological emission sources) are not expected to be significant sources of criteria pollutant emissions because these units operate on an intermittent test and/or emergency basis. Thus, these emissions are not expected to significantly impact ambient air quality or visibility in Class I areas, and they are likely to be regulated by the VDEQ via an Exclusionary General Permit - the permit that currently regulates all non-radiological emission sources on the NAPS site.

2.3.3 Onsite Meteorological Measurements Program

2.3.3.1 Onsite Meteorological Measurements Program for Station Operation

The existing onsite meteorological monitoring program would be used for the ESP site. Detailed information about the existing program is described in Section 2.3 of the NAPS UFSAR (Reference 13). The existing program is ideally suited for the ESP-required onsite meteorological measurements, because the ESP site is within the existing NAPS site.

2.3.3.1.1 General Program Description

Based on the NAPS UFSAR (Reference 13), the existing onsite meteorological measurements program meets the requirements of 10 CFR 50.47 (Reference 23) and the criteria set forth in NUREG-0696 (Reference 24), NUREG-0737 (Reference 25), NUREG-0654, Appendix 2 (Reference 26), as well as the system accuracy presented in the Proposed Revision 1 to RG 1.23 (Reference 27).

The onsite meteorological program has three basic functions:

- Makes meteorological measurements
- Makes real-time predictions of atmospheric effluent transport and diffusion
- Enables remote interrogation of the atmospheric measurements and predictions by appropriate organizations

Meteorological measurements are available from both a primary and backup system, as required in 10 CFR 50, Appendix E (Reference 28). The backup system functions when the primary system is out of service, thus providing assurance that basic meteorological information is available during and immediately following an accidental airborne radioactivity release.

Because of the proximity of the new units to the existing units, meteorological parameters collected at the onsite primary and backup towers would be representative of the dispersion conditions at the ESP site.

The primary NAPS meteorological monitoring program consists of a Rohn Model 80, guyed, 160-foot tower located approximately 1900 feet east of the Unit 1 reactor containment building. Sensors are located at the 10-meter, 48.4-meter, and ground levels. Wind speed, wind direction, horizontal wind direction fluctuation, ambient temperature, one-half of differential temperature, and dew point temperature are measured at the 10-meter elevation. Wind speed, wind direction, horizontal wind direction fluctuation, and one-half of differential temperature are measured at the 48.4-meter elevation. Precipitation is monitored at the ground level. Signal cables are routed through conduit from each location into the instrument shelter at the base of the tower. Inside the shelter, the signals are routed to the appropriate signal-conditioning equipment whose outputs go to: 1) digital data recorders, and 2) an interface with the intelligent remote multiplex system.

The NAPS backup meteorological monitoring site consists of a Rohn Model 25, freestanding 10-meter tower. This tower is located approximately 1300 feet northeast of the Unit 1 containment building and serves as the backup meteorological monitoring site. A sensor at the top of the mast monitors wind speed, wind direction, and horizontal wind direction fluctuation. The signal path, instrument shelter, and data recording are identical to those described at the primary tower. All three parameters are interfaced to the intelligent remote multiplexing system equipment.

2.3.3.1.2 Location, Elevation, and Exposure of Instruments

The location of the primary meteorological tower is shown on Figure 2.3-23. Distances and bearings to ground features in the vicinity of the primary tower are shown on Figure 2.3-24. The nearest major structure is the training center building (completed in 1982) located 740 feet from the tower on a line of bearing of 205 degrees from true north. The minor structures, forming the recreational facility in the immediate vicinity of the tower have been evaluated as having no adverse effect on the measurements taken at the tower. Trees in the immediate vicinity of the tower have been topped to heights of 10–15 feet. The nearest contiguous tree line is more than 500 feet away from the tower and tree heights are 40 to 50 feet (Reference 13, Section 2.3.3.2.2).

The PPE shows that the highest structure at the ESP site would be about 234 feet above grade level. The primary tower is located about 2500 feet east of the proposed plant envelope. Since the primary tower is located more than 10 building heights away from the tallest structure within the plant envelope, the structure would not influence the meteorological measurements (Reference 27). The backup tower is located about 1800 feet to the closest ESP plant envelope boundary. However, the tallest structure (234 feet above grade) could be located about 650 feet west of the eastern edge plant envelope boundary. As a result, the backup tower would be located about 2400 feet away from the highest structure. Therefore, the structure would not influence the meteorological measurements taken at the backup either. These towers and the original satellite tower have the same relative proximity to Lake Anna.

Ground cover at the location is characteristically native grasses. Comparable cover is maintained at the base of the tower.

The primary tower is a guyed, triaxial, open-lattice structure. The lower level instrumentation is at 32.8 feet (10 m) above ground level. The upper instrumentation is at 158.9 feet above the finished plant grade of 271 ft mean sea level (msl).

The wind sensors are positioned so that the tower would not influence the prevailing south-southwest wind flow detected by the sensors. The wind speed, wind direction, and horizontal wind direction fluctuation sensors are mounted on booms longer than one times the tower face width.

Ambient temperature, differential temperature, and dew point temperature sensors are housed in motor-aspirated shields to insulate them from thermal radiation. These shields have a less than 0.2°F error at a maximum solar radiation of 1.6 gm-cal/cm^2/min (Reference 13, Section 2.3.3.2.2).

At the primary meteorological monitoring site, a lithium chloride dew point sensor measures dew point temperature at the 32.8-foot (10-meter) level. The sensor signals are input into a dew point processor, which provides output signals proportional to the ambient dew point temperatures. The dew point levels are recorded to an accuracy of at least ±1.5°C (2.7°F), in accordance with (Reference 27). The backup tower does not collect dew point temperature.

At the primary meteorological monitoring site, precipitation is monitored at the ground level. The precipitation is measured with a recording rain gauge that has a resolution of 0.25 mm (0.01 in.). The accuracy is at least ±10 percent of the total accumulated catch, in accordance with Reference 27. The backup tower does not collect precipitation.

2.3.3.1.3 Meteorological Sensor Type and Performance Specifications

Wind speed, wind direction, and horizontal wind direction fluctuation are measured at both the lower and upper tower levels. Electro-mechanical instruments are used to measure wind speed and wind direction, and horizontal wind direction fluctuation is calculated by the digital data acquisition system.

Temperature is measured at the 32.8-foot level and differential temperature is measured between the 32.8-foot and 158.9-foot level. The sensors consist of one single-element, high-precision, platinum resistance temperature sensor located at the 158.9-foot level for measuring part of the differential temperature; and 1 single-element, precision, platinum resistance sensor located at 32.8-foot level for measuring ambient temperature and the other part of differential temperature. The sensors' signals are input into a temperature/delta temperature processor, which provides output signals proportional to an ambient and differential (ΔT) temperature.

A lithium chloride dew point sensor measures dew point temperature at the 32.8-foot level. The sensor signals are input into a dew point processor, which provides output signals proportional to the ambient dew point temperatures (Reference 13, Section 2.3.3.2.3).

2.3.3.1.4 Instrument Calibration and Maintenance

The meteorological monitoring installation is calibrated not less than semi-annually. Inspection, service, and maintenance are performed as required to ensure not less than 90 percent data recovery (Reference 27). Instrument technicians have the requisite expertise to service and, in the event of a system failure, repair the monitoring equipment. The on-site instrument group provides these technicians.

An inventory of spare sensors and parts are maintained for the replacement of major components in the event of a system outage. Redundant recording systems are incorporated into the program to further minimize data loss due to recorder failure. As an example, for this ESP application, the data recovery rates for more recent observations are presented. As shown in Table 2.3-10, the data recovery rates for meteorological parameters (wind direction, wind speed, and atmospheric stability class) used for the dispersion analyses presented in Section 2.3.4 and Section 2.3.5 are very high and exceed the 90 percent requirement stated in Reference 27.

2.3.3.1.5 Data Recording Systems

a. **Control Room Systems**

Meteorological data collected from the primary and backup towers would be electronically sent to the designated control room and technical support center (TSC) to provide direct access to operators in the event of emergency. The required meteorological parameters are collected by the emergency response facility (ERF) data system, via the intelligent remote multiplex system (Reference 13). The parameters are also placed in the ERF database, thus making the site meteorological field data available for display in the local emergency operations facility (LEOF), the corporate emergency response center (CERC), and the central emergency operations facility (CEOF) located in the CERC.

Table 2.3-11 and Table 2.3-12 list each meteorological input parameter and its transmitted location for the primary tower and backup tower, respectively. Table 2.3-11 and Table 2.3-12 describe data that can be made available for remote interrogation at any time. During emergency conditions, selected meteorological parameters can be made available to the NRC through the emergency response data system (ERDS). Once activated, this meteorological data is transmitted from the ERF computer, via modem, to the NRC operations center (Reference 13, Section 2.3.3.2.5.1).

b. **Tower Base Shelter Systems**

A nominal 8 ft x 8 ft x 18 ft shelter is at the meteorological tower's base. The shelter is insulated, and thermostatically controlled heat and air conditioning maintain an interior temperature within a range appropriate for proper equipment operation. The enclosure is located so as to minimize any micrometeorological effects on the tower instrumentation. Equipment and circuitry for two separate data recording systems are housed in the enclosure.

Microprocessor-based data acquisition systems are the primary method of data acquisition. The sensor analog signals are collected, processed, and telemetered to a system computer. The data acquisition systems have a built-in battery, which maintains the time and date and initialized parameters. In addition to the power-up diagnostic checks, memory diagnostic tests are continually being performed to insure data integrity (Reference 13, Section 2.3.3.2.5.2).

The instruments and data acquisition systems detailed herein are consistent with the current level of technology for meteorological monitoring and the accuracy of the components ensures system accuracy consistent with proposed Revision 1 to RG 1.23 (Reference 27).

c. **Meteorological Data Analysis Procedure**

The collected data are used to generate a sequential file of 1-hour values for each parameter. The average values are calculated by the digital data collection system.

In addition to being transmitted real-time to the ERF system, the data are telemetered daily to a computer in the corporate office. Personnel in the air quality department check the data for representativeness and reasonability. The data are compared with those recorded from other offsite meteorological towers, as well as with the real-time data received at the corporate meteorological operations center. The current calendar month of data is maintained on a personal computer. At the end of each month, the data are transferred to the corporate mainframe computer for inclusion in the historical database.

This sequential file is used as the database for all subsequent data summaries and historical calculations. Routine data summaries are generated for each day, each calendar month, and each calendar year on certain meteorological parameters recorded on strip charts in the control room or the existing units. An annual summary is provided to health physics personnel by the air quality department. Other data summaries are prepared by the air quality department upon request.

The format of the onsite data summaries conforms to the recommended format found in RG 1.23, Table 1 (Reference 21). To facilitate comparison, the joint frequency distributions of wind speed and wind direction for each stability class, as defined by horizontal wind sigma and differential temperature, are displayed side by side. Joint frequency distributions for each wind sensor are presented (Reference 13, Section 2.3.3.2.5.2).

2.3.4 Short-Term (Accident) Diffusion Estimates

2.3.4.1 Basis

To evaluate potential health effects for DBAs, a hypothetical accident is postulated to predict upper-limit concentrations and dosages that might occur in the event of a radiological release. The NRC-sponsored PAVAN computer code (Reference 29)was used to estimate relative ground-level

air concentrations (χ/Qs) at the EAB and LPZ for potential accidental releases of radioactive material.

Recent readily available site meteorological data (1996–1998) were used for a quantitative evaluation of the hypothetical accident at the ESP site. Onsite data provide representative measurements of local dilution conditions appropriate to the ESP site, and are reasonably representative of long-term conditions. The use of the recent 3-year data for dispersion analysis involving accidental releases is consistent with the approach used in the license renewal application for the existing units (Reference 30), also satisfies the requirements of RG 4.7 (Reference 31).

According to 10 CFR 100 (Reference 32), it is necessary to consider the dosages for various time periods immediately following the onset of a postulated ground-level release at the exclusion distance and for the duration of exposure for the LPZ and population center distances. Therefore, relative air concentrations (χ/Qs) are estimated for various time periods ranging from 2-hours to 30 days.

Meteorological data were used to determine various hypothetical accident conditions as specified in RG 1.145 (Reference 33). Compared to an elevated release, a ground-level release usually results in higher ground-level concentrations at downwind receptors due to less dilution from shorter traveling distances. Because the ground level release scenario provides a bounding case, elevated releases were not evaluated.

The PAVAN program implements the guidance provided in RG 1.145 and performs the following calculation procedures. The code computes χ/Q values at the EAB and LPZ for each combination of wind speed and atmospheric stability for each of the 16 downwind direction sectors. The χ/Q values for each sector are then ranked in descending order, and an associated cumulative frequency distribution is derived based on the frequency distribution of wind speed and stabilities for that sector. The χ/Q value that is equaled or exceeded 0.5 percent of the total time becomes the maximum sector-dependent χ/Q value.

The χ/Q values are also ranked independent of wind direction into a cumulative frequency distribution for the entire site. The PAVAN Program then selects the X/Q values that are equaled or exceeded 5 percent of the total time.

The larger of the two values, the maximum sector-dependent 0.5 percent χ/Q and the overall site 5 percent χ/Q value, is used to represent the χ/Q value for a 0–2 hour time period. To determine χ/Q values for longer time periods, the program calculates an annual average χ/Q value using the procedure described in RG 1.111 (Reference 34). The program then uses logarithmic interpolation between the 0-to-2-hour χ/Q values and the annual average χ/Q values to calculate the values for intermediate time periods (i.e., 8 hours, 16 hours, 72 hours, and 624 hours). As suggested in NUREG/CR-2858, each of the sector-specific 0–2-hour χ/Q values provided in the PAVAN output

file were examined for “reasonability” by comparing them with the ordered χ/Q values presented in the model output.

The PAVAN model was configured to calculate offsite χ/Q values assuming both wake-credit allowed and wake-credit not-allowed. As described in Section 2.1, the EAB is the perimeter of a 5000-foot-radius circle from the center of the abandoned Unit 3 containment. There are no residential areas in the EAB. The PPE indicates that the highest expected structure would be about 234 feet above grade level. Therefore, the closest EAB is more than 10 building heights away from the boundary of the plant envelope developed for the ESP site. As a result, the entire EAB is located beyond the wake influence zone that would be induced by a containment building. The LPZ is a 6-mile-radius circle centered at the Unit 1 containment building. Because it is located further away from the plant site than the EAB, the “wake-credit not allowed” scenario of the PAVAN results was used for the χ/Q analysis at the EAB and LPZ.

To be conservative, the shortest distances between the ESP plant envelope boundaries to the 5000-ft-radius circle for each downwind sector were entered as input to calculate the χ/Q values at the EAB. Similarly, the shortest distance from the ESP plant envelope area boundary to the LPZ was entered as input to calculate the X/Q values at the LPZ. With respect to the ESP site, the shortest distance between the ESP plant envelope area and the LPZ is 8843 m (about 5.5 mi.) measured from the southwest of the plant envelope area.

The PAVAN model input data are presented below:

- Meteorological Data: Three-year (January 1, 1996 to December 31, 1998) combined onsite joint frequency distribution of wind speed, wind direction, and atmospheric stability.
- Type of Release: Ground level
- Wind Sensor Height: 33 ft
- Vertical Temperature Difference: 33 ft–158.9 ft
- Number of Wind Speed Categories: 7
- Release Height: 33 ft (default height)
- Distances From the Release Point to the EAB: See Table 2.3-13
- Distances From the Release Point to the LPZ: 8843 m (5.5 miles) for all downwind sectors

2.3.4.2 PAVAN Modeling Results

To calculate the maximum χ/Q values, the shortest distances from the plant parameter envelope boundary to the EAB at each downwind sector were used. These distances are presented in Table 2.3-13. As presented in the table, the maximum 0–2 hours 0.5 percentile direction-dependent χ/Q value (2.26×10^{-4} sec/m^3) is greater than the corresponding 5 percentile overall site χ/Q value (1.56×10^{-4} sec/m^3) at the EAB. Therefore, the direction-dependent 0.5 percentile χ/Q values were used as the proper χ/Q values at EAB.

To be conservative, this shortest distance has been used as the LPZ distance for all downwind sectors in PAVAN modeling. Similarly, Table 2.3-14 shows the maximum 0–2 hours 0.5 percentile direction-dependent χ/Q value (4.65×10^{-5} sec/m^3) is greater than the corresponding 5 percentile overall site χ/Q value (2.72×10^{-5} sec/m^3) at the LPZ. Therefore, the direction-dependent 0.5 percentile χ/Q values were used at the LPZ.

The maximum χ/Q values presented in Table 2.3-13 and Table 2.3-14 for the EAB and LPZ, respectively, are summarized below.

Table 2.3-3 PAVAN Results (0.5% Limiting Case, 1996-1998 Meteorological Data)

Source Location	Receptor Location	0–2 hr (Dir, Dist)	0–8 hr (Dir, Dist)	8–24 hr (Dir, Dist)	1–4 days (Dir, Dist)	4–30 days (Dir, Dist)	Annual (Dir, Dist)
Plant Envelope	EAB	2.26E-04 (SE, 1300m)	1.43E-04 (SE, 1300m)	1.14E-04 (ESE, 1420m)	7.05E-05 (ESE, 1420m)	3.55E-05 (ESE, 1420m)	1.54E-05 (ESE, 1420m)
Plant Envelope	LPZ	4.65E-05* (ESE, 8843m)	2.05E-05 (ESE, 8843m)	1.36E-05 (ESE, 8843m)	5.58E-06 (ESE, 8843m)	1.55E-06 (ESE, 8843m)	3.25E-07 (ESE, 8843m)

* The 0–2-hour χ/Q value is reported here for reference only. It is not required based on RG 1.145.

2.3.5 Long-Term (Routine) Diffusion Estimates

2.3.5.1 Basis

The NRC-sponsored XOQDOX computer code (Reference 35) was used to estimate χ/Q values due to routine releases. The XOQDOQ model implements assumptions outlined in RG 1.111 (Reference 34). A straight-line trajectory was assumed between the release point and all receptors by the XOQDOQ model. (Reference 35) Radiological impacts of normal plant operation on members of the public are described in Part 3: Section 5.4.

The primary function of the XOQDOQ computer code, obtained from RSICC (Reference 36), is to calculate annual χ/Q values and annual average relative deposition, D/Q values, at interested receptors (i.e., EAB, LPZ, nearest milk cow, residence, garden, meat animal, etc.). The χ/Q and D/Q values due to intermediate releases, which occur during routine operation, may also be evaluated using the XOQDOQ model. The program assumes that the material released to the atmosphere is a Gaussian distribution around the plume centerline. In estimating concentrations for longer time periods, the Gaussian distribution is assumed to be evenly distributed within the directional sector.

Input data and assumptions in the XOQDOQ modeling are presented below:

- Meteorological Data: Three-year combined (1996–1998) onsite joint frequency distribution of wind speed, wind direction and atmospheric stability.

- Type of Release: Ground level
- Wind Sensor Height: 33 ft
- Vertical Temperature Difference: 33 ft–158.9 ft
- Number of wind speed categories: 7
- Release Height: 33 ft (default height)
- Minimum Building Cross-Sectional Area: 2250 m^2
- Distances from the release point to the nearest residence, nearest site boundary, milk cow, vegetable garden, milk goat, meat animal: See Table 2.3-15.

For dispersion analysis, a smaller cross-sectional area usually results in higher ground level concentrations. To be conservative, the minimum building cross-sectional area of 2250 m^2 was used to evaluate building downwash effect.

When compared to elevated releases, ground level releases usually produced higher pollutant concentrations for receptors located at ground level. Therefore, ground level releases were conservatively assumed in the χ/Q analysis. Distances from the Unit 1 containment building to various interested receptors (nearest residence, garden, meat animal and vegetable garden) for each directional sector are provided in Reference 37, Appendix C. However, because the plant envelope area proposed for the ESP site is an area (not a point), the shortest distances from any point of the plant envelope to the interested receptors were re-calculated for each directional sector. The results are presented in Table 2.3-15. The maximum annual χ/Q (no decay) at the EAB (0.88 mile to the ESE of the plant envelope) is 3.70×10^{-6} sec/m^3. The maximum annual average χ/Q value calculated for the nearest residence (0.96 mile to the NNE of the plant envelope) is 2.4×10^{-6} sec/m^3. The maximum annual χ/Q for the nearest vegetable garden (0.94 mile NE of the plant envelope) is 2.0×10^{-6} sec/m^3. Finally, the maximum annual χ/Q for the nearest meat animal (1.37 miles to the SE of the plant envelope) is 1.4×10^{-6} sec/m^3.

Table 2.3-16 summarizes the maximum χ/Q and D/Q values predicted by the XOQDOQ model for the sensitive receptors due to routine releases. Table 2.3-17 summarizes the annual average χ/Q values at distances between 0.25 mile to 50 miles and for various segment boundaries.

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Table 2.3-5 Climatological Extremes at Selected NWS and Cooperative Observing Stations in the ESP Site Area (Date of Occurrence)

Parameter	Partlow 3WNW	Louisa	Piedmont Research Station	Gordonsville 3S	Fredericksburg Nat'l Park	Charlottesville 2W	Richmond
Maximum Temperature	106°F[a] (8/53, 9/53)	104°F[b] (c)	106°F[d] (9/54, 7/59)	100°F[e] (07/23/98)	106°F[e] (09/01/53)	107°F[f] (09/07/54)	105°F[g] (07/77)
Minimum Temperature	–16°F[a] (1/53, 1/70)	–21°F[b] (02/05/96)	–11°F[d] (02/05/96)	–18°F[e] (02/05/96)	–12°F[e] (01/28/35)	–10°F[f] (01/19/94)	–12°F[g] (1/40)
Maximum Monthly Rainfall	16.20 in.[e] (9/75)	16.33 in.[e] (8/69)	13.32 in.[e] (8/55)	14.69 in.[e] (6/95)	16.20 in.[e] (7/45)	17.96 in.[f] (9/87)	18.87 in.[g] (7/45)
Maximum Monthly Snowfall	41.0 in.[a] (1/66)	32.2 in.[e] (1/66)	32.0 in.[d] (1/87)	27.8 in.[e] (1/87)	30.5 in.[e] (1/87)	29.8 in.[e] (3/60)	28.5 in.[g] (1/40)
Maximum 24-hr Rainfall	5.45 in.[a] (08/12/55)	11.18 in.[b] (08/20/69)	7.85 in.[d] (06/22/72)	9.30 in.[e] (06/28/95)	6.17 in.[e] (10/16/42)	9.20 in.[f] (09/08/87)	8.79 in.[g] (08/55)
Maximum 24-hr Snowfall	20.0 in.[a,e] (1/66, 3/62)	16.0 in.[b] (01/07/96)	18.0 in.[e] (03/06/62)	17.0 in.[e] (03/06/62)	17.0 in.[e] (01/24/40)	20.7 in.[e] (03/06/62)	21.6 in.[g] (1/40)
Fastest Mile Wind Speed	N/A[h]	N/A	N/A	N/A	N/A	N/A	68 mph[i] (10/54)
Fastest Mile Wind Direction	N/A	N/A	N/A	N/A	N/A	N/A	SE[i] (10/54)

a. Reference 12

b. Reference 10

c. Extreme maximum temperature occurred on more than two occasions at Louisa – 7/30/53, 8/31/53 and 9/7/54.

d. Reference 11

e. Reference 40

f. Reference 8

g. Reference 1

h. NA = Measurements not made

i. Reference 6

Table 2.3-6 Richmond Climatological Data

NORMALS, MEANS, AND EXTREMES

RICHMOND, VA (RIC)

LATITUDE: 37° 30′ 40″ N LONGITUDE: 77° 19′ 24″ W ELEVATION (FT): GRND: 164 BARO: 167 TIME ZONE: EASTERN (UTC + 5) WBAN: 13740

	ELEMENT	POR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F	NORMAL DAILY MAXIMUM	30	45.3	49.3	58.4	68.9	76.2	83.6	87.5	85.7	79.7	69.3	59.7	49.7	67.8
	MEAN DAILY MAXIMUM	83	47.4	50.3	58.9	69.3	77.5	85.1	88.3	86.5	80.8	70.6	60.5	50.0	68.8
	HIGHEST DAILY MAXIMUM	74	81	83	93	96	100	104	105	102	103	99	86	81	105
	YEAR OF OCCURRENCE		2002	1932	1938	1990	1941	1952	1977	1983	1954	1941	1993	1998	JUL 1977
	MEAN OF EXTREME MAXS.	83	69.5	71.2	80.2	87.9	91.0	96.0	97.5	96.0	93.1	85.4	77.9	70.0	84.6
	NORMAL DAILY MINIMUM	30	27.6	29.7	37.0	45.3	54.6	63.3	68.3	66.8	59.9	47.2	38.4	31.1	47.4
	MEAN DAILY MINIMUM	83	28.4	30.0	36.6	45.4	54.7	63.5	68.0	66.6	60.1	47.9	38.5	30.9	47.5
	LOWEST DAILY MINIMUM	74	-12	-10	11	23	31	40	51	46	35	21	10	-1	-12
	YEAR OF OCCURRENCE		1940	1936	1960	1985	1956	1967	1965	1934	1974	1962	1933	1942	JAN 1940
	MEAN OF EXTREME MINS.	83	10.3	14.4	21.5	30.9	41.0	51.1	57.8	55.7	45.5	32.4	22.8	14.7	33.2
	NORMAL DRY BULB	30	36.4	39.5	47.7	57.1	65.4	73.5	77.9	76.3	69.8	58.3	49.0	40.4	57.6
	MEAN DRY BULB	83	38.0	40.1	47.8	57.4	66.2	74.3	78.2	76.6	70.5	59.2	49.6	40.4	58.2
	MEAN WET BULB	19	34.1	36.6	42.1	50.8	59.4	67.3	71.6	66.6	63.9	53.8	45.1	36.7	52.3
	MEAN DEW POINT	19	27.0	28.9	34.3	43.5	54.4	63.2	68.1	63.7	60.3	49.0	39.0	29.9	46.8
	NORMAL NO. DAYS WITH:														
	MAXIMUM ≥ 90°	30	0.0	0.0	*	0.8	1.9	8.2	15.0	10.9	3.6	0.3	0.0	0.0	40.7
	MAXIMUM ≤ 32°	30	3.5	1.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	7.2
	MINIMUM ≤ 32°	30	21.6	18.3	10.3	1.9	*	0.0	0.0	0.0	0.0	1.3	9.2	18.3	80.9
	MINIMUM ≤ 0°	30	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
H/C	NORMAL HEATING DEG. DAYS	30	873	705	528	254	80	8	0	1	27	225	470	748	3919
	NORMAL COOLING DEG. DAYS	30	0	1	8	33	107	277	415	367	187	33	6	1	1435
RH	NORMAL (PERCENT)	30	69	66	63	62	70	72	74	76	76	74	70	69	70
	HOUR 01 LST	30	75	73	72	73	83	86	88	90	89	87	80	76	81
	HOUR 07 LST	30	80	79	78	76	81	83	85	89	90	89	84	81	83
	HOUR 13 LST	30	57	53	50	46	53	54	56	57	57	53	52	56	54
	HOUR 19 LST	30	66	62	57	54	63	66	68	72	75	76	69	68	66
S	PERCENT POSSIBLE SUNSHINE	46	54	58	62	66	65	69	68	66	65	63	59	54	62
W/O	MEAN NO. DAYS WITH:														
	HEAVY FOG(VISBY≤1/4 MI)	75	2.7	2.1	1.7	1.6	1.9	1.5	2.0	2.4	2.9	3.3	2.3	2.8	27.2
	THUNDERSTORMS	67	0.2	0.4	1.6	2.5	5.3	6.5	8.1	6.3	2.9	1.0	0.6	0.2	35.6
CLOUDINESS	MEAN:														
	SUNRISE-SUNSET (OKTAS)	1			5.6		5.6	3.2							
	MIDNIGHT-MIDNIGHT (OKTAS)	1			5.6										
	MEAN NO. DAYS WITH:														
	CLEAR	1	2.0	1.0	9.0		9.0	10.0							
	PARTLY CLOUDY	1		1.0	5.0		4.0	8.0							
	CLOUDY	1	7.0	4.0	10.0		8.0	1.0							
PR	MEAN STATION PRESSURE(IN)	30	29.91	29.89	29.85	29.81	29.81	29.81	29.83	29.86	29.89	29.92	29.92	29.93	29.87
	MEAN SEA-LEVEL PRES. (IN)	19	30.12	30.11	30.05	29.99	30.00	29.99	30.01	30.04	30.08	30.12	30.13	30.14	30.06
WINDS	MEAN SPEED (MPH)	45	8.3	8.7	9.3	9.2	7.9	7.5	7.1	6.6	7.0	7.2	7.7	7.9	7.9
	PREVAIL.DIR(TENS OF DEGS)	28	01	01	36	19	19	20	19	19	36	36	19	36	19
	MAXIMUM 2-MINUTE:														
	SPEED (MPH)	8	38	39	37	46	41	45	33	44	46	37	36	40	46
	DIR. (TENS OF DEGS)		31	22	36	33	30	26	29	36	09	10	30	15	09
	YEAR OF OCCURRENCE		2000	2002	2003	1999	1997	2000	1999	1996	2003	1996	2003	1996	SEP 2003
	MAXIMUM 5-SECOND:														
	SPEED (MPH)	8	48	49	49	56	60	55	48	59	72	46	46	48	72
	DIR. (TENS OF DEGS)		31	26	22	25	28	27	19	32	10	10	27	16	10
	YEAR OF OCCURRENCE		2000	1997	1996	1998	1996	2000	2003	2000	2003	1996	2003	1996	SEP 2003
PRECIPITATION	NORMAL (IN)	30	3.55	2.98	4.09	3.18	3.96	3.54	4.67	4.18	3.98	3.60	3.06	3.12	43.91
	MAXIMUM MONTHLY (IN)	66	7.97	5.97	8.65	7.31	8.87	9.24	18.87	14.10	16.60	9.39	7.64	7.07	18.87
	YEAR OF OCCURRENCE		1978	1979	1984	1987	1972	1938	1945	1955	1999	1971	1959	1973	JUL 1945
	MINIMUM MONTHLY (IN)	66	0.64	0.48	0.94	0.64	0.87	0.38	0.51	0.52	0.26	0.01	0.17	0.40	0.01
	YEAR OF OCCURRENCE		1981	1978	1966	1963	1965	1980	1983	1943	1978	2000	2001	1980	OCT 2000
	MAXIMUM IN 24 HOURS (IN)	66	3.31	2.67	3.43	2.97	3.40	4.61	5.73	8.79	6.52	6.50	4.07	3.16	8.79
	YEAR OF OCCURRENCE		1962	1979	1992	1987	2003	1963	1969	1955	1999	1961	1956	1958	AUG 1955
	NORMAL NO. DAYS WITH:														
	PRECIPITATION ≥ 0.01	30	10.7	9.5	10.5	9.2	11.0	9.6	11.1	9.0	8.7	7.5	8.1	9.7	114.6
	PRECIPITATION ≥ 1.00	30	1.0	0.7	1.0	0.8	1.0	0.8	1.3	1.2	1.2	1.2	0.8	0.5	11.5
SNOWFALL	NORMAL (IN)	30	4.3	4.8	1.4	0.*	0.0	0.0	0.0	0.0	0.0	0.*	0.3	1.6	12.4
	MAXIMUM MONTHLY (IN)	64	28.5	21.4	19.7	2.0	T	0.0	T	0.0	0.0	T	7.3	12.5	28.5
	YEAR OF OCCURRENCE		1940	1983	1960	1940	1994		2003			1979	1953	1958	JAN 1940
	MAXIMUM IN 24 HOURS (IN)	64	21.6	16.8	12.1	2.0	T	0.0	T	0.0	0.0	T	7.3	7.5	21.6
	YEAR OF OCCURRENCE		1940	1983	1962	1940	1994		2003			1979	1953	1966	JAN 1940
	MAXIMUM SNOW DEPTH (IN)	79	18	20	13	1	0	0	0	0	0	0	6	9	20
	YEAR OF OCCURRENCE		1922	1922	1980	1964							1938	1958	FEB 1922
	NORMAL NO. DAYS WITH:														
	SNOWFALL ≥ 1.0	30	1.1	1.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	3.5

published by: NCDC Asheville, NC 3

Source: *Richmond, Virginia, 2003 Local Climatological Data, Annual Summary with Comparative Data*, NCDC, NESDIS, NOAA. (Reference 1).

Table 2.3-7 Climatological Normals (Means) at Selected NWS and Cooperative Observing Stations in the ESP Site Area

Station	Normal Annual Temperatures (°F)			Normal Annual Rainfall (inches)	Normal Annual Snowfall (inches)
	Daily Max	Daily Min	Daily Mean		
Partlow 3WNW [a]	68.9	41.5	55.2	42.24	18.6
Louisa [b]	67.1	41.2	54.2	44.02	16.8
Piedmont Research Station [c]	65.3	44.8	55.1	44.64	18.8
Gordonsville 3S [d]	—	—	—	45.42	—
Fredericksburg Nat'l Park [d]	68.4	43.5	55.9	42.72	—
Charlottesville 2W [e]	67.7	46.3	57.0	48.87	17.8
Richmond [f]	67.8	47.4	57.6	43.91	12.4

a. Reference 12
b. Reference 10
c. Reference 11
d. Reference 39
e. Reference 8
f. Reference 1

Table 2.3-8 ESP Site Mean Wind Speeds (mph) 1974-1987

Elevation	Spring (Mar, Apr, May)	Summer (Jun, Jul, Aug)	Fall (Sept, Oct, Nov)	Winter (Dec, Jan, Feb)	Annual
Upper Level	9.6	7.5	8.3	9.2	8.6
Lower Level	7.1	5.4	5.9	6.6	6.3

Source: Reference 13

Table 2.3-9 ESP Site Vertical Stability (ΔT) and Low Level Wind Speed Distribution 1974-1987

	Vertical Stability Categories						
Period	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Spring							
Frequency (%)	20.04	5.41	4.86	29.87	24.18	7.92	7.71
Wind Speed (MPH)	(8.6)	(8.4)	(8.6)	(7.9)	(6.3)	(4.0)	(2.9)
Summer							
Frequency (%)	25.33	5.38	5.10	29.52	27.21	6.42	1.44
Wind Speed (MPH)	(6.1)	(6.2)	(6.2)	(5.7)	(4.3)	(3.2)	(2.9)
Fall							
Frequency (%)	21.28	4.16	4.25	28.71	25.57	10.26	6.14
Wind Speed (MPH)	(6.9)	(7.1)	(7.4)	(6.8)	(4.9)	(3.4)	(3.2)
Winter							
Frequency (%)	13.39	4.82	4.85	35.10	27.55	8.09	6.60
Wind Speed (MPH)	(7.6)	(7.8)	(8.2)	(7.4)	(5.6)	(3.5)	(2.8)
Annual							
Frequency (%)	20.00	4.91	4.74	30.69	26.08	8.22	5.46
Wind Speed (MPH)	(7.2)	(7.4)	(7.6)	(7.0)	(5.2)	(3.5)	(3.0)

Source: Reference 13

Table 2.3-10 Meteorological Data Recovery Rates (percent) (ESP Site, January 1, 1996 – December 31, 2001)

	ΔT Included		ΔT not Included	
Year	33-ft Wind Data	150-ft Wind Data	33-ft Wind Data	150-ft Wind Data
1996	98.88	99.30	98.92	99.48
1997	98.96	90.09	99.36	99.20
1998	99.21	99.43	99.12	99.34
1999	98.91	98.90	99.45	99.44
2000	98.73	98.76	99.23	99.24
2001	98.88	91.78	99.76	92.59

Source: NAPS onsite meteorological monitoring program

Table 2.3-11 Primary Tower Parameters

	Transmitted Locations		
Parameter	ERF Data Base	Control Room	Remote Interrogation
Wind Direction (upper)	X	X	X
Wind Speed (upper)	X	X	X
Sigma theta (upper)			X
Wind Direction (lower)	X	X	X
Wind Speed (lower)	X	X	X
Sigma theta (lower)			X
Ambient Temperature (lower)	X	X	X
Dew point (lower)			X
Delta Ambient Temperature (upper-lower)	X	X	X
Precipitation			X

Note: All parameters going to the ERF database are available for printout in the existing TSC and EOF. The Units 1 & 2 control room parameters are hardwired.

Source: Reference 13

Table 2.3-12 Backup Tower Parameters

Parameter	Transmitted Locations		
	ERF Data Base	Control Room	Remote Interrogation
Wind Speed	X	X	X
Wind Direction	X	X	X
Sigma Theta	X	X	X

Note: All parameters going to the ERF database are available for printout in the existing TSC and EOF. The Units 1 & 2 control room parameters are hardwired.

Source: Reference 13

Table 2.3-13 PAVAN Results for χ/Q Values at the EAB

Plant Name: North Anna ESP
Data Period: 1996-1998 JFD
Type of Release: Ground-Level Release
Source of Data: Onsite
Comments: Data period: 1/1/96 - 12/31/98
Program: PAVAN, 10/76, 8/79 Revision, Implementation of Regulatory Guide 1.145

Meteorological Instrumentation
Wind Sensors Height: 32.8 ft
ΔT Heights: 32.8 ft–158.9 ft

0 Relative Concentration (χ/Q) Values (sec/cubic meter) versus Averaging Time

Downwind Sector	Distance (Meters)	0–2 Hours	0–8 Hours	8–24 Hours	1–4 Days	4–30 Days	Annual Average	Hours Per Year Max 0-2 hr χ/Q Is Exceeded in Sector	Downwind Sector
N	1378	1.07E-04	7.04E-05	5.70E-05	3.61E-05	1.88E-05	8.42E-06	4.7	N
NNE	1399	1.17E-04	7.79E-05	6.37E-05	4.11E-05	2.20E-05	1.02E-05	4.2	NNE
NE	1432	1.10E-04	7.17E-05	5.78E-05	3.62E-05	1.85E-05	8.15E-06	7.1	NE
ENE	1474	1.13E-04	6.78E-05	5.25E-05	3.01E-05	1.35E-05	5.08E-06	8.5	ENE
E	1435	1.56E-04	9.92E-05	7.91E-05	4.84E-05	2.39E-05	1.01E-05	16.4	E
ESE	1420	2.20E-04	1.42E-04	1.14E-04	7.05E-05	3.55E-05	1.54E-05	40.5	ESE
SE	1300	2.26E-04	1.43E-04	1.13E-04	6.89E-05	3.37E-05	1.40E-05	43.7	SE
SSE	1086	1.30E-04	8.61E-05	7.01E-05	4.49E-05	2.37E-05	1.08E-05	26.0	SSE
S	954	8.87E-05	6.32E-05	5.33E-05	3.69E-05	2.17E-05	1.14E-05	10.5	S
SSW	877	8.89E-05	6.24E-05	5.23E-05	3.57E-05	2.06E-05	1.05E-05	11.4	SSW
SW	872	9.03E-05	6.24E-05	5.19E-05	3.47E-05	1.95E-05	9.66E-06	11.9	SW
WSW	865	9.30E-05	6.34E-05	5.23E-05	3.45E-05	1.90E-05	9.14E-06	12.9	WSW
W	872	1.16E-04	7.97E-05	6.59E-05	4.37E-05	2.43E-05	1.18E-05	21.7	W
WNW	902	1.02E-04	6.83E-05	5.59E-05	3.61E-05	1.94E-05	9.01E-06	12.5	WNW

Table 2.3-13 PAVAN Results for χ/Q Values at the EAB

Plant Name: North Anna ESP
Data Period: 1996-1998 JFD
Type of Release: Ground-Level Release
Source of Data: Onsite
Comments: Data period: 1/1/96 - 12/31/98
Program: PAVAN, 10/76, 8/79 Revision, Implementation of Regulatory Guide 1.145
0

Meteorological Instrumentation
Wind Sensors Height: 32.8 ft
ΔT Heights: 32.8 ft–158.9 ft

Relative Concentration (χ/Q) Values (sec/cubic meter) versus Averaging Time

Downwind Sector	Distance (Meters)	0–2 Hours	0–8 Hours	8–24 Hours	1–4 Days	4–30 Days	Annual Average	Hours Per Year Max 0-2 hr χ/Q Is Exceeded in Sector	Downwind Sector
NW	988	9.67E-05	6.40E-05	5.21E-05	3.33E-05	1.75E-05	7.98E-06	9.8	NW
NNW	1165	8.20E-05	5.17E-05	4.10E-05	2.49E-05	1.21E-05	5.04E-06	4.6	NNW
Max χ/Q		2.26E-04				Total Hours Around Site:		246.5	
Site Limit		1.56E-04	1.06E-04	8.78E-05	5.80E-05	3.19E-05	1.54E-05		

00.5 Percent χ/Q to an Individual Is Limiting

Table 2.3-14 PAVAN Results for χ/Q Values at the LPZ

USNRC Computer Code-PAVAN, Version 2.0

Plant Name: North Anna ESP
Data Period: 1996-1998 JFD
Type of Release: Ground-Level Release
Source of Data: Onsite
Comments: Data period: 1/1/96 - 12/31/98
Program: PAVAN, 10/76, 8/79 Revision, Implementation of Regulatory Guide 1.145
0 Relative Concentration (χ/Q) Values (sec/cubic meter) versus Averaging Time

Meteorological Instrumentation
Wind Sensors Height: 32.8 ft
ΔT Heights: 32.8 ft–158.9 ft

Downwind Sector	Distance (Meters)	0-2 Hours	0-8 Hours	8-24 Hours	1-4 Days	4-30 Days	Annual Average	Hours Per Year Max 0-2 hr χ/Q Is Exceeded in Sector	Downwind Sector
N	8843	1.47E-05	6.88E-06	4.70E-06	2.06E-06	6.30E-07	1.48E-07	2.3	N
NNE	8843	1.77E-05	8.35E-06	5.73E-06	2.53E-06	7.81E-07	1.86E-07	2.5	NNE
NE	8843	1.69E-05	7.83E-06	5.33E-06	2.31E-06	6.93E-07	1.59E-07	5.0	NE
ENE	8843	1.79E-05	7.72E-06	5.07E-06	2.03E-06	5.48E-07	1.10E-07	7.0	ENE
E	8843	2.86E-05	1.27E-05	8.46E-06	3.51E-06	9.90E-07	2.11E-07	15.8	E
ESE	8843	4.65E-05	2.05E-05	1.36E-05	5.58E-06	1.55E-06	3.25E-07	43.7	ESE
SE	8843	4.48E-05	1.88E-05	1.22E-05	4.74E-06	1.22E-06	2.34E-07	39.3	SE
SSE	8843	1.51E-05	6.72E-06	4.49E-06	1.87E-06	5.34E-07	1.15E-07	18.2	SSE
S	8843	6.73E-06	3.29E-06	2.30E-06	1.06E-06	3.49E-07	8.94E-08	5.7	S
SSW	8843	6.03E-06	2.90E-06	2.01E-06	9.08E-07	2.90E-07	7.19E-08	166.2	SSW
SW	8843	6.14E-06	2.90E-06	2.00E-06	8.86E-07	2.76E-07	6.61E-08	4.7	SW
WSW	8843	5.91E-06	2.78E-06	1.91E-06	8.41E-07	2.60E-07	6.18E-08	4.1	WSW
W	8843	8.48E-06	3.95E-06	2.69E-06	1.17E-06	3.56E-07	8.27E-08	8.6	W

Table 2.3-14 PAVAN Results for χ/Q Values at the LPZ

USNRC Computer Code-PAVAN, Version 2.0

Plant Name: North Anna ESP
Data Period: 1996-1998 JFD
Type of Release: Ground-Level Release
Source of Data: Onsite
Comments: Data period: 1/1/96 - 12/31/98
Program: PAVAN, 10/76, 8/79 Revision, Implementation of Regulatory Guide 1.145
0 Relative Concentration (χ/Q) Values (sec/cubic meter) versus Averaging Time

Meteorological Instrumentation
Wind Sensors Height: 32.8 ft
ΔT Heights: 32.8 ft–158.9 ft

Downwind Sector	Distance (Meters)	0-2 Hours	0-8 Hours	8-24 Hours	1-4 Days	4-30 Days	Annual Average	Hours Per Year Max 0-2 hr χ/Q Is Exceeded in Sector	Downwind Sector
WNW	8843	7.81E-06	3.55E-06	2.39E-06	1.02E-06	2.97E-07	6.61E-08	4.7	WNW
NW	8843	8.54E-06	3.86E-06	2.59E-06	1.10E-06	3.18E-07	7.00E-08	3.2	NW
NNW	8843	8.42E-06	3.71E-06	2.46E-06	1.01E-06	2.83E-07	5.94E-08	2.4	NNW
Max χ/Q		4.65E-05				Total Hours Around Site:		333.6	
Site Limit		2.72E-05	1.31E-05	9.07E-06	4.10E-06	1.31E-06	3.25E-07		

00.5 Percent χ/Q to an Individual Is Limiting

Table 2.3-15 ESP Application Nearby Sensitive Receptors

	Nearest Resident		Nearest Site Boundary		Milk* Cow	Meat Animal		Milk* Goat	Veg. Garden 500 ft^2	
Sector	(mile)	(km)	(mile)	(km)		(mile)	(km)		(mile)	(km)
N	1.48	2.38	0.87	1.40		2.18	3.51		1.78	2.86
NNE	0.96	1.54	0.88	1.42		1.56	2.51		1.66	2.67
NE	0.94	1.51	0.90	1.45		1.44	2.32		0.94	1.51
ENE	2.18	3.51	0.91	1.47		2.58	4.15		2.18	3.51
E	1.38	2.22	0.89	1.43		3.58	5.76		1.38	2.22
ESE	1.77	2.85	0.88	1.42		None	None		3.57	5.74
SE	1.37	2.20	0.83	1.34		1.37	2.20		1.37	2.20
SSE	0.91	1.46	0.73	1.17		2.71	4.36		1.21	1.95
S	1.01	1.63	0.62	0.99		None	None		1.11	1.79
SSW	1.1	1.77	0.57	0.92		1.90	3.06		1.50	2.41
SW	2.78	4.47	0.54	0.87		None	None		2.78	4.47
WSW	1.22	1.96	0.55	0.88		1.22	1.96		1.52	2.45
W	1.30	2.09	0.54	0.87		4.20	6.76		4.80	7.72
WNW	0.98	1.58	0.56	0.90		3.98	6.40		None	None
NW	0.88	1.42	0.62	0.99		None	None		0.98	1.58
NNW	0.93	1.50	0.72	1.16		1.93	3.11		1.13	1.82

Note: No milk cow or goats within a 5-mile radius of the NAPS. Source: Reference 37.

Table 2.3-16 XOQDOQ Predicted Maximum χ/Q and D/Q Values at Specific Points of Interest

Type of Location	Direction from Site	Distance (miles)	χ/Q (No Decay)	χ/Q (2.26 Day Decay)	χ/Q (8 Day Decay)	D/Q
Residence	NNE	0.96	2.4E-06	2.4E-06	2.1E-06	7.2E-09
EAB	ESE	0.88	3.7E-06	3.7E-06	3.3E-06	1.2E-08[a]
Meat Animal	SE	1.37	1.4E-06	1.4E-06	1.2E-06	3.1E-09[b]
Veg. Garden	NE	0.94	2.0E-06	2.0E-06	1.8E-06	6.0E-09

Notes:
χ/Q – sec/m^3
D/Q – $1/m^2$

a. direction = south

b. direction = north-northeast

Table 2.3-17 XOQDOQ Predicted Maximum Annual Averages (Ground-Level Release)

No Decay Undepleted

	Distance in Miles From the Site										
ESE	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
χ/Q (s/m^3)	2.685E-5	8.740E-6	4.697E-6	3.103E-6	1.742E-6	1.163E-6	8.527E-7	6.634E-7	5.373E-7	4.482E-7	3.822E-7
	Distance in Miles From the Site										
ESE	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00
χ/Q (s/m^3)	3.317E-7	1.934E-7	1.325E-7	7.833E-8	5.418E-8	4.079E-8	3.239E-8	2.668E-9	2.257E-8	1.948E-8	1.709E-8
	Segment Boundaries in Miles From the Site										
ESE	0.5 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 10	10 – 20	20 - 30	30 - 40	40 - 50	
χ/Q (s/m^3)	4.887E-6	1.787E-6	8.596E-7	5.394E-7	3.831E-7	1.971E-7	7.964E-8	4.100E-8	2.675E-8	1.951E-8	

2.26 Day Decay, Undepleted

	Distance in Miles From the Site										
ESE	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
χ/Q (s/m^3)	2.681E-5	8.712E-6	4.674E-6	3.083E-6	1.725E-6	1.148E-6	8.388E-7	6.504E-7	5.251E-7	4.365E-7	3.711E-7
	Distance in Miles From the Site										
ESE	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00
χ/Q (s/m^3)	3.210E-7	1.841E-7	1.241E-7	7.095E-8	4.750E-8	3.462E-8	2.662E-8	2.124E-8	1.740E-8	1.455E-8	1.237E-8
	Segment Boundaries in Miles From the Site										
ESE	0.5 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 10	10 – 20	20 - 30	30 - 40	40 - 50	
χ/Q (s/m^3)	4.864E-6	1.770E-6	8.458E-7	5.272E-7	3.719E-7	1.878E-7	7.233E-8	3.485E-8	2.131E-8	1.459E-8	

Table 2.3-17 XOQDOQ Predicted Maximum Annual Averages (Ground-Level Release)

8.0 Day Decay, Depleted

	Distance in Miles From the Site										
ESE	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
χ/Q (s/m^3)	2.540E-5	7.974E-6	4.180E-6	2.711E-6	1.475E-6	9.592E-7	6.875E-7	5.240E-7	4.166E-7	3.415E-7	2.866E-7
	Distance in Miles From the Site										
ESE	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00
χ/Q (s/m^3)	2.450E-7	1.344E-7	8.739E-8	4.735E-8	3.047E-8	2.153E-8	1.614E-8	1.261E-8	1.015E-8	8.357E-9	7.007E-9
	Segment Boundaries in Miles From the Site										
ESE	0.5 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 10	10 - 20	20 - 30	30 - 40	40 - 50	
χ/Q (s/m^3)	4.370E-6	1.521E-6	6.945E-7	4.187E-7	2.874E-7	1.381E-7	4.874E-8	2.176E-8	1.268E-8	8.388E-9	

Relative Deposition/Area

	Distance in Miles from Site										
NNE	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
D/Q ($1/m^2$)	6.2570E-8	2.116E-8	1.086E-8	6.671E-9	3.326E-9	2.017E-9	1.364E-9	9.882E-10	7.514E-10	5.920E-10	4.793E-10
	Distance in Miles from Site										
NNE	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00
D/Q ($1/m^2$)	3.964E-10	1.943E-10	1.219E-10	6.161E-11	3.729E-11	2.500E-11	1.792E-11	1.345E-11	1.046E-11	8.355E-12	6.820E-12
	Segment Boundaries in Miles From the Site										
NNE	0.5 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 10	10 - 20	20 - 30	30 - 40	40 - 50	
D/Q ($1/m^2$)	1.129E-8	3.487E-9	1.388E-9	7.583E-10	4.820E-10	2.070E-10	6.420E-10	2.544E-11	1.359E-11	8.410E-12	

Table 2.3-18 Selected Site Characteristic Ambient Dry-Bulb and Wet-Bulb Temperatures

Parameter		Temperature (°F)
Maximum Dry-Bulb	2% annual exceedance	90 (75 concurrent wet-bulb)
	0.4% annual exceedance	95 (77 concurrent wet-bulb)
	0% exceedance	104.9 (79 concurrent wet-bulb)
	100-year return period	109
Minimum Dry-bulb	1% annual exceedance	18
	0.4% annual exceedance	14
	100-year return period	–19
Maximum Wet-bulb	0.4% annual exceedance	79
	0% exceedance	84.9
	100-year return period	88

Sources: Exceedance temperatures from Reference 41; 100-year return period temperatures calculated using data from Reference 42, Reference 43, and Reference 44.

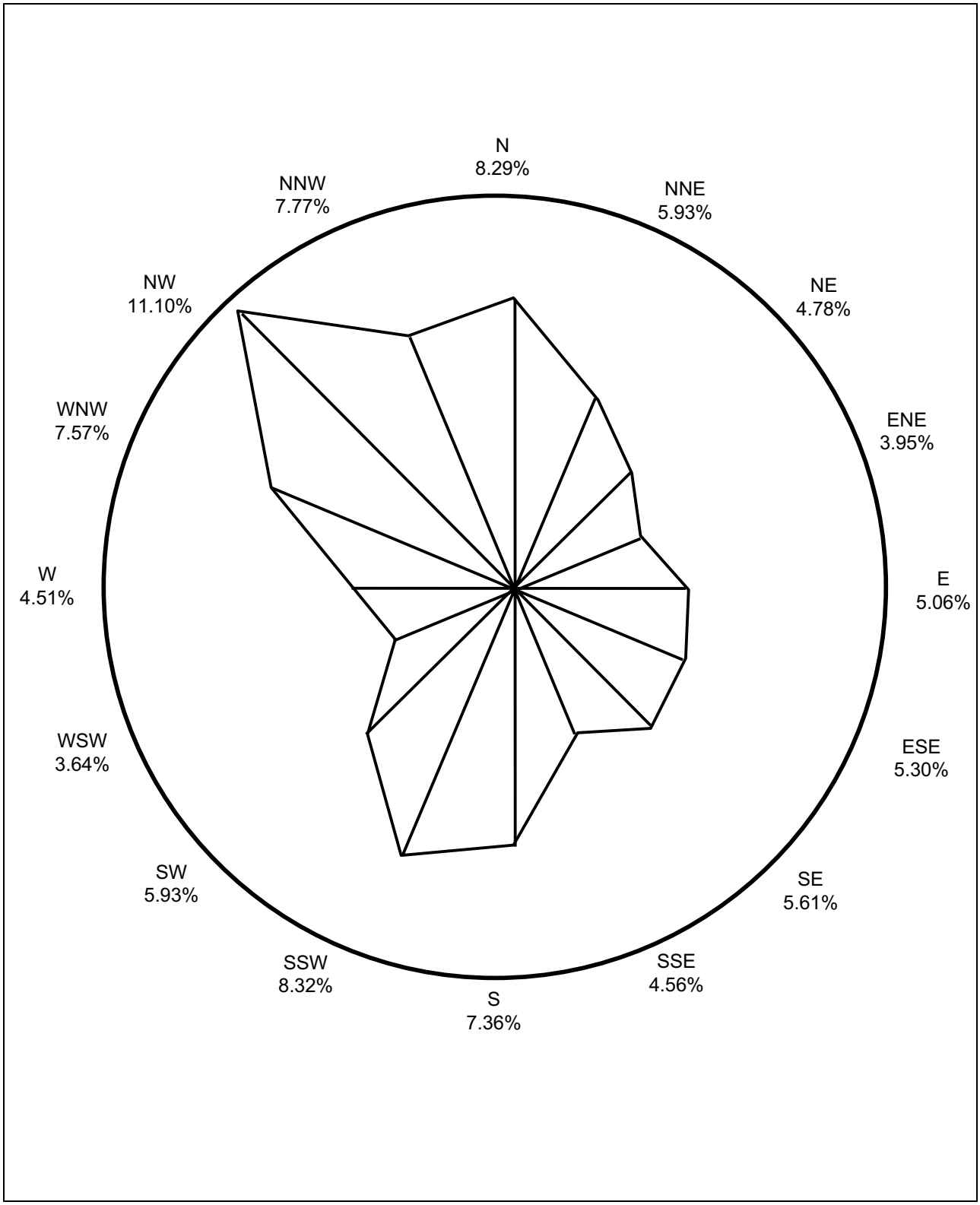


Figure 2.3-1 North Anna Seasonal Wind Direction Roses: Low-Level Winds: 1974–1987: Season = Spring

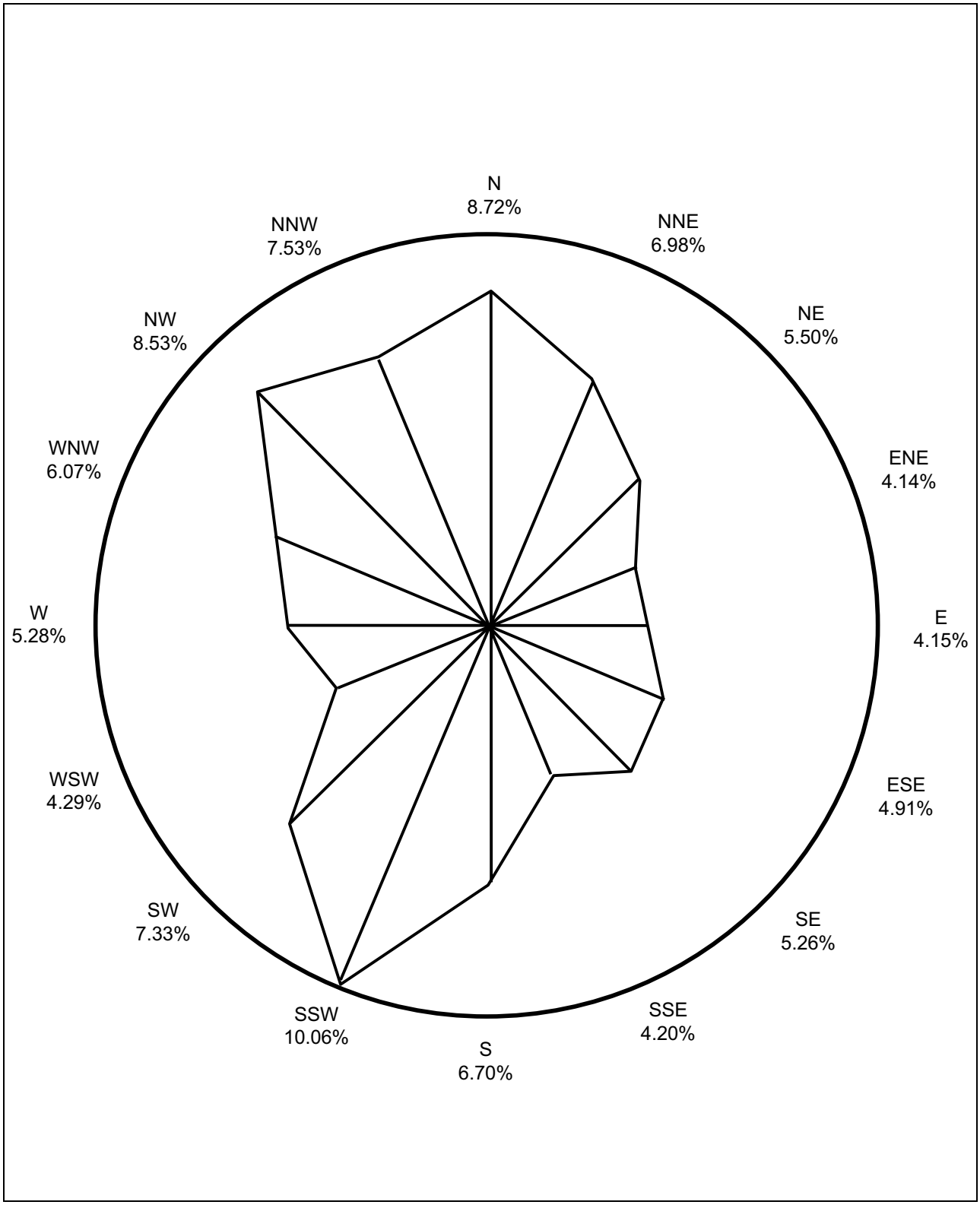


Figure 2.3-2 North Anna Seasonal Wind Direction Roses: High-Level Winds: 1974–1987: Season = Spring

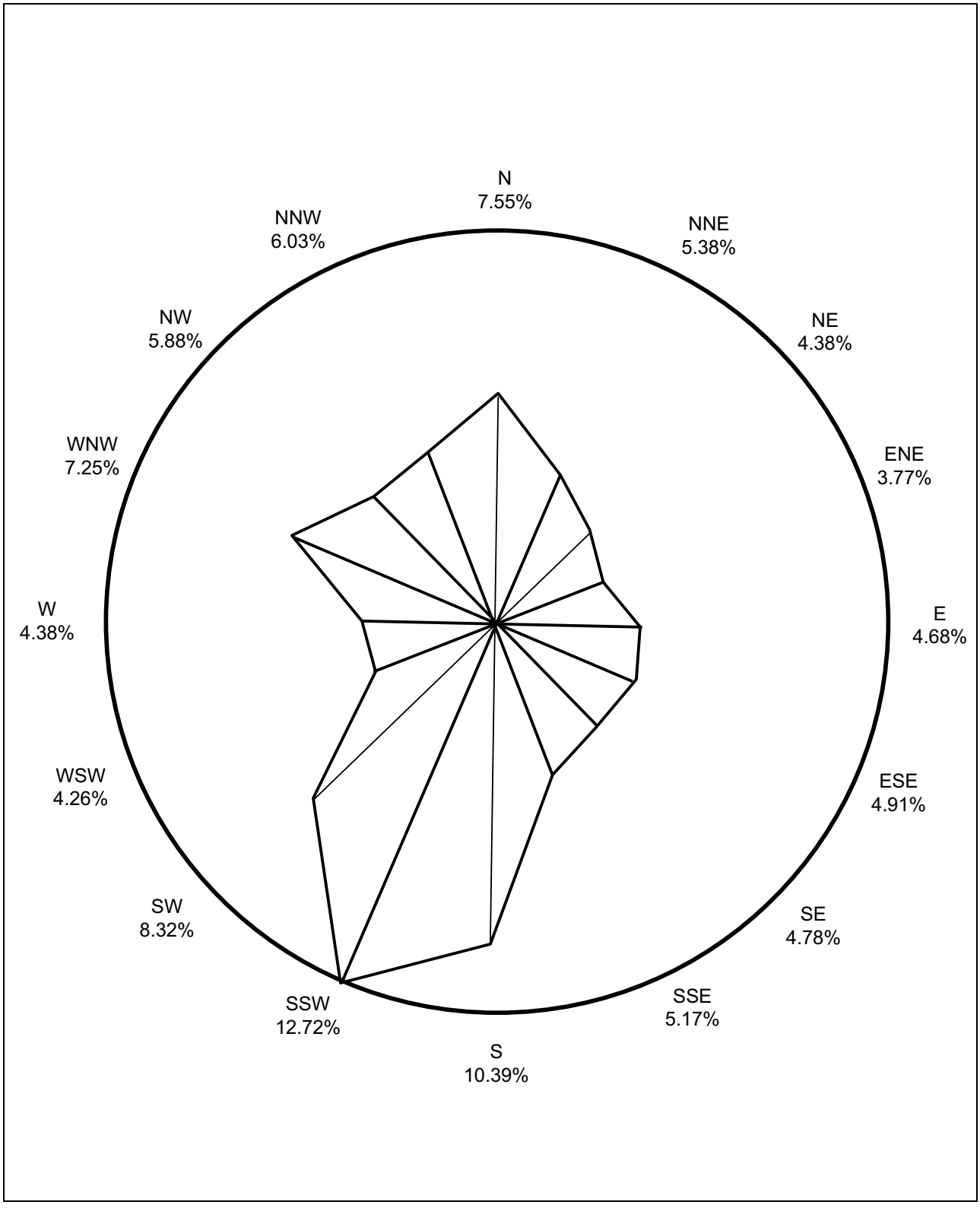


Figure 2.3-3 North Anna Seasonal Wind Direction Roses: Low-Level Winds: 1974–1987: Season = Summer

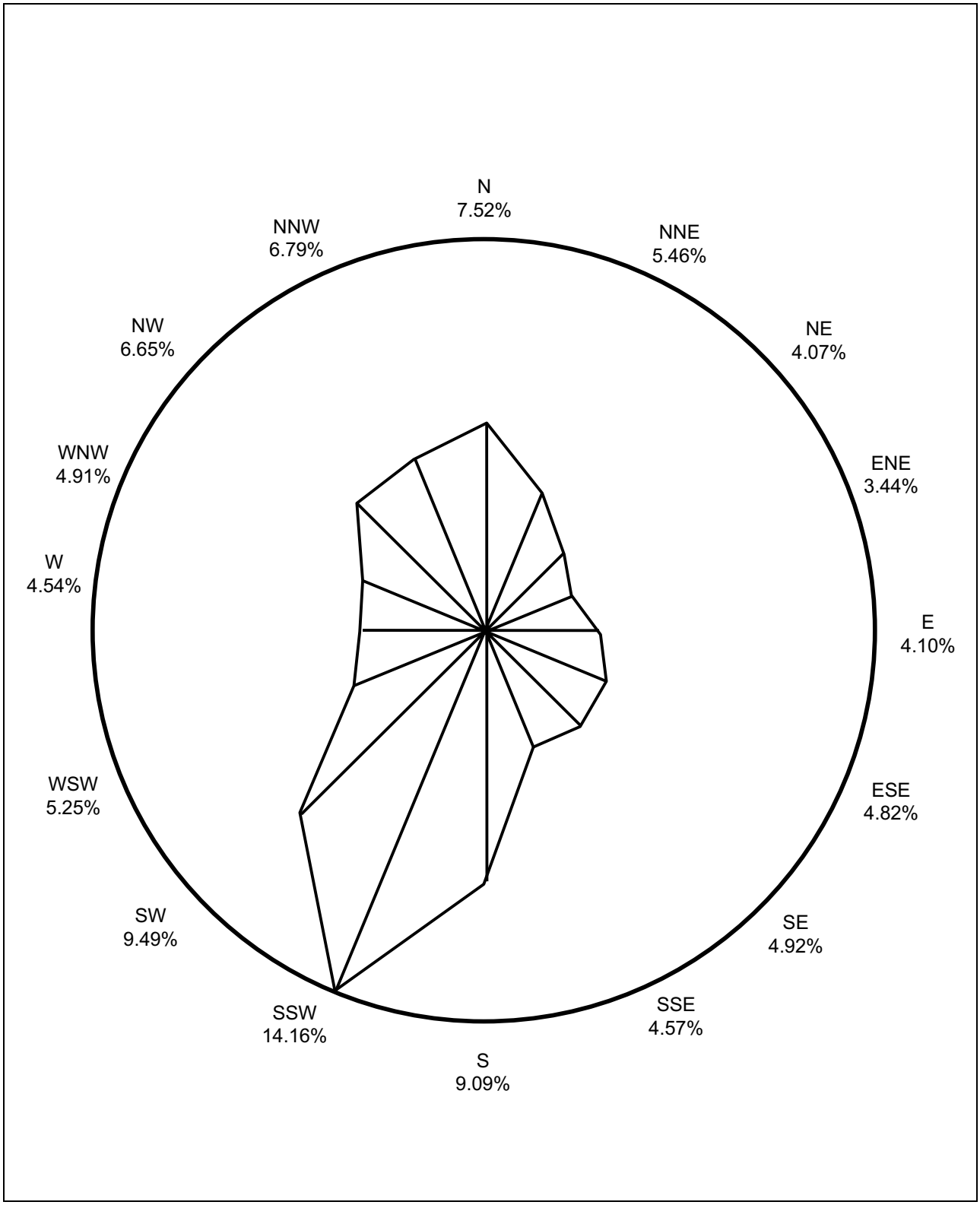


Figure 2.3-4 North Anna Seasonal Wind Direction Roses: High-Level Winds: 1974–1987: Season = Summer

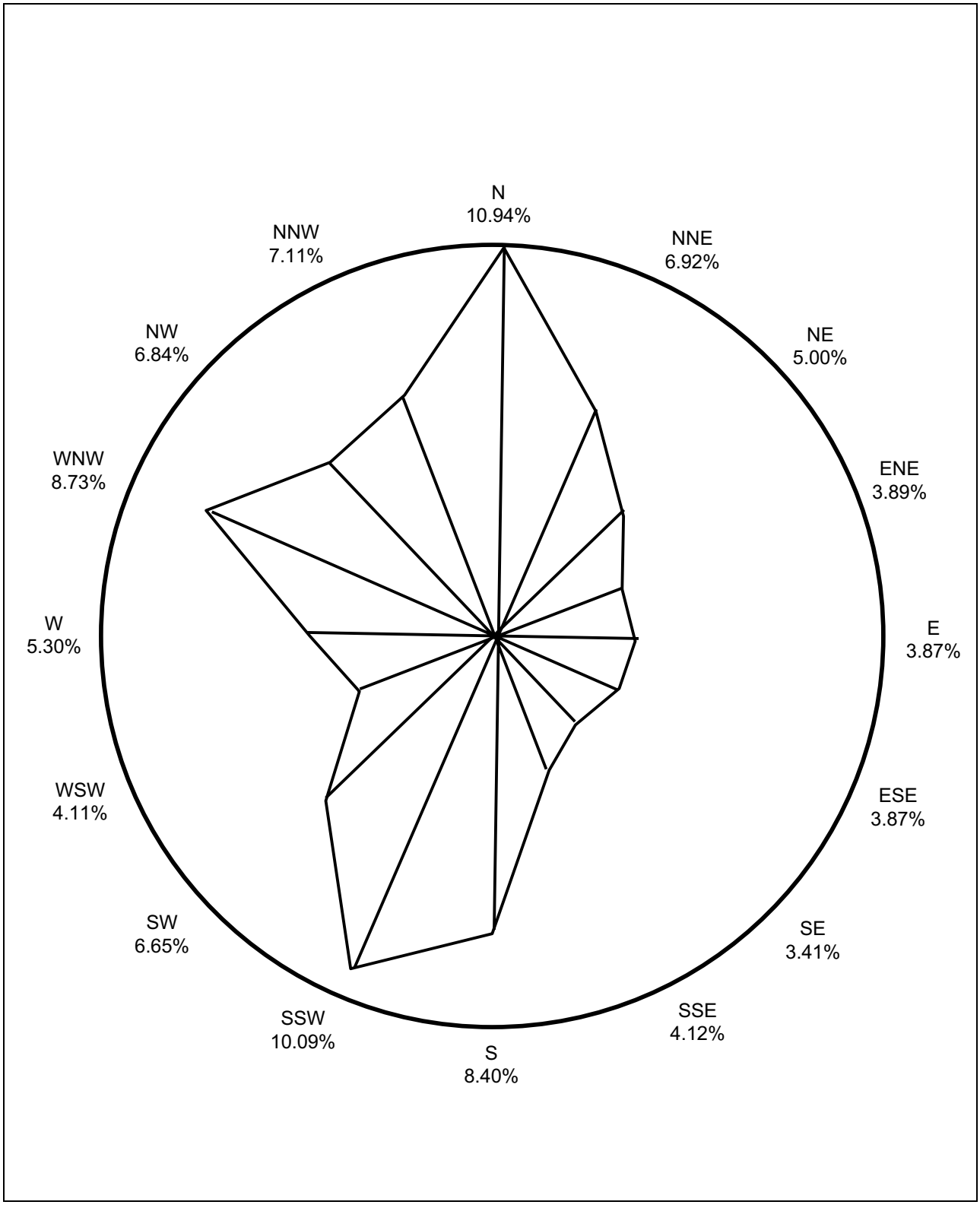


Figure 2.3-5 North Anna Seasonal Wind Direction Roses: Low-Level Winds: 1974–1987: Season = Fall

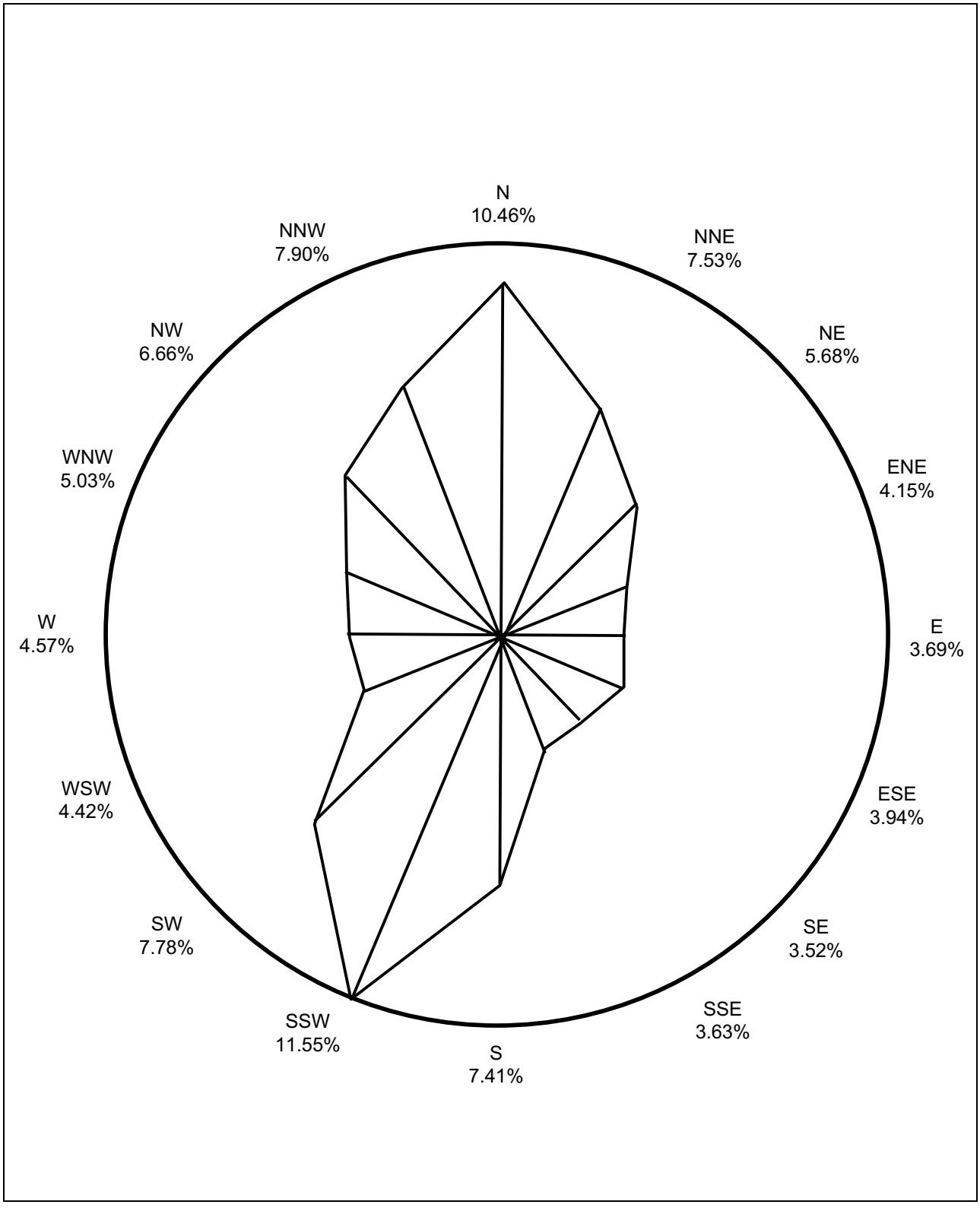


Figure 2.3-6 North Anna Seasonal Wind Direction Roses: High-Level Winds: 1974–1987: Season = Fall

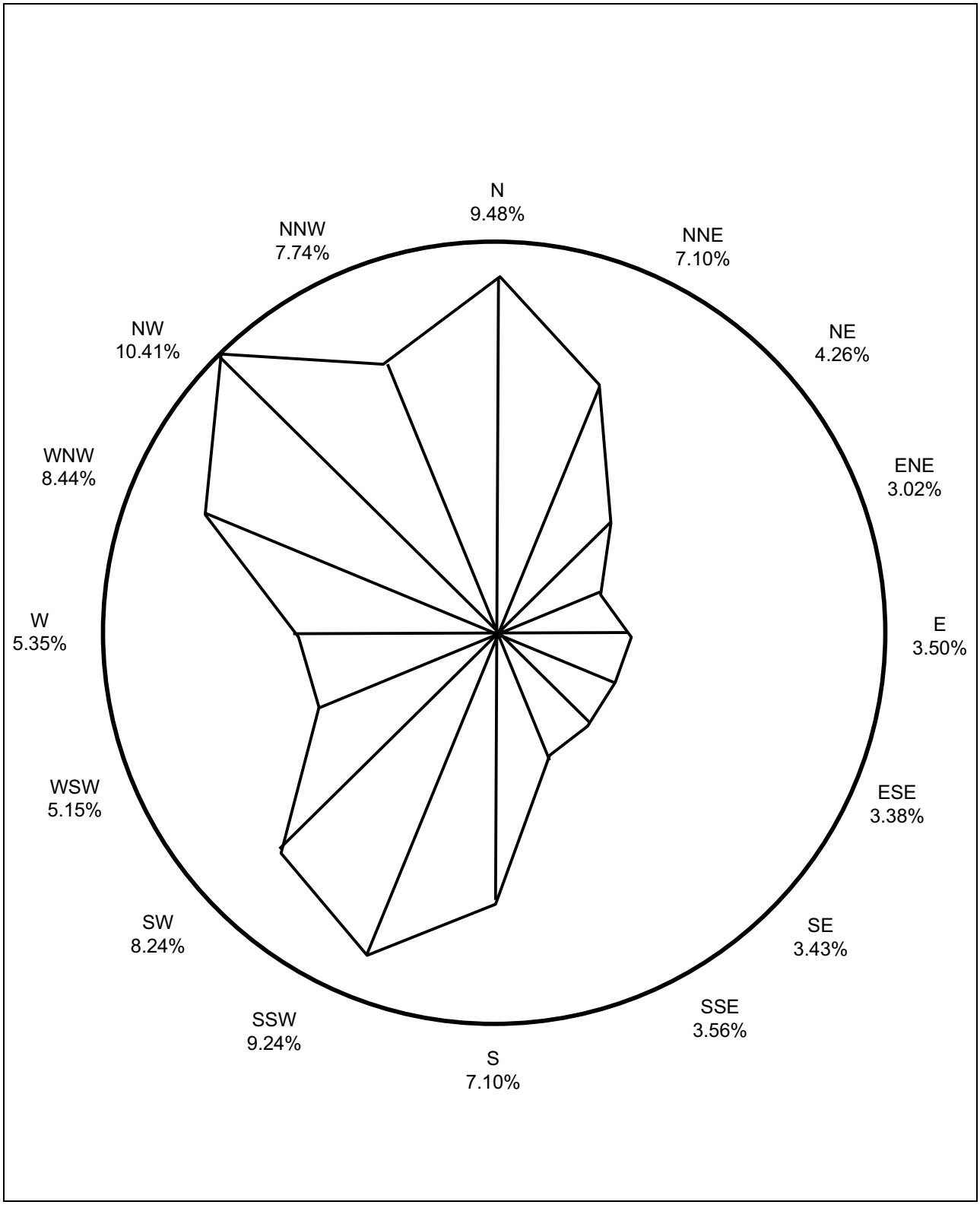


Figure 2.3-7 North Anna Seasonal Wind Direction Roses: Low-Level Winds: 1974–1987: Season = Winter

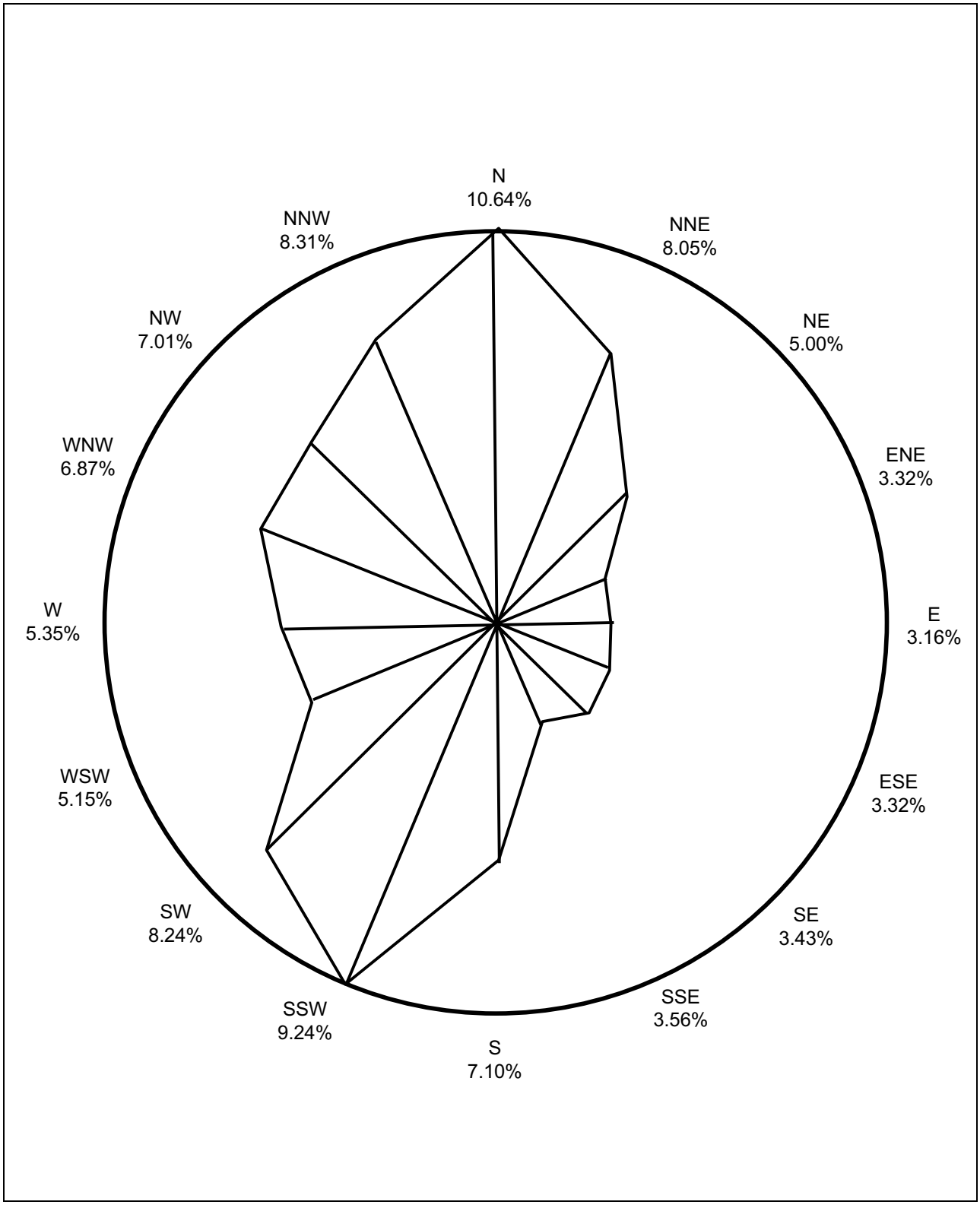


Figure 2.3-8 North Anna Seasonal Wind Direction Roses: High-Level Winds: 1974–1987: Season = Winter

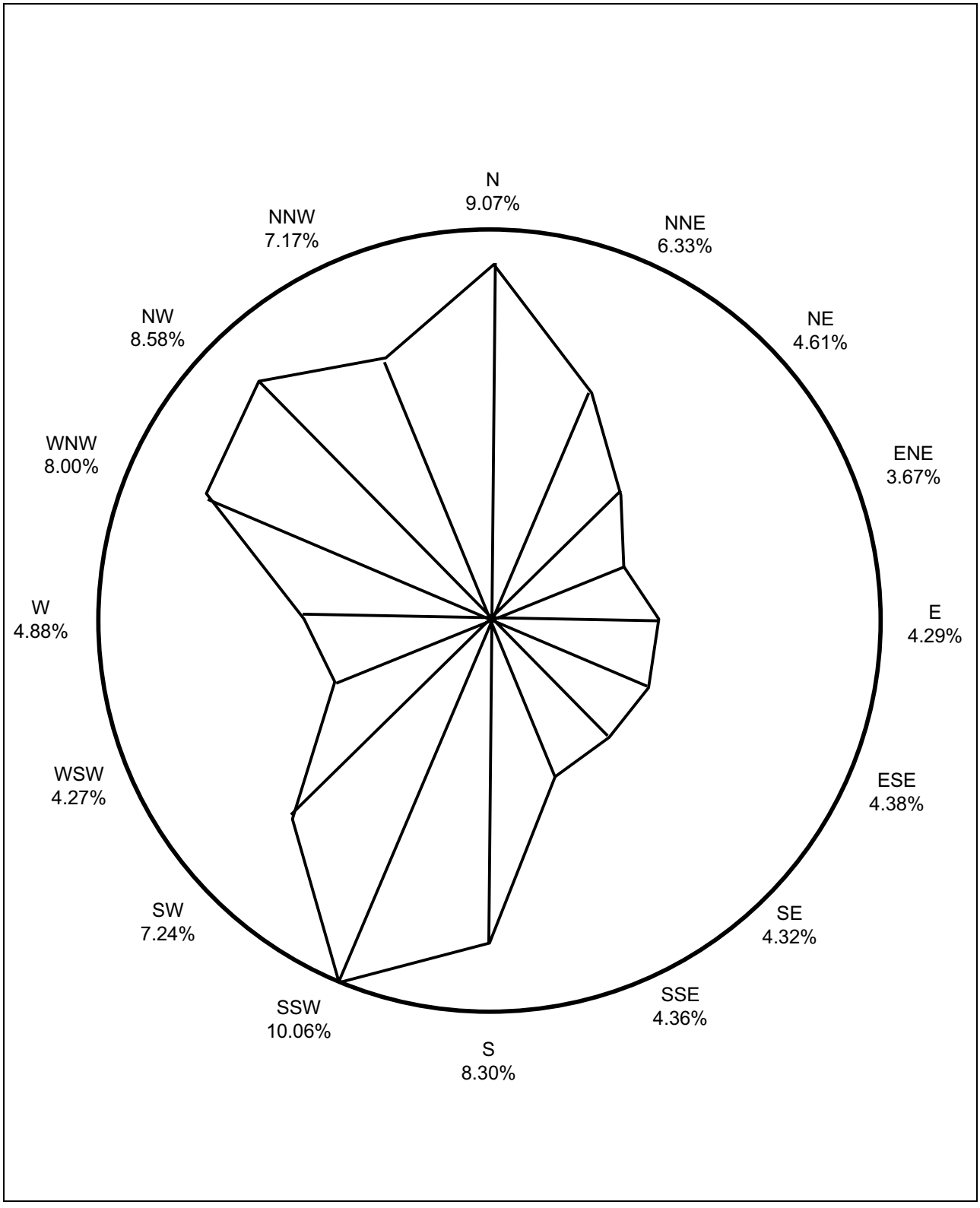


Figure 2.3-9 North Anna Seasonal Wind Direction Roses: Low-Level Winds: 1974–1987: Season = Overall

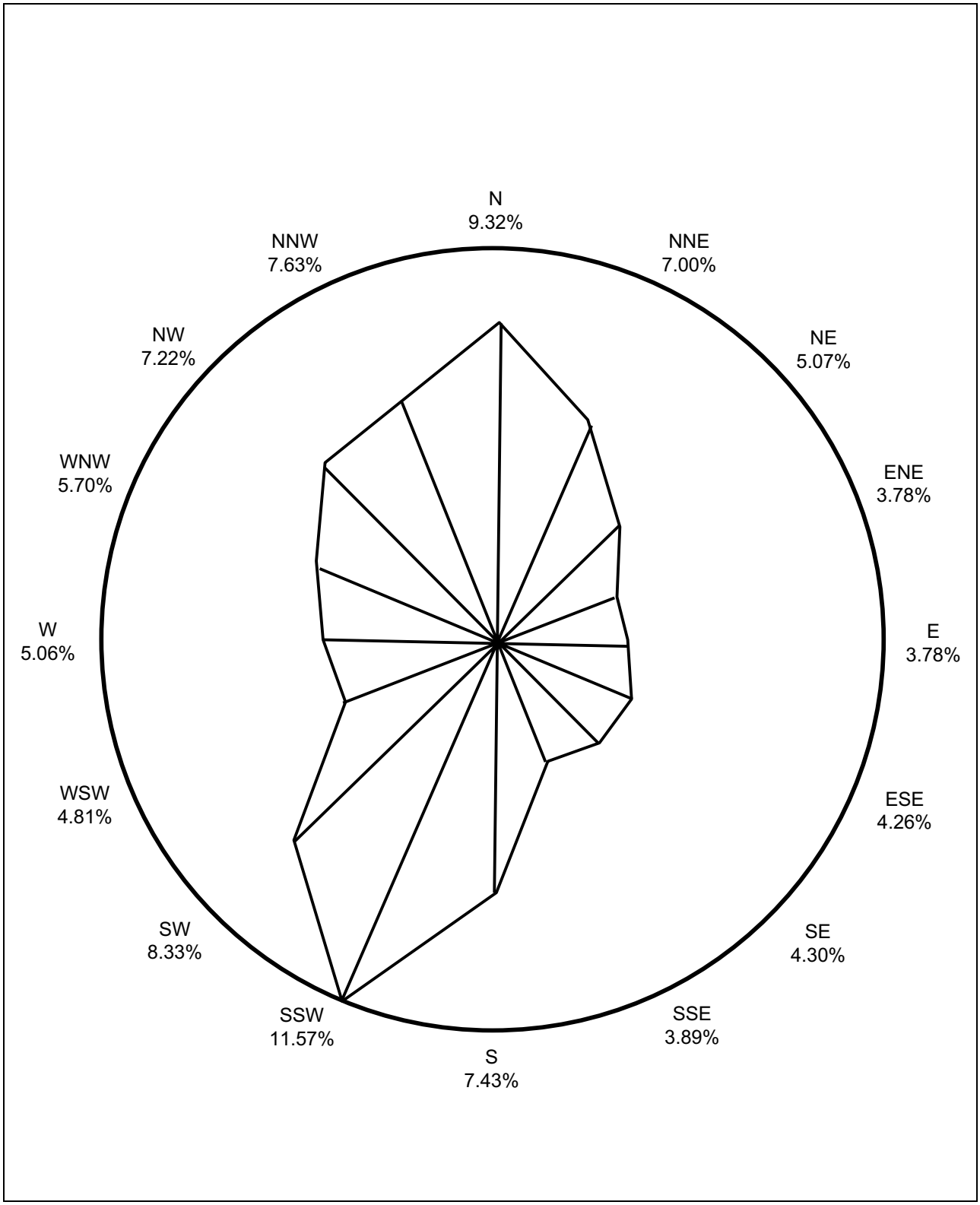


Figure 2.3-10 North Anna Seasonal Wind Direction Roses: High-Level Winds: 1974–1987: Season = Overall

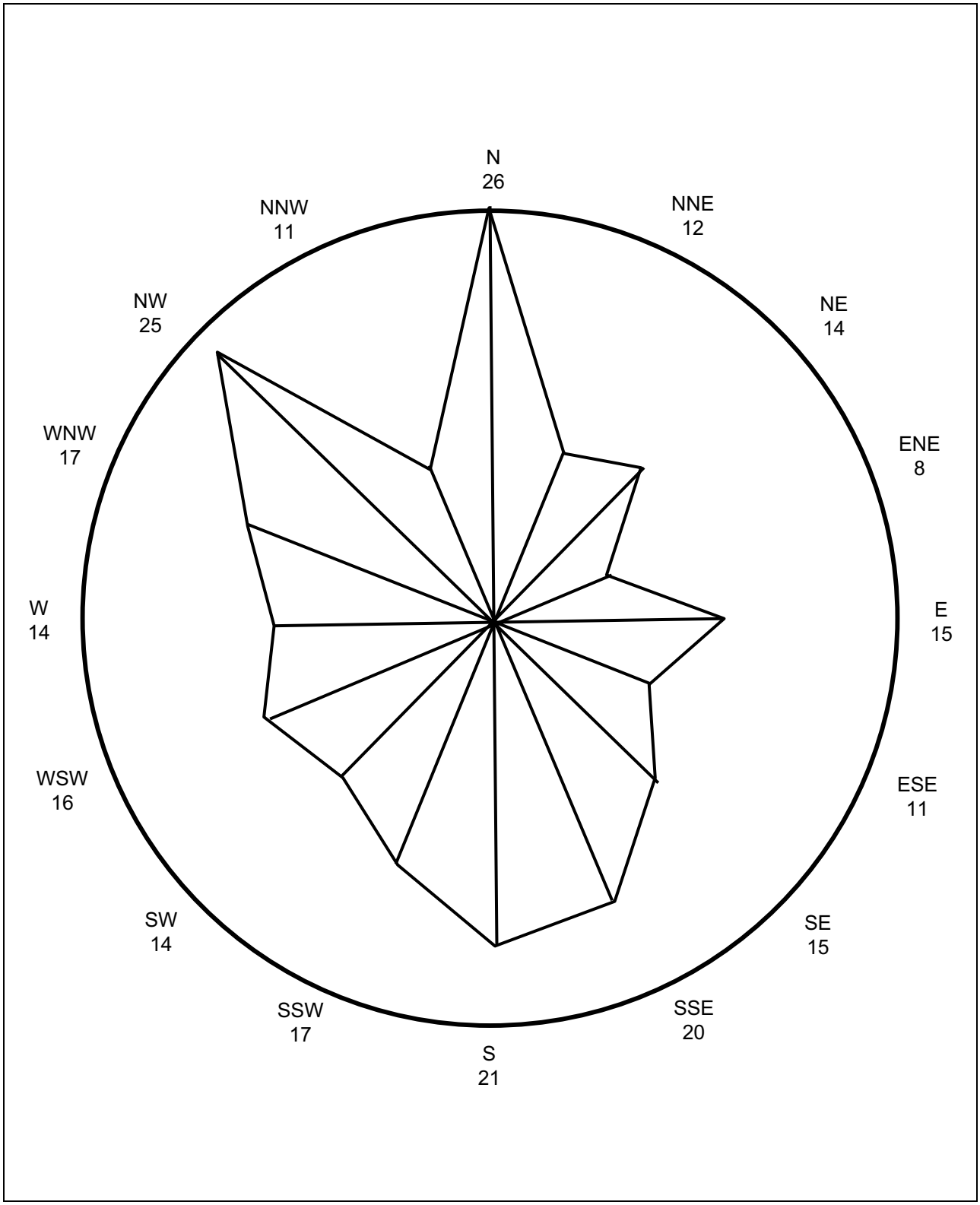


Figure 2.3-11 North Anna Seasonal Wind Persistence Roses: Low-Level Winds: 1974–1987: Season = Spring

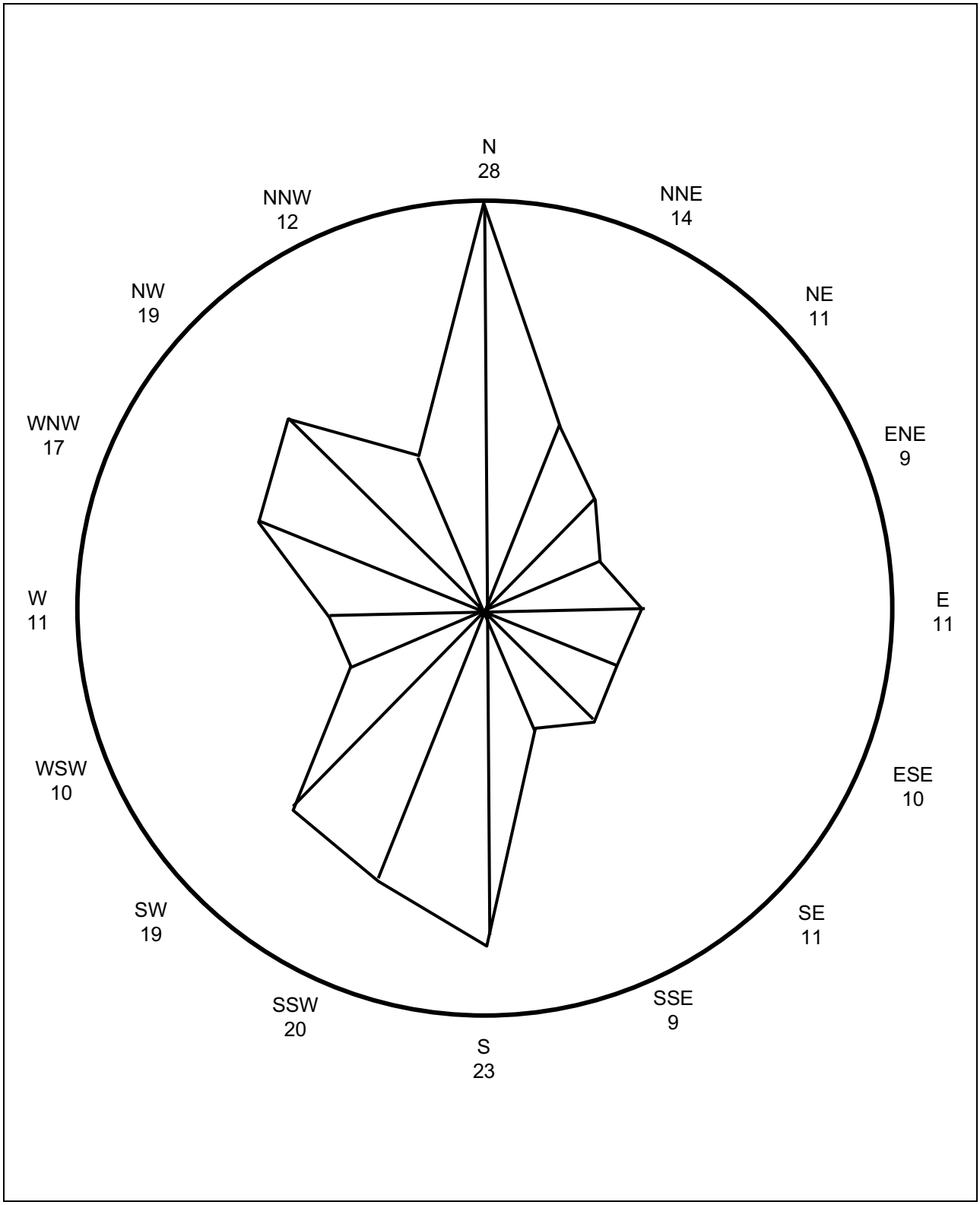


Figure 2.3-12 North Anna Seasonal Wind Persistence Roses: High-Level Winds: 1974–1987: Season = Spring

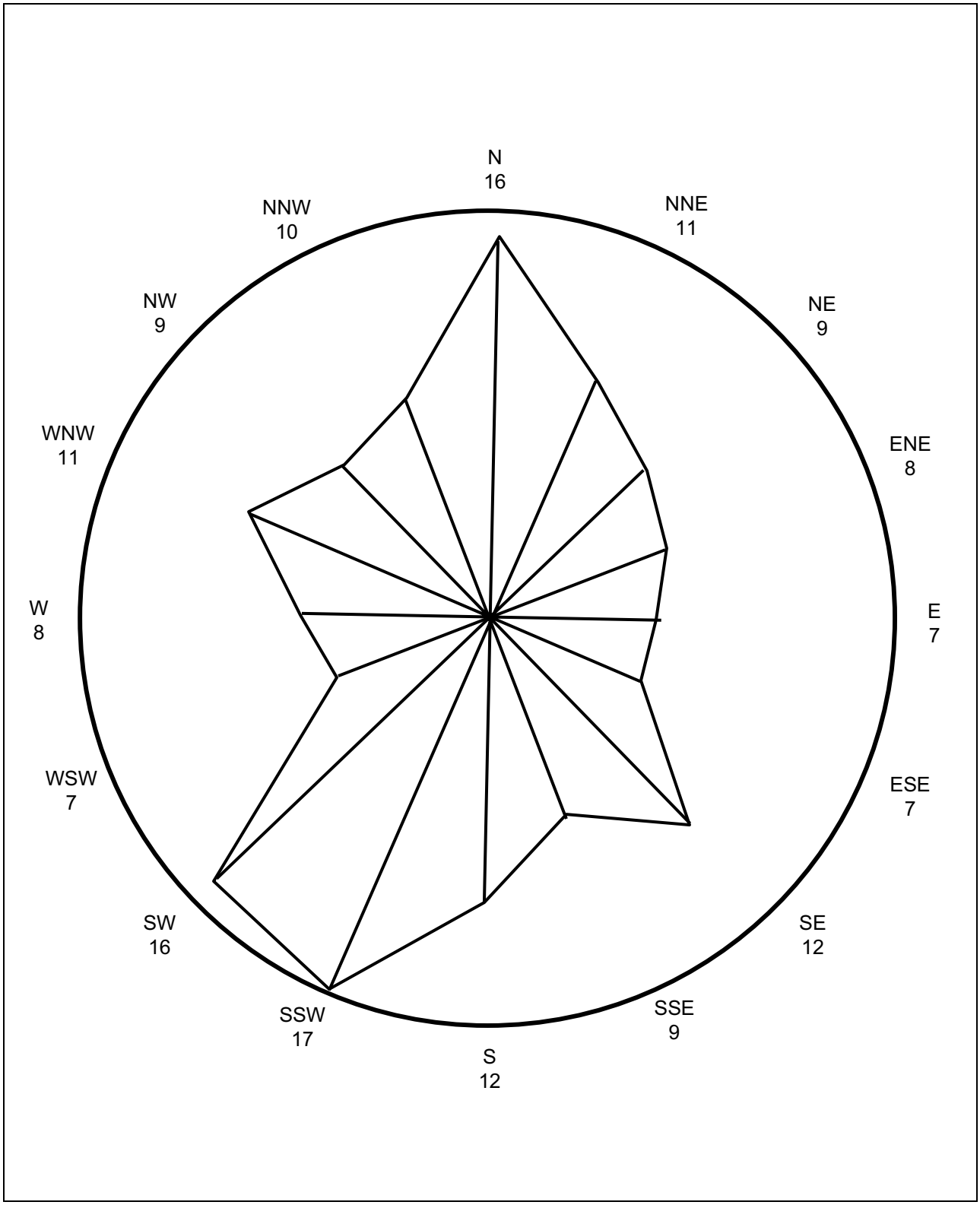


Figure 2.3-13 North Anna Seasonal Wind Persistence Roses: Low-Level Winds: 1974–1987: Season = Summer

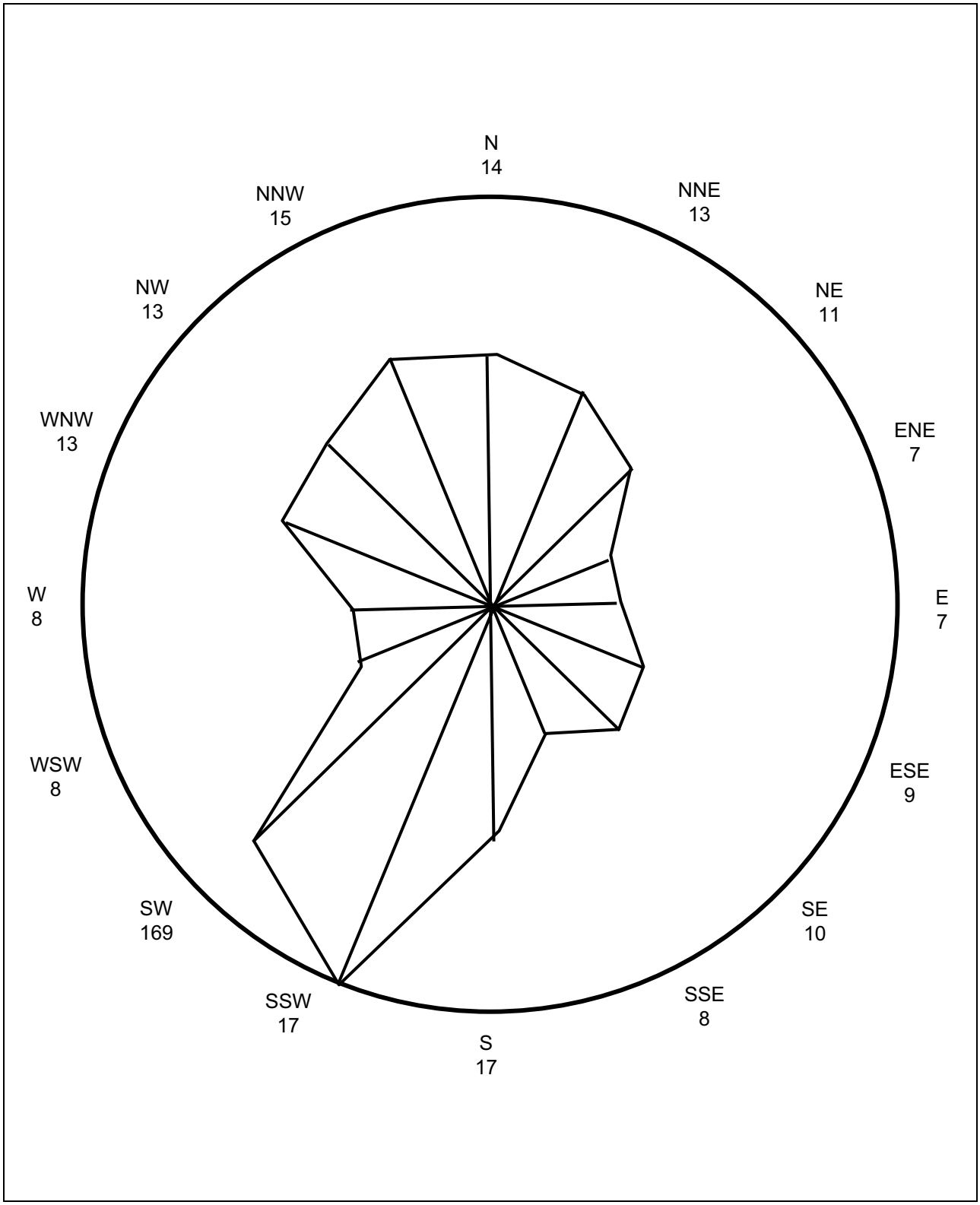


Figure 2.3-14 North Anna Seasonal Wind Persistence Roses: High-Level Winds: 1974–1987: Season = Summer

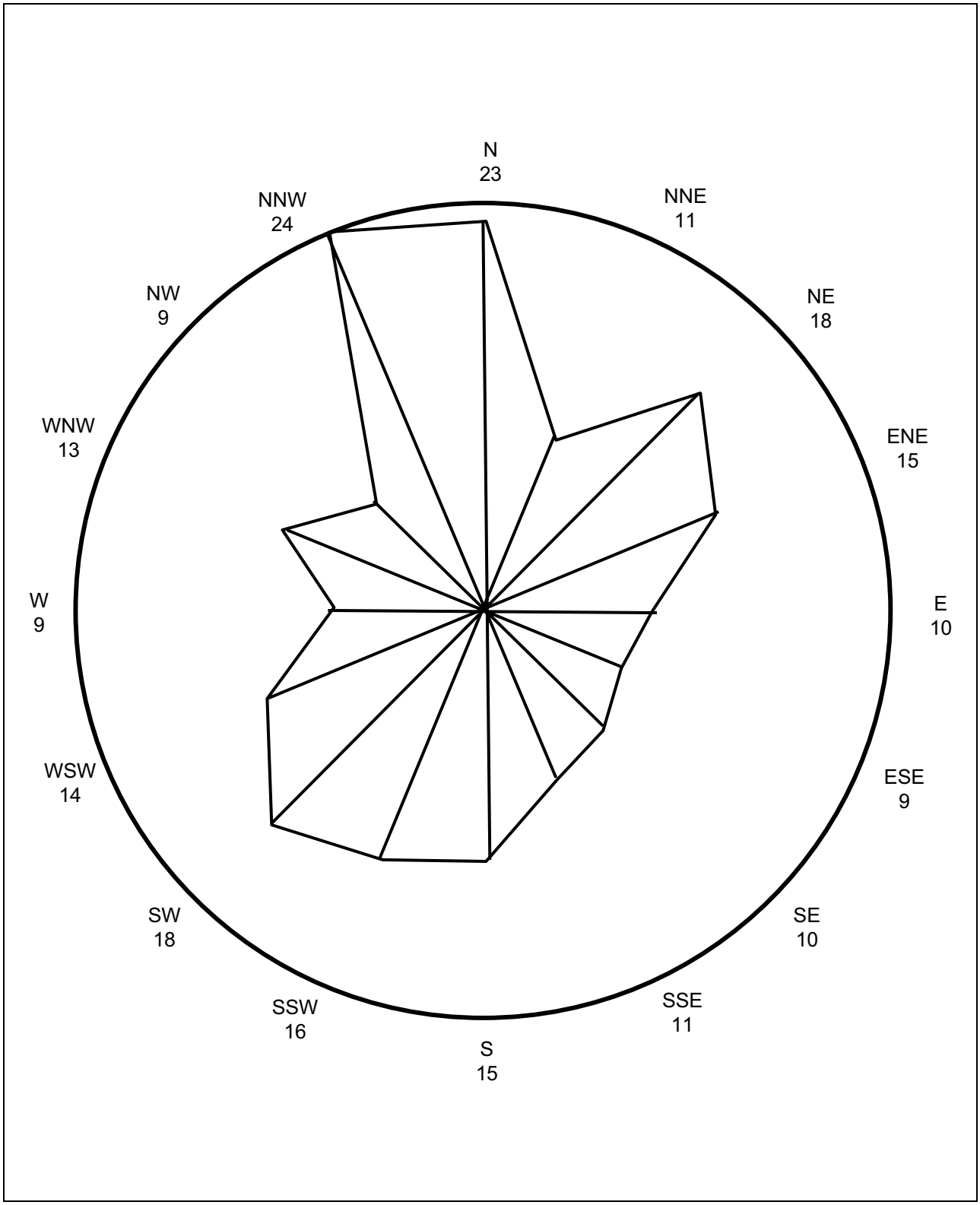


Figure 2.3-15 North Anna Seasonal Wind Persistence Roses: Low-Level Winds: 1974–1987: Season = Fall

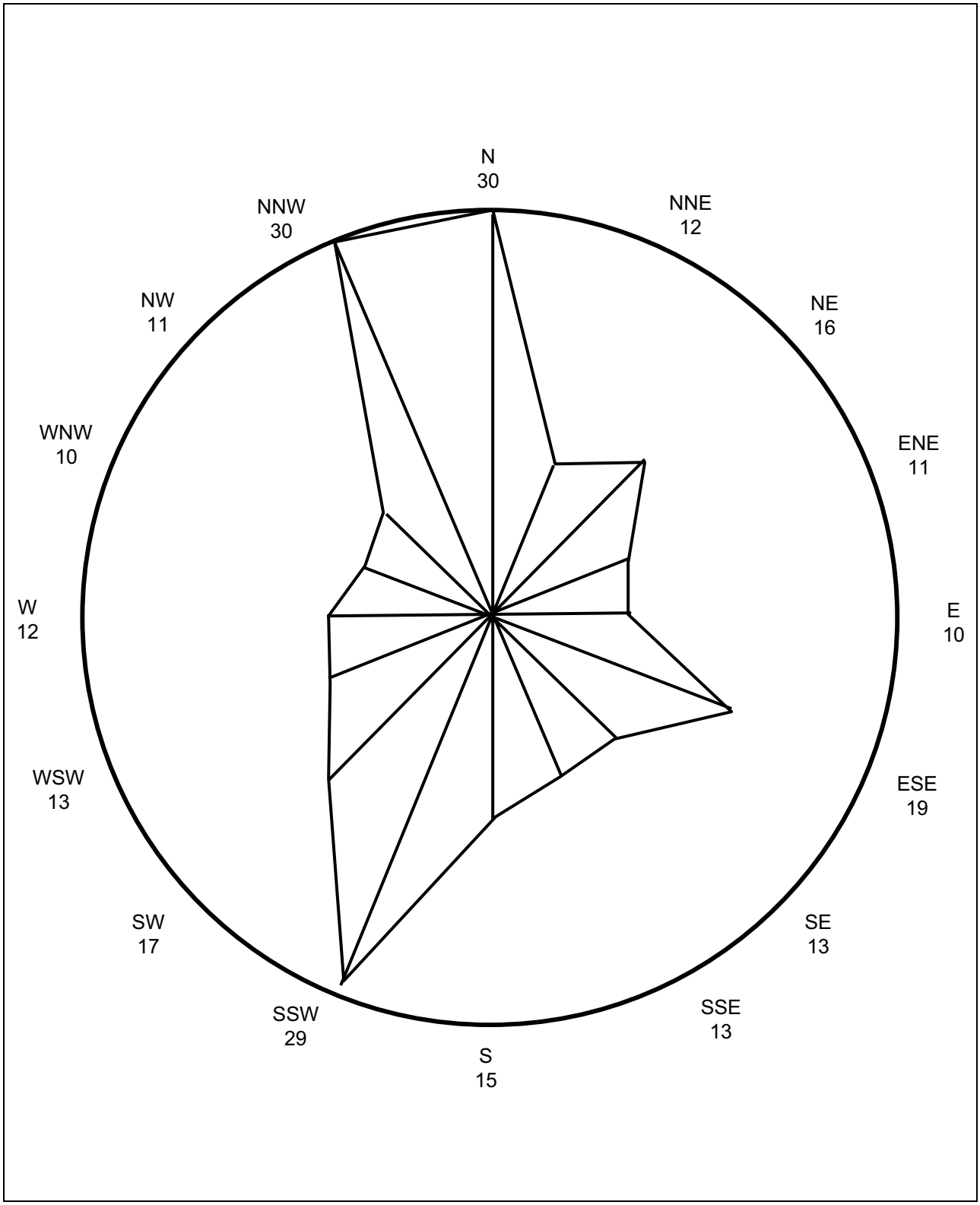


Figure 2.3-16 North Anna Seasonal Wind Persistence Roses: High-Level Winds: 1974–1987: Season = Fall

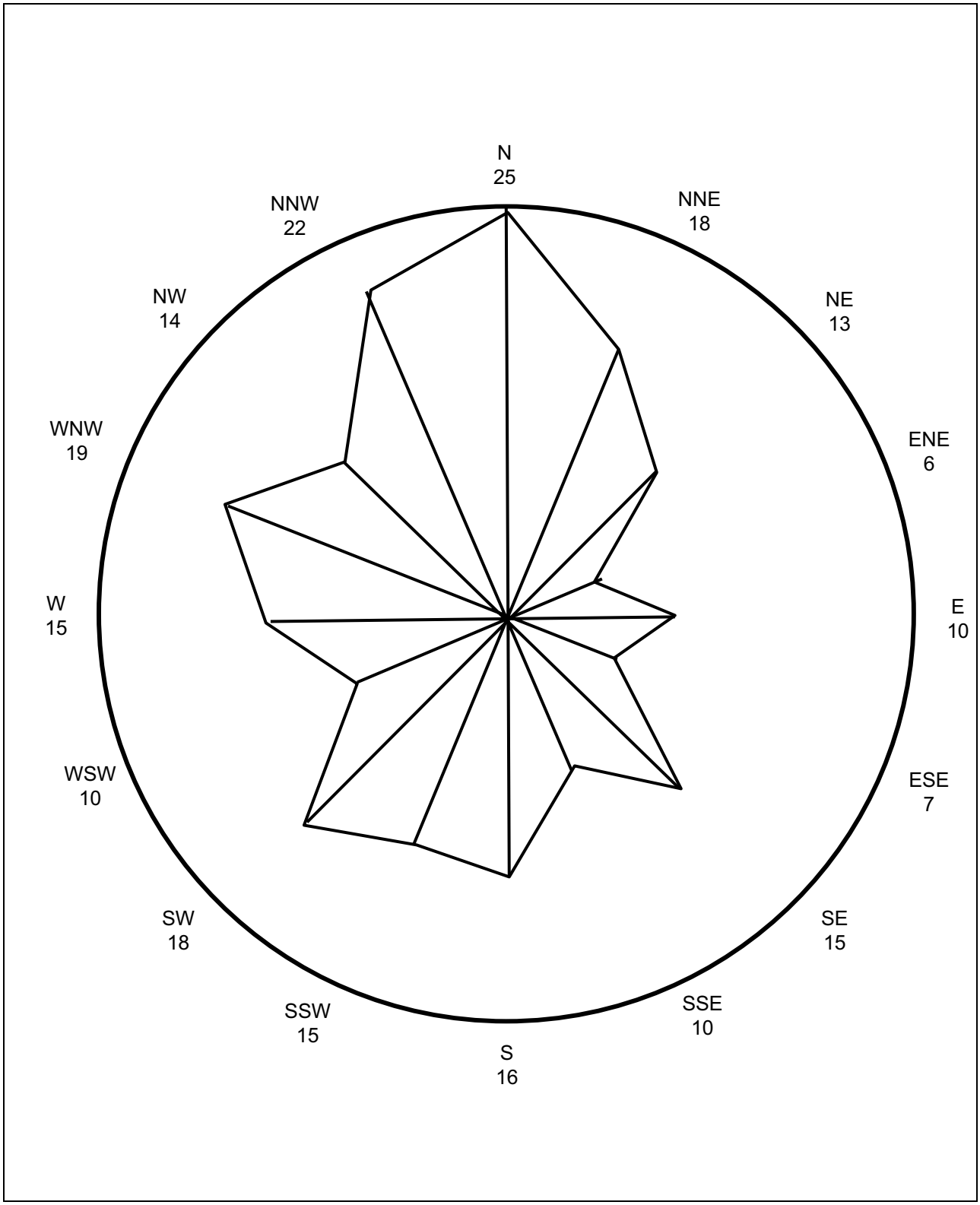


Figure 2.3-17 North Anna Seasonal Wind Persistence Roses: Low-Level Winds: 1974–1987: Season = Winter

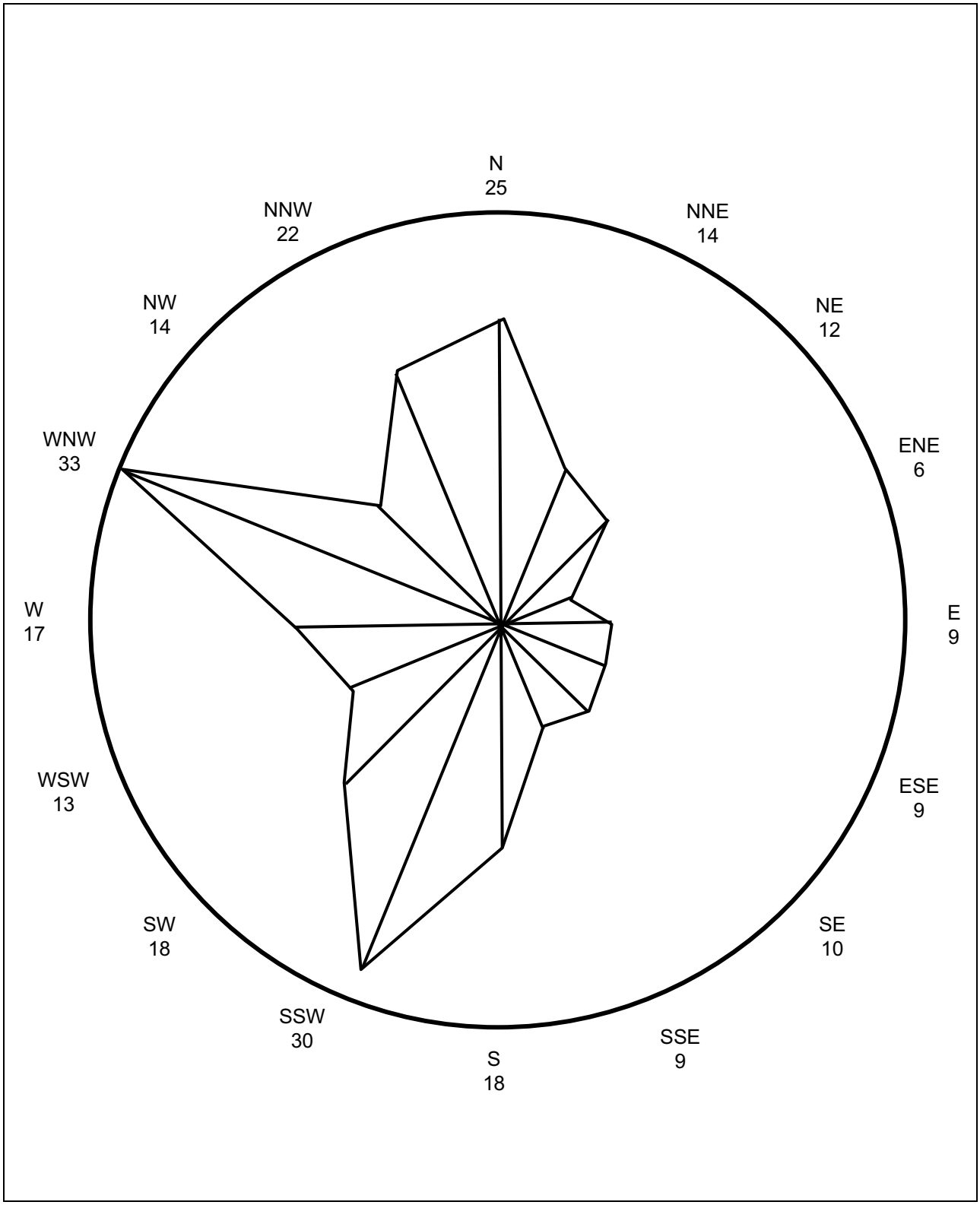


Figure 2.3-18 North Anna Seasonal Wind Persistence Roses: High-Level Winds: 1974–1987: Season = Winter

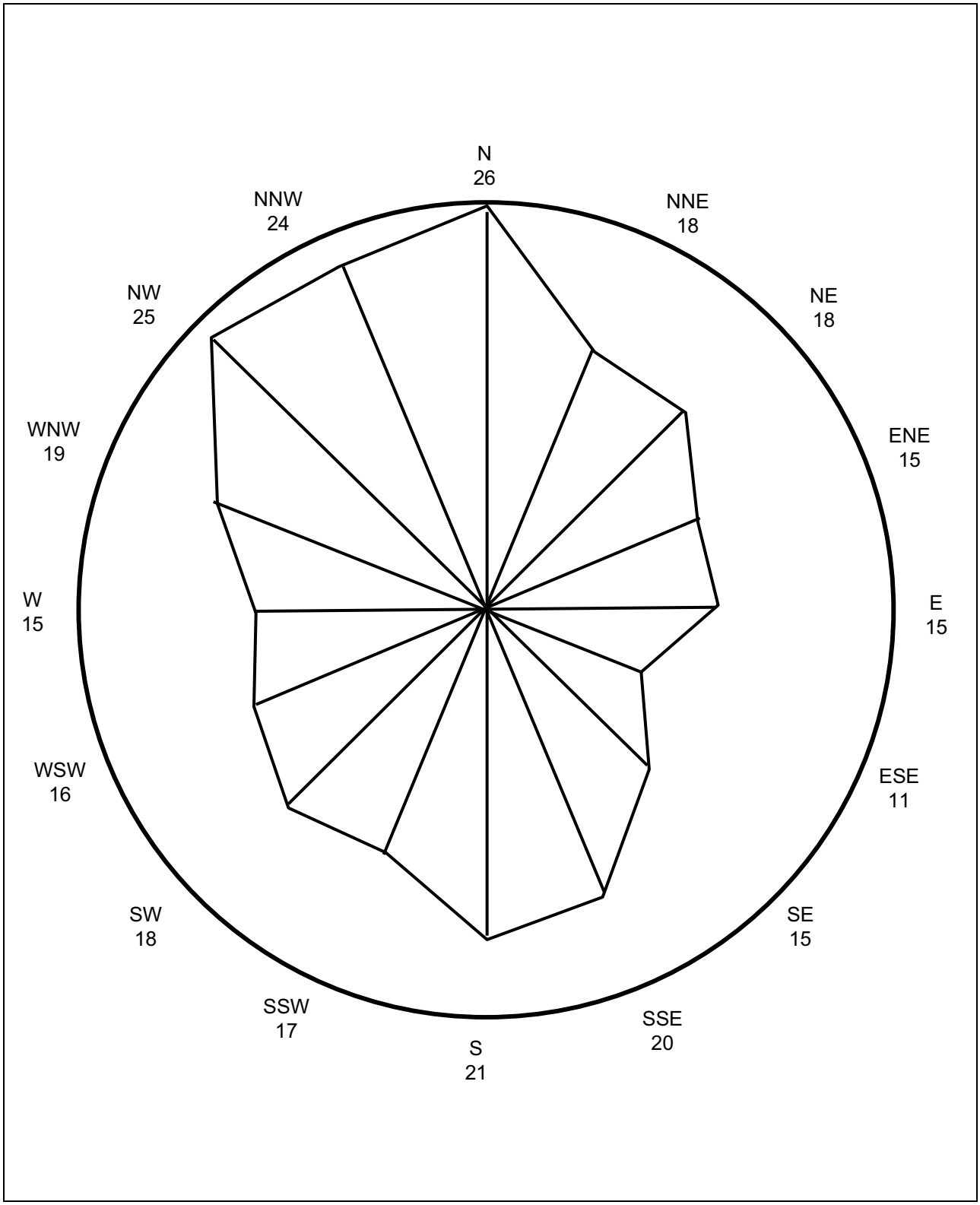


Figure 2.3-19 North Anna Seasonal Wind Persistence Roses: Low-Level Winds: 1974–1987: Season = Overall

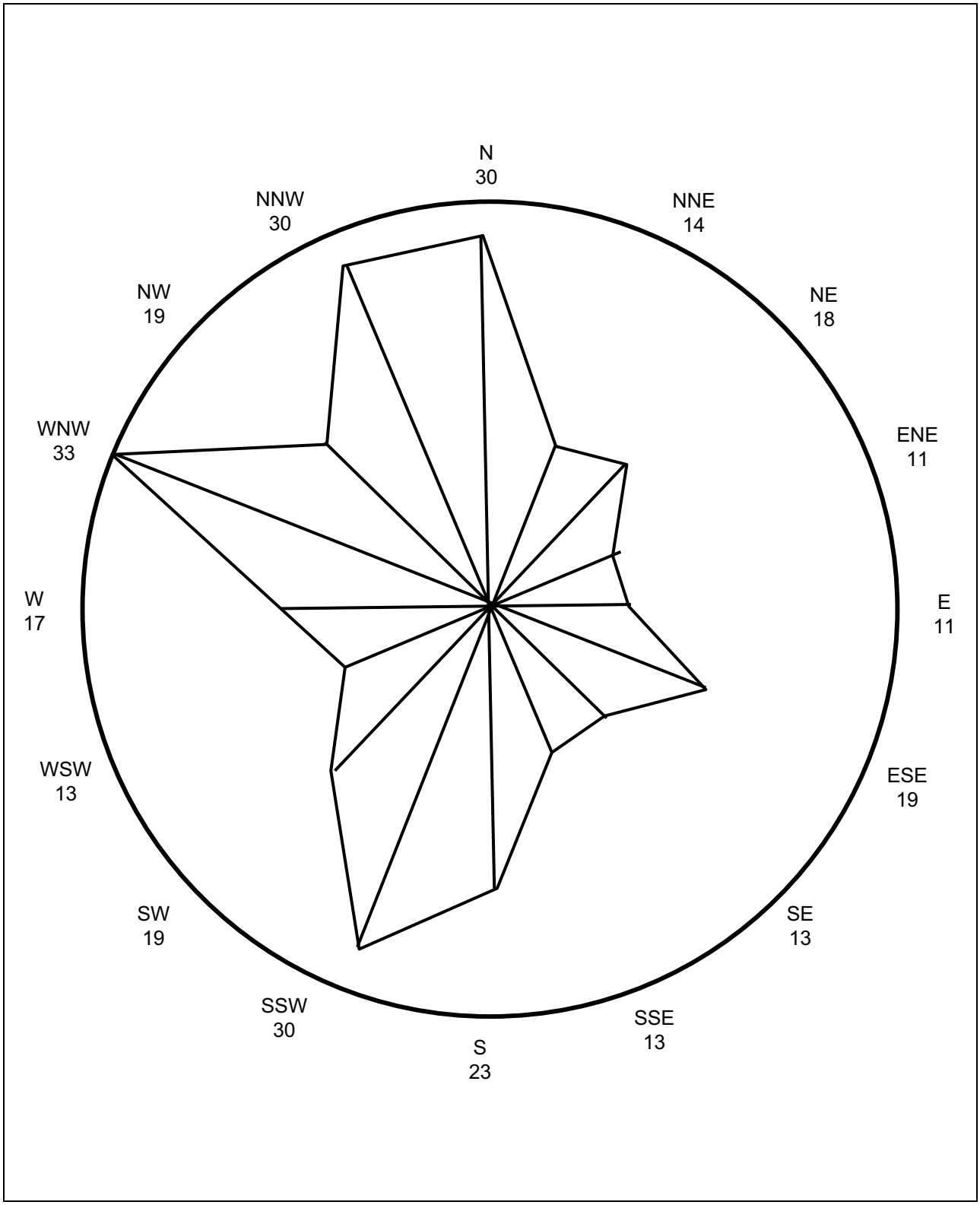


Figure 2.3-20 North Anna Seasonal Wind Persistence Roses: High-Level Winds: 1974–1987: Season = Overall

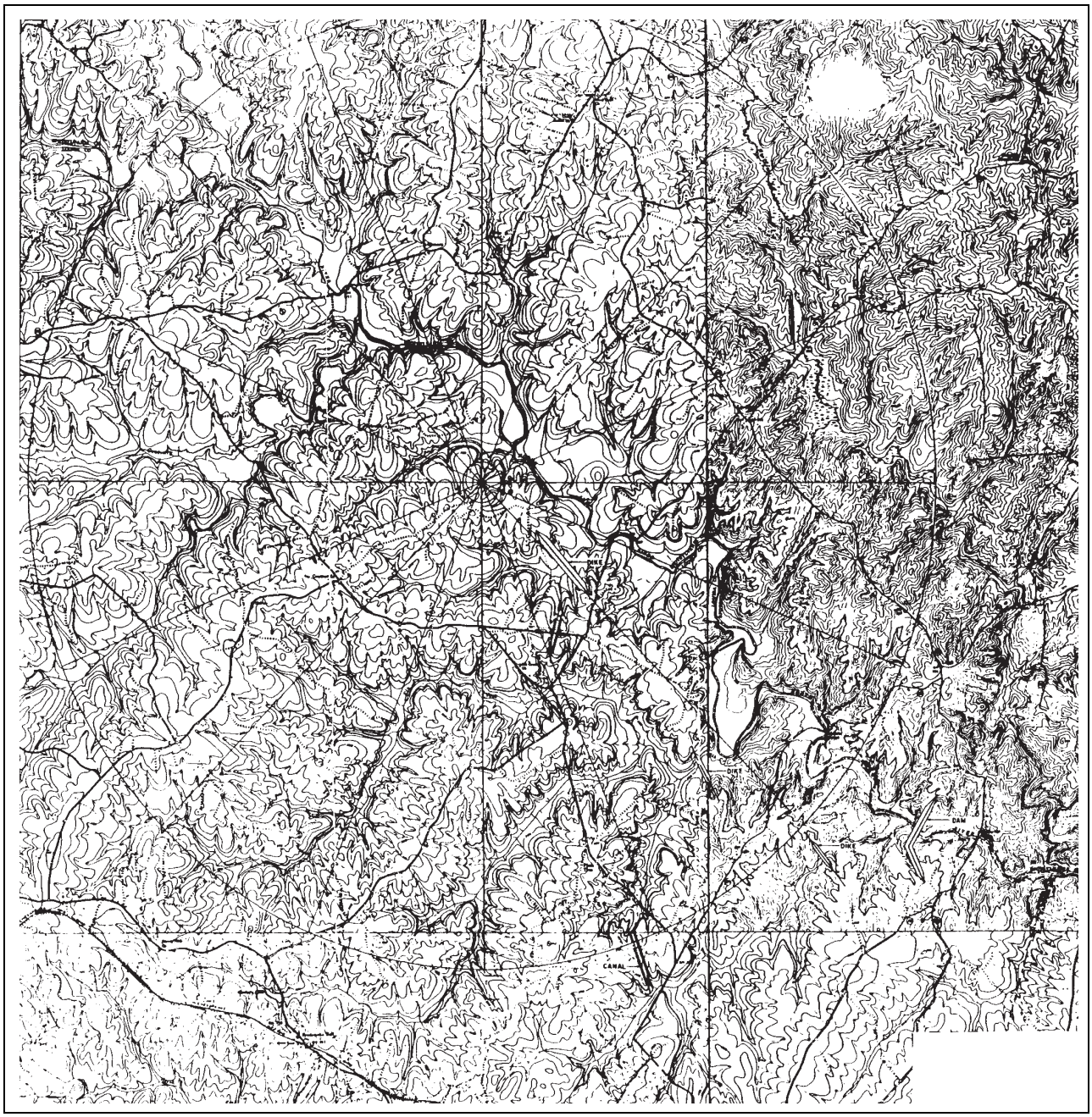
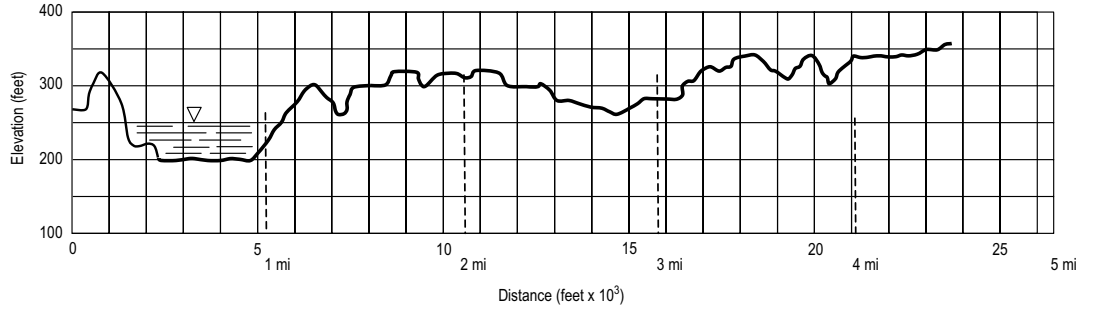
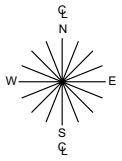
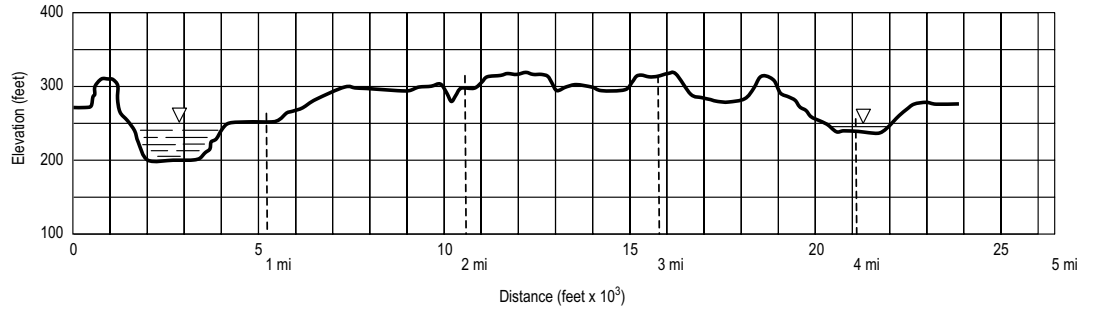


Figure 2.3-21 Topographic Map

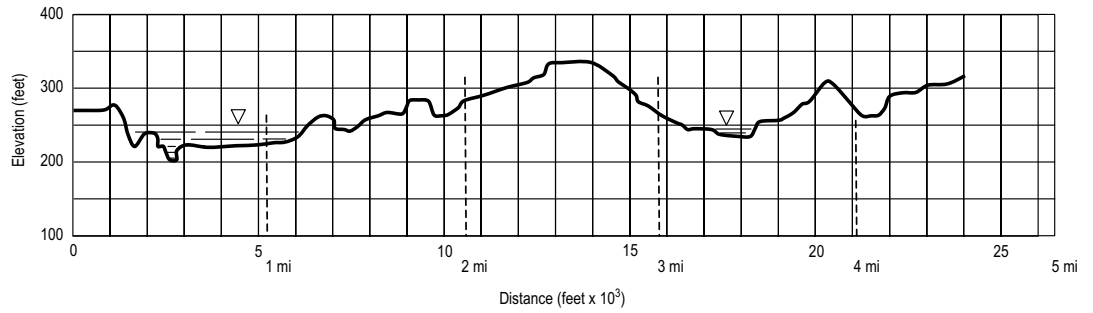




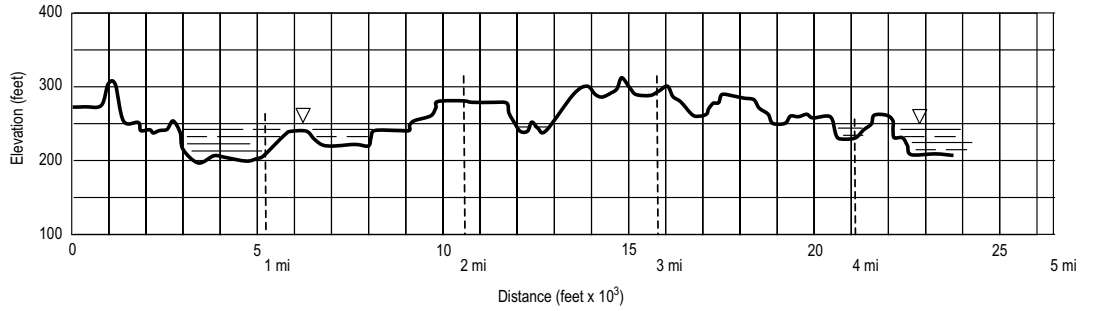
From Reactor 3 to Reference Point (Lat. 38°-07'-12", Long. 77°-04'-20")



From Reactor 3 to Reference Point (Lat. 38°-04'-20", Long. 77°-43'-57")



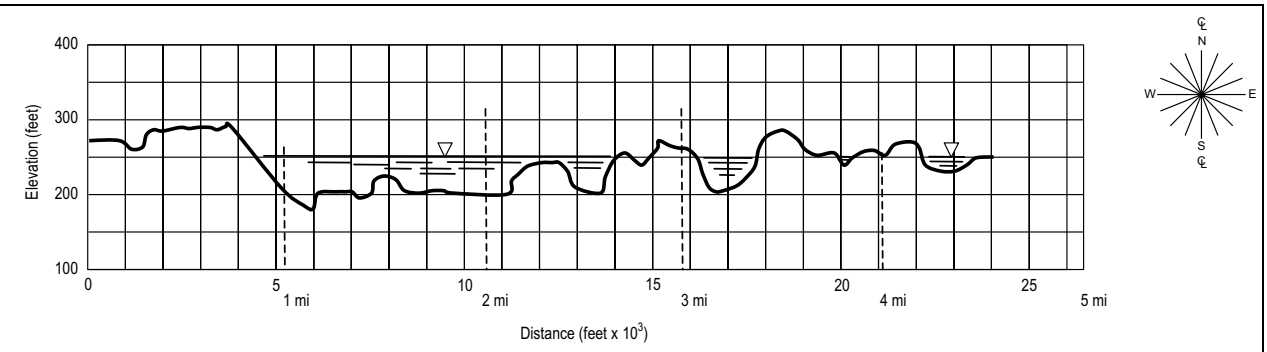
From Reactor 3 to Reference Point (Lat. 38°-03'-02", Long. 77°-42'-51")



From Reactor 3 to Reference Point (Lat. 38°-03'-03", Long. 77°-42'-30")

Figure 2.3-22 Vertical Profiles (Sheet 1 of 4)

Source: Reference 13



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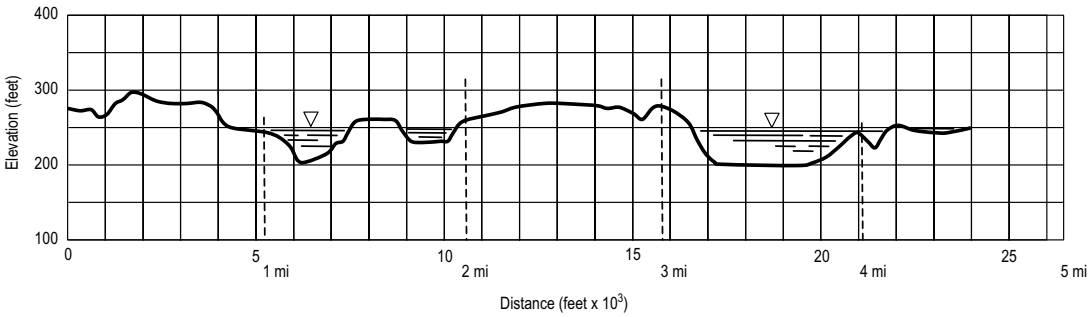

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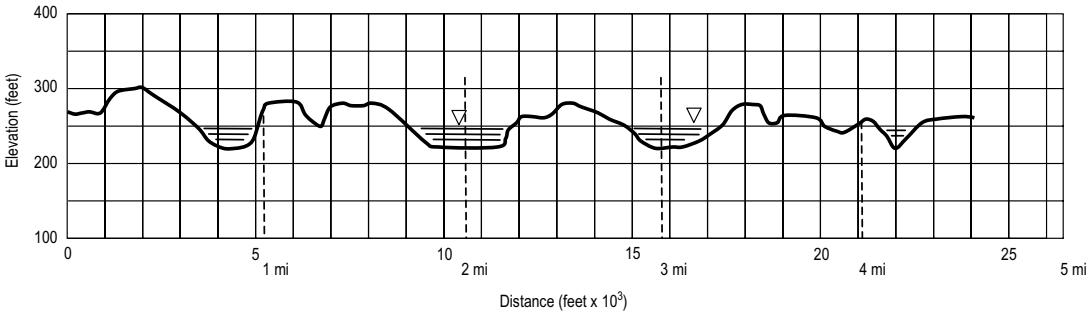
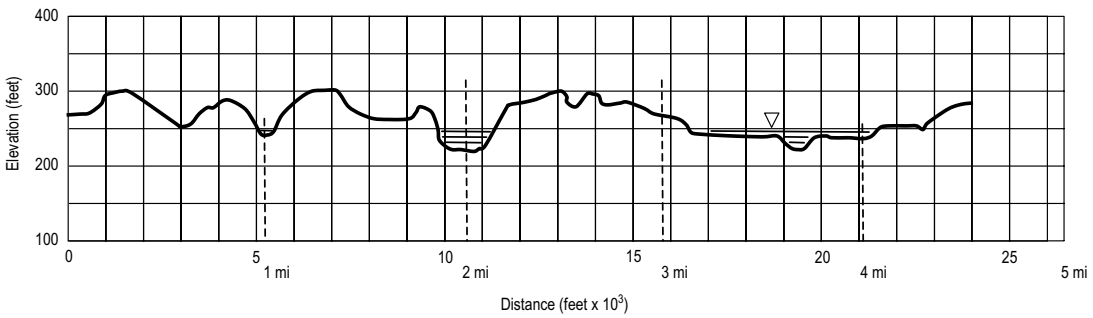


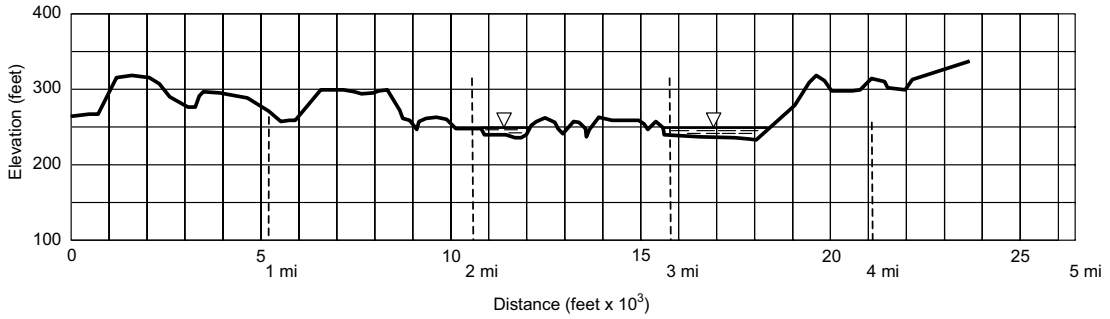
From Reactor 3 to Reference Point (Lat. 38°-00'-00", Long. 77°-45'-30")

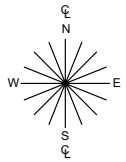


From Reactor 3 to Reference Point (Lat. 37°-59'-59", Long. 77°-47'-28")

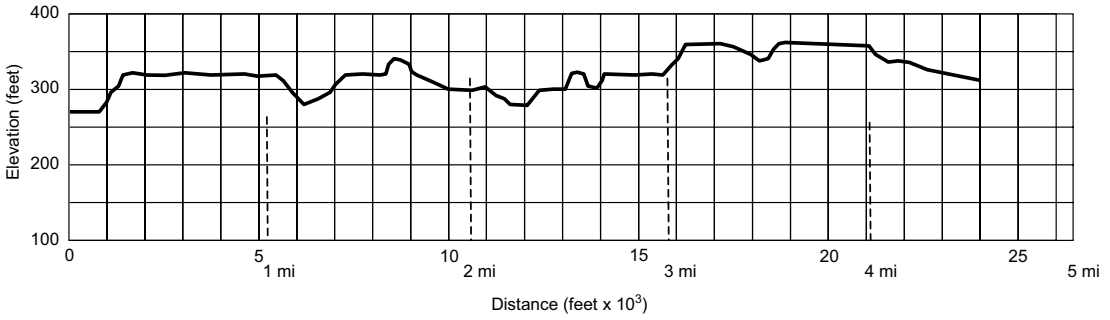
Figure 2.3-22 Vertical Profiles (Sheet 2 of 4)

Source: Reference 13

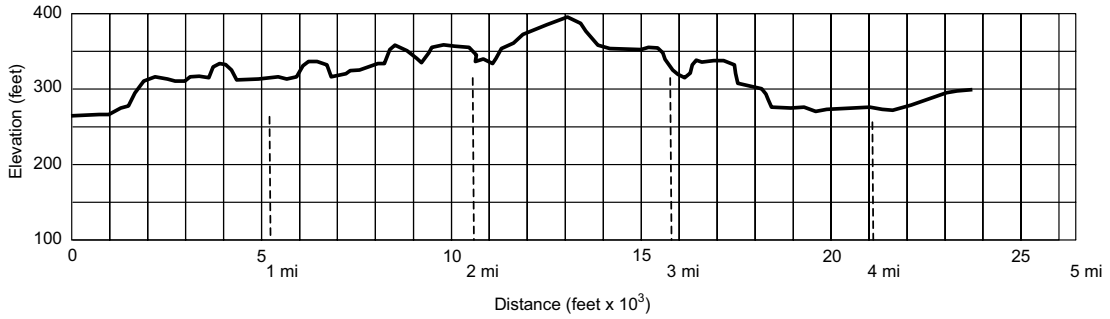




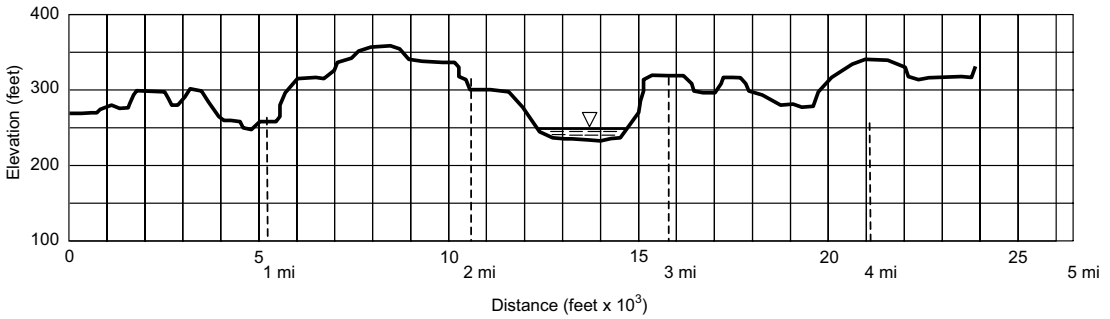
From Reactor 3 to Reference Point (Lat. 38°-00'-00", Long. 77°-49'-28")



From Reactor 3 to Reference Point (Lat. 38°-00'-00", Long. 77°-30'-39")



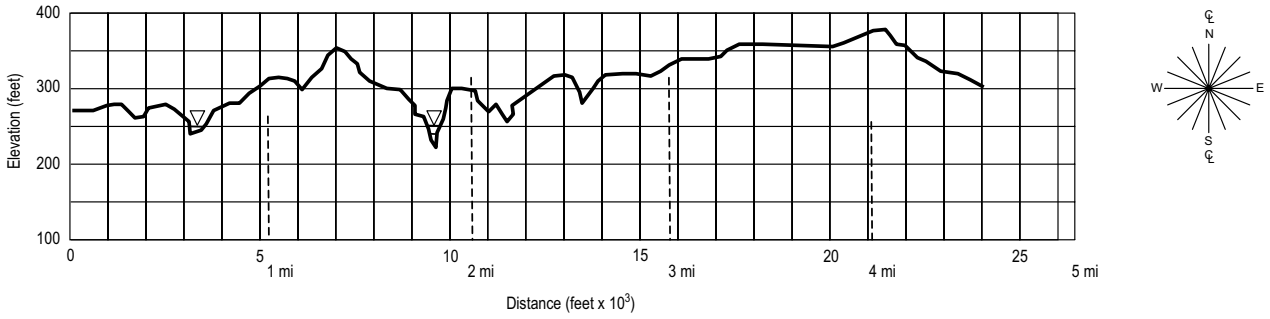
From Reactor 3 to Reference Point (Lat. 38°-01'-37", Long. 77°-32'-03")



From Reactor 3 to Reference Point (Lat. 38°-03'-30", Long. 77°-52'-28")

Figure 2.3-22 Vertical Profiles (Sheet 3 of 4)

Source: Reference 13



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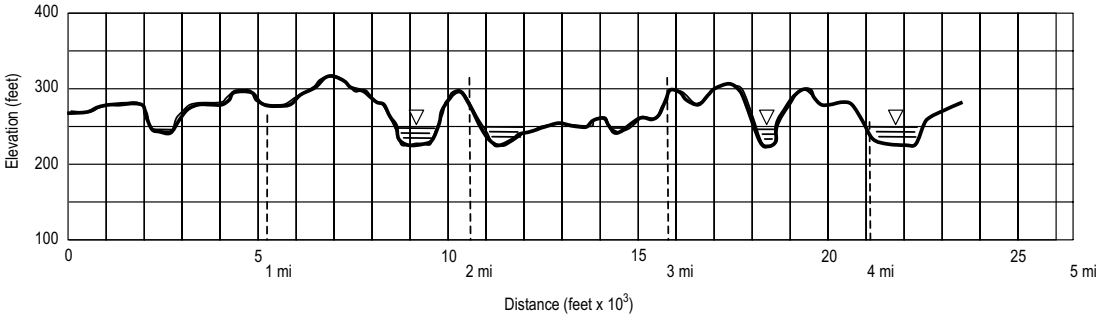
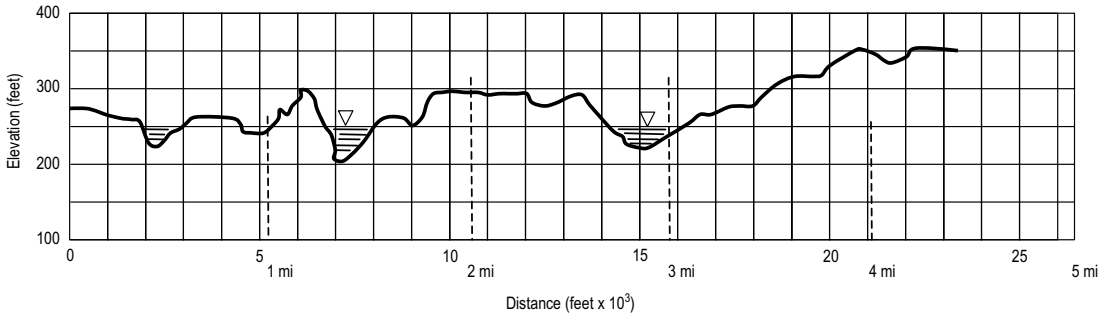
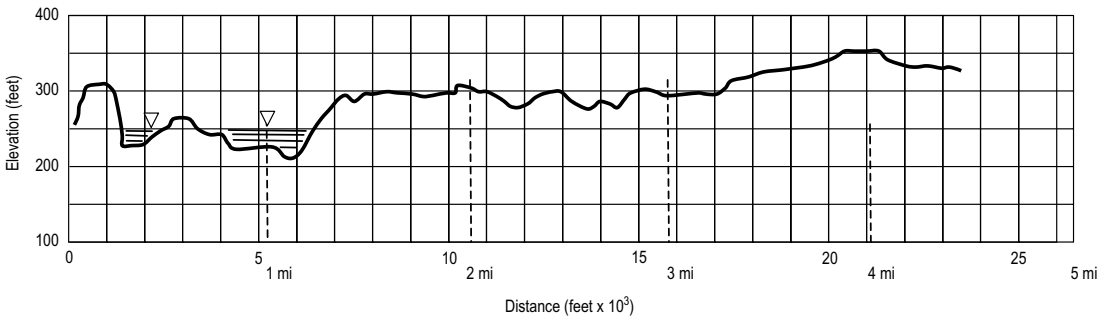


From Reactor 3 to Reference Point (Lat. 38°-06'-20", Long. 77°-50'-59")



From Reactor 3 to Reference Point (Lat. 38°-07'-12", Long. 77°-47'-23")



From Reactor 3 to Reference Point (Lat. 38°-07'-30", Long. 77°-47'-23")

Figure 2.3-22 Vertical Profiles (Sheet 4 of 4)

Source: Reference 13

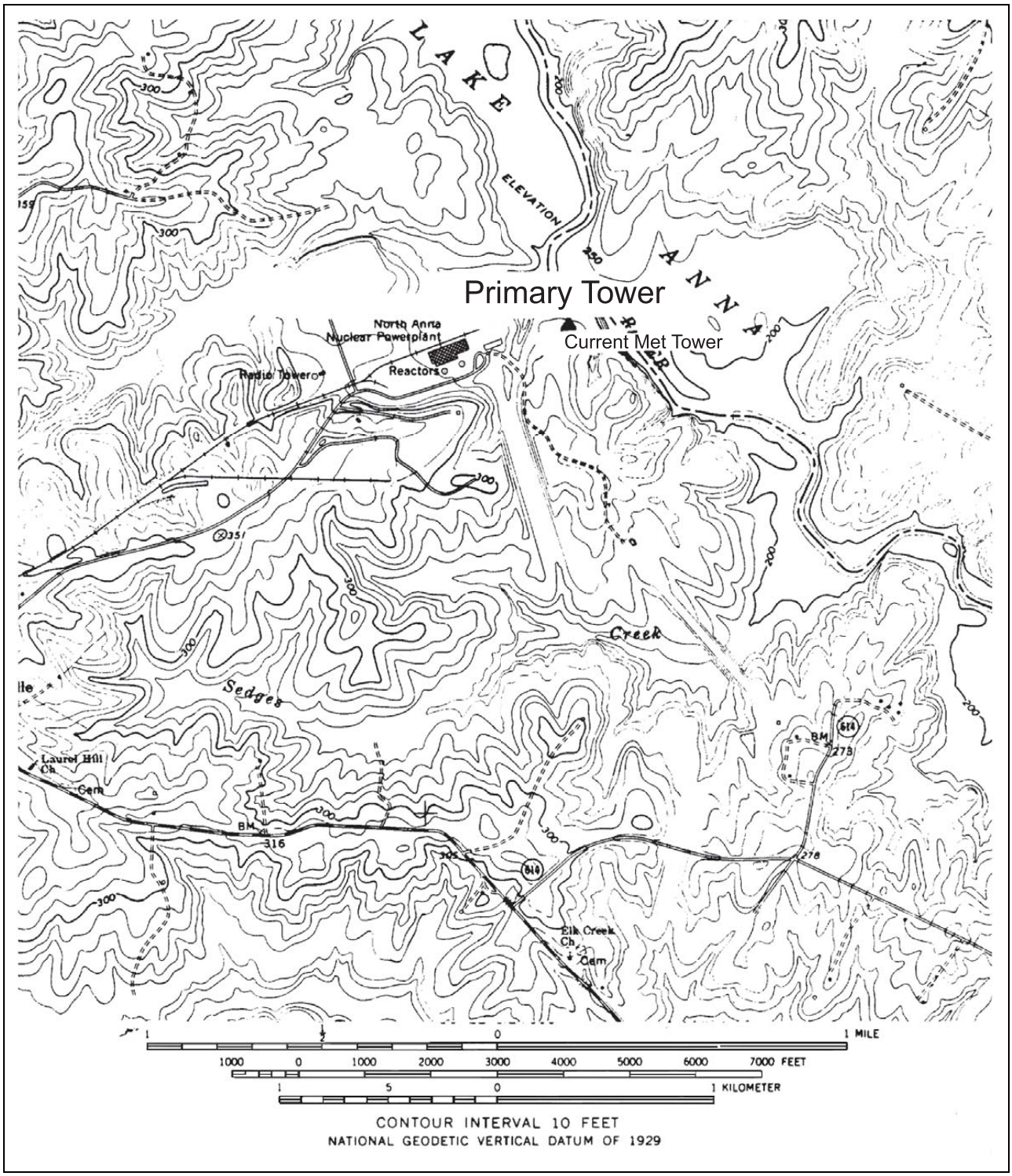
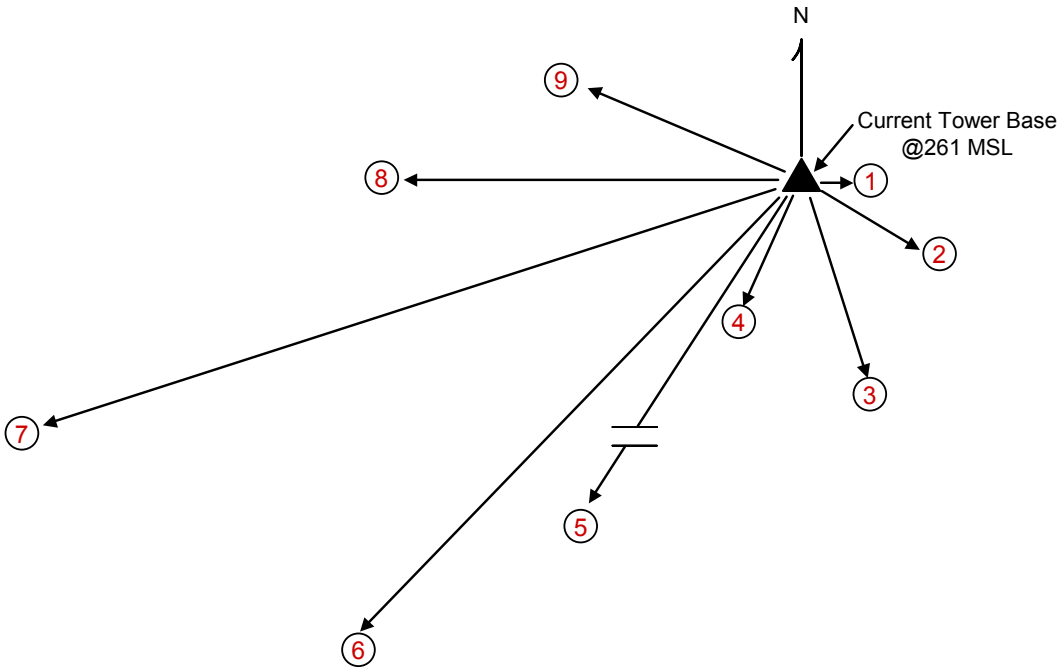


Figure 2.3-23 Location of Meteorological Tower

Source: Reference 13



Approximated Directions and Distances

1	Basketball Backboard	095°	100'
2	30 x 50 Pavilion	122°	222'
3	20 x 30 Pavilion	160°	294'
4	Softball Backstop	200°	203'
5	Nearest Contiguous Tree Line		>500'
6	Training Center	205°	740'
7	Unit 1 Containment	250°	1750'
8	Original Tower	272°	1020'
9	Back-up Tower	–	–

Figure 2.3-24 Location of Meteorological Tower Relative to Local Ground Features
Source: Reference 13

2.4 Hydrology

2.4.1 Hydrologic Description

This section identifies the interface of the new units with the hydrosphere, the hydrological causal mechanisms that may require special plant design bases or operating limitations with regard to floods and water supply requirements, and the surface water and groundwater uses that may be affected by operation of new units at the ESP site.

2.4.1.1 Site and Facilities

The water source for the new units on the ESP site is an impoundment of the North Anna River, referred to as Lake Anna. This impoundment was created by a dam constructed across the North Anna River as part of the overall development of the NAPS site. The North Anna Reservoir currently serves as the principal water source for the two existing units, which use once-through cooling systems to dissipate heat from the turbine condensers.

The ESP site is situated approximately 5 miles upstream from the main dam and adjacent to the existing units. The grade of the proposed site would have the same minimum elevation as the existing units, which is 271 ft msl (Reference 1). There are no natural drainage features that require changes to accommodate new units at the ESP site. Figure 1.2-4 shows the external structures and components, to the extent known, of the new units that might be constructed at the ESP site.

New Unit 3 would use a closed-cycle, dry and wet cooling tower system for the circulating water system. A separate service water cooling system would use a closed-cycle wet cooling tower to dissipate waste heat from auxiliary heat exchangers not cooled by the plant circulating water system. The system is described in Part 3: Section 3.4.1.1. Make-up water for the wet cooling towers would be supplied from the North Anna Reservoir at a maximum instantaneous rate of 49.6 cubic feet per second (cfs). Blowdown discharge from the wet cooling towers would be returned to the reservoir via the WHTF at a maximum instantaneous rate of 12.4 cfs.

New Unit 4 would use a closed-cycle cooling system with dry cooling towers in which the exhaust from the plant's steam turbines would be directed to a surface condenser where the heat of vaporization would be rejected to a closed loop of cooling water. The heated cooling water would be circulated to the finned tubes of the dry cooling towers where heat content of the cooling water would be transferred to the ambient air. To increase heat rejection to the atmosphere, electric motor driven fans would be used to force airflow across the finned tubes. After passing through the cooling towers, the cooled water would be recirculated back to the surface condenser to complete the closed-cycle cooling water loop. Except for the initial filling of the cooling water loop, Unit 4 would have no make-up water need since dry tower systems typically have no evaporative water losses and would have no continuous blowdown discharge to the WHTF. In the event that the cooling water loop used an open pump sump configuration with a free surface, a small amount of evaporation losses, estimated to be about 1 gpm (0.002 cfs), will occur. Any make-up water

necessary to replenish the small evaporative losses for Unit 4 would be obtained from the North Anna Reservoir. The plant service water cooling system for Unit 4 would use dry cooling towers, which would have minimal to no make-up water requirements.

2.4.1.2 Hydrosphere

2.4.1.2.1 Hydrologic Characteristics of Streams, Lakes, and Groundwater

The North Anna River originates in the eastern slopes of the Southwestern Mountains in the Appalachian mountain range near Gordonsville, Virginia, and follows a southeasterly course to its confluence with the South Anna River 5 miles northeast of Ashland, Virginia, where the Pamunkey River is formed. The Pamunkey continues on a general southeasterly course to West Point, Virginia, where it is joined by the Mattaponi River to form the York River. The York River flows into the Chesapeake Bay about 15 miles north of Hampton, Virginia (Reference 1). The North Anna River drains a watershed area of 343 square miles above the dam, which is located about 4 miles north of Bumpass, Virginia, and about a half mile upstream of Virginia Route 601.

As shown in Figure 2.4-1, Lake Anna is about 17 miles long and inundates several small tributaries; thereby, resulting in an irregular shape having a shoreline length of approximately 272 miles. To provide optimum thermal performance for the existing units, Lake Anna is separated into two segments by a series of dikes and canals. The larger segment of about 9600 acres is referred to as the North Anna Reservoir and functions as a storage impoundment to ensure adequate water supplies for condenser cooling. The smaller segment, called the WHTF, has an area of about 3400 acres and functions primarily as a heat exchanger for transferring most of the existing units heat rejection to the atmosphere. When both existing units are operating, eight circulating water pumps draw water from Lake Anna at a rate of 4246 cfs, circulate it through the condensers, and return it to the reservoir via the WHTF (Reference 1).

The principal tributaries of Lake Anna include the North Anna River, Pamunkey Creek, and Contrary Creek. Several smaller tributaries drain to the lake as well. Only two of the tributaries draining into Lake Anna are gauged: Pamunkey Creek at Lahore, Virginia (USGS 01670180), and Contrary Creek Near Mineral, Virginia (USGS 01670300). The Pamunkey Creek station gauges a drainage area of 40.5 square miles, while the daily streamflow record extends from August 1989 through July 1993 (Reference 2). The Contrary Creek station gauges a drainage area of 5.53 square miles. The daily streamflow record for this station extends from October 1975 through January 1987 (Reference 3). The remaining 297 square miles of the 343 square mile Lake Anna watershed are not gauged and cannot be characterized accurately for inflows to the impoundment. Inflows can be estimated, however, from records obtained from the North Anna River near Doswell, Virginia, which has a record that measures streamflow from April 1929 through September 1988. This gauging station is located approximately 15 miles downstream of the dam and gauges a drainage area of 441 square miles (Reference 4).

Using the portion of the Doswell, Virginia record preceding dam closure (i.e., April 1929 through December 1971), inflows to Lake Anna were estimated. The flows at Doswell are larger than the flows at the dam due to the larger contributing drainage area. Thus, these flows were adjusted by multiplying by the ratio of the drainage area at the dam to the drainage area at Doswell, Virginia. Table 2.4-2 summarizes the observed and estimated mean monthly inflows to Lake Anna estimated as described above.

Outflows from Lake Anna have been measured on the North Anna River near Partlow, Virginia, which is located just downstream of the dam at the Virginia Route 601 bridge. The drainage area at this stream gauge is 344 square miles. The daily streamflow record for this gauging station extends from October 1978 through September 1995. The discharge at this station reflects the regulated outflow from Lake Anna for the entire period of record since the dam was completed in 1972. (Reference 5) Table 2.4-2 summarizes the mean monthly outflows from the Lake Anna impoundment using streamflow data from the U.S. Geological Survey (USGS). Note that the period of record for the estimated total inflow precedes the closure of the North Anna Dam whereas the period of record for the outflow occurs after dam closure. Mean monthly outflows may, therefore, exceed the mean monthly inflows for some months.

Lake Anna water levels have been recorded since the existing units began operating. The available record extends from August 1978 through March 2003. Mean monthly water levels were calculated from these data and are summarized in Table 2.4-2.

Section 2.4.12 describes the regional and local groundwater environments.

2.4.1.3 Existing and Proposed Water Control Structures

The North Anna Dam is the only existing water control structure on the North Anna River. The design basis of the North Anna Dam is described in the NAPS UFSAR (Reference 1).

The dam is an earth-filled structure about 5000 feet long, with a central concrete spillway about 200 feet long. The dam crest is at Elevation 265 ft msl and has a width of 30 feet. The dam has a maximum height above the streambed of about 90 feet and contains approximately 900,000 cubic yards of compacted earth materials. The concrete spillway section is founded on sound bedrock and the earthen section of the dam is founded partly on firm residual soils and partly on the bedrock. (Reference 1)

The earth dam section is constructed of local soils with a cross-section of a homogeneous-type compacted fill provided with vertical chimney and horizontal downstream foundation drains constructed of select pervious sand. An upstream impervious blanket is provided where it is necessary to lengthen the seepage path through residual foundation materials. Earth slopes are protected with riprap, and, where necessary, they are placed on suitable filters. Other earth slopes are seeded with grass. A service road is constructed on the dam crest. The stability of the earth dam is ensured through the use of conservative design procedures coupled with closely controlled

construction techniques. The structure is designed with factors of safety that adequately resist all applied loads and forces, which is presented in greater detail in the NAPS UFSAR (Reference 1).

The concrete spillway contains three radial crest gates, each 40 feet wide by 35 feet high, separated by 10-foot-wide concrete piers. The discharge capacity of each of the three main gates is shown in Figure 2.4-3. The crest of the spillway ogee is at Elevation 219 feet msl. Concrete gravity walls on each side of the spillway retain the earth portions of the dam.

A spillway bridge is provided at Elevation 265 feet msl for access to each of the individual electric motor-operated gate hoists. An auxiliary generator at the dam operates the spillway gate hoists if normal power supplies are interrupted. Two adjustable skimmer gates are provided for regulating small releases. The discharge capacity of each of the two skimmer gates, which measure 8.5 feet by 8.5 feet, is shown in Figure 2.4-4. A concrete apron downstream of the spillway provides energy dissipation for Lake Anna releases.

The North Anna Dam also incorporates at its base an 855-kW hydroelectric power plant that is owned and operated by Virginia Power. The hydroelectric facility consists of two separate generating units (Units 5A and 5B), each unit possessing a single state, open runner-type vertical turbine. Peak operational efficiency is at a flow of 40 cfs for Unit 5A and 133 cfs for Unit 5B. Water for the hydroelectric facility, which is withdrawn from near the surface of Lake Anna (depth of less than 7 feet), flows through a skimmer gate and associated sluice pipe that is connected to a 5-foot-diameter penstock. The water is then directed by a bifurcation piece through 24-inch and 48-inch conduits to Units 5A and 5B, respectively. After passing through the turbines, water is discharged into the North Anna River just downstream of the dam's spillway (Reference 6).

While Lake Anna was constructed for power generation purposes, it also provides the additional benefits of low streamflow augmentation, flood control, and recreation. The normal pool level is maintained at an elevation of 250 feet msl. The Commonwealth of Virginia requires a 40-cubic-feet-per-second minimum discharge of water from the North Anna Dam except under drought conditions. These minimum flow requirements are established to maintain in-stream flows and water quality in the North Anna River below the dam and in the Pamunkey and York Rivers, which are further downstream. Should drought conditions occur such that the Lake Anna water surface elevations fall below 248 feet msl, Virginia Power may reduce releases below 40 cfs, in accordance with the Lake Level Contingency Plan as stipulated in Part I.F of the Virginia Pollutant Discharge Elimination System (VPDES) Permit (Reference 7). A flood surcharge of 15 feet above the normal pool level is provided for flood storage. The total Lake Anna volume of 550,000 acre-feet is allocated as described in Table 2.4-1(Reference 1):

Table 2.4-1 Lake Anna Storage Allocation

Purpose	Volume (acre-feet)
Minimum recreational pool and inactive storage below 246 feet msl	255,000
Conservation and active storage, 246 to 250 feet msl	50,000
Flood control storage, 250 to 265 feet msl	245,000
Total storage	550,000

No additional water control structures are necessary or proposed for the new units on the ESP site.

2.4.1.4 Surface Water and Groundwater Users

Surface water users whose intakes could be adversely affected by the accidental release of contaminants were identified using the water use database maintained by the VDEQ (Reference 8). This database includes users whose average daily withdrawal in any single month exceeds 10,000 gallons per day (gpd). Users on Lake Anna are limited to the existing units which use the lake for cooling water. Data reported for the 1996-2001 period indicates an average annual use of 744,313 million gallons per year. Users on the North Anna River include the Bear Island Paper Co. and the Doswell Water Treatment Plant. The Bear Island Paper Co. is located at the confluence of the North Anna River and the Little River. Data given for the 1996-2001 period indicates an average annual use of 252.22 million gallons per year. The Doswell Water Treatment Plant obtains its water from the North Anna River and supplies water to major customers in the Doswell area, including the Bear Island Paper Co., the Doswell Limited Partnership electric generation facility, Paramount's Kings Dominion Amusement Park, and provides supplemental water to the Hanover County suburban service area. The plant is rated at 4.0 million gallons per day (mgpd). There are no other known users of either the North Anna River or the Pamunkey River into which it flows, until it reaches the York River some 60 miles downstream at West Point, Virginia, where the St. Laurent Paper Products plant is located. Although the St. Laurent Paper Products is included in the VDEQ water use database, they reported no withdrawals for the 1996-2001 period.

Section 2.4.12 identifies groundwater users that may be affected by operation of new units on the ESP site.

Table 2.4-2 Mean Monthly Hydrologic Statistics for Lake Anna

Month	Pamunkey Creek Inflow[a] (cfs)	Contrary Creek Inflow[b] (cfs)	Estimated Total Inflow[c] (cfs)	Outflow[d] (cfs)	Water Level[e] (ft msl)
January	61.2	7.97	411	401	249.79
February	37.5	9.37	449	507	249.89
March	49.0	8.92	497	601	249.95
April	62.0	8.36	454	485	249.91
May	43.0	4.33	286	330	249.88
June	23.9	2.46	171	215	249.77
July	19.3	1.34	161	133	249.59
August	9.72	3.40	228	134	249.43
September	14.5	1.20	125	109	249.12
October	31.8	3.16	174	138	248.97
November	31.8	5.05	218	244	249.14
December	47.6	5.46	298	265	249.49

a. USGS 01670180 Pamunkey Creek at Lahore, Virginia, September 1989 – April 1993 (Reference 2).

b. USGS 01670300 Contrary Creek Near Mineral, Virginia, October 1975 – December 1986 (Reference 3).

c. USGS 01671000 North Anna River Near Doswell, Virginia, January 1929 – December 1971 (Reference 4), scaled to Lake Anna drainage area.

d. USGS 01670400 North Anna River Near Partlow, Virginia, October 1978 – September 1995 (Reference 5).

e. August 1978 – March 2003.

2.4.2 Floods

2.4.2.1 Flood History

Annual peak discharges for flooding events that have occurred on the North Anna River and available annual peak North Anna Reservoir water levels, since completion of the dam, are presented in Table 2.4-14. The flood history information for the period of record was obtained from the North Anna UFSAR (Reference 1) and from USGS stream gage records (Reference 4) (Reference 5). The reservoir water level data presented for the period of record from 1979 to 1995 is obtained from Lake Anna water level data compiled by Virginia Power.

The largest flood of record on the North Anna River occurred in 1969, with a peak discharge of 24,800 cfs at the Doswell, Virginia USGS gaging station, approximately 15 miles downstream from the dam and 14 miles downstream of the Partlow, Virginia gaging station (Reference 4). The flood that occurred as a result of hurricane Agnes in 1972 nearly matched the flood of record with a peak discharge of 24,000 cfs at Doswell, VA. Although the North Anna Dam had been completed in December 1971, the reservoir was not yet filled, thus the water level in North Anna Reservoir during this event was well below the normal pool elevation of 250.00 ft msl.

Since completion of the dam and subsequent filling of the reservoir, the largest flood of record occurred on two separate occasions, February 1979 and June 1995. For both of these events, the peak discharge at the Partlow gaging station was measured to be 11,700 cfs with a peak water level in Lake Anna of 252.0 ft msl, measured at the dam.

2.4.2.2 Flood Design Considerations

The design basis flood for the ESP site was determined by considering a number of different flooding possibilities. The possibilities applicable to this site include the probable maximum flood (PMF) on streams and rivers, potential dam failures, probable maximum surge and seiche flooding, and ice effect flooding. Each of these flooding scenarios was investigated in conjunction with stream flooding on the North Anna River as per guidelines addressed in ANSI/ANS-2.8-1992 (Reference 9). Details of the individual scenarios are presented in Section 2.4.3 through Section 2.4.7.

The highest water level from among the number of flooding possibilities is selected as the design basis flooding level. For the ESP site, the design basis flooding level was derived from the PMF on Lake Anna produced by the PMP (Section 2.4.3.1) over the lake's watershed. The PMP was developed using Hydro-Meteorological Reports (HMR) 51 and 52, published by the NOAA (Reference 10) (Reference 11). Wind generated setup and runup elevations were also considered in conjunction with the maximum still water level on Lake Anna to produce a design basis flooding level of 267.39 ft msl at the site. Details of the flooding level determination are presented in Section 2.4.3.

Elevations for safety-related components and structures are not yet established for the new units. However, the grade elevation in the power block area of the ESP site has been established at Elevation 271.0 ft msl, providing 3.61 ft of freeboard above the design basis flooding level. This is the same grade elevation as the existing units. Therefore, all above grade, safety-related structures, systems and components of the new units would be located above the Lake Anna design basis flooding level.

2.4.2.3 Effects of Local Intense Precipitation

The design basis for local intense precipitation at the ESP site is the PMP. The PMP values presented and listed in Section 2.4.3.1 were developed for the 343 square-mile Lake Anna watershed. The drainage areas for storm water conveyance facilities around the ESP site would be less than one square mile. Additionally, the time of concentration for these facilities would also be much shorter than for the Lake Anna watershed. Thus, a different set of PMP values appropriate for smaller watersheds and storm durations of less than one hour and drainage areas one square mile or less were used for local intense precipitation at the site. These values were obtained from HMR 52 (Reference 11) and are listed in Table 2.4-3.

Table 2.4-3 North Anna Power Station Local Probable Maximum Precipitation Values

Duration	1-Hour Multiplier	PMP Depth (in)
6-hour	1.527	27.9
1-hour	1.0	18.3
30-minutes	0.749	13.7
15-minutes	0.522	9.6
5-minutes	0.333	6.1

(Values are for a 1-mi^2 drainage area.)

The site layout and facilities at the ESP site have not been finalized. Thus, the location and design of storm water conveyance facilities have not been determined. These tasks would be performed as part of detailed engineering and described in the COL application. The general design of the storm water conveyance facilities would be to discharge the runoff to Lake Anna. Using the PMP values listed in Table 2.4-3, storm water conveyance facilities would be designed such that the peak discharges from the PMP would not flood safety-related facilities of the new units or of the existing units. Drainage facilities used during the construction phase of the new units would also be designed such that safety-related facilities of the existing units would not be adversely affected by flood elevations as a result of the local PMP and construction of the new units. In addition, applicable federal, state, and local storm water management regulations would be followed in the design of storm water conveyance facilities.

2.4.3 Probable Maximum Flood on Streams and Rivers

Two previous Lake Anna PMF analyses have been performed. The first analysis was performed for the original Unit 1 and 2 NAPS Final Safety Analysis Report. The second analysis was performed in 1976 to update the runoff model unit hydrograph based on water level observations since the construction of North Anna Dam. The 1976 analysis is described in the current North Anna UFSAR (Reference 1). The PMP values used in the 1976 analysis were based on information contained in the NWS's Hydro-Meteorological Report (HMR) No. 33 (Reference 12). Since 1976, the NWS, now under the NOAA, has updated PMP estimates and published HMR Nos. 51, 52 and 53 to reflect the updated estimates (Reference 10) (Reference 11) (Reference 13). In general, the PMP estimates in the later HMRs are greater and of longer duration than those presented in HMR No. 33. Thus, for this section, the PMF analysis has been revised to incorporate the updated PMP information from HMR Nos. 51, 52, and 53.

The present analysis consisted of developing the PMP estimates from the current HMRs. The runoff unit hydrograph and precipitation losses used in the 1976 study were compared with observed results from storms that have occurred since 1976 and adjusted as necessary. Also, the flood inflow hydrograph and still water elevations in Lake Anna were computed using the U.S. Army Corps of Engineer's (USACE's) computer program, HEC-1 (Reference 14). The backwater effects along with appropriate wind-generated setup and wave run-up in accordance with ANS/ANSI-2.8-1992 (Reference 9) were added to the still water elevation to determine the final PMF elevation and design basis flooding level at the ESP site. Details of the analysis are presented in Section 2.4.3.1 through Section 2.4.3.6.

The results of the analysis indicate a design basis flooding elevation of 267.39 ft msl at the ESP site, which is 3.61 ft below the ESP site grade elevation of 271.0 ft msl. Since the ESP site grade elevation is above the design basis flooding level, all above-grade, safety-related structures, systems, and components of the new units would be located above the design basis flooding elevation.

2.4.3.1 Probable Maximum Precipitation

The PMP was developed according to procedures outlined in HMR Nos. 51, 52, and 53 (Reference 10) (Reference 11) (Reference 13). The values are presented in Table 2.4-4. They have been estimated based on the size and shape of the combined North Anna Reservoir and WHTF watershed drainage area in accordance with the procedures outlined in HMR No. 52 (Reference 11). The 343 square mile watershed drainage area is shown on Figure 2.4-5. The PMP isohyetal pattern was oriented over the watershed such that the maximum precipitation volume over the entire drainage area has been obtained. The 72-hour PMP storm was temporally distributed according to guidelines in HMR No. 52 and ANS/ANSI-2.8-1992 (Reference 11) (Reference 9) and is shown in Table 2.4-7.

Table 2.4-4 Maximum Precipitation Depths

6-hour Incremental Depths		Total PMP Depths	
6-Hour Increment	Incremental PMP Depth (in)	Storm Duration (hr)	Total PMP Depth (in)
1	17.71	6	17.71
2	3.67	12	21.38
3	2.24	24	24.89
4	1.27	48	29.09
5	1.27	72	30.65
6	1.07		
7	0.98		
8	0.88		
9	0.59		
10	0.39		
11	0.29		
12	0.29		

For the runoff analysis, an antecedent storm condition was assumed as indicated in ANS/ANSI-2.8-1992 (Reference 9). A rainstorm equivalent to 40 percent of the PMP was initially modeled, followed by three days with no precipitation, and then the full 72-hour PMP storm was applied. Based on the historical snowfall information for the NAPS region, snowmelt does not make a significant contribution to flooding situations (Reference 15). Therefore, antecedent snow-pack conditions were not considered in the PMF analysis.

2.4.3.2 Precipitation Losses

Precipitation losses for the 1976 study were determined by comparing the rainfall-runoff relationships for various storms. Precipitation losses were determined using historical storms and the HEC-1 loss rate parameter optimization (Reference 1).

In addition to the historical storms investigated for the 1976 study, three additional storms were investigated in the present study to determine precipitation losses, including the influence of recent data. The storms occurred in February 1979, March 1994, and June 1995, and were selected because they produced high water levels in the North Anna Reservoir. Hourly precipitation data for these storms were collected from various precipitation gaging stations near the watershed from the National Climatic Data Center (Reference 16). The Theissen polygon method was used to

determine a watershed basin average precipitation for each storm (Reference 17). The precipitation weighting and basin average precipitation for each storm are shown in Table 2.4-8 through Table 2.4-10. For these three recent storms, the HEC-1 loss rate parameters were also optimized by comparing the North Anna Dam outflow HEC-1 results with North Anna Dam discharges calculated from observed Lake Anna water levels and gate openings. The precipitation loss rates from the recent storms were factored with the loss rates for the storms analyzed in the 1976 study, and loss rates were determined for the PMF runoff analysis. The loss rates for each of the actual storms and the loss rates for the 1976 and present PMF storms are shown in Table 2.4-11.

2.4.3.3 **Runoff Model**

The revised 1976 analysis used the unit hydrograph method to determine the PMF levels in Lake Anna. The unit hydrograph was developed using historical rainfall records from nearby precipitation stations and historical stage-discharge data for the dam. The procedure, as presented in the NAPS UFSAR, is outlined below:

1. An isohyetal map of total storm rainfall for each storm was plotted and a Thiessen's polygon was drawn on the isohyetal map to determine the distribution of basin rainfall.

2. Mass curves of rainfall were drawn to define the time distribution of rainfall.

3. The base flow was subtracted from the measured stream flow hydrograph to obtain the runoff hydrograph for each storm.

4. The basin infiltration was adjusted to balance rainfall excess with flood runoff.

5. Using the runoff hydrograph and the time distribution of rainfall excess for guidance, the unit hydrograph for each flood was determined.

From the individual unit hydrographs, a composite unit hydrograph for the combined WHTF and North Anna Reservoir watershed was developed. The composite unit hydrograph used in the 1976 HEC-1 runoff model for the combined watershed drainage area (322.7 square miles), excluding the reservoir and WHTF surface areas, is shown on Figure 2.4-6. A separate runoff hydrograph was developed for the drainage area comprising the reservoir and WHTF surface areas (20.3 square miles). This second hydrograph directly reflected the storm precipitation pattern. No infiltration losses were used for the runoff over the combined reservoir and WHTF surface areas.

For the current analysis, the precipitation data for each of the three recent storms presented in Section 2.4.3.2 was applied to the 1976 watershed and lake unit hydrographs. The resulting runoff hydrographs were then combined and routed through Lake Anna using the computer program HEC-1 (Reference 14). The HEC-1 computed discharges from Lake Anna for each storm were then compared with Lake Anna discharges calculated based on gate opening data and water levels measured at the dam during the storms. Adjustments were made to both the base flow and the

precipitation loss (infiltration) coefficients. Comparisons of the HEC-1 computed Lake Anna discharges with the discharges based on measured water levels are shown on Figure 2.4-7 through Figure 2.4-9. The results indicated that the 1976 unit hydrograph produced inflow hydrographs that accurately represent the observed lake discharge hydrographs for recent storms. Thus, the same 1976 unit hydrographs were used for the present PMF runoff analysis.

Routing of flood flows through Lake Anna was accomplished using the level pool reservoir routing procedure in HEC-1. For modeling purposes, the reservoir and the WHTF were treated as a single storage facility, Lake Anna. Four dividing dikes, one of which allows limited flow exchange, separate the two facilities. The top crest elevation of the dikes is 260 ft msl. However, there is a 350-foot long saddle in Dike 3 at Elevation 253.5 ft msl, which functions as a spillway for the WHTF. Thus, once the water level in either storage facility rises above 253.5 ft msl, equalization of the water level between the two facilities occurs. In view of the fact that flow between the two facilities is restricted for elevations below 253.5 ft msl, the reservoir modeling used in HEC-1 conservatively assumed that all rainfall and runoff was routed only through the North Anna Reservoir until the water level reached Elevation 253.5 ft msl. This is equivalent to assuming that the WHTF was full to Elevation 253.5 ft msl at the beginning of the PMF. The Lake Anna stage-storage data provided to the HEC-1 model reflected the conservative modeling approach for the WHTF. For elevations below 253.5 ft msl, only the North Anna Reservoir's storage volume was input into the model and made available for runoff and rainfall storage. For elevations above 253.5 ft msl, the storage from both facilities was input into the model and made available. The stage-storage curve for the combined WHTF and North Anna Reservoir, reflecting the conservative approach described, is shown on Figure 2.4-10.

Two adjustable skimmer gates and three spillway radial gates provide control of the discharge from the North Anna Dam, as described in Section 2.4.1.2. The stage-discharge relationship used in the HEC-1 runoff model was based on the adopted spillway rule curve and is the same that was used in the previous 1976 PMF analysis. The skimmer gate and spillway discharge capacities are shown on Figure 2.4-3 and Figure 2.4-4.

The present PMF runoff analysis was performed by applying the PMP values in Section 2.4.3.1 to the watershed and lake surface area unit hydrographs, combining the two hydrographs, and routing the resultant inflow hydrograph through Lake Anna.

2.4.3.4 Probable Maximum Flood Flow

The computed PMF inflow hydrograph to the combined WHTF and North Anna Reservoir is shown in Figure 2.4-11. The peak PMF inflow discharge is about 302,100 cfs, and the peak discharge over the dam is about 141,000 cfs. The controlling PMF hydrograph shows a result of the runoff from a 72-hour storm with precipitation values equal to 40 percent of the PMP, followed by three days with no precipitation and then the 72-hour PMP storm.

There are no other dams in existence on the North Anna River, either upstream or downstream of the ESP site. The only impoundments in the Lake Anna drainage area are small farm ponds and two small recreational lakes, Lake Louisa and Lake Orange, whose failures would not produce any measurable effect on the Lake Anna water levels. Thus, these effects were not included in the PMF flow.

2.4.3.5 Water Level Determination

The PMF inflow hydrograph was routed through the combined reservoir using HEC-1 to determine the maximum still water level associated with the PMF. This routing resulted in a peak outflow of 141,000 cfs with a maximum water level at the dam of 264.07 ft msl. These values may be compared with the 1976 analysis that resulted in a peak outflow discharge of 142,000 cfs and a peak water level of 264.2 ft msl.

For the 1976 analysis, included in the NAPS UFSAR, a backwater profile curve was developed for the peak discharge of 142,000 cfs, indicating the lake level at the NAPS site to be about 0.2 feet higher than the water level at the dam (Reference 1). Since the peak outflow discharge for the present analysis is slightly less than the previous discharge, the results of the previous backwater analysis have been conservatively applied to the elevation computed for this PMF analysis. By adding the backwater effect of 0.2 ft to the PMF still water elevation of 264.07 ft msl at the dam, the PMF still water elevation at the site is 264.27 ft msl.

2.4.3.6 Coincident Wind Wave Activity

In accordance with procedures outlined in ANS/ANSI-2.8-1992, the wave setup and run-up generated by a 2-year return period wind speed were added to the PMF still water elevation to determine the maximum PMF water level at the ESP site (Reference 9). The 2-year overland wind speed for the site was determined by investigating data presented in ANS/ANSI 2.8-1992 and NUREG/CR-2639 (Reference 9) (Reference 18). From these two references a fastest-mile 2-year wind speed of 50 mph, measured 30 feet above the ground over land, was selected. This translates to a fastest-mile 2-year wind speed over water of 56.0 mph (Reference 19). The fetch diagram used to determine an effective fetch length of 4700 ft with a maximum fetch of 10,600 ft is shown on Figure 2.4-12.

Using these values and procedures outlined in the U.S. Bureau of Reclamation publication, *Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams,* (Reference 19) and the USACE–*Shore Protection Manual* (Reference 20), a significant wave height of 2.15 ft and a maximum wave height of 3.60 ft were calculated. From these values a maximum wind set-up value of 0.09 ft and a wave run-up value of 3.03 ft were calculated. Adding the wind setup and wave run-up values to the PMF still-water elevation at the site resulted in a maximum PMF elevation at the site of 267.39 ft msl.

2.4.4 Potential Dam Failures

As indicated in Section 2.4.1.1, the ESP site is located adjacent to Lake Anna and approximately 5 miles upstream of the North Anna Dam. Lake Anna was created to supply water to the existing power station. Amendment 15 to the North Anna Unit 1 and 2 Preliminary Safety Analysis Report (PSAR) (Reference 21) demonstrates that the design of the North Anna Dam complies with the requirements associated with Seismic Class I structures. Thus, as described in the NAPS UFSAR, a seismically induced failure of the dam is not credible (Reference 1).

Lake Anna would serve as the make-up water source for the wet cooling towers proposed for Unit 3. These include the wet cooling towers used for the circulating water system and the wet cooling towers used for service water cooling. As described in Section 2.4.11.6, the ultimate heat sink (UHS) would consist of a mechanical draft cooling tower over a buried water storage basin or other passive water storage facility as required by the reactor design. The UHS facilities would provide a source of water for the service water system in the event that the primary source becomes unavailable. Therefore, adequate service water would be immediately available to maintain any new unit or units in a safe condition, even if Lake Anna were to be drained due to a dam failure. No safety-related structures or systems of any new units would be adversely affected by the loss of water in Lake Anna due to dam failure.

No other dams exist on the North Anna River, either upstream or downstream of the ESP site. The only impoundments in the area are small farm ponds and two small recreational lakes – Lake Louisa and Lake Orange – that are located on small tributaries to the North Anna River and whose failures would not produce any measurable effect on the Lake Anna, North Anna Dam, or any safety-related systems.

2.4.5 Probable Maximum Surge and Seiche Flooding

Since the ESP site is not located on an estuary or open coast, surge or seiche flooding would not produce maximum water levels at the site. The maximum surge and seiche flooding is to be considered using an antecedent water level corresponding to the 100-year maximum water level in the lake (Reference 22). The published Flood Insurance Study for Louisa County, Virginia, indicates only an approximate flood hazard area for Lake Anna (Reference 23). From the flood hazard shading, an approximate flood elevation of 255 ft msl was estimated. This elevation is 9.07 ft below the maximum still-water elevation of 264.07 ft msl, as presented in Section 2.4.3.

Section 2.4.3 describes the analysis of wind setup (surge) and wave runup completed as part of the PMF evaluation. This analysis indicates that the maximum fetch length at the site is 10,600 ft, and the effective fetch length is 4700 feet. Given these relatively short lengths, the surges and waves produced from winds generated in a probable maximum hurricane or from the oscillatory waves generated by lake reflection or harbor resonance would not be sufficient to produce water levels greater than the still water level resulting from the PMP over the watershed.

2.4.6 Probable Maximum Tsunami Flooding

Since the site is at an inland location and not located on an estuary or open coast, tsunami flooding is not a design consideration.

2.4.7 Ice Effects

2.4.7.1 Ice Conditions

Ice at a nuclear power plant site can occur in any one of the following forms:

- Surface ice and its associated forces
- Anchor ice formation on components
- Frazil ice that could clog intake flow passages
- Ice jams that can affect flow path to the intake
- Ice accumulation on roofs of safety related structures and components.

Historical data quantifying ice and snow conditions at the NAPS site have been collected and evaluated and are presented in Section 2.4.7.3.

The following subsections describe the cooling water system for the existing units and the new units. A summary of the historic ice conditions at the NAPS site, as well as ice prediction and its effects on the design of the new units are included.

2.4.7.2 Description of the Cooling Water System

The existing units use a once-through cooling system that withdraws water from the North Anna Reservoir, circulates it through condensers, and returns the water to the reservoir via the WHTF, as is described in Section 2.4.1. The emergency cooling water and normal service water are provided from a service water reservoir (SWR) equipped with a spray system. This SWR is completely separated from the North Anna Reservoir and the WHTF. However, normal make-up water for the SWR is pumped from the plant intake structure on the North Anna Reservoir.

For the new units, Unit 3 would use a closed-cycle, dry and wet cooling tower system for the main condenser. Make-up water for the wet cooling towers would be supplied from the North Anna Reservoir. Blowdown discharge from the wet cooling towers would be returned to the reservoir via the WHTF. Unit 4 would use a closed-cycle cooling system and dry towers, which would typically have no evaporative losses. Therefore, no make-up water for Unit 4 would be obtained from the North Anna Reservoir. In the event that the secondary cooling water loop of the selected dry tower system incorporates a pump sump with a free water surface, a small amount of evaporation will occur. The evaporation from this surface has been estimated to be about 1 gpm (0.002 cfs). Any Unit 4 make-up water would be provided from the reservoir through separate pumps located inside a new pump intake structure. The plant service water cooling system for Unit 3 would use wet cooling towers. Make-up water for these wet cooling towers would be supplied from the North Anna

Reservoir via make-up water pumps or other water supply pumps located in the new pump intake structure. The service water cooling tower blowdown discharge would be discharged to the WHTF and returned to the North Anna Reservoir. Dry cooling towers would be used to cool plant service water for Unit 4. Dry cooling towers would be used to cool plant service water for Unit 4. The emergency cooling water for both Units 3 and 4 would be provided from a separate underground concrete storage basin covered by cooling towers to dissipate the rejected heat from the reactor during emergency conditions or from a passive water storage facility.

The cooling designs for Units 3 and 4 separate the normal cooling and the emergency cooling water systems. There is no system interconnection or inter-system reliance between normal and emergency cooling. The discussion and analysis presented in this section demonstrates that the normal closed-cycle, dry and wet cooling tower (Unit 3) and closed-cycle, dry cooling tower (Unit 4) systems are reliable and would not be affected by ice conditions in the lake. Furthermore, this section includes data analysis and discussion of the effect of combined snow and winter PMP on safety-related structures.

2.4.7.3 Historical Ice Formation

The climate at the ESP site is influenced throughout the year by the Chesapeake Bay climate. The long-term mean daily air temperature in Richmond ranges from about 38.0°F in January to 78.2°F in July, while the mean daily minimum air temperature for January is 28.4°F and for March is 36.6°F (Reference 24).

Snowfall in the region is infrequent and does not accumulate with debilitating impact. The maximum monthly snowfall in Richmond, Virginia occurred in January 1940 with a depth of 28.5 inches. The maximum monthly snowfall in recent years occurred in February 1983 with a depth of 21.4 inches. The maximum 24-hour snowfall in Richmond, Virginia occurred during January 1940 with a total snowfall of 21.6 inches (Reference 24). Charlottesville, Virginia snowfall data have also been examined. The maximum monthly snowfall observed in Charlottesville was 29.8 inches, which occurred in March 1960.

Assuming a snow density of 0.1, the estimated maximum monthly water equivalent for the snowfall at Richmond, Virginia is 2.85 inches in January to 1.97 inches in March. This depth is equivalent to a maximum load of 15 pounds per square foot. For the maximum 24-hour snowfall, the estimated water equivalent is 2.2 inches, which is equivalent to approximately 12 pounds per square foot on the ground. For the snowfall in Charlottesville, the equivalent water depth is approximately 3 inches, and approximately 16 pounds per square foot.

The combination of moderate air temperature and the relatively low winter precipitation does not lead to excessive snow and ice formation. Although, historically snowfall and ice have occurred at the site, accumulation has lasted for only short periods of a few days. Based on snow depth measurements recorded at the NAPS site, a maximum snow depth of 32 inches was observed on

the roofs and on the ground in the winter of 1995–1996. The equivalent water depth for this snowfall is approximately 3.2 inches, which is equivalent to 17 pounds per square foot.

These historical monthly snow depths indicate that the maximum equivalent weight of water ranges from 15 to 17 pounds per square foot.

During the winter of 1977, after the construction of the dam and the filling of Lake Anna, and before the operation of the plant, an ice sheet was formed on the lake. However, since the beginning of the operation of the existing units, ice sheets have formed only on the upper reaches of Lake Anna, upstream of Route 208. This region is approximately 3 miles upstream of the cooling water intake the new units.

Ice formation has occurred on the transmission towers and switchyard at the ESP site during freezing rainfall. To date, events such as these have not affected the operation of the existing units. According to NAPS operation records, there have been no incidents of ice blockage of storm drains.

2.4.7.4 **Frazil Ice**

Research on the properties of frazil ice indicates that the nature and quantities of ice produced depends on the rate of cooling within a critical temperature range. Frazil ice forms when the water temperature is below 0°C (32°F), and the rate of super cooling is greater than 0.01°C (0.018°F) per hour in turbulent flows, and there is no surface ice sheet to prevent the cooling (Reference 25) (Reference 26). This type of ice, which is in the shape of discoids and spicules (Reference 25) typically forms in shallow flowing water, such as in rivers and lakes, when the flow velocity is approximately 2 feet per second (fps) (0.6 meters per second) (Reference 27).

If a submerged intake is located in shallow water where frazil ice is forming, ice may grow directly on metal surfaces such as the trash rack and/or traveling water screens. This type of frazil ice is called anchor ice (Reference 26).

At Lake Anna, formation of frazil ice is precluded due to the circulation of the Unit 1 and 2 condenser cooling water and current heat load. Historic water temperature data at the intake of North Anna Units 1 and 2 have shown that the minimum intake water temperature reached has been 1.2°C (34.2°F) with only one unit in operation.

The data presented in Table 2.4-12, obtained by Virginia Power as part of their thermal monitoring program, show the number of days during which the intake water temperature fell below 4°C (39.2°F). These data indicate that the water temperature at the intake during the winter months has historically been above freezing. Thus, even in the presence of surface turbulence generated by winds, frazil ice would not form due to high surface temperature. With the operation of the existing units, frazil ice would not be expected to form at the intakes of the new units.

If, for some reason, Units 1 and 2 do not operate for a prolonged period in the winter, the lake water temperature would eventually decrease at a rate dependent on the prevailing air temperature and

wind. Under these conditions supercooling could lead to the formation of frazil ice. However, for frazil ice to form, sufficient turbulence is required. The design of the new intake would be such that approach velocities would be 1 fps or less. This low flow would not produce sufficient turbulence to generate frazil ice, based on criteria stated in Reference 27 and others. Turbulence also can be generated by strong and sustained wind over the lake during the same climatic conditions. Even though historical wind data at Richmond, Virginia (Reference 24) do not show the occurrence of such events, it is possible that such winds could develop over an open water body such as Lake Anna. If extreme events were to occur during a period when Units 1 and 2 are not operating, it is possible that frazil ice could form in the intake area. In the event that it does, safety-related facilities would not be adversely affected. The UHS would provide a source of cooling and service water, if needed, to maintain the plant in a safe mode should the North Anna Reservoir intake become inoperable due to frazil ice formation. Further information on the UHS is found in Section 2.4.11.

The formation of anchor ice on the trash racks and screens would be assessed during the design of the intake and described in the COL application.

2.4.7.5 **Surface Ice**

The formation of a surface ice sheet in a cooling water lake can exert forces on the contact structures due to ice expansion or to the drag force caused by wind acting on unrestrained ice sheets.

Shoreline intakes designed with approach channels can become obstructed by ice jams. This is possible at lake intakes where wind may drive the ice toward the shoreline. However, trash racks prevent the entry of large pieces of ice from broken ice sheets (Reference 28).

However, if the existing units were off-line during a relatively sustained freezing weather period, the formation of surface ice is possible, based on examination of the mean daily air temperature for the 1961–1995 time period. The data show that there were several years in which the mean daily temperature in the December through March time frame was below freezing for one to three weeks.

The maximum ice thickness that could have formed under historic low air temperatures with no units in service has been predicted. The meteorological data for the Piedmont Research Station (Reference 61) have been analyzed to determine the degree-days below freezing. In the December 1976 through March 1977 period, there were about 322 cumulative degree-days below freezing. Using this information and employing Assur's method as presented in Chow (Reference 29) (Reference 30), the calculated ice thickness is approximately 17.1 inches. This ice layer would not impact water flow upon restart due to the water depth at the new intakes (a minimum of approximately 10 feet). Instead, this surface ice layer would insulate and provide protection against the formation of frazil ice. However, the formation of surface ice can exert a high load on the intake structure wall in contact with the water. Ice forces would be accounted for in the design of the intake and described in the COL application. It should also be noted that the intakes and associated pumps for the new units would not be safety-related facilities. Emergency cooling

and service water needed to maintain the new units in a safe mode would be supplied by a separate UHS. Therefore, no safety-related facilities would be affected by ice layer formation on the lake.

Upon restart of the existing units and the circulation of warm water, the ice would gradually melt and break. The velocity induced by the flow can cause some of the ice floes to be withdrawn or moved by the water (Reference 31). Although the design of the intake has not been developed to enable the determination of ice floe size that might be withdrawn, the presence of trash racks and traveling screens would prevent such ice from reaching the pumps. The accumulation of ice at the trash racks and traveling screens could clog them and reduce the flow capacity of the intake structure. However, since emergency cooling and needed service water would be provided by the UHS, no safety-related facilities would be affected by ice floe accumulation on the lake.

2.4.7.6 Ice and Snow Roof Loads on Safety Related Structures

Historical data indicate that since the existing units were put into operation, snowfall in Richmond and at the ESP site has been infrequent and without debilitating impacts when compared to other "snow" regions in the country, as presented in Section 2.4.7.3. The presence of snow/ice accumulation could cause blockage of the roof drains and its effects must be considered in the design of the roofs of the safety-related structures.

According to RG 1.70, Section 2.3.1.2, the weight of a 48-hour winter PMP and the weight of a 100-year return-period snow pack should be considered for the design of the roofs of safety-related structures. Based on the climatological conditions at the site, the weight of a 100-year snow pack is estimated to be 30.5 pounds per square foot and the 48-hour winter PMP is estimated to be 20.75 inches, as indicated in Section 2.3.1.

The maximum load experienced by the roof structure, due to precipitation, is dependent on the roof design/configuration. For example, the roof load could be governed by the maximum accumulation of snow and a surcharge due to the loading from the overflow depth as runoff flows over the roof. The design capacity of the roof structure, and possibly other design features, which demonstrate acceptable roofing structure performance for the selected reactor design, would be described in the COL application.

2.4.7.7 Effect of Ice and Snow Accumulation on Site Drainage

Historic observations at the ESP site do not indicate the presence of ice and snow that would cause blockage of the storm drains. From the winter air temperature data summarized in Table 2.4-13, mean daily temperatures below freezing in the winter have historically lasted between 5 to 16 consecutive days. This introduces the possibility of blockage of small catch basins and drains. However, the design of on-site drainage facilities would assume that culverts, catch basins, and storm drains are blocked. With this assumption, the drainage facilities would be designed to pass the flows from the PMP without flooding any safety-related facility. Therefore, local flooding

produced by PMP, coincident with ice and snow on the ground, would be precluded. Details of site drainage are presented in Section 2.4.2.3.

2.4.8 Cooling Water Canals and Reservoirs

As described in Section 2.4.1, new Unit 3 would use a closed-cycle, dry and wet cooling tower system for the circulating water system. A separate, service water cooling system would use a closed-cycle wet cooling tower for dissipation of waste heat from auxiliary heat exchangers not cooled by the plant circulating water system. Make-up water for the wet cooling towers would be supplied from the North Anna Reservoir at a maximum instantaneous rate of 49.6 cfs. Blowdown discharge from the wet cooling towers would be returned to the reservoir at a maximum instantaneous rate of 12.4 cfs, via a new outfall adjacent to the existing units' outfall at the head of the discharge channel and the WHTF.

As described in Section 2.4.1, new Unit 4 would use a closed-cycle cooling system with dry cooling towers to transfer the rejected heat to the atmosphere during normal plant operation. Dry towers would be used for both main condenser and plant service water cooling. These dry cooling systems would have practically no make-up water requirements, and no blowdown discharge. A dedicated pump bay in the new structure would be used to supply a small amount of make-up water to Unit 4, as required by the pump configuration selected for the closed-loop cooling water systems.

The UHS for the new units would consist of a mechanical draft cooling tower over a buried water storage basin or other passive water storage facility, as required by the reactor type. These UHS facilities would have their own source of water, independent of the lake, for safety-related cooling in the event that use of the UHS is required. Therefore, the North Anna Reservoir and the WHTF would not be safety-related facilities. The design basis for these existing non-safety-related cooling facilities is presented in the following paragraphs.

As indicated in Section 2.4.1.2, a series of dikes and canals divide Lake Anna into two segments, the smaller segment forming the WHTF and the larger segment forming the North Anna Reservoir (Figure 2.4-1). Circulating water for the existing units is withdrawn from the North Anna Reservoir at the existing screen well and pump house near the power station and, from there, is pumped through the condenser and discharged through circulating water discharge tunnels into the circulating water discharge canal at the upstream end of the WHTF (Figure 2.4-13). The circulating water then flows through the ponds and interconnecting canals of the WHTF for heat dissipation, and reaches Dike 3 at the easternmost end of the WHTF. Dike 3 contains six submerged adjustable skimmer wall gates through which the circulating water is discharged to the North Anna Reservoir, as shown in Figure 2.4-14. About 40 percent of the rejected heat is lost to the atmosphere in the WHTF, mainly through evaporation. The remaining heat is dissipated in the main reservoir with only a small percentage of heat released from the North Anna Dam. (Reference 1)

Three dikes and two canals form and interconnect the three ponds of the WHTF. Hydraulic losses of circulating water as it flows through the canals and the Dike 3 skimmer wall structure cause the

water level in the upstream end of the WHTF to be about 1.5 feet higher than the normal North Anna Reservoir pool level. (Reference 1)

The dikes used to create the WHTF consist of compacted earth materials, except for a 700-foot length of the easternmost dike, Dike 3, which is constructed of dumped rock fill. The submerged skimmer wall discharge structure is constructed within this rock fill section. The rock fill section serves as an emergency overflow for the WHTF. The crest of the rock fill section is at Elevation 253.5 ft msl, while the crest of the earth fill section for the remainder of the dikes is at Elevation 260 ft msl. Thus during high water conditions, when the water level in the WHTF exceeds Elevation 253.5 ft msl, the rock fill section would be overtopped, thereby allowing excess flood waters to enter the main body of the reservoir without causing the differential level between the reservoir and the WHTF to exceed 2 feet. It is expected that the emergency overflow spillway would operate once in approximately 100 years. (Reference 1)

The earth dikes have a crest width of 26 feet and a side slope of 2.5 to 1 (horizontal to vertical). Each side slope has rip-rap erosion protection. Diversion pipes through the base of each dike, which were necessary for construction purposes, have been closed off with stop logs and left intact during the filling of Lake Anna. (Reference 1)

The discharge canal and the two interconnecting canals in the WHTF are each designed to convey approximately 8000 cfs (Reference 1). This capacity is in excess of the circulating water flow rate of 4246 cfs from the existing units plus the blowdown discharge of 12.4 cfs from the new Unit 3 wet cooling towers, the total being 4258 cfs. The new Unit 4 would not discharge any cooling water to the WHTF. Therefore, with the addition of Units 3 and 4, the normal design water level of Elevation 251.5 feet for the WHTF would not be affected, since total flow through the facility is less than the original 8000 cfs design capacity of the cooling water canals and discharge structure.

The canals are constructed through soil and bedrock and are unpaved. Erosion protection is provided by vegetation along all banks, except in the vicinity of the circulating water discharge structure at Dike 3, where riprap is provided (Reference 1).

The physical characteristics and design parameters for the North Anna Reservoir and the North Anna Dam are described in Section 2.4.1. Discussion of the PMF level in the North Anna Reservoir and its derivation is provided in Section 2.4.3. The effects of potential dam failures, probable maximum surge and seiche flooding, and ice effect flooding are addressed in Section 2.4.4, Section 2.4.5, and Section 2.4.7, respectively.

2.4.9 **Channel Diversions**

The possibility of an upstream diversion of the North Anna River is considered extremely remote. Historical information indicates that the river has not had a major change of course in recent history (Reference 1) (Reference 6). Inspection of US Geological Survey 7.5-minute topographic maps and pre-Lake Anna aerial photography shows that the North Anna River lies in a valley that is at least

250 feet lower than the surrounding drainage divide. There is no apparent man-made or natural event (e.g., earthquake, subsidence, landslide, or ice blockage) that could divert the North Anna River from its current drainage basin. Thus, the flow of water into Lake Anna from the North Anna River and tributaries is secure from unexpected upstream diversions.

2.4.10 Flooding Protection Requirements

The maximum design basis Lake Anna flood elevation, presented in Section 2.4.2, is 267.39 ft msl. This elevation is below the site grade at Elevation 271.0 ft msl. Since the ESP site grade is above the maximum water level, including wind setup and wave runup, the possibility of flooding above-grade, safety-related structures, systems, and components of the new units at the ESP site is precluded. Rip-rap protection of the slope embankment at the make-up water intake location on Lake Anna would be provided to prevent wave activity from eroding the embankment near the on-shore intake structure. It should be noted that although protection would be provided for this structure, the make-up water intake is not a safety-related facility.

As mentioned in Section 2.4.2, the effects of intense local precipitation would be considered in the design of drainage facilities for the ESP site. These facilities would be designed such that the peak discharge from the local PMP would not produce flood elevations that would pose a flooding hazard to any safety-related structure, system, or component of the potential new generation units at the ESP site. Additionally, the design of the drainage facilities would incorporate measures to ensure that the existing units safety-related facilities would not be subject to flooding during the construction or operation of the new units. Applicable NRC, federal, state, and local storm water management regulations would be followed in the design of the drainage facilities.

2.4.11 Low Water Considerations

2.4.11.1 Low Flow in Streams

Prior to construction of the North Anna Dam, the average daily flow measured at Doswell, Virginia was 370 cfs (Reference 32). The lowest instantaneous flow recorded at Doswell, Virginia, was 1 cfs; however, the lowest recorded flow for a 24-hour period was 2 cfs. (Reference 1)

Since construction of the dam, minimum release requirements have maintained the low flows in the North Anna River downstream of the dam at flow rates higher than those listed above. For lake water elevations at or above Elevation 248 ft msl, a minimum release of 40 cfs is mandated. For water levels below 248 ft msl the release may be lowered in accordance with the criteria set forth in VPDES Permit Number VA0052451, which requires a minimum instantaneous release from the dam of no less than 20 cfs. (Reference 7) The minimum daily flows recorded at Partlow, Virginia (1978–1995) and Doswell, Virginia (1972–1988) since construction of the dam are 38 and 40 cfs, respectively (Reference 5) (Reference 4). Since 1995, Lake Anna water level and dam operation data compiled by Virginia Power, indicate that the minimum release from the dam during this period was 20 cfs (occurring during severe drought conditions).

Lake Anna, which was formed by the construction of the North Anna Dam on the North Anna River, provides cooling water for the existing units. Lake Anna would provide make-up water for the cooling towers proposed for the new units, as described in Section 2.4.1. Currently, the lake is maintained at an operating water level of 250 ft msl. The existing units can continue to operate with lake water levels as low as Elevation 242.0 ft msl before shutdown of the units must occur in accordance with the plant's Technical Requirements Manual (Reference 33). For the new units, the anticipated minimum lake level for operation is also Elevation 242.0 ft msl. All intake elevations would be based on this elevation, with sufficient margin to ensure plant operation during low water events. The historic low water levels in Lake Anna are presented in Section 2.4.11.3.

Although low water levels could conceivably require a shutdown of the existing units and the new units, no safety-related structures, systems or components at the existing units or the new units would be affected. Thus, low water levels do not pose a safety-related risk to either the existing or new units. The UHS for the new units would also be unaffected by low water levels in the lake. Details on the design basis for the UHS of the new units are addressed in Section 2.4.11.6.

2.4.11.2 Low Water Resulting from Surges, Seiches, or Tsunami

As presented in Section 2.4.11.1, Lake Anna does not provide the cooling water to safety-related structures, systems, or components. In accordance with RG 1.70, low water resulting from surges, seiches, or tsunami need only be considered when such conditions could affect safety-related facilities. A low-water surge of 0.3 feet below the lake's still water level during a probable maximum hurricane has been estimated in the UFSAR for the existing units (Reference 1). Low water conditions as a result of icing have also been considered and are described in Section 2.4.7.

2.4.11.3 Historical Low Water

Table 2.4-5 shows the annual minimum recorded water levels on Lake Anna since the commencement of plant operations in 1978. The lowest minimum recorded water level on the lake was Elevation 245.1 ft msl on October 10, 2002. This low water level followed the driest September to August period and the third driest October to September period in the 108-year record for Virginia state-wide precipitation (Reference 34) (Reference 35). Prior to this historic low, the lowest recorded water level was Elevation 247.4 ft msl in 2001. Since 1978, the water level has fallen below Elevation 248.0 ft msl on five occasions, and below Elevation 247.0 ft msl only once. Historic low water flows are presented in Section 2.4.11.1.

Table 2.4-5 Lake Anna Annual Minimum Water Level

Year	Minimum Water Level ft msl	Year	Minimum Water Level ft msl	Year	Minimum Water Level ft msl
1978	249.03	1987	248.90	1996	249.80
1979	249.01	1988	248.40	1997	249.10
1980	248.38	1989	249.42	1998	247.60
1981	248.00	1990	249.51	1999	247.60
1982	249.02	1991	248.50	2000	249.20
1983	248.11	1992	249.30	2001	247.40
1984	248.87	1993	247.90	2002	245.10
1985	249.18	1994	249.40		
1986	248.16	1995	248.80		

During drought conditions, the water level in the lake is determined by a combination of the lake inflow, dam release, lake evaporation, and any consumptive uses of water. The heat load rejected from the existing units influences lake evaporation. The closed-cycle, dry and wet cooling system for Unit 3 would consume additional water through cooling tower evaporation and reduce water levels during times of drought when inflow is insufficient to replace outflows from dam releases and evaporation. Water level impacts during drought conditions would, however, be mitigated through use of the dry towers, as is described in Part 3: Section 5.2. Unit 4 would use a closed-cycle cooling system with dry towers that typically have no evaporative losses, require no make-up water to replace evaporative loses, and have no blowdown discharge compared to mechanical (or natural) draft cooling towers. In the event the secondary cooling water loop of the selected dry tower system incorporates a pump sump with a free water surface, a small amount of evaporation will occur. The evaporation from this surface has been estimated to be about 1 gpm (0.002 cfs). Any make-up water necessary to replace these evaporative losses would be supplied from the reservoir. Given a make-up water demand of 1 gpm or less, Unit 4 operation would not impact Lake Anna water levels. The effects of new units on the Lake Anna water levels are presented in Section 2.4.11.4.

2.4.11.4 Future Controls

Other than the required releases from the North Anna Dam, the only other consumptive water user for Lake Anna is the existing units. To determine the impact of new units on Lake Anna water levels, a water budget analysis of the lake with the existing and future units was performed. This analysis

can be found in Part 3: Section 5.2.2. The period analyzed extended from October 1979 to April 2003 with two different water use scenarios investigated, which are described below.

Existing — The existing units running at a plant capacity factor of 93%, which is in excess of their historical operating experience.

Proposed — The existing units running as described above; new Unit 3 with an assumed 96 percent capacity factor using a closed-cycle, dry and wet cooling tower system, withdrawing make-up water from the North Anna Reservoir and discharging blowdown to the WHTF; and new Unit 4 using a closed-cycle, dry cooling system with no make-up water need and no blowdown discharge to the WHTF.

The minimum calculated Lake Anna water levels for the Existing and Proposed scenarios are 245.1 and 244.2 ft msl, respectively. The durations of low lake water levels from the analysis are shown in Table 2.4-6. The minimum operating level for existing Units 1 & 2 and new Unit 3 (Elevation 242.0 ft msl) is below the minimum calculated under the Proposed scenario. Therefore, there would be no new impacts of low-flow conditions on the operation of either the existing Units 1 and 2 or new Unit 3. Table 5.2-3 in Part 3: Section 5.2.2 compares the Lake Anna low outflow frequency for the Existing and Proposed scenarios.

Table 2.4-6 Lake Anna Low Water Level Durations

Lake Level (ft msl)	Percent of the Time Water Level Is Less Than Indicated Value	
	Existing	Proposed
248.0	5.2%	7.0%
246.0	1.1%	1.4%
244.0	0%	0%
242.0	0%	0%

Existing – Unit 1 and 2 using once-through cooling

Proposed – Units 1 and 2 using once-through cooling; Unit 3 using closed-cycle cooling system with dry and wet cooling towers; Unit 4 using closed-cycle cooling system with dry cooling towers.

2.4.11.5 Plant Requirements

Based on the calculated water levels and the cooling system selected for the new units, a minimum plant operating lake level would be established in the COL application. When the lake water level falls below this elevation, a plant shutdown sequence would be initiated. All sump inverts, pump levels, and submergence requirements would be based on the minimum plant operating lake level.

Lake Anna would not directly supply cooling water to any safety-related facilities and would not serve as the UHS.

2.4.11.6 Heat Sink Dependability Requirements

The UHS concept used for the new units would depend on the reactor type selected. According to the PPE, certain reactor types (e.g., the AP1000, IRIS, and PBMR reactors) do not require a conventional UHS to provide safety-related cooling during emergency shutdown. Some (e.g., the AP1000 and IRIS reactors) make use of a passive cooling system and utilize water stored in onsite tanks. Others (e.g., the PBMR) provide for safety-related decay heat removal by the RCCS boil-off mode.

For the other three reactor types listed in the PPE and any other reactor requiring a UHS, the concept would consist of a mechanical-draft cooling tower separate from the condenser circulating water system. The UHS cooling tower would be located over a concrete basin water reservoir with sufficient water to maintain the plant in a safe shutdown mode for 30 days. Since the cooling tower basin for the UHS would contain its own 30-day water supply, water levels in Lake Anna would not affect the ability of the UHS to provide emergency cooling for safe shutdown. A detailed description of the UHS, if required by the reactor design selected, would be provided in the COL application.

2.4.12 Groundwater

2.4.12.1 Description and Onsite Use

2.4.12.1.1 Regional Hydrogeology

The region within a 200-mile radius around the ESP site encompasses parts of six physiographic provinces as described in Section 2.5.1.1.1. These include, from east to west, the Continental Shelf, Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau Physiographic Provinces. Groundwater occurrence is of significance to the ESP site only within the Piedmont Province. However, a brief discussion of groundwater within the other provinces, except the Continental Shelf off the east coast, is included below to provide a more complete picture of regional hydrogeologic conditions.

Unconsolidated to semiconsolidated deposits and bedrock throughout the region comprise the aquifers and intervening confining layers that determine the hydrogeologic characteristics of the subsurface materials. When two or more aquifers are grouped together they are considered to constitute an aquifer system. Within the site region, the aquifers and aquifer systems have generally been grouped into three categories based on the degree of consolidation of the materials comprising them. (Reference 36) Quaternary age deposits are generally unconsolidated; Cretaceous and Tertiary age materials are generally considered to be semiconsolidated; and Precambrian, Paleozoic, and early Mesozoic age materials are generally consolidated. In some areas, particularly the Piedmont Physiographic Province, unconsolidated materials overlying the

bedrock are derived from in situ weathering of the consolidated rock strata. In other areas such as stream valleys, unconsolidated sediments of sand and gravel generally occur as alluvial deposits.

a. **Coastal Plain Physiographic Province**

Within the Coastal Plain Physiographic Province in the site region (200-mile radius), 6 regional aquifers, consisting primarily of semiconsolidated sands separated by clay confining layers, have been described as comprising the Northern Atlantic Coastal Plain aquifer system. These 6 aquifers, from youngest to oldest, are the: 1) Surficial aquifer, 2) Chesapeake aquifer, 3) Castle Hayne-Aquia aquifer, 4) Severn-Magothy aquifer, 5) Peedee-upper Cape Fear aquifer, and 6) Potomac aquifer. Local aquifers and confining units of limited areal extent and variable thickness comprise all or part of these regional aquifers on a site-specific basis. The Coastal Plain sediments are thin along the western boundary of the province, where they terminate at the contact with the Piedmont Province, and they thicken in an easterly to southeasterly direction. The sediments, ranging in age from Holocene to Early Cretaceous, overlie crystalline igneous and metamorphic rocks that are an eastward extension of the bedrock underlying the Piedmont Physiographic Province. (Reference 36) In Virginia, these sediments reach a thickness of over 3000 feet at the Atlantic Ocean shoreline.

Almost half of Virginia's groundwater use occurs in the Coastal Plain Province. Groundwater is withdrawn from the unconfined Surficial aquifer and from the deeper confined aquifers of the Northern Atlantic Coastal Plain aquifer system. These aquifers are recharged principally in their outcrop area along the western boundary of the province and, to a lesser degree, from leakage through the overlying strata. The thickness and areal extent of the aquifers results in a very large storage capacity for groundwater, more than that of aquifers in any other physiographic province in Virginia. The quality of the groundwater in the 6 regional aquifers is generally good, except where they approach the coastline and saltwater begins to intrude into them. (Reference 37)

The U.S. Environmental Protection Agency (EPA) has designated two aquifers within the Coastal Plain Physiographic Province of Virginia as Sole Source Aquifers. EPA defines a Sole Source Aquifer as:

"…one which supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer. These areas can have no alternative drinking water source(s) that could physically, legally, and economically supply all those who depend upon the aquifer for drinking water."

The designation protects an area's groundwater resource by requiring that the EPA review any proposed projects receiving federal financial assistance within the designated area. All such projects are subject to review to ensure that they do not substantially impact the groundwater source. The two Coastal Plain Sole Source Aquifers in Virginia are located at the southern end of the Delmarva Peninsula in Accomack and North Hampton Counties, about 120 miles

southeast of the ESP site. The aquifers are the Columbia, correlative with the Surficial aquifer, and the Yorktown-Eastover aquifer, correlative with the upper portion of the Chesapeake aquifer. (Reference 38)

An area southeast of the site has been designated as the Eastern Virginia Ground Water Management Area by the VDEQ. Groundwater withdrawal in this area is permitted based on need and an evaluation by the VDEQ of the impacts of proposed withdrawals. The area, comprised of several counties or portions thereof in southeastern Virginia, lies entirely within the Coastal Plain Province. (Reference 39)

b. **Piedmont Physiographic Province**

In addition to the Surficial aquifer system in the unconsolidated deposits in the Piedmont Physiographic Province in the site region (200-mile radius), three types of aquifers are present within the consolidated rock strata. The consolidated aquifer types are comprised of crystalline and undifferentiated sedimentary rocks, carbonate rocks, and early Mesozoic age rift-basin sedimentary and ignaceous rocks. Although the crystalline rocks form the predominate aquifers in the Piedmont Province, the carbonate rocks, which are primarily found from Maryland northward in the Piedmont, form the most productive aquifers. (Reference 36) Development of significant water supplies generally occurs within a few hundred feet of the ground surface due to the presence of water-bearing fractures, which tend to decrease in size and number with depth. The potential for groundwater development in the Piedmont Province is much lower than for the Coastal Plain Province. Yields from wells in the Piedmont commonly range from 3 to 20 gallons per minute (gpm). Wells yielding in excess of 50 gpm are considered to be exceptional and are generally in areas of extensive fracture or fault systems that are often found along the western margin of the Piedmont Province at its boundary with the Blue Ridge Mountains. (Reference 37) No Sole Source Aquifers have been designated in the Piedmont Province of Virginia (Reference 38). A more complete description of groundwater conditions in the Piedmont Province in the vicinity of the ESP site is provided in Section 2.4.12.1.2.

c. **Blue Ridge Physiographic Province**

The Blue Ridge Physiographic Province lies along the western boundary of the Piedmont Province and consists of a relatively narrow band of mountains with the highest elevations in Virginia. Igneous and metamorphic rocks are generally found along the eastern flank of the Blue Ridge Province while sedimentary rocks are generally found on the western flank. Bedrock underlies a generally thin layer of soil and weathered rock. Beneath the weathered zone, the rock is relatively impervious, with groundwater generally occurring in fractures in the rock. (Reference 37)

Goundwater development is most likely achieved along the lower slopes of the mountains. However, well yields are generally low in the Blue Ridge Province (less than 50 gpm) and

withdrawal is primarily used for domestic purposes. (Reference 37) (Reference 40) Groundwater emanating from springs is common and is often used as a source of domestic water supply.

d. **Valley and Ridge Physiographic Province**

The Valley and Ridge Physiographic Province lies about 50 miles west of the ESP site and is separated from the Piedmont Province by the Blue Ridge Province. Aquifers underlying the Valley and Ridge Province occur within Paleozoic age folded and faulted rock strata of sedimentary origin. The strata consist mostly of sandstone, shale, and limestone, with minor amounts of coal, dolomite and conglomerate. Locally, the rocks have been metamorphosed into quartzite, slate, and marble. (Reference 36)

Carbonate and sandstone layers form the principal aquifers in the Virginia through New Jersey portion of the Valley and Ridge Province. Carbonate rocks, primarily limestone, generally form most of the more productive aquifers and underlie valleys within the province. The folded rock strata and network of surface streams in the Valley and Ridge have resulted in the creation of a series of shallow, isolated, local groundwater flow systems. Recharge to these flow systems is generally a result of direct precipitation and the down-gradient movement of surface and subsurface water from the ridges to the valley floors. Groundwater flow paths are generally short, except where carbonate-rock aquifers consist of an extensive network of solution openings. Yields to wells in carbonate-rock strata of the Valley and Ridge Province in western Virginia can range from 150 to 1000 gpm, but may be less in rocks with fewer fractures or solution cavities. (Reference 36)

e. **Appalachian Plateau Physiographic Province**

The eastern boundary of the Appalachian Plateau Physiographic Province is over 100 miles west of the ESP site. Aquifers underlying the Province occur in Paleozoic age sedimentary rock strata. These strata are nearly flat-lying to gently folded and consist mainly of shale, sandstone, conglomerate, and carbonate rocks. Most of the aquifers are sandstone of Pennsylvanian and Mississippian age. Locally, carbonate rocks of Mississippian age are also productive aquifers, and small volumes of water are obtained from conglomerate beds of Pennsylvanian age. (Reference 36)

Recharge to the bedrock aquifers in the Appalachian Plateau Province from precipitation is limited due to generally thin soil cover and the highly dissected nature of the land surface, resulting in slopes that facilitate runoff. Groundwater circulation is generally limited to local or intermediate-scale flow systems rather than large-scale regional flow. This results in a relatively shallow zone of fresh water, underlain by saline water or brine within close proximity to the ground surface. The limited circulation of fresh water can generally be attributed to one or more of the following factors:

- the flat-lying nature of the rock strata impeding the vertical movement of groundwater;

- less intense fracturing of the rock strata compared with that in the Valley and Ridge Province and a decrease in the number of fractures with depth; and
- a lack of solution-riddled carbonate rock units like those in the Valley and Ridge Province that facilitate the vigorous circulation of groundwater.

Yields to wells in southwestern Virginia are generally less than 12 gpm but may reach 50 gpm in carbonate rock strata. (Reference 36)

2.4.12.1.2 Local Hydrogeology

Recharge to aquifers in the Piedmont Physiographic Province occurs largely as infiltration of local precipitation in interstream areas. That portion of the precipitation that does not migrate laterally through the unconsolidated surficial materials for discharge to nearby streams or low areas percolates vertically downward to the bedrock, where it enters water-bearing openings in the rock. (Reference 36) The average recharge to aquifers from precipitation in the Piedmont Province of Virginia is estimated to be about 8 to 10 inches per year (Reference 41) (Reference 42). Although an intricate network of rivers and streams that follow a dendritic drainage pattern generally dissects the Piedmont Province, some of the drainage (or portions thereof) follow nearly straight courses that are controlled by joint or fault systems in the underlying bedrock. Those streams passing through the area from other geologic provinces provide a secondary source of recharge to the groundwater. The Piedmont Province of Virginia is estimated to have as much as 1.5 billion gallons of water per square mile held in storage in the consolidated and unconsolidated aquifers. This volume of water is considered suitable for domestic and other small supply requirements. (Reference 42)

In the area around the ESP site, the bedrock consists of Precambrian to Paleozoic age crystalline metamorphic and igneous rocks, while the overlying unconsolidated material is largely a weathering product (residual soil or saprolite) of the underlying bedrock. Groundwater in the crystalline rocks is stored and transmitted through joints and fractures in the rocks, while the main body of the rock between the joints and fractures is essentially impermeable. The number and extent of the joints/fractures, and the width of the openings between their surfaces, generally decrease with depth, thus limiting the significance of the water-transmitting capability of the bedrock to its upper few hundred feet. (Reference 37)

Saprolite at the ESP site is generally exposed at the ground surface or underlies a thin layer of residual soil or fill. The saprolite extends to the top of the rock from which it was derived; however, the contact between the saprolite and sound rock may be gradational and not well defined (Reference 1). The saprolite is reported to range in thickness from about 2 to 125 feet and is of variable lithology, depending on the type of parent material from which it was derived (Reference 43). Borings drilled as part of the ESP subsurface investigation program penetrated saprolite to depths ranging from about 6 to 35 feet (Appendix 2.5.4B). The saprolite penetrated by

these borings is classified as a micaceous, silty-clayey, fine to coarse sand or sandy silt, with occasional rock fragments.

Bedrock beneath the saprolite at the ESP site belongs to the Ta River Metamorphic Suite. In the site area, these rocks are predominantly biotite gneiss and schist with smaller amounts of amphibolite gneiss. (Reference 44) The results of borings at the ESP site indicate the main rock type to be a gneiss. The gneiss is generally described as quartz gneiss with some biotite quartz gneiss; and interbedded quartz gneiss, biotite quartz gneiss, and hornblende gneiss. The rock exhibits a variable weathering profile and joint/fracture presence. The degree of jointing and fracturing is the controlling factor for groundwater movement through the rock.

Groundwater at the ESP site occurs in unconfined conditions in both the saprolite and underlying bedrock. The results of previous investigations at the site indicate that a hydrologic connection exists between the saprolite and the bedrock. (Reference 45) This condition has been confirmed as part of the ESP subsurface investigation program (Appendix 2.5.4B) by the presence of nearly equal water level elevations recorded in two observation wells (OW-845 and OW-846, Table 2.4-15) installed adjacent to each other and sealed in the bedrock and saprolite, respectively. At the ESP site, the water table is considered to be a subdued reflection of the ground surface and, therefore, the direction of groundwater movement is toward areas of lower elevations (Reference 45). Measurements made on a quarterly basis between December 2002 and September 2003 and again in February 2005 in observation wells at the site exhibit water level elevations ranging from about Elevation 241 ft msl to Elevation 314 ft msl, with corresponding ground surface elevations of about Elevation 283 and Elevation 335 ft msl, respectively (Table 2.4-15). The measurements shown in Table 2.4-15 represent four quarterly rounds of groundwater level measurements and a supplementary measurement taken at the ESP site to characterize seasonal variability in the water levels. Figure 2.4-15 presents hydrographs based on the water levels provided in this table for the nine observation wells (OW-841 through OW-849) installed during the ESP subsurface investigation program and three existing long-term site monitoring wells (P-10, P-14, and P-18). The other wells that were monitored (P- and WP-) were installed previously for NAPS groundwater monitoring purposes around the SWR and the ISFSI, respectively.

A piezometric head contour map (Figure 2.4-16), prepared using the water levels measured in March 2003 (Table 2.4-15), indicates that groundwater flow is generally to the north and east, toward Lake Anna. Freshwater Creek and Elk Creek, both of which flow to Lake Anna, form hydrologic boundaries to the west and south of the site, respectively (Reference 46). Because the water levels in the observation wells are generally above the top of the well screen, the water level elevation represents the piezometric head. An evaluation of the piezometric head contours shown on Figure 2.4-16 indicates a hydraulic gradient toward Lake Anna of about 3 feet per 100 feet. This gradient compares with an initial hydraulic gradient estimated for the site before the filling of Lake Anna of 8 feet per 100 feet. At that time, groundwater flow was toward the North Anna River or its

tributaries. (Reference 43) Prior to the filling of Lake Anna, it was estimated that a gradient of 6 feet per 100 feet would develop following filling of the lake (Reference 1).

Prior to construction of the existing units, it was predicted that the filling of Lake Anna would raise the base level of groundwater discharge about 50 feet. It was estimated that this would result in a small rise in the water table where it intersects the surface of the impoundment area. Beyond this zone of intersection, however, it was estimated that the filling of the lake would have only a minor effect on the water table, and that the water table in the area of the existing units would essentially remain unchanged. (Reference 43)

The nine groundwater observation wells installed at the site as part of the ESP subsurface investigation program were tested using the slug test method to determine hydraulic conductivity values for the saprolite and underlying shallow bedrock (Appendix 2.5.4B). Hydraulic conductivities calculated for the saprolite, based on tests in eight of the wells, range from 0.2 to 3.4 ft/day, with a geometric mean value of 1.3 ft/day. The hydraulic conductivity of the shallow bedrock, as determined from two tests in one of the wells, is estimated to be about 2 to 3 ft/day, although the results of the test are of limited value due to the short duration of stable water level recovery measurements. Table 2.4-16 summarizes the available hydraulic conductivity data.

Laboratory tests performed on samples of saprolite from the site indicate a bulk density for this material of 125 to 130 pounds per cubic foot (pcf). Bulk densities for the bedrock range from 145 pcf for highly to moderately weathered rock to 163 pcf for moderately weathered to fresh rock. Laboratory tests to determine moisture contents of saprolite samples indicate an average moisture content of about 26 percent, while the moisture content in the vadose zone ranges from about 11 to 40 percent with an average of about 22 percent. Using the average moisture content of 26 percent and a value of 2.68 for the specific gravity of the saprolite (Reference 1), the void ratio of the saprolite is estimated to be about 0.7. A total porosity of about 41 percent is estimated from this void ratio and an effective porosity of about 33 percent is estimated based on 80 percent of the total porosity. The specific yield of the saprolite at the ESP site was not determined; however, an estimate of this value taken from published literature for materials of similar composition indicates that it may be in the range of 0.30 to 0.33 (Reference 47).

Based on the estimated hydraulic gradient, hydraulic conductivity, and effective porosity indicated above, groundwater beneath the ESP site is expected to flow toward Lake Anna at a rate of about 0.12 ft/day. Using a distance of approximately 1800 feet from the center of the overall plant footprint for the new units to the closest point along the shoreline of Lake Anna, the groundwater travel time from the ESP site to Lake Anna is estimated to be about 40 years.

2.4.12.1.3 **Plant Groundwater Use**

Groundwater withdrawal for use by the existing units is accomplished from 4 water supply wells permitted for public use by the Virginia Department of Health (VDH). These 4 wells (Nos. 2, 3A, 4 [new], and 6) comprise a single water supply system at the site. A 5th well (No. 4 [old]) was

originally part of this system but is no longer used and is considered to be available for emergency purposes only. A separately permitted (NANIC) well provides the water supply for the North Anna Nuclear Information Center. A new well was constructed at the site in 2003 to support an increase in water demand at the security training building. The proposed location of this well was evaluated by the VDH prior to its construction. The locations of these wells are shown on Figure 2.4-17 and the wells are described in Table 2.4-17. Four small wells not requiring permits at the NAPS site provide minor additional water for plant use (Reference 6). The locations of these 4 wells are not well documented. One of the wells is likely to be the well used to supply the Metrology laboratory and its location is shown on Figure 2.4-17. A second will is located at the Security Training Building in the vicinity of the newly constructed will described above.

The four active wells comprising the primary groundwater supply system for the existing units have individual capacities ranging from 9 to 55 gpm and a total capacity of 160 gpm. However, these four wells are permitted for a total design capacity of only 53,040 gpd or about 37 gpm. This capacity is currently dictated by the available storage tank capacity at the site. The NANIC well has a measured capacity of 74 gpm but a design capacity of 19,600 gpd or only about 14 gpm. (Reference 48) (Reference 49)

As a condition of the well permits, Virginia Power is required to submit an annual report of water withdrawals for the previous year to the VDEQ by January 31 of each year. Table 2.4-18 shows the monthly withdrawal quantities that were reported for the year ending December 31, 2002. It can be determined from this table that the four combined primary wells withdrew a combined average of almost 14 gpm for the year, and that the NANIC well withdrew an average of a little over 1 gpm. The highest total monthly withdrawal in 2002 for the five wells averaged almost 38 gpm in January. This is less than the highest previously reported monthly withdrawal average of 41 gpm in March 1994 (Reference 6). The four wells not requiring permitting are also not required to report their withdrawals, but based on their small size and limited use they are not expected to add more than 1 or 2 gpm to the average withdrawal by the permitted wells (Reference 6).

Any groundwater supply required by the new units would likely come from an increase in the storage capacity for the existing wells or from drilling additional wells. In either event, additional groundwater withdrawal by the new units is not expected to impact any offsite wells due to: 1) their distance from the site, 2) the direction of the hydraulic gradient toward Lake Anna and the lake's recharge effect, and 3) the existence of hydrologic divides between the ESP site and the offsite wells.

2.4.12.2 **Groundwater Sources and Use**

Groundwater for use in the vicinity of the ESP site is obtained from springs and wells in either the saprolite or underlying crystalline bedrock. Most wells completed in the saprolite have been excavated either by hand digging or augering. These wells are susceptible to becoming dry due to seasonal fluctuations in the water table. Drilled wells generally extend through the saprolite to

depths of up to several hundred feet in the underlying bedrock. These wells are cased from the ground surface to the top of bedrock. (Reference 50) The production of groundwater in the vicinity of the ESP site is generally not sufficient to satisfy large water demands because of the relatively low yield of the aquifers, as presented in Section 2.4.12.1.2. The majority of groundwater development in the area is for domestic and agricultural use, with some public, light industrial and commercial use (Reference 45).

There are no known users of large quantities of groundwater within 25 miles of the ESP site (Reference 1). The vast majority of wells in the area yield less than 50 gpm (Reference 50). Based on the presence of Lake Anna and the hydrologic boundary it presents to groundwater movement north and east of the ESP site, further discussion of groundwater use in the vicinity of the site is limited to Louisa County.

Every 5 years, the USGS compiles national water-use estimates and publishes a report containing the results of this effort. Data from the latest available report, for the year 1995, are provided on the USGS website for Virginia, by county or independent city (Reference 51). The following groundwater withdrawal estimates for Louisa County, in millions of gallons per day (mgpd), are provided by withdrawal category:

- Public water supply = 0.18 mgpd
- Domestic water supply = 1.45 mgpd
- Commercial/Industrial water supply = 0.10 mgpd
- Thermoelectric power water supply = 0.02 mgpd
- Agricultural water supply = 0.05 mgpd

The VDEQ requires that any groundwater user in Virginia whose average daily withdrawal during any single month exceeds 10,000 gpd provide a report by January 31 of each year containing water withdrawal and use data for the previous year. The only exceptions to this regulation are agricultural users who have slightly modified requirements based on their location, withdrawal or withdrawal facility. (Reference 8) For the year 2001, no withdrawals were reported for Louisa County that meet or exceed this threshold.

A study previously performed for Louisa County included the compilation and evaluation of records of wells permitted by the Louisa County Health Department (Reference 50). These records addressed 2155 drilled wells and 1743 dug or augered (bored) wells. The majority of the drilled wells serve single-family residences. The locations of the wells are currently referenced only to county tax maps.

The average yield of all wells in Louisa County is estimated to be about 14.5 gpm. However, the average yield of public wells is estimated to be about 42 gpm. The public water supply wells have an average depth of nearly 300 feet, and almost all are less than about 400 feet deep. The residential wells are generally only 100 to 200 feet deep. The Louisa County and previous studies

in the Piedmont Province suggest that yields from individual wells in this area can vary greatly over distances as small as 100 feet. (Reference 50)

Recent evidence for a connection between well yield and Lake Anna is contained in the Lake Anna Special Area Plan (Reference 52). This plan indicates that average well yields are higher in areas adjacent to Lake Anna than in other areas of the Lake Anna watershed, which are, in turn, slightly higher than in other areas of Louisa County. It has been concluded that these higher yields are likely due to the presence of Lake Anna, which enhances groundwater recharge.

There are 45 public water supplies in Louisa County capable of obtaining their water from springs or wells. Data describing these public water supplies are presented in Table 2.4-19. The public supplies closest to the existing units are Lake Anna Plaza, about 2.6 miles to the northwest, and Jerdone Island, about 4.3 miles to the south-southeast. Based on their distance from the ESP site and the presence of one or more arms of Lake Anna between the site and these public water supplies, any impact the new units may have on the aquifers beneath the site is not expected to affect these supplies. Likewise, withdrawal by these public supplies would not affect the ability of the new units to withdraw groundwater for potable water needs.

Private water wells provide about 80 percent of the domestic water supply to residents of Louisa County (Reference 53). The residential water supply well nearest the existing units is located about one mile to the south-southeast in Lot 32 of the Aspen Hill subdivision. Based on its distance from the ESP site and the presence of Sedges Creek between the ESP site and this well, any impact the new units may have on the aquifers beneath the site would not affect the domestic water supply provided by this well. Likewise, withdrawal by the well would not affect the ability of the new units to withdraw groundwater for potable water needs.

Population growth projections for Louisa County by the year 2015 range from about 32,000 to 46,000. Such growth would result in an estimated public water supply demand of between 2.8 and 4.1 mgd for an average day and between 4.5 and 6.6 mgd on a peak day. This water supply demand is expected to be satisfied largely by the use of surface water sources such as Northeast Creek Reservoir and Lake Gordonsville. However, these sources are expected to be supplemented by groundwater supply where available. To meet projected water demands beyond the year 2015, a large groundwater supply may need to be considered in conjunction with the development of alternative surface water sources. (Reference 50)

2.4.12.3 **Monitoring or Safeguard Requirements**

Groundwater monitoring for the ESP site takes place through programs implemented for both the existing units and as part of Dominion's ESP effort. Current groundwater monitoring programs for the existing units are addressed in Station Administrative Procedure Number VPAP-2103N (Reference 54), and NAPS Engineering Periodic Test Procedure Number 0-PT-75.7 (Reference 55). The results of these programs are reported to the NRC on a yearly or as-required basis.

Station Administrative Procedure Number VPAP-2103N, the Offsite Dose Calculation Manual (ODCM) for the existing units, establishes the requirements for the Radiological Environmental Monitoring Program and specifies the conduct of the program. Groundwater samples are collected and tested in accordance with the directions provided in the ODCM.

Engineering Periodic Test Procedure Number 0-PT-75.7 provides instructions for measuring and evaluating groundwater levels beneath the SWR with respect to seepage through the embankment. Seven open-tube standpipe piezometers (P-10, P-14, and P-18 through 22) are currently monitored in accordance with the test procedure, along with two additional piezometers (P-23 and P-24) that are monitored for information purposes only Figure 2.4-16.

A third groundwater monitoring effort at the site consists of three monitoring wells located around the ISFSI. These wells, shown as WP-1 through WP-3 in the ISFSI SAR, Figure 2-11 (Reference 46), are sampled yearly and the samples are tested for radiological constituents in accordance with a request from the Louisa County Board of Supervisors.

Because the existing units' groundwater monitoring wells were not considered to be of sufficient areal extent to determine groundwater levels beneath the ESP site, 9 additional observation wells were installed as part of the ESP subsurface investigation program. Water levels in these 9 wells and 10 of the existing units' monitoring wells were measured quarterly for one year, followed by a supplementary measurement in February 2005, to provide data on groundwater flow direction, gradient, and seasonal groundwater level fluctuations at the site.

As part of detailed engineering, an evaluation of the existing NAPS groundwater monitoring programs, with respect to placement of the new units, would be performed to determine if any additional sampling of existing wells or construction of new monitoring wells would be required to adequately monitor for impacts on groundwater. This evaluation would include a review of the observation wells installed for the ESP application to determine if they can be used as part of any longer-term groundwater monitoring program. The results would be described in the COL application.

Safeguards would be used to minimize the potential for adverse impacts to the groundwater by construction and operation of the new units. These safeguards may include the use of lined containment structures around storage tanks and hazardous materials storage areas, emergency cleanup procedures to capture and remove surface contaminants, or other measures deemed necessary to prevent or minimize adverse impacts to the groundwater beneath the ESP site.

2.4.12.4 **Design Bases for Subsurface Hydrostatic Loading**

The existing units plant grade is at Elevation 271 feet. The containment (reactor) building and associated structures for new units on the ESP site would be constructed at the same plant grade elevation. Previous studies conducted for NAPS resulted in a prediction that maximum groundwater elevations beneath the site in the plant area could reach as high as Elevation 265 to 270 feet

(Reference 1). This estimate was based on a simplified water table profile sloping uniformly from Elevation 271 feet at the toe of the slope south of abandoned Units 3 and 4 (north of the SWR) to Elevation 250 feet at Lake Anna.

One groundwater observation well (OW-844) was constructed at the existing plant grade as part of the ESP subsurface investigation program (Appendix 2.5.4B). The well is located near the toe of the slope north of the SWR (Figure 2.4-16). A second well (OW-841) was constructed in the partially backfilled excavation for abandoned Units 3 and 4. The top of this well is about 20 feet below the plant grade. Maximum measured groundwater level elevations in these wells ranged from about Elevation 250 feet in OW-841 to Elevation 267 feet in OW-844 between December 2002 and February 2005 (Table 2.4-15). Considering the general conformance of the location of OW-844 with the water table profile presented above, these groundwater levels and the piezometric head contours shown on Figure 2.4-16 support the design groundwater level determined for the existing units as described above.

Based on the preceding information, a design groundwater level ranging from Elevation 265 to 270 feet in the plant area of the ESP site appears to be reasonable. For other structures that may be constructed at higher elevations in support of new units on the ESP site, a higher design groundwater level may be justified.

2.4.13 Accidental Releases of Liquid Effluents to Ground and Surface Waters

The PPE approach adopted in this ESP application allows for the possibility of different reactor designs at the ESP site. The locations, volumes, and radionuclide inventories of any above- or below-ground tanks that might be associated with these designs are currently unknown. Therefore, appropriate source term values would be developed and the consequences of accidental releases of liquid effluents to ground and surface waters would be evaluated in the COL application. The results of these analyses would be provided in the COL application and reviewed against the applicable 10 CFR 20 effluent limits.

Site-specific distribution coefficients (K_d's) important to subsurface hydrological transport have been established for use in any future assessment of accidental releases of liquid effluents to ground and surface waters. Values were obtained from on-site measurements of soil characteristics. The process involved characterizing the radionuclide inventory that could potentially be released as a liquid effluent, identifying the radionuclides for which the distribution coefficient is a parameter important to subsurface hydrological transport, and determining distribution coefficient values from onsite measurements for the radionuclides for which the distribution coefficient is an important parameter. The various steps of the process are described below.

The radionuclide inventory was estimated from information included in the AP1000 Design Control Document (Reference 62), for the effluent holdup tank liquid phase and the waste holdup tank, and in the ABWR Standard Safety Analysis Report (Reference 63), for the low conductivity waste collection tank, both of which list the radionuclides that are expected to be present in their liquid

radwaste systems and their corresponding activities. From these liquid radwaste inventories, a composite list of radionuclides and activities was generated, using the more conservative activity from the two reactor designs.

The radionuclides on the list described above were then screened to identify those for which the distribution coefficient would be a parameter important to subsurface hydrological transport. This was accomplished by assuming an instantaneous release of the radwaste inventory to the saturated zone and then accounting for the radioactive decay that would occur during transport from the point of release to Lake Anna. For screening purposes, the distribution coefficient was assumed to be zero and no credit for adsorption or retardation was taken in estimating the saturated zone travel time. The groundwater travel time from the center of the ESP site to Lake Anna was estimated to be about 16 years based on data included in Section 2.4.12.1.2. (This travel time calculation used the maximum observed hydraulic conductivity of 3.4 ft/day, a horizontal hydraulic gradient of 0.03 ft/ft, an effective porosity of 0.33, and a travel distance of 1800 ft.) The activities remaining after 16 years of decay were then compared to the values identified in 10 CFR 20, Appendix B, Table 2, Column 2. If the remaining activity for a given radionuclide was less than its 10 CFR 20 value, then the distribution coefficient was considered to be not important to subsurface hydrological transport for that particular radionuclide. If the remaining activity was greater that its 10 CFR 20 value, the distribution coefficient was considered important to subsurface hydrological transport and the radionuclide was retained for further evaluation. The radionuclides retained in this case include Fe-55, Co-60, Sr-90, Cs-134, and Cs-137.

Distribution coefficients for each of the retained radionuclides were obtained using onsite soil measurements. Distribution coefficients are dependent on soil's physical and chemical characteristics. The physical and chemical properties of the ESP site soils have been characterized as part of the ESP subsurface investigation. Section 2.5.4.2.2 indicates that about 75 percent of the Zone IIA saprolites are coarse-grained materials (sands), while about 25 percent are fined-grained materials (silts and clays). The coarse-grained are composed of 30–40 percent quartz, 20–30 percent microline, 25–40 percent clay minerals, and 5–20 percent mica. Although the clay content of the fine-grained soils was not determined, it is reasonable to assume 50–80 percent clay minerals. The site soils therefore have relatively high clay content. For some elements, distribution coefficients are dependent on the pH. Section 2.5.4.2.5 indicates that the pH of the Zone IIA saprolites ranges from 5.7 to 6.9.

Based on the onsite soil measurements described above, and considering the possibility that fill with differing characteristics could be imported during construction, distribution coefficients were determined for Co, Cs, Fe, and Sr. Distribution coefficients for Co and Fe were obtained from Sheppard and Thibault (Reference 64) by selecting the soil type that yields the most conservative value. In the case of Co, the K_d value for sand of 60 cm^3/g was chosen, while the K_d value for clay of 165 cm^3/g was selected for Fe. The K_d value for Cs was obtained from EPA (Reference 65). To ensure conservatism, a K_d value of 30 cm^3/g was selected, which represents lower end of the

range for soils having a clay content in the range of 4–20 percent and a mica content less than 5 percent. A K_d value of 15 cm^3/g for Sr was obtained from EPA (Reference 65) by conservatively assuming 4–20 percent clay content and a pH between 5 and 8 and picking the lower end of the range. These values are summarized in Table 2.4-20. Distribution coefficients for some other elements, namely Mn, Ru, and Zn, have also been included to allow for the possibility that the saturated zone travel time could be less than 16 years if the release were to occur near the edge of the ESP site footprint as opposed to the center. These values were determined in a manner similar to Co and Fe.

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Table 2.4-7 Probable Maximum Precipitation Temporal Distribution

Time (hours)	Time Increment	Incremental PMP Depth (in)
0 to 6	12	0.29
6 to 12	11	0.29
12 to 18	10	0.39
18 to 24	9	0.59
24 to 30	4	1.27
30 to 36	2	3.67
36 to 42	1	17.71
42 to 48	3	2.24
48 to 54	5	1.27
54 to 60	6	1.07
60 to 66	7	0.98
66 to 72	8	0.88

Table 2.4-8 February 1979 Rainfall Data

		Station Measured Precipitation (in.)			
Date	**Time**	**Columbia #44192900 (3 mi^2)**	**Piedmont #44671200 (307 mi^2)**	**Elkwood #44272900 (34 mi^2)**	**Basin Weighted Average**
24 Feb	6am – 9am	0	0	0	0.00
	9am – 12pm	0.6	0.4	0.3	0.39
	12pm – 3pm	0.3	0.5	0.6	0.51
	3pm – 6pm	0.5	0.3	0.3	0.30
	6pm – 9pm	0.8	0.5	0.3	0.48
	9pm – 12am	0.1	0.1	0.1	0.10
25 Feb	12am – 3am	0	0	0.1	0.01
	3am – 6am	0	0	0	0.00
	6am – 9am	0.1	0	0	0.00
	9am – 12pm	0	0	0	0.00
	12pm – 3pm	0.3	0.1	0	0.09
	3pm – 6pm	0.6	0.6	0.7	0.61
	6pm – 9pm	0.2	0.3	0.4	0.31
	9pm – 12am	0.1	0.1	04	0.13
	Total	3.6	2.9	3.2	2.94

Table 2.4-9 March 1994 Rainfall Data

		Station Measured Precipitation (in.)			
Date	**Time**	**Bremo Bluff #440399302 (0 mi^2)**	**Culpeper #44215904 (343 mi^2)**	**Richmond #44720102 (0 mi^2)**	**Basin Weighted Average**
27 Mar	12am – 3am	0	0	0	0.00
	3am – 6am	0.2	0.4	0.01	0.40
	6am – 9am	0.7	0.7	0.43	0.70
	9am – 12pm	0	0.1	0.46	0.10
	12pm – 3pm	0	0	0	0.00
	3pm – 6pm	0	0	0	0.00
	6pm – 9pm	0.3	0.2	0	0.20
	9pm – 12am	0.2	0.5	0.44	0.50
28-Mar	12am – 3am	0.5	0.7	0.01	0.70
	3am – 6am	0.4	0.3	0	0.30
	6am – 9am	0.3	0.1	0.12	0.10
	9am – 12pm	0.2	0	0.32	0.00
	12pm – 3pm	0	0	0.04	0.00
	3pm – 6pm	0.1	0.1	0.1	0.10
	6pm – 9pm	0.1	0.3	0.05	0.30
	9pm – 12am	0.2	0.2	0.15	0.20
29 Mar	12am – 3am	0.3	0.2	0.2	0.20
	3am – 6am	0.2	0.19*	0.17	0.19
	6am – 9am	0.1	0.06*	0.02	0.06
	9am – 12pm	0	0.04*	0.07	0.04
	Total	3.8	4.1	2.59	4.09

* Due to missing data at the station, the value is estimated from data at Richmond and Bremo Bluff.

Table 2.4-10 June 1995 Rainfall Data

		Station Measured Precipitation (in)		
Date	Time	Piedmont #44671204 (343 mi^2)	Richmond #44720102 (0 mi^2)	Basin Weighted Average
27 Jun	12am – 3am	0.7	0.0	0.7
	3am – 6am	1.7	0.0	1.7
	6am – 9am	3.4	0.0	3.4
	9am – 12pm	0.1	0.0	0.1
	12pm – 3pm	0.0	0.0	0.00
	3pm – 6pm	0.0	0.02	0.00
	6pm – 9pm	0.0	0.0	0.00
	9pm – 12am	0.0	0.0	0.00
	Total	5.9	0.02	5.90

Table 2.4-11 Lake Anna Watershed HEC-1 Precipitation Loss Rates

	HEC-1 Precipitation Loss Coefficients			
Storm	DKLTR	ERAIN	RTIOL	STRKR
June 1972*	4.02	0.55	3.86	0.44
April 1973*	1.93	0.34	22.07	0.14
March 1975*	0.00	0.52	10.39	0.12
1976 PMF Storm	2.00	0.47	12.11	0.233
February 1979	0.00	0.60	12.11	0.01
March 1994	0.80	0.55	12.11	0.10
June 1995	5.20	0.50	12.11	0.15
2003 PMF Storm	1.37	0.54	12.11	0.10

* Storms investigated in 1976 PMF analysis

ERAIN - Exponent of precipitation for loss rate function
RITOL – Loss coefficient recession constant
STRKR – Initial value of loss coefficient (in/hr)
DKLTRR – Initial accumulated rain loss during which the loss coefficient is increased (in)

Table 2.4-12 Historic Minimum Intake Water Temperature of Less Than 4°C (39.2°F) During the Operation of North Anna Units 1 and 2 from 1978 to 2001

Date	Temperature Range °C (°F)	Remarks
Feb 7, 1979–Feb 24, 1979	1.2–3.7 (34.2–38.7)	Only Unit 1 was in Operation
Feb 2–Feb 21, 1980	2.8–3.9 (37–39)	Only Unit 1 was in Operation
Jan 14–Feb 5, 1982	2.1–3.8 (35.8–38.8)	Unit 2 was put into operation in Fall 1980
Feb 1–Feb 7, 1985	3.0–3.9 (37.4–39)	Units 1 and 2 in operation
Dec 24, 1989–Jan 4, 1990	2.9–3.6 (37.2–38.5)	Units 1 and 2 in operation
Jan 19–28, 1994	2.1–3.9 (35.8–39 F)	Units 1 and 2 in operation
Feb 3–10, 1996	3.1–3.8 (37.6–38.8)	Units 1 and 2 in operation
Jan 26–29,2001	3.6–3.8 (38.5–38.8)	Units 1 and 2 in operation

Table 2.4-13 Deleted

Table 2.4-14 Annual Peak Discharges On the North Anna River

Water Year	Date[a]	Peak Flow at Doswell (cfs)[b]	Peak Flow at Partlow (cfs)[c]	Peak North Anna Reservoir Water Level at Dam (ft msl)
1972	Jun. 22, 1972	23,300	-[d]	239.0[e]
1973	Apr. 28, 1973	7100	-	-
1974	Sep. 7, 1974	6180	-	-
1975	Sep. 26, 1975	11,600	-	-
1976	Jan. 1, 1976	6520	-	-
1977	Oct. 21, 1976	4160	-	-
1978	Jan 26, 1978	9730	-	-
1979	Feb. 26, 1979	13,900[f]	11,700	252.00
1980	Oct. 2, 1979	7700[f]	6050	251.10
1981	Feb. 11, 1981	-	87	248.95
1982	Feb. 4, 1982	4750	4080	250.90
1983	Apr. 25, 1983	5990	5200	250.97
1984	Mar. 30, 1984	11,700	9030	251.72
1985	Feb. 2, 1985	4650[g]	2240	250.34
1986	Nov. 5, 1985	10,700[f]	8690	251.51
1987	Apr. 17, 1987	-	6660	251.16
1988	Nov. 30, 1987	-	4810	250.80
1989	May 6, 1989	-	6680	251.25
1990	May 29, 1990	-	5230	250.89
1991	Jan. 12, 1991	-	4620	250.74
1992	Feb. 26, 1992	-	1970	250.20
1993	Mar. 5, 1993	-	8230	251.80
1994	Nov. 28, 1993	-	8690	251.60
1995	Jun. 27, 1995	-	11,700	252.00

a. Date shown corresponds to peak flow shown at Parlow and peak North Anna Reservoir water level.

b. Gage # 01671000, Drainage Area: 441 square miles.

c. Gage # 01670400, Drainage Area: 344 square miles.

d. Blank cells (-) represent dates outside the period of data record or missing data.

e. Lake Anna Reservoir was not yet completely filled.

f. The peak discharge at Doswell occurred one day later than indicated at Partlow.

g. The peak discharge at Doswell occurred on Aug. 19, 1985.

Table 2.4-15 Quarterly Groundwater Level Elevations

Observation Well No.	Well Depth* (ft)	Reference Point Elev. (ft)	Reference Point Stickup** (ft)	Top of Well Screen Elev. (ft)	Well Screen Length (ft)	Groundwater Level Elevations Date of Measurement				
						12/17/02	03/17/03	06/17/03	09/29/03	02/01/05
OW-841	34.3	251.6	1.5	228.1	9.7	248.9	249.6	249.6	249.3	249.1
OW-842	49.6	336.7	1.5	297.8	9.6	307.5	308.9	310.8	312.0	314.2
OW-843	49.2	320.6	1.5	282.1	9.7	285.1	288.1	290.8	290.2	290.7
OW-844	24.6	273.5	1.5	257.6	9.6	265.5	266.7	267.3	266.4	266.2
OW-845	55.0	297.3	1.5	253.0	9.7	272.7	274.9	277.4	277.3	277.1
OW-846	32.7	297.3	1.5	273.5	9.8	272.5	274.8	277.1	277.0	276.8
OW-847	49.8	319.7	1.5	280.6	9.6	285.4	287.0	289.5	290.8	293.3
OW-848	47.3	284.5	1.5	240.8	5.0	241.7	242.9	243.6	244.0	243.2
OW-849	49.8	298.5	1.5	259.4	9.7	265.5	269.5	271.7	270.8	269.5
P-10	22.5	286.4	2.4	267.0	5	274.4	274.8	275.2	275.2	275.3
P-14	N/A	327.1	N/A	N/A	N/A	271.6	272.2	272.8	273.1	273.8
P-18	N/A	329.0	N/A	N/A	N/A	285.7	286.5	287.5	288.4	289.9
P-19	58.5	322.3	N/A	N/A	5	284.3	285.2	286.3	287.3	288.9
P-20	61.0	320.6	N/A	N/A	5	274.9	275.4	275.8	275.0	276.7
P-21	58.5	319.2	N/A	N/A	5	Dry	261.2	262.0	262.4	263.4
P-22	60.0	320.5	N/A	N/A	5	276.8	277.8	278.6	278.9	279.5
P-23	41.2	296.4	1.9	258.7	5	261.1	262.6	263.3	263.1	263.5
P-24	25.0	293.4	2.3	271.3	5	276.4	277.1	278.4	278.3	278.4
WP-3	N/A	317.9(?)	N/A	266.5	5	299.7	301.0	302.8	302.3	302.1

Table 2.4-15 Quarterly Groundwater Level Elevations

Observation Well No.	Well Depth* (ft)	Reference Point Elev. (ft)	Reference Point Stickup** (ft)	Top of Well Screen Elev. (ft)	Well Screen Length (ft)	Groundwater Level Elevations Date of Measurement				
						12/17/02	03/17/03	06/17/03	09/29/03	02/01/05
Lake Anna Water Level Elevation						248.1	250.1	250.4	250.1	250.1
Service Water Reservoir Water Level Elevation						314.6	313.3	314.6	314.6	314.5

OW- wells installed in December 2002 as part of ESP Subsurface Investigation Program

P- wells installed previously to monitor NAPS Units 1 and 2 Service Water Reservoir

WP- well installed previously as part of Interim Spent Fuel Storage Installation monitoring program

* Below ground surface at time of installation

** Above ground surface at time of installation

N/A - not available

Table 2.4-16 Hydraulic Conductivity Values

Observation Well No.	Depth Interval Tested (ft)	Elevation	Material	Hydraulic Conductivity	
				cm/sec	ft/day
PT-1 (a)	Near-surface	Unknown	Saprolite	2.8×10^{-5}	0.08
PT-2 (a)	Near-surface	Unknown	Saprolite	1.4×10^{-5}	0.04
P-10 (b)	14.5 - 22.5	269.5 - 261.5	Saprolite	6.1×10^{-4} to 6.1×10^{-5}	1.7 to 0.17
P-24 (b)	16.8 - 25.0	274.3 - 266.1	Saprolite	2.9×10^{-4} to 6.6×10^{-6}	0.8 to 0.02
P-23 (b)	33.7 - 41.2	260.7 - 253.2	Saprolite	6.6×10^{-5}	0.19
OW-844 (c)	12.7 - 24.6	259.3 - 247.4	Saprolite	9.9 to 8.9×10^{-5}	0.28 to 0.25
OW-841 (c)	20.1 - 34.3	230.0 - 215.8	Saprolite	8.2 to 7.8×10^{-4}	2.3 to 2.2
OW-846 (c)	20.3 - 32.7	275.5 - 263.1	Saprolite	1.2×10^{-3} to 6.8×10^{-4}	3.4 to 1.9
OW-847 (c)	35.0 - 49.8	283.2 - 268.4	Saprolite	2.3 to 2.1×10^{-4}	0.66 to 0.58
OW-842 (c)	35.3 - 49.6	299.9 - 285.6	Saprolite	3.3×10^{-4}	0.93
OW-849 (c)	35.6 - 49.8	261.4 - 247.2	Saprolite	1.1×10^{-3} to 7.0×10^{-4}	3.2 to 2.0
OW-843 (c)	36.4 - 49.2	282.7 - 269.9	Saprolite	4.9 to 4.5×10^{-4}	1.4 to 1.3
OW-848 (c)	39.1 - 47.3	243.9 - 235.7	Saprolite	1.2×10^{-3} to 9.9×10^{-4} (d)	3.4 to 2.8 (d)
OW-845 (c)	39.7 - 55.0	256.1 - 240.8	Quartz Gneiss	1.1×10^{-3} to 6.3×10^{-4} (e)	3.1 to 1.8 (e)
Laboratory Test Results					
B-48 a	3.5	290.5	Sandy silt	1×10^{-6}	0.003
B-8 a	5.5	293.5	Fine sand, tr. silt	1×10^{-6}	0.003
B-2 a	15.5	269.5	Fine to med. sand, w/clayey silt	4×10^{-5}	0.11
B-15 a	36	281	Silty fine sand	1.3×10^{-5}	0.04

a. Reference 43

b. Reference 56

c. Appendix 2.5.4B

d. Results may not be accurate due to static water level approximately 0.5 ft below top of well screen.

e. Results may not be accurate due to short duration of stable water level recovery measurements.

Table 2.4-17 North Anna Power Station Water Supply Wells

Well	Depth (ft)	Measured Yield (gpd)	Design Yield (gpd)	Water Treatment
No. 2 [a,b]	385	12,960	53,040	Chlorination (normally not in use)
No. 3A [a,b]	185	74,880		
No. 4 (new) [a,b]	305	63,360		
No. 6 [a,b]	375	79,200		
No. 4 (old) [a,b] (not used)	200	77,760	NA	NA
NANIC [a,c]	260	106,560	19,600	Calcite filtration
Security Training Building	Unknown	Unknown	Unknown	Unknown

a. Reference 50

b. Reference 48

c. Reference 49

Table 2.4-18 North Anna Power Station Groundwater Use[a] January 1, 2002 to December 31, 2002 (Millions of Gallons)

Month	Well #2	Well #3A	Well #4	Well #6	NANIC
January	0.0032	0.4268	0.4519	0.7444	0.0485
February	0.0032	0.1395	0.4010	0.5095	0.0467
March	0.0025	0.0263	0.1050	0.1642	0.0555
April	0.0046	0.0368	0.1253	0.1459	0.0474
May	0.0076	0.0376	0.2565	0.1041	0.0690
June	0.0021	0.0531	0.2524	0.1458	0.0502
July	0.0018	0.0511	0.3585	0.0189	0.0525
August	0.0077	0.0611	0.3434	0.0526	0.0656
September	0.0071	0.1020	0.4018	0.1655	0.0474
October	0.0062	0.0874	0.2118	0.1574	0.0651
November	0.0148	0.0694	0.2126	0.1846	0.0586
December	0.0037	0.2005	0.0648	0.2070	0.0482
Total	0.0645	1.2916	3.1850	2.5999	0.6547
Monthly Average	0.0054	0.1076	0.2654	0.2167	0.0546

a. Reference 57

Table 2.4-19 Public Groundwater Supplies In Louisa County

Installation	Type [a]	Water Source	Depth (ft)	Measured Yield (gpd)	Design Yield (gpd)	Population Served[a]	Active/ Inactive [a]
Town of Louisa [b] (primary source is surface water)	Community	spring	NA	38,880		1950	
		3 wells	200–405	43,200–53,280			
Town of Mineral [b]	Community	2 springs	NA	57,600		670	A
		4 wells	200–600	14,400–165,600			
Acorn West Trailer Park [b]	Community	well	120	8640		70	I
Apple Grove School [a]	Transient Non-Community					200	I
Blue Ridge Shores [b]	Community	4 wells	163–405	288,000	160,000	1450	A
Bumpass Park/Lake Anna Rescue [a]	Transient Non-Community					250	A
Burger King Zion Crossroads [a]	Transient Non-Community					250	A
Cable Form [a]	Transient Non-Community					11	I
Christopher Run Campground [a]	Transient Non-Community					608	A
Country Side II [a]	Transient Non-Community					50	I
Crescent Inn Restaurant [a]	Transient Non-Community					150	A
Crossing Point (VA Oil Co) [b]	Non-Transient Non-Community	2 wells	305	21,600–28,800	10,400	45	A
Deb's Place [a]	Transient Non-Community					50	I

Table 2.4-19 Public Groundwater Supplies In Louisa County

Installation	Type [a]	Water Source	Depth (ft)	Measured Yield (gpd)	Design Yield (gpd)	Population Served[a]	Active/ Inactive [a]
East End Elementary School [b]		well	345	61,920	31,200		
Expressions Learning Center [b]	Non-Transient Non-Community	well	205	17,280		45	A
Green Springs School [a]	Transient Non-Community					300	I
Jerdone Island [b,c]	Community	well	200	83,520	19,600	49	A
Jouette Elementary School [b]	Non-Transient Non-Community	well	345	61,920	19,600	741	A
Junction Restaurant [a]	Transient Non-Community					25	I
Junction Restaurant [a]	Transient Non-Community					50	I
Klockner Barrier Films [b]		well	305	53,280	22,000		
Klockner-Pentaplast [b]	Non-Transient Non-Community	2 wells	205–280	21,600–57,600	44,000	526	A
Lake Anna Estates Trailer Park [a]	Community					50	I
L A Pizza [a]	Transient Non-Community					25	I
Lake Anna Plaza [d]	Community	2 wells	335–230	11,520–86,400	41,200	100	A
Louisa County Senior Center [a]	Transient Non-Community					45	I
Louisa County Water Authority [a,b]	Non-Transient Non-Community	well	550	34,560		192	I
Louisa County Zion Crossroads [a]	Non-Transient Non-Community					600	A

Table 2.4-19 Public Groundwater Supplies In Louisa County

Installation	Type [a]	Water Source	Depth (ft)	Measured Yield (gpd)	Design Yield (gpd)	Population Served [a]	Active/ Inactive [a]
Louisa Day Care Center [a]	Transient Non-Community					30	I
Louisa Intermediate School [a]	Transient Non-Community					900	I
Mount Garland School [a]	Transient Non-Community					140	I
Ole Country Inn [a]	Transient Non-Community					50	I
Prospect Hill [a]	Transient Non-Community					50	A
Raynell's [a]	Transient Non-Community					25	I
Sandra Carter [a]	Community					36	I
Shenandoah Crossing [b]	Non-Transient Non-Community	2 wells	280–300	123,840–97,920	98,400	850	A
Siebert's Amoco & Dairy Queen [a]	Transient Non-Community					950	A
Six-o-Five Village [b]	Community	2 wells	310–365	64,800–10,800	10,700	201	A
Small Country Campground [a]	Transient Non-Community					112	A
Tavern on the Rail [a]	Transient Non-Community					150	A
Trevillians Elementary School [b]	Non-Transient Non-Community	well	204	57,600	19,600	676	A
Trevilians Square Apartments [a]	Community					61	A

Table 2.4-19 Public Groundwater Supplies In Louisa County

Installation	Type [a]	Water Source	Depth (ft)	Measured Yield (gpd)	Design Yield (gpd)	Population Served[a]	Active/ Inactive [a]
Twin Oaks Community [b]	Community	well	250 [e]	7200		75	A
West End Elementary School [b]		well	204	57,600	20,000		
Wooden Nickle [a]	Transient Non-Community					25	I

Note:Blank entries indicate data not provided in cited reference.

a. Reference 58
b. Reference 50
c. Reference 59
d. Reference 60
e. Reference 1

Table 2.4-20 Distribution Coefficients Important to Subsurface Hydrological Transport

Radionuclide	Distribution Coefficient K_d (cm^3/g)	Source
Mn-54	50	Reference 64
Fe-55	165	Reference 64
Co-60	60	Reference 64
Zn-65	200	Reference 64
Sr-90	15	Reference 65
Ru-106	55	Reference 64
Cs-134	30	Reference 65
Cs-137	30	Reference 65

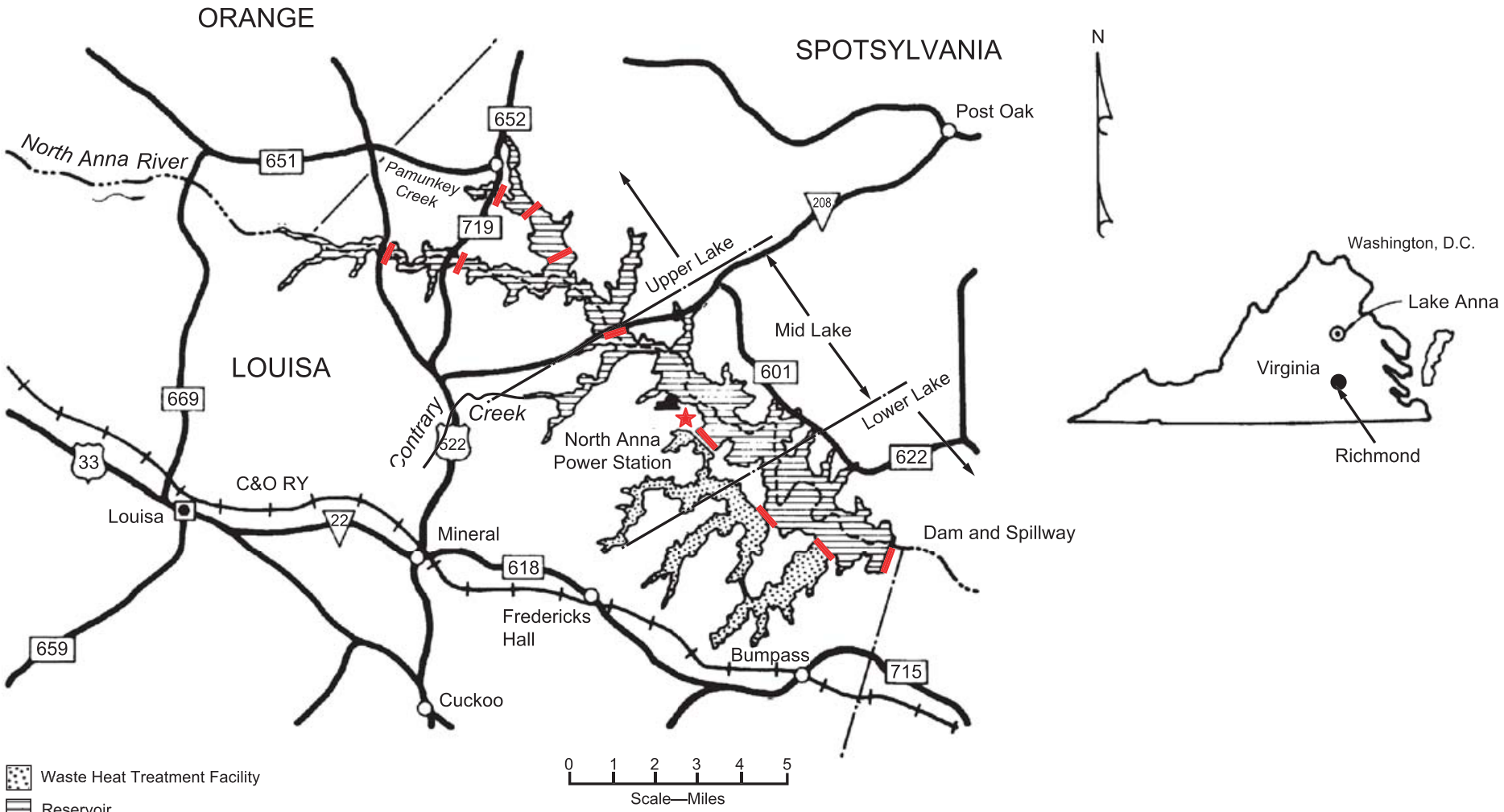

Figure 2.4-1 Lake Anna Hydrologic Features

Figure 2.4-2 Deleted

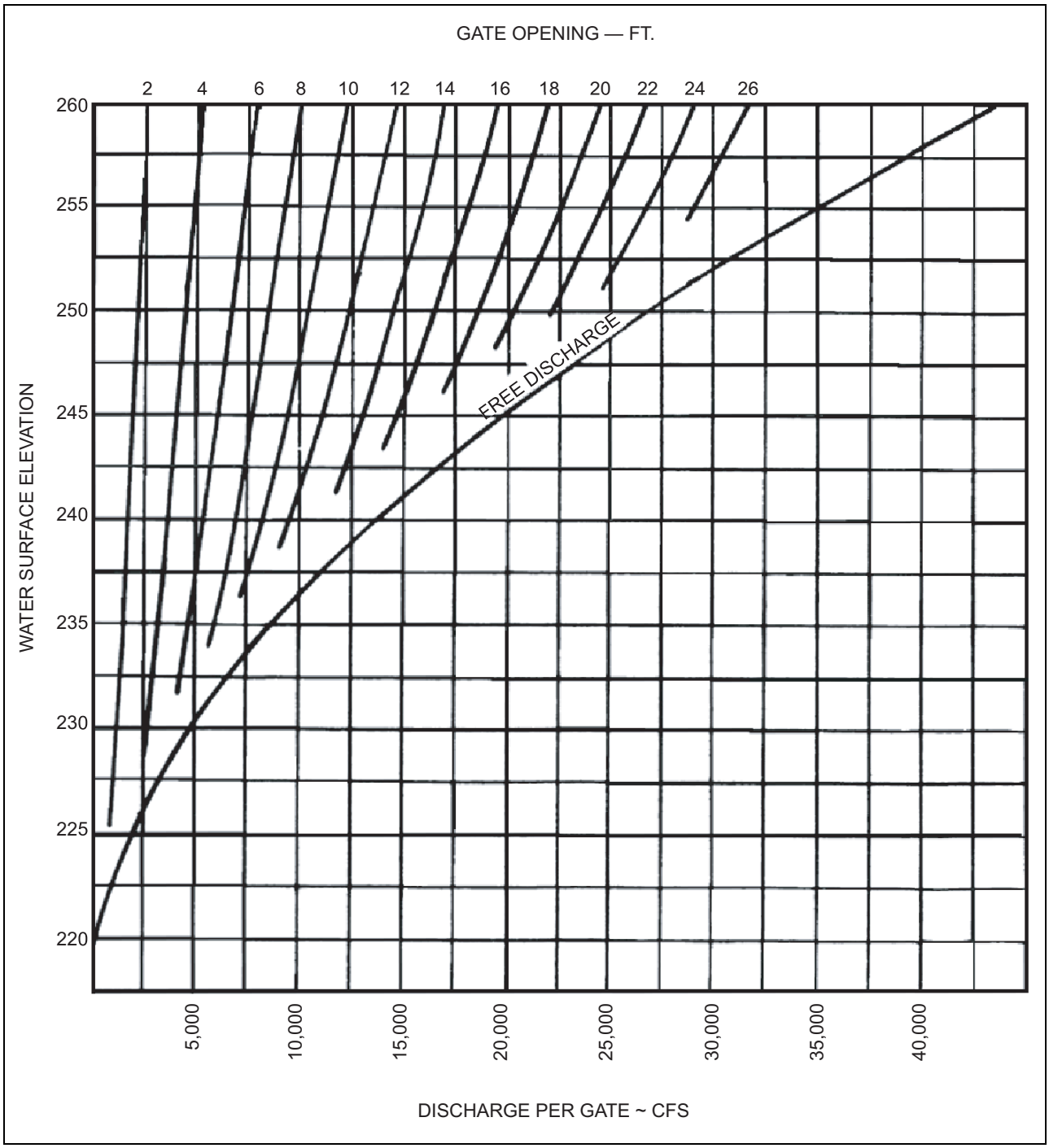

Figure 2.4-3 Spillway and Discharge Capacity (One Gate of Three) North Anna Dam

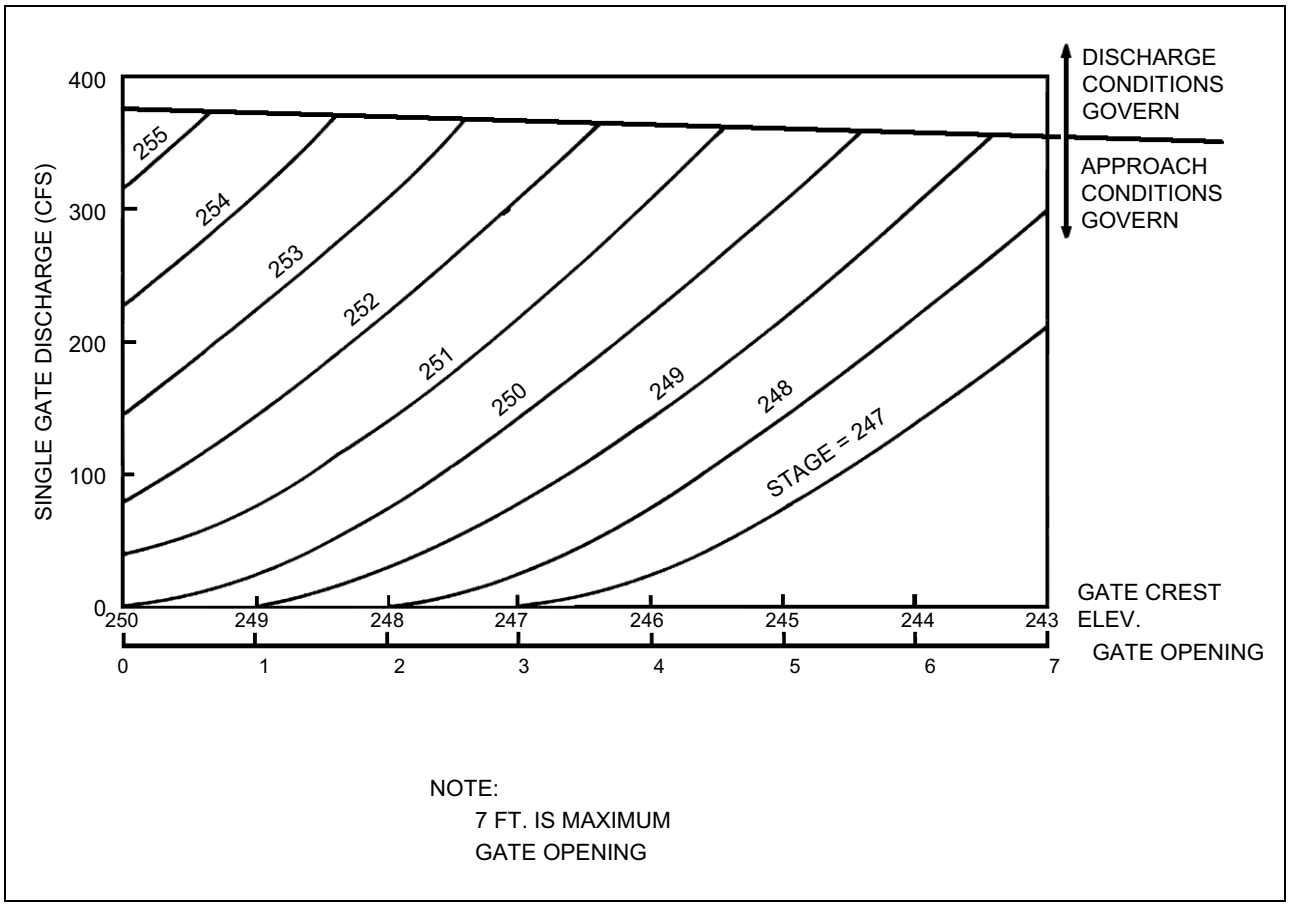

Figure 2.4-4 Skimmer Gate Discharge Capacity North Anna Dam

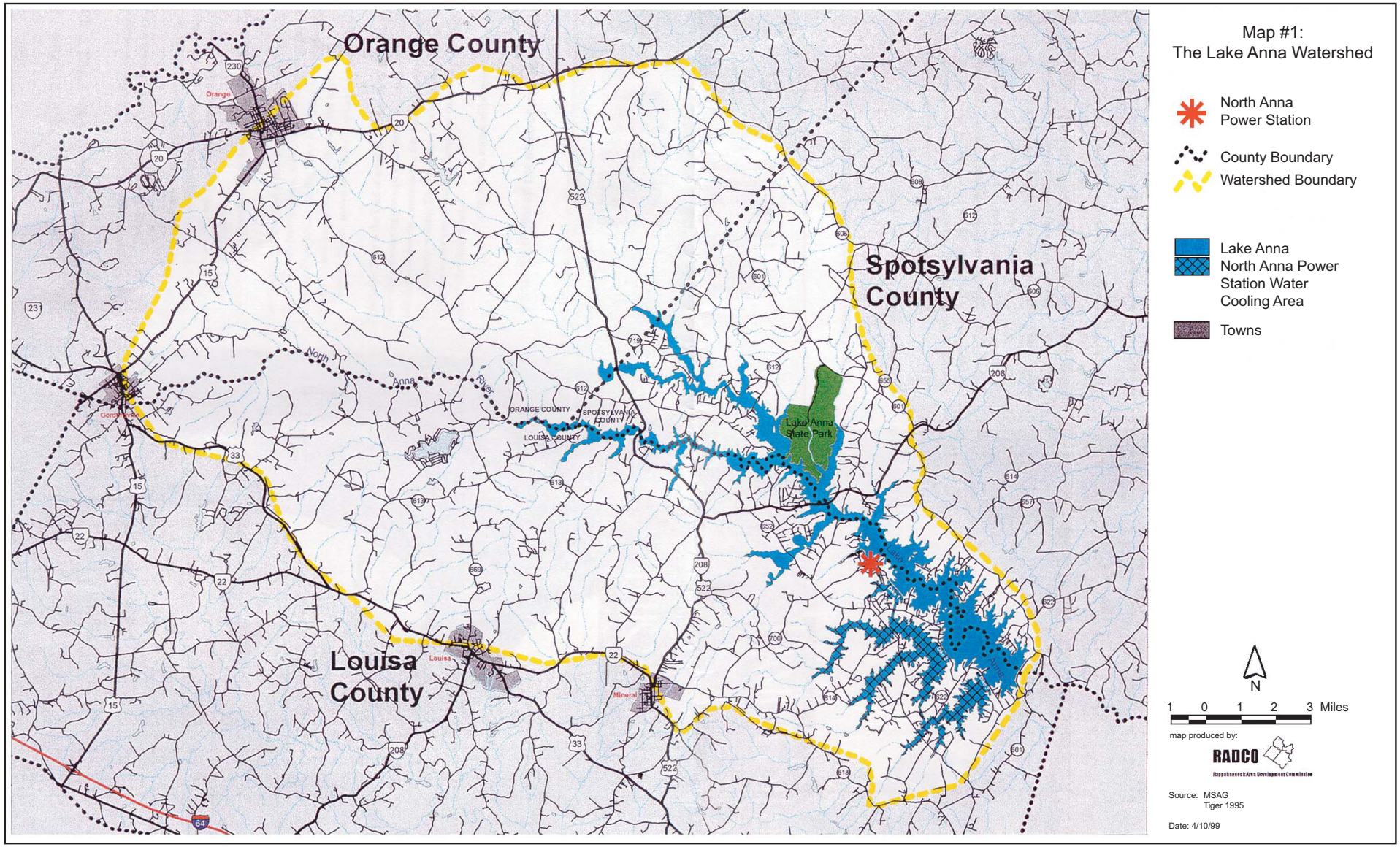

Figure 2.4-5 Combined Lake Anna and WHTF Drainage Area

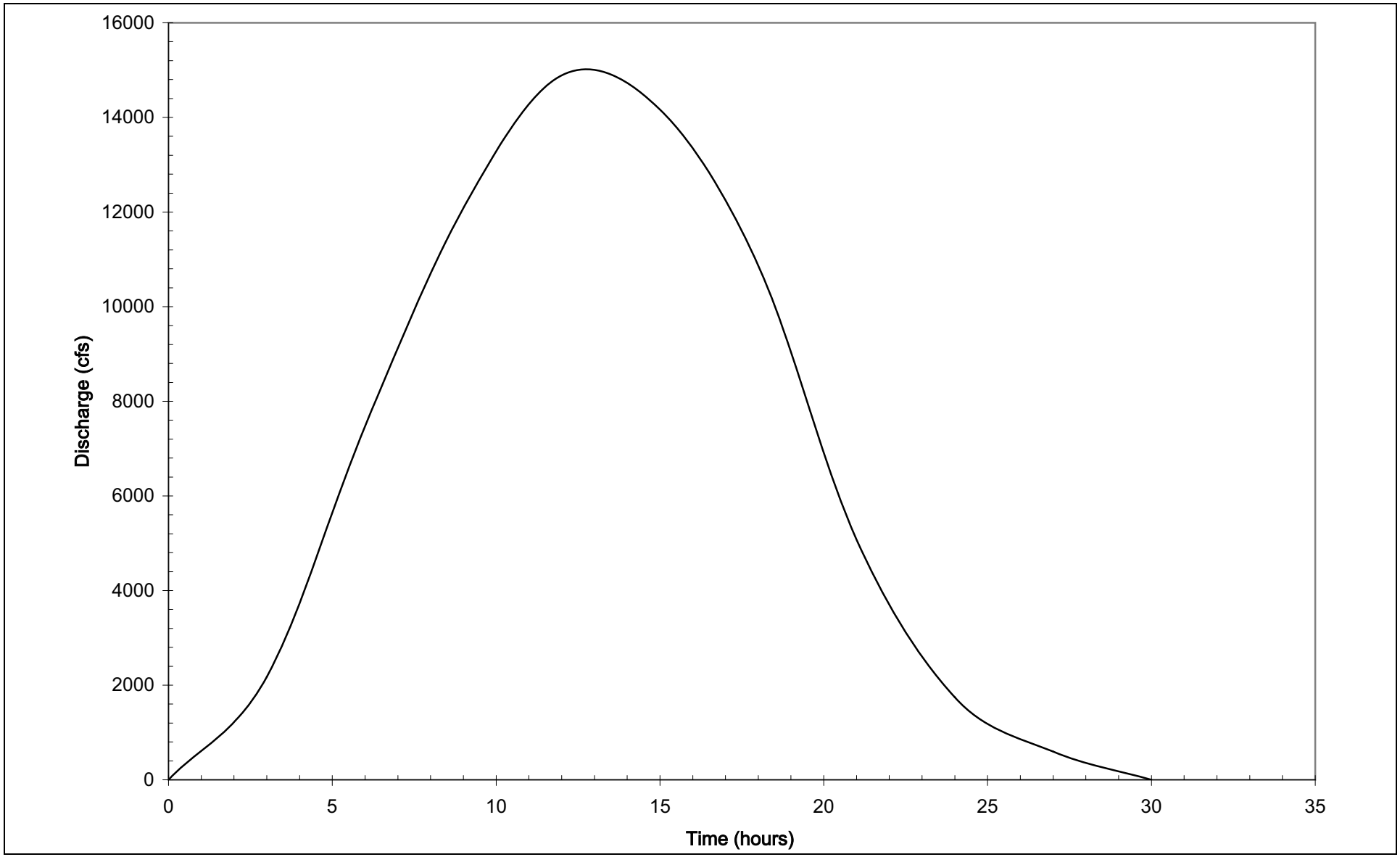

Figure 2.4-6 Combined North Anna Reservoir and WHTF Watershed: 3-Hour Unit Hydrograph



Figure 2.4-7 1979 Storm Outflow Hydrograph Comparison



Figure 2.4-8 1994 Storm Outflow Hydrograph Comparison

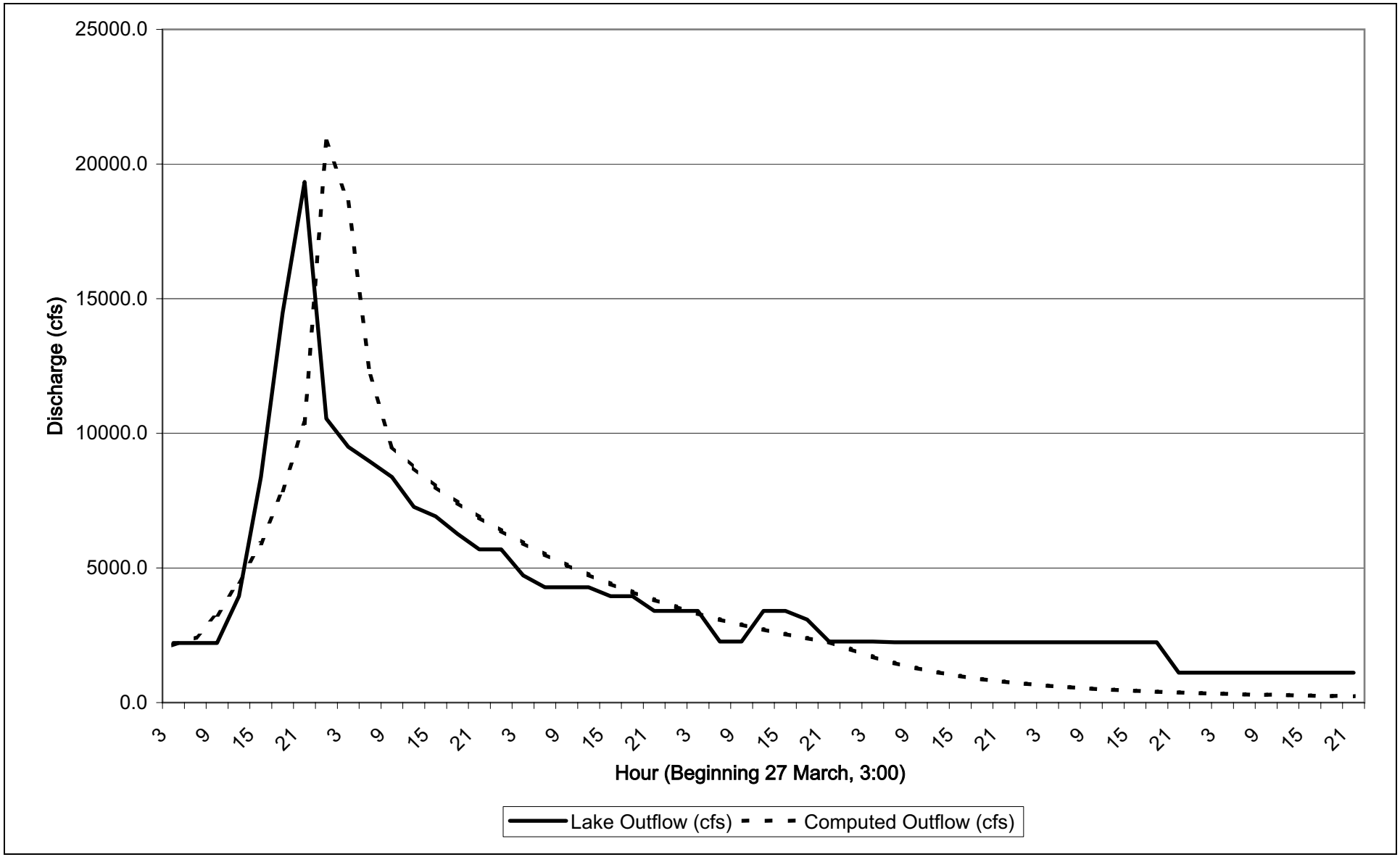

Figure 2.4-9 1995 Storm Outflow Hydrograph Comparison

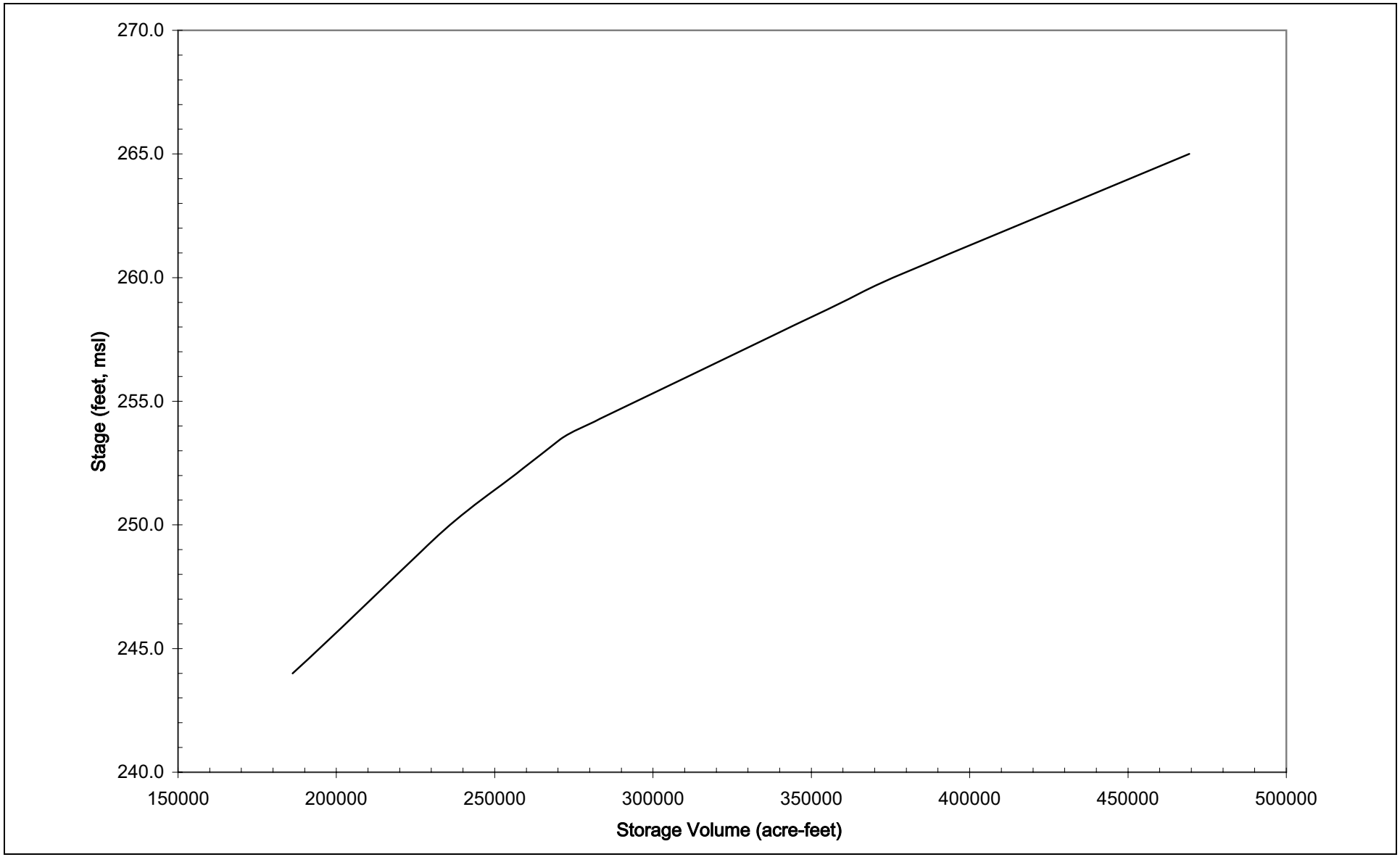

Figure 2.4-10 North Anna Reservoir & WHTF Combined Stage-Storage

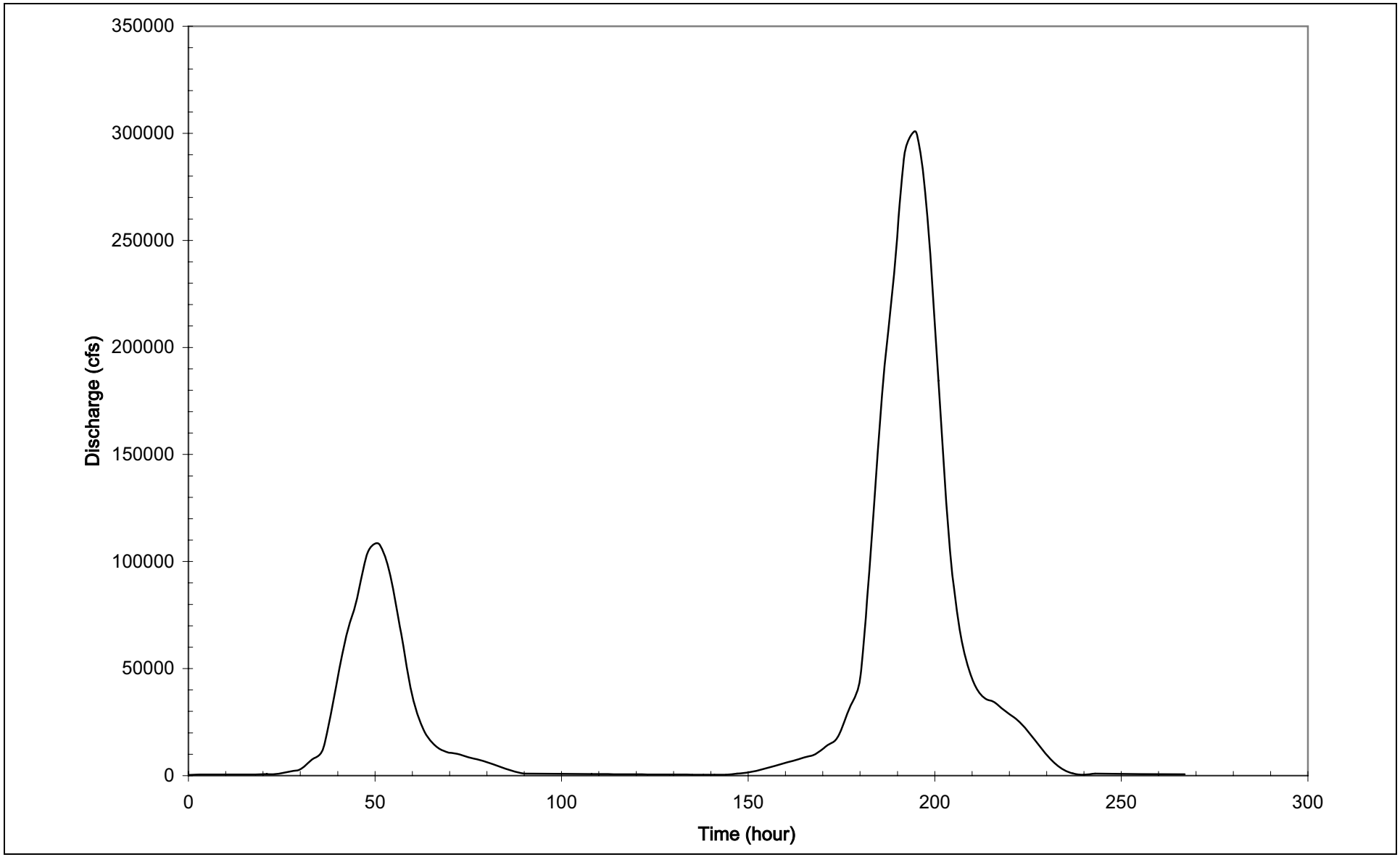

Figure 2.4-11 Combined North Anna Reservoir & WHTF PMF Inflow Hydrograph

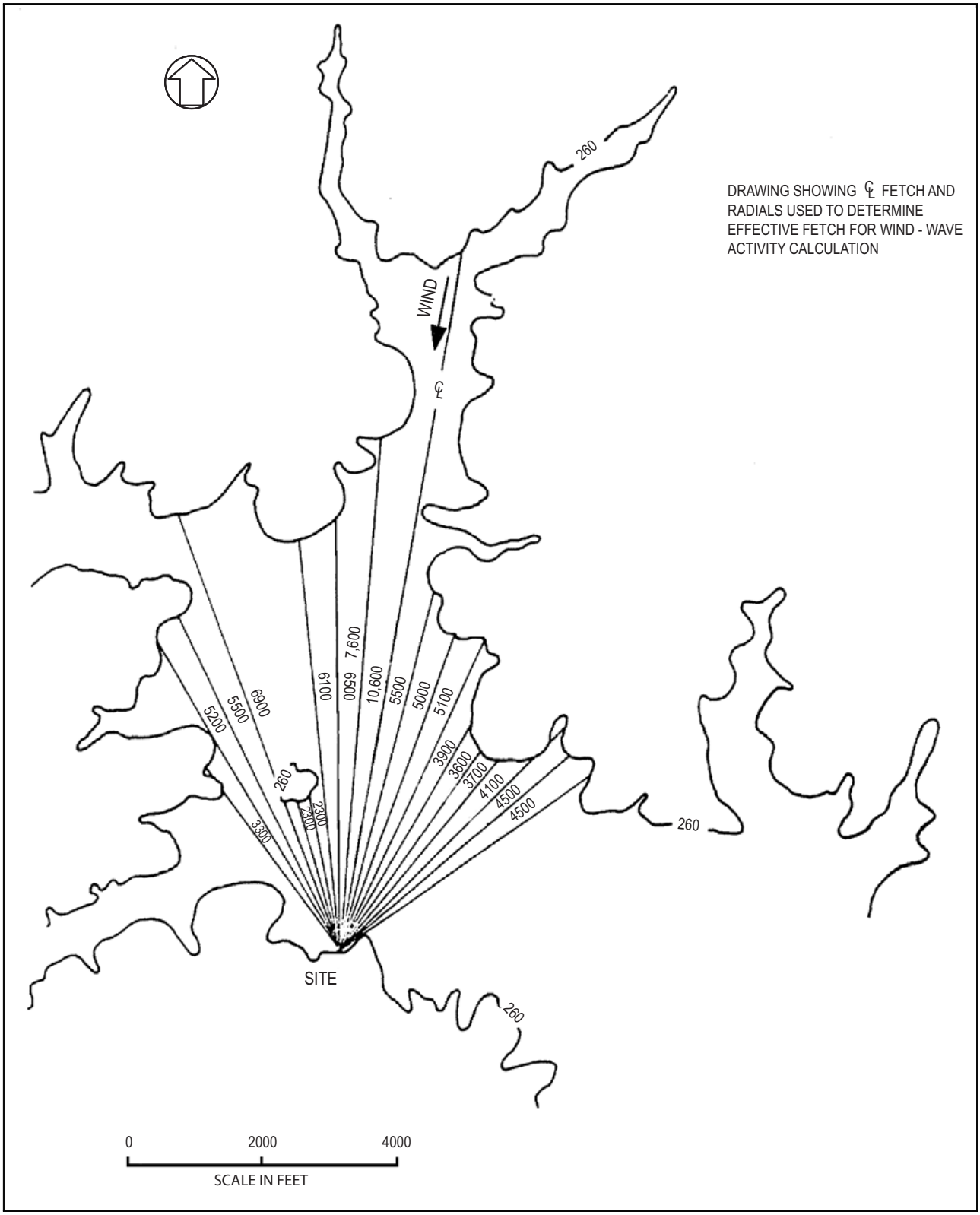

Figure 2.4-12 North Anna Site - Fetch Diagram

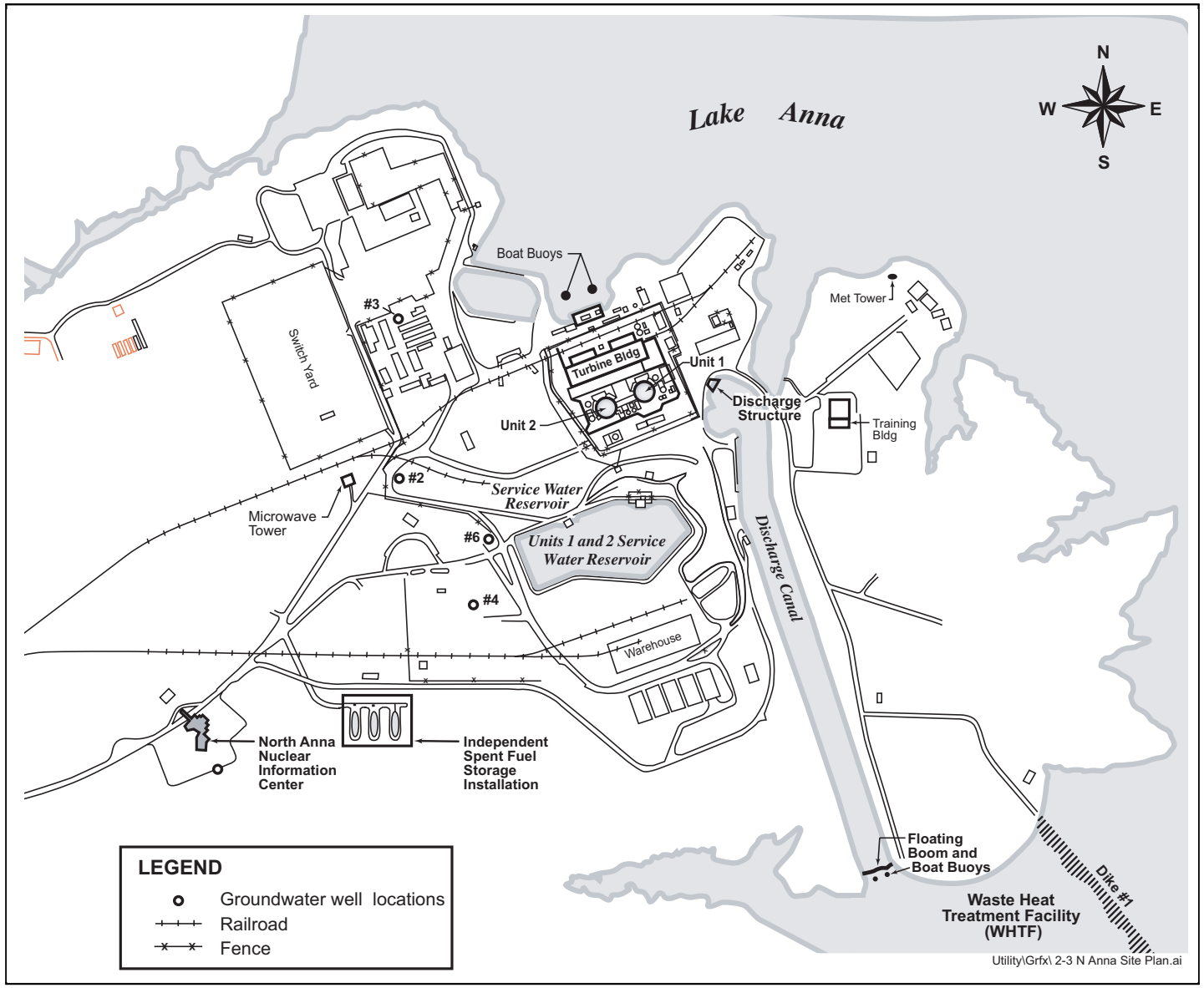

Figure 2.4-13 Existing Cooling Water Canals and Reservoirs

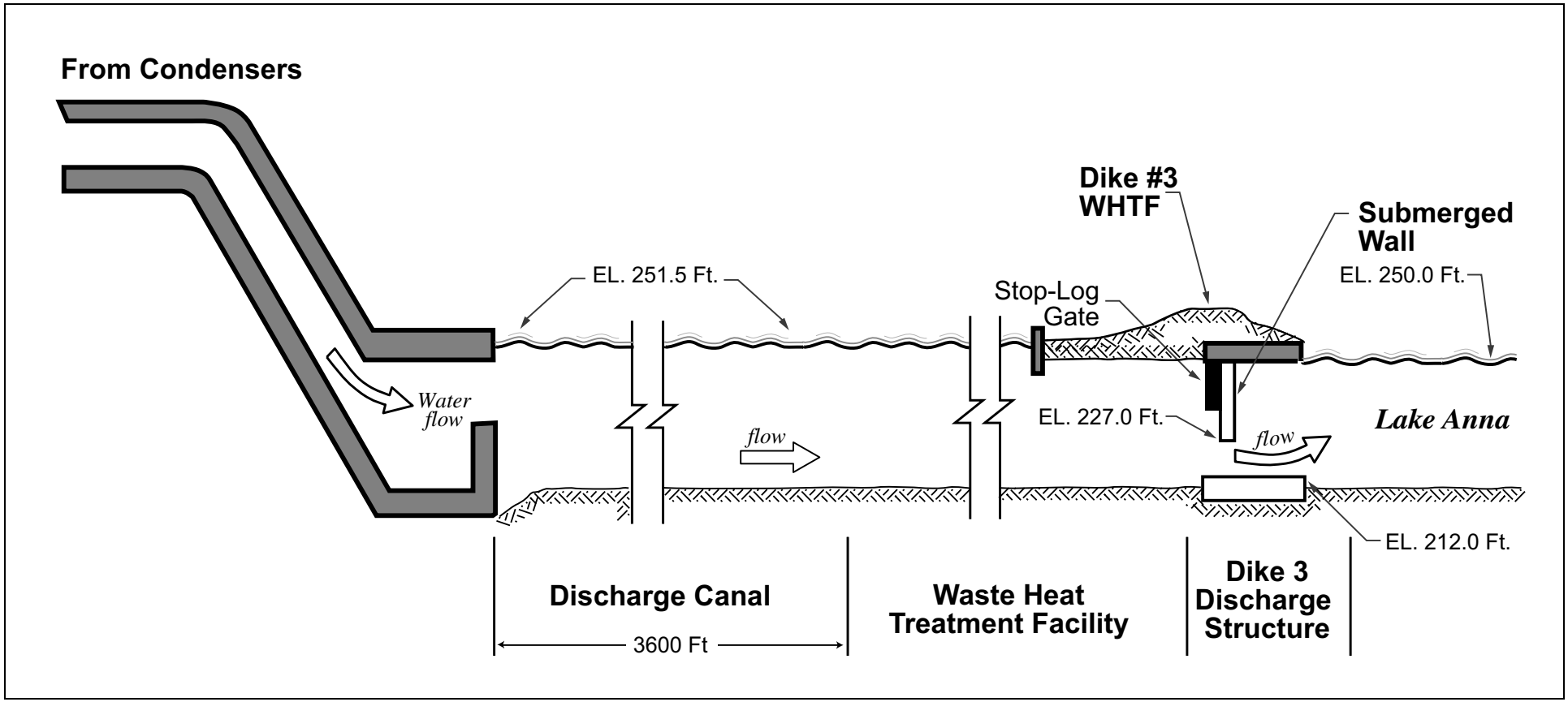

Figure 2.4-14 Schematic Cross-Sectional Diagram of Water Discharge System at Dike 3 WHTF

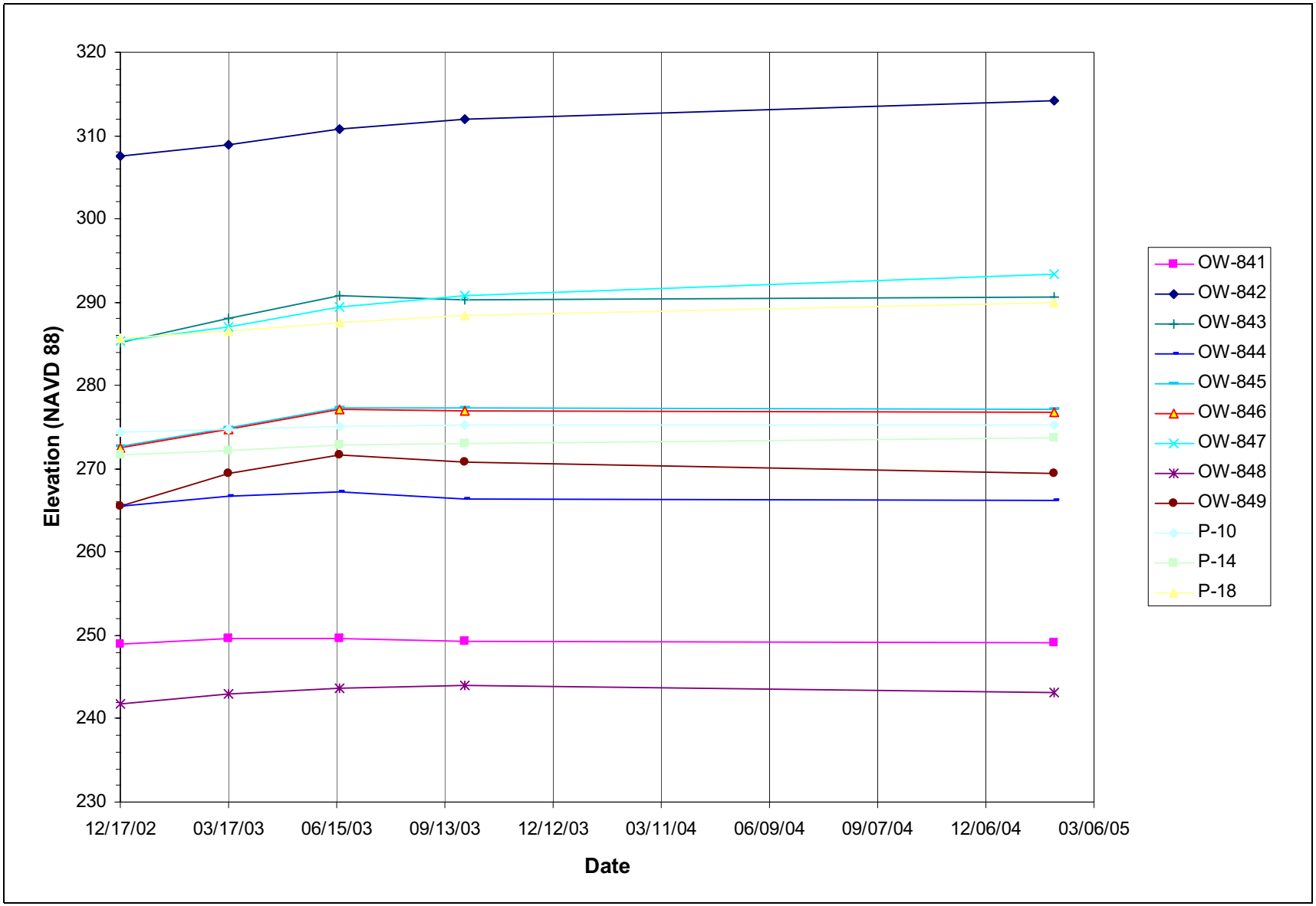

Figure 2.4-15 Groundwater Level Hydrographs

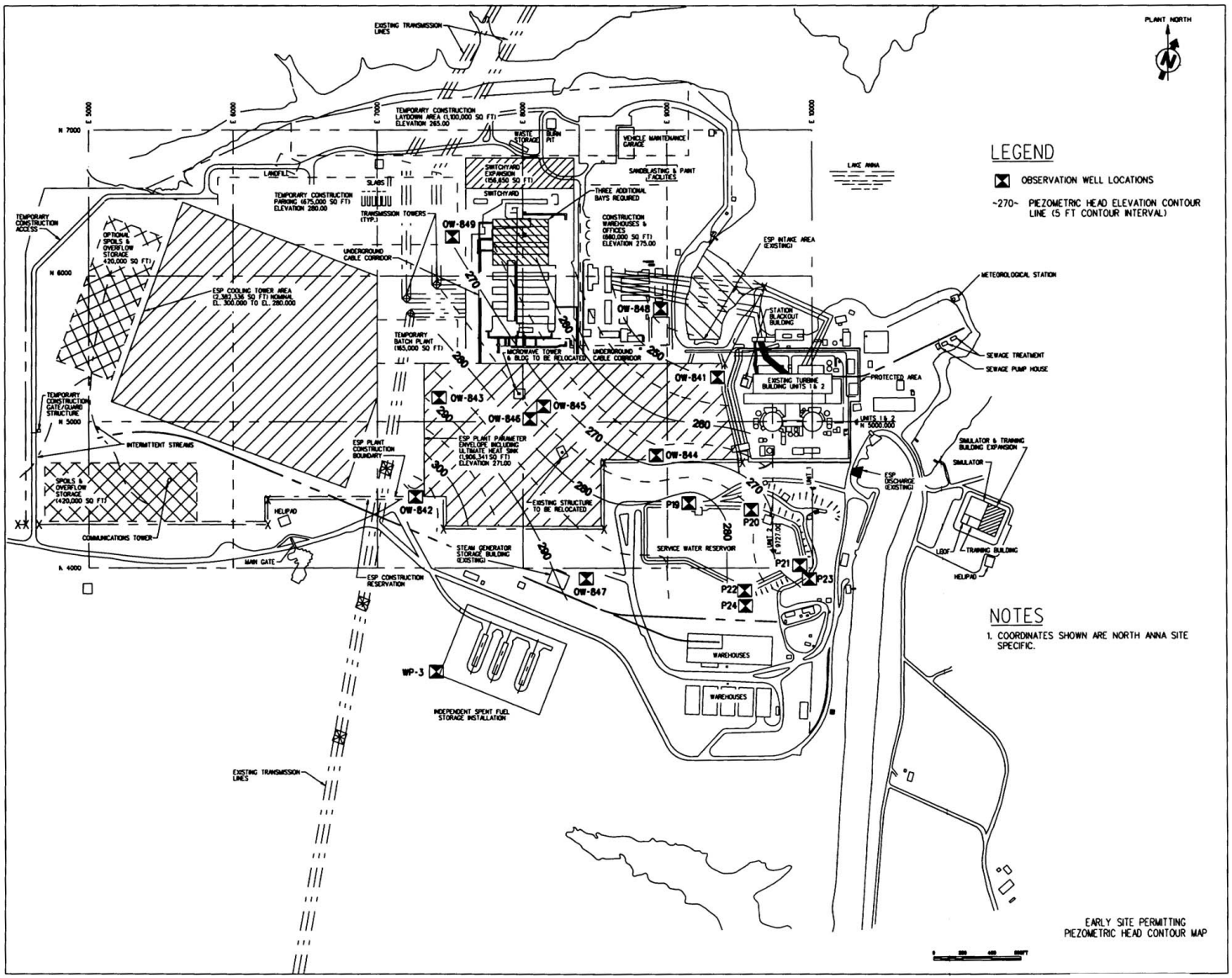

Figure 2.4-16 Piezometric Head Contour Map

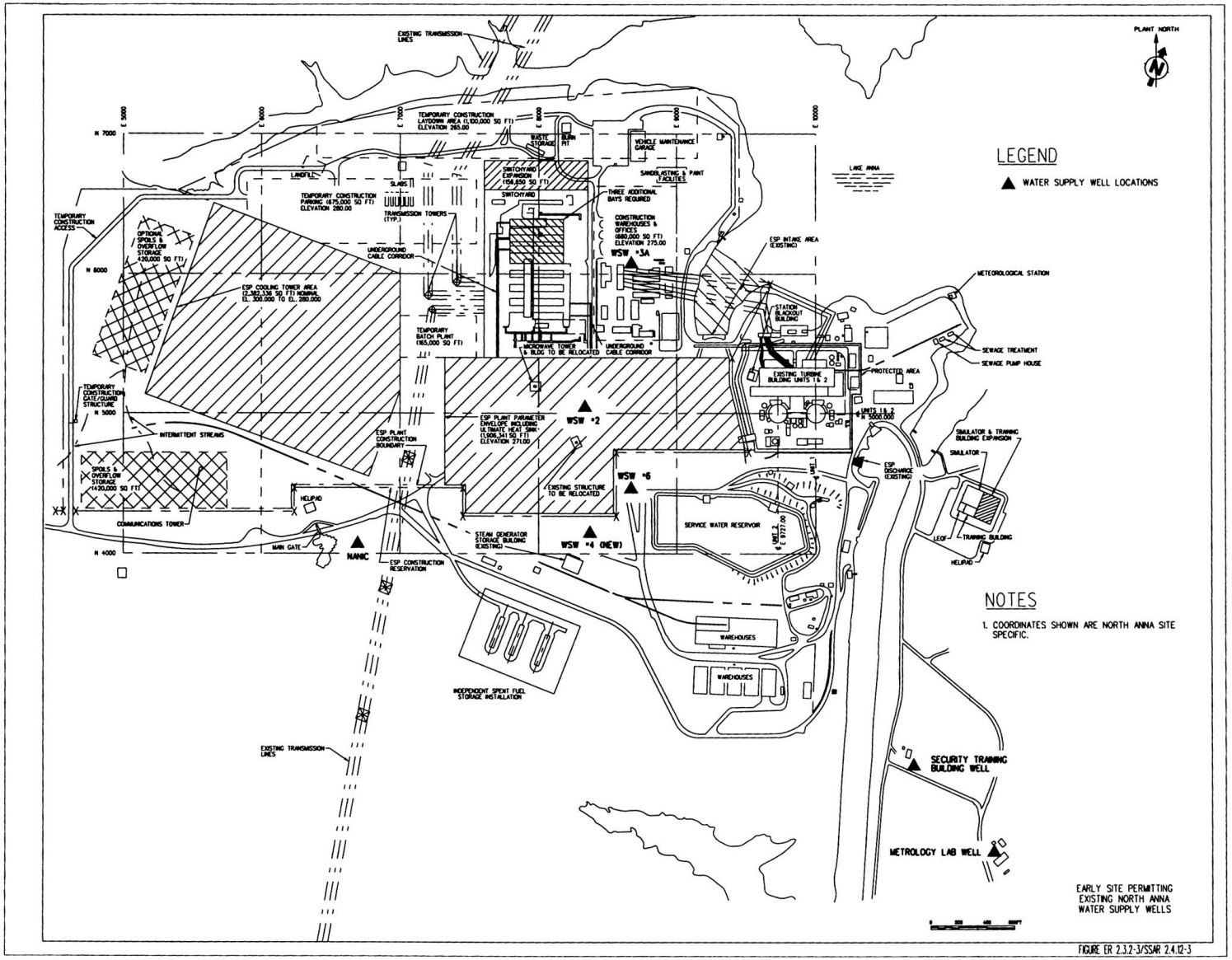

Figure 2.4-17 Existing North Anna Water Supply Wells

2.5 Geology, Seismology, and Geotechnical Engineering

This section presents information on the geological, seismological and geotechnical engineering properties of the ESP site. Section 2.5.1 describes basic geological and seismologic data, focusing on those data developed since publication of the EPRI 1986 seismic source model (Reference 1) for the Central and Eastern United States. Section 2.5.2 describes the vibratory ground motion at the site, including an updated seismicity catalog, description of seismic sources, and development of the SSE and Operating Basis Earthquake (OBE) design ground motions. Section 2.5.3 describes the potential for surface faulting in the site area, and Section 2.5.4, Section 2.5.5 and Section 2.5.6 describe the stability of surface materials and foundations at the site.

RG 1.165, Appendix D, “Geological, Seismological and Geophysical Investigations to Characterize Seismic Sources” (Reference 2), provides guidance for the level of investigation recommended at different distances from a proposed site for a nuclear facility. The site region is that area within 200 miles (320 km) of the site location. The site vicinity is that area within 25 miles (40 km) of the site location. The site area is that area within 5 miles (8 km) of the site location. The site is that area within 0.6 mile (1 km) of the site location. These terms, site region, site vicinity, site area, and site, are used in Section 2.5.1 through Section 2.5.3 to describe these specific areas of investigation. These terms are not applicable to other sections of the SSAR.

2.5.1 Basic Geologic and Seismic Information

This section presents information on the geological and seismological characteristics of the ESP site region and area. The information is divided into two parts. Section 2.5.1.1 describes the geologic and tectonic setting of the site region and Section 2.5.1.2 describes the geology and structural geology of the site area. The geological and seismological information was developed in accordance with the guidance presented in RG 1.70, Section 2.5.1, “Basic Geologic and Seismic Information” (Reference 3), and RG 1.165, “Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion,” and is intended to satisfy the requirements of 10 CFR 100, “Reactor Site Criteria,” Section 100.23, “Geologic and Seismic Siting Criteria,” paragraph (c) “Geological, Seismological and Engineering Characteristics” (Reference 4). The geological and seismological information presented in this section are used as a basis for evaluating the geologic, seismic, and man-made hazards at the site.

RG 1.165 states that the vibratory design ground motion for a new nuclear power plant may be developed using either the EPRI or Lawrence Livermore National Laboratory (LLNL) probabilistic seismic hazard methodology. As described in Section 2.5.2, the EPRI methodology has been used to develop the SSE and OBE design ground motions for the ESP site. RG 1.165 further requires that the geological, seismological, and geophysical database be updated and any new data be evaluated to determine whether revisions to the 1986 EPRI seismic source model would be required (presented in Section 2.5.2). This section, therefore, provides an update of the geological, seismological, and geophysical database for the ESP site, focusing on whether any data published

since 1986 would indicate a significant change to the 1986 EPRI seismic source model. In addition, the geotechnical properties of the ESP site location are described to evaluate the ground motion site response characteristics of the site and other non-tectonic geologic and man-made hazards at the site (presented in Section 2.5.4).

The geological and seismological information presented in this section was developed from a review of previous reports prepared for the existing units and abandoned Units 3 and 4, published geologic literature, interpretation of aerial photography, and a subsurface investigation and field and aerial reconnaissance conducted in preparation of this ESP application. Previous site-specific reports reviewed include the UFSAR (Reference 5) and the ISFSI Safety Analysis Report (Reference 6). Reports prepared by Dames and Moore for design and construction of the existing units (Reference 7) and the abandoned Units 3 and 4 (Reference 8) (Reference 9) were also reviewed. A review of published geologic literature was used to supplement and update the existing geological and seismological information. This literature was identified using the GeoRef database (American Geological Institute) and the USGS library catalogue. In addition, relevant unpublished geologic literature, studies and projects were identified by contacting the USGS and State geological surveys and universities. A list of the references used to compile the geological and seismological information presented in the following sections is provided at the end of Section 2.5.

2.5.1.1 Regional Geology

This section discusses the physiography, geologic history, stratigraphy, and tectonic setting within a 200-mile radius of the ESP site. Summaries of these aspects of regional geology are presented to provide the framework for evaluation of the geologic and seismologic hazards presented in the succeeding sections.

2.5.1.1.1 Regional Physiography and Geomorphology

The ESP site lies within the Piedmont Physiographic Province (Figure 2.5-1). The area within a 200-mile radius of the site (site region) encompasses parts of five other physiographic provinces. These are: the Coastal Plain Physiographic Province and the Continental Shelf Physiographic Province, which are located successively east of the Piedmont Province and the Blue Ridge Physiographic Province, the Valley and Ridge Physiographic Province, and the Appalachian Plateau Physiographic Province, which are located successively west and northwest of the Piedmont Province (Reference 10).

Each of the physiographic provinces present within the site region is presented in the following sections. The physiographic provinces in the site region are shown on Figure 2.5-1.

a. **Piedmont Physiographic Province**

   The Piedmont Physiographic Province is a rolling to hilly area that extends from the Fall Line on the east to the foot of the Blue Ridge Mountains on the west (Figure 2.5-1). The Fall Line is a low east-facing scarp that separates crystalline rocks of the Piedmont Province to the west

from less resistant sedimentary rocks of the Coastal Plain Province to the east (Reference 11). The Piedmont Province is about 40 miles wide in northern Virginia and broadens southwards to about 165 miles along the Virginia-North Carolina border. Elevations range from about 800 to 1500 feet along the western border of the province and slope eastward to elevations of about 200 feet at the Fall Line (Reference 12).

The Piedmont Province is divided into the Piedmont Upland section to the east and the Piedmont Lowland section to the west (section is referred to as subprovince in some publications) (Figure 2.5-1). The Piedmont Upland section is underlain by metamorphosed sedimentary and crystalline rocks of Precambrian to Paleozoic age. These lithologies are relatively resistant and their erosion has resulted in a moderately irregular surface. Topographically higher terrain is underlain by Cambrian quartzites and Precambrian crystalline rocks (Reference 13). The Piedmont Lowland section is a less rugged terrain containing fault-bounded basins filled with sedimentary and igneous rocks of Triassic and Early Jurassic age. Valleys are developed on sandstone and shale strata and trend northeast-southwest, parallel to the strike of the bedrock. Higher and more rugged terrain is underlain by intrusive and extrusive rocks consisting predominantly of diabase and basalt (Reference 13).

The Piedmont Province is characterized by deeply weathered bedrock and a relative paucity of solid rock outcrop (Reference 14). Saprolites that cover the bedrock may reach thicknesses of up to 300 feet. In the hillslope areas, the saprolite is capped locally by colluvium (Reference 15).

b. **Coastal Plain Physiographic Province**

The Coastal Plain Physiographic Province extends eastward from the Fall Line to the coastline (Figure 2.5-1). The Coastal Plain Province is a low-lying, gently rolling terrain developed on a wedge-shaped mass of Cretaceous, Tertiary and Quaternary age non-metamorphosed sedimentary rocks that thicken toward the coast. The thickness of the sediments at the New Jersey coastline is about 4000 feet, but the sediments attain thicknesses of as much as 8000 feet along the coast of Maryland and about 10,000 feet along the coast of North Carolina (Reference 16). Topographic relief is generally less than 200 feet and the topographic gradient is usually less than 5 feet per mile (Reference 13).

Northeast of the Chesapeake Bay, the Coastal Plain consists of extensive areas of nearly level plain, less than 100 feet above sea level. This morphology resulted from deposition and erosion associated with the rise and fall of sea level during Pleistocene time. Southwest of the Chesapeake Bay, marine and fluvial terraces developed during the Pliocene and Pleistocene. As a result of post-Pleistocene sea level rise, the outline of the present day coastline is controlled by the configuration of drowned valleys, typified by the deeply recessed

Chesapeake and Delaware Bays. Exposed headlands and shorelines have been modified by the development of barrier islands and extensive lagoons (Reference 13).

c. **Continental Shelf Physiographic Province**

The Continental Shelf Physiographic Province is the submerged continuation of the Coastal Plain Province and extends from the shoreline to the continental slope (Figure 2.5-1). The shelf is characterized by a shallow gradient and many shallow water features that are relicts of lower sea levels (Reference 13). The shelf extends eastward for about 75 to 80 , where sediments reach a maximum thickness of about 40,000 feet (Reference 17).

The Continental Shelf can effectively be separated into two geomorphic regions based on the 100 m bathymetric contour. Southeast of the 100 m bathymetric contour, the contours essentially follow the morphology of the shelf edge. Northwest of the 100 m bathymetric contour, the majority of the shelf is characterized by linear, low relief features, more closely aligned with the present shoreline (Reference 13).

d. **Blue Ridge Physiographic Province**

The Blue Ridge Physiographic Province is bounded on the east by the Piedmont Province and on the west by the Valley and Ridge Province (Figure 2.5-1). The Blue Ridge Province, aligned in a northeast-southwest direction, is a deeply dissected mountainous area, divided into two distinctly different parts by the Roanoke River, which flows to the southeast (Reference 12).

North of the Roanoke River a single ridge dominates the topography. The ridge is about 10 miles wide and summit elevations range from 2000 to over 3500 feet (Reference 18). Much of the mountain range is underlain by a pervasively faulted anticlinorium, a large composite anticline composed of lesser folds (Reference 19) that is strongly asymmetrical. South of the Roanoke River, the province becomes broader, reaching a width of more than 50 miles along the North Carolina border, with higher elevations than exhibited by the northern ridge. South of the border it becomes a mountainous upland with elevations typically ranging from 2400 to 3000 feet and a few peaks rising to elevations of over 5000 feet (Reference 20). The Blue Ridge is composed chiefly of granite, greenstone and other crystalline rocks along the crest and eastern slopes of the anticlinorium. On the steeper western slope, it is underlain by sandstones and shales (Reference 12).

e. **Valley and Ridge Physiographic Province**

The Valley and Ridge Physiographic Province lies west of the Blue Ridge Province and east of the Appalachian Plateau Province (Figure 2.5-1). It is aligned in a northeast-southwest direction and is between 25 and 50 miles wide. The Great Valley portion of the province, to the east, is divided into many distinct lowlands by ridges or knobs, the largest lowland being the Shenandoah Valley. Elevations within the Shenandoah Valley typically range between 500 and 1200 feet. The Valley and Ridges (Appalachian Mountains) portion of the province, to the west, is characterized by a series of roughly parallel ridges and valleys, some of which are

long and narrow (Reference 12). Elevations within the Valley and Ridges range from about 1000 to 4500 feet (Reference 20). The Great Valley typically is underlain by long belts of limestone and shale, while the rocks of the Valley and Ridges consist of more resistant sandstone and other quartz-rich rocks (Reference 12).

f. **Appalachian Plateau Physiographic Province**

The Appalachian Plateau Physiographic Province lies west of the Valley and Ridge Province (Figure 2.5-1). The Allegheny Front is the topographic and structural boundary between the Appalachian Plateau on the west and the Valley and Ridge Province on the east (Reference 15). It is a bold, high escarpment, underlain primarily by clastic sedimentary rocks capped by sandstone and conglomerates. In eastern West Virginia, elevations along this escarpment reach 4790 feet (Reference 21). The rocks of the Appalachian Plateau to the west lie flat or are gently folded and consist of sandstone, shale and coal. In southwest Virginia, the Appalachian Plateau has an average elevation of about 2000 feet. It is deeply dissected by streams into a maze of deep, narrow valleys and high narrow ridges (Reference 12).

2.5.1.1.2 Regional Geologic History

The geologic and tectonic setting of the ESP site region is the product of a long, complex history of continental and island arc collisions and rifting, spanning a period of over 1 billion years. This history of deformation imparts a pre-existing structural grain in the crust that is important for understanding the current seismotectonic setting of the region. Episodes of continental collisions have produced a series of accreted terranes separated, in part, by low angle detachment faults. Sources of modern day seismicity may occur in the overlying exposed or buried terranes or may occur along structures within the North American basement buried beneath the accreted terranes. That is, regional seismicity may not be related to any known surface structure. Intervening episodes of continental rifting have produced high angle normal or transtensional faults that either sole downward into detachment faults or penetrate entirely through the accreted terranes. Understanding the history of evolution and geometry of these pre-existing crustal faults, therefore, is important for identifying potentially active faults and evaluating the distribution of historical seismicity within the tectonic context of the site region.

Major tectonic events in the site region include five compressional orogenies and two extensional episodes (Reference 22). Currently the site region is located on the passive, divergent trailing margin of the North American plate following the last episode of continental extension and rifting. Each of these episodes of deformation is described in the following sections.

a. **Grenville Orogeny**

The first of the compressional orogenies was the Grenville orogeny that occurred during Middle to Late Precambrian time as a result of the convergence of the ancestral North American and African tectonic plates. During this orogeny, various terranes were accreted onto the edge of the ancestral North American plate, forming the Grenville Mountains

(Reference 22), which were likely the size of the present day Himalayas (Reference 23). The Grenville orogeny was followed by several hundred million years of tectonic quiescence, during which time the Grenville Mountains were eroded and their basement rocks exposed. In Virginia, the Grenville basement rocks are exposed in the Blue Ridge Province and portions of the Piedmont Province (Reference 23).

b. **Late Precambrian Extensional Episode**

Following the Grenville orogeny, crustal extension and rifting began during Late Precambrian time, which caused the separation of the North America and African plates and created the proto-Atlantic Ocean (Iapetus Ocean). Rifting is interpreted to have occurred over a relatively large area, sub-parallel to the present day Appalachian mountain range (Reference 22). During rifting, the newly formed continental margin began to subside and accumulate sediment. Initial sedimentation resulted in an eastward thickening wedge of clastic sediments consisting of graywackes, arkoses, and shales deposited unconformably on the Grenville basement rocks. These rocks are presently exposed on the eastern side of the Blue Ridge Anticlinorium (Reference 13). Subsequent sedimentation included a transgressive sequence of additional clastic sediments followed by a thick and extensive sequence of carbonate sediments. Remnants of the rocks formed from these sediments can be found within the Valley and Ridge and Piedmont Provinces (Reference 23). Accumulation of this eastward thickening wedge of clastic and carbonate sediments is thought to have occurred from the Middle to Late Cambrian into Ordovician time (Reference 13).

c. **Penobscot Orogeny**

During Late Cambrian time, as the now tectonically stable continental margin continued to subside, micro-continents and volcanic arcs, characteristic of an intra-oceanic island-arc terrane, began to develop in the proto-Atlantic Ocean as a result of east-directed oceanic subduction and initial closing of the proto-Atlantic. The Penobscot orogeny, the earliest known Paleozoic orogeny in the Appalachian region, is thought to have been caused by crustal convergence and accretion of these volcanic arcs thrust over micro-continents along the North American plate margin (Figure 2.5-2). This orogeny is considered to represent the beginning of the convergent phase in the closing of the proto-Atlantic Ocean (Reference 22). Subsequent convergent phases in the closing of the proto-Atlantic include the Taconic and Acadian orogenies and the Allegheny orogeny that finally closed the proto-Atlantic in the Permian.

d. **Taconic Orogeny**

The Taconic orogeny occurred during Middle to Late Ordovician time and was caused by continued collision of micro-continents and volcanic arcs with eastern North America along an eastward dipping subduction zone during progressive closure of the proto-Atlantic Ocean (Figure 2.5-2). Taconic terranes are preserved today in the Piedmont in a series of belts

representing island-arcs and micro-continents. They include the Chopawamsic belt, the Carolina Slate belt, the Eastern Slate belt and the Goochland-Raleigh belt. These Taconic terranes are considered to have collided with and accreted to eastern North America at different times during the orogeny (Reference 23).

Accretion of the island-arcs and micro-continents to the eastern margin of North America created a mountain system, the Taconic Mountains, that became a major barrier between the proto-Atlantic to the east and the carbonate platform to the west. The growth of this barrier transformed the area underlain by carbonate sediments to the west into a vast, elongate sedimentary basin, the Appalachian Basin. The present day Appalachian Basin extends from the Canadian Shield in southern Quebec and Ontario Provinces, Canada, southwestward to central Alabama, approximately parallel to the Atlantic coastline (Reference 24). The formation of the Appalachian Basin is one of the most significant consequences of the Taconic orogeny in the region defined by the Valley and Ridge and Appalachian Plateau Provinces. The Taconic mountain system was the source of most of the siliclastic sediment that accumulated in the Appalachian Basin during Late Ordovician and Early Silurian time. A continent-wide transgression in Early Silurian time brought marine shales and carbonate sedimentation eastward over much of the basin, and a series of transgressions and regressions thereafter repeatedly shifted the shoreline and shallow marine facies. Carbonate deposition continued in the eastern part of the basin into Early Devonian time (Reference 25).

e. **Acadian Orogeny**

The Acadian orogeny occurred during the Middle to Late Devonian Period and was caused by the collision of the micro-continent Avalon (formerly Armorica) with eastern North America. At its peak, the orogeny produced a continuous chain of mountains along the east coast of North America and brought with it associated volcanism and metamorphism. Remnants of the Avalon terrane (the Acadian Mountains) can be found in the Piedmont Province within the pre-existing Taconic Goochland belt, Carolina Slate belt and the Chopawamsic belt (Reference 23). The Acadian orogeny ended the largely quiescent environment that dominated the Appalachian Basin during the Silurian, as vast amounts of terrigenous sediment from the Acadian Mountains were introduced into the basin and formed the Catskill clastic wedge. Thick accumulations of clastic sediments belonging to the Catskill Formation are spread throughout the Valley and Ridge Province (Reference 25). During the Mississippian Period, the Acadian Mountains were completely eroded and the basement rocks of the Avalon terrane were exposed (Reference 23).

f. **Allegheny Orogeny**

The Allegheny orogeny occurred during the Late Carboniferous Period and extended into the Permian Period. The orogeny represents the final convergent phase in the closing of the proto-Atlantic Ocean in the Paleozoic. Metamorphism and magmatism were significant events

during the early part of the Allegheny orogeny. The Allegheny orogeny was caused by the collision of the North American and African plates and produced the Allegheny Mountains. As the African continent thrust westward over North America, the Taconic and Acadian terranes were detached and also were thrust westward over Grenville basement rocks (Reference 23). The northwest movement of the displaced rock mass above the thrust was progressively converted into deformation of the rock mass, primarily in the form of thrust faults and fold-and-thrust structures, as seen in the Blue Ridge and Piedmont Provinces. The youngest manifestation of the Allegheny orogeny was northeast-trending strike-slip faults and shear zones in the Piedmont Province. The extensive thick and undeformed Appalachian Basin and its underlying sequence of carbonate sediments were deformed and a fold-and-thrust array of structures, long considered the classic Appalachian structure, was impressed upon the basin. The tectonism produced the Allegheny Mountains and a vast alluvial plain to the northwest. The Allegheny Front in the Appalachian Plateau Province is thought to represent the westernmost extent of the Allegheny orogeny. Rocks throughout the Valley and Ridge Province are thrust faulted and folded up to this front, whereupon they become relatively flat and only slightly folded west of the Allegheny Front (Reference 26).

g. **Early Mesozoic Extensional Episode**

Crustal extension during Early Mesozoic time (Late Triassic and Early Jurassic) marked the opening of the Atlantic Ocean. This extensional episode produced numerous local, closed basins ("Triassic basins") along eastern North America (Reference 26). The elongate basins generally trend northeast, parallel to the pre-existing Paleozoic structures. The basins range in length from less than 20 miles to over 100 miles and in width from less than 5 miles to over 50 miles. Generally, the basins are asymmetric half-grabens with the principal faults located along the western margin of the basins. Triassic and Jurassic age rocks that fill the basins primarily consist of clastic sediments interbedded with basaltic volcanics.

h. **Cenozoic History**

The Early Mesozoic extensional episode gave rise to the Cenozoic Mid-Atlantic spreading center. The Atlantic seaboard presently represents the trailing passive margin related to the spreading at the Mid-Atlantic ridge. Ridge push forces resulting from the Mid-Atlantic spreading center are believed to be responsible for the NE-SW directed horizontal compressive stress presently observed along the Atlantic seaboard.

During Cenozoic time, as the Atlantic Ocean opened, the newly formed continental margin cooled and subsided, leading to the present day passive trailing divergent continental margin. As the continental margin developed, continued erosion of the Appalachian Mountains produced extensive sedimentation within the Coastal Plain. The Cenozoic history of the Atlantic continental margin, therefore, is preserved in the sediments of the Coastal Plain Province, and under water along the continental shelf. The sedimentary record is of a gently

east-dipping, seaward-thickening wedge of sediments, caused by both subsidence of the continental margin and fluctuations in sea level. Sediments of the Coastal Plain Province cover igneous and metamorphic basement rocks and part or all of some of the Triassic basin rift deposits (Reference 13).

During the Quaternary Period much of the northern United States experienced multiple glaciations interspersed with warm interglacial episodes. The last (Wisconsian) Laurentide ice sheet advanced over much of North America during the Pleistocene. The southern limit of glaciation extended into parts of northern Pennsylvania and New Jersey, but did not cover the ESP site vicinity. South of the ice sheet, periglacial environments persisted throughout the site region (Reference 27). Present-day Holocene landscapes therefore, are partially the result of geomorphic processes responding to isostatic uplift, eustatic sea level change, and alternating periglacial and humid to temperate climatic conditions (Reference 28).

2.5.1.1.3 Regional Stratigraphy

The regional stratigraphy within each of the physiographic provinces is presented below. The generalized stratigraphy within a 200-mile radius of the ESP site is shown on Figure 2.5-3. The stratigraphy shown on Figure 2.5-3 is from a portion of The Geologic Map of the United States (Reference 29). The classification of the rock units shown on Figure 2.5-3 is illustrated by the legend that accompanies the figure. The rock units are essentially classified based on age and type. Rocks of approximately the same age are shown at the same horizontal level in the legend. Successive vertical columns show different rock types and facies.

a. **Piedmont Physiographic Province**

There are two distinct divisions to the rocks of the Piedmont Physiographic Province. The first is a set of Late Precambrian and Paleozoic age crystalline rocks and the second is a set of Early Mesozoic (Triassic) age sedimentary rocks deposited locally in down-faulted basins within the crystalline rocks (Reference 30) (Figure 2.5-3). The rocks are overlain by residual soils derived from weathering of the crystalline rocks, and by Quaternary age alluvium and colluvium.

1. **Crystalline Rocks (Late Precambrian and Paleozoic)**

Crystalline rocks of the Piedmont Province primarily occur within the Piedmont Upland section. The crystalline rocks consist of deformed and metamorphosed meta-sedimentary, meta-igneous, and meta-volcanic rocks intruded by mafic dikes and granitic plutons (Reference 31). The rocks belong to a number of northeast-trending belts that are defined on the basis of rock type, structure and metamorphic grade (Reference 32) and are interpreted to have formed along and offshore of ancestral North America (Reference 33). From east to west the main lithotectonic belts are: the Goochland-Raleigh belt; the Carolina and Eastern slate belts; the Charlotte, Milton, and Chopawamsic belts; and the

Western Piedmont belt (Reference 32) (Figure 2.5-4). These lithotectonic belts are presented in the following paragraphs.

Goochland-Raleigh Belt

The Goochland-Raleigh belt stretches southward from Fredericksburg, Virginia, to the North Carolina State line east of the Spotsylvania fault (presented in Section 2.5.1.1.4) (Reference 34) (Figure 2.5-4). The Goochland belt (Virginia) is composed predominantly of granulite facies (high grade) metamorphic rocks and the Raleigh belt (North Carolina) is composed of sillimanite (very high grade) metamorphic rocks (Reference 30). The Goochland-Raleigh belt is interpreted to be a micro-continent that was accreted to ancestral North America during the Taconic orogeny. Some geologists believe that the micro-continent was rifted from ancestral North America during the proto-Atlantic rifting while others believe that it formed outbound of ancestral North America (exotic or suspect terrane). Rocks of the Goochland-Raleigh belt are considered to be the oldest rocks of the Piedmont Province and bear many similarities to the Grenville age rocks of the Blue Ridge Province (Reference 35).

The Po River Metamorphic Suite and the Goochland terrane, that lie southeast of the Spotsylvania fault, make up the easternmost part of the Goochland-Raleigh belt. The Po River Metamorphic Suite was named after the Po River in the Fredericksburg area and comprises amphibolite grade (high grade) metamorphic rocks, predominantly biotite gneiss and lesser amounts of hornblende gneiss and amphibolite (Reference 36). The age of this unit is uncertain, but it has been assigned a provisional age of Precambrian to Early Paleozoic (Reference 37). The Goochland terrane was first studied along the James River west of Richmond, Virginia, and contains the only dated Precambrian rocks east of the Spotsylvania fault. It is a Precambrian granulite facies (very high grade) metamorphic terrane comprised of, from the base up, the State Farm Gneiss, the Sabot Amphibolite, and the Maidens Gneiss. The Maidens Gneiss, which is the most widespread unit, is lithologically similar to the Po River Metamorphic Suite and is co-extensive with it. It is a heterogeneous formation and dominant layered lithologies include garnet-biotite-quartz plagioclase gneiss, biotite-quartz-plagioclase-potassium feldspar-augen gneiss, and biotite granitic gneiss (Reference 36).

Carolina Slate and Eastern Slate Belts

The Carolina Slate belt extends southward from southern Virginia to central Georgia, while the Eastern Slate belt is located predominantly in North Carolina, east of the Goochland-Raleigh belt (Figure 2.5-4). Both the Carolina and Eastern Slate belts are composed of greenschist facies (low grade) metamorphic rocks (Reference 30), including meta-graywacke, tuffaceous argillites, quartzites, and meta-siltstones (Reference 32). The Carolina and Eastern Slate belts are interpreted to be island-arcs that were accreted to ancestral North America during the Taconic orogeny. The island-arcs are interpreted to

have been transported from somewhere in the proto-Atlantic Ocean, and are therefore considered to be exotic or suspect terranes. Rocks of the Carolina and Eastern Slate belts generally are considered to be Early Paleozoic in age. Granitic and gabbro-rich plutons that intrude the belts generally are considered to be Middle to Late Paleozoic in age (Reference 32).

Charlotte, Milton, and Chopawamsic Belts

The Charlotte, Milton and Chopawamsic belts comprise a broad central part of the Piedmont Province from Virginia to Georgia (Figure 2.5-4). The belts are interpreted to be part of an island-arc and consist predominantly of meta-sedimentary and meta-volcanic rocks.

The Charlotte belt extends southward from northern North Carolina to Georgia (Figure 2.5-4). Meta-sedimentary rocks within this belt consist of epidote-bearing gneiss and migmatite. The Milton belt extends southward from southern Virginia to northern North Carolina (Figure 2.5-4) and is characterized by strongly foliated gneiss and schist (Reference 32). The Chopawamsic belt extends southward from northern to central Virginia (Figure 2.5-4). The ESP site is located within the Chopawamsic belt.

The Chopawamsic belt, also referred to as the "Chopawamsic Volcanic Belt" (Reference 38) and the "Central Virginia Volcanic-Plutonic Belt (Reference 39), takes its name from exposures along Chopawamsic Creek in northern Virginia. The belt trends northeastward from the North Carolina state line, crosses the James River between Richmond and Charlottesville and continues northeastward to south of Washington D.C., where it is covered by Coastal Plain deposits. The Chopawamsic belt is bounded on the west by the Chopawamsic fault and on the east by the Spotsylvania fault. The Chopawamsic belt is interpreted to be an island-arc that was accreted to ancestral North America during the Taconic orogeny. The Chopawamsic belt is regarded as an exotic or suspect terrain. Rocks in the Chopawamsic belt have long been known to be Early Paleozoic in age. Recent U-Pb studies consistently yield Ordovician ages for Chopawamsic volcanic rocks and Rb-Sr and U-Pb dating of granite rocks give late Ordovician ages (Reference 35).

The Chopawamsic belt is comprised of the Chopawamsic Formation and the Ta River Metamorphic Suite. The Chopawamsic Formation and the Ta River Metamorphic Suite are interpreted to have formed as an island-arc. The Chopawamsic Formation is interpreted to have formed as the continent-ward side of the island-arc and the Ta River Metamorphic Suite as the ocean-ward side (Reference 40). The Chopawamsic Formation consists of a sequence of felsic, intermediate and mafic meta-volcanic rocks with subordinate meta-sedimentary rocks. The Ta River Metamorphic Suite consists of a sequence of amphibolites and amphibole-bearing gneisses with subordinate ferruginous

quarzites and biotite gneiss. Rocks of the Ta River Metamorphic Suite are generally thought to be more mafic and to have experienced higher-grade regional metamorphism than the rocks of the Chopawamsic Formation (Reference 35).

The Chopawamsic Formation and Ta River Metamorphic Suite are unconformably overlain by the Quantico and Arvonia Formations. The Quantico and Arvonia Formations consist of meta-sedimentary rocks including slates, phyllites, schists, and quartzites. These meta-sedimentary rocks are considered to have been deposited in successor basins after the subjacent terranes were eroded and formed depositional troughs. Rocks of the Arvonia Formation are exposed in the Arvonia and Long Island synclines, while rocks of the Quantico Formation are exposed in the Quantico syncline (Figure 2.5-5). Rocks of the Arvonia, Long Island, and Quantico synclines form three belts across the central Virginia Piedmont, the Quantico synclines to the southeast and the Arvonia and Long Island synclines to the north (Reference 35).

The Chopawamsic Formation and the Ta River Metamorphic Suite are intruded by a number of granite plutons. The number of plutons and their relation to one another, however, remains uncertain (Reference 35). Rocks of the Falmouth Intrusive Suite intrude the Ta River Metamorphic Suite and Quantico Formation in the form of dikes, sills, and small irregular intrusions (Reference 37).

Western/Inner Piedmont Belt

The Western Piedmont belt, referred to as the Inner Piedmont belt in some publications, extends southward from Virginia through North Carolina and into Georgia (Figure 2.5-4). It is composed of greenschist facies (low grade) and amphibolite facies (high grade) meta-sedimentary rocks. These meta-sedimentary rocks enclose blocks of meta-basalt, ultramafic rocks, granite and other quasi-exotic lithologies and are called mélanges (Reference 40). These mélanges are interpreted to have formed in a Cambrian-Ordovician back-arc or marginal basin that lay on the continent-ward side of an island-arc terrane (Reference 36).

Two distinct types of mélange deposits occur within a collage of thrust slices in the Western Piedmont belt. The first type is a block-in-phyllite mélange that constitutes the Mine Run Complex of Virginia. It consists of a variety of meta-plutonic, meta-volcanic, mafic, and ultramafic blocks enclosed within a matrix of phyllite or schist and meta-sandstones of feldspathic or quartz meta-graywacke. The Mine Run complex is interpreted to consist of four imbricated thrust slices (numbered I through IV), each with its own distinctive exotic block content (Reference 36).

The second mélange type within the Western Piedmont belt is a meta-diamictite and contains a less extensive variety of exotic blocks, the most common being mafic and ultramafic blocks. The exotic blocks are enclosed in a micaceous quartzofeldspathic

matrix, which has contemporaneously deposited schist and quartz-lump fragments as its characterizing features. Several varieties of meta-diamictite have been recognized in Virginia and described as the Lunga Reservoir and Purcell Branch Formations (Reference 36).

The mélanges of the Western Piedmont are overlain unconformably by Ordovician age meta-sedimentary rocks and are intruded by Ordovician age and Late Ordovician or Early Silurian age felsic plutons, such as the Lahore and Ellisville plutons (Reference 36).

2. **Sedimentary Rocks (Early Mesozoic)**

Mesozoic sedimentary rocks of the Piedmont Province occur primarily within the Piedmont Lowland section. The sediments were deposited in a series of northeast-trending down-faulted basins faulted into crystalline rocks. Structurally, the basins are half-grabens with a main fault on the western side only (Reference 30). Sediments filling the basins include intermontane fanglomerates, fresh-water limestone, mudstones, siltstones and sandstones, and basic igneous and volcanic rocks (Reference 31). The Lower Mesozoic sediments deposited in these basins usually are referred to as Triassic basin deposits, although the basins are now known to also contain Lower Jurassic rocks. The Culpepper basin in the Piedmont Lowland section of Virginia is the largest basin, but numerous smaller basins include the Richmond, Farmville, and Danville, which are scattered throughout the Piedmont Lowland section (Reference 30).

3. **Surficial Sediments (Cenozoic)**

Surficial sediments in the Piedmont Province consist of residual and transported material. The residual soils have developed in place from weathering of the underlying rocks, while the transported material – alluvium and colluvium – has been moved by water or gravity and laid down as unconsolidated deposits of clay, silt, sand, gravel and rock fragments (Reference 41). Surficial sediments in the Piedmont Upland section are interpreted to be the product of Cenozoic weathering, Quaternary periglacial erosion and deposition, and recent anthropogenic activity (Reference 42).

Residual soil in the Piedmont Province consists of completely decomposed rock and saprolite. Residual soils occur almost everywhere, except where erosion has exposed the bedrock on ridges and in valley bottoms. Soils produced by the weathering of rock but which retain the basic visual structure of the original rock are called saprolites. Saprolite comprises the bulk of residual soil in the Piedmont Province and is defined as an earthy material in which the major rock-forming minerals (other than quartz) have been altered to clay but the material retains most of the textural and structural characteristics of the parent rock. The saprolite forms by chemical weathering, its thickness and mineralogy being dependent on topography, parent rock lithology and the presence of surface and/or groundwater (Reference 28).

Relief affects the formation of soils by causing differences in internal drainage, runoff, soil temperatures, and geologic erosion. In steep areas where there is rapid runoff, little percolation of water through the soil and little movement of clay, erosion is severe and removes soil as rapidly as it forms. Gently sloping areas, on the other hand, are well drained and geologic erosion in these areas is generally slight. The characteristics of the underlying rock strongly influence the kind of changes that take place during weathering. Because of differences in these characteristics, the rate of weathering varies for different rock types. The igneous, metamorphic and sedimentary rocks of the Piedmont Province are all sources of parent material for the soils. Gabbro, an igneous rock that is fairly resistant to weathering, produces soils that are between about 3 and 5 feet thick. Granite gneiss, however, weathers deeply and produces soils that range in thickness from about 6 to 20 feet (Reference 41).

Colluvium in the Piedmont Province occurs discontinuously on hilltops and side slopes, while thicker colluvium occurs in small valleys lacking perennial streams. Alluvium is present in all valleys with perennial streams (Reference 42).

b. **Coastal Plain Physiographic Province**

The Coastal Plain Physiographic Province is underlain by Mesozoic and Cenozoic age fluvial and marine, predominantly clastic, sedimentary materials that dip gently to the east and southeast (Reference 31). The Mesozoic and Cenozoic stratigraphic units that have been mapped on the surface and in the subsurface of the Coastal Plain comprise a lower sequence of Jurassic and Early Cretaceous age terrestrial sediments and an overlying sequence of well defined marine stratigraphic units, primarily Late Cretaceous and Tertiary in age. Quaternary deposits that overlie the Tertiary age sediments are found predominantly as valley fill, caps on upland ridges and hills, and as a relatively thin blanket in the coastal areas (Figure 2.5-3). The Quaternary age strata are generally not thicker than 50 feet (Reference 13).

c. **Blue Ridge Physiographic Province**

The Blue Ridge Physiographic Province is underlain by a broad, northeast-trending, structurally complex metamorphic terrane (Reference 43). In its widest place, the Blue Ridge is over 20 miles wide and can be traced southward from south-central Maryland through Virginia into North Carolina (Reference 44). The Blue Ridge terrain consists of stratified meta-sedimentary rocks and meta-basalts of Early Paleozoic and Late Precambrian age and an underlying gneissic and granitic basement-rock complex of Middle to Late Precambrian age (Figure 2.5-3).

d. **Valley and Ridge Physiographic Province**

The Valley and Ridge Physiographic Province is underlain primarily by layered sedimentary rock that has been intensely folded and locally thrust faulted. The sedimentary rocks range in age from Cambrian to Pennsylvanian. The valley areas within the Great Valley are underlain

predominantly by thick sequences of limestone, dolomite and shale. The upland areas of the Valley and Ridges (Appalachian Mountains) to the west are underlain predominantly by resistant sandstones and conglomerates, while the lowland areas are underlain predominantly by less resistant shale, siltstone, sandstone and limestone (Reference 16) (Reference 24) (Figure 2.5-3).

e. **Appalachian Plateau Physiographic Province**

The Appalachian Plateau Physiographic Province is underlain by rocks that are continuous with those of the Valley and Ridge Province, but in the Appalachian Plateau the layered rocks are nearly flat-lying or gently tilted and warped, rather than being intensely folded and faulted (Reference 16). Rocks of the Allegheny Front along the eastern margin of the province consist of thick sequences of sandstone and conglomerate, interbedded with shale, ranging in age from Devonian to Pennsylvanian. Rocks of the Appalachian Plateau west of the Allegheny Front are less resistant and consist of Permian age sandstone, shale and coal (Reference 12) (Reference 21) (Figure 2.5-3).

2.5.1.1.4 Regional Tectonic Setting

In 1986, the EPRI developed a seismic source model for the Central and Eastern United States (CEUS), which included the ESP site region (Reference 1). The EPRI source model included the independent interpretations of six Earth Science Teams and reflected the general state of knowledge of the geoscience community as of 1986. The seismic source models developed by each of the six teams were based on the tectonic setting and the occurrence, rates, and distribution of historical seismicity. The original seismic sources identified by EPRI (Reference 1) are thoroughly described in the EPRI 1986 reports and are summarized in Section 2.5.2.2.

Since 1986, additional geological, seismological, and geophysical research has been completed in the ESP site region. The focus of this section is to summarize the current state of knowledge on the tectonic setting and tectonic structures in the site region and to highlight new information acquired since 1986 that is relevant to the assessment of seismic sources. The following sections describe the site region in terms of plate tectonic evolution, origin and orientation of tectonic stress, and primary tectonic features and seismic sources. Historical seismicity occurring in the site region is described in Section 2.5.2.1.

a. **Plate Tectonic Evolution of the Appalachian Orogenic Belt at the Latitude of the Site Region**

The ESP site lies within the central Appalachians region of Virginia, which is part of the northeast-trending Appalachian orogenic belt, that extends nearly the entire length of the eastern United States. The Appalachian orogenic belt formed during the Paleozoic Era by a series of compressional tectonic events along the Precambrian continental margin of eastern North America. The geologic history of the region surrounding the site was presented in Section 2.5.1.1.2.

The Appalachian orogenic belt has been subdivided in different ways by geologists studying the region. These subdivisions include provinces (physiographic and geologic), belts, and terranes. Provinces, which are generally more regional in extent, have been defined based on both physiography (landforms) and geology. As described in Section 2.5.1.1.1, six Physiographic Provinces have been defined across Virginia. From west to east these are the Appalachian Plateau, Valley and Ridge, Blue Ridge, Piedmont, Coastal Plain, and Continental Shelf Physiographic Provinces. Provinces of the Appalachian orogen, such as the Piedmont Province, have been subdivided into different lithotectonic belts of similar rock type and tectonic origin (Figure 2.5-4). Some of the belts have been further subdivided by some researchers (Reference 45) (Reference 46) into individual terranes. The two terms, belt and terrane, are used interchangeably in this section to represent fault-bounded blocks of crust that are internally homogeneous in terms of stratigraphy and tectonic history.

Figure 2.5-6 is a simplified tectonic map showing the five onshore physiographic provinces of Virginia and the belts and terranes within the Blue Ridge and Piedmont Provinces, as delineated by Hatcher (Reference 45) and Horton and others (Reference 46) since publication of the 1986 EPRI study. As described by these authors the following is a brief discussion of the major subdivisions of the Virginia Appalachian orogenic belt and the rock protoliths of these regions from west to east (excluding the Appalachian Plateau Province). The Valley and Ridge Province is a belt of sedimentary rocks originally deposited on North American crust and deformed by folds and thrust faults. The Blue Ridge Province is a thrust-bounded sheet of crystalline rocks with overlying sedimentary strata. The Jefferson terrane is the easternmost terrane within this province and is composed of sedimentary and volcanic rocks. The Western Piedmont, Chopawamsic, Carolina Slate, and Goochland belts belong to the Piedmont Province. The southern terrane of the Western Piedmont belt in Virginia is the Smith River terrane (Reference 45), and like the Jefferson terrane of the Blue Ridge Province, is composed of sedimentary and volcanic rocks. The Chopawamsic and Carolina Slate belts both consist of volcanic and intrusive rocks, whereas the Goochland terrane is composed of intrusive rocks interpreted by some to be continental crust. The Coastal Plain Province is composed of a sequence of predominantly Cretaceous and Tertiary marine sediments overlying crystalline rocks.

There is general agreement that folded strata in the Valley and Ridge Province and the crystalline rocks in the Blue Ridge Province are native to North America (Reference 40) (Reference 45) (Reference 47) and that these units have been transported westward from their original position along Paleozoic east-dipping, west-verging thrust faults. Interpretations differ primarily over the origin and emplacement of belts and terranes in the Piedmont Province.

Modern plate tectonic reconstructions of the southern and central Appalachian orogenic belt published since the 1986 EPRI study interpret that at least some of the major regional

Paleozoic deformation events (e.g., the Taconic, Acadian and Allegheny orogenies) are associated with collisions of exotic or suspect terranes with ancestral North America (Reference 40) (Reference 45) (Reference 47) (Reference 48). Major differences between plate tectonic models arise from varying interpretations of which belts/terranes represent exotic or suspect terranes (allochthons) and the location of primary tectonic boundaries or sutures that juxtapose such exotic terranes against North American crust. The most important of these differences are described in the following paragraphs as they relate to the age and geometry of tectonic sutures and accreted terranes along the eastern North American margin.

In a reconstruction by Hatcher (Reference 45), bedrock east of the Blue Ridge was accreted to North America during the Taconic and Acadian orogenies. These orogenies are interpreted to be the result of collisions of two distinct terranes with North America at the latitude of central Virginia (Figure 2.5-2). The Taconic orogeny is attributed to collision and suturing of a volcanic island arc, which is interpreted to have formed in the Iapetus Ocean east of North America during the Paleozoic, above an east-dipping subduction zone. In this model, the Smith River and Jefferson terranes (Figure 2.5-6) are interpreted to be remnants of the accretionary complex that formed above the subduction zone on the west side of the island arc, and the Chopawamsic volcanics are interpreted to be the remnants of the arc itself (Figure 2.5-2). The Taconic suture between North America and the accreted units is interpreted to be the thrust fault underlying the Smith River and Jefferson terranes (Figure 2.5-6 and Figure 2.5-2). During Taconic accretion, an east-dipping thrust fault west of the Chopawamsic terrane is interpreted to have detached a slice of North American continental basement and displaced it westward to form the Blue Ridge nappe (Figure 2.5-2).

In the Hatcher (Reference 45) model, accretion of the Carolina Slate belt occurred during the Acadian orogeny, although others interpret that the Caroline Slate belt was accreted during the Taconic orogeny. Later strike-slip displacement along the continental margin during the subsequent transpressional Allegheny orogeny in early Mississippian to Permian time juxtaposed the Goochland terrane against the Chopawamsic terrane and Carolina Slate belt along the Spotsylvania thrust fault (Figure 2.5-6 and Figure 2.5-2). Final closure of the Iapetus Ocean and collision of Africa with North America occurred during the Allegheny orogeny (Reference 45).

An alternative model proposed by Glover and others (Reference 47) in 1995, which incorporates detailed geologic and geophysical investigations across the Appalachian belt in central Virginia, interprets fewer exotic terranes in the amalgam of Paleozoic belts and terranes, and infers a different geometry for the major Paleozoic sutures (Figure 2.5-7). This model represents the only significant alternative interpretation of the origin and affinity of the crust east of the Spotsylvania thrust fault in the region of the ESP site published since the 1986 EPRI study. Glover and others attribute the Taconic orogeny to collision of an exotic Chopawamsic volcanic arc, but interpret most of the sedimentary and volcanic rocks of the

Smith River and Jefferson terranes to have originally been deposited on the passive margin of North America, rather than accreted with the arc. Accordingly, Glover and others place the Taconic suture in the central Piedmont east of the location proposed by Hatcher (Reference 45) (Figure 2.5-8).

Glover and others correlate the Chopawamsic volcanics with the rocks of the Carolina Slate belt, concluding that all of these rocks were part of a single island arc terrane (Carolina terrane) that collided with ancestral North America during the Taconic orogeny. If this is correct, then the western fault boundary of the Carolina Slate belt is a Taconic suture, not an Acadian suture, as proposed by Hatcher (Reference 45). Glover and others propose that the Acadian orogeny is associated with dextral transpressional deformation as the Iapetus Ocean progressively closed and Africa began to impinge on North America, and thus is not associated with a collisional suture at the latitude of Virginia. They interpret the Allegheny orogeny to be the final collision and suturing of Africa to North America.

Based in part on analysis of seismic reflection data (Figure 2.5-8), Glover and others interpret the Goochland terrane not to be exotic to North America, but rather a deep slice of North American basement that was detached during the Allegheny orogeny and thrust westward along the Spotsylvania thrust fault, similar to the initial formation of the Blue Ridge Mountains during the Taconic orogeny (Figure 2.5-2). The Spotsylvania thrust fault, in the site vicinity, is interpreted to cut across Taconic units in the Piedmont, leaving them as isolated klippe. The Taconic suture is interpreted to be offset and repeated by the Spotsylvania thrust fault, and present beneath the deposits of the Coastal Plain Province as well as in the Piedmont Province (Figure 2.5-8).

Despite varying interpretations of the origin and emplacement of fault-bounded belts and terranes, there is good agreement among tectonic models regarding first-order structural features of the Appalachian orogenic belt. In Virginia, the North American basement of the Iapetan passive margin underlies the Valley and Ridge, Blue Ridge, and Western Piedmont Provinces. Deformed rocks in these provinces west of the Spotsylvania thrust fault lie above a basal decollement (thrust), which is at a depth of about 3 to 6 miles below the ground surface in the site vicinity (Figure 2.5-8). The basal decollement is a low angle thrust fault that dips gently southeast and separates the overlying Appalachian crust from the underlying North American basement. Given the shallow depth to the decollement, it is unlikely that the Paleozoic thrust faults within these provinces have rupture widths sufficient to generate large earthquakes. Although potential seismogenic sources may be present within the North American basement below the decollement (Reference 49), the location, dimensions and geometry of these deeper sources is not necessarily expressed in the exposed fold-thrust structures above the detachment. Tectonic models generally agree that major Paleozoic faults east of the Chopawamsic terrane, such as the Spotsylvania thrust fault, are not detached at

shallow levels and penetrate deep into the crust, possibly extending to the base of the crust (Reference 47) (Figure 2.5-8).

Wheeler (Reference 49) noted that many earthquakes in the eastern part of the Piedmont Province and beneath the Coastal Plain Province are associated spatially with faults related to rifting that occurred during the Mesozoic Era. Normal faults in this region that bound Triassic basins may be listric into the Paleozoic detachment faults or may penetrate through the crust as high angle faults. If active in the modern tectonic setting, Triassic normal faults east of the Chopawamsic terrane have greater potential for generating large earthquakes by virtue of their larger potential rupture dimensions.

b. **Tectonic Stress in the Mid-Continent Region**

Expert teams that participated in the 1986 EPRI evaluation of intra-plate stress found that tectonic stress in the CEUS region is primarily characterized by NE-SW-directed horizontal compression. In general, the expert teams concluded that the most likely source of tectonic stress in the mid-continent region was ridge-push force associated with the Mid-Atlantic ridge, transmitted to the interior of the North American plate by the elastic strength of the lithosphere. Other potential forces acting on the North American plate were judged to be less significant in contributing to the magnitude and orientation of the maximum compressive principal stress. Some of the expert teams noted that deviations from the regional NE-SW trend of principal stress may be present along the east coast of North America and in the New Madrid region. They assessed the quality of stress indicator data and discussed various hypotheses to account for what were interpreted as variations in the regional stress trajectories.

Since 1986, an international effort to collate and evaluate stress indicator data has resulted in publication of a new World Stress Map (Reference 50) (Reference 51). Data for this map are ranked in terms of quality, and plate-scale trends in the orientations of principal stresses are assessed qualitatively based on analysis of high-quality data (Reference 52). Subsequent statistical analyses of stress indicators confirmed that the trajectory of the maximum compressive principal stress is uniform across broad continental regions at a high level of statistical confidence. In particular, the NE-SW orientation of principal stress in the CEUS inferred by the EPRI experts is statistically robust, and is consistent with the theoretical trend of compressive forces acting on the North American plate from the mid-Atlantic ridge (Reference 53).

The more recent assessments of lithospheric stress do not support inferences by some EPRI expert teams that the orientation of the principal stress may be locally perturbed in the New England area, along the east coast of the United States, or in the New Madrid region. Zoback and Zoback (Reference 50) summarized a variety of data, including well-bore breakouts, results of hydraulic fracturing studies, and newly calculated focal mechanisms, which indicate that the New England and eastern seaboard regions of the U.S. are characterized by

horizontal NE-SW to E-W compression. Similar trends are present in the expanded set of stress indicators for the New Madrid region. Zoback and Zoback grouped all of these regions, along with a large area of eastern Canada, with the CEUS in an expanded “Mid-Plate” stress province characterized by NE-SW directed horizontal compression.

In addition to better documenting the orientation of stress, research conducted since 1986 has addressed quantitatively the relative contributions of various forces that may be acting on the North American plate to the total stress within the plate. Richardson and Reding (Reference 54) performed numerical modeling of stress in the continental U.S. interior, and considered the contribution to total tectonic stress to be from three classes of forces:

- Horizontal stresses that arise from gravitational body forces acting on lateral variations in lithospheric density. These forces commonly are called buoyancy forces. Richardson and Reding emphasize that what is commonly called ridge-push force is an example of this class of force. Rather than a line-force that acts outwardly from the axis of a spreading ridge, ridge-push arises from the pressure exerted by positively buoyant, young oceanic lithosphere near the ridge against older, cooler, denser, less buoyant lithosphere in the deeper ocean basins (Reference 55). The force is an integrated effect over oceanic lithosphere ranging in age from about 0 to 100 million years (Reference 56). The ridge-push force is transmitted as stress to the interior of continents by the elastic strength of the lithosphere.
- Shear and compressive stresses transmitted across major plate boundaries (strike-slip faults and subduction zones).
- Shear tractions acting on the base of the lithosphere from relative flow of the underlying asthenospheric mantle.

Richardson and Reding concluded that the observed NE-SW trend of principal stress in the CEUS dominantly reflects “ridge-push” body forces. They estimated the magnitude of these forces to be about 2 to 3×10^{12} N/m (i.e., the total vertically integrated force acting on a column of lithosphere 1 m (3.28 ft) wide), which corresponds to average equivalent stresses of about 40 to 60 MPa distributed across a 30-mile thick elastic plate. Richardson and Reding found that the fit of the model stress trajectories to data was improved by the addition of compressive stress (about 5 to 10 MPa) acting on the San Andreas fault and Caribbean plate boundary structures. The fit of the model stresses to data further indicated that shear stresses acting on these plate boundary structures must also be in the range of 5 to 10 MPa.

Richardson and Reding noted that the general NE-SW orientation of principal stress in the CEUS also could be reproduced in numerical models that assume a shear stress, or “drag,” acting on the base of the North American plate. Richardson and Reding (Reference 54) and Zoback and Zoback (Reference 50) do not favor this as a significant contributor to total stress in the mid-continent region, however, because it predicts or requires that the horizontal

compressive stress in the lithosphere increases by an order of magnitude moving east to west, from the eastern seaboard to the Great Plains. Zoback and Zoback noted that the state of stress in the southern Great Plains is characterized by NNE-SSW extension, which is contrary to this prediction. They further observed that the level of background seismic activity is generally higher in the eastern United States than in the Great Plains, which is not consistent with the prediction of the basal drag model that compressive stresses (and presumably rates of seismic activity) should be higher in the middle parts of the continent than along the eastern margin.

Analyses of regional tectonic stress in the CEUS since the 1986 EPRI studies have not significantly altered the characterization of the NE-SW orientation of the maximum compressive principal stress. The orientation of a planar tectonic structure relative to the principal stress direction determines the magnitude of shear stress resolved onto the structure. Given that the current interpretation of the orientation of principal stress is similar to that adopted in the 1986 EPRI studies, a new evaluation of the seismic potential of tectonic features based on a favorable or unfavorable orientation to the stress field would yield similar results. Thus, there is no significant change in the understanding of the static stress in the CEUS since the publication of the EPRI source models in 1986, and there are no significant implications for existing characterizations of potential activity of tectonic structures.

c. **Principal Tectonic Structures**

Principal tectonic structures within the 200-mile ESP site region can be divided into four categories based on their age of formation or reactivation. These categories include structures that were most recently active during Paleozoic, Mesozoic, Tertiary, or Quaternary time. Most of the Paleozoic and Mesozoic structures are regional scale, and geologically and geophysically recognizable. The Mesozoic rift basins and bounding faults show a high degree of parallelism with the structural grain of the Appalachian orogenic belt, which generally reflects reactivation of pre-existing Paleozoic structures. Tertiary and Quaternary structures are generally more localized and may be related to reactivation of portions of older bedrock structures.

1. **Paleozoic Tectonic Structures**

The central and western portions of the ESP site region encompass portions of the Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau Physiographic Provinces. Rocks and structures within these provinces are associated with thrust sheets that formed during convergent Appalachian orogenic events of the Paleozoic Era. Tectonic structures of this affinity also exist beneath the sedimentary cover of the Coastal Plain Province. These types of structures include the following: 1) sutures juxtaposing allochthonous (tectonically transported) rocks with North American crust, 2) regionally extensive Appalachian thrust faults and oblique-slip shear zones, and 3) a multitude of

smaller structures that accommodated Paleozoic deformation within individual blocks or terranes (Figure 2.5-8). The majority of these structures dip eastward and shallow into a low angle, basal Appalachian decollement. The Appalachian orogenic crust is relatively thin across the Valley and Ridge Province, Blue Ridge Province, and western part of the Piedmont Province, and thickens eastward beneath the eastern part of the Piedmont Province and the Coastal Plain Province (Figure 2.5-8). Below the decollement are rocks that form the North American basement complex. The basement rocks contain northeast-striking Iapetan normal faults that formed during the Late Precambrian to Cambrian rifting of the Iapetus Ocean.

Researchers have observed that much of the sparce seismicity in eastern North America occurs within the North American basement below the basal decollement. Therefore, seismicity within the Appalachians may be unrelated to the abundant, shallow thrust sheets mapped at the surface (Reference 49). For example, seismicity in the Giles County seismic zone, located in the Valley and Ridge Province, is occurring at depths ranging from 3 to 16 miles (5 to 25 km) (Figure 2.5-8) (Reference 57), which is generally below the Appalachian thrust sheets and basal decollement (Reference 58).

Paleozoic faults within 200 miles of the site are shown on Figure 2.5-3 and Figure 2.5-9. No seismicity is attributed to these faults and published literature does not indicate that any of these faults offset late Cenozoic deposits or exhibit geomorphic expression indicative of Quaternary deformation. Crone and Wheeler (Reference 59) do not show any of these faults to be potentially active Quaternary faults. Therefore, these Paleozoic structures in the site region are not considered to be capable tectonic sources, as defined in RG 1.165, Appendix A.

Major Paleozoic tectonic structures within the 25-mile ESP site vicinity include the Hylas shear zone, Spotsylvania thrust fault, Long Branch thrust fault, Chopawamsic thrust fault, Lake of the Woods thrust fault, and the Mountain Run fault zone (Figure 2.5-10). The Spotsylvania, Chopawamsic, and Long Branch thrust faults extend to within 5 miles of the ESP site. Four smaller faults also extend to within 5 miles of the site (Figure 2.5-11). Additional smaller Paleozoic faults are present within 25 miles of the site and are typically associated with larger Paleozoic structures and accommodate internal deformation within the intervening structural blocks. None of the faults located within 25 miles of the site are considered to be capable tectonic sources, as defined in RG 1.165, Appendix A.

Between 5 and 25 miles from the site, the Hylas shear zone, Mountain Run fault zone, and Lake of the Woods thrust fault are prominent structural features. These structures exhibit mylonitic textures, indicative of the ductile conditions in which they formed during the Paleozoic Era. The Hylas shear zone, for example, comprises a 1.5-mile wide zone of ductile shear fabric and mylonites, and was active between 330 and 220 million years ago based on the presence of mylonitized and unmylonitized intrusive rocks across the fault

zone (Reference 60). The Hylas shear zone and Mountain Run fault zone also locally border Mesozoic basins and appear to have been locally reactivated during Mesozoic extension to accommodate growth of the basins. The Mountain Run fault zone exhibits geomorphic expression suggestive of potential Tertiary or Quaternary reactivation. The Mountain Run fault zone is discussed in greater detail in this section under Quaternary Tectonic Features. Based on review of published literature and historical seismicity, there is no reported geomorphic expression, historical seismicity, or Quaternary deformation along either the Hylas shear zone or Lake of the Woods thrust fault. Diffuse, scattered seismicity occurs throughout the CVSZ, but is not spatially concentrated or aligned with either of these two structures. Crone and Wheeler (Reference 59) provide a compilation and evaluation of Quaternary fault, liquefaction features, and possible tectonic features in the Central and Eastern United States. They do not show the Hylas shear zone or the Lake of the Woods thrust fault as suspect Quaternary features. These structures are not considered to be capable tectonic sources.

No new information has been published since 1986 on any Paleozoic fault in the site region that would cause a significant change in the EPRI seismic source model.

2. **Mesozoic Tectonic Structures**

Mesozoic basins have long been considered potential sources for earthquakes along the eastern seaboard and were considered by most of the EPRI teams in their definition of seismic sources (Reference 1). A series of elongate rift basins of early Mesozoic age are exposed in a belt extending from Nova Scotia to South Carolina. These rift basins, also commonly referred to as Triassic basins, exhibit a high degree of parallelism with the surrounding structural grain of the Appalachian orogenic belt. The rift basins formed during extension and thinning of the crust as Africa and North America rifted apart to form the modern Atlantic Ocean.

Generally, the exposed rift basins are asymmetric half-grabens (Figure 2.5-8) with the primary rift-bounding faults on the western margin of the half-grabens. Typically, in a rift basin, strata dip toward the western border fault zone, and so basin deposits are thickest along this margin. Ratcliffe and others (Reference 61) interpret most Mesozoic basins appear to have formed as a result of extensional reactivation of east-dipping, low-angle Paleozoic thrust fault. At depth, the faults are believed to merge with the low angle thrust faults that formed during the compressional tectonics that characterize the Paleozoic orogenies (Figure 2.5-8). As a result, the rift-bounding normal faults are listric at depth and merge into the low angle basal decollement (Reference 62). Others interpret that the rift-bounding faults penetrate the Paleozoic Appalachian thrust faults (Reference 49). The Triassic basins, therefore, are relatively shallow crustal features and rocks of Triassic and Jurassic age that fill the basins are generally comprised of a sequence of continental clastic sediments interbedded with basaltic volcanics (Reference 63).

There are numerous Triassic basins within a 200-mile radius of the ESP site (Figure 2.5-9). Basins exposed in the Piedmont and Blue Ridge Provinces include the Culpeper, Newark, Gettysburg, Taylorsville, Richmond, Scottsville, Farmville, Danville, and the Deep River basins. Five of these basins are located within 50 miles of the site. These are the Culpeper, Taylorsville, Richmond, Scottsville, and Farmville basins. Two of these basins (Culpeper and Taylorsville) are within 25 miles of the site. There are also several basins buried beneath the Atlantic Coastal Plain and Continental Shelf (Figure 2.5-9).

The Culpeper basin is located about 20 miles northwest of the site. The Taylorsville basin is located about 22 miles southeast of the site and the Richmond basin is about 30 miles southeast of the site. The smaller Scottsville and Farmville basins are located about 40 miles southwest of the site (Figure 2.5-9 and Figure 2.5-10). All five of these structures are asymmetric basins, with the major basin-forming fault located along the western margin of the basin. The Culpeper basin, unlike the other basins, also has a complex of faults along its eastern margin. One such fault along the eastern margin of the basin is the Mountain Run fault zone.

Given the acquisition of additional offshore seismic profiles since the 1986 EPRI study, more buried Mesozoic basins are recognized today than were known during the EPRI study. However, all of the exposed major basins closest to the site were known to exist during the 1980s and several were incorporated into seismic sources by the different EPRI teams. No new data have been developed to demonstrate that any of the Mesozoic basins are currently active, and Crone and Wheeler (Reference 59) do not recognize any basin-margin faults that have been reactivated during the Quaternary in the site region. Therefore, all of the information on timing of displacement was available and incorporated into the EPRI seismic source models in 1986. No Mesozoic basin in the site region is associated with a known capable tectonic source, and no new information has been developed since 1986 that would require a significant revision to the EPRI seismic source model. Seismicity potentially associated with reactivation of faults bordering or beneath the Mesozoic basins is captured in the existing EPRI seismic source model. There is no new published information on rate or size of earthquakes potentially associated with the Mesozoic Basins that would cause a significant change in the 1986 EPRI source parameters.

3. **Tertiary Tectonic Structures**

Within a 200-mile radius of the ESP site, only a few faults have been active during the Tertiary Period. These faults generally occur in the Coastal Plain Province where Tertiary strata have exhibited deformation during this period (Figure 2.5-9). These faults include the Brandywine fault system in Maryland, the National Zoo faults in Washington, D.C., the Dutch Gap fault in Virginia, and several other small, unnamed faults that displace Tertiary

strata (Reference 64). Within 25 miles of the site, the only fault zone with well-documented Tertiary displacement is the Stafford fault system, which is presented in the following paragraphs.

Stafford Fault System

The Stafford fault system approaches to within 16.5 miles of the site to the northeast (Figure 2.5-10). The 42-mile long fault system was identified and described by Newell and others (Reference 65) and consists of a series of northeast-striking, northwest-dipping, high-angle reverse faults including, from north to south, the Dumfries, Fall Hill, Hazel Run, and Brooke faults. These individual faults are 10 to 25 miles long and are separated from one another by 1.2- to 2.5-mile wide en echelon left step-overs. The left-stepping pattern and horizontal slickensides found on the Dumfries fault suggest a component of dextral shear on the fault system (Reference 66).

Locally, the Stafford fault system coincides with the Fall Line and a northeast-trending portion of the Potomac River. Mixon and Newell (Reference 67) suggest that the Fall Line and river deflection may be tectonically controlled. Following discovery of the fault system by Newell and others (Reference 65), Dames & Moore (Reference 9) performed an investigation of the origin and age of the fault system. Detailed drilling, trenching, and mapping in the Fredericksburg region showed that the youngest identifiable fault movement on any of the four primary faults comprising the Stafford fault system was pre-middle Miocene in age (more than 10 million years ago).

Subsequent studies performed along the Stafford fault system, however, better document the timing and origin of the fault system. Slip during the Mesozoic and Tertiary is documented by displacement of Ordovician bedrock over lower Cretaceous bedrock along the Dumfries fault and abrupt thinning of the Paleocene Aquia Formation across multiple strands of the fault system (Reference 66). Minor late Tertiary activity of the fault system is documented by an 11-inch displacement of a Pliocene terrace along the Rappahannock River by the Fall Hill fault (Reference 68) (Reference 69) and an 18-inch displacement of upland gravels of Miocene or Pliocene age on the Hazel Run fault (Reference 68). These latter displacements indicate post middle to late Pliocene activity along the Stafford fault system.

All of the information on timing of displacement was available and incorporated into the EPRI seismic source models in 1986. No new significant information has been developed since 1986 regarding the activity of the Stafford fault system. Field and aerial reconnaissance performed for this ESP application also did not reveal any geologic or geomorphic features indicative of potential Quaternary activity along the fault system. Similarly, Crone and Wheeler (Reference 59) do not show the Stafford fault system as a Quaternary structure in their compilation of active tectonic features in the CEUS. The

Stafford fault system, therefore, is not a capable tectonic source and there is no new information developed since 1986 that would require a significant revision to the EPRI seismic source model.

4. **Quaternary Tectonic Features**

In an effort to provide a comprehensive database of Quaternary features, Crone and Wheeler (Reference 59) compiled geological information on Quaternary faults, liquefaction features, and possible tectonic features in the CEUS. They evaluated and classified these features into one of four categories (Classes A, B, C, D) based on geological evidence of Quaternary faulting or deformation. The definitions of the Crone and Wheeler classes are provided in Table 2.5-1**.** Within a 200-mile radius of the ESP site, 11 potential Quaternary features were identified (Figure 2.5-12, Table 2.5-2). Based on their evaluation, Crone and Wheeler (Reference 59) characterized only the Central Virginia seismic zone (CVSZ) as having geologic evidence demonstrating the existence of a Quaternary fault of tectonic origin (Class A). The small set of faults at Pembroke in Giles County, Virginia, were assigned to Class B and the remaining nine features were assigned to Class C. The paleo-liquefaction features within the CVSZ demonstrate the presence of a Holocene active seismogenic source. None of the other features identified by Crone and Wheeler (Reference 59) have demonstrated evidence of Quaternary activity that would imply recurrent activity in the past 500,000 years.

Within approximately 25 of the site, Crone and Wheeler (Reference 59) found only two features described in the literature that exhibited potential evidence for Quaternary activity (Figure 2.5-12, Table 2.5-2). These two features are the paleo-liquefaction features within the CVSZ, and the Mountain Run fault zone. Both of these features are described below. The CVSZ does not represent a tectonic fault, and therefore, is not considered a capable tectonic source. Similarly, the Mountain Run fault, which was categorized as a Class C feature in the Crone and Wheeler (Reference 59) evaluation, does not exhibit evidence of Quaternary slip and, therefore, is not a capable tectonic source.

In 1998, Weems defined and named seven fall lines across the Piedmont and Blue Ridge Provinces of North Carolina and Virginia. These fall lines are based on the alignment of short stream segments with anomalously steep gradients. Weems (Reference 70) explores possible ages and origins (rock hardness, climatic, and tectonic) of the fall lines and “based on limited available evidence favors a neo-tectonic origin” for these geomorphic features during the Quaternary. A review of Weems study (Reference 70) reveals that no direct evidence is presented for a neo-tectonic origin, no formal, consistent criteria are used to define the fall lines, and geologic and geomorphic observations along some of the fall lines actually demonstrate either a lack of tectonic activity or a strong correlation to changes in bedrock lithology. Therefore, these features postulated by Weems (Reference 70) are not considered to represent capable tectonic sources.

Paleo-Liquefaction Features within the Central Virginia Seismic Zone

Two sites of Holocene liquefaction have been reported within the CVSZ (Reference 59) (Reference 71). These sites include an area of probable late Holocene (2,000 to 3,000 years old) liquefaction along the James River and a possible area of early- to mid-Holocene (~5,000 years old) liquefaction along the Rivanna River (Reference 71). In an April 2004 discussion, Dr. Obermeier suggested that a third site of possible early- to mid-Holocene liquefaction may also be present along the South Anna River

The presence of these probable or possible paleo-liquefaction features on the James, Rivanna, and South Anna Rivers, about 25–30 miles from the site, shows that the CVSZ reflects both an area of paleo-seismicity as well as observed historical seismicity. Based on the absence of widespread paleo-liquefaction, however, Obermeier and McNulty (Reference 71) conclude that an earthquake of Magnitude 7 or larger has not occurred within the seismic zone in the last 2000–3000 years, or in the eastern portion of the seismic zone for the last 5000 years. They also conclude that the geologic record of one or more magnitude 6 or 7 earthquakes might be concealed between streams, but that such events could not have been abundant in the seismic zone. In addition, these isolated locations of paleo-liquefaction may have been produced by local shallow moderate magnitude earthquakes of **M** 5.5 to 6.5. Thus, the presence of these liquefaction features does not indicate a change in the smallest maximum magnitude level assigned to the CVSZ in the 1986 EPRI study. Because the causative faults remain unidentified, the CVSZ is best characterized as a seismogenic source and not a capable tectonic source, as defined by RG 1.165.

Mountain Run Fault Zone

The Mountain Run fault zone is located along the eastern margin of the Culpeper basin and lies approximately 18 miles northwest of the site (Figure 2.5-9 and Figure 2.5-5). The 75-mile long fault zone is mapped from the eastern margin of the Triassic Culpeper basin near the Rappahannock River southwestward to near Charlottesville, Virginia (Reference 72). The fault zone is a broad zone of sheared rocks, mylonites, breccias, and phyllites of variable width.

The Mountain Run fault zone is interpreted to have formed initially as a thrust fault upon which back-arc basin rocks (mélange deposits) of the Mine Run Complex were accreted onto ancestral North America at the end of the Ordovician (Reference 36). This suture separates the Blue Ridge and Piedmont terranes (Reference 73). Subsequent reactivation of the fault during the Paleozoic and/or Mesozoic produced strike-slip and dip-slip movements. Horizontal slickensides found in boreholes at several places near the foot of the Mountain Run scarp suggest strike-slip movement and small-scale folds in the uplands near the scarp suggest a dextral sense of slip (Reference 40). The timing of the reverse and strike-slip histories of the fault zone, and associated mylonitization and brecciation, is

constrained to be pre-Early Jurassic, based on the presence of undeformed Early Jurassic diabase dikes that cut rocks of the Mountain Run fault zone (Reference 40).

The northeast-striking Mountain Run fault zone is one of the most clearly recognizable faults in the region (Reference 40). Two pronounced northwest-facing scarps occur along the fault zone, including the 1-mile long Kelly's Ford scarp located directly northeast of the Rappahannock River and the 7-mile long Mountain Run scarp located along the southeast margin of the linear Mountain Run drainage (Figure 2.5-5). Conspicuous bedrock scarps in the Piedmont, an area characterized by deep weathering and subdued topography, has led some experts to suggest that the fault has experienced a Late Cenozoic phase of movement (Reference 40) (Reference 73).

Near Everona, Virginia, a small reverse fault, found in an excavation, vertically displaces "probable Late Tertiary" gravels by 5 feet (Reference 73). Others have estimated that the offset colluvial gravels are Pleistocene age (Reference 62). This Everona fault, which has no geomorphic expression, is located about 1/2 mile west of the Mountain Run fault zone. Due to their proximity, these two features are considered to be part of the same zone of faults (Everona fault-Mountain Run fault zone) (Reference 59). Crone and Wheeler (Reference 59) assessed that the faulting at Everona is likely to be of Quaternary age, but because the likelihood has not been tested by detailed paleo-seismological or other investigations, this feature has been assigned to Class C.

Field and aerial reconnaissance performed for this ESP application did not reveal any geologic or geomorphic features indicative of potential Quaternary activity along the Mountain Run fault zone. A review of 1:24,000 scale topographic maps revealed that the steeper portions of the Mountain Run scarp correlate with the areas where the Mountain Run (stream) is impinging on the scarp. In addition, the northwest side of the narrow Mountain Run valley is steepest where the stream is impinging on that side of the valley. These observations suggest that the scarp most likely formed due to erosion, as southeastward-migrating streams impinge against the more resistant rocks of the Mountain Run fault zone.

All of the information on timing of displacement of the Mountain Run fault zone and associated faults was available and incorporated into the EPRI seismic source models in 1986. No significant new information has been developed since 1986 regarding the activity of the Mountain Run fault zone. Similarly, Crone and Wheeler (Reference 59) do not show the Mountain Run fault zone as a known Quaternary structure in their compilation of active tectonic features in the CEUS, having assigned it to Class C. It is concluded that the Mountain Run fault zone is not a capable tectonic source and that no new information has been developed since 1986 that would require a significant revision to the EPRI seismic source model.

East Coast Fault System

The postulated East Coast fault system (ECFS) is located approximately 70 miles southeast of the site (Figure 2.5-3). The 370-mile long fault system, which was identified and described by Marple and Talwani (Reference 74), consists of three, 125-mile-long segments extending from the Charleston area in South Carolina northeastward to near the James River in Virginia (Figure 2.5-13). The three segments were initially referred to as the southern, central, and northern zones of river anomalies (ZRA-S, ZRA-C, ZRA-N) and are herein referred to as the southern, central and northern segments of the ECFS. The southern segment is located in South Carolina, the central segment is located primarily in North Carolina, and the northern segment extends from northeast North Carolina to southeast Virginia, and is located about 70 miles southeast of the ESP site. Marple and Talwani (Reference 74) have mapped the northern terminus of the fault system between the Blackwater River and James River, southeast of Richmond. Identification of the fault system is based on the alignment of geomorphic features along Coastal Plain rivers, areas of uplift, and local faulting (Reference 74).

The southern segment of the fault system, first identified by Marple and Talwani (Reference 75) as an approximately 125-mile long and 6-9-mile wide zone of river anomalies, has been attributed to the presence of a buried fault zone. The southern end of this segment is associated with the Woodstock fault, a structure defined by fault-plane solutions of micro-earthquakes and thought to be the causative source of the 1886 Charleston earthquake (Reference 74). The southern segment is geomorphically the most well defined segment of the fault system and is associated with micro-seismicity at its southern end. This segment was included as an alternative geometry to the areal source for the 1886 Charleston earthquake in the 2002 USGS hazard model (presented in more detail in Section 2.5.2) for the National Seismic Hazard Mapping Project (Reference 76).

The central and northern segments of the fault system were not included in the 2002 USGS model, nor were they considered in the workshops to develop the USGS model (Reference 77). The segments also were not presented in workshops or included in models for the Trial Implementation Project (TIP), a study that characterized seismic sources and ground motion attenuation models at two nuclear power plant sites in the southeastern United States (Reference 78).

The ECFS represents, in part, a new tectonic feature that was not known to the EPRI Earth Science Teams in 1986. The 1986 EPRI models include areal sources to model the Charleston seismic source; therefore, the southern segment of the ECFS is in essence covered by the different Charleston sources zone geometries. However, the central and northern segments represent a new tectonic feature in the Coastal Plain that postdates the EPRI studies. The closest approach of the northern segment to the site is approximately 70 miles as described above.

Although the postulated ECFS represents a potentially new tectonic feature in the Coastal Plain of Virginia and North Carolina (Reference 74), aerial reconnaissance and independent analyses of the evidence presented by Marple and Talwani (Reference 74) for the northern segment indicate that this segment of the fault zone probably does not exist and, if it exists, is not a capable tectonic source. Current compilations of seismic sources also suggest that others interpret a low confidence that the northern segment of the ECFS exists. For example, Crone and Wheeler (Reference 59) do not include the northern and central segments of the fault in their compilation of potentially active Quaternary faults. In addition, workshops convened for the 2002 USGS seismic hazard model (Reference 77) and for the TIP project (Reference 78) do not identify the northern and central segments of the fault system as a Quaternary active fault. As a member of both the USGS and TIP workshops, Talwani did not propose the northern and central segments of the fault system for consideration as a potential source of seismic activity. In addition, Marple and Talwani (Reference 74) do not argue that the northern and central segments of the fault system are associated with any seismicity.

In summary, the northern segment of the ECFS, as postulated by Marple and Talwani (Reference 74), is located approximately 70 miles southeast of the site. Marple and Talwani (Reference 74) further suggest that the southern segment of the fault system may be the source of the 1886 Charleston earthquake, implying that the northern and central segments may produce earthquakes of similar size. Although geomorphic analyses and aerial reconnaissance performed for this ESP application indicate that the northern segment of the fault zone probably does not exist or has a very low probability of activity if it does exist, given the proximity of the fault to the site and uncertainty regarding the existence and activity of the fault, a sensitivity analysis was performed to evaluate the fault's potential contribution to hazard at the ESP site. The results of this sensitivity analysis are described in Section 2.2.2.6.2.

d. **Seismic Sources Defined by Regional Seismicity**

Within 200 miles of the ESP site, two seismic sources are defined by a concentration of small to moderate earthquakes. These two sources have produced the two largest historical earthquakes in the state of Virginia and have been identified as seismogenic sources in the 1986 EPRI studies as well as more recent seismic hazard models (Reference 57) (Reference 79). These two seismic sources are the Central Virginia and Giles County seismic zones (Figure 2.5-14).

1. **Central Virginia Seismic Zone**

The CVSZ is an area of persistent, low-level seismicity in the Piedmont Province (Figure 2.5-14). The zone extends about 75 miles in a north-south direction and about 90 miles in an east-west direction from Richmond to Lynchburg (Reference 80). The ESP

site is located near the northern boundary of the CVSZ. The largest historical earthquake to occur in the CVSZ was the body-wave magnitude (m_b) 5.0 Goochland County event on December 23, 1875 (Reference 80). The maximum intensity estimated for this event was Modified Mercalli Intensity (MMI) VII in the epicentral region. Isoseismals indicate that the ESP site experienced shaking of Intensity V (Reference 81).

Seismicity in the CVSZ ranges in depth from about 2 to 11 miles (Reference 82). Coruh and others (Reference 83) suggest that seismicity in the central and western parts of the zone may be associated with west-dipping reflectors that form the roof of a detached antiform, while seismicity in the eastern part of the zone near Richmond may be related to a near-vertical diabase dike swarm of Mesozoic age. However, given the depth distribution of 2 to 11 miles (Reference 82) and broad spatial distribution, it is difficult to uniquely attribute the seismicity to any known geologic structure and it appears that the seismicity extends both above and below the Appalachian detachment.

No capable tectonic sources have been identified within the CVSZ, but two paleo-liquefaction sites, as presented previously, have been identified within the seismic zone (Reference 59) (Reference 71). The paleo-liquefaction sites reflect pre-historical occurrences of seismicity within the CVSZ, and do not indicate the presence of a capable tectonic source.

The 1986 EPRI source model includes various source geometries and parameters to capture the seismicity of the CVSZ. Subsequent hazard studies have used maximum magnitude (M_{max}) values that are within the range of maximum magnitudes used by the six EPRI models. Collectively, upper-bound maximum values of M_{max} used by the EPRI teams range from m_b 6.6 to 7.2 (presented in Section 2.5.2.2). More recently, Bollinger (Reference 79) has estimated an M_{max} of m_b 6.4 for the Central Virginia seismic source. Chapman and Krimgold (Reference 57) have used an M_{max} of m_b 7.25 for the Central Virginia seismic source and most other sources in their seismic hazard analysis of Virginia. This more recent estimate of M_{max} is similar to the M_{max} values used in the 1986 EPRI studies. Similarly, the distribution and rate of seismicity in the Central Virginia seismic source have not changed since the 1986 EPRI study (presented in Section 2.5.2.2.8). Thus, there is no change to the source geometry or rate of seismicity. Therefore, the conclusion is that no new information has been developed since 1986 that would require a significant revision to the EPRI seismic source model.

2. **Giles County Seismic Zone**

The Giles County seismic zone is located in Giles County, southwestern Virginia, near the border with West Virginia. The largest known earthquake to occur in Virginia and the second largest earthquake in the entire southeastern United States is the 1897 m_b 5.8

Giles County event. The earthquake would have produced an MMI VIII in the epicentral area (Reference 84) and Intensity V at the ESP site (Reference 81).

Earthquakes in the Giles County seismic zone occur at depths between 3 and 16 miles and appear to define a 25-mile long tabular zone striking N44E and dipping steeply southeast beneath the Valley and Ridge thrust sheets (Reference 57) (Reference 58). The lack of seismicity in the shallow Appalachian thrust sheets, estimated to be about 2 to 3.5 miles thick, implies that the seismogenic structures in the Giles County seismic zone are unrelated to the surface geology of the Appalachian orogen (Reference 58). Potential structures most likely responsible for the seismicity in Giles County are Iapetan normal faults within the Iapetan passive margin of the North American basement beneath the Appalachian thrust sheets (Reference 49) (Reference 58).

No capable tectonic sources have been identified within the Giles County seismic zone, but a zone of small Late Pliocene to Early Quaternary age faults have been identified within the Giles County seismic zone, near Pembroke, Virginia (Reference 59). The Pembroke zone is a set of extensional faults exposed in terrace deposits overlying limestone bedrock along the New River (Reference 85) (Reference 86). These faults were rated by Crone and Wheeler as Class B (Reference 59) (Table 2.5-1 and Table 2.5-2) because it has not yet been determined whether the faults are tectonic or the result of solution collapse. The shallow Pembroke faults do not appear to be related to the seismicity within the Giles County seismic zone, which is occurring beneath the Appalachian basal decollement in the North American basement.

The EPRI source model includes various source geometries and parameters to represent the seismicity of the Giles County seismic zone. Subsequent hazard studies have used M_{max} values that were within the range of maximum magnitudes used by the six EPRI models. Collectively, upper-bound maximum values of M_{max} used by the EPRI teams ranged from m_b 6.6 to 7.2 (presented in Section 2.5.2.2). More recently, Bollinger (Reference 79) estimated an M_{max} of m_b 6.3 for the Giles County seismic source using three different methods. Chapman and Krimgold (Reference 57) used an M_{max} of m_b 7.25 for the Giles County zone and most other sources in their seismic hazard analysis of Virginia. Both of these more recent estimates of M_{max} are similar to the range of M_{max} values used in the 1986 EPRI studies. Therefore, no new information has been developed since 1986 that would require a significant revision to the EPRI seismic source model.

3. **Selected Seismogenic and Capable Tectonic Sources Beyond the Site Region**

Because of the potential for distant, large earthquakes in the CEUS contributing to the long period ground motion hazard, a discussion of three additional seismic sources based on seismicity is provided in the following paragraphs. These sources include the Eastern

Tennessee, New Madrid and Charleston seismic sources, which produced the largest historical earthquakes in the CEUS (Figure 2.5-14).

Eastern Tennessee Seismic Zone

The ESP site is located over 300 miles east of the Eastern Tennessee seismic zone, which is a pronounced seismic source in the central and southeastern United States (Figure 2.5-14). The zone, located in the Valley and Ridge Province of eastern Tennessee, is about 185-miles long and 30-miles wide and has not produced a damaging earthquake in historical time (Reference 87). However, this zone has produced the second highest release of seismic strain energy in the CEUS during the 1980s, when normalized by crustal area (Reference 87).

Earthquakes in the Eastern Tennessee seismic zone are occurring at depths between 3 and 16 miles but none have exceeded a moment magnitude (**M**) of 4.6 (Reference 88). The mean focal depth within the seismic zone is 9 miles, which is well below the Appalachian basal decollement's maximum depth of 3 miles. The lack of seismicity in the shallow Appalachian thrust sheets implies that the seismogenic structures in the Eastern Tennessee zone are unrelated to the surface geology of the Appalachian orogen. Potential structures most likely responsible for the seismicity in Eastern Tennessee are reactivated Iapetan normal faults within the Iapetan passive margin beneath the Appalachian thrust sheets (Reference 49) (Reference 58).

The majority of earthquake focal mechanisms show right-lateral slip on northerly-trending planes or left-lateral slip on easterly-trending planes (Reference 88). Statistical analyses of focal mechanisms and epicenter locations suggest that seismicity is occurring on a series of northeast-trending en echelon basement faults, intersected by several east-west-trending faults (Reference 88).

Earthquakes within the Eastern Tennessee seismic zone cannot be attributed to known faults (Reference 87) and no capable tectonic sources have been identified within the seismic zone. However, the seismicity is spatially associated with major geophysical lineaments. The large majority of seismicity lies between the New York-Alabama lineament on the west and the Clingman and Ococee lineaments on the east (Reference 89).

The EPRI source model includes various source geometries and parameters to represent the seismicity of the Eastern Tennessee seismic zone. Subsequent hazard studies have used M_{max} values that were within the range of maximum magnitudes used by the six EPRI models. Collectively, upper-bound maximum values of M_{max} used by the EPRI teams ranged from m_b 6.6 to 7.4. Using three different methods specific to the Eastern Tennessee seismic source, Bollinger (Reference 79) estimated an M_{max} of m_b 6.45. Chapman and Krimgold (Reference 57) used a M_{max} of m_b 7.25 for the Eastern

Tennessee zone and most other sources in their seismic hazard analysis of Virginia. Both of these more recent estimates of M_{max} are similar to the range of M_{max} values used in the 1986 EPRI studies. Therefore, it is concluded that no new information has been developed since 1986 that would require a significant revision to the EPRI seismic source model.

Charleston Seismic Zone

The Charleston seismic source lies about 375 miles south of the ESP site. The August 31, 1886, Charleston, South Carolina, earthquake is the largest historical event to occur in the eastern United States. The event produced MMI X shaking in the epicentral area and was felt strongly as far away as Chicago (MMI V) (Reference 90). As a result of this earthquake, considerable effort has gone into identifying the source of the earthquake and recurrence history of large magnitude events in the region (Reference 74) (Reference 91).

The 1886 Charleston earthquake produced no identifiable primary tectonic surface deformation, and, therefore, the source of the earthquake has been inferred based on the geology, geomorphology, and instrumental seismicity of the region. Talwani (Reference 92) infers that the 1886 event was produced by the north-northeast-striking Woodstock fault (inferred from seismicity) near its intersection with the northwest-striking Ashley River fault (also inferred from seismicity). Marple and Talwani (Reference 74) have more recently suggested that a northeast-trending zone of river anomalies, referred to as the ECFS, represents the causative fault for the 1886 Charleston event. The southern segment of the ECFS coincides with a linear zone of micro-seismicity that defines the northeast-trending Woodstock fault of Talwani (Reference 92) and the isoseismal zone from the 1886 earthquake.

Johnston (Reference 90) estimated a magnitude of **M** 7.3 $\pm$0.26 for the 1886 Charleston event. More recently, Bakun and Hopper (Reference 93) estimated a smaller magnitude of **M** 6.8 with a 95 percent confidence level corresponding to a range of **M** 6.4 to 7.1. Both of these more recent estimates of M_{max} are similar to the upper-bound maximum range of M_{max} values used in the 1986 EPRI studies (m_b 6.8 to 7.5). Therefore, no new information has been developed since 1986 that would require a significant revision to the EPRI seismic source model in terms of magnitude.

Because there is very little surface expression of faults within the Charleston seismic zone, earthquake recurrence estimates are based largely on dates of paleo-liquefaction events. The most recent summary of paleo-liquefaction data (Reference 91) suggests a mean recurrence time of 550 years for Charleston, which was used in the 2002 USGS model (Reference 76). This recurrence interval is less than the 650 year recurrence

interval used in the 1996 USGS hazard model, and is roughly an order of magnitude less than the seismicity-based recurrence estimates used in the 1986 EPRI studies.

Therefore, the most significant update of source parameters in the Charleston seismic zone since the 1986 EPRI study is the reduction of the recurrence interval from several thousand years based on seismicity data to the characteristic recurrence of 550 years based on paleoseismic observations. This new information was incorporated into a sensitivity analysis to evaluate its significance to hazard at the ESP site. This sensitivity analysis is described in Section 2.5.2.

New Madrid Seismic Zone

The New Madrid seismic zone extends from southeastern Missouri to southwestern Tennessee and is over 620 miles west of the ESP site. The New Madrid seismic zone lies within the Reelfoot Rift and is defined by post-Eocene to Quaternary faulting and historical seismicity. Given the significant distance between the site and the seismic zone, the New Madrid seismic zone did not contribute to 99 percent of the hazard at the NAPS site in the 1986 EPRI study. However, it is described in this section because several recent studies provide significant new information regarding magnitude and recurrence interval for the seismic zone.

The New Madrid seismic zone is approximately 125-miles long and 25-miles wide. Research conducted since 1986 has identified three distinct fault segments embedded within the seismic zone. These three fault segments include a southern northeast-trending dextral slip fault, a middle northwest-trending reverse fault, and a northern northeast-trending dextral strike-slip fault (Reference 94). In the current east-northeast to west-southwest directed regional stress field, Precambrian and Late Cretaceous age extensional structures of the Reelfoot Rift appear to have been reactivated as right-lateral strike-slip and reverse faults.

The New Madrid seismic zone historically has produced three large magnitude earthquakes between December 1811 and February 1812 (Reference 95). The December 16, 1811 earthquake is associated with strike-slip fault displacement along the southern portion of the New Madrid seismic zone. Johnston (Reference 90) estimated a magnitude of **M** 8.1 ±0.31 for the December 16, 1811 event. However, Hough and others (Reference 95) have re-evaluated the isoseismal data for the region and concluded that the December 16 event had a magnitude of **M** 7.2 to 7.3. Bakun and Hopper (Reference 93) have similarly concluded this event had a magnitude of **M** 7.2.

The February 7, 1812, New Madrid earthquake is associated with reverse fault displacement along the middle part of the New Madrid seismic zone (Reference 96). This earthquake most likely occurred along the northwest-trending Reelfoot Fault that extends approximately 43 miles from northwestern Tennessee to southeastern Missouri. The

Reelfoot Fault is a northwest-trending southwest-vergent reverse fault. The Reelfoot Fault forms a topographic scarp developed as a result of fault-propagation folding (Reference 97) (Reference 98) (Reference 99) (Reference 100). Johnston (Reference 90) estimated a magnitude of **M** 8.0 ±0.33 for the February 7, 1812 event. However, Hough and others (Reference 95) have re-evaluated the isoseismal data for the region and concluded that the February 7 event had a magnitude of **M** 7.4 to 7.5. More recently, Bakun and Hopper (Reference 93) estimated a similar magnitude of **M** 7.4.

The January 23, 1812, earthquake is associated with strike-slip fault displacement on the East Prairie Fault along the northern portion of the New Madrid seismic zone. Johnston (Reference 90) estimated a magnitude of **M** 7.8 ±0.33 for the January 23, 1812, event; however, Hough and others (Reference 95) have re-evaluated the isoseismal data for the region and have concluded that the January 23 event had a magnitude of **M** 7.1. More recently, Bakun and Hopper (Reference 93) have estimated a similar magnitude of **M** 7.1.

Because there is very little surface expression of faults within the New Madrid seismic zone, earthquake recurrence estimates are based largely on dates of paleo-liquefaction and offset geological features. The most recent summary of paleo-liquefaction data (Reference 101) suggests a mean recurrence time of 500 years, which was used in the 2002 USGS model (Reference 76). This recurrence interval is half of the 1000-year recurrence interval used in the 1996 USGS hazard model, and an order of magnitude less than the seismicity-based recurrence estimates used in the 1986 EPRI studies.

The upper-bound maximum values of M_{max} used in the 1986 EPRI study range from m_b 7.2 to 7.9. Since the EPRI study, estimates of M_{max} have generally been within the range of maximum magnitudes used by the six EPRI models. The most significant update of source parameters in the New Madrid seismic zone since the 1986 EPRI study is the reduction of the recurrence interval to 500 years. This new information on recurrence interval for the New Madrid Seismic zone is addressed for the probabilistic seismic hazards analysis (PSHA) at the ESP site in Section 2.5.2.6.2.

2.5.1.1.5 Regional Gravity and Magnetic Data

Regional maps of the gravity and magnetic fields in North America were published by the Geological Society of America (GSA) in 1987 as part of the society's Decade of North American Geology (DNAG) project. The maps present the potential field data at 1:5,000,000-scale, and thus are useful for identifying and assessing gravity and magnetic anomalies with wavelengths on the order of tens of kilometers or greater. More recent gravity and magnetic data have been incorporated in studies of crustal-scale structure of the Appalachian orogen in Virginia (Reference 102). These studies combine geologic map data and reflection seismic data to evaluate the down-dip geometry of major Appalachian tectonic units. Comparison of the crustal structure

with potential field data facilitates geologic interpretation of gravity and magnetic anomalies visible on the regional maps. All of this information was published following the 1986 EPRI study.

a. **Gravity Data**

Gravity data compiled at 1:5,000,000 scale for the DNAG project provide additional documentation of previous observations that the gravity field in the eastern United States at the latitude of Virginia is characterized by a long-wavelength, east-to-west gradient (Reference 103). Bouguer gravity values increase eastward from about –80 mgal in the Valley and Ridge Province of western Virginia to about +10 mgal in the Coastal Plain Province (Reference 104), corresponding to an approximately 90 mgal regional anomaly across the width of the state. This regional gradient is called the “Piedmont gravity gradient” (Reference 103), and is interpreted to reflect the eastward thinning of the North American continental crust and the associated positive relief on the Moho discontinuity with proximity to the Atlantic margin.

The Piedmont gravity gradient is punctuated by several smaller positive anomalies with wavelengths ranging from about 15 to 30 miles, and amplitudes of about 10 to 20 mgal. Most of these anomalies are associated with accreted Taconic terranes such as the Chopawamsic terrane. Collectively, they form a gravity high superimposed on the regional Piedmont gradient that can be traced NE-SW on the 1:5,000,000 DNAG map relatively continuously along the trend of the Appalachian orogenic belt through North Carolina, Virginia, and Maryland. The continuity of this positive anomaly diminishes to the southwest in South Carolina, and the trend of the anomaly is deflected eastward in Maryland, Pennsylvania, and Delaware (Reference 104).

The short-wavelength anomalies and possible associations with upper crustal structure are illustrated by combining gravity profiles with seismic reflection data and geologic data (Reference 102) (Reference 103). In some cases, short-wavelength positive anomalies are associated with antiformal culminations in Appalachian thrust sheets. For example, there is a positive anomaly associated with the anticline at the western edge of the Blue Ridge nappe along the Interstate I-64 transect of Harris and others (Reference 103). The anomaly is presumably due to the presence of denser rocks transported from depth and thickened by antiformal folding in the hanging wall of the thrust. In other cases, positive anomalies are directly associated with east-dipping, thrust-bounded bodies of relatively denser rock. For example, Glover and Klitgord (Reference 102) show that a local positive gravity anomaly is associated with an east-dipping body of meta-volcanic rock near the boundary between the eastern Piedmont and Coastal Plain Provinces in central Virginia; they interpret that this body of meta-volcanic rocks is the preserved Taconic suture at this latitude.

In general, expression of Triassic basins as local gravity lows at the 1:5,000,000 scale of the DNAG map is modest to non-existent. There is a discernible, low-amplitude negative gravity

anomaly associated with the Richmond Basin, but no obvious or pronounced gravity low associated with the Culpeper Basin (Reference 104).

Gravity data published since the mid-1980s confirm and provide additional documentation of previous observations of a gradual “piedmont gravity gradient” across the Blue Ridge and Piedmont Provinces of Virginia. Harris and others (Reference 103) depict this gradient as an 80 mgal increase from west to east over a distance of about 85 miles. The presence of the “Piedmont Gravity Anomaly” was known at the time of the 1986 EPRI study. This anomaly is a first-order feature of the gravity field and is interpreted to reflect eastward thinning of the North American crust and lithosphere. Second-order features in the regional field primarily reflect density variations in the upper crust associated with the boundaries and geometries of Appalachian thrust sheets and accreted terranes. Negative anomalies in Virginia associated with Triassic basins are third-order features of the regional gravity field.

b. **Magnetic Data**

Magnetic data compiled for the DNAG project reveal numerous NE-SW-trending magnetic anomalies, generally parallel to the structural features of the Appalachian orogenic belt (Reference 104). Unlike the gravity field, the magnetic field is not characterized by a regional, long-wavelength gradient that spans the east-west extent of the state. A magnetic profile along Interstate I-64 published to accompany a seismic reflection profile (Reference 103) shows an approximately constant 11-gamma background field punctuated by anomalies with wavelengths of about 6 to 30 miles. Harris and others (Reference 103) concluded that anomalies in the magnetic field primarily are associated with upper-crustal variations in magnetic susceptibility and, unlike the gravity data, do not provide information on crustal-scale features in the lithosphere.

The most prominent magnetic anomalies in Virginia lie in a NE-SW-trending band across the central part of the state (Reference 104). These anomalies are associated with accreted Taconic units such as the Smith River, Jefferson, and Chopawamsic terranes. The high magnetic intensities of these units probably are due to the presence of island-arc-related mafic and ultramafic rocks. Lower intensities are associated with the Goochland terrane and related eastern Piedmont units, which primarily represent thrust-bounded slices of autochthonous (in place) North American basement. Discrete magnetic lows associated with the Richmond and Culpeper basins are discernible at the 1:5,000,000 scale of the DNAG map (Reference 104). The low magnetic intensities presumably arise because the basin fill deposits are derived from a provenance region that contains fewer mafic and ultramafic rocks than the underlying bedrock terranes.

A magnetic profile along an approximately WNW-ESE transect through central Pennsylvania (Reference 102) indicates that paired high and low magnetic anomalies are associated with the western margins of crustal units truncated by thrust faults. Many of these anomalies have

very high amplitudes and short wavelengths. For example, there is a 400-600 nT anomaly associated with the western margin of the Blue Ridge thrust nappe. Similarly, there is a 1500-2000 nT anomaly associated with the western edge of the Jefferson and Smith River terranes, and an 800 nT anomaly associated with a body of meta-volcanic rocks within the Goochland terrane that Glover and Klitgord (Reference 102) interpret as the Taconic suture.

Magnetic data published since the mid-1980s provide additional information on the geometry and extent of anomalies associated with fault-bounded upper crustal units, primarily in the Blue Ridge and Piedmont Provinces. The magnetic data provide additional characterization of the geophysical properties of upper crustal rocks, as well as supporting evidence for interpretation of seismic reflection data (Reference 102) (Reference 103). The magnetic data published since 1986 does not reveal any new anomalies related to geologic structures that were not previously identified prior to the 1986 EPRI study.

2.5.1.2 Site Area Geology

The following sections present a summary of geologic conditions of the ESP site and site area (5-mile radius). They provide information concerning the physiography, stratigraphy, geologic history, geologic structure, engineering geology and groundwater conditions relative to the ESP site. The information presented in these sections is based on a review of previous NAPS reports, geologic literature, and the results of recent geotechnical and geologic field reconnaissance investigations conducted at and in the vicinity of the ESP site.

2.5.1.2.1 Site Area Physiography and Geomorphology

The ESP site is located within the Piedmont Upland section of the Piedmont Physiographic Province. It is situated approximately 15 miles west of the Fall Line boundary between the Piedmont and Coastal Plain Physiographic Provinces.

The site is bordered by Lake Anna to the north and east, and to the south and west by forest and brushwood-covered land interspersed with an occasional farm (Reference 6). The area is well dissected by streams; the inter-stream divides being generally fairly wide and sloping or rolling. Some of the divides become steeper along the lower tributaries of the larger streams, and along these tributaries entrenchment has been rapid (Reference 41) (Figure 2.5-15).

The topography in the site region is characteristic of the Piedmont Upland section, with a gently undulating surface varying in elevation from about 200 to 500 feet (Reference 5). The slopes in the region typically range from 2 to 5 percent, with steeper slopes along the lower tributaries of some of the larger streams ranging from 7 to 10 percent (Figure 2.5-15).

Site grade for the existing units is at an approximate elevation of 271 feet. The ground surface generally rises to the west and south to elevations of over 300 feet (Figure 2.5-16).

2.5.1.2.2 Site Area Geologic History

Since Early Paleozoic time, rocks of the Piedmont Physiographic Province have undergone extensive tectonic activity, primarily from three compressional orogenies (Taconic, Acadian, and Allegheny) during the Paleozoic Era and one extensional episode during the Mesozoic Era (as presented in Section 2.5.1.1.2). These orogenies produced a very complex regional pattern of folding and faulting. The texture, mineralogy, and structure of rocks in the Piedmont Province, with the exception of Triassic age rocks, generally reflect the effects of these major episodes of tectonic activity. The rocks exhibit varying degrees of metamorphism, depending on their location in relation to the axis of major stress, which generally trends northeast-southwest (Reference 8).

The ESP site is located within the previously described Chopawamsic lithotectonic belt (Section 2.5.1.1.3). Within a 5-mile radius of the site are the Western Piedmont and the Goochland-Raleigh belts, approximately 4.5 miles west and east of the site, respectively (Figure 2.5-11). The rocks within these belts are believed to be derived from sediments deposited in an intra-oceanic island-arc subduction zone, situated eastward of ancestral North America. Rocks of the Mine Run Complex within the Western Piedmont belt are interpreted to have formed in a back-arc marginal sea between ancestral North America and an offshore island-arc. Rocks of the Chopawamsic Formation and Ta River Metamorphic Suite, within the Chopawamsic belt, are interpreted to have formed this island-arc. East of the island-arc, rocks of the Po River Metamorphic Suite, within the Goochland-Raleigh belt, are interpreted to have formed as a micro-continent. Successive thrusting and deformation of rocks within each of these belts in a general northwest direction during Paleozoic time has produced the present day bedrock conditions at and in the vicinity of the ESP site (Figure 2.5-17).

During the Penobscot orogeny westward and northward thrusting of the island-arc terrain was initiated. Sediment was shed from the Chopawamsic island-arc (Figure 2.5-5) into the eastern parts of the back-arc basin, where sediments of the Mine Run Complex were accumulating (Reference 40).

During the subsequent Taconic orogeny, which occurred during Middle to Late Ordovician, the Chopawamsic island-arc terrane and back-arc basin deposits continued to be thrust westward and were accreted to the eastern margin of ancestral North America. The rocks were episodically folded and faulted and plutonism occurred. Granitoids were emplaced in the back-arc terrane and tonalites were emplaced in the island-arc terrane (Reference 33). This period of deformation and metamorphism was followed by an interval of uplift and erosion during the Late Ordovician and Early Silurian. To the east, sand and pelitic sediments were unconformably deposited on the volcanic and plutonic rocks of the foundered and eroded island-arc rocks. These sediments now constitute the meta-sedimentary Quantico Formation (Reference 33). The Quantico Formation outcrops approximately 2 miles west of the ESP site. At about the same time as the sediments of the Quantico Formation were being deposited, the Ellisville pluton intruded rocks of the back-arc basin terrane. The Ellisville pluton outcrops approximately 5 miles west of the ESP site.

During the Acadian orogeny the micro-continent that had formed eastward of the island-arc terrane, comprised of rocks of the Po River Metamorphic Suite, was thrust westward onto the island-arc terrane. By Devonian time, the back-arc basin and island-arc terranes and the micro-continent were all believed to have been accreted over the continental crust (Reference 40).

During the Allegheny orogeny that followed in the Late Carboniferous Period, the generally undeformed Quantico Formation and the subjacent Ta River Metamorphic Suite were folded into structurally conformable upright isoclinal folds. The unconformity between the Chopawamsic and Quantico Formations became a decollement along which the Long Branch thrust fault developed (presented in Section 2.5.1.2.4). The upright isoclinal folding is inferred to be related to the westward thrusting of rocks of the Po River Metamorphic Suite along the developing Spotsylvania thrust fault. With continuing deformation, the upright isoclinal folds to the east of the Quantico synclinorium became westward-verging recumbent folds (Reference 40). The Po River Metamorphic Suite was metamorphosed to amphibolite grade and polydeformed. It is thought that much of the deformation and metamorphism occurred before westward thrusting along the Long Branch and related faults and the juxtaposition, probably toward the end of the Allegheny orogeny, of the eastern, higher grade metamorphic terranes with the greenschist facies rocks of the Chopawamsic Formation. The granitoids of the Falmouth Intrusive Suite generally intruded rocks within the Chopawamsic belt prior to final thrusting along the Long Branch fault (Reference 40). Rocks of the Falmouth Intrusive Suite lie approximately 2 miles southwest and 3.5 northeast of the ESP site (Figure 2.5-11).

During the Mesozoic extensional episode a series of northeast-trending grabens and half-grabens formed in the Piedmont Province, predominantly along the boundaries of the Western Piedmont belt. Within the ESP site area no such basins exist. The closest basin to the site, the Culpeper Basin, lies about 20 miles northwest of the site.

During Cenozoic time, the area surrounding the ESP site was subject to erosion along the passive continental margin. Erosion continued during the Pleistocene glacial and interglacial periods. Periglacial environments persisted in the area of the ESP site during this time. Weathering processes characteristic of periglacial environments include frost-shattering, freeze-thaw cycles, accelerated wind erosion and accelerated solifluction. These weathering processes in conjunction with down-cutting of streams and rivers during Cenozoic time have produced the residual soils that cover bedrock at the ESP site.

2.5.1.2.3 Site Area Stratigraphy

The ESP site is underlain by rocks of the Ta River Metamorphic Suite, which are in turn underlain by rocks of the Chopawamsic Formation and the Mine Run Complex. The Ta River Metamorphic Suite is juxtaposed against the Quantico Formation west of the site and is juxtaposed against the Po River Metamorphic Suite east of the site along north-northwest trending faults (Figure 2.5-11). The Ta River Metamorphic Suite is intruded by rocks of the Falmouth Intrusive Suite to the southwest

and northeast of the site. Rocks of the Mine Run Complex and Chopawamsic Formation are intruded by the Ellisville pluton west of the site. Surficial sediments at the site are comprised predominantly of residual soil and saprolite, which mantles most of the site. Alluvium in the vicinity of the site is generally found along stream channels, and marine and fluvial sands and gravels are found locally capping the tops of hills and hill slopes.

Extensive geological and geotechnical data for the ESP site are available as a result of investigations completed for the existing units and for the abandoned Units 3 and 4. Sixty borings were completed to depths ranging between 20 and 150 feet during the investigation for the existing units (Reference 7). Forty-seven borings were completed to depths ranging between 40 and 175 feet for the abandoned Units 3 and 4 (Reference 8). Additional borings were completed in the areas of the SWR (Reference 5) and the ISFSI (Reference 6). The results of the borings are presented in detail Section 2.5.4.

In addition to the existing geological and geotechnical data for the existing units, 7 new borings, 8 cone penetrometer tests (CPTs), 2 seismic cone penetrometer tests, and cross-hole and down-hole seismic tests were performed as part of the ESP application subsurface investigation program. The borings and geotechnical testing are presented in detail in Section 2.5.4. The data developed are presented in Appendix 2.5.4B.

The sequence and configuration of the stratigraphic units within a 5-mile radius of the site are shown in Table 2.5-3 and on Figure 2.5-11 and Figure 2.5-17, respectively. The configuration of the stratigraphic units within a 0.6-mile radius of the site is shown on Figure 2.5-18.

a. **Po River Metamorphic Suite (Late Precambrian to Early Paleozoic)**

   The Po River Metamorphic Suite is juxtaposed along the Spotsylvania thrust fault against the Ta River Metamorphic Suite, east and southeast of the site (Figure 2.5-11 and Figure 2.5-17). The Po River Metamorphic Suite belongs to the Goochland-Raleigh lithotectonic belt of the Piedmont Upland section. A provisional age of Late Precambrian to Early Paleozoic has been assigned to the rocks of the Po River Metamorphic Suite (Reference 66).

   Rocks of the Po River Metamorphic Suite are within the amphibolite facies (high grade) of regional metamorphism (Reference 40) and consist of predominantly of biotite gneiss and schist. Characteristically, the gneiss is a dark colored, layered and foliated rock with micaceous minerals and quartz and feldspar typically concentrated in dark and light layers. Feldspar also occurs as large augen-shaped grains. Hornblende-bearing gneiss is found within the Po River, but in subordinate amounts compared to the biotite gneiss. It resembles the biotite gneiss in color and texture but contains varying amounts of hornblende as well as biotite. Garnetiferous mica schist is also found locally within the Po River and has a foliation conformable with the adjacent gneisses (Reference 66).

   Many foliated gneissic granitoid rocks, including pegmatoids, exist in tabular bodies as well as non-tabular masses in the Po River. The tabular granitoid and pegmatoid bodies form

concordant sill-like layers that range from less than 2.5 centimeters (cm) to as much as 7.6 m thick. Locally, granitoid layers about 0.5 to 1.0 cm thick are conformable with the foliation in the gneiss. The non-tabular, irregularly shaped granitoid bodies generally form relatively large masses that may be parts of plugs or plutons of various sizes (Reference 66).

b. **Ta River Metamorphic Suite (Cambrian and/or Ordovician)**

The Ta River Metamorphic Suite underlying the site is bounded on the east by the Spotsylvania thrust fault and on the west is juxtaposed against the Quantico Formation by a series of unnamed faults (Figure 2.5-11). Two thrust-fault-bounded slivers of the Ta River Metamorphic Suite are located west of the Quantico Formation (Figure 2.5-11 and Figure 2.5-17). The Ta River Metamorphic Suite belongs to the northeast-trending Chopawamsic lithotectonic belt of the Piedmont Upland section. Rocks of the Ta River Metamorphic Suite are thought to be Cambrian and/or Ordovician in age (Reference 35).

The Ta River Metamorphic Suite is intruded by plutonic rocks to the southwest (Elk Creek pluton) and northeast (Northeast Creek pluton) of the site (Figure 2.5-11). The rocks are correlative with the Falmouth Intrusive Suite.

The Ta River Metamorphic Suite is thousands of feet thick (Reference 105) and the rocks within the suite are within the amphibolite facies (high grade) of regional metamorphism (Reference 40). The rocks are dark-gray to black gneisses, which range from amphibolite through various types of amphibolite gneiss to biotite gneiss. In the site area, the rocks are predominantly biotite gneiss and schist with smaller amounts of amphibolite gneiss. Regional metamorphism is considered to be of a higher grade in this area than to the north (Reference 66). Descriptions of the amphibolitic gneisses have ranged from well-foliated and rarely layered (Reference 66) to poorly to well lineated and massive to well layered. Layers of biotite gneiss, ferruginous quartz and minor felsic meta-volcanic rocks are common and quartz-epidote lenses and veins often occur in the amphibole-bearing rocks (Reference 105).

Borings completed during previous subsurface investigations (Reference 7) (Reference 8) and borings completed as part of the recent ESP application subsurface investigation program (presented in Section 2.5.4) encountered rocks of the Ta River Metamorphic Suite at the ESP site. The main rock types at the site are shown on Figure 2.5-18 and consist of gray to dark gray:

- quartz gneiss with some biotite quartz gneiss,
- hornblende gneiss, biotite quartz gneiss, and quartz gneiss, and
- quartz mica schist.

Residual soil and saprolite at the ESP site have been categorized as Zone I and II respectively, while bedrock has been categorized as Zone III, III-IV and IV, based on the degree of weathering of the rock (Reference 7) (Reference 8). Zone III rocks are generally

highly to moderately weathered; Zone III-IV rocks are slightly to moderately weathered; and Zone IV rocks are slightly weathered to fresh.

Borings B-801 to B-805 encountered moderately to highly weathered rock (Zone III) at depths ranging between about 6 feet (Elevation 266) and 31 feet (Elevation 261) below the ground surface. This Zone III rock ranges in thickness from about 1-foot to 18 feet, and is comprised of brown, orange, tan, and gray, biotite quartz gneiss and quartz gneiss, with traces of clay, iron oxide staining, epidote, chlorite, pyrite and magnetite. Slightly weathered to moderately weathered rock (Zone III-IV) was encountered in the borings at depths ranging between about 8 feet (Elevation 263) and 39 feet (Elevation 232) below the ground surface. The Zone III-IV rock ranges in thickness from about 2 feet to 37 feet and is comprised of gray to dark gray, quartz gneiss and biotite quartz gneiss. The top of the slightly weathered to fresh rock (Zone IV) was encountered in the borings at depths ranging between about 20 feet (Elevation 229) and 76 feet (Elevation 195) below the ground surface and is comprised of dark gray, quartz gneiss and biotite quartz gneiss.

In boring B-806, alternating zones of moderately to highly weathered rock (Zone III) and slightly weathered to moderately weathered rock (Zone III-IV) were encountered throughout much of the boring. The Zone III rock was encountered at depths of about 8 feet (Elevation 292), 15 feet (Elevation 284), 26 feet (Elevation 273), and 56 feet (Elevation 243) below the ground surface. The alternating Zone III-IV rock was encountered at depths of about 11 feet (Elevation 288), 21 feet (Elevation 278), 33 feet (Elevation 266) and 60 feet (Elevation 239) below the ground surface. The boring was terminated at a depth of 65 feet below the ground surface, approximately 1 foot into slightly weathered to fresh rock (Zone IV).

In boring B-807, alternating zones of moderately to highly weathered rock (Zone III) and residual soils were encountered throughout the full depth of the boring. The Zone III rock was initially encountered at a depth of about 35 feet (Elevation 276) below the ground surface and was 14 feet thick. A second zone of this rock was encountered at a depth of about 56 feet (Elevation 255) below the ground surface and extended for 16 feet, whereupon the boring was terminated.

The borings drilled as part of the ESP application subsurface investigation program (presented in Section 2.5.4) revealed severely weathered, fractured and jointed intervals in the Zone III-IV and Zone IV rock. Severely weathered fracture zones were encountered in Zone III-IV rock at varying depths, ranging from about 11 feet (Elevation 260) to 81 feet (Elevation 211) below the ground surface. These fracture zones were encountered in four of the borings (B-802, B-803, B-805, and B-806) and ranged in thickness from about 0.5 to 1-foot thick. Characteristically they exhibit clay filling, iron oxide staining, and quartz. Significant water loss during drilling occurred in two of the fracture zones in boring B-803. Joints (typically sets of 3 to 10 joints) in the slightly weathered to fresh (Zone IV) rock typically exhibit clay filling, iron oxide staining, quartz, mica, and traces of chlorite and manganese oxide.

Several quartz, potassium feldspar and mica bands were encountered during the drilling of boring B-803. The bands were encountered in the slightly weathered to fresh (Zone IV) rock at depths ranging between about 115 feet (Elevation 177) and 147 feet (Elevation 145) below the ground surface. Quartz bands were also encountered in several of the borings. Borings performed as part of the previous subsurface investigation programs (Reference 7) (Reference 8) also encountered occasional quartz seams, in addition to bands containing abundant mica and hornblende, and occasional chlorite, epidote and pyrite.

Petrographic analyses of thin sections prepared from the quartz gneiss at the ESP site have revealed the predominant minerals to be quartz and feldspar (alkali and plagioclase). According to these analyses, quartz makes up between 34 and 40 percent of the total volume of the rock; alkali feldspar makes up between about 21 and 37 percent of the total volume of the rock, and plagioclase feldspar makes up between 23 and 33 percent of the total volume of the rock. Biotite is the only major ferromagnesian mineral. Accessory minerals include muscovite, vermiculite, magnetite and hematite. Minor accessory minerals include sphene, zircon, cordierite, apatite and epidote (Reference 106).

c. **Chopawamsic Formation (Cambrian and/or Ordovician)**

The Ta River Metamorphic Suite is underlain by the Chopawamsic Formation (Figure 2.5-17). The formation crops out west and northwest of the site and is bounded on the east by the Long Branch thrust fault and on the west by the Chopawamsic thrust fault (Figure 2.5-11). The Chopawamsic Formation belongs to the Chopawamsic lithotectonic belt of the Piedmont Upland section. Rocks of the Chopawamsic Formation are thought to be Cambrian and/or Ordovician in age (Reference 35).

The Chopawamsic Formation is several thousand feet thick (Reference 105). Rocks within the formation are typically within the greenschist facies (low grade) of regional metamorphism and characteristically contain an albite-chlorite-epidote mineral assemblage (Reference 40). The Chopawamsic Formation consists of laterally discontinuous lenses and tongues of meta-volcanic and meta-sedimentary rocks. The meta-volcanic rocks include silic, intermediate, and mafic varieties, some of which are interpreted to be flows as indicated by their highly vesicular character. Fragmental rocks within the formation are mainly breccia and tuff. Fine-grained feldspathic schist and phyllite of the formation are mineralogically and chemically similar to the more distinctive volcanic rocks and may be tuffaceous. Schist, meta-arenite, and, locally, amphibole-free gneiss of probable sedimentary origin are interlayered with the meta-volcanic rocks; the proportion of meta-sedimentary rocks varies from place to place along the formation. Silic meta-volcanic rock typically is light gray; some varieties have small phenocrysts of quartz and/or feldspar. Some felsic meta-volcanic rocks contain albitic plagioclase and quartz in a finer grained, quartzofeldspathic groundmass and have been classified as keratophyres. Intermediate meta-volcanic rocks are dark to light green and commonly have a nematoblastic groundmass texture formed by aligned prismatic

amphibole intergrown with fine-grained quartz and feldspar. Mafic rocks of the Chopawamsic Formation include amphibolite greenstone, and various dark schists (Reference 66).

The Chopawamsic Formation lies close to the Ellisville pluton, which intruded the Mine Run Complex west of the site (Figure 2.5-11 and Figure 2.5-17). The enclosing rocks of the pluton show recognizable contact metamorphism. The phyllitic country rocks near the intrusive contact have been metamorphosed to schists and gneissic rocks, and megacrystic muscovite and biotite are common in addition to kyanite and staurolite. On the eastern side of the pluton within the Chopawamsic Formation, kyanite is present in fine-grained sulfidic schist, which is interlayered with meta-felsite and with chloritoid-bearing phyllite and schist. Minerals found in the Chopawamsic Formation within the thermal aureole of the Ellisville pluton include gahnite, margarite, tourmaline, allanite-clinozoisite, and chlorite (Reference 40).

d. **Mine Run Complex (Cambrian to Ordovician)**

The Chopawamsic Formation is underlain by mélanges of the Mine Run Complex (Figure 2.5-17). Mélange Zone II of the Mine Run Complex outcrops west and northwest of the site and is bounded on the east by the Chopawamsic thrust fault and on the west by the Lake of the Woods thrust fault (Figure 2.5-11). Mélange Zones III and IV outcrop successively northwest of Mélange Zone II. The Mine Run Complex belongs to the Western Piedmont lithotectonic belt of the Piedmont Upland section. The mélanges of the Mine Run Complex are estimated to be Cambrian to Ordovician in age (Reference 36).

The Mine Run Complex is hundreds of feet thick (Reference 105). The mélanges of the complex are typically within the greenschist facies (low grade) of regional metamorphism and are characterized by chlorite-muscovite or chlorite-muscovite-garnet assemblages (Reference 40). Mélange Zone II contains felsic and mafic meta-volcanic blocks and granitoid blocks of altered tonalite and granodiorite in a schist and phyllite mélange matrix. The exotic blocks of the mélange are petrographically similar to rocks within the Chopawamsic Formation and are interpreted as fragments of the Chopawamsic Formation (Reference 66). Mélange Zone III contains metamorphosed mafic and ultramafic blocks, while Mélange Zone IV contains mafic and ultramafic blocks.

The mélanges of the Mine Run Complex are intruded by the Ellisville pluton. The phyllitic country rocks near the intrusive contact have been metamorphosed to schists and gneissic rocks and megacrystic muscovite and biotite are common in addition to kyanite and staurolite. Chlorite also occurs within the thermal aureole of the pluton (Reference 40).

e. **Quantico Formation (Ordovician)**

The Quantico Formation is faulted against the Ta River Metamorphic Suite and the Chopawamsic Formation west of the site (Figure 2.5-11 and Figure 2.5-17). It is bounded on the west by the Long Branch thrust fault and on the east by a series of smaller thrust faults. The Quantico Formation formed within the northeast-southwest trending Quantico

synclinorium. The Quantico formation belongs to the Chopawamsic lithotectonic belt of the Piedmont Upland section. Fossils contained in the formation indicate a Late Ordovician age (Reference 35).

Within the Quantico synclinorium, the Quantico Formation is at garnet-staurolite grade (high grade) metamorphism. The Quantico Formation is comprised of dark-gray phyllite and micaceous, fine- to medium-grained staurolite schist and biotite-muscovite garnetiferous schist that locally contains kyanite. Calc-silicate layers are also present and quartzite forms discontinuous lenses within the formation and locally at its base (Reference 66). The formation thickness has been estimated at 300 feet (Reference 105).

f. **Ellisville Pluton (Silurian)**

The Ellisville pluton intrudes the Mine Run Complex west of the site (Figure 2.5-11 and Figure 2.5-17). The pluton is interpreted to have formed along the continental margin of ancestral North America after accretion of the back-arc basin and island-arc terrane. It is interpreted to have formed from a crustal source, as opposed to a mantle source. It is considered to have intruded and thermally metamorphosed the surrounding country rock during the Silurian Period (Reference 40). A general depth of emplacement of about 11 to 8 miles is estimated for the Ellisville pluton with a temperature of emplacement of about 760°C. Gravity data suggests that the Ellisville pluton may have an appreciable subsurface extension to the northeast from its surface exposure (Reference 33).

The Ellisville pluton is composed almost entirely of coarse- to medium-grained biotite granodiorite that is commonly mesocratic, equigranular to porphyritic in texture, and massive to strongly foliated. It contains granitoid intrusions or inclusions of Cambrian and Silurian age and a Late Precambrian to Cambrian age amphibolitic xenolith (Reference 66).

g. **Falmouth Intrusive Suite (Carboniferous)**

Two small irregularly shaped plutons containing rocks of the Falmouth Intrusive Suite intrude the Ta River Metamorphic Suite (Figure 2.5-11). The Elk Creek and Northeast Creek plutons intrude the Ta River suite southwest and northeast of the site, respectively. Rocks of the Falmouth Intrusive Suite are the youngest felsic rocks in the area and have been isotopically dated as Carboniferous in age (Reference 40).

The Falmouth Intrusive Suite is composed of fine-grained monzogranite and pegmatitic granite, fine-grained granodiorite and, less commonly tonalite. The granitoids are strongly to weakly foliated and are marked by the exceptional development of myrmekite (Reference 66).

h. **Residual Soil and Saprolite (Cenozoic)**

Residual Soil

The ESP site and surrounding area is generally mantled by residual soil derived from the weathering of the underlying metamorphic rocks. Weathering has destroyed all parent

geologic structure in the residual soils to an average depth of 4 to 5 feet. The residual soil generally consists of clay, silt, and sand-sized particles with minor rock fragments (Reference 5).

Residual soil was encountered in only one of the borings drilled at the site as part of the ESP subsurface investigation (B-804). It extends from the ground surface to a depth of 1.5 feet below the ground surface in this boring. The soil consists of red and brown, slightly gravelly sandy clay.

Saprolite

Saprolite is encountered at the ground surface or underlies residual soil at the ESP site and in the surrounding area. The saprolite is derived from weathering of the underlying metamorphic rock, but retains many of the structural and mineralogical features of the rock. The saprolite extends to the top of the rock from which it was derived, although the contact between the saprolite and underlying rock may be gradational and poorly defined (Reference 5).

At the ESP site, the saprolite has been categorized based on its general composition and grain-size (presented in Section 2.5.4). Zone IIA saprolite is divided into coarse-grained saprolite, comprised of sand-size particles, and fine-grained saprolite, comprised of clay- and/or silt-size particles. Zone IIA saprolite typically contains less than 10 percent rock fragments. Zone IIB saprolite consists predominantly of sand-size particles and contains between 10 and 50 percent rock fragments.

Borings drilled as part of the ESP subsurface investigation program (Section 2.5.4) encountered Zone IIA saprolite from the ground surface or just below the ground surface to depths of between 6 feet (Elevation 265.5) and 35 feet (Elevation 261.4). The saprolite consists of orange, brown, tan, and gray, micaceous, silty, clayey, fine to coarse sand, and sandy silt with occasional rock fragments. Zone IIB saprolite was encountered at depths of between 21 feet (Elevation 289.6) and 49 feet (Elevation 261.6) below the ground surface and ranges in thickness from 7 to 14 feet. It consists of brown, orange, tan and gray, micaceous silty, slightly clayey, fine to coarse sand with some to many rock fragments.

Results of mineralogical tests performed on samples of saprolite derived from the quartz gneiss at the ESP site indicate that the saprolite consists of quartz, kaolin, mica and feldspar. X-ray diffraction tests further indicate that the portion of the sample less than 2 microns in diameter consists of 85 percent kaolinite and 15 percent mixed-layer minerals (Reference 7). In fact, additional studies conducted on the clay mineralogy of the saprolite indicate that the major clay mineral is halloysite, which is a hydrated form of kaolinite. Lesser amounts of the clay minerals illite and montmorillinite are also found in the saprolite (Reference 5).

i. **Sand and Gravel (Miocene)**

Miocene age sand and gravel commonly cap interfluve areas and constitute the thin Coastal Plain outliers capping the higher hills where deposits directly overlie the crystalline rocks (Figure 2.5-11). The sand and gravel unit reaches a thickness of up 33 feet (Reference 66).

The sand and gravel unit consists of gray to light yellowish gray, fine-to-coarse gravelly sand, sandy gravel, silt and kaolinitic clay. The sand and gravel are commonly oxidized to yellowish orange and yellowish and reddish brown. Pebbles and cobbles in the unit are mainly quartz, quartzite, and crystalline rocks and are commonly well rounded, deeply etched, and crumbly in part (Reference 66).

j. **Alluvium (Quaternary)**

Alluvium in the site area has been deposited mainly in the stream channels and along their flood plains (Figure 2.5-11). Along the steeper valley walls at the margins of the deposits, they grade into colluvium. The alluvium is mainly Holocene in age, but may include low-lying Pleistocene terrace deposits. The thickness of the alluvium along the major streams is as much as 49 feet (Reference 66).

The alluvium consists of light-to-medium gray and yellowish gray, fine-to-coarse gravelly sand and sandy gravel, silt, and clay. Clasts in the alluvium consist mainly of vein quartz, quartzite, and other metamorphic rocks (Reference 66).

k. **Artificial Material**

Artificial material (fill) is present at the ESP site in areas associated with construction of the existing units and abandoned Units 3 and 4. Borings performed as part of the ESP application subsurface investigation program encountered fill to depths of between 2.5 and 19 feet below the ground surface. The fill consists of a mixture of orange, brown, and tan sand, silt and clay. The maximum thickness of fill (19 feet) was encountered in boring B-801 in the excavated and partially backfilled powerblock area for abandoned Units 3 and 4.

2.5.1.2.4 Site Area Structural Geology

The local structural geology of the ESP site described in this section is based primarily on a summary of published geologic mapping (Reference 66) (Reference 105) and results of earlier investigations performed at the NAPS site (Reference 7) (Reference 9) (Reference 107). Structural features at and within a 5-mile radius of the ESP site consist of a series of northeast-striking faults and folds (anticlines and synclines) within the metamorphic bedrock.

Seven bedrock faults have been identified within a 5-mile radius of the ESP site (Figure 2.5-11):

- Spotsylvania thrust
- Chopawamsic thrust
- Long Branch thrust

- Sturgeon Creek fault
- Unnamed fault (“a”) traversing the NAPS site
- Unnamed fault (“b”) separating the Ta River Metamorphic Suite from the Quantico Formation
- Unnamed fault (“c”) separating the Northeast Creek pluton from the Quantico Formation

The faults are described in detail in Section 2.5.3. None of these faults are considered capable tectonic sources, as defined in RG 1.165, Appendix A. One of the faults traverses the NAPS site (unnamed fault “a”) and was the subject of intensive studies following its exposure within the excavations for abandoned Units 3 and 4 (Reference 9). This fault is briefly described within this section of the report, but a more comprehensive summary of the fault and investigations is provided in Section 2.5.3.

The Spotsylvania, Chopawamsic, and Long Branch thrust faults are northeast striking, east-dipping Paleozoic structures that can be mapped for tens of miles within the Piedmont Province (Reference 66). The Spotsylvania and Chopawamsic thrust faults bound the eastern and western margins of the Chopawamsic belt, respectively, and therefore represent the largest surficial tectonic structures within the site area.

The Sturgeon Creek fault and the three unnamed faults (“a”, “b”, and “c” on Figure 2.5-11) also strike northeast; however, they are smaller structures than the other three thrust faults. The fault closest to the ESP site is the unnamed fault (“a”) that traverses the site. This fault has been given a length of about 3000 feet through the site by Dames & Moore (Reference 9) (Figure 2.5-18) based on geologic mapping of excavations and trenches. The fault consists of 4 individual shear zones and chlorite seams and generally strikes N65°E and dips between 45 degrees and 50 degrees to the northwest (Reference 108). Dames & Moore (Reference 9) concluded that the fault was not capable and the AEC (Reference 108) agreed stating:

> “The North Anna fault zone is neither genetically nor structurally related to any known, capable fault. Thus the staff concludes that the faults are not “capable,” as defined by Appendix A of 10 CFR Part 100.”
> (Refer to Section 2.5.3 for additional discussion.)

The three largest folds within a 5-mile radius of the ESP site include, from west to east, the Quantico synclinorium, the Rappahannock anticlinorium, and the Matta nappe (Figure 2.5-5). These structures exhibit multiple phases of metamorphism and deformation of Paleozoic age (Reference 40). The Quantico synclinorium and Rappahannock anticlinorium are located within the Chopawamsic belt, which is bounded on the west by the Chopawamsic thrust fault and on the east by the Spotsylvania thrust fault (Figure 2.5-11). East of the Chopawamsic belt, lies the Matta nappe, a west-verging, recumbently folded sheet of Po River Metamorphic Suite rocks that was thrust westward over the island-arc terrane by the Spotsylvania thrust fault (Figure 2.5-5). Because the nappe contains northeast-trending, generally upright folds parallel to compositional layering, the Matta nappe is considered a large-scale recumbent foliation fold (Reference 40).

The Rappahannock anticlinorium, which is bounded by the Long Branch and Spotsylvania faults, extends southwest from Stafford, Virginia, to the James River and beyond (Reference 36). Most of the folds along the Rappahannock anticlinorium are foliation folds formed by the folding of an earlier schistocity (Reference 40). In the site area, foliation folds within the Ta River Metamorphic Suite are upright, northeast plunging or doubly plunging (Figure 2.5-11). The youngest set of folds within the Rappahannock anticlinorium and Matta nappe refold the earlier foliation folds (Reference 40).

West of the Rappahannock anticlinorium lies the Quantico synclinorium, a large upright foliation fold that is mapped over 20 miles parallel to the Long Branch thrust fault. Near the southern end of the fold, the Sturgeon Creek fault curves to the southwest into the axis of the Quantico synclinorium (Reference 40).

The ESP site lies within the complexly folded Ta River Metamorphic Suite of the Rappahannock anticlinorium. On Figure 2.5-11, 3 anticlines and 2 synclines, trending northeast and ranging in length from 1.5 to 5 miles, are mapped within the Rappahannock anticlinorium near the site. The folds are closely spaced with axes approximately 0.1 to 0.2 miles apart. Foliations in the metamorphic rocks range in dip from 40 degrees to vertical (Figure 2.5-11).

The most detailed mapping at the site was performed by Dames & Moore in a series of reports in the early 1970s as part of the site-specific studies for the existing NAPS site (Reference 7) (Reference 8) (Reference 9). Field mapping was supplemented with geotechnical borings, bedrock exposures in excavations, and geophysical surveys. The mapping delineated different compositional layering within the gneisses and schists. These rocks, which were later classified as the Ta River Metamorphic Suite, were split into three main rock types at the site and consist of gray to dark gray quartz gneiss with biotite, interbedded with a biotite quartz gneiss; and interbedded quartz gneiss, biotite quartz gneiss and hornblende gneiss. The distribution of these bedrock units illustrates the folding at the site (Figure 2.5-18).

The most prominent folds at the site are the northerly plunging syncline/anticline pair located in the western portion of the site (Figure 2.5-18). The axis of the syncline passes near an area of exposed bedrock (quarry area shown on Figure 2.5-18) and foliations near the axis of the fold dip steeply (65–90 degrees).

In the deeply weathered Piedmont Province, the presence of a thick saprolite limits the quantity and quality of structural observations and measurements in competent bedrock materials. However, because the ESP site contains deep excavations and abundant subsurface explorations, a much greater amount of structural data is available for the site than the surrounding region. Exposures of bedrock, and therefore structural observations within the site, are concentrated in the excavations for the existing units and abandoned Units 3 and 4, foundation excavations for other structures, and cuts for roads and railroad spurs (Figure 2.5-18). There are still large portions of the site where detailed structural measurements (orientations of foliations, joints, and fractures) are sparse.

Foliation in the metamorphic bedrock is generally oriented northeasterly across much of the site. However, due to the deformed and folded nature of the metamorphic rocks, the strikes and dips are highly variable. Dips of the foliation in the metamorphic rocks at the site range from as low as ≈15 degrees to as steep as 90 degrees. The majority of dips measured at the site are typically steeper than 45 degrees.

The existing units and abandoned Units 3 and 4 are located in an area of northeast-striking, northwest-dipping bedrock foliations, which may represent the northwest flank of an anticline (Figure 2.5-11 and Figure 2.5-5). Bedrock foliations generally strike about N45°E and dip moderately to the northwest in this portion of the site. Specifically, foliation orientations within excavations for abandoned Units 3 and 4 strike N55-75°E and dip 40-60°NW (Reference 107).

The mapping of joints and fractures from rock outcrops and rock cores recovered from borings drilled during previous site investigations (Reference 7) reveal that the bedrock is extensively jointed. The joint pattern was characterized by Dames & Moore (Reference 7) from field outcrops and test pits excavated into the saprolite, prior to mapping exposures in the large foundation excavations at the site. Several joint sets were identified by the initial studies.

- Release joints are one of the most abundant sets of joints in the gneiss. They strike slightly east of north, dip steeply to the west, are usually tight and smooth and rarely show any shear movement or contain any clay fill.
- Bedding plane joints are also abundant. They form parallel to schistosity, are generally smooth, tight, and rarely contain clay fill.
- Several sets of cross joints strike east-west, dip steeply to the north, are smooth and contain some clay fill, while other sets are essentially horizontal, rough and generally highly weathered with as much as 2 inches of clay fill. These joints are limited in areal extent.
- Two sets of diagonal joints in the gneiss strike northeast and northwest, are usually smooth, contain some clay fill, and are slickensided in places. These joints are characterized as extensive and widely spaced.
- A set of joints that strike northeast and dip moderately to the southeast commonly exhibit reverse shear movements. These discontinuities are more common near the hornblende gneiss contact and are believed to be the result of minor adjustments of the rock mass during folding. They are clay-filled, smooth, and show displacements of up to 1.5 feet.

Detailed mapping of excavation walls for the abandoned Unit 3 and 4 reactor containment structures revealed a less weathered, more intact rock mass than was available in earlier studies of the site by Dames & Moore (Reference 7). The deep excavations revealed three major joint sets and less prominent sets similar to the joint pattern observed near the ground surface. The orientation, properties, and spacing of major joint sets in excavations for abandoned Units 3 and 4 were characterized by Stone & Webster Engineering Corporation (Reference 107) as follows:

- Strike N20E, dip 70-90°NW – tightly closed, clean with occasional iron staining, smooth, and spaced at 8- to 24-inch intervals.
- Strike N55-75E, dip 40-60°NW (foliation plane joints) – tightly closed, variably iron stained, smooth, and spaced at 6- to 36-inch intervals.
- Strike N50-80E, dip 20-55°SE (cross foliation joints) – closed, iron stained to moderately weathered, rough, discontinuous, and spaced at irregular intervals.

In the excavation for abandoned Unit 3, a minor joint set exhibits strike of N20-60W and dip of 40-65°SW and is spaced at irregular intervals. In the abandoned Unit 4 excavation, a minor joint set was found to strike N40E and dip 60-85°NW. This set is tightly closed and spaced at 8- to 24-inch intervals.

2.5.1.2.5 Site Area Geologic Hazard Evaluation

The only geologic hazard determined to be associated with the ESP site is earthquake activity with its resulting vibratory ground motion effects and potential for surface faulting. A detailed discussion of earthquakes and their effects on the ESP site is provided in Section 2.5.2 and Section 2.5.3.

2.5.1.2.6 Site Engineering Geology Evaluation

Evaluation of engineering geology conditions at the ESP site has been performed based on a review of existing site-specific reports, geologic and geotechnical investigations, and geologic literature. The results of the geotechnical investigations are presented in detail in Section 2.5.4.

a. **Engineering Behavior of Soil and Rock**

Soil

The saprolite at the ESP site is comprised of micaceous silty, clayey sand and sandy silt/clay with occasional-to-many relict rock fragments. Depending on the degree of weathering, the saprolite more or less retains the fabric or structure of the parent bedrock. Weathering tends to decrease with increasing depth, resulting in a boundary between the saprolite and weathered bedrock that is generally not well defined. While the saprolite has the relict structure of the parent bedrock, its engineering properties typically resemble those of a soil. It exhibits certain aspects that are characteristic of both cohesive and cohesionless soils.

The saprolite at the site has been categorized into Zone IIA and Zone IIB saprolite, based on its general composition and grain size (Section 2.5.4). Zone IIA saprolite has been classified as silty sand (SM), clayey sand (SC), and high and low plasticity silt and clay (MH, ML, CH, and CL). Zone IIB saprolite has been classified as silty sand (SM). Zone IIA saprolite is the more weathered of the two saprolites and contains less than 10 percent relict rock fragments. An average SPT N-value of 20 blows per foot (bpf) for this saprolite indicates medium dense conditions. Zone IIB saprolite contains between 10 and 50 percent relict rock fragments, and an average SPT N-value of 100 bpf. Section 2.5.4 provides an extensive discussion of the geotechnical properties of the saprolite at the ESP site.

The presence of mica in the saprolite is likely to reduce its maximum compacted density and increase its compressibility. The SWR pump house for the existing units was constructed on about 65 feet of Zone IIA saprolite, consisting mainly of sandy silt, with frequent layers of micaceous sandy silt. For about two years after its construction, the pumphouse structure underwent relatively high settlement that declined significantly thereafter. The settlement was caused by the weight of the SWR dike fill built up around the pumphouse. The micaceous nature of the material is considered to have played a major role in the settlement. High compressibilties and low maximum densities of the saprolite, therefore, preclude using it as engineered fill at the ESP site.

The geotechnical engineering design properties of the saprolite are presented and presented in Section 2.5.4. The behavior of the saprolite with respect to liquefaction and slope stability is presented in Section 2.5.4 and Section 2.5.5, respectively.

Rock

Bedrock at the ESP site is comprised predominantly of gray to dark gray quartz gneiss with biotite, interbedded with a biotite quartz gneiss; and interbedded quartz gneiss, biotite quartz gneiss and hornblende gneiss of the Ta River Metamorphic Suite. The gneiss is a hard, foliated rock, which exhibits various degrees of weathering. It is the degree of weathering of the rock that affects its engineering behavior and properties.

The gneiss at the site has been categorized into Zone III, Zone III-IV, and Zone IV based on its degree of weathering. Zone III is the uppermost weathered part of the bedrock. It is highly to moderately weathered and fractured and contains traces of clay and iron oxide. Based on the results of the borings drilled for the ESP investigation (Appendix 2.5.4B) and previous geotechnical investigations (Reference 7) (Reference 8), the average percentage of rock core recovered by borings in Zone III is 60 percent and the average rock quality designation (RQD) value is 20 percent. An RQD of 20 percent is indicative of poor quality rock (Reference 109).

Zones III-IV and IV are considerably less weathered, the degree of weathering typically decreasing with increasing depth. Zone III-IV is slightly to moderately weathered and Zone IV is slightly weathered to fresh. Based on the results of the borings drilled for the ESP investigation (Appendix 2.5.4B) and previous geotechnical investigations (Reference 7) (Reference 8), the average percentage of rock core recovered from Zones III-IV and IV are 90 percent and 100 percent, respectively. The average RQD values for Zones III-IV and IV are 50 percent and 95 percent, respectively. RQD values of between 50 and 90 percent are indicative of fair to excellent quality rock (Reference 109). Therefore, the boring results indicate that Zones III-IV and IV are suitable bearing surfaces on which to found the Category I plant structures. The joints and fractures present in both zones are not considered to be of sufficient density or areal extent to affect the engineering behavior of the rock with respect to its foundation bearing capacity or integrity.

Geologic mapping of foundation rock performed during excavation for the abandoned Units 3 and 4 (Reference 107) revealed primarily fresh and sound gneiss, with weathering generally limited to the joints and shear zones. Major joint sets were reported as generally tightly closed and clean with some iron staining. While not evenly distributed throughout the rock mass, minor joint sets were reported to yield rhombic blocks of intact gneiss with side dimensions of about 1 foot to 2 feet. Minor overbreak and the development of rock wedges, caused by jointing in the rock, were reported during excavation.

The slipping of rock wedges and the "popping" of rock blocks would be likely to occur during excavation at the site can be caused not only by the interception and condition of joints in the rock mass but also by stress relief in the rock. The gneiss has been tectonically stressed and so residual stress in the rock is likely to be relieved by slippage along foliations and joints, the "popping" of rock blocks, and the opening of joints. These adjustments to stress are likely to be minor and any unstable rock wedges or blocks would either be removed or adequately supported; open joints would be filled with cement grout.

The geotechnical engineering design properties of the bedrock are presented and presented in Section 2.5.4. The behavior of the bedrock with respect to slope stability is presented in Section 2.5.5.

b. **Zones of Alteration, Weathering and Structural Weakness**

Borings drilled as part of the ESP investigation (Appendix 2.5.4B) and previous geotechnical investigations (Reference 7) (Reference 8), and excavations for construction of the existing units and abandoned Units 3 and 4 (Reference 107) indicate that the gneiss at the ESP site is moderately to intensely jointed. Several joint sets have been identified at the site, namely foliation plane joints and cross foliation joints. They are typically of limited extent, slightly rough to smooth, and contain iron oxide and some clay fill indicative of minor shear movement. Those joints that are continuous over a larger area of the site are generally tight, smooth, and seldom show any shear movement or clay fill.

Micro-shear zones and zones of severely weathered and fractured rock have also been identified in the gneiss at the site. The micro-shear zones have developed within the foliation, and are discontinuous. They reflect minor adjustment to stress during regional deformation.

Several zones of severely weathered and fractured rock were encountered in the borings drilled as part of the ESP investigation (Appendix 2.5.4B). The zones were typically found in slightly weathered to moderately weathered gneiss at depths ranging between 11 feet (Elevation 260) and 81 feet (Elevation 211) below the ground surface. The zones are typically 0.5 to 1-foot thick and contain quartz, clay and iron oxides.

Because of the tendency for zones of severely weathered and fractured rock to weather further upon exposure, they would be removed and replaced with cement grout where

encountered in excavations for the new units. This would ensure adequate bearing capacity of the foundation rock mass.

c. **Deformational Zones**

A shear zone was found in the Ta River Metamorphic Suite during the excavation for abandoned Units 3 and 4. The shear zone was investigated by Dames and Moore (Reference 9) and the results presented to the U.S. Atomic Energy Commission (Reference 105). The results of the investigation concluded that movement occurred along the shear zone approximately 200 million years ago, and that movement has not occurred since, or at least not within the last one million years, given the relatively undisturbed thickness of residual soil that overlies the shear zone. The results of the investigation also concluded that the shear zone is of limited extent, and while it was traced through the existing units foundation area, no evidence of movement was observed along this section of the shear zone.

The U.S. Atomic Energy Commission, following a review of the results of the above mentioned investigation, concluded that the shear zone at the site is not “capable”, within the meaning of Section III(g) of 10 CFR 100, Appendix A (Reference 108).

d. **Prior Earthquake Effects**

There is no physical evidence of any fissuring, liquefaction, landsliding, lurching, or caving of banks to indicate that past earthquake ground shaking has disturbed either the surficial sediments or bedrock beneath the ESP site. Given the relatively low intensity of historic ground shaking at the site, it its not expected that these types of features would have formed during the historical period. Given the lack of seismically-induced features in the geologic record, there is no evidence of any prior earthquake effects at the site.

The maximum earthquake intensity the site has experienced historically is MMI V. The site experienced this level of shaking in both the 1897 Giles County and 1875 Goochland County earthquakes, the two largest earthquakes to occur in the State of Virginia. The m_b 5.8 Giles County earthquake occurred on May 31, 1897 and produced MMI VII-VIII shaking in the epicentral area of Pearisburg in southwestern Virginia. Isoseismal maps of this event show that the ESP site experienced MMI V (Reference 58). The earlier m_b 5.0 event centered in Goochland County occurred on December 23, 1875 and is the largest earthquake to occur in the CVSZ. The maximum intensity estimated for this event is MMI VII in the epicentral region (Reference 80). The ESP site is located within the CVSZ, which is an area of persistent, low-level seismicity in the Piedmont Province (as presented in Section 2.5.1.1.4).

e. **Effects of Human Activities**

Mineral Extraction

Massive sulfide and gold deposits have been mined from meta-sedimentary and meta-volcanic rocks of the Chopawamsic belt in the vicinity of the ESP site from the 1700s to

1974. The deposits have been mined predominantly in and around the town of Mineral, approximately 7 miles west of the site. Deposits within a 5-mile radius of the site have been designated the Allah Cooper, Sulfur, Cofer, and Old Dominion. The Allah Cooper deposit is about 3 miles northwest of the site, while the Sulfur, Cofer and Old Dominion deposits are approximately 5 miles southwest of the site (Reference 110) (Reference 111) (Reference 112) (Reference 113).

Based on published documentation of these mining activities and their proximity to the site, the ESP site has not been affected, nor would it be affected, by these mining activities.

Groundwater Withdrawal

Regional groundwater (presented in Section 2.4.12) withdrawal from the surficial sediments and bedrock around the ESP site is not an issue due to the low withdrawal quantities and limited areal extent of the withdrawals. Withdrawals at the site have included temporary dewatering for foundation construction of the existing units and abandoned Units 3 and 4. No adverse affects from this dewatering are reported to have occurred. Current site groundwater withdrawal is generally limited to water supply wells for plant drinking and process water purposes. No adverse affects as a result of these water supply withdrawals have been documented.

f. **Construction Groundwater Control**

Groundwater at the ESP site generally occurs at depths ranging from about 6 to 58 feet below the present day ground surface. The exception to this is the area of the abandoned Unit 3 and 4 excavation, which was partially backfilled and where groundwater is within about 2 feet of the ground surface. Groundwater levels at the site would likely result in the need for temporary dewatering of foundation excavations extending below the water table. Dewatering would be performed in a manner that would minimize drawdown effects on the surrounding environment. Drawdown effects would be expected to be limited to the ESP site and no offsite users would be anticipated to be affected.

g. **Unforeseen Geologic Features**

Future excavations for safety-related structures would be geologically mapped. Unforeseen geologic features that are encountered would be evaluated. The NRC would be notified when any excavations for safety-related structures are open for their examination and evaluation.

2.5.1.2.7 Site Groundwater Conditions

Groundwater is present in unconfined conditions in both the surficial sediments and underlying bedrock at the ESP site. Between December 2002 and June 2003, nine observation wells installed at the site as part of the subsurface investigation program have exhibited groundwater level elevations ranging from about Elevation 241 to Elevation 311. Hydraulic conductivity values for the saprolite in which eight of the wells were screened, based on the results of slug tests in the wells,

range from about 0.2 to 3.4 ft/day. The hydraulic conductivity of the shallow bedrock in which one of the wells was screened is estimated to be about 2 to 3 ft/day. Groundwater movement at the site is generally to the north and east, toward Lake Anna.

A detailed discussion of the site groundwater conditions is provided in Section 2.4.12.

2.5.2 Vibratory Ground Motion

The purpose of Section 2.5.2 is to determine ground motions at the ESP site from possible earthquakes that might occur in the NAPS site region and beyond. The information provided in this section complies with NUREG-0800, Section 2.5.2, Revision 3 (Reference 114). The procedure described in RG 1.165 (Reference 2) has been used with certain modifications as presented below, and has its basis in the seismic hazard calculations published by EPRI (Reference 115). As recommended in RG 1.165, the following general steps were undertaken:

- Review and update EPRI seismic source models
- Review and update EPRI ground motion models
- Perform sensitivity studies or updated probabilistic seismic hazard analyses to determine whether any new seismic source or ground motion models significantly increase the published EPRI results
- Derive SSE ground motions from the original or updated seismic hazard results

Section 2.5.2.1 through Section 2.5.2.4 document the review and update of the available EPRI seismic source and ground motion models. Section 2.5.2.5 summarizes basic information about the seismic wave transmission characteristics of the ESP site with reference to more detailed discussion of all engineering aspects of the shallow subsurface in Section 2.5.4.

Section 2.5.2.6 describes development of the SSE ground motion for the ESP site. The selected SSE ground motion is based on two approaches: a reference probability approach in accordance with RG 1.165 and a “performance-based approach.”

Development of the reference probability approach begins with implementation of the provisions of RG 1.165, specifically Regulatory Position 2 and Appendix E. As presented in Section 2.5.2.6.5, the combined effect of new seismic source/seismicity information is small, leading to an increase of only several percent in the longer period (1 Hz) 10^{-5} median seismic hazard at the ESP site and no significant increase in the higher-frequency (10 Hz) motion. The effect of the new EPRI ground motion models (Reference 116) is complex, depending on interplay between details of both the median ground motion relations and their aleatory uncertainties, and the impact varies for different ground motion spectral frequencies and specified seismic hazard levels. At the highest-frequency (10 Hz) ground motion and seismic hazard level (10^{-5} median seismic hazard) specified under RG 1.165 guidance, increased aleatory uncertainty in the new EPRI ground motion models results in spectral accelerations over 55 percent higher than the previous EPRI model. Therefore, the change in ground motion models would likely result in significant changes in hazard predictions for the selected plant sites used to estimate the reference probability as shown in RG 1.165, Table B.1. If general revisions to PSHA methods or data bases result in significant changes in hazard predictions for the selected plant sites in Table B.1 of RG 1.165, Appendix B, the RG provides the methodology that should be used to determine a revised reference probability. The procedure specified in RG 1.165, Appendix B, to establish a reference probability requires a three-step

calculation of the seismic hazard results for the 29 sites of Table B.1. First, the seismic hazard must be determined at each site for spectral responses at 5 and 10 Hz. Second, the composite annual probability of exceeding each site's licensing-basis SSE must be determined for spectral responses at 5 and 10 Hz using median hazard estimates. Finally, a reference probability must be determined by finding the median of the distribution of annual exceedance probabilities for the 29 plants in Table B.1. Any revised calculation of the reference probability, therefore, would require a new seismic analysis for the remaining 28 sites of Table B.1.

As an alternative to performance of a complete new 29-site reference probability analysis, a reference probability corresponding to a mean 5×10^{-5} annual probability of exceedance was used for this approach. This is an estimate of the reference probability that would result from a 29-site analysis, taking into account current ground motion equations, new seismic sources, and current estimates of recurrence intervals of large earthquakes in the central and eastern U.S. These changes are described in Section 2.5.2.6.7.

The second approach used to select the SSE ground motion was a "performance-based approach" as described in Section 2.5.2.6.7. This approach uses a methodology adopted from three recent studies that recommend seismic design levels for nuclear facilities in the United States. These studies are DOE 1020 (Reference 117), a draft ASCE standard (Reference 118), and NUREG/CR-6728 (Reference 119). This approach develops a "performance-based-spectrum" that has a mean annual frequency of 10^{-5} of unacceptable performance of nuclear structures, systems, and components as a result of seismically initiated events. The performance-based spectrum is achieved by starting from a ground motion spectrum with a selected mean annual frequency of exceedance, and modifying this spectrum by a scale factor that is based on the slope of the mean seismic hazard curve between 10^{-4} and 10^{-5}. Although based on a different statistic (mean rather than median ground motion of RG 1.165), the same source and ground motion models are used in both cases and only seismic hazard curves at the ESP site need be used to develop the SSE.

The reference probability and performance-based approaches yield similar amplitudes over the range of frequencies. Conservatively, the selected SSE ground motion is chosen to envelope both approaches.

The derivation of the selected vertical SSE spectrum is described in Section 2.5.2.6.7. The derivation of the OBE, as a simple multiple of the SSE, is given in Section 2.5.2.7.

2.5.2.1 **Seismicity**

The seismic hazard analysis conducted by EPRI (Reference 115) relied on an analysis of historical seismicity in the Central and Eastern United States (CEUS) to estimate seismicity parameters (rates of activity and Richter b-values) for individual seismic sources. The historical earthquake catalog used in the EPRI analysis was complete through 1984. To evaluate the potential significance of any re-interpretation of past earthquakes of more recent sesimicity, the EPRI

earthquake catalog was reviewed and updated for the ESP site region for the time period from 1985 through 2001.

2.5.2.1.1 Regional Seismicity Catalog Used for 1989 EPRI Study

Many seismic networks record earthquakes in the CEUS. A large effort was made during the EPRI study to combine available data on historical earthquakes, and to develop a homogeneous earthquake catalog that contained all recorded earthquakes for the region. “Homogeneous” means that estimates of body-wave magnitude m_b for all earthquakes are consistent, that duplicate earthquakes have been eliminated, that non-earthquakes (e.g., mine blasts and sonic booms) have been eliminated, and that significant events in the historical record have not been missed. Thus, the EPRI catalog forms a strong basis on which to estimate seismicity parameters.

2.5.2.1.2 Updated Seismicity Data

The EPRI catalog includes earthquakes in the CEUS through 1984. To extend the catalog, several more recent sources of data were examined. The region within 200 miles of the ESP site was used to guide the selection of catalogs and events, to concentrate on the area that has the most significance to seismic hazard at the ESP site. This region is bounded by the latitude-longitude window 35°–41°N and 74°–82°W. Regarding magnitude scales for this region, a variety of body-wave magnitudes or their equivalents have been used in the CEUS, including m_b, m_{bLg}, m_N, and m_{Lg}. For the purpose of this section, these magnitudes are considered equal.

The most complete regional catalog for recent times is considered to be that published by the Virginia Polytechnic Institute and State University (VT) and maintained by Martin Chapman of VT. This catalog is available through 2001 for the states of Virginia, Maryland, Delaware (south of 40°N), West Virginia (south of 40°N), North Carolina, South Carolina, Georgia, Florida, Alabama, Tennessee (east of 88°W), and Kentucky (east of 88°W). This catalog is considered the authoritative catalog for the southeastern US by the Advanced National Seismic System (ANSS) website (quake.geo.berkeley.edu/anss). It is considered complete since 1985 down to m_b = 3.0 for the states surrounding the ESP site.

North of the southern border of Pennsylvania (approximately 39.7°N) the VT catalog is not complete. To supplement the catalog of earthquakes within 200 miles of the site but north of 39.7°N, the catalog from ANSS was used. This catalog is considered complete through May 15, 2003 for $m_b \geq 3$.

The VT catalog and the ANSS catalog were merged, using the VT catalog for latitudes below 39.7°N and using the ANSS catalog for latitudes of 39.7°N and higher, and retaining only earthquakes with $m_b \geq 3.0$. This gave 97 earthquakes from the VT catalog (1985 through 2001) and 45 earthquakes from the ANSS catalog (1985 through May 15, 2003), 8 of which occurred in 2002 and 2003. Most of the VT catalog events had m_b magnitude values assigned instrumentally, with coda and intensity-based magnitudes also assigned in some cases. (One earthquake from the VT catalog north of 39.7°N with coda magnitude = 3.0 was retained because it was not included in the

ANSS catalog). For conservatism the largest of the magnitude assignments was used in later analysis. Some of the ANSS catalog events (north of 39.7°N) indicated ML (local magnitude), **M** (moment magnitude), or unknown magnitude values. These were taken to be equivalent to m_{Lg}. This approximation for these low-magnitude earthquakes was considered acceptable because the region where the ANSS catalog was used (north of 39.7°N) does not include the CVSZ, the dominant source of seismic hazard at the ESP site, as presented in Section 2.5.2.6.1. Further, only 6 ANSS earthquakes occurred within 200 miles of the ESP site, i.e., at latitudes less than 41°N.

The result of the above process was a catalog of 30 earthquakes (24 from the VT catalog, 1985 through 2001, and 6 from the ANSS catalog, 1985 through May 15, 2003) within the region bounded by 35°–41°N and 74°–82°W, again, which defines a region including everything within 200 miles of the ESP site. These earthquakes are listed in Table 2.5-4.

For the purpose of mapping updated regional seismicity along with the EPRI 1989 (Reference 115) seismic source model beyond 200 miles of the ESP site—specifically, outside the area bounded by 35°–41°N and 74°–82°W—the ANSS catalog alone was used to supplement the seismicity catalog update presented above for events from 1985 onward, retaining the EPRI catalog for events through 1984. As with the update of the seismicity within 200 miles of the ESP site, the largest of the magnitude assignments in the ANSS catalog was used.

2.5.2.2 Geologic Structures and EPRI Seismic Source Model for the Site Region

As described in Section 2.5.1, a comprehensive review of available geological, seismological, and geophysical data has been performed for the ESP site region and adjoining areas. The following sections summarize in some detail seismic source interpretations from the 1989 EPRI study and the interpretations of new sources based on more recent data.

Based on evaluation of this information, no new information was found that would suggest potentially significant modifications to the EPRI seismic source model with the following three exceptions:

- The ECFS represents a new postulated seismic source along the Atlantic Seaboard, as described in Section 2.5.1. The northern segment comes within 70 miles of the ESP site.
- The average recurrence interval for large magnitude earthquakes in the Charleston seismic source zone currently is believed to be 550 years based on paleoliquefaction data, rather than several thousand years based on seismicity used in the EPRI seismic source model, and the Charleston source geometry has been modified to include the possibility that the Charleston earthquake occurred on the southern segment of the ECFS.
- The average recurrence interval for large magnitude earthquakes in the New Madrid seismic zone currently is believed to be 500 years based on paleoliquefaction data, rather than several thousand years based on seismicity used in the EPRI seismic source model.

Sensitivity analyses were performed to evaluate the potential significance of the ECFS and of the new reference model for a characteristic Charleston-type earthquake to seismic hazard at the ESP site, as described in Section 2.5.2.6.3. Based on the results of these analyses it is shown that the effect of the current model for recurrence of large New Madrid-type earthquakes is not significant.

2.5.2.2.1 Summary of EPRI Seismic Sources

This section summarizes the seismic sources and parameters used in the 1989 EPRI project (Reference 115). The description of seismic sources is limited to those sources within 200 miles of the ESP site (the "site region") and those at distances greater than 200 miles that may impact the hazard at the ESP site.

In the EPRI project, six independent Earth Science Teams (ESTs) evaluated geologic, geophysical, and seismological data to develop seismic sources in the CEUS. These sources were used to model the occurrence of future earthquakes and evaluate earthquake hazards at nuclear power plant sites across the CEUS. The six ESTs involved in the EPRI project were the Bechtel Group, Dames & Moore, Law Engineering, Rondout Associates, Weston Geophysical Corporation, and Woodward-Clyde Consultants. Each team produced a report (Volumes 5 through 10 of Reference 120) providing detailed descriptions of how they identified and defined seismic sources. The results were implemented into a probabilistic seismic hazard analysis (PSHA) reported in Reference 115. For the computation of hazard in the 1989 study, a few of the seismic source parameters were modified or simplified from the original parameters determined by the six ESTs. The parameters used in final PSHA calculations are summarized in Reference 121, which is the primary source for the seismicity parameters used in this study. Each of the six ESTs provided more detailed descriptions of the philosophy and methodology used in evaluating tectonic features and establishing the seismic sources (refer to Volumes 5 through 10 of Reference 120).

The seismic source models developed for each of the six EPRI teams are shown on Figure 2.5-19 through Figure 2.5-24. Within each figure, the sources that contributed 99 percent of the North Anna site hazard are shown in color and are labeled. For the 1989 EPRI seismic hazard calculations, a screening criterion was implemented so that all sources whose combined hazard was less than 1 percent of the total hazard were excluded from the analysis (Reference 115, Section 2). Earthquakes with body-wave magnitude $m_b \geq 3.0$ are also shown on Figure 2.5-19 through Figure 2.5-24 to show the spatial relationship between seismicity and seismic sources. Earthquake epicenters include events from the EPRI earthquake catalog for the period between 1627 and 1984, updated with seismicity in the CEUS for the period between 1985 and 2001 as described in Section 2.5.2.1.2.

The maximum magnitude, closest distance, and probability of activity of each team's seismic sources are summarized in Table 2.5-5 through Table 2.5-10. These tables present the parameters assigned to each source and specify whether or not the source contributed to 99 percent of the site hazard in the original EPRI seismic hazard analyses. The tables also indicate whether new

information has been identified that would lead to a revision of the source's geometry, maximum earthquake magnitude, or recurrence parameters. The seismicity recurrence parameters (a- and b-values) used in the EPRI seismic hazard study were computed for each 1-degree latitude and longitude cell that intersects any portion of a seismic source.

The nomenclature used by each team to describe the various seismic sources in the CEUS varies from team to team. That is, a number of different names may have been used by the EPRI teams to describe the same or similar tectonic features or sources, or one team may describe seismic sources that another team does not. For example, the Woodward-Clyde team identified their source that covers the seismicity of central Virginia as the "State Farm Complex" source, whereas most of the other teams named their source as the CVSZ. Each team's source names, data, and rationale are included in their team-specific documentation (Volumes 5 through 10 of Reference 120).

The EPRI seismic hazard study expressed maximum magnitude (M_{max}) values in terms of body-wave magnitude (m_b), whereas most modern seismic hazard analyses describe M_{max} in terms of moment magnitude (**M**). To provide a consistent comparison between magnitude scales, the current study uses an average of three individual magnitude conversion relations (Reference 122) (Reference 123) (Reference 124) to convert m_b to **M** and vice-versa. Throughout this section, the largest assigned values of M_{max} distributions assigned by the ESTs to seismic sources are presented for both magnitude scales, to give perspective on the maximum earthquakes that were considered possible in each source. For example, EPRI m_b values of M_{max} are followed by the equivalent **M** value.

The following sections describe the most significant EPRI sources for each of the six ESTs, with respect to the ESP site. For each team, the listed sources contributed to 99 percent of the total seismic hazard for that team at the ESP site. The assessment of these and other EPRI sources within the site region has found that the EPRI source parameters (maximum magnitude, geometry, recurrence) are sufficient to capture the current understanding of the seismic hazard in the site region.

Except for the three specific cases described earlier, no new seismological, geological, or geophysical information in the literature published since the publication of the 1986 EPRI source model (Reference 120) suggests that these sources should be modified. The three cases where new information requires modification of the EPRI source characterizations is the addition of the northern segment of the ECFS (ECFS-N) as a new potential seismic source, the new recurrence and geometry parameters for the existing Charleston source (modeled after the southern segment of the ECFS (ECFS-S), and the new recurrence parameters for the New Madrid source. These cases are presented in Section 2.5.2.6.3, and sensitivity analyses are performed for the new ECFS and the modified Charleston source in Section 2.5.2.6.5.

2.5.2.2.2 Sources Used for EPRI PSHA – Bechtel Group

Bechtel Group identified and characterized four seismic sources that contributed to 99 percent of the hazard at the ESP site. All four of these sources are within the site region and are the:

- Central Virginia (E)
- Southern Appalachians Region (BZ5)
- Bristol Block (24)
- Atlantic Coastal Region (BZ4)

Also identified within the site region were seven other seismic sources that did not contribute to 99 percent of the hazard at the site. These sources included the:

- Stafford Fault
- Eastern Mesozoic Basins
- New York-Alabama Lineament
- Lebanon Trend
- Giles County
- SE Craton Region
- SE Appalachians

Seismic sources identified by the Bechtel Group team within the site region are listed in Table 2.5-5. A map showing the locations and geometries of the Bechtel seismic sources is provided in Figure 2.5-19. Seismic sources identified by the Bechtel Group that contribute most to the site hazard are the CVSZ and Southern Appalachians Region sources. Following is a brief discussion of each of the seismic sources that contributed to 99 percent of the site hazard.

a. **Central Virginia (E)**

   The ESP site is located within the CVSZ (E) approximately 15 miles south of its northern boundary. The source was defined exclusively on the basis of seismicity in the central Virginia region. No tectonic features were identified within the source. The largest maximum earthquake magnitude (M_{max}) that the Bechtel Group assigned to this zone was body-wave magnitude (m_b) 6.6 (**M** 6.5).

b. **Southern Appalachians Region (BZ5)**

   The ESP site is located within the Southern Appalachians Region background source (BZ5). It is a large background source that extends from New York to Georgia and encompasses a majority of the site region. The largest M_{max} assigned by the Bechtel Group to this zone was m_b 6.6 (**M** 6.5).

c. **Bristol Trends (24)**

The Bristol Trends source (24) is about 38 miles northwest of the ESP site. This source was defined based on series of magnetic and gravity lows bordered on the west by the New York-Alabama lineament and on the east by the Clingman lineament. The largest M_{max} assigned by the Bechtel Group to this zone was m_b 6.6 (**M** 6.5).

d. **Atlantic Coastal Region (BZ4)**

The Atlantic Coastal Region background source (BZ4) is located about 90 miles southeast and east of the ESP site. This source is a large background zone that extends from offshore New England to Georgia and encompasses the easternmost portion of the site region. The largest M_{max} assigned by the Bechtel Group to this zone was m_b 7.4 (**M** 7.9).

2.5.2.2.3 Sources Used for EPRI PSHA – Dames & Moore

Dames & Moore identified and characterized 7 seismic sources that contributed to 99 percent of the hazard at the ESP site. All 7 of these sources are within the site region and include:

- CVSZ (40)
- Southern Cratonic Margin (41)
- Southern Appalachian Mobile Belt (53)
- Newark-Gettysburg Basin (42)
- Connecticut Basin (47)
- Appalachian Fold Belts (4)
- Kink in Fold Belt (4B)

Also identified within the site region were 12 other seismic sources that did not contribute to 99 percent of the hazard. These less significant sources include the Stafford Fault Zone, Hopewell Fault Zone, several Triassic basins, and two combination zones.

Seismic sources identified by Dames & Moore within the site region are listed in Table 2.5-6. A map showing the locations and geometries of these seismic sources is provided in Figure 2.5-20. The seismic source identified by Dames & Moore that contributes the most to the North Anna site hazard is the CVSZ. Following is a discussion of each of the seismic sources that contribute to 99 percent of the hazard at the ESP site.

a. **Central Virginia (40)**

The CVSZ (40) is about 15 miles south of the ESP site. This source was defined based on the pattern of clustered seismicity in the central Virginia area. No known tectonic features were associated with this seismic activity. The largest M_{max} assigned by the Dames & Moore team to this zone was m_b 7.2 (**M** 7.5).

b. **Southern Cratonic Margin (41)**

The ESP site is located within the Southern Cratonic Margin default zone (41), a large background source. This large default zone is located between the Appalachian Fold Belt (4) and the Southern Appalachian Mobile Belt (53) and includes the region of continental margin deformed during Mesozoic rifting. Located within this default zone are many Triassic basins and border faults. The largest M_{max} assigned by the Dames & Moore team to this zone was m_b 7.2 (**M** 7.5).

c. **Southern Appalachians Mobile Belt (53)**

The Southern Appalachians Mobile Belt default zone (53) is about four miles east of the ESP site. This default source comprises crustal rocks that have undergone several periods of divergence and convergence. The source is bounded on the east by the East Coast magnetic anomaly and on the west by the westernmost boundary of the Appalachian gravity gradient. The largest M_{max} assigned by the Dames & Moore team to this zone was m_b 7.2 (**M** 7.5).

d. **Newark-Gettysburg Basin (42)**

The Newark-Gettysburg Basin source (42) is about 20 miles northwest of the ESP site. This source incorporates the Newark, Gettysburg, and Culpeper Triassic basins that formed during Mesozoic rifting. The largest M_{max} assigned by the Dames & Moore team to this zone was m_b 7.2 (**M** 7.5).

e. **Connecticut Basin (47)**

The Connecticut Basin (47) source is about 25 miles east of the ESP site. Similar to the Newark-Gettysburg Basin (42), this source was defined based on the presence of a Triassic basin and the assumption that the bounding Mesozoic rift structures could be reactivated. The largest earthquake maximum magnitude value assigned by the Dames & Moore team to this zone was m_b 7.2 (**M** 7.5).

f. **Appalachian Fold Belts (4)**

The Appalachian Fold Belts source (4) is about 46 miles west of the ESP site. This source extends from New York to Alabama and consists of the Appalachian folded mountain belt of Paleozoic age. The largest M_{max} assigned by the Dames & Moore team to this zone was m_b 7.2 (**M** 7.5).

g. **Kink in Fold Belt (4B)**

The Kink in Fold Belt source (4B) is about 90 miles west of the ESP site. Kinks in Paleozoic fold belts were defined based on bends of the fold belts and areas of greater seismicity. Kink (4B) includes the zone of seismicity in the Giles County area and was thought to contain the arm of a failed rift. The largest M_{max} assigned by the Dames & Moore team to this zone was m_b 7.2 (**M** 7.5).

2.5.2.2.4 Sources Used for EPRI PSHA – Law Engineering

Law Engineering identified and characterized 14 seismic sources that contributed to 99 percent of the hazard at the ESP site. These sources include:

- Eastern Basement (17)
- seven individual mafic plutons (M19, M20, M21, M22, M23, M24, M27)
- Eastern Basement Background (217)
- Eastern Piedmont (107)
- Reactivated Eastern Seaboard Normal (22)
- Mesozoic Basins (C09)
- two combination sources (C10 and C11)

Law Engineering also identified 15 other seismic sources within the site region that did not contribute to 99 percent of the hazard. The majority of these 15 are mafic pluton seismic sources.

Seismic sources identified by Law Engineering within the site region are listed in Table 2.5-7. A map showing the locations and geometries of the Law Engineering seismic sources is provided in Figure 2.5-21. Seismic sources identified by the Law Engineering team that contribute most to the North Anna site hazard are the Eastern Basement (17) and local mafic pluton source (M22). Following is a brief discussion of each of the seismic sources that contributed to 99 percent of the site hazard.

a. **Eastern Basement (17)**

   The ESP site is located within the Eastern Basement source (17) approximately 5 miles from its eastern boundary. This source was defined as an area containing pre-Cambrian and Cambrian normal faults, developed during the opening of the Iapetus Ocean, in the basement rocks beneath the Appalachian decollement. The Giles County and eastern Tennessee zones of seismicity are included in this source. The largest M_{max} assigned by the Law Engineering team to this zone was m_b 6.8 (**M** 6.8).

b. **Mafic Plutons (M19, M20, M21, M22, M23, M24, M27)**

   The seven most significant mafic pluton sources (M19, M20, M21, M22, M23, M24, M27) are located between 23 and 159 miles from the ESP site. Mafic pluton M22 is located 23 miles west of the site and represents one of the two most significant sources to the site. Law Engineering considered pre- and post-metamorphic plutons in the Appalachians to be stress concentrators, and therefore, earthquake sources. Law Engineering did not define a seismic source in central Virginia, but the plutons, of small areal extent, capture a majority of the seismicity of central Virginia, due to the method in which 70 percent of the seismicity from the surrounding 1 degree square area (111 km x 111 km) was assigned to each pluton. A single M_{max} of m_b 6.8 (**M** 6.8) was assigned by the Law Engineering team to all mafic pluton sources.

c. **Eastern Basement Background (217)**

The ESP site is located within the Eastern Basement Background source (217) approximately five miles west of its eastern boundary. This source was characterized as a seismotectonic region having a negative Bouger gravity field (Appalachian gravity low) and a pattern of long wavelength magnetic anomalies. The western boundary is the New York-Alabama lineament and the eastern boundary is the Appalachian gravity gradient. The largest M_{max} assigned by the Law Engineering team to this zone was m_b 5.7 (**M** 5.3).

d. **Eastern Piedmont (107)**

The Eastern Piedmont (107) is about four miles east of the ESP site. This source was characterized as a seismotectonic region having a positive Bouger gravity field and a pattern of short wavelength magnetic anomalies. Law Engineering interpreted this source to represent a crustal block underlain by mafic or transitional crust east of the relict North American continental margin. The largest M_{max} assigned by the Law Engineering team to this zone was m_b 5.7 (**M** 5.3).

e. **Reactivated Eastern Seaboard Normal (22)**

The Reactivated Eastern Seaboard Normal (22) source is about four miles east of the ESP site. This source was characterized as a region along the eastern seaboard in which Mesozoic normal faults are reactivated as high-angle reverse faults. A single M_{max} of m_b 6.8 (**M** 6.8) was assigned by the Law Engineering team to this zone.

f. **Mesozoic Basins (C09)**

The Mesozoic basins (C09) source includes eight bridged basins, the closest of which is about 18 miles from the ESP site. This source was defined based on northeast-trending, sediment-filled troughs in basement rock bounded by normal faults. The largest M_{max} assigned by the Law Engineering team to this zone was m_b 7.4 (**M** 7.9).

g. **Combination sources (GC11, C10)**

The two combination sources (C10 and C11) represent Mesozoic Basins excluding the Charleston region, and the Reactivated Eastern Seaboard zone excluding the Charleston region. The largest M_{max} assigned by the Law Engineering team to both combination sources was m_b 6.8 (**M** 6.8).

2.5.2.2.5 Sources Used for EPRI PSHA – Rondout Associates

Rondout identified and characterized three seismic sources that contributed to 99 percent of the hazard at the ESP site. All three sources are within the site region and include:

- Central Virginia (29)
- Giles County (30)
- Shenandoah (28)

Rondout also identified eight other seismic sources within the site region that did not contribute to 99 percent of the hazard at the site. These sources include:

- Quakers
- Norfolk Fracture Zone
- Appalachian
- Grenville
- Four combination zones

Seismic sources identified by Rondout within the site region are listed in Table 2.5-8. A map showing the locations and geometries of the Rondout seismic sources is shown in Figure 2.5-22. The seismic source identified by Rondout that contributes the most to the ESP site hazard is the CVSZ. Following is a discussion of each of the seismic sources that contribute to 99 percent of the hazard at the North Anna site.

a. **Central Virginia (29)**

The ESP site is on the northern boundary of the Rondout's Central Virginia source. This source was defined based on seismicity and the possible intersection of the extension of the Norfolk fault zone and the northeast-trending linear zone defined by aeromagnetic, gravity, and volcanic-plutonic rocks. The largest M_{max} assigned by Rondout to this source was m_b 7.0 (**M** 7.2).

b. **Shenandoah (30)**

The ESP site is on the southern boundary of the Shenandoah source. The site lies essentially on the border of the adjacent Shenandoah and central Virginia sources (Figure 2.5-22). This Shenandoah source was defined based on geophysical and geologic features. The source includes the intersection of the Pittsburg-Washington lineament and the strong gravity gradient associated with the edge of the ancient Paleozoic craton. It also includes both the post-Cretaceous Brandywine and Stafford fault zones. Rondout assigned an M_{max} of m_b 6.5 (**M** 6.3) to this source.

c. **Giles County (28)**

The Giles County source (28) is located about 117 miles west of the ESP site. This source was defined based on historical seismicity, most notably the 1897 m_b 5.8 Giles County earthquake. The largest M_{max} assigned by Rondout to this source was m_b 7.0 (**M** 7.2).

2.5.2.2.6 Sources Used for EPRI PSHA – Weston Geophysical

Weston Geophysical identified and characterized seven seismic sources that contributed to 99 percent of the hazard at the ESP site. All seven of these sources are within the site region and include:

- CVSZ (22)

- Six combination zones (C21, C22, C34, C35, C23, C19)

Weston also identified 30 seismic sources within the site region that did not contribute to 99 percent of the hazard at the site. The majority of these sources are combination zones.

Seismic sources identified by Weston within the site region are listed in Table 2.5-9. A map showing the locations and geometries of the Weston seismic sources is provided in Figure 2.5-24. The seismic source identified by Weston that contributes the most to the site hazard is the CVSZ. Following is a discussion of each of the seismic sources that contribute to 99 percent of the hazard at the site.

a. **Central Virginia Seismic Zone (22)**

   The ESP site is located within the CVSZ (22) about 10 miles south of the northern boundary. This source is defined based on a northwest trending alignment of seismicity that extends from Richmond to Waynesboro, Virginia. The largest M_{max} value assigned by Weston to this zone was m_b 6.6 (**M** 6.5).

b. **Source Combinations (C21, C19, C22, C23, C34, C35)**

   The ESP site is located within four different combination sources (C21, C22, C34, C35) defined by the Weston team. Two additional combination sources, C23 and C19, are located 10 and 27 miles from the site. Five of the combination sources represent the combination of different seismic sources within a large South Coastal Plain Background zone (104). The other sources within this background zone include the CVSZ (22), the Charleston seismic zone (25), the South Carolina seismic zone (26), and Mesozoic basins (28B, C, D, and E). The largest M_{max} assigned by the Weston team to each of these six combination sources was m_b 6.6 (**M** 6.5).

2.5.2.2.7 Sources Used for EPRI PSHA – Woodward-Clyde Consultants

Woodward-Clyde identified and characterized five seismic sources that contributed to 99 percent of the hazard at the ESP site. Three of these sources are within the site region and are:

- State Farm Complex (27)
- Central Virginia Gravity Saddle (26)
- North Anna Background (B22)

The two seismic sources outside the site region are the South Carolina Gravity Saddle (29) and South Carolina Gravity Saddle No. 2 (29A).

Woodward-Clyde also identified eight seismic sources within the site region that did not contribute to 99 percent of the hazard at the site. These sources include:

- Richmond Basin
- Newark Basin

- Tyrone-Mt. Union Lineament
- Pittsburg-Washington Lineament
- New Jersey Isostatic Gravity Saddle
- Three combination zones

Seismic sources identified by Woodward-Clyde within the site region are listed in Table 2.5-10. A map showing the locations and geometries of the Woodward-Clyde seismic sources is provided in Figure 2.5-23. Seismic sources identified by the Woodward-Clyde team that contribute most to the ESP site hazard are the Central Virginia Gravity Saddle, State Farm Complex, and the North Anna Background zones. Following is a brief discussion of each of the seismic sources that contributed to 99 percent of the site hazard.

a. **State Farm Complex (27)**

The State Farm Complex source is about 3 miles south of the ESP site. This source was defined based on pre-Cambrian gneissic terrain located in central Virginia and bounded on the east by the Richmond Basin and on the west by Goochland fault. There is a strong concentration of seismicity on either side of the feature, which is centered in the CVSZ. The largest M_{max} assigned by Woodward-Clyde to this source was m_b 6.9 (**M** 7.0).

b. **Central Virginia Gravity Saddle (26)**

The Central Virginia Gravity Saddle source is about 3 miles southwest of the ESP site. This source was defined based on a saddle in the northeast-trending gravity high associated with the Appalachians. Central Virginia seismicity is located along the south and southwest of the gravity saddle. This source is an alternative interpretation of the seismicity in the central Virginia area. The largest M_{max} assigned by Woodward-Clyde to this zone was m_b 7.0 (**M** 7.2).

c. **North Anna Background (B22)**

The ESP site is located within the Woodward-Clyde North Anna Background source, a large rectangular background source that is centered on the site. The largest M_{max} assigned by Woodward-Clyde to this zone was m_b 6.6 (**M** 6.5).

d. **South Carolina Gravity Saddle (29 and 29A)**

The South Carolina Gravity Saddle (29) and the South Carolina Gravity Saddle No. 2 (29A) are about 259 and 264 miles from the site, respectively. The largest M_{max} assigned to both of these sources was m_b 7.4 (**M** 7.9).

2.5.2.2.8 Characterization of the Central Virginia Seismic Zone

In the 1989 EPRI seismic hazard study (Reference 115), the CVSZ represented the most significant seismic source for the North Anna site (see Section 2.5.2.6.1 below). The EPRI study was designed to elicit multiple expert opinions in an effort to capture the epistemic uncertainty related to lack of knowledge regarding seismic sources in the CEUS. The six ESTs characterized the CVSZ

differently, as shown on Figure 2.5-25 and listed in Table 2.5-11. In spite of these different interpretations, the central portion of each source represents the densest cluster of earthquake activity in the region. The largest M_{max} for these different characterizations of the CVSZ range from m_b 6.6 to 7.2 (**M** 6.5 to 7.5), as listed in Table 2.5-11.

All ESTs, with the exception of Law Engineering, identified a source representing the CVSZ. Law Engineering instead identified multiple mafic plutons in the region. The seismicity parameters for these mafic plutons were calculated from a large region surrounding each pluton, which effectively captures the majority of seismicity in central Virginia. The mafic plutons, therefore, indirectly represent a local seismic source for Law Engineering (see Reference 120, Volume 7).

Since the EPRI study, one probable and two possible liquefaction features have been found within the CVSZ. As described in Section 2.5.1.1.4, these new observations are consistent with the M_{max} values and recurrence parameters assigned by the EPRI teams. The lack of widespread liquefaction features in the 300 km of stream exposures searched within the CVSZ, despite the presence of mid- to late-Holocene potentially liquefiable deposits, has led some researchers (Reference 71) to conclude that it is unlikely that any earthquakes have occurred in the area investigated in excess of **M** ~7 during the Holocene.

2.5.2.2.9 Post-EPRI Source Characterization Studies

Since the EPRI seismic hazard project (Reference 115), studies have been performed to characterize seismic sources within the North Anna site region for probabilistic seismic hazard analyses. These studies include:

- Sources and parameters for the Savannah River nuclear site (Reference 125),
- Seismic hazard of Virginia (Reference 126), and
- The USGS's National Seismic Hazard Mapping Project (Reference 123) (Reference 127).

These references are reviewed in the following paragraphs.

Bollinger (Reference 125) specified sources, recurrence rates, focal depths, and maximum magnitudes for earthquake sources in the southeastern United States to be used in probabilistic seismic hazard analyses at the Savannah River nuclear site in South Carolina (Table 2.5-12). Bollinger's approach to seismic zonation in the Eastern United States was based primarily on the historical record of earthquake activity. Maximum magnitudes were derived from a combination of three different estimates based on the 1000-year earthquake, the maximum historical earthquake plus one magnitude unit, and the calculated values from various published relationships between magnitude and fault rupture area. Bollinger identified three seismic sources within the North Anna site region (200-mile radius). These sources were the CVSZ, the Giles County seismic zone, and a complementary background zone (Table 2.5-12).

The CVSZ was defined by Bollinger as a rectangular zone centered on the majority of the seismicity in the central Virginia area. The maximum magnitude earthquake value estimated for this source

was m_b 6.4 (Reference 125). For the Giles County and complimentary background zone, M_{max} values of m_b 6.3 and m_b 5.75 were used, respectively. The M_{max} values for the Central Virginia, Giles County, and complementary background sources in the Bollinger (Reference 125) study are lower than the largest M_{max} values assigned by most of the EPRI teams.

In 1994, a seismic hazard assessment of Virginia was performed to examine the seismic hazard within Virginia on a county-by-county basis (Reference 126). Seismic sources and earthquake frequency-magnitude recurrence relationships were defined using the results of network monitoring by the Seismological Observatory at Virginia Polytechnic Institute and State University and using published geologic and geophysical investigations. The study defined a total of 10 seismic sources (Table 2.5-13). Within the North Anna site region, Chapman and Krimgold (Reference 126) defined seven contiguous, non-overlapping sources based primarily on patterns of seismicity. The two most prominent areas of historical seismicity within the site region were defined as the Central Virginia and Giles County seismic zones. An M_{max} value of **M** 7.53 (converted to m_b 7.25) was assigned to all sources in their model, with the exception of New Madrid. Chapman and Krimgold assumed that a Charleston-size event was capable of occurring in any of the sources within the North Anna site region. Subsequent to the Chapman and Krimgold study, Johnston (Reference 90) reduced his magnitude estimate of the Charleston earthquake to **M** 7.3 from the prior estimate of **M** 7.53 (as cited in (Reference 126). Using the magnitude conversion described in Section 2.5.2.2.1, **M** = 7.3 converts to m_b=7.1, which is within the range of largest M_{max} values (m_b 6.6 to 7.2) assigned by the EPRI teams to both the Central Virginia and Giles County seismic zones. Thus these later studies are consistent with the interpretations of the EPRI teams.

In 2002, the USGS produced updated seismic hazard maps for the coterminous United States based on new seismological, geophysical, and geological information (Reference 127). The 2002 maps reflect changes to the source model used to construct the previous version of the national seismic hazard maps made in 1996 (Reference 123). The most significant changes to the CEUS portion of the source model included changes in the recurrence and geometry of the Charleston source; and changes in the recurrence, M_{max}, and geometry of the New Madrid sources. Unlike the EPRI models that incorporated many local sources, the USGS source model in the CEUS includes only a small number of sources. The hazard is largely based on historical seismicity and the variation of that seismicity within large background or “maximum magnitude” zones. Within the ESP site region, the USGS model has only defined a single seismic source (the Extended Margin Background zone), which covers nearly the entire eastern and southeastern United States. The USGS assigned a single M_{max} value of **M** 7.5 (m_b 7.2) to this zone (Table 2.5-14). This magnitude exceeds many of the individual EPRI team estimates of M_{max} for sources defined within the area covered by the USGS Extended Margin Background zone. However, because all Dames & Moore sources were assigned M_{max} values up to m_b 7.2 and selected sources from other teams were assigned M_{max} values up to m_b 7.4, the USGS **M** 7.5 (m_b 7.2) magnitude does not represent an inconsistency with the range of values assigned by EPRI teams.

The most significant impact of the 2002 USGS model (Reference 127) on seismic hazard for the ESP site is the updated Charleston source parameters. Modifications of the recurrence and geometry of the fault were the most significant changes to this South Carolina source. The USGS (Reference 127) also revised estimates of M_{max}. These new estimates of Charleston source parameters have been incorporated into the seismic hazard calculations conducted here for the ESP site, as described in Section 2.5.2.6.3, Section 2.5.2.6.6 and Section 2.5.2.6.7.

2.5.2.3 Correlation of Seismicity with Geologic Structures and EPRI Sources

The final part of the review and update of the 1989 EPRI seismic source model was a correlation of updated seismicity with the 1989 model source. The EPRI seismicity catalog covers earthquakes in the CEUS for the time period from 1627 to 1984. This catalog has been updated for this ESP study for the time period from 1985 to 2001 as described in Section 2.5.2.1. Figure 2.5-19 through Figure 2.5-25 show the distribution of earthquake epicenters from both the EPRI (pre-1985) and updated (post-1984) earthquake catalogs in comparison to the seismic sources identified by each of the ESTs.

Comparison of the updated earthquake catalog to the EPRI earthquake catalog yields the following conclusions:

- The updated catalog does not show any earthquakes within the site region that can be associated with a known geologic structure. As described in Section 2.5.1, the majority of seismicity in the ESP site region appears to be occurring at depth within the basement beneath the Appalachian decollement.
- The updated catalog does not show a unique cluster of seismicity that would suggest a new seismic source outside of the EPRI seismic source model.
- The updated catalog does not show a pattern of seismicity that would require significant revision to the EPRI seismic source geometry.
- The updated catalog does not show or suggest any increase in M_{max} for any of the EPRI seismic sources.
- The updated catalog does not show any increase in seismicity parameters (rate of activity, b value) for any of the EPRI seismic sources (see Section 2.5.2.6.5).

2.5.2.4 1989 EPRI Probabilistic Seismic Hazard Analysis, Deaggregation, and 1 Hz, 2.5 Hz, 5 Hz, and 10 Hz Spectral Velocities

A probabilistic seismic hazard analysis (PSHA) was conducted for the NAPS site during the 1989 EPRI study ((Reference 115). The procedure used by EPRI to calculate the 1989 results is consistent with RG 1.165, Regulatory Position 3. This section reviews and replicates the 1989 EPRI PSHA for the NAPS site. RG 1.165 Regulatory Position 4 and Appendices C and F describe how to use PSHA results to determine the controlling earthquake(s) (defined by a magnitude(s) and

distance(s) and the SSE design response spectrum. The procedure uses 1 Hz, 2.5 Hz, 5 Hz, and 10 Hz 10^{-5} median spectral velocity values. The controlling earthquake(s) and spectral velocities for these frequencies are also presented in this section.

The 1989 EPRI study developed seismic source interpretations based on inputs from six ESTs, as described in Section 2.5.2.2. For ground motion estimation, the 1989 EPRI study used three ground motion models, as described below. The 1989 EPRI study used these source interpretations and ground motion models to calculate seismic hazard for peak ground acceleration (PGA) and for 5 spectral frequencies (1, 2.5, 5, 10, and 25 Hz). Results were published for 57 nuclear plant sites in the CEUS (Reference 115) in the form of seismic hazard curves for PGA and uniform hazard spectra.

Three ground motion models were used in the 1989 EPRI PSHA study (see Reference 115, Table 4-1) for peak ground acceleration (PGA) and for spectral response at the five spectral frequencies. These are summarized in Table 2.5-15.

For all models and all frequencies, an aleatory uncertainty (sigma [natural log ground motion]) of 0.5 was used. These ground motion models were used without any correction for soil conditions, because, for purposes of the 1989 EPRI study, the North Anna site was considered a rock site.

For the ESP seismic hazard evaluation, the 1989 EPRI PSHA was reproduced using the 1989 seismic sources and 1989 ground motion models. Risk Engineering Inc.'s proprietary software FRISK88 was used for these calculations. The main results used in this replication were the PGA results (see Table 2.5-16) available for North Anna (see Reference 115, Appendix E, Table 3-61). Seismic hazard curves are available in digital form only for PGA in Reference 115. Selected results were checked for 1 Hz, 2.5 Hz, 5 Hz, and 10 Hz (see Table 2.5-17) based on spectral results for specific exceedance probabilities in Reference 115.

Seismic sources used to represent the seismic hazard for each of the six ESTs that participated in the 1989 EPRI study are listed in Table 2.5-18. These sources were used for the North Anna site in the original 1989 study, as documented in EPRI's computer input files.

The first step consisted of conducting a seismic hazard calculation for PGA for the ESP site. Results of this calculation are compared to the 1989 results in Table 2.5-16.

As listed in Table 2.5-16, the 1989 EPRI results are available only to 2 digits accuracy, which could lead to ±5 percent apparent difference: 1.049E-3 would be represented in 1989 as 1.0E-3 and in 2003 as 1.05E-3, leading to +5 percent apparent difference. On average over the nine seismic hazards compared, the average difference in annual probability of exceedance was +1.1 percent. The difference in ground motion for a given hazard would be even less, because seismic hazard H is related to ground motion amplitude *a* by:

$$H = C\, a^{-K} \qquad \text{Equation 2.5.2-1}$$

(see Equation 3 of Kennedy and Short (1994) (Reference 128)) where C is a constant and K is the slope of the hazard-vs-amplitude curve on log-log scale. From Reference 128, K typically ranges from 3.3 to 1.66. Equation 2.5.2-1 can be rewritten as:

$$a = C^{1/K} H^{-1/K} \qquad \text{Equation 2.5.2-2}$$

With K from 3.3 to 1.66, Equation 2.5.2-2 means that a 1.1 percent change in hazard corresponds to 0.3 percent to 0.7 percent change in ground motion amplitude. This difference is much less than the total uncertainty in seismic hazard and results from differences in numerical integration techniques in the FRISK88 code versus the EPRI code. This comparison confirms that the EPRI 1989 seismic sources and ground motion equations are being modeled correctly by the current application of the FRISK88 code.

The second step consisted of calculating seismic hazard for 1, 2.5, 5, and 10 Hz spectral velocity. FRISK88 was run at these four spectral frequencies to calculate seismic hazard and determine the median 10^{-5} hazard. These were compared to the 1989 EPRI seismic hazard results, as listed in Table 2.5-17. The apparent difference in values of spectral velocity in Table 2.5-17 is small, as it was for PGA, and results from numerical differences in how FRISK88 calculates seismic hazard compared to the software used in the EPRI study.

The third step was to apply the magnitude-distance deaggregation procedure described in RG 1.165 (Reference 2), using these PSHA results. In summary, this procedure requires deaggregating the seismic hazard at the median 10^{-5} ground motion at 1 Hz, 2.5 Hz, 5 Hz, and 10 Hz, combining the 1 and 2.5 Hz deaggregations, combining the 5 and 10 Hz deaggregations, and computing magnitudes and distances of controlling earthquakes for each combination.

Deaggregation plots following this procedure are shown in Figure 2.5-26 and Figure 2.5-27. The body-wave magnitude m_b and epicentral distance r_{epi} of controlling earthquakes were determined and are shown in Table 2.5-23. (For purposes of discussion in Section 2.5.2.6, equivalent moment magnitude **M** and closest distance, r_{CD}, values are also given in Table 2.5-20)

2.5.2.5 Seismic Wave Transmission Characteristics of the Site

The subsurface materials at the ESP site are described in detail in Section 2.5.4. The material characterization is summarized below. The foundation materials are divided into Zones I through IV:

- I Residual clays and clay silts – all structures of parent rock are lost
- IIA Saprolite – core stone less than 10 percent of volume of overall mass
- IIB Saprolite – core stone 10 to 50 percent of soil mass
- III Weathered rock – core stone more than 50 percent of volume of mass
- IV Parent rock – slightly weathered to fresh rock below zone of isolated core stones

In addition to these five categories, a sixth category termed Zone III-IV, representing a slightly to moderately weathered rock, was added to further describe the soil and rock with regard to engineering properties.

The containment (reactor) building and primary supporting safety-related structures would be founded on sound bedrock, either Zone IV or Zone III-IV. However, other safety-related structures (possibly the diesel generator building and certain tanks) may be founded on the Zone III weathered rock or the Zone II saprolitic soils.

The seismic wave transmission characteristics of the site materials are described in Section 2.5.4.7. The description includes the shear wave velocity profile for the site and the variation of shear modulus and damping with strain for Zone II and III materials. As discussed in Section 2.5.4.7, Zone III-IV and IV rock materials behave elastically. Both generic and specific shear wave velocity profiles are described. The generic profile extends from plant grade at an elevation of 271 ft to depths at which the bedrock under the site is estimated to reach a velocity of about 9200 fps. This generic profile is used to evaluate amplification of the 9200 fps hard rock SSE ground motion to the top of competent rock, selected to be at the top of the Zone III-IV material (representative elevation of 250 ft), with a best-estimate shear wave velocity of about 3300 fps. A location-specific profile, differing from the generic profile in its uppermost 70 ft, is used to evaluate liquefaction potential and slope stability at a site typical of the area occupied by the slope to the south of the existing units. Section 2.5.4.6 and Section 2.5.4.7 describe the site-specific acceleration-time history developed for the hard rock SSE and the results of rock and soil column amplification/attenuation analyses.

2.5.2.6 Safe Shutdown Earthquake Ground Motion

RG 1.165 Regulatory Position 2 and Appendix E specify how to develop an SSE ground motion by updating the 1989 EPRI PSHA to include more recent information on seismic sources and ground motion. The following sections describe the information that was used to update the 1989 EPRI study.

2.5.2.6.1 New Regional Earthquake Catalog

Section 2.5.2.1.2 discusses updated seismicity information that was used to extend the 1989 EPRI seismic data to 2001. The effect of this additional data was examined to determine if it would have an impact on seismic hazard. This was accomplished by examining the effect of recent seismicity (1985 to 2001) on the seismic sources that dominate the seismic hazard at the ESP site.

As background for these calculations, the 1989 EPRI study (Reference 115) identified all seismic sources within 200 km of each site and included them in screening calculations. The 1989 study also included the New Madrid, Charleston, and La Malbaie sources in screening calculations for a site if they were within 500 km of that site. The screening included all sources for a given EST that contributed to 99 percent of the seismic hazard at one peak ground acceleration amplitude and one

1-sec spectral velocity amplitude (meaning that the composite contribution of all sources that were eliminated contributed less than 1 percent of the seismic hazard at those amplitudes). See Reference 115, Page 2-16, for further details of this screening process. The sources included for the North Anna site following screening during the 1989 study were used as the starting point for the current calculations.

Seismic hazard was calculated for PGA and 1 Hz spectral response, for each of the EPRI ESTs and for each seismic source used in the 1989 EPRI calculations. Figure 2.5-28 through Figure 2.5-33 show the mean hazards by source for each team for 1 Hz. This spectral frequency increases the relative contribution of more distant sources compared to PGA.

The significant seismic sources, i.e., the sources that contribute most of the hazard at the mean 10^{-5} level, are summarized in Table 2.5-19. This table indicates that representations of the CVSZ dominate the hazard at the ESP site. This is not surprising, since the CVSZ is the closest seismic source to the site. There are other contributing sources (such as the local background source for the Bechtel and Woodward-Clyde teams) representing regional sources that are active under scenarios when the source representing central Virginia seismicity is not active. Also, local smoothing of seismicity parameters by the EPRI teams means that these background sources are representing the higher seismicity in the central Virginia area. Local smoothing in the context of the EPRI study means that historical seismicity in the local area was used to estimate the activity rate in each degree cell within a large source; the historical seismicity was not smoothed over a very broad region. Thus regions such as the CVSZ that have had higher-than-average seismicity in the past would have that higher activity represented by the background source.

The local mafic pluton sources specified by the Law Engineering team had seismicity parameters calculated from historical seismicity in the 111 x 111 km area surrounding each mafic pluton, assigning 70 percent of this seismicity to the mafic pluton (see Reference 120, Volume 7, pages 6-7 to 6-8). This in effect assigned 70 percent of the central Virginia seismicity to mafic pluton sources in central Virginia. The conclusion is that various representations of seismicity for the central Virginia area and for the local background seismicity generally dominate the seismic hazard at the ESP site.

Table 2.5-19 identifies sources representing the CVSZ as dominating the seismic hazard at the site. The fundamental question to be addressed is whether seismicity recorded since 1984 indicates that the seismic activity rates used in the 1989 EPRI study (Reference 115) are inadequate or not sufficiently conservative for assessment of the seismic hazard at the ESP site. This question is addressed in Section 2.5.2.6.5.

2.5.2.6.2 New Maximum Magnitude Information

Geological and seismological data published since the 1986 EPRI seismic source model are presented in Section 2.5.1 and Section 2.5.2.1. Based on a review of these data, there are no significant changes in the EPRI maximum magnitude (M_{max}) parameters, with the exception of the

Charleston seismic source. The review of M_{max} for each EPRI EST is provided in Table 2.5-5 through Table 2.5-10.

For the Charleston seismic source, a new geologic structure has been identified as the possible source of the 1886 Charleston earthquake, the southern segment of the ECFS (ECFS-S) (Reference 74). This new source is described further in Section 2.5.2.6.3.

For sensitivity analysis, the ECFS-S is treated as an alternative geometry for the Charleston seismic source with a characteristic M_{max}. For the M_{max} values, the 2002 USGS values and weights are used (Reference 127). These characteristic M_{max} values range from **M** 6.8 to 7.5, meaning that the large magnitude earthquake occurs with a specified mean recurrence interval. By contrast, the six EPRI ESTs designated exponential magnitude distributions for sources representing the Charleston region and estimated the following maximum magnitudes for those sources (Reference 121):

Team	**Charleston M_{max} range**
Bechtel	m_b 6.8 to 7.4 (**M** 6.8 to 7.9)
Dames & Moore	m_b 6.6 to 7.2 (**M** 6.5 to 7.5)
Law Engineering	m_b 6.8 (**M** 6.8)
Rondout	m_b 6.6 to 7.0 (**M** 6.5 to 7.2)
Weston Geophysical	m_b 6.6 to 7.2 (**M** 6.5 to 7.5)
Woodward-Clyde Consultants	m_b 6.7 to 7.5 (**M** 6.7 to 8.0)

For some teams (e.g., the Law Engineering team), the 1989 EPRI interpretations are at the low end of current interpretations (see below). This difference and the shorter recurrence interval prompted a reevaluation of seismic hazard with the current interpretation of maximum magnitude for the Charleston seismic zone, as presented in Section 2.5.2.2.9.

In 1994, EPRI published a five-volume study on *The Earthquakes of Stable Continental Regions* (Johnston, et al., Reference 195). Volume 1 of the study, “Assessment of Large Earthquake Potential,” presents results from a worldwide database of earthquakes within stable continental regions (SCRs) to assess the relationship, if any, between maximum magnitude and specific tectonic environments. Initial results of the study were provided to the EPRI teams for the EPRI SOG PSHA. Thus, the fundamental observation of the Johnston, et al. (Reference 195) worldwide database associating the largest SCR earthquakes with Mesozoic and younger extended crust was known to the EPRI teams at the time of the EPRI SOG study. Results of the Johnston, et al. study (Reference 195) do not provide new information that would significantly change the maximum magnitude estimates or source zone geometries of the 1989 EPRI SOG seismic source model for the following reasons: 1) the Johnston, et al. study (Reference 195) was initiated in the mid-1980s

specifically for use by the teams in their development of the EPRI SOG seismic source model; 2) preliminary results of the study were available to the EPRI teams; and 3) all of the estimates of maximum magnitude and source zone geometry drawn from the Johnston, et al. study (Reference 195) are generally enveloped by one or more of the EPRI teams.

2.5.2.6.3 New Seismic Source Characterizations

Review of the updated geological, seismological and geophysical data base relative to the 1986 EPRI seismic source model generally shows that there are no significant changes to the EPRI source model with three exceptions as identified in Section 2.5.2.2.

- Identification of the postulated ECFS along the Atlantic seaboard
- Revision to the recurrence interval and source geometry of the Charleston seismic source
- Revision to the recurrence interval of the New Madrid seismic source

A sensitivity analysis was performed for the ECFS and the revised Charleston seismic source to evaluate the significance of these sources to hazard at the ESP site. Both of these sources are treated as active in addition to the sources designated by the EPRI ESTs in the sensitivity analysis. This sensitivity analysis is presented in Section 2.5.2.6.5.

a. **East Coast Fault System**

The ECFS is modeled as being located along the Atlantic seaboard and consists of three segments: the northern (ECFS-N), central (ECFS-C), and southern (ECFS-S) (Reference 74; Figure 2.5-13), as described in Section 2.5.1.1.4. The northern segment is located approximately 70 miles southeast of the ESP site. The southern segment extends through the Charleston meizoseismal zone and is postulated to be the source of the 1886 Charleston earthquake, implying that similar large magnitude earthquakes can occur on the northern and central segments of the ECFS.

Given the proximity of the northern segment to the ESP site, a sensitivity analysis was performed to evaluate the fault's potential contribution to hazard at the ESP site. The southern segment of the ECFS constitutes a possible alternative source geometry for the Charleston source zone, and is described further below.

Source parameters for the northern segment of the ECFS are shown on Figure 2.5-34. This logic tree shows four parameters: 1) probability of existence, 2) probability of activity, 3) maximum magnitude, and 4) recurrence interval.

For the ECFS-N segment, the fault was assumed to have a probability of existence of 0.1 and a probability of activity (given existence) of 0.1. M_{max} parameters and weights used in the USGS national seismic hazard map (Reference 127) for the Charleston source were adopted for the northern segment of the ECFS. Recurrence values and weights were selected to be 550 years [0.1], 25,000 years [0.5], and 50,000 years [0.4], respectively.

The probability of existence and probability of activity are assigned low weights (0.1) because the existence of the fault is not well documented and is highly uncertain, and because there is no direct geologic, geomorphic, or seismologic evidence that the fault exists as a tectonic feature or is active, if it does exist (described in Section 2.5.1.1.4).

b. **Charleston Seismic Source**

New data published since the 1986 EPRI study suggest revisions to the recurrence interval and source geometry to the Charleston seismic source. For the sensitivity analysis in Section 2.5.2.6.5, the USGS source parameters (Reference 127) were adopted, as shown on Figure 2.5-35. The magnitudes (**M**) and weights used in the USGS model also were adopted for the sensitivity analysis, although the range in magnitudes falls within the EPRI seismic source model characterization of the Charleston source. A recurrence interval of 550 years was used based on recent paleoliquefaction studies. This recurrence interval implies much more frequent events than the seismicity-based recurrence interval modeled by the EPRI ESTs of several thousand years. The southern segment of the ECFS was used as an alternative source geometry for the sensitivity analysis. In this approach, the southern segment was assumed to be active with a characteristic magnitude with mean recurrence interval of 550 years. This approach is conservative in that the mean recurrence interval may not be directly associated with earthquakes as large as the assumed maximum magnitudes.

c. **New Madrid Seismic Source**

The New Madrid seismic source is located over 600 miles west of the ESP site. Therefore, the results of revising the recurrence parameters of the Charleston seismic source approximately 300 miles south of the ESP site are used to evaluate whether the revised recurrence parameters for the New Madrid seismic source would significantly increase hazard at the ESP site.

2.5.2.6.4 New Ground Motion Models

The ground motion models developed by the 2003 EPRI-sponsored study (Reference 116) were used to examine the effects on seismic hazard of current estimates of seismic shaking as a function of earthquake magnitude and distance. For general area sources, nine estimates of median ground motion are combined with four estimates of aleatory uncertainty, giving 36 combinations. For fault sources in rifted regions, which applies to the ECFS fault segments, 12 estimates of median ground motion are combined with four estimates of aleatory uncertainty, giving 48 combinations. When both area sources and faults are active, a specific correlation of area source models and fault source models is used to represent ground motion models that might apply together. These families of models (36 for area sources, 48 for fault sources) represent the epistemic uncertainty in ground motion, and contribute to the epistemic uncertainty in seismic hazard.

2.5.2.6.5 Sensitivity Studies of New Geoscience Information

The effect of new geoscience information (new seismic sources, new magnitudes, new recurrence parameters, and new ground motion models) was addressed by examining the effect of this new information on median seismic hazard at levels of 10^{-5} per year. The baseline for comparison purposes was the seismic hazard calculated using the 1989 EPRI seismic sources and ground motion models (see Section 2.5.2.4).

a. **Effect of New Earthquake Catalog on 1989 EPRI Seismic Hazard Results**

In Section 2.5.2.6.1, the CVSZ was identified as the zone that dominates the seismic hazard at the ESP site. To examine the effect of additional seismicity data from 1985 to 2001, we chose the representations of the CVSZ by the Bechtel and Rondout teams as representative. Figure 2.5-36 indicates the geometry of the CVSZ as modeled by these teams. These represent two alternative interpretations; in the Bechtel team source, the ESP site is encompassed by the CVSZ, and for the Rondout team source, the ESP site lies on the northern boundary of the source. Figure 2.5-36 also indicates locations of earthquakes identified in Table 2.5-4 as occurring in the region between 1985 and 2001. Five earthquakes have occurred during this time period, and all five fall within the CVSZ as modeled by both the Bechtel and Rondout teams.

In addition, a seismic source consisting of a polygon with an approximate 200-mile radius was selected for investigation. This source encompasses the entire region that contributed to the seismic hazard at North Anna from the 1989 EPRI study, both for high and low frequencies (see Figure 2.5-26 and Figure 2.5-27).

The seismicity in these three sources was investigated by running program EQPARAM (from the EPRI EQHAZARD package) first for the original EPRI catalog, to replicate the results obtained in the 1989 study (Reference 115). This confirmed that the proper parameters from the 1989 study were being used. Then an equivalent analysis was run using the augmented earthquake catalog (through 2001). Full smoothing of a- and b-values was selected for the comparison, because this was a common choice of many ESTs in the 1989 EPRI study. Further, if comparisons were to be made on an individual degree-cell basis, the rates in some cells might increase and in others might decrease, and for a source such as the CVSZ, a composite rate would have to be used to compare seismic rates using the earthquake catalog through 1984, to those using the earthquake catalog through 2001. The choice of full smoothing achieves this composite rate directly and automatically, since it is a composite rate for the entire source.

From the a- and b-values calculated with EQPARAM, recurrence rates for difference magnitudes were calculated. Figure 2.5-37, Figure 2.5-38, and Figure 2.5-39 compare the annual recurrence rates for the three sources for seismicity through 1984 and seismicity

through 2001. For all three sources, the augmented catalog indicates that seismicity rates have decreased.

The conclusion is that the seismicity recorded from 1985 to 2001 does not indicate that seismic activity rates have increased in those sources contributing most to the hazard at the ESP site under the assumptions of the 1989 EPRI study. For this reason, the seismic activity rates as derived in the 1989 EPRI study (Reference 115) were used to calculate seismic hazard at the ESP site with the EPRI seismic sources.

b. **Effect of New Maximum Magnitude Information**

As presented in Section 2.5.2.6.2, recent characterization of the Charleston Source indicates that **M** 6.8 to 7.5 earthquakes are possible on structures in the Charleston area and on the southern segment of the ECFS. The effect of these large magnitude earthquakes (which fall within the range of 1989 EPRI values) is considered in conjunction with the seismic sources themselves and their recurrence rates (see Section 2.5.2.6.5).

No other information was identified that would cause estimates of the magnitudes in the 1989 EPRI seismic sources to increase.

c. **Effect of New Seismic Source Characterization**

The effects of the ECFS-N (northern) and ECFS-S (southern) fault segments were examined by calculating seismic hazard from these two fault segments and comparing this seismic hazard to that from the 1989 EPRI seismic sources. It was appropriate to use the latest ground motion interpretations in this comparison, so that the effect for example of distant sources was properly assessed. Thus for these comparisons the 2003 EPRI ground motion models (described in Section 2.5.2.6.4) were used.

Figure 2.5-40 and Figure 2.5-41 show 1 Hz spectral acceleration seismic hazard curves (median and mean, respectively) at the ESP site for the original 1989 EPRI seismic sources, for the ECFS-N and ECFS-S faults individually, and for the combined hazard of the 1989 seismic sources and the ECFS-N and ECFS-S faults. The ECFS-N fault hazard does not show on Figure 2.5-40 for median hazard, because this fault has only a 1 percent probability of existing and being active (see Section 2.5.2.6.3). The median hazard from this fault alone is therefore zero. Figure 2.5-40 and Figure 2.5-41 indicate that the ECFS-S fault increases the total median and mean hazard by several percent at the 10^{-5} hazard level. This fault should therefore be included in seismic hazard calculations for the ESP site. The ECFS-N fault, however, results in much lower hazard than from the 1989 EPRI seismic sources, so this fault need not be included in calculations.

Figure 2.5-42 and Figure 2.5-43 show a similar comparison for 10 Hz spectral acceleration. In this case neither the ECFS-S or ECFS-N faults indicates much increase in seismic hazard. The reason is that 10 Hz ground motion is dominated by closer sources than 1 Hz ground motion, so the distant ECFS-S and ECFS-N faults have little effect on seismic hazard.

d. **Effect of New Ground Motion Models**

The effect of the 2003 EPRI ground motion models was determined by calculating seismic hazard using these models and the 1989 EPRI seismic sources, and comparing hazard to that using the 1989 EPRI ground motion (see Section 2.5.2.6.5).

Figure 2.5-44 shows a comparison of 10 Hz seismic hazard for the 1989 ground motion models and the 2003 ground motion models. For ground motions above those corresponding to annual frequencies around 10^{-4} there is a significant increase for both the median and mean hazard. For ground motions below those corresponding to annual frequencies around 10^{-3}, the 2003 ground motion models indicate less hazard for both the median and mean.

Figure 2.5-44A shows a comparison of 5 Hz seismic hazard. For ground motions above those corresponding to annual frequencies around 10^{-4}, the 2003 median exceeds the 1989 median. For ground motions below those corresponding to annual frequencies around 10^{-5}, the 2003 models indicate less mean hazard than the 1989 models.

Figure 2.5-44B shows a comparison of 2.5 Hz seismic hazard. For all ground motions the 1989 mean exceeds the 2003 mean. For ground motions above those corresponding to annual frequencies around 10^{-4}, the 2003 median exceeds the 1989 median.

Figure 2.5-45 shows a similar comparison for 1 Hz. For this spectral frequency the 1989 and 2003 models indicate about the same median hazard at all annual frequency levels, but the 2003 mean hazard is significantly lower than the 1989 mean hazard.

A major difference between the 1989 and 2003 ground motion models is that the estimates of aleatory uncertainty are larger in the 2003 study. In 1989, a standard deviation of natural log (ground motion) of 0.5 was used for all frequencies, whereas in 2003, values of 0.6 and 0.7 are common (they vary depending on magnitude, distance, and frequency). At annual frequencies of 10^{-5}, which are sensitive to the tails of the ground motion aleatory distribution, this difference in standard deviation increases seismic hazard. This would likely be true for any CEUS location. A compensating factor at low frequencies (1 and 2.5 Hz) is the use of ground motion models that reflect a two-corner source, which acts to reduce low frequency ground motion estimates from those used in 1989. Thus the median 1 Hz seismic hazard is about the same for both models. The mean amplitudes using the 2003 ground motion models are closer to the median amplitudes than is the case for the 1989 models, reflecting convergence on what are reasonable models to use for ground motion estimation in the eastern US. In 1989, the ground motion models were quite diverse, with one model developed by estimating peak ground acceleration and velocity, then using spectral amplification factors to estimate spectral amplitudes. In 2003, the available models estimate spectral amplitudes directly.

2.5.2.6.6 Updated EPRI Probabilistic Seismic Hazard Analysis, Deaggregation, and 1 Hz, 2.5 Hz, 5 Hz, and 10 Hz Spectral Accelerations Incorporating Significant Increases Based on the Above Sensitivity Studies

The PSHA was recomputed for the ESP site incorporating the 2003 EPRI ground motion models and adding the ECFS-S fault. The ECFS-S fault was added to each of the six Earth Science Team's interpretations, since the occurrence of a large (**M** 6.8 to 7.5) earthquake with a mean recurrence interval of 550 years at Charleston was not modeled by the EPRI teams.

The results of the updated seismic hazard calculations are summarized in Table 2.5-22, compared to the results from the 1989 models (from Table 2.5-21). The largest difference is at 10 Hz, where the updated models indicate higher ground motion amplitudes for both the 10^{-5} median and mean by 47 percent to 55 percent. At 1 Hz, 2.5 Hz, and 5 Hz, the updated models indicate a higher median 10^{-5} ground motion amplitude but a lower mean 10^{-5} ground motion amplitude. At 1 Hz, the updated models and 1989 models indicate only a 6 percent increase in the median and a 39 percent decrease in the mean 10^{-5} ground motion amplitude.

The seismic hazard results were deaggregated using the procedure described in RG 1.165, which deaggregates the hazard according to the contribution to the median 10^{-5} hazard. Deaggregation plots are shown in Figure 2.5-46 and Figure 2.5-47. The body-wave magnitude m_b and epicentral distance r_{epi} of controlling earthquakes were calculated and are listed in Table 2.5-23.

2.5.2.6.7 Selected SSE Ground Motion

Figure 2.5-48 shows the hard rock (9,200 fps control point) horizontal and vertical SSE ground motion spectra selected for the North Anna ESP site. These spectra were established in consideration of two alternate approaches described in this section: a reference probability approach and a performance-based approach. The SSE spectra shown in Figure 2.5-48 have been conservatively selected to envelop both approaches.

a. **RG 1.165 Reference Probability Approach**

   The goal in selecting an SSE ground motion spectrum is to achieve a seismic design that provides adequate protection of the public health and safety. RG 1.165, Appendix B (Reference 2) outlines a means of achieving this goal by establishing a reference probability (RP) for the SSE ground motion that is equivalent to the safest 50 percent of existing nuclear plants. This approach ensures that the seismic design of a new plant would be equivalent, in terms of annual probability of exceedance, to existing plants.

   RG 1.165, Appendix B sets an RP level based on seismic hazard results from the LLNL (Reference 129) and EPRI (Reference 115) studies. RG 1.165, Appendix B, Section B.3 recognizes, however, that there are situations in which it is appropriate to establish a new RP on which design-basis ground motions should be calculated, including, "…if general revisions to PSHA methods or data bases result in significant changes in hazard predictions for the

selected plant sites in Table B.1." As discussed in the following paragraphs, the PSHA and related analyses performed for the North Anna ESP site indicate that a new RP is appropriate.

The following three factors contribute to a change in the reference probability recommended in RG 1.165:

1. **2003 EPRI Ground Motion Models**

   The revised EPRI ground motion models (Reference 116) indicate generally higher ground motions and aleatory uncertainties at high frequency amplitudes of interest than previous models. The 2003 EPRI ground motion models (Reference 116) are a general revision to PSHA methods since the EPRI (Reference 115) and LLNL (Reference 129) studies that likely would result in significant changes in hazard predictions. These new EPRI models would likely change estimates of seismic hazard for the sites listed in RG 1.165, Table B.1.

2. **Shorter Recurrence Interval Estimates**

   An additional general revision to the data bases is that the estimate of the mean recurrence interval for large earthquakes in the New Madrid, Missouri, region and in the Charleston, South Carolina, region has decreased since the EPRI (Reference 115) and LLNL (Reference 129) studies based on tectonic interpretations in the CEUS in the 1980s. At that time, mean recurrence intervals for major earthquakes were thought to be several thousand years or longer, but current estimates indicate recurrence intervals on the order of 550 years (see Section 2.5.2.6.1). These shorter mean recurrence intervals increase the seismic hazard at sites affected by large earthquakes in these regions. Therefore, the sites listed in RG 1.165, Table B.1 that are relatively close to New Madrid or Charleston would potentially have a greater seismic hazard than was used in deriving the RP in RG 1.165.

   Also, recent studies of seismic hazard have led to the designation of new seismic sources in the central U. S. A source in central Illinois that models earthquakes as large as **M** = 7.5 in that region will increase the seismic hazard of nuclear plants in that area. Studies in Arkansas have led to the designation of the Saline River lineament as a potential fault, which will affect the seismic hazard of nuclear plants near the southern Mississippi River.

3. **Use of the Mean Hazard**

   Use of the mean hazard instead of the median hazard will imply a higher reference probability for a fixed ground motion level, since the mean hazard curve lies above the median hazard curve.

The combined effect of these three factors could increase the reference probability by a factor of 5 or more, i.e., the reference probability for the mean hazard may be 5×10^{-5} or higher. Thus, for the North Anna ESP site, an SSE ground motion level consistent with a mean hazard of

5×10^{-5} is appropriate. These changes lead to a higher reference probability, but imply a seismic design for a new plant that is equivalent in annual probability of exceedance to 50 percent of existing plants.

Table 2.5-24 shows the spectral accelerations calculated for a 5×10^{-5} mean annual frequency, for 1 Hz, 2.5 Hz, 5 Hz, and 10 Hz. The seismic hazard at these frequencies and spectral accelerations were deaggregated. Figure 2.5-49 and Figure 2.5-50 show deaggregation plots for the combined magnitude-distance deaggregation at low frequencies (1 and 2.5 Hz) and high frequencies (5 and 10 Hz), respectively.

The controlling magnitudes and distances were calculated according to the procedure in RG 1.165, Appendix C, applied however to the mean 5×10^{-5} amplitudes rather than the median 1×10^{-5} amplitudes. Additionally, the procedure in RG 1.165 was changed to use the mean hazard in each magnitude-distance bin, rather than the median hazard. The resulting controlling magnitudes and distances are shown in Table 2.5-25. For high frequencies these were calculated in terms of body-wave magnitude m_b and epicentral distance r_{epi}, and were converted to moment magnitude **M** and closest distance r_{CD} for purposes of scaling spectra according to Reference 119, which uses **M** and r_{CD}. For low frequencies, distance bins corresponding to $R > 100$ km contributed 23 percent of the mean 5×10^{-5} hazard, so (following the guidance in RG 1.165) the controlling magnitude and distance were recalculated using only distant bins ($R > 100$ km). The hazard from these bins came predominantly from the ECFS-S fault, so the deaggregated magnitude and distance directly represent **M** and r_{CD}.

Figure 2.5-51 shows a plot of the horizontal scaled spectra calculated using an RP of mean 5×10^{-5} and the procedure of Reference 2. The low-frequency scaling used a spectral shape based on the magnitude and distance indicated in Table 2.5-25 for 1 and 2.5 Hz, scaled to the average amplitude calculated for 1 and 2.5 Hz. The high-frequency scaling used a spectral shape based on the magnitude and distance indicated in Table 2.5-25 for 5 and 10 Hz, scaled to the average amplitude calculated for 5 and 10 Hz. Both spectral shapes were based on the recommendations in Reference 119. When deaggregating magnitude and distance by contribution to the mean hazard, Figure 2.5-49 and Figure 2.5-50 indicate that the deaggregations at high and low frequencies are different. These figures indicate that the hazard at high frequencies results from earthquakes in the Central Virginia seismic zone ($m_b \approx 5.5$ to 6 at a distance of about 20 km). However, a substantial portion (23 percent) of the low-frequency hazard results from distant earthquakes ($R > 100$ km). As a result, the scaled low- and high-frequency spectra in Figure 2.5-51 have different shapes.

The assumptions used here regarding seismic sources and ground motion models are those described in previous sections as being the most relevant and up-to-date for the ESP site. For seismic sources, the 1989 EPRI seismic sources (Reference 115) were used with the addition of the ECFS-S fault representing an alternative geometry and more frequent occurrence of large earthquakes in the Charleston, South Carolina area. For ground motion, the 2003 EPRI

ground motion model (Reference 116) was used, consisting of estimated spectral accelerations at 7 structural frequencies at 5 percent of critical damping, and including a quantification of aleatory and epistemic uncertainties.

b. **Performance-Based Approach**

The selected SSE spectrum for the North Anna ESP site is also supported by a performance-based approach as described in this section. A performance-based spectrum was developed that has, as its goal, achieving a mean annual frequency of 10^{-5} of unacceptable performance of nuclear structures, systems, and components (SSCs) as a result of seismically-initiated events. This goal is recommended by three studies undertaken in recent years to recommend seismic design levels for nuclear facilities in the United States, as described below. This performance goal approach establishes a risk level (annual frequency of onset of significant inelastic deformation) for all structural periods that does not require recalibration of new designs to the hazard implied by a suite of specific existing plant designs when considered in the light of new geoscience information and/or hypotheses, as is the case when re-evaluation of the reference probability is called for under the provisions of Reference 2. For the performance-based approach, the ground motion level for the SSE spectrum is selected to ensure that the annual probability of seismic effects on the plant, measured in terms of seismically induced core damage, is as low as calculated at other nuclear plants in the U. S. designed to current standards. The effect of any new geoscience information and/or hypotheses need only be considered at the ESP plant site.

The performance-based spectrum is derived so that the mean frequency of onset of significant inelastic deformation (FOSID) for SSCs is 10^{-5} per year. The FOSID is a conservative estimate of the frequency of unacceptable performance for an individual SSC, and the frequency of unacceptable performance of an individual SSC is a conservative estimate of the frequency of seismically induced core damage (or the SCDF, the seismic core damage frequency). Thus, the goal (discussed below) of achieving a mean SCDF of 10^{-5} is achieved in a conservative fashion by designating a design spectrum based on a mean FOSID of 10^{-5}.

As background on selection of the performance goal of 10^{-5} per year, Figure 2.5-52 shows mean SCDFs of nuclear plants where these frequencies have been quantified through seismic probabilistic risk assessments (SPRAs). For this purpose, the summary of SPRA results presented in NUREG-1742 (Reference 196) are used. NUREG-1742 presents SCDFs for 27 U.S. nuclear plants with up-to-date SPRAs. Twenty-five of these plants have results calculated using EPRI seismic hazard curves, and 18 plants have results calculated using LLNL seismic hazard curves. For the 16 plants where common results are available, 13 plants show that the LLNL hazard curves lead to higher calculated SCDFs. In one case, the results were higher by a factor of 100. For the comparisons shown here, the SCDF results obtained using the EPRI seismic hazard curves were selected as most comparable to the North Anna ESP analysis. Figure 2.5-52 shows the cumulative distribution of mean SCDF for the 25 plants, using a

logarithmic scale for SCDF. The 10^{-5} criterion for mean FOSID falls at about the 40 percent point of the existing plant cumulative distribution, meaning that about 60 percent of the 25 plants have an SCDF higher than this value. And, as indicated earlier, if an SPRA were performed using an SSE ground motion spectrum to achieve an annual FOSID goal of 10^{-5}, the plant's SCDF would be even less than this frequency.

The performance-based spectrum is achieved by starting from a ground motion spectrum with a mean 10^{-4} annual frequency of exceedance, and modifying this spectrum by a scale factor that is based on the slope of the mean seismic hazard curve between 10^{-4} and 10^{-5}. The scale factor (SF) is defined as:

$$SF = \max(1.0, 0.6 \times A_R^{0.8}) \qquad \text{Equation 2.5.2-3}$$

where A_R is the multiplicative increase in ground motion corresponding to a decrease in seismic hazard from mean 10^{-4} to mean 10^{-5}. A_R and SF are determined on a frequency-by-frequency basis. The amplitude A(*f*) defining the performance-based SSE ground motion spectrum at each frequency *f* is then calculated as:

$$A(f) = SA_4 \times SF \qquad \text{Equation 2.5.2-4}$$

where SA_4 is the spectral acceleration corresponding to 10^{-4} mean annual frequency of exceedance. For sites and conditions in which the seismic hazard curve is very steep (i.e., A_R is 1.89 or less), SF = 1, and $A(f) = SA_4$. For most sites and frequencies in the CEUS at mean annual frequencies of 10^{-4}, A_R is in the range 2 to 4 (Reference 117, page C-9), and the 1×10^{-4} mean annual frequency of exceedance spectrum (SA_4) will be increased by a SF of 1.04 (for A_R=2) to 1.82 (for A_R=4) to achieve a 10^{-5} mean annual FOSID.

This approach to recommending design levels based on scaling the 10^{-4} mean annual frequency of exceedance spectrum to achieve a 10^{-5} mean annual FOSID has received substantial interest in recent years. The DOE (Reference 117) uses a SF on the 10^{-4} hazard spectrum for performance-category 4 SSCs (the most critical) to specify a design level that will have less than 10 percent probability of unacceptable performance, given the occurrence of the 10^{-4} ground motion. A SF dependent on the slope of the seismic hazard curve is presented in Reference 117, Appendix C, and is illustrated graphically in Reference 128, upon which Reference 117 is based. Equation 2.5.2-3 above is taken from Reference 128, Equations 15a and 15b, with the coefficients given in Reference 128, Table 2-5.

Under research sponsored by the NRC (Reference 119), Risk Engineering, Inc. recommended a SF to convert a uniform hazard spectrum to a "uniform reliability spectrum" that achieves an approximately constant annual frequency of nuclear plant component failure that is a factor of

10 less than that of the uniform hazard spectrum. The SF recommended in Reference 119 also depends on the slope of the hazard curve between the mean 10^{-4} hazard and the mean 10^{-5} hazard.

A subcommittee of the American Society of Civil Engineers developed seismic design criteria for nuclear facilities (Reference 118) that are based on seismic hazard results. Scaling the mean 10^{-4} ground motion by a slope-dependent SF is shown to achieve a performance goal that is 0.1 times the 10^{-4} mean ground motion frequency. This subcommittee also recommended the SF used in Equation 2.5.2-3.

Table 2.5-26 shows the mean 10^{-4} and mean 10^{-5} ground motion amplitudes, the calculated values of A_R, the calculated values of the SF, and the resulting performance-based spectral amplitudes A(*f*). These results were calculated using the same source and ground motion assumptions as for the reference probability approach. Table 2.5-26 shows that the SF increases the mean 10^{-4} spectrum by a factor of 1.40 to 1.64 across the frequency range 0.5 Hz to 100 Hz.

The performance-based spectrum calculations were made for the seven frequencies shown in Table 2.5-26. These are the frequencies available from the 2003 EPRI ground motion model: 0.5, 1, 2.5, 5, 10, 25, and 100 Hz (the last being equivalent to PGA). Figure 2.5-53 shows the resulting spectrum. For frequencies intermediate to the above 7 frequencies, interpolation was used to scale spectral shapes to the amplitudes shown in Table 2.5-26. The interpolation was done using spectral shapes from Reference 119 and weights based on the inverse logarithmic distance between the intermediate frequency and adjacent frequencies. Magnitude- and distance-dependent spectral shapes for high frequencies (>3.5 Hz) and low frequencies (<3.5 Hz) were based on the high- and low-frequency magnitude-distance pairs described in the previous section and reported in Table 2.5-25. Equal weights were given to the one- and two-corner source models in Reference 119. This procedure gives a realistic spectral shape at all frequencies.

c. **Selection of Enveloping Horizontal SSE Spectrum**

Figure 2.5-54A shows four horizontal ground spectra—the mean 5×10^{-5} return period RG 1.165 high- and low-frequency scaled spectra (from Figure 2.5-51), the performance-based spectrum (from Figure 2.5-53) and the selected hard rock SSE spectrum (previously shown in Figure 2.5-48), which is the envelope of the other three spectra. As shown in Figure 2.5-54A, the envelope of the high- and low-frequency RG 1.165 spectra indicates amplitudes very similar to the performance-based spectrum for frequencies of 1 Hz and higher. The selected horizontal SSE spectrum has been drawn to conservatively envelop both the mean 5×10^{-5} RP RG 1.165 spectra and the performance-based spectrum.

For further perspective, Figure 2.5-54B compares three spectra and available discrete spectral values from the 1989 EPRI and LLNL studies recognized in Reference 2:

1. The mean 5×10^{-5} RP RG 1.165 envelope spectrum (from Figure 2.5-51).
2. The performance-based spectrum (from Figure 2.5-53).
3. The selected SSE spectrum, which is the envelope of the above two.
4. "1989 EPRI" spectral values, which are median 10^{-5} spectral values for the North Anna site described in Reference 115.
5. "1989 LLNL" spectral values, which are estimated median 10^{-5} spectral values calculated using a parabolic extrapolation from results published in Reference 129, using median ground motions for annual probabilities from 2×10^{-3} to 10^{-4} to estimate median ground motions for an annual probability of 10^{-5} (results for annual probabilities less than 10^{-4} are not available in Reference 129).

Figure 2.5-54B shows that all spectra and spectral values are similar, giving further credibility to the selected SSE spectrum.

The spectra shown in Figure 2.5-48, Figure 2.5-51, Figure 2.5-53, Figure 2.5-54A, and Figure 2.5-54B represent scaled free-field hard rock control point ground motion spectra (9200 fps shear wave velocity) for 5 percent of critical damping. Figure 2.5-54B(1) shows the high-frequency spectrum-compatible time history that was developed, and Figure 2.5-54B(2) shows the low-frequency spectrum-compatible time history. These spectra and time histories do not include any effects such as structure, embedment, or incoherence of seismic waves due to base mat size. Such effects would have to be determined on a design-specific basis as part of detailed engineering, and their effect would be to modify the selected SSE spectra shown in Figure 2.5-48 for appropriate design levels of SSCs of that specific design.

Section 2.5.4.7 describes currently available subsurface shear wave velocity and related material property information for the site. Based on the actual location of new units, additional subsurface information would be obtained during detailed engineering and described in the COL application, and would include borings to greater depths at these locations. Based on currently available data, a generic site velocity profile has been developed. This best-estimate profile has been used to estimate the amplification of the 9200 fps hard rock ESP site SSE ground motion at a control point located on the top of competent Zone III-IV rock. As identified in Table 2.5-45, the shear wave velocities for the Zone III-IV material range from 2500 to 4500 fps, with a best estimate wave velocity of 3300 fps. A shear wave velocity of 3300 fps has been used in the control point SSE analysis. The elevation of the top surface of the Zone III-IV material varies across the site, as shown in Figure 2.5-57 and Figure 2.5-58. The

top of the Zone III-IV material has been chosen to be at a representative elevation of 250 ft in the control point SSE analysis.

Both high frequency and low frequency time histories were developed for the evaluation of the effect of site-specific subsurface shear wave velocities between the 9200 fps and 3300 fps control points. These time histories were made to match spectra that, in composite, matched the SSE spectrum but that, individually, are based on the high and low frequency reference probability response spectra shapes. Considering Figure 2.5-54A, for example, the low frequency time history was fit to a spectrum defined by the SSE spectrum for frequencies less than 1.5 Hz and by the 5×10^{-5} per year low frequency reference probability spectral values for higher frequencies. The high frequency time history was fit to a spectrum defined by the SSE spectrum for frequencies greater than 1.5 Hz and by the 5×10^{-5} per year high frequency reference probability spectral values for lower frequencies.

The average magnitude and distance (M-bar and D-bar) values for the two scaled target spectra are given in Table 2.5-25. Based on these magnitude and distance values, two horizontal seed input time histories were selected from the database of Central and Eastern United States time histories given in Reference 171. The seed time histories selected were:

- CEUS modified San Ramon - Kodak, 180 degree horizontal component from the 1980 Livermore earthquake (high-frequency controlling earthquake).
- CEUS modified Kashmar, longitudinal component from the 1978 Tabas, Iran earthquake (low-frequency controlling earthquake).

Their 5%-damped response spectra were matched to the high- and low-frequency target spectra, respectively, satisfying the spectral matching criteria of Reference 171.

A stochastic model described in Reference 170, with some modifications to account for the conditions at the ESP site, was used to generate 50 randomizations of the generic ESP site rock column velocity profile between elevations with shear wave velocities of 9200 fps and 3300 fps. In addition to the site-specific material property characterizations outlined in Section 2.5.4.7, generic guidance about the correlation between shear wave velocity and its uncertainty as a function of depth and depth-wise correlation structure of the ln(Vs) (the natural logarithm of the shear wave velocity) residuals from Reference 170, and uncertainty in damping consistent with the variability observed in Reference 197, were adopted. Finally, damping was taken as the same for all sub-layers within any given profile (that is, fully correlated between layers), but was allowed to vary between one artificial rock column and the next.

A set of SHAKE2000 runs were performed on each of the 50 artificial rock profiles using the two input hard rock motions. The site was modeled by horizontal layers, each 7.5 ft thick, overlying a uniform half-space of hard bedrock subjected to the vertically propagating shear wave time histories. The response spectra from the SHAKE analyses were defined at 140

frequencies from 0.1 to 100 Hz. The enveloped log-average spectrum for the Zone III-IV hypothetical rock outcrop control point at Elevation 250 ft and shear wave velocity of 3300 fps was fit with a smooth fitting function. See Figure 2.5-54B(3). The resultant fitting function was used to obtain the response spectrum for the same set of 21 frequencies. This 21-frequency set of response spectral ordinates defines the rock response spectrum for the corresponding hypothetical rock outcrop control point on the top of Zone III-IV material. This spectrum is shown in Figure 2.5-48A.

d. **Development of Vertical SSE Spectra**

The applicable V/H ratios used to develop the selected vertical hard rock SSE spectrum (5 percent of critical damping) are listed in Table 2.5-27. The vertical SSE spectrum is calculated by multiplying the selected horizontal SSE spectral amplitude at each frequency by the applicable V/H ratio for that frequency. The selected horizontal and vertical spectra are plotted in Figure 2.5-48 for the hard rock SSE.

Hard Rock SSE Spectrum

The applicable V/H ratios used to develop the selected vertical hard rock SSE spectrum (5 percent of critical damping) are listed in Table 2.5-27. The vertical SSE spectrum is calculated by multiplying the selected horizontal SSE spectral amplitude at each frequency by the applicable V/H ratio for that frequency. The selected horizontal and vertical spectra are plotted in Figure 2.5-48 for the hard rock SSE.

Zone III-IV Hypothetical Rock Outcrop Control Point SSE Spectrum

The horizontal SSE spectral accelerations, V/H ratios, and vertical SSE spectral accelerations for the Zone III-IV hypothetical rock outcrop control point are listed in Table 2.5-27A. The vertical SSE spectrum is calculated by multiplying the selected horizontal SSE spectral amplitude at each frequency by the applicable V/H ratio for that frequency. The selected horizontal and vertical spectra are plotted in Figure 2.5-48A.

To confirm the appropriateness of the V/H ratios listed in Table 2.5-27A, a site-specific analysis was performed. For the site-specific analysis, the stochastic point source model was used with an implementation of random vibration theory to model both horizontal and vertical spectra. The vertical ground motion was extended to consider P-SV waves. This approach has been used to develop the recommended V/H ratios in Reference 171 and has been shown to predict general trends in V/H ratios for earthquakes recorded in the Western United States. The model has been validated against empirical V/H ratio data from the 1989 Loma Prieta earthquake for rock site conditions.

Two site-specific P-wave profiles were developed that are consistent with the base shear wave profile used in the site analysis. These two P-wave profiles were developed by applying two Poisson's ratio models as a function of depth to the base shear wave profile. These two Poisson's ratio models are based on measured shear and compression wave data for the

North Anna site, with the more recent data from the ESP investigation being assigned a larger weight of 0.75 and the older data from the investigation for Units 1 and 2 having a weight of 0.25 in the analysis. Both the horizontal and vertical ground motions were computed assuming a linear response. Four magnitude-distance values and associated weights based on the 5–10 Hz PSHA deaggregation were used in the analysis to develop the horizontal and vertical ground motions. Relative weights for each of the four cases were used in combining the spectral ratios. A constant damping level of 2.0 percent was used. For each case, a total of 100 realizations were performed for both the horizontal and vertical ground motions. Statistics were computed for the suite of V/H spectral ratios. Additional damping levels of 0.5 percent, 1.0, and 5.0 percent were computed in a sensitivity study.

The results of the site-specific analysis confirm the appropriateness of the V/H ratios listed in Table 2.5-27A. Compared with the Table 2.5-27A values, the mean V/H ratios from the site-specific analysis are, on average, approximately 30 percent lower (ranging from 18–35 percent lower) over the complete frequency range of 100 Hz to 0.1 Hz. At the 84th percentile, the site-specific V/H ratio values are on average 8 percent lower (ranging from 19 percent lower to 5 percent higher) over the entire frequency range than the Table 2.5-27A V/H ratio values.

The comparison results provide justification that the V/H ratios given in Reference 171 and used in Table 2.5-27A are appropriate for the North Anna ESP site. To maintain a hazard-consistent level in scaling the horizontal ground motions, the fractile level needed for the V/H ratio is between the 50th and 84th percentile. The exact percentile level would depend on frequency, site, design considerations, and judgment.

2.5.2.6.8 Additional Sensitivity Studies

In evaluating the selected SSE ground motion spectrum, it is useful to understand how sensitive the spectrum is to the assumptions underlying its calculation. This gives perspective on the selected SSE spectrum as an appropriate ground motion to adopt for seismic design at the site. For these additional sensitivity studies, the same assumptions on seismic sources and ground motion models were used as for the reference probability and performance-based approaches. The sensitivity of the mean 5×10^{-5} spectral acceleration was studied for a range of structural frequencies. The mean 5×10^{-5} is the RP discussed in previous sections, and the sensitivity of spectral accelerations at this RP gives a good indication of how the selected SSE spectrum (which is an envelope of three spectra) would change as a result of alternative assumptions. An alternative minimum magnitude and an alternative model of ground motion aleatory uncertainty were examined for the sensitivity studies.

a. **Spectrum Based on Alternative Minimum Magnitude**

Standard practice for seismic hazard investigations in the central and eastern U.S. has been to use a minimum body-wave magnitude of $m_b = 5$ for calculations. For example, the EPRI and

LLNL seismic hazard studies (Reference 115) (Reference 129) referenced in RG 1.165 use a lower-bound magnitude of m_b = 5.0. This m_b value corresponds to approximately moment magnitude **M** = 4.6 using the magnitude conversion method described in Section 2.5.2.2.1. There is abundant evidence that earthquakes with **M** less than 5 do not cause damage to nuclear plant structures and equipment. Reference 130 studied the lower-bound magnitude issue specifically as it affects seismic hazard calculations for nuclear plants in the U.S. and concluded:

"A magnitude of **M** 5.0 is a threshold for which there is a reasonable engineering assurance that ground motions associated with smaller events will not damage NPP components." (Reference 130, page 8-9).

Thus, it is appropriate to calculate seismic hazard on the basis of lower-bound **M** = 5.0, which is approximately m_b=5.4.

To examine this sensitivity, the base-case models were adopted except that the lower-bound magnitude m_b was set to 5.4, and the seismic hazard analysis for the ESP site was recalculated with this change. The mean 5×10^{-5} spectral accelerations were calculated for the seven frequencies available from the 2003 EPRI ground motion model: 0.5, 1, 2.5, 5, 10, 25, and 100 Hz (the last being equivalent to PGA).

Table 2.5-28 shows lower mean 5×10^{-5} spectral accelerations for the alternative M_{min} than for the base case, as would be expected for an increased lower-bound magnitude. Table 2.5-28 shows that the assumption of a more realistic lower-bound **M** = 5.0 would lower the reference probability approach ground motion spectrum by a substantial factor (by about 1 percent at 1 Hz, 20 percent at 10 Hz, and up to 23 percent for higher frequencies). Thus, there is substantial conservatism in the selected ground motion spectrum.

b. **Spectrum Based on Revised Aleatory Uncertainties in Ground Motion**

The EPRI ground motion model (Reference 116) has aleatory uncertainties that are higher than those reported based on empirical studies of ground motions recorded in California. This is illustrated in Figure 2.5-54C, which compares aleatory standard deviations (of log spectral acceleration) vs. frequency for **M** = 5.5 and r_{CD}=20 km for the 2003 EPRI model and for four empirical studies that used recorded California strong-motion data. The values labeled "EPRI" are weighted-average values of four models of aleatory uncertainties recommended in the EPRI study (Reference 116). The EPRI model uncertainties lie above those reported for California, particularly for frequencies of 5 Hz and higher. The standard deviation of log spectral acceleration is an important parameter in the seismic hazard calculations, and increasing it by 0.1 (from 0.65 to 0.75, for example) can cause a large increase in calculated seismic hazard. In Figure 2.5-54C, "AS97" represents the Abrahamson-Silva model (Reference 131), "SEA97" represents the Sadigh et al. model (Reference 132), "C97"

represents the Campbell model (Reference 133), and "BJF97" represents the Boore-Joyner-Fumal model (Reference 134).

Certainly epistemic uncertainties in the ground motions for the CEUS should be higher than those in California, because of the lack of strong-motion data in the former region with which to verify models. This difference is taken into account explicitly in the EPRI study. But it is not obvious that aleatory uncertainties should be higher for ground motions in the eastern U.S. than in California. To gain additional perspective on the seismic hazard at the ESP site, it is useful and appropriate to examine the seismic hazard using aleatory uncertainties in ground motion that are typical of what is observed in California data.

To accomplish this, the Abrahamson-Silva model of aleatory uncertainty (Reference 131) was chosen. This model is similar to that of Reference 132 (labeled "SEA97" in Figure 2.5-54C). The other two references did not report a significant change in aleatory uncertainty with magnitude (Reference 134) or frequency (Reference 133), both of which are important considerations in this sensitivity study. The Abrahamson-Silva model of sigma was substituted for the aleatory uncertainty model reported in the EPRI 2003 study, to determine the potential effect of using an empirically based estimate of this uncertainty.

Table 2.5-28 documents the mean 5×10^{-5} spectral accelerations calculated using the alternative sigmas. These results show that a significant decrease in the mean 5×10^{-5} spectral accelerations would occur if empirically based aleatory ground motion uncertainties were used in place of those reported in the 2003 EPRI ground motion study (by about 9 percent at 1 Hz, 5 percent at 10 Hz, and up to about 17 percent for higher frequencies). Stated another way, this sensitivity study shows considerable conservatism in the spectral accelerations associated with the reference probability level.

c. **Summary**

These additional sensitivity studies show considerable conservatism in the selected SSE spectrum for the ESP site, particularly for frequencies above 10 Hz. If either or both of the assumptions related to lower-bound magnitude or aleatory ground motion uncertainties were adopted, the selected SSE spectrum based on the mean 5×10^{-5} amplitudes would decrease. This gives considerable credibility and justification to the selected SSE spectrum as an appropriate spectrum for design.

It must be emphasized that the selected SSE spectra shown in Figure 2.5-48 represent a scaled spectra of free-field rock ground motion spectra for 5 percent of critical damping without any effects such as structure, embedment, or incoherence of seismic waves due to base mat size. Such effects must be determined on a design-specific basis, and their effect would be to modify the spectra shown in Figure 2.5-48 for appropriate design levels of SSCs of that specific design.

2.5.2.6.9 Additional Modification of the Selected Spectrum

The selected SSE ground motion spectra presented in Section 2.5.2.6.7 could be termed the Seismological Design Spectrum (SDS). The SDS represents the maximum elastic responses of a number of damped, single-frequency oscillators mounted on small, light pads on the free ground surface. Such small oscillators would not have sufficient mass to cause the modification of the input motion and would probably experience the high accelerations predicted by the SDS.

However, studies have shown that large structures will modify the ground motion and therefore the shaking experienced by these structures would be different than those predicted by the SDS. These studies have also shown that the ground response spectrum obtained from purely seismological considerations (i.e., SDS) have produced ground motions with significant high frequency content in the CEUS. Comparison of spectra obtained from the recorded motions on the basemat of large structures with input motions having high-frequency energy similar to the SDS shows substantial differences (Reference 135); the accelerations calculated from the recorded motions being far less than those of the input motion, particularly in the high frequency range. The reason for this difference is that the ground motions input to the basemat are actually modified by the presence of large structures and the modifications become significant at higher frequencies, especially above 10 Hz.

Based on these studies, it was concluded that the SDS is an unrealistic input for the analysis and design of structures (Reference 136). In order to obtain a realistic design spectrum, the Engineering Design Spectrum (EDS), factors must be considered that affect the shape of the spectrum experienced by structures with large base mats, such as those typical of nuclear power plants.

Factors that affect the ground motion of the EDS compared to the ground motion of the SDS include the following:

- Horizontal spatial variation and incoherence of the ground motion,
- Vertical spatial variation of the ground motion, scattering effects, and soil-structure interaction.

The first factor is more prominent for structures with large plan dimensions and would reduce the input into the structure at high frequencies. This effect is more pronounced at rock sites. The vertical spatial variation is more prominent at soil sites and again would reduce the amplitude of high frequency motions (Reference 136). Incoherence has been recognized in the national standard for seismic analysis of safety-related structures and significant reductions in the SDS have been recommended (Reference 137).

In addition to the spatial variations of the ground motions, field observations after strong ground motions indicate that the high-frequency accelerations are less damaging to well-engineered structures (Reference 136). This is attributed to the fact that responses to high frequency motions are associated with small displacements and well-engineered structures have ample capacity to dissipate the corresponding limited energy without significant damage. Structures suffer severe damage only when the story drifts are relatively large, as observed during earthquake damage

inspections. Large story drifts occur when the energy content of the input motion is high between about 1 and 10 Hz. Above 10 Hz, the energy content is low and the story drifts are small. As a result, the response to high-frequency input motion is essentially elastic and no visible damage occurs. Modification of this nature to the UHS would be based on the principle of equal risk (i.e., equal factor of safety) across the entire frequency range.

The reduction in spectral accelerations in the high frequency range is also justified considering the responses of the sub-systems. It is known that high frequency content of the ground motion will be visible in the in-structure response spectra, if response analyses are performed with appropriate time steps and refined models. However, these high spectral accelerations are accompanied by small displacements and most sub-systems have adequate energy dissipation capability to accommodate such small displacements without failure. Nonlinear time history analyses demonstrate that these high-frequency motions are less damaging compared to low-frequency motions (Reference 136). Based on these studies, methodology for the reduction of spectral accelerations in the high frequency range have been developed (Reference 136).

Consideration of both the spatial variations of the ground motion and the non-damaging nature of the high frequency content lead to the conclusion that the SDS is only the first step in determining the design spectra for the analysis and design of typical nuclear power plant structures and equipment. The SDS must be modified considering the above factors to obtain the EDS. The EDS represents the proper input into the large nuclear power plant structures.

Another aspect of the high frequency content of the ground motion is the difficulty of capturing these effects as the motions propagate through the structure. Use of the SDS without modification would make it difficult to obtain realistic structural responses, as the analytical methods would have to be much more refined. In addition, structural response is unlikely to be significantly influenced by the high frequency content of the ground motion because of the filtering due to the presence of low natural frequency modes with high participation factors, which is typical for nuclear plant structures. Therefore, a method that will maintain a sufficient degree of accuracy in the predicted seismic responses while obviating the need for such refined modeling would be more practical.

2.5.2.6.10 **Approach to Develop the EDS**

The selected SSE design response spectra based on the SDS have, as expected, high spectral accelerations in the high frequency range. The traditional spectra used in the design of nuclear power plants, such as RG 1.60 spectra that were developed from a small set of empirical western U.S. earthquake time histories from generally large earthquakes at generally large distances, have the amplified region between 1 and 10 Hz that is the area of greatest engineering concern for structures. However, the SDS peak for the ESP site occurs around 30 Hz. As presented above, the high spectral accelerations in the high frequency range are not realistic design bases for the SSCs of nuclear power plants.

The issues presented above can be effectively addressed by developing an EDS that would take into account plant-specific structural characteristics and site soil conditions as well as the SDS. Because a specific reactor design has not yet been selected, development of the EDS is not included in this ESP application. As part of the COL application, the following information would be provided to develop the EDS:

- Studies on spatial variation of the ground motion would be performed to determine its effects on the spectral accelerations at the site. Such studies would consider the variability in soil data. Both horizontal and vertical spatial variation and incoherence effects would be examined.
- Using the conceptual design data for the safety-related structures of a specific reactor design, the energy dissipation characteristics of these structures, subject to high-frequency ground motions, would be determined. In these evaluations, available experimental and observational data would be used to calibrate the predicted analytical results. The end product would be a frequency-dependent factor that would be applied to the SDS that would produce a uniform factor of safety against failure under seismic loads, across the entire frequency range.
- The EDS combining the data from the preceding steps would be developed.

Thus, the EDS would be determined from a synthesis of the site-specific seismic parameters submitted in the ESP application and the plant-specific parameters that would be described in the COL application. The final outcome would be a realistic EDS that would be the input for seismic analysis and design of a specific plant design's SSCs.

2.5.2.7 Operating Basis Earthquake

A detailed analysis was not undertaken to establish the OBE ground motion. Rather, the simple decision was used to establish the OBE spectrum as one-third of the SSE spectrum in accordance with 10 CFR 50, Appendix S. Figure 2.5-55 plots the hard rock OBE spectra and the selected hard rock SSE spectra from Figure 2.5-48. Figure 2.5-55A plots the OBE spectra and the SSE spectra from Figure 2.5-48A for the control point SSE analysis at the top of Zone III-IV material. These spectra are based on 5 percent critical damping, as are all other spectra presented in Section 2.5.2.

2.5.3 Surface Faulting

There is no potential for tectonic fault rupture and there are no capable tectonic sources within the 5-mile radius of the ESP site. A capable tectonic source is a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation, such as faulting or folding at or near the earth's surface in the present seismotectonic regime (Reference 2). The following sections provide the data, observations, and references to support this conclusion. Information contained in these sections was developed in accordance with RG 1.165 (Reference 2), and is intended to satisfy 10 CFR 100.23, "Geologic and Seismic Siting Criteria" (Reference 4).

2.5.3.1 Geological, Seismological, and Geophysical Investigations

The following investigations were performed to assess the potential for surface fault rupture at and within a 5-mile radius of the ESP site:

- Compilation and review of existing data
- Interpretation of aerial photography
- Field reconnaissance
- Aerial reconnaissance
- Review of seismicity
- Discussions with current researchers in the area

An extensive body of existing information is available for the ESP site. This information is contained in three principal sources:

1. Work performed for the existing units (Reference 5) (Reference 7); abandoned Units 3 and 4 (Reference 9); and the ISFSI (Reference 6). These studies and their results were reviewed and accepted by the NRC (AEC) as part of previous licensing efforts for these facilities.

2. Published and unpublished geologic mapping performed primarily by the USGS and the Virginia Division of Mineral Resources.

3. Seismicity data compiled and analyzed in published journal articles and, more recently, as part of this ESP application (presented in Section 2.5.2.1).

The existing information was supplemented by aerial and field reconnaissance efforts within the 25-mile radius ESP site vicinity and interpretation of aerial photography along all known faults within the 5-mile radius ESP site area. These studies were performed to verify, where possible, the existence of mapped bedrock faults in the site area and to assess the presence or absence of geomorphic features indicative of potential Quaternary fault activity along the mapped faults.

2.5.3.1.1 Previous Site Investigations

Previous site investigations performed for the existing units are summarized in the UFSAR (Reference 5). As cited in the UFSAR, these previous investigations provide the following results documenting the absence of Quaternary faults at and within the area of the ESP site:

1. Interpretation of air photos and topographic maps. This interpretation revealed no evidence of surface rupture, surface warping, or the offset of geomorphic features indicative of active faulting.

2. Seismicity analysis. This analysis showed that no macroseismic activity has occurred in the site area; the closest epicentral location is about 30 miles (50 km) away.

3. Detailed geologic mapping and inspection of excavations during construction. This mapping revealed no evidence of geologically recent or active faulting.

4. Borings drilled at the site. Borehole data has provided evidence of the continuity of strata across the site and the inspection of soil samples and rock core has revealed no adverse effects indicative of geologically recent active faulting.

Subsequent to the initial site investigations performed for the existing units and abandoned Units 3 and 4, a minor bedrock fault associated with a chlorite seam was encountered during foundation excavations for the abandoned Units 3 and 4. This prompted a comprehensive trenching, mapping, and soil stratigraphic study to evaluate the recency of movement of the fault. This study documented the absence of Quaternary deformation along the minor bedrock fault (Reference 9), demonstrating that the fault is not capable in accordance with 10 CFR 100, Appendix A, criteria at that time. The results and conclusions of this study were reviewed and accepted by the NRC (AEC) (Reference 108).

At the time of the original studies for NAPS in 1973 (Reference 9), there were no published maps showing bedrock faults within a 5-mile radius of the site. The closest significant bedrock faults mapped prior to 1973 were the border faults of the Triassic Culpeper Basin approximately 20 miles (32 km) west-northwest of the site (Reference 7).

Since 1973, extensive mapping of the Virginia Piedmont Province, principally by Louis Pavlides of the USGS, has greatly improved knowledge of the bedrock stratigraphy and structure within the area of the ESP site. The Piedmont mapping by Pavlides is incorporated in the Fredericksburg 1:100,000 scale map by Mixon and others (Reference 66), a portion of which comprises Figure 2.5-11. This mapping provides the principal basis for the recognition of bedrock faults within the site area.

In addition, the USGS recently completed a compilation of all Quaternary faults, liquefaction features, and possible tectonic features in the eastern United States (Reference 59). This compilation does not show any Quaternary faults within a 5-mile radius of the site. The nearest

Quaternary features summarized by Crone and Wheeler (Reference 59) are two paleo-liquefaction sites documented by Obermeier and McNulty (Reference 71) on the James and Rivanna Rivers within the CVSZ (presented in Section 2.5.2.2.8). Both of these sites are located over 25 miles from the ESP site.

2.5.3.2 Geological Evidence, or Absence of Evidence, for Surface Deformation

As shown on Figure 2.5-11, seven bedrock faults are mapped within pre-Cambrian and Paleozoic rocks within 5 miles of the ESP site (Reference 66) (Reference 105). These seven bedrock faults are:

- Chopawamsic fault
- Spotsylvania thrust fault
- Unnamed fault traversing the North Anna site (fault “a”)
- Sturgeon Creek fault
- Long Branch thrust fault
- Unnamed fault separating the Ta River Metamorphic Suite from the Quantico Formation (fault “b”)
- Unnamed fault separating the Northeast Creek pluton from the Quantico Formation (fault “c”)

No deformation or geomorphic features indicative of potential Quaternary activity have been reported in the literature for these faults, and none were identified during aerial and field reconnaissance and air photo interpretation undertaken for the current ESP study. Several of the faults may have been locally reactivated during the Triassic episode of continental rifting (presented in Section 2.5.1.1.4); although, none of these faults border Triassic basins, indicating that Triassic reactivation, if any, was not significant enough to produce a Triassic basin or depocenter.

The unnamed bedrock fault (“a”) that traverses the North Anna site was exposed during foundation excavations for abandoned Units 3 and 4. Detailed investigations of this fault (Reference 9) provide direct evidence for the absence of Quaternary faulting (presented in Section 2.5.3.2.2). Thus, this fault is not a capable tectonic source, a position supported by the NRC (AEC) (Reference 108).

2.5.3.2.1 Chopawamsic and Spotsylvania Thrust Faults

The Chopawamsic and Spotsylvania thrust faults bound the eastern and western margins of the Chopawamsic belt, respectively. These two faults are regional Appalachian structures that have been mapped for tens of miles within the Piedmont Province (Reference 66). The Chopawamsic belt is interpreted to be an island-arc accreted to the North American continent during the Paleozoic age Taconic orogeny (presented in Section 2.5.2.1.1).

The Chopawamsic thrust fault is located about 4.5 miles (7 km) northwest of the site and strikes north to northeast (Figure 2.5-11). It is interpreted to be a thrust fault that transported the island-arc

Chopawamsic belt westward onto the Mine Run Complex (presented in Section 2.5.1.1.2) (Reference 40). Due to the fault's minimal exposure, there is little direct evidence for the continuity of the fault (Reference 66). However, interpretations of a thrust fault within a seismic reflection profile that was run along Interstate I-64 (Reference 103) indicate that this structure may extend for a distance of over 45 miles (70 km) (Reference 40).

The Spotsylvania thrust fault is located about 4.5 miles (7 km) southeast of the site (Figure 2.5-11). This northeast-striking fault is well documented by aeromagnetic and aero-radiometric data (Reference 138) (Reference 37). The fault juxtaposes rocks of the Ta River Metamorphic Suite (Chopawamsic belt) on the west against rocks of the Po River Metamorphic Suite (Goochland belt) on the east, but is not exposed at the surface within the Fredericksburg 1:100,000 quadrangle (Reference 66). The fault is defined by a 1.5-mile wide zone of faulting rather than a single fault (Reference 105) (Reference 37). The Spotsylvania thrust fault was first recognized as an aeromagnetic and aero-radiometric lineament (Reference 138), and initially was referred to as Neuschel's Lineament. Specific studies of this feature by Dames & Moore (Reference 139) demonstrate that the Spotsylvania thrust fault exhibits negligible vertical deformation of a pre- to early-Cretaceous erosion surface and is not related to Tertiary faulting along the younger Stafford fault zone (presented in Section 2.5.1.1.4). The fault was determined by the NRC (AEC) to be not capable within the definition of 10 CFR 100, Appendix A (Reference 140). The Spotsylvania fault is also referred to as the Spotsylvania high-strain zone, which may connect southwest to the Hyco and Central Piedmont shear zones as a major structural boundary for a total length of over 300 miles (480 km) in the southern Appalachians (Reference 35).

The Chopawamsic and Spotsylvania thrust faults are not associated with seismicity and do not exhibit geomorphic evidence of potential Quaternary activity. In their recent compilation of Quaternary faults in the eastern United States, Crone and Wheeler (Reference 59) do not show either fault as a Quaternary feature. Therefore, it is concluded that these faults are not capable tectonic sources within the area of the ESP site.

2.5.3.2.2 Unnamed Fault Traversing the North Anna Site

As previously indicated, an unnamed fault (fault "a") was discovered in the foundation excavations for the abandoned Units 3 and 4 (Figure 2.5-11). A comprehensive study was performed by Dames & Moore (Reference 9) to evaluate the fault's location, geometry, and age. This study included detailed mapping of the excavation exposures, three fault trenches, interpretation of aerial photography, and a detailed soil profile analysis. Based on geologic mapping and trenching, the fault was mapped for a distance of about 3000 feet (Figure 2.5-18) (Plate 3 of Reference 9). Dames & Moore (Reference 9) concluded that the fault was not capable, in accordance with 10 CFR 100, Appendix A criteria, based on the following conditions:

- Direct evidence of no displacement of saprolitic soils in excess of 1 million years old
- Absence of geomorphic expression

- Potassium/argon (K/Ar) dating of chlorite infilling along the fault ranging from 214 to 303 million years old

In 1974, the NRC (AEC) issued Supplement No. 3 to the Safety Evaluation for Units 3 and 4, accepting the conclusion that the fault is not capable (Reference 106). Specifically, the NRC (AEC) made the following statement:

> Regarding the age and most recent movement on the fault zone: The most recent movement on the fault zone occurred at least one to two million years ago according to dating of overlying saprolites and probably more that 200,000,000 years ago during the last significant tectonism in the Virginia Piedmont Province, which occurred in the Triassic Period. The major events associated with this tectonism were the emplacement of diabase dikes and the formation of down-faulted sedimentary basins. Earthquakes in the Piedmont Province do not correlate with known tectonic structures. No historic earthquake in this province has been known to cause faulting at or near the surface. The North Anna fault zone is neither genetically nor structurally related to any known, capable fault. Thus the staff concludes that the faults are not “capable” as defined by Appendix A of 10 CFR Part 100.

Subsequent to the Dames & Moore (Reference 9) site investigation, Pavlides (Reference 36) (Reference 141) extended this fault farther north and south of the North Anna site, for a total length of about 7 miles (11 km) (Figure 2.5-11). Aerial reconnaissance, field reconnaissance and air photo interpretation carried out for this ESP application, however, did not reveal any evidence for the existence of the fault as mapped by Pavlides. Bedrock exposures are poor to non-existent along the entire length of the fault, and there is no geomorphic expression of the fault trace. Since 1973, no new information has been published that would suggest potential Quaternary activity of the fault at the site. The absence of geomorphic expression along the entire fault length, as mapped by Pavlides (Reference 36), combined with the original Dames & Moore study (Reference 9) and investigations carried out for this ESP, support the interpretation that the fault traversing the North Anna site is not a capable tectonic source and that the position previously expressed by the NRC (AEC) (Reference 106) remains valid.

2.5.3.2.3 Sturgeon Creek Fault

The Sturgeon Creek fault is located about 1.2 miles (2 km) northwest of the site (Figure 2.5-11). The fault has a strike of about N70°E in the vicinity of Sturgeon Creek, but changes to a more southerly strike of N30-40°E south of the North Anna River, where it becomes coincident with the axial region of the Quantico syclinorium along Freshwater Creek (Reference 66). The fault, which has a mapped length of 10.5 miles (17 km), sinistrally displaces the faulted contact between the Quantico Formation and Ta River Metamorphic Suite by about 1.4 miles (2 km). More recent mapping to the south does not extend the Sturgeon Creek fault into the adjacent Richmond 1:100,000 scale map sheet (Reference 105) (Figure 2.5-11).

Field and aerial reconnaissance and interpretation of aerial photography carried out for this ESP application shows that there are no geomorphic features indicative of potential Quaternary activity along the fault and that the fault does not appear to offset any Quaternary surficial deposits. A linear reach of Freshwater Creek is present locally along the fault, but this appears likely to be a result of straightening by man, perhaps related to earlier mining operations. Based on the absence of geomorphic expression, absence of seismicity, and absence of offset of Quaternary surficial deposits it is concluded that the Sturgeon Creek fault is not a capable tectonic source.

2.5.3.2.4 Other Faults Within the Chopawamsic Terrane

Three other bedrock faults are mapped within the Chopawamsic terrane within 5 miles of the ESP site. These are the Long Branch thrust fault and two unnamed faults: one that juxtaposes the Quantico Formation against the Ta River Metamorphic Suite (fault “b”), and another that juxtaposes the Quantico Formation against the Northeast Creek pluton (fault “c”) (Figure 2.5-11).

The Long Branch thrust fault, which borders the Quantico Formation on the northwest side, has a mapped length of over 45 miles (70 km) across the Fredericksburg and Richmond map sheets (Reference 66) (Reference 105). The fault is located about 2.2 miles (3.5 km) west of the site and strikes about N30°E. It is thought that the westward thrusting of the Long Branch fault began near the end of the Allegheny orogeny after much of the regional Allegheny amphibolite grade metamorphism had occurred (Reference 40). The Long Branch thrust fault is locally dextrally displaced by other minor bedrock faults within the Chopawamsic belt at distances beyond the 5-mile radius from the site area (Reference 66).

The two unnamed faults (“b” and “c”) are located east of the Long Branch thrust fault, approximately 1 and 4 miles (1.5 and 6.5 km) west and north of the site, respectively (Figure 2.5-11). The longer of the two faults (fault “b”) juxtaposes the Quantico Formation on the west with rocks of the Ta River Metamorphic Suite and the Elk Creek and Northeast Creek plutons on the east. This fault is mapped for a total distance of about 16 miles (26 km), is offset by the Sturgeon Creek fault, and is truncated at its northern end by unnamed fault “c” (Reference 66) (Reference 105). Unnamed fault “c” has a mapped length of 3.4 miles (5.5 km) and juxtaposes the Northeast Creek pluton against the Quantico Formation (Figure 2.5-11).

None of the faults described above are associated with any gravity or magnetic anomaly, or any seismicity, nor do they exhibit any geomorphic or Quaternary stratigraphic evidence of recent activity. Therefore, it is concluded that the Long Branch thrust fault and the two unnamed faults are related to the Paleozoic tectonic regime and are not capable tectonic sources.

2.5.3.3 Correlation of Earthquakes with Capable Tectonic Sources

No reported historical earthquake epicenters have been associated with bedrock faults within the 25-mile radius of the ESP site vicinity (Figure 2.5-56). Micro-earthquake monitoring for NAPS was initially conducted over a 2.5-year period from January 21, 1974, to August 1, 1976, and was

subsequently extended an additional year to August 1, 1977 (Reference 142). The purpose of the monitoring program was to determine if seismic activity could be associated with faults in the site area or if Lake Anna was producing reservoir-induced seismicity. Micro-earthquakes detected in the 3.5 years of monitoring could not be associated either with faults in the site area or with the impoundment of Lake Anna (Reference 5) (Reference 143) (Reference 144).

Four stations of the original 17-station network were incorporated into Virginia Polytechnic Institute and State University's Central Virginia Monitoring Network for the specific purpose of monitoring any changes in seismicity in the region of NAPS. To date, no changes in local earthquake occurrence have been observed that would alter the conclusions reached in 1977 regarding the lack of association of micro-earthquakes with the presence of Lake Anna or with faults in the site area. Micro-earthquakes observed in the site area appear to be part of, or are occurring at, a level no greater than the spatially varying background activity found in the CVSZ.

2.5.3.4 Ages of Most Recent Deformations

As presented in Section 2.5.3.2, none of the seven faults within 5 miles of the ESP site exhibit evidence of Quaternary activity. All of the faults formed during the Paleozoic Era as part of the regional Taconic orogeny, and locally they may have been reactivated during the later Paleozoic Acadian and Allegheny orogenies or during Triassic continental rifting (presented in Section 2.5.1.1.4). Based on a review of the available literature, no studies have been published that suggest or document post-Triassic activity on any of these structures. Therefore, the seven bedrock faults mapped within 5 miles of the site are considered to be old structures that formed during the Paleozoic age Appalachian orogenies or early Mesozoic age rifting.

2.5.3.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

The seven faults identified in the site area are located within the Chopawamsic belt, which is interpreted to be an island-arc that was accreted to North America during the Middle to Late Ordovician Taconic orogeny. Following accretion, rocks of the Chopawamsic belt and other rocks of the Piedmont Province were deformed and thrust westward during the Acadian and Allegheny orogenies that occurred from Devonian to Permian time. Locally, these rocks may also have been affected by extensional tectonics during Triassic rifting (presented in Section 2.5.1.1.4).

As described in Section 2.5.3.2, the Chopawamsic, Spotsylvania, and Long Branch thrust faults are regional easterly-dipping faults that extend northeast and southwest of the site for tens of miles. The four other faults within the site area are much shorter in length and are located within the Appalachian thrust sheets and, therefore, do not represent structures that penetrate deep into the crust (presented in Section 2.5.1.1.4).

2.5.3.6 Characterization of Capable Tectonic Sources

Based on previous discussions, there are no capable tectonic sources within 5 miles of the ESP site.

2.5.3.7 Designation of Zones of Quaternary Deformation Requiring Detailed Fault Investigation

There are no zones of Quaternary deformation requiring detailed investigation within the site area. A zone of minor faulting associated with chlorite seams (fault “a”) was encountered in the foundation excavation for abandoned Units 3 and 4. Investigation of this minor fault showed that the zone of faulting is not capable (Reference 9) (Reference 108), in accordance with 10 CFR 100, Appendix A. Subsequent air photo interpretation, aerial reconnaissance, and field reconnaissance of the fault trace carried out for this ESP application confirms the conclusion reached by Dames & Moore (Reference 9), and no further investigation of this fault is considered necessary.

2.5.3.8 Potential for Tectonic or Non-Tectonic Deformation at the Site

The potential for tectonic deformation at the site is negligible. Since the original site studies in the early 1970s, no new information has been reported to suggest the existence of any Quaternary surface faults or capable tectonic sources within the site area. In addition, there is no evidence of non-tectonic deformation at the site, such as glacially induced faulting, collapse structures, growth faults, salt migration, or volcanic intrusion.

2.5.4 Stability of Subsurface Materials and Foundations

This section presents information on the stability of subsurface materials and foundations at the ESP site. The information has been developed in accordance with Review Standard RS-002, "Processing Applications for Early Site Permits" (Reference 145), following the guidance presented in RG 1.70, Section 2.5.4 (Reference 3), and the regulatory guides referenced in the subsections that follow. This geological, geophysical, geotechnical and seismological information is used as a basis to evaluate the stability of subsurface materials and foundations at the site.

Information presented in this section was developed from a review of reports prepared for the existing units and abandoned Units 3 and 4, geotechnical literature, and a subsurface investigation conducted for preparation of this ESP. Reports reviewed include the UFSAR (Reference 5) and the ISFSI Safety Analysis Report (Reference 6). Reports prepared by Dames and Moore for design and construction of the existing units (Reference 146) and the abandoned Units 3 and 4 (Reference 8) (Reference 9) were also reviewed.

The additional field and laboratory investigations performed for the ESP were intended to confirm the already large volume of geotechnical data developed for the existing units and the abandoned Units 3 and 4 within the ESP site area. Additional structure-specific exploration and testing would be performed during detailed engineering and would be described in the COL application.

2.5.4.1 Geologic Features

Section 2.5.1.1 describes the regional geology, including regional physiography and geomorphology, regional geologic history, regional stratigraphy, and the regional tectonic setting. Section 2.5.1.2 addresses site-specific geology and structural geology, including site physiography and geomorphology, site geologic history, site stratigraphy, site structural geology, and a site geologic hazard evaluation.

2.5.4.2 Properties of Subsurface Materials

2.5.4.2.1 Introduction

This section describes the static and dynamic engineering properties of the ESP site subsurface materials. An overview of the subsurface profile and materials is given in Section 2.5.4.2.2. The field investigations, described in Section 2.5.4.3, are summarized in Section 2.5.4.2.3. The saprolitic soils were studied in the investigation for the existing units. However, a more intensive investigation of these materials was undertaken during construction of the existing units when larger-than-expected settlements were recorded at the SWR pump house. Many undisturbed samples were recovered during these investigations, and laboratory testing included extensive dynamic as well as static testing. These tests and their results are summarized in Section 2.5.4.2.4, along with laboratory testing performed recently for the ESP investigation. The engineering properties of the subsurface materials are presented in Section 2.5.4.2.5.

2.5.4.2.2 Description of Subsurface Materials

Dames and Moore (Reference 146) (Reference 8) divided the site soils into five zone categories:

- I Residual clays and clay silts – all structures of parent rock are lost
- IIA Saprolite – core stone less than 10 percent of volume of overall mass
- IIB Saprolite – core stone 10 to 50 percent of volume of the overall mass
- III Weathered rock – core stone more than 50 percent of volume of the overall mass
- IV Parent rock – slightly weathered to fresh rock below zone of isolated core stones

These zones have worked as a successful means for classifying the soil and rock with regard to engineering properties. This zone system was used in the UFSAR for the existing units and is also used in this ESP SSAR.

The materials overlying the parent Zone IV rock represent a continuously more pronounced form of in-place weathering. Both Dames and Moore and the UFSAR adopted an additional zone, termed Zone III-IV, to represent this slightly to moderately weathered rock. The Zone III-IV terminology is also used in this ESP application.

The following is a brief description of the subsurface materials, giving the soil and rock constituents, and their range of thickness encountered at the site. The information was taken from the 140 borings made to date at the site (outlined in Section 2.5.4.3.1). For reference, the existing site elevations in the areas explored range from about Elevation 250 to 330 feet, with a median of about Elevation 290 feet. The plant grade of the existing units is Elevation 271 feet. This is the powerblock elevation used for the new units. The engineering properties are provided in Section 2.5.4.2.5.

a. **Zone IV Bedrock**

The Zone IV bedrock is fresh to slightly weathered gneiss bedrock. Gneiss is a metamorphic rock that exhibits a banded texture (foliation) in which light and dark bands alternate. It is composed of feldspar, quartz, and one or more other minerals such as mica and hornblende. The recently completed ESP investigation (Reference 147, reproduced as Appendix 2.5.4B) describes the bedrock as a quartz gneiss with biotite (a dark mica) in the majority of cores, but also references biotite quartz gneiss and occasionally biotite gneiss. A detailed description of the bedrock is contained in Section 2.5.1.2.3.

The top of Zone IV (including Zone III-IV) bedrock encountered in the borings made at the ESP site range from Elevation 188 feet to 298 feet. Typical depths are illustrated on the subsurface profiles on Figure 2.5-57 and Figure 2.5-58. The locations of these profiles are shown on Figure 2.5-61.

b. **Zone III Weathered Rock**

The weathered rock has the same constituents as the parent rock. It is described as moderately to highly weathered rock, sometimes with unweathered seams and sometimes with high fracture frequency. It is defined as having at least 50 percent core stone.

The top of Zone III bedrock encountered in the borings made at the site range from Elevation 205 feet to 298 feet. The maximum thickness measured is 67 feet. Typical depths are illustrated on the subsurface profiles on Figure 2.5-57 and Figure 2.5-58.

c. **Zone IIA and IIB Saprolites**

Saprolites are a further stage of weathering beyond weathered rock. Saprolites have been produced by the disintegration and decomposition of the bedrock in place and have not been transported. Saprolites are classified as soils but still contain the relict structure of the parent rock, and they typically still contain some core stone of the parent rock. The ESP site saprolites in many instances maintain the foliation characteristics of the parent rock. They are classified primarily as silty sands, although there are also sands, clayey sands, sandy silts, clayey silts and clays, depending very much on their degree of weathering. The fabric is anisotropic. The texture shows angular geometrically interlocking grains with a lack of void network, very unlike the well-pronounced voids found in marine or alluvial sands and silts.

The distribution of the Zone IIA and IIB saprolites varies throughout the site. On average, the Zone IIB saprolites represent about 20 percent of the saprolites on site and are typically very dense silty sands with from 10 to 50 percent core stone. These soils were even rock-cored in some of the borings during the earlier investigations (Reference 8). The thickest Zone IIB deposit encountered in the borings was 37 feet.

The overlying Zone IIA saprolites comprise, on average, about 80 percent of the saprolitic materials on site. About 75 percent of the Zone IIA saprolites are classified as coarse grained (sands, silty sands), while the remainder are fine grained (clayey sands, sandy and clayey silts, and clays). A detailed breakdown of these percentages is given in Table 2.5-29. The saprolites typically become finer toward the ground surface. The thickest Zone IIA deposit encountered in the borings was 101 feet.

d. **Zone I and Fill**

There is typically very little of the Zone I residual soil onsite—on average, less than 1 percent of the soil is Zone I. The Zone I soils are either at the surface or are immediately below fill placed during construction of the earlier units. This fill is generally made up of Zone IIA soils. For any future foundations, Zone I soils and existing fills would be excavated. Thus, they are not considered further here.

e. **Subsurface Profiles**

Figure 2.5-57 and Figure 2.5-58 illustrate typical subsurface profiles across the powerblock area proposed for the ESP. The locations of these profiles are shown in Figure 2.5-61. These profiles are presented with respect to excavation for the new units in Section 2.5.4.5 and for bearing capacity considerations in Section 2.5.4.10.

2.5.4.2.3 Field Investigations

The exploration programs performed previously for the existing units and abandoned Units 3 and 4, the SWR, and the ISFSI, and new investigations for the ESP site are described in Section 2.5.4.3. The borings from previous explorations are summarized in Table 2.5-30 through Table 2.5-37. The borings, observation wells, and cone penetrometer tests from the ESP site exploration program are summarized in Table 2.5-38 and Table 2.5-39. The soil sampling and rock coring results are summarized in Table 2.5-40 and Table 2.5-41. Previous geophysical surveys and new surveys for the ESP are described in Section 2.5.4.4.

2.5.4.2.4 Laboratory Testing

As with the field exploration, numerous laboratory tests of soil and rock samples were performed previously for the existing units and new tests have been performed for the ESP site investigation. The types and numbers of these tests are shown in Table 2.5-42. Note that the large majority of the tests on the Zone IIA saprolitic soils were performed for the various SWR investigations. The following paragraphs focus on these SWR tests and on the tests performed recently for the ESP site subsurface investigation.

a. **Laboratory Tests for SWR**

The laboratory testing of the SWR soils focused on the strength, compressibility and liquefaction potential of the Zone IIA saprolites. A large number of undisturbed thin-walled tube samples were taken. Thin sections were made from five undisturbed samples to assess the fabric, texture, and mineralogy of the saprolite. One of the boreholes was angled in an attempt to obtain undisturbed samples for unconsolidated-undrained (UU) triaxial tests perpendicular to the foliation of the saprolite. The laboratory tests are summarized in the following paragraphs.

1. **Cyclic Triaxial Tests**

Between November 1975 and June 1976, Geotechnical Engineers, Inc. (GEI) of Winchester, Massachusetts, performed 18 stress-controlled consolidated-undrained cyclic triaxial tests on undisturbed samples from 11 borings located on or adjacent to the SWR dike. Three tests were aborted due to testing/equipment failure. The 15 remaining tests were run primarily to provide input for liquefaction analysis of the soils beneath the SWR dike.

It should be noted that these tests were conducted by one of the country's premier geotechnical firms during the period when cyclic triaxial testing was at its zenith. This type of testing declined appreciably during the 1980s when field test results became the accepted input into liquefaction analysis. By the 1990s it was difficult to find a testing laboratory with the equipment or experience to perform these tests. In short, it would be difficult to obtain the quality of these GEI cyclic triaxial test results today.

Appendix 2.5.4A contains the details and results of the testing. This portion of the appendix is made up from parts of UFSAR Appendix E, Attachments 1 through 4. It contains the following information for each of the 15 tests:

- A summary table of the details and results of each test
- A plot of octahedral shear stress ratio versus number of cycles to reach 5 percent maximum compressive strain
- A plot of octahedral shear stress ratio versus consolidation stress
- Detailed visual descriptions of each of the samples
- Grain size curves of each of the test samples
- Plots of cyclic axial strain (compression, double amplitude and extension) versus cycle number for each of the tests

2. **Static Triaxial Tests**

Eight consolidated-undrained triaxial compression tests with pore pressure measurements were performed on undisturbed samples from SWR borings. The results of these tests are tabulated in Appendix 2.5.4A. Five of the tests were run on the in-situ Zone IIA saprolite, while three were conducted on compacted dike fill. Three of the in-situ saprolite samples failed along foliation planes.

Eighty undisturbed thin-walled tube samples were later obtained from borings on or close to the SWR dike. Sixty-two unconsolidated-undrained triaxial tests were performed on samples from these tubes. Details and results of these tests are tabulated in Appendix 2.5.4A. The table includes the mode of failure of each sample.

This portion of the appendix is made up of parts of Appendix E and UFSAR Appendix E, Attachment 4.

3. **Consolidation Tests**

Fifteen one-dimensional consolidation tests were performed on undisturbed samples from SWR borings. Tests were run at both constant rate of strain and by incremental loading. Non-plastic samples (which included most of the samples) were tested in sections cut from the thin-walled sampling tubes. Details and results of these tests are tabulated in

Appendix 2.5.4A. This portion of the appendix is made up from parts of UFSAR Appendix E.

4. **Thin Sections**

   Twenty-seven thin sections from undisturbed samples from five borings were examined under plane and polarized light at magnifications up to 400X, to determine in a qualitative manner the fabric, texture, and mineralogy of the saprolite beneath the SWR dike.

   The descriptions of the fabric, texture, and mineralogy of the Zone IIA saprolite contained in the UFSAR Appendix 3E, Attachment 4, are included in Appendix 2.5.4A.

b. **Laboratory Tests for ESP**

The laboratory testing for the ESP investigation was performed in accordance with the guidance presented in RG 1.138 (Reference 148), including Draft RG DG-1109 (Reference 149). The laboratory work was performed under an approved quality program with work procedures developed specifically for the ESP project. Soil and rock samples were shipped under chain-of-custody protection from the storage area (described in Section 2.5.4.3.2) to the testing laboratory. If required, samples were further divided and/or shipped to the appropriate testing laboratory under chain-of-custody rules. Laboratory testing was performed at the MACTEC laboratories in Raleigh, North Carolina (all soil testing except chemical analysis), and Atlanta, Georgia (all rock testing), and at Severn Trent Laboratory in Savannah, Georgia (chemical analysis).

The types and numbers of laboratory tests performed on the soil samples and rock cores from the ESP exploration program are included on Table 2.5-42. The numbers of tests were purposely limited in light of the large number of tests performed for previous investigations. The ESP tests focused primarily on the following tasks:

- Verifying the basic properties of the Zone IIA saprolite (e.g., grain size)
- Obtaining chemical test results on the Zone IIA saprolite (for corrosiveness toward buried steel and aggressiveness toward buried concrete)
- Obtaining additional strength and elastic modulus data for the bedrock on which the main safety-related structures would be founded

The details and results of the laboratory testing are included in Appendix 2.5.4B. Appendix 2.5.4B includes references to the industry standards used for each specific laboratory test. The results of the tests on soil samples are shown on Table 2.5-43. All of the samples tested are in-situ Zone IIA saprolite, except the three samples from B-801 (fill), and the bottom two samples from B-807 (Zone IIB saprolite). Table 2.5-44 summarizes the results of the unconfined compression tests on the rock cores. The ESP laboratory test results were similar to those obtained in the previous testing.

2.5.4.2.5 Engineering Properties

The engineering properties for Zones IIA, IIB, III, III-IV, and IV, derived from the previous studies and from ESP field exploration and laboratory testing programs, are provided in Table 2.5-45. The engineering properties obtained from the ESP field exploration and laboratory testing program were similar to those obtained from the previous field and laboratory testing programs.

The following paragraphs briefly describe the sources and/or methods used to develop the selected properties shown in Table 2.5-45.

a. **Rock Properties**

The Recovery and Rock Quality Designations (RQD) are based on the results provided in Table 2.5-41. The unconfined compressive strength is based on the ESP rock strength results shown in Table 2.5-44 and the rock strengths from the investigations for the existing units (Reference 146). The unit weight is based on the values measured in the ESP rock strength tests (Appendix 2.5.4B).

The elastic modulus values are based on the values shown in Table 2.5-44. These values agree well with those derived from the geophysical tests performed for the ESP exploration program as described in Section 2.5.4.4.2. The shear modulus values are derived from the elastic modulus values using the Poisson's ratio values tabulated in Table 2.5-45, which are based on the values provided in Table 2.5-44. Low and high strain modulus values are essentially the same for high strength rock that is, for the Zone IV rock. Similarly, no strain softening is assumed for the Zone III-IV rock. Some strain softening has been allowed for the Zone III rock. Low strain is defined here as 10^{-4} percent while high strain is taken as 0.25 to 0.5 percent, the amount of strain frequently associated with settlement of structures on soil.

The shear and compression wave velocities are based on the cross-hole and down-hole seismic tests performed as part of the ESP exploration program (Appendix 2.5.4B). These results are in agreement with the results of the geophysical tests performed for the existing units (Reference 146), and are summarized in Section 2.5.4.4.2.

b. **Soil Properties**

Grain size curves from 13 sieve analyses of Zone IIA silty sand samples from the ESP laboratory testing program (Appendix 2.5.4B) fit within the envelope of the 12 sieve analyses of Zone IIA silty sands sampled from borings near the SWR pump house (Reference 5, Figure 3.8-51). The range of fines in Table 2.5-45 for the coarse-grained Zone IIA soil is from these curves.

The natural moisture content of the fine-grained Zone IIA saprolite is the median value of 108 moisture content tests performed on fine-grained Zone IIA saprolites for the existing units, SWR, ISFSI, and ESP investigations. The range of moisture content in these tests was 14 to 56 percent.

The undrained shear strength of the fine-grained Zone IIA saprolite is estimated from SPT N-values and CPT results, as well as from the results of 18 unconsolidated-undrained triaxial compression tests and three unconfined compression tests. The effective strength parameters for the fine-grained saprolite are based on the results of consolidated-undrained triaxial tests on fine-grained saprolite run for the ISFSI and SWR investigations.

The effective angle of internal friction of the medium dense coarse-grained saprolite (N = 20 blows/foot) would typically be taken as around 35 degrees (Reference 150). However, the high silt content and the presence of low plasticity clay minerals reduce this angle. Consolidated-undrained triaxial tests reported in UFSAR Appendices 2C and 3E produced internal friction angles ranging from 23 to 33 degrees, with a median of 30.8 degrees. Thus, an angle of 30 degrees was selected. The average effective cohesive component from the Appendix 2C tests was 0.275 kps per square foot (ksf). A value of 0.25 ksf was selected for the cohesive component.

A large amount of testing was performed after low unit weights were measured in the Zone IIA saprolites in the SWR area (Reference 5, Appendix 3E, Attachment 4). It is concluded that there are isolated lower densities, but these are not typical. UFSAR Table 3.8-13 identifies 125 pounds per cubic foot (pcf) as a design total unit weight. The 130 pcf used in Table 2.5-45 for the Zone IIB saprolites reflects the high relative density of that material.

The SPT design N-value of 20 blows/foot for the Zone IIA saprolite is conservatively based on the results reported in Table 2.5-40. Those results show median N-values for the ESP and ISFSI investigations of 21 blows/foot, with the median N-values for the existing units, abandoned Units 3 and 4, and SWR investigations, ranging from 25 to 52 blows/foot.

The shear wave velocities measured in the ESP cross-hole seismic tests (Appendix 2.5.4B) in the Zone IIA sandy silt from 7.5 to 27 feet depth range from 650 to 1350 fps, with an average of 998 fps. The CPT seismic results are somewhat higher. The UFSAR has a value of 950 fps for the Zone IIA saprolite. The 950 fps average value has been selected for the Zone IIA saprolite in Table 2.5-45. This is presented in more detail in Section 2.5.4.7.1.

For the Zone IIB saprolite, the shear wave velocity derived from the low strain value of shear modulus is in good agreement with the results from the CPT seismic tests, at around 1600 fps. The profile of shear wave velocity versus depth for the saprolite is given in Section 2.5.4.7.

The high strain (i.e., in the range of 0.25 to 0.5 percent) elastic modulus values for the coarse-grained Zone IIA saprolite and the Zone IIB saprolite have been derived using the relationship with SPT N-value given in Davie and Lewis (Reference 151). The high strain elastic modulus for the fine-grained Zone IIA saprolite has been derived using the relationship with undrained shear strength given in Davie and Lewis (Reference 151). The Zone IIA coarse and fine-grained values have been adjusted slightly to obtain a common value. The shear

modulus values have been obtained from the elastic modulus values using the relationship between elastic modulus, shear modulus and Poisson's ratio (Reference 150).

The low strain (i.e., 10^{-4} percent) shear modulus for the Zone IIA saprolite has been derived from the shear wave velocity of 950 fps. The low strain shear modulus of the Zone IIB saprolite has been derived from the shear wave velocity of 1600 fps. The elastic modulus values have been obtained from the shear modulus values using the relationship between elastic modulus, shear modulus, and Poisson's ratio (Reference 150).

The recompression ratio and the coefficient of secondary compression are the values derived from the settlement studies performed for the SWR pump house, as detailed in UFSAR Appendix 3E.

The values of unit coefficient of subgrade reaction are based on values for medium dense sand (Zone IIA saprolite) and very dense sand (Zone IIB saprolite) provided by Terzaghi (Reference 152).

The earth pressure coefficients are Rankine values, assuming level backfill and a zero friction angle between the soil and the wall.

c. **Chemical Properties**

Chemical tests were performed on selected Zone IIA samples. In addition to the tests performed for the ESP investigation (results shown in Table 2.5-43), chemical tests were previously performed on two samples from the subsurface investigation for the existing units (Reference 146). The six pH test results ranged from 5.7 to 6.9, in the mildly corrosive to neutral range. The six sulfate test results ranged from about 1 to 28 parts per million (ppm), which indicates no aggressiveness toward concrete. Three of the chloride test results ranged from 100 to 170 milligrams per kilogram (mg/kg), indicating little corrosive potential toward buried steel. The fourth chloride test produced 920 mg/kg, indicating potential corrosiveness toward buried steel.

2.5.4.3 Exploration

Section 2.5.4.3.1 summarizes previous subsurface investigations performed at the NAPS site, while Section 2.5.4.3.2 summarizes the ESP exploration program.

2.5.4.3.1 Previous Subsurface Investigation Programs

The locations of these borings and their depth ranges are shown on Figure 2.5-59.

a. **Existing Units Borings**

Sixty borings were performed from August through October 1968, with boring depths ranging from 20 to 150 feet, averaging 93 feet (Reference 146). Borings used standard penetration test sampling, Dames and Moore soil samplers, and NX-size double-tube core barrels for rock coring. Boring locations, depths, etc. are summarized in Table 2.5-30 and Table 2.5-31. Test

pits and trenches were also dug. Geophysical surveys conducted during this investigation are summarized in Section 2.5.4.4.1.

b. **Abandoned Units 3 & 4 Borings**

Forty-seven borings were performed during June and July 1971, with boring depths ranging from 40 to 175 feet, averaging 74 feet (Reference 8). Borings used standard penetration test sampling, Dames and Moore soil samplers, Denison thin-walled tube samplers, and NX-size double-tube core barrels for rock coring. Boring locations, depths, etc. are summarized in Table 2.5-32 and Table 2.5-33. Test pits and trenches were also dug.

c. **SWR Borings**

Twenty-two borings were performed during September 1975 (UFSAR Appendix 3E), and May 1976 (UFSAR Appendix 3E, Attachment 4) to address NRC concerns raised during licensing of the existing units. Boring depths ranged from 27 to 105 feet, and averaged 70 feet. Borings used standard penetration test sampling and thin-walled tube samplers. Boring locations, depths, etc., are summarized in Table 2.5-34 and Table 2.5-35.

d. **ISFSI Borings**

Nine borings were performed in April and July 1994 with boring depths ranging from 59 to 115 feet, averaging 81 feet (ISFSI SAR). Borings used standard penetration test sampling, thin-walled tube samplers, and NX-size double-tube core barrels for rock coring. Boring locations, depths, etc., are summarized in Table 2.5-36 and Table 2.5-37.

2.5.4.3.2 ESP Subsurface Investigation Program

The subsurface investigation for the ESP application was performed in November and December 2002 over a substantial portion of the ESP site to cover the area enveloped for the new units as well as cooling towers for the new units (Reference 147, Appendix 2.5.4B). This investigation consisted of relatively few exploration points, and was designed primarily to confirm the results obtained from the previous extensive investigations.

Additional structure-specific exploration and testing would be performed during detailed engineering and would be described in the COL application. The ESP exploration point locations are shown in Figure 2.5-60. The exploration points from the ESP investigation are combined with the boring locations from all of the previous investigations in Figure 2.5-61.

The scope of work and the special methods used to collect data are listed below:

- Seven exploratory borings (MACTEC Engineering and Consulting, Raleigh, North Carolina)
- Nine observation wells (MACTEC Engineering and Consulting, Raleigh, North Carolina)
- Eight cone penetrometer tests (CPT) plus 2 down-hole seismic cone tests and 2 pore pressure dissipation tests (Applied Research Associates, South Royalton, Vermont)

- Two sets of cross-hole seismic tests and 1 down-hole seismic test (Grumman Exploration, Columbus, Ohio)
- Survey of all exploration points (Stantec Consulting, Richmond, Virginia)
- Laboratory testing of borehole samples and cores (MACTEC, Raleigh, North Carolina, and Atlanta, Georgia, laboratories, and Severn Trent Laboratory of Savannah, Georgia)

The exploration program was performed using RG 1.132 (Reference 153), including Draft RG DG-1101 (Reference 154). The fieldwork was performed under an audited and approved quality program and work procedures developed specifically for the ESP project. The subsurface investigation and sample/core collection were directed by the MACTEC site manager who was on site at all times during the field operations. A Bechtel geotechnical engineer or geologist, along with a Dominion representative, were also on site continuously during these operations. MACTEC's QA/QC expert was on site part of the time. The draft boring and well logs were prepared in the field by MACTEC geologists.

Dominion personnel used electromagnetic and ground penetrating radar methods to check each planned exploration location for the presence of underground utilities. Some planned locations were adjusted to provide the necessary utility clearances. A digging, drilling and cutting permit for each exploration location was obtained before any drilling or CPT work was performed.

An on-site storage facility for soil samples and rock cores was established before the fieldwork began. This facility is within the limited access and climate controlled A Level area of the existing units' warehouse facility. Samples and cores were stored within a secured 6-foot high chain link enclosure erected in the A Level area. Each sample and core was logged into an inventory system. Samples removed from the facility were noted in the sample inventory logbook. A chain-of-custody form was also completed for all samples removed from the facility.

Details and results of the exploration program are contained in Appendix 2.5.4B. The borings, observation wells, and CPTs are summarized below. The laboratory tests are summarized and the results presented in Section 2.5.4.2. The geophysical tests are summarized and the results presented in Section 2.5.4.4.

a. **Borings and Samples/Cores**

The seven borings drilled ranged from 50 to 170 feet in depth, averaging 85 feet. The 170-foot deep boring was 30 feet deeper than the deepest reactor design being considered for the ESP. The borings were advanced in soil using rotary wash drilling techniques until standard penetration test (SPT) refusal occurred. Steel casing was then set into the rock, and the holes were advanced using wireline rock coring equipment consisting of a 5-foot long "NQ" core barrel with a split inner barrel.

The soil was sampled using an SPT sampler at 2.5-foot intervals to about 15 feet depth and at 5-foot intervals below 15 feet. The SPT was performed with rope and cathead, and was

conducted in general accordance with ASTM D 1586 (Reference 155). The recovered soil samples were visually described and classified by the onsite geologist. A selected portion of the soil sample was placed in a glass sample jar with a moisture proof lid. The sample jars were labeled, placed in boxes, and transported to the on-site storage area.

Rock coring was performed in general accordance with ASTM D 2113 (Reference 156). After removal from the split inner barrel, the recovered rock was carefully placed in wooden core boxes. The onsite geologist visually described the core, noting the presence of joints and fractures, and distinguishing natural breaks from mechanical breaks. The geologist also computed the percentage recovery and the rock quality designation (RQD). Filled core boxes were transported to the on-site sample storage facility, where a photograph of each core was taken.

The boring logs and the photographs of the rock cores are in Appendix 2.5.4B. Borehole locations, depths, etc. are summarized in Table 2.5-38 and Table 2.5-39. The soil and rock materials encountered in the ESP borings were similar to those found in the previous sets of borings conducted at the NAPS site.

b. **Observation Wells**

Eight of the observation wells were screened in soil and/or weathered rock and had depths ranging from about 25 to 50 feet. Boreholes for these wells were advanced with hollow stem augers. Samples were obtained at 5-foot intervals to provide information on an appropriate depth to set the slotted screen. The ninth well (OW-845) was screened in rock. This 55-foot-deep well was advanced using a rotary air-percussion drill rig without samples being taken. After the designated depth of each well was reached, and the PVC screen and casing set, the sand pack and bentonite seal were placed, and then a grout plug was placed from the top of the bentonite seal to the ground surface. Each well was capped with a locked steel cap and surrounded with a concrete pad.

Each well was developed by pumping. The well was considered developed when the pH and conductivity stabilized and the pumped water was reasonably free of suspended sediment. Permeability tests were then performed in each well in general accordance with ASTM D 4044, Section 8 (Reference 157), using a procedure that is commonly termed the slug test method. Slug testing involves establishing a static water level, lowering a solid cylinder (slug) into the well to cause an increase in water level in the well, and monitoring the time rate for the well water to return to the pre-test static level. The slug is then rapidly removed to lower the water level in the well, and the time rate for the water to recover to the pre-test static level is again measured. Electronic transducers and data loggers were used to measure the water levels and times during the test.

Appendix 2.5.4B contains the boring logs for the observation wells, the well installation records, the well development records, and the well permeability test results. Observation well locations, depths, etc. are summarized in Table 2.5-38 and Table 2.5-39.

c. **Cone Penetrometer Tests**

The cone penetrometer tests (CPTs) were advanced using a 30-ton self-contained truck rig. Each CPT was advanced to refusal, to depths ranging from 4 to 58 feet. The piezocone tests were performed in general accordance with ASTM D 5778 (Reference 158). The pore pressure filter was located immediately behind the cone tip. Down-hole seismic testing was performed in two of the CPTs (CPT-822 and CPT-825, see Section 2.5.4.4). Pore pressure dissipation tests were performed at a 27 feet depth in CPT-823, and at a 32.5 feet depth in CPT-827.

The CPT logs, shear wave time of arrival records, and pore pressure versus time plots are contained in Appendix 2.5.4B. CPT locations, depths, etc., are summarized in Table 2.5-38 and Table 2.5-39.

2.5.4.4 Geophysical Surveys

Section 2.5.4.4.1 summarizes previous geophysical investigations performed at the NAPS site, while Section 2.5.4.4.2 summarizes the ESP site geophysical program.

2.5.4.4.1 Previous Geophysical Survey Programs

Several geophysical studies were performed for the investigation for the existing units.

A seismic refraction survey was performed throughout the NAPS property between May and November 1968 (Reference 159). The seismic (compression wave) velocities measured in the "relatively unweathered rock" (Stratum IV) ranged from 13,000 to 16,000 fps. Seismic (compression wave) velocities measured in weathered rock were around 5000 fps. In-hole geophysical measurements were taken in two of the Dames and Moore sample bore holes and one well using a Birdwell 3-D velocity recorder and a Birdwell density recorder (Reference 146). Shear and compression wave velocities and in-situ densities obtained from the velocity and density recorders are summarized in Dames and Moore (Reference 146). Shear wave velocities in the Zone IV rock ranged from about 4000 to 8000 fps. The corresponding compression wave velocities were about 8000 to 16,000 fps. Unit weights ranged from about 140 to 170 pcf.

Weston Geophysical performed seismic cross-hole tests for 40 feet below Elevation 246.6 feet between the Unit 1 and 2 reactors (Reference 160) to provide data pertaining to the rock condition between the two reactor units prior to blasting below that elevation. They obtained shear wave velocities in the Zone IV rock between 5000 and 6000 fps.

The UFSAR gives cross-hole seismic survey shear wave velocities in the dam site area ranging from 800 to 850 fps for the near-surface soils. The shear wave velocity given for the saprolite (Stratum IIA) is 950 fps.

Dames and Moore (Reference 8) indicate that no additional geophysical testing was performed for abandoned Units 3 and 4. Data from the existing units were considered in the site evaluation for the abandoned Units 3 and 4. No separate geophysical investigations were performed for the SWR area or the ISFSI.

2.5.4.4.2 ESP Geophysical Surveys

Two cross-hole seismic tests, one down-hole seismic test in a borehole, and two down-hole seismic tests using a cone penetrometer were performed during the ESP site investigation.

a. **Cross-Hole Seismic Tests**

Cross-hole seismic tests were performed immediately adjacent to borings B-802 and B-805 (see Figure 2.5-60). The B-802 location was used to obtain readings in rock while the B-805 location was used to obtain readings in soil. The tests were performed in accordance with ASTM D 4428/D 4428M (Reference 161).

At the B-802 location, an air percussion drill was used to advance borings B-802A, B and C for the cross-hole tests. These holes were in-line, nominally 10 feet apart. The borings were 90 feet deep with about 70 feet in rock. Inclinometer casing was grouted into each hole to enable a deviation survey to be performed. Distances between holes 802B and 802C ranged from 10.18 feet at the top to 13.33 feet at the bottom. The distances measured in the deviation survey at each test depth were used in the seismic velocity computations.

At the B-805 location, rotary wash drilling with one of the geotechnical drill rigs was used to advance boreholes B-805A, B and C to 30 feet depth. These holes were in-line, nominally 10 feet apart. As with the deeper B-802 holes, inclinometer casing was grouted into each hole to enable a deviation survey to be performed. Distances between holes 805A and 805B ranged from 9.91 feet at the top to 9.11 feet at the bottom. The distances measured in the deviation survey at each test depth were used in the seismic velocity computations.

Details of the equipment used to create the seismic compression and shear waves, and to measure the seismic wave velocities are given in Appendix 2.5.4B, which also contains a detailed description of the results. These results are summarized below.

Tests in borings B-802A, B, and C were performed at 5-foot intervals in rock from 27 to 90 feet depth. However, only shear wave velocity results were obtained from 27 to 45 feet depth. Severe high frequency noise appeared to have degraded the results in general, but particularly below 45 feet depth. All of the compression wave forms were obscured by high-frequency noise. The shear wave velocities in rock between 27 and 45 feet depth ranged from 4500 to 6000 fps.

Tests in borings B-805A, B, and C were performed at 2.5 to 5-foot intervals in soil from near the surface to 27 feet depth. The seismic waveforms were reasonably clear, except for the bottom interval, close to the rock interface. The shear wave velocities ranged from about 610 to 1380 fps, the compression wave velocities ranged from about 1240 to 6550 fps, and the computed dynamic Poisson's ratio ranged from 0.27 to 0.49.

b. **Down-Hole Seismic Tests in a Bore Hole**

Since the cross-hole tests in borings B-802A, B, and C yielded no compression wave results and gave no shear wave velocity results below 45 feet depth, down-hole seismic testing was conducted in boring B-802B. Details of the equipment used to create the seismic compression and shear waves and to measure the seismic wave velocities are given in Appendix 2.5.4B, which also contains a detailed description of the results and the method used to compute the results. These results are summarized below.

The shear wave was reasonably well defined to 45 feet depth, less well defined from 45 to 65 feet depth, and not defined below 65 feet depth. Between 22.5 and 65 feet depth, shear wave velocities ranged from about 3400 fps to 6380 fps. Reasonable data were obtained for the compression wave. Between 22.5 and 87 feet depth, compression wave velocities ranged from about 10,000 fps to 16,600 fps. The computed dynamic Poisson's ratio ranged from 0.38 to 0.45.

c. **Down-Hole Seismic Tests with Cone Penetrometer**

The tests were performed at 5-foot intervals in CPT-822 and CPT-825 (see Figure 2.5-60). Only shear waves were generated. The wave arrival was recorded by a geophone attached near the bottom of the cone string.

The shear wave arrival time versus depth are plotted in Appendix 2.5.4B. In CPT-822, the computed shear wave velocity between 10 and 22 feet depth was about 1275 fps. In CPT-825, the computed shear wave velocity between 6 and 30 feet depth was 1175 fps. Between 30 and 45 feet depth the computed velocity was about 1660 fps, and between 45 and 52 feet depth the computed velocity was about 2438 fps.

d. **Discussion and Interpretation of Results**

Recommended design values of shear and compression wave velocities for each zone are provided in Section 2.5.4.2. The profile of shear wave velocity versus depth for the saprolite is given in Section 2.5.4.7.

2.5.4.5 Excavation and Backfill

This section describes the following topics:

- The extent (horizontally and vertically) of anticipated safety-related excavations, fills and slopes
- Excavation methods and stability

- Backfill sources and quality control
- Construction dewatering impacts

2.5.4.5.1 Extent of Excavations, Fills and Slopes

Within the ESP site envelope (Figure 2.5-61) that would contain safety-related structures, including the UHS, the existing elevation ranges from about Elevation 250 to 340 feet. (The Elevation 250 feet area is the backfilled excavation for the abandoned Units 3 and 4.) The subsurface profiles in Figure 2.5-57 and Figure 2.5-58 provide an impression of the grade elevation range across the ESP site. Plant grade for the new units would be at Elevation 271 feet. The base of the containment (reactor) building foundations for the new units would range from Elevation 238.25 to Elevation 131 feet, depending on the reactor design selected.

Construction of the new units would require a substantial amount of excavation. The excavation would be both in soil and in rock. Filling would consist almost entirely of backfilling around structures back up to plant grade. The only new permanent slope that may be created would be to the west of the SWR to accommodate the buried UHSs if required by the selected design. The amount (if any) of this cut depends on the type of design selected. The top of the slope would be at least 200 feet from the top of the SWR embankment, the same distance as for the existing slope to the north of the SWR. Thus, the slope would not impact the SWR. This slope is presented in Section 2.5.5. The slopes discussed in the following sections would be temporary slopes for construction purposes.

2.5.4.5.2 Excavation Methods and Stability

a. **Excavation in Soil**

   Excavation in the soils (Zones IIA and IIB) and any existing fills would be achieved with conventional excavating equipment. Excavation would adhere to OSHA regulations (Reference 162). Where space permits, the excavation would be open-cut, with slopes no steeper than 1.5-H to 1-V. Since the saprolitic soils can be highly erosive, even temporary slopes cut into the saprolite would be sealed and protected. Where there is insufficient space for open-cut slopes, vertical cuts would be supported with sheet pile or soldier pile and lagging walls. For the excavations envisaged for the new containment (reactor) buildings, UHS, etc., support for these walls would be provided by tiebacks, angled down and anchored into the bedrock, where possible.

b. **Excavation in Rock**

   Excavation in the Zone III moderately to severely weathered rock would be achieved using conventional earthmoving equipment. Tied-back sheet piles or soldier piles and lagging would be used to support the excavation.

   Excavation made for the abandoned Units 3 and 4 in the slightly to moderately weathered rock (Zone III-IV) and fresh to slightly weathered rock (Zone IV) is documented in Stone and

Webster (Reference 163). Techniques employed were similar to those used for the existing units (Reference 164) but with "lessons learned" applied. The proposed methods of rock excavation outlined below are based, in part, on the methods that worked successfully for the existing units and the abandoned Units 3 and 4.

- Controlled blasting techniques, including cushion blasting, pre-splitting and line drilling may be used, with appropriately dimensioned bench lifts. The blasted faces would be vertical except where the foliation dip is into the excavation. There, the excavation would be parallel to the foliation dip (typically about 1-H to 1-V).
- Any blasting would be strictly controlled to preserve the integrity of the rock outside the excavations and to prevent damage to existing structures, equipment, and freshly poured concrete. Peak particle velocity would be measured and kept within specified limits that would be a function of distance from the blast.
- The rock would be reinforced to ensure adequate support and safety. Reinforcing would include, installation of rock bolts in finished rock faces (typically at around 5-foot centers), and the use of welded wire mesh.
- The excavation would be mapped and photographed by experienced geologists. Necessary measures would be taken, if weathered or fractured zones were encountered. Instrumentation such as slope indicators and extensometers would be installed to monitor rock movements, especially on the foliation dip slopes.

Alternatives to blasting for the excavation of rock at the ESP site would be reviewed and considered prior to selection of the final excavation method. The alternative excavation methods to be considered may include one or more of the following:

- Thermal lance – A long pipe with a high temperature, enhanced oxygen flame. Used to cut slots in rock, or in boreholes to cause thermal expansion and splitting between adjacent holes.
- Plasma gun – Creates an electric arc at a spark gap. The device is inserted into boreholes filled with water and a spark is initiated, creating an explosion that breaks a cone of rock toward the free face of the excavation.
- Pile driver and expanding metal slug – An aluminum cylinder is inserted to the full depth of a close-fitting borehole. The cylinder is impacted by a pile driver with a rod-type mandrel that causes the aluminum cylinder to expand radially, fracturing the rock outwards from the borehole.
- Drilling and expansive grout – Holes are drilled into the rock and a grout mix is poured into them. As the grout begins to set, it expands, cracking the rock mass between adjacent boreholes.

- Hydraulic splitter – A bar consisting of two overlapping wedges is inserted into a pre-drilled hole. A hydraulic piston moves one of the wedges in an axial direction relative to the other wedge, causing the wedges to lock tightly in the hole. Further movement of the wedges causes the rock to split laterally outward from the borehole.
- Hoe ram – A percussion hammer is mounted on a backhoe and used to break the rock by chipping.
- Diamond wire saw – A steel cable with diamond-impregnated beads along its length is joined into a continuous loop. The cable is driven in a circular fashion while cutting angles and directions are controlled using pulleys.
- Trenching machine – A heavy-duty chain-type trench excavator using carbide cutting teeth to excavate rock.
- Water jet – High-pressure water jets that cut slots in rock with or without the use of an abrasive.

In addition to cost and schedule, other items to be considered in the evaluation of excavation methods would include vibration effects, hardness of the rock, and rock fabric. Almost all of the methods would generate some vibration that would be evaluated with respect to its effect on the existing units. The hardness of the rock would be considered with respect to the ability of each method to penetrate a potentially significant thickness of rock in a relatively confined area. The rock fabric refers to natural partings in the rock that can be taken advantage of with respect to breakage and removal of the rock in manageable size blocks.

2.5.4.5.3 Backfill Sources and Quality Control

Although a large amount of saprolitic soil would be excavated for the new units, this material would not be used as structural fill to support or back fill structures.

Structural fill would be either lean concrete or a sound, well-graded granular material, either a sandy gravel or a gravelly sand, with less than 10 percent passing the No. 200 sieve. This material does not exist naturally on site. However, given the large amount of rock that would need to be excavated for the new units, it could be economical to set up a crushing and blending plant onsite to produce crushed aggregate to the required gradation specifications for use as structural fill. The soundness of the aggregate would be confirmed using sulfate soundness and Los Angeles abrasion tests. This structural fill would be compacted to at least 95 percent of the maximum dry density as determined by ASTM D 1557 (Reference 165). The fill would be compacted to within 3 percent of its optimum moisture content. As an alternative or supplement to the onsite crushed rock, dense graded aggregate can be used as structural fill material. Dense Graded Aggregate such as Size 21A or 21B as specified by the Virginia Department of Transportation Road and Bridge Specifications (Reference 166) are suitable materials.

An onsite soils testing laboratory would be established to control the quality of the fill materials and the degree of compaction and to ensure the fill conforms to the requirements of the earthwork specification. The soil-testing firm would be independent of the earthwork contractor and would have an approved quality program. Sufficient laboratory compaction (modified Proctor) and grain size distribution tests would be performed to ensure that variations in the fill material are accounted for. Field density tests would be performed a minimum of one per 10,000 square feet of fill placed.

2.5.4.5.4 Control of Groundwater During Excavation

Construction dewatering is presented in Section 2.5.4.6.2. Since the saprolitic soils can be highly erosive, sumps and ditches constructed for dewatering would be lined. The tops of excavations would be sloped back to prevent runoff down the excavated slopes during heavy rainfall.

2.5.4.6 Groundwater Conditions

2.5.4.6.1 Groundwater Measurements and Elevations

Groundwater is present in unconfined conditions in both the surficial sediments and underlying bedrock at the ESP site. The groundwater generally occurs at depths ranging from about 6 to 58 feet below the present day ground surface. The exception to this is the area of the abandoned Units 3 and 4 excavation that was partially backfilled, where groundwater is within about 2 feet of the ground surface.

Nine observation wells installed at the site as part of the ESP subsurface investigation program have exhibited groundwater levels ranging from about Elevation 241 to Elevation 311 feet between December 2002 and June 2003. The logs and details of these wells, and tests in the wells, are given in Appendix 2.5.4B. Hydraulic conductivity values for the saprolite in which eight of the wells were screened, based on the results of the slug tests in the wells, range from 0.2 to 3.4 feet/day. The hydraulic conductivity of the shallow bedrock in which one of the wells was screened is estimated to be about 2 to 3 feet/day. Groundwater movement at the site is generally to the north and east, toward Lake Anna. A detailed description of groundwater conditions is provided in Section 2.4.12.

Groundwater levels at the site may require temporary dewatering of foundation excavations extending below the water table during construction of the new units. Dewatering would be performed in a manner that would minimize drawdown effects on the surrounding environment. Drawdown effects are expected to be limited to the NAPS site. The relatively low permeability of the saprolite and underlying rock means that sumps and pumps should be sufficient for successful construction dewatering, as presented in Section 2.5.4.6.2.

The design ground water level for the new units ranges from Elevation 265 to 270 feet. Derivation of this level is presented in Section 2.4.12.

2.5.4.6.2 Construction Dewatering

Dewatering for all major excavations could be achieved by gravity-type systems.

a. **Soils**

Due to the relatively impermeable nature of even the coarse-grained saprolite, sump-pumping of ditches would be adequate to dewater the soil. These ditches would be advanced below the progressing excavation grade.

During the construction of the existing units, plant excavation and dewatering appeared to have been significant in causing local groundwater levels to decline. However, the extent of the area of influence of the dewatering was estimated to be less than 500 feet due to the low permeability of the materials being dewatered (Reference 164).

b. **Rock**

Sump-pumping would be used to collect water from relief drains that would be installed in the major rock excavation walls to prevent hydrostatic pressure buildup behind the walls. Such relief wells were spaced on 20-foot centers around the perimeters of the abandoned Units 3 and 4 containment excavations.

Although an approximately 40-foot head existed between excavation grade and the North Anna Reservoir during the final stages of excavation for the abandoned Units 3 and 4, no dewatering difficulties were encountered, due to the tight nature of the joints in the rock below Elevation 241 feet.

2.5.4.7 Response of Soil and Rock to Dynamic Loading

The containment (reactor) buildings for the new units would be founded on Zone III-IV or Zone IV bedrock. However, other safety-related structures may be founded on the Zone III weathered bedrock, the Zone IIB very dense saprolitic sand, and/or the Zone IIA saprolitic sand. The seismic acceleration at the sound bedrock level would be amplified or attenuated up through the weathered rock and soil column. To estimate this amplification or attenuation, the following data are required.

- Shear wave velocity profile of the weathered rock and overlying soil
- Variation with strain of the shear modulus and damping values of the weathered rock and soil
- Site-specific seismic acceleration-time history

2.5.4.7.1 Shear Wave Velocity Profile

Various measurements were made at the ESP site to obtain estimates of the shear wave velocity in the soil and rock. These are summarized in Section 2.5.4.4. The materials of interest here are the Zone IIA and Zone IIB saprolitic soils, the Zone III weathered rock, and the Zone III-IV slightly to moderately weathered rock.

In some locations, the top of Zone III-IV or Zone IV bedrock is found close to or even above planned plant grade. (This applies to most locations along the east-west subsurface profile in Figure 2.5-57.) In such cases, safety-related structures would be founded on bedrock or on a thin layer of lean concrete or compacted structural fill on the bedrock. In other locations, sound bedrock is relatively deep. (This applies to the northern and southern portions of the north-south subsurface profile in Figure 2.5-58.) In this case, some safety-related structures (excluding the reactors) may be founded on the Zone III weathered rock, Zone IIB saprolite, or Zone IIA saprolite. The shear wave velocity profiles shown on Figure 2.5-62 focus on this latter situation. Note that Figure 2.5-62 shows the top of Zone III-IV or Zone IV rock at 55 feet depth, i.e., there is 55 feet of weathered rock and soil above the competent rock. This 55-foot thick soil and weathered rock profile is typical of the area occupied by the slope to the south of the existing units. This slope is analyzed in Section 2.5.5. The soil thickness is generally greater in this profile than within the plant parameter envelope (PPE), where the best estimate of thickness, based on the plant grade of Elevation 271 feet, is 21 feet. (This is referred to in Section 2.5.2.5 as the generic profile and is briefly described in the next paragraph.) The 55-foot profile will provide more seismic amplification than the thinner soil profile within the PPE, resulting in higher acceleration values and a correspondingly more conservative liquefaction analysis. In the soil column amplification/attenuation analysis in Section 2.5.4.7.4, the top of the Zone III-IV rock is assumed to be at 55-foot depth, and the top of the Zone IV rock is at 70-foot depth.

The generic profile extends from plant grade at an elevation of 271 ft to depths at which bedrock under the site is estimated to reach a velocity of about 9200 fps. This generic profile is used in Section 2.5.2.6.7 to evaluate amplification of the 9200 fps hard rock ESP site SSE ground motion to the top of competent rock within Zone III-IV, with a shear wave velocity of about 3300 fps, at an elevation of 250 ft.

Figure 2.5-62, Profile (a), shows the shear wave velocity values measured in Zone IIA saprolite for the ESP subsurface exploration program using cross-hole seismic and CPT down-hole seismic testing. The cross-hole seismic profile is the profile interpreted in Appendix 2.5.4B (Reference 147) from the cross-hole test measurements. Also shown is the shear wave velocity of 950 fps given in the UFSAR for the saprolite. This is the same average design value given in Table 2.5-45 for the Zone IIA saprolite for the ESP evaluation. The design shear wave velocity versus depth profile shown on Figure 2.5-62, Profile (a), is anchored about the design value of 950 fps for the Zone IIA saprolite but reflects the expected increasing values with depth demonstrated in the cross-hole and down-hole seismic tests.

As noted in Section 2.5.4.10.2, any Zone IIA saprolites supporting safety-related structures would be improved to reduce potential settlement. To compute the response of the improved Zone IIA saprolite to dynamic loading, the shear wave velocity through the improved soil is required. As noted in Section 2.5.4.12, vibro-stone columns would be a suitable ground improvement method for the Zone IIA saprolites. The stone column diameter and spacing would be designed to improve the

overall stiffness of the saprolite by a factor of about 3. The shear wave velocities of the improved Zone IIA saprolite were computed based on this increase in stiffness. These computed shear wave velocities and the unimproved Zone IIA shear wave velocities are shown on Figure 2.5-62, Profile (b).

Figure 2.5-62, Profile (b), also shows the shear wave velocity values interpreted in Appendix 2.5.4B from the CPT-825 down-hole seismic tests taken to refusal at 52-feet depth during the ESP subsurface exploration program. The subsurface materials below 30 feet depth are interpreted in the CPT log as a silty sand and sandy silt mix. These could be either Zone IIB saprolitic sands or Zone III weathered rock (or both). From 30 to 40 feet depth, the design profile uses the shear wave velocity for the Zone IIB saprolite from Table 2.5-45 (1600 fps), which is very close to the 1650 fps measured in the CPT-825 down-hole seismic test. From 40 to 55 feet depth, the design profile uses the shear wave velocity for the Zone III weathered rock from Table 2.5-45 (2000 fps). This is close to the mean of the two CPT-825 down-hole seismic velocities measured in this zone, as shown in Figure 2.5-62, Profile (b).

As noted above, Zone III-IV is assumed to extend from 55 to 70 feet depth. Shear wave velocity for this rock is 3300 fps, derived from several values measured in the down-hole seismic test performed adjacent to boring B-802, and from elastic modulus values from unconfined compression tests (Section 2.5.4.2.5). The shear wave velocity of the Zone IV rock at 70 feet depth is taken as 6300 fps, the best estimate value from Table 2.5-45.

The shear wave velocity design profiles shown in Figure 2.5-62, Profile (b), plus the shear wave velocity of the Zone III-IV rock from 55 to 70 feet depth is used in the seismic amplification/attenuation analysis. Four soil profiles are used:

1. Profile from 0 to 70 feet, with 30 feet of unimproved Zone IIA saprolite, 10 feet of Zone IIB saprolite, 15 feet of Zone III rock, and 15 feet of Zone III-IV rock.

2. Profile from 30 to 70 feet depth for foundation sitting on 10 feet of Zone IIB saprolite, 15 feet of Zone III weathered rock, and 15 feet of Zone III-IV rock.

3. Profile from 40 to 70 feet depth for foundation sitting on 15 feet of Zone III weathered rock and 15 feet of Zone III-IV rock.

4. Profile from 0 to 70 feet, with 30 feet of improved Zone IIA saprolite, 10 feet of Zone IIB saprolite, 15 feet of Zone III weathered rock, and 15 feet of Zone III-IV rock.

2.5.4.7.2 Variation of Shear Modulus and Damping with Strain

a. **Shear Modulus**

The variation of soil shear modulus values of sands, gravels and clays with shear strain is well-documented by researchers such as Seed and Idriss (Reference 167), Seed, Wong, Idriss and Tokimatsu (Reference 168), and Sun, Golesorkhi and Seed (Reference 169). This

research along with additional work has been summarized by EPRI (Reference 170). Normalized shear modulus reduction curves are shown in Figure 2.5-63.

Curve 1 in Figure 2.5-63 is for the Zone IIA saprolite (both unimproved and improved). This modulus reduction curve is the average of: 1) the Seed and Idriss (Reference 167) average curve for sand, and 2) five curves from Reference 170 that take into account several factors including reference strain and effective vertical stress. One of the five Reference 170 curves is a low plasticity clay curve to account for the cohesive component of the Zone IIA saprolite.

Curve 2 in Figure 2.5-63 is for the Zone IIB saprolite. This is the modulus reduction curve recommended by Reference 168 for gravels, based on tests of four different gravels and crushed stone samples. The Zone IIB saprolite contains the relict structure of the parent rock, and, with up to 50 percent of core rock remaining in the saprolite, would behave more like a gravel or crushed stone than a sand.

Solid rock does not exhibit the strain softening characteristics of soil. Like steel and concrete, sound rock has essentially the same modulus (shear and elastic) throughout the strain range. The elastic modulus values computed from the stress-strain measurements (relatively high strain) on samples of sound rock core, obtained during the ESP subsurface investigation, are similar to those calculated from the ultra low strain cross-hole seismic tests. Thus the Zone III-IV rock has no modulus reduction curve. However, at some stage of weathering, rock becomes sufficiently decomposed to exhibit modulus reduction. The Zone III moderately to severely weathered rock is considered to fall into this sufficiently weathered state. Unlike soils, relatively little research has been performed on weathered rock. Curve 3 in Figure 2.5-63 (Reference 169) has been developed for mudstone (a soft rock) with a shear wave velocity of 1500 fps. Section 2.5.4.7.1 shows that Zone III has a shear wave velocity of 2000 fps. Mudstone Curve 3 is used for shear modulus input in the soil/rock column amplification/attenuation analysis for the Zone III weathered rock. As would be expected the shear modulus attenuation is significantly less than exhibited by the sand and gravel curves.

When the specific locations of safety-related structures are determined, if structures such as the diesel generator building and/or certain tanks are founded on saprolite or weathered rock, samples of foundation soils from those locations would be tested to determine location-specific shear modulus degradation relationships.

b. **Damping**

The publications cited above address the variation of soil damping with cyclic shear strain as well as the variation of shear modulus with shear strain. Figure 2.5-64 plots the variation of the equivalent damping ratio of saprolite and weathered rock as a function of cyclic shear strain.

Curve 1 in Figure 2.5-64 is for the Zone IIA saprolite (both unimproved and improved). This damping ratio versus cyclic shear strain curve is the average of: 1) the Seed and Idriss (Reference 167) average curve for sand, and 2) seven curves from Reference 170 that take

into account several factors including reference strain and effective vertical stress. One of the seven Reference 170 curves is a low plasticity clay curve to account for the cohesive component of the Zone IIA saprolite.

Curve 2 in Figure 2.5-64 is for the Zone IIB saprolite. This is the Seed, et al. (Reference 168) curve for gravels. Curve 3 in Figure 2.5-64 is for the Zone III weathered rock. This curve was derived by comparing Curve 3 in Figure 2.5-63 with Curves 1 and 2 in Figure 2.5-63, and applying the differences proportionally to Figure 2.5-64.

There is no variation of damping ratio of the Zone III-IV rock with cyclic shear strain. However, this rock has some intrinsic damping properties. A value of damping ratio of 2 percent was selected.

2.5.4.7.3 Site Specific Acceleration-Time Histories

Two single horizontal-component acceleration time histories were developed to be spectrum-compatible for use in the rock column amplification analysis of Section 2.5.2.6.7 and the soil column amplification analysis described in Section 2.5.4.7.4. These time histories represent the high frequency and low frequency range of the horizontal hard rock SSE spectrum of Figure 2.5-48. These two time histories are described in Section 2.5.2.6.7.

2.5.4.7.4 Soil Column Amplification/Attenuation Analysis

The SHAKE2000 computer program was used to compute the site dynamic responses for the soil and rock profiles described in Section 2.5.4.7.1. The computation was performed in the frequency domain using the complex response method. The analysis used the acceleration-time histories described in Section 2.5.4.7.3. For the low frequency case, an earthquake with moment magnitude of 7.2 and an acceleration at bedrock level of 0.21g was used in the SHAKE2000 analysis, while for the high frequency case, an earthquake with moment magnitude of 5.4 and an acceleration at bedrock level of 0.43g was used.

SHAKE2000 uses an equivalent linear procedure to account for the non-linearity of the soil and weathered rock by employing an iterative procedure to obtain values for shear modulus and damping that are compatible with the equivalent uniform strain induced in each sublayer. At the outset of the analysis, a set of properties (based on the values of shear modulus and damping presented in Section 2.5.4.7.1, and total unit weight) was assigned to each sublayer of the soil and rock profile. The analysis was conducted using these properties and the shear strain induced in each sublayer was calculated. The shear modulus and damping ratio for each sublayer was then modified based on the shear modulus and damping ratio versus strain relationships presented in Section 2.5.4.7.2. The analysis was repeated until strain-compatible modulus and damping values were achieved.

The zero period acceleration (ZPA) results for the SHAKE2000 analysis for the four soil profiles listed at the end of Section 2.5.4.7.1 are shown in Table 2.5-46 for both the low frequency and high

frequency cases, with V_s values based on the best estimate shear wave velocity values given in Table 2.5-45. Values of G_{max} (proportional to the square of V_s) were varied in the SHAKE analysis to determine the impact on the ZPA, using G_{max} values that were 67 percent and 150 percent of the best estimate G_{max} values derived from the V_s values in Table 2.5-46. For Profile 1, which is used in the liquefaction and slope stability analysis, the ZPA at the ground surface increased from 0.46g in Table 2.5-46 for the low frequency case to 0.57g using 150 percent G_{max}. For the high frequency case, the ZPA at the ground surface increased from 0.91g in Table 2.5-46 to 0.99g using 150 percent G_{max}. The ZPA results for Profile 1 using 150 percent G_{max} are also shown in Table 2.5-46. The 0.57g and 0.99g values were used for the peak ground acceleration in the liquefaction and slope stability analyses.

2.5.4.8 Liquefaction Potential

Soil liquefaction is a process by which loose, saturated, granular deposits lose a significant portion of their shear strength due to pore pressure buildup resulting from cyclic loading, such as that caused by an earthquake. Soil liquefaction can occur, leading to foundation bearing failures and excessive settlements, when all of the following criteria are met.

1. Design ground acceleration is high.
2. Soil is saturated (i.e., close to or below the water table).
3. Site soils are sands or silty sands in a loose or medium dense condition.

The first criterion is met for the ESP site, and the second criterion applies in many areas of the NAPS site. However, the third criterion, involving the type and density of the soil, is much less clearly applicable. The Zone IIB soils are extremely dense and the Zone III weathered rock has over 50 percent core stone and has typically been sampled by rock coring. Neither of these materials meets the loose or medium dense criterion, and neither has liquefaction potential. Any structural fill required would be a well compacted, well graded crushed stone that is not liquefiable. The only material presented here regarding liquefaction is the Zone IIA saprolitic soil.

For the ESP site, most safety-related structures would be founded on sound bedrock. However, some safety-related supporting structures (diesel generator, certain pump structures, tanks, etc.) may be founded close to plant grade, and, depending on their location within the ESP site, could be underlain by Zone IIA saprolitic soil.

There has been no historical evidence of the Zone IIA saprolitic soils undergoing liquefaction at the ESP site. UFSAR Appendix 3E, Attachment 4, indicates that examination of the structure and fabric of the material “leads to the conclusion that the saprolite is not susceptible to liquefaction.” UFSAR Section 2.5 does not even mention liquefaction potential. The structure and fabric of the saprolite and their impact on liquefaction potential is presented in Section 2.5.4.8.1.

As discussed in Section 2.5.4.10, the Zone IIA saprolite has relatively high resistance to bearing failure but can produce excessive settlements under certain conditions. Where this soil forms the foundation material for safety-related structures, it would be improved (as discussed in Section 2.5.4.12) to decrease potential settlement to acceptable values. This improvement would be designed to ensure that the improved soil had a factor of safety against liquefaction equal to or greater than 1.1 (Section 2.5.4.8.2), at the SSE ground motion.

Despite its apparent low potential for liquefaction, the Zone IIA saprolite at the NAPS site has been the subject of several liquefaction analyses. These analyses are examined in Section 2.5.4.8.3 in light of the accelerations being assumed for the ESP. In addition, state-of-the-art liquefaction analysis is performed on potentially liquefiable samples obtained from the recent ESP exploration program, and is presented in Section 2.5.4.8.4.

In Section 2.5.4.8.1 through Section 2.5.4.8.4, Draft RG DG-1105 (Reference 172), is used as a guide.

2.5.4.8.1 Effect of Soil Structure and Fabric on Liquefaction Potential

The following is a summary of the description in UFSAR Appendix 3E, Attachment 4, based on the results of examination of the 27 thin-sections of the Zone IIA silty sands noted in Section 2.5.4.2.4. The full description is contained in Appendix 2.5.4A.

As would be expected with these residual soils, the fabric is that of the parent rock, a biotitic quartz gneiss. There is strong foliation in the saprolite, dipping at angles of about 50 degrees to the horizontal. The fabric is strongly anisotropic. The texture shows angular geometrically interlocking grains with a lack of void network. The mineralogy also reflects the parent rock, with 30–40 percent quartz, 20 to 30 percent microline, 25 to 40 percent clay minerals, and 5 to 20 percent biotite (mica). The major clay mineral is halloysite (a hydrated form of kaolinite) with lesser amounts of illite and montmorillonite. Much of the halloysite is in the form of aggregates that are larger than 2 micrometers (μm) and, therefore, would be classified as silt, allowing the sand to be classified as non-plastic.

The fabric of the saprolite contrasts strongly with that of an alluvial or marine deposited sand. Sand shows no foliation and no interlocking of grains, even though the grains can be quite angular. The thin sand section also shows a well-developed void network unlike that of saprolite. The fabric of saprolite is, therefore, not one of a transported soil but one of the parent rock material. The fabric is anisotropic, i.e., it has strongly directional properties.

The most striking feature of the saprolite is the angularity and interlocking nature of the grains. The geometric interlocking of the grains and the lack of a void network that would allow re-orientation of grains indicates that the saprolite could not liquefy.

2.5.4.8.2 Acceptable Factor of Safety Against Liquefaction

DG-1105 (Reference 172) suggests that factors of safety (FS) ≤1.1 against liquefaction are considered low, FS ≈ 1.1 to 1.4 are considered moderate, and FS ≥1.4 are considered high. The Committee on Earthquake Engineering (Reference 173) states, "There is no general agreement on the appropriate margin (factor) of safety, primarily because the degree of conservatism thought desirable at this point depends upon the extent of the conservatism already introduced in assigning the design earthquake. If the design earthquake ground motion is regarded as reasonable, a safety factor of 1.33 to 1.35...is suggested as adequate. However, when the design ground motion is excessively conservative, engineers are content with a safety factor only slightly in excess of unity."

The SSE at rock for the existing units has a maximum acceleration of 0.12g. This was amplified to 0.18g in the soil. The seismic margin maximum acceleration in soil (Reference 174) was 0.30g. The maximum ESP acceleration (using the high frequency earthquake) at Zone IV bedrock with a shear wave velocity of about 6300 fps is 0.43g, amplified at the unimproved soil surface to 0.99g, as discussed in Section 2.5.4.7.4 and shown in Table 2.5-46.

Based on the above facts, a FS ≥1.1 is considered adequate for the Zone IIA soils at the ESP site.

2.5.4.8.3 Previous Liquefaction Analyses

In December 1994, a detailed liquefaction analysis of the NAPS site soils was performed for a seismic margin assessment (Reference 174). A maximum acceleration of 0.30g, magnitude of 6.8, and the following three approaches to liquefaction assessment were employed.

- For the main plant area, a version of the Seed and Idriss (Reference 175), Simplified Procedure based on SPTs was used. The procedure was modified to account for the age of the saprolite because it is much older than the Holocene deposits on which the Seed and Idriss approach is based. Pavich et al. (Reference 176) estimate the saprolite to be 0.8 and 1.6 million years old, while Virginia Power (Reference 164) suggests an age between 0.66 and 2.3 million years. The Geotechnics (Reference 174) analysis also took some credit for the over-consolidated nature of the saprolites. The analysis did not take into account the structure and fabric of the saprolite. A magnitude scaling factor of 1.60 was used in the analysis for the magnitude 6.8 earthquake. The liquefaction analysis in the main plant gave FS values against liquefaction ranging from 1.54 to 3.51.
- For the main plant area, a threshold shear strain analysis (Reference 177) was applied. The analysis used an average shear wave velocity in the saprolite of 950 fps (same as the ESP average value). The FS against liquefaction was just under 3.0 for a magnitude 6.5 earthquake.
- For the SWR, the results of the 15 stress-controlled cyclic triaxial tests described in Section 2.5.4.2.4 were used as the basis of the analysis. The FS values against liquefaction ranged from 1.51 to 1.99 for the SWR facilities (pump house, valve house, tie-in vault, service water lines). Analysis of the SWR embankment gave FS values ranging from 0.91 to 3.61, with an average of more than 1.5. The few FS values less than 1 occurred in localized zones.

Geotechnics (Reference 174) concluded that overall factors of safety across the embankment are well within acceptable limits, and there is no consistent pattern of low safety factors across the foundation that would indicate that significant movements of the embankment would occur.

2.5.4.8.4 Liquefaction Analyses Performed for ESP

a. **Magnitude and Acceleration Values for ESP Liquefaction Analyses**

As noted in Section 2.5.4.7.3, two earthquakes were used in the liquefaction analysis. The low frequency earthquake had a magnitude of 7.2 and an acceleration at Zone IV bedrock with a shear wave velocity of about 6300 fps of 0.21g. The high frequency earthquake had a magnitude of 5.4 and an acceleration at the same depth of 0.43g.

Table 2.5-46 shows the zero period acceleration values for the four soil/rock profiles described in Section 2.5.4.7.1. Since the Zone IIB saprolite and the Zone III weathered rock are non-liquefiable, Profiles 2 and 3 in Table 2.5-46 are not considered in the liquefaction analysis. In Profile 4, the Zone IIA saprolite is improved, i.e., this would be the profile for any safety-related structures founded on the Zone IIA saprolite. The soil would be improved sufficiently to ensure that the improved soil had a factor of safety against liquefaction equal to or greater than 1.1 (Section 2.5.4.8.2), at the SSE ground motion. In Profile 1, the Zone IIA saprolite (upper 30 feet) is not improved. Thus, Profile 1 is the only profile that is considered in the liquefaction analysis. As noted in Section 2.5.4.7.4, the ZPA at the ground surface increased from 0.46g to 0.57g for the low frequency case, and 0.91g to 0.99g for the high frequency case using 150 percent G_{max} (Table 2.5-46). The 0.57g and 0.99g values are used for the peak ground acceleration for the liquefaction analyses described in the following paragraphs.

b. **Updated Seismic Margin Assessment**

The seismic margin assessment described in Section 2.5.4.8.3 for the main plant area was modified in the ESP evaluation, maintaining the same assumptions as used in the original study but substituting the ESP design accelerations and moment magnitudes in soil of 0.57g and 7.2 (low frequency), and 0.99g and 5.4 (high frequency). Magnitude scaling factors of 1.13 and 2.5 were used in the analysis for the low and high frequency earthquakes, respectively. The resulting FS values ranged from about 0.55 to 1.7, with average values close to but lower than 1.1.

c. **Analysis of ESP Samples and CPT Results**

Liquefaction analysis of each sample of Zone IIA saprolite obtained by SPT sampling during the ESP subsurface investigation was performed to determine the FS against liquefaction. The CPT results were also analyzed. The analysis conservatively ignored the age, overconsolidation, and mineralogy/fabric effects of the saprolite. Cohesive samples and/or samples above the groundwater table were considered non-susceptible to liquefaction.

The analysis followed the method proposed by Youd, et al. (Reference 178). This state-of-the-art liquefaction methodology is based on the evolution of the Seed and Idriss "Simplified Procedure" over the past 25 years. Magnitude scaling factors of 1.13 and 2.5 were used in the analysis for the moment magnitude 7.2 (low frequency) and 5.4 (high frequency) earthquakes, respectively. The K_σ factor for high overburden pressures was incorporated into the analysis, using a relative density of 60 percent.

Using the peak ground accelerations and magnitude scaling factors for the low and high frequency earthquakes described above, the analysis of the SPT results gave FS values against liquefaction greater than 1.1 for those samples that were liquefiable, except for three samples. For the eight CPTs performed, the liquefaction analysis showed 5-foot thick zones in two CPTs and a 22-foot thick zone in another CPT where the FS against liquefaction was less than 1.1.

d. **Liquefaction Analysis Using Shear Wave Velocity Criteria**

The design values of shear wave velocity shown in Figure 2.5-62 and tabulated on Table 2.5-46 were corrected for overburden pressure using the method outlined in Youd, et al. (Reference 178). The resulting values all fell into the "No Liquefaction" zone on Figure 9 of Reference 178. When the lower-bound values of shear wave velocity shown in Table 2.5-45 were used in the liquefaction analysis, most of the top 20 feet of the profile fell into the "Liquefaction" zone on Figure 9 of Reference 178.

e. **Dynamic Settlement**

Using the method outlined in Tokimatsu and Seed (Reference 179), the maximum estimated dynamic settlement of the Zone IIA saprolite due to earthquake shaking was about 5 inches.

2.5.4.8.5 Conclusions about Liquefaction

The conclusions from the foregoing sections on the analysis of liquefaction potential are as follows:

- No historical signs of liquefaction have been observed at the North Anna Site.
- Only the Zone IIA saprolites fall into the gradation and relative density categories where liquefaction would be considered possible.
- The age, structure, fabric, and mineralogy of these saprolites lower the potential for liquefaction very substantially.
- For a conventional liquefaction analysis, a FS $\geq$1.1 is adequate, based on the conservative estimate of the ESP design seismic acceleration.
- A seismic margin liquefaction analysis of the main plant area, modified to use the ESP seismic parameters (M = 7.2 with 0.57g peak ground acceleration for low frequency and M = 5.4 with 0.99g peak ground acceleration for high frequency), and ignored structure, fabric, and mineralogy effects, gave average FS values that were generally close to but lower than 1.1.

- A state-of-the-art liquefaction analysis of the ESP SPT samples using the low and high frequency ESP seismic parameters gave FS values greater than 1.1 for all except three SPT results analyzed.
- A state-of-the-art liquefaction analysis of the ESP CPT measurements using the low and high frequency ESP seismic parameters indicated an approximately 22-foot thick zone and two 5-foot thick zones where the FS against liquefaction was less than 1.1.
- A state-of-the art liquefaction analysis of the shear wave velocity profile using shear wave velocity profile, using shear wave velocity values corrected for overburden pressure, indicated no liquefaction when the design shear wave velocity values were used but indicated liquefaction of most of the top 20 feet when the lower bound shear wave velocity values were used.
- Estimated maximum dynamic settlements due to earthquake shaking are about 5 inches.

Based on the above analysis results, it can be concluded that some of the Zone IIA saprolitic soils have a potential for liquefaction based on the low and high frequency ESP seismic parameters. The liquefaction analysis did not take into account the beneficial effects of age, structure, fabric, and mineralogy. If safety-related structures are founded on the Zone IIA saprolitic soils, these soils would be improved to reduce potential settlements to within acceptable tolerances, as outlined in Section 2.5.4.10 and Section 2.5.4.12. This improvement would be designed to ensure that the improved soil had a factor of safety against liquefaction equal to or greater than 1.1 (Section 2.5.4.8.2), at the SSE ground motion.

2.5.4.9 Earthquake Design Basis

The SSE is derived, and presented in detail, in Section 2.5.2.6.

The OBE is derived and presented in Section 2.5.2.7.

2.5.4.10 Static Stability

As with the existing units and the abandoned Units 3 and 4, the containment (reactor) buildings at the ESP site would be founded on Zone III-IV or Zone IV bedrock. Depending on the location of the containment (reactor) buildings within the ESP site, the top of this bedrock could be below the level of the shallower reactor designs (PBMR and AP1000 in particular). See the subsurface profiles in Figure 2.5-57 and Figure 2.5-58. In such cases, excavation would be made to sound bedrock, and then lean concrete would be poured up to the bottom of the reactor foundation.

In some locations, the top of Zone III-IV or Zone IV bedrock is found close to or even above planned plant grade. (This applies to most locations along the east-west subsurface profile in Figure 2.5-57.) In such cases, safety-related structures would be founded on bedrock or on a thin layer of lean concrete or compacted structural fill on the bedrock. In other locations, sound bedrock is relatively deep. (This applies to the northern and southern portions of the north-south subsurface profile in Figure 2.5-58.) In this case, safety-related structures (excluding the reactors) may be

founded on the Zone III weathered rock, Zone IIB saprolite, or Zone IIA saprolite. The following sections on bearing capacity and settlement focus on this latter situation. (As noted in Section 2.5.4.10.2, any Zone IIA saprolites supporting safety-related structures would be improved to reduce potential settlement.)

2.5.4.10.1 Bearing Capacity

The allowable bearing capacity values for each zone are given in Table 2.5-47.

The Zone IIA allowable bearing capacity value of 4 ksf is based on Terzaghi's bearing capacity equations modified by Vesic (Reference 180). The analysis includes consideration of the effective strength parameters for the coarse-grained material, and both the undrained and effective strength parameters for the fine-grained material given in Table 2.5-45. As presented in Section 2.5.4.10.2, settlement considerations usually dominate when this material is used for supporting foundations, and the actual allowable bearing capacity may be less than 4 ksf, especially for larger foundations, if the soils are not improved.

The Zone IIB allowable bearing capacity value of 8 ksf is based on Terzaghi's bearing capacity equations modified by Vesic (Reference 180), using the effective angle of friction given in Table 2.5-45. Since the Zone IIB soil is usually found beneath the groundwater table, the effective unit weight of the soil has been used in computing the 8 ksf value.

The Zone III allowable bearing capacity of 16 ksf is based on the value of 20 percent of the ultimate crushing strength given in several building codes (Reference 181). The ultimate crushing strength is given as 0.6 kips per square inch (ksi) (86 ksf) in Table 2.5-45. The 16 ksf value is slightly lower than the 20 ksf given for weathered rock in Table 2.5-2 of the UFSAR. It should be noted that although the 16 ksf allowable bearing capacity is greater than the maximum bearing pressures from any of the reactor designs being considered in this ESP, the containment (reactor) buildings would not be founded on the Zone III weathered rock.

The Zone III-IV and Zone IV bedrock have design unconfined compressive strengths of 4 ksi (576 ksf) and 12 ksi (1728 ksf), respectively (Table 2.5-45). Allowable bearing capacities of these materials are much higher than any applied structure bearing pressure. If excavation during construction reveals any weathered or fractured zones at foundation level, such zones would be overexcavated and replaced with lean concrete. The allowable values of the bearing capacity of 80 ksf and 160 ksf for Zone III-IV and Zone IV rock, respectively, are presumptive values based on various building codes for moderately weathered to fresh foliated rock (Reference 181).

2.5.4.10.2 Settlement Analysis

For the large mat foundations that support the major power plant structures, general considerations based on geotechnical experience indicate that settlement should be limited to 2 inches, while differential settlement limit should be limited to 3/4 inch (Reference 182). For footings that support

smaller plant components, the total settlement should be limited to 1 inch, while the differential settlement limit should be limited to 1/2 inch (Reference 182).

Settlement at the ESP site is only a consideration for structures that would be founded directly on the Zone IIA saprolite. The underlying materials consist of either extremely dense saprolitic sand (Zone IIB), weathered rock (Zone III) or sound rock (Zones III-IV and IV), and produce negligible settlement, as presented next.

a. **Settlement of Zones IIB, III, III-IV and IV**

   Any settlement of these materials is essentially elastic. A foundation has been analyzed for settlement assuming a conservative profile of 20 feet of Zone IIB underlain by 30 feet of Zone III, 50 feet of Zone III-IV, and 400 feet of Zone IV. The stiffness values used are the high-strain elastic modulus values given in Table 2.5-45. The foundation, a large one with an assumed size of 150 feet by 300 feet, has an average bearing pressure of 6 ksf (e.g., a turbine building). The computed total settlement of this structure was less than 1/2 inch.

b. **Settlement of Zone IIA**

   As noted earlier, larger than expected settlements were recorded beneath the existing units' SWR pump house. The 4.6 inches of settlement were due to the weight of the pump house itself and the 30 feet of embankment fill that was built up around it, and occurred over a 30-month period. The in-situ soil that settled beneath the pump house consisted of about 65 feet thickness of Zone IIA mainly micaceous sandy silt. The primary cause of this fairly large settlement appears to be the 5 to 20 percent mica content of these saprolites, along with a significant portion of low plasticity clay minerals.

   The settlement of the SWR pump house is an extreme case, due to the fact that 65 feet of mainly micaceous sandy silt underlying the pump house is thicker than is typically found on site, (the SWR pump house is at a higher elevation than the rest of the site, at about Elevation 300 feet). Also, the saprolite is commonly a more granular silty sand (Table 2.5-29). Nevertheless, the potential for excessive settlement of the Zone IIA saprolite makes the material unsuitable for support of any safety-related structure without ground improvement. Ground improvement is presented in Section 2.5.4.12.

2.5.4.11 Design Criteria

Applicable design criteria are covered in various sections. The criteria summarized below are geotechnical criteria. Other geotechnical-related criteria that pertain to structural design (such as wall rotation, sliding, overturning) are not included.

Section 2.5.4.8 specifies that the acceptable factor of safety against liquefaction of site soils should be ≥ 1.1.

Bearing capacity and settlement criteria are presented in Section 2.5.4.10. Table 2.5-47 provides allowable bearing capacity values for the site subsurface materials. Generally acceptable total and

differential settlements are limited to 2 inches and 3/4 inch, respectively, for mat foundations, and 1 inch and 1/2 inch, respectively, for footings.

Section 2.5.5.2 specifies that the minimum acceptable long-term static factor of safety against slope stability failure is 1.5. Section 2.5.5.3 specifies that the minimum acceptable long-term seismic factor of safety against slope stability failure is 1.1.

2.5.4.12 Techniques to Improve Subsurface Conditions

As noted in Section 2.5.4.10.2, before the Zone IIA saprolitic soils can be used to support safety-related foundations, they would have to be improved to eliminate potential excessive settlements. Among the many choices for ground improvement that are available, the vibro-stone column is one of the most suitable techniques for reducing the settlement potential of the Zone IIA saprolitic soils. Vibro-stone columns have several advantages, including reduction of settlement, improvement of bearing capacity, and reduction of liquefaction potential, in addition to providing better resistance than piles or piers to seismic lateral forces.

Vibro-stone columns construction is accomplished by down-hole vibratory methods. A vibratory probe, typically about 18 inches in diameter, penetrates the ground under its own weight, aided by water jets or compressed air, and is advanced to the base of the stratum requiring improvement. Crushed stone is poured into the annulus and is densified by the vibrator. The end product is a series of highly compacted stone columns, typically about 3 feet in diameter, spaced on about 5- to 8-foot centers. For sites with loose to medium dense alluvial or marine sands, the sands themselves are densified by the technique. For sites with cohesive soils, or with soils that do not densify appreciably from vibratory energy (e.g., the Zone IIA saprolite), the ground improvement is predominantly due to the increased stiffness of the stone column. In soils that experience pore pressure buildup during seismic events, the stone columns can provide partial pressure relief from this buildup.

The stone column spacing defines the degree of soil improvement that is accomplished. The settlement improvement ratio (SIR) is defined as the ratio of foundation settlement for original ground conditions to foundation settlement for improved ground conditions. For the North Anna Zone IIA saprolite, the desired SIR would be between 2 and 3. The appropriate stone column spacing can be computed from published empirical correlations based on SIR (Reference 193). Full-scale load tests involving several stone columns are performed on the improved and unimproved soil to confirm degree of improvement (Reference 194).

APPENDIX 2.5.4A
TRIAXIAL AND CONSOLIDATION TESTS OF SOILS AT SWR

This appendix contains the details and results of the cycle triaxial testing performed in 1975 and 1976 on locations on and around the existing units SWR. This information resides in the North Anna Units 1 and 2 UFSAR. For convenience, the appendix replicates portions of the North Anna UFSAR, Appendix E, Attachments 1 through 4. It contains the following information for each of the tests:

- A summary table of the details and results of each test.
- A plot of octahedral shear stress ratio versus number of cycles to reach 5 percent maximum compressive strain.
- A plot of octahedral shear stress ratio versus consolation stress.
- Detailed visual descriptions of each of the samples.
- Grain size curves of each of the test samples.
- Plots of cyclic axial strain (compression, double amplitude and extension) versus cycle number for each of the tests.

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Table 8
SUMMARY OF CYCLIC TRIAXIAL TESTS

Test No.	Boring No.	Sample No.	Depth ft.	Initial Water Content %	Dry Ujnit Weight (*s*) In the Tube (6) γ d pcf	Dry Ujnit Weight (*s*) Triaxial Specimen Initial γ di pct	Dry Ujnit Weight (*s*) Triaxial Specimen After Consol. γ dc pct	Eff. Confining Press.	Consol. Stress Ration	Cyclic Deviator Stress	Cyclic Stress Ratio	Octa–hedral Shear Stress Ratio		Number of Cycle to Reach Maximum Compressive Strain equal to (*s*)			% Finer than #200 Sieve %
CR-1	SWR7	ST5	42.5-43.1	26.1	94	93	95	1.0	2.0	1.47	0.74	0.52	-	2(3)	5	8	44
CR-2	SWR9	ST2	22.5-23.1	23.7	89	88	91	0.7	2.0	0.76	0.54	0.39	-	5(3)	13	30	21
CR-3	P11	ST3	37.3-37.9	20.2	99	96	100	1.0	2.0	1.14	0.57	0.40	-	32	95	152	29
CR-4	P12	ST2	17.5-18.1	18.4	106	103	105	0.4	3.0	0.80	1.00	0.56	-	41	119	213	32
CR-5	SWR3	ST3	42.6-44.2	18.7	108	105	108	1.5	1.5	1.05	0.35	0.28	-	24	39	65	22
CR-6	SWR5	ST5	57.2-58.9	27.1	94	90	94	1.5	1.5	1.24	0.41	0.33	-	73	120	122	23
CR-7	SWR9	ST1	17.1-18.5	32.6	83	80	83	1.0	1.5	1.01	0.50	0.41	-	34(4)	126	194	31
CR-8	P15	ST24	66.0-68.0	24.2	102.4	101.1	-	-	-	-(9)	-	-	-	-	-	-	-
CR-9	P16	ST7	37.5-39.5	17.8	(7)	104.1	107.2	2.5	-	-(10)	-	-	-	-	-	-	-
CR-10	P15	ST24	66.0-68.0	21.7	107.3	106.4	111.1	2.5	1.0	1.94	0.39	0.37	-	1	1	5	(11)
CR-11	P17	ST9	47.5-49.5	33.9	87.6	86.3	90.9	2.5	1.0	1.46	0.29	0.28	-	2	7	16	(11)
CR-12	P16	ST7	37.5-39.5	21.2	(7)	92.1	95.3	2.5	1.0	-(8)	-	-	-	-	-	-	-
CR-13	P17	ST9	47.5-49.5	28.0	93.7	92.8	97.6	2.5	1.0	1.20	0.24	0.23	-	14	23	37	(11)
CR-14	SWR11	ST1	19.5-21.5	29.4	94.4	93.2	96.9	1.0	1.0	0.79	0.40	0.37	-	3	74	171	(11)
CR-15	P15	ST10	31.0-33.0	19.5	94.1	93.3	96.2	1.5	1.5	1.69	0.56	0.46	-	1	1	2	(11)

Table 8 (continued)
SUMMARY OF CYCLIC TRIAXIAL TESTS

Test No.	Boring No.	Sample No.	Depth ft.	Initial Water Content %	Dry Ujnit Weight (*s*) In the Tube (6) γ d pcf	Triaxial Specimen Initial γ di pct	Triaxial Specimen After Consol. γ dc pct	Eff. Confining Press.	Consol. Stress Ration	Cyclic Deviator Stress	Cyclic Stress Ratio	Octa–hedral Shear Stress Ratio		Number of Cycle to Reach Maximum Compressive Strain equal to (*s*)			% Finer than #200 Sieve %
CR-16	SWR11	ST1	19.5-21.5	32.3	89.3	88.5	92.1	1.0	1.0	0.94	0.47	0.44	-	1	4	19	(11)
CR-17	SWR13	ST9	47.5-49.5	36.9	74.2	73.3	75.9	1.5	1.5	1.30	0.43	0.35	-	1	1	2	(11)
CR-18	SWR13	ST9	47.5-49.5	33.3	73.7	73.5	76.0	1.5	1.5	0.85	0.28	0.23	-	6	6	13	(11)

Notes:

1. Due to high mica content, the specimens swelled after extrusion from the tube and therefore, the initial dry unit weights of the triaxial specimen are lower than the dry unit weights in the tube.
2. At no point during any test did the effective confining pressure reach zero.
3. In test CR-1 and CR-2, the specimens reached a double amplitude stain of 2.5% in the cycle preceding the one listed.
4. In test CR-7, the specimen reached a double amplitude stain of 2.5% in 17 cycles.
5. In all tests except those noted, the maximum compressive strain of 2.5%, 5%, and 10% occured at the same time or earlier than the double amplitude strain of 2.5%, 5%, and 10% respectively.
6. Calculated from tube inside diameter.
7. Annular space of approximately 0.03 mm unit weight not valid.
8. Test not reported error during load application.
9. Test aborted - Membrane leakage.
10. Test aborted - cell malfunction.
11. Sieve analyses incomplete as of June 11, 1976.

DESCRIPTION OF UNDISTURBED SAMPLES

BORING NO. SWR7

Project North Anna Power Station

Project No. 75260
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Sample No. and Depth ft.	Section No.	Length of Section in.	Description
ST5 42.5-43.1	-	7.0	Tan micaceous very silty medium to fine sand. Minerals vary from black to white and appear in spots and streaks throughout the specimen. Fines are non-plastic. (Residual Soil) Specimen swelled after extrusion from the tube due to the large mica content. Failure occurred in compression by developing 2 shear planes in the top half of the specimen.

N03EA120

DESCRIPTION OF UNDISTURBED SAMPLES

BORING NO. SWR9

Project No. 75260

Project North Anna Power Station

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Sample No. and Depth ft.	Section No.	Length of Section in.	Description
ST2 22.5- 23.1	-	7.0	Mottled gray, tan, rust orange and black micaceous silty fine sand. Coloring occurs in streaks, pockets and zones throughout the specimen showing structure of parent rock. (Residual Soil) Specimen swelled after extrusion from the tube due to the large mica content. Failure occurred in compression primarily by bulging and shearing in the top half of specimen.

N03EA121

DESCRIPTION OF UNDISTURBED SAMPLES

BORING NO. P11

Project No. 75260

Project North Anna Power Station

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Sample No. and Depth ft.	Section No.	Length of Section in.	Description
ST3	-	6.9	Multicolored micaceous silty medium to fine sand. Minerals are rust orange, brown, black, white and green in color. Some banding of light and dark minerals at about 30° from horizontal. Fines non-plastic. (Residual Soil) Specimen swelled after extrusion from the tube due to the large mica content. Failure occurred in compression by developing a shear plane at about 45° in the lower half of the specimen.

N03EA122

DESCRIPTION OF UNDISTURBED SAMPLES

BORING NO. P12

Project No. 75260

Project North Anna Power Station

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Sample No. and Depth ft.	Section No.	Length of Section in.	Description
ST2 17.5-18.1	-	7.0	Tan to black brown micaceous silty medium to fine sand. Minerals occur in bands and streaks at approximately 45°. Grains are subangular. Top half of specimen is predominantly dark minerals. Bottom half is predominantly tan-white minerals. (Residual Soil) Specimen swelled after extrusion from the tube due to the large mica content. Failure occurred in compression in bottom half of specimen by developing a shear plane at approximately 45°, parallel to banding of minerals.

N03EA123

DESCRIPTION OF UNDISTURBED SAMPLES

BORING NO. SWR3

Project North Anna Power Station

Project No. 75260

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Sample No. and Depth ft.	Section No.	Length of Section in.	Description
ST3	-	7.2	Tan slightly micaceous silty medium to fine sand. Minerals vary from black to white and are banded at approximately 40° from the vertical. One very prominent band of intact quartz crystals up to 16 mm wide is located in the bottom half of the specimen (Residual Soil). The specimen swelled after extrusion from the tube due to the mica content of the soil. Failure occurred in compression by developing 2 shear planes in the top half of the specimen.

N03EA216

DESCRIPTION OF UNDISTURBED SAMPLES

BORING NO. SWR5

Project North Anna Power Station

Project No. 75260

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Sample No. and Depth ft.	Section No.	Length of Section in.	Description
ST5	-	7.2	Multicolored silty micaceous medium to fine sand. Colors range from black to white and green to brown. Minerals are banded at approximately 45°. (Residual Soil) The specimen swelled after extrusion from the tube due to the mica content of the soil. Failure occurred in compression by developing one well defined shear plane parallel to foliation of minerals.

N03EA217

DESCRIPTION OF UNDISTURBED SAMPLES

BORING NO. SWR9

Project [illegible] Project No. 75260

Page [illegible]

Sample No. and Depth ft.	Section No.	Length of Section in.	Description
ST1	-	7.0	Mottled tan, light brown and black very micaceous silty fine sand. Coloring of minerals occurs in spots and streaks and generally trend 45° from vertical. Bottom half of specimen contains one streak of black silty fine sand up to 10 mm wide and 45° from vertical. (Residual Soil) The specimen swelled after extrusion from the tube due to the mica content of the soil. Failure occurred in compression by developing a shear plane in the top 2/3 of the specimen parallel to banding of minerals.

N03EA218

Table 9
PRELIMINARY VISUAL DESCRIPTIONS OF CYCLIC TRIAXIAL TEST SAMPLES[a]

Test Number[b]	Description
CR-10	Grey/white saprolite breaks down to fine sand with silt, fine mica flakes throughout, top 3.5 cm, layered black and white, white layers clayey, foliation dips at 56°.
CR-11	Brown saprolite, fine silty sand, contains 3mm wide layer of med. sand size quartz particles, folation dips at 45° for top 1/4 of sample, then bends around to dip 60° in opposite direction.
CR-13	Orange-brown saprolite, silty fine to medium sand, band of orange-white clayey med. to coarse sound, foliation dips at 60°, possible failure plane at 35° in top 1/3 of sample.
CR-14	Yellowish-green saprolite, fine to med. sand, 2 to 3 mm layers of very fine mica flakes, foliation dips at 34°.
CR-15	Orange-brown saprolite, silty fine to med. sand, micaceous, contains occasional angular quartz particles to 5 mm, contains zones that are slightly plastic, foliation dips at 45°.
CR-16	Mottled yellow-green saprolite mostly fine to med. sand, slightly silty, fine to med. mica flakes.
CR-17	Mottled orange-brown saprolite, silty fine to med. sand, foliation dips at 43°.
CR-18	Mottled orange-pink saprolite silty sand, foliation at 53°.

a. Sample descriptions are preliminary pending completion of laboratory classification tests.

b. Descriptions for aborted tests are not included.

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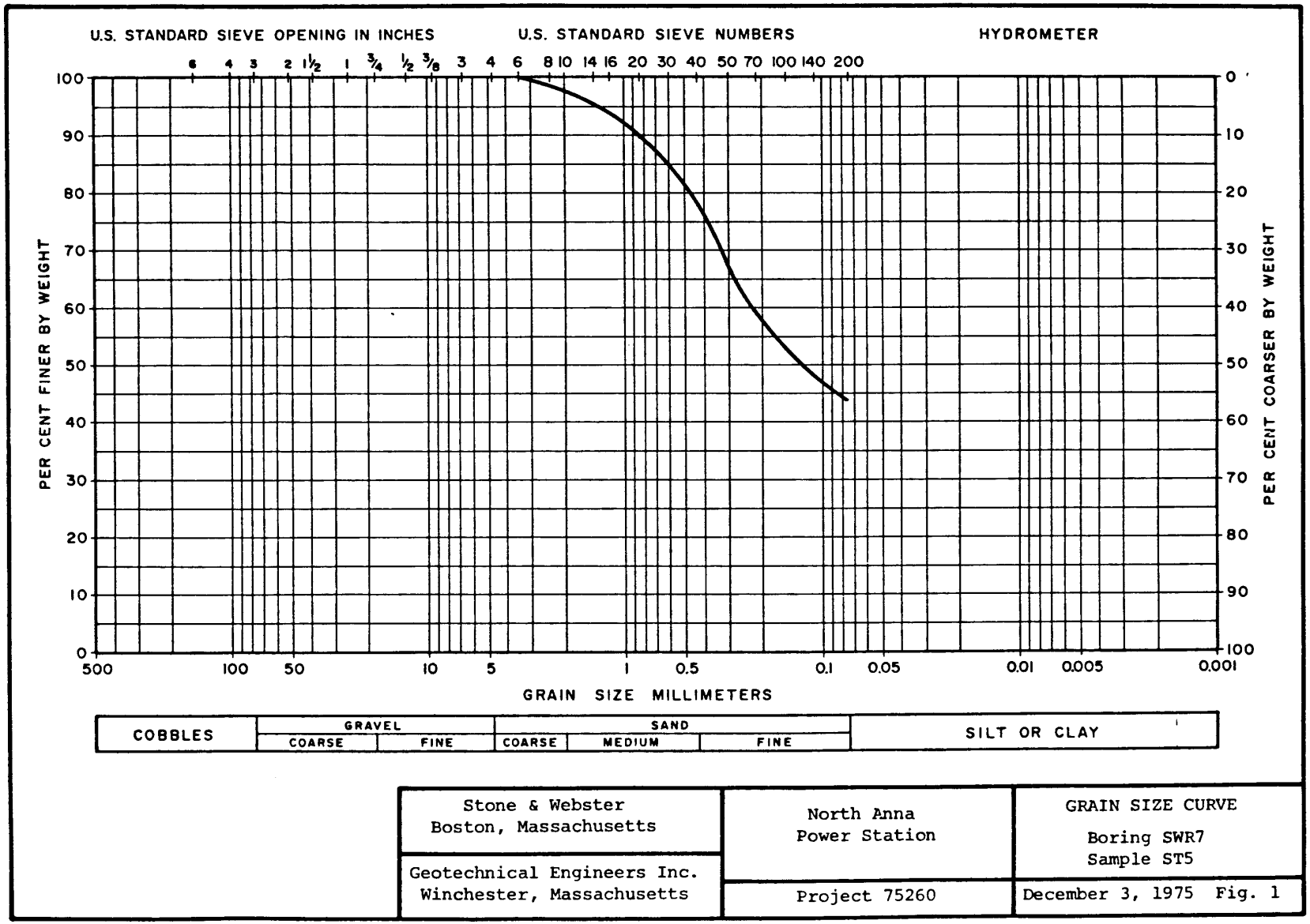

Stone & Webster Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring SWR7 Sample ST5
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 3, 1975 Fig. 1

N03EA109

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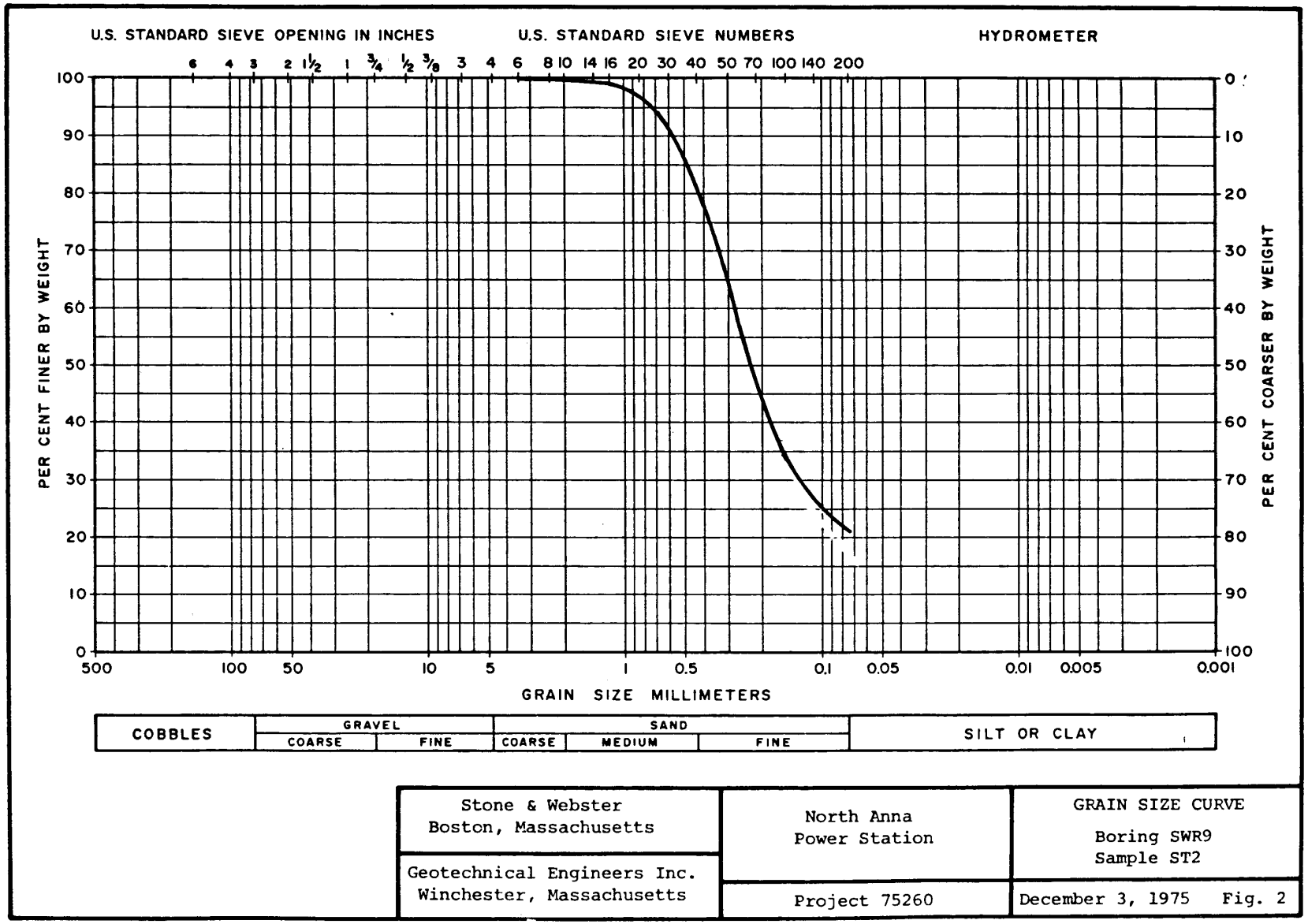
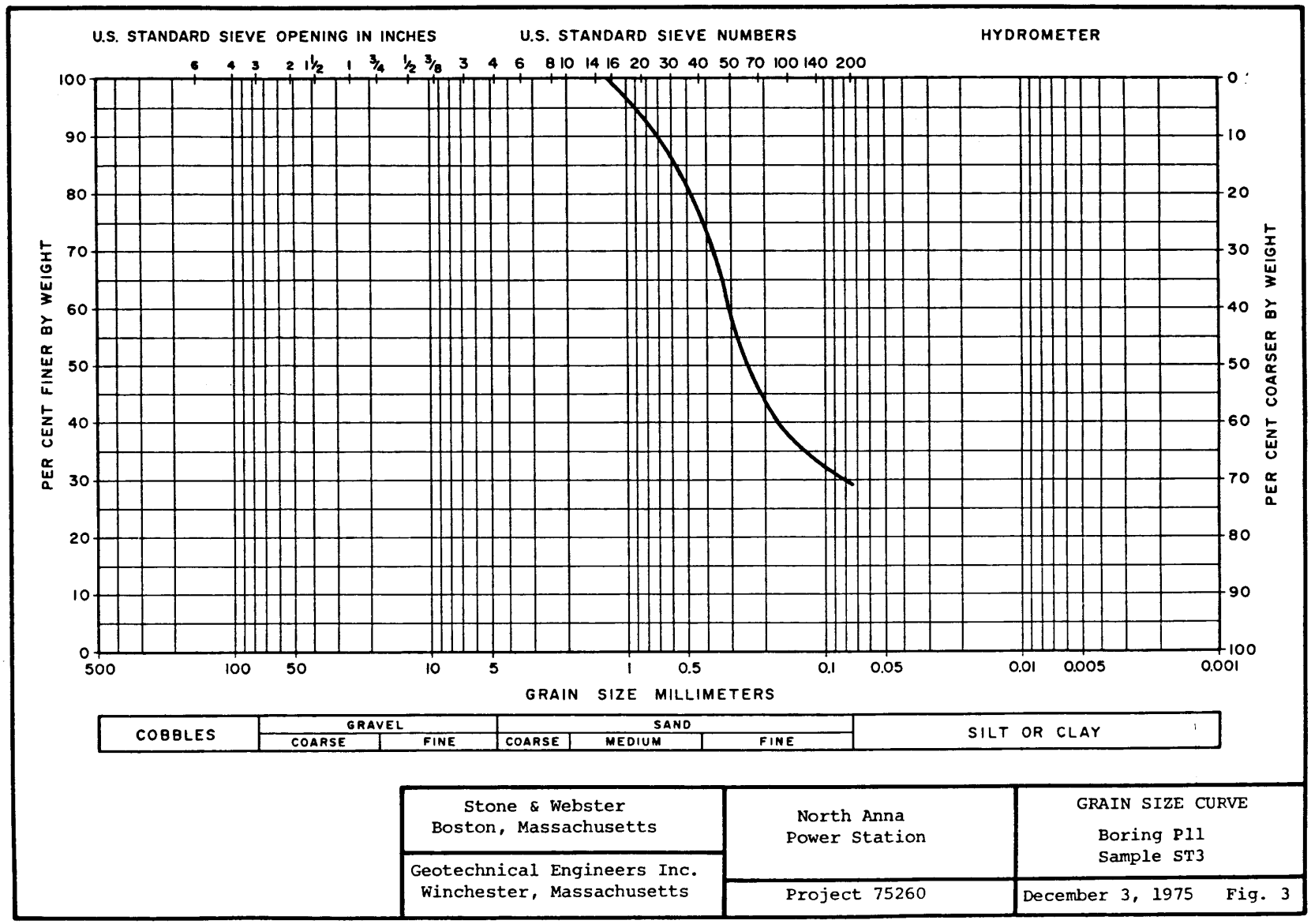


Stone & Webster Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring SWR9 Sample ST2
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 3, 1975 Fig. 2

N03EA110

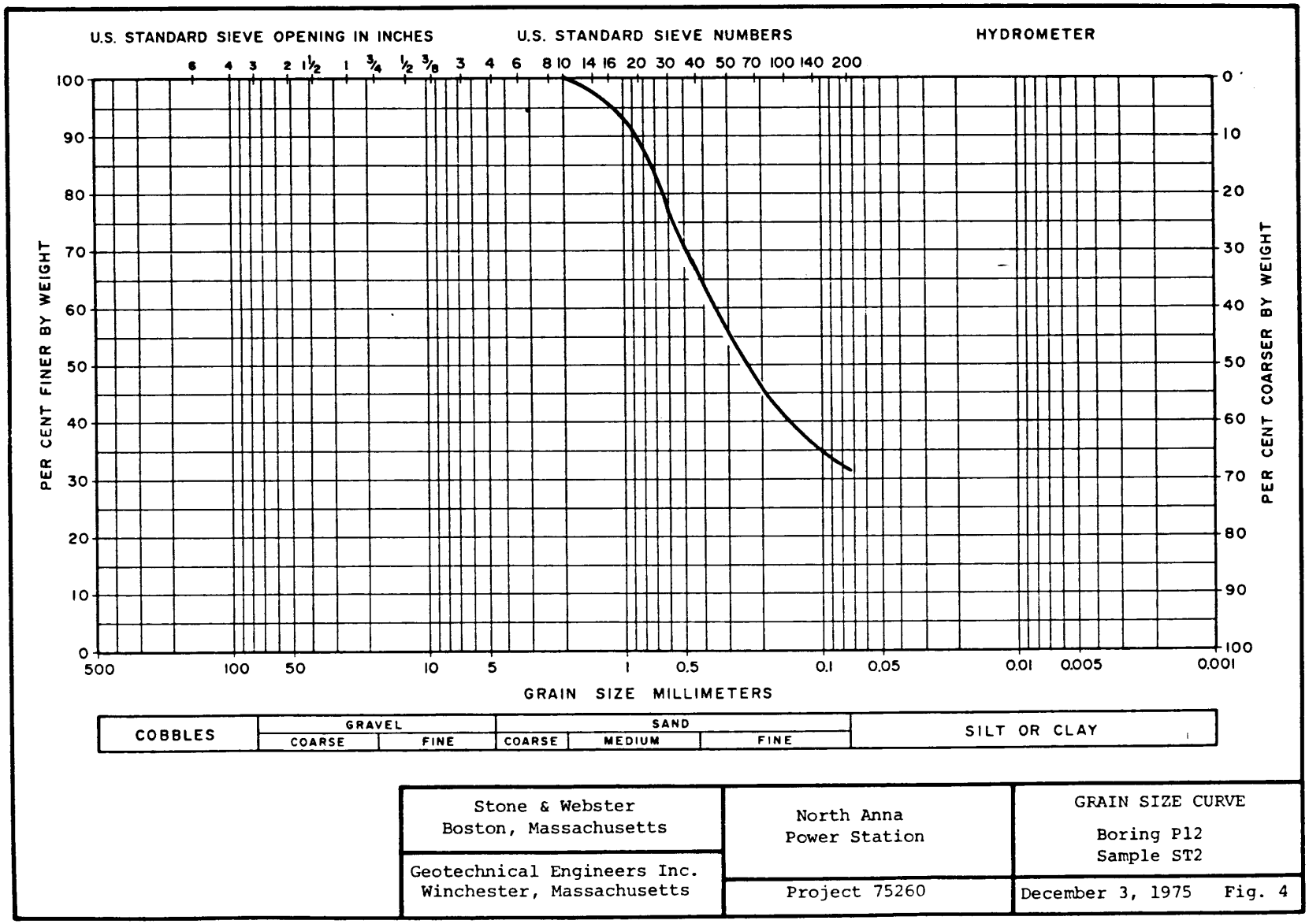
Lab. 4-3 rev. 0 28 May 74



Stone & Webster Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring P11 Sample ST3
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 3, 1975 Fig. 3

N03EA111

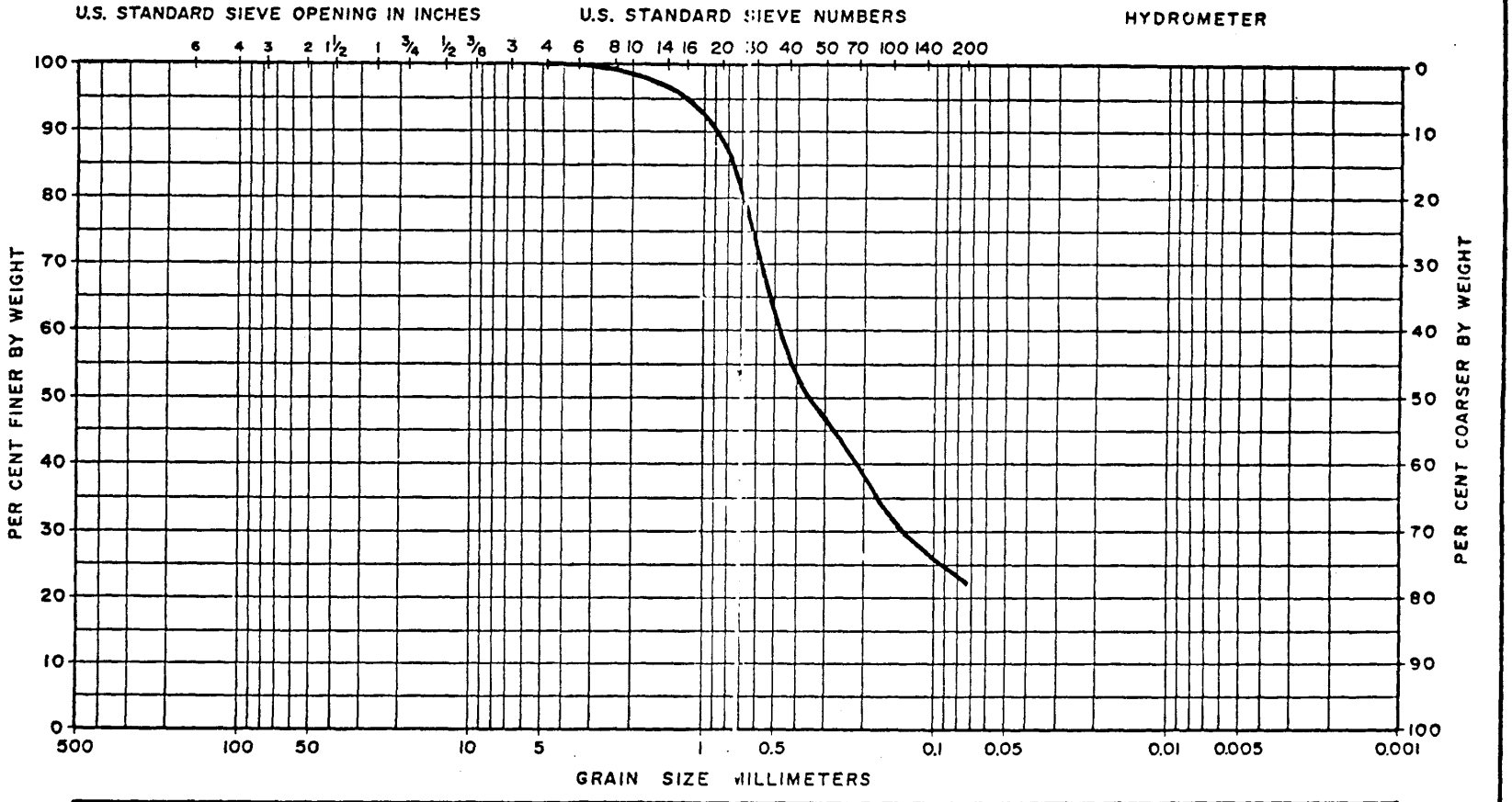
Lab. 4-3 rev. 0 28 May 74



Stone & Webster Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring P12 Sample ST2
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 3, 1975 Fig. 4

N03EA112

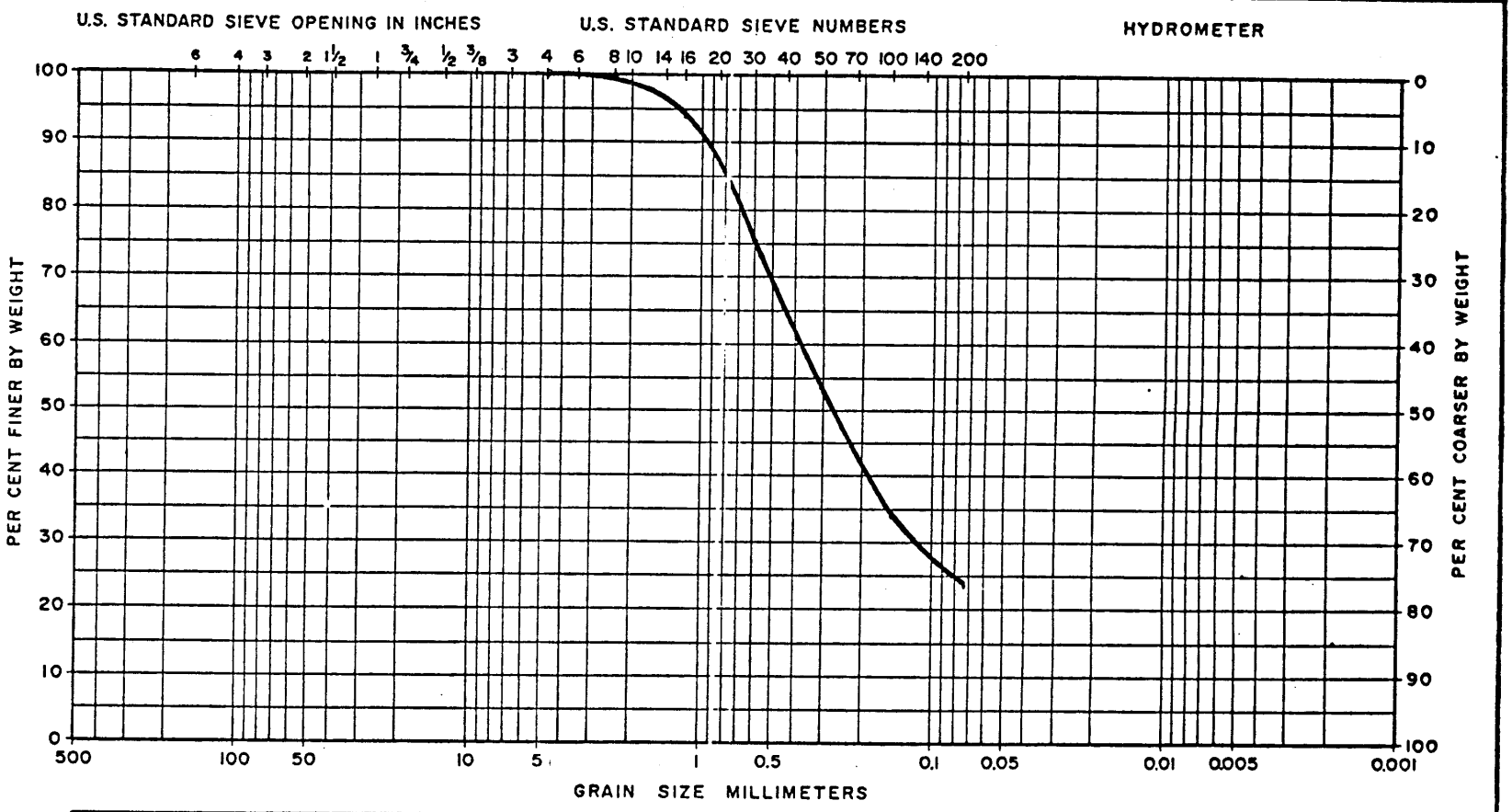
Lab. 4-3 rev. 0 28 May 74



Stone & Webster Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring SWR3 Sample ST3
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 30, 1975 Fig. 1

N03EA205

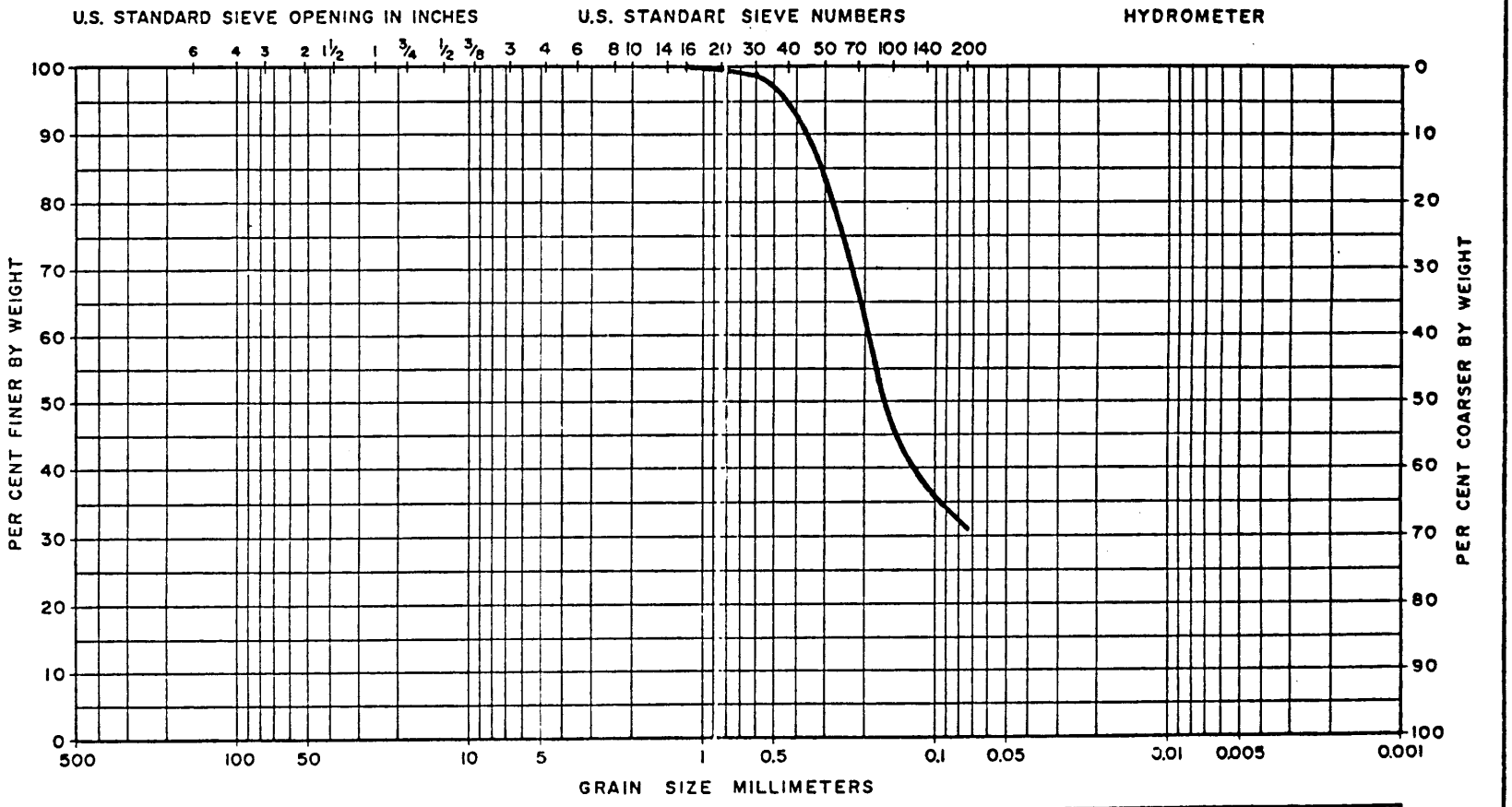
Lab. 4-3 rev. 0 28 May 74



Stone & Webster Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring SWR5 Sample ST5
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 30, 1975 Fig. 2

N03EA206

Lab. 4-3 rev. 0 28 May 74

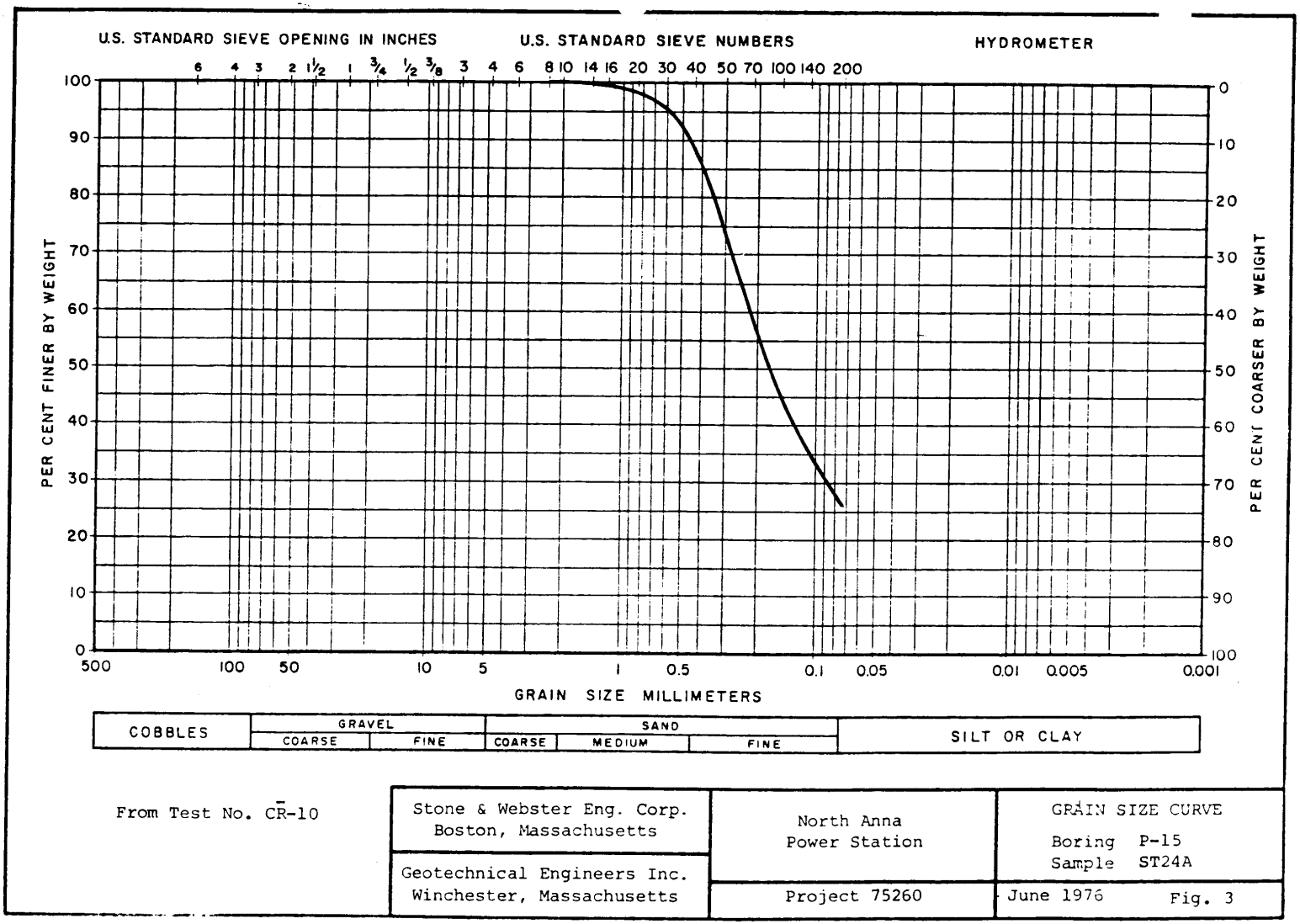


Stone & Webster Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring SWR9 Sample ST1
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 30, 1975 Fig. 3

N03EA207

N03EA319

Lab. 4 rev. 0 28 May 74

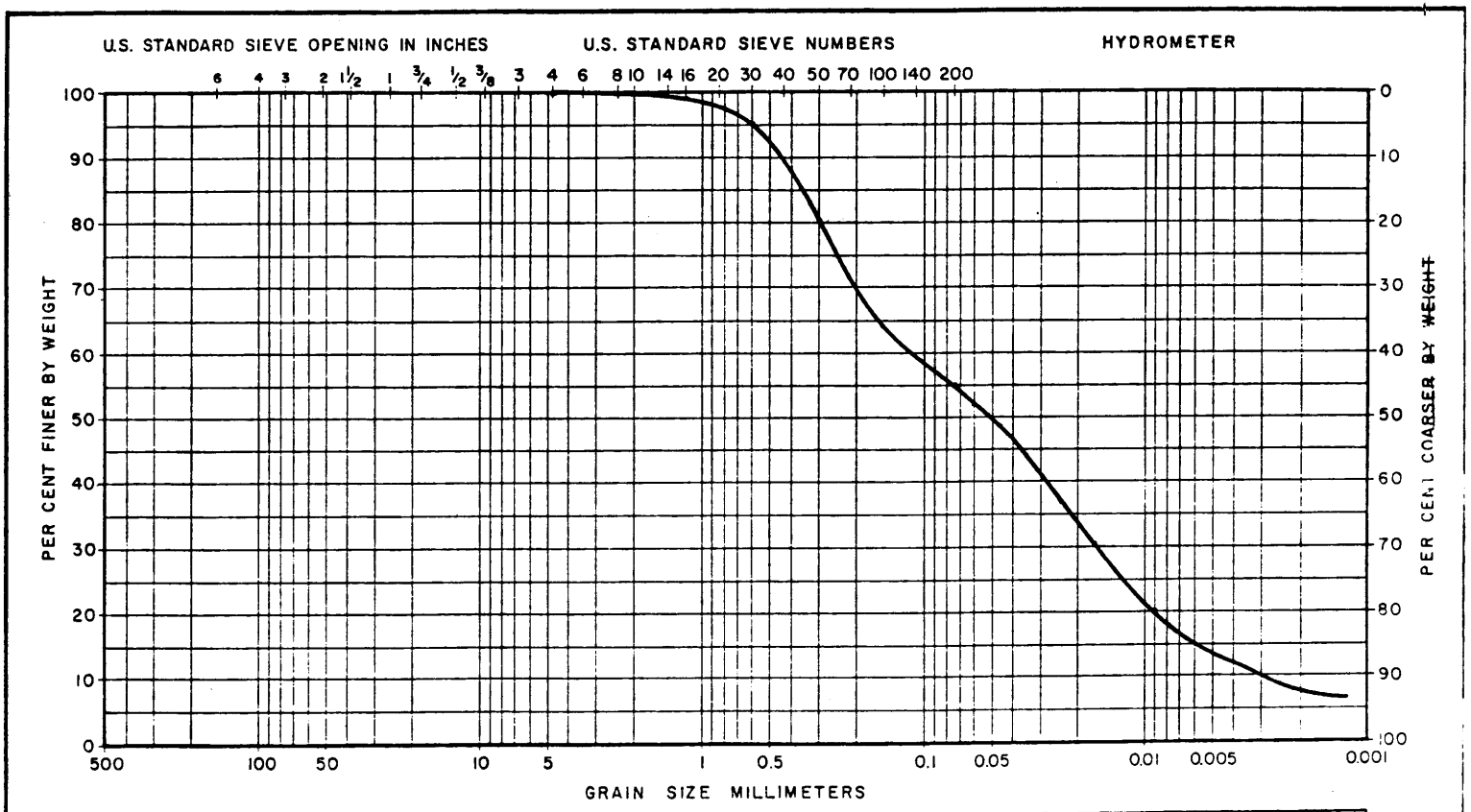


From Test No. CR-10

Stone & Webster Eng. Corp. Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring P-15 Sample ST24A
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	June 1976 Fig. 3

N03EA324

Lab. 3 rev. 0 28 May 74

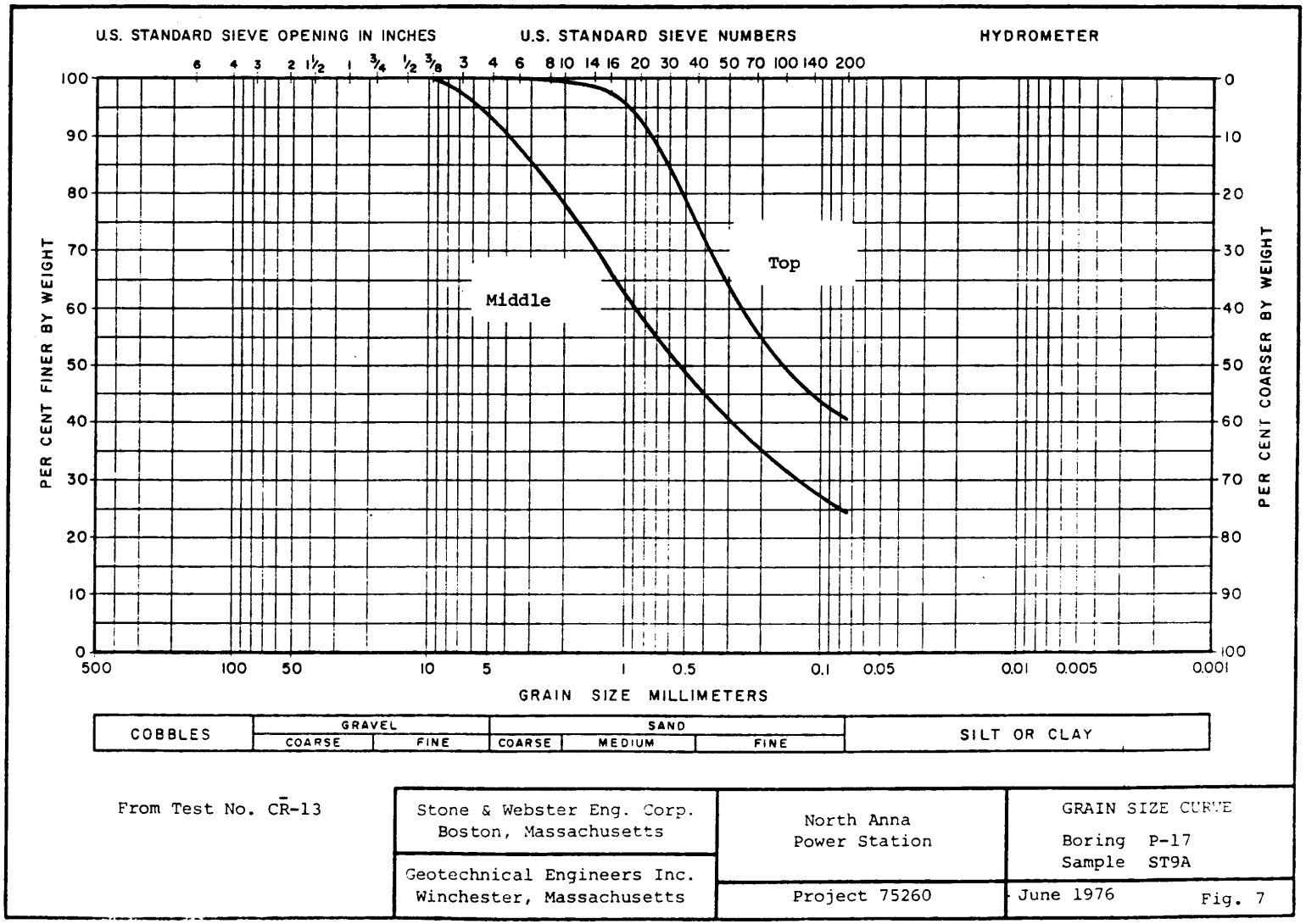


From Test No. CR-11

Stone & Webster Eng. Corp. Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring P-17 Sample ST9B
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	June 1976 Fig. 8

N03EA323

Lab. 4 rev. 0 28 May 74

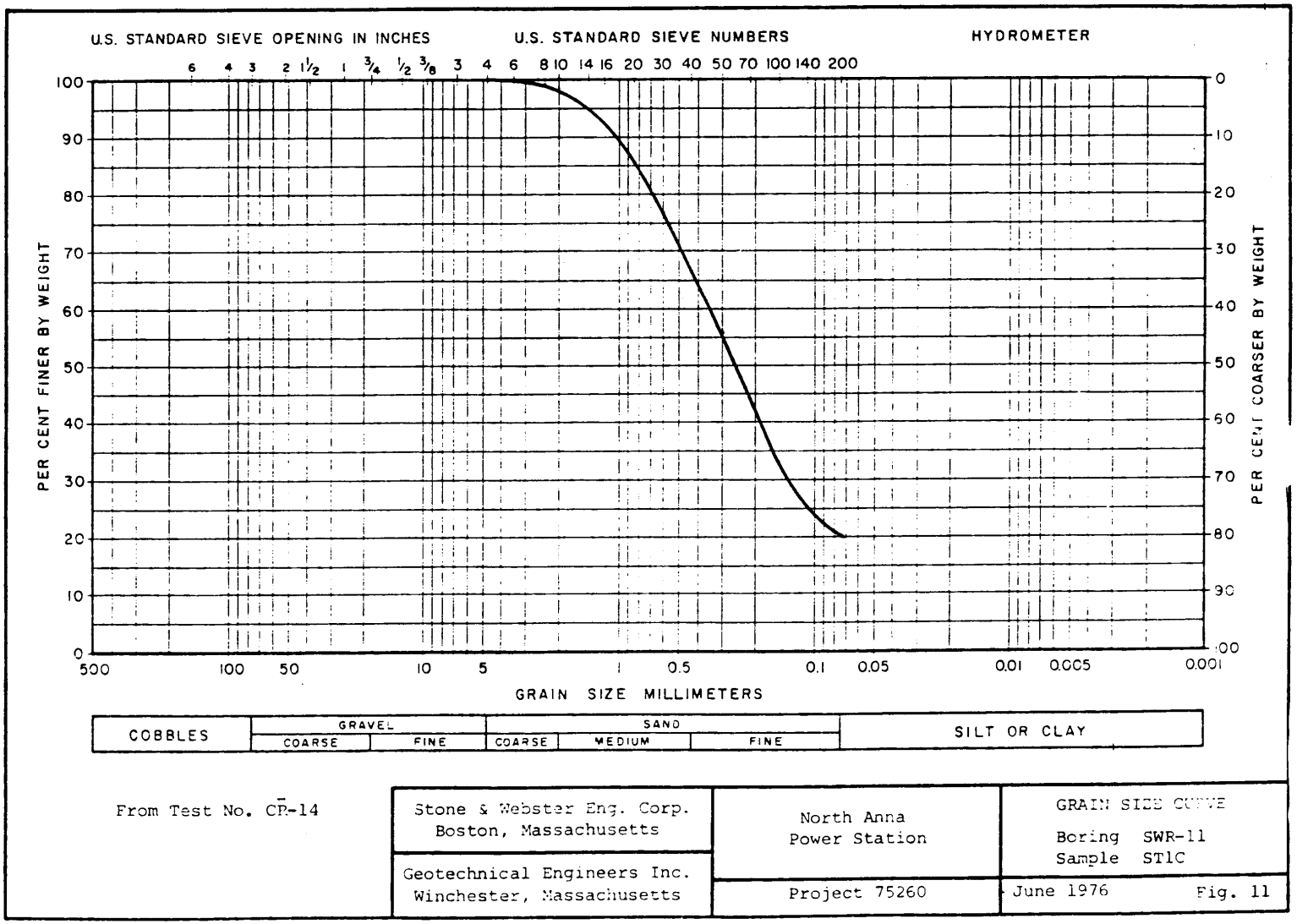


From Test No. CR-13

Stone & Webster Eng. Corp. Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring P-17 Sample ST9A
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	June 1976 Fig. 7

N03EA327

Lab. rev. 0 28 May 74

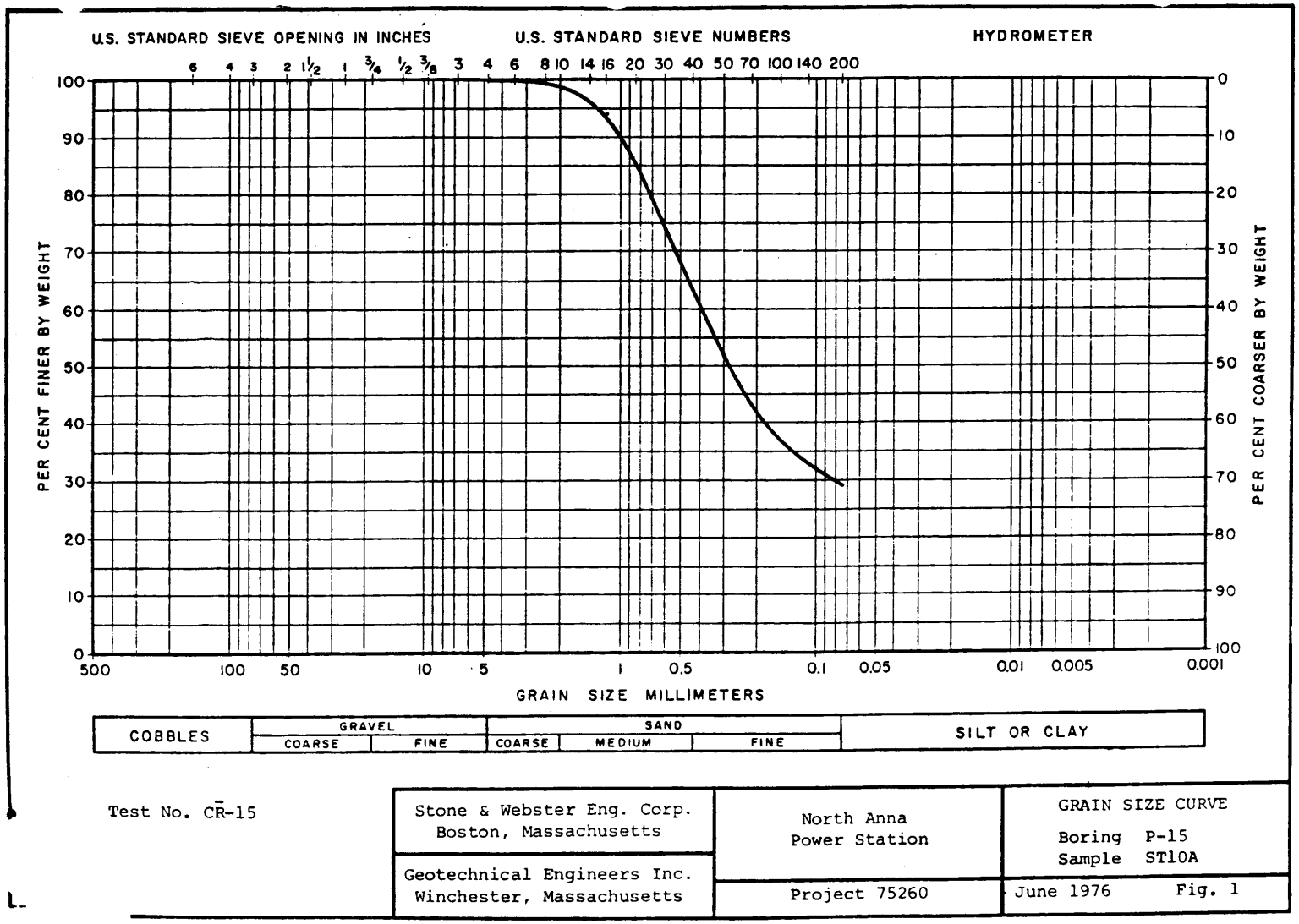


From Test No. CR-14

Stone & Webster Eng. Corp. Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring SWR-11 Sample ST1C
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	June 1976 Fig. 11

N03EA317

Lab. rev. 0 28 May 74

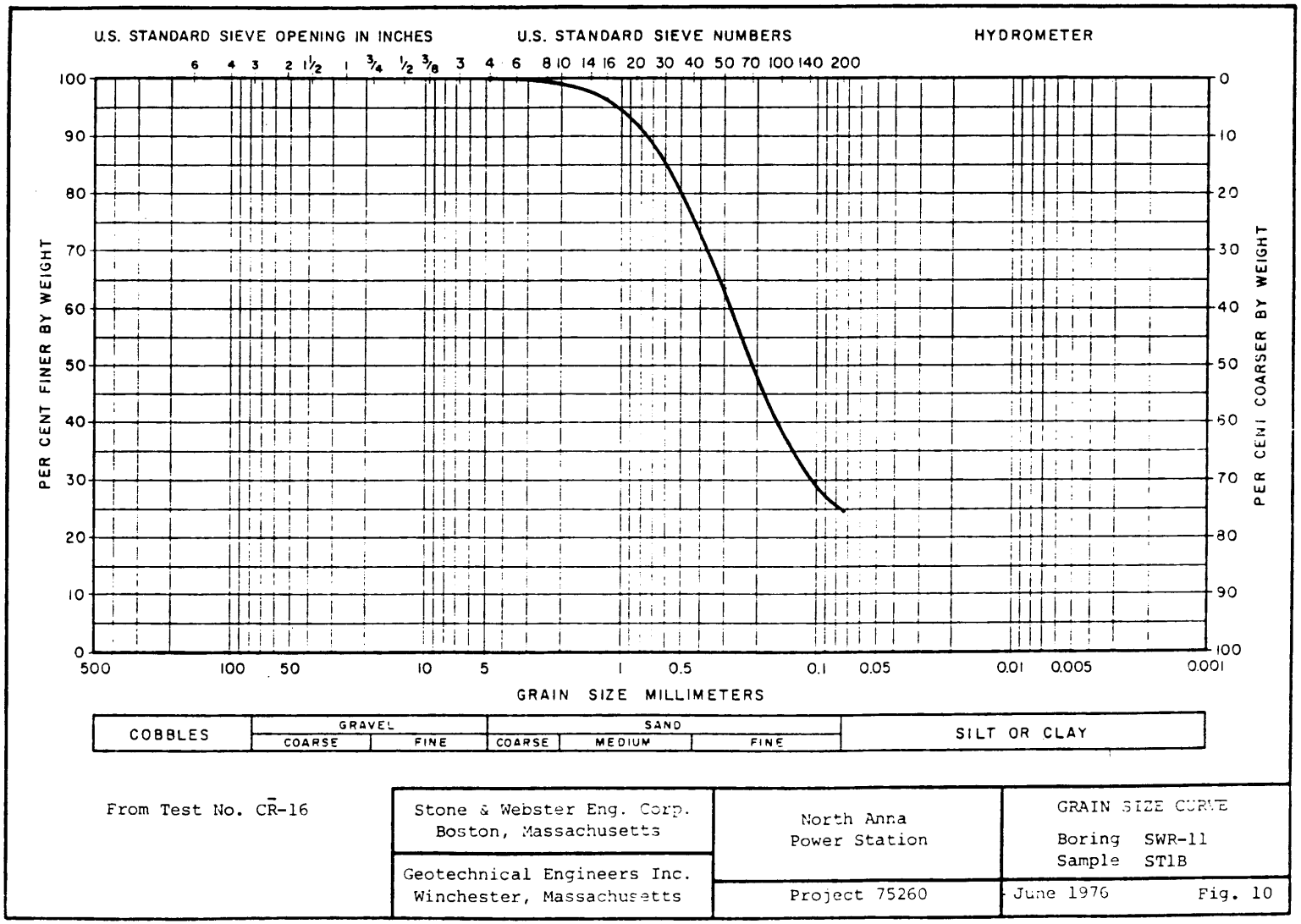


Test No. CR-15

Stone & Webster Eng. Corp. Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring P-15 Sample ST10A
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	June 1976 Fig. 1

N03EA326

Lab. rev. 0 28 May 74

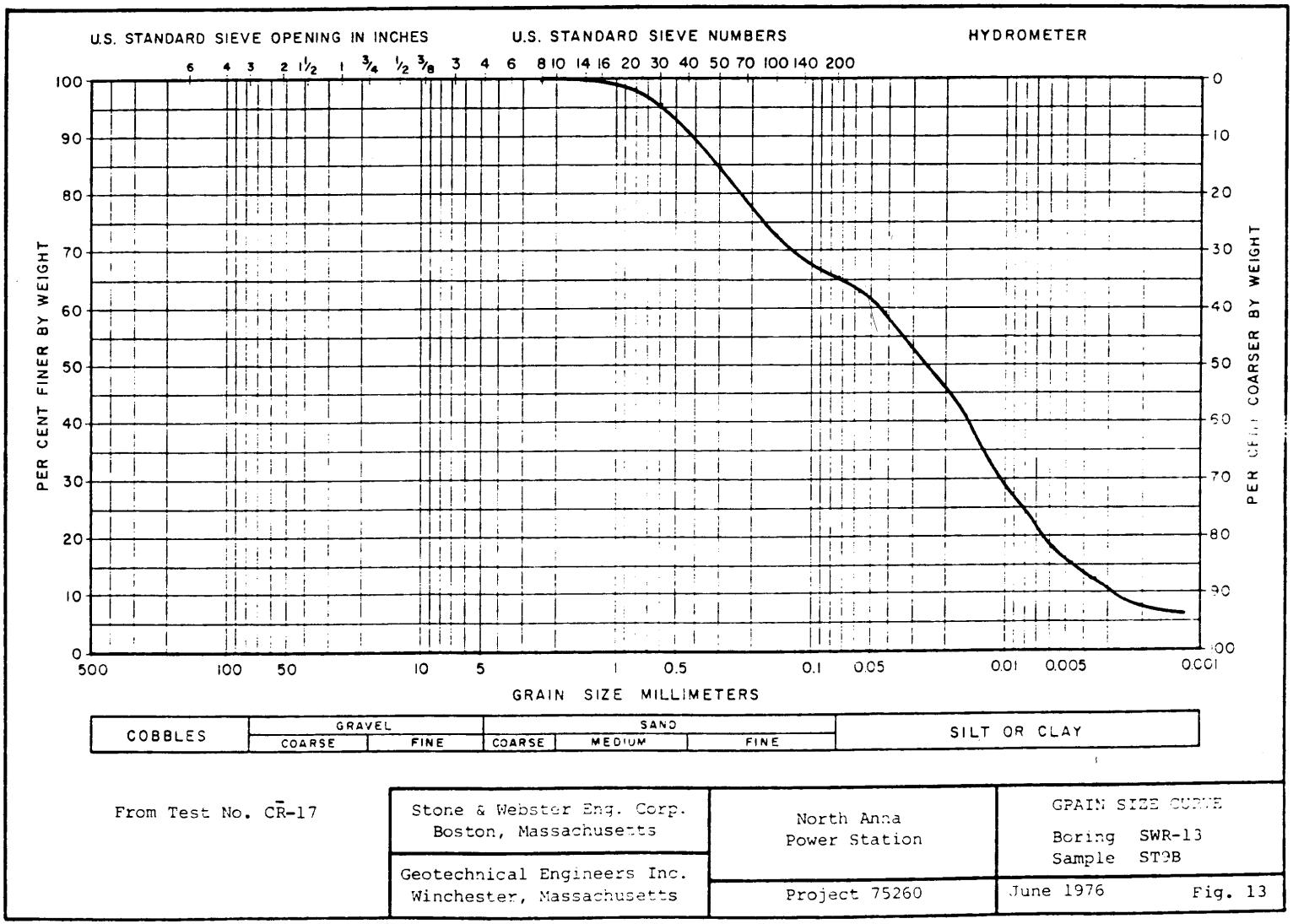


From Test No. CR-16

Stone & Webster Eng. Corp. Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring SWR-11 Sample ST1B
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	June 1976 Fig. 10

N03EA329

Lab. - rev. 0 28 May 74 -

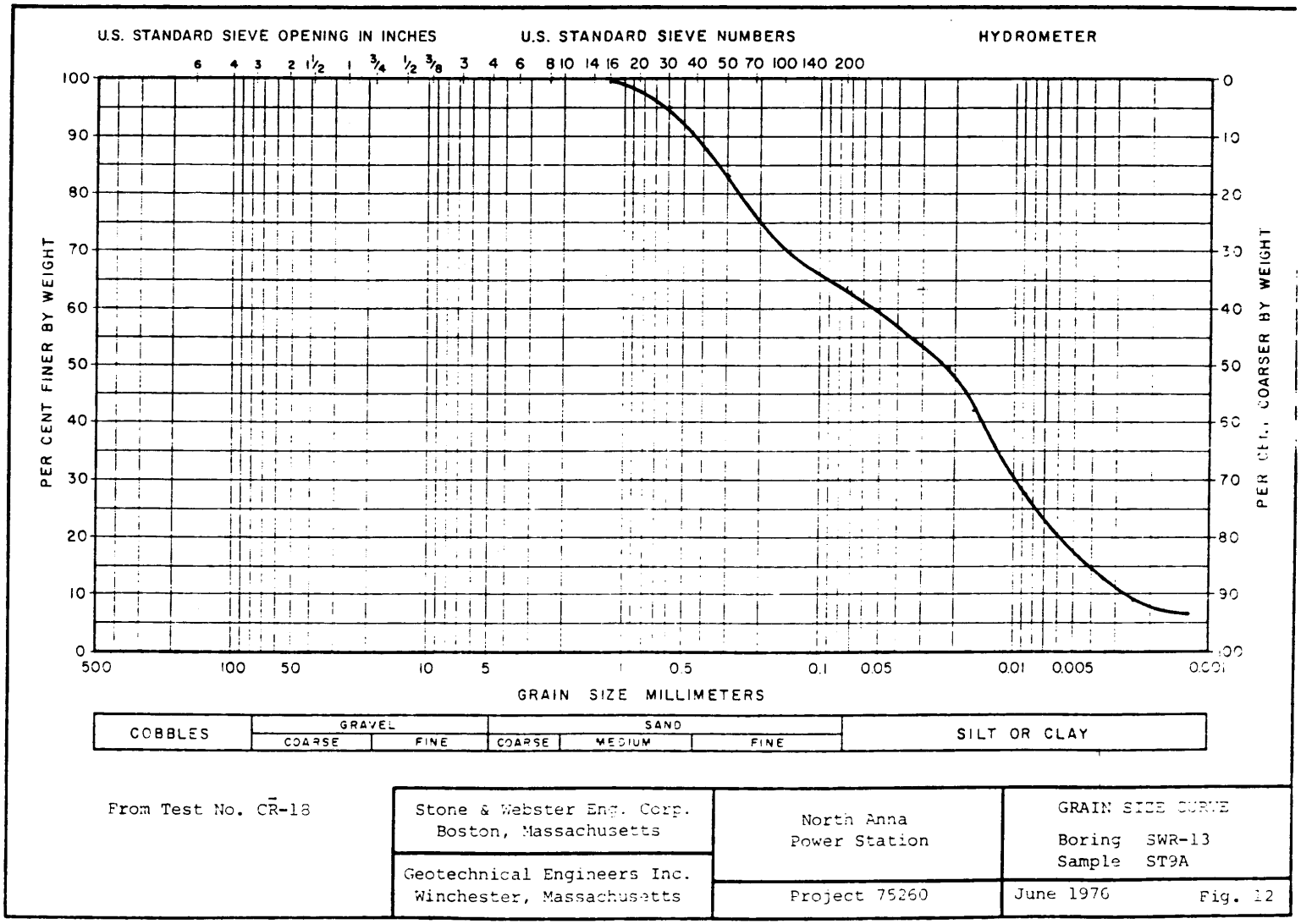


From Test No. CR-17

Stone & Webster Eng. Corp. Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring SWR-13 Sample ST3B
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	June 1976 Fig. 13

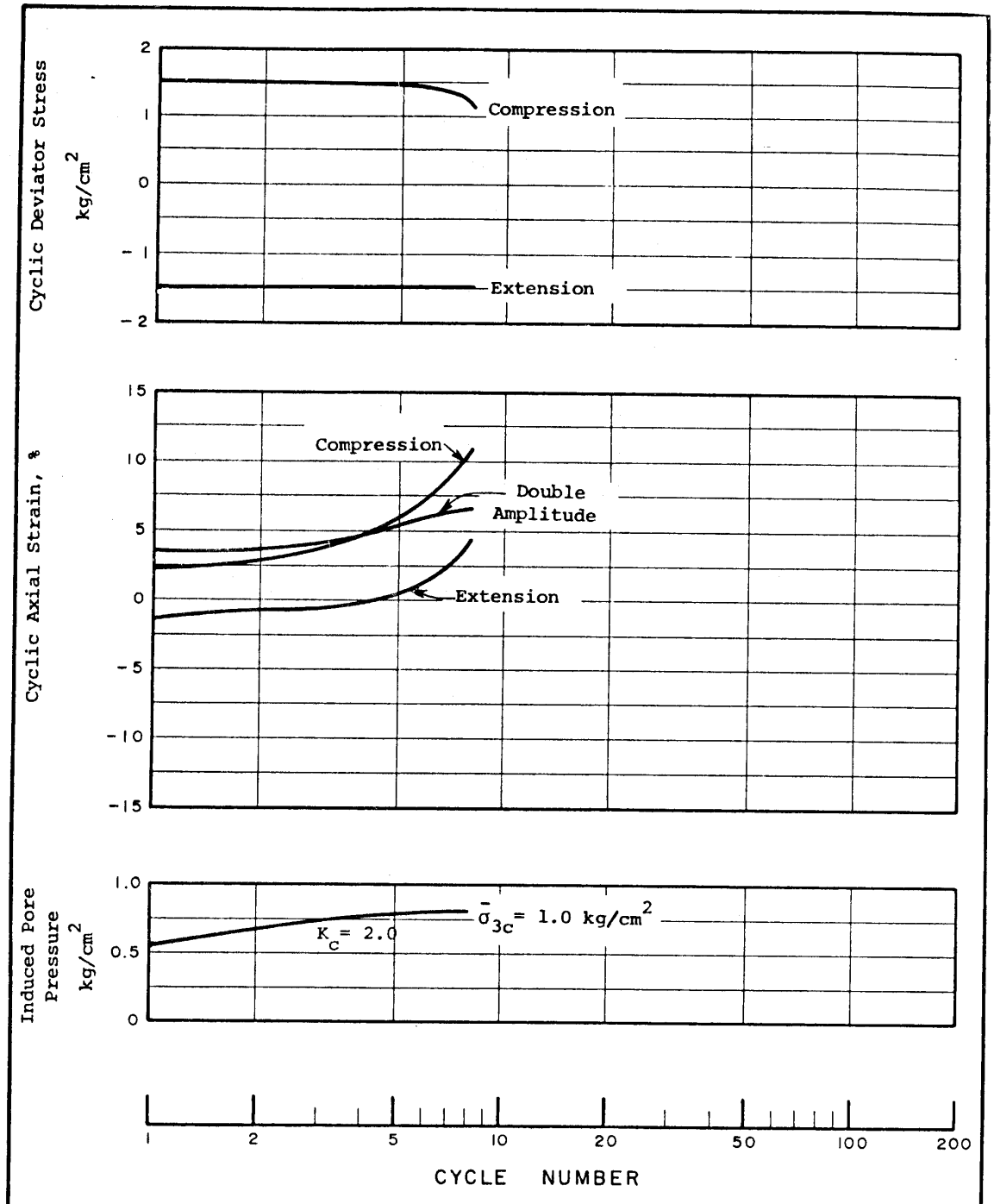
N03EA328

Lab. 4-3 rev. 0 28 May 74



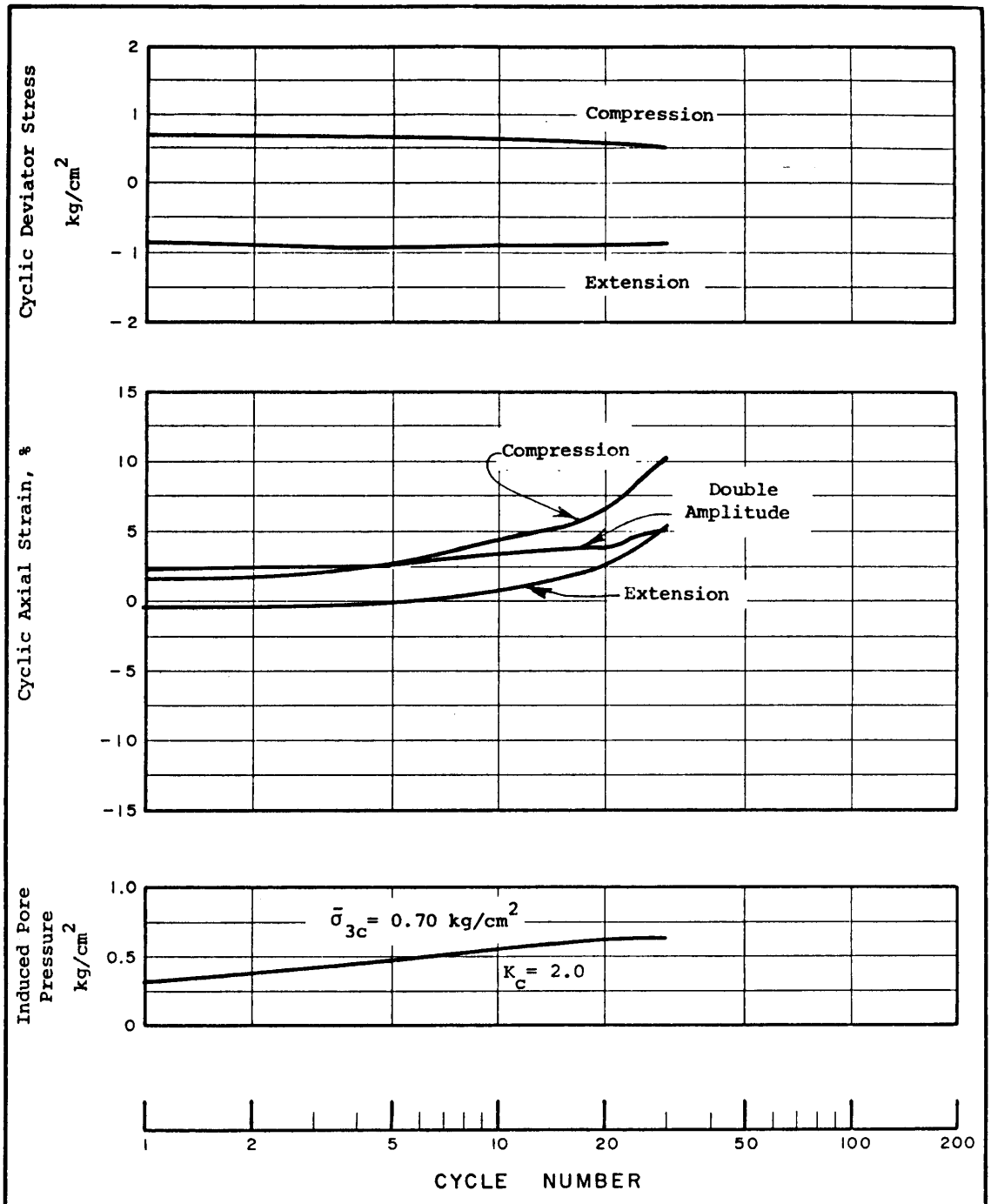
From Test No. CR-18

Stone & Webster Eng. Corp. Boston, Massachusetts	North Anna Power Station	GRAIN SIZE CURVE Boring SWR-13 Sample ST9A
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	June 1976 Fig. 12



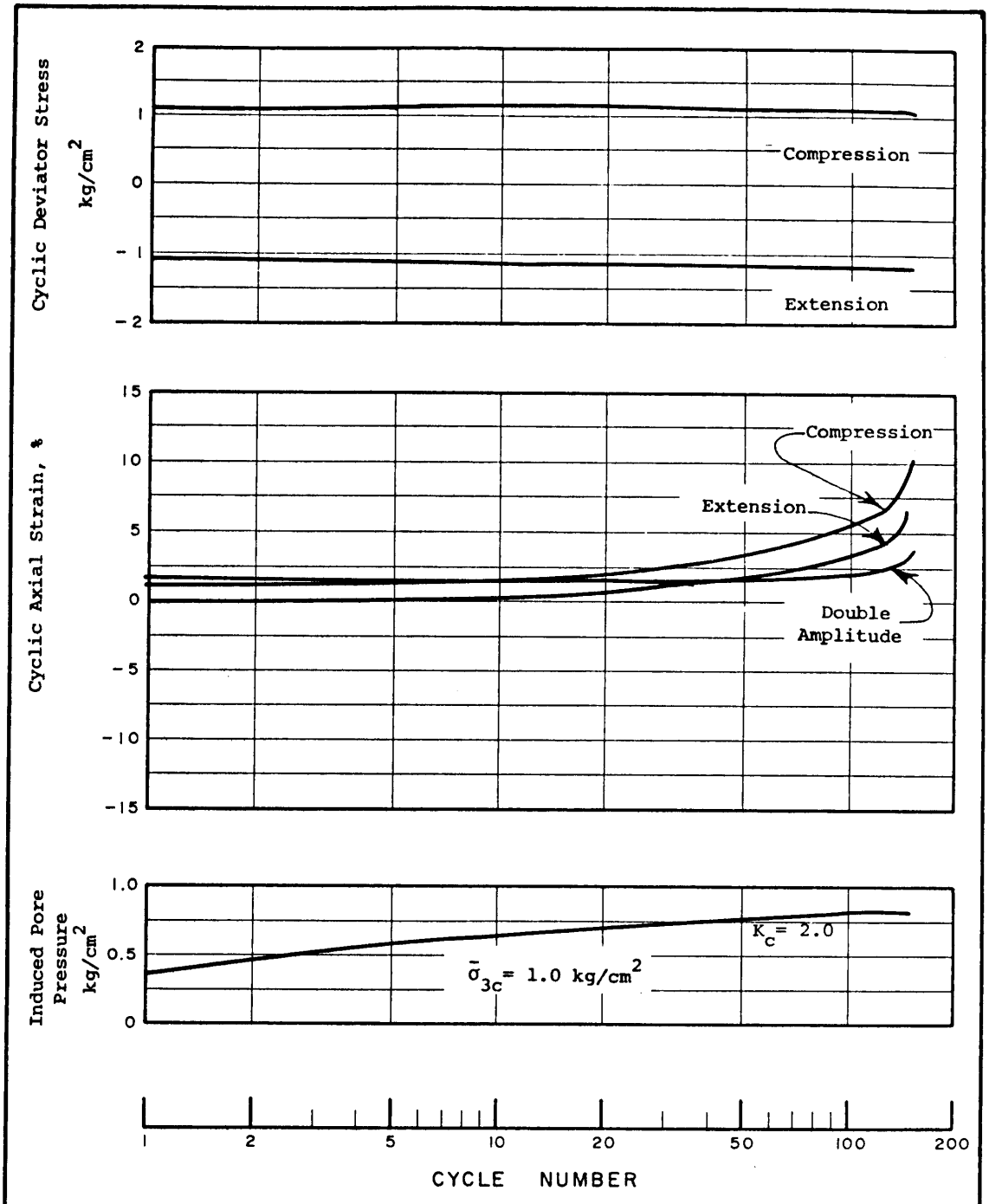
Stone & Webster Boston, Massachusetts	North Anna Power Station	CYCLIC LOAD TEST CR-1 Boring SWR7 Sample ST5
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 3, 1975 Fig. 5

N03EA113



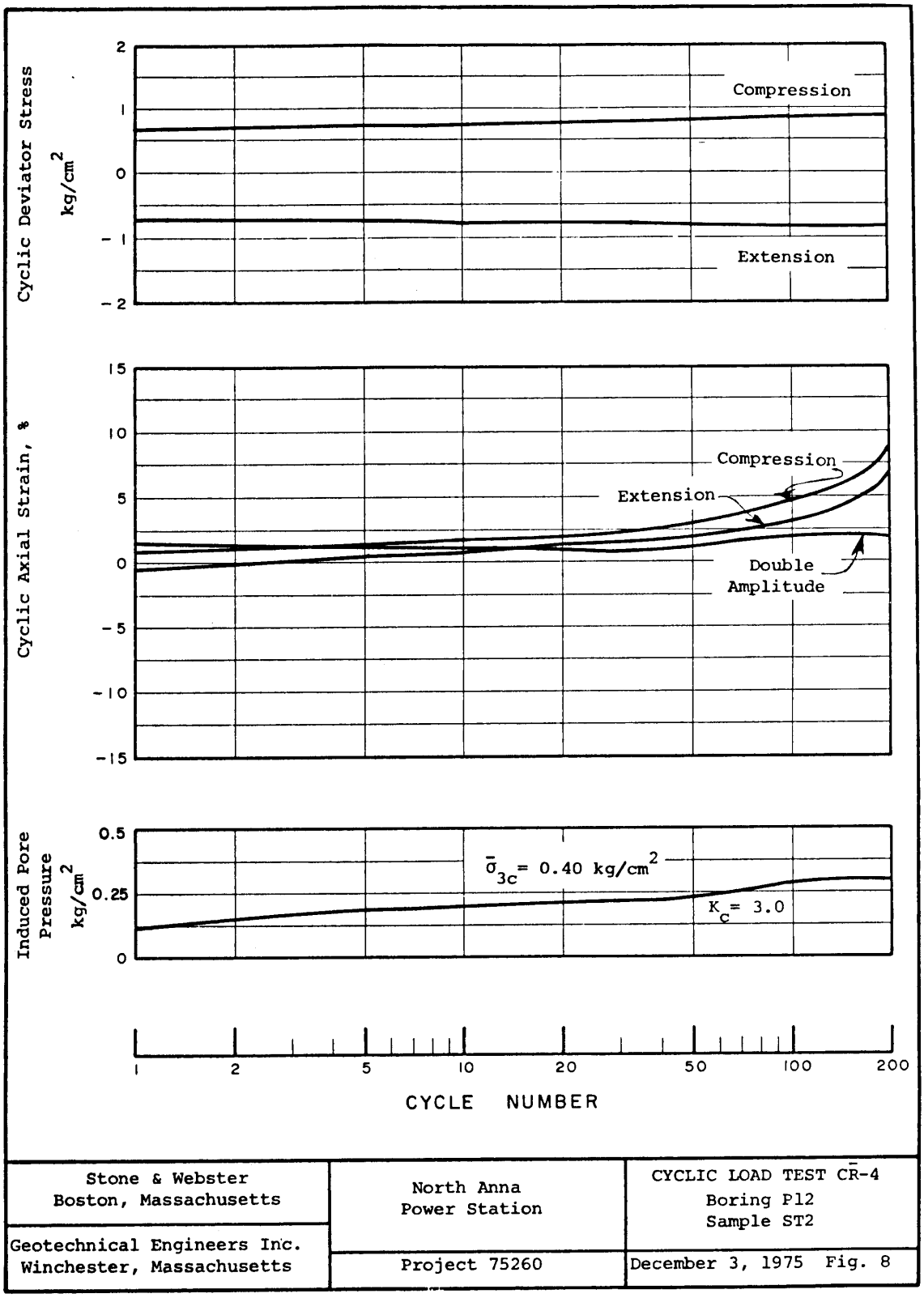
Stone & Webster Boston, Massachusetts	North Anna Power Station	CYCLIC LOAD TEST C̄R-2 Boring SWR9 Sample ST2
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 3, 1975 Fig. 6

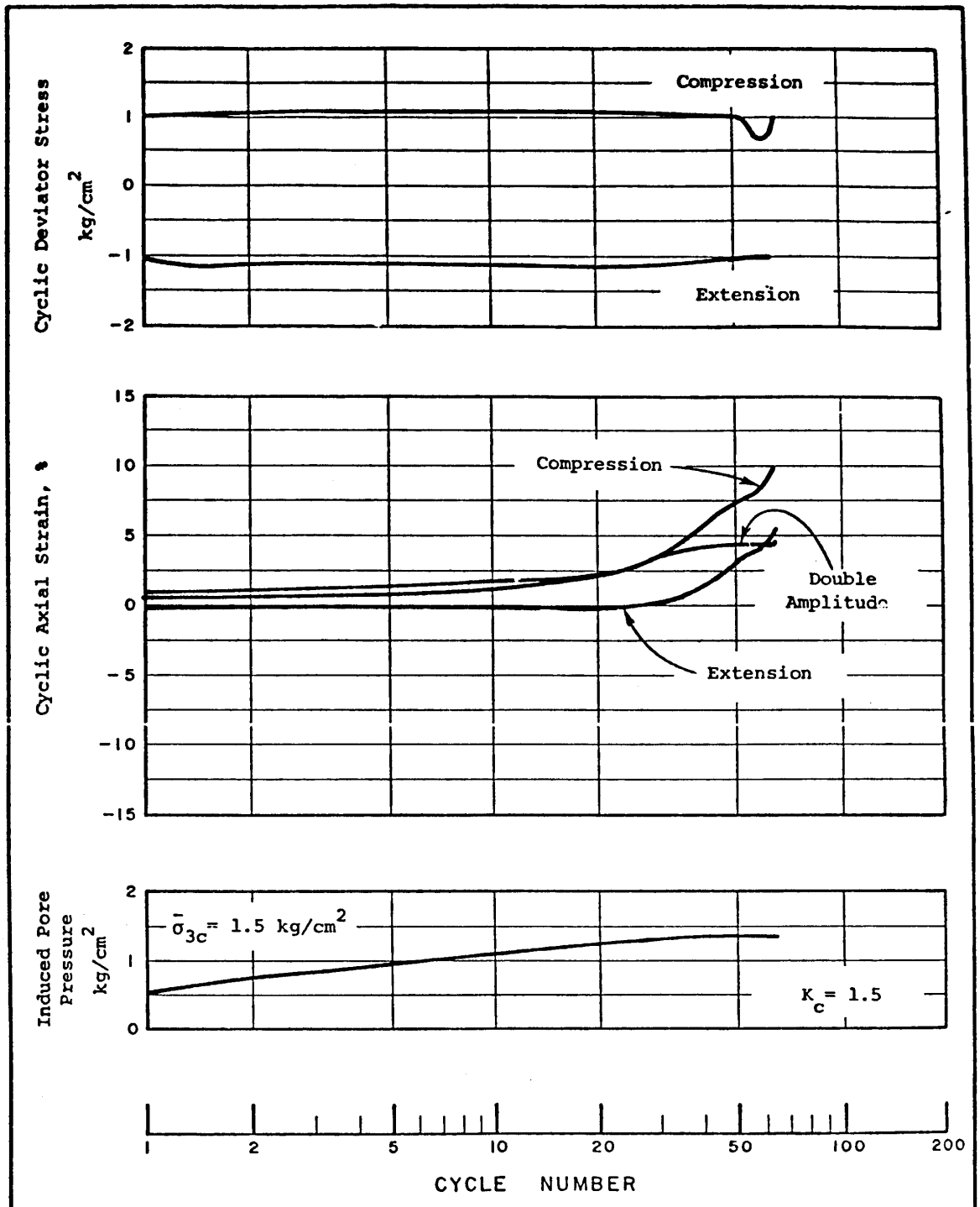
N03EA114



Stone & Webster Boston, Massachusetts	North Anna Power Station	CYCLIC LOAD TEST $\bar{CR}$-3 Boring P11 Sample ST3
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 3, 1975 Fig. 7

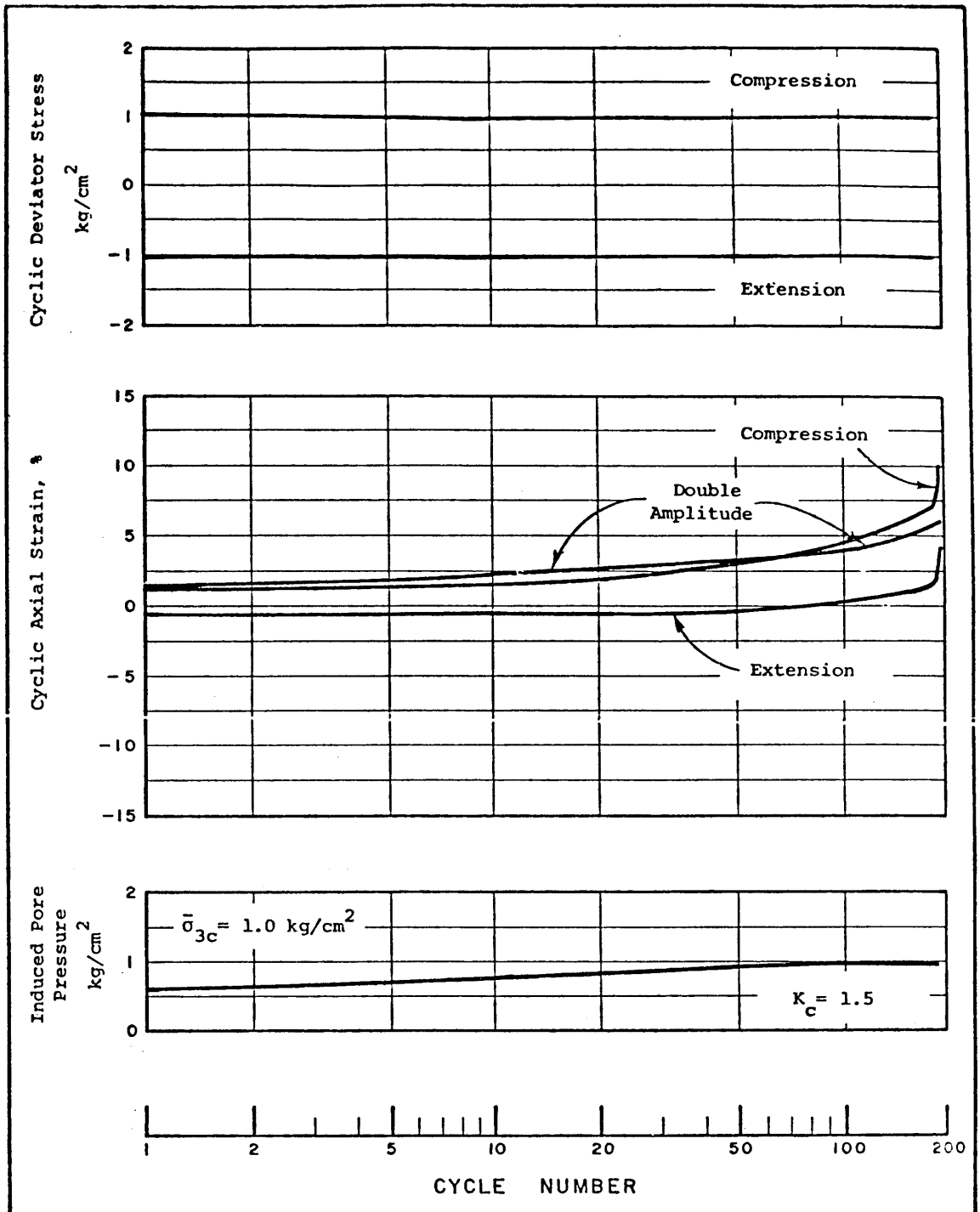
N03EA115


Cyclic Deviator Stress
kg/cm2
2
1
0
-1
-2
Compression
Extension
Cyclic Axial Strain, %
15
10
5
0
-5
-10
-15
Compression
Extension
Double
Amplitude
Induced Pore
Pressure
kg/cm2
0.5
0.25
0
σ̄3c = 0.40 kg/cm2
Kc = 3.0
1
2
5
10
20
50
100
200
CYCLE NUMBER
Stone & Webster
Boston, Massachusetts
North Anna
Power Station
CYCLIC LOAD TEST CR-4
Boring P12
Sample ST2
Geotechnical Engineers Inc.
Winchester, Massachusetts
Project 75260
December 3, 1975 Fig. 8
N03EA116



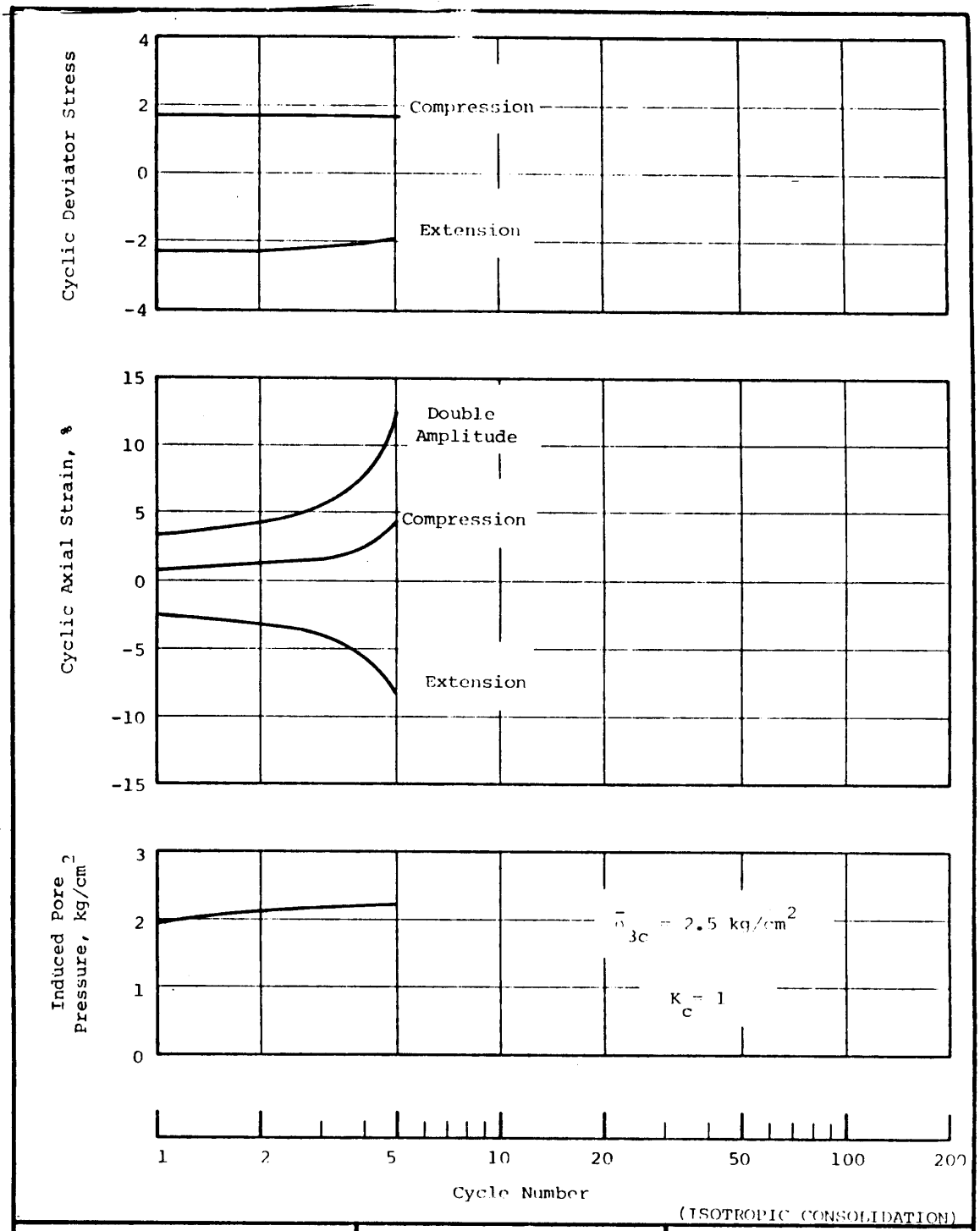
Stone & Webster Boston, Massachusetts	North Anna Power Station	CYCLIC LOAD TEST CR-5 Boring SWR3 Sample ST3
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 30,1975 Fig. 4

N03EA208

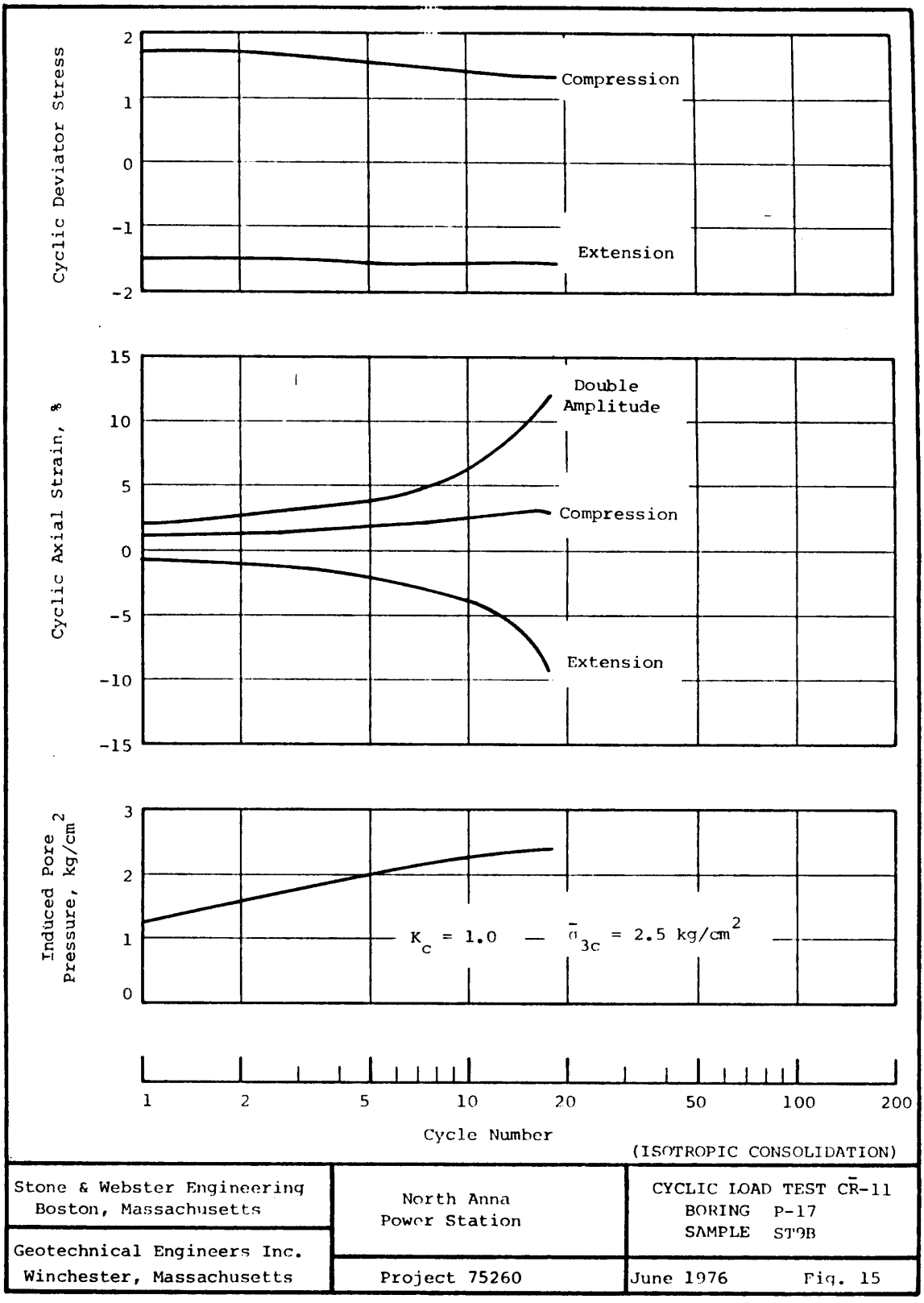


Stone & Webster Boston, Massachusetts	North Anna Power Station	CYCLIC LOAD TEST C̄R-7 Boring SWR9 Sample ST1
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	December 30, 1975 Fig. 6

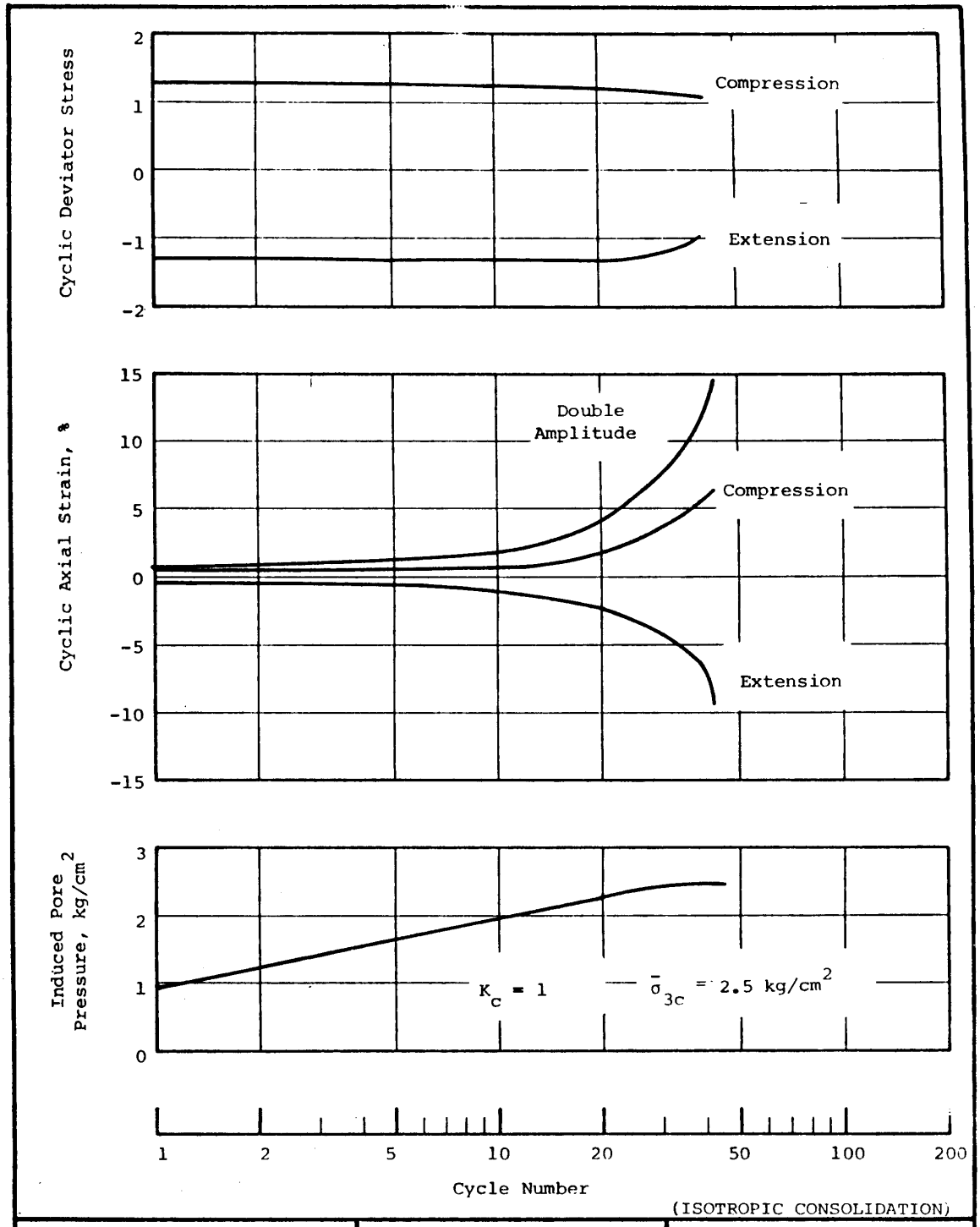
N03EA210


Cyclic Deviator Stress
4
2
0
-2
-4
Compression
Extension
Cyclic Axial Strain, %
15
10
5
0
-5
-10
-15
Double
Amplitude
Compression
Extension
Induced Pore Pressure, kg/cm2
3
2
1
0
σ̄3c = 2.5 kg/cm2
Kc = 1
1
2
5
10
20
50
100
200
Cycle Number
(ISOTROPIC CONSOLIDATION)
Stone & Webster Engineering
Boston, Massachusetts
North Anna
Power Station
CYCLIC LOAD TEST CR-10
BORING P-15
SAMPLE ST24A
Geotechnical Engineers Inc.
Winchester, Massachusetts
Project 75260
June 1976
Fig. 14

N03EA330

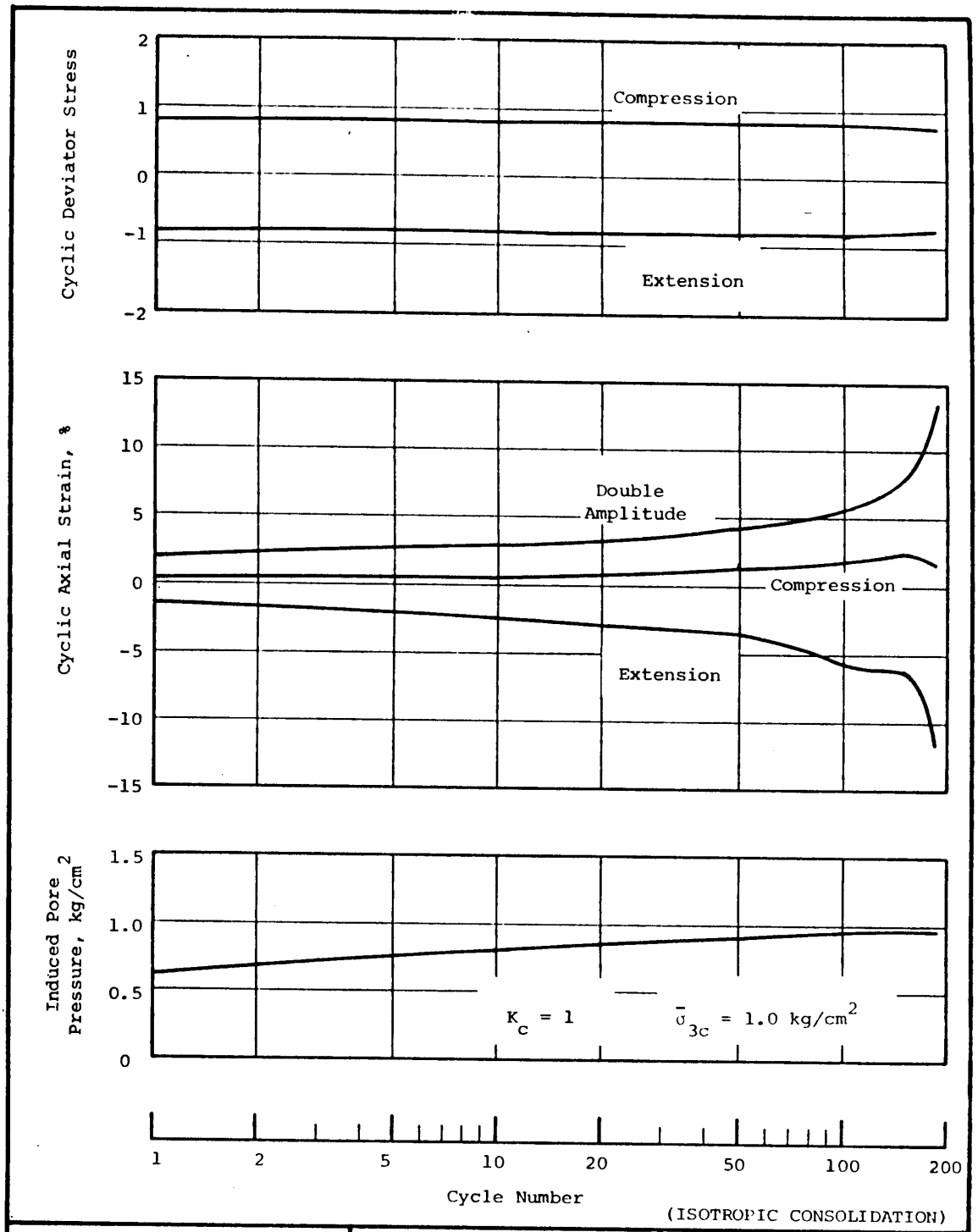

Cyclic Deviator Stress
2
1
0
-1
-2
Compression
Extension
Cyclic Axial Strain, %
15
10
5
0
-5
-10
-15
Double Amplitude
Compression
Extension
Induced Pore Pressure, kg/cm2
3
2
1
0
K_c = 1.0
$\bar{\sigma}_{3c}$ = 2.5 kg/cm2
1
2
5
10
20
50
100
200
Cycle Number
(ISOTROPIC CONSOLIDATION)
Stone & Webster Engineering
Boston, Massachusetts
North Anna
Power Station
CYCLIC LOAD TEST $\bar{CR}$-11
BORING P-17
SAMPLE ST9B
Geotechnical Engineers Inc.
Winchester, Massachusetts
Project 75260
June 1976
Fig. 15

N03EA331

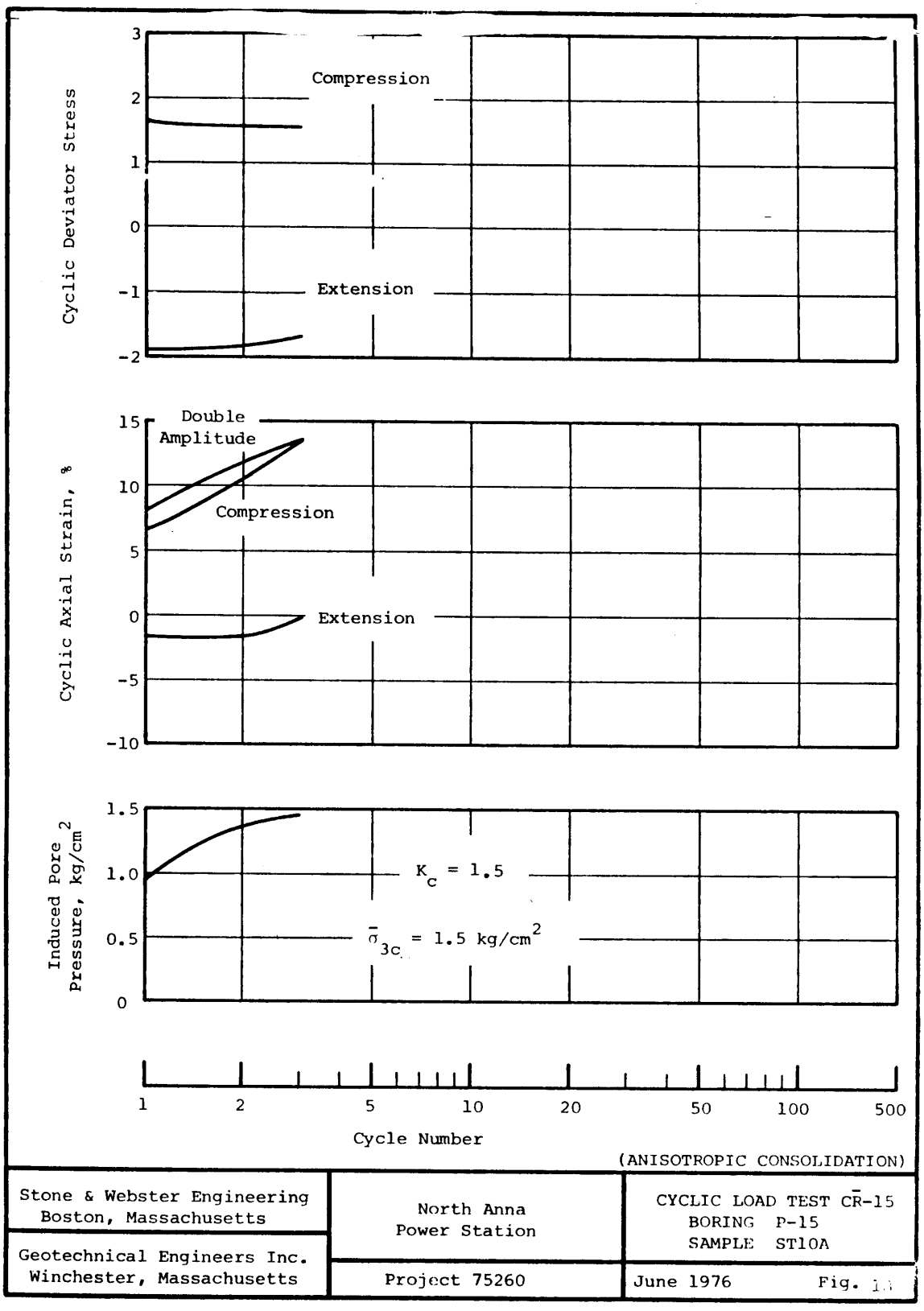


Stone & Webster Engineering Boston, Massachusetts	North Anna Power Station	CYCLIC LOAD TEST $\bar{CR}$-13 BORING P-17 SAMPLE ST9A
Geotechnical Engineers Inc. Winchester, Massachusetts	Project 75260	June 1976 Fig. 16

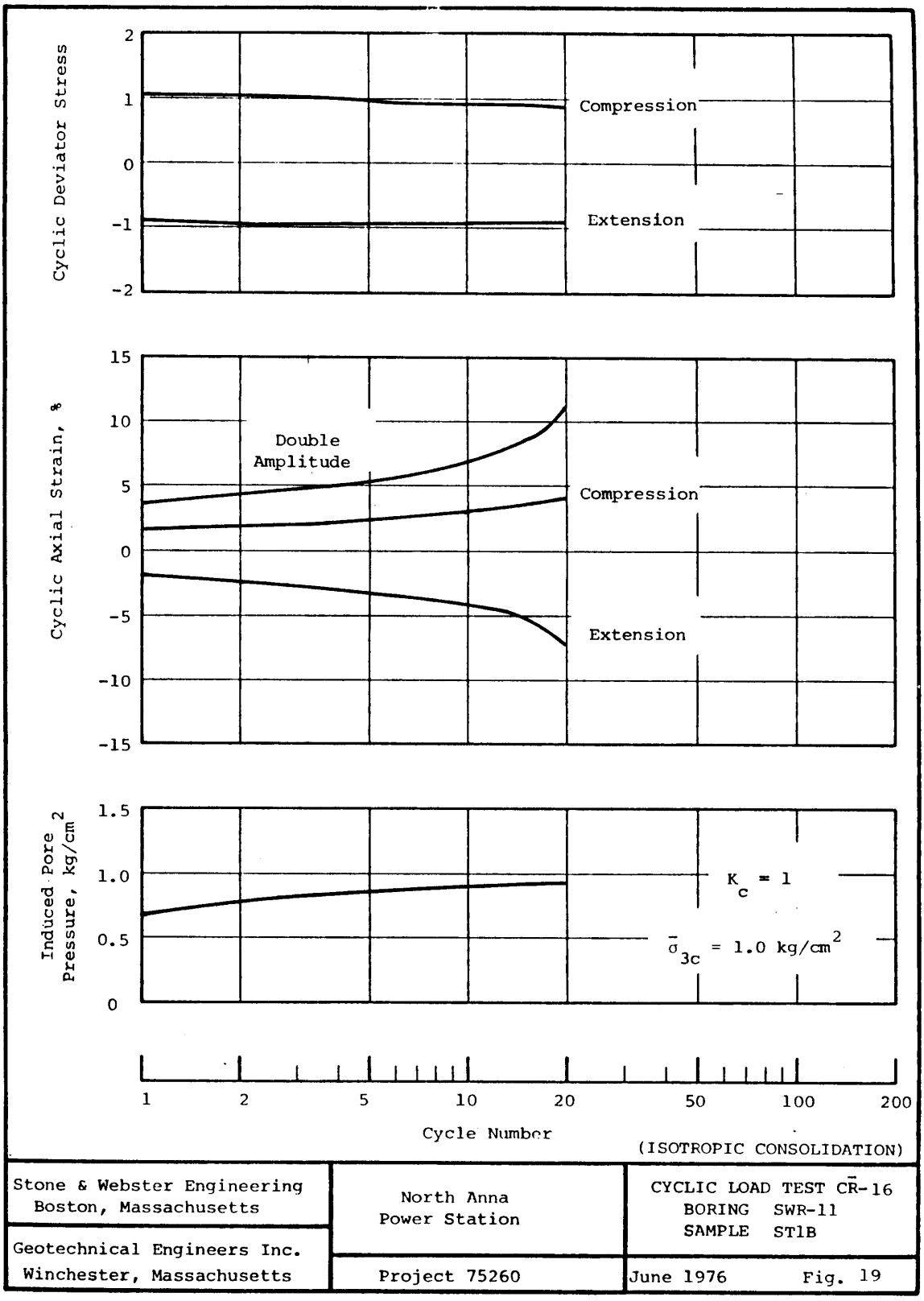
N03EA332


Cyclic Deviator Stress
2
1
0
-1
-2
Compression
Extension
Cyclic Axial Strain, %
15
10
5
0
-5
-10
-15
Double
Amplitude
Compression
Extension
Induced Pore Pressure, kg/cm 2
1.5
1.0
0.5
0
K_c = 1
$\bar{\sigma}_{3c}$ = 1.0 kg/cm^2
1
2
5
10
20
50
100
200
Cycle Number
(ISOTROPIC CONSOLIDATION)
Stone & Webster Engineering
Boston, Massachusetts
North Anna
Power Station
CYCLIC LOAD TEST $\bar{CR}$-14
BORING SWR-11
SAMPLE ST1C
Geotechnical Engineers Inc.
Winchester, Massachusetts
Project 75260
June 1976
Fig. 17

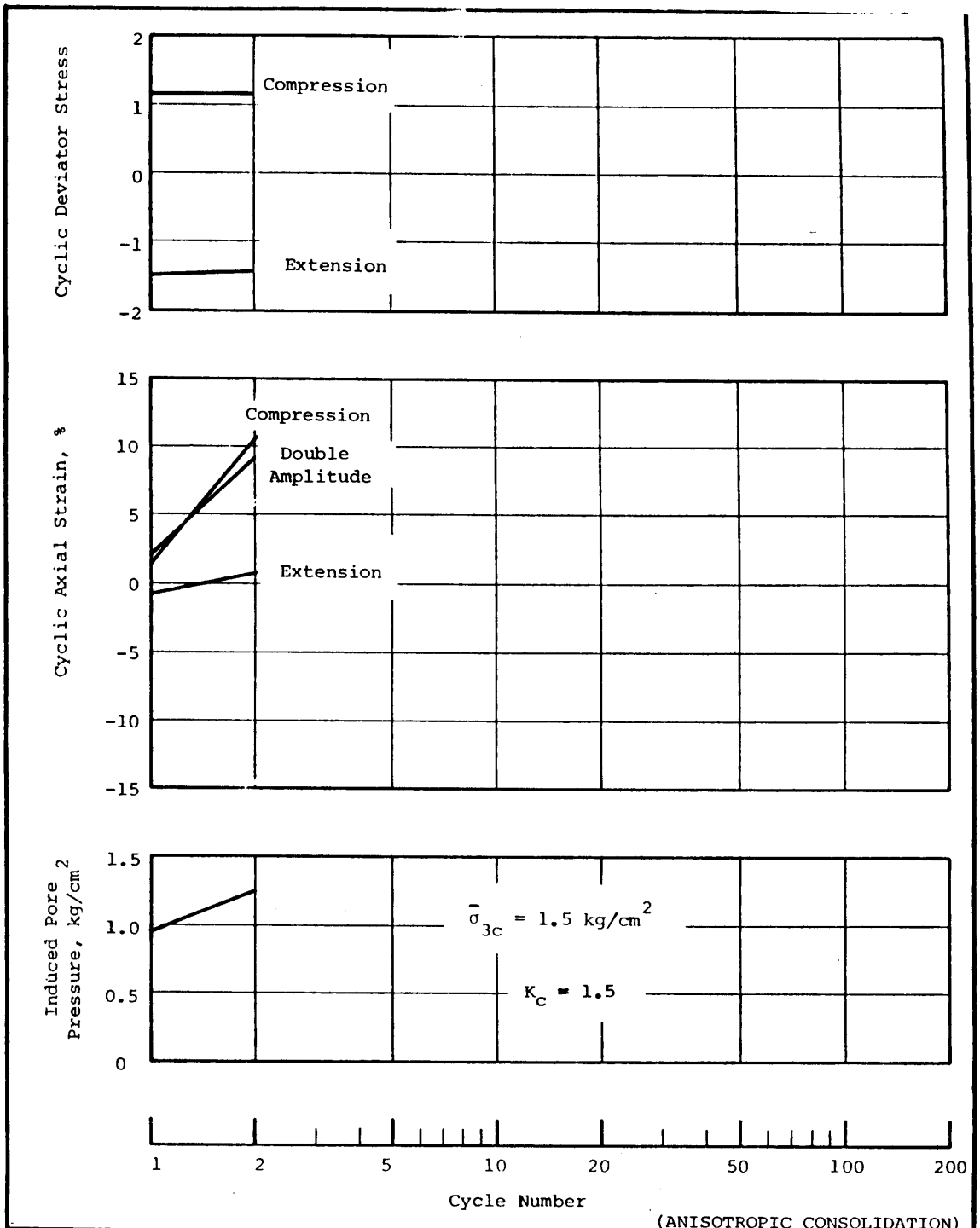
N03EA333


Cyclic Deviator Stress
3
2
1
0
-1
-2
Compression
Extension
Cyclic Axial Strain, %
15
10
5
0
-5
-10
Double
Amplitude
Compression
Extension
Induced Pore Pressure, kg/cm2
1.5
1.0
0.5
0
K_c = 1.5
$\bar{\sigma}_{3c}$ = 1.5 kg/cm^2
1
2
5
10
20
50
100
500
Cycle Number
(ANISOTROPIC CONSOLIDATION)
Stone & Webster Engineering
Boston, Massachusetts
North Anna
Power Station
CYCLIC LOAD TEST $\bar{CR}$-15
BORING P-15
SAMPLE ST10A
Geotechnical Engineers Inc.
Winchester, Massachusetts
Project 75260
June 1976
Fig. 11

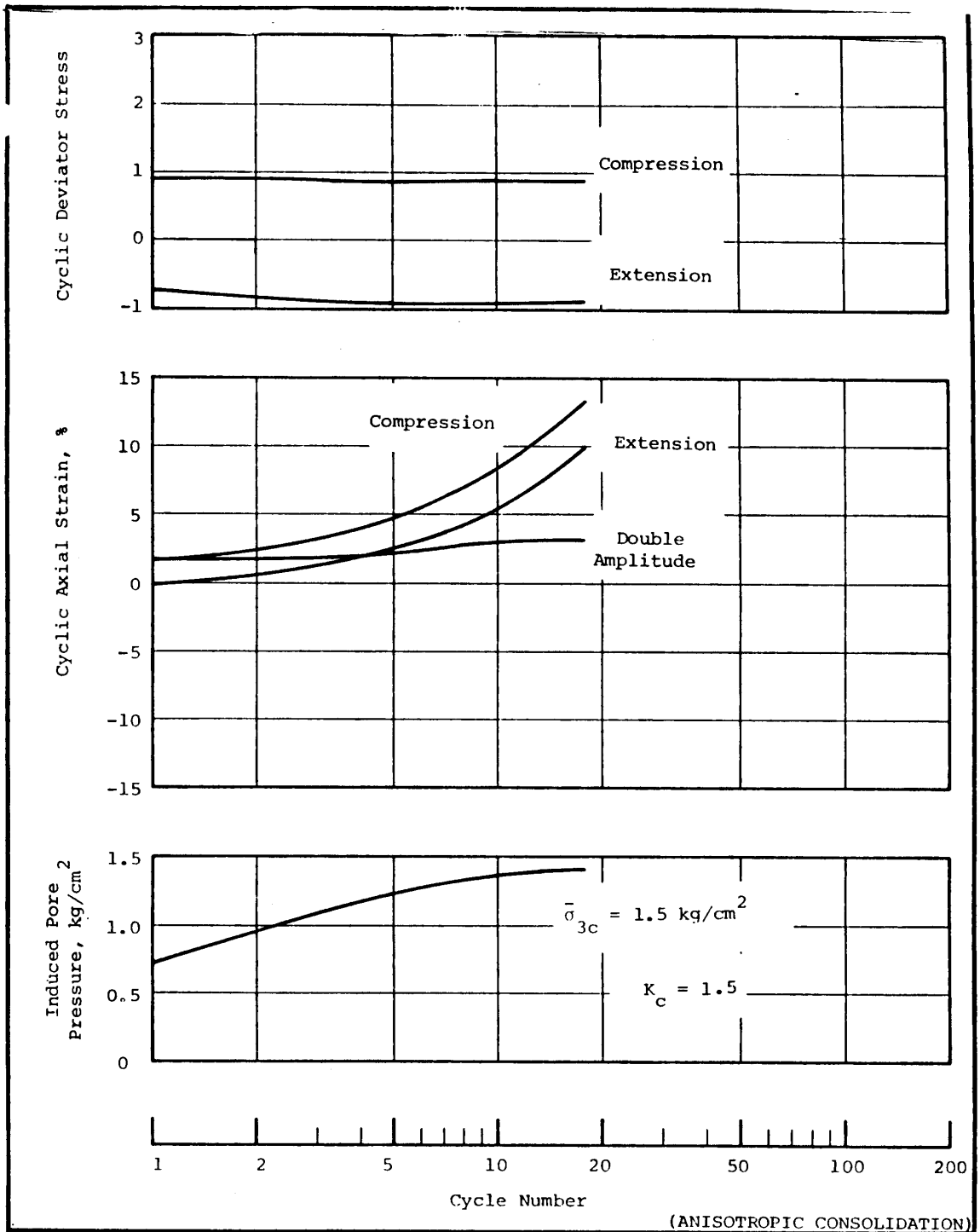
N03EA334


Cyclic Deviator Stress
2
1
0
-1
-2
Compression
Extension
Cyclic Axial Strain, %
15
10
5
0
-5
-10
-15
Double Amplitude
Compression
Extension
Induced Pore Pressure, kg/cm2
1.5
1.0
0.5
0
K_c = 1
$\bar{\sigma}_{3c}$ = 1.0 kg/cm2
1
2
5
10
20
50
100
200
Cycle Number
(ISOTROPIC CONSOLIDATION)
Stone & Webster Engineering
Boston, Massachusetts
Geotechnical Engineers Inc.
Winchester, Massachusetts
North Anna
Power Station
Project 75260
CYCLIC LOAD TEST $\bar{CR}$-16
BORING SWR-11
SAMPLE ST1B
June 1976
Fig. 19

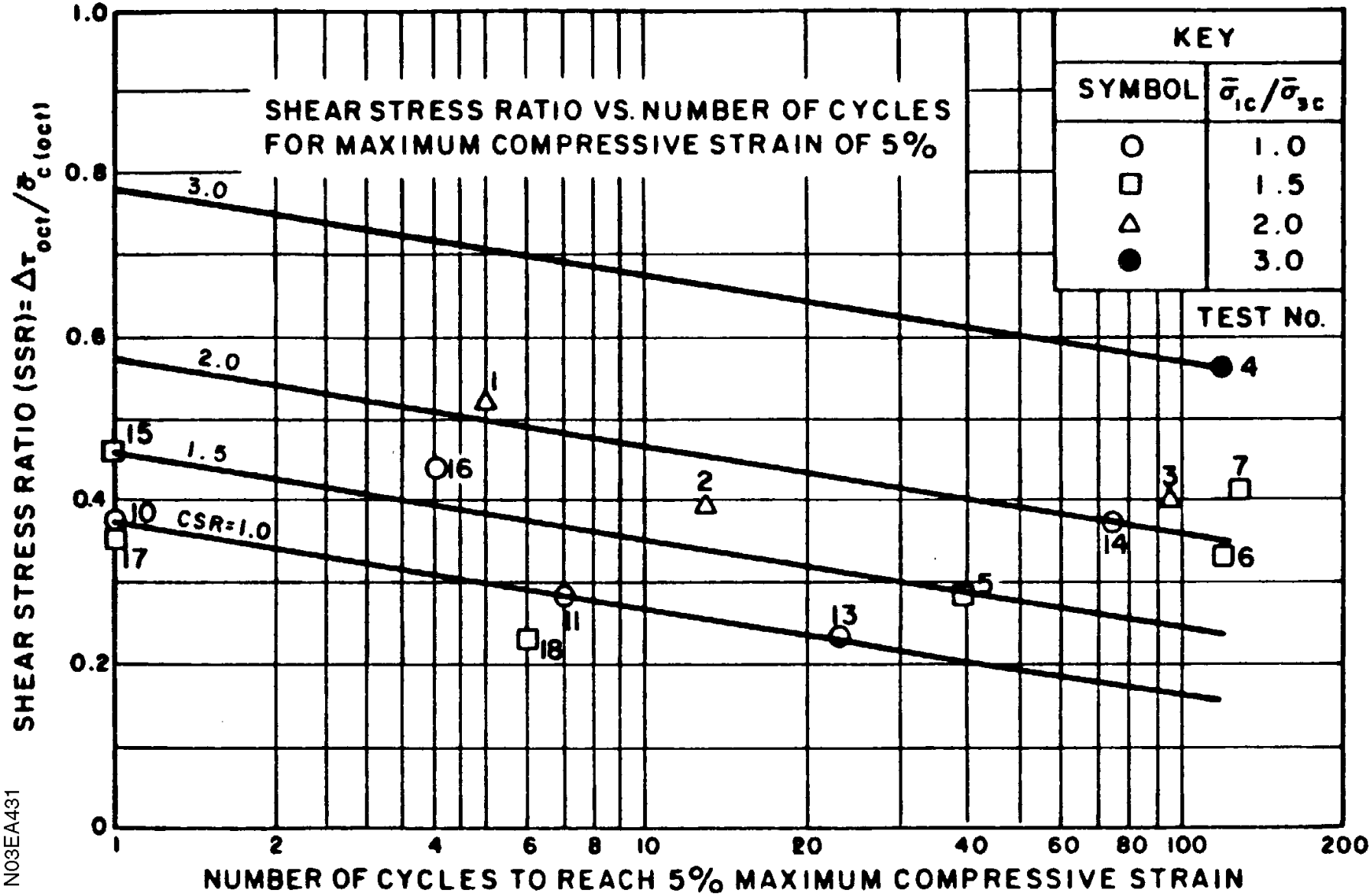
N03EA335


Cyclic Deviator Stress
2
1
0
-1
-2
Compression
Extension
Cyclic Axial Strain, %
15
10
5
0
-5
-10
-15
Compression
Double
Amplitude
Extension
Induced Pore Pressure, kg/cm2
1.5
1.0
0.5
0
$\bar{\sigma}_{3c}$ = 1.5 kg/cm^2
K_c = 1.5
1
2
5
10
20
50
100
200
Cycle Number
(ANISOTROPIC CONSOLIDATION)
Stone & Webster Engineering
Boston, Massachusetts
North Anna
Power Station
CYCLIC LOAD TEST $C\bar{R}$-17
BORING SWR-13
SAMPLE ST9B
Geotechnical Engineers Inc.
Winchester, Massachusetts
Project 75260
June 1976
Fig. 20

N03EA336


Cyclic Deviator Stress
3
2
1
0
-1
Compression
Extension
Cyclic Axial Strain, %
15
10
5
0
-5
-10
-15
Compression
Extension
Double
Amplitude
Induced Pore Pressure, kg/cm2
1.5
1.0
0.5
0
$\bar{\sigma}_{3c}$ = 1.5 kg/cm^2
K_c = 1.5
1
2
5
10
20
50
100
200
Cycle Number
(ANISOTROPIC CONSOLIDATION)
Stone & Webster Engineering
Boston, Massachusetts
North Anna
Power Station
CYCLIC LOAD TEST $\bar{CR}$-18
BORING SWR-13
SAMPLE ST9A
Geotechnical Engineers Inc.
Winchester, Massachusetts
Project 75260
June 1976
Fig. 21

N03EA337


SHEAR STRESS RATIO VS. NUMBER OF CYCLES
FOR MAXIMUM COMPRESSIVE STRAIN OF 5%
KEY
SYMBOL
$\bar{\sigma}_{1c}/\bar{\sigma}_{3c}$
1.0
1.5
2.0
3.0
TEST NO.
3.0
2.0
1.5
CSR=1.0
SHEAR STRESS RATIO (SSR)= $\Delta\tau_{oct}/\bar{\sigma}_{c(oct)}$
NUMBER OF CYCLES TO REACH 5% MAXIMUM COMPRESSIVE STRAIN
0
0.2
0.4
0.6
0.8
1.0
1
2
4
6
8
10
20
40
60
80
100
200
N03EA431

SHEAR STRESS RATIO (SR) VS. CONSOLIDATION STRESS RATIO (CSR) FOR 5% MAX COMPRESSIVE STRAIN IN 10 CYCLES

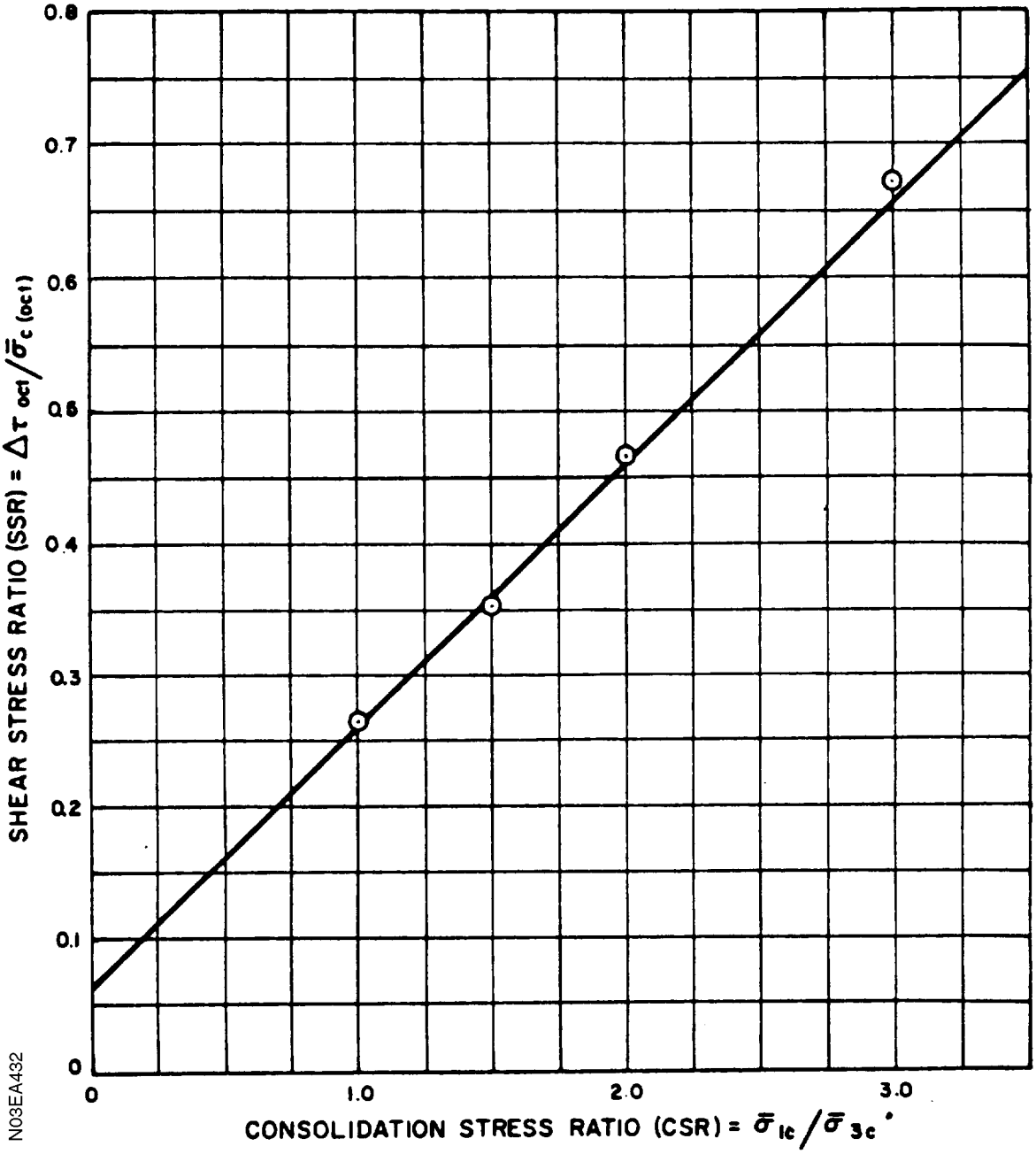


Table 3E-3

RESULTS OF CONSOLIDATION TESTS

Test Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Boring number	P-11	P-11	P-11	SI-1	SI-1	SI-1	P-12	P-12	SI-2	SWR-6	P-10	SWR-4	SWR-4	SWR-4	SWR-4
Sample number	2F	3F	5F	3B	5F	6E	1F	2F	1F	4G	2B	2D	3E	5D	6
Depth, ft	24.0	37.9	48.8	40.1	52.7	63.0	8.5	18.1	13.3	58.5	22.1	28.3	39.9	63.2	77.5
Group symbol	ML-SM	SM	SM	SM	SM	SM	CH-SC	SM	SM	SM	SM	SM	SM	SM-ML	SM
Percent fines	54	29	24	30	15	31	57	25	18	33	18	36	25	48	34
Initial w_o,%	28.4	21.8	21.9	27.2	15.7	31.0	21.2	14.6	11.1	46.3	22.1	23.5	24.4	22.3	19.9
Initial d_o, pcf	90.9	95.6	95.8	86.4	104.2	90.3	103.0	98.8	99.2	66.4	112.5	92.5	93.2	91.9	96.8
Initial e_o	0.869	0.776	0.771	0.965	0.625	0.879	0.648	0.719	0.712	1.561	0.507	0.808	0.823	0.828	0.755
Type of loading	I	CRS	I	CRS	I	I	CRS	I	I	I	I	CRS	I	CRS	I
Rate of loading [a]	1000	0.079	1	0.096	1000	1000	0.090	1000	I	1000	1000	0.070	1000	0.096	1000
Maximum $\bar{\sigma}_v$, ksf	58.6	51.9	39.9	59.4	3.2	3.2	38.5	3.2	44.6	8.1	3.2	42.4	3.2	43.0	3.2
C_c	0.306	0.237	0.225	0.375	-	-	0.280	-	0.123	-	-	0.279	-	0.234	-
C_s, 10^{-2}	-	1.55	-	3.25	-	-	1.80	-	-	-	-	2.20	-	2.22	-
C, x 10^{-4}	7.05	-	-	-	8.83	5.67	-	2.51	-	42.2	14.4	-	7.32	-	7.07

a. For incrementally loaded tests (I), elapsed time in min for load increments; for constant rate of strain tests (CRS), rate of vertical strain in percent strain per min.

Table 3E-4
RESULTS OF CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS

Type of Material	Dike Fill			Foundation		Foundation with Foliation		
Test Number	1	2	3	4	5	6	7	8
Boring number	P-12	SWR-6	SWR-6	SI-2	SWR-4	SWR-6	SWR-6	SWR-4
Sample number	1D	1D	2E	1D	3D	3D	4F	1F
Depth, ft	7.9	12.7	23.6	12.1	42.2	43.1	57.2	12.9
Group symbol	CH-SC	SM-MH	MH-SM	SM	SM	SM	SM	ML-SM
Percent fines	57	48	58	18	25	31	33	57
Initial w_o,%	24.6	24.8	34.1	14.3	23.5	39.8	36.2	28.9
Initial $\sqrt{d_o}$, pcf	93.9	92.5	82.0	89.7	95.5	83.3	72.3	85.6
Initial e_o	0.783	0.808	1.042	0.865	0.752	1.135	1.314	0.954
Consolidated w_c,%	22.3	23.5	30.8	9.4	21.0	33.7	27.6	27.1
Consolidated $\sqrt{d_c}$ 1, pcf	97.2	94.3	85.7	93.1	99.2	80.5	79.5	87.8
Consolidated e_c	0.722	0.774	0.952	0.797	0.686	1.079	1.104	0.906
ν_o, kips/ft^2	6.5	8.6	9.4	23.1	14.4	8.6	9.4	7.9
$\bar{\sigma}_c$, kips/ft^2	3.00	2.00	4.00	5.00	4.50	5.00	8.00	2.50
At $(\bar{\sigma}_1/\bar{\sigma}_3)$ max								
$\bar{\sigma}_3$, ksf	1.60	1.22	2.23	2.65	3.01	3.69	3.27	1.75
$\bar{\sigma}_1 - \bar{\sigma}_3$, ksf	3.40	3.31	5.85	5.66	6.19	3.14	4.29	1.66
$\bar{\sigma}_1/\bar{\sigma}_3$	3.13	3.71	3.63	3.14	3.06	1.85	2.31	1.95
$(\nu - \nu_0)/(\sigma_1 - \sigma_3)$	0.41	0.24	0.30	0.42	0.24	0.42	1.10	0.45
θ, %	4.8	2.8	3.3	9.9	5.7	1.6	7.8	1.2
ϕ', degrees[a]	31.1	35.1	34.7	31.1	30.5	17.3	23.3	18.8

a. $\phi' = \arcsin\dfrac{(\bar{\sigma}_1/\bar{\sigma}_3) - 1}{(\bar{\sigma}_1/\bar{\sigma}_3) + 1}$.

Table 1

SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING P-15

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	Dry Unit Weight γ_d B (pcf)	Dry Unit Weight γ_d C (pcf)	Dry Unit Weight γ_d D (pcf)	Void Ratio e A	Void Ratio e E	Saturation S A (%)	Saturation S E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^su At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-1A	7.4	312.6	CH-SC	60	26.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Bent deeply inward
ST-1B	7.6	312.4	SC-CH	48	25.4	98.8	97.0	96.1	—	0.693	0.740	98.3	92.0	—	—	—	—	—	—	
ST-1F	8.0	312.0	Preserved in tube																	
ST-1G	8.5	311.5	SM-ML	34	24.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-2A	10.0	310.0	SC-CH	47	28.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good
ST-2B	10.2	309.8	Preserved in tube																	
ST-2E	10.4	309.6	CH-SC	55-65	28.4	96.2	94.3	93.8	93.0	0.738	0.798	103.1	95.4	2.54	1.35	4.13	8.9	2.06	Shearing	
ST-2F	10.9	309.1	CH-SC	59	28.0	97.7	95.9	91.7	—	0.712	0.824	105.4	91.1	2.89	1.35	5.65	10.2	2.78	Shearing	
ST-2G	11.3	308.7	CH-SC	54	22.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-3A	13.0	307.0	CH-SC	61	26.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Many small dents
ST-3D	13.2	306.8	Preserved in tube																	
ST-3E	13.7	306.3	CH-SC	65-75	22.9	104.5	102.4	—	100.4	0.600	0.666	102.3	92.2	2.57	1.73	8.51	11.0	4.06	Shearing	
ST-3F	14.2	305.8	CH-SC	55-65	22.8	104.4	102.4	101.3	—	0.602	0.651	101.5	93.9	2.88	1.73	4.89	7.8	2.44	Shearing	
ST-3G	14.8	305.2	CH-SC	61	35.7	—	—	—	—	—	—	—	—	—	—	—	—	—		
ST-4A	15.5	304.5	CH SC	64	30.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good
ST-4D	15.7	304.3	Preserved in tube																	
ST-4E	15.8	304.2	CH-SC	57	22.5	104.7	102.8	101.2	100.8	0.597	0.659	101.0	91.5	2.54	1.98	8.34	6.1	4.22	Shearing and bulging	
ST-4F	16.3	303.7	SC-CH	48	22.9	103.7	101.7	94.5	—	0.613	0.770	100.1	79.7	2.88	1.98	6.89	10.4	3.26	Shearing	
ST-4G	16.9	303.1	CH-SC	52	19.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-5A	18.0	302.0	CH-SC	58	22.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	One deep inward dent
ST-5B	18.2	301.8	CH-SC	52	19.9	109.8	107.8	104.8	—	0.523	—	102.0	—	—	—	—	—	—	—	
ST-5F	18.7	301.3	Preserved in tube																	
ST-5G	19.2	300.8	SM	26	12.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-6A	21.0	299.0	SC-CH	45	27.5															Bent deeply inward
ST-6B	21.2	298.8	SC-CH	44	30.1															
ST-6F	21.7	298.3	Discarded																	
ST-6G	22.4	297.6	CH-SC	51	35.9															
ST-7A	23.5	296.5	SC-CH	47	28.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Two large dents
ST-7E	23.8	296.2	CH-SC	53	24.1	100.2	98.3	95.8	95.3	0.669	0.755	96.5	85.5	2.49	2.90	5.80	9.2	2.87	Shearing	
ST-7F	24.3	295.7	CH-SC	50	22.7	104.6	102.6	102.8	—	0.599	0.627	101.6	97.0	2.85	2.90	7.25	15	3.43	Shearing	
ST-7G	24.8	295.2	CH-SC	52	27.8	—	—	—	—	—	—	—	—	—	—	—	—	—		

Table 1 (continued)

SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING P-15

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	B (pcf)	C (pcf)	D (pcf)	Void Ratio e A	E	Saturation S A (%)	E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	$^s u$ At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-8A	26.0	294.0	ML	85-90	31.3															—
Interface between embankment and foundation at about elevation 292.5																				
ST-9A	28. 5	291.5	SC-CL	48	19.7	—	—	—	—	—	—	—	—	—	—	—	—	—		Good
ST-9E	28.6	291.4	Preserved in tube																	
ST-9F	29.7	290.3	SM	30-40	17.3	98.5	96.6	93.1	—	0.698	0.796	66.4	58.2	2.87	3.54	6.94	11.5	3.28	With foliation at 50°	
ST-9G	30.3	289.7	SM	33	16.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-10A	31.0	289.0	SM	10-15	23.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Not
ST-10B	31.1	288.9	SM	30	22.8	93.8	92.0	91.1	—	0.783	0.836	78.0	73.1	—	—	—	—	—	—	viewed
ST-10D	31.5	288.5	Provided to Geotechnical Engineers, Inc., for cyclic triaxial testing																	
ST-11A	33.5	286.5	SM	30	20.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good
ST-11E	33.7	286.3	Preserved in tube																	
S-11F	34.6	285.4	SM	20-25	14.9	102.6	100.7	96.4	—	0.630	0.735	63.4	54.3	2.88	4.15	7.74	12.9	3.68	Shear across foliation	
ST-11G	35.2	284.8	SM	23	13.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-12A	36.0	284.0	SM	10-15	17.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	One
ST-12B	36.1	283.9	SM	10-15	17.0	100.1	98.2	97.2	—	0.671	0.720	67.9	63.3	—	—	—	—	—	—	very
ST-12E	36.4	283.6	Preserved in tube																	small
ST-12F	36.9	283.1	SM	20-25	16.1	107.2	105.1	97.6	—	0.560	0.713	77.0	60.5	2.89	4.45	8.00	>15	3.86	With foliation at 45°	dent
ST-12G	37.4	282.6	SM	21	15.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-13A	38.5	281.5	SM	26	18.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair
ST-13E	38.7	281.3	Preserved in tube																	
ST-13F	39.6	280.4	SM	15-25	13.3	106.0	104.0	95.5	—	0.578	0.751	61.7	47.5	2.89	4.78	9.51	10.4	4.52	Shear across foliation	
ST-13G	40.2	279.8	SM	22	13.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-14A	41.0	279.0	SM	10-20	16.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very
ST-14B	41.1	278.9	SM	10-20	15.9	101.7	99.8	97.4	—	0.644	0.717	66.2	59.4	—	—	—	—	—	—	good
ST-14E	41.4	278.6	Preserved in tube																	
ST-14F	42.0	278.0	SM	20-25	15.4	108.2	106.1	99.4	—	0.546	0.682	75.6	60.5	2.89	5.08	8.77	9.4	4.35	Slip along clay seam	
ST-14G	42.5	277.5	SM	23	13.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-15A	43.5	276.5	SP	4	13.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good
ST-15E	43.6	276.4	Preserved in tube																	

Table 1 (continued)

SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING P-15

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	Dry Unit Weight γ_d B (pcf)	Dry Unit Weight γ_d C (pcf)	Dry Unit Weight γ_d D (pcf)	Void Ratio e A	Void Ratio e E	Saturation S A (%)	Saturation S E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	$^s u$ At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-15F	44.5	275.5	SM	20-25	17.1	110.7	108.5	99.3	—	0.511	0.684	89.7	67.0	2.88	5.39	8.85	>15	3.84	With foliation at 45°	
ST-15G	45.0	275.0	SM	23	15.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-16A	46.0	274.0	SM	10-20	17.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair, but out-of-round
ST-16B	46.2	273.8	SM	10-20	19.7	100.9	99.0	97.3	—	0.657	0.719	80.4	73.4	—	—	—	—	—	—	
ST-16E	46.5	273.5	Preserved in tube																	
ST-16F	47.0	273.0	SM	19	13.9	117.0	114.8	108.3	—	0.429	0.544	86.8	68.5	2.89	5.70	10.17	7.6	5.06	With foliation at 55°	
ST-16G	47.6	272.4	SM	10-20	15.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-17A	48.5	271.5	SM	10-20	18.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very good
ST-17D	48.7	271.3	Preserved in tube																	
ST-17E	49.1	270.9	SM	15-20	16.5	112.2	110.0	103.5	—	0.490	0.616	90.2	71.8	2.88	5.96	9.34	>15	3.60	With foliation at 40°	
ST-17F	49.7	270.3	SM	15-20	15.3	116.0	113.7	106.6	—	0.442	0.569	92.8	72.1	2.89	6.04	4.99	3.4	2.56	Slip along clay joint	
ST-17G	50.2	269.8	SM	18	16.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-18A	51.0	269.0	SM	10-20	16.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very good
ST-18B	51.2	268.8	SM	10-20	17.0	109.6	107.5	103.4	—	0.526	0.617	86.6	73.8	—	—	—	—	—	—	
ST-18E	51.5	268.5	Preserved in tube																	
ST-18F	52.2	267.8	SM	30-35	21.1	107.3	105.3	99.2	—	0.599	0.686	101.2	82.4	2.88	6.35	3.40	8.2	1.69	With foliation 50°	
ST-18G	52.7	267.3	SM	39	37.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-19A	53.5	266.5	SM	35-45	41.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	One deep
ST-19D	53.7	266.3	SM	15-20	17.8	108.9	106.9	105,2	—	0.536	0.590	89.0	80.9	2.88	6.56	6.95	>15	2.72	With foliation at 45°	
ST-19E	54.1	265.9	SM	18	17.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-19F	54.2	265.8	SM	15-20	18.8	110.4	108.3	103.9	—	0.515	0.610	97.8	82.6	2.89	6.61	2.24	13.6	1.10	In clean sand layer	Inward dent
ST-19G	54.7	265.3	SM	30	17.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-20A	56.0	264.0	SM	25-35	23.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair
ST-20B	56.2	263.8	SM	25-35	28.0	98.4	96.5	94.9	—	0.699	0.762	67.4	98.5	—	—	—	—	—	—	
ST-20E	56.5	263.5	Preserved in tube																	
ST-20F	57.2	262.8	SM	26	20.0	109.8	107.8	101.3	—	0.523	0.651	102.5	82.3	2.87	6.96	4.08	3.8	1.35	With foliation at 50°	
ST-20G	57.7	262.3	SM	31	25.0		—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-21A	58.5	261.5	SM	21	21.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very good
ST-21D	58.7	261.3	Preserved in tube																	
ST-21E	59.3	260.7	SM	15-20	20.1	109.6	107.6	102.0	—	0.526	0.640	102.4	84.2	2.89	7.24	4.25	9.3	2.00	With foliation at 40°	
ST-21F	59.8	260.2	SM	15-20	21.1	108.9	106.9	102.7	—	0.536	0.628	105.5	90.0	2.89	7.31	5.64	8.2	1.80	With foliation at 55°	

Table 1 (continued)

SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING P-15

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	B (pcf)	C (pcf)	D (pcf)	Void Ratio e A	E	Saturation S A (%)	E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	$^s u$ At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-21G	60.3	259.7	SM	17	22.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-22A	61.0	259.0	SM	20-30	20.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good
ST-22B	61.2	258.8	SM	20-30	22.0	107.1	105.1	101.6	—	0.561	0.646	105.1	91.3	—	—	—	—	—	—	
ST-22D	61.5	258.5	Preserved in tube																	Good
ST-22E	61.7	258.3	SP-SM	5-10	19.4	113.3	111.1	104.7	—	0.476	0.597	109.2	87.1	2.90	7.54	3.55	8.1	1.76	Shearing	
ST-22F	62.2	257.8	SM	17	18.2	119.2	116.9	115.7	—	0.403	0.445	121.0	109.6	2.87	7.59	6.54	5.0	2.90	Shear across foliation	
ST-22G	62.7	257.3	SM	31	29.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-23A	63.5	256.5	SP-SM	8-12	23.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good, one small dent
ST-23B	63.7	256.3	Preserved in tube																	
ST-23D	64.3	255.7	SP-SM	8-12	27.1	—	—	—	91.3	—	0.832	—	87.3	Constant-volume direct shear test						
ST-23E	64.5	255.5	Preserved in tube																	
ST-23F	64.7	255.3	SM	18	18.9	119.2	116.9	114.8	—	0.403	0.457	125.7	110.8	2.87	7.92	2.77	3.2	1.40	With foliation at 60°	
ST-23G	65.8	254.2	SP-SM	8-12	21.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-24A	66.0	254.0	SM	15-25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Not viewed
ST-24B	66.2	253.8	SM	24	37.9	92.5	90.7	89.9	—	0.808	0.860	125.7	118.1	—	—	—	—	—	—	
ST-24D	66.5	253.5	Provided to Geotechnical Engineers, Inc., for cyclic triaxial testing																	
ST-25A	69.5	250.5	SM	10-15	23.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair
ST-25D	69.7	250.3	Preserved in tube																	
ST-25E	70.2	249.8	SM	10-15	27.0	98.3	96.5	91.4	—	0.701	0.830	103.2	87.2	2.88	8.60	4.37	7.6	2.18	Shearing and bulging	
ST-25F	70.8	249.2	SM	31	25.6	104.2	102.2	95.1	—	0.605	0.758	113.4	90.5	2.87	8.67	2.48	>15	0.82	Along thin clay layer	
ST-25G	71.4	248.6	SM	25-30	14.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

Table 2
SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING P-16

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	Dry Unit Weight γ_d B (pcf)	Dry Unit Weight γ_d C (pcf)	Dry Unit Weight γ_d D (pcf)	Void Ratio e A	Void Ratio e E	Saturation S A (%)	Saturation S E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^{s}u At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-1A	7.5	312.5	Empty																	Good
ST-1B	7.5	312.5	CH-SC	65-75	24.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-1C	7.7	312.3	CH-SC	65-75	25.5	97.3	95.4	—	—	0.719	—	95.0	—	—	—	—	—	—	—	
ST-1F	8.0	312.0	Preserved in tube																	
ST-1G	9.0	311.0	CH-SC	78	37.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-2A	12.5	307.5	CH-SC	56	25.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair
ST-2E	12.6	307.4	Preserved in tube																	
ST-2F	13.5	306.5	CH-SC	55-60	20.6	109.0	107.0	103.3	—	0.534	0.619	103.4	89.2	2.87	1.66	6.59	14.8	3.00	Bulging and shearing	
ST-2G	14.0	306.0	CH-SC	52	19.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-3A	17.5	302.5	ML-SM	55-65	20.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very
ST-3B	17.6	302.4	ML-SM	55-65	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	good
ST-3C	17.7	302.3	ML-SM	55-65	25.7	101.1	99.1	98.9	—	0.654	0.691	105.3	99.7	—	—	—	—	—	—	
ST-3F	18.1	301.9	Preserved in tube																	
ST-3G	19.1	300.9	SM	27	21.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-4A	22.5	297.5	ML-SM	54	29.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good
ST-4E	22.7	297.3	Preserved in tube																	
ST-4F	23.7	296.3	ML-SM	50-55	23.7	99.2	97.3	95.6	—	0.686	0.749	92.6	84.8	2.87	2.82	6.12	9.9	3.00	Shearing	
ST-4G	24.3	295.7	ML-SM	50	25.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-5A	27.5	292.5	ML-SM	65-75	32.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair
ST-5B	27.7	292.3	ML-SM	65-75	31.5	87.9	86.2	84.6	—3	0.90	0.977	93.5	86.4	—	—	—	—	—	—	
ST-5E	28.0	292.0	Preserved in tube																	
ST-5F	28.7	291.3	ML-SM	55-65	23.0	102.6	100.6	98.6	—	0.630	0.696	97.8	88.6	2.87	3.41	7.85	14.4	3.71	Shearing	
ST-5G	29.2	290.8	ML-SM	61	23.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-6A	32.5	287.5	ML-SM	55-60	18.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good
ST-6E	32.7	287.3	Preserved in tube																	
ST-6F	33.7	286.3	ML-SM	70-80	31.0	86.9	85.2	84.8	—	0.924	0.972	89.9	85.5	2.87	4.00	6.19	12.0	2.98	Shearing	
ST-6G	34.4	285.6	SM	10-15	19.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Interface between embankment and foundation at exactly elevation 285.9 (near bottom of test specimen)																				
ST-7A	37.5	282.5	SM	10-20	34.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Not
ST-7B	37.7	282.3	SM	10-20	31.2	88.2	86.4	86.1	—	0.896	0.942	93.3	88.8	—	—	—	—	—	—	viewed
ST-7C	38.0	282.0	Provided to Geotechnical Engineers, Inc., for cyclic triaxial testing																	

Table 2 (continued)
SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING P-16

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	Dry Unit Weight γ_d B (pcf)	Dry Unit Weight γ_d C (pcf)	Dry Unit Weight γ_d D (pcf)	Void Ratio e A	Void Ratio e E	Saturation S A (%)	Saturation S E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^{s}u At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-8	42.5	277.5	Provided to USAE Waterways Experiment Station for cyclic triaxial testing																	Not viewed
ST-9A	47.5	272.5	SM	10-20	33.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair
ST-9B	47.7	272.3	SM	10-20	30.8	91.2	89.4	89.2	—	0.834	0.875	99.0	94.3	—	—	—	—	—	—	
ST-9D	48.0	272.0	Provided to USAE Waterways Experiment Station																	
ST-9E	48.4	271.6	SM	10-20	31.0	92.9	91.2	88.5	—	0.800	0.890	103.8	93.3	—	—	—	—	—	—	
ST-9F	48.9	271.1	SM	10-20	29.8	93.7	91.9	88.6	—	0.785	0.887	101.7	90.0	—	—	—	—	—	—	
ST-9G	49.3	270.7	SM	20	30.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-10	52.5	267.5	Provided to USAE Waterways Experiment Station for cyclic triaxial testing																	Not viewed
ST-11A	57.5	262.5	SM	10-15	22.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Bent
ST-11B	57.7	262.3	SM	10-15	20.4	106.8	104.7	104.4	—	0.566	0.602	96.6	90.8	—	—	—	—	—	—	deeply
ST-11E	58.0	262.0	SM	10-15	22.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	inward
ST-11F	58.4	261.6	SP-SM	8-12	21.0	107.2	105.1	101.7	—	0.560	0.644	100.5	87.4	2.87	7.09	5.67	13.5	1.91	Bulging	
ST-11G	59.0	261.0	SM	21	23.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-12A	62.5	257.5	SM	17	23.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Large
ST-12E	62.6	257.4	SM	15-20	23.4	104.0	101.9	98.9	—	0.608	0.691	103.1	90.8	—	—	—	—	—	—	inward
ST-12F	63.1	256.9	SM	15-20	19.1	109.5	107.4	—	—	0.527	—	97.1	—	—	—	—	—	—	—	dent
ST-12G	63.9	256.1	SM	15	15.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-13A	67.5	252.5	SM	20-30	20.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very
ST-13B	67.8	252.2	SM	20-30	20.8	108.9	106.6	106.0	—	0.536	0.578	104.0	96.4	—	—	—	—	—	—	good
ST-13E	68.1	251.9	Preserved in tube																	
ST-13F	68.4	251.6	SM	25-30	20.2	109.5	107.3	101.1	—	0.527	0.654	102.7	82.8	2.88	8.34	2.35	6.8	1.17	Shearing	
ST-13G	69.0	251.0	SM	26	22.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

Table 3
SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING P-17

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	Dry Unit Weight γ_d B (pcf)	Dry Unit Weight γ_d C (pcf)	Dry Unit Weight γ_d D (pcf)	Void Ratio e A	Void Ratio e E	Saturation S A (%)	Saturation S E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	$^{\delta}u$ At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-1A	7.5	312.5	CH-SC	55-60	18.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Not viewed
ST-1B	7.8	312.2	CH-SC	55-60	26.2	97.4	95.6	—	—	0.717	—	97.9	—	—	—	—	—	—	—	
ST-1F	8.1	311.9	Preserved in tube																	
ST-1G	—																			
ST-2A	12.5	307.5	CH-SC	66	33.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Bent deeply inward
ST-2F	12.6	307.4	Preserved in tube																	
ST-2G	13.9	306.1	SC-CH	44	22.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-3A	17.5	302.5	MH	70-80	30.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good
ST-3B	17.8	302.2	MH-SM	55-65	22.2	105.6	103.5	104.2	—	0.584	0.605	101.9	98.3	—	—	—	—	—	—	
ST-3F	18.1	301.9	Preserved in tube																	
ST-3G	19.3	300.7	CH-SC	54	16.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-4A	22.5	297.5	Preserved in tube																	
ST-4F	23.8	296.2	SM-ML	40-50	23.9	100.7	99.8	96.0	—	0.661	0.742	105.8	94.3	—	—	—	—	—	—	Very good
ST-4G	24.2	295.8	SM-ML	45	26.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-5A	27.5	292.5	MH-SM	55-60	24.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Deeply dented
ST-5F	27.6	292.4	Preserved in tube																	
ST-5G	28.1	291.9	ML-SM	55	24.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Interface between embankment and foundation at about elev. 288.0																				
ST-6A	32.5	287.5	SC-CH	40-48	17.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very good
ST-6E	32.7	287.3	Preserved in tube																	
ST-6F	33.6	286.4	SC-CH	35-40	13.9	114.4	112.2	110.6	—	0.462	0.512	80.6	72.8	2.88	3.99	11.19	9.0	5.50	Shearing	
ST-6G	34.1	285.9	SC-CH	38	15.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-7A	37.5	282.5	SM-ML	40-48	29.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very good
ST-7B	37.8	282.2	SM-ML	40-48	34.0	88.1	86.4	86.6	—	0.898	0.931	101.5	97.9	—	—	—	—	—	—	
ST-7E	38.2	281.8	Preserved in tube																	
ST-7F	38.7	281.3	SM-ML	35-45	31.9	86.1	84.5	83.4	—	0.942	1.005	90.8	85.1	2.87	4.63	3.40	14.6	1.59	Shearing	
ST-7G	39.2	280.8	SM-ML	44	36.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-8	42.5	277.5	Provided to USAE Waterways Experiment Station for cyclic triaxial testing																	
ST-9A	47.5	272.5	SM-ML	30-45	45.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Not viewed
ST-9B	47.8	272.2	SM-ML	30-40	38.4	86.3	84.6	82.9	—	0.938	1.017	109.7	101.2	—	—	—	—	—	—	
ST-9C	48.1	271.9	Provided to Goetechnical Engineers, Inc., for cyclic triaxial testing																	

Table 3 (continued)
SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING P-17

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	Dry Unit Weight γ_d B (pcf)	Dry Unit Weight γ_d C (pcf)	Dry Unit Weight γ_d D (pcf)	Void Ratio e A	Void Ratio e E	Saturation S A (%)	Saturation S E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^su At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-10	52.5	267.5	Provided to USAE Waterways Experiment Station for cyclic triaxial testing																	
ST-11A	57.5	262.5	SM	12-22	27.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very good
ST-11B	57.8	262.2	SM	12-22	38.8	95.6	93.7	93.0	—	0.749	0.798	110.2	103.4	—	—	—	—	—	—	
ST-11E	58.1	261.9	SM-ML	40	40.2	83.5	81.8	81.4	—	1.043	1.054	107.4	102.2	2.87	7.07	2.28	10.7	1.09	With foliation at 60°	
ST-11F	58.7	261.3	SM-ML	40-45	46.5	77.5	76.0	74.6	—	1.158	1.242	107.6	100.3	2.87	7.13	2.41	10.5	1.18	Shearing	
ST-11G	59.2	260.8	SM-ML	44	49.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-12A	62.5	257.5	GP	3-8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	One small dent
ST-12B	62.6	257.4	SM	20-30	27.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-12D	62.7	257.3	Preserved in tube																	
ST-12E	62.9	257.1	SM	25-35	21.9	105.0	130.0	97.9	—	0.593	0.708	99.0	82.9	2.88	7.65	8.07	14.5	3.24	Bulging	
ST-12F	63.5	256.5	SM	10-20	31.1	93.6	91.8	87.3	—	0.787	0.916	105.9	91.0	2.90	7.74	4.51	12.1	2.04	Shearing	
ST-12G	64.0	256.0	SM	28	31.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-13A	67.5	252.5	SM	15-20	22.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	One deep inward dent
ST-13B	67.8	252.2	SM	15-20	20.6	110.4	108.4	105.7	—	0.515	0.582	107.2	94.9	—	—	—	—	—	—	
ST-13F	68.1	251.9	SM	15-20	23.3	106.0	104.0	101.5	—	0.578	0.648	108.0	96.4	2.88	8.31	3.19	7.2	1.54	With foliation at 55°	
ST-134G	68.6	251.4	EMPTY																	
ST-14A	72.5	247.5	SM	15-25	26.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Badly dented
ST-14F	72.6	247.4	SM	—	—	Sample disturbed: void in center due to separation on horizontal plane														
ST-14G	73.6	246.4	SM	18	26.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

Table 4

SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING SWR-11

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	Dry Unit Weight γ_d B (pcf)	Dry Unit Weight γ_d C (pcf)	Dry Unit Weight γ_d D (pcf)	Void Ratio e A	Void Ratio e E	Saturation S A (%)	Saturation S E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^{s}u At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-1	19.5	276.5	Provided to Geotechnical Engineers, Inc., for cyclic triaxial testing																	Not viewed
ST-2A	25.0	271.0	SM	25-35	42.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very
ST-2B	25.2	270.8	SM	25-35	43.7	79.9	78.4	78.6	—	1.093	1.128	107.2	103.8	—	—	—	—	—	—	good
ST-2E	25.7	270.3	Preserved in tube																	
ST-2F	26.1	269.9	SM	20-30	32.8	93.6	1.8	90.7	—	0.787	0.844	111.7	104.2	2.89	3.41	1.40	>15	0.51	In clay seam at 65°	
ST-2G	26.8	269.2	SM	20-30	25.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-3A	30.5	265.5	SM	15-20	37.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very
ST-3B	30.7	265.3	SM	15-20	33.1	101.0	99.0	96.5	—	0.656	0.733	135.2	121.0							good
ST-3G	31.0	265.0	SM	29	24.2															

Table 6
SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING SWR-13

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	Dry Unit Weight γ_d B (pcf)	Dry Unit Weight γ_d C (pcf)	Dry Unit Weight γ_d D (pcf)	Void Ratio e A	Void Ratio e E	Saturation S A (%)	Saturation S E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^{s}u At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-1A	13.9	275.1	SM	10-15	41.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair
ST-1B	14.1	274.9	SM	10-15	27.7	90.2	89.0	90.1	—	0.842	0.856	88.2	86.7	—	—	—	—	—	—	
ST-1E	14.3	274.7	Preserved in tube																	
ST-1F	14.9	274.1	SM	10-15	40.3	82.8	81.3	80.5	—	1.020	1.077	105.9	100.3	—	—	—	—	—	—	
ST-1G	15.3	273.7	SM	10-15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-2A	16.0	273.0	Preserved in tube																	Very
ST-2F	16.6	272.4	SM	20-25	48.5	77.2	75.8	—	70.0	1.166	1.389	111.5	93.6	1.43	2.24	1.19	12.7	0.55	Bulging and shearing	good
ST-2G	17.0	272.0	SM	19	40.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ST-3A	18.0	271.0	Empty																	Very
ST-3B	18.0	271.0	SM	15-25	38.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	good
ST-3C	18.4	270.6	SM	15-25	45.4	79.2	77.8	76.8	—	1.111	1.177	109.5	103.4	—	—	—	—	—	—	
ST-3F	18.6	270.4	SM	15	41.9	81.5	79.9	78.9	—	1.052	1.120	106.7	100.3	2.88	2.50	1.36	>15	0.55	With foliation at 50°	
ST-3G	19.1	269.9	SM	15	42.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-4A	20.1	268.9	Preserved in tube																	Very
ST-4F	21.1	267.9	SM	15-20	42.4	81.3	79.6	78.2	74.9	1.057	1.233	107.5	92.2	1.44	2.80	1.39	>15	0.57	Bulging in weak zone	good
ST-4G	21.3	267.7	SM	17	42.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-5A	22.1	266.9	Empty																	Good
ST-5B	22.3	266.7	SM	10-20	40.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-5C	22.6	266.4	SM	10-20	43.7	80.0	78.4	79.0	—	1.090	1.117	107.4	104.8	—	—	—	—	—	—	
ST-5F	22.8	266.2	SM	30	49.2	74.9	73.5	71.3	—	1.233	1.345	106.9	98.0	2.89	3.01	1.38	7.3	0.66	With foliation at 50°	
ST-5G	23.3	265.7	SM	25-30	36.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-6A	24.2	264.8	SM	15-20	55.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very
ST-6B	24.4	264.6	SM	15-20	57.3	69.4	68.1	—	—	1.410	1.456	108.9	105.5	—	—	—	—	—	—	good
ST-6E	24.6	264.4	Preserved in tube																	
ST-6F	25.2	263.8	SM	18	39.0.	86.0	84.3	81.3	—	0.945	1.057	110.6	98.9	2.89	3.31	1.32	12.4	0.59	In clean sand layer	
ST-6G	25.6	264.4	SM	15-20	40.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-7A	26.2	262.8	SM	10-15	37.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very
ST-7B	26.4	262.6	SM	10-15	47.5	76.3	74.8	—	—	1.192	—	106.8	—	—	—	—	—	—	—	good
ST-7E	26.7	262.3	Preserved in tube																	
ST-7F	27.2	261.8	SM	29	40.6	83.7	82.1	79.7	—	0.998	1.098	109.0	99.1	2.89	3.55	1.32	12.7	0.63	With foliation at 40°	
ST-7G	27.6	261.4	SM	25-30	38.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

Table 6 (continued)
SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING SWR-13

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	B (pcf)	C (pcf)	D (pcf)	Void Ratio e A	E	Saturation S A (%)	E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^su At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-8A	28.3	260.7	SM	15-20	30.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very
ST-8D	28.4	260.6	Preserved in tube																	good
ST-8E	28.8	260.2	SM	15-20	23.9	91.1	89.3	87.6	—	0.836	0.909	105.5	97.0	2.89	3.76	1.32	12.0	0.58	With foliation at 60°	
ST-8F	29.2	259.8	SM	15-20	30.2	94.4	92.8	90.8	—	0.772	0.842	104.8	96.1	—	—	—	—	—	—	
ST-8G	29.5	259.5	SM	20	27.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ST-9A	47.5	272.5	SM-ML	35-45	36.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Not
ST-9B	47.8	272.2	SM-ML	35-45	35.6	76.9	75.4	74.6	—	1.175	1.242	81.2	76.8	—	—	—	—	—	—	viewed
ST-9C	48.1	271.1	Provided to Geotechnical Engineers, Inc., for cyclic triaxial testing																	
ST-10A	52.2	267.5	Empty																	Good
ST-10D	52.6	267.4	Preserved in tube																	
ST-10E	53.2	266.8	SM-ML	40-45	39.9	77.0	75.5	74.4	—	1.172	1.248	91.2	85.7	2.87	6.48	3.79	10.9	1.88	Slip on weak seam	
ST10F	53.7	266.3	SM-ML	40-45	39.2	75.7	74.3	73.4	—	1.209	1.278	86.9	82.2	2.87	6.54	5.43	5.7	2.68	Bulging	
ST-10G	54.2	265.8	SM-ML	46	42.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-11A	57.5	262.5	SM	30-40	32.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Few
ST-11B	57.8	262.2	SM	30-40	32.0	90.8	89.1	86.9	—	0.842	0.924	101.9	92.8	—	—	—	—	—	—	small
ST-11D	58.1	261.9	Preserved in tube																	dents
ST-11E	58.4	261.6	SM	10-15	15.4	113.7	111.5	108.7	—	0.471	0.538	70.6	76.7	2.88	7.14	5.84	4.6	2.54	Shear in quartz vein	
ST-11F	59.0	261.0	SM	30-40	28.8	93.2	90.9	88.9	—	0.794	0.881	97.2	87.6	—	—	—	—	—	—	
ST-11G	59.3	260.7	SM	30-40	24.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-12A	62.5	257.5	SM	20-30	23.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair
ST-12C	62.6	257.4	Preserved in tube																	
ST-12D	63.3	256.7	SM-ML	45	37.3	—	—	—	79.4	—	1.106	—	90.4	Constant-volume direct shear test						
ST-12E	63.5	256.5	Preserved in tube																	
ST-12F	63.8	256.2	SM	35-40	41.3	80.8	79.3	76.9	—	1.070	1.175	103.4	94.2	2.87	7.81	2.51	12.0	1.19	With foliation at 60°	
ST-12G	64.4	255.6	SM	40	42.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-13A	67.5	252.5	SM-ML	40-45	47.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	One
ST-13B	67.7	252.3	SM-ML	43	37.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	small
ST-13C	68.0	252.0	SM-ML	40-45	42.0	82.3	80.7	—	—	1.032	—	109.1	—	—	—	—	—	—	—	dent
ST-13D	68.3	251.7	SM-ML	40-45		—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-13E	68.4	251.6	SM-ML	40-45	36.6	86.1	84.4	82.2	—	0.942	1.034	104.1	94.9	2.87	8.39	2.27	13.8	1.00	With foliation at 60°	

Table 6 (continued)
SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING SWR-13

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	Dry Unit Weight γ_d B (pcf)	Dry Unit Weight γ_d C (pcf)	Dry Unit Weight γ_d D (pcf)	Void Ratio e A	Void Ratio e E	Saturation S A (%)	Saturation S E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^{s}u At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-13F	69.0	251.0	SM-ML	50	47.4	75.5	74.1	72.2	—	1.215	1.316	104.6	96.5	—	—	—	—	—	—	
ST-13G	69.4	250.6	SM-ML	40-45	36.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

Table 5
SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING SWR-12

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d A (pcf)	Dry Unit Weight γ_d B (pcf)	Dry Unit Weight γ_d C (pcf)	Dry Unit Weight γ_d D (pcf)	Void Ratio e A	Void Ratio e E	Saturation S A (%)	Saturation S E (%)	Unconsolidated-Undrained Compression Test: Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^{s}u At 8% (kef)	Mode of Failure Specimen	Condition of Tube Cutting Edge
ST-1A	7.5	312.5	ML-SM	55-65	24.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good
ST-1B	7.9	312.1	ML-SM	55-65	27.8		94.1	94.2	—	0.744	0.775	100.1	96.1	—	—	—	—	—	—	
ST-1E	8.2	311.8	Preserved in tube																	
ST-1F	9.0	311.0	SM	29	19.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-1G	9.2	310.8	CH-SC		29.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-2A	12.5	307.5	ML-SM	60-70	26.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair
ST-2E	12.6	307.4	Preserved in tube																	
ST-2F	13.5	306.5	SM-ML	45-50	20.4			103.8	—	0.533	0.611	102.6	89.5	—	—	—	—	—	—	
ST-2G	14.0	306.0	SM-ML	48	20.3	—	—	—	—											
ST-3A	17.5	302.5	ML	70-80	25.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Not
ST-3B	17.8	302.2	ML	70-80	24.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	viewed
ST-3C	18.1	301.9	SM-ML	20-30	23.9	102.0	100.1	100.1	—	0.640	0.671	100.1	95.5	—	—	—	—	—	—	
ST-3F	18.4	301.6	Preserved in tube																	
ST-3G																				
ST-4A	22.5	297.5	SM-ML	49	25.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fair
ST-4E	22.7	297.3	Preserved in tube																	
ST-4F	23.8	296.2	SM-ML	40-45	26.0	97.6	95.8	92.1	—	0.713	0.816	97.7	85.4	2.87	2.84	4.90	6.6	2.31	Shearing	
ST-4G	24.3	295.7	CH-SC	62	28.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Interface between embankment and foundation at exactly elevation 295.8 (near bottom of test specimen)																				
ST-5A	27.5	292.5	SM-ML	30-40	21.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Few
ST-5B	27.8	292.2	SM-ML	30-40	31.2	77.3	75.8	74.9	—	1.163	1.233	71.9	67.8	—	—	—	—	—	—	small
ST-5E	28.2	291.8	Consumed for visual-manual examination																	dents
ST-5F	29.0	291.0	SM-ML	30-40	34.3	71.0	68.7	—	—	1.355	—	67.8	—	—	—	—	—	—	—	
ST-5G	29.3	290.7	SM-ML	30-40	35.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-6A	32.5	287.5	SM	20-30	19.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very
ST-6D	32.7	287.3	SM	31	23.5	89.3	87.5	84.9	—	0.873	0.970	72.1	64.9	2.87	3.92	5.17	6.0	1.92	With foliation at 50°	good
ST-6E	33.3	286.7	ML-SM	53	33.3	71.9	70.5	—	—	1.326	—	67.3	—	—	—	—	—	—	—	
ST-6F	33.8	286.2	CH	90-95		73.6	70.8	—	—	1.323	—	78.8	—	—	—	—	—	—	—	
ST-6G	34.3	285.7	ML	70-80	36.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

Table 5 (continued)
SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING SWR-12

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d				Void Ratio e		Saturation S		Unconsolidated-Undrained Compression Test						Condition of Tube Cutting Edge
						A (pcf)	B (pcf)	C (pcf)	D (pcf)	A	E	A (%)	E (%)	Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^{s}u At 8% (kef)	Mode of Failure Specimen	
ST-7A	37.5	282.5	SM	10-15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Few
ST-7B	37.7	282.3	SM	10-15	29.0	79.4	77.9	—	—	1.106	—	70.3	—	—	—	—	—	—	—	small
ST-7E	38.0	282.0	Preserved in tube																	dents
ST-7F	38.9	281.1	SM	10-15	16.5	85.8	84.2	75.3	—	0.949	1.221	46.6	36.2	—	—	—	—	—	—	
ST-7G	39.3	280.7	SM	10-15	18.0	—	—	—	—	—	—	—	—	—	—	—	—	—		
ST-8A	42.5	266.5	SM	33	23.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Good
ST-8E	42.6	277.4	Preserved in tube																	
ST-8F	43.6	276.4	SM	30-35	23.5	84.1	82.5	80.8	—	0.988	1.070	63.7	58.9	2.88	5.30	6.04	15.0	2.65	Shear across foliation	
ST-8G	44.2	275.8	SM	34	22.7	—	—	—	—	—	—	—	—	—	—	—	—	—		
ST-9A	30.3	258.7	Empty																	Very
ST-9B	30.6	258.4	SM	10-20	24.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	good
ST-9C	30.9	258.1	SM	10-20	23.5	108.1	101.1	99.9	—	0.622	0.674	101.3	98.6	—	—	—	—	—	—	
ST-9F	31.2	257.8	SM	10-15	22.0	100.2	104.2	101.0	—	0.575	0.656	102.5	89.9	2.88	4.06	4.29	>15	1.43	Bulging	
ST-9G	31.6	257.4	SM	10-15	21.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-10A	32.4	256.6	SM	24	30.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Very
ST-10D	32.5	256.5	Preserved in tube																	
ST-10E	32.7	256.3	SM	20-25	22.4	105.4	103.2	101.5	—	0.587	0.648	104.6	94.7	2.88	4.25	2.20	15.0	0.90	With foliation at 50°	
ST-10F	33.2	255.8	SM	15-20	24.0	104.0	102.0	97.8	96.1	0.608	0.740	105.8	86.9	1.42	4.31	4.40	11.3	1.91	Bulging	
ST-10G	33.5	255.5	SM-ML	43	34.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-11A	34.8	254.2	SM	15-25	26.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
ST-11B	35.0	254.0	SM	15-25	26.1	98.5	96.6	96.7	—	0.698	0.729	102.9	98.5	—	—	—	—	—	—	
ST-11E	35.2	253.8																		
ST-11F																				
ST-11G																				

Table 5 (continued)
SUMMARY OF LABORATORY TESTING OF UNDISTURBED SAMPLES FROM BORING SWR-12

Sample Number	Depth (ft)	Elevation (ft)	USCS Group Symbol	Fines (%)	Water Content (wt %)	Dry Unit Weight γ_d				Void Ratio e		Saturation S		Unconsolidated-Undrained Compression Test						Condition of Tube Cutting Edge
						A (pcf)	B (pcf)	C (pcf)	D (pcf)	A	E	A (%)	E (%)	Specimen Diameter (in.)	σ_c (kef)	q_u (max) (kef)	ε_f (%)	^{s}u At 8% (kef)	Mode of Failure Specimen	
ST-12A	36.5	252.5	Preserved in tube																	Bent deeply inward
ST-12E	36.7	252.3	SM	25-35	31.5	94.2	92.4	91.3	—	0.775	0.832	108.9	101.5	2.87	4.75	1.54	11.3	0.74	With foliation at 45°	
ST-12F	37.2	251.8	SM	29	31.8	94.2	92.3	90.3	86.6	0.775	0.931	110.0	91.5	1.43	4.80	2.18	>15	0.96	Shearing	
ST-12G	37.5	251.5	SM	15-20	29.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

respectively) gave stress-strain curves (Figure 11 Sheets 6-7) showing a relative freedom from disturbance.

3. Composition of Saprolite

Thin sections of samples from borings SWR-3, SWR-4, SWR-5, SWR-7, and P-10 (Table 7) were examined in order to determine in a qualitative manner the fabric, texture, and mineralogy of the saprolite beneath the service water reservoir dike (see boring location plan, Figure 12).

The analysis was undertaken to clarify some of the results of soil classification and laboratory analyses, and to clarify the engineering behavior of the saprolite. Twenty-seven thin sections were examined under plane and polarized light at various magnifications up to 400x.

Sections were cut at various angles to the visible banding in undisturbed samples. Part a of Figure 13 shows a section cut perpendicular to the plane of foliation. Other sections were cut parallel to the foliation in both felsic (quartz- and feldspar-rich) layers and mafic (biotite-rich) layers to see if any minerals were oriented in the plane of foliation. Large sections (1.75-inch x 2-inch) were cut horizontally across six of the samples, and small sections (1-inch x 1.75-inch) were cut vertically at the ends of the large sections. A wide range of orientations of section to foliation resulted from the procedure.

Percentage of minerals present in the thin sections was estimated by scanning the sections under low magnification or by projection of the thin section onto a screen using a slide projector. Size of grains was estimated by using a micrometer eyepiece in the polarizing microscope. Major minerals were identified by standard optical petrographic techniques; accessory and trace minerals were ignored for this analysis.

Fabric

The fabric of the saprolite is shown in Part a of Figure 13. The fabric is that of the parent rock, a biotitic granite gneiss. The saprolite consists of irregular planar bands of light-colored minerals in interlocking grains and irregular bands of dark-colored minerals in elongate grains. The strong foliation evident in the saprolite dips at angles of about 50 degrees from the horizontal. Some elongation of feldspar and quartz in the plane of the foliation occurs in one section, but no elongation is apparent in the direction perpendicular to the strike. Within the gneissic bands, the felsic grains are well interlocked and not strongly oriented. The biotite grains are strongly oriented with basal planes parallel to the plane of foliation. There is no apparent preferred alignment or elongation of the biotite within the plane of foliation. The biotite layers appear to be planes along which slippage could take place more readily than along the intervening well-interlocked felsic layers.

The fabric of the saprolite contrasts strongly with that of a sand (Part b of Figure 13). The sand shows no foliation and no interlocking of grains, even though the grains are quite angular.

The sand thin section also shows a well-developed void network unlike that of the saprolite. The fabric of saprolite is therefore not one of a transported soil but one of the parent rock material. The fabric is anisotropic; that is, it has strongly directional properties.

Texture

The textural relationships of the North Anna saprolite are shown in Parts a and c of Figure 13. Visual estimates of grain size in the thin sections yields a range of 0.05 to 10 mm. However, most of the grains fall in a much narrower range of about 0.1 to 2 mm. These size ranges are for discrete mineral grains observable under the microscope. Many "grains" with very sharp boundaries are composed of minute particles of clay minerals. The size of the individual clay minerals is too small to ascertain under the magnification available, but is smaller than 0.010 mm in most cases.

Therefore, although the grain size of the clay mineral aggregations or parent "grains" are similar to surrounding minerals in the interlocked fabric, the size of the clay within the "grains" is much smaller.

The most striking textural feature of the saprolite is the angularity and interlocking nature of the grains. There is no indication that individual grains are arranged so as to be able to reorient. On the contrary, any change in orientation of one grain would affect the surrounding grains because they are so completely locked geometrically in the overall fabric. The interlocking nature of the grains is shown in Part c of Figure 13.

The textural relationship of void space to grains is difficult to ascertain in the thin sections studied. There is no apparent volumetrically identifiable void network extensive enough to allow reorientation of grains (compare Parts a and b of Figure 13). Void space must occur along grain interfaces and within clay mineral aggregates as well as irregular joints and partially filled fractures. Many of the grains are fractured, but it is not known how much of the fracturing is due to the thin sectioning process. Clearly, some of the fractures are geologic because they are stained by weathering products.

The geometric interlocking of the grains and the lack of a void network that would allow reorientation of grains indicates that the saprolite could not liquefy.

Mineralogy

The mineralogy of the saprolite reflects to a large degree the mineralogy of the parent gneiss. The parent rock is composed mostly of quartz, microcline (potassium feldspar), and plagioclase (sodium-calcium feldspar), with minor to moderate amounts of biotite (brown to black mica). Other constituents are of minor importance and were ignored for the purposes of this investigation.

The mineralogy of the saprolite in thin section is seen to consist of quartz, microcline, clay minerals (unidentified as to type), and biotite. Much of the biotite is bleached and shows low birefringence. This is no doubt due to weathering and incipient hydration of the biotite. Quartz and microcline are clear and unaltered in thin section. There has been no significant corrosion of the grain boundaries. Plagioclase was identified only in one section, SWR-4 sample 6A2 from a depth of 77 feet (see Table 7). This grain is shown in Part c of Figure 13. Even at a depth of 77 feet, the plagioclase is nearly 50% altered to clay minerals. Clay aggregations in other thin sections retain the polygonal form of plagioclase grains and are therefore interpreted to be alteration products of plagioclase. The mineralogy of the clay aggregates are discussed in another section of this report.

The mineralogy of the saprolite therefore reflects a weathering process in which plagioclase feldspar has been converted to clay minerals, biotite has been bleached and partially hydrated, and quartz and microcline have remained unaffected. The weathering and change in mineral composition has not disrupted the relic fabric or significantly increased visible void space.

Visual estimates of mineral percentages yield the following:

Quartz	30% - 40%
Microcline	20% - 30%
Clay minerals	25% - 40%
Biotite	5% - 20%

Depth Relationships

Section P-10 sample 1 taken from a depth of 3 feet is not saprolite. No relic rock fabric is preserved. Each grain is an individual in a matrix of biotite and clay minerals with no apparent preferred orientation. The mineralogy is similar to that of the saprolite but the original fabric has been destroyed. This sample is interpreted to have been disturbed by near surface activity, either climatic or man-induced.

The saprolite from the greatest depth (77 feet) is somewhat less altered than that from samples above. Plagioclase is still recognizable and biotite is relatively fresh. Little iron oxide staining occurs at this depth. As depth decreases, the only apparent change is that plagioclase is entirely altered to clay, biotite becomes progressively more bleached, and straining is more abundant and pervasive. No significant change in fabric or texture occurs with decreasing depth until near the surface.

Clay Mineralogy

Dr. R. Torrence Martin has studied the clay mineralogy of samples taken just above those used for thin sectioning in the borings listed in Table 7. Previously he had also reported on the

Table 7
DATA FOR SAMPLES THIN SECTIONED

Boring Number	Sample Number	Depth Below Original Ground, ft	Percent Fines	Percent Water Content
P-10	1E	3	26	19
SWR-5	4B[a]	26	35	26
SWR-7	7B	26	38	23
SWR-4	2A1[a]	27	36	24
SWR-3	4E	60	23	15
SWR-4	6A2[a]	77	34	20

a. Oriented sections obtained.

a. Saprolite thin section cut perpendicular to relict foliation (SWR-4-6A2). Light bands composed of quartz, feldspar and clay minerals. Dark bands are biotite. Fabric and texture identical to parent rock. (plane light)

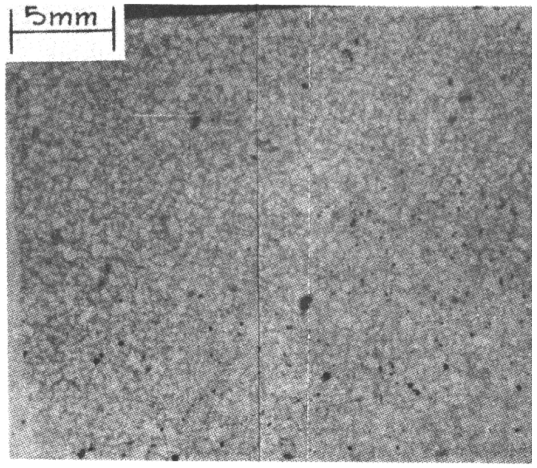
b. Thin section of sand. Grains are separate and void space is readily apparent. Dark grains are opaque minerals, gray is epoxy cement (void space) and white grains are mostly quartz with some fledspar. (plane light)

c. Photomicrograph of saprolite (SWR4-6A2) showing interlocking grains of quartz, microcline, plaqioclase and clay after plaqioclase. The grain with the striped appearance is plaqioclase feldspar. The very fine grained white material is clay. Light and dark grains not mottled with clay specks are quartz and microcline. Note retention of polygonal outline of grains which have been altered to clay. (Polarized light)

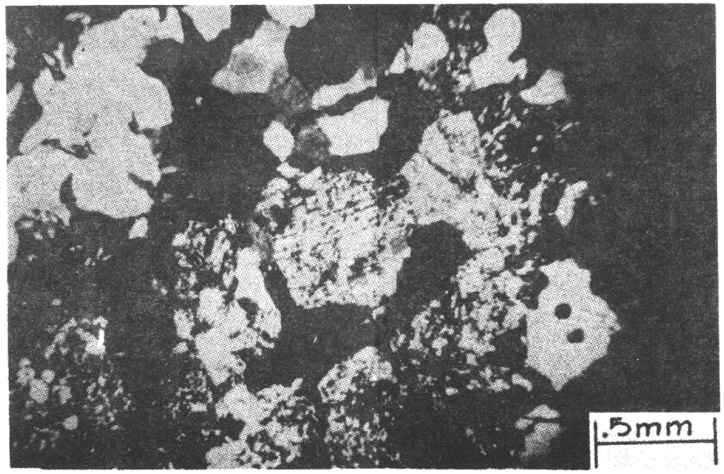
d. Photomicrograph of halloysite (SWR-3-4F) under scanning electron microscope. Note small plates and tube arrangement of particles. Void space within the aggregate of clay particles is large. Size corresponds to fine



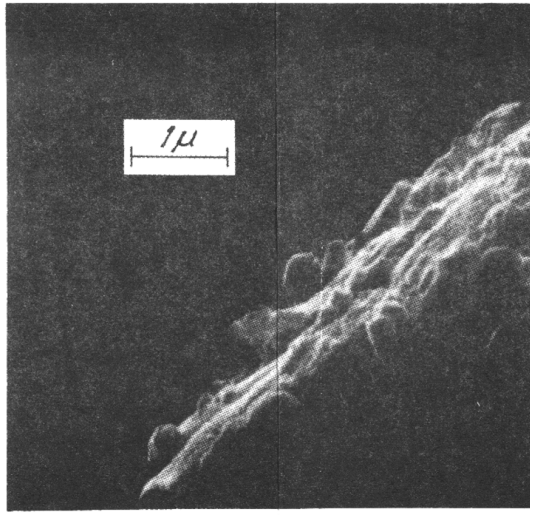
(a)



(b)



(c)



(d)

EA430

FINAL REPORT

RESULTS OF GEOTECHNICAL EXPLORATION AND TESTING
NORTH ANNA ESP PROJECT
LOUISA COUNTY, VIRGINIA

February 11, 2003

Prepared By

MACTEC ENGINEERING AND CONSULTING
RALEIGH NORTH CAROLINA

MACTEC PROJECT NUMBER 30720-2-5400

Submitted To

BECHTEL POWER CORPORATION
FREDERICK, MD

BECHTEL SUBCONTRACT NUMBER 24830-006-HC4-CY00-00001

24830-006-VOA-CY00-00004-002

BECHTEL

SUPPLIER DOCUMENT REVIEW STATUS

STATUS NO.

1 ☑ Work may proceed.
2 ☐ Revise and resubmit. Work may proceed subject to incorporation of changes indicated.
3 ☐ Revise and resubmit. Work may not proceed.
4 ☐ Review not required. Work may proceed.

Permission to proceed does not constitute acceptance or approval of design details, calculations, analyses, test methods or materials developed or selected by the supplier and does not relieve supplier from full compliance with contractual obligations.

Reviewed	Civil	Elec./CS	Nuc./ Mech.	Plant Design	QS	M&QS	Arch.	G&HES
								JRD

BY Richard Baker DATE 6/18/03

GA-41258SM Rev. 10/95

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SECTION 1
INTRODUCTION

MACTEC Engineering and Consulting (MACTEC) was retained by Bechtel Power Corporation (BECHTEL) to conduct a geotechnical exploration and associated laboratory testing at the North Anna Power Station in Louisa County, Virginia. MACTEC executed its services per BECHTEL Subcontract Number 24830-006-HC4-CY00-00001.

The geotechnical services were completed as part of the Early Site Permitting (ESP) project for Dominion Power. The field work commenced on November 18, 2002 and was completed on December 18, 2002. Surveying activities to locate the actual test locations were completed on January 8, 2003.

The Scope of Work was defined in Exhibit D of the Subcontract which included BECHTEL Technical Specification 24830-006-SR9-CY00-00001-000, and is briefly described below.

- Locate exploration points by survey.
- Coordinate the location of underground utilities with plant personnel prior to advancing any exploratory activities.
- Drill geotechnical exploratory borings at locations specified by BECHTEL, adjusting as necessary to accommodate access and utility conflicts. Geotechnical borings were completed at seven locations identified as B-801 through B-807.
- Conduct Standard Penetration Testing (SPT) to obtain samples of soil, undisturbed sampling of soil as directed by BECHTEL field representatives, and rock coring to obtain samples of rock.
- Prepare field logs for all drilling and sampling and transfer all samples to a secure, on-site sample storage facility.
- Seal all boreholes by grouting.
- Complete drilling, with selective soil sampling, for the installation of water level observation wells at nine locations identified as OW-841 through OW-849. Soil sampling was not included in the technical specifications but was requested by BECHTEL's field representatives.
- Develop observation wells and conduct field permeability testing using slug testing methods.
- Install locking well covers and concrete well pads at observation well locations.
- Conduct cone penetrometer testing (CPT) at specified locations. The project specifications called for CPT testing at seven locations. However, due to site access issues and shallow refusal, the CPT testing program was modified to include testing at eight locations (not including offset tests). Test numbers for completed CPT locations are as follows: CPT-821 to CPT-825, CPT-827, CPT-828, and CPT-830.

- Conduct cross-hole seismic tests at one location (B-802) using a three hole array. Due to subsurface conditions encountered at the B-802 location, BECHTEL approved additional cross-hole testing at a second location (B-805).
- Conduct laboratory testing on soil and rock samples as assigned by Bechtel.
- Provide a summary report for all testing.
- Provide daily reports of all field activities.
- The Technical Specifications included provisions for test pits. However, no test pits were assigned or completed.

Sampling and testing related to the geotechnical exploration was designated as "Safety-Related" by BECHTEL. As such, the work was completed under a Quality Assurance Program meeting the Code of Federal Regulations 10CFR50, Appendix B and conforming to the provisions of ANSI/ASME N45.2-1977.

This data report describes the field and laboratory testing methods and presents the results.

SECTION 2
TEST METHODS

2.1 Surveying

The surveying for the project was conducted in two phases. The initial phase was to complete preliminary boring layout based on initial coordinates for test locations provided by BECHTEL. After completing an initial assessment of test locations and potential utility and access conflicts, it was determined that the test points in the central plant area would be identified by MACTEC and BECHTEL personnel by locating them relative to existing site features and structures. Preliminary test locations away from the central plant area and in wooded areas were located by the surveyor (Stantec Consulting, a MACTEC subcontractor) using conventional survey methods.

The second phase was done after completion of all testing. The surveyor returned to the site and determined locations and elevations of the actual test points. Elevations were referenced to NAVD 88. BECHTEL requested that all horizontal locations be provided in Commonwealth of Virginia Grid coordinates. During project startup, it was found that the grid coordinates shown on original plant drawings were referenced to the 1927 plane grid. Since the plant construction, Virginia has adopted a revised grid (the 1983 grid). No drawings were located which linked plant features to the 1983 grid, and the plant itself has its own coordinate grid. Available current Virginia reference monuments are tied to the 1983 grid system; however, it is possible to convert 1983 grid points to the older 1927 grid system. BECHTEL requested that the survey use the 1983 grid references and that a table for all points be prepared showing both the 1983 and the 1927 coordinates. In addition, two existing plant monuments were located by survey to provide a link to previous surveys and coordinates. Survey reference points linked to the current 1983 Virginia grid could not be identified on the plant site. Therefore, the surveyors ran a traverse into the plant from Louisa County Monuments TR 2001 and TR 22 to establish control points.

Prior to the completion of the survey, several markers identifying test locations were removed or damaged. The test locations impacted included: CPT-821, CPT-821A, CPT-821B, B-802 (geotechnical boring only), and CPT-823. Approximate locations for each of these test points were reestablished by MACTEC personnel and located by the surveyors. The locations for these subject points are noted as approximate in the Survey Results Table included in Appendix B. A plan showing the locations of all test locations is also included in Appendix B.

2.2 Utility Location

Representatives of MACTEC and BECHTEL used preliminary survey locations and physical features to mark planned locations of borings, wells, cross-hole test sites, and CPT probes. These preliminary locations were provided to Dominion Power plant personnel for utility clearance.

Dominion personnel used electromagnetic and ground penetrating radar methods to check the planned test locations for the presence of underground utilities. The planned locations were adjusted as required by Dominion Power to provide the necessary utility clearances.

A Digging, Drilling, and Cutting (DD&C) permit for the boring and testing operations was written by Dominion Power and provided to MACTEC for field use. The DD&C was appended to include each new test location as utility clearance was provided. A representative of Dominion Power was present at each test location until the drilling had advanced to a depth of at least ten feet.

2.3 Drilling Equipment/Methods

Drilling equipment mobilized to the site included the following:

- CME 550 Drill Rig mounted on an ATV carrier
- CME 45 Drill Rig mounted on a trailer
- Deitrich D-50 Drill Rig mounted on a tracked carrier
- Ingersoll Rand Model T3W truck mounted air-rotary rig

In addition, a rubber tired ATV with a 300-gallon water tank was mobilized to the site and used to haul materials and supply water to the drill rigs.

Borings were advanced in soil using rotary wash drilling techniques until SPT refusal (defined as the physical inability to advance the hole using wash drilling procedures or 50 blows for one inch or less of penetration, whichever occurred first) was encountered. Once SPT refusal was encountered, a steel casing was set, and the holes were advanced using wire-line rock coring equipment and procedures described in ASTM D 2113. A five foot long "NQ" core barrel with a split inner barrel was use for all rock coring. Fresh water obtained from Lake Anna was used for all drilling and coring operations. In Boring B-805, a slurry formed by mixing bentonite with fresh water was used. Four inch diameter casing was used to stabilize the upper portions of each boring as necessary.

Hollow stem augers, with a 4.25-inch inside diameter and a nominal 8-inch outside diameter, were used to advance all observation well holes except for OW-845. Soil samples were obtained at 2.5-foot and 5-foot intervals in the augered holes as described in Section 2.4. OW-845 was drilled using the rotary air percussion rig in order to advance into rock. No soil samples were obtained in OW-845.

The holes required for cross-hole testing in rock, B-802A, B-802B and B-802C, were advanced using the rotary air percussion drill rig. A 10-inch diameter bit was used through soil and weathered rock zones and a 6-inch diameter bit was used in rock. No sampling was done in these holes.

The holes for the cross-hole testing in soil, B-805A, B-805B and B-805C, were advanced using rotary wash techniques. A 6-inch diameter bit was used to advance these holes to the top of rock. No sampling was done in these holes.

Specific equipment used at each borehole is included on the borehole logs included in Appendix C.

All boreholes and the cross-hole casings were filled prior to demobilizing from the site using a cement-bentonite grout. The cross-hole casing at B-802B was left open for possible additional testing. As required in specification section 4.1.2, the grout was placed by pumping through a tremie pipe inserted to the bottom of the borehole. The grout mixture specified in 4.1.2 (7 gallons of water and 5 pounds of bentonite per 94-pound sack of cement) proved too thick to pump with conventional pumps. MACTEC proposed and BECHTEL's field representative approved use of the same grout mix used for observation well installation for sealing the boreholes.

2.4 Sampling in Geotechnical Borings

Soil sampling in the geotechnical borings (B-801 through B-807) was conducted at intervals ranging from 2.5 feet to 5 feet using equipment and methods described in ASTM D 1586. The sampler was typically driven a minimum of 18 inches in soil with blows recorded for each six inch interval of penetration. In very hard soils and weathered rock, driving was terminated at 100 blows and the actual penetration recorded, (e.g., 100 blows / 3 inches).

The split spoon sampler was opened at the drill site and the recovered materials were visually described and classified by MACTEC's rig geologist. A selected portion of the sample (typically the material for the lower portion of the sample) was placed in a glass sample jar with a moisture proof lid. Sample jars were labeled, placed in cardboard boxes, and transported to an on-site storage area.

The technical specifications defined SPT refusal as 50 blows for 6 inches or less of penetration. For the purposes of determining the depth at which to begin rock coring procedures, BECHTEL agreed that refusal to soil drilling would be defined as physical inability to advance the hole using wash drilling procedures or 50 blows for one inch or less of penetration, whichever occured first. In practice, the sampler was typically struck with 100 blows and the actual penetration measured and recorded on the boring logs.

Rock recovered by the coring process was carefully removed from the split inner barrel and placed in wooden core boxes with wooden blocks used to mark ends of runs. When core recovery was less than 100%, the rig geologist placed foam spacers in the core box to mark the estimated locations for the missing material. Filled core boxes were taken to the on-site sample storage facility. Photographs of the cores were taken at the sample storage facility. Core Photographs are included in Appendix C.

The rig geologist visually described the core and noted the presence of joints and fractures, distinguishing mechanical breaks from natural breaks where possible. The rig geologist also calculated percent recovery and Rock Quality Designation, (RQD) prior to moving the core from the drill site. Core descriptions as well as drilling data, recovery data and RQD are shown on the Core Boring Report for each borehole included in Appendix C.

2.5 Observation Wells

2.5.1 Well Installation

Nine observation wells were installed on the site as part of this project – eight screened in the soil/weathered rock zone and one screened in the rock. The wells were installed per section 5.3 of the specification.

Boreholes for all observation wells except OW-845 were advanced using hollow stem augers with a 4.25-inch inside diameter and a nominal 8-inch outside diameter. The holes were advanced to depths specified by BECHTEL's field representative. Although not required in the specifications, BECHTEL requested that samples be obtained at approximately 5-foot intervals during the drilling for soil classification purposes (except at well OW-845). A split spoon sampler was driven by an automatic hammer for sampling purposes. The driving resistances obtained with automatic hammers are known to be typically lower than those obtained with manually operated hammers due to differences in energy delivered to the drill rods. Manually operated hammers using rope and cathead were used in the geotechnical borings, and are believed to have been used in previous explorations done at the site in the 1970's.

As agreed with BECHTEL representatives, the driving resistances for the samples obtained using the automatic hammer in the observation well boreholes are not to be relied upon for use in correlations based on standard penetration test values or for comparisons with data obtained using manually operated hammers. Therefore, driving resistance data has not been included on the borehole logs for the observation wells which are included in Appendix D. The driving data was recorded, however, and is included on the field logs maintained by the rig geologist.

Borehole depths shown on the borehole logs indicate the total depth drilled and sampled. Due to small amounts of drill spoil at the base of the augers, or due to the sampler advancing beyond the augered depth, the total depth shown on the borehole log may be slightly greater than the well depth reported on the companion well installation record.

Soil samples obtained from the split spoon sampler in the observation well boreholes were placed in glass sample jars with moisture-proof lids. The jars were labeled and placed in cardboard boxes and transported to the on-site sample storage facility.

One observation well, OW-845, extended into rock. The hole for this well was advanced using the rotary air percussion drill rig. No samples of soil or rock were obtained from this borehole.

Upon reaching the designated depth for a well, slotted PVC casing connected to solid sections was set. A sand pack and bentonite seal were then placed. A grout plug was placed from the top of the bentonite seal to the ground surface in each borehole. The grout mix specified in specifications was found too thick to pump with the equipment on site. A modified grout mix consisting of one bag of Portland Cement (94 pounds), 2.5 pounds of bentonite and 7 gallons of water was proposed by MACTEC and accepted by BECHTEL's field representative. The modified mix was used for all well installations.

The depth of the screened interval, length of the screen and general well configuration were designated in the field for each well by BECHTEL's field representative. Since the ground surface elevations at the well sites were not determined until after the well pads were placed, the top of the PVC casing elevation, less the casing stickup above ground surface as measured at the time of installation, was used to back-calculate the ground surface elevation shown on well installation records and the well borehole logs. All water depth measurements are referenced to the top of the PVC casing. The elevation of the top of the casing was also used along with measurements of the well sections to calculate elevations for the well monitoring interval. Well installation logs showing the details of the construction for all wells are included in Appendix D. A summary table with pertinent observation well information is shown in the Summary Table in Appendix A.

All wells were capped with a locked steel well cover extending approximately two feet above grade. A concrete pad, two feet square and six inches thick, was also placed around each well cover per the specification.

2.5.2 Well Development

After well installation was completed, wells were developed by pumping. The development procedure agreed to with BECHTEL was to remove 2 to 3 standing well volumes of water initially by pumping, cycling the pump on and off to create a surging effect. After initial pumping, the procedure called for removal of 6 standing well volumes while monitoring pH and conductivity with a field meter and visually observing the turbidity. The wells were considered developed when the pH and conductivity stabilized and the pumped water was reasonably free of suspended sediment.

Well development records are attached in Appendix D. These records indicate most wells produced moderate to high inflows of water. All wells were developed satisfactorily using the planned procedure.

2.5.3 Field Permeability Tests

Field permeability testing was conducted in each observation well using procedures described in Section 8 of ASTM D 4044. This procedure is commonly termed the slug test method. Slug testing involves establishing a static water level, lowering a solid cylinder into the well to cause an increase of water level in the well and monitoring the time rate for the well water level to return to the pre-test static level. This method is commonly called the "slug-in" method. After that stabilization, the slug is rapidly removed to create a lowering of the water level in the well, and the time rate for water to recover to the pre-test static level is recorded. This method is commonly called the "slug-out" method. Electronic transducers and data loggers are used for measuring the water levels and times during the test. Due to the rates of recovery and adverse weather conditions at the time of testing, the slug-in and slug-out tests were conducted at different times in some wells.

A summary sheet with the calculated coefficients of permeability from the slug tests is included in Appendix A. The field records, data logger output sheets, and analysis/calculations are attached as Appendix E.

2.5.4 Water Level Measurements

On December 17, 2002, after completion of the field permeability testing, MACTEC representatives checked water levels in all wells installed plus additional wells designated by BECHTEL. Measurements were made using an electric water level meter and referenced to the top of the casing. Some of the previously-existing wells had no reference mark at the top of the casing; in these cases, the higher side of the casing, if applicable, was used as the reference point. The water levels recorded are shown on the table in Appendix A. For two of the wells - WP-3 and WP-4 – no elevations of the tops of the casings were available from Dominion. These two wells are not part of the normal network monitored by Dominion personnel.

2.6 Cone Penetometer Testing

Locations for seven Cone Penetrometer Tests, (CPT) were included in the original scope of work for this project. Specified probe depths ranged from 30 to 40 feet below ground surface. MACTEC personnel staked the probes at the specified locations; however, due to soft, wet ground conditions, several of the probes were relocated to more accessible locations. All test locations were approved by the BECHTEL field representative and cleared by plant utility personnel prior to pushing.

CPT testing was completed by Applied Research Associates, Inc. (ARA), a subcontractor to MACTEC. ARA utilized a 30-ton self-contained truck rig to complete the work. Each probe was advanced to cone refusal, (the limit of the pushing capacity of the rig). Seismic testing was completed at intervals of five feet in CPT-822 and CPT-825. Pore pressure dissipation tests were completed in CPT-827 and 823. All testing was done in accordance with project specifications and ASTM-5778

Refusal was encountered at a depth of less than 10 feet at three test locations, CPT-821, CPT-824 and CPT-828. At CPT-821, two offset probes were attempted which also refused at a shallow depth. Utility conflicts prevented an offset test location at CPT-824.

CPT tests were numbered from CPT-821 to CPT-830; however, CPT-826 and CPT-829 were not completed due to utility and site access issues. Results for all CPT testing are included in Appendix F

2.7 Cross-Hole Testing

Cross-hole testing was conducted at two locations - B-802 and B-805. The methods of ASTM D 4438/D 4428M were specified in section 8.1 of the specifications. Section 8.1 called for one borehole in each cross-hole array to be sampled in accordance with section 4.8.2 of the specifications. After reviewing the planned depth of the cross-hole testing (90 feet) and based on the anticipated presence of rock above the assigned depth, MACTEC proposed and Bechtel approved drilling and sampling to be done in an offset boring. The drilled and sampled borings are identified as B-802 and B-805. The cross-hole test holes are identified as B-802A, B-802B and B-802C and B-805A, B-805B and B805C.

The provisions of ASTM D 4428/D 4428M call for a maximum borehole size of six inches for cross-hole testing. The cross-hole equipment needs a minimum diameter of 2-7/8 inches to accommodate the geophones. These considerations require an outside casing diameter of about 4 inches maximum to assure adequate space for grout placement; thus the 6-inch diameter hole is also practically the minimum hole size. Standard rock coring bits used in geotechnical exploratory work do not produce a 6-inch diameter borehole. In order to advance a borehole through soil and into rock, the soil portion of the hole must be larger than the desired hole in the rock to prevent collapse of the soil. Thus, it was concluded that cross-hole testing in soil and in rock could not be accomplished in the same set of casings.

MACTEC proposed that two sets of cross-hole casings be installed at location B-802 with one set for testing below the soil-rock interface and one set for testing above the soil-rock interface. However, it was found that the depth to rock at location B-802 was very shallow, approximately 8 to 10 feet. Discussions with Grumman Exploration, MACTEC's subcontract geophysicist, indicated that with such a shallow depth to rock, cross-hole testing in the soil would yield limited, if any, reasonable results due to refraction of the seismic waves off the rock surface causing interference. Options considered were to reduce the spacing between the casings or to relocate the soil test casings to another spot where the depth to rock was greater. Because geotechnical boring B-805, located in the general vicinity of B-802 and at a similar elevation, had indicated a depth to rock of about 30 feet, BECHTEL approved conducting the soil cross-hole testing at location B-805.

For location B-802, the air percussion drill was used to advance boreholes for the cross-hole tests. A 10-inch diameter borehole was advanced slightly into rock and an 8-inch diameter PVC casing set to stabilize the soil portion of the hole. A 6-1/8 inch diameter bit was used to extend the boreholes to the assigned termination depths of 90 feet.

For location B-805, rotary wash drilling with one of the geotechnical drill rigs using a 6-inch diameter bit was used to advance the boreholes to approximately 30 feet.

Because the specification required a deviation survey of the cross-hole casings, inclinometer casing as manufactured by The Slope Indicator Company was installed in each borehole. Centralizers were placed on the casing, and the annular space between the casing and the borehole was filled with Portland cement grout.

Installation of the cross-hole casings encountered minor difficulties during the grout placement at B-802A. Excessive grout take was noted. During the drilling of B-802A, a relatively large inflow of water had been noted. MACTEC concluded the large grout take was due to grout flowing into open fractures in the rock. Grouting was suspended and resumed the following day with successful completion. Grout losses were not noted in the other two boreholes at the B-802 location.

ASTM D 4428/4428M calls for a grout unit weight in rock of 140 pounds per cubic foot (pcf). To achieve this unit weight, a cement-water mix with a water-reducing admixture was planned due to concerns about the ability to pump the mix. Field work found that a unit weight of about 128 pcf was the maximum that could be achieved and still maintain a mix fluid enough to pump. Since the primary concern with the grout was to achieve a continuous fill of the annular space, the lower unit weight was considered acceptable. Discussions with Grumman indicated the difference in unit weight considered over an approximate 1-inch layer would not affect the seismic velocity measurements.

After setting the casings, and after the cross-hole testing, a deviation survey was conducted in each of the inclinometer casings. The survey was done with a Slope Indicator Digitilt probe, and the data was recorded by a Slope Indicator DataMate recorder. The surveyor later established the grid coordinates for the center of each casing as well as the bearing of the inclinometer reference groove. Horizontal distances between each pair of cross-hole receiver casings were computed at 2-foot increments from the top down using the deviation survey results. These distances were furnished to Grumman for their use in analyzing the cross-hole velocity data. Appendix G contains a drawing showing the orientation of the cross-hole casings, the results of the deviation survey and the computed distances.

The cross-hole velocity measurements were performed on December 12, 2002 by Grumman. MACTEC, in consultation with Grumman, reviewed the available borehole data to select one end of each array as the energy source hole with the other two casings used for the receiver geophones. Due to the large amount of grout used in B-802A, this casing was used for the energy source. Casings for the energy source were pumped/bailed prior to testing to remove water.

The cross-hole measurements were made using a manually-actuated, reversible polarity, shear wave impulse source to create a shock wave at each test depth. Triaxial geophones were lowered into each receiver casing and positioned such that for each test, the impulse source and the geophones were at the same depth relative to the ground surface. Tests were conducted at 5-foot intervals in the rock test location (B-802) as required by the specifications. At location B-805, due to the relatively short length of the casings, tests were conducted at 2.5-foot intervals to 21 feet, then at 5-foot intervals to obtain more data points.

The cross-hole testing was conducted in accordance with ASTM D4428/D4428M ("preferred method") with the following minor deviations:

- A timing accuracy test was not performed at the site as the system had been calibrated within two weeks prior to the filed testing.
- Separate tests for P-wave and S-wave were not conducted as the equipment used has an adequate sampling rate to allow proper interpretation.
- Arrival times were visually observed at the site on the computer monitor, but arrival times were not determined in the field as it is more accurate to evaluate the data and determine arrival times using computer assistance later.

The signals produced by the impulse sources and received by the geophones were recorded by a Geometrics Model S12 signal enhancement seismograph. The data were analyzed by Grumman to produce estimated values for Vp (compression wave velocity) and Vs (shear wave velocity) at the test depths. The results are presented in the figures and tables in Appendix H.

During the analysis, it was found that a background high frequency noise signal was present at the B-802 location. The source of the noise was judged as external to the test equipment. As a result of the interference, estimated values for Vp could not be obtained, and Vs values could not be interpreted at test depths below 45 feet. Grumman believes that downhole testing using one of the casings may have a potential for improved data quality in light of the interference signal. One casing (B-802B) was left open to allow for possible future testing.

Subsequent to the original field work, downhole seismic testing was conducted in Boring B-802B. Reasonable data were obtained for Vp. The shear wave was reasonably well-defined to a depth of 45 feet, but less well-defined to 65 feet. Below approximately 65 feet, the shear wave appeared to be absent. The results of the test are presented in the report, figures and tables in Appendix J.

SECTION 3
SAMPLE STORAGE

3.1 On-Site Sample Storage Facility

At the request of BECHTEL and consistent with MACTEC's quality requirements, an on-site sample storage facility was established. The sample storage facility was located within the "A Level" area of the plant's warehouse facility. The "A Level" has limited access and is climate controlled. MACTEC personnel erected sections of chain link fence, six feet high, to form the approximately 12-foot square area. A locking gate was included in one of the side sections.

Upon sample transport to the warehouse facility, MACTEC personnel first logged each sample container, (boxes of glass jars or rock core boxes) into the plant's "Non-Stock" inventory system. The non-stock inventory number was then placed on the sample container. The sample containers were then placed into the secured sample storage area and logged into the project sample inventory log book.

Any samples removed from the facility were noted in the sample inventory log book. A chain of custody form was also completed for all samples removed from the facility.

SECTION 4
LABORATORY TESTING

Laboratory testing of soil and rock samples was completed based on the BECHTEL Geotechnical Laboratory Test Assignment sheet dated December 18, 2002. Laboratory testing of soil included moisture content, Atterberg Limits, grain size and chemical analysis. Nineteen pieces of rock core were tested for unconfined compressive strength. Six of the test specimens were instrumented with strain gages to allow measurement of stress-strain curves and calculation of modulus of elasticity.

All testing of soil samples except for chemical analysis, was completed in MACTEC's Raleigh, NC laboratory. All rock testing was completed at MACTEC's Atlanta, GA laboratory. Testing was completed in accordance with Section 10.0 – Laboratory Testing, of the project specifications.

For the rock testing, MACTEC's field geologist obtained intact sections of core from the depth intervals designated on the assignment sheet in all but one case. Core pieces were longer than would be required for testing to allow for preparation. Due to insufficient intact length of rock in one assigned interval (B-804, 35-38'), MACTEC's field geologist selected a piece of rock of the same type from the next core run for testing. The substitute piece was from 38.9 to 39.9 feet. Mr. John Davie of Bechtel was advised of the substitution and concurred.

Chemical testing for pH, sulfates and chlorides in selected soil samples as assigned by Bechtel was conducted using EPA methods SW9045 and 9056/300.0. The testing was done by Severn Trent Laboratory (STL) of Savannah, Georgia, a subcontractor to MACTEC.

All soil and rock samples were shipped under Chain-of-Custody from the site storage area to MACTEC's Raleigh, North Carolina laboratory. If required, samples were further divided and/or shipped to the appropriate testing laboratory under Chain-of Custody.

The rock core specimens were prepared in accordance with ASTM D 4543-01. The testing was done at the "as-received" moisture content. The unconfined compressive strength tests were conducted in accordance with ASTM D 2938—95 with minor modifications as noted on the summary sheet. The testing with stress-strain measurements was conducted in accordance with ASTM D 3148-96. Two of the test specimens had length to diameter ratios that were less than the 2.0 minimum recommended by ASTM. The actual ratios were 1.8 and 1.9. In addition, two samples had diameters that were very slightly less (.006") than the minimum recommended in the ASTM standard. The diameter deviation is not significant relative to the test results.

Modulus of elasticity values for the rock cores tested with stress-strain measurements were calculated using the average slope method, with the Poisson's ratios computed over

the same interval used for the modulus. For one sample, this method yielded a value of Poisson's ratio of 0.54, which suggests the core was deforming plastically over the interval chosen. The stress-strain curve for this test also exhibited two distinct slope portions. The modulus value and Poisson's ratio for the portion of the curve in the initial stress range were calculated and resulted in a more reasonable value for Poisson's ratio. For completeness, both results are included in Appendix I.

Summary sheets for the laboratory testing results are included in Appendix A. Copies of the Laboratory Assignment sheets and the results of all soil and rock testing are included in Appendix I.

A summary sheet showing the unconfined compressive strengths and moduli of elasticity is attached in Appendix A. Full reports for the tests are included in Appendix I.

LIST OF APPENDICIES

Appendix A	Tables of Summary Test Data
Appendix B	Survey Data and Test Location Plan
Appendix C	Geotechnical Borings Logs, Core Boring Reports, and Photographs
Appendix D	Observation Well Logs and Development Records
Appendix E	Well Permeability Test Results
Appendix F	Cone Pentrometer Test Results
Appendix G	Deviation Survey Data
Appendix H	Cross-Hole Test Data
Appendix I	Laboratory Testing Data
Appendix J	Downhole Seismic Test Data

APPENDIX A
TABLES OF SUMMARY TEST DATA

OBSERVATION WELL SUMMARY NORTH ANNA ESP PROJECT BECHTEL SUBCONTRACT NO. 24830-006-HC4-CY00-00001 MACTEC JOB NO. 30720-2-5400				
Well Number	Total Depth, ft *	Top of Casing Elevation, ft**	Measurement Interval Elevations, ft ***	Water Level Elevation, ft (Date) ****
OW-841	34.3	251.6	215.8 – 230.0	249.2 (12-13-02)
OW-842	49.6	336.7	285.6 - 299.9	307.4 (12-12-02)
OW-843	49.2	320.6	269.9 - 282.7	284.9 (12-12-02)
OW-844	24.6	273.5	247.4 - 259.3	265.0 (12-13-02)
OW-845	55.0	297.3	240.8 - 256.1	272.6 (12-12-02)
OW-846	32.7	297.3	263.1 - 275.5	272.5(12-12-02)
OW-847	49.8	319.7	268.4 - 283.2	285.3 (12-12-02)
OW-848	47.3	284.5	235.7 – 243.9	241.9 (12-13-02)
OW-849	49.8	298.5	247.2 – 261.4	265.4 (12-13-02)

* Measured relative to ground surface.
** Casing is 1.5 ft above ground surface at time of drilling.
*** Includes interval from bottom of well casing to top of sand pack.
**** Water level measured immediately prior to slug testing, after well development.

Prepared by: _____ Date: 2-4-03
Checked by: _____ Date: 2-4-03

First Quarterly Water Level Summary (12-17-02)
North Anna ESP Project

Observation Point	Depth to Water below Ref. Pt. (ft)	Elevation (ft)		Remarks: Time, Weather Conditions Observation Point Condition, etc.
		Ref. Pt.	Water	
				Partly Cloudy, low 40's
OW-841	2.7	251.6	248.9	No cap on PVC casing inside locking cover
OW-842	29.2	336.7	307.5	
OW-843	35.5	320.6	285.1	
OW-844	8.0	273.5	265.5	
OW-845	24.6	297.3	272.7	
OW-846	24.8	297.3	272.5	
OW-847	34.3	319.7	285.4	
OW-848	42.8	284.5	241.7	
OW-849	33.0	298.5	265.5	No cap on PVC casing inside locking cover
P-10	12.0	286.4	274.4	Ref Pt. mark is fading
P-14	55.5	327.1	271.6	No mark for Ref Pt.
P-18	43.3	329.0	285.7	No mark for Ref Pt.
P-19	38.0	322.3	284.3	
P-20	45.7	320.6	274.9	
P-21	Dry to 58	319.2		No mark for Ref Pt.
P-22	43.7	320.5	276.8	
P-23	35.3	296.4	261.1	
P-24	17.0	293.4	276.4	
WP-3	18.2	*		Sediment in bottom at 43.4'; No mark for Ref Pt.
WP-4	NA	*		Water level is below pump; No mark for Ref Pt.

* No elevation available for top of casing

Service Water Reservoir Elevation 314.6 ft.
Lake Level Elevation 248.1 ft.

Wells labeled OW were installed by MACTEC in November and December, 2002.
All other wells listed were installed by others at unknown times.

Elevations for OW points obtained by Stantec as part of current project.
Elevations for other points furnished by Dominion.

Field Measurements by M. Howe
Sheet Prepared by: _____ Date: _____
Checked by: _____ Date: 1/3/03

North Anna ESP Project
Summary Table of Hydraulic Conductivity (K) Results
MACTEC Job Number: 30720-2-5400

WELL ID	DATE OF TEST	K VALUE RESULTS				COMMENTS
		SLUG IN		SLUG OUT		
		FT/DAY	CM/SEC	FT/DAY	CM/SEC	
OW-841	12/13/2002	2.2E+00	7.8E-04	2.3E+00	8.2E-04	
OW-842	12/12/2002			9.3E-01	3.3E-04	
	12/17/2002	9.3E-01	3.3E-04			
OW-843	12/12/2002			1.4E+00	4.9E-04	
	12/17/2002	1.3E+00	4.5E-04			
OW-844	12/13/2002	2.5E-01	8.9E-05	2.8E-01	9.9E-05	
OW-845	12/12/2002	1.8E+00	6.3E-04	3.1E+00	1.1E-03	K values are questionable (see graph)
	12/17/2002	NA	NA			Recovery to quick to calculate K values (see graph)
OW-846	12/12/2002	1.9E+00	6.8E-04	3.4E+00	1.2E-03	
OW-847	12/13/2002	5.8E-01	2.1E-04			
	12/17/2002			6.6E-01	2.3E-04	
OW-848	12/13/2002	3.4E+00	1.2E-03	2.8E+00	9.9E-04	K value may be overestimated due to H2O level below top of screen
OW-849	12/13/2002	2.0E+00	7.0E-04	3.2E+00	1.1E-03	

Notes:
Prepared by / date: BWJ / 12-20-02
Checked by / date: WSP / 12-27-02

MACTEC

MACTEC ENGINEERING AND CONSULTING, INC.
RALEIGH, NORTH CAROLINA

REPORT OF STANDARD TEST METHOD FOR
LABORATORY DETERMINATION OF WATER CONTENT OF SOIL AND ROCK BY MASS
(ASTM D 2216)

PROJECT NAME: North Anna ESP
MACTEC PROJECT NUMBER: 30720-2-5400
BECHTEL JOB NO: 24830
DATE: 2/11/03

SAMPLE IDENTIFICATION			NATURAL	LIQUID & PLASTIC LIMITS			% FINER				USCS
BORING	TYPE	DEPTH (feet)	MOISTURE (%)	LL	PL	PI	#200 SIEVE	pH	CHLORIDES mg/kg	SULFATES mg/kg	CLASSIFICATION
B-801	SS-1	0-1.5	22.2	39	29	10		6.3	130.0	< 27	
B-801	SS-5	8.5-10					39.9				
B-801	SS-6	13.5-15					55.1				
B-802	SS-2	3.7-5.2					19.5				
B-803	SS-3	6.1-7.6	18.9	30	26	4					
B-803	SS-4	8.6-10.1	23.2				24.4				
B-803	SS-6	13.7-15.3					20.9	5.7	100.0	< 23	
B-803	SS-8	23.6-25.1					18.5				
B-804	SS-3	3.5-5					54.2				
B-804	SS-6	11-12.5					46.1				
B-804	SS-8	18.5-20					22.1				
B-805	SS-4	7.5-9	27.2	NP	NP	NP	27.5				SM
B-805	SS-7	18.5-20					25.1				
B-806	SS-3	5.6-7.1					27.1	6.7	920.0	< 24	
B-807	SS-3	4.5-6	40.1	49	45	4					
B-807	SS-6	12.3-13.8	42.8	46	40	6		5.7	170.0	< 28	
B-807	SS-8	21.8-23.3	28.9	41	34	7	42.6				SM-SC
B-807	SS-10	31.5-33	26.7				37.7				
B-807	SS-12	41.4-42.9	21.8				44.2				

PREPARED BY: _____
Trudy L. Mullins, Laboratory Manager

TESTING EQUIPMENT:

SCALES:	3.1.99
OVEN:	5.1.10
WASH SIEVE:	5.4.39
TECHNICIAN:	JLB
CALCULATIONS:	JLB
CHECKED BY:	TLM

REVIEWED BY: _____
Stephen J. Criscenzo
Principal Professional

APPROVED BY: _____
J. Allan Tice, P.E.
Principal Engineer/Project Manager
Registered Virginia, 5264

MACTEC

Summary of Laboratory Rock Core Tests on Intact Specimens
Unconfined Compressive Strength and Modulus of Elasticity

Project No.: 30720-2-5400
Project Name: North Anna ESP

Boring No.	Depth (ft)	MACTEC Lab ID #	Unconfined Compressive Strength (psi)	Modulus of Elasticity, psi	Poisson's Ratio
B-805	41.3-41.9	001639	3,400	336,000*	0.15*
B-804	38.9-39.9	001640	27,150		
B-804	43.5-44.9	001641	25,200		
B-805	80.8-81.6	001642	4,430		
B-801	48.7-49.7	001644	28,420	8,670,000	0.27
B-804	49.9-50.5	001645	12,300	3,190,000	0.43
B-801	24.1-24.8	001646	27,210		
B-806	42.6-43.2	001648	2,720		
B-802	20.4-21.0	001649	8,640		
B-802	66.0-66.7	001650	14,710	4,613,000	0.24
B-806	25.1-25.8	001651	610		
B-803	54.1-54.7	001652	13,010		
B-803	129.4-130.1	001653	26,730		
B-802	85.3-85.9	001654	9,370		
B-803	70.4-71.1	001655	23,210	7,133,000	0.34
B-803	90.3-91.0	001656	27,590		
B-803	155.6-156.4	001657	22,030	7,173,000	0.33
B-802	44.9-45.6	001658	11,760		
B-806	64.1-64.5	001659	27,360		

Modulus of Elasticity and Poisson's ratio computed using average slope method.

* These values represent low-stress portion of stress-strain curve. Values computed over middle portion of curve indicate E = 522,000 and Poisson's Ratio of 0.54. A value of .54 suggests plastic behavour of the core at the higher stress levels.

Prepared by: [signature] Date: 2/5/03

Checked by: SJZ Date: 2/5/03

APPENDIX B
SURVEY DATA AND TEST LOCATION PLAN

North Anna Survey Data Table

02-03-03

		NAVD88 DATUM			STATE PLANE COORDINATES (NAD83) SOUTH ZONE		STATE PLANE COORDINATES (NAD27) NORTH ZONE	
BORING	DONE	ELEV. TO TOP OF BLUE CAP	GROUND ELEVATION	BEARING (TO A END)	NORTHING	EASTING	NORTHING	EASTING
B-801	✓		248.9		3910351.5739	11686737.9892	144033.5657	2203739.9220
B-802	✓		271.5		3909956.9016	11686380.8110	143638.8229	2203382.8334
B-802A	✓	271.222	271.1	N 71°36'22" W	3909943.5519	11686399.2814	143625.4774	2203401.3062
B-802B	✓	271.356	271.2	N 39°11'34" W	3909945.4028	11686389.7511	143627.3262	2203391.7756
B-802C	✓	271.446	271.4	S 80°00'35" E	3909947.3175	11686379.7512	143629.2387	2203381.7756
B-803	✓		292.4		3909921.5113	11685763.7633	143603.3008	2202765.8066
B-804	✓		320.0		3909497.2390	11685134.7547	143178.9007	2202136.8990
B-805	✓		271.1		3910361.5788	11686246.9595	144043.4649	2203248.9012
B-805A	✓	271.028	271.2	S 59°19'30" E	3910364.0260	11686236.6888	144045.9099	2203238.6302
B-805B	✓	271.126	271.4	N 73°02'24" E	3910354.9867	11686240.7396	144036.8716	2203242.6828
B-805C	✓	271.016	271.3	N 77°19'54" E	3910345.9275	11686244.7671	144027.8134	2203246.7121
B-806	✓		299.2		3909416.2434	11683977.2831	143097.6599	2200979.4688
B-807	✓		310.6		3909849.0828	11683980.4378	143530.4933	2200982.5350
CPT			GROUND ELEVATION					
CPT-821 *	✓		271		3909965	11686353	143647	2203355
CPT-821A *	✓		271		3909957	11686348	143639	2203350
CPT-821B *	✓		271		3909966	11686367	143648	2203369
CPT-822	✓		271.1		3910375.4066	11686237.2013	144057.2904	2203239.1404
CPT-823 **	✓		296.3		3909850.0235	11685756.1761	143531.8125	2202758.2343
CPT-824	✓		276.1		3910054.2670	11686009.5911	143736.1071	2203011.6016
CPT-825	✓		332.5		3909477.9442	11685267.2998	143159.6345	2202269.4452
CPT-827	✓		277.1		3910688.2442	11683569.4372	144369.5540	2200571.3722
CPT-828	✓		270.0		3910652.8241	11683066.3705	144334.0281	2200068.3241
CPT-830	✓		307.5		3909848.9822	11686000.3856	143530.8236	2203002.4386
OBS. WELL		ELEV. TOP OF PVC CASING						
OW-841	✓	251.622			3910556.1514	11686804.1141	144238.1541	2203806.0030
OW-842	✓	336.740			3909034.7635	11685149.1315	142716.4352	2202151.3705
OW-843	✓	320.580			3909725.1724	11685056.8319	143406.8139	2202058.9310
OW-844	✓	273.507			3909908.8159	11686589.6454	143590.7828	2203591.6732
OW-845	✓	297.309			3909858.6642	11685741.1107	143540.4499	2202743.1674
OW-846	✓	297.270			3909845.0918	11685721.8162	143526.8736	2202723.8761
OW-847	✓	319.720			3908945.4511	11686447.6923	142627.4022	2203449.9225
OW-848	✓	284.512			3910853.3688	11686272.7632	144535.2523	2203274.6027
OW-849	✓	298.536			3910786.2446	11684731.0221	144467.7996	2201732.9106

* These points were not field located but placed by MACTEC's estimated location, the elevations were established from a field survey of the surrounding area.
** This is a field located point of the estimated location of CPT 823.
*** Virginia State Plane NAD83 (South Zone) coordinates converted to State Plane NAD27 (North Zone) using Corpscon for Windows version 5.11.08

I hereby certify that field surveys were performed in accordance with applicable project specifications (11/22/02 – 12/30/02) under my supervision to determine the values listed in this table except where noted. All data was collected directly from Louisa County Survey Control Monuments (pair # 14, monuments 2001 to 22) using the coordinates provided in Virginia State Plane, NAD83 – South Zone (U.S. Survey Foot) and the reference datum of NAVD 88. The NAD27 coordinates were derived via office computations as noted.

David R. Gardy, LS # 001751

COMMONWEALTH OF VIRGINIA
DAVID R. GARDY
No. 1751
02/03/03
LAND SURVEYOR

APPENDIX C
GEOTECHNICAL BORING LOGS, CORE BORING REPORTS, AND PHOTOGRAPHS

MAJOR DIVISIONS			GROUP SYMBOLS		TYPICAL NAMES
COARSE GRAINED SOILS (More than 50% of material is LARGER than No. 200 sieve size)	GRAVELS (More than 50% of coarse fraction is LARGER than the No. 4 sieve size)	CLEAN GRAVELS (Little or no fines)		GW	Well graded gravels, gravel - sand mixtures, little or no fines.
				GP	Poorly graded gravels or grave - sand mixtures, little or no fines.
		GRAVELS WITH FINES (Appreciable amount of fines)		GM	Silty gravels, gravel - sand - silt mixtures.
				GC	Clayey gravels, gravel - sand - clay mixtures.
	SANDS (More than 50% of coarse fraction is SMALLER than the No. 4 Sieve Size)	CLEAN SANDS (Little or no fines)		SW	Well graded sands, gravelly sands, little or no fines.
				SP	Poorly graded sands or gravelly sands, little or no fines.
		SANDS WITH FINES (Appreciable amount of fines)		SM	Silty sands, sand - silt mixtures
				SC	Clayey sands, sand - clay mixtures.
FINE GRAINED SOILS (More than 50% of material is SMALLER than No. 200 sieve size)	SILTS AND CLAYS (Liquid limit LESS than 50)			ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts and with slight plasticity.
				CL	Inorganic lays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
				OL	Organic silts and organic silty clays of low plasticity.
	SILTS AND CLAYS (Liquid limit GREATER than 50)			MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
				CH	Inorganic clays of high plasticity, fat clays
				OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS				PT	Peat and other highly organic soils.

BOUNDARY CLASSIFICATIONS: Soils possessing characteristics of two groups are designated by combinations of group symbols.

SILT OR CLAY	SAND			GRAVEL		Cobbles	Boulders
	Fine	Medium	Coarse	Fine	Coarse		

No.200 No.40 No.10 No.4 3/4" 3" 12"

U.S. STANDARD SIEVE SIZE

Reference: The Unified Soil Classification System, Corps of Engineers, U.S. Army Technical Memorandum No. 3-357, Vol. 1, March, 1953 (Revised April, 1960)

	GROUP SYMBOLS	TYPICAL NAMES
ROCK	WR	Weathered Rock
	HR	Hard Rock

▽ Water Table at time of drilling ▼ Water Table after 24 hours

Correlation of Penetration Resistance with Relative Density and Consistency

SAND & GRAVEL		SILT & CLAY	
No. of Blows	Relative Density	No. of Blows	Consistency
0 - 4	Very Loose	0 - 1	Very Soft
5 - 10	Loose	2 - 4	Soft
11 - 20	Firm	5 - 8	Firm
21 - 30	Very Firm	9 - 15	Stiff
31 - 50	Dense	16 - 30	Very Stiff
Over 50	Very Dense	Over 31	Hard

KEY TO SYMBOLS AND DESCRIPTIONS

MACTEC

MACTEC
3301 Atlantic Avenue
Raleigh, NC 27604

GEOTECHNICAL BORING LOG
SHEET 1 OF 2

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-801			**0 HR.** 1.3
COLLAR ELEV. 248.9 ft **(NAVD 88)**	**NORTHING** 3,910,351.57 **(NAD 83)**	**EASTING** 11,686,737.99 **(NAD 83)**	**24 HR.** 1.0
TOTAL DEPTH 49.8 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/3/02	**COMPLETED** 12/4/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
248.9	0.0				Ground Surface				248.9 0.00
248.9	0.0	3	3	7	10	SS-1			Fill: Orange, brown, and tan, stiff, fine to coarse sandy, silty, CLAY (CL)
247.4	1.5	5	4	6	10	SS-2			246.9 2.0 Fill: Brown, stiff, micaceous, slightly fine sandy, SILT (ML)
245.4	3.5	4	4	6	10	SS-3			245.4 3.5 Fill: Brown and tan, loose to firm, micaceous, silty, fine to coarse SAND (SM)
242.9	6.0	5	7	9	16	SS-4			
240.4	8.5	7	7	8	15	SS-5			236.9 12.0
235.4	13.5	3	3	3	6	SS-6			Fill: Brown and tan, firm, micaceous, clayey, fine to coarse sandy SILT (ML)
230.4	18.5	10	43	57/0.1ft	100/0.6ft	SS-7			229.9 19.0
228.9	20.0	50/0.0ft			100/0.0ft	SS-8			228.9 20.0 Weathered Rock: Gray, QUARTZ GNEISS Hard Rock: Gray, slightly weathered to fresh, closely to widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and trace magnetite
211.5	37.4								

BECHTEL 5400).GDT 2/4/03

MACTEC
3301 Atlantic Avenue
Raleigh, NC 27604

GEOTECHNICAL BORING LOG
SHEET 2 OF 2

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-801			**0 HR.** 1.3
COLLAR ELEV. 248.9 ft **(NAVD 88)**	**NORTHING** 3,910,351.57 **(NAD 83)**	**EASTING** 11,686,737.99 **(NAD 83)**	**24 HR.** 1.0
TOTAL DEPTH 49.8 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/3/02	**COMPLETED** 12/4/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
211.5	37.4				Continued from previous page				
									Hard Rock: Gray, slightly weathered to fresh, closely to widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and trace magnetite *(continued)*
199.1	49.8								Boring and Coring terminated at 49.8 ft in Hard Rock: Very slightly weathered to fresh, moderately closely fractured, very hard, Quartz Gneiss with biotite (5%) and trace magnetite Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated) Drilling Fluid: Water Borehole filled by grouting 12/13/02
174.1	74.8								

BECHTEL 5400.4C_DOT.GDT 2/4/03

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CORE BORING REPORT

SHEET 1 OF 1

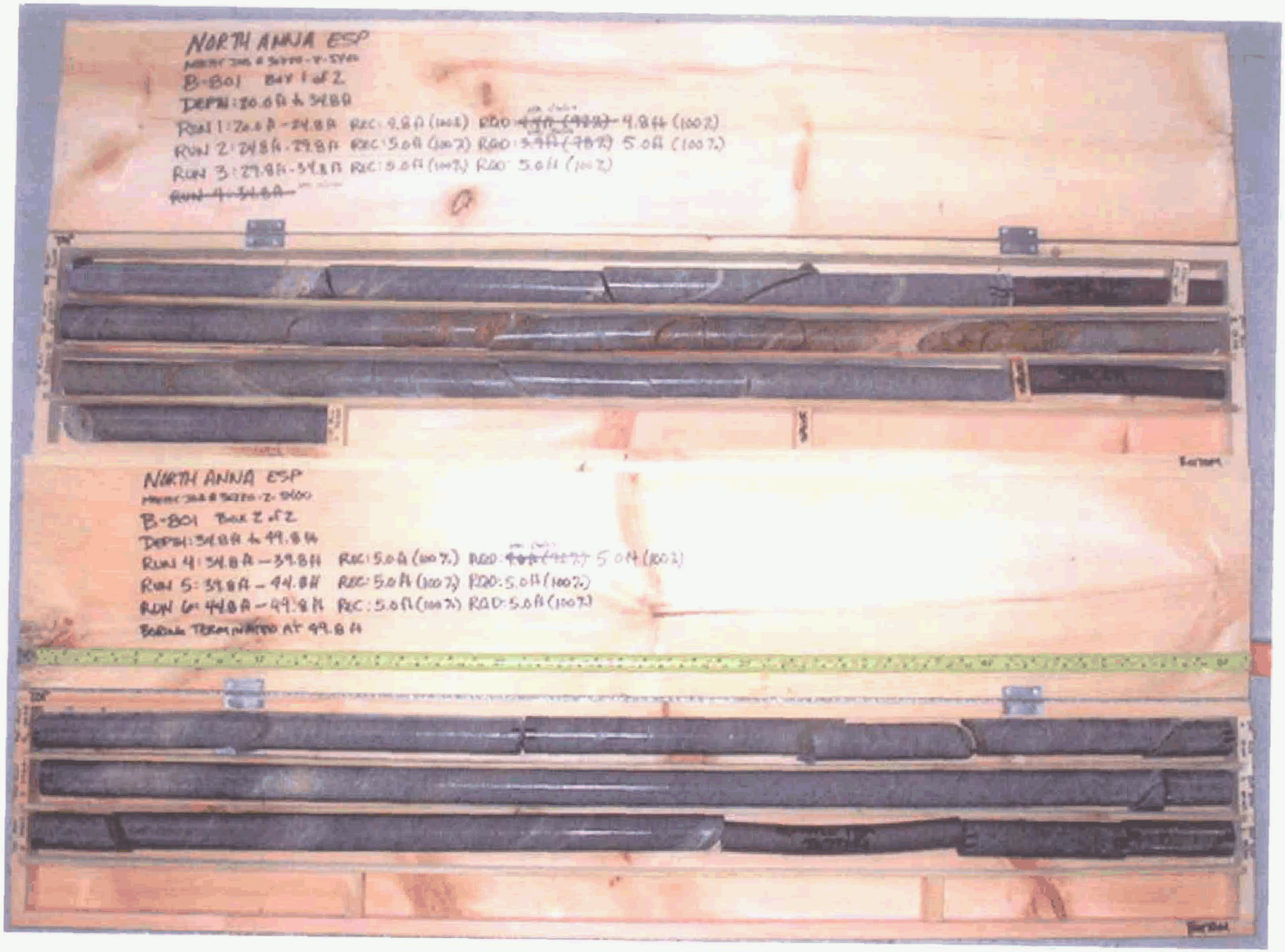
BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-801			**0 HR.** 1.3
COLLAR ELEV. 248.9 ft **(NAVD 88)**	**NORTHING** 3,910,351.57 **(NAD 83)**	**EASTING** 11,686,737.99 **(NAD 83)**	**24 HR.** 1.0
TOTAL DEPTH 49.8 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/3/02	**COMPLETED** 12/4/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 29.8 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Begin Coring @ 20.0 ft
228.9	20.0	4.8	3:36 4:19 5:54 5:17 2:51/0.8	(4.8) 100%	(4.8) 100%	RUN 1				228.9 (20.0) Hard Rock: Gray, slightly weathered to fresh, closely to widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and trace magnetite (2 joints at 30-35° with trace clay; 1 joint at 70° with trace clay; 2 coarse quartz and potassic feldspar veins at 60° with gradational margins from 20.9ft to 21.3ft and 22.2ft to 22.8ft)
224.1	24.8									
		5.0	3:19 3:18 3:31 3:35 3:40	(5.0) 100%	(5.0) 100%	RUN 2				(4 joints at 70° with clay and orange Fe stain; 1 joint at 30° with orange Fe stain)
219.1	29.8									
		5.0	3:55 4:01 5:50 5:51 8:26	(5.0) 100%	(5.0) 100%	RUN 3				(5 joints at 40-50° with trace clay; 1 joint at 20° with trace clay)
214.1	34.8									
		5.0	13:12 9:34 3:26 3:29 5:25	(5.0) 100%	(5.0) 100%	RUN 4				(2 joints at 40° with clay, quartz, and orange Fe stain; 2 joints at 60-70° with trace clay)
209.1	39.8									
		5.0	4:26 3:50 3:58 3:40 3:55	(5.0) 100%	(5.0) 100%	RUN 5				(1 joint at 40° with trace clay)
204.1	44.8									
		5.0	3:49 4:51 4:23 5:00 6:14	(5.0) 100%	(5.0) 100%	RUN 6				(2 joints at 30-40° with trace clay and orange Fe stain)
199.1	49.8									199.1 (49.8) Boring and Coring terminated at 49.8 ft in Hard Rock: Very slightly weathered to fresh, moderately closely fractured, very hard, Quartz Gneiss with biotite (5%) and trace magnetite
										Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated)
										Drilling Fluid: Water
										Borehole filled by grouting 12/13/02

0A.GPJ NC_DOT.GDT 2/3/03

BECHTEL CORE1 L


NORTH ANNA ESP
B-801 BOX 1 of 2
DEPTH: 20.0 ft to 39.8 ft
RUN 1: 20.0 ft - 24.8 ft REC: 4.8 ft (100%) RQD 4.8 ft (100%)
RUN 2: 24.8 ft - 29.8 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 3: 29.8 ft - 34.8 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
NORTH ANNA ESP
B-801 Box 2 of 2
DEPTH: 34.8 ft to 49.8 ft
RUN 4: 34.8 ft - 39.8 ft REC: 5.0 ft (100%) RQD 5.0 ft (100%)
RUN 5: 39.8 ft - 44.8 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 6: 44.8 ft - 49.8 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
BORING TERMINATED AT 49.8 ft

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GEOTECHNICAL BORING LOG

SHEET 1 OF 3

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-802			**0 HR.** 5.2
COLLAR ELEV. 271.5 ft **(NAVD 88)**	**NORTHING** 3,909,956.90 **(NAD 83)**	**EASTING** 11,686,380.81 **(NAD 83)**	**24 HR.** 3.4
TOTAL DEPTH 90.0 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/9/02	**COMPLETED** 12/10/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
271.5	0.0				Ground Surface				
271.5	0.00								
270.5	1.0	26	22	14	36	SS-1			Fill: Gray, dense, silty, fine to coarse sandy, GRAVEL (GM)
268.5	3.0								
267.8	3.7	15	22	22	44	SS-2			Residual: Tan and gray, dense, slightly micaceous, silty, fine to coarse SAND (SM)
265.5	6.0								
265.5	6.0	12	38	62/0.2ft	100/0.7ft	SS-3			Weathered Rock: Brown, BIOTITE QUARTZ GNEISS
263.2	8.3	50/0.0ft			100/0.0ft	SS-4			Hard Rock: Gray with tan, orange, and brown Fe stain, moderately severe to moderately weathered, very closely to closely fractured, moderately hard to hard, BIOTITE QUARTZ GNEISS
245.9	25.6								Hard Rock: Dark gray, slightly weathered to fresh, very closely to moderately closely fractured, hard, BIOTITE QUARTZ GNEISS
234.1	37.4								

BECHTEL 5400A C_DOT.GDT 2/4/03

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GEOTECHNICAL BORING LOG
SHEET 2 OF 3

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-802			**0 HR.** 5.2
COLLAR ELEV. 271.5 ft **(NAVD 88)**	**NORTHING** 3,909,956.90 **(NAD 83)**	**EASTING** 11,686,380.81 **(NAD 83)**	**24 HR.** 3.4
TOTAL DEPTH 90.0 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/9/02	**COMPLETED** 12/10/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
234.1	37.4				Continued from previous page				
									Hard Rock: Dark gray, slightly weathered to fresh, very closely to moderately closely fractured, hard, BIOTITE QUARTZ GNEISS *(continued)*
215.5	56.0								Hard Rock: Gray and pink, locally with orange Fe stain, slightly weathered, very closely to moderately closely fractured, hard, QUARTZ GNEISS with Biotite (5%)
200.2	71.3								Hard Rock: Dark gray, very slightly weathered to fresh, closely to moderately closely fractured, hard, BIOTITE QUARTZ GNEISS
196.7	74.8								

NC_DOT.GDT 2/4/03

BECHTEL_5400.

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GEOTECHNICAL BORING LOG
SHEET 3 OF 3

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-802			**0 HR.** 5.2
COLLAR ELEV. 271.5 ft **(NAVD 88)**	**NORTHING** 3,909,956.90 **(NAD 83)**	**EASTING** 11,686,380.81 **(NAD 83)**	**24 HR.** 3.4
TOTAL DEPTH 90.0 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/9/02	**COMPLETED** 12/10/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
196.7	74.8				Continued from previous page				
									Hard Rock: Dark gray, very slightly weathered to fresh, closely to moderately closely fractured, hard, BIOTITE QUARTZ GNEISS *(continued)*
186.6	84.9								Hard Rock: Gray, slightly to very slightly weathered, closely to moderately closely fractured, hard, QUARTZ GNEISS with Biotite (5%)
181.5	90.0								Boring and Coring terminated at 90.0 ft in Hard Rock: Slightly to very slightly weathered, closely to moderately closely fractured, hard, Quartz Gneiss with biotite (5%) Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated) Drilling Fluid: Water Borehole filled by grouting 12/13/02
159.3	112.2								

BECHTEL 5400A DOT.GDT 2/4/03

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CORE BORING REPORT

SHEET 1 OF 3

BECHTEL

BECHTEL PROJECT NO. 24830	MACTEC PROJECT NUMBER: 30720-2-5400	COUNTY LOUISA, VA	GEOLOGIST M. Lear
PROJECT NAME: NORTH ANNA ESP			WATER LEVEL (ft)
BORING NO. B-802			0 HR. 5.2
COLLAR ELEV. 271.5 ft (NAVD 88)	NORTHING 3,909,956.90 (NAD 83)	EASTING 11,686,380.81 (NAD 83)	24 HR. 3.4
TOTAL DEPTH 90.0 ft	DRILL MACHINE CME-550, ATV	DRILL METHOD Rotary Wash/Core	HAMMER TYPE 140 lb. Manual, #5
DATE STARTED 12/9/02	COMPLETED 12/10/02	SURFACE WATER DEPTH N/A	
CORE SIZE NQ	TOTAL RUN 81.7 ft	DRILLER K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Begin Coring @ 8.3 ft
263.2	8.3	1.6	2:29	(1.6) 100%	(0.5) 31%	RUN 1				263.2 Hard Rock: Gray with tan, orange, and brown Fe stain, moderately severe to moderately weathered, very closely to closely fractured, moderately hard to hard, BIOTITE QUARTZ GNEISS 8.3
261.6	9.9		1:19/0.6							
		5.0	1:43	(4.3) 86%	(2.1) 42%	RUN 2				(5 joints at 50-60° with clay and orange Fe stain) (11 joints at 50-60° with clay and orange Fe stain; 5 joints at 0-10° with clay and orange Fe stain; Severely weathered fracture zone with no recovery from 11.3ft to 12.0ft)
			1:40							
			2:03							
			1:53							
256.6	14.9		1:48							
		5.0	1:15	(4.0) 80%	(2.3) 46%	RUN 3				(9 joints at 50-60° with clay and orange Fe stain; Severely weathered fracture zone with no recovery from 17.6ft to 18.6ft)
			1:22							
			1:05							
			1:17							
251.6	19.9		1:15							
		5.0	1:04	(4.5) 90%	(3.6) 72%	RUN 4				(5 joints at 50-60° with brown Fe stain; 2 joints at 0-10° with brown Fe stain; Severely weathered fracture zone with no recovery from 24.4ft to 24.9ft)
			1:00							
			1:11							
			1:20							
246.6	24.9		1:45							
		5.0	2:11	(4.8) 96%	(3.9) 78%	RUN 5				245.9 (5 joints at 50-60° with brown and orange Fe stain; 1 joint at 70-80° with orange Fe stain) 25.6
			1:32							Hard Rock: Dark gray, slightly weathered to fresh, very closely to moderately closely fractured, hard, BIOTITE QUARTZ GNEISS
			1:24							
			1:24							
241.6	29.9		1:30							
		5.0	1:31	(5.0) 100%	(4.4) 88%	RUN 6				(10 joints at 40-50° with trace orange Fe stain)
			1:38							
			1:33							
			1:53							
236.6	34.9		1:56							
		5.0	1:17	(4.4) 88%	(4.2) 84%	RUN 7				(1 joint at 68° with clay and quartz; Severely weathered fracture zone with no recovery from 37.9ft to 38.5ft)
			1:19							
			1:34							
			1:50							
231.6	39.9		1:33							
		5.0	1:27	(5.0) 100%	(3.3) 66%	RUN 8				(11 joints at 0-10° with trace clay and brown Fe stain; 4 joints at 50-60° with trace clay; 1 joint at 70° with clay and chlorite)
			1:55							
			1:45							
			2:01							
226.6	44.9		1:53							
		5.0	1:54	(5.0)	(4.8)	RUN 9				(3 joints at 40-50° with trace clay, chlorite, and red and orange Fe stain)

BECHTEL CORE1 L( )A.GPJ NC_DOT.GDT 2/3/03

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CORE BORING REPORT

SHEET 2 OF 3

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-802			**0 HR.** 5.2
COLLAR ELEV. 271.5 ft **(NAVD 88)**	**NORTHING** 3,909,956.90 **(NAD 83)**	**EASTING** 11,686,380.81 **(NAD 83)**	**24 HR.** 3.4
TOTAL DEPTH 90.0 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/9/02	**COMPLETED** 12/10/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 81.7 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Continued from previous page
			1:42	100%	96%					Hard Rock: Dark gray, slightly weathered to fresh, very closely to moderately closely fractured, hard, BIOTITE QUARTZ GNEISS *(continued)*
			1:43							
			1:48							
221.6	49.9		1:56							
		5.0	1:32	(5.0) 100%	(5.0) 100%	RUN 10				(1 joint at 60°)
			1:34							
			1:39							
			1:36							
216.6	54.9		1:43							
		5.0	1:14	(5.0) 100%	(4.0) 80%	RUN 11				(4 joints at 50-60° with brown Fe stain; 4 joints at 30-40° with brown Fe stain)
215.5	56.0									
			1:42							Hard Rock: Gray and pink, locally with orange Fe stain, slightly weathered, very closely to moderately closely fractured, hard, QUARTZ GNEISS with Biotite (5%)
			1:58							
			2:17							
211.6	59.9		2:15							
		5.0	1:37	(5.0) 100%	(3.6) 72%	RUN 12				(6 joints at 30-40° with trace clay; 2 joints at 50-60° with brown Fe stain; 1 joint at 70° with clay, quartz, and red Fe stain)
			1:43							
			1:40							
			2:20							
206.6	64.9		2:51							
		5.0	2:40	(5.0) 100%	(4.0) 80%	RUN 13				(5 joints at 30-40° with orange Fe stain; 4 joints at 0-10° with trace clay; 1 joint at 60° with clay, quartz, and orange Fe stain)
			2:45							
			2:43							
			2:36							
201.6	69.9		2:55							
		5.0	2:35	(5.0) 100%	(4.8) 96%	RUN 14				(3 joints at 40-50° with trace clay)
200.2	71.3									
			2:52							Hard Rock: Dark gray, very slightly weathered to fresh, closely to moderately closely fractured, hard, BIOTITE QUARTZ GNEISS
			2:43							
			2:45							
196.6	74.9		2:15							
		5.0	1:23	(5.0) 100%	(3.6) 72%	RUN 15				(11 joints at 30-40° with brown Fe stain; 2 joints at 50-60° with trace clay)
			1:27							
			1:21							
			1:18							
191.6	79.9		1:05							
		5.0	1:13	(5.0) 100%	(4.5) 90%	RUN 16				(4 joints at 30-40° with trace clay and orange Fe stain; 2 joints at 60-70° with trace clay and chlorite)
			1:18							
			1:19							

BECHTEL CORE1 LC A.GPJ NC_DOT.GDT 2/3/03

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CORE BORING REPORT

SHEET 3 OF 3

BECHTEL

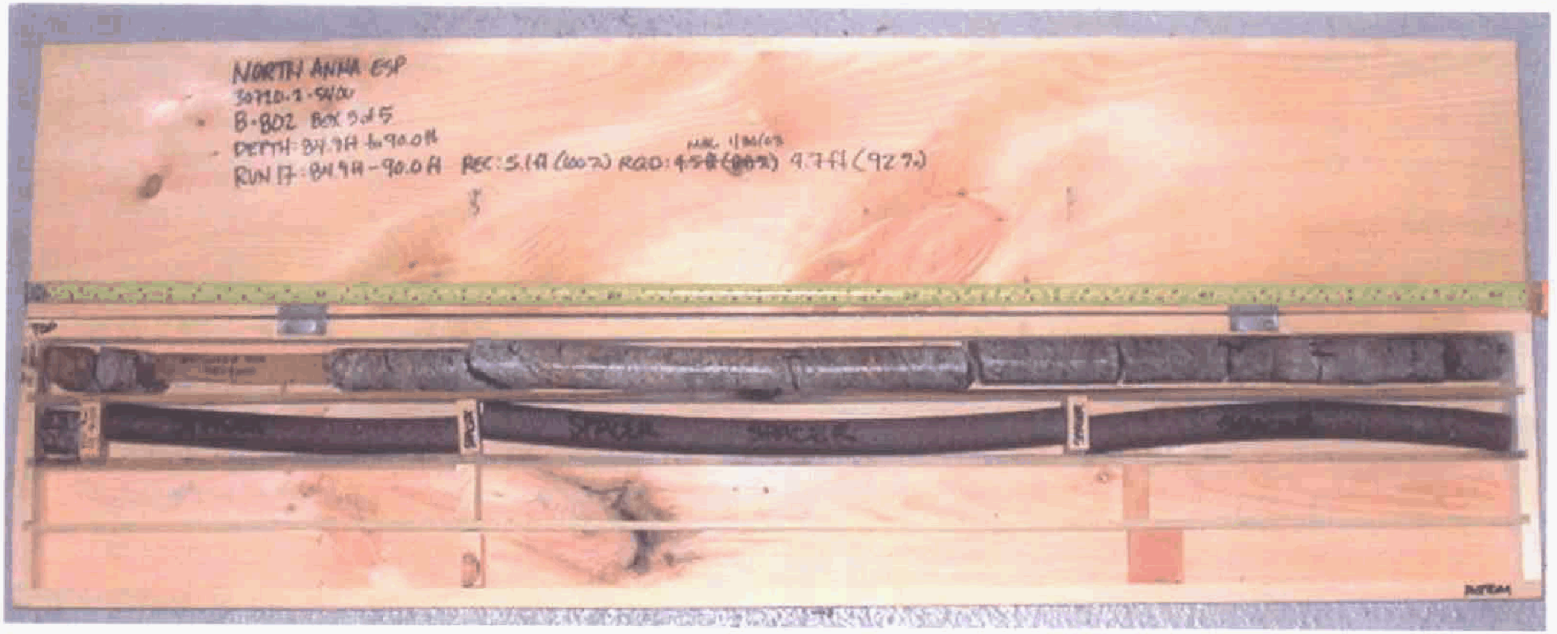
BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-802			**0 HR.** 5.2
COLLAR ELEV. 271.5 ft **(NAVD 88)**	**NORTHING** 3,909,956.90 **(NAD 83)**	**EASTING** 11,686,380.81 **(NAD 83)**	**24 HR.** 3.4
TOTAL DEPTH 90.0 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/9/02	**COMPLETED** 12/10/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 81.7 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Continued from previous page
			1:20							Hard Rock: Dark gray, very slightly weathered to fresh, closely to moderately closely fractured, hard, BIOTITE QUARTZ GNEISS *(continued)*
			1:20							
186.6	84.9									186.6 — 84.9
		5.1	1:24	(5.1) 100%	(4.7) 92%	RUN 17				Hard Rock: Gray, slightly to very slightly weathered, closely to moderately closely fractured, hard, QUARTZ GNEISS with Biotite (5%) (4 joints at 30-40°; 1 joint at 70° with chlorite)
			1:21							
			1:23							
			1:30							
			1:57/1.1							
181.5	90.0									181.5 — 90.0
										Boring and Coring terminated at 90.0 ft in Hard Rock: Slightly to very slightly weathered, closely to moderately closely fractured, hard, Quartz Gneiss with biotite (5%)
										Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated)
										Drilling Fluid: Water
										Borehole filled by grouting 12/13/02

BECHTEL CORE1 LL JA.GPJ NC DOT.GDT 2/3/03


NORTH ANNA ESP
30720-2-5400
B-802 Box 1 of 5
DEPTH: 8.3ft to 24.9ft
RUN 1: 8.3ft - 9.9ft REC: 1.6ft (100%) RQD: 0.5ft (31%)
RUN 2: 9.9ft - 14.9ft REC: 4.3ft (86%) RQD: 2.1ft (42%)
RUN 3: 14.9ft - 19.9ft REC: 4.0ft (80%) RQD: 2.3ft (46%)
RUN 4: 19.9ft - 24.9ft REC: 4.5ft (90%) RQD: 3.6ft (72%)
TOP
NO RECOVERY
SPACER
BOTTOM
NORTH ANNA ESP
30720-2-5400
B-802 Box 2 of 5
DEPTH: 24.9ft to 44.9ft
RUN 5: 24.9ft - 29.9ft REC: 4.8ft (96%) RQD: 3.9ft (78%)
RUN 6: 29.9ft - 34.9ft REC: 5.0ft (100%) RQD: 4.4ft (88%)
RUN 7: 34.9ft - 39.9ft REC: 4.4ft (88%) RQD: 4.2ft (84%)
RUN 8: 39.9ft - 44.9ft REC: 5.0ft (100%) RQD: 3.3ft (66%)
TOP


NORTH ANNA ESP
30720-2-5900
B-802 Box 3 of 5
Depth: 44.9 ft to 64.9 ft
Run 9: 44.9 ft – 49.9 ft Rec: 5.0 ft (100%) RQD: 4.8 ft (96%)
Run 10: 49.9 ft – 54.9 ft Rec: 5.0 ft (100%) RQD: 5.0 ft (100%)
Run 11: 54.9 ft – 59.9 ft Rec: 5.0 ft (100%) RQD: 4.0 ft (80%)
Run 12: 59.9 ft – 64.9 ft Rec: 5.0 ft (100%) RQD: 3.6 ft (72%)
TOP
BOTTOM
NORTH ANNA ESP
30720-2-5900
B-802 Box 4 of 5
Depth: 64.9 ft to 84.9 ft
Run 13: 64.9 ft – 69.9 ft Rec: 5.0 ft (100%) RQD: 4.0 ft (80%)
Run 14: 69.9 ft – 74.9 ft Rec: 5.0 ft (100%) RQD: 4.8 ft (96%)
Run 15: 74.9 ft – 79.9 ft Rec: 5.0 ft (100%) RQD: 3.6 ft (72%)
Run 16: 79.9 ft – 84.9 ft Rec: 5.0 ft (100%) RQD: 4.5 ft (90%)
TOP
BOTTOM


NORTH ANNA ESP
B-802 BOX 5 of 5
DEPTH: 84.9ft to 90.0ft
RUN 17: 84.9ft - 90.0ft REC: 5.1ft (100%) RQD: 4.7ft (92%)
SPACER
SPACER

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Raleigh, NC 27604

GEOTECHNICAL BORING LOG

SHEET 1 OF 5

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER:** 30720-2-5400	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-803			**0 HR.** 20.9
COLLAR ELEV. 292.4 ft **(NAVD 88)**	**NORTHING** 3,909,921.51 **(NAD 83)**	**EASTING** 11,685,763.76 **(NAD 83)**	**24 HR.** 21.0
TOTAL DEPTH 170.3 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/22/02	**COMPLETED** 12/2/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
292.4	0.0				Ground Surface				
292.4	0.0	3	5	7	12	SS-1			292.4 0.00 Residual: Brown, orange, and tan, loose, clayey, gravelly, coarse SAND (SC)
288.8	3.6	16	19	12	31	SS-2			289.9 2.5 Residual: Tan, dense, slightly clayey, fine to coarse sandy, GRAVEL (GP)
286.3	6.1	5	7	7	14	SS-3			286.9 5.5 Residual: Orange and tan, firm, slightly gravelly, clayey, fine to coarse SAND (SC)
283.8	8.6	11	13	9	22	SS-4			284.4 8.0 Residual: Orange, tan, whitish tan, and grayish white, firm to dense, micaceous, silty, fine to coarse SAND (SM)
281.3	11.1	6	6	7	13	SS-5			
278.7	13.7	10	12	11	23	SS-6			
273.8	18.6	10	9	9	18	SS-7			
268.8	23.6	14	14	17	31	SS-8			
263.8	28.6	17	14	16	30	SS-9			
258.8	33.6	43	57/0.4ft		100/0.9ft	SS-10			261.4 31.0 Weathered Rock: Gray and orange Fe stained, BIOTITE QUARTZ GNEISS
255.0	37.4								

NC_DOT.GDT 2/4/03

BECHTEL 5400

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GEOTECHNICAL BORING LOG

SHEET 2 OF 5

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-803			**0 HR.** 20.9
COLLAR ELEV. 292.4 ft **(NAVD 88)**	**NORTHING** 3,909,921.51 **(NAD 83)**	**EASTING** 11,685,763.76 **(NAD 83)**	**24 HR.** 21.0
TOTAL DEPTH 170.3 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/22/02	**COMPLETED** 12/2/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
255.0	37.4				Continued from previous page				
253.8	38.6	50/0.5ft			100/0.5ft	SS-11			Weathered Rock: Gray and orange Fe stained, BIOTITE QUARTZ GNEISS *(continued)*
248.8	43.6	50/0.2ft			100/0.2ft	SS-12			
243.6	48.8	50/0.0ft			100/0.0ft	SS-13			Hard Rock: Grayish white, slightly to very slightly weathered, closely to moderately closely fractured, hard, QUARTZ GNEISS with Biotite (5%)
233.9	58.5								Hard Rock: Gray, very slightly weathered, closely to moderately closely fractured, very hard, QUARTZITE
232.0	60.4								Hard Rock: Gray and pink, locally with orange Fe stain, very slightly weathered to fresh, very closely to very widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%) and trace pyrite
217.6	74.8								

BECHTEL 5400.VC DOT.GDT 2/4/03

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GEOTECHNICAL BORING LOG

SHEET 3 OF 5

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER:** 30720-2-5400	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-803			**0 HR.** 20.9
COLLAR ELEV. 292.4 ft **(NAVD 88)**	**NORTHING** 3,909,921.51 **(NAD 83)**	**EASTING** 11,685,763.76 **(NAD 83)**	**24 HR.** 21.0
TOTAL DEPTH 170.3 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/22/02	**COMPLETED** 12/2/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
217.6	74.8				Continued from previous page				
									Hard Rock: Gray and pink, locally with orange Fe stain, very slightly weathered to fresh, very closely to very widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%) and trace pyrite *(continued)*
180.2	112.2								

BECHTEL 5400.iC DOT.GDT 2/4/03

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GEOTECHNICAL BORING LOG

SHEET 4 OF 5

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-803			**0 HR.** 20.9
COLLAR ELEV. 292.4 ft **(NAVD 88)**	**NORTHING** 3,909,921.51 **(NAD 83)**	**EASTING** 11,685,763.76 **(NAD 83)**	**24 HR.** 21.0
TOTAL DEPTH 170.3 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/22/02	**COMPLETED** 12/2/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
180.2	112.2				Continued from previous page				Hard Rock: Gray and pink, locally with orange Fe stain, very slightly weathered to fresh, very closely to very widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%) and trace pyrite *(continued)*
142.8	149.6								

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GEOTECHNICAL BORING LOG
SHEET 5 OF 5

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-803			**0 HR.** 20.9
COLLAR ELEV. 292.4 ft **(NAVD 88)**	**NORTHING** 3,909,921.51 **(NAD 83)**	**EASTING** 11,685,763.76 **(NAD 83)**	**24 HR.** 21.0
TOTAL DEPTH 170.3 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/22/02	**COMPLETED** 12/2/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
142.8	149.6				Continued from previous page				
									Hard Rock: Gray and pink, locally with orange Fe stain, very slightly weathered to fresh, very closely to very widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%) and trace pyrite *(continued)*
122.1	170.3								Boring and Coring terminated at 170.3 ft in Hard Rock: Fresh, very widely fractured, very hard, Quartz Gneiss with biotite (5%), magnetite (1%) and trace pyrite Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated) Drilling Fluid: Water Borehole filled by grouting 12/9/03
105.4	187.0								

BECIC_DOT.GDT 2/4/03

BECHTEL 5400.

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CORE BORING REPORT

SHEET 1 OF 4

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-803			**0 HR.** 20.9
COLLAR ELEV. 292.4 ft **(NAVD 88)**	**NORTHING** 3,909,921.51 **(NAD 83)**	**EASTING** 11,685,763.76 **(NAD 83)**	**24 HR.** 21.0
TOTAL DEPTH 170.3 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/22/02	**COMPLETED** 12/2/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 121.5 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Begin Coring @ 48.8 ft
243.6	48.8	1.6	2:38	(1.3) 81%	(1.3) 81%	RUN 1				243.6 48.8 Hard Rock: Grayish white, slightly to very slightly weathered, closely to moderately closely fractured, hard, QUARTZ GNEISS with Biotite (5%) (2 joints at 45° with trace clay and white mica)
242.0	50.4		1:08/0.6							
		5.0	2:12	(5.0) 100%	(5.0) 100%	RUN 2				(2 joints at 20° with trace clay; 1 joint at 50° with clay and orange Fe stain; 1 joint at 70° with clay and brown Fe stain)
			1:48							
			2:12							
			2:21							
237.0	55.4		2:44							
		5.0	3:02	(4.4) 88%	(3.3) 66%	RUN 3				(1 joint at 50° with clay and brown Fe stain; Severely weathered fracture zones with no recovery from 56.9ft to 57.3ft and 58.3ft to 58.5ft - **Severe water loss in these zones for duration of drilling**)
			2:24							
			1:10							
			3:18							233.9 58.5 Hard Rock: Gray, very slightly weathered, closely to moderately closely fractured, very hard, QUARTZITE
			6:17							
232.0	60.4									232.0 60.4
		5.0	1:53	(5.0) 100%	(5.0) 100%	RUN 4				Hard Rock: Gray and pink, locally with orange Fe stain, very slightly weathered to fresh, very closely to very widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%) and trace pyrite (1 joint at 60° with trace clay, white mica, and brown Fe stain; 2 joints at 30-35° with white mica and orange Fe stain)
			2:40							
			3:52							
			4:25							
227.0	65.4		5:00							
		5.0	4:13	(5.0) 100%	(4.4) 88%	RUN 5				(7 joints at 0-10° with white mica and orange Fe stain; 1 joint at 30° with white mica)
			4:33							
			5:16							
			4:56							
222.0	70.4		5:59							
		4.9	6:27	(4.9) 100%	(4.5) 92%	RUN 6				(3 joints at 0-10° with white mica and orange Fe stain; 2 joints at 30-35° with white mica and orange Fe stain; 1 joint at 60° with clay and brown Fe stain)
			5:40							
			5:44							
			6:02							
217.1	75.3		8:21/0.9							
		5.0	6:36	(5.0) 100%	(5.0) 100%	RUN 7				(1 joint at 40° with clay and orange Fe stain; 2 joints at 70° with clay, orange Fe stain, and Mn oxide; 1 joint at 80-85° with orange Fe stain)
			7:43							
			7:55							
			10:05							
212.1	80.3		12:53							
		5.0	1:45	(4.9) 98%	(4.4) 88%	RUN 8				(3 joints at 0-10° with white mica, clay, and brown Fe stain; 1 joint at 45° with brown Fe stain; 1 joint at 75° orange Fe stain; Severely weathered fracture zone from 81.0ft to 81.3ft)
			1:53							
			3:00							
			2:56							
207.1	85.3		2:25							
		5.0	2:41	(5.0)	(5.0)	RUN 9				(1 joint at 70° with trace clay)

BECHTEL CORE1.LC A.GPJ NC_DOT.GDT 2/3/03

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CORE BORING REPORT
SHEET 2 OF 4

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-803			**0 HR.** 20.9
COLLAR ELEV. 292.4 ft **(NAVD 88)**	**NORTHING** 3,909,921.51 **(NAD 83)**	**EASTING** 11,685,763.76 **(NAD 83)**	**24 HR.** 21.0
TOTAL DEPTH 170.3 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/22/02	**COMPLETED** 12/2/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 121.5 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Continued from previous page
			2:58	100%	100%					Hard Rock: Gray and pink, locally with orange Fe stain, very slightly weathered to fresh, very closely to very widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%) and trace pyrite *(continued)*
			2:21							
			3:35							
202.1	90.3		3:53							
		5.0	3:04	(5.0) 100%	(5.0) 100%	RUN 10				(1 joint at 75° with clay and chlorite)
			3:47							
			7:56							
			6:05							
197.1	95.3		6:26							
		5.0	7:13	(5.0) 100%	(5.0) 100%	RUN 11				(1 joint at 80-90° with trace clay and brown Fe stain; 1 joint at 50° with brown Fe stain)
			8:11							
			8:09							
			9:45							
192.1	100.3		15:22							
191.1	101.3	1.0	29.20	(1.0) 100%	(1.0) 100%	RUN 12				(No joints)
		4.0	3:07	(4.0) 100%	(4.0) 100%	RUN 13				(1 joint at 50°)
			2:08							
			2:07							
187.1	105.3		2:08							
		5.0	2:05	(5.0) 100%	(5.0) 100%	RUN 14				(No joints)
			2:10							
			2:22							
			2:34							
182.1	110.3		2:31							
		5.0	2:55	(5.0) 100%	(5.0) 100%	RUN 15				(1 joint at 30° with coarse white mica)
			3:05							
			3:06							
			3:50							
177.1	115.3		4:28							
		5.0	3:49	(5.0) 100%	(5.0) 100%	RUN 16				(Coarse quartz and potassium feldspar vein/zone from 115.3ft to 116.3ft at 65°)
			7:09							
			11:48							
			22:34							
172.1	120.3		7:35							
		5.0	3:45	(5.0) 100%	(5.0) 100%	RUN 17				(1 joint at 55° with chlorite mineralization)
			2:03							
			2:06							

A.GPJ NC_DOT.GDT 2/3/03

BECHTEL CORE1 LC

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CORE BORING REPORT

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-803			**0 HR.** 20.9
COLLAR ELEV. 292.4 ft **(NAVD 88)**	**NORTHING** 3,909,921.51 **(NAD 83)**	**EASTING** 11,685,763.76 **(NAD 83)**	**24 HR.** 21.0
TOTAL DEPTH 170.3 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/22/02	**COMPLETED** 12/2/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 121.5 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Continued from previous page
			2:38							Hard Rock: Gray and pink, locally with orange Fe stain, very slightly weathered to fresh, very closely to very widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%) and trace pyrite *(continued)*
167.1	125.3		3:04							
		5.0	3:32	(5.0) 100%	(5.0) 100%	RUN 18				(No joints)
			4:07							
			5:04							
			7:35							
162.1	130.3		13:00							
		5.0	3:15	(5.0) 100%	(5.0) 100%	RUN 19				(No joints)
			3:45							
			3:57							
			4:25							
157.1	135.3		4:15							
		5.0	4:30	(5.0) 100%	(5.0) 100%	RUN 20				(Coarse quartz, potassium feldspar, and white mica vein/zone from 137.8ft to 138.3ft at 60° with gradational margins)
			5:51							
			7:19							
			10:29							
152.1	140.3		17:14							
		5.0	14:21	(5.0) 100%	(5.0) 100%	RUN 21				(Coarse quartz, potassium feldspar, and white mica vein/zone from 144.3ft to 144.8ft at 65° with gradational margins)
			18:42							
			9:26							
			2:18							
147.1	145.3		2:22							
		5.0	2:03	(5.0) 100%	(5.0) 100%	RUN 22				(Coarse quartz, potassium feldspar, and white mica vein/zone from 147.0ft to 147.1ft at 60° with gradational margins)
			2:34							
			2:36							
			2:40							
142.1	150.3		2:47							
		5.0	3:31	(5.0) 100%	(5.0) 100%	RUN 23				(No joints)
			3:39							
			4:14							
			4:45							
137.1	155.3		6:16							
		3.0	3:20	(3.0) 100%	(3.0) 100%	RUN 24				(No joints)
			7:56							
			10:54							
134.1	158.3									
		2.0	3:53	(2.0) 100%	(2.0) 100%	RUN 25				(No joints)
132.1	160.3		2:55							
		5.0	2:47	(5.0)	(5.0)	RUN 26				(No joints)

A.GPJ NC_DOT.GDT 2/3/03

BECHTEL CORE1 LC

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CORE BORING REPORT

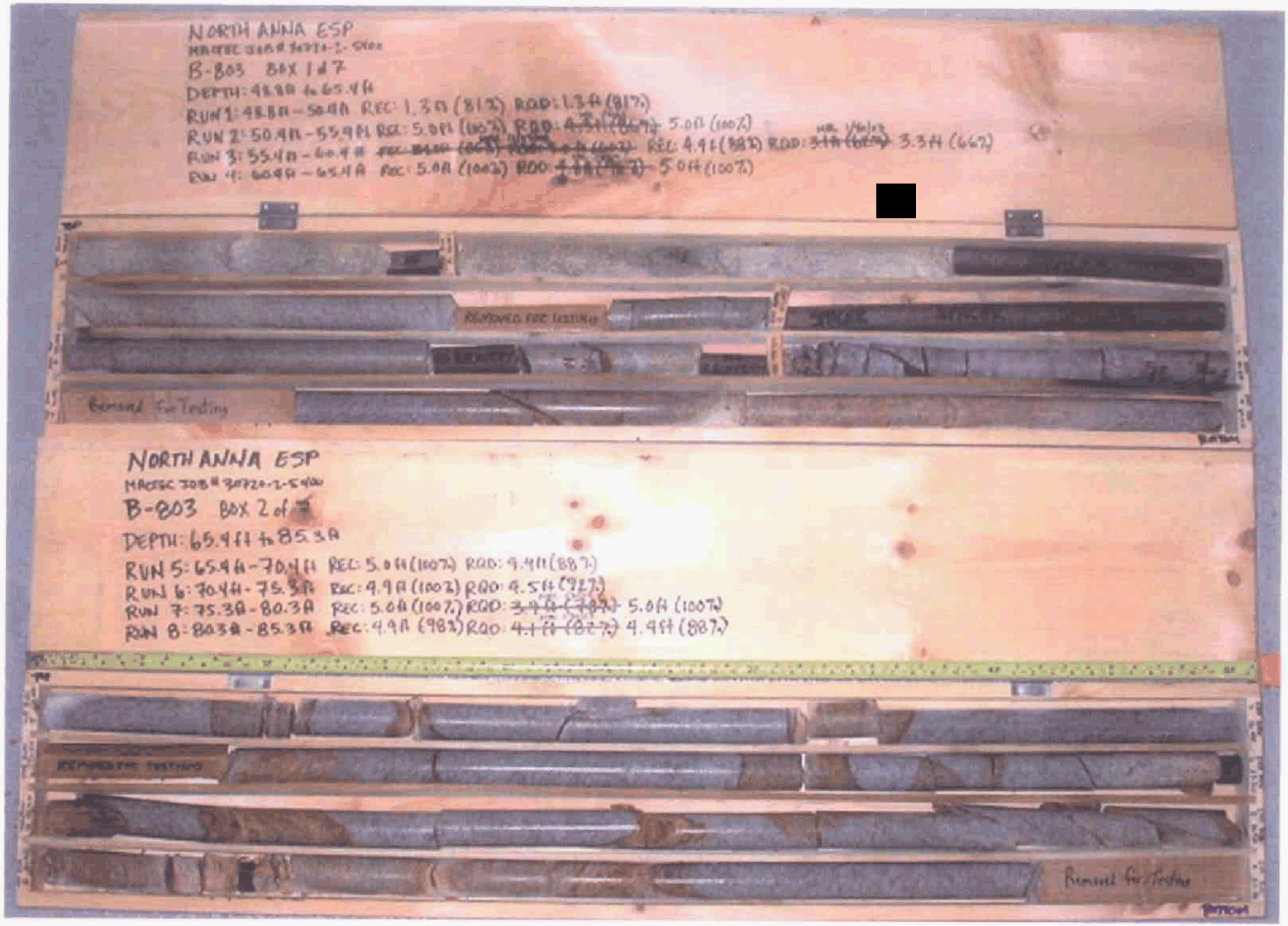
SHEET 4 OF 4

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-803			**0 HR.** 20.9
COLLAR ELEV. 292.4 ft **(NAVD 88)**	**NORTHING** 3,909,921.51 **(NAD 83)**	**EASTING** 11,685,763.76 **(NAD 83)**	**24 HR.** 21.0
TOTAL DEPTH 170.3 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/22/02	**COMPLETED** 12/2/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 121.5 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Continued from previous page
			2:22 2:19 2:41 2:40	100%	100%					Hard Rock: Gray and pink, locally with orange Fe stain, very slightly weathered to fresh, very closely to very widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%) and trace pyrite *(continued)*
127.1	165.3									
		5.0	2:53 2:57 3:31 3:45 3:31	(5.0) 100%	(5.0) 100%	RUN 27				(No joints)
122.1	170.3									122.1 — 170.3
										Boring and Coring terminated at 170.3 ft in Hard Rock: Fresh, very widely fractured, very hard, Quartz Gneiss with biotite (5%), magnetite (1%) and trace pyrite
										Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated)
										Drilling Fluid: Water
										Borehole filled by grouting 12/9/03

BECHTEL CORE1 LC JA.GPJ NC_DOT.GDT 2/3/03


NORTH ANNA ESP
B-803 BOX 1 of 7
DEPTH: 48.8ft to 65.4ft
RUN 1: 48.8ft - 50.8ft REC: 1.3ft (81%) RQD: 1.3ft (81%)
RUN 2: 50.4ft - 55.9ft REC: 5.0ft (100%) RQD: 5.0ft (100%)
RUN 3: 55.4ft - 60.4ft REC: 4.9ft (98%) RQD: 3.3ft (66%)
RUN 4: 60.4ft - 65.4ft REC: 5.0ft (100%) RQD: 5.0ft (100%)
Remand for Testing
NORTH ANNA ESP
B-803 BOX 2 of 7
DEPTH: 65.4ft to 85.3ft
RUN 5: 65.4ft - 70.4ft REC: 5.0ft (100%) RQD: 4.9ft (88%)
RUN 6: 70.4ft - 75.3ft REC: 4.9ft (100%) RQD: 4.5ft (92%)
RUN 7: 75.3ft - 80.3ft REC: 5.0ft (100%) RQD: 5.0ft (100%)
RUN 8: 80.3ft - 85.3ft REC: 4.9ft (98%) RQD: 4.9ft (88%)
Remand for Testing


NARTHANNA ESP
B-803 BOX 5 of 7
DEPTH: 85.5 ft & 105.5 ft 105.2 ft
RUN 9: 85.5 ft - 90.3 ft REC: 5.0 ft (100%) RQD: 4.8 ft (96%)
RUN 10: 90.3 ft - 95.3 ft REC: 5.0 ft (100%) RQD: 4.9 ft (98%) = 5.0 ft (100%)
RUN 11: 95.3 ft - 100.3 ft REC: 5.0 ft (100%) RQD: 4.9 ft (98%) = 5.0 ft (100%)
RUN 12: 100.3 ft - 101.3 ft REC: 1.0 ft (100%) RQD: 1.0 ft (100%)
RUN 13: 101.3 ft - 105.3 ft REC: 3.9 ft (98%) RQD: 3.9 ft (98%)
4.0 ft (100%) RQD: 4.0 ft (100%)
BKB 1-22-03
TOP
NARTHANNA ESP
B-803 BOX 6 of 7
DEPTH: 105.2 ft & 120.2 ft
RUN 14: 105.3 ft & 110.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 15: 110.3 ft & 115.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 16: 115.3 ft & 120.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
TOP
SPACER
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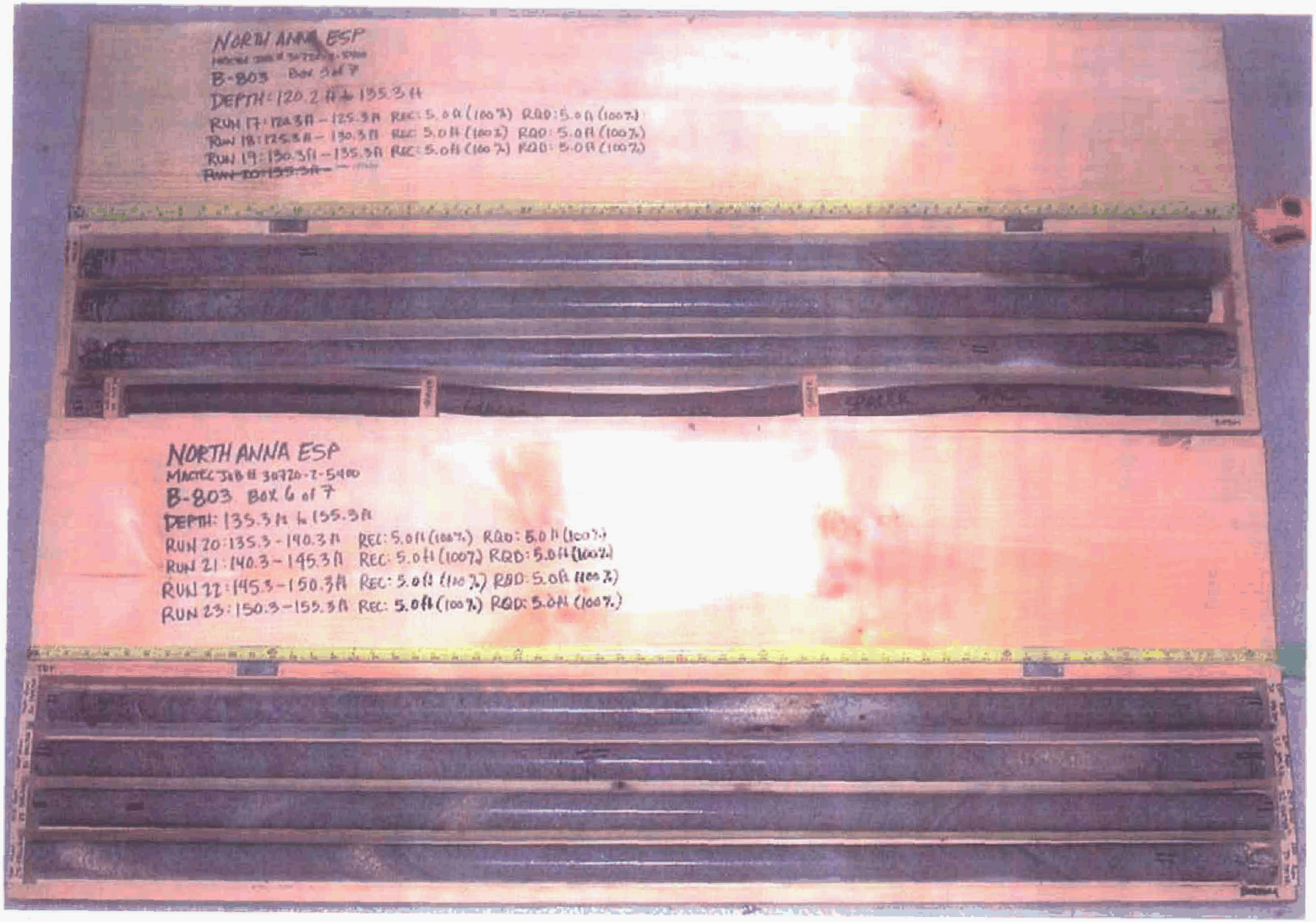
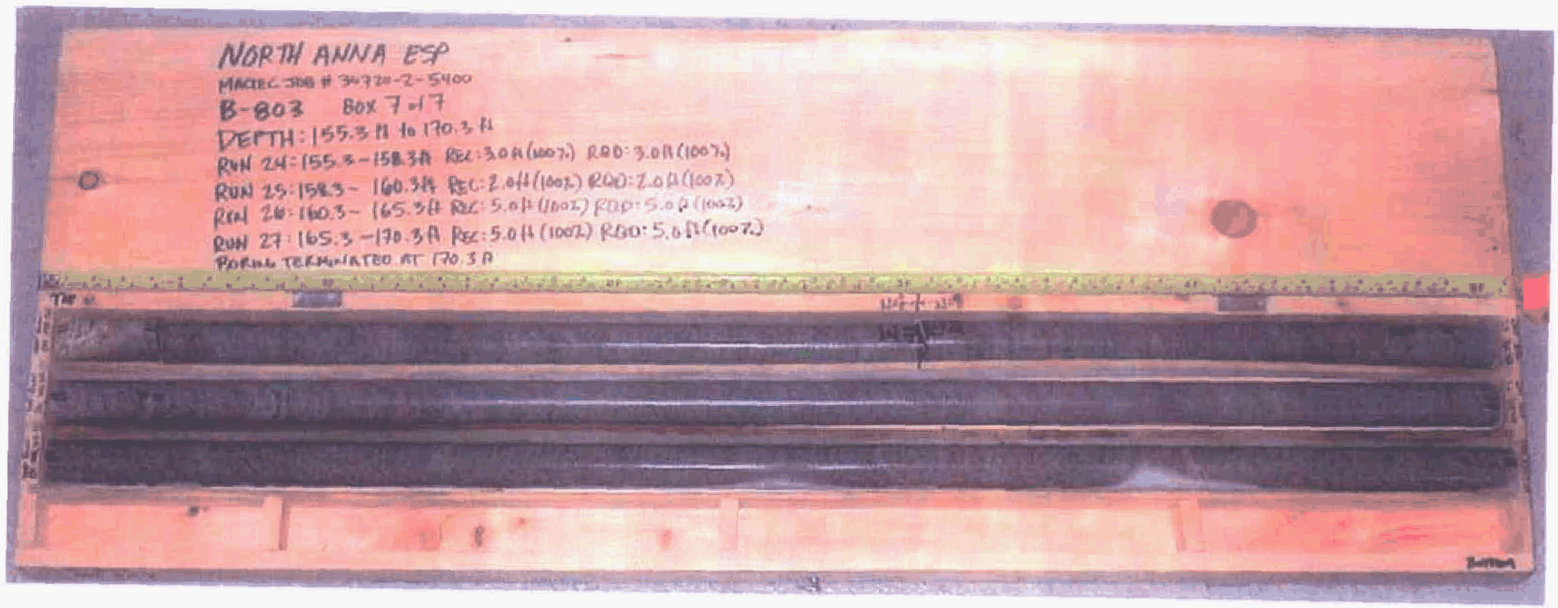
SPACER


NORTH ANNA ESP
B-803 Box 5 of 7
DEPTH: 120.2 ft to 155.3 ft
RUN 17: 120.3 ft – 125.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 18: 125.3 ft – 130.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 19: 130.3 ft – 135.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
NORTH ANNA ESP
MACTEC JOB # 30720-2-5400
B-803 Box 6 of 7
DEPTH: 135.3 ft to 155.3 ft
RUN 20: 135.3 – 140.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 21: 140.3 – 145.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 22: 145.3 – 150.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 23: 150.3 – 155.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)


NORTH ANNA ESP
MACTEC 308 # 34720-2-5400
B-803 Box 7 of 7
DEPTH: 155.3 ft to 170.3 ft
RUN 24: 155.3 - 158.3 ft REC: 3.0 ft (100%) RQD: 3.0 ft (100%)
RUN 25: 158.3 - 160.3 ft REC: 2.0 ft (100%) RQD: 2.0 ft (100%)
RUN 26: 160.3 - 165.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 27: 165.3 - 170.3 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
BORING TERMINATED AT 170.3 ft

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GEOTECHNICAL BORING LOG
SHEET 1 OF 2

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-804			**0 HR.** 26.3
COLLAR ELEV. 320.0 ft **(NAVD 88)**	**NORTHING** 3,909,497.24 **(NAD 83)**	**EASTING** 11,685,134.75 **(NAD 83)**	**24 HR.** 28.6
TOTAL DEPTH 59.9 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/4/02	**COMPLETED** 12/6/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
320.0	0.0				Ground Surface				
320.0	0.0	4	5	8	13	SS-1			Residual: Reddish brown, stiff, slightly gravelly, slightly sandy, CLAY (CL)
318.5	1.5	7	6	7	13	SS-2			Residual: Brown, stiff, micaceous, fine sandy, SILT (ML)
316.5	3.5	4	3	3	6	SS-3			
314.0	6.0	2	3	3	6	SS-4			Residual: Brown, orangish brown, gray, and tan, loose to very firm, micaceous, slightly clayey, silty, fine to medium SAND (SM) with relict rock fabric
311.5	8.5	2	2	3	5	SS-5			
309.0	11.0	3	2	3	5	SS-6			
306.5	13.5	2	3	6	9	SS-7			
301.5	18.5	11	12	12	24	SS-8			
296.5	23.5	50/0.4ft			100/0.4ft	SS-9			
291.5	28.5	50/0.3ft			100/0.3ft	SS-10			
286.6	33.4	50/0.0ft			100/0.0ft	SS-11			
282.6	37.4								

320.0 — 0.00
318.5 — 1.5
315.0 — 5.0
297.5 — 22.5
286.6 — 33.4
285.4 — 34.6
284.7 — 35.3

Weathered Rock: Gray, QUARTZ GNEISS

Hard Rock: Tan and gray, moderately to slightly weathered, very closely to closely fractured, moderately hard to hard, QUARTZ GNEISS with Biotite (5%)

Weathered Rock: No recovery - Interpreted as QUARTZ GNEISS

Hard Rock: Gray, locally with tan and orange

NC_DOT.GDT 2/4/03

BECHTEL 540(

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GEOTECHNICAL BORING LOG
SHEET 2 OF 2

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-804			**0 HR.** 26.3
COLLAR ELEV. 320.0 ft **(NAVD 88)**	**NORTHING** 3,909,497.24 **(NAD 83)**	**EASTING** 11,685,134.75 **(NAD 83)**	**24 HR.** 28.6
TOTAL DEPTH 59.9 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/4/02	**COMPLETED** 12/6/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
282.6	37.4				Continued from previous page				
									Fe stain, very slightly weathered to fresh, moderately closely to widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%) Hard Rock: Gray, locally with tan and orange Fe stain, very slightly weathered to fresh, moderately closely to widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%) *(continued)*
260.1	59.9								Boring and Coring terminated at 59.9 ft in Hard Rock: Very slightly weathered to fresh, widely fractured, very hard, Quartz Gneiss with biotite (5%) and magnetite (1%) Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated) Drilling Fluid: Water Borehole filled by grouting 12/17/02
245.2	74.8								

BECHTEL 5406 NC DOT.GDT 2/4/03

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CORE BORING REPORT

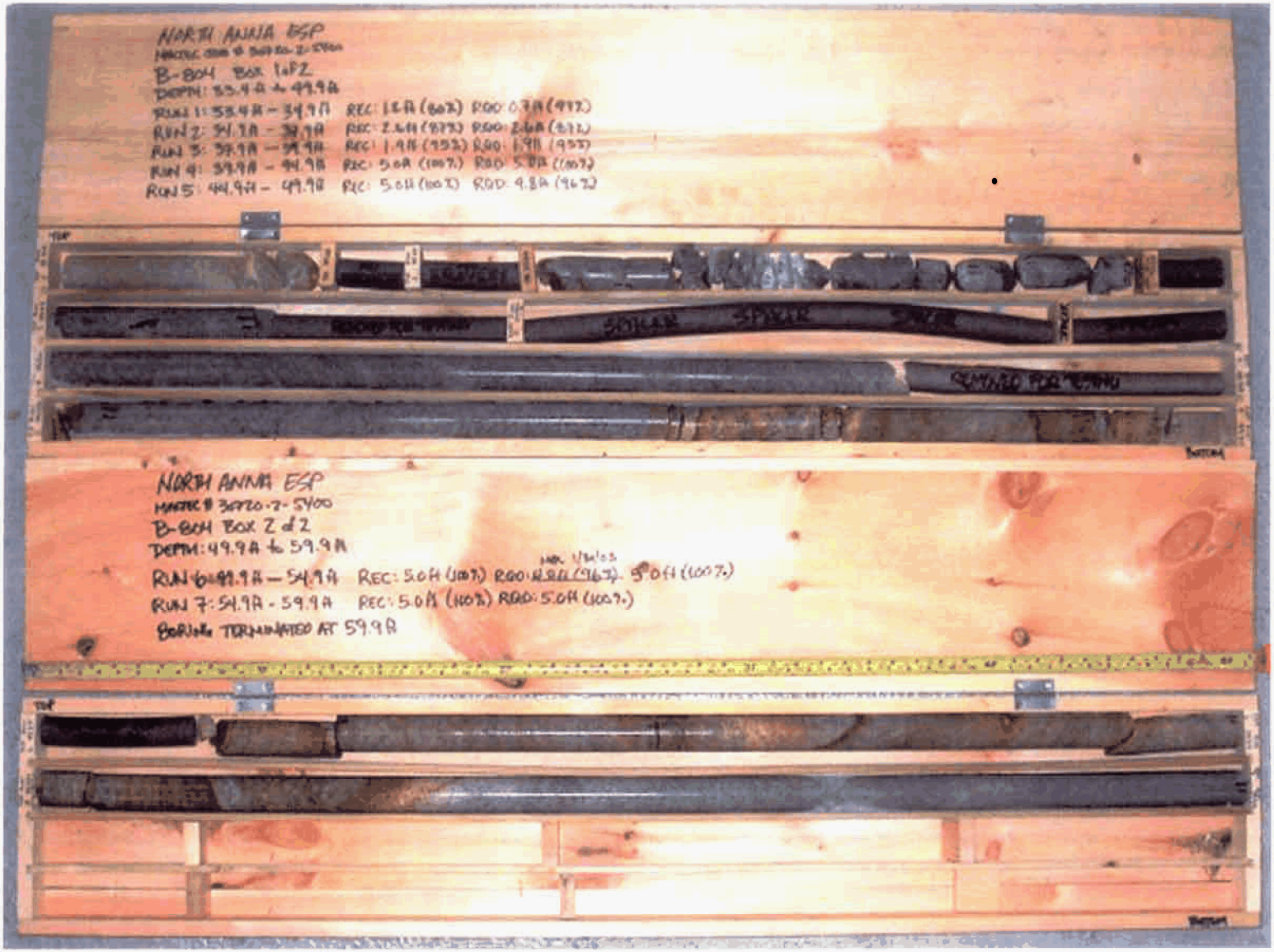
SHEET 1 OF 1

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-804			**0 HR.** 26.3
COLLAR ELEV. 320.0 ft **(NAVD 88)**	**NORTHING** 3,909,497.24 **(NAD 83)**	**EASTING** 11,685,134.75 **(NAD 83)**	**24 HR.** 28.6
TOTAL DEPTH 59.9 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/4/02	**COMPLETED** 12/6/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 26.5 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Begin Coring @ 33.4 ft
286.6	33.4	1.5	1:43	(1.2) 80%	(0.7) 47%	RUN 1				286.6 Hard Rock: Tan and gray, moderately to slightly weathered, very closely to closely fractured, moderately hard to hard, QUARTZ GNEISS with Biotite (5%) 33.4
285.1	34.9		0:50/0.5							285.4 34.6
										284.7 Weathered Rock: No recovery - Interpreted as QUARTZ GNEISS 35.3
		3.0	2:50	(2.6) 87%	(2.6) 87%	RUN 2				Hard Rock: Gray, locally with tan and orange Fe stain, very slightly weathered to fresh, moderately closely to widely fractured, hard to very hard, QUARTZ GNEISS with Biotite (5%) and Magnetite (trace to 1%)
			2:53							
			3:01							
282.1	37.9									
		2.0	2:19	(1.9) 95%	(1.9) 95%	RUN 3				(No Joints)
280.1	39.9		2:37							
		5.0	1:25	(5.0) 100%	(5.0) 100%	RUN 4				(2 joints at 40-50° with trace clay, white mica, and orange Fe stain)
			1:25							
			1:29							
			1:44							
275.1	44.9		1:40							
		5.0	2:07	(5.0) 100%	(4.8) 96%	RUN 5				(5 joints at 0-10° with trace clay and orange Fe stain)
			2:31							
			2:14							
			1:43							
270.1	49.9		1:33							
		5.0	1:21	(5.0) 100%	(5.0) 100%	RUN 6				(2 joints at 55° with orange Fe stain)
			1:35							
			1:34							
			1:52							
265.1	54.9		1:54							
		5.0	1:45	(5.0) 100%	(5.0) 100%	RUN 7				(1 joint at 10° with trace clay)
			2:04							
			1:54							
			2:00							
260.1	59.9		2:14							260.1 59.9
										Boring and Coring terminated at 59.9 ft in Hard Rock: Very slightly weathered to fresh, widely fractured, very hard, Quartz Gneiss with biotite (5%) and magnetite (1%)
										Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated)
										Drilling Fluid: Water
										Borehole filled by grouting 12/17/02

BECHTEL COREI LL JA.GPJ NC_DOT.GDT 2/3/03


NORTH ANNA ESP
B-804 BOX 1 of 2
DEPTH: 33.4 ft to 49.9 ft
RUN 1: 33.4 ft - 34.9 ft REC: 1.5 ft (86%) RQD: 0.7 ft (91%)
RUN 2: 34.9 ft - 39.9 ft REC: 2.6 ft (97%) RQD: 2.6 ft (81%)
RUN 3: 39.9 ft - 44.9 ft REC: 1.9 ft (95%) RQD: 1.9 ft (95%)
RUN 4: 39.9 ft - 44.9 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
RUN 5: 44.9 ft - 49.9 ft REC: 5.0 ft (100%) RQD: 4.8 ft (96%)
NORTH ANNA ESP
B-804 BOX 2 of 2
DEPTH: 49.9 ft to 59.9 ft
RUN 6: 49.9 ft - 54.9 ft REC: 5.0 ft (100%) RQD: 4.8 ft (96%) 5.0 ft (100%)
RUN 7: 54.9 ft - 59.9 ft REC: 5.0 ft (100%) RQD: 5.0 ft (100%)
BORING TERMINATED AT 59.9 ft

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GEOTECHNICAL BORING LOG

SHEET 1 OF 3

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-805			**0 HR.** 10.6
COLLAR ELEV. 271.1 ft **(NAVD 88)**	**NORTHING** 3,910,361.58 **(NAD 83)**	**EASTING** 11,686,246.96 **(NAD 83)**	**24 HR.** 9.6
TOTAL DEPTH 90.1 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Mud Rotary/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/20/02	**COMPLETED** 11/22/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
271.1	0.0				Ground Surface				
271.1	0.0	3	6	6	12	SS-1			271.1 0.00 Residual: Orange and tan, stiff to very stiff, micaceous, slightly sandy, SILT (ML)
268.6	2.5	8	11	9	No Recovery 20	SS-2			
266.2	4.9	6	7	7	14	SS-3			266.6 4.5 Residual: Black, red, orange and white, micaceous, stiff to hard, slightly sandy, SILT (ML) with relict rock fabric
263.6	7.5	5	7	10	17	SS-4	▽		263.6 7.5 Residual: Black, orange, and white, dense to very dense, micaceous, silty, fine SAND (SM) with relict rock fabric
260.5	10.6	12	12	13	25	SS-5			
257.6	13.5	18	19	19	38	SS-6			
252.6	18.5	11	14	20	34	SS-7			
247.6	23.5	44	56/0.2ft		100/0.7ft	SS-8			
242.7	28.4	50/0.05ft			100/0.05ft	SS-9			242.7 28.4 Weathered Rock: Black and orange Fe stained, BIOTITE GNEISS
									240.0 31.1 Hard Rock: Black and white, slightly weathered, closely fractured, moderately hard, BIOTITE GNEISS
									238.9 32.2 Weathered Rock: Partial recovery, BIOTITE GNEISS
									235.5 35.6 Hard Rock: Black and white, moderately weathered, very closely to closely fractured, medium to moderately hard, BIOTITE GNEISS
233.7	37.4								234.3 36.8

.C DOT.GDT 2/4/03

BECHTEL 5400/

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GEOTECHNICAL BORING LOG
SHEET 2 OF 3

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-805			**0 HR.** 10.6
COLLAR ELEV. 271.1 ft **(NAVD 88)**	**NORTHING** 3,910,361.58 **(NAD 83)**	**EASTING** 11,686,246.96 **(NAD 83)**	**24 HR.** 9.6
TOTAL DEPTH 90.1 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Mud Rotary/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/20/02	**COMPLETED** 11/22/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
233.7	37.4				Continued from previous page				
232.4	38.7								Weathered Rock: No recovery - Interpreted as BIOTITE GNEISS *(continued)*
									Hard Rock: Gray, black, and white, moderately to very slightly weathered, very closely to moderately closely fractured, moderately hard to hard, locally slightly schistose, BIOTITE GNEISS
196.3	74.8								196.5 / 74.6

NC_DOT.GDT 2/4/03

BECHTEL 5400

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GEOTECHNICAL BORING LOG
SHEET 3 OF 3

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-805			**0 HR.** 10.6
COLLAR ELEV. 271.1 ft **(NAVD 88)**	**NORTHING** 3,910,361.58 **(NAD 83)**	**EASTING** 11,686,246.96 **(NAD 83)**	**24 HR.** 9.6
TOTAL DEPTH 90.1 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Mud Rotary/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/20/02	**COMPLETED** 11/22/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
196.3	74.8				Continued from previous page				
									195.4 Weathered Rock: No recovery - Interpreted as BIOTITE GNEISS *(continued)* 75.7
									Hard Rock: Gray, black, and white, moderately weathered to fresh, very closely to widely fractured, moderately hard to hard, slightly schistose, BIOTITE GNEISS
									181.0 90.1
									Boring and Coring terminated at 90.1 ft in Hard Rock: Slightly weathered to fresh, closely to moderately closely fractured, hard, slightly schistose, Biotite Gneiss
									Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated)
									Drilling Fluid: Water/Bentonite (weight unknown)
									Borehole filled by grouting 12/6/02
158.9	112.2								

BECHTEL 5406 VC_DOT.GDT 2/4/03

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CORE BORING REPORT

SHEET 1 OF 2

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-805			**0 HR.** 10.6
COLLAR ELEV. 271.1 ft **(NAVD 88)**	**NORTHING** 3,910,361.58 **(NAD 83)**	**EASTING** 11,686,246.96 **(NAD 83)**	**24 HR.** 9.6
TOTAL DEPTH 90.1 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Mud Rotary/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/20/02	**COMPLETED** 11/22/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 61.6 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Begin Coring @ 28.5 ft
242.6	28.5	1.6	1:25	(0.0) 0%	(N/A)	RUN 1				Weathered Rock: No recovery - Interpreted as BIOTITE GNEISS
241.0	30.1		0:52/0.6							
		5.0	1:45	(2.9) 58%	(1.1) 22%	RUN 2				
			1:08							240.0 — 31.1
			1:06							Hard Rock: Black and white, slightly weathered, closely fractured, moderately hard, BIOTITE GNEISS
			1:09							238.9 — 32.2
			0:41							Weathered Rock: Partial recovery, BIOTITE GNEISS
236.0	35.1									
		5.0	1:40	(2.6) 52%	(0.4) 8%	RUN 3				235.5 — 35.6
			1:22							(2 joints at 0-10° with trace clay; 2 joints at 30-35° with trace clay; 1 joint at 20° with Quartz and Biotite; 1 joint at 50° with Quartz and Biotite)
			1:37							234.3 — 36.8
			1:31							Hard Rock: Black and white, moderately weathered, very closely to closely fractured medium to moderately hard, BIOTITE GNEISS — 37
			2:10							Weathered Rock: No recovery - Interpreted as BIOTITE GNEISS
231.0	40.1									232.4 — 38.7
		5.0	1:12	(5.0) 100%	(2.8) 56%	RUN 4				Hard Rock: Gray, black, and white, moderately to very slightly weathered, very closely to moderately closely fractured, moderately hard to hard, locally slightly schistose, BIOTITE GNEISS
			1:28							(14 joints at 30-35° with trace clay and Fe stain; 2 joints at 0-10°)
			1:37							
			1:45							
			1:49							
226.0	45.1									
		5.0	1:25	(4.0) 80%	(2.1) 42%	RUN 5				(7 joints at 30-35° with trace clay and Fe stain; 5 joints at 10-20°; Severely weathered fracture zone with no recovery from 48.1ft to 49.1ft)
			1:21							
			1:22							
			1:18							
			1:31							
221.0	50.1									
		5.0	1:35	(4.5) 90%	(4.1) 82%	RUN 6				(5 joints at 30-35° with trace clay; Severely weathered fracture zone with no recovery from 53.ft to 53.6ft)
			1:18							
			0:57							
			1:16							
			1:37							
216.0	55.1									
		5.0	1:12	(4.5) 90%	(3.6) 72%	RUN 7				(1 joint at 30°; 3 joints at 15-20° with trace clay and Fe stain; 0.2ft wide Quartz vein at 56.2ft; Severely weathered fracture zone with no recovery from 56.8ft to 57.3ft)
			1:00							
			1:10							
			1:39							
			1:53							
211.0	60.1									
		5.0	1:45	(4.1) 82%	(3.7) 74%	RUN 8				(5 joints at 30° with trace clay and Fe stain; 0.2ft wide coarse Quartz and Hornblende vein at 60°; Severely weathered fracture zone with no recovery from 62.9ft to 63.8ft)
			2:11							
			1:33							
			1:53							
			2:06							
206.0	65.1									
		5.0	1:56	(5.0)	(3.5)	RUN 9				(11 joints at 10-15° with clay and Fe stain; 1 joint at 60°)

BECHTEL CORE1 L 40A.GPJ NC_DOT.GDT 2/3/03

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CORE BORING REPORT

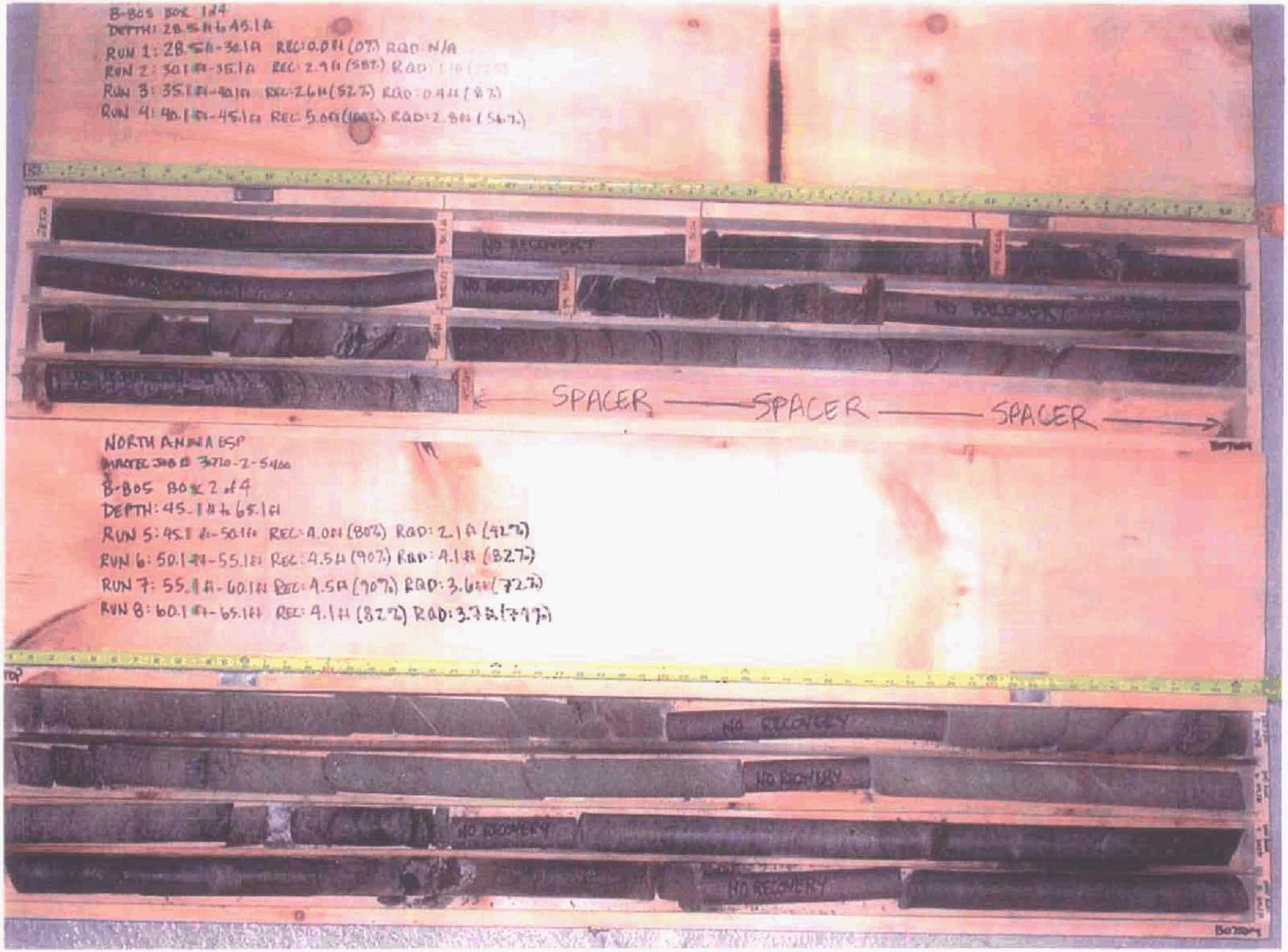
SHEET 2 OF 2

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-805			**0 HR.** 10.6
COLLAR ELEV. 271.1 ft **(NAVD 88)**	**NORTHING** 3,910,361.58 **(NAD 83)**	**EASTING** 11,686,246.96 **(NAD 83)**	**24 HR.** 9.6
TOTAL DEPTH 90.1 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Mud Rotary/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 11/20/02	**COMPLETED** 11/22/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 61.6 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Continued from previous page
			1:42	100%	70%					Hard Rock: Gray, black, and white, moderately to very slightly weathered, very closely to moderately closely fractured, moderately hard to hard, locally slightly schistose, BIOTITE GNEISS *(continued)*
			1:38							
			1:41							
201.0	70.1		1:58							
		5.0	1:34	(4.5) 90%	(3.8) 76%	RUN 10				(2 joints at 50° with clay and Fe stain; 4 joints at 30-35° with clay and Fe stain)
			1:58							
			2:07							
			2:02							
196.0	75.1		1:12							196.5 74.6
										Weathered Rock: No recovery - Interpreted as BIOTITE GNEISS
		5.0	1:10	(4.4) 88%	(4.0) 80%	RUN 11				195.4 75.7
			2:16							Hard Rock: Gray, black, and white, moderately weathered to fresh, very closely to widely fractured, moderately hard to hard, slightly schistose, BIOTITE GNEISS
			2:08							
			2:12							
191.0	80.1		2:16							
		5.0	1:44	(5.0) 100%	(4.6) 92%	RUN 12				(4 joints at 50° with trace clay and Quartz; 0.1ft wide Quartz vein at 50° at 84.0ft)
			1:37							
			1:56							
			1:33							
186.0	85.1		1:57							
		5.0	2:05	(5.0) 100%	(4.4) 88%	RUN 13				(5 joints at 30-35° with clay, Quartz, and Fe stain; 2 joints at 60-65° with clay, Quartz, and Fe stain; 3 joints at 0-10° with trace clay)
			2:19							
			2:39							
			1:52							
181.0	90.1		1:51							181.0 90.1
										Boring and Coring terminated at 90.1 ft in Hard Rock: Slightly weathered to fresh, closely to moderately closely fractured, hard, slightly schistose, Biotite Gneiss
										Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated)
										Drilling Fluid: Water/Bentonite (weight unknown)
										Borehole filled by grouting 12/6/02

BECHTEL COREJ LC A.GPJ NC_DOT.GDT 2/3/03


B-BOS BOX 1 of 4
DEPTH: 28.5 ft to 45.1 ft
RUN 1: 28.5 ft - 30.1 ft REC: 0.0 ft (0%) RQD: N/A
RUN 2: 30.1 ft - 35.1 ft REC: 2.9 ft (58%) RQD: 1.1 ft (22%)
RUN 3: 35.1 ft - 40.1 ft REC: 2.6 ft (52%) RQD: 0.4 ft (8%)
RUN 4: 40.1 ft - 45.1 ft REC: 5.0 ft (100%) RQD: 2.8 ft (56%)
NO RECOVERY
NO RECOVERY
NO RECOVERY
SPACER
SPACER
SPACER
NORTH ANNA ESP
PROJECT NO. 3270-2-5466
B-BOS BOX 2 of 4
DEPTH: 45.1 ft to 65.1 ft
RUN 5: 45.1 ft - 50.1 ft REC: 4.0 ft (80%) RQD: 2.1 ft (42%)
RUN 6: 50.1 ft - 55.1 ft REC: 4.5 ft (90%) RQD: 4.1 ft (82%)
RUN 7: 55.1 ft - 60.1 ft REC: 4.5 ft (90%) RQD: 3.6 ft (72%)
RUN 8: 60.1 ft - 65.1 ft REC: 4.1 ft (82%) RQD: 3.7 ft (74%)
NO RECOVERY
NO RECOVERY
NO RECOVERY
NO RECOVERY


NDETH ANNJA ESP
B-B05 Box 4 of 4
DEPTH: 85.1A & 90.1A
RUN 13: 85.1A & 90.1A REC: 5.0A (100%) RQD: 4.4A (88%)

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GEOTECHNICAL BORING LOG

SHEET 1 OF 2

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER:** 30720-2-5400	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-806			**0 HR.** 6.3
COLLAR ELEV. (NAVD 88)	**NORTHING** 3,909,416.24 (NAD 83)	**EASTING** 11,683,977.28 (NAD 83)	**24 HR.** FIAD
TOTAL DEPTH 64.5 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/12/02	**COMPLETED** 12/13/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
299.2	0.0				Ground Surface				299.2 0.00
298.7	0.5	14	27	15	42	SS-1			Fill: Tan, dense, silty, sandy, GRAVEL (GM) (Railroad Bed)
296.0	3.2	9	7	15	22	SS-2			296.7 2.5 Residual: Brown and dark gray, firm to very firm, micaceous, clayey, fine to coarse SAND (SC)
293.6	5.6	9	10	8	18	SS-3	▽		
291.2	8.0	50/0.3ft			100/0.3ft	SS-4			291.7 7.5 Weathered Rock: BIOTITE GNEISS
289.0	10.2	50/0.0ft			100/0.0ft	SS-5			288.4 10.8 Hard Rock: Dark gray, moderately to slightly weathered, very closely to closely fractured, moderately hard to hard, BIOTITE GNEISS with Epidote (5%)(7 joints at 40-50° with clay; Severely weathered fracture zone with no recovery from 10.8ft to 11.4ft)
									284.7 14.5
									283.9 15.3 Hard Rock: Grayish white, moderately weathered, very close to closely fractured, moderately hard, QUARTZ GNEISS with Biotite (5%)
									Weathered Rock: Partial recovery - Interpreted as BIOTITE GNEISS
									278.2 21.0 Hard Rock: Dark gray, moderately to slightly weathered, very closely to closely fractured, moderately hard to hard, BIOTITE GNEISS with Epidote (5%)
									273.4 25.8 Weathered Rock: Partial recovery - Interpreted as BIOTITE GNEISS
									265.8 33.4 Hard Rock: Dark to light gray, locally with orange Fe stain, moderately to slightly weathered, very closely to moderately closely fractured, moderately hard to hard, BIOTITE GNEISS
261.8	37.4								

BECHTEL 5406 NC_DOT.GDT 2/4/03

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GEOTECHNICAL BORING LOG
SHEET 2 OF 2

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-806			**0 HR.** 6.3
COLLAR ELEV. (NAVD 88)	**NORTHING** 3,909,416.24 (NAD 83)	**EASTING** 11,683,977.28 (NAD 83)	**24 HR.** FIAD
TOTAL DEPTH 64.5 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/12/02	**COMPLETED** 12/13/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
261.8	37.4				Continued from previous page				
									Hard Rock: Dark to light gray, locally with orange Fe stain, moderately to slightly weathered, very closely to moderately closely fractured, moderately hard to hard, BIOTITE GNEISS *(continued)*
243.4	55.8								Weathered Rock: Partial recovery - Brown, BIOTITE GNEISS
238.8	60.4								Hard Rock: Dark gray, moderately weathered, v. close to closely fractured, moderately hard, BIOTITE GNEISS
235.6	63.6								Hard Rock: Gray, slightly weathered to fresh, closely fractured, hard, QUARTZ GNEISS with Biotite (5%)
234.7	64.5								Boring and Coring terminated at 64.5ft in Hard Rock: Slightly weathered to fresh, closely fractured, hard, Quartz Gneiss with Biotite (5%)
224.4	74.8								Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated) Drilling Fluid: Water Borehole filled by grouting 12/12/02

VC_DOT.GDT 2/4/03

BECHTEL 5400

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CORE BORING REPORT

SHEET 1 OF 2

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-806			**0 HR.** 6.3
COLLAR ELEV. **(NAVD 88)**	**NORTHING** 3,909,416.24 **(NAD 83)**	**EASTING** 11,683,977.28 **(NAD 83)**	**24 HR.** FIAD
TOTAL DEPTH 64.5 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/12/02	**COMPLETED** 12/13/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 54.3 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Begin Coring @ 10.2 ft
289.0	10.2	4.3	2:02 1:34 2:05 2:03	(3.7) 86%	(2.8) 65%	RUN 1				288.4 — 10.8 Hard Rock: Dark gray, moderately to slightly weathered, very closely to closely fractured, moderately hard to hard, BIOTITE GNEISS with Epidote (5%)(7 joints at 40-50° with clay; Severely weathered fracture zone with no recovery from 10.8ft to 11.4ft)
284.7	14.5		0:25/0.3							284.7 — 14.5
		2.6	1:23 1:34	(0.8) 31%	(0.6) 23%	RUN 2				283.9 — 15.3 Hard Rock: Grayish white, moderately weathered, very close to closely fractured, moderately hard, QUARTZ GNEISS with Biotite (5%) Weathered Rock: Partial recovery - Interpreted as BIOTITE GNEISS
282.1	17.1		0:57/0.6							
			0:45/0.4							
281.5	17.7	2.4	1:54 1:31	(0.4) 17%	(0.0) 0%	RUN 3				
279.7	19.5									
279.1	20.1	5.0	1:09 0:57 1:22 1:15 1:19	(3.5) 70%	(1.2) 24%	RUN 4				278.2 — 21.0 Hard Rock: Dark gray, moderately to slightly weathered, very closely to closely fractured, moderately hard to hard, BIOTITE GNEISS with Epidote (5%)
274.7	24.5									
272.9	26.3	1.8	1:14 0:57/0.8	(1.4) 78%	(1.2) 67%	RUN 5				273.4 — 25.8 Weathered Rock: Partial recovery - Interpreted as BIOTITE GNEISS
269.7	29.5	3.2	1:03/0.2 1:48 1:47 1:45	(0.3) 9%	(0.0) 0%	RUN 6				
266.1	33.1	3.6	1:52 1:01 1:45 1:22/0.6	(0.0) 0%	(0.0) 0%	RUN 7				
264.7	34.5	1.4	1:02/0.4 1:36	(1.1) 79%	(0.4) 29%	RUN 8				265.8 — 33.4 (3 Joints at 30-40° with trace clay) Hard Rock: Dark to light gray, locally with orange Fe stain, moderately to slightly weathered, very closely to moderately closely fractured, moderately hard to hard, BIOTITE GNEISS (6 Joints at 30-40° with trace clay and orange Fe stain; 1 joint at 80-90° with clay, quartz and orange Fe stain)
259.7	39.5	5.0	1:39 1:34 1:40 1:31 1:21	(5.0) 100%	(3.4) 68%	RUN 9				
254.7	44.5	5.0	1:41 1:31 1:23 1:30 1:27	(5.0) 100%	(3.9) 78%	RUN 10				(13 Joints at 30-40° with trace clay and orange Fe stain)
		5.0	1:24 1:21 1:20	(4.7) 94%	(4.0) 80%	RUN 11				(5 Joints at 30-40° with orange Fe stain; Severely weathered fracture zone with partial recovery from 49.0ft to 49.5ft)

BECHTEL CORE1 LA 0A.GPJ NC_DOT.GDT 2/3/03

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CORE BORING REPORT
SHEET 2 OF 2

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Lear
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-806			**0 HR.** 6.3
COLLAR ELEV. **(NAVD 88)**	**NORTHING** 3,909,416.24 **(NAD 83)**	**EASTING** 11,683,977.28 **(NAD 83)**	**24 HR.** FIAD
TOTAL DEPTH 64.5 ft	**DRILL MACHINE** CME-550, ATV	**DRILL METHOD** Rotary Wash/Core	**HAMMER TYPE** 140 lb. Manual, #5
DATE STARTED 12/12/02	**COMPLETED** 12/13/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NQ	**TOTAL RUN** 54.3 ft	**DRILLER** K. Pendley	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Continued from previous page
			1:15							Hard Rock: Dark to light gray, locally with orange Fe stain, moderately to slightly weathered, very closely to moderately closely fractured, moderately hard to hard, BIOTITE GNEISS *(continued)*
			1:20							
249.7	49.5									
		5.0	1:31	(4.5) 90%	(3.7) 74%	RUN 12				(7 joints at 30-40° with trace clay and orange Fe stain; Severely weathered fracture zone with no recovery from 49.5ft to 50.0ft)
			1:34							
			1:25							
			1:30							
			1:41							
244.7	54.5									
		5.0	2:15	(3.0) 60%	(0.0) 0%	RUN 13				(3 Joints at 30-40° with clay; 2 joints at 0-10° with clay and Fe stain)
			2:16							
243.4										55.8
			1:35							Weathered Rock: Partial recovery - Brown, BIOTITE GNEISS
			1:34							
			2:30							
239.7	59.5									
		5.0	2:19	(4.8) 96%	(2.0) 40%	RUN 14				
			1:55							
238.8										60.4
			1:35							Hard Rock: Dark gray, moderately weathered, v. close to closely fractured, moderately hard, BIOTITE GNEISS
			2:11							
			5:46							
235.6										63.6
234.7	64.5									Hard Rock: Gray, slightly weathered to fresh, closely fractured, hard, QUARTZ GNEISS with Biotite (5%) 64.5
										Boring and Coring terminated at 64.5ft in Hard Rock: Slightly weathered to fresh, closely fractured, hard, Quartz Gneiss with Biotite (5%)
										Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated)
										Drilling Fluid: Water
										Borehole filled by grouting 12/12/02

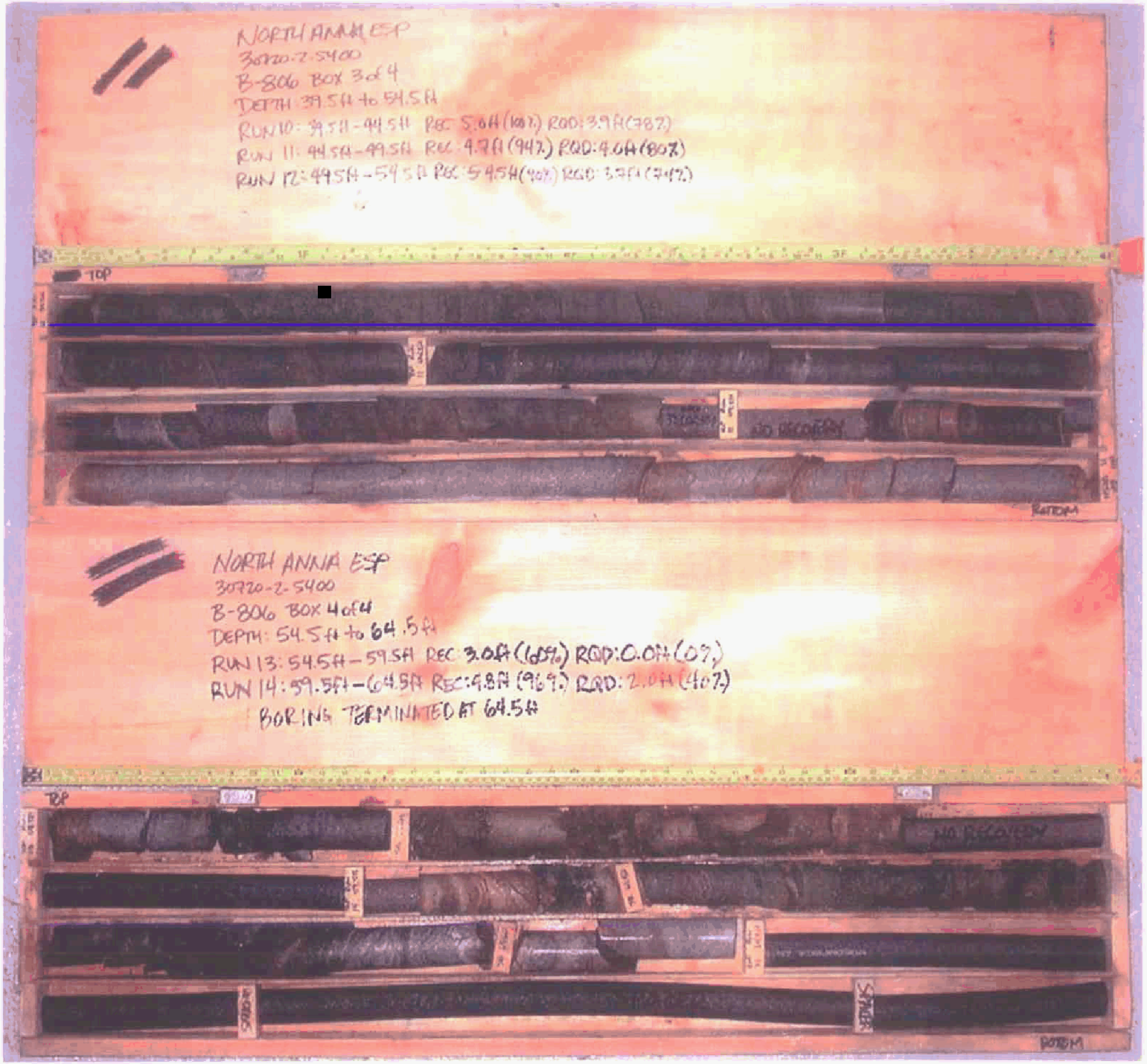
BECHTEL CORE1 LC A.GPJ NC_DOT.GDT 2/3/03

NORTH ANNA ESP
30720-2-5400
B-806 BOX 1 of 4
DEPTH: 10.2 ft to 24.5 ft
RUN 1: 10.2 ft – 14.5 ft REC: 3.7 ft (86%) RQD: 2.8 ft (65%)
RUN 2: 14.5 ft – 17.1 ft REC: 0.8 ft (32%) RQD: 0.6 ft (23%)
RUN 3: 17.1 ft – 19.5 ft REC: 0.4 ft (17%) RQD: 0.0 ft (0%)
RUN 4: 19.5 ft – 24.5 ft REC: 3.5 ft (70%) RQD: 1.2 ft (24%)



NORTH ANNA ESP
30720-2-5400
B-806 BOX 2 of 4
DEPTH: 24.5 ft to 39.5 ft
RUN 5: 24.5 ft – 26.3 ft REC: 1.4 ft (78%) RQD: 1.2 ft (67%)
RUN 6: 26.3 ft – 29.5 ft REC: 0.3 ft (9%) RQD: 0.0 ft (0%)
RUN 7: 29.5 ft – 33.1 ft REC: 0.0 ft (0%) RQD: 0.0 ft (0%)
RUN 8: 33.1 ft – 34.5 ft REC: 1.1 ft (79%) RQD: 0.4 ft (29%)
RUN 9: 34.5 ft – 39.5 ft REC: 5.0 ft (100%) RQD: 3.4 ft (68%)




NORTH ANNA ESP
30720-2-5400
B-806 BOX 3 of 4
DEPTH: 39.5ft to 54.5ft
RUN 10: 39.5ft - 44.5ft REC: 5.0ft (100%) RQD: 3.9ft (78%)
RUN 11: 44.5ft - 49.5ft REC: 4.7ft (94%) RQD: 4.0ft (80%)
RUN 12: 49.5ft - 54.5ft REC: 5.0ft (100%) RQD: 3.7ft (74%)
TOP
NO RECOVERY
BOTTOM
NORTH ANNA ESP
30720-2-5400
B-806 BOX 4 of 4
DEPTH: 54.5ft to 64.5ft
RUN 13: 54.5ft - 59.5ft REC: 3.0ft (60%) RQD: 0.0ft (0%)
RUN 14: 59.5ft - 64.5ft REC: 4.8ft (96%) RQD: 2.0ft (40%)
BORING TERMINATED AT 64.5ft
TOP
NO RECOVERY
BOTTOM

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GEOTECHNICAL BORING LOG
SHEET 1 OF 3

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** B. Deobald
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-807			**0 HR.** ND
COLLAR ELEV. (NAVD 88)	**NORTHING** 3,909,849.08 (NAD 83)	**EASTING** 1,163,980.43 (NAD 83)	**24 HR.** FIAD
TOTAL DEPTH 72.1 ft	**DRILL MACHINE** CME-45C, Trailer	**DRILL METHOD** Mud Rotary/Core	**HAMMER TYPE** 140 lb. Manual
DATE STARTED 12/12/02	**COMPLETED** 12/13/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
310.6	0.0				Ground Surface				
310.6	0.0	2	5	7	12	SS-1			Residual: Orange, tan, and white, stiff to very stiff, micaceous, clayey, fine sandy, SILT (ML), locally with rock fragments
308.3	2.3	3	7	10	17	SS-2			
306.1	4.5	2	7	8	15	SS-3			
303.6	7.0	3	5	7	12	SS-4			
300.9	9.7	3	5	8	13	SS-5			
298.3	12.3	3	5	8	13	SS-6			
295.8	14.8	4	9	12	21	SS-7			
288.9	21.7	2	8	14	22	SS-8			Residual: Orange, tan, and white, very stiff, micaceous, clayey, silty, fine SAND (SM), locally with rock fragments
284.1	26.5	20	30	70		SS-9			Residual: Gray, white, and orange, very dense, micaceous, silty, fine to coarse SAND (SM) with rock fragments
279.2	31.4	45	40	40	80	SS-10			
274.2	36.4								Weathered Rock: Interpreted as QUARTZ GNEISS
273.2	37.4	50/0.2ft			100/0.2ft	SS-11			

310.6 — 0.00
289.6 — 21.0
285.6 — 25.0
275.6 — 35.0

NC_DOT.GDT 2/4/03
BECHTEL 5406

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GEOTECHNICAL BORING LOG
SHEET 2 OF 3

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** B. Deobald
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-807			**0 HR.** ND
COLLAR ELEV. (NAVD 88)	**NORTHING** 3,909,849.08 (NAD 83)	**EASTING** 1,163,980.43 (NAD 83)	**24 HR.** FIAD
TOTAL DEPTH 72.1 ft	**DRILL MACHINE** CME-45C, Trailer	**DRILL METHOD** Mud Rotary/Core	**HAMMER TYPE** 140 lb. Manual
DATE STARTED 12/12/02	**COMPLETED** 12/13/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
273.2	37.4				Continued from previous page				
									Weathered Rock: Interpreted as QUARTZ GNEISS *(continued)*
269.3	41.3	38	35	65/0.4ft	100/0.9ft	SS-12			
264.3	46.3	90	10/0.1ft		100/0.6ft	SS-13			261.6 — 49.0
									Residual: No recovery - Interpreted as very dense, silty, SAND (SM)
259.3	51.3	30	50	37	87	SS-14			
254.4	56.2	50/0.1ft			100/0.1ft	SS-15			254.6 — 56.0
									Weathered Rock: Interpreted as QUARTZ GNEISS
									253.5 — 57.1
									Hard Rock: Tan, pink, and black, Fe stained, moderately severe to moderately weathered, very closely to closely fractured, moderately hard, QUARTZ GNEISS
									238.5 — 72.1
235.8	74.8								Boring and Coring terminated at 72.1ft in Hard Rock: Moderately severe to moderately weathered, very closely to closely fractured, moderately hard, Quartz Gneiss

.C_DOT.GDT 2/4/03

BECHTEL 5400.

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GEOTECHNICAL BORING LOG

SHEET 3 OF 3

SEE ATTACHED CORE BORING REPORT FOR CORING DETAILS

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** B. Deobald
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-807			**0 HR.** ND
COLLAR ELEV. (NAVD 88)	**NORTHING** 3,909,849.08 (NAD 83)	**EASTING** 1,163,980.43 (NAD 83)	**24 HR.** FIAD
TOTAL DEPTH 72.1 ft	**DRILL MACHINE** CME-45C, Trailer	**DRILL METHOD** Mud Rotary/Core	**HAMMER TYPE** 140 lb. Manual
DATE STARTED 12/12/02	**COMPLETED** 12/13/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
235.8	74.8				Continued from previous page				
									Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated)
									Drilling Fluid: Water/Mud (weight unknown)
									Borehole filled by grouting 12/17/02
198.4	112.2								

BECHTEL 5400.:C DOT.GDT 2/4/03

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RALEIGH, NC 27604

CORE BORING REPORT

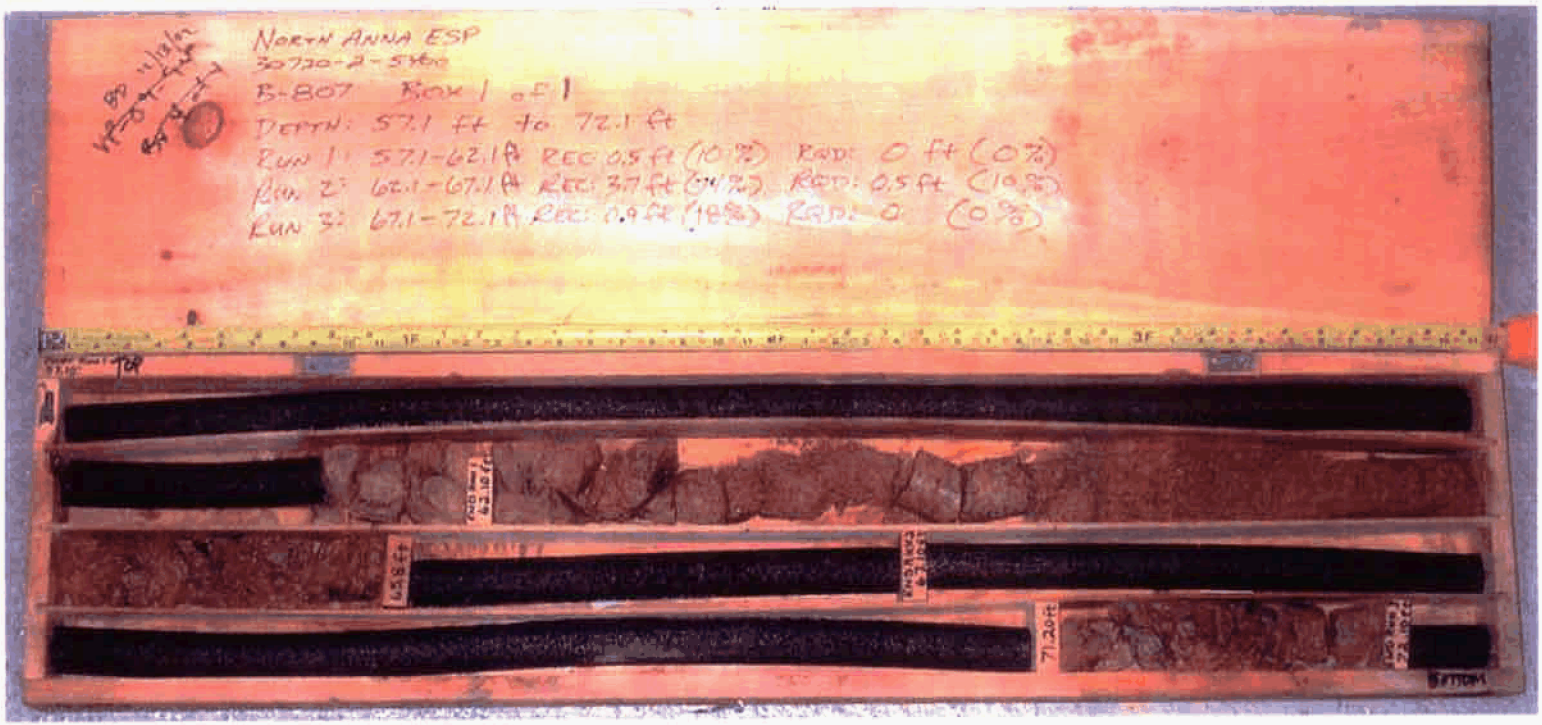
SHEET 1 OF 1

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** B. Deobald
PROJECT NAME: NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. B-807			**0 HR.** ND
COLLAR ELEV. **(NAVD 88)**	**NORTHING** 3,909,849.08 **(NAD 83)**	**EASTING** 1,163,980.43 **(NAD 83)**	**24 HR.** FIAD
TOTAL DEPTH 72.1 ft	**DRILL MACHINE** CME-45C, Trailer	**DRILL METHOD** Mud Rotary/Core	**HAMMER TYPE** 140 lb. Manual
DATE STARTED 12/12/02	**COMPLETED** 12/13/02	**SURFACE WATER DEPTH** N/A	
CORE SIZE NWD4	**TOTAL RUN** 15.0 ft	**DRILLER** D. White	

ELEV. (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS
										Begin Coring @ 57.1 ft
253.5	57.1	5.0	3:08 2:10 2:15 2:20 2:40	(0.5) 10%	(0.0) 0%	RUN 1				253.5 Hard Rock: Tan, pink, and black, Fe stained, moderately severe to moderately weathered, very closely to closely fractured, moderately hard, QUARTZ GNEISS 57.1
248.5	62.1	5.0	2:00 2:10 2:30 2:40 2:50	(3.7) 74%	(0.5) 10%	RUN 2				
243.5	67.1	5.0	2:20 2:20 1:40 2:00 2:00	(0.9) 18%	(0.0) 0%	RUN 3				
238.5	72.1									238.5 72.1 Boring and Coring terminated at 72.1ft in Hard Rock: Moderately severe to moderately weathered, very closely to closely fractured, moderately hard, Quartz Gneiss Bits Used: 3" Roller cone; N-size core bit (Face discharge, diamond impregnated) Drilling Fluid: Water/Mud (weight unknown) Borehole filled by grouting 12/17/02

BECHTEL COREI LC A.GPJ NC_DOT.GDT 2/3/03


NORTH ANNA ESP
30730-2-5460
B-807 BOX 1 of 1
DEPTH: 57.1 ft to 72.1 ft
RUN 1: 57.1-62.1 ft REC 0.5 ft (10%) RQD: 0 ft (0%)
RUN 2: 62.1-67.1 ft REC: 3.7 ft (74%) RQD: 0.5 ft (10%)
RUN 3: 67.1-72.1 ft REC: 0.9 ft (18%) RQD: 0 (0%)
TOP
71.20 ft
BOTTOM

APPENDIX D
OBSERVATION WELL LOGS
OBSERVATION WELL INSTALLATION RECORDS
WELL DEVELOPMENT RECORDS

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OBSERVATION WELL BORING LOG

SHEET 1 OF 1

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-841			**0 HR.** ND
COLLAR ELEV. 250.1 ft **(NAVD 88)**	**NORTHING** 3,910,556.15 **(NAD 83)**	**EASTING** 11,686,804.11 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 35.6 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 11/25/02	**COMPLETED** 11/26/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
250.1					Ground Surface				250.1 — 0.00
250.1	0.0					1			Fill: Orange, tan, and brown mottled, loose, micaceous, silty, fine to coarse SAND (SM)
245.3	4.8					2			
240.3	9.8				**Samples were obtained for descriptive purposes only**	3			
235.4	14.7					4			233.1 — 17.0
230.2	19.9					5			Residual: Tan and orange mottled, very dense, silty, fine to coarse SAND (SM) with relict rock fabric
224.9	25.2					6			228.1 — 22.0
220.3	29.8					7			Weathered Rock: GNEISS sampled as tan to orange mottled, very dense, silty, fine to coarse SAND (SM) with relict rock fabric
216.4	33.7					8			223.1 — 27.0
									Residual: Tan to orange mottled, very dense, silty, fine to coarse SAND (SM) with relict rock fabric
									218.1 — 32.0
									Weathered Rock: GNEISS sampled as orange to tan mottled, very dense, silty, fine to coarse SAND (SM)
									214.5 — 35.6
									Boring terminated at 35.6 ft in Weathered Rock: GNEISS sampled as very dense, silty, fine to very coarse SAND (SM)

BECHTEL OBS OG 5400A.GPJ NC_DOT.GDT 2/3/03

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OBSERVATION WELL BORING LOG

SHEET 1 OF 2

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-842			**0 HR.** ND
COLLAR ELEV. 335.2 ft **(NAVD 88)**	**NORTHING** 3,909,034.76 **(NAD 83)**	**EASTING** 11,685,149.13 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 51.0 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 12/3/02	**COMPLETED** 12/3/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
335.2					Ground Surface				
335.2	0.0					1			335.2 — 0.00 Fill: Brown, firm, slightly fine to medium sandy, clayey, SILT (ML)
332.7	2.5								332.7 — 2.5 Residual: Tan, brown, green, black, and white mottled, firm to dense, locally micaceous, silty, fine to medium SAND (SM) with relict rock fabric and locally with manganese oxide staining
330.7	4.5					2			
					Samples were obtained for descriptive purposes only				
325.7	9.5					3			
320.7	14.5					4			
315.7	19.5					5			
310.7	24.5					6			
305.7	29.5					7			
300.7	34.5					8			

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SHEET 2 OF 2

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-842			**0 HR.** ND
COLLAR ELEV. 335.2 ft **(NAVD 88)**	**NORTHING** 3,909,034.76 **(NAD 83)**	**EASTING** 11,685,149.13 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 51.0 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 12/3/02	**COMPLETED** 12/3/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
297.8					Continued from previous page				
295.7	39.5					9			Residual: Tan, brown, green, black, and white mottled, firm to dense, locally micaceous, silty, fine to medium SAND (SM) with relict rock fabric and locally with manganese oxide staining *(continued)*
290.7	44.5				**Samples were obtained for descriptive purposes only**	10			
287.0	48.2					11			
284.2	51.0								Boring terminated at 51.0 ft in Residual: Very firm, micaceous, silty, fine SAND (SM) with relict rock fabric See Well Installation Record for well construction details

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SHEET 1 OF 2

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-843			**0 HR.** ND
COLLAR ELEV. 319.1 ft **(NAVD 88)**	**NORTHING** 3,909,725.17 **(NAD 83)**	**EASTING** 11,685,056.83 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 51.0 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 12/4/02	**COMPLETED** 12/4/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
319.1					Ground Surface				319.1 0.0
319.1	0.0					1			Residual: Dark green to yellow, firm to dense, very slightly micaceous, silty, fine SAND (SM) with relict rock fabric
314.6	4.5					2			
					Samples were obtained for descriptive purposes only				312.1 7.0 Residual: Orange, brown, and pink mottled, stiff, very slightly fine sandy, SILT (ML) with relict rock fabric and manganese oxide stain
309.6	9.5					3			
304.6	14.5					4			302.1 17.0 Residual: Orange, brown, dark green, and yellow mottled, firm to dense, locally micaceous, silty, fine SAND (SM) with relict rock fabric and manganese oxide stain
299.6	19.5					5			
294.6	24.5					6			
289.6	29.5					7			
284.6	34.5					8			

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SHEET 2 OF 2

BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-843			**0 HR.** ND
COLLAR ELEV. 319.1 ft **(NAVD 88)**	**NORTHING** 3,909,725.17 **(NAD 83)**	**EASTING** 11,685,056.83 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 51.0 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 12/4/02	**COMPLETED** 12/4/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
281.7					Continued from previous page				
279.6	39.5					9			Residual: Orange, brown, dark green, and yellow mottled, firm to dense, locally micaceous, silty, fine SAND (SM) with relict rock fabric and manganese oxide stain *(continued)*
274.6	44.5				**Samples were obtained for descriptive purposes only**	10			
271.1	48.0					11			
268.1	51.0								Boring terminated at 51.0 ft in Residual: Firm, micaceous, silty, fine SAND (SM) with relict rock fabric and manganese oxide stain See Well Installation Record for well construction details

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-844			**0 HR.** 18.7
COLLAR ELEV. 272.0 ft **(NAVD 88)**	**NORTHING** 3,909,908.82 **(NAD 83)**	**EASTING** 11,686,589.64 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 26.2 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 11/23/02	**COMPLETED** 11/23/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
272.0					Ground Surface				272.0 0.00
272.0	0.0					1			Fill: Orange and brown, firm to loose, silty, fine SAND (SM) with trace quartz rock fragments and abandoned conduit/construction debris
267.5	4.5					2			265.0 7.0
					Samples were obtained for descriptive purposes only				Residual: Black and white, dense to very dense, silty, fine SAND (SM) with relict rock fabric
262.5	9.5					3			
257.5	14.5					4	▽		
252.5	19.5					5			249.5 22.5
248.1	23.9					6			Weathered Rock: BIOTITE GNEISS sampled as gray to black, very dense, silty, fine SAND (SM) Auger refusal at 24.6ft
									245.8 26.2
									Boring terminated at 26.2 ft in Weathered Rock: BIOTITE GNEISS sampled as very dense, silty, fine SAND (SM) See Well Installation Record for well construction details

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** S. Criscenzo
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-845			**0 HR.** ND
COLLAR ELEV. 295.8 ft **(NAVD 88)**	**NORTHING** 3,909,858.66 **(NAD 83)**	**EASTING** 11,685,741.11 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 35.0 ft	**DRILL MACHINE** Ingersol Rand T3W	**DRILL METHOD** Air Rotary 6 1/8"	**HAMMER TYPE** N/A
DATE STARTED 12/3/02	**COMPLETED** 12/3/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
295.8					Ground				295.8 0.00
									0 - 55 feet drilled without sampling
									240.8 55.5
									Boring terminated at 55.0 ft

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-846			**0 HR.** ND
COLLAR ELEV. 295.8 ft **(NAVD 88)**	**NORTHING** 3,909,845.09 **(NAD 83)**	**EASTING** 11,685,721.82 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 33.5 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 11/22/02	**COMPLETED** 11/22/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
295.8					Ground Surface				295.8 0.00
295.8	0.0					1			Residual: Orange, yellow, tan, and brown, loose to very dense, silty, fine to coarse SAND (SM) locally with gravel and relict rock fabric
291.8	4.0					2			
286.3	9.5				Samples were obtained for descriptive purposes only	3			
281.3	14.5					4			
276.3	19.5					5			
271.3	24.5					6			
266.3	29.5					7			
									262.3 33.5
									Boring terminated at auger refusal 33.5 ft on Hard Rock: QUARTZ GNEISS See Well Installation Record for well construction details

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-847			**0 HR.** ND
COLLAR ELEV. 318.2 ft **(NAVD 88)**	**NORTHING** 3,908,945.45 **(NAD 83)**	**EASTING** 11,686,447.69 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 51.8 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 11/26/02	**COMPLETED** 11/26/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
318.2					Ground Surface				
318.2	0.0					1			Residual: Orange, brown, and tan mottled, firm to stiff, micaceous, locally medium to coarse sandy, clayey, SILT (ML) locally with manganese oxide stain
313.4	4.8					2			
					Samples were obtained for descriptive purposes only				
308.6	9.6					3			
303.4	14.8					4			
298.3	19.9					5			
296.2	22.0								Residual: Orange, yellow, tan, and brown mottled, loose to very firm, micaceous, silty, fine to coarse SAND (SM) with relict rock fabric and locally with manganese oxide stain and trace angular quartz rock fragments
293.1	25.1					6			
288.0	30.2					7			
283.0	35.2					8			

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-847			**0 HR.** ND
COLLAR ELEV. 318.2 ft **(NAVD 88)**	**NORTHING** 3,908,945.45 **(NAD 83)**	**EASTING** 11,686,447.69 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 51.8 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 11/26/02	**COMPLETED** 11/26/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
280.8					Continued from previous page				
280.2									38.0 Residual: Yellow, green, tan, brown, and white mottled, stiff to very stiff, micaceous, SILT (ML) with relict rock fabric and locally with manganese oxide stain
278.0	40.2					9			
272.8	45.4				Samples were obtained for descriptive purposes only	10			
269.9	48.3					11			
266.4									51.8 Boring terminated at 51.8 ft in Residual: Very stiff, micaceous, SILT (ML) with relict rock fabric See Well Installation Record for well construction details

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-848			**0 HR.** ND
COLLAR ELEV. 283.0 ft **(NAVD 88)**	**NORTHING** 3,910,853.37 **(NAD 83)**	**EASTING** 11,686,272.76 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 47.4 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 11/24/02	**COMPLETED** 11/24/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
283.0					Ground Surface				
283.0	0.0					1			Fill: Brown, loose, silty, fine SAND (SM) with trace quartz rock fragments
278.2	4.8					2			
276.0	7.0								Residual: Gray to brown, firm, very slightly fine sandy, clayey, SILT (ML)
272.7	10.3				**Samples were obtained for descriptive purposes only**	3			
270.5	12.5								Residual: Gray, brown, and tan, locally mottled, dense to very dense, micaceous, silty, fine to medium SAND (SM) with relict rock fabric
268.2	14.8					4			
263.0	20.0					5			
257.9	25.1					6			
252.9	30.1					7			
252.0	31.0								Weathered Rock: BIOTITE GNEISS sampled as brown, gray, tan, and black mottled, very dense, micaceous, silty, fine SAND (SM) with relict rock fabric
247.9	35.1					8			

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-848			**0 HR.** ND
COLLAR ELEV. 283.0 ft **(NAVD 88)**	**NORTHING** 3,910,853.37 **(NAD 83)**	**EASTING** 11,686,272.76 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 47.4 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 11/24/02	**COMPLETED** 11/24/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
245.6					Continued from previous page				
242.9	40.1					9			Weathered Rock: BIOTITE GNEISS sampled as brown, gray, tan, and black mottled, very dense, micaceous, silty, fine SAND (SM) with relict rock fabric *(continued)*
237.7	45.3				**Samples were obtained for descriptive purposes only**	10			
235.6	47.4								Boring terminated at auger refusal at 47.4ft in Weathered Rock: BIOTITE GNEISS sampled as very dense, silty, fine SAND (SM) with relict rock fabric See Well Installation Record for well construction details

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BECHTEL

BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-849			**0 HR.** ND
COLLAR ELEV. 297.0 ft **(NAVD 88)**	**NORTHING** 3,910,786.24 **(NAD 83)**	**EASTING** 11,684,731.02 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 51.0 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 12/6/02	**COMPLETED** 12/6/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
297.0					Ground Surface				
297.0	0.0					1			Residual: Ornage, stiff, slightly clayey, SILT (ML) with root fragments
294.5	2.5								
292.5	4.5					2			Residual: Orange and tan mottled, loose to firm, locally micaceous, silty, fine to coarse SAND (SM) with relict rock fabric, quartz rock fragments, and trace Fe staining
287.5	9.5				**Samples were obtained for descriptive purposes only**	3			
282.5	14.5					4			
277.5	19.5					5			
272.5	24.5					6			
267.5	29.5					7			
265.0	32.0								Residual: Tan and orange mottling, very firm to very dense, micaceous, slightly clayey, slightly silty, poorly graded, fine to coarse SAND (SP) with relict rock fabric
262.5	34.5					8			

BECHTEL OBS W 5400A.GPJ NC_DOT.GDT 2/3/03

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OBSERVATION WELL BORING LOG

SHEET 2 OF 2

BECHTEL

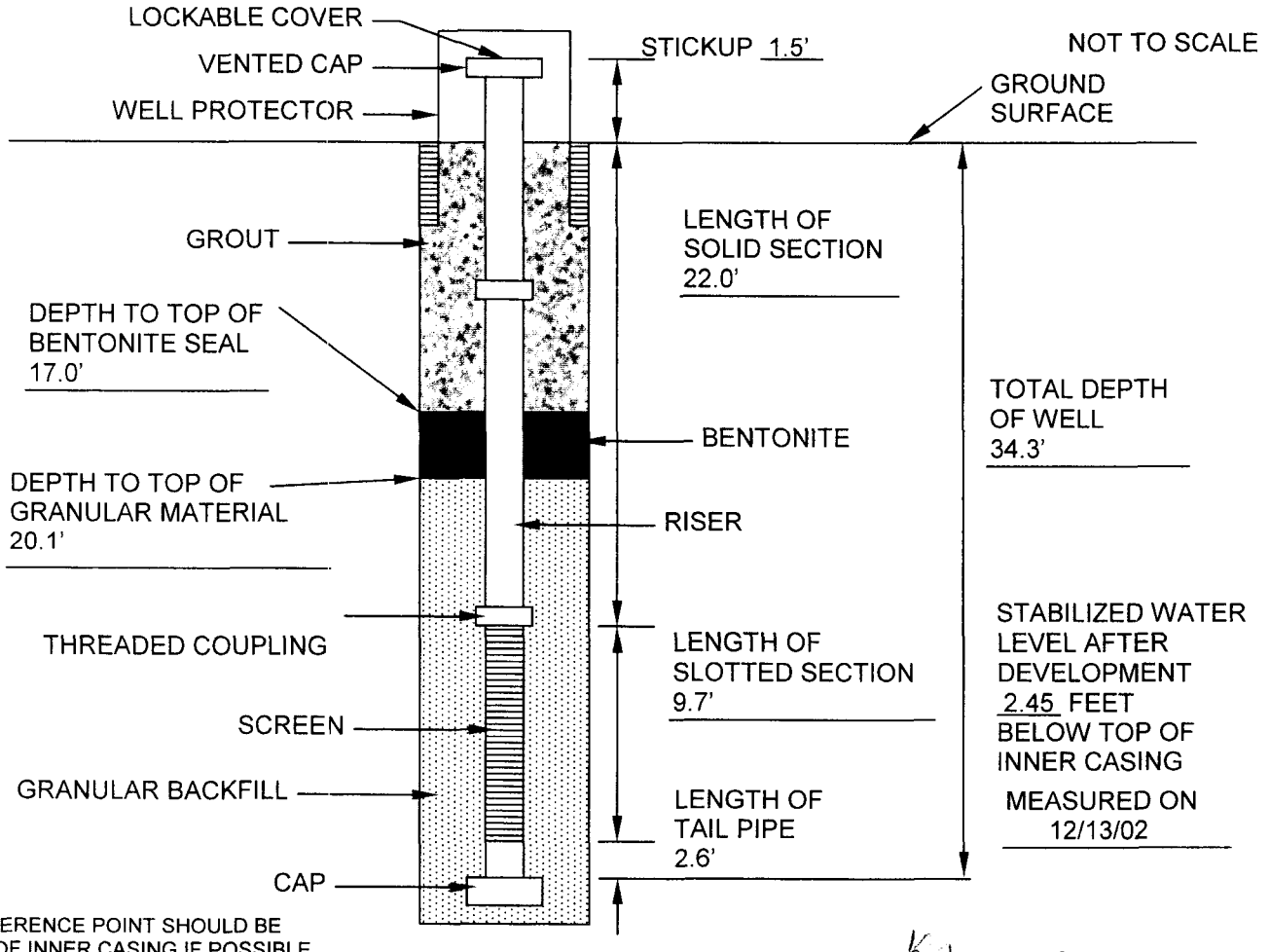
BECHTEL PROJECT NO. 24830	**MACTEC PROJECT NUMBER: 30720-2-5400**	**COUNTY** LOUISA, VA	**GEOLOGIST** M. Howe
PROJECT NAME NORTH ANNA ESP			**WATER LEVEL (ft)**
BORING NO. OW-849			**0 HR.** ND
COLLAR ELEV. 297.0 ft **(NAVD 88)**	**NORTHING** 3,910,786.24 **(NAD 83)**	**EASTING** 11,684,731.02 **(NAD 83)**	**24 HR.** ND
TOTAL DEPTH 51.0 ft	**DRILL MACHINE** Diedrich D-50	**DRILL METHOD** HSA 4.25"	**HAMMER TYPE** 140 lb. Automatic
DATE STARTED 12/6/02	**COMPLETED** 12/6/02	**SURFACE WATER DEPTH** N/A	

ELEV. (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 20 40 60 80 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
259.6					Continued from previous page				
257.5	39.5								Residual: Tan and orange mottling, very firm to very dense, micaceous, slightly clayey, slightly silty, poorly graded, fine to coarse SAND (SP) with relict rock fabric *(continued)*
						9			
252.5	44.5					10			
					Samples were obtained for descriptive purposes only				
248.7	48.3					11			
246.0	51.0								Boring terminated at 51.0 ft in Residual: Very firm, slightly micaceous, slightly clayey, slightly silty, poorly graded, fine to coarse SAND (SP) with relict rock fabric See Well Installation Record for well construction details

BECHTEL_OBS W... G 5400A.GPJ NC_DOT.GDT 2/3/03

OBSERVATION WELL INSTALLATION RECORD

JOB NAME	**NORTH ANNA ESP**	JOB NUMBER	**37020-2-5400**
WELL NUMBER	**OW-841**	INSTALLATION DATE	**11/26/02**
LOCATION (NAD83)	**3910556.15N 11686804.11E**		
GROUND SURFACE ELEVATION (NAVD88)	**250.1 ft**	REFERENCE POINT ELEVATION * (NAVD88)	**251.6 ft**
GRANULAR BACKFILL MATERIAL	**#2 Well Gravel**	SLOT SIZE	**0.010 in.**
SCREEN MATERIAL	**PVC Schd. 40-Standard**	SCREEN DIAMETER	**2 in.**
RISER MATERIAL	**PVC Schd. 40-Standard**	RISER DIAMETER	**2 in.**
DRILLING TECHNIQUE	**HSA 4$^{1/4}$ in. I.D.**	DRILLING CONTRACTOR	**MACTEC – Atlanta, GA**
BOREHOLE DIAMETER	**8 in.**	MACTEC FIELD REPRESENTATIVE	**Matt Howe**
LOCK BRAND	**Masterlock**	SIZE/MODEL	**N/A**
KEY CODE/COMBINATION	**0536**		



* REFERENCE POINT SHOULD BE TOP OF INNER CASING IF POSSIBLE

KJ 2-5-03

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OBSERVATION WELL INSTALLATION RECORD

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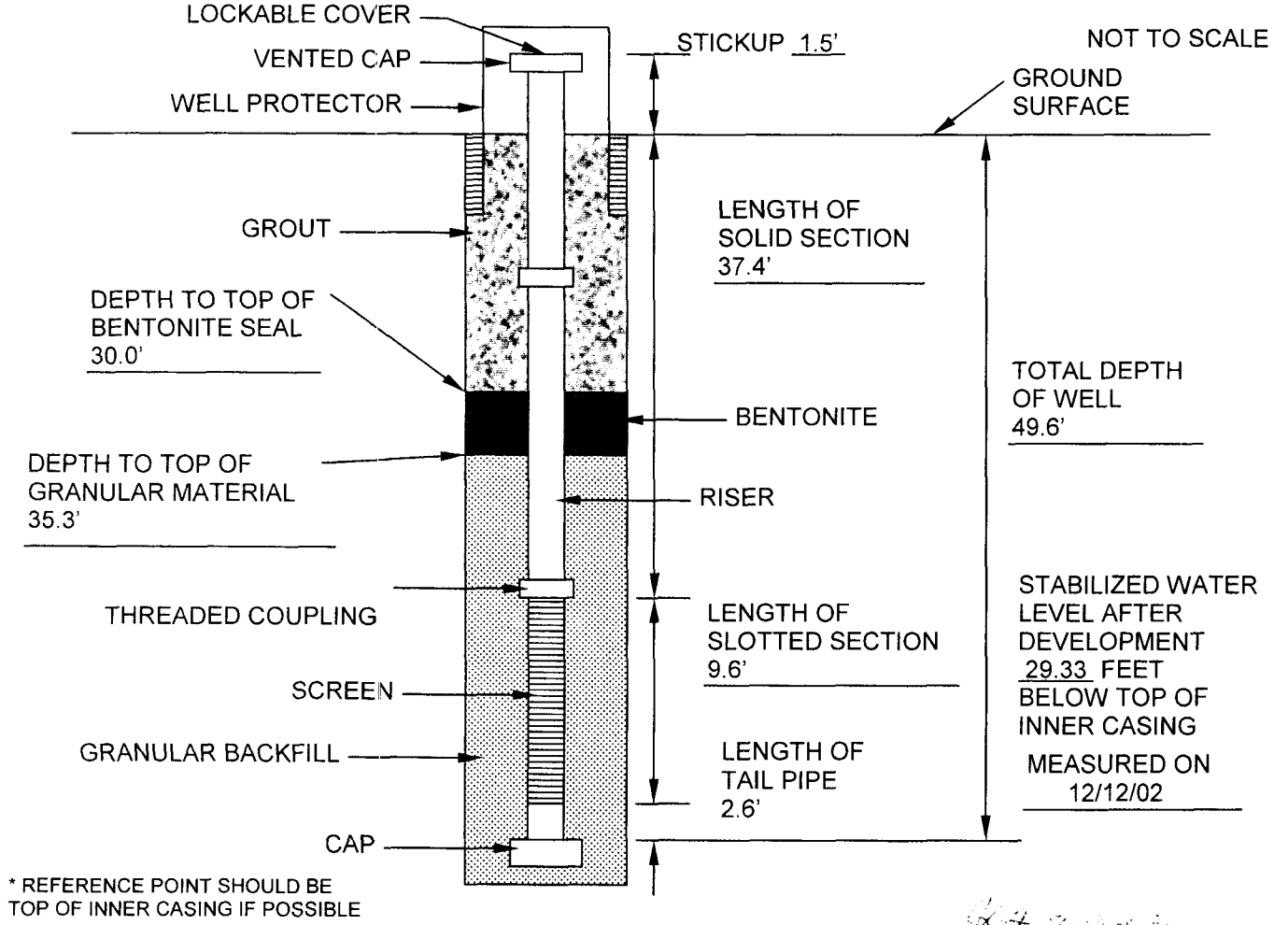
JOB NAME	**NORTH ANNA ESP**	JOB NUMBER	**37020-2-5400**
WELL NUMBER	**OW-842**	INSTALLATION DATE	**12/03/02**
LOCATION (NAD83)	**3909034.76N 11685149.13E**		
GROUND SURFACE ELEVATION (NAVD88)	**335.2 ft**	REFERENCE POINT ELEVATION * (NAVD88)	**336.7 ft**
GRANULAR BACKFILL MATERIAL	**#2 Well Gravel**	SLOT SIZE	**0.010 in.**
SCREEN MATERIAL	**PVC Schd. 40-Standard**	SCREEN DIAMETER	**2 in.**
RISER MATERIAL	**PVC Schd. 40-Standard**	RISER DIAMETER	**2 in.**
DRILLING TECHNIQUE	**HSA 4$^{1/4}$ in. I.D.**	DRILLING CONTRACTOR	**MACTEC – Atlanta, GA**
BOREHOLE DIAMETER	**8 in.**	MACTEC FIELD REPRESENTATIVE	**Matt Howe**
LOCK BRAND	**Masterlock**	SIZE/MODEL	**N/A**
KEY CODE/COMBINATION	**0536**		



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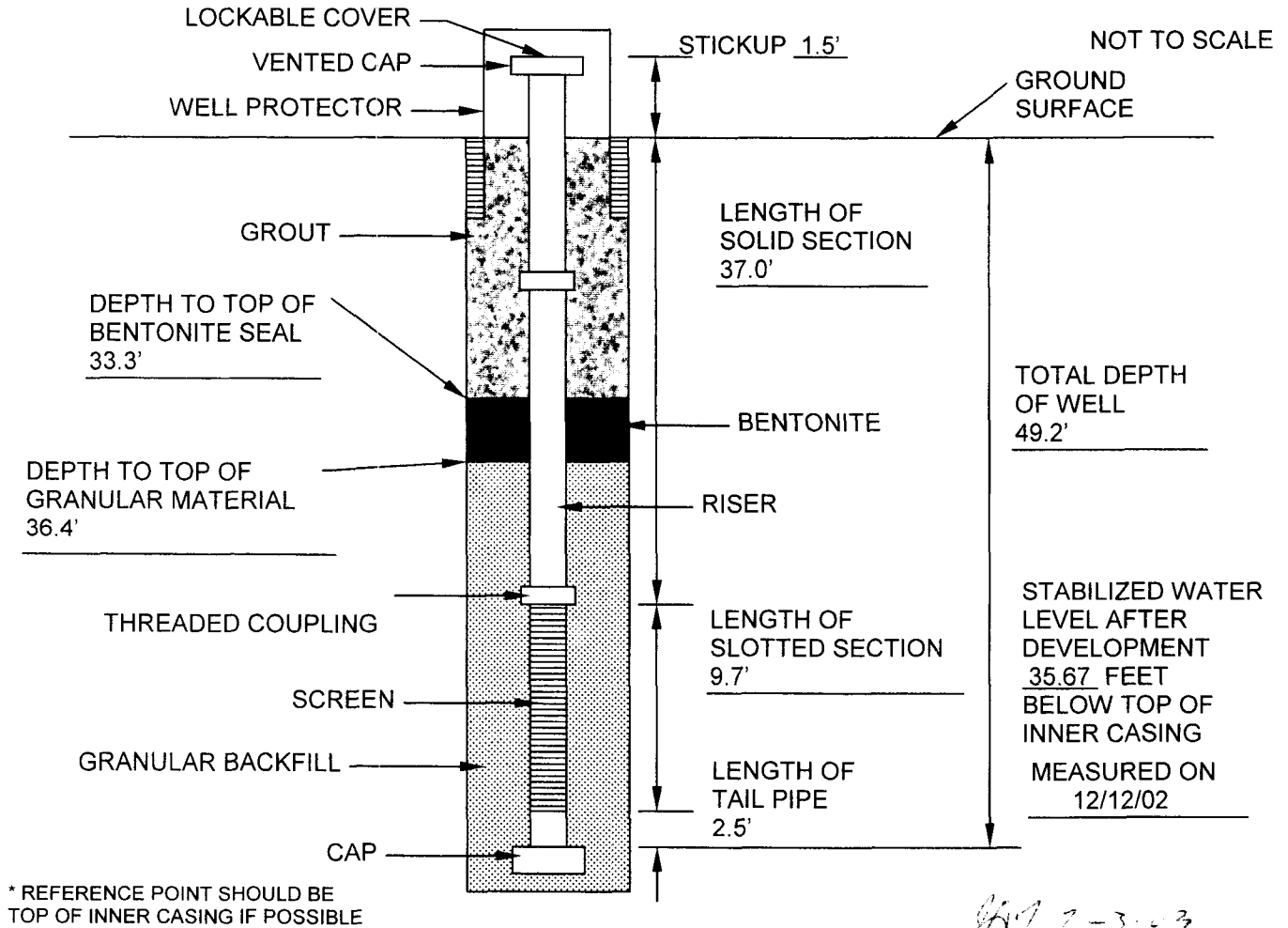
JOB NAME	**NORTH ANNA ESP**	JOB NUMBER	**37020-2-5400**
WELL NUMBER	**OW-843**	INSTALLATION DATE	**12/04/02**
LOCATION (NAD83)	**3909725.17N 11685056.83E**		
GROUND SURFACE ELEVATION (NAVD88)	**319.1 ft**	REFERENCE POINT ELEVATION * (NAVD88)	**320.6 ft**
GRANULAR BACKFILL MATERIAL	**#2 Well Gravel**	SLOT SIZE	**0.010 in.**
SCREEN MATERIAL	**PVC Schd. 40-Standard**	SCREEN DIAMETER	**2 in.**
RISER MATERIAL	**PVC Schd. 40-Standard**	RISER DIAMETER	**2 in.**
DRILLING TECHNIQUE	**HSA 4$^{1/4}$ in. I.D.**	DRILLING CONTRACTOR	**MACTEC – Atlanta, GA**
BOREHOLE DIAMETER	**8 in.**	MACTEC FIELD REPRESENTATIVE	**Matt Howe**
LOCK BRAND	**Masterlock**	SIZE/MODEL	**N/A**
KEY CODE/COMBINATION	**0536**		



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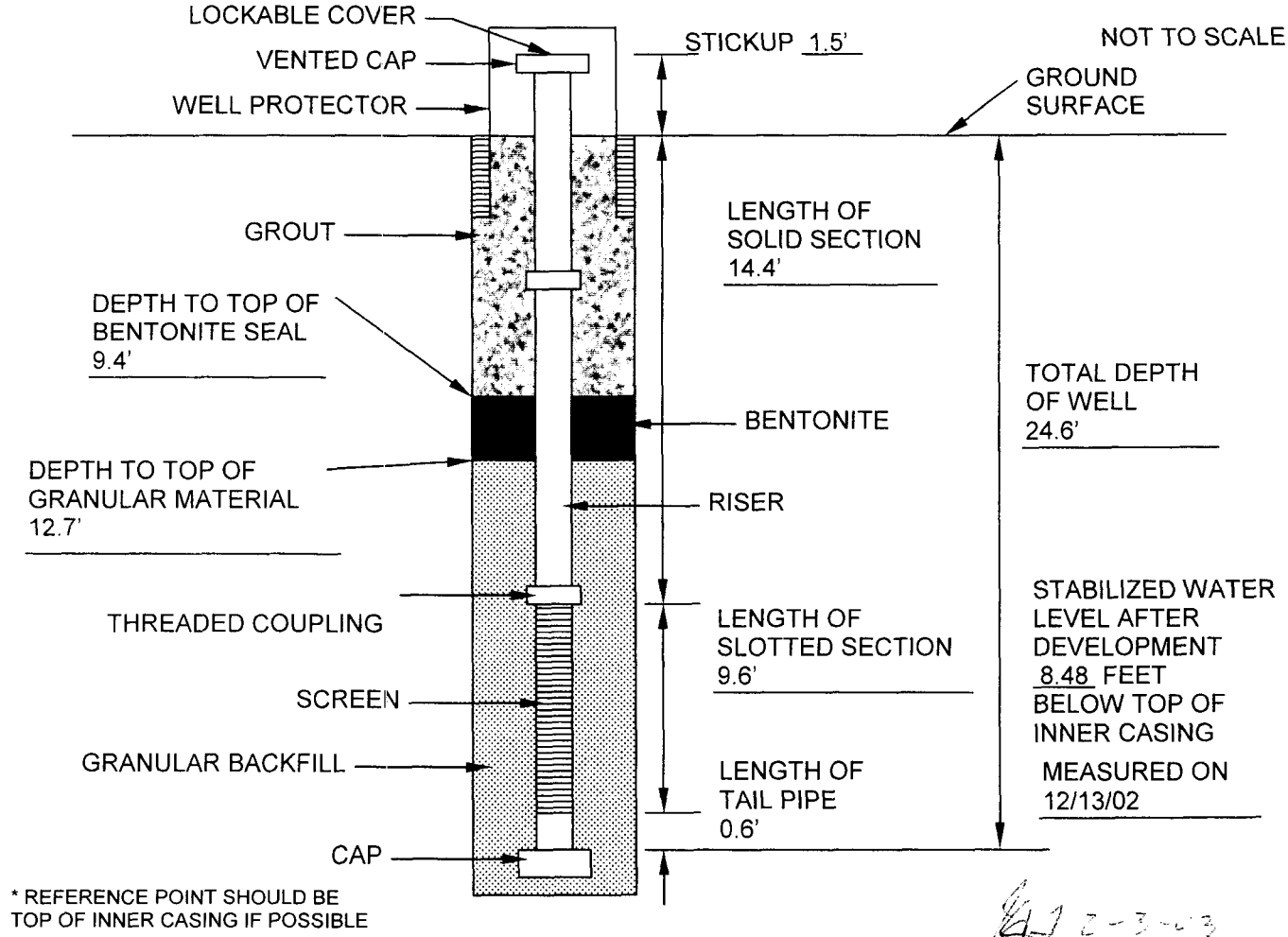
JOB NAME	**NORTH ANNA ESP**	JOB NUMBER	**37020-2-5400**
WELL NUMBER	**OW-844**	INSTALLATION DATE	**11/24/02**
LOCATION (NAD83)	**3909908.82N 11686589.65E**		
GROUND SURFACE ELEVATION (NAVD88)	**272.0 ft**	REFERENCE POINT ELEVATION * (NAVD88)	**273.5 ft**
GRANULAR BACKFILL MATERIAL	**#2 Well Gravel**	SLOT SIZE	**0.010 in.**
SCREEN MATERIAL	**PVC Schd. 40-Standard**	SCREEN DIAMETER	**2 in.**
RISER MATERIAL	**PVC Schd. 40-Standard**	RISER DIAMETER	**2 in.**
DRILLING TECHNIQUE	**HSA 4$^{1/4}$ in. I.D.**	DRILLING CONTRACTOR	**MACTEC – Atlanta, GA**
BOREHOLE DIAMETER	**8 in.**	MACTEC FIELD REPRESENTATIVE	**Matt Howe**
LOCK BRAND	**Masterlock**	SIZE/MODEL	**N/A**
KEY CODE/COMBINATION	**0536**		



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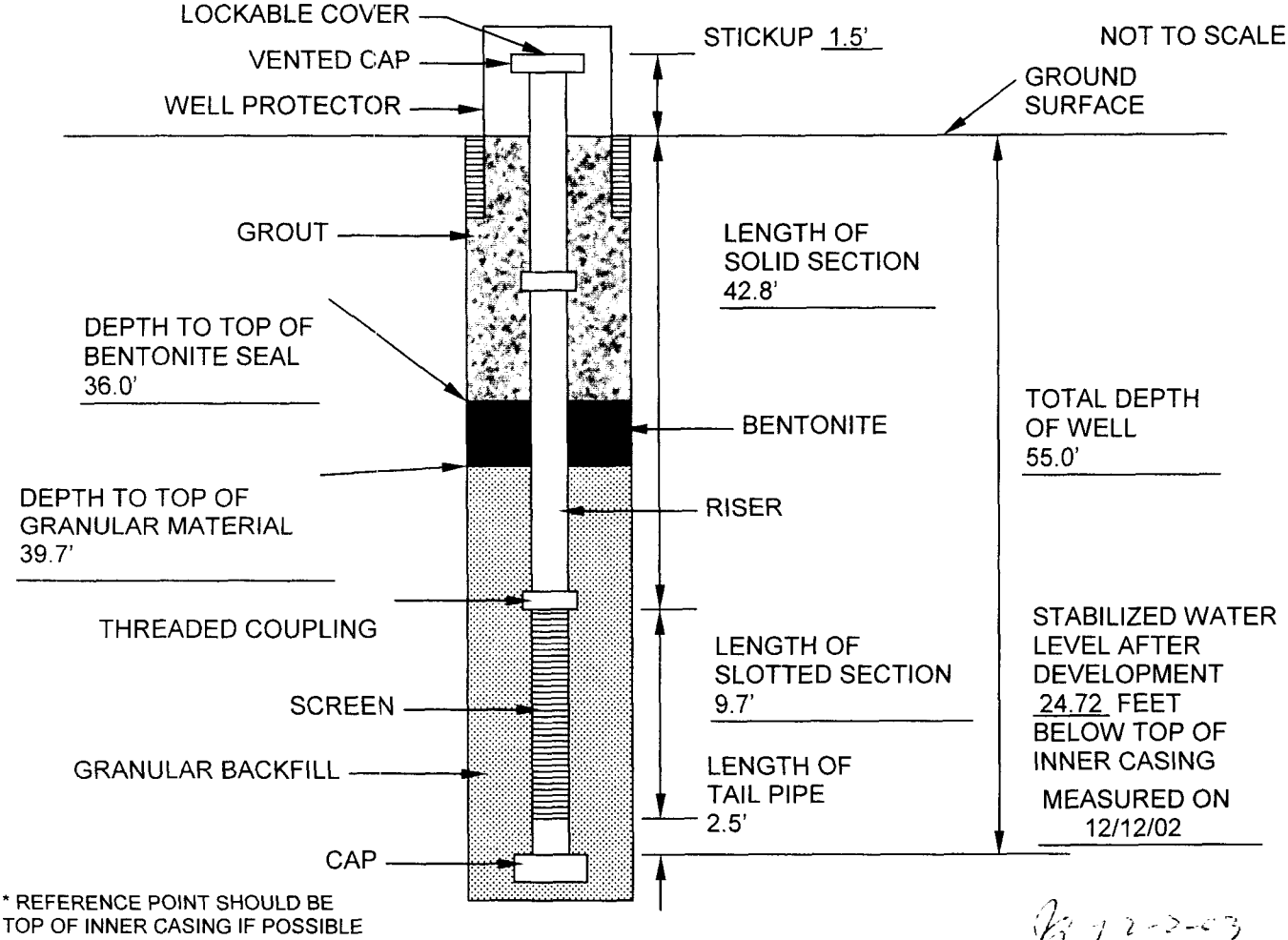
JOB NAME	**NORTH ANNA ESP**	JOB NUMBER	**37020-2-5400**
WELL NUMBER	**OW-845**	INSTALLATION DATE	**12/03/02**
LOCATION (NAD83)	**3909858.66N 11685741.11E**		
GROUND SURFACE ELEVATION (NAVD88)	**295.8 ft**	REFERENCE POINT ELEVATION * (NAVD88)	**297.3 ft**
GRANULAR BACKFILL MATERIAL	**#2 Well Gravel**	SLOT SIZE	**0.010 in.**
SCREEN MATERIAL	**PVC Schd. 40-Standard**	SCREEN DIAMETER	**2 in.**
RISER MATERIAL	**PVC Schd. 40-Standard**	RISER DIAMETER	**2 in.**
DRILLING TECHNIQUE	**Air Rotary**	DRILLING CONTRACTOR	**Bedford Well Drilling**
BOREHOLE DIAMETER	**6 1/8 in.**	MACTEC FIELD REPRESENTATIVE	**S. Criscenzo – MACTEC** **L. Matthews – Bechtel**
LOCK BRAND	**Masterlock**	SIZE/MODEL	**N/A**
KEY CODE/COMBINATION	**0536**		



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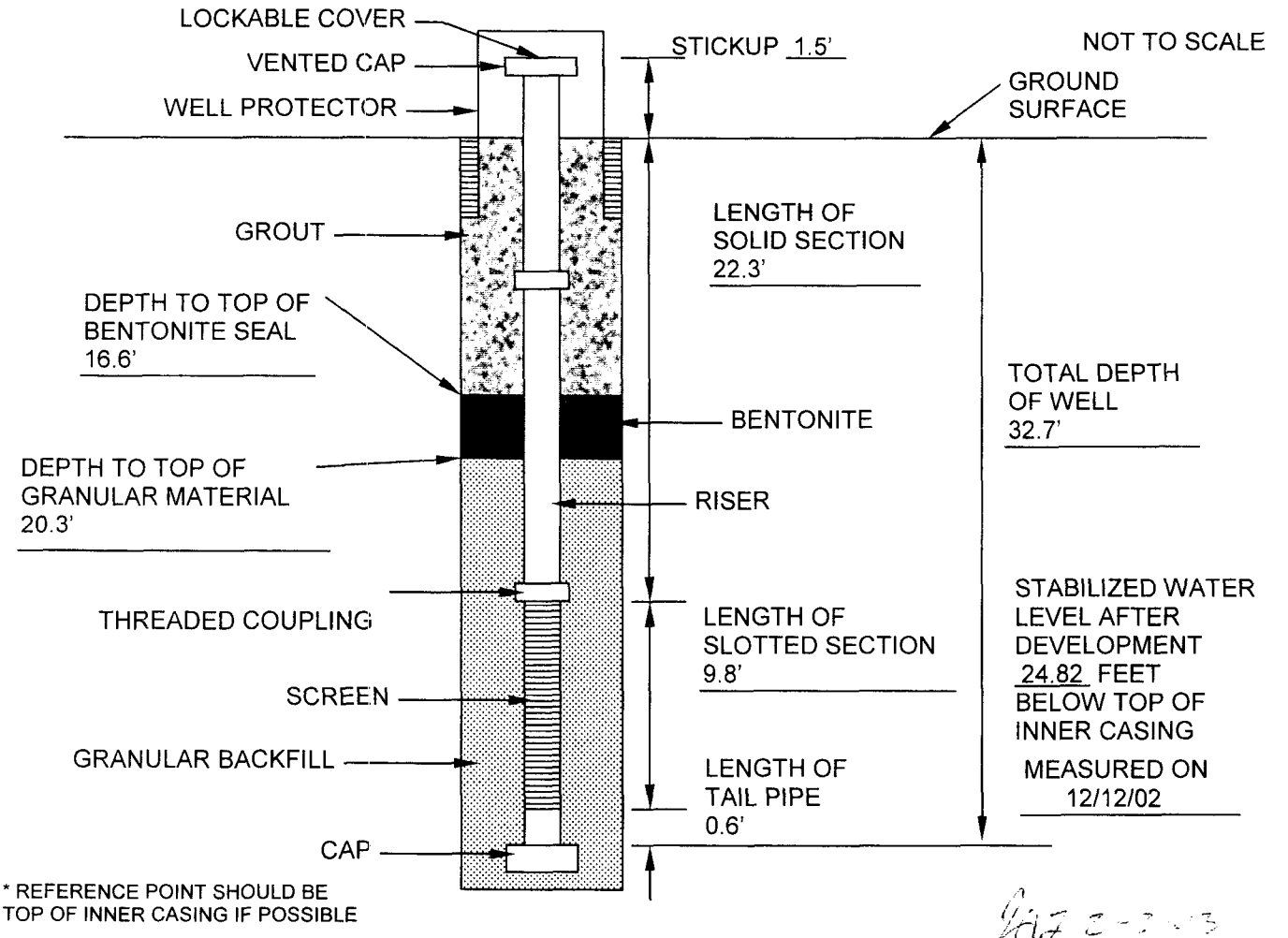
JOB NAME	**NORTH ANNA ESP**	JOB NUMBER	**37020-2-5400**
WELL NUMBER	**OW-846**	INSTALLATION DATE	**11/23/02**
LOCATION (NAD83)	**3909845.09N 11685721.82E**		
GROUND SURFACE ELEVATION (NAVD88)	**295.8 ft**	REFERENCE POINT ELEVATION * (NAVD88)	**297.3 ft**
GRANULAR BACKFILL MATERIAL	**#2 Well Gravel**	SLOT SIZE	**0.010 in.**
SCREEN MATERIAL	**PVC Schd. 40-Standard**	SCREEN DIAMETER	**2 in.**
RISER MATERIAL	**PVC Schd. 40-Standard**	RISER DIAMETER	**2 in.**
DRILLING TECHNIQUE	**HSA 4$^{1/4}$ in. I.D.**	DRILLING CONTRACTOR	**MACTEC – Atlanta, GA**
BOREHOLE DIAMETER	**8 in.**	MACTEC FIELD REPRESENTATIVE	**Matt Howe**
LOCK BRAND	**Masterlock**	SIZE/MODEL	**N/A**
KEY CODE/COMBINATION	**0536**		



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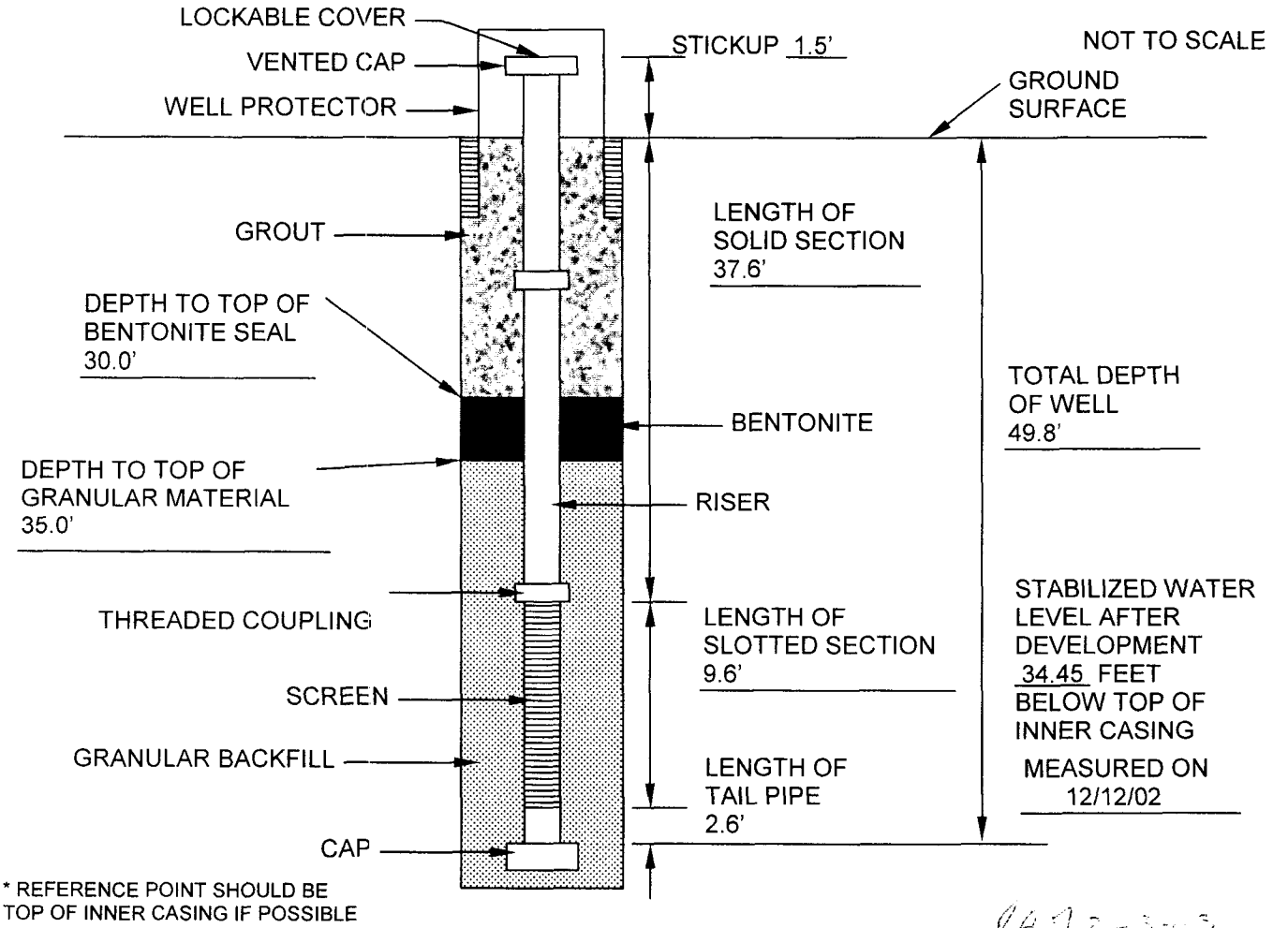
OBSERVATION WELL INSTALLATION RECORD

JOB NAME	**NORTH ANNA ESP**	JOB NUMBER	**37020-2-5400**
WELL NUMBER	**OW-847**	INSTALLATION DATE	**12/03/02**
LOCATION (NAD83)	**3908945.45N 11686447.69E**		
GROUND SURFACE ELEVATION (NAVD88)	**318.2 ft**	REFERENCE POINT ELEVATION * (NAVD88)	**319.7 ft**
GRANULAR BACKFILL MATERIAL	**#2 Well Gravel**	SLOT SIZE	**0.010 in.**
SCREEN MATERIAL	**PVC Schd. 40-Standard**	SCREEN DIAMETER	**2 in.**
RISER MATERIAL	**PVC Schd. 40-Standard**	RISER DIAMETER	**2 in.**
DRILLING TECHNIQUE	**HSA 4 1/4 in. I.D.**	DRILLING CONTRACTOR	**MACTEC – Atlanta, GA**
BOREHOLE DIAMETER	**8 in.**	MACTEC FIELD REPRESENTATIVE	**Matt Howe**
LOCK BRAND	**Masterlock**	SIZE/MODEL	**N/A**
KEY CODE/COMBINATION	**0536**		



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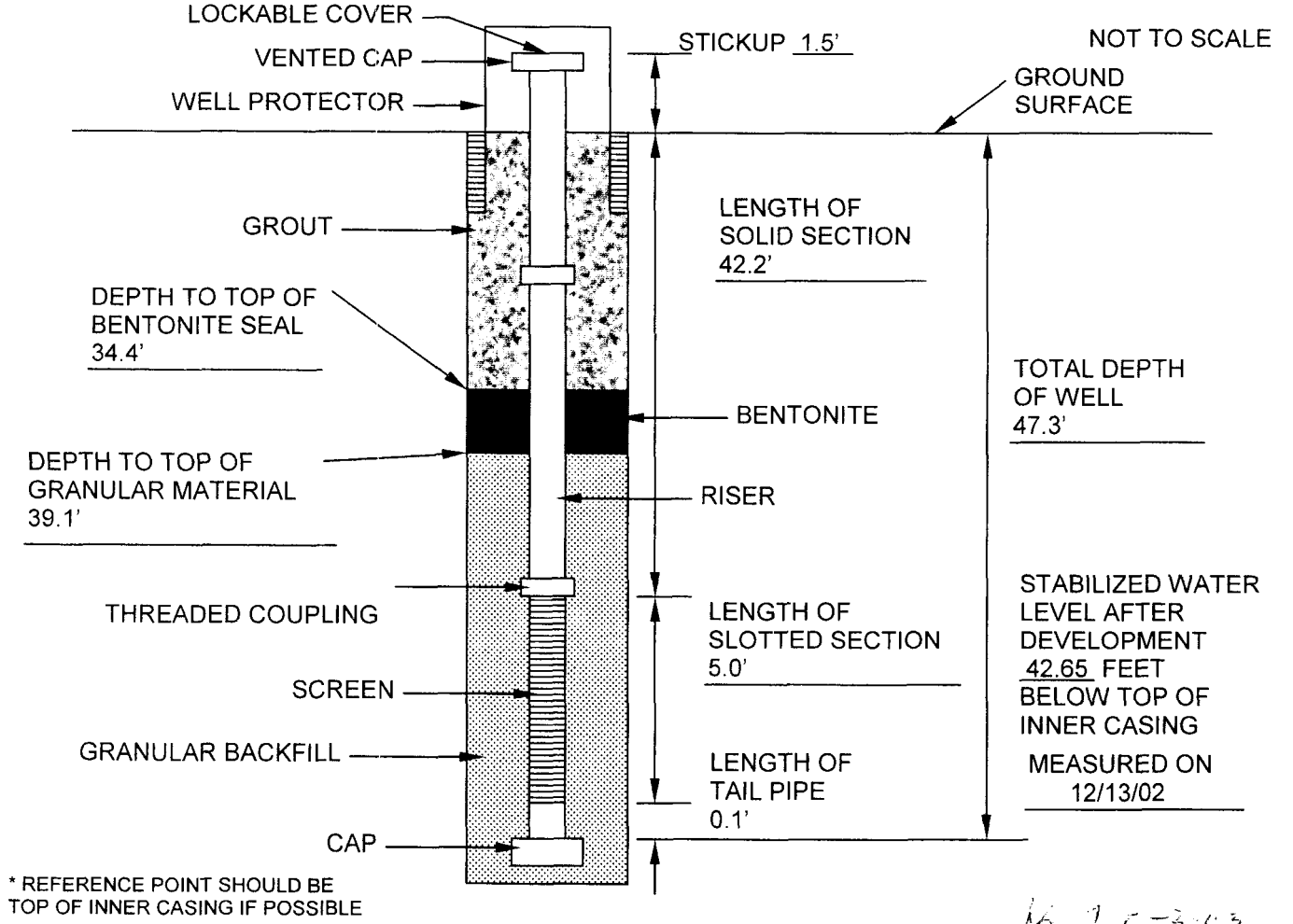
JOB NAME	**NORTH ANNA ESP**	JOB NUMBER	**37020-2-5400**
WELL NUMBER	**OW-848**	INSTALLATION DATE	**11/25/02**
LOCATION (NAD83)	**3910853.37N 11686272.76E**		
GROUND SURFACE ELEVATION (NAVD88)	**283.0 ft**	REFERENCE POINT ELEVATION * (NAVD88)	**284.5 ft**
GRANULAR BACKFILL MATERIAL	**#2 Well Gravel**	SLOT SIZE	**0.010 in.**
SCREEN MATERIAL	**PVC Schd. 40-Standard**	SCREEN DIAMETER	**2 in.**
RISER MATERIAL	**PVC Schd. 40-Standard**	RISER DIAMETER	**2 in.**
DRILLING TECHNIQUE	**HSA 4$^{1/4}$ in. I.D.**	DRILLING CONTRACTOR	**MACTEC – Atlanta, GA**
BOREHOLE DIAMETER	**8 in.**	MACTEC FIELD REPRESENTATIVE	**Matt Howe**
LOCK BRAND	**Masterlock**	SIZE/MODEL	**N/A**
KEY CODE/COMBINATION	**0536**		



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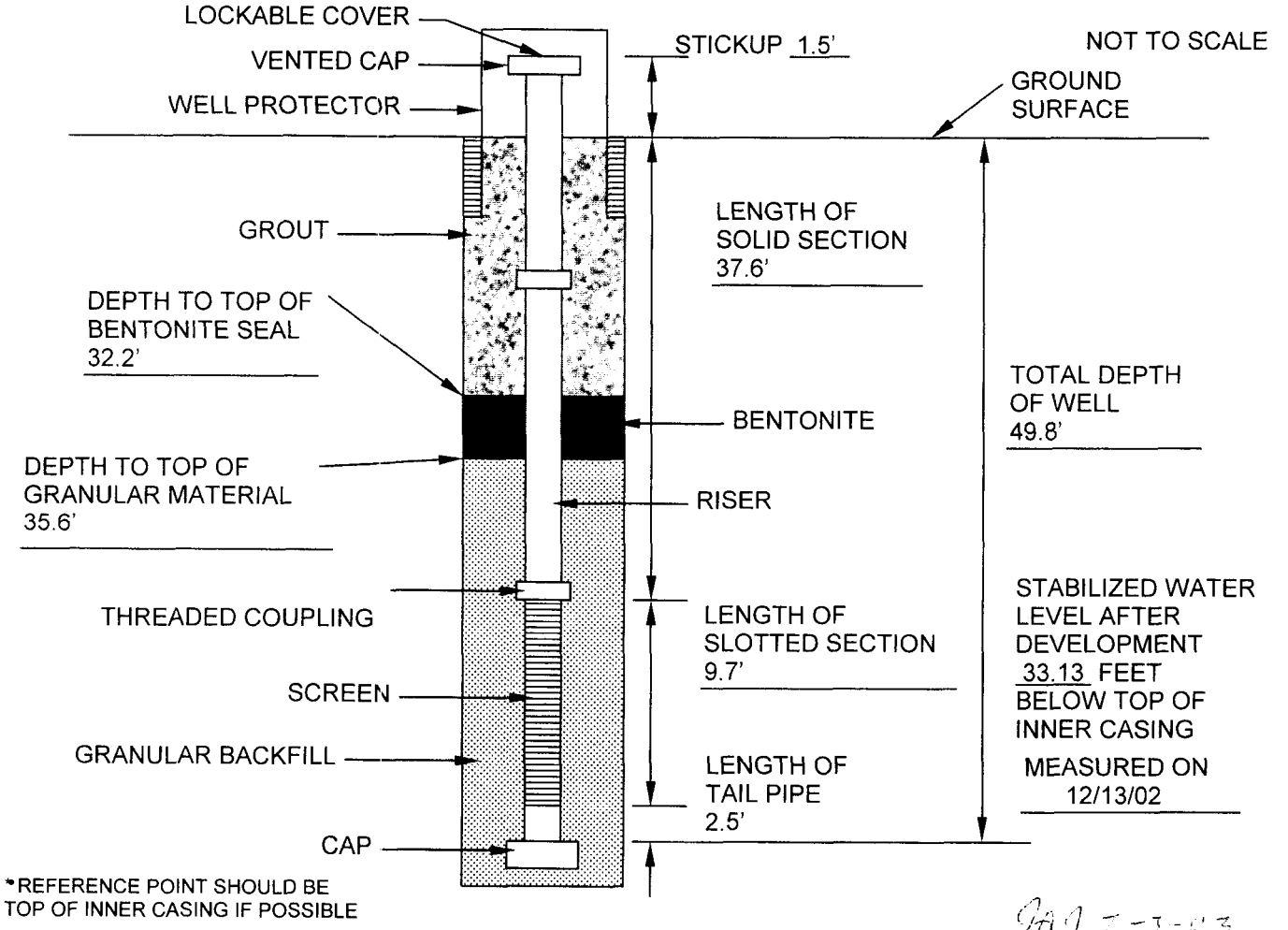
OBSERVATION WELL INSTALLATION RECORD

OBSERVATION WELL INSTALLATION RECORD

JOB NAME	**NORTH ANNA ESP**	JOB NUMBER	**37020-2-5400**
WELL NUMBER	**OW-849**	INSTALLATION DATE	**12/06/02**
LOCATION (NAD83)	**3910786.24N 11684731.02E**		
GROUND SURFACE ELEVATION (NAVD88)	**297.0 ft**	REFERENCE POINT ELEVATION * (NAVD88)	**298.5 ft**
GRANULAR BACKFILL MATERIAL	**#2 Well Gravel**	SLOT SIZE	**0.010 in.**
SCREEN MATERIAL	**PVC Schd. 40-Standard**	SCREEN DIAMETER	**2 in.**
RISER MATERIAL	**PVC Schd. 40-Standard**	RISER DIAMETER	**2 in.**
DRILLING TECHNIQUE	**HSA 4$^{1/4}$ in. I.D.**	DRILLING CONTRACTOR	**MACTEC – Atlanta, GA**
BOREHOLE DIAMETER	**8 in.**	MACTEC FIELD REPRESENTATIVE	**Matt Howe**
LOCK BRAND	**Masterlock**	SIZE/MODEL	**N/A**
KEY CODE/COMBINATION	**0536**		



*REFERENCE POINT SHOULD BE TOP OF INNER CASING IF POSSIBLE

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OBSERVATION WELL INSTALLATION RECORD

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Observation Well Development Woksheet

MACTEC JOB NUMBER **30720-2-5400** OBSERVATION WELL NUMBER OW-841

SITE NAME **North Anna Power Station**

DATE (MO/DAY/YR) 12/10/02 TIME (MILITARY) 0815

FIELD PERSONNEL Grimes + Howe

WEATHER CONDITIONS Cloudy + Low 30's

TOTAL WELL DEPTH (TWD) ~~35.60~~ WSK 12/11/02 35.80 FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE 1.5 FT.

DESCRIPTION OF MEASURING POINT T.O.C.

DEPTH TO GROUNDWATER (DGW) ~~35.60~~ WSK 12/10/02 2.63 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: Submersible whale pump

TOTAL VOLUME OF WATER REMOVED 33 GAL. CASING DIAMETER 2 IN.

CASING MATERIAL PVC ☒ S.S. ☐ TEFLON ☐ OTHER N/A

SCREENED INTERVAL (FROM ID PLATE) 23.5 - 33.2 (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☒	NO ☐	COMMENTS purged 5 gallons and let rest
LOCKING CAP	YES ~~☒~~ WSK 12/10/02	NO ☒	5 minutes. Purged another
PROTECTIVE POST/ABUTMENT	YES ☐	NO ☒	5 gallons and let rest
NONPOTABLE LABEL	YES ☐	NO ☒	5 minutes. Started w/ development
ID PLATE	YES ☐	NO ☒	
WELL INTEGRITY SATISFACTORY	YES ☒	NO ☐	

WELL YIELD LOW ☐ MODERATE ☐ HIGH ☒ COMMENTS

GROUNDWATER PARAMETERS

VOLUME (GAL.)	5	10	15	20	25	30	~~35~~ 33 WSK 12/10/02
pH (S.U.)	6.94	6.68	6.52	6.66	6.67	6.67	6.98
SP. COND. (µ~~MHOS~~ mS/CM) 12/10/02 WSK	0.312	0.229	0.240	0.199	0.202	0.297	0.258
WATER TEMP. (°C)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TURBIDITY*	(3)	(2)	(2)	(1)	(1)	(1)	(1)

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH OK [signature]

TWD - DGW x 0.167 x 6 = development amount in gallons

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Observation Well Development Woksheet

MACTEC JOB NUMBER 30720-2-5400 OBSERVATION WELL NUMBER OW-842

SITE NAME North Anna Power Station

DATE (MO/DAY/YR) 12/10/02 TIME (MILITARY) 1530

FIELD PERSONNEL Grimes + Howe

WEATHER CONDITIONS cloudy low 30's

TOTAL WELL DEPTH (TWD) 51.16 FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE 1.5' FT.

DESCRIPTION OF MEASURING POINT T.O.C.

DEPTH TO GROUNDWATER (DGW) 29.14 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: Submersible whale pump

TOTAL VOLUME OF WATER REMOVED 22 GAL. CASING DIAMETER 2 IN.

CASING MATERIAL PVC ☒ S.S. ☐ TEFLON ☐ OTHER ~~2~~ 12/10/02

SCREENED INTERVAL (FROM ID PLATE) 37.4 – 45.3 (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☒	NO ☐	COMMENTS Purged 3 gallons and let rest
LOCKING CAP	YES ☒	NO ☐	5 gallons. Purged 3 more gallons and
PROTECTIVE POST/ABUTMENT	YES ☐	NO ☒	let rest 5 minutes. Started
NONPOTABLE LABEL	YES ☐	NO ☒	purging development volumes.
ID PLATE	YES ☐	NO ☒	
WELL INTEGRITY SATISFACTORY	YES ☒	NO ☐	

WELL YIELD LOW ☐ MODERATE ☐ HIGH ☒ COMMENTS

GROUNDWATER PARAMETERS

VOLUME (GAL.)	3	6	~~12~~ 9	~~15~~ 12	~~18~~ 15	~~22~~ 18	22
pH (S.U.)	7.30	7.28	7.15	7.13	7.08	7.04	7.03
SP. COND. (µ~~MHOS~~/CM)	0.210	0.205	0.192	0.181	0.174	0.167	0.163
WATER TEMP. (°C)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TURBIDITY*	(2)	(2)	(2)	(2)	(1)	(1)	(1)

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

TWD - DGW *0.167 *6 = development volume in gallons

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Observation Well Development Worksheet

MACTEC JOB NUMBER **30720-2-5400** OBSERVATION WELL NUMBER OW-843

SITE NAME **North Anna Power Station**

DATE (MO/DAY/YR) 11/10/02 TIME (MILITARY) 1625

FIELD PERSONNEL Grimes & Howe

WEATHER CONDITIONS Cloudy & Low 30's

TOTAL WELL DEPTH (TWD) ~~51.00~~ WSE 11/14/02 50.90 FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE 1.5 FT.

DESCRIPTION OF MEASURING POINT T.O.C.

DEPTH TO GROUNDWATER (DGW) 35.74 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: Submersible whale pump

TOTAL VOLUME OF WATER REMOVED 16 30 GAL. CASING DIAMETER 2 IN.

CASING MATERIAL PVC ☒ S.S. ☐ TEFLON ☐ OTHER N/A

SCREENED INTERVAL (FROM ID PLATE) 40.2 - 49.9 (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☒	NO ☐	COMMENTS Purged 2.5 gallons, left rest
LOCKING CAP	YES ☒ WSE 11/14/02	NO ☒	5 minutes. Purged 2.5 more gallons,
PROTECTIVE POST/ABUTMENT	YES ☐	NO ☒	left rest 5 minutes, started
NONPOTABLE LABEL	YES ☐	NO ☒	development. Purged 14
ID PLATE	YES ☐	NO ☒	additional gallons to stabilize
WELL INTEGRITY SATISFACTORY	YES ☒	NO ☐	PM

WELL YIELD LOW ☐ MODERATE ☒ HIGH ☐ COMMENTS

GROUNDWATER PARAMETERS

	WSE 11/14/02	WSE 11/14/02	WSE 11/14/02	WSE 11/14/02	WSE 11/14/02	12/16/02 MRH	
VOLUME (GAL.)	~~3~~ 2.5	~~6~~ 5.0	~~9~~ 7.5	~~12~~ 10.0	~~15~~ 12.5	~~16~~ 15	17.5
pH (S.U.)	9.90	9.87	9.72	9.46	9.20	8.62	8.19
SP. COND. (~~µMHOS~~/CM) WSE 11/14/02 MLS	0.187	0.182	0.177	0.172	0.171	0.170	0.167
WATER TEMP. (°C)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TURBIDITY*	(2)	(2)	(2)	(2)	(2)	(1)	(1)

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

WSE 11/14/02 ~~twice weekly~~ →

TWD - DTW * 0.167 * 6 = development amount in gallons

See continuation sheet

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Observation Well Development Woksheet

MACTEC JOB NUMBER 30720-2-5400 OBSERVATION WELL NUMBER OW-843 continuation

SITE NAME North Anna Power Station

DATE (MO/DAY/YR) _____ TIME (MILITARY) _____

FIELD PERSONNEL _____

WEATHER CONDITIONS _____

TOTAL WELL DEPTH (TWD) _____ FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE _____ FT.

DESCRIPTION OF MEASURING POINT _____

DEPTH TO GROUNDWATER (DGW) WSG 12/11/02 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: _____

TOTAL VOLUME OF WATER REMOVED _____ GAL. CASING DIAMETER _____ IN.

CASING MATERIAL PVC ☐ S.S. ☐ TEFLON ☐ OTHER _____

SCREENED INTERVAL (FROM ID PLATE) _____ (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING YES ☐ NO ☐ COMMENTS _____

LOCKING CAP YES ☐ NO ☐

PROTECTIVE POST/ABUTMENT YES ☐ NO ☐

NONPOTABLE LABEL YES ☐ NO ☐

ID PLATE YES ☐ NO ☐

WELL INTEGRITY SATISFACTORY YES ☐ NO ☐

WELL YIELD LOW ☐ MODERATE ☐ HIGH ☐ COMMENTS _____

GROUNDWATER PARAMETERS

VOLUME (GAL.)	20	22.5	25	27.5	30	
pH (S.U.)	7.82	7.66	7.55	7.49	7.41	
12/11/02 SP. COND. (~~µMHOS~~ mS/CM)	0.165	0.164	0.163	0.161	0.160	
WATER TEMP. (°C)	N/A	N/A	N/A	N/A	N/A	
TURBIDITY*	(1)	(1)	(1)	(1)	(1)	

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH OK JAL

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Observation Well Development Woksheet

MACTEC JOB NUMBER 30720-2-5400 OBSERVATION WELL NUMBER OW-844

SITE NAME North Anna Power Station

DATE (MO/DAY/YR) 12/10/02 TIME (MILITARY) 1120

FIELD PERSONNEL Grimes & Howe

WEATHER CONDITIONS Cloudy, low 30's

TOTAL WELL DEPTH (TWD) ~~25.82~~ 26.10 wsb 12/11/02 FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE 1.5 FT.

DESCRIPTION OF MEASURING POINT T.O.C.

DEPTH TO GROUNDWATER (DGW) 8.95 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: Submersible whale pump

TOTAL VOLUME OF WATER REMOVED 17 GAL. CASING DIAMETER 2 IN.

CASING MATERIAL PVC ☒ S.S. ☐ TEFLON ☐ OTHER

SCREENED INTERVAL (FROM ID PLATE) 14.4 - 24.0 (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☒	NO ☐	COMMENTS
LOCKING CAP	YES ☒	NO ☐	
PROTECTIVE POST/ABUTMENT	YES ☐	NO ☒	
NONPOTABLE LABEL	YES ☐	NO ☒	
ID PLATE	YES ☐	NO ☒	
WELL INTEGRITY SATISFACTORY	YES ☒	NO ☐	

WELL YIELD LOW ☒ MODERATE ☒ wsb 12/10/02 HIGH ☐ COMMENTS

purged 3 gallons let rest 5 minutes. Purged another 2.5 gallons & well dried up, let rest. Dried up ~14.25 gallons, let rest. Dried up @ 19.75 gallons let rest. 1250-1736 @ 1730 DGW = 8.91. DGW @ 0935 on 12/11/02 = 8.83, well Dry @ 32 gallons

GROUNDWATER PARAMETERS

VOLUME (GAL.)	3	6	9	12	15	17
pH (S.U.)	8.47	7.97	8.38	7.82	7.40	7.46
wsb 12/11/02 SP. COND. (~~µMHOS~~ mS/CM)	0.202	0.195	0.223	0.190	0.185	0.187
WATER TEMP. (°C)	n/a	n/a	n/a	n/a	n/a	n/a
TURBIDITY*	(3)	(3)	(4)	(3)	(3)	(2)

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

wsb 12/11/02 ~~pmc readings~~

TWD - DGW * 0.167 * 6 = development amount in gallons

OK [signature]

See continuation sheet

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Observation Well Development Worksheet

MACTEC JOB NUMBER **30720-2-5400** OBSERVATION WELL NUMBER OW-844 Orientation

SITE NAME **North Anna Power Station**

DATE (MO/DAY/YR) _____ TIME (MILITARY) _____

FIELD PERSONNEL _____

WEATHER CONDITIONS _____

TOTAL WELL DEPTH (TWD) _____ FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE _____ FT.

DESCRIPTION OF MEASURING POINT TOC

DEPTH TO GROUNDWATER (DGW) 12/11/07 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: _____

TOTAL VOLUME OF WATER REMOVED _____ GAL. CASING DIAMETER _____ IN.

CASING MATERIAL PVC ☐ S.S. ☐ TEFLON ☐ OTHER _____

SCREENED INTERVAL (FROM ID PLATE) _____ (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☐	NO ☐	COMMENTS
LOCKING CAP	YES ☐	NO ☐	
PROTECTIVE POST/ABUTMENT	YES ☐	NO ☐	
NONPOTABLE LABEL	YES ☐	NO ☐	
ID PLATE	YES ☐	NO ☐	
WELL INTEGRITY SATISFACTORY	YES ☐	NO ☐	

WELL YIELD LOW ☐ MODERATE ☐ HIGH ☐ COMMENTS _____

GROUNDWATER PARAMETERS

VOLUME (GAL.)	20	23	26	29	32	
pH (S.U.)	7.63	7.72	7.67	7.66	7.62	
12/11/07 mS SP. COND. (~~µMHOS~~/CM)	0.201	0.207	0.199	0.209	0.200	
WATER TEMP. (°C)	n/a	n/a	n/a	n/a	n/a	
TURBIDITY*	(2)	(2)	(2)	(2)	(2)	

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

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Observation Well Development Worksheet

MACTEC JOB NUMBER 30720-2-5400 OBSERVATION WELL NUMBER OW-875

SITE NAME North Anna Power Station

DATE (MO/DAY/YR) 12/9/02 TIME (MILITARY) 1550

FIELD PERSONNEL Crews & Howe

WEATHER CONDITIONS Partly Sunny ~35's

TOTAL WELL DEPTH (TWD) ~~55.72~~ 56.50 usgs 12/11/02 FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE 1.5' FT.

DESCRIPTION OF MEASURING POINT T.O.C.

DEPTH TO GROUNDWATER (DGW) 24.69 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ ~~OTHER~~: Whale submersible pump

TOTAL VOLUME OF WATER REMOVED 31 GAL. CASING DIAMETER 2 IN.

CASING MATERIAL PVC ☒ S.S. ☐ TEFLON ☐ OTHER N/A

SCREENED INTERVAL (FROM ID PLATE) 43.6 - 53.3 (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☒	NO ~~☒~~ not installed	COMMENTS
LOCKING CAP	YES ☒	NO ☐	- purged 2.5 gallons, and shut pump off for 15 minutes.
PROTECTIVE POST/ABUTMENT	YES ~~☒~~ not installed	NO ☒	- purged 2.5 gallons, left rest 15 minutes. Purged 5 gallons
NONPOTABLE LABEL	YES ☐	NO ☒	left sit overnight ~~to~~ on 12/9/02
ID PLATE	YES ☐	NO ☒	before purging development volume.
WELL INTEGRITY SATISFACTORY	YES ☒	NO ☐	12/10/02 - DGW - 24.69 @ 1310

WELL YIELD LOW ☐ MODERATE ☒ HIGH ☐ COMMENTS

GROUNDWATER PARAMETERS

	~~1st~~ 1/10/02 at 1310	~~1st~~ 1/10/02 at 1315	~~1st~~ 1/10/02 at 1320	~~1st~~ 1/10/02 at 1325	~~1st~~ 1/10/02 at 1330	~~1st~~ 1/10/02 at 1335
VOLUME (GAL.)	~~6.5~~	~~+2.0~~	~~+1.5~~	~~+1.5~~	~~+1.5~~	31
pH (S.U.)	5.87	5.83	5.87	5.83	5.81	5.80
~~1st~~ SP. COND. (~~µMHOS~~/CM)	0.089 mS	0.098	0.095	0.096	0.095	0.096
WATER TEMP. (°C)	N/A	N/A	N/A	N/A	N/A	N/A
TURBIDITY*	(1)	(1)	(1)	(1)	(1)	(1)
DGW 12/10/02 =	24.77	0.08				

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

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TD - DGW * 0.167 * 6 = development amount in gallons

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Observation Well Development Worksheet

MACTEC JOB NUMBER **30720-2-5400** OBSERVATION WELL NUMBER OW-846

SITE NAME **North Anna Power Station**

DATE (MO/DAY/YR) 12/9/07 TIME (MILITARY) 1615

FIELD PERSONNEL Grimes & Howe

WEATHER CONDITIONS Partly Sunny and in the 30's

TOTAL WELL DEPTH (TWD) ~~35.60~~ 34.30 12/11/07 wsl FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE _____ FT.

DESCRIPTION OF MEASURING POINT T.O.C.

DEPTH TO GROUNDWATER (DGW) 24.82 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: Submersible whale pump

TOTAL VOLUME OF WATER REMOVED 9.33 GAL. (wsl 12/10/07) CASING DIAMETER 2 IN.

CASING MATERIAL PVC ☒ S.S. ☐ TEFLON ☐ OTHER N/A

SCREENED INTERVAL (FROM ID PLATE) _____ (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☒	NO ☐	COMMENTS	pumped 1 gallon, let rest 5
LOCKING CAP	YES ☒	NO ☐		minutes, pumped another gallon
PROTECTIVE POST/ABUTMENT	YES ☐	NO ☒		let rest 5 minutes. Pumped
NONPOTABLE LABEL	YES ☐	NO ☒		1 gallon let rest 5 minutes. Pumped 1
ID PLATE	YES ☐	NO ☒		gallon let rest 5 minutes.
WELL INTEGRITY SATISFACTORY	YES ☒	NO ☐		removed development volume
WELL YIELD LOW ☐ MODERATE ☐ HIGH ☒			COMMENTS	7 additional 24 gallons to clear up sediment.

GROUNDWATER PARAMETERS

VOLUME (GAL.)	1.5	3.0	4.5	6.0	7.5	9.0
pH (S.U.)	5.01	5.19	5.16	5.09	5.16	5.07
~~HIGH~~ low SP. COND. (~~µMHOS~~ mS/CM)	0.245	0.226	0.229	0.233	0.~~HS~~	0.237
WATER TEMP. (°C)	N/A	N/A	N/A	N/A	N/A	N/A
TURBIDITY* visual	(4)	(4)	(4)	(3)	(3)	(3)
~~DTW~~ DGW on	12/10/07 =	24.93				

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

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TD - DGW * 0.167 * L = development amount

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Observation Well Development Woksheet

MACTEC JOB NUMBER 30720-2-5400 OBSERVATION WELL NUMBER OW-847

SITE NAME North Anna Power Station

DATE (MO/DAY/YR) 12/10/02 TIME (MILITARY) 1410

FIELD PERSONNEL Grimes & Howe

WEATHER CONDITIONS Cloudy & Low 30's

TOTAL WELL DEPTH (TWD) ~~50.83~~ 51.30 WSG 12/11/02 FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE 1.5 FT.

DESCRIPTION OF MEASURING POINT T.O.C

DEPTH TO GROUNDWATER (DGW) 34.18 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER WSG 12/11/02 ☐ OTHER: Submersible whale pump

TOTAL VOLUME OF WATER REMOVED ~~17~~ 28 GAL. CASING DIAMETER 2 IN.

CASING MATERIAL PVC ☒ S.S. ☐ TEFLON ☐ OTHER N/A

SCREENED INTERVAL (FROM ID PLATE) 37.6' - 45.5 (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☒	NO ☐	COMMENTS Pumped 3 gallons and let
LOCKING CAP	YES ☒	NO ☐	rest 5 minutes. Pumped
PROTECTIVE POST/ABUTMENT	YES ☐	NO ☒	3 more gallons, let rest
NONPOTABLE LABEL	YES ☐	NO ☒	5 minutes. Started pumping
ID PLATE	YES ☐	NO ☒	development volumes. Pulled
WELL INTEGRITY SATISFACTORY	YES ☒	NO ☐	11 additional gallons to clear

WELL YIELD LOW ☐ MODERATE ☒ HIGH ☐ COMMENTS up sediment.

GROUNDWATER PARAMETERS

VOLUME (GAL.)	3	6	9	12	15	17
pH (S.U.)	7.48	7.11	7.10	7.16	7.25	7.04
SP. COND. (~~µMHOS~~ mS/CM) WSG 12/11/02	0.134	0.103	0.101	0.102	0.119	0.107
WATER TEMP. (°C)	N/A	N/A	N/A	N/A	N/A	N/A
TURBIDITY*	(4)	(4)	(3)	(3)	(2)	(2)

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

WSG 12/11/02 More readings →

TWD - DGW * 0.167 * 8 = well development amount in gallons

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See continuation sheet

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Observation Well Development Worksheet

MACTEC JOB NUMBER **30720-2-5400** OBSERVATION WELL NUMBER OW-847 continuation

SITE NAME **North Anna Power Station**

DATE (MO/DAY/YR) _____ TIME (MILITARY) _____

FIELD PERSONNEL _____

WEATHER CONDITIONS _____

TOTAL WELL DEPTH (TWD) _____ FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE _____ FT.

DESCRIPTION OF MEASURING POINT _____

DEPTH TO GROUNDWATER (DGW) WSC 1/11/02 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: _____

TOTAL VOLUME OF WATER REMOVED _____ GAL. CASING DIAMETER _____ IN.

CASING MATERIAL PVC ☐ S.S. ☐ TEFLON ☐ OTHER _____

SCREENED INTERVAL (FROM ID PLATE) _____ (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☒	NO ☐	COMMENTS
LOCKING CAP	YES ☐	NO ☐	
PROTECTIVE POST/ABUTMENT	YES ☒	NO ☒	
NONPOTABLE LABEL	YES ☒	NO ☐	
ID PLATE	YES ☐	NO ☒	
WELL INTEGRITY SATISFACTORY	YES ☐	NO ☐	

WELL YIELD LOW ☐ MODERATE ☐ HIGH ☐ COMMENTS _____

GROUNDWATER PARAMETERS

VOLUME (GAL.)	20	23	26			
pH (S.U.)	6.94	7.05	7.04			
1/11/02 WSC MS SP. COND. (~~µMHOS~~/CM)	0.092	0.096	0.112			
WATER TEMP. (°C)	n/a	n/a	n/a			
TURBIDITY*	(2)	(1)	(1)			

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

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Observation Well Development Woksheet

MACTEC JOB NUMBER 30720-2-5400 OBSERVATION WELL NUMBER OW-848

SITE NAME North Anna Power Station

DATE (MO/DAY/YR) 12/10/02 TIME (MILITARY) 0920

FIELD PERSONNEL Grimes + Howe

WEATHER CONDITIONS Cloudy in low 30's

TOTAL WELL DEPTH (TWD) ~~49.30~~ 48.87 wsb 12/10/02 FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE 1.5' FT.

DESCRIPTION OF MEASURING POINT T.O.C

DEPTH TO GROUNDWATER (DGW) 42.79 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: Submersible whale pump

TOTAL VOLUME OF WATER REMOVED ~~6.5~~ 8.5 GAL. CASING DIAMETER 2 IN.

CASING MATERIAL PVC ☑ S.S. ☐ TEFLON ☐ OTHER N/A

SCREENED INTERVAL (FROM ID PLATE) 42.2 - 47.22 (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☒	NO ☐	COMMENTS Removed 1 gallon + let rest
LOCKING CAP	YES ☒	NO ☐	5 minutes. Removed 1 gallon +
PROTECTIVE POST/ABUTMENT	YES ☐	NO ☒	let rest for 5 minutes. Removed
NONPOTABLE LABEL	YES ☐	NO ☒	1 gallon + let 8 wsb 12/10/02 rest
ID PLATE	YES ☐	NO ☒	5 minutes prior to developing
WELL INTEGRITY SATISFACTORY	YES ☒	NO ☐	pulled an additional 2 gallons

WELL YIELD LOW ☐ MODERATE ☒ HIGH ☐ COMMENTS to clear up sediment

GROUNDWATER PARAMETERS

VOLUME (GAL.)	1	2	3	4	5	6	6.5
pH (S.U.)	8.87	8.60	9.38	8.78	8.43	8.25	7.88
SP. COND. (~~µMHOS~~ mS/CM)	0.200	0.230	0.186	0.281	0.293	0.307	0.314
WATER TEMP. (°C)	N/A ~~(3)~~ ~~(4)~~	~~t~~ wsb 12/10/02	N/A	N/A	N/A	N/A	N/A
TURBIDITY*	(4)	(4)	(4)	(4)	(4)	(3)	(3)

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

wsb 12/10/02 ~~More readings~~

TWD - DGW + 0.167 * 6 - development amount in gallons

OK JCL see continuation sheet

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Observation Well Development Worksheet

MACTEC JOB NUMBER **30720-2-5400** OBSERVATION WELL NUMBER OW-848 continuation

SITE NAME **North Anna Power Station**

DATE (MO/DAY/YR) _____ TIME (MILITARY) _____

FIELD PERSONNEL _____

WEATHER CONDITIONS _____

TOTAL WELL DEPTH (TWD) _____ FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE _____ FT.

DESCRIPTION OF MEASURING POINT _____

DEPTH TO GROUNDWATER (DGW) WSE 11/16/07 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: _____

TOTAL VOLUME OF WATER REMOVED _____ GAL. CASING DIAMETER _____ IN.

CASING MATERIAL PVC ☐ S.S. ☐ TEFLON ☐ OTHER _____

SCREENED INTERVAL (FROM ID PLATE) _____ (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☐	NO ☐	COMMENTS _____
LOCKING CAP	YES ☐	NO ☐	_____
PROTECTIVE POST/ABUTMENT	YES ☐	NO ☐	_____
NONPOTABLE LABEL	YES ☐	NO ☐	_____
ID PLATE	YES ☐	NO ☐	_____
WELL INTEGRITY SATISFACTORY	YES ☐	NO ☐	_____

WELL YIELD LOW ☐ MODERATE ☐ HIGH ☐ COMMENTS _____

GROUNDWATER PARAMETERS

VOLUME (GAL.)	7.5	8.5				
pH (S.U.)	7.49	7.42				
(Hach WSE ms) SP. COND. (~~µMHOS~~/CM)	0.353	0.368				
WATER TEMP. (°C)	n/a	n/a				
TURBIDITY*	(2)	(1)				

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

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Observation Well Development Worksheet

MACTEC JOB NUMBER **30720-2-5400** OBSERVATION WELL NUMBER OW-849

SITE NAME **North Anna Power Station**

DATE (MO/DAY/YR) 12/11/02 TIME (MILITARY) 1350

FIELD PERSONNEL Grimes & Deobald

WEATHER CONDITIONS rainy and Low 30's

TOTAL WELL DEPTH (TWD) 51.30 FT. (DEPTH BELOW MEASURING POINT)

HEIGHT OF MEASURING POINT ABOVE LAND SURFACE 1.5 FT.

DESCRIPTION OF MEASURING POINT T.O.C.

DEPTH TO GROUNDWATER (DGW) 33.15 FT. (DEPTH BELOW MEASURING POINT)

METHOD OF WELL EVACUATION DISPOSABLE BAILER ☐ OTHER: Submersible Whale Pump

TOTAL VOLUME OF WATER REMOVED 18.5 GAL. CASING DIAMETER 2 IN.

CASING MATERIAL PVC ☒ S.S. ☐ TEFLON ☐ OTHER N/A

SCREENED INTERVAL (FROM ID PLATE) 37.6 - 47.3 (DEPTHS BELOW LAND SURFACE - FT.)

STEEL GUARD PIPE AROUND CASING	YES ☒	NO ☐	COMMENTS	Pumped 3 gallons, let rest 5
LOCKING CAP	YES ☐	NO ☐		minutes, Pumped 5 more gallons,
PROTECTIVE POST/ABUTMENT	YES ☐	NO ☒		let rest 5 minutes, Started
NONPOTABLE LABEL	YES ☐	NO ☒		pumping development volumes
ID PLATE	YES ☐	NO ☒		
WELL INTEGRITY SATISFACTORY	YES ☒	NO ☐		

WELL YIELD LOW ☐ MODERATE ☐ HIGH ☒ COMMENTS

GROUNDWATER PARAMETERS

VOLUME (GAL.)	3	6	9	12	15	18.5
pH (S.U.)	6.95	6.84	6.80	6.74	6.74	6.62
SP. COND. (µMHOS/CM) (use 12/11/02 ms)	0.117	0.099	0.089	0.084	0.083	0.078
WATER TEMP. (°C)	N/A	N/A	N/A	N/A	N/A	N/A
TURBIDITY*	(2)	(2)	(2)	(1)	(1)	(1)

* VISUAL DETERMINATION ONLY (1) CLEAR (2) SLIGHT (3) MODERATE (4) HIGH

OK JAT

APPENDIX E
WELL PERMEABILITY TEST RESULTS

Slug - In

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/13/02	**Time:** 0820	**Observation Well No.:**	OW-841
Weather Conditions:	cloudy in upper 30's		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	35.80 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.7 ft	**Depth interval of screened portion:**	22.0 - 31.7 ft
Depth to Groundwater:	2.45 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
WSE 12/11/02 ~~35.80~~ 2.63	12-10-02
2.89	12-09-02

Comments/Remarks

Slug 1 volume = 0.08 ft³

Slug 2 volume = 0.08 ft³

Transducer S/N → 6407

Hermit S/N → 45449

Set transducer @ 20' below TOC

WSE

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Vell: OW-841
est Date: 12/13/2002
Test Type: Recovery (slug in)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BWhite 12/20/02

WELL DATA

SWL =	2.45	(ft BTOC)
WD =	35.80	(ft BTOC)
WD =	34.30	(ft BGS)
DTSP =	20.10	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.7	(ft)
Lw =	33.35	(ft)
Le/rw =	29.39	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	1.425	(ft) from plot
yt =	0.472	(ft) from plot
t =	0.644	(minutes) from plot
ln(Re/rw) =	2.70	
K =	**2.2E+00**	**(ft/day)**
K =	**7.8E-04**	**(cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln{(H-Lw)/rw)}/(Le/rw)]^-1= 2.70

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 3.23

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.39	2.49	0.35	2.08

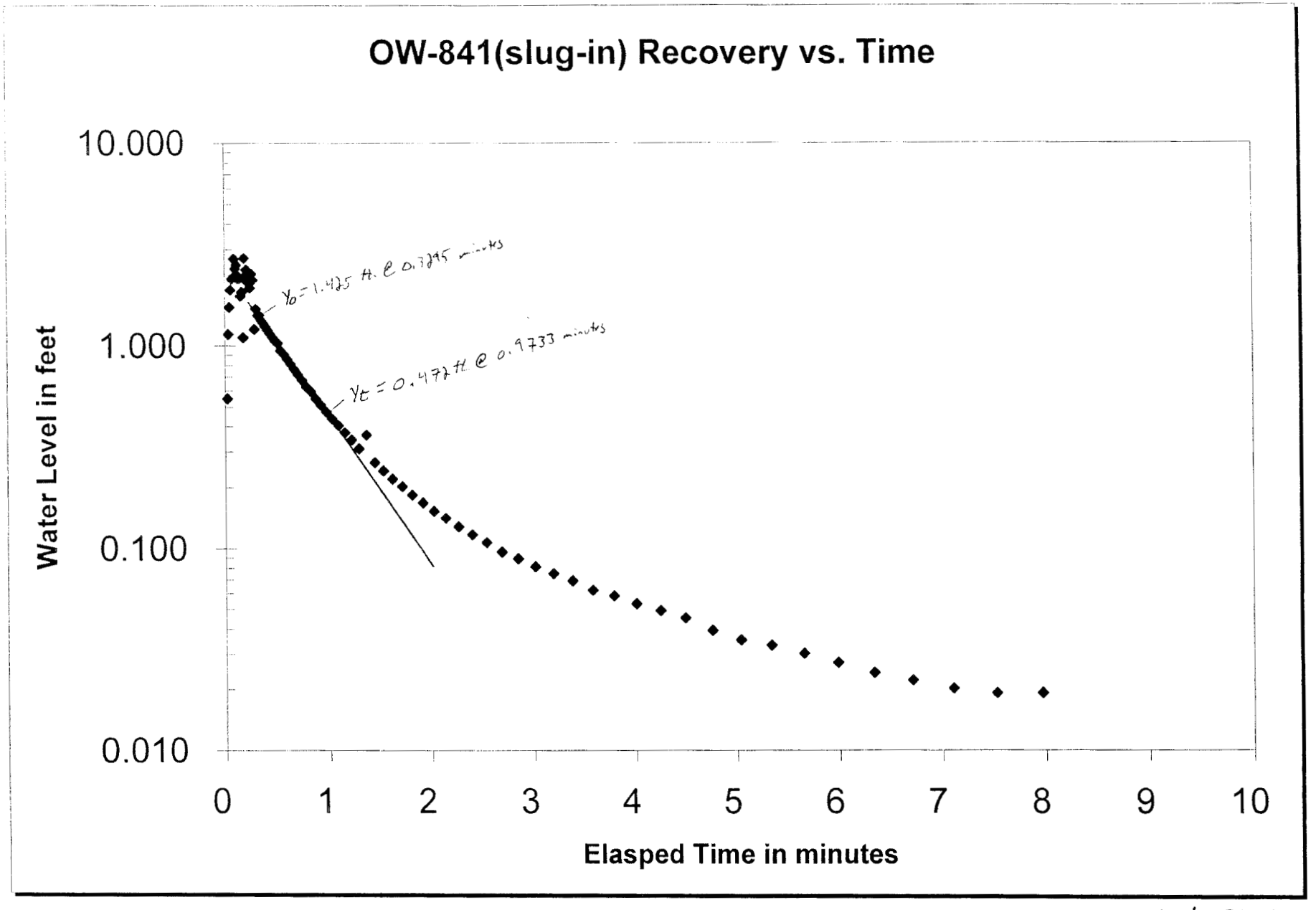
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0.000	2.45	0
0.011	-3.00	0.001	2.449	-0.001
0.022	-0.26	0.550	1.9	-0.55
0.033	0.06	1.142	1.308	-1.142
0.044	0.19	1.561	0.889	-1.561
0.055	0.28	1.901	0.549	-1.901
0.066	0.33	2.157	0.293	-2.157
0.077	0.34	2.175	0.275	-2.175
0.088	0.43	2.708	-0.258	-2.708
0.099	0.38	2.423	0.027	-2.423
0.11	0.40	2.533	-0.083	-2.533
0.121	0.34	2.169	0.281	-2.169
0.132	0.35	2.223	0.227	-2.223
0.143	0.33	2.157	0.293	-2.157
0.154	0.25	1.776	0.674	-1.776
0.165	0.27	1.854	0.596	-1.854
0.176	0.04	1.102	1.348	-1.102
0.187	0.44	2.726	-0.276	-2.726
0.198	0.35	2.233	0.217	-2.233
0.209	0.38	2.396	0.054	-2.396
0.22	0.32	2.076	0.374	-2.076
0.231	0.32	2.083	0.367	-2.083
0.2427	0.29	1.946	0.504	-1.946
0.2552	0.36	2.286	0.164	-2.286
0.2683	0.33	2.129	0.321	-2.129
0.2823	0.08	1.210	1.24	-1.21
0.2972	0.18	1.530	0.92	-1.53
0.3128	0.15	1.419	1.031	-1.419
0.3295	0.15	1.425	1.025	-1.425
0.3472	0.13	1.341	1.109	-1.341
0.3658	0.11	1.295	1.155	-1.295
0.3857	0.10	1.249	1.201	-1.249
0.4067	0.08	1.201	1.249	-1.201
0.4288	0.06	1.152	1.298	-1.152
0.4523	0.04	1.106	1.344	-1.106
0.4772	0.02	1.059	1.391	-1.059
0.5035	0.01	1.033	1.417	-1.033
0.5315	-0.02	0.948	1.502	-0.948
0.5612	-0.04	0.909	1.541	-0.909
0.5925	-0.06	0.861	1.589	-0.861
0.6257	-0.09	0.814	1.636	-0.814
0.6608	-0.12	0.766	1.684	-0.766
0.6982	-0.14	0.722	1.728	-0.722
0.7377	-0.17	0.675	1.775	-0.675
0.7795	-0.20	0.625	1.825	-0.625
0.8238	-0.23	0.595	1.855	-0.595
0.8708	-0.26	0.549	1.901	-0.549
0.9207	-0.29	0.510	1.94	-0.51
0.9733	-0.33	0.472	1.978	-0.472
1.0292	-0.36	0.436	2.014	-0.436
1.0883	-0.39	0.405	2.045	-0.405
1.151	-0.43	0.373	2.077	-0.373
1.2173	-0.46	0.344	2.106	-0.344
1.2877	-0.51	0.311	2.139	-0.311
1.3622	-0.44	0.363	2.087	-0.363
1.4412	-0.58	0.265	2.185	-0.265
1.5248	-0.62	0.241	2.209	-0.241
1.6133	-0.66	0.220	2.23	-0.22
1.7072	-0.69	0.202	2.248	-0.202
1.8065	-0.74	0.184	2.266	-0.184
1.9118	-0.77	0.168	2.282	-0.168
2.0233	-0.82	0.153	2.297	-0.153
2.1415	-0.85	0.141	2.309	-0.141
2.2667	-0.89	0.128	2.322	-0.128
2.3992	-0.93	0.117	2.333	-0.117
2.5397	-0.97	0.107	2.343	-0.107
2.6885	-1.02	0.096	2.354	-0.096
2.846	-1.05	0.089	2.361	-0.089
3.0128	-1.09	0.081	2.369	-0.081
3.1897	-1.12	0.075	2.375	-0.075
3.377	-1.16	0.069	2.381	-0.069
3.5753	-1.21	0.062	2.388	-0.062
3.7855	-1.24	0.058	2.392	-0.058
4.0082	-1.28	0.053	2.397	-0.053
4.244	-1.31	0.049	2.401	-0.049
4.4938	-1.35	0.045	2.405	-0.045
4.7585	-1.41	0.039	2.411	-0.039
5.0388	-1.46	0.035	2.415	-0.035
5.3357	-1.48	0.033	2.417	-0.033
5.6502	-1.52	0.030	2.42	-0.03
5.9833	-1.57	0.027	2.423	-0.027
6.3362	-1.62	0.024	2.426	-0.024
6.71	-1.66	0.022	2.428	-0.022
7.106	-1.70	0.020	2.43	-0.02
7.5253	-1.72	0.019	2.431	-0.019
7.9697	-1.72	0.019	2.431	-0.019



CHKD: BKS 12/20/02

Slug-out

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/13/02	**Time:** 0835	**Observation Well No.:**	OW-841
Weather Conditions:	cloudy in upper 30's		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	35.50 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.7 ft	**Depth interval of screened portion:**	22.0-31.70 ft
Depth to Groundwater:	2.45 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
~~35.50~~ 2.63	12/10/02
2.59	12/09/02

Comments/Remarks

USGS
Slug #2 → volume = 0.08 ft³
Transducer S/N = 6407
Mount S/N = 45449

Set transducer @ 20' below TOC

WSG

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-841
Test Date: 12/13/2002
Test Type: Recovery (slug out)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BH Jones 12/20/02

WELL DATA

SWL =	2.45	(ft BTOC)
WD =	35.80	(ft BTOC)
WD =	34.30	(ft BGS)
DTSP =	20.10	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.7	(ft)
Lw =	33.35	(ft)
Le/rw =	29.39	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	2.180	(ft) from plot
yt =	0.829	(ft) from plot
t =	0.540	(minutes) from plot
ln(Re/rw) =	2.70	

K = 2.3E+00 (ft/day)

K = 8.2E-04 (cm/sec)

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1= 2.70

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 3.23

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.39	2.49	0.35	2.08

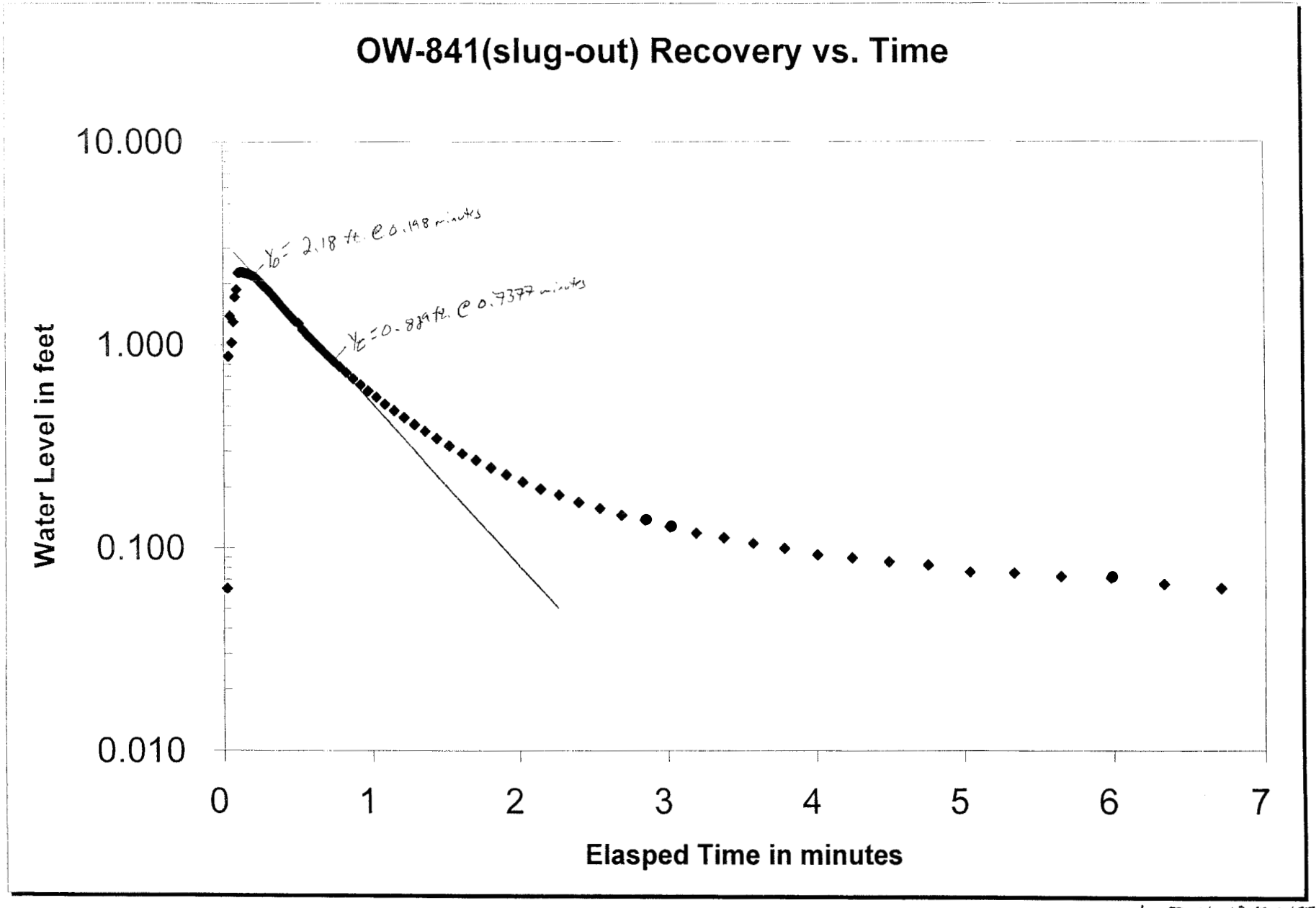
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0.000	2.45	0
0.011	#NUM!	0.000	2.45	0
0.022	-1.20	0.063	2.513	0.063
0.033	-0.06	0.877	3.327	0.877
0.044	0.14	1.385	3.835	1.385
0.055	0.01	1.024	3.474	1.024
0.066	0.11	1.299	3.749	1.299
0.077	0.23	1.716	4.166	1.716
0.088	0.27	1.870	4.32	1.87
0.099	0.35	2.259	4.709	2.259
0.11	0.36	2.269	4.719	2.269
0.121	0.36	2.280	4.73	2.28
0.132	0.36	2.267	4.717	2.267
0.143	0.35	2.262	4.712	2.262
0.154	0.35	2.249	4.699	2.249
0.165	0.35	2.236	4.686	2.236
0.176	0.35	2.223	4.673	2.223
0.187	0.34	2.206	4.656	2.206
0.198	0.34	2.180	4.63	2.18
0.209	0.33	2.160	4.61	2.16
0.22	0.33	2.128	4.578	2.128
0.231	0.32	2.086	4.536	2.086
0.2427	0.31	2.046	4.496	2.046
0.2552	0.30	1.995	4.445	1.995
0.2683	0.29	1.949	4.399	1.949
0.2823	0.28	1.911	4.361	1.911
0.2972	0.27	1.860	4.31	1.86
0.3128	0.26	1.804	4.254	1.804
0.3295	0.24	1.746	4.196	1.746
0.3472	0.23	1.687	4.137	1.687
0.3658	0.21	1.626	4.076	1.626
0.3857	0.19	1.561	4.011	1.561
0.4067	0.18	1.500	3.95	1.5
0.4288	0.16	1.437	3.887	1.437
0.4523	0.14	1.375	3.825	1.375
0.4772	0.12	1.312	3.762	1.312
0.5035	0.11	1.281	3.731	1.281
0.5315	0.07	1.185	3.635	1.185
0.5612	0.05	1.119	3.569	1.119
0.5925	0.02	1.058	3.508	1.058
0.6257	0.00	0.998	3.448	0.998
0.6608	-0.03	0.942	3.392	0.942
0.6982	-0.05	0.884	3.334	0.884
0.7377	-0.08	0.829	3.279	0.829
0.7795	-0.11	0.780	3.23	0.78
0.8238	-0.14	0.732	3.182	0.732
0.8708	-0.17	0.681	3.131	0.681
0.9207	-0.20	0.636	3.086	0.636
0.9733	-0.23	0.593	3.043	0.593
1.0292	-0.26	0.552	3.002	0.552
1.0883	-0.29	0.511	2.961	0.511
1.151	-0.32	0.474	2.924	0.474
1.2173	-0.36	0.438	2.888	0.438
1.2877	-0.39	0.405	2.855	0.405
1.3622	-0.42	0.376	2.826	0.376
1.4412	-0.46	0.346	2.796	0.346
1.5248	-0.50	0.318	2.768	0.318
1.6133	-0.53	0.292	2.742	0.292
1.7072	-0.57	0.271	2.721	0.271
1.8065	-0.60	0.249	2.699	0.249
1.9118	-0.64	0.230	2.68	0.23
2.0233	-0.67	0.212	2.662	0.212
2.1415	-0.71	0.196	2.646	0.196
2.2667	-0.74	0.183	2.633	0.183
2.3992	-0.77	0.168	2.618	0.168
2.5397	-0.80	0.157	2.607	0.157
2.6885	-0.84	0.145	2.595	0.145
2.846	-0.86	0.137	2.587	0.137
3.0128	-0.90	0.127	2.577	0.127
3.1897	-0.93	0.118	2.568	0.118
3.377	-0.95	0.112	2.562	0.112
3.5753	-0.98	0.105	2.555	0.105
3.7855	-1.00	0.099	2.549	0.099
4.0082	-1.04	0.092	2.542	0.092
4.244	-1.05	0.089	2.539	0.089
4.4938	-1.07	0.085	2.535	0.085
4.7585	-1.09	0.082	2.532	0.082
5.0388	-1.12	0.076	2.526	0.076
5.3357	-1.12	0.075	2.525	0.075
5.6502	-1.14	0.072	2.522	0.072
5.9833	-1.15	0.071	2.521	0.071
6.3362	-1.18	0.066	2.516	0.066
6.71	-1.20	0.063	2.513	0.063



CHK'D: BWJ 12/20/02

Slug - In

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/12/02	**Time:** 1015	**Observation Well No.:**	[illegible]
Weather Conditions: [illegible]			
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	57.16 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	7.9 ft	**Depth interval of screened portion:**	37.4-45.3 ft
Depth to Groundwater:	29.23 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
29.14	12/10/02
29.22	12/06/02
29.33	12/12/02

Comments/Remarks

Used Slug #2 Volume = 0.25 ft³

Transducer Sh = 5.10 ft

Casing Sh = 45.39

[illegible]

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-842
Test Date: 12/17/2002
Test Type: Recovery (slug in)

Conducted by: Grimes and Howe
Entered/date: WSG/12/18/2002
Checked/date: 12/20/02

WELL DATA

SWL =	29.23	(ft BTOC)
WD =	51.16	(ft BTOC)
WD =	49.66	(ft BGS)
DTSP =	35.30	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	7.9	(ft)
Lw =	21.93	(ft)
Le/rw =	23.94	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	2.670	(ft) from plot
yt =	0.589	(ft) from plot
t =	2.343	(minutes) from plot
ln(Re/rw) =	2.38	
K =	**9.3E-01**	**(ft/day)**
K =	**3.3E-04**	**(cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H:

ln(Re/rw) = [(1.1/(ln(Lw/rw)))+(A+Bln((H-Lw)/rw))/(Le/rw)]^-1= 2.38

Where: Lw = H:

ln(Re/rw) = [(1.1/(ln(Lw/rw)))+(C/(Le/rw))]^-1 = 2.94

Calculation of Coefficients

Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
20	2.23	0.29	1.75
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

23.94	2.34	0.31	1.89

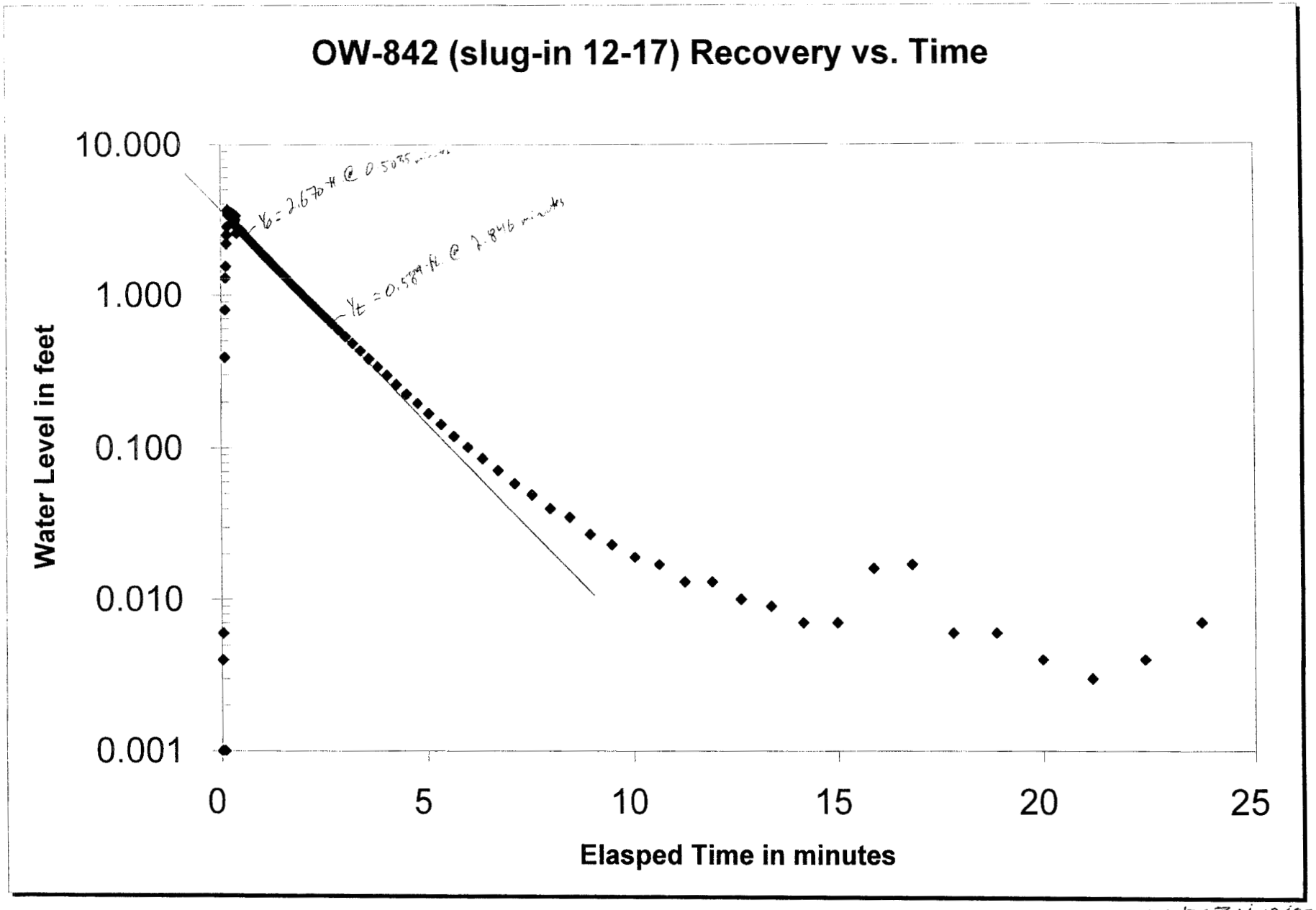
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0.000	29.23	0
0.011	-3.00	0.001	29.229	-0.001
0.022	-2.40	0.004	29.226	-0.004
0.033	-2.22	0.006	29.224	-0.006
0.044	-3.00	0.001	29.229	-0.001
0.055	-3.00	0.001	29.229	-0.001
0.066	#NUM!	0.000	29.23	0
0.077	-3.00	0.001	29.229	-0.001
0.088	-0.41	0.390	28.84	-0.39
0.099	-0.10	0.800	28.43	-0.8
0.11	0.11	1.299	27.931	-1.299
0.121	0.19	1.552	27.678	-1.552
0.132	0.34	2.184	27.046	-2.184
0.143	0.40	2.501	26.729	-2.501
0.154	0.45	2.841	26.389	-2.841
0.165	0.56	3.651	25.579	-3.651
0.176	0.53	3.390	25.84	-3.39
0.187	0.55	3.535	25.695	-3.535
0.198	0.55	3.586	25.644	-3.586
0.209	0.53	3.411	25.819	-3.411
0.22	0.55	3.547	25.683	-3.547
0.231	0.55	3.522	25.708	-3.522
0.2427	0.53	3.422	25.808	-3.422
0.2552	0.53	3.350	25.88	-3.35
0.2683	0.54	3.502	25.728	-3.502
0.2823	0.52	3.282	25.948	-3.282
0.2972	0.54	3.463	25.767	-3.463
0.3128	0.49	3.079	26.151	-3.079
0.3295	0.49	3.079	26.151	-3.079
0.3472	0.50	3.149	26.081	-3.149
0.3658	0.53	3.360	25.87	-3.36
0.3857	0.41	2.569	26.661	-2.569
0.4067	0.45	2.793	26.437	-2.793
0.4288	0.44	2.773	26.457	-2.773
0.4523	0.44	2.737	26.493	-2.737
0.4772	0.43	2.693	26.537	-2.693
0.5035	0.43	2.670	26.56	-2.67
0.5315	0.41	2.589	26.641	-2.589
0.5612	0.40	2.533	26.697	-2.533
0.5925	0.40	2.484	26.746	-2.484
0.6257	0.38	2.425	26.805	-2.425
0.6608	0.37	2.371	26.859	-2.371
0.6982	0.36	2.312	26.918	-2.312
0.7377	0.35	2.256	26.974	-2.256
0.7795	0.34	2.190	27.04	-2.19
0.8238	0.33	2.129	27.101	-2.129
0.8708	0.31	2.060	27.17	-2.06
0.9207	0.30	1.994	27.236	-1.994
0.9733	0.28	1.925	27.305	-1.925
1.0292	0.27	1.860	27.37	-1.86
1.0883	0.25	1.782	27.448	-1.782
1.151	0.24	1.725	27.505	-1.725
1.2173	0.22	1.643	27.587	-1.643
1.2877	0.19	1.566	27.664	-1.566
1.3622	0.17	1.491	27.739	-1.491
1.4412	0.15	1.421	27.809	-1.421
1.5248	0.13	1.346	27.884	-1.346
1.6133	0.10	1.271	27.959	-1.271
1.7072	0.08	1.198	28.032	-1.198
1.8065	0.05	1.124	28.106	-1.124
1.9118	0.02	1.054	28.176	-1.054
2.0233	-0.01	0.980	28.25	-0.98
2.1415	-0.04	0.911	28.319	-0.911
2.2667	-0.07	0.844	28.386	-0.844
2.3992	-0.11	0.776	28.454	-0.776
2.5397	-0.15	0.713	28.517	-0.713
2.6885	-0.19	0.649	28.581	-0.649
2.846	-0.23	0.589	28.641	-0.589
3.0128	-0.27	0.534	28.696	-0.534
3.1897	-0.32	0.481	28.749	-0.481
3.377	-0.37	0.430	28.8	-0.43
3.5753	-0.42	0.381	28.849	-0.381
3.7855	-0.47	0.338	28.892	-0.338
4.0082	-0.53	0.297	28.933	-0.297
4.244	-0.59	0.259	28.971	-0.259
4.4938	-0.65	0.225	29.005	-0.225
4.7585	-0.71	0.196	29.034	-0.196
5.0388	-0.77	0.168	29.062	-0.168
5.3357	-0.84	0.143	29.087	-0.143
5.6502	-0.92	0.119	29.111	-0.119
5.9833	-1.00	0.101	29.129	-0.101
6.3362	-1.07	0.085	29.145	-0.085
6.71	-1.15	0.071	29.159	-0.071
7.106	-1.24	0.058	29.172	-0.058
7.5253	-1.31	0.049	29.181	-0.049
7.9697	-1.40	0.040	29.19	-0.04
8.4403	-1.46	0.035	29.195	-0.035
8.9388	-1.57	0.027	29.203	-0.027
9.4668	-1.64	0.023	29.207	-0.023
10.0262	-1.72	0.019	29.211	-0.019
10.6187	-1.77	0.017	29.213	-0.017
11.2462	-1.89	0.013	29.217	-0.013
11.911	-1.89	0.013	29.217	-0.013
12.6152	-2.00	0.010	29.22	-0.01
13.361	-2.05	0.009	29.221	-0.009
14.151	-2.15	0.007	29.223	-0.007
14.9878	-2.15	0.007	29.223	-0.007
15.8743	-1.80	0.016	29.214	-0.016
16.8133	-1.77	0.017	29.213	-0.017
17.808	-2.22	0.006	29.224	-0.006
18.8617	-2.22	0.006	29.224	-0.006
19.9777	-2.40	0.004	29.226	-0.004
21.1598	-2.52	0.003	29.227	-0.003
22.412	-2.40	0.004	29.226	-0.004
23.7385	-2.15	0.007	29.223	-0.007



CHK'D: BWJ 12/20/02

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/12/02	**Time:** 0955	**Observation Well No.:**	OW-847
Weather Conditions:	Foggy in the 40s		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	51.16 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	27.9 ft WSS 12/12/02	**Depth interval of screened portion:**	37.4-45.3 ft
Depth to Groundwater:	29.33 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
29.14	12/10/02
29.22	12/06/02

Comments/Remarks

[illegible]

Slug 2 → volume = [illegible]

Transducer SN = 6407

Hermit SN = 45449

WSS

See transducer 45' below TOC

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-842
Test Date: 12/12/2002
Test Type: Recovery (slug out)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BWJ 12/20/02

WELL DATA

SWL =	29.33	(ft BTOC)
WD =	51.16	(ft BTOC)
WD =	49.66	(ft BGS)
DTSP =	35.30	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	7.9	(ft)
Lw =	21.83	(ft)
Le/rw =	23.94	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	2.548	(ft) from plot
yt =	0.771	(ft) from plot
t =	1.857	(minutes) from plot
ln(Re/rw) =	2.38	
K =	**9.3E-01**	**(ft/day)**
K =	**3.3E-04**	**(cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [(1.1/(ln(Lw/rw))}+{A+Bln((H Lw)/rw)}/(Le/rw)]^-1 = 2.38

Where: Lw = H;

ln(Re/rw) = [(1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 2.94

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
20	2.23	0.29	1.75
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

23.94	2.34	0.31	1.89

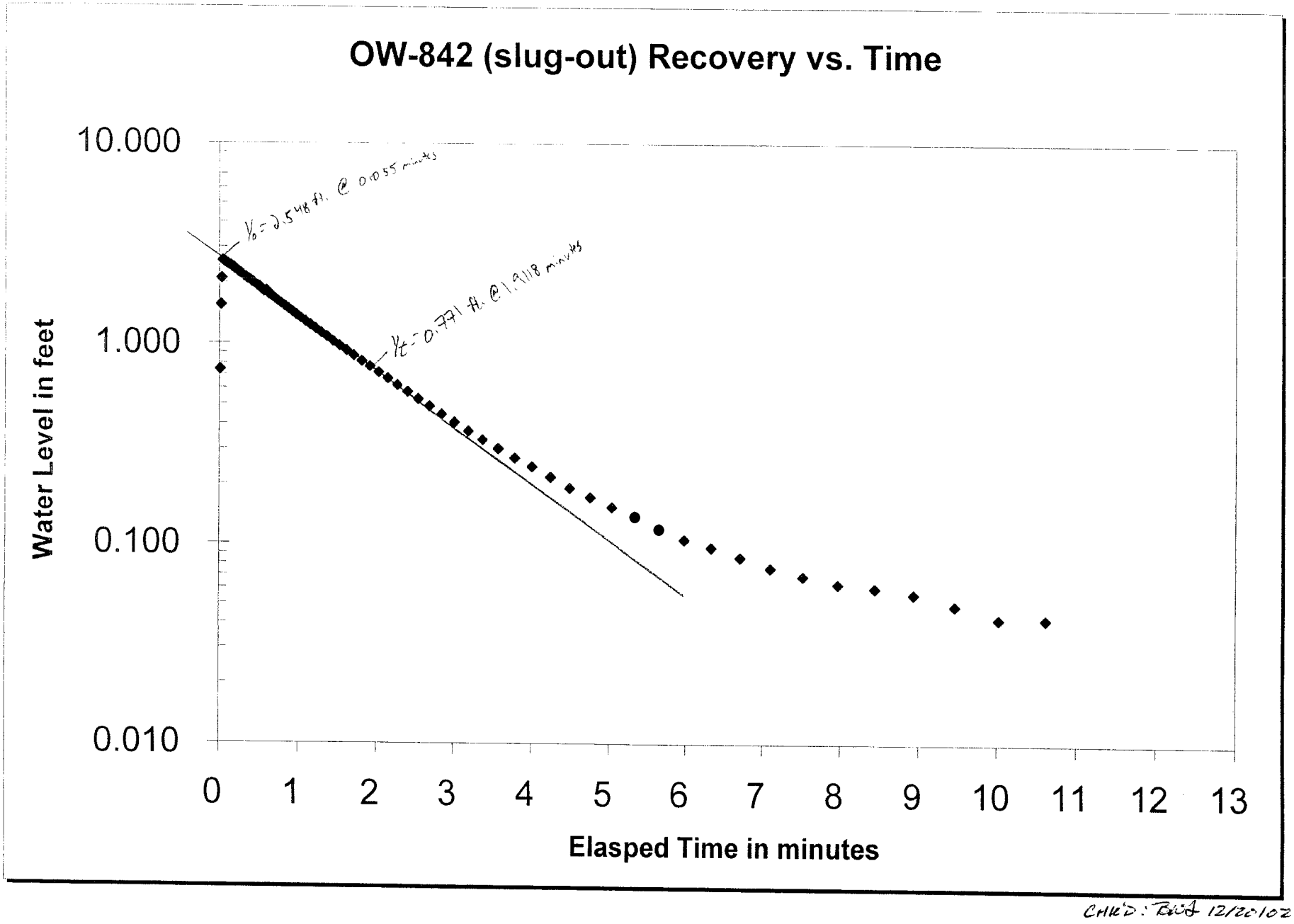
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0.000	29.33	29.33
0.011	-0.13	0.741	30.071	30.071
0.022	0.19	1.546	30.876	30.876
0.033	0.32	2.089	31.419	31.419
0.044	0.41	2.561	31.891	31.891
0.055	0.41	2.548	31.878	31.878
0.066	0.40	2.519	31.849	31.849
0.077	0.40	2.524	31.854	31.854
0.088	0.40	2.486	31.816	31.816
0.099	0.39	2.468	31.798	31.798
0.11	0.39	2.468	31.798	31.798
0.121	0.39	2.442	31.772	31.772
0.132	0.39	2.432	31.762	31.762
0.143	0.39	2.436	31.766	31.766
0.154	0.38	2.390	31.72	31.72
0.165	0.38	2.378	31.708	31.708
0.176	0.38	2.384	31.714	31.714
0.187	0.37	2.330	31.66	31.66
0.198	0.37	2.322	31.652	31.652
0.209	0.37	2.318	31.648	31.648
0.22	0.36	2.299	31.629	31.629
0.231	0.36	2.266	31.596	31.596
0.2427	0.35	2.246	31.576	31.576
0.2552	0.35	2.232	31.562	31.562
0.2683	0.35	2.216	31.546	31.546
0.2823	0.34	2.193	31.523	31.523
0.2972	0.34	2.168	31.498	31.498
0.3128	0.33	2.143	31.473	31.473
0.3295	0.33	2.131	31.461	31.461
0.3472	0.32	2.094	31.424	31.424
0.3658	0.32	2.072	31.402	31.402
0.3857	0.31	2.059	31.389	31.389
0.4067	0.30	2.015	31.345	31.345
0.4288	0.30	2.003	31.333	31.333
0.4523	0.29	1.961	31.291	31.291
0.4772	0.28	1.927	31.257	31.257
0.5035	0.28	1.912	31.242	31.242
0.5315	0.27	1.843	31.173	31.173
0.5612	0.26	1.802	31.132	31.132
0.5925	0.26	1.827	31.157	31.157
0.6257	0.24	1.744	31.074	31.074
0.6608	0.23	1.704	31.034	31.034
0.6982	0.22	1.662	30.992	30.992
0.7377	0.21	1.617	30.947	30.947
0.7795	0.20	1.574	30.904	30.904
0.8238	0.18	1.530	30.86	30.86
0.8708	0.17	1.482	30.812	30.812
0.9207	0.16	1.435	30.765	30.765
0.9733	0.14	1.386	30.716	30.716
1.0292	0.13	1.335	30.665	30.665
1.0883	0.11	1.287	30.617	30.617
1.151	0.09	1.236	30.566	30.566
1.2173	0.07	1.184	30.514	30.514
1.2877	0.05	1.133	30.463	30.463
1.3622	0.03	1.082	30.412	30.412
1.4412	0.01	1.028	30.358	30.358
1.5248	-0.01	0.977	30.307	30.307
1.6133	-0.03	0.925	30.255	30.255
1.7072	-0.06	0.872	30.202	30.202
1.8065	-0.09	0.820	30.15	30.15
1.9118	-0.11	0.771	30.101	30.101
2.0233	-0.14	0.720	30.05	30.05
2.1415	-0.17	0.671	30.001	30.001
2.2667	-0.21	0.623	29.953	29.953
2.3992	-0.24	0.576	29.906	29.906
2.5397	-0.27	0.531	29.861	29.861
2.6885	-0.31	0.489	29.819	29.819
2.846	-0.35	0.448	29.778	29.778
3.0128	-0.39	0.409	29.739	29.739
3.1897	-0.43	0.370	29.7	29.7
3.377	-0.47	0.335	29.665	29.665
3.5753	-0.52	0.302	29.632	29.632
3.7855	-0.57	0.271	29.601	29.601
4.0082	-0.61	0.245	29.575	29.575
4.244	-0.66	0.217	29.547	29.547
4.4938	-0.72	0.191	29.521	29.521
4.7585	-0.77	0.171	29.501	29.501
5.0388	-0.82	0.153	29.483	29.483
5.3357	-0.86	0.137	29.467	29.467
5.6502	-0.92	0.119	29.449	29.449
5.9833	-0.98	0.105	29.435	29.435
6.3362	-1.02	0.096	29.426	29.426
6.71	-1.07	0.086	29.416	29.416
7.106	-1.12	0.076	29.406	29.406
7.5253	-1.16	0.069	29.399	29.399
7.9697	-1.20	0.063	29.393	29.393
8.4403	-1.22	0.060	29.39	29.39
8.9388	-1.25	0.056	29.386	29.386
9.4668	-1.31	0.049	29.379	29.379
10.0262	-1.38	0.042	29.372	29.372
10.6187	-1.38	0.042	29.372	29.372
11.2462	-1.38	0.042	29.372	29.372
11.911	-1.38	0.042	29.372	29.372
12.6152	-1.38	0.042	29.372	29.372



CHK'D: RWA 12/20/02

Slug - 2a

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date:	[illegible]	**Time:**	[illegible]
Observation Well No.:	[illegible]		
Weather Conditions:	[illegible]		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	**Rising Head** or **Falling Head** (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	[illegible] ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.2 ft	**Depth interval of screened portion:**	[illegible] ft
Depth to Groundwater:	34.53 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
35.74	[illegible]
35.63	[illegible]
35.67	[illegible]

Comments/Remarks

[illegible]

[illegible]

[illegible]

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-843
Test Date: 12/17/2002
Test Type: Recovery (slug in)

Conducted by: Grimes and Howe
Entered/date: WSG/12/18/2002
Checked/date: BWA mg 12/20/02

WELL DATA

SWL =	35.53	(ft BTOC)
WD =	50.90	(ft BTOC)
WD =	49.40	(ft BGS)
DTSP =	36.40	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.7	(ft)
Lw =	15.37	(ft)
Le/rw =	29.39	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	1.569 (ft) from plot
yt =	0.518 (ft) from plot
t =	0.993 (minutes) from plot
ln(Re/rw) =	2.33
K =	**1.3E+00 (ft/day)**
K =	**4.5E-04 (cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1= 2.33

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 2.78

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.39	2.49	0.35	2.08

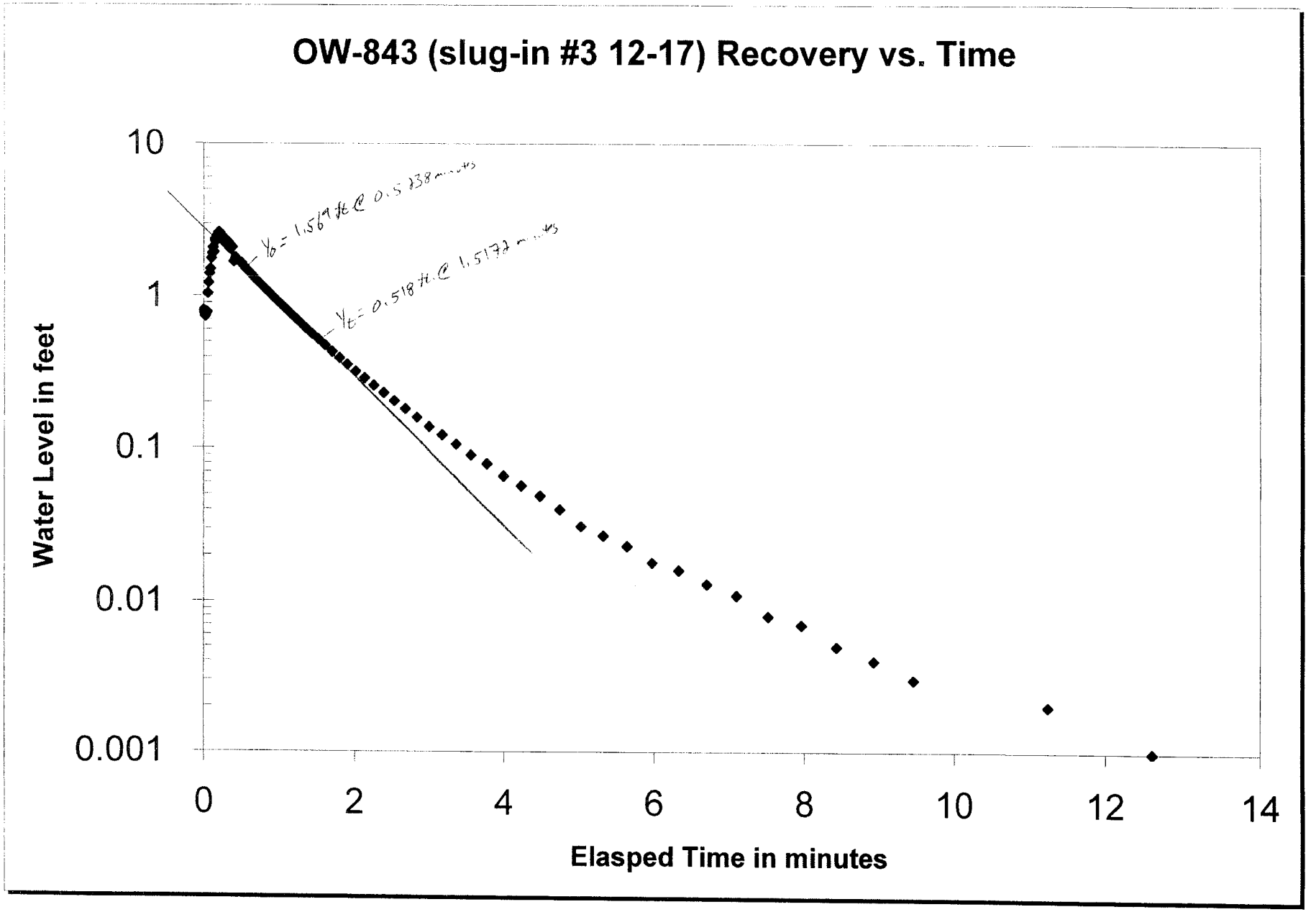
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y Adjusted (ft)	WL (ft BTOC)	Data Logger results
0	-0.10	0.803	34.727	0
0.0112	-0.12	0.766	34.764	0.037
0.0223	-0.13	0.733	34.797	0.07
0.0335	-0.12	0.758	34.772	0.045
0.0447	-0.11	0.779	34.751	0.024
0.0558	0.02	1.036	34.494	-0.233
0.067	0.09	1.221	34.309	-0.418
0.0782	0.15	1.398	34.132	-0.595
0.0893	0.18	1.502	34.028	-0.699
0.1005	0.25	1.762	33.768	-0.959
0.1117	0.28	1.908	33.622	-1.105
0.1228	0.32	2.078	33.452	-1.275
0.134	0.29	1.937	33.593	-1.134
0.1452	0.37	2.355	33.175	-1.552
0.1563	0.36	2.275	33.255	-1.472
0.1675	0.39	2.472	33.058	-1.669
0.1787	0.39	2.483	33.047	-1.68
0.1898	0.42	2.611	32.919	-1.808
0.201	0.42	2.63	32.9	-1.827
0.2122	0.41	2.596	32.934	-1.793
0.2233	0.40	2.531	32.999	-1.728
0.235	0.39	2.447	33.083	-1.644
0.2475	0.38	2.4	33.13	-1.597
0.2607	0.38	2.426	33.104	-1.623
0.2747	0.35	2.258	33.272	-1.455
0.2895	0.36	2.265	33.265	-1.462
0.3052	0.34	2.196	33.334	-1.393
0.3218	0.36	2.266	33.264	-1.463
0.3395	0.31	2.054	33.476	-1.251
0.3582	0.31	2.032	33.498	-1.229
0.378	0.32	2.094	33.436	-1.291
0.399	0.22	1.677	33.853	-0.874
0.4212	0.25	1.785	33.745	-0.982
0.4447	0.24	1.732	33.798	-0.929
0.4695	0.23	1.687	33.843	-0.884
0.4958	0.22	1.658	33.872	-0.855
0.5238	0.20	1.569	33.961	-0.766
0.5535	0.18	1.512	34.018	-0.709
0.5848	0.16	1.454	34.076	-0.651
0.618	0.15	1.397	34.133	-0.594
0.6532	0.13	1.335	34.195	-0.532
0.6905	0.11	1.277	34.253	-0.474
0.73	0.09	1.22	34.31	-0.417
0.7718	0.07	1.162	34.368	-0.359
0.8162	0.04	1.102	34.428	-0.299
0.8632	0.02	1.046	34.484	-0.243
0.913	-0.01	0.983	34.547	-0.18
0.9657	-0.03	0.928	34.602	-0.125
1.0215	-0.06	0.871	34.659	-0.068
1.0807	-0.09	0.82	34.71	-0.017
1.1433	-0.12	0.763	34.767	0.04
1.2097	-0.15	0.711	34.819	0.092
1.28	-0.18	0.661	34.869	0.142
1.3545	-0.21	0.61	34.92	0.193
1.4335	-0.25	0.562	34.968	0.241
1.5172	-0.29	0.518	35.012	0.285
1.6057	-0.32	0.475	35.055	0.328
1.6995	-0.36	0.432	35.098	0.371
1.7988	-0.41	0.393	35.137	0.41
1.9042	-0.45	0.356	35.174	0.447
2.0157	-0.49	0.32	35.21	0.483
2.1338	-0.54	0.289	35.241	0.514
2.259	-0.59	0.258	35.272	0.545
2.3915	-0.64	0.231	35.299	0.572
2.532	-0.69	0.204	35.326	0.599
2.6808	-0.74	0.181	35.349	0.622
2.8383	-0.80	0.159	35.371	0.644
3.0052	-0.86	0.138	35.392	0.665
3.182	-0.91	0.122	35.408	0.681
3.3693	-0.97	0.106	35.424	0.697
3.5677	-1.05	0.09	35.44	0.713
3.7778	-1.10	0.079	35.451	0.724
4.0005	-1.18	0.066	35.464	0.737
4.2363	-1.24	0.057	35.473	0.746
4.4862	-1.31	0.049	35.481	0.754
4.7508	-1.40	0.04	35.49	0.763
5.0312	-1.51	0.031	35.499	0.772
5.328	-1.57	0.027	35.503	0.776
5.6425	-1.64	0.023	35.507	0.78
5.9757	-1.74	0.018	35.512	0.785



CHK'D: BAH 12/20/12

Slug-out

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date:	~~1245~~ 12/11/02	**Time:** 1245	**Observation Well No.:** OW-843
Weather Conditions:	Partly Sunny in 40's		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	50.90 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.7 ft	**Depth interval of screened portion:**	40.2-49.9 ft
Depth to Groundwater:	35.69 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
35.74	12/10/02

Comments/Remarks

Used Slug 2 → volume = 0.05 ft3

Transducer → SM = 6407

Element → 45449

S.A.

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WSC

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-843
Test Date: 12/12/2002
Test Type: Recovery (slug out)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BW Jones 12/20/02

WELL DATA

SWL =	35.69	(ft BTOC)
WD =	50.90	(ft BTOC)
WD =	49.40	(ft BGS)
DTSP =	36.40	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.7	(ft)
Lw =	15.21	(ft)
Le/rw =	29.39	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	1.873	(ft) from plot
yt =	0.817	(ft) from plot
t =	0.692	(minutes) from plot
ln(Re/rw) =	2.33	

K = 1.4E+00 (ft/day)

K = 4.9E-04 (cm/sec)

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [(1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw))/(Le/rw)]^-1= 2.33

Where: Lw = H;

ln(Re/rw) = [(1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 2.78

Calculation of Coefficients

Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.39	2.49	0.35	2.08

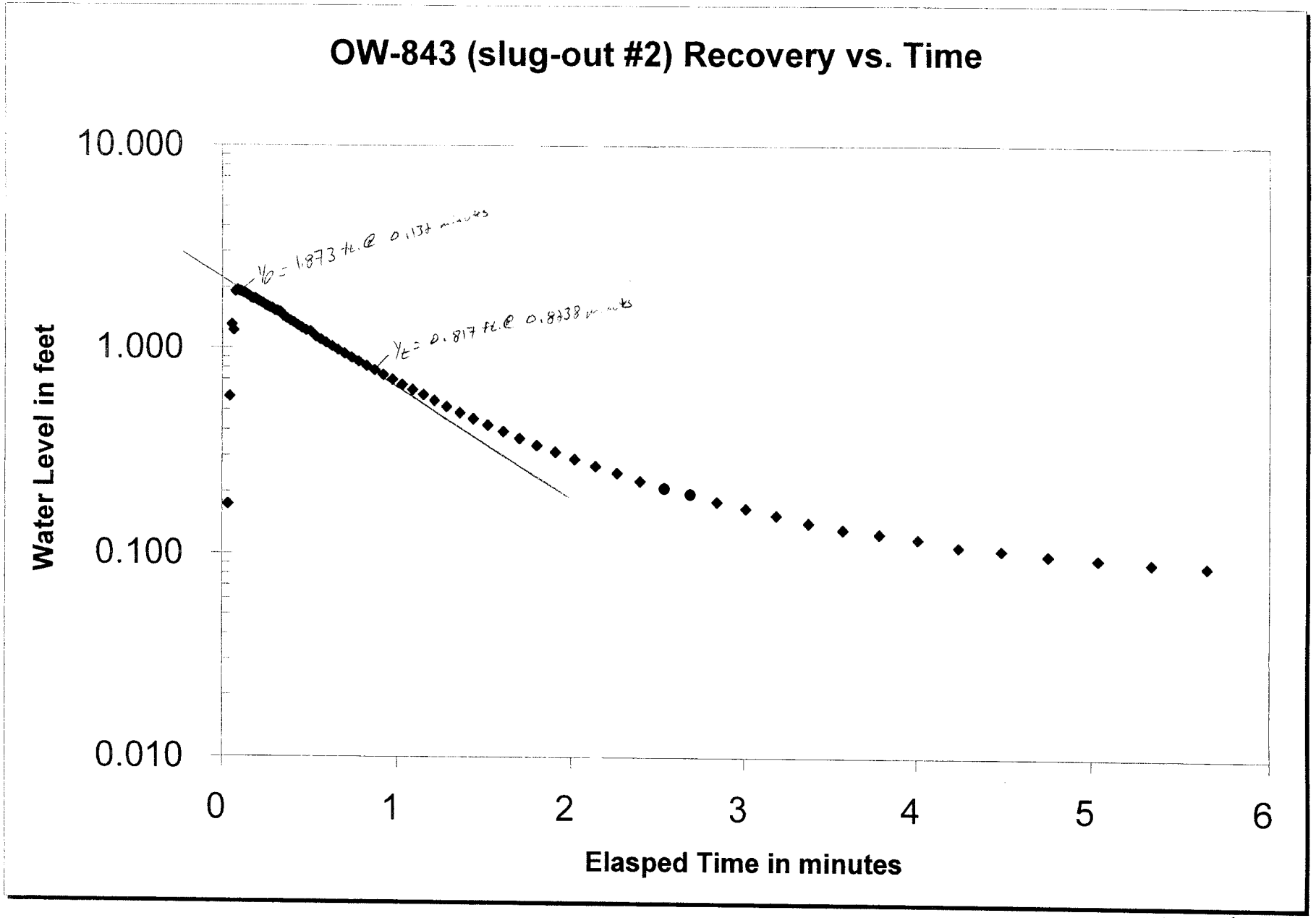
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0.000	35.69	35.69
0.011	-2.40	0.004	35.694	35.694
0.022	-2.22	0.006	35.696	35.696
0.033	-0.76	0.174	35.864	35.864
0.044	-0.24	0.578	36.268	36.268
0.055	0.12	1.307	36.997	36.997
0.066	0.09	1.223	36.913	36.913
0.077	0.28	1.912	37.602	37.602
0.088	0.29	1.941	37.631	37.631
0.099	0.28	1.918	37.608	37.608
0.11	0.28	1.906	37.596	37.596
0.121	0.27	1.882	37.572	37.572
0.132	0.27	1.873	37.563	37.563
0.143	0.26	1.839	37.529	37.529
0.154	0.26	1.813	37.503	37.503
0.165	0.25	1.778	37.468	37.468
0.176	0.25	1.761	37.451	37.451
0.187	0.25	1.760	37.45	37.45
0.198	0.24	1.738	37.428	37.428
0.209	0.23	1.709	37.399	37.399
0.22	0.23	1.689	37.379	37.379
0.231	0.22	1.666	37.356	37.356
0.2427	0.21	1.636	37.326	37.326
0.2552	0.21	1.616	37.306	37.306
0.2683	0.20	1.592	37.282	37.282
0.2823	0.20	1.579	37.269	37.269
0.2972	0.19	1.540	37.23	37.23
0.3128	0.18	1.530	37.22	37.22
0.3295	0.18	1.508	37.198	37.198
0.3472	0.16	1.441	37.131	37.131
0.3658	0.15	1.406	37.096	37.096
0.3857	0.14	1.372	37.062	37.062
0.4067	0.13	1.343	37.033	37.033
0.4288	0.11	1.299	36.989	36.989
0.4523	0.10	1.264	36.954	36.954
0.4772	0.09	1.227	36.917	36.917
0.5035	0.08	1.210	36.9	36.9
0.5315	0.06	1.141	36.831	36.831
0.5612	0.04	1.105	36.795	36.795
0.5925	0.03	1.062	36.752	36.752
0.6257	0.01	1.021	36.711	36.711
0.6608	-0.01	0.980	36.67	36.67
0.6982	-0.03	0.940	36.63	36.63
0.7377	-0.05	0.898	36.588	36.588
0.7795	-0.07	0.858	36.548	36.548
0.8238	-0.09	0.817	36.507	36.507
0.8708	-0.11	0.779	36.469	36.469
0.9207	-0.13	0.738	36.428	36.428
0.9733	-0.15	0.700	36.39	36.39
1.0292	-0.18	0.662	36.352	36.352
1.0883	-0.20	0.625	36.315	36.315
1.151	-0.23	0.592	36.282	36.282
1.2173	-0.26	0.555	36.245	36.245
1.2877	-0.28	0.519	36.209	36.209
1.3622	-0.31	0.486	36.176	36.176
1.4412	-0.34	0.455	36.145	36.145
1.5248	-0.37	0.424	36.114	36.114
1.6133	-0.40	0.395	36.085	36.085
1.7072	-0.44	0.366	36.056	36.056
1.8065	-0.47	0.339	36.029	36.029
1.9118	-0.50	0.315	36.005	36.005
2.0233	-0.54	0.290	35.98	35.98
2.1415	-0.57	0.269	35.959	35.959
2.2667	-0.60	0.249	35.939	35.939
2.3992	-0.64	0.227	35.917	35.917
2.5397	-0.68	0.211	35.901	35.901
2.6885	-0.71	0.197	35.887	35.887
2.846	-0.74	0.180	35.87	35.87
3.0128	-0.78	0.167	35.857	35.857
3.1897	-0.81	0.155	35.845	35.845
3.377	-0.85	0.142	35.832	35.832
3.5753	-0.88	0.132	35.822	35.822
3.7855	-0.90	0.126	35.816	35.816
4.0082	-0.92	0.119	35.809	35.809
4.244	-0.96	0.109	35.799	35.799
4.4938	-0.98	0.105	35.795	35.795
4.7585	-1.00	0.099	35.789	35.789
5.0388	-1.02	0.095	35.785	35.785
5.3357	-1.04	0.091	35.781	35.781
5.6502	-1.06	0.088	35.778	35.778



CHKD: BKS 12/22/10

Slug - In

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/13/02	**Time:** 0710	**Observation Well No.:**	~~8~~ OW-844 12/11/02
Weather Conditions:	Cloudy upper 30's		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	26.10 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.6 ft	**Depth interval of screened portion:**	14.4-24.0 ft
Depth to Groundwater:	8.48 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
8.95	12/10/02
8.91	12/10/02
8.83	12/11/02
8.90	12/06/02

Comments/Remarks

Used Slug # 2 → volume = 0.08 ft³

Transducer S/N → 5407

Hermit S/N → 45449

Set transducer @ 20' below TOC

WSG

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-844
Test Date: 12/13/2002
Test Type: Recovery (slug in)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: EWJ 12/20/02

WELL DATA

SWL =	8.48	(ft BTOC)
WD =	26.10	(ft BTOC)
WD =	24.60	(ft BGS)
DTSP =	12.70	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.6	(ft)
Lw =	17.62	(ft)
Le/rw =	29.09	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	3.022	(ft) from plot
yt =	2.000	(ft) from plot
t =	1.868	(minutes) from plot
ln(Re/rw) =	2.38	
K =	**2.5E-01**	**(ft/day)**
K =	**8.9E-05**	**(cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)}^-1= 2.38

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 2.86

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.09	2.48	0.34	2.06

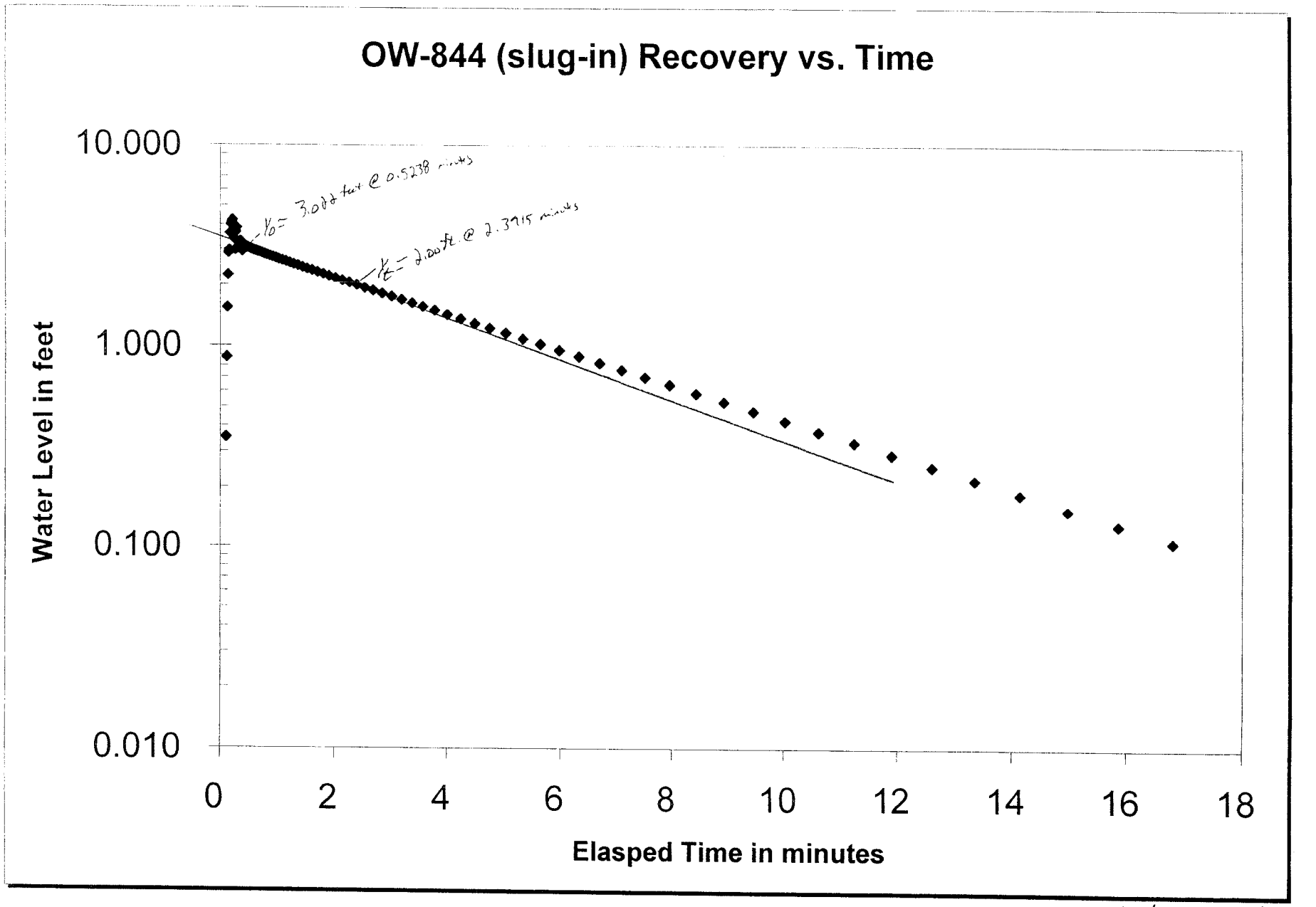
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0.000	8.48	0
0.0112	-3.00	0.001	8.479	0.001
0.0223	#NUM!	0.000	8.48	0
0.0335	-3.00	0.001	8.479	-0.001
0.0447	-2.40	0.004	8.476	-0.004
0.0558	-2.40	0.004	8.476	-0.004
0.067	-2.22	0.006	8.474	-0.006
0.0782	-2.22	0.006	8.474	-0.006
0.0893	-2.22	0.006	8.474	-0.006
0.1005	-0.45	0.352	8.128	-0.352
0.1117	-0.06	0.879	7.601	-0.879
0.1228	0.19	1.537	6.943	-1.537
0.134	0.35	2.235	6.245	-2.235
0.1452	0.46	2.874	5.606	-2.874
0.1563	0.47	2.973	5.507	-2.973
0.1675	0.56	3.609	4.871	-3.609
0.1787	0.60	4.000	4.48	-4
0.1898	0.60	4.025	4.455	-4.025
0.201	0.62	4.124	4.356	-4.124
0.2122	0.63	4.229	4.251	-4.229
0.2233	0.57	3.697	4.783	-3.697
0.235	0.53	3.382	5.098	-3.382
0.2475	0.59	3.859	4.621	-3.859
0.2607	0.47	2.980	5.5	-2.98
0.2747	0.56	3.671	4.809	-3.671
0.2895	0.59	3.859	4.621	-3.859
0.3052	0.49	3.072	5.408	-3.072
0.3218	0.49	3.097	5.383	-3.097
0.3395	0.52	3.292	5.188	-3.292
0.3582	0.52	3.287	5.193	-3.287
0.378	0.47	2.940	5.54	-2.94
0.399	0.48	3.019	5.461	-3.019
0.4212	0.49	3.068	5.412	-3.068
0.4447	0.49	3.072	5.408	-3.072
0.4695	0.49	3.088	5.392	-3.088
0.4958	0.48	3.046	5.434	-3.046
0.5238	0.48	3.022	5.458	-3.022
0.5535	0.48	3.002	5.478	-3.002
0.5848	0.47	2.976	5.504	-2.976
0.618	0.47	2.953	5.527	-2.953
0.6532	0.47	2.928	5.552	-2.928
0.6905	0.46	2.904	5.576	-2.904
0.73	0.46	2.874	5.606	-2.874
0.7718	0.45	2.845	5.635	-2.845
0.8162	0.45	2.818	5.662	-2.818
0.8632	0.45	2.790	5.69	-2.79
0.913	0.44	2.756	5.724	-2.756
0.9657	0.44	2.723	5.757	-2.723
1.0215	0.43	2.687	5.793	-2.687
1.0807	0.42	2.648	5.832	-2.648
1.1433	0.42	2.615	5.865	-2.615
1.2097	0.41	2.574	5.906	-2.574
1.28	0.40	2.534	5.946	-2.534
1.3545	0.40	2.494	5.986	-2.494
1.4335	0.39	2.446	6.034	-2.446
1.5172	0.38	2.407	6.073	-2.407
1.6057	0.37	2.359	6.121	-2.359
1.6995	0.36	2.311	6.169	-2.311
1.7988	0.35	2.261	6.219	-2.261
1.9042	0.34	2.212	6.268	-2.212
2.0157	0.33	2.159	6.321	-2.159
2.1338	0.32	2.100	6.38	-2.1
2.259	0.31	2.054	6.426	-2.054
2.3915	0.30	2.000	6.48	-2
2.532	0.29	1.934	6.546	-1.934
2.6808	0.27	1.877	6.603	-1.877
2.8383	0.26	1.813	6.667	-1.813
3.0052	0.24	1.753	6.727	-1.753
3.182	0.23	1.687	6.793	-1.687
3.3693	0.21	1.624	6.856	-1.624
3.5677	0.19	1.560	6.92	-1.56
3.7778	0.17	1.494	6.986	-1.494
4.0005	0.15	1.425	7.055	-1.425
4.2363	0.13	1.360	7.12	-1.36
4.4862	0.11	1.291	7.189	-1.291
4.7508	0.09	1.222	7.258	-1.222
5.0312	0.06	1.158	7.322	-1.158
5.328	0.04	1.087	7.393	-1.087
5.6425	0.01	1.021	7.459	-1.021
5.9757	-0.02	0.955	7.525	-0.955
6.3285	-0.05	0.889	7.591	-0.889
6.7023	-0.08	0.825	7.655	-0.825
7.0983	-0.12	0.762	7.718	-0.762
7.5177	-0.15	0.700	7.78	-0.7
7.962	-0.19	0.644	7.836	-0.644
8.4327	-0.24	0.582	7.898	-0.582
8.9312	-0.28	0.528	7.952	-0.528
9.4592	-0.32	0.474	8.006	-0.474
10.0185	-0.37	0.423	8.057	-0.423
10.611	-0.43	0.374	8.106	-0.374
11.2385	-0.48	0.331	8.149	-0.331
11.9033	-0.54	0.289	8.191	-0.289
12.6075	-0.60	0.252	8.228	-0.252
13.3533	-0.67	0.216	8.264	-0.216
14.1433	-0.74	0.183	8.297	-0.183
14.9802	-0.82	0.152	8.328	-0.152
15.8667	-0.89	0.128	8.352	-0.128
16.8057	-0.98	0.105	8.375	-0.105



CHKD: BWS 12/2010

Slug-out

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date:	~~12/12/02~~ 12/13/02 ~~12/14/02~~	**Time:**	0750
Observation Well No.:	OW-844		
Weather Conditions:	cloudy, upper 30's		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	26.10 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.6 ft	**Depth interval of screened portion:**	14.4-24.0 ft
Depth to Groundwater:	8.48 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
8.95	12/10/02
8.91	12/10/02
8.83	12/11/02
8.90	12/06/02

Comments/Remarks

[illegible]

Slug [illegible] → [illegible] ft³

Transducer [illegible] → [illegible]

[illegible] → [illegible]

File header labeled as OW-844 out [illegible]

[illegible] the slug-out test [illegible] OW-844

[illegible]

[illegible]

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-844
Test Date: 12/13/2002
Test Type: Recovery (slug out)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BWL 12/20/02

WELL DATA

SWL =	8.48	(ft BTOC)
WD =	26.10	(ft BTOC)
WD =	24.60	(ft BGS)
DTSP =	12.70	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.6	(ft)
Lw =	17.62	(ft)
Le/rw =	29.09	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	3.318	(ft) from plot
yt =	2.052	(ft) from plot
t =	1.966	(minutes) from plot
ln(Re/rw) =	2.38	

K = 2.8E-01 (ft/day)

K = 9.9E-05 (cm/sec)

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [(1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1= 2.38

Where: Lw = H;

ln(Re/rw) = [(1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 2.86

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.09	2.48	0.34	2.06

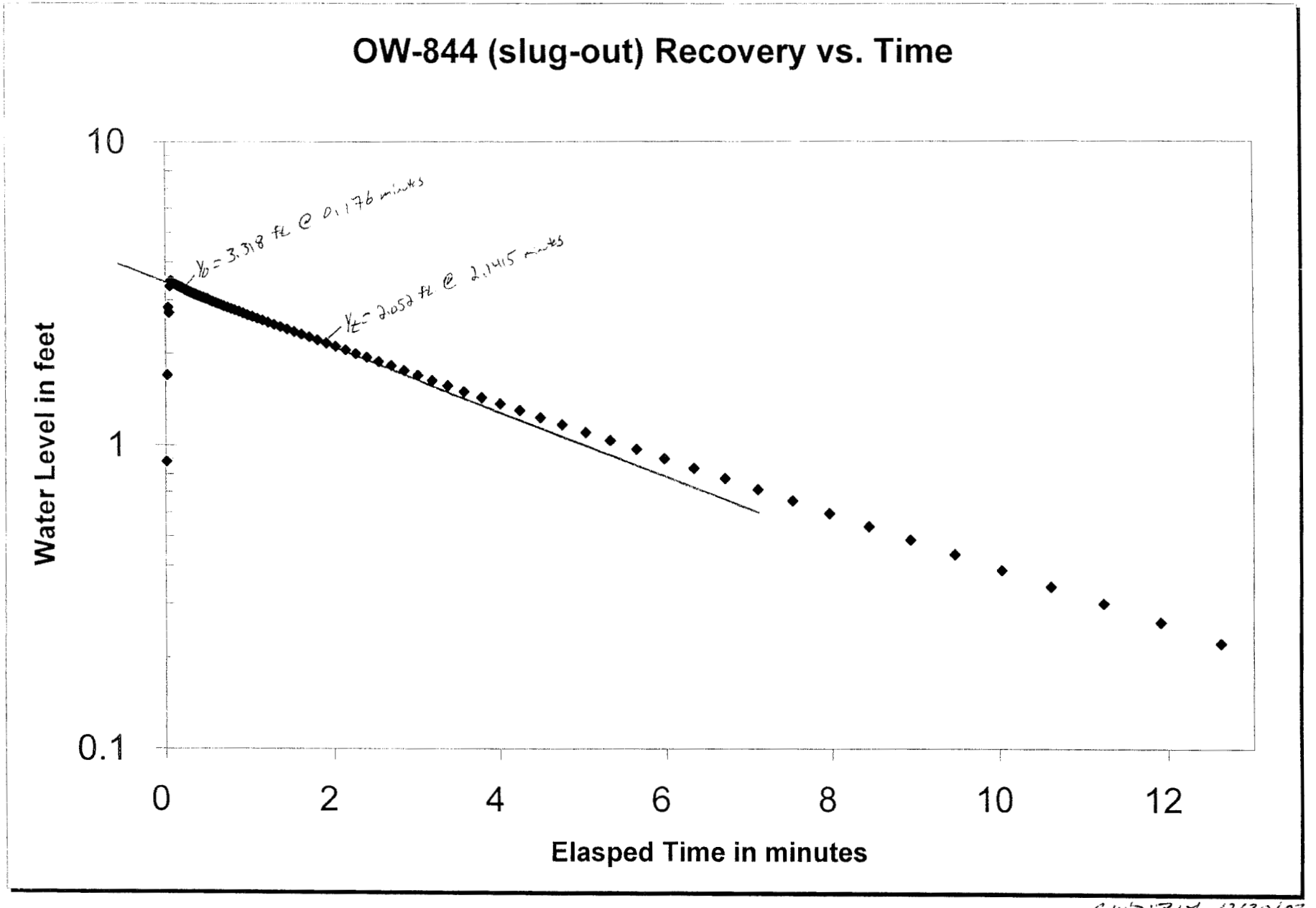
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0	8.48	0
0.011	-0.06	0.881	9.361	0.881
0.022	0.23	1.7	10.18	1.7
0.033	0.45	2.844	11.324	2.844
0.044	0.44	2.726	11.206	2.726
0.055	0.52	3.327	11.807	3.327
0.066	0.54	3.479	11.959	3.479
0.077	0.54	3.459	11.939	3.459
0.088	0.54	3.44	11.92	3.44
0.099	0.53	3.419	11.899	3.419
0.11	0.53	3.396	11.876	3.396
0.121	0.53	3.38	11.86	3.38
0.132	0.53	3.365	11.845	3.365
0.143	0.53	3.352	11.832	3.352
0.154	0.52	3.341	11.821	3.341
0.165	0.52	3.328	11.808	3.328
0.176	0.52	3.318	11.798	3.318
0.187	0.52	3.307	11.787	3.307
0.198	0.52	3.302	11.782	3.302
0.209	0.52	3.282	11.762	3.282
0.22	0.51	3.263	11.743	3.263
0.231	0.51	3.251	11.731	3.251
0.2427	0.51	3.24	11.72	3.24
0.2552	0.51	3.228	11.708	3.228
0.2683	0.51	3.215	11.695	3.215
0.2823	0.51	3.202	11.682	3.202
0.2972	0.50	3.187	11.667	3.187
0.3128	0.50	3.174	11.654	3.174
0.3295	0.50	3.16	11.64	3.16
0.3472	0.50	3.144	11.624	3.144
0.3658	0.50	3.128	11.608	3.128
0.3857	0.49	3.11	11.59	3.11
0.4067	0.49	3.094	11.574	3.094
0.4288	0.49	3.077	11.557	3.077
0.4523	0.49	3.057	11.537	3.057
0.4772	0.48	3.039	11.519	3.039
0.5035	0.48	3.029	11.509	3.029
0.5315	0.48	2.991	11.471	2.991
0.5612	0.47	2.97	11.45	2.97
0.5925	0.47	2.946	11.426	2.946
0.6257	0.47	2.923	11.403	2.923
0.6608	0.46	2.896	11.376	2.896
0.6982	0.46	2.868	11.348	2.868
0.7377	0.45	2.841	11.321	2.841
0.7795	0.45	2.812	11.292	2.812
0.8238	0.44	2.782	11.262	2.782
0.8708	0.44	2.751	11.231	2.751
0.9207	0.43	2.719	11.199	2.719
0.9733	0.43	2.683	11.163	2.683
1.0292	0.42	2.649	11.129	2.649
1.0883	0.42	2.611	11.091	2.611
1.151	0.41	2.574	11.054	2.574
1.2173	0.40	2.534	11.014	2.534
1.2877	0.40	2.492	10.972	2.492
1.3622	0.39	2.45	10.93	2.45
1.4412	0.38	2.406	10.886	2.406
1.5248	0.37	2.36	10.84	2.36
1.6133	0.36	2.311	10.791	2.311
1.7072	0.35	2.264	10.744	2.264
1.8065	0.34	2.213	10.693	2.213
1.9118	0.33	2.162	10.642	2.162
2.0233	0.32	2.108	10.588	2.108
2.1415	0.31	2.052	10.532	2.052
2.2667	0.30	1.996	10.476	1.996
2.3992	0.29	1.939	10.419	1.939
2.5397	0.27	1.879	10.359	1.879
2.6885	0.26	1.82	10.3	1.82
2.846	0.24	1.756	10.236	1.756
3.0128	0.23	1.695	10.175	1.695
3.1897	0.21	1.63	10.11	1.63
3.377	0.20	1.567	10.047	1.567
3.5753	0.18	1.499	9.979	1.499
3.7855	0.16	1.433	9.913	1.433
4.0082	0.14	1.367	9.847	1.367
4.244	0.11	1.299	9.779	1.299
4.4938	0.09	1.23	9.71	1.23
4.7585	0.07	1.164	9.644	1.164
5.0388	0.04	1.097	9.577	1.097
5.3357	0.01	1.031	9.511	1.031
5.6502	-0.02	0.965	9.445	0.965
5.9833	-0.05	0.898	9.378	0.898
6.3362	-0.08	0.834	9.314	0.834
6.71	-0.11	0.771	9.251	0.771
7.106	-0.15	0.709	9.189	0.709
7.5253	-0.19	0.65	9.13	0.65
7.9697	-0.23	0.591	9.071	0.591
8.4403	-0.27	0.536	9.016	0.536
8.9388	-0.32	0.484	8.964	0.484
9.4668	-0.36	0.433	8.913	0.433
10.0262	-0.42	0.384	8.864	0.384
10.6187	-0.47	0.339	8.819	0.339
11.2462	-0.53	0.298	8.778	0.298
11.911	-0.59	0.259	8.739	0.259
12.6152	-0.66	0.221	8.701	0.221


OW-844 (slug-out) Recovery vs. Time
Water Level in feet
10
1
0.1
0
2
4
6
8
10
12
Elasped Time in minutes
Y_0 = 3.318 ft @ 0.176 minutes
Y_t = 2.052 ft @ 2.1415 minutes
CHK'D: BWS 12/20/02

Slug - In

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/12/02	**Time:** 1530	**Observation Well No.:**	OW-945
Weather Conditions:	Partly Sunny in 50's		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	56.50 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.7 ft	**Depth interval of screened portion:**	43.6-53.3 ft
Depth to Groundwater:	24.72 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
24.69	12/09/02
24.69	12/10/02
24.72	12/06/02

Comments/Remarks

Slug #2 volume = 0.08 ft3
Transducer s/n = 6407
Hermit s/n = 45299

Slug transducer @ 45' below TOC

WSG

Slug test 12/13/02 @ 1145

Depth to water 24.67
Transducer s/n = 257
Hermit s/n = 45449
Slug #2 → volume = 0.08 ft3

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-845
Test Date: 12/12/2002
Test Type: Recovery (slug in)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BWJ 12/20/02

WELL DATA

SWL =	24.72	(ft BTOC)
WD =	56.50	(ft BTOC)
WD =	55.00	(ft BGS)
DTSP =	39.70	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.7	(ft)
Lw =	31.78	(ft)
Le/rw =	29.39	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	0.048 (ft) from plot
yt =	0.025 (ft) from plot
t =	0.470 (minutes) from plot
ln(Re/rw) =	2.70

* K = **1.8E+00 (ft/day)**

* K = **6.3E-04 (cm/sec)**

* DATA IS QUESTIONABLE (SEE GRAPH)

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1= 2.70

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 3.23

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.39	2.49	0.35	2.08

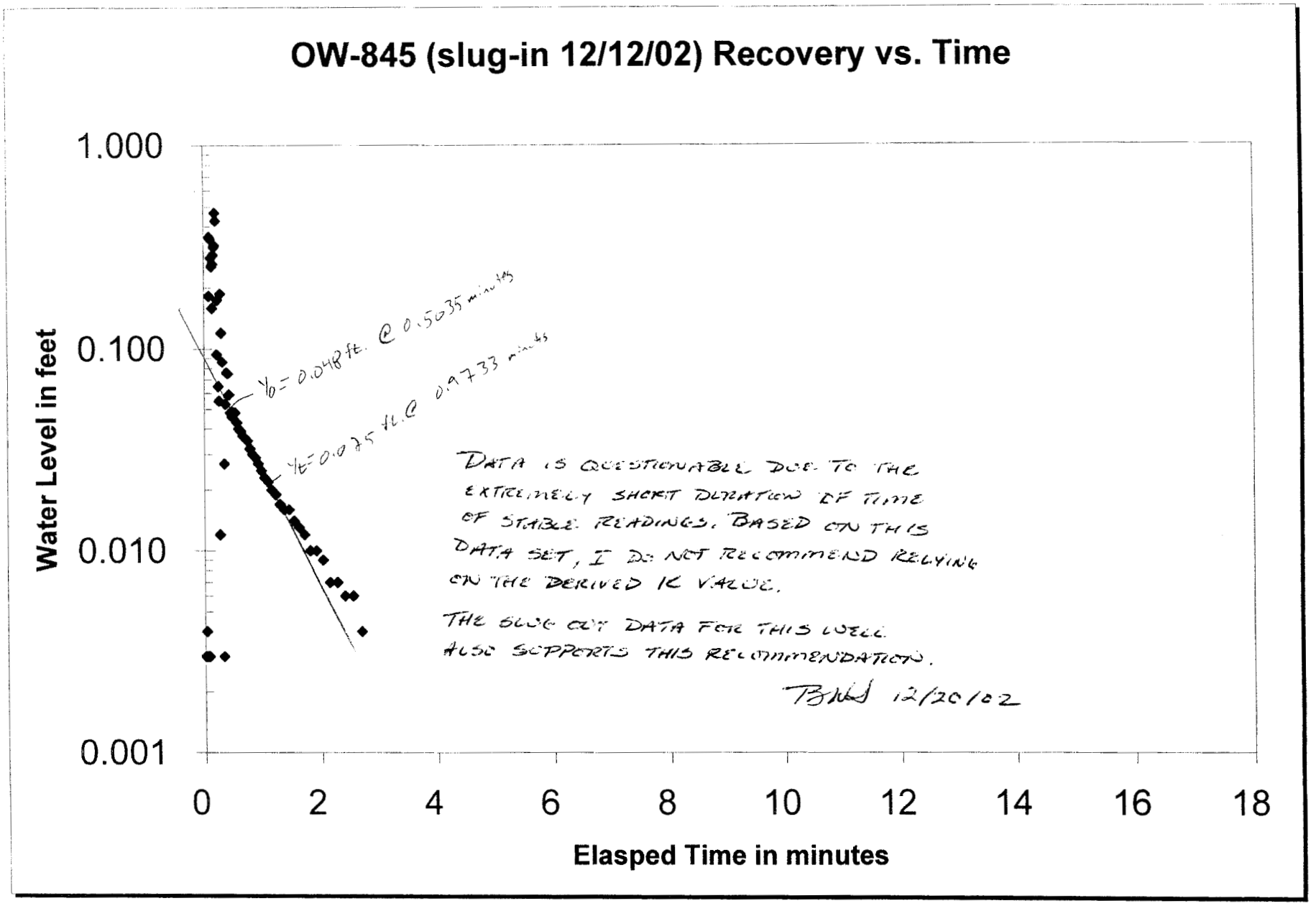
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0.000	24.72	0
0.011	-2.52	0.003	24.717	-0.003
0.022	-2.52	0.003	24.717	-0.003
0.033	-2.40	0.004	24.716	-0.004
0.044	-2.52	0.003	24.717	-0.003
0.055	-2.52	0.003	24.717	-0.003
0.066	-2.52	0.003	24.717	-0.003
0.077	-2.52	0.003	24.717	-0.003
0.088	-0.74	0.182	24.538	-0.182
0.099	-0.45	0.356	24.364	-0.356
0.11	-0.46	0.349	24.371	-0.349
0.121	-0.55	0.281	24.439	-0.281
0.132	-0.59	0.255	24.465	-0.255
0.143	-0.80	0.159	24.561	-0.159
0.154	-0.58	0.262	24.458	-0.262
0.165	-0.54	0.291	24.429	-0.291
0.176	-0.50	0.317	24.403	-0.317
0.187	-0.49	0.324	24.396	-0.324
0.198	-0.33	0.467	24.253	-0.467
0.209	-0.37	0.427	24.293	-0.427
0.22	-1.03	0.094	24.626	-0.094
0.231	-0.76	0.174	24.546	-0.174
0.2427	-1.19	0.065	24.655	-0.065
0.2552	-1.26	0.055	24.665	-0.055
0.2683	-1.92	0.012	24.708	-0.012
0.2823	-0.73	0.187	24.533	-0.187
0.2972	-0.92	0.120	24.6	-0.12
0.3128	-1.07	0.086	24.634	0.086
0.3295	-2.52	0.003	24.717	0.003
0.3472	-1.57	0.027	24.693	0.027
0.3658	-1.28	0.053	24.667	-0.053
0.3857	-1.12	0.076	24.644	-0.076
0.4067	-1.12	0.075	24.645	-0.075
0.4288	-1.23	0.059	24.661	-0.059
0.4523	-1.32	0.048	24.672	-0.048
0.4772	-1.34	0.046	24.674	-0.046
0.5035	-1.32	0.048	24.672	-0.048
0.5315	-1.32	0.048	24.672	-0.048
0.5612	-1.37	0.043	24.677	-0.043
0.5925	-1.40	0.040	24.68	-0.04
0.6257	-1.41	0.039	24.681	-0.039
0.6608	-1.43	0.037	24.683	-0.037
0.6982	-1.44	0.036	24.684	-0.036
0.7377	-1.46	0.035	24.685	-0.035
0.7795	-1.49	0.032	24.688	-0.032
0.8238	-1.52	0.030	24.69	-0.03
0.8708	-1.54	0.029	24.691	-0.029
0.9207	-1.57	0.027	24.693	-0.027
0.9733	-1.60	0.025	24.695	-0.025
1.0292	-1.64	0.023	24.697	-0.023
1.0883	-1.66	0.022	24.698	-0.022
1.151	-1.70	0.020	24.7	-0.02
1.2173	-1.72	0.019	24.701	-0.019
1.2877	-1.77	0.017	24.703	-0.017
1.3622	-1.80	0.016	24.704	-0.016
1.4412	-1.80	0.016	24.704	-0.016
1.5248	-1.85	0.014	24.706	-0.014
1.6133	-1.89	0.013	24.707	-0.013
1.7072	-1.92	0.012	24.708	-0.012
1.8065	-2.00	0.010	24.71	-0.01
1.9118	-2.00	0.010	24.71	-0.01
2.0233	-2.05	0.009	24.711	-0.009
2.1415	-2.15	0.007	24.713	-0.007
2.2667	-2.15	0.007	24.713	-0.007
2.3992	-2.22	0.006	24.714	-0.006
2.5397	-2.22	0.006	24.714	-0.006
2.6885	-2.40	0.004	24.716	-0.004


OW-845 (slug-in 12/12/02) Recovery vs. Time
1.000
0.100
0.010
0.001
Water Level in feet
0
2
4
6
8
10
12
14
16
18
Elasped Time in minutes
Yo = 0.048 ft. @ 0.5035 minutes
Ye = 0.075 ft. @ 0.9733 minutes
DATA IS QUESTIONABLE DUE TO THE EXTREMELY SHORT DURATION OF TIME OF STABLE READINGS. BASED ON THIS DATA SET, I DO NOT RECOMMEND RELYING ON THE DERIVED K VALUE.
THE SLUG OUT DATA FOR THIS WELL ALSO SUPPORTS THIS RECOMMENDATION.
12/20/02

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date:	12/12	**Time:**	15
Observation Well No.:			
Weather Conditions:			
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	**Rising Head** or **Falling Head** (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	ft	**Depth interval of screened portion:**	ft
Depth to Groundwater:	ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date

Comments/Remarks

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-845
Test Date: 12/17/2002
Test Type: Recovery (slug in)

Conducted by: Grimes and Howe
Entered/date: WSG/12/18/02
Checked/date: BHG 12/20/02

WELL DATA

SWL =	24.65	(ft BTOC)
WD =	56.50	(ft BTOC)
WD =	55.00	(ft BGS)
DTSP =	39.70	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.7	(ft)
Lw =	31.85	(ft)
Le/rw =	29.39	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =		(ft) from plot
yt =		(ft) from plot
t =		(minutes) from plot
ln(Re/rw) =	2.70	
K =	**#DIV/0!**	**(ft/day)**
K =	**#DIV/0!**	**(cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1= 2.70

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 3.23

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.39	2.49	0.35	2.08

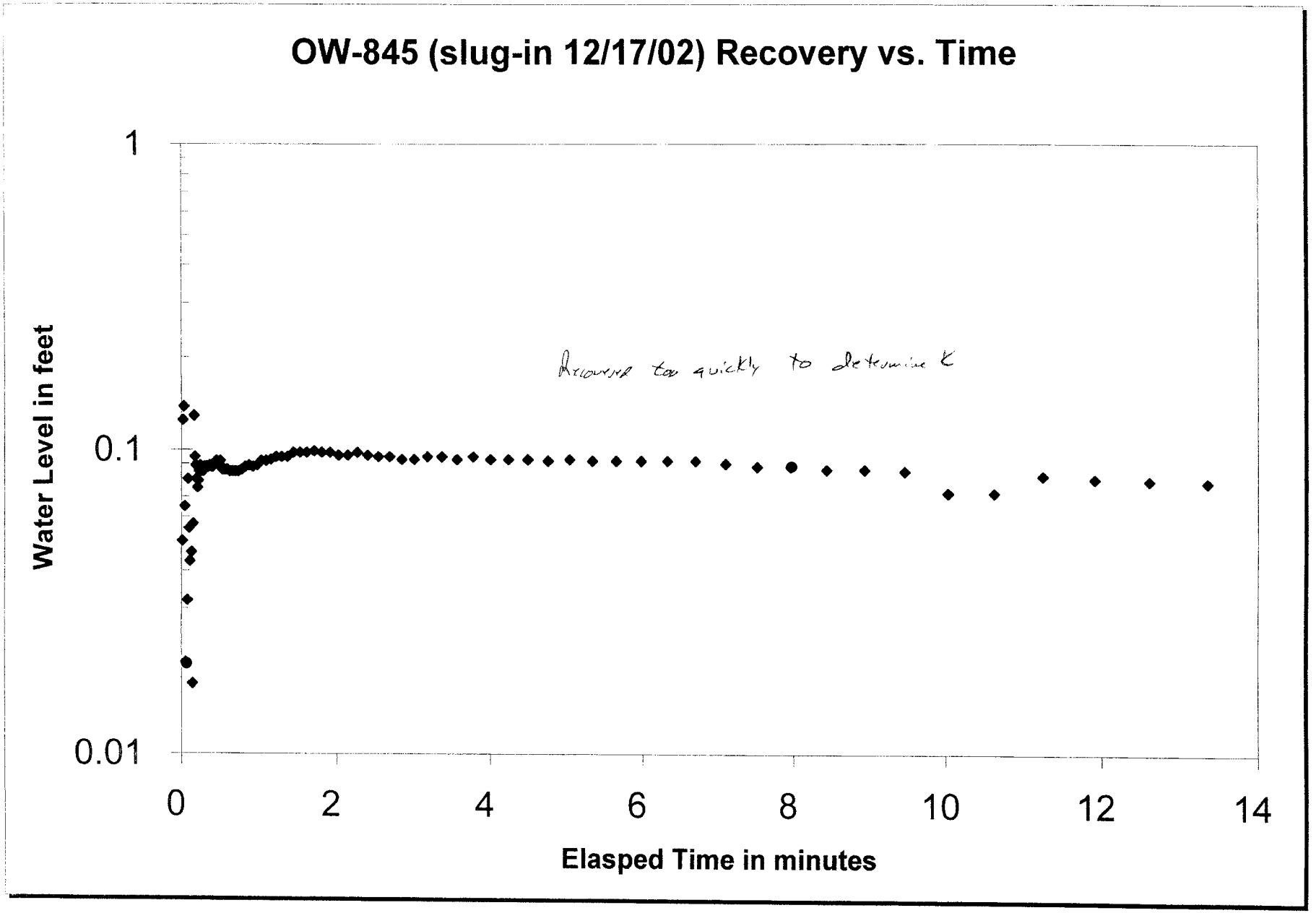
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0	24.65	0
0.011	-1.30	0.05	24.6	0.05
0.022	-0.90	0.125	24.525	0.125
0.033	-0.86	0.138	24.512	0.138
0.044	-1.19	0.065	24.585	0.065
0.055	-1.70	0.02	24.63	0.02
0.066	#NUM!	-0.01	24.66	-0.01
0.077	-1.49	0.032	24.618	0.032
0.088	-1.10	0.08	24.57	0.08
0.099	-1.26	0.055	24.595	0.055
0.11	-1.37	0.043	24.607	0.043
0.121	-3.00	0.001	24.649	0.001
0.132	-1.34	0.046	24.604	0.046
0.143	-1.77	0.017	24.633	0.017
0.154	-1.24	0.057	24.593	0.057
0.165	-0.89	0.129	24.521	0.129
0.176	-1.02	0.095	24.555	0.095
0.187	-1.05	0.089	24.561	0.089
0.198	-1.10	0.08	24.57	0.08
0.209	-1.12	0.075	24.575	0.075
0.22	-1.10	0.079	24.571	0.079
0.231	-1.07	0.085	24.565	0.085
0.2427	-1.05	0.089	24.561	0.089
0.2552	-1.06	0.088	24.562	0.088
0.2683	-1.07	0.085	24.565	0.085
0.2823	-1.07	0.085	24.565	0.085
0.2972	-1.06	0.088	24.562	0.088
0.3128	-1.06	0.088	24.562	0.088
0.3295	-1.06	0.088	24.562	0.088
0.3472	-1.06	0.088	24.562	0.088
0.3658	-1.05	0.089	24.561	0.089
0.3857	-1.06	0.088	24.562	0.088
0.4067	-1.06	0.088	24.562	0.088
0.4288	-1.05	0.09	24.56	0.09
0.4523	-1.04	0.092	24.558	0.092
0.4772	-1.05	0.09	24.56	0.09
0.5035	-1.04	0.092	24.558	0.092
0.5315	-1.07	0.086	24.564	0.086
0.5612	-1.07	0.086	24.564	0.086
0.5925	-1.07	0.086	24.564	0.086
0.6257	-1.07	0.085	24.565	0.085
0.6608	-1.07	0.085	24.565	0.085
0.6982	-1.07	0.085	24.565	0.085
0.7377	-1.07	0.085	24.565	0.085
0.7795	-1.07	0.086	24.564	0.086
0.8238	-1.06	0.088	24.562	0.088
0.8708	-1.05	0.089	24.561	0.089
0.9207	-1.06	0.088	24.562	0.088
0.9733	-1.05	0.089	24.561	0.089
1.0292	-1.04	0.092	24.558	0.092
1.0883	-1.04	0.092	24.558	0.092
1.151	-1.03	0.093	24.557	0.093
1.2173	-1.02	0.095	24.555	0.095
1.2877	-1.02	0.095	24.555	0.095
1.3622	-1.02	0.095	24.555	0.095
1.4412	-1.01	0.098	24.552	0.098
1.5248	-1.01	0.098	24.552	0.098
1.6133	-1.01	0.098	24.552	0.098
1.7072	-1.00	0.099	24.551	0.099
1.8065	-1.01	0.098	24.552	0.098
1.9118	-1.01	0.098	24.552	0.098
2.0233	-1.02	0.096	24.554	0.096
2.1415	-1.02	0.096	24.554	0.096
2.2667	-1.01	0.098	24.552	0.098
2.3992	-1.02	0.096	24.554	0.096
2.5397	-1.02	0.095	24.555	0.095
2.6885	-1.02	0.095	24.555	0.095
2.846	-1.03	0.093	24.557	0.093
3.0128	-1.03	0.093	24.557	0.093
3.1897	-1.02	0.095	24.555	0.095
3.377	-1.02	0.095	24.555	0.095
3.5753	-1.03	0.093	24.557	0.093
3.7855	-1.02	0.095	24.555	0.095
4.0082	-1.03	0.093	24.557	0.093
4.244	-1.03	0.093	24.557	0.093
4.4938	-1.03	0.093	24.557	0.093
4.7585	-1.04	0.092	24.558	0.092
5.0388	-1.03	0.093	24.557	0.093
5.3357	-1.04	0.092	24.558	0.092
5.6502	-1.04	0.092	24.558	0.092
5.9833	-1.04	0.092	24.558	0.092
6.3362	-1.04	0.092	24.558	0.092
6.71	-1.04	0.092	24.558	0.092
7.106	-1.05	0.09	24.56	0.09
7.5253	-1.06	0.088	24.562	0.088
7.9697	-1.06	0.088	24.562	0.088
8.4403	-1.07	0.086	24.564	0.086
8.9388	-1.07	0.086	24.564	0.086
9.4668	-1.07	0.085	24.565	0.085
10.0262	-1.14	0.072	24.578	0.072
10.6187	-1.14	0.072	24.578	0.072
11.2462	-1.09	0.082	24.568	0.082
11.911	-1.10	0.08	24.57	0.08
12.6152	-1.10	0.079	24.571	0.079
13.361	-1.11	0.078	24.572	0.078



CHK'D: BWS 12/20/02

Slug - out

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/12/02	**Time:** 1510	**Observation Well No.:**	OW-845
Weather Conditions: Partly sunny in 90s	WSH 12/12/02		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	56.50 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.7 ft	**Depth interval of screened portion:**	43.6 - 53.3 ft
Depth to Groundwater:	24.72 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
24.69	12/09/02
24.69	12/10/02

Comments/Remarks

[illegible]
Slug #2 → Volume = 0.08 ft³
Transducer SN = 6407
Heart SN = 45449

Set transducer @ 45' below TOC

WSH

Recovery Test on 12/13/02 ~1120
used slug #2 → Volume = 0.08 ft³
Transducer SN = 257
Heart SN = 45449

Depth to water = 24.67

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-845
Test Date: 12/12/2002
Test Type: Recovery (slug out)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BWGrimes 12/20/02

WELL DATA

SWL =	24.72	(ft BTOC)
WD =	56.50	(ft BTOC)
WD =	55.00	(ft BGS)
DTSP =	39.70	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.7	(ft)
Lw =	31.78	(ft)
Le/rw =	29.39	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	0.065	(ft) from plot
yt =	0.027	(ft) from plot
t =	0.369	(minutes) from plot
ln(Re/rw) =	2.70	

K = 3.1E+00 (ft/day)

K = 1.1E-03 (cm/sec)

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1= 2.70

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 3.23

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.39	2.49	0.35	2.08

Coefficients Table

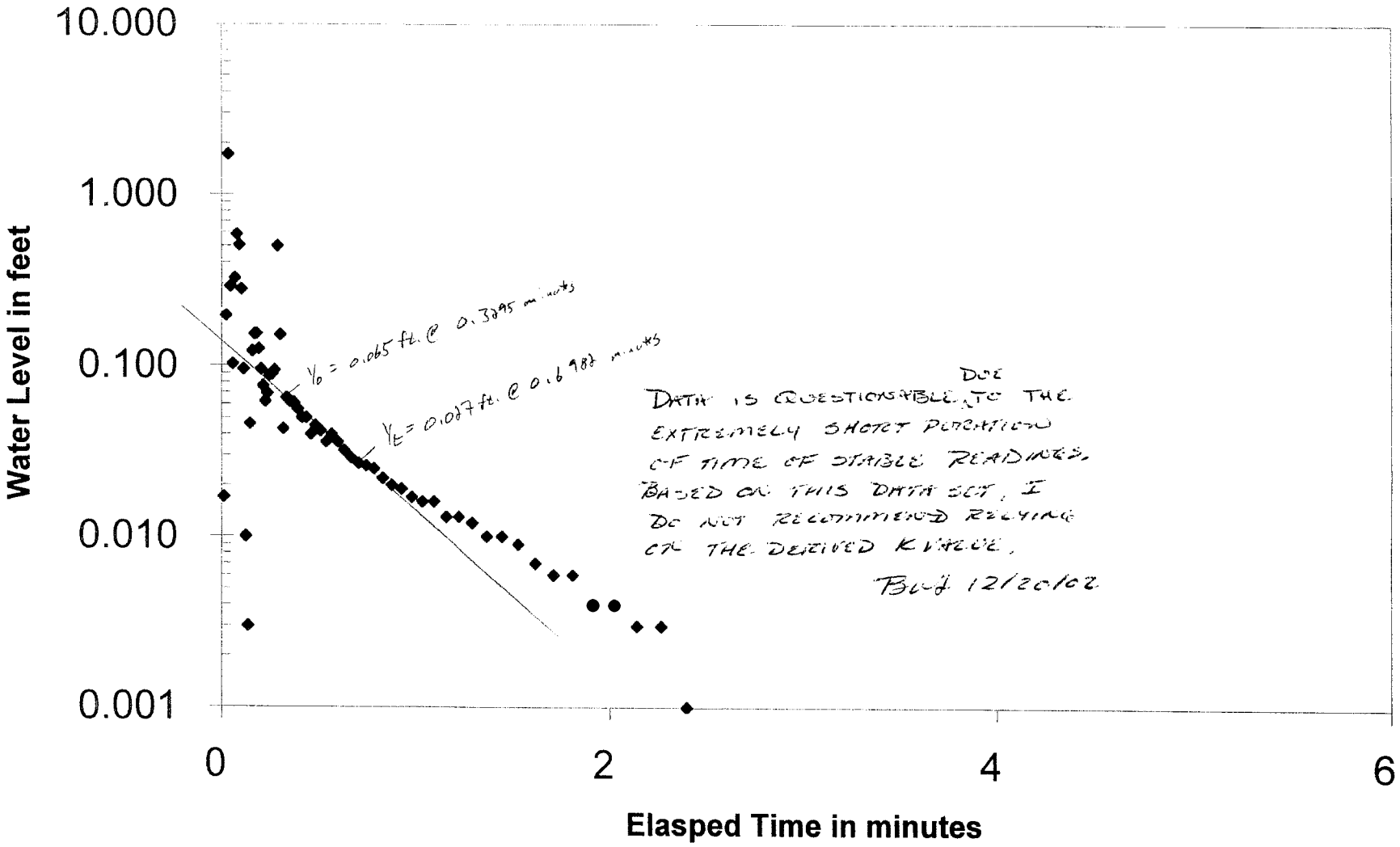
Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0.000	24.72	24.72
0.011	-1.77	0.017	24.737	24.737
0.022	-0.71	0.196	24.916	24.916
0.033	0.24	1.720	26.44	26.44
0.044	-0.54	0.290	25.01	25.01
0.055	-0.99	0.102	24.822	24.822
0.066	-0.49	0.324	25.044	25.044
0.077	-0.23	0.585	25.305	25.305
0.088	-0.30	0.506	25.226	25.226
0.099	-0.55	0.280	25	25
0.11	-1.02	0.095	24.815	24.815
0.121	-2.00	0.010	24.73	24.73
0.132	-2.52	0.003	24.723	24.723
0.143	-1.34	0.046	24.766	24.766
0.154	-0.92	0.121	24.841	24.841
0.165	-0.82	0.153	24.873	24.873
0.176	-0.81	0.154	24.874	24.874
0.187	-0.90	0.125	24.845	24.845
0.198	-1.02	0.095	24.815	24.815
0.209	-1.12	0.076	24.796	24.796
0.22	-1.21	0.062	24.782	24.782
0.231	-1.16	0.069	24.789	24.789
0.2427	-1.06	0.088	24.808	24.808
0.2552	-1.05	0.089	24.809	24.809
0.2683	-1.03	0.094	24.814	24.814
0.2823	-0.30	0.501	25.221	25.221
0.2972	-0.82	0.151	24.871	24.871
0.3128	-1.37	0.043	24.763	24.763
0.3295	-1.19	0.065	24.785	24.785
0.3472	-1.21	0.062	24.782	24.782
0.3658	-1.21	0.061	24.781	24.781
0.3857	-1.25	0.056	24.776	24.776
0.4067	-1.30	0.050	24.77	24.77
0.4288	-1.30	0.050	24.77	24.77
0.4523	-1.40	0.040	24.76	24.76
0.4772	-1.35	0.045	24.765	24.765
0.5035	-1.38	0.042	24.762	24.762
0.5315	-1.44	0.036	24.756	24.756
0.5612	-1.40	0.040	24.76	24.76
0.5925	-1.44	0.036	24.756	24.756
0.6257	-1.49	0.032	24.752	24.752
0.6608	-1.54	0.029	24.749	24.749
0.6982	-1.57	0.027	24.747	24.747
0.7377	-1.59	0.026	24.746	24.746
0.7795	-1.60	0.025	24.745	24.745
0.8238	-1.66	0.022	24.742	24.742
0.8708	-1.70	0.020	24.74	24.74
0.9207	-1.72	0.019	24.739	24.739
0.9733	-1.77	0.017	24.737	24.737
1.0292	-1.80	0.016	24.736	24.736
1.0883	-1.80	0.016	24.736	24.736
1.151	-1.89	0.013	24.733	24.733
1.2173	-1.89	0.013	24.733	24.733
1.2877	-1.92	0.012	24.732	24.732
1.3622	-2.00	0.010	24.73	24.73
1.4412	-2.00	0.010	24.73	24.73
1.5248	-2.05	0.009	24.729	24.729
1.6133	-2.15	0.007	24.727	24.727
1.7072	-2.22	0.006	24.726	24.726
1.8065	-2.22	0.006	24.726	24.726
1.9118	-2.40	0.004	24.724	24.724
2.0233	-2.40	0.004	24.724	24.724
2.1415	-2.52	0.003	24.723	24.723
2.2667	-2.52	0.003	24.723	24.723
2.3992	-3.00	0.001	24.721	24.721
2.5397	#NUM!	0.000	24.72	24.72
2.6885	#NUM!	0.000	24.72	24.72
2.846	#NUM!	-0.001	24.719	24.719
3.0128	#NUM!	-0.001	24.719	24.719
3.1897	#NUM!	-0.001	24.719	24.719
3.377	#NUM!	-0.003	24.717	24.717
3.5753	#NUM!	-0.003	24.717	24.717
3.7855	#NUM!	-0.004	24.716	24.716
4.0082	#NUM!	-0.003	24.717	24.717
4.244	#NUM!	-0.004	24.716	24.716
4.4938	#NUM!	-0.004	24.716	24.716
4.7585	#NUM!	-0.004	24.716	24.716
5.0388	#NUM!	-0.004	24.716	24.716

OW-845 (slug-out #2 12/12) Recovery vs. Time



Slug - In

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/12/02	**Time:** 1625	**Observation Well No.:**	OW-846
Weather Conditions: partly sunny in 50's			
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	34.32 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.45 ft	**Depth interval of screened portion:**	22.4-32.05 ft
Depth to Groundwater:	24.82 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
24.82	~~12/9/02~~ 12/09/02
24.84	12/06/02

Comments/Remarks

wsb 12/12/02

used slug #2 → volume = 0.08 ft3

Transducer S/N → 6407

Hermit S/N → 45299

Set transducer @ 32 below TOC

wsb

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-846
Test Date: 12/12/2002
Test Type: Recovery (slug in)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: B W Howe 12/20/02

WELL DATA

SWL =	24.82	(ft BTOC)
WD =	34.30	(ft BTOC)
WD =	32.80	(ft BGS)
DTSP =	20.30	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.19	(ft)
Le =	9.75	(ft)
Lw =	9.48	(ft)
Le/rw =	29.55	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	0.704	(ft) from plot
yt =	0.495	(ft) from plot
t =	1.069	(minutes) from plot
ln(Re/rw) =	2.13	
K =	**1.9E+00**	**(ft/day)**
K =	**6.8E-04**	**(cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1= 2.13

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 2.50

Calculation of Coefficients

Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.55	2.49	0.35	2.08

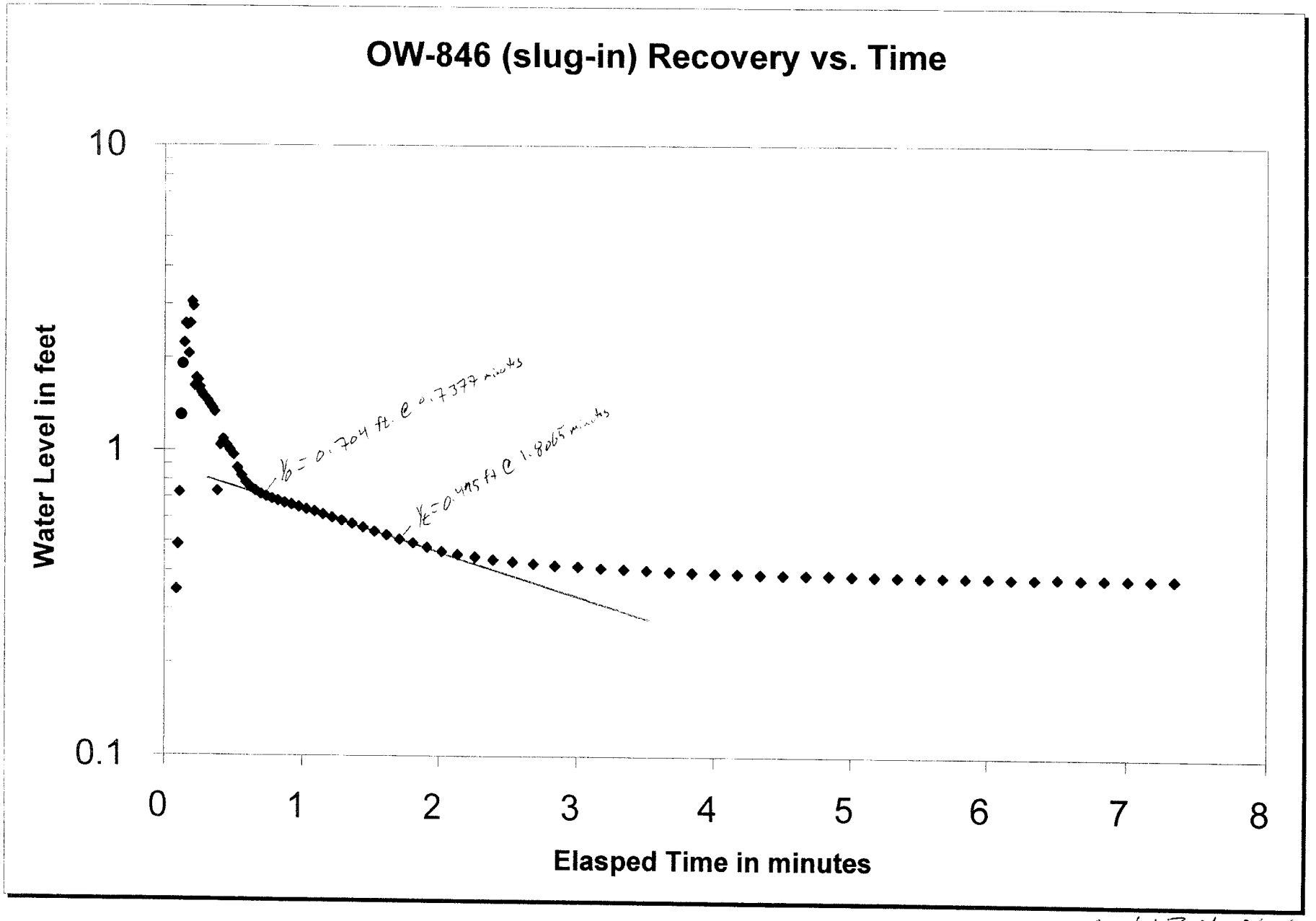
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0	24.82	0
0.011	-3.00	0.001	24.819	0.001
0.022	-3.00	0.001	24.819	0.001
0.033	-2.52	0.003	24.817	0.003
0.044	-2.40	0.004	24.816	0.004
0.055	-2.40	0.004	24.816	0.004
0.066	-2.40	0.004	24.816	0.004
0.077	-2.52	0.003	24.817	0.003
0.088	-0.46	0.347	24.473	-0.347
0.099	-0.31	0.488	24.332	-0.488
0.11	-0.14	0.725	24.095	-0.725
0.121	0.12	1.308	23.512	-1.308
0.132	0.28	1.91	22.91	-1.91
0.143	0.35	2.238	22.582	-2.238
0.154	0.41	2.593	22.227	-2.593
0.165	0.41	2.558	22.262	-2.558
0.176	0.31	2.062	22.758	-2.062
0.187	0.41	2.593	22.227	-2.593
0.198	0.49	3.061	21.759	-3.061
0.209	0.47	2.96	21.86	-2.96
0.22	0.21	1.617	23.203	-1.617
0.231	0.24	1.718	23.102	-1.718
0.2427	0.23	1.692	23.128	-1.692
0.2552	0.20	1.6	23.22	-1.6
0.2683	0.19	1.538	23.282	-1.538
0.2823	0.18	1.501	23.319	-1.501
0.2972	0.17	1.478	23.342	-1.478
0.3128	0.16	1.449	23.371	-1.449
0.3295	0.15	1.407	23.413	-1.407
0.3472	0.14	1.374	23.446	-1.374
0.3658	0.13	1.336	23.484	-1.336
0.3857	-0.14	0.732	24.088	-0.732
0.4067	0.02	1.04	23.78	-1.04
0.4288	0.04	1.087	23.733	-1.087
0.4523	0.02	1.04	23.78	-1.04
0.4772	0.00	1.002	23.818	-1.002
0.5035	-0.02	0.964	23.856	-0.964
0.5315	-0.06	0.872	23.948	-0.872
0.5612	-0.08	0.823	23.997	-0.823
0.5925	-0.11	0.783	24.037	-0.783
0.6257	-0.12	0.754	24.066	-0.754
0.6608	-0.13	0.734	24.086	-0.734
0.6982	-0.14	0.717	24.103	-0.717
0.7377	-0.15	0.704	24.116	-0.704
0.7795	-0.16	0.692	24.128	-0.692
0.8238	-0.17	0.682	24.138	-0.682
0.8708	-0.17	0.671	24.149	-0.671
0.9207	-0.18	0.662	24.158	-0.662
0.9733	-0.19	0.65	24.17	-0.65
1.0292	-0.19	0.639	24.181	-0.639
1.0883	-0.20	0.629	24.191	-0.629
1.151	-0.21	0.615	24.205	-0.615
1.2173	-0.22	0.6	24.22	-0.6
1.2877	-0.23	0.587	24.233	-0.587
1.3622	-0.24	0.573	24.247	-0.573
1.4412	-0.25	0.557	24.263	-0.557
1.5248	-0.27	0.541	24.279	-0.541
1.6133	-0.28	0.526	24.294	-0.526
1.7072	-0.29	0.508	24.312	-0.508
1.8065	-0.31	0.495	24.325	-0.495
1.9118	-0.32	0.48	24.34	-0.48
2.0233	-0.33	0.465	24.355	-0.465
2.1415	-0.34	0.455	24.365	-0.455
2.2667	-0.35	0.447	24.373	-0.447
2.3992	-0.36	0.438	24.382	-0.438
2.5397	-0.37	0.431	24.389	-0.431
2.6885	-0.37	0.425	24.395	-0.425
2.846	-0.38	0.419	24.401	-0.419
3.0127	-0.38	0.416	24.404	-0.416
3.1793	-0.39	0.411	24.409	-0.411
3.346	-0.39	0.408	24.412	-0.408
3.5127	-0.39	0.405	24.415	-0.405
3.6793	-0.40	0.401	24.419	-0.401
3.846	-0.40	0.399	24.421	-0.399
4.0127	-0.40	0.396	24.424	-0.396
4.1793	-0.40	0.395	24.425	-0.395
4.346	-0.41	0.393	24.427	-0.393
4.5127	-0.41	0.392	24.428	-0.392
4.6793	-0.41	0.391	24.429	-0.391
4.846	-0.41	0.391	24.429	-0.391
5.0127	-0.41	0.389	24.431	-0.389
5.1793	-0.41	0.388	24.432	-0.388
5.346	-0.41	0.386	24.434	-0.386
5.5127	-0.41	0.386	24.434	-0.386
5.6793	-0.41	0.386	24.434	-0.386
5.846	-0.41	0.385	24.435	-0.385
6.0127	-0.41	0.385	24.435	-0.385
6.1793	-0.42	0.383	24.437	-0.383
6.346	-0.42	0.383	24.437	-0.383
6.5127	-0.41	0.385	24.435	-0.385
6.6793	-0.42	0.383	24.437	-0.383
6.846	-0.42	0.383	24.437	-0.383
7.0127	-0.42	0.382	24.438	-0.382
7.1793	-0.42	0.382	24.438	-0.382
7.346	-0.42	0.382	24.438	-0.382



CHKD: BWJ 12/20/02

Slug-out

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/12/02	**Time:** ~~1335~~ 1535	**Observation Well No.:**	OW-846
Weather Conditions: partly sunny in 50's 12/12/02 [illegible]			
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	34.30 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.75 ft	**Depth interval of screened portion:**	22.4-32.15 ft
Depth to Groundwater:	24.82 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
24.82	~~12/9/02~~ 12/12/02

Comments/Remarks

Slug [illegible] - [illegible]
Transducer = [illegible]
[illegible] SW = [illegible]

[illegible] transducer @ 32' below TOC

[illegible]

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number 30720-2-5400

Well: OW-846
Test Date: 12/12/2002
Test Type: Recovery (slug-out)

Conducted by: Grimes&Howe
Entered/date: Grimes/12/15/02
Checked/date: BNJones 12/20/02

WELL DATA

SWL =	24.82	(ft BTOC)
WD =	34.30	(ft BTOC)
WD =	32.80	(ft BGS)
DTSP =	20.30	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.19	(ft)
Le =	9.75	(ft)
Lw =	9.48	(ft)
Le/rw =	29.55	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	1.707	(ft) from plot
yt =	1.162	(ft) from plot
t =	0.652	(minutes) from plot
ln(Re/rw) =	2.13	

K = 3.4E+00 (ft/day)

K = 1.2E-03 (cm/sec)

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [(1.1/(ln(Lw/rw)))+(A+Bln((H-Lw)/rw))/(Le/rw)]^-1= 2.13

Where: Lw = H;

ln(Re/rw) = [(1.1/(ln(Lw/rw)))+(C/(Le/rw))]^-1 = 2.50

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.55	2.49	0.35	2.08

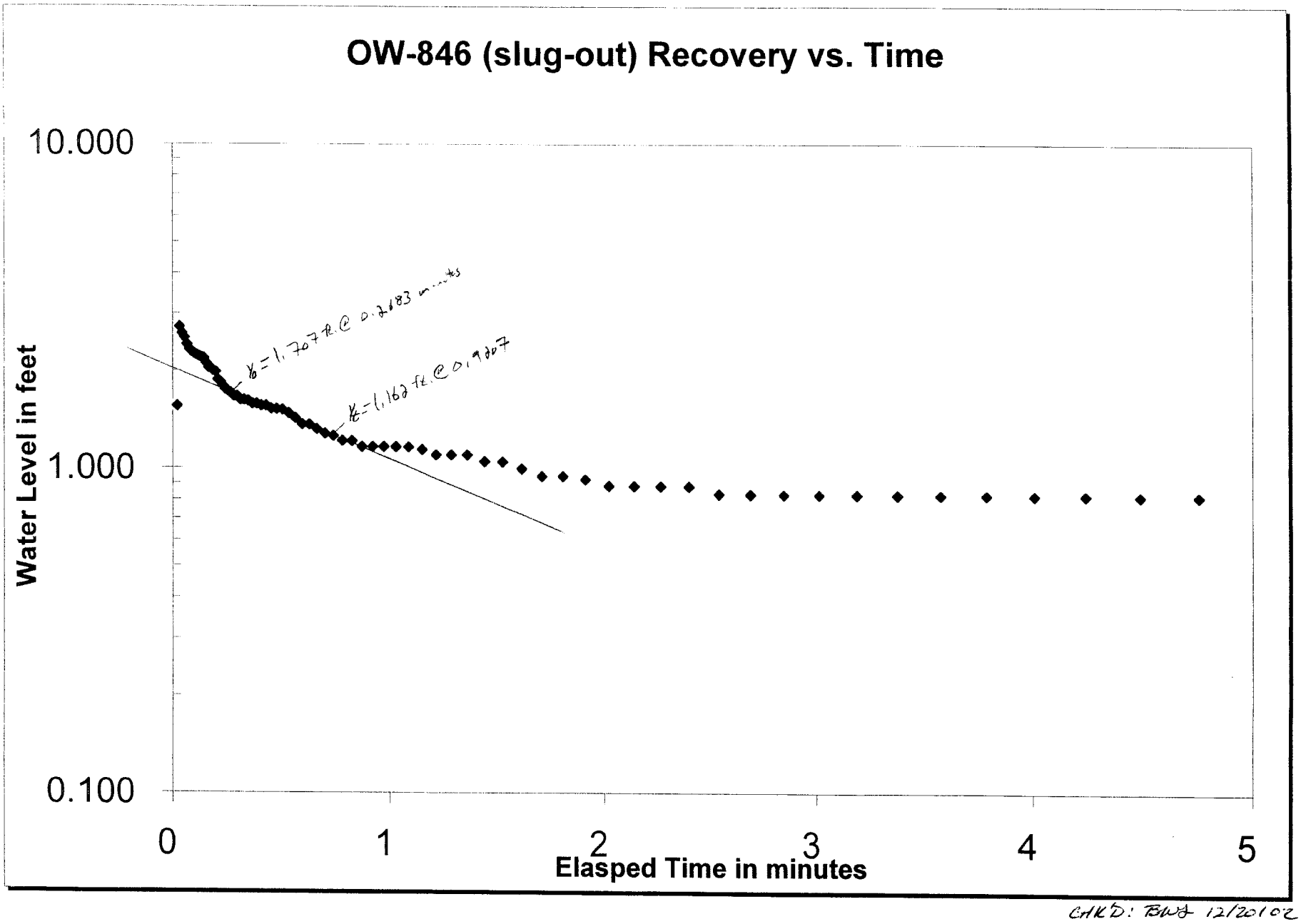
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0.000	24.82	24.82
0.011	-3.00	0.001	24.821	24.821
0.022	0.19	1.552	26.372	26.372
0.033	0.44	2.727	27.547	27.547
0.044	0.42	2.604	27.424	27.424
0.055	0.40	2.528	27.348	27.348
0.066	0.38	2.412	27.232	27.232
0.077	0.37	2.334	27.154	27.154
0.088	0.36	2.293	27.113	27.113
0.099	0.35	2.262	27.082	27.082
0.11	0.35	2.238	27.058	27.058
0.121	0.35	2.218	27.038	27.038
0.132	0.34	2.201	27.021	27.021
0.143	0.34	2.185	27.005	27.005
0.154	0.32	2.113	26.933	26.933
0.165	0.31	2.043	26.863	26.863
0.176	0.31	2.033	26.853	26.853
0.187	0.30	1.997	26.817	26.817
0.198	0.30	1.981	26.801	26.801
0.209	0.27	1.874	26.694	26.694
0.22	0.27	1.842	26.662	26.662
0.231	0.25	1.796	26.616	26.616
0.2427	0.24	1.752	26.572	26.572
0.2552	0.24	1.729	26.549	26.549
0.2683	0.23	1.707	26.527	26.527
0.2823	0.22	1.665	26.485	26.485
0.2972	0.22	1.664	26.484	26.484
0.3128	0.21	1.621	26.441	26.441
0.3295	0.21	1.621	26.441	26.441
0.3472	0.21	1.611	26.431	26.431
0.3658	0.20	1.576	26.396	26.396
0.3857	0.20	1.576	26.396	26.396
0.4067	0.19	1.556	26.376	26.376
0.4288	0.19	1.556	26.376	26.376
0.4523	0.18	1.522	26.342	26.342
0.4772	0.18	1.520	26.34	26.34
0.5035	0.18	1.512	26.332	26.332
0.5315	0.17	1.475	26.295	26.295
0.5612	0.15	1.424	26.244	26.244
0.5925	0.13	1.364	26.184	26.184
0.6257	0.13	1.361	26.181	26.181
0.6608	0.12	1.317	26.137	26.137
0.6982	0.11	1.276	26.096	26.096
0.7377	0.10	1.255	26.075	26.075
0.7795	0.08	1.213	26.033	26.033
0.8238	0.08	1.212	26.032	26.032
0.8708	0.07	1.163	25.983	25.983
0.9207	0.07	1.162	25.982	25.982
0.9733	0.07	1.162	25.982	25.982
1.0292	0.06	1.160	25.98	25.98
1.0883	0.06	1.159	25.979	25.979
1.151	0.06	1.139	25.959	25.959
1.2173	0.04	1.097	25.917	25.917
1.2877	0.04	1.097	25.917	25.917
1.3622	0.04	1.096	25.916	25.916
1.4412	0.02	1.045	25.865	25.865
1.5248	0.02	1.042	25.862	25.862
1.6133	0.00	0.994	25.814	25.814
1.7072	-0.03	0.943	25.763	25.763
1.8065	-0.03	0.942	25.762	25.762
1.9118	-0.04	0.922	25.742	25.742
2.0233	-0.06	0.880	25.7	25.7
2.1415	-0.06	0.879	25.699	25.699
2.2667	-0.06	0.877	25.697	25.697
2.3992	-0.06	0.876	25.696	25.696
2.5397	-0.08	0.829	25.649	25.649
2.6885	-0.08	0.827	25.647	25.647
2.846	-0.08	0.826	25.646	25.646
3.0128	-0.08	0.824	25.644	25.644
3.1897	-0.08	0.823	25.643	25.643
3.377	-0.09	0.821	25.641	25.641
3.5753	-0.09	0.820	25.64	25.64
3.7855	-0.09	0.820	25.64	25.64
4.0082	-0.09	0.818	25.638	25.638
4.244	-0.09	0.817	25.637	25.637
4.4938	-0.09	0.814	25.634	25.634
4.7585	-0.09	0.814	25.634	25.634
5.0388	-0.09	0.811	25.631	25.631
5.3357	-0.10	0.793	25.613	25.613
5.6502	-0.11	0.768	25.588	25.588
5.9833	-0.12	0.764	25.584	25.584
6.3362	-0.12	0.762	25.582	25.582
6.71	-0.12	0.761	25.581	25.581
7.106	-0.12	0.760	25.58	25.58
7.5253	-0.12	0.757	25.577	25.577
7.9697	-0.12	0.755	25.575	25.575
8.4403	-0.12	0.752	25.572	25.572
8.9388	-0.12	0.751	25.571	25.571
9.4668	-0.12	0.750	25.57	25.57
10.0262	-0.13	0.747	25.567	25.567
10.6187	-0.13	0.745	25.565	25.565
11.2462	-0.13	0.742	25.562	25.562
11.911	-0.13	0.738	25.558	25.558
12.6152	-0.13	0.737	25.557	25.557
13.361	-0.14	0.732	25.552	25.552
14.151	-0.14	0.729	25.549	25.549
14.9878	-0.14	0.725	25.545	25.545
15.8743	-0.14	0.719	25.539	25.539
16.8133	-0.15	0.715	25.535	25.535
17.808	-0.15	0.711	25.531	25.531
18.8617	-0.15	0.706	25.526	25.526
19.9777	-0.15	0.704	25.524	25.524



CHK'D: BWS 12/2010Z

Slug - In

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/12/02	**Time:** 1310	**Observation Well No.:**	OW-847
Weather Conditions:	partly cloudy 50's		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	57.30 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	7.9 ft	**Depth interval of screened portion:**	37.6-45.5 ft
Depth to Groundwater:	34.45 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
34.18	12/10/02
34.36	12/06/02
34.31	12/13/02
34.45	12/12/02

Comments/Remarks

Slug 1 volume = 0.08 ft³
Slug 2 volume = 0.08 ft³
USGS
Transducer S/N → 6407
Hermit S/N → 45449

Set transducer 45' below TOC

USGS

Retrieve test on 12/13/02 @ 1055
Change some equipment
Depth to water = 34.31
Set transducer @ 45' below TOC

USGS this test for calculations
USGS 12/16/02

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-847
Test Date: 12/13/2002
Test Type: Recovery (slug in)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BH Jones 12/20/02

WELL DATA

SWL =	34.31	(ft BTOC)
WD =	51.30	(ft BTOC)
WD =	49.80	(ft BGS)
DTSP =	35.00	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	7.9	(ft)
Lw =	16.99	(ft)
Le/rw =	23.94	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	2.480	(ft) from plot
yt =	1.195	(ft) from plot
t =	1.620	(minutes) from plot
ln(Re/rw) =	2.27	

K = 5.8E-01 (ft/day)

K = 2.1E-04 (cm/sec)

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)}^-1= 2.27

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 2.78

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
20	2.23	0.29	1.75
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

23.94	2.34	0.31	1.89

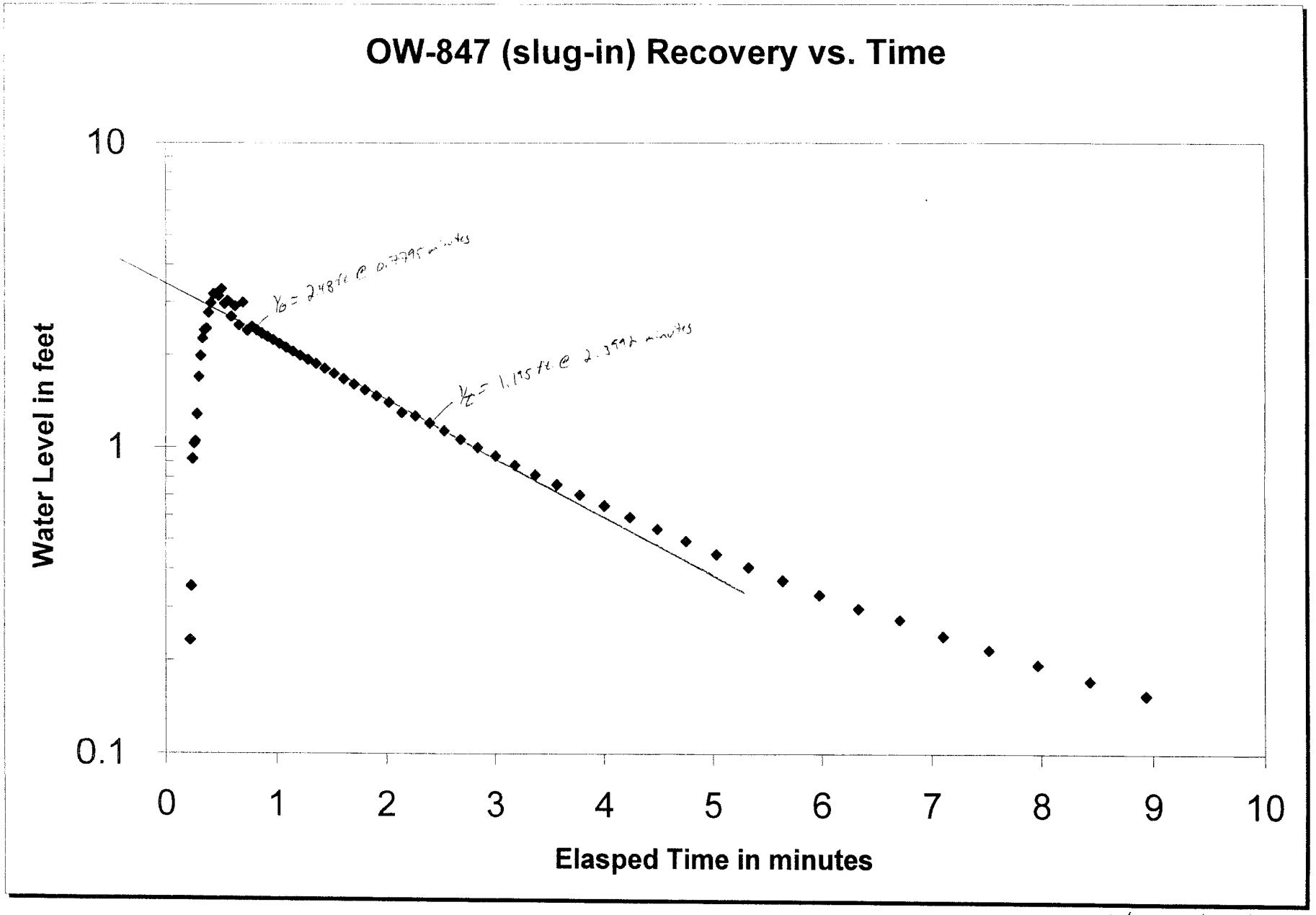
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0	34.31	0
0.011	-2.40	0.004	34.306	0.004
0.022	-2.40	0.004	34.306	0.004
0.033	-2.40	0.004	34.306	0.004
0.044	-2.40	0.004	34.306	0.004
0.055	-2.52	0.003	34.307	0.003
0.066	-3.00	0.001	34.309	0.001
0.077	-2.40	0.004	34.306	0.004
0.088	-2.52	0.003	34.307	0.003
0.099	-3.00	0.001	34.309	0.001
0.11	#NUM!	0	34.31	0
0.121	-2.52	0.003	34.307	0.003
0.132	-2.52	0.003	34.307	0.003
0.143	-3.00	0.001	34.309	0.001
0.154	-3.00	0.001	34.309	0.001
0.165	-3.00	0.001	34.309	0.001
0.176	-3.00	0.001	34.309	0.001
0.187	#NUM!	0	34.31	0
0.198	-3.00	0.001	34.309	0.001
0.209	#NUM!	0	34.31	0
0.22	-0.63	0.233	34.077	-0.233
0.231	-0.45	0.352	33.958	-0.352
0.2427	-0.04	0.916	33.394	-0.916
0.2552	0.01	1.028	33.282	-1.028
0.2683	0.02	1.045	33.265	-1.045
0.2823	0.11	1.277	33.033	-1.277
0.2972	0.23	1.692	32.618	-1.692
0.3128	0.30	1.986	32.324	-1.986
0.3295	0.36	2.269	32.041	-2.269
0.3472	0.38	2.418	31.892	-2.418
0.3658	0.39	2.447	31.863	-2.447
0.3857	0.44	2.764	31.546	-2.764
0.4067	0.47	2.975	31.335	-2.975
0.4288	0.50	3.189	31.121	-3.189
0.4523	0.50	3.194	31.116	-3.194
0.4772	0.50	3.149	31.161	-3.149
0.5035	0.52	3.318	30.992	-3.318
0.5315	0.47	2.966	31.344	-2.966
0.5612	0.48	3.028	31.282	-3.028
0.5925	0.43	2.679	31.631	-2.679
0.6257	0.46	2.905	31.405	-2.905
0.6608	0.40	2.508	31.802	-2.508
0.6982	0.48	2.991	31.319	-2.991
0.7377	0.38	2.41	31.9	-2.41
0.7795	0.39	2.48	31.83	-2.48
0.8238	0.38	2.417	31.893	-2.417
0.8708	0.37	2.359	31.951	-2.359
0.9207	0.36	2.299	32.011	-2.299
0.9733	0.35	2.243	32.067	-2.243
1.0292	0.34	2.181	32.129	-2.181
1.0883	0.33	2.119	32.191	-2.119
1.151	0.31	2.057	32.253	-2.057
1.2173	0.30	1.993	32.317	-1.993
1.2877	0.29	1.931	32.379	-1.931
1.3622	0.27	1.868	32.442	-1.868
1.4412	0.26	1.8	32.51	-1.8
1.5248	0.24	1.734	32.576	-1.734
1.6133	0.22	1.665	32.645	-1.665
1.7072	0.20	1.599	32.711	-1.599
1.8065	0.19	1.533	32.777	-1.533
1.9118	0.17	1.464	32.846	-1.464
2.0233	0.14	1.396	32.914	-1.396
2.1415	0.11	1.292	33.018	-1.292
2.2667	0.10	1.261	33.049	-1.261
2.3992	0.08	1.195	33.115	-1.195
2.5397	0.05	1.13	33.18	-1.13
2.6885	0.03	1.061	33.249	-1.061
2.846	0.00	0.999	33.311	-0.999
3.0128	-0.03	0.937	33.373	-0.937
3.1897	-0.06	0.875	33.435	-0.875
3.377	-0.09	0.815	33.495	-0.815
3.5753	-0.12	0.758	33.552	-0.758
3.7855	-0.15	0.701	33.609	-0.701
4.0082	-0.19	0.647	33.663	-0.647
4.244	-0.23	0.592	33.718	-0.592
4.4938	-0.27	0.542	33.768	-0.542
4.7585	-0.31	0.494	33.816	-0.494
5.0388	-0.35	0.447	33.863	-0.447
5.3357	-0.39	0.405	33.905	-0.405
5.6502	-0.44	0.367	33.943	-0.367
5.9833	-0.48	0.329	33.981	-0.329
6.3362	-0.53	0.296	34.014	-0.296
6.71	-0.57	0.272	34.038	-0.272
7.106	-0.62	0.24	34.07	-0.24
7.5253	-0.67	0.216	34.094	-0.216
7.9697	-0.71	0.193	34.117	-0.193
8.4403	-0.77	0.171	34.139	-0.171
8.9388	-0.81	0.154	34.156	-0.154



CHK'D: "BLH" 12/20/02

Slug out

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/17/02	**Time:** 0840	**Observation Well No.:**	[illegible]
Weather Conditions:	[illegible]		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	(Rising Head) or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	51.3 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	7.9 ft	**Depth interval of screened portion:**	[illegible] ft
Depth to Groundwater:	34.34 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
34.18	12/10/02
34.36	12/16/02
34.31	12/13/02
34.45	12/12/02

Comments/Remarks

[illegible]

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-847
Test Date: 12/17/2002
Test Type: Recovery (slug out)

Conducted by: Grimes and Howe
Entered/date: WSG/12/18/02
Checked/date: BWD 12/18/02

WELL DATA

SWL =	34.34	(ft BTOC)
WD =	51.30	(ft BTOC)
WD =	49.80	(ft BGS)
DTSP =	35.00	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	7.9	(ft)
Lw =	16.96	(ft)
Le/rw =	23.94	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	3.543	(ft) from plot
yt =	2.387	(ft) from plot
t =	0.761	(minutes) from plot
ln(Re/rw) =	2.27	
K =	**6.6E-01**	**(ft/day)**
K =	**2.3E-04**	**(cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [(1.1/(ln(Lw/rw)))+(A+B*ln((H-Lw)/rw))/(Le/rw)]^-1 = 2.27

Where: Lw = H;

ln(Re/rw) = [(1.1/(ln(Lw/rw)))+(C/(Le/rw))]^-1 = 2.78

Calculation of Coefficients

Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
20	2.23	0.29	1.75
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

23.94	2.34	0.31	1.89

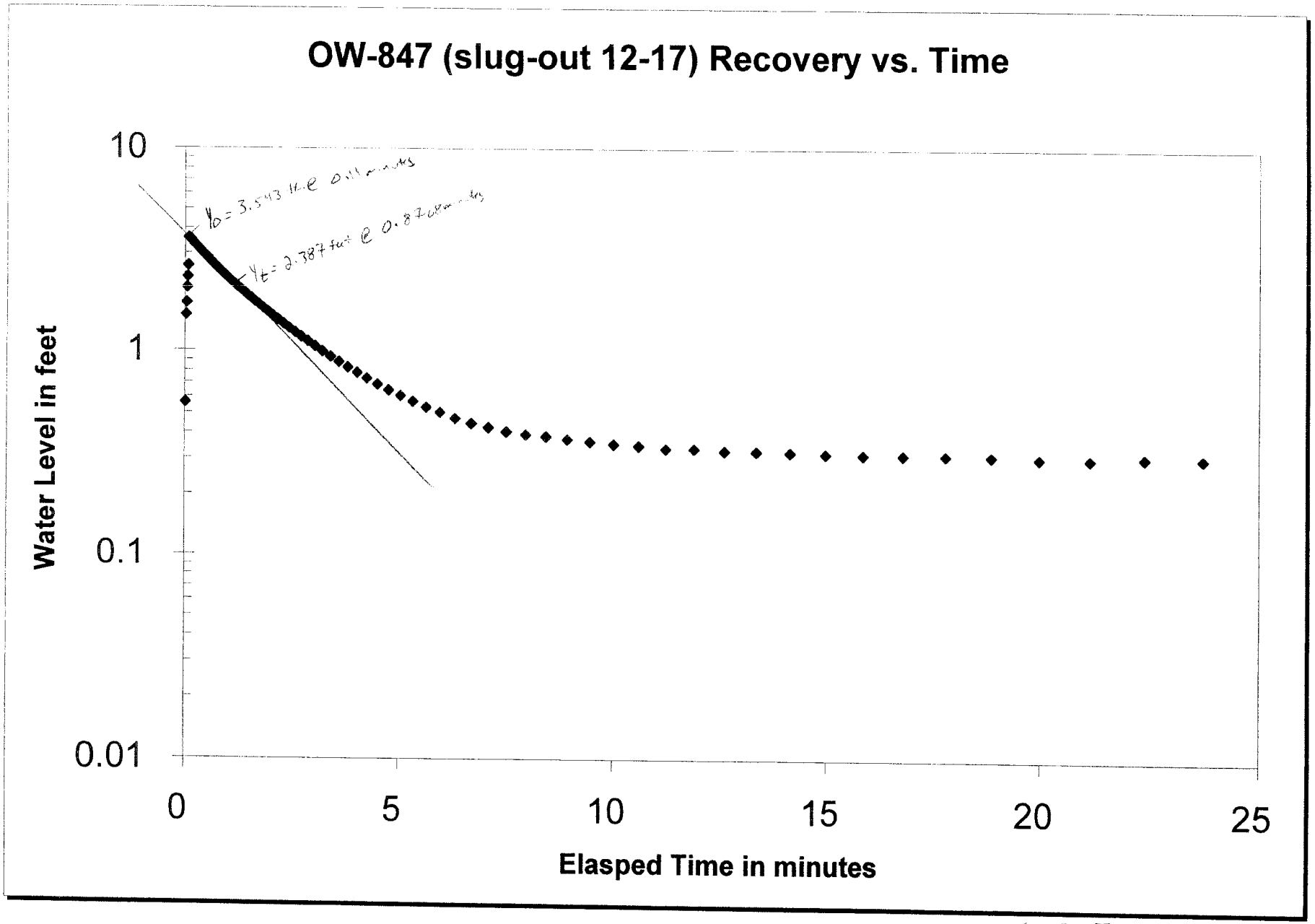
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.30	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0	34.34	0
0.011	#NUM!	-0.001	34.339	-0.001
0.022	-0.25	0.562	34.902	0.562
0.033	0.17	1.487	35.827	1.487
0.044	0.23	1.706	36.046	1.706
0.055	0.31	2.024	36.364	2.024
0.066	0.36	2.294	36.634	2.294
0.077	0.41	2.6	36.94	2.6
0.088	0.55	3.576	37.916	3.576
0.099	0.55	3.554	37.894	3.554
0.11	0.55	3.543	37.883	3.543
0.121	0.55	3.513	37.853	3.513
0.132	0.54	3.484	37.824	3.484
0.143	0.54	3.46	37.8	3.46
0.154	0.54	3.438	37.778	3.438
0.165	0.53	3.427	37.767	3.427
0.176	0.53	3.406	37.746	3.406
0.187	0.53	3.388	37.728	3.388
0.198	0.53	3.368	37.708	3.368
0.209	0.52	3.346	37.686	3.346
0.22	0.52	3.32	37.66	3.32
0.231	0.52	3.303	37.643	3.303
0.2427	0.52	3.277	37.617	3.277
0.2552	0.51	3.254	37.594	3.254
0.2683	0.51	3.234	37.574	3.234
0.2823	0.51	3.207	37.547	3.207
0.2972	0.50	3.187	37.527	3.187
0.3128	0.50	3.162	37.502	3.162
0.3295	0.50	3.131	37.471	3.131
0.3472	0.49	3.096	37.436	3.096
0.3658	0.49	3.064	37.404	3.064
0.3857	0.48	3.033	37.373	3.033
0.4067	0.48	3	37.34	3
0.4288	0.47	2.962	37.302	2.962
0.4523	0.47	2.928	37.268	2.928
0.4772	0.46	2.892	37.232	2.892
0.5035	0.46	2.875	37.215	2.875
0.5315	0.45	2.811	37.151	2.811
0.5612	0.44	2.77	37.11	2.77
0.5925	0.44	2.728	37.068	2.728
0.6257	0.43	2.682	37.022	2.682
0.6608	0.42	2.636	36.976	2.636
0.6982	0.41	2.59	36.93	2.59
0.7377	0.41	2.544	36.884	2.544
0.7795	0.40	2.494	36.834	2.494
0.8238	0.39	2.442	36.782	2.442
0.8708	0.38	2.387	36.727	2.387
0.9207	0.37	2.336	36.676	2.336
0.9733	0.36	2.282	36.622	2.282
1.0292	0.35	2.223	36.563	2.223
1.0883	0.34	2.166	36.506	2.166
1.151	0.32	2.107	36.447	2.107
1.2173	0.31	2.047	36.387	2.047
1.2877	0.30	1.988	36.328	1.988
1.3622	0.28	1.926	36.266	1.926
1.4412	0.27	1.863	36.203	1.863
1.5248	0.26	1.801	36.141	1.801
1.6133	0.24	1.737	36.077	1.737
1.7072	0.22	1.673	36.013	1.673
1.8065	0.21	1.609	35.949	1.609
1.9118	0.19	1.546	35.886	1.546
2.0233	0.17	1.48	35.82	1.48
2.1415	0.15	1.417	35.757	1.417
2.2667	0.13	1.352	35.692	1.352
2.3992	0.11	1.29	35.63	1.29
2.5397	0.09	1.228	35.568	1.228
2.6885	0.07	1.167	35.507	1.167
2.846	0.04	1.108	35.448	1.108
3.0128	0.02	1.049	35.389	1.049
3.1897	0.00	0.991	35.331	0.991
3.377	-0.03	0.935	35.275	0.935
3.5753	-0.05	0.882	35.222	0.882
3.7855	-0.08	0.83	35.17	0.83
4.0082	-0.11	0.783	35.123	0.783
4.244	-0.13	0.734	35.074	0.734
4.4938	-0.16	0.688	35.028	0.688
4.7585	-0.19	0.646	34.986	0.646
5.0388	-0.22	0.607	34.947	0.607
5.3357	-0.24	0.57	34.91	0.57
5.6502	-0.27	0.534	34.874	0.534
5.9833	-0.30	0.505	34.845	0.505
6.3362	-0.33	0.472	34.812	0.472
6.71	-0.35	0.446	34.786	0.446
7.106	-0.37	0.427	34.767	0.427
7.5253	-0.39	0.407	34.747	0.407
7.9697	-0.40	0.394	34.734	0.394
8.4403	-0.41	0.386	34.726	0.386
8.9388	-0.43	0.374	34.714	0.374
9.4668	-0.44	0.364	34.704	0.364
10.0262	-0.45	0.355	34.695	0.355
10.6187	-0.46	0.348	34.688	0.348
11.2462	-0.47	0.337	34.677	0.337
11.911	-0.47	0.337	34.677	0.337
12.6152	-0.48	0.329	34.669	0.329
13.361	-0.48	0.328	34.668	0.328
14.151	-0.49	0.324	34.664	0.324
14.9878	-0.50	0.319	34.659	0.319
15.8743	-0.50	0.316	34.656	0.316
16.8133	-0.50	0.315	34.655	0.315
17.808	-0.50	0.314	34.654	0.314
18.8617	-0.51	0.312	34.652	0.312
19.9777	-0.52	0.304	34.644	0.304
21.1598	-0.52	0.302	34.642	0.302
22.412	-0.51	0.308	34.648	0.308
23.7385	-0.51	0.306	34.646	0.306
25.1435	-0.52	0.302	34.642	0.302



CHKD: BLB 12/20/02

Slug - 7in

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/13/02	**Time:** 1310	**Observation Well No.:**	OW-848
Weather Conditions:	Rainy & upper 30's		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	48.87 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	5.02 ft	**Depth interval of screened portion:**	42.2-47.2 ft
Depth to Groundwater:	42.65 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
42.79	12/10/02
43.02	12/06/02

Comments/Remarks

used slug #2 ⇒ volume = 0.08 ft³

Transducer S/n = 6407

Hermit S/n = 45279

Set transducer @ ~~45'~~ below TOC
48' — [illegible] 21 [illegible] storage

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-848
Test Date: 12/13/2002
Test Type: Recovery (slug in)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BWJones 12/20/02

WELL DATA

SWL =	42.65	(ft BTOC)
WD =	48.87	(ft BTOC)
WD =	47.37	(ft BGS)
DTSP =	39.10	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.19	(ft)
Le =	5.02	(ft)
Lw =	6.22	(ft)
Le/rw =	15.21	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	1.537	(ft) from plot
yt =	0.953	(ft) from plot
t =	1.255	(minutes) from plot
ln(Re/rw) =	1.67	
K =	**3.4E+00**	**(ft/day)**
K =	**1.2E-03**	**(cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1= 1.67

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 2.13

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
15	2.1	0.27	1.5
25	2.4	0.31	1.9

Interpolated values of A, B and C for Le/rw

15.21	2.11	0.27	1.51

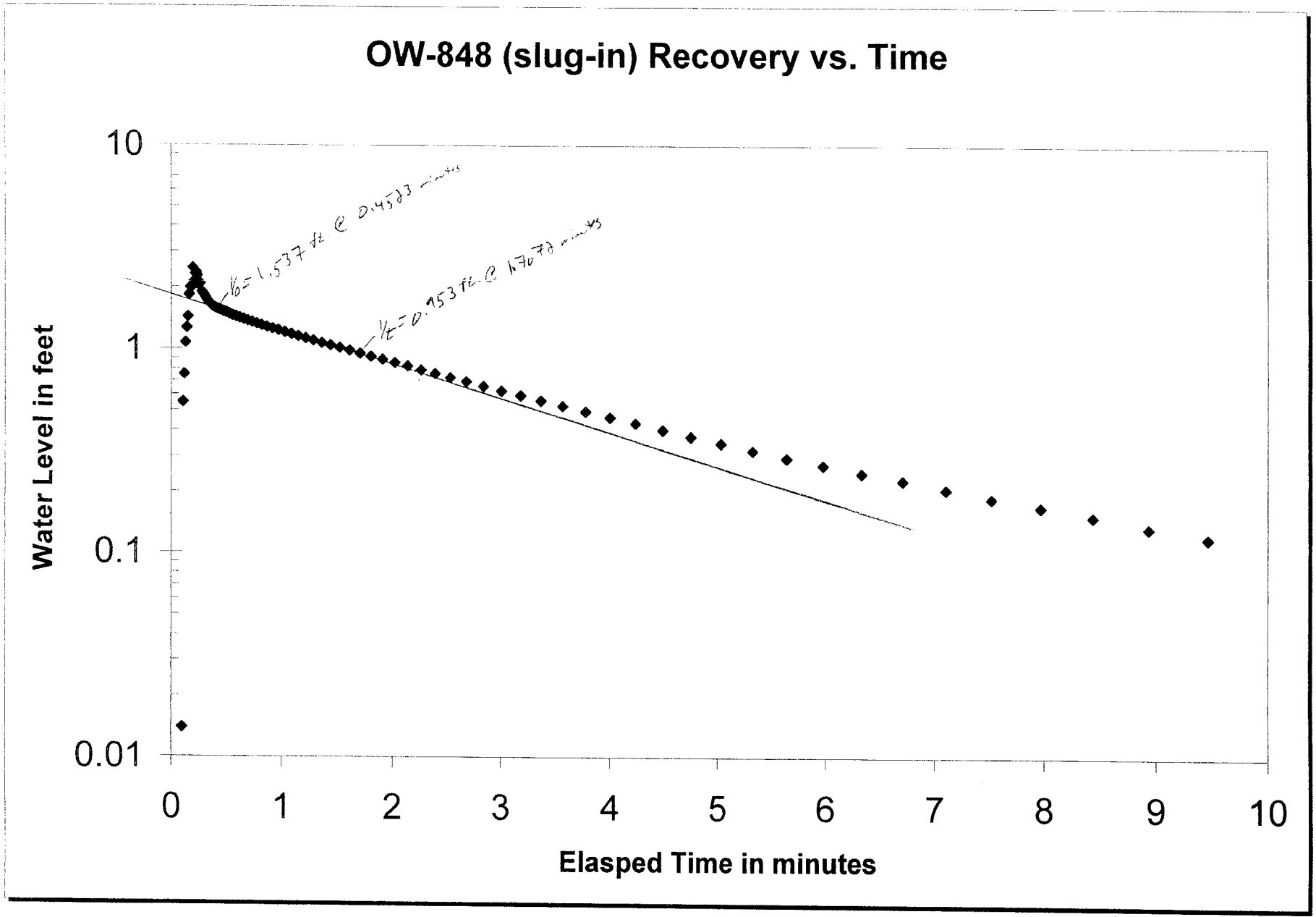
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0	42.65	0
0.011	-3.00	0.001	42.649	0.001
0.022	-2.52	0.003	42.647	0.003
0.033	-3.00	0.001	42.649	0.001
0.044	-3.00	0.001	42.649	0.001
0.055	#NUM!	0	42.65	0
0.066	-2.52	0.003	42.647	0.003
0.077	-3.00	0.001	42.649	0.001
0.088	-3.00	0.001	42.649	0.001
0.099	-1.85	0.014	42.636	-0.014
0.11	-0.26	0.55	42.1	-0.55
0.121	-0.12	0.752	41.898	-0.752
0.132	0.03	1.073	41.577	-1.073
0.143	0.10	1.261	41.389	-1.261
0.154	0.16	1.429	41.221	-1.429
0.165	0.26	1.831	40.819	-1.831
0.176	0.30	1.991	40.659	-1.991
0.187	0.30	1.995	40.655	-1.995
0.198	0.39	2.48	40.17	-2.48
0.209	0.33	2.128	40.522	-2.128
0.22	0.37	2.318	40.332	-2.318
0.231	0.37	2.358	40.292	-2.358
0.2427	0.36	2.266	40.384	-2.266
0.2552	0.31	2.042	40.608	-2.042
0.2683	0.32	2.078	40.572	-2.078
0.2823	0.28	1.893	40.757	-1.893
0.2972	0.26	1.837	40.813	-1.837
0.3128	0.25	1.778	40.872	-1.778
0.3295	0.24	1.718	40.932	-1.718
0.3472	0.22	1.672	40.978	-1.672
0.3658	0.21	1.633	41.017	-1.633
0.3857	0.20	1.603	41.047	-1.603
0.4067	0.20	1.577	41.073	-1.577
0.4288	0.19	1.557	41.093	-1.557
0.4523	0.19	1.537	41.113	-1.537
0.4772	0.18	1.518	41.132	-1.518
0.5035	0.18	1.508	41.142	-1.508
0.5315	0.17	1.478	41.172	-1.478
0.5612	0.16	1.457	41.193	-1.457
0.5925	0.16	1.437	41.213	-1.437
0.6257	0.15	1.414	41.236	-1.414
0.6608	0.14	1.392	41.258	-1.392
0.6982	0.14	1.372	41.278	-1.372
0.7377	0.13	1.349	41.301	-1.349
0.7795	0.12	1.329	41.321	-1.329
0.8238	0.12	1.304	41.346	-1.304
0.8708	0.11	1.28	41.37	-1.28
0.9207	0.10	1.257	41.393	-1.257
0.9733	0.09	1.233	41.417	-1.233
1.0292	0.08	1.208	41.442	-1.208
1.0883	0.07	1.182	41.468	-1.182
1.151	0.06	1.155	41.495	-1.155
1.2173	0.05	1.128	41.522	-1.128
1.2877	0.04	1.101	41.549	-1.101
1.3622	0.03	1.073	41.577	-1.073
1.4412	0.02	1.043	41.607	-1.043
1.5248	0.01	1.013	41.637	-1.013
1.6133	-0.01	0.984	41.666	-0.984
1.7072	-0.02	0.953	41.697	-0.953
1.8065	-0.04	0.921	41.729	-0.921
1.9118	-0.05	0.89	41.76	-0.89
2.0233	-0.07	0.858	41.792	-0.858
2.1415	-0.08	0.827	41.823	-0.827
2.2667	-0.10	0.792	41.858	-0.792
2.3992	-0.12	0.761	41.889	-0.761
2.5397	-0.14	0.728	41.922	-0.728
2.6885	-0.16	0.695	41.955	-0.695
2.846	-0.18	0.659	41.991	-0.659
3.0128	-0.20	0.626	42.024	-0.626
3.1897	-0.23	0.593	42.057	-0.593
3.377	-0.25	0.56	42.09	-0.56
3.5753	-0.28	0.527	42.123	-0.527
3.7855	-0.31	0.495	42.155	-0.495
4.0082	-0.33	0.463	42.187	-0.463
4.244	-0.36	0.433	42.217	-0.433
4.4938	-0.39	0.403	42.247	-0.403
4.7585	-0.43	0.374	42.276	-0.374
5.0388	-0.46	0.347	42.303	-0.347
5.3357	-0.49	0.32	42.33	-0.32
5.6502	-0.53	0.294	42.356	-0.294
5.9833	-0.57	0.271	42.379	-0.271
6.3362	-0.61	0.247	42.403	-0.247
6.71	-0.64	0.227	42.423	-0.227
7.106	-0.69	0.205	42.445	-0.205
7.5253	-0.73	0.185	42.465	-0.185
7.9697	-0.77	0.168	42.482	-0.168
8.4403	-0.82	0.151	42.499	-0.151
8.9388	-0.88	0.133	42.517	-0.133
9.4668	-0.92	0.119	42.531	-0.119
10.0262	-0.97	0.106	42.544	-0.106


OW-848 (slug-in) Recovery vs. Time
Water Level in feet
10
1
0.1
0.01
0
1
2
3
4
5
6
7
8
9
10
Elasped Time in minutes

Slug-out

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date:	12/10/02	**Time:**	1425 1345
Observation Well No.:	OW 848		
Weather Conditions:			
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	8.87 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	5.02 ft	**Depth interval of screened portion:**	42.2 - 47.2 ft
Depth to Groundwater:	42.65 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
42.79	12/10/02
43.02	12/06/02

Comments/Remarks

[illegible] slug [illegible]

Transducer SN → [illegible]

[illegible] SN → [illegible]

[illegible] transducer 47' below TOC

WSG

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-848
Test Date: 12/13/2002
Test Type: Recovery (slug out)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BNHmes 12/20/02

WELL DATA

SWL =	42.65	(ft BTOC)
WD =	48.87	(ft BTOC)
WD =	47.37	(ft BGS)
DTSP =	39.10	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.19	(ft)
Le =	5.02	(ft)
Lw =	6.22	(ft)
Le/rw =	15.21	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	1.229	(ft) from plot
yt =	0.785	(ft) from plot
t =	1.426	(minutes) from plot
ln(Re/rw) =	1.67	

K = 2.8E+00 (ft/day)

K = 9.9E-04 (cm/sec)

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [(1.1/(ln(Lw/rw)))+(A+Bln((H-Lw)/rw))/(Le/rw)]^-1= 1.67

Where: Lw = H;

ln(Re/rw) = [(1.1/(ln(Lw/rw)))+(C/(Le/rw))]^-1 = 2.13

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
15	2.1	0.27	1.5
25	2.4	0.31	1.9

Interpolated values of A, B and C for Le/rw

15.21	2.11	0.27	1.51

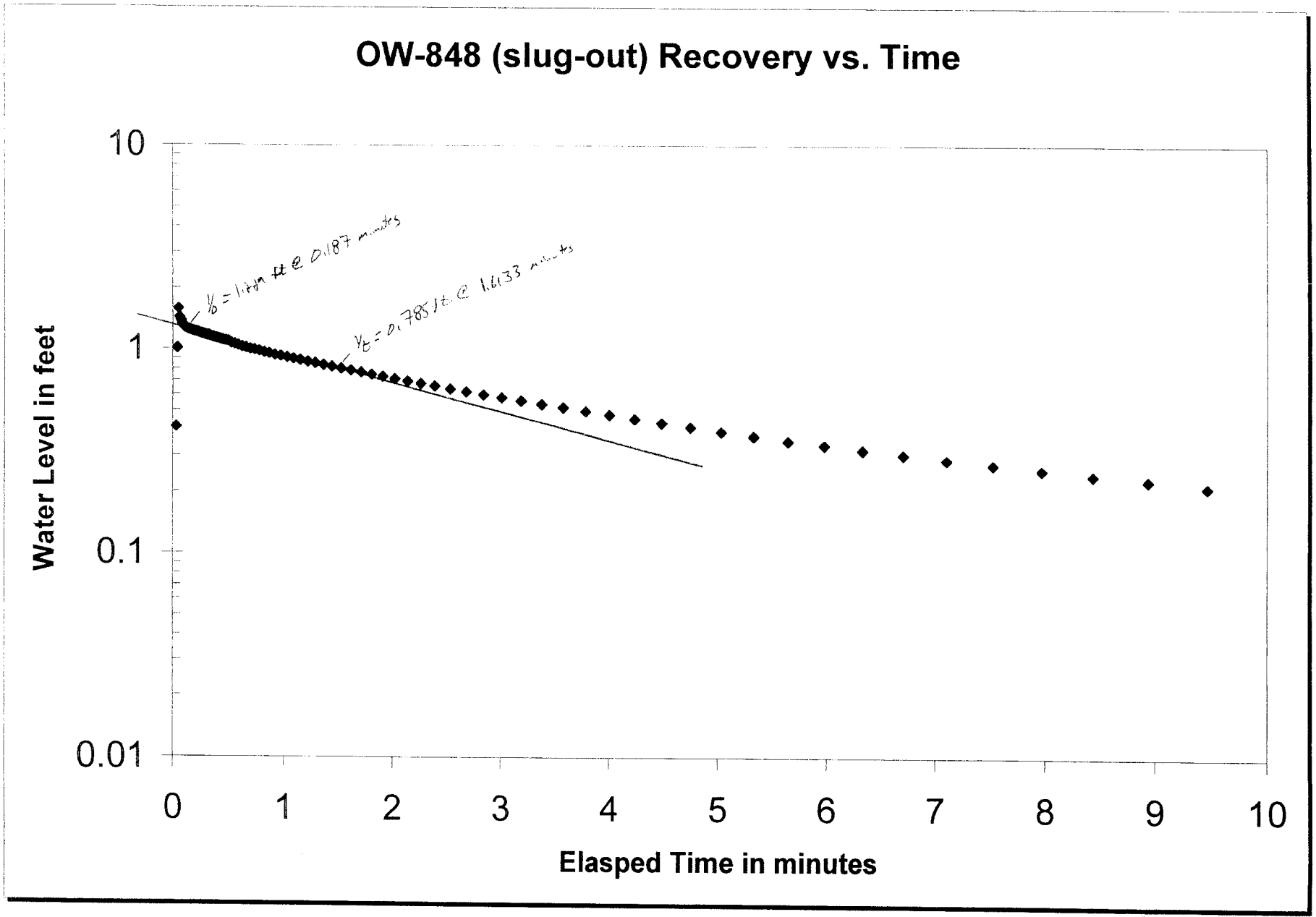
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0	42.65	0
0.011	-3.00	0.001	42.651	0.001
0.022	-2.52	0.003	42.653	0.003
0.033	-0.38	0.415	43.065	0.415
0.044	0.00	1.01	43.66	1.01
0.055	0.20	1.582	44.232	1.582
0.066	0.16	1.433	44.083	1.433
0.077	0.14	1.38	44.03	1.38
0.088	0.12	1.33	43.98	1.33
0.099	0.11	1.3	43.95	1.3
0.11	0.11	1.28	43.93	1.28
0.121	0.10	1.268	43.918	1.268
0.132	0.10	1.258	43.908	1.258
0.143	0.10	1.254	43.904	1.254
0.154	0.10	1.245	43.895	1.245
0.165	0.09	1.239	43.889	1.239
0.176	0.09	1.232	43.882	1.232
0.187	0.09	1.229	43.879	1.229
0.198	0.09	1.221	43.871	1.221
0.209	0.09	1.219	43.869	1.219
0.22	0.08	1.212	43.862	1.212
0.231	0.08	1.209	43.859	1.209
0.2427	0.08	1.201	43.851	1.201
0.2552	0.08	1.194	43.844	1.194
0.2683	0.08	1.189	43.839	1.189
0.2823	0.07	1.182	43.832	1.182
0.2972	0.07	1.176	43.826	1.176
0.3128	0.07	1.168	43.818	1.168
0.3295	0.07	1.165	43.815	1.165
0.3472	0.06	1.155	43.805	1.155
0.3658	0.06	1.145	43.795	1.145
0.3857	0.06	1.136	43.786	1.136
0.4067	0.05	1.129	43.779	1.129
0.4288	0.05	1.118	43.768	1.118
0.4523	0.05	1.11	43.76	1.11
0.4772	0.04	1.1	43.75	1.1
0.5035	0.04	1.096	43.746	1.096
0.5315	0.03	1.07	43.72	1.07
0.5612	0.02	1.057	43.707	1.057
0.5925	0.02	1.043	43.693	1.043
0.6257	0.01	1.029	43.679	1.029
0.6608	0.01	1.017	43.667	1.017
0.6982	0.00	1.001	43.651	1.001
0.7377	0.00	0.993	43.643	0.993
0.7795	-0.01	0.98	43.63	0.98
0.8238	-0.02	0.963	43.613	0.963
0.8708	-0.02	0.951	43.601	0.951
0.9207	-0.03	0.935	43.585	0.935
0.9733	-0.03	0.924	43.574	0.924
1.0292	-0.04	0.911	43.561	0.911
1.0883	-0.05	0.895	43.545	0.895
1.151	-0.06	0.881	43.531	0.881
1.2173	-0.06	0.865	43.515	0.865
1.2877	-0.07	0.851	43.501	0.851
1.3622	-0.08	0.835	43.485	0.835
1.4412	-0.09	0.819	43.469	0.819
1.5248	-0.10	0.802	43.452	0.802
1.6133	-0.11	0.785	43.435	0.785
1.7072	-0.11	0.769	43.419	0.769
1.8065	-0.12	0.75	43.4	0.75
1.9118	-0.13	0.733	43.383	0.733
2.0233	-0.15	0.714	43.364	0.714
2.1415	-0.16	0.696	43.346	0.696
2.2667	-0.17	0.677	43.327	0.677
2.3992	-0.18	0.659	43.309	0.659
2.5397	-0.20	0.637	43.287	0.637
2.6885	-0.21	0.618	43.268	0.618
2.846	-0.22	0.597	43.247	0.597
3.0128	-0.24	0.578	43.228	0.578
3.1897	-0.25	0.557	43.207	0.557
3.377	-0.27	0.535	43.185	0.535
3.5753	-0.29	0.516	43.166	0.516
3.7855	-0.31	0.495	43.145	0.495
4.0082	-0.32	0.475	43.125	0.475
4.244	-0.34	0.453	43.103	0.453
4.4938	-0.36	0.433	43.083	0.433
4.7585	-0.38	0.413	43.063	0.413
5.0388	-0.41	0.393	43.043	0.393
5.3357	-0.43	0.374	43.024	0.374
5.6502	-0.45	0.354	43.004	0.354
5.9833	-0.47	0.337	42.987	0.337
6.3362	-0.50	0.319	42.969	0.319
6.71	-0.52	0.303	42.953	0.303
7.106	-0.54	0.286	42.936	0.286
7.5253	-0.57	0.27	42.92	0.27
7.9697	-0.59	0.255	42.905	0.255
8.4403	-0.62	0.24	42.89	0.24
8.9388	-0.64	0.227	42.877	0.227
9.4668	-0.68	0.211	42.861	0.211



CHK'D: BWB 12/20/02

Slug - In

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/13/02	**Time:** 0915	**Observation Well No.:**	OW-849
Weather Conditions:	Cloudy in upper 30's		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	51.30 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.7 ft	**Depth interval of screened portion:**	37.6-47.3ft
Depth to Groundwater:	33.13 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
33.15	12/11/02

Comments/Remarks

Used Slug # 2 → volume = 0.08 ft³

Transducer S/N → 6407

Hermit S/N → 45449

Set Transducer @ 45' below TOC

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-849
Test Date: 12/13/2002
Test Type: Recovery (slug in)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BHowe 12/20/02

WELL DATA

SWL =	33.13	(ft BTOC)
WD =	51.30	(ft BTOC)
WD =	49.80	(ft BGS)
DTSP =	35.60	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.7	(ft)
Lw =	18.17	(ft)
Le/rw =	29.39	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	1.493	(ft) from plot
yt =	0.542	(ft) from plot
t =	0.588	(minutes) from plot
ln(Re/rw) =	2.44	
K =	**2.0E+00**	**(ft/day)**
K =	**7.0E-04**	**(cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1= 2.44

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 2.94

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.39	2.49	0.35	2.08

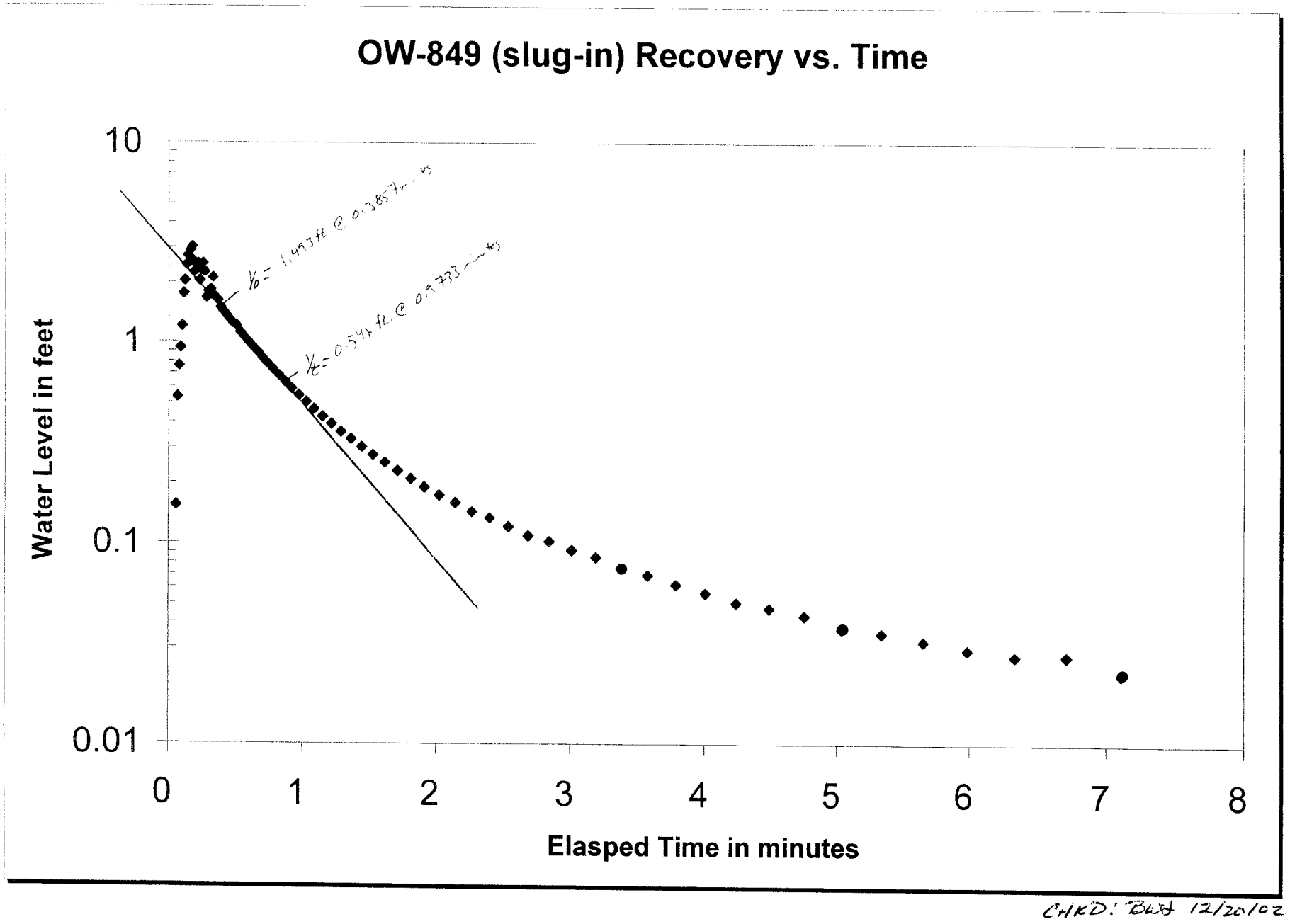
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0	33.13	0
0.011	-3.00	0.001	33.129	0.001
0.022	#NUM!	0	33.13	0
0.033	-3.00	0.001	33.129	0.001
0.044	-2.52	0.003	33.127	0.003
0.055	-0.81	0.155	32.975	-0.155
0.066	-0.27	0.533	32.597	-0.533
0.077	-0.12	0.759	32.371	-0.759
0.088	-0.03	0.935	32.195	-0.935
0.099	0.08	1.205	31.925	-1.205
0.11	0.24	1.757	31.373	-1.757
0.121	0.31	2.039	31.091	-2.039
0.132	0.39	2.449	30.681	-2.449
0.143	0.43	2.72	30.41	-2.72
0.154	0.40	2.517	30.613	-2.517
0.165	0.46	2.903	30.227	-2.903
0.176	0.48	3.028	30.102	-3.028
0.187	0.41	2.546	30.584	-2.546
0.198	0.36	2.281	30.849	-2.281
0.209	0.39	2.436	30.694	-2.436
0.22	0.39	2.483	30.647	-2.483
0.231	0.31	2.042	31.088	-2.042
0.2427	0.36	2.307	30.823	-2.307
0.2552	0.40	2.49	30.64	-2.49
0.2683	0.35	2.249	30.881	-2.249
0.2823	0.22	1.674	31.456	-1.674
0.2972	0.25	1.798	31.332	-1.798
0.3128	0.26	1.837	31.293	-1.837
0.3295	0.32	2.113	31.017	-2.113
0.3472	0.22	1.674	31.456	-1.674
0.3658	0.21	1.628	31.502	-1.628
0.3857	0.17	1.493	31.637	-1.493
0.4067	0.15	1.425	31.705	-1.425
0.4288	0.14	1.365	31.765	-1.365
0.4523	0.12	1.304	31.826	-1.304
0.4772	0.10	1.245	31.885	-1.245
0.5035	0.08	1.214	31.916	-1.214
0.5315	0.05	1.12	32.01	-1.12
0.5612	0.03	1.06	32.07	-1.06
0.5925	0.00	1.002	32.128	-1.002
0.6257	-0.02	0.945	32.185	-0.945
0.6608	-0.05	0.892	32.238	-0.892
0.6982	-0.08	0.833	32.297	-0.833
0.7377	-0.11	0.779	32.351	-0.779
0.7795	-0.14	0.729	32.401	-0.729
0.8238	-0.17	0.679	32.451	-0.679
0.8708	-0.20	0.631	32.499	-0.631
0.9207	-0.23	0.585	32.545	-0.585
0.9733	-0.27	0.542	32.588	-0.542
1.0292	-0.30	0.502	32.628	-0.502
1.0883	-0.33	0.464	32.666	-0.464
1.151	-0.37	0.426	32.704	-0.426
1.2173	-0.41	0.393	32.737	-0.393
1.2877	-0.44	0.359	32.771	-0.359
1.3622	-0.48	0.331	32.799	-0.331
1.4412	-0.52	0.303	32.827	-0.303
1.5248	-0.56	0.276	32.854	-0.276
1.6133	-0.60	0.253	32.877	-0.253
1.7072	-0.64	0.23	32.9	-0.23
1.8065	-0.68	0.21	32.92	-0.21
1.9118	-0.72	0.191	32.939	-0.191
2.0233	-0.76	0.174	32.956	-0.174
2.1415	-0.80	0.16	32.97	-0.16
2.2667	-0.84	0.144	32.986	-0.144
2.3992	-0.87	0.134	32.996	-0.134
2.5397	-0.92	0.121	33.009	-0.121
2.6885	-0.96	0.109	33.021	-0.109
2.846	-0.99	0.102	33.028	-0.102
3.0128	-1.04	0.092	33.038	-0.092
3.1897	-1.07	0.085	33.045	-0.085
3.377	-1.12	0.075	33.055	-0.075
3.5753	-1.16	0.069	33.061	-0.069
3.7855	-1.21	0.062	33.068	-0.062
4.0082	-1.25	0.056	33.074	-0.056
4.244	-1.30	0.05	33.08	-0.05
4.4938	-1.33	0.047	33.083	-0.047
4.7585	-1.37	0.043	33.087	-0.043
5.0388	-1.43	0.037	33.093	-0.037
5.3357	-1.46	0.035	33.095	-0.035
5.6502	-1.49	0.032	33.098	-0.032
5.9833	-1.54	0.029	33.101	-0.029
6.3362	-1.57	0.027	33.103	-0.027
6.71	-1.57	0.027	33.103	-0.027
7.106	-1.66	0.022	33.108	-0.022



CHKD: BWH 12/20/02

Slug out

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date: 12/13/02	**Time:** 09:35	**Observation Well No.:**	DW 549
Weather Conditions:	Cloudy in upper 30's		
Method of Slug Withdrawl (circle one):	water, mechanical, or pressure	**Test Method:**	Rising Head or Falling Head (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	51.30 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.7 ft	**Depth interval of screened portion:**	37.6 - 47.3 ft
Depth to Groundwater:	33.13 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
33.15	12/11/02

Comments/Remarks

Used Slug #2 → Volume = 0.08 ft³
Transducer S/N → 6-107
Permanent S/N = 45449

Set transducer @ 45' below TOC

WSL

Two additional Slug out tests on 12/13/02
Start @ 1510. Used Slug #2 = Volume = 0.08 ft³
Transducer S/N → 6-107
Permanent S/N → 45449
Depth to water 33.06

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-849
Test Date: 12/13/2002
Test Type: Recovery (slug out)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date: BW Howe 12/20/02

WELL DATA

SWL =	33.06	(ft BTOC)
WD =	51.30	(ft BTOC)
WD =	49.80	(ft BGS)
DTSP =	35.60	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.7	(ft)
Lw =	18.24	(ft)
Le/rw =	29.39	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	2.895	(ft) from plot
yt =	1.695	(ft) from plot
t =	0.194	(minutes) from plot
ln(Re/rw) =	2.44	
K =	**3.2E+00**	**(ft/day)**
K =	**1.1E-03**	**(cm/sec)**

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1 = 2.44

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 2.94

Calculation of Coefficients
Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

Interpolated values of A, B and C for Le/rw

29.39	2.49	0.35	2.08

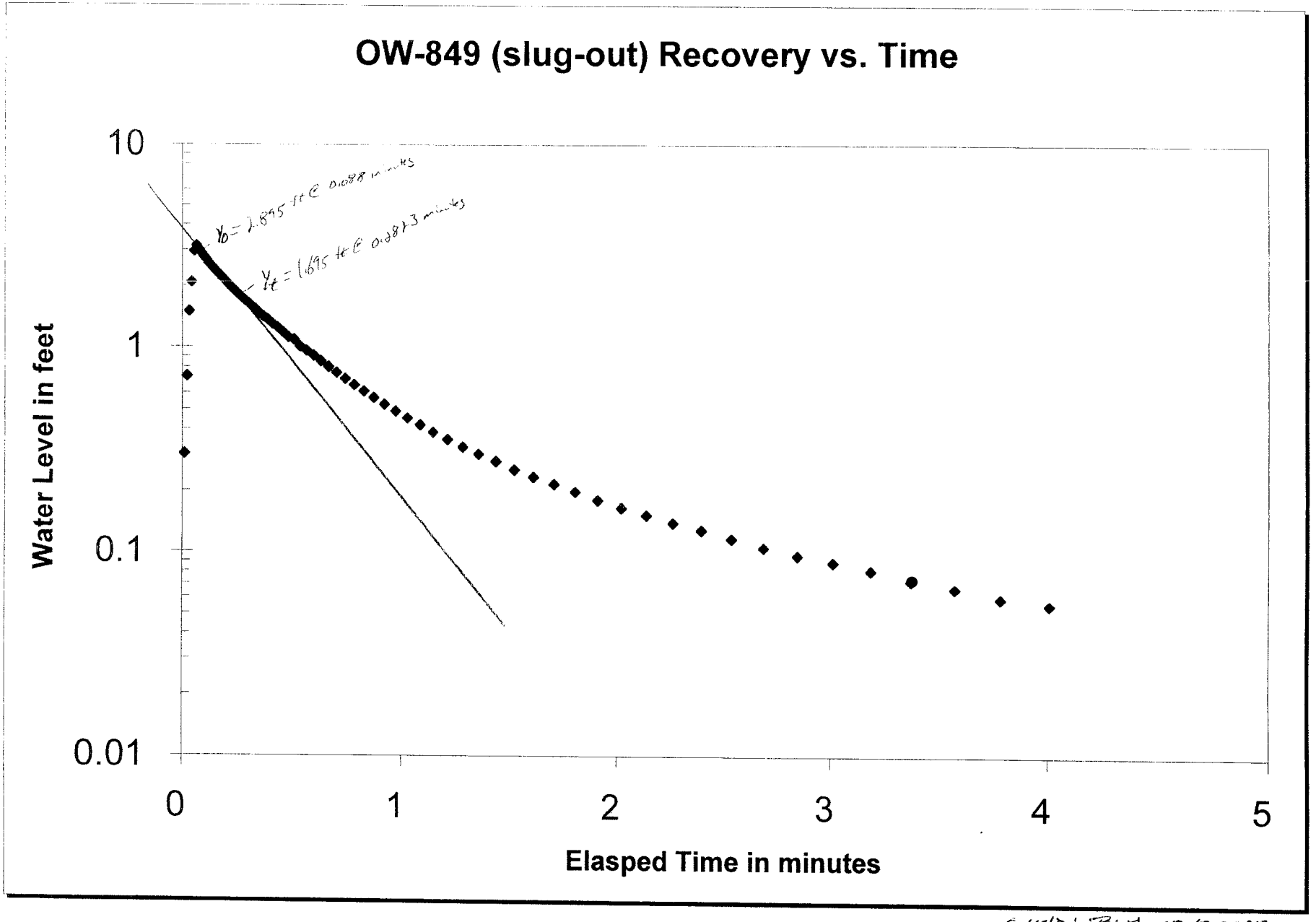
Coefficients Table

Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0	33.06	0
0.011	-0.52	0.303	33.363	0.303
0.022	-0.14	0.722	33.782	0.722
0.033	0.17	1.491	34.551	1.491
0.044	0.32	2.08	35.14	2.08
0.055	0.47	2.964	36.024	2.964
0.066	0.50	3.153	36.213	3.153
0.077	0.48	3.015	36.075	3.015
0.088	0.46	2.895	35.955	2.895
0.099	0.44	2.784	35.844	2.784
0.11	0.43	2.692	35.752	2.692
0.121	0.41	2.59	35.65	2.59
0.132	0.40	2.512	35.572	2.512
0.143	0.39	2.429	35.489	2.429
0.154	0.37	2.354	35.414	2.354
0.165	0.36	2.283	35.343	2.283
0.176	0.35	2.218	35.278	2.218
0.187	0.33	2.15	35.21	2.15
0.198	0.32	2.083	35.143	2.083
0.209	0.31	2.027	35.087	2.027
0.22	0.29	1.968	35.028	1.968
0.231	0.28	1.916	34.976	1.916
0.2427	0.27	1.862	34.922	1.862
0.2552	0.26	1.804	34.864	1.804
0.2683	0.24	1.749	34.809	1.749
0.2823	0.23	1.695	34.755	1.695
0.2972	0.22	1.643	34.703	1.643
0.3128	0.20	1.583	34.643	1.583
0.3295	0.18	1.525	34.585	1.525
0.3472	0.17	1.466	34.526	1.466
0.3658	0.15	1.412	34.472	1.412
0.3857	0.13	1.359	34.419	1.359
0.4067	0.11	1.298	34.358	1.298
0.4288	0.10	1.245	34.305	1.245
0.4523	0.07	1.182	34.242	1.182
0.4772	0.05	1.118	34.178	1.118
0.5035	0.04	1.09	34.15	1.09
0.5315	0.00	1.006	34.066	1.006
0.5612	-0.02	0.96	34.02	0.96
0.5925	-0.04	0.907	33.967	0.907
0.6257	-0.07	0.854	33.914	0.854
0.6608	-0.10	0.801	33.861	0.801
0.6982	-0.12	0.752	33.812	0.752
0.7377	-0.15	0.702	33.762	0.702
0.7795	-0.18	0.656	33.716	0.656
0.8238	-0.21	0.611	33.671	0.611
0.8708	-0.24	0.569	33.629	0.569
0.9207	-0.28	0.529	33.589	0.529
0.9733	-0.31	0.489	33.549	0.489
1.0292	-0.34	0.453	33.513	0.453
1.0883	-0.38	0.42	33.48	0.42
1.151	-0.41	0.387	33.447	0.387
1.2173	-0.45	0.357	33.417	0.357
1.2877	-0.48	0.328	33.388	0.328
1.3622	-0.52	0.303	33.363	0.303
1.4412	-0.55	0.279	33.339	0.279
1.5248	-0.60	0.254	33.314	0.254
1.6133	-0.63	0.234	33.294	0.234
1.7072	-0.67	0.216	33.276	0.216
1.8065	-0.70	0.198	33.258	0.198
1.9118	-0.74	0.18	33.24	0.18
2.0233	-0.78	0.165	33.225	0.165
2.1415	-0.82	0.152	33.212	0.152
2.2667	-0.86	0.139	33.199	0.139
2.3992	-0.89	0.128	33.188	0.128
2.5397	-0.94	0.116	33.176	0.116
2.6885	-0.98	0.105	33.165	0.105
2.846	-1.02	0.096	33.156	0.096
3.0128	-1.05	0.089	33.149	0.089
3.1897	-1.09	0.081	33.141	0.081
3.377	-1.14	0.072	33.132	0.072
3.5753	-1.18	0.066	33.126	0.066
3.7855	-1.23	0.059	33.119	0.059
4.0082	-1.26	0.055	33.115	0.055



CHK'D: BWS 12/20/02

LAW
RESOURCES CREATING SOLUTIONS

LAW Engineering and Environmental Services, Inc.
5710 Oleander Drive
Suite 110
Wilmington, NC 28403

JOB NO. 30770-2-5400 SHEET 1 OF 2
PHASE _____ TASK _____
JOB NAME NORTH ANNA ESP PROJECT
BY BWJ DATE 12/18/02
CHECKED BY [illegible] DATE 12/20/02

SPREADSHEET VERIFICATION

WELL: OW-841 (SLUG OUT)
TEST DATE: 12/13/02
TEST TYPE: RECOVERY (SLUG OUT)

CONDUCTED BY: GRIMES & HOWE
ENTERED/DATE: 12/15/02

DATA COLLECTED USING HERMIT 3000

HAND CALC'S TO VERIFY SPREAD SHEET FORMULAS

SPREAD SHEET USES BOWER & RICE METHOD

L_e/r_w VALUES FOR A, B & C OBTAINED FROM SPREAD SHEET CALC'S

WELL DATA
SWL = 2.45' (BTOC)
WD = 35.80' (BTOC)
WD = 34.30' (BGS)
DTSP = 20.10' (BGS)
rc = 0.08' (2" WELL)
N = 0.30

RW = 0.33' (RADIUS OF 8" BOREHOLE)
RC (ADJ) = 0.08'

$$(1)\quad K = \frac{(r_c^2 \ln(R_e/r_w))}{2 L_e}\left(\frac{1}{t}\right)\left(\ln \frac{y_o}{y_t}\right)$$

$\ln(R_e/r_w) = 2.70$ (FROM SPREADSHEET)
CALC'S NEXT PAGE

L_e = 9.7' (LENG. OF WELL)
L_w = 33.35' (WD - SWL)
L_e/r_w = 29.39'
H = 50' (EST. AQUIFER THICKNESS)
t = 0.7377 - 0.198 (MINUTES) = 0.5397 (FROM COMPUTER GRAPH)

$$K = \left(\frac{(0.0064\,ft^2 \times 2.7)}{19.4'}\right)\frac{1}{0.54\,m}\left(\ln \frac{2.18}{0.829}\right) = 0.96686$$

y_o = 2.18
y_t = 0.829
FROM COMPUTER GRAPH / BEST FIT LINE

$$K = \frac{0.00089\,ft}{32.4\,sec}(0.96686)$$

K = 2.66×10^{-5} ft/sec × 30.48 cm/ft 2.66×10^{-5} ft/s ✓

K = 2.29 ft/d 2.29 ft/d ✓

K = 8.2E-04 cm/sec ✓ 8.2×10^{-4} cm/s ✓

LAW
RESOURCES CREATING SOLUTIONS

LAW Engineering and Environmental Services, Inc.
5710 Oleander Drive
Suite 110
Wilmington, NC 28403

JOB NO. 30770-2-5400 SHEET 2 OF 2
PHASE _____ TASK _____
JOB NAME NORTH ANNA ESP PROJECT
BY BWJ DATE 12/18/02
CHECKED BY KP DATE 12/20/02

SPREADSHEET VERFICATION CON'T

WELL: OW-841 (SLUGOUT)

$$\ln(R_e/r_w) = \left[\frac{1.1}{\ln(L_e/r_w)} + \frac{A + B\ \ln[(H - L_w) \div r_w]}{L_e/r_w}\right]^{-1}$$

COMPUTER
A = 2.49
B = 0.35

$$= \left[\frac{1.1}{3.38} + \frac{(2.49 + (0.35 \times 3.912))}{29.39'}\right]^{-1}$$

$$= [0.3254 + 0.1314]^{-1}$$

$$= 0.457^{-1}$$

$$= 2.189 \text{ OR } 2.2$$

COMPUTER $\ln(R_e/r_w) = 2.7$

DIFFERENCE IN CALC'S & COMPUTER

HAND GENERATED GRAPH

$Y_0 = 2.16' / \overset{+}{0.209}$

$Y_t = 0.552 / 1.0292$

0.82 min = 49.2 sec

BOWER & RICE CURVES (BY HAND)

A = 2.49
B = 0.45

$$\ln(R_e/r_w) = \left[\frac{1.1}{3.38} + \frac{(2.49 + (0.45 \times 3.912)}{29.39}\right]^{-1} = 0.47^{-1} = 2.128$$

2.127 ✓

$$K = \left(\frac{0.0064\ ft^2 \times 2.128}{19.4'}\right)\left(\frac{1}{49.2\ sec}\right) \ln\left(\frac{2.16}{0.552}\right)$$

$$K = (0.00070202')(0.02033/sec)(1.36431)$$

$$= 0.000019467\ ft/sec$$

0.00001947 ft/s ✓

$$= 1.682\ ft/d$$

x 30.48 cm/sec

$$= 5.93\ E\text{-}04\ cm/sec$$

0.0006 cm/sec ✓

Slug-out

MACTEC

MACTEC Engineering and Consulting
3301 Atlantic Avenue
Raleigh, North Carolina

Slug Test Data Sheet

MACTEC Job Name:	North Anna ESP	**MACTEC Job Number:**	30720-2-5400
Date:	12/13/07	**Time:** 0835	**Observation Well No.:** OW-841
Weather Conditions:	cloudy in upper 30's		
Method of Slug Withdrawl (circle one):	water, **mechanical**, or **pressure**	**Test Method:**	**Rising Head** or **Falling Head** (circle)
Diameter of Screen:	2 in.	**Diameter of Casing:**	2 in.
Total Well Depth:	35.30 ft below reference point	**Reference Point:**	Permanent mark on top of casing
Length of Screened Section:	9.7 ft	**Depth interval of screened portion:**	21.0 - 31.70 ft
Depth to Groundwater:	2.45 ft below reference point		

Groundwater Measurements Collected Prior to Slug Test

Depth to Groundwater	Date
~~35.80~~ 2.63	12/10/07
2.89	12/09/07

Comments/Remarks

USGS

Slug #2 → volume = 0.08 ft³

Transducer S/N = 6407

Minimit S/N = 45449

SPT transducer @ 20' below TOC

North Anna ESP Project
Hydraulic Conductivity (K) Calculation Worksheet
MACTEC Job Number: 30720-2-5400

Well: OW-841
Test Date: 12/13/2002
Test Type: Recovery (slug out)

Conducted by: Grimes and Howe
Entered/date: 12/15/02
Checked/date:

WELL DATA

SWL =	2.45	(ft BTOC)
WD =	35.80	(ft BTOC)
WD =	34.30	(ft BGS)
DTSP =	20.10	(ft BGS)
rc =	0.08	(ft)
n =	0.30	
rw =	0.33	(ft)
rc (adjusted) =	0.08	(ft)
Le =	9.7	(ft)
Lw =	33.35	(ft)
Le/rw =	29.39	
H =	50.00	(ft)

CALCULATION OF K

K = [(rc^2 ln(Re/rw))/2Le]*(1/t)ln(yo/yt)

yo =	2.180	(ft) from plot
yt =	0.829	(ft) from plot
t =	0.540	(minutes) from plot
ln(Re/rw) =	2.70	
K =	2.3E+00	(ft/day)
K =	8.2E-04	(cm/sec)

TEST DATA

Elapsed time (min)	Log y	y (ft)	WL (ft BTOC)	Data Logger results
0	#NUM!	0.000	2.45	0
0.011	#NUM!	0.000	2.45	0
0.022	-1.20	0.063	2.513	0.063
0.033	-0.06	0.877	3.327	0.877
0.044	0.14	1.385	3.835	1.385
0.055	0.01	1.024	3.474	1.024
0.066	0.11	1.299	3.749	1.299
0.077	0.23	1.716	4.166	1.716
0.088	0.27	1.870	4.32	1.87
0.099	0.35	2.259	4.709	2.259
0.11	0.36	2.269	4.719	2.269
0.121	0.36	2.280	4.73	2.28
0.132	0.36	2.267	4.717	2.267
0.143	0.35	2.262	4.712	2.262
0.154	0.35	2.249	4.699	2.249
0.165	0.35	2.236	4.686	2.236
0.176	0.35	2.223	4.673	2.223
0.187	0.34	2.206	4.656	2.206
0.198	0.34	2.180	4.63	2.18
0.209	0.33	2.160	4.61	2.16
0.22	0.33	2.128	4.578	2.128
0.231	0.32	2.086	4.536	2.086
0.2427	0.31	2.046	4.496	2.046
0.2552	0.30	1.995	4.445	1.995
0.2683	0.29	1.949	4.399	1.949
0.2823	0.28	1.911	4.361	1.911
0.2972	0.27	1.860	4.31	1.86
0.3128	0.26	1.804	4.254	1.804
0.3295	0.24	1.746	4.196	1.746
0.3472	0.23	1.687	4.137	1.687
0.3658	0.21	1.626	4.076	1.626
0.3857	0.19	1.561	4.011	1.561
0.4067	0.18	1.500	3.95	1.5
0.4288	0.16	1.437	3.887	1.437
0.4523	0.14	1.375	3.825	1.375
0.4772	0.12	1.312	3.762	1.312
0.5035	0.11	1.281	3.731	1.281
0.5315	0.07	1.185	3.635	1.185
0.5612	0.05	1.119	3.569	1.119
0.5925	0.02	1.058	3.508	1.058
0.6257	0.00	0.998	3.448	0.998
0.6608	-0.03	0.942	3.392	0.942
0.6982	-0.05	0.884	3.334	0.884
0.7377	-0.08	0.829	3.279	0.829
0.7795	-0.11	0.780	3.23	0.78
0.8238	-0.14	0.732	3.182	0.732
0.8708	-0.17	0.681	3.131	0.681
0.9207	-0.20	0.636	3.086	0.636
0.9733	-0.23	0.593	3.043	0.593
1.0292	-0.26	0.552	3.002	0.552
1.0883	-0.29	0.511	2.961	0.511

Calculation of ln(Re/rw)

Where: Lw < H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{A+Bln((H-Lw)/rw)}/(Le/rw)]^-1= 2.70

Where: Lw = H;

ln(Re/rw) = [{1.1/(ln(Lw/rw))}+{C/(Le/rw)}]^-1 = 3.23

Calculation of Coefficients

Value range for Le/rw from Table of Coefficients

Le/rw	A	B	C
25	2.4	0.31	1.9
30	2.5	0.35	2.1

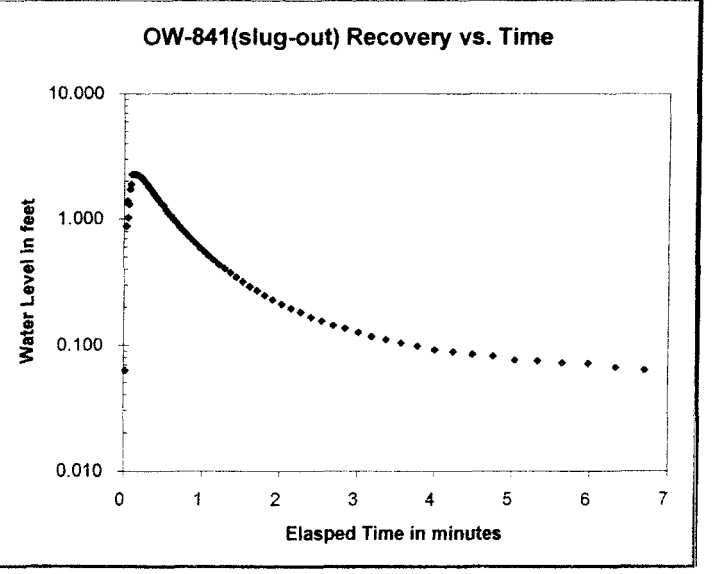
Interpolated values of A, B and C for Le/rw

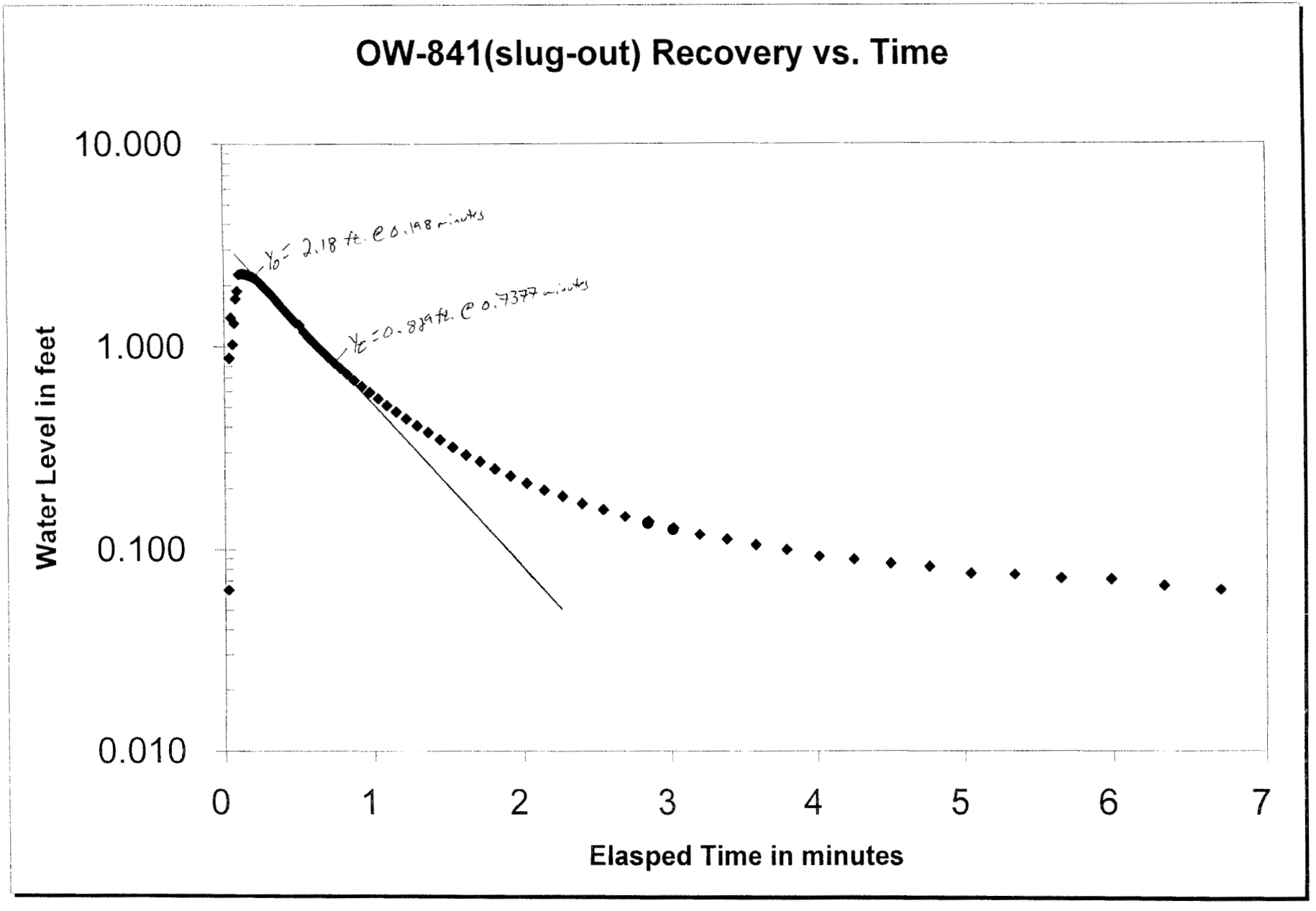
29.39	2.49	0.35	2.08

Coefficients Table

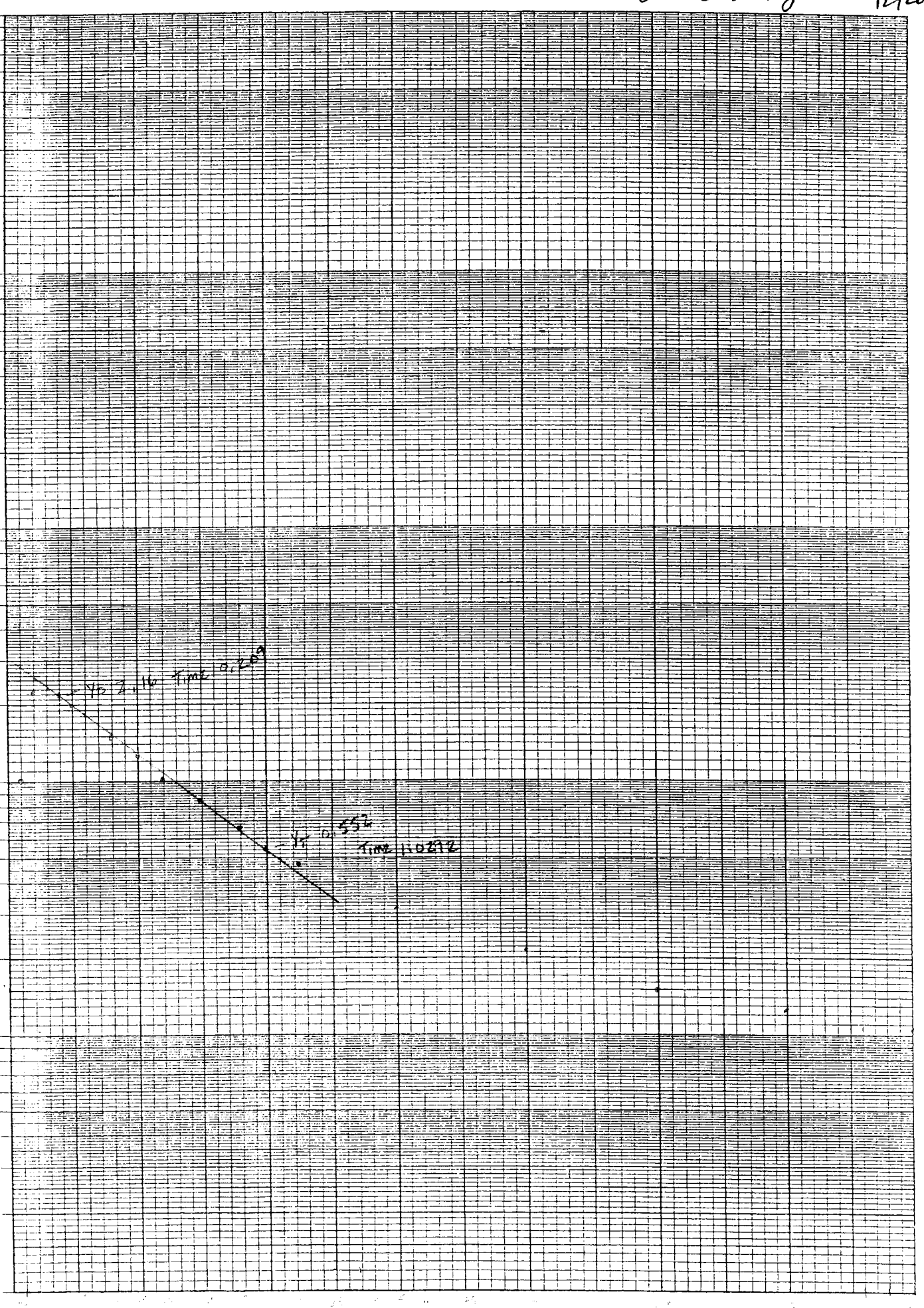
Le/rw	A	Le/rw	B	Le/rw	C
4	1.75	4	0.25	4	0.75
5	1.76	5	0.25	5	0.85
6	1.77	6	0.25	6	0.90
7	1.80	7	0.25	7	1.00
8	1.83	8	0.25	8	1.10
9	1.90	9	0.25	9	1.20
10	1.95	10	0.25	10	1.30
15	2.10	15	0.27	15	1.50
20	2.23	20	0.29	20	1.75
25	2.40	25	0.31	25	1.90
30	2.50	30	0.35	30	2.10
40	2.75	40	0.45	40	2.45
50	3.00	50	0.50	50	2.70
60	3.45	60	0.52	60	3.00
70	3.70	70	0.60	70	3.40
80	3.90	80	0.65	80	3.60
90	4.20	90	0.70	90	3.85
100	4.50	100	0.75	100	4.20
150	5.45	150	0.98	150	5.70
200	6.10	200	1.20	200	7.00
250	6.70	250	1.30	250	8.00
300	7.10	300	1.50	300	8.80
400	7.75	400	1.90	400	9.90
500	8.20	500	2.20	500	10.60
600	8.50	600	2.33	600	11.10
700	8.70	700	2.50	700	11.50
800	8.90	800	2.70	800	11.80
900	9.00	900	2.75	900	12.00
1000	9.20	1000	2.83	1000	12.40
1500	9.50	1500	3.18	1500	12.90

Reference: Bouwer(1989), Bouwer and Rice(1976)




OW-841(slug-out) Recovery vs. Time
10.000
1.000
0.100
0.010
Water Level in feet
0
1
2
3
4
5
6
7
Elasped Time in minutes
Yo= 2.18 ft. @ 0.198 minutes
Yt=0.829 ft. @ 0.7377 minutes

checked by: SCP 12/20/02



KEUFFEL & ESSER CO.

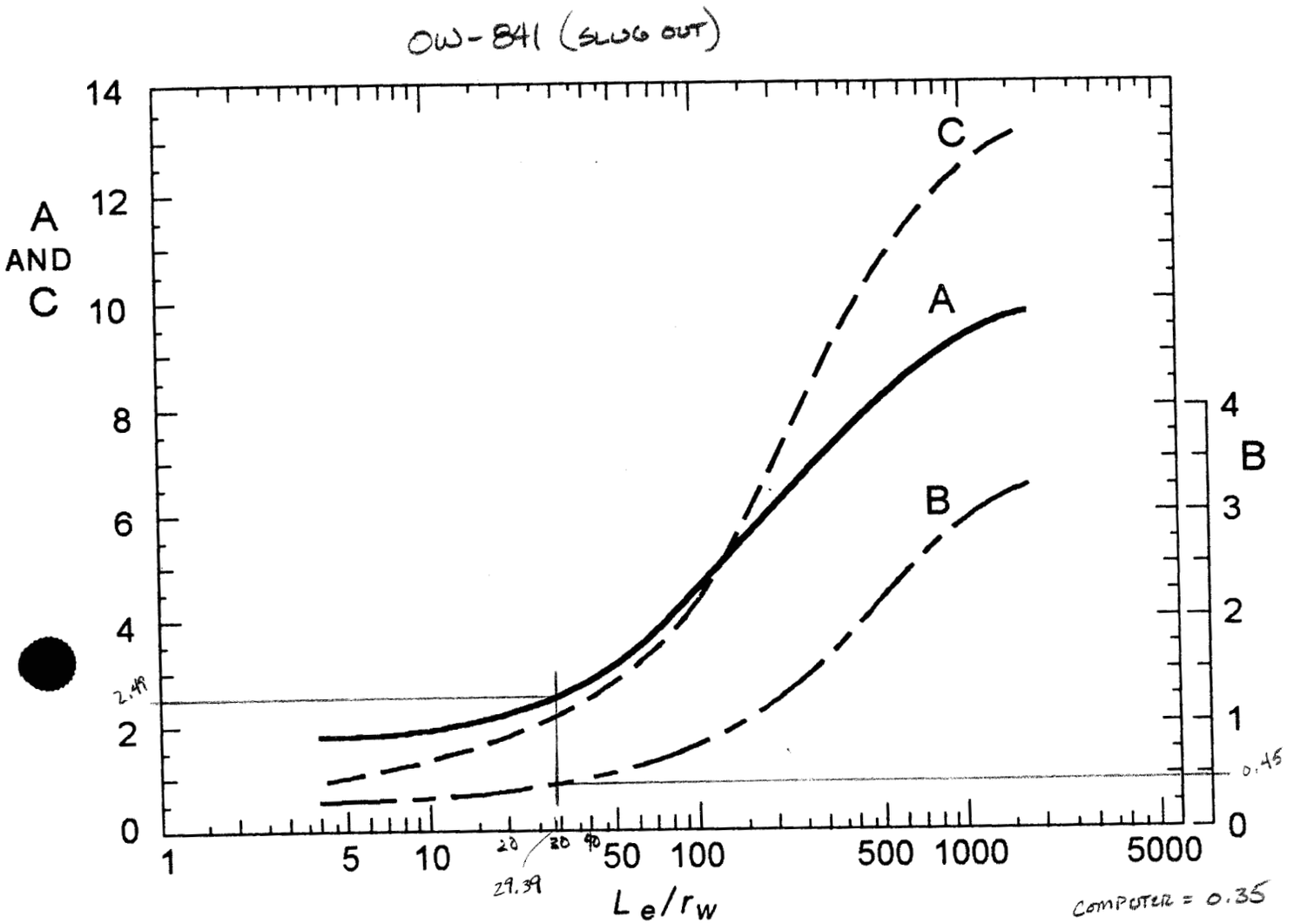


Figure 31.5 Dimensionless parameters A, B, and C as a function of L_e/r_w for calculation of $\ln(R_e/r_w)$ in the Bouwer and Rice slug test. (Bouwer, H., 1989: The Bouwer and Rice slug test. *Ground Water*, 27(3), p. 304–309. Reprinted by permission of Ground Water Publishing Company. Copyright 1989. All rights reserved.)

HYDRAULIC CONDUCTIVITY

Since time (t) and displacement (s) are the only variables in logarithmic equation), the plot of t versus s on a semi-log paper must show a straight line. However, the drawdown of the water table in the aquifer becomes more significant during ater part of the test, the basic assumption of equation (31.4) does not hold any more lata points start to deviate from the straight line.

The slope of the best-fitting straight line through field data is found as:

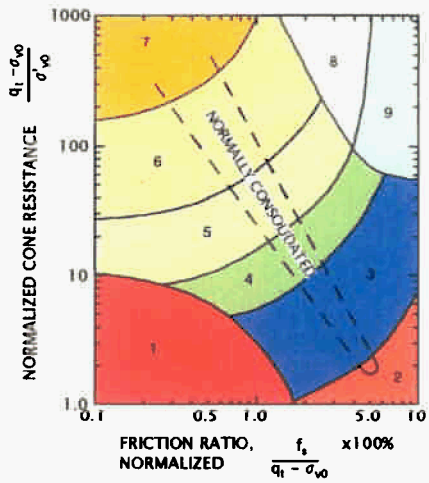
APPENDIX F
CONE PENTROMETER TEST RESULTS

CPT Soil Classification Legend

Zone	Q_t/N	Description
1	2	Sensitive, Fine Grained
2	1	Organic Soils-Peats
3	1.5	Clays-Clay to Silty Clay
4	2	Silt Mixtures-Clayey Silt to Silty Clay
5	3	Sand Mixtures-Silty Sand to Sandy Silt
6	4.5	Sands-Clean Sand to Silty Sand
7	6	Gravelly Sand to Sand
8	1	Very Stiff Sand to Clayey Sand *
9	2	Very Stiff, Fine Grained *

(*) *Heavily Overconsolidated or Cemented*

Normalized Friction Ratio Classification Chart



(Ref. Robertson, 1990)

Coefficient of Permeability (cm/s)

Zone	Description	Permeability
1	Sensitive Fines	10^{-5}
2	Organic Soils-Peats	10^{-5}
3	Clays	10^{-7}
4	Silt Mixtures	10^{-6}
5	Sand Mixtures	10^{-4}
6	Sands	10^{-2}
7	Gravelly Sands	10^{-1}
8	Very Stiff Sands	10^{-5}
9	Very Stiff Fines	10^{-6}

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The classification profiles can be very detailed due to the high spatial resolution afforded by collecting one sample every 2 cm (0.8 in) for CPT profiles. Frequently significant variability in soil types over small changes in elevation can be observed in the profiles. To provide a simplified soil stratigraphy for comparison to standard boring logs, a layering and generalized classification system was implemented. Layer thicknesses are determined based on the variability of the SBT profile. The layer sequence begins at the ground surface and layer thicknesses are determined based upon changes in the standard deviation of the SBT number. Whenever an additional 6-inch increment deviates from the previous increment, a new layer is started, otherwise, this material is added to the layer above and the next 6-inch section is evaluated. The soil type for the layer is determined by the mean value for the complete layer.

The lithology text seen on the plots is determined according to the following conditions:

Mean Value	Abbreviation	Description
1 – 2.25	Sen Clay	Sensitive Clay
>2.25 – 2.75	Soft Clay	Soft Clay
>2.75 – 3.25	Clay	Clay
>3.25 – 3.75	Si Clay	Silty Clay
>3.75 – 4.25	Cl Silt	Clayey Silt
>4.25 – 4.75	Sa Fine Gr	Sand – Fine Grained
>4.75 – 5.75	Sand Mix	Sand Mix
>5.75 – 6.75	Sand	Sand
>6.75 – 7.5	Gr Sand	Gravelly Sand
>7.5 – 8.5	OC	Over Consolidated
>8.5 – 9	OC-Clay	Over Consolidated-Clay

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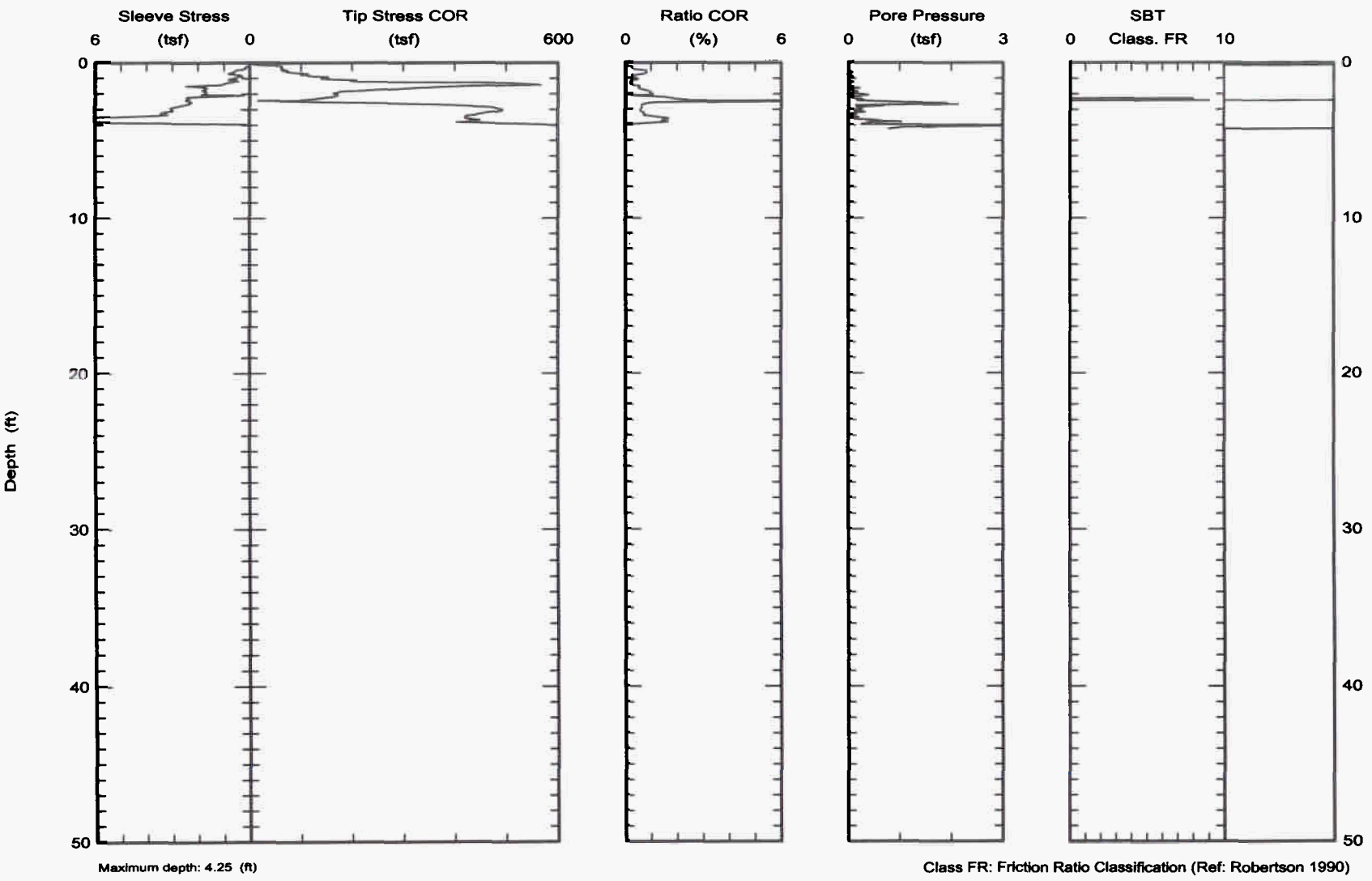
Northing: 3909965
Easting: 11686353
Elevation: 271

Date: 11/Dec/2002
Test ID: CPT-821
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Maximum depth: 4.25 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

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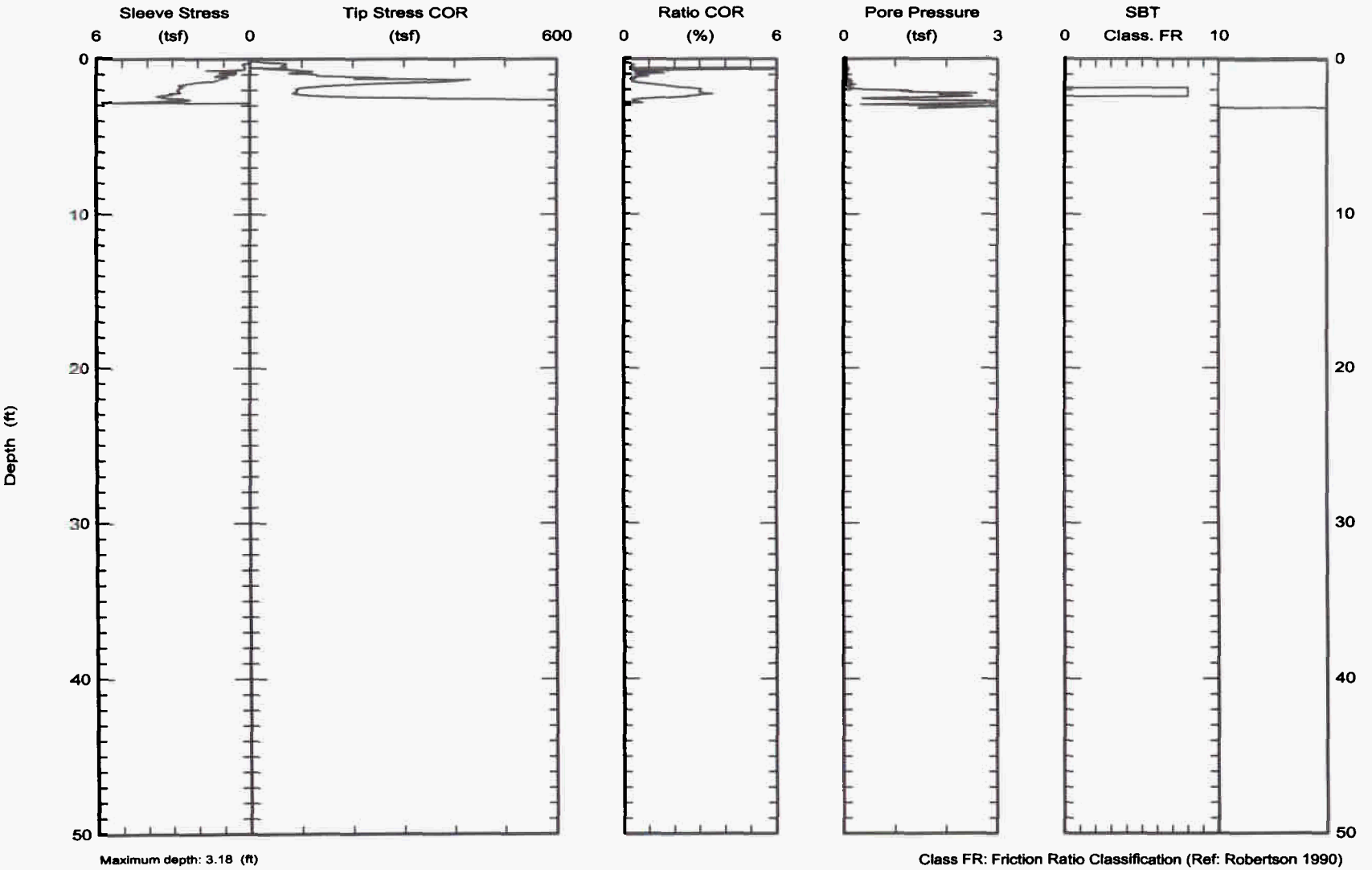
Northing: 3909957
Easting: 11686348
Elevation: 271

Date: 11/Dec/2002
Test ID: CPT-821A
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Maximum depth: 3.18 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

Test ID: CPT-821A
File: 311D0202C.ECP

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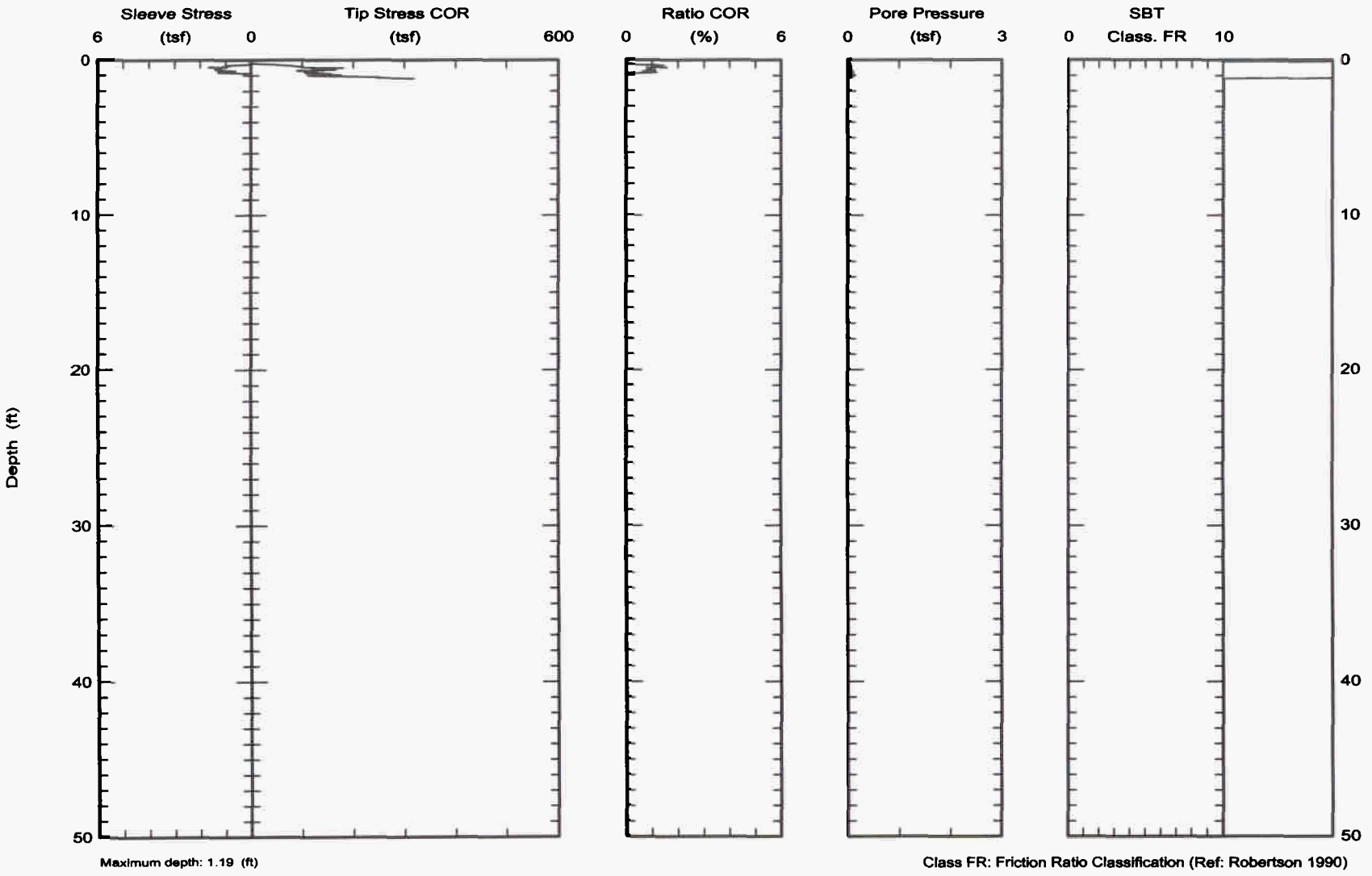
Northing: 3909966
Easting: 11686367
Elevation: 271

Date: 11/Dec/2002
Test ID: CPT-821B
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Test ID: CPT-821B
File: 311D0203C.ECP

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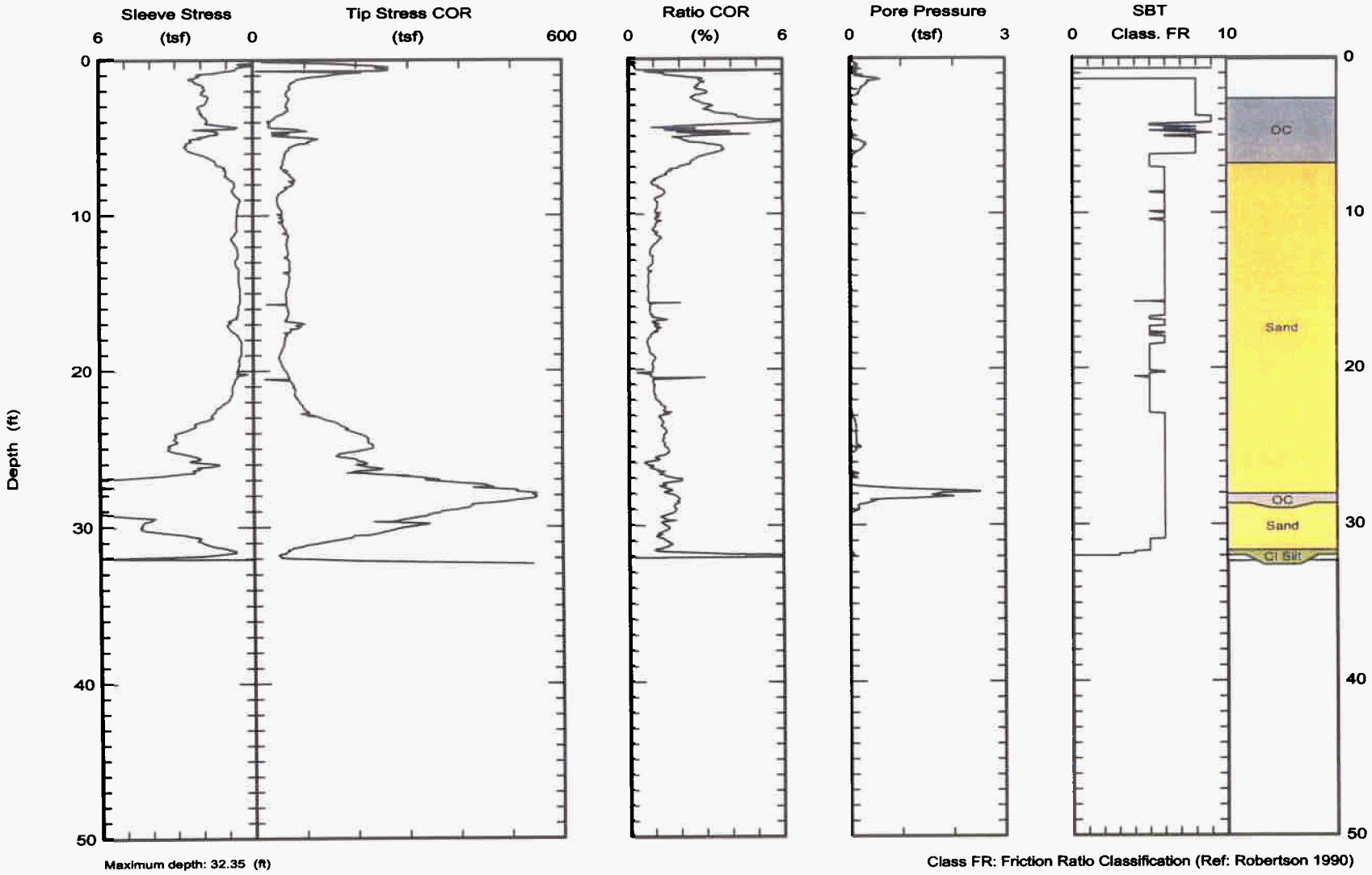
Email: cpt@ned.ara.com
http://www.ara.com

Northing: 3909850.0235
Easting: 11685756.1761
Elevation: 296.3

Date: 11/Dec/2002
Test ID: CPT-823
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Maximum depth: 32.35 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

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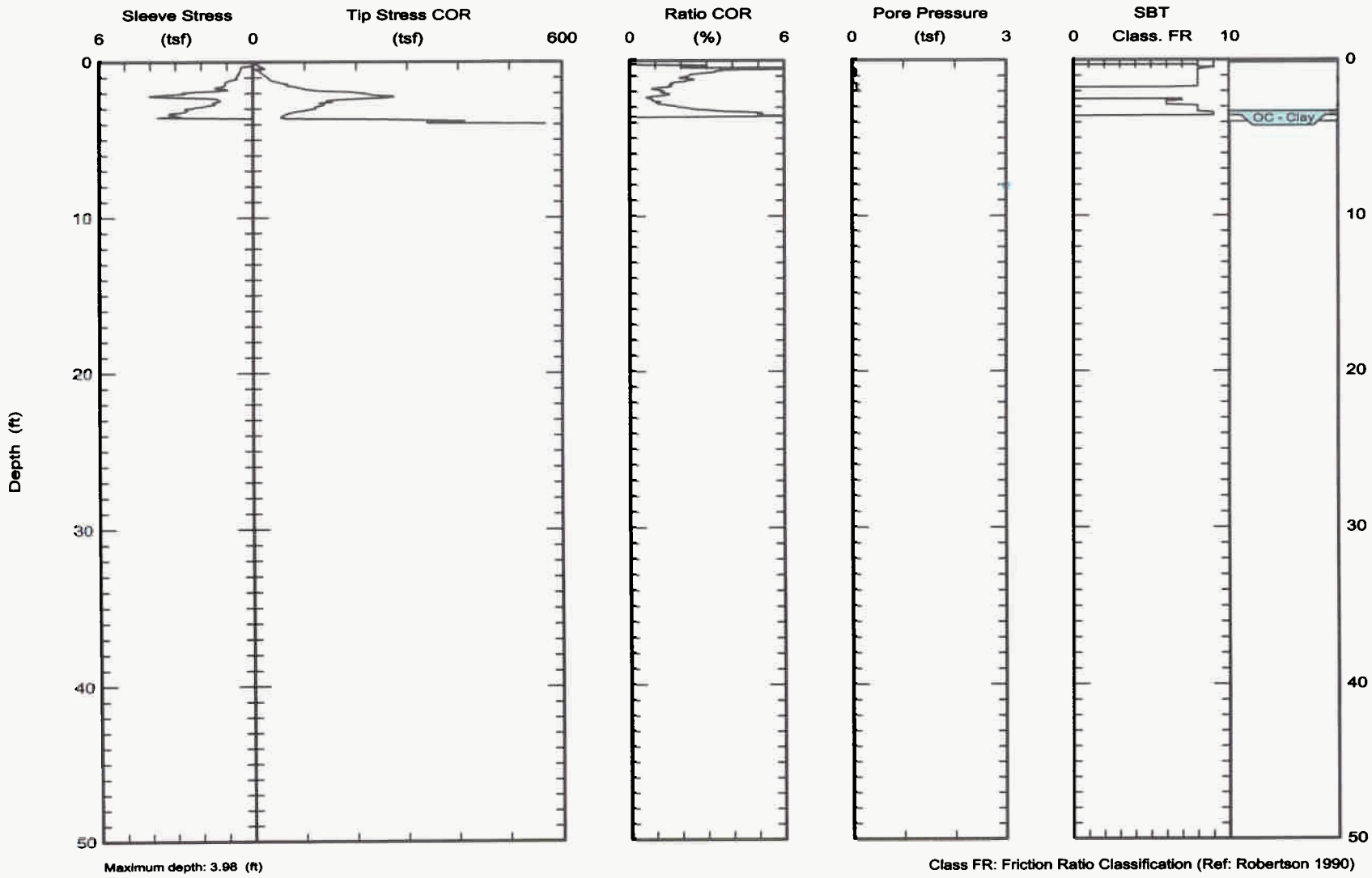
Email: cpt@ned.ara.com
http://www.ara.com

Northing: 3910054.2670
Easting: 11686009.5911
Elevation: 276.1

Date: 11/Dec/2002
Test ID: CPT-824
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



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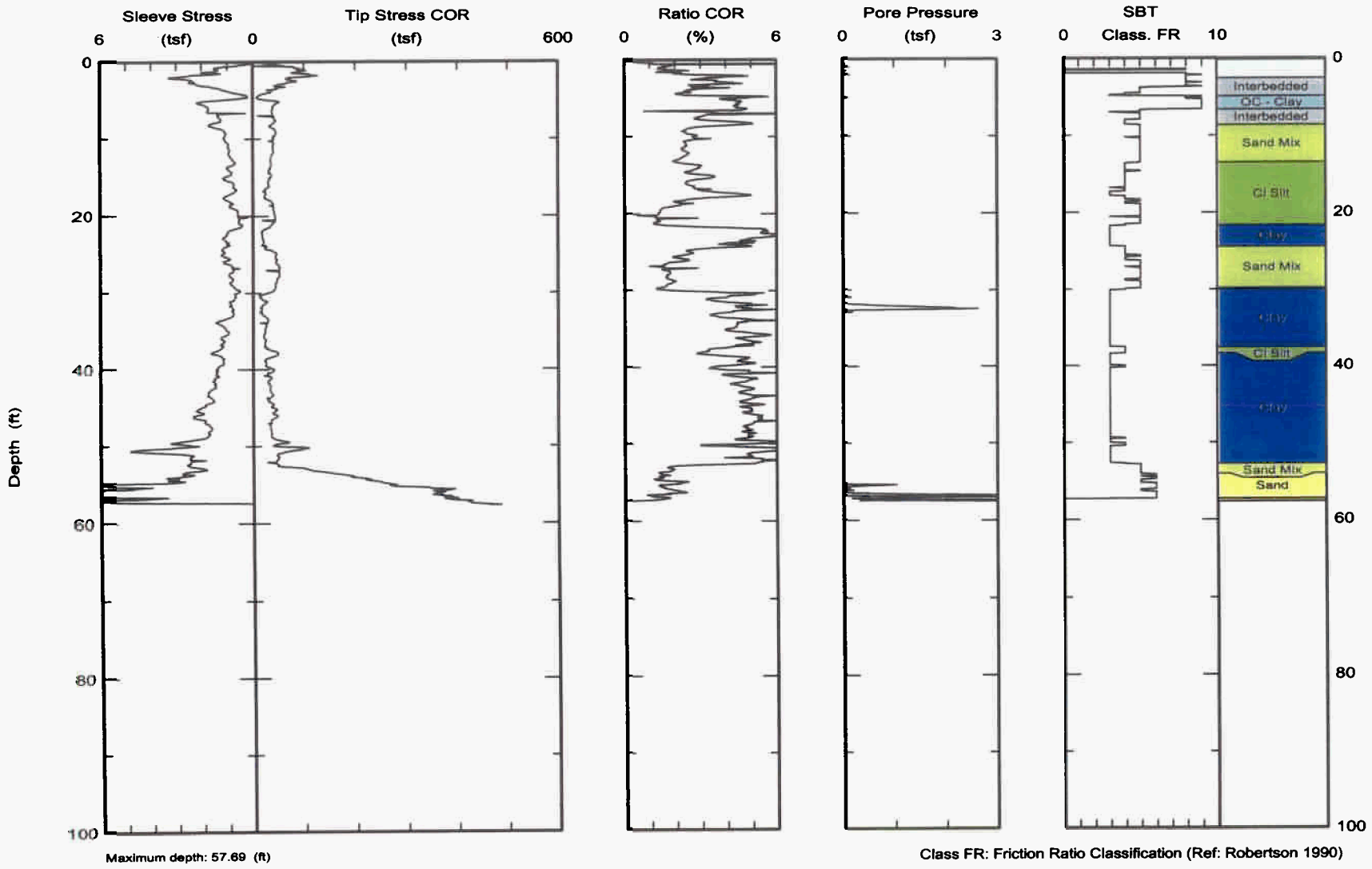
Email: cpt@ned.ara.com
http://www.ara.com

Northing: 3910688.2442
Easting: 11683569.4372
Elevation: 277.1

Date: 12/Dec/2002
Test ID: CPT-827
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Maximum depth: 57.69 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

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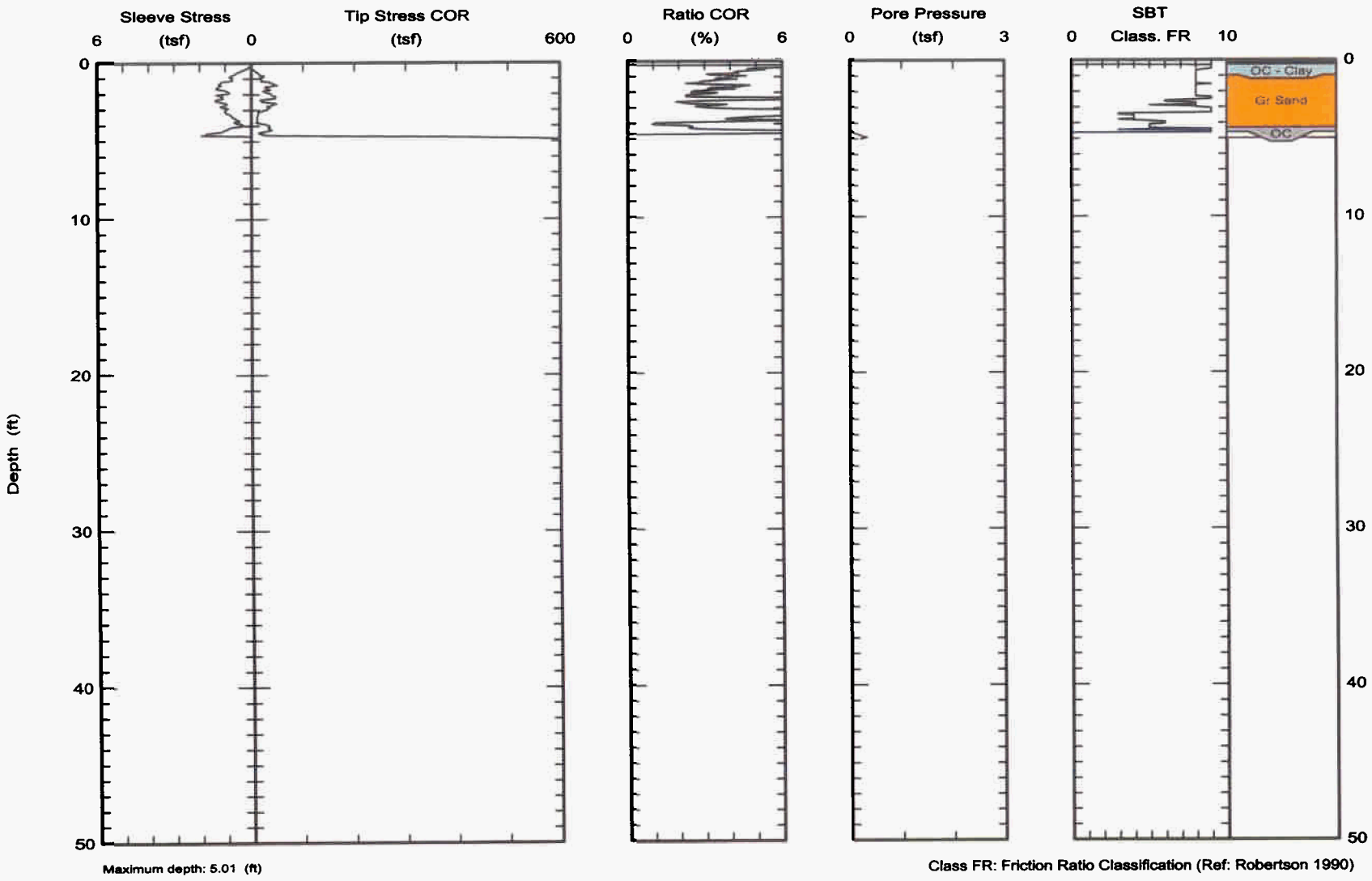
Northing: 3910652.8241
Easting: 11683066.3705
Elevation: 270.0

Date: 12/Dec/2002
Test ID: CPT-828
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Maximum depth: 5.01 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

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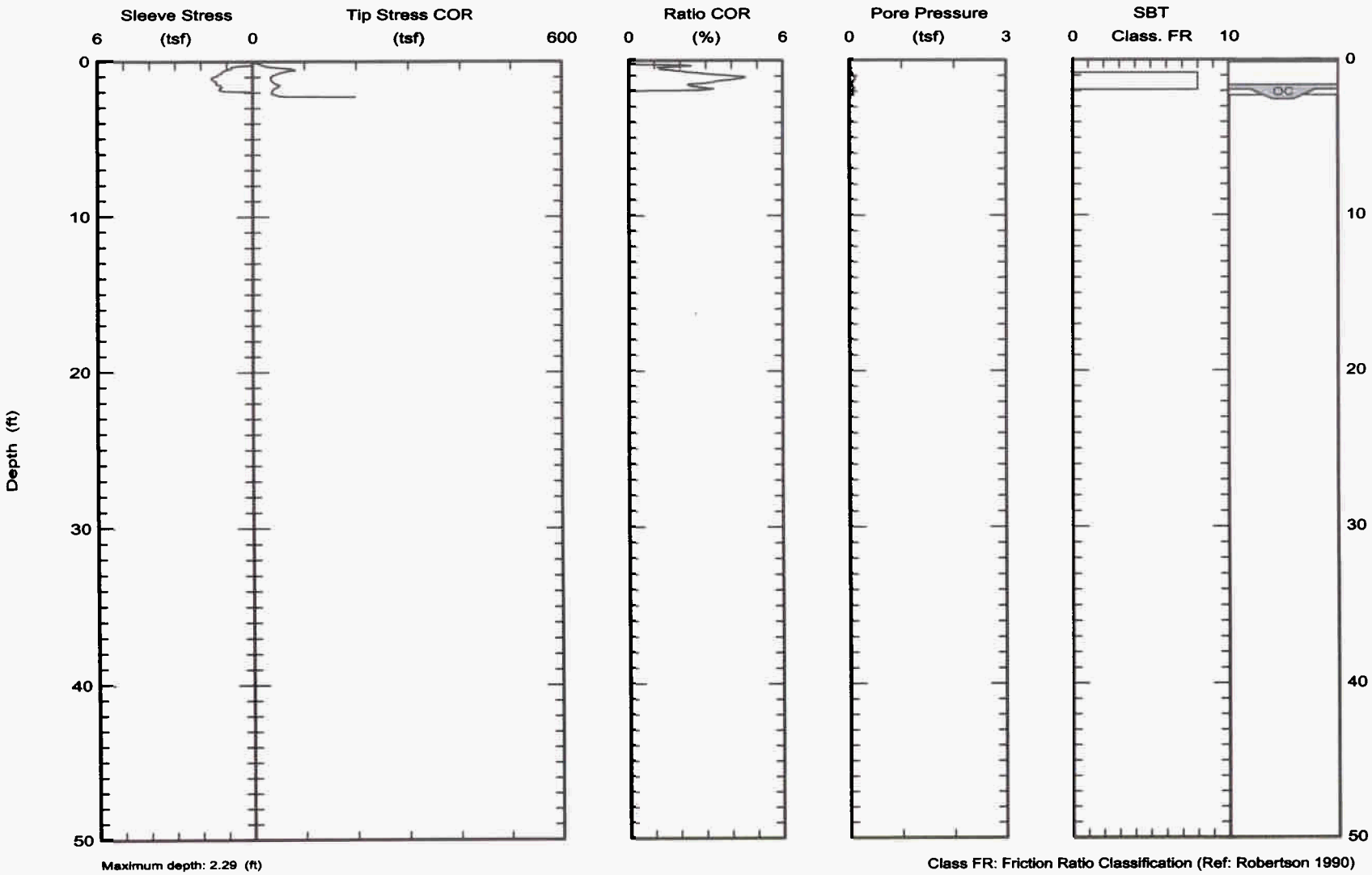
Northing: 3910652.8241
Easting: 11683066.3705
Elevation: 270.0

Date: 12/Dec/2002
Test ID: CPT-828
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Maximum depth: 2.29 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

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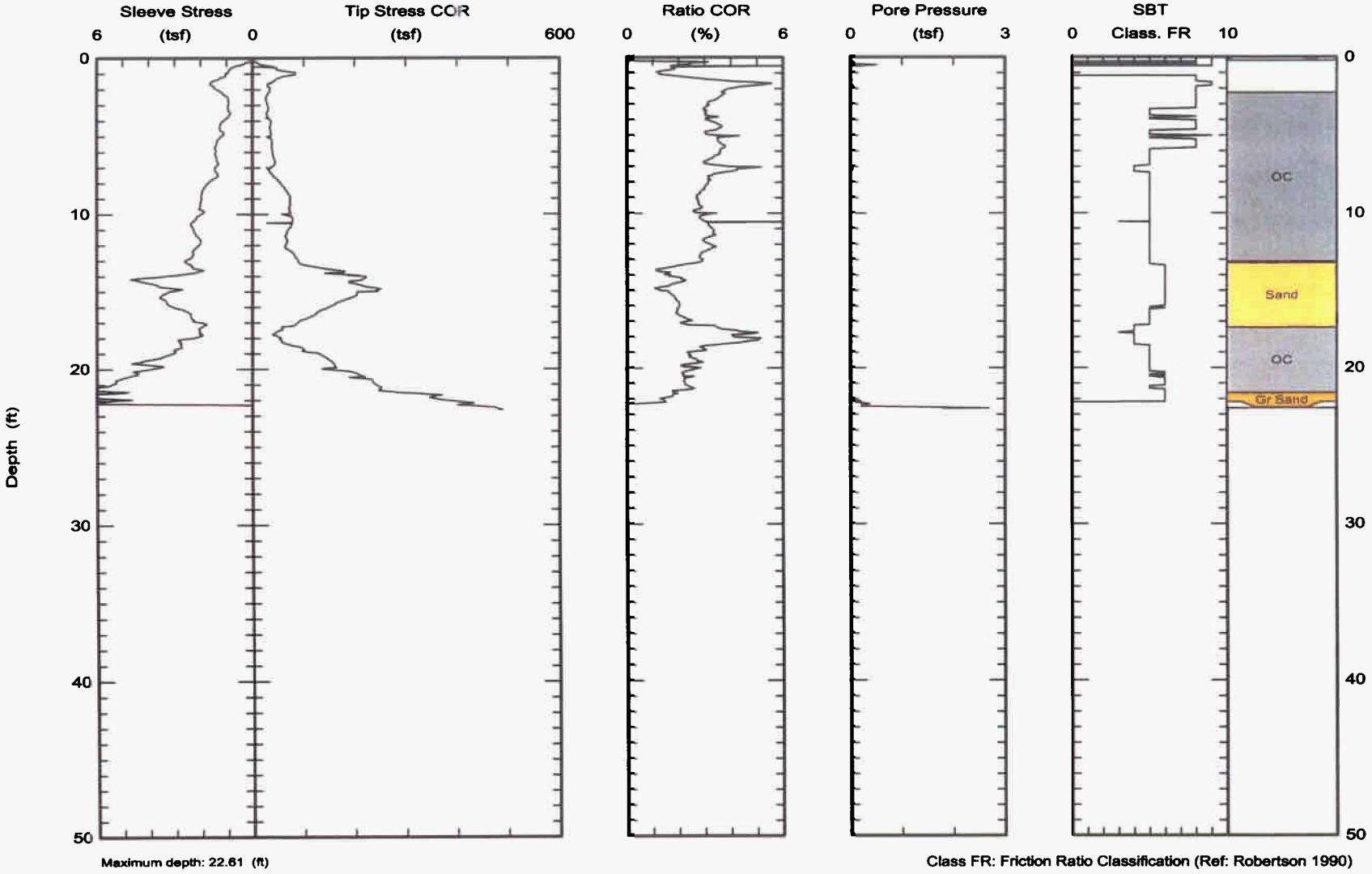
http://www.ara.com

Northing: 3910375.4066
Easting: 11686237.2013
Elevation: 271.1

Date: 12/Dec/2002
Test ID: CPT-822
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Maximum depth: 22.61 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

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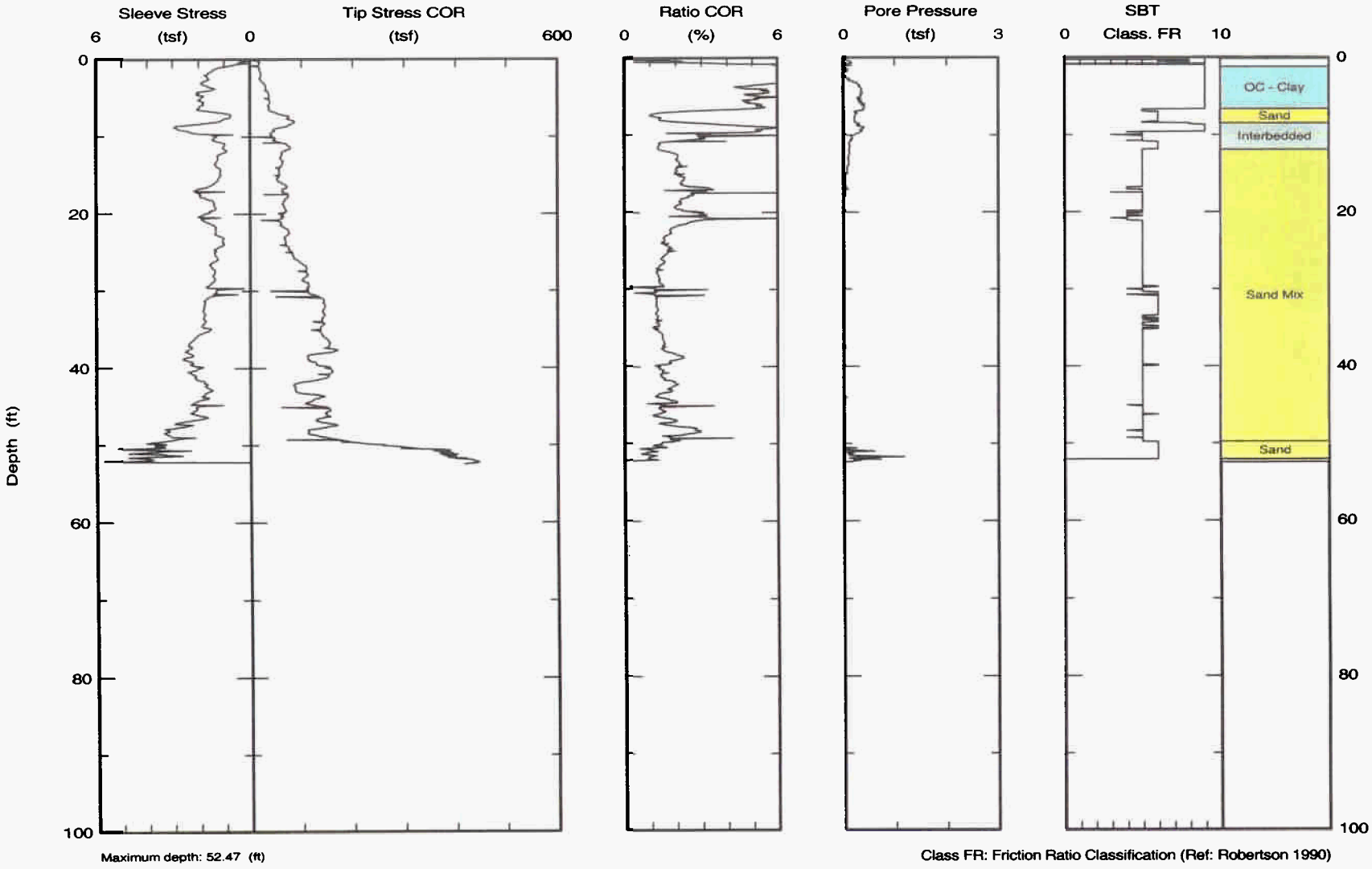
Northing: 3909477.9442
Easting: 11685267.2998
Elevation: 332.5

Date: 12/Dec/2002
Test ID: CPT-825
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Maximum depth: 52.47 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

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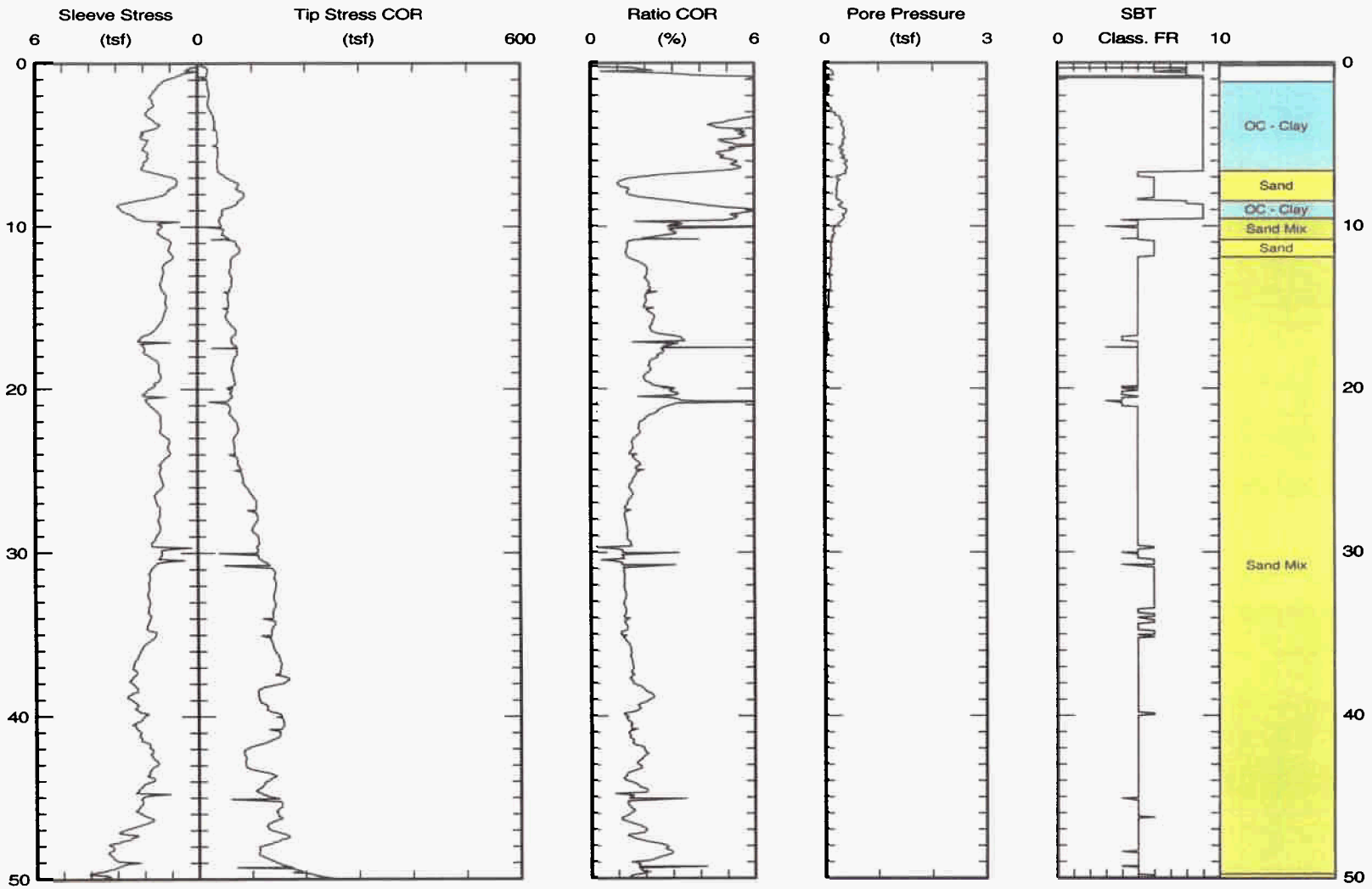
802-763-8348
Email: cpt@ned.ara.com
http://www.ara.com

Northing: 3909477.9442
Easting: 11685267.2998
Elevation: 332.5

Date: 12/Dec/2002
Test ID: CPT-825
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Maximum depth: 52.47 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

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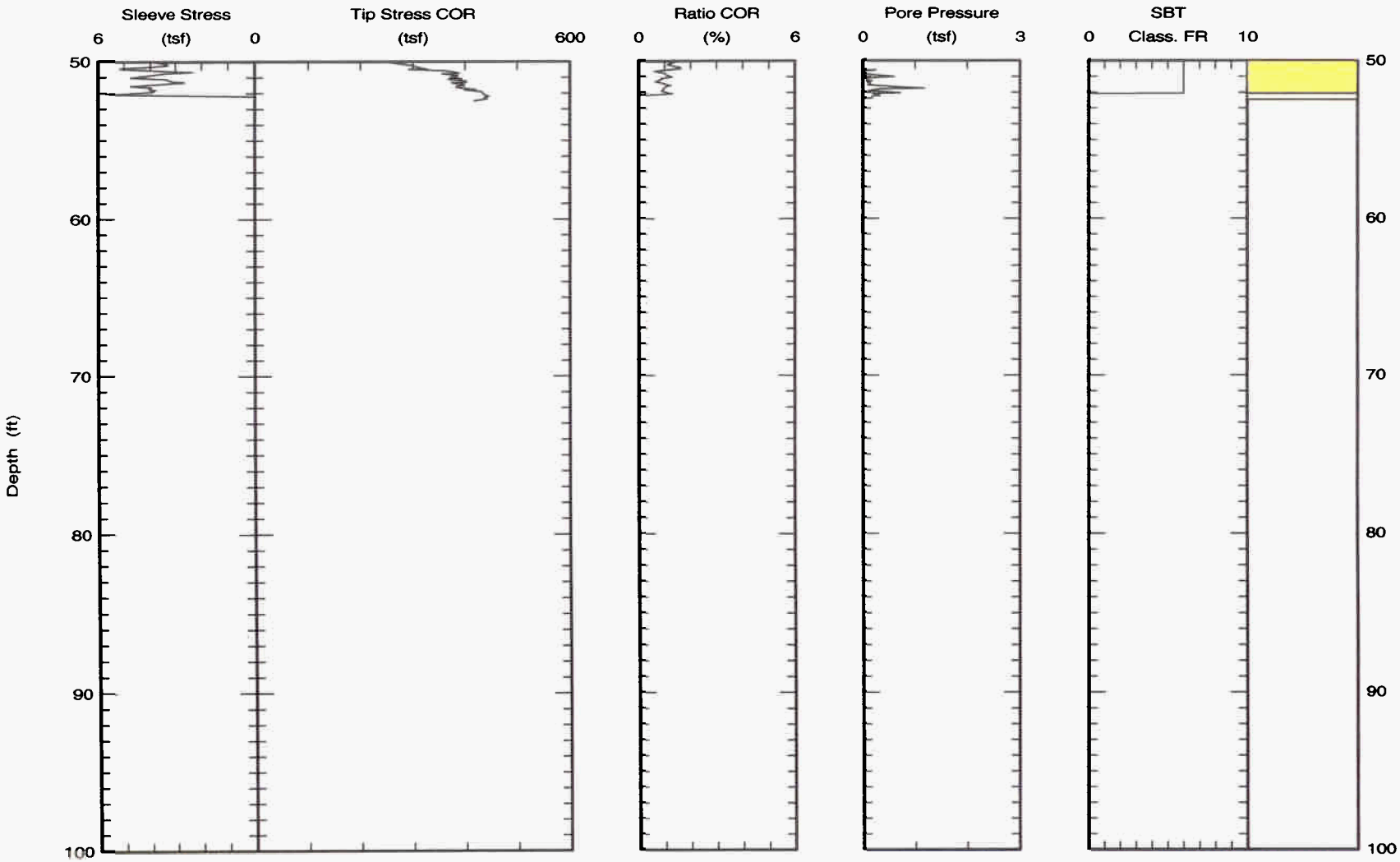
South Royalton, VT 05068
802-763-8348
Email: cpt@ned.ara.com
http://www.ara.com

Northing: 3909477.9442
Easting: 11685267.2998
Elevation: 332.5

Date: 12/Dec/2002
Test ID: CPT-825
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP



Maximum depth: 52.47 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

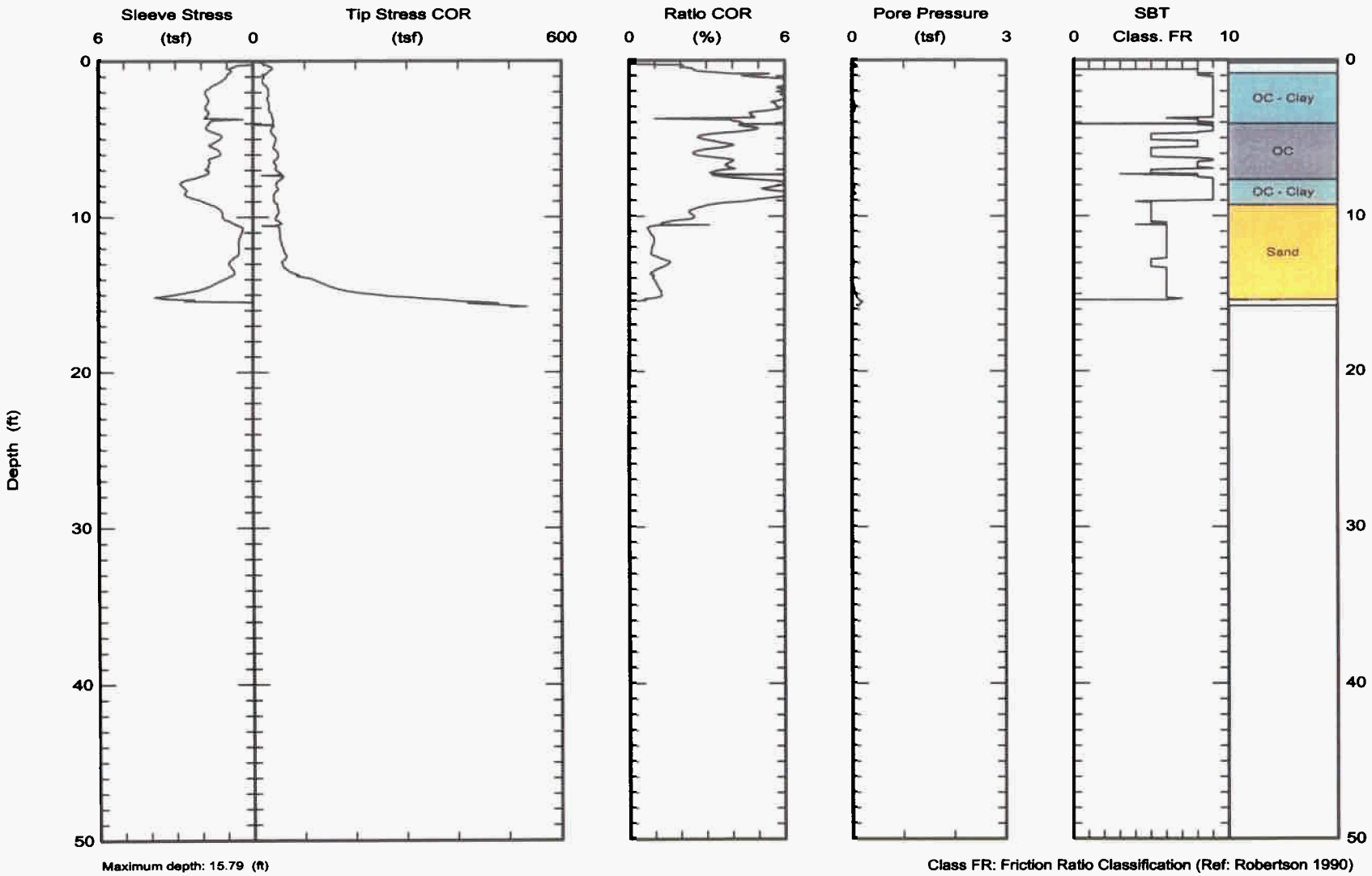
Test ID: CPT-825
File: 312D0207C.ECP

Applied Research Associates
South Royalton, VT 05068
802-763-8348
Email: cpt@ned.ara.com
http://www.ara.com

Northing: 3909848.9822
Easting: 11686000.3856
Elevation: 307.5

Date: 12/Dec/2002
Test ID: CPT-830
Project: 5737

Client: MACTEC
Site: NORTH ANNA ESP

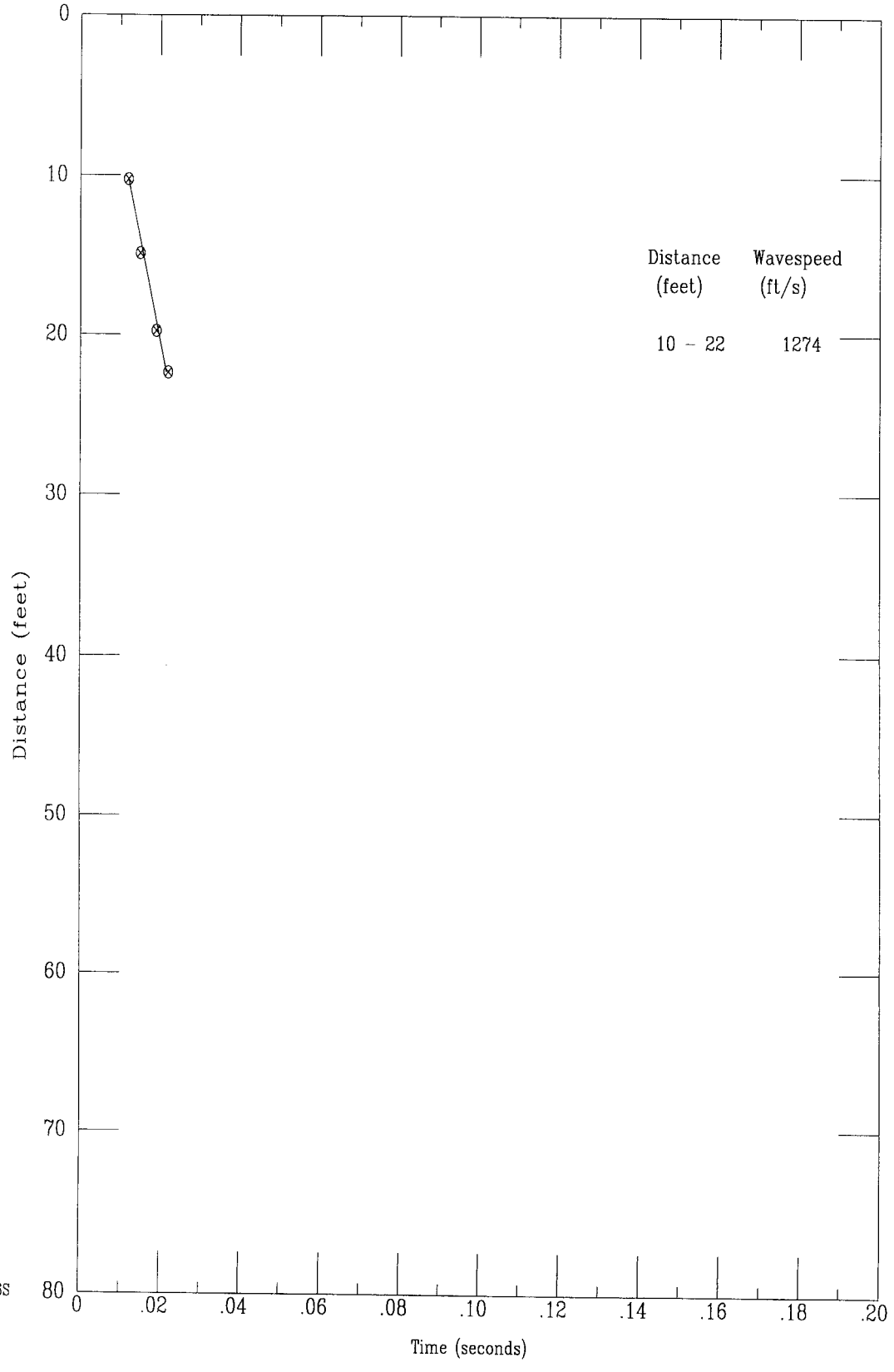


Maximum depth: 15.79 (ft)

Class FR: Friction Ratio Classification (Ref: Robertson 1990)

CPT-822 APPLIED RESEARCH ASSOCIATES, INC. 12/Dec/2002

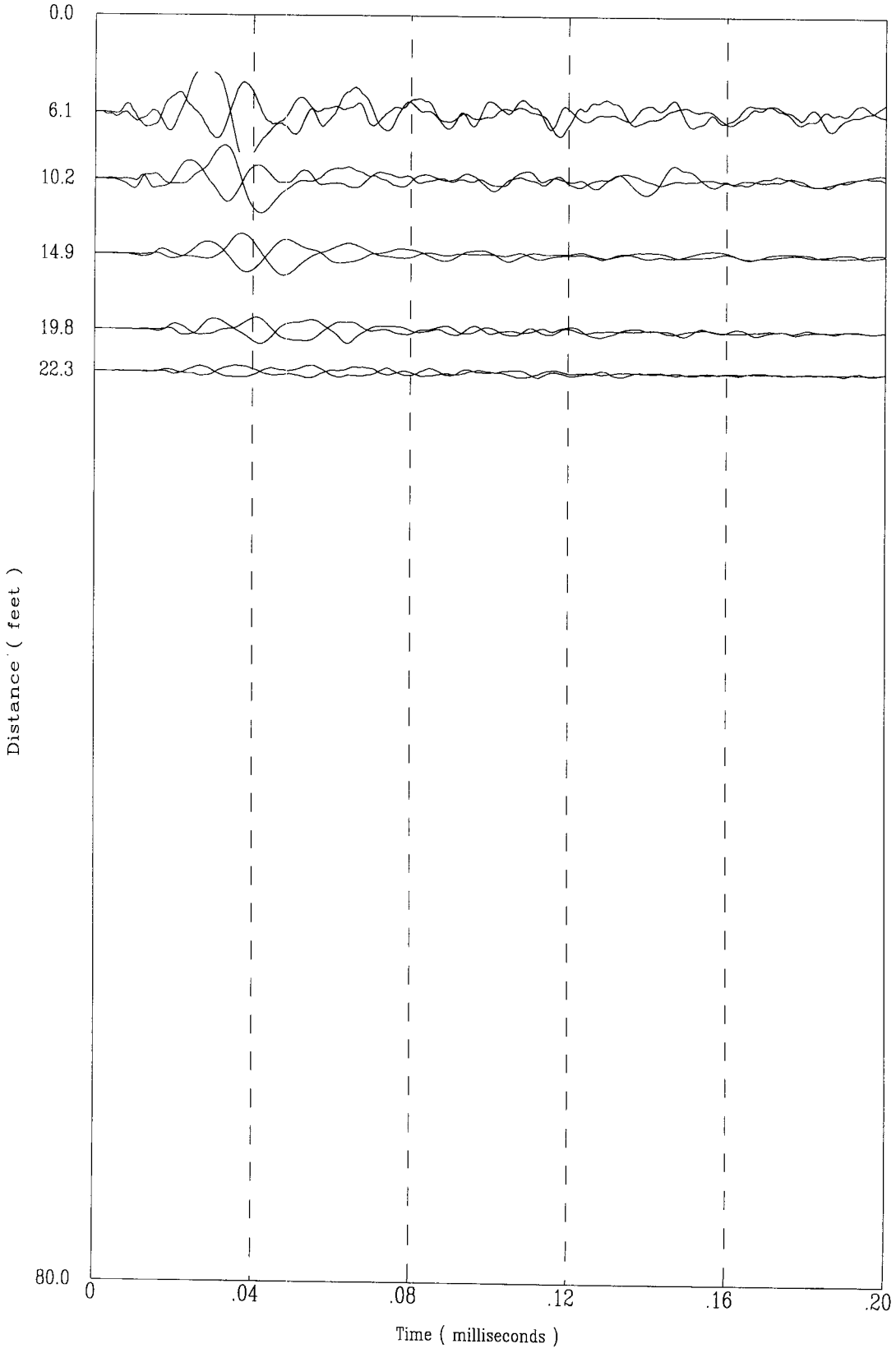
Shear Wave Time of Arrival



File 312d206S

Applied Research Associates
CPT-822

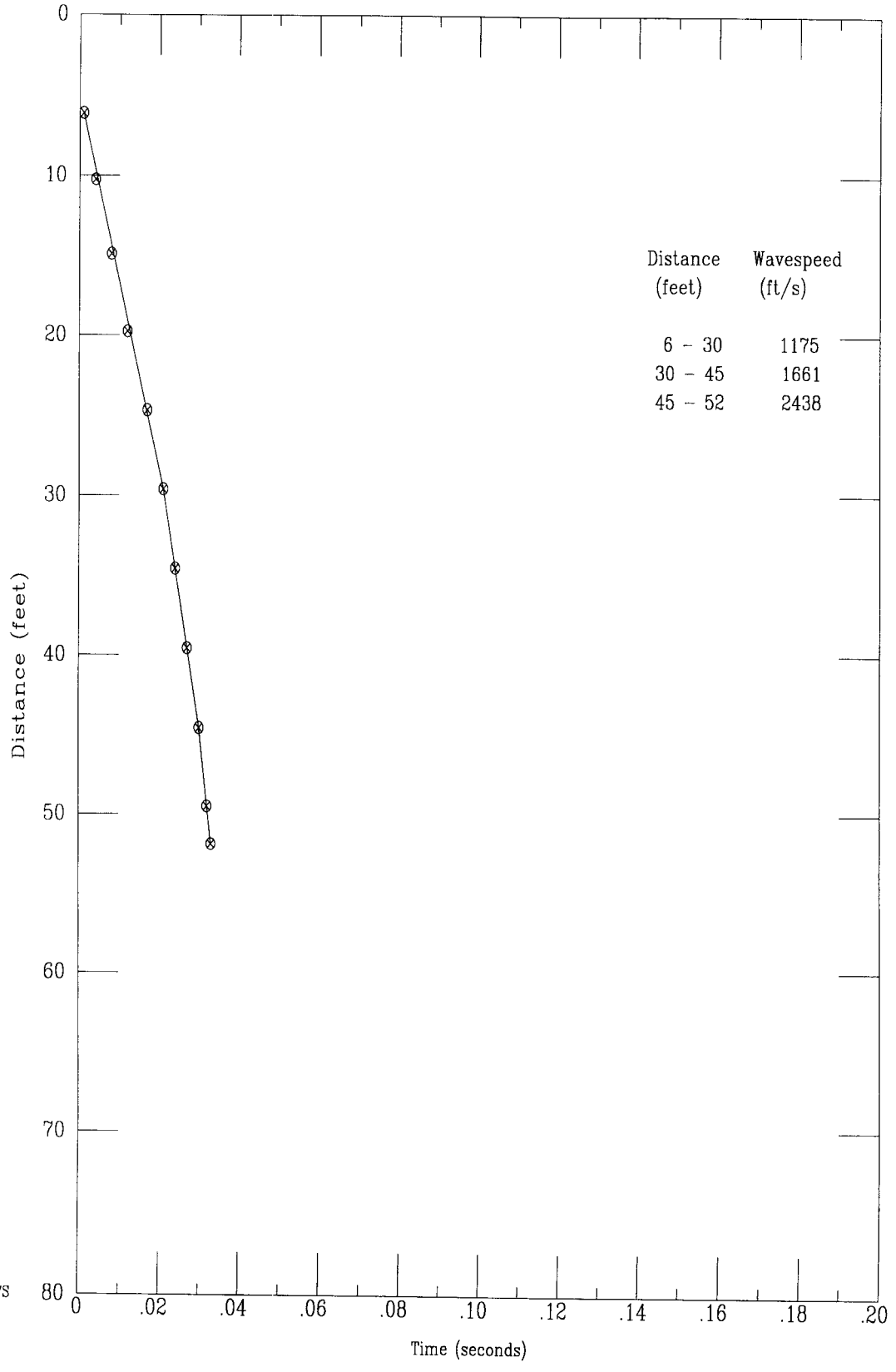
S Wave
12/Dec/2002



File 312d206S

CPT-825 APPLIED RESEARCH ASSOCIATES, INC. 12/12/02

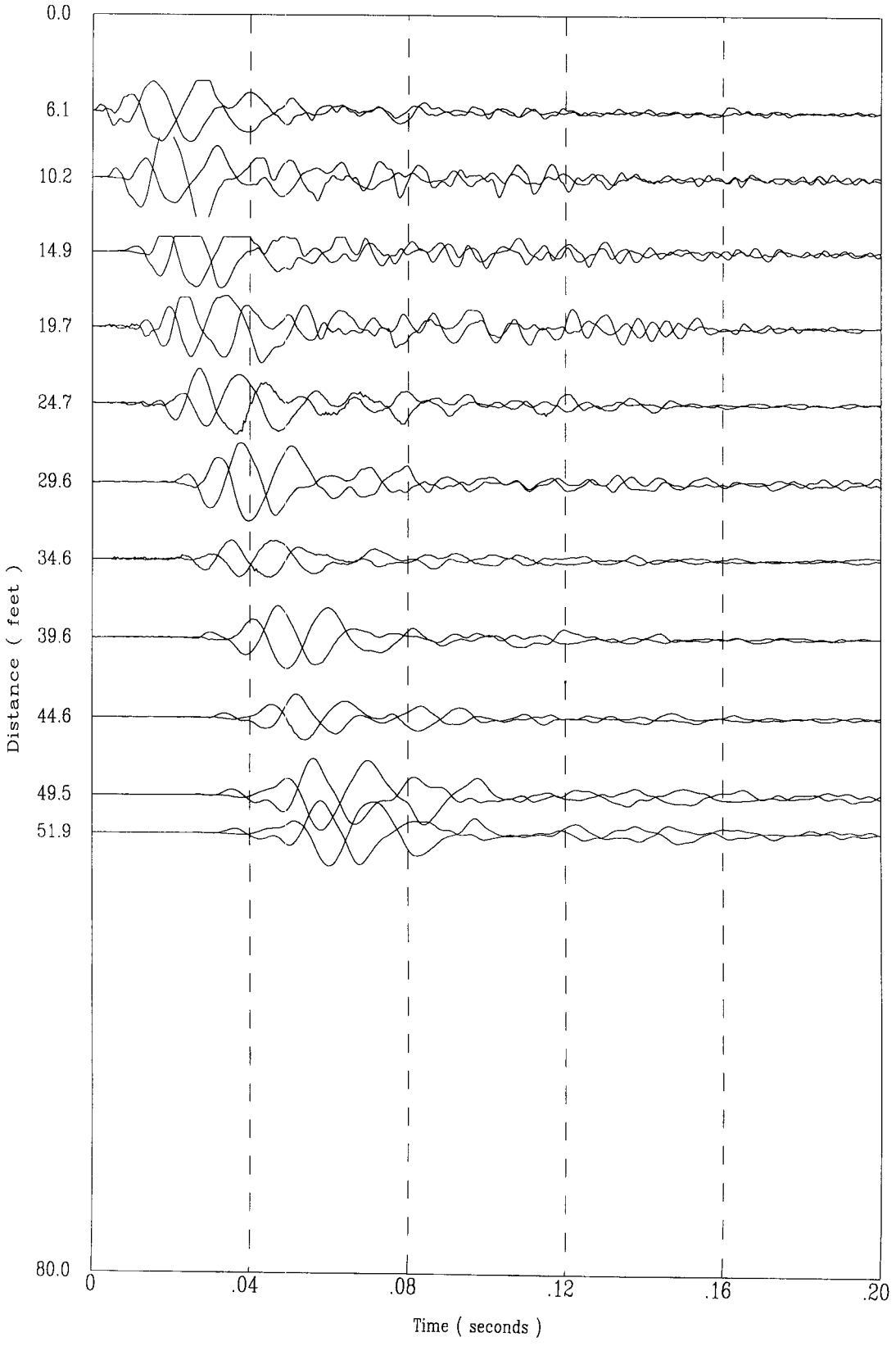
Shear Wave Time of Arrival



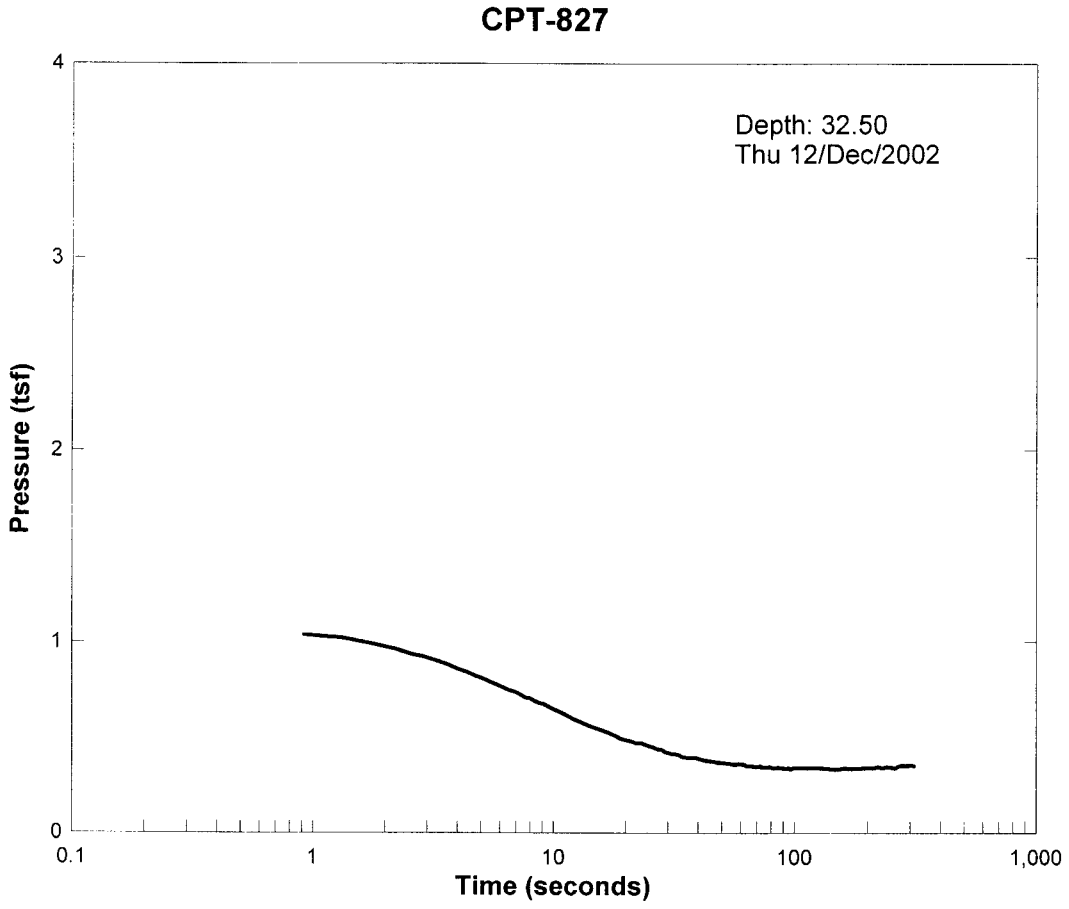
File 312D207S

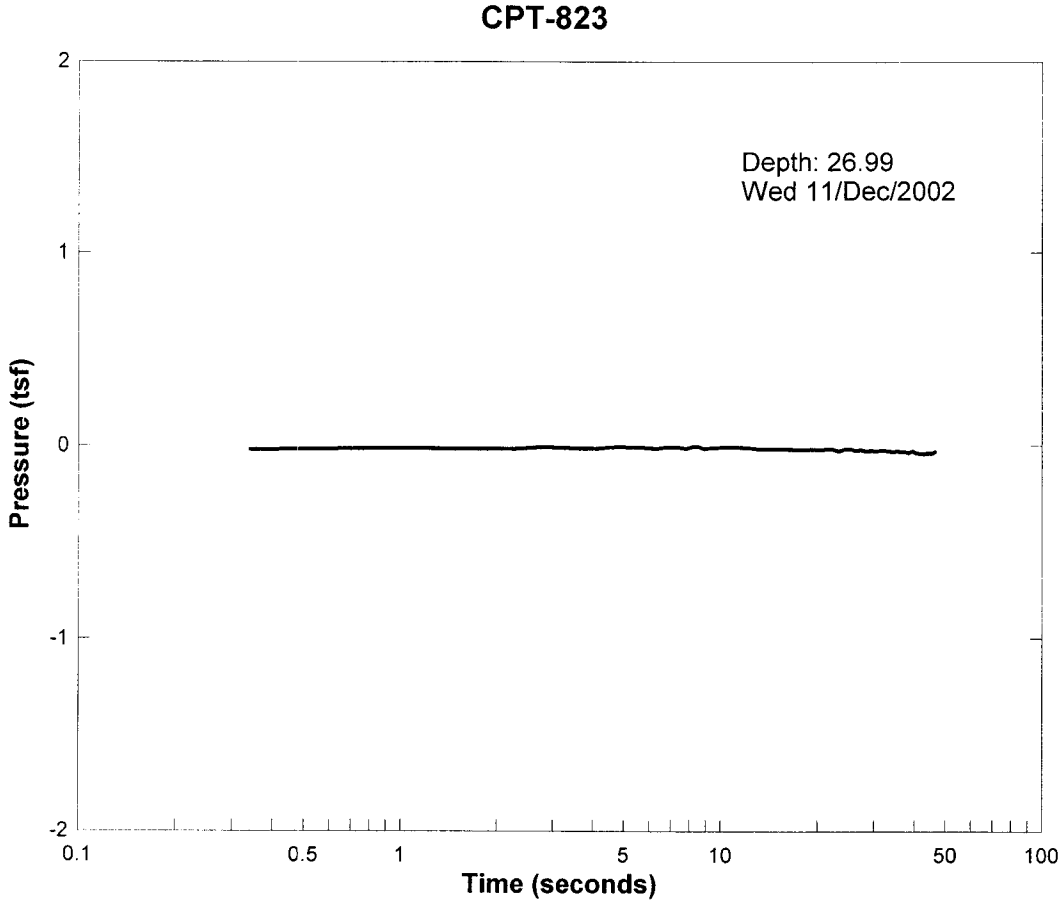
Applied Research Associates
CPT-825

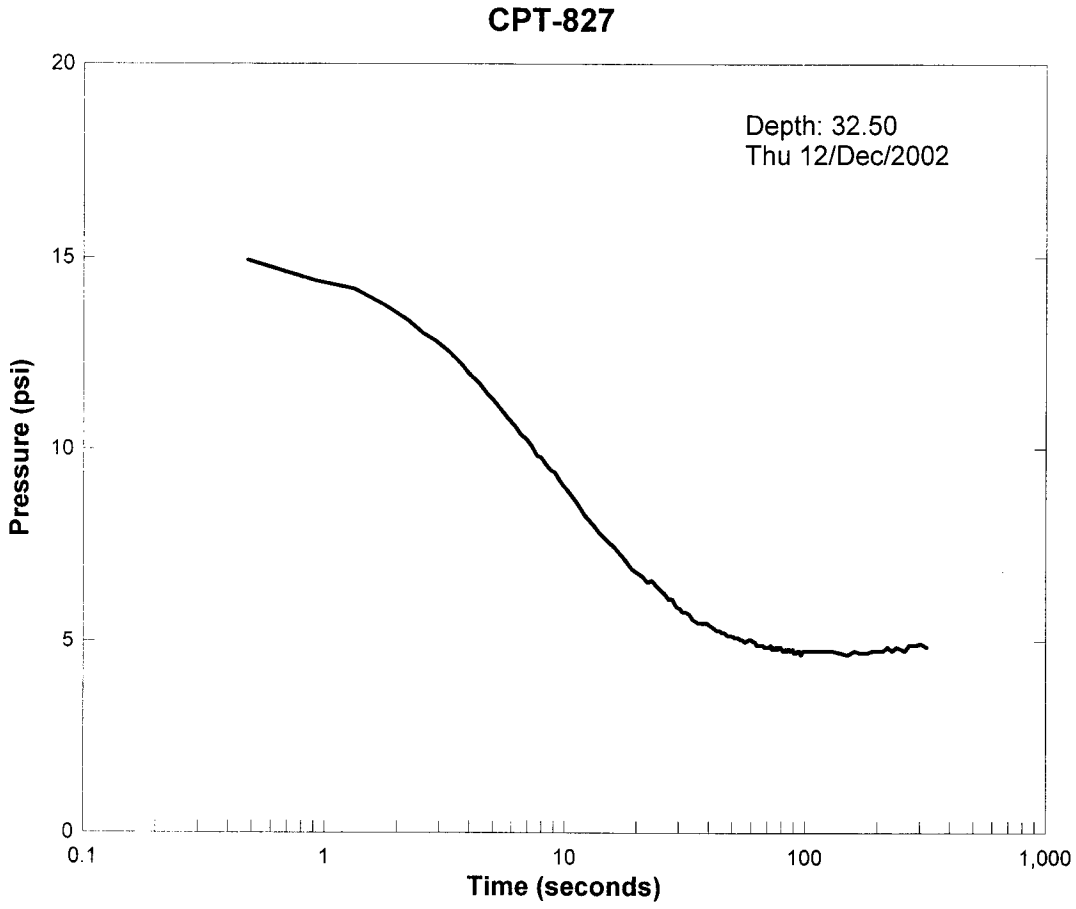
S Wave
12/Dec/2002

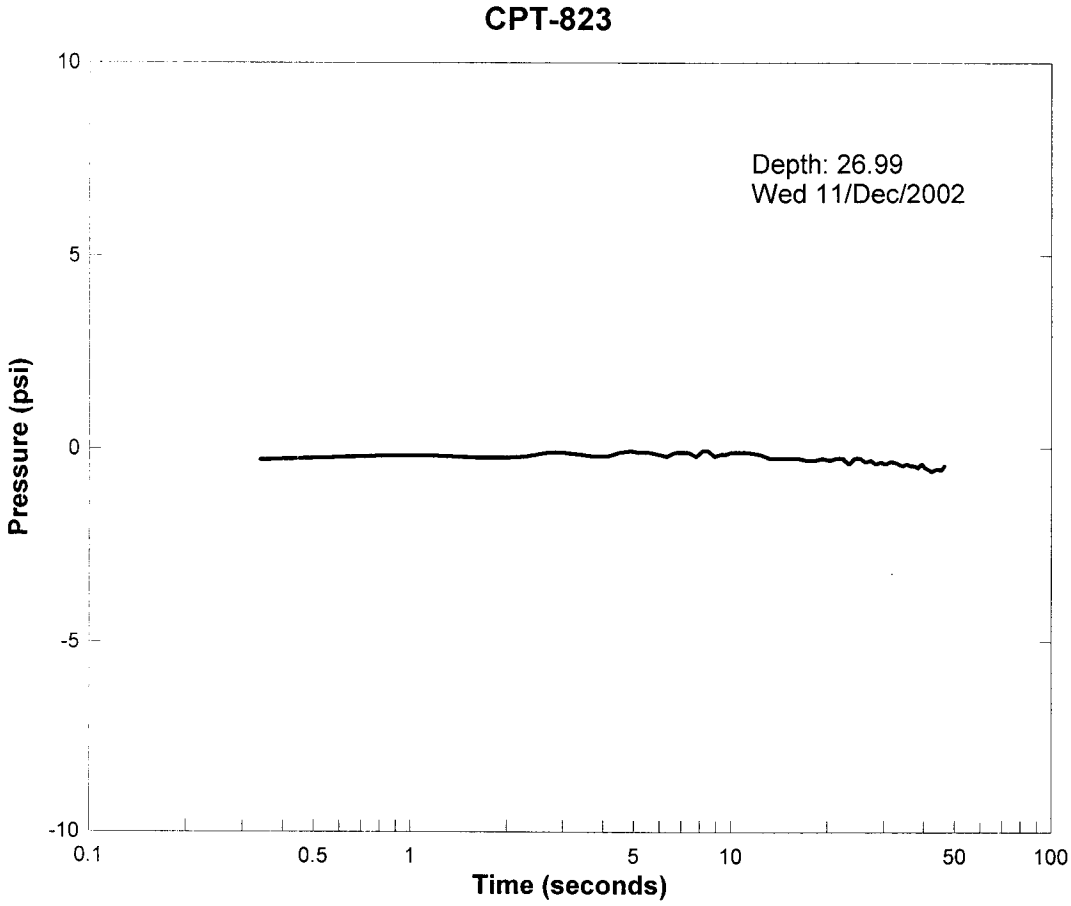


File 312d207S

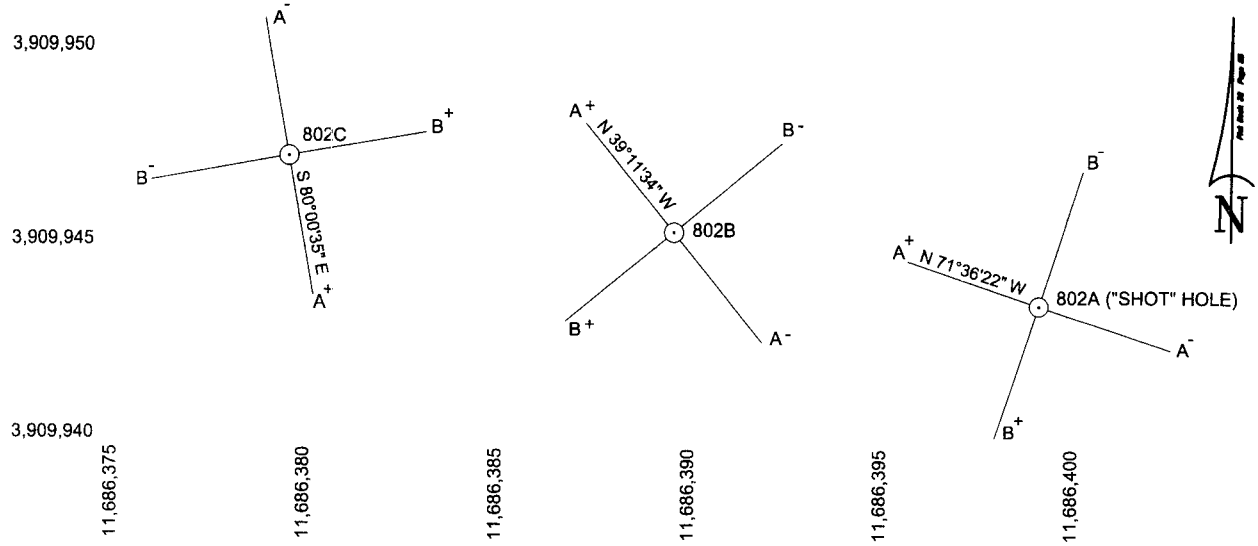

CPT-827
Depth: 32.50
Thu 12/Dec/2002
Pressure (tsf)
0
1
2
3
4
0.1
1
10
100
1,000
Time (seconds)


CPT-823
Depth: 26.99
Wed 11/Dec/2002
Pressure (tsf)
2
1
0
-1
-2
0.1
0.5
1
5
10
50
100
Time (seconds)

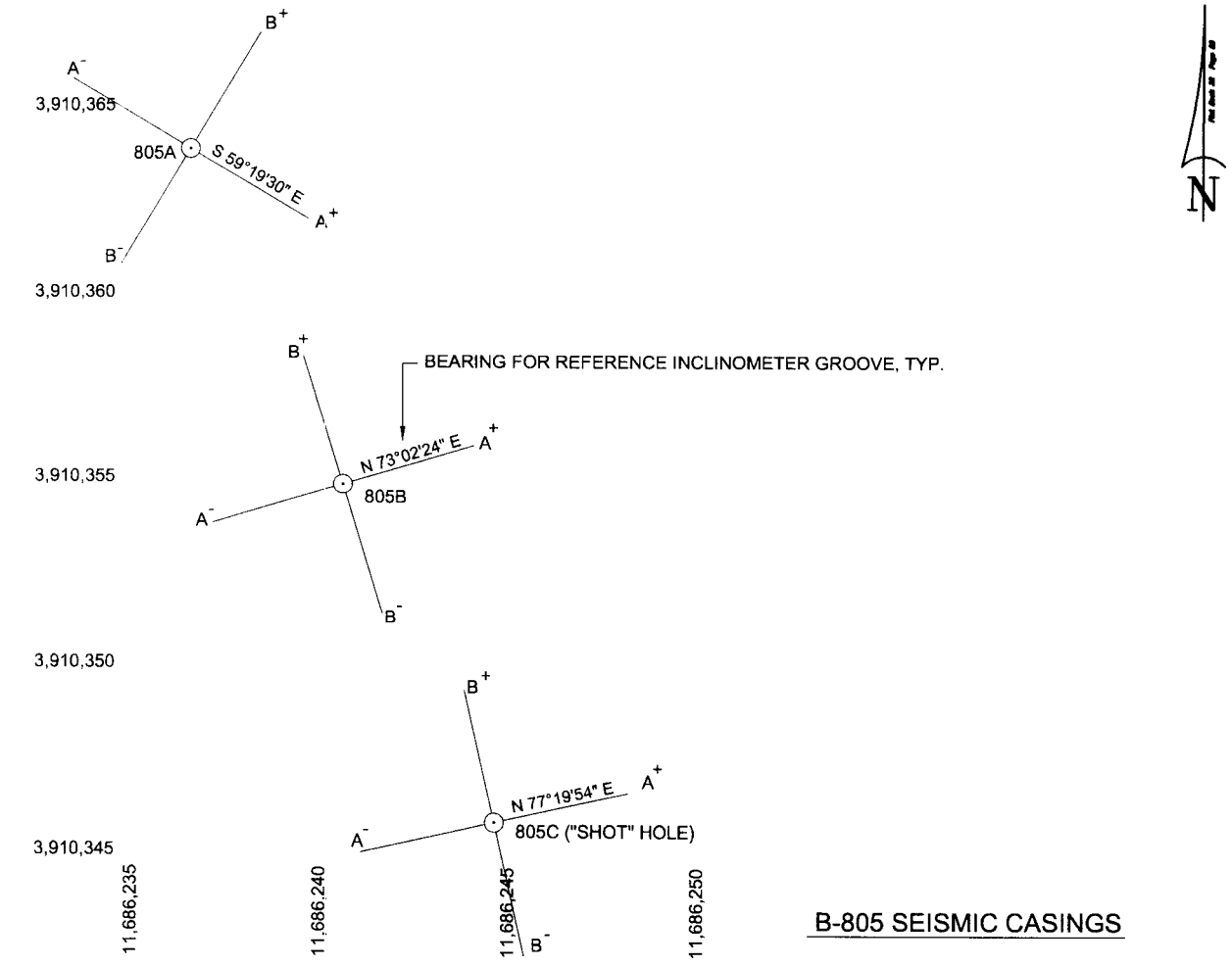

CPT-827
Depth: 32.50
Thu 12/Dec/2002
Pressure (psi)
20
15
10
5
0
0.1
1
10
100
1,000
Time (seconds)


CPT-823
Depth: 26.99
Wed 11/Dec/2002
Pressure (psi)
10
5
0
-5
-10
0.1
0.5
1
5
10
50
100
Time (seconds)

APPENDIX G
DEVIATION SURVEY CROSSHOLE CASINGS



B-802 SEISMIC CASINGS



B-805 SEISMIC CASINGS

P:\30720\PROJECTS\5400 North Anna\POINTS.DWG

MACTEC

MACTEC ENGINEERING AND CONSULTING OF GEORGIA INC.
3301 ATLANTIC AVENUE RALEIGH, NORTH CAROLINA

ORIENTATION OF
INCLINOMETER GROOVES
B-802 & B-805 SEISMIC CASINGS
NORTH ANNA ESP

DRAWN: R.R.	DATE: FEB, 2003
DFT CHECK:	SCALE: 1"=5'
ENG CHECK:	JOB: 30720-2-5400
APPROVAL:	DRAWING: DEV-1

REFERENCE: Survey by Stantec, Inc. with NAD 83 grid coordinates

CROSSHOLE CASING DISTANCE CALCULATION SHEET

NORTH ANNA ESP PROJECT — Prepared by: [illegible] — Date: 1/8/03

MACTEC JOB NO. 30720-2-5400 — Checked by: [illegible] — Date: 1/8/03

Depth, ft	B-802B N	B-802B E	B-802C N	B-802C E	Delta N	Delta E	Distance
0	3909945.4	11686389.75	3909947.32	11686379.75	-1.92	10	10.18
2	3909945.37	11686389.78	3909947.351	11686379.78	-1.9804829	10.00133	10.20
4	3909945.349	11686389.82	3909947.38	11686379.81	-2.0309254	10.00289	10.21
6	3909945.34	11686389.85	3909947.411	11686379.84	-2.0708418	10.00788	10.22
8	3909945.34	11686389.89	3909947.444	11686379.87	-2.1047587	10.01786	10.24
10	3909945.345	11686389.93	3909947.482	11686379.9	-2.1366617	10.03111	10.26
12	3909945.355	11686389.97	3909947.524	11686379.92	-2.1682145	10.04924	10.28
14	3909945.369	11686390.02	3909947.568	11686379.94	-2.1990804	10.07537	10.31
16	3909945.385	11686390.06	3909947.613	11686379.96	-2.2278018	10.10417	10.35
18	3909945.4	11686390.11	3909947.659	11686379.98	-2.2598641	10.13585	10.38
20	3909945.408	11686390.17	3909947.708	11686380	-2.3001778	10.17056	10.43
22	3909945.416	11686390.23	3909947.759	11686380.02	-2.3423062	10.20679	10.47
24	3909945.425	11686390.28	3909947.812	11686380.04	-2.3868399	10.24617	10.52
26	3909945.433	11686390.34	3909947.865	11686380.06	-2.4316464	10.2854	10.57
28	3909945.44	11686390.4	3909947.919	11686380.07	-2.4795983	10.32441	10.62
30	3909945.443	11686390.45	3909947.974	11686380.09	-2.5308555	10.36344	10.67
32	3909945.445	11686390.51	3909948.034	11686380.11	-2.5890269	10.40188	10.72
34	3909945.438	11686390.57	3909948.101	11686380.14	-2.6631264	10.43323	10.77
36	3909945.43	11686390.64	3909948.175	11686380.17	-2.7453954	10.46598	10.82
38	3909945.424	11686390.71	3909948.254	11686380.21	-2.8292467	10.5041	10.88
40	3909945.425	11686390.78	3909948.332	11686380.24	-2.9073323	10.54328	10.94
42	3909945.432	11686390.86	3909948.412	11686380.26	-2.9801422	10.59473	11.01
44	3909945.439	11686390.94	3909948.492	11686380.29	-3.0523317	10.64779	11.08
46	3909945.452	11686391.01	3909948.573	11686380.31	-3.1217929	10.70229	11.15
48	3909945.464	11686391.08	3909948.656	11686380.32	-3.1918497	10.75848	11.22
50	3909945.474	11686391.16	3909948.736	11686380.34	-3.2619055	10.8181	11.30
52	3909945.486	11686391.24	3909948.816	11686380.35	-3.3298867	10.88116	11.38
54	3909945.5	11686391.32	3909948.892	11686380.37	-3.3921496	10.94756	11.46
56	3909945.516	11686391.4	3909948.967	11686380.38	-3.4506326	11.01946	11.55
58	3909945.534	11686391.49	3909949.043	11686380.39	-3.5093853	11.09775	11.64
60	3909945.552	11686391.59	3909949.122	11686380.41	-3.5704056	11.18126	11.74
62	3909945.573	11686391.69	3909949.208	11686380.42	-3.6342864	11.26986	11.84

64	3909945.594	11686391.8	3909949.308	11686380.44	-3.713479	11.35945	11.95
66	3909945.614	11686391.91	3909949.414	11686380.47	-3.8003499	11.44776	12.06
68	3909945.633	11686392.02	3909949.523	11686380.49	-3.8891598	11.53719	12.18
70	3909945.652	11686392.13	3909949.633	11686380.51	-3.9805984	11.62695	12.29
72	3909945.669	11686392.24	3909949.741	11686380.53	-4.0722546	11.71166	12.40
74	3909945.688	11686392.35	3909949.845	11686380.55	-4.1567401	11.79414	12.51
76	3909945.706	11686392.45	3909949.943	11686380.58	-4.2371288	11.87528	12.61
78	3909945.721	11686392.56	3909950.042	11686380.6	-4.3204107	11.9564	12.71
80	3909945.734	11686392.66	3909950.14	11686380.62	-4.4058201	12.03837	12.82
82	3909945.746	11686392.76	3909950.237	11686380.64	-4.4905526	12.12202	12.93
84	3909945.758	11686392.86	3909950.33	11686380.66	-4.5722656	12.20489	13.03
86	3909945.772	11686392.97	3909950.421	11686380.68	-4.6490619	12.28451	13.13
88	3909945.792	11686393.07	3909950.509	11686380.7	-4.7176571	12.36482	13.23
90	3909945.816	11686393.16	3909950.594	11686380.72	-4.7776835	12.44622	13.33

CALCULATION OF DEVIATION AT INCREMENTAL DEPTHS FOR CROSSHOLE CASINGS

Casing No. B-802B Prepared by: JDL Date: 1/8/03

Checked by: BKB Date: 1/8/03

Depth, ft	A Deviation	B Deviation	Resultant	Angle y	calc angle	Delta N(in)	delta E (in)	N (ft)	E(ft)
0	0	0	0	0				3909945.4	11686389.75
2	-0.5338	-0.0922	0.54	9.80	41.00	-0.36	0.41	3909945.37	11686389.78
4	-0.9816	-0.2414	1.01	13.82	36.98	-0.61	0.81	3909945.349	11686389.82
6	-1.3363	-0.4968	1.43	20.39	30.41	-0.72	1.23	3909945.34	11686389.85
8	-1.6147	-0.8318	1.82	27.25	23.55	-0.73	1.67	3909945.34	11686389.89
10	-1.8586	-1.2389	2.23	33.69	17.11	-0.66	2.13	3909945.345	11686389.93
12	-2.0798	-1.705	2.69	39.34	11.46	-0.53	2.64	3909945.355	11686389.97
14	-2.303	-2.2378	3.21	44.18	6.62	-0.37	3.19	3909945.369	11686390.02
16	-2.5229	-2.8099	3.78	48.08	2.72	-0.18	3.77	3909945.385	11686390.06
18	-2.7706	-3.3878	4.38	50.72	0.08	-0.01	4.38	3909945.4	11686390.11
20	-3.0994	-3.9571	5.03	51.93	1.13	0.10	5.03	3909945.408	11686390.17
22	-3.4507	-4.5432	5.71	52.78	1.98	0.20	5.70	3909945.416	11686390.23
24	-3.8198	-5.1557	6.42	53.47	2.67	0.30	6.41	3909945.425	11686390.28
26	-4.176	-5.7562	7.11	54.04	3.24	0.40	7.10	3909945.433	11686390.34
28	-4.5437	-6.3283	7.79	54.32	3.52	0.48	7.78	3909945.44	11686390.4
30	-4.9435	-6.8842	8.48	54.32	3.52	0.52	8.46	3909945.443	11686390.45
32	-5.376	-7.4366	9.18	54.14	3.34	0.53	9.16	3909945.445	11686390.51
34	-5.8906	-7.9354	9.88	53.41	2.61	0.45	9.87	3909945.438	11686390.57
36	-6.469	-8.4998	10.68	52.73	1.93	0.36	10.68	3909945.43	11686390.64
38	-7.0603	-9.1205	11.53	52.26	1.46	0.29	11.53	3909945.424	11686390.71
40	-7.6118	-9.8093	12.42	52.19	1.39	0.30	12.41	3909945.425	11686390.78
42	-8.1154	-10.559	13.32	52.45	1.65	0.38	13.31	3909945.432	11686390.86
44	-8.6227	-11.3222	14.23	52.71	1.91	0.47	14.22	3909945.439	11686390.94
46	-9.0677	-12.096	15.12	53.14	2.34	0.62	15.10	3909945.452	11686391.01
48	-9.5069	-12.8702	16.00	53.55	2.75	0.77	15.98	3909945.464	11686391.08
50	-9.9854	-13.6574	16.92	53.83	3.03	0.89	16.89	3909945.474	11686391.16
52	-10.4726	-14.4691	17.86	54.10	3.30	1.03	17.83	3909945.486	11686391.24
54	-10.9574	-15.3298	18.84	54.44	3.64	1.20	18.81	3909945.5	11686391.32
56	-11.4547	-16.2494	19.88	54.82	4.02	1.39	19.83	3909945.516	11686391.4
58	-11.9717	-17.2171	20.97	55.19	4.39	1.60	20.91	3909945.534	11686391.49
60	-12.5328	-18.2544	22.14	55.53	4.73	1.83	22.07	3909945.552	11686391.59
62	-13.1165	-19.3733	23.40	55.90	5.10	2.08	23.30	3909945.573	11686391.69

64	-13.7554	-20.5507	24.73	56.20	5.40	2.33	24.62	3909945.594	11686391.8
66	-14.4144	-21.7363	26.08	56.45	5.65	2.57	25.95	3909945.614	11686391.91
68	-15.071	-22.9109	27.42	56.66	5.86	2.80	27.28	3909945.633	11686392.02
70	-15.7339	-24.0763	28.76	56.84	6.04	3.02	28.60	3909945.652	11686392.13
72	-16.3771	-25.1914	30.05	56.97	6.17	3.23	29.87	3909945.669	11686392.24
74	-17.005	-26.3155	31.33	57.13	6.33	3.45	31.14	3909945.688	11686392.35
76	-17.6395	-27.4416	32.62	57.27	6.47	3.67	32.41	3909945.706	11686392.45
78	-18.2861	-28.5245	33.88	57.34	6.54	3.86	33.66	3909945.721	11686392.56
80	-18.9504	-29.5824	35.13	57.36	6.56	4.01	34.90	3909945.734	11686392.66
82	-19.6205	-30.6288	36.37	57.36	6.56	4.15	36.14	3909945.746	11686392.76
84	-20.2944	-31.6766	37.62	57.35	6.55	4.29	37.37	3909945.758	11686392.86
86	-20.9304	-32.7283	38.85	57.40	6.60	4.47	38.59	3909945.772	11686392.97
88	-21.5011	-33.7978	40.06	57.54	6.74	4.70	39.78	3909945.792	11686393.07
90	-22.0306	-34.9133	41.28	57.75	6.95	4.99	40.98	3909945.816	11686393.16

CALCULATION OF DEVIATION AT INCREMENTAL DEPTHS FOR CROSSHOLE CASINGS

Casing No. B-802C Prepared by: CLJ Date: 1-21-03

Checked by: BK B Date: 1/8/03

Depth, ft	A Deviation	B Deviation	Resultant	Angle y	calc angle	Delta N(in)	Delta E(in)	N (ft)	E (ft)
0	0	0	0	0				3909947.32	11686379.75
2	0.3226	0.433	0.54	53.31	43.31	0.37	0.39	3909947.351	11686379.78
4	0.6355	0.8462	1.06	53.09	43.09	0.72	0.77	3909947.38	11686379.81
6	0.9288	1.2691	1.57	53.80	43.80	1.09	1.14	3909947.411	11686379.84
8	1.1698	1.7208	2.08	55.79	45.79	1.49	1.45	3909947.444	11686379.87
10	1.3973	2.219	2.62	57.80	47.80	1.94	1.76	3909947.482	11686379.9
12	1.5893	2.7624	3.19	60.09	50.09	2.44	2.04	3909947.524	11686379.92
14	1.7333	3.3302	3.75	62.50	52.50	2.98	2.29	3909947.568	11686379.94
16	1.8734	3.899	4.33	64.34	54.34	3.51	2.52	3909947.613	11686379.96
18	1.9973	4.4875	4.91	66.01	56.01	4.07	2.75	3909947.659	11686379.98
20	2.124	5.1077	5.53	67.42	57.42	4.66	2.98	3909947.708	11686380
22	2.257	5.7442	6.17	68.55	58.55	5.27	3.22	3909947.759	11686380.02
24	2.3784	6.4109	6.84	69.65	59.65	5.90	3.46	3909947.812	11686380.04
26	2.4835	7.0805	7.50	70.67	60.67	6.54	3.68	3909947.865	11686380.06
28	2.5747	7.7587	8.17	71.64	61.64	7.19	3.88	3909947.919	11686380.07
30	2.6726	8.4427	8.86	72.43	62.43	7.85	4.10	3909947.974	11686380.09
32	2.7854	9.1856	9.60	73.13	63.13	8.56	4.34	3909948.034	11686380.11
34	2.976	10.0373	10.47	73.49	63.49	9.37	4.67	3909948.101	11686380.14
36	3.2242	10.9906	11.45	73.65	63.65	10.26	5.08	3909948.175	11686380.17
38	3.4522	11.9856	12.47	73.93	63.93	11.20	5.48	3909948.254	11686380.21
40	3.694	12.9878	13.50	74.12	64.12	12.15	5.89	3909948.332	11686380.24
42	3.8054	13.9795	14.49	74.77	64.77	13.11	6.18	3909948.412	11686380.26
44	3.9106	14.9683	15.47	75.36	65.36	14.06	6.45	3909948.492	11686380.29
46	3.9643	15.9706	16.46	76.06	66.06	15.04	6.68	3909948.573	11686380.31
48	3.9926	16.9805	17.44	76.77	66.77	16.03	6.88	3909948.656	11686380.32
50	4.0186	17.9674	18.41	77.39	67.39	17.00	7.08	3909948.736	11686380.34
51	4.031	18.9355	19.36	77.98	67.98	17.95	7.26	3909948.816	11686380.35
54	4.0459	19.8677	20.28	78.49	68.49	18.86	7.43	3909948.892	11686380.37
56	4.0517	20.7802	21.17	78.97	68.97	19.76	7.60	3909948.967	11686380.38
58	4.0277	21.7061	22.08	79.49	69.49	20.68	7.74	3909949.043	11686380.39
60	4.0162	22.6718	23.02	79.95	69.95	21.63	7.89	3909949.122	11686380.41
62	4.009	23.7077	24.04	80.40	70.40	22.65	8.06	3909949.208	11686380.42

64	4.0382	24.9307	25.26	80.80	70.80	23.85	8.31	3909949.308	11686380.44
66	4.0872	26.2402	26.56	81.15	71.15	25.13	8.58	3909949.414	11686380.47
68	4.1098	27.5635	27.87	81.52	71.52	26.43	8.83	3909949.523	11686380.49
70	4.1218	28.9061	29.20	81.88	71.88	27.75	9.08	3909949.633	11686380.51
72	4.1453	30.2366	30.52	82.19	72.19	29.06	9.33	3909949.741	11686380.53
74	4.2043	31.5038	31.78	82.40	72.40	30.30	9.61	3909949.845	11686380.55
76	4.2941	32.7226	33.00	82.52	72.52	31.48	9.91	3909949.943	11686380.58
78	4.3589	33.935	34.21	82.68	72.68	32.66	10.19	3909950.042	11686380.6
80	4.4064	35.1403	35.42	82.85	72.85	33.84	10.44	3909950.14	11686380.62
82	4.4323	36.3216	36.59	83.04	73.04	35.00	10.67	3909950.237	11686380.64
84	4.4774	37.4674	37.73	83.19	73.19	36.12	10.92	3909950.33	11686380.66
86	4.5451	38.5896	38.86	83.28	73.28	37.21	11.18	3909950.421	11686380.68
88	4.584	39.6696	39.93	83.41	73.41	38.27	11.40	3909950.509	11686380.7
90	4.6267	40.7078	40.97	83.52	73.52	39.29	11.63	3909950.594	11686380.72

CROSSHOLE CASING DISTANCE CALCULATION SHEET

NORTH ANNA ESP PROJECT
MACTEC JOB NO. 30720-2-5400

Prepared by: JAS Date: 1-9-03
Checked by: BKB Date: 1/9/03

	B-805A		B-805B				
Depth, ft	N	E	N	E	Delta N	Delta E	Distance, ft
0	3910364.026	11686236.69	3910354.987	11686240.74	9.039	-4.051	9.91
2	3910364.048	11686236.68	3910354.982	11686240.73	9.066090599	-4.048924	9.93
4	3910364.064	11686236.67	3910354.973	11686240.71	9.091124818	-4.041354	9.95
6	3910364.074	11686236.66	3910354.968	11686240.69	9.106526772	-4.034219	9.96
8	3910364.07	11686236.64	3910354.968	11686240.67	9.10207588	-4.031221	9.95
10	3910364.049	11686236.62	3910354.979	11686240.65	9.070460818	-4.031622	9.93
12	3910364.017	11686236.58	3910354.989	11686240.63	9.028436542	-4.044928	9.89
14	3910363.971	11686236.53	3910354.98	11686240.6	8.990443387	-4.061367	9.87
16	3910363.911	11686236.48	3910354.969	11686240.56	8.942413297	-4.076217	9.83
18	3910363.843	11686236.43	3910354.963	11686240.52	8.880154132	-4.090536	9.78
20	3910363.767	11686236.37	3910354.97	11686240.48	8.796807952	-4.104496	9.71
22	3910363.681	11686236.32	3910354.989	11686240.43	8.691540767	-4.111241	9.61
24	3910363.582	11686236.26	3910355.026	11686240.35	8.556378063	-4.087378	9.48
26	3910363.47	11686236.2	3910355.078	11686240.24	8.391564746	-4.039951	9.31
28	3910363.348	11686236.14	3910355.152	11686240.12	8.196011243	-3.978371	9.11
	0						

CALCULATION OF DEVIATION AT INCREMENTAL DEPTHS FOR CROSSHOLE CASINGS

Casing No. B-805B Prepared by: DAZ Date: 1-9-03

Checked by: BKB Date: 1/8/03

Depth, ft	A Deviatior	B Deviatior	Resultant	Angle y	calc angle	Delta N, in	Delta E, in	N, ft	E, ft
0	0	0	0	0				3910354.987	11686240.74
2	-0.1464	-0.0211	0.147913	8.201318	25.16132	-0.0628878	-0.1338779	3910354.982	11686240.73
4	-0.3782	-0.0581	0.382637	8.733639	25.69364	-0.1658956	-0.3448036	3910354.973	11686240.71
6	-0.6029	-0.059	0.60578	5.589188	22.54919	-0.2323024	-0.5594685	3910354.968	11686240.69
8	-0.8122	0.012	0.812289	0.846466	16.11353	-0.2254439	-0.7803768	3910354.968	11686240.67
10	-1.0296	0.2098	1.050758	11.51739	5.442607	-0.0996629	-1.0460208	3910354.979	11686240.65
12	-1.2893	0.4128	1.353772	17.7537	0.793701	0.01875279	-1.353642	3910354.989	11686240.63
14	-1.681	0.4306	1.735274	14.36778	2.592219	-0.0784818	-1.7334988	3910354.98	11686240.6
16	-2.1408	0.4267	2.18291	11.27236	5.687645	-0.2163377	-2.1721638	3910354.969	11686240.56
18	-2.6179	0.4992	2.665071	10.79596	6.164036	-0.2861628	-2.6496626	3910354.963	11686240.52
20	-3.0605	0.7224	3.144602	13.281	3.679	-0.2017783	-3.1381217	3910354.97	11686240.48
22	-3.5659	1.1131	3.73559	17.33582	0.375817	0.02450245	-3.7355099	3910354.989	11686240.43
24	-4.3709	1.8226	4.735677	22.63541	5.675407	0.4683236	-4.7124633	3910355.026	11686240.35
26	-5.4053	2.795	6.08517	27.34281	10.38281	1.09669397	-5.9855288	3910355.078	11686240.24
28	-6.5424	4.0685	7.704264	31.8761	14.9161	1.98311109	-7.4446599	3910355.152	11686240.12
30	-7.6099	5.7158	9.517402	36.91023	19.95023	3.24737374	-8.9462568	3910355.258	11686239.99

CALCULATION OF DEVIATION AT INCREMENTAL DEPTHS FOR CROSSHOLE CASINGS

Casing No. B-805A Prepared by: [illegible] Date: 1-9-03

Checked by: [illegible] Date: 1/8/03

Depth, ft	A Deviation	B Deviation	Resultant	Angle x	calc angle	Delta N, in	Delta E in	N, ft	E, ft
0	0	0	0	0				3910364.026	11686236.689
2	-0.2275	0.1699	0.283941	36.75286	67.43286	0.262199	-0.108967	3910364.048	11686236.680
4	-0.4315	0.2784	0.513516	32.82975	63.50975	0.459602	-0.229052	3910364.064	11686236.670
6	-0.6029	0.3144	0.679953	27.54112	58.22112	0.578019	-0.358092	3910364.074	11686236.659
8	-0.7382	0.18	0.759828	13.70339	44.38339	0.531467	-0.543031	3910364.07	11686236.644
10	-0.8414	-0.1761	0.859631	11.82103	18.85897	0.277867	-0.813483	3910364.049	11686236.621
12	-1.0464	-0.7464	1.285327	35.50037	4.820368	-0.108009	-1.280781	3910364.017	11686236.582
14	-1.2605	-1.5166	1.972038	50.26883	19.58883	-0.661161	-1.857903	3910363.971	11686236.534
16	-1.4266	-2.4456	2.83128	59.74356	29.06356	-1.375378	-2.474769	3910363.911	11686236.483
18	-1.5682	-3.4795	3.816565	65.73906	35.05906	-2.192313	-3.124089	3910363.843	11686236.429
20	-1.6651	-4.6018	4.893784	70.10802	39.42802	-3.108083	-3.780072	3910363.767	11686236.374
22	-1.7194	-5.8397	6.087564	73.59383	42.91383	-4.145008	-4.458401	3910363.681	11686236.317
24	-1.7122	-7.2053	7.405942	76.6327	45.9527	-5.32314	-5.148996	3910363.582	11686236.260
26	-1.6291	-8.725	8.875787	79.42373	48.74373	-6.672529	-5.852943	3910363.47	11686236.201
28	-1.5034	-10.3483	10.45694	81.73391	51.05391	-8.132754	-6.573115	3910363.348	11686236.141

DEVIATION SURVEY RECORDS FOR ALL THREE CASINGS
(ONLY SURVEYS FOR RECEIVER CASINGS USED IN CALCULATIONS)

SITE : NANPP
INSTALLATION : 802A
DESCRIPTION : Entered Manually

CURRENT SURVEY : 12/20/2002 1:35:39 PM
Probe Serial No : 2591

DATE PRINTED : 12/20/2002 1:52:48 PM

Data Reduction for A Axis:

Depth (ft)	Current A0	Current A180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	113	-126	0.1147	-0.1147
4	80	-88	0.0806	-0.1954
6	23	-33	0.0269	-0.2222
8	-1	-7	0.0029	-0.2251
10	-18	10	-0.0134	-0.2117
12	-48	41	-0.0427	-0.1690
14	-106	94	-0.0960	-0.0730
16	-129	123	-0.1210	0.0480
18	-155	143	-0.1430	0.1910
20	-178	169	-0.1666	0.3576
22	-214	204	-0.2006	0.5582
24	-238	229	-0.2242	0.7824
26	-261	251	-0.2458	1.0282
28	-267	258	-0.2520	1.2802
30	-278	271	-0.2635	1.5437
32	-292	284	-0.2765	1.8202
34	-310	301	-0.2933	2.1134
36	-299	292	-0.2837	2.3971
38	-261	253	-0.2467	2.6438
40	-233	222	-0.2184	2.8622
42	-209	197	-0.1949	3.0571
44	-147	140	-0.1378	3.1949
46	-148	137	-0.1368	3.3317
48	-151	145	-0.1421	3.4738
50	-149	140	-0.1387	3.6125
52	-127	116	-0.1166	3.7291
54	-110	103	-0.1022	3.8314
56	-92	83	-0.0840	3.9154
58	-88	80	-0.0806	3.9960
60	-105	97	-0.0970	4.0930
62	-130	119	-0.1195	4.2125
64	-122	112	-0.1123	4.3248
66	-146	135	-0.1349	4.4597
68	-157	151	-0.1478	4.6075
70	-194	182	-0.1805	4.7880
72	-227	216	-0.2126	5.0006
74	-269	263	-0.2554	5.2560
76	-320	307	-0.3010	5.5570
78	-330	322	-0.3130	5.8699
80	-353	343	-0.3341	6.2040
82	-382	370	-0.3610	6.5650
84	-385	377	-0.3658	6.9307

Depth (ft)	Current A0	Current A180	Current Incr. Dev. (in)	Cum. Dev. (in)
86	-441	428	-0.4171	7.3478
88	-496	488	-0.4723	7.8202
90	-573	561	-0.5443	8.3645

SITE : NANPP
INSTALLATION : 802A
DESCRIPTION : Entered Manually

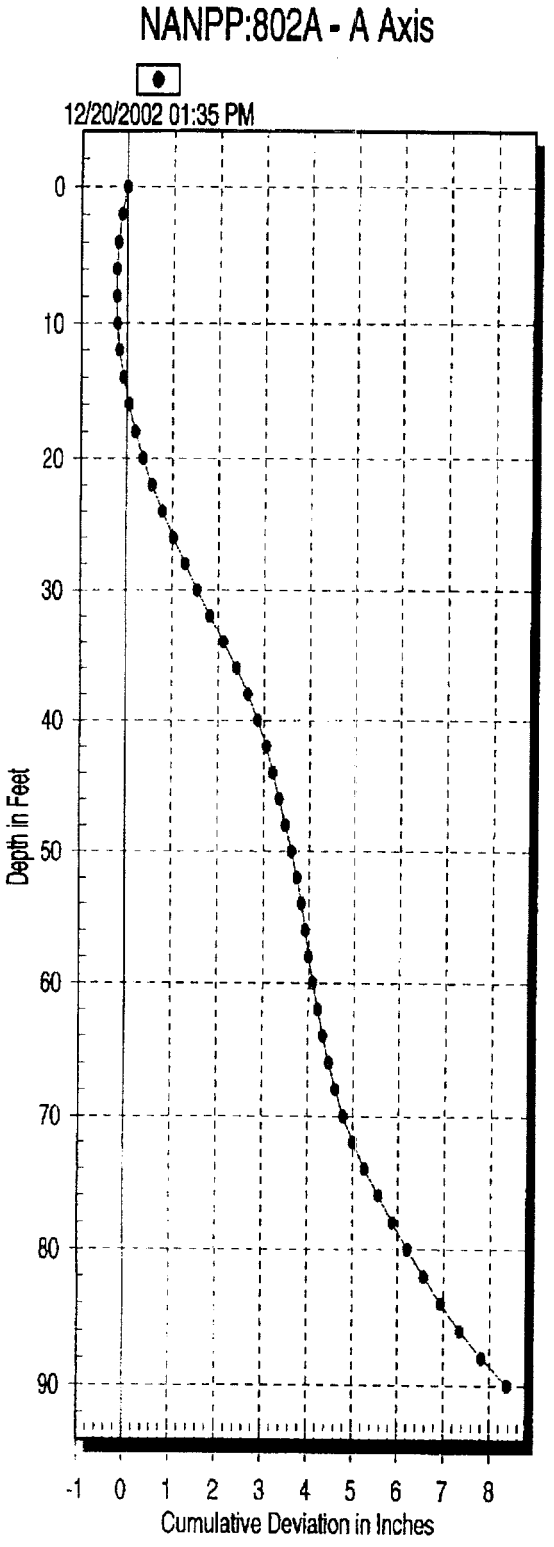
CURRENT SURVEY : 12/20/2002 1:35:39 PM
Probe Serial No : 2591

DATE PRINTED : 12/20/2002 1:52:48 PM

Data Reduction for B Axis:

Depth (ft)	Current B0	Current B180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	344	-348	0.3322	-0.3322
4	306	-312	0.2966	-0.6288
6	221	-239	0.2208	-0.8496
8	108	-117	0.1080	-0.9576
10	8	-17	0.0120	-0.9696
12	-91	85	-0.0845	-0.8851
14	-72	73	-0.0696	-0.8155
16	-58	54	-0.0538	-0.7618
18	-31	28	-0.0283	-0.7334
20	-12	6	-0.0086	-0.7248
22	-27	21	-0.0230	-0.7018
24	-14	12	-0.0125	-0.6893
26	-34	27	-0.0293	-0.6600
28	-66	63	-0.0619	-0.5981
30	-89	83	-0.0826	-0.5155
32	-99	97	-0.0941	-0.4214
34	-80	84	-0.0787	-0.3427
36	-64	58	-0.0586	-0.2842
38	-34	31	-0.0312	-0.2530
40	-8	3	-0.0053	-0.2477
42	28	-30	0.0278	-0.2755
44	92	-96	0.0902	-0.3658
46	108	-113	0.1061	-0.4718
48	147	-153	0.1440	-0.6158
50	198	-200	0.1910	-0.8069
52	210	-208	0.2006	-1.0075
54	246	-239	0.2328	-1.2403
56	272	-276	0.2630	-1.5034
58	276	-280	0.2669	-1.7702
60	250	-256	0.2429	-2.0131
62	216	-219	0.2088	-2.2219
64	266	-268	0.2563	-2.4782
66	267	-278	0.2616	-2.7398
68	258	-264	0.2506	-2.9904
70	251	-257	0.2438	-3.2342
72	235	-241	0.2285	-3.4627
74	214	-208	0.2026	-3.6653
76	164	-179	0.1646	-3.8299
78	152	-155	0.1474	-3.9773
80	142	-146	0.1382	-4.1155
82	119	-125	0.1171	-4.2326
84	114	-116	0.1104	-4.3430

Depth (ft)	Current B0	Current B180	Current Incr. Dev. (in)	Cum. Dev. (in)
86	84	-89	0.0830	-4.4261
88	16	-23	0.0187	-4.4448
90	-24	18	-0.0202	-4.4246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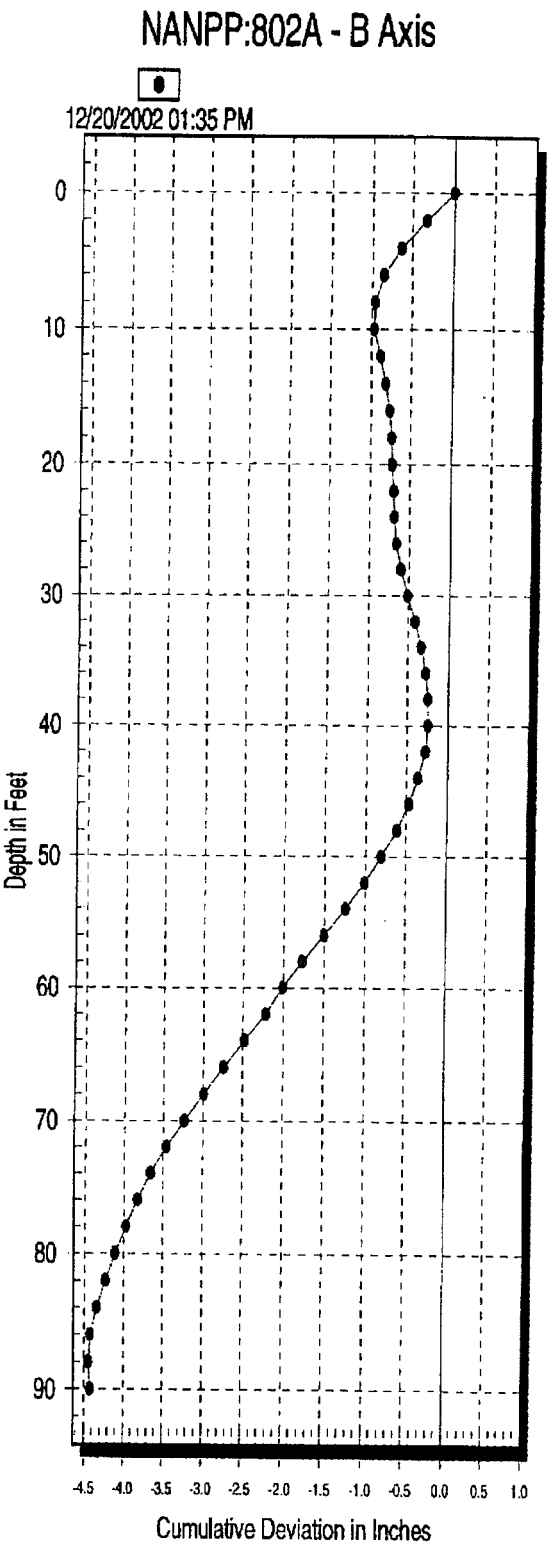
12/20/2002 01:35 PM
Depth in Feet
0
10
20
30
40
50
60
70
80
90
-1 0 1 2 3 4 5 6 7 8
Cumulative Deviation in Inches


NANPP:802A - B Axis
12/20/2002 01:35 PM
Depth in Feet
0
10
20
30
40
50
60
70
80
90
-4.5 -4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0
Cumulative Deviation in Inches

SITE : NANPP
INSTALLATION : 802B
DESCRIPTION : Entered Manually

CURRENT SURVEY : 12/20/2002 1:54:55 PM
Probe Serial No : 2591

DATE PRINTED : 12/20/2002 2:03:40 PM

Data Reduction for A Axis:

Depth (ft)	Current A0	Current A180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	545	-567	0.5338	-0.5338
4	461	-472	0.4478	-0.9816
6	364	-375	0.3547	-1.3363
8	282	-298	0.2784	-1.6147
10	248	-260	0.2438	-1.8586
12	225	-236	0.2213	-2.0798
14	227	-238	0.2232	-2.3030
16	223	-235	0.2198	-2.5229
18	254	-262	0.2477	-2.7706
20	336	-349	0.3288	-3.0994
22	360	-372	0.3514	-3.4507
24	379	-390	0.3691	-3.8198
26	367	-375	0.3562	-4.1760
28	378	-388	0.3677	-4.5437
30	411	-422	0.3998	-4.9435
32	446	-455	0.4325	-5.3760
34	528	-544	0.5146	-5.8906
36	597	-608	0.5784	-6.4690
38	609	-623	0.5914	-7.0603
40	570	-579	0.5515	-7.6118
42	512	-537	0.5035	-8.1154
44	523	-534	0.5074	-8.6227
46	456	-471	0.4450	-9.0677
48	450	-465	0.4392	-9.5069
50	493	-504	0.4786	-9.9854
52	500	-515	0.4872	-10.4726
54	501	-509	0.4848	-10.9574
56	516	-520	0.4973	-11.4547
58	533	-544	0.5170	-11.9717
60	580	-589	0.5611	-12.5328
62	602	-614	0.5837	-13.1165
64	658	-673	0.6389	-13.7554
66	681	-692	0.6590	-14.4144
68	677	-691	0.6566	-15.0710
70	685	-696	0.6629	-15.7339
72	667	-673	0.6432	-16.3771
74	646	-662	0.6278	-17.0050
76	654	-668	0.6346	-17.6395
78	667	-680	0.6466	-18.2861
80	686	-698	0.6643	-18.9504
82	692	-704	0.6701	-19.6205
84	695	-709	0.6739	-20.2944

Depth (ft)	Current A0	Current A180	Current Incr. Dev. (in)	Cum. Dev. (in)
86	659	-666	0.6360	-20.9304
88	590	-599	0.5707	-21.5011
90	549	-554	0.5294	-22.0306

SITE : NANPP
INSTALLATION : 802B
DESCRIPTION : Entered Manually

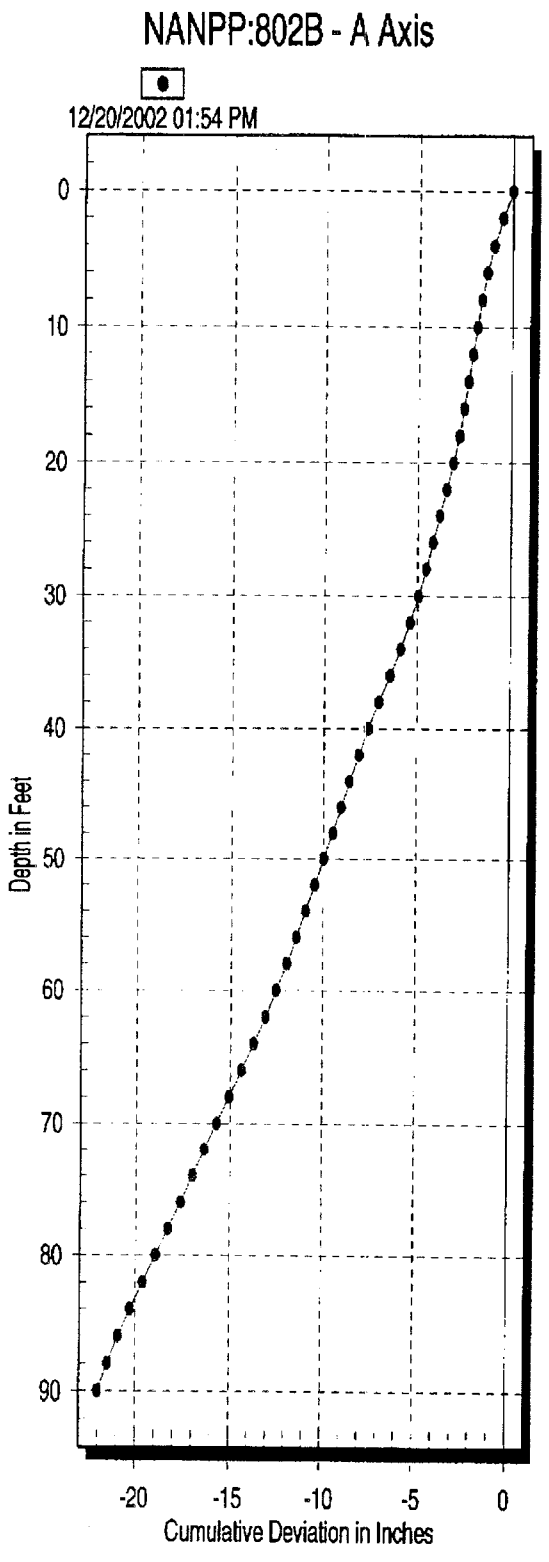
CURRENT SURVEY : 12/20/2002 1:54:55 PM
Probe Serial No : 2591

DATE PRINTED : 12/20/2002 2:03:40 PM

Data Reduction for B Axis:

Depth (ft)	Current B0	Current B180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	93	-99	0.0922	-0.0922
4	156	-155	0.1493	-0.2414
6	264	-268	0.2554	-0.4968
8	346	-352	0.3350	-0.8318
10	423	-425	0.4070	-1.2389
12	483	-488	0.4661	-1.7050
14	554	-556	0.5328	-2.2378
16	596	-596	0.5722	-2.8099
18	600	-604	0.5779	-3.3878
20	593	-593	0.5693	-3.9571
22	613	-608	0.5861	-4.5432
24	639	-637	0.6125	-5.1557
26	624	-627	0.6005	-5.7562
28	593	-599	0.5722	-6.3283
30	578	-580	0.5558	-6.8842
32	574	-577	0.5525	-7.4366
34	516	-523	0.4987	-7.9354
36	588	-588	0.5645	-8.4998
38	645	-648	0.6206	-9.1205
40	716	-719	0.6888	-9.8093
42	778	-784	0.7498	-10.5590
44	803	-787	0.7632	-11.3222
46	810	-802	0.7738	-12.0960
48	805	-808	0.7742	-12.8702
50	820	-820	0.7872	-13.6574
52	847	-844	0.8117	-14.4691
54	898	-895	0.8606	-15.3298
56	954	-962	0.9197	-16.2494
58	1004	-1012	0.9677	-17.2171
60	1077	-1084	1.0373	-18.2544
62	1144	-1187	1.1189	-19.3733
64	1225	-1228	1.1774	-20.5507
66	1235	-1235	1.1856	-21.7363
68	1222	-1225	1.1746	-22.9109
70	1211	-1217	1.1654	-24.0763
72	1161	-1162	1.1150	-25.1914
74	1170	-1172	1.1242	-26.3155
76	1172	-1174	1.1261	-27.4416
78	1126	-1130	1.0829	-28.5245
80	1101	-1103	1.0579	-29.5824
82	1096	-1084	1.0464	-30.6288
84	1092	-1091	1.0478	-31.6766

Depth (ft)	Current B0	Current B180	Current Incr. Dev. (in)	Cum. Dev. (in)
86	1092	-1099	1.0517	-32.7283
88	1110	-1118	1.0694	-33.7978
90	1154	-1170	1.1155	-34.9133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Depth in Feet
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30
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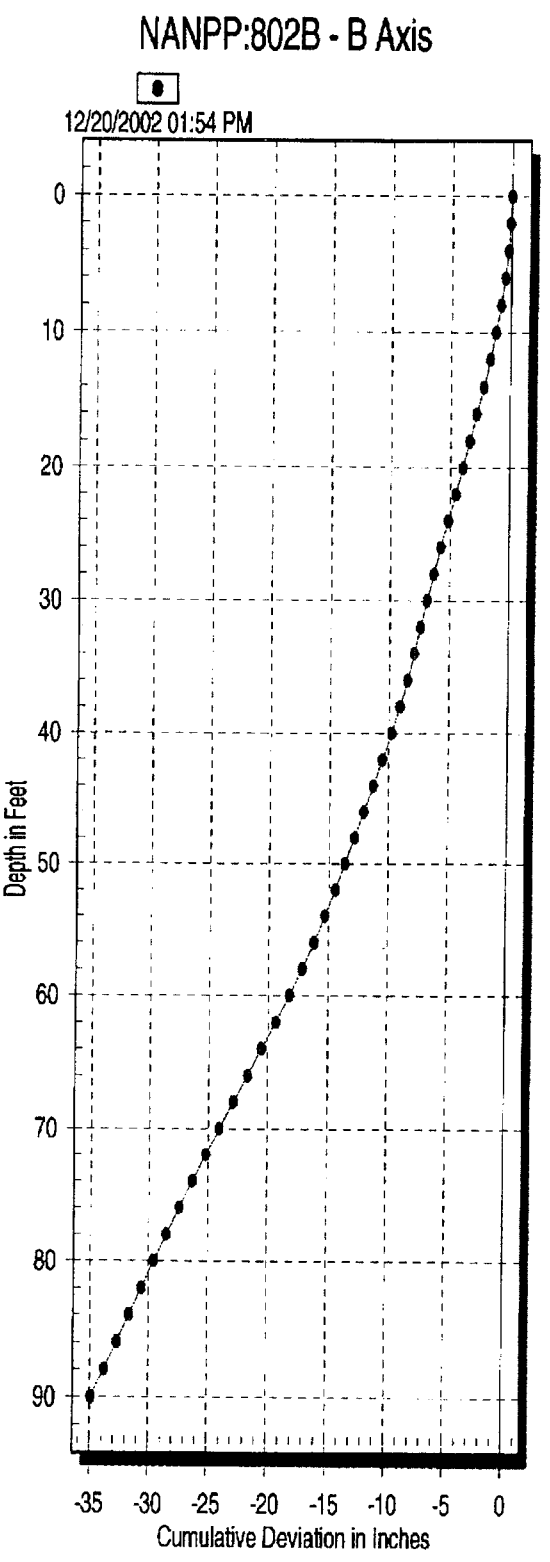
0
Cumulative Deviation in Inches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Depth in Feet
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-15
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-5
0
Cumulative Deviation in Inches

SITE : NANPP
INSTALLATION : 802C
DESCRIPTION : Entered Manually

CURRENT SURVEY : 12/20/2002 2:04:16 PM
Probe Serial No : 2591

DATE PRINTED : 12/20/2002 2:12:11 PM

Data Reduction for A Axis:

Depth (ft)	Current A0	Current A180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	-347	325	-0.3226	0.3226
4	-331	321	-0.3130	0.6355
6	-311	300	-0.2933	0.9288
8	-256	246	-0.2410	1.1698
10	-243	231	-0.2275	1.3973
12	-204	196	-0.1920	1.5893
14	-155	145	-0.1440	1.7333
16	-151	141	-0.1402	1.8734
18	-133	125	-0.1238	1.9973
20	-136	128	-0.1267	2.1240
22	-146	131	-0.1330	2.2570
24	-131	122	-0.1214	2.3784
26	-115	104	-0.1051	2.4835
28	-99	91	-0.0912	2.5747
30	-109	95	-0.0979	2.6726
32	-123	112	-0.1128	2.7854
34	-204	193	-0.1906	2.9760
36	-266	251	-0.2482	3.2242
38	-246	229	-0.2280	3.4522
40	-212	199	-0.1973	3.6494
42	-169	156	-0.1560	3.8054
44	-117	102	-0.1051	3.9106
46	-60	52	-0.0538	3.9643
48	-38	21	-0.0283	3.9926
50	-30	24	-0.0259	4.0186
52	-18	8	-0.0125	4.0310
54	-19	12	-0.0149	4.0459
56	-10	2	-0.0058	4.0517
58	19	-31	0.0240	4.0277
60	5	-19	0.0115	4.0162
62	1	-14	0.0072	4.0090
64	-36	25	-0.0293	4.0382
66	-60	42	-0.0490	4.0872
68	-30	17	-0.0226	4.1098
70	-20	5	-0.0120	4.1218
72	-34	15	-0.0235	4.1453
74	-65	58	-0.0590	4.2043
76	-100	87	-0.0898	4.2941
78	-74	61	-0.0648	4.3589
80	-55	44	-0.0475	4.4064
82	-34	20	-0.0259	4.4323
84	-53	41	-0.0451	4.4774

Depth (ft)	Current A0	Current A180	Current Incr. Dev. (in)	Cum. Dev. (in)
86	-79	62	-0.0677	4.5451
88	-36	45	-0.0389	4.5840
90	-50	39	-0.0427	4.6267

SITE : NANPP
INSTALLATION : 802C
DESCRIPTION : Entered Manually

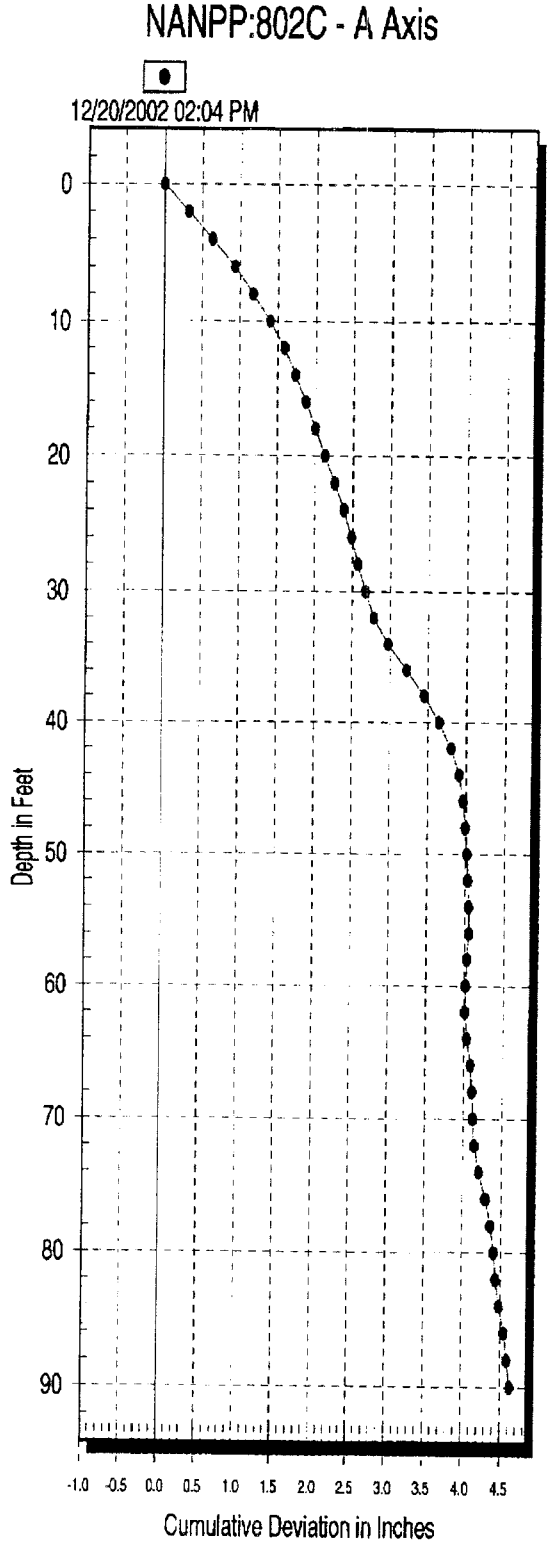
CURRENT SURVEY : 12/20/2002 2:04:16 PM
Probe Serial No : 2591

DATE PRINTED : 12/20/2002 2:12:11 PM

Data Reduction for B Axis:

Depth (ft)	Current B0	Current B180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	-452	450	-0.4330	0.4330
4	-430	431	-0.4133	0.8462
6	-440	441	-0.4229	1.2691
8	-470	471	-0.4517	1.7208
10	-520	518	-0.4982	2.2190
12	-565	567	-0.5434	2.7624
14	-592	591	-0.5678	3.3302
16	-593	592	-0.5688	3.8990
18	-614	612	-0.5885	4.4875
20	-648	644	-0.6202	5.1077
22	-662	664	-0.6365	5.7442
24	-692	697	-0.6667	6.4109
26	-696	699	-0.6696	7.0805
28	-706	707	-0.6782	7.7587
30	-715	710	-0.6840	8.4427
32	-755	751	-0.7229	9.1656
34	-905	911	-0.8717	10.0373
36	-995	991	-0.9533	10.9906
38	-1039	1034	-0.9950	11.9856
40	-1044	1044	-1.0022	12.9878
42	-1031	1035	-0.9917	13.9795
44	-1028	1032	-0.9888	14.9683
46	-1040	1048	-1.0022	15.9706
48	-1053	1051	-1.0099	16.9805
50	-1027	1029	-0.9869	17.9674
52	-1006	1011	-0.9682	18.9355
54	-969	973	-0.9322	19.8677
56	-951	950	-0.9125	20.7802
58	-964	965	-0.9259	21.7061
60	-1010	1002	-0.9658	22.6718
62	-1080	1078	-1.0358	23.7077
64	-1274	1274	-1.2230	24.9307
66	-1365	1363	-1.3094	26.2402
68	-1378	1379	-1.3234	27.5635
70	-1398	1399	-1.3426	28.9061
72	-1387	1385	-1.3306	30.2366
74	-1323	1317	-1.2672	31.5038
76	-1272	1267	-1.2187	32.7226
78	-1263	1263	-1.2125	33.9350
80	-1256	1255	-1.2053	35.1403
82	-1230	1231	-1.1813	36.3216
84	-1192	1195	-1.1458	37.4674

Depth (ft)	Current B0	Current B180	Current Incr. Dev. (in)	Cum. Dev. (in)
86	-1170	1168	-1.1222	38.5896
88	-1122	1128	-1.0800	39.6696
90	-1082	1081	-1.0382	40.7078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12/20/2002 02:04 PM
Depth in Feet
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20
30
40
50
60
70
80
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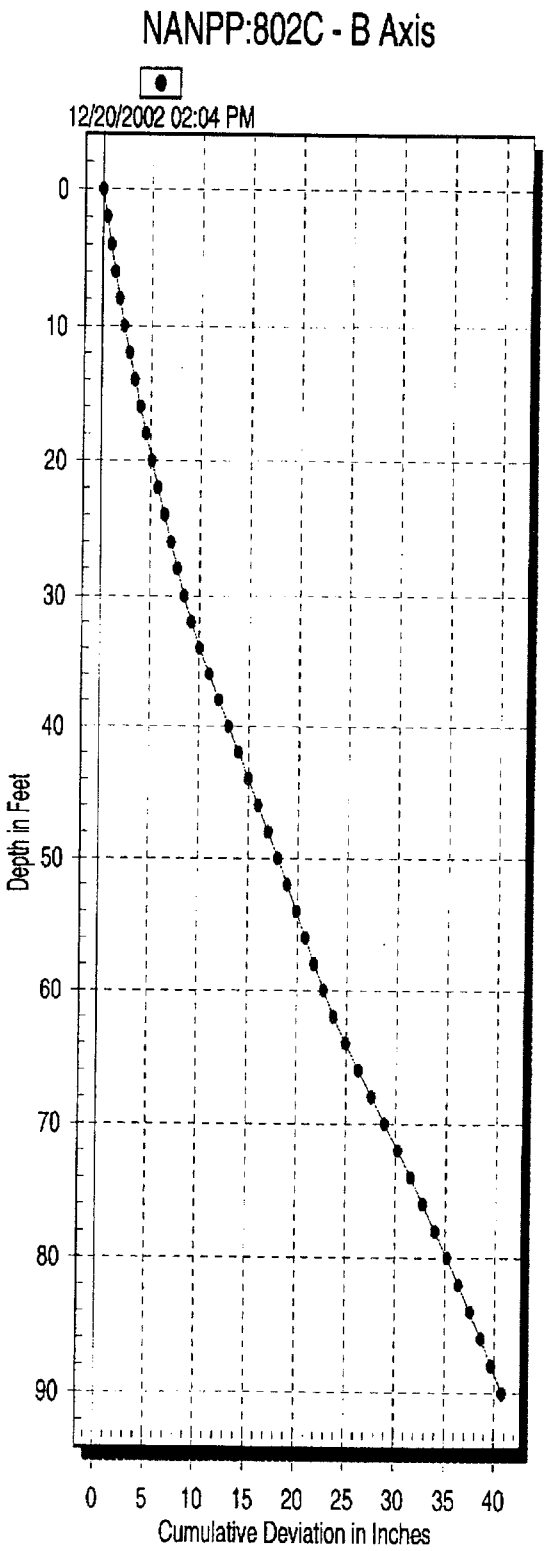
Cumulative Deviation in Inches


NANPP:802C - B Axis
12/20/2002 02:04 PM
Depth in Feet
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10
20
30
40
50
60
70
80
90
0 5 10 15 20 25 30 35 40
Cumulative Deviation in Inches

SITE : NANPP
INSTALLATION : 805A
DESCRIPTION : Entered Manually

CURRENT SURVEY : 12/19/2002 5:28:37 PM
Probe Serial No : 2591

DATE PRINTED : 1/14/2003 1:27:11 PM

Data Reduction for A Axis:

Depth (ft)	Current A0	Current A180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	230	-244	0.2275	-0.2275
4	209	-216	0.2040	-0.4315
6	172	-185	0.1714	-0.6029
8	137	-145	0.1354	-0.7382
10	104	-111	0.1032	-0.8414
12	210	-217	0.2050	-1.0464
14	218	-228	0.2141	-1.2605
16	168	-178	0.1661	-1.4266
18	144	-151	0.1416	-1.5682
20	97	-105	0.0970	-1.6651
22	53	-60	0.0542	-1.7194
24	-13	2	-0.0072	-1.7122
26	-92	81	-0.0830	-1.6291
28	-135	127	-0.1258	-1.5034

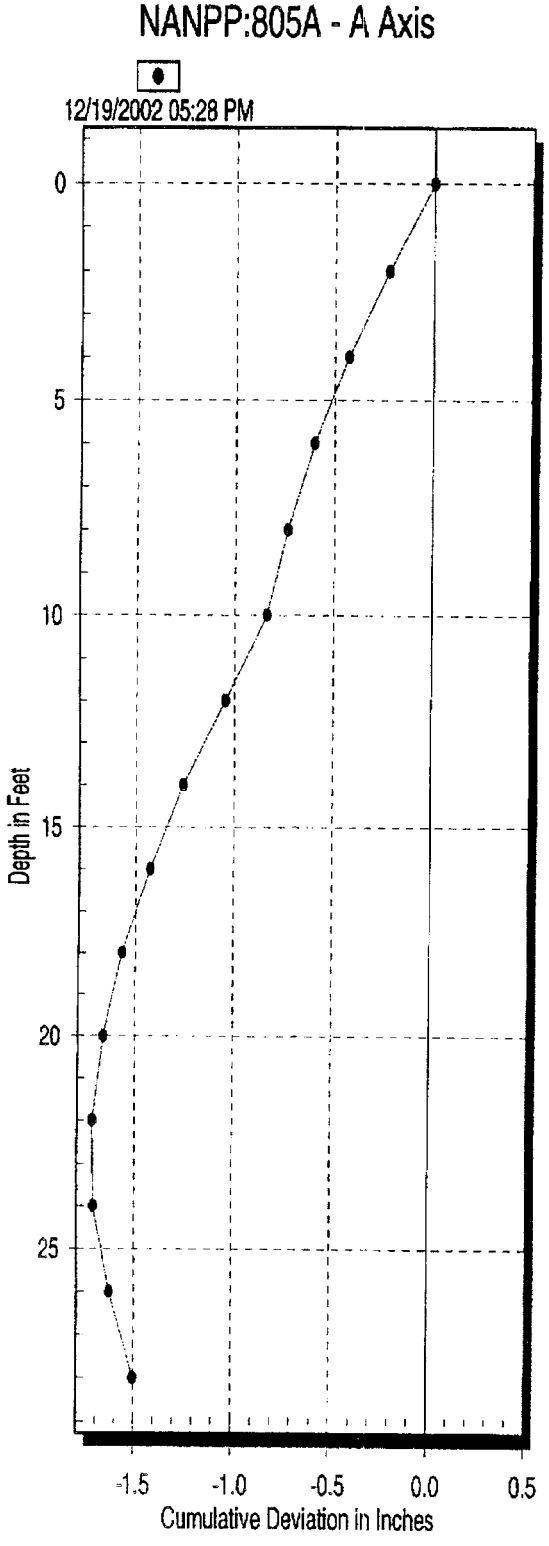
SITE : NANPP
INSTALLATION : 805A
DESCRIPTION : Entered Manually

CURRENT SURVEY : 12/19/2002 5:28:37 PM
Probe Serial No : 2591

DATE PRINTED : 1/14/2003 1:27:11 PM

Data Reduction for B Axis:

Depth (ft)	Current B0	Current B180	Current Incr. Dev. (in)	Cum. Dev. (In)
0	0	0	0.0000	0.0000
2	-178	176	-0.1699	0.1699
4	-116	110	-0.1085	0.2784
6	-42	33	-0.0360	0.3144
8	134	-146	0.1344	0.1800
10	366	-380	0.3581	-0.1781
12	586	-598	0.5683	-0.7464
14	796	-809	0.7704	-1.5168
16	964	-971	0.9288	-2.4456
18	1073	-1081	1.0339	-3.4795
20	1166	-1172	1.1222	-4.6018
22	1285	-1294	1.2379	-5.8397
24	1419	-1426	1.3656	-7.2053
26	1576	-1590	1.5197	-8.7250
28	1687	-1695	1.6234	-10.3483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12/19/2002 05:28 PM
0
5
10
15
20
25
Depth in Feet
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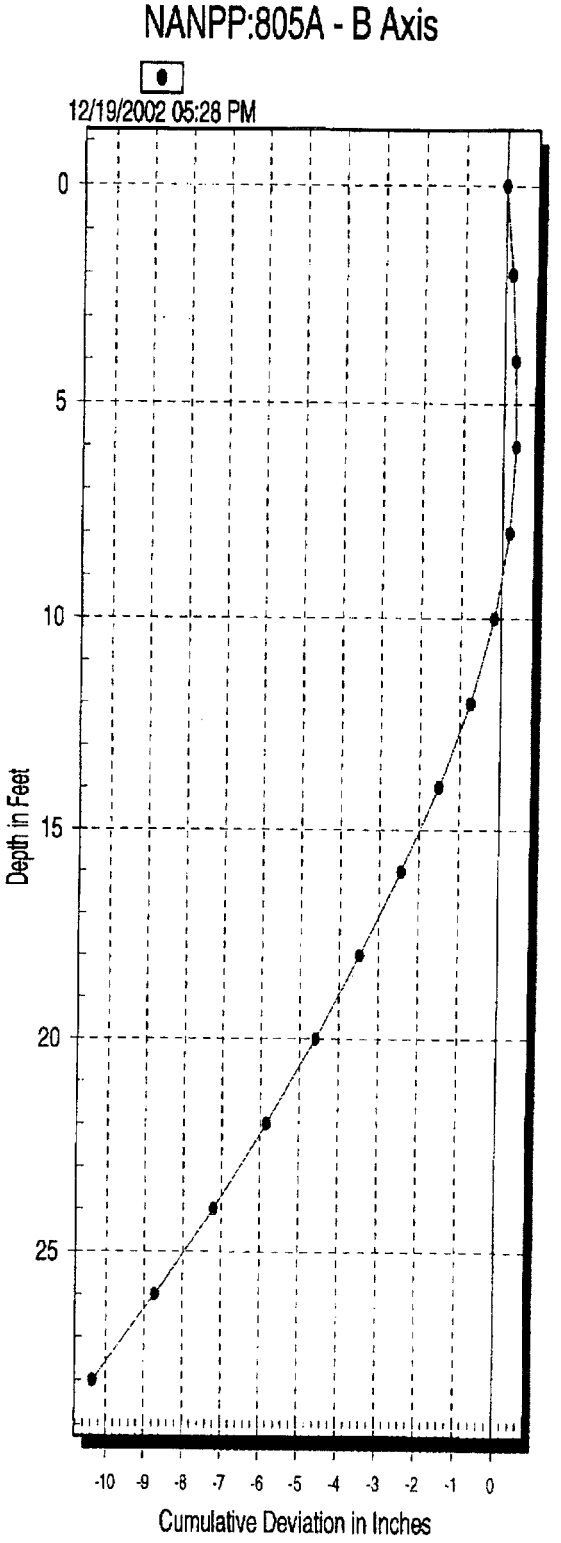
Cumulative Deviation in Inches


NANPP:805A - B Axis
12/19/2002 05:28 PM
0
5
10
15
20
25
Depth in Feet
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-9
-8
-7
-6
-5
-4
-3
-2
-1
0
Cumulative Deviation in Inches

SITE : NANPP
INSTALLATION : 805B
DESCRIPTION : Entered Manually

CURRENT SURVEY : 12/20/2002 12:14:33 PM
Probe Serial No : 2591

DATE PRINTED : 12/20/2002 2:18:14 PM

Data Reduction for A Axis:

Depth (ft)	Current A0	Current A180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	144	-161	0.1464	-0.1464
4	237	-246	0.2318	-0.3782
6	228	-240	0.2246	-0.6029
8	213	-223	0.2093	-0.8122
10	222	-231	0.2174	-1.0296
12	264	-277	0.2597	-1.2893
14	402	-414	0.3917	-1.6810
16	475	-483	0.4598	-2.1408
18	491	-503	0.4771	-2.6179
20	457	-465	0.4426	-3.0605
22	523	-530	0.5054	-3.5659
24	831	-846	0.8050	-4.3709
26	1072	-1083	1.0344	-5.4053
28	1178	-1191	1.1371	-6.5424
30	1107	-1117	1.0675	-7.6099

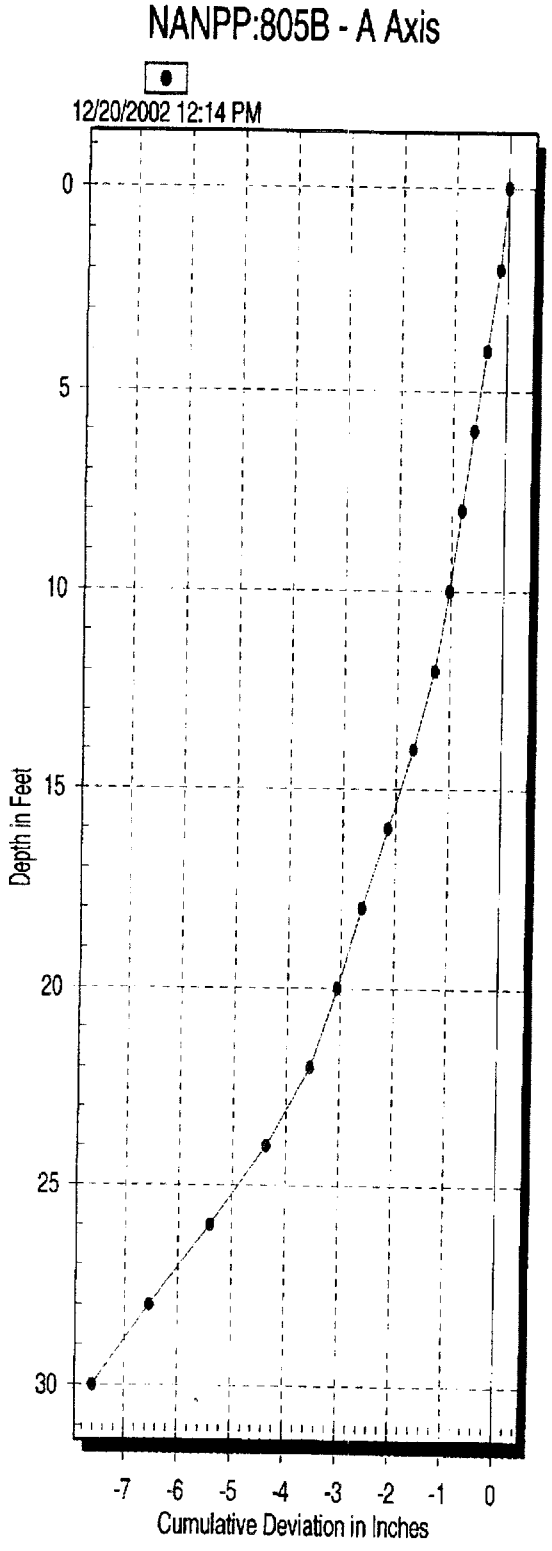
SITE : NANPP
INSTALLATION : 805B
DESCRIPTION : Entered Manually

CURRENT SURVEY : 12/20/2002 12:14:33 PM
Probe Serial No : 2591

DATE PRINTED : 12/20/2002 2:18:14 PM

Data Reduction for B Axis:

Depth (ft)	Current B0	Current B180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	24	-20	0.0211	-0.0211
4	39	-38	0.0370	-0.0581
6	1	-1	0.0010	-0.0590
8	-78	70	-0.0710	0.0120
10	-207	205	-0.1978	0.2098
12	-218	205	-0.2030	0.4128
14	-19	18	-0.0178	0.4306
16	5	-3	0.0038	0.4267
18	-78	73	-0.0725	0.4992
20	-235	230	-0.2232	0.7224
22	-409	405	-0.3907	1.1131
24	-741	737	-0.7094	1.8226
26	-1017	1009	-0.9725	2.7950
28	-1329	1324	-1.2734	4.0685
30	-1715	1717	-1.6474	5.7158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12/20/2002 12:14 PM
0
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10
15
20
25
30
Depth in Feet
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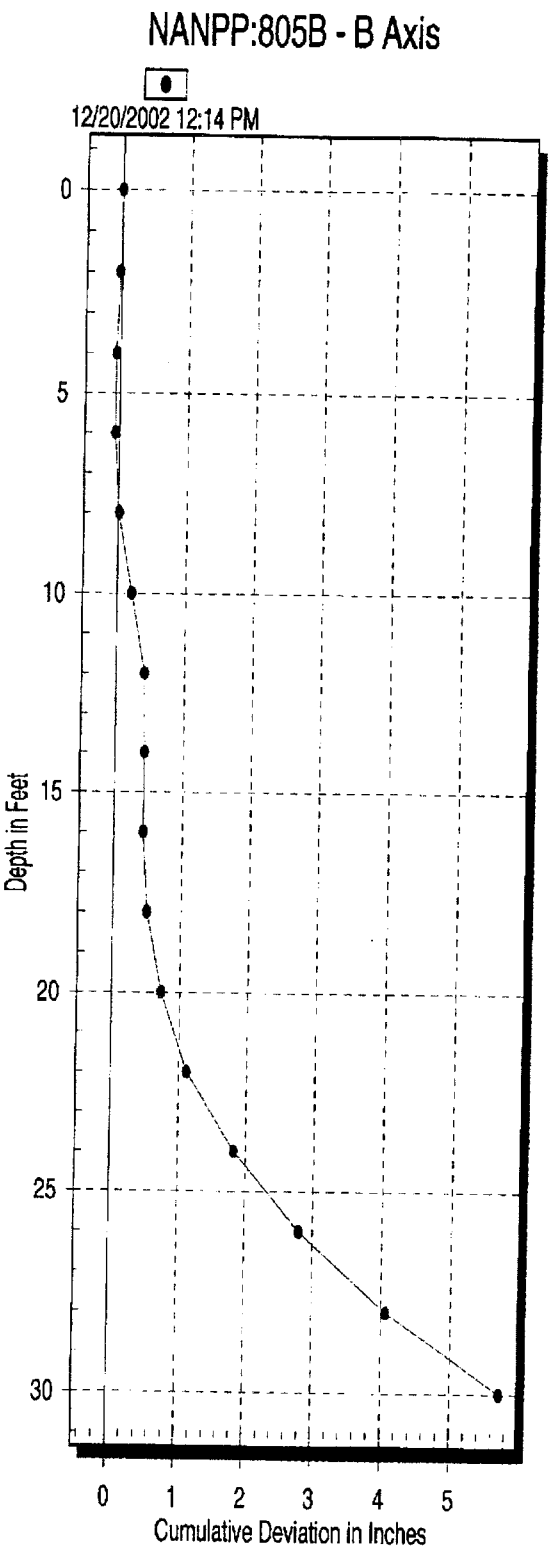
-6
-5
-4
-3
-2
-1
0
Cumulative Deviation in Inches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12/20/2002 12:14 PM
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5
10
15
20
25
30
Depth in Feet
0
1
2
3
4
5
Cumulative Deviation in Inches

SITE : NANPP
INSTALLATION : 805C
DESCRIPTION : Entered Manually

CURRENT SURVEY : 12/20/2002 12:27:39 PM
Probe Serial No : 2591

DATE PRINTED : 12/20/2002 1:32:57 PM

Data Reduction for A Axis:

Depth (ft)	Current A0	Current A180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	-82	62	-0.0691	0.0691
4	-63	49	-0.0538	0.1229
6	-42	28	-0.0336	0.1565
8	10	-21	0.0149	0.1416
10	9	-19	0.0134	0.1282
12	-101	92	-0.0926	0.2208
14	-280	270	-0.2640	0.4848
16	-438	430	-0.4166	0.9014
18	-433	420	-0.4094	1.3109
20	-210	198	-0.1958	1.5067
22	-62	52	-0.0547	1.5614
24	61	-77	0.0662	1.4952
26	101	-110	0.1013	1.3939
28	205	-204	0.1963	1.1976
30	303	-316	0.2971	0.9005

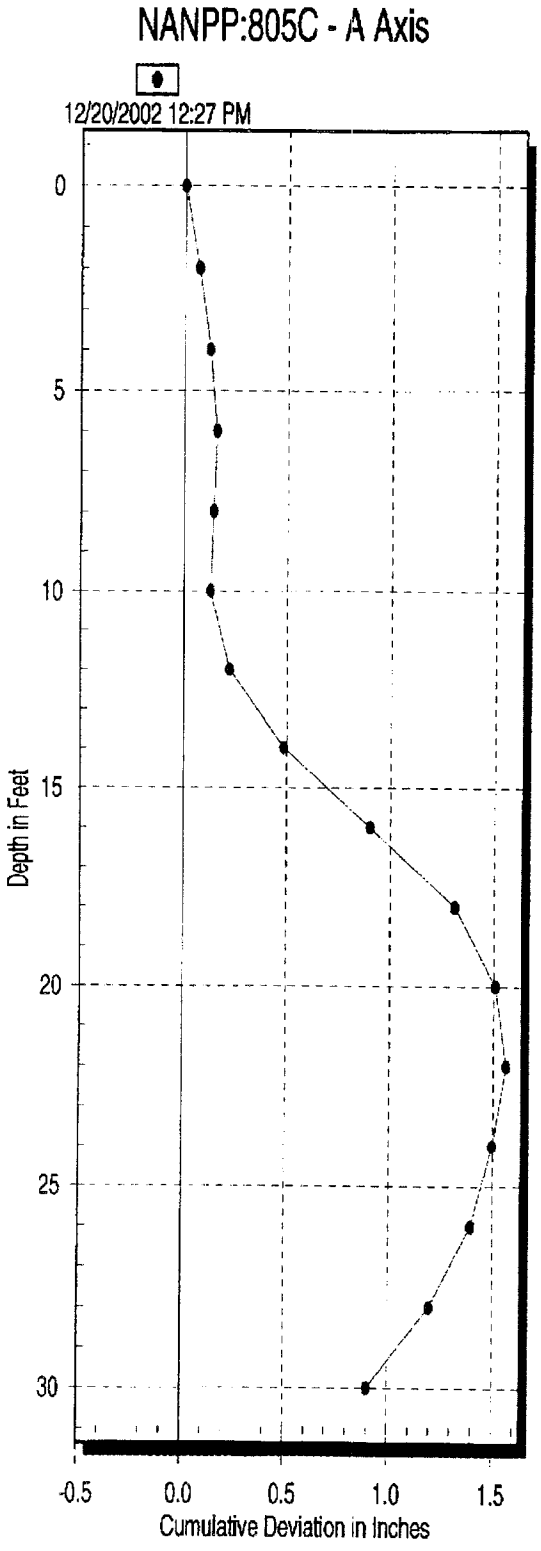
SITE : NANPP
INSTALLATION : 805C
DESCRIPTION : Entered Manually

CURRENT SURVEY : 12/20/2002 12:27:39 PM
Probe Serial No : 2591

DATE PRINTED : 12/20/2002 1:32:57 PM

Data Reduction for B Axis:

Depth (ft)	Current B0	Current B180	Current Incr. Dev. (in)	Cum. Dev. (in)
0	0	0	0.0000	0.0000
2	-75	77	-0.0730	0.0730
4	4	1	0.0014	0.0715
6	41	-40	0.0389	0.0326
8	29	-34	0.0302	0.0024
10	-11	16	-0.0130	0.0154
12	-86	84	-0.0816	0.0970
14	-194	206	-0.1920	0.2890
16	-336	332	-0.3206	0.6096
18	-484	481	-0.4632	1.0728
20	-610	599	-0.5803	1.6531
22	-796	791	-0.7618	2.4149
24	-1062	1059	-1.0181	3.4330
26	-1222	1209	-1.1669	4.5998
28	-1488	1476	-1.4227	6.0226
30	-1869	1848	-1.7842	7.8067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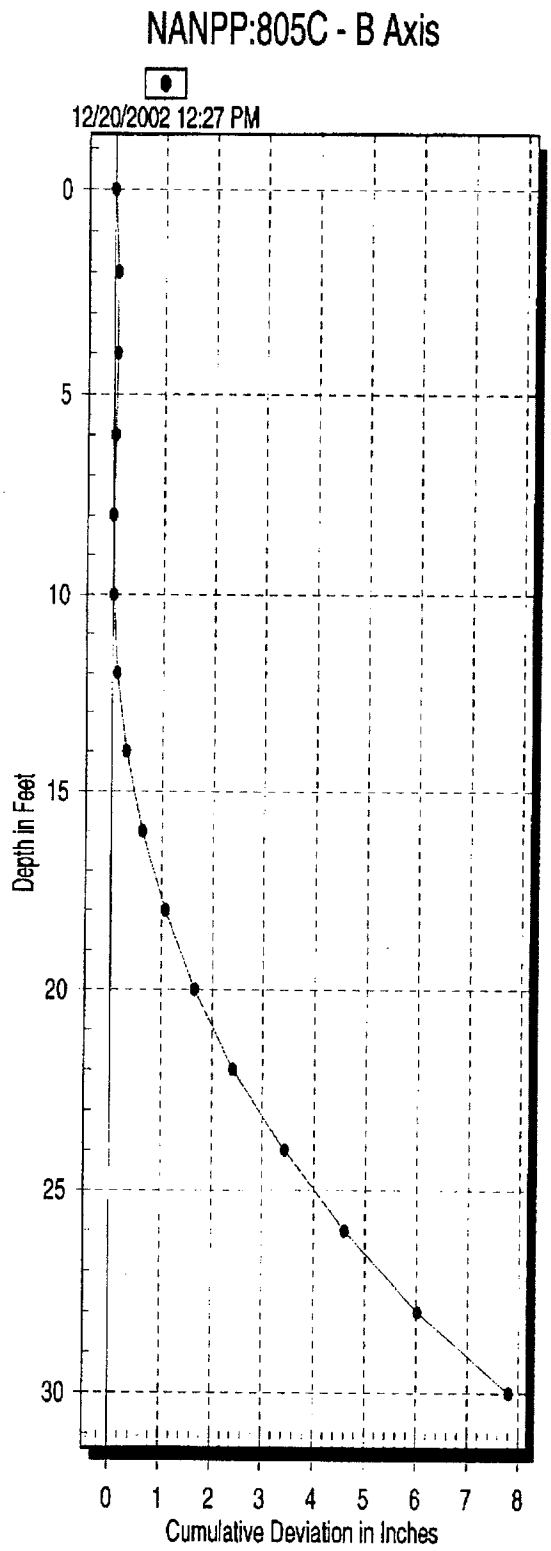
12/20/2002 12:27 PM
Depth in Feet
0
5
10
15
20
25
30
-0.5
0.0
0.5
1.0
1.5
Cumulative Deviation in Inches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12/20/2002 12:27 PM
Depth in Feet
0
5
10
15
20
25
30
0
1
2
3
4
5
6
7
8
Cumulative Deviation in Inches

APPENDIX H
CROSSHOLE SEISMIC REPORT AND DATA

Grumman Exploration, Inc.
2309 Dorset Road
Columbus, Ohio 43221
(614) 488-7860 tel; (614) 488-8945 fax

Non-destructive Subsurface Exploration
Near-surface Geophysics

January 14, 2003

Mr. J. Allan Tice
Mactec Engineering and Consulting Services, Inc.
3301 Atlantic Avenue
Raleigh, NC 22080

RE: Report of Cross-hole Seismic Testing, North Anna ESP Project, North Anna Nuclear Facility, Lake Anna, Virginia, GEI Project No. 01-22089, MACTEC JOB NO. 30720-2-5400

Dear Al:

Grumman Exploration, Inc. has completed the cross-hole seismic testing at the above referenced site located on Lake Anna, Virginia. This letter-report summarizes the field procedures used and results of the tests performed at this site. The attached spreadsheets and plots summarize the estimated seismic velocities for the boreholes tested.

Project Description

Mactec Engineering and Consulting Services, Inc. is engaged in geotechnical investigations at the above referenced site. Cross-hole seismic testing was requested to assist in the evaluation and design of possible structures and foundations proposed for this location. Among the requirements and assumptions of the cross-hole testing procedure are: homogeneous isotropic subsurface materials, horizontal layering of subsurface materials, receiver hole verticality, minimal lateral stratigraphic variability and low ambient noise. Estimating a P or S wave arrival time onset can be complicated by the presence of noise and other interfering wave trains.

Field Procedures

Grumman Exploration, Inc. conducted cross-hole seismic tests using boreholes B-805a, b, and c , and B-802a, b and c on December 12, 2002 as specified by Mactec Engineering and Consulting Services, Inc. The cross-hole seismic tests were performed in accordance with D-ASTM D4428/D4428M, with minor, approved exceptions noted on the field log. The depth of the two sets of test borings was approximately 29-ft and 92-ft for borings B-805 and B-802 respectively. The cross-hole tests in B-802 was performed in the bedrock portion of the hole (deeper than ~25-ft), while the testing performed in B-805 was performed entirely in the unconsolidated portion of the overburden. The receiver borings were lined with 2.875" diameter PVC inclinometer casing that were grouted in-place using a cement bentonite grout. Borehole deviation surveys were performed by Mactec Engineering and Consulting Services, Inc.

The following field equipment and procedures were used to conduct the tests:

- Geometrics, Inc. SmartSeis S-12, 12 channel, digital signal enhancement seismograph,
- Dual triaxial geophones, with mechanical sidewall clamping mechanisms [receiver holes], and
- Reversible polarity, dowhole impulse hammer source with trigger [shot hole]

In B-805 (soil/weathered rock boring), the tests were performed at intervals that corresponded to the approximate centers of the soil sampling intervals. In B-802, the tests were performed at 5-ft intervals to the end of the boring. The nominal receiver hole separation at the ground surface was approximately 10-ft however borehole deviation surveys were performed by Mactec Engineering and Consulting Services, Inc. The test preparation procedures consisted of lowering each geophone to the desired test depth in each receiver hole. The impulse source was placed in the shot hole to the corresponding testing depth. The impulse source was activated multiple times until a satisfactory signal response was obtained. Two separate tests were performed at each depth. Between 2 and 6 impacts per test were stacked to help enhance the P and S-wave signatures and cancel spurious noise effects. Sampling intervals of 0.03125 and 0.064 milli-seconds [msec] and record lengths (sweep-times) of between 64 and 128 milli-seconds were used. A total of 2048 samples were digitally recorded per channel per shot and no filtering was used during acquisition. The seismograph was calibrated by the manufacturer two-weeks prior to the tests and the geophones were also manufactured and purchased new within three weeks of the tests. Sources of possible noise and other interfering vibrations included vehicle traffic, construction activity, heavy machinery operation and nearby concrete cutting operations.

The data were observed and recorded in the field during acquisition and later returned to the offices of Grumman Exploration, Inc. for further review and analysis. The analysis consisted of estimating the earliest onset of the P-wave and S wave for each depth level tested. Some of the S-waves were analyzed by comparing similar S-wave onsets, peaks and/or zero crossings

across the seismic traces. A computer program developed by Grumman Exploration, Inc. was used to extract and display the raw, unfiltered P and S-wave traces for each test interval. No alteration (e.g. filtering, processing) of the raw signals was performed. Using the arrival time estimates and the measured ground-level receiver-hole separation distance, P and S wave velocities were calculated for each depth interval. The vertically aligned geophones (channels 1 and 4) were used primarily for the S-wave analysis and the lateral geophones for the compressional (p-wave) assessment. Copies of the seismic waveforms used in the interpretation are attached.

Cross-hole Seismic Testing Results

The attached spreadsheets summarizes the cross-hole seismic testing results for test hole locations B-802 and B-805 at the North Anna ESP Project site. Each spreadsheet represents a separate test performed at each depth. The spreadsheets include summaries of the P and S-wave arrival times, the calculated estimates of apparent P-wave and S-wave velocity and poisson's ratio for each test interval. Graphs illustrating these results are also included with each spreadsheet and as separate figures.

B-805 (soil/unconsolidated overburden)

The cross-hole seismic waveforms were reasonably clear and uncomplicated by noise interference with the exception of the deepest test intervals, near the bedrock contact. The downhole seismic impulse source is optimized for the Shear (S)-wave and the S-wave onset was more readily apparent than the earlier P-wave on the waveforms for B-805. The compressional (P)-wave onset was complicated by high-frequency noise, particularly at the deepest test intervals. The computed compressional wave velocities (Vp) generally appear higher than would be anticipated given the observed soil/overburden profile. Possible explanations for the elevated Vp include the presence of higher velocity weathered bedrock within the overburden, saturation of the deeper test intervals, and possible P-wave arrival time estimation inaccuracies caused by excessive noise interference.

B-802 (bedrock)

Severe high frequency noise appears to have severely degraded the overall quality of the B-802 results and complicated the interpretation of these results. A possible shear wave arrival was apparent only on the tests performed from 27-ft to approximately 45-ft. Deeper than 45-ft, no apparent shear-wave could be discerned from the results. Although excessive high-frequency noise severely complicated all of the recorded waveforms, no clear late-time waveforms (e.g. possible shear-waves) were apparent on the deeper records (>~45-ft). No compressional wave waves could be clearly interpreted on the seismic records. The compressional waveforms, if present, may have been obscured by the high-frequency noise. The observation of the P-wave onset may have been further complicated by the anticipated high Vp in the bedrock interval and resultant very small arrival time differential between receiver locations. The bedrock within the test area appears to readily transmit high-frequency noise from various noise sources throughout

the site. An attempt to filter the seismic traces was performed, however, the results did not appear to improve the interpretation of the waveforms.

General Qualifications

It is considered possible that one or more of the circumstances noted below may have affected the P and S-wave velocities or their estimation through various regions of the subsurface. Bias in the arrival time picks and consequently the velocity estimates may be the result of one or more possible circumstances including: inaccuracies in the wave arrival time picks, irregular or incomplete borehole annular space filling, refraction effects, lateral stratigraphic changes, limitations on the resolution of the digitized signal, and the presence of interfering noise and other wavetrains.

The cross-hole seismic data presented herein represent estimates of subsurface properties in the interval between the two receiver boreholes tested using the measurement procedures described above. No warranty, certification, or statement of fact, either expressed or implied, regarding actual subsurface properties surrounding the borehole tested is contained herein. If questions or uncertainties exist regarding the actual parameter values, supplemental in-situ or laboratory tests or other invasive explorations should be conducted to document actual subsurface material properties. No inference of subsurface properties can be made for depth intervals not tested.

Grumman Exploration, Inc. has appreciated this opportunity to be of service again to Mactec Engineering and Consulting Services, Inc. If you have any questions or comments regarding this report, please feel free to contact us.

Sincerely,

Grumman Exploration, Inc.

David L. Grumman, Jr.
President/Geophysicist

Attachments:

Spreadsheets:
B802 Xhole Seismic.xls
B805 Xhole Seismic.xls
Figure 1 (B-805)
Figure 2 (B-802)
Field data acquisition logs for B-802 and B-805

Grumman Exploration, Inc.
2309 Dorset Road, Columbus, Ohio 43221
(614) 488-7860 tel, (614) 488-8945 fax

Cross-Hole Seismic Testing Summary Table

Test/Well ID: **B-802**
Project: **Noth Anna ESP Project**
Location: North Anna Power Station, Mineral, Virginia
Client/Owner: Mactec
Well Descr.: 2.875" PVC/inclinometer, grouted, ~92' depth

Test Date: 12/12/2002
Calc. Date: 1/14/2003
Field Staff: dlg
Data Proc by: dlg

Grumman Exploration, Inc.
2309 Dorset Road
Columbus, Ohio 43221-3145
(614) 488-7860 tel

Test Interval Depth (ft)	Interval Velocity (ft/sec) V_p	Interval Velocity (ft/sec) V_s	Soil Density (pcf) γ	Shear Modulus G	Bulk Modulus K	Young's Modulus E	Poisson's Ratio υ	Depth (ft)	Material Descr/Class
27.00		4508						27.00	
30.00		5334						30.00	
30a		5204						30a	
35.00		5997						35.00	
40.00		5208						40.00	
40a		5468						40a	
45.00		5556						45.00	
50.00								50.00	
55.00								55.00	
60.00								60.00	
60a								60a	
65.00								65.00	

Downhole Seismic Testing Field Data Spreadsheet

Test/Well ID: B-802

Project: **Noth Anna ESP Project**

Location: North Anna Power Station, Mineral, Virginia

Client/Owner: Mactec

Grumman Exploration, Inc.

Nominal Test Hole Separation: ~10 ft

Test Depth	Notes	Est'd Velocity (fps) V_P	Est'd Velocity (fps) V_S	Esimated Wave Arrival Time (msec) P_{805B}	Esimated Wave Arrival Time (msec) P_{805A}	Esimated Wave Arrival Time (msec) S_{805B}	Esimated Wave Arrival Time (msec) S_{805A}	receiver separation (ft)[1]
27.0			4508	n/a	n/a	2.25	4.60	10.593
30.0			5334	n/a	n/a	2.00	4.00	10.668
30a	repeat		5204	n/a	n/a	1.95	4.00	10.668
35.0			5997	n/a	n/a	1.50	3.30	10.794
40.0			5208	n/a	n/a	2.10	4.20	10.937
40a	repeat		5468	n/a	n/a	2.05	4.05	10.937
45.0			5556	n/a	n/a	2.50	4.50	11.112
50.0				n/a	n/a	n/a	n/a	11.299
55.0				n/a	n/a	n/a	n/a	11.504
60.0				n/a	n/a	n/a	n/a	11.737
60a	repeat			n/a	n/a	n/a	n/a	11.737
65.0				n/a	n/a	n/a	n/a	12.007
70.0				n/a	n/a	n/a	n/a	12.289
75.0				n/a	n/a	n/a	n/a	12.557
80.0				n/a	n/a	n/a	n/a	12.819
80a	repeat			n/a	n/a	n/a	n/a	12.819
85.0				n/a	n/a	n/a	n/a	13.084
89.00				n/a	n/a	n/a	n/a	13.283

Field Equipment: EG&G SmartSeis S-12, 12-channel, signal enhancement siesmograph

Two Triaxial Geophones, 10-ft nominal surface separation distance centered at depth indicated

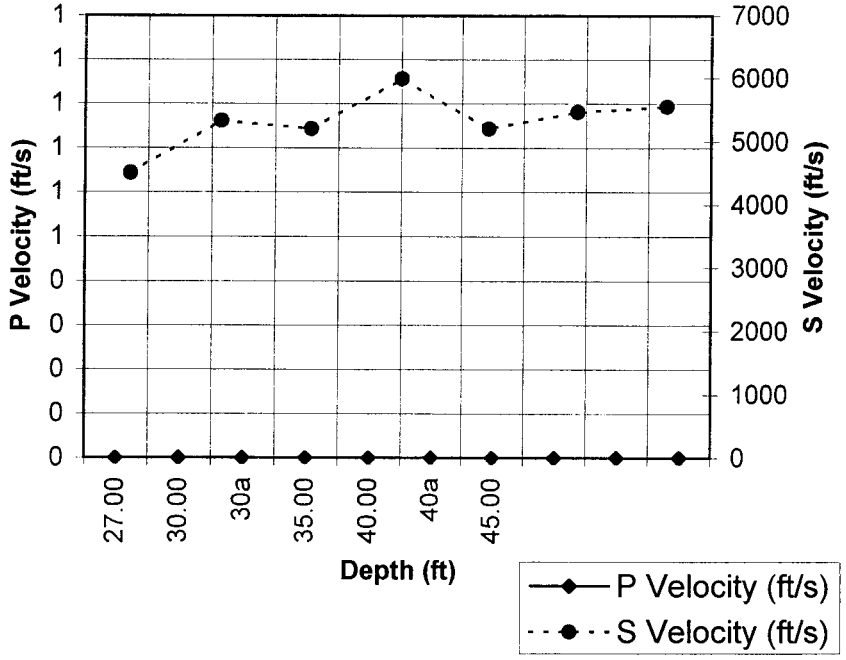
Downhole, reversible polarity hammer source

[1] Per checked deviation survey provded by Mactec

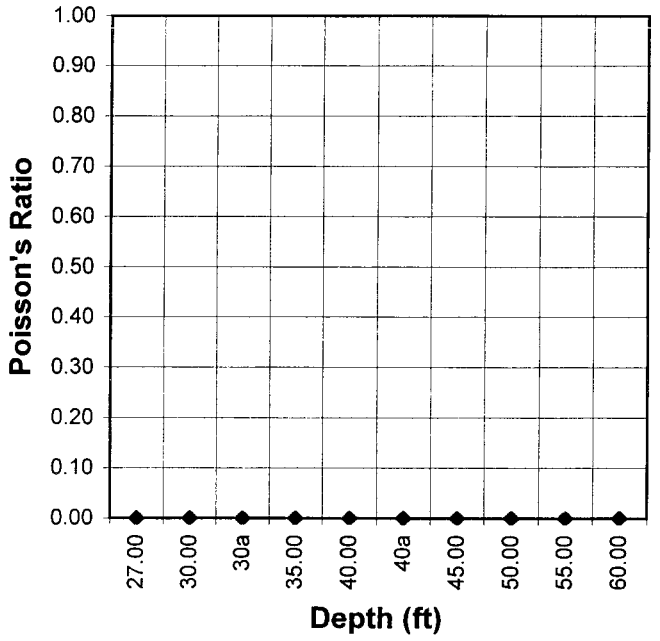
n/a uninterpretable/poor quality waveform

Test/Well ID: B-802
Project: **Noth Anna ESP Project**
Location: North Anna Power Station, Mineral, Virginia
Client/Owner: Mactec

P and S Velocity vs Depth



Poisson's Ratio vs Depth



Grumman Exploration, Inc.
2309 Dorset Road
Columbus, Ohio 43221-3145
(614) 488-7860 tel

Cross-Hole Seismic Testing Summary Table

Test/Well ID: **B-805**
Project: **Noth Anna ESP Project**
Location: North AnnaPower Station, Mineral, Virginia
Client/Owner: Mactec
Well Descr.: 2.875" PVC/inclinometer, grouted, ~29' depth

Test Date: 12/12/2002
Calc. Date: 1/14/2003
Field Staff: dlg
Data Proc by: dlg

Grumman Exploration, Inc.
2309 Dorset Road
Columbus, Ohio 43221-3145
(614) 488-7860 tel

Test Interval Depth (ft)	Interval Velocity (ft/sec) V_p	Interval Velocity (ft/sec) V_s	Soil Density (pcf) γ	Shear Modulus G	Bulk Modulus K	Young's Modulus E	Poisson's Ratio υ	Depth (ft)	Material Descr/Class
3.50	1243	612					0.340	3.50	
6.00	1245	701					0.268	6.00	
6.00	1660	604					0.424	6.00	
8.50	1658	650					0.409	8.50	
11.00	1652	748					0.371	11.00	
13.50	4936	977					0.480	13.50	
16.00	6552	936					0.490	16.00	
18.50	5741	1072					0.482	18.50	
21.00	5683	1380					0.469	21.00	
26.00	5478	1023					0.482	26.00	
26.00		1150						26.00	
27.00		1047						27.00	

Downhole Seismic Testing Field Data Spreadsheet

Test/Well ID: B-805

Project: **Noth Anna ESP Project** — Grumman Exploration, Inc.

Location: North AnnaPower Station, Mineral, Virginia — Nominal Test Hole Separation:

Client/Owner: Mactec — ~10 ft

Test Depth	Notes	Est'd Velocity (fps) V_P	V_S	Esimated Wave Arrival Time (msec) P_{805B}	P_{805A}	S_{805B}	S_{805A}	receiver separation (ft)[1]
3.5		1243	612	13.00	21.00	19.50	35.75	9.94398
6.0		1245	701	11.00	19.00	17.40	31.60	9.96011
6.0	repeat	1660	604	11.50	17.50	20.50	37.00	9.96011
8.5		1658	650	10.00	16.00	15.60	30.90	9.94764
11.0		1652	748	11.50	17.50	19.50	32.75	9.90961
13.5		4936	977	10.00	12.00	15.50	25.60	9.87221
16.0		6552	936	3.50	5.00	15.00	25.50	9.82763
18.5		5741	1072	1.50	3.20	10.60	19.70	9.75956
21.0		5683	1380	2.80	4.50	13.00	20.00	9.66105
26.0		5478	1023	2.20	3.90	11.40	20.50	9.31341
26.0	repeat		1150	3.60	n/a	11.40	19.50	9.31341
27.0			1047	3.00	n/a	10.70	19.50	9.21198

Field Equipment: EG&G SmartSeis S-12, 12-channel, signal enhancement siesmograph

Two Triaxial Geophones, 10-ft nominal surface separation distance centered at depth indicated

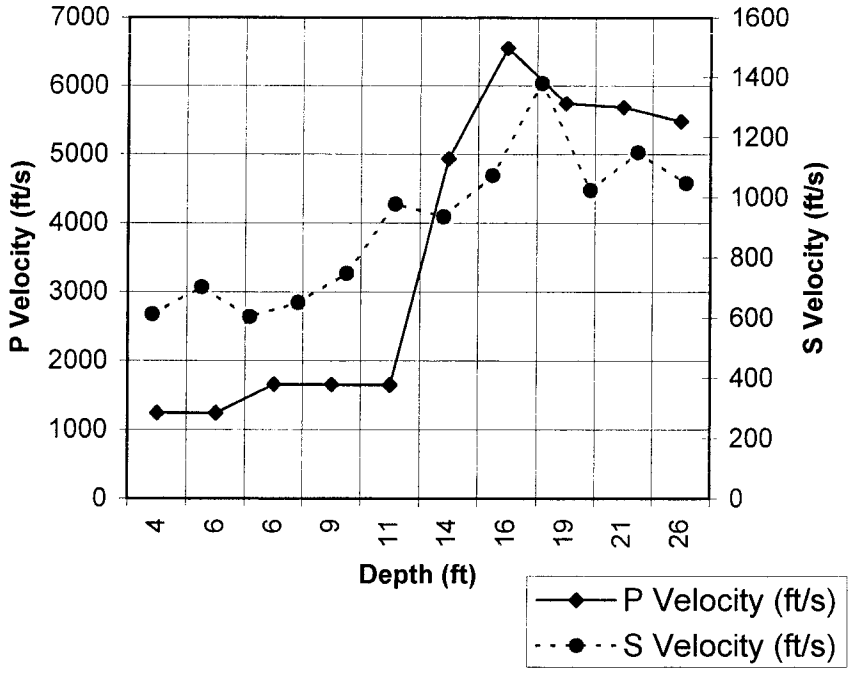
Downhole, reversible polarity hammer source

[1] Per checked deviation survey provded by Mactec

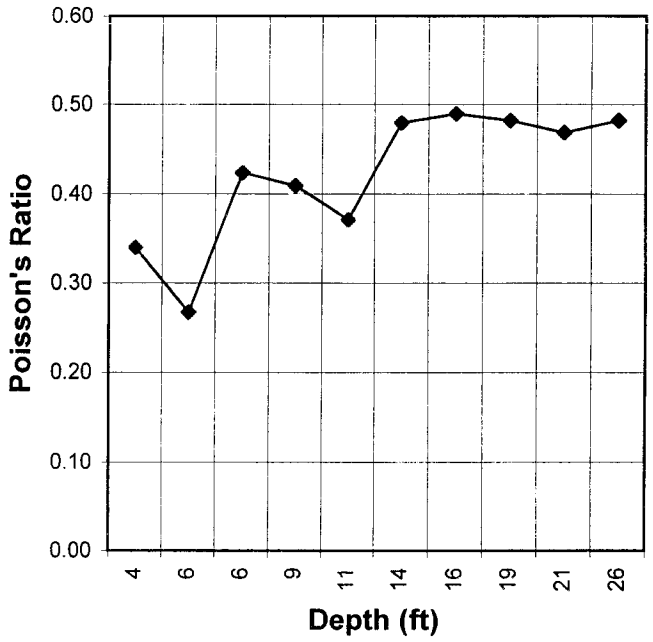
n/a uninterpretable/poor quality waveform

Test/Well ID: B-805
Project: **Noth Anna ESP Project**
Location: North AnnaPower Station, Mineral, Virginia
Client/Owner: Mactec

P and S Velocity vs Depth

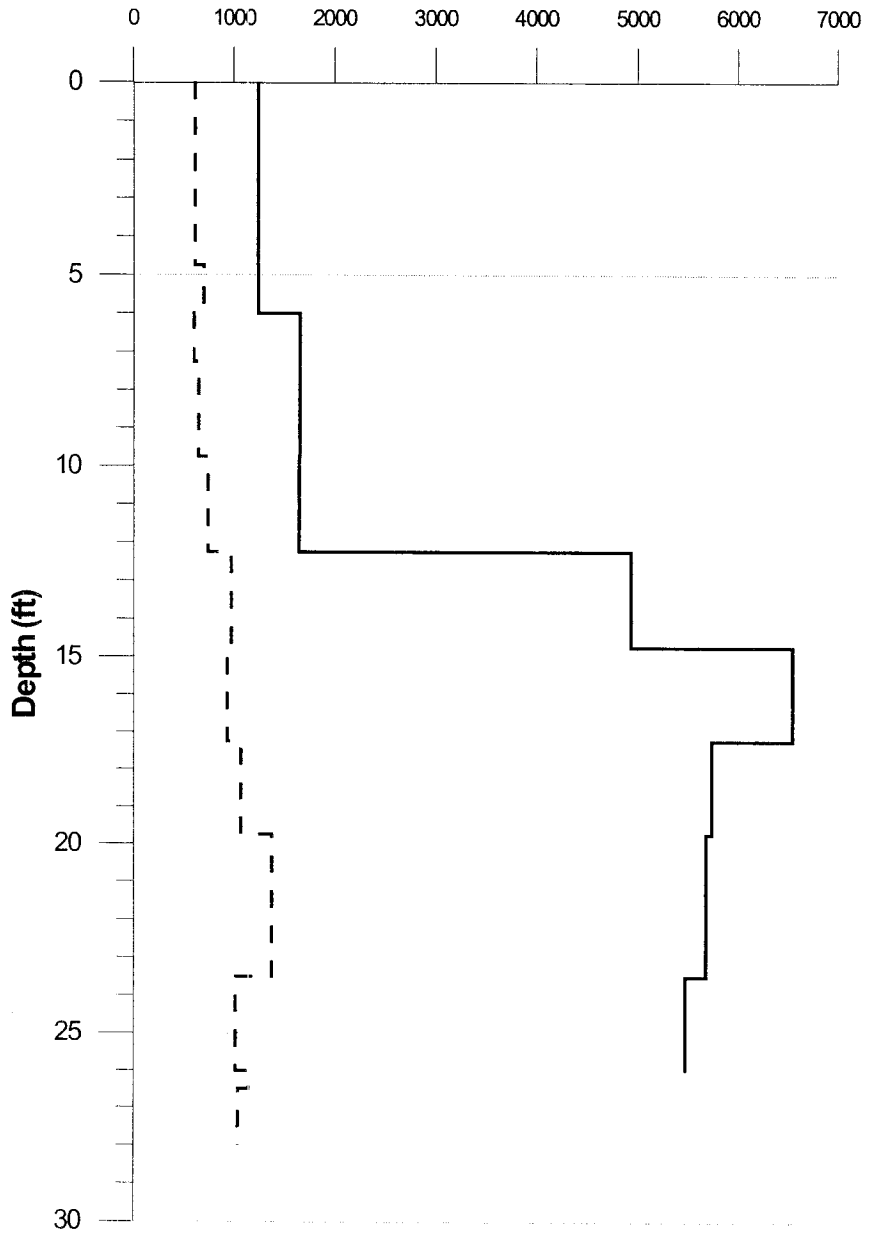


Poisson's Ratio vs Depth



Grumman Exploration, Inc.
2309 Bethel Road
Columbus, Ohio 43220-3145
(614) 488-7860 tel

Estimated Velocity (fps) B-805



Legend
- - - - - S-wave Velocity (fps)
——— P-wave Velocity (fps)

Grumman Exploration, Inc.
2309 Dorset Road, Columbus, Ohio 43221
Near-surface Geophysics, Non-destructive Subsurface Exploration

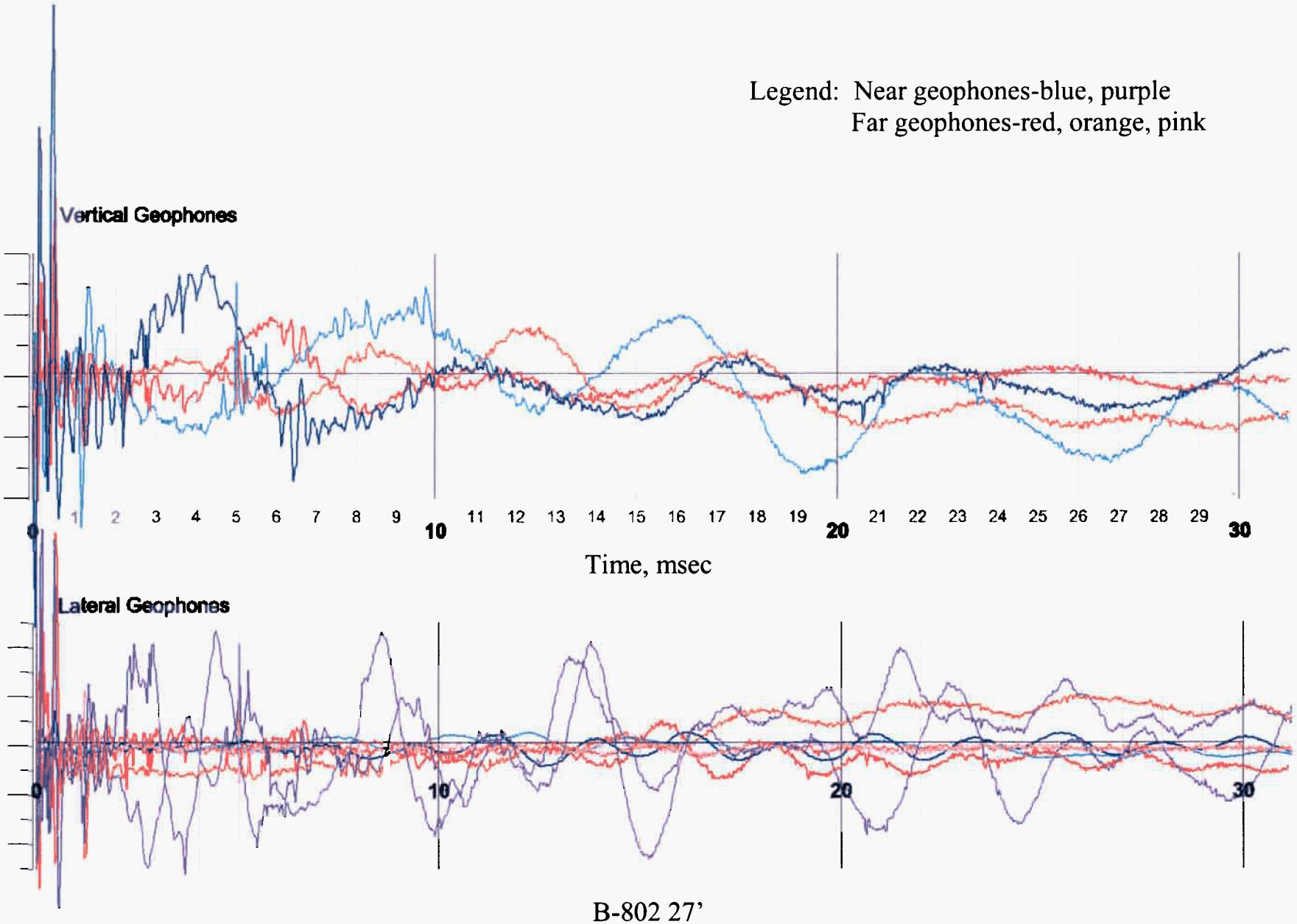
Project: North Anna ESP Project			
Location: North Anna power Station, Mineral, Virginia			
Client: Mactec Eng. Svcs.	By: dlg	Date: 1/10/03	
Project No.: 01-22089	Checked:	Scale: nts	

Figure 1 | Title: B-805, Estimated Velocity vs. Depth

WAVE FORMS FROM FIELD DATA

B-802 INCLUDES BOTH VERTICAL AND LATERAL GEOPHONES
B-805 INCLUDES ONLY THE VERTICAL GEOPHONES

GRAPHS ARE CAPTIONED BY BOREHOLE LOCATION AND DEPTH
AN "a" AFTER THE DEPTH INDICATES A REPEAT READING


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
0
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Time, msec
Lateral Geophones
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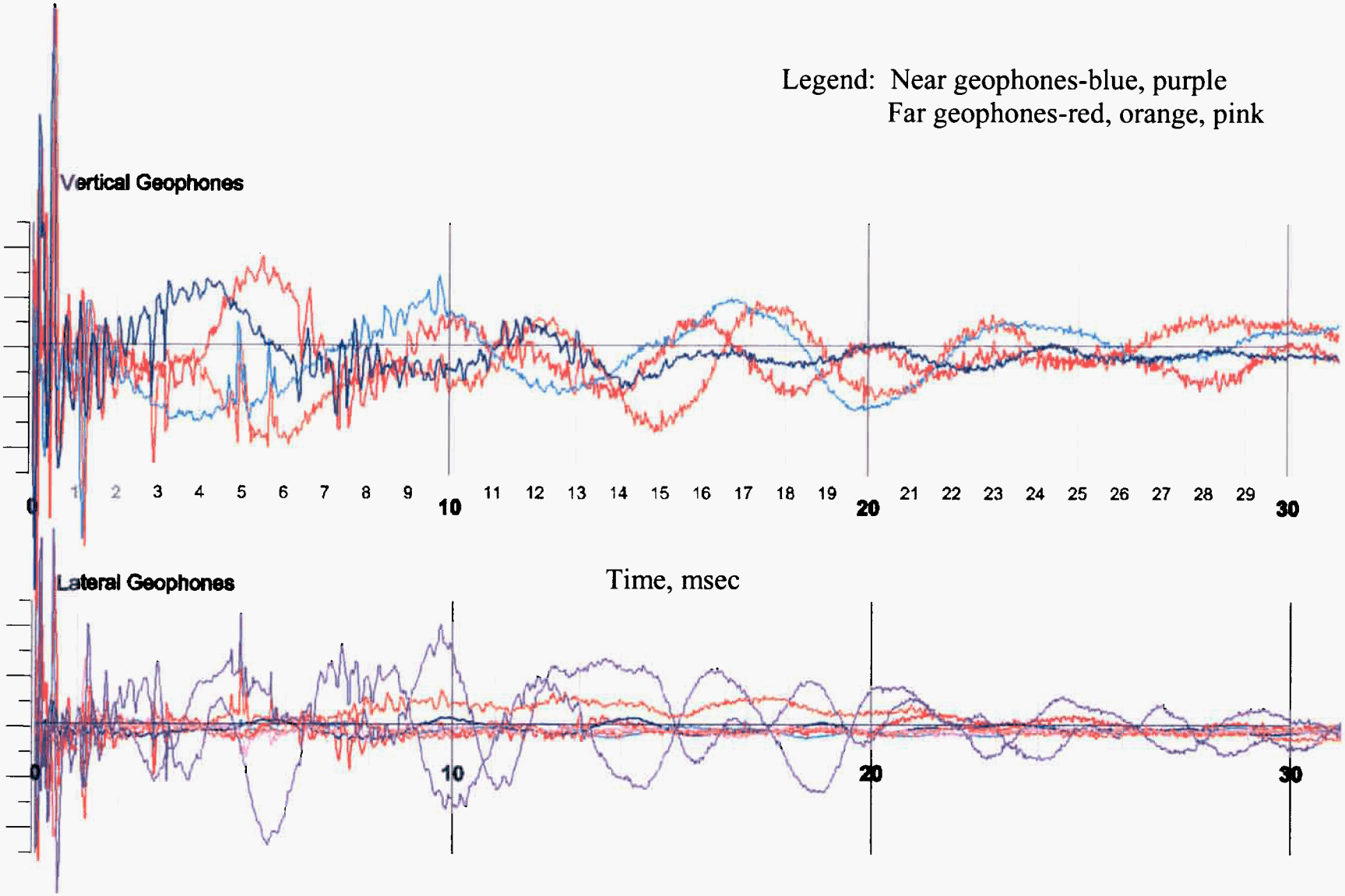
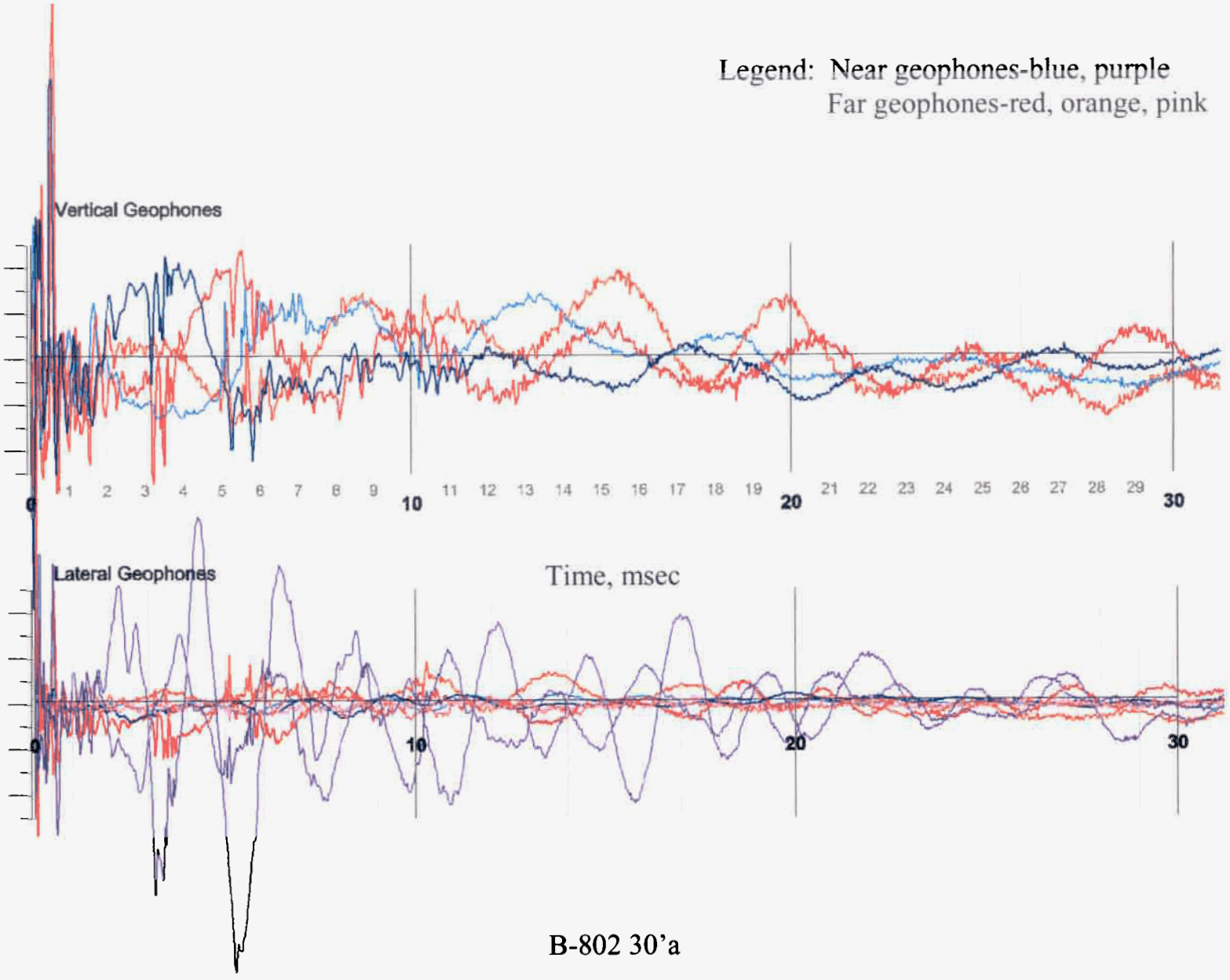
20
30

B-802 27'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Lateral Geophones
0 10 20 30
Time, msec

B-802 30'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
Lateral Geophones
Time, msec
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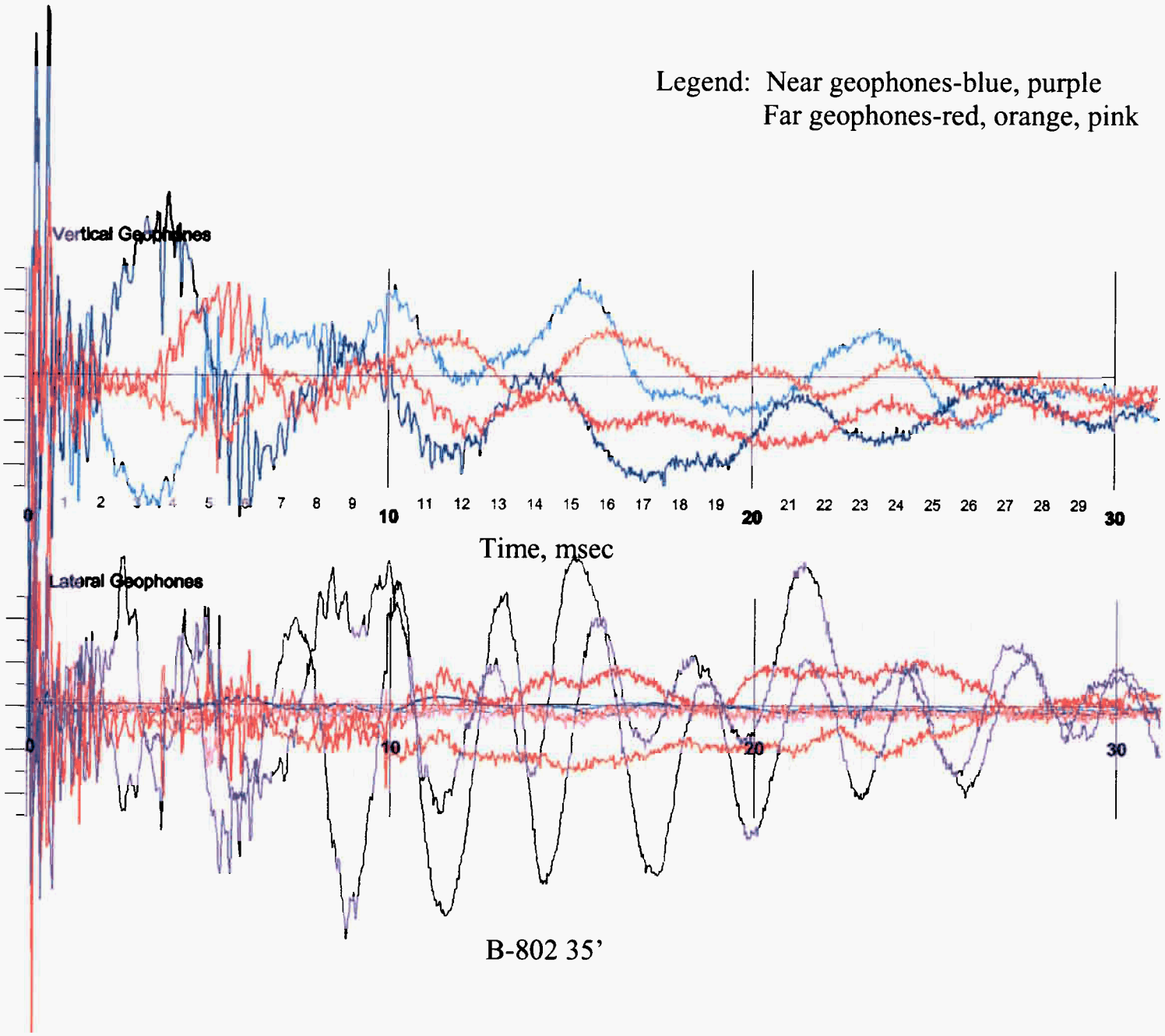
B-802 30'a


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
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Time, msec
Lateral Geophones
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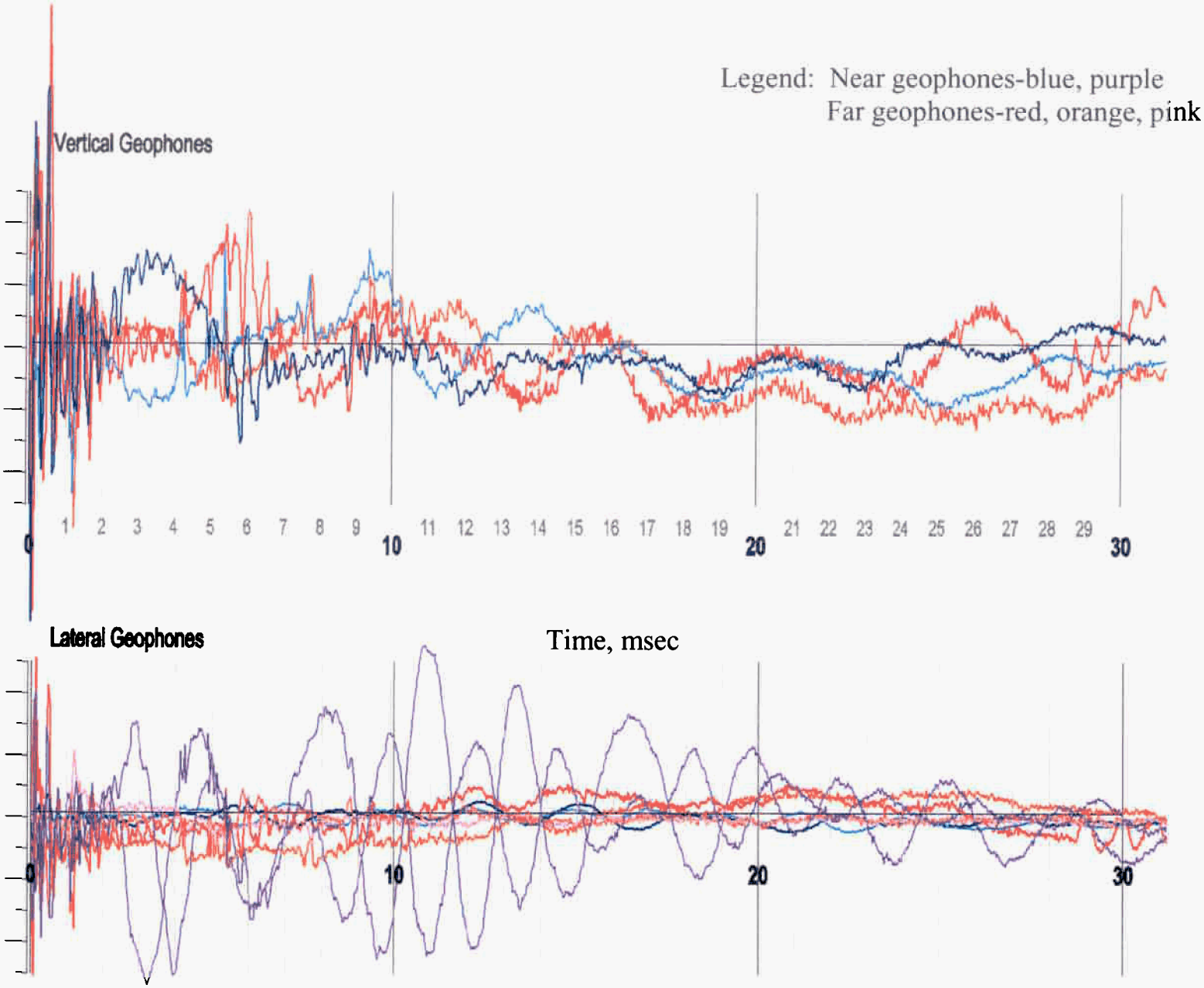
30
B-802 35'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
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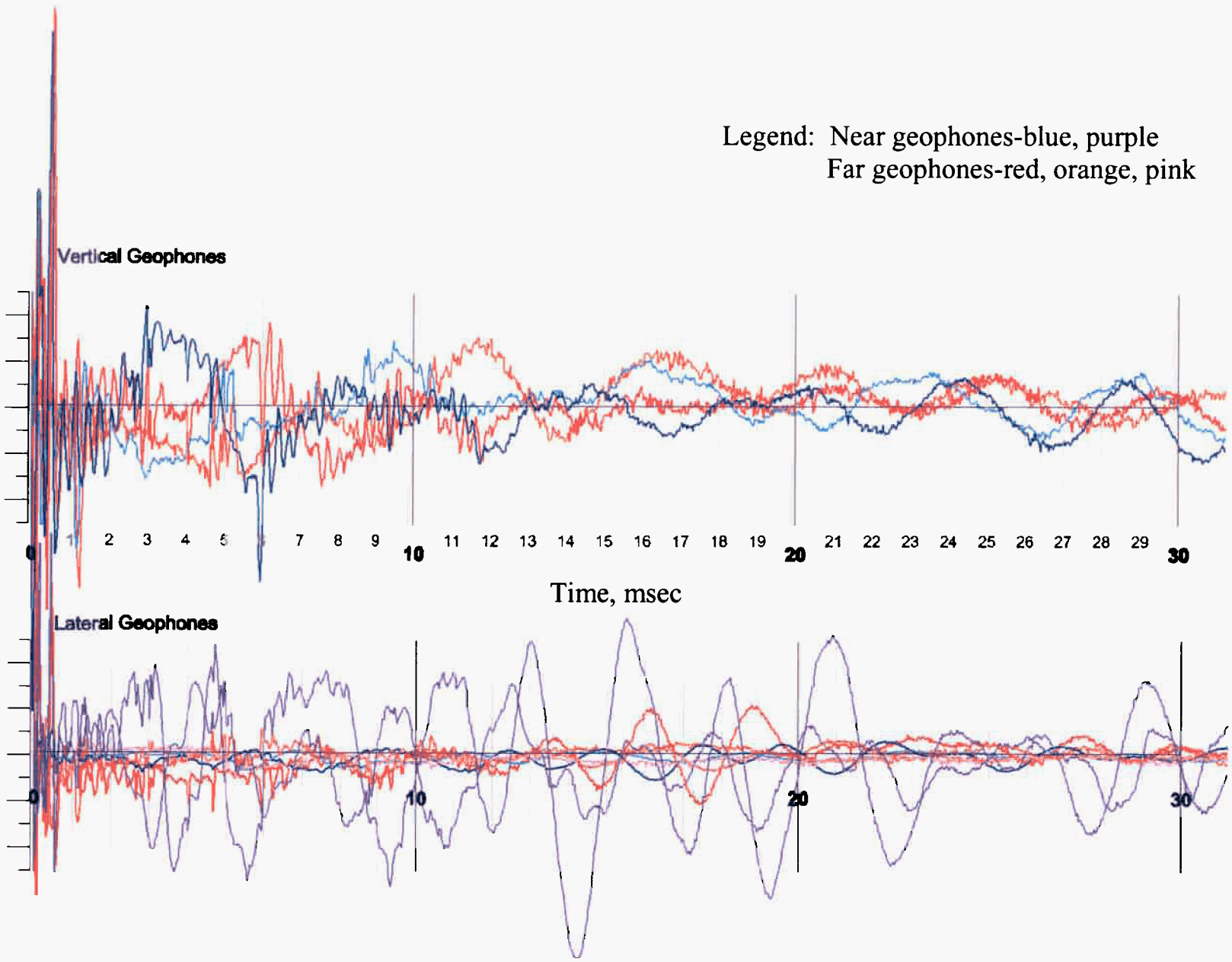
Lateral Geophones
Time, msec
0 10 20 30

B-802 40'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
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Time, msec
Lateral Geophones
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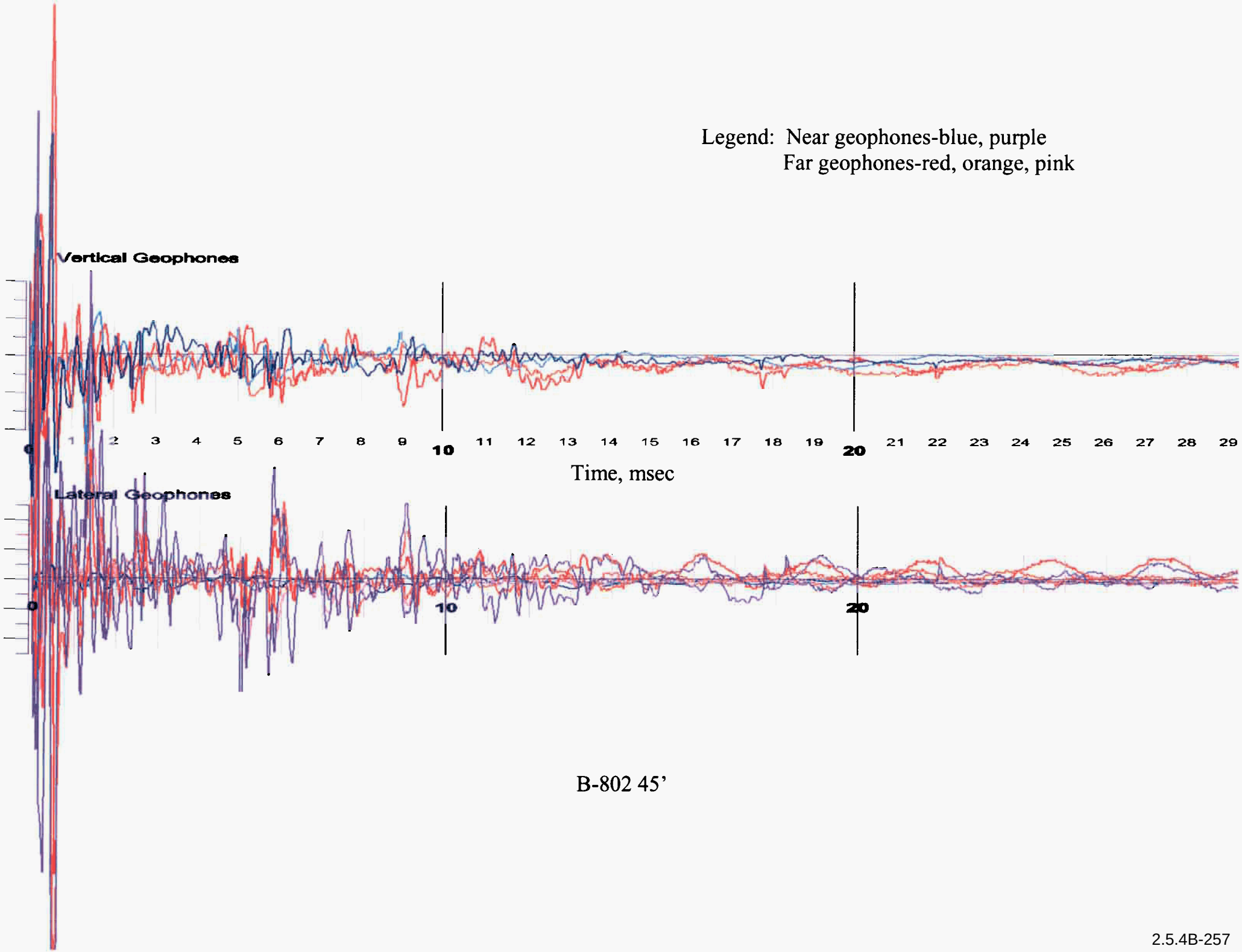
B-802 40'a


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
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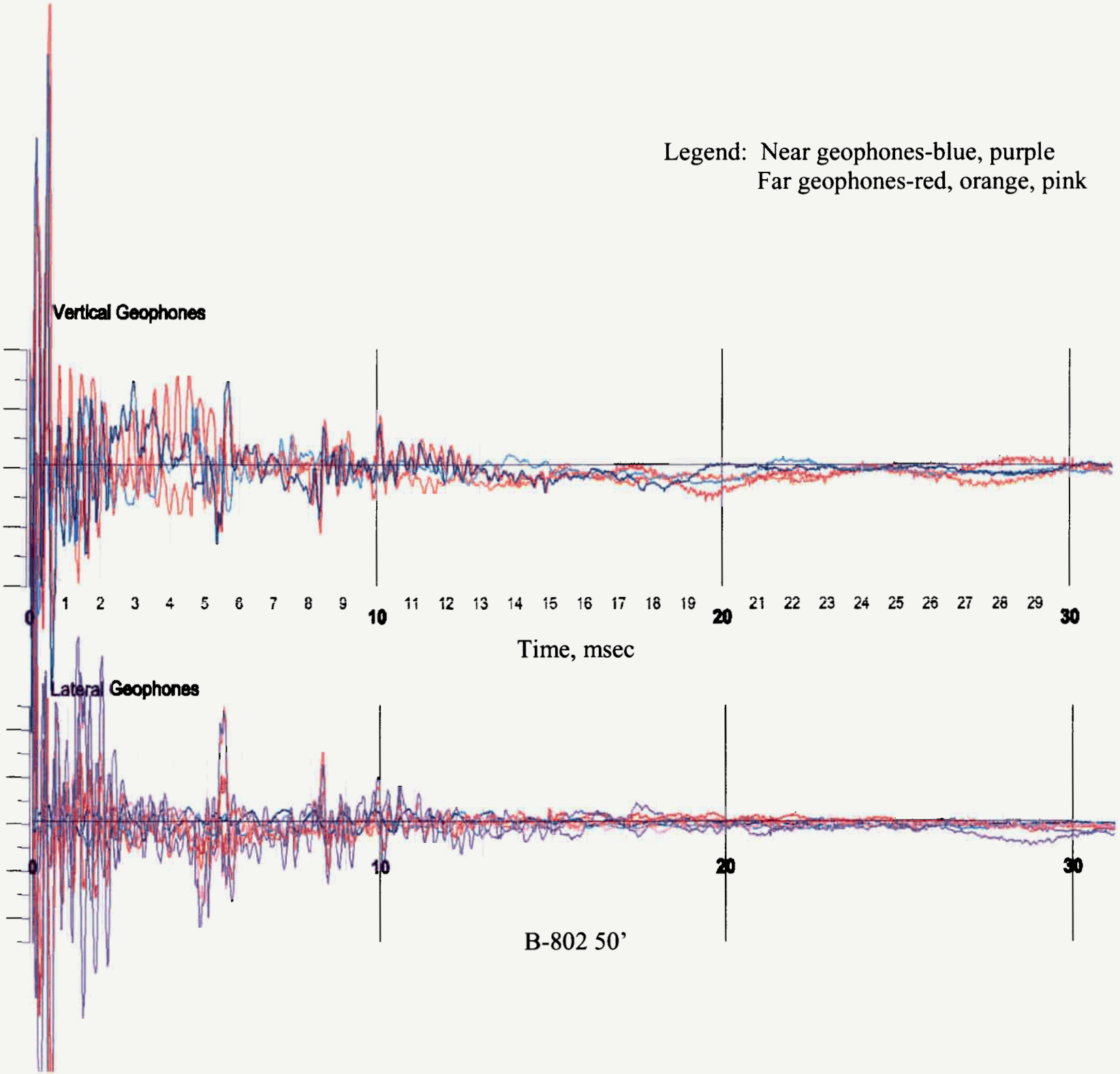
28
29
Time, msec
Lateral Geophones
0
10
20

B-802 45'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
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14
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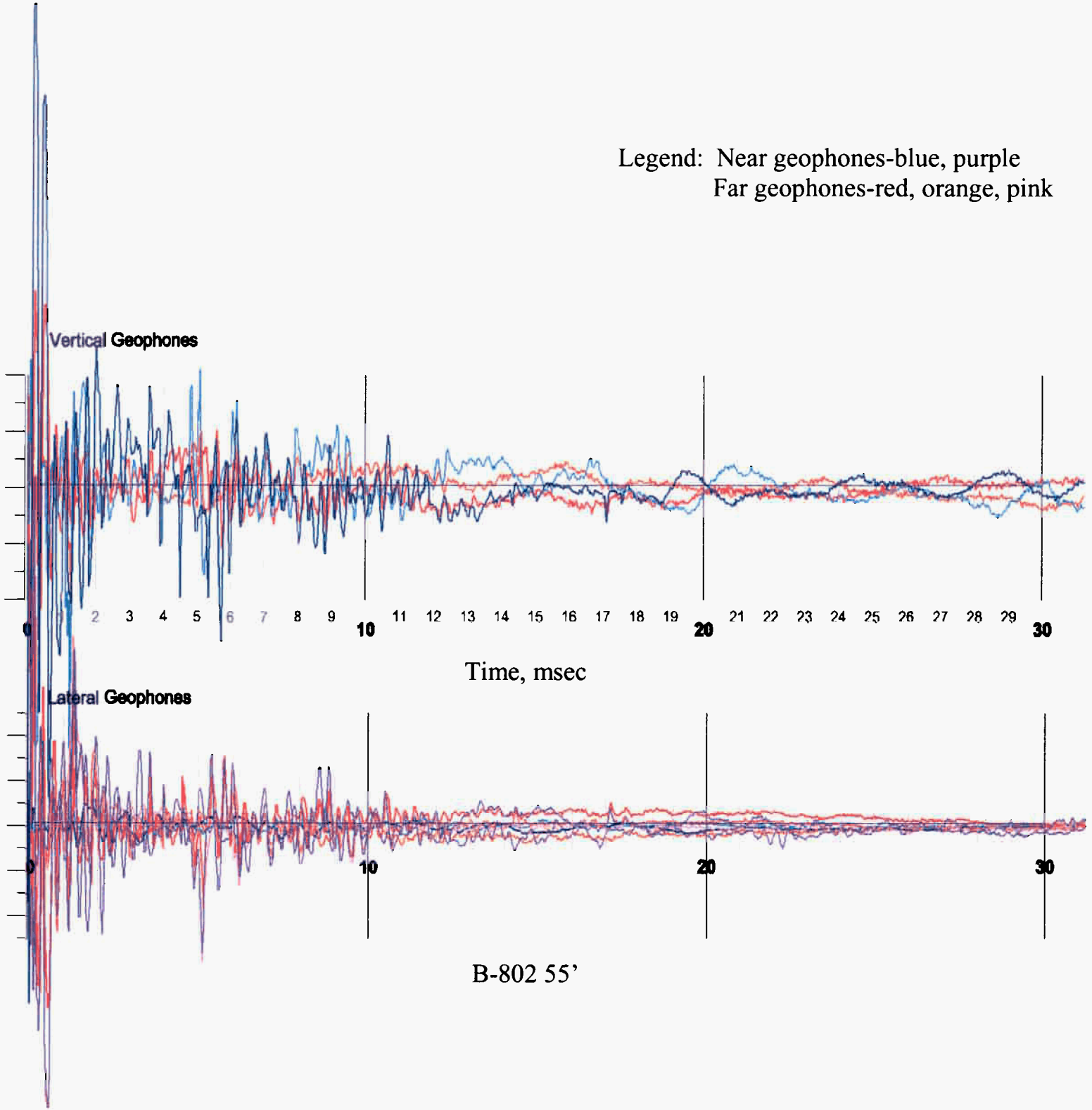
26
27
28
29
30
Time, msec
Lateral Geophones
0
10
20
30
B-802 50'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
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11
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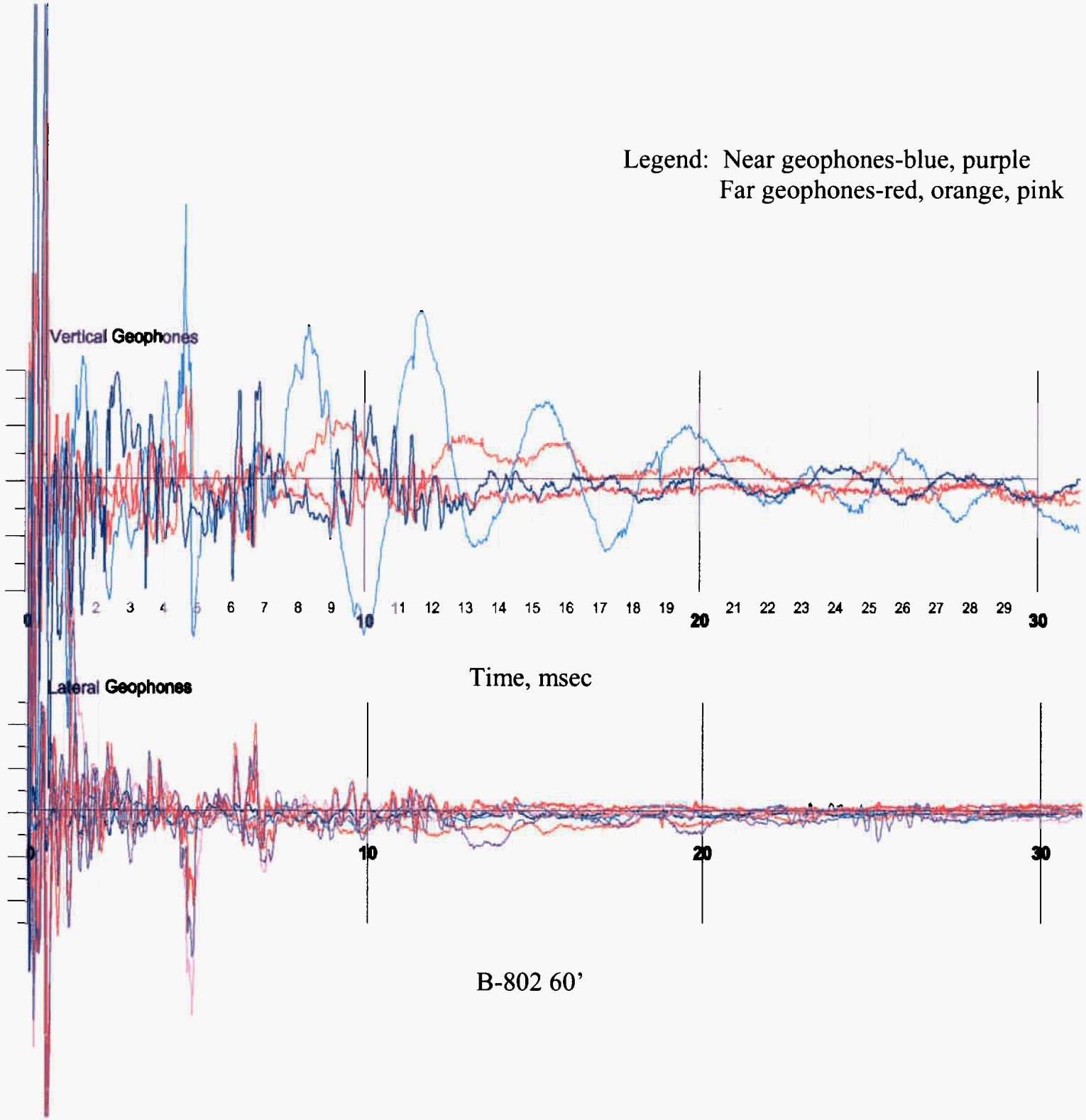
30
Time, msec
Lateral Geophones
0
10
20
30
B-802 55'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
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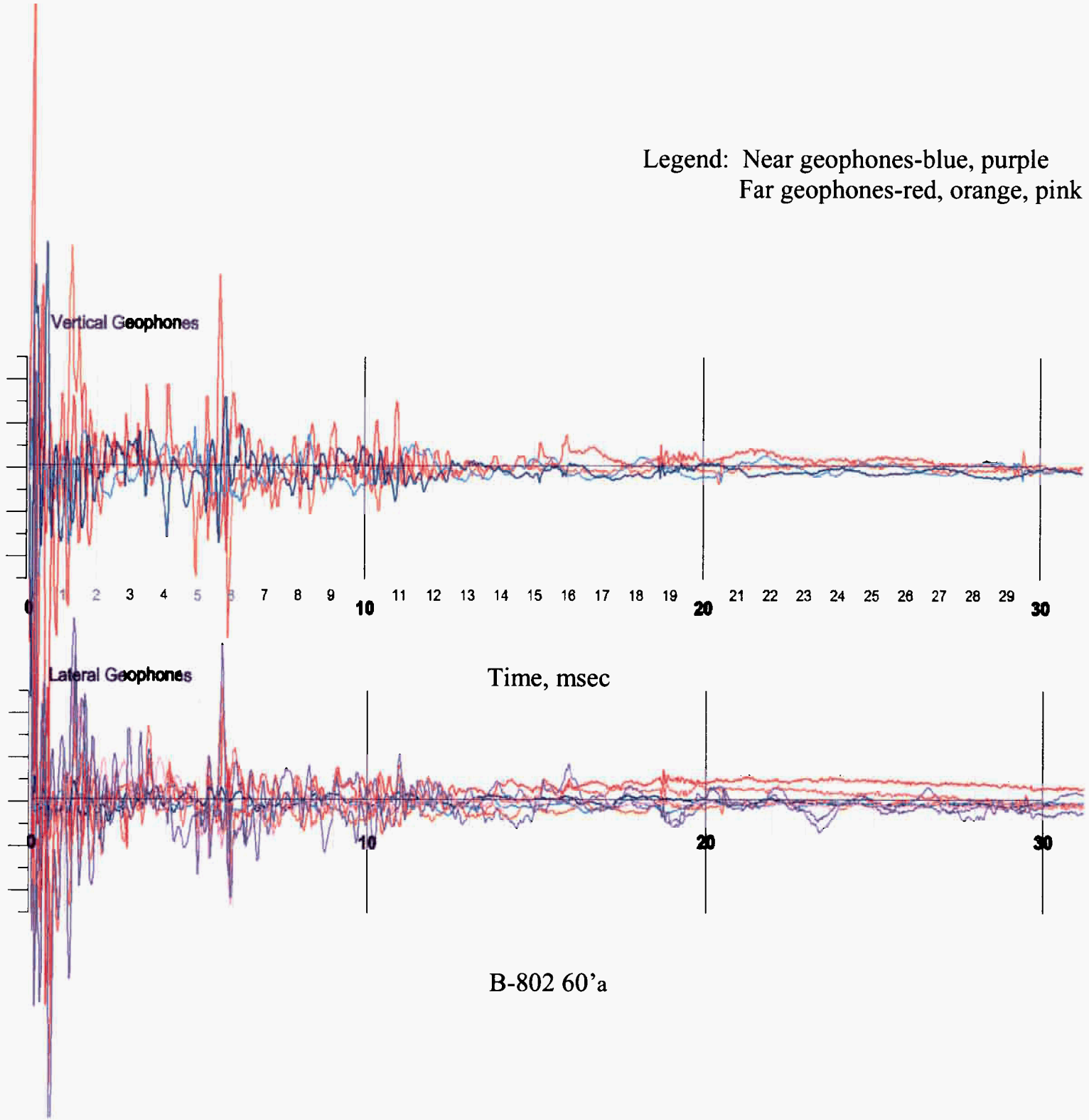
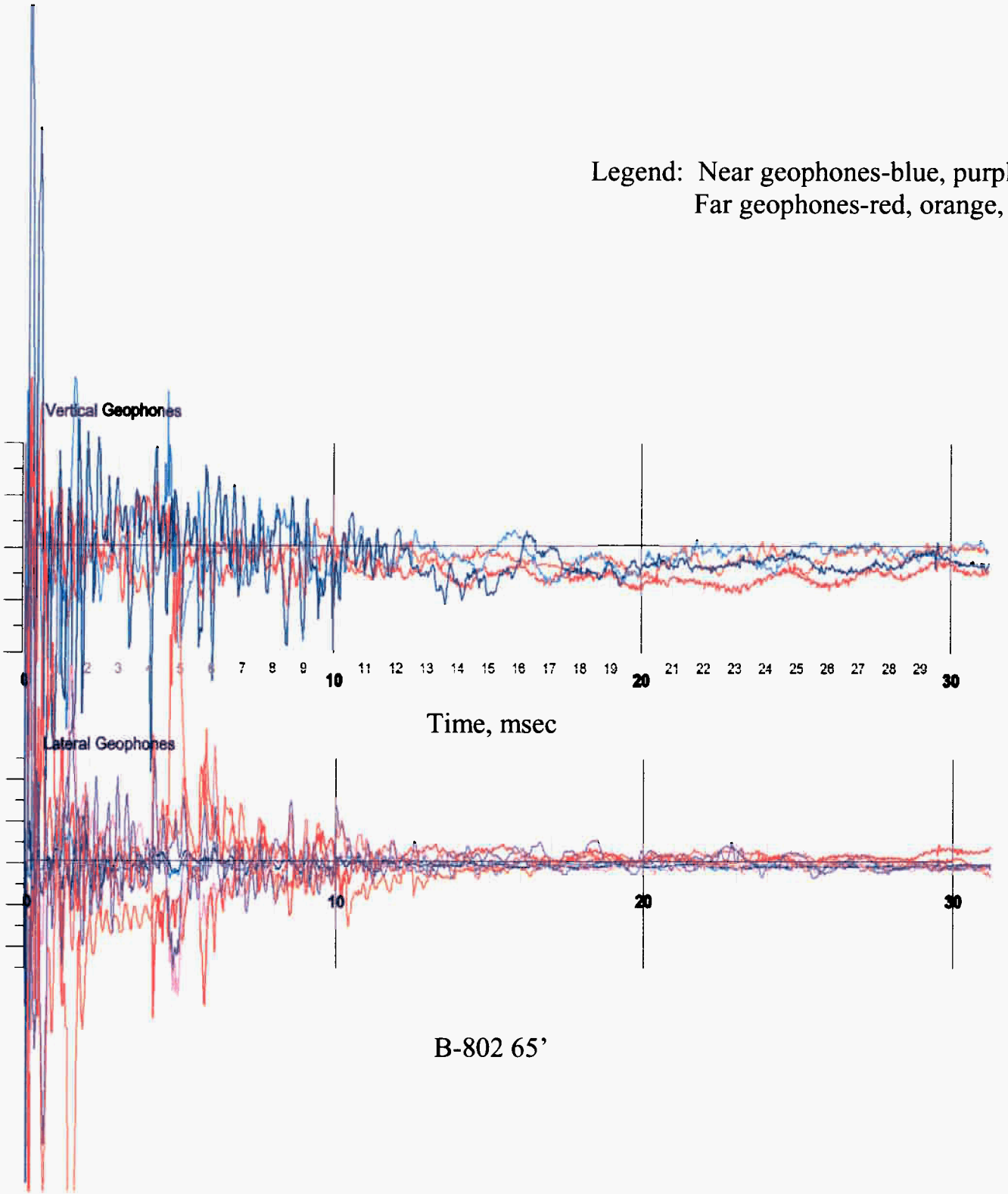
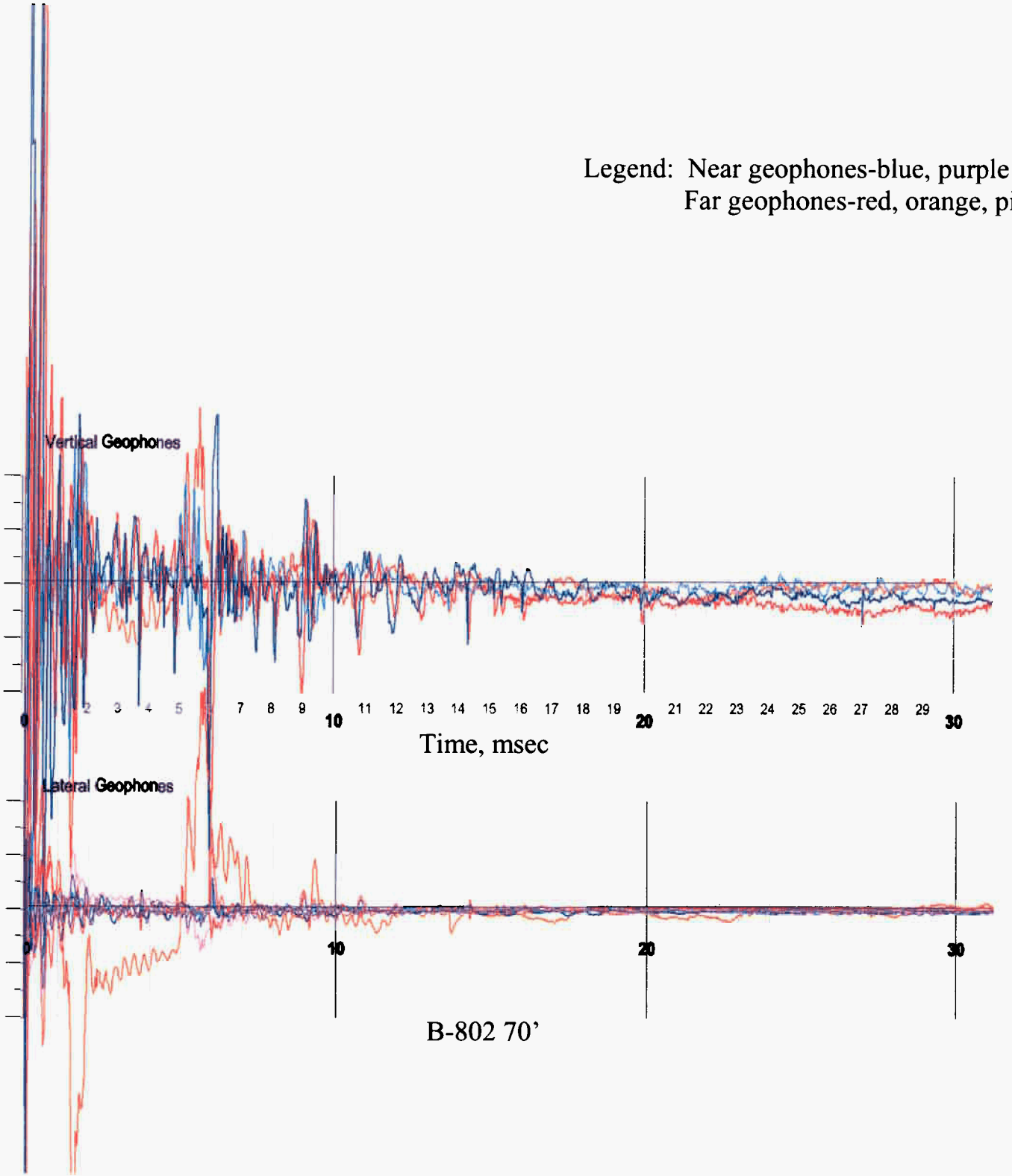
28
29
30
Time, msec
Lateral Geophones
0
10
20
30
B-802 60'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Lateral Geophones
0 10 20 30
Time, msec
B-802 60'a


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
Lateral Geophones
Time, msec
B-802 65'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
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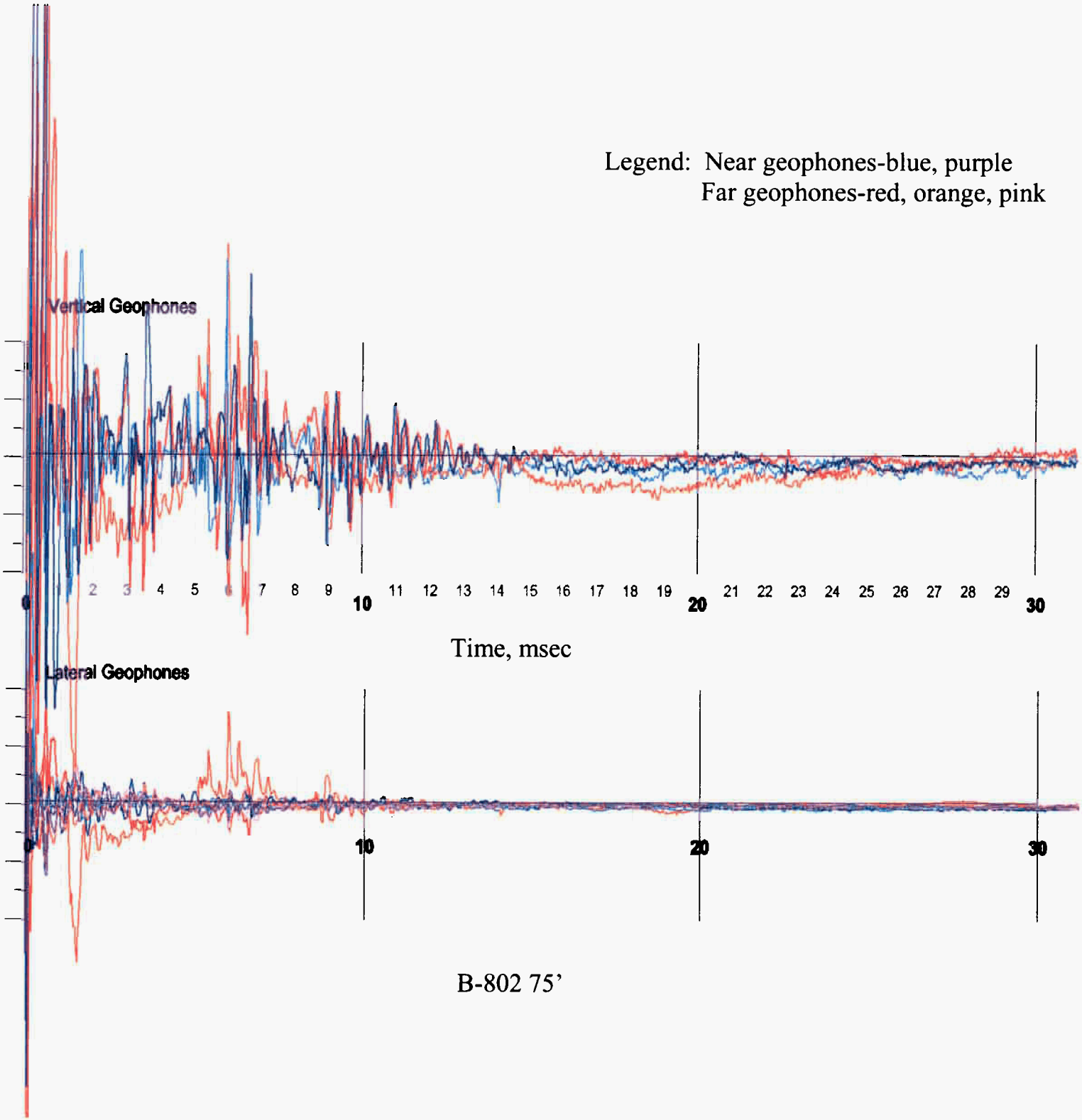
Time, msec
Lateral Geophones
0 10 20 30
B-802 70'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
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15
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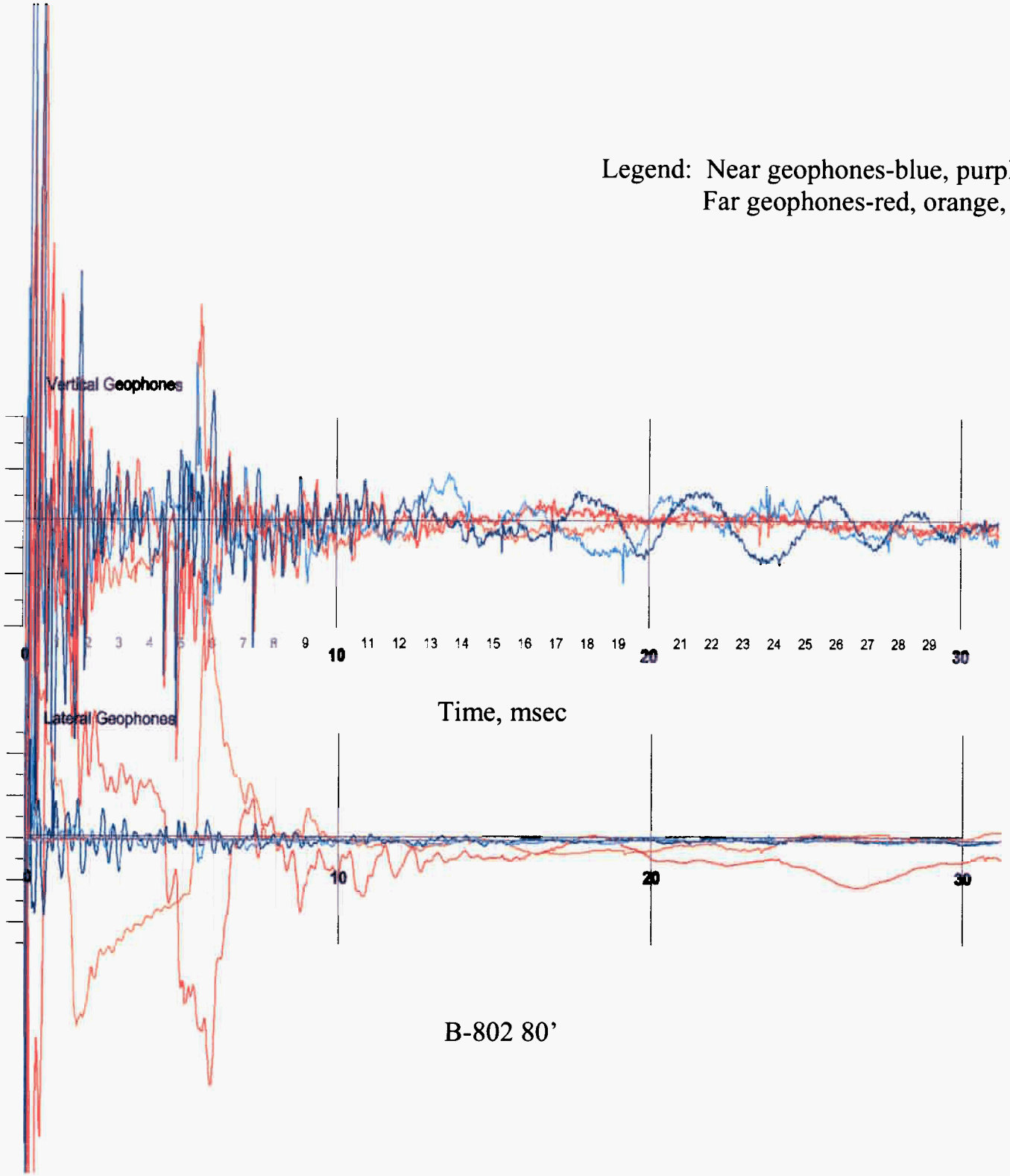
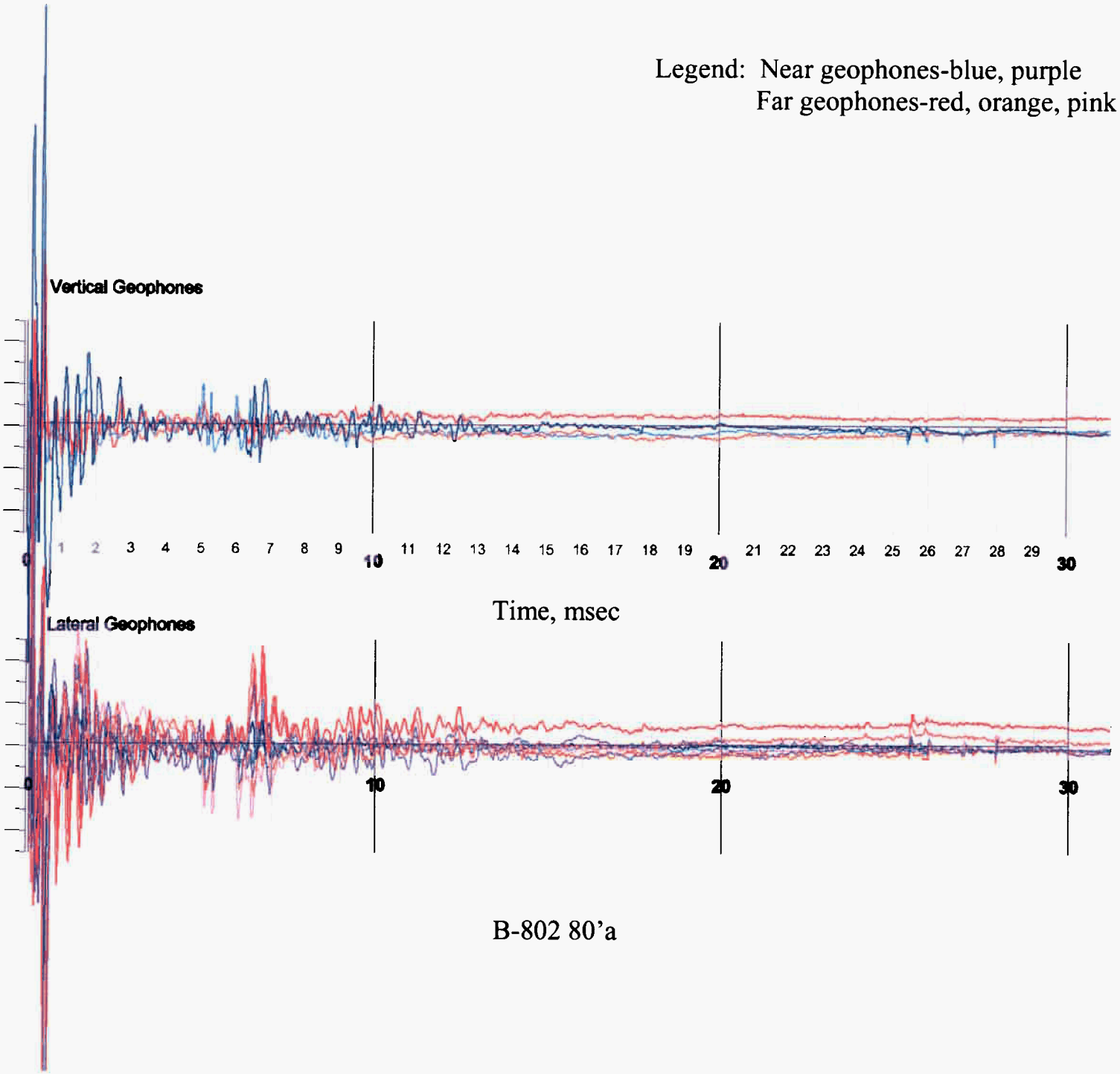
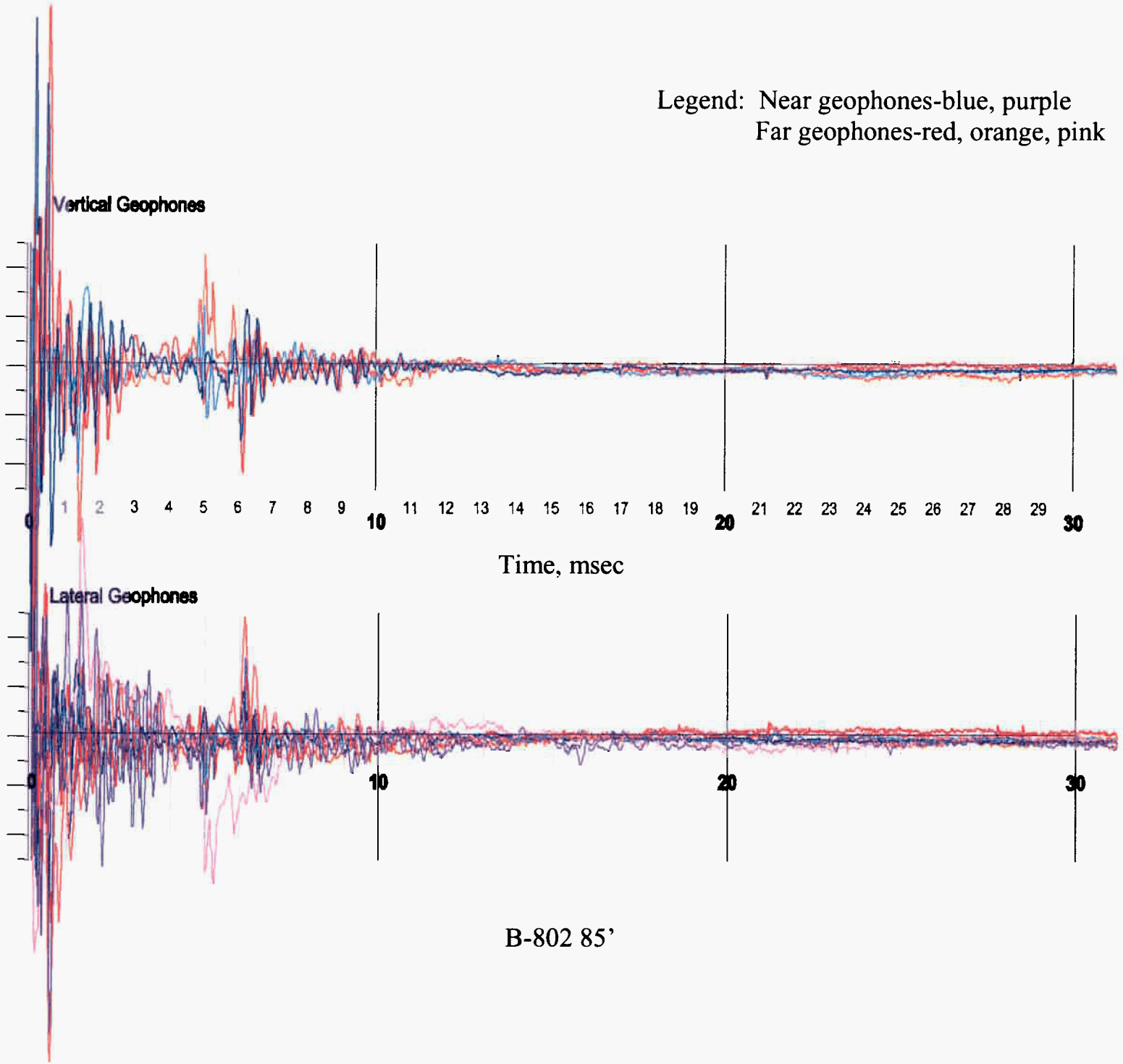
19
20
21
22
23
24
25
26
27
28
29
30
Time, msec
Lateral Geophones
0
10
20
30

B-802 75'


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
Lateral Geophones
Time, msec
B-802 80'

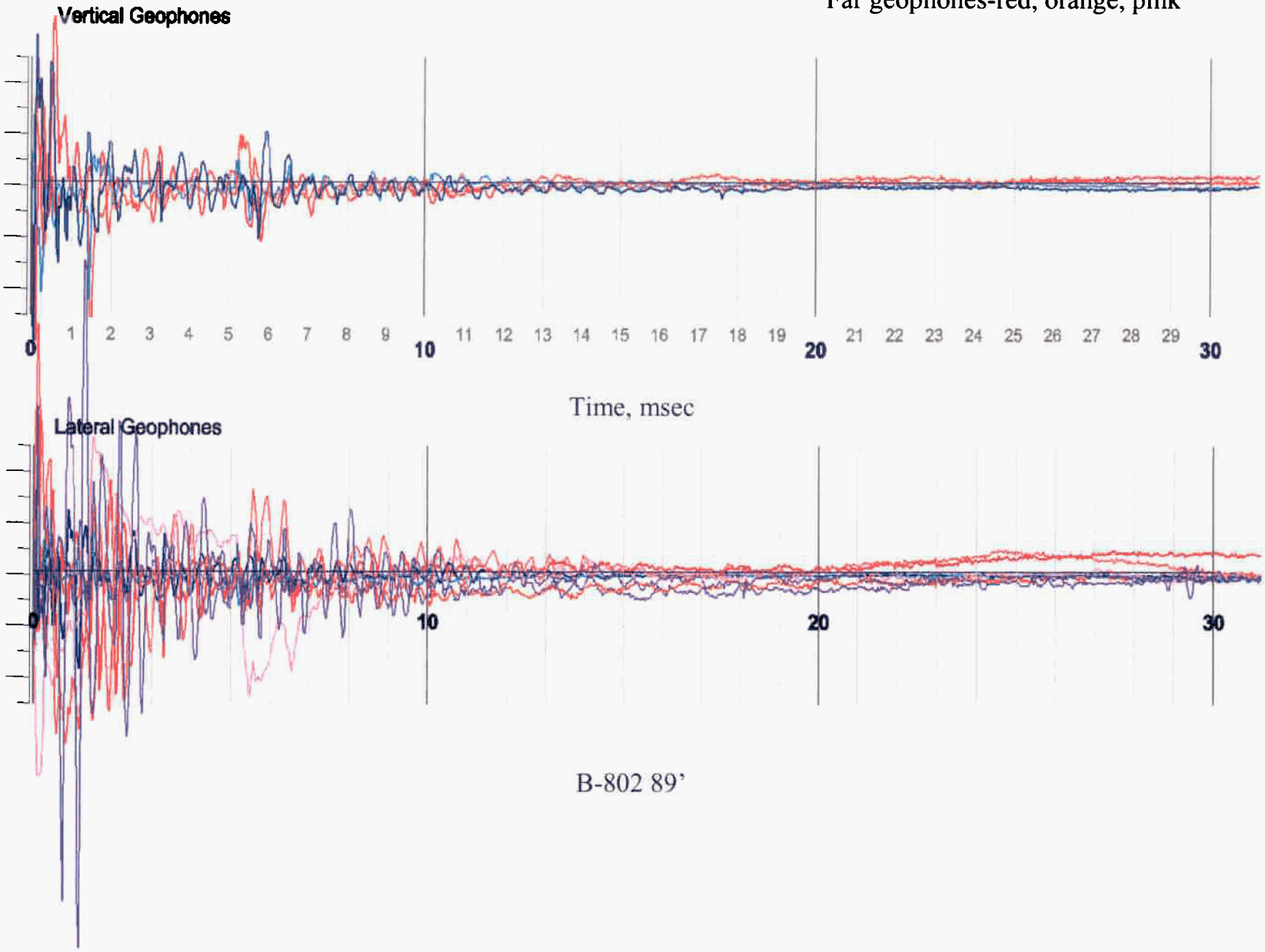

Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Time, msec
Lateral Geophones
0 10 20 30

B-802 80'a


Legend: Near geophones-blue, purple
Far geophones-red, orange, pink
Vertical Geophones
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Time, msec
Lateral Geophones
0 10 20 30

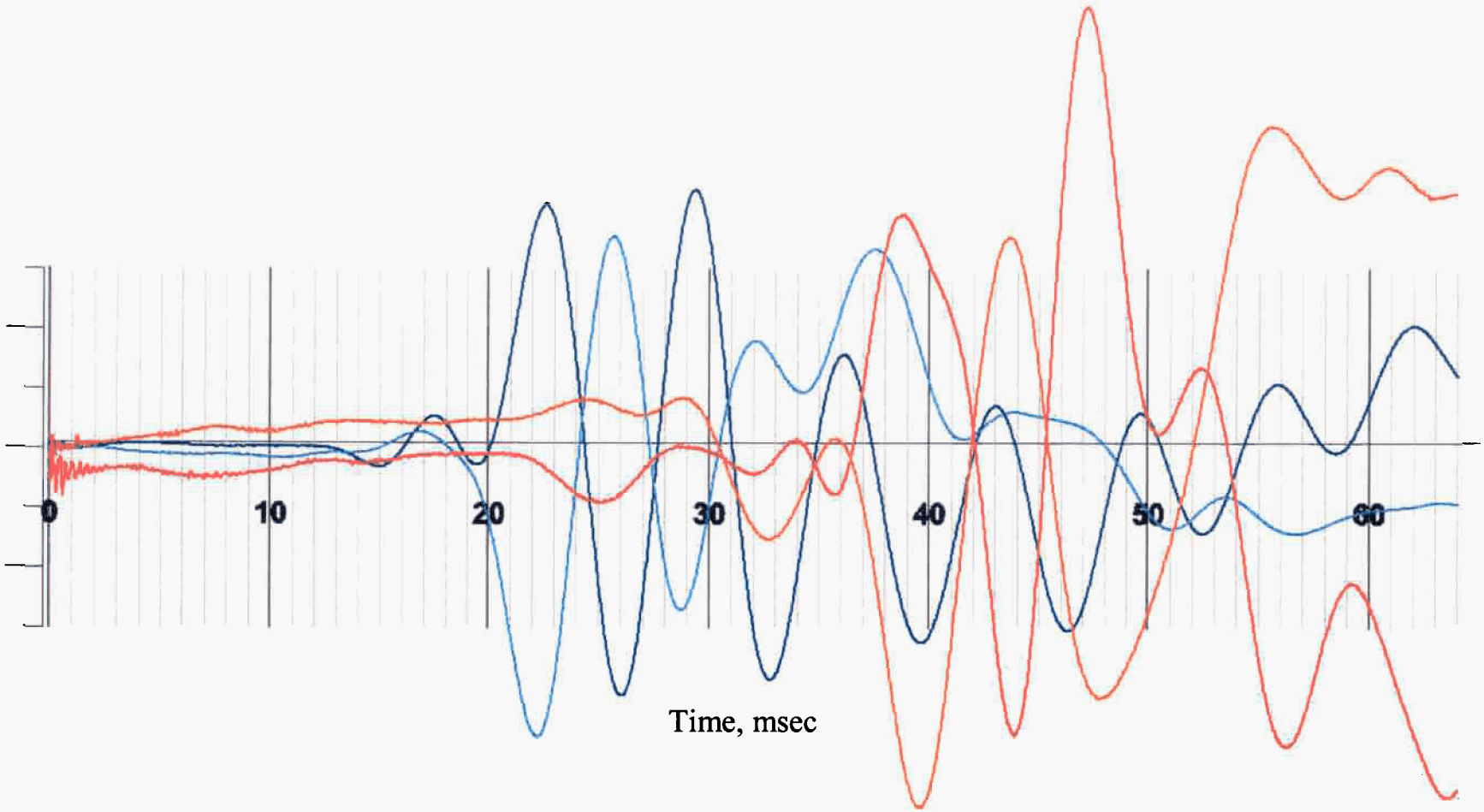
B-802 85'

Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



B-802 89'

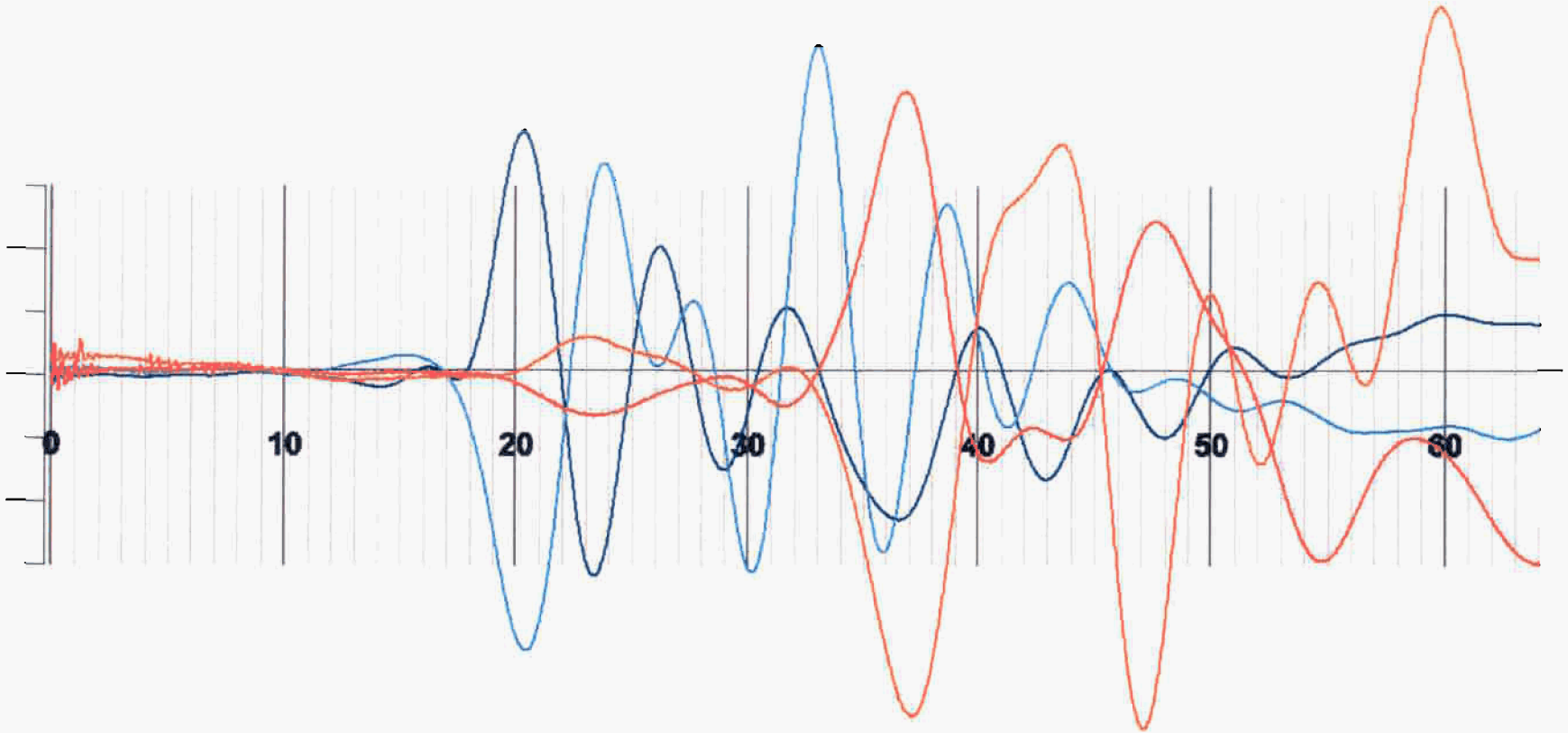
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 03'

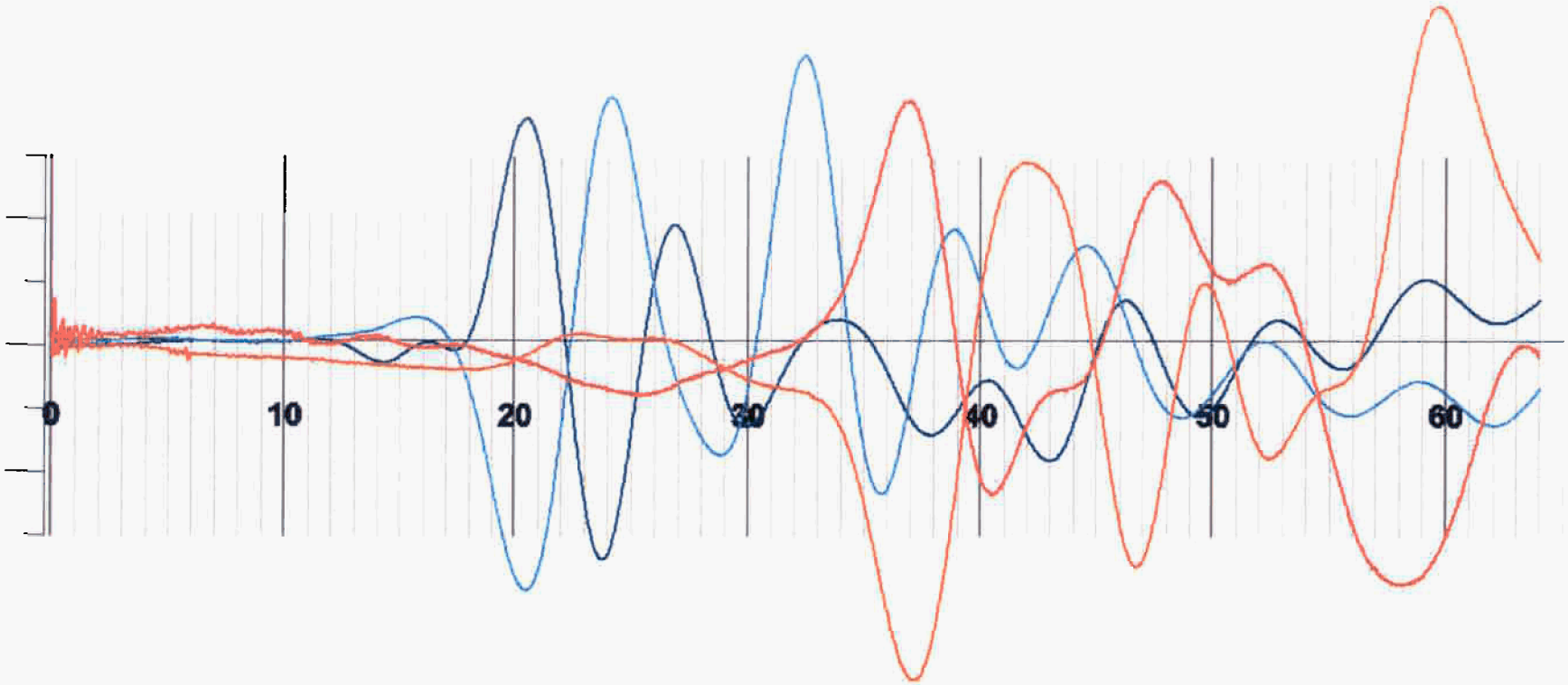
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 06'

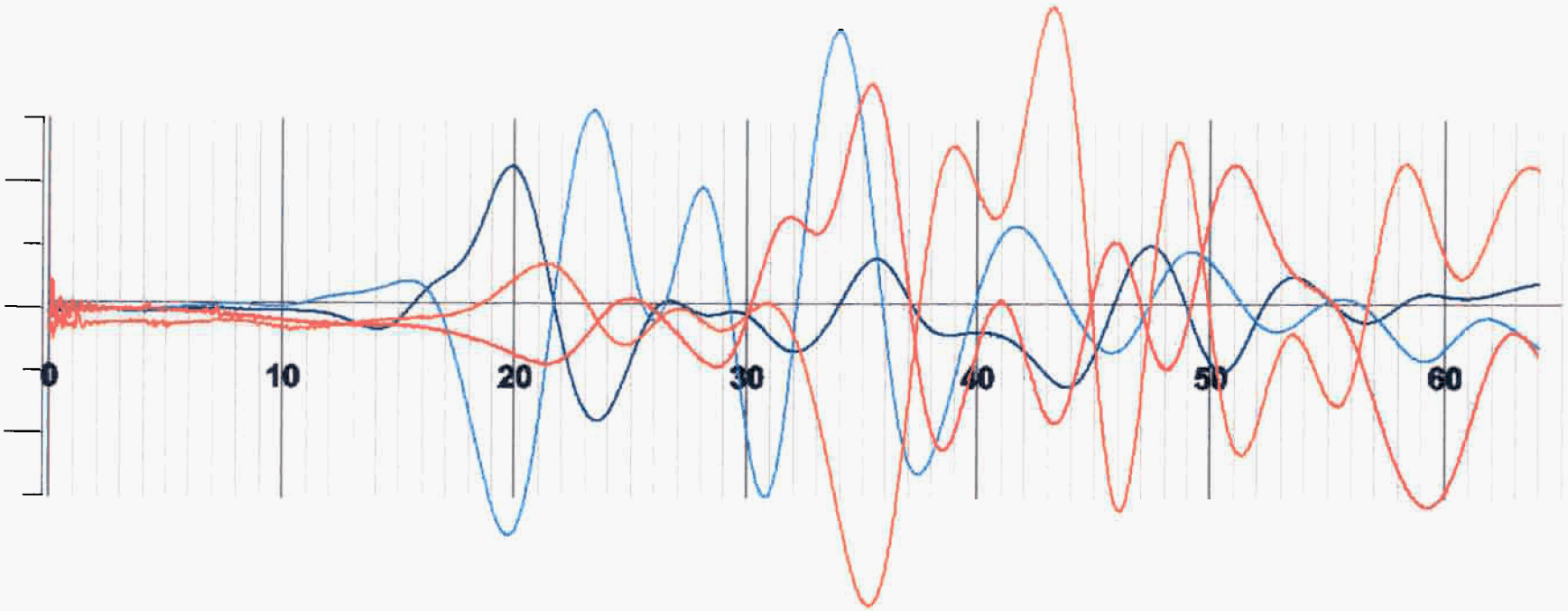
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 06'a

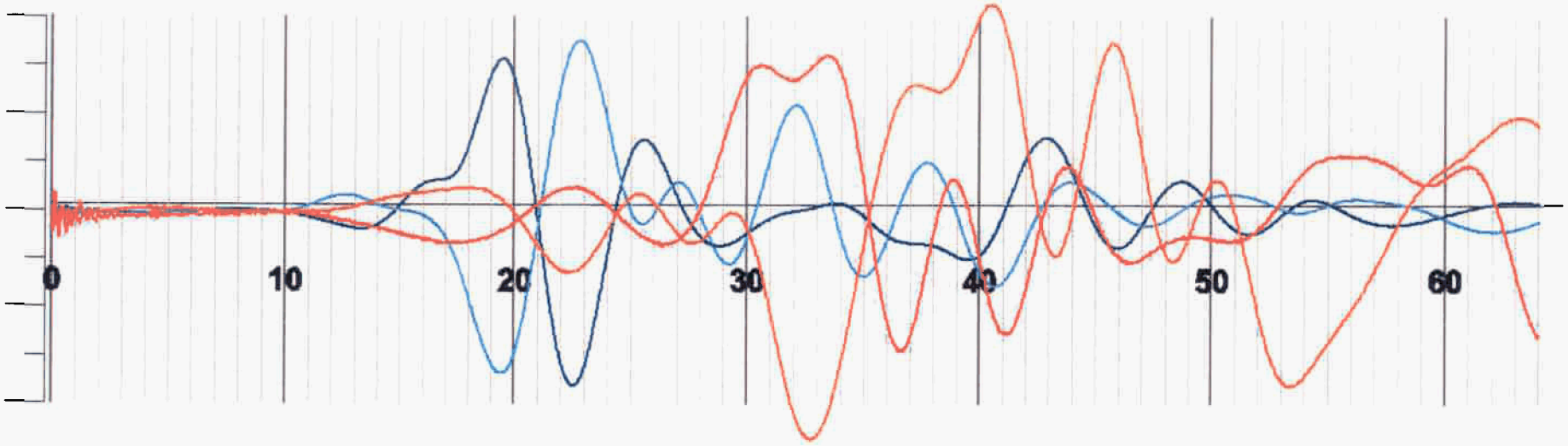
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 08.5'

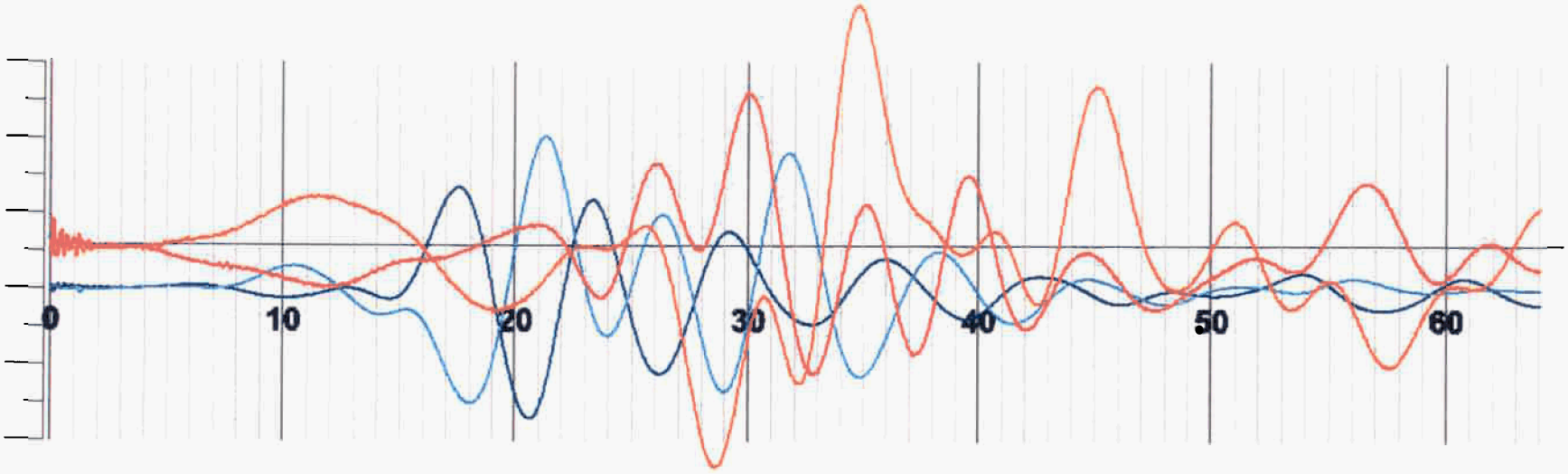
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 11’

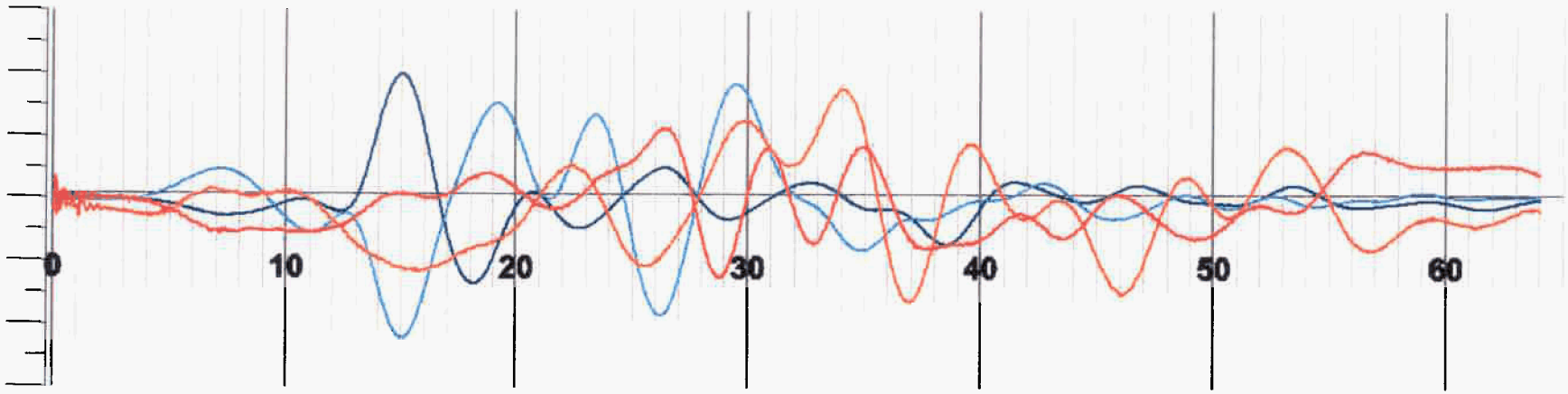
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 13’

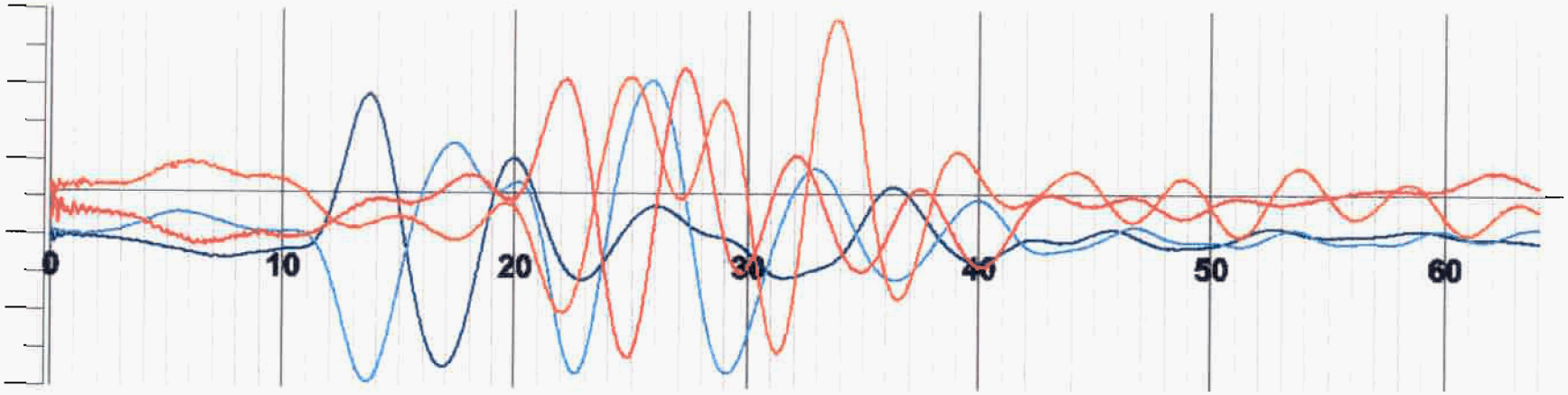
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 16'

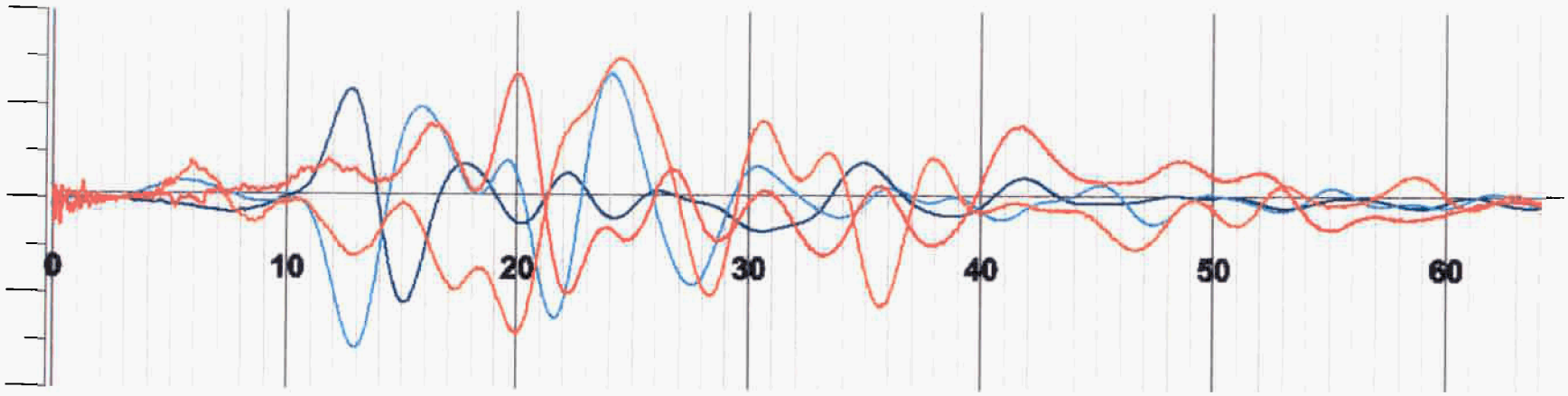
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 18.5'

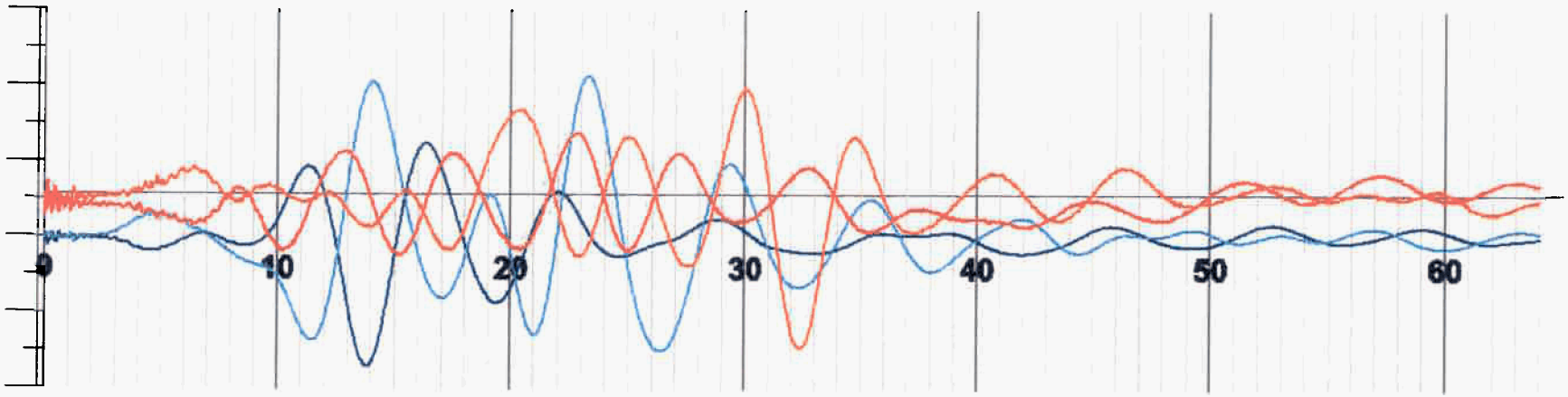
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 21'

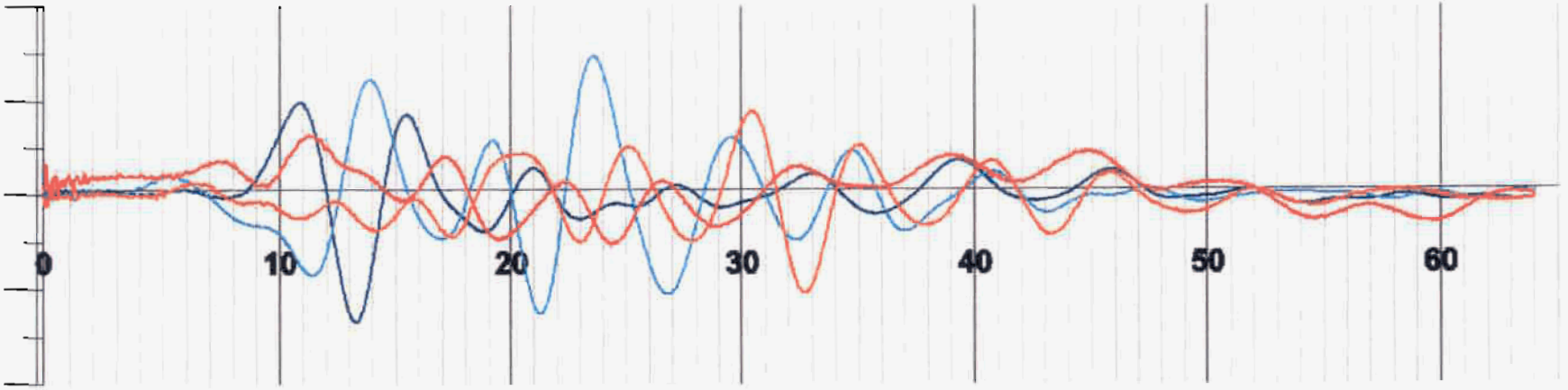
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 26'

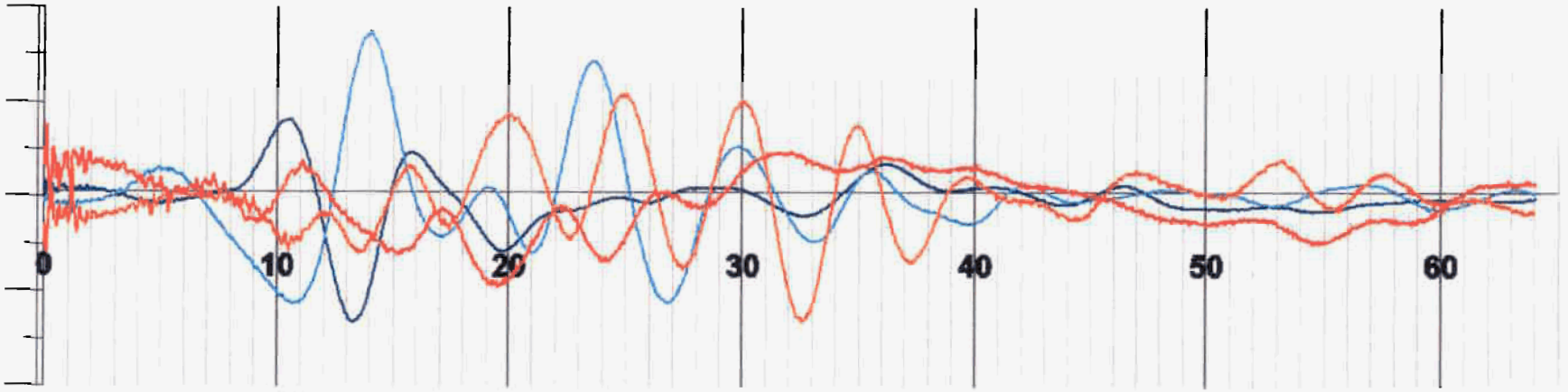
Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 26'a

Legend: Near geophones-blue, purple
Far geophones-red, orange, pink



Time, msec

B-805 27'

APPENDIX I
LABORATORY TESTING DATA

GEOTECHNICAL LABORATORY TEST ASSIGNMENT

Date 11/27/2002-12/18/02 Job Name North Anna ESP Job No. 24830 Requested By John Davie

SAMPLE LOCATION				PHYSICAL PROPERTIES									STRENGTH TESTS							COM-PACTION			CONSOLIDATION
								Grain Size Analysis															NOTE: Stress increments and rebound cycles, ksf.
Boring No.	Sample Type/No.	Sample Depth, Ft	Sample Number	Moisture Content	Unit Weight	Specific Gravity	Atterberg Limits	Sieve Only	Sieve + Hydrometer	Chemical Analysis (pH, chloride, sulphate)	Organic Content		Unconsolidated-Undrained Triaxial	Consolidated-Undrained Triaxial (3-stage w/pore-pressure meas.)	Unconfined Compression (rock) w/stress-strain	Unconfined Compression (rock) without stress-strain curve	Confining Pressure	Direct Shear	Point Load Test	Standard (A, B, C, D)	Modified (A, B, C, D)	CER	
805	jar	7.5-9	SS4	x			x		x														
"	"	18.5-20	SS7					x															
"	core	40-45	run4												x								
"	core	80-85	run12													x							
803	jar	6.1-7.6	SS3	x			x																
"	jar	8.6-10.1	SS4					x															
"	jar	13.7-15.1	SS6						x	x													
"	jar	23.6-25.1	SS8					x															
"	core	50-55	run2													x							
"	core	70-75	run6												x								
"	core	90-95	run10													x							
"	core	125-130	run18													x							
"	core	155-158	run24												x								
801	jar	0-1.5	SS1	x			x																
"	jar	8.5-10	SS5					x															

REMARKS: Please contact John Davie of Bechtel if there are any questions: Phone (301) 228-7647; Fax (301) 682-6415; e-mail JDAVIE@BECHTEL.COM. For unconfined compression testing of rock cores, select typical rock core samples.

GEOTECHNICAL LABORATORY TEST ASSIGNMENT

Date 11/27/2002-12/18/02 Job Name North Anna ESP Job No. 24830 Requested By John Davie

SAMPLE LOCATION				PHYSICAL PROPERTIES										STRENGTH TESTS								COM-PACTION			CONSOLIDATION
								Grain Size Analysis																	NOTE: Stress increments and rebound cycles, ksf.
Boring No.	Sample Type/No.	Sample Depth, Ft	Sample Number	Moisture Content	Unit Weight	Specific Gravity	Atterberg Limits	Sieve Only	Sieve + Hydrometer	Chemical Analysis (pH, chloride, sulphate)	Organic Content			Unconsolidated-Undrained Triaxial	Consolidated-Undrained Triaxial (3-stage w/pore-pressure meas.)	Unconfined Compression (rock) w/stress-strain	Unconfined Compression (rock) without stress-strain curve	Confining Pressure	Direct Shear	Point Load Test		Standard (A, B, C, D)	Modified (A, B, C, D)	CBR	
801	jar	13.5-15	SS6						x	x															
"	core	20-25	run1														x								
"	core	45-50	run6													x									
804	jar	3.5-5	SS3					x																	
"	jar	11-12.5	SS6					x																	
"	jar	18.5-20	SS8					x																	
803	core	35-40 35-38	run3 run2	4/6/03													x								
"	core	40-45	run4														x								
"	core	50-55	run6													x									
802	jar	3.7-5.2	SS2					x																	
"	core	20-25	run4														x								
"	core	45-50	run9														x								
"	core	65-70	run13													x									
"	core	85-90	run17														x								

REMARKS: Please contact John Davie of Bechtel if there are any questions: Phone (301) 228-7647; Fax (301) 682-6415; e-mail JDAVIE@BECHTEL.COM. For unconfined compression testing of rock cores, select typical rock core samples.

GEOTECHNICAL LABORATORY TEST ASSIGNMENT

Date 11/27/2002-12/18/02 Job Name North Anna ESP Job No. 24830 Requested By John Davie

SAMPLE LOCATION				PHYSICAL PROPERTIES										STRENGTH TESTS								COM-PACTION			CONSOLIDATION
								Grain Size Analysis																	
Boring No.	Sample Type/No.	Sample Depth, Ft	Sample Number	Moisture Content	Unit Weight	Specific Gravity	Atterberg Limits	Sieve Only	Sieve + Hydrometer	Chemical Analysis (pH, chloride, sulphate)	Organic Content			Unconsolidated-Undrained Triaxial	Consolidated-Undrained Triaxial (3-stage w/pore-pressure meas.)	Unconfined Compression (rock) w/stress-strain	Unconfined Compression (rock) without stress-strain curve	Confining Pressure	Direct Shear	Point Load Test		Standard (A, B, C, D)	Modified (A, B, C, D)	CBR	NOTE: Stress increments and rebound cycles, ksf.
806	jar	5.6-7.1	SS3						x	x															
"	core	24.5-26	run5														x								
"	core	40-45	run10														x								
"	core	60-65	run14														x								
807	jar	4.5-6	SS4	x			x																		
"	jar	12.3-13.5	SS6	x			x			x															
"	jar	21.8-23.3	SS-8	x			x		x																
"	jar	31.5-33	SS10					x																	
"	jar	41.4-42.6	SS12					x																	

REMARKS: Please contact John Davie of Bechtel if there are any questions: Phone (301) 228-7647; Fax (301) 682-6415; e-mail JDAVIE@BECHTEL.COM. For unconfined compression testing of rock cores, select typical rock core samples.

MACTEC

MACTEC ENGINEERING AND CONSULTING, INC.
RALEIGH, NORTH CAROLINA

REPORT OF STANDARD TEST METHOD FOR
LABORATORY DETERMINATION OF WATER CONTENT OF SOIL AND ROCK BY MASS
(ASTM D 2216)

PROJECT NAME: North Anna ESP
MACTEC PROJECT NUMBER: 30720-2-5400
BECHTEL JOB NO: 24830
DATE: 2/11/03

SAMPLE IDENTIFICATION			NATURAL	LIQUID & PLASTIC LIMITS			% FINER				USCS
BORING	TYPE	DEPTH (feet)	MOISTURE (%)	LL	PL	PI	#200 SIEVE	pH	CHLORIDES mg/kg	SULFATES mg/kg	CLASSIFICATION
B-801	SS-1	0-1.5	22.2	39	29	10		6.3	130.0	< 27	
B-801	SS-5	8.5-10					39.9				
B-801	SS-6	13.5-15					55.1				
B-802	SS-2	3.7-5.2					19.5				
B-803	SS-3	6.1-7.6	18.9	30	26	4					
B-803	SS-4	8.6-10.1	23.2				24.4				
B-803	SS-6	13.7-15.3					20.9	5.7	100.0	< 23	
B-803	SS-8	23.6-25.1					18.5				
B-804	SS-3	3.5-5					54.2				
B-804	SS-6	11-12.5					46.1				
B-804	SS-8	18.5-20					22.1				
B-805	SS-4	7.5-9	27.2	NP	NP	NP	27.5				SM
B-805	SS-7	18.5-20					25.1				
B-806	SS-3	5.6-7.1					27.1	6.7	920.0	< 24	
B-807	SS-3	4.5-6	40.1	49	45	4					
B-807	SS-6	12.3-13.8	42.8	46	40	6		5.7	170.0	< 28	
B-807	SS-8	21.8-23.3	28.9	41	34	7	42.6				SM-SC
B-807	SS-10	31.5-33	26.7				37.7				
B-807	SS-12	41.4-42.9	21.8				44.2				

PREPARED BY: _____
Trudy L. Mullins, Laboratory Manager

TESTING EQUIPMENT:

SCALES:	3.1.99
OVEN:	5.1.10
WASH SIEVE:	5.4.39
TECHNICIAN:	JLB
CALCULATIONS:	JLB
CHECKED BY:	TLM

REVIEWED BY: _____
Stephen J. Criscenzo
Principal Professional

APPROVED BY: _____
J. Allan Tice, P.E.
Principal Engineer/Project Manager
Registered Virginia, 5264

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.3	59.8	39.9	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.56	0.24	0.15					

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-801 SS-5 8.5-10'		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-801 SS-5 8.5-10'

Date: 1/2/2003

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Remarks:

ND=NOT DETERMINED

SPECIFIC GRAVITY

IS ASSUMED

Figure No. 4

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 4

Date: 1/2/2003
Project No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-801 SS-5 8.5-10'
Sample Description: B-801 SS-5 8.5-10'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-4 Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 4

Mechanical Analysis Data

	Initial
Dry sample and tare=	150.96
Tare =	0.00
Dry sample weight =	150.96

Tare for cumulative weight retained= 0

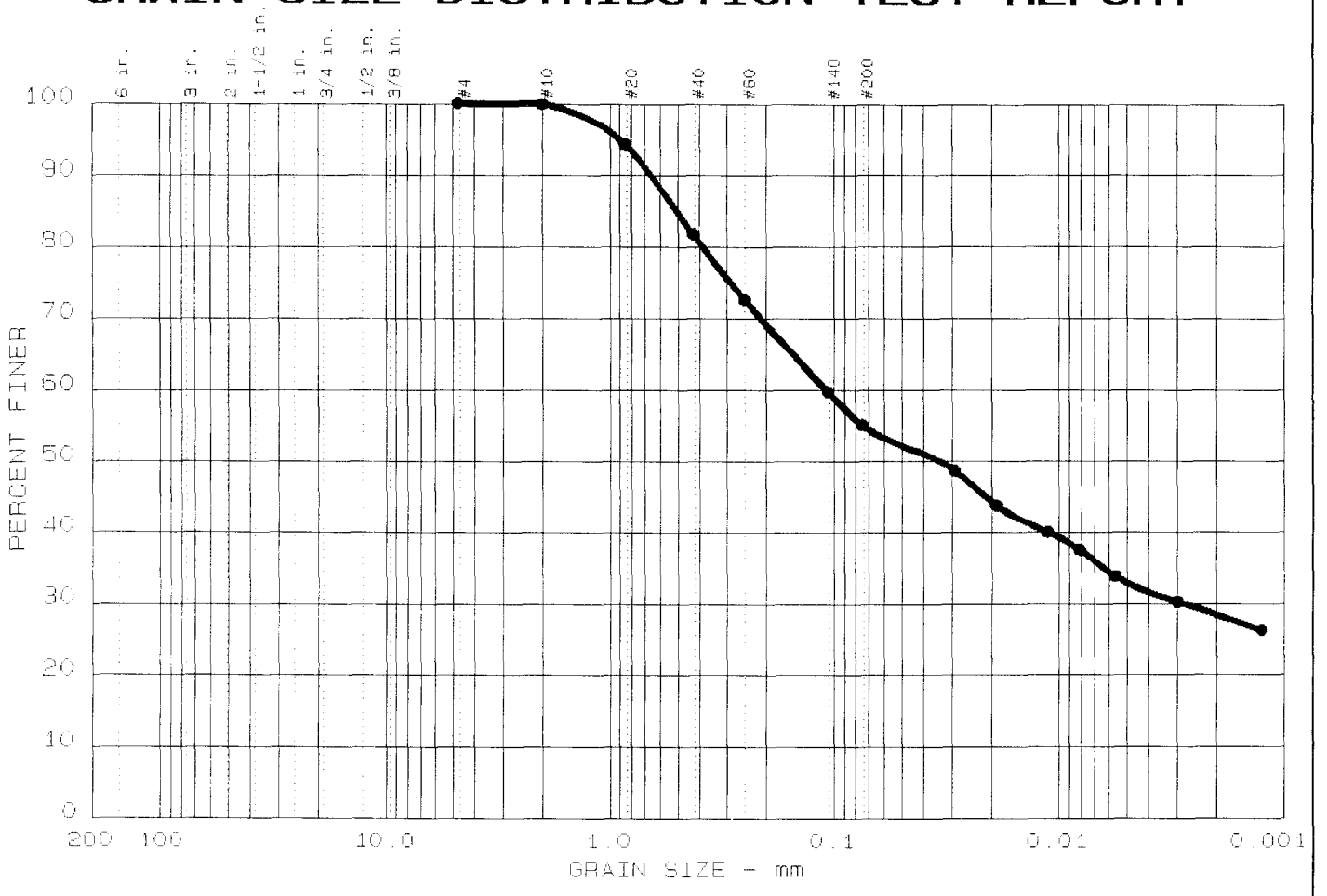
Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.46	99.7
# 20	6.52	95.7
# 40	33.55	77.8
# 60	58.58	61.2
# 140	84.15	44.3
# 200	90.76	39.9

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 0.3 % SAND = 59.8
% FINES = 39.9

D85= 0.56 D60= 0.239 D50= 0.151

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75 mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.1	44.8	22.3	32.8

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.50	0.11	0.03	0.003				

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-801 SS-6 13 5-15'		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-801 SS-6 13.5-15'

Date: 1/2/2003

Remarks:

ND=NOT DETERMINED

SPECIFIC GRAVITY

IS ASSUMED

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Figure No. 3

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 3

Date: 1/2/2003
Project No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-801 SS-6 13.5-15'
Sample Description: B-801 SS-6 13.5-15'
USCS Class: ML Liquid limit: ND
AASHTO Class: A-4(0) Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 3

Mechanical Analysis Data

	Initial
Dry sample and tare=	91.60
Tare =	0.00
Dry sample weight =	91.60

Sample split on number 10 sieve
Split sample data:
Sample and tare = 81.22 Tare = 0 Sample weight = 81.22
Cumulative weight retained tare= 0
Tare for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.08	99.9
# 20	4.54	94.3
# 40	14.71	81.8
# 60	22.21	72.6
# 140	32.68	59.7
# 200	36.40	55.1

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 99.9
Weight of hydrometer sample: 81.22
Calculated biased weight= 81.29
Table of composite correction values:

Temp, deg C:	15.3	20.3	27.1
Comp. corr:			

- 6.5 - 5.0 - 3.0
Meniscus correction only=-1
Specific gravity of solids= 2.63
Specific gravity correction factor= 1.005
Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

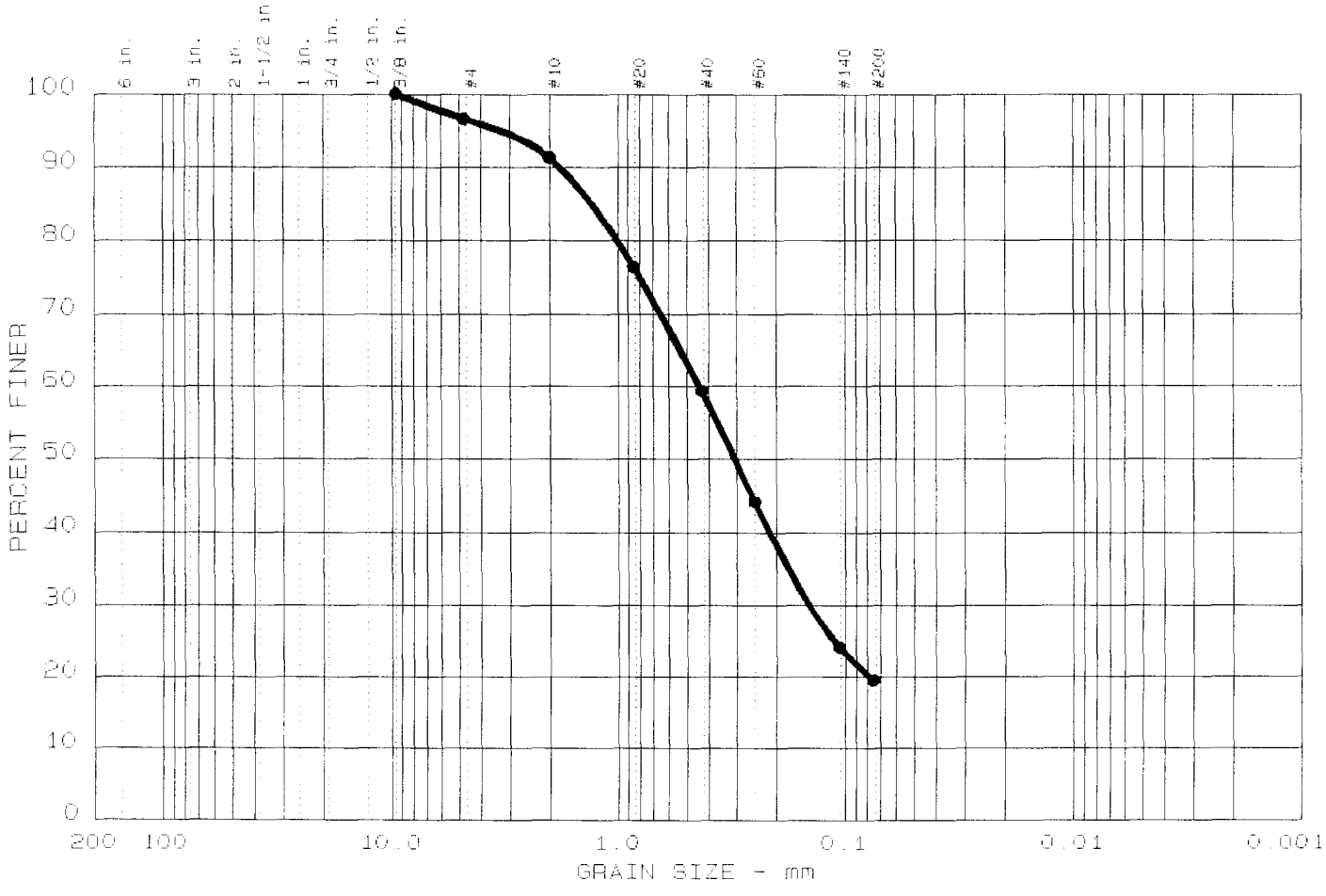
Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
2.0	21.4	44.0	39.3	0.0135	43.0	9.2	0.0290	48.6
5.0	21.4	40.0	35.3	0.0135	39.0	9.9	0.0190	43.7
15.0	21.4	37.0	32.3	0.0135	36.0	10.4	0.0112	39.9
30.0	21.4	35.0	30.3	0.0135	34.0	10.7	0.0081	37.5
65.0	21.3	32.0	27.3	0.0135	31.0	11.2	0.0056	33.7
240.0	21.7	29.0	24.4	0.0134	28.0	11.7	0.0030	30.2
1440.0	21.0	26.0	21.2	0.0136	25.0	12.2	0.0012	26.2

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 0.1 % SAND = 44.8
% SILT = 22.3 % CLAY = 32.8

D85= 0.50 D60= 0.107 D50= 0.033
D30= 0.0028

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	8.7	71.8	19.5	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	1.29	0.44	0.31	0.143				

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-802 SS-2 3.7-5.2'		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-802 SS-2 3.7-5.2'

Date: 1-2-2003

Remarks:

ND=NOT DETERMINED.

SPECIFIC GRAVITY

IS ASSUMED

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Figure No. 1

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 15

e: 1-2-2003
ject No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-802 SS-2 3.7-5.2'
Sample Description: B-802 SS-2 3.7-5.2'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-2-4(0) Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 1

Mechanical Analysis Data

Initial
Dry sample and tare= 174.16
Tare = 0.00
Dry sample weight = 174.16
Tare for cumulative weight retained= 0

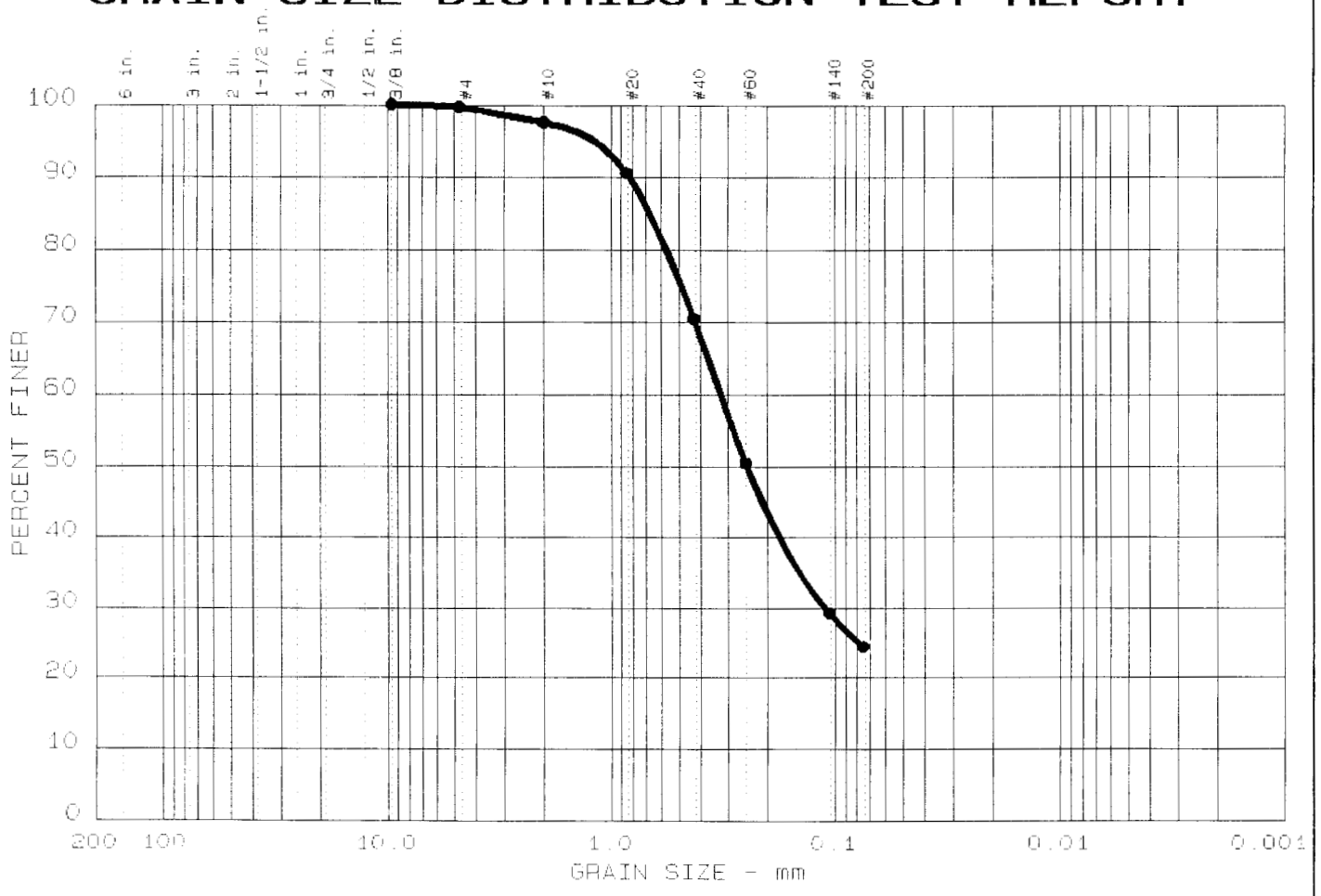
ieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
# 4	5.93	96.6
# 10	15.16	91.3
# 20	41.13	76.4
# 40	71.05	59.2
# 60	97.38	44.1
# 140	132.15	24.1
# 200	140.21	19.5

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 8.7 % SAND = 71.8
% FINES = 19.5

D85= 1.29 D60= 0.437 D50= 0.305
D30= 0.1429

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75 mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	2.5	73.1	24.4	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.67	0.32	0.25	0.111				

MATERIAL DESCRIPTION	USCS	AASHTO
● B-803 SS-4 8.5-10.1'		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-803 SS-4 8.6-10.1'

Date: 1/2/2003

Remarks:
ND=NOT DETERMINED
SPECIFIC GRAVITY
IS ASSUMED

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Figure No. 5

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 5

Date: 1/2/2003
Project No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-803 SS-4 8.6-10.1'
Sample Description: B-803 SS-4 8.6-10.1'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-2-4 Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 5

Mechanical Analysis Data

	Initial
Dry sample and tare=	112.71
Tare =	0.00
Dry sample weight =	112.71

Tare for cumulative weight retained= 0

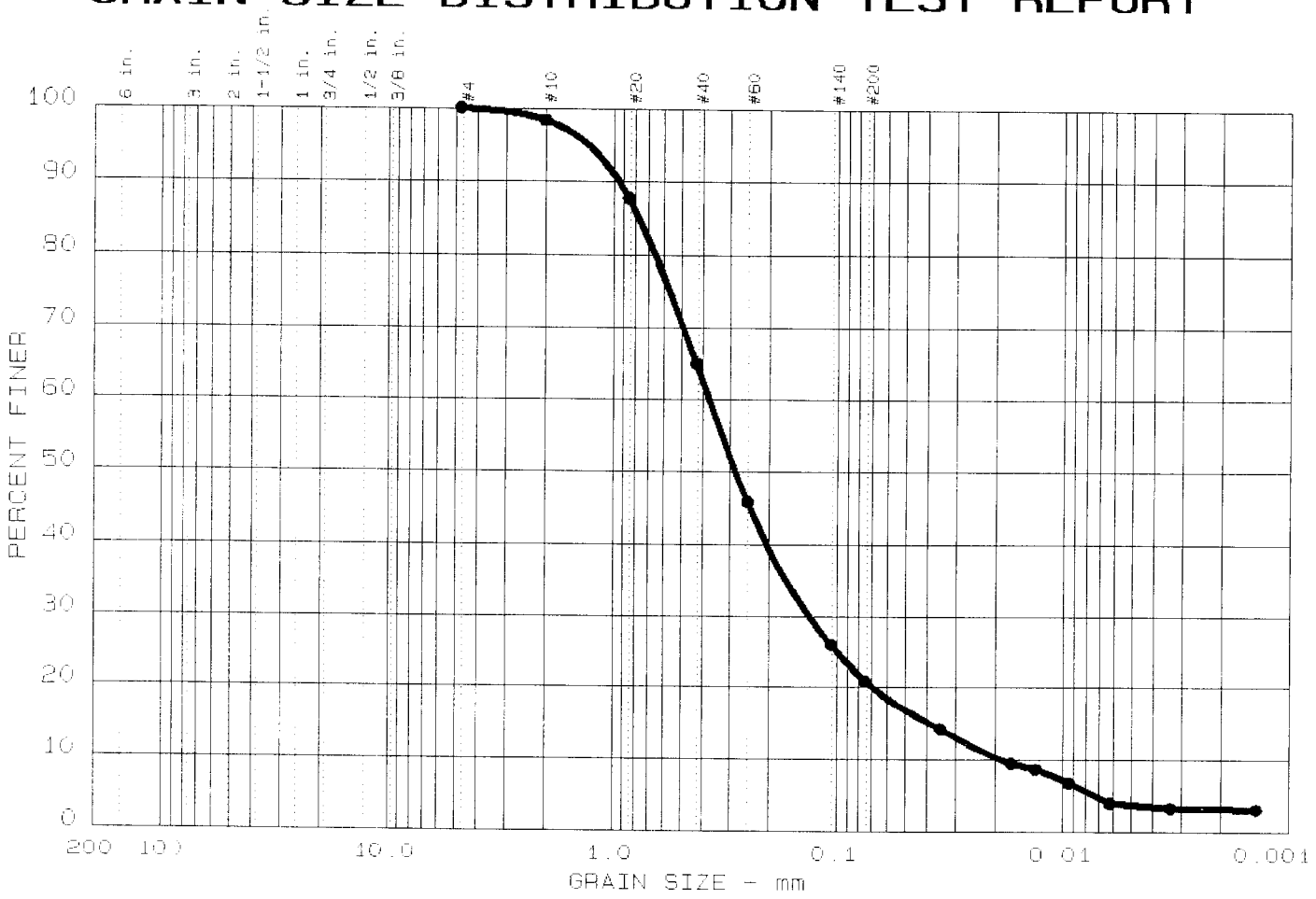
Sieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
# 4	0.36	99.7
# 10	2.78	97.5
# 20	10.58	90.6
# 40	33.34	70.4
# 60	55.82	50.5
# 140	79.83	29.2
# 200	85.21	24.4

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 2.5 % SAND = 73.1
% FINES = 24.4

D85= 0.67 D60= 0.322 D50= 0.246
D30= 0.1113

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	1.7	77.4	17.2	3.7

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.76	0.37	0.28	0.132	0.0386	0.0187	2.51	20.0

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-803 SS-6 13.7-15.3		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-803 SS-6 13.7-15.3'

Date: 1/2/2003

Remarks:
ND=NOT DETERMINED
SPECIFIC GRAVITY
IS ASSUMED

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Figure No. 2

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 2

Date: 1/2/2003
Project No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-803 SS-6 13.7-15.3'
Sample Description: B-803 SS-6 13.7-15.3'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-2-4(0) Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 2

Mechanical Analysis Data

	Initial
Dry sample and tare=	174.53
Tare =	0.00
Dry sample weight =	174.53

Sample split on number 10 sieve
Split sample data:
Sample and tare = 105.59 Tare = 0 Sample weight = 105.59
Cumulative weight retained tare= 0
Tare for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	2.96	98.3
# 20	11.36	87.7
# 40	35.82	65.0
# 60	56.40	45.8
# 140	77.72	25.9
# 200	83.16	20.9

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 98.3
Weight of hydrometer sample: 105.59
Calculated biased weight= 107.41
Table of composite correction values:

Temp, deg C:	15.3	20.3	27.1
Comp. corr:			

- 6.5 - 5.0 - 3.0
Meniscus correction only=-1
Specific gravity of solids= 2.63
Specific gravity correction factor= 1.005
Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

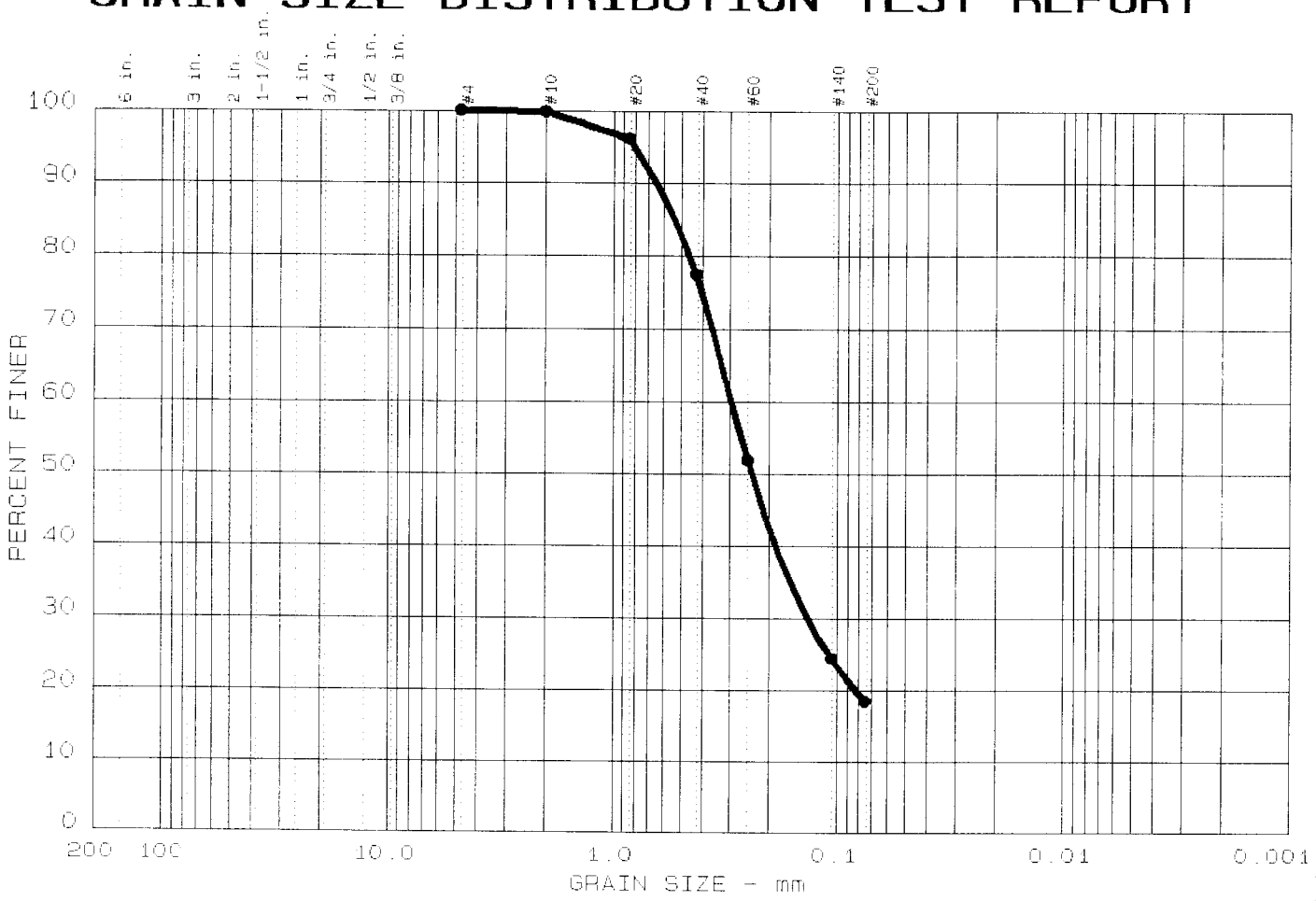
Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
2.0	20.9	20.0	15.2	0.0136	19.0	13.2	0.0348	14.2
9.0	20.9	15.0	10.2	0.0136	14.0	14.0	0.0169	9.5
15.0	21.0	14.0	9.2	0.0136	13.0	14.2	0.0132	8.6
30.0	20.9	12.0	7.2	0.0136	11.0	14.5	0.0094	6.7
71.0	20.9	9.0	4.2	0.0136	8.0	15.0	0.0062	3.9
246.0	21.7	8.0	3.4	0.0134	7.0	15.1	0.0033	3.2
1440.0	21.1	8.0	3.2	0.0135	7.0	15.1	0.0014	3.0

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 1.7 % SAND = 77.4
% SILT = 17.2 % CLAY = 3.7

D85= 0.76 D60= 0.373 D50= 0.283
D30= 0.1323 D15= 0.03859 D10= 0.01869
Cc = 2.5119 Cu = 19.9526

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75 mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.2	81.3	18.5	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.53	0.30	0.24	0.135				

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-803 SS-8 23.6-25.1'		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-803 SS-8 23.6-25.1'

Date: 1-2-2003

Remarks:
ND=NOT DETERMINED
SPECIFIC GRAVITY
IS ASSUMED

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Figure No. 6

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 10

Date: 1-2-2003
Project No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-803 SS-8 23.6-25.1'
Sample Description: B-803 SS-8 23.6-25.1'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-2-4 Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 6

Mechanical Analysis Data

Initial

Dry sample and tare= 142.55
Tare = 0.00
Dry sample weight = 142.55
Tare for cumulative weight retained= 0

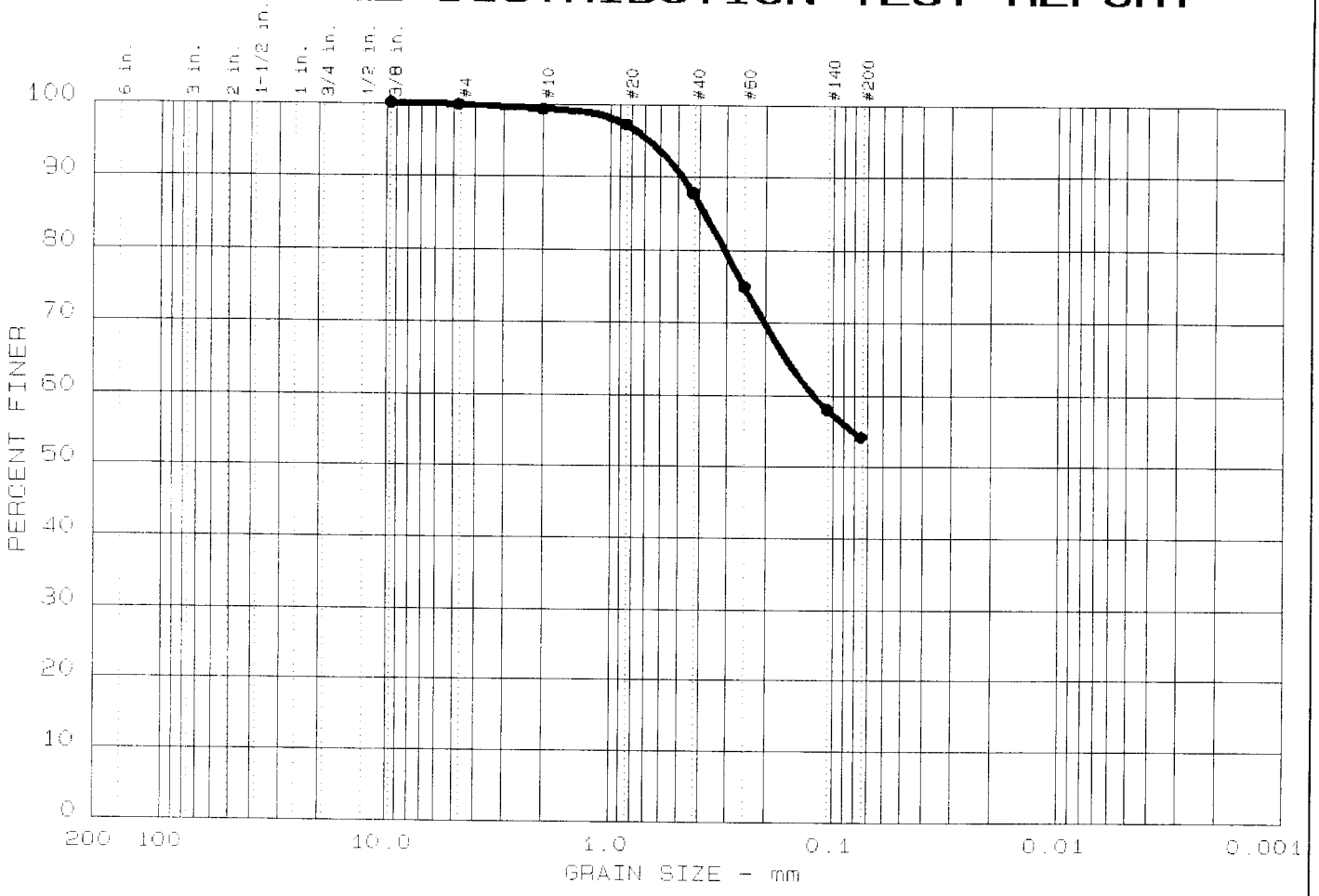
Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.26	99.8
# 20	5.41	96.2
# 40	32.09	77.5
# 60	68.56	51.9
# 140	107.81	24.4
# 200	116.12	18.5

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 0.2 % SAND = 81.3
% FINES = 18.5

D85= 0.53 D60= 0.295 D50= 0.240
D30= 0.1347

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.7	45.1	54.2	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.37	0.12						

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-804 SS-3 3.5-5'		

Project No.: 30720-2-540C
Project: NORTH ANNA ESP
● Location: B-804 SS-3 3.5-5'

Date: 1-2-2003

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Remarks:

ND=NOT DETERMINED.

SPECIFIC GRAVITY

IS ASSUMED

Figure No. 7

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 11

e: 1-2-2003
oject No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-804 SS-3 3.5-5'
Sample Description: B-804 SS-3 3.5-5'
USCS Class: ML Liquid limit: ND
AASHTO Class: A-4 Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 7

Mechanical Analysis Data

Initial
Dry sample and tare= 135.24
Tare = 0.00
Dry sample weight = 135.24
Tare for cumulative weight retained= 0

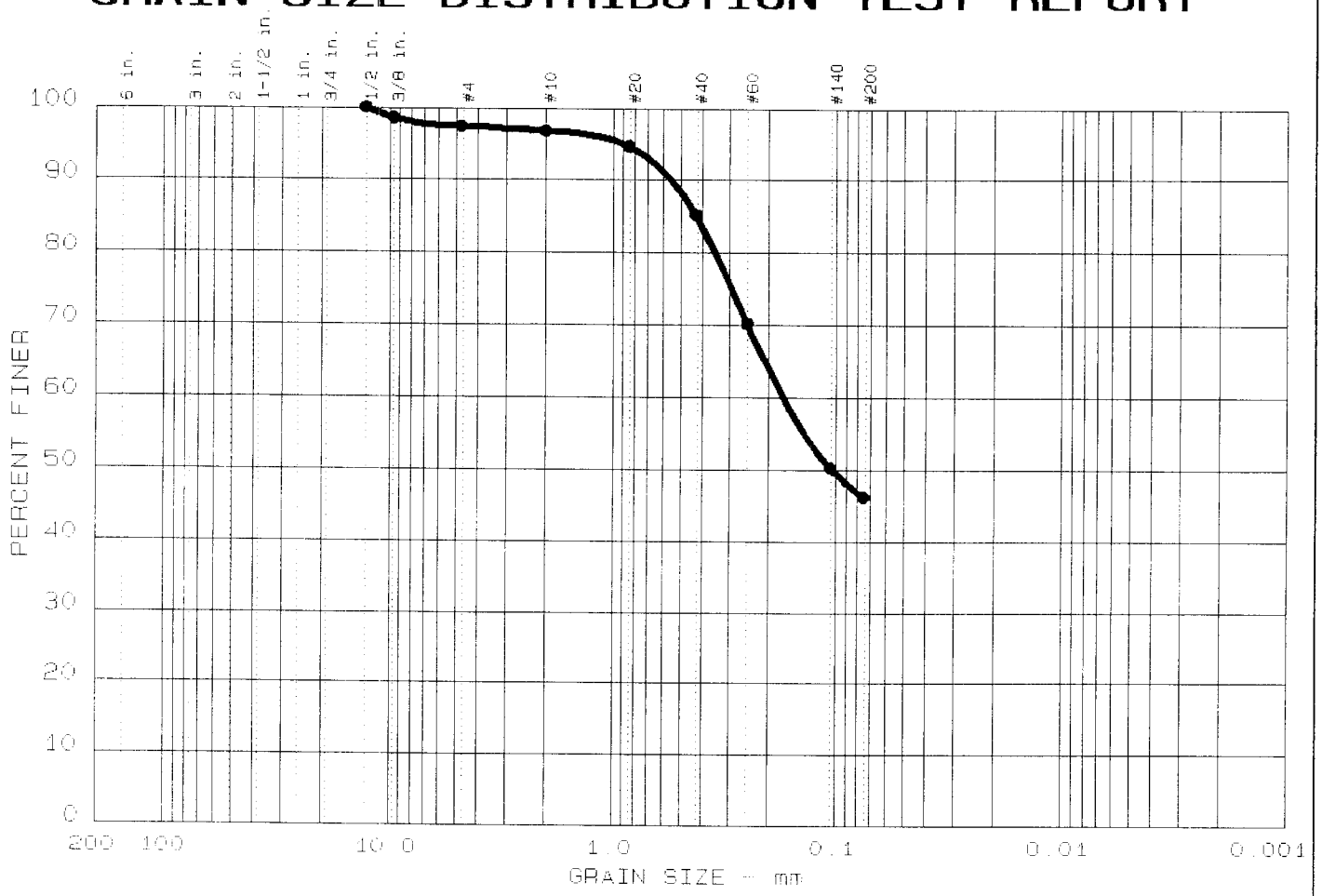
ieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
# 4	0.22	99.8
# 10	1.00	99.3
# 20	3.84	97.2
# 40	16.42	87.9
# 60	33.97	74.9
# 140	56.91	57.9
# 200	62.03	54.1

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 0.7 % SAND = 45.1
% FINES = 54.2

D85= 0.37 D60= 0.122

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	3.3	50.6	46.1	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.42	0.17	0.10					

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-804 SS-6 11-12 5'		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-804 SS-6 11-12.5'

Date: 1-2-2003

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Remarks:

ND=NOT DETERMINED

SPECIFIC GRAVITY

IS ASSUMED

Figure No. 8

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 12

Date: 1-2-2003
Project No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-804 SS-6 11-12.5'
Sample Description: B-804 SS-6 11-12.5'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-4 Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 8

Mechanical Analysis Data

Initial
Dry sample and tare= 176.24
Tare = 0.00
Dry sample weight = 176.24
Tare for cumulative weight retained= 0

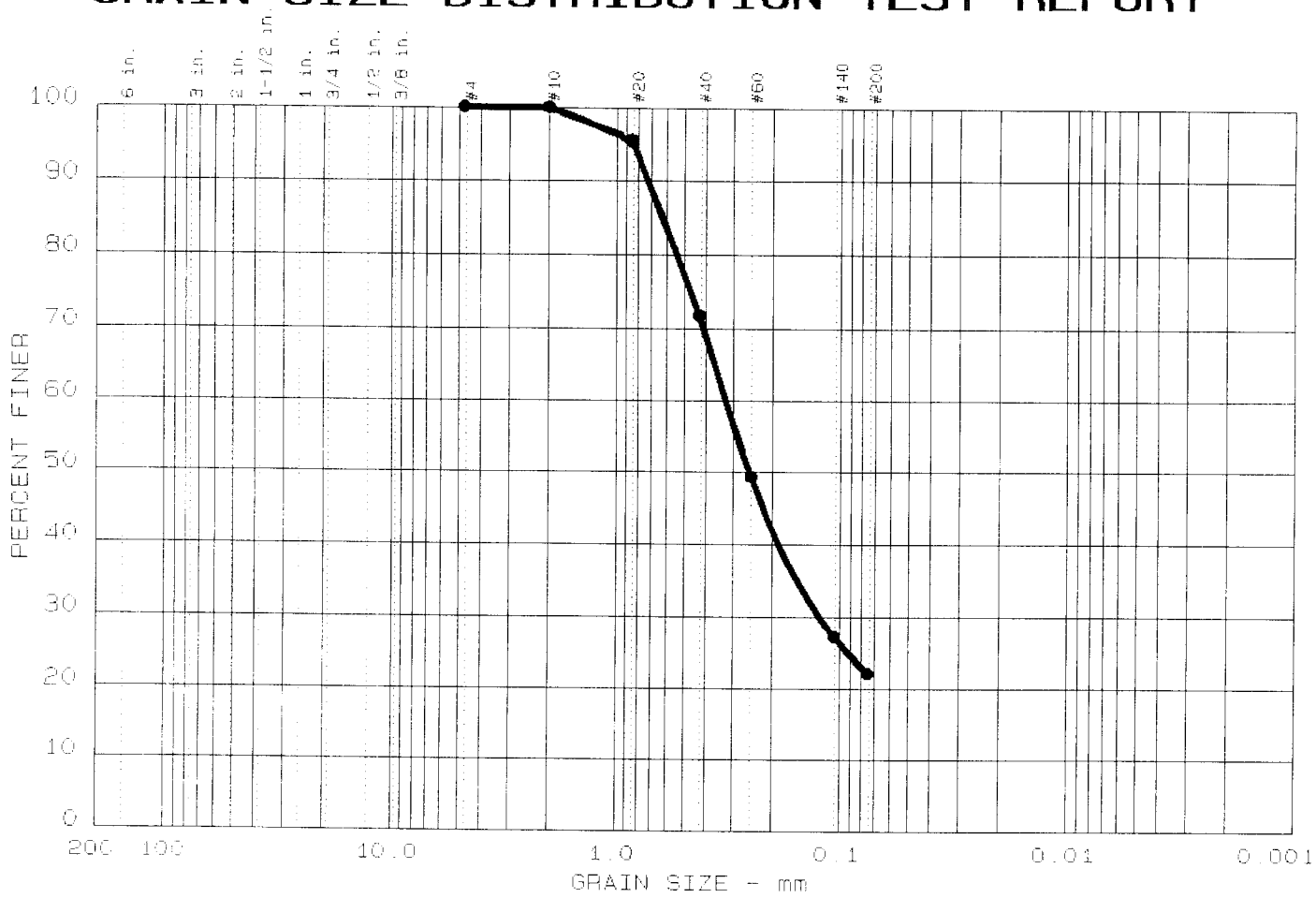
Sieve	Cumul. Wt. retained	Percent finer
0.5 inches	0.00	100.0
0.375 inches	2.58	98.5
# 4	4.58	97.4
# 10	5.74	96.7
# 20	9.55	94.6
# 40	26.11	85.2
# 60	52.51	70.2
# 140	87.74	50.2
# 200	94.90	46.2

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 3.3 % SAND = 50.6
% FINES = 46.1

D85= 0.42 D60= 0.172 D50= 0.103

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75 mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.0	77.9	22.1	

	LL	PI	D_{95}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_C	C_U
●	ND	ND	0.62	0.32	0.25	0.123				

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-804 SS-8 18.5-20'		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-804 SS-8 18.5-20'

Date: 1-2-2003

Remarks:

ND=NOT DETERMINED.

SPECIFIC GRAVITY

IS ASSUMED

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Figure No. 9

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 13

e: 1-2-2003
oject No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-804 SS-8 18.5-20'
Sample Description: B-804 SS-8 18.5-20'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-2-4 Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 9

Mechanical Analysis Data

Initial
Dry sample and tare= 133.91
Tare = 0.00
Dry sample weight = 133.91
Tare for cumulative weight retained= 0

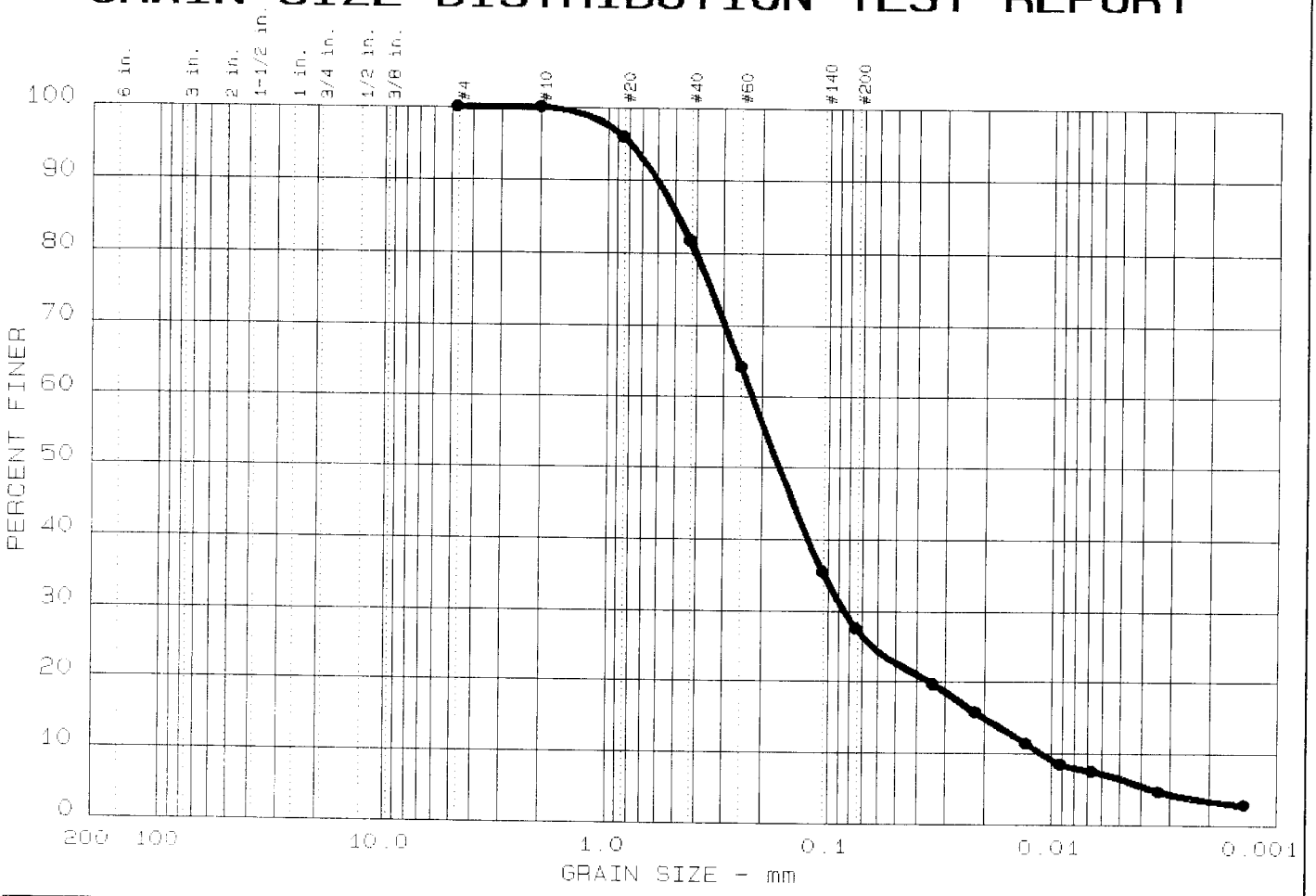
Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.04	100.0
# 20	5.94	95.6
# 40	37.80	71.8
# 60	67.88	49.3
# 140	97.44	27.2
# 200	104.29	22.1

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 0.0 % SAND = 77.9
% FINES = 22.1

D85= 0.62 D60= 0.324 D50= 0.254
D30= 0.1230

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75 mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.0	76.9	16.7	6.4

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NP	NP	0.48	0.22	0.17	0.085	0.0201	0.0112	2.91	19.7

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-805 SS-4 7.5-9'	SM	A-2-4 (0)

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-805 SS-4 7.5-9'

Date: 1/2/2002

Remarks:
ND=NOT DETERMINED.
SPECIFIC GRAVITY
IS ASSUMED

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Figure No. 1

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 1

Date: 1/2/2003
Project No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-805 SS-4 7.5-9'
Sample Description: B-805 SS-4 7.5-9'
USCS Class: SM Liquid limit: NP
AASHTO Class: A-2-4(0) Plasticity index: NP

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 1

Mechanical Analysis Data

Initial
Dry sample and tare= 168.13
Tare = 0.00
Dry sample weight = 168.13
Sample split on number 10 sieve
Split sample data:
Sample and tare = 99.56 Tare = 0 Sample weight = 99.56
Cumulative weight retained tare= 0
Tare for cumulative weight retained= 0

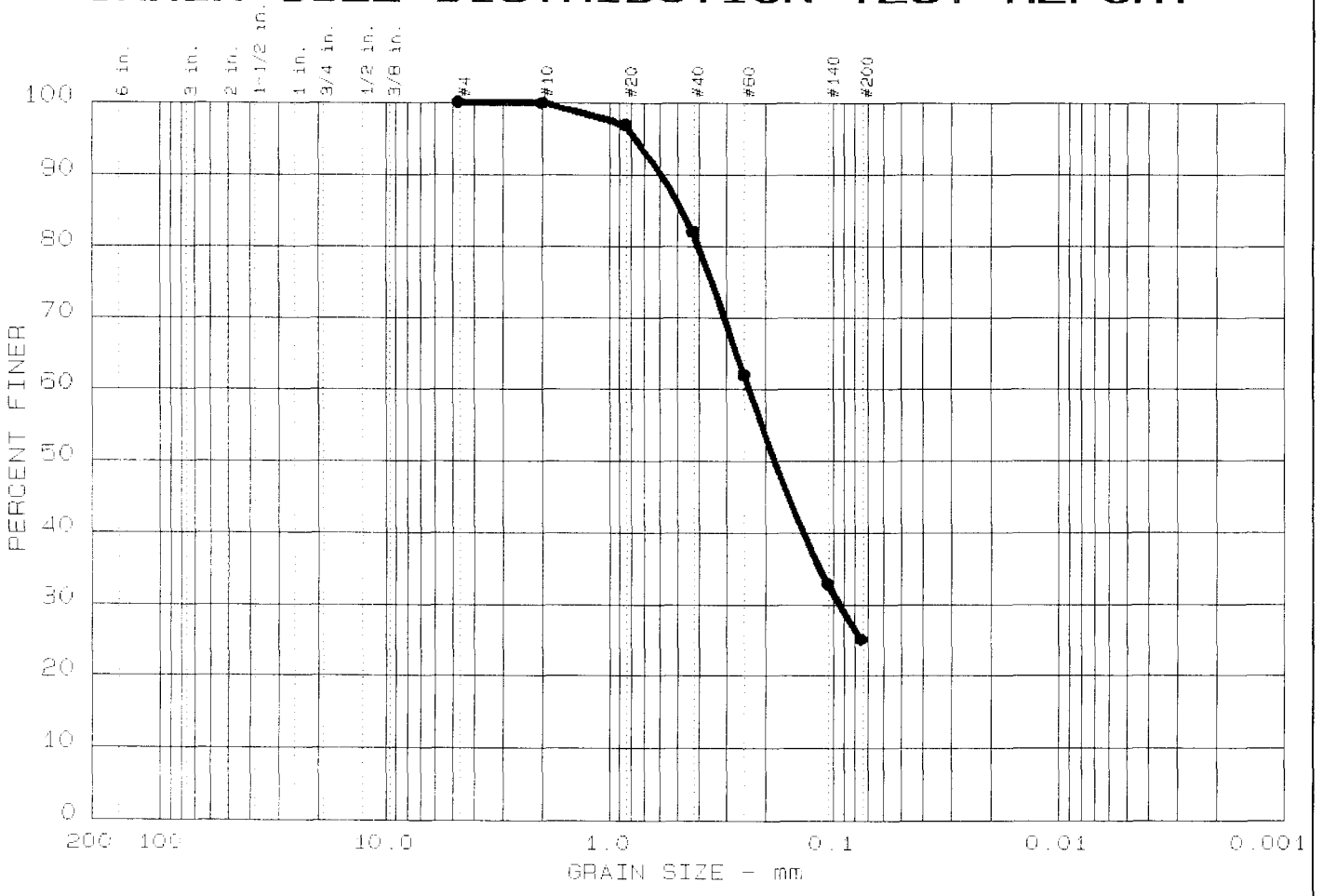
Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.02	100.0
# 20	4.08	95.9
# 40	18.13	81.8
# 60	35.61	64.2
# 140	64.22	35.5
# 200	72.15	27.5

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 99.56
Calculated biased weight= 99.57
Table of composite correction values:

Temp, deg C:	15.3	20.3	27.1
Comp. corr:			

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.1	74.8	25.1	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.47	0.24	0.18	0.094				

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-805 SS-7 18.5-20'		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-805 SS-7 18.5-20'

Date: 1-2-2003

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Remarks:

ND=NOT DETERMINED

SPECIFIC GRAVITY

IS ASSUMED

Figure No. 10

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 14

Date: 1-2-2003
Project No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-805 SS-7 18.5-20'
Sample Description: B-805 SS-7 18.5-20'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-2-4 Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 10

Mechanical Analysis Data

Initial
Dry sample and tare= 120.52
Tare = 0.00
Dry sample weight = 120.52
Tare for cumulative weight retained= 0

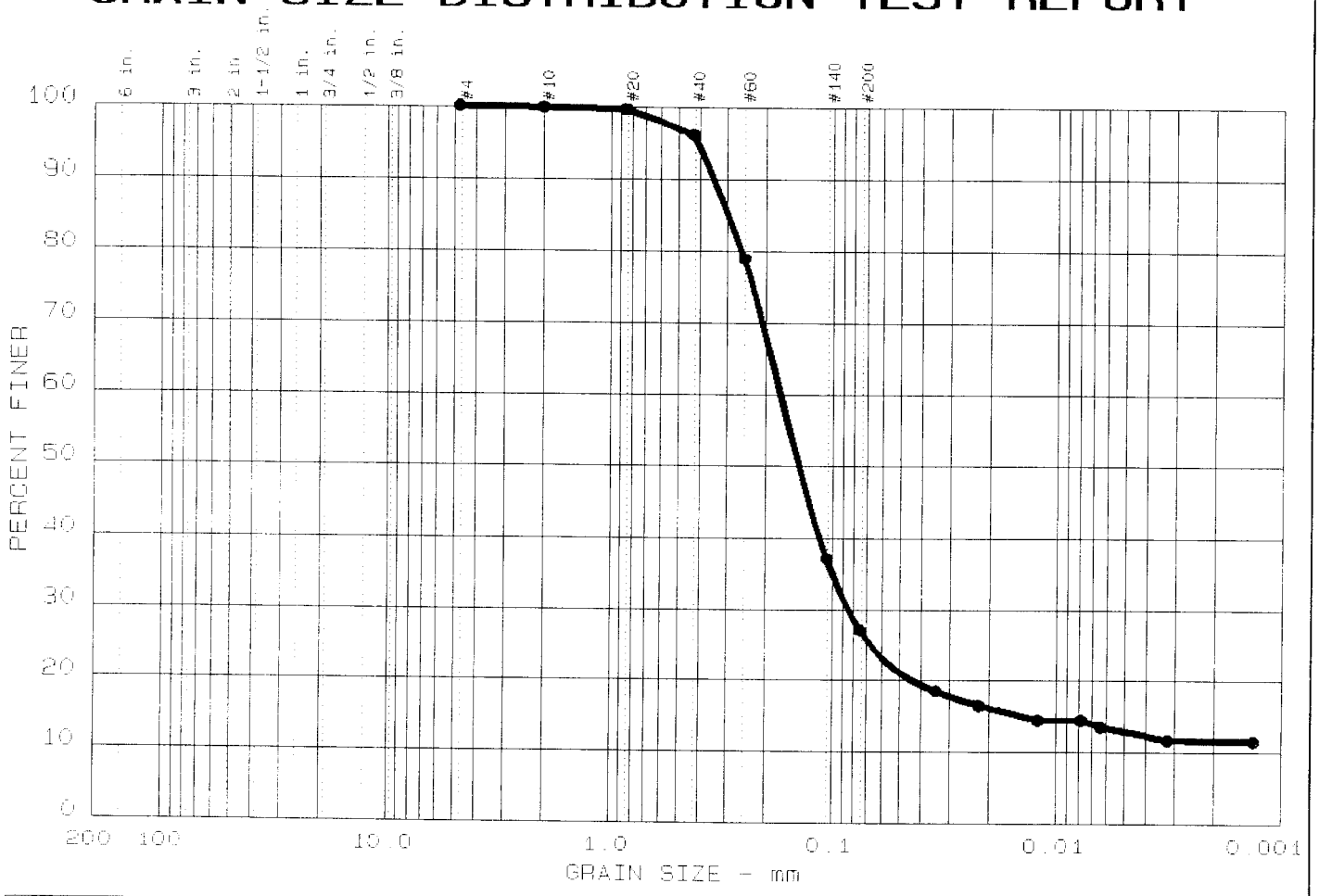
Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.11	99.9
# 20	3.76	96.9
# 40	21.65	82.0
# 60	45.83	62.0
# 140	80.96	32.8
# 200	90.24	25.1

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 0.1 % SAND = 74.8
% FINES = 25.1

D85= 0.47 D60= 0.237 D50= 0.182
D30= 0.0942

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.2	72.7	14.3	12.8

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.29	0.17	0.14	0.084	0.0138			

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-806 SS-3 5.6-7.1'		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-806 SS-3 5.6-7.1'

Date: 1-2-2002

Remarks:

ND=NOT DETERMINED

SPECIFIC GRAVITY

IS ASSUMED

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Figure No. 2

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 16

Date: 1-2-2003
Project No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-806 SS-3 5.6-7.1'
Sample Description: B-806 SS-3 5.6-7.1'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-2-4(0) Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 2

Mechanical Analysis Data

	Initial
Dry sample and tare=	120.73
Tare =	0.00
Dry sample weight =	120.73

Sample split on number 10 sieve
Split sample data:
Sample and tare = 98.05 Tare = 0 Sample weight = 98.05
Cumulative weight retained tare= 0
Tare for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.21	99.8
# 20	0.21	99.6
# 40	3.62	96.1
# 60	20.51	78.9
# 140	61.66	37.0
# 200	71.41	27.1

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 99.8
Weight of hydrometer sample: 98.05
Calculated biased weight= 98.22
Table of composite correction values:

Temp, deg C:	15.3	20.3	27.1
Comp. corr:			

- 6.5 - 5.0 - 3.0
Meniscus correction only=-1
Specific gravity of solids= 2.63
Specific gravity correction factor= 1.005
Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

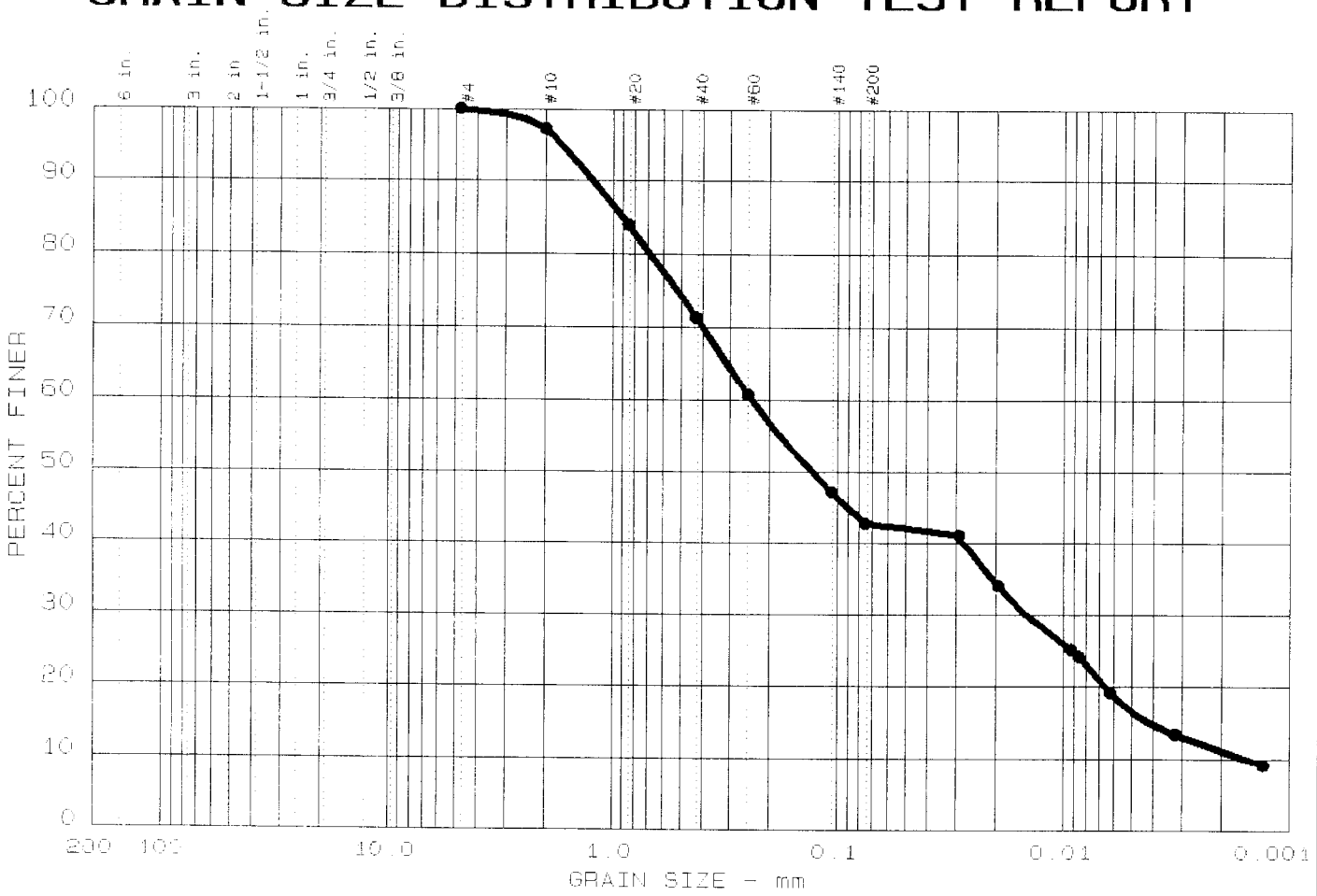
Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
2.0	20.5	23.0	18.1	0.0136	22.0	12.7	0.0344	18.5
5.0	20.5	21.0	16.1	0.0136	20.0	13.0	0.0220	16.4
17.0	20.6	19.0	14.1	0.0136	18.0	13.3	0.0121	14.4
41.0	20.6	19.0	14.1	0.0136	18.0	13.3	0.0078	14.4
62.0	20.9	18.0	13.2	0.0136	17.0	13.5	0.0063	13.5
244.0	21.6	16.0	11.4	0.0135	15.0	13.8	0.0032	11.6
1440.0	21.1	16.0	11.2	0.0135	15.0	13.8	0.0013	11.5

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 0.2 % SAND = 72.7
% SILT = 14.3 % CLAY = 12.8

D85= 0.29 D60= 0.171 D50= 0.141
D30= 0.0842 D15= 0.01382

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	2.7	54.6	26.1	16.6

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_C	C_U
●	41	7	0.90	0.24	0.13	0.015	0.0041	0.0015	0.58	154.9

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-807 SS-8 21.8-23.3'	SM-SC	A-5(1)

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-807 SS-8 21.8-23.3'

Date: 1-2-2003

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Remarks:

ND=NOT DETERMINED

SPECIFIC GRAVITY

IS ASSUMED

Figure No. 3

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 17

e: 1-2-2003
oject No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-807 SS-8 21.8-23.3'
Sample Description: B-807 SS-8 21.8-23.3'
USCS Class: SM-SC Liquid limit: 41
AASHTO Class: A-5(1) Plasticity index: 7

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 3

Mechanical Analysis Data

	Initial
Dry sample and tare=	183.66
Tare =	0.00
Dry sample weight =	183.66

Sample split on number 10 sieve
it sample data:
Sample and tare = 97.65 Tare = 0 Sample weight = 97.65
Cumulative weight retained tare= 0
Tare for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	5.04	97.3
# 20	13.34	84.0
# 40	26.07	71.3
# 60	36.65	60.8
# 140	50.37	47.1
# 200	54.83	42.6

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 97.3
Weight of hydrometer sample: 97.65
Calculated biased weight= 100.41
Table of composite correction values:

Temp, deg C:	15.3	20.3	27.1
Comp. corr:			

- 6.5 - 5.0 - 3.0
Meniscus correction only=-1
Specific gravity of solids= 2.63
Specific gravity correction factor= 1.005
Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

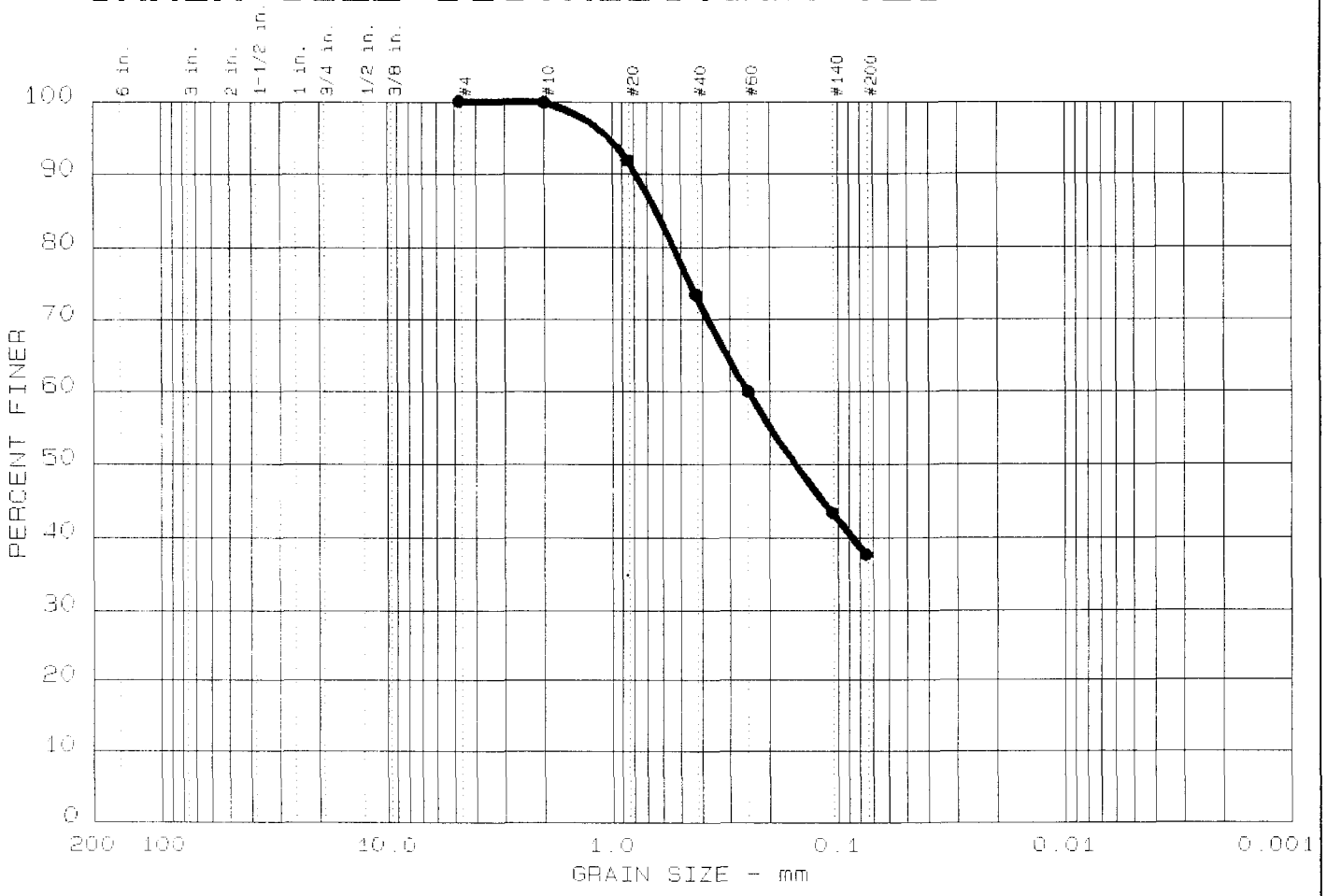
Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
2.0	20.3	46.0	41.0	0.0137	45.0	8.9	0.0289	41.0
5.0	20.3	39.0	34.0	0.0137	38.0	10.1	0.0194	34.0
25.0	20.4	30.0	25.0	0.0137	29.0	11.5	0.0093	25.0
30.0	20.4	29.0	24.0	0.0137	28.0	11.7	0.0085	24.0
60.0	20.8	24.0	19.1	0.0136	23.0	12.5	0.0062	19.2
240.0	21.6	18.0	13.4	0.0135	17.0	13.5	0.0032	13.4
1539.0	21.0	14.0	9.2	0.0136	13.0	14.2	0.0013	9.2

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 2.7 % SAND = 54.6
% SILT = 26.1 % CLAY = 16.6

D85= 0.90 D60= 0.240 D50= 0.129
D30= 0.0146 D15= 0.00412 D10= 0.00155
Cc = 0.5754 Cu = 154.8817

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.1	62.2	37.7	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.64	0.25	0.15					

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-807 SS-10 31.5-33'		

Project No.: 30720-2-5400
Project: NORTH ANNA ESP
● Location: B-807 SS-10 31.5-33'

Date: 1-2-2003

Remarks:
ND=NOT DETERMINED
SPECIFIC GRAVITY
IS ASSUMED

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Figure No. 4

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 18

e: 1-2-2003
oject No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-807 SS-10 31.5-33'
Sample Description: B-807 SS-10 31.5-33'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-4(0) Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 4

Mechanical Analysis Data

Initial
Dry sample and tare= 180.87
Tare = 0.00
Dry sample weight = 180.87
Tare for cumulative weight retained= 0

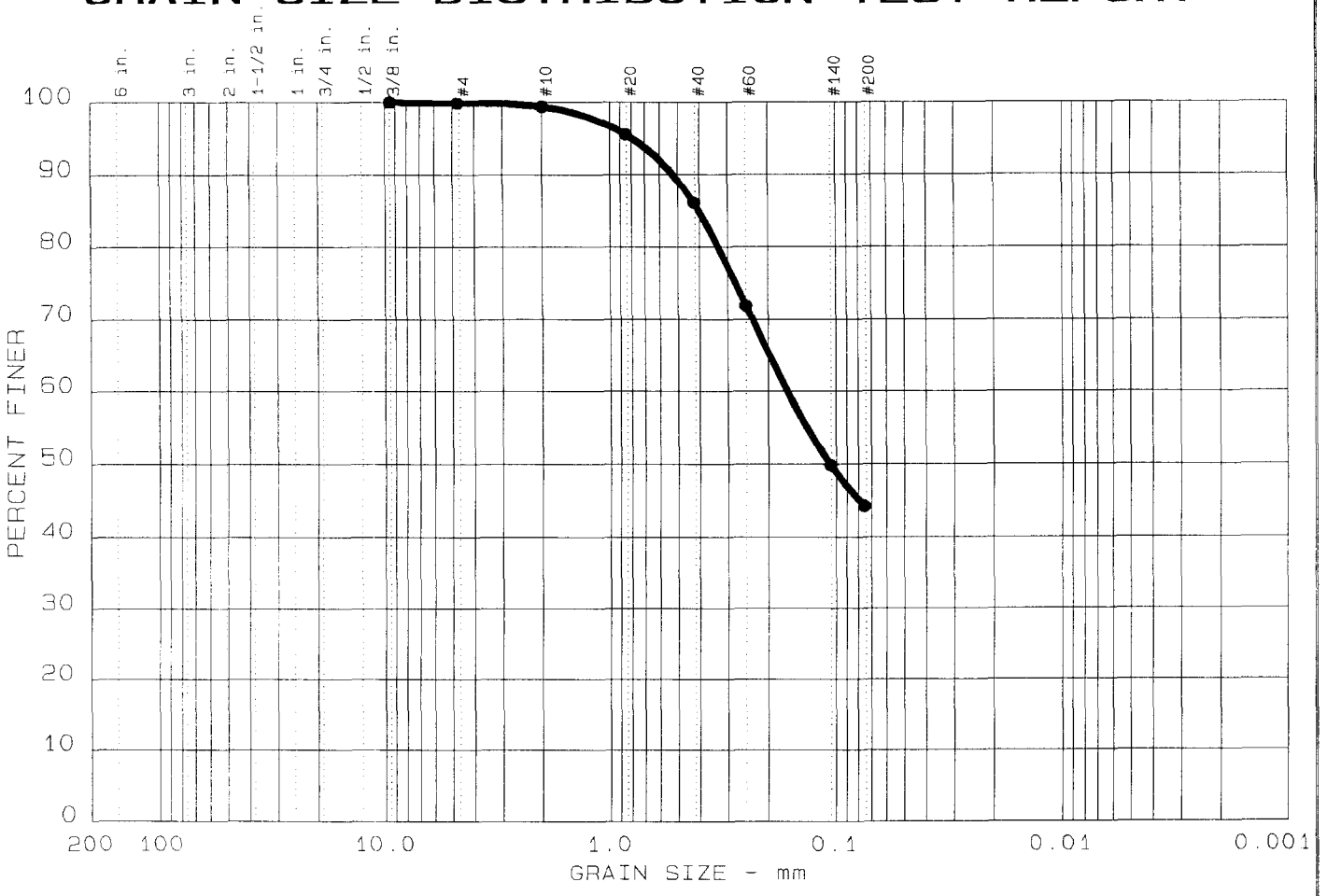
Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.25	99.9
# 20	14.68	91.9
# 40	47.99	73.5
# 60	72.48	59.9
# 140	102.54	43.3
# 200	112.82	37.6

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 0.1 % SAND = 62.2
% FINES = 37.7

D85= 0.64 D60= 0.251 D50= 0.155

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75 mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.6	55.2	44.2	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	ND	ND	0.40	0.16	0.11					

	MATERIAL DESCRIPTION	USCS	AASHTO
●	B-807 SS-12 41.4-42.9'		

Project No.: 30720-2-5400

Project: NORTH ANNA ESP

● Location: B-807 SS-12 41.4-42.9'

Date: 1-2-2003

Remarks:

ND=NOT DETERMINED.

SPECIFIC GRAVITY

IS ASSUMED

GRAIN SIZE DISTRIBUTION TEST REPORT

LAW ENGINEERING, INC.

Figure No. 5

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 19

e: 1-2-2003
. oject No.: 30720-2-5400
Project: NORTH ANNA ESP

Sample Data

Location of Sample: B-807 SS-12 41.4-42.9'
Sample Description: B-807 SS-12 41.4-42.9'
USCS Class: SM Liquid limit: ND
AASHTO Class: A-4(0) Plasticity index: ND

Notes

Remarks: ND=NOT DETERMINED. SPECIFIC GRAVITY IS ASSUMED
Fig. No.: 5

Mechanical Analysis Data

Initial
Dry sample and tare= 151.70
Tare = 0.00
Dry sample weight = 151.70
Tare for cumulative weight retained= 0

ieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
# 4	0.15	99.9
# 10	0.87	99.4
# 20	6.70	95.6
# 40	21.05	86.1
# 60	42.60	71.9
# 140	76.12	49.8
# 200	84.59	44.2

Fractional Components

Gravel/Sand based on #10 sieve
Sand/Fines based on #200 sieve
% + 75mm. = 0.0 % GRAVEL = 0.6 % SAND = 55.2
% FINES = 44.2

D85= 0.40 D60= 0.164 D50= 0.106

MACTEC

Unconfined Compressive Strength of Intact Rock Core Specimens
(ASTM D2938-95) (Modified[1,3])

Project No.: 30720-2-5400.07.800
Project Name: North Anna ESP

Tested By: Daniel Johnson
Test Date: 1/21/2003
Reviewed By: Thomas Dobras
Review Date: 1/27/2003

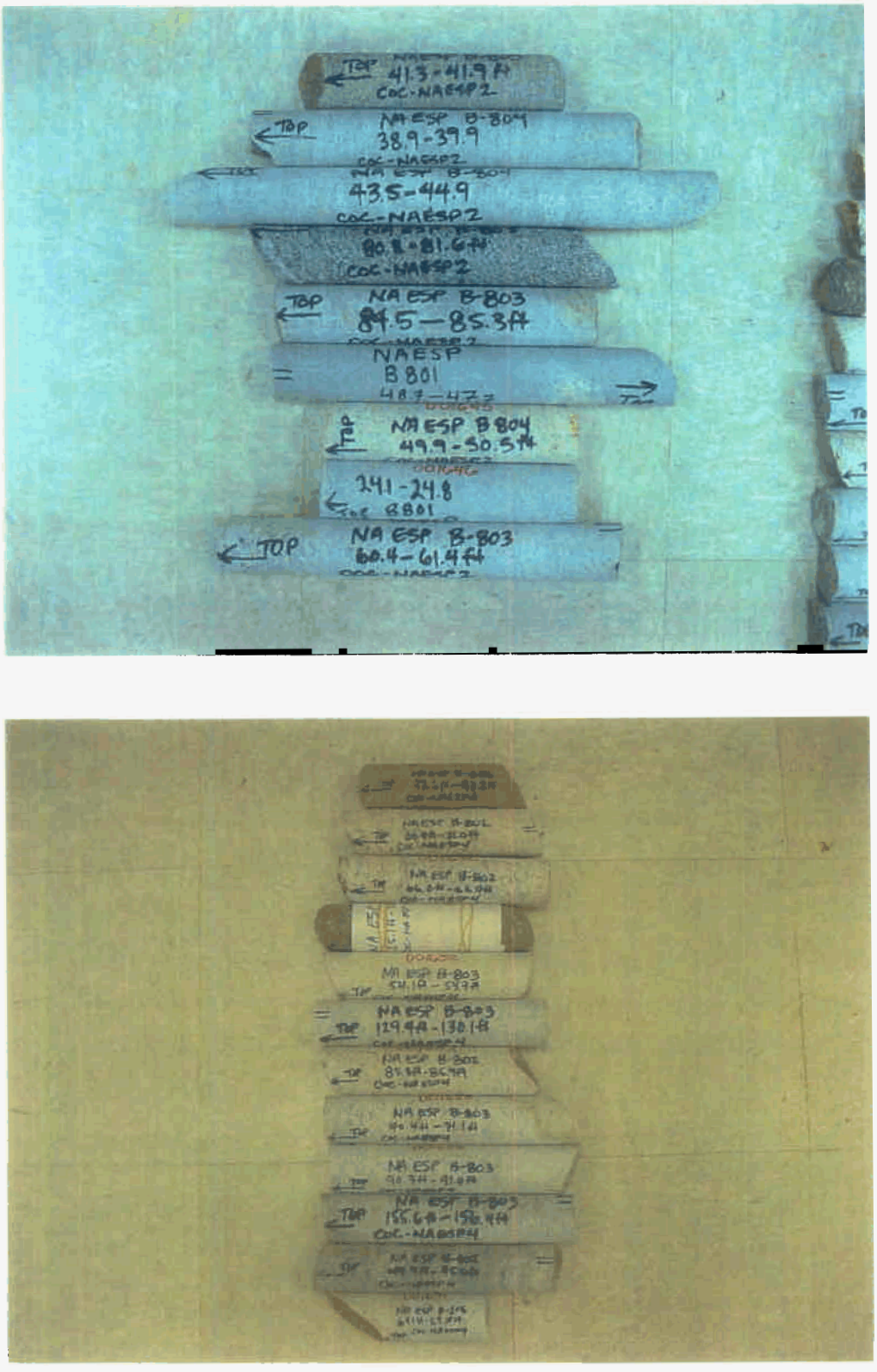
Specimen Specifications:

[2] Minimum diameter - 47mm (1.85")
[3] L/D ratio 2.0<L/D<2.5
[4] Straightness: 0.02" maximum gap
[5] Flatness: 0.0015" difference between maximum and minimum readings

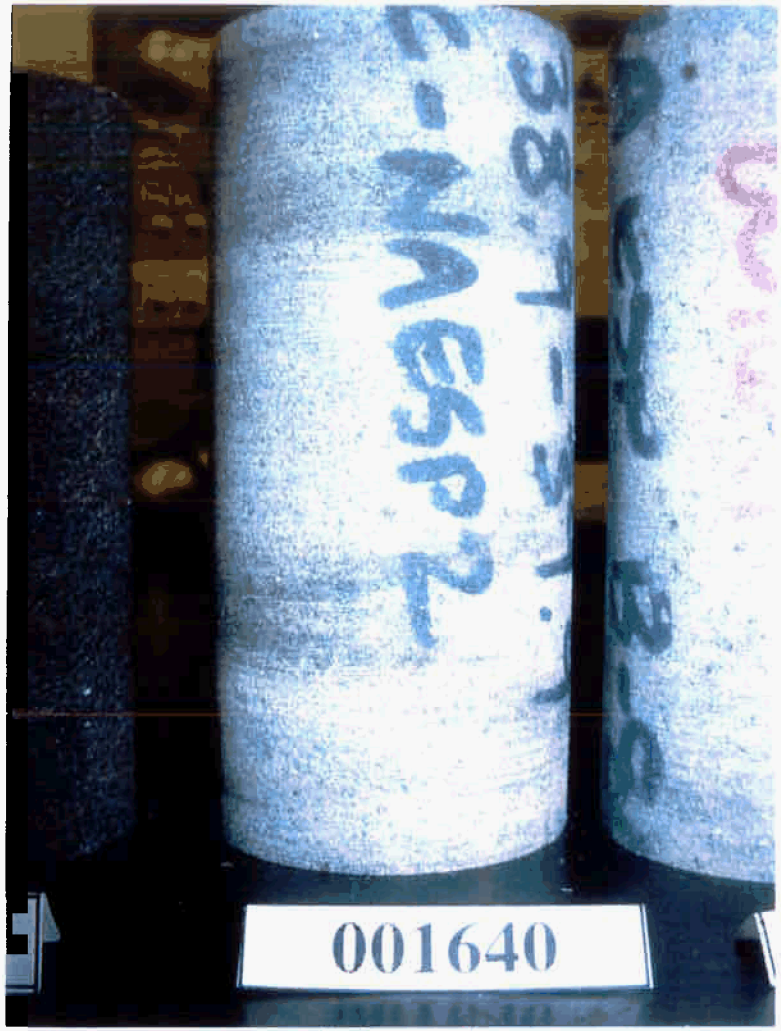
Boring No.	Depth (ft)	MACTEC Lab ID #	Moisture Content (%)	Dry Density (pcf)	Specimen Diameter (D) (in)	Specimen Length (L) (in)	L/D Ratio	Type of Break	Rate of Loading (lbs/min)	Unconfined Compressive Strength (psi)
B-805	41.3-41.9	001639	0.2	169.6	1.859	3.685	2.0	Shear	800	3,400
B-804	38.9-39.9	001640	0.1	162.5	1.868	3.986	2.1	Cone	15,000	27,150
B-804	43.5-44.9	001641	0.1	163.0	1.868	4.000	2.1	Cone	14,000	25,200
B-805	80.8-81.6	001642	0.2	181.3	1.854	3.774	2.0	Shear	6,000	4,430
B-801	48.7-49.7	001644	0.1	164.0	1.863	4.051	2.2	Cone	10,000	28,420
B-804	49.9-50.5	001645	0.1	162.3	1.863	3.943	2.1	Cone & Shear	5,000	12,300
B-801	24.1-24.8	001646	0.1	164.0	1.864	4.010	2.2	Cone	14,000	27,210
B-806	42.6-43.2	001648	0.3	169.4	1.853	3.264	1.8	Cone & Shear	4,000	2,720
B-802	20.4-21.0	001649	0.2	160.8	1.861	3.973	2.1	Shear	6,000	8,640
B-802	66.0-66.7	001650	0.3	160.4	1.859	3.757	2.0	Cone & Split	5,000	14,710
B-806	25.1-25.8	001651	1.2	144.5	1.844	3.918	2.1	Crumbled	800	610
B-803	54.1-54.7	001652	0.1	162.4	1.858	3.830	2.1	Shear	12,000	13,010
B-803	129.4-130.1	001653	0.1	164.3	1.868	4.096	2.2	Shear	14,000	26,730
B-802	85.3-85.9	001654	0.3	161.8	1.859	3.773	2.0	Cone & Shear	10,000	9,370
B-803	70.4-71.1	001655	0.1	163.4	1.866	4.168	2.2	Cone & Shear	10,000	23,210
B-803	90.3-91.0	001656	0.1	163.0	1.872	3.903	2.1	Shear	14,000	27,590
B-803	155.6-156.4	001657	0.1	164.2	1.873	3.910	2.1	Cone & Shear	10,000	22,030
B-802	44.9-45.6	001658	0.1	175.5	1.862	4.105	2.2	Cone & Shear	8,000	11,760
B-806	64.1-64.5	001659	0.1	163.6	1.844	3.589	1.9	Cone & Shear	15,000	27,360

Comments:

[1] Top bearing plate to specimen diameter ratio was 1.67 (Per Section 5.4 of ASTM D2938, max. allow. is 1.1)
[2] All specimen diameters except as shaded met the minimum requirements per ASTM D4543-01.
[3] Specimens shown were outside the allowable tolerance for L/D ratio or were less than the minimum diameter
[4] Straightness of elements was determined by Procedure A as referenced in ASTM D4543-01, Section 5.1.1.
[5] Flatness of the specimen was determined by Procedure B as referenced in ASTM D4543-01, Section 5.2.2.
Physical description of the samples is listed on a separate report.
Test temperature was room temperature, 20-22 ^{0} C. Lab Id#s 001643 and 001647 not assigned.



SAMPLES FOR STRENGTH TESTING AS RECEIVED IN LAB



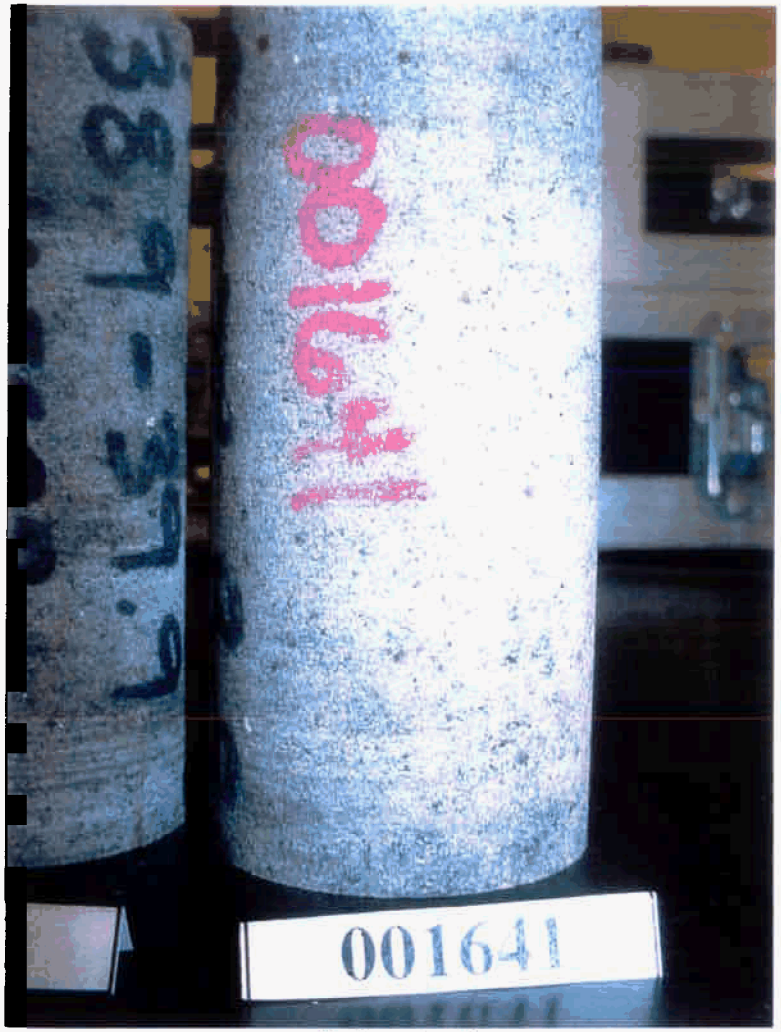
Before testing



After Testing

B-804 **Depth (ft): 38.9-39.9**

Physical Description: Fresh, very hard, Quartz Gneiss with weak foliation at 50-60°



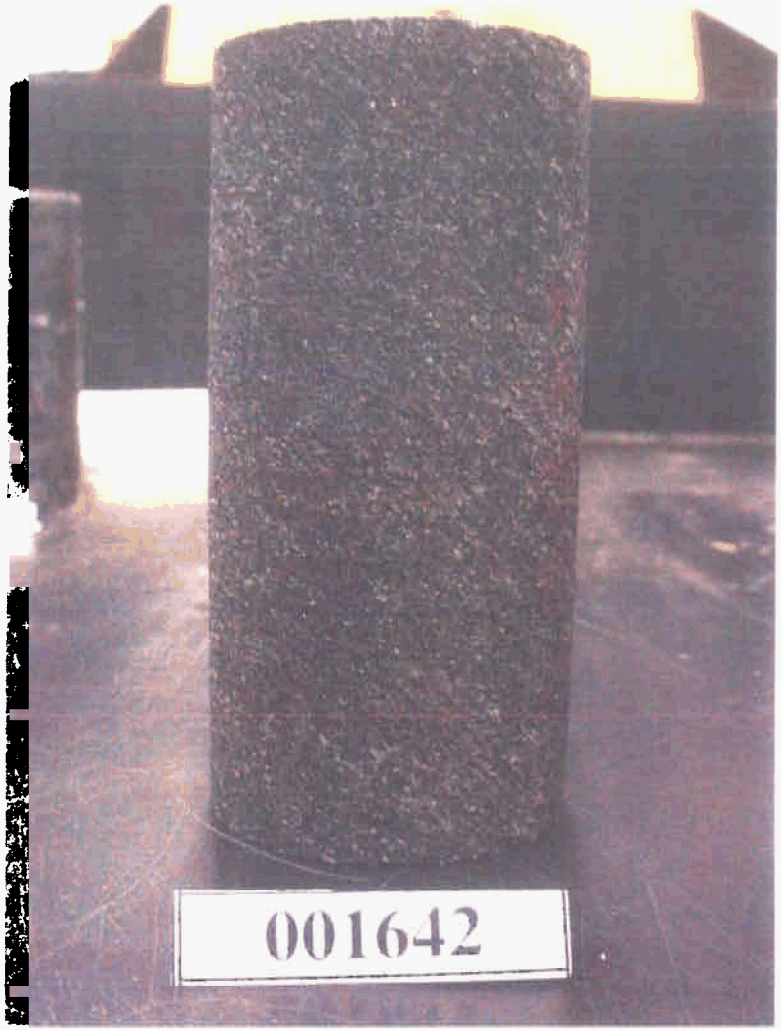
Before testing



After testing

B-804 **Depth (ft): 43.5-44.9**

Physical Description: Very slightly weathered, hard, Quartz Gneiss with weak foliation at 50-60°



Before testing



After testing

B-805 **Depth (ft): 80.8-81.6**

Physical Description: Fresh, hard, Biotite Gneiss with strong foliation at 50-60°



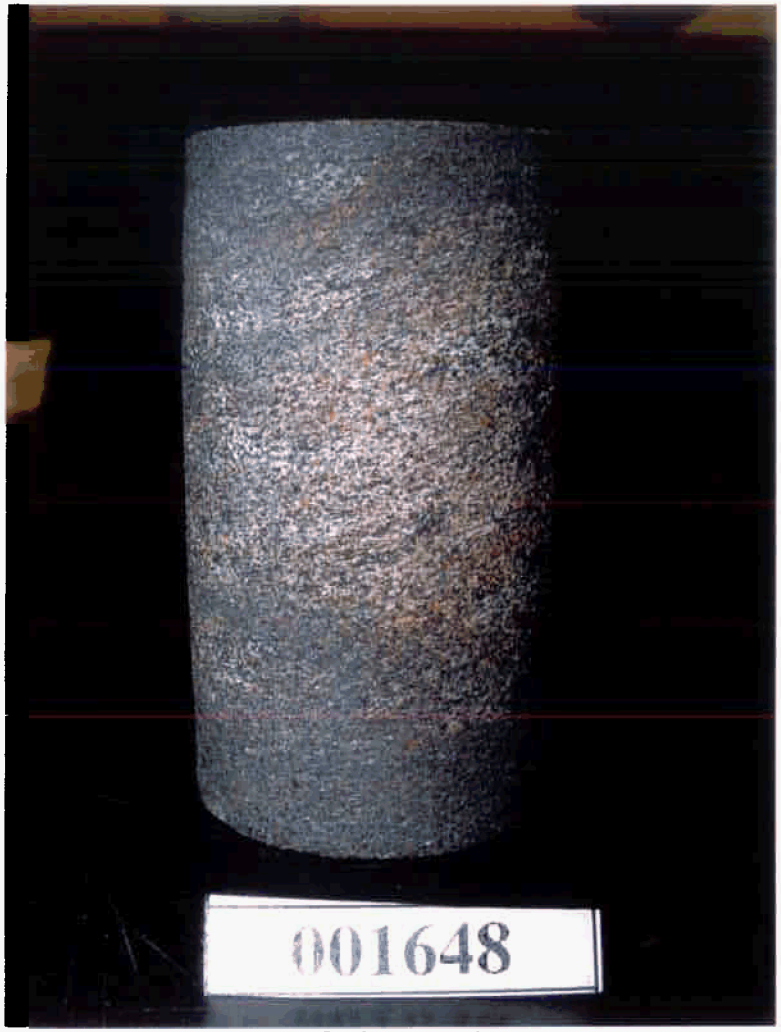
Before testing



After testing

B-801 **Depth (ft): 24.1-24.8**

Physical Description: Very slightly weathered, hard, Quartz Gneiss with weak foliation at 50-60°



Before testing



After testing

B-806 **Depth (ft): 42.6-43.2**

Physical Description: Moderately weathered, moderately hard, Biotite Gneiss with strong foliation at 30-40°



Before testing



After testing

B-802 **Depth (ft): 20.4-21.0**

Physical Description: Moderately weathered, hard, Quartz Gneiss with strong foliation at 50-60°



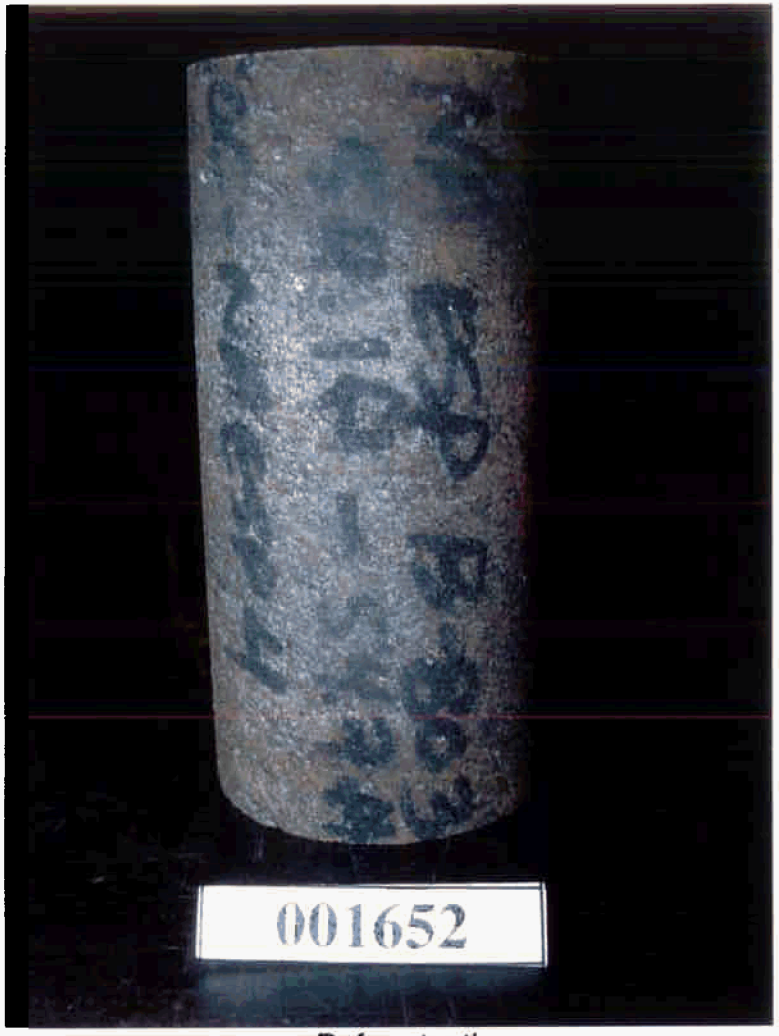
Before testing



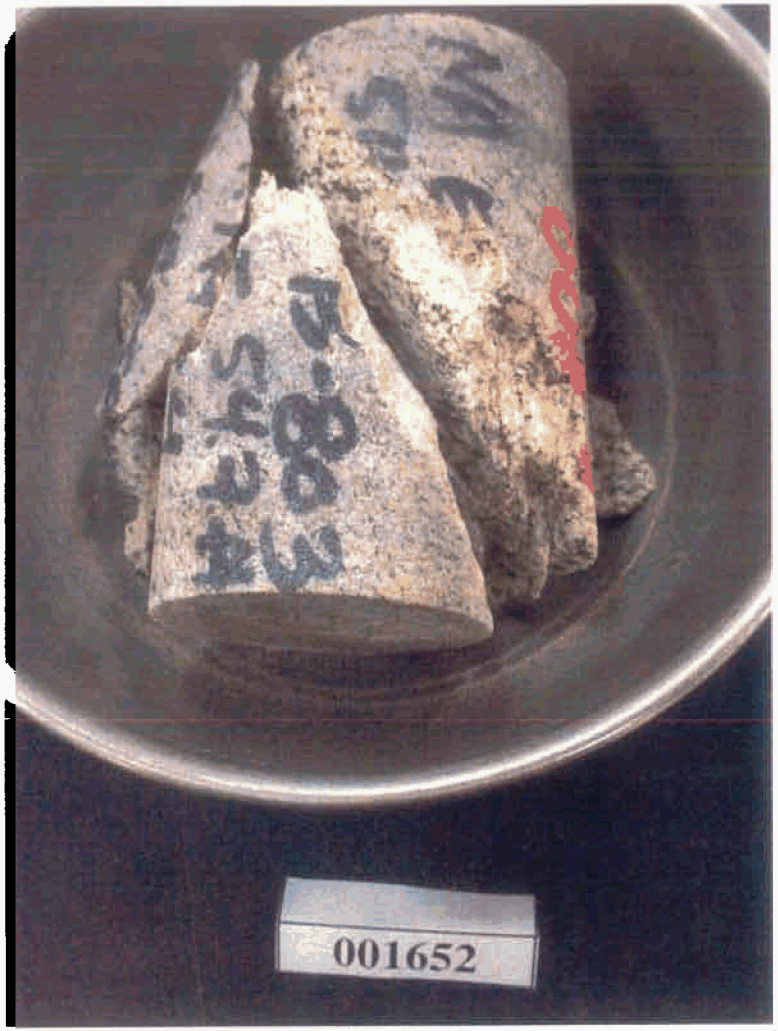
After testing

B-806 **Depth (ft): 25.1-25.8**

Physical Description: Moderately weathered, moderately hard, Biotite Gneiss with strong foliation at 30-40°



Before testing



After testing

B-803 **Depth (ft): 54.1-54.7**

Physical Description: Slightly weathered, hard, Quartz Gneiss with weak foliation at 50-60°



Before testing



After testing

B-803 **Depth (ft): 129.4-130.1**

Physical Description: Fresh, very hard, Quartz Gneiss with weak foliation at 50-60°



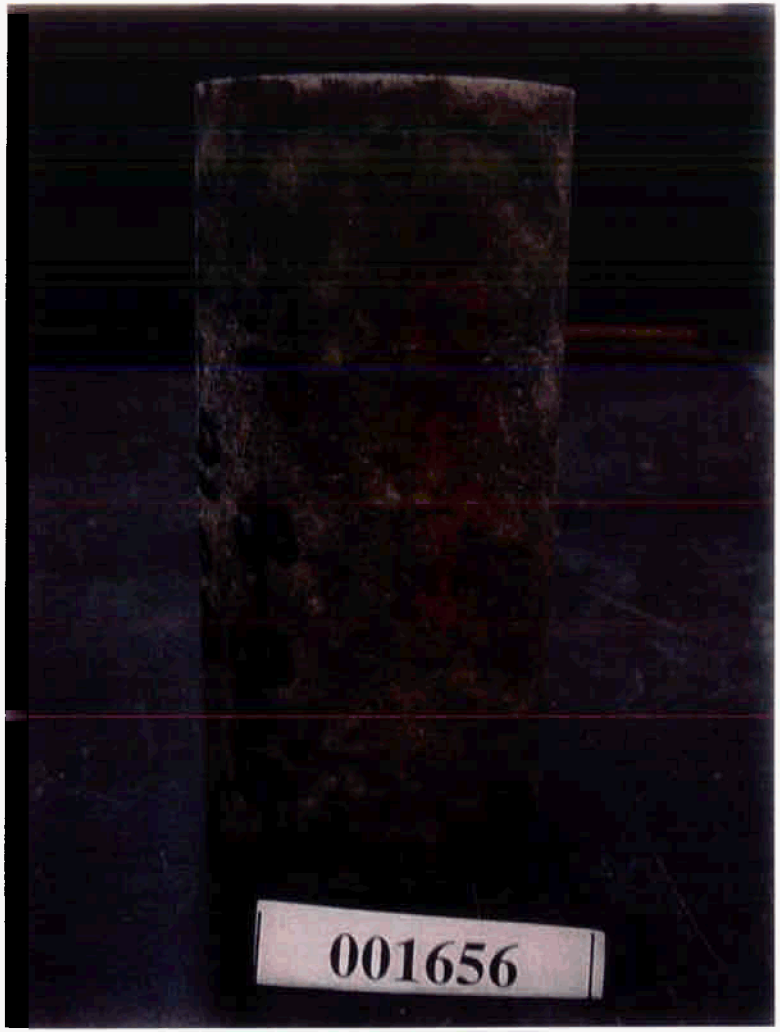
Before testing



After testing

B-802 **Depth (ft): 85.3-85.9**

Physical Description: Slightly weathered, hard, Quartz Gneiss with weak foliation at 50-60°



Before testing



After testing

B-803 **Depth (ft): 90.3-91.0**

Physical Description: Fresh, very hard, Quartz Gneiss with weak foliation at 50-60°



Before testing



After testing

B-802 **Depth (ft): 44.9-45.6**

Physical Description: Slightly weathered, hard, Biotite Quartz Gneiss with strong foliation at 50-60°



Before testing



After testing

B-806 **Depth (ft): 64.1-64.5**

Physical Description: Fresh, Quartz Gneiss with weak foliation at 50-60°

MACTEC

Elastic Modulii of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001639	**Gage Factor:**	2.090
Sample I.D.:	B-805 Depth 41.3-41.9 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	1/28/2003

Specimen Information	
Average Diameter, inch	1.859
Average Height, inch	3.685
Moisture Content (%)	0.2
Ultimate Load, lb_f	9222

RUN # 2

Load, lb_f	Longitudinal ε μ inch/inch	Transverse ε μ inch/inch
0	-11	11
400	-550	19
800	-969	24
1,200	-1426	69
1,600	-1865	125
2,000	-2283	220
2,400	-2624	340
2,800	-2948	470
3,200	-3272	600
3,600	-3578	755
4,000	-3850	915
4,400	-4144	1109
4,800	-4425	1319
5,200	-4701	1560
5,600	-4966	1818
6,000	-5251	2119
7,000	-5967	2990
8,000	-6803	4240
9,000	-7966	6300

MACTEC

Elastic Moduli of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001639	**Gage Factor:**	2.09
Sample I.D.:	B-805 Depth 41.3-41.9 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	01/28/03

Average Diameter, inch	1.859
Average Length, inch	3.685
Length/Diameter ratio	2.0
Specimen Area, inch^2	2.714
Moisture Content (%)	0.2
Rate of loading (lbs/min)	800
Compressive Strength, psi	**3,400**
Longitudinal e Correction, inch/inch	-0.000011
Transverse e Correction, inch/inch	0.000011
Modulus of Elasticity, psi	**522,000**
Poisson's Ratio	**0.54**

RUN # 2		
Stress, psi	**Longitudinal e** inch/inch	**Transverse e** inch/inch
0	0.000000	0.000000
147	0.000539	-0.000008
295	0.000958	-0.000013
442	0.001415	-0.000058
589	0.001854	-0.000114
737	0.002272	-0.000209
884	0.002613	**-0.000329**
1,032	0.002937	-0.000459
1,179	**0.003261**	-0.000589
1,326	0.003567	-0.000744
1,474	0.003839	-0.000904
1,621	0.004133	**-0.001098**
1,768	0.004414	-0.001308
1,916	0.004690	-0.001549
2,063	**0.004955**	-0.001807
2,211	0.005240	-0.002108
2,579	0.005956	-0.002979
2,947	0.006792	-0.004229
3,316	0.007955	-0.006289

Note : Points chosen are in Bold.

Comments: Material description and photographs submitted in separate report

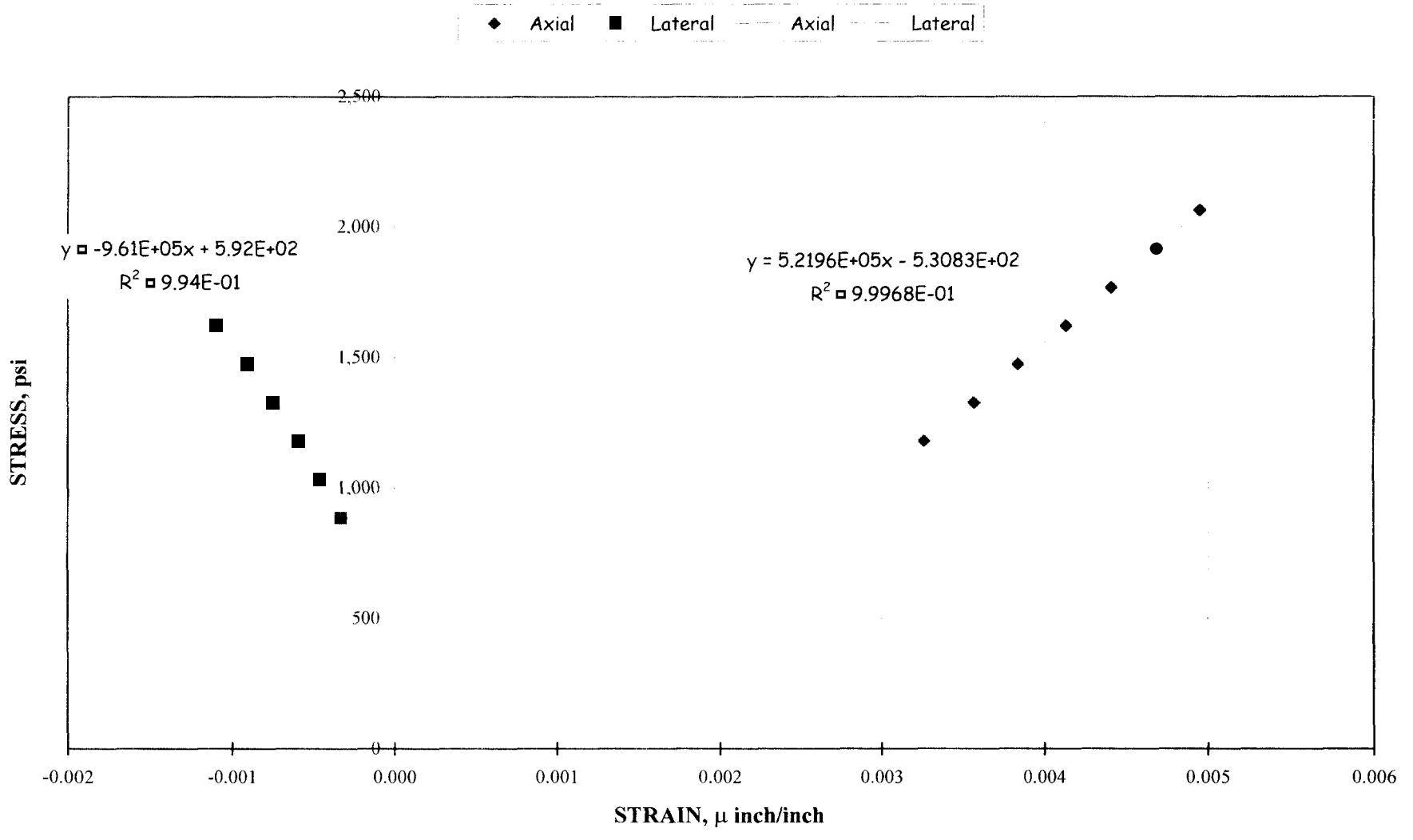
Test temperature was room temperature at 20-22 ^{0}C

Analysis using middle portion of curve. Poisson's ratio indicates plastic deformation

Analysis was rerun using lower portion of curve. See attached sheet.

MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001639 Boring No. B-805 (41.3-41.9 ft)



MACTEC

Elastic Moduli of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001639	**Gage Factor:**	2.09
Sample I.D.:	B-805 Depth 41.3-41.9 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	J. A. Tice ~~Thomas N. Dobras~~ 2-5-03
Test Date:	01/24/03	**Review Date:**	01/28/03

Average Diameter, inch	1.859
Average Length, inch	3.685
Length/Diameter ratio	2.0
Specimen Area, inch^2	2.714
Moisture Content (%)	0.2
Rate of loading (lbs/min)	800
Compressive Strength, psi	**3,400**
Longitudinal e Correction, inch/inch	-0.000011
Transverse e Correction, inch/inch	0.000011
Modulus of Elasticity, psi	**336,000**
Poisson's Ratio	**0.15**

RUN # 2

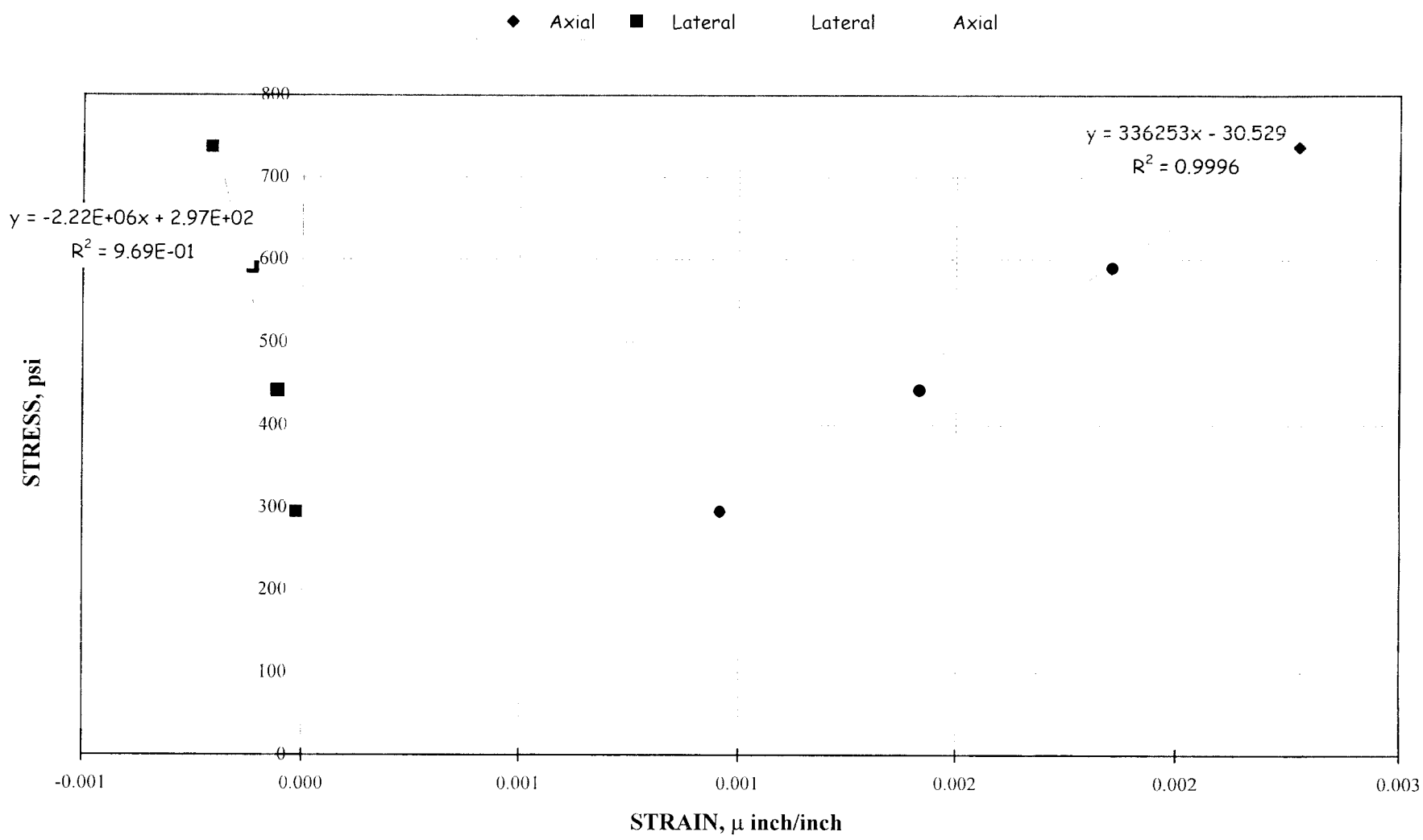
Stress, psi	Longitudinal e inch/inch	Transverse e inch/inch	Longitudinal Modulus	Transverse Modulus	Poisson's Ratio	Volumetric Strain ε_v
0	0.000000	0.000000	273415.144	-18421345.31	0.014842	0
147	0.000539	-0.000008	351720.197	-29474152.49	0.011933	0.000523
295	**0.000958**	**-0.000013**	322474.316	-3274905.832	0.098468	0.000932
442	0.001415	-0.000058	335696.498	-2631620.758	0.127563	0.001299
589	0.001854	-0.000114	352561.633	-1551271.184	0.227273	0.001626
737	**0.002272**	**-0.000209**	432172.324	-1228089.687	0.351906	0.001854
884	0.002613	-0.000329	454848.032	-1133621.25	0.401235	0.001955
1,032	0.002937	-0.000459	454848.032	-1133621.25	0.401235	0.002019
1,179	0.003261	-0.000589	481603.799	-950779.1126	0.506536	0.002083
1,326	0.003567	-0.000744	541804.274	-921067.2653	0.588235	0.002079
1,474	0.003839	-0.000904	501261.097	-759643.1054	0.659864	0.002031
1,621	0.004133	-0.001098	524451.112	-701765.5355	0.747331	0.001937
1,768	0.004414	-0.001308	533952.038	-611496.9396	0.873188	0.001798
1,916	0.004690	-0.001549	556116.085	-571204.5056	0.973585	0.001592
2,063	0.004955	-0.001807	517090.395	-489603.8619	1.05614	0.001341
2,211	0.005240	-0.002108	514562.718	-422993.0036	1.21648	0.001024
2,579	0.005956	-0.002979	440702.041	-294741.5249	1.495215	-2E-06
2,947	0.006792	-0.004229	316790.117	-178848.0127	1.771281	-0.001666
3,316	0.007955	-0.006289				-0.004623

Note : Points chosen are in Bold.

Comments: Material description and photographs submitted in separate report
Test temperature was room temperature at 20-22 °C
Analysis using lower portion of curve 2-5-03

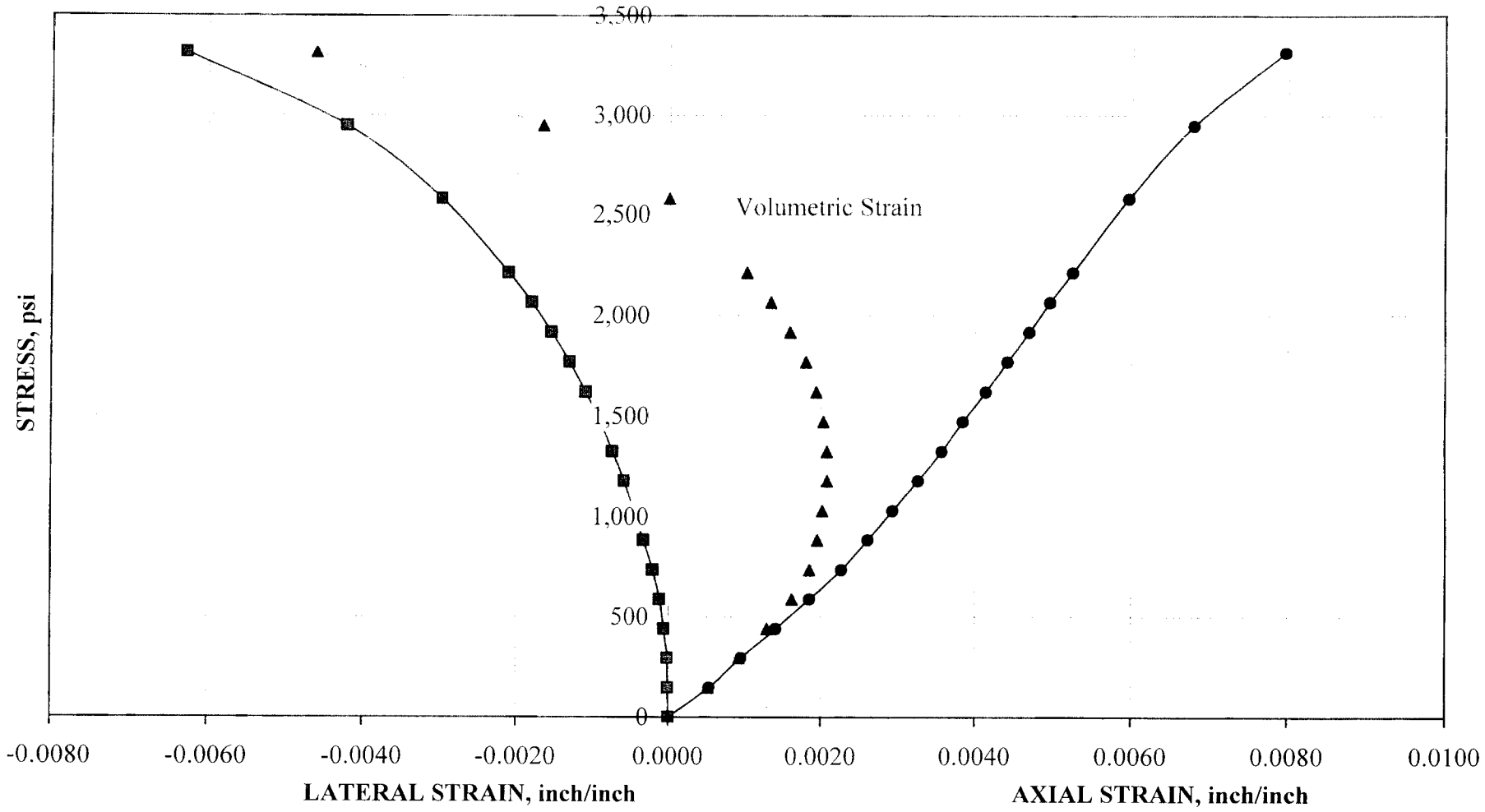
MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001639 Boring No. B-805 (41.3-41.9 ft)



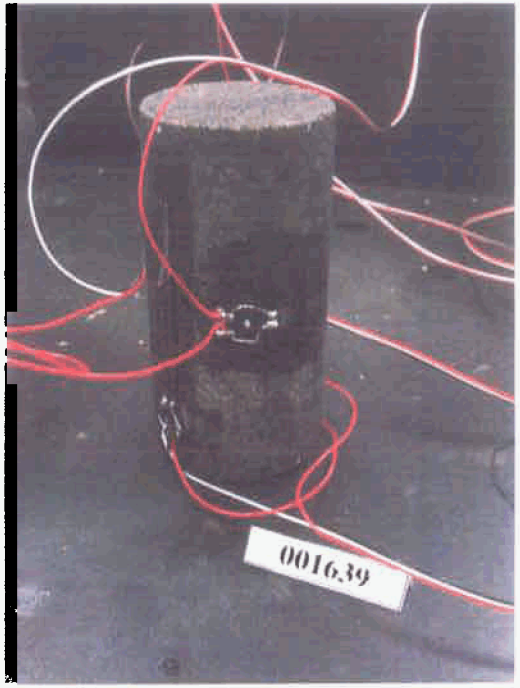
MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001639 Boring No. B-805 (41.3-41.9)
(ft)





Before testing



Before testing with strain gauges attached


After testing

B-805 **Depth (ft): 41.3-41.9**

Physical Description: Slightly weathered, moderately hard, Biotite Gneiss with strong foliation at 50-60°

MACTEC

Elastic Modulii of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001644	**Gage Factor:**	2.090
Sample I.D.:	B-801 Depth 48.7-49.7 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	1/28/2003

Specimen Information	
Average Diameter, inch	1.863
Average Height, inch	4.051
Moisture Content (%)	0.1
Ultimate Load, lb_f	77,484

RUN # 2

Load, lb_f	**Longitudinal ε** μ inch/inch	**Transverse ε** μ inch/inch
0	-15	24
5,000	-301	65
10,000	-539	112
15,000	-768	161
20,000	-983	214
25,000	-1196	268
30,000	-1406	330
35,000	-1618	400
40,000	-1827	473
45,000	-2034	551
50,000	-2248	644
55,000	-2459	759
60,000	-2677	910
65,000	-2898	1128
70,000	-3126	1499
75,000	-3328	2300

MACTEC

Elastic Moduli of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001644	**Gage Factor:**	2.09
Sample I.D.:	B-801 Depth 48.7-49.7 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	01/28/03

Average Diameter, inch	1.863
Average Length, inch	4.051
Length/Diameter ratio	2.2
Specimen Area, inch^2	2.726
Moisture Content (%)	0.1
Rate of loading (lbs/min)	10,000
Compressive Strength, psi	**28,420**
Longitudinal e Correction, inch/inch	-0.000015
Transverse e Correction, inch/inch	0.000024
Modulus of Elasticity, psi	**8,670,000**
Poisson's Ratio	**0.27**

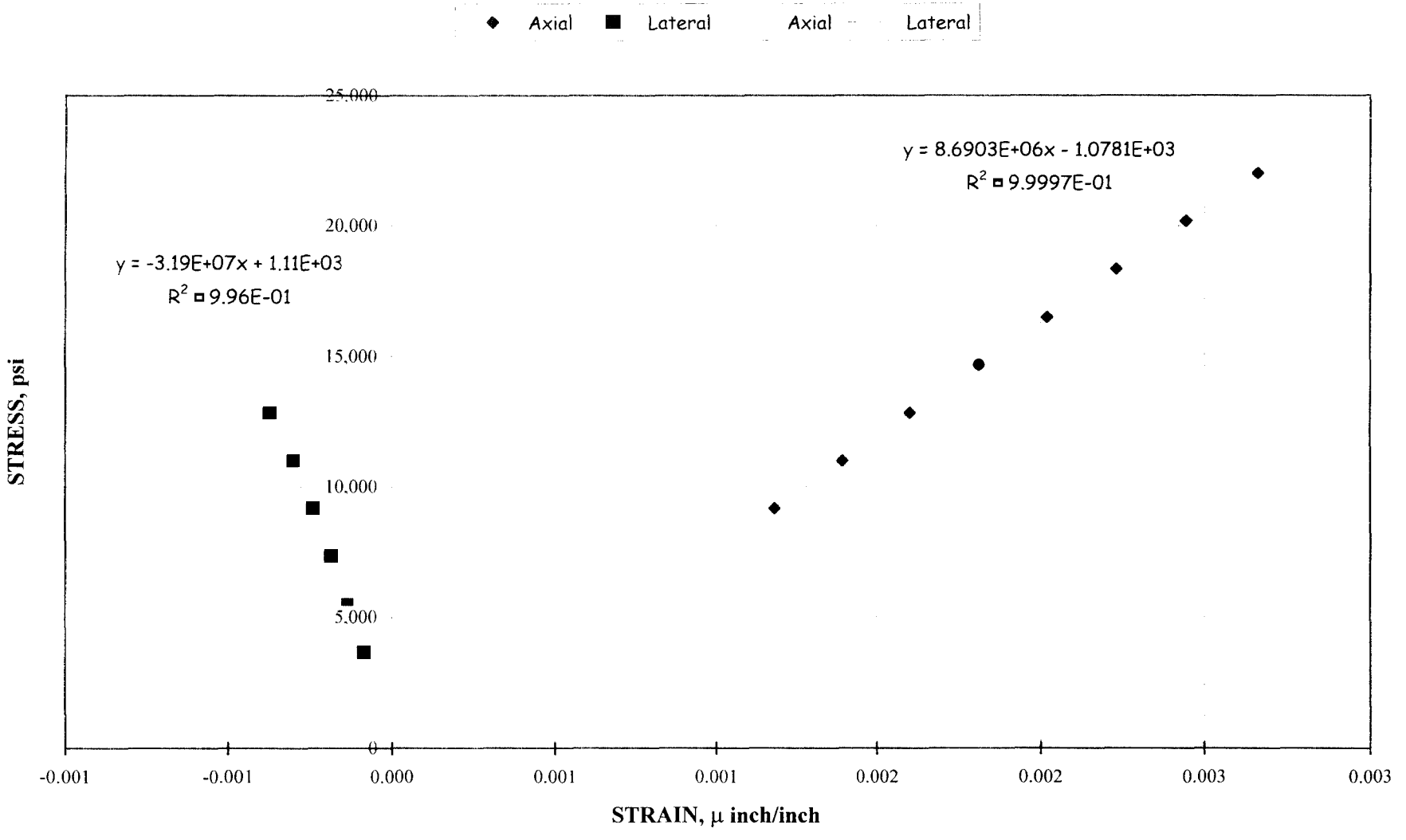
RUN # 2		
Stress, psi	**Longitudinal e** inch/inch	**Transverse e** inch/inch
0	0.000000	0.000000
1,834	0.000286	-0.000041
3,668	0.000524	**-0.000088**
5,503	0.000753	-0.000137
7,337	0.000968	-0.000190
9,171	**0.001181**	-0.000244
11,005	0.001391	-0.000306
12,840	0.001603	**-0.000376**
14,674	0.001812	-0.000449
16,508	0.002019	-0.000527
18,342	0.002233	-0.000620
20,177	0.002444	-0.000735
22,011	**0.002662**	-0.000886
23,845	0.002883	-0.001104
25,679	0.003111	-0.001475
27,513	0.003313	-0.002276

Note : Points chosen are in Bold.

Comments: Material description and photographs submitted in separate report
Test temperature was room temperature at 20-22 ^{0}C

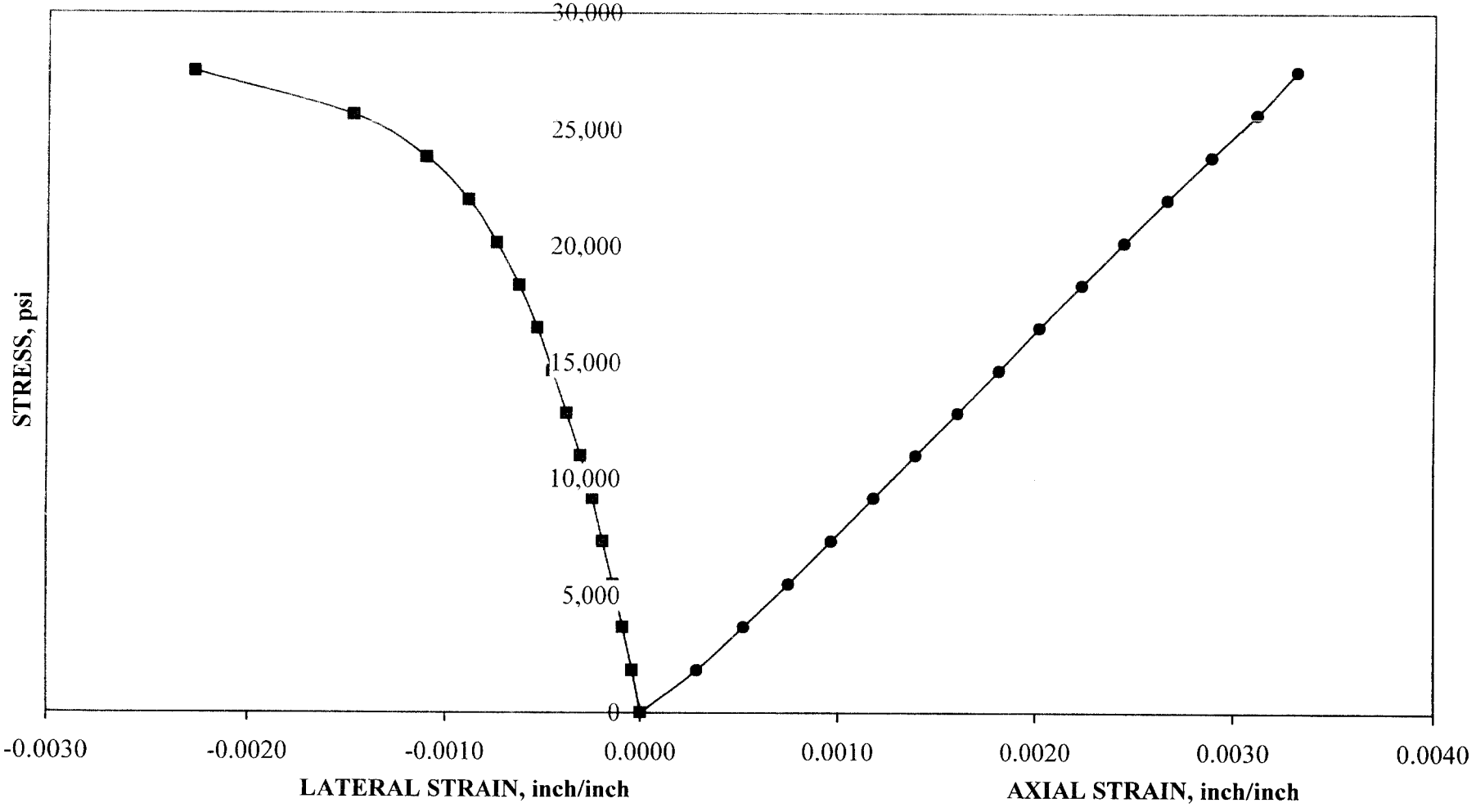
MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001644 Boring No. B-801 (48.7-49.7 ft)



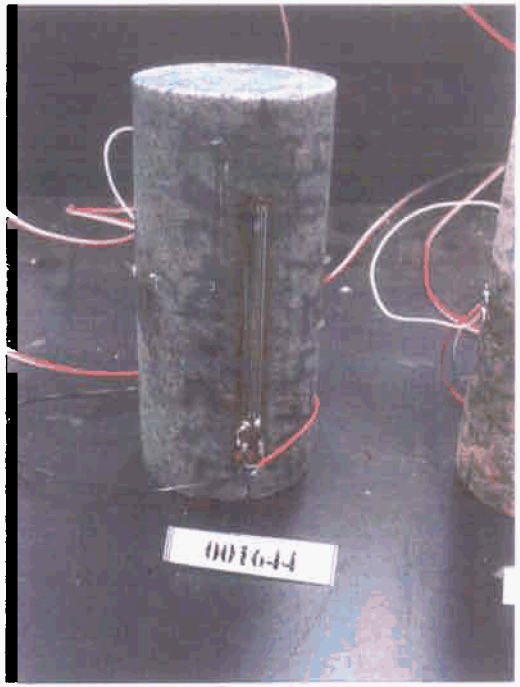
MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001644 Boring No. B-801 (48.7-49.7 ft)

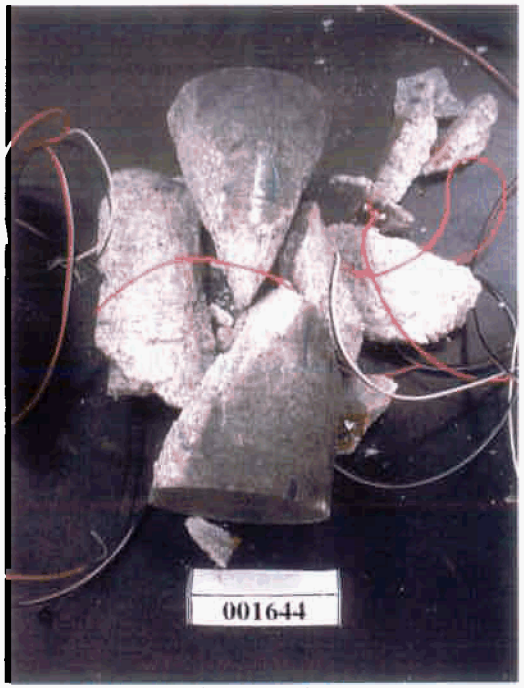




Before testing



Before testing with strain gauges attached



After testing

B-801 **Depth (ft): 48.7-49.7**

Physical Description: Fresh, very hard, Quartz Gneiss with weak foliation at 50-60°

MACTEC

Elastic Modulii of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001645	**Gage Factor:**	2.090
Sample I.D.:	B-804 Depth 49.9-50.5 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	1/28/2003

Specimen Information	
Average Diameter, inch	1.863
Average Height, inch	3.943
Moisture Content (%)	0.1
Ultimate Load, lb_f	33,532

RUN # 2

Load, lb_f	**Longitudinal ε** μ inch/inch	**Transverse ε** μ inch/inch
0	-8	10
2,000	-641	80
4,000	-1065	180
6,000	-1423	279
8,000	-1718	380
10,000	-1980	476
12,000	-2211	573
14,000	-2443	673
16,000	-2670	802
18,000	-2938	998
20,000	-3198	1235
22,000	-3461	1514
24,000	-3735	1855
26,000	-4012	2287
28,000	-4298	2824
30,000	-4609	3582
32,000	-4960	4737

MACTEC

Elastic Moduli of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001645	**Gage Factor:**	2.09
Sample I.D.:	B-804 Depth 49.9-50.5 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	01/28/03

Average Diameter, inch	1.863
Average Length, inch	3.943
Length/Diameter ratio	2.1
Specimen Area, inch^2	2.726
Moisture Content (%)	0.1
Rate of loading (lbs/min)	5000
Compressive Strength, psi	**12,300**
Longitudinal e Correction, inch/inch	-0.000008
Transverse e Correction, inch/inch	0.000010
Modulus of Elasticity, psi	**3,190,000**
Poisson's Ratio	**0.43**

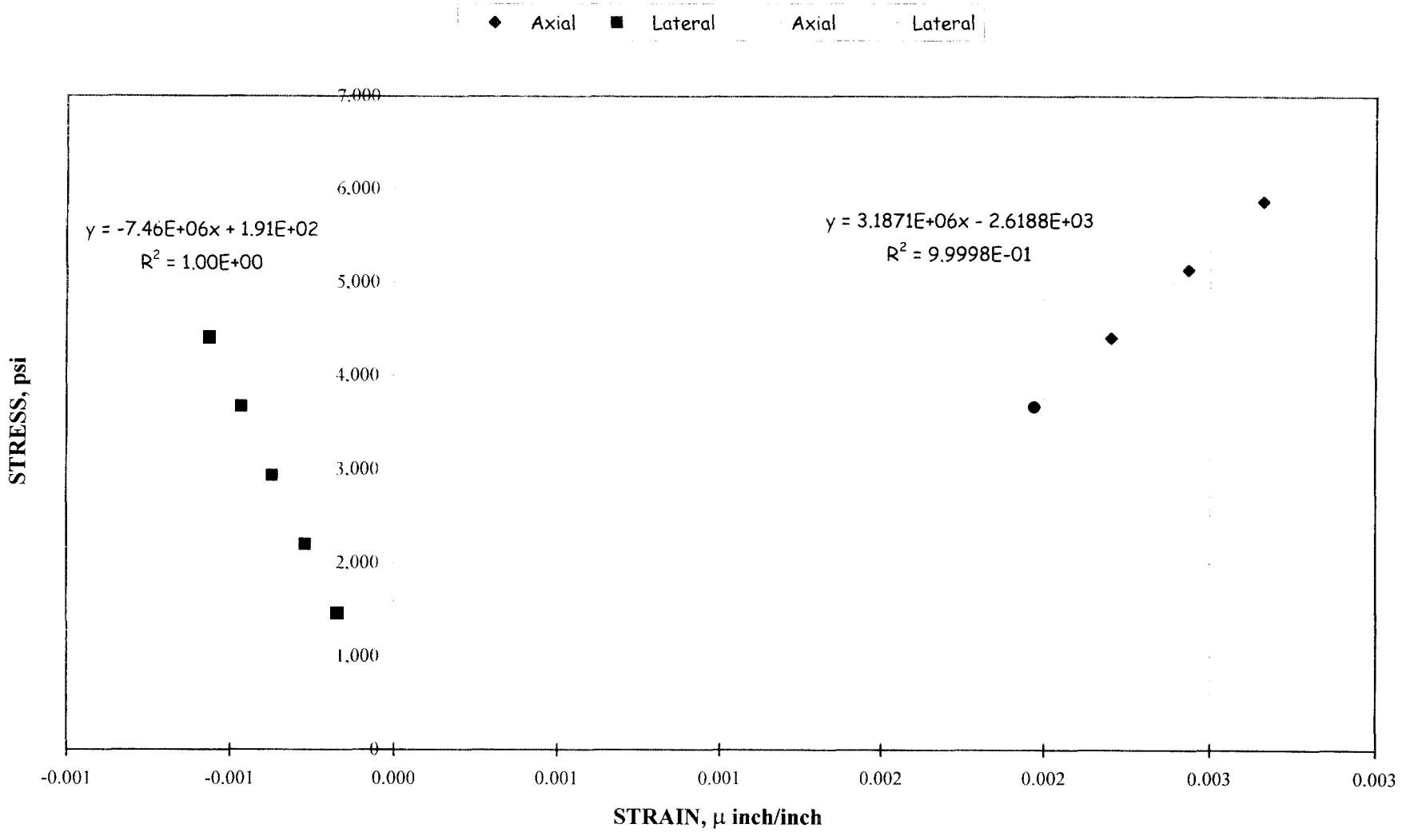
RUN # 2		
Stress, psi	**Longitudinal e** inch/inch	**Transverse e** inch/inch
0	0.000000	0.000000
734	0.000633	-0.000070
1,467	0.001057	**-0.000170**
2,201	0.001415	-0.000269
2,935	0.001710	-0.000370
3,668	**0.001972**	-0.000466
4,402	0.002203	**-0.000563**
5,136	0.002435	-0.000663
5,870	**0.002662**	-0.000792
6,603	0.002930	-0.000988
7,337	0.003190	-0.001225
8,071	0.003453	-0.001504
8,804	0.003727	-0.001845
9,538	0.004004	-0.002277
10,272	0.004290	-0.002814
11,005	0.004601	-0.003572

Note : Points chosen are in Bold.

Comments: Material description and photographs submitted in separate report
Test temperature was room temperature at 20-22 ^{0}C

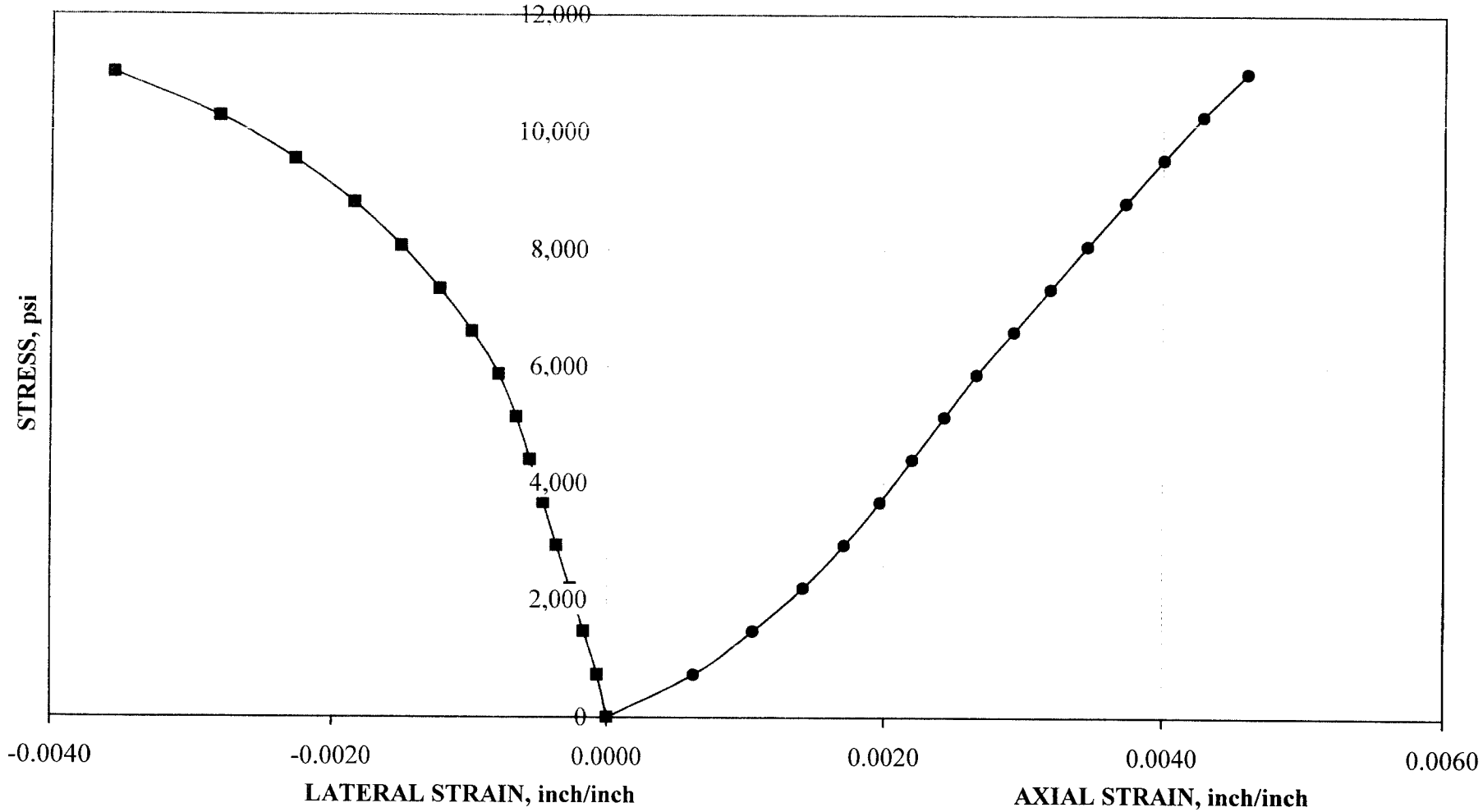
MACTEC

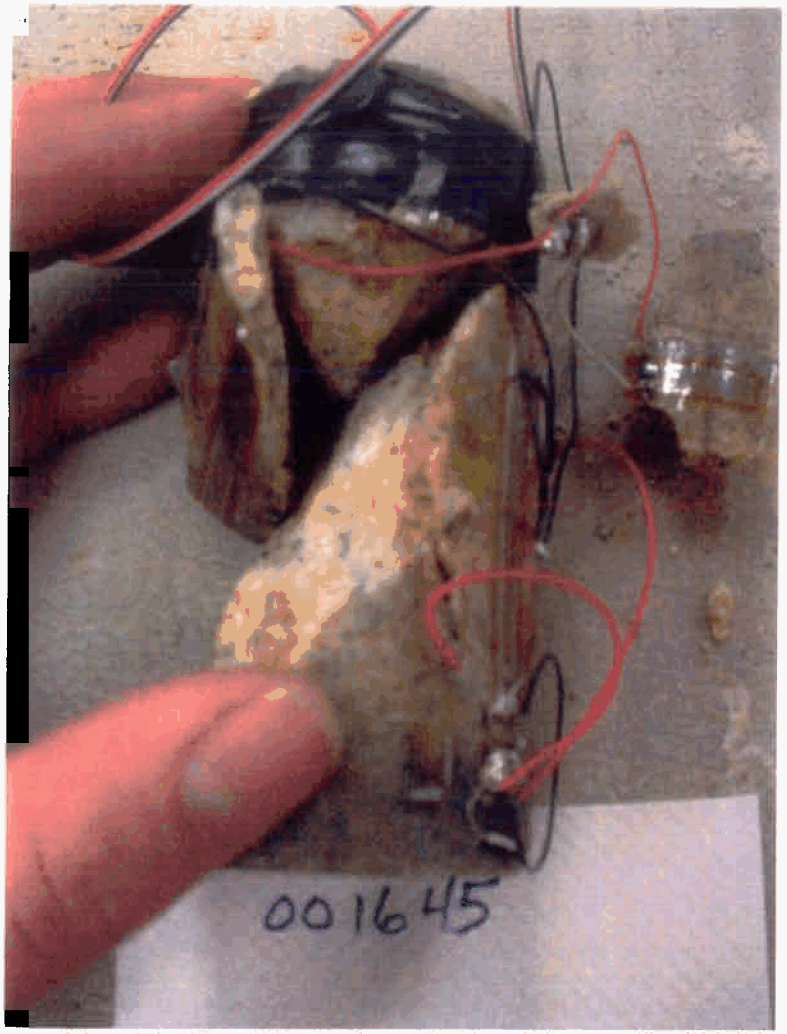
North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001645 Boring No. B-804 (49.9-50.5 ft)



MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001645 Boring No. B-804 (49.9-50.5 ft)





After Testing (No Before Testing Picture Available)

B-804 **Depth (ft): 49.9-50.5**

Physical Description: Fresh, very hard, Quartz Gneiss with weak foliation at 50-60°

MACTEC

Elastic Modulii of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001650	**Gage Factor:**	2.090
Sample I.D.:	B-802 Depth 66.0-66.7 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	1/28/2003

Specimen Information	
Average Diameter, inch	1.859
Average Height, inch	3.757
Moisture Content (%)	0.3
Ultimate Load, lb_f	39,933

RUN # 2

Load, lb_f	**Longitudinal ε** μ inch/inch	**Transverse ε** μ inch/inch
0	-11	10
1,000	-193	17
2,000	-374	24
3,000	-535	39
4,000	-678	45
5,000	-798	56
6,000	-912	68
7,000	-1020	81
8,000	-1122	97
9,000	-1221	111
10,000	-1316	127
12,000	-1503	161
14,000	-1677	196
16,000	-1844	233
18,000	-1995	271
20,000	-2142	312
25,000	-2500	424
30,000	-2830	565
35,000	-3139	761

MACTEC

Elastic Moduli of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001650	**Gage Factor:**	2.09
Sample I.D.:	B-802 Depth 66.0-66.7 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	01/28/03

Average Diameter, inch	1.859
Average Length, inch	3.757
Length/Diameter ratio	2.0
Specimen Area, inch^2	2.714
Moisture Content (%)	0.3
Rate of loading (lbs/min)	5000
Compressive Strength, psi	**14,710**
Longitudinal e Correction, inch/inch	-0.000011
Transverse e Correction, inch/inch	0.000010
Modulus of Elasticity, psi	**4,613,000**
Poisson's Ratio	**0.24**

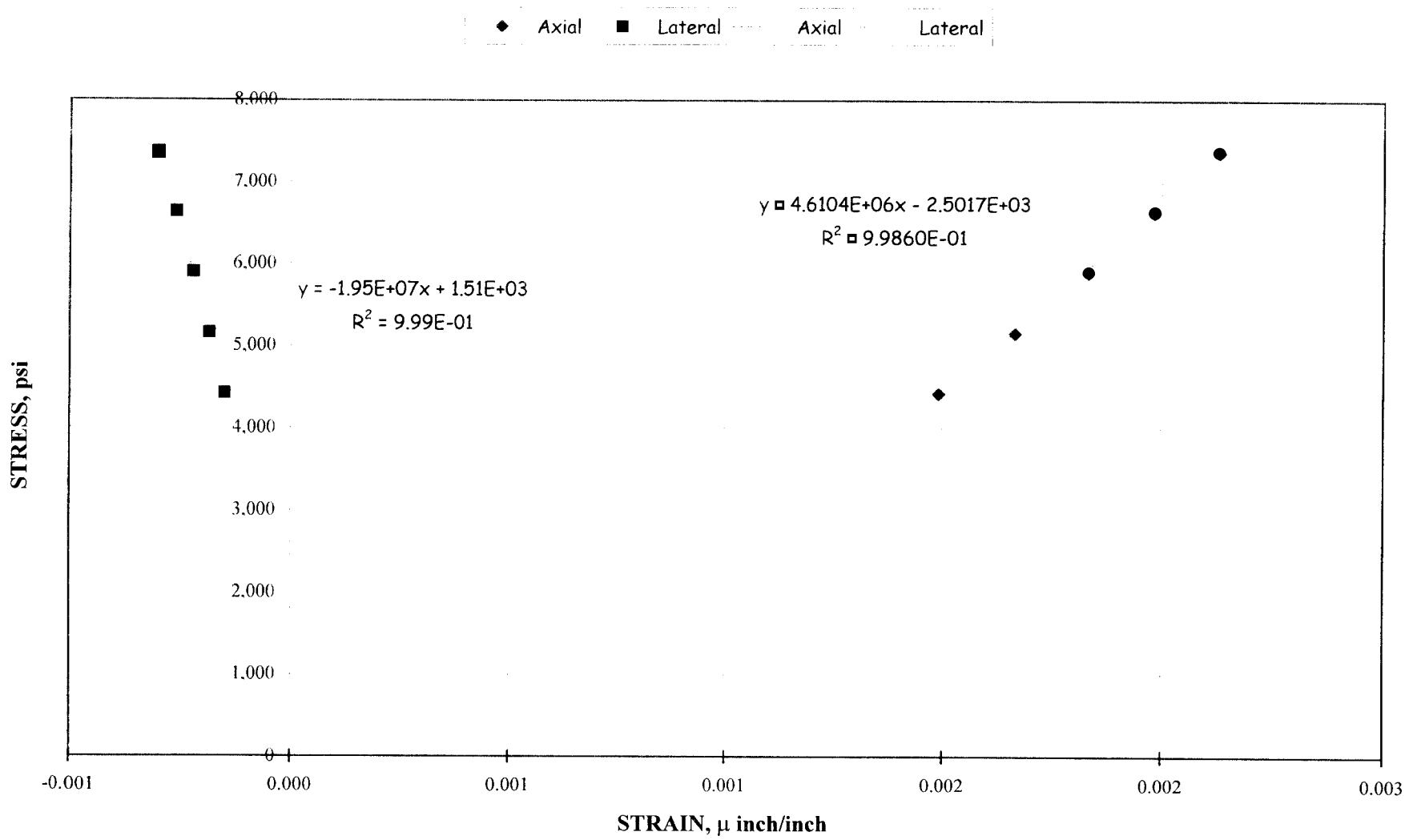
RUN # 2		
Stress, psi	**Longitudinal e** inch/inch	**Transverse e** inch/inch
0	0.000000	0.000000
368	0.000182	-0.000007
737	0.000363	-0.000014
1,105	0.000524	-0.000029
1,474	0.000667	-0.000035
1,842	0.000787	-0.000046
2,211	0.000901	-0.000058
2,579	0.001009	-0.000071
2,947	0.001111	-0.000087
3,316	0.001210	-0.000101
3,684	0.001305	-0.000117
4,421	**0.001492**	**-0.000151**
5,158	0.001666	-0.000186
5,895	0.001833	-0.000223
6,632	0.001984	-0.000261
7,369	**0.002131**	**-0.000302**
9,211	0.002489	-0.000414
11,053	0.002819	-0.000555
12,895	0.003128	-0.000751

Note : Points chosen are in Bold.

Comments: Material description and photographs submitted in separate report
Test temperature was room temperature at 20-22 ^{0}C

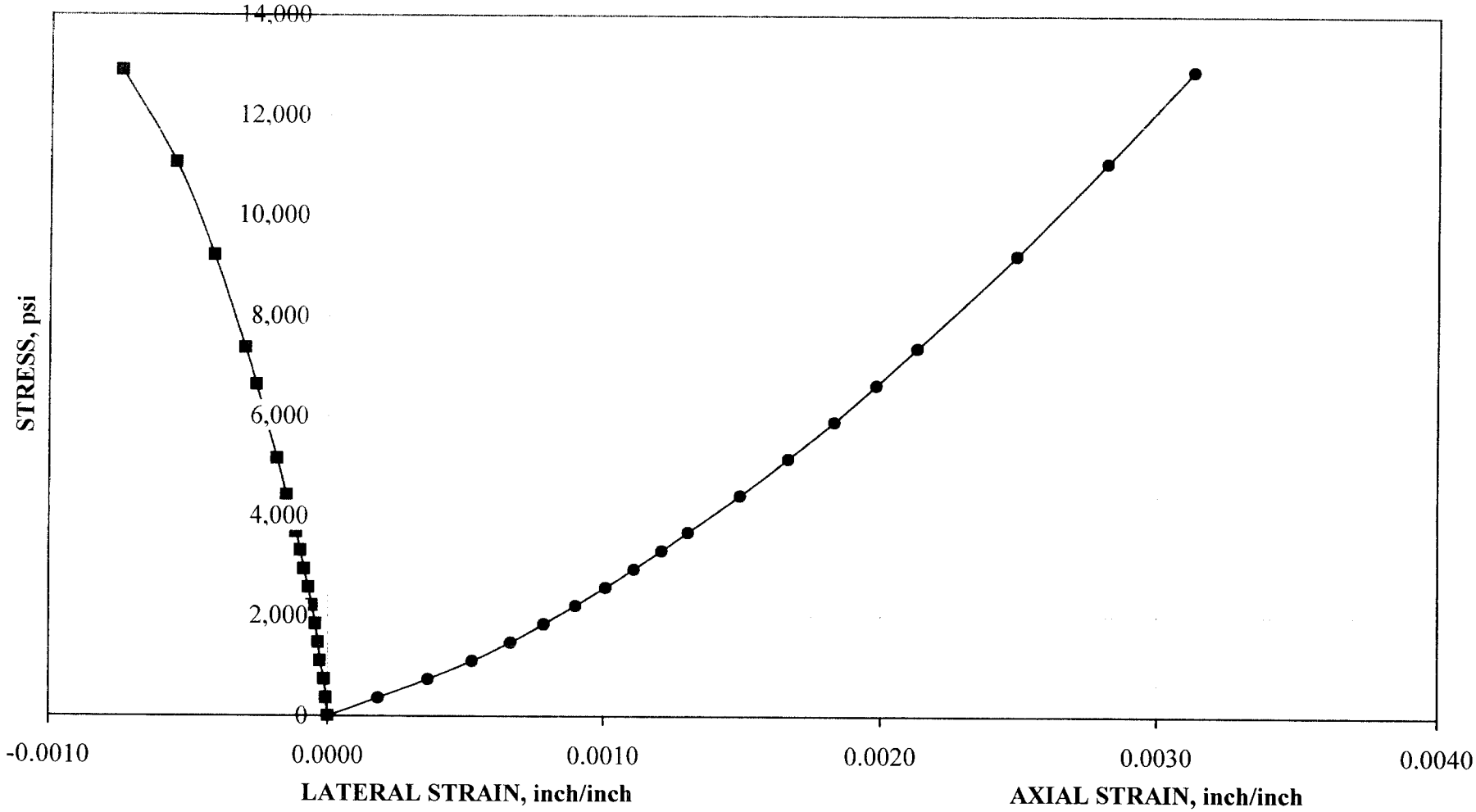
MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001650 Boring No. B-802 (66.0-66.7 ft)



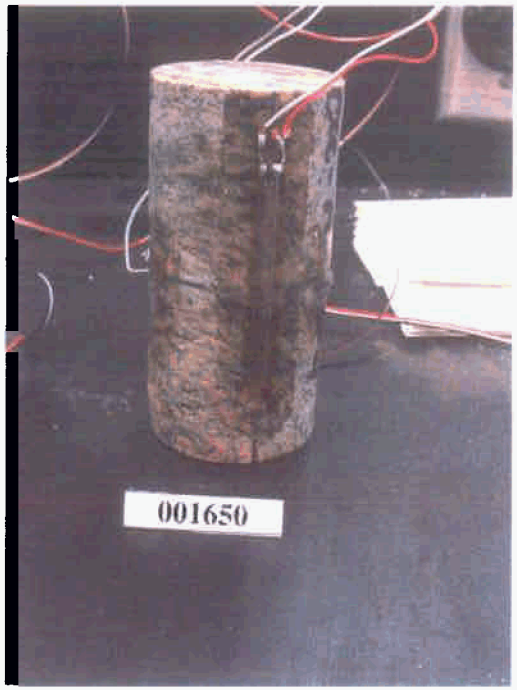
MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001650 Boring No. B-802 (66.0-66.7 ft)





Before testing



Before testing with strain gauges attached



After testing

B-802 **Depth (ft): 66.0-66.7**

Physical description: Slightly weathered, hard, Quartz Gneiss with strong foliation at 30-40°

MACTEC

Elastic Modulii of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001655	**Gage Factor:**	2.090
Sample I.D.:	B-803 Depth 70.4-71.1 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	1/28/2003

Specimen Information	
Average Diameter, inch	1.866
Average Height, inch	4.168
Moisture Content (%)	0.1
Ultimate Load, lb_f	63,464

RUN # 2		
Load, lb_f	**Longitudinal ε** μ inch/inch	**Transverse ε** μ inch/inch
0	-8	8
1,000	-110	16
2,000	-233	24
3,000	-348	34
4,000	-462	43
5,000	-572	55
6,000	-673	67
7,000	-770	81
8,000	-859	94
9,000	-945	107
10,000	-1023	123
12,000	-1177	152
14,000	-1317	183
16,000	-1448	216
18,000	-1572	248
20,000	-1692	282
25,000	-1971	371
30,000	-2237	468
35,000	-2494	580
40,000	-2741	713
45,000	-2988	883
50,000	-3230	1120
55,000	-3468	1520
60,000	-3689	2223

MACTEC

Elastic Moduli of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001655	**Gage Factor:**	2.09
Sample I.D.:	B-803 Depth 70.4-71.1 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	01/28/03

Average Diameter, inch	1.866
Average Length, inch	4.168
Length/Diameter ratio	2.2
Specimen Area, inch^2	2.735
Moisture Content (%)	0.1
Rate of loading (lbs/min)	10,000
Compressive Strength, psi	**23,210**
Longitudinal e Correction, inch/inch	-0.000008
Transverse e Correction, inch/inch	0.000008
Modulus of Elasticity, psi	**7,133,000**
Poisson's Ratio	**0.34**

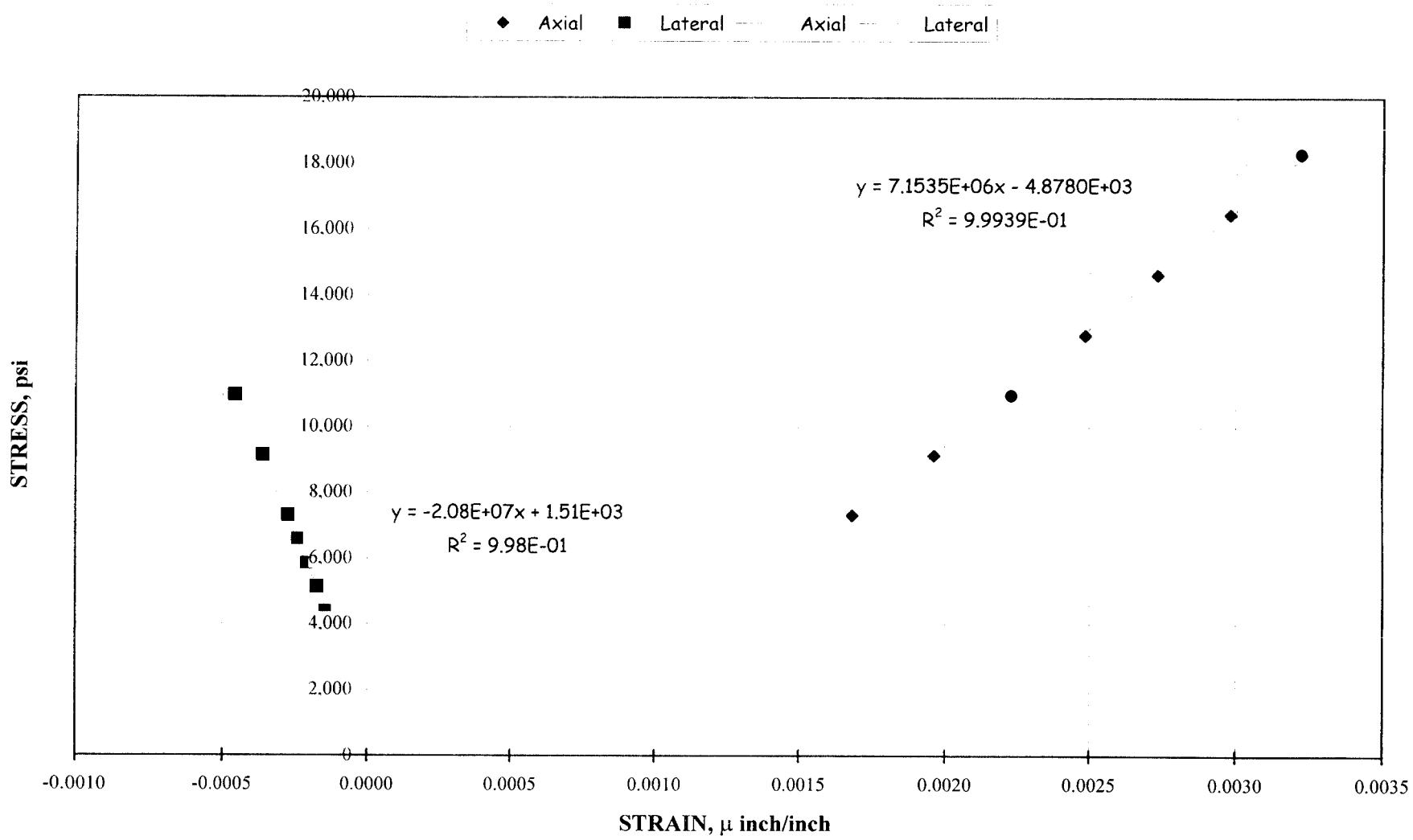
RUN # 2		
Stress, psi	**Longitudinal e** inch/inch	**Transverse e** inch/inch
0	0.000000	0.000000
366	0.000102	-0.000008
731	0.000225	-0.000016
1,097	0.000340	-0.000026
1,463	0.000454	-0.000035
1,828	0.000564	-0.000047
2,194	0.000665	-0.000059
2,560	0.000762	-0.000073
2,925	0.000851	-0.000086
3,291	0.000937	-0.000099
3,657	0.001015	-0.000115
4,388	0.001169	**-0.000144**
5,119	0.001309	-0.000175
5,851	0.001440	-0.000208
6,582	0.001564	-0.000240
7,313	**0.001684**	-0.000274
9,142	0.001963	-0.000363
10,970	0.002229	**-0.000460**
12,798	0.002486	-0.000572
14,627	0.002733	-0.000705
16,455	0.002980	-0.000875
18,283	**0.003222**	-0.001112
20,112	0.003460	-0.001512
21,940	0.003681	-0.002215

Note : Points chosen are in Bold.

Comments: Material description and photographs submitted in separate report
Test temperature was room temperature at 20-22°C

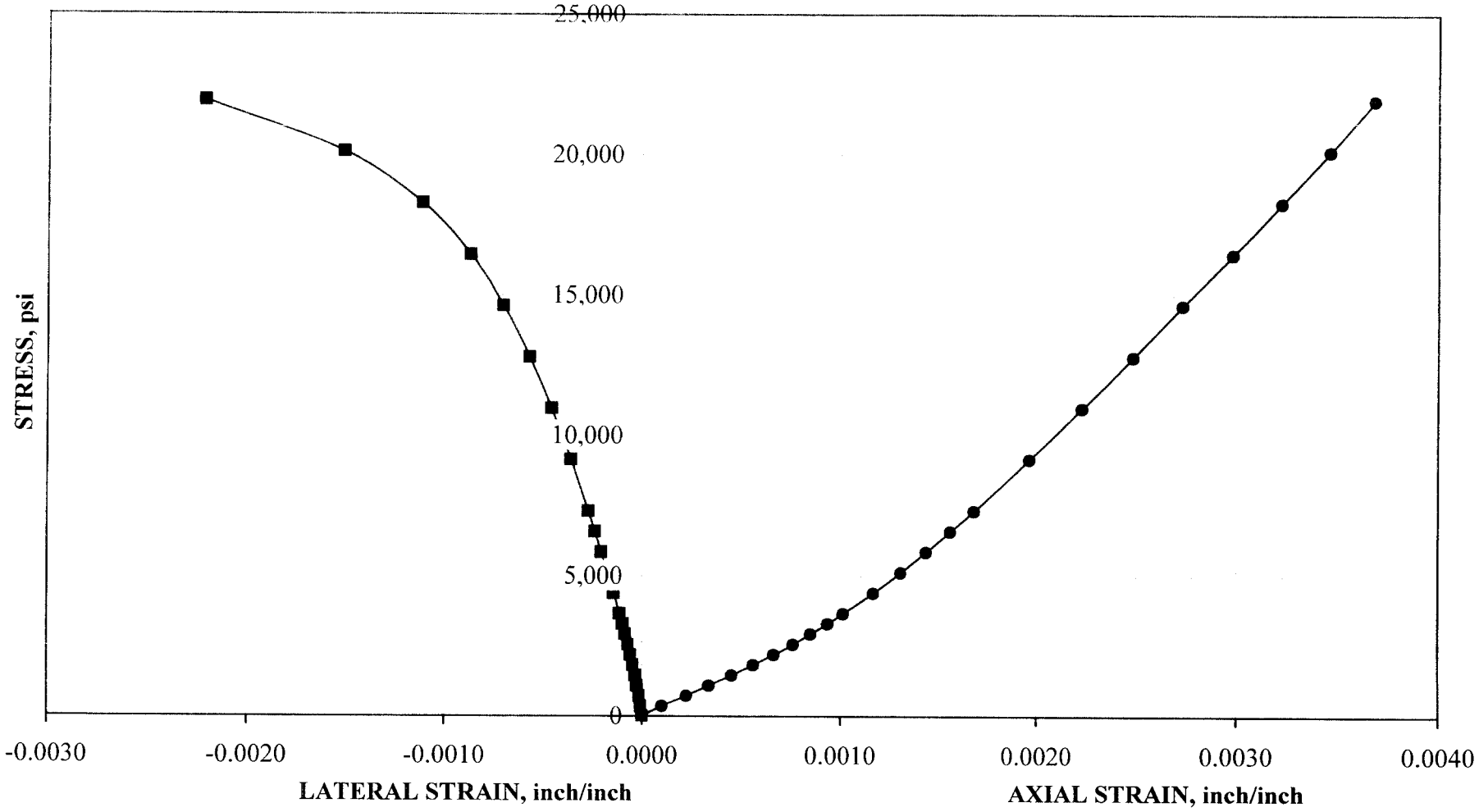
MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001655 Boring No. B-803 (70.4-71.1 ft)



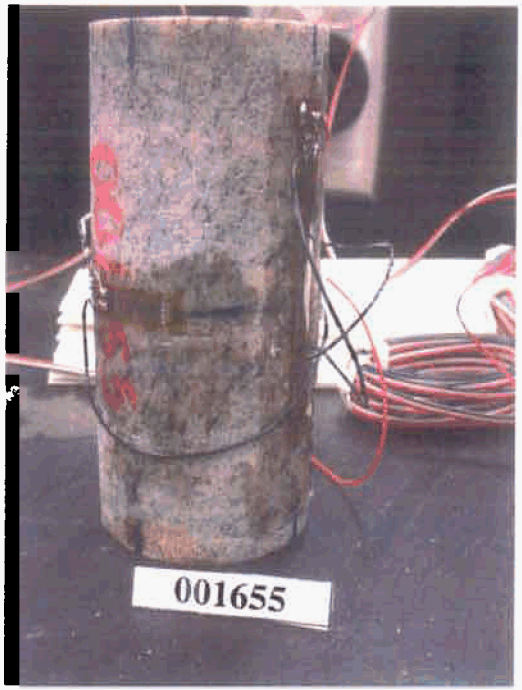
MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001655 Boring No. B-803 (70.4-71.1 ft)





Before testing



Before testing with strain gauges attached



After testing

B-803 **Depth (ft): 70.4-71.1**

Physical Description: Very slightly weathered, hard, Quartz Gneiss with weak foliation at 50-60°

MACTEC

Elastic Modulii of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001657	**Gage Factor:**	2.090
Sample I.D.:	B-803 Depth 155.6-156.4 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	1/28/2003

Specimen Information	
Average Diameter, inch	1.873
Average Height, inch	3.91
Moisture Content (%)	0.1
Ultimate Load, lb_f	60,698

RUN # 2		
Load, lb_f	**Longitudinal ε** μ inch/inch	**Transverse ε** μ inch/inch
0	-9	10
5,000	-469	57
10,000	-815	114
15,000	-1130	179
20,000	-1420	250
25,000	-1688	325
30,000	-1945	411
35,000	-2197	504
40,000	-2447	610
45,000	-2700	730
50,000	-2958	874
55,000	-3227	1064
60,000	-3554	1366

MACTEC

Elastic Moduli of Intact Rock Core Specimens in Uniaxial Compression

ASTM D 3148-96

Project Name:	North Anna ESP	**Transverse Strain Gage Series:**	EA-06-20CBW-120
Project Number:	30720-2-5400.07.800	**Longitudinal Strain Gage Series:**	EA-06-500BH-120
MACTEC Lab ID:	001657	**Gage Factor:**	2.09
Sample I.D.:	B-803 Depth 155.6-156.4 ft	**Excitation Voltage:**	2.0 V
Tested By:	David Jensen	**Reviewed by:**	Thomas N. Dobras
Test Date:	01/24/03	**Review Date:**	01/28/03

Average Diameter, inch	1.873
Average Length, inch	3.910
Length/Diameter ratio	2.1
Specimen Area, inch^2	2.755
Moisture Content (%)	0.1
Rate of loading (lbs/min)	10,000
Compressive Strength, psi	**22,030**
Longitudinal e Correction, inch/inch	-0.000009
Transverse e Correction, inch/inch	0.000010
Modulus of Elasticity, psi	**7,173,000**
Poisson's Ratio	**0.33**

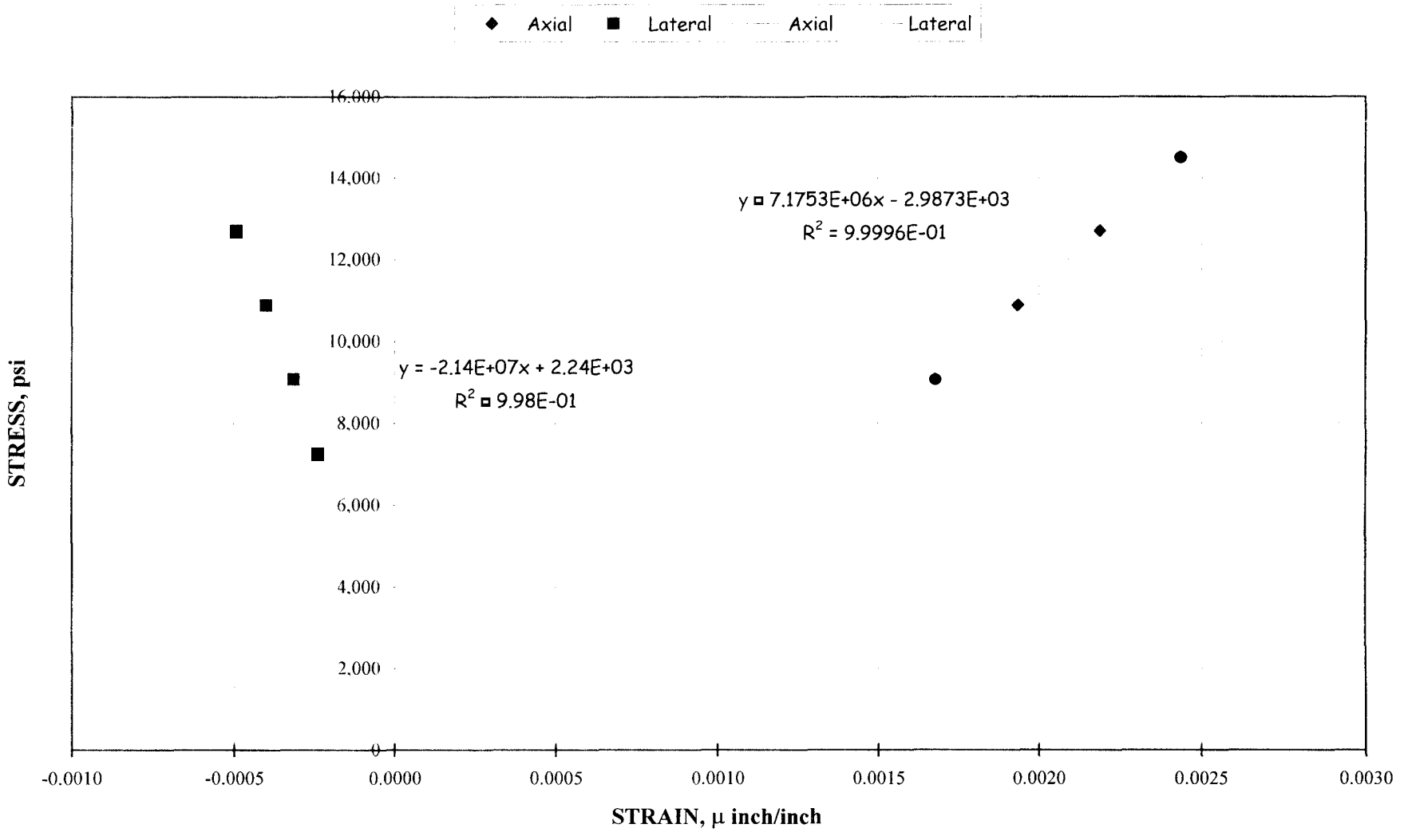
RUN # 2		
Stress, psi	**Longitudinal e** inch/inch	**Transverse e** inch/inch
0	0.000000	0.000000
1,815	0.000460	-0.000047
3,629	0.000806	-0.000104
5,444	0.001121	-0.000169
7,259	0.001411	**-0.000240**
9,073	**0.001679**	-0.000315
10,888	0.001936	-0.000401
12,703	0.002188	**-0.000494**
14,518	**0.002438**	-0.000600
16,332	0.002691	-0.000720
18,147	0.002949	-0.000864
19,962	0.003218	-0.001054
21,776	0.003545	-0.001356

Note : Points chosen are in Bold.

Comments: Material description and photographs submitted in separate report
Test temperature was room temperature at 20-22 ^{0}C

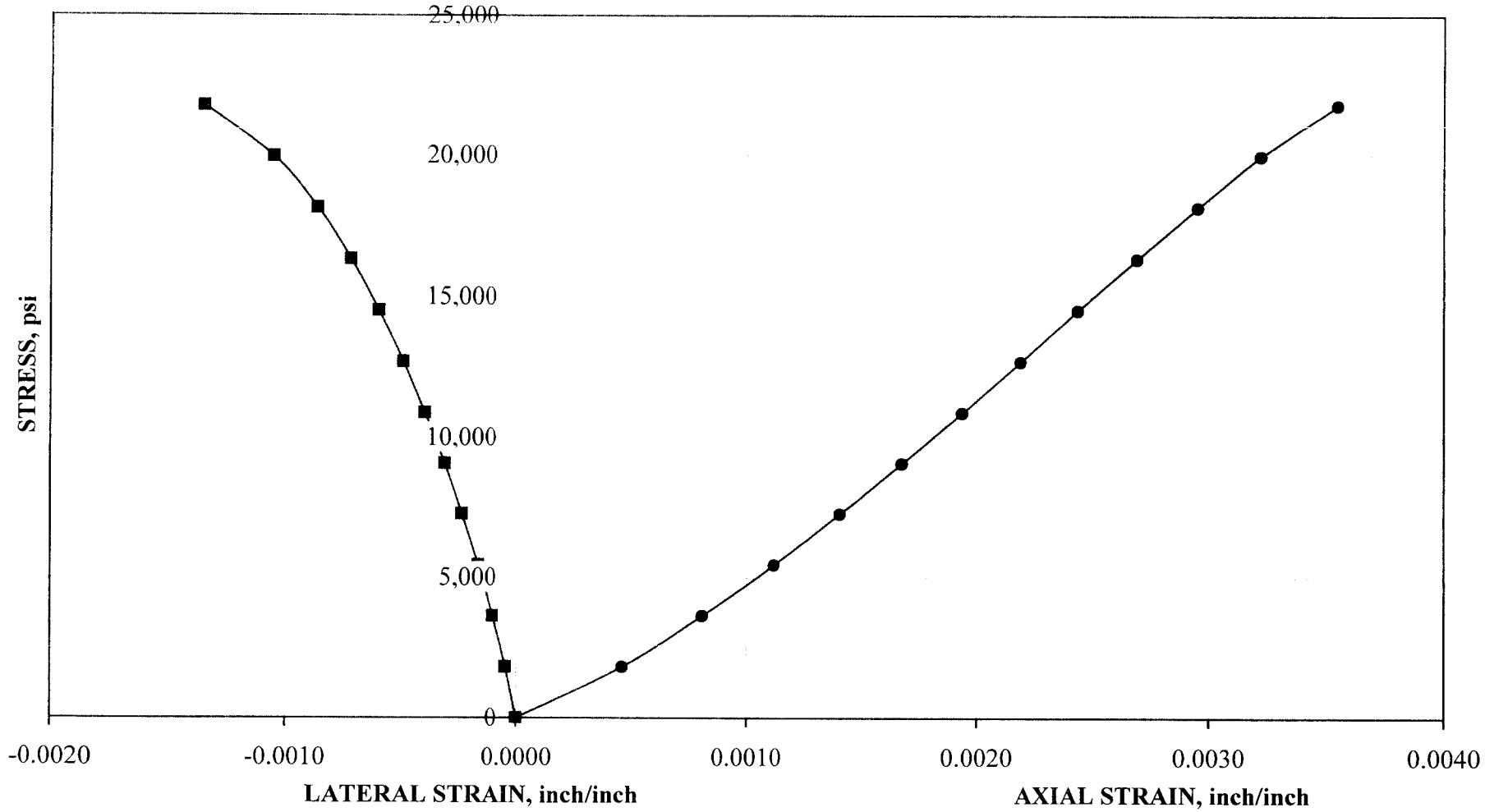
MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001657 Boring No. B-803 (155.6-156.4 ft)



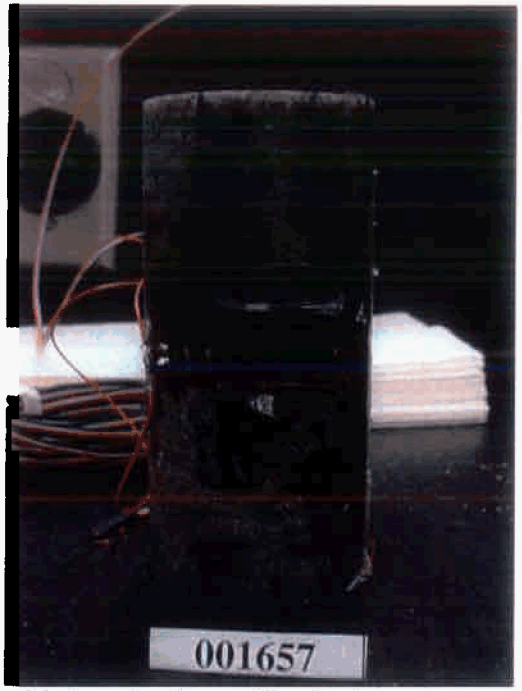
MACTEC

North Anna ESP Project 30720-2-5400
MODULUS OF ELASTICITY
MACTEC Lab ID 001657 Boring No. B-803 (155.6-156.4 ft)





Before testing



Before testing with strain gauges attached



After testing

B-803 **Depth (ft): 155.6-156.4**

Physical Description: Fresh, very hard, Quartz Gneiss with weak foliation at 50-60°

APPENDIX J
DOWNHOLE SEISMIC REPORT AND DATA

Grumman Exploration, Inc.
2309 Dorset Road
Columbus, Ohio 43221
(614) 488-7860 tel; (614) 488-8945 fax

Non-destructive Subsurface Exploration
Near-surface Geophysics

March 17, 2003

Mr. J. Allan Tice
Mactec Engineering Services, Inc.
3301 Atlantic Avenue
Raleigh, NC 22080

RE: Report of Supplemental Downhole Seismic Testing at the North Anna Power Station ESP, Mineral Virginia, GEI Project No. 01-22089, MACTEC JOB NO. 30720-2-5400

Dear Al:

Grumman Exploration, Inc. has completed the downhole seismic testing at the above referenced project site located near Mineral, Virginia. This letter-report summarizes the field procedures used and results of the tests performed at this site. The attached spreadsheets and plots summarize the estimated seismic velocities and derived parameters for the borehole tested.

Project Description

Mactec Engineering Services, Inc. is engaged in geotechnical investigations at the site. Downhole seismic testing of a single borehole was requested to supplement an earlier cross-hole seismic test that may have yielded inconclusive results. Among the requirements and assumptions of the downhole testing procedure are: homogeneous isotropic subsurface materials, consistent annular space material, filling and diameter, and minimal ambient noise.

Field Procedures

Grumman Exploration, Inc. conducted downhole seismic tests at borehole B-802b on February 12, 2003 as specified by Mactec Engineering Services, Inc. B-802b was part of a three borehole set that was originally installed for cross-hole seismic tests. The borehole was lined with approximately 92-ft of 2.875" diameter inclinometer casing and was grouted in-place

using a cement bentonite grout according to ASTM D4428/D4428M. Approximately 50-ft of water in the cased hole was removed prior to testing.

The following field equipment and procedures were used to conduct the tests:

- Geometrics, Inc. SmartSeis S-12, 12 channel, digital signal enhancement seismograph,
- Four triaxial downhole geophones, 10-ft separation with leaf-spring sidewall clamping mechanisms, and
- Sledge hammer source, steel plate and weighted wood plank.

Tests were performed at 5-ft intervals from approximately 10-ft to 84-ft. Note that a 10-ft geophone separation was used to provide a longer measurement time interval between geophones in the anticipated high velocity bedrock. The seismograph sampling rate was 64 microseconds (0.064 msec) with a total sweep time of 128 milliseconds. A total of 2048 samples for each of the 12-channels were acquired for each shot. A pre-trigger delay of 5-msec was used to provide additional data in a brief time window just prior to the initiation of the test. The test preparation procedures consisted of lowering the geophones to the desired test depth and releasing the sidewall clamping mechanism on each geophone. Three tests were performed at each test depth using multiple impacts from a sledgehammer striking an aluminum plate. The attached summary sheet describes the test nomenclature and test positions. The impact plate was struck from three positions: ground-surface (vertical, P-wave) and opposite sides of the horizontal plank (lateral, S wave, opposing polarities). The impacts from opposite sides of the plank were used to help identify the onset of the shear wave by observing the reversal in wave polarity. Between 2 and 7 impacts were stacked to help enhance the compressional (P) and shear (S) wave signatures and cancel spurious noise effects. A 4WD vehicle was used to weight the plank.

The data were observed and recorded in the field during acquisition. Both low and high-pass digital filters (250 Hz and 10 Hz, respectively) were used to help reduce interfering noise effects within the borehole. A preliminary assessment of the first five interval tests was performed in the field to observe the processed initial test results and adjust the acquisition parameters as needed. Upon the completion of the testing, the data were returned to the offices of Grumman Exploration, Inc. for further review and analysis.

A computer program developed by Grumman Exploration, Inc. was used to extract and display the P and S-wave traces for the geophones used for each test interval. Using the arrival time estimates, P and S wave velocities were calculated for each depth interval. The velocity calculation was based on the difference in arrival times and an assumed straight-line travel distances to each geophone using the in-hole depth to each geophone and the ground-level offset distance of the seismic impulse. An attachment summarizes the velocity calculation methodology.

Grumman Exploration, Inc.
2309 Dorset Road, Columbus, Ohio 43221
(614) 488-7860 tel, (614) 488-8945 fax

The analysis consisted of estimating P-wave and S wave arrivals for each depth level tested. Three general approaches were used to estimate the compressional and shear wave arrival times:

- Composite plots illustrating all the results from all geophones at all test depths to observe general data trends;
- Multi-geophone arrival time assessment: examining the arrival time differences between successive geophones for each test position, repeated for all test positions; and
- Single-geophone assessment: examining the arrival time differences between individual geophones for different test depths, repeated for all four geophones.

The criteria for selecting arrival times included (1) observing the apparent first onset of the P or S-wave, and/or (2) identifying a characteristic waveform, peak, polarity reversal, zero-crossing or shape that was consistently present between successive records. Apparently erroneous or unrealistically high or low velocity estimates were eliminated from the data summary tables. Because four geophones were used for each test, multiple velocity estimates for some of the test intervals were available.

Downhole Seismic Testing Results

The attached spreadsheets summarize the downhole seismic testing results for test borehole B-802b at the North Anna Power Station ESP site in Mineral, Virginia. The spreadsheet includes a summary of the compressional wave velocity (Vp) and the shear wave velocity (Vs). Some of the interval velocity estimates were averaged if multiple test results were available for that interval. Plots of these results are also included. The following paragraphs summarize some of the results of the downhole seismic tests:

- High Compressional wave velocities: The estimated compressional wave velocities ranged between 10,000 feet-per-second (fps) to over 16,000 fps. It is not clear why significantly lower Vp estimates occurred in the 70-ft to 85-ft depth interval. For very high velocity materials, such as occur at the North Anna ESP site, small variations in the arrival time estimates (on the order of 0.1 millisecond) can cause large changes in the Vp estimates (e.g. >1,500 fps for every 0.1 msec arrival time difference for material with Vp over 12,000 fps). Consequently, signal resolution limitations, interfering noise and slight biases in the arrival time estimates can all contribute to disproportionate, large variations in the Vp estimates. Other possible explanations for the apparent lower velocity levels may be attributable to geologic factors such as the possible presence of fracture zones and fracture filling, changes in lithology, enhanced weathering, and anisotropy.

- Shear Wave velocities were correspondingly high and were estimated in the range of 3,500 to 6,300 fps in the areas were reliable shear wave information was available. The

shear wave information appeared less reliable and thus more inconclusive below approximately 45-ft.

- Compressional waveforms: The compressional wave onset was fairly clear throughout the borehole. P-wave arrival times became more inconsistent and unreliable below approximately 65-ft where more coincident p-wave arrivals occurred (i.e. approx. same arrival time for different depths). Possible refraction effects, geologic conditions and noise interference may be responsible for some of the irregular P-wave arrivals.

- Shear waveforms: the shear-wave was generally well defined to a depth of approximately 45-ft. Although well-defined S-wave waveforms appeared to be present below 45-ft, the waveforms below this depth tended to provide more unrealistic velocity estimates and consequently fewer of the S-wave results were used below 45-ft. Below approximately 65-ft, the S-wave appears to be absent. The higher amplitude signals with the appearance of an S-wave may actually represent noise wavetrains because (a) maximum seismograph amplification of the waveforms and (b) the signal peaks all occur at approximately the same time. Ambient vibrations in the 30 to 40 Hz range are apparent in the records from bottom 20-ft of B-802b. Possible explanations for the apparent loss of signal in the lowermost sections of the borehole include excessive interfering ambient noise and possible incomplete grout filling or grout set-up within the annular space near the hole bottom.

Bias in the arrival time picks and consequently the velocity estimates could result from one or more possible circumstances including: difficulty in estimating the S and P wave arrival times, irregular or incomplete borehole annular space filling, refraction effects (non-straight line travel path), limitations on the resolution of the digitized signal, and the presence of interfering noise and other wavetrains.

General Qualifications

The downhole seismic data presented herein represent estimates of subsurface properties in the immediate vicinity of the boreholes tested using the measurement procedures described above. No warranty, certification, or statement of fact, either expressed or implied, regarding actual subsurface properties surrounding the borehole tested is contained herein. If questions or uncertainties exist regarding the actual parameter values, supplemental in-situ or laboratory tests or other invasive explorations should be conducted to document actual subsurface material properties. No inference of subsurface properties can be made for depth intervals not tested.

Grumman Exploration, Inc.
2309 Dorset Road, Columbus, Ohio 43221
(614) 488-7860 tel, (614) 488-8945 fax

Grumman Exploration, Inc. has appreciated this opportunity to be of service again to Mactec Engineering Services, Inc. If you have any questions or comments regarding this report, please feel free to contact us.

Sincerely,

Grumman Exploration, Inc.

David L. Grumman, Jr.
President/Geophysicist

Grumman Exploration, Inc.
2309 Dorset Road, Columbus, Ohio 43221
(614) 488-7860 tel, (614) 488-8945 fax

Downhole Seismic Testing Summary Table

Test/Well ID: B-802b
Project: **North Anna ESP**
Location: Mineral, VA
Client/Owner: Mactec
Well Descr.: 2.875" PVC, grouted, ~91' depth

Test Date: 2/12/2003
Calc. Date: 3/17/2003
Field Staff: dlg
Data Proc by: dlg

Grumman Exploration, Inc.
2309 Dorset Road
Columbus, Ohio 43221-3145
(614) 488-7860 tel

Eqp: Geometrics S-12 Seismograph
4 triaxial geophones
sledge hammer impulse source

Test Interval Depth (ft)	Interval Velocity (ft/sec) V_p	V_s	Soil Density (pcf) γ	Shear Modulus G	Bulk Modulus K	Young's Modulus E	Poisson's Ratio υ	Depth (ft)	Material Descr/Class
2.50	4526	385					0.496	2.50	
7.50	6603	854					0.491	7.50	
12.50		3435						12.50	
17.50	11813	1482					0.492	17.50	
22.50	13798	5278					0.414	22.50	
27.50	10854	3398					0.446	27.50	
32.50	14047	4513					0.442	32.50	
37.50	14106							37.50	
42.50	16502	6364					0.413	42.50	
47.50	14468	6382					0.379	47.50	
52.50	16559	5371					0.441	52.50	
55.00	13623							55.00	
57.00	13260							57.00	
57.50	16576	5835					0.429	57.50	
62.50	16590							62.50	
67.00	13280							67.00	
67.50	16601	6030					0.424	67.50	
77.00	9970							77.00	
87.00	9976							87.00	

Notes: Blank value denotes uninterpretable data

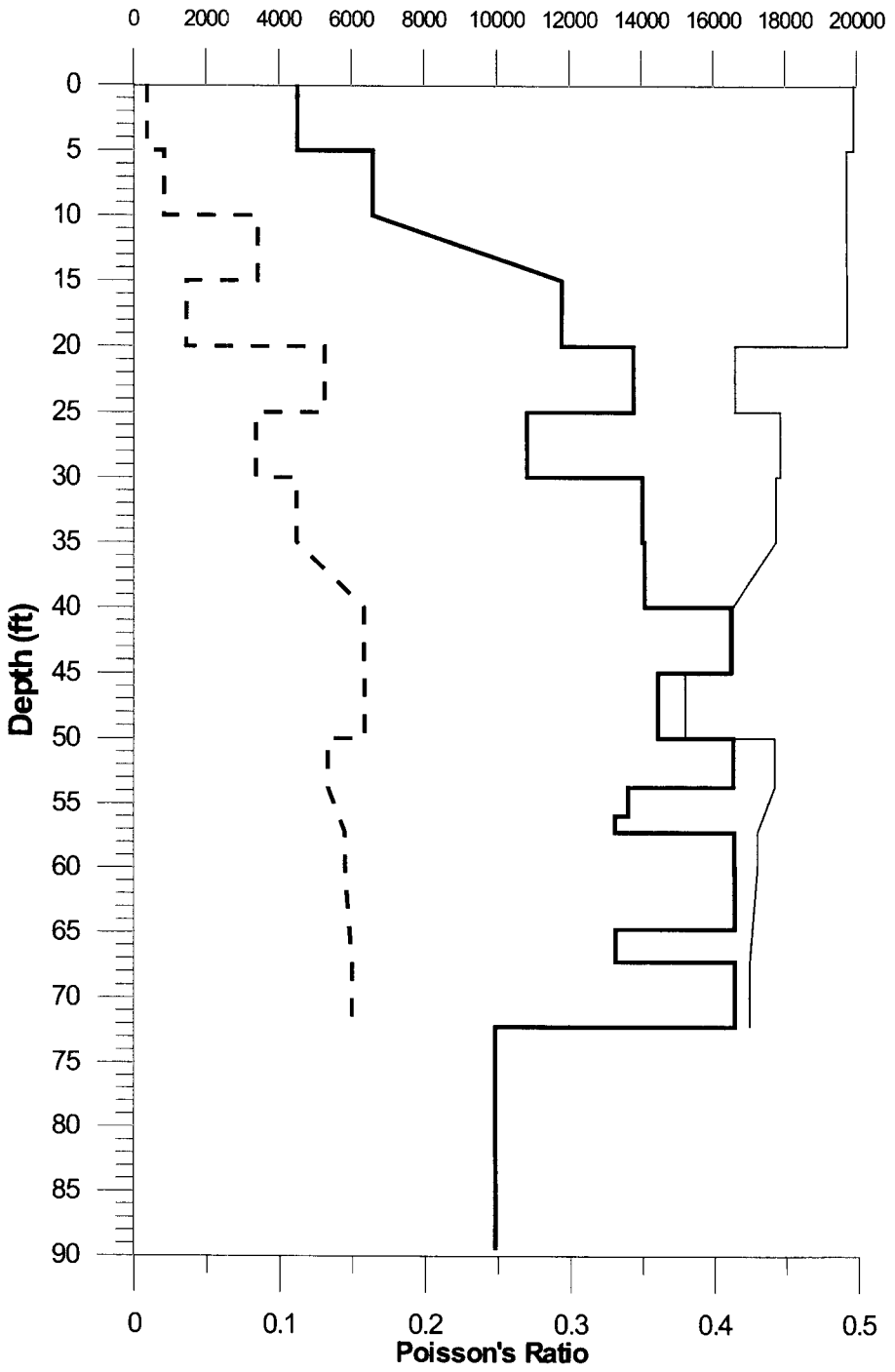
	Project:	North Anna ESP			Grumman Exploration, Inc. 2003				
	Borehole:	B-802b		Location:	Mineral, VA				
				Wave Type :	Shear				
				Ground Offset	7.35	ft			
	Arrival Time Est's, Geophones A, B, C and D							Velocity	
Depth	A.1	A.2	B.1	C.1	C.2	D.1	D.2	Avg (fps)	Depth
0.0	15.00								0.0
2.5	385							385	2.5
5.0	19.00		19.00						5.0
7.5	880		828					854	7.5
10.0	23.00		23.25						10.0
12.5			3435					1435	12.5
15.0	22.40		24.50	15.00					15.0
17.5	1123		1842					1482	17.5
20.0	26.50		27.00	20.30					20.0
22.5	5278							5278	22.5
25.0	27.40		27.05	23.00		25.00			25.0
27.5	3577			3219				3398	27.5
30.0	28.75		29.25	24.50		25.90			30.0
32.5	3901		3901			5737		1513	32.5
35.0	30.00		30.50	25.25		26.75			35.0
37.5									37.5
40.0	32.00		30.90	27.00		27.20			40.0
42.5				3569		6158		6364	42.5
45.0	31.00	35.00	30.80	27.75		28.00			45.0
47.5		6176		3588				6382	47.5
50.0	26.00	35.80	31.50	28.50		30.50	29.40		50.0
52.5						7074	3668	5371	52.5
55.0	28.25		31.60		30.00	31.20	30.75		55.0
57.5							5835	5835	57.5
60.0	29.90		32.10		36.60	31.70	31.60		60.0
62.5									62.5
65.0			31.50		37.50		32.25		65.0
67.5			6213				5848	6030	67.5
70.0			32.30		41.75		33.10		70.0
72.5									72.5
75.0					41.00				75.0
77.5									77.5
80.0									80.0
82.5									82.5
85.0									85.0
87.5									87.5
90.0									90.0

Notes: Shaded cells are geophone locations w/ est'd arrival times (msec),
Red values are velocity estimates (fps) for depth interval
questionable/erroneous velocity estimates blanked

P	Project:	North Anna ESP			Grumman Exploration, Inc. 2003				
	Borehole:	B-802b		Location:	Mineral, VA				
				Wave Type :	Compression				
				Ground Offset	6.00	ft			
	Arrival Time Est's, Geophones A, B, C and D					Velocity			
Depth	A	B	C	D	Avg (fps	Depth			
0.0	6.90					0.0			
2.5	4526				4526	2.5			
5.0	7.30	7.50				5.0			
7.5	5502	7703			6603	7.5			
10.0	8.00	8.00				10.0			
12.5						12.5			
15.0	11.00	11.60	10.60			15.0			
17.5			11813		11813	17.5			
20.0	12.20	11.80	11.00			20.0			
22.5			13798		13798	22.5			
25.0	14.80	11.40	11.35	11.70		25.0			
27.5				10854	10854	27.5			
30.0	16.30	12.15	12.30	12.15		30.0			
32.5				14047	14047	32.5			
35.0	12.40	12.00	11.80	12.50		35.0			
37.5	14106				14106	37.5			
40.0	12.75	12.75	12.60	13.10		40.0			
42.5			16502		16502	42.5			
45.0	12.00	13.40	12.90	13.00		45.0			
47.5		12401	16535		14468	47.5			
50.0	12.60	13.80	13.20	13.75		50.0			
52.5			16559		16559	52.5			
55.0	12.6	12.75	13.50			55.0			
57.5	16576				16576	57.5			
60.0	13.10	13.50		14.00		60.0			
62.5				16590	16590	62.5			
65.0		13.60		14.30		65.0			
67.5		16601			16601	67.5			
70.0		13.90		14.65		70.0			
55.0	12.80			13623	13623	55.0			
57.0	13260			13.90	13260	57.0			
59.0	13.10					59.0			
				14.70		0.0			
65.0		13.60				65.0			
67.0		13280			13280	67.0			
69.0		13.90				69.0			
						0.0			
75.0			14.40			75.0			
77.0			9970		9970	77.0			
79.0			14.80			79.0			
						0.0			
85.0				15.80		85.0			
87.0				9976	9976	87.0			
89.0				15.20		89.0			
						0.0			

Notes: Shaded cells are geophone locations w/ est'd arrival times (msec),
Red values are velocity estimates (fps) for depth interval
questionable/erroneous velocity estimates blanked

Estimated Velocity (fps) B-802b



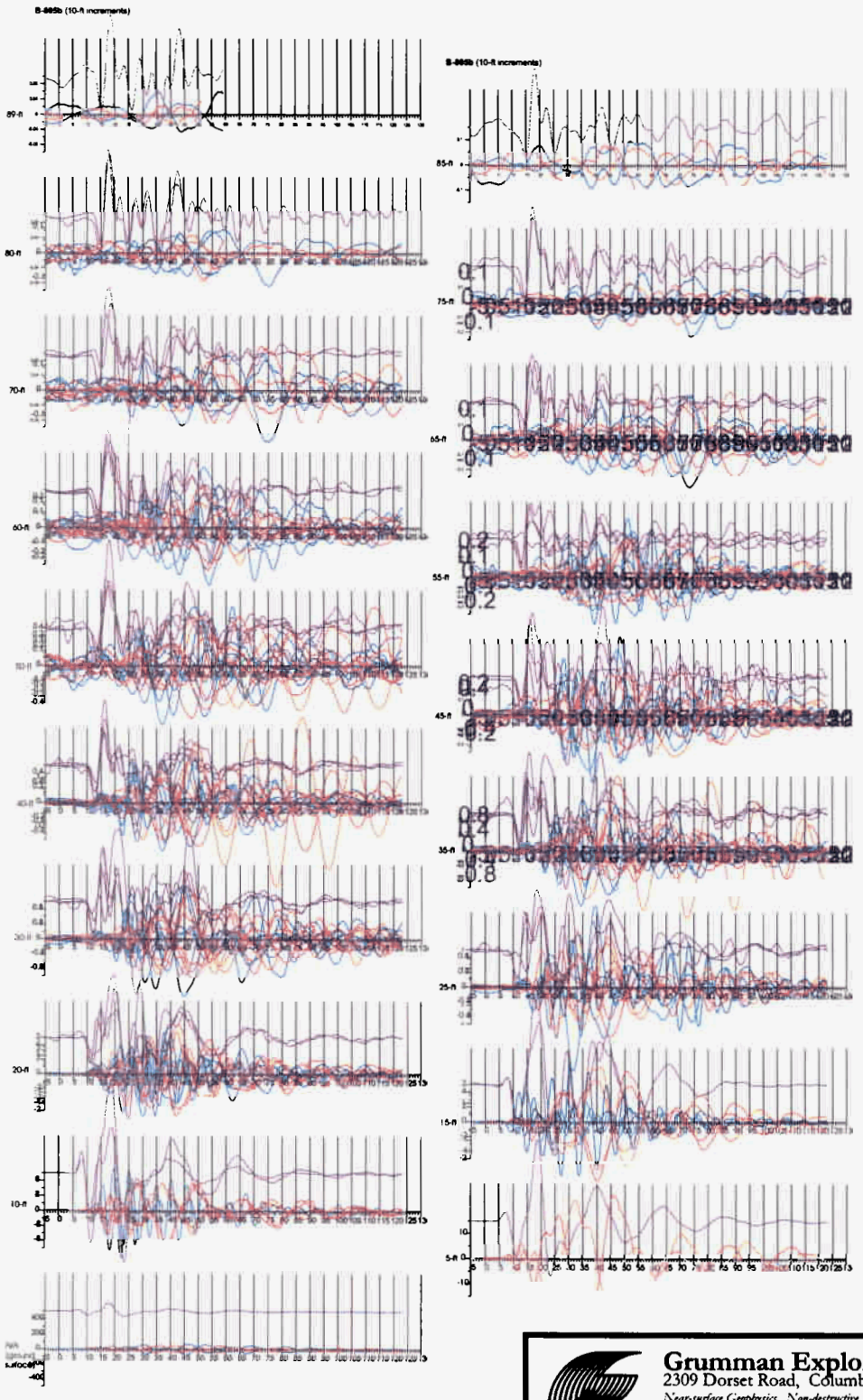
Legend

- P-wave Velocity (fps)
- S-wave Velocity (fps)
- Poisson's Ratio

Grumman Exploration, Inc.
2309 Dorset Road, Columbus, Ohio 43221
Near-surface Geophysics, Non-destructive Subsurface Exploration

Project	North Anna ESP Project - Downhole Seismic		
Location	North Anna Power Station, Mineral, Virginia		
Client	Mactec Eng. Svcs.	By dlg	Date 2/20/03
Project No.	01-22089	Checked	Scale nts

Figure	Title
1	B-802b, Estimated Velocity vs. Depth



Legend

Vertical Geophone (compressional)

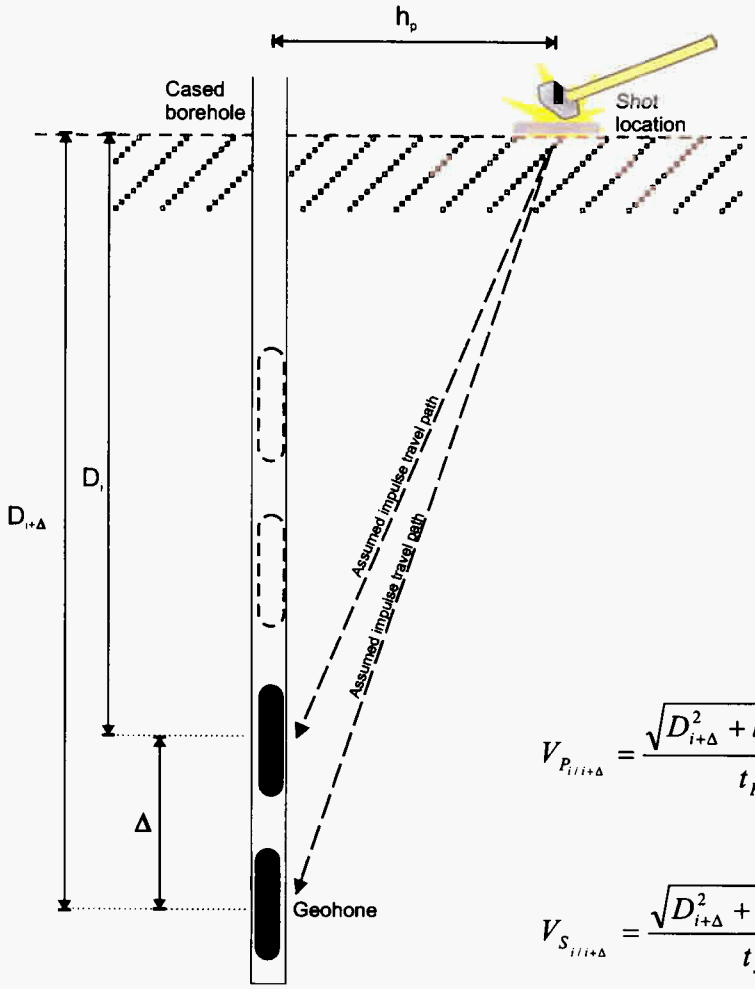
Lateral Geophone #1 (opposing polarities)

Lateral Geophone #2 (opposing polarities)

Grumman Exploration, Inc.
2309 Dorset Road, Columbus, Ohio 43221
Near-surface Geophysics, Non-destructive Subsurface Exploration

Project	North Anna ESP Project - Downhole Seismic		
Location	North Anna Power Station, Mineral, Virginia		
Client	Mactec Eng. Svcs.	By dlg	Date 2/20/03
Project No.	01-22089	Checked	Scale nts

Figure 2 | Title B-802b, Recorded Downhole Waveforms



$$V_{P_{i/i+\Delta}} = \frac{\sqrt{D_{i+\Delta}^2 + h_p^2} - \sqrt{D_i^2 + h_p^2}}{t_{P_{i+\Delta}} - t_{P_i}}$$

$$V_{S_{i/i+\Delta}} = \frac{\sqrt{D_{i+\Delta}^2 + h_s^2} - \sqrt{D_i^2 + h_s^2}}{t_{S_{i+\Delta}} - t_{S_i}}$$

$V_{P_{i/i+\Delta}}$ = Compressional wave velocity for the depth interval i to $i+\Delta$

$V_{S_{i/i+1}}$ = Shear wave velocity for the depth interval i to $i+\Delta$

Δ = Vertical distance/separation between successive geophones

D_i , $D_{i+\Delta}$ = Geophone depth at test depth i, Geophone depth at test depth i+Δ

t_{S_i} , $t_{S_{i+\Delta}}$ = Estimated arrival times for the shear wave for successive geophones

h_p , h_s = Ground offset distance between shot location and center of borehole for the compressional and shear wave shots, respectively

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Near-surface Geophysics, Non-destructive Subsurface Exploration

Project: DOWNHOLE SEISMIC CALCULATIONS			
Location			
Client	By: dlg	Date: 3/01/03	
Project No.	Checked	Scale: nts	

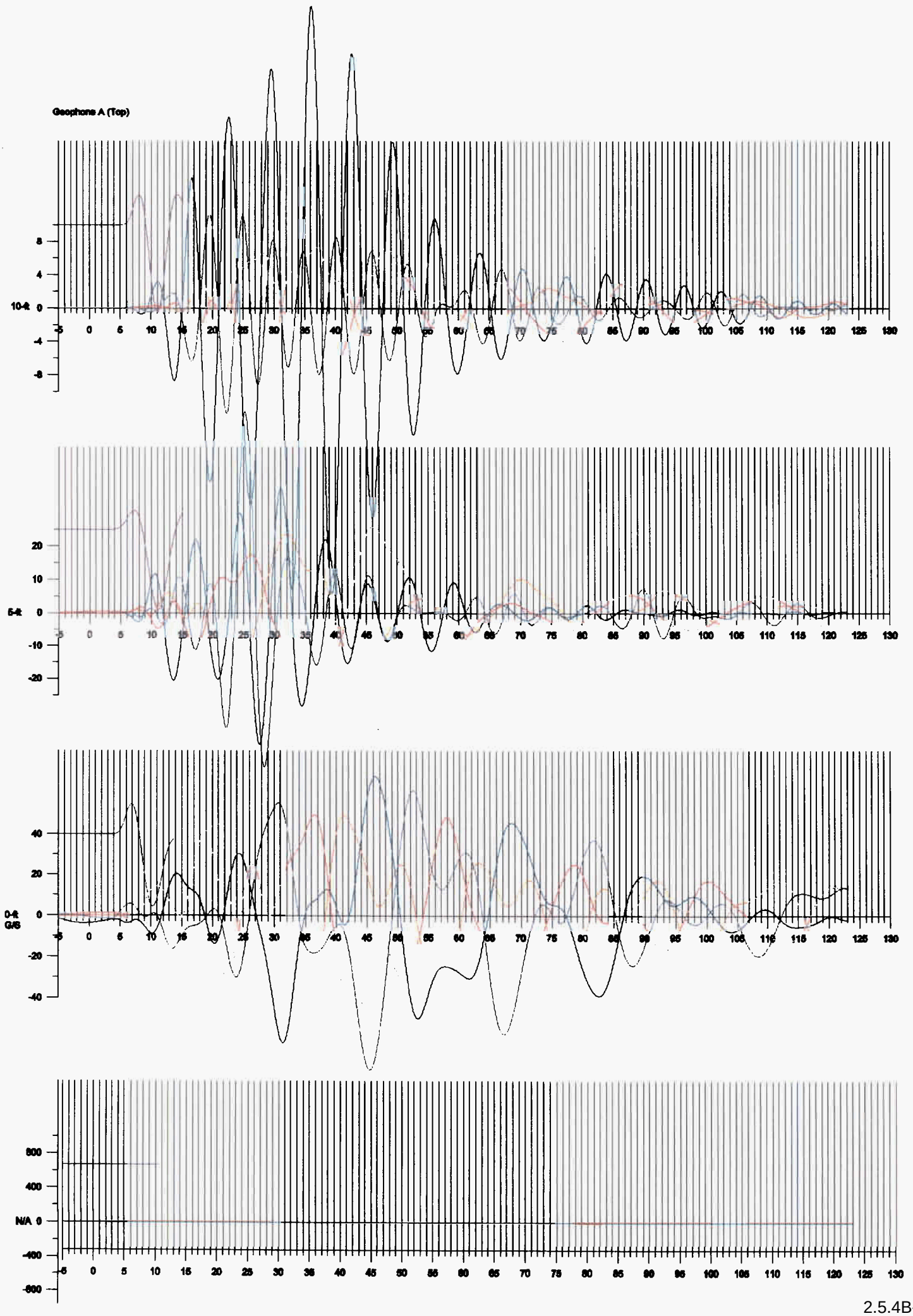
Figure	Title
	Schematic Downhole Computations

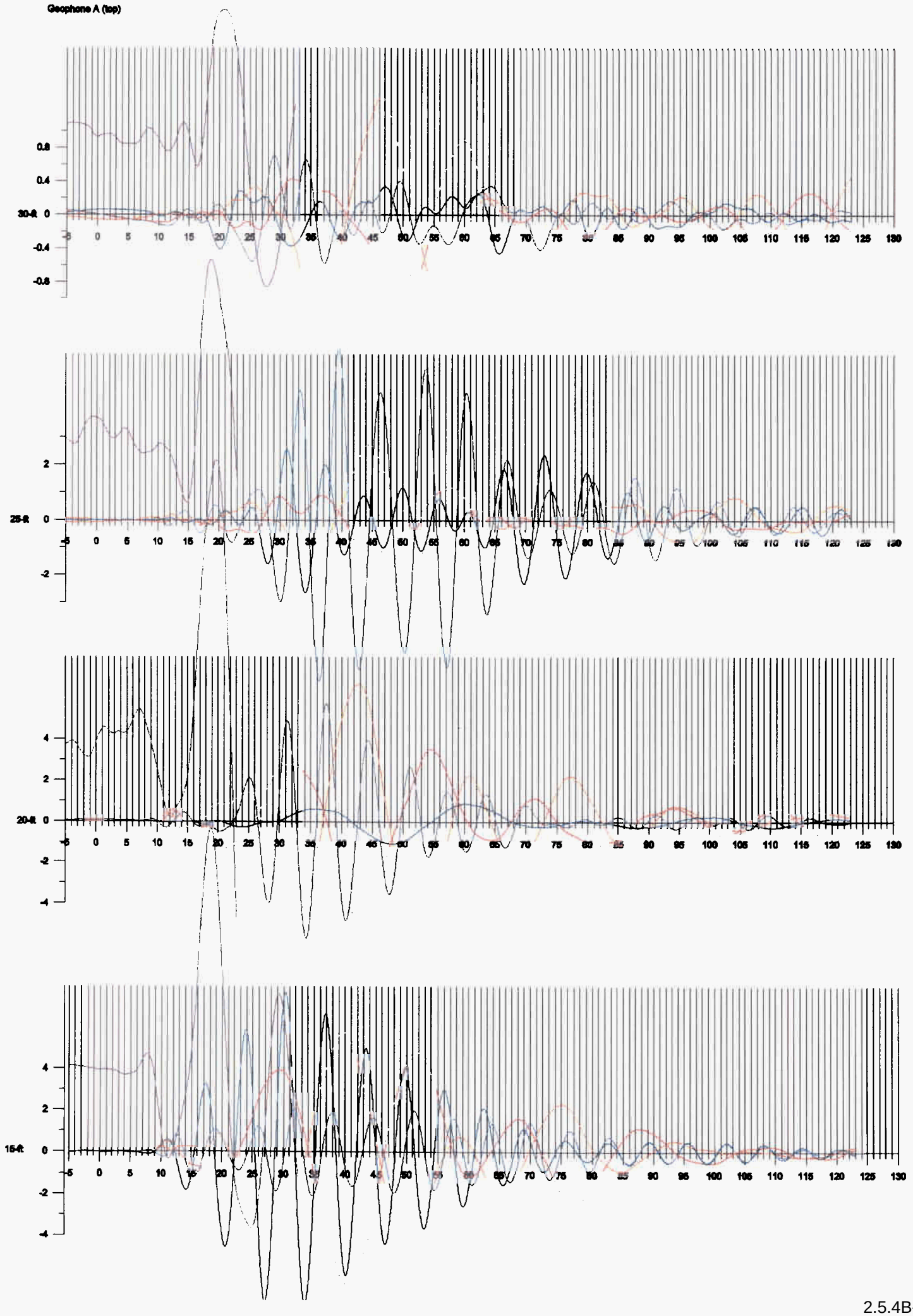
WAVE FORMS FROM FIELD DATA

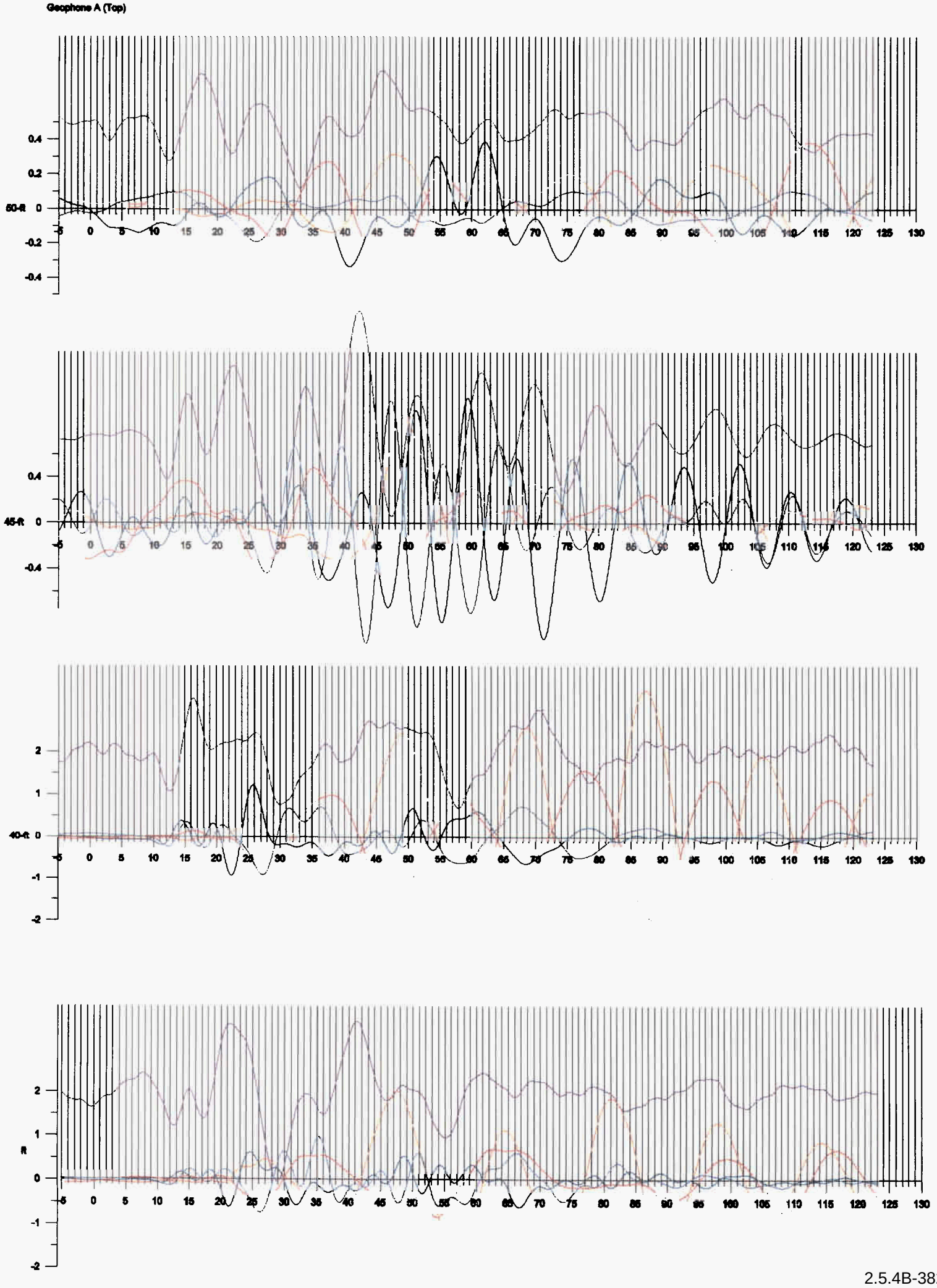
Wave forms from each geophone are presented on a series of sheets. Each sheet shows data from the indicated geophone at different depths below the surface as shown on the left side of the sheet, reading from bottom to top of the sheet. There are four geophones – A (at the top of the array), B (at the top middle of the array), C (at the bottom middle of the array) and D (at the bottom of the array). The horizontal axis is time in milliseconds. The vertical axis is amplitude of the signal and has a variable scale.

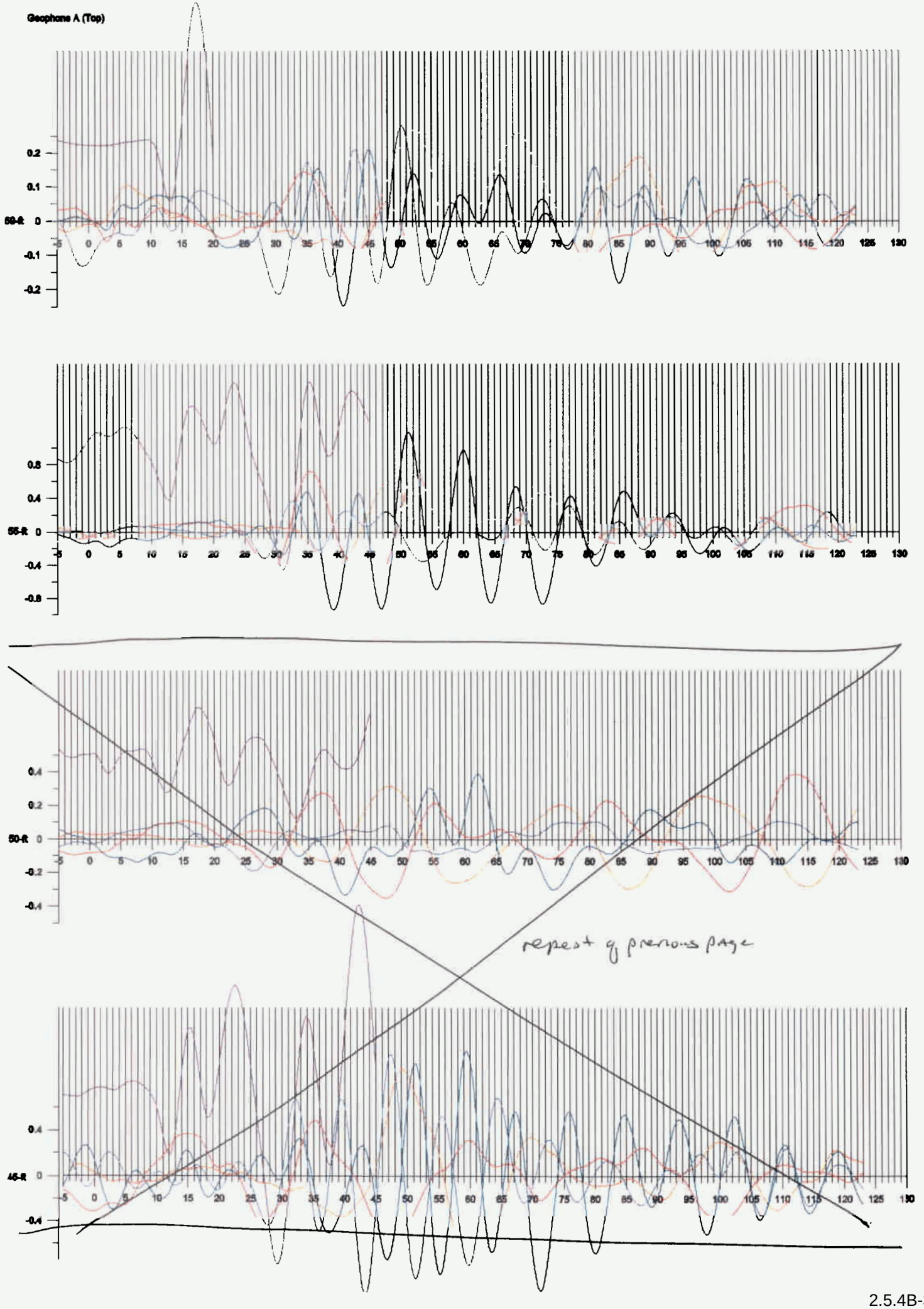
The color plots are coded as follows:

Purple	- vertical signal
Red	- lateral signal geophone 1
Orange	- lateral signal geophone 1, opposite polarity
Light Blue	- lateral signal geophone 2
Dark Blue	- lateral signal geophone 2, opposite polarity

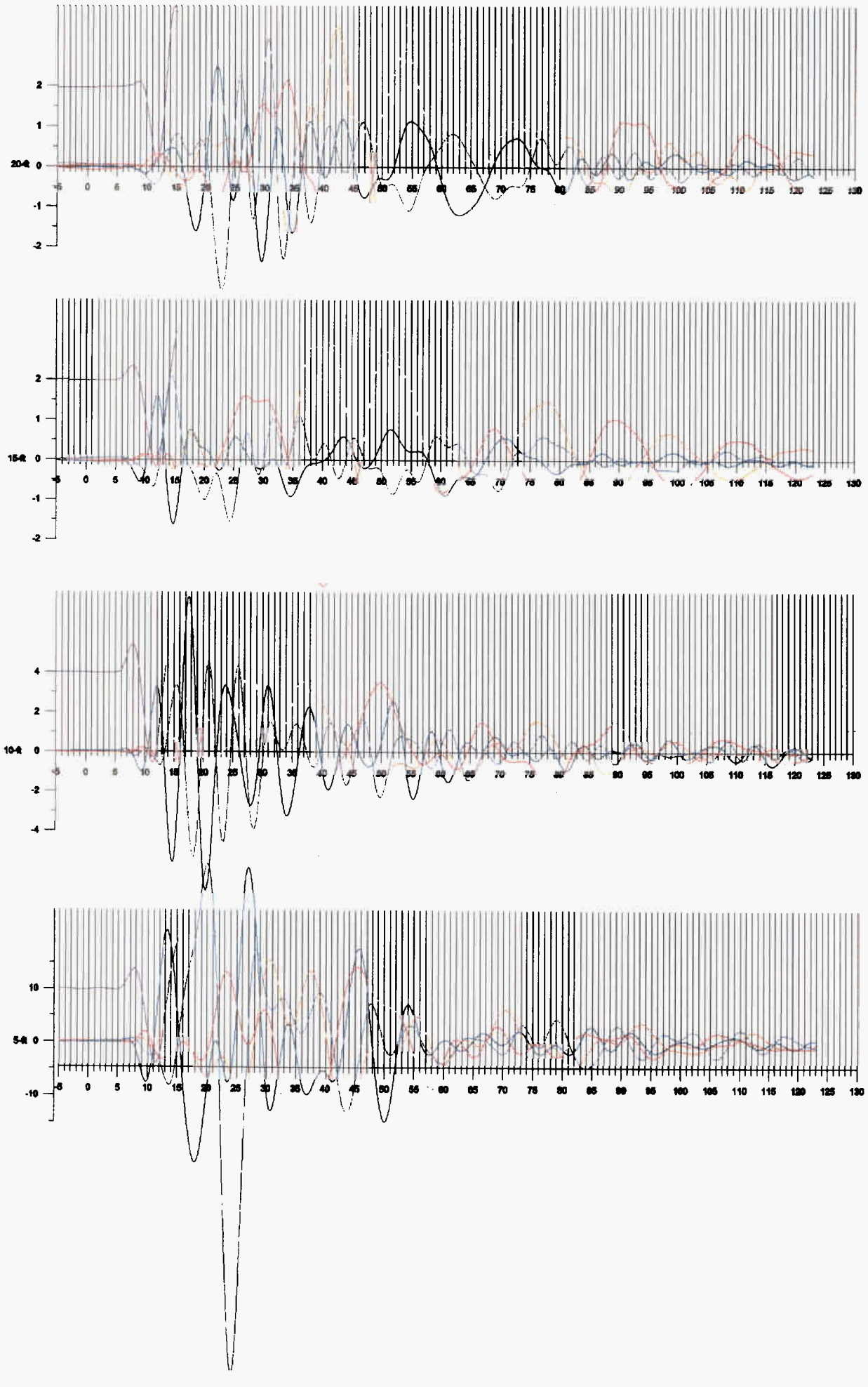

Geophone A (Top)
10-ft
5-ft
0-ft
G/S
N/A


Geophone A (top)
30-ft
25-ft
20-ft
15-ft

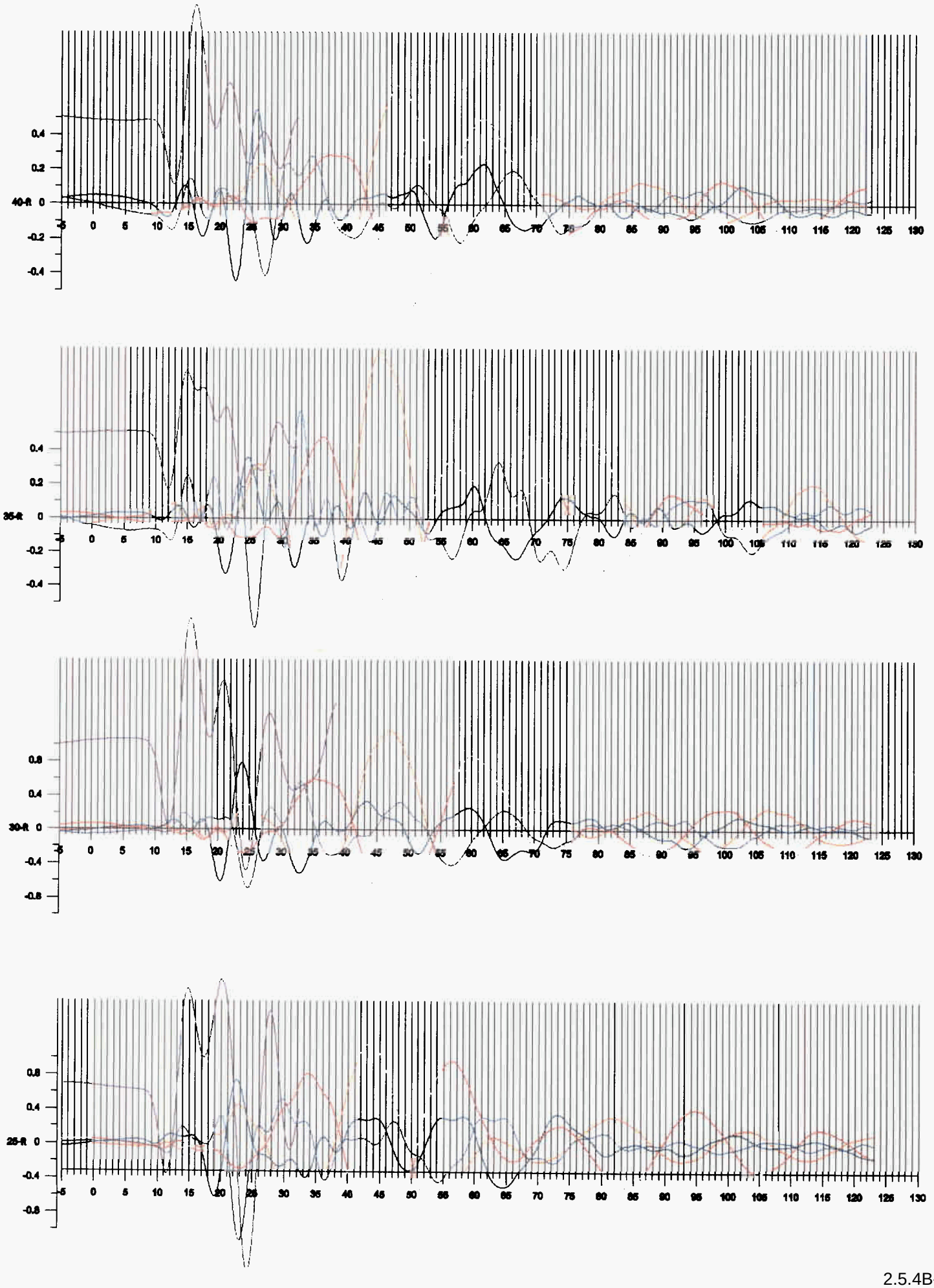

Geophone A (Top)
50-ft
45-ft
40-ft
ft


Geophone A (Top)
60-R
55-R
50-R
45-R
repeat of previous page

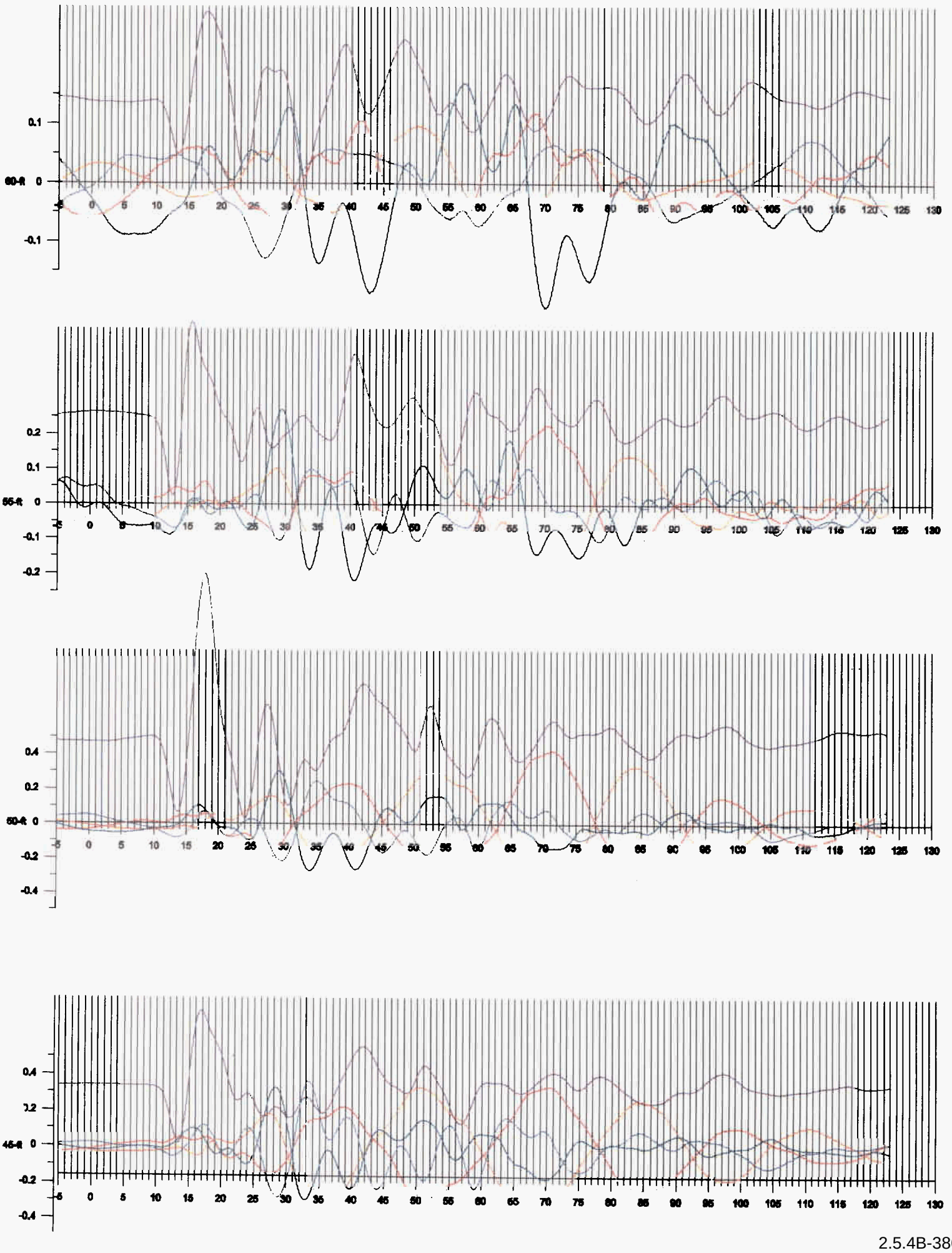
Geophone B (add-ht)



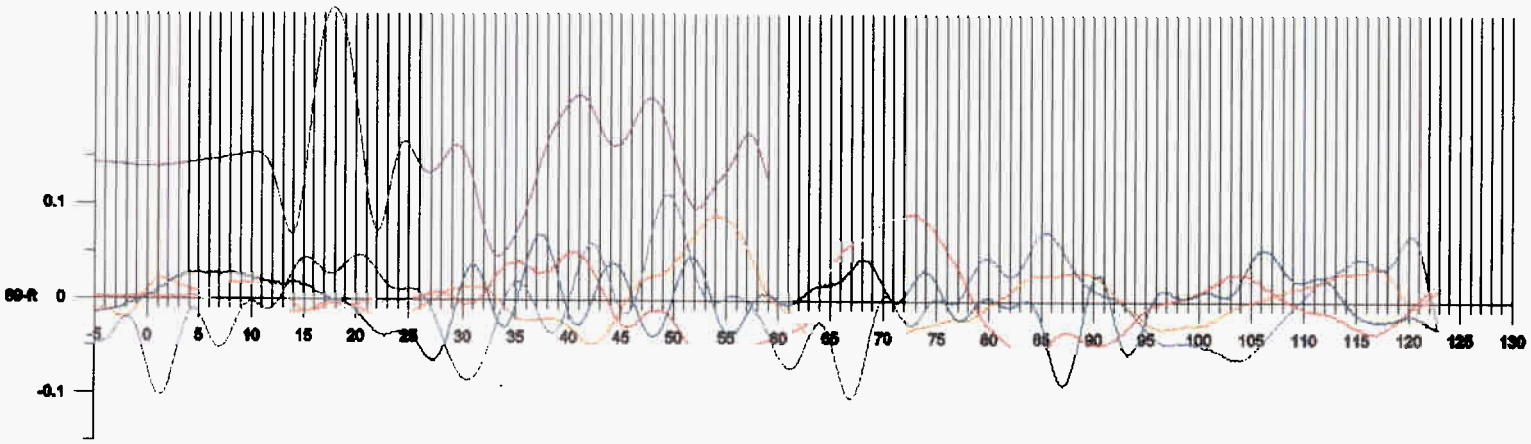
Geophone B (mid-ht)

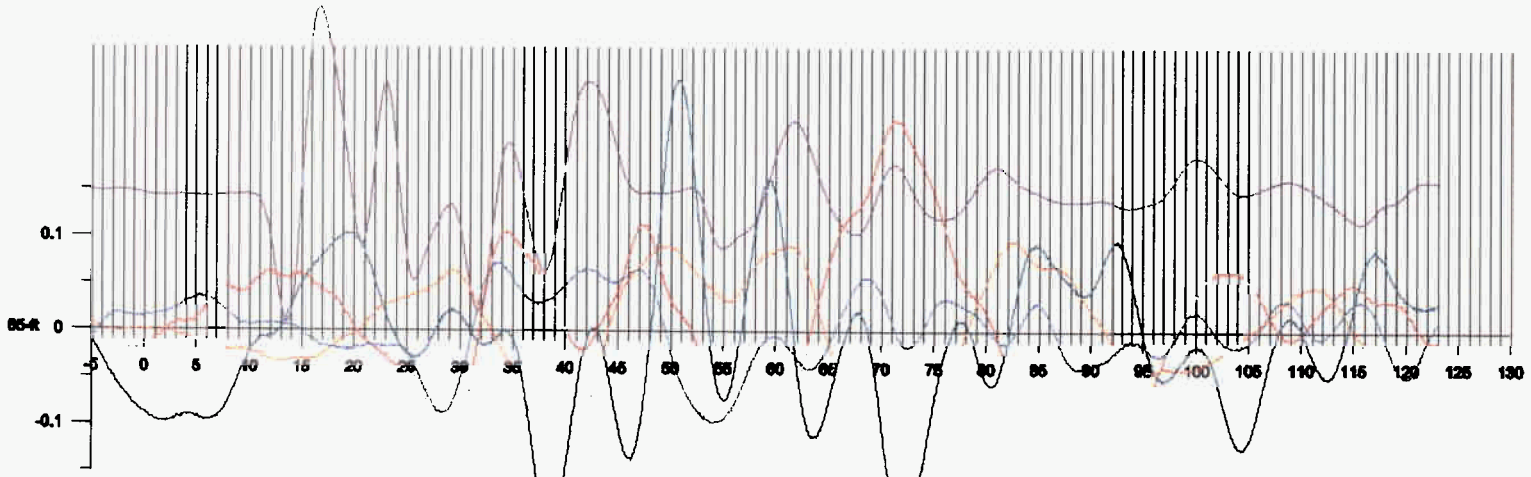


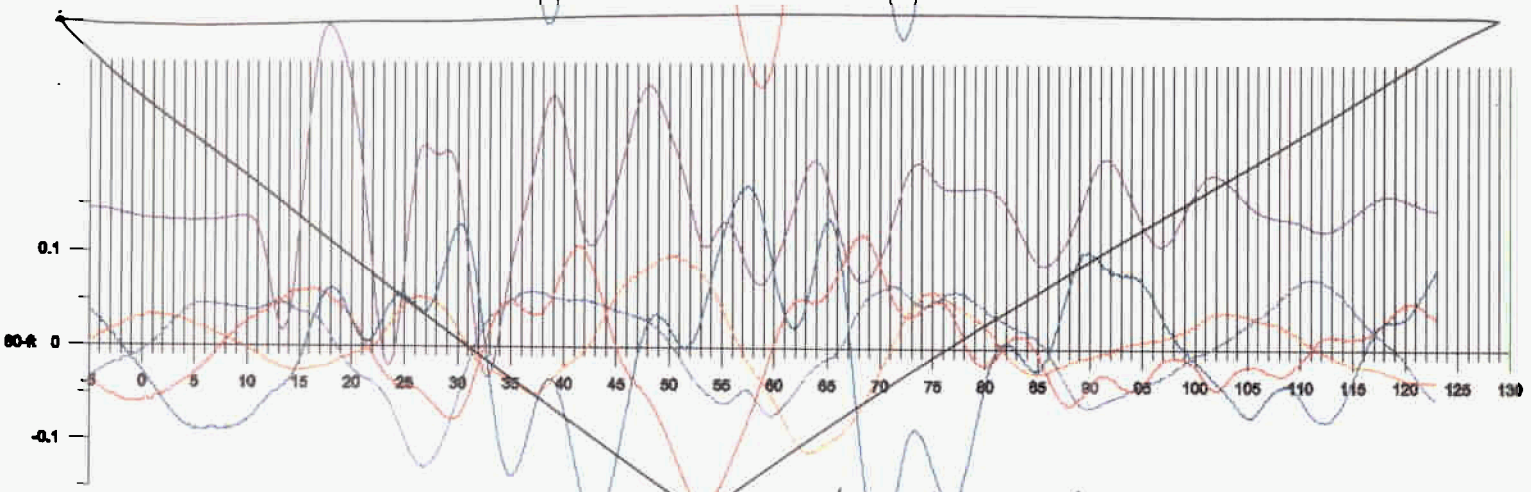
Geophone B (Mid-ht)



Geophone B (mid hi)







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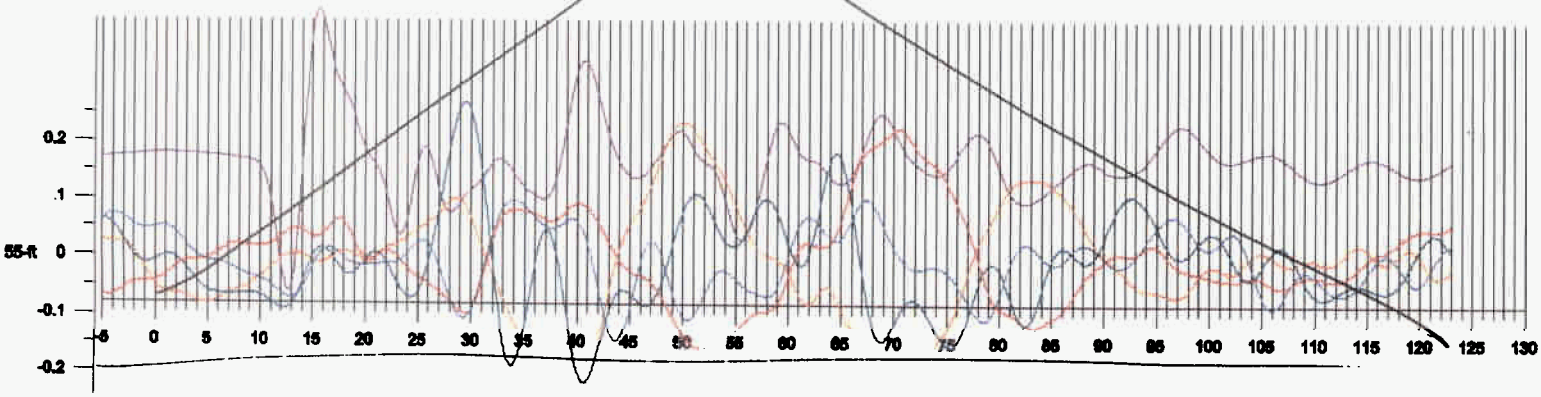
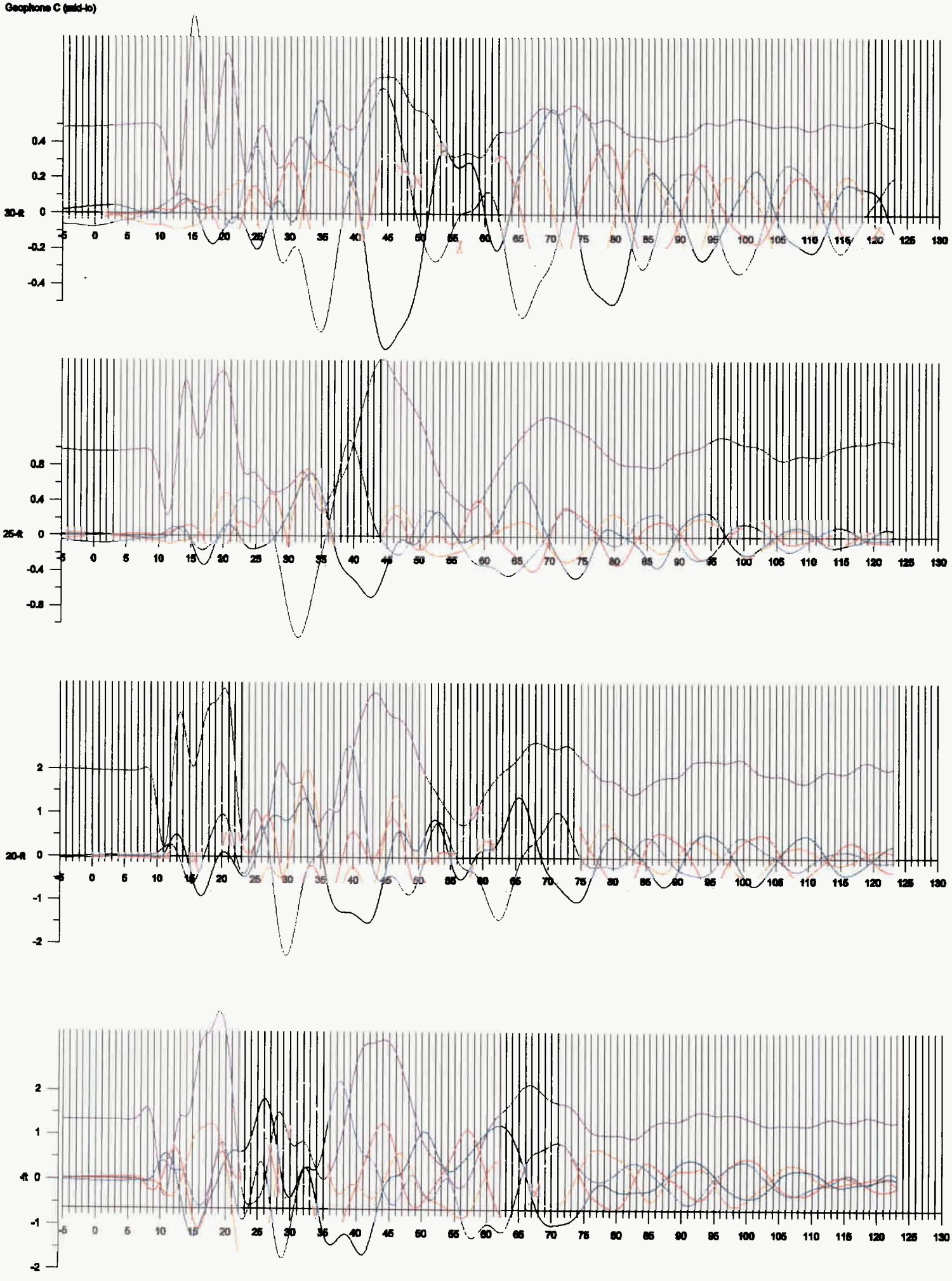
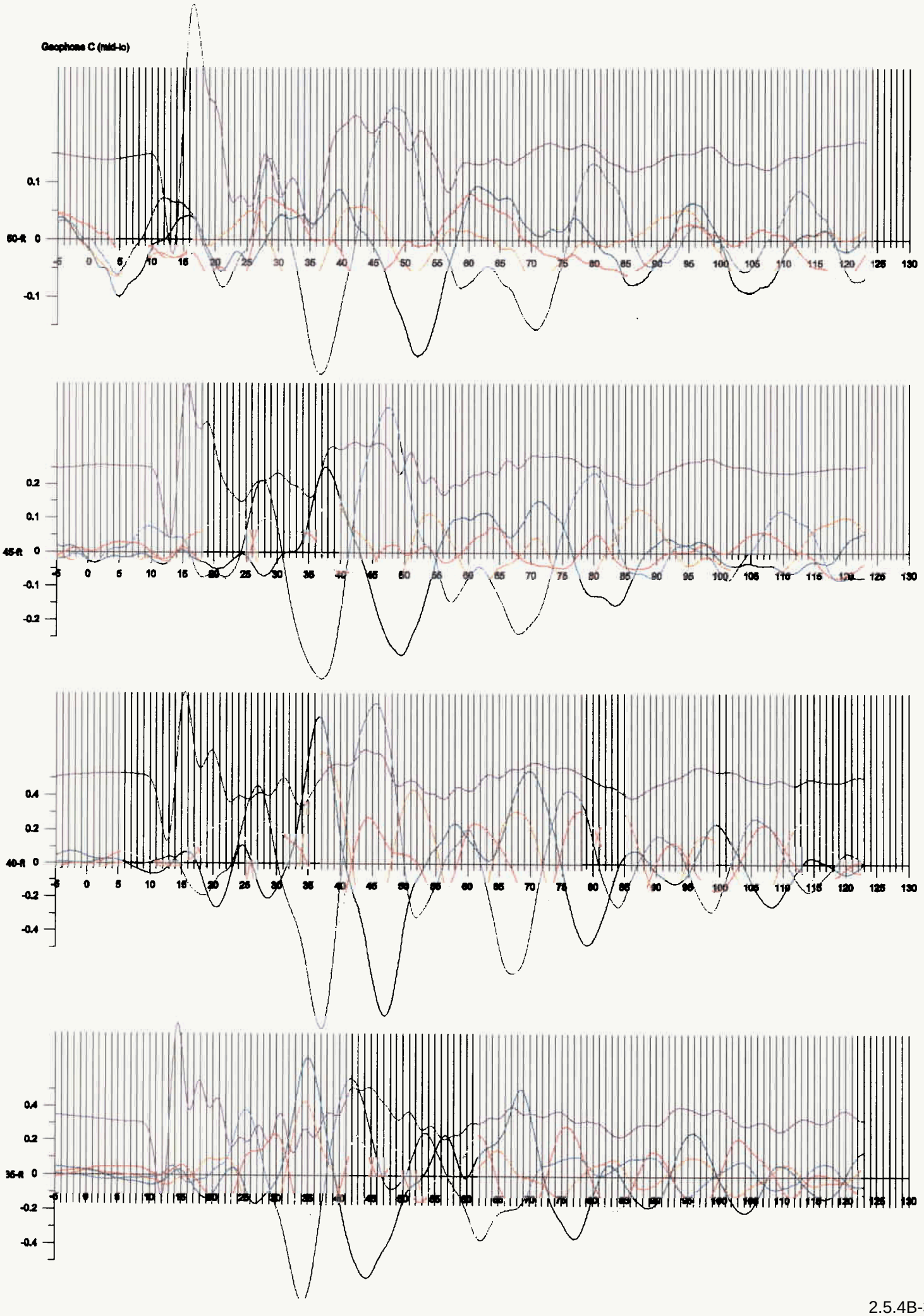
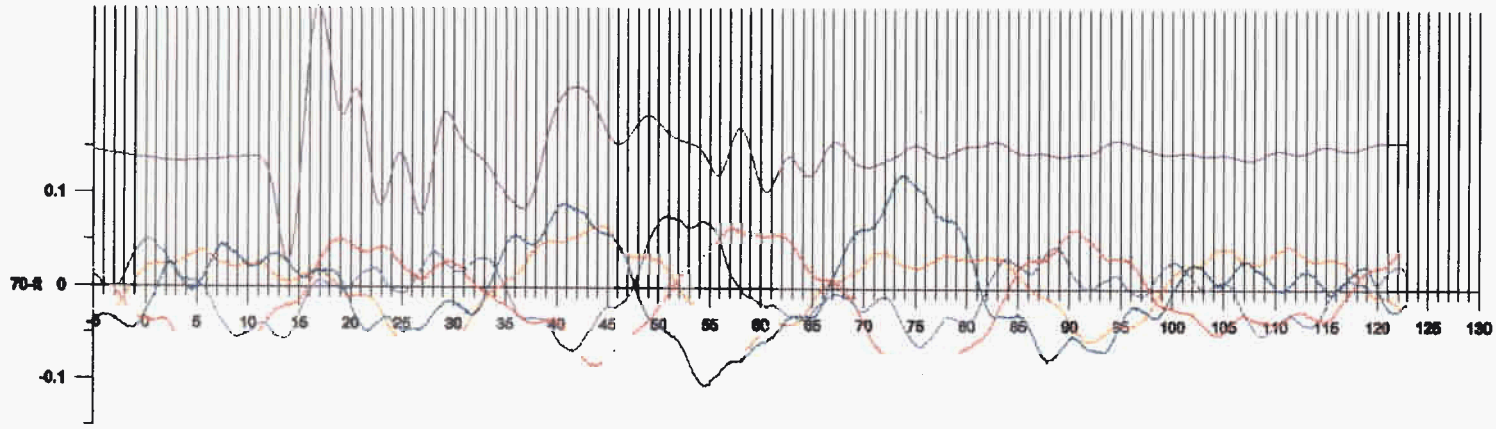
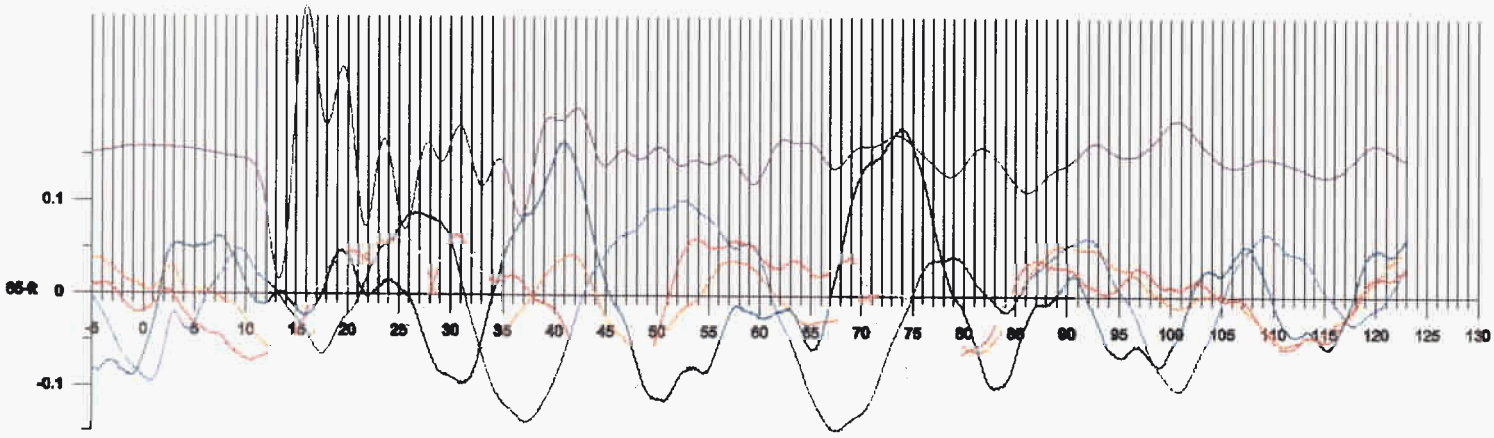


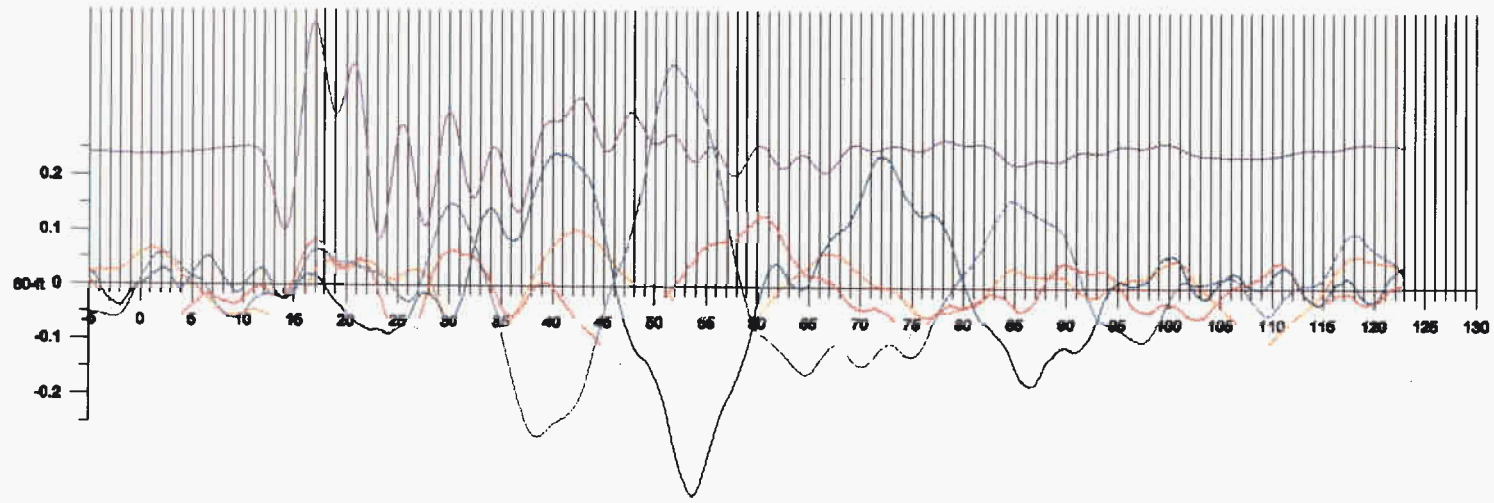

Geophone C (mid-lo)
30-ft
25-ft
20-ft
-ft

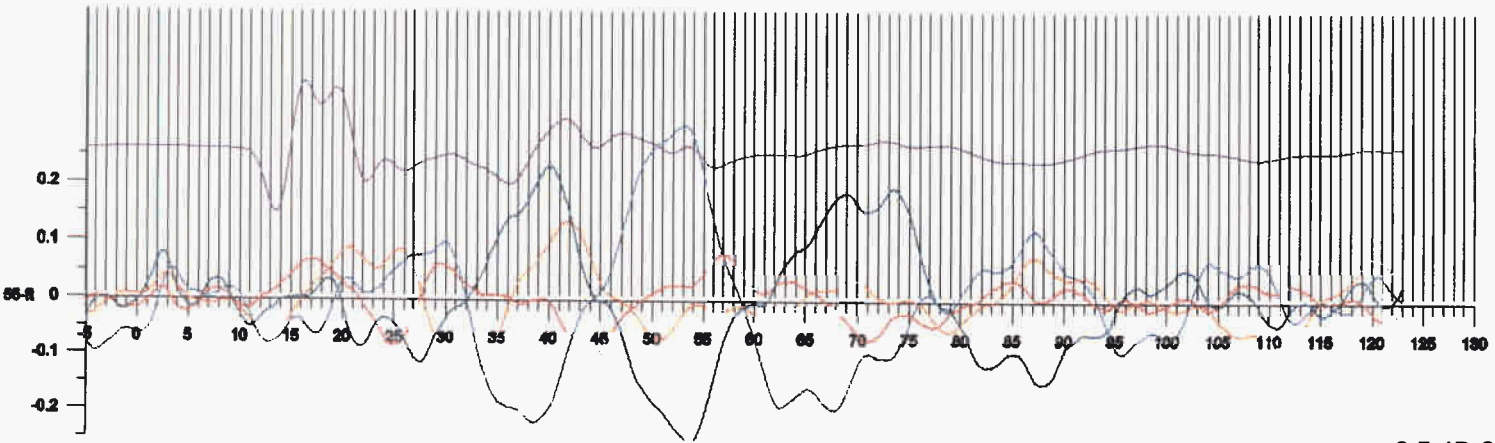

Geophone C (mid-lo)
50-ft
45-ft
40-ft
35-ft

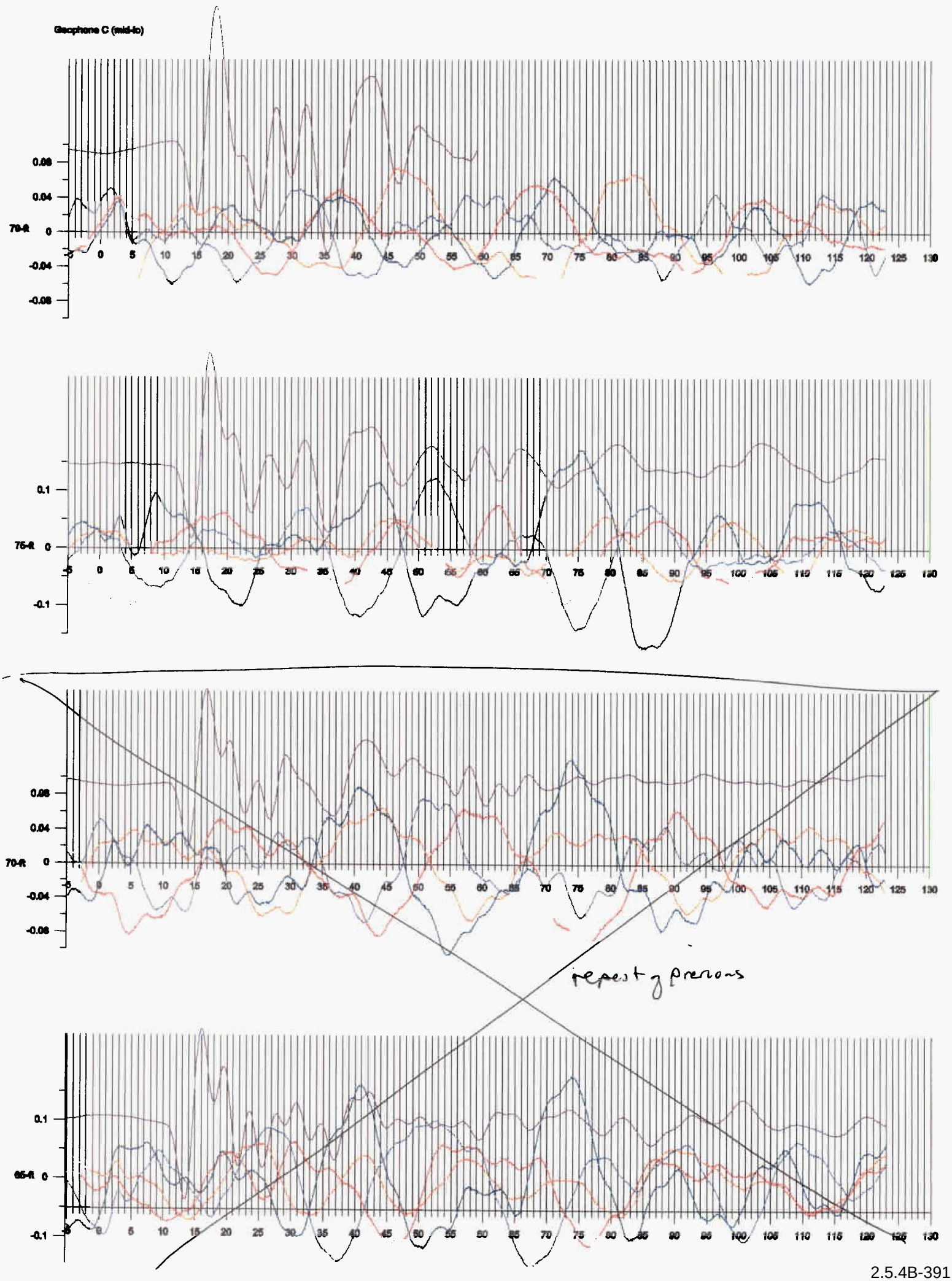
Geophone C (mid-lo)

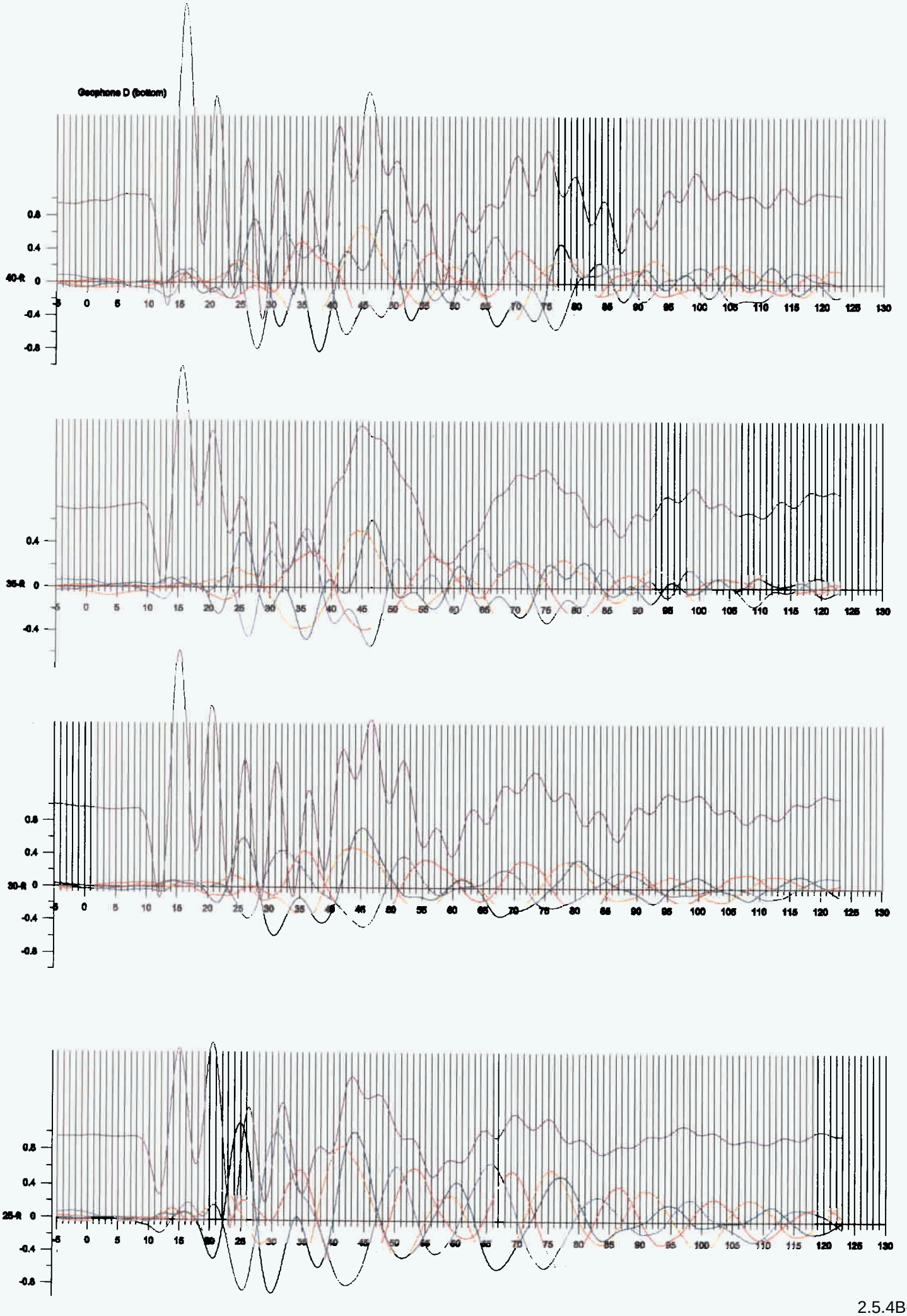


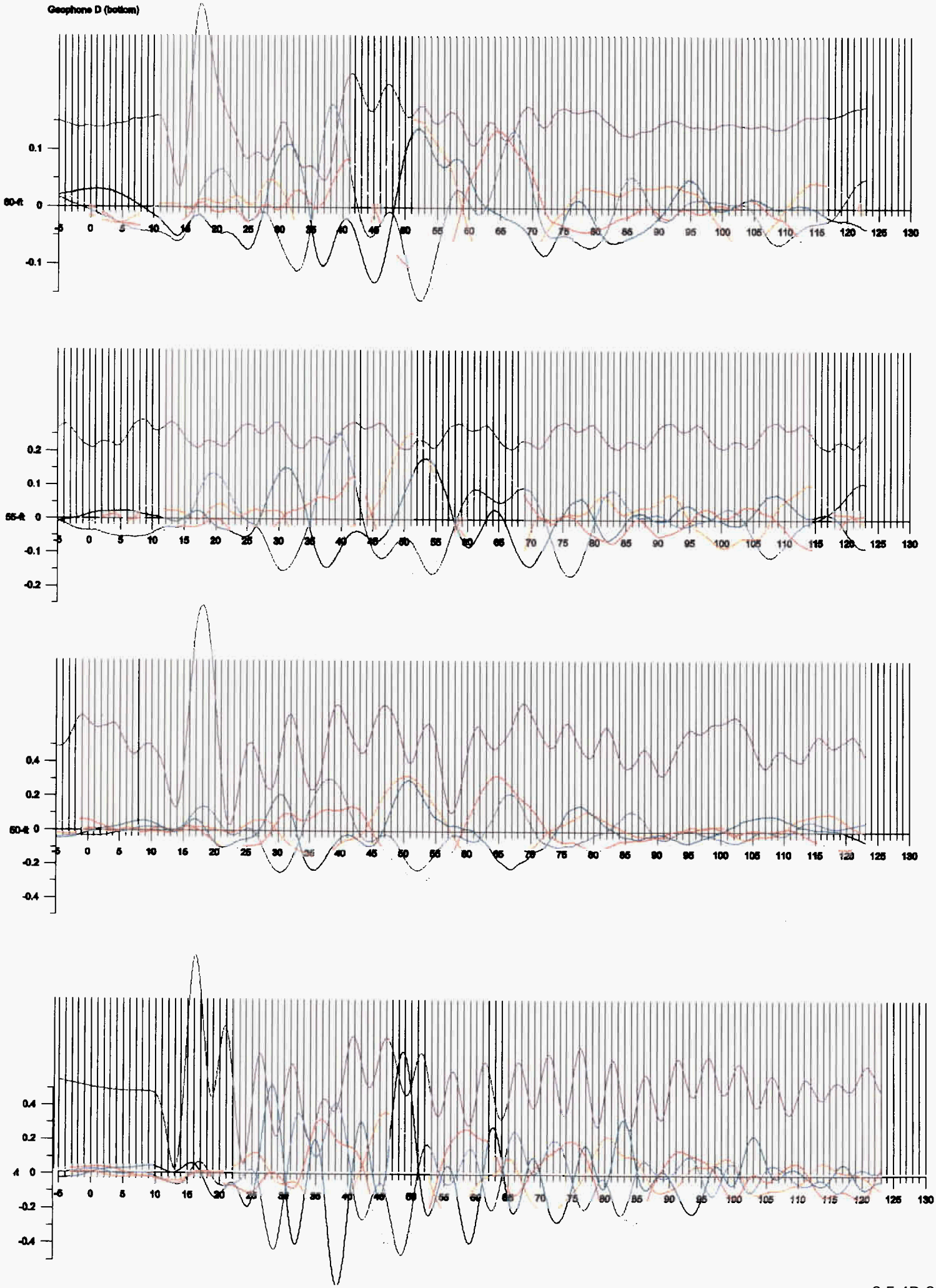


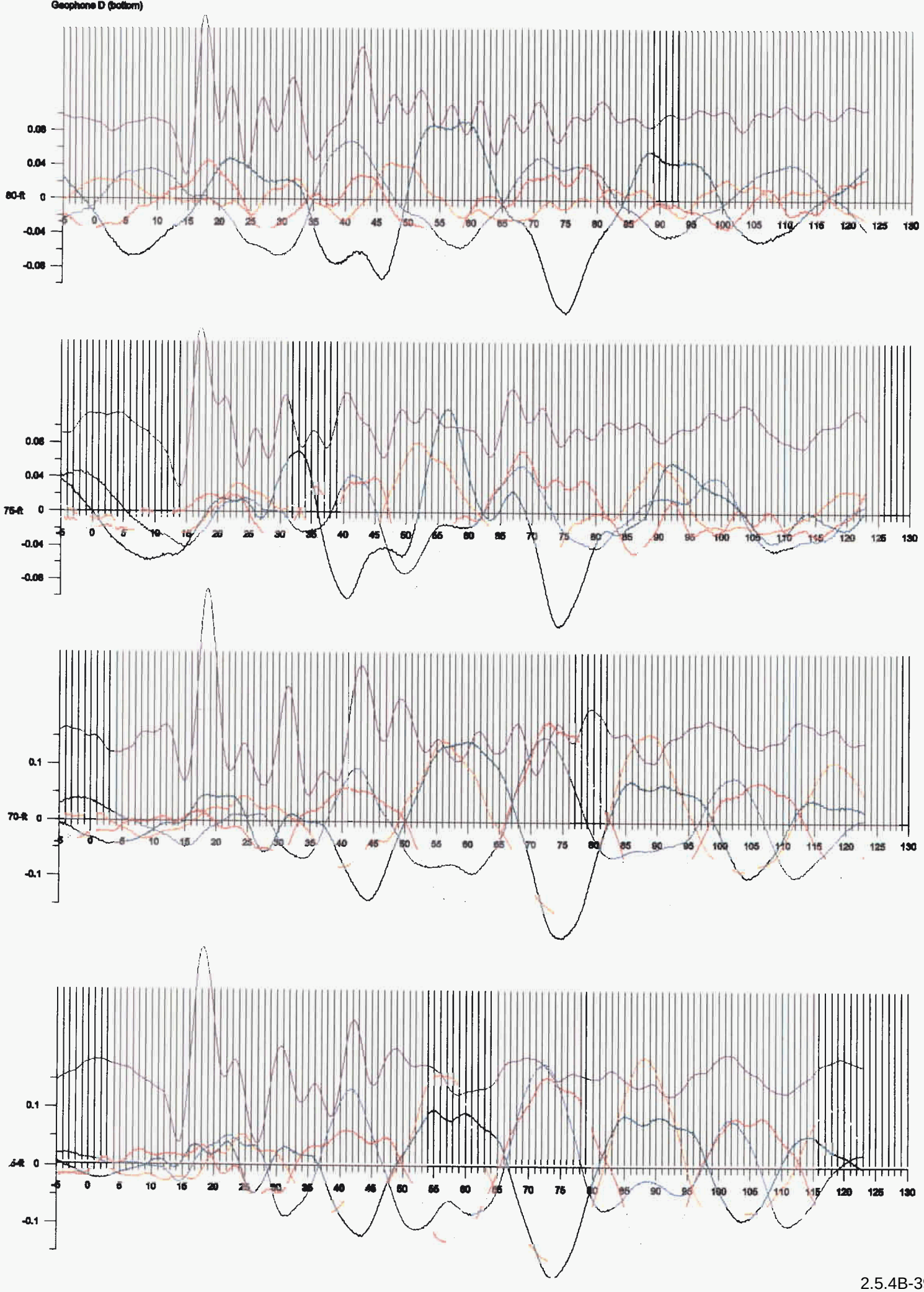




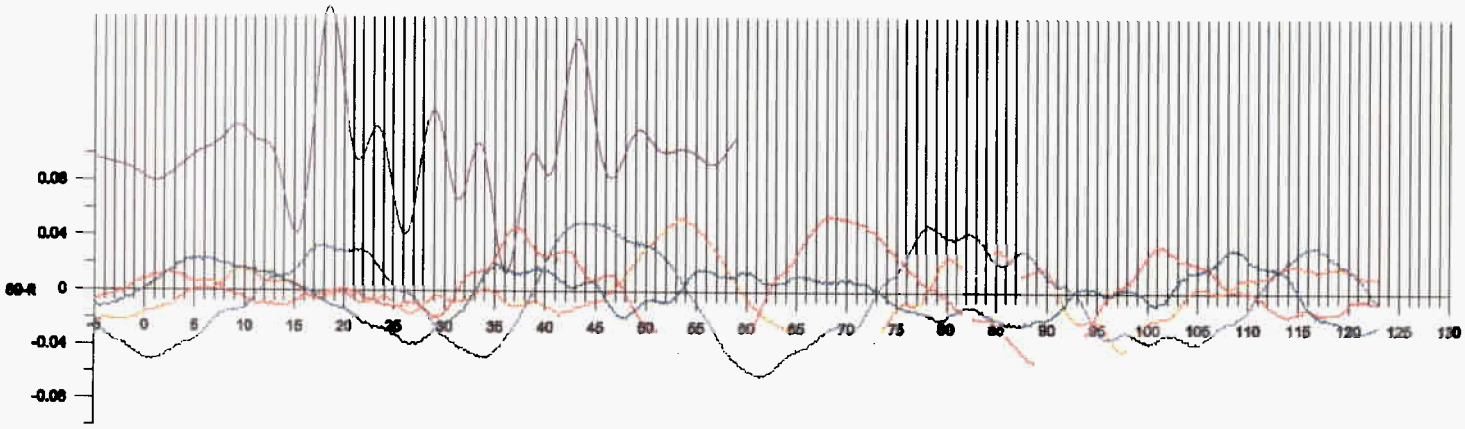

Geophone C (mid-lo)
70-R
75-R
65-R
repeat previous

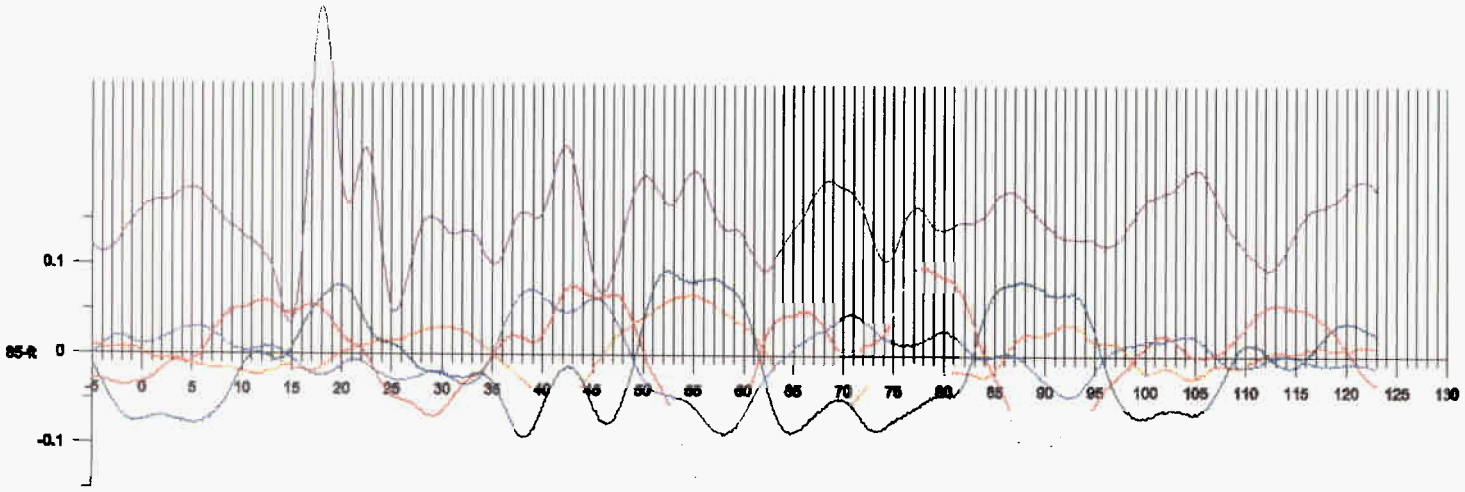

Geophone D (bottom)
40-R
35-R
30-R
25-R

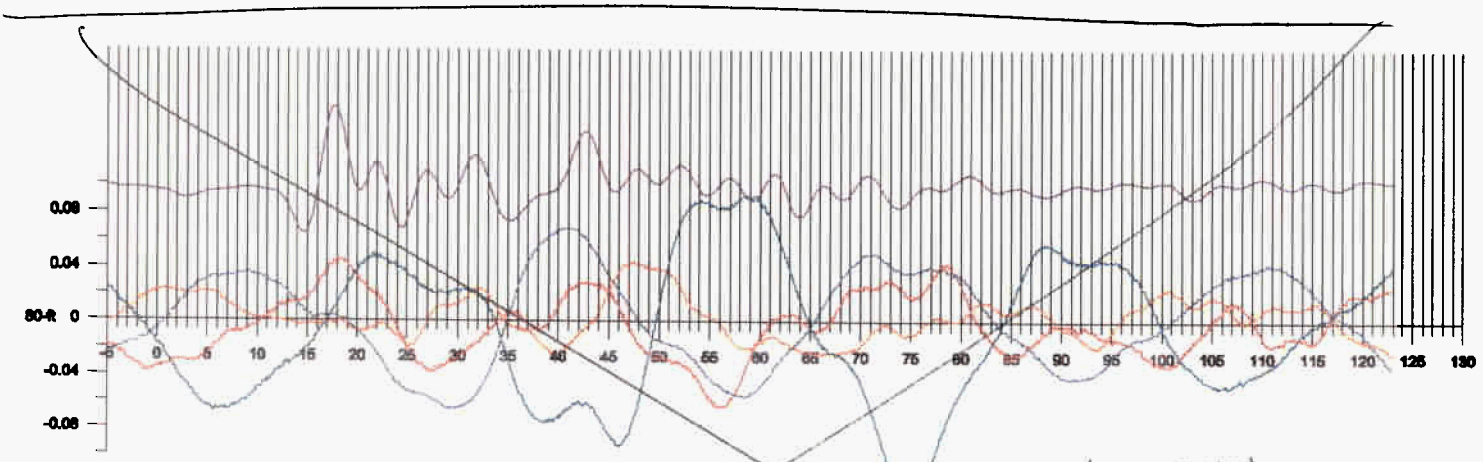

Geophone D (bottom)
60-ft
55-ft
50-ft


Geophone D (bottom)
80-ft
75-ft
70-ft
0.08
0.04
0
-0.04
-0.08
0.1
-0.1
-5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130

Geophone D (bottom)







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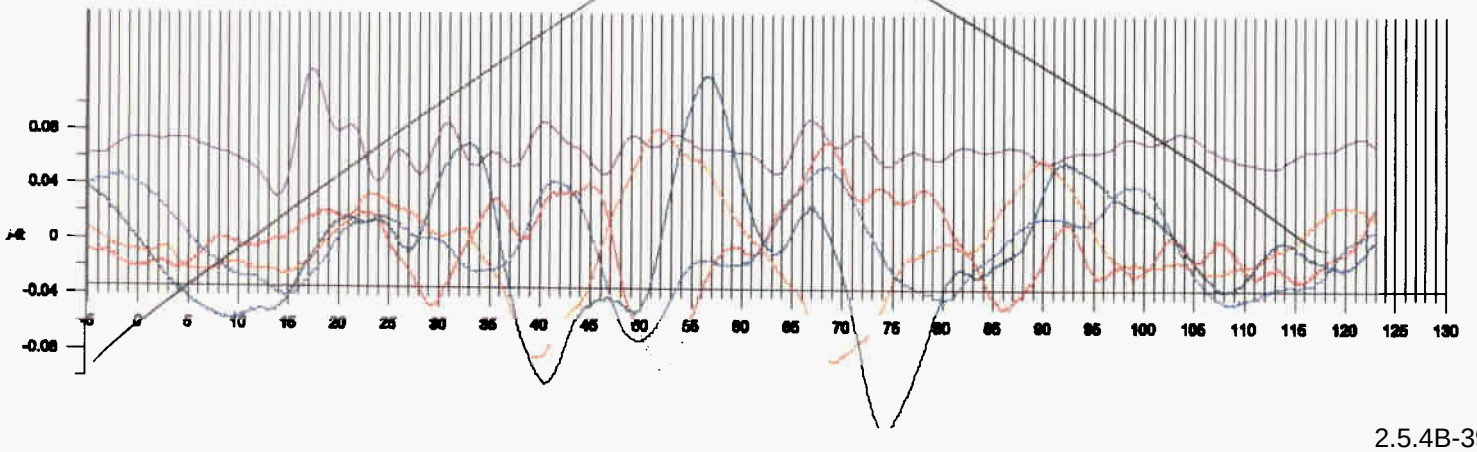

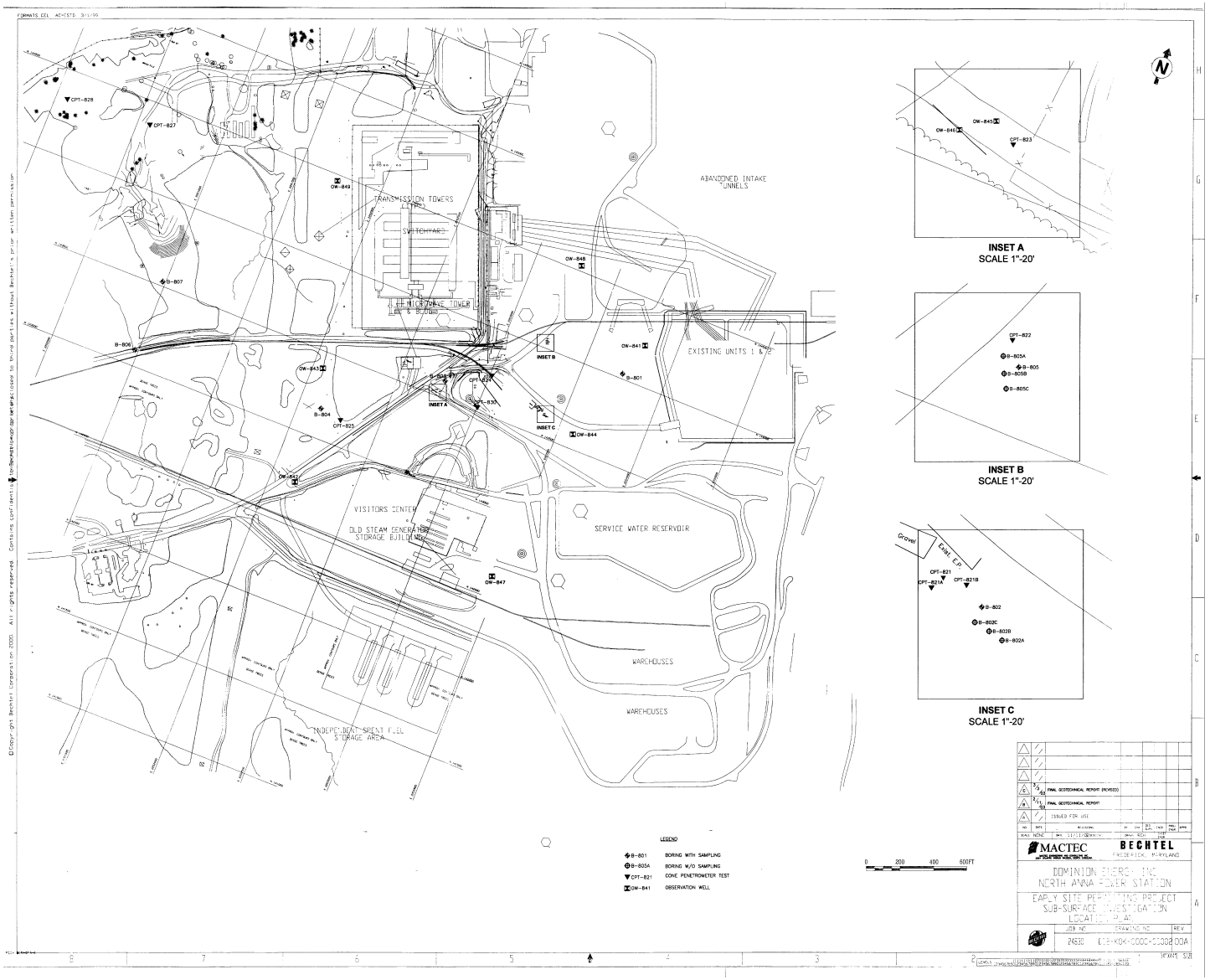

Figure 2.5-4B-1 Sub-Surface Investigation Location Plan

2.5.5 Stability of Slopes

This section presents information on the stability of permanent slopes at the NAPS site. The information has been developed in accordance with Review Standard RS-002, "Processing Applications for Early Site Permits" (Reference 145), following the guidance presented in RG 1.70, Section 2.5.5 (Reference 3). The geological, geophysical, geotechnical and seismological information presented in this section is used as a basis to evaluate the stability of specific slopes at the site.

The information presented in this section was developed from a review of reports prepared for the existing units and the abandoned Units 3 and 4, geotechnical literature, and a subsurface investigation conducted for preparation of this ESP application. The review included the site-specific reports from the UFSAR (Reference 5), and reports prepared by Dames and Moore regarding the design and construction of the existing units (Reference 7) and the abandoned Units 3 and 4 (Reference 8).

A 55-foot high, 2-horizontal to 1-vertical (2h:1v) slope descends from north of the SWR down to south of the existing excavation made for abandoned Units 3 and 4. This slope was excavated during construction of the existing units, and is almost entirely in cut material. The top of this slope is 200 feet from the top of the SWR embankment, and thus any potential instability of the slope would have no impact on the stability of the SWR embankment.

The only new permanent slope that may be created in association with the new units would be to the west of the SWR to accommodate the buried UHSs for certain new unit designs. The amount (if any) of this cut depends on the design that would be selected. The maximum slope height envisioned is about 55 feet, cut at a 2h:1v slope. The top of the slope would be at least 200 feet from the top of the SWR embankment, the same distance as for the existing slope to the north of the SWR. Thus, any instability of the new slope would not impact the SWR.

Although instability of the existing and possible new 2h:1v slopes would not impact the SWR, sloughing or collapse of these slopes could impact the new units, depending on their final location. The stability of these slopes is addressed in the following sections. The new slopes of the non-safety-related, deepened intake channel, which would be used for the normal cooling water system supply of the new units, would be analyzed during detailed design, if required. Such analysis is not part of the ESP SSAR.

2.5.5.1 Existing Slope Characteristics

The location and direction of the existing 2h:1v slope to the north of the SWR is shown in plan view in Figure 2.5-65; the location is also shown in the photograph in Figure 2.5-66. The photograph in Figure 2.5-67 shows the existing slope clearly, descending from the SWR to close to the excavation for the now abandoned Unit 3 and 4 containment buildings. The structure behind the slope on the SWR embankment is the Unit 1 and 2 valve house, which was originally designed to be the now

abandoned Unit 3 and 4 pump house. A cross-section through the existing slope is shown on Figure 2.5-68.

2.5.5.1.1 Slope Borings

As shown in Figure 2.5-65, two borings (B-15 and B-18) were performed previously on or close to the area of the slope. These borings were conducted for the Unit 1 and 2 investigation. The profiles of these borings are included in Figure 2.5-68. The boring logs are presented in Section 2.5.5.3. No additional exploration for the slope was made during the ESP exploration program.

2.5.5.1.2 Slope Subsurface Conditions

The ESP site soils and bedrock are described in detail in Section 2.5.4.2.2. As can be seen from Figure 2.5-68, the soils in the slope consist almost entirely of Zone IIA saprolites. Saprolites are a further stage of weathering beyond weathered rock. They have been derived by in-place disintegration and decomposition and have not been transported. Saprolites are classified as soils but still contain the relict structure of the parent rock, and they also typically still contain some core stone of the parent rock. The North Anna saprolites in many instances maintain the foliation characteristics of the parent rock. They are mainly classified as silty sands, although there are also sands, clayey sands, sandy silts, clayey silts and clays, depending very much on their degree of weathering. The fabric is strongly anisotropic. The texture shows angular geometrically interlocking grains with a lack of void network, very unlike the well-pronounced voids found in marine or alluvial sands and silts. The Zone IIA saprolites comprise, on average, about 80 percent of the saprolitic materials onsite. About 75 percent of the Zone IIA saprolites are classified as coarse-grained (sands, silty sands) while the remainder are fine-grained (clayey sands, sandy and clayey silts, and clays). The majority of the saprolites obtained from the borings in the slope area are dense silty sands.

The bedrock beneath the Zone IIA saprolite ranges from moderately to severely weathered (Zone III), to fresh to slightly weathered (Zone IV). The bedrock throughout the North Anna site is classified as a gneiss, which is a metamorphic rock that exhibits a banded texture (foliation) in which light and dark bands alternate. It is composed of feldspar, quartz, and one or more other minerals such as mica and hornblende. The majority of the bedrock obtained from the borings in the slope area is a dark green or gray to black biotite hornblende gneiss.

The engineering properties of the site soils and bedrock are described in Section 2.5.4.2.5 and are tabulated in Table 2.5-45. These properties are based on extensive field and laboratory testing described in Section 2.5.4.3 and Section 2.5.4.2, respectively.

The liquefaction characteristics of all of the Zone IIA saprolite are thoroughly examined in Section 2.5.4.8. That section concludes that the results of the liquefaction analysis indicate that some of the Zone IIA saprolitic soils have a potential for liquefaction based on the ESP seismic parameters. The liquefaction analysis did not take into account the beneficial effects of age, structure, fabric, and mineralogy.

2.5.5.1.3 Slope Phreatic Surface

The postulated phreatic surface is shown in Figure 2.5-68 for the existing slope. This surface has been developed from the water table levels derived in Section 2.4.12. The depth of this phreatic surface precludes any potential for liquefaction of the near-surface soils in the slope.

2.5.5.2 Design Criteria and Analyses

2.5.5.2.1 Required Factor of Safety

The following factors of safety are proposed by the Department of the Army (Reference 183):

Condition	Minimum Factor of Safety
End of Construction	1.4
Long-Term Static (non-seismic)	1.5
Long-Term Seismic	1.1

2.5.5.2.2 Stability of Existing Slope

The photograph in Figure 2.5-67 of the existing 2h:1v slope to the north of the SWR was taken about 20 years ago. The condition of the slope is essentially the same today. It was thoroughly inspected during the ESP site investigation. The slope shows no signs of distress.

2.5.5.2.3 Analysis of Existing Slope

The static and dynamic stability of the existing slope to the north of the SWR was analyzed using the computer program SLOPE/W (Reference 184).

a. **Long-Term Static Analysis**

   The SLOPE/W Program used the Bishop method of slices (Reference 185) for analysis of the long-term static condition. The analysis assumed the saprolite was predominantly coarse grained (as shown in borings B-15 and B-18 close to the slope). The effective strength parameters given in Table 2.5-45 were an angle of internal friction ϕ' = 30 degrees and effective cohesion c′ = 0.25 ksf for the coarse-grained saprolite.

   The input to the analysis and the results are shown in Figure 2.5-69. The computed factor of safety is about 1.75. This value is above the minimum 1.5 factor of safety required.

b. **Seismic Slope Stability Analysis**

   The pseudo-static approach is used as a first approximation for the seismic analysis of slopes. In this approach, the horizontal and vertical seismic forces are assumed to act on the slope in a static manner, that is, as a constant static force. This is an obviously conservative approach, since the actual seismic event occurs for only a short period of time, and during that time, the forces alternate their direction at a relatively high frequency. Also, the pseudo-static analysis tends to be run using the peak seismic acceleration; the mean acceleration during the design

seismic event is significantly less than the peak value. A pseudo-static analysis using peak acceleration values can be a useful tool in a limit analysis where the peak acceleration is relatively low. In such analyses, the computed factor of safety may well exceed the minimum of 1.1, thus requiring no further analysis. However, where the peak seismic acceleration values are high, the pseudo-static analysis produces unreasonably low safety factor values.

The pseudo-static analysis was run using SLOPE/W. For the high frequency earthquake, the peak horizontal acceleration used was 0.65g. This is the average peak acceleration in the top 55 feet of unimproved soil shown in Table 2.5-46 for 150 percent G_{max}. (The maximum horizontal acceleration is 0.99g at the ground surface.) The vertical acceleration used was 0.325g. The computed factor of safety was significantly less than the required 1.1. For the low frequency earthquake, the equivalent peak horizontal acceleration used was 0.26g with a vertical acceleration of 0.13g. The computed factor of safety was slightly less than 1.1.

Seed (Reference 186), in the 19th Rankine Lecture, addressed the over-conservatism intrinsic in the pseudo-static analysis. He looked at the more rational approach proposed by Newmark (Reference 187), where the effective acceleration time-history is integrated to determine velocities and displacements of the slope. He also examined dams in California that had been subjected to seismic forces, including several dams that survived the 1906 San Francisco earthquake. Based on his studies, he concluded that for embankments that consist of materials that do not tend to build up large pore pressures or lose significant percentages of their shear strength during seismic shaking, seismic coefficients of only 0.15g are adequate to ensure acceptable embankment performance for earthquakes up to Magnitude M = 8.25 with peak ground accelerations of 0.75g. For earthquakes in the range of M = 6.5, Seed recommends a horizontal seismic coefficient of only 0.1g with a vertical seismic coefficient of zero.

The liquefaction analysis of the Zone IIA saprolite indicated some of the material has a potential for liquefaction. However, its age, fabric and interlocking angular grain structure, along with the significant portion of low plasticity clay minerals present in the material, have been demonstrated to give the grain structure a low susceptibility to pore pressure build-up or liquefaction (Section 2.5.4.8). This material would not lose a significant proportion of its shear strength during shaking. Thus, for the low frequency earthquake, with a design Magnitude M = 7.2, the pseudo-static analysis should be limited to a horizontal acceleration of only 0.15g.

Although the 0.99g computed peak ground acceleration from the high frequency earthquake at North Anna is greater than the 0.75g referenced by Seed, the highest accelerations are in the top 5 feet of the soil – the average acceleration in the soil is closer to 0.62g below the top 5 feet. In addition, the design high frequency earthquake has a relatively low energy (Magnitude 5.4), which is significant when estimating its potential impact on slope stability. Thus, at North Anna, a pseudo-static design using an inertia force of 0.1g will be adequate for the high frequency earthquake.

The pseudo-static analysis was again run using SLOPE/W. This time the horizontal accelerations used were 0.1g and 0.15g, with zero vertical acceleration. The computed factors of safety were greater than 1.1. The input to the analysis and the results for the 0.1g case are shown in Figure 2.5-70.

Other researchers have also recommended substantially reducing the peak acceleration when applying the pseudo-static analysis. Kramer (Reference 188) recommends using an acceleration of 50 percent of the peak acceleration. Using the average peak acceleration for the high frequency earthquake in the top 55 feet of 0.65g, the horizontal input using Kramer's recommendation would be 0.325g and the vertical input would be 0.1625g. This level of input provides a factor of safety against slope failure just above 0.9. Although this is somewhat less than the required factor of safety of 1.1, it is considered marginal based on the high level of seismic acceleration being applied and the relatively low energy level of the design earthquake. For the low frequency earthquake, where the average peak acceleration in the top 55 feet is about 0.26g, the horizontal input using Kramer's recommendations would be 0.13g and the vertical input would be about 0.065g. This results in a factor of safety of greater than the required 1.1.

Based on the possibility of some liquefaction in the slope area and the marginal results obtained using Kramer's method, measures would be taken to ensure the safety of the slope and of the structures that may be located close to the bottom of the slope. These measures are outlined in Section 2.5.5.6.

2.5.5.3 Logs of Borings

As noted in Section 2.5.5.1, two sample borings were drilled on or close to the existing 2h:1v slope to the north of the SWR. The logs of borings B-15 and B-18 are reproduced in Figure 2.5-71 and Figure 2.5-72, respectively.

2.5.5.4 Compacted Fill

The existing 2h:1v slope described and analyzed in the previous sections is a cut slope and does not contain fill materials in any significant quantity.

2.5.5.5 Proposed New Slope

As noted at the beginning of Section 2.5.5, a new slope may be excavated to the west of the SWR to accommodate UHSs for the new units. The new slope would be approximately the same height and would have the same 2h:1v slope as the existing slope presented in Section 2.5.5.1 through Section 2.5.5.4. It would also be a cut slope like the existing slope, and would comprise similar materials to those in the existing slope. Therefore, the analytical conclusions for the existing slope would apply to the new slope, namely the new slope would be stable under seismic and long-term static conditions.

If the selected design for the new units requires that the new slope be constructed, and it is deemed that any failure of the slope could impact the new units, then investigation and analysis of the slope would be performed as part of detailed engineering and described in the COL application. If the analysis, based on the subsurface investigation results, showed an inadequate factor of safety against slope failure, then the design would be modified to eliminate any risk of slope failure. Such modifications are outlined in Section 2.5.5.6.

2.5.5.6 Conclusions

Existing slopes and embankments that are not impacted by the new units (such as the SWR embankments) are not analyzed. New slopes of the non-safety-related, deepened intake channel, which would be used for the normal cooling water system supply of the new units, would be analyzed during detailed design, if required. Such analysis is not part of the ESP SSAR.

The only existing slope whose failure could adversely affect the safety of the new units because of its proximity to the ESP site is a 55-foot high, 2h:1v slope that descends from north of the SWR down to south of the existing excavation made for abandoned Units 3 and 4. The slope is made almost entirely in cut material. Static long-term analyses of the existing slope using the computer program SLOPE/W gave values of factor of safety in excess of the minimum 1.5 required. Pseudo-static analyses using ESP design values of horizontal and vertical seismic acceleration gave safety factor values less than the minimum acceptable value of 1.1 for the high frequency earthquake. However, when the seismic input was modified to conform to the reductions given by Seed (Reference 186), the computed safety factors against slope failure were in excess of 1.1. The Seed reductions are considered reasonable and valid. When the Kramer recommendations were applied, the computed factor of safety against seismic slope failure was considered satisfactory for the low frequency earthquake and marginal for the high frequency earthquake. Based on the possibility of some liquefaction in the slope area and the marginal results obtained using Kramer's method, measures would be taken to ensure the safety of the slope and of the structures that may be located close to the bottom of the slope. These measures could include reducing the slope steepness, removing and replacing materials that could lose significant strength during the design earthquake, ground improvement measures such as soil nailing, moving structures further from the toe of the slope, and/or providing walls/barriers to protect those structures.

A new slope may be excavated to the west of the SWR to accommodate UHSs for the new units. The new slope would be approximately the same height, would have the same 2h:1v slope, and would have the same soil and rock characteristics as the existing slope that was analyzed. If analysis during the design stage of this slope indicates unacceptable factors of safety against slope failure, modifications such as those proposed for the existing slope in the previous paragraph would be employed.

2.5.6 **Embankments and Dams**

Because Lake Anna would only be used for normal plant cooling of the new units, the North Anna Dam, which is designed and constructed to meet requirements for a seismic Category I structure in support of the existing units, was not re-analyzed as part of this application. Analysis of the new non-safety-related deepened intake channel slopes for the new units would be performed during detailed design.

Construction of the new units would not adversely affect the slopes of the SWR for the existing units. There is an existing 55-foot high embankment to the north of the SWR and to the south of the new units. A similar embankment may be constructed to the west of the SWR to accommodate the buried UHS of certain reactor designs that might be constructed on the ESP site. Instability of these slopes could affect the new units. This is described and presented in Section 2.5.5.

In summary, there are no embankments and dams to be addressed in this section.

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Table 2.5-1 Definitions of Classes Used in the Compilation of Quaternary Faults, Liquefaction Features, and Deformation in the Central and Eastern United States (After Crone and Wheeler, 2000)

Class Category	Definition
Class A	Geologic evidence demonstrates the existence of a Quaternary fault of tectonic origin, whether the fault is exposed for mapping or inferred from liquefaction to other deformational features.
Class B	Geologic evidence demonstrates the existence of a fault or suggests Quaternary deformation, but either: 1) the fault might not extend deeply enough to be a potential source of significant earthquakes, or 2) the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A.
Class C	Geologic evidence is insufficient to demonstrate: 1) the existence of tectonic fault, or 2) Quaternary slip or deformation associated with the feature.
Class D	Geologic evidence demonstrates that the feature is not a tectonic fault or feature; this category includes features such as demonstrated joints or joint zones, landslides, erosional or fluvial scarps, or landforms resembling fault scarps, but of demonstrable non-tectonic origin.

Table 2.5-2 Quaternary Faults, Liquefaction Features, and Possible Tectonic Features Within the Site Region (200-Mile Radius) (Modified from Crone)

Feature	State	County	Physiographic Province	Distance from Site (mi.)	Class	Post-EPRI Info. (1986)	Fault Length (mi.)
Central VA Seismic zone	VA	14 counties	Piedmont	0	A	No	NA[a]
Mountain Run/Everona fault zone	VA	Orange, Culpeper, Fauquier	Piedmont	19	C	No	60–90
Lebanon Church fault	VA	Albemarle	Blue Ridge	45	C	No	NR[b]
Upper Marlboro faults	MD	Prince Georges	Coastal Plain	75	C	No	NA[a]
Old Hickory faults	VA	Dinwiddie, Sussex	Coastal Plain	78	C	Yes	0.6–0.09
Stanleytown-Villa Heights fault	VA	Henry	Piedmont	144	C	No	~0.1
Lancaster fault zone	PA	Lancaster	Piedmont	157	C	No	NA[a]
Lindside fault zone	VA, WV	Giles (VA)	Appalachian Plateaus	162	C	Yes	>30
Pembroke faults	VA	Giles	Valley and Ridge	163	B	Yes	NA[a]
Hares Crossroads fault	NC	Johnston	Coastal Plain	165	C	No	NR[b]
Cacoosing Valley earthquake	PA	Berks	Valley and Ridge	186	C	Yes	NA[a]

a. NA: Not Applicable

b. NR: Not Reported

Table 2.5-3 Site Area Stratigraphic Column (5-Mile Radius)

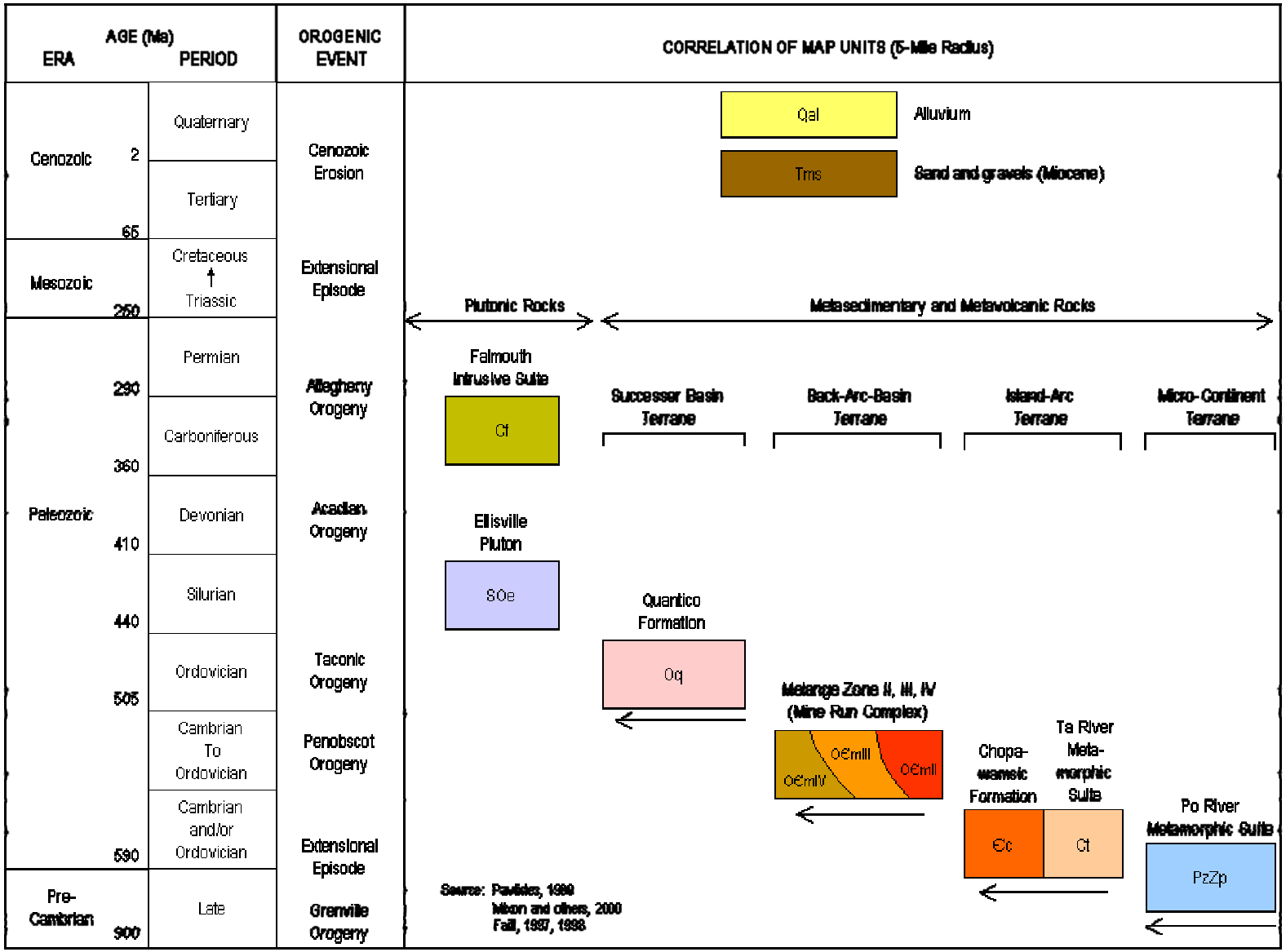


Table 2.5-4 Earthquakes 1985-2001, m≥3.0, within 35°N–41°N and 74°W–82°W

Year	Month	Day	Latitude North	Longitude West	Depth km	m_b	m(coda)	m(int)	ML	m(unk)	Source
1985	6	10	37.248	80.485	11.1	3.2	2.8	3.3			VT
1986	3	26	37.245	80.494	11.9		2.9	3.3			VT
1986	12	3	37.58	77.458	1.6		1.5	3.3			VT
1986	12	10	37.585	77.468	1.2	2.5	2.2	3.5			VT
1986	12	24	37.583	77.458	1		1.6	3.3			VT
1987	1	13	37.584	77.465	2.5		1.9	3.3			VT
1988	5	28	39.753	81.613	0					3.4	ANSS
1988	8	27	37.718	77.775	14.3		2.7	3.3			VT
1990	1	13	39.366	76.851	4.1	2.5	2.6	3.5			VT
1991	3	15	37.746	77.909	15.5	3.8	3.3	3.5			VT
1991	4	22	37.942	80.205	14.8	3.5	3.5	3.3			VT
1991	6	28	38.231	81.335	7	3.0					VT
1991	8	15	40.786	77.657	1					3.0	ANSS
1992	1	9	40.363	74.341	7.9					3.1	ANSS
1993	3	10	39.233	76.882	5		2.5	3.3			VT
1993	3	15	39.197	76.87	0.9	2.7	2.1	3.5			VT
1993	7	12	36.035	79.823	5	2.7		3.3			VT
1993	10	28	39.25	76.77			2.1	3.3			VT
1993	10	28	39.25	76.77			1.8	3.3			VT
1994	1	16	40.327	76.007	5	4.2					ANSS
1994	1	16	40.33	76.037	5	4.6					ANSS
1994	8	6	35.101	76.786	0	3.6	3.8	3.5			VT
1995	6	26	36.752	81.481	1.8	3.4	3.3				VT
1995	7	7	36.493	81.833	10	3.0	3.1				VT
1997	11	14	40.146	76.252	5				3.0		ANSS
1997	11	14	40.741	76.549	0		3.0				VT
1998	6	5	35.554	80.785	9.4	3.2	3.4				VT
1998	10	21	37.422	78.439	12.6	3.8	3.4				VT
2001	9	22	38.026	78.396	0.4	3.2	2.5				VT
2001	12	4	37.726	80.752	8.5	3.1					VT

Table 2.5-5 Summary of Bechtel Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
Sources within 200 mi (320 km)										
E	Central Virginia	0	0	0.35	5.4 [0.10] 5.7 [0.40] 6.0 [0.40] 6.6 [0.10]	1 [0.33] 2 [0.34] 4 [0.33]	Yes	No	No	No
BZ5	S. Appalachians	0	0	1.00	5.7 [0.10] 6.0 [0.40] 6.3 [0.40] 6.6 [0.10]	1 [0.33] 2 [0.34] 3 [0.33]	Yes	No	No	No
24	Bristol Trends	61	38	0.25	5.7 [0.10] 6.0 [0.40] 6.3 [0.40] 6.6 [0.10]	1 [0.33] 2 [0.34] 4 [0.33]	Yes	No	No	No
BZ4	Atlantic Coastal Region	144	90	1.00	6.6 [0.10] 6.8 [0.40] 7.1 [0.40] 7.4 [0.10]	1 [0.33] 2 [0.34] 3 [0.33]	Yes	No	No	No
17	Stafford fault zone	0	0	0.10	5.4 [0.10] 5.7 [0.40] 6.0 [0.40] 6.6 [0.10]	1 [0.33] 2 [0.34] 4 [0.33]	No	No	No	No
13	Eastern Mesozoic Basins	5	3	0.10	5.4 [0.10] 5.7 [0.40] 6.0 [0.40] 6.6 [0.10]	1 [0.33] 2 [0.34] 4 [0.33]	No	No	No	No
25	NY-Alabama Lineament	189	118	0.30	5.4 [0.10] 5.7 [0.40] 6.0 [0.40] 6.6 [0.10]	1 [0.33] 2 [0.34] 4 [0.33]	No	No	No	No
23	Lebanon Trend	211	131	0.05	5.4 [0.10] 5.7 [0.40] 6.0 [0.40] 6.6 [0.10]	1 [0.33] 2 [0.34] 4 [0.33]	No	No	No	No
19	Giles County	221	137	0.35	5.7 [0.10] 6.0 [0.40] 6.3 [0.40] 6.6 [0.10]	1 [0.33] 2 [0.34] 4 [0.33]	No	No	No	No

Table 2.5-5 Summary of Bechtel Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
BZ6	SE. Craton Region	229	142	1.00	5.4 [0.10] 5.7 [0.40] 6.0 [0.40] 6.6 [0.10]	1 [0.33] 2 [0.34] 3 [0.33]	No	No	No	No
F	SE. Appalachians	274	170	0.35	5.4 [0.10] 5.7 [0.40] 6.0 [0.40] 6.6 [0.10]	1 [0.33] 2 [0.34] 4 [0.33]	No	No	No	No
Selected Sources Beyond 200 mi (320 km)										
H	Charleston Area	545	339	0.50	6.8 [0.20] 7.1 [0.40] 7.4 [0.40]	1 [0.33] 2 [0.34] 4 [0.33]	No	Yes; ECFS Southern Section	No	Yes; RI of 550 yrs
N3	Charleston Faults	579	359	0.53	6.8 [0.20] 7.1 [0.40] 7.4 [0.40]	1 [0.33] 2 [0.34] 4 [0.33]	No	Yes; ECFS Southern Section	No	Yes; RI of 550 yrs

a. Closest Distance between site and source measured in Bechtel GIS system using EPRI source files.

b. Pa = probability of activity; from Reference 121

c. Maximum Magnitude (M_{max}) and weights (wts.); from Reference 121

d. Smoothing options are defined as follows (from Reference 121):
1 = constant a, constant b (no prior b);
2 = low smoothing on a, high smoothing on b (no prior b);
3 = low smoothing on a, low smoothing on b (no prior b);
4 = low smoothing on a, low smoothing on b (weak prior of 1.05).
Weights on magnitude intervals are [1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0].

e. Did the source contribute to 99% of EPRI hazard calculated at NAPS?; from Table 2.5-18.

f. No, unless new geometry proposed in literature.

g. No, unless EPRI M_{max} exceeded in literature. For Charleston, M_{max} from Reference 127 and weights even though new magnitude estimates do not generally exceed majority of EPRI M_{max} values.

h. RI = recurrence interval; assumed no change if no new paleoseismic data or rate of seismicity has not significantly changed per Section 2.5.2.6.5.

Table 2.5-6 Summary of Dames & Moore Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
Sources within 200 mi (320 km)										
41	S. Cratonic Margin (Default Zone)	0	0	0.12	6.1 [0.80] 7.2 [0.20]	1 [0.75] 2 [0.25]	Yes	No	No	No
53	S. Appalachian Mobile Belt (Default Zone)	6	4	0.26	5.6 [0.80] 7.2 [0.20]	1 [0.75] 2 [0.25]	Yes	No	No	No
40	Central VA Seismic Zone	24	15	1.00	6.6 [0.80] 7.2 [0.20]	1 [0.75] 2 [0.25]	Yes	No	No	No
42	Newark-Gettysburg Basin	32	20	0.40	6.3 [0.75] 7.2 [0.25]	3 [0.75] 4 [0.25]	Yes	No	No	No
47	Connecticut Basin	41	25	0.28	6.0 [0.75] 7.2 [0.25]	3 [0.75] 4 [0.25]	Yes	No	No	No
4	Appalachian Fold Belts	74	46	0.35	6.0 [0.80] 7.2 [0.20]	1 [0.75] 2 [0.25]	Yes	No	No	No
4B	Kink in Fold Belt (Giles Co. Area)	145	90	0.65	6.2 [0.75] 7.2 [0.25]	3 [0.75] 4 [0.25]	Yes	No	No	No
44	Stafford Fault Zone	34	21	1.00	5.0 [0.80] 7.2 [0.20]	1 [0.69] 2 [0.23] 3 [0.06] 4 [0.02]	No	No	No	No
C01	Combination zone 4-4A-4B-4C-4D	74	46	NA	6.0 [0.80] 7.2 [0.20]	1 [0.75] 2 [0.25]	No	No	No	No
45	Hopewell Fault Zone	87	54	1.00	5.0 [0.80] 7.2 [0.20]	1 [0.69] 2 [0.23] 3 [0.06] 4 [0.02]	No	No	No	No
46	Dan River Basin	118	74	0.28	6.0 [0.75] 7.2 [0.25]	3 [0.75] 4 [0.25]	No	No	No	No
4C	Kink in Fold Belt	173	108	0.65	5.0 [0.75] 7.2 [0.25]	3 [0.75] 4 [0.25]	No	No	No	No
48	Buried Triassic Basins	175	108	0.28	6.0 [0.75] 7.2 [0.25]	3 [0.75] 4 [0.25]	No	No	No	No

Table 2.5-6 Summary of Dames & Moore Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
8	E. Marginal Basin	188	117	0.08	5.6 [0.80] 7.2 [0.20]	1 [0.75] 2 [0.25]	No	No	No	No
C02	Combination zone 8-9	188	117	NA	5.6 [0.80] 7.2 [0.20]	1 [0.75] 2 [0.25]	No	No	No	No
49	Jonesboro Basin	204	127	0.28	6.0 [0.75] 7.2 [0.25]	3 [0.75] 4 [0.25]	No	No	No	No
6	Rome Trough	218	135	0.24	5.0 [0.75] 7.2 [0.25]	3 [0.75] 4 [0.25]	No	No	No	No
7	Dunkard Basin	281	175	0.38	5,7 [0.75] 7.2 [0.25]	3 [0.75] 4 [0.25]	No	No	No	No
50	Buried Triassic Basins	290	180	0.28	6.0 [0.75] 7.2 [0.25]	3 [0.75] 4 [0.25]	No	No	No	No
Selected Sources Beyond 200 mi (320 km)										
54	Charleston Seismic Zone	533	331	1.00	6.6 [0.75] 7.2 [0.25]	1 [0.22] 2 [0.08] 3 [0.52] 4 [0.18]	No	Yes; ECFS Southern Section	No	Yes; RI of 550 yrs

a. Closest Distance between site and source measured in Bechtel GIS system using EPRI source files.

b. Pa = probability of activity; from Reference 121

c. Maximum Magnitude (M_{max}) and weights (wts.); from Reference 121

d. Smoothing options are defined as follows (from Reference 121):
1 = No smoothing on a, no smoothing on b (strong prior of 1.04);
2 = No smoothing on a, no smoothing on b (weak prior of 1.04);
3 = Constant a, constant b (strong prior of 1.04);
4 = Constant a, constant b (weak prior of 1.04).
Weights on magnitude intervals are [0.1, 0.2, 0.4, 1.0, 1.0, 1.0, 1.0]

e. Did the source contribute to 99% of EPRI hazard calculated at NAPS?; from Table 2.5-18.

f. No, unless new geometry proposed in literature.

g. No, unless EPRI M_{max} exceeded in literature. For Charleston, M_{max} from Reference 127 and weights even though new magnitude estimates do not generally exceed majority of EPRI M_{max} values.

h. RI = recurrence interval; assumed no change if no new paleoseismic data or rate of seismicity has not significantly changed per Section 2.5.2.6.5.

Table 2.5-7 Summary of Law Engineering Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
Sources within 200 mi (320 km)										
17	Eastern Basement	0	0	0.62	5.7[0.20] 6.8 [0.80]	1b [1.00]	Yes	No	No	No
217	Eastern Basement Background	0	0	1.00	4.9[0.50] 5.7 [0.50]	1b [1.00]	Yes	No	No	No
GC011	22 - 35	7	4	NA	6.8 [1.00]	2a [1.00]	Yes	No	No	No
107	Eastern Piedmont	7	4	1.00	4.9[0.30] 5.5[0.40] 5.7 [0.30]	1a [1.00]	Yes	No	No	No
22	Reactivated E. Seaboard Normal	7	4	0.27	6.8 [1.00]	2a [1.00]	Yes	No	No	No
M22	Mafic Pluton	23	14	0.43	6.8 [1.00]	5 [1.00]	Yes	No	No	No
GC09	Mesozoic Basins (8 - Bridged)	28	18	NA	5.0[0.20] 5.8[0.50] 7.4 [0.30]	1c [1.00]	Yes	No	No	No
C10	Combination Zone 8-35	28	18	NA	6.8 [1.00]	2a [1.00]	Yes	No	No	No
M21	Mafic Pluton	47	29	0.43	6.8 [1.00]	5 [1.00]	Yes	No	No	No
M23	Mafic Pluton	73	45	0.43	6.8 [1.00]	5 [1.00]	Yes	No	No	No
M20	Mafic Pluton	79	49	0.43	6.8 [1.00]	5 [1.00]	Yes	No	No	No
M24	Mafic Pluton	81	50	0.43	6.8 [1.00]	5 [1.00]	Yes	No	No	No
M27	Mafic Pluton	152	94	0.43	6.8 [1.00]	5 [1.00]	Yes	No	No	No
M19	Mafic Pluton	159	98	0.43	6.8 [1.00]	5 [1.00]	Yes	No	No	No
GC13	22 - 24 - 35	7	4	NA	6.8 [1.00]	2a [1.00]	No	No	No	No
GC12	22 - 24	7	4	NA	6.8 [1.00]	2a [1.00]	No	No	No	No
105	Northern Coastal Plain	60	37	1.00	4.6[0.90] 4.9 [0.10]	1a [1.00]	No	No	No	No
M25	Mafic Pluton	84	52	0.43	6.8 [1.00]	5 [1.00]	No	No	No	No
M26	Mafic Pluton	112	70	0.43	6.8 [1.00]	5 [1.00]	No	No	No	No

Table 2.5-7 Summary of Law Engineering Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
8	Mesozoic Basins	194	120	0.27	6.8 [1.00]	a and b values calculated for C09	No	No	No	No
M28	Mafic Pluton	200	124	0.43	6.8 [1.00]	5 [1.00]	No	No	No	No
M18	Mafic Pluton	211	131	0.43	6.8 [1.00]	5 [1.00]	No	No	No	No
M29	Mafic Pluton	220	136	0.43	6.8 [1.00]	5 [1.00]	No	No	No	No
112	Ohio-Pennsylvania Block	223	138	1.00	4.6 [0.20] 5.1 [0.50] 5.5 [0.30]	1a [1.00]	No	No	No	No
M30	Mafic Pluton	240	149	0.43	6.8 [1.00]	5 [1.00]	No	No	No	No
M17	Mafic Pluton	272	169	0.43	6.8 [1.00]	5 [1.00]	No	No	No	No
M16	Mafic Pluton	281	175	0.43	6.8 [1.00]	5 [1.00]	No	No	No	No
101	Western New England	313	194	1.00	4.5 [0.15] 5.5 [0.85]	1c [1.00]	No	No	No	No
M31	Mafic Pluton	321	199	0.43	6.8 [1.00]	5 [1.00]	No	No	No	No
Selected Sources Beyond 200 mi (320 km)										
35	Charleston Seismic Zone	560	348	0.45	6.8 [1.00]	2a [1.00]	No	Yes; ECFS Southern Section	No	Yes; RI of 550 yrs

a. Closest Distance between site and source measured in Bechtel GIS system using EPRI source files.

b. Pa = probability of activity; from Reference 121

c. Maximum Magnitude (M_{max}) and weights (wts.); from Reference 121

d. Smoothing options are defined as follows (from Reference 121):
1a = High smoothing on a, constant b (strong prior of 1.05);
1b = High smoothing on b, constant b (strong prior of 1.00);
1c = High smoothing on a, constant b (strong prior of 0.95);
1d = High smoothing on a, constant b (strong prior of 0.90);
1e = High smoothing on a, constant b (strong prior of 0.70);
2a = Constant a, constant b (strong prior of 1.05);
2c = Constant a, constant b (strong prior of 0.95);
2d = Constant a, constant b (strong prior of 0.90).
Weights on magnitude intervals are all 1.0 for above options.
3a = High smoothing on a, constant b (strong prior of 1.05).
Weights on magnitude intervals are [0.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0] for option 3a.

e. Did the source contribute to 99% of EPRI hazard calculated at NAPS?; from Table 2.5-18.

f. No, unless new geometry proposed in literature.

g. No, unless EPRI M_{max} exceeded in literature. For Charleston, M_{max} from Reference 127 and weights even though new magnitude estimates do not generally exceed majority of EPRI M_{max} values.

h. RI = recurrence interval; assumed no change if no new paleoseismic data or rate of seismicity has not significantly changed per Section 2.5.2.6.5.

Table 2.5-8 Summary of Rondout Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
Sources within 200 mi (320 km)										
29	Central VA	0	0	1.00	6.6 [0.30] 6.8 [0.60] 7.0 [0.10]	1 [1.00] (a=-0.900, b=0.930)	Yes	No	No	No
30	Shenandoah	0	0	0.96	5.2 [0.30] 6.3 [0.55] 6.5 [0.15]	1 [1.00] (a=-1.710, b=1.010)	Yes	No	No	No
28	Giles County	188.4	117	1.00	6.6 [0.30] 6.8 [0.60] 7.0 [0.10]	1 [1.00] (a=-1.130, b=0.900)	Yes	No	No	No
49	Appalachian	66.9	42	1.00	4.8 [0.20] 5.5 [0.60] 5.8 [0.20]	2 [1.00]	No	No	No	No
C01	Background 49	67	42	NA	4.8 [0.20] 5.5 [0.60] 5.8 [0.20]	3 [1.00]	No	No	No	No
C09	49+32	67	42	NA	4.8 [0.20] 5.5 [0.60] 5.8 [0.20]	3 [1.00]	No	No	No	No
50	Grenville	106.9	66	1.00	4.8 [0.20] 5.5 [0.60] 5.8 [0.20]	2 [1.00]	No	No	No	No
C07	50 (02) + 12	107	66	NA	4.8 [0.20] 5.5 [0.60] 5.8 [0.20]	3 [1.00]	No	No	No	No
C02	Background 50	107	66	NA	4.8 [0.20] 5.5 [0.60] 5.8 [0.20]	3 [1.00]	No	No	No	No
32	Norfolk Fracture Zone	114.1	71	0.67	5.8 [0.15] 6.5 [0.60] 6.8 [0.25]	1 [1.00] (a=-2.110, b=1.040)	No	No	No	No
31	Quakers	210.3	131	1.00	5.8 [0.15] 6.5 [0.60] 6.8 [0.25]	1 [1.00] (a=-1.200, b=0.960)	No	No	No	No
Selected Sources Beyond 200 mi (320 km)										
24	Charleston	526	327	1.00	6.6 [0.20] 6.8 [0.60] 7.0 [0.20]	1 [1.00] (a=-0.710, b=1.020)	No	Yes; ECFS Southern Section	No	Yes; RI of 550 yrs

a. Closest Distance between site and source measured in Bechtel GIS system using EPRI source files.

b. Pa = probability of activity; from Reference 121

c. Maximum Magnitude (M_{max}) and weights (wts.); from Reference 121

d. Smoothing options are defined as follows (from Reference 121):
1, 6, 7, 8 = a, b values as listed above, with weights shown;
3 = Low smoothing on a, constant b (strong prior of 1.0);
5 = a, b values as listed above, with weights shown.

e. Did the source contribute to 99% of EPRI hazard calculated at NAPS?; from Table 2.5-18.

f. No, unless new geometry proposed in literature.

g. No, unless EPRI $M_{\mathbf{max}}$ exceeded in literature. For Charleston, $M_{\mathbf{max}}$ from Reference 127 and weights even though new magnitude estimates do not generally exceed majority of EPRI $M_{\mathbf{max}}$ values.

h. RI = recurrence interval; assumed no change if no new paleoseismic data or rate of seismicity has not significantly changed per Section 2.5.2.6.5.

Table 2.5-9 Summary of Weston Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
Sources within 200 mi (320 km)										
22	Central VA Seismic Zone	0	0	0.82	5.4 [0.19] 6.0 [0.65] 6.6 [0.16]	1b [1.00]	Yes	No	No	No
C21	104-25	0	0	NA	5.4 [0.24] 6.0 [0.61] 6.6 [0.15]	1a [0.30] 2a [0.70]	Yes	No	No	No
C22	104-26	0	0	NA	5.4 [0.24] 6.0 [0.61] 6.6 [0.15]	1a [0.30] 1b [0.70]	Yes	No	No	No
C34	104-28BE-26	0	0	NA	5.4 [0.24] 6.0 [0.61] 6.6 [0.15]	1a [0.20] 1b [0.80]	Yes	No	No	No
C35	104-28BE-25	0	0	NA	5.4 [0.24] 6.0 [0.61] 6.6 [0.15]	1a [0.20] 1b [0.80]	Yes	No	No	No
C23	104-22-26	17	10	NA	5.4 [0.80] 6.0 [0.14] 6.6 [0.06]	1a [0.50] 2a [0.50]	Yes	No	No	No
C19	103-23-24	43	27	NA	5.4 [0.26] 6.0 [0.58] 6.6 [0.16]	1a [1.00]	Yes	No	No	No
104	Southern Coastal Plain	0	0	1.00	5.4 [0.24] 6.0 [0.61] 6.6 [0.15]	1a [0.20] 2a [0.80]	No	No	No	No
C25	104-28BCDE	0	0	NA	5.4 [0.24] 6.6 [0.61] 6.6 [0.15]	1a [0.30] 2a [0.70]	No	No	No	No
C20	104-22	17	10	NA	6.0 [0.85] 6.6 [0.15]	1a [0.30] 2a [0.70]	No	No	No	No
C24	104-22-25	17	10	NA	5.4 [0.80] 6.0 [0.14] 6.6 [0.06]	1a [0.50] 2a [0.50]	No	No	No	No
C26	104-28BCDE-22	17	11	NA	5.4 [0.24] 6.0 [0.61] 6.6 [0.15]	1a [0.30] 2a [0.70]	No	No	No	No
C27	104-28BCDE-22-25	17	11	NA	5.4 [0.30] 6.0 [0.70]	1a [0.70] 2a [0.30]	No	No	No	No
C28	104-28BCDE-22-26	17	11	NA	5.4 [0.30] 6.0 [0.70]	1a [0.70] 2a [0.30]	No	No	No	No

Table 2.5-9 Summary of Weston Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
28B	Zone of Mesozoic Basin	24	15	0.26	5.4 [0.65] 6.0 [0.25] 6.6 [0.10]	1b [1.00]	No	No	No	No
C01	28A thru E	24	15	NA	5.4 [0.65] 6.0 [0.25] 6.6 [0.10]	1b [1.00]	No	No	No	No
28E	Zone of Mesozoic Basin	41	25	0.26	5.4 [0.65] 6.0 [0.25] 6.6 [0.10]	1b [1.00]	No	No	No	No
103	Southern Appalachians	43	27	1.00	5.4 [0.26] 6.0 [0.58] 6.6 [0.16]	1a [0.20] 2a [0.80]	No	No	No	No
C17	103-23	43	27	NA	5.4 [0.26] 6.0 [0.58] 6.6 [0.16]	1a [0.70] 2a [0.30]	No	No	No	No
C18	103-24	43	27	NA	5.4 [0.26] 6.0 [0.58] 6.6 [0.16]	1a [0.70] 1b [0.30]	No	No	No	No
28D	Zone of Mesozoic Basin	116	72	0.26	5.4 [0.65] 6.0 [0.25] 6.6 [0.10]	1b [1.00]	No	No	No	No
28C	Zone of Mesozoic Basin	142	88	0.26	5.4 [0.65] 6.0 [0.25] 6.6 [0.10]	1b [1.00]	No	No	No	No
23	Giles County Seismic Zone	213	132	0.90	6.0 [0.81] 6.6 [0.19]	1b [1.00]	No	No	No	No
102	Appalachian Plateau	234	145	1.00	5.4 [0.62] 6.0 [0.29] 6.6 [0.09]	1a [0.20] 2a [0.80]	No	No	No	No
101	S. Ontario-Ohio-Indiana	236	147	1.00	5.4 [0.19] 6.0 [0.68] 6.6 [0.13]	1a [0.20] 2a [0.80]	No	No	No	No
C12	101-7	236	147	NA	5.4 [0.19] 6.0 [0.68] 6.6 [0.13]	1a [0.70] 2a [0.30]	No	No	No	No
C13	101-8	236	147	NA	5.4 [0.19] 6.0 [0.68] 6.6 [0.13]	1a [0.70] 2a [0.30]	No	No	No	No
C14	101-29	236	147	NA	5.4 [0.19] 6.0 [0.68] 6.6 [0.13]	1a [0.70] 2a [0.30]	No	No	No	No

Table 2.5-9 Summary of Weston Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
C15	101-7-8	236	147	NA	5.4 [0.19] 6.0 [0.68] 6.6 [0.13]	1a [0.70] 2a [0.30]	No	No	No	No
C16	101-7-8-29	236	147	NA	5.4 [0.19] 6.0 [0.68] 6.6 [0.13]	1a [1.00]	No	No	No	No
24	New York-Alabama-Clingman	255	159	0.90	5.4 [0.26] 6.0 [0.58] 6.6 [0.16]	1b [1.00]	No	No	No	No
21	New York Nexus	296	184	1.00	5.4 [0.62] 6.0 [0.29] 6.6 [0.09]	1b [`.00]	No	No	No	No
28A	Mesozoic Basin	296	184	0.26	5.4 [0.65] 6.0 [0.25] 6.6 [0.10]	1b [1.00]	No	No	No	No
C07	21-19	296	184	NA	5.4 [0.62] 6.0 [0.29] 6.6 [0.09]	1b [0.70] 2b [0.30]	No	No	No	No
C08	21-19-10A	296	184	NA	5.4 [0.62] 6.0 [0.29] 6.6 [0.09]	1b [0.70] 2b [0.30]	No	No	No	No
C09	21-19-10A-28A	320	199	NA	5.4 [0.62] 6.0 [0.29] 6.6 [0.09]	1b [1.00]	No	No	No	No
C10	21-19-28A	320	199	NA	5.4 [0.62] 6.0 [0.29] 6.6 [0.09]	1b [1.00]	No	No	No	No
Selected Sources Beyond 200 mi (320 km)										
25	Charleston Seismic Zone	532	330	0.99	6.6 [0.90] 7.2 [0.10]	1b [1.00]	No	Yes; ECFS Southern Section	No	Yes; RI of 550 yrs

a. Closest Distance between site and source measured in Bechtel GIS system using EPRI source files.

b. Pa = probability of activity; from Reference 121

c. Maximum Magnitude (M_{max}) and weights (wts.); from Reference 121

d. Smoothing options are defined as follows (from Reference 121):
   1a = Constant a, constant b (medium prior of 1.0);
   1b = Constant a, constant b (medium prior of 0.9);
   1c = Constant a, constant b (medium prior of 0.7);
   2a = Medium smoothing on a, medium smoothing on b (medium prior of 1.0);
   2b = Medium smoothing on a, medium smoothing on b (medium prior of 0.9);
   2c = Medium smoothing on a, medium smoothing on b (medium prior of 0.7).

e. Did the source contribute to 99% of EPRI hazard calculated at NAPS?; from Table 2.5-18.

f. No, unless new geometry proposed in literature.

g. No, unless EPRI M_{max} exceeded in literature. For Charleston, M_{max} from Reference 127 and weights even though new magnitude estimates do not generally exceed majority of EPRI M_{max} values.

h. RI = recurrence interval; assumed no change if no new paleoseismic data or rate of seismicity has not significantly changed per Section 2.5.2.6.2.

Table 2.5-10 Summary of Woodward-Clyde Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
Sources within 200 mi (320 km)										
B22	North Anna Background	0	0	1.00	5.8 [0.33] 6.2 [0.34] 6.6 [0.33]	1 [0.25] 6 [0.25] 7 [0.25] 8 [0.25]	Yes	No	No	No
26	Central VA Gravity Saddle	4	3	0.434	5.4 [0.33] 6.5 [0.34] 7.0 [0.33]	2 [0.25] 3 [0.25] 4 [0.25] 5 [0.25]	Yes	No	No	No
27	State Farm Complex	5	3	0.474	5.6 [0.33] 6.3 [0.34] 6.9 [0.33]	2 [0.25] 3 [0.25] 4 [0.25] 5 [0.25]	Yes	No	No	No
28	Richmond Basin	41	26	0.092	5.3 [0.33] 6.0 [0.34] 7.2 [0.33]	3 [0.33] 4 [0.34] 5 [0.33]	No	No	No	No
61	Tyrone-Mt. Union Lineament	76	47	0.048	5.4 [0.33] 6.5 [0.34] 7.1 [0.33]	3 [0.33] 4 [0.34] 5 [0.33]	No	No	No	No
63	Pittsburg-Washington Lineament	186	116	0.050	5.4 [0.33] 6.3 [0.34] 7.1 [0.33]	3 [0.33] 4 [0.34] 5 [0.33]	No	No	No	No
21	New Jersey Isostatic Gravity Saddle	192	120	0.135	5.3 [0.33] 6.5 [0.34] 6.9 [0.33]	2 [0.10] 3 [0.10] 4 [0.10] 5 [0.10] 9 [0.60] (a=-1.406, b=1.020)	No	No	No	No
21A	New Jersey Isostatic Gravity Saddle No. 2 (Combo C2)	192	120	0.045	5.5 [0.33] 6.3 [0.34] 7.1 [0.33]	2 [0.10] 3 [0.10] 4 [0.10] 5 [0.10] 9 [0.60] (a=-1.406, b=1.020)	No	No	No	No
31A	Blue Ridge Combination - Alternate Configuration	209	130	0.211	5.9 [0.33] 6.3 [0.34] 7.0 [0.33]	2 [0.25] 3 [0.25] 4 [0.25] 5 [0.25]	No	No	No	No

Table 2.5-10 Summary of Woodward-Clyde Seismic Sources

Source	Description	Distance[a] (km)	Distance[a] (mi)	Pa[b]	M_{max} (m_b) and Wts.[c]	Smoothing Options and Wts.[d]	Contributed to 99% of EPRI Hazard[e]	New Information to Suggest Change in Source: Geometry?[f]	New Information to Suggest Change in Source: M_{max}?[g]	New Information to Suggest Change in Source: RI?[h]
53	SE NY/NJ/PA NOTA Zone	247	153	0.100	5.5 [0.33] 6.3 [0.34] 6.8 [0.33]	2 [0.10] 3 [0.10] 4 [0.10] 5 [0.10] 9 [0.60] (a=-1.406, b=1.020)	No	No	No	No
22	Newark Basin	259	161	0.078	5.5 [0.33] 6.5 [0.34] 7.1 [0.33]	2 [0.10] 3 [0.10] 4 [0.10] 5 [0.10] 9 [0.60] (a=-1.503, b=0.776)	No	No	No	No
	Selected Sources Beyond 200 mi (320 km)									
29	S. Carolina Gravity Saddle (Extended)	416	259	0.122	6.7 [0.33] 7.0 [0.34] 7.4 [0.33]	2 [0.25] 3 [0.25] 4 [0.25] 5 [0.25]	Yes	No	No	No
29A	SC Gravity Saddle No. 2 (Combo C3)	426	264	0.305	6.7 [0.33] 7.0 [0.34] 7.4 [0.33]	2 [0.25] 3 [0.25] 4 [0.25] 5 [0.25]	Yes	No	No	No
29B	SC Gravity Saddle No. 3 (NW Portion)	416	259	0.183	5.4 [0.33] 6.0 [0.34] 7.0 [0.33]	2 [0.25] 3 [0.25] 4 [0.25] 5 [0.25]	No	No	No	No
30	Charleston (includes NOTA)	551	342	0.573	6.8 [0.33] 7.3 [0.34] 7.5 [0.33]	2 [0.10] 3 [0.10] 4 [0.10] 5 [0.10] 9 [0.60] (a = -1.005, b = 0.852)	No	Yes; ECFS Southern Section	No	Yes; RI of 550 yrs

a. Closest Distance between site and source measured in Bechtel GIS system using EPRI source files.

b. Pa = probability of activity; from Reference 121

c. Maximum Magnitude (M_{max}) and weights (wts.); from Reference 121

d. Smoothing options are defined as follows (from Reference 121):
   1 = Low smoothing on a, high smoothing on b (no prior);
   2 = High smoothing on a, high smoothing on b (no prior);
   3 = High smoothing on a, high smoothing on b (moderate prior of 1.0);
   4 = High smoothing on a, high smoothing on b (moderate prior of 0.9);
   5 = High smoothing on a, high smoothing on b (moderate prior of 0.8);
   6 = Low smoothing on a, high smoothing on b (moderate prior of 1.0);
   7 = Low smoothing on a, high smoothing on b (moderate prior of 0.9);
   8 = Low smoothing on a, high smoothing on b (moderate prior of0.8).
   Weights on magnitude intervals are all 1.0.
   9 = a and b values as listed.

e. Did the source contribute to 99% of EPRI hazard calculated at NAPS?; from Table 2.5-18.

f. No, unless new geometry proposed in literature.

g. No, unless EPRI M_{max} exceeded in literature. For Charleston, M_{max} from Reference 127 and weights even though new magnitude estimates do not generally exceed majority of EPRI M_{max} values.

h. RI = recurrence interval; assumed no change if no new paleoseismic data or rate of seismicity has not significantly changed per Section 2.5.2.6.5.

Table 2.5-11 Comparison of EPRI Characterizations of the Central Virginia Seismic Zone

EPRI Team	Source	Description	Distance[a] km	Distance[a] mi	Pa[b]	M_{max} (m_b) and Wts.[c]	Largest M_{max} Value Considered by EPRI Team m_b	Largest M_{max} Value Considered by EPRI Team **M**[e]	Contributed to 99% of EPRI Hazard[d]
Bechtel	E	Central Virginia	0	0	0.35	5.4 [0.10] 5.7 [0.40] 6.0 [0.40] 6.6 [0.10]	6.6	6.49	Yes
Dames & Moore	40	Central VA Seismic Zone	24	15	1.00	6.6 [0.80] 7.2 [0.20]	7.2	7.51	Yes
Law Engineering[f]	na	na	na	na	na	na	na	na	na
Rondout	29	Central VA	0	0	1.00	6.6 [0.30] 6.8 [0.60] 7.0 [0.10]	7.0	7.16	Yes
Weston	22	Central VA Seismic Zone	0	0	0.82	5.4 [0.19] 6.0 [0.65] 6.6 [0.16]	6.6	6.49	Yes
Woodward-Clyde Consultants	26	Central VA Gravity Saddle	4	3	0.434	5.4 [0.33] 6.5 [0.34] 7.0 [0.33]	7.0	7.16	Yes

Range of Largest M_{max} Value Considered by EPRI Teams = m_b 6.6 - 7.2 **M** 6.5 - 7.5

Average of Largest M_{max} Values for 5 EPRI Teams (m_b) = 6.9

Average of Largest M_{max} Values for 5 EPRI Teams (**M**) = 7.0

a. Closest distance between site and source measured in Bechtel GIS system using EPRI source files.

b. Pa = probability of activity; from Reference 121

c. Maximum Magnitude (M_{max}) and weights (wts.); from Reference 121

d. Source contribution to 99% of EPRI hazard at North Anna from Table 2.5-18.

e. m_b converted from **M** as described in Section 2.5.2.2.1.

f. Law Engineering team did not define a Central VA seismic zone, but did define several mafic pluton sources in the central VA area. The seismicity parameters for the pluton sources were calculated from a large region surrounding each pluton, which effectively captured a majority of seismicity from the CVSZ, as described in Section 2.5.2.6.1.

Table 2.5-12 Seismic Source Zone Parameters from Bollinger Study (Reference 125)

Source	Description	a	b	M_{max} m_{bLg}[a]	Ms[a]	M[b]	Focal Depth Distribution (km) Upper Bound (D_U) 10% Quantile	Focal Depth Distribution (km) Lower Bound (D_L) 90% Quantile
RZ6	Central VA	1.18	0.64	6.40	7.10	6.20	4.5	13.4
RZ3	Giles County, VA	1.07	0.64	6.30	6.80	6.06	4.4	15.1
CZ1	Complementary (Background)	2.70	0.84	5.75	5.80	5.36	3.3	18.5
LZ1	Charleston, SC	1.69	0.77	6.90	8.10	6.98	5.0	10.2
RZ4A	Eastern TN	2.72	0.90	7.35	8.75	7.78	7.6	20.8
RZ4	Eastern TN	2.72	0.90	6.45	7.15	6.27	7.6	20.8
RZ5	NW SC and SW NC	2.14	0.82	6.00	6.20	5.66	2.3	11.2
LZ3	South Carolina Piedmont and Coastal Plain	1.86	0.80	6.00	6.20	5.66	0.8	7.4
LZ4	SC Fall Line	1.58	0.81	6.25	6.50	5.99	0.9	6.1
LZ2	Bowman, SC	1.34	0.78	6.00	6.20	5.66	2.4	5.8
LZ5	Area of LZ3 minus Area of LZ4	1.70	0.80	6.00	6.20	5.66	0.9	6.5
LZ6	Savannah River Site	1.34	0.80	6.50	7.20	6.34	0.8	7.4
RZ1	New Madrid, MO (small)	3.32	0.91	7.35	8.75	7.78	3.0	11.6
RZ2	New Madrid, MO (large)	3.43	0.88	6.70	7.65	6.65	2.8	12.4

a. m_b and Ms values presented in Reference 125. The m_b to Ms conversion was defined by Nuttli in a written communication to Bollinger.

b. **M** converted from m_{bLg} as described in Section 2.5.2.6.5.

Table 2.5-13 Seismic Source Zone Parameters from Chapman and Krimgold Study (Reference 126)

Source	Description	Approx. Distance[a] km	Approx. Distance[a] mi.	Area (sq. km)	a[b]	b[b]	M_{max}[c,d] (m_{bLg})	(M)	M_{max}[e] (m_b)
1	Giles County, VA	210	130	5.1×10^3	1.07	0.64	7.25	7.53	7.22
2	Central VA	0	0	2.0×10^4	1.18	0.64	7.25	7.53	7.22
3	Eastern TN	510	317	3.7×10^4	2.72	0.90	7.25	7.53	7.22
4	Southern Appalachians (VA, NC, SC, TN)	150	93	7.6×10^4	2.42	0.84	7.25	7.53	7.22
5	Northern VA, MD	60	37	4.3×10^4	1.63	0.84	7.25	7.53	7.22
6	Central Appalachians (PA, NJ, NY)	180	112	6.8×10^4	2.84	0.98	7.25	7.53	7.22
7	Piedmont - Coastal Plain	25	16	4.4×10^5	2.32	0.84	7.25	7.53	7.22
8	Charleston, SC	570	354	1.2×10^3	1.69	0.77	7.25	7.53	7.22
9	Appalachian Foreland (TN, KY, OH, WVA, PA)	175	109	6.5×10^5	3.36	1.00	7.25	7.53	7.22
10	New Madrid, MO	1015	631	6.1×10^3	3.32	0.91	7.25	7.53	7.22

a. Closest Distance between site and source estimated (approximately) from Figure 1 in Reference 126.

b. a and b values from Reference 126.

c. Values listed in Reference 126. With the exception of New Madrid, they assumed all sources would have the same M_{max} as the largest EQ to have occurred in the southeastern U.S. region, the 1886 Charleston, SC event.

d. Note that more recent estimates of Charleston EQ magnitude are lower than **M** 7.53.
M 7.3 +0.26/-0.26 Reference 90
M 6.8 +0.3/-0.4 Reference 189

e. m_b converted from **M** as described in Section 2.5.2.2.1.

Table 2.5-14 Summary of Selected USGS Seismic Sources (Reference 127)

Description	M_{max} (M) and Wts.	Largest M_{max} Value Considered by USGS	
		M	m_b [a]
Sources within 200 mi (320 km)			
Extended Margin Background	7.5 [1.00]	7.5	7.20
Selected Sources Beyond 200 mi (320 km)			
Charleston	6.8 [0.20] 7.1 [0.20] 7.3 [0.45] 7.5 [0.15]	7.5	7.20
New Madrid	7.3 [0.15] 7.5 [0.20] 7.7 [0.50] 8.0 [0.15]	8.0	7.49
Stable Craton Background	7.0 [1.00]	7.0	6.91

a. m_b converted from **M** as described in Section 2.5.2.2.1.

Table 2.5-15 1989 EPRI PSHA Study Models

Model	Description	Weight
McGuire et al. (Reference 189)	Model developed by EPRI	0.5
Boore and Atkinson (Reference 190)	Published model	0.25
Nuttli (Reference 191)	Published model for peak parameters, combined with Newmark-Hall (Reference 192) amplification factors	0.25

Table 2.5-16 Comparison of PGA Results for North Anna Using 1989 EPRI Sources and Ground Motion Models

Ground motion (PGA)	Original 1989[a]	Replicated 1989	Difference[a]
Mean 50 cm/s^2	1.6E-3	1.62E-3	+1%
50% 50 cm/s^2	1.4E-3	1.32E-3	-5%
85% 50 cm/s^2	2.9E-3	2.92E-3	+1%
Mean 250 cm/s^2	7.0E-5	7.09E-5	+1%
50% 250 cm/s^2	4.8E-5	4.79E-5	0
85% 250 cm/s^2	1.3E-4	1.35E-4	+4%
mean 500 cm/s^2	9.3E-6	9.46E-6	+2%
50% 500 cm/s^2	5.5E-6	5.62E-6	+2%
85% 500 cm/s^2	1.7E-5	1.76E-5	+4%

a. 1989 results are only available to 2 digits accuracy in Reference 115, which could lead to a +5% apparent difference.

Table 2.5-17 Comparison of Spectral Velocity Results for North Anna Using 1989 EPRI Sources and Ground Motion Models

Parameter	Original 1989[a]	Replicated 1989	Difference
Median 1E-5 1 Hz amplitude	14.0 cm/s	14.2 cm/s	+1%
Median 1E-5 2.5 Hz amplitude	14.5 cm/s	14.5 cm/s	0%
Median 1E-5 5 Hz amplitude	13.3 cm/s	13.7 cm/s	+3%
Median 1E-5 10 Hz amplitude	10.4 cm/s	10.3 cm/s	-1%

a. Reference 115, Appendix E, Table 3-62

Table 2.5-18 Seismic Sources Contributing to 99% of Hazard for Each 1989 EPRI Team

Earth Science Team	Sources used
Bechtel	24, E, BZ4, BZ5
Dames & Moore	4, 40, 41, 42, 47, 4b, 53
Law Engineering	17, 107, 22, 217, C09, C10, C11, M19, M20, M21, M22, M23, M24, M27
Rondout Associates	28, 29, 30
Woodward-Clyde Cons.	26, 27, 29, 29A, B22
Weston Geophysical Corp.	22, C19, C21, C22, C23, C34, C35

Table 2.5-19 Significant Seismic Source at North Anna by 1989 EPRI Team

Earth Science Team	Seismic source	Description
Bechtel	E	Central VA seismic zone
	BZ5	Local background
Dames & Moore	40	Central VA seismic zone
Law Engineering	17	Eastern basement
	M22	Local mafic pluton source
Rondout Association	29	Central VA seismic zone
Woodward-Clyde Consultants	27	Central VA seismic zone
	26	Alternate Central VA seismic zone
	B22	Local background
Weston Geophysical Corporation	22	Central VA seismic zone

Table 2.5-20 Controlling Earthquake Magnitude and Distances Using 1989 EPRI Sources and Ground Motion Models

	m_b	M[a]	r_{epi}, km	r_{CD}[b], km
Low frequency (1 and 2.5 Hz)	6.2	5.9	25	23
High frequency (5 and 10 Hz)	5.9	5.5	18	17

a. **M** converted from m_b as described in Section 2.5.2.2.1.

b. r_{CD} converted from r_{epi} as given in Reference 116, model F3.

Table 2.5-21 Spectral Amplitudes Using 1989 EPRI Sources And Ground Motion Models

Frequency	Median/Mean	1989 Ground Motions
1 Hz	10^{-5} median	0.0910 g
	10^{-5} mean	0.219 g
2.5 Hz	10^{-5} median	0.232 g
	10^{-5} mean	0.519 g
5 Hz	10^{-5} median	0.439 g
	10^{-5} mean	0.753 g
10 Hz	10^{-5} median	0.660 g
	10^{-5} mean	0.827 g

Table 2.5-22 Updated Seismic Hazard Results at ESP Site

Frequency	Median/Mean	Updated Models	1989 Models	Difference
1 Hz	10^{-5} median	0.0961 g	0.0910 g	+6%
	10^{-5} mean	0.134 g	0.219 g	-39%
2.5 Hz	10^{-5} median	0.316 g	0.232 g	+36%
	10^{-5} mean	0.364 g	0.519 g	-30%
5 Hz	10^{-5} median	0.639 g	0.439 g	+46%
	10^{-5} mean	0.735 g	0.753 g	-2%
10 Hz	10^{-5} median	1.020 g	0.660 g	+55%
	10^{-5} mean	1.216 g	0.827 g	+47%

Table 2.5-23 Controlling Earthquake Magnitude and Distances, Updated Models (Using Median 10^{-5} Ground Motion)

	m_b	M[a]	r_{epi}, km	r_{CD}[b], km
Low frequency (1 and 2.5 Hz)	5.9	5.6	20	19
high frequency (5 and 10 Hz)	5.7	5.3	15	15

a. **M** converted from m_b as described in Section 2.5.2.2.1.

b. r_{CD} converted from r_{epi} as given in Reference 116, model F3.

Table 2.5-24 Spectral Accelerations Corresponding to Mean 5×10^{-5} Annual Frequency

Frequency	Spectral Acceleration at 5×10^{-5}, g	Combined frequency, Hz	Average spectral Acceleration, g
1	0.0652	1.75	0.118
2.5	0.170		
5	0.339	7.5	0.443
10	0.547		

Table 2.5-25 Controlling Earthquake Magnitudes and Distances Corresponding to Mean 5×10^{-5} Annual Frequency

Frequencies	M	r_{CD}, km
Low (1 and 2.5 Hz) (using distant events only)	7.2	308
High (5 and 10 Hz)	5.4	20

Table 2.5-26 Summary of Performance-Based Spectrum Calculations

Frequency Hz	Mean 1×10^{-4} Amplitude, g	Mean 1×10^{-5} Amplitude, g	A_R	SF	A(*f*), g
0.5	0.0298	0.0944	3.17	1.51	0.0450
1	0.0463	0.134	2.89	1.40	0.0650
2.5	0.120	0.364	3.03	1.46	0.175
5	0.235	0.735	3.13	1.49	0.351
10	0.373	1.216	3.26	1.54	0.578
25	0.569	1.99	3.50	1.63	0.930
100 (PGA)	0.214	0.753	3.52	1.64	0.351

Table 2.5-27 Selected Horizontal SSE Amplitudes, V/H Ratios from Reference 171, and Resulting Vertical SSE Amplitudes

Frequency Hz	Selected Horizontal SSE Amplitudes, g	V/H Ratio	Selected Vertical SSE Amplitudes, g
100	0.374	1.00	0.374
50	0.780	1.12[a]	0.877
30	0.924	0.94[a]	0.866
25	0.930	0.88	0.818
20	0.869	0.83[a]	0.717
10	0.578	0.75	0.434
8	0.499	0.75	0.375
6	0.405	0.75	0.304
5	0.351	0.75	0.263
4	0.266	0.75	0.200
3	0.200	0.75	0.150
2.5	0.175	0.75	0.131
2	0.145	0.75	0.109
1	0.0651	0.75	0.0488
0.8	0.0581	0.75	0.0436
0.6	0.0498	0.75	0.0373
0.5	0.0450	0.75	0.0338
0.4	0.0337	0.75	0.0253
0.3	0.0229	0.75	0.0172
0.2	0.0129	0.75	0.00965
0.1	0.00412	0.75	0.00309

a. V/H ratios calculated by log-log interpretation.

Table 2.5-27A Selected Zone III-IV Control Point Horizontal SSE Amplitudes, V/H Ratios from Reference 171, and Resulting Vertical SSE Amplitudes

Frequency Hz	Selected Horizontal SSE Amplitudes, g	V/H Ratio	Selected Vertical SSE Amplitudes, g
100	0.555	1.00	0.555
50	1.195	1.12	1.33
30	1.470	0.94	1.38
25	1.476	0.88	1.29
20	1.446	0.83	1.20
10	0.945	0.75	0.708
8	0.717	0.75	0.537
6	0.481	0.75	0.360
5	0.376	0.75	0.282
4	0.287	0.75	0.215
3	0.214	0.75	0.160
2.5	0.179	0.75	0.134
2	0.142	0.75	0.106
1	0.0677	0.75	0.0507
0.8	0.0576	0.75	0.0432
0.6	0.0488	0.75	0.0366
0.5	0.0429	0.75	0.0321
0.4	0.0343	0.75	0.0257
0.3	0.0233	0.75	0.0174
0.2	0.01298	0.75	0.00973
0.1	0.00382	0.75	0.00286

Table 2.5-28 Mean 5×10^{-5} Spectral Amplitudes for RG 1.165 Reference Probability Approach and for Sensitivity Studies

Frequency	Mean 5×10^{-5} Spectral Amplitude (g), RG 1.165 RP Approach	Mean 5×10^{-5} Spectral Amplitude (g) Using Alternate M_{min}	Change From RG 1.165 RP Approach	Mean 5×10^{-5} Spectral Amplitude (g) Using Alternative Sigma	Change From RG 1.165 RP Approach
PGA	0.319	0.246	-22.9%	0.297	-6.9%
25 Hz	0.845	0.651	-23.0%	0.702	-16.9%
10 Hz	0.547	0.437	-20.1%	0.517	-5.5%
5 Hz	0.339	0.287	-15.3%	0.329	-2.9%
2.5 Hz	0.17	0.156	-8.2%	0.162	-4.7%
1 Hz	0.0652	0.0642	-1.5%	0.0592	-9.2%
0.5 Hz	0.0434	0.0428	-1.4%	0.0336	-22.6%

Table 2.5-29 Zone IIA Constituents

Location	Thickness Sampled, ft	Coarse-Grained		Fine-Grained		SC
		SP/GP	SM	ML	MH/CL/CH	
Units 1&2	2204	9.4%	67.8%	1.5%	20.3%	1%
Units 3&4	1112	17.5%	78.8%	3.7%	—[a]	—
SWR	1223	23.3%	44.7%	22.7%	6.3%	3%
ISFSI	451	—	45.5%	2.4%	47%	5.1%
ESP	105	2.4%	68.5%	20.2%	—	8.9%
Average		10.5%	61.1%	10.1%	14.7%	3.6%

Sources: Table 2.5-30 through Table 2.5-36, and Table 2.5-38

a. Dash in box denotes absence of that constituent at that location

Table 2.5-30 Summary of Units 1&2 Borings—Soils

Borehole Details					Soil Zone Thickness				Zone IIA N-Values		
	Northing	Easting	Elev.	Depth	Fill	I	IIA	IIB		Range	Median
Boring	ft	ft	ft	ft	ft	ft	ft	ft	No.	blows/ft	blows/ft
1	144,104	2,204,897	275	87	–[a]	1	35	—	7	24 to 600	138
2	144,381	2,204,733	285	97	—	3	29	—	—	—	—
3	144,667	2,204,564	279	80	—	2	33	—	—	—	—
4	144,000	2,204,665	291	104	—	—	25	—	—	—	—
5	144,175	2,204,567	294	116	—	1	20	7	—	—	—
6	144,348	2,204,464	289	110	—	1	28	—	—	—	—
7	144,559	2,204,340	275	151	—	—	55	—	—	—	—
8	143,897	2,204,438	299	97	—	1	7	—	—	—	—
9	144,176	2,204,273	281	92	—	8	55	—	—	—	—
10	144,463	2,204,108	256	79	—	2	31	—	7	17 to 1220	151
11	143,794	2,204,206	307	107	—	—	22	7	—	—	—
12	143,964	2,204,103	289	106	—	1	17	—	—	—	—
13	144,139	2,204,000	270	90	—	—	—	24	—	—	—
14	144,358	2,203,876	275	87	—	1	42	—	—	—	—
15	143,742	2,203,980	317	117	—	5	34	5	—	—	—
16	143,971	2,203,814	297	117	—	—	30	—	—	—	—
17	144,253	2,203,655	271	94	—	1	67	—	—	—	—
18	143,582	2,203,751	314	130	—	1	21	—	—	—	—
19	143,751	2,203,649	298	120	—	3	22	—	—	—	—
20	143,932	2,203,549	283	104	—	2	18	—	—	—	—
21	144,144	2,203,423	275	93	—	10	37	—	—	—	—
22	143,479	2,203,521	317	123	—	4	49	—	—	—	—
23	143,758	2,203,356	305	97	—	1	7	10	—	—	—
24	144,041	2,203,191	293	90	—	3	57	—	—	—	—
25	143,371	2,203,289	305	112	—	1	49	—	—	—	—
26	143,655	2,203,126	297	97	—	4	2	—	—	—	—
27	143,938	2,202,959	279	92	—	4	36	—	4	16 to 107	36
28	144,060	2,204,552	295	115	—	—	25	—	—	—	—

Table 2.5-30 Summary of Units 1&2 Borings—Soils

Borehole Details					Soil Zone Thickness				Zone IIA N-Values		
	Northing	Easting	Elev.	Depth	Fill	I	IIA	IIB		Range	Median
Boring	ft	ft	ft	ft	ft	ft	ft	ft	No.	blows/ft	blows/ft
29	144,129	2,204,515	294	115	—	13	7	—	—	—	—
30	144,015	2,204,418	293	92	—	—	24	—	—	—	—
31	144,036	2,204,256	281	100	—	—	7	—	—	—	—
32	143,960	2,204,294	288	109	—	—	15	—	—	—	—
34	144,297	2,204,385	286	86	—	—	45	—	—	—	—
35	144,238	2,204,136	273	75	—	—	40	5	—	—	—
36	144,206	2,204,139	272	72	—	—	60	—	—	—	—
37	144,711	2,204,201	251	65	—	—	50	—	—	—	—
38	144,675	2,204,103	244	57	—	—	40	—	—	—	—
39	143,985	2,204,582	293	112	—	—	31	15	—	—	—
40	143,892	2,204,320	297	112	—	4	11	27	—	—	—
41	143,335	2,203,820	326	77	—	—	77	—	—	—	—
42	142,737	2,204,067	305	76	—	—	76	—	—	—	—
43	143,737	2,204,722	285	60	—	2	42	8	6	69 to 140	88
44	143,119	2,204,974	275	76	—	—	76	—	—	—	—
45	143,282	2,204,569	309	76	—	—	76	—	—	—	—
46	143,167	2,204,242	317	75	—	4	71	—	—	—	—
47	143,528	2,204,284	302	76	—	—	76	—	—	—	—
48	143,020	2,204,469	294	76	—	6	70	—	—	—	—
49	144,222	2,204,490	291	120	—	—	42	—	—	—	—
50	144,123	2,204,232	287	83	—	—	53	—	9	4 to 65	9
51	144,703	2,202,598	253	20	—	—	2	—	—	—	—
52	143,765	2,202,970	285	27	—	9	18	—	—	—	—
53	144,082	2,202,414	301	27	—	19	8	—	—	—	—
54	144,402	2,201,850	300	27	—	3	24	—	—	—	—
55	144,474	2,202,231	323	27	—	9	18	—	—	—	—
101	145,187	2,203,051	282	92	—	5	36	—	—	—	—
102	142,058	2,205,639	288	100	—	—	70	15	—	—	—

Table 2.5-30 Summary of Units 1&2 Borings—Soils

Borehole Details					Soil Zone Thickness				Zone IIA N-Values		
	Northing	Easting	Elev.	Depth	Fill	I	IIA	IIB		Range	Median
Boring	ft	ft	ft	ft	ft	ft	ft	ft	No.	blows/ft	blows/ft
103	141,134	2,206,732	265	125	—	—	80	22	7	22 to 277	52
104	143,840	2,204,196	304	150	—	—	19	—	—	—	—
105	144,041	2,204,072	274	150	—	—	30	—	2	6 to 7	7
106	144,206	2,203,930	274	150	—	—	57	13	—	—	—
60			**290**	**93**	**0%**	**5%**	**89%**	**6%**	**42**		**52**
Total			**Median**		**Percentage**				**Total**		**Median**

Source: Reference 146

a. Dash in box denotes absence of that soil in boring, or no test performed.

Table 2.5-31 Summary of Units 1 & 2 Borings—Rock

Borehole Details					Top of Rock Elevation		Median Recovery/RQD					
	Northing	Easting	Depth	Elev.	III	III-IV or IV	III		III-IV		IV	
Boring	ft	ft	ft	ft	ft	ft	Rec.	RQD	Rec.	RQD	Rec.	RQD
1	144,104	2,204,897	87	275	216	239	64%	0%	87%	9%	100%	46%
2	144,381	2,204,733	97	285	–[a]	253	—	—	—	—	79%	63%
3	144,667	2,204,564	80	279	245	226	100%	52%	—	—	96%	32%
4	144,000	2,204,665	104	291	—	267	—	—	90%	0%	90%	22%
5	144,175	2,204,567	116	294	273	251	92%	70%	100%	35%	95%	55%
6	144,348	2,204,464	110	289	259	234	83%	22%	100%	86%	98%	93%
7	144,559	2,204,340	151	275	—	220	—	—	—	—	98%	62%
8	143,897	2,204,438	97	299	—	289	—	—	—	—	75%	40%
9	144,176	2,204,273	92	281	218	215	29%	25%	—	—	100%	97%
10	144,463	2,204,108	79	256	216	223	55%	33%	—	—	81%	70%
11	143,794	2,204,206	107	307	285	212	60%	0%	—	—	100%	28%
12	143,964	2,204,103	106	289	—	268	—	—	—	—	97%	80%
13	144,139	2,204,000	90	270	246	240	22%	0%	91%	75%	100%	85%
14	144,358	2,203,876	87	275	225	211	30%	0%	—	—	90%	70%
15	143,742	2,203,980	117	317	278	249	50%	20%	—	—	93%	82%
16	143,971	2,203,814	117	297	—	267	—	—	—	—	100%	90%
17	144,253	2,203,655	94	271	—	203	—	—	—	—	100%	97%
18	143,582	2,203,751	130	314	292	225	10%	0%	—	—	87%	60%
19	143,751	2,203,649	120	298	273	234	25%	8%	—	—	75%	66%
20	143,932	2,203,549	104	283	263	245	33%	16%	—	—	95%	88%
21	144,144	2,203,423	93	275	235	206	25%	0%	—	—	96%	66%
22	143,479	2,203,521	123	317	264	254	43%	15%	57%	11%	91%	44%
23	143,758	2,203,356	97	305	287	274	76%	56%	—	—	95%	78%
24	144,041	2,203,191	90	293	—	233	—	—	—	—	80%	71%
25	143,371	2,203,289	112	305	255	205	0%	0%	—	—	100%	73%
26	143,655	2,203,126	97	297	291	288	96%	65%	—	—	70%	59%
27	143,938	2,202,959	92	279	239	210	17%	0%	—	—	78%	40%

Table 2.5-31 Summary of Units 1 & 2 Borings—Rock

Borehole Details					Top of Rock Elevation		Median Recovery/RQD					
	Northing	Easting	Depth	Elev.	III	III-IV or IV	III		III-IV		IV	
Boring	ft	ft	ft	ft	ft	ft	Rec.	RQD	Rec.	RQD	Rec.	RQD
28	144,060	2,204,552	115	295	—	270	—	—	100%	25%	100%	38%
29	144,129	2,204,515	115	294	—	274	—	—	100%	63%	—	—
30	144,015	2,204,418	92	293	—	269	—	—	100%	60%	100%	77%
31	144,036	2,204,256	100	281	274	230	80%	42%	47%	17%	90%	47%
32	143,960	2,204,294	109	288	—	273	—	—	—	—	97%	50%
34	144,297	2,204,385	86	286	206	241	62%	9%	—	—	80%	47%
35	144,238	2,204,136	75	273	233	—	50%	29%	—	—	—	—
36	144,206	2,204,139	72	272	—	212	—	—	75%	42%	—	—
37	144,711	2,204,201	65	251	—	201	—	—	—	—	75%	43%
38	144,675	2,204,103	57	244	—	204	—	—	—	—	67%	32%
39	143,985	2,204,582	112	293	243	262	90%	42%	67%	18%	88%	70%
40	143,892	2,204,320	112	297	282	228	70%	21%	49%	4%	—	—
41	143,335	2,203,820	77	326	—	—	—	—	—	—	—	—
42	142,737	2,204,067	76	305	—	—	—	—	—	—	—	—
43	143,737	2,204,722	60	285	—	—	—	—	—	—	—	—
44	143,119	2,204,974	76	275	—	—	—	—	—	—	—	—
45	143,282	2,204,569	76	309	—	—	—	—	—	—	—	—
46	143,167	2,204,242	75	317	—	—	—	—	—	—	—	—
47	143,528	2,204,284	76	302	—	—	—	—	—	—	—	—
48	143,020	2,204,469	76	294	—	—	—	—	—	—	—	—
49	144,222	2,204,490	120	291	—	249	—	—	83%	62%	85%	33%
50	144,123	2,204,232	83	287	—	234	—	—	—	—	95%	92%
51	144,703	2,202,598	20	253	251	—	65%	17%	—	—	—	—
52	143,765	2,202,970	27	285	—	—	—	—	—	—	—	—
53	144,082	2,202,414	27	301	—	—	—	—	—	—	—	—
54	144,402	2,201,850	27	300	—	—	—	—	—	—	—	—
55	144,474	2,202,231	27	323	—	—	—	—	—	—	—	—

Table 2.5-31 Summary of Units 1 & 2 Borings—Rock

Borehole Details					Top of Rock Elevation		Median Recovery/RQD					
	Northing	Easting	Depth	Elev.	III	III-IV or IV	III		III-IV		IV	
Boring	ft	ft	ft	ft	ft	ft	Rec.	RQD	Rec.	RQD	Rec.	RQD
101	145,187	2,203,051	92	282	242	236	83%	40%	—	—	82%	62%
102	142,058	2,205,639	100	288	—	—	—	—	—	—	—	—
103	141,134	2,206,732	125	265	—	—	—	—	—	—	—	—
104	143,840	2,204,196	150	304	—	298	—	—	55%	17%	100%	88%
105	144,041	2,204,072	150	274	244	242	80%	67%	—	—	92%	79%
106	144,206	2,203,930	150	274	216	204	57%	4%	96%	40%	100%	95%
60			**5589**	**290**	**250**	**236**	**58%**	**18%**	**88%**	**30%**	**92%**	**66%**
Total			**Total**	**Median**								

Source: Reference 146

a. Dash in box denotes absence of that rock in boring, and no Recovery/RQD recorded.

Table 2.5-32 Summary of Units 3 & 4 Borings—Soils

Borehole Details					Soil Zone Thickness				Zone IIA N-Values		
	Northing	Easting	Elev.	Depth	Fill	I	IIA	IIB		Range	Median
Boring	ft	ft	ft	ft	ft	ft	ft	ft	No.	blows/ft	blows/ft
601	144,563	2,203,695	269	64	5	—	19	—	2	16 to 100	58
602	144,490	2,203,510	277	70	21	—	—	—	—	—	—
603	144,495	2,203,615	274	85	14	—	19	20	2	105 to 175	140
604	144,500	2,203,731	270	85	3	—	16	10	1	40	40
605	144,425	2,203,535	277	70	15	—	14	—	3	35 to 123	54
606	144,338	2,203,843	270	70	2	—	22	11	4	18 to 140	48
607	144,235	2,203,570	270	65	2	—	26	7	5	13 to 250	32
608	144,270	2,203,882	270	87	2	—	33	37	3	31 to 146	143
609	144,232	2,203,803	271	90	2	—	54	7	5	13 to 140	21
610	144,188	2,203,705	271	96	2	—	70	9	8	22 to 225	27
611	144,165	2,203,610	271	76	2	—	48	—	5	15 to 220	33
612	144,125	2,203,515	270	80	7	—	46	5	1	13	13
613	144,195	2,203,910	270	65	2	—	42	—	7	15 to 90	30
614	144,160	2,203,825	271	70	2	—	38	—	5	18 to 33	23
615	144,125	2,203,723	270	65	2	—	33	4	4	12 to 44	28
616	144,100	2,203,638	271	64	1	—	32	—	5	9 to 45	24
617	144,063	2,203,548	271	70	2	—	38	5	7	26 to 136	94
618	144,140	2,203,930	270	54	2	—	32	—	5	14 to 44	32
619	144,065	2,203,749	271	49	1	—	12	—	2	65 to 110	87
620	144,108	2,203,859	270	46	1	—	9	3	1	40	40
621	144,005	2,203,700	271	50	–[a]	—	2	—	—	—	—
622	143,510	2,203,535	271	79	1	—	19	10	3	41 to 360	210
623	143,915	2,203,670	272	79	2	—	12	—	2	49 to 510	275
624	143,960	2,203,985	271	175	1	—	9	—	2	49 to 150	100
625	143,905	2,203,845	270	40	5	—	—	—	1	6	6
626	143,870	2,203,686	272	150	1	—	7	—	1	119	119
627	143,911	2,204,068	271	78	3	—	7	—	—	—	—

Table 2.5-32 Summary of Units 3 & 4 Borings—Soils

Borehole Details					Soil Zone Thickness				Zone IIA N-Values		
	Northing	Easting	Elev.	Depth	Fill	I	IIA	IIB		Range	Median
Boring	ft	ft	ft	ft	ft	ft	ft	ft	No.	blows/ft	blows/ft
628	143,878	2,203,980	271	78	3	—	—	—	—	—	—
629	143,795	2,203,780	272	79	1	—	—	—	—	—	—
630	143,775	2,203,725	271	78	3	—	—	—	—	—	—
631	143,345	2,204,005	322	105	—	11	77	—	8	13 to 262	48
632	143,815	2,204,355	294	75	1	—	15	18	3	44 to 116	56
633	143,880	2,204,570	284	59	8	—	5	15	—	—	—
634	143,945	2,204,790	284	62	8	—	25	8	5	23 to 145	65
635	143,995	2,204,960	275	65	-	2	19	18	—	—	—
636	144,415	2,203,750	270	70	3	—	26	15	5	15 to 400	200
637	144,340	2,203,570	271	75	10	—	20	—	3	14 to 200	42
638	144,660	2,203,660	268	50	3	—	5	20	1	116	116
639	144,590	2,203,475	274	61	23	—	8	10	2	128 to 160	144
640	144,290	2,203,935	269	82	-	—	47	35	8	22 to 242	50
641	143,205	2,203,855	270	88	2	—	55	—	10	16 to 300	28
642	144,175	2,203,655	271	75	2	—	52	—	7	19 to 94	26
643	144,109	2,203,586	270	72	2	—	30	8	6	18 to 400	55
644	143,825	2,203,745	271	50	5	—	-	—	—	—	—
645	143,895	2,204,010	271	78	5	—	-	—	—	—	—
646	144,665	2,203,790	268	47	8	—	39	—	8	20 to 240	68
647	144,705	2,203,430	256	40	—	—	28	—	5	13 to 200	44
47			**271**	**71**	**12%**	**1%**	**71%**	**16%**	**155**	**—**	**50**
Total			**Median**		**Percentage**				**Total**		**Median**

Source: Reference 8

a. Dash in box denotes absence of that soil in boring, or no test performed.

Table 2.5-33 Summary of Units 3 & 4 Borings—Rock

Borehole Details					Top of Rock El.		Median Recovery/RQD					
	Northing	Easting	Depth	Elev.	III	IV or III-IV	III		III-IV		IV	
Boring	ft	ft	ft	ft	ft	ft	Rec.	RQD	Rec.	RQD	Rec.	RQD
601	144,563	2,203,695	64	269	237	245	98%	39%	95%	73%	—	—
602	144,490	2,203,510	70	277	238	255	84%	30%	69%	29%	—	—
603	144,495	2,203,615	85	274	209	230	57%	6%	100%	50%	100%	85%
604	144,500	2,203,731	85	270	251	190	75%	27%	—	—	100%	69%
605	144,425	2,203,535	70	277	248	—	98%	45%	—	—	—	—
606	144,338	2,203,843	70	270	205	223	20%	0%	100%	60%	—	—
607	144,235	2,203,570	65	270	235	227	—	—	100%	55%	—	—
608	144,270	2,203,882	87	270	235	188	75%	23%	—	—	93%	49%
609	144,232	2,203,803	90	271	208	—	87%	14%	—	—	—	—
610	144,188	2,203,705	96	271	–[a]	191	—	—	100%	86%	—	—
611	144,165	2,203,610	76	271	—	221	—	—	—	—	97%	96%
612	144,125	2,203,515	80	270	—	212	—	—	—	—	98%	75%
613	144,195	2,203,910	65	270	226	—	100%	51%	—	—	—	—
614	144,160	2,203,825	70	271	231	224	70%	5%	93%	55%	97%	69%
615	144,125	2,203,723	65	270	232	227	—	—	78%	60%	—	—
616	144,100	2,203,638	64	271	238	227	67%	53%	95%	83%	—	—
617	144,063	2,203,548	70	271	226	221	96%	44%	—	—	94%	94%
618	144,140	2,203,930	54	270	—	236	—	—	—	—	100%	90%
619	144,065	2,203,749	49	271	249	258	92%	0%	—	—	93%	93%
620	144,108	2,203,859	46	270	259	257	—	—	—	—	99%	77%
621	144,005	2,203,700	50	271	269	246	69%	65%	—	—	100%	100%
622	143,510	2,203,535	79	271	246	241	75%	10%	—	—	100%	84%
623	143,915	2,203,670	79	272	258	234	80%	35%	—	—	100%	87%
624	143,960	2,203,985	175	271	—	261	—	—	—	—	98%	80%
625	143,905	2,203,845	40	270	—	265	—	—	—	—	100%	90%
626	143,870	2,203,686	150	272	—	264	—	—	94%	40%	98%	91%
627	143,911	2,204,068	78	271	261	246	75%	20%	100%	66%	100%	91%
628	143,878	2,203,980	78	271	258	242	90%	9%	100%	61%	100%	90%

Table 2.5-33 Summary of Units 3 & 4 Borings—Rock

Borehole Details					Top of Rock El.		Median Recovery/RQD					
	Northing	Easting	Depth	Elev.	III	IV or III-IV	III		III-IV		IV	
Boring	ft	ft	ft	ft	ft	ft	Rec.	RQD	Rec.	RQD	Rec.	RQD
629	143,795	2,203,780	79	272	269	262	50%	20%	100%	80%	100%	90%
630	143,775	2,203,725	78	271	268	251	100%	58%	100%	75%	100%	75%
631	143,345	2,204,005	105	322	—	234	—	—	52%	28%	—	—
632	143,815	2,204,355	75	294	262	—	80%	70%	—	—	—	—
633	143,880	2,204,570	59	284	257	229	70%	15%	100%	50%	—	—
634	143,945	2,204,790	62	284	251	—	96%	60%	—	—	—	—
635	143,995	2,204,960	65	275	224	236	86%	23%	—	—	86%	52%
636	144,415	2,203,750	70	270	241	—	60%	18%	—	—	—	—
637	144,340	2,203,570	75	271	241	227	65%	35%	50%	29%	85%	81%
638	144,660	2,203,660	50	268	—	239	—	—	75%	35%	—	—
639	144,590	2,203,475	61	274	232	218	70%	8%	—	—	85%	50%
640	144,290	2,203,935	82	269	222	—	95%	39%	—	—	-	-
641	143,205	2,203,855	88	270	214	197	75%	35%	—	—	100%	73%
642	144,175	2,203,655	75	271	217	208	100%	20%	—	—	98%	70%
643	144,109	2,203,586	72	270	230	218	60%	40%	90%	70%	-	-
644	143,825	2,203,745	50	271	266	256	93%	31%	90%	30%	-	-
645	143,895	2,204,010	78	271	—	266	—	—	100%	40%	100%	68%
646	144,665	2,203,790	47	268	—	—	—	—	—	—	—	—
647	144,705	2,203,430	40	256	228	—	80%	25%	—	—	—	—
47			**3461**	**271**	**238**	**234**	**80%**	**27%**	**95%**	**60%**	**100%**	**82%**
Total			**Total**	**Median**								

Source: Reference 8

a. Dash in box denotes absence of that rock in boring, and no Recovery/RQD recorded.

Table 2.5-34 Summary of Service Water Reservoir Borings—Soils

Borehole Details					Soil Zone Thickness				Zone IIA N-Values		
	Northing	Easting	Elev.	Depth	Fill	I	IIA	IIB		Range	Median
Boring	ft	ft	ft	ft	ft	ft	ft	ft	No.	blows/ft	blows/ft
P-10	142,876	2,204,869	283	27	–[a]	—	27	—	4	20 to 142	34
P-11	143,495	2,204,410	324	53	13	—	40	—	7	13 to 23	16
P-12	143,561	2,204,416	298	30	—	—	30	—	4	17 to 25	18
P-15	143,150	2,204,700	321	72	28	—	44	—	1	19	19
P-16	143,050	2,204,607	321	70	32	—	38	—	7	18 to 107	28
P-17	142,958	2,204,529	321	77	32	—	45	—	9	17 to 137	22
S1-1	143,495	2,204,430	326	92	12	—	80	—	12	17 to 100	26
S1-2	143,565	2,204,435	297	75	—	—	75	—	7	15 to 100	33
S1-3	143,078	2,204,777	285	64	—	—	64	—	9	31 to 155	63
SWR-1	143,470	2,204,492	306	58	—	—	43	15	27	9 to 24	17
SWR-2	143,438	2,204,492	306	58	—	—	50	8	33	11 to 84	18
SWR-3	143,076	2,203,686	321	100	—	—	100	—	19	12 to 142	45
SWR-4	143,396	2,203,983	320	101	—	—	101	—	20	16 to 400	30
SWR-5	143,391	2,204,753	321	105	26	—	79	—	17	12 to 226	23
SWR-6	143,127	2,204,712	321	104	15	—	89	—	18	16 to 400	25
SWR-7	142,942	2,204,532	321	82	15	—	67	—	13	8 to 37	19
SWR-8	142,951	2,204,302	321	72	10	—	62	—	13	9 to 109	25
SWR-9	142,982	2,204,061	321	67	12	—	55	—	11	8 to 274	50
SWR-10	143,133	2,204,685	321	64	31	—	33	—	13	14 to 36	21
SWR-11	142,980	2,204,685	286	38	16	—	22	—	5	17 to 300	48
SWR-12	142,893	2,204,598	289	49	15	—	34	—	—	—	—
SWR-13	143,242	2,204,792	321	72	27	—	45	—	9	13 to 62	22
22			**321**	**71**	**18.5%**	**0**	**80%**	**1.5%**	**258**		**25**
Total			**Median**		**Percentage**				**Total**		**Median**

Source: Reference 5

a. Dash in box denotes absence of that soil in boring, or no test performed.

Table 2.5-35 Summary of Service Water Reservoir Borings—Rock

Borehole Details					Top of Rock Elev.[a]	
	Northing	Easting	Depth	Elev.	III	III-IV or IV
Boring	ft	ft	ft	ft	ft	ft
P-10	142,876	2,204,869	27	283	–[b]	—
P-11	143,495	2,204,410	53	324	—	—
P-12	143,561	2,204,416	30	298	—	—
P-15	143,150	2,204,700	72	321	—	—
P-16	143,050	2,204,607	70	321	—	—
P-17	142,958	2,204,529	77	321	—	—
S1-1	143,495	2,204,430	92	326	—	234
S1-2	143,565	2,204,435	75	297	—	222
S1-3	143,078	2,204,777	64	285	—	221
SWR-1	143,470	2,204,492	58	306	248	—
SWR-2	143,438	2,204,492	58	306	248	—
SWR-3	143,076	2,203,686	100	321	—	221
SWR-4	143,396	2,203,983	101	320	—	219
SWR-5	143,391	2,204,753	105	321	—	216
SWR-6	143,127	2,204,712	104	321	—	217
SWR-7	142,942	2,204,532	82	321	—	—
SWR-8	142,951	2,204,302	72	321	—	—
SWR-9	142,982	2,204,061	67	321	—	—
SWR-10	143,133	2,204,685	64	321	—	—
SWR-11	142,980	2,204,685	38	286	—	—
SWR-12	142,893	2,204,598	49	289	—	—
SWR-13	143,242	2,204,792	72	321	—	—
22			**1530**	**321**	**248**	**221**
Total			**Total**	**Median**		

Source: Reference 5

a. Top of rock is estimated since there was no rock coring.

b. Dash in box denotes absence of that rock in boring.

Table 2.5-36 Summary of ISFSI Borings—Soils

Borehole Details					Soil Zone Thickness				Zone IIA N-Values		
	Northing	Easting	Elev.	Depth	Fill	I	IIA	IIB		Range	Median
Boring	ft	ft	ft	ft	ft	ft	ft	ft	No.	blows/ft	blows/ft
F-2	142,000	2,202,990	320	70	–[a]	—	65	—	14	14 to 78	18
F-4	141,982	2,202,850	317	59	—	—	34	15	9	15 to 125	21
F-5	141,982	2,203,200	318	115	—	—	64	—	15	9 to 44	25
F-6	141,864	2,202,850	316	59	—	—	44	—	11	13 to 110	19
F-7	141,864	2,203,000	320	105	—	—	75	—	18	10 to 165	21
F-8	141,864	2,203,200	318	69	—	—	35	29	9	16 to 36	24
F-9	141,746	2,202,850	311	105	—	—	55	4	13	7 to 56	21
F-10	141,746	2,203,000	315	74	—	—	50	19	12	20 to 80	27
F-11	141,746	2,203,200	309	69	—	—	29	10	8	32 to 160	42
9			**317**	**70**	**0**	**0**	**85.4**	**14.6**	**109**		**21**
Total			**Median**		**Percentage**				**Total**		**Median**

Source: Reference 6

a. Dash in box denotes absence of that soil in boring, or no test performed.

Table 2.5-37 Summary of ISFSI Borings—Rock

Borehole Details					Top of Rock Elev.	Avg. Recovery/ RQD	
	Northing	Easting	Depth	Elev.	III	III	
Boring	ft	ft	ft	ft	ft	Rec.	RQD
F-2	142,000	2,202,990	70	320	255	0%	0%
F-4	141,982	2,202,850	59	317	268	50%	20%
F-5	141,982	2,203,200	115	318	254	15%	0%
F-6	141,864	2,202,850	59	316	272	23%	6%
F-7	141,864	2,203,000	105	320	245	11%	0%
F-8	141,864	2,203,200	69	318	254	80%	0%
F-9	141,746	2,202,850	105	311	252	20%	4%
F-10	141,746	2,203,000	74	315	246	95%	36%
F-11	141,746	2,203,200	69	309	260	41%	8%
9			**725**	**317**	**254**	**23%**	**4%**
Total			**Total**	**Median**			

Source: Reference 5

Table 2.5-38 Summary of ESP Borings, Observation Wells, and CPTs—Soils

Borehole/OW/CPT Details					Soil Zone Thickness				IIA N-Values		
Boring/ OW/CPT	Northing ft	Easting ft	Elev. ft	Depth ft	Fill ft	I ft	IIA ft	IIB ft	No.	Range blows/ft	Median blows/ft
B-801	144,034	2,203,740	249	50	19	—	—	—	—	—	—
B-802	143,639	2,203,383	271	90	3	—	3	—	1	44	44
B-803	143,603	2,202,766	292	170	–[a]	—	31	—	9	12 to 31	22
B-804	143,179	2,202,137	320	60	—	2	21	—	8	5 to 24	8
B-805	144,043	2,203,249	271	90	—	—	23	5	8	12 to 100	22
B-806	143,098	2,200,979	299	65	2	—	6	—	2	18 to 22	20
B-807	143,530	2,200,983	311	72	—	—	21	21	10	12 to 100	16
7			**292**	**72**	**15%**	**1%**	**67%**	**17%**	**38**	—	**21**
Total			**Median**		**Percentage**				**Total**		**Median**
					Soil Thickness, ft						
OW-841	144,238	2,203,806	252	34	24						
OW-842	142,716	2,202,151	337	50	50						
OW-843	143,407	2,202,059	321	49	49						
OW-844	143,591	2,203,592	274	25	24						
OW-845	143,540	2,202,743	297	55	33						
OW-846	143,527	2,202,724	297	33	33						
OW-847	142,627	2,203,450	320	50	50						
OW-848	144,535	2,203,275	285	47	33						
OW-849	144,468	2,201,733	299	50	50						
9			**297**	**49**	**33**						
Total			**Median**								
CPT-821	143,647	2,203,355	271	4	4						
CPT-822	144,057	2,203,239	271	23	23						
CPT-823	143,532	2,202,758	296	32	32						
CPT-824	143,736	2,203,012	276	4	4						
CPT-825	143,160	2,202,269	333	52	52						
CPT-827	144,370	2,200,571	277	58	58						
CPT-828	144,334	2,200,068	270	5	5						
CPT-830	143,531	2,203,002	308	16	16						
8			**276**	**20**	**20**						
Total			**Median**								

Source: Reference 147

a. Dash in box denotes absence of that soil in boring, or no test performed.

Table 2.5-39 Summary of ESP Borings, Observation Wells, and CPTs—Rock

Borehole/OW/CPT Details					Top of Rock Elev.		Median Recovery/RQD					
							III		III-IV		IV	
Boring/ OW/CPT	Northing ft	Easting ft	Depth ft	Elev. ft	III ft	III-IV or IV ft	Rec.	RQD	Rec.	RQD	Rec.	RQD
B-801	144,034	2,203,740	50	249	230	229	–[a]	—	—	—	100%	100%
B-802	143,639	2,203,383	90	271	265	263	—	—	88%	44%	100%	84%
B-803	143,603	2,202,766	170	292	262	244	—	—	—	—	100%	100%
B-804	143,179	2,202,137	60	320	298	287	—	—	80%	47%	100%	98%
B-805	144,043	2,203,249	90	271	243	232	—	—	90%	70%	100%	90%
B-806	143,098	2,200,979	65	299	292	288	25%	5%	86%	65%	—	—
B-807	143,530	2,200,983	72	311	276	254	—	—	46%	0%	—	—
7			**597**	**292**	**265**	**254**	**25%**	**5%**	**86%**	**47%**	**100%**	**98%**
Total			**Total**	**Median**								
OW-841	144,238	2,203,806	34	252	228							
OW-842	142,716	2,202,151	50	337	—							
OW-843	143,407	2,202,059	49	321	—							
OW-844	143,591	2,203,592	25	274	250							
OW-845	143,540	2,202,743	55	297	264							
OW-846	143,527	2,202,724	33	297	—							
OW-847	142,627	2,203,450	50	320	—							
OW-848	144,535	2,203,275	47	285	252							
OW-849	144,468	2,201,733	50	299	—							
9			**393**	**297**	**251**							
Total			**Total**	**Median**								
CPT-821	143,647	2,203,355	4	271								
CPT-822	144,057	2,203,239	23	271								
CPT-823	143,532	2,202,758	32	296								
CPT-824	143,736	2,203,012	4	276								
CPT-825	143,160	2,202,269	52	333								
CPT-827	144,370	2,200,571	58	277								
CPT-828	144,334	2,200,068	5	270								
CPT-830	143,531	2,203,002	16	308								
8			**194**	**276**								
Total			**Total**	**Median**								

a. Dash in box denotes absence of that soil in boring, or no test performed. Source: Reference 147.

Table 2.5-40 Summary of Soil Sampling Results

Location	No. of Boreholes	Borehole Median, ft			Percentage per Zone				Zone IIA N-Values	
		Elevation	Total Depth	Soil Thickness	Fill %	I %	IIA %	IIB %	Number	Median blows/ft
Units 1&2	60	290	93	40	0	5	89	6	42	52
Units 3&4	47	271	71	34	12	1	71	16	155	50
SWR	22	321	71	71	18	0	80	2	258	25
ISFSI	9	317	70	64	0	0	85	15	109	21
ESP	7	292	72	23	15	1	67	17	38	21

Sources: Reference 5, Reference 6, Reference 146, Reference 8 and Reference 147

Table 2.5-41 Summary of Rock Coring Results

Location	III			III-IV			IV		
	Thickness ft	Recovery %	RQD %	Thickness ft	Recovery %	RQD %	Thickness ft	Recovery %	RQD %
Units 1&2	702	58	18	493	88	30	1896	92	66
Units 3&4	647	88	27	491	95	60	732	100	82
ISFSI	197	23	4	–[a]	–	–	–	–	–
ESP	94	25	5	91	86	47	255	100	98

Sources: Reference 6, Reference 146, Reference 8 and Reference 147

a. Dash in box denotes absence of that rock in boring, or no recovery/RQD recorded.

Table 2.5-42 Summary of Laboratory Tests Performed

Test	Units 1 & 2	SWR	ISFSI	ESP	Total
Soil					
Moisture content	72	339	30	9	**450**
Percent passing #200 sieve	—[a]	260	-	-	**260**
Sieve analysis	15	63	19	10	**107**
Sieve and hydrometer analysis	-	4	-	5	**9**
Atterberg limits [b]	4	16	13	5	**38**
Unit weight	71	163	11	-	**245**
Mineral analysis (thin section)	1	27	-	-	**28**
Permeability	4	-	1	-	**5**
pH	2	-	-	4	**6**
Sulfate	2	-	-	4	**6**
Chloride	-	-	-	4	**4**
Moisture density (Proctor)	2	-	3	-	**5**
CBR	-	-	3	-	**3**
Consolidation	5	15[c]	3	-	**23**
Unconfined compression	2	-	5	-	**7**
Triaxial compression (UU)	19[d]	62	5	-	**86**
Triaxial compression (CIU) w/pp	5	8	6	-	**19**
Triaxial compression (cyclic)	2	15	-	-	**17**
Direct shear	-	2	-	-	**2**
Shockscope	3	-	-	-	**3**
Rock					
Unit weight	-	-	-	19	**19**
Unconfined compression	24	-	-	13	**37**
Unconfined compression w/stress-strain	6	-	-	6	**12**

Sources: Reference 5, Reference 6, Reference 146, Reference 8 and Reference 147.

a. Dash denotes no test performed.

b. Atterberg limit tests only listed for plastic samples tested.

c. Includes 5 constant strain tests with pore pressure measurement.

d. Includes 8 tests on prepared soil samples.

Table 2.5-43 Summary of ESP Laboratory Test Results

Sample Identification			Moisture Content %	Atterberg Limits			% Finer #200 Sieve	Chemical Tests		
Boring	Sample Number	Depth ft		Liquid Limit	Plastic Limit	Plasticity Index		pH	Chlorides mg/kg	Sulfates Mg/kg
B-801	SS-1	0-1.5	22.2	39	29	10		6.3	130	<27
B-801	SS-5	8.5-10	–[a]	—	—	—	39.9	—	—	—
B-801	SS-6	13.5-15	—	—	—	—	55.1	—	—	—
B-802	SS-2	3.7-5.2	—	—	—	—	19.5	—	—	—
B-803	SS-3	6.1-7.6	18.9	30	26	4	-	—	—	—
B-803	SS-4	8.6-10.1	23.2	—	—	—	24.4	—	—	—
B-803	SS-6	13.7-15.3	—	—	—	—	20.9	5.7	100	<23
B-803	SS-8	23.6-25.1	—	—	—	—	18.5	—	—	—
B-804	SS-3	3.5-5	—	—	—	—	54.2	—	—	—
B-804	SS-6	11-12.5	—	—	—	—	46.1	—	—	—
B-804	SS-8	18.5-20	—	—	—	—	22.1	—	—	—
B-805	SS-4	7.5-9	27.2	NP[b]	NP	NP	27.5	—	—	—
B-805	SS-7	18.5-20	—	—	—	—	25.1	—	—	—
B-806	SS-3	5.6-7.1	—	—	—	—	27.1	6.7	920	<24
B-807	SS-3	4.5-6	40.1	49	45	4	—	—	—	—
B-807	SS-6	12.3-13.8	42.8	46	40	6	—	5.7	170	<28
B-807	SS-8	21.8-23.8	28.9	41	34	7	42.6	—	—	—
B-807	SS-10	31.5-33	26.7	—	—	—	37.7	—	—	—
B-807	SS-12	41.4-42.9	21.8	—	—	—	44.2	—	—	—

Source: Reference 147

a. Dash denotes no test performed.

b. NP – Non Plastic

Table 2.5-44 Summary of ESP Laboratory Test Results—Rock

Boring Number	Depth, ft	Zone	Unconfined Compressive Strength, ksi	Modulus of Elasticity, ksi	Poisson's Ratio
B-801	24.1-24.8	IV	27.21	–[a]	—
B-801	48.7-49.7	IV	28.42	8670	0.27
B-802	20.4-21.0	III-IV	8.64	—	—
B-802	44.9-45.6	IV	11.76	—	—
B-802	66.0-66.7	IV	14.71	4613	0.24
B-802	85.3-85.9	IV	9.37	—	—
B-803	54.1-54.7	IV	13.01	—	—
B-803	70.4-71.1	IV	23.21	7133	0.34
B-803	90.3-91.0	IV	27.59	—	—
B-803	129.4-130.1	IV	26.73	—	—
B-803	155.6-156.4	IV	22.03	7173	0.33
B-804	38.9-39.9	IV	27.15	—	—
B-804	43.5-44.9	IV	25.20	—	—
B-804	49.9-50.5	IV	12.30	3190	0.43
B-805	41.3-41.9	III-IV	3.40	336	0.15
B-805	80.8-81.6	IV	4.43	—	—
B-806	25.1-25.8	III	0.61	—	—
B-806	42.6-43.2	III-IV	2.72	—	—
B-806	64.1-64.5	IV	27.36	—	—

Source: Reference 147

a. Dash denotes no test performed.

Table 2.5-45 Summary of Geotechnical Engineering Properties

Stratum	IIA		IIB	III	III-IV	IV
	Coarse-grained	Fine-grained				
Description	Saprolite	Saprolite	Saprolite w/10 to 50% Core Stone	Moderately to Highly Weathered Quartz Gneiss w/Biotite	Slightly to Moderately Weathered Quartz Gneiss w/Biotite	Fresh to Slightly Weathered Quartz Gneiss w/Biotite
Rock properties						
Recovery,%	—	—	—	60	90	100
RQD,%	—	—	—	20	50	95
Unconfined compressive strength, ksi	—		—	0.6	4	12
USCS symbol	SP, SM, SC	ML, CL, MH, CH	Mainly SM	—	—	—
Range of fines content,%	15 to 45	—	—	—	—	—
Natural moisture content, w,%	—	26	—	—	—	—
Undrained shear strength, c_u, ksf	—	2.0	—	—	—	—
Effective cohesion, c′, ksf	0.25	0.5	—	—	—	—
Effective friction angle, ϕ', degrees	30	25	40	—	—	—
Total unit weight, γ, pcf	125		130	145	163	163
SPT N-value, N_{60}, blows/ft	20		100	—	—	—
Shear and compression wave velocity						
Shear wave velocity range, ft/sec	600 to 1350		No range available	1500 to 2500	2500 to 4500	4000 to 8000
Shear wave velocity best estimate, ft/sec	950		1600	2000	3300	6300
Compression wave velocity best estimate, ft/sec	2100		3500	4500	7400	14,000

Table 2.5-45 Summary of Geotechnical Engineering Properties

Stratum	IIA		IIB	III	III-IV	IV
	Coarse-grained	Fine-grained				
Description	Saprolite	Saprolite	Saprolite w/10 to 50% Core Stone	Moderately to Highly Weathered Quartz Gneiss w/Biotite	Slightly to Moderately Weathered Quartz Gneiss w/Biotite	Fresh to Slightly Weathered Quartz Gneiss w/Biotite
Elastic and shear moduli						
Elastic modulus (high strain), E_{hs}	1200 ksf		3500 ksf	120 ksi	1000 ksi	3750 ksi
Elastic modulus (low strain), E_{ls}	9500 ksf		28,000 ksf	300 ksi	1000 ksi	3750 ksi
Shear modulus (high strain), G_{hs}	450 ksf		1300 ksf	50 ksi	375 ksi	1400 ksi
Shear modulus (low strain), G_{ls}	3500 ksf		10,000 ksf	125 ksi	375 ksi	1400 ksi
Consolidation characteristics						
Recompression ratio, RR	0.015		—	—	—	—
Coeff. of secondary compression, C_α	0.0008		—	—	—	—
Coeff. of subgrade reaction, k_1, kcf	230		1500	-	-	-
Coefficient of sliding against concrete	0.35		0.45	0.6	0.65	0.7
Poisson's ratio, μ (high strain)	0.35		0.3	0.33	0.33	0.33
Static earth pressure coefficients						
Active, K_a	0.33		0.22	—	—	—
Passive, K_p	3.0		4.6	—	—	—
At-rest, K_o	0.5		0.36	—	—	—
Hydraulic conductivity, cm/sec	5×10^{-4}		—	—	—	—

Note:Dash denotes no design parameter given

Table 2.5-46 ZPA Results from SHAKE Analysis

		Profile 1					
Depth, ft	V_s, ft/sec	G_{max}	150% G_{max}	Profile 2	Profile 3	V_s, ft/sec	Profile 4
Low Frequency Case							
0.0	700	0.458g	0.567g	–[a]	–	1275	0.415g
2.5	700	0.394g	0.503g	–	–	1275	0.396g
5.0	700	0.328g	0.357g	–	–	1275	0.338g
7.5	700	0.314g	0.329g	–	–	1275	0.247g
10.0	700/950	0.255g	0.283g	–	–	1275/1380	0.245g
12.5	950	0.286g	0.268g	–	–	1380	0.239g
15.0	950	0.272g	0.273g	–	–	1380	0.224g
17.5	950	0.323g	0.228g	–	–	1380	0.212g
20.0	950/1200	0.300g	0.269g	–	–	1380/1500	0.199g
22.5	1200	0.265g	0.294g	–	–	1500	0.205g
25.0	1200	0.310g	0.281g	–	–	1500	0.239g
27.5	1200	0.302g	0.252g	–	–	1500	0.241g
30.0	1200/1600	0.219g	0.268g	0.463g	-	1500/1600	0.275g
35.0	1600	0.223g	0.286g	0.361g	-	1600	0.300g
40.0	1600/2000	0.229g	0.185g	0.359g	0.393g	1600/2000	0.224g
45.0	2000	0.223g	0.180g	0.335g	0.353g	2000	0.232g
50.0	2000	0.180g	0.164g	0.301g	0.250g	2000	0.193g
55.0	2000/3300	0.181g	0.162g	0.212g	0.213g	2000/3300	0.174g
60.0	3300	0.175g	0.158g	0.184g	0.227g	3300	0.169g
65.0	3300	0.157g	0.159g	0.171g	0.229g	3300	0.171g
70.0	3300	0.151g	0.158g	0.151g	0.214g	3300	0.163g
Outcrop	6300	0.213g	0.213g	0.213g	0.213g	6300	0.213g
High Frequency Case							
0.0	700	0.906g	0.989g	–[a.]	-	1275	0.918g
2.5	700	0.792g	0.860g	-	-	1275	0.872g
5.0	700	0.612g	0.752g	-	-	1275	0.748g
7.5	700	0.654g	0.669g	-	-	1275	0.698g
10.0	700/950	0.703g	0.810g	-	-	1275/1380	0.605g

Table 2.5-46 ZPA Results from SHAKE Analysis

		Profile 1					
Depth, ft	V_s, ft/sec	G_{max}	150% G_{max}	Profile 2	Profile 3	V_s, ft/sec	Profile 4
High Frequency Case (continued)							
12.5	950	0.698g	0.762g	-	-	1380	0.474g
15.0	950	0.632g	0.776g	-	-	1380	0.486g
17.5	950	0.627g	0.753g	-	-	1380	0.557g
20.0	950/1200	0.558g	0.744g	-	-	1380/1500	0.619g
22.5	1200	0.511g	0.834g	-	-	1500	0.648g
25.0	1200	0.590g	0.826g	-	-	1500	0.695g
27.5	1200	0.658g	0.722g	-	-	1500	0.726g
30.0	1200/1600	0.630g	0.607g	1.034g	-	1500/1600	0.667g
35.0	1600	0.674g	0.532g	0.902g	-	1600	0.746g
40.0	1600/2000	0.652g	0.535g	0.680g	0.989g	1600/2000	0.506g
45.0	2000	0.535g	0.493g	0.572g	0.853g	2000	0.428g
50.0	2000	0.425g	0.416g	0.498g	0.542g	2000	0.389g
55.0	2000/3300	0.321g	0.435g	0.411g	0.414g	2000/3300	0.346g
60.0	3300	0.312g	0.423g	0.400g	0.371g	3300	0.336g
65.0	3300	0.291g	0.384g	0.378g	0.358g	3300	0.303g
70.0	3300	0.286g	0.366g	0.451g	0.339g	3300	0.343g
Outcrop	6300	0.431g	0.431g	0.431g	0.431g	6300	0.431g

a. Dash denotes soil not present.

Soil/Rock Columns

1. Profile from 0 to 70 feet, with 30 feet of unimproved Zone IIA saprolite, 10 feet of Zone IIB saprolite, 15 feet of Zone III rock, and 15 feet of Zone III-IV rock.
2. Profile from 30 to 70 feet depth for foundation sitting on 10 feet of Zone IIB saprolite, 15 feet of Zone III weathered rock, and 15 feet of Zone III-IV rock.
3. Profile from 40 to 70 feet depth for foundation sitting on 15 feet of Zone III weathered rock and 15 feet of Zone III-IV rock.
4. Profile from 0 to 70 feet, with 30 feet of improved Zone IIA saprolite, 10 feet of Zone IIB saprolite, 55 feet of Zone III weathered rock, and 15 feet of Zone III-IV rock.

Table 2.5-47 Allowable Bearing Capacity Values

Zone	Allowable Bearing Capacity, ksf
IIB	8
III	16
III-IV	80[a]
IV	160[a]

Note: The above values include a factor of safety against bearing failure of at least 3.
Minimum assumed foundation width is 5 feet. Minimum assumed foundation depth is 3 feet.

a. The new containment (reactor) buildings would be founded on Zone III-IV or Zone IV material.

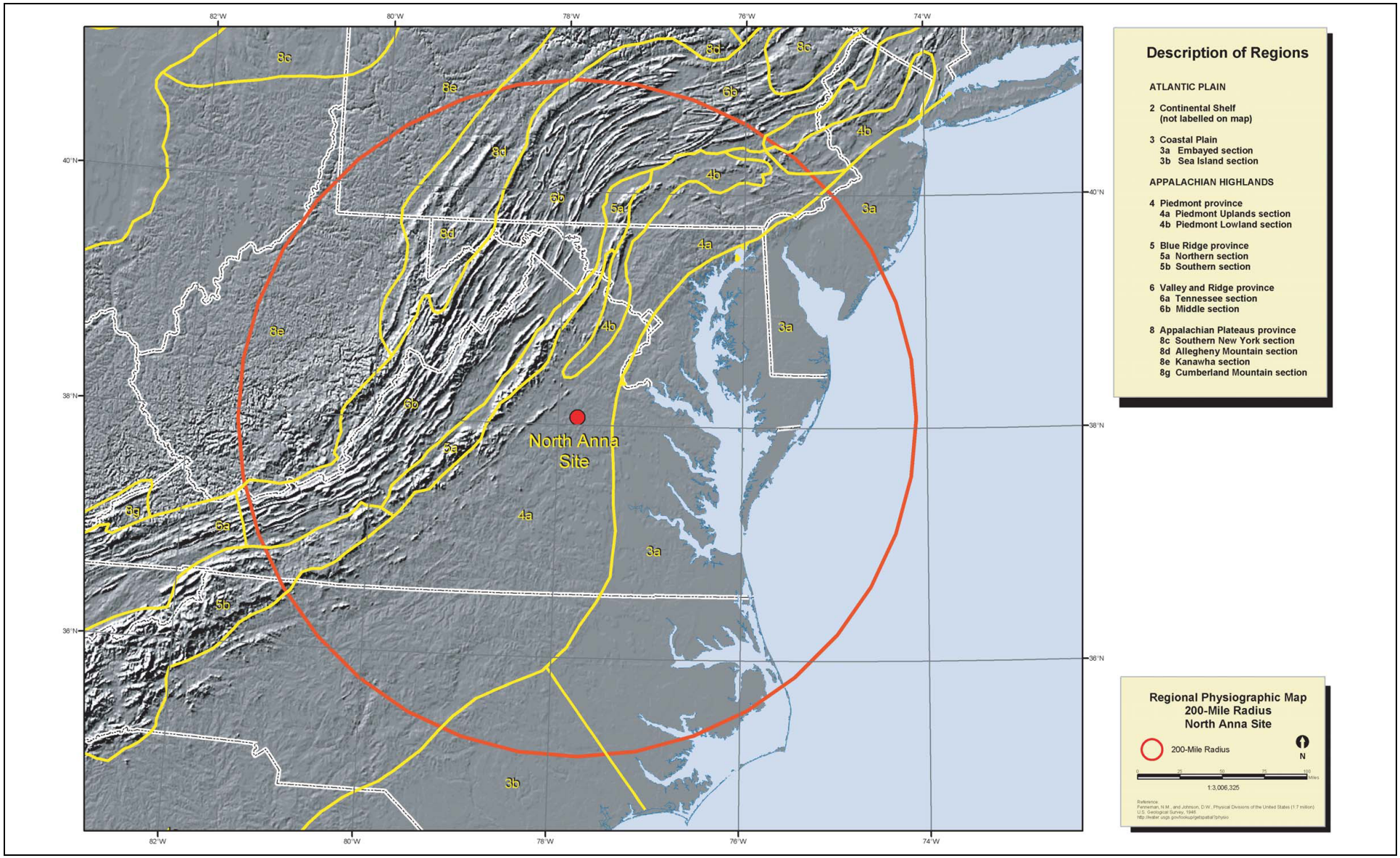
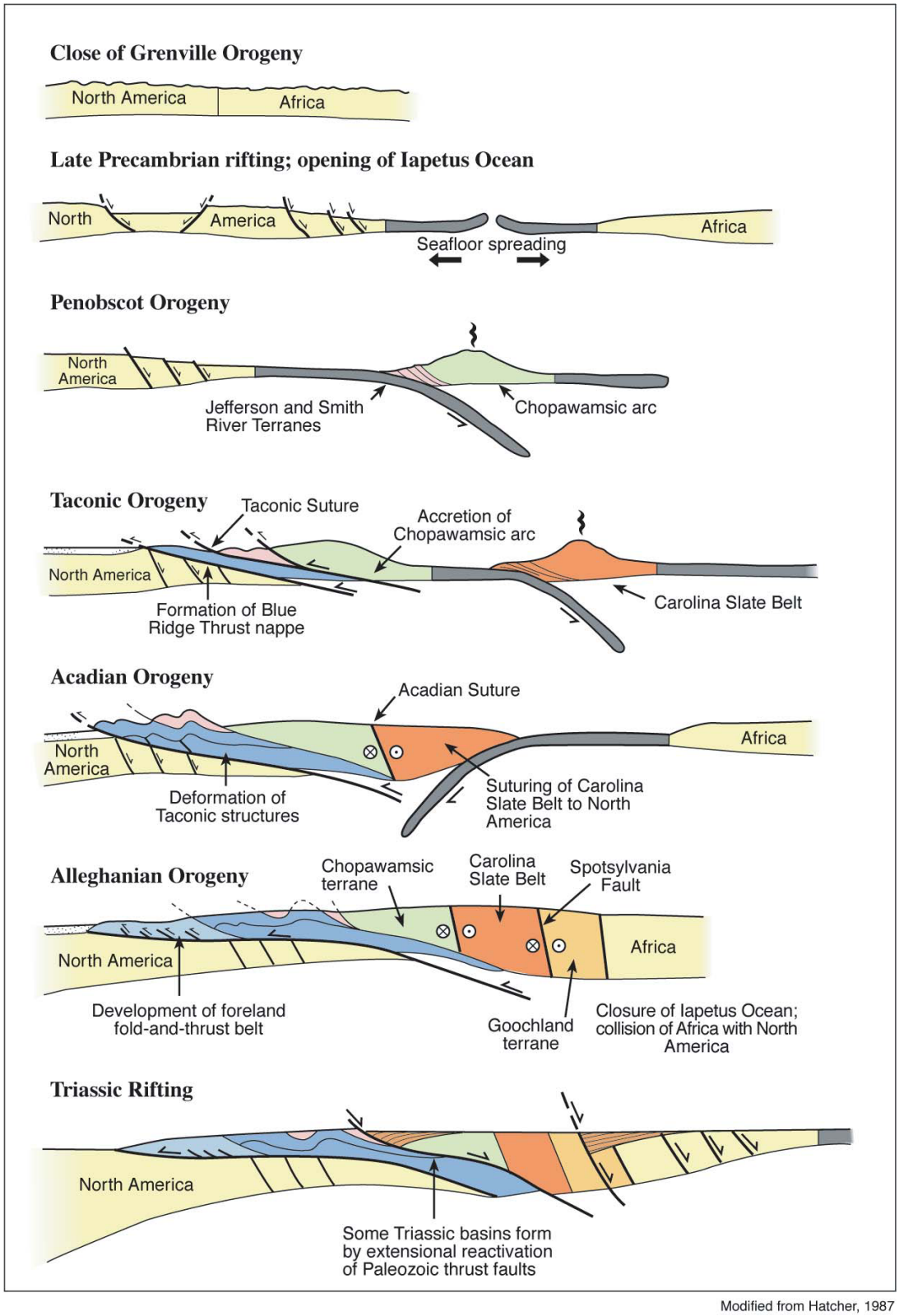


Figure 2.5-1 Regional Physiographic Map (200-Mile Radius)



Modified from Hatcher, 1987

Figure 2.5-2 Evolution of the Appalachian Orogen (after Hatcher, 1987)

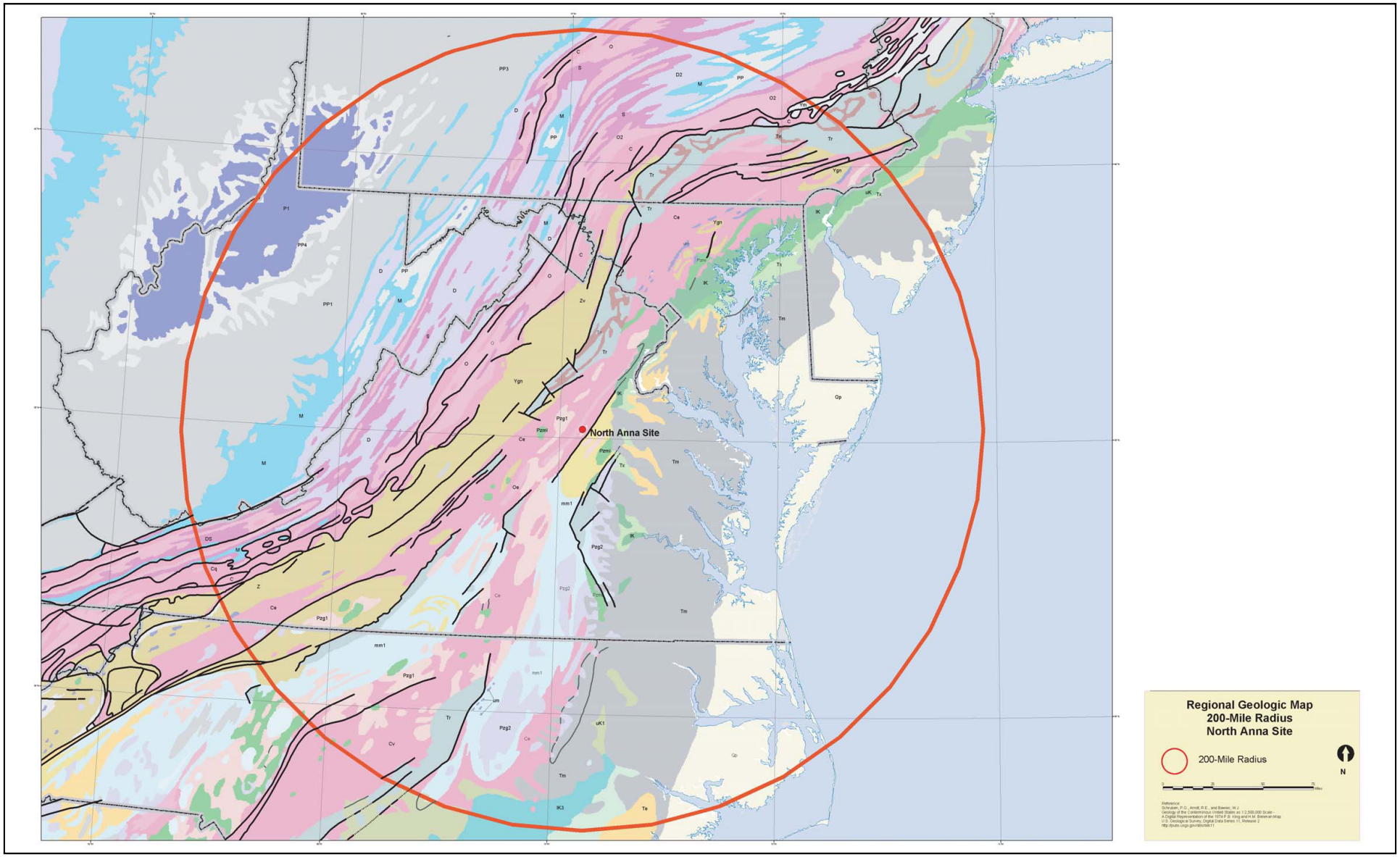


Figure 2.5-3 Regional Geologic Map (200-Mile Radius) (Sheet 1 of 2)

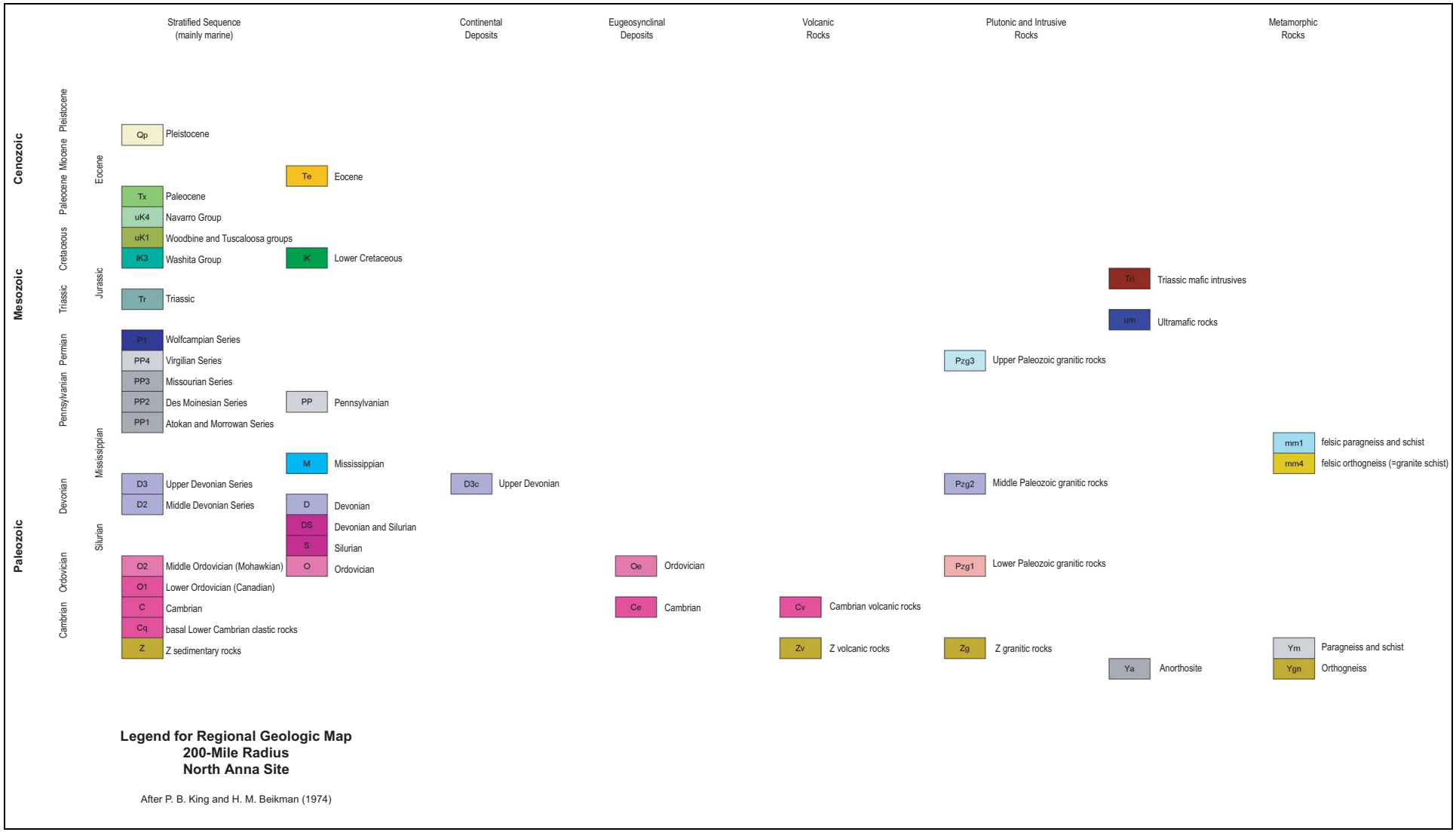


Figure 2.5-3 Regional Geologic Map (200-Mile Radius) (Sheet 2 of 2)

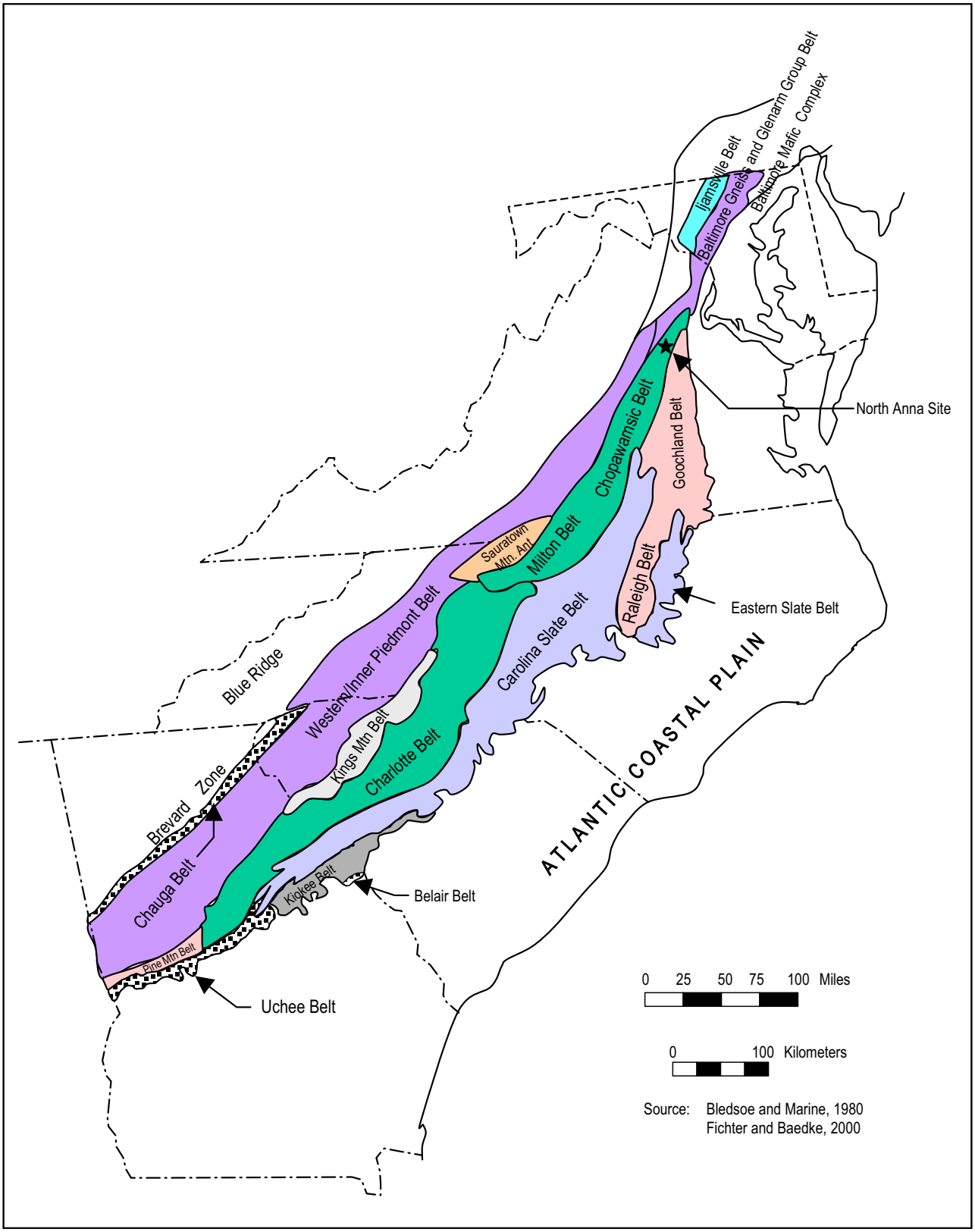


Figure 2.5-4 Lithotectonic Belts of the Piedmont Province

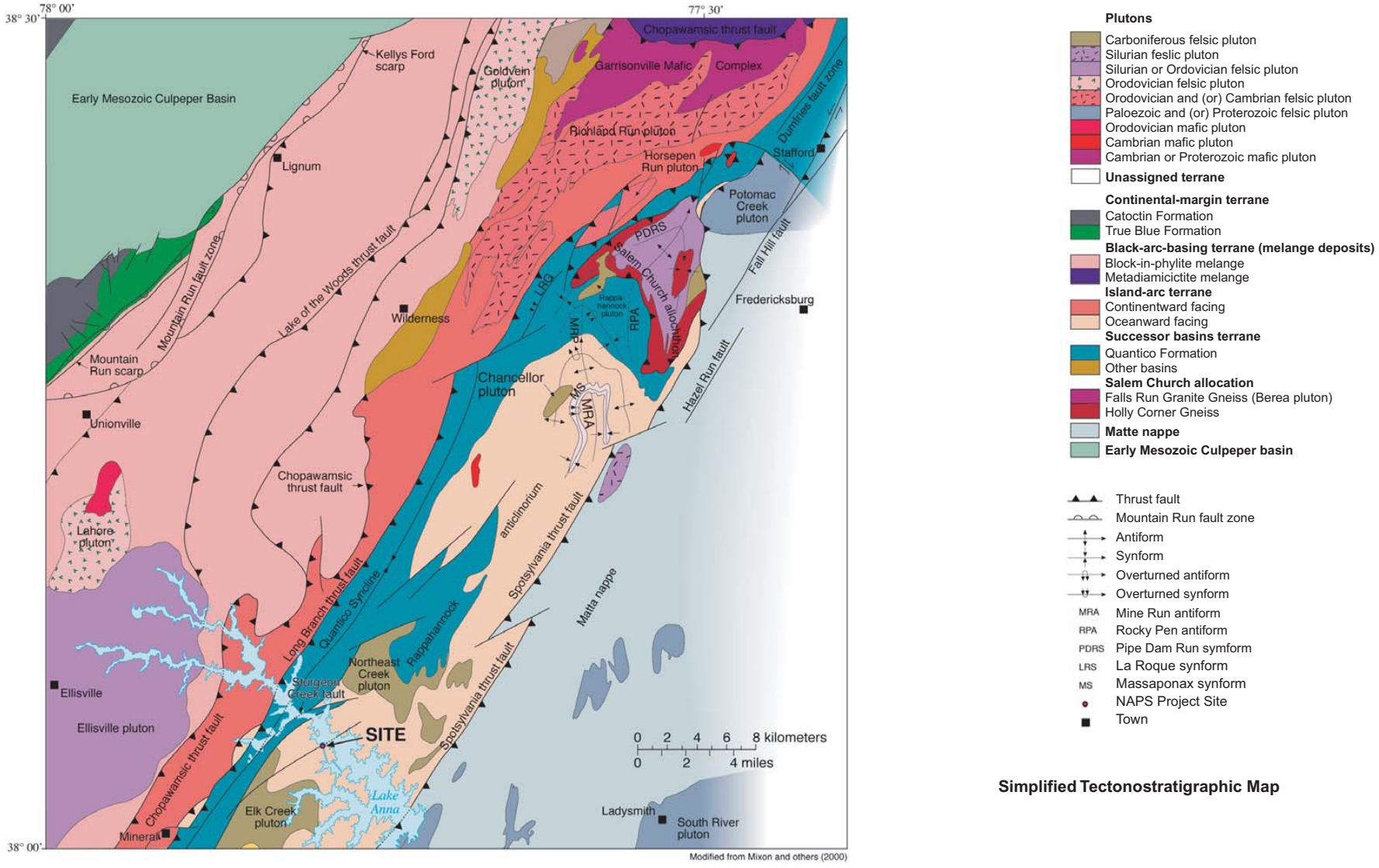


Figure 2.5-5 Simplified Tectonostratigraphic Map

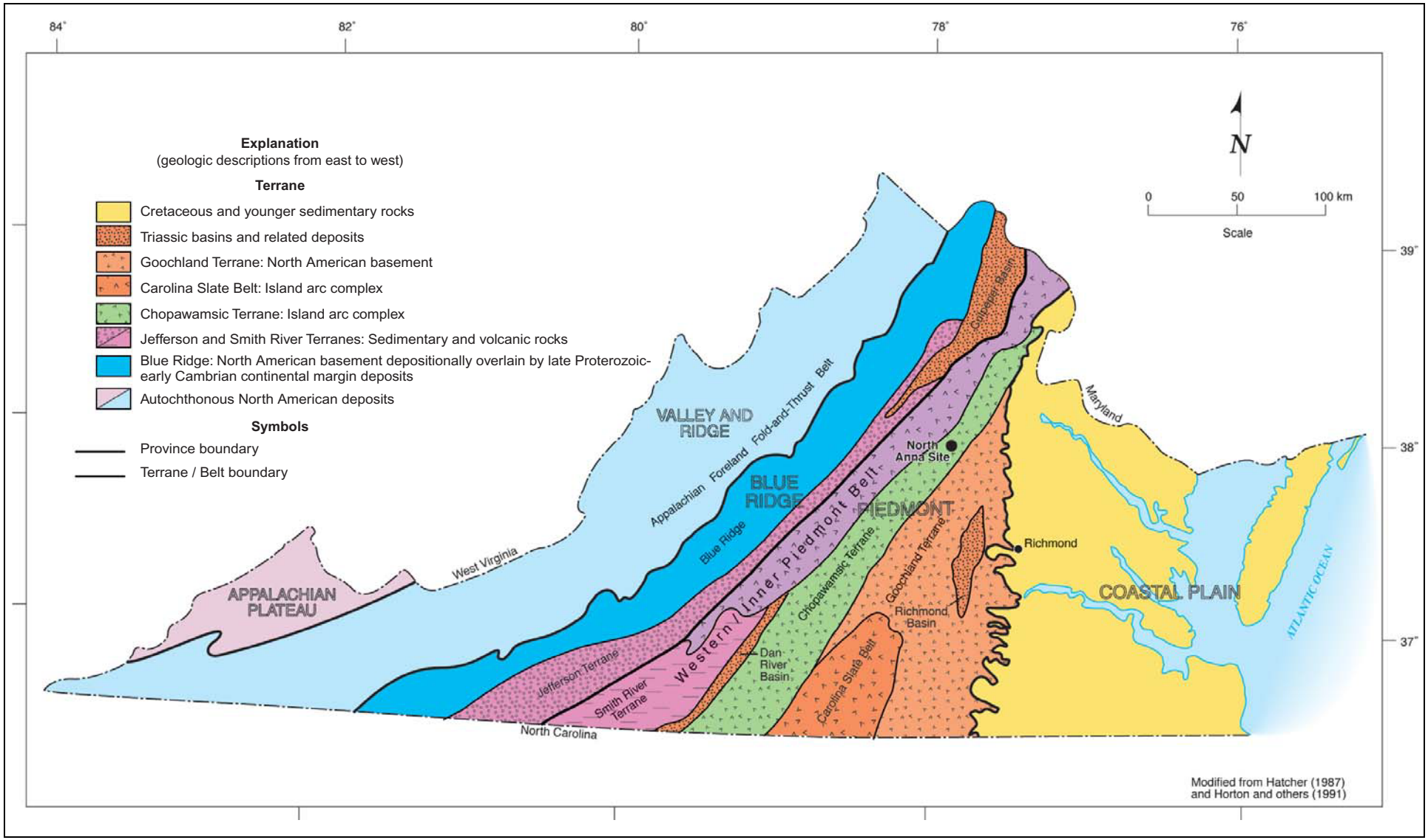


Figure 2.5-6 Simplified Tectonic Map of Virginia

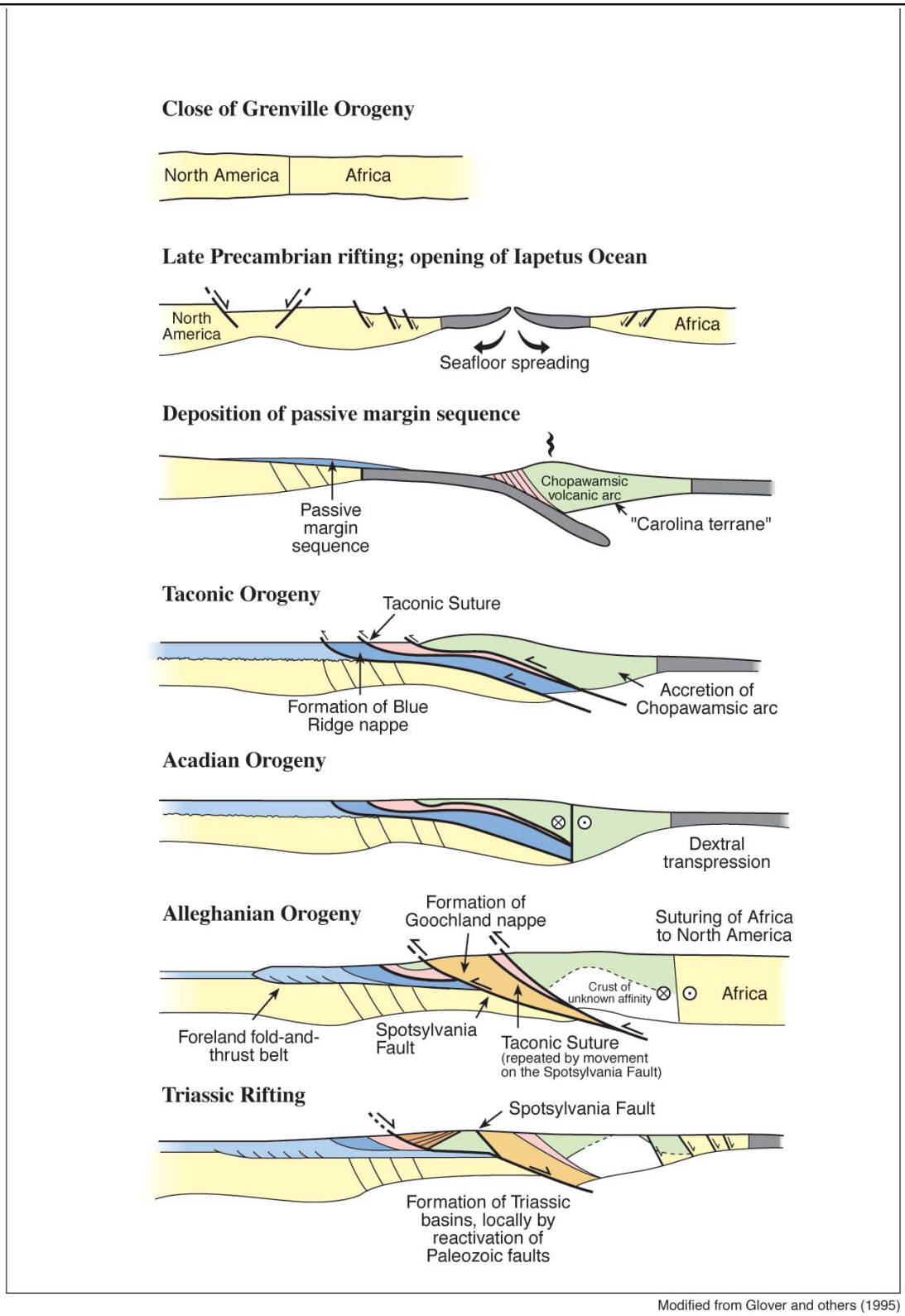


Figure 2.5-7 Evolution of the Appalachian Orogen (after Glover and others, 1995)

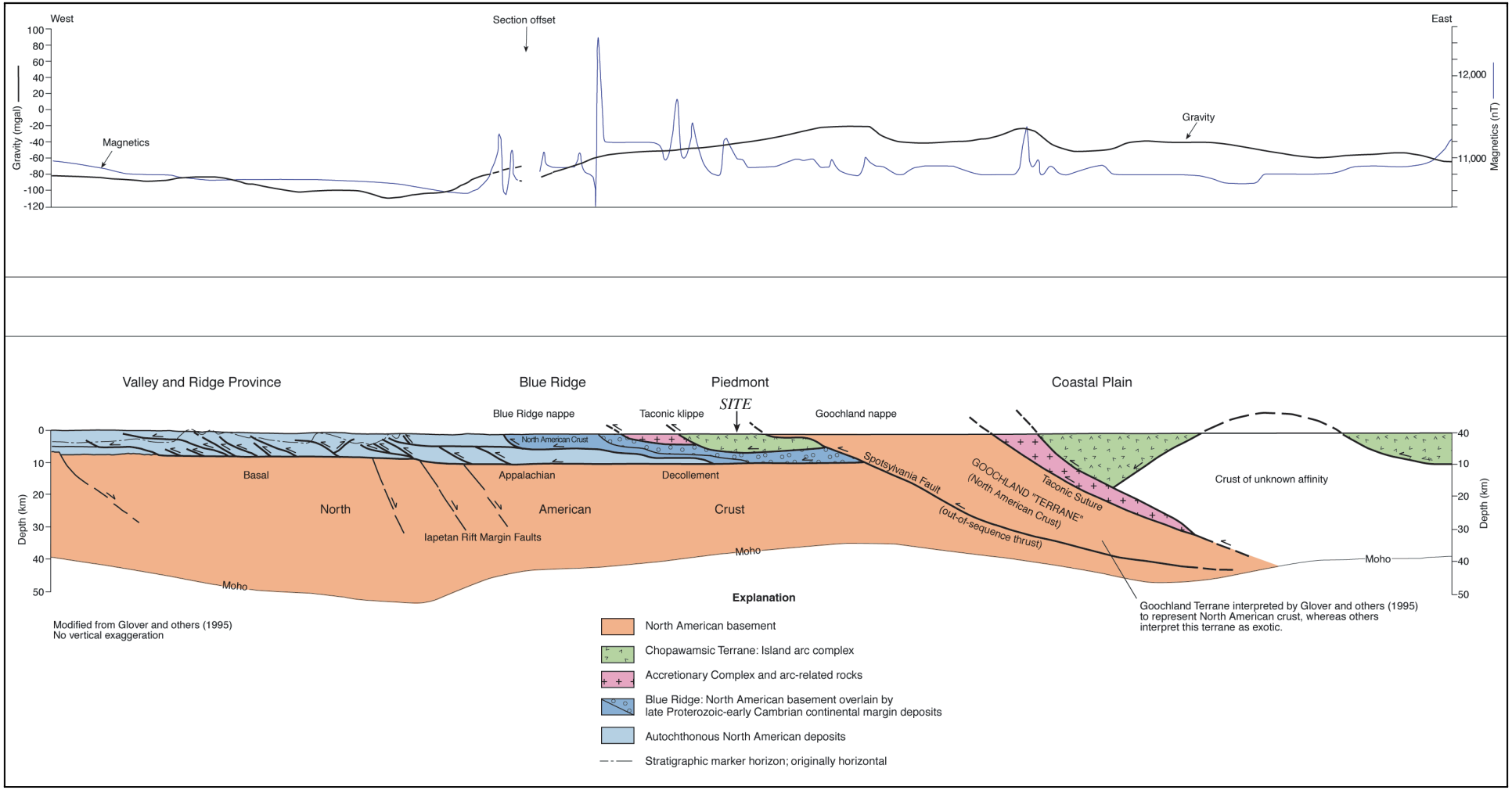


Figure 2.5-8 Crustal Section Through Appalachian Orogen (200-mile radius)

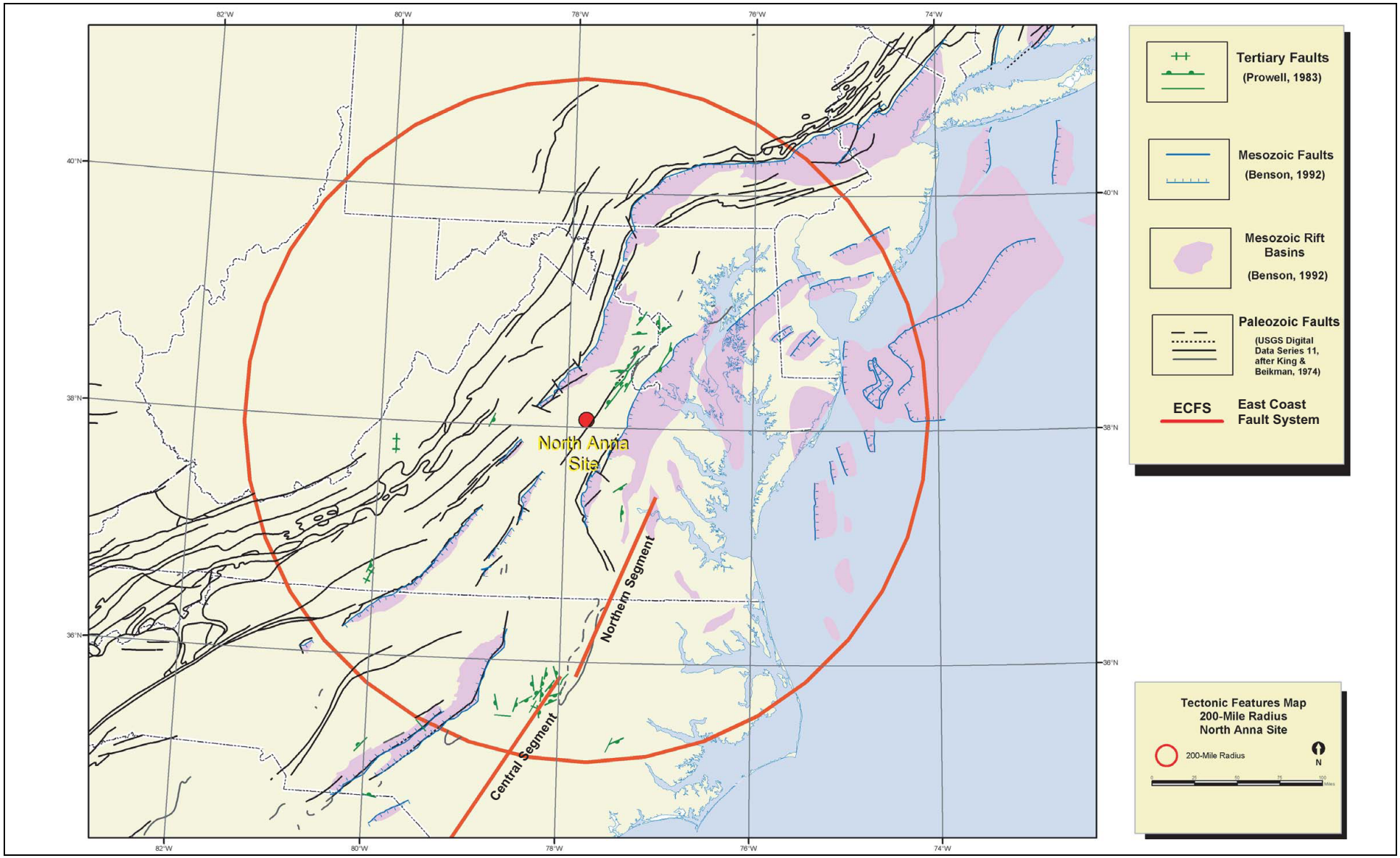


Figure 2.5-9 Tectonic Features Map (200-mile radius)

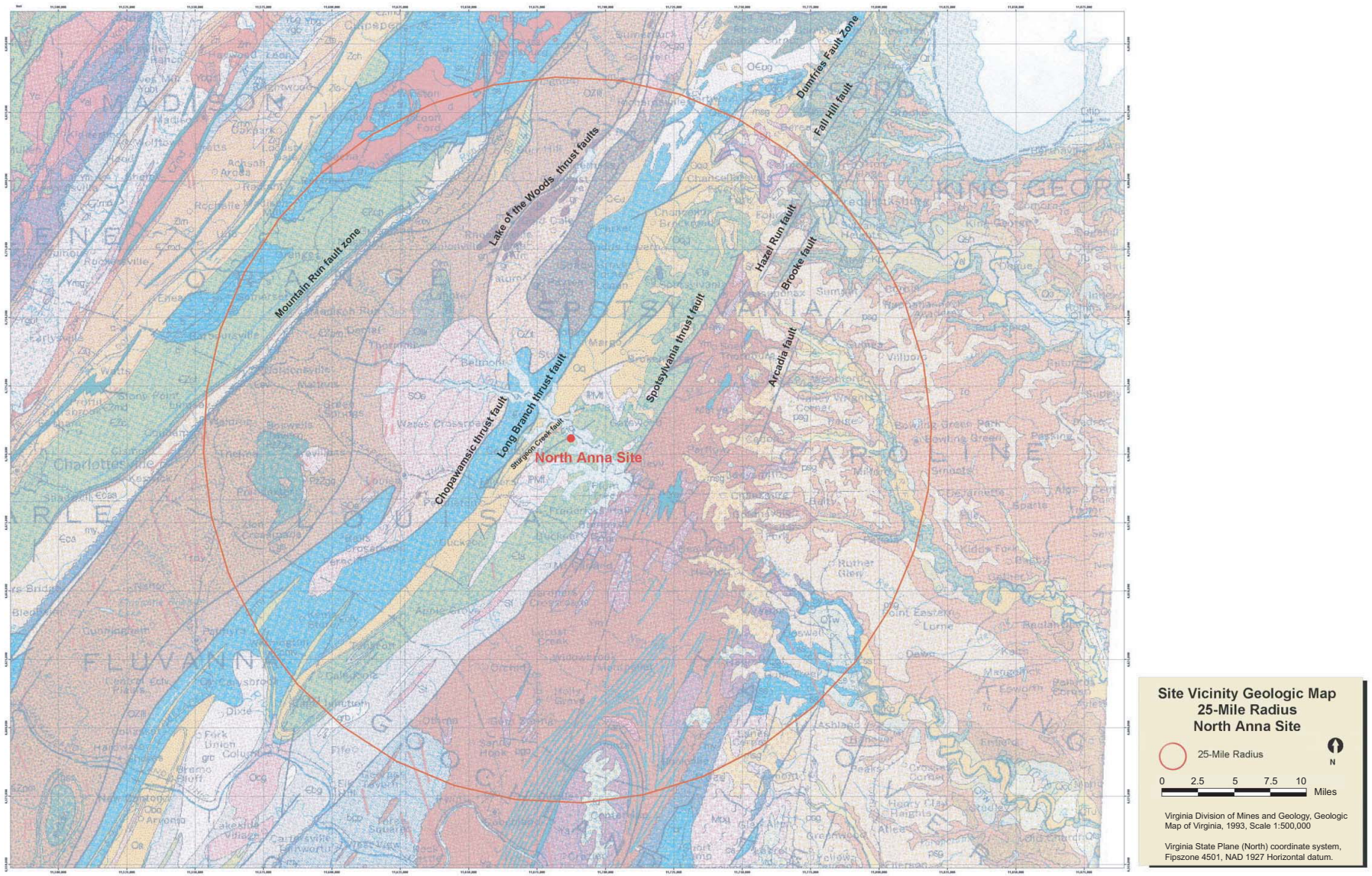


Figure 2.5-10 Site Vicinity Geologic Map (25-Mile Radius) (Sheet 1 of 2)

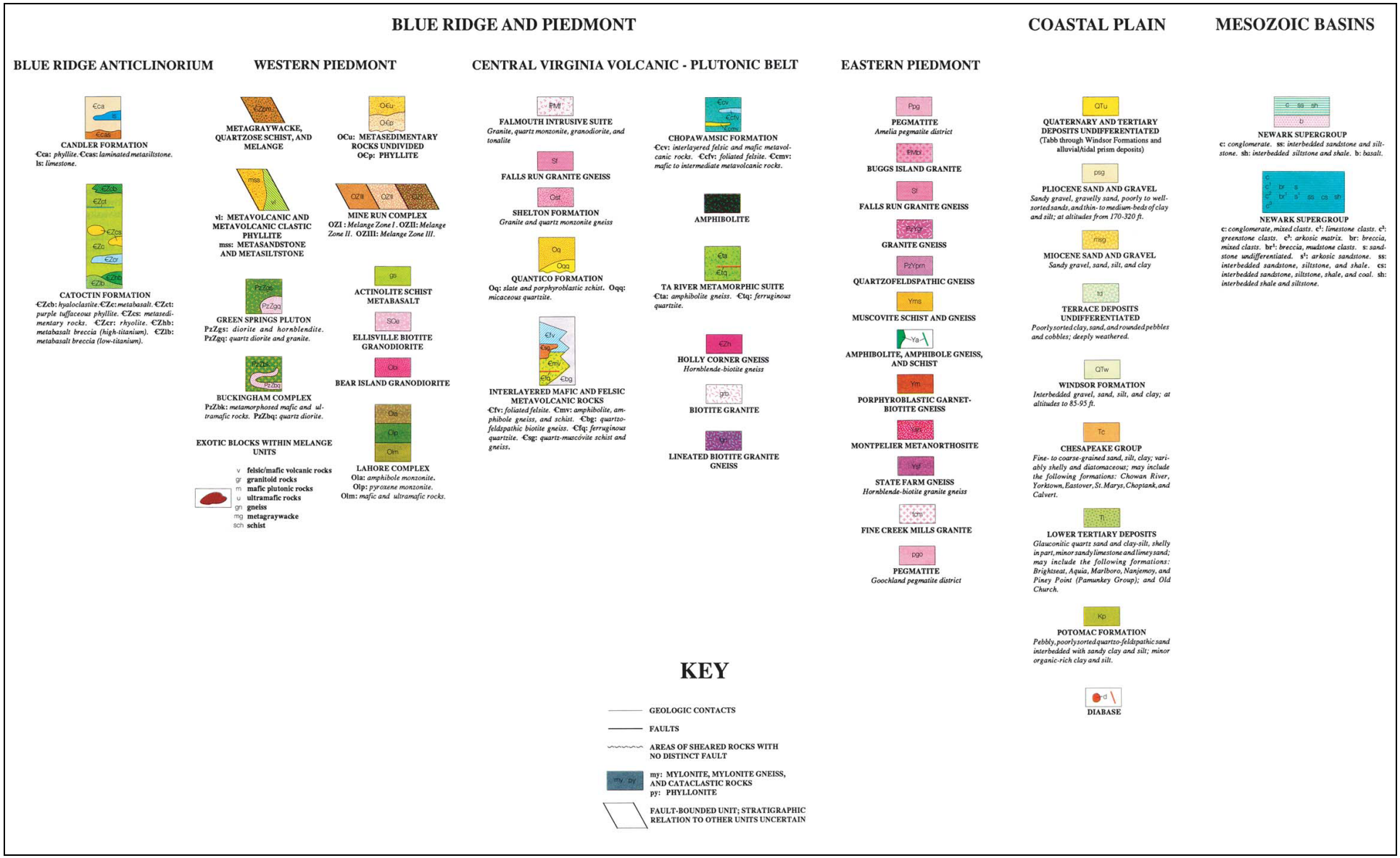


Figure 2.5-10 Site Vicinity Geologic Map (25-Mile Radius) (Sheet 2 of 2)

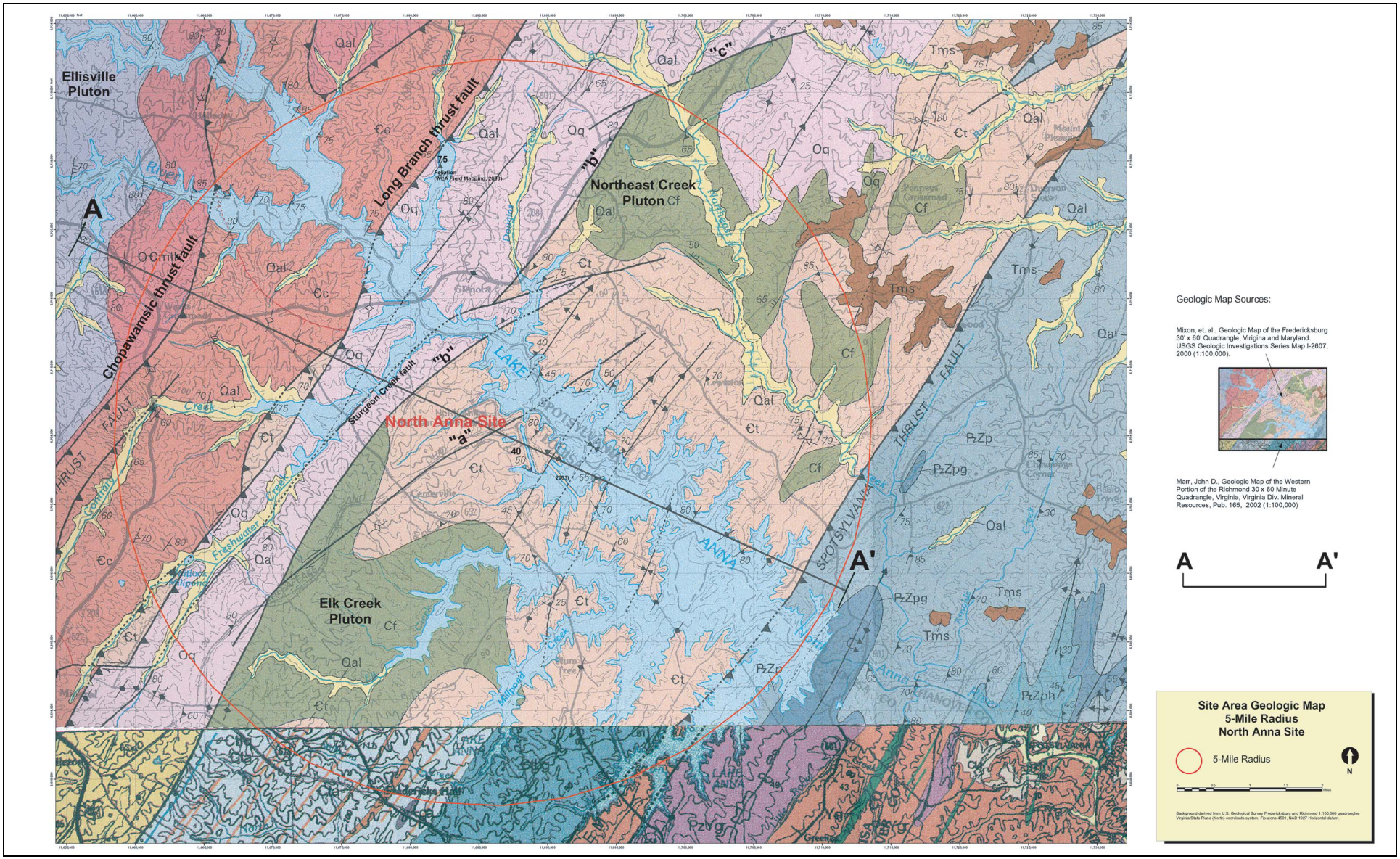


Figure 2.5-11 Site Area Geologic Map (5-Mile Radius) (Sheet 1 of 2)

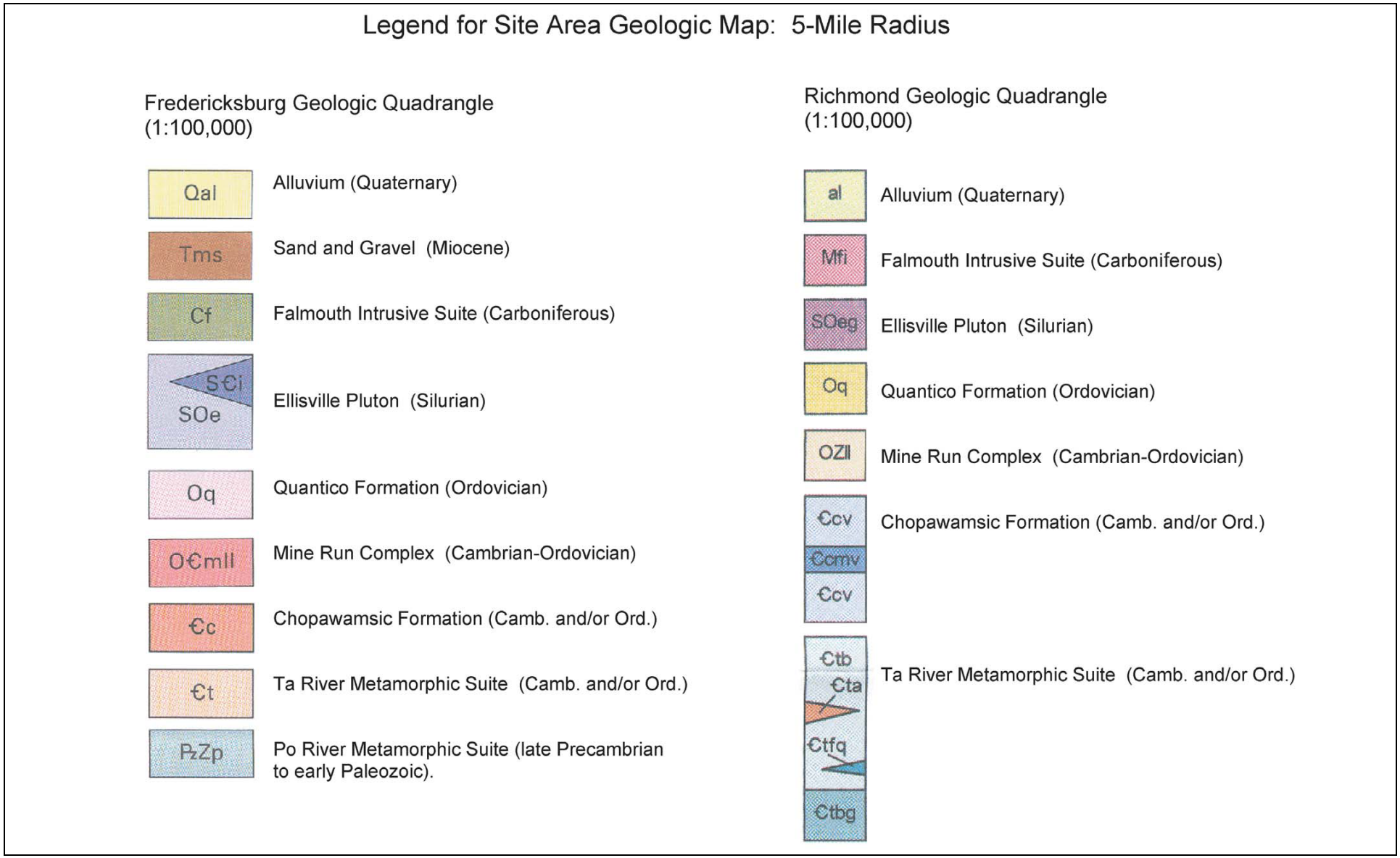


Figure 2.5-11 Site Area Geologic Map (5-Mile Radius) (Sheet 2 of 2)

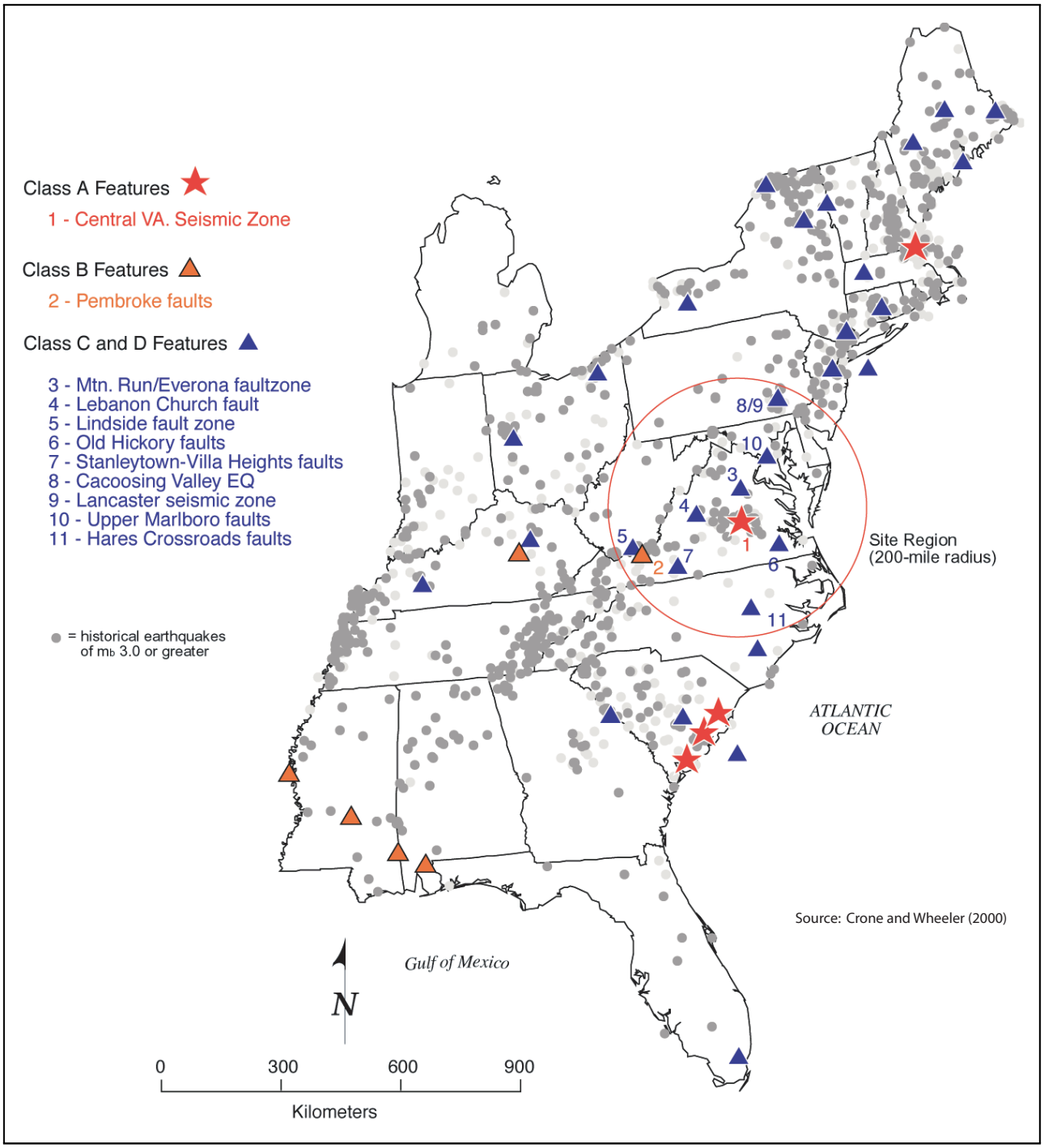


Figure 2.5-12 Quaternary Features Map

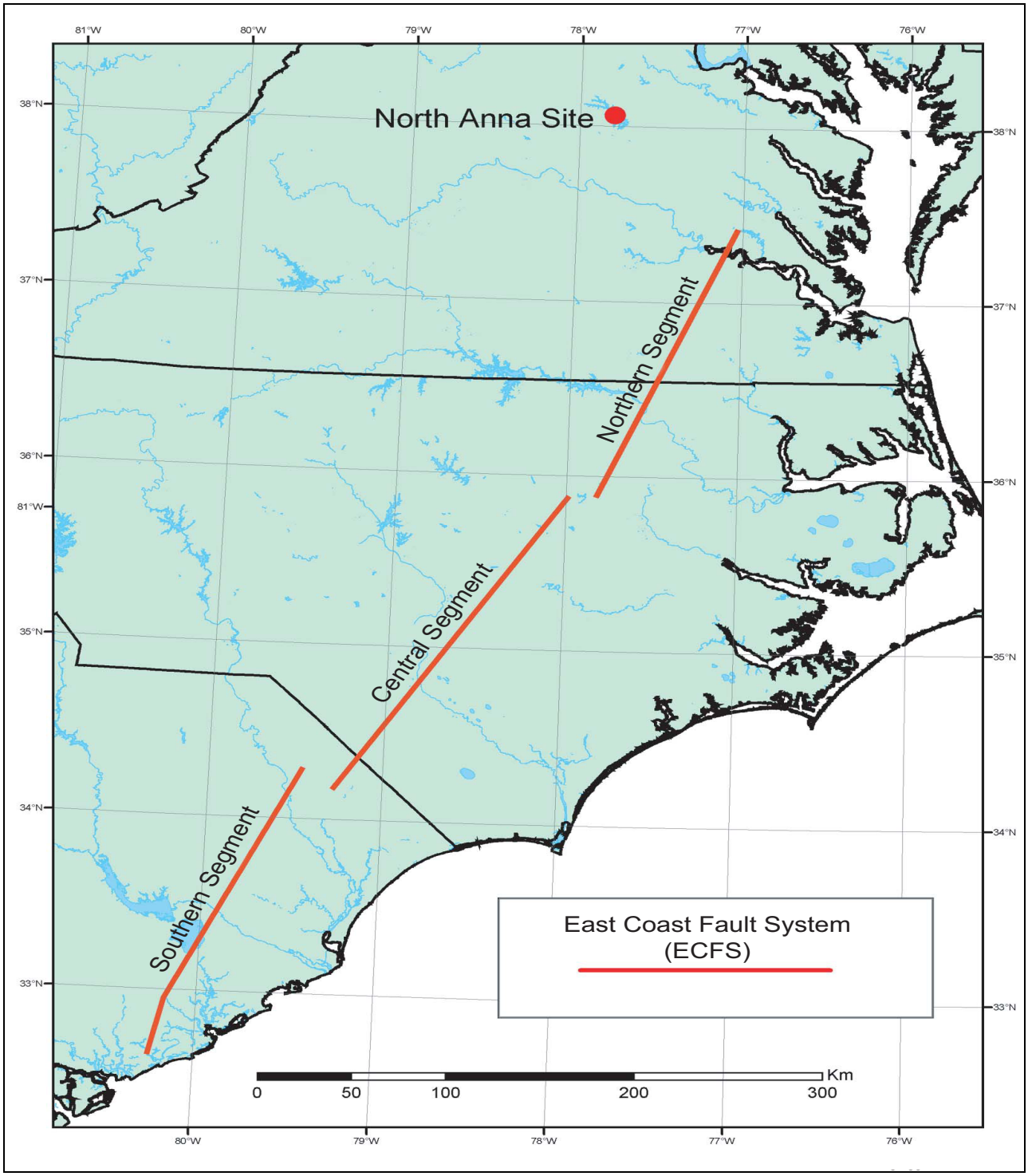


Figure 2.5-13 Northern, Central, and Southern Segments of the East Coast Fault System

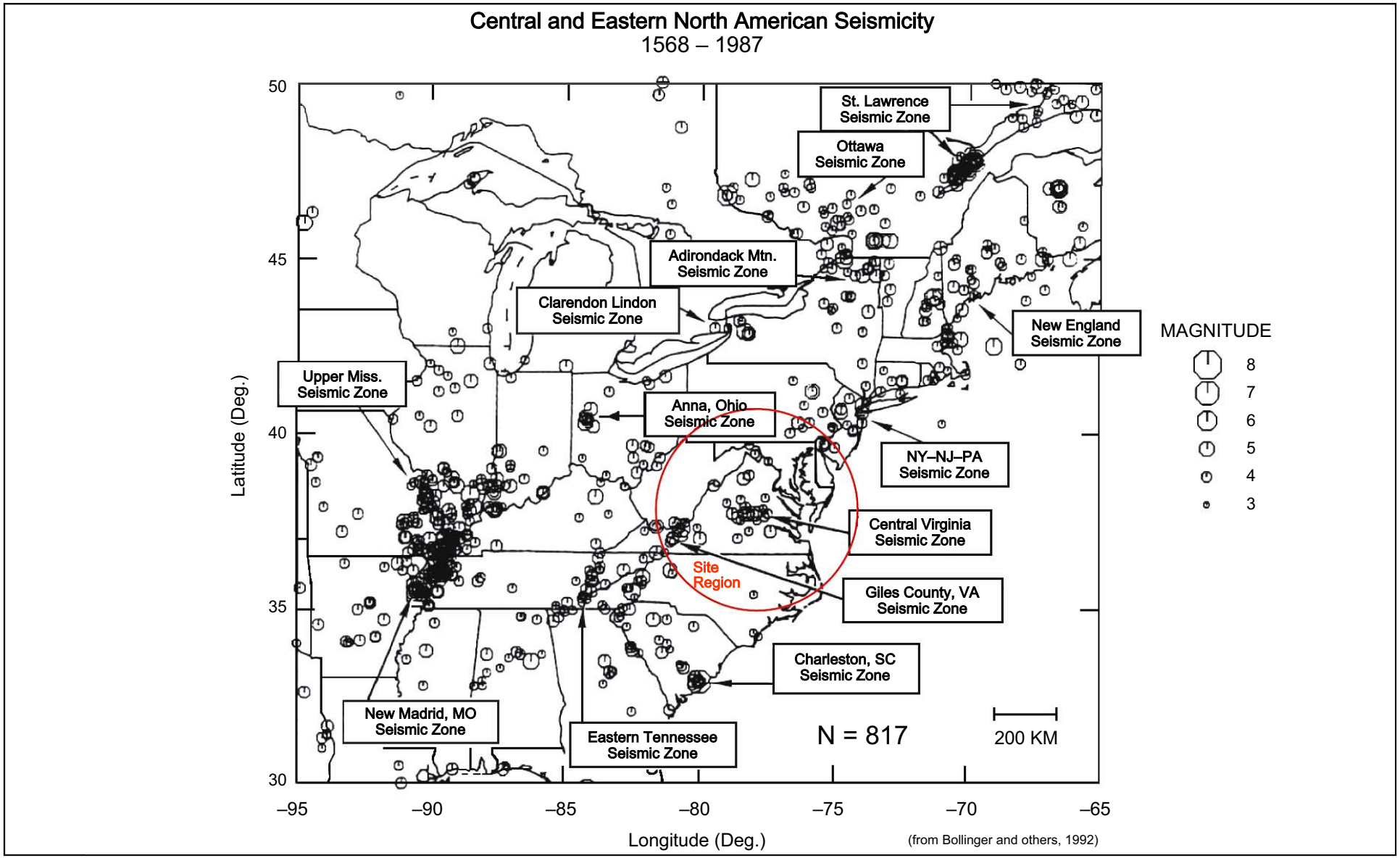


Figure 2.5-14 Seismic Source Zones and Seismicity in Central and Eastern North America

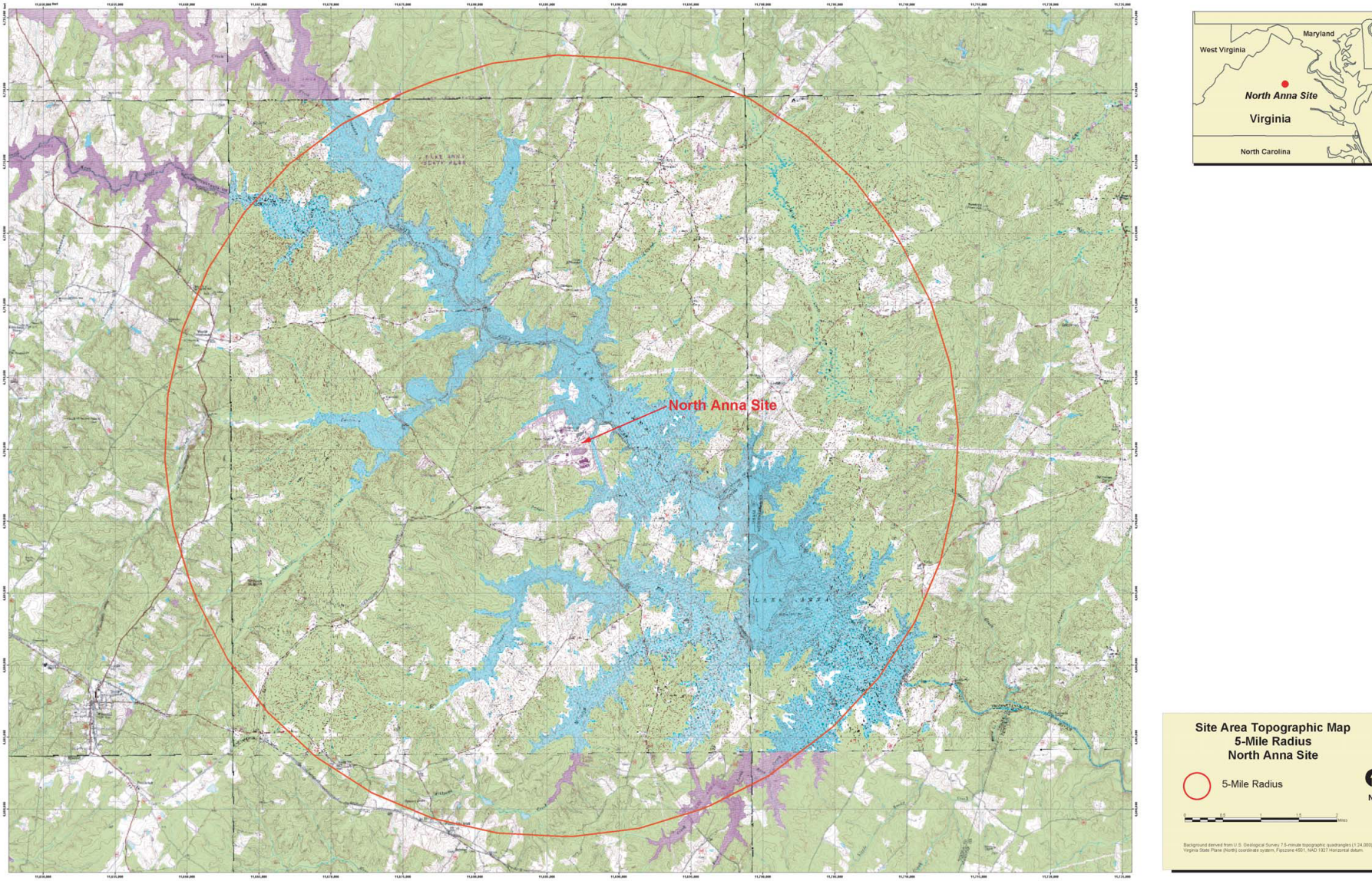


Figure 2.5-15 Site Area Topographic Map (5-Mile Radius)

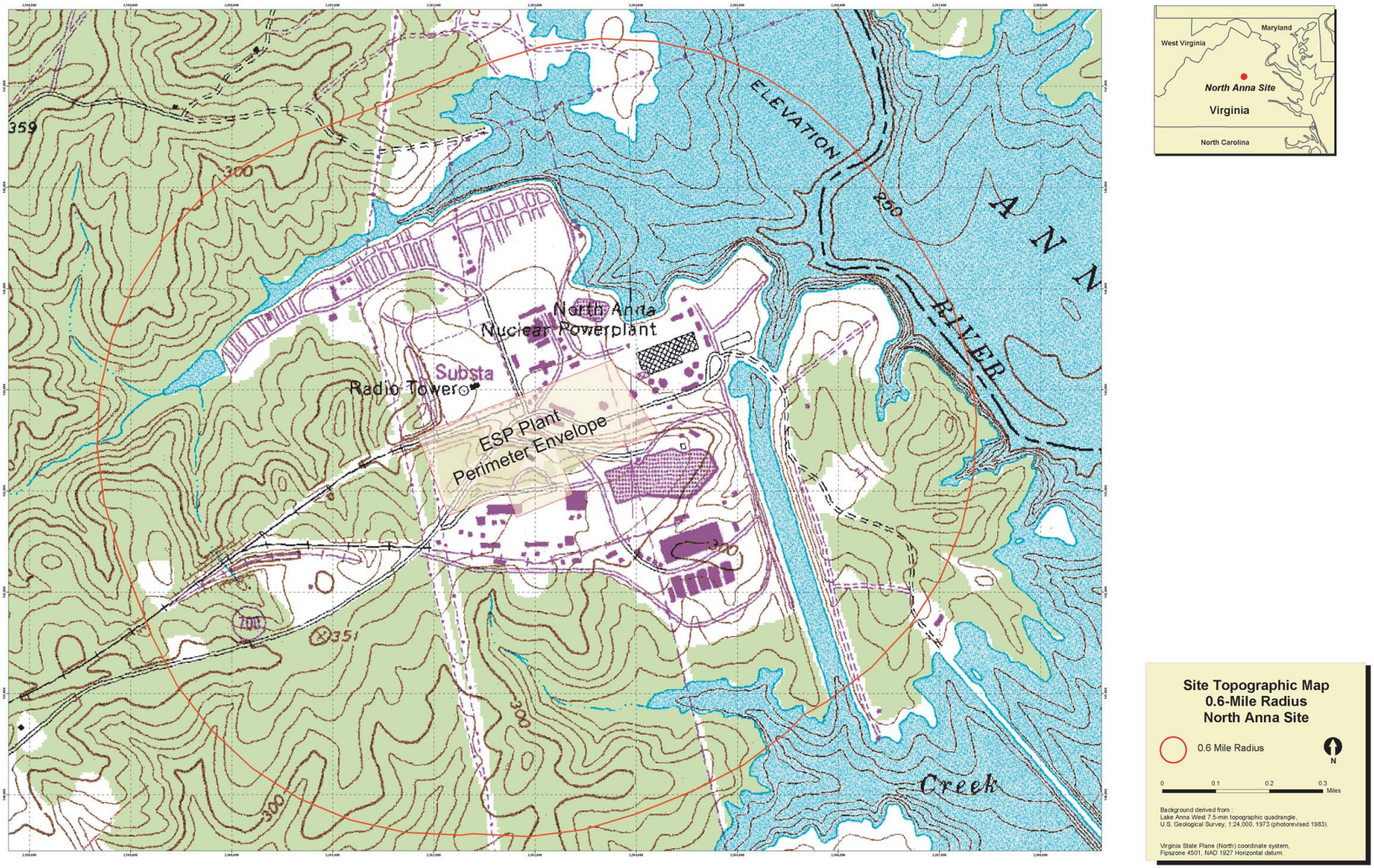


Figure 2.5-16 Site Topographic Map (0.6-Mile Radius)

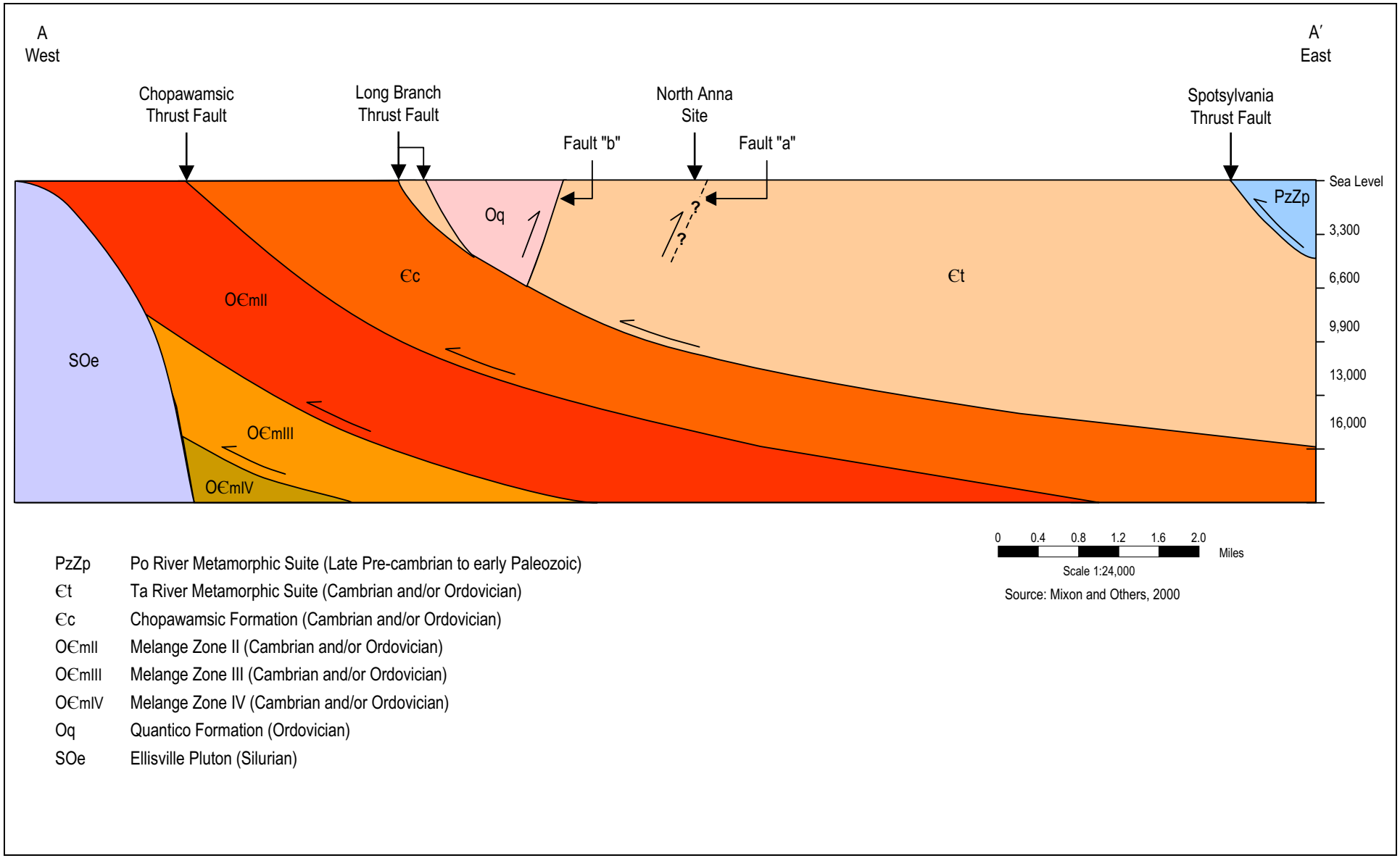


Figure 2.5-17 Site Area Geologic Cross Section A-A' (5-Mile Radius)

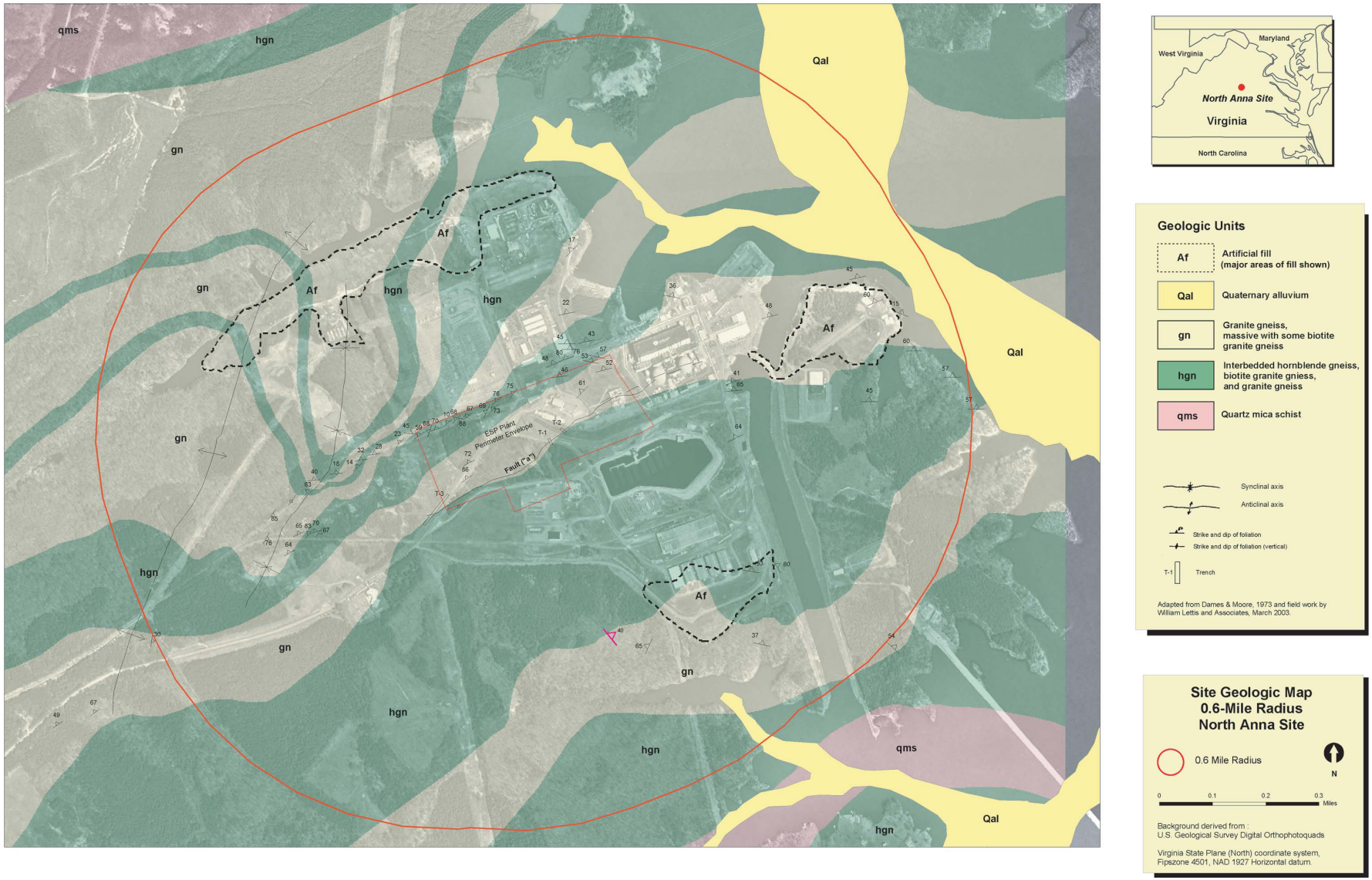


Figure 2.5-18 Site Geologic Map (0.6-Mile Radius)

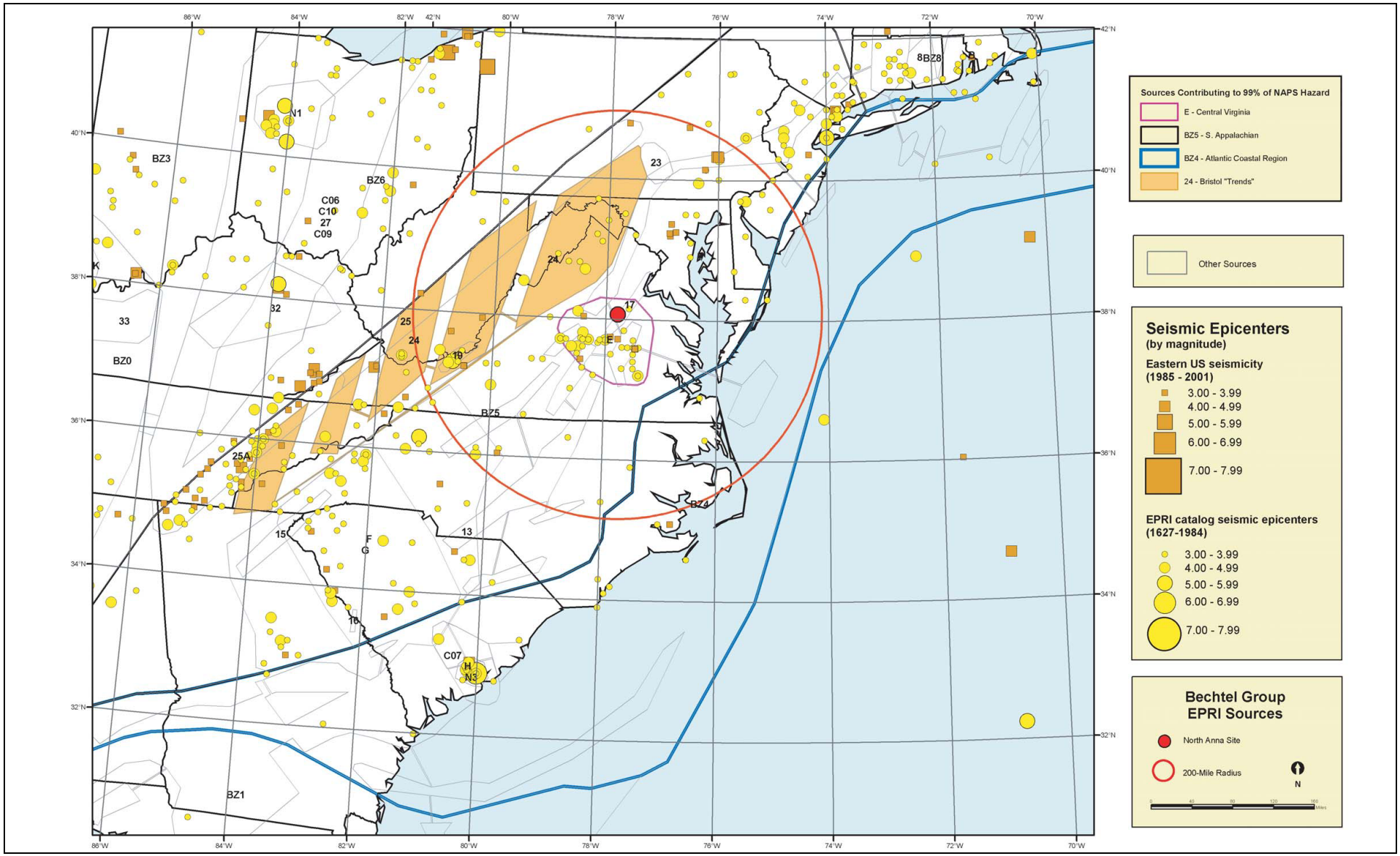


Figure 2.5-19 Bechtel Group EPRI Sources

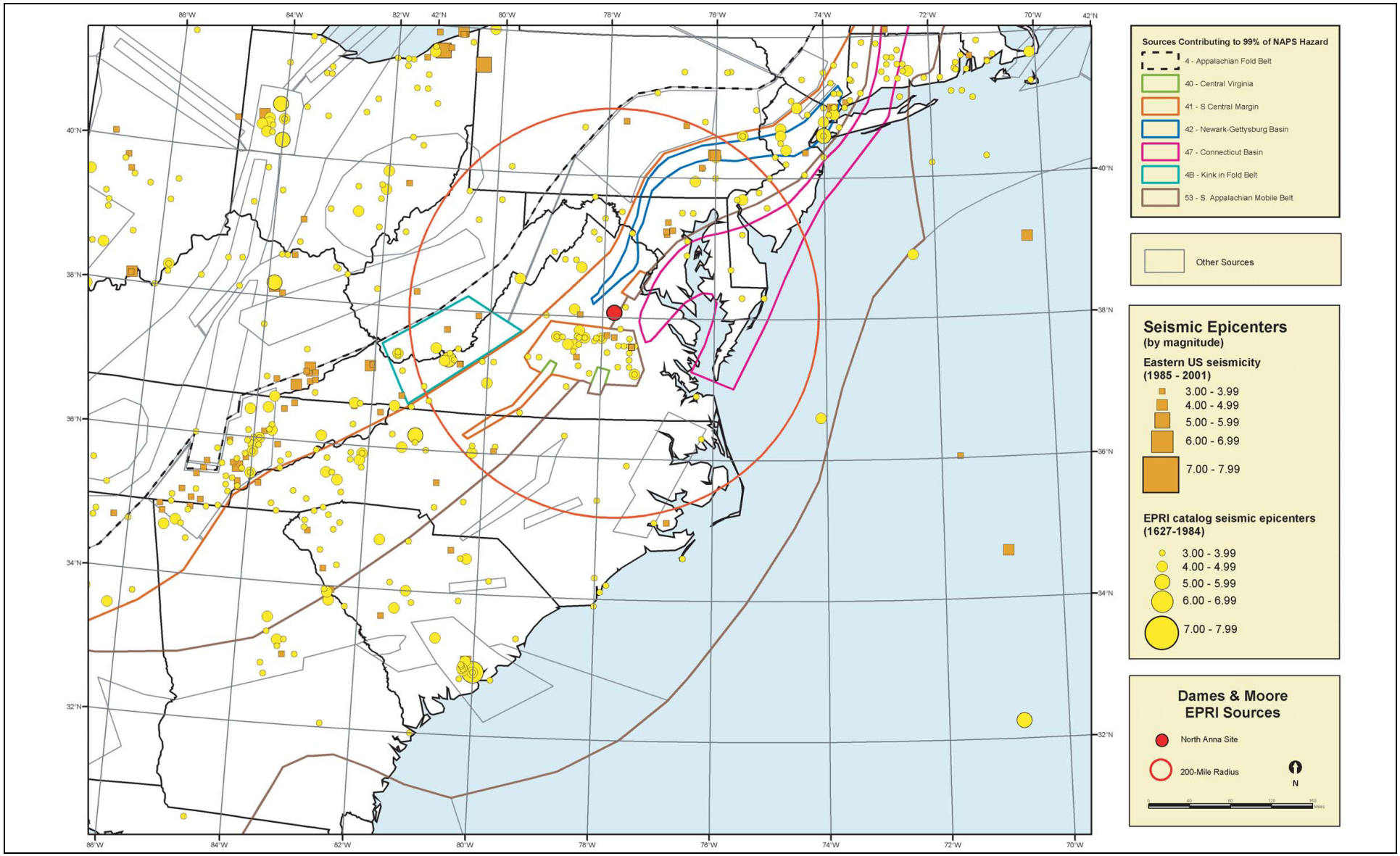


Figure 2.5-20 Dames & Moore EPRI Sources

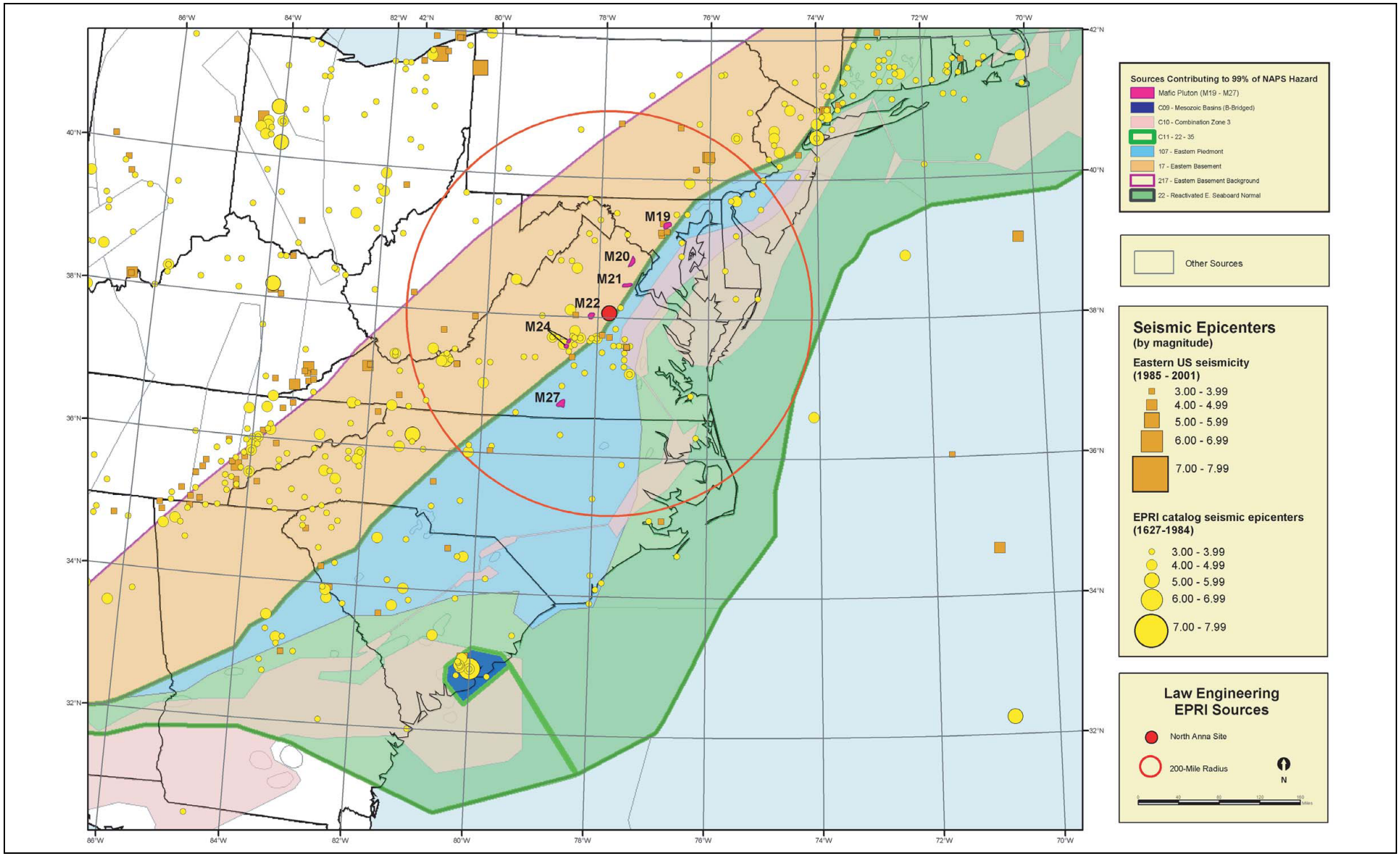


Figure 2.5-21 Law Engineering EPRI Sources

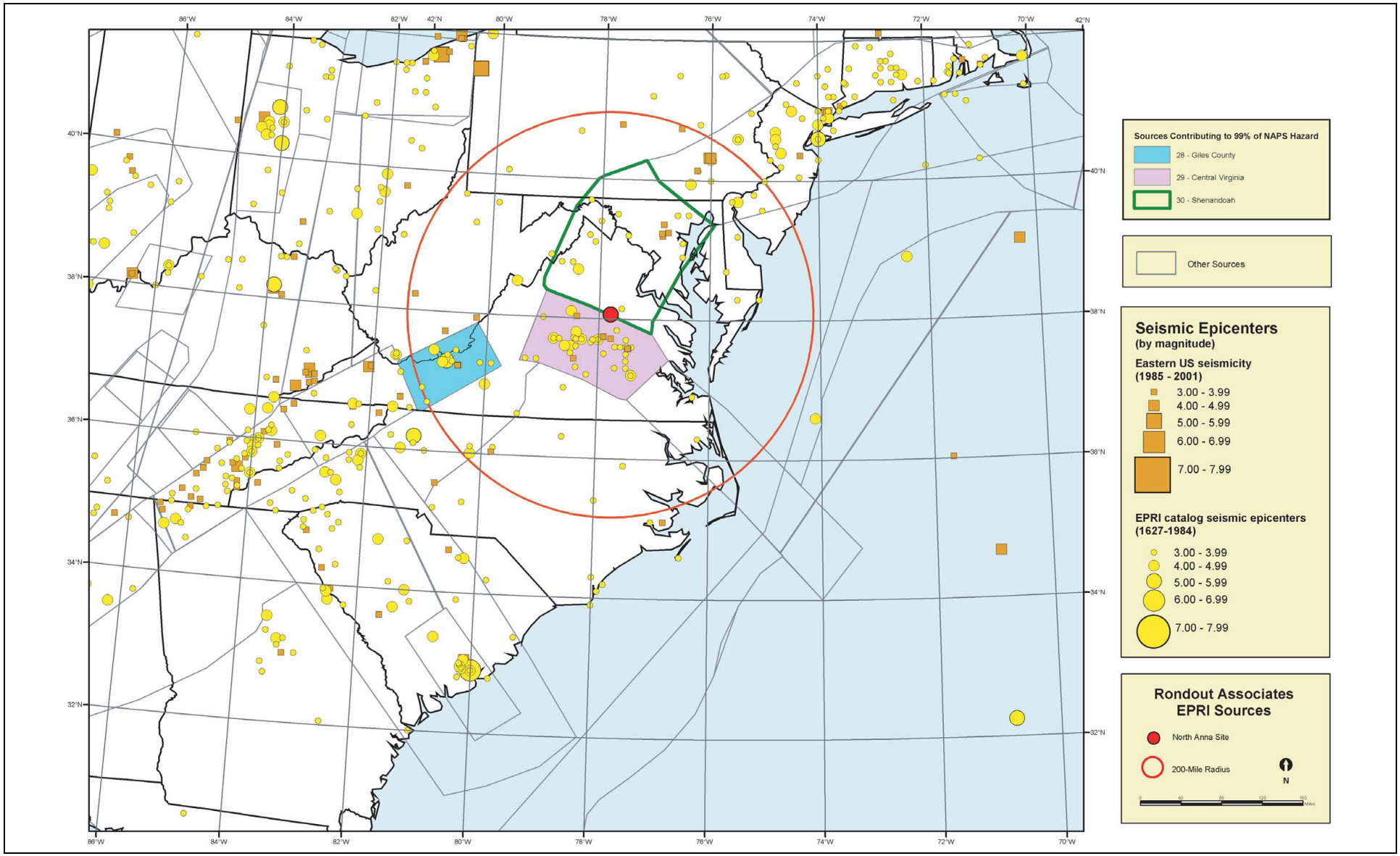


Figure 2.5-22 Rondout Associates EPRI Sources

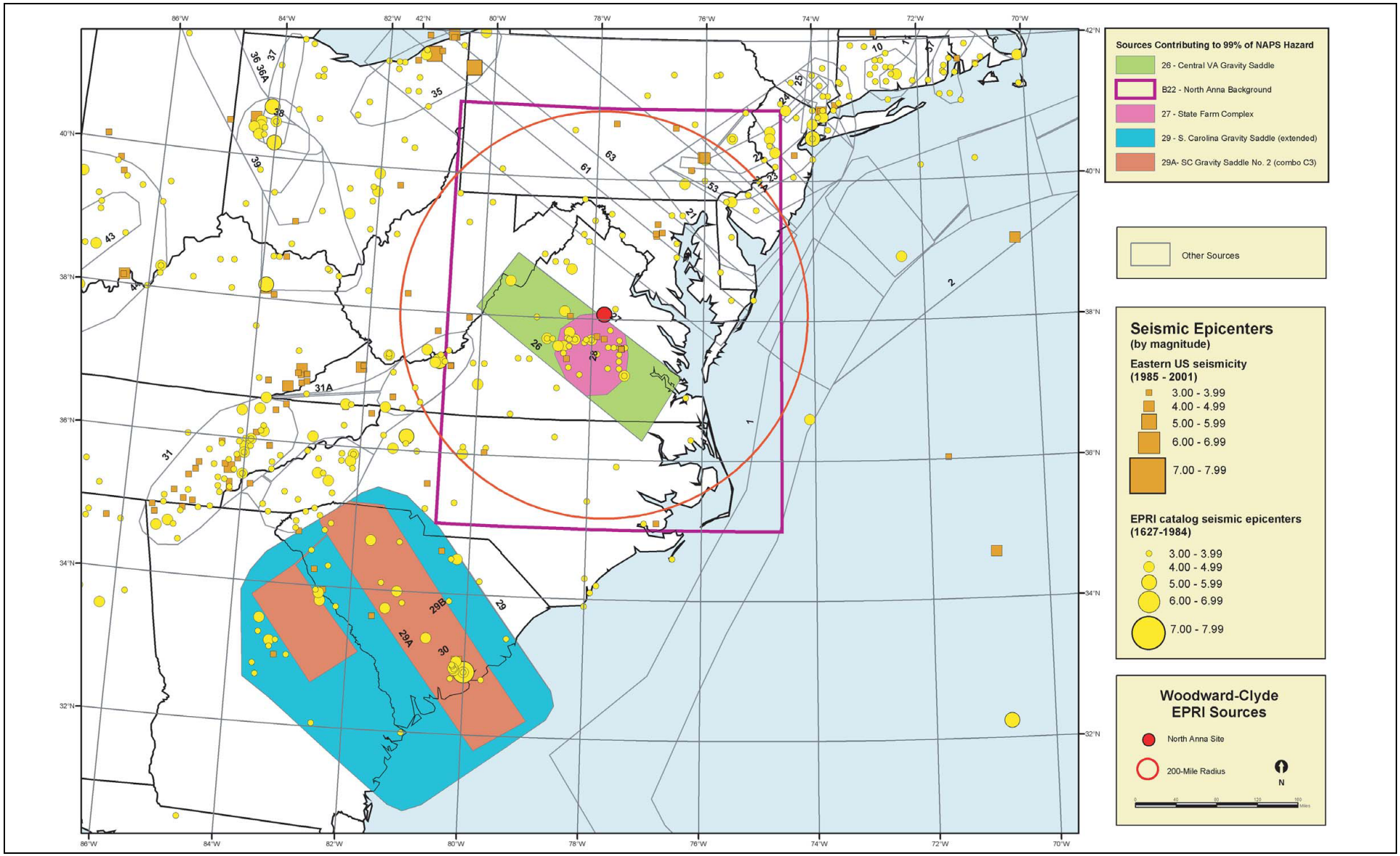


Figure 2.5-23 Woodward-Clyde EPRI Sources

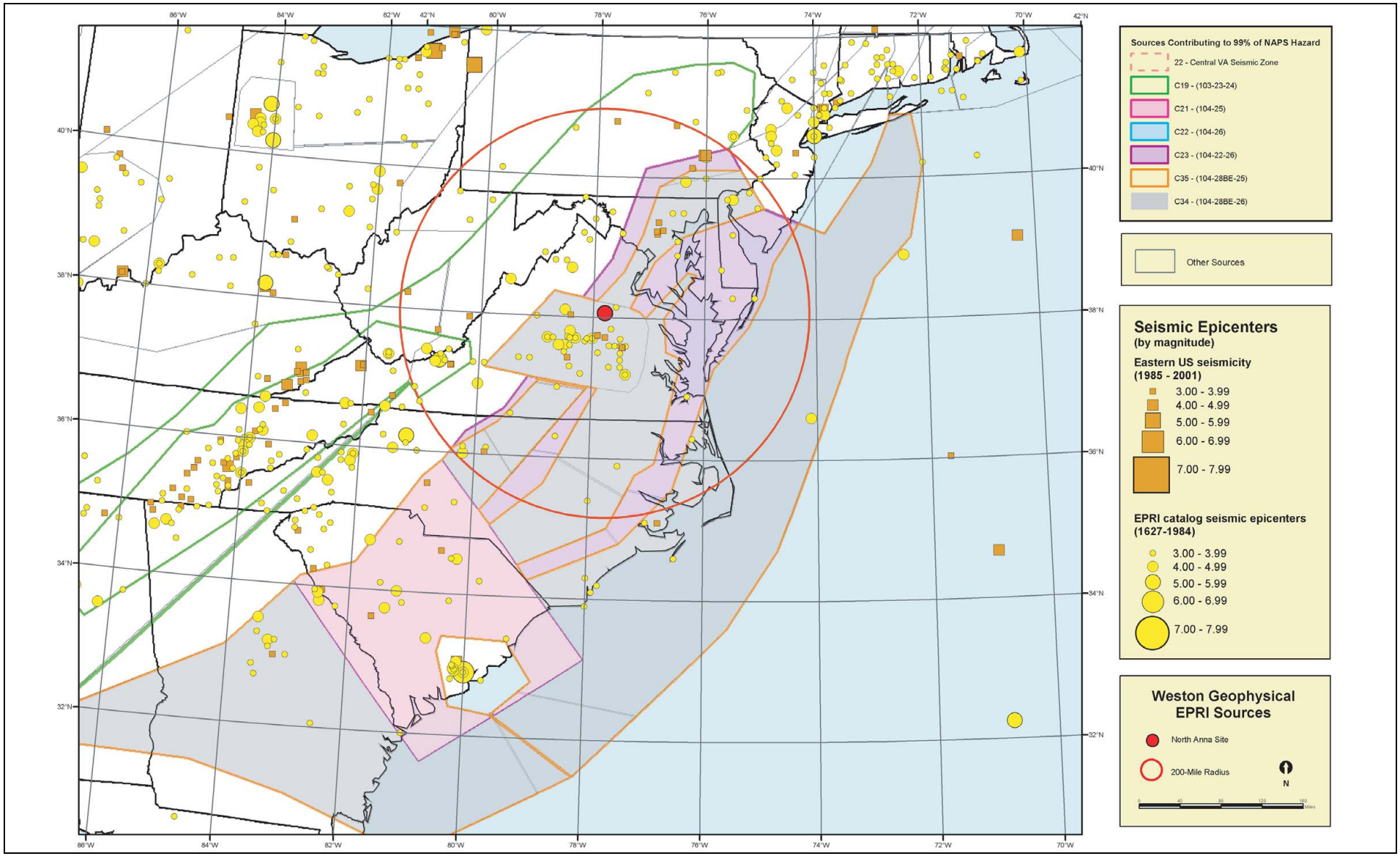


Figure 2.5-24 Weston EPRI Sources

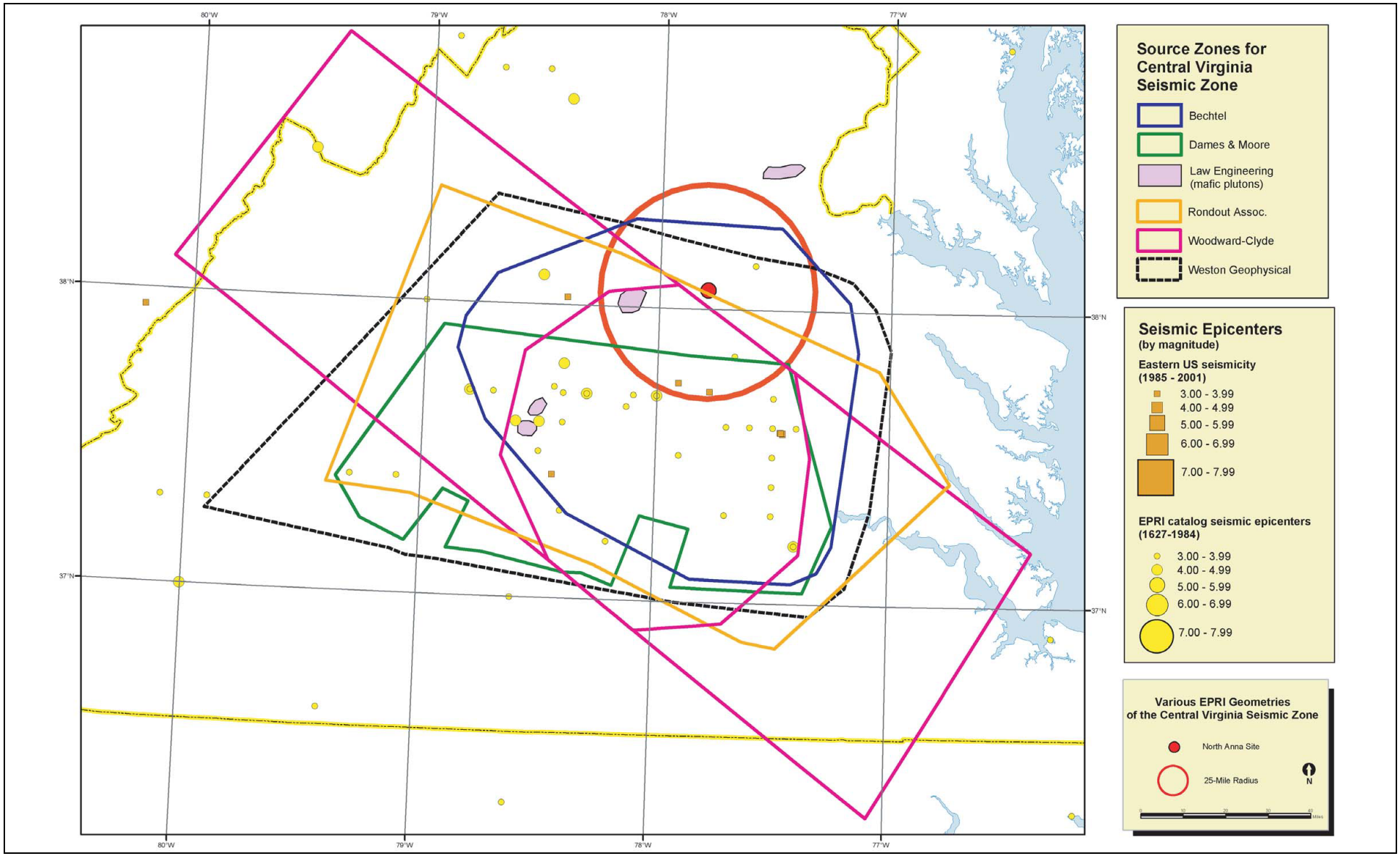


Figure 2.5-25 Various EPRI Geometries of the Central Virginia Seismic Zone

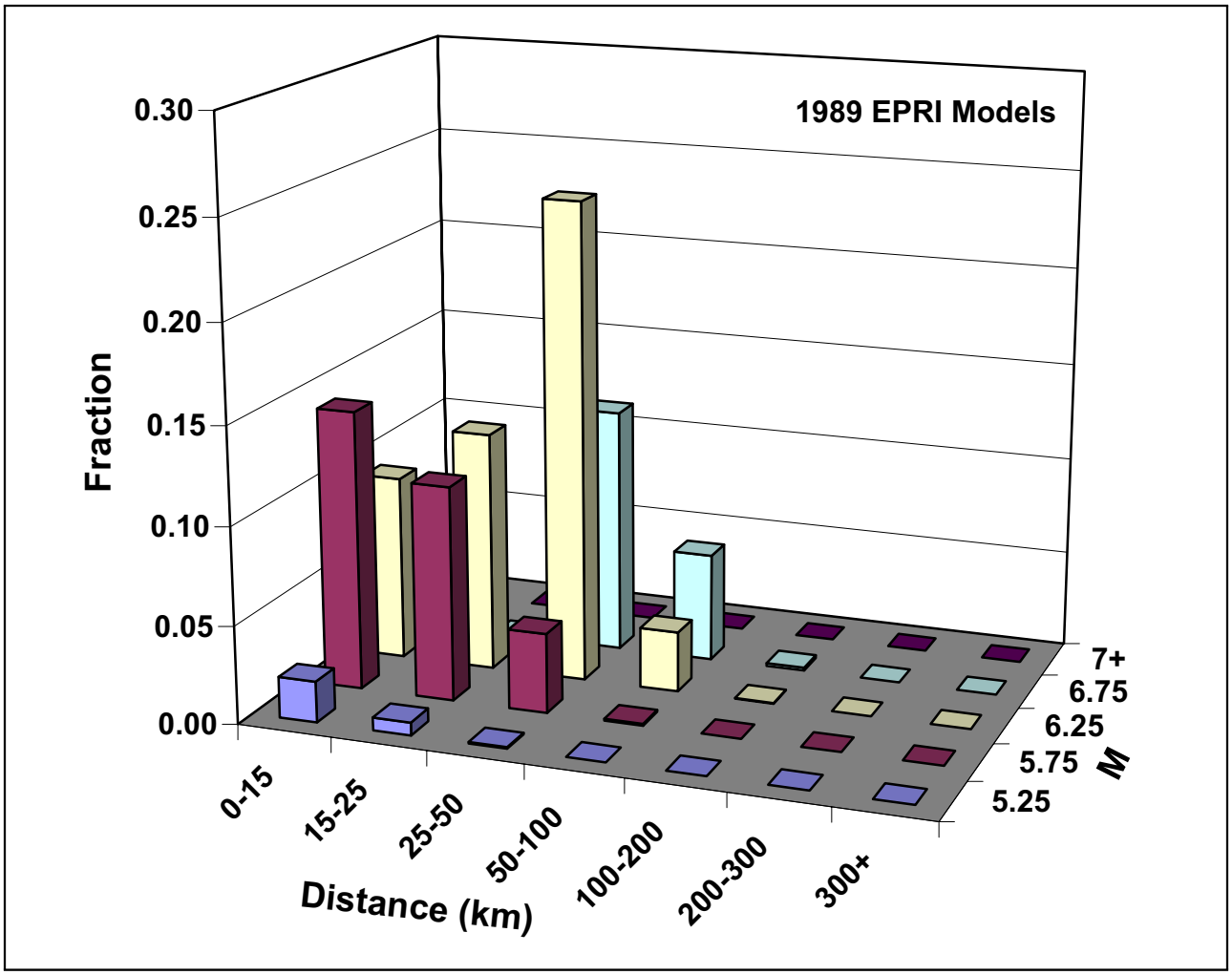


Figure 2.5-26 Low-Frequency, 10^{-5} Median, Magnitude-Distance Deaggregation Using 1989 EPRI Sources and Ground Motion

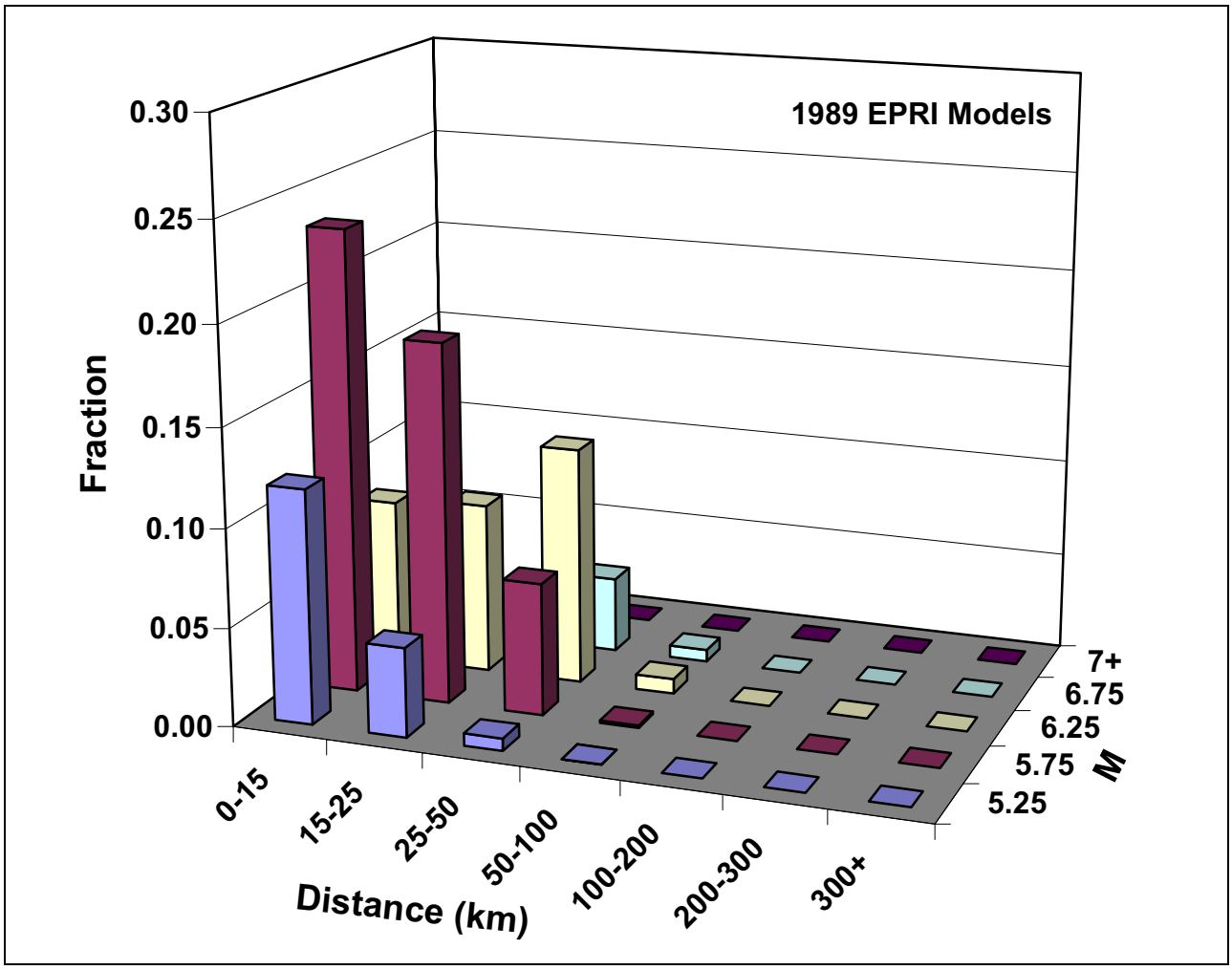


Figure 2.5-27 High-Frequency, 10^{-5} Median, Magnitude-Distance Deaggregation Using 1989 EPRI Sources and Ground Motion

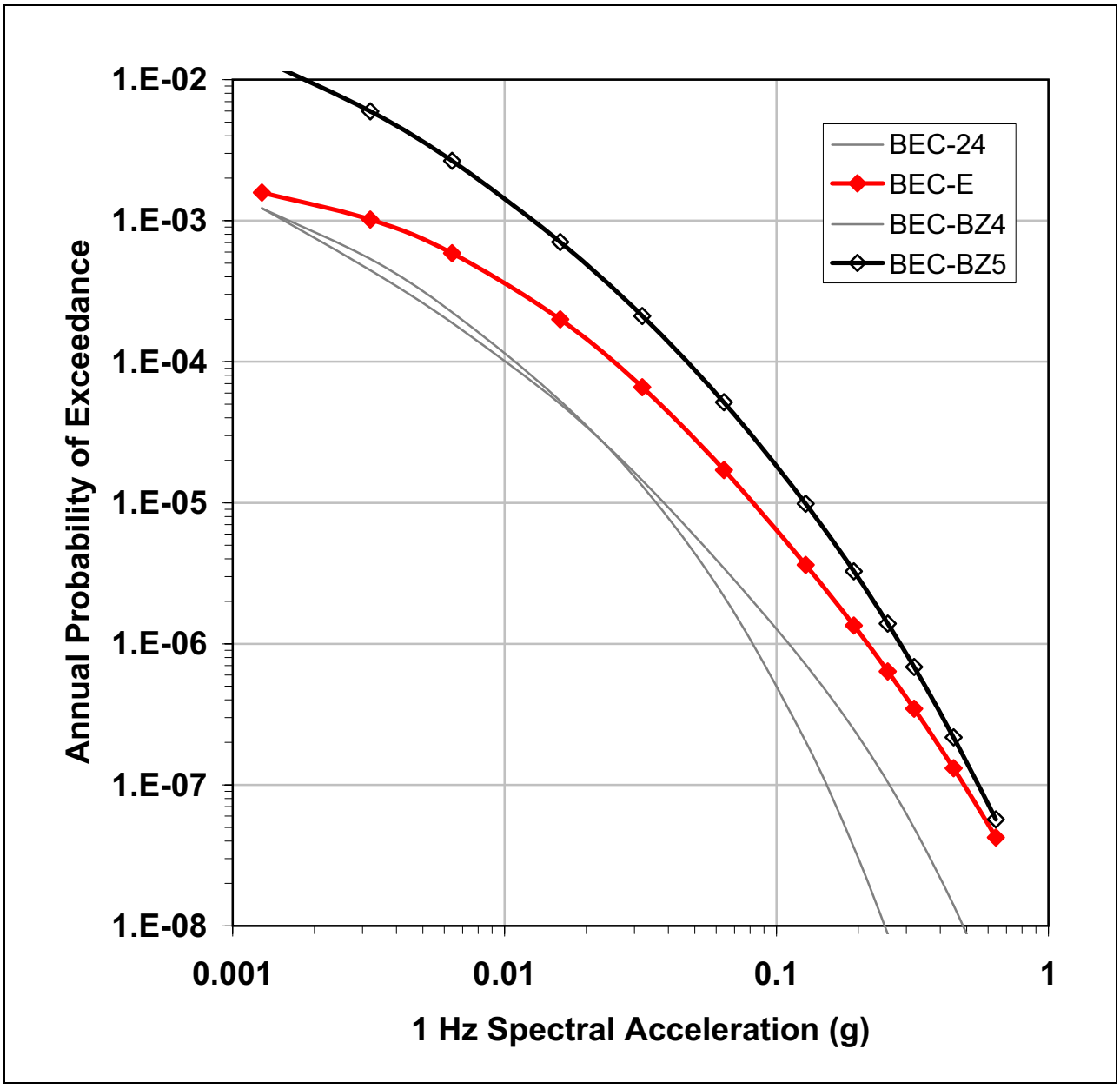


Figure 2.5-28 1989 EPRI 1 Hz Mean Hazard Contribution by Source (Bechtel); Sources Contributing Most to ESP Site Hazard Are Emphasized

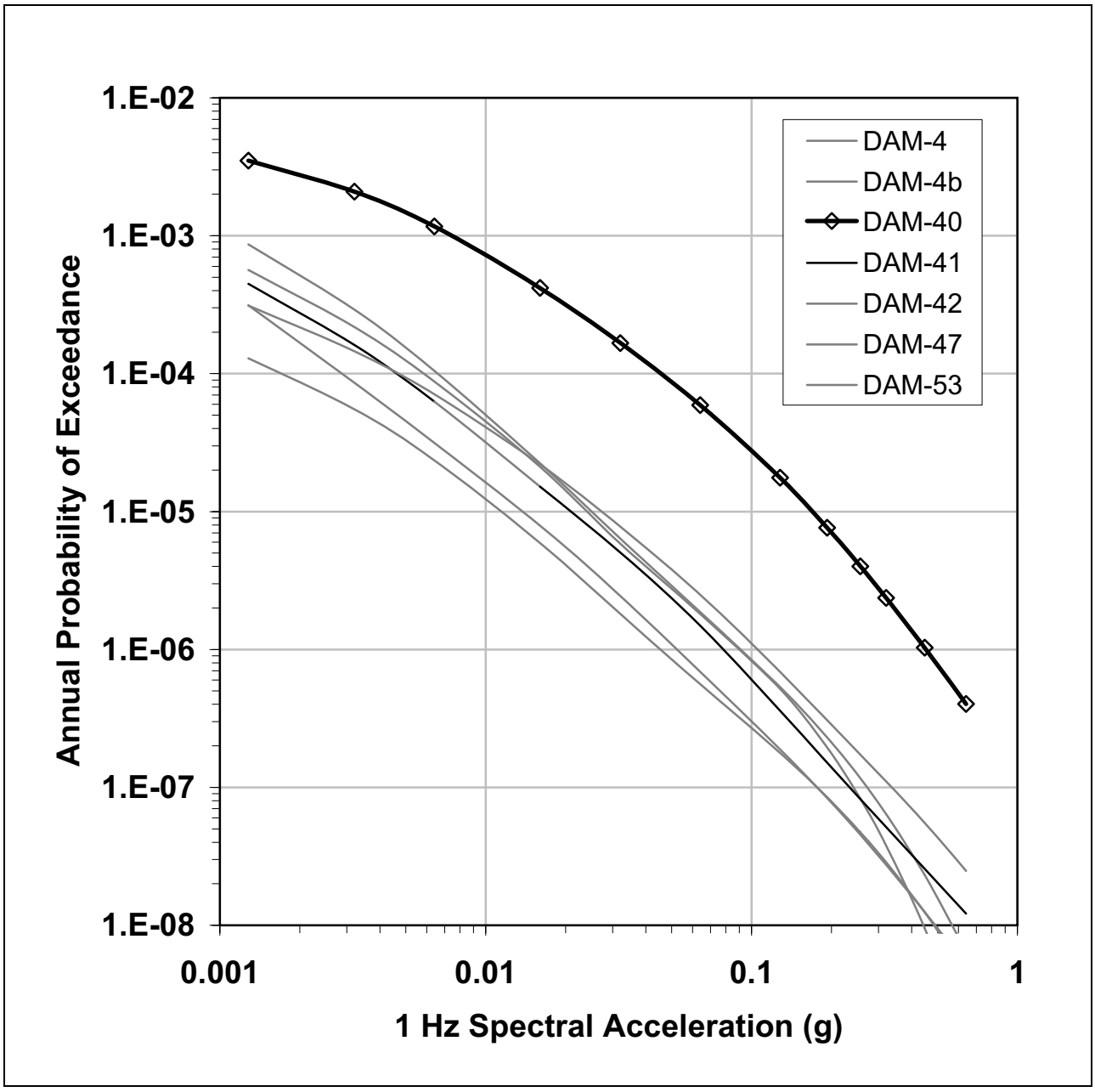


Figure 2.5-29 1989 EPRI Hazard 1 Hz Mean Contribution by Source (Dames & Moore); Sources Contributing Most to ESP Site Hazard Are Emphasized

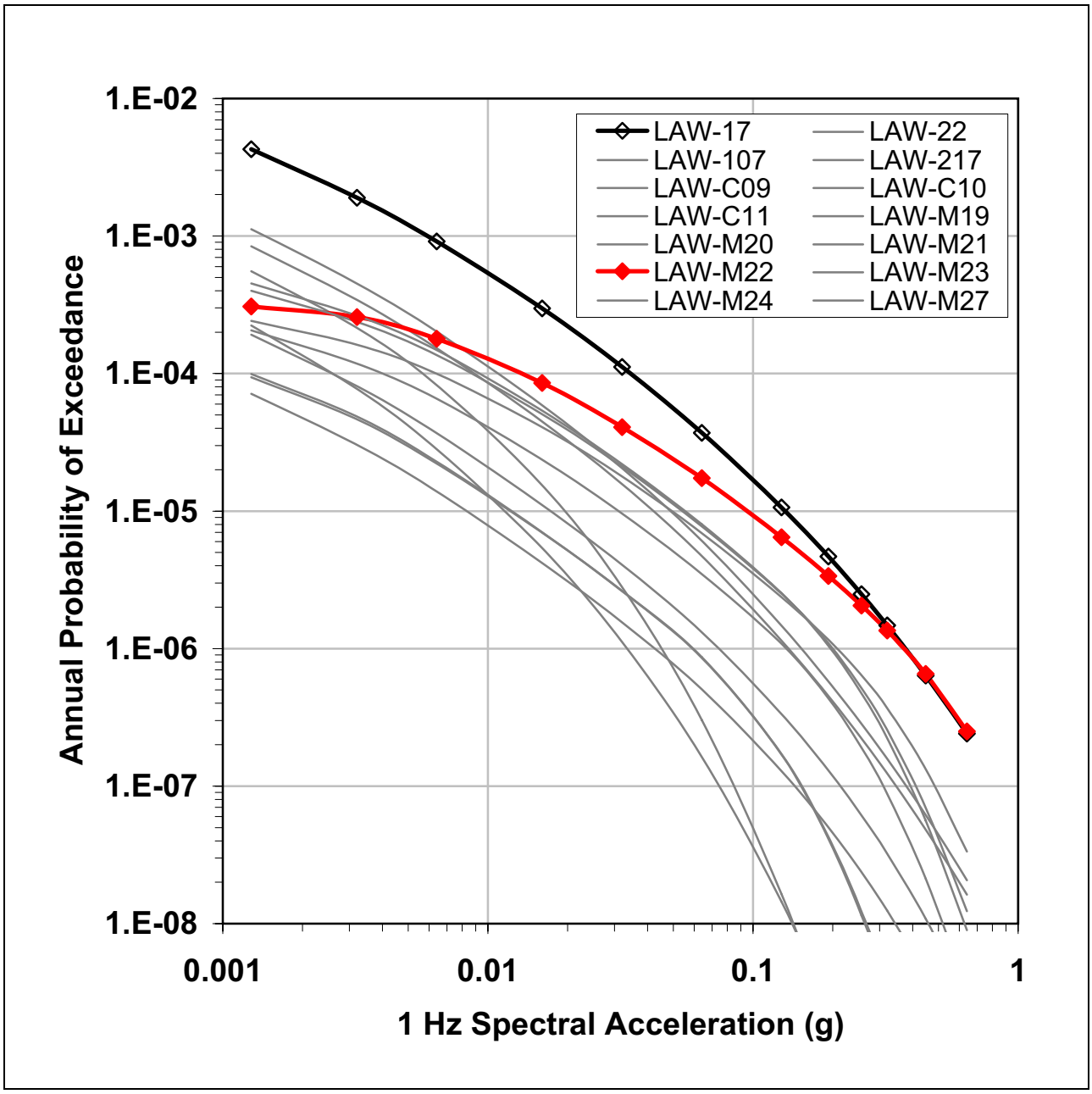


Figure 2.5-30 1989 EPRI 1 Hz Mean Hazard Contribution by Source (Law Engineering); Sources Contributing Most to ESP Site Hazard Are Emphasized

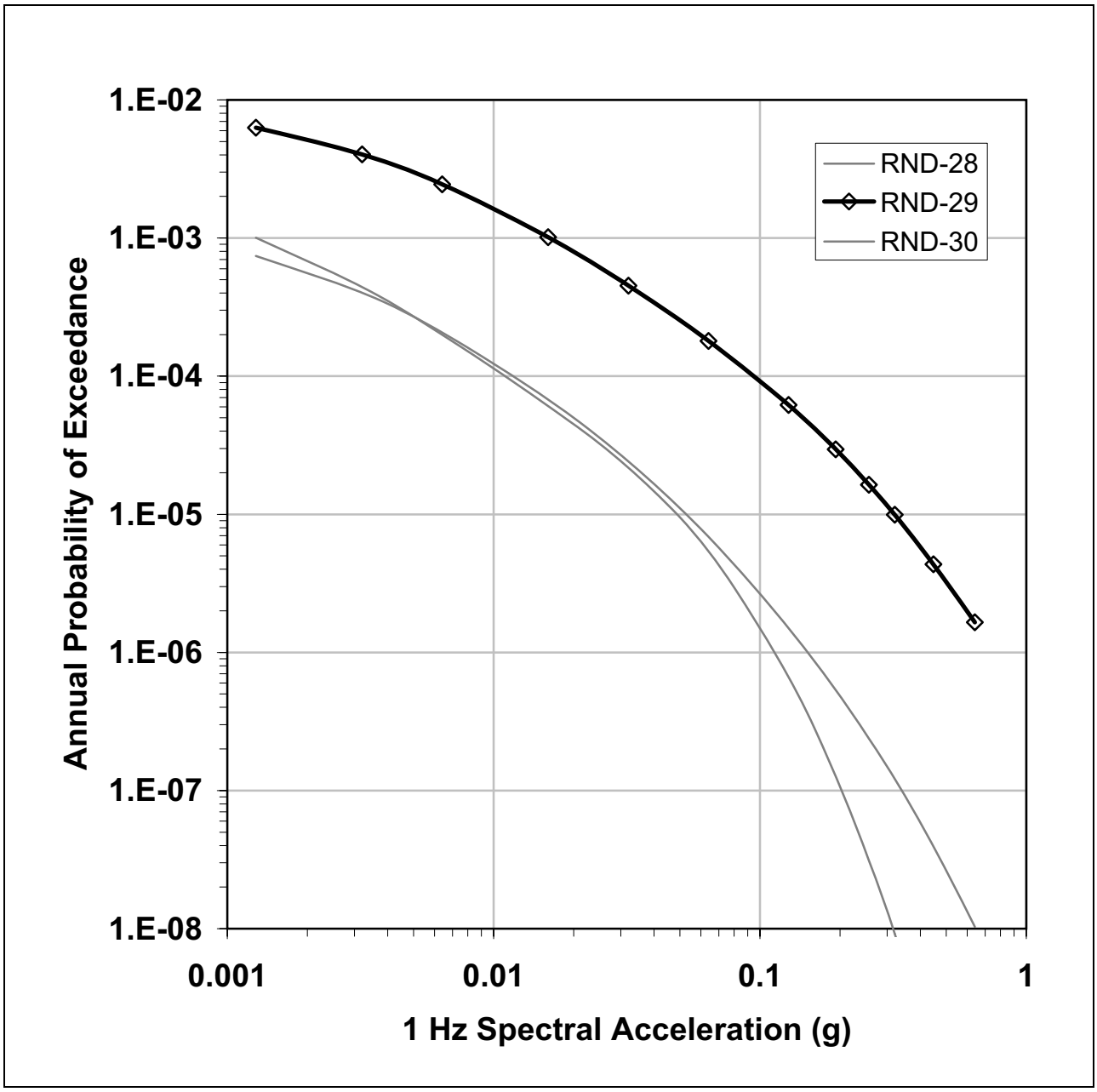


Figure 2.5-31 1989 EPRI 1 Hz Hazard Contribution by Source (Rondout Team); Sources Contributing Most to ESP Site Hazard Are Emphasized

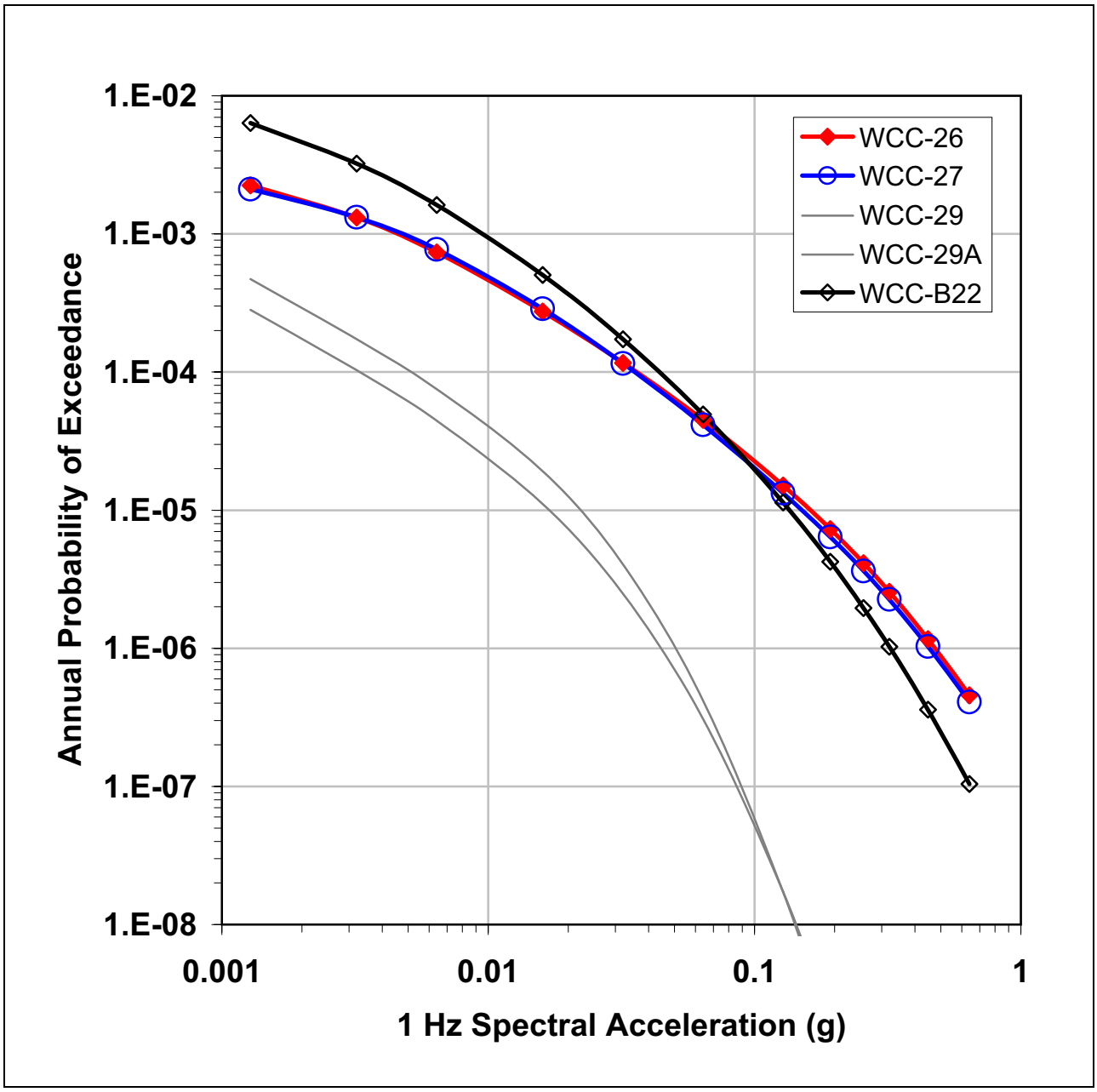


Figure 2.5-32 1989 EPRI 1 Hz Hazard Contribution by Source (Woodward-Clyde); Sources Contributing Most to ESP Site Hazard Are Emphasized

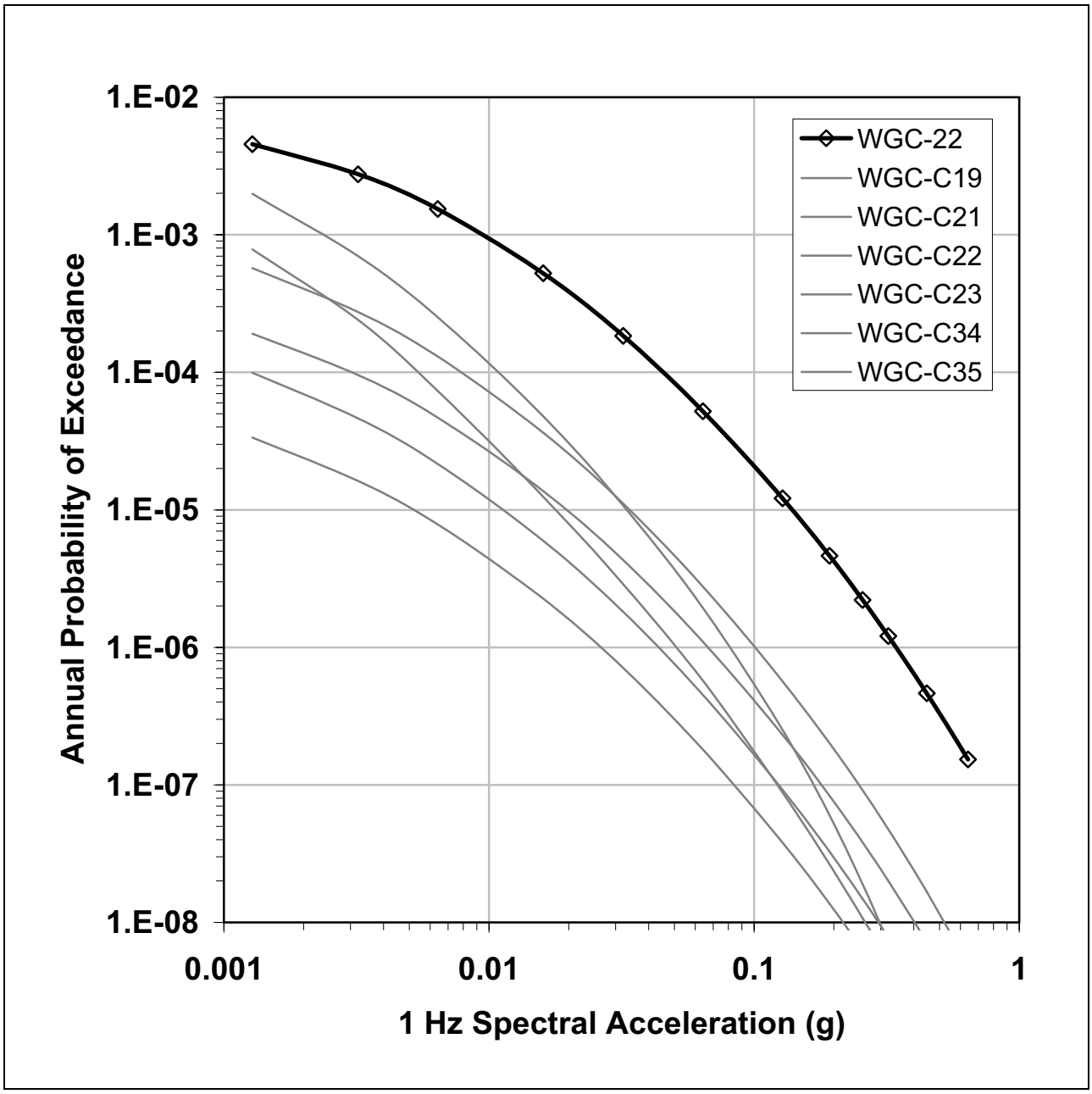


Figure 2.5-33 1989 EPRI 1 Hz Hazard Contribution by Source (Weston Geophysical); Sources Contributing Most to ESP Site Hazard Are Emphasized

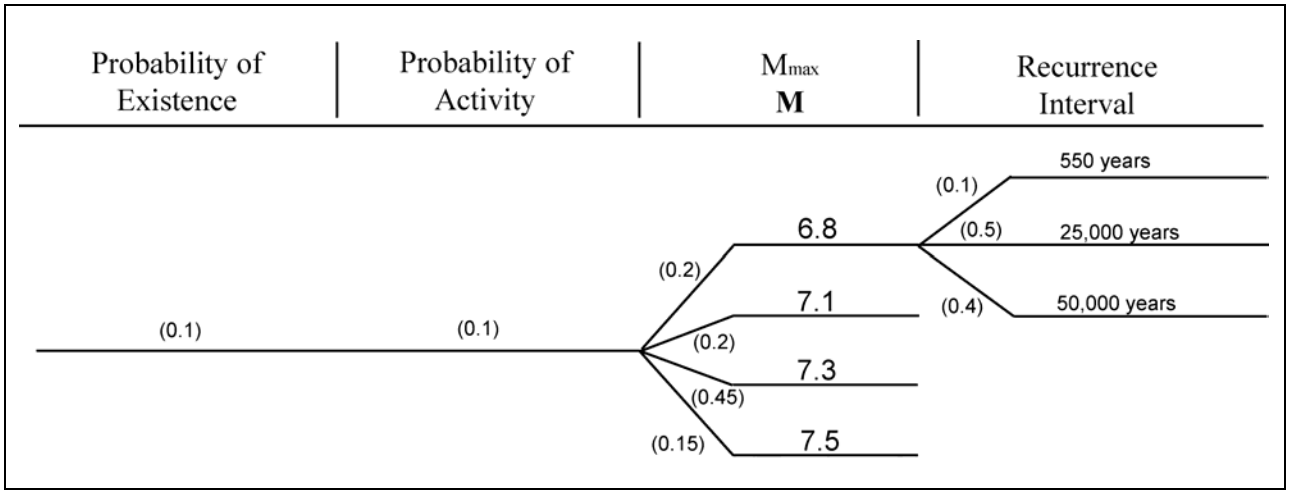


Figure 2.5-34 Logic Tree for ECFS Northern Segment

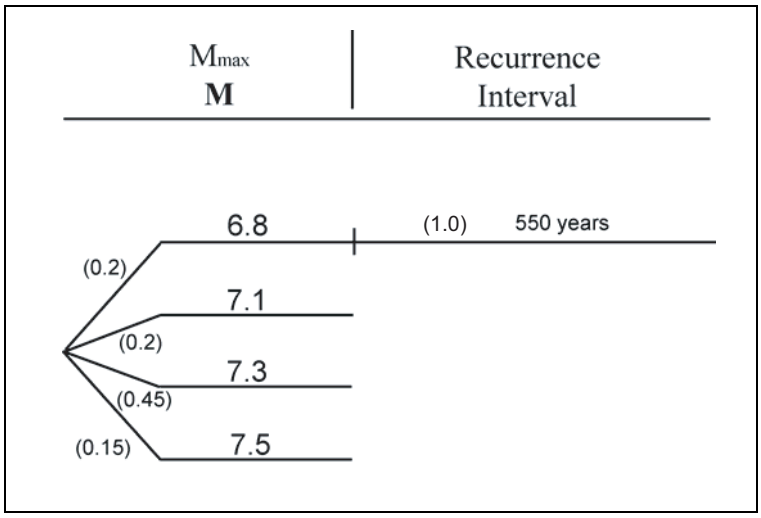


Figure 2.5-35 Logic Tree for the Updated Charleston Source (ECFS Southern Segment)

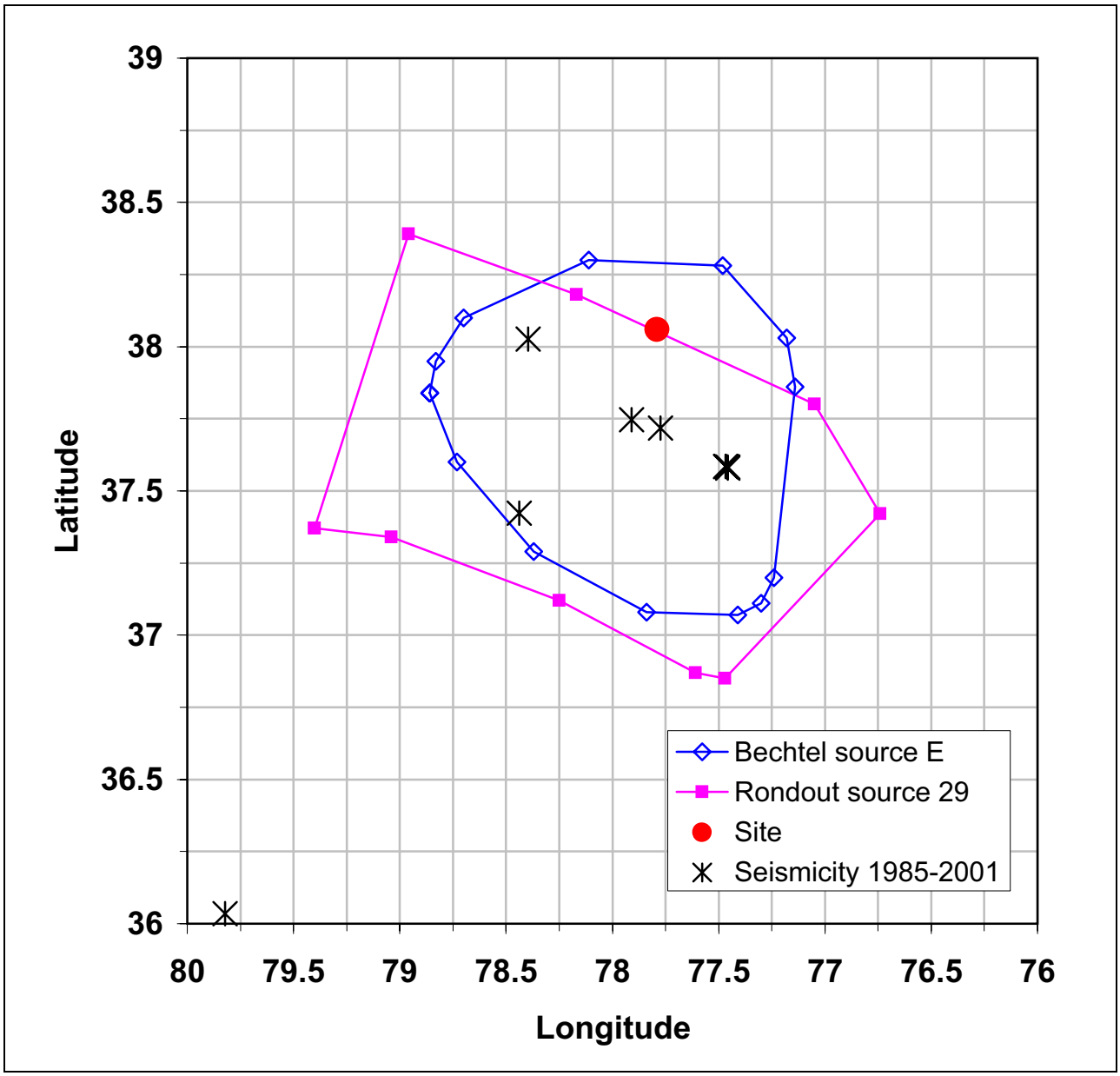


Figure 2.5-36 Bechtel and Rondout Team Representations of Central Virginia Seismic Zone, and Seismicity in the Region Recorded from 1985 to 2001

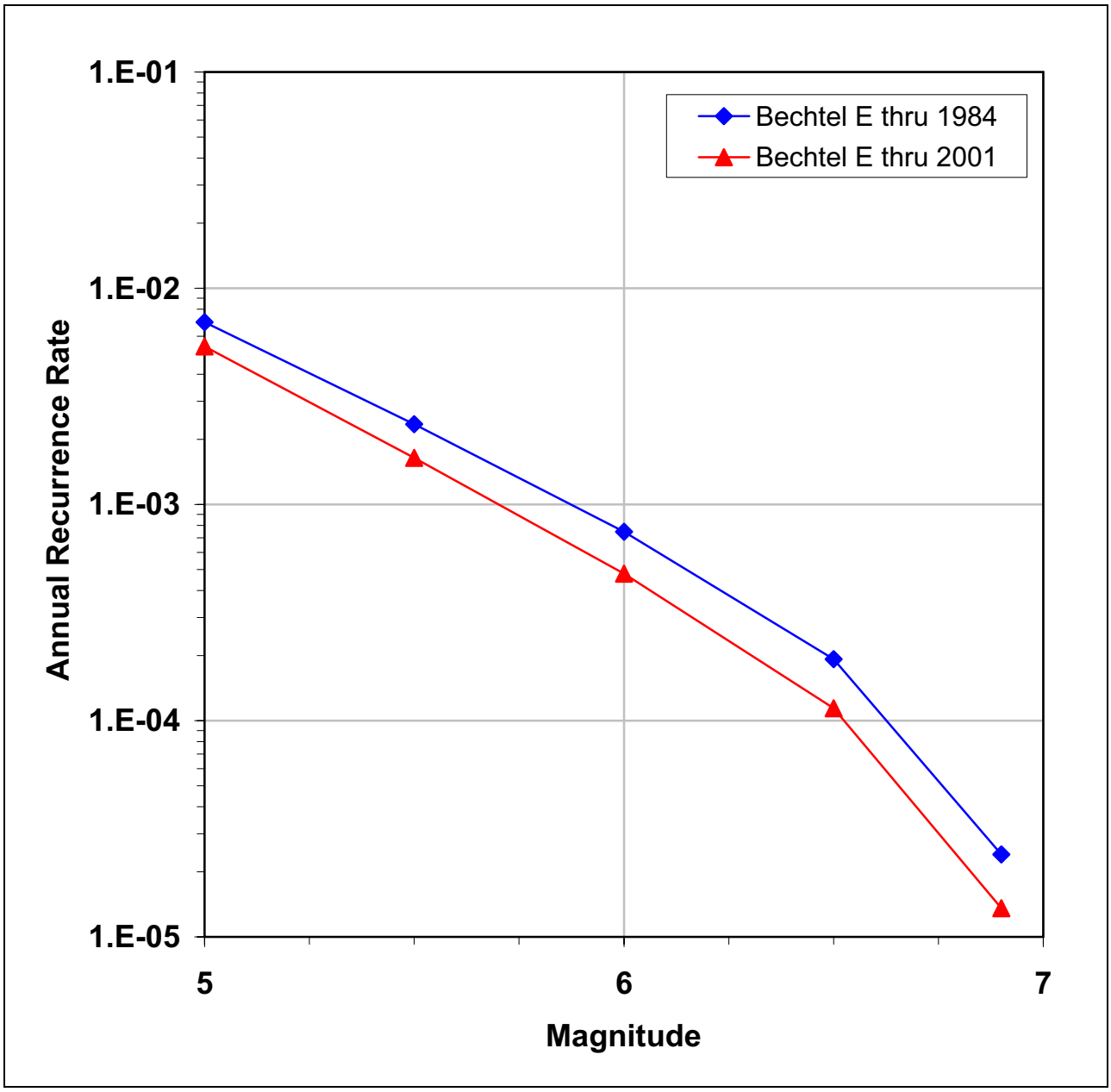


Figure 2.5-37 Comparison of Seismic Activity Rates for Bechtel Source E Considering Original EPRI (through 1984) and Updated (through 2001) Earthquake Catalogs

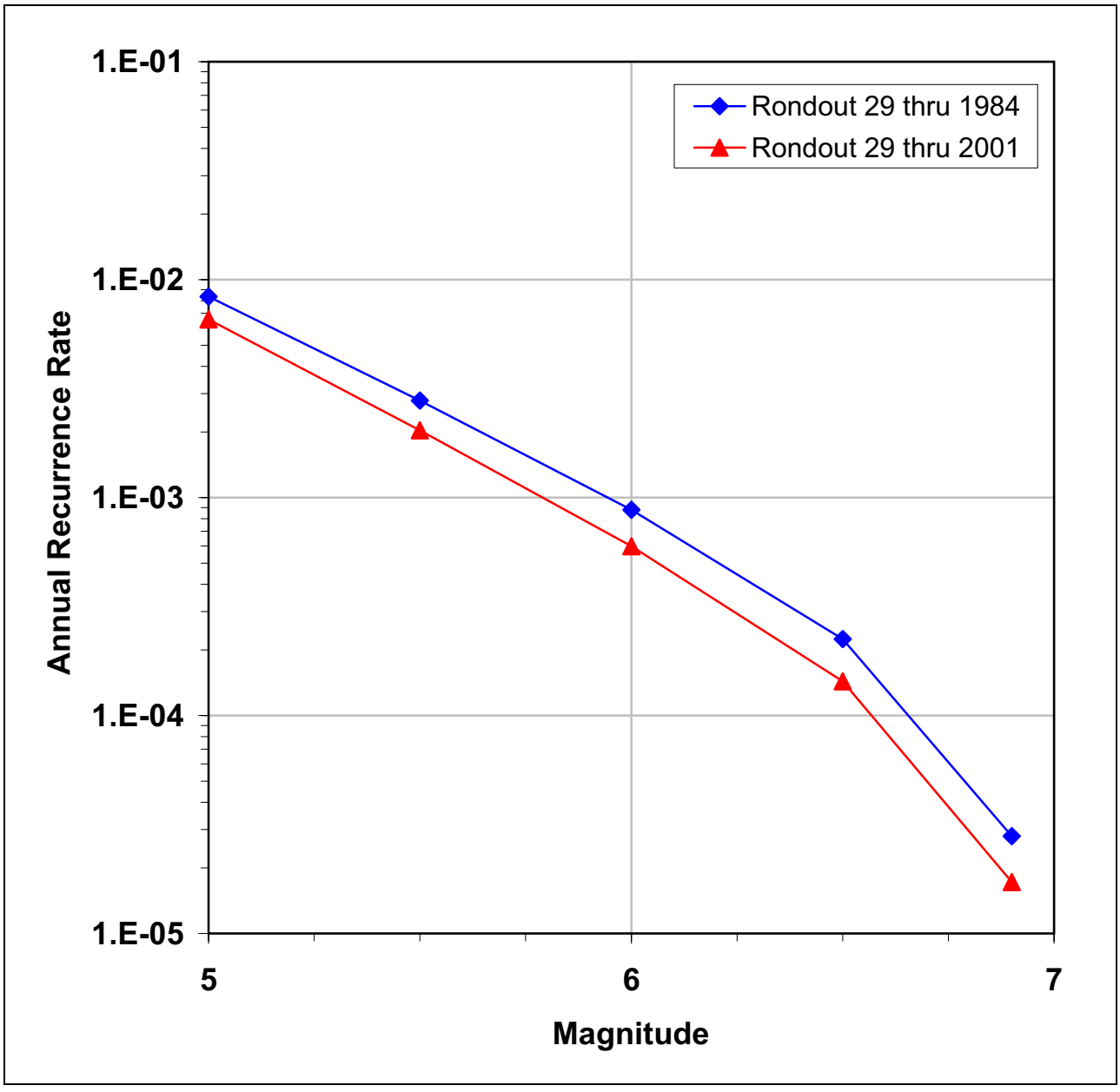


Figure 2.5-38 Comparison of Seismic Activity for Rondout Source 29 Considering Original EPRI (through 1984) and Updated (through 2001) Earthquake Catalogs

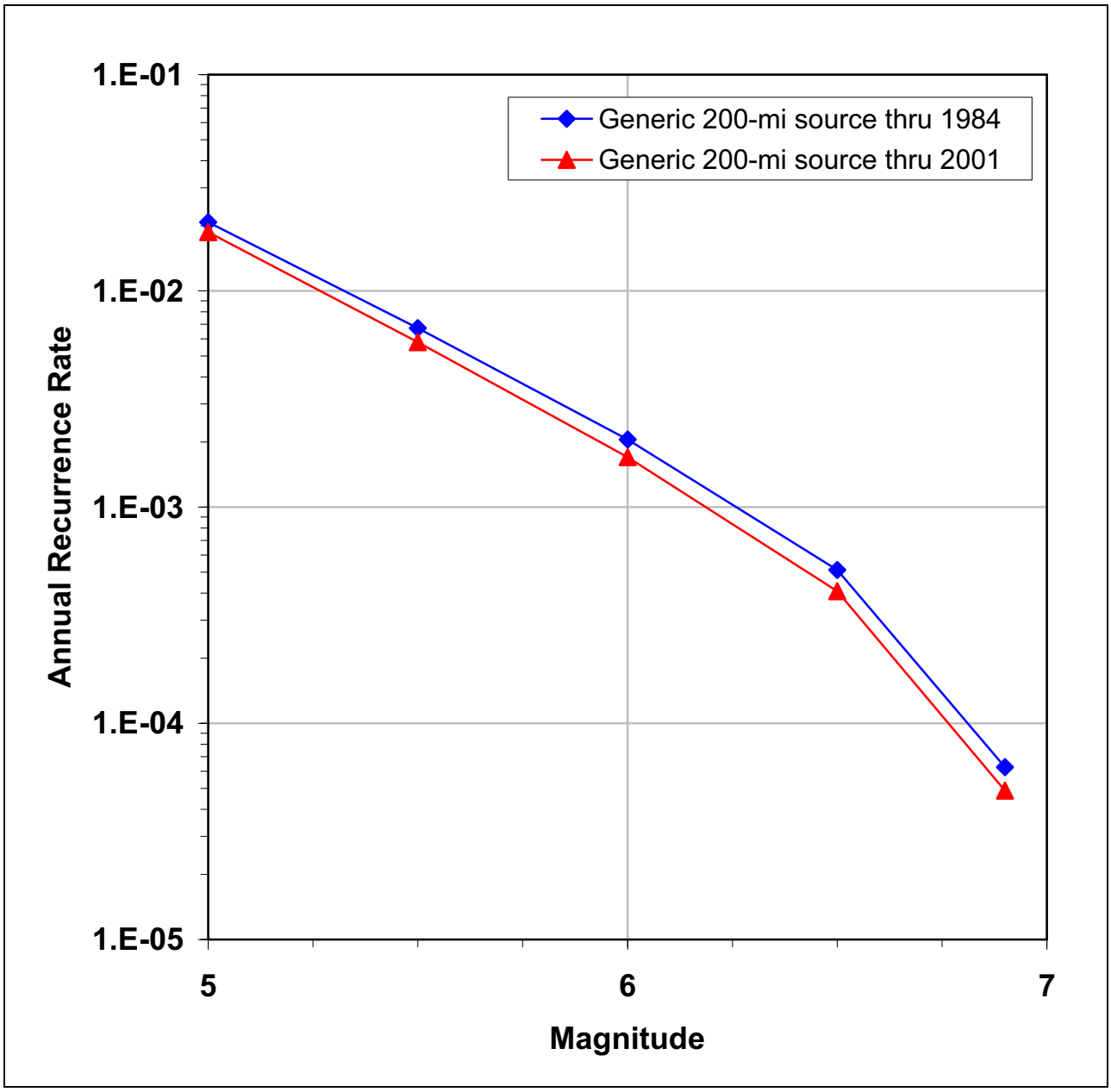


Figure 2.5-39 Comparison of Seismic Activity for 200-Mile Radius Source Around North Anna Considering Original EPRI (through 1984) and Updated (through 2001) Earthquake Catalogs

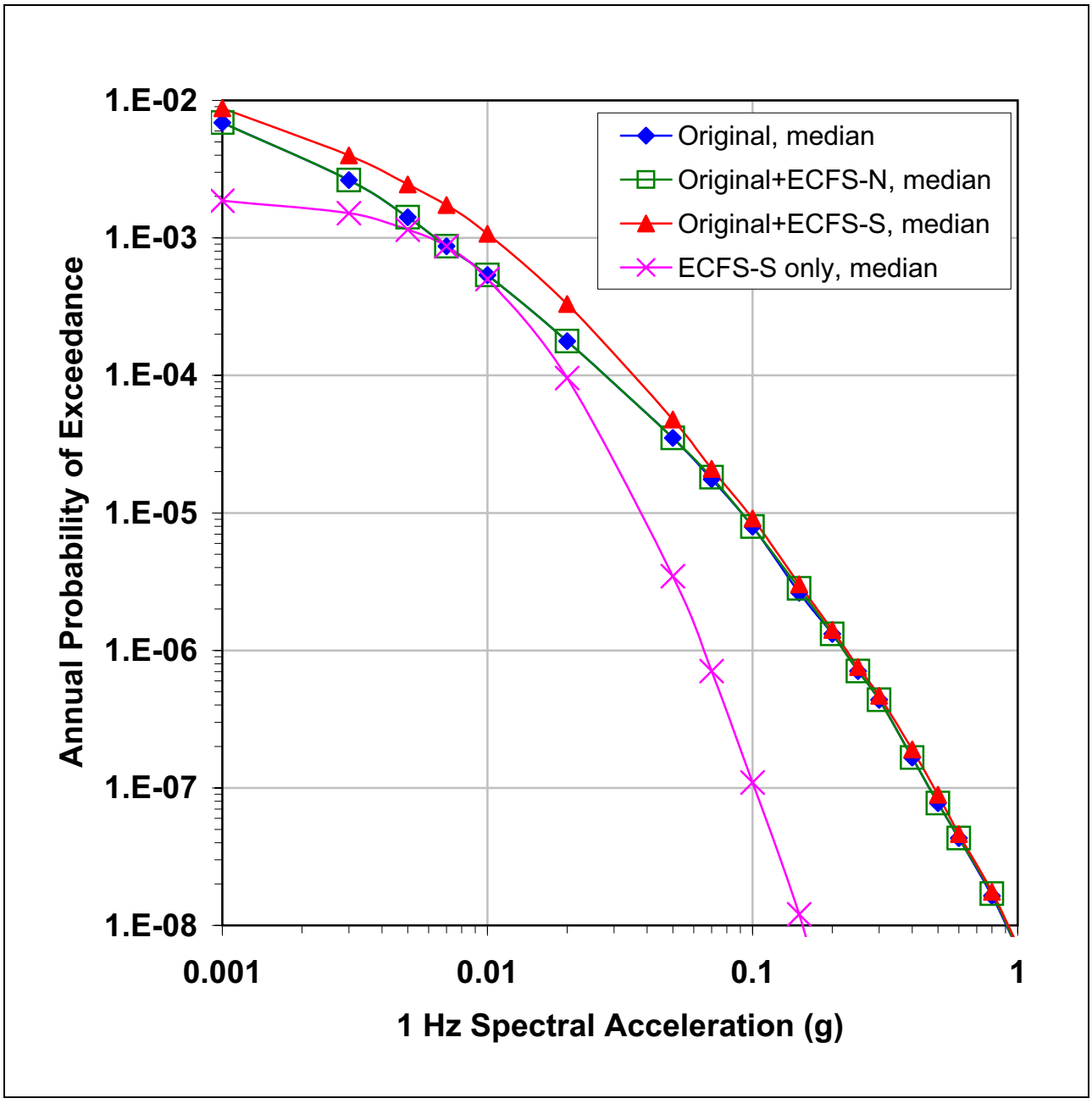


Figure 2.5-40 Effect of ECFS Faults on Median, 1 Hz Seismic Hazard

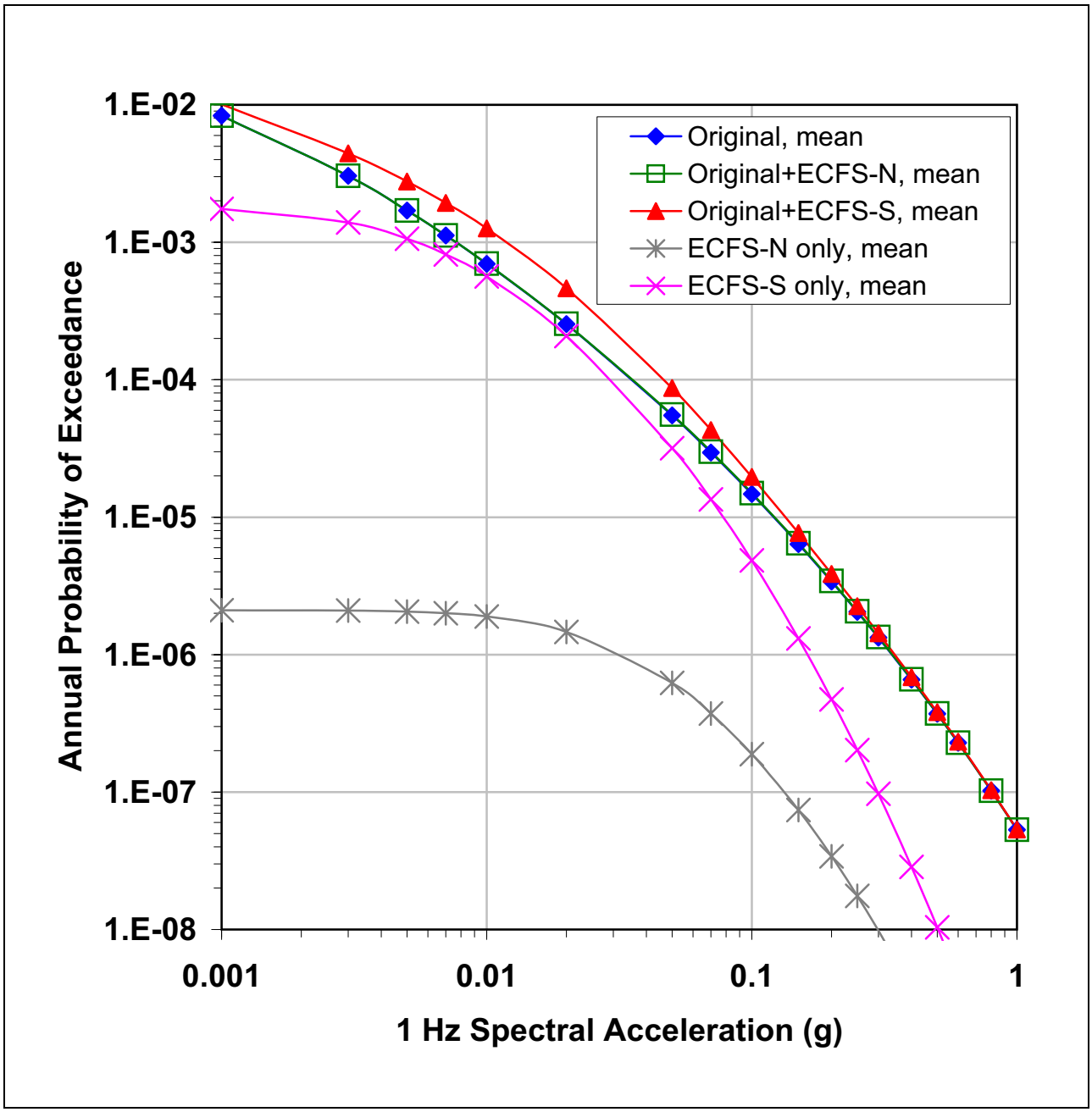


Figure 2.5-41 Effect of ECFS Faults on Mean, 1 Hz Seismic Hazard

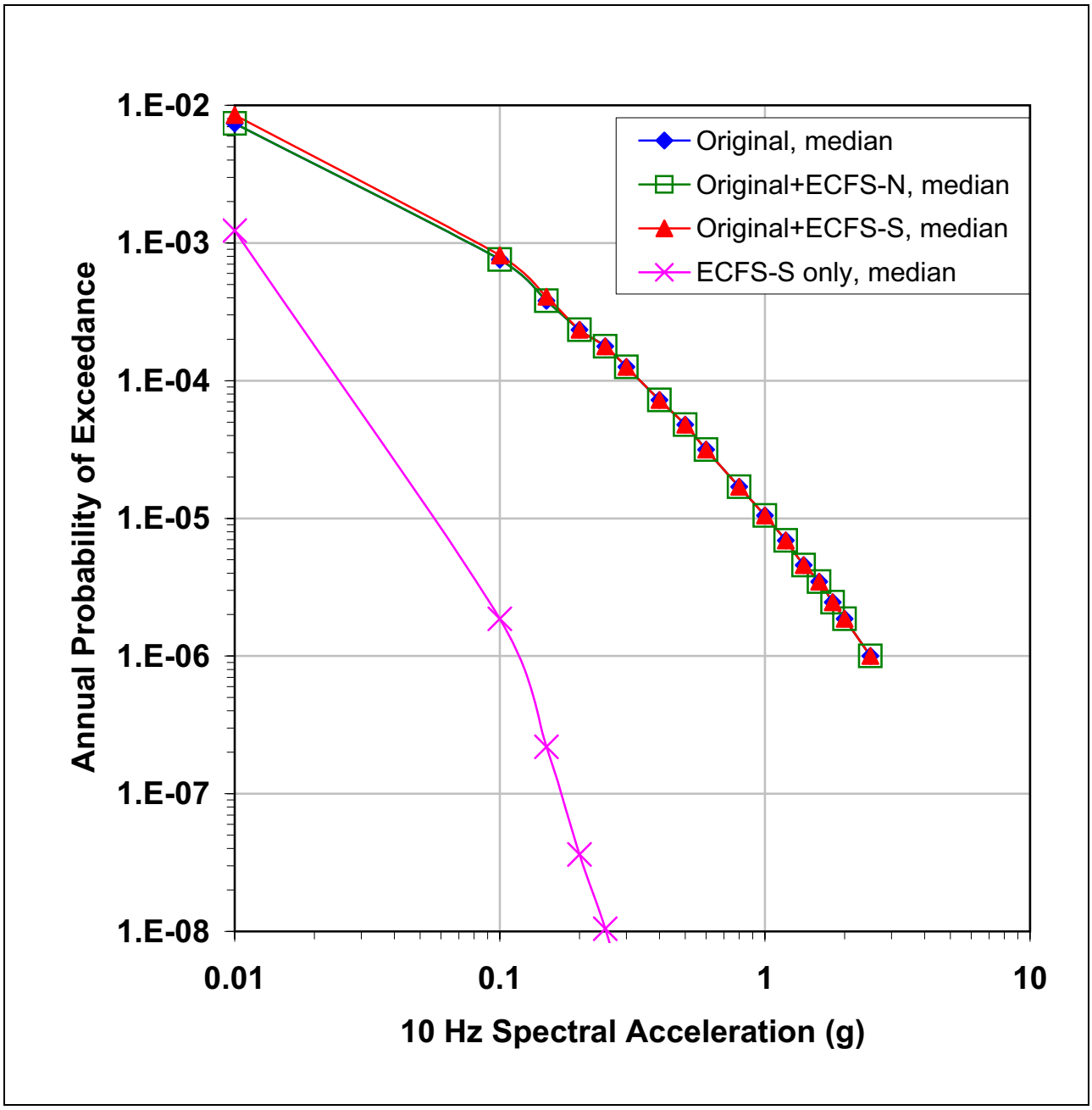


Figure 2.5-42 Effect of ECFS Faults on Median, 10 Hz Seismic Hazard

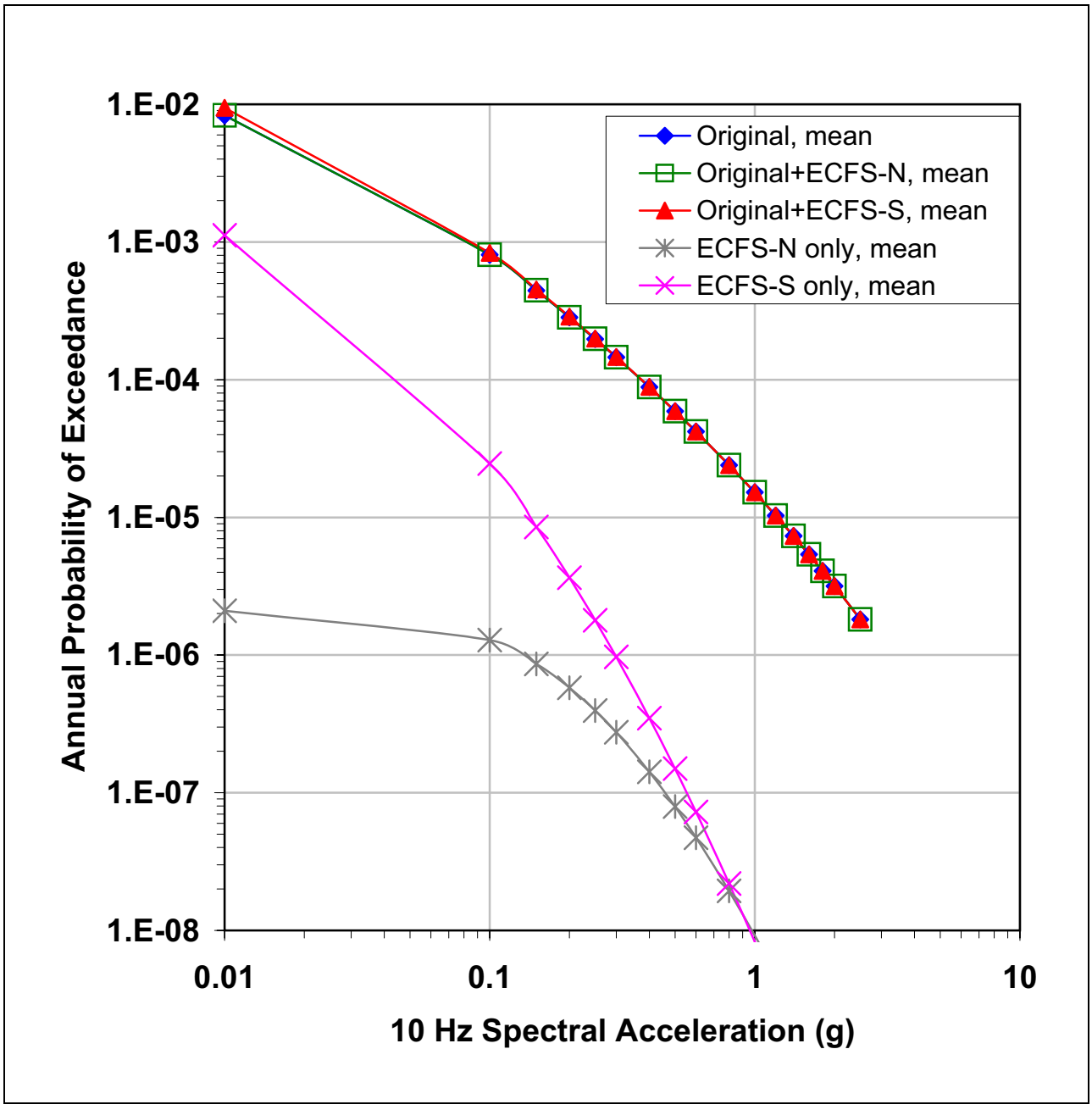


Figure 2.5-43 Effect of ECFS Faults on Mean, 10 Hz Seismic Hazard

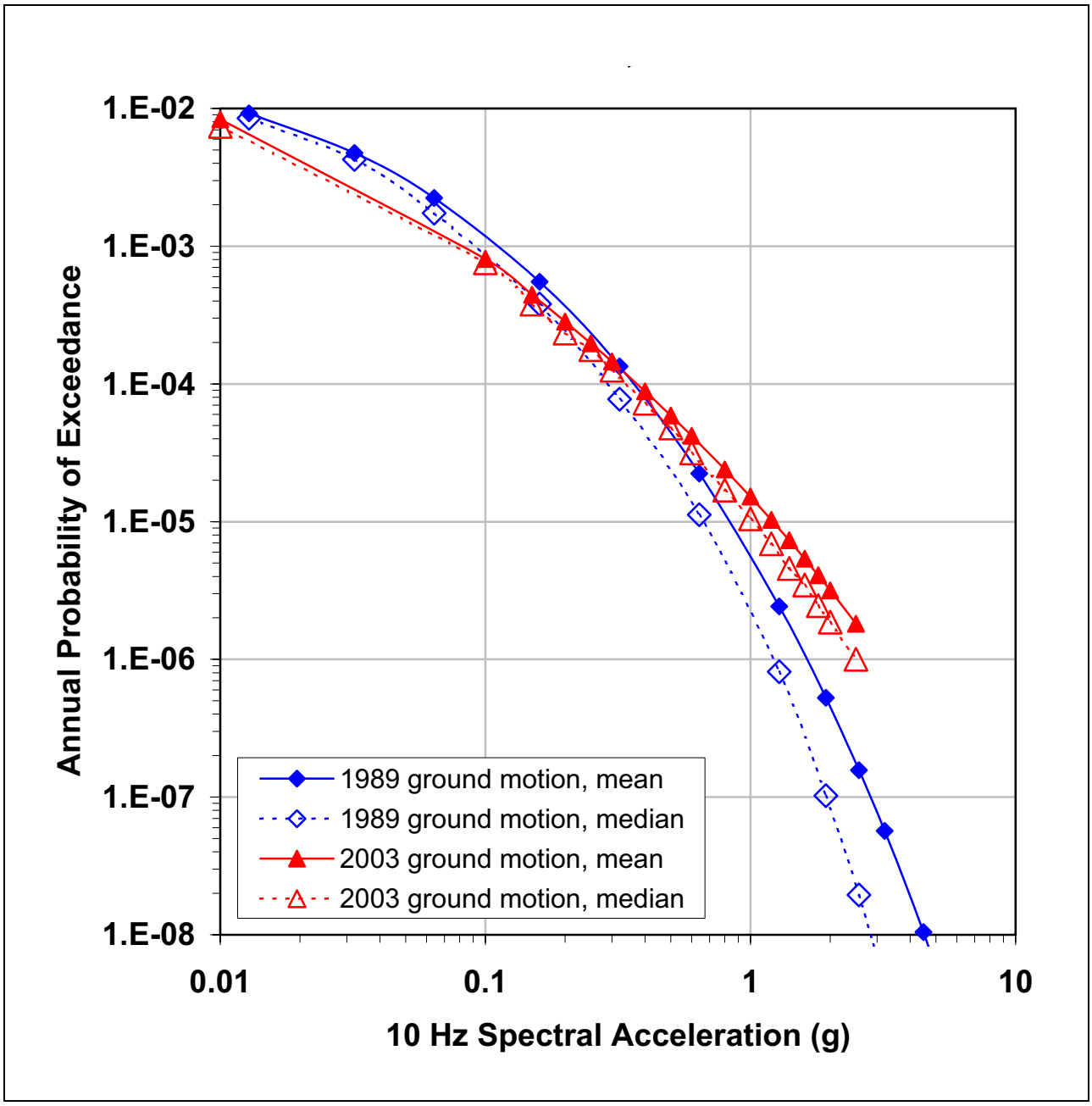


Figure 2.5-44 Sensitivity of 10 Hz Seismic Hazard to 1989 and 2003 Ground Motion Models

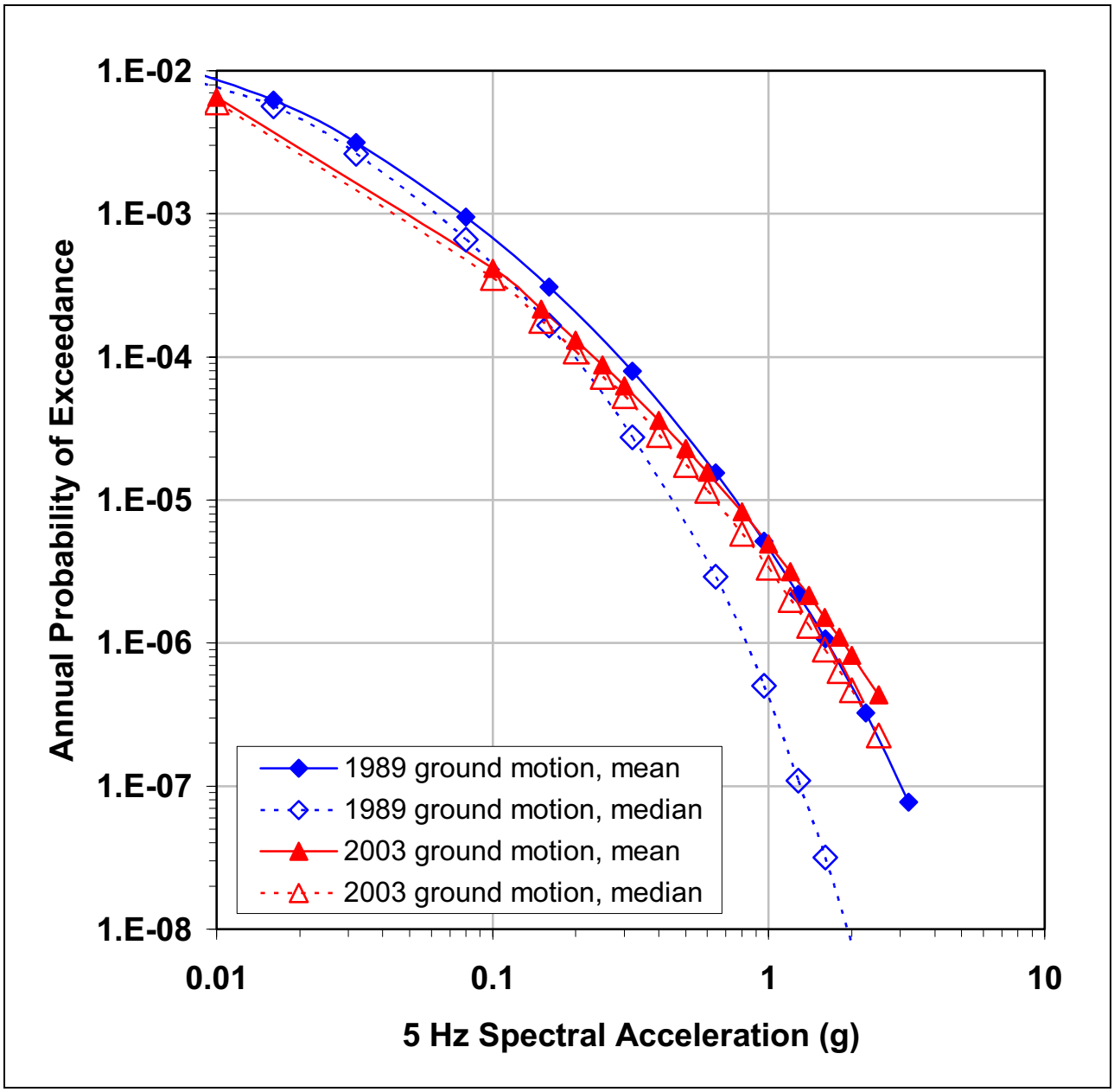


Figure 2.5-44A Sensitivity of 5 Hz Seismic Hazard to 1989 and 2003 Ground Motion Models

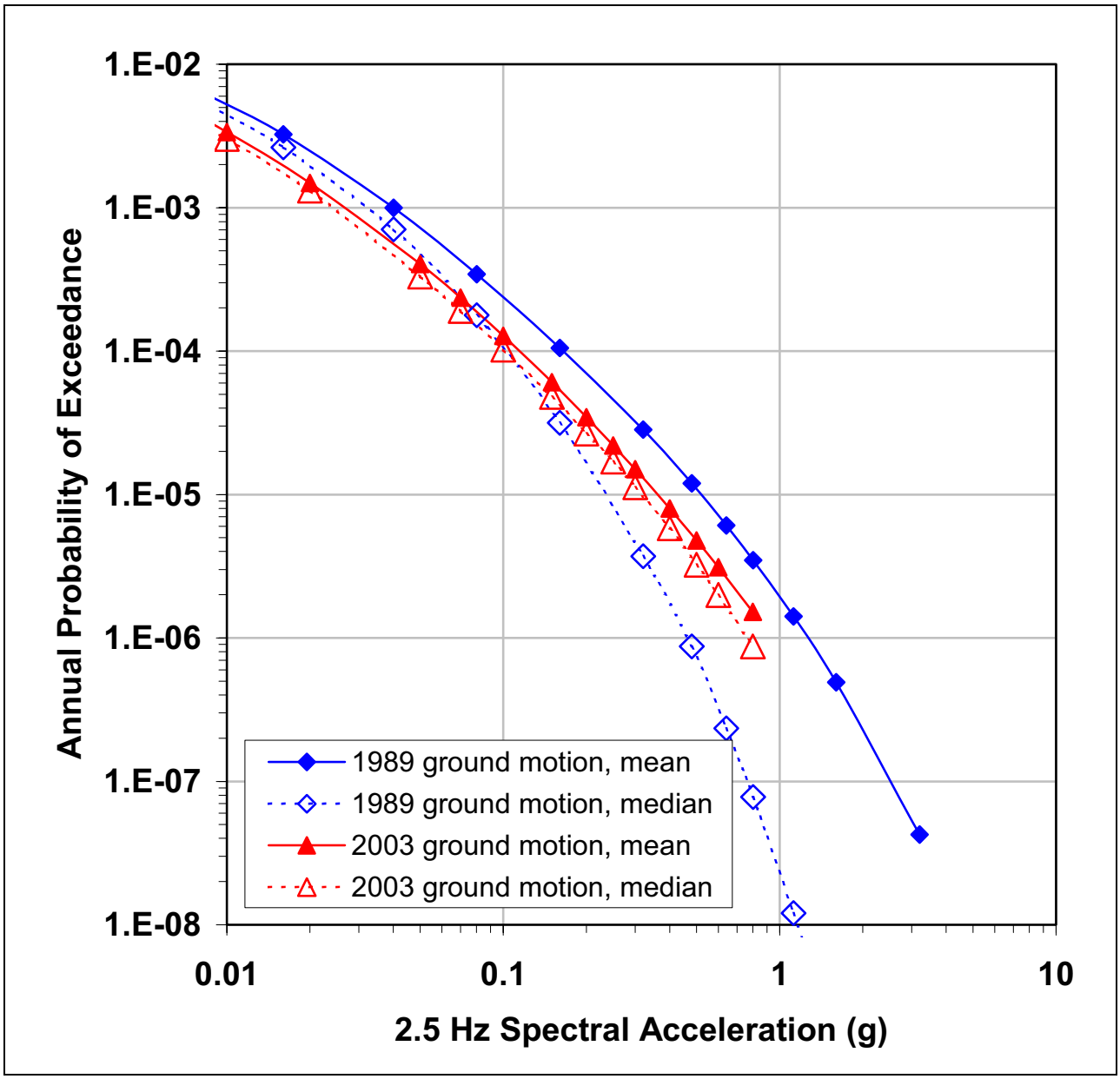


Figure 2.5-44B Sensitivity of 2.5 Hz Seismic Hazard to 1989 and 2003 Ground Motion Models

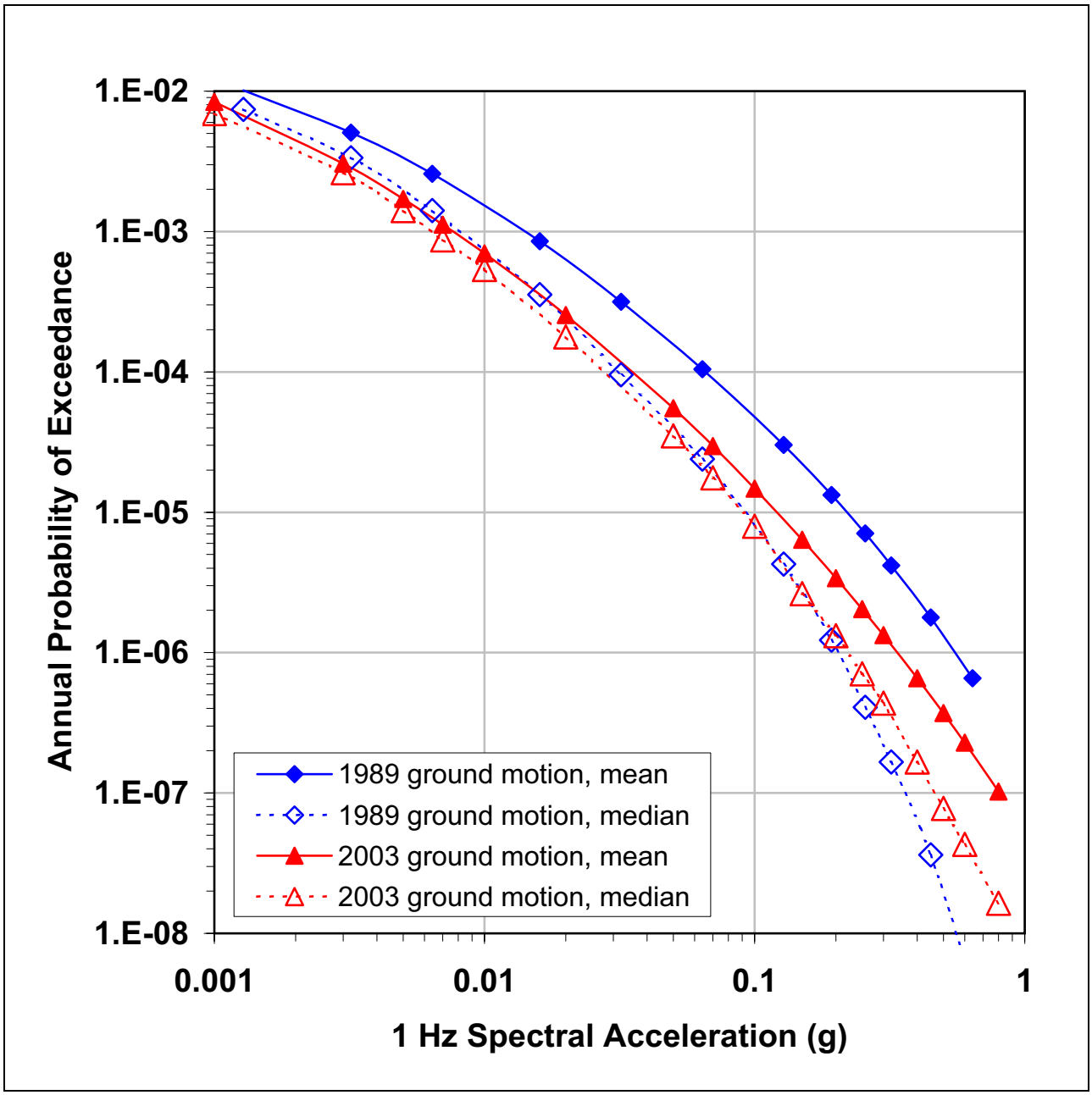


Figure 2.5-45 Sensitivity of 1 Hz Seismic Hazard to 1989 and 2003 Ground Motion Models

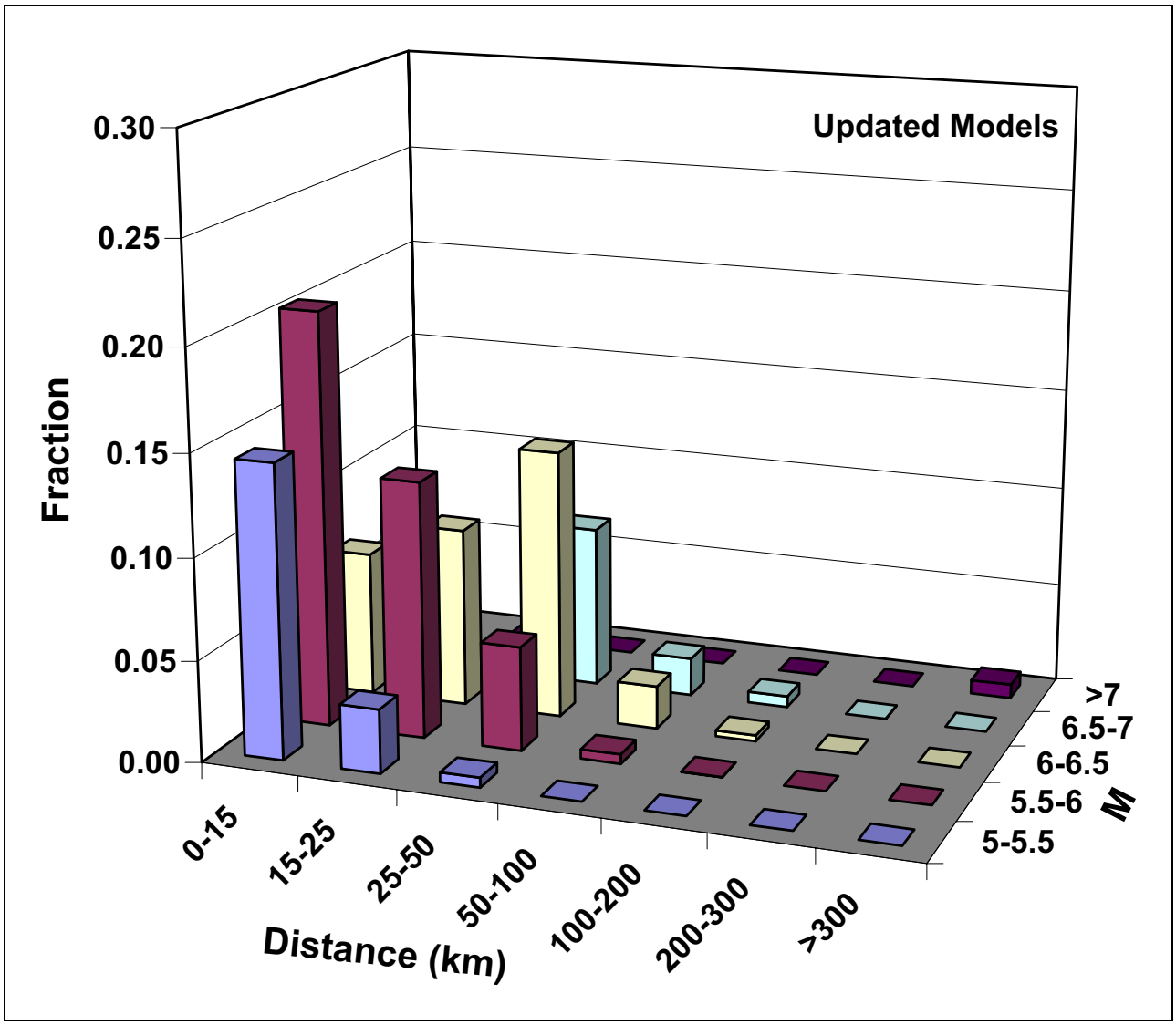


Figure 2.5-46 Low-Frequency, 10^{-5} Median, Magnitude-Distance Deaggregation Using Updated Source and Ground Motion Models

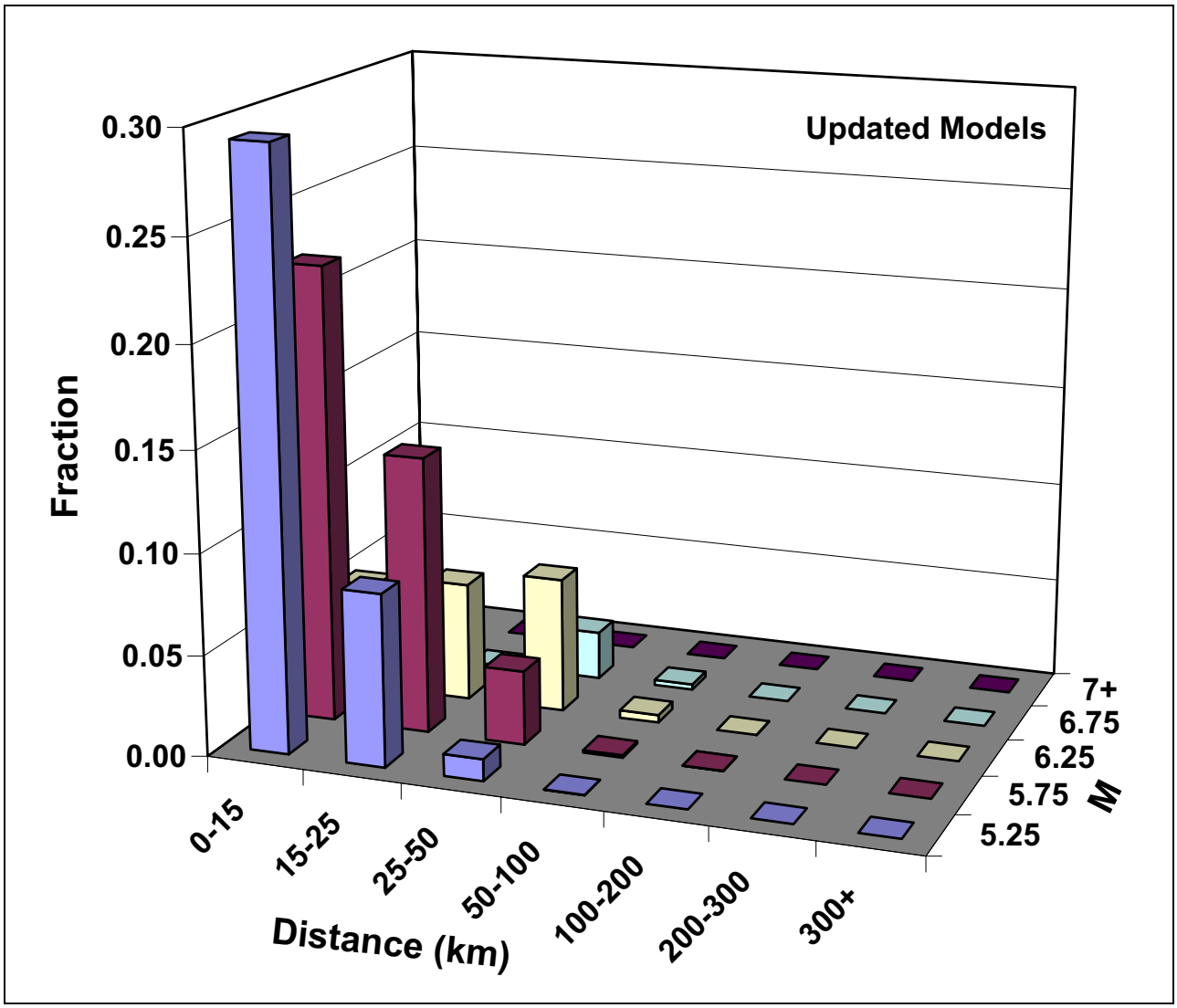


Figure 2.5-47 High-Frequency, 10^{-5} Median, Magnitude-Distance Deaggregation Using Updated Source and Ground Motion Models

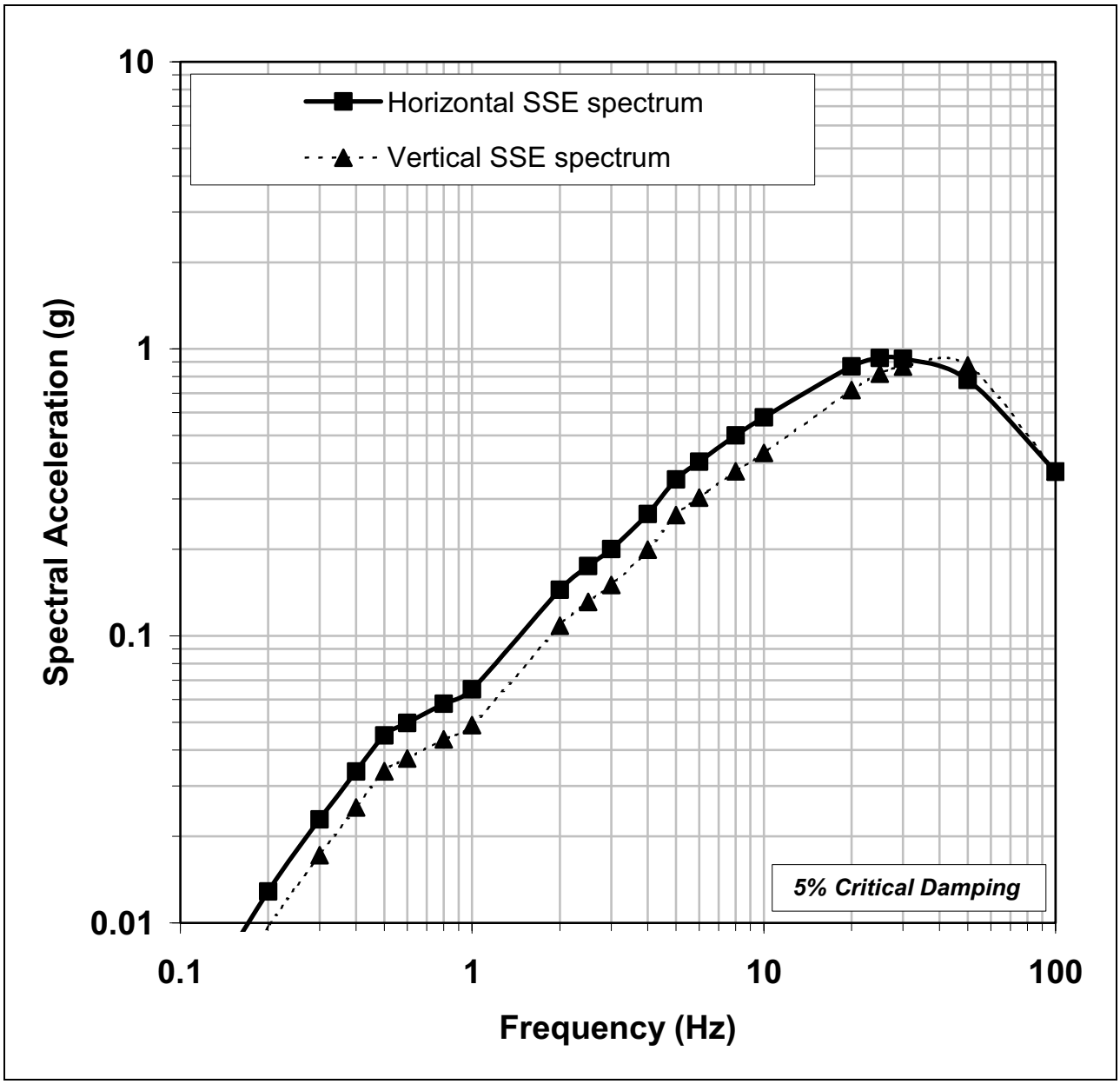


Figure 2.5-48 Selected Horizontal and Vertical Hard Rock SSE Spectra for the North Anna ESP Site

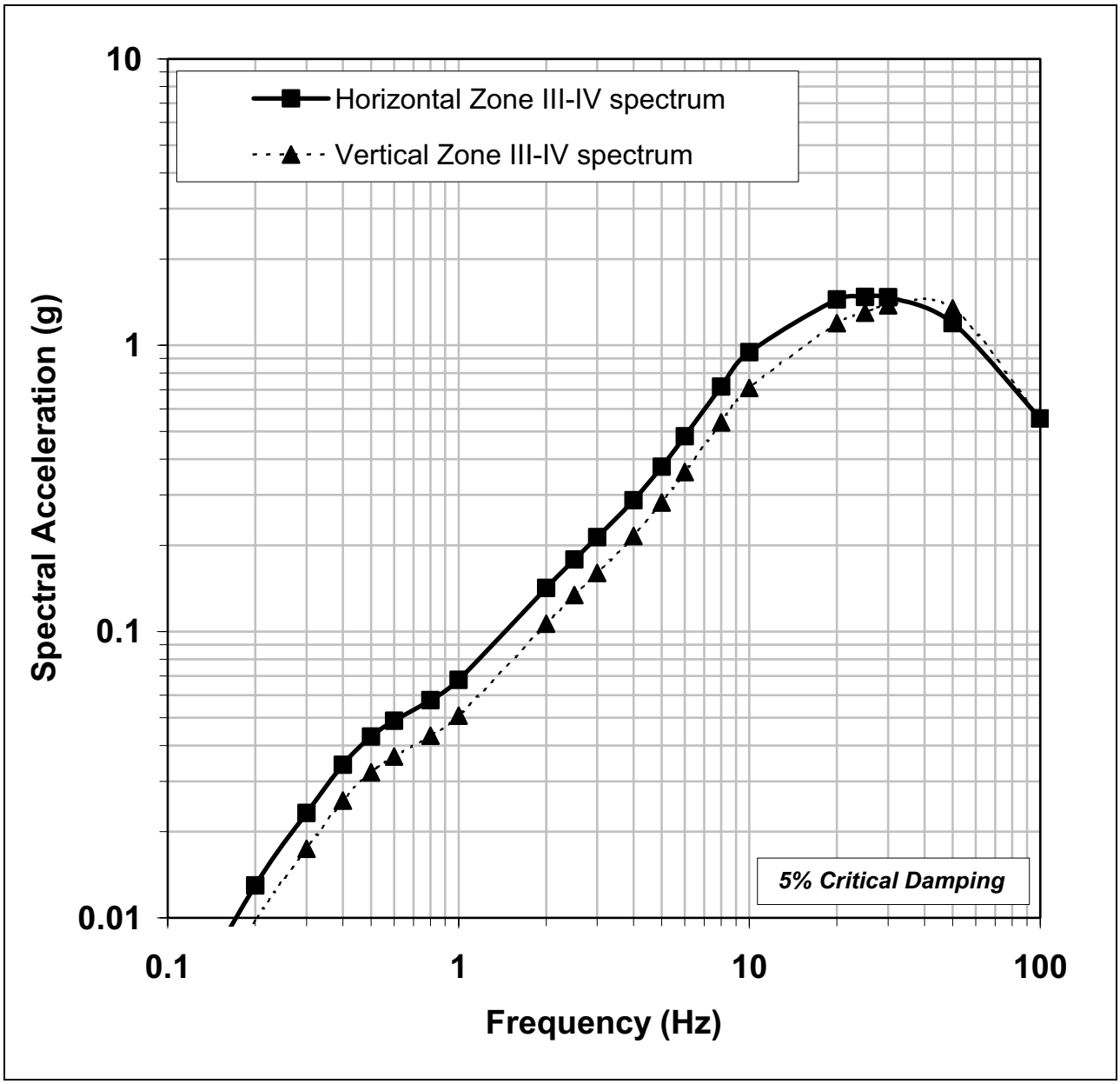


Figure 2.5-48A Selected Horizontal and Vertical Response Spectra for the Hypothetical Rock Outcrop Control Point SSE at the Top of Zone III-IV Material (Representative Elevation 250 ft, 3,300 ft/sec Shear Wave Velocity)

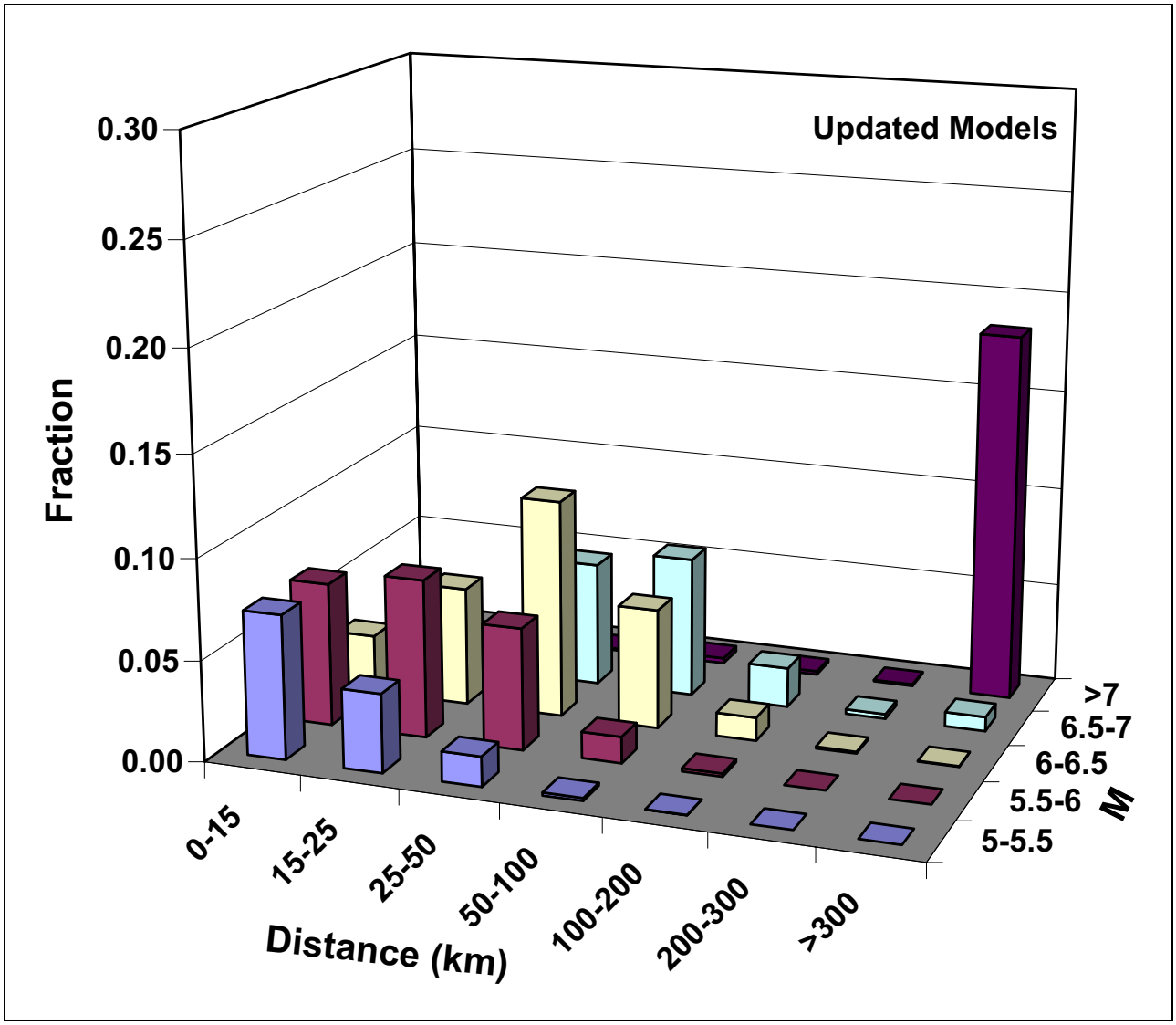


Figure 2.5-49 Magnitude-Distance Deaggregation for Low-Frequencies (1 and 2.5 Hz) at a Mean Annual Frequency of 5×10^{-5} Using Updated Source and Ground Motion Models

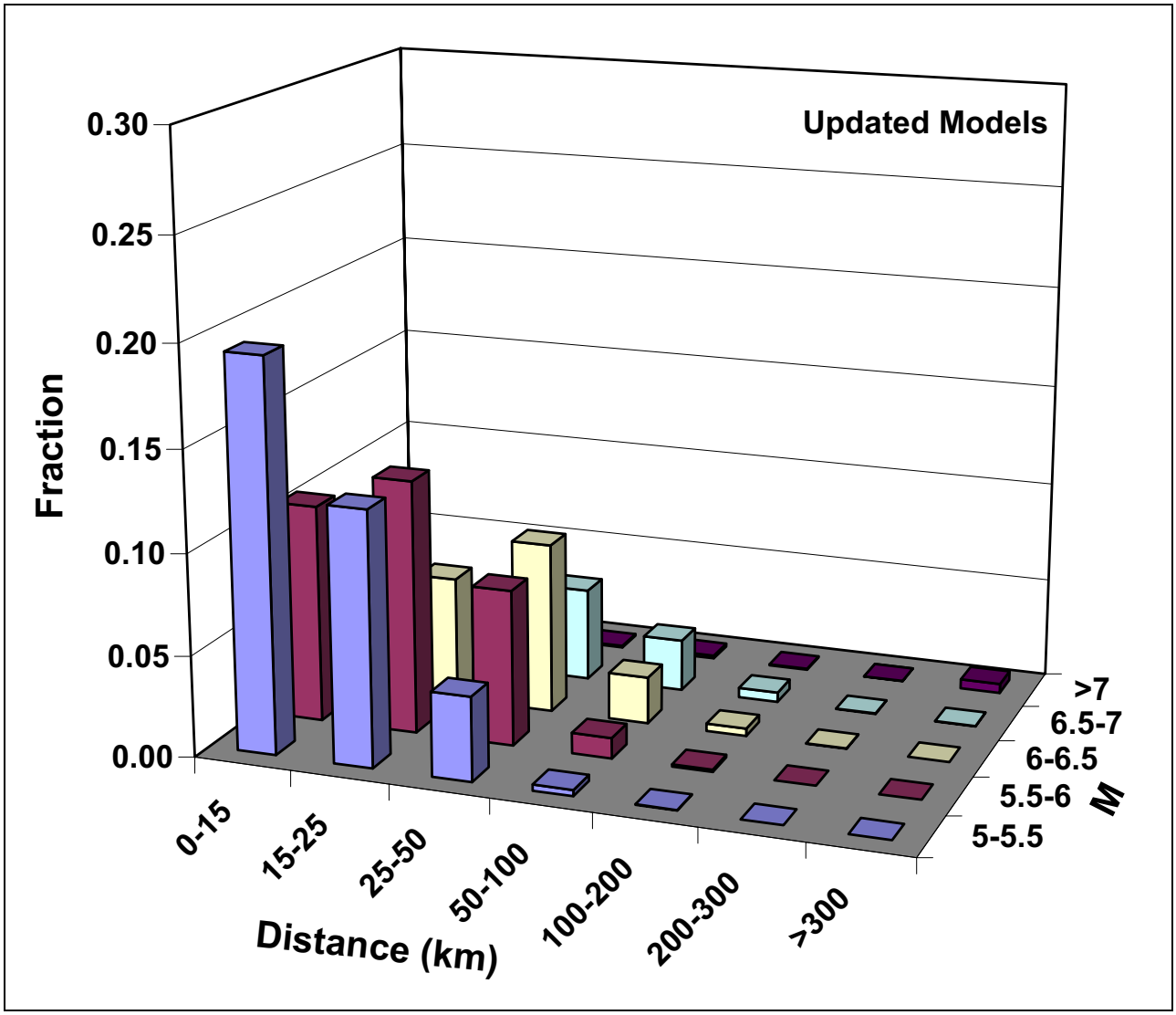


Figure 2.5-50 Magnitude-Distance Deaggregation for High-Frequencies (5 and 10 Hz) at a Mean Annual Frequency of 5×10^{-5} Using Updated Source and Ground Motion Models

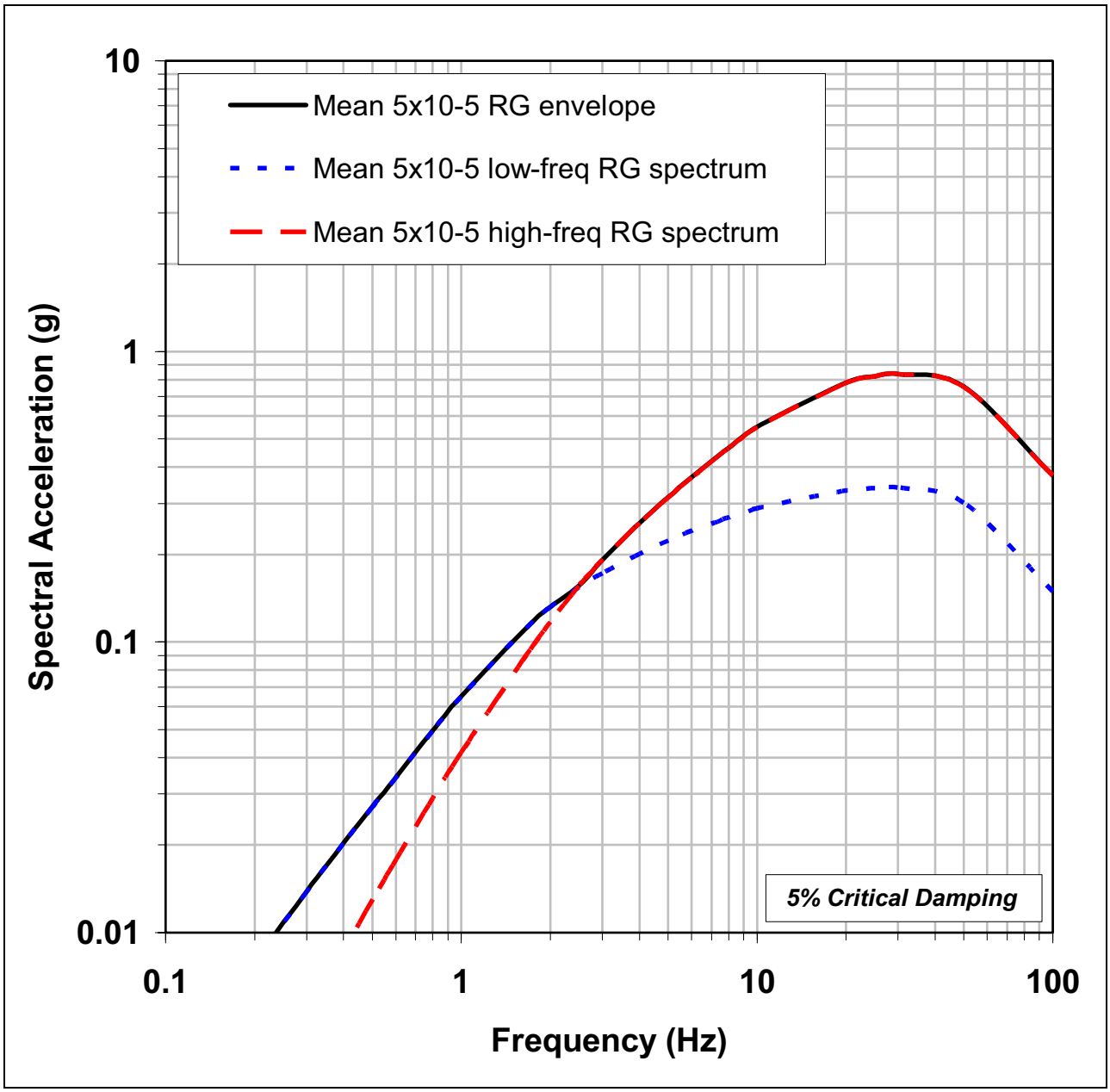


Figure 2.5-51 Low-Frequency, High-Frequency, and Envelope Horizontal Hard Rock SSE Spectra for RG 1.165 Reference Probability Approach Using 5×10^{-5}

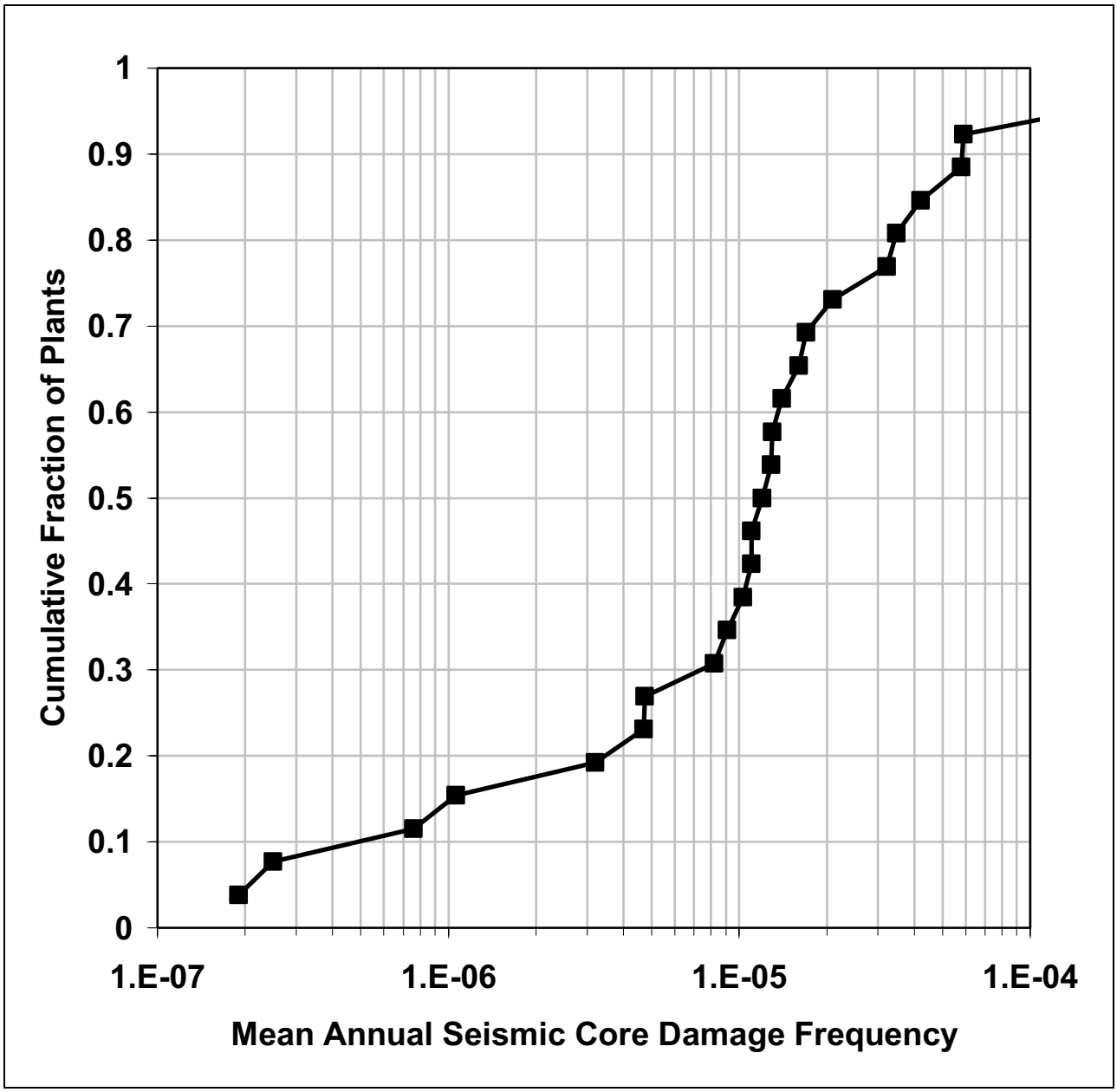


Figure 2.5-52 Cumulative Distribution of Seismic Core Damage Frequency (SCDF) for 25 Existing U.S. Nuclear Plants as Reported in NUREG-1742 (Reference 196)

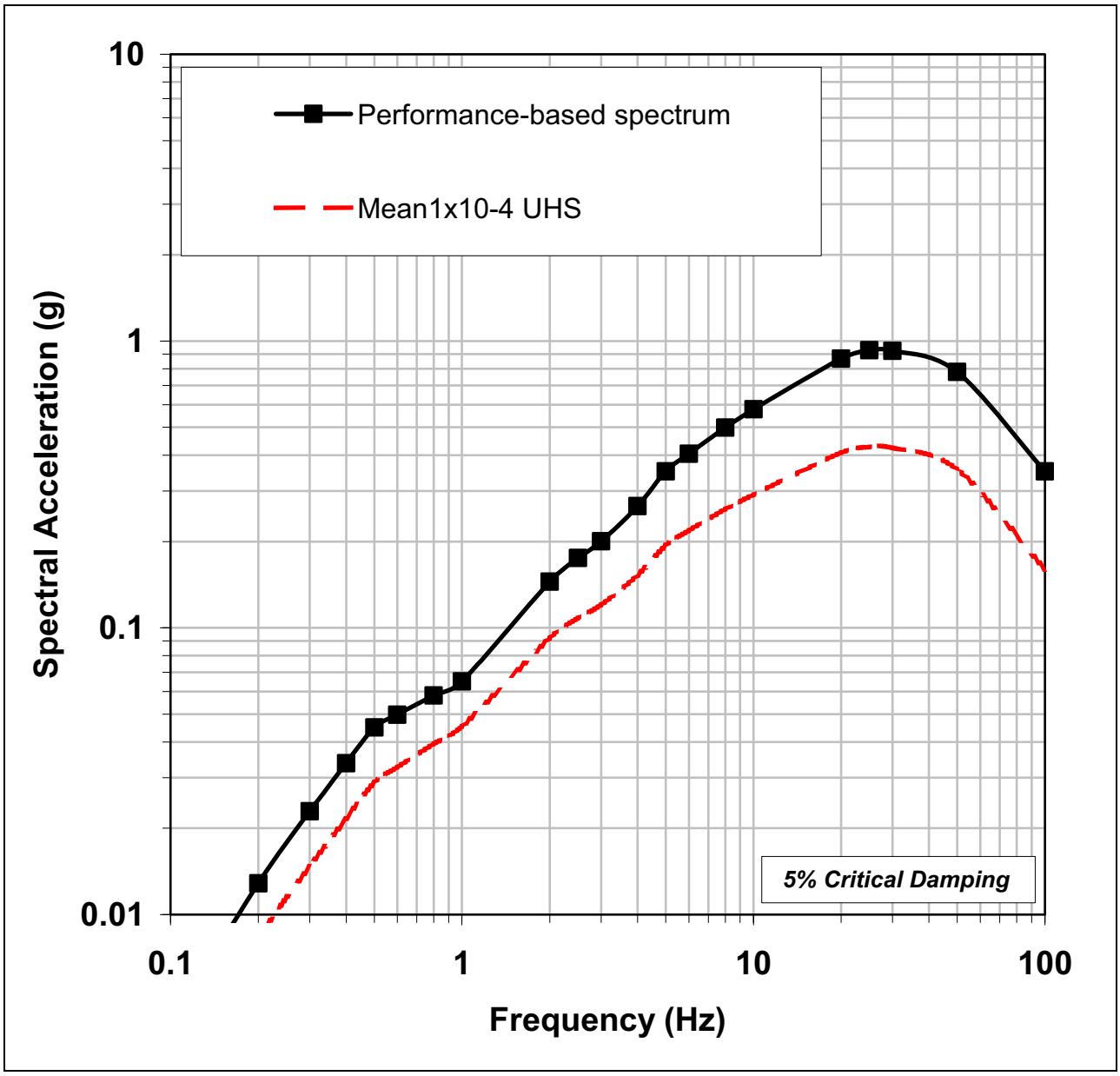


Figure 2.5-53 Performance-Based Horizontal Hard Rock SSE Spectrum, and Mean 10^{-4} Horizontal Uniform Hazard Spectrum

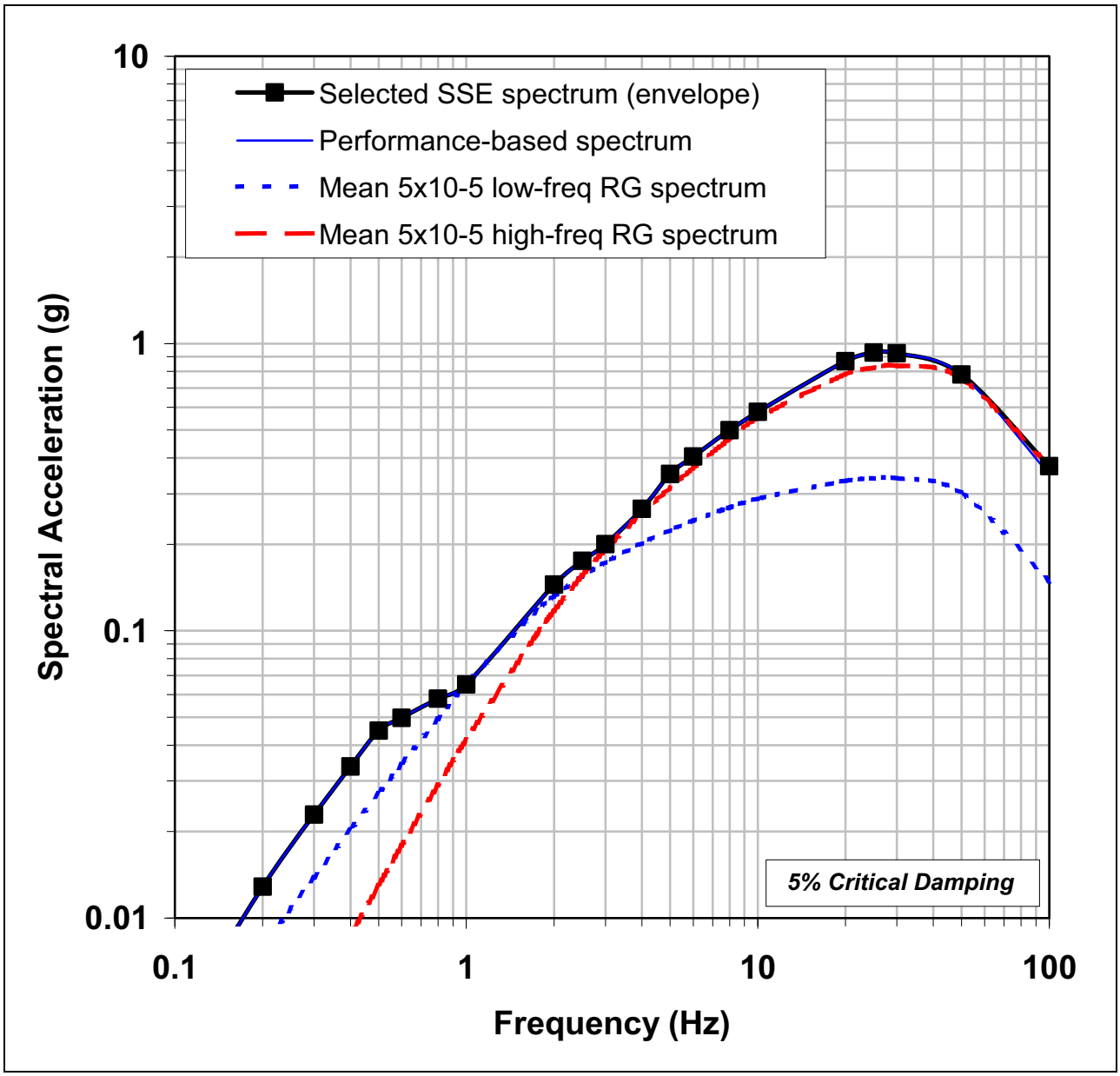


Figure 2.5-54A Comparison of Performance-Based Spectrum, Mean 5 × 10^{-5} Scaled Spectra, and Selected Hard Rock SSE Spectrum (Which Envelops the Other Three)

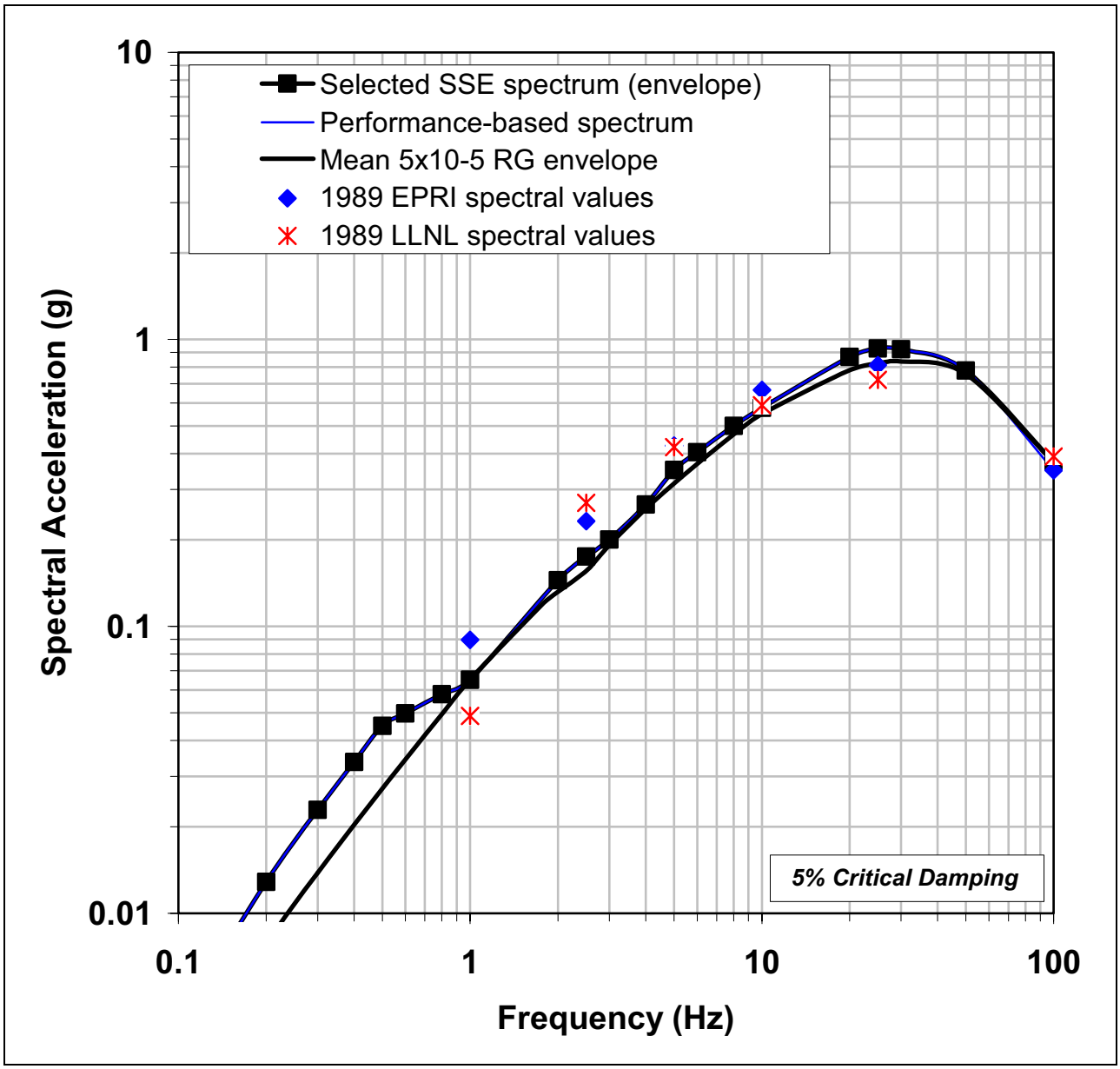


Figure 2.5-54B Comparison of Mean 5×10^{-5} RG 1.165 Envelope, 1989 EPRI (Reference 115), 1989 LLNL (Extrapolated from Reference 129), and Selected Hard Rock SSE Spectra

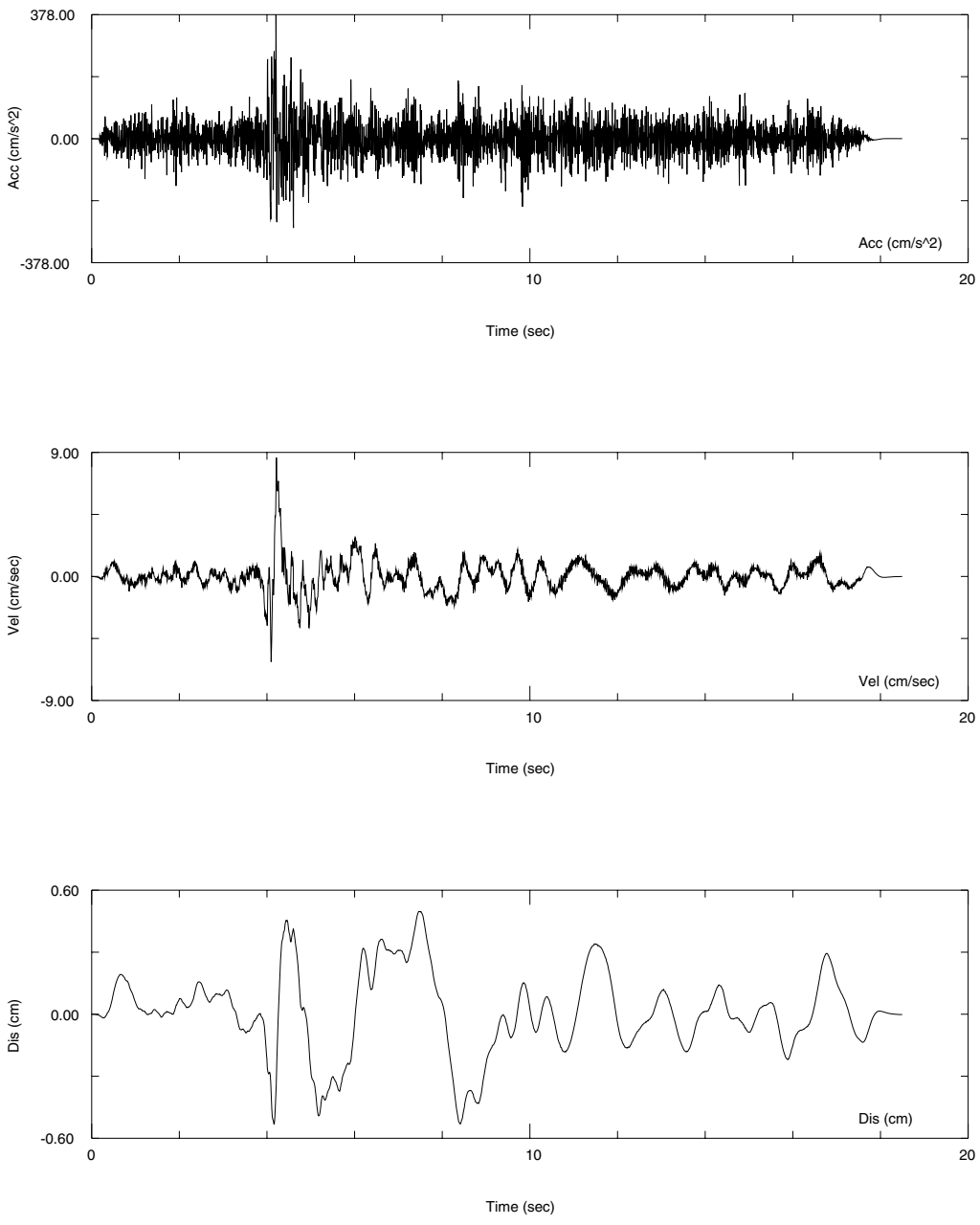


Figure 2.5-54B(1) Time History Developed To Be Spectrum-Compatible with the High-Frequency Target Spectrum for the Hard Rock SSE

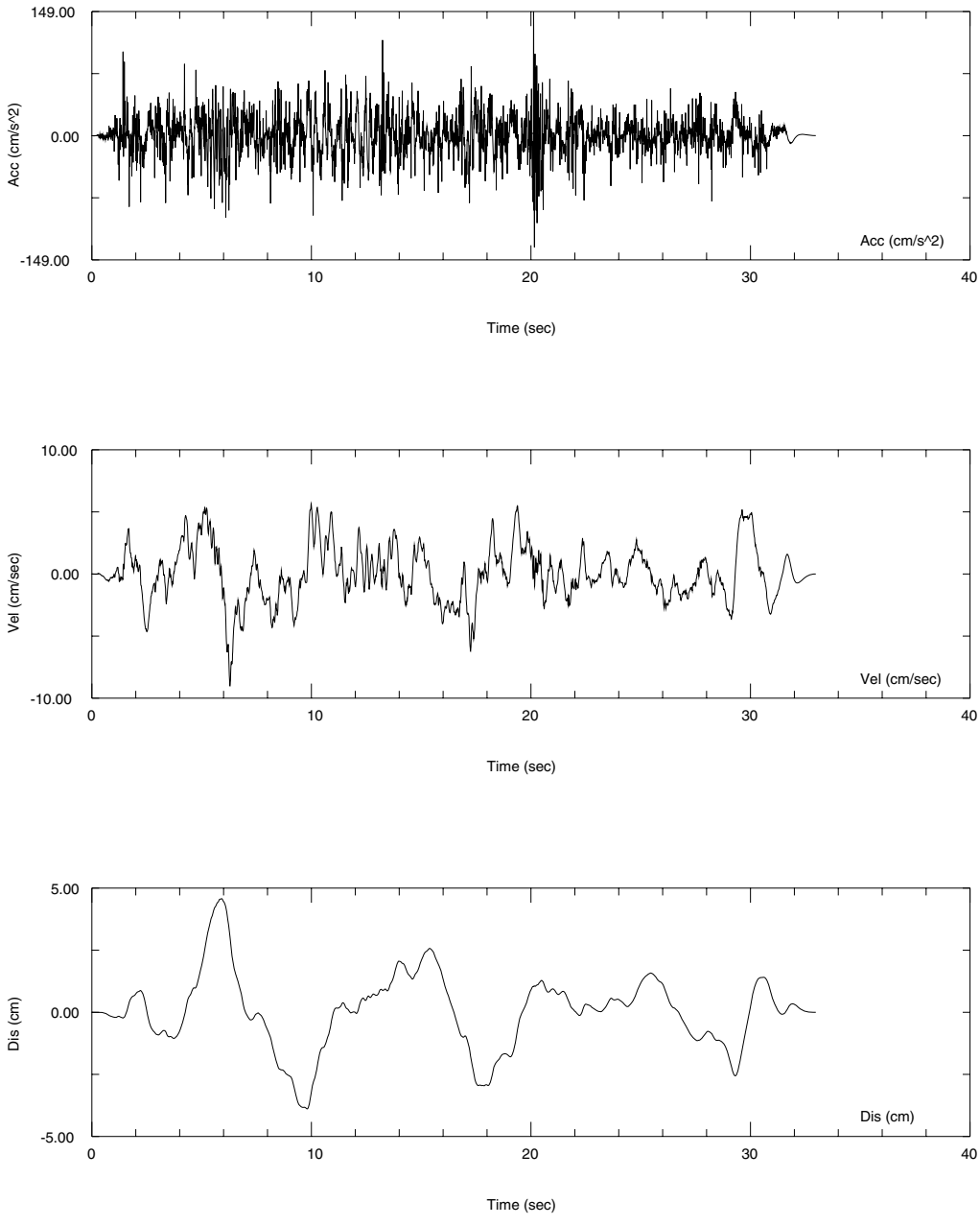


Figure 2.5-54B(2) Time History Developed To Be Spectrum-Compatible with the Low-Frequency Target Spectrum for the Hard Rock SSE

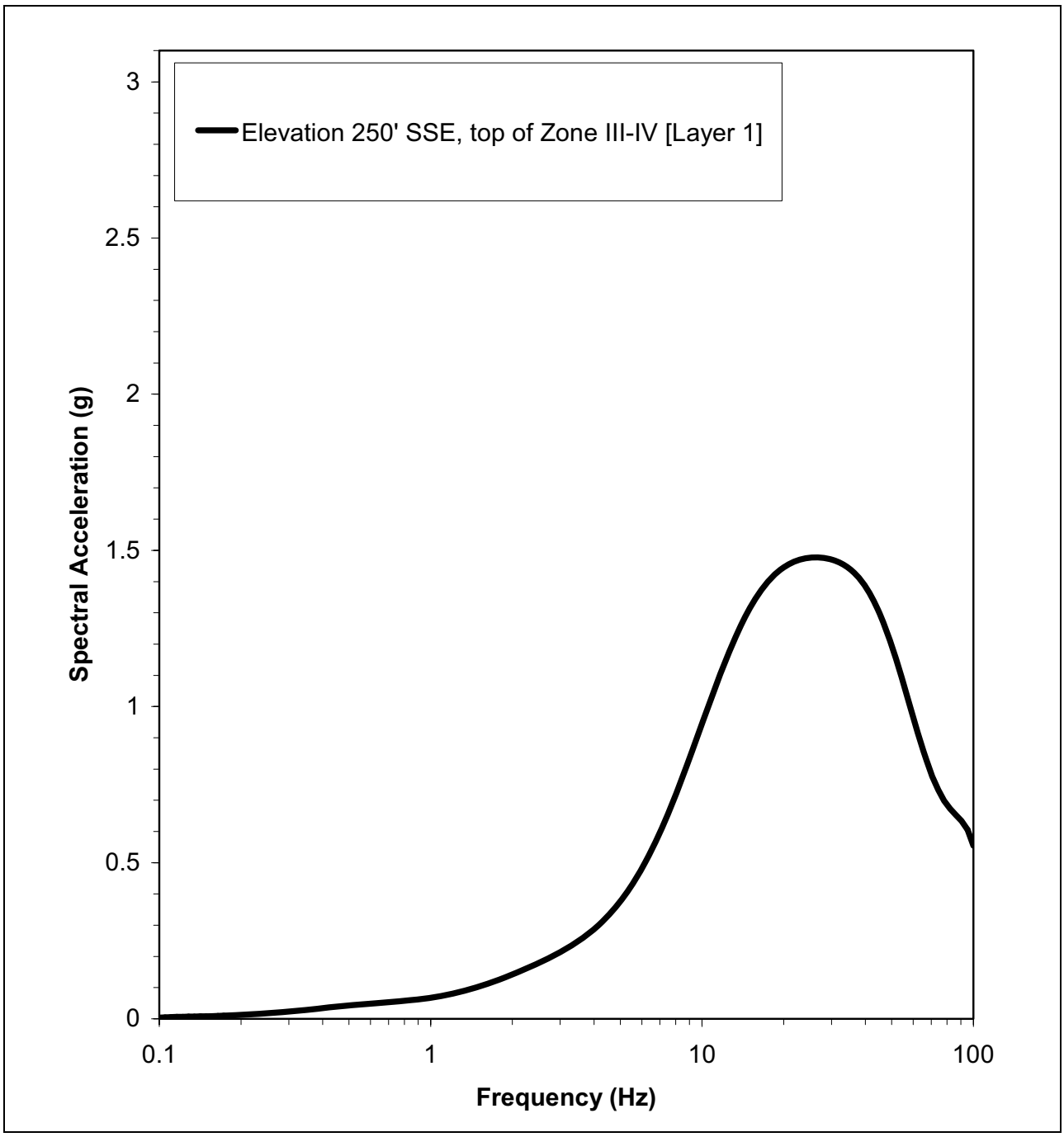


Figure 2.5-54B(3) Smooth Fitting Function Through the SHAKE Analysis Response Spectrum Results for the Hypothetical Rock Outcrop Control Point at the Top of Zone III-IV Material (Representative Elevation 250 ft, 3300 ft/sec Shear Wave Velocity)

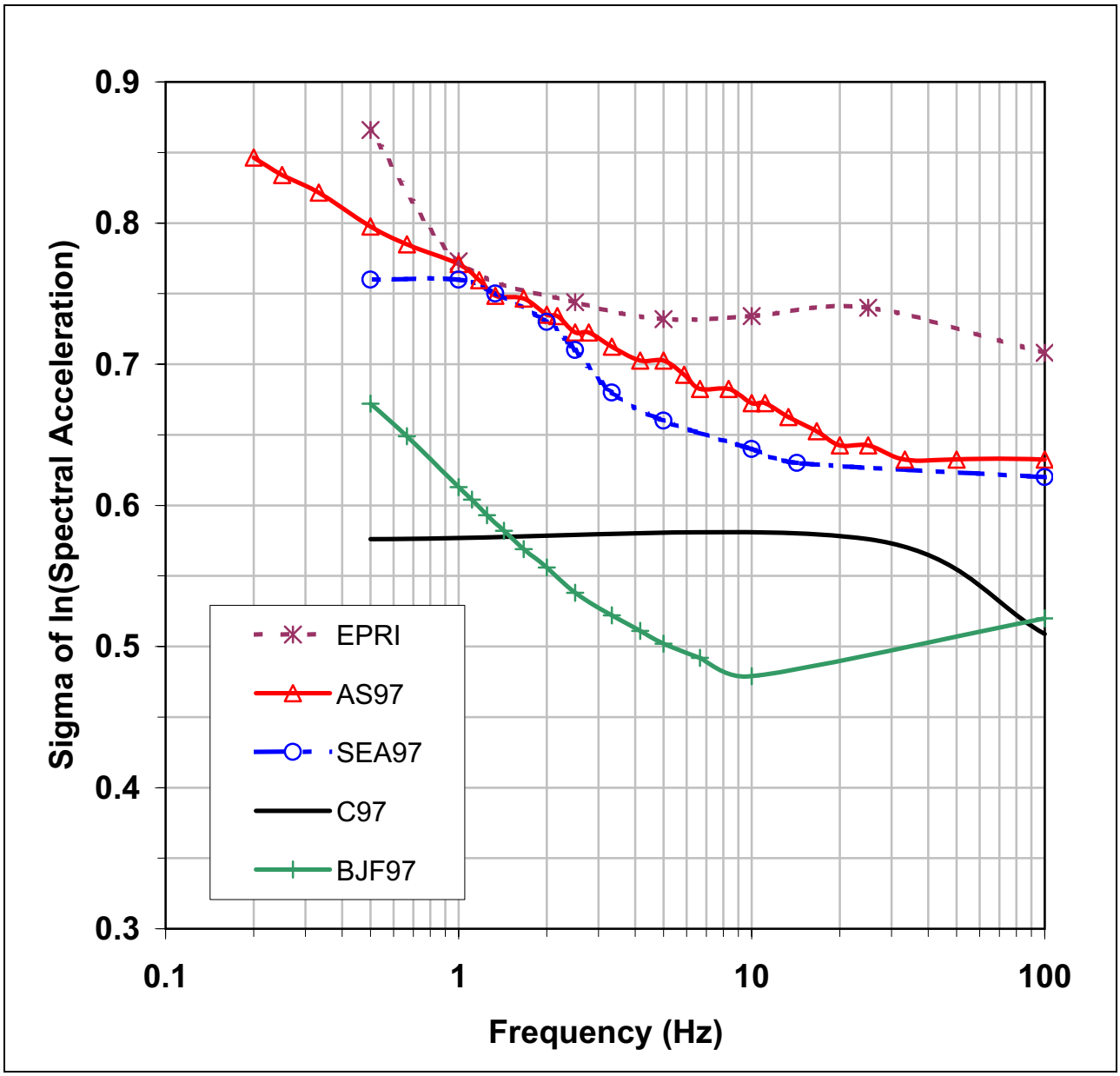


Figure 2.5-54C Comparison of Aleatory Sigmas Reported for California with Weighted Average Aleatory Sigma from EPRI Ground Motion 2003 Models for M = 5.5, R_{CD} = 20 km

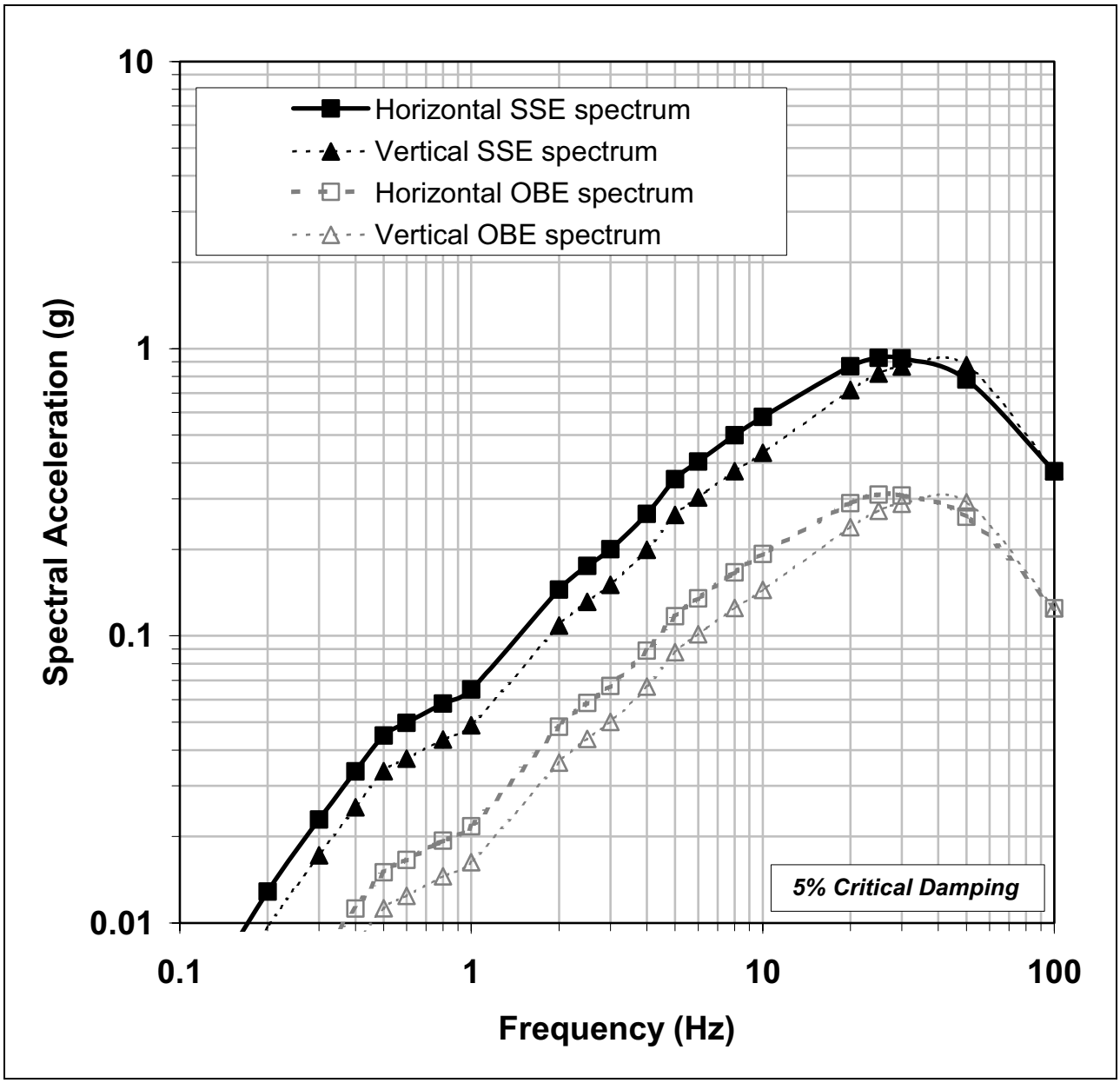


Figure 2.5-55 Selected Horizontal and Vertical SSE and OBE Spectra Based on Updated Models (5% Critical Damping)

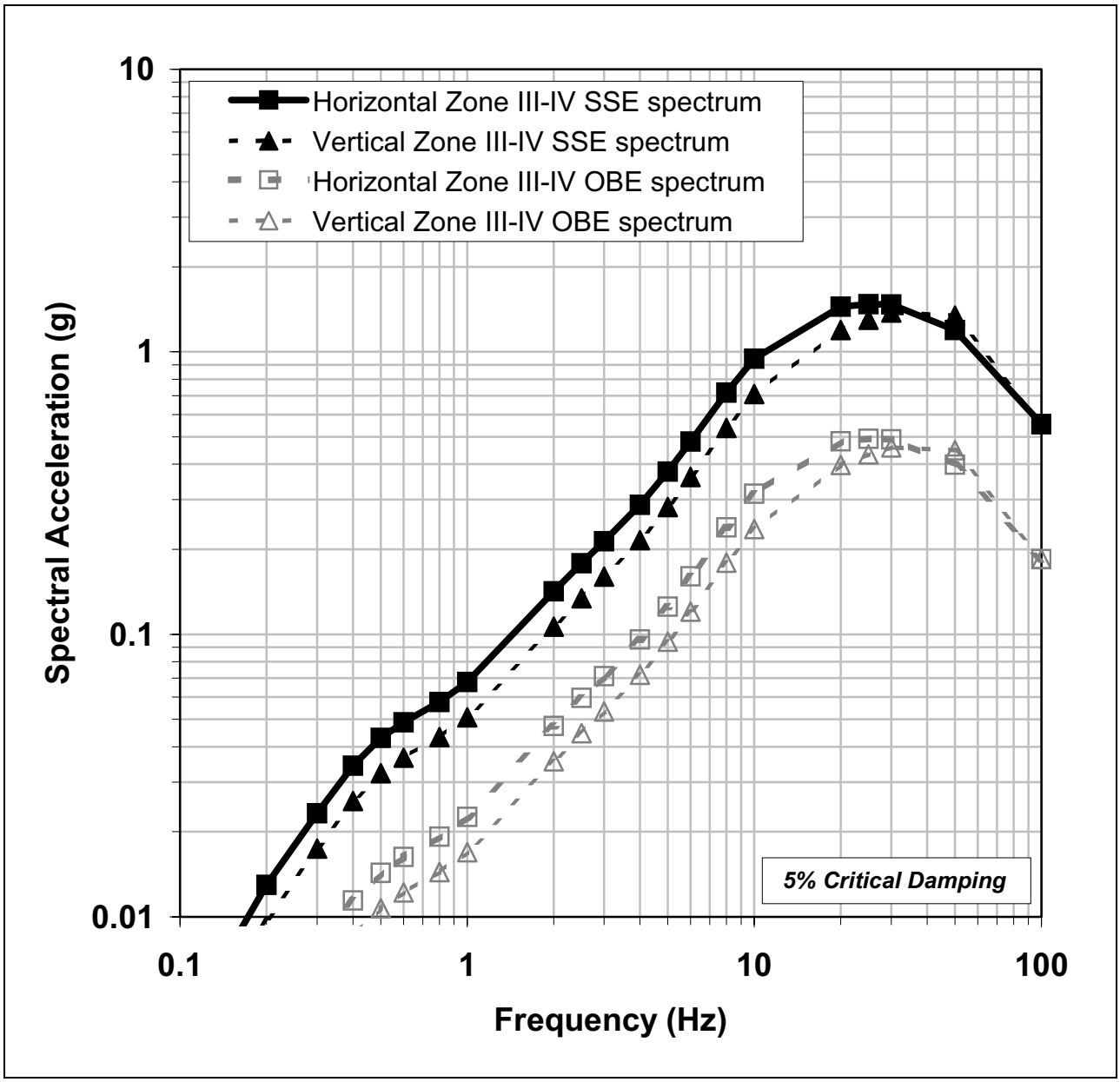


Figure 2.5-55A Selected Horizontal and Vertical OBE and SSE Spectra for the Hypothetical Rock Outcrop Control Point at the Top of Zone III-IV Material (Representative Elevation 250 ft, 3300 ft/sec Shear Wave Velocity)

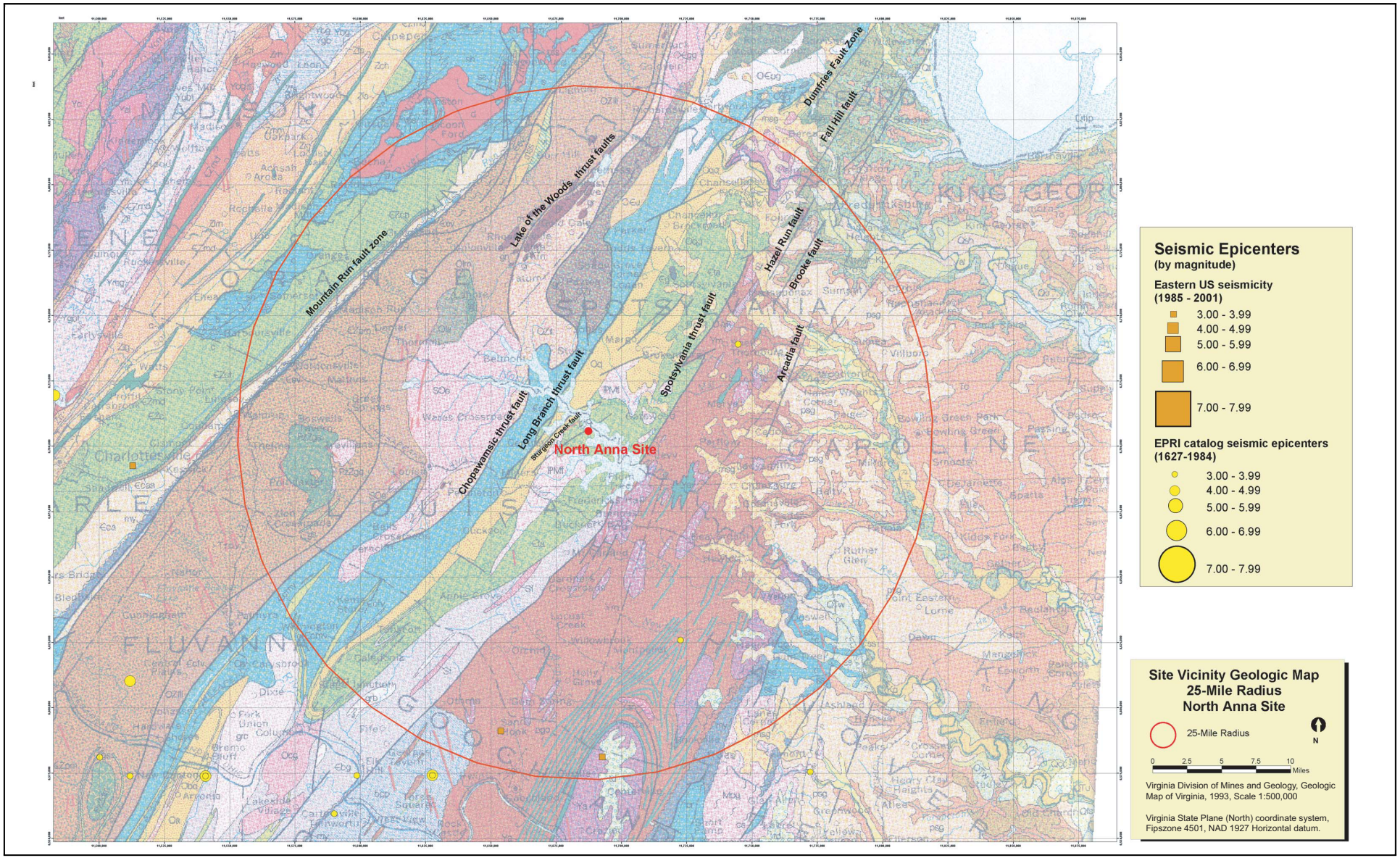


Figure 2.5-56 Site Vicinity Geologic Map and Seismicity (25-Mile Radius)

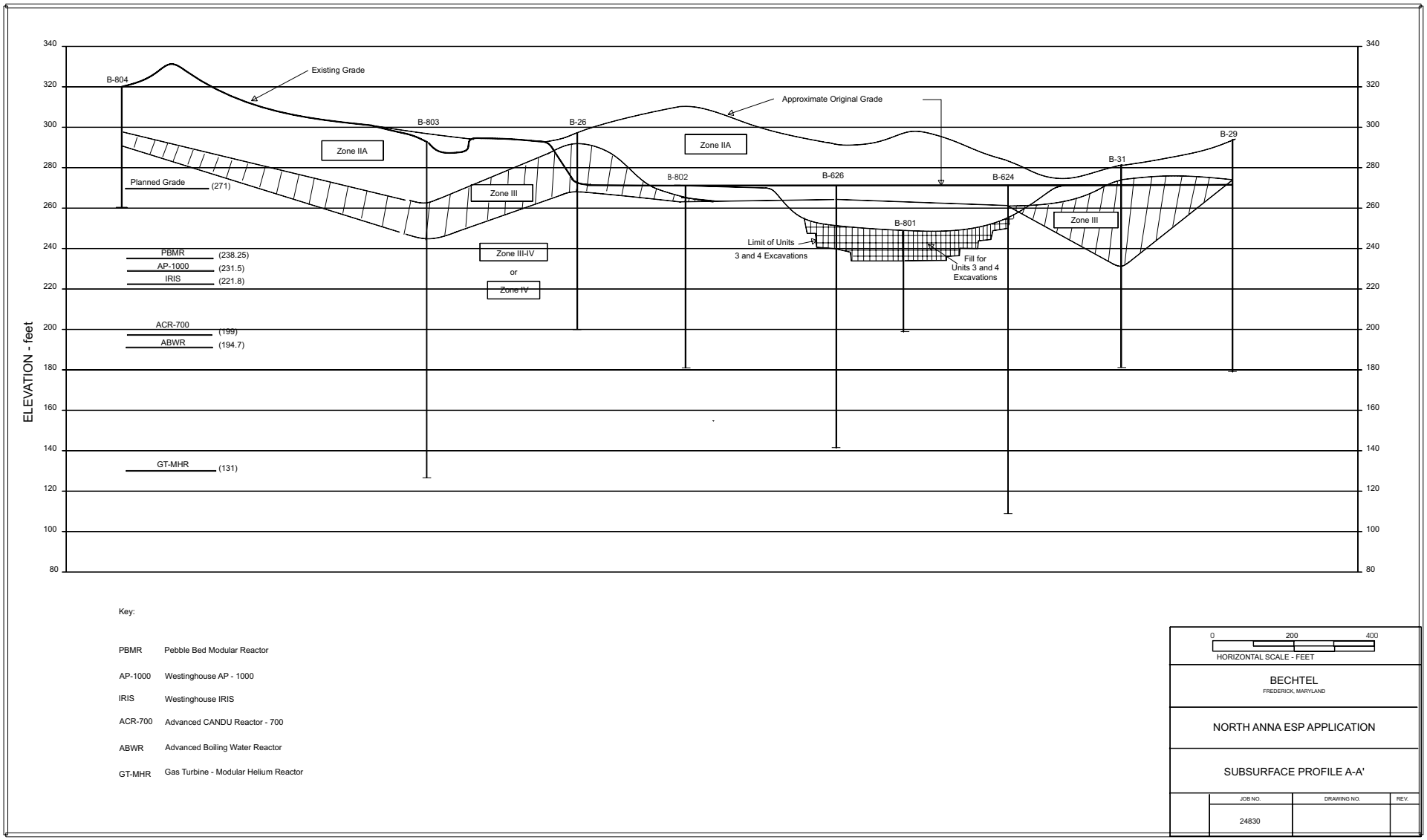


Figure 2.5-57 Subsurface Profile A-A'

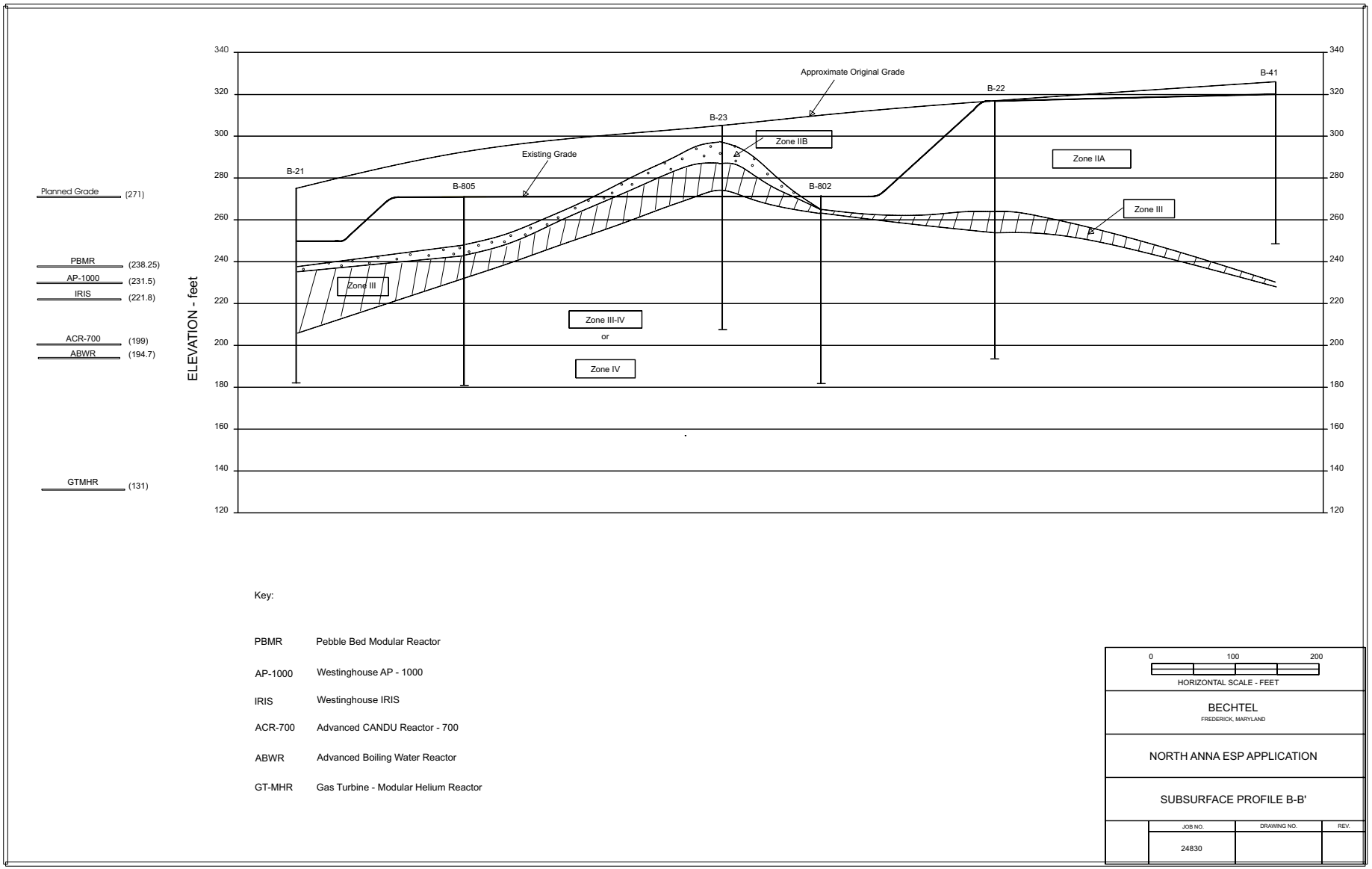


Figure 2.5-58 Subsurface Profile B-B'

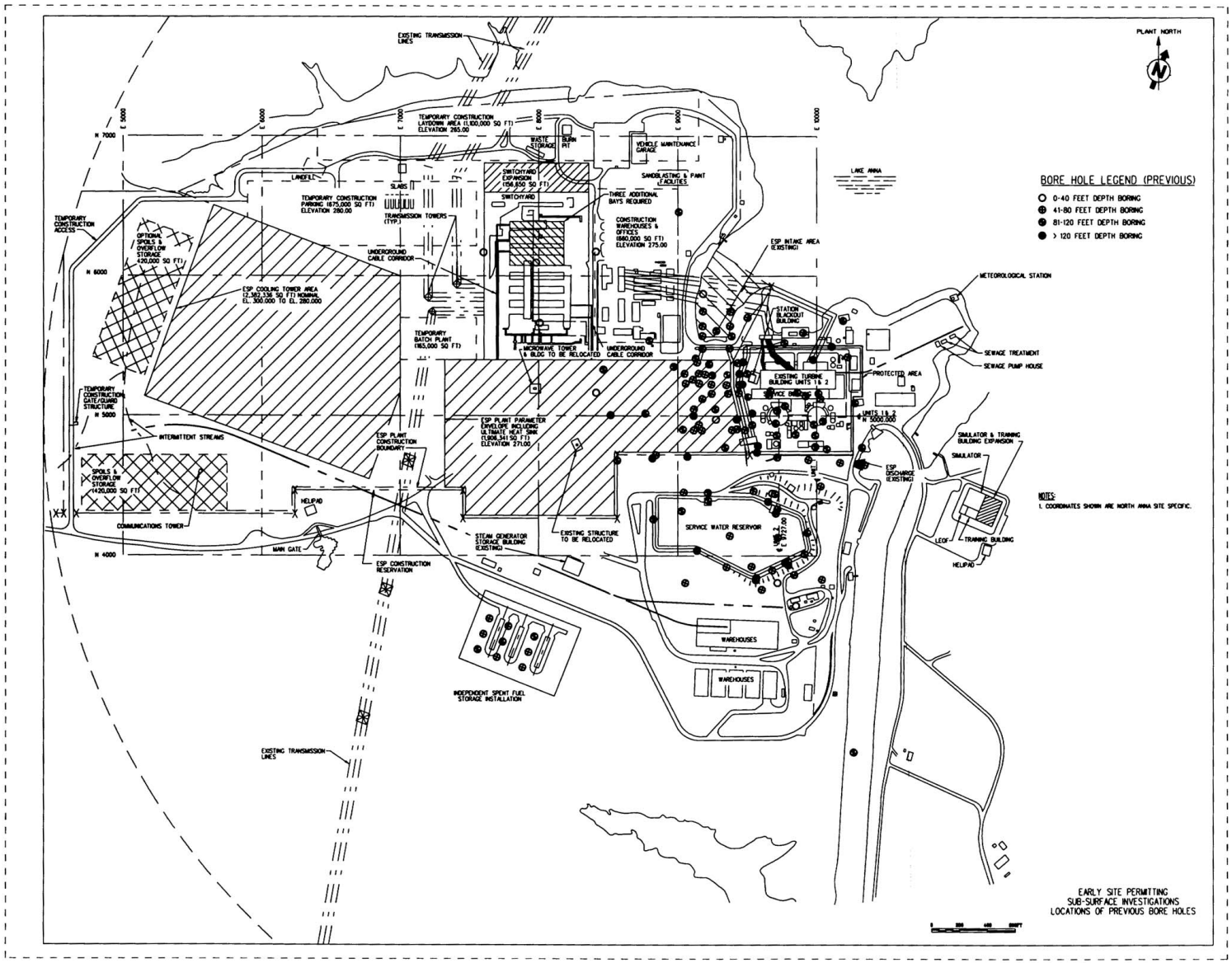


Figure 2.5-59 Locations of Previous Boreholes

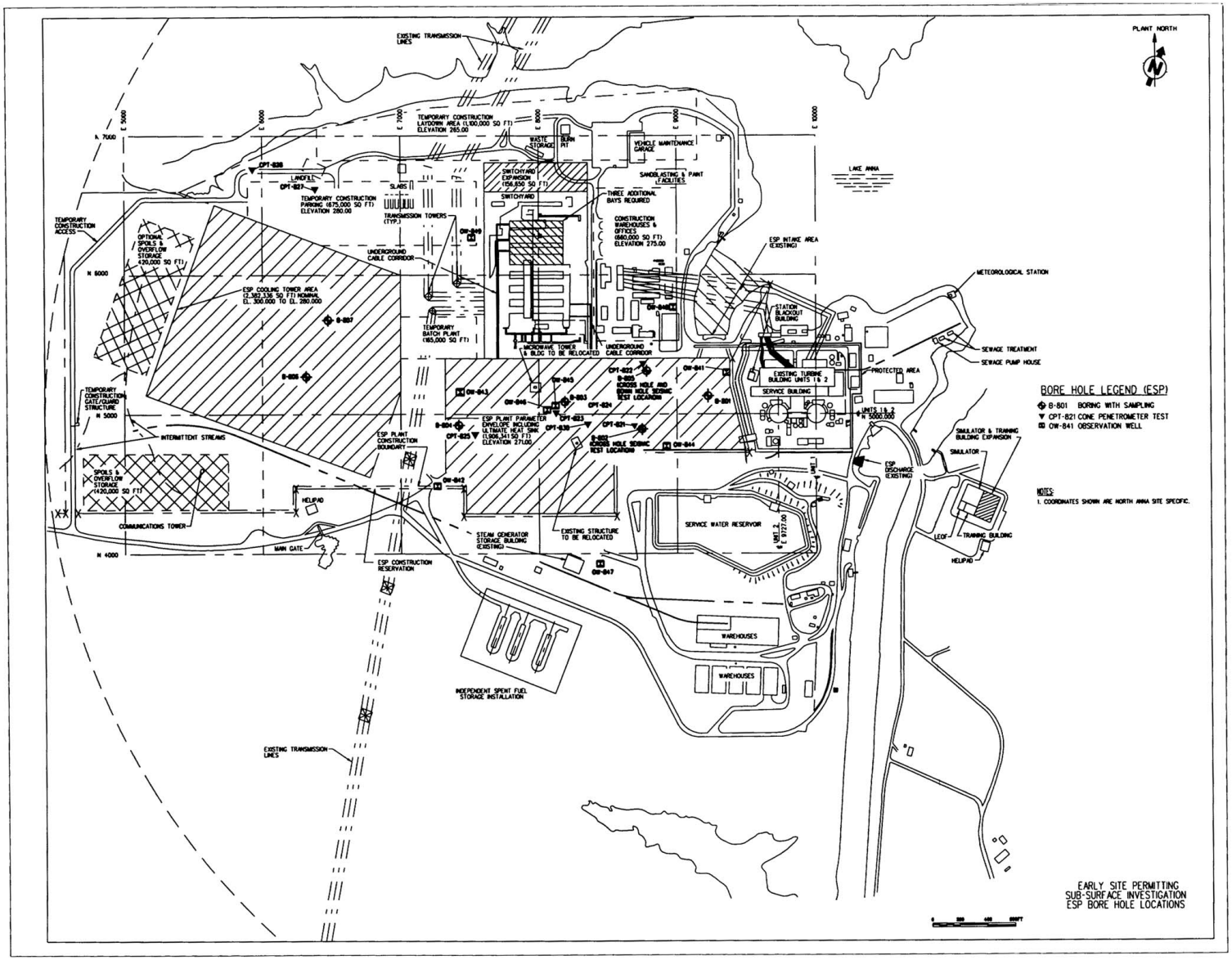


Figure 2.5-60 ESP Borehole Locations

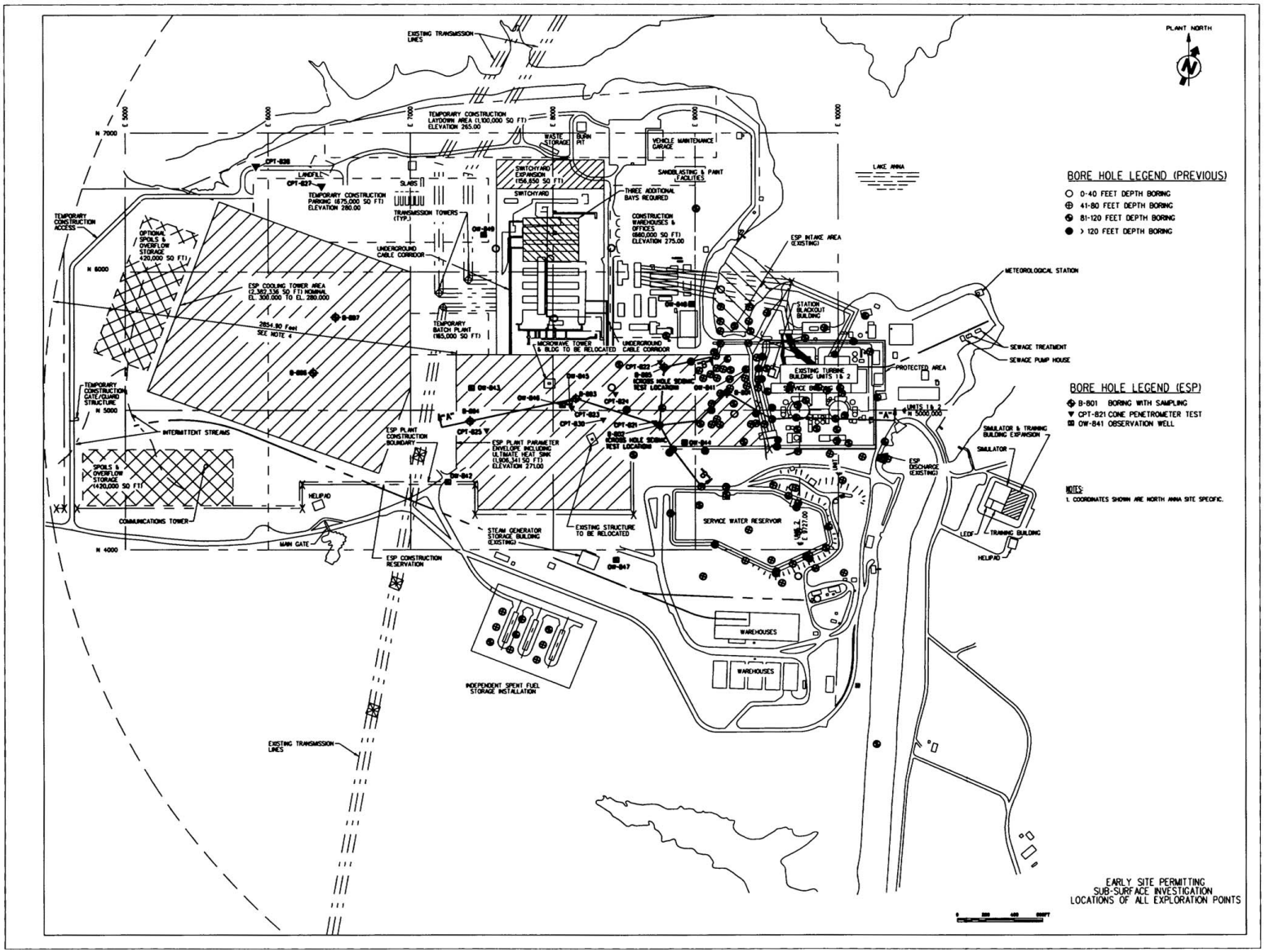


Figure 2.5-61 Locations of All Exploration Points

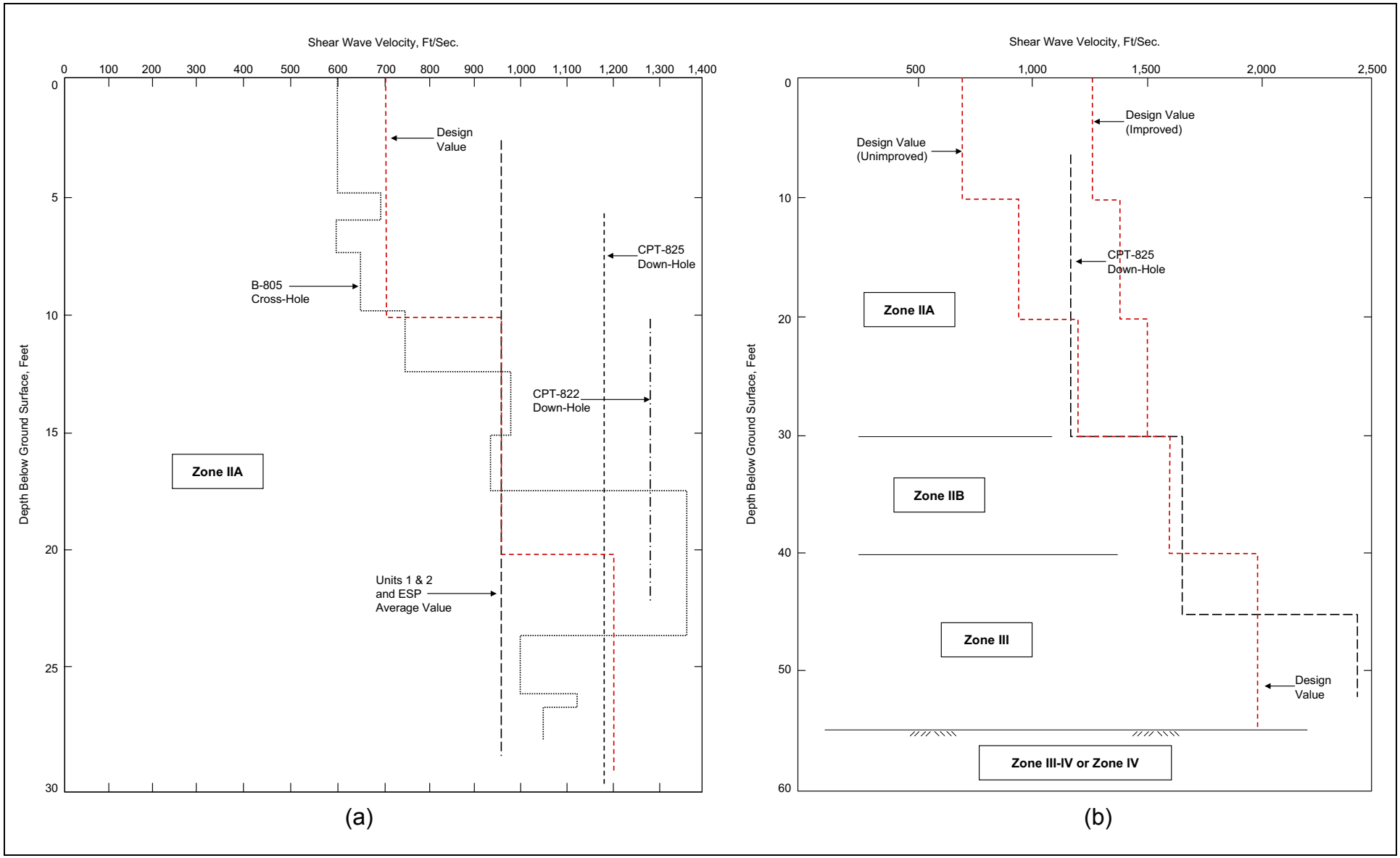


Figure 2.5-62 Zone IIA Shear Wave Velocity Profile (a) Full-Depth Shear Wave Velocity Profile (b)

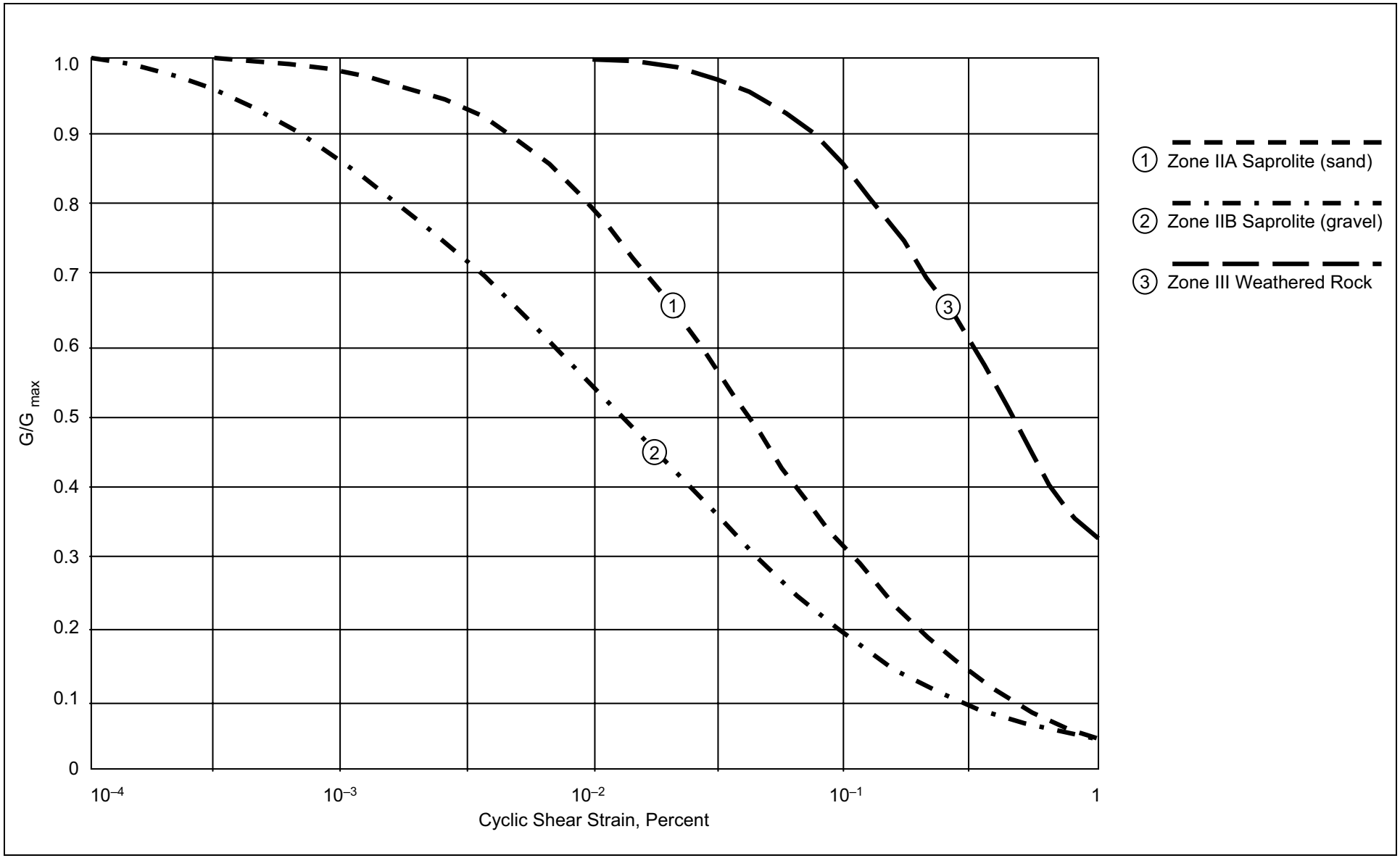


Figure 2.5-63 Variation of Normalized Shear Modulus with Cycle Shear Strain

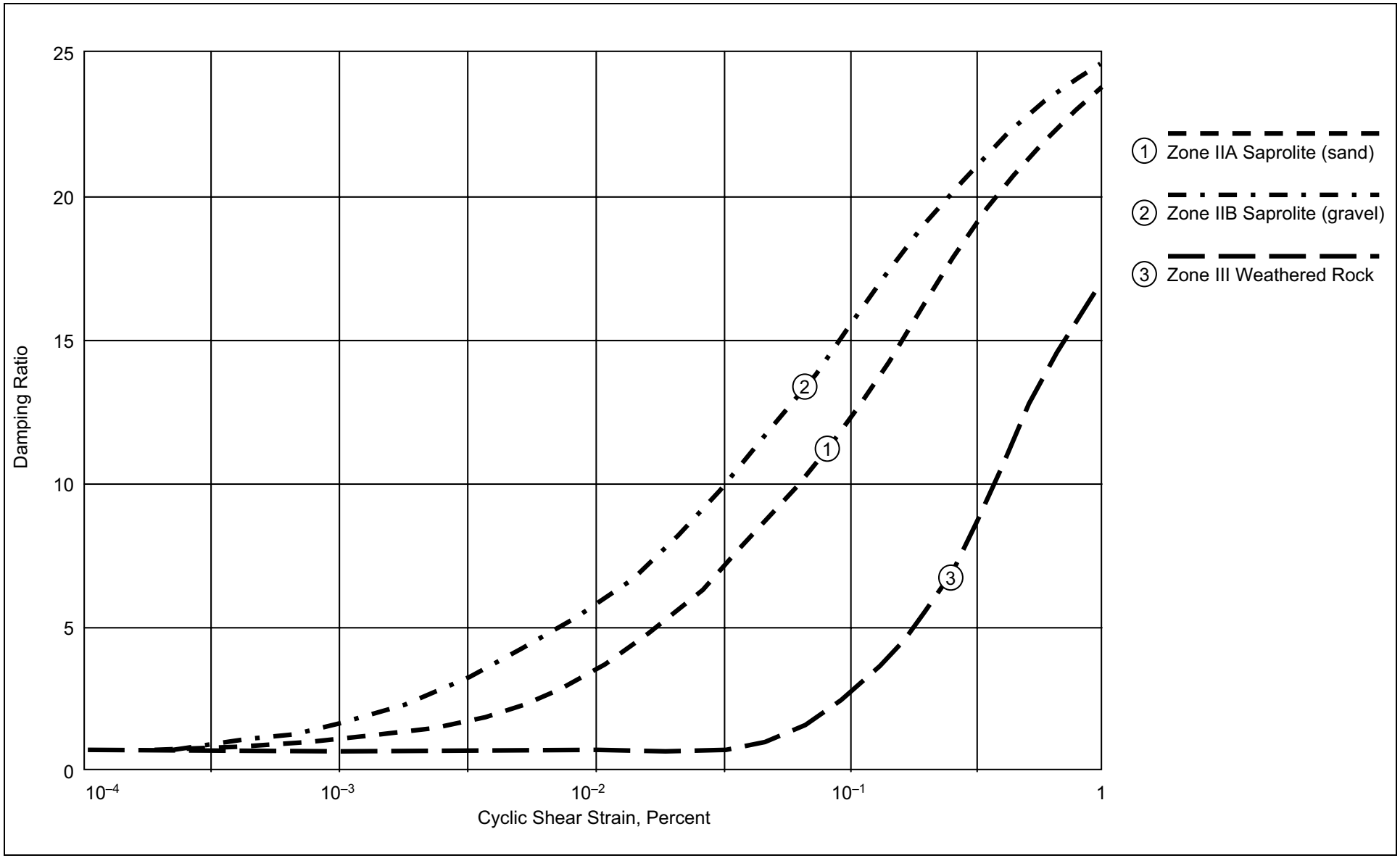


Figure 2.5-64 Variation of Damping Ratio with Cyclic Shear Strain

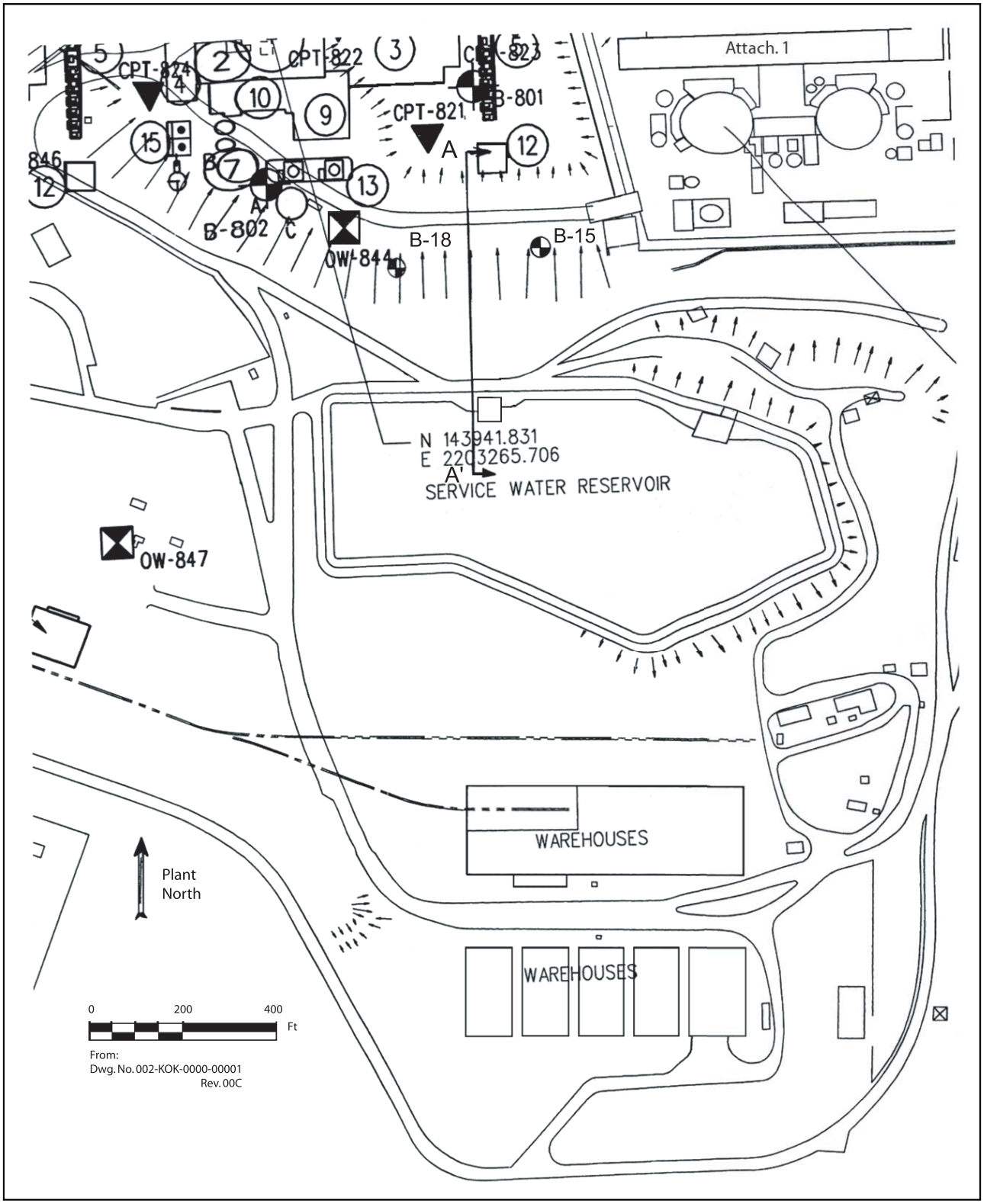


Figure 2.5-65 Plan View of Slope North of the SWR

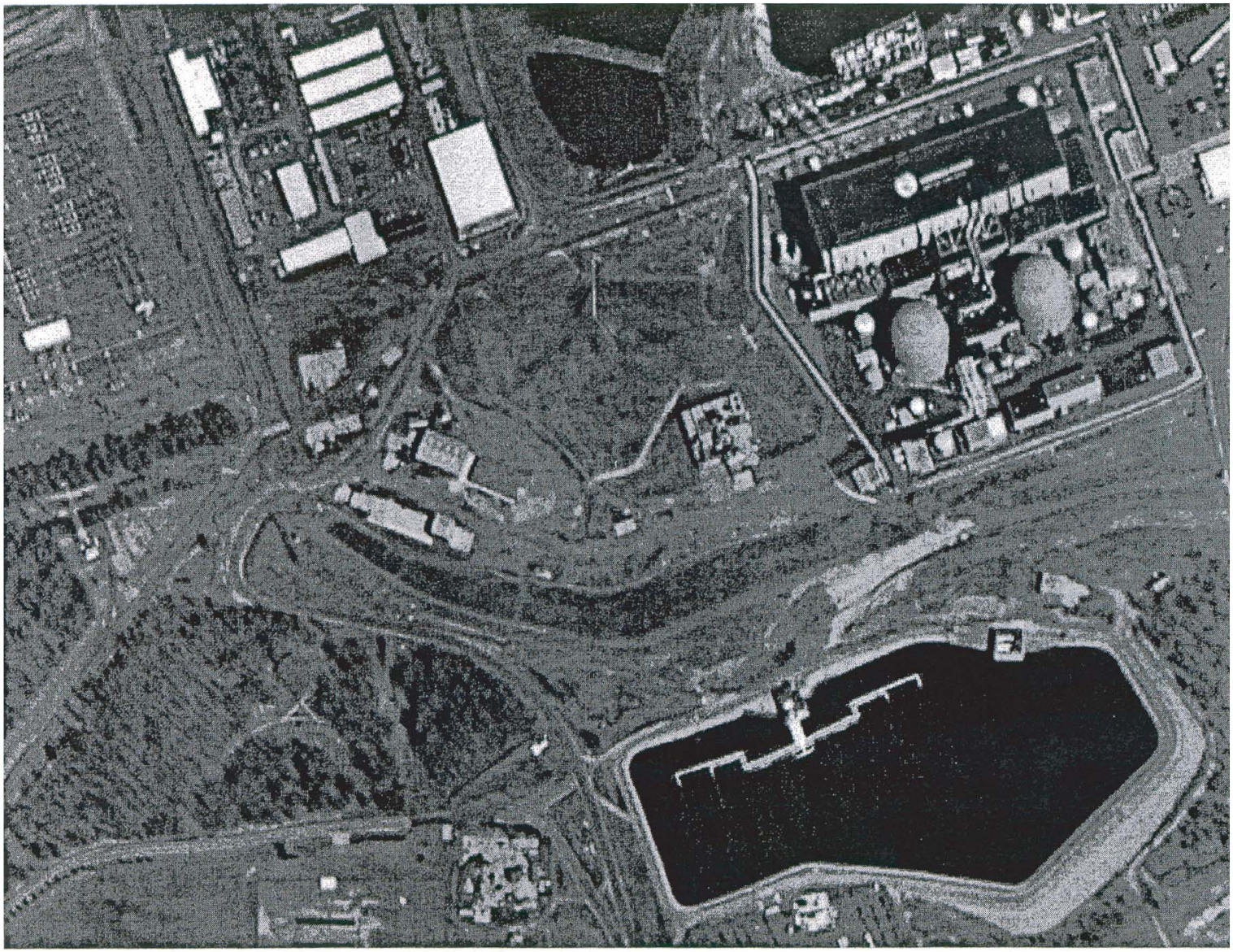


Figure 2.5-66 Photograph of Plan View of Slope North of the SWR

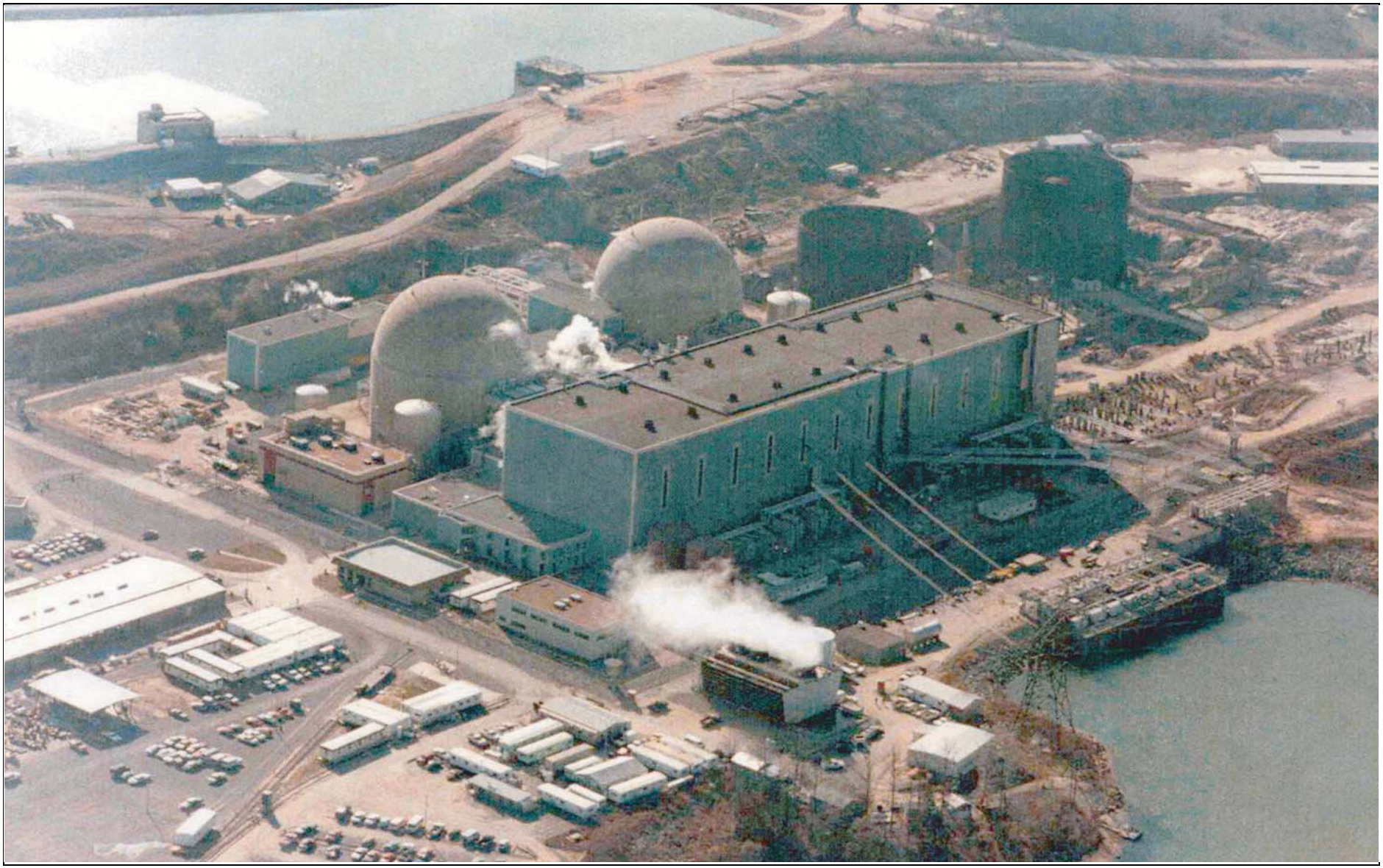


Figure 2.5-67 Photograph of Slope North of the SWR

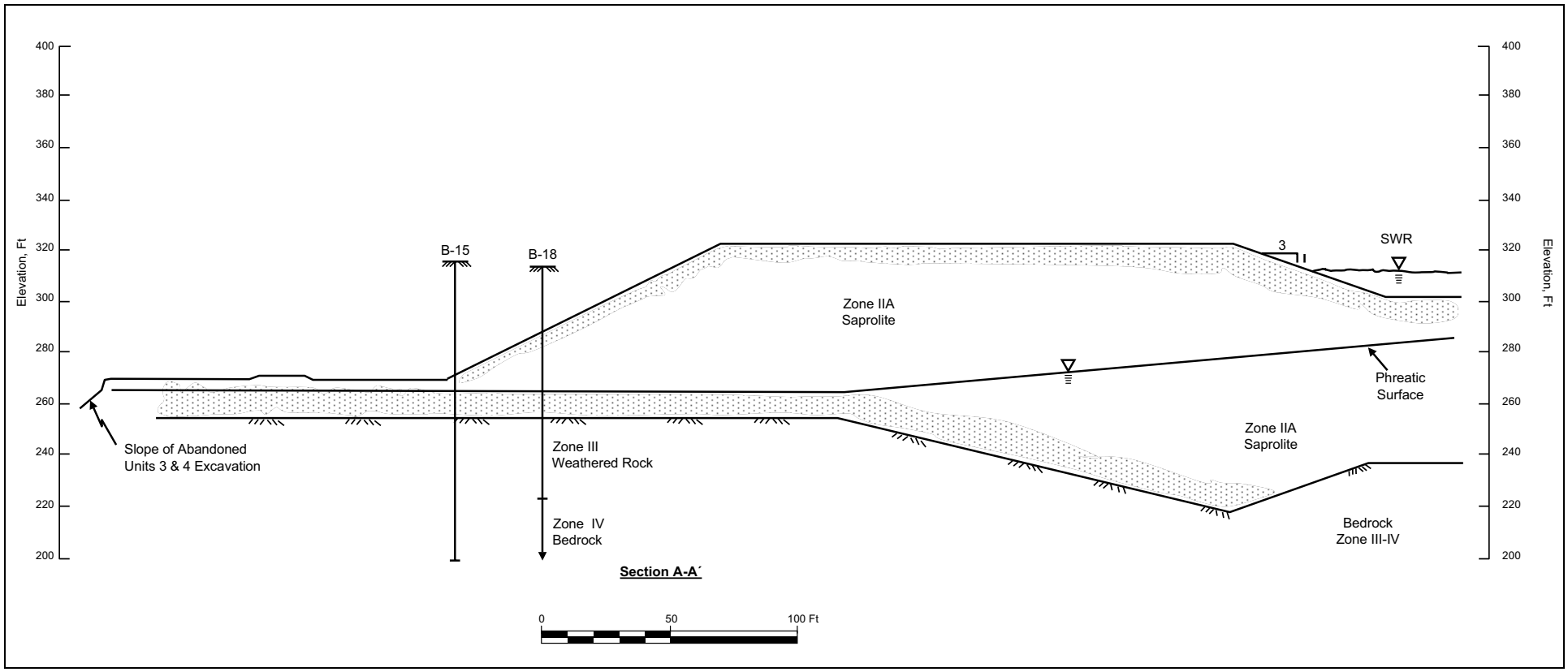
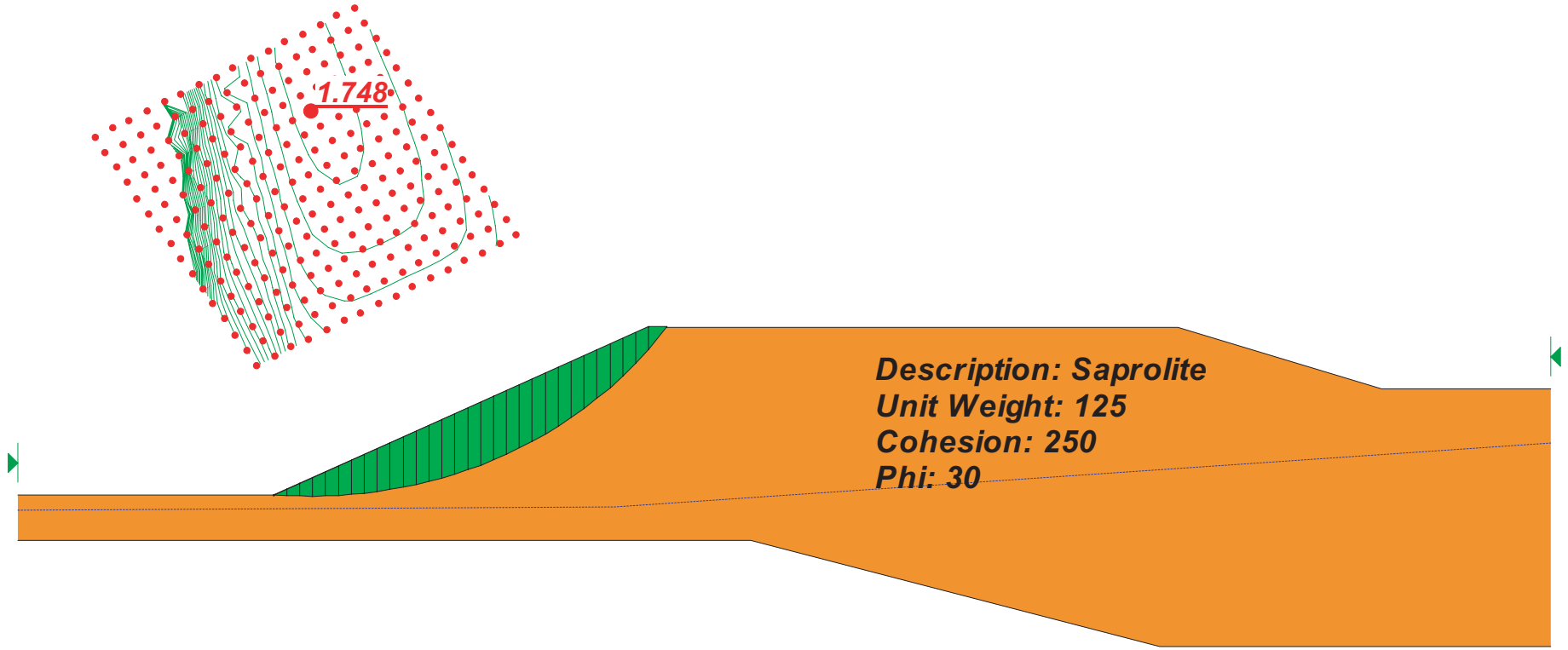


Figure 2.5-68 Cross-Section of Existing Slope North of the SWR



Description: North Anna Existing Slope
Comments: 2H:1V Slope - Saprolite
File Name: Existing NC 1.slp
Last Saved Date: 9/2/2003
Analysis Method: Bishop
P.W.P. Option: Piezometric Lines / Ru
Seismic Coefficient: (none)

Figure 2.5-69 SLOPE/W Analysis of Long-Term Static Case

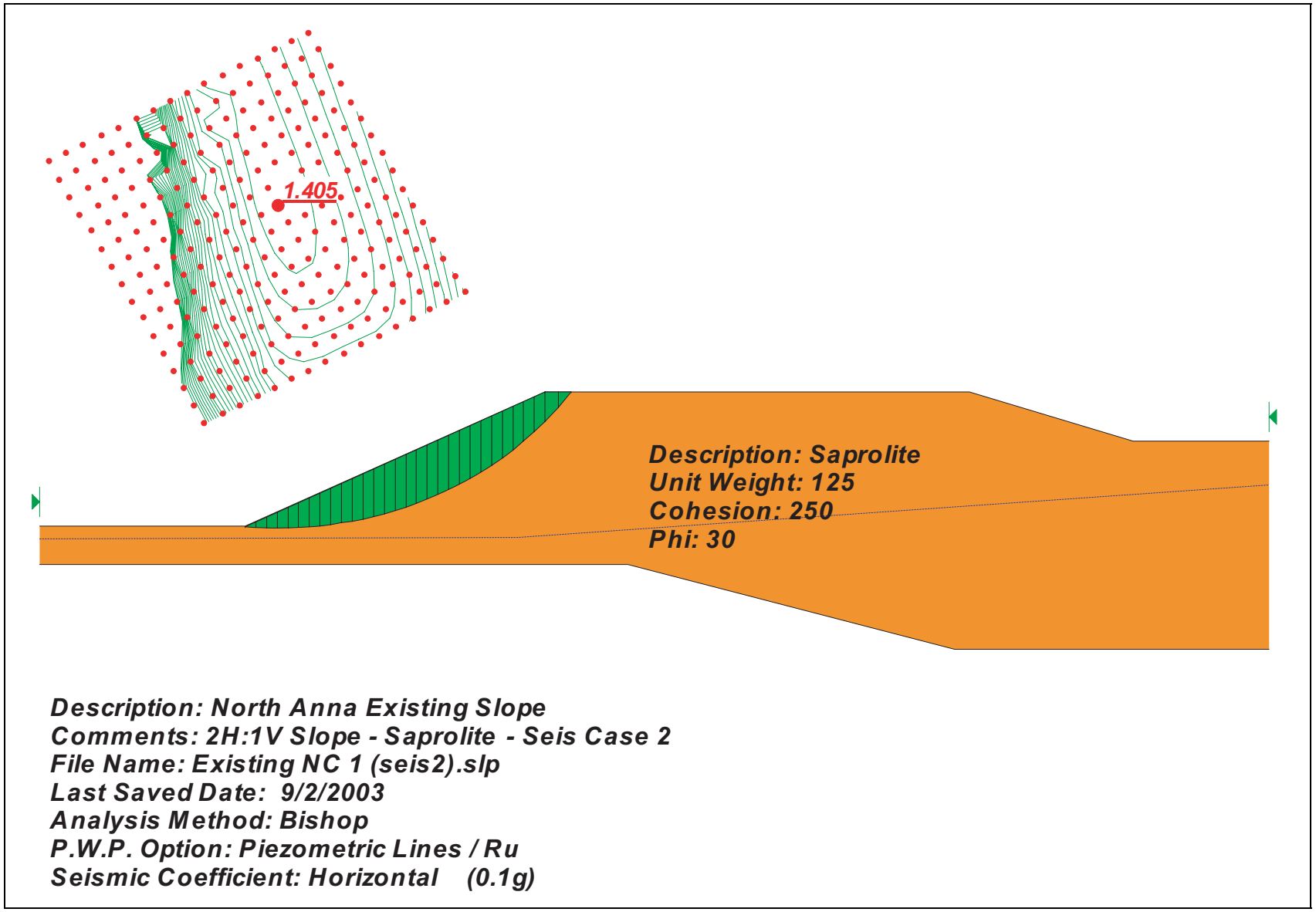


Figure 2.5-70 SLOPE/W Analysis of Seismic Case

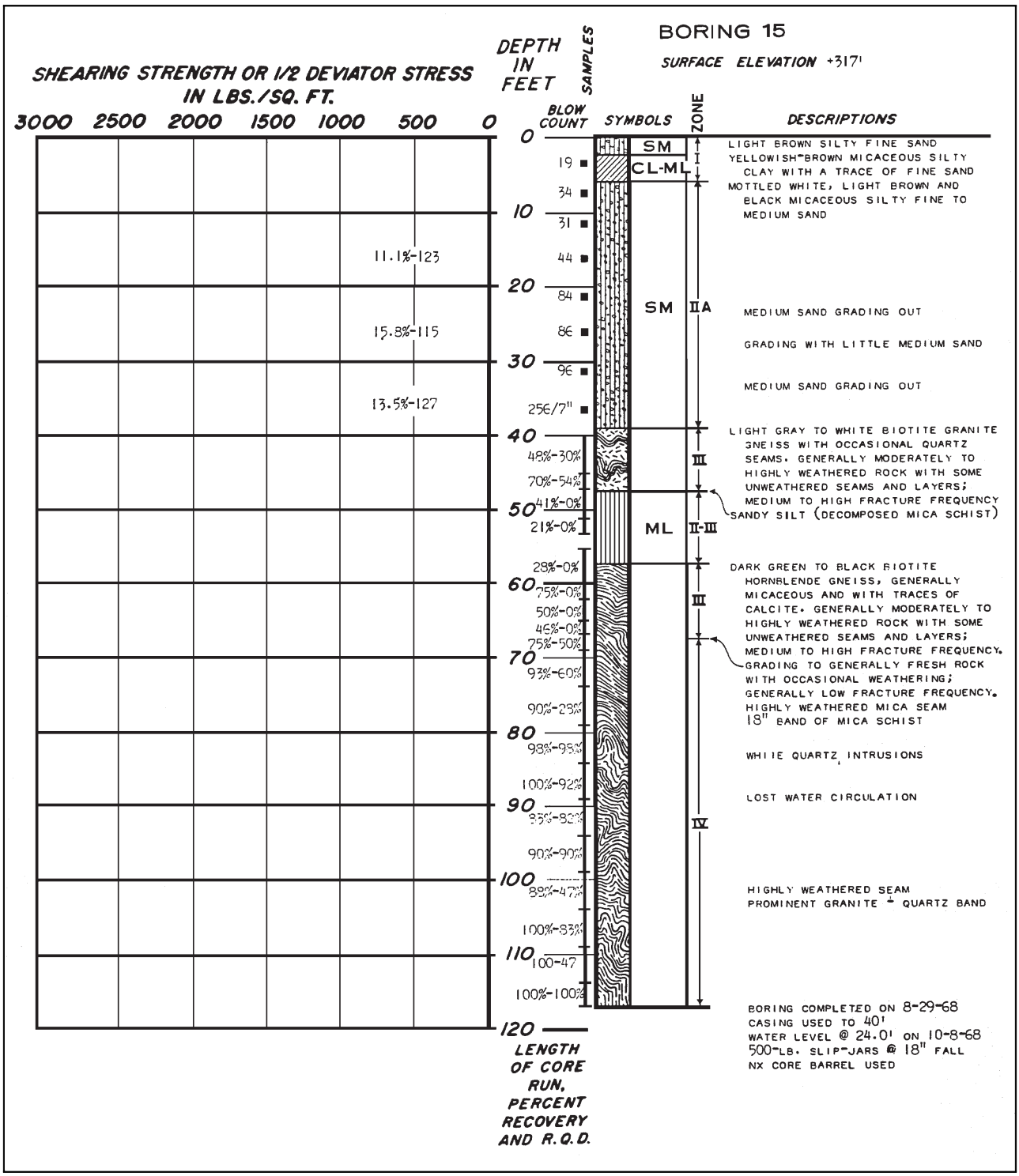


Figure 2.5-71 Log of Boring B-15

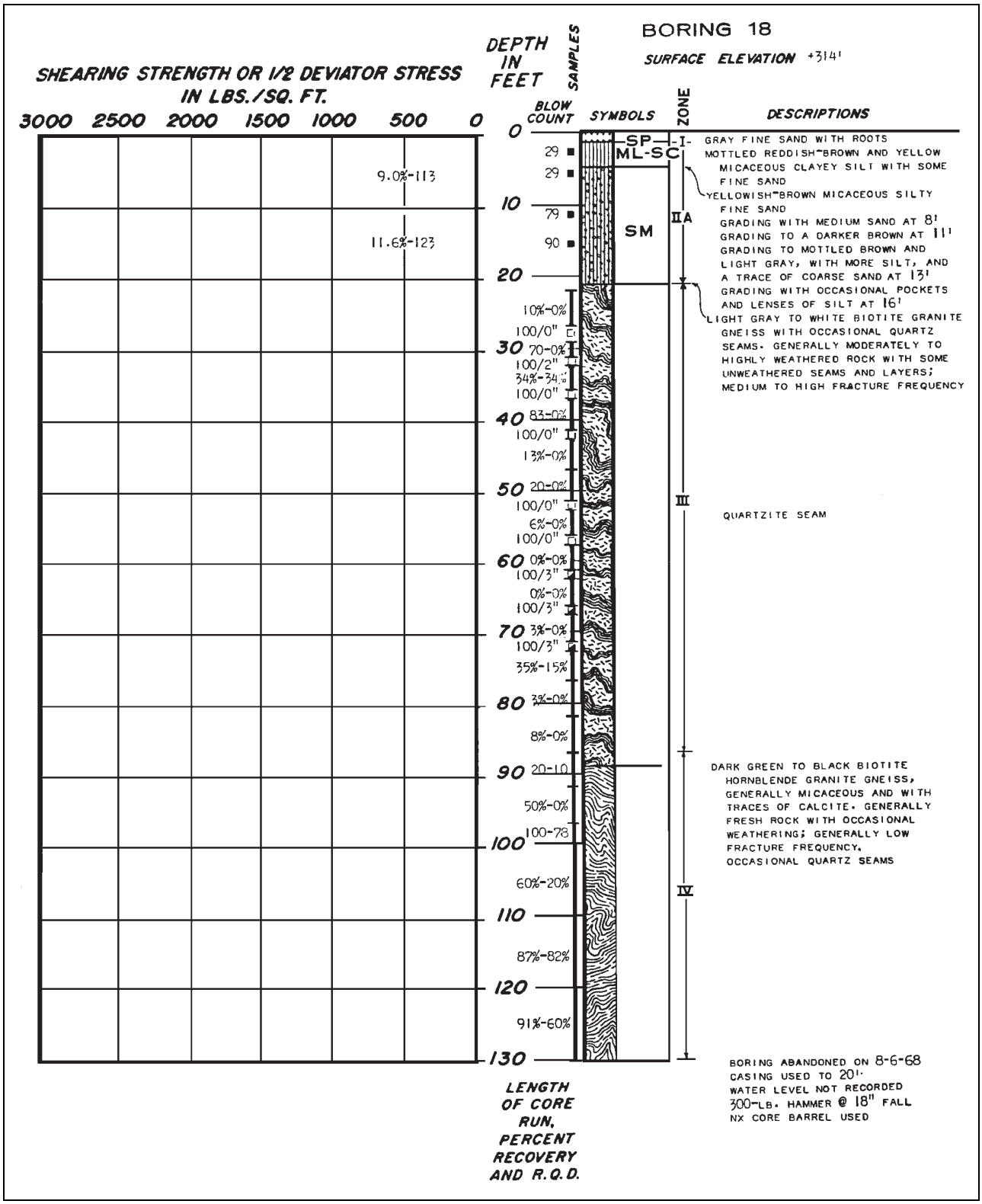


Figure 2.5-72 Log of Boring B-18

Chapter 3 Design of Structures, Components, Equipment, and Systems

3.5.1.6 Aircraft Hazards

Information regarding aircraft hazards is contained in SSAR Section 2.2.2.6 and Section 2.2.3.2.1.

Section 3.5 References

None

Chapter 13 Conduct of Operations

13.3 Emergency Planning

13.3.1 Emergency Planning Overview

This chapter provides the emergency planning information required by NRC regulations necessary to support an ESP application. That includes information required by 10 CFR 52.17(b)(1) regarding identification of potential impediments to emergency planning, and information required by 10 CFR 52.17(b)(3) regarding descriptions of contacts and arrangements made with local, state and federal governmental agencies with emergency planning responsibilities.

13.3.2 Major Features Emergency Plan

A major features emergency plan is also included in accordance with 10 CFR 52.17(b)(2)(I) as part of this ESP application. The Major Features Emergency Plan takes advantage of the emergency planning resources, capabilities, and organization that Virginia Power has already established and currently maintains at the NAPS site. If Dominion were to proceed with the development of new units at the ESP site, it would enter into an arrangement with Virginia Power to coordinate and implement an integrated emergency plan, in effect extending the existing emergency planning and preparedness to the new units. However, because some aspects of emergency preparedness require detailed design information which does not yet exist, some details of the plan that would be specific to the new units cannot be fully described at this time. Thus only the major features of the emergency plan are provided at this time.

13.3.2.1 Identification of Physical Characteristics

Pursuant to 10 CFR 52.17(b)(1), physical characteristics unique to the ESP site have been analyzed to determine whether they could pose a significant impediment to the development of emergency plans. A preliminary analysis of the evacuation times, utilizing the evacuation time estimate (ETE) methods recommended in NUREG-0654, Revision 1, Supplement 2 (Section II), has been used to identify these characteristics, including seasonal recreational visitors around the lake, school populations, etc. (Reference 16). A description of the analysis methods and results is provided in the most recent ETE, referenced in Section 13.3.2.1.1 (Reference 42).

13.3.2.1.1 Site Characteristics

The ESP site is located on a peninsula along the southern shore of Lake Anna in Louisa County, Virginia. The existing units are licensed under provisions of Title 10 of the Code of Federal Regulations, Part 50 (License Numbers NPF-4 and NPF-7). The ESP site is approximately 40 miles north-northwest of Richmond, Virginia; 36 miles east of Charlottesville, Virginia; and 22 miles southwest of Fredericksburg, Virginia. An ISFSI, licensed under provisions of 10 CFR 72, is also located at the NAPS site (License Number SNM-2507). Emergency planning activities for the new

units at the ESP site would be coordinated with emergency planning for the other licensed facilities at the NAPS site for an integrated emergency response. For example, an emergency declared under provisions of any current or future license may necessitate protective actions at shared facilities or at other licensed facilities. Response actions would be integrated to the extent necessary and addressed in future emergency plan implementing procedures, as appropriate.

ETEs have been calculated (in 1981, 1990–1991, and 2001) The NAPS Emergency Plan (NAEP) (Reference 24) requires that the existing ETE be provided to the Commonwealth of Virginia Department of Emergency Management (DEM) following the 10-year census. The purpose is to determine whether an updated ETE should be calculated for the NAPS plume exposure pathway Emergency Planning Zone (EPZ) described in Section 13.3.2.2.1.a.

13.3.2.1.2 Evacuation Time Estimate Analysis

The most recent ETE for the NAEP is based on Census 2000 data, and is applicable to the ESP site (Reference 42). The total permanent resident population within the plume exposure pathway EPZ for the existing units has been calculated to be 20,292 (the 1990–1991 and 1981 estimates were 20,196 and 14,610 respectively) (Reference 40) (Reference 41). This report breaks down the population numbers by 16 sectors and 2-mile, 5-mile, and 10-mile rings. The ETE considers permanent residents, transients, and persons in special facilities, including school populations.

Analyses of ETEs have identified no institutional populations in the EPZ other than public schools. The majority of the population is composed of permanent residents with seasonal recreational visitors on or around Lake Anna. Avenues of movement across the waterway are limited to seven crossings, one on the lower side of Lake Anna. However, emergency traffic is expected to flow away from the NAPS site (which includes the ESP site) rather than across the water. The road network is determined to be adequate to accommodate the vehicular traffic anticipated.

13.3.2.2 Major Features of the Emergency Plan

The major features of the emergency plan described herein have been prepared in accordance with 10 CFR 52.17(b)(2)(i), considering the guidance of NUREG-0654/FEMA-REP-1, Revision 1, Supplement 2. 10 CFR 50, Appendix E (Reference 5), has also been utilized. Optional information is included where appropriate.

The ESP site is one with pre-existing nuclear facilities that has existing state and local emergency plans. The ESP application, therefore, relies on and refers to information contained in these existing plans. No significant differences have been identified between major features proposed in the ESP application and the major features presented in existing plans and relied on in the ESP application.

Differences between emergency planning information relative to this chapter and the guidance provided by NUREG-0654, Supplement 2, including planning standards or evaluation criteria not addressed, are identified and explained in Section 13.3.4.

13.3.2.2.1 Emergency Planning Zones

Title 10, Code of Federal Regulations, Part 50, Appendix E, provides that the size of the EPZ for a nuclear power plant shall be determined in relation to local emergency response needs and capabilities. This is because the appropriate size of the EPZ depends on conditions surrounding the site including demography, topography, land characteristics, access routes, and jurisdictional boundaries. For nuclear power plants of 250 megawatts thermal or greater, Appendix E provides that the plume exposure pathway EPZ shall consist of an area about 10 miles (16 kilometers) in radius. Generic guidance for the ingestion exposure pathway emergency planning zone (IPZ) describes an area about 50 miles (80 kilometers) in radius.

When recommending the size of these EPZs in 1978, the NRC/EPA Task Force on Emergency Planning considered the 1975 Reactor Safety Study (WASH-1400). (Reference 12) The NRC/EPA Task Force on Emergency Planning determined that this study was the best available source of information on the relative likelihood of large accidental releases of radioactivity, given a core melt event (Reference 14).

Since that time, significant advances have been made in understanding the timing, magnitude, and chemical form of fission product releases from severe nuclear power plant accidents (Reference 11). This Major Features Emergency Plan has been developed assuming a plume exposure pathway EPZ of 10 miles in radius and an IPZ of about 50 miles in radius. The plan recognizes that the size of these areas is subject to change if later analyses, design-specific factors, and legislative or regulatory initiatives warrant.

a. **Plume Exposure Pathway Emergency Planning Zone**

   The plume exposure pathway EPZ is the area of interest associated with whole body external exposure to gamma radiation from a plume and deposited materials, and inhalation exposure from a passing radioactive plume. The duration of primary exposures could range in length from hours to days. The plume exposure pathway EPZ consists of an area about 10 miles in radius around the Dominion ESP site (See Figure 13.3-1). Parts of the Counties of Caroline, Hanover, Louisa, Orange, and Spotsylvania, Virginia, lie within the plume exposure pathway EPZ. Collectively, these counties are referred to as the risk jurisdictions. (Reference 31)

b. **Ingestion Exposure Pathway Emergency Planning Zone**

   The ingestion exposure pathway EPZ, that is, the IPZ, is the area of interest for exposure primarily from ingestion of water or foods such as milk and fresh vegetables that have been contaminated with radioactive materials. The duration of primary exposure could range from hours to months. The IPZ consists of an area about 50 miles in radius around the ESP site (See Figure 13.3-2). The Cities of Charlottesville, Fredericksburg and Richmond, Virginia; all or parts of the Counties of Albemarle, Amelia, Buckingham, Caroline, Chesterfield, Culpeper, Cumberland, Essex, Fauquier, Fluvanna, Goochland, Green, Hanover, Henrico, King and

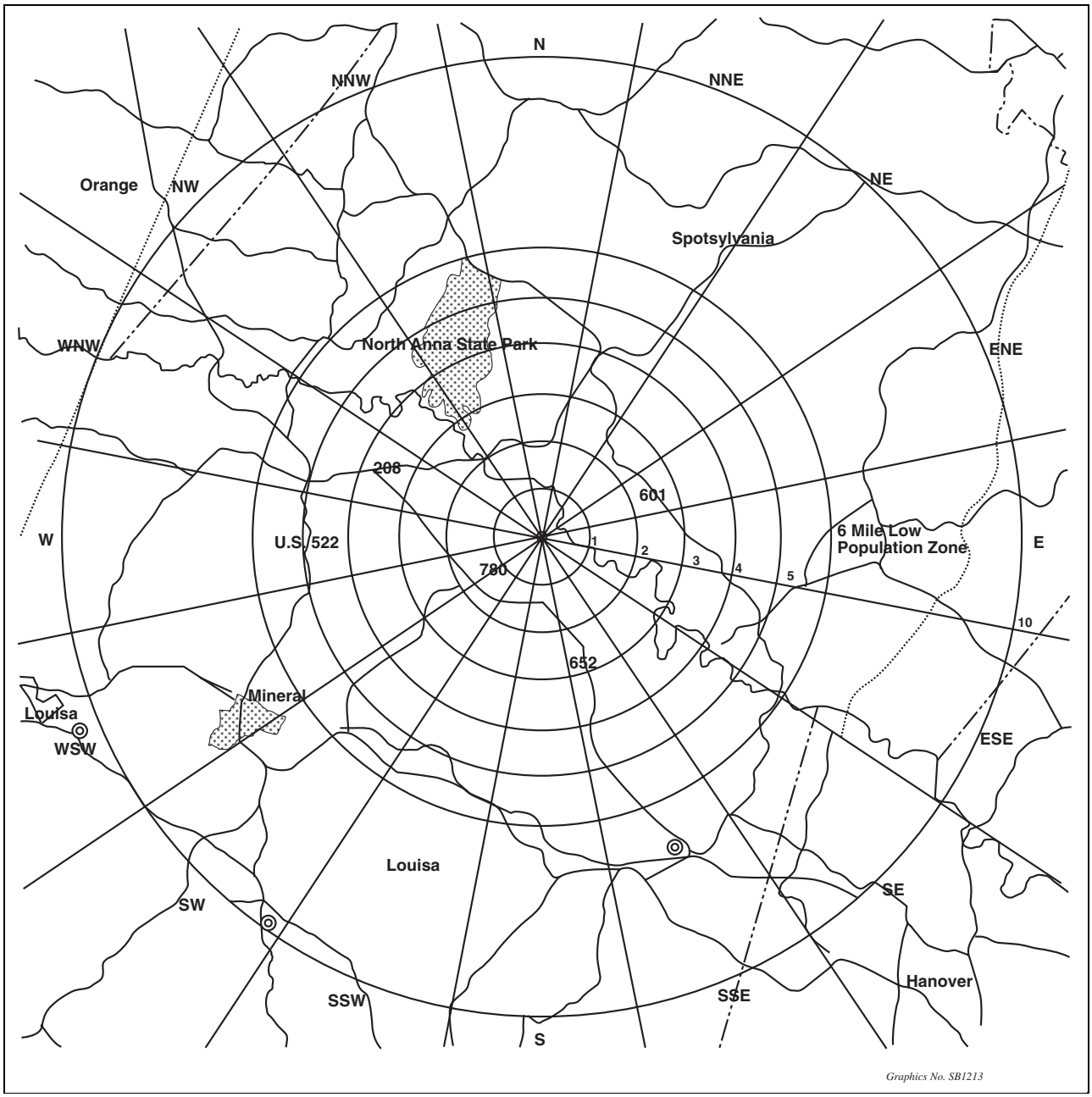


Figure 13.3-1 Plume Exposure Pathway Emergency Planning Zone

Queen, King George, King William, Louisa, Madison, Nelson, Orange, Page, Powhatan, Prince William, Rappahannock, Rockingham, Spotsylvania, Stafford, and Westmoreland, Virginia; and part of Charles County, Maryland, lie within the IPZ.

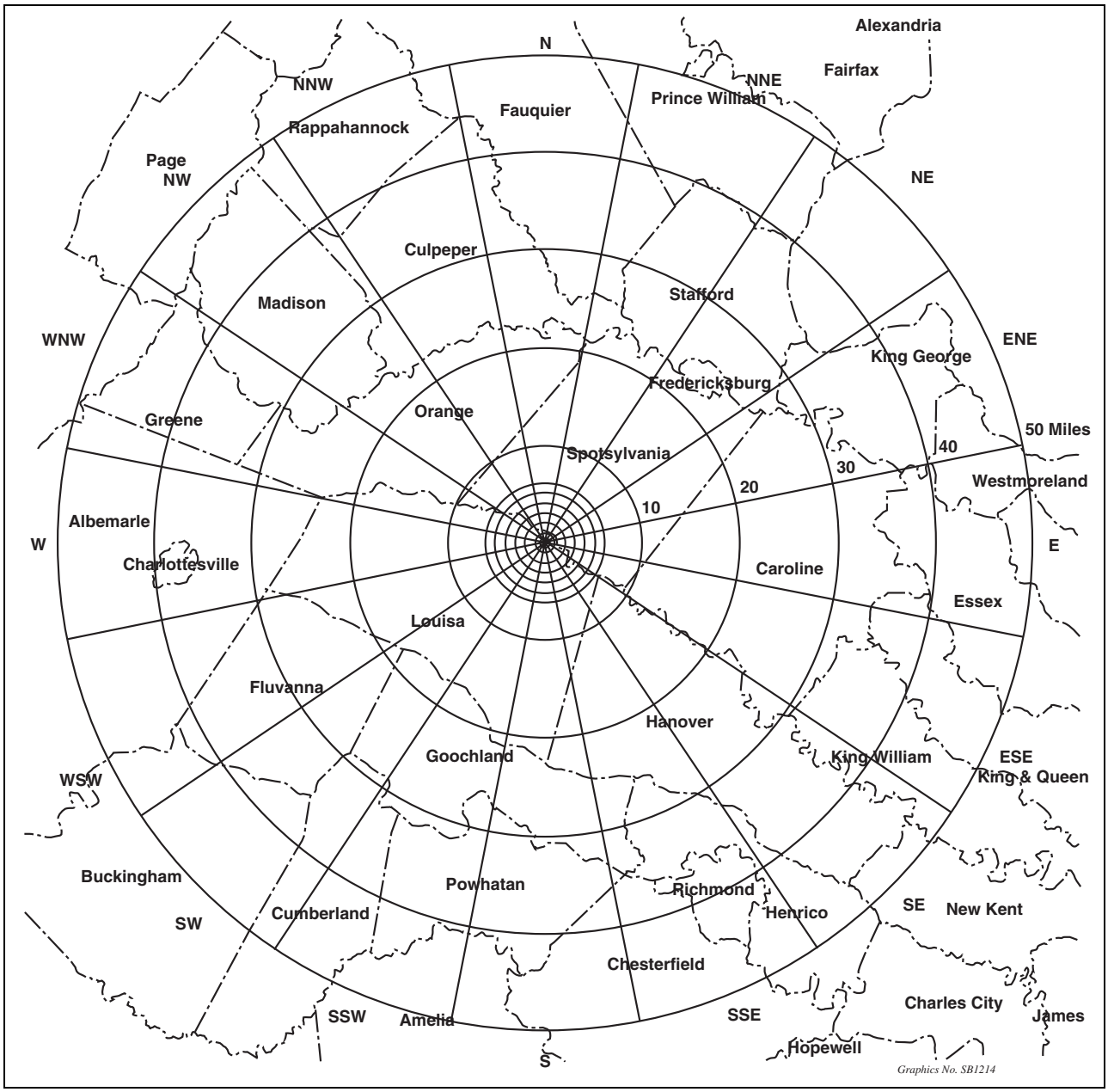


Figure 13.3-2 Ingestion Exposure Pathway Emergency Planning Zone

13.3.2.2.2 Planning Standards and Evaluation Criteria

NUREG-0654, Supplement 2, presents planning standards and evaluation criteria applicable for a major features emergency plan. The subsections that follow address these planning standards and evaluation criteria.

a. **Assignment of Responsibility (Organization Control)**

Primary responsibilities of risk jurisdiction response organizations, the Commonwealth of Virginia, the federal government, and private sector organizations are described below.

1. **Local Response Organizations**

The elected officials of local governments have responsibility for radiological emergency response within their jurisdictions. Because time is a major factor in realizing the benefits of protective action in the event of a radiological emergency, certain of these actions are predetermined and are implemented without delay upon notification of a radiological emergency.

In the event of an emergency of any classification made pursuant to emergency action levels (EALs) (Section 13.3.2.2.2.d), Dominion would notify response organizations as described in Section 13.3.2.2.2.e. Dominion would communicate with the Director of Emergency Services of each risk jurisdiction who has the capability of activating their Emergency Operations Centers (EOC). Dominion would rely on these jurisdictions to provide assistance in the event that an evacuation from the site requires a remote assembly point or for any services they are capable of providing to mitigate the results of the emergency.

The authority and responsibilities of Louisa County are presented in the Louisa County Radiological Emergency Response Plan (RERP) (Reference 32). The Louisa County RERP:

- Assigns responsibilities to county offices and organizations for radiological emergency response and preparedness
- Sets forth procedures for disseminating warning of radiological emergencies to the citizens of the county
- Specifies response actions for specific emergency classifications
- Delineates the policies and concepts under which the county government would operate during a radiological emergency response

Upon notification, the Louisa County Sheriff's Office would notify the County Coordinator of Emergency Services, or a designated representative, who would perform the following tasks:

- Verify the notification from the ESP site
- Initiate the key county official's alert system
- Iinitiate public warning procedures, as authorized by the Commonwealth of Virginia
- Prepare for evacuation of people from the affected area if authorized by the Commonwealth of Virginia

The County Coordinator of Emergency Services, or designated representative, would activate and ensure that the EOC is manned 24 hours a day when conditions warrant.

Once initial notifications are complete, Dominion's onsite emergency organization described in Section 13.3.2.2.2.b would provide periodic status reports to the County Coordinator of Emergency Services. These reports would include any changes in status or emergency classification. Prior to establishment of the County EOC the County Sheriff's Office would serve as the local point of contact for official communications within and outside of the county. When the EOC is established, this responsibility would transfer to the EOC.

The Sheriffs of Louisa and Spotsylvania Counties provide police support, traffic control, and additional security. They coordinate their efforts with the Virginia State Police (VSP), as described in Section 13.3.2.2.2.a.2.

The local county health department is the primary health response agency within the affected risk jurisdictions. Their efforts are coordinated with the VDH, as described in Section 13.3.2.2.2.a.2

The authority and responsibilities of Caroline, Hanover, Orange, and Spotsylvania Counties during a radiological emergency are presented in their respective RERPs. The existing RERPs apply to the radiological emergencies within these localities caused by events at the NAPS site and would apply to events at the ESP site. The Caroline, Hanover, Orange, and Spotsylvania County RERPs are identical to the Louisa RERP, as described above, except for information that is specific to the respective counties. (Reference 32) (Reference 33) (Reference 34) (Reference 35) (Reference 36)

2. **Commonwealth of Virginia Response Organization**

The Commonwealth of Virginia's organization for response to radiological emergencies is based on normal governmental structures and channels of communication. The Governor, in the role of Director of Emergency Management, directs the emergency response through the State Coordinator of Emergency Management. The State Coordinator of Emergency Management coordinates the overall response, and the VDH provides technical advice and assistance on radiological accident assessment, protective action, radiological control, and radiological monitoring.

The Virginia EOC is in Chesterfield County, Virginia. The Virginia DEM sends appropriate liaison personnel to the Emergency Operations Facility (EOF) upon activation.

In the event that an emergency of any classification is declared, pursuant to the Emergency Classification System Action Levels (Section 13.3.2.2.2.d), Dominion would make notifications as described in the section on Notification and Methods of Procedures (Section 13.3.2.2.2.e). Upon declaration of an Alert or higher emergency class, the DEM

would notify the VDH (Radiological Health Program). The VDH would implement its response procedures in accordance with the Commonwealth of Virginia's RERP. As part of the planned response, a team is sent to the EOF to provide a direct interface between the VDH and Dominion's Emergency Response Organization (ERO). After the initial immediate actions, subsequent protective actions are taken based on the results of the Commonwealth of Virginia evaluation of the radiological situation and the company's recommendations. Commonwealth of Virginia and federal agencies provide assistance as required. VDH personnel, in coordination with the DEM, provide technical advice and assistance on radiological accident assessment, protective actions, radiological exposure control, and radiological monitoring. The VDH provides assistance to the local county health department emphasizing the special requirements for those individuals who are contaminated with radioactivity. Accident assessment personnel, as part of the Radiological Emergency Response Team, would operate from the Virginia EOC. More specific information is contained within the Commonwealth of Virginia RERP (Reference 31).

The Commonwealth of Virginia would also provide police support. In the event of an emergency, the dispatcher at the VSP headquarters is normally notified. The first response would most likely be from police units based in the local area. Additional units dispatched from other parts of the commonwealth would supplement these resources. The VSP would provide traffic control and additional security and would coordinate their efforts with those of the local law enforcement agencies (e.g., the local County Sheriffs of Louisa and Spotsylvania) as described in Section 13.3.2.2.2.a.1.

The VDGIF would provide assistance via their knowledge of local terrain and by monitoring Lake Anna.

Additional Commonwealth of Virginia organizations having possible responsibilities in a radiological emergency are listed in the Commonwealth of Virginia RERP, Annex I-V to Volume II, Appendix 2, Organization. Requests by Dominion for support services from these organizations would be coordinated through the DEM.

3. **Federal Response Organizations**

   In the event that an emergency classification is made pursuant to the early action levels, Dominion would make notifications as described in Section 13.3.2.2.2.e. Dominion personnel would maintain contact with the NRC to ensure that accurate information and assessment of the emergency are available to the federal government.

   Details of federal assistance are described in Section 13.3.2.2.2.c.

4. **Private Sector Response Organizations**

   Support would be obtained from the cognizant Architect/Engineer, the Nuclear Steam Supply System vendor, and other consultants and vendors, as appropriate, to respond

during the emergency and recovery operations. Experienced personnel with in-depth expertise in plant design, engineering, and construction would be involved to aid in solving critical technical problems. Dominion would identify these consultants and vendors, as necessary, when their relationship is referenced in a COL application.

Private-sector response may also include radiological laboratories and other facilities and organizations, as described in Section 13.3.2.2.2.c.

5. **Major Elements of Emergency Response: Functions and Responsibilities**

   The Virginia RERP and the risk jurisdiction RERPs apply to the radiological emergencies caused by events at the existing units and would also apply to events at the new units. The following major elements of emergency response are addressed therein.

   - Command and control
   - Alerting and notification
   - Communications
   - Public information
   - Accident assessment
   - Public health and sanitation
   - Social services
   - Fire and rescue
   - Traffic control
   - Emergency medical services
   - Law enforcement
   - Transportation
   - Protective response
   - Radiological exposure control

   The legal bases for these authorities are detailed in their respective plans. The DEM provides amendments to these plans to the Federal Emergency Management Agency. (Reference 7)

6. **Contacts and Arrangements**

   The existing licensed facilities maintain within the NAEP a letter of agreement with the DOE, Field Office, Oak Ridge, and with the following Commonwealth of Virginia agencies:

   - Department of Emergency Management
   - Department of Health

- Department of State Police
- Department of Game and Inland Fisheries
- Medical College of Virginia (MCV) Hospitals and Physicians, Virginia Commonwealth University (VCU) Health Systems

The existing licensed facilities maintain within the NAEP letters of agreement with the following local agencies:

- Louisa County Administrator
- Louisa County Volunteer Firefighter's Association
- Louisa County Sheriff
- Emergency Medical Services Association of Louisa County (Lake Anna Rescue, Inc., Louisa County Rescue Squad, Inc., Holly Grove Rescue Squad, Inc., Mineral Volunteer Rescue Squad, and Trevilians Volunteer Fire Department, Inc.)
- Spotsylvania County Sheriff
- Spotsylvania Volunteer Fire Department, Inc.
- Spotsylvania County Coordinator
- Orange County Sheriff
- Orange County Administrator
- Caroline County Department of Fire & Rescue
- Caroline County Sheriff
- Hanover County Administrator
- Hanover County Sheriff

Dominion provided an overview of the Dominion ESP project to DEM Management staff members on February 20, 2003 and to risk jurisdiction coordinators of emergency management on March 24, 2003. The NRC licensing process, emergency preparedness requirements for ESP applicants, and Dominion's schedule for preparing and submitting this ESP application were described. No impediment to pursuing an ESP has been identified by Commonwealth of Virginia or risk jurisdiction response organizations.

b. **Onsite Emergency Organization**

A description of the onsite emergency organization would be provided in a COL application. This onsite emergency organization would include an emergency coordinator, qualified in accordance with Section 13.3.2.2.2.o.1. The emergency coordinator would respond with the following actions:

- Classify and declare emergency classes as described in Section 13.3.2.2.2.d,

- Initiate notifications as described in Section 13.3.2.2.2.e,
- Approve any planned exposures greater than 10 CFR 20 annual limits when appropriate, as described in Section 13.3.2.2.2.k.

The onsite emergency organization would provide for the key functions of accident assessment, radiological monitoring and analysis, security, fire-fighting, first aid and rescue, and communications. (Reference 16)

1. **Interfaces**

   Interfaces between and among the onsite functional areas of emergency activity, local services support, and State and local government response organization are shown in Figure 13.3-3.

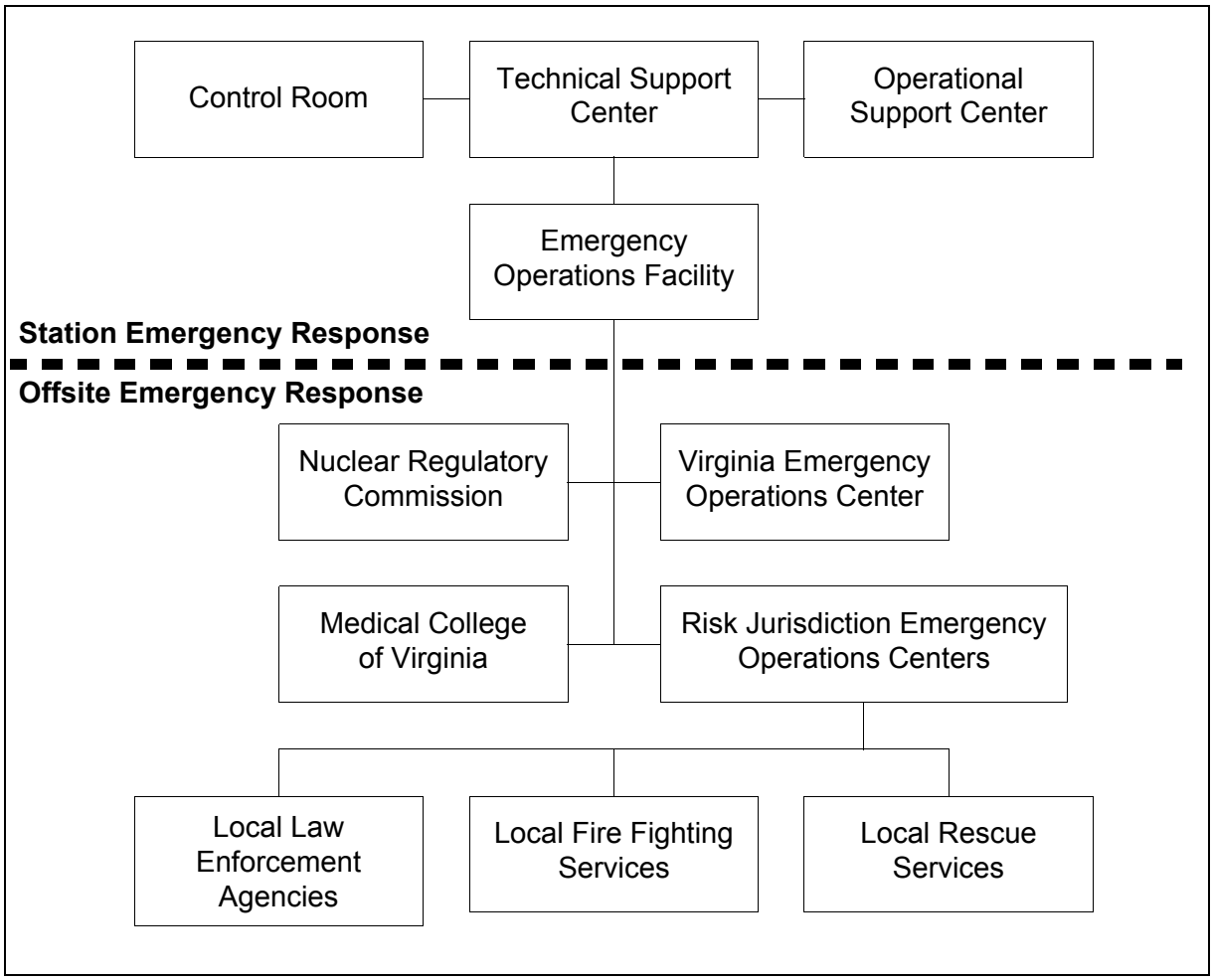


Figure 13.3-3 Onsite-Offsite Interface

2. **Services**

   The existing units maintain agreements for police, fire-fighting, rescue squad, medical, and hospital services. (Reference 24) These agreements would apply to the ESP site. Contacts and arrangements for these services are described in Section 13.3.2.2.2.a.6. Rescue squads meet the licensure requirements established by the VDH Office of Emergency Medical Services. (Reference 8)

   Provisions for maintaining agreements for services are described in Section 13.3.2.2.2.p.4, and Section 13.3.3.

c. **Emergency Response Support and Resources**

Circumstances prompting the implementation of an emergency response may necessitate augmentation of Dominion's resources. Such assistance may be requested from the federal government, radiological laboratories, and nuclear or other facilities and organizations.

1. **Federal Assistance**

   The Federal Response Plan (FRP) provides the mechanism for coordinating the delivery of federal assistance and resources to augment efforts of state and local governments overwhelmed by a major disaster or emergency. The FRP supports implementation of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as well as individual agency statutory authorities, and supplements other federal emergency operations plans developed to address specific hazards. The U.S. Department of Homeland Security (DHS) has primary responsibility for coordinating federal emergency preparedness, planning, management, and disaster assistance functions, including the establishment of federal disaster assistance policy. The DHS has the lead in developing and maintaining the FRP. (Reference 25)

   Under provisions of Homeland Security Presidential Directive 5, Management of Domestic Incidents, DHS has been assigned the task to develop a National Response Plan (NRP) that integrates the federal government's domestic prevention, preparedness, response, and recovery plans into one all-discipline, all-hazards plan. DHS also has been assigned the task to develop a National Incident Management System to provide a consistent nationwide approach for all levels of government to work effectively and efficiently together to prepare for, respond to, and recover from domestic incidents, regardless of their cause, size, or complexity. Dominion would incorporate these initiatives, as appropriate, in a COL application. (Reference 30)

   The Federal Radiological Emergency Response Plan (FRERP) (Reference 26) outlines the federal government's concept of operations based on specific authorities for responding to radiological emergencies. It also describes federal policies and planning considerations on which the concept of operations for the FRERP and federal agency-specific response plans are based, and specifies authority and responsibility of

each federal agency that may have a significant role in such emergencies. The concept of operations for a response provides for the designation of one agency as the Lead Federal Agency (LFA) and for the establishment of on-scene, interagency response centers. In a response to an emergency involving a radiological hazard, the LFA under the FRERP is responsible for federal oversight of onsite activities and federal assistance in conducting radiological monitoring and assessment and developing protective action recommendations.

The NRC is the LFA for an emergency that occurs at a commercial nuclear power reactor. When a radiological emergency warrants action under the Stafford Act, DHS uses the FRP to coordinate the non-radiological response to consequences off site in support of the affected State and local governments. If the FRERP and FRP are implemented concurrently, the Federal On-Scene Commander (FOC) under the FRERP coordinates the FRERP response with the Federal Coordinating Officer (FCO), who is responsible for coordinating all federal support for state and local governments. The FRERP describes the responsibilities of both the LFA and other federal agencies that may be involved and the functions of each of the on-scene centers. Involved federal agencies include the following:

- Department of Agriculture
- Department of Commerce
- Department of Defense
- Department of Energy
- Department of Health and Human Services
- Department of Housing and Urban Development
- Department of the Interior
- Department of Justice
- Department of State
- Department of Transportation
- Department of Veterans Affairs
- Environmental Protection Agency
- Federal Emergency Management Agency
- General Services Administration
- National Aeronautics and Space Administration

- National Communications System
- Nuclear Regulatory Commission

Under provisions of the FRERP, DOE may respond to a state or LFA request for assistance by dispatching a Radiological Assistance Program (RAP) team (Reference 29). The DOE Regional Coordinating Office with responsibility for the geographic area where the ESP site is situated is the Oak Ridge Operations Office in Oak Ridge, Tennessee. The DOE Radiological Assistance Plan, Region 2, includes the states of Arkansas, Louisiana, Mississippi, Missouri, Tennessee, and West Virginia; the Commonwealths of Kentucky, Virginia, and Puerto Rico; and the U.S. Virgin Islands (Reference 27). If the situation requires more assistance than a RAP team can provide, DOE would alert or activate additional resources. These resources may include the establishment of a Federal Radiological Monitoring and Assessment Center (FRMAC) to be used as an on-scene coordination center for federal radiological assessment activities. The FRMAC is charged with defining and monitoring the radiological impact of a nuclear or radiological release. Because the effects of radiological contamination may last beyond an immediate emergency, FRMAC serves as a coordination point for radiological monitoring, assessment, evaluation, and reporting activities for the area surrounding a radiological incident, including decontamination, recovery, and long-term environmental monitoring. The FRMAC provides for the coordinated management of federal technical response activities related to a radiological emergency. It has three primary goals:

- Assisting the Commonwealth of Virginia and LFA with personnel, equipment, and technical resources, as needed
- Collecting offsite environmental radiological data
- Providing the relevant Commonwealth of Virginia agencies and the LFA offsite environmental radiological data and related assessments

A FRMAC advance party can be expected at the site within 6 to 14 hours following the order to deploy, depending on the availability of airports near the ESP site. Richmond International Airport is a major commercial facility, about an 85-minute drive from the ESP site. Smaller airports located within about an hour of the ESP site may also be used. (Reference 24)

Under provisions of the United States Government Interagency Domestic Terrorism Concept of Operations Plan, the operational response to a terrorist threat employs a coordinated, interagency process organized through the LFA concept. In this circumstance, responsibility is assigned to the DOJ and is delegated to the FBI. Initially, the FBI functions as the on-scene manager, while FEMA retains authority and responsibility to coordinate all federal assistance to state and local governments for

consequence management. On-scene federal management transfers from the FBI to the FCO when directed by the Attorney General. (Reference 28)

2. **Radiological Laboratories**

   Radiological count laboratory resources are available through the Commonwealth of Virginia to respond to an emergency at the ESP site. These resources include those facilities listed below. Estimated travel times to the ESP site are provided parenthetically.

   - University of Virginia, Charlottesville, Virginia (45 minutes)
   - Virginia Commonwealth Laboratories, Richmond, Virginia (75 minutes)
   - MCV, Richmond, Virginia (75 minutes)
   - Newport News Shipbuilding & Drydock, Newport News, Virginia (3 1/2 hours)
   - VDH Radiological Health Program Mobile Laboratory (1 hour)

   If required at the time of the event, these additional resources can be obtained through purchase agreements with private institutions. These agreements would not be prepared in advance, but would be negotiated on an as-needed basis. (Reference 24)

3. **Assistance from Other Facilities and Organizations**

   Dominion Resources, Inc. (DRI), including its subsidiaries Virginia Power and Dominion, is one of the nation's largest producers of energy. In 2003, DRI's portfolio consisted of nearly 24,000 MW of electric power transmitted over 6,000 miles of transmission lines, 5.7 trillion cubic feet equivalent of natural gas reserves, 7,700 miles of natural gas pipeline, and the nation's largest natural gas storage system with more than 960 billion cubic feet of storage capacity. In addition to the NAPS site, the nuclear program of the DRI companies consists of the Surry Power Station in Virginia and the Millstone Power Station in Connecticut (Reference 45). Assistance can be made available from these facilities and organizations as necessary. The EOF described in Section 13.3.2.2.2.h, would coordinate this assistance. Contacts and arrangements for assistance from outside the company are presented in the next subsection.

   Like other U.S. organizations that operate commercial nuclear power plants, Virginia Power is a member of the Institute of Nuclear Power Operations (INPO). INPO's role in event of an emergency is to provide assistance in identifying and mobilizing the nuclear industry. Specifically, INPO facilitates technical information flow from the affected utility to the nuclear industry, locates replacement equipment and personnel with technical expertise, obtains technical information and industry experience regarding plant components and systems, and provides an INPO liaison to facilitate the interface between INPO and the member. To support these functions, INPO maintains a dedicated emergency notification system, designates INPO staff members to respond to requests for assistance, and maintains a dedicated Emergency Response Center. (Reference 38)

4. **Contacts and Arrangements for Assistance**

   Assistance from outside DRI's organization would be coordinated from the EOF described in Section 13.3.2.2.2.h. This includes interfaces with all levels of government and private sector response organizations, as described in Section 13.3.2.2.2.a, and other commercial nuclear operators as described in the sections that follow.

d. **Emergency Classification System**

The following emergency classification scheme would be used in the event of an emergency:

- Notification of Unusual Event – Unusual events are in process or have occurred which indicate a potential degradation of the level of safety of the plant. No releases of radioactive material requiring offsite response or monitoring are expected unless further degradation of a safety system occurs.
- Alert – Events are in process or have occurred which involve an actual or potential substantial degradation of the level of safety of the plant. Any releases are expected to be limited to small fractions of the EPA Protective Action Guideline exposure level.
- Site Area Emergency – Events are in process or have occurred which involve actual or likely major failures of plant functions needed for protection of the public. Any releases are not expected to exceed EPA Protective Action Guideline exposure levels at or beyond the site boundary.
- General Emergency – Events are in process or have occurred which involve actual or imminent substantial core degradation or melting with potential loss of containment integrity. Releases can be reasonably expected to exceed EPA Protective Action Guideline exposure levels offsite for more than the immediate site area.

1. **Emergency Action Levels**

   EAL criteria would be used to determine the need for notification and participation of local agencies, the Commonwealth of Virginia, the NRC, and other federal agencies. EAL criteria discriminate between the emergency classification scheme levels described in Section 13.3.2.2.2.d. The EALs would be used for determining when and what type of protective measures should be considered within and outside the NAPS site boundary to protect health and safety.

   The classification system is not intended to include minor deviations during normal operation. It may be discovered that an event or condition that met the classification criteria had existed, but the basis for declaration of the emergency class no longer exists at the time of discovery. For example, the event may have rapidly concluded or been discovered during a post-event review. Actual declaration of an emergency class is not warranted in these circumstances, although notification to the NRC and the DEM is necessary.

The EALs and plant-specific initiating conditions would be based on in-plant conditions and instrumentation, onsite and offsite monitoring, and hazards to station operation (e.g., as set forth in Appendix 1 of NUREG-0654/ FEMA-REP-1, Revision 1; RG 1.101, Revision 3; or other applicable documents) (Reference 9) (Reference 15). Dominion would propose site-specific EALs in the COL application. These EALs would be discussed and agreed on with the Commonwealth of Virginia and local governmental authorities and submitted to the NRC for approval. Thereafter, they would be reviewed with the Commonwealth of Virginia and local governmental authorities on an annual basis. After initial approval, changes to these EALs and initiating criteria would be made without NRC approval only if the changes do not decrease the effectiveness of the plans and the revised plans continue to meet the standards of 10 CFR 50.47(b)(4) and the requirements of 10 CFR 50, Appendix E.

2. **Emergency Classification Levels**

   The Commonwealth of Virginia RERP and local government RERPs would provide an emergency classification level scheme consistent with that established by Dominion as required by 44 CFR 350.5(a)(4).

e. **Notification Methods and Procedures**

Dominion would provide means for notifying the Commonwealth of Virginia and risk jurisdictions, ERO personnel, and the populace within the plume exposure pathway's EPZ described in Section 13.3.2.2.1.a.

1. **Basis for Notification**

   Upon initial classification and declaration of an emergency class, as described in Section 13.3.2.2.2.d, an individual qualified in accordance with radiological emergency response training (Section 13.3.2.2.2.o) would assume emergency coordinator responsibilities. This individual would initiate notifications applicable to the emergency class and event.

   The Commonwealth of Virginia and risk jurisdictions would be notified promptly following declaration of an emergency class, including any classes that are immediately terminated. The capability for notifying these agencies within 15 minutes after declaring an emergency would be maintained (Reference 5). The content of the notification would include the class of the emergency and information regarding whether a release is in progress. The Commonwealth of Virginia would be notified of any recommended protective measures. Additional information, including meteorological data, would be provided in later notifications as it becomes available (Reference 15). As described in the EALs section (Section 13.3.2.2.2.d), the Commonwealth of Virginia would be notified if it is discovered that an event or condition that met the classification criteria, had existed, but that the basis

for declaration of the emergency class no longer existed at the time of discovery (Reference 19).

The NRC Operations Center would be notified immediately thereafter and not later than one hour after the classification of an emergency as described in Section 13.3.2.2.2.d. The ERDS would be activated as soon as possible but not later than one hour after declaring an emergency class of alert, site area emergency, or general emergency. An open, continuous communication channel with the NRC Operations Center would be maintained upon request by the NRC (Reference 4).

2. **Alerting, Notifying and Mobilizing Emergency Response Personnel**

   At the Notification of Unusual Event emergency class, onsite notification would be limited to personnel involved in event response and the NRC Senior Resident Inspector.

   Dominion's ERO and uninvolved onsite personnel would promptly be made aware of an emergency that is initially classified and declared as an Alert or higher event promptly, unless doing so poses a threat to personnel safety. Severe weather and a security breach are examples of situations that may dictate suspension or deferral of the processes for alerting, notifying, and mobilizing emergency response personnel. However, these activities would be implemented as quickly as achievable, given the specific situation. The normal processes for alerting, notifying, and mobilizing the ERO are multifaceted, including alarms, announcements, pagers, telephones, on-line messages, etc.

   NAPS site personnel, including security personnel, and/or personnel from the VDGIF would alert individuals within the Exclusion Area.

3. **Means for Notifying and Instructing the Public**

   Protective Action Zones (PAZ), primary evacuation routes, and evacuation assembly centers (EAC) have been established in the event that an evacuation is recommended. This information is published and distributed by the Commonwealth of Virginia (Reference 31).

   Dominion would rely on the already installed Alert and Notification System (ANS) already installed around the NAPS site to support the new units. Sirens have been installed using the guidance contained in NUREG-0654/FEMA-REP-1, Revision 1, and FEMA-REP-10 (Reference 21). The purpose of the ANS is to ensure that essentially 100 percent of the population within 5 miles of the site can be alerted within 15 minutes and that essentially 100 percent of the population from 5 to 10 miles from the site who may not have received the initial notification can be alerted within 45 minutes (Reference 15). The FEMA approved the ANS for the existing units in 1987, pursuant to 44 CFR 350 (Reference 44). Virginia Power is responsible for maintaining and periodically testing the ANS, including sirens located throughout the plume exposure pathway EPZ described in Section 13.3.2.2.1.a.

The Commonwealth of Virginia and risk jurisdictions have ultimate responsibility for warning the public. Should it be necessary, Commonwealth of Virginia and local authorities, with the assistance of the VSP, would alert the public within the plume exposure pathway EPZ described in Section 13.3.2.2.1.a. The primary method of alerting the public is by sounding the ANS sirens. Other alerting methods may include telephone communications, television and radio communications via the Emergency Alert System (EAS) stations, public address systems, bull horns from patrol cars, and personal contact. Details are provided in the Commonwealth of Virginia RERP and local RERPs.

Members of the public within the plume exposure pathway EPZ described in Section 13.3.2.2.1.a would be informed of what actions to take after being alerted. Upon being alerted, they would be instructed to turn on their radios or television sets to the EAS to receive further instructions. Louisa and Spotsylvania Counties and the Commonwealth of Virginia have 24-hour-a-day capability to activate the ANS sirens. The Commonwealth of DEM prepares messages sent out over the EAS. Written, pre-planned messages intended for transmittal to the public via radio and television stations would be consistent with the emergency classification level scheme described in Section 13.3.2.2.2.d. The messages would give instructions with regard to specific actions to be taken by the occupants of the inhabited area. The messages would, as appropriate, give instructions on the nature of the emergency and information concerning the recommended protective action, sheltering, thyroid blocking potassium iodide, or evacuation. (Reference 31)

f. **Emergency Communications**

Dominion would provide the means for prompt communications with the Commonwealth of Virginia, risk jurisdiction, and federal government EROs; the means to alert and activate the ESP site ERO; and arrangements for communicating with medical support facilities.

1. **Communication With the Commonwealth of Virginia**

   Dominion would maintain the capability for notifying the Commonwealth of Virginia within 15 minutes after declaring an emergency as described in Section 13.3.2.2.2.d would be maintained (Reference 5). The content of the notification is described in Section 13.3.2.2.2.e (Reference 15).

2. **Communication With the Risk Jurisdictions**

   Dominion would maintain the capability for notifying the risk jurisdictions within 15 minutes after declaring an emergency as described in Section 13.3.2.2.2.d would be maintained (Reference 5). The content of the notification is described in Section Section 13.3.2.2.2.e (Reference 15).

3. **Communication With Federal Response Organizations**

   Dominion would maintain the capability for notifying the NRC Operations Center immediately after notifying the Commonwealth of Virginia and the risk jurisdictions, and not later than one hour after classifying an emergency, as described in Section 13.3.2.2.2.d, would be maintained (Reference 4). Requests for federal assistance would be communicated to the LFA as described in Section 13.3.2.2.2.c, or the cognizant department, agency, bureau, or service, as appropriate (Reference 29).

4. **Communication With the Dominion Emergency Response Organization**

   The ESP site ERO would be alerted for activation via multiple communications methods, e.g., plant alarms and/or announcements, pagers, telephones, on-line messages, etc.

5. **Communication With Medical Support Facilities**

   Communication can be maintained with the hospital service described in Section 13.3.2.2.2.l, from the ESP site. The ESP site would also be able to communicate with the ambulance by use of an ultra-high frequency radio or mobile telephone, and the ambulance can communicate with the hospital service by way of the Hospital Emergency and Administrative Radio system or mobile telephone.

g. **Public Education and Information**

Dominion would implement an emergency information program for the public and the news media.

1. **Informing the Public**

   Information describing the emergency notification process and actions that should be taken in the event of an emergency is provided to the public within the NAPS site plume exposure pathway EPZ on an annual basis, as described in Section 13.3.2.2.1.a. The following information is provided to the public:

   - Educational information on radiation
   - Contact points for obtaining additional information
   - Protective measures (e.g., evacuation routes and relocation centers, sheltering, respiratory protection, radio-protective drugs)
   - Special needs of the handicapped and the transient population

   (Reference 22)

   Dominion would coordinate its public information efforts with the Commonwealth of Virginia and local authorities to ensure that the public is informed by using the best means available. These means may include the following:

   - Information in telephone books

- Utility bill inserts
- Postings in public areas
- Publications (e.g., brochures, calendars) distributed on a periodic basis

Dominion intends to rely on the already established Virginia Power program for informing the public in the area surrounding the ESP site (Reference 24).

2. **Informing the News Media**

   A program to acquaint the news media with the following information is offered on an annual basis:

   - Emergency plans
   - Information concerning radiation
   - Points of contact for release of public information in an emergency

   Dominion intends to rely on the already established program for informing the media in the area surrounding the ESP site.

h. **Emergency Facilities and Equipment**

Dominion would make provisions for emergency facilities and equipment to support an emergency response. However, because the detailed information needed to support a complete description of emergency facilities and equipment is not available at this time, Dominion does not seek approval of this major feature. This discussion in this subsection is provided only for general information and completeness.

1. **Technical Support Center**

   Dominion would make provisions for a TSC located near the control room. Personnel reporting to the TSC would plant provide management and technical support to the control room staff during emergency conditions. The TSC would have technical and data displays and plant records available to assist in the detailed analysis and diagnosis of abnormal plant conditions. The TSC would be the primary onsite communications center for the plant during an emergency. (Reference 18)

2. **Operational Support Center**

   Dominion would provide for an Operational Support Center (OSC) assembly area separate from the control room and the TSC. Personnel reporting to the OSC can be assigned duties in support of emergency operations. (Reference 18)

3. **Emergency Operations Facility**

   Dominion would provide for an EOF for the management of the overall licensee emergency response (including coordination with federal, Commonwealth of Virginia, and risk jurisdiction officials), coordination of radiological and environmental assessments, and

determination of recommended public protective actions. The EOF would have technical and data displays and plant records available to assist in the diagnosis of plant conditions. The EOF staff would evaluate the potential or actual release of radioactive materials to the environment. The EOF would be the primary offsite communications center for the plant during an emergency. (Reference 18)

4. **Emergency Operations Centers**

   The Commonwealth of Virginia and the risk jurisdictions have established EOCs for use in directing and controlling emergency response functions.

i. Accident Assessment

Dominion would provide methods, systems, and equipment for assessing and monitoring actual or potential offsite consequences of a radiological emergency condition.

1. **Contacts and Arrangements for Meteorological Information**

   The existing units' Meteorological Monitoring System has the capability for collecting data used for making near real-time predictions of the atmospheric effluent transport and diffusion. The primary tower and backup tower have been sited to provide an accurate representation of regional meteorological conditions (Reference 23). The data would be accessible to the new unit's control room, the TSC, and the EOF (Reference 18). Suitable meteorological information would be made available to the Commonwealth of Virginia as described in Section 13.3.2.2.2.e (Reference 15).

   The NOAA is the primary agency within the DOC responsible for providing assistance to the federal, state, and local organizations responding to a radiological emergency under provisions of the FRERP as described in Section 13.3.2.2.2.c. Within NOAA, the NWS is the primary source of weather data, forecasts, and warnings for the United States. The Weather Forecast Office Baltimore/Washington in Sterling, Virginia, has jurisdiction over the area of the Dominion ESP site. (Reference 26)

2. **Contacts and Arrangements for Field Monitoring**

   Dominion would make provisions to obtain offsite data by field monitoring within the plume exposure pathway's EPZ described in Section 13.3.2.2.1.a. These field-monitoring activities would be coordinated from the EOF, described in Section 13.3.2.2.2.h. Dominion would coordinate its field monitoring efforts with the VDH under provisions of the Commonwealth of Virginia RERP (Reference 31).

3. **Contacts and Arrangements for Locating and Tracking Plume**

   Dominion and the Commonwealth of Virginia would rely on the DOE for airborne radioactive plume tracking under provisions of the FRERP as described in Section 13.3.2.2.2.c. (Reference 26) (Reference 27) (Reference 29) (Reference 31)

j. **Protective Response**

This section describes a range of protective actions for the public and emergency workers in the plume exposure pathway EPZ (Section 13.3.2.2.1.a), guidelines for choosing protective actions during an emergency, and protective actions associated with the IPZ.

1. **Evacuation of Onsite Individuals**

   Emergency assembly areas have been established outside the existing units Protected Area to facilitate the dissemination of information to personnel. The same areas would be used to support the new units. Dominion may elect to direct an early personnel release in the absence of radiological or chemical agents necessitating evacuee monitoring. If evacuation of onsite individuals is necessary, evacuees would be directed to either the primary or secondary remote assembly area (RAA) depending on specific radiological and environmental conditions. (see Figure 13.3-4)

   Evacuees would use personal vehicles for transportation. Evacuees would be surveyed for contamination following events involving a release, and would be decontaminated, if necessary, prior to being released from the RAA. Decontamination agents and supplies are available at the NAPS site and can be transported to the RAAs to provide decontamination capabilities. (Reference 24)

2. **Protective Action Recommendations**

   The senior Dominion representative in the EOF (or the senior Dominion representative in the Control Room or TSC if the EOF is not yet activated) would be responsible to the Commonwealth of Virginia for recommending offsite protective actions. The Commonwealth of Virginia and risk jurisdictions are responsible for notifying the public and implementing the appropriate protective measures as described in Section 13.3.2.2.2.e.3. Protective action recommendations are to be made to the Commonwealth of Virginia within 15 minutes of declaring a General Emergency under provisions of Section 13.3.2.2.2.d. It is anticipated that the initial protective action recommendation is to be based on plant conditions. Follow-up protective action recommendations that Dominion may make to the Commonwealth of Virginia would be based on current meteorological data such as wind direction, wind speed and stability class, and dose projections. This guidance is based on NUREG-0654/FEMA-REP-1, Supplement 3, and EPA 400-R-92-001 (Reference 17) (Reference 22).

3. **Evacuation Time Estimates**

   The most recent NAEP ETE, based on Census 2000 data, is applicable to the ESP site. Evaluation time estimates based on different affected population areas and weather conditions range from 85 minutes to 105 minutes. (Reference 42)

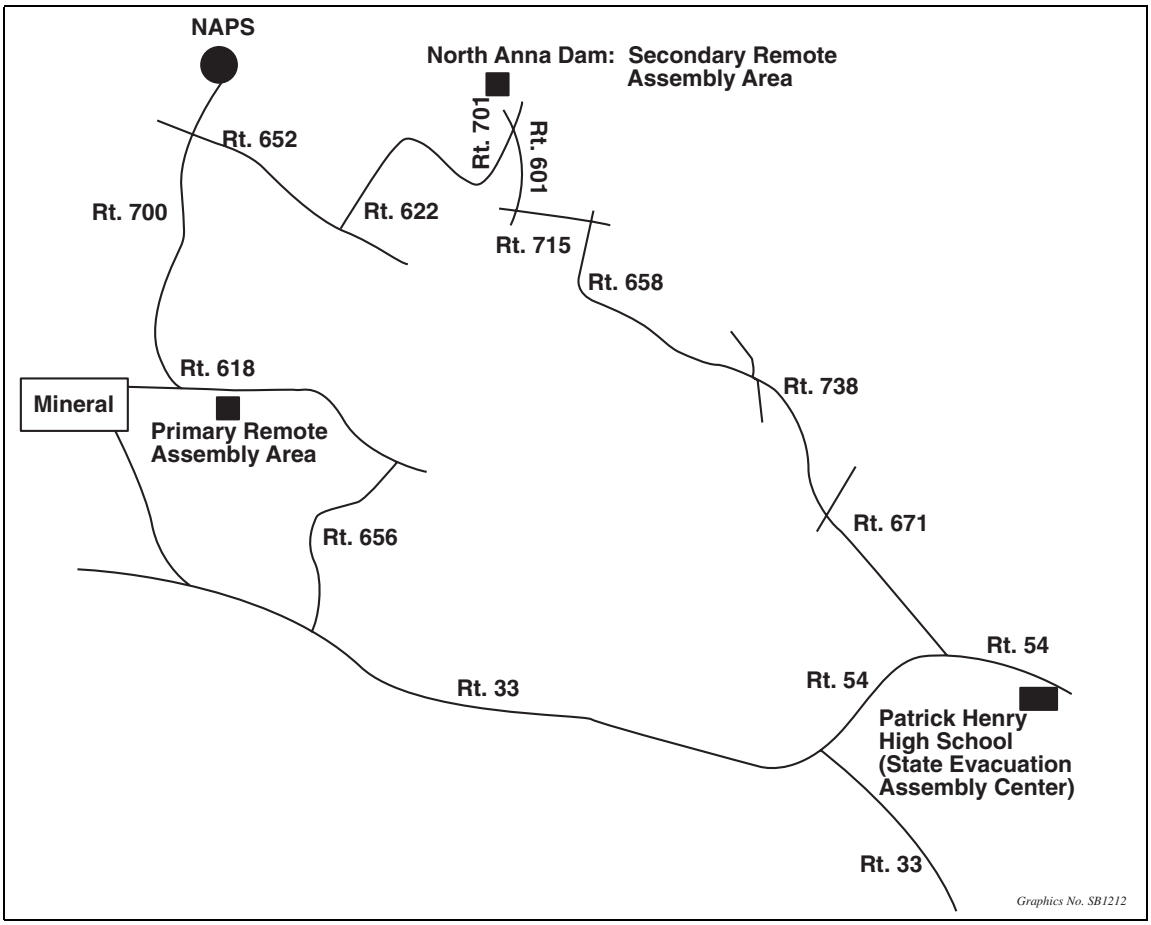


Figure 13.3-4 Remote Assembly Areas

4. **Implementation of Protective Measures**

   The most recent NAEP ETE includes maps showing the site and the plume exposure pathway EPZ described in Section 13.3.2.2.1.a, transportation networks (evacuation routes), topographical features, political boundaries, and PAZ. Population information is presented in a 2-mile, 5-mile and 10-mile ring and 16-sector format map. Population information is presented in tables by 2-mile, 5-mile and 10-mile ring and 16-sector format and by PAZ.

   The means for notifying the transient and resident population is described in Section 13.3.2.2.2.e.3.

k. **Radiological Exposure Control**

   Dominion would make provisions for controlling radiological exposures of emergency workers in an emergency.

1. **Guidelines on Dose Limits**

   Dominion would maintain dose within the limits of 10 CFR 20 limits under normal operating conditions. (Reference 1) Emergency response personnel may, because of necessity, receive a once-in-a-lifetime exposure to contamination and radiation up to the 10 CFR 20 annual limits, not including accumulated occupational exposure. These limits apply to the following activities:

   - Removing injured persons
   - Undertaking corrective actions
   - Performing assessment actions
   - Performing field radiological measurements in the plume exposure pathway EPZ described in Section 13.3.2.2.1.a
   - Providing first aid
   - Performing personnel decontamination
   - Providing ambulance service
   - Providing medical treatment services
   - Exposure in excess of these limits would be controlled as described in Section 13.3.2.2.2.k.4.

2. **Onsite Radiation Protection Program**

   Emergency exposure may be authorized for such needs as removal of injured personnel, undertaking corrective actions, performing assessment actions, providing first aid, performing personnel decontamination, providing ambulance service, providing medical treatment, etc. Guidelines for emergency exposure limits are consistent with EPA Emergency Worker and Life Saving Activity Protective Action Guides. (Reference 20).

   The existing units radiological protection procedures specify levels of permissible radioactive contamination for workers and equipment. Actions are required to be taken when levels for equipment or areas exceed these limits. Any detected personnel contamination initiates appropriate evaluation and decontamination in accordance with these procedures. These procedures would be applicable for the ESP site or this function would be addressed in future radiological protection procedures.

   The existing units have onsite contamination control procedures that provide for access control. These procedures state the criteria for permitting the return of the areas and their contents to normal use. These procedures would be applicable for the ESP site or this function would be addressed in future radiological protection procedures.

   No food supplies are grown on the ESP site and the water supplies come from deep wells (Reference 23). The existing units have procedures to monitor contamination in areas

designated as permissible for employees to eat and drink during the emergency and recovery phases of operations. These procedures would be applicable for the ESP site or this function would be addressed in future radiological protection procedures.

3. **Tracking Doses**

   Emergency workers at the ESP site would receive direct reading and permanent record dosimeters. Dose records would be maintained in accordance with existing units radiological protection procedures or future radiological protection procedures.

4. **Authorization of Exposure Above Dose Limits**

   Approval from the emergency coordinator is necessary for planned exposures greater than the 10 CFR 20 annual limits. Under limited circumstances, exposure levels greater than 5 times the 10 CFR 20 annual limits may be allowed, but only on a voluntary basis to persons fully aware of the risks involved. Selection criteria for volunteer emergency workers includes consideration of those who are in good physical health, are familiar with the consequences of emergency exposure, and are not a declared pregnant adult. It is preferable, though not mandatory, that volunteers be older than 45 years of age and not be females capable of reproduction. (Reference 1) (Reference 20)

Table 13.3-1 Dose Limit Guidelines

Emergency Worker Activity	Dose Limit	Condition
All	5 Rem TEDE	
Protecting valuable property	10 Rem TEDE	Lower dose not practicable.
Lifesaving or protection of large populations	25 Rem TEDE	Lower dose not practicable.
Lifesaving or protection of large population	>25 Rem TEDE	Only on a voluntary basis to persons fully aware of the risks involved.

TEDE = Total effective dose equivalent.

5. **Decontamination**

   If onsite personnel are required to relocate or routinely leave the site during an emergency, Dominion would provide adequate supplies for personnel decontamination, clothing, and a means for decontaminating the clothing. If radio-iodine contamination of the skin is determined, or needed supplies, instruments, or equipment are contaminated; then provisions would be made to provide for decontamination as specified in the existing units' radiological protection procedures or this function would be addressed in future radiological protection procedures. (Reference 24)

Health Physics personnel can perform the decontamination task at the existing units or the ESP site, the RAA, or if necessary, at Patrick Henry High School in Hanover County. (Reference 34)

Personnel with wounds that become contaminated would be decontaminated to the extent achievable or prepared for transport to the hospital service described in Section 13.3.2.2.2.l. (Reference 24)

l. **Medical and Public Health Support**

Dominion would make contacts and arrangements for medical services for contaminated injured individuals.

1. **Arrangements for Hospital Services**

Virginia Power has made arrangements with the MCV in Richmond, Virginia, to provide medical assistance to personnel injured or exposed to radiation and/or radioactive material. MCV has developed its own emergency plan, designed to provide medical care in the case of a radiation emergency. The MCV Radiation Emergency Plan supports the NAPS site in case of occupational and/or major accidents, including contaminated personnel. MCV's plan establishes a specialized area of the hospital for treatment with appropriate Health Physics functions, and implements a coded system to alert hospital team members. Radiation monitoring equipment, dosimetry, and protective clothing are available at MCV.

Based on the quality of the facilities at MCV, the NRC has accepted the absence of arrangements for a back-up hospital. (Reference 13) Arrangements for the use of MCV's facilities would apply to the ESP site. In the event of a need for their support, a call ahead to MCV would be made to alert them to activate their Radiation Emergency Plan. (Reference 37)

2. **Arrangements for Medical Services**

The Commonwealth of Virginia Radiation Emergency Response Plan contains lists indicating the location of public, private, and military hospitals and other medical service facilities within the Commonwealth of Virginia that are capable of providing medical support for any contaminated or injured individual. The listing includes the name, location, type of facility, capacity, and radiological capabilities. Contacts and arrangements are described in the plan.

m. **Recovery and Re-entry Planning and Post-Accident Operations**

NUREG-0654, Supplement 2, Section V, deems that the Recovery and Re-entry Planning and Post-accident Operations planning standard is inappropriate for the ESP application. This section is included herein to conform to the emergency plan structure anticipated for a COL application.

n. **Exercises and Drills**

NUREG-0654, Supplement 2, Section V, deemed that the Exercises and Drills planning standard is inappropriate for the ESP application phase. This section is included herein to conform to the structure anticipated for a COL application's Emergency Plan.

o. **Radiological Emergency Response Training**

Personnel designated to fill ERO positions at the existing units receive training in accordance with the Nuclear Power Station Emergency Preparedness Training (NPSEPT) Program Guide. The NPSEPT Program Guide contains the curriculum design and requirements for program management, implementation, evaluation, and documentation. Emergency preparedness training not conducted by the Nuclear Emergency Preparedness (NEP) staff is conducted pursuant to supporting department training program guidance. NEP verifies that this departmental training is consistent with the provisions of the NPSEPT Program Guide. These training programs, taken collectively, establish the initial training and retraining requirements for the existing units' ERO positions.

The existing units' Site Vice-President is responsible for ensuring that station personnel are trained in accordance with the NPSEPT Program Guide. Department directors, managers, and supervisors are responsible for ensuring that their personnel receive training. The Director Nuclear Protection Services and Emergency Preparedness is responsible for developing and scheduling training programs that meet the requirements of this plan and for maintaining records to document the training. NEP personnel, other than those designated to develop training programs, independently verify that the training required by the NPSEPT Program Guide is accomplished.

Dominion intends to rely on the existing NPSEPT Program Guide to provide the framework for conducting specialized initial training and periodic retraining for Dominion personnel at the new units. Specific training requirements for ERO personnel supporting the new units would be incorporated into the NPSEPT Program Guide.

1. **Training for Response Organization Coordinators**

   Emergency Plan training for ERO coordinators would address assessing emergencies, emergency assessment and classification, notification systems, site evacuation, emergency radiation exposure authorization, offsite support group capabilities, organizational interfaces and recovery.

2. **Training for Accident Assessment**

   Emergency Plan training for ERO accident assessment personnel would address the means for determining the magnitude of and for continually assessing the impact of the release of radioactive materials, including EALs for event classification and means for

determining when and what type of protective measures should be considered within and outside the site boundary to protect health and safety.

3. **Training for Radiological Monitoring and Analysis**

   Emergency Plan training for personnel performing the radiological monitoring and analysis functions would address control of ERO personnel performing radiological monitoring and analysis, dose assessment, emergency exposure evaluation, and protective measures.

4. **Training for Police, Security, and Fire-Fighting Personnel**

   Dominion has no police powers. Training for local law enforcement agencies is addressed in Section 13.3.2.2.2.o.6. Emergency Plan training for onsite security personnel would address emergency organizational interfaces and communications systems to supplement training which would be described in a COL application. Emergency Plan training for onsite fire-fighting personnel would address emergency organizational interfaces and communications systems to supplement training, which would be described in a COL application.

5. **Training for First Aid and Rescue Personnel**

   Emergency Plan training for onsite first aid personnel would address emergency organizational interfaces and communications systems that would be described in a COL application. Onsite fire-fighting personnel, who provide the onsite rescue functions, are described in Section 13.3.2.2.2.o.4.

6. **Training for Local Support Services Personnel**

   The local support services personnel who support the existing units during an emergency receive training as part of their own emergency preparedness programs. For example, the Commonwealth of Virginia and local governments conduct training for their personnel as part of their RERP program. The existing units offers site-specific emergency response training on an annual basis to personnel in local support organizations that have agreed to provide assistance. The organizations include the Commonwealth of Virginia Department of State Police and local county sheriffs' departments, volunteer fire companies, and rescue squads. This annual training addresses the following topics:

   - The basic scope of the NAEP
   - Emergency classifications
   - Notification methods
   - Basic radiation protection
   - Station access procedure
   - The individual, by title, in the station ERO who would direct their activities onsite

- Definition of their support roles
- Site access procedures

The same or similar training would be provided to personnel providing local support services to the new units at the ESP site.

7. **Training for Medical Support Personnel**

   Arrangements for medical support personnel who may support the existing units or the new units at the ESP site during an emergency are addressed in Section 13.3.2.2.2.l. The qualifications of personnel who may perform these functions are provided by their accrediting organization; such as, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). The existing units and the ESP site would respond to requests for site-specific emergency response training for medical support personnel who have agreed to provide assistance similar to that described in Section 13.3.2.2.2.o.6.

8. **Training for Communicators**

   Emergency Plan training for ERO communicators would address notifications and reports to offsite authorities, communication and data acquisition systems and organizational interfaces.

p. **Responsibility for the Planning Effort**

Responsibility for the planning effort resides with Virginia Power's NEP Department. This department exists under the Nuclear Protection Services and Emergency Preparedness organization within Virginia Power's Nuclear Business Unit.

1. **Training for Individuals Responsible for the Planning Effort**

   Individuals responsible for the planning effort would be afforded training commensurate with their duties and existing knowledge, skills and abilities. This may include site-specific offerings such as plant systems training and offerings from external sources, e.g., the FEMA Emergency Management Institute (EMI), the National Emergency Training Center, the Harvard School of Public Health, Nuclear Energy Institute (NEI), etc.

2. **Responsibility for Radiological Emergency Response Planning**

   The Virginia Power Senior Vice President – Nuclear Operations and Chief Nuclear Officer, who possesses the overall authority for maintaining emergency preparedness, has delegated the responsibility for program implementation to the Senior Vice President – Nuclear Operations, and program maintenance to the Vice President – Nuclear Support Services. The Senior Vice President – Nuclear Operations has delegated the responsibility for NAPS site emergency preparedness to the NAPS Site Vice President. The Vice President – Nuclear Support Services has delegated the responsibility for maintaining emergency preparedness to the Director Nuclear Protection Services and

Emergency Preparedness. This responsibility would be extended to the ESP site. (Reference 23)

3. **Plan Development and Coordination**

   The Director-Nuclear Protection Services and Emergency Preparedness is responsible for developing the ESP site Major Features Emergency Plan and coordinating this plan with other response organizations. Provisions for maintaining this plan are addressed in Section 13.3.2.2.2.p.4. (Reference 23)

4. **Plan and Agreement Maintenance**

   NUREG-0654, Supplement 2, Section V, Evaluation Criterion P.4, provides that "[e]ach organization shall update its plan and agreements as needed." Following approval of the emergency planning information in the Dominion ESP site Major Features Emergency Plan, there is no requirement to update the plan or its supporting-organization agreements until after an operating license is issued. Dominion would update the emergency planning information as necessary in a COL application. Any changes that represent a decrease in the effectiveness of the previously approved information with respect to the standards of 10 CFR 50.47(b) or requirements of 10 CFR 50, Appendix E, would be specifically identified and addressed.

5. **Distribution of Emergency Plans**

   The ESP site Emergency Plan would be prepared when a COL application is made. Upon issuance, the Emergency Plan and approved changes thereto would be forwarded to organizations and appropriate individuals with responsibility for its implementation. Revised pages would be marked to show where changes have been made. Revised pages would be dated or marked with a revision number associated with an effective date.

6. **Emergency Plan Content**

   The ESP site major features emergency plan addresses the evaluation criteria contained in NUREG-0654, Supplement 2, Section V, as shown in Table 13.3-2 (Reference 16).

Table 13.3-2 Cross Reference to NUREG-0654, Supplement 2

Evaluation Criteria	Major Features Emergency Plan Section	Evaluation Criteria	Major Features Emergency Plan Section
A.1	13.3.2.2.2.a.1, 13.3.2.2.2.a.4	J.3	13.3.2.2.2.j.3
A.2.a – A.2.b	State & Local Plans Only	J.4.a – J.4.c	13.3.2.2.2.j.4
A.3	13.3.2.2.2.a.6	J.4.d – J.4.l	State & Local Plans Only
B.1	13.3.2.2.2.b.1	J.5	State & Local Plans Only
B.2	13.3.2.2.2.b.2	K.1.a – K.1.h	13.3.2.2.2.k.1
C.1	13.3.2.2.2.c.1	K.2	13.3.2.2.2.k.2
C.2	13.3.2.2.2.c.2	K.3.a – K.3.b	13.3.2.2.2.k.3
C.3	13.3.2.2.2.c.3	K.4	13.3.2.2.2.k.4
C.4	13.3.2.2.2.c.4	K.5.a – K.5.b	13.3.2.2.2.k.5
D.1	13.3.2.2.2.d.1	L.1	13.3.2.2.2.l.1
D.2	State & Local Plans Only	L.2	State Plan Only
E.1	13.3.2.2.2.e.1	M	Section 13.3.2.2.2.m
E.2	13.3.2.2.2.e.2	N	Section 13.3.2.2.2.n
E.3	13.3.2.2.2.e.3	O.1.a	13.3.2.2.2.o.1
F.1.a	13.3.2.2.2.f.1, 13.3.2.2.2.f.2	O.1.b	13.3.2.2.2.o.2
F.1.b	13.3.2.2.2.f.3	O.1.c	13.3.2.2.2.o.3
F.1.c	13.3.2.2.2.f.4	O.1.d	13.3.2.2.2.o.4
F.2	13.3.2.2.2.f.5	O.1.e	Omitted
G.1	13.3.2.2.2.g.1	O.1.f	13.3.2.2.2.o.5
G.2	13.3.2.2.2.g.2	O.1.g	13.3.2.2.2.o.6
H.1	13.3.2.2.2.h.1, 13.3.2.2.2.h.2	O.1.h	13.3.2.2.2.o.7
H.2	13.3.2.2.2.h.3	O.1.i	13.3.2.2.2.o.8
H.3	State & Local Plans Only	P.1	13.3.2.2.2.p.1
I.1	13.3.2.2.2.i.1	P.2	13.3.2.2.2.p.2
I.2	13.3.2.2.2.i.2	P.3	13.3.2.2.2.p.3
I.3	13.3.2.2.2.i.3	P.4	13.3.2.2.2.p.4
J.1	13.3.2.2.2.j.1	P.5	13.3.2.2.2.p.5
J.2	13.3.2.2.2.j.2	P.6	13.3.2.2.2.p.6

13.3.3 Contracts and Arrangements

Pursuant to 10 CFR 52.17(b)(3), a description of contacts and arrangements made with local, state, and federal governmental agencies with emergency planning responsibilities, and documentation thereof, is provided herein.

- U. S. Department of Energy – Field Office, Oak Ridge.
- Commonwealth of Virginia Department of Emergency Management
- Commonwealth of Virginia Department of Health
- Commonwealth of Virginia Department of State Police
- Commonwealth of Virginia Department of Game and Inland Fisheries
- MCV Hospitals and Physicians, VCU Health Systems
- Louisa County Administrator
- Louisa County Volunteer Firefighter's Association
- Louisa County Sheriff
- Emergency Medical Services Association of Louisa County
    - Lake Anna Rescue, Inc.
    - Louisa County Rescue Squad, Inc.
    - Holly Grove Rescue Squad, Inc.
    - Mineral Volunteer Rescue Squad
    - Trevilians Volunteer Fire Department, Inc.
- Spotsylvania County Sheriff
- Spotsylvania Volunteer Fire Department, Inc.
- Spotsylvania County Coordinator
- Orange County Sheriff
- Orange County Administrator
- Caroline County Department of Fire & Rescue
- Caroline County Sheriff
- Hanover County Administrator
- Hanover County Sheriff

Supporting organization agreements would be updated when referenced in a COL application.

Dominion provided an overview of the ESP project to DEM staff members on February 20, 2003 and to risk jurisdiction coordinators of emergency management on

March 24, 2003. The NRC licensing process, emergency preparedness requirements for ESP applicants, and Dominion's schedule for preparing and submitting this ESP application Anna were described at both meetings. During the discussions regarding the ESP process, no impediments to pursuing an ESP was identified by Commonwealth of Virginia or risk jurisdiction response organizations.

It is Dominion's understanding that the NRC would coordinate reviews and schedules relative to the ESP site's Major Features Emergency Plan with the Federal Emergency Management Agency (FEMA) in accordance with their current memorandum of understanding.

13.3.4 Conformance with NUREG-0652, Supplement 2

Differences between emergency planning information relative to this ESP application and the guidance provided by NUREG-0654, Supplement 2, including planning standards or evaluation criteria not addressed, are cross-referenced and described below:

Section	Description of Difference(s)
II	References to future emergency plan implementing procedures describing integration of response actions with current or future licensees are made herein.
III.A	The possible application of analyses performed subsequent to the WASH-1400 report, design-specific factors, and legislative or regulatory initiatives may affect the size of the plume exposure pathway EPZ described in Section 13.3.2.2.1.a and the IPZ described in Section 13.3.2.2.1.b is noted.
V.A.1	Private sector response from the Architect/Engineer and the nuclear steam system supplier are not addressed as these organizations have not yet been identified.
V.A.3 and V.B.2	Letters of agreement with supporting agencies are the existing letters of agreement in the NAEP.
V.C.1	Affect of the yet-to-be-issued NRP upon this plan are unknown.
V.C.2	Radiological count laboratory resources would be obtained through purchase agreements with private institutions. These purchase agreements are not prepared in advance, but would be negotiated on an as needed basis.
V.D.1	Emergency Action Levels may be developed in accordance with Appendix 1 of NUREG-0654/FEMA-REP-1, Revision 1, or RG 1.101, Revision 3; or other applicable guidance that may be available at the time application is made for a COL. RG 1.101, Revision 4, provides for use of an EAL scheme not referenced in NUREG-0654, Supplement 2 (Reference 16) (Reference 10). The yet-to-be-selected design may dictate use of yet another EAL scheme, or a site-specific model may be needed.
V.G.1	Emergency planning information, including that presented in the ESP Major Features Plan would be updated when it is referenced in a combined license application.

Section	Description of Difference(s)
V.J.4.a	Population information by PAZ is presented in tables rather than in a map.
V.J.4.b	Location of Emergency Assembly Centers are listed rather than appearing on a map.
V.K.2, V.K.3 and V.K.5	References to future radiological protection procedures are made herein.
V.L.1	Based on the quality of facilities at MCV, arrangements for a back-up hospital were excluded.
O.1.d and O.1.f	References to future Security Plan, Fire Protection Program and Accident Prevention Manual are made herein.
V.O.1.h	Provisions for responding to requests for site-specific emergency response training for medical support personnel are included in lieu of a description of a training program for instructing and qualifying such personnel.
V.P.5	Revised pages would be dated or marked with a revision number associated with an effective date in lieu of dating each page.

Section 13.3 References

1. 10 CFR 20, *Standards for Protection Against Radiation*, U.S. Nuclear Regulatory Commission.

2. 10 CFR 50.47, *Emergency Plans*, U.S. Nuclear Regulatory Commission.

3. 10 CFR 50.54, *Conditions of Licenses*, U.S. Nuclear Regulatory Commission.

4. 10 CFR 50.72, *Immediate Notification Requirements for Operating Nuclear Power Reactors*, U.S. Nuclear Regulatory Commission.

5. 10 CFR 50, Appendix E, *Emergency Planning and Preparedness for Production and Utilization Facilities*, U.S. Nuclear Regulatory Commission.

6. 10 CFR 52, *Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants*, U.S. Nuclear Regulatory Commission.

7. 44 CFR 350, *Review and Approval of State and Local Radiological Emergency Plans and Preparedness*, Federal Emergency Management Agency.

8. 12 VAC 5-31, *Virginia Emergency Medical Services Regulations*, Commonwealth of Virginia State Board of Health, April 23, 2003.

9. Regulatory Guide 1.101, *Emergency Planning and Preparedness for Nuclear Power Reactors*, Revision 3, U.S. Nuclear Regulatory Commission, August 1992.

10. Regulatory Guide 1.101, *Emergency Planning and Preparedness for Nuclear Power Reactors*, Revision 4, U.S. Nuclear Regulatory Commission, July 2003.

11. Regulatory Guide 1.183, *Alternative Radiological Source Terms For Evaluating Design Basis Accidents At Nuclear Power Reactors*, U.S. Nuclear Regulatory Commission, July 2000.

12. NUREG-75/014, *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, October 1975 (WASH-1400).

13. NUREG-0053, *Safety Evaluation Report related to the operation of North Anna Power Station, Unit 2*, Supplement No. 11, U.S. Nuclear Regulatory Commission, August 1980.

14. *NUREG-0396; EPA 520/1-78-016, Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, December 1978.

15. NUREG-0654/FEMA-REP-1, *Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, November 1980.

16. NUREG-0654/FEMA-REP-1, Supplement 2, *Criteria for Emergency Planning in an Early Site Permit Application*. Draft Report Comment, U.S. Nuclear Regulatory Commission, April 1, 1996.

17. NUREG-0654/FEMA-REP-1, Supplement 3, *Criteria for Protective Action Recommendations for Severe Accidents*, Draft Report of Interim Use and Comment, U.S. Nuclear Regulatory Commission, July 1, 1996.

18. NUREG-0696, *Functional Criteria for Emergency Response Facilities*, U.S. Nuclear Regulatory Commission, January 1, 1981.

19. NUREG-1022, *Event Reporting Guidelines: 10 CFR 50.72 and 50.73*, Revision 2, U.S. Nuclear Regulatory Commission, October 1, 2000.

20. EPA 400-R-92-001, *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*, Environmental Protection Agency, May 1992.

21. FEMA-REP-10, *Guide for the Evaluation of Alert and Notification Systems for Nuclear Power Plants*, Federal Emergency Management Assistance, November 1985.

22. FEMA-REP-11, *Guide to Preparing Emergency Public Information Materials Federal Emergency Management Assistance*.

23. *North Anna Power Station Updated Final Safety Analysis Report*, Revision 38.

24. *North Anna Power Station Emergency Plan*, Revision 28, Dominion, July 1, 2003.

25. *Federal Response Plan*, Federal Emergency Management Agency, January 2003.

26. *Federal Radiological Emergency Response Plan (FRERP)*, Federal Emergency Management Agency, May 1, 1996.

27. *U.S. Department of Energy Radiological Assistance Program Region 2, Regional Plan*, U.S. Department of Energy, October 1997.

28. *United States Government Interagency Domestic Terrorism Concept of Operations Plan (CONPLAN)*, Department of Justice Federal Bureau of Investigation, January 2001.

29. U.S. Department of Energy Order 151.1A, *Comprehensive Emergency Management System*, U.S. Department of Energy, November 1, 2000.

30. *Homeland Security Presidential Directive (HSPD) 5*, *"Management of Domestic Incidents,"* Department of Homeland Security, February 28, 2003.

31. *Commonwealth of Virginia Emergency Operations Plan, Volume III*, Commonwealth of Virginia Radiological Emergency Response Plan, March 2002.

32. *Louisa County Radiological Emergency Response Plan*, March 2002.

33. *Caroline County Radiological Emergency Response Plan*, March 2002.

34. *Hanover County Radiological Emergency Response Plan*, March 2002.

35. *Orange County Radiological Emergency Response Plan*, March 2002.

36. *Spotsylvania County Radiological Emergency Response Plan*, March 2002.

37. *Medical College of Virginia Hospital (MCVH)/Virginia Commonwealth University (VCU) Radiation Emergency Plan*, December 5, 2000.

38. INPO 03-001, *Emergency Resources Manual*, Institute of Nuclear Power Operations, January 2003.

39. *Nuclear Power Station Emergency Preparedness Training (NPSEPT) Program Guide*, Dominion, February 2003.

40. *North Anna Nuclear Power Station Estimation of Evacuation Times*, PRC Voorhees (company formed by 1967 merger of Planning Research Corporation and Alan M. Voorhees & Associates), March 1981.

41. *Population and Evacuation Study,* Virginia Polytechnic Institute and State University Center for Transportation Research, April 6, 1990 with update dated December 10, 1991.

42. *Evacuation Time Estimates for the North Anna Power Station and Surrounding Jurisdictions*, Innovative Emergency Management, Incorporated, November 2, 2001.

43. EPPOS1, *Acceptable Deviations From Appendix 1 of NUREG-0654 Based Upon the Staff's Regulatory Analysis Of NUMARC/NESP-007, "Methodology For Development of Emergency Action Levels," Emergency Preparedness Position*, U.S. Nuclear Regulatory Commission, June 5, 1995.

44. Letter from Julius W. Becton, Jr., Director, (U.S.) Federal Emergency Management Agency, to The Honorable Gerald L. Baliles, Governor, Commonwealth of Virginia, September 2, 1987.

45. Dominion Home Page (www.dom.com)

13.6 Industrial Security

The development area for the new units is west of and adjacent to the existing units on the NAPS site. The protected area of the existing units would be extended to encompass the new units.

Like the existing units, physical protection of the new units would be based on controlling access to the NAPS site and the new units, screening operating personnel, monitoring security equipment, designing and arranging station features, and obtaining assistance from local law enforcement personnel.

The characteristics of the ESP site are such that implementation of the applicable requirements of 10 CFR 73.55 and RG 4.7, as well as the post-9/11 NRC Orders can be met. The NAPS site is sufficiently large to provide adequate distances between structures and the probable location of a security boundary.

The ESP site is located on the shore of Lake Anna. For the existing units, Virginia Power has a security program in place in compliance with the NRC Order for Interim Compensatory Measures dated February 25, 2002 that addresses waterborne threats to the site without the need to restrict access to the lake. In the event that new units are added to the site, it is anticipated that those requirements would continue to be met.

The final design of the new units power block and supporting buildings would utilize design features as appropriate to assure that the existing security distances outlined in the regulations above as well as the Design Basis Threat and any Interim Compensatory measures that may apply are adequate. The COL application would address the specific design features to assure site security as well as include the design of security monitoring equipment and methods to screen station operating personnel.

There are no security hazards in the vicinity. The ESP site is located in Louisa County in the Commonwealth of Virginia. A written agreement with Louisa County is currently in place to establish a single point of contact for police response to the NAPS site. Louisa County has mutual aid agreements in place if necessary. Auxiliary agreements also exist with other neighboring jurisdictions to provide support during station emergencies.

Chapter 15 Accident Analyses

15.1 Selection of Accidents

The radiological consequences of accidents are assessed to demonstrate that new units could be sited at the ESP site without undue risk to the health and safety of the public. The assessment uses site-specific accident meteorology with the radiological analyses in selected reactor designs to analyze the suitability of the ESP site. The assessment uses a robust and conservative set of surrogate DBAs that is representative of the range of reactor designs being considered for the ESP site. The DBAs include a spectrum of events, including those of relatively greater probability of occurrence as well as those that are less probable but have greater severity.

The set of accidents selected focuses on three light water reactor (LWR) designs: AP1000, ABWR, and ESBWR. These three designs have been chosen because these are standard designs that have recognized bases for postulated accident analyses. The accidents for some of the newer reactor types being considered are not as well defined as those for these LWRs and, hence, the accepted analytical methodologies and assumptions applied to LWRs may not apply to these newer reactors. However, because of their greater potential for inherent safety, the accident radiological consequences of the other reactors being considered for the site are expected to be bounded by the AP1000, the ABWR, and the ESBWR. If one of these other designs is eventually selected for the ESP site, the COL application would either verify that the AP1000, the ABWR, and the ESBWR doses are bounding or provide a complete evaluation of accident radiological consequences compared with regulatory limits.

The following LWR accidents are identified in the SRP, NUREG-0800 (Reference 1), as those that should be considered for radiological consequences:

- SRP Section 15.1.5, PWR Main Steam Line Break
- SRP Section 15.2.8, Feedwater System Pipe Break
- SRP Section 15.3.3, Locked Rotor Accident
- SRP Section 15.3.4, Reactor Coolant Pump Shaft Break
- SRP Section 15.4.8, PWR Rod Ejection Accident
- SRP Section 15.4.9, BWR Control Rod Drop Accident
- SRP Section 15.6.2, Failure of Small Lines Carrying Primary Coolant Outside Containment
- SRP Section 15.6.3, PWR Steam Generator Tube Failure
- SRP Section 15.6.4, BWR Main Steam Line Break
- SRP Section 15.6.5, Loss-of-Coolant Accident
- SRP Section 15.7.4, Fuel Handling Accident

RG 1.183 (Reference 2) includes a subset of these accidents. In addition, a cleanup water line break is evaluated for the ABWR and the ESBWR.

The radiological consequences from the above DBAs are analyzed. This set of accidents provides a reasonable basis for evaluating the suitability of the ESP site.

Section 15.1 References

1. NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants,* NRC, 1987.

2. Regulatory Guide 1.183, *Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,* NRC, July 2000.

15.2 Evaluation Methodology

Doses for the representative DBAs are evaluated at the EAB and the LPZ. These doses must meet the site acceptance criteria provided in 10 CFR 50.34 and 10 CFR 100 (Reference 1 and Reference 2, respectively). Although the emergency safety features are expected to prevent core damage and mitigate releases of radioactivity, the loss-of-coolant accidents (LOCAs) analyzed presume substantial meltdowns of the core with the release of significant amounts of fission products. The postulated LOCAs are expected to more closely approach 10 CFR 50.34 limits than the other DBAs of greater probability of occurrence but lesser magnitude of activity releases. For these accidents, the calculated doses are compared to the acceptance criteria in RG 1.183 and NUREG-0800, to demonstrate that the consequences of the postulated accidents are acceptable.

The evaluations use short-term accident atmospheric dispersion factors (χ/Q). The χ/Qs are calculated using the methodology of RG 1.145 (Reference 3) and site-specific meteorological data. The following site-specific χ/Q values from Section 2.3.4.2 are used in these evaluations:

Site-Specific χ/Q Values

	χ/Q (sec/m^3)	
Time	**EAB**	**LPZ**
0–2 hr	2.26E-4	-
0–8 hr	-	2.05E-5
8–24 hr	-	1.36E-5
24–96 hr	-	5.58E-6
96–720 hr	-	1.55E-6

The accident doses are expressed as total effective dose equivalent (TEDE), consistent with 10 CFR 50.34. The TEDE consists of the sum of the committed effective dose equivalent (CEDE) from inhalation and either the deep dose equivalent (DDE) or the effective dose equivalent (EDE) from external exposure. The CEDE is determined using the dose conversion factors in Federal Guidance Report 11 (Reference 4), while the DDE and the EDE are based on dose conversion factors in Federal Guidance Report 12 (Reference 5).

Section 15.2 References

1. 10 CFR 50.34, Code of Federal Regulations, *Contents of Applications; Technical Information.*

2. 10 CFR 100, Code of Federal Regulations, *Reactor Site Criteria.*

3. Regulatory Guide 1.145, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, Revision 1, NRC, November 1982.

4. Federal Guidance Report 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,* U. S. Environmental Protection Agency, EPA-520/1-88-020, 1988.

5. Federal Guidance Report 12, *External Exposure to Radionuclides in Air, Water, and Soil,* U. S. Environmental Protection Agency, EPA-402-R-93-081, 1993.

6. TID-14844, *Calculation of Distance Factors for Power and Test Reactor Sites,* U. S. Atomic Energy Commission, March 1962.

15.3 Source Terms

Doses are calculated based on the time-dependent activities released to the environment during each DBA. The activities are based on the analyses used to support the reactor standard safety analysis reports. Different reactor technologies use different source terms and approaches in defining the activity releases. The ABWR source term is based on TID-14844 (Reference 1). Environmental releases are calculated using the guidance in NUREG-0800 and RGs 1.3 and 1.25 (Reference 2 and Reference 3, respectively). The AP1000 and ESBWR source terms, methodologies, and assumptions are based on the alternative source term methods outlined in RG 1.183. The activity releases and doses for the AP1000, the ABWR, and the ESBWR are based on 102 percent of core thermal power.

The ABWR activity releases are scaled up from a power level of 4005 MWt (102 percent of 3926 MWt, as specified in the design certification) to 4386 MWt (102 percent of 4300 MWt, the power proposed for a new ABWR unit at the ESP site), an adjustment factor of 1.10. As the ESBWR design has not yet been certified by the NRC, the ESBWR design control document activity releases are increased by 25 percent to allow for uncertainty.

The IRIS and ACR-700 source term information are preliminary, but the AP1000 LOCA is expected to bound the worst-case accident release for these advanced reactor concepts. The advanced gas reactor designs (GT-MHR and PBMR) use mechanistic accident source terms and postulate relatively small environmental releases, compared with the water reactor technologies. The activity releases to the environment are typically provided by the reactor vendors as part of their standard design packages.

Section 15.3 References

1. TID-14844, *Calculation of Distance Factors for Power and Test Reactor Sites,* U. S. Atomic Energy Commission, March 1962.

2. Regulatory Guide 1.3, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors,* Revision 2, NRC, June 1974.

3. Regulatory Guide 1.25 (Safety Guide 25), *Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors,* NRC, March 1972.

15.4 Radiological Consequences

For the AP1000 and ABWR accidents identified in Section 15.1, site-specific doses are calculated by multiplying the design certification doses by the ratio of the site χ/Qs to design certification χ/Qs. The following design certification χ/Qs are used (Reference 1) (Reference 2):

Design Certification χ/Q Values and Ratios to Site χ/Q Values

		χ/Q (sec/m^3)		Ratio (Site/DC)	
	Time (hr)	**AP1000**	**ABWR**	**AP1000**	**ABWR**
EAB	0–2	6.00E-04	1.37E-03	3.77E-01	1.65E-01
LPZ	0–8	1.35E-04	1.56E-04	1.52E-01	1.31E-01
	8–24	1.00E-04	9.61E-05	1.36E-01	1.42E-01
	24–96	5.40E-05	3.36E-05	1.03E-01	1.66E-01
	96–720	2.20E-05	7.42E-06	7.05E-02	2.09E-01

Details about the methodology and assumptions pertaining to each of the accidents, such as activity release paths and the credited mitigation features, may be found in the design certification documents for the AP1000 (Reference 1), the ABWR (Reference 2), and the ESBWR (Reference 3).

As the ABWR design certification document presents whole body and thyroid doses, an equivalent TEDE value is estimated by multiplying the thyroid dose by 0.03 and adding the product to the whole body dose, in accordance with RG 1.183. Also, consistent with the activity releases in Section 15.3, the ABWR doses are scaled up by a factor of 1.10 from a power level of 4005 MWt (102 percent of 3926 MWt, as specified in the design certification) to 4386 MWt (102 percent of 4300 MWt, the power proposed for a new ABWR unit at the ESP site).

As the ESBWR design has not yet been certified by the NRC, the doses are calculated based on activity releases, which include a margin of 25 percent to allow for uncertainty. The TEDE dose from an isotope for a given time period is calculated by adding the CEDE from inhalation and the EDE from external exposure. The CEDE is calculated by multiplying the isotopic activity by the site χ/Q value, the breathing rate of the individual located offsite, and the effective inhalation dose conversion factor from Federal Guidance Report 11. The EDE is calculated by multiplying the isotopic activity by the site χ/Q value and the effective submersion dose conversion factor from Federal Guidance Report 12.

A summary of the resulting accident doses is presented in Table 15.4-1. This table also compares the accident doses to the recommended limits in RG 1.183 and NUREG-0800 and shows that the evaluated dose consequences are within the recommended limits.

The TEDE dose limits in Table 15.4-1 are taken from RG 1.183, Table 6, for all accidents except PWR Reactor Coolant Pump Shaft Break (SRP Section 15.3.4) and Failure of Small Lines Carrying Primary Coolant Outside Containment (SRP Section 15.6.2). For these two accidents, NUREG-0800 indicates that the dose limit is a “small fraction” or 10 percent of the 10 CFR 100 guideline of 25 Rem, meaning a limit of 2.5 Rem.

The doses summarized in Table 15.4-1 are based on the time-dependent doses presented in Table 15.4-2 to Table 15.4-31 for each of the accidents. In addition to doses, the latter tables show the activities released to the environment.

Section 15.4 References

1. AP1000 Document No. APP-GW-GL-700, AP1000 Design Control Document, Tier 2 Material, Westinghouse, Revision 2, 2002.

2. Document 23A6100, *ABWR Standard Safety Analysis Report,* General Electric, Revision 8.

3. Document 26A6642, ESBWR Design Control Document, Tier 2 Material, General Electric, Revision 1.

Table 15.4-1 Summary of Design Basis Accident Doses

SRP Section	Accident	Reactor	TEDE (Rem) EAB	TEDE (Rem) LPZ	TEDE (Rem) Limit
15.1.5	PWR Main Steam Line Break				
	Pre-Existing Iodine Spike	AP1000	2.6E-01	6.1E-02	25
	Accident-Initiated Iodine Spike	AP1000	3.0E-01	2.2E-01	2.5
15.2.8	Feedwater System Pipe Break	AP1000	See Note 1		2.5
		ABWR	See Note 2		2.5
		ESBWR	4.6E-05	4.2E-06	2.5
15.3.3	Reactor Coolant Pump Rotor Seizure (Locked Rotor Accident)	AP1000	9.4E-01	9.1E-02	2.5
		ABWR/ESBWR	Not Postulated		2.5
15.3.4	Reactor Coolant Pump Shaft Break	AP1000	See Note 3		2.5
		ABWR/ESBWR	Not Postulated		2.5
15.4.8	PWR Rod Ejection Accident	AP1000	1.1E+00	2.5E-01	6.3
15.4.9	BWR Control Rod Drop Accident	ABWR/ESBWR	Not Postulated		6.3
15.6.2	Failure of Small Lines Carrying Primary Coolant Outside Containment	AP1000	4.9E-01	4.6E-02	2.5
		ABWR	4.3E-02	3.9E-03	2.5
		ESBWR	3.0E-02	6.5E-03	2.5
15.6.3	PWR Steam Generator Tube Rupture				
	Pre-Existing Iodine Spike	AP1000	1.1E+00	5.2E-02	25
	Accident-Initiated Iodine Spike	AP1000	5.7E-01	3.7E-02	2.5
15.6.4	BWR Main Steam Line Break				
	Pre-Existing Iodine Spike	ABWR	5.1E-01	4.6E-02	25
	Equilibrium Iodine Activity	ABWR	2.5E-02	2.3E-03	2.5
	Pre-Existing Iodine Spike	ESBWR	2.1E+00	1.9E-01	25
	Equilibrium Iodine Activity	ESBWR	1.1E-01	9.6E-03	2.5
15.6.5	Loss-of-Coolant Accident	AP1000	9.3E+00	1.5E+00	25
		ABWR	1.8E+00	2.1E+00	25
		ESBWR	1.4E+00	9.1E-01	25

Table 15.4-1 Summary of Design Basis Accident Doses

SRP Section	Accident	Reactor	TEDE (Rem)		
			EAB	LPZ	Limit
15.7.4	Fuel Handling Accident	AP1000	9.0E-01	9.1E-02	6.3
		ABWR	6.2E-01	5.7E-02	6.3
		ESBWR	1.2E+00	1.1E-01	6.3
	Cleanup Water Line Break	ABWR	3.2E-03	2.9E-04	2.5
		ESBWR	1.8E-01	1.6E-02	2.5

Note:

1. The AP1000 design certification indicates that the doses for the feedwater system pipe break are bounded by the main steam line break (Reference 1, Section 15.2.8.3).
2. The ABWR design certification indicates that the doses for the feedwater system pipe break are bounded by the cleanup water line break (Reference 2, Section 15.2.8).
3. The AP1000 design certification indicates that the doses for the reactor coolant pump shaft break are bounded by the reactor coolant pump rotor seizure (Reference 1, Section 15.3.4.2).
4. The ABWR design certification indicates that there are no radiological consequences for the reactor coolant pump rotor seizure, the reactor coolant pump shaft break, and the control rod drop accident (Reference 2, Sections 15.3.3.5, 15.3.4.5, and 15.4.10.6).
5. The ESBWR design certification indicates that there are no radiological consequences for the reactor coolant pump rotor seizure, the reactor coolant pump shaft break, and the control rod drop accident (Reference 3).

Table 15.4-2 Activity Releases for AP1000 Main Steam Line Break, Pre-Existing Iodine Spike

	Activity Release (Ci)				
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–72 hr**	**Total**
Kr-85m	2.30E-01	3.82E-01	2.26E-01	2.03E-02	8.58E-01
Kr-85	9.47E-01	2.83E+00	7.47E+00	2.17E+01	3.29E+01
Kr-87	9.24E-02	4.49E-02	1.76E-03	2.84E-07	1.39E-01
Kr-88	3.77E-01	4.59E-01	1.34E-01	2.72E-03	9.73E-01
Xe-131m	4.28E-01	1.27E+00	3.26E+00	8.78E+00	1.37E+01
Xe-133m	5.31E-01	1.51E+00	3.45E+00	6.69E+00	1.22E+01
Xe-133	3.95E+01	1.15E+02	2.87E+02	7.03E+02	1.14E+03
Xe-135m	1.02E-02	4.44E-05	0.00E+00	0.00E+00	1.02E-02
Xe-135	1.04E+00	2.31E+00	2.78E+00	1.11E+00	7.24E+00
Xe-138	1.34E-02	3.81E-05	0.00E+00	0.00E+00	1.34E-02
I-130	4.98E-01	4.74E-01	6.95E-01	4.36E-01	2.10E+00
I-131	3.37E+01	4.05E+01	1.03E+02	2.67E+02	4.44E+02
I-132	4.02E+01	1.39E+01	2.68E+00	2.16E-02	5.68E+01
I-133	6.03E+01	6.35E+01	1.17E+02	1.30E+02	3.71E+02
I-134	8.24E+00	5.47E-01	4.77E-03	1.50E-08	8.79E+00
I-135	3.56E+01	2.73E+01	2.51E+01	5.60E+00	9.36E+01
Cs-134	1.91E+01	6.52E-01	1.72E+00	5.00E+00	2.65E+01
Cs-136	2.84E+01	9.57E-01	2.47E+00	6.69E+00	3.85E+01
Cs-137	1.38E+01	4.70E-01	1.24E+00	3.61E+00	1.91E+01
Cs-138	1.02E+01	3.41E-03	1.48E-06	0.00E+00	1.02E+01
Total	2.93E+02	2.72E+02	5.58E+02	1.16E+03	2.28E+03

Table 15.4-3 Doses for AP1000 Main Steam Line Break, Pre-Existing Iodine Spike

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	**EAB**	**LPZ**	**(Site/AP1000)**	**EAB**	**LPZ**
0–2 hr	7.00E-01		3.77E-01	2.64E-01	
0–8 hr		2.40E-01	1.52E-01		3.64E-02
8–24 hr		8.00E-02	1.36E-01		1.09E-02
24–96 hr		1.30E-01	1.03E-01		1.34E-02
96–720 hr		0.00E+00	7.05E-02		0.00E+00
Total	7.00E-01	4.50E-01		2.64E-01	6.08E-02
Limit				25	25

Table 15.4-4 Activity Releases for AP1000 Main Steam Line Break, Accident-Initiated Iodine Spike

	Activity Release (Ci)				
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–72 hr**	**Total**
Kr-85m	2.30E-01	3.82E-01	2.26E-01	2.03E-02	8.58E-01
Kr-85	9.47E-01	2.83E+00	7.47E+00	2.17E+01	3.29E+01
Kr-87	9.24E-02	4.49E-02	1.76E-03	2.84E-07	1.39E-01
Kr-88	3.77E-01	4.59E-01	1.34E-01	2.72E-03	9.73E-01
Xe-131m	4.28E-01	1.27E+00	3.26E+00	8.78E+00	1.37E+01
Xe-133m	5.31E-01	1.51E+00	3.45E+00	6.69E+00	1.22E+01
Xe-133	3.95E+01	1.15E+02	2.87E+02	7.03E+02	1.14E+03
Xe-135m	1.02E-02	4.44E-05	0.00E+00	0.00E+00	1.02E-02
Xe-135	1.04E+00	2.31E+00	2.78E+00	1.11E+00	7.24E+00
Xe-138	1.34E-02	3.81E-05	0.00E+00	0.00E+00	1.34E-02
I-130	6.84E-01	3.33E+00	5.27E+00	3.30E+00	1.26E+01
I-131	3.92E+01	1.92E+02	5.18E+02	1.35E+03	2.10E+03
I-132	9.12E+01	3.26E+02	7.46E+01	6.00E-01	4.92E+02
I-133	7.75E+01	3.81E+02	7.54E+02	8.34E+02	2.05E+03
I-134	3.03E+01	6.23E+01	8.85E-01	2.78E-06	9.35E+01
I-135	5.57E+01	2.59E+02	2.61E+02	5.82E+01	6.34E+02
Cs-134	1.91E+01	6.52E-01	1.72E+00	5.00E+00	2.65E+01
Cs-136	2.84E+01	9.57E-01	2.47E+00	6.69E+00	3.85E+01
Cs-137	1.38E+01	4.70E-01	1.24E+00	3.61E+00	1.91E+01
Cs-138	1.02E+01	3.41E-03	1.48E-06	0.00E+00	1.02E+01
Total	4.09E+02	1.35E+03	1.92E+03	3.00E+03	6.68E+03

Table 15.4-5 Doses for AP1000 Main Steam Line Break, Accident-Initiated Iodine Spike

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	8.00E-01		3.77E-01	3.01E-01	
0–8 hr		6.40E-01	1.52E-01		9.72E-02
8–24 hr		4.20E-01	1.36E-01		5.71E-02
24–96 hr		6.30E-01	1.03E-01		6.51E-02
96–720 hr		0.00E+00	7.05E-02		0.00E+00
Total	8.00E-01	1.69E+00		3.01E-01	2.19E-01
Limit				2.5	2.5

Table 15.4-5a Activity Releases for ABWR Cleanup Water Line Break

	Activity Release (Ci)
Isotope	0–2 hr
I-131	2.40E+00
I-132	5.62E+00
I-133	6.80E+00
I-134	9.46E+00
I-135	7.39E+00
Total	3.17E+01

Table 15.4-5b Doses for ABWR Cleanup Water Line Break

	ABWR EAB Dose (S_v)			χ/Q Ratio	Site TEDE (Rem)	
Time	W. Body	Thyroid	TEDE	(Site/ABWR)	EAB	LPZ
0–2 hr	1.70E-04	1.70E-04	1.75E-04	1.65E-01	3.16E-03	
0–8 hr	1.70E-04	1.70E-04	1.75E-04	1.50E-02		2.87E-04
8–24 hr						0.00E+00
24–96 hr						0.00E+00
96–720 hr						0.00E+00
Total	1.70E-04	1.70E-04	1.75E-04		3.16E-03	2.87E-04
Limit					2.5	2.5

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. Since the ABWR design certification document does not include an LPZ dose for this accident, the site LPZ dose is obtained by multiplying the ABWR EAB dose by the ratio of site LPZ χ/Q to ABWR EAB χ/Q. The site doses include a multiplier of 1.10 for power adjustment.

Table 15.4-5c Activity Releases for ESBWR Feedwater System Pipe Break

	Activity Release (Ci)
Isotope	0–2 hr
I-131	4.39E-03
I-132	4.05E-02
I-133	2.94E-02
I-134	7.43E-02
I-135	4.05E-02
Total	1.89E-01

Table 15.4-5d Doses for ESBWR Feedwater System Pipe Break

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
0–2 hr	4.63E-05	
0–8 hr		4.20E-06
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	4.63E-05	4.20E-06
Limit	2.5	2.5

Table 15.4-6 Activity Releases for AP1000 Locked Rotor Accident

	Activity Release (Ci)
Isotope	**0–2 hr**
Kr-85m	4.09E+02
Kr-85	3.77E+01
Kr-87	6.05E+02
Kr-88	1.05E+03
Xe-131m	1.87E+01
Xe-133m	1.02E+02
Xe-133	3.33E+03
Xe-135m	1.63E+02
Xe-135	8.01E+02
Xe-138	6.48E+02
I-130	4.15E+00
I-131	1.83E+02
I-132	1.33E+02
I-133	2.31E+02
I-134	1.44E+02
I-135	2.04E+02
Cs-134	5.83E+00
Cs-136	1.85E+00
Cs-137	3.42E+00
Cs-138	3.05E+01
Rb-86	6.69E-02
Total	8.11E+03

Table 15.4-7 Doses for AP1000 Locked Rotor Accident

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	2.50E+00		3.77E-01	9.42E-01	
0–8 hr		6.00E-01	1.52E-01		9.11E-02
8–24 hr		0.00E+00	1.36E-01		0.00E+00
24–96 hr		0.00E+00	1.03E-01		0.00E+00
96–720 hr		0.00E+00	7.05E-02		0.00E+00
Total	2.50E+00	6.00E-01		9.42E-01	9.11E-02
Limit				2.5	2.5

Table 15.4-8 Activity Releases for AP1000 Rod Ejection Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Kr-85m	2.85E+02	6.48E+01	3.87E+01	3.53E+00	5.01E-05	3.92E+02
Kr-85	1.24E+01	5.60E+00	1.49E+01	6.70E+01	5.71E+02	6.71E+02
Kr-87	4.86E+02	2.60E+01	1.03E+00	1.67E-04	0.00E+00	5.13E+02
Kr-88	7.49E+02	1.18E+02	3.49E+01	7.18E-01	1.68E-08	9.03E+02
Xe-131m	1.22E+01	5.46E+00	1.42E+01	5.72E+01	2.31E+02	3.20E+02
Xe-133m	6.62E+01	2.81E+01	6.49E+01	1.69E+02	1.06E+02	4.34E+02
Xe-133	2.18E+03	9.58E+02	2.40E+03	8.53E+03	1.68E+04	3.09E+04
Xe-135m	2.18E+02	5.30E-02	4.33E-09	0.00E+00	0.00E+00	2.18E+02
Xe-135	5.39E+02	1.72E+02	2.09E+02	8.69E+01	3.58E-01	1.01E+03
Xe-138	8.89E+02	1.38E-01	3.19E-09	0.00E+00	0.00E+00	8.89E+02
I-130	5.93E+00	7.28E+00	4.32E+00	4.06E-01	5.88E-04	1.79E+01
I-131	1.64E+02	2.45E+02	2.31E+02	6.20E+01	3.33E+01	7.35E+02
I-132	1.90E+02	9.94E+01	9.85E+00	1.65E-02	0.00E+00	2.99E+02
I-133	3.29E+02	4.40E+02	3.18E+02	4.56E+01	4.81E-01	1.13E+03
I-134	2.18E+02	2.85E+01	1.37E-01	8.96E-08	0.00E+00	2.47E+02
I-135	2.91E+02	2.97E+02	1.19E+02	4.79E+00	1.46E-04	7.12E+02
Cs-134	3.15E+01	6.22E+01	6.03E+01	1.55E+01	1.03E+01	1.80E+02
Cs-136	8.98E+00	1.75E+01	1.67E+01	4.10E+00	1.31E+00	4.86E+01
Cs-137	1.83E+01	3.62E+01	3.51E+01	9.04E+00	6.05E+00	1.05E+02
Cs-138	1.13E+02	7.05E+00	1.68E-03	0.00E+00	0.00E+00	1.20E+02
Rb-86	3.70E-01	7.27E-01	6.96E-01	1.73E-01	6.79E-02	2.03E+00
Total	6.81E+03	2.62E+03	3.57E+03	9.06E+03	1.78E+04	3.98E+04

Table 15.4-9 Doses for AP1000 Rod Ejection Accident

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	3.00E+00		3.77E-01	1.13E+00	
0–8 hr		1.40E+00	1.52E-01		2.13E-01
8–24 hr		2.60E-01	1.36E-01		3.54E-02
24–96 hr		4.60E-02	1.03E-01		4.75E-03
96–720 hr		1.20E-02	7.05E-02		8.45E-04
Total	3.00E+00	1.72E+00		1.13E+00	2.54E-01
Limit				6.3	6.3

Table 15.4-10 Doses for AP1000 Failure of Small Lines Carrying Primary Coolant Outside Containment

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	1.30E+00		3.77E-01	4.90E-01	
0–8 hr		3.00E-01	1.52E-01		4.56E-02
8–24 hr		0.00E+00	1.36E-01		0.00E+00
24–96 hr		0.00E+00	1.03E-01		0.00E+00
96–720 hr		0.00E+00	7.05E-02		0.00E+00
Total	1.30E+00	3.00E-01		4.90E-01	4.56E-02
Limit				2.5	2.5

Note: No activity release information is available for this accident.

Table 15.4-11 Activity Releases for ABWR Failure of Small Lines Carrying Primary Coolant Outside Containment

	Activity Release (Ci)		
Isotope	**0–2 hr**	**2–8 hr**	**Total**
I-131	2.01E+00	2.16E+00	4.17E+00
I-132	1.76E+01	1.76E+01	3.52E+01
I-133	1.36E+01	1.43E+01	2.79E+01
I-134	2.93E+01	2.69E+01	5.62E+01
I-135	1.95E+01	2.01E+01	3.96E+01
Total	8.20E+01	8.11E+01	1.63E+02

Table 15.4-12 Doses for ABWR Failure of Small Lines Carrying Primary Coolant Outside Containment

	ABWR EAB Dose (S_V)			χ/Q Ratio	Site TEDE (Rem)	
Time	**W. Body**	**Thyroid**	**TEDE**	**(Site/ABWR)**	**EAB**	**LPZ**
0–2 hr	9.40E-04	4.80E-02	2.38E-03	1.65E-01	4.30E-02	
0–8 hr	9.40E-04	4.80E-02	2.38E-03	1.50E-02		3.90E-03
8–24 hr						0.00E+00
24–96 hr						0.00E+00
96–720 hr						0.00E+00
Total	9.40E-04	4.80E-02	2.38E-03		4.30E-02	3.90E-03
Limit					2.5	2.5

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. Since the ABWR design certification document does not include an LPZ dose for this accident, the site LPZ dose is obtained by multiplying the ABWR EAB dose by ratio of site LPZ χ/Q to ABWR EAB χ/Q. The site doses include a multiplier of 1.10 for power adjustment.

Table 15.4-12a Activity Releases for ESBWR Failure of Small Lines Carrying Primary Coolant Outside Containment

	Activity Release (Ci)		
Isotope	**0–2 hr**	**2–8 hr**	**Total**
I-131	6.13E+00	1.05E+01	1.66E+01
I-132	8.03E+00	7.35E+00	1.54E+01
I-133	1.51E+01	2.35E+01	3.86E+01
I-134	8.78E+00	4.60E+00	1.34E+01
I-135	1.39E+01	1.85E+01	3.24E+01
Total	5.19E+01	6.45E+01	1.16E+02

Table 15.4-12b Doses for ESBWR Failure of Small Lines Carrying Primary Coolant Outside Containment

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
2–4 hr	3.04E-02	
0–8 hr		6.46E-03
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	3.04E-02	6.46E-03
Limit	2.5	2.5

Note: The maximum EAB dose occurs between 2 and 4 hours, and it is calculated based on the χ/Q between 0 and 2 hours.

Table 15.4-13 Activity Releases for AP1000 Steam Generator Tube Rupture, Pre-Existing Iodine Spike

	Activity Release (Ci)			
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**Total**
Kr-85m	5.67E+01	1.91E+01	2.50E-02	7.58E+01
Kr-85	2.25E+02	1.07E+02	4.44E-01	3.32E+02
Kr-87	2.46E+01	3.56E+00	3.02E-04	2.82E+01
Kr-88	9.44E+01	2.61E+01	1.80E-02	1.21E+02
Xe-131m	1.02E+02	4.82E+01	1.96E-01	1.50E+02
Xe-133m	1.26E+02	5.83E+01	2.19E-01	1.85E+02
Xe-133	9.37E+03	4.41E+03	1.75E+01	1.38E+04
Xe-135m	3.61E+00	5.78E-03	0.00E+00	3.62E+00
Xe-135	2.51E+02	1.00E+02	2.35E-01	3.51E+02
Xe-138	4.78E+00	4.99E-03	0.00E+00	4.78E+00
I-130	1.81E+00	6.12E-02	2.90E-01	2.16E+00
I-131	1.22E+02	5.97E+00	3.32E+01	1.61E+02
I-132	1.43E+02	8.53E-01	2.08E+00	1.46E+02
I-133	2.19E+02	8.68E+00	4.41E+01	2.72E+02
I-134	2.78E+01	5.16E-03	4.57E-03	2.78E+01
I-135	1.28E+02	3.06E+00	1.26E+01	1.44E+02
Cs-134	1.65E+00	6.35E-02	2.27E-01	1.94E+00
Cs-136	2.45E+00	9.30E-02	3.30E-01	2.87E+00
Cs-137	1.19E+00	4.58E-02	1.64E-01	1.40E+00
Cs-138	5.71E-01	3.07E-06	6.00E-07	5.71E-01
Total	1.09E+04	4.79E+03	1.12E+02	1.58E+04

Table 15.4-14 Doses for AP1000 Steam Generator Tube Rupture, Pre-Existing Iodine Spike

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	**EAB**	**LPZ**	**(Site/AP1000)**	**EAB**	**LPZ**
0–2 hr	3.00E+00		3.77E-01	1.13E+00	
0–8 hr		3.20E-01	1.52E-01		4.86E-02
8–24 hr		2.60E-02	1.36E-01		3.54E-03
24–96 hr		0.00E+00	1.03E-01		0.00E+00
96–720 hr		0.00E+00	7.05E-02		0.00E+00
Total	3.00E+00	3.46E-01		1.13E+00	5.21E-02
Limit				25	25

Table 15.4-15 Activity Releases for AP1000 Steam Generator Tube Rupture, Accident-Initiated Iodine Spike

	Activity Release (Ci)			
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**Total**
Kr-85m	5.67E+01	1.91E+01	2.50E-02	7.58E+01
Kr-85	2.25E+02	1.07E+02	4.44E-01	3.32E+02
Kr-87	2.46E+01	3.56E+00	3.02E-04	2.82E+01
Kr-88	9.44E+01	2.61E+01	1.80E-02	1.21E+02
Xe-131m	1.02E+02	4.82E+01	1.96E-01	1.50E+02
Xe-133m	1.26E+02	5.83E+01	2.19E-01	1.85E+02
Xe-133	9.37E+03	4.41E+03	1.75E+01	1.38E+04
Xe-135m	3.61E+00	5.78E-03	0.00E+00	3.62E+00
Xe-135	2.51E+02	1.00E+02	2.35E-01	3.51E+02
Xe-138	4.78E+00	4.99E-03	0.00E+00	4.78E+00
I-130	7.30E-02	1.19E-02	3.13E-02	1.16E-01
I-131	4.90E+00	1.15E+00	3.55E+00	9.60E+00
I-132	5.79E+00	1.75E-01	2.30E-01	6.20E+00
I-133	8.79E+00	1.68E+00	4.73E+00	1.52E+01
I-134	1.12E+00	1.18E-03	5.21E-04	1.12E+00
I-135	5.15E+00	6.01E-01	1.36E+00	7.11E+00
Cs-134	1.65E+00	6.35E-02	2.27E-01	1.94E+00
Cs-136	2.45E+00	9.30E-02	3.30E-01	2.87E+00
Cs-137	1.19E+00	4.58E-02	1.64E-01	1.40E+00
Cs-138	5.71E-01	3.07E-06	6.00E-07	5.71E-01
Total	1.03E+04	4.78E+03	2.93E+01	1.51E+04

Table 15.4-16 Doses for AP1000 Steam Generator Tube Rupture, Accident-Initiated Iodine Spike

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	1.50E+00		3.77E-01	5.65E-01	
0–8 hr		1.80E-01	1.52E-01		2.73E-02
8–24 hr		7.20E-02	1.36E-01		9.79E-03
24–96 hr		0.00E+00	1.03E-01		0.00E+00
96–720 hr		0.00E+00	7.05E-02		0.00E+00
Total	1.50E+00	2.52E-01		5.65E-01	3.71E-02
Limit				2.5	2.5

Table 15.4-17 Activity Releases for ABWR Main Steam Line Break

	Activity Release (Ci)	
Isotope	Pre-Existing	Equilibrium Activity
I-131	4.32E+01	2.16E+00
I-132	4.20E+02	2.10E+01
I-133	2.95E+02	1.48E+01
I-134	8.25E+02	4.14E+01
I-135	4.32E+02	2.16E+01
Kr-83m	7.22E-02	1.20E-02
Kr-85m	1.27E-01	2.12E-02
Kr-85	4.02E-04	6.68E-05
Kr-87	4.35E-01	7.22E-02
Kr-88	4.38E-01	7.27E-02
Kr-89	1.75E+00	2.92E-01
Kr-90	4.58E-01	7.54E-02
Xe-131m	3.13E-04	5.20E-05
Xe-133m	6.03E-03	1.00E-03
Xe-133	1.69E-01	2.80E-02
Xe-135m	5.15E-01	8.55E-02
Xe-135	4.79E-01	7.98E-02
Xe-137	2.19E+00	3.64E-01
Xe-138	1.67E+00	2.79E-01
Xe-139	7.66E-01	1.28E-01
Total	2.02E+03	1.02E+02

Table 15.4-18 Doses for ABWR Main Steam Line Break, Pre-Existing Iodine Spike

	ABWR EAB Dose (S_v)			χ/Q Ratio	Site TEDE (Rem)	
Time	W. Body	Thyroid	TEDE	(Site/ABWR)	EAB	LPZ
0–2 hr	1.30E-02	5.10E-01	2.83E-02	1.65E-01	5.11E-01	
0–8 hr	1.30E-02	5.10E-01	2.83E-02	1.50E-02		4.64E-02
8–24 hr						0.00E+00
24–96 hr						0.00E+00
96–720 hr						0.00E+00
Total	1.30E-02	5.10E-01	2.83E-02		5.11E-01	4.64E-02
Limit					25	25

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. Since the ABWR design certification document does not include an LPZ dose for this accident, the site LPZ dose is obtained by multiplying the ABWR EAB dose by ratio of site LPZ χ/Q to ABWR EAB χ/Q. The site doses include a multiplier of 1.10 for power adjustment.

Table 15.4-19 Doses for ABWR Main Steam Line Break, Equilibrium Iodine Activity

	ABWR EAB Dose (S_v)			χ/Q Ratio	Site TEDE (Rem)	
Time	W. Body	Thyroid	TEDE	(Site/ABWR)	EAB	LPZ
0–2 hr	6.20E-04	2.60E-02	1.40E-03	1.65E-01	2.53E-02	
0–8 hr	6.20E-04	2.60E-02	1.40E-03	1.50E-02		2.29E-03
8–24 hr						0.00E+00
24–96 hr						0.00E+00
96–720 hr						0.00E+00
Total	6.20E-04	2.60E-02	1.40E-03		2.53E-02	2.29E-03
Limit					2.5	2.5

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. Since the ABWR design certification document does not include an LPZ dose for this accident, the site LPZ dose is obtained by multiplying the ABWR EAB dose by ratio of site LPZ χ/Q to ABWR EAB χ/Q. The site doses include a multiplier of 1.10 for power adjustment.

Table 15.4-19a Activity Releases for ESBWR Main Steam Line Break

	Activity Release (Ci)	
Isotope	**Pre-Existing**	**Equilibrium Activity**
I-131	1.96E+02	9.79E+00
I-132	1.86E+03	9.45E+01
I-133	1.35E+03	6.75E+01
I-134	3.38E+03	1.72E+02
I-135	1.92E+03	9.45E+01
Kr-85m	1.72E-02	1.72E-02
Kr-85	6.75E-05	6.75E-05
Kr-87	5.74E-02	5.74E-02
Kr-88	5.74E-02	5.74E-02
Xe-133	2.46E-02	2.46E-02
Xe-135	6.75E-02	6.75E-02
Total	8.70E+03	4.39E+02

Table 15.4-19b Doses for ESBWR Main Steam Line Break, Pre-Existing Iodine Spike

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
0–2 hr	2.12E+00	
0–8 hr		1.92E-01
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	2.12E+00	1.92E-01
Limit	25	25

Table 15.4-19c Doses for ESBWR Main Steam Line Break, Equilibrium Iodine Activity

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
0–2 hr	1.06E-01	
0–8 hr		9.64E-03
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	1.06E-01	9.64E-03
Limit	2.5	2.5

Table 15.4-20 Activity Releases for AP1000 Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Kr-85m	6.31E+02	3.14E+03	1.87E+03	1.71E+02	2.43E-03	5.82E+03
Kr-85	3.22E+01	2.64E+02	7.05E+02	3.17E+03	2.70E+04	3.12E+04
Kr-87	6.87E+02	1.26E+03	4.97E+01	8.11E-03	0.00E+00	1.99E+03
Kr-88	1.50E+03	5.76E+03	1.70E+03	3.49E+01	8.16E-07	8.99E+03
Xe-131m	3.20E+01	2.62E+02	6.79E+02	2.74E+03	1.11E+04	1.48E+04
Xe-133m	1.74E+02	1.37E+03	3.15E+03	8.21E+03	5.15E+03	1.80E+04
Xe-133	5.71E+03	4.62E+04	1.16E+05	4.11E+05	8.10E+05	1.39E+06
Xe-135m	3.33E+01	2.62E+00	2.14E-07	0.00E+00	0.00E+00	3.59E+01
Xe-135	1.31E+03	8.33E+03	1.01E+04	4.21E+03	1.73E+01	2.40E+04
Xe-138	1.14E+02	6.83E+00	1.58E-07	0.00E+00	0.00E+00	1.20E+02
I-130	3.22E+01	4.58E+01	2.96E+00	1.11E+00	1.99E-02	8.21E+01
I-131	9.13E+02	1.45E+03	1.56E+02	3.74E+02	1.12E+03	4.01E+03
I-132	8.77E+02	7.93E+02	7.64E+00	2.29E-02	0.00E+00	1.68E+03
I-133	1.81E+03	2.70E+03	2.16E+02	1.63E+02	1.62E+01	4.91E+03
I-134	7.16E+02	3.04E+02	1.26E-01	1.07E-07	0.00E+00	1.02E+03
I-135	1.53E+03	1.97E+03	8.31E+01	9.55E+00	4.95E-03	3.59E+03
Cs-134	1.46E+02	2.16E+02	8.06E+00	1.88E-01	1.59E+00	3.72E+02
Cs-136	4.15E+01	6.13E+01	2.25E+00	4.72E-02	2.03E-01	1.05E+02
Cs-137	8.50E+01	1.26E+02	4.70E+00	1.10E-01	9.39E-01	2.17E+02
Cs-138	2.67E+02	5.25E+01	6.92E-04	0.00E+00	0.00E+00	3.19E+02
Rb-86	1.72E+00	2.54E+00	9.37E-02	2.03E-03	1.05E-02	4.37E+00
Sb-127	1.10E+01	2.01E+01	7.13E-01	1.16E-02	1.60E-02	3.18E+01
Sb-129	2.63E+01	3.65E+01	4.83E-01	1.01E-04	1.00E-09	6.33E+01
Te-127m	1.42E+00	2.64E+00	9.83E-02	2.27E-03	1.77E-02	4.18E+00
Te-127	9.83E+00	1.59E+01	3.65E-01	5.63E-04	2.72E-06	2.61E+01
Te-129m	4.85E+00	9.00E+00	3.33E-01	7.47E-03	4.79E-02	1.42E+01
Te-129	1.35E+01	9.71E+00	8.54E-03	7.27E-10	0.00E+00	2.32E+01
Te-131m	1.46E+01	2.60E+01	8.29E-01	6.86E-03	1.60E-03	4.14E+01

Table 15.4-20 Activity Releases for AP1000 Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Te-132	1.46E+02	2.68E+02	9.42E+00	1.44E-01	1.60E-01	4.24E+02
Sr-89	4.16E+01	7.74E+01	2.87E+00	6.54E-02	4.60E-01	1.22E+02
Sr-90	3.59E+00	6.68E+00	2.48E-01	5.82E-03	4.97E-02	1.06E+01
Sr-91	4.64E+01	7.52E+01	1.74E+00	2.76E-03	1.44E-05	1.23E+02
Sr-92	3.80E+01	4.50E+01	3.26E-01	1.06E-05	0.00E+00	8.33E+01
Ba-139	3.64E+01	2.98E+01	4.73E-02	2.03E-08	0.00E+00	6.63E+01
Ba-140	7.35E+01	1.36E+02	5.00E+00	1.05E-01	4.41E-01	2.15E+02
Mo-99	9.77E+00	1.78E+01	6.19E-01	8.79E-03	7.72E-03	2.82E+01
Tc-99m	7.30E+00	1.10E+01	1.94E-01	1.08E-04	2.73E-08	1.85E+01
Ru-103	7.82E+00	1.45E+01	5.38E-01	1.21E-02	8.11E-02	2.30E+01
Ru-105	4.19E+00	5.87E+00	7.97E-02	1.82E-05	2.40E-10	1.01E+01
Ru-106	2.57E+00	4.79E+00	1.78E-01	4.16E-03	3.46E-02	7.58E+00
Rh-105	4.71E+00	8.45E+00	2.76E-01	2.64E-03	8.48E-04	1.34E+01
Ce-141	1.76E+00	3.26E+00	1.21E-01	2.71E-03	1.72E-02	5.16E+00
Ce-143	1.59E+00	2.84E+00	9.20E-02	8.29E-04	2.34E-04	4.51E+00
Ce-144	1.32E+00	2.47E+00	9.19E-02	2.14E-03	1.77E-02	3.91E+00
Pu-238	4.13E-03	7.70E-03	2.86E-04	6.71E-06	5.73E-05	1.22E-02

Table 15.4-20 Activity Releases for AP1000 Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Pu-239	3.63E-04	6.77E-04	2.52E-05	5.90E-07	5.04E-06	1.07E-03
Pu-240	5.34E-04	9.92E-04	3.69E-05	8.65E-07	7.39E-06	1.57E-03
Pu-241	1.19E-01	2.23E-01	8.30E-03	1.94E-04	1.66E-03	3.52E-01
Np-239	2.04E+01	3.72E+01	1.27E+00	1.67E-02	1.17E-02	5.89E+01
Y-90	3.68E-02	6.70E-02	2.32E-03	3.25E-05	2.75E-05	1.06E-01
Y-91	5.35E-01	9.94E-01	3.69E-02	8.43E-04	6.09E-03	1.57E+00
Y-92	4.18E-01	5.46E-01	5.77E-03	5.86E-07	0.00E+00	9.70E-01
Y-93	5.81E-01	9.48E-01	2.25E-02	4.05E-05	2.91E-07	1.55E+00
Nb-95	7.20E-01	1.34E+00	4.95E-02	1.11E-03	7.23E-03	2.12E+00
Zr-95	7.17E-01	1.33E+00	4.94E-02	1.13E-03	8.29E-03	2.11E+00
Zr-97	6.66E-01	1.15E+00	3.26E-02	1.38E-04	7.58E-06	1.84E+00
La-140	7.66E-01	1.38E+00	4.58E-02	4.84E-04	1.97E-04	2.19E+00
La-141	5.37E-01	7.26E-01	8.69E-03	1.31E-06	0.00E+00	1.27E+00
La-142	3.47E-01	3.06E-01	6.67E-04	6.96E-10	0.00E+00	6.53E-01
Nd-147	2.79E-01	5.16E-01	1.89E-02	3.88E-04	1.49E-03	8.16E-01
Pr-143	6.28E-01	1.16E+00	4.27E-02	9.01E-04	3.95E-03	1.84E+00
Am-241	5.40E-05	1.00E-04	3.74E-06	8.75E-08	7.48E-07	1.59E-04
Cm-242	1.27E-02	2.37E-02	8.81E-04	2.04E-05	1.64E-04	3.75E-02
Cm-244	1.56E-03	2.91E-03	1.08E-04	2.53E-06	2.16E-05	4.61E-03
Total	1.72E+04	7.52E+04	1.35E+05	4.30E+05	8.54E+05	1.51E+06

Table 15.4-21 Doses for AP1000 Loss-of-Coolant Accident

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	**EAB**	**LPZ**	**(Site/AP1000)**	**EAB**	**LPZ**
1–3 hr	2.48E+01		3.77E-01	9.34E+00	
0–8 hr		9.20E+00	1.52E-01		1.40E+00
8–24 hr		3.30E-01	1.36E-01		4.49E-02
24–96 hr		3.10E-01	1.03E-01		3.20E-02
96–720 hr		2.90E-01	7.05E-02		2.04E-02
Total	2.48E+01	1.01E+01		9.34E+00	1.49E+00
Limit				25	25

Note: For the EAB, the period from 1 to 3 hours yields the maximum two-hour dose.

Table 15.4-22 Activity Releases for ABWR Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
I-131	2.84E+02	1.25E+02	1.01E+03	9.52E+03	6.80E+04	7.90E+04
I-132	3.85E+02	3.63E+01	3.55E+01	0.00E+00	0.00E+00	4.57E+02
I-133	5.92E+02	2.21E+02	1.29E+03	3.64E+03	7.39E+02	6.48E+03
I-134	5.62E+02	1.17E+00	0.00E+00	0.00E+00	0.00E+00	5.63E+02
I-135	5.62E+02	1.45E+02	3.63E+02	1.83E+02	0.00E+00	1.25E+03
Kr-83m	3.57E+02	5.09E+02	1.66E+02	0.00E+00	0.00E+00	1.03E+03
Kr-85	4.47E+01	3.38E+02	2.40E+03	2.38E+04	3.13E+05	3.40E+05
Kr-85m	9.24E+02	3.17E+03	4.78E+03	7.69E+02	0.00E+00	9.64E+03
Kr-87	1.31E+03	1.07E+03	1.01E+02	0.00E+00	0.00E+00	2.48E+03
Kr-88	2.32E+03	5.48E+03	3.76E+03	3.25E+02	0.00E+00	1.19E+04
Kr-89	1.98E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.98E+02
Xe-131m	2.33E+01	1.65E+02	1.22E+03	1.04E+04	6.80E+04	7.98E+04
Xe-133	8.35E+03	5.85E+04	4.12E+05	3.04E+06	9.20E+06	1.27E+07
Xe-133m	3.28E+02	2.38E+03	1.51E+04	8.31E+04	7.95E+04	1.80E+05
Xe-135	1.01E+03	5.02E+03	1.66E+04	1.28E+04	0.00E+00	3.55E+04
Xe-135m	5.33E+02	8.87E-02	0.00E+00	0.00E+00	0.00E+00	5.33E+02
Xe-137	5.62E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.62E+02
Xe-138	2.19E+03	1.48E-01	0.00E+00	0.00E+00	0.00E+00	2.19E+03
Total	2.05E+04	7.72E+04	4.59E+05	3.18E+06	9.73E+06	1.35E+07

Table 15.4-23 Doses for ABWR Loss-of-Coolant Accident

	ABWR EAB Dose (S_v)			ABWR LPZ Dose (S_v)			χ/Q Ratio	Site TEDE (Rem)	
Time	W. Body	Thyroid	TEDE	W. Body	Thyroid	TEDE	(Site/ABWR)	EAB	LPZ
0–2 hr	4.10E-02	1.90E+00	9.80E-02				1.65E-01	1.77E+00	
0–8 hr				1.00E-02	3.10E-01	1.93E-02	1.31E-01		2.78E-01
8–24 hr				8.00E-03	2.00E-01	1.40E-02	1.42E-01		2.17E-01
24–96 hr				1.10E-02	7.90E-01	3.47E-02	1.66E-01		6.31E-01
96–720 hr				9.00E-03	1.10E+00	4.20E-02	2.09E-01		9.61E-01
Total	4.10E-02	1.90E+00	9.80E-02	3.80E-02	2.40E+00	1.10E-01		1.77E+00	2.09E+00
Limit								25	25

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. The site doses include a multiplier of 1.10 for power adjustment.

Table 15.4-23a Activity Releases for ESBWR Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Co-58	2.28E-03	2.22E-02	3.89E-02	4.18E-02	2.61E-02	1.31E-01
Co-60	2.19E-03	2.16E-02	3.76E-02	4.10E-02	2.89E-02	1.31E-01
Kr-85	6.59E+00	3.23E+02	2.72E+03	2.08E+04	5.31E+04	7.70E+04
Kr-85m	1.14E+02	3.01E+03	5.21E+03	8.50E+02	0.00E+00	9.19E+03
Kr-87	1.17E+02	8.60E+02	1.08E+02	0.00E+00	0.00E+00	1.09E+03
Kr-88	2.68E+02	5.12E+03	4.30E+03	1.63E+02	0.00E+00	9.85E+03
Rb-86	1.38E-01	1.00E+00	1.72E+00	1.79E+00	8.25E-01	5.48E+00
Sr-89	3.53E+00	3.46E+01	6.01E+01	6.43E+01	3.88E+01	2.01E+02
Sr-90	3.48E-01	3.42E+00	5.98E+00	6.51E+00	4.63E+00	2.09E+01
Sr-91	3.95E+00	3.06E+01	2.63E+01	5.00E+00	0.00E+00	6.58E+01
Sr-92	3.18E+00	1.45E+01	2.88E+00	1.25E-01	0.00E+00	2.06E+01
Y-90	6.34E-03	1.70E-01	9.06E-01	2.51E+00	4.25E+00	7.84E+00
Y-91	4.59E-02	4.70E-01	8.96E-01	1.03E+00	6.38E-01	3.08E+00
Y-92	4.89E-01	1.01E+01	8.31E+00	3.75E-01	0.00E+00	1.93E+01
Y-93	4.94E-02	3.87E-01	3.45E-01	7.25E-02	0.00E+00	8.54E-01
Zr-95	6.39E-02	6.26E-01	1.09E+00	1.18E+00	7.25E-01	3.68E+00
Zr-97	6.16E-02	5.28E-01	6.10E-01	2.25E-01	0.00E+00	1.43E+00
Nb-95	6.43E-02	6.30E-01	1.11E+00	1.20E+00	8.25E-01	3.83E+00
Mo-99	8.30E-01	7.86E+00	1.23E+01	9.88E+00	1.00E+00	3.19E+01
Tc-99m	7.46E-01	7.24E+00	1.19E+01	1.01E+01	8.75E-01	3.09E+01
Ru-103	6.66E-01	6.52E+00	1.13E+01	1.21E+01	6.88E+00	3.75E+01
Ru-105	3.48E-01	2.09E+00	8.88E-01	3.75E-02	0.00E+00	3.36E+00
Ru-106	2.33E-01	2.28E+00	3.99E+00	4.34E+00	3.04E+00	1.39E+01
Rh-105	4.05E-01	3.88E+00	5.85E+00	3.74E+00	1.25E-01	1.40E+01
Sb-127	9.09E-01	8.69E+00	1.40E+01	1.23E+01	1.75E+00	3.76E+01
Sb-129	2.18E+00	1.30E+01	5.25E+00	1.25E-01	0.00E+00	2.05E+01
Te-127	9.29E-01	8.96E+00	1.49E+01	1.39E+01	3.13E+00	4.18E+01
Te-127m	1.22E-01	1.20E+00	2.09E+00	2.29E+00	1.54E+00	7.24E+00

Table 15.4-23a Activity Releases for ESBWR Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Te-129	2.41E+00	1.62E+01	1.15E+01	6.75E+00	3.50E+00	4.04E+01
Te-129m	4.09E-01	4.02E+00	6.98E+00	7.35E+00	4.13E+00	2.29E+01
Te-131m	1.22E+00	1.11E+01	1.53E+01	8.75E+00	2.50E-01	3.66E+01
Te-132	1.24E+01	1.19E+02	1.88E+02	1.59E+02	1.88E+01	4.96E+02
I-131	6.66E+01	5.13E+02	9.33E+02	1.44E+03	7.00E+02	3.65E+03
I-132	7.88E+01	3.44E+02	2.45E+02	1.89E+02	2.25E+01	8.79E+02
I-133	1.31E+02	9.10E+02	1.22E+03	7.63E+02	1.25E+01	3.04E+03
I-134	4.96E+01	5.10E+01	3.75E-01	0.00E+00	0.00E+00	1.01E+02
I-135	1.11E+02	6.07E+02	4.16E+02	5.38E+01	0.00E+00	1.19E+03
Xe-133	1.08E+03	5.19E+04	4.08E+05	2.51E+06	1.20E+06	4.18E+06
Xe-135	3.68E+02	1.40E+04	5.13E+04	3.80E+04	0.00E+00	1.04E+05
Cs-134	1.16E+01	8.50E+01	1.48E+02	1.63E+02	1.14E+02	5.21E+02
Cs-136	4.03E+00	2.92E+01	5.00E+01	5.05E+01	2.00E+01	1.54E+02
Cs-137	7.54E+00	5.52E+01	9.60E+01	1.05E+02	7.50E+01	3.39E+02
Ba-139	2.96E+00	7.50E+00	3.00E-01	0.00E+00	0.00E+00	1.08E+01
Ba-140	6.26E+00	6.10E+01	1.04E+02	1.06E+02	4.00E+01	3.18E+02
La-140	1.40E-01	4.41E+00	2.37E+01	5.83E+01	4.35E+01	1.30E+02
La-141	4.50E-02	2.56E-01	9.13E-02	2.50E-03	0.00E+00	3.95E-01
La-142	2.84E-02	8.09E-02	4.50E-03	0.00E+00	0.00E+00	1.14E-01
Ce-141	1.49E-01	1.46E+00	2.54E+00	2.69E+00	1.46E+00	8.30E+00
Ce-143	1.35E-01	1.23E+00	1.75E+00	1.05E+00	2.50E-02	4.19E+00
Ce-144	1.21E-01	1.19E+00	2.08E+00	2.26E+00	1.55E+00	7.20E+00
Pr-143	5.46E-02	5.40E-01	9.68E-01	1.06E+00	4.63E-01	3.09E+00
Nd-147	2.38E-02	2.31E-01	3.94E-01	3.95E-01	1.39E-01	1.18E+00
Np-239	1.69E+00	1.59E+01	2.44E+01	1.88E+01	1.38E+00	6.21E+01
Pu-238	2.98E-04	2.93E-03	5.11E-03	5.54E-03	4.00E-03	1.79E-02
Pu-239	3.59E-05	3.53E-04	6.19E-04	6.80E-04	4.75E-04	2.16E-03
Pu-240	4.65E-05	4.56E-04	7.98E-04	8.75E-04	6.13E-04	2.79E-03

Table 15.4-23a Activity Releases for ESBWR Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Pu-241	1.35E-02	1.33E-01	2.31E-01	2.53E-01	1.78E-01	8.08E-01
Am-241	6.08E-06	5.97E-05	1.06E-04	1.15E-04	9.25E-05	3.79E-04
Cm-242	1.43E-03	1.40E-02	2.44E-02	2.65E-02	1.76E-02	8.39E-02
Cm-244	6.91E-05	6.77E-04	1.19E-03	1.29E-03	9.13E-04	4.14E-03
Total	2.46E+03	7.82E+04	4.76E+05	2.58E+06	1.25E+06	4.39E+06

Table 15.4-23b Doses for ESBWR Loss-of-Coolant Accident

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
2–4 hr	1.41E+00	
0–8 hr		4.14E-01
8–24 hr		2.66E-01
24–96 hr		2.03E-01
96–720 hr		2.72E-02
Total	1.41E+00	9.10E-01
Limit	25	25

Note: The maximum EAB dose occurs between 2 and 4 hours, and it is calculated based on the χ/Q between 0 and 2 hours.

Table 15.4-24 Activity Releases for AP1000 Fuel Handling Accident

	Activity Release (Ci)
Isotope	**0–2 hr**
Kr-85m	2.68E-03
Kr-85	1.10E+03
Xe-131m	5.36E+02
Xe-133m	1.29E+03
Xe-133	6.94E+04
Xe-135m	4.37E-01
Xe-135	1.32E+02
I-130	3.52E-02
I-131	2.90E+02
I-132	1.54E+02
I-133	1.91E+01
I-135	1.36E-02
Total	7.29E+04

Table 15.4-25 Doses for AP1000 Fuel Handling Accident

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	**EAB**	**LPZ**	**(Site/AP1000)**	**EAB**	**LPZ**
0–2 hr	2.40E+00		3.77E-01	9.04E-01	
0–8 hr		6.00E-01	1.52E-01		9.11E-02
8–24 hr		0.00E+00	1.36E-01		0.00E+00
24–96 hr		0.00E+00	1.03E-01		0.00E+00
96–720 hr		0.00E+00	7.05E-02		0.00E+00
Total	2.40E+00	6.00E-01		9.04E-01	9.11E-02
Limit				6.3	6.3

Table 15.4-26 Activity Releases for ABWR Fuel Handling Accident

	Activity Release (Ci)
Isotope	**0–2 hr**
I-131	1.35E+02
I-132	1.66E+02
I-133	1.39E+02
I-134	6.74E-06
I-135	2.25E+01
Kr-83m	7.04E+00
Kr-85m	9.34E+01
Kr-85	5.23E+02
Kr-87	1.35E-02
Kr-88	2.66E+01
Kr-89	8.90E-11
Xe-131m	9.14E+01
Xe-133m	1.20E+03
Xe-133	3.08E+04
Xe-135m	2.42E+02
Xe-135	6.98E+03
Xe-137	2.27E-10
Xe-138	4.70E-10
Total	4.04E+04

Table 15.4-27 Doses for ABWR Fuel Handling Accident

	ABWR EAB Dose (S_v)			χ/Q Ratio	Site TEDE (Rem)	
Time	W. Body	Thyroid	TEDE	(Site/ABWR)	EAB	LPZ
0–2 hr	1.20E-02	7.50E-01	3.45E-02	1.65E-01	6.23E-01	
0–8 hr	1.20E-02	7.50E-01	3.45E-02	1.50E-02		5.65E-02
8–24 hr						0.00E+00
24–96 hr						0.00E+00
96–720 hr						0.00E+00
Total	1.20E-02	7.50E-01	3.45E-02		6.23E-01	5.65E-02
Limit					6.3	6.3

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. The site LPZ dose is obtained by multiplying ABWR EAB dose by ratio of site LPZ χ/Q to ABWR EAB χ/Q. The site doses include a multiplier of 1.10 for power adjustment.

Table 15.4-28 Activity Releases for ESBWR Fuel Handling Accident

	Activity Release (Ci)
Isotope	0–2 hr
I-131	3.00E+02
I-132	2.43E+02
I-133	1.92E+02
I-134	1.05E-05
I-135	3.17E+01
Kr-85m	2.77E+02
Kr-85	1.01E+03
Kr-87	4.39E-02
Kr-88	8.78E+01
Xe-133	8.10E+04
Xe-135	2.13E+04
Total	1.04E+05

Table 15.4-29 Doses for ESBWR Fuel Handling Accident

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
0–2 hr	1.24E+00	
0–8 hr		1.13E-01
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	1.24E+00	1.13E-01
Limit	6.3	6.3

Table 15.4-30 Activity Releases for ESBWR Cleanup Water Line Break

	Activity Release (Ci)
Isotope	**0–2 hr**
I-131	3.48E+01
I-132	7.05E+01
I-133	9.28E+01
I-134	1.22E+02
I-135	9.59E+01
Total	4.16E+02

Table 15.4-31 Doses for ESBWR Cleanup Water Line Break

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
0–2 hr	1.75E-01	
0–8 hr		1.59E-02
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	1.75E-01	1.59E-02
Limit	2.5	2.5

Chapter 17 Quality Assurance

The Early Site Permit Application Development Quality Assurance Manual establishes the quality assurance plan for the development of the ESP application. The plan has been structured around Virginia Power's operational Quality Assurance Plan for the existing units and uses many of the same procedures and programs.

17.1 ESP Quality Assurance

The Early Site Permit Application Development Quality Assurance Manual is included in Section 17.1.

Dominion	**Quality Assurance Manual**	
Title: Early Site Permit Application Development Quality Assurance Manual		
Process/Program Owner: **Project Manager – Early Site Permit Project**		
	Revision Number **2**	**Effective Date** **August 29, 2003**

Revision Summary

Revision 2:

- Changed title of Senior Vice President and Chief Nuclear Officer to Senior Vice President – nuclear Operations and chief Nuclear Officer to comply with corporate structure.
- Revised Section 3, General Description, Objective to reference the operational Quality Assurance Topical Report for specific guidance on implementation of 10 CRF50 Appendix B.
- Deleted Appendix B Table 2 as it is not needed with the above change to Section 3.

Signatures on File in Records Management

Prepared by: _____/_____
Spencer W. Semmes 8/19/03

Reviewed By:	Reviewed By:	Approved By:
Marvin L. Smith 8/19/03 _____/_____ Project Manager - ESP	Kerry L. Rhoads for R. M. Berryman 08/25/2003 _____/_____ Director Nuclear Oversight	Eugene S. Grecheck 8/25/03 _____/_____ Vice President Nuclear Support Services

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1. Introduction

This manual delineates the Quality Assurance Plan for the development of an Early Site Permit Application for the addition of new nuclear generation. It has been developed with guidance from ASME-NQA-1-2000.

The Quality Assurance Program (QA Program) outlines the organization, programs and procedural requirements that will assure that the application is developed in a quality manner and, where appropriate, in accordance with 10CFR50 Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants."

In order to simplify the QA process for the Early Site Permit Application development, elements of the operating QA program shall be used to assure quality. The operating QA program, VEP-1-5A, Operational Quality Assurance Program Topical Report has detailed implementing procedures in place, but has been developed to specifically exclude construction activities. The Early Site Permit Application Development Quality Assurance Manual provides details for the QA process for the development of an Early Site Permit Application and specifies the use of the processes in place that meet the operating QA program.

Where applicable, items that may or will affect the operating unit or units shall be addressed under the operating QA program, VEP-1-5A, Operational Quality Assurance Program Topical Report. In selected cases as stated in this document, the existing operating QA program. VEP-1-5A will govern compliance with this program. Also, many procedures and instructions that comply with the Operational Quality Assurance Program shall also be used to comply with this program.

Control, revision and approval of this manual will be performed in accordance with Section 20, Issuance and Revision of the Early Site Permit Application Development QA Manual.

2. Organization

General Description - Early Site Permit Development Organization

There are five groups within the Early Site Permit Development Organization which affect the quality of the Early Site Permit Application. These groups are Early Site Permit Project, Nuclear Operations, Nuclear Engineering, Nuclear

Support Services, and Nuclear Oversight. The Nuclear Organization is shown in Appendix A. A more specific description of the responsibilities of each group is listed below.

A. Early Site Permit Project

The Early Site Permit Project is responsible for development of the Early Site Permit Application, coordinating the technical input required, managing subcontractors and assuring that all licensing requirements are met. The Early Site Permit Project is the design authority for development of the Early Site Permit.

B. Nuclear Support Services

Nuclear Support Services is responsible for support of the Early Site Permit Organization by providing licensing and operations support, personnel training, nuclear security and emergency preparedness support. The Early Site Permit Project is part of the Nuclear Support Services organization.

Supply Chain Management (Generation) is responsible for providing material management, procurement, procurement engineering and other supply chain functions. The Supply Chain Management (Generation) Group is matrixed to Nuclear Support Services.

C. Nuclear Operations

Nuclear Operations is responsible for operation and maintenance of the Nuclear Stations and Independent Spent Fuel Storage Installations (ISFSIs). In addition, Nuclear Operations is responsible for quality inspection activities for on site work, including that to support the Early Site Permit application development, as necessary.

D. Nuclear Engineering

Nuclear Engineering is responsible for support of the Early Site Permit Organization by providing engineering services and records management. The engineering departments provide design engineering support.

Information Technology is responsible for providing information technology services to the nuclear organization. The Information Technology Group is matrixed to Nuclear Engineering.

E. Nuclear Oversight

Nuclear Oversight is responsible for independently planning and performing activities to verify the development and effective implementation of nuclear management's quality assurance programs for engineering, procurement, and construction activities associated with the Early Site Permit development.

Nuclear Management

A. Senior Vice President – Nuclear Operations and Chief Nuclear Officer

The Senior Vice President - Nuclear Operations and Chief Nuclear Officer has corporate responsibility for and directs the planning and development of the Early Site Permit Organization staff, and organization resources.

B. Vice President Nuclear Support Services

The Vice President Nuclear Support Services is responsible to the Senior Vice President - Nuclear Operations and Chief Nuclear Officer and has the responsibility for development of the Early Site Permit Application.

The Vice President Nuclear Support Services has overall responsibility for implementing the quality assurance program for the Early Site Permit Organization.

1. Project Manager – Early Site Permit Project

The Project Manager – Early Site Permit Project is responsible to the Vice President Nuclear Support Services for developing the Early Site Permit Application and assuring that the Application meets all of the requirements of the quality assurance program.

The Project Manager – Early Site Permit Project has overall authority for all activities in support of the development of the application. He is responsible for vendor interface for all vendor-related activities, such as collecting and analyzing data and conducting testing for site suitability. He is also responsible for coordinating actions of Dominion personnel and departments.

2. Director Nuclear Licensing & Operations Support

Director Nuclear Licensing & Operations Support is responsible to the Vice President Nuclear Support Services for providing regulatory compliance support, and providing licensing support through NRC communications.

3. Director Nuclear Protection Services & Emergency Preparedness

Director Nuclear Protection Services & Emergency Preparedness is responsible to the Vice President Nuclear Support Services for providing nuclear station security, plant and ISFSI access programs, station safety and loss prevention, and fitness for duty programs. The Director Nuclear Protection Services & Emergency Preparedness is also responsible for the overall management of Nuclear Emergency Preparedness activities and is responsible for development of the emergency planning sections of the Application. Additional responsibilities include controlling site access, implementation of the Fitness for Duty program and ensuring that construction or ESP activities do not breach security measures of the operating plants.

4. Director Nuclear Training

Director Nuclear Training is responsible to the Vice President Nuclear Support Services for the training of personnel who operate or support the Nuclear Stations. Training responsibilities include: determining the need for training based on information provided by the Early Site Permit Organization, developing performance-based training programs, implementing training programs to support employee and organization needs, and evaluating training programs. Additional responsibilities include assuring that personnel are properly trained to respond to potential hazards while on site.

5. Director Supply Chain Management (Generation)

The Director Supply Chain Management (Generation) is responsible to the Vice President Nuclear Support Services for the material management, purchasing, procurement engineering, and vendor surveillance functions. This responsibility is exercised in a matrixed-reporting role.

C. Director Nuclear Oversight

The Director Nuclear Oversight is responsible to the Senior Vice President - Nuclear Operations and Chief Nuclear Officer for assuring the compliance with the Quality Assurance Program for Early Site Permit Application development. The Director Nuclear Oversight may make recommendations to the Early Site Permit Development Organization's management. If the Director of Nuclear Oversight disagrees with any actions taken by the Early Site Permit Development Organization and is unable to obtain resolution, the Director Nuclear Oversight shall bring the matter to the attention of the Senior Vice President - Nuclear Operations and Chief Nuclear Officer who will determine the final disposition.

1. Supervisor Nuclear Quality (Vendor Programs)

The Supervisor Nuclear Quality (Vendor Programs) is responsible to the Director Nuclear Oversight for assuring compliance with the established vendor Quality Assurance Programs and for evaluating the quality programs of vendors and contractors performing ESP activities important to safety. This is accomplished by scheduling and conducting triennial external audits, annual vendor Quality Assurance Program evaluations, reviewing audits conducted by external organizations (e.g., other utilities and NUPIC), and maintenance of the Safety-Related Vendors List and the Commercial Grade Vendors List.

2. Nuclear Specialist (Audit Coordinator)

The Nuclear Specialist (Audit Coordinator) is responsible to the Director Nuclear Oversight for assuring compliance with the Operational Quality Assurance Program, administration of the internal audit program, and interfacing with corporate Nuclear Oversight personnel.

D. Vice President Nuclear Engineering

The Vice President Nuclear Engineering is responsible to the Senior Vice President - Nuclear Operations and Chief Nuclear Officer and has corporate responsibility for supporting development of the Early Site Permit Application through engineering, projects, and nuclear analysis and fuel activities.

1. Director Information Technology Business Account (Generation)

The Director Information Technology Business Account (Generation) is responsible to the Vice President Nuclear Engineering for information technology direction and support of the Nuclear Business Unit. This responsibility is exercised in a matrixed-reporting role. Responsibilities include network infrastructure maintenance and upgrade, network and application security, network operations, automation strategy, application development and support, and automation training. Additional responsibilities include the evaluation of software quality for that software utilized within Dominion.

2. Director Nuclear Engineering

The Director of Nuclear Engineering is responsible to the Vice President Nuclear Engineering for implementing the operational quality assurance program in the following areas:

- Design Engineering
- Configuration Management
- Site Engineering
- Records Management

Responsibilities of these groups include implementing engineering standards for nuclear design control, engineering evaluation of generic industry issues, management of engineering resources for specific tasks, and engineering programs.

a. Manager Design Engineering

The Manager Design Engineering is responsible to the Director Nuclear Engineering for orchestrating the resources of the corporate discipline engineering groups, and Site Design Engineering to support the competing needs of projects, general site support activities and program support. The Manager Design Engineering shall also ensure that appropriate discipline engineering resources are dedicated to the maintenance of the design basis infrastructure and support of assigned programs.

b. Manager Nuclear Site Engineering

The Manager Nuclear Site Engineering is responsible to the Director Nuclear Engineering for managing engineering resources in Systems Engineering, Component Engineering, and Test and Inspection Engineering. The Manager Nuclear Site Engineering also provides a day-to-day interface with Station management.

c. Manager Nuclear Engineering

The Manager Nuclear Engineering is responsible to the Director Nuclear Engineering for managing activities related to the control and availability of design and licensing basis information, configuration management, and the control of nuclear records through effective implementation of the records management program.

E. Senior Vice President Nuclear Operations

The Senior Vice President Nuclear Operations is the corporate individual responsible to the Senior Vice President – Nuclear Operations and Chief Nuclear Officer for the operation of the Nuclear Stations and ISFSIs. The Senior Vice President Nuclear Operations has overall responsibility for implementing the quality assurance program for the operational phase of the Nuclear Stations and ISFSIs.

F. Site Vice President

Responsible to the Senior Vice President Nuclear Operations for the overall safe and efficient operation of the station and ISFSI, and for the implementation of quality assurance requirements in the areas specified by the Operational Quality Assurance Program.

For the purposes of this program, the description of the duties of the Site Vice President and staff will be limited to those that impact the Early Site Permit Application Development. All other topics are addressed in the Operational Quality Assurance Program.

The Site Vice President has supervisory control over all Company personnel within the station organization and administrative control over all other Company and non-Company individuals within the nuclear site's

boundary. The Site Vice President is the local representative of Company management and is empowered to implement all Company policy with regard to operations of the facility, support of Company public relations policy, and employee relations policies. The Site Vice President is also responsible for coordinating station functions with offsite (Company and non-Company) agencies and services, and ensuring station personnel are adequately trained in accordance with the Emergency Plan. The Site Vice President fulfills the position of Plant Manager identified in the ISFSI Technical Specifications.

Director Nuclear Station S&L (Safety and Licensing)

The Director Nuclear Station S&L is responsible to the Site Vice President for directing and coordinating nuclear safety issues at the station and ISFSI. The Director Nuclear Station S&L is independent of cost and scheduling concerns associated with operations, maintenance, construction, and modification activities. The Director Nuclear Station S&L is responsible for being cognizant of licensing and regulatory issues, administering the Commitment Tracking System (CTS), coordinating the station quality inspection program, and coordinating activities related to non-radiological environmental protection.

3. Quality Assurance Program

General Description

Objective

The objective of the Dominion Quality Assurance Program for Early Site Permit Applications is to comply with the criteria as expressed in 10 CFR 50, Appendix B, as amended, and with the quality assurance program requirements for nuclear power plants as described in the Operational Quality Assurance Program Topical Report, VEP-1-5A. This program, its policies and procedures are described herein: the Early Site Permit Quality Assurance Program; the Nuclear Business Unit Standard (NBUS); and the corporate and station procedures. This program applies to those quality-related activities that involve the functions of safety-related structures, systems, and components associated with the construction of nuclear power stations and those non-safety-related components described in the Site Safety Analysis Report. Examples of safety-related

activities for the ESP program include, but are not limited to, site geotechnical investigations, seismic analysis, and meteorological analysis.

Other portions of the Early Site Permit Application shall be developed under a graded approach to quality, with appropriate controls applied to ensure accuracy of information and conformance/compliance with applicable codes, standards, regulatory requirements, and industry practices.

Elements of the Operational Quality Assurance Program, VEP-1-5A, Operational Quality Assurance Program Topical Report, shall be used to assure compliance with this document. The existing programs and procedures to support the Operational Quality Assurance Program shall also be used. These programs include a Design Control process (which also controls engineering vendor and Architect-Engineer interface) and Record Retention processes.

Designated activities may be performed under a contractor's Quality Assurance Program approved by the Dominion Quality Assurance Program. The contractor's Quality Assurance Program when used for activities will comply with the criteria expressed in 10 CFR 50, Appendix B, as amended, and with the Regulatory Guides and ANSI Standards as listed in Table 2. Periodic audits and assessments of those programs are performed to assure compliance with Dominion procedures. In addition, routine interfaces with project personnel assure that quality expectations are met.

The goal of this program is to assure the accurate, efficient and detailed development of an Early Site Permit Application in accordance with sound engineering principles.

Site development in preparation for construction is not within the scope of the Early Site Permit Project

This Quality Assurance Plan applies to those ESP activities that can affect either directly or indirectly the safety-related site characteristics or analysis of those characteristics. In addition, this plan applies to engineering activities that are used to characterize the site or analyze that characterization.

In general, the requirements specified here are detailed in implementing procedures that are either Dominion implementing procedures, or vendor implementing procedures governed by a vendor quality program. Vendor

quality programs shall be verified to be in compliance with this Dominion plan in accordance with administrative procedures.

Process

The program provides written policies, standards, procedures, and instructions covering engineering, design, procurement, periodic surveillance, and supporting tests, for the development of the Application. Nuclear Business Unit (NBU) policies establish commitments to the Quality Assurance Program. Detailed procedures and instructions are issued in accordance with and to meet the requirements of this document. Audit and inspection programs have been implemented to assure that these procedures are being correctly applied.

Nuclear Oversight personnel, both station and corporate, report through a line of management completely separate from operational, Early Site Permit application development, and production management and influences, and fulfill the following three-part role:

1. Audit to ensure that the overall development of the Application is carried out in accordance with applicable codes and standards, NRC guides and regulations, company policies and commitments.
2. Serve as a management tool for station and corporate management personnel, illuminating problem areas, detecting trends, and providing recommendations regarding solution of problem areas when applicable.
3. Provide all levels of management with an independent source of information regarding the quality aspect of Application development and comment resolution.

Issue Resolution

Differences of opinion between Nuclear Oversight personnel and other departments are resolved by the cognizant Manager or Director and the Director Nuclear Oversight or are forwarded through normal administrative chains of both individuals for resolution at the executive level. Final decision-making authority rests with the Senior Vice President and Chief Nuclear Officer.

Audits

Nuclear Oversight conducts audits in accordance with the Quality Assurance Program and performs other duties as directed by the Director Nuclear Oversight. Nuclear Oversight representatives have access to all

areas at any time deemed necessary for audits and activities related to quality. They have access to station and corporate records required for in-depth auditing of Application development, including confidential personnel records (but only to the extent necessary to verify personnel qualifications or other information related to quality).

The station staff, under the guidance of the Director Nuclear Station S&L (Safety and Licensing) conducts inspections of work at the stations.

Other personnel assigned to conduct assessments and inspections in accordance with the Quality Assurance Program have access to all areas of the station necessary to accomplish those activities.

Quality Assurance Program

The Dominion Quality Assurance Program for the Early Site Permit Application Development is displayed in a point-by-point comparison to Appendix B, 10 CFR 50 in Table 1.

Identification of Safety Related Design Basis Activities

Safety Related Design Basis Activities are defined as those activities, including sampling, testing, data collection and supporting engineering calculations and reports that will be used to determine the bounding physical parameters of the site. The development of the Application will involve site testing, data collection and calculations that may create or bound safety related design basis data. Site testing and data collection of information pertaining to the physical characteristics of the site will be considered safety related. In addition, calculations and other engineering data that bounds or characterizes the site will be classified as safety related.

Periodic Review of the Quality Assurance Program

Audits of activities required by the Quality Assurance Program for the Early Site Permit Application development will be conducted at least once per 24 months during the application development and NRC review processes. These audits are performed under the cognizance of the Director of Nuclear Oversight.

Qualification of Nuclear Oversight Personnel

The Director Nuclear Oversight shall have a four-year accredited engineering or science degree or equivalent with a minimum of ten years experience related to electric power generating facilities. At least five years of overall

experience shall have been in a supervisory capacity, two years of which should have involved quality assurance related matters.

The Supervisor Nuclear Quality (Vendor Programs) shall have a four-year accredited engineering or science degree, or equivalent with a minimum of two years overall experience or equivalent training in power plant operations is a prerequisite with at least one year of this experience involved in nuclear power station quality assurance program implementation.

The Nuclear Specialist (Audit Coordinator) shall have a four-year accredited engineering or science degree, or equivalent with a minimum of two years overall experience or equivalent training in power plant operations is a prerequisite with at least one year of this experience involved in nuclear power station quality assurance program implementation.

Personnel in the key positions listed will meet or exceed the above requirements or, as an alternative, the applicable requirements of paragraph 4.4.5 of ANSI/ANS 3.1 (Draft 12/79) as clarified in VEP-1-5A, Operational Quality Assurance Program Topical Report.

Qualification of Other Support Personnel

The Manager Vendor Quality shall have a four-year accredited engineering or science degree, or equivalent with a minimum of two years overall experience or equivalent training in power plant operations. At least one year of this experience shall be involved in nuclear power station quality assurance program implementation.

Replacement personnel in the key positions listed will meet or exceed the applicable requirements of ANSI/ANS 3.1 (Draft 12/79) as clarified in VEP-1-5A, Operational Quality Assurance Program Topical Report.

Certification of Nuclear Oversight Personnel

The certification of Nuclear Oversight personnel is accomplished in accordance with the Quality Assurance Certification Program. This program provides for the certification and recertification of auditors and lead auditors. The program outlines the qualification and certification requirements for personnel and requires the individual to be certified prior to performing specified audit functions. Nuclear Oversight management has the responsibility to certify audit personnel.

Certification of Other Support Personnel

The certification of maintenance and modification inspection personnel [i.e., Quality Maintenance Team (QMT) and station Quality Control inspectors)], Material Verification personnel and Vendor Surveillance personnel is accomplished in accordance with the approved certification programs. These programs outline the qualification and certification requirements of personnel and require the individual to be certified prior to performing specified functions.

Indoctrination and Training

All personnel performing or managing activities affecting quality shall receive indoctrination and training in their job responsibilities and authority, general criteria including applicable codes and standards, regulatory commitments, company procedures and quality assurance program requirements.

A training program shall be established for those individuals responsible for work affecting safety related design basis activities.

Records of required training shall be maintained in accordance with section 18 of this program.

4. Design Control

The Nuclear Design Control Program (NDCP), delineates procedures to assure that design basis, regulatory requirements, codes and standards are correctly translated into specifications, drawings, procedures, or instructions for those items classified as safety related and that design changes, including field changes, are subject to design control measures commensurate with those applied to the original design and the applicable specified design requirements. Nuclear Standards describe the design control program.

The responsibility for the development, identification of requirements, monitoring, and implementation of an effective design control program is delegated to the Vice President Nuclear Engineering with input as appropriate from Vice President Nuclear Support Services. If changes to the operating units are required to support the development of the Early Site Permit Application, those activities shall be governed by VEP-1-5A, Operational Quality Assurance Program Topical Report.

The NDCP provides for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program. When a testing program is solely used to test the adequacy of a design, the test will be conducted under adverse design conditions. The provisions of this section assure that individuals other than those who performed the original design perform the verifying or checking process. These individuals are identified and their authority and responsibility is described. The NDCP also identifies the design documents that are required to be reviewed and the personnel responsible for their review and revisions, to assure that design characteristics can be controlled, inspected and tested, and that inspection and test criteria are identified. Design documents, design change documents and revisions thereto are distributed to responsible supervisors to determine whether revisions to controlled design and operating documents are necessary. Design documents and reviews, records and changes thereto are collected, stored and maintained in a systematic and controlled manner.

The NDCP establishes measures for the selection and review for suitability of application of materials, parts, equipment and processes that are essential to safety-related or safety significant functions. These measures include the use of valid and applicable industry standards and specifications, materials and prototype hardware testing programs, and design reviews. In the event of a design modification to a system which is safety related, engineering studies are initiated to evaluate parts, equipment, processes, and material suitability for repair of such equipment or components; previously approved items are used without further review. Previously approved materials, parts or components used for a different application are reviewed for suitability prior to approval for their new application.

Quality measures are assured through all levels of the design control program by the design control organization, station and corporate support organizations. Any errors or deficiencies noted in the design process are documented on the design change forms and subsequently corrected. Any non-conforming conditions identified are documented and corrected in accordance with the Corrective Action Process (section 17).

Procedures for design controls, analysis, and reviews have as their basis the applicable portions of documents referenced in the Nuclear Design Control Manual, and include ANSI N45.2.11-1974 as modified in Table 17.2.0 of VEP-1-5A, Operational Quality Assurance Program Topical Report.

An Engineering Standard is used to establish the interface between the company and contractors for design activities. The standard requires that the licensee's program requirements be followed in the preparation, review and

approval of design documents such as design changes, specifications and drawings.

Suitable design controls are applied to such disciplines as reactor physics; seismic stress, thermal, hydraulic, radiation and accident analysis, compatibility of materials; and accessibility for inservice inspection, maintenance and repair. Designs are reviewed to assure that (1) design characteristics can be controlled, inspected, and tested, and (2) inspection and test criteria are identified.

Some activities described in this section are included in the operational QA program and may not be needed for ESP application development. Examples of safety-related activities for the ESP program include, but are not limited to, site geotechnical investigations, seismic analysis, and meteorological analysis.

5. Procurement Document Control

Administrative procedures describe the program for completing procurement documents including review, approval, document control, and change control. In addition, references to procedures that govern the actions of Nuclear Oversight and Vendor Surveillance are made which include provisions for access to the suppliers' facilities and records, for source inspection or audit, and qualification of vendors prior to the initiation of quality related actions when the need for such inspection and/or audit has been determined. This program also provides for records to be prepared, maintained, made available for review, or delivered to the Company prior to use or installation of the hardware, such as drawings, specifications, procedures, procurement documents, inspection and test records, personnel and procedure qualifications, material, chemical and physical tests results, and the identification of quality assurance requirements applicable to the items or services purchased, including sub-tier procurement requirements when required.

Administrative procedures are established to ensure that procurement documents reference all actions required by a supplier in accordance with the applicable codes, specifications, and drawings. Any non-conforming conditions identified shall be documented and corrected in accordance with the Corrective Action Process (section 17).

Procurement documents incorporate the design basis technical and quality requirements including the applicable regulatory requirements, component

and material identification requirements, drawings, specifications, codes and industrial standards, test and inspection requirements, and special instructions for special processes such as welding, heat treating, non-destructive testing and cleaning as applicable. Design basis information is developed in accordance with the Design Control process (Section 4).

Procurement documents for spare or replacement parts of safety-related structures, systems and components are subject to technical and quality controls at least equivalent to those used on the original equipment.

Procurement documents are prepared, reviewed, and approved as delineated in administrative controls. Copies of procurement documents, or equivalent documents such as Receiving Reports or Requisitioner's Purchase Orders, are retained and are available for review. The Operational Quality Assurance Program Topical Report, VEP-1-5A, Table 17.2-0 contains the standards, requirements or guides from which the procedures implementing this section are based.

Some activities described in this section are included in the operational QA program and may not be needed for ESP application development. For development of the ESP Application, activities subject to this criterion are limited to the procurement of vendor services.

6. Instructions, Procedures and Drawings

Detailed written procedures are established, approved, implemented, and maintained to control development of the Application.

Other activities affecting quality of safety related items within the scope of 10 CFR 50, Appendix B are prescribed by documented instructions, procedures, or drawings of a type appropriate to the circumstances. These activities are accomplished in accordance with these instructions, procedures, or drawings. Applicable instructions, procedures, or drawings include for reference appropriate qualitative and/or quantitative acceptance criteria for determining that important activities have been satisfactorily accomplished.

Administrative procedures describe the requirements for developing, reviewing, approving, and controlling procedures, instructions and drawings used for testing as well as design development, administrative, and other activities performed in support of development of the Application. These requirements include references, prerequisites, precautions, limitations, manufacturer's specifications, check-off lists, and acceptance criteria (as

appropriate). When applicable the acceptance limits and requirements contained in the design and procurement documents constitute a portion of the acceptance criteria referenced and contained in written testing procedures.

Changes to procedures or instructions require the procedure or instruction to be revised before a change can be implemented. The revision process will have the same level of review as the original procedure or instruction. Drawing changes are controlled under the Design Control process (Section 4).

New procedures and instructions and procedure or instruction revisions are also reviewed using an Activity Screening to determine if any impact exists on the operating unit and if so, whether a safety evaluation is required. If the procedure, instruction or drawing has an impact on the operating unit, review and approval of the procedure, instruction or drawing shall be accomplished in accordance with VEP-1-5A, Operational Quality Assurance Program Topical Report. Revisions that do not require a safety evaluation and have no impact on the operating unit are reviewed by cognizant management prior to implementation. The Operational Quality Assurance Program Topical Report, VEP-1-5A, Table 17.2-0 contains the standards, requirements or guides from which the procedures, drawings and instructions implementing this section are based.

7. Document Control

Measures are established and documented describing the control of documents, such as procedures, instructions, and drawings, to provide for their review, approval, and issue, and changes thereto, prior to release and to assure they are adequate and the quality requirements are stated. Normally changes to documents are reviewed and approved by the same organizations that performed the original review and approval; however, this responsibility may be delegated to other qualified responsible organizations. Approved changes are incorporated into procedures and drawings and other appropriate documents associated with the change. Procedures, drawings and instructions and changes thereto are processed, distributed and controlled and obsolete copies are disposed of. The company maintains a record of all holders of procedures and drawings and an index of all procedures and drawings, listing the current revision date. Instructions require that a copy of the appropriate procedure be available at the activity location prior to the commencement of that activity. These measures are addressed in the Administrative Procedures for each station.

Administrative procedures list certain documents that require strict administrative control for distribution, revision, and routing. These documents are categorized as “Controlled Documents.” Examples of controlled documents are Station Procedures, and Station Drawings. Also set forth are the distribution and controlling procedures for design and procurement documents. The Operational Quality Assurance Program Topical Report, VEP-1-5A, Table 17.2-0 contains the standards, requirements or guides from which the procedures implementing this section are based. Record Retention will be in accordance with Table 17.2-2 of VEP-1-5A.

8. Control of Purchased Material, Equipment and Services

An evaluation of suppliers is performed prior to contract award, except in emergency situations where an item or service is needed to preclude development or deterioration of an unsafe condition at the plant, by one or more of the following: (1) A review of the supplier’s capability to comply with the elements of 10 CFR 50, Appendix B that are applicable to the type of material, equipment, or service being procured, (2) A review of previous records and performances of suppliers who have provided similar articles of the type being procured, (3) A survey of the supplier’s facilities and quality assurance program to determine his capability to supply a product or service which meets the design, manufacturing, and quality requirements, or (4) A review of qualification information supplied by another utility or outside organization.

Surveillance of suppliers during fabrication, inspection, testing, and shipment of materials, equipment, and components is planned and performed in accordance with written procedures to assure conformance to the purchase order requirements as applicable. These procedures provide for:

a. Instructions that specify the characteristics or processes to be witnessed, inspected or verified, and accepted; the method of surveillance and the extent of documentation required; and those responsible for implementing these instructions. Surveillance shall be performed on those items where verification of procurement requirements cannot be determined on receipt.

b. Audits and/or inspections which assure that the supplier complies with all quality requirements.

Administrative procedures describe the requirements for controlling purchased material, equipment, and services including commercial grade

items for use on safety-related applications. The requirements applied to spare and replacement parts are at least equivalent to those applied to the original parts.

Inspections and surveillance of suppliers of nuclear safety-related items is performed under the direction of the Vice President Nuclear Engineering and the Vice President Nuclear Support Services. The results of these actions are documented and filed. The periodic inspections assure that applicable material and equipment received at the station meet the requirements of the specifications, purchase orders, code, drawings, or other purchasing documents. This assurance includes the review of documentation received, physical inspection, cleanliness, packaging, marking or functional testing, as required.

Purchased items are normally under the control of the Supply Chain Management (Generation) organization. This organization is authorized to contact system organizations and NSSS, A/E contractors and subcontractors through the auspices of system representatives for assistance as required. Verification of these activities is accomplished under the direction of the Director Nuclear Oversight.

Any non-conforming conditions identified are documented and corrected in accordance with the Corrective Action Process (section 17).

Periodic evaluations of procurement history of the suppliers are performed by Nuclear Oversight to verify continued supplier capability.

Documentation concerning the quality of material, components, and equipment received is reviewed by a representative of the Vice President Nuclear Engineering or the Vice President Nuclear Support Services for conformance with the Purchase Requisition and Purchase Order. The Operational Quality Assurance Program Topical Report, VEP-1-5A, Table 17.2-0 contains the standards, requirements or guides from which the procedures implementing this section are based.

9. Identification and Control of Materials, Parts and Components

During the development of an Early Site Permit Application, no safety-related materials, parts or components will be procured or used. For this reason, this criterion is not applicable to the development of an Early Site Permit Application.

10. Control of Special Processes

The safety-related scope of the development of the ESP application will not involve the use of special processes. For this reason, this criterion is not applicable to the development of an Early Site Permit Application.

11. Inspection

Inspection procedures for those activities affecting quality will be established as appropriate, prior to work being performed. Written procedures will be developed as needed to include inspection hold points.

Examinations, measurements, or tests of materials or components associated with safety-related equipment and systems are performed for each work operation, where necessary, to assure quality. If inspection is impossible or inappropriate, indirect control by monitoring methods, equipment, and personnel is provided. Both methods are provided when control is inadequate without both.

Examinations, measurements, or tests that require witnessing are identified as “inspection hold” points in procedures. The inspection performed at a hold point is specific in nature; quality characteristics and acceptance/rejection criteria are included or qualitative criteria such as operability checks, compliance with procedural steps, or cleanliness instructions are specified. The inspection is documented by signature or initials on the written procedure form.

The inspection program requires that inspectors be assigned as appropriate for the activity being inspected. An inspector may be a member of the organization performing the activity. However, they must be qualified and shall not be the person performing the activity or the supervisor directly responsible for the activity. Maintenance and modification inspection personnel are under the administrative direction of the Quality Inspection Coordinator when performing Quality Control inspections. Personnel so assigned shall become familiar with the procedure being used and other pertinent documents such as technical manuals and drawings prior to performing the inspection.

Maintenance and modification inspection personnel, Material Verification personnel and Vendor Surveillance personnel meet the qualification requirements of ANSI N45.2.6-1978, under NRC Regulatory Guide 1.58 as clarified in VEP-1-5A, Operational Quality Assurance Program Topical Report

Table 17.2-0. The inspectors' qualifications are periodically reviewed for recertification.

Generally, all physical inspections are under the control of the on-site organization. However, the Site Vice President is authorized to request assistance as required from corporate support organizations.

Additionally, inspection activities pertaining to Design Control (Section 4); Procurement Document Control (Section 5); and Corrective Action (Section 17) shall be controlled in accordance with provisions established for this function in the referenced sections contained herein. The Operational Quality Assurance Program Topical Report, VEP-1-5A, Table 17.2-0 contains the standards, requirements or guides from which the procedures implementing this section are based.

Some activities described in this section are included in the operational QA program and may not be needed for ESP application development. The performance of site geotechnical investigations is an example of a safety-related activity for the ESP program that may involve inspections to assure compliance with procedures.

12. Test Control

Testing done in support of the Early Site Permit application development will be controlled by written test procedures. These test procedures will include or reference:

1. The requirements and acceptance limits contained in applicable design and procurement documents.

2. Test prerequisites such as the availability of adequate and appropriate equipment and calibrated instrumentation; trained, qualified, and licensed or certified personnel; the completeness of the item to be tested; suitable and controlled environmental conditions; provisions for data collection and storage.

3. Instructions for performing the test.

4. Inspection points as appropriate.

5. Acceptance and rejection criteria.

6. Methods of documenting or recording test data and results.

Any instrumentation used shall be in a calibration program. This program provides, by the use of equipment history data, status, records, and performance schedules, for the date that calibration is due and indicates the status of calibration. The identity of person(s) performing calibration is provided on the calibration documents. The Operational Quality Assurance Program Topical Report, VEP-1-5A, Table 17.2-0 contains the standards, requirements or guides from which the procedures implementing this section are based.

13. Control of Measuring and Test Equipment

A program has been established and documented in administrative procedures that describes the calibration technique and frequency, maintenance, and control of all “Measuring and Test Equipment” (portable instruments, tools, gauges, fixtures, reference and transfer standards, and non-destructive test equipment) which are used in the measurement, inspection, maintenance, and monitoring of safety-related components, systems, and structures. Measuring and test equipment does not include: measuring equipment used for preliminary checks or utility troubleshooting where accuracy is not required. There is also no intention to imply a need for special calibration and control measures of rulers, tape measures, levels, and other basic tools if normal commercial practices provide adequate accuracy. Controls for measuring and test equipment include the transportation, storage, and protection of the equipment; the handling of associated documents giving the status of all items under the calibration system such as maintenance history, calibration test data, and individual log sheets assigned to each device; and the permanent marking of each device by a unique number.

The maintenance, calibration technique, and frequency of calibration of measuring and test equipment utilized in activities affecting quality are normally performed as specified in the manufacturer’s instruction manual or in approved written procedures. In some cases the calibration interval may be assigned or changed based on accumulated experience by trained technicians. The recall system may include provisions for the temporary extension of the calibration due date under certain conditions specified in approved procedures.

If standards are not available or there is some special reason that procedures cannot be followed, the modified procedures and/or interval are documented, including justification. In other cases, rather than require calibration at

specified intervals, procedures may specify the device be calibrated prior to use, as in the case of torque wrenches or micrometers. Where permitted by commercially available state of the art equipment, reference standards are no more than 1/4 the error allowed in the measuring and test equipment calibrated by that standard.

Measuring and test equipment used on safety-related systems or equipment are calibrated utilizing reference standards whose calibration has a known valid relationship to nationally recognized standards, such as the National Institute of Standards and Technology (NIST), or accepted values of natural physical constants. If no national standard exists, the basis for calibration is documented. Whether the device is calibrated at the power station or at an NIST traceable outside laboratory, one or more stickers are affixed on a conspicuous surface identifying, but not limited to, date of calibration and next calibration due date.

When measuring and test equipment utilized in activities affecting quality are found to be out of calibration an evaluation will be performed and documented concerning the validity of previous tests and the acceptability of devices previously tested. All previous tests and measurements performed during the current or proceeding calibration cycle shall be redone if the evaluation so indicates.

Implementation of the measuring and test equipment programs is assured through Nuclear Oversight audits and through inspections by the appropriate line organizations during performance of work. The Operational Quality Assurance Program Topical Report, VEP-1-5A, Table 17.2-0 contains the standards, requirements or guides from which the procedures implementing this section are based.

14. Handling, Storage and Shipping

Measures have been established in administrative procedures to provide adequate methods by qualified personnel for the classification, packaging, cleaning, preservation, shipping, storage, and handling of material and equipment received at the station.

These measures, prepared in accordance with design and specification requirements, define responsibility, levels of cleanliness, tagging, and storage levels for categorized items.

The procedures also control cleaning, handling, storage, packaging, shipping, and preservation of materials, components, and systems to preclude damage, loss, or deterioration by environmental conditions such as temperature or humidity. Implementation of these measures is verified through inspections by Materials Verification and Vendor Surveillance inspectors.

The Operational Quality Assurance Program Topical Report, VEP-1-5A, Table 17.2-0 contains the standards, requirements or guides from which the procedures implementing this section are based.

Some activities described in this section are included in the operational QA program and may not be needed for ESP application development. The handling, storage, and potential shipping of soil samples taken during site geotechnical investigations is an example of a safety-related activity for the ESP program that is subject to this criterion

15. Inspection, Test and Operating Status

Measures for the identification and documentation of the inspection and test status for items to prevent inadvertent bypassing of specified inspections and tests are established in administrative procedures and in station operating procedures. These measures define the three general categories of inspection and test status for items: Accept, Reject, or Hold. They provide for status identification through the use of stickers, tags, record cards, test records, check-off lists, or logs.

The operating status of items and/or equipment is identified through records, checklists, or operational tagging systems that are maintained to indicate the status and authority to operate the item and/or equipment and is not generally applicable to the ESP application development.

Testing to support the ESP project is controlled by specific test procedures that assure that all evolutions are controlled.

The application and removal of the various status tags, stickers, and other indicators is controlled by Station Procedures.

16. Nonconforming Materials, Parts, or Components

A documented system for controlling non-conformances observed during receipt inspection, storage, fabrication and erection, installation, initial and/or

acceptance testing, or initial operation is established and provides for the preparation, issuing, and distribution of Deviation Reports and Discrepant Shipment Reports in accordance with prescribed procedures.

Due to the scope of the ESP application development project, no parts or materials are expected to be received from offsite sources. This section governs soil and site characterization samples and their storage and shipment (if necessary).

Specifically, instructions require that the individual discovering a non-conformance identifies, describes, and documents the non-conformance on a Deviation Report or a Discrepant Shipment Report in accordance with administrative procedures.

When a non-conforming item is identified, it is placed in the hold area established in the storeroom or other segregated location, if practical, and identified with a hold tag to prevent its inadvertent use. If material is dispositioned as “reject” the hold tag shall remain attached to the material/component until loaded for departure from site and shall only be removed in accordance with approved procedures by authorized personnel at that time.

Hold items may be released on a risk basis following the documented approval of such risk release by the Site Vice President on a Release on a Risk Basis Form. Each risk release is handled on a case basis and depends on the nature of the hold status. The basis and conditions of the release are described on the form, including the criteria for clearing the original hold status.

Rejected material is not risk released.

A Deviation Report or a Discrepant Shipment Report for a non-conforming material, part, or component dispositioned “accept as is” requires an engineering analysis and approval. The results of this review and approval are documented and become a part of station records.

Should the disposition of a non-conformance require the rework or repair of materials, parts, components, systems, or structures, such rework or repair is reinspected or retested by a method which is at least equal to the original inspection or test method. The inspection requirements and the inspection, rework, or repair procedures are documented and become a part of station records.

The disposition and approval of non-conformances are the responsibility of the on-site organization. However, the Site Vice President has the authority to request assistance as appropriate from Corporate support organizations or from Nuclear Oversight.

The Station Deviation Reports trends are periodically reviewed for conditions adverse to quality by station management.

Implementation and verification of the procedures for the control of non-conformances are assured through audits and inspections.

Non-conformances found at a vendor's facility during surveillances are controlled by procedures administered by Nuclear Engineering.

17. Corrective Action

Corrective action measures are established as an integral part of the processing and resolving of non-conformances and failures in service. Through these measures, assurance is confirmed that significant adverse quality conditions are identified, documented, their cause determined, and the corrective actions have been taken that preclude repetition of the adverse quality conditions. Verification of the proper implementation of corrective action measures and close-out of corrective action documentation is assured through the monitoring effort of the staff and the audits conducted by Nuclear Oversight. Adverse conditions significant to quality, the cause of the conditions, and the initiation of corrective action are reported to appropriate levels of both offsite and onsite management by use of Deviation Reports and audit findings. If further corrective action is required the appropriate management program for performing, tracking and closing the issue will be used.

Nuclear Engineering maintains a program to evaluate complex design concerns that may lead to adverse quality conditions at the nuclear stations. The Potential Problem Reporting (PPR) system allows for detailed, multidiscipline reviews of complex design concerns that may yield station deviation reports. Many design concerns cannot be determined to be adverse to quality until a detailed design review is performed. The PPR process controls this activity as part of the Nuclear Design Control Program.

The procedures for processing a Deviation Report require that each adverse condition significant to quality be categorized as either requiring a Licensee Event Report, Special Report or NRC Notification or as a non-reportable

deviation. Non-reportable deviation refers to deviations not reportable to the Nuclear Regulatory Commission. The reporting requirements differ for each of the categories of deviation but require the appropriate levels of management be notified in each case.

The corrective action program is controlled in accordance with VEP-1-5A, Operational Quality Assurance Program Topical Report. This program will be used to resolve all corrective action items.

Authority to Stop Work

Nuclear Oversight and inspection personnel have the authority, and the responsibility, to stop work in progress which is not being done in accordance with approved procedures or where safety or equipment integrity may be jeopardized. This extends to off-site work performed by vendors furnishing safety-related materials and services to the Company.

Imposition of "Stop Work"

A. **Nuclear Oversight -** The Nuclear Oversight or inspection representative advises the cognizant supervisor or supervisory personnel to stop work in progress whenever they determine that it is not being conducted in accordance with applicable procedures, instructions, guides, or standards or may jeopardize the safe operation of the station. Nuclear Oversight representatives inform the Director Nuclear Oversight of the stop work order. Inspection personnel inform the Director Nuclear Station S&L of the stop work order. The Director Nuclear Oversight or the Director Nuclear Station S&L then notifies the Vice President Nuclear Support Services of the decision to stop work because of adverse quality conditions.

B. **Vice President Nuclear Support Services -** The Vice President Nuclear Support Services evaluates the determination to stop work.

1. If the Vice President Nuclear Support Services concurs with the decision to stop work, the necessary corrective action is initiated. Only after the discrepancy has been corrected and the corrective action approved by the initiating organization does work resume.

2. In the event the Vice President Nuclear Support Services does not concur with the decision to stop work, direction may be given to resume work by notifying the Director Nuclear Oversight and the appropriate supervisory personnel in the organization of the decision. The issue shall also be referred to the Senior Vice

President - Nuclear Operations and Chief Nuclear Officer for review and approval.

C. **Senior Vice President - Nuclear Operations and Chief Nuclear Officer -** The Senior Vice President - Nuclear Operations and Chief Nuclear Officer is responsible for approving or disapproving the Vice President Nuclear Support Services' decision in those cases where the Senior Vice President - Nuclear Operations and Chief Nuclear Officer does not concur with the decision to resume work following a stop work order.

D. **Director Nuclear Oversight -** The Director Nuclear Oversight may refer any issues concerning the handling of "stop work" to the Senior Vice President and Chief Nuclear Officer. The Director Nuclear Oversight may direct imposition of "stop work" whenever such action is deemed to be appropriate. Imposition of offsite "stop work" performed by vendors shall be controlled by appropriate administrative procedures.

18. Quality Assurance Records

The requirements and responsibilities for quality assurance records transmittal, retention, and maintenance subsequent to completion of work at the power station have been established and are documented in administrative procedures.

VEP-1-5A, Operational Quality Assurance Program Topical Report will govern the requirements and commitments for the retention and storage of Quality Assurance Records.

19. Audits

Internal audits of selected aspects of construction phase activities are performed with a frequency commensurate with safety significance and in a manner which assures that biennial (2 years) audits of safety-related activities are completed. In addition, due to the relatively short nature of the application development process, an audit will be scheduled of the project prior to application submittal. The audits are scheduled on a formal preplanned audit schedule. The audit system is reviewed periodically and revised as necessary to assure coverage commensurate with current and planned activities. Additional audits may be performed as deemed necessary by management. The scope of the audit is determined by the quality status and safety importance of the activities being performed. These audits are conducted by

trained personnel not having direct responsibilities in the area being audited and in accordance with preplanned and approved audit plans or checklists.

Nuclear Oversight is delegated the responsibility for conducting periodic internal and external audits. Internal audits are conducted to determine the adequacy of programs and procedures, that they are meaningful, and comply with the overall Quality Assurance Program. External audits determine the adequacy of vendor and contractor 10 CFR 50, Appendix B QA Programs. An audit includes an objective evaluation of quality-related practices, procedures, and instructions; the effectiveness of implementation; and the conformance with policy and directives. An audit also includes the evaluation of work area, activities, processes, and items and the review of documents and records. Provisions are established requiring that audits be performed in those areas where the requirements of Appendix B to 10 CFR 50 are being implemented. These areas include as a minimum, but are not limited to, those activities associated with the preparation, review, approval, and control of design and design changes, procurement documents, instructions, procedures, and drawings; receiving and plant inspections; indoctrination and training programs; and the remaining criteria in Appendix B to 10 CFR 50.

The results of each audit are reported in writing to the Project Manager, the Vice President Nuclear Support Services and the Senior Vice President – Nuclear Operations and Chief Nuclear Officer. Additional internal distribution is made to other concerned management levels in accordance with approved procedures.

Management responds to all audits and initiates corrective action where indicated. Where corrective action measures are indicated, documented follow-up of applicable areas through inspections, review, re-audits, or other appropriate means is conducted to verify implementation of assigned corrective action.

If the Director Nuclear Oversight determines the response to an internal audit finding is unacceptable or if a finding response is not received in the time allotted or if corrective action for a finding is not accomplished as indicated on the response, the matter is brought to the attention of the Vice President Nuclear Support Services or appropriate Corporate Director for resolution. If the Director Nuclear Oversight does not agree with the resolution proposed, the Director of Nuclear Oversight notifies appropriate levels of management in accordance with established escalation procedures. The escalation of external audit issues identified by Nuclear Oversight is controlled by administrative procedures. The responsibility for analyzing audit reports for trends and effectiveness lies with the Director Nuclear Oversight. As trends are discovered or if the effectiveness of the program is in question, the

analysis of the Director Nuclear Oversight is forwarded to the management level consistent with the seriousness of the problem.

The Operational Quality Assurance Program Topical Report, VEP-1-5A, Table 17.2-0 contains the standards, requirements or guides from which the procedures implementing this section are based.

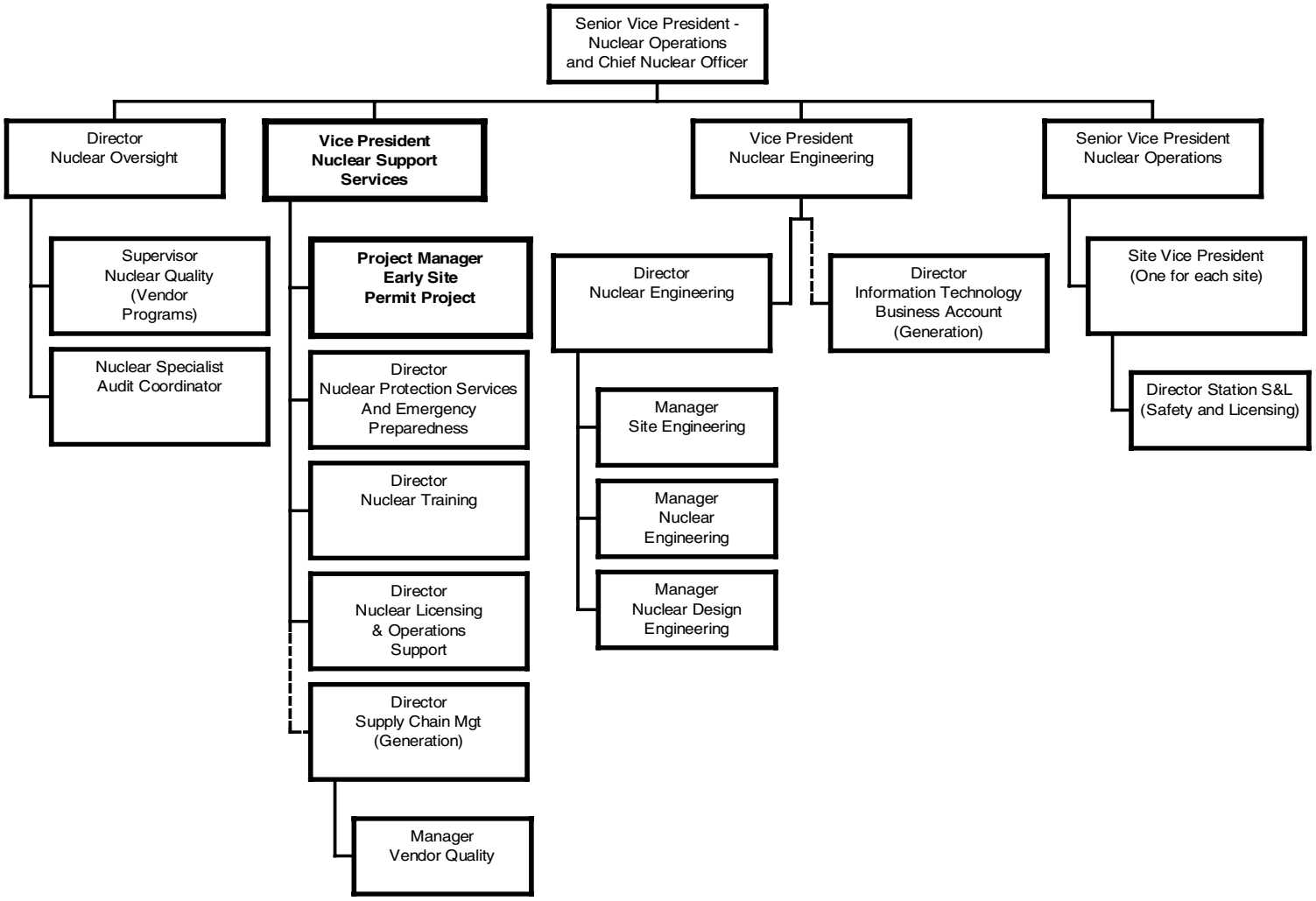
20. Issuance and Revision of the Early Site Permit Application Development QA Manual

Until the submittal of the Early Site Permit Application, the administrative control of this manual will be the responsibility of the Project Manager – Early Site Permit Project. This manual shall be revised as appropriate to incorporate additional commitments as they are established during the application development process. New revisions to the manual will be reviewed, at a minimum, by the Project Manager - Early Site Permit Project, and the Director of Nuclear Oversight and approved by the Vice President, Nuclear Support Services.

Distribution of this manual will be controlled in accordance with Section 7.

Appendix A
FIGURES

Figure 1
NUCLEAR ORGANIZATION



Appendix B
TABLES

Table 1
Relationship of the Early Site Permit Application Development QA Manual to Appendix B, 10 CFR 50

Appendix B 10 CFR 50 Criterion	QA Manual Section	Title	Abstract
I	2	Organization	Defines the relationship of departments to the quality assurance effort associated with the development of an ESP
II	3	Quality Assurance Program	Defines the Construction Quality Assurance program, its overall responsibility and provisions.
III	4	Design Control	Defines the policy, responsibility and procedures for exercising design control
IV	5	Procurement Document Control	Establishes the policy for procurement control
V	6	Instructions, Procedures and Drawings	Establishes guidelines for preparing instructions, procedures and drawings
VI	7	Document Control	Establishes policy for control of procedures, documents and instructions
VII	8	Control of Purchased Material, Equipment and Services	Establishes methods for assuring that purchased items conform to the specified quality requirements
VIII	9	Identification and Control of Material, Parts and Components	Not applicable to ESP Development
IX	10	Control of Special Processes	Not applicable to ESP Development
X	11	Inspection	Establishes a program for inspection activities affecting quality

Table 1 (continued)

Relationship of the Early Site Permit Application Development QA Manual to Appendix B, 10 CFR 50

Appendix B 10 CFR 50 Criterion	QA Manual Section	Title	Abstract
XI	12	Test Control	Establishes a program to control testing through written test procedures
XII	13	Control of Measuring and Test Equipment	Establishes a policy for control and calibration of test and measuring equipment
XIII	14	Handling, Storage and Shipment	Establishes policy for this function as related to material and equipment.
XIV	15	Inspection, Test, and Operating Status	Makes reference to appropriate administrative procedures which govern this function.
XV	16	Non-Conforming Material, Parts and Services	Establishes policy for reporting and controlling non-conforming materials, parts, or components.
XVI	17	Corrective Action	Establishes the policy for identifying, documenting, notifying, determining causes and preventing defects from occurring
XVII	18	Quality Assurance Records	Assures maintenance, identification, and retrieveability of records
XVIII	19	Audits	Defines policy and procedures for audit programs

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PART 3: ENVIRONMENTAL REPORT

Chapter 1 Introduction

This Environmental Report (ER) is submitted pursuant to 10 CFR 52.17(a)(2) and 10 CFR Part 51 to support the application of Dominion Nuclear North Anna LLC (Dominion) for an early site permit (ESP). The report provides information to the Nuclear Regulatory Commission (NRC) sufficient to facilitate the preparation of an environmental impact statement in accordance with the National Environmental Policy Act (NEPA). In preparing this ER, Dominion has relied on the NRC's guidance contained in NUREG-1555, Regulatory Guide (RG) 4.2, and reference material contained in NUREG-1437 and NUREG-1437, Supplement 7.

1.1 The Proposed Action

This section provides a description of the proposed action, the applicant, site location, the plant facilities assumed for environmental analysis, and the applicant's pre-application public involvement.

The proposed action is the issuance of an ESP approving a site (the ESP site) within the existing North Anna Power Station (NAPS) site as suitable for the construction, operation, and decommissioning of new nuclear power generation facilities (new units). The proposed action does not include any decision or approval to build the new units, which are matters that would be considered only upon the filing of an application for a combined license (COL).

The purpose and need for the proposed action is to allow the applicant, Dominion Nuclear North Anna, LLC (Dominion), to determine whether the ESP site is suitable for new units before incurring the substantial additional time and expense of designing and seeking approval to construct such facilities at the ESP site. This process allows early resolution of those safety and environmental issues relating to the ESP site, and facilitates subsequent utility decision making and NRC licensing.

While the actual construction and operation of new units is not currently proposed, this environmental report does analyze the environmental impacts that would result from the construction, operation, and decommissioning of new units at the ESP site. These impacts are analyzed in order to determine whether the ESP site is suitable for new units, and to resolve as many of those issues as is practicable.

Dominion has included a site redress plan as part of its application for an ESP. If an ESP application contains a site redress plan, the permit holder may perform certain activities described in 10 CFR 50.10(e)(1) without further authorization, provided that the environmental impact statement prepared by the NRC for the permit has concluded that the activities would not result in any significant environmental impact which cannot be redressed. The impacts of the activities described in 10 CFR 50.10(e) are addressed in this environmental report.

1.1.1 The Applicant and Owner

Dominion is the applicant for the ESP addressed in this environmental report. Dominion is an indirect, wholly-owned subsidiary of Dominion Resources, Inc. (DRI).

The NAPS site, which encompasses the ESP site for which an ESP is sought, is owned by Virginia Electric & Power Company (Virginia Power) and Old Dominion Electric Cooperative (ODEC) as tenants in common. These companies also own all land outside the NAPS site boundary that forms Lake Anna, up to the expected high-water marks. Virginia Power is the licensed operator of the existing units, with control of the existing facilities and the authority to act as ODEC's agent. Virginia Power is also a wholly-owned subsidiary of DRI, and supports this application.

If Dominion decides to proceed with the development of new units at the ESP site, it would first enter into and obtain the appropriate regulatory approvals of an agreement to purchase or lease the ESP site.

1.1.2 Site Location

The ESP site is wholly within the confines of the NAPS site, which is located on a peninsula on the southern shore of Lake Anna, approximately 5 miles upstream of the North Anna Dam. Lake Anna, developed to supply cooling water for the power station, is approximately 17 miles long, with 272 miles of shoreline. The ESP site is located in Louisa County, Virginia, near the town of Mineral.

The NAPS site was originally intended for the construction of four nuclear units. The original Units 3 and 4 were abandoned after initial construction activities were terminated. These units were to be constructed adjacent to and west of the existing Units 1 and 2. The ESP site is in the same general location as the abandoned Units 3 and 4. The NAPS site is zoned as industrial.

Geographically, the ESP site is approximately 40 miles north-northwest of Richmond, Virginia; 36 miles east of Charlottesville, Virginia; and 22 miles southwest of Fredericksburg, Virginia. Interstates 95 and 64 pass 16 miles to the east and 18 miles to the southwest of the ESP site, respectively. The portion of the NAPS site for which an ESP is sought is shown on Figure 1.1-1.

1.1.3 Reactor Information

This ESP application is intended to demonstrate the suitability of the ESP site for construction and operation of up to two new units.

No specific plant design has been chosen for the ESP site. Instead, a set of bounding plant parameters has been developed to envelop future site development. This plant parameters envelope (PPE) is based on the addition of power generation from two distinct units, to be designated as North Anna Units 3 and 4. Each unit represents a portion of the total generation capacity to be added and would consist of one or more reactors or reactor modules. These multiple reactors or modules (the number of which may vary depending on the reactor type selected) would be grouped into distinct operating units. The total nuclear generating capacity to be added would

not exceed 4500 MWt per unit. Additional information regarding reactors addressed in the PPE is provided in Chapter 3.

1.1.4 Cooling System Information

For normal plant cooling, a closed-cycle, dry and wet cooling tower system, with make-up water supply from Lake Anna, would be used for the new Unit 3, whereas closed-cycle cooling, using dry towers, would be used for Unit 4.

Lake Anna is divided into two parts separated by earthen dikes. The North Anna Reservoir is the source of water for the existing units. The Waste Heat Treatment Facility (WHTF) receives cooling water discharges from the existing units.

Make-up water for the Unit 3 closed-cycle, dry and wet tower system would be withdrawn from the North Anna Reservoir through a new intake structure located on a cove on the south shore of the lake, which was originally planned for the intake of the abandoned Units 3 and 4. This new structure would be adjacent to the existing units' intake structure. All cooling system discharges for both the existing units and the Unit 3 wet cooling tower blowdown would be sent to the WHTF via the existing discharge canal.

The new dry tower system of Unit 4 would introduce either no, or negligible, evaporative losses, and no additional heat load to Lake Anna.

Additional information on the cooling system is provided in Section 3.4.

1.1.5 Transmission System Information

The NAPS site is interconnected with the regional power grid system via three 500 kV transmission lines and one 230 kV transmission line from the station's switchyard. Any two 500 kV transmission lines, together with the 230 kV transmission line, are expected to have sufficient capacity to carry the total output of the existing units and the new units. If Dominion decides to proceed with development of new units at the ESP site, a system study (load flow) modeling these lines with the new units' power contribution would be performed at that time to confirm this conclusion. Additional information regarding the existing transmission system for the NAPS site is provided in Section 3.7.

1.1.6 Pre-Application Public Involvement

Dominion has established and maintains a positive relationship with the local population, civic leaders, and state and local governmental authorities in the area surrounding the ESP site. In a public opinion survey conducted in 2000, 86 percent of the population living in Louisa County believed that the existing units were a positive feature for the county.

In addition, Dominion has conducted an outreach program to pro-actively inform the local population of its interest in the NAPS site for purposes of early site permitting. Communications and meetings with various groups have been an ongoing practice since March 2002, when Dominion

representatives first met with the Louisa County Board of Supervisors and advised them of Dominion's interest in early site permitting. Since that time, Dominion representatives have met with a variety of state and local authorities and other members of the public. Examples of interactions with stakeholders initiated by Dominion are listed below:

- July 2002 meeting with the Lake Anna Civic Association
- February 2003 meeting with the Virginia Department of Environmental Quality (VDEQ)
- February 2003 meeting with the Virginia Department of Emergency Management
- February 2003 meeting with the Virginia Department of Game and Inland Fisheries (VDGIF)
- March 2003 meeting with the Virginia Secretary of Natural Resources
- March 2003 meeting with emergency preparedness coordinators representing counties surrounding the North Anna site
- March 2003 meeting with Louisa County Board of Supervisors
- April 2003 meeting with the Virginia Department of Conservation and Recreation (VDCR)
- May 2003 meeting with VDEQ, VDGIF, VDCR, Department of Historic Resources, Department of Health, Department of Agriculture and Consumer Affairs, and Department of Transportation
- Teleconferences with non-government environmental organizations, such as the Chesapeake Bay Foundation

On April 1, 2003, the NRC held public meetings in the vicinity of the ESP site. The purpose of those meetings was to: 1) inform the public regarding elements of NRC's Part 52 regulations involving ESPs, and 2) advise the public of its opportunities to become involved in the licensing process. Notices of those public meetings were provided in the Federal Register and in local newspapers.

1.1.7 **Construction Start Date**

Because the ESP does not constitute a decision or approval to build new units, there is no date established for commencement of construction. Site preparation (pre-construction) activities authorized by 10 CFR 52.25 could be initiated after receipt of the ESP at any time during the 20-year permit term. It is estimated that such site preparation activities (pre-construction) would take between 12 to 18 months to complete. If a decision were made to build new units, construction of new units is estimated to occur over a 5 to 7-year period, presuming that the start of a second unit would lag that of the first by at least 12 months, commencing after NRC issuance of a COL.

Section 1.1 References

None

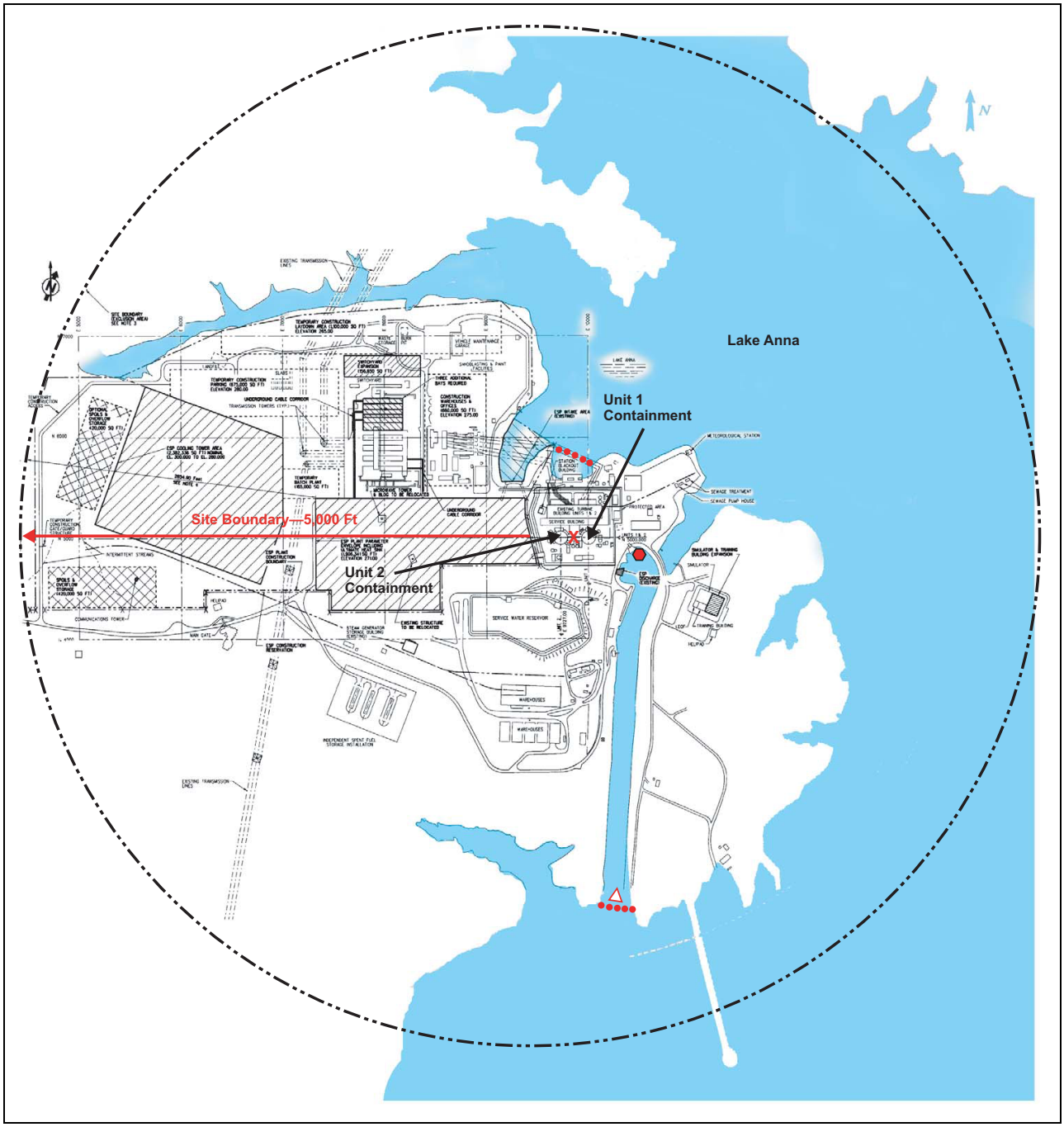

Figure 1.1-1 ESP Site

1.2 Status of Reviews, Approvals, and Consultations

A Coastal Zone Management Act compliance certification was provided to the VDEQ for concurrence review. This certification of compliance with Virginia's Coastal Program is due to Lake Anna's shoreline border with Spotsylvania County and North Anna River downstream flow into tidal areas. Appropriate regulatory approvals of an agreement between Dominion and the current site owners would be necessary before Dominion conducts any site preparation activities. Consultations with other federal and state agencies in connection with the preparation of the environmental impact statement for this ESP application, including consultations under the Endangered Species Act and National Historic Preservation Act, will be necessary.

Numerous reviews, approvals and consultations would be required for the construction of the new units. Table 1.2-1 provides a list of the environmental-related authorizations, permits, and certifications potentially required by federal, state, regional, local, and affected Native American tribal agencies for activities related to the construction and operation of any new units at the ESP site (Reference 1) (Reference 2) (Reference 3) (Reference 4).

The structure of the summary table is based primarily on NUREG-1555 guidance. Because the purpose of this application is to establish the acceptability of the proposed site for future development, the permits identified as being required for construction and operation are not needed to support issuance of the ESP. Because these permits will not be obtained until Dominion makes a decision to proceed with the development of the site, numbers and expiration dates for these permits do not currently exist.

Section 1.2 References

1. NUREG-1555, *Environmental Standard Review Plan*, Section 2 “Status of Reviews, Approvals, and Consultations”, U.S. Nuclear Regulatory Commission, October 1999.

2. NUREG-1437*, Generic Environmental Impact Statement for License Renewal of Nuclear Power Plants, Supplement 7*, Section 1.5, “Compliance and Consultations,” and Appendix E, Virginia Electric and Power Company’s Compliance Status and Consultation Correspondence,” USNRC, November 2002.

3. Virginia Department of Environmental Quality (VDEQ), www.deq.state.va.us, February 12, 2003.

4. *Lake Anna Special Area Plan*, Lake Anna Special Area Plan Committee, March 2000.

Table 1.2-1 Federal, State, and Local Authorizations

Agency	Authority	Requirement	License/ Permit No. (a)	Expiration Date (a)	Activity Covered
FAA	49 USC 1501	Construction Notice			Notice of erection of structures (>200 feet) potentially impacting air navigation.
Lake Anna Special Area Plan Committee		Conditional Land Use Approval	N/A	N/A	Local land use approval – Lake Overlay District.
NRC	Atomic Energy Act (AEA), 10 CFR 51, 10 CFR 52.17	EIS	N/A	N/A	Environmental effects of construction and operation of a reactor
NRC	10 CFR 52, Subpart C	Combined License			Combined construction permit and operating license for a nuclear power facility
NRC	10 CFR 52, Subpart A	Early Site Permit			Approval of the site for one or more nuclear power facilities, and approval of limited construction as per 10 CFR 50.10(e)(1)
NRC	10 CFR 30	By-product License			Approval to possess special nuclear materials
NRC	10 CFR 70	Special Nuclear Materials License			Approval to possess fuel
SCC					Approval of the purchase or lease of the site
SCC	VA Code 56-580D				Approval for construction of new generating facility
USACE	Clean Water Act (CWA)	Section 404 Permit (individual, regional, general)			Disturbance or crossing wetland areas or navigable waters
USACE	Rivers and Harbors Act	Section 10 Permit			Impacts to navigable waters of the U.S.
USFWS	Endangered Species Act	Consultation regarding potential to adversely impact protected species. Letter of Concurrence	N/A	N/A	Concurrence with no adverse impact or consultation on appropriate mitigation measures

Table 1.2-1 Federal, State, and Local Authorizations

Agency	Authority	Requirement	License/ Permit No. (a)	Expiration Date (a)	Activity Covered
USFWS	Migratory Bird Treaty Act	Federal or State Permit			Adverse impact on protected species (e.g., eagles, ospreys) and/or their nests
VDEQ	9 VAC 5-20-160	Registration.			Annual re-certification of air emission sources.
VDEQ	Federal Clean Air Act Amendments (CAAA) Title V9 VAC 5-80-50	Title V Operating Permit.			Operation of air emission sources.
VDEQ	9 VAC 5-80-120	Minor Source - General Permit.			Construction and operation of minor air emission sources.
VDEQ	FWCA 9 VAC 25-10	Virginia Pollutant Discharge Elimination System Permit (VPDES).			Regulated limits of pollutants in liquid discharge to surface water
VDEQ	FWCA 9 VAC 25-150	General Permit Registration Statement for storm water discharges from industrial activity (VAR5).			General permit to discharge storm water from site during operations
VDEQ	FWCA 9 VAC 25-180	General Permit NOT for storm water discharges from industrial activity (VAR5).			Termination of coverage under the general permit for storm water discharge associated with operational site activities
VDEQ	Federal Clean Water Act 9 VAC 25-180	General Permit Notice of Termination (NOT) for storm water discharges from construction activities (VAR4).			Termination of coverage under the general permit for storm water discharge from construction site activities
VDEQ	9 VAC 25-210	Virginia Water Protection Permit (Individual or General)			Permit to dredge, fill, discharge pollutants into or adjacent to surface water. Joint application with USACE Section 404 permit.

Table 1.2-1 Federal, State, and Local Authorizations

Agency	Authority	Requirement	License/ Permit No. (a)	Expiration Date (a)	Activity Covered
VDEQ	Federal Clean Water Act	Section 401 Certification			Compliance with water quality standards.[b]
VDEQ	Federal Clean Water Act (FWCA) 9 VAC 25-220	Surface Water Withdrawal Permit			Permit to draw water from Lake Anna (unless otherwise regulated by State Water Control Board)
VDEQ	Coastal Zone Management Act, Section 307.	Consistency determination.			Compliance with Virginia Coastal Program.
VDEQ	Virginia Coastal Resources Management Program	Consistency determination			Compliance with Virginia Coastal Program.
VDEQ	Federal Clean Water Act 9 VAC 25-180	General Permit Registration Statement for storm water discharges from construction activities (VAR10).			General permit to discharge storm water from site during construction
VDHR	National Historic Preservation Act, 36 CFR 800	Cultural Resources Survey/Review	N/A	N/A	Confirm site does not contain protected historic/cultural resources
VMRC	9 VAC 25-210	VMRC Permit			Permit to fill submerged land. Joint application with USACE Section 404 permit.

N/A - Not applicable (A license or permit is not required at the ESP stage)

a. The information does not currently exist. Licenses and permits would be applied for and received at the appropriate time, which may not be until the COL phase.

b. A certification under Section 401 of the Federal Water Pollution Control Act (FWPCA) is not appropriate at this time because a specific scope and schedule for pre-construction activities and determination of specific activities that would result in a discharge have not been established. To address the timing of this certification, the ESP should include a condition prohibiting Dominion from conducting any pre-construction activity that would result in a discharge into navigable waters without first submitting to the NRC a Virginia Water Protection Permit (which under Virginia's State Water Control Law at Va. Code § 62.1-44.15:5(A) constitutes the certification required under FWPCA § 401), or a determination by VDEQ that no certification is required.

Chapter 2 Environmental Description

Chapter 2 describes the existing environmental conditions for the ESP site (see Section 1.1). The environmental description provides sufficient detail to identify those environmental resources that have the potential to be impacted by the construction, operation, or decommissioning of the new units. The environmental description, where referenced, includes the following definitions:

- NAPS site - the property within the NAPS site boundary, or fence line, including the Exclusion Area Boundary (EAB).
- ESP site - the property within the NAPS site intended for the construction and operation of new units
- Vicinity - the area within a 6-mile radius of the ESP site.
- Region - the area within a 50-mile radius of the ESP site.

The environmental description is segregated into the following discrete elements as outlined in NUREG-1555:

- Land
- Water
- Ecology
- Socioeconomics
- Geology
- Meteorology and air quality
- Related federal project activities

2.1 Site Location

The ESP site is contained within the NAPS site. The location for the new units would be confined to the plant envelope area see Figure 2.1-1. The eastern boundary of the ESP site is approximately 570 feet west of the center of the existing Unit 1 containment building. Universal Transverse Mercator (UTM) coordinates for the ESP plant envelope are not provided.

The ESP site is located in rural Louisa County in the northeastern portion of Virginia, approximately 7 miles east of the town of Mineral, Virginia, which had a population of 424 according to the 2000 census survey. The site is at the end of State Route 700 on a peninsula of the southern shore of Lake Anna. The earth dam that creates Lake Anna is about 5 miles southeast of the site. The North Anna River flows southeasterly, joining the South Anna River to form the Pamunkey River about 27 miles southeast of the site. Figure 2.1-2 shows the general location of the ESP site and localities surrounding the site within 10 miles.

Regionally, as shown in Figure 2.1-3, the site is about 40 miles north-northwest of Richmond, Virginia; 36 miles east of Charlottesville, Virginia; and 22 miles southwest of Fredericksburg, Virginia. Interstate 95 and U.S. Route 1 (parallel to I-95), the two principal highways joining Richmond with the rest of the eastern corridor, pass within 15 and 16 miles, respectively, east of the site.

Section 2.1 References

None

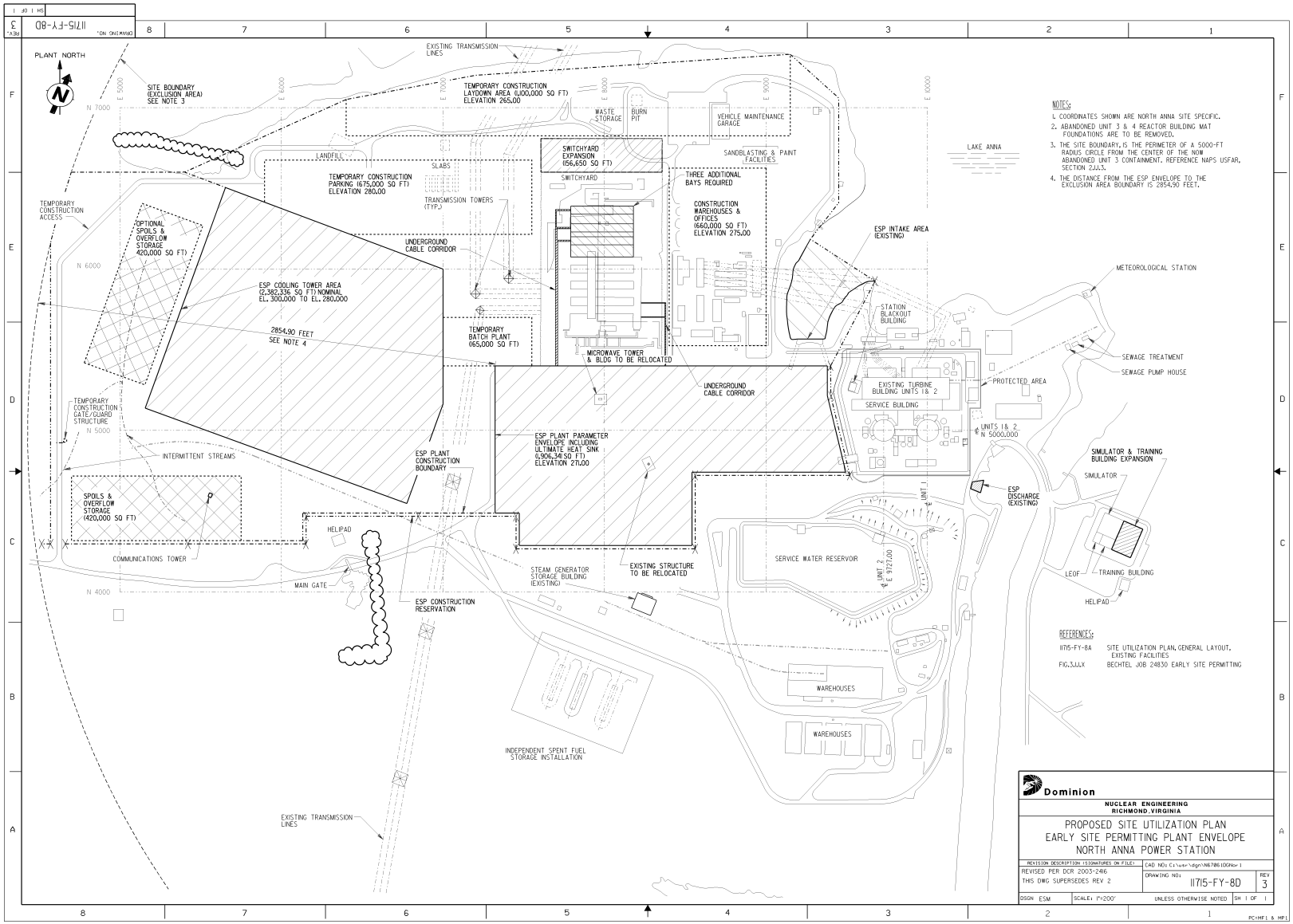

Figure 2.1-1 North Anna ESP Site Boundaries

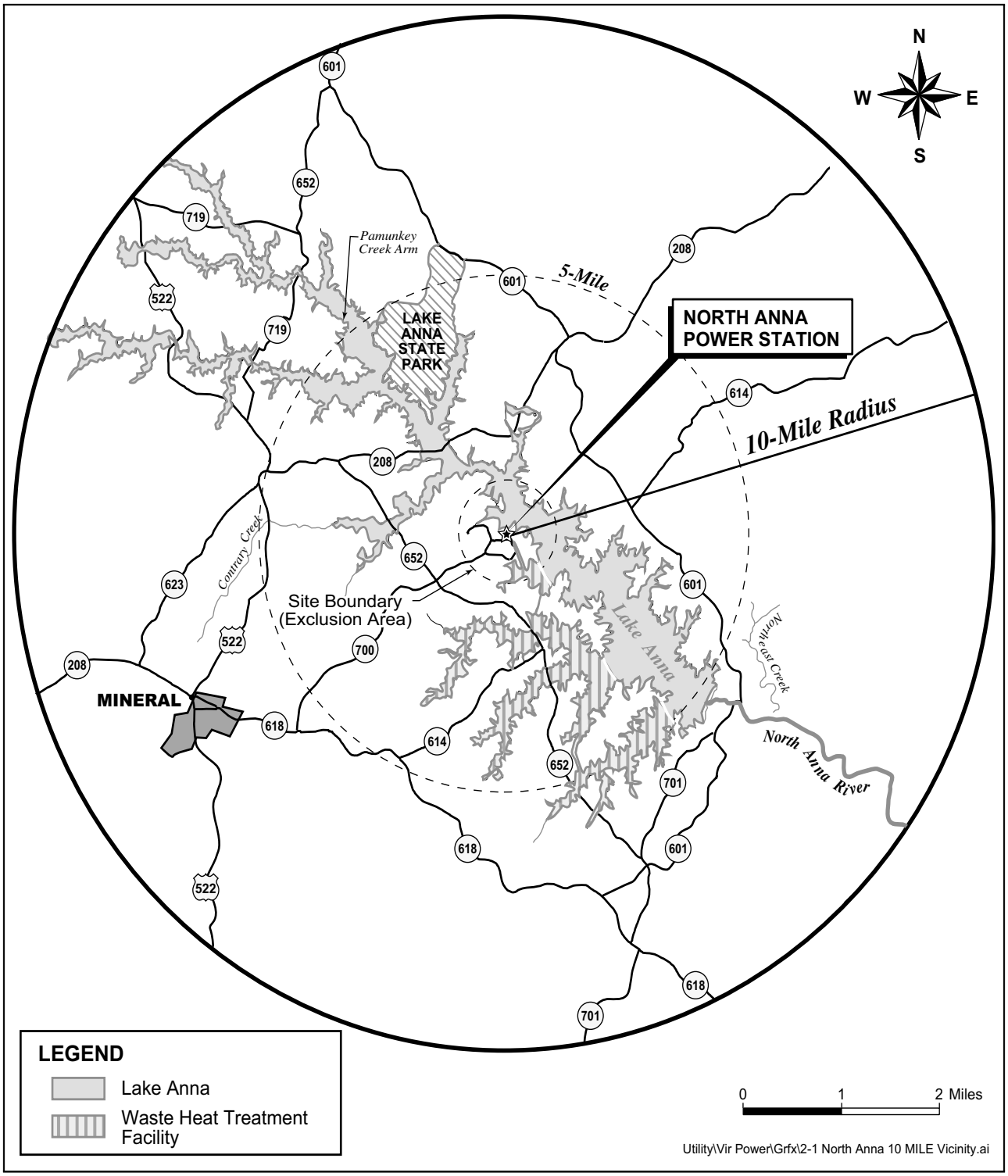

Figure 2.1-2 10 Mile North Anna Vicinity Map

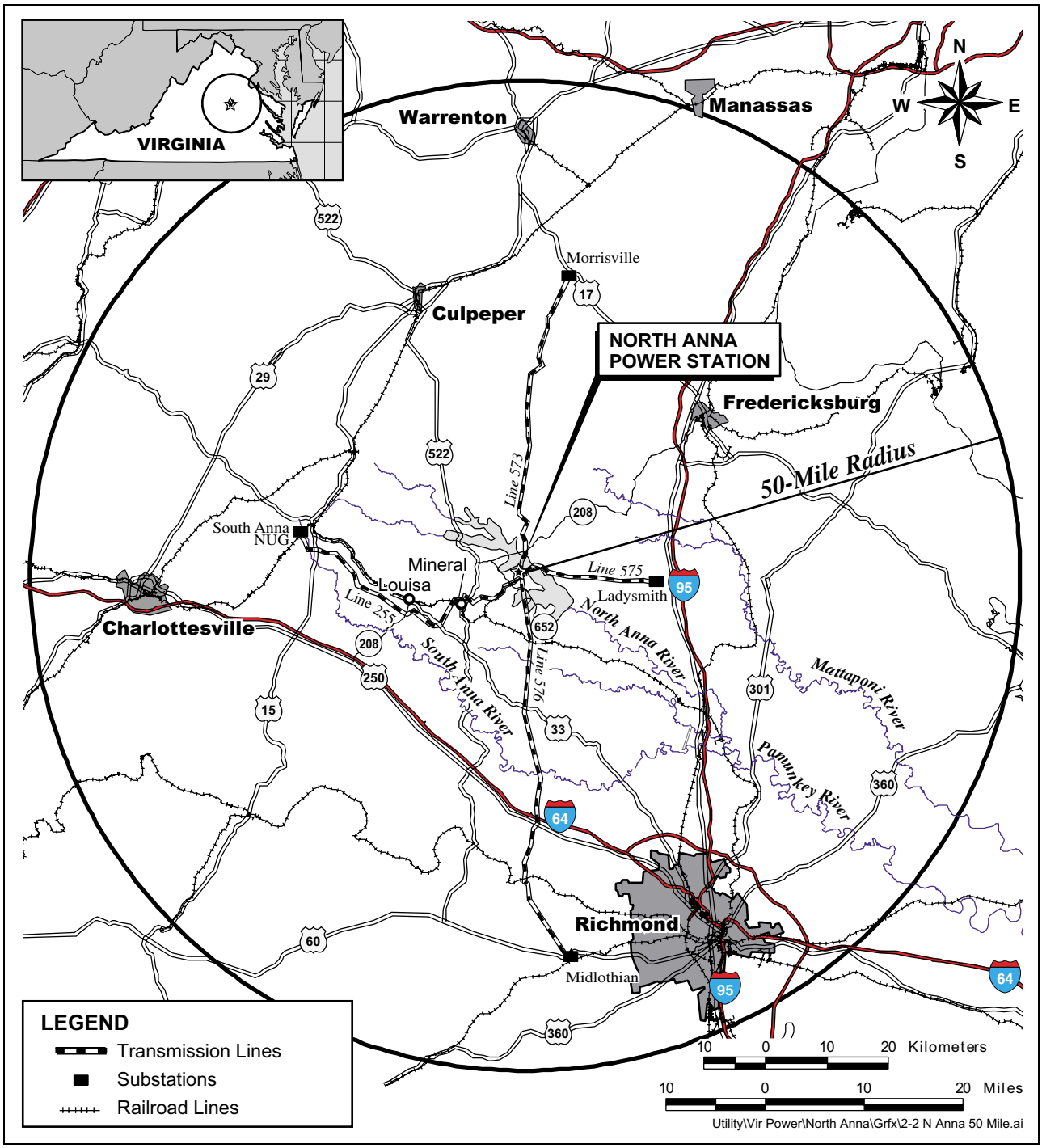

Figure 2.1-3 North Anna Power Station 50 Mile View

2.2 Land

This section describes the land characteristics of the areas within the ESP site (and where appropriate, the NAPS site) that are identified in this ESP application. This description was used as a baseline to assess the potential impacts on land uses that would result from the construction, operation, and decommissioning of the new units. This section is further segregated into three subsections: 1) site and vicinity, 2) transmission corridors and offsite areas, and 3) the region. These subsections include spatial considerations (e.g., region, vicinity, and site) as well as the nature and extent of current land uses and planned future land uses, where applicable, as referenced.

2.2.1 The Site and Vicinity

The ESP site is within the existing boundaries of the NAPS site, with the new units to be sited adjacent to the existing Units 1 and 2. The ESP site is situated on a peninsula of Lake Anna's southern shore at the end of State Route 700 (see Figure 2.1-2). Geographically, the ESP site is located within the central Piedmont Plateau of Virginia. The topography of the NAPS site is characterized as a gently undulating surface that varies from 60 m (200 ft) to 150 m (500 ft) above mean sea level (msl). Forests primarily of pine and hardwoods cover the majority of the peninsula on which NAPS is sited.

Regionally, the ESP site is approximately 40 miles north-northwest of Richmond, Virginia; 36 miles east of Charlottesville, Virginia; 22 miles southwest of Fredericksburg, Virginia, and 70 miles southwest of Washington, D.C. Interstates 95 and 64 pass within 16 miles to the east and 18 miles to the south of the ESP site, respectively (see Figure 2.1-3).

2.2.1.1 Site Description

The ESP site is located in Louisa County in northeastern Virginia. Virginia Power and ODEC own, and Virginia Power controls, all of the land within the NAPS site boundary, both above and beneath water surfaces, including those portions of the North Anna Reservoir and WHTF, that lie within the site boundary. Both companies also own all the land outside the NAPS site boundary that forms Lake Anna, up to their expected high-water marks (i.e., Elevation 255 feet above msl). Virginia Power purchased and owns a total of 18,643 acres of rural land (approximately 80 percent forested) for the original development of NAPS, including the land for Lake Anna; the earthen dams, dikes, railroad spur, roads and bridges; and miscellaneous other structures and facilities. Virginia Power also owns and operates the North Anna Hydroelectric Project, an 855 kW-capacity hydroelectric power plant at the base of the North Anna Dam.

Lake Anna, a man-made reservoir, was created in 1971 by erecting a dam on the main stem of the North Anna River. The lake is approximately 27 km (17 miles) long with 435 km (272 miles) of irregular shoreline and approximately 3900 ha (9600 acres) of water surface. Lake Anna was created primarily as a source of cooling water for the power station, although it has become a

popular recreation area. The dam provides downstream flood control. Lake Anna is not used as a source of potable or industrial water.

Virginia Power has granted easements to landowners abutting Lake Anna (including the WHTF) who request permission to use Virginia Power property for the erection of docks, jetties, or other recreational structures for access to the lake waters. These structures require a re-approval by Virginia Power with each property ownership transaction, and all permissions are expressly revocable. Public boaters have access to the lake, and private boaters have access to the WHTF.

No public or commercial highways, railroads, transmission corridors (other than those owned and operated by Virginia Power), or major waterways traverse the ESP site. Ingress and egress from the ESP site is primarily through a Virginia Power-owned and maintained access road off State Route 700.

The Virginia Department of Mines, Minerals, and Energy maintains maps of Louisa County showing mines that are currently active or that are known to have commercial value. The maps indicate no mines with commercial value (i.e., either metallic or non-metallic) exist within or adjacent to the ESP site.

The primary land cover on the NAPS site is pine and pine-hardwood mixed forest (70 percent). Portions of the NAPS site are used for facility activities (20 percent) and as cleared areas (10 percent). Facility uses include electricity generation, maintenance and distribution facilities, warehouses, training and administration buildings, lagoons and settling basin, parking lots, roads, a railroad line, information center, and the Independent Spent Fuel Storage Installation (ISFSI). Cleared areas include the landscaped grounds, open areas, lay down areas, three historic cemeteries, security weapons range, and the John Goode Recreation Area, a recreation and picnic area for use by employees of DRI and its subsidiaries only (see Figure 2.2-1).

2.2.1.2 **The Vicinity**

There are no communities in the vicinity of the ESP site. The nearest largest community is the town of Mineral, Virginia, (2000 Census population of 424) located in Louisa County, 7 miles west of the site. The town of Louisa (2000 population of 1401) is approximately 12 miles west of the ESP site. Lake Anna State Park lies 5 miles northwest of the NAPS site and provides public facilities for picnicking, fishing, boat launching, swimming, and biking (see Figure 2.1-2 and Figure 2.1-3).

The Commonwealth of Virginia mandates that cities and counties have comprehensive land use plans, and all three counties surrounding the Lake (Louisa, Orange, and Spotsylvania) have such plans. Figure 2.2-2 and Figure 2.2-3 show land use classifications in Louisa and Spotsylvania counties for the NAPS site and vicinity. Table 2.2-2 shows a breakdown of land use, type, and area in those counties.

The predominant land use in Louisa County, and a major contributor to the Louisa economy, is forestry, which uses approximately 68 percent of the county's land area. Most of the forested land is

privately owned. Agricultural lands occupy 23.5 percent and water resources occupy about 3 percent of land. Developed land occupies 6 percent and residential development predominates with 5.5 percent.

Louisa county experienced a 25 percent population growth (i.e., approximately 5100 additional people) between 1990 and 2000. However, there has been little industrial growth. Residential land use increased from 1.8 percent in 1979 to 5.5 percent by 2000. The county has prepared over 50 industrial sites for development. Many have access to various combinations of rail, gas, water, and sewer. Louisa County has recently updated its Comprehensive Plan (Reference 1), which defines nine goals for future development in the county. These goals include preserving the rural character of Louisa County through designation of “growth centers” to accommodate future growth in a manner consistent with maintaining the rural heritage of the county and a healthy, diverse economy, as well as providing job opportunities for Louisa County citizens.

Spotsylvania County, which consists of forests and agriculture, is fast-growing because of its proximity to Washington, D.C. and northern Virginia. Spotsylvania County has also recently updated its Comprehensive Plan (Reference 2) to define several development goals that allow for the maintenance of the historic, agricultural, and forested character of the county, while recognizing the need to sustain residential and business growth and community services for the benefit of county residents.

In Orange County to the northwest, 95 percent of the land consists of forests and agriculture and is beginning to be impacted by development.

Recreational and retirement development has grown substantially in the immediate vicinity of Lake Anna. Land between the many embayments remains privately held. Lake Anna has influenced land use development in Louisa, Orange, and Spotsylvania counties. Residential development of mid-to-upscale homes characterizes development around the lake. Prior to 1998, the three counties did not coordinate land use planning activities in the Lake Anna watershed. In 1998, however, a committee was formed to examine the watershed and to develop a plan that enables the counties to coordinate their efforts to address growth and protect the Lake Anna region.

The final Lake Anna Special Area Plan was issued in March 2000 (Reference 3). Several major findings resulted from the Special Area Plan Committee’s examination. These include:

- Development patterns of sprawl threaten the rural character, the environment, and the existing quality of life in the Lake Anna watershed
- Responsibility for on-going review of environmental conditions in the watershed is unclear.
- The environmental database necessary for responsible and informed decision-making is not available.

The Committee developed “priority recommendations” to address the major findings. These included:

- Create a Lake Anna Watershed Overlay District in all three counties with a charter to maintain the rural character of the area by implementing a cooperative, coordinated, consistent watershed program for Lake Anna.
- Charge the Lake Anna Advisory Committee to track progress toward meeting plan goals and to prepare and submit annual reports on progress made.
- Develop monitoring programs for both tributaries and the lake that address levels of heavy metals, nutrients and other pollutants and help to identify reductions strategies for fecal contamination.

2.2.2 Transmission Corridors and Offsite Areas

NAPS has three 500-kV transmission lines and one 230-kV transmission line leaving the site from the switchyard. Each transmission line occupies a separate right-of-way. The rights-of-way range in width from 37 to 84 meters (120 to 275 feet) and in length from 24 to 66 km (15 to 41 miles), covering a total of approximately 1174 hectares (2900 acres) (Reference 4). The rights-of-way extend from NAPS to the north, south, east, and west, terminating in Morrisville, Midlothian, Ladysmith, and at the South Anna non-utility generator, respectively Figure 2.2-4.

The NAPS transmission corridors were constructed between 1973 and 1984. The corridors pass through land use categories typical of north-central Virginia, such as row crops, pastures, forests, and abandoned (old) fields. In addition, the transmission corridors pass through more natural habitat types, such as hardwood and pine-hardwood forests, bottomland hardwood forests, and shrub boggs. No areas designated by the U. S. Fish and Wildlife Service (USFWS) or VDEQ as “critical habitat” for endangered species exist at the ESP site or along or adjacent to associated transmission line. In addition, the transmission corridors do not cross any state or federal parks, wildlife refuges, or wildlife management areas. Physical features (e.g., length, width, and route) of each of the transmission lines associated with NAPS are described in Table 2.2-1.

Corridors in timberlands and in the vicinity of road crossings are maintained by Virginia Power on a 3-year cycle by mowing or, if inaccessible to mowers, by use of nonrestricted-use herbicides. In other areas (e.g., wetlands, dense vegetation), hand-cutting treatments are used. (Reference 5)

Vegetation treatments have been developed in cooperation with the VDCR Natural Heritage Program. Areas of rare and sensitive plant species are identified and avoided, or modified treatment practices are used to avoid adverse impacts. In addition, wildlife food plots and Christmas tree plantations are located along the corridors and supported through cost sharing by Virginia Power. (Reference 4)

Virginia Power allows landowners, hunting clubs, and conservation organizations to establish wildlife food plots, Christmas tree plantations (not to exceed a height of 15 feet), gardens, athletic

and park facilities, and drain fields under transmission lines. Land uses not permitted under the transmission lines include permanent structures (i.e., houses and barns), trash and brush stockpiling, wells, septic systems, and ATV trails. (Reference 5)

Based on an initial evaluation, any two 500 kV transmission lines, together with the 230 kV transmission line to have sufficient capacity to carry the total output of the existing units and the new units. If Dominion decides to proceed with development of new units at the ESP site, a system study (load flow) modeling these lines with the new units' power contribution would be performed, to confirm this conclusion. Additional information regarding the existing transmission system for NAPS is provided in Section 3.7.

2.2.3 **The Region**

The region, defined as 50 miles beyond the ESP site boundary, includes all or portions of the following counties in Virginia: Amelia, Albemarle, Buckingham, Caroline, Chesterfield, Culpeper, Cumberland, Essex, Fauquier, Fluvanna, Goochland, Greene, Hanover, Henrico, King and Queen, King George, King William, Louisa, Madison, New Kent, Orange, Page, Powhatan, Prince William, Rappahannock, Richmond, Rockingham, Spotsylvania, Stafford, and Westmoreland. The region also includes a portion of Charles County in Maryland.

Major waterways, highways, roads, railroads, and other transportation routes in the region are shown in Figure 2.1-2 and Figure 2.1-3. There are two major airports within the region, Richmond International Airport and Charlottesville-Albemarle County Airport, approximately 45 miles southeast and 40 miles west of the ESP site, respectively. There are three smaller airports within 15 miles of the ESP site; Lake Anna Airport (Bumpass, VA), Louisa County Airport and Cub Field, 7 miles south-southwest, 11 miles west-southwest, and 10 miles southwest of the ESP site, respectively.

Fourteen counties in the eastern part of the region (i.e., Caroline, Chesterfield, Essex, Hanover, Henrico, King and Queen, King George, King William, New Kent, Prince William, Richmond, Stafford, Spotsylvania, Westmoreland) are within the VDEQ designated Chesapeake Bay Coastal Zone Management Area.

The following federally designated special land use classified areas exist within the region; George Washington Birthplace National Monument, Fredericksburg and Spotsylvania National Military Park, Thomas Stone National Historic Site, Richmond National Battlefield, Maggie L. Walker National Historic Site, Shenandoah National Park, Rappahannock National Wildlife Refuge, and Featherstone National Wildlife Refuge. There are no national forests, wilderness areas or wild and scenic rivers within the region. There are several Virginia state parks within the region. The closest, Lake Anna State Park, is approximately 5 miles northwest of the ESP site.

There are no Native American tribal land use plans for areas within the region. The closest reservations, the Mattaponi and Pamunkey, are outside of the ESP site region.

Land use within the region varies with distance from major population centers and high use transportation corridors. The metropolitan areas of Richmond, Fredericksburg, and Charlottesville, and the transportation corridors associated with Interstates 95 and 64 contain the highest density of residential, commercial, and industrial land use. As detailed in Section 2.2.1, land use in the immediate vicinity of ESP site and the areas outside the noted metropolitan areas and transportation corridors remains primarily in forestry and agriculture. A survey of land use development plans (i.e., comprehensive county plans) for the counties immediately adjacent to the ESP site indicate a primary goal of striking a balance between maintaining the historic rural character of the area with the recognized need for limited residential growth and business development. (Reference 1) (Reference 2)

The primary land use classifications for the region are representative of those noted for the Commonwealth of Virginia as a whole. The region, comprising about 20 percent of the total area of Virginia, encompasses four main land use classes: to the north are mainly urban areas surrounding Washington D.C. and cropland; to the east is primarily cropland; to the south is a mixture of cropland and pasture; and to the west is a mixture of forests and pasture. (Reference 6) (Reference 7)

Forests dominate Virginia, covering approximately 55.6 percent of the state's total land area (Table 2.2-3). The second most prevalent land use in Virginia is agriculture, covering 25.9 percent of the total land area. Cropland accounts for 2903 square miles, about 7.1 percent of the total area; pasture and hay production account for 6845.3 square miles, or about 16.8 percent of the state's land. Urban areas comprise 6029 square miles of land area, approximately 14.8 percent; and inland waters account for the remaining 3.7 percent.

In 2000, the four principal crops in Virginia in terms of acreage harvested, were hay (1,320,000 acres), soybeans (490,000 acres), corn (330,000 acres), and winter wheat (205,000 acres). The four principal livestock and products in Virginia for 2000, in terms of cash receipts, were broiler chickens ($441,320,000), cattle and calves ($307,862,000), wholesale milk ($278,832,000), and turkeys ($237,941,000) (Reference 11). In 2001, the four principal crops in Charles County Maryland in terms of total production were corn for grain (909,00 bushels), tobacco (450,000 bushels), soybeans (446,000 bushels), and wheat (169,000 bushels) (Reference 9).

Section 2.2 References

1. *Comprehensive Plan,* Louisa County Department of Planning/Zoning, County of Louisa, Virginia, September 4, 2001.

2. *2002 Comprehensive Plan*, Spotsylvania County Planning Department, Spotsylvania County, Virginia, February 12, 2002.

3. *Lake Anna Special Area Plan,* Special Area Plan Committee, March 2000.

4. Final Supplement 7 to the Generic Environmental Impact Statement (GEIS) Regarding License Renewal for the North Anna Power Station, Units 1 and 2, November 2002.

5. *Transmission Lines-Right-of-Way Encroachments,* Informational Bulletin, Department of Forestry, Dominion Energy, 2003.

6. Virginia County Data, Virginia Agricultural Statistics Service, 1997 Census Data, www.nass.usda.gov/va/page1.htm and www.nass.usda.gov/va/vpage2.htm (accessed July 10, 2003).

7. 1997 Census of Agriculture Volume 1: Part 46, Chapter 1, Virginia State-Level Data, Maps, United States Department of Agricultural, www.nass.usda.gov/census/census97/volume1/va-46/va1maps.pdf (accessed July 10, 2003).

8. *Land Use Classifications for Louisa County, Virginia (Site and Vicinity),* Louisa County Department of Planning/Zoning, Louisa County (Virginia), 2002.

9. Charles County 2001 Agricultural Profile, Charles County Agricultural Statistics www.nass.usda.gov/md/charles.pdf (accessed July 10, 2003).

10. *Land Use Classifications for Spotsylvania County, Virginia (Site and Vicinity),* Spotsylvania County Planning Department, Spotsylvania County (Virginia), 2002.

11. Virginia Agriculture – Facts and Figures, Virginia Department of Agriculture and Consumer Services (VCACS), 2000. www.vdacs.state.va.us/agfacts/index.html (accessed January 27, 2003).

12. Water Quality Assessment Report, Virginia Department of Environmental Quality (VDEQ), 2002, 2002 305(b), Table 2.1-2, Virginia Statewide Land Use Summary.

Table 2.2-1 North Anna Transmission Rights-of-Way[a]

		Length		Width	Area	
					Hectares (acres)	Construction Date
Substation	**kV**	**km (mi.)**	**Direction**	**m (ft)**	**(acres)**	**Date**
Morrisville	500	53 (33)	N	72 (235)	366 (905)	1973
Midlothian[b]	500	66 (41)	S	72 (235)	469 (1160)	1979
Ladysmith	500	24 (15)	E	84 (275)	192 (475)	1976
South Anna	230	50 (31)	W	30-37 (100-120)	146 (360)	1984
Total		193 (120)			1174 (2900)	

a. Source: Reference 4, Table 2-1

b. The transmission line to Midlothian Substation runs an additional 26 km (16 mi.) in a shared right-of-way with a non-North Anna line.

Table 2.2-2 Land Use in Louisa, Orange and Spotsylvania Counties[a]

County and Land Use	Hectares	Acres	Percent of Total
Louisa County			
Residential	7,322	17,655	5.0
Agriculture	31,979	79,019	23.5
Forest	92,474	228,500	68.0
Water	3,994	9,868	3.0
Other[b]	649	1,605	0.5
Total Louisa	136,418	336,646	100.0[c]
Orange County			
Developed Land[d]	4,597	11,360	5.0
Agriculture	34,021	84,064	37.0
Forest	53,330	131,776	58.0
Water	N/A[e]	N/A	N/A
Total Orange	91,948	227,200	100.0[c]
Spotsylvania County			
Residential	22,793	56,320	22.0
Developed Land[f]	3,108	7,680	3.0
Agriculture	18,649	46,080	18.0
Forest	53,874	133,120	52.0
Other	5,180	12,800	5.0
Total Spotsylvania	103,604	256,000	100.0

a. Source: Reference 4, Table 2-9.

b. Includes commercial and industrial lands.

c. Numbers have been adjusted to achieve a total of 100 percent.

d. Developed land is defined to include residential, commercial, industrial, and public use.

e. N/A – Not available

f. Developed land is defined to include industrial and commercial.

Table 2.2-3 Virginia Statewide Land Use Summary[a]

Land Use	Square Miles (hectares)	Percent of Total
Commercial Forest	20,059 (5,195,154)	49.2
National Forests	2,550 (660,447)	6.4
Total Forested Land	22,609 (5,855,601)	55.6
Cropland	2,903 (751,977)	7.1
Pasture/Hay	6,845 (1,772,925)	16.8
Other	828 (214,477)	2.0
Total Agricultural Land	10,577 (2,739,379)	25.9
Other (Including Urban)	6,029 (1,561,530)	14.8
Inland Waters	1,526 (395,336)	3.7
Total Area	40, 741 (10,551,845)	100.0

a. Source: Reference 12, Table 2.1-2

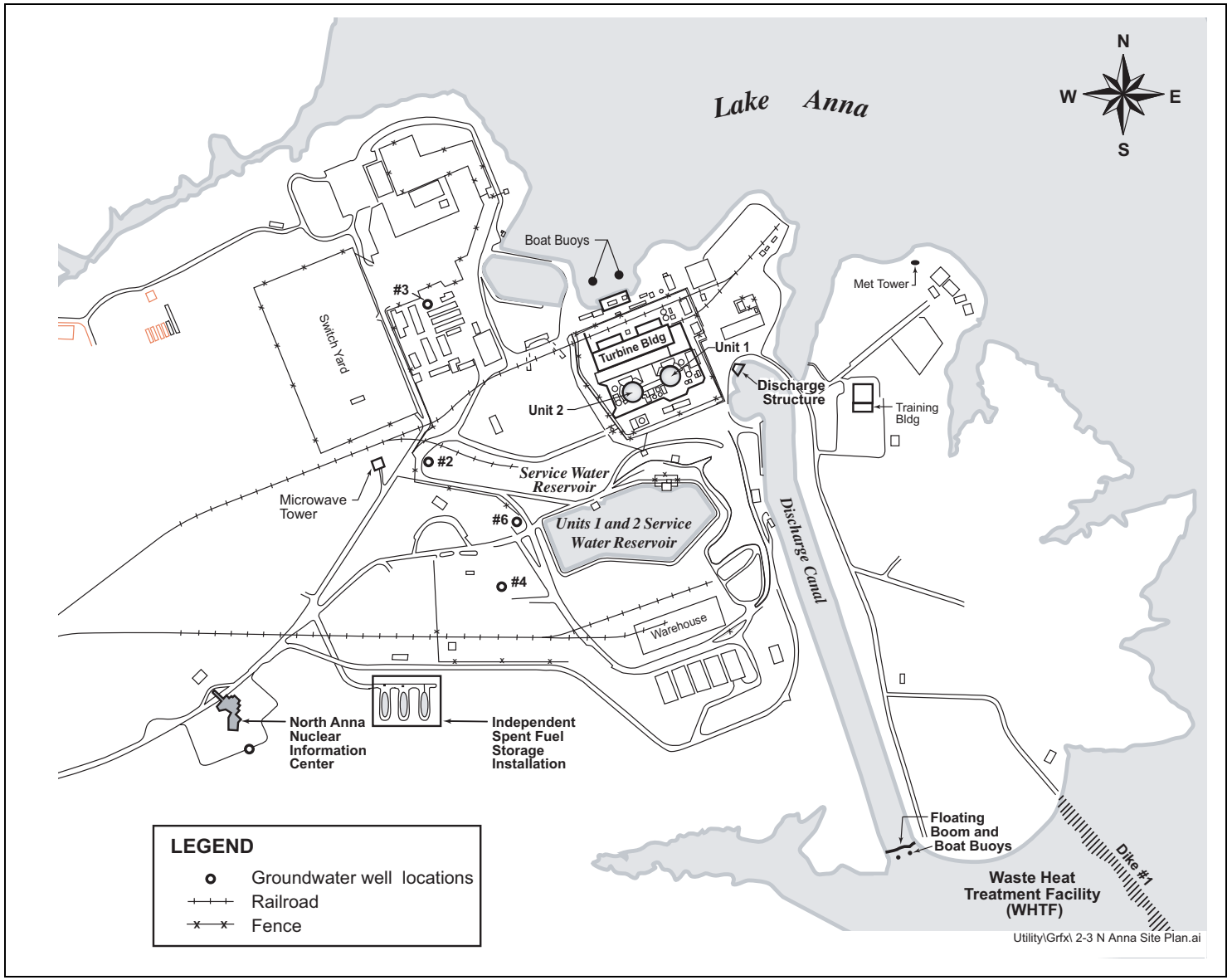

Figure 2.2-1 Existing NAPS Site Detail Map

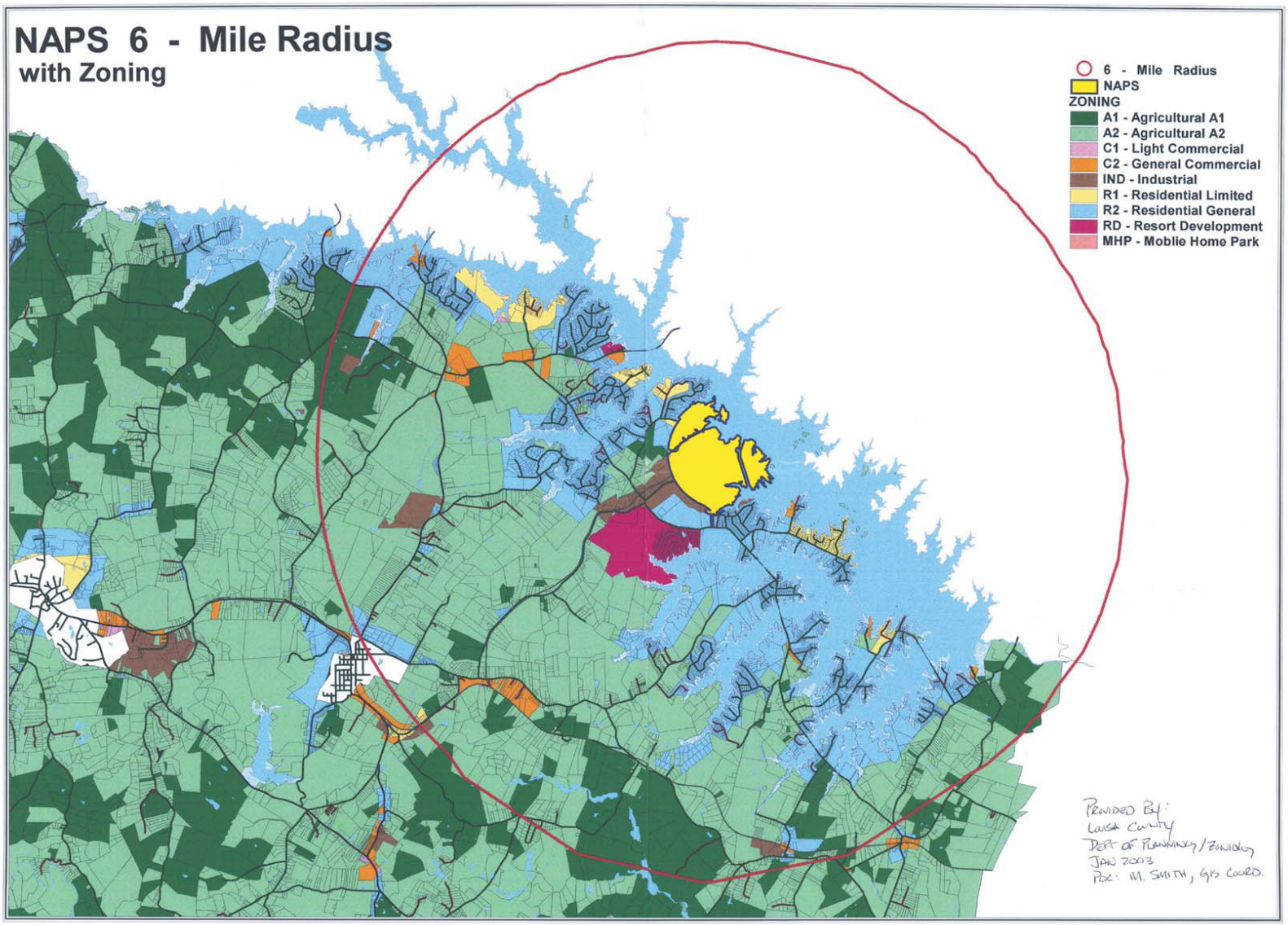

Figure 2.2-2 Land Use Classifications for Louisa County, Virginia (Site and Vicinity)
Source: Reference 8

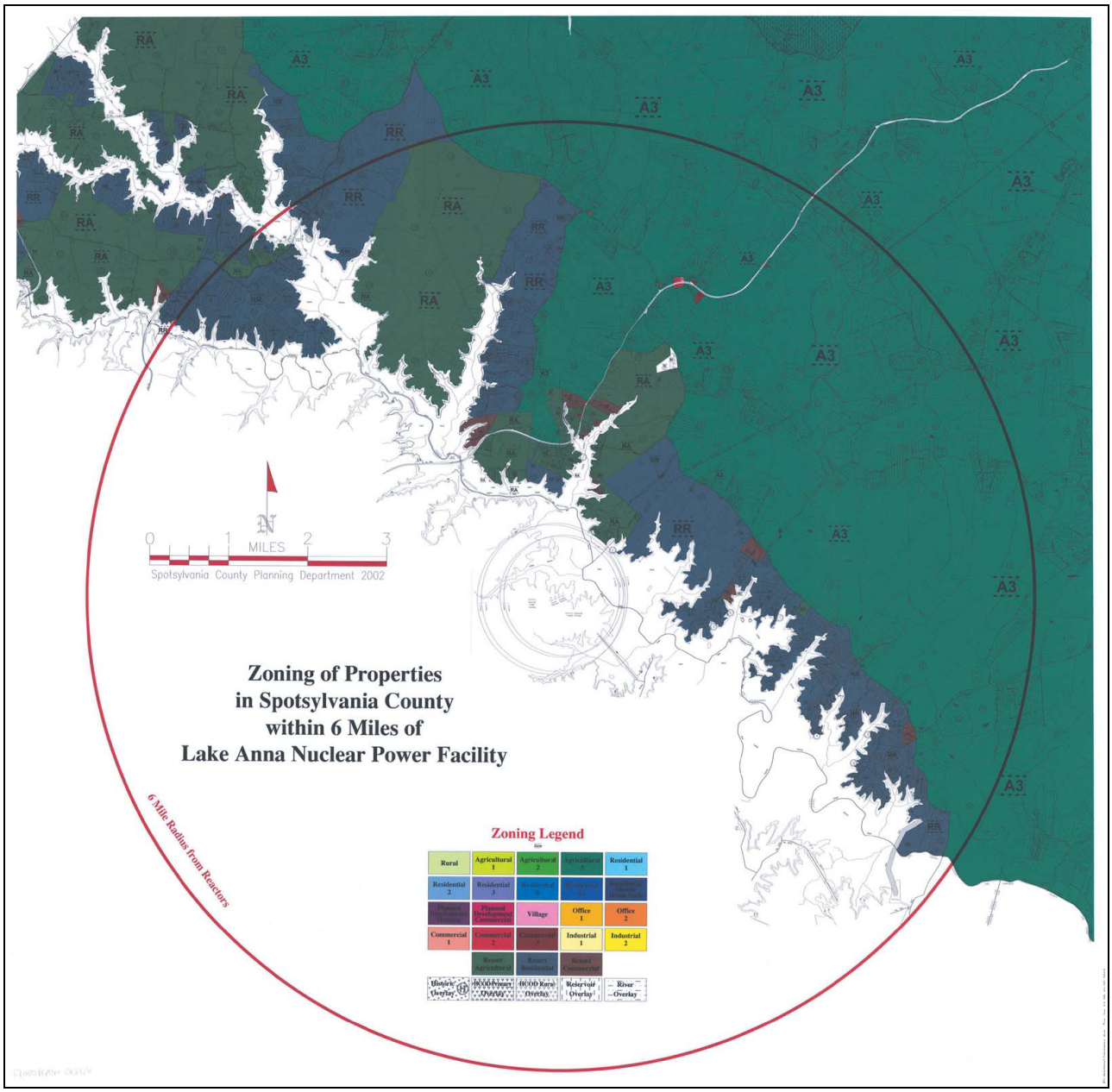

Figure 2.2-3 Land Use Classifications for Spotsylvania County, Virginia (Site and Vicinity)

Source: Reference 10

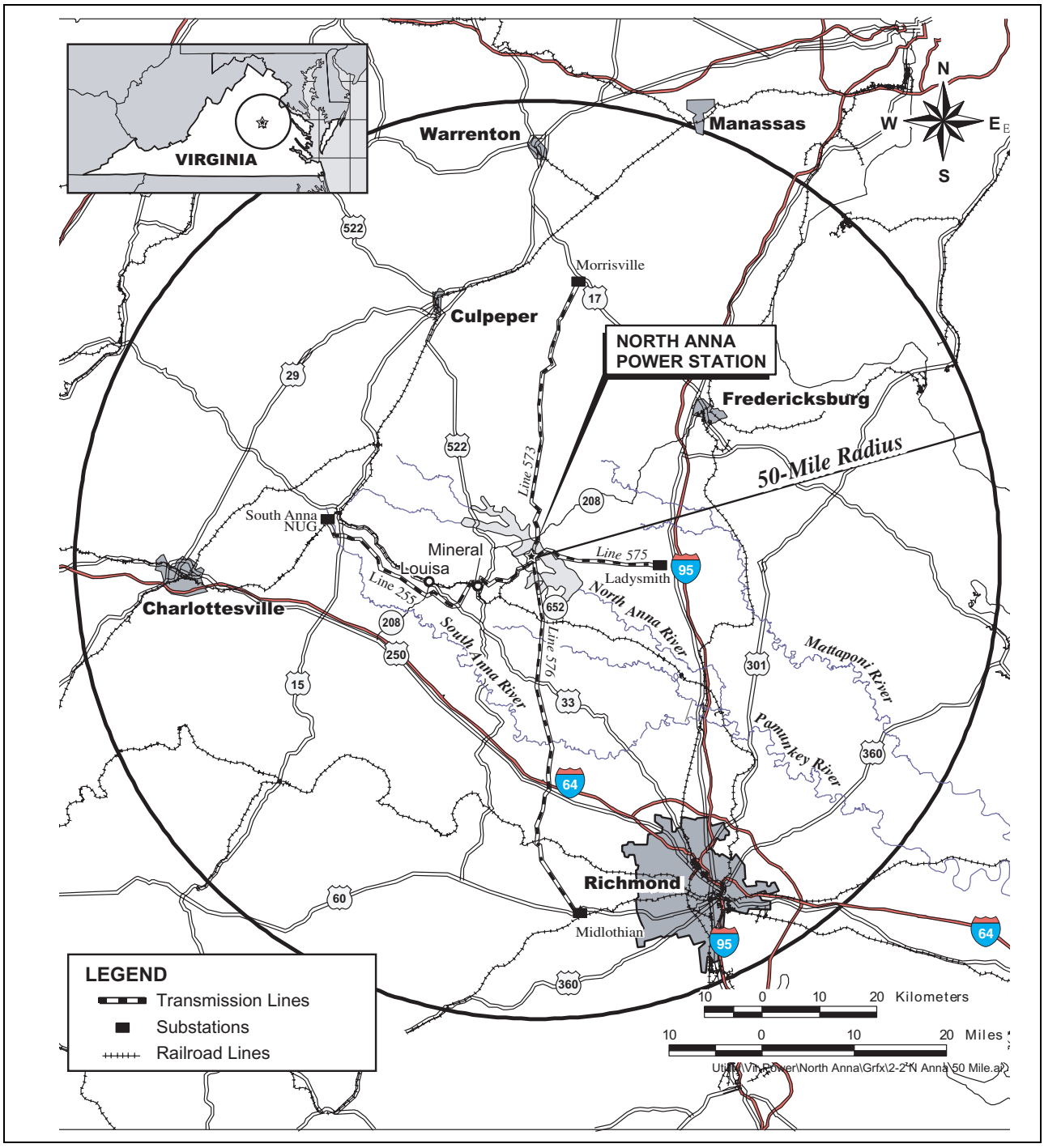

Figure 2.2-4 Existing Transmission Line Corridors

2.3 Water

This section includes site-specific and regional descriptions of the hydrology, water use, and water quality conditions that could affect, or be affected by, the construction, operation, or decommissioning of new units at the ESP site. The site-specific and regional surface water and groundwater information establishes the baseline hydrologic conditions against which to assess potential construction or operational impacts and the adequacy of related monitoring programs. The potential construction and operational impacts to water resources are presented in Chapter 4, and Chapter 5, respectively. Monitoring programs are presented in Chapter 6.

2.3.1 Hydrology

This section describes surface water bodies and groundwater aquifers that could affect the plant water supply, or that could be affected by the construction or operation of new units at the ESP site. The site-specific and regional data on the physical and hydrological characteristics of surface water and groundwater are summarized to provide the basic data for an evaluation of impacts on water bodies, aquifers, aquatic ecosystems, and social and economic structures of the area.

The following descriptions are based on a review of the NAPS Updated Final Safety Analysis Report (UFSAR) (Reference 1) and the Environmental Report Supplement (Reference 2), unless otherwise noted. The information has been verified and updated using current hydrologic databases.

2.3.1.1 Surface Water

The ESP site is located on the southern shore of Lake Anna adjacent to the existing units and approximately 8 km (5 miles) upstream of the North Anna Dam. Lake Anna was created by constructing a dam across the North Anna River as part of the overall development of the NAPS site. The North Anna Reservoir currently serves as the water source for the existing units, which use a once-through cooling system to dissipate heat from the turbine condensers.

Lake Anna is the primary surface water body that could affect plant water supply, or be affected by the construction and operation of new units at the ESP site based on the cooling systems proposed for the new units. New Unit 3 would use a closed-cycle, dry and wet cooling tower system for the circulating water system. A separate, service water cooling system would use a closed-cycle, wet cooling tower for dissipation of waste heat from auxiliary heat exchangers not cooled by the plant circulating water system. Make-up water for the wet cooling towers would be supplied from the North Anna Reservoir at a maximum instantaneous rate of 49.6 cubic feet per second (cfs). Blowdown discharge from the wet cooling towers would be returned to the reservoir at a maximum instantaneous rate of 12.4 cfs via the WHTF. New Unit 4 would use a closed-cycle cooling system with dry cooling towers in which the exhaust from the plant's steam turbines would be directed to a surface condenser where the heat of vaporization would be rejected to a closed loop of cooling water. The heated cooling water would be circulated to the finned tubes of the dry cooling towers

where heat content of the cooling water would be transferred to the ambient air. To increase heat rejection to the atmosphere, electric motor driven fans would be used to force airflow across the finned tubes. After passing through the cooling towers, the cooled water would be recirculated back to the surface condenser to complete the closed-cycle cooling water loop. Except for the initial filling of the cooling water loop, Unit 4 would have no make-up water need since dry tower systems typically have no evaporative water losses and would have no continuous blowdown discharge to the WHTF. In the event that the cooling water loop would use an open pump sump configuration with a free surface, a small amount of evaporation losses, estimated to be on the order of 1 gpm (0.002 cfs), would occur. Any make-up water necessary to replenish the small evaporative losses for Unit 4 would be obtained from the North Anna Reservoir. The plant service water cooling system for Unit 4 would use dry cooling towers, which would have minimal to no make-up water requirements.

The North Anna River rises in the eastern slopes of the Southwestern Mountains in the Appalachian Range near Gordonsville, Virginia, and flows along a southeasterly course to its confluence with the South Anna River 5 miles northeast of Ashland, Virginia, where the Pamunkey River is formed. The Pamunkey continues on a general southeasterly course to West Point, Virginia, where it is joined by the Mattaponi River to form the York River. The York River flows into the Chesapeake Bay about 15 miles north of Hampton, Virginia. The North Anna River drains a watershed of 343 square miles above the dam, which is located about 4 miles north of Bumpass, Virginia, and about 0.5 mile upstream of Virginia Route 601.

As shown in Figure 2.3-1, Lake Anna is about 17 miles long and inundates several small tributaries, thereby resulting in an irregular shape with a shoreline length of approximately 272 miles. To provide optimum thermal performance for the existing units, Lake Anna is separated into two sections by three dikes. The larger section of about 9600 acres, termed the North Anna Reservoir, is a storage impoundment for plant cooling water. The smaller section, the WHTF, has an area of about 3400 acres and functions as a heat exchanger to transfer most of the existing units' heat rejection to the atmosphere.

The elevation-volume curves for the North Anna Reservoir and the WHTF are provided in Figure 2.3-2. When both existing units are operating, eight circulating water pumps draw water from the North Anna Reservoir at a rate of 4246 cfs, circulate it through the condensers, and discharge it to the WHTF. Water moves through the three lagoons of the WHTF and back into the North Anna Reservoir at Dike 3 (Figure 2.3-1).

The North Anna Dam is an earth-filled structure about 5000 feet long and 90 feet high, with a central concrete spillway about 200 feet long. The dam crest is at Elevation 265 ft msl and has a width of 30 feet. The concrete spillway contains three radial crest gates, each 40 feet wide by 35 feet high, separated by concrete piers 10 feet wide. The discharge capacity of each of the three main gates is shown in Figure 2.3-4. The crest of the spillway ogee is at Elevation 219 ft msl. Two adjustable skimmer gates are provided for regulating small releases. The discharge capacity of

each of the skimmer gates, which measure 8.5 feet by 8.5 feet, is shown in Figure 2.3-5. A concrete apron downstream from the spillway provides energy dissipation for releases from the North Anna Dam.

The North Anna Dam also incorporates at its base a small hydroelectric power plant of 855-kW capacity owned and operated by Virginia Power. The hydroelectric facility consists of two separate generating units (Units 5A and 5B), each unit possessing a single-state, open runner-type vertical turbine. Peak operational efficiency is at a flow of 40 cfs for Unit 5A and 133 cfs for Unit 5B. Water for the hydroelectric facility is withdrawn from near the surface of Lake Anna (depth of less than 7 feet). It comes through a skimmer gate and associated sluice pipe that is connected to a 5-foot diameter penstock. Water is then directed by a bifurcation piece through 24- and 48-inch conduits to Units 5A and 5B, respectively. After passing through the turbines, water is discharged into the North Anna River just downstream of the dam's spillway. (Reference 3)

The normal pool level for the North Anna Reservoir is maintained at Elevation 250 ft msl. The Commonwealth of Virginia requires a minimum discharge of 40 cfs from the North Anna Dam, except under drought conditions. These minimum flow requirements are established to maintain instream flows and water quality in the North Anna River below the dam, and in the Pamunkey and York Rivers further downstream. Should drought conditions occur and the Lake Anna water surface elevations fall below 248 ft msl, Virginia Power may reduce releases below 40 cfs in accordance with the Lake Level Contingency Plan as stipulated in Part I.F of the Virginia Pollutant Discharge Elimination System (VPDES) Permit (Reference 4). A flood surcharge of 15 feet above the normal pool level is provided for flood storage. The total Lake Anna volume of 550,000 acre-feet is allocated as described in Table 2.3-1.

Table 2.3-1 Lake Anna Storage Allocation

Purpose	Volume (acre-feet)
Minimum recreational pool and inactive storage below 246 ft msl	255,000
Conservation and active storage, 246 to 250 ft msl	50,000
Flood control storage, 250 to 265 ft msl	245,000
Total storage	550,000

Streamflows have been gauged at various locations in the North Anna River watershed. Table 2.3-2 summarizes the stream gauge site numbers, names, drainage areas, and periods of record, while Table 2.3-8 provides the associated monthly streamflow statistics. Figure 2.3-6 indicates the locations of the stream gauging stations. Inflows to Lake Anna have been gauged at Pamunkey Creek at Lahore, Virginia, and Contrary Creek, Near Mineral, Virginia. The Pamunkey Creek station gauges a drainage area of 40.5 square miles, while the Contrary Creek station gauges a drainage area of 5.53 square miles. Inflows from the remaining 297 square miles of the 343-square mile

Lake Anna catchment are not gauged. Outflows from Lake Anna have been measured on the North Anna River near Partlow, Virginia, which is located just downstream of the dam at the Virginia Route 601 bridge. The drainage area at this stream gauge is 344 square miles. Additional stream gauging stations are located further downstream on the North Anna River near Doswell, Virginia, and at Hart Corner Near Doswell, Virginia.

Table 2.3-2 USGS Stream Gauge Data

Site Number	Name	Location	Drainage Area (square miles)	Period of Record	Source
01670180	Pamunkey Creek at Lahore, VA	Latitude 38°11'33", Longitude 77°58'09"	40.5	1989-08-25 1993-07-19	(Reference 5)
01670300	Contrary Creek Near Mineral, VA	Latitude 38°03'53", Longitude 77°52'45"	5.53	1975-10-01 1987-01-09	(Reference 6)
01670400	North Anna River Near Partlow, Virginia	Latitude 38°00'46", Longitude 77°42'05"	344	1978-10-01 1995-10-09	(Reference 7)
01671000	North Anna River Near Doswell, VA	Latitude 37°53'15", Longitude 77°29'15"	441	1929-04-01 1988-09-30	(Reference 8)
01671020	North Anna River at Hart Corner Near Doswell, VA	Latitude 37°51'00", Longitude 77°25'41"	463	1979-10-01 2001-09-30	(Reference 9)
01673000	Pamunkey River Near Hanover, VA	Latitude 37°46'03", Longitude 77°19'57"	1081	1941-10-01 2001-09-30	(Reference 10)

Lake Anna water levels have been recorded since the existing units were placed into operation. The available record begins in August 1978 and continues to be recorded for each day. Table 2.3-3 summarizes the water level elevation statistics. Section 5.2.2 describes the historical variations in the Lake Anna water level and the dependability of the impoundment in more detail. That section also describes the net losses due to evaporation, including the forced evaporation associated with the existing units and the new units. Section 2.4.1.8 describes the wetlands located within the ESP site. Part 2: Section 2.4.3 provides the design basis flood elevation for Lake Anna.

Table 2.3-3 Monthly Water Level Statistics for Lake Anna, August 1978 through March 2003 (ft msl)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
N	22	23	24	22	21	23	24	25	22	23	24	24
Min	247.42	247.36	247.15	247.30	247.67	247.21	246.66	245.87	245.57	245.21	246.29	247.46
Mean	249.79	249.89	249.95	249.91	249.88	249.77	249.59	249.43	249.12	248.97	249.14	249.49
Max	250.25	250.39	250.30	250.21	250.15	250.12	250.12	250.06	250.11	250.10	250.13	250.31

Table 2.3-3 Monthly Water Level Statistics for Lake Anna, August 1978 through March 2003 (ft msl)

N = number of monthly observations (months with incomplete daily data excluded)
Min = minimum monthly value
Mean = average monthly value
Max = maximum monthly value

The hydrodynamic characteristics of Lake Anna are presented in Section 5.3.1.1. Section 5.3.2.1 provides information on the temperature distribution, stratification, and seasonal variation of density-induced currents.

2.3.1.2 Groundwater Aquifers

The ESP site lies within the Piedmont Physiographic Province. Three types of groundwater aquifers are present within the consolidated rocks of the Piedmont, along with a surficial aquifer system in the overlying unconsolidated sediments. The three consolidated-rock aquifers consist of: 1) crystalline and undifferentiated sedimentary rocks, 2) carbonate rocks, and 3) early Mesozoic age rift-basin sedimentary and igneous rocks. The unconsolidated sediments are likely to consist of residual soil, saprolite (bedrock that has been weathered to a soil but that retains the rock structure), or alluvial deposits along stream channels. Although crystalline rocks form the predominant aquifers in the Piedmont Province, carbonate rocks, which are primarily found in the portion of the Piedmont that extends from Maryland northward, form the most productive aquifers. (Reference 11)

Recharge to aquifers in the Piedmont aquifers occurs largely as infiltration of local precipitation in interstream areas. That portion of the precipitation that does not migrate laterally through the unconsolidated surficial materials for discharge to nearby streams or low areas percolates vertically downward to the bedrock, where it enters water-bearing openings in the rock. (Reference 11) The average recharge to aquifers from precipitation in the Virginia Piedmont is estimated to be about 8 to 10 inches per year (Reference 12) (Reference 13). Although an intricate network of rivers and streams that follow a dendritic drainage pattern generally dissects the Piedmont Province, some of the drainage (or portions thereof) follow nearly straight courses that are controlled by joint or fault systems in the underlying bedrock. Those streams passing through the area from other geologic provinces provide a secondary source of recharge to the groundwater. The Piedmont Province of Virginia is estimated to have as much as 1.5 billion gallons of water per square mile held in storage in the consolidated and unconsolidated aquifers. This volume of water is considered suitable for domestic and other small supply requirements. (Reference 13)

In the area around the ESP site, the bedrock consists of Precambrian to Paleozoic age crystalline metamorphic and igneous rocks, while the overlying unconsolidated material is largely a weathering product (residual soil or saprolite) of the underlying bedrock. Groundwater in the crystalline rocks is stored and transmitted through joints and fractures in the rocks, while the main body of the rock

between the joints and fractures is essentially impermeable. The number and extent of the joints/fractures, and the width of the openings between their surfaces, generally decrease with depth, thus limiting the significance of the water-transmitting capability of the bedrock to its upper few hundred feet. (Reference 14)

Saprolite at the ESP site is generally exposed at the ground surface or underlies a thin layer of residual soil or fill. The saprolite extends to the top of the rock from which it was derived; however, the contact between the saprolite and sound rock may be gradational and not well defined (Reference 1). The saprolite is reported to range in thickness from about 2 to 125 feet and is of variable lithology, depending on the type of parent material from which it was derived (Reference 15). Borings drilled at the ESP site as part of the ESP subsurface investigation program penetrated saprolite to depths ranging from about 6 to 35 feet (Part 2: Appendix 2.5.4B). The saprolite penetrated by these borings is classified as a micaceous, silty-clayey, fine-to-coarse sand or sandy silt, with occasional rock fragments.

Bedrock beneath the saprolite belongs to the Ta River Metamorphic Suite. In the site area, these rocks are predominantly biotite gneiss and schist with smaller amounts of amphibolite gneiss. (Reference 16) The results of borings at the ESP site indicate the main rock type to be gneiss. The gneiss is generally described as quartz gneiss with some biotite quartz gneiss; and quartz gneiss, biotite quartz gneiss, and hornblende gneiss. The rock exhibits a variable weathering profile and joint/fracture presence. The degree of jointing and fracturing is the controlling factor for groundwater movement through the rock.

Groundwater at the ESP site occurs in unconfined conditions in both the saprolite and underlying bedrock. The results of previous investigations at the NAPS site indicate that a hydrologic connection exists between the saprolite and the bedrock. (Reference 17) This condition has been confirmed as part of the ESP subsurface investigation program (Part 2: Appendix 2.5.4B) by the presence of nearly equal water level elevations recorded in 2 observation wells (OW-845 and OW-846, Table 2.3-2) installed adjacent to each other and sealed in the bedrock and saprolite, respectively. At the ESP site, the water table is considered to be a subdued reflection of the ground surface and, therefore, the direction of groundwater movement is toward areas of lower elevations (Reference 17). Measurements made between December 2002 and June 2003 in observation wells at the ESP site exhibit water level elevations ranging from about Elevation 241 ft msl to Elevation 311 ft msl, with corresponding ground surface elevations of about Elevation 283 ft msl and Elevation 335 ft msl, respectively (Table 2.3-9). The measurements shown in Table 2.3-9 represent three quarterly rounds of groundwater level measurements taken at the ESP site to characterize seasonal variability in the water levels. Figure 2.3-7 presents hydrographs based on the water levels provided in this table for the nine observation wells (OW-841 through OW-849 on Figure 2.3-8) installed as part of the ESP subsurface investigation program. The other wells that were monitored (P- and WP-) were previously installed to monitor groundwater beneath the Service Water Reservoir (SWR) and the ISFSI, respectively.

A piezometric head contour map (Figure 2.3-8), prepared using the water levels measured in March 2003 (Table 2.3-9), indicates that groundwater flow is generally to the north and east, toward Lake Anna (). Freshwater Creek and Elk Creek, both of which flow to Lake Anna, form hydrologic boundaries to the west and south of the site, respectively (Reference 18). Because the water levels in the observation wells are generally above the top of the well screen, the water level elevation represents the piezometric head. An evaluation of the piezometric head contours shown on Figure 2.3-8 indicates a hydraulic gradient toward Lake Anna of about 3 feet per 100 feet. This gradient compares with an initial hydraulic gradient estimated for the NAPS site before the filling of Lake Anna of 8 feet per 100 feet (Reference 15). Prior to the filling of Lake Anna, it was estimated that a gradient of 6 feet per 100 feet would develop following the filling of the lake (Reference 1).

Prior to construction of the existing units, it was predicted that the filling of Lake Anna would raise the base level of groundwater discharge about 50 feet. It was estimated that this would result in a small rise in the water table where it intersects the surface of the impoundment area. Beyond this zone of intersection, however, it was estimated that the filling of the lake would have only a minor effect on the water table, and that the water table in the area of the existing units would essentially remain unchanged. (Reference 15) More recent evidence of the connection between Lake Anna and the surrounding groundwater regime is contained in the Lake Anna Special Area Plan (Reference 19). This Plan indicates that average well yields are higher in areas adjacent to the lake than in other areas of the Lake Anna watershed which are, in turn, slightly higher than in other areas of Louisa County. It was concluded that these higher yields are likely due to the presence of the lake, which enhances groundwater recharge.

The nine groundwater observation wells installed at the site as part of the ESP subsurface investigation program were tested using the slug test method to determine hydraulic conductivity values for the saprolite and underlying shallow bedrock (Part 2: Appendix 2.5.4B). Hydraulic conductivities calculated for the saprolite, based on tests in eight of the wells, range from about 0.2 to 3.4 feet per day, with a geometric mean value of 1.3 feet per day. The hydraulic conductivity of the shallow bedrock, as determined from the tests in one of the wells, is estimated to be about 2 to 3 feet per day, although the results of the test are of limited value due to the short duration of stable water level recovery measurements. Table 2.3-10 summarizes the available hydraulic conductivity data.

Laboratory tests performed on samples of saprolite from the site indicate a bulk density for this material of 125 to 130 pounds per cubic foot (pcf). Bulk densities for the bedrock range from 145 pcf for highly to moderately weathered rock to 163 pcf for moderately weathered to fresh rock. Laboratory tests to determine moisture contents of saprolite samples indicate an average moisture content of about 26 percent, while the moisture content in the vadose zone ranges from about 11 to 40 percent with an average of about 22 percent. Using the average moisture content of 26 percent and a value of 2.68 for the specific gravity of the saprolite (Reference 1), the void ratio of the saprolite is estimated to be about 0.7. A total porosity of about 41 percent is estimated from this

void ratio and an effective porosity of about 33 percent is estimated based on 80 percent of the total porosity. The specific yield of the saprolite was not determined; however, an estimate of this value taken from published literature for materials of similar composition indicates that it may be in the range of 0.30 to 0.33 (Reference 20).

Based on the estimated hydraulic gradient, hydraulic conductivity, and effective porosity indicated above, groundwater beneath the ESP site is expected to flow toward Lake Anna at a rate of about 0.12 feet per day. Using a distance of approximately 1800 feet from the center of the proposed overall plant footprint for the new units to the closest point along the shoreline of Lake Anna, the groundwater travel time from the ESP site to Lake Anna is estimated to be about 40 years.

No aquifers in the Piedmont Province of Virginia have been designated as sole source by the U.S. Environmental Protection Agency (EPA) (Reference 21). The aquifer (designated as sole source) nearest the ESP site is about 120 miles to the southeast, at the southern end of the Delmarva Peninsula in Accomack and North Hampton Counties, Virginia, within the Coastal Plain Physiographic Province. An area southeast of the site has been designated as the Eastern Virginia Ground Water Management Area by the VDEQ. Groundwater withdrawal in this area is permitted based on need and an evaluation by the VDEQ of the impacts of proposed withdrawals. The area, comprised of several counties or portions thereof in southeastern Virginia, lies entirely within the Coastal Plain Province. (Reference 22)

2.3.2 Water Use

This section describes surface water and groundwater uses that could affect or be affected by the construction, operation, or decommissioning of new units at the ESP site. Included are descriptions of the types of consumptive and non-consumptive water uses, identification of their locations, and quantification of water withdrawals and returns. Plant water use is described in Section 3.3.

2.3.2.1 Surface Water

The surface water bodies that are within the hydrologic system in which the ESP site is located and that may affect or be affected by the construction, operation, or decommissioning of new units include Lake Anna and associated downstream surface water bodies. These downstream surface water bodies include the North Anna River from below the North Anna Dam to its confluence with the South Anna River where the Pamunkey River is formed, the Pamunkey River to its confluence with the Mattaponi River where the York River is formed, the York River estuary to the Chesapeake Bay, and the Chesapeake Bay. Figure 2.3-9 illustrates these surface water bodies.

Consumptive surface water users within this hydrologic system have been identified from the water use database maintained by VDEQ (Reference 24), which includes users whose average daily withdrawal during any single month exceeds 10,000 gallons per day (gpd). Users include the existing units, Bear Island Paper Company, the Doswell Water Treatment Plant, and St. Laurent Paper Products Corporation. Figure 2.3-10 identifies the locations of these surface water

withdrawals. Table 2.3-4 identifies the water use and the water body from which withdrawals are made, while Table 2.3-5 summarizes the monthly withdrawal rates. These data indicate that withdrawal of water by the existing units from the North Anna Reservoir for cooling purposes represents the single largest consumptive use in the affected hydrologic system. Virtually all of the water withdrawn from the North Anna Reservoir portion of Lake Anna is returned to the reservoir via the WHTF (Reference 1). A portion of the returned water is lost to the atmosphere by evaporation as presented in Section 5.2.2.

Table 2.3-4 Consumptive Surface Water Users in the Affected Hydrologic System[a]

Facility	Water Use	Water Body
NAPS Unit 1	Cooling	Lake Anna
NAPS Unit 2	Cooling	Lake Anna
Bear Island Paper, Ashland Plant	Manufacturing	North Anna River
Doswell Water Treatment Plant	Municipal water system	North Anna River
St. Laurent Paper, West Point Plant	Manufacturing	Pamunkey River

a. (Reference 24)

No known future surface water withdrawals from the affected hydrologic system are planned for Louisa County, even though the county population and water supply demand is projected to increase (Reference 25). The surface water sources, such as Northeast Creek Reservoir and Lake Gordonsville, that are anticipated to supply the future demand are located outside the Lake Anna watershed and the affected hydrologic system.

Surface water bodies within a 10-km (6.2-mile) radius of the ESP site include Lake Anna and some of its tributaries, as illustrated on Figure 2.3-10. Non-consumptive water use of these surface water bodies is primarily recreational. Public use of the North Anna Reservoir includes fishing, boating, swimming, and water skiing. Public access is provided via Lake Anna State Park, which is on the Spotsylvania County side of the Lake. In the mid-1990s total park attendance peaked, reaching 180,000 visitors in 1997. In 1998, attendance decreased to about 142,500 visitors, with the beach area being the destination for about 20% of the park visitors. Access to the WHTF is limited to adjacent property owners. Recreational use of Lake Anna is seasonal with higher usage rates in the summer months. Future non-consumptive water use of the lake is expected to continue to be primarily recreational at usage rates comparable to current levels. (Reference 26)

The Commonwealth of Virginia's Surface Water Management Act of 1989 and associated regulations (9 VAC 25-220-10 et seq.) impose legal restrictions on surface water withdrawals where surface water resources have a history of low flow conditions that threaten important in-stream and off-stream uses. The purposes of these regulations are to maintain surface water flow at minimum

Table 2.3-5 Consumptive Surface Water Use Statistics for the Affected Hydrologic System[a]

Month	NAPS Unit 1	NAPS Unit 2	Bear Island Paper, Ashland Plant	St. Laurent Paper, West Point Plant[b, c]	Doswell [c] Water Treatment Plant
			(Millions of Gallons)		
January	24,930	24,833	8.02	-	-
February	20,555	22,645	24.32	-	-
March	21,869	20,445	8.15	-	-
April	26,665	21,845	14.15	-	-
May	33,653	36,947	8.36	-	-
June	37,693	39,465	19.70	-	-
July	41,975	41,975	40.78	-	-
August	41,713	41,749	35.33	-	-
September	32,319	31,303	29.63	-	-
October	32,974	34,136	22.92	-	-
November	30,818	29,278	31.53	-	-
December	27,573	26,954	12.33	-	-
Annual	372,737	371,576	252.22	-	-
Daily[d]	1,021	1,018	0.70	-	4.0[e]

a. Reference 24 numeric data represent mean values for the 1996-2001 period.
b. Listed in the VDEQ water use database, but no withdrawals reported in the 1996-2001 period.
c. Data not available.
d. Million gallons per day.
e. Rated capacity.

levels during periods of drought, ensure assimilation of treated wastewater, and support of aquatic and other water-dependent wildlife. In an area designated by the State Water Control Board as a surface water management area, water withdrawals of 300,000 gallons per month or more are required to have a surface water withdrawal permit. Permits and certificates must include a conservation plan that is activated during low-flow surface water conditions. As of October 2001, the Virginia State Water Control Board had not designated any surface water management areas in the state (Reference 27).

2.3.2.2 Groundwater Use

Groundwater for use at and in the vicinity of the ESP site is obtained from springs and wells in either the saprolite or underlying crystalline bedrock. Most wells completed in the saprolite have been excavated either by hand digging or augering. These wells are susceptible to becoming dry due to seasonal fluctuations in the water table. Drilled wells generally extend through the saprolite to depths of up to several hundred feet in the underlying bedrock. These wells are cased from the ground surface to the top of bedrock. (Reference 25) The production of groundwater in the vicinity of the ESP site is generally not sufficient to satisfy large water demands because of the relatively low yield of the aquifers, as presented in Section 2.3.1.2. The majority of groundwater development in the area is for domestic and agricultural use, with some public, light industrial and commercial use (Reference 28).

The following sections discuss groundwater use in the vicinity of the ESP site and by the existing units. Aquifers designated by the EPA as sole source are presented with respect to the ESP site in Section 2.3.1.2.

2.3.2.2.1 Local Use

There are no known users of large quantities of groundwater within 25 miles of the ESP site (Reference 1). The vast majority of wells in the area yield less than 50 gallons per minute (gpm) (Reference 25). Based on the presence of Lake Anna and the hydrologic boundary it presents to groundwater movement north and east of the ESP site, further discussion of groundwater use in the vicinity of the ESP site is limited to Louisa County.

Every 5 years, the U. S. Geological Survey (USGS) compiles national water-use estimates and publishes a report containing the results of this effort. Data from the latest available report, for the year 1995, are provided on the USGS web site for Virginia, by county or independent city (Reference 29). The following groundwater withdrawal estimates for Louisa County, in millions of gallons per day (mgpd), are provided by withdrawal category:

- Public water supply = 0.18 mgpd
- Domestic water supply = 1.45 mgpd
- Commercial/Industrial water supply = 0.10 mgpd
- Thermoelectric power water supply = 0.02 mgpd
- Agricultural water supply = 0.05 mgpd

VDEQ requires that any groundwater user in Virginia whose average daily withdrawal during any single month exceeds 10,000 gpd provide a report by January 31 of each year stating the water withdrawal and use data for the previous year. The only exceptions to this regulation are agricultural users who have slightly modified requirements based on their location, withdrawal, or withdrawal facility. (Reference 24) For the year 2001, no withdrawals were reported for Louisa County that meet or exceed this threshold.

A study previously performed for Louisa County included the compilation and evaluation of records of wells permitted by the Louisa County Health Department. (Reference 25) These records addressed 2155 drilled wells and 1743 dug or augered (bored) wells. The majority of the drilled wells serve single-family residences. The locations of the wells are currently referenced only to county tax maps.

The average yield of all wells in Louisa County is estimated to be about 14.5 gpm. However, the average yield of public wells is estimated to be about 42 gpm. The public water supply wells have an average depth of nearly 300 feet, and almost all are less than about 400 feet deep. The residential wells are generally only 100 to 200 feet deep. The Louisa County and previous studies in the Piedmont Province suggest that yields from individual wells in this area can vary greatly over distances as small as 100 feet. (Reference 25)

There are 45 public water supplies in Louisa County capable of obtaining their water from springs or wells. Data describing these public water supplies are presented in Table 2.3-11. The public supplies closest to the existing units are Lake Anna Plaza, about 2.6 miles to the northwest, and Jerdone Island, about 4.3 miles to the south-southeast. Based on their distance from the ESP site and the presence of one or more arms of Lake Anna between the site and these public water supplies, any impact the new units may have on the aquifers beneath the site is not expected to affect these supplies. Likewise, withdrawal by these public supplies is not expected to affect the ability of the new units to withdraw groundwater for potable water needs.

Private water wells provide about 80 percent of the domestic water supply to residents of Louisa County (Reference 30). The residential water supply well nearest the existing units is located about one mile to the south-southeast in Lot 32 of the Aspen Hill subdivision. Based on its distance from the ESP site and the presence of Sedges Creek between the site and this well, any impact the new units may have on the aquifers beneath the ESP site would not affect the domestic water supply provided by this well. Likewise, withdrawal by the well would not affect the ability of the new units to withdraw groundwater for potable water needs.

Population growth projections for Louisa County by the year 2015 range from about 32,000 to 46,000. Such growth would result in an estimated public water supply demand of between 2.8 and 4.1 mgpd for an average day and between 4.5 and 6.6 mgpd on a peak day. This water supply demand is expected to be satisfied largely by the use of surface water sources such as Northeast Creek Reservoir and Lake Gordonsville. However, these sources are expected to be supplemented by groundwater supply where available. To meet projected water demands beyond the year 2015, a large groundwater supply may need to be considered in conjunction with the development of alternative surface water sources. (Reference 25)

2.3.2.2.2 **On-Site Use**

Groundwater withdrawal for use by the existing units is accomplished from 4 water supply wells permitted for public use by the Virginia Department of Health (VDH). These 4 wells (Nos. 2, 3A, 4

[new], and 6) comprise a single water supply system at the site. A 5th well (No. 4 [old]) is no longer used as part of this system, but is available for emergency purposes only. A separately permitted well (NANIC) provides the water supply for the North Anna Nuclear Information Center. A new well was constructed at the site in 2003 to support an increase in water demand at the security training building. The proposed location of this well was evaluated by the VDH prior to its construction. The locations of these wells are shown on Figure 2.3-11 and the wells are described in Table 2.3-6. Four small wells not requiring permits at the NAPS site provide minor additional water for plant use (Reference 3). The locations of these 4 wells are not well documented. One of the wells is likely to be the well used to supply the Metrology laboratory and its location is shown on Figure 2.3-11. A second well is located at the security training building in the vicinity of the newly constructed well described above.

Table 2.3-6 North Anna Power Station Water Supply Wells

Well	Depth (ft)	Measured Yield (gpd)	Water Treatment
No. 2 [a, b]	385	12,960	Chlorination (normally not in use)
No. 3A [a, b]	185	74,880	
No. 4 (new) [a, b]	305	63,360	
No. 6 [a, b]	375	79,200	
No. 4 (old) [a, b] (not used)	200	77,760	NA
NANIC [a, c]	260	106,560	Calcite filtration
Security Training Building	d	d	d

a. Reference 25
b. Reference 31
c. Reference 32
d. Information not available.

The 4 active wells comprising the primary groundwater supply system for the new units have individual capacities ranging from 9 to 55 gpm and a total capacity of 160 gpm. However, these 4 wells are permitted for a total design capacity of only 53,040 gpd or about 37 gpm. This capacity is currently dictated by the available storage tank capacity at the site. The NANIC well has a measured capacity of 74 gpm (106,560 gpd) but a design capacity of 19,600 gpd. (Reference 31) (Reference 32)

As a condition of the well permits, Virginia Power is required to submit to the VDEQ by January 31 of every year an annual report of water withdrawals for the previous year. Table 2.3-12 shows the monthly withdrawal quantities that were reported for the year ending December 31, 2002. It can be

determined from this table that the 4 primary wells withdrew a combined average of almost 14 gpm for the year, and that the NANIC well withdrew an average of a little over 1 gpm. The highest total monthly withdrawal in 2002 for the 5 wells averaged almost 38 gpm in January. The highest reported monthly withdrawal average was 41 gpm in March 1994 (Reference 3). The four wells not requiring permits are also not required to report their withdrawals, but based on their small size and limited use they are not expected to add more than 1 or 2 gpm to the average withdrawal by the permitted wells (Reference 3).

Any groundwater supply required by the new units would likely come from an increase in the storage capacity for the existing wells or from drilling additional wells. In either event, additional groundwater withdrawal by the new units is not expected to impact any offsite wells due to: 1) their distance from the site, 2) the direction of the hydraulic gradient toward Lake Anna and the lake's recharge effect, and 3) the existence of hydrologic divides between the ESP site and the offsite wells.

2.3.3 Water Quality

This section describes the water quality characteristics of surface water bodies and groundwater aquifers that could affect plant water use and effluent disposal, or be affected by the construction, operation, or decommissioning of new units at the ESP site. Site-specific and regional data on the physical, chemical, and biological water quality characteristics of surface water and groundwater are summarized to provide the basic data for evaluating water quality impacts on water bodies, aquifers, aquatic ecosystems, and water use.

2.3.3.1 Surface Water

As described in Section 2.3.1, it is anticipated that new Unit 3 would use a closed-cycle, dry and wet cooling tower system for the main condenser, with make-up water for the wet cooling towers being supplied from the North Anna Reservoir and blowdown discharge being returned to the reservoir via the WHTF. It is anticipated that new Unit 4 would use a closed-cycle cooling system with dry system cooling towers with small make-up water requirements (1 gpm or less) supplied from the North Anna Reservoir and no blowdown discharge to the WHTF. Therefore, Lake Anna is the primary surface water body that could affect plant water use and effluent disposal, or be affected by the construction and operation of new units at the ESP site.

An extensive set of water temperature data for Lake Anna has been collected in accordance with the VPDES monitoring requirements for the existing units. The VPDES permit (Reference 4) requires continuous monitoring of temperature at 11 stations. Temperature measurements are taken hourly at the surface at Stations 1 through 9 inclusive and 11 and at a depth of 3 meters at Station 10. Figure 2.3-12 identifies the locations of the fixed continuous temperature recorders. The VPDES permit (Reference 4) also requires that a quarterly thermal plume survey be conducted at 14 stations located along the length of the North Anna Reservoir. At each station, temperature

measurements are taken from the water surface to the lake bottom at one-meter intervals. Figure 2.3-12 identifies the locations of these stations, which are designated as Stations A through N.

Water temperature statistics from 4 of the fixed continuous monitors are summarized in Table 2.3-7. The locations of these stations are as follows:

- North Anna Reservoir near the cooling water intakes for the existing units (Station 2/NALINT)
- The end of the discharge canal leading into Lagoon 1 of the WHTF (Station 7/NADISC1)
- Upstream of Dike 3 in Lagoon 3 of the WHTF (Station 9/NAWHTF3)
- North Anna Reservoir across from Burrus Point (Station 3/NALBRPT)

The same data are plotted in Figure 2.3-13 from 1978 through 2001 to illustrate temporal trends.

Table 2.3-7 Daily Water Temperature Statistics for Lake Anna

Statistic	Station 2 (NALINT)	Station 7 (NADISC1)	Station 9 (NAWHTF3)	Station 3 (NALBRPT)
Number measurements	8087	8175	8301	7823
Average, °F	63.8	77.1	69.7	65.6
Minimum, °F	34.2	39.4	36.1	34.7
Maximum, °F	90.1	102.2	95.0	89.4
80% quantile, °F	80.6	92.1	85.5	81.1
90% quantile, °F	83.7	96.1	88.7	84.2
95% quantile, °F	85.1	97.7	90.1	85.8
99% quantile, °F	87.3	100.2	92.5	87.6

Additional physical and chemical water quality parameters were measured as part of a Clean Water Act (CWA) 316(a) demonstration for the existing units (Reference 33). Fifteen physical and chemical parameters, in addition to water temperature, were monitored at 14 water quality stations in the North Anna Reservoir and the WHTF. The locations of these stations are shown on Figure 2.3-12. Eight of these water quality monitoring stations coincide with current fixed continuous temperature recorders, while the remaining six were located independently. Virginia Power has also measured selected water quality parameters at the same 14 water quality stations to support their operation of the existing units. Table 2.3-13 summarizes the water quality data obtained from the sources cited above for each of the water quality stations.

Pre-existing environmental stresses on the water quality of Lake Anna are described in the CWA 316(a) demonstration report (Reference 33). One known impact is associated with acid mine drainage into Contrary Creek due to historical mining of the Contrary Creek watershed for pyrite ore. This drainage produced higher concentrations of metals and an acidic pH in the Contrary

Creek arm of Lake Anna relative to the rest of the lake, which is evident in the data presented in Table 2.3-13.

Other known lake water impacts include elevated concentrations of nutrients associated with the application of fertilizers for crop production in the watershed. With declining agricultural activity in recent years, however, nutrient concentrations have decreased and stabilized since inundation. Compared to other regional lakes, there does not appear to be an excess of nutrients (Reference 33).

Several tributaries to the North Anna Reservoir, and portions of North Anna Reservoir, appear on the VDEQ's 303(d) list of impaired waters (Reference 34). Many of these waterways have been listed based on the presence of fecal coliform bacteria. The source of fecal coliform bacteria is stated to be unknown in the 303(d) report. Sources might include livestock, wildlife, failing septic systems, pets, and waste from boats (Reference 19). Contrary Creek, Goldmine Creek, and Lake Anna are listed due to the presence of polychlorinated biphenyls in fish tissues at concentrations in excess of the human health-based screening value. The source of this impairment is unknown. Contrary Creek has also been listed because of low pH.

The known permitted discharges to Lake Anna are limited to those from the existing units. These sources and permitted discharge limits are described in the VPDES permit (Reference 4).

2.3.3.2 Groundwater Aquifers

Groundwater at the ESP site occurs under water table conditions at depths ranging from about 6 to 58 feet in the saprolite and underlying metamorphic bedrock. The most dependable supplies of groundwater are obtained by wells drilled into the lower part of the weathered zone and the upper part of the underlying fractured bedrock (Reference 35). As presented in Section 2.3.2, the existing units obtain potable water from wells in these zones. Regionally, this aquifer can be considered a Piedmont crystalline aquifer (Reference 13). This aquifer is the primary groundwater aquifer that could affect plant water use and effluent disposal, or be affected by the construction, operation, or decommissioning of new units at the ESP site.

No site-specific data are available to establish the physical, chemical, and biological water quality characteristics of the groundwater at the ESP site. However, a number of studies have been conducted to characterize the water quality of the Piedmont crystalline aquifers in the region. Data published in these studies are expected to be representative of site conditions. Table 2.3-14 summarizes these regional data.

In comparison with groundwater in widely scattered regions of the world, the water in the Piedmont region ranks among the best in chemical quality (Reference 36). The groundwater from most light-colored crystalline metamorphic and igneous rocks of the region is generally soft (hardness ≤60 mg/l), slightly acidic (pH <7.0), and low in dissolved solids; while that from the dark-colored crystalline metamorphic and igneous rocks is generally harder, slightly more alkaline, and

moderately higher in dissolved solids (Reference 36). As Figure 2.3-13 illustrates, water from the crystalline rocks contains a balanced mixture of calcium, magnesium, and sodium ions. This figure also indicates that the water is rich in bicarbonate ions. The crystalline igneous and metamorphic rocks of the Piedmont province also have relatively high levels of naturally occurring radioactivity in the groundwater (Reference 37).

Based on the Louisa County Water Testing Program undertaken in 1992, there is evidence of groundwater quality degradation near the ESP site due to coliform contamination (Reference 19). Of the 119 wells tested by Louisa County in 1992, 29 wells were in the Lake Anna watershed. Of those 29, 18 were residential, 10 were on farms, and one was at a quarry. Sixteen of the 29 wells were in the lakeside area. All wells in the Louisa County Water Testing Program were tested for pH, total and fecal coliforms, metals, anions, and total organic carbon. Of the 29 wells in the Lake Anna watershed, total and fecal coliforms were present in 41 percent and 31 percent of the wells, respectively. Sources of this coliform contamination likely include the septic systems typically used by the residential developments and farms surrounding Lake Anna. Of the remaining parameters for which tests were conducted, only manganese and nitrate were found at elevated levels in the Louisa County portion of the Lake Anna watershed. Four of the 29 wells had manganese present at concentrations in excess of the secondary maximum contaminant level of 0.05 mg/l. One well, located on a farm, had nitrate present at a concentration in excess the maximum contaminant level of 10 mg/l. (Reference 19)

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Table 2.3-8 Monthly Streamflow Statistics (cfs)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pamunkey Creek at Lahore, VA												
N	4	4	3	4	3	3	3	3	4	3	3	4
Min	25.7	25	37.9	35.3	19.9	14.4	14.9	1.46	2.03	2.3	6.25	24.6
Mean	61.2	37.5	49.0	62.0	43.0	23.9	19.3	9.72	14.5	31.8	31.8	47.6
Max	91.5	53.5	65.3	114	81	32.8	26.6	16.6	22.2	57.1	49.1	87.7
Contrary Creek near Mineral, VA												
N	11	11	11	11	11	11	11	11	11	12	12	12
Min	1.69	3.49	2.05	2.18	1.66	0.63	0.31	0.1	0.13	0.67	0.68	1.64
Mean	7.97	9.37	8.92	8.36	4.33	2.46	1.34	3.40	1.20	3.16	5.05	5.46
Max	20.1	25.5	21.9	21.1	12.8	6.76	2.27	14.3	4.13	10.5	19	8.68
North Anna River near Partlow, VA												
N	17	17	17	17	17	17	17	17	17	17	17	17
Min	45.2	55.6	51.8	55.7	53.5	46.1	45.7	49.1	44.3	42.4	44	45.4
Mean	401	507	601	485	330	215	133	134	109	138	244	265
Max	926	1361	1762	1378	947	784	563	478	530	1085	1230	682
North Anna River near Doswell, VA												
N	58	58	58	59	59	59	59	59	59	59	59	59
Min	68.1	87.2	77.7	91.6	111	71.2	32.2	14.7	6.16	5.45	24.8	53.2
Mean	554	602	645	592	368	244	210	269	177	230	285	407
Max	1974	1767	1515	1922	1043	1325	1321	2688	1490	1345	1464	1723
North Anna River at Hart Corner near Doswell, VA												
N	22	22	22	22	22	22	22	22	22	22	22	22
Min	71.9	100	90.5	108	61.9	50.6	47.7	49.3	41.7	43.7	46.7	75.2
Mean	536	677	820	648	424	244	159	155	144	207	315	377
Max	1389	2660	2345	1887	1217	795	591	614	1185	1428	1561	1320
Pamunkey River near Hanover, VA												
N	60	60	60	60	60	60	60	60	60	60	60	60
Min	197	396	248	434	197	82	91.9	63.1	30.3	60.6	113	166
Mean	1434	1624	1883	1535	1027	680	501	619	427	581	727	1114
Max	4334	7118	5430	5009	2821	4293	2747	6381	2939	3461	3505	3782

N = number of monthly observations
Min = minimum monthly value
Mean = average monthly value
Max = maximum monthly value

Table 2.3-9 Quarterly Groundwater Level Elevations

Observation Well No.	Well Depth* (ft)	Reference Point Elev. (ft)	Reference Point Stickup** (ft)	Top of Well Screen Elev. (ft)	Well Screen Length (ft)	Groundwater Level Elevations		
						12/17/02	03/17/03	06/17/03
OW-841	34.3	251.6	1.5	228.1	9.7	248.9	249.6	249.6
OW-842	49.6	336.7	1.5	297.8	9.6	307.5	308.9	310.8
OW-843	49.2	320.6	1.5	282.1	9.7	285.1	288.1	290.8
OW-844	24.6	273.5	1.5	257.6	9.6	265.5	266.7	267.3
OW-845	55.0	297.3	1.5	253.0	9.7	272.7	274.9	277.4
OW-846	32.7	297.3	1.5	273.5	9.8	272.5	274.8	277.1
OW-847	49.8	319.7	1.5	280.6	9.6	285.4	287.0	289.5
OW-848	47.3	284.5	1.5	240.8	5.0	241.7	242.9	243.6
OW-849	49.8	298.5	1.5	259.4	9.7	265.5	269.5	271.7
P-10	22.5	286.4	2.4	267.0	5	274.4	274.8	275.2
P-14	N/A	327.1	N/A	N/A	N/A	271.6	272.2	272.8
P-18	N/A	329.0	N/A	N/A	N/A	285.7	286.5	287.5
P-19	58.5	322.3	N/A	N/A	5	284.3	285.2	286.3
P-20	61.0	320.6	N/A	N/A	5	274.9	275.4	275.8
P-21	58.5	319.2	N/A	N/A	5	Dry	261.2	262.0
P-22	60.0	320.5	N/A	N/A	5	276.8	277.8	278.6
P-23	41.2	296.4	1.9	258.7	5	261.1	262.6	263.3
P-24	25.0	293.4	2.3	271.3	5	276.4	277.1	278.4
WP-3	N/A	317.9(?)	N/A	266.5	5	299.7	301.0	302.8
Lake Anna Water Level Elevation						248.1	250.1	250.4
Service Water Reservoir Water Level Elevation						314.6	313.3	314.6

OW - wells installed in December 2002 as part of ESP Subsurface Investigation Program.
P - wells installed previously to monitor NAPS Units 1 and 2 Service Water Reservoir.
WP - well installed previously as part of Independent Spent Fuel Storage Installation monitoring program.
* Below ground surface at time of installation.
** Above ground surface at time of installation.
N/A - not available

Table 2.3-10 Hydraulic Conductivity Values

Observation Well No.	Depth Interval Tested (ft)	Elevation	Material	Hydraulic Conductivity	
				cm/sec	ft/day
PT-1[a]	Near-surface	Unknown	Saprolite	2.8×10^{-5}	0.08
PT-2[a]	Near-surface	Unknown	Saprolite	1.4×10^{-5}	0.04
P-10[b]	14.5 - 22.5	269.5 - 261.5	Saprolite	6.1×10^{-4} to 6.1×10^{-5}	1.7 to 0.17
P-24[b]	16.8 - 25.0	274.3 - 266.1	Saprolite	2.9×10^{-4} to 6.6×10^{-6}	0.8 to 0.02
P-23[b]	33.7 - 41.2	260.7 - 253.2	Saprolite	6.6×10^{-5}	0.19
OW-844[c]	12.7 - 24.6	259.3 - 247.4	Saprolite	9.9 to 8.9×10^{-5}	0.28 to 0.25
OW-841[c]	20.1 - 34.3	230.0 - 215.8	Saprolite	8.2 to 7.8×10^{-4}	2.3 to 2.2
OW-846[c]	20.3 - 32.7	275.5 - 263.1	Saprolite	1.2×10^{-3} to 6.8×10^{-4}	3.4 to 1.9
OW-847[c]	35.0 - 49.8	283.2 - 268.4	Saprolite	2.3 to 2.1×10^{-4}	0.66 to 0.58
OW-842[c]	35.3 - 49.6	299.9 - 285.6	Saprolite	3.3×10^{-4}	0.93
OW-849[c]	35.6 - 49.8	261.4 - 247.2	Saprolite	1.1×10^{-3} to 7.0×10^{-4}	3.2 to 2.0
OW-843[c]	36.4 - 49.2	282.7 - 269.9	Saprolite	4.9 to 4.5×10^{-4}	1.4 to 1.3
OW-848[c]	39.1 - 47.3	243.9 - 235.7	Saprolite	1.2×10^{-3} to 9.9×10^{-4} [d]	3.4 to 2.8 [d]
OW-845[c]	39.7 - 55.0	256.1 - 240.8	Quartz Gneiss	1.1×10^{-3} to 6.3×10^{-4} [e]	3.1 to 1.8 [e]
Test Results					
B-48[a]	3.5	290.5	Sandy silt	1×10^{-6}	0.003
B-8[a]	5.5	293.5	Fine sand, tr. silt	1×10^{-6}	0.003
B-2[a]	15.5	269.5	Fine to med. sand, w/clayey silt	4×10^{-5}	0.11
B-15[a]	36	281	Silty fine sand	1.3×10^{-5}	0.04

a. Reference 15

b. Reference 23

c. Part 2: Appendix 2.5.4B

d. Results may not be accurate due to static water level approximately 0.5 ft below top of well screen.

e. Results not be accurate due to short duration of stable water level recovery measurements.

Table 2.3-11 Public Groundwater Supplies In Louisa County

Installation	Type[a]	Water Source	Depth (ft)	Measured Yield (gpd)	Design Yield (gpd)	Population Served [a]	Active/ Inactive [(a)]
Town of Louisa [(b)] (primary source is surface water)	Community	spring	NA	38,880		1950	
		3 wells	200–405	43,200–53,280			
Town of Mineral [(b)]	Community	2 springs	NA	57,600		670	A
		4 wells	200–600	14,400–165,600			
Acorn West Trailer Park [(b)]	Community	well	120	8640		70	I
Apple Grove School [(a)]	Transient Non-Community					200	I
Blue Ridge Shores [(b)]	Community	4 wells	163–405	288,000	160,000	1450	A
Bumpass Park/Lake Anna Rescue [(a)]	Transient Non-Community					250	A
Burger King Zion Crossroads [(a)]	Transient Non-Community					250	A
Cable Form [(a)]	Transient Non-Community					11	I
Christopher Run Campground [(a)]	Transient Non-Community					608	A
Country Side II [(a)]	Transient Non-Community					50	I
Crescent Inn Restaurant [(a)]	Transient Non-Community					150	A
Crossing Point (VA Oil Co) [(b)]	Non-Transient Non-Community	2 wells	305	21,600–28,800	10,400	45	A
Deb's Place [(a)]	Transient Non-Community					50	I

Table 2.3-11 Public Groundwater Supplies In Louisa County

Installation	Type[a]	Water Source	Depth (ft)	Measured Yield (gpd)	Design Yield (gpd)	Population Served [a]	Active/ Inactive [(a)]
East End Elementary School [(b)]		well	345	61,920	31,200		
Expressions Learning Center [(b)]	Non-Transient Non-Community	well	205	17,280		45	A
Green Springs School [(a)]	Transient Non-Community					300	I
Jerdone Island [(b,c)]	Community	well	200	83,520	19,600	49	A
Jouette Elementary School [(b)]	Non-Transient Non-Community	well	345	61,920	19,600	741	A
Junction Restaurant [(a)]	Transient Non-Community					25	I
Junction Restaurant [(a)]	Transient Non-Community					50	I
Klockner Barrier Films [(b)]		well	305	53,280	22,000		
Klockner-Pentaplast [(b)]	Non-Transient Non-Community	2 wells	205–280	21,600–57,600	44,000	526	A
Lake Anna Estates Trailer Park [(a)]	Community					50	I
L A Pizza [(a)]	Transient Non-Community					25	I
Lake Anna Plaza [(d)]	Community	2 wells	335–230	11,520–86,400	41,200	100	A
Louisa County Senior Center [(a)]	Transient Non-Community					45	I
Louisa County Water Authority [(a,b)]	Non-Transient Non-Community	well	550	34,560		192	I
Louisa County Zion Crossroads [(a)]	Non-Transient Non-Community					600	A

Table 2.3-11 Public Groundwater Supplies In Louisa County

Installation	Type[a]	Water Source	Depth (ft)	Measured Yield (gpd)	Design Yield (gpd)	Population Served [a]	Active/ Inactive [(a)]
Louisa Day Care Center [(a)]	Transient Non-Community					30	I
Louisa Intermediate School [(a)]	Transient Non-Community					900	I
Mount Garland School [(a)]	Transient Non-Community					140	I
Ole Country Inn [(a)]	Transient Non-Community					50	I
Prospect Hill [(a)]	Transient Non-Community					50	A
Raynell's [(a)]	Transient Non-Community					25	I
Sandra Carter [(a)]	Community					36	I
Shenandoah Crossing [(b)]	Non-Transient Non-Community	2 wells	280–300	123,840–97,920	98,400	850	A
Siebert's Amoco & Dairy Queen [(a)]	Transient Non-Community					950	A
Six-o-Five Village [(b)]	Community	2 wells	310–365	64,800–10,800	10,700	201	A
Small Country Campground [(a)]	Transient Non-Community					112	A
Tavern on the Rail [(a)]	Transient Non-Community					150	A
Trevillians Elementary School [(b)]	Non-Transient Non-Community	well	204	57,600	19,600	676	A
Trevilians Square Apartments [(a)]	Community					61	A

Table 2.3-11 Public Groundwater Supplies In Louisa County

Installation	Type[a]	Water Source	Depth (ft)	Measured Yield (gpd)	Design Yield (gpd)	Population Served [a]	Active/ Inactive [(a)]
Twin Oaks Community [(b)]	Community	well	250 [(e)]	7200		75	A
West End Elementary School [(b)]		well	204	57,600	20,000		
Wooden Nickle [(a)]	Transient Non-Community					25	I

Note: Blank entries indicate data not provided in cited reference.

a. Reference 38
b. Reference 25
c. Reference 39
d. Reference 40
e. Reference 1

Table 2.3-12 North Anna Power Station Groundwater Use[a] January 1, 2002 to December 31, 2002

Month	Well #2	Well #3A	Well #4	Well #6	NANIC
	(Millions of Gallons)				
January	0.0032	0.4268	0.4519	0.7444	0.0485
February	0.0032	0.1395	0.4010	0.5095	0.0467
March	0.0025	0.0263	0.1050	0.1642	0.0555
April	0.0046	0.0368	0.1253	0.1459	0.0474
May	0.0076	0.0376	0.2565	0.1041	0.0690
June	0.0021	0.0531	0.2524	0.1458	0.0502
July	0.0018	0.0511	0.3585	0.0189	0.0525
August	0.0077	0.0611	0.3434	0.0526	0.0656
September	0.0071	0.1020	0.4018	0.1655	0.0474
October	0.0062	0.0874	0.2118	0.1574	0.0651
November	0.0148	0.0694	0.2126	0.1846	0.0586
December	0.0037	0.2005	0.0648	0.2070	0.0482
Total	0.0645	1.2916	3.1850	2.5999	0.6547
Monthly Average	0.0054	0.1076	0.2654	0.2167	0.0546

a. Reference 41

Table 2.3-13 Water Quality Statistics for Lake Anna

Statistic	Hardness (mg/l as $CaCO_3$)	Turbidity (NTU)	Dissolved Oxygen (mg/l)	Total Phosphate (mg/l as P)	Ortho-phosphate (mg/l as P)	Meta-phosphate (mg/l as P)	Ammonia (mg/l as N)	Nitrate (mg/l as N)	Alkalinity (mg/l as $CaCO_3$)	Sulfate (mg/l as SO_4)	Copper (mg/l as Cu)	Iron (mg/l as Fe)	Lead (mg/l as Pb)	Zinc (mg/l as Zn)	pH (SU)
Pamunkey Creek Arm of Lake Anna at Route 719 Bridge (Station 5/NAL719N)															
Observations	84	192	192	97	49	79	106	99	192	116	22	99	5	33	206
Average	18.92	8.07	8.41	0.05	0.02	0.04	0.07	0.48	14.62	7.70	0.02	0.30	0.12	0.02	7.07
Maximum	39.3	37	13.6	0.33	0.26	0.21	0.24	3.16	21.2	17.5	0.05	3.4	0.3	0.15	8.9
Minimum	7.8	0.4	0.1	0.01	0	0	0.01	0.01	6.8	1.6	0.003	0.01	0.002	0.01	6.3
North Anna River Arm of Lake Anna at Route 719 Bridge (Station 6/NAL719S)															
Observations	84	192	192	94	45	88	95	95	192	115	24	98	9	34	206
Average	18.37	6.80	8.63	0.05	0.02	0.04	0.05	0.41	14.64	7.46	0.02	0.34	0.13	0.02	7.08
Maximum	39.3	41	14.2	0.16	0.05	0.16	0.2	2.05	25.8	18	0.04	6.81	0.38	0.11	8.5
Minimum	8.9	0.4	0	0.01	0	0	0.01	0.01	6.1	1.3	0.001	0.05	0.002	0.01	6.2
Lake Anna at Route 208 Bridge (Station 4/NAL208)															
Observations	51	192	192	53	8	50	73	80	192	80	28	102	7	66	213
Average	14.14	3.46	8.50	0.04	0.06	0.04	0.07	0.15	10.83	8.16	0.06	0.48	0.10	0.03	6.90
Maximum	22.2	20	13.8	0.3	0.3	0.25	0.91	0.58	19.3	11.6	1.1	22.15	0.38	0.11	7.4
Minimum	5.1	0.3	0.1	0.01	0.01	0.01	0.01	0.01	7.1	4	0.003	0.03	0	0.01	5.6
Contrary Creek Arm of Lake Anna															
Observations	36	176	176	8	5	5	36	32	167	36	50	85	6	78	191
Average	17.81	3.84	8.88	0.07	0.03	0.09	0.06	0.09	5.51	17.15	0.07	0.78	0.11	0.28	6.09
Maximum	32.5	40.4	13.5	0.32	0.06	0.26	0.35	0.22	15.2	39.8	0.22	6.4	0.18	1.14	7.4
Minimum	12	0.2	0.2	0.01	0.01	0.01	0.01	0.01	0	10.6	0.01	0.07	0.01	0.01	3.8

Note: Blank entries indicate no data available.

Table 2.3-13 Water Quality Statistics for Lake Anna

Statistic	Hardness (mg/l as $CaCO_3$)	Turbidity (NTU)	Dissolved Oxygen (mg/l)	Total Phosphate (mg/l as P)	Ortho-phosphate (mg/l as P)	Meta-phosphate (mg/l as P)	Ammonia (mg/l as N)	Nitrate (mg/l as N)	Alkalinity (mg/l as $CaCO_3$)	Sulfate (mg/l as SO_4)	Copper (mg/l as Cu)	Iron (mg/l as Fe)	Lead (mg/l as Pb)	Zinc (mg/l as Zn)	pH (SU)
Lake Anna at North Anna Power Station Intakes (Station 2/NALINT)															
Observations	72	178	178	76	29	59	89	102	178	105	27	94	11	60	199
Average	14.14	2.66	8.46	0.04	0.03	0.04	0.07	0.39	10.13	9.06	0.02	0.23	0.07	0.02	6.89
Maximum	27.4	13	13.2	0.45	0.16	0.29	0.19	1.57	18	18	0.04	3.97	0.19	0.043	7.5
Minimum	5.2	0.6	0.1	0	0	0	0.01	0.04	6.9	3.5	0.001	0.03	0.002	0.008	5.1
Lake Anna at Mid Lake															
Observations	36	72	72	42	11	38	56	68	72	67	2	52	2	26	93
Average	13.65	2.42	8.30	0.05	0.07	0.04	0.07	0.17	9.17	8.44	0.02	0.38	0.01	0.02	6.88
Maximum	18.8	9.5	12.8	0.35	0.25	0.14	0.19	0.48	15	14	0.03	8.96	0.02	0.04	7.3
Minimum	10.3	0.6	0.2	0.01	0.01	0.01	0.02	0.05	6.9	3.6	0.003	0.03	0.001	0.01	6.1
Lake Anna Near Burrus Point															
Observations	33	72	72	14	6	13	36	36	72	36		35		18	72
Average	13.37	2.29	8.26	0.12	0.07	0.10	0.07	0.15	9.19	8.52		0.10		0.01	6.92
Maximum	18.8	6	12.8	0.45	0.18	0.41	0.12	0.34	16.4	11.8		0.16		0.02	7.3
Minimum	1.2	0.2	0.6	0.01	0.02	0.01	0.03	0.06	7.3	7.3		0.04		0.01	6.7
Lake Anna Near Dike 3 (Station 10/NALST10)															
Observations	36	72	72	13	5	10	36	36	72	36		36		21	72
Average	13.70	2.23	8.29	0.10	0.22	0.02	0.08	0.15	9.00	8.34		0.11		0.01	6.90
Maximum	17.1	7.4	12.5	0.9	0.9	0.04	0.13	0.3	12.1	9.8		0.17		0.03	7.2
Minimum	10.3	0.7	4.7	0.01	0.02	0.01	0.03	0.06	5	7.2		0.03		0.01	6.3

Note: Blank entries indicate no data available.

Table 2.3-13 Water Quality Statistics for Lake Anna

Statistic	Hardness (mg/l as $CaCO_3$)	Turbidity (NTU)	Dissolved Oxygen (mg/l)	Total Phosphate (mg/l as P)	Ortho-phosphate (mg/l as P)	Meta-phosphate (mg/l as P)	Ammonia (mg/l as N)	Nitrate (mg/l as N)	Alkalinity (mg/l as $CaCO_3$)	Sulfate (mg/l as SO_4)	Copper (mg/l as Cu)	Iron (mg/l as Fe)	Lead (mg/l as Pb)	Zinc (mg/l as Zn)	pH (SU)
Lake Anna at the Dam															
Observations	84	192	192	79	31	61	99	115	192	116		101		69	213
Average	15.27	3.03	7.89	0.03	0.01	0.03	0.10	0.39	10.64	9.01		0.29		0.03	6.86
Maximum	42.8	17	12.8	0.09	0.05	0.08	0.84	2.13	34.4	18.8		5.19		0.15	7.3
Minimum	5.1	0.2	0	0.01	0	0.01	0.01	0.01	6.6	3.5		0.01		0.01	6.2
Lagoon 1 of the WHTF (Station 7/NADISC1)															
Observations	72	180	180	75	35	59	92	100	180	101		85		44	194
Average	14.98	2.65	8.66	0.03	0.02	0.02	0.06	0.39	10.02	9.03		0.15		0.03	6.92
Maximum	29.1	8.5	13	0.17	0.16	0.08	0.18	1.57	18	16.8		0.71		0.17	7.3
Minimum	6.1	0.2	5	0	0	0	0.01	0.05	6.3	0.3		0.01		0.01	6.4
Elk Creek Arm of the Waste Heat Treatment Facility															
Observations		174	174						174						174
Average		2.48	8.69						9.91						6.98
Maximum		6.9	13.2						14.4						7.6
Minimum		0.2	1.2						6.2						6.5
Millpond Creek Arm of the Waste Heat Treatment Facility															
Observations		180	180						180						180
Average		2.66	8.56						9.76						6.97
Maximum		17	13						16.5						7.4
Minimum		0.2	0.3						6.5						6.5

Note: Blank entries indicate no data available.

Table 2.3-13 Water Quality Statistics for Lake Anna

Statistic	Hardness (mg/l as $CaCO_3$)	Turbidity (NTU)	Dissolved Oxygen (mg/l)	Total Phosphate (mg/l as P)	Ortho-phosphate (mg/l as P)	Meta-phosphate (mg/l as P)	Ammonia (mg/l as N)	Nitrate (mg/l as N)	Alkalinity (mg/l as $CaCO_3$)	Sulfate (mg/l as SO_4)	Copper (mg/l as Cu)	Iron (mg/l as Fe)	Lead (mg/l as Pb)	Zinc (mg/l as Zn)	pH (SU)
Lagoon 2 of the WHTF (Station 8/NAWHTF2)															
Observations	24	183	183	30	1	30	48	56	183	56	2	39	1	14	204
Average	13.06	2.36	8.08	0.04	0.13	0.04	0.05	0.17	9.75	8.30	0.03	0.20	0.02	0.02	6.90
Maximum	17.1	6.2	12.7	0.41	0.13	0.41	0.1	0.66	16	13.4	0.03	0.88	0.02	0.1	7.4
Minimum	10.3	0.2	0.2	0.01	0.13	0.01	0	0.01	6.6	6	0.02	0.04	0.02	0.01	6.2
Lagoon 3 of the WHTF (Station 9/NAWHTF3)															
Observations	69	180	179	71	30	56	84	101	180	101	24	89	6	45	200
Average	14.81	2.54	8.36	0.03	0.04	0.03	0.07	0.39	9.53	9.06	0.03	0.19	0.11	0.02	6.90
Maximum	32.5	7.2	12.7	0.4	0.42	0.15	0.14	2.89	17	16.8	0.05	3.01	0.18	0.06	7.3
Minimum	4.4	0.2	1.5	0.01	0	0	0.01	0	6.2	3.5	0.01	0.03	0.01	0.01	6.2

Note: Blank entries indicate no data available.

Table 2.3-14 Water Quality Data for the Piedmont Crystalline Aquifers

Parameter	Average	Maximum	Minimum	Source
Total Dissolved Solids (mg/l)	100	200	40	Reference 37
	70-150	250		Reference 42
	60-120			Reference 43
Hardness (mg/l as $CaCO_3$)	40	100	10	Reference 37
	10-50	100	10	Reference 42
	20-70			Reference 43
Nitrate (mg/l as N)	0.05	1	< 0.01	Reference 37
	< 10	20		Reference 42
Chloride (mg/l)	1-20	40	1	Reference 42
Sulfate (mg/l)	1-40	100	1	Reference 42
Calcium (mg/l)	5-20	60	5	Reference 42
Magnesium (mg/l)	5-20	60	5	Reference 42
Silica (mg/l)	20-35	45	15	Reference 42
Iron (mg/l)	20	600	< 10	Reference 37
	< 0.3			Reference 42
Bicarbonate (mg/l as HCO_3)	30-100	150	15	Reference 42
pH	5.5-6.8	7.5	5.5	Reference 42

Note: Blank entries indicate data not provided in cited reference.

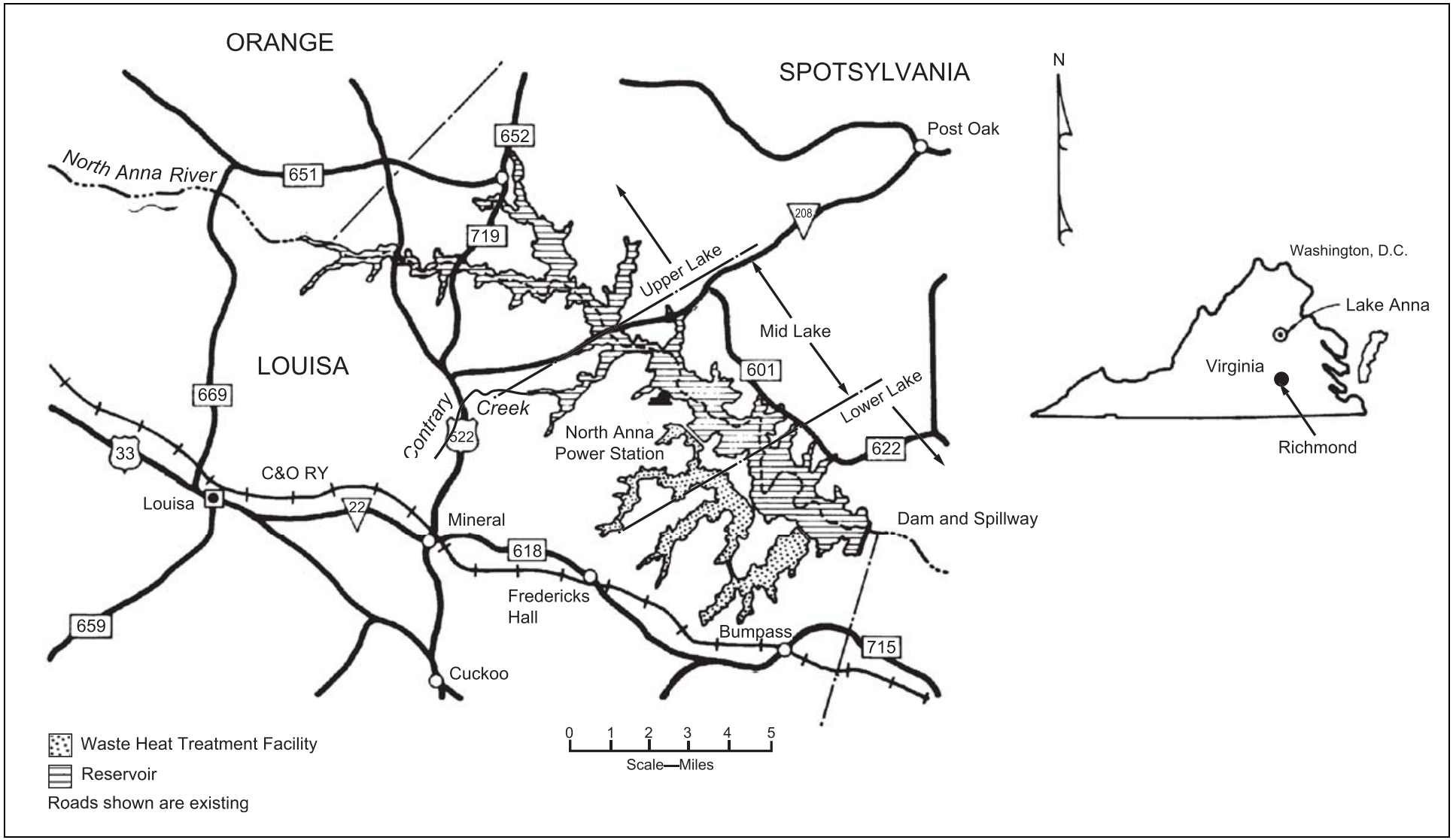

Figure 2.3-1 Lake Anna

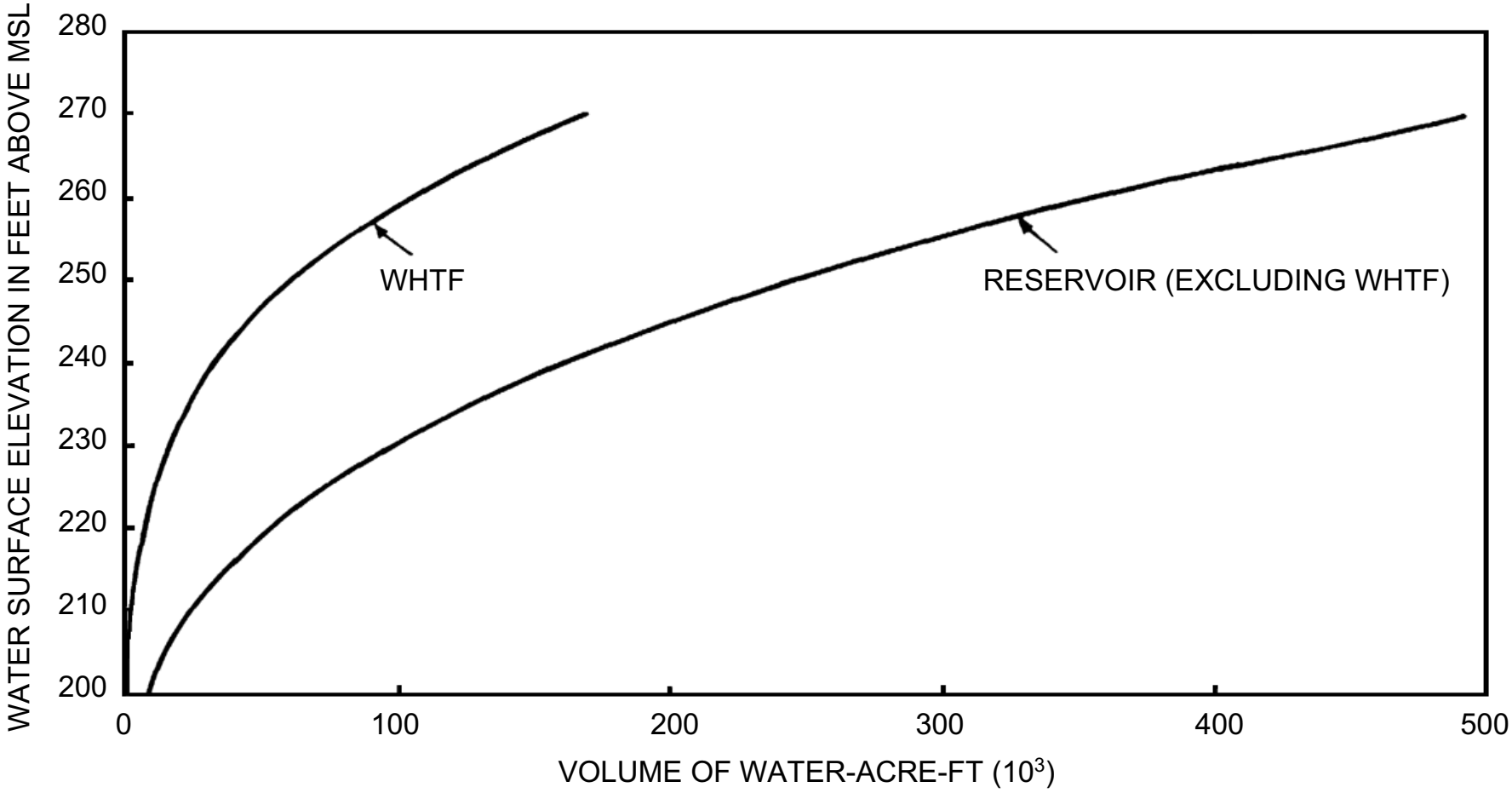

Figure 2.3-2 Elevation-Storage Curves for North Anna Reservoir and Waste Heat Treatment Facility

Figure 2.3-3 Deleted

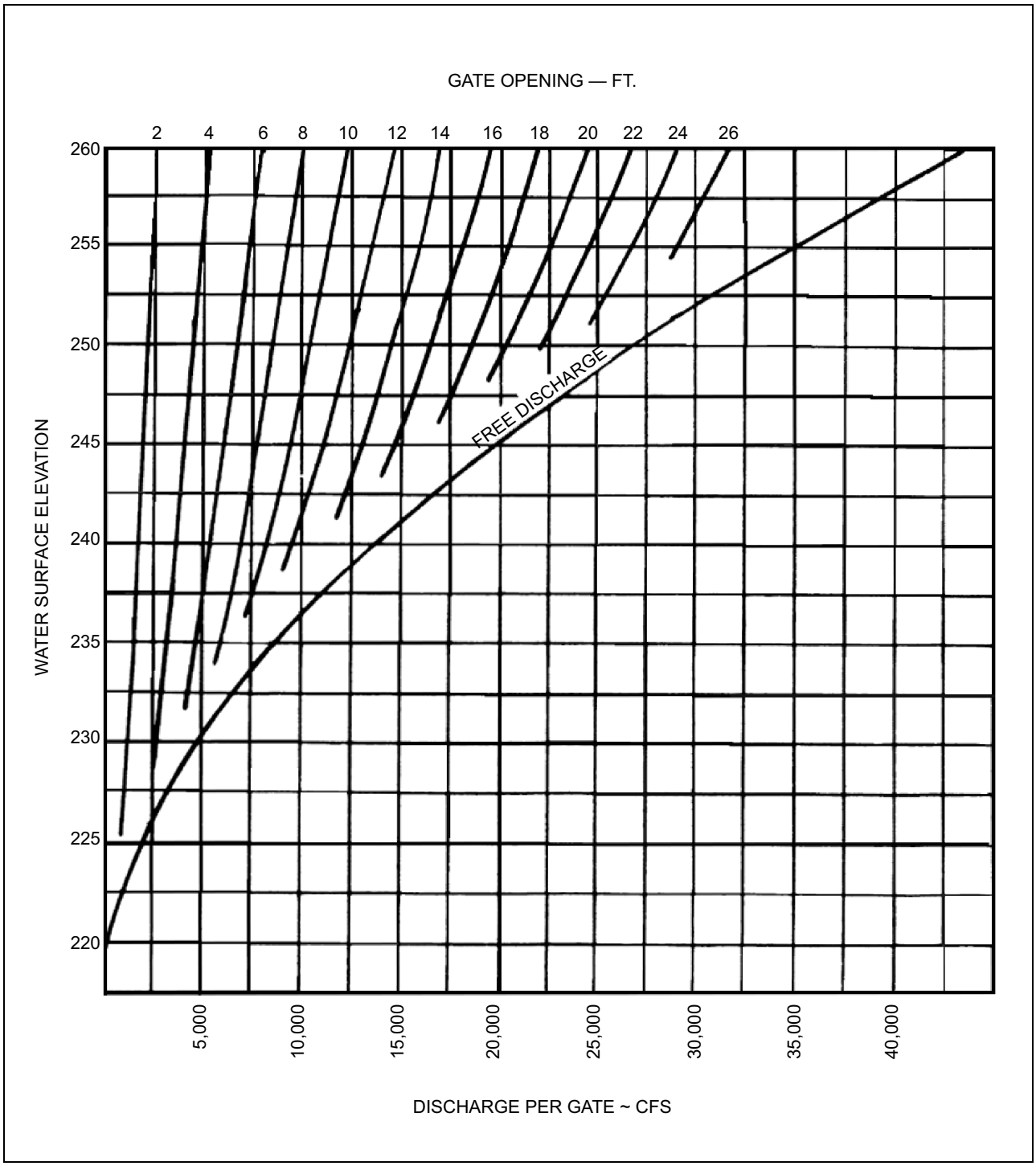

Figure 2.3-4 Spillway Discharge Capacity (One Gate of Three) North Anna Dam

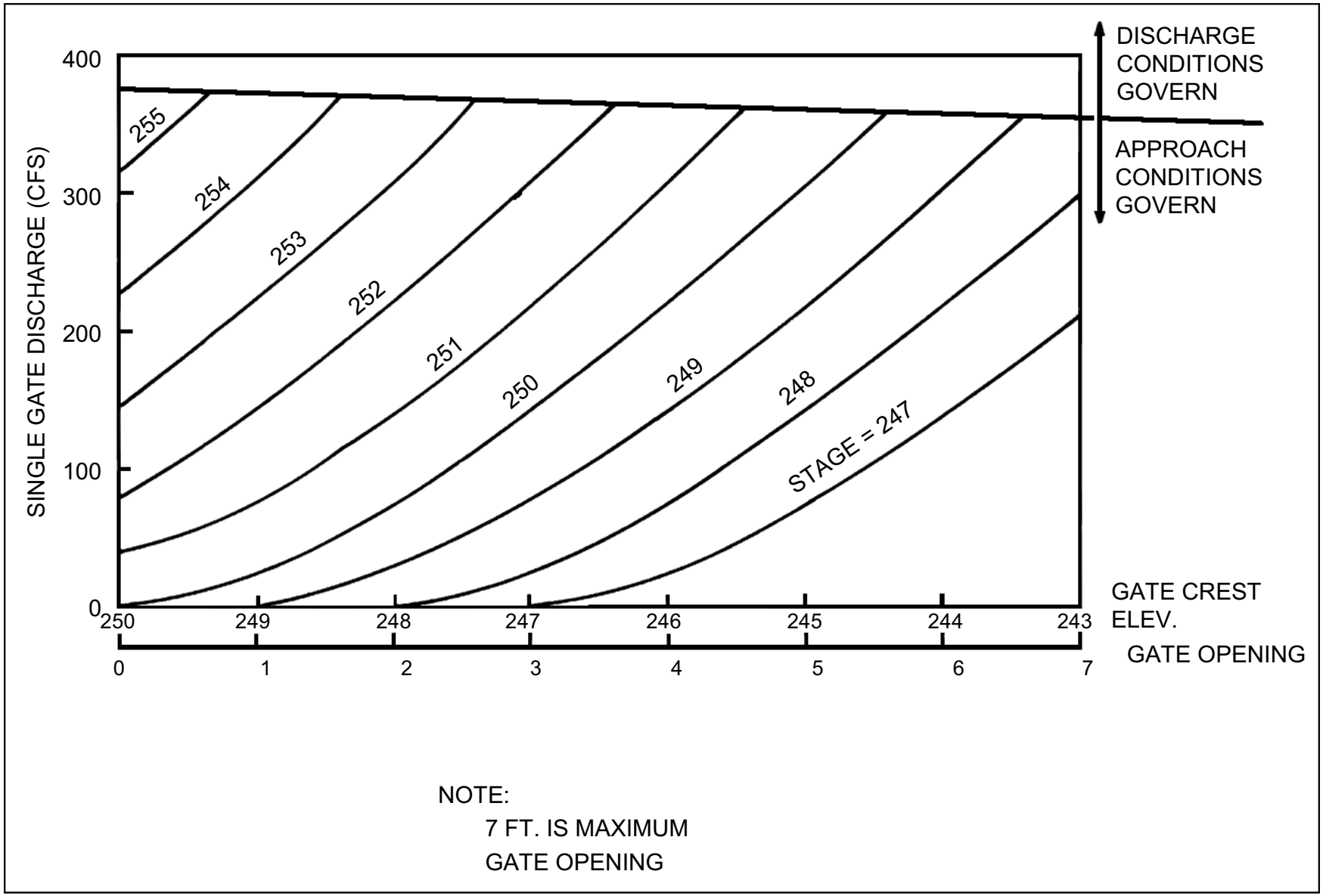

Figure 2.3-5 Skimmer Gate Discharge Capacity for North Anna Dam

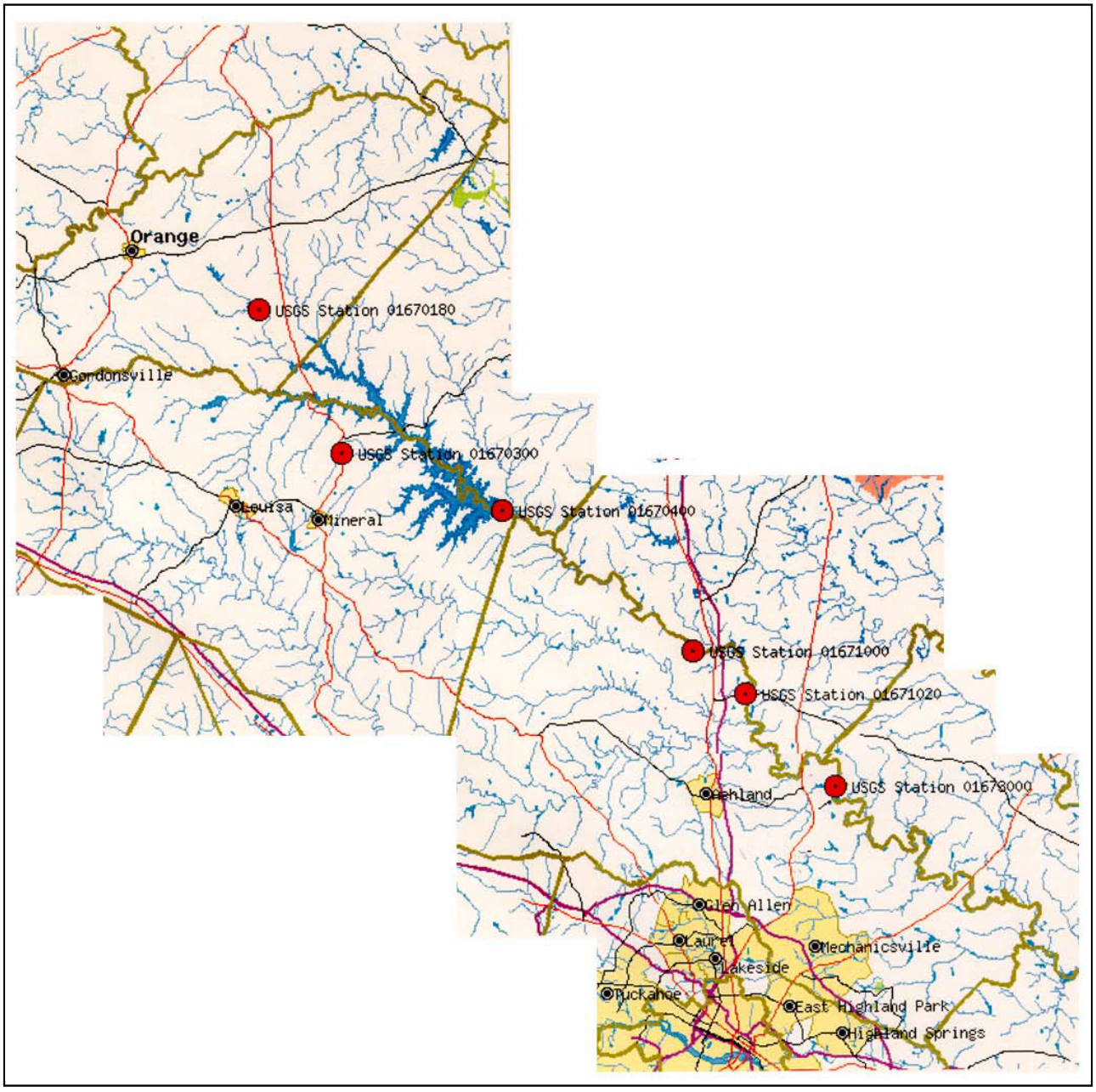

Figure 2.3-6 Locations of USGS Stream Gauging Stations in the North Anna River Watershed

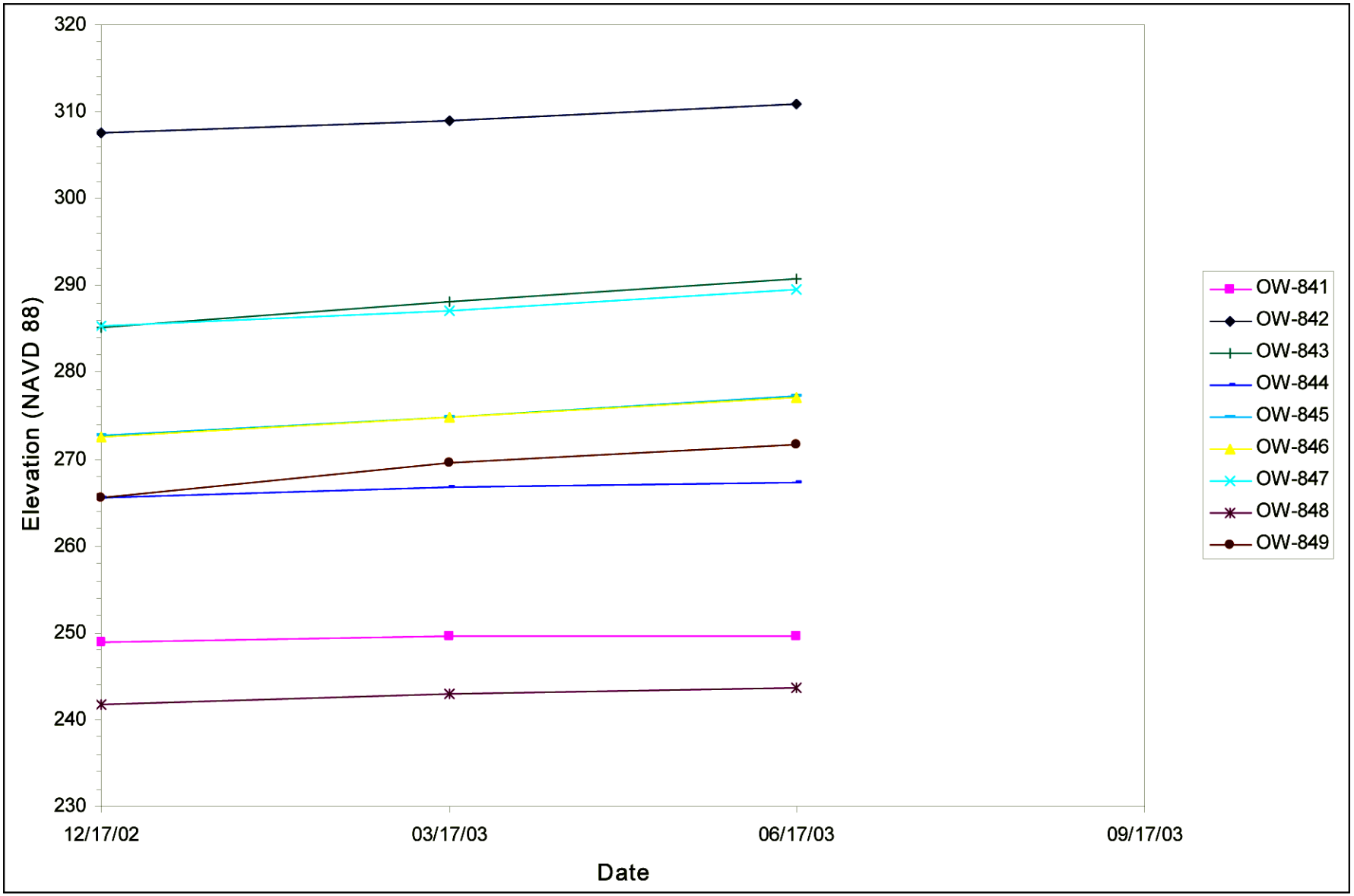

Figure 2.3-7 Ground Water Level Hydrographs

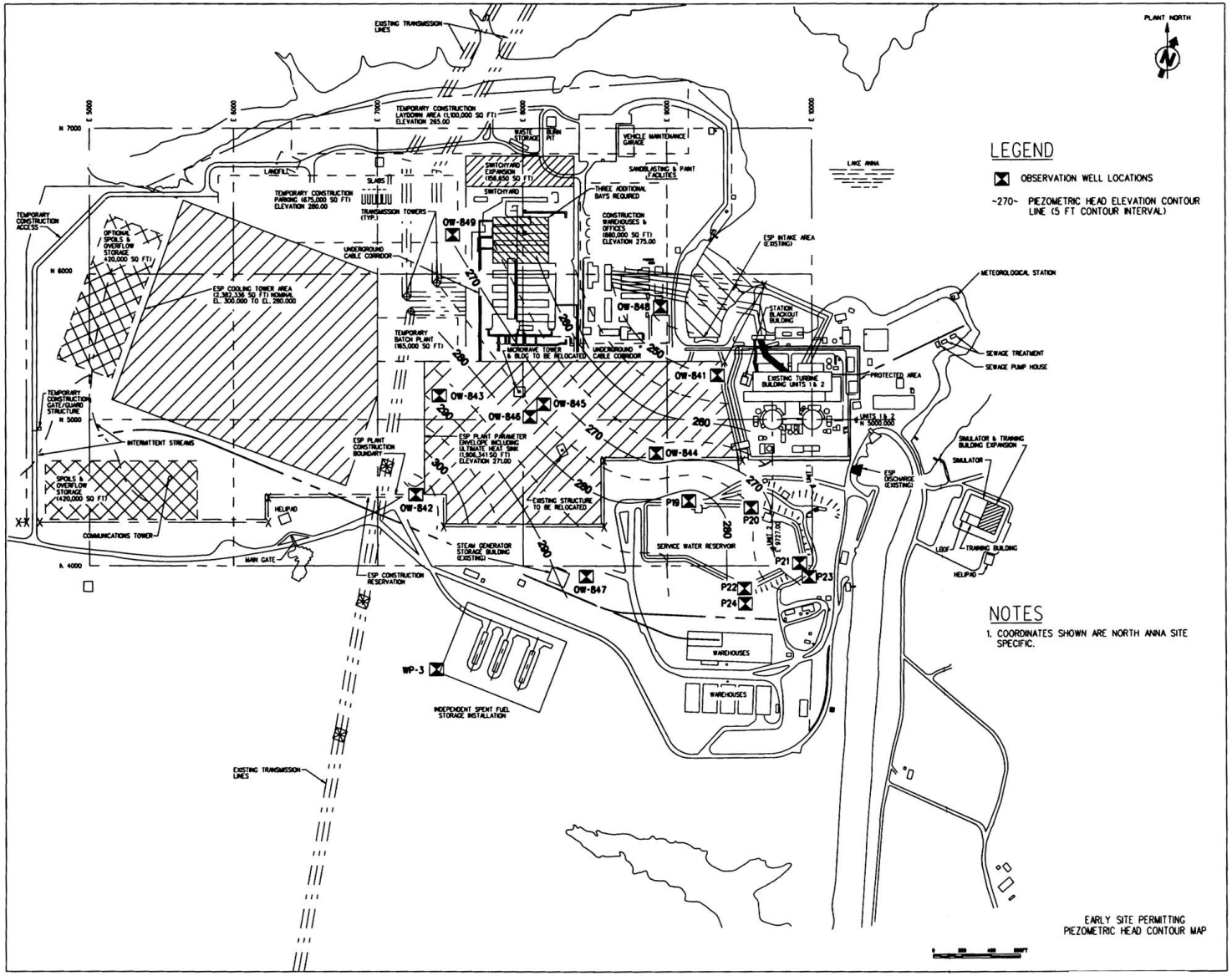

Figure 2.3-8 Piezometric Head Contour Map

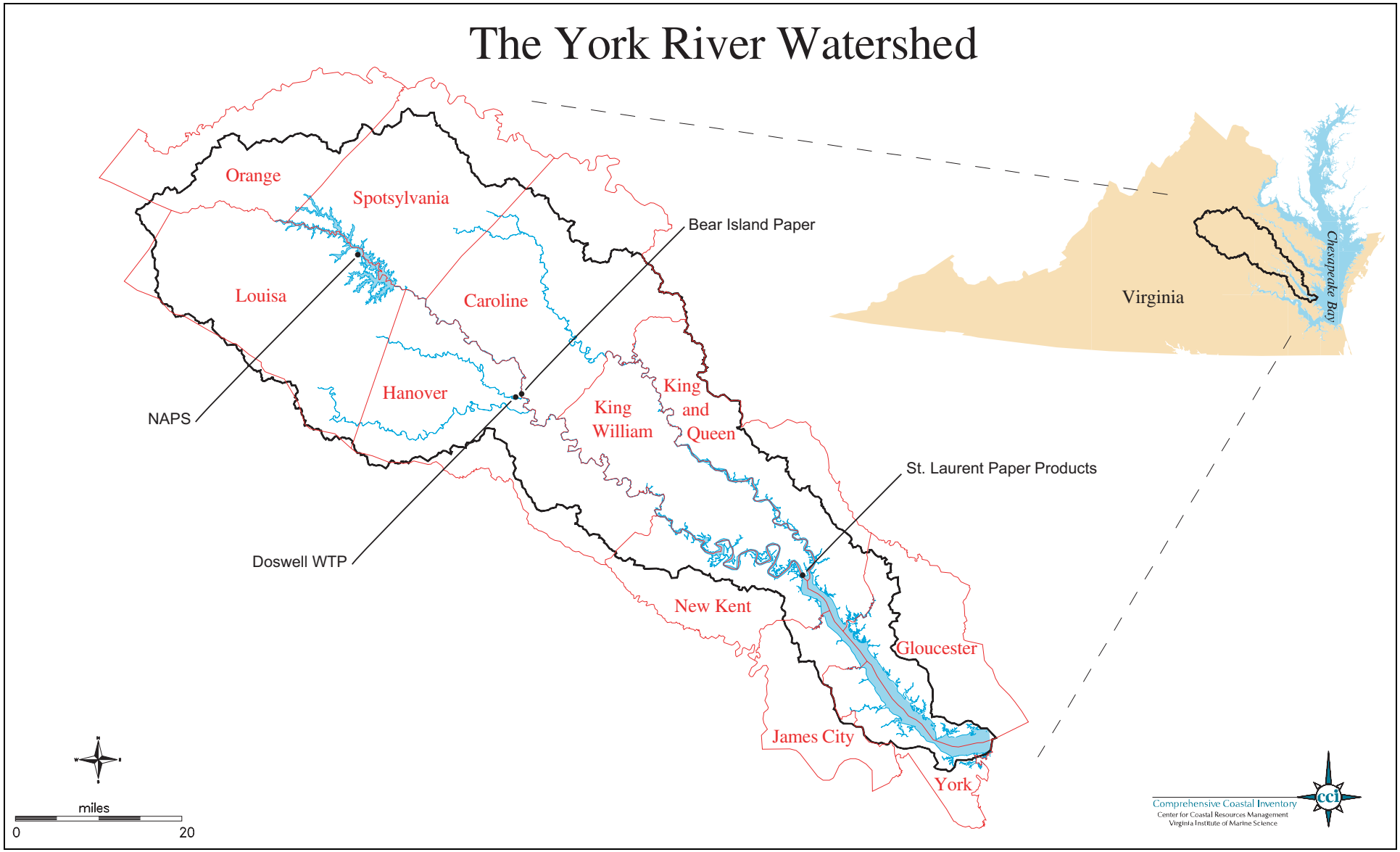

Figure 2.3-9 Surface Water Bodies That Could Affect or Be Affected by Plant Water Use

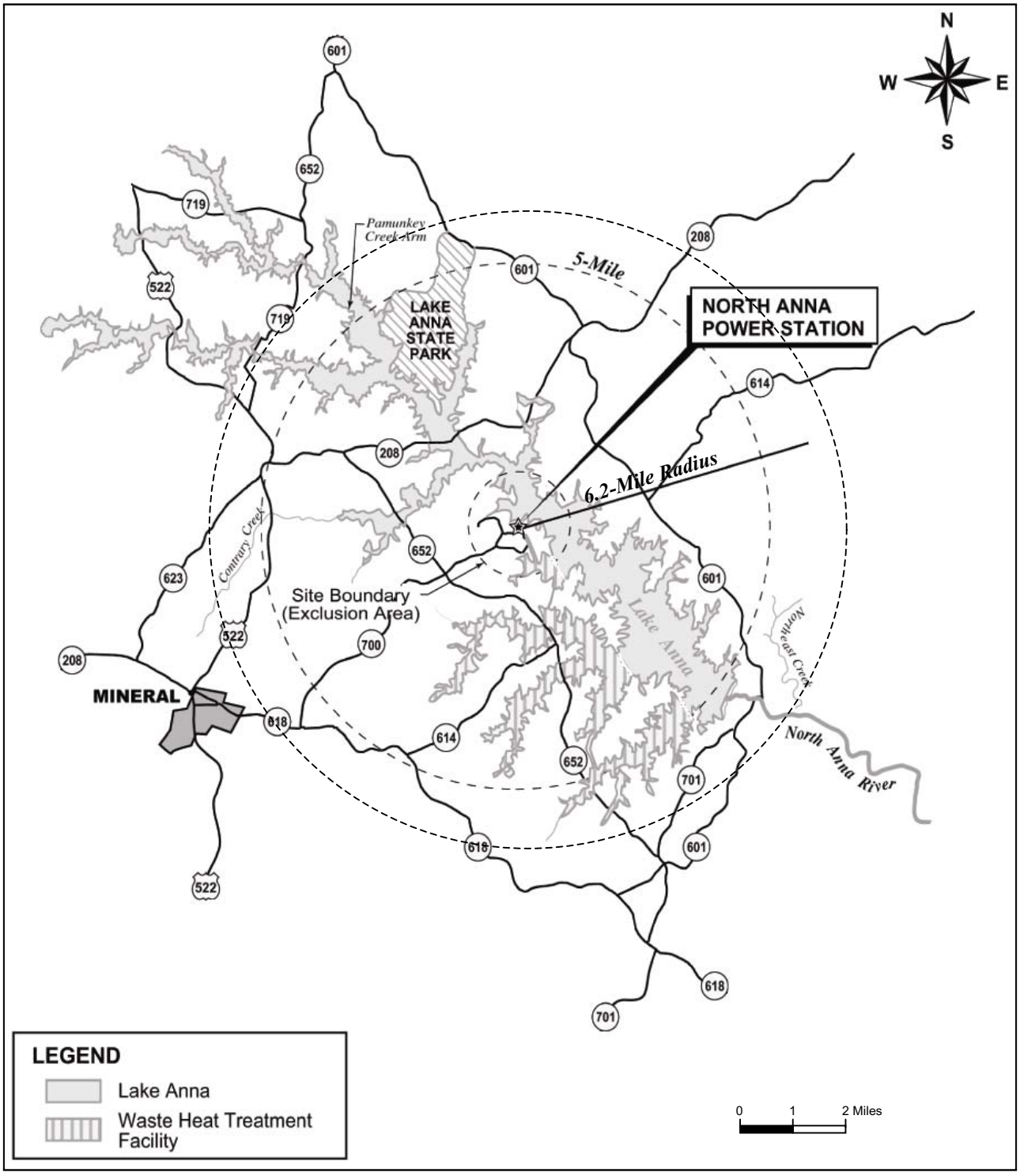

Figure 2.3-10 Surface Water Bodies Within 10 Kilometers (6.2 Miles)

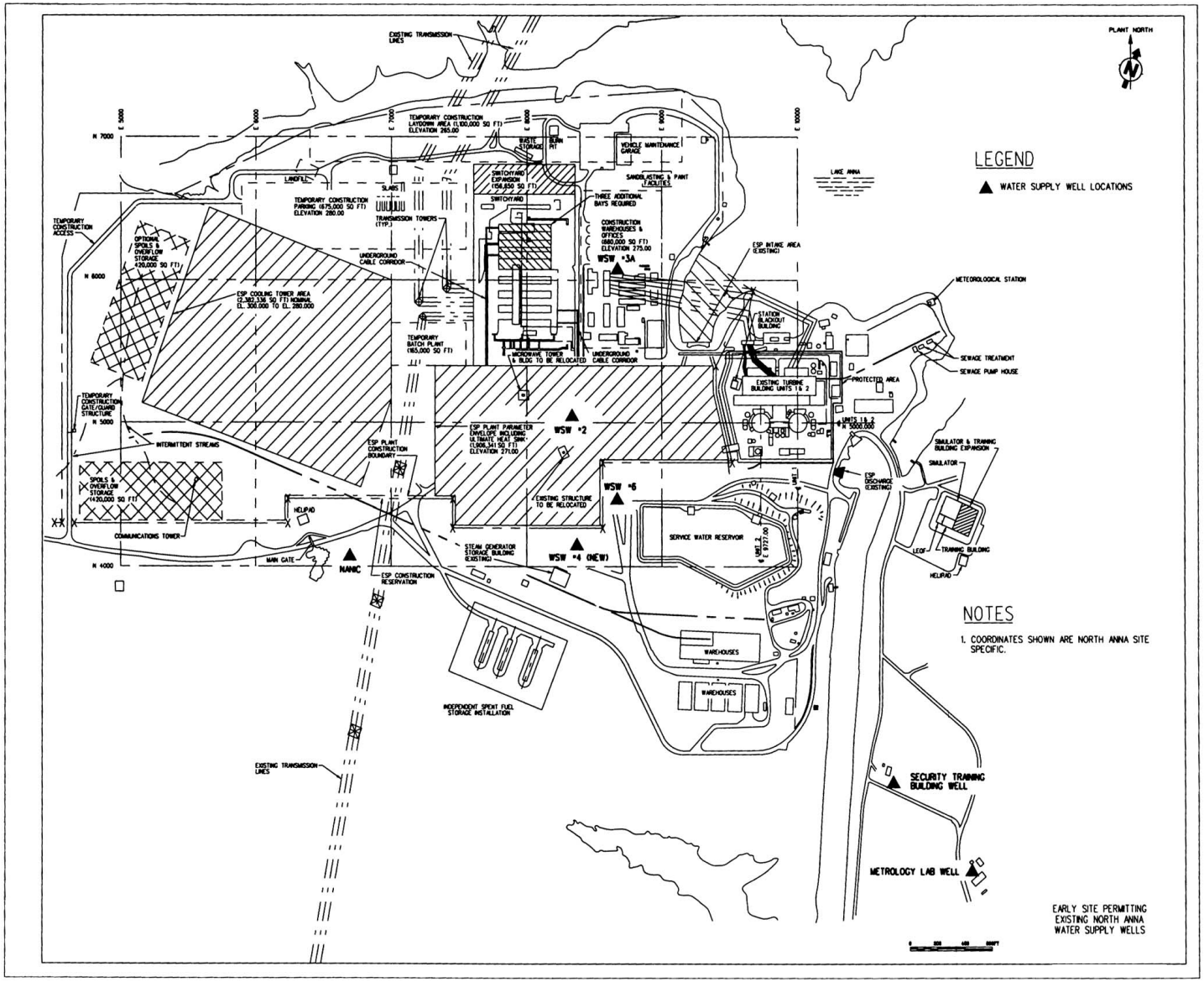

Figure 2.3-11 Existing Water Supply Wells

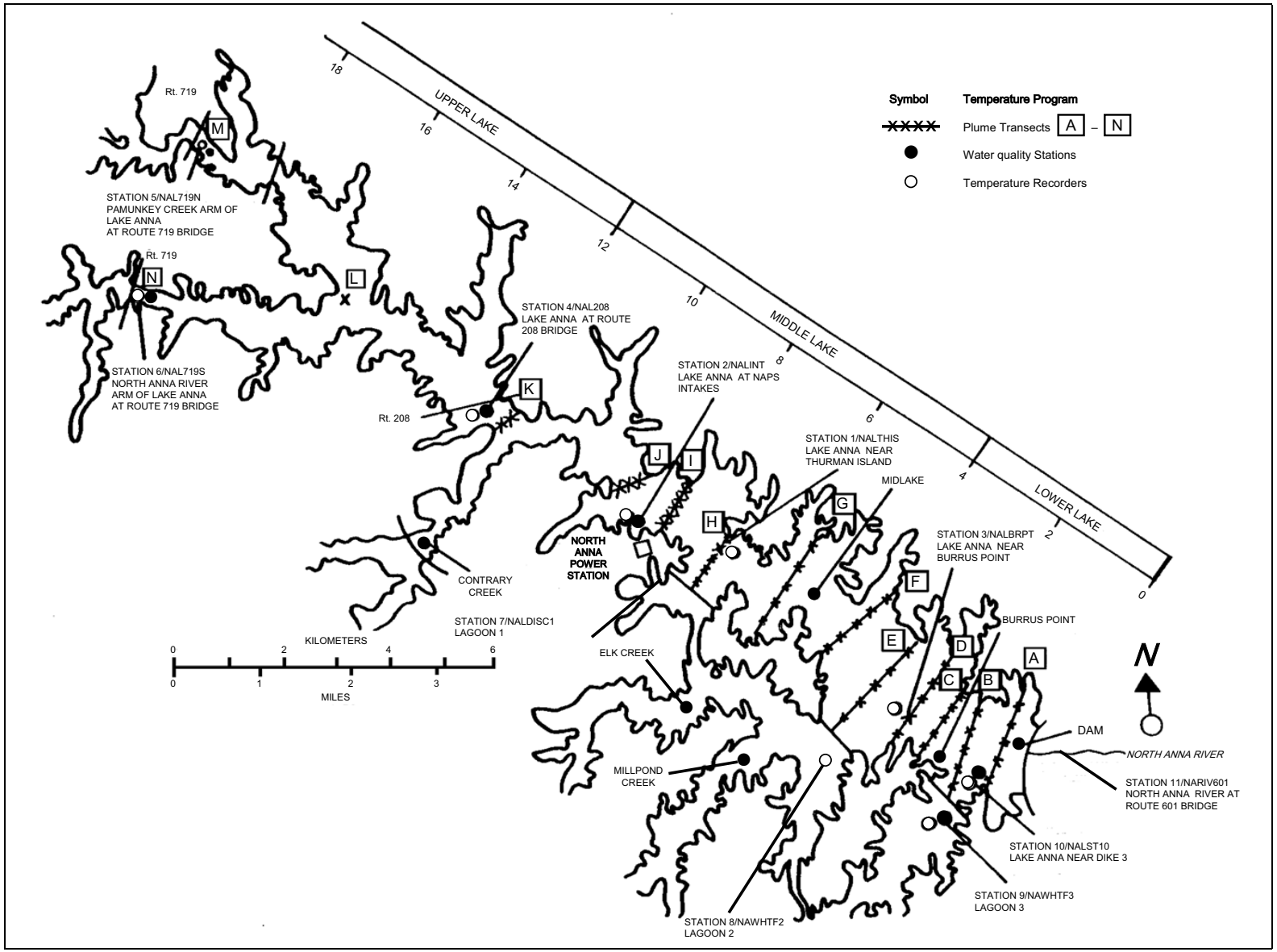

Figure 2.3-12 Temperature and Water Quality Sampling Stations

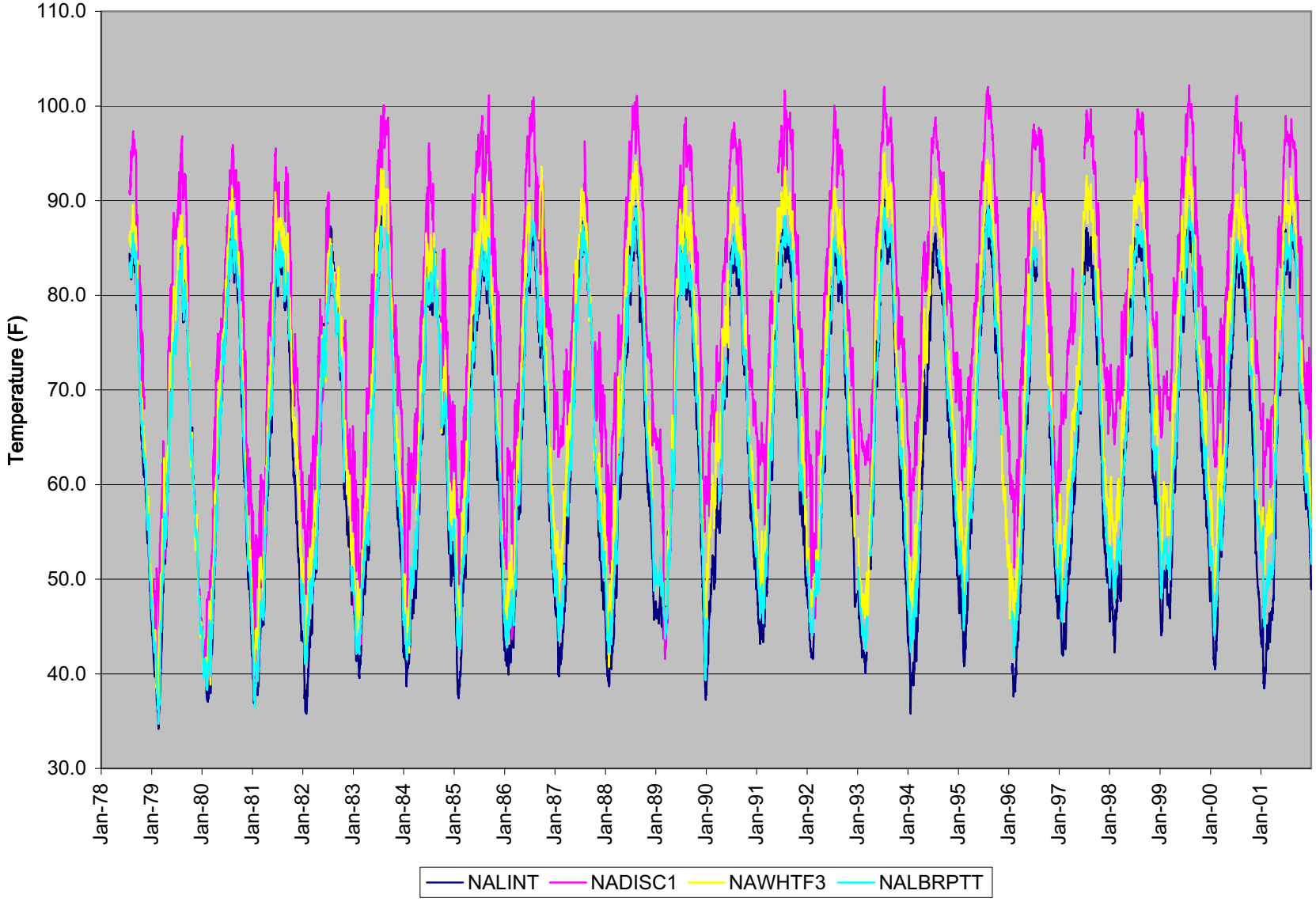

Figure 2.3-13 Temporal Variation in Lake Anna Water Temperature at Selected Locations

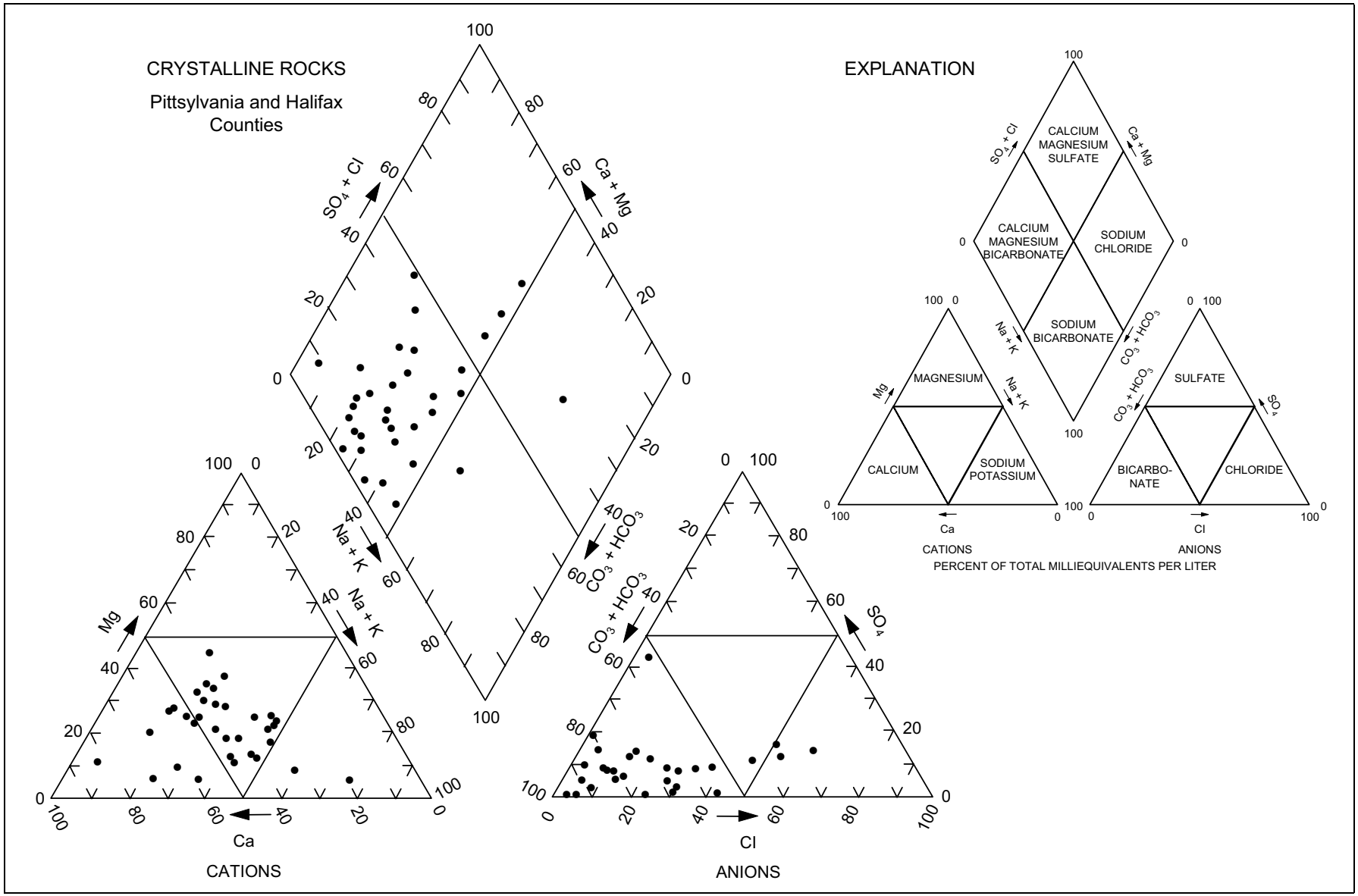

Figure 2.3-14 Water Quality in Crystalline Terrane (Pittsylvania and Halifax Counties, Virginia)

2.4 Ecology

This section describes the terrestrial and aquatic ecological resources that exist within the ESP site, vicinity, and correlating transmission corridors, and potential impacts on those resources from the new units. Ecological resources are those species and habitats that are considered "important" as presented in NUREG-1555, Tables 2.4.1-1 and 2.4.2-1. The description of ecological resources focuses on the terrestrial and aquatic environments that could affect or be affected by the construction or operation of the new units.

2.4.1 Terrestrial Ecology

This section describes the terrestrial ecology of the ESP site. Chapter 4 describes the impact of the construction of new units on the terrestrial ecology of the ESP site, and Chapter 5 describes the impact of the new units' operation on the terrestrial ecology.

The ESP site is located in the Piedmont Physiographic Province. This portion of north-central Virginia, settled in the Colonial era, no longer contains virgin forests. Land use surrounding the ESP site is an irregular patchwork of row crops, pastures, pine plantations, abandoned (old) fields, and second growth forests of hardwoods and mixed pine-hardwoods.

Construction activities would occur within the NAPS site boundary, so no discussion of the terrestrial environment except at the NAPS site is presented here. Current land use at the ESP site is presented in Section 2.2. Approximately 30 percent of the NAPS site consists of generation and maintenance facilities, parking lots, roads, cleared areas, and mowed grass. No other pre-existing NAPS-generated site stresses or stressors to wildlife are known. Hardwood forests exist on the approximately 70 percent of the site that has not been cleared for the construction or operation of the existing units. These wooded areas are remnants of forests that were used for timber production prior to acquisition by Virginia Power and are dominated by a variety of oaks, yellow poplar, sweet gum, and red maple trees. Scattered loblolly pines, Virginia pines, and short-leaf pines exist in some wooded areas. Electric transmission corridors that originate at the existing units pass through forested and agricultural lands typical of north central Virginia.

2.4.1.1 Terrain

The Piedmont region of Virginia is characterized by gently rolling hills with scattered moderately steep ridges; although moderately steep ridges are absent from the ESP site. The rolling terrain at the site extends down slope to the waters of Lake Anna, resulting in essentially no marsh habitat along the shoreline. Hydrophytic vegetation, such as cattail and rushes, are typically absent or extend only 1 to 3 feet beyond the shoreline.

2.4.1.2 Wildlife Species

Wildlife species found in the forested portions of the NAPS site are those typically found in upland Piedmont forests of north-central Virginia. Frequently observed mammals, such as the white-tailed

deer, raccoon, opossum, gray squirrel, and gray fox, exist at the site, as do smaller mammals such as moles, shrews, and a variety of mice and voles. Woodchucks live in the grassy areas near forest edges at the NAPS site, and beavers occur in Lake Anna and its tributaries. Various birds, reptiles, and amphibians (e.g., snakes, lizards, and toads) live in uplands and along the edge of Lake Anna.

2.4.1.3 Common Bird Species

Virginia Power has cooperated with the National Audubon Society in conducting periodic "Christmas Bird Counts" during December or January. Common bird species recorded in upland areas on and near the NAPS site during these surveys include the American crow, blue jay, Carolina chickadee, mourning dove, black vulture, turkey vulture, European starling, song sparrow, white-throated sparrow, dark-eyed junco, Northern cardinal, house finch, tufted titmouse, red-bellied woodpecker, downy woodpecker, and Northern flicker (Reference 1).

Birds known to nest within forested areas at the NAPS site, along forested edges, and in open areas (e.g., Northern cardinal, Carolina chickadee, blue jay) commonly nest in upland Virginia habitats. Virginia Power has placed bluebird nest boxes in suitable habitats at the NAPS site and has constructed roofed structures for swallows in some locations. Eastern bluebirds annually utilize the nest boxes, and barn swallows nest beneath the roofed structures.

2.4.1.4 Wading Birds and Waterfowl

Several species of residential and migratory wading birds and waterfowl utilize Lake Anna. Virginia Power biologists have documented breeding at Lake Anna by mallards, wood ducks, and Canada geese (Reference 2, Section 4.5). Virginia Power, in association with the Louisa County Chapter of Ducks Unlimited, has placed wood duck nest boxes on Lake Anna and wood ducks have utilized several of these nest boxes (Reference 2, Section 4.5). Belted kingfishers, great blue herons, and green-backed herons are present at Lake Anna throughout the year, and kingfishers and green-backed herons presumably nest on or near Lake Anna's shoreline. Great blue herons typically nest in rookeries, and because there are no known rookeries at Lake Anna (Reference 3), it is unlikely that great blue herons nest on the lake.

Waterfowl are typically most abundant at Lake Anna during the winter. Lake Anna provides important habitat for migratory waterfowl on the Atlantic Flyway, especially during extremely cold winters when the elevated water temperature from station operation maintains a large ice-free body of water. The most common ducks observed during winter are mallard, American black duck, bufflehead, and greater scaup. The Canada goose, American coot, ringed-billed gull, and herring gull are also abundant on Lake Anna during the winter. (Reference 1) (Reference 2, Section 4.5).

2.4.1.5 Critical Habitat

No areas designated by the USFWS as critical habitat for endangered species exist at or near the ESP site, or along or adjacent to associated transmission lines. In addition, the transmission corridors do not cross any state or federal parks, wildlife refuges, or wildlife management areas.

2.4.1.6 Endangered Species

The USFWS maintains current lists of threatened or endangered species at its website (Reference 4). The VDGIF also maintains lists of state protected species at its website (Reference 3). These lists have been consulted to determine the species that might live at the ESP site. This review identified no protected species other than those previously identified by Virginia Power.

Bald eagles, state and federally classified as threatened, are occasionally observed along Lake Anna. However, there are no known eagle nests at the ESP site (Reference 5). The nearest known bald eagle nest is near the north end of Lake Anna, approximately 10 miles upstream of the existing units. Dominion is not aware of any eagle nests along NAPS-associated transmission lines.

Loggerhead shrikes, classified by the state as threatened, have been observed in the vicinity of NAPS during Christmas bird counts, but breeding loggerhead shrikes have not been recorded at the NAPS site or along the transmission corridors (Reference 3). Loggerhead shrikes inhabit mowed or grazed grassy areas and margins of wooded areas.

With the exception of the bald eagle and loggerhead shrike, terrestrial species that are federally- and/or state-listed as endangered or threatened species are not known to exist at the NAPS site or along the transmission corridors.

2.4.1.7 Rare Plant Species

The transmission corridors are managed to prevent woody growth from reaching the transmission lines. The removal of woody species can provide outstanding grassland and bog-like habitat for many rare plant species dependent on open conditions. Virginia Power has cooperated with the VDCR's Natural Heritage Program in rare plant surveys within transmission corridors. The Natural Heritage Program prepared reports on the results of the rare plant species surveys. Although several rare plant species have been located along other Virginia Power transmission corridors, no endangered or threatened plants were noted along the corridors associated with the NAPS site.

2.4.1.8 Wetlands

Two intermittent streams flowing north into an unnamed arm of Lake Anna, just northwest of the power-block area bisect the area where cooling towers would be located. A narrow band of wetlands is associated with each of these streams. Wetlands within and around the ESP site have been delineated and property surveys have been conducted to present to the U.S. Army Corps of Engineers for confirmation, and in preparation of appropriate wetlands permitting. See Figure 2.4-5

and Figure 2.4-6. These permitting actions will include decision-making for implementing approved mitigation options, when necessary. (Reference 44).

2.4.1.9 Important Species

No “important species” as defined by NUREG-1555 live on the NAPS site, and with the exception of the wetlands described above, no “important habitats” exist on the NAPS site. Important species are those that are: listed by the state or federal government as threatened or endangered, proposed for listing as threatened or endangered, commercially or recreationally valuable, essential to the maintenance or survival of species that are rare or commercially or recreationally valuable, critical to the structure and function of the local terrestrial ecosystem, or biological indicators. Important habitats are wildlife sanctuaries, refuges, or preserves; habitats identified by state or federal agencies as unique, rare, or of priority for protection; wetlands, floodplains, or other resources specifically protected by federal or state regulations; or land areas identified as “critical habitat” for threatened or endangered species.

2.4.1.10 Proposed Site

Section 4.1.1 provides information on the acreage that would comprise the construction site. Much of the proposed laydown area consists of dirt roads, cleared areas, parking lots, buildings, and weedy habitats. The western portion of the current and proposed laydown area can be classified as “old-field” habitat. None of the current or proposed laydown area is forested. The area proposed for temporary offices is an existing office complex; thus, natural habitats are absent from this area. Generally, wildlife species found in the forested portions of the ESP site and support areas are those typically found in the forested portions of the NAPS site and in upland Piedmont forests of north-central Virginia. Wildlife species in the old-field habitat of the laydown area and in the transmission rights-of-way within the ESP site would include most of those found in the adjacent wooded areas.

2.4.2 Aquatic Ecology

2.4.2.1 North Anna Drainage System

The North Anna River rises in Louisa and Orange Counties, Virginia, and flows east for about 60 miles before joining the South Anna River to form the Pamunkey River Figure 2.4-1. The Pamunkey River flows to the southeast, joining with the Mattaponi River to form the York River, which flows into the Chesapeake Bay north of the Hampton Roads area of Virginia. The entire North Anna River watershed is approximately 600 square miles (Reference 6).

Lake Anna, built to supply cooling water for the power station, was created in 1971 by erecting a dam on the main stem of the North Anna River, just upstream of the confluence of the North Anna River and Northeast Creek (Figure 2.4-2). Lake Anna drains an area of 343 square miles (Reference 2). The dam is approximately 90 feet high and 5,000 feet long and contains

900,000 cubic yards of earth and rock (Reference 6). Lake Anna began filling in January 1972 and reached full pool in December of that year (Reference 6). For discussion purposes, Lake Anna may be divided into two distinct bodies of water, the WHTF and the North Anna Reservoir. The WHTF is the smaller body of water into which existing units' waste heat is discharged via the discharge canal. The North Anna Reservoir is the larger body of water and is physically separated from the WHTF by a series of dikes.

Lake Anna is approximately 17 miles long, with 272 miles of shoreline. It is relatively shallow (maximum depth 90 feet; average depth approximately 25 feet at full pool), with a surface area of 13,000 acres (Reference 6). The normal elevation of the reservoir is 250 ft msl, at which stage it holds 305,000 acre-feet of water (Reference 6). The Commonwealth of Virginia requires a 40-cfs minimum discharge of water from the North Anna Dam, except under extreme drought conditions. These minimum flow requirements have been established to maintain instream flows and water quality in the North Anna River below the dam and in the Pamunkey and York Rivers further downstream (Figure 2.4-1). Should these types of drought conditions occur, and Lake Anna surface water levels fall to 248 ft msl, Virginia Power would begin reducing releases incrementally below the 40 cfs level in accordance with the Lake Level Contingency Plan, as stipulated in Part I.F of the VPDES Permit.

Prior to impoundment, water quality in the North Anna River was degraded by sedimentation and acid mine drainage from Contrary Creek, an 8.5-mile-long tributary that flowed into the river from the west, near the town of Mineral, Virginia (Figure 2.4-2). Land adjacent to Contrary Creek had been the site of extensive iron pyrite mining operations during the late 19th and early 20th centuries (Reference 2). When the mine was abandoned (circa 1920), mine shafts and tailings piles were left exposed to the weather. Runoff from the mine area was acidic, with high concentrations of metals. Virtually no aquatic life was found in Contrary Creek downstream of the mine site (Reference 6). Prior to impoundment, the density and diversity of fish and benthic macroinvertebrates were markedly reduced in the North Anna River immediately downstream of its confluence with Contrary Creek. Subtle changes were evident as far as 15 miles downstream, although water quality was generally satisfactory (Reference 2).

In 1976, the Virginia State Water Control Board, in association with the EPA, attempted to reclaim previously-mined and disturbed areas along Contrary Creek to reduce the impacts of sedimentation and acid mine drainage (Reference 2). The reclamation project reduced, to some extent, erosion and sedimentation in the area.

The creation of Lake Anna has mitigated most water quality impacts from Contrary Creek area runoff. Low-pH creek water is neutralized as it mixes with higher-pH reservoir water. Heavy metals are removed from the water column by adsorption to clay particles and the subsequent settling of these particles. Chemical precipitation (and co-precipitation with iron) may also remove zinc and copper ions from Contrary Creek water when it mixes with Lake Anna water.

A comprehensive study of Lake Anna's water quality and aquatic communities was conducted in support of a CWA Section 316(a) Demonstration for NAPS (Reference 2). This evaluation was based on five years (1973-1977) of pre-operational studies and eight years (1978-1985) of operational studies. Water quality, water temperature, and biological monitoring were conducted in upper, middle, and lower portions of the North Anna Reservoir, and in the North Anna River below the reservoir.

Water quality in Lake Anna has historically been good to excellent. Turbidity levels are generally low, except during periods of heavy inflows from tributary streams.

Nutrient levels (nitrates and phosphates) from flooded farmland were elevated in the years following impoundment of the river and its valley, but stabilized in the 1980s at low levels sufficient to support a thriving community of benthic macroinvertebrates, plankton, and fish. As noted previously, there have been no indications of nutrient enrichment or eutrophication in Lake Anna, beyond those associated with normal reservoir aging. Lake Anna and the North Anna River are not among the water bodies designated by the Virginia State Water Control Board as "nutrient-enriched waters." (Reference 7)

Recently, the Virginia DEQ has listed several of the upper-lake tributaries in its 303(d) list of impaired waters because of seasonal exceedances of fecal coliform. Also portions of the North Anna Reservoir itself have been added because of high values of PCBs in certain fish tissue analyses.

Since its creation, the North Anna Reservoir has developed into three ecological areas that were identified in the CWA 316(a) Demonstration as upper lake, mid- lake, and lower lake (Reference 2). The physical characteristics are different among the areas. The upper lake is primarily riverine and shallow (average depth of 13 feet), and shows some evidence of stratification in summer. The mid-lake is deeper and stratifies in summer. It receives waters from Contrary Creek that, because of years of mining in its floodplain, are sometimes low in pH and high in metals. The lower lake is the deepest part of the reservoir, with an average depth of 36 feet. It is clearer (with more light penetration), and shows pronounced annual patterns of winter mixing and summer stratification. The epilimnion (warm layer above the thermocline) was generally 8 feet deep during pre-operational years and 26 to 33 feet deep during operational years. The increase in depth of the epilimnion appears to be related to the heated discharge entering the reservoir from Dike 3 (see Figure 2.4-3) and the withdrawal of cooler, deeper water at the existing units intake (Reference 2). The heated discharge, attendant mixing, and withdrawal of water at the intake have also increased the depth of oxygenation, with the layer of water holding at least 5 milligrams per liter of dissolved oxygen increasing from 16 feet (pre-operational) to 29 feet (operational).

The existing units use a once-through cooling system that withdraws water from mid-Lake and discharges it into a discharge canal. The canal is approximately 3600 feet long and discharges into the WHTF, which was formed by diking off a portion of Lake Anna. The cooling water residence

time in the WHTF is approximately 14 days, depending on condenser flow rate. More than half the existing units' waste heat is dissipated in the WHTF. The only discharge from the WHTF into the North Anna Reservoir is through Dike 3, which abuts the lower lake near the dam. The discharge is a submerged, high-velocity jet that promotes rapid mixing with reservoir waters.

Temperature monitoring at Lake Anna indicates that the shallower upper lake warms earlier in spring and reaches maximum temperature in summer sooner than the lower lake. The lower lake, with its greater depth and volume, warms more slowly in spring and retains its heat later in the year. It is estimated that the heat contributed by the existing units corresponds to about 10 percent of the solar heat entering the reservoir on summer days. (Reference 2)

From 1975 through 1985, Virginia Power monitored water temperatures at 10 (7 in North Anna Reservoir and 3 in WHTF) Lake Anna locations, as part of a CWA Section 316(a) Demonstration for NAPS (Reference 2, Section 3.5, Table 3.5-2). Temperatures were recorded hourly at most of these locations. Highest (hourly average) temperatures recorded in June, July, and August over this period were 91.8°F at an upper lake location in 1984, 92.7°F at an upper lake location in 1977, and 91.6°F at a lower lake location in 1980, respectively. The highest (hourly average) water temperature before the existing units began operating (92.7°F) was measured on July 19, 1977, at the northern-most location (Pamunkey Creek arm). The highest (hourly average) water temperature measured in an operational year was 92.3°F, recorded in July 1983. (Reference 2)

In recent years, Virginia Power has continued to monitor Lake Anna water temperatures, using fixed temperature recorders at 7 locations in North Anna Reservoir and 3 locations in the WHTF (Figure 2.4-4). This temperature monitoring is part of a larger post-316(a) Demonstration environmental monitoring effort that includes fish population studies. To allow for direct comparisons with historical data, temperatures in Lake Anna are reported as monthly means of daily high, mean, and low temperatures. The range of temperatures and between-location temperature trends recorded over a recent six-year period (1995–2000) have shown strong similarities to historical data (Reference 8) (Reference 9) (Reference 10) (Reference 11) (Reference 12) (Reference 13). These temperature data do not indicate an overall long-term warming trend in North Anna Reservoir. Further, differences in temperature throughout the reservoir continue to be small, regardless of time of year or power station operating levels. Virginia Power submits annual reports to VDEQ and VDGIF on water temperatures and fisheries monitoring in Lake Anna and the lower North Anna River.

2.4.2.2 Biological Communities of Lake Anna

The Environmental Impact Statement for NAPS License Renewal (Reference 5) summarizes studies of phytoplankton, zooplankton, and benthic organisms conducted by Virginia Power over the 1973-1985 period. These studies are not reviewed here. The plankton and benthos communities that developed over the first several years of the existing units' operation were typical of those seen in other Piedmont reservoirs.

The long narrow arm of Lake Anna just northwest of the power-block area is associated with two small intermittent streams that could be affected by the new units. Following heavy rainfall, these streams flow in a northerly direction into Lake Anna. Due to their intermittent nature, neither stream supports significant numbers or diversity of fish.

Because of the importance of recreational fishing in Lake Anna, its fish community has been the subject of wide-ranging studies. Abundance and distribution of fish were evaluated over a period from 1975-1985, using a variety of sampling methods to ensure that gear selectivity did not bias results. Larval fish studies, creel surveys, and a number of special studies focused on the reproduction and growth of important species, such as largemouth bass (*Micropterus salmoides*). Seasonal movement and habitat preferences of striped bass (*Morone saxatilis*) were investigated, using ultrasonic tags.

From 1975 through 1985, 39 species of fish (representing 12 families) were found in Lake Anna Reference 2. Species included those historically found in the North Anna River, those that had been in local farm ponds inundated by the new reservoir, and nine species (four non-native) introduced by the VDGIF.

The community structure remained relatively stable over the 1975–1985 period, with some year-to-year variation in species composition. These variations were caused by 1) normal population fluctuations, 2) reservoir aging, 3) the introduction of forage species and competing predators, 4) the installation of fish attractors and artificial habitat, and 5) the increase in *Corbicula fluminia* (Asiatic clam) densities. Post-1975 changes included 1) a decline in relative abundance of yellow perch (*Perca flavescens*) and black crappie (*Pomoxis nigromaculatus*), 2) an increase in the relative abundance of white perch (*Morone americana*) and threadfin shad (*Dorosoma petenense*), and 3) an increase in redear sunfish (*Lepomis microlophus*) abundance, with a corresponding decrease in pumpkinseed (*Lepomis gibbosus*). None of these changes appeared to be related to existing units operation.

From 1975 to 1984, the mean standing crop ranged between 232 and 296 pounds of fish per acre, but it increased substantially in 1985 (to 417 pounds per acre) because of a large increase in introduced threadfin shad and an increase in the abundance of gizzard shad (*Dorosoma cepedianum*). Both species provide forage for Lake Anna's game fish, which include largemouth bass, walleye (*Stizostedion vitreum*), and striped bass. Lake Anna appears to support a standing crop of fish higher than most U.S. reservoirs, with thriving populations of several forage species and highertrophiclevel (gamefish) species.

Standing stocks of largemouth bass, Lake Anna's most popular sport fish, remained stable over the 1975–1985 period. In 1985, Lake Anna produced more largemouth bass of "citation" size (eight pounds or more) than any other lake or reservoir in Virginia. Life history studies of Lake Anna largemouth bass, summarized in the 316(a) Demonstration (Reference 2), suggest that the

reproductive success, feeding ecology, and growth of this species were similar in pre-operational and operational years.

Four non-native fish species (striped bass, walleye, threadfin shad, and blueback herring (*Alosa aestivalis*) have been stocked in the North Anna Reservoir by the VDGIF since 1972. Striped bass, introduced in 1973, have been stocked annually since 1975. They provide a "put-grow-and-take" fishery. Streams, including the North Anna River, that flow into the North Anna Reservoir lack the flow, depth, and length to support striped bass spawning runs. Studies show that striped bass grow and provide a substantial recreational fishery, but adults are subject to late-summer habitat restrictions (may be restricted to cooler-water refuge areas). As a consequence, they may lose weight and show a decline in condition. Walleyes are also stocked annually by the VDGIF and are highly sought-after game fish.

Threadfin shad, introduced in 1983 to provide additional forage for striped bass and other top-of-the-food-chain predators, are vulnerable to cold shock and winter kills, and would not be able to survive in Lake Anna if it were not for power station operation. Threadfin shad appear to be thriving and are an important source of food for game fish. Blueback herring, stocked by the VDGIF in 1980 as a forage species, have not been as successful.

In 1994, a fifth non-native species, the herbivorous grass carp (*Ctenopharyngodon idella*), was stocked by Virginia Power (with the approval of the VDGIF) in the WHTF to control the growth of the nuisance submersed aquatic plant hydrilla (*Hydrilla verticillata*).

In addition to the previously described stocking programs, which are designed to expand fishing opportunities in the North Anna Reservoir, Virginia Power, in cooperation with VDGIF, placed 20 underwater fish structures in the reservoir over the 1983–1990 period to provide additional fish habitat in areas with "clean" bottoms (Reference 14). The structures, consisting of conically-shaped piles of cinder blocks, small trees, and brush (secured to the blocks) were designed to provide escape cover for young fish and spawning and feeding areas for larger fish. Although designed to provide habitat for largemouth bass, black crappie, and bluegill (*Lepomis macrochirus*) in particular, these fish structures benefit a variety of other species.

As noted previously in this section, Virginia Power has continued to monitor fish populations in Lake Anna since 1986, as part of a larger post-316(a) Demonstration environmental monitoring program. Fisheries monitoring over a recent six-year period (1995–2000) reveals a balanced reservoir fish community comprised of healthy populations of top-of-the-food-chain predators (e.g., largemouth bass and striped bass) and the forage species on which they feed (e.g., threadfin shad and gizzard shad), panfish (e.g., bluegill, redear sunfish, redbreast), and catfish (channel catfish and white catfish), in particular.

Lake Anna is well known as a producer of trophy largemouth bass and large numbers of striped bass. In 2000, Lake Anna ranked third in the Commonwealth of Virginia in producing trophy

certificate ("citation") largemouth bass (Reference 13), with 72 fish meeting the standard (at least 22 inches in length or 8 pounds in weight).

2.4.2.2.1 Commercially-Important Fisheries

There is no commercial fishing on Lake Anna or the North Anna River. There are professional fishing guides who regularly take clients fishing for largemouth, striped bass and walleye on the North Anna Reservoir, but there are no commercial fishing operations in the sense that fish are netted or trapped and sold at market. Professional fishing guides must adhere to state fishing regulations, and are prohibited by law from selling their catch.

2.4.2.2.2 Recreationally Important Fisheries

Lake Anna is a popular destination for anglers from central and northern Virginia. Its healthy fish populations and its proximity to the cities of Washington, D.C., Richmond, and Charlottesville mean that the reservoir is heavily fished, particularly in spring and fall. In summer, an influx of recreational boaters, water-skiers, and jet skiers discourages some fishermen. The heated effluent that flows into the North Anna Reservoir at Dike 3 creates conditions conducive to good fishing in winter, making the reservoir a popular fishing spot when cold weather slows or shuts down fishing at other ponds and lakes in the region.

The VDGIF estimated that 42,731 anglers fished Lake Anna for 232,439 hours over a 12-month period in 2000 and 2001. The species most often sought were largemouth bass, striped bass, and crappie, with 69 percent, 15 percent, and 12 percent of anglers, respectively, pursuing these species (Reference 15). Black crappie, not largemouth bass, was the species most often harvested. Depending on the time of year, species such as bluegill, white perch, channel catfish, and walleye are also sought by Lake Anna fishermen.

2.4.2.2.3 Important North Anna Reservoir Species

The VDGIF manages the fisheries of the North Anna Reservoir "…with particular emphasis on providing quality largemouth and striped bass fisheries within the capacity of available habitat" (Reference 16). As a consequence, the VDGIF district biologists who conduct monitoring studies and research on the fishes of the North Anna Reservoir focus on these two species, both highly esteemed by local anglers. Other species, such as black crappie and channel catfish, are monitored by VDGIF but are not as actively managed.

a. **Largemouth bass**

   Electro-fishing catch rates for largemouth bass greater than 8 inches long in the North Anna Reservoir have been high in recent years (Reference 16) (Reference 17) (Reference 18). Young-of-the-year catch rates, although lower, have been indicative of consistent recruitment. Structural indices of the largemouth bass population indicate a population dominated by larger, older individuals. Growth of younger (1-to-4 year old) largemouth bass is excellent; however, growth of older bass (5 years and older) is below the district average (Reference 16).

On average (all age classes considered), largemouth bass in the North Anna Reservoir grow more rapidly than largemouth bass in other large Virginia impoundments (Reference 18).

In summary, largemouth bass tend to grow rapidly in their first four years of life, “plateau” at age 5, and grow relatively slowly thereafter. The population contains a high proportion of harvestable individuals, and provides excellent opportunities for anglers seeking larger, trophy-sized fish.

b. **Striped bass**

Annual stockings of fry and fingerlings sustain the North Anna Reservoir’s striped bass population. Normally, between 100,000 and 200,000 fingerlings are stocked annually, which equates to between 10 and 20 fish per acre (Reference 16). VDGIF is experimenting with lower (5 fish/acre) stocking rates to determine if recruitment is significantly affected.

Striped bass growth patterns in the North Anna Reservoir vary from year to year, with some of the variability apparently related to the size of fish stocked (dependent on size of fish supplied by hatcheries). Generally speaking, young striped bass grow rapidly, and reach harvestable size (20 inches) in about 30 months (Reference 16). Estimates of annual mortality range from 35 to 50 percent, depending on the cohort evaluated, with the lower percentage likely more accurate (Reference 16) (Reference 17) (Reference 18). Excellent year classes in 1997, 1998, and 1999 should provide outstanding fishing in 2003 and beyond. All three year classes should be of harvestable size by 2003.

Since the early 1990s, VDGIF has been evaluating late-summer striped bass habitat in the North Anna Reservoir, taking temperature and dissolved oxygen profiles at representative locations in the reservoir. In July-August 2000, temperature and dissolved oxygen profiles revealed that portions of the North Anna Reservoir, in the area between NAPS and the Lake Anna Dam, did not provide acceptable striped bass habitat (water temperature less than 26°C and dissolved oxygen concentration greater than 2.0 milligrams per liter) (Reference 17). However, the striped bass habitat uplake of the existing units was acceptable, and striped bass were presumed to have moved to these uplake areas seeking cooler, oxygenated water. This late-summer dispersal of striped bass has been observed in other southeastern reservoirs (Reference 19). No late-summer die-offs of striped bass have been observed in the North Anna Reservoir although they have occurred in reservoirs in North Carolina, South Carolina, Tennessee, and Alabama (Reference 20) (Reference 21).

c. **Black Crappie**

Based on experimental gill net catches, black crappie abundance in North Anna Reservoir was very high in 1997 and 1998, but has declined in recent years (Reference 16) (Reference 17) (Reference 18). Growth of black crappie is good, and agrees with other impoundments in the region. There is considerable year-to-year variability in population size structure (i.e., average size of fish captured), but it is unclear if this is an indication of changes in age composition or

changes in growth rates. The catch-per-unit-effort of "quality" black crappie declined by 50 percent between 1997 and 1998, an indication that (fishing) mortality is high. Most crappie (92 percent) caught in gill nets were caught in the "upper lake" (Reference 16).

d. **Catfish**

Channel catfish ranked fifth in abundance in gill nets in 1997 and fourth in abundance in 1998 (Reference 16). Much higher numbers of channel catfish and white catfish were captured in gill nets in 1998 than in 1997, but this phenomenon was attributed to low reservoir levels (related to drought) rather than an actual increase in numbers of catfish. VDGIF reports provide no information on age and growth, condition, or age/size structure of catfish populations.

e. **Shad**

Because threadfin shad abundance is cyclic, gizzard shad serve in most years as North Anna Reservoir's forage base (Reference 16). Gizzard shad are regarded by fisheries managers as a less-than-ideal forage species, because their rapid growth makes them unavailable to predators in a year or two. Threadfin shad, while the ideal size, are subject to mass die-offs from low temperatures or sudden temperature changes. In 1997 and 1998, gizzard shad numbered second and first, respectively, in North Anna Reservoir gill net catches. Threadfin shad were seventh in 1997 and eighth in 1998. Most shad (71 percent in 1997 and 76 percent in 1998) were caught in the upper reservoir (Reference 16).

2.4.2.2.4 Nuisance Species

Virginia Power first collected the non-native Asiatic clam in benthos samples in 1979. Densities increased sharply thereafter, as this species with its high reproductive potential quickly occupied suitable habitat in the reservoir (Reference 2). In response to NRC Generic Letter 89-13, Virginia Power initiated a semi-annual sampling program in the fall of 1990 to monitor Asiatic clam in the North Anna Reservoir, the WHTF, and the emergency SWR. Virginia Power biologists collect replicate samples at two North Anna Reservoir locations (i.e., at the intake and a location in mid lake), two WHTF locations, and a single location in the existing units' SWR. They report the total number and density of clams at the various locations and discuss population trends in semi-annual reports.

These monitoring studies indicate that total numbers and densities of Asiatic clam at the various locations in the North Anna Reservoir and the WHTF show sizable fluctuations between years, mostly as a result of spawning activity (Reference 22) (Reference 23) (Reference 24) (Reference 25) (Reference 26) (Reference 27) (Reference 28) (Reference 29) (Reference 30). Small "sand-sized" clams less than 2 millimeters long are sometimes locally abundant immediately after spawning takes place, and inflate numbers and densities at a particular sampling location.

Asiatic clam numbers in the WHTF near the existing units discharge show the most dramatic fluctuations. For example, densities of clams at this location declined from 1,619 clams per square

meter in Spring 1992 to 11 clams per square meter in fall 1992 (Reference 31) (Reference 32). Clams in this area are subject to “boom and bust” cycles, because under extreme conditions (high plant operating levels, high ambient temperatures, drought), water temperatures can get high enough to cause localized die-offs.

Larger (i.e., greater than 15 millimeters in length), older (i.e., 1 to 3 years old) Asiatic clams are uncommon in North Anna Reservoir samples, generally comprising less than 10 percent of the total collected (Reference 17) (Reference 23) (Reference 24) (Reference 25) (Reference 26) (Reference 27) (Reference 28) (Reference 29) (Reference 30). Larger Asiatic clams are generally uncommon in WHTF samples as well, but sometimes make up a significant percentage (i.e., greater than 50 percent) of the total at WHTF-3 when sample sizes are small (Reference 24) (Reference 25) (Reference 26) (Reference 29).

Although Asiatic clam shells have been observed in the SWR, Virginia Power biologists have collected no live clams at this location. The SWR is treated with algicides and molluscicides, preventing Asiatic clam from becoming established in this small reservoir.

When Virginia Power compared 1990-2002 Asiatic clam survey results to similar surveys conducted in the 1980s, data indicated a decline in the North Anna Reservoir population. The highest totals recorded in the spring in the 1980s were in 1988 and 1985, when 294 and 194 clams, respectively, were collected in replicate samples from a mid lake location. The highest totals recorded in the fall were in 1987 and 1986, when 1,227 and 237 clams were collected in replicate samples from a mid lake location. The highest number of clams collected over the 1990-2002 period from the mid lake location was 148, in Spring 1994 sampling. Operational experience at the existing units provides further evidence of a stable or declining North Anna Reservoir Asiatic clam population: no condenser tube blockages have been reported since Asiatic clam appeared in the North Anna Reservoir in the late 1970s.

In the course of monitoring Asiatic clam populations, Virginia Power also looks for evidence that the zebra mussel (*Dreissena polymorpha*) has invaded Lake Anna. Biologists conducting clam surveys examine all bottom samples for the presence of this nuisance species, which became established in the Great Lakes region in the late 1980s after being inadvertently introduced from Northern Europe. Zebra mussels have clogged pipes in power plants and municipal water systems and disrupted the ecological balance of streams, lakes, and reservoirs into which they have been introduced.

As of the end of 2002, Virginia Power biologists had observed no zebra mussels in the North Anna Reservoir or the WHTF. Dissolved calcium levels in North Anna Reservoir and the WHTF are well below those known to promote shell growth in zebra mussels, which should limit its establishment in those waterbodies (Reference 30). Zebra mussels are known from only one location in the state of Virginia: Millbrook Quarry, in Prince William County, Virginia, approximately 60 miles north of the site. This population, believed to have been unintentionally introduced by SCUBA divers, was

discovered in August 2002 by a recreational diver who subsequently notified the VDGIF (Reference 33) (Reference 34).

2.4.2.2.5 Threatened and Endangered Aquatic Species

Virginia Power has monitored fish populations in Lake Anna and the North Anna River for more than 25 years. No federally- or state-listed fish species has been collected in any of these monitoring studies, nor has any listed species been observed in creel surveys or occasional special studies conducted by Virginia Power biologists. No state- or federally-listed fish species' range includes Lake Anna or the North Anna River, and none is believed to occur in counties adjacent to Lake Anna or the North Anna River (i.e., Caroline, Hanover, Louisa, Orange, and Spotsylvania Counties).

Based on VDGIF and VDCR (Division of Natural Heritage) databases, one federally-listed mussel species, one state-listed mussel species, and one mussel species that is a candidate for federal listing occur in counties that border Lake Anna or the North Anna River. None of the three has been found in Lake Anna or the North Anna River.

The dwarf wedgemussel (*Alasmidonta heterodon*) was historically found in Hanover, Louisa, and Spotsylvania Counties (Reference 35). It is listed as endangered by both the Commonwealth of Virginia and the USFWS. The USFWS Recovery Plan for the species, completed in 1993, indicated that one population survived in these counties, in the South Anna River, in Louisa County (Reference 36). The VDGIF Fish and Wildlife Information Service database currently lists a "remnant" population in the South Anna River in Louisa County, presumably the same population (Reference 37).

The VDCR database lists another mussel species, the slippershell mussel (*Alasmidonta viridis*), as occurring in Orange County. The slippershell mussel is listed by the Commonwealth of Virginia as endangered, but it has no federal status. Given the known distribution of this species, Virginia Power believes the reported occurrence of the slippershell mussel in Orange County may be in error. The slippershell mussel is widely distributed in the Upper Mississippi River basin and the Ohio River and Tennessee River sub-basins, including three streams in southwestern Virginia, but is not found in Atlantic Slope drainages (Reference 38) (Reference 39) (Reference 40).

A third mussel species reported as occurring in the vicinity of the NAPS site, the fluted kidneyshell mussel (*Ptychobranchus subtentum*), is a candidate for federal listing. The VDGIF's Fish and Wildlife Information Service database lists this species as occurring in a stream or streams in Louisa County. However, based on the fact that all other confirmed accounts of this species are confined to mountain streams in southwestern Virginia that are tributaries of the Tennessee River, it is unlikely that a disjunct population would occur several hundred miles away in a river system that flows eastward to the Atlantic Ocean. Virginia Power believes the reported occurrence of the fluted kidneyshell mussel in Louisa County may be in error.

None of these mussel species were collected in pre-impoundment surveys of the North Anna River, and none have been collected in more recent years during routine monitoring surveys.

2.4.2.3 Biological Communities of North Anna River

The North Anna River joins the South Anna River 23 miles downstream of the North Anna Dam, forming the Pamunkey River. Before 1972, when the river was impounded, flows varied considerably (1 to 24,000 cfs) from year to year and water quality was degraded by acid mine drainage from Contrary Creek. After 1972, fluctuations in flow were moderated (40 to 16,000 cfs from 1972 through 1985) and water quality has improved as a result of reclamation activities at the Contrary Creek mine site and the acid-neutralizing effect of Lake Anna's waters.

Water quality downstream of the North Anna Dam is strongly influenced by conditions in the reservoir and releases at the dam. Water moving from the North Anna Reservoir to the North Anna River is less turbid and more chemically stable than the pre-impoundment flow. Dissolved oxygen levels are high (averaging 9.6 milligrams per liter over the 1981–1985 period) immediately downstream of the North Anna Dam, and increase further downstream, presumably as a result of turbulent mixing (Reference 2).

Summer water temperatures from 1970 to 1985 were higher near the North Anna Dam than further downstream, reflecting temperatures in the reservoir. The highest water temperature recorded in pre-operational years in the river was 89.4°F in July 1977, at a location 0.6 miles below the dam. The highest temperature recorded in the river in operational years was slightly higher, 90.9°F, recorded in August 1983 at the same location.

Historically, the North Anna River periphyton community below the North Anna Dam was dominated by diatoms and was similar to that of other Southeastern streams. The benthic macroinvertebrate community in the stretch of the river below the dam was dominated by filter-feeding caddisflies that feed on seston (living and dead plankton, plus particulate matter) from the North Anna Reservoir. Farther downstream, macroinvertebrate communities showed more diversity and were similar to those of the South Anna River, which served as a control.

In pre-impoundment surveys, the fish community of the North Anna River downstream of the Contrary Creek inflow was dominated by pollution-tolerant species. In the years following impoundment (and reclamation of the Contrary Creek mine site), there was a steady increase in measures of abundance and diversity (species richness) of fish. In 1984–85, 38 species from 10 families were found in the North Anna River, compared to 25 species from 8 families in the control stream, the South Anna River. When species from the North Anna Reservoir were subtracted from the North Anna River totals, the 2 fish communities showed striking similarities, indicating that the operation of the existing units had little or no effect on fish populations downstream from the dam.

In 2000, the number of fish collected at 4 stations downstream of the North Anna Dam was low but similar to 1989, 1993, and 1996 collections. High spring flows and cancelled surveys in the fall may have contributed to the low fish numbers. Experience has shown that high flows are associated with low electrofishing catch rates, and vice versa. Although the number of fish collected in 2000 was low, the species composition of the catch was similar to previous years, with 6 species comprising 80 percent of the electrofishing catch by number and 6 species comprising 83 percent of the electrofishing catch by weight. All indications are that the low catch in 2000 was an anomaly, and the North Anna River continues to support a healthy, well-balanced community of aquatic organisms.

2.4.2.3.1 Commercially-Important Fisheries

As noted in Section 2.4.2.2, there is no commercial fishing in Lake Anna or the North Anna River. There are no runs of anadromous fish in the North Anna River. The North Anna River is a tributary of the Pamunkey River, which has an annual run of American shad; but these shad do not move into the North Anna River (Reference 41) (Reference 42). The Pamunkey Tribal Council operates an American shad hatchery on the Pamunkey River approximately 75 miles downstream of the North Anna Dam. Shad reared at this facility are normally stocked in the Pamunkey River and the James River as fry.

Young American eels (*Anguilla rostrata*) are found in the North Anna River, but are not sought by commercial fishermen. The American eel is a catadromous species, meaning that these fish begin their lives in the open ocean, then migrate into coastal rivers where they spend more of their lives in fresh water. (Reference 43) Upon reaching sexual maturity, at age 5 to 7 years, the eels migrate back to the ocean where they spawn and die. Eels in the North Anna River are juveniles, also known as “yellow eels.”

2.4.2.3.2 Recreationally-Important Fisheries

The lower North Anna River below the North Anna Dam is small, approximately 75 to 150 feet wide, but supports a diverse assemblage of stream fishes. It is a popular fishing spot. Unless stream flow is unusually high, powerboats are impractical: most anglers fish from shore or from canoes and kayaks. Recreational fishermen generally seek one or more of the following fish species: largemouth bass, smallmouth bass, or redbreast sunfish. Bluegill and redear sunfish are present as well, but receive less attention from anglers.

2.4.2.3.3 Important Species in North Anna River

Although the VDGIF periodically surveys the fish of the lower North Anna River and monitors the condition of the recreational fishery, it does not actively manage these populations. VDGIF is most concerned about the largemouth bass and smallmouth bass populations in the lower river, as these are the species most often sought by anglers and the species most likely to attain harvestable size. Recent VDGIF surveys have indicated that largemouth bass and smallmouth bass populations are healthy, despite the river’s limited supply of forage.

a. **Largemouth Bass and Smallmouth Bass**

Since 1987, Virginia Power biologists have gathered data on the abundance and distribution of these bass species in the lower North Anna River via direct (snorkel) observation (Reference 13). Biologists swim established transects at four locations in the lower river, counting and categorizing (by size) all bass that are observed and noting the type of cover being used. Historically, largemouth bass have dominated the fish counts at upstream locations, while smallmouth bass have been more prevalent at downstream locations (Reference 13). In recent years, both species have occupied the entire study area. As a general rule, however, largemouth bass are more abundant at the upstream locations and smallmouth bass are more abundant at the downstream locations. Density estimates for both largemouth and smallmouth bass at all locations were lower in 2000 than average densities for the entire study period, but dense growth of hydrilla adjacent to stream banks limited the ability of observers to accurately count fish (Reference 13).

b. **Redbreast**

Redbreast ranked first in abundance in North Anna River electrofishing samples in 1998, 1999, and 2000, and have ranked in the top four every year since 1981 (Reference 13). The redbreast is found across the coastal plain and Piedmont of Virginia in warm-water creeks and rivers of low-to-moderate gradient (Reference 41). It is an adaptable species, and may also be found in ponds, lakes, reservoirs, and even slightly brackish waters near the coast. The redbreast of the lower North Anna River appear to be a typical stream-dwelling population, with unremarkable growth rates, food habits, and spawning habits.

2.4.2.3.4 Nuisance Species

Asiatic clams first appeared in benthos samples from the North Anna River during the operational phase of the NAPS 316(a) study, conducted over the period 1981–1985. By the end of this period, Asiatic clams were firmly established in the lower North Anna River and were a “major” component of the benthos at several sampling locations (Reference 2).

2.4.2.3.5 Threatened and Endangered Aquatic Species

As presented in Section 2.4.2.2, Virginia Power has monitored fish populations in Lake Anna and the North Anna River for more than 25 years. No federally-listed or state-listed fish species has been collected in any of these monitoring studies, nor has any listed species been observed in creel surveys or occasional special studies conducted by Virginia Power biologists. No state- or federally-listed fish species’ range includes Lake Anna or the North Anna River, and none is believed to occur in counties adjacent to Lake Anna or the North Anna River (i.e., Caroline, Hanover, Louisa, Orange, and Spotsylvania Counties).

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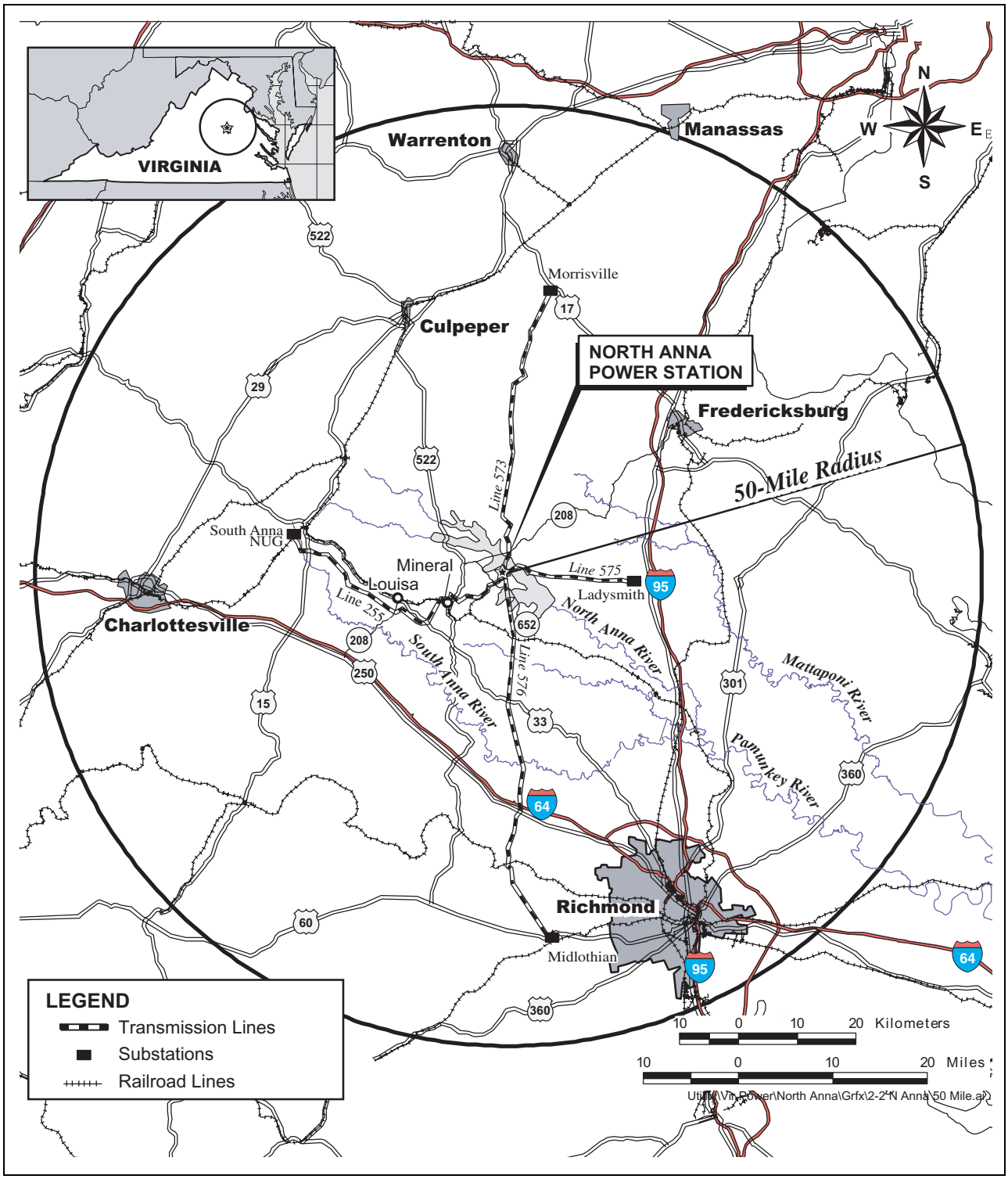

Figure 2.4-1 Lake Anna and the North Anna River

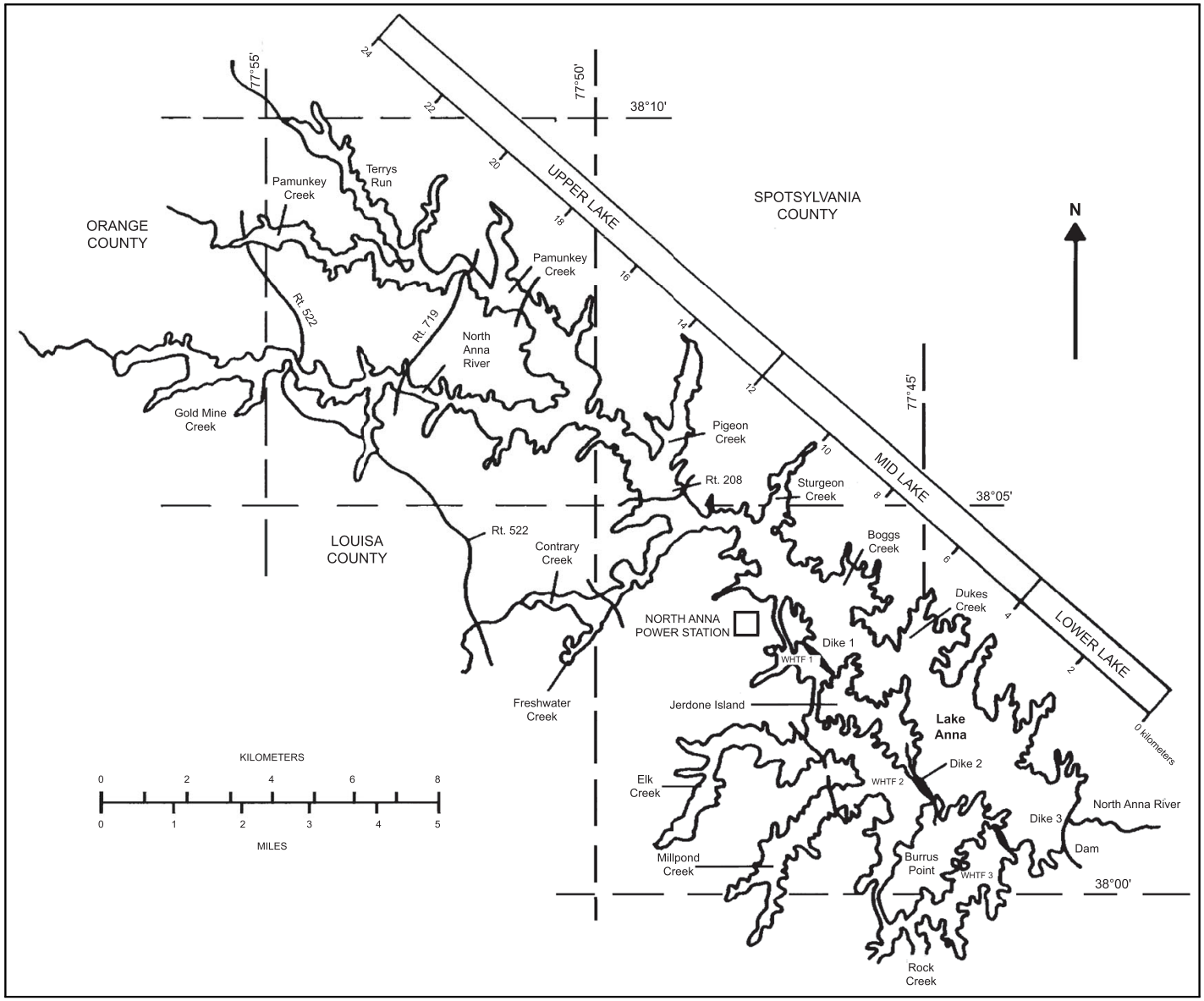

Figure 2.4-2 North Anna River; Northeast Creek; Contrary Creek

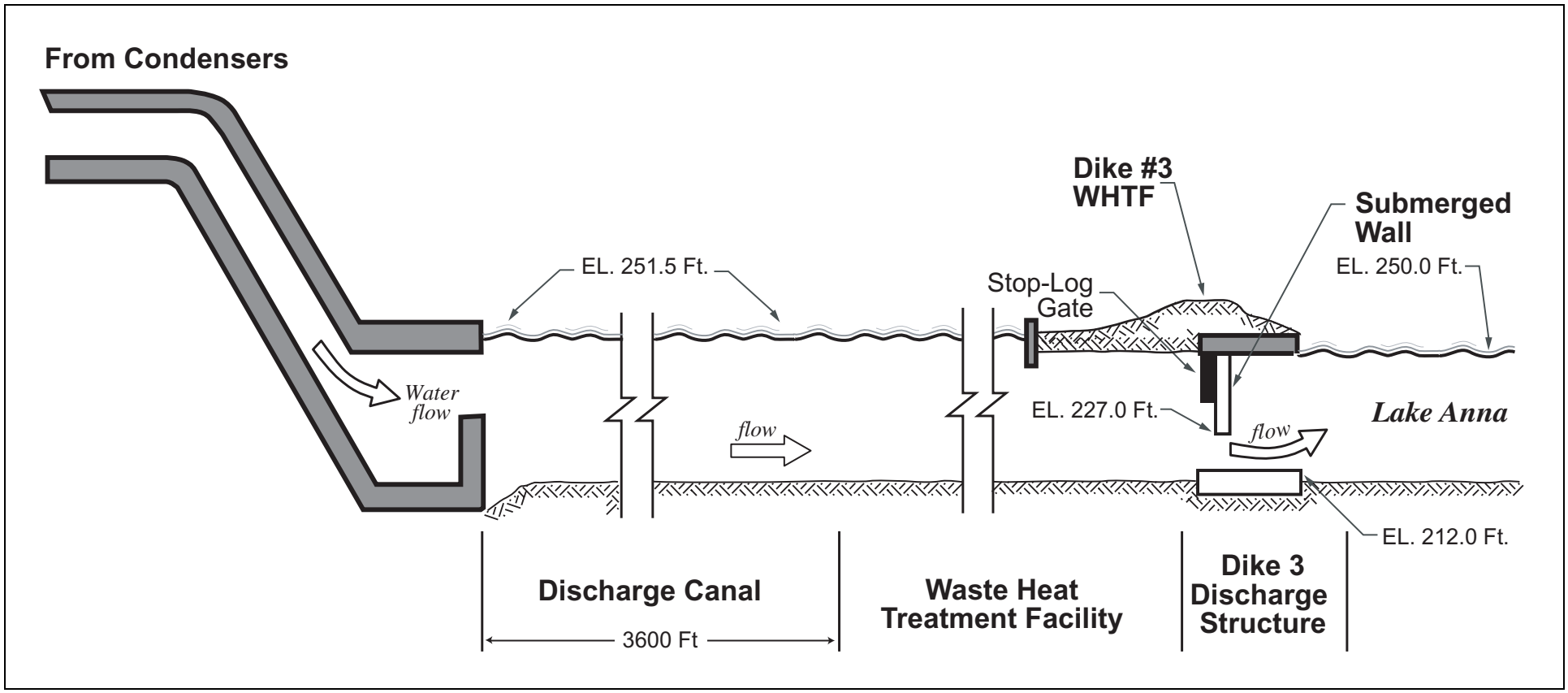

Figure 2.4-3 Schematic Cross-Sectional Diagram of Water-Discharge System at Dike 3 WHTF

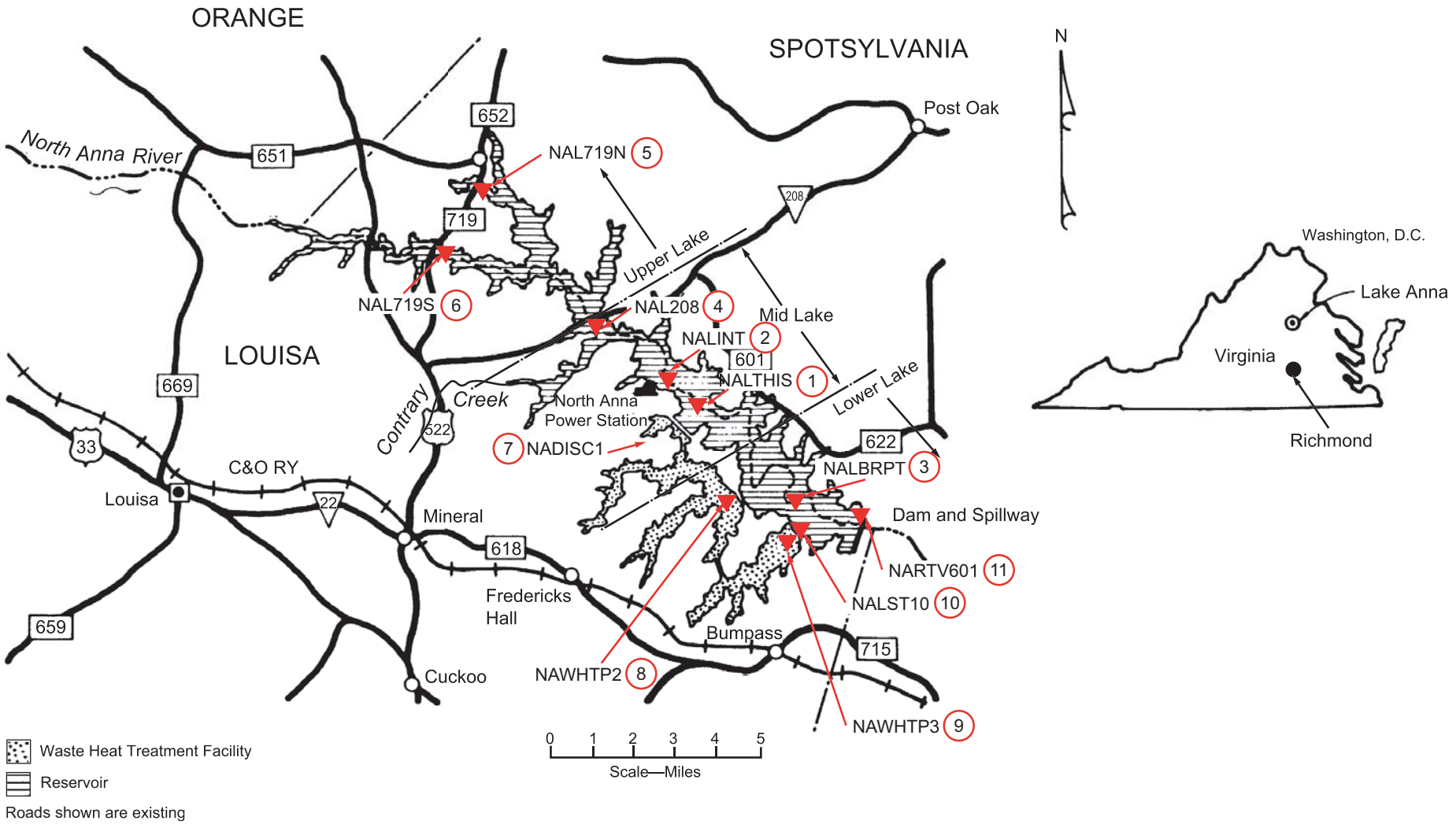

CHART 1
APPROXIMATE LOCATIONS OF FIXED ENDECO TEMPERATURE RECORDS.

Figure 2.4-4 Location of Temperature Sensors - Lake Anna

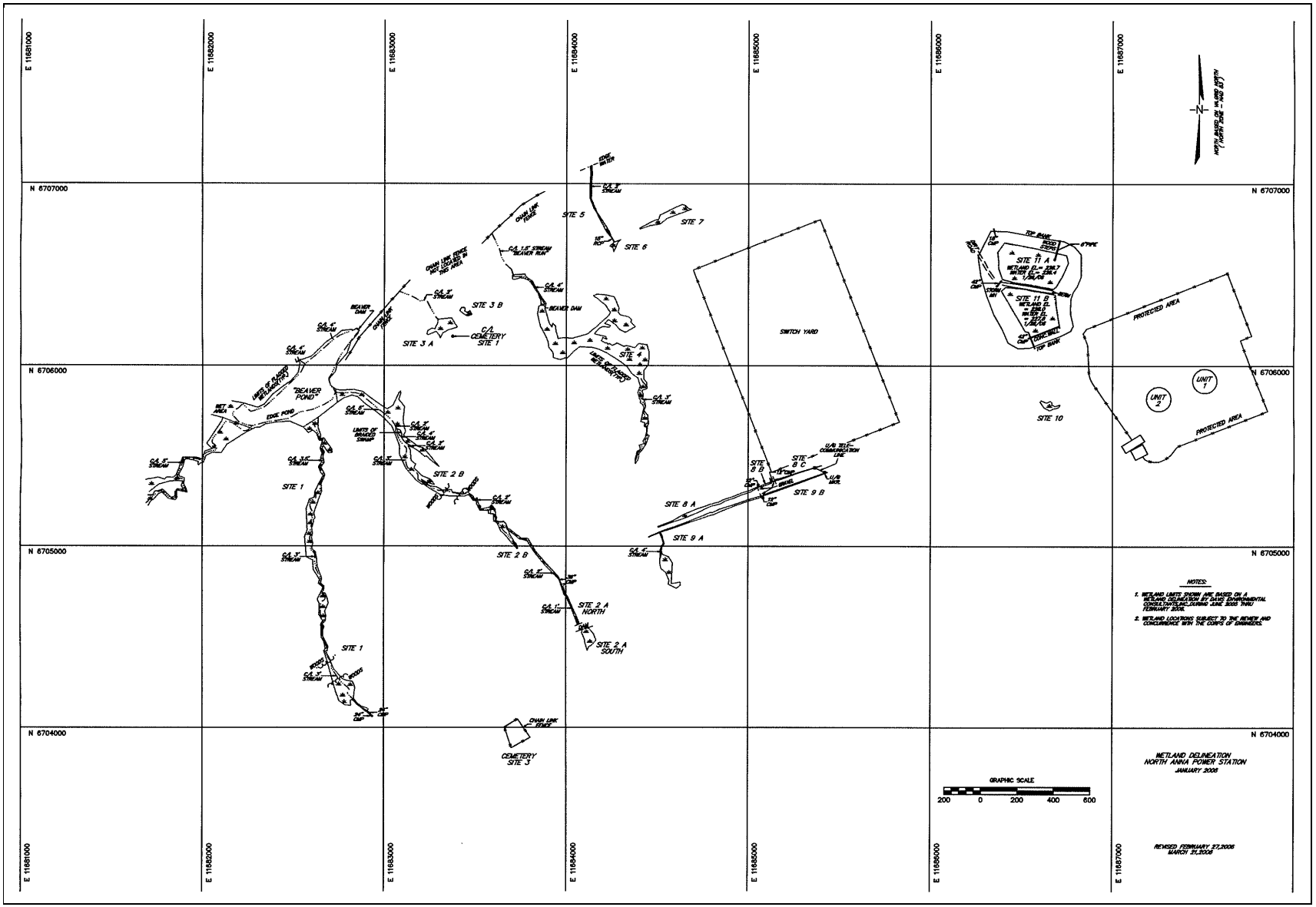

Figure 2.4-5 Overall ESP Site Wetlands Survey

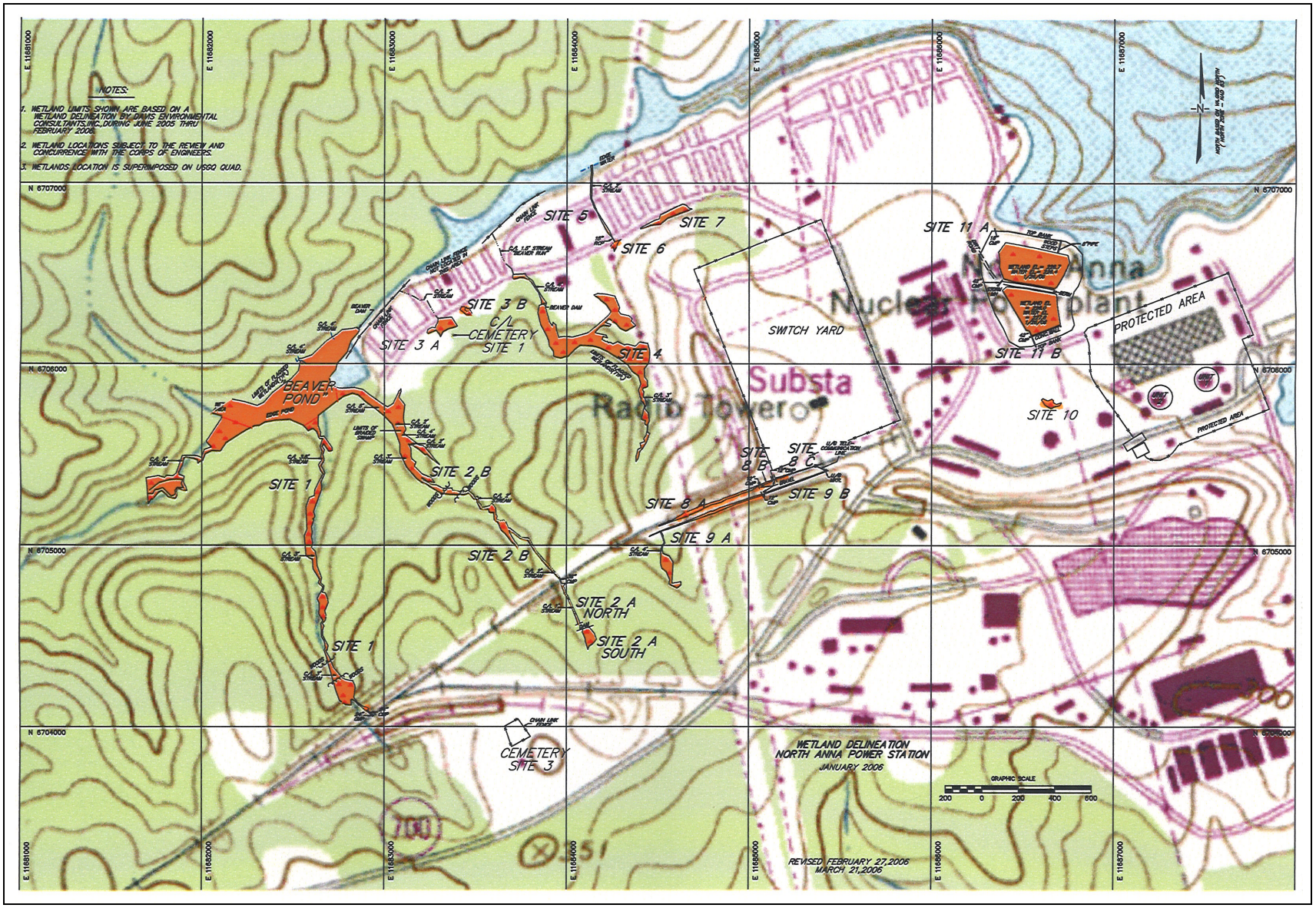

Figure 2.4-6 Sketched ESP Site Wetlands on Topo

2.5 Socioeconomics

This section presents the socioeconomic resources that have the potential to be impacted by the construction, operation, and decommissioning of the new units. The section is divided into four subsections: 1) demographics, 2) community characteristics, 3) historic properties, and 4) environmental justice. These subsections include spatial (e.g., regional, vicinity, and site) and temporal (e.g., 10-year increments of population growth) considerations, where appropriate, as referenced.

2.5.1 Demography

The population distribution surrounding the ESP site, up to an 80-km (50-mi.) radius, has been estimated, based on the most recent U.S. Census Bureau decennial census data (Reference 1). The population distribution encompasses nine concentric rings at 2 km (1.2 mi.), 4 km (2.5 mi.), 6 km (3.7 mi.), 8 km (5.0 mi.), 10 km (6.2 mi.), 16 km (10 mi.), 40 km (24.9 mi.), 60 km (37.3 mi.), and 80 km (50 mi.), and 16 directional sectors. The projected population estimates for Years 2010, 2020, 2030, 2040, and 2065 have been calculated with a formula adopted from the Weldon Cooper Center for Public Service (Reference 2) using the 1990 Census and 2000 Census data as the base.

2.5.1.1 Resident Population Within 16 km (10 miles)

Figure 2.5-1 shows the general locations of the municipalities and other features within 10 miles (16 km) of the ESP site. According to the 2000 Census survey, Mineral, which has a population of 424 located within about 1 square mile (incorporated), is the largest community within 10 miles of the site (Reference 5). As reported in NAPS UFSAR (Reference 4, Section 2.1.3.1), the population in 1990 was 452. Therefore, the population of Mineral has remained constant during the past decade.

The population distribution within 16 km (10 miles) of the site has been computed by overlaying the 2000 Census block points data (the smallest unit of census data) (Reference 1) on the grid shown on Figure 2.5-1, and summing the population of the census block points falling in each of the polar sectors comprising the grid. The census block-point summation and allocation has been accomplished using the Landview 5 (LV5) software, operating directly on census data, and the MARPLOT mapping software (Reference 1). The system can display Census 2000 demographic data, jurisdictional entities, and many statistical entities of the U.S. Census Bureau. It can also calculate Census 2000 population, racial distribution, census block count, and housing unit count within a user-defined radius. Using MARPLOT, the grid system was created as shown on Figure 2.5-1. LV5 was designed to summarize the population distribution and other information, once the user selected an area of interest within the grid system. The entire grid system is evenly divided into 16 directions, each direction consisting of 22.5 degrees.

The population distributions and related information have been recorded on a spreadsheet to tabulate the results at the distances of interest for all sixteen directions. In order to generate more accurate counts, census block points were used in LV5 to calculate population distributions.

Population projections for the area within 10 miles of the ESP site up to 65 years from the 2000 census were developed. The formula used for average annual growth (percentage of growth) is adopted from Reference 2. The Weldon Cooper Center for Public Service group has performed the 2001 provisional population estimates for the Commonwealth of Virginia.

$$\text{Annual Average Growth} = \frac{\text{Log}_{10}(\text{Population}_{2000} / \text{Population}_{1990})}{(2000 - 1990) \times 0.4342945}$$

The 1990 population distributions within each county and city considered in Virginia and Maryland were also obtained from the U.S. Census Bureau (Reference 25). The same formula is also used for projection of the transient population up to the year 2065. The 10-mile population distribution for Year 2000 is shown on Figure 2.5-3. The 16-km (10-mile) resident and transient population projections for the years 2010, 2020, 2030, 2040, and 2065 are given in Figure 2.5-4 through Figure 2.5-7.

In 2000, the total population within 16 km (10 mi.) of the ESP site was 15,511. Based on the average annual growth, the estimated population for 2010 is 20,996. This is a projected increase of 35.4 percent. In 2020, an estimated 26,480 people will live within the 16-km (10-mi) radius of the site. This constitutes a 26.1 percent increase from 2010. For each decade, there is a slight downward trend in the percent increase of the population. The growth between 2020 and 2030 is projected to be 20.7 percent and between 2030 and 2040 to be 17.2 percent. Table 2.5-1 presents the population distribution within a 16-km (10-mi) radius of the ESP site for four decades (2000 to 2040).

Table 2.5-2 presents the estimated sex distribution of the population within a 16-km (10-mi) radius of the ESP site. The ratio of men to women is fairly consistent throughout the different concentric rings. The ratio of men to women in Virginia is slightly over 96 men to every 100 women (see Table 2.5-3). The ratio of men to women living within the 16-km (10-mi) radius of the ESP site is about the same: 97 men to every 100 women.

Table 2.5-4 presents the estimated age distribution of the population within a 16-km (10-mi) radius of the ESP site. The number of individuals in the 20-to-24 age group and the 65 and over age group is significantly lower than the rest of the age groups. However, this is typical of the Commonwealth of Virginia as a whole (see Table 2.5-14). The percentage of each age group tends to be very similar across each concentric ring. There appear to be no large groupings of any specific age group.

Table 2.5-6 presents the racial and ethnic distribution of the population within a 16-km (10-mi) radius of the ESP site. The white population is by far the majority within the 0- to 16-km (0- to

10-mi.) radius, with 12,805 people (82.6 percent of the population). However, the percentage of white people living within a given radius changes throughout the entire 16-km (10-mi.) radius from 94.3 percent in the 2-km (1.2-mi.) radius to 76.4 percent in the 8-km (5-mi.) radius to 83.6 percent in the 16-km (10-mi.) radius.

The percentage of black people living within a given radius also changes greatly throughout the entire 16-km (10-mi) radius from 4.8 percent in the 2-km (1.2-mi.) radius to 21.5 percent in the 8-km (5-mi.) radius to 13.5 percent in the 16-km (10-mi.) radius. The overall percentage of black people within the 0- to 16-km (0- to 10-mi.) radius from the site is 14.9 percent (2309 people).

Table 2.5-7 presents the estimated income distribution of the population within a 16-km (10-mi.) radius of the ESP site. Income distribution provided in the 2000 census data set has been recorded only up to Year 1999. Most of the individuals 15 years of age and older earn below $25,000 per year. Within the 0- to 16-km (0- to 10-mi.) radius, an estimated 5404 individuals (approximately 45.7 percent) earn less than $25,000. This is consistent with the overall Virginia numbers within one percent (see Table 2.5-7). The percentage of individuals earning between $50,000 and $75,000, between $75,000 and $100,000, and over $100,000 increases almost consistently throughout the different concentric rings.

Overall, the characteristics of the population within each concentric ring are basically the same.

2.5.1.2 Resident Population Between 16 km (10 miles) and 80 km (50 miles)

The 80-km (50-mi.) radius around the ESP site covers thirty counties and four cities in Virginia and one county in Maryland (See Figure 2.5-2). The Town of Louisa is approximately 12 miles to the west of the site. The population of the town has increased from 1088 (Reference 4) to 1400 (Reference 9, Section 2.2.8.5) between 1990 and 2002. About 40 miles south-southwest of the site is Richmond, Virginia, with a population of 197,790 in the Year 2000. About 36 miles west of the ESP site is Charlottesville, Virginia, which has a population of 45,049 according to the 2000 Census. About 22 miles northeast of the ESP site is Fredericksburg, Virginia, with a population of 19,279. The nearest population center with more than 25,000 residents is the City of Charlottesville. The closest point of Fredericksburg is 22 miles to the northeast with a projected 2065 population of about 20,950.

In addition to the thirty counties within Virginia, the 80-km (50-mi.) radius from the ESP site also encompasses Charles County, Maryland. The population distribution within that 80-km (50-mi.) radius for Charles County, which at its closest point is 37 miles northeast from the site, is 9270 based on the 2000 census data.

The 80-km (50-mi.) Year 2000 resident and transient population distribution throughout the four concentric distance rings and the 16 directional sectors is shown on Figure 2.5-8. The resident and transient population projections for the area between 16 and 80 km (10 and 50 mi.) for years 2010, 2020, 2030, 2040, and 2065 are based on the same methodology as the 16-km (10-mi.)

projections. These population projections throughout the four concentric rings and the 16 directional sectors are given in Figure 2.5-9 through Figure 2.5-12A.

The total population within 80 km (50 mi.) of the ESP site is 1,538,156, according to the 2000 Census. Based on the average annual growth, the estimated 2010 population is 1,849,908, which is a projected increase of 20.3 percent. Table 2.5-8 presents the population distribution within an 80-km (50-mi) radius of the site for four decades (2000 to 2040).

In 2020, an estimated 2,161,660 people will live within the 80-km (50-mi) radius. This constitutes a 16.9 percent increase from 2010. For each decade, there is a slight downward trend in the percent increase of the population. The growth between 2020 and 2030 is projected to be 14.4 percent and between 2030 and 2040 to be 12.6 percent.

Table 2.5-9 presents the estimated sex distribution of the population within an 80-km (50-mi.) radius of the ESP site. The population within this 80-km (50-mi.) radius contains about 94 males for every 100 females. This is a bit lower than the overall state of Virginia, which averages slightly over 96 men to every 100 women (See Table 2.5-3).

The estimated sex distribution throughout the 80-km (50-mi.) radius is fairly consistent. The distribution within each concentric ring is basically the same and is very close to the ratio for Virginia as a whole (see Table 2.5-3).

Table 2.5-10 presents the estimated age distribution of the population within an 80-km (50-mi.) radius of the ESP site. The age group with the largest percentage of people is the 25- to 44-year-old age group. The next largest age group is the 0- to 19-year-old age group. This could be based on the fact that most parents are between the ages of 25 and 44, and their children, would be 19 years old and younger.

For each age group, the percentages are fairly consistent, regardless of the size of the population within the specific radius; although, there are a couple of inconsistencies. These inconsistencies include the 0-to-16-km (0-to-10-mi.) radius's 25-to-44 age group (which is lower than the same group in the other concentric circles) and the 0-to-16 km (0-to-10 mi.) radius's 0-to-19 age group (which is higher than the same group in the other concentric circles).

Table 2.5-11 presents the racial and ethnic distribution of the population within an 80-km (50-mi.) radius of the ESP site. The ratio of the white population to the black population within 80-km (50-mile) radius is 3 to 1 (see Table 2.5-12) which is consistent with the ratio of 3.7 to 1 for the Commonwealth of Virginia in its entirety.

The black population increases significantly between the 60-km (37.3-mi.) radius and the 80-km (50-mi.) radius. This increase is due to the population of the City of Richmond. In Richmond, the ratio of white individuals to black individuals is 67 to 100 (see Table 2.5-12).

Table 2.5-13 presents the estimated income distribution of the population within an 80-km (50-mi.) radius of the ESP site. The largest percentage of the population earned less than $25,000 in 1999.

This was consistent with the rest of the state. The distribution of earnings within each concentric ring is fairly consistent throughout the entire 80-km (50-mi.) radius from the ESP site.

The majority of current NAPS employees reside in Henrico, Louisa, Orange, and Spotsylvania counties. Spotsylvania and Louisa counties are two of the fastest growing counties in Virginia. While Virginia as a whole has increased in population by 13.4 percent between 1990 and 2000, Spotsylvania and Louisa counties have increased in population by 45.4 percent and 23.3 percent, respectively. Henrico and Orange counties have also surpassed the Virginia average by increasing in population by 18.6 and 18.9 percent, respectively. However, the City of Richmond decreased in population by 2.5 percent in the same time period.

Table 2.5-3 presents the sex distribution of the population in the counties that contribute most of the current NAPS employees, in comparison to the entire state of Virginia. The counties' sex-distributed populations closely track within one percent. The exceptions are Henrico County and the City of Richmond in which both locations have a larger female population.

Table 2.5-14 presents the age distribution of the population in the counties that contribute most of the current NAPS employees in comparison with the entire state of Virginia. The counties' age-distributed populations closely track within 3 percent. The exceptions are Spotsylvania County's 0-to-19 age group (which is 4.8 percentage points higher than the Virginia average), Orange County's 25-to-44 age group (which is 3.8 percentage points lower than the Virginia average), and Orange County's 65-and-older age group (which is 6 percentage points higher than the Virginia average).

Table 2.5-12 presents the racial and ethnic distribution of the population in the counties that contribute most of the current NAPS employees in comparison with the entire state of Virginia. The counties' racial and ethnic-distributed populations closely track within 5 percent. The exceptions are Orange County's white population group (which is 12.1 percentage points higher than the Virginia average), the City of Richmond's white population group (which is 34 percentage points lower than the Virginia average), Spotsylvania County's white population group (which is 10.6 percentage points higher than the Virginia average), Orange County's black population group (which is 5.8 percentage points lower than the Virginia average), the City of Richmond's black population group (which is 37.6 percentage points higher than the Virginia average), and Spotsylvania County's black population group (which is 7.1 percentage points lower than the Virginia average).

Table 2.5-7 presents the income distribution of the population in the counties that contribute most of the current NAPS employees in comparison with the entire state of Virginia. The counties' income-distributed populations closely track within 4 percent. The exceptions are Henrico County's $1000-$25,000 income group (which is 5.3 percentage points lower than the Virginia average), Louisa County's $1000-$25,000 income group (which is 5.5 percentage points higher than the Virginia average), the City of Richmond's $1000-$25,000 income group (which is 9.8 percentage points higher than the Virginia average), Spotsylvania County's $1000-$25,000 income group

(which is 6.3 percentage points lower than the Virginia average), and Henrico County's $25,000-to-$50,000 income group (which is 6.6 percentage points higher than the Virginia average).

The population distributions throughout the 9 concentric rings and the 16 directional sectors extending to a 50-mile radius for the Present Date, Startup Date, and 40-year Date are summarized in Table 2.5-15. The startup date was conservatively assumed to be around Year 2025, based on the assumption that the period of ESP approval is between 2005 and 2025.

2.5.1.3 Transient Population

2.5.1.3.1 Transient Population Within 16 km (10 miles)

Information concerning transient population for the area has been collected from several sources, because the information is not available from the 2000 census data. The area within 10 miles (16 kilometers) of the ESP site is predominantly rural and is characterized by farmland and wooded tracts of land. Since there are no significant industrial or commercial facilities in the area, and none are anticipated (Reference 4, Section 2.1.3.3), the transient employment population is likely to move out of, rather than into, the area.

Recreational use of Lake Anna, including Lake Anna State Park, is the greatest contributor to transient population in the area. The usage of the lake was estimated from a number of contributing factors including the number of boat ramps, wet slips, campsites, picnic areas, etc. These contributing factors are listed in Table 2.5-16.

An estimate of lake usage on a peak weekend day in the peak summer season has been developed based on representative usage of recreational facilities (e.g., boating, picnicking, camping) provided by the VDCR (Reference 4, Section 2.1.3.3) and the Lake Anna recreational facilities listed in Table 2.5-16. However, residents should have been included in the census data. This estimate does not include use by local residents with their own docks. In addition, many residents without docks keep their boats in marina wet slips or use the boat ramps and are, therefore, included in the lake usage.

There are six marinas in the vicinity of the ESP site. The closest is 1.4 miles north-northeast of the site. The remaining marinas are from 2 to 2.5 miles distant. A survey of several of the marinas indicate that their actual boat launches, per ramp, ranged from 15 to 40 per peak day, which is significantly lower than the number of 80 per day provided by the VDCR as an upper limit, and that the usage per ramp has dropped as new ramps are added. This was attributed to parking space limitations and the fact that the lake usage by recreational boaters may be approaching saturation. A rate of 50 launches per ramp per day was selected as being more representative of Lake Anna conditions.

Based on 50 launches per ramp per day, these marinas and other boat ramps, including those at Lake Anna State Park, could provide access for up to 1450 pleasure craft on Lake Anna. Peak day

usage estimates for boats moored in wet slips ranged from 30 to 50 percent. Assuming that all slips are rented, 150 additional boats would be added, bringing the total, excluding boats from private docks, to 1600. The resulting transient population at three persons per boat would be 4800 (Reference 4, Section 2.1.3.3).

The two commercial campgrounds, with a combined total of more than 200 campsites, has been estimated by the Virginia State Department of Conservation and Recreation to contribute about 650 persons to the transient population assuming three persons per campsites. The number of picnickers has been estimated at 450. Since both campsites have boat ramps, significant double counting is likely (Reference 4, Section 2.1.3.3)

Lake Anna State Park provides facilities for picnicking, fishing, boat launching, swimming and biking. The Lake Anna State Park Manager estimated a peak daily attendance of 4372 from June 2002 through August 2002, and an annual attendance of 187,302 between July 1, 2001 and June 30, 2002, based on traffic counts. Double counting is likely as boaters are included in the traffic count.

The resulting estimated total peak daily transient population on Lake Anna (including the WHTF and Lake Anna State Park) is less than 11,270 (see Table 2.5-17). Since use of the WHTF is limited to residents and their guests, there are no public boat ramps. The WHTF transient population, estimated at less than 1,000, is based on one guest for each resident in the polar sectors encompassing the WHTF.

Annual transient population is uncertain because of the dramatic drop in boating on weekdays and during non-summer months. Based on the Lake Anna State Park data, assuming 180 days of operation, the average daily attendance is less than one quarter of the peak daily attendance. Conservatively assuming that the average attendance, excluding the park, is one half the peak daily figure, the total annual attendance would be about 807,300, based on a 180-day season.

Transient population within 16 km of the ESP site combined with the resident population in that area for Year 2000 and for projected years 2010, 2020, 2030, 2040, and 2065 are presented in Figure 2.5-3 through Figure 2.5-7.

2.5.1.3.2 Transient Population Between 16 km (10 miles) and 80 km (50 miles)

It is difficult to provide an accurate count of the transient population between 10-mile (16-km) and 50-mile (80-km) concentric circles from the ESP site. There are colleges, schools and hospitals within 50 miles. However, compared to the resident population within the same area, use of these facilities by transient population is expected to be insignificant.

Between 16 km and 80 km of the ESP site, the only major recreational facility that induces a significant amount of transient population is Paramount's Kings Dominion Amusement Park. Paramount's Kings Dominion is 35 miles southeast from the site. The park opens from March to November and hosts about 2 to 2.5 million visitors annually. According to the park's public relations

manager, the park could experience slow growth in the future, until it reaches its current maximum capacity of 2.875 million visitors per year (i.e., an additional 15 percent above the current attendance). On average, the park opens to the public about 138 days per year (Reference 6). Using the maximum capacity of the park and the average number of days open, the average daily park visitor count is conservatively estimated to be 20,830.

There is no official count of visitors that come from areas outside the 50-mile radius from the ESP site. However, the majority of the park visitors are expected to come from Richmond and Fredericksburg areas due to their proximity to the park. It is conservatively assumed that 40 percent of the daily park visitors come from areas outside the 50-mile radius. The 8350 park visitors from further than 50 miles are considered transient population and the number is included in the population distribution estimates (See Table 2.5-15).

Transient population between 16 km and 80 km of the ESP site combined with the resident population in that area for Year 2000 and for projected years 2010, 2020, 2030, 2040, and 2065 are presented in Figure 2.5-8 through Figure 2.5-12A.

2.5.1.4 Migrant Labor

Migrant laborers are typically members of minority or low-income populations. Because migrant workers travel and can temporarily spend a significant amount of time in an area without being actual residents, they may be unavailable for census counts. Therefore, migrant workers could be under-represented in U.S. Census Bureau minority and low-income population counts.

Migrant workers do not harvest agricultural crops in Louisa County; however, they do re-plant forest land that has been harvested. Over the past 5 years, most completely harvested forestland in Louisa County has been reforested (replanted) or allowed to regenerate naturally. Planting takes place from late January through March and is often done under Virginia Department of Forest contract. Data on the number of migrant workers participating in the planting are not available, but the number is considered to be small. Given the expected small number of migrant workers, and the probability of the population being concentrated in a single location, their temporary domicile would not be long in duration. Therefore, migrant workers would not materially change the population characteristics of any particular census tract within Louisa County.

2.5.1.5 Population Density

Given an approved ESP period of 20 years and an assumed ESP approval date of 2005, the startup date of new units is conservatively assumed to be 2025. Assuming an operational period of 40 years for new units, new unit operations could extend until 2065.

Figure 2.5-13 shows the actual cumulative populations in Year 2000 and projected cumulative population in Year 2065 as a function of 10-mile to 50-mile radial distances from the site. On the same figure, population density curves, spanning the same radial distances, are shown for 500 persons per square mile, and of 1000 persons per square mile.

By inspection of the curves for actual population densities of Year 2000 and Year 2065 projections, it is concluded that at the time of initial site approval and within about 5 years thereafter, the population densities, including weighted transient population, averaged over any radial distance out to 20 miles (cumulative population at a distance divided by the circular area at that distance), would not exceed 500 persons per square mile. The results conform to the guidance in RG 4.7, Regulatory Position C.4 (Reference 7).

Similarly, by inspection and projection of the same curves to account for trends over the lifetime of the new units, it is concluded that the expected population densities, including weighted transient population, averaged over any radial distance out to 30 miles (cumulative population at a distance divided by the area at that distance), would not exceed: 1) 500 persons per square mile at the time of initial operation, and 2) 1000 persons per square mile over the lifetime of new units (Reference 8).

2.5.2 **Community Characteristics**

The region around the ESP site has a medium density population (Reference 9). The permanent workforce at the existing units consists of approximately 850 employees. During planned outages of an existing unit (every 18 months/unit), an additional 700 to 1000 workers are onsite for a period of 30 to 40 days. During construction of the new units, a peak workforce of approximately 5000 would be expected. Depending on the reactor design selected and the scheduling of the installation of the new units, this peak workforce could be onsite for 5 to 7 years. Approximately 720 new employees would be required for the operation of the new units. For planned outages, about the same number of additional workers could be expected for a new unit as is used for an existing unit.

The communities with the greatest potential to be impacted socio-economically by the installation and operation of new units at the ESP site are in Henrico, Louisa, Orange, Hanover, and Spotsylvania Counties, and the City of Richmond because most employees reside in one of these counties. These counties are in central Virginia, which has experienced a steady growth in population and economic activity in the last decade. As presented in Section 2.5.1, the population growth over the last decade has been greatest in Louisa and Spotsylvania Counties. Conversely, the City of Richmond population during this period has declined.

The existing socio-economic situation of the area around the NAPS site has been addressed in detail by the Environmental Report (ER) prepared by Virginia Power as part of its Application for Renewed Operating Licenses for NAPS Units 1 and 2 (Reference 10), and by the Supplemental Environmental Impact Statement (SEIS) prepared by the NRC for the license renewal of NAPS Units 1 and 2 (Reference 11). Although both documents have been prepared within the last two years, the information provided in these documents has been updated when more recent information was available and pertinent to the installation of new units at the ESP site. The following discussion is based primarily on these sources.

2.5.2.1 Economy

Information on the population distribution (by county and by distance from the ESP site), including breakdowns by age, sex, race and ethnic background, are presented in Section 2.5.1. Tables on estimated income distribution are also provided, identifying income group by distance from the ESP site and county. These tables include similar information for the Commonwealth of Virginia as a point of comparison in assessing whether the area around the ESP site is similar to the rest of the state. The conclusion is that, in general, there are no great differences in the income distributions between the area around the ESP site and throughout the state as a whole.

Percent unemployment, individual poverty rates, and median household incomes for the five counties of interest and the City of Richmond have been obtained from the Virginia Employment Commission (VEC) website (Reference 12) and include data generated by the U.S. Census Bureau from the 2000 Census (Reference 13). The information is presented in Table 2.5-18.

Similar data for Virginia as a whole are also presented to provide a point of comparison for the local data. The unemployment rates, individual poverty rates, and median household incomes for Charles County in Maryland and for the State of Maryland are also presented in this table, because the 80 km (50 mile) radius that defines the potential area of impact for the new units includes part of Charles County. Furthermore, the history of major construction at NAPS shows that part of the construction work force has originated from Maryland. (Reference 10) The data have been obtained from the Maryland website for the Maryland Department of Labor, Licensing, and Regulation (Reference 14), and includes data generated by the U.S. Census Bureau from the 2000 Census.

Based on Table 2.5-18, the total civilian labor force in the region (November 2002) was 434,366, of which 65,349 were in Charles County, Maryland.

2.5.2.1.1 Hanover County, Henrico County, and the City of Richmond

Henrico County, Hanover County, and the City of Richmond are part of the Richmond-Petersburg metropolitan statistical area (MSA), which is home to approximately 1 million people (Reference 15). Of this number, 262,300 people live in Henrico County, 86,320 in Hanover County, and 197,790 in the City of Richmond. The MSA is located approximately 161 km (100 miles) from Washington, D.C. and is the primary economic driving force within an 80-km (50-mile) radius of the ESP site. This MSA has a transportation network of trucking and railroad terminals, interstate highway access to main east-west and north-south corridors, and an international airport. The CSX Corporation headquarters is located in Richmond. The Port of Richmond, the westernmost inland port, has direct access to the Atlantic Ocean, serving both domestic and international markets. A map of the area, taken from the North Anna License Renewal Application (Reference 10), is presented as Figure 2.5-16. Paramount's Kings Dominion, located in Hanover County, is a major tourist attraction for the area.

The Richmond area is headquarters for more than 35 major corporations, including 12 Fortune 1000 companies, of which 6 are Fortune 500 companies, and 3 are Forbes 500 largest companies.

Capital One Financial Corporation is the largest private employer in the area. Service is the largest employment sector in the MSA, followed by retail and wholesale trades, manufacturing, finance, and construction. (Reference 15)

Approximately 45 percent of resident workers in Henrico County commute to jobs outside the county, as compared to almost 64 percent of resident workers in Hanover County and about 40 percent of resident workers in the City of Richmond. The unemployment rate for Henrico County is 3.3 percent, as of November 2002, which is higher than the 2.4 percent for Hanover County and lower than the corresponding rate of 5.8 percent for the City of Richmond. (Reference 12)

2.5.2.1.2 Louisa County

Louisa County is in the triangle between Richmond, Fredericksburg, and Charlottesville. Interstate 64 runs east-west through the county, as does a CSX rail line. Louisa County, with a population of 25,627, continues to be a rural community with most of the land forested or under cultivation. There are two incorporated towns in the county, Louisa and Mineral, both of which are within 15 miles of the ESP site. Because the ESP site is located there, Louisa County has benefited economically more from the plant than the other counties that could be impacted by the installation of the new units. Table 2.5-19 lists the top five employers in the county, their product, and the number of employees. The remaining 14 employers have less than 100 employees, with most generally having fewer than 25 employees. (Reference 16)

There has been relatively little growth in industry in the last ten years although there has been significant growth in population. The county is actively pursuing additional industries in an effort to diversify and expand its industrial base. Almost 62 percent of the resident workers in Louisa County commute to jobs outside the county. (Reference 12)

The existing units operations have contributed more than 50 percent of the property taxes paid to Louisa County over the past decade, and, therefore, have allowed the property tax assessment rates to remain below those of neighboring counties. While recognizing the benefits of the existing units, the county is still looking to expand its industrial base so as to become less dependent on one facility.

2.5.2.1.3 Orange County

Orange County, with a population of 25,881, has two incorporated towns, Orange and Gordonsville, and one planned, gated residential community, Lake of the Woods. It borders the northwestern extent of Lake Anna and is about 72 miles from Richmond, 75 miles from Washington, D.C., and 25 miles from Charlottesville, the home of the University of Virginia. Agribusiness is the main business sector in Orange County; although, manufacturing has played a significant role for over 80 years. Approximately 97 percent of the land in Orange County is forested, under cultivation, or pasture land. (Reference 17)

Of the 11,925 resident workers in the county, approximately 53 percent commute to jobs outside the county (Reference 12). According to the Chamber of Commerce, there are over 535 businesses and industries in the county, most of which employ fewer than 25 workers, many employing fewer than 10 workers. Major private employers in the county, defined by Orange County as having 25 or more employees, are listed in Table 2.5-20 (Reference 17).

2.5.2.1.4 Spotsylvania County

Spotsylvania County, with a population of 90,395, is midway between Washington, D.C. and Richmond. Its southwestern border is the North Anna River, most of which was flooded when Lake Anna was formed as a source of cooling water for the power station.

Economically, the county is more associated with the Washington, D.C. area through commuting patterns of its residents and federal procurement opportunities. Almost 60 percent of the resident workers commute to jobs outside the county. (Reference 12)

Although agriculture and forestry have been important components of the county's economy, the relative economic importance of these industries has declined over the years as the commercial and industrial base of the county has grown. Additionally, the number of employees in the state, local, or federal government sectors has increased significantly over the last ten years. Major private employers in Spotsylvania (defined by Spotsylvania County to be those with 100 or more employees) are listed in Table 2.5-21 (Reference 18).

In addition to the private employers, the Spotsylvania County Government employs about 600 workers; that is, the county is the second largest employer in the county, second only to Capital One.

2.5.2.2 Taxes

In Virginia, counties and towns collect most of their taxes through property taxes and sales taxes. Property taxes include business personal property and individual tangible personal property as well as real estate. business personal property includes such items as office furniture, fixtures, equipment, machinery and tools. (Reference 19)

Annual power station property taxes are paid to Louisa, Orange, and Spotsylvania Counties. Table 2-15 of the SEIS (Reference 11) presents the breakdown of property taxes collected by each county, the amount paid, and the percent of total property taxes that the payment represents. The total budget for each county is also presented for comparison purposes. Data are presented for the period of 1995 to 2000. The preponderance of the property taxes paid for the power station goes to Louisa County, and represents about 46 percent of the total property taxes collected by the county. The other two counties are paid taxes that represent about 1.5 percent of the total property taxes collected by each. Overall, the property taxes paid to Louisa County amounted to about 22.5 percent of the total budget for the county during the 1995–2000 time period. The SEIS points out that the property tax payments would be expected to decline as the existing facility depreciates.

The SEIS also points out that the potential effects of electric utility deregulation within Virginia are not known. However, it is reasonable to conclude that the installation of new units should result in a relative increase in property tax payments even with the depreciation of the existing units.

The SEIS discusses the relatively large increases in the economy of Henrico County over the past two decades due to the increased business investments in the Richmond area, as well as in the economy of Spotsylvania due partly to the large increase in government and other white collar workers who have chosen to live in Spotsylvania. To a lesser extent, Orange and Louisa Counties have benefited from this growth in the economies of Henrico and Spotsylvania Counties. Louisa County has benefited from the growth in second and retirement homes that have been constructed around Lake Anna. Since these homes have generally been upscale, the land values around the lake have increased significantly. Property tax revenues have also risen as a result of this construction as well as with construction of moderately priced houses around the county.

Many of these moderately-priced houses are intended to accommodate workers who commute to the Richmond-Petersburg MSA or to Washington, D.C., or to companies around the Dulles Airport and the Capital Beltway. The Louisa County land use planning document anticipates that such construction would continue at a rate of about 300 new homes per year for the foreseeable future. However, such increases in home building also require to some extent increased expenditures for infrastructure, which would tend to offset the increased property taxes paid to the county. If the current efforts by Louisa County to attract industry are successful and if the numbers of new homes continue to increase, increased property tax revenues as well as increases in sales tax revenues may be sufficient to offset the depreciation of the existing units. However, as is discussed in more detail in Section 5.8.2, new units would result in an increase in property tax revenues that would more than offset any decreases due to the depreciation of the existing units. (Reference 16)

2.5.2.3 Schools and Recreational Areas

Each county and the City of Richmond have a public school system for kindergarten through high school (Reference 13). The numbers at each level of school is dependent on the size of the local population, being greatest in the Richmond-Petersburg MSA. The Richmond-Petersburg MSA also has a number of private schools for grammar through high school education. Higher educational facilities, both public and private, are located in the Richmond-Petersburg MSA and in Spotsylvania, with none located in either Louisa or Orange Counties. However, both Louisa and Orange Counties are in close proximity to such facilities in the areas mentioned and to the University of Virginia in Charlottesville. During previous major construction activities at the NAPS site, the construction workforce did not require relocation of large numbers of workers into the area. Therefore, unless there is a need for relocation of a large number of construction workers into either or both of these counties, the SEIS (Reference 11) conclusion that any impacts on the school systems would be small, also applies to the construction of the new units. This construction-related information is addressed in more detail in Section 4.4.2.

All of the surrounding counties and the City of Richmond have established parks and other recreational areas for their residents. In Louisa and Orange Counties, these areas typically consist of one or two parks plus playing fields at the local schools. However, as is presented in Section 2.5.1.3, the Lake Anna area has become established as a recreational center not only for the local residents of Louisa, Orange, and Spotsylvania Counties, but also for other in-state and out-of-state visitors. The SEIS (Reference 11) conclusion that any impacts on these parks and other recreational areas would be small, generally applies to the construction of new nuclear generating unit(s), so long as there is no relocation of a large number of construction workers into the counties that border the lake.

A potential exists for negative transportation impacts on the number of people from outside the bordering counties who use the lake recreationally. The potential for negative impacts on the numbers of people using Lake Anna during construction of the new facility and suggested mitigation measures to avoid or reduce these impacts is addressed in more detail in Section 4.4.2.

2.5.2.4 Housing

Approximately 80 percent of the permanent employees at the NAPS site live in Hanover, Henrico (including the City of Richmond), Louisa, Orange, or Spotsylvania Counties, with the greatest number living in Louisa County. A detailed breakdown, by county and city (Reference 11, Table 2-5) shows that the number of permanent employees living in Louisa, Spotsylvania, and Orange Counties are 237, 186, and 120, respectively.

A breakdown, by county, of housing units by number occupied and vacant in 1990 and 2000, is presented in Table 2-6 of the SEIS (Reference 11). “Vacant” housing is equated to “available” housing. However, a review of the U.S. Census Bureau’s 2000 Census data reveals that there is a further breakdown of the category “vacant” housing, pertinent sections of which are presented in Table 2.5-22.

This detailed breakdown of “vacant” units is not of concern when renewing operating licenses, nor for planned outages of each existing unit. However, the number of “vacant” housing units that are “for seasonal, recreational, or occasional use” is important in relation to construction. In this case, “vacant” units should not automatically be considered to be available to those members of the large construction workforce who decide to relocate to the area during the installation of the new units. This category of “vacant” housing units would not be available for use by the longer-term workforce and could represent an issue associated with the new units, especially if a larger percentage of the workforce decides to relocate to the area around the ESP site for the duration of their work. However, the “for rent” and “for sale” vacant housing units should be considered as available for their use, if needed. Such use would be in competition with the housing demands from the projected population growth in each county and the City of Richmond. This situation is addressed further in Section 4.4.2.

2.5.2.5 Public Services

Public services addressed here include water supply, education, and transportation. These services provide a baseline from which construction period impacts and operational impacts can be estimated.

2.5.2.5.1 Water Supply

As described in the SEIS, Henrico County buys its water from the City of Richmond whose source of water supply is the James River. Spotsylvania County supplies most residential, commercial, and industrial areas via a public water system that draws from the Ni River. Additional water capacity is being constructed in both Richmond City and Spotsylvania County.

In Louisa and Orange Counties, groundwater is the primary source of water for the residents, excluding the towns of Louisa and Orange. About 80 percent of Louisa County residents and about 90 percent of Orange County residents rely on groundwater.

The residents of these more rural counties normally have individual septic systems rather than access to a sewer system with a publicly owned treatment works (POTW).

The SEIS identifies a concern regarding access to the public water supplies in the towns surrounding the NAPS site, if new employees associated with the new units were to settle in these towns. The SEIS states that there are plans to construct new treatment plants or expand existing facilities in the towns, which would alleviate these concerns.

Table 1-7 of the SEIS presents the projected population growth in 2010 for the surrounding counties and the City of Richmond. For Louisa County and Orange County, the projected growth in population between Years 2000 and 2010 is 4,380 and 3,920, respectively – values that are similar to the numbers being projected for a peak construction workforce brought in to add new units. These projected population growths and their possible impacts on the local infrastructure, including water and sewer services, have been incorporated into the comprehensive land use plans for both counties. The potential impact of construction and operation on the infrastructure of the area, including the water and sewer systems, is considered further in Section 4.4.2 and Section 5.8.2, respectively.

2.5.2.5.2 Education

The SEIS provides information on the number of high schools, middle schools, and elementary schools in each surrounding county and incorporated municipality. A review of this information reveals that Louisa and Orange Counties have school systems that could potentially limit the number of students that could be assimilated by their educational systems if a sudden large influx of families were to relocate into these areas. For Louisa County, with one high school, one middle school, and three elementary schools, a large influx of families with children at these levels of education could tax the capacity of these schools. For Orange County, with one high school, one middle school, and five elementary schools, a large influx of families with children in middle or high

school could similarly tax the capacity of the school system. This issue is addressed in Section 4.4.2.

2.5.2.5.3 Transportation

The area within the 80-km (50-mile) radius of the ESP site is serviced by Interstate 95, running in a north-south direction between Washington, D.C. and Richmond, and Interstate 64, running between Richmond and Charlottesville; as well as numerous Virginia highways and local roads Figure 2.5-16. According to the SEIS, all local roads in the NAPS area carry a level-of-service designation "B." Designation "B" means that there is stable traffic flow, such that the freedom to select speed is unaffected, but the freedom to maneuver is slightly diminished. The potential impacts during construction and operation, including likely measures that can be implemented to reduce these impacts during each phase, are addressed in Section 4.4.2 and Section 5.8. Of primary concern is the seasonal use of Lake Anna and the resulting traffic on local roads in the vicinity of NAPS.

2.5.2.5.4 Police, Fire, and Medical Facilities

The police force of each of the counties within the 80-km (50-mile) radius about the ESP site consists of a County Sheriff who is typically headquartered in the County Seat and who is assisted by Sheriff's Deputies who patrol the entire area of the county. The Sheriff's Department also normally dispatches emergency services through the 911 system in each county. The incorporated towns and cities within the counties have their own police force. The more heavily populated areas of Henrico County and the City of Richmond also have a Division of Police.

Volunteer fire departments protect Hanover, Orange, Louisa, and Henrico counties and the City of Richmond as shown in Table 2.5-23. Emergency medical protection is provided in each county by volunteer rescue squads. The County Sheriff's Department in each county dispatches these volunteer rescue squads. The independent towns in these counties each have their own volunteer fire departments. Both Henrico County and the City of Richmond have more extensive fire departments and EMS units.

Contacts and arrangements made by Virginia Power with local, state, and federal governmental agencies with emergency planning responsibilities are identified in Part 2: Section 13.3.3.

Medical facilities generally consist of local physicians' offices in the counties. However, there are major medical facilities in Fredericksburg, Charlottesville, Mechanicsville, and the City of Richmond that are readily accessible to the populations of the counties.

2.5.3 Historic Properties

The region surrounding the ESP site has been identified as having prehistoric and historic Native American and historic Euro-American resources. To assess known and potential cultural resource sites surrounding the site, surveys have been conducted for items of historic, archaeologic, and geologic interest. The results are included in the application for license renewal (Reference 10).

Reconnaissance-level archaeological and historical investigations were completed for both the site and the lakebed, with few results. A few artifacts were noted in the area, but the investigator identified them as insignificant and determined that no further evaluations were necessary. In addition, records in the Louisa County Historical Society files identified 33 historic-period cemeteries along the river. Many of the cemeteries were avoided by adjusting project boundaries although, some were removed prior to inundation. Five cemeteries are recorded as on or near NAPS site.

The above referenced environmental report concludes that there are no sites or items of historic, archaeologic, or geologic significance within the vicinity of NAPS. The report conclusions are based on the review of available literature and several database sources. In addition to the work that was completed in 1973 (Presented in Section 2.5.3.2) (Reference 20), a cultural resource assessment for the area within 1-mile of the NAPS fence line and the site itself was commissioned by Dominion and completed in 2001. The results are documented in a report prepared by Louis Berger Group, Inc., (Reference 21) the conclusions of which are summarized in Section 2.5.3.2.

Virginia Power consulted with the State Historic Preservation Office (SHPO) regarding NAPS license renewal. No issues were identified as a result of that consultation. Dominion has initiated informal discussions with the SHPO regarding evaluation for an ESP and those discussions would continue throughout the review process.

Should archaeological resources or artifacts be discovered during pre-construction activities, personnel would be instructed to stop work. Dominion would contact the appropriate organization and/or regulatory agency for proper evaluation and designation, in accordance with the existing procedures.

2.5.3.1 Description of Historic Properties near the ESP site

There are three counties in the vicinity of the ESP site. Table 2.5-24 lists each county and the number of known historic places listed on the National Register of Historic Places (NRHP) (Reference 22) within these respective counties.

Of the 60 national historical sites identified in Table 2.5-24, four sites exist within 10 miles of the ESP site. These sites are listed and described in Table 2.5-25.

Figure 2.5-19 locates the NRHP sites near the ESP site.

2.5.3.2 Description of Historic Properties Within the NAPS Site

The Louis Berger Group, Inc. completed a cultural resource assessment (Reference 21) of the NAPS site and a 1-mile-radius surrounding the existing units (study area) during the license renewal project time period, and the assessment included the following activities:

- A background investigation of related information to compile known information about the NAPS study area; and

- The delineation of areas within the study area containing potential archaeological resources.

The investigations were conducted in accordance with the National Historic Preservation Act of 1966, the Archaeological and Historical Preservation Act of 1974, Executive Order 11593, and Title 36 of the Code of Federal Regulations, Part 660-66 and 800 (as appropriate). The field investigations and technical report met the qualifications specified in the Secretary of the Interior's Standards and Guidelines for Archaeology and Historic Preservation (FR 48:190:44716-44742). The qualifications of the Project Manager and Project Archaeologist who performed the investigations met or exceeded the requirements described in the Secretary of the Interior's Professional Qualifications Standards (FR 48:190:44716-44743).

Examination of archaeological and historical site files at the Virginia Department of Historic Resources' archives has indicated that no recorded cultural resource sites are known to exist at the NAPS site. Similarly, review of historical documentation at the Louisa County Historical Museum, including historic maps dating between 1751 and 1863, have indicated few historic resources in the study area, other than an early road paralleling the south side of the North Anna River, which appears to be near the western boundary of the NAPS site. An unpublished map, based on county deeds from 1765 to 1815, shows the presence of the Jerdones Mill on the North Anna River bank, just upriver from the NAPS site, along with the associated Jerdones Mill Road. The same map shows an Old Mine Road within the North Anna site area.

No extant historic architectural resources have been identified within the study area and no historic architectural resources are present within the NAPS site. There are five architectural resources within a 1.5-mile radius of the NAPS site; however, the report's conclusions state that none of these resources are affected by current or planned activities. As a follow-up to the initial assessment, five known historic-period cemeteries have been recorded, three of which lie within the administrative boundary of the NAPS site (see Figure 2.5-18) and two that are located south of the North Anna Dam where no activities are planned.

Conclusions made in the report include that previously undisturbed lands within the NAPS site boundary have the potential to contain both unrecorded prehistoric and historic archaeological properties. On the basis of this conclusion, the NAPS site has been classified with respect to the potential for discovering archaeological resources. The three classifications are areas with the following:

- No Potential for Archaeological Resources
- Low Potential for Archaeological Resources
- Moderate-to-High Potential for Archaeological Resources

For areas with low and moderate to high potential for containing archaeological resources (see Figure 2.5-17), subsurface testing would be performed, dependent on existing ground conditions, prior to any ground disturbing activities.

2.5.3.3 Transmission Line Rights-of-Way

The NAPS site transmission line rights-of-way (ROW) have been categorized and inventoried and do not cross over any known archaeological or historic sites of significance (Reference 20).

2.5.3.4 Native American Sites

Among the six state-recognized Indian tribes in Virginia, the closest tribal reservations belong to the Pamunkey and Mattaponi Tribes. The Pamunkey Tribe Reservation is approximately 53 miles southeast of the ESP site and was confirmed to the Tribe in 1658 by the Governor, the Council, and the General Assembly of Virginia. The Mattaponi Indian Reservation, also established in 1658, is approximately 62 miles southeast of the ESP site. There are no known Native American cultural or religious tribal resources that exist within the NAPS site.

2.5.4 Environmental Justice

Federal agencies must identify and address, as applicable to their actions, disproportionately high and adverse human health or environmental impacts of its activities on minority or low-income populations. The NRC has committed to undertake environmental justice reviews in consideration of the NEPA of 1969 and the 1997 Council of Environmental Quality (CEQ) guidance.

For the purpose of the ESP environmental justice review, the geographic distribution of minority and low-income populations within 80 km (50 miles) of the ESP site have been determined, employing data from the 2000 Census and applying the following definitions from Appendix D of LIC-203 (Reference 23):

A minority population or low-income population exists if either of the following criteria are met:

1. A “minority population” is considered to be present if: 1) The minority population in the census block group or environmental impact site exceeds 50 percent, or 2) the minority population percentage of the environmental impact area is significantly greater (typically at least 20 percentage points) than the minority population percentage in the geographic area chosen for the comparative analysis, for example, the county or State, or

2. A “low-income population” is considered to be present if: 1) the low-income population in the census block group or environmental impact area exceeds 50 percent, or 2) the percentage of households below the poverty level in an environmental impact area is significantly greater (typically at least 20 percentage points) than the low-income population percentage in the geographic area chosen for the comparative analysis.

For this review, the percentage of any minority or low-income population within census tracts that could potentially be affected by the installation of new units has been calculated and compared to the corresponding percentage of minority or low-income populations within the entire Commonwealth of Virginia or State of Maryland (for Charles County, MD) as appropriate, to

determine if they exceed the State values for each category by at least 20 percent. All census tracts with at least 50 percent of their area within the 80-km (50-mile) radius around the ESP site are included in the analysis.

Using the Census Bureau's LandView 5 software and 2000 Census data for the region of interest (ROI) (Reference 24), the distributions of minority populations and low-income populations were developed. The results are shown on Figure 2.5-14 and Figure 2.5-15, respectively.

Generally, the minority populations are found in the sectors to the east through the southwest about the ESP site. There is a black minority population within Louisa County about 20 km southwest, and a similar size black minority population in the southeastern part of Caroline County, where it borders Hanover and King William Counties. About 60 to 80 km to the east and southeast of the site, there are large black minority populations in King and Queen, Essex, and Westmoreland Counties. These three counties are only partially within the area defined by the 80-km radius.

A large, black minority population exists in the City of Richmond and adjoining parts of Henrico County (60 to 80 km southeast of the site). To the south-southwest about 44 km distant, there is a small, black minority population in the northern part of Powhatan County. Another large, black minority population exists in the northern part of Buckingham County, about 60 to 80 km south-southwest of the site.

Charlottesville, approximately 58 km west of the site, contains small populations of minority Asians and blacks. Small, black minority populations also exist to the northeast in Fredericksburg and Stafford County, and a small Hispanic minority population is in Prince William County about 80 km northeast.

A small, low-income population exists, about 60 to 80 km south-southeast of the site, in the City of Richmond. Another, small, low-income population exists in Charlottesville.

The potential for disproportionate human health or environmental impacts on minority or low-income populations associated with the construction and operation of new units is evaluated and presented in Section 4.4.3 and Section 5.8.3, respectively. The potential impacts on minority and low-income populations at alternative sites are part of the more global evaluation of the environmental impacts associated with locating a new nuclear generating station that is presented in Section 9.3.

Section 2.5 References

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10. *Environmental Report* (ER) prepared by Dominion as Appendix E of the North Anna Power Station Units 1 and 2 Application for Renewed Operating Licenses, Dominion Virginia Power, May 2001.

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Table 2.5-1 Population Distribution from 2000 to 2040 Within 16-km (10-mi) of the ESP Site

Year	0 to 2 km (0–1.2 mi.)	2 to 4 km (1.2–2.5 mi.)	4 to 6 km (2.5–3.7 mi.)	6 to 8 km (3.7–5.0 mi.)	8 to 10 km (5.0–6.2 mi.)	10 to 16 km (6.2–10 mi.)	Total
2000	210	717	1394	1351	2218	9621	15,511
2010*	263	943	1884	1837	2986	13,083	20,996
2020*	316	1169	2375	2322	3753	16,545	26,480
2030*	369	1395	2865	2808	4521	20,007	31,965
2040*	422	1621	3355	3293	5288	23,469	37,449

* All populations in this year are estimates.

Table 2.5-2 Estimated Sex Distribution of Population in 2000 Within 16-km (10-mi.) of the ESP Site

	0 to 2 km (0–1.2 mi.)		2 to 4 km (1.2–2.5 mi.)		4 to 6 km (2.5–3.7 mi.)		6 to 8 km (3.7–5.0 mi.)		8 to 10 km (5.0–6.2 mi.)		10 to 16 km (6.2–10 mi.)	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Male	104	49.5	350	48.8	687	49.3	665	49.2	1,092	49.2	4,738	49.2
Female	106	50.5	367	51.2	707	50.7	686	50.8	1,126	50.8	4,883	50.8
Total	210	—	717	—	1394	—	1351	—	2218	—	9621	—

Table 2.5-3 Sex Distribution of Population in the Major Employee-Contributing Counties and Virginia

	Henrico		Louisa		Orange		City of Richmond		Spotsylvania		Virginia	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Male	122,922	46.9	12,611	49.2	12,524	48.4	92,068	46.5	44,532	49.3	3,471,895	49.0
Female	139,378	53.1	13,016	50.8	13,357	51.6	105,722	53.5	45,863	50.7	3,606,620	51.0
Total	262,300	—	25,627	—	25,881	—	197,790	—	90,395	—	7,078,515	--

Table 2.5-4 Estimated Age Distribution of Population in 2000 Within 16-km (10-mi.) of the ESP Site

Age Group	0 to 2 km (0–1.2 mi.)		2 to 4 km (1.2–2.5 mi.)		4 to 6 km (2.5–3.7 mi.)		6 to 8 km (3.7–5.0 mi.)		8 to 10 km (5.0–6.2 mi.)		10 to 16 km (6.2–10 mi.)	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
0–19	53	27.6	200	28.8	412	29.8	394	29.8	656	29.5	2885	29.9
20–24	8	4.2	36	5.2	64	4.6	66	5.0	110	4.9	471	4.9
25–44	62	32.3	220	31.7	434	31.4	420	31.8	694	31.2	3,000	31.1
45–64	46	24.0	171	24.6	333	24.1	318	24.1	536	24.1	2,294	23.8
65+	23	12.0	68	9.8	140	10.1	124	9.4	229	10.3	991	10.3

Table 2.5-5 Estimated Income Distribution of Population Within 16-km (10-mi) of the ESP Site (for ages greater than 15)

Income Group*	0 to 2 km (0–1.2 mi.)		2 to 4 km (1.2–2.5 mi.)		4 to 6 km (2.5–3.7 mi.)		6 to 8 km (3.7–5.0 mi.)		8 to 10 km (5.0–6.2 mi.)		10 to 16 km (6.2–10 mi.)	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
$0	18	12.3	65	12.6	119	11.4	114	11.2	189	11.1	822	11.1
$1–$25	75	51.4	249	48.3	482	46.0	465	45.6	789	46.5	3,344	45.2
$25–$50	40	27.4	143	27.7	297	28.3	297	29.1	480	28.3	2,127	28.7
$50–$75	9	6.2	43	8.3	103	9.8	98	9.6	166	9.8	742	10.0
$75–$100	2	1.4	9	1.7	26	2.5	27	2.6	42	2.5	197	2.7
$100+	2	1.4	7	1.4	21	2.0	18	1.8	32	1.9	168	2.3
Total	146	—	516	—	1,048	—	1,019	—	1,698	—	7,400	—

* All incomes are in thousands of dollars.

Table 2.5-6 Racial & Ethnic Distribution of Population in 2000 Within 16-km (10-mi.) of the ESP Site

Race Group	0 to 2 km (0–1.2 mi.)		2 to 4 km (1.2–2.5 mi.)		4 to 6 km (2.5–3.7 mi.)		6 to 8 km (3.7–5.0 mi.)		8 to 10 km (5.0–6.2 mi.)		10 to 16 km (6.2–10 mi.)	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
White	198	94.3	615	85.8	1,171	84.0	1,032	76.4	1,748	78.8	8,041	83.6
Black	10	4.8	83	11.6	187	13.4	290	21.5	437	19.7	1,302	13.5
Indian	2	1.0	1	0.1	7	0.5	5	0.4	2	0.1	41	0.4
Asian	0	0.0	2	0.3	15	1.1	1	0.1	9	0.4	57	0.6
Hawaiian	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0	4	0.0
Other	0	0.0	1	0.1	1	0.1	4	0.3	0	0.0	24	0.2
Multi	0	0.0	15	2.1	13	0.9	19	1.4	21	0.9	152	1.6
Hispanic	2	1.0	10	1.4	12	0.9	5	0.4	14	0.6	92	1.0
Total*	210	—	717	—	1,394	—	1,351	—	2,218	—	9,621	—

* Total does not include Hispanic category.

Table 2.5-7 Income Distribution of Population in the Major Employee-Contributing Counties and Virginia (For Ages Greater Than 15)

Race Group	Henrico		Louisa		Orange		City of Richmond		Spotsylvania		Virginia	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
$0	17,410	8.4	2,319	11.3	2,364	11.3	15,444	9.6	7,468	11.0	594,604	10.6
< $25	85,966	41.4	10,678	52.2	10,312	49.1	90,896	56.5	27,350	40.4	2,627,798	46.7
$25 - $50	67,249	32.4	5,360	26.2	5,762	27.5	37,779	23.5	20,517	30.3	1,449,617	25.8
$50 - $75	21,065	10.1	1,429	7.0	1,693	8.1	9,216	5.7	8,299	12.3	521,861	9.3
$75- $100	7,515	3.6	360	1.8	373	1.8	3,128	1.9	2,189	3.2	208,019	3.7
$100+	8,502	4.1	314	1.5	484	2.3	4,346	2.7	1,843	2.7	221,729	3.9
Total	207,707	—	20,460	—	20,988	—	160,809	—	67,666	—	5,623,628	—

*All incomes are in thousands of dollars.

Table 2.5-8 Population Distribution from 2000 to 2040 Within 80-km (50-mi) of the ESP Site

Year	0 to 16 km (0 – 10 mi.)	16 to 40 km (10–24.9 mi.)	40 to 60 km (24.9–37.3 mi.)	60 to 80 km (37.3– 50 mi.)	Total
2000	15,511	185,456	487,842	849,347	1,538,156
2010*	20,996	239,813	604,455	984,645	1,849,908
2020*	26,480	294,169	721,067	1,119,943	2,161,660
2030*	31,965	348,526	837,680	1,255,241	2,473,411
2040*	37,449	402,883	954,292	1,390,539	2,785,163

* All populations in this year are estimates.

Table 2.5-9 Estimated Sex Distribution of Population in 2000 Within 80-km (50-mi.) of the ESP Site

	0 to 16 km (0 – 10 mi.)		16 to 40 km (10 – 24.9 mi.)		40 to 60 km (24.9–37.3 mi.)		60 to 80 km (37.3 – 50 mi.)		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
Male	7,636	49.2	90,484	48.8	236,507	48.5	411,186	48.4	745,813	48.5
Female	7,875	50.8	94,972	51.2	251,335	51.5	438,168	51.6	792,350	51.2
Total	15,511	—	185,456	—	487,842	—	849,354	—	1,538,163	—

Table 2.5-10 Estimated Age Distribution of Population in 2000 Within 80-km (50-mi) of the ESP Site

Age Group	0 to 16 km (0 – 10 mi.)		16 to 40 km (10 – 24.9 mi.)		40 to 60 km (24.9–37.3 mi.)		60 to 80 km (37.3 – 50 mi.)		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
0 to 19	4,600	29.8	53,939	29.1	138,057	28.3	246,080	29.0	442,676	28.8
20 to 24	755	4.9	11,006	5.9	27,944	5.7	59,135	7.0	98,840	6.4
25 to 44	4,830	31.2	56,643	30.5	157,037	32.2	270,643	32.0	489,153	31.8
45 to 64	3,698	23.9	43,210	23.3	111,462	22.8	190,145	22.4	348,515	22.7
65+	1,575	10.2	20,640	11.1	53,355	10.9	83,352	9.8	158,922	10.3
Total*	15,458	—	185,438	—	487,855	—	849,355	—	1,538,106	—

* Differences in totals are due to calculation round-off.

Table 2.5-11 Racial & Ethnic Distribution of Population in 2000 Within 80-km (50-mi) of the Site

Race Group	0 to 16 km (0–10 mi.)		16 to 40 km (10–24.9 mi.)		40 to 60 km (24.9–37.3 mi.)		60 to 80 km (37.3–50 mi.)		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
White	12,805	82.6	146,841	79.2	392,074	80.4	543,709	64.0	1,095,429	71.2
Black	2309	14.9	31,687	17.1	69,776	14.3	253,248	29.8	357,020	23.2
Indian	58	0.4	607	0.3	1452	0.3	2972	0.3	5,089	0.3
Asian	84	0.5	1,767	1.0	12,632	2.6	18,690	2.2	33,173	2.2
Hawaiian	5	0.0	66	0.0	202	0.0	555	0.1	828	0.1
Other	30	0.2	1,744	0.9	4,257	0.9	14,282	1.7	20,313	1.3
Multi	220	1.4	2,744	1.5	7,449	1.5	15,891	1.9	26,304	1.7
Hispanic	135	0.9	4,276	2.3	11,285	2.3	31,374	3.7	47,070	3.1
Total*	15,511	—	185,456	—	487,842	—	849,347	—	1,538,156	—

* Total does not include Hispanic category.

Table 2.5-12 Racial and Ethnic Distribution of Population in the Major Employee-Contributing Counties and Virginia

Race Group	Henrico		Louisa		Orange		City of Richmond		Spotsylvania		Virginia	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
White	180,761	68.9	19,617	76.5	21,833	84.4	75,744	38.3	74,924	82.9	5,120,110	72.3
Black	64,805	24.7	5530	21.6	3566	13.8	113,108	57.2	11,255	12.5	1,390,293	19.6
Indian	920	0.4	108	0.4	53	0.2	479	0.2	288	0.3	21,172	0.3
Asian	9451	3.6	64	0.3	88	0.3	2471	1.2	1243	1.4	261,025	3.7
Hawaiian	82	0.0	3	0.0	5	0.0	157	0.1	45	0.1	3946	0.1
Other	2562	1.0	46	0.2	102	0.4	2948	1.5	941	1.0	138,900	2.0
Multi	3719	1.4	259	1.0	234	0.9	2883	1.5	1699	1.9	143,069	2.0
Hispanic	5946	2.3	182	0.7	330	1.3	5074	2.6	2536	2.8	329,540	4.7
Total*	262,300	—	25,627	—	25,881	—	197,790	—	90,395	—	7,078,515	—

* Total does not include Hispanic category.

Table 2.5-13 Estimated Income Distribution of Population Within 80-km (50-mi) of the ESP Site (For Ages Greater Than 15)

Income Group[a]	0 to 16 km (0 – 10 mi.)		16 to 40 km (10 – 24.9 mi.)		40 to 60 km (24.9–37.3 mi.)		60 to 80 km (37.3 – 50 mi.)		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
$0	1327	11.2	15,406	10.6	36,982	9.7	67,138	10.1	120,853	10.0
$1–$25	5404	45.7	66,395	45.9	163,203	42.8	297,535	44.7	532,537	44.2
$25 - $50	3384	28.6	40,735	28.1	113,734	29.8	186,066	28.0	343,919	28.6
$50 - $75	1161	9.8	14,365	9.9	39,156	10.3	66,472	10.0	121,154	10.1
$75-$100	303	2.6	4,013	2.8	14,533	3.8	23,955	3.6	42,804	3.6
$100+	248	2.1	3,874	2.7	14,151	3.7	24,112	3.6	42,385	3.5
Total	11,827	—	144,788	—	381,759	—	665,278	—	1,203,652	—

a. All incomes are in thousands of dollars.

Table 2.5-14 Age Distribution of Population in the Major Employee-Contributing Counties and Virginia

Age Group	Henrico		Louisa		Orange		City of Richmond		Spotsylvania		Virginia	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
0 to 19	69,875	26.6	6,787	26.5	6,499	25.1	50,724	25.6	29,131	32.2	1,937,086	27.4
20 to 24	15,380	5.9	1,159	4.5	1,134	4.4	18,386	9.3	4,603	5.1	480,574	6.8
25 to 44	86,166	32.9	7,656	29.9	7,184	27.8	62,712	31.7	29,062	32.2	2,237,655	31.6
45 to 64	58,278	22.2	6,710	26.2	6,620	25.6	39,839	20.1	20,073	22.2	1,630,867	23.0
65+	32,601	12.4	3,315	12.9	4,444	17.2	26,129	13.2	7,526	8.3	792,333	11.2
Total	262,300	—	25,627	—	25,881	—	197,790	—	90,395	—	7,078,515	—

Table 2.5-15 Population Distribution Table

	Distances (km)								
Sectors	**0–2**	**2–4**	**4–6**	**6–8**	**8–10**	**10–16**	**16–40**	**40–60**	**60–80**
North									
Present Date (2002)	0	25	125	149	254	262	9,688	11,808	32,461
Startup Date (2025)	0	49	246	293	498	512	14,710	15,276	41,822
40-year Date (2040)	0	65	324	386	656	676	17,985	17,537	47,926
North-Northeast									
Present Date (2002)	20	93	19	131	170	856	14,662	34,780	133,414
Startup Date (2025)	38	181	36	256	333	1,676	28,608	63,124	209,729
40-year Date (2040)	51	239	48	338	439	2,211	37,704	81,610	259,500
Northeast									
Present Date (2002)	2	10	262	187	142	784	81,323	63,006	60,243
Startup Date (2025)	4	19	512	365	278	1,535	137,973	117,941	93,921
40-year Date (2040)	6	25	676	482	366	2,025	174,918	153,768	115,885
East-Northeast									
Present Date (2002)	0	37	80	25	0	1,432	13,493	8,733	18,066
Startup Date (2025)	0	73	156	49	0	2,804	25,376	12,790	24,452
40-year Date (2040)	0	96	206	65	0	3,698	33,126	15,436	28,616
East									
Present Date (2002)	0	87	49	50	158	741	8,123	2,193	4,565
Startup Date (2025)	0	171	96	98	310	1,450	11,234	2,872	5,824
40-year Date (2040)	0	225	127	130	408	1,912	13,262	3,315	6,644
East-Southeast									
Present Date (2002)	0	16	187	206	77	724	7,305	4,783	9,717
Startup Date (2025)	0	32	365	404	152	1,372	9,609	6426	12,800
40-year Date (2040)	0	42	482	532	200	1,794	11,111	7498	14,811
Southeast									
Present Date (2002)	0	136	15	40	42	485	5,537	40,418	68,717
Startup Date (2025)	0	205	22	60	63	782	9,249	66,451	106,438
40-year Date (2040)	0	251	27	73	77	976	11,669	83,429	131,038

Table 2.5-15 Population Distribution Table

	Distances (km)								
Sectors	**0–2**	**2–4**	**4–6**	**6–8**	**8–10**	**10–16**	**16–40**	**40–60**	**60–80**
South-Southeast									
Present Date (2002)	39	12	52	71	125	717	8,239	220,811	374,800
Startup Date (2025)	58	17	79	107	188	1,089	13,731	304,881	447,880
40-year Date (2040)	71	21	96	131	229	1,332	17,312	359,710	495,541
South									
Present Date (2002)	61	2	128	13	119	487	6,648	17,891	48,351
Startup Date (2025)	92	3	193	19	180	734	10,192	29,482	73,642
40-year Date (2040)	112	4	235	23	220	896	12,503	37,042	90,136
South-Southwest									
Present Date (2002)	0	37	0	243	25	314	6,366	6,531	7,437
Startup Date (2025)	0	55	0	366	38	474	9,173	10,313	11,488
40-year Date (2040)	0	67	0	447	46	578	11,003	12,780	14,130
Southwest									
Present Date (2002)	10	30	13	0	140	963	3,280	3,852	6,072
Startup Date (2025)	16	46	19	0	212	1,453	4,955	6,814	8,750
40-year Date (2040)	19	56	23	0	258	1,773	6,047	8,746	10,496
West-Southwest									
Present Date (2002)	0	14	65	121	322	866	6,142	16,351	8,600
Startup Date (2025)	0	21	98	183	486	1,308	9,814	31,685	13,010
40-year Date (2040)	0	25	119	224	594	1,596	12,208	41,685	15,886
West									
Present Date (2002)	85	117	2	46	141	271	4,655	33,491	78,028
Startup Date (2025)	128	177	3	69	213	409	7,021	44,190	100,553
40-year Date (2040)	156	216	4	85	260	499	8,565	51,167	115,244
West-Northwest									
Present Date (2002)	0	95	168	50	213	276	6,980	14,230	12,016
Startup Date (2025)	0	144	254	76	322	476	10,028	22,879	19,679
40-year Date (2040)	8	175	310	93	393	607	12,017	28,519	24,676

Table 2.5-15 Population Distribution Table

	Distances (km)								
Sectors	**0–2**	**2–4**	**4–6**	**6–8**	**8–10**	**10–16**	**16–40**	**40–60**	**60–80**
Northwest									
Present Date (2002)	0	26	229	53	423	475	7,582	9,939	3,231
Startup Date (2025)	0	39	346	95	828	909	10,658	11,573	3,675
40-year Date (2040)	0	48	422	123	1,093	1,192	12,665	12,638	3,965
North-Northwest									
Present Date (2002)	4	25	99	63	19	660	6,304	22,349	10,688
Startup Date (2025)	6	49	194	124	36	1,292	9,018	32,677	13,930
40-year Date (2040)	8	65	256	163	48	1,704	10,787	39,412	16,044
Annual Total									
Present Date (2002)	221	762	1,492	1,448	2,372	10,313	196,327	511,165	876,407
Startup Date (2025)	343	1,282	2,620	2,565	4,137	18,276	321,348	779,373	1,187,592
40-year Date (2040)	422	1,621	3,355	3,293	5,288	23,469	402,883	954,292	1,390,539

Cumulative Total	**0–80 km**
Present Date (2002)	1,600,506
Startup Date (2025)	2,317,535
40-year Date (2040)	2,785,163

Table 2.5-16 Lake Anna Recreational Facilities

Facility	Distance	Number of Wet Slips	Number of Ramps	Camp Sites
Marinas				
Anna Point	2.3 miles NNW	25	1	—
Dukes Creek	2.2 miles E	55	5	—
High Point	2.3 miles NNW	50	4	—
Lake Anna	1.4 miles NNE	160	2	—
Rocky Branch	2.3 miles NNE	—	4	—
Sturgeon Creek	2 miles N	36	5	—
Public Landings				
Christopher Run Campground	6 miles WNW	—	1	152
Hunters Landing	6.6 miles NW	—	1	—
Lake Anna Campground	2.5 miles NW	—	1	61
Lake Anna Landing	9 miles NW	—	1	—
Lake Anna State Park	4.3 miles NNW	—	2	—
Pleasants Landing	5.6 miles SE	—	1	—
Sullivan's Landing	8 miles NW	—	1	—
Total		326	29	213

Source: Reference 4, Table 2.1-1.
Note: "—"means no data was reported in source.

Table 2.5-17 Tourist Attractions, Parks and Recreational Areas

Facility	Location	Annual Usage	Peak Daily Usage *	Comments
Lake Anna Recreational Usage	1.4 Mi, NNE	530,000	5900 **	Annual usage based on 180 days at 2,950 people per day.
Waste Heat Treatment Facility	—	90,000	<1,000	Peak daily usage based on doubling the resident population in cooling lagoon sectors (one guest per resident). Annual usage based on 180 days at 500 people per day.
Lake Anna State Park	2.8 Mi, NNW	187,300	4370	Annual use was 187,300 between July 1, 2001 and June 2002. Park closed in winter. Use includes occupants of boats launched at the park.
Paramount's Kings Dominion Amusement Park	35 Mi, SE	2,875,000	20,835	Annual use was 2 to 2.5 million between March and November. Add 15% to calculate maximum capacity. Park closed in winter.

* Peak daily usage is based on a peak weekend day during the summer.

** This number is based on an average of 3 persons per boat, campsite and picnic area.

Table 2.5-18 Employment and Income Statistics by State, County, and City

	Work Force (November 2002)[a]	Unemployment (% November 2002)[a]	Poverty (% Estimated 1999)[b]	Median Household Income (1999)[b]
Hanover County	50,114	2.4	4.2	$58,082
Henrico	147,138	3.3	6.7	$47,903
Louisa	10,577	5.3	9.0	$38,177
Orange	12,364	3.9	8.9	$41,285
City of Richmond	100,290	5.8	17.9	$30,169
Spotsylvania	48,534	2.2	5.5	$55,534
Commonwealth of Virginia	3,773,075	3.6	9.0	$44,848
State of Maryland	2,908,759	3.9	8.0	$49,781
Charles County, MD	65,349	2.8	6.5	$57,408

a. Virginia Employment Commission; Maryland Department of Labor, Licensing and Regulation.

b. 2000 Census Data.

Table 2.5-19 Major Employers in Louisa County, Virginia

Employer	Product	Number of Employees
Dominion Energy	Power Generation	1500
Kloeckner-Pentaplast	Rigid PVC	630
Klearfold, Inc.	Plastic Packing	176
Tradewinds of Virginia	Wood Products	130
Tri-Dim	Filters	100

Table 2.5-20 Major Private Employers in Orange County, Virginia

Employer	Product	Employees
Von Holtzbrinck Publishing Svcs.	Book Distribution Center	305
American Woodmark Corp.	Cabinet Components	300
American Press, Inc.	Printer of Periodicals and Catalogs	250
RIDGID Products	Plumbing/Drain Equipment	211

Table 2.5-20 Major Private Employers in Orange County, Virginia

Employer	Product	Employees
A, B, &C Group	Direct Marketing	138
Battlefield Farms, Inc.	Bedding and Holiday Plants	80
General Shale	Brick	80
Klockner/Intertrans Carrier Co.	Motor Carrier/Distribution Center	72
Elcotel/Technology Service Group	Telephones and Parts	70
Zamma Corp.	Molding and Furniture Components	45
Central Virginia Newspapers, Inc.	Newspaper Publishing and Printing	34
MSAG Data Consultants, Inc.	Computer Mapping/Data	26
Atlantic Research Corp.	Rocket Propulsion Systems	25

Table 2.5-21 Major Private Employers in Spotsylvania County, Virginia

Employer	Product	Employees
Capital One	Call Center	1200
CVS Pharmacy	Distribution Center	450
General Products Company	Manufacturing	375
Diversified Mailing Services	Commercial Mailing Service	300
General Motors	Manufacturing	300
Sheridan Books	Printing	250
Rappahannock Electric Cooperative	Electric Service	250
Printpack Inc.	Flexible	180
Kaeser Compressors, Inc.	Air Compressors	175
Simmons USA	Bedding	130
E-OIR Measurements, Inc.	Sensor Technology Firm	125
Walter Grinders	Tool Grinding Machines	120
National Coach Works	Charter Motor Coach Services	115
United Parcel Service	Package Delivery/Pickup Service	110
A. Smith Bowman Distillery	Manufacturer of Distilled Spirits	100
Carlisle Motion Control	Manufacturer of Brake Lining	100
The Shockey Precast Group	Manufacturer of Precast Concrete	100

Table 2.5-22 Vacant Housing Units by County During 2000

County	Total Vacant	For Rent	For Sale Only	For Seasonal, Recreational, or Occasional Use	Remainder of Vacant Units
Henrico	4449	1970	806	454	1219
Louisa	1910	73	124	1226	487
Orange	1204	116	170	484	434
Spotsylvania	2021	359	449	564	649
Richmond City	7733	3113	849	249	3522

Table 2.5-23 Regional Fire Stations and Emergency Service Centers

Hanover County	**Orange County**	**Louisa County**
Henry Vol. Fire	Barboursville Fire Department	Louisa Vol. Fire
Mechanicsville Vol. Fire	Gordonsville Fire Department	Mineral Vol. Fire
Eastern Hanover Vol. Fire	Orange Fire Department	Bumpass Vol. Fire
Black Creek Vol. Fire	Lake of the Woods Fire Department	Holly Grove Vol. Fire
Farrington Vol. Fire	Mine Run Fire Department	Locust Creek Vol. Fire
Hanover County Vol. Fire	Rapidan Fire Department	Trevillians Vol. Fire
Beaverdam Vol. Fire	Lake of the Woods Rescue Squad	Zion Crossroad Vol. Fire
Hanover Industrial Airpark Fire	Orange County Rescue Squad	Louisa Rescue
Montpelier Vol. Fire		Mineral Rescue
Rockville Vol. Fire	**Henrico County**	Holly Grove Rescue
Ashland Vol. Fire & Rescue	5 Fire Stations & Fire Medic Units	Lake Anna Rescue
West Hanover Vol. Fire & Rescue	15 Fire Stations	
East Hanover Rescue	Fire Rescue 33 (Tuckahoe #1 VRS)	**City of Richmond**
Ashcake Rescue	Fire Rescue 34 (Tuckahoe #2 VRS)	21 Fire Companies
Emergency Operations Center	Fire Rescue 32 (Lakeside VRS)	EMS Headquarters
	Fire Rescue 31 (Henrico VRS)	

Table 2.5-24 Historic Sites in Counties Near the ESP Site

County	Number of Listed Historic Sites
Louisa	13
Spotsylvania	15
Hanover	32
Total	60

Table 2.5-25 Historic Sites within the Vicinity

Historic Site	County	Approximate Distance from ESP site	National Register of Historic Places (NRHP) Number
Andrew's Tavern	Spotsylvania	4 miles	88-136
DESCRIPTION: Samuel Andrews built Andrews Tavern in 1815. The site is currently a private residence. The building's craftsmanship, combined with its hall and parlor plan, make it a model of the Federal provincial architecture of Piedmont Virginia. The property retains a high degree of integrity, in both its buildings and setting. During its 186 years, Andrews Tavern has served as a post office, tavern, polling place, school, store, militia site, and residence. **SIGNIFICANCE:** Event, Architecture/Engineering **NOTE:** Spotsylvania Board of Supervisors removed Andrews Tavern from the historic properties register at the request of the property owner in mid-2001. It remains on the Virginia and National listings.			
Cuckoo House	Louisa	9 miles	54-16
DESCRIPTION: Captain Henry Pendleton erected the present building in 1781 on the site of an old tavern. Some are of the opinion that part of the present structure is a portion of the old Cuckoo Tavern. The home is built of brick laid in the common bond, the plan of architecture being the shape of the letter "T." Cuckoo was originally the site of an old tavern, known at one time as King's Ordinary and afterwards known as Cuckoo Tavern. Jack Jouett was the "other rider" the night of famous Paul Revere's ride to warn the Virginia General Assembly that the British were coming. It was from the Cuckoo Tavern that Jouett rode to Charlottesville to warn the Virginia General Assembly of the British approach. The tavern was the stopping place for the aristocrats. **SIGNIFICANCE:** Architecture/Engineering, Event			
Jerdone Castle	Louisa	7 miles	54-45
DESCRIPTION: It is estimated that John Jerdone erected the structure in the early 1750's. The house is a rectangular frame building, with a lean-to on the East side. It is one and one-half stories. An addition to the house was made in the 1850's. **SIGNIFICANCE:** Architecture/Engineering, Person			
Prospect Hill	Spotsylvania	9 miles	88-56
DESCRIPTION: The Holladay family has owned The Prospect Hill property since 1798. The name Prospect Hill is believed to be attributed to the extraordinary view of the surrounding country from the property site. The main house was erected in 1812. The frame structure has two stories and an attic. Waller Holladay, scholar and a poet, was educated as a lawyer; but did not practice long. He is closely linked to Thomas Jefferson and Edmund and John Randolph (of Roanoke). The home had been raided by Union soldiers. **SIGNIFICANCE:** Event, Architecture/Engineering, Person			

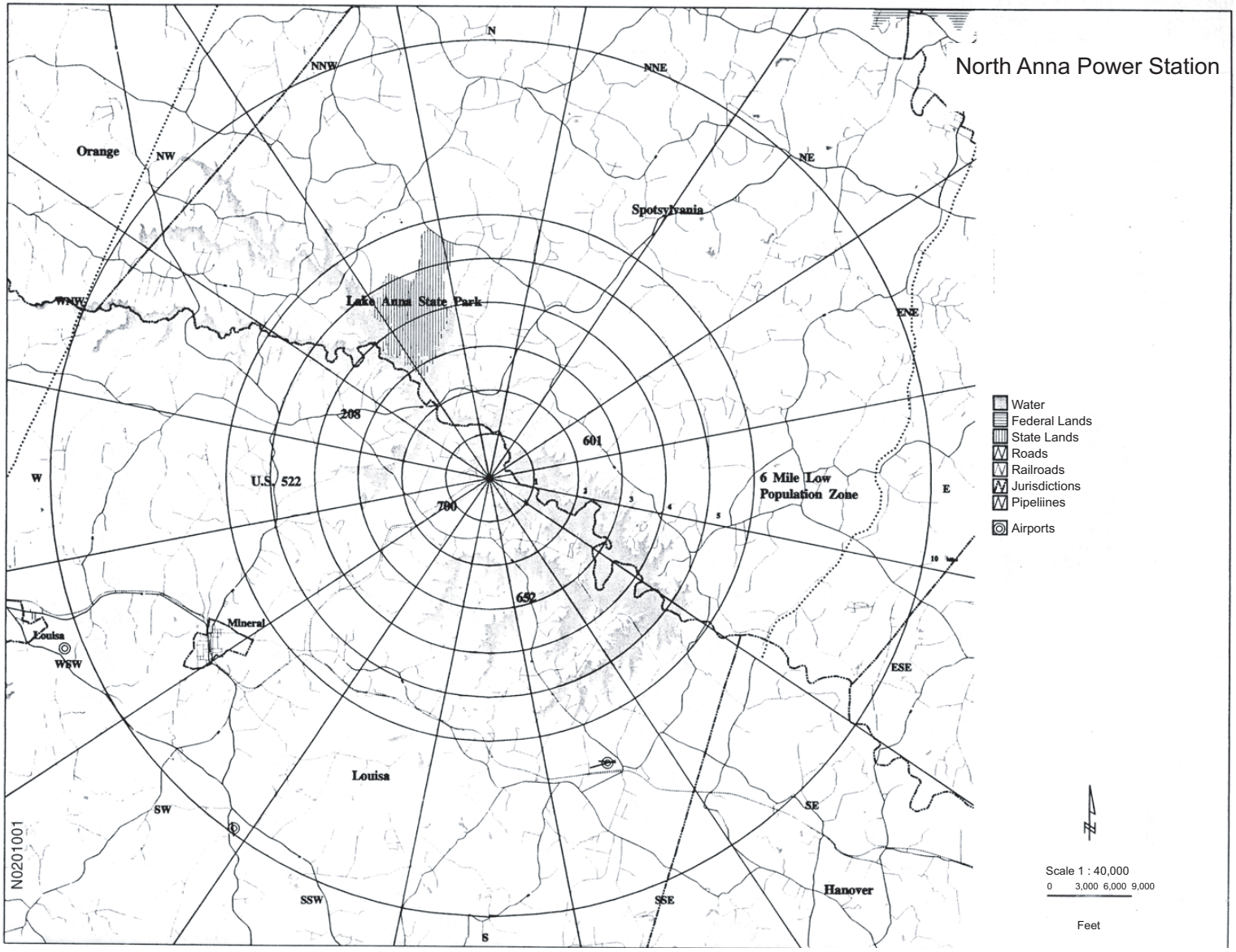


Figure 2.5-1 10-Mile Surrounding Area

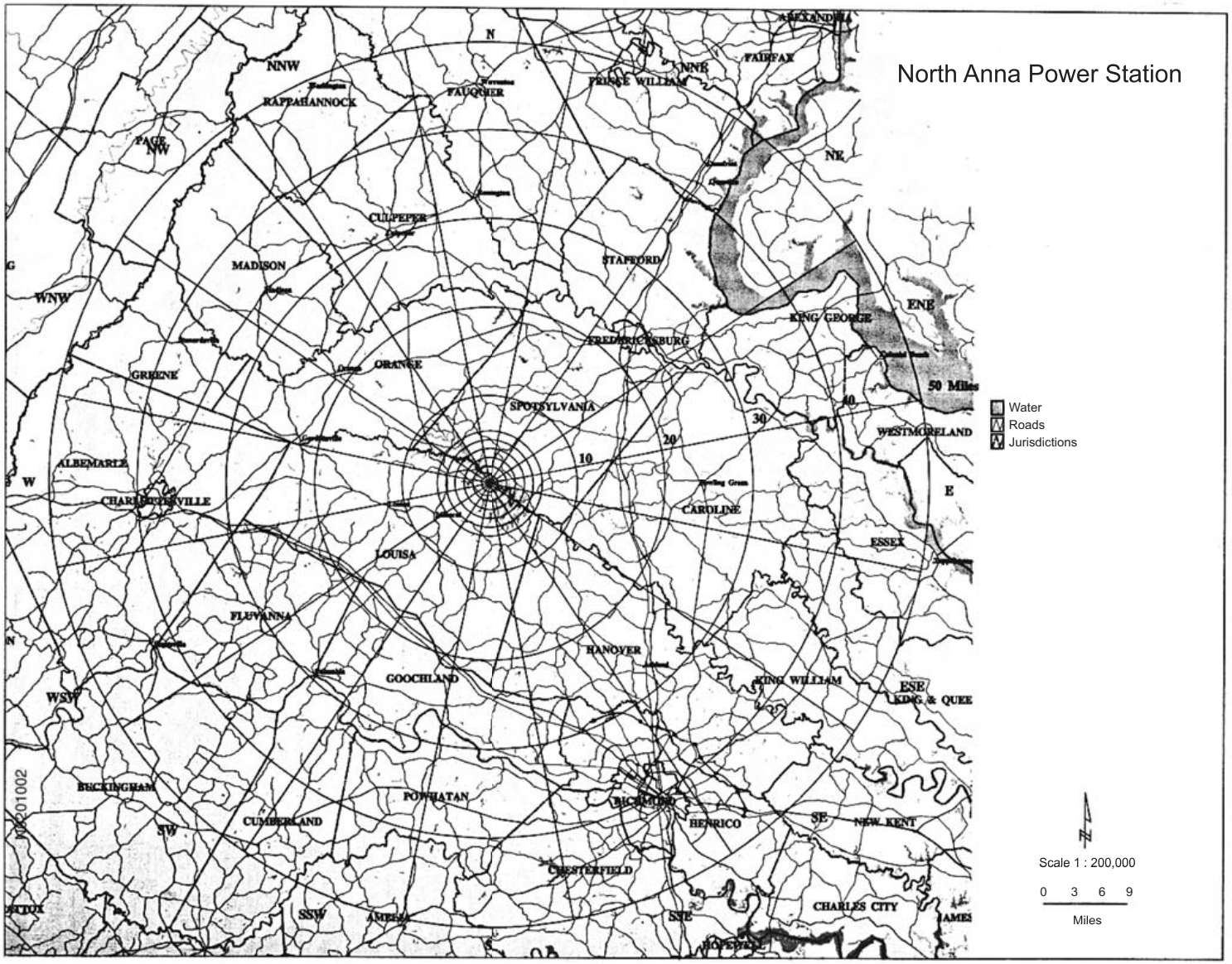
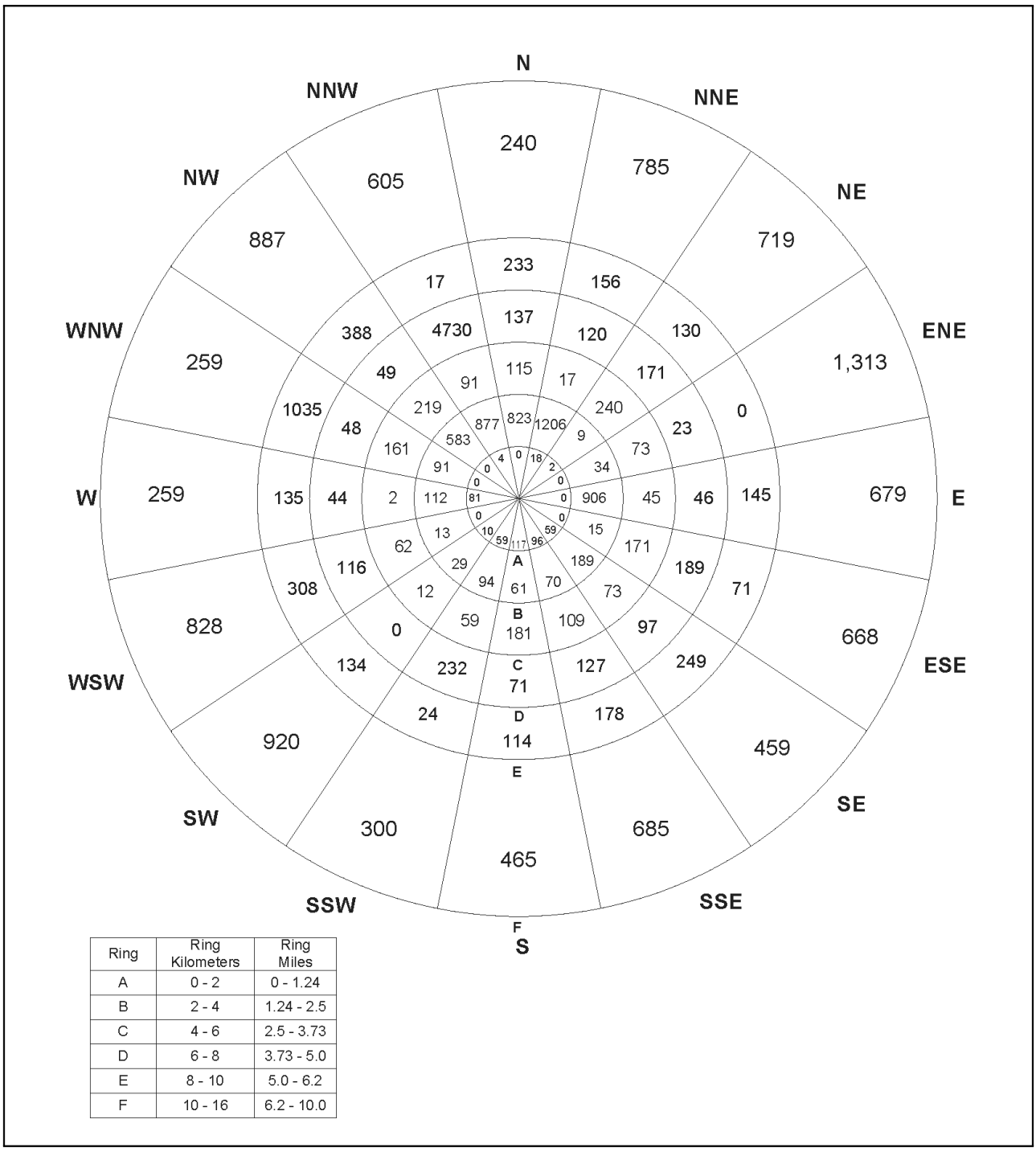


Figure 2.5-2 50-Mile Surrounding Area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300
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828
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887
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130
115
17
171
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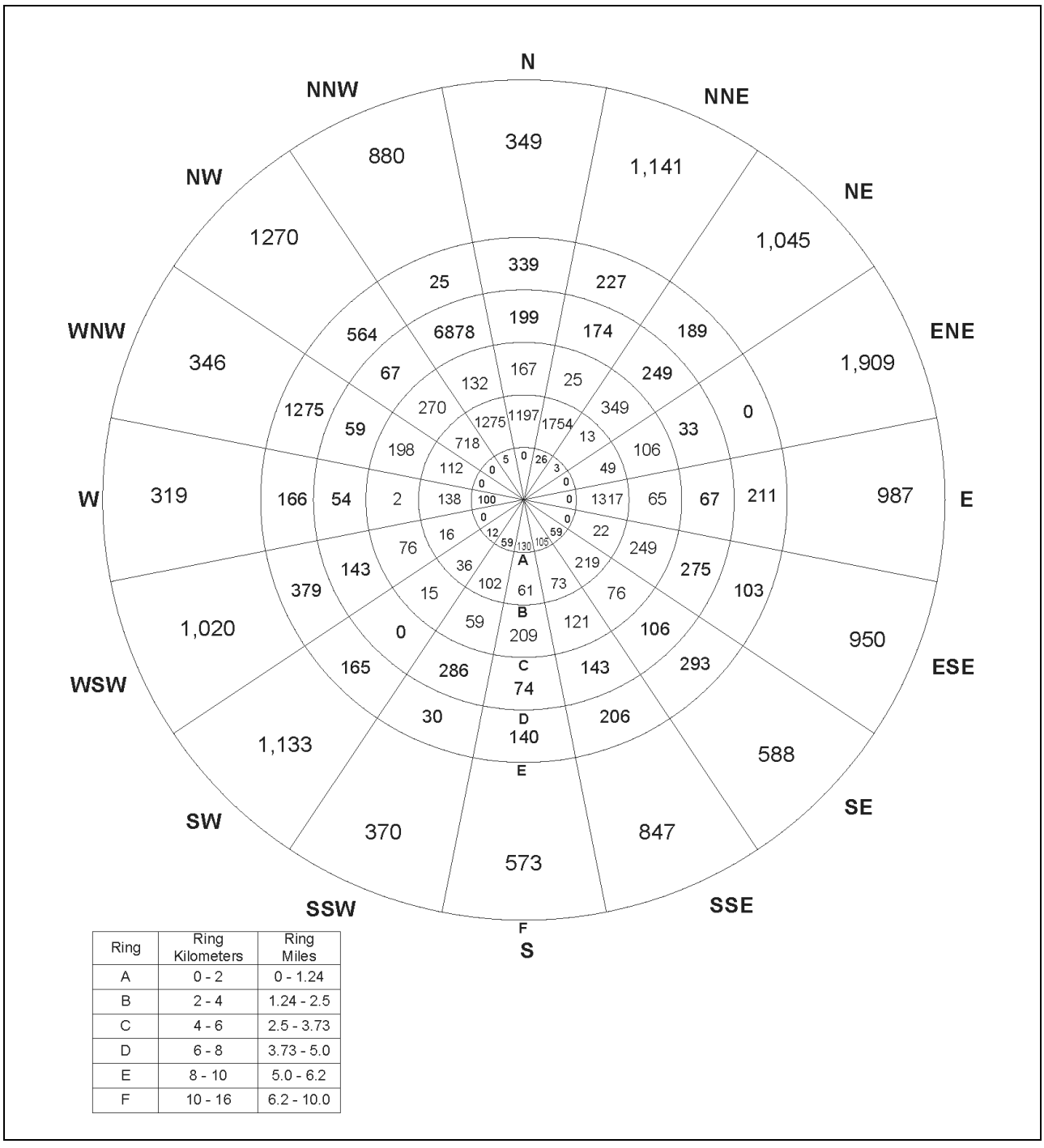
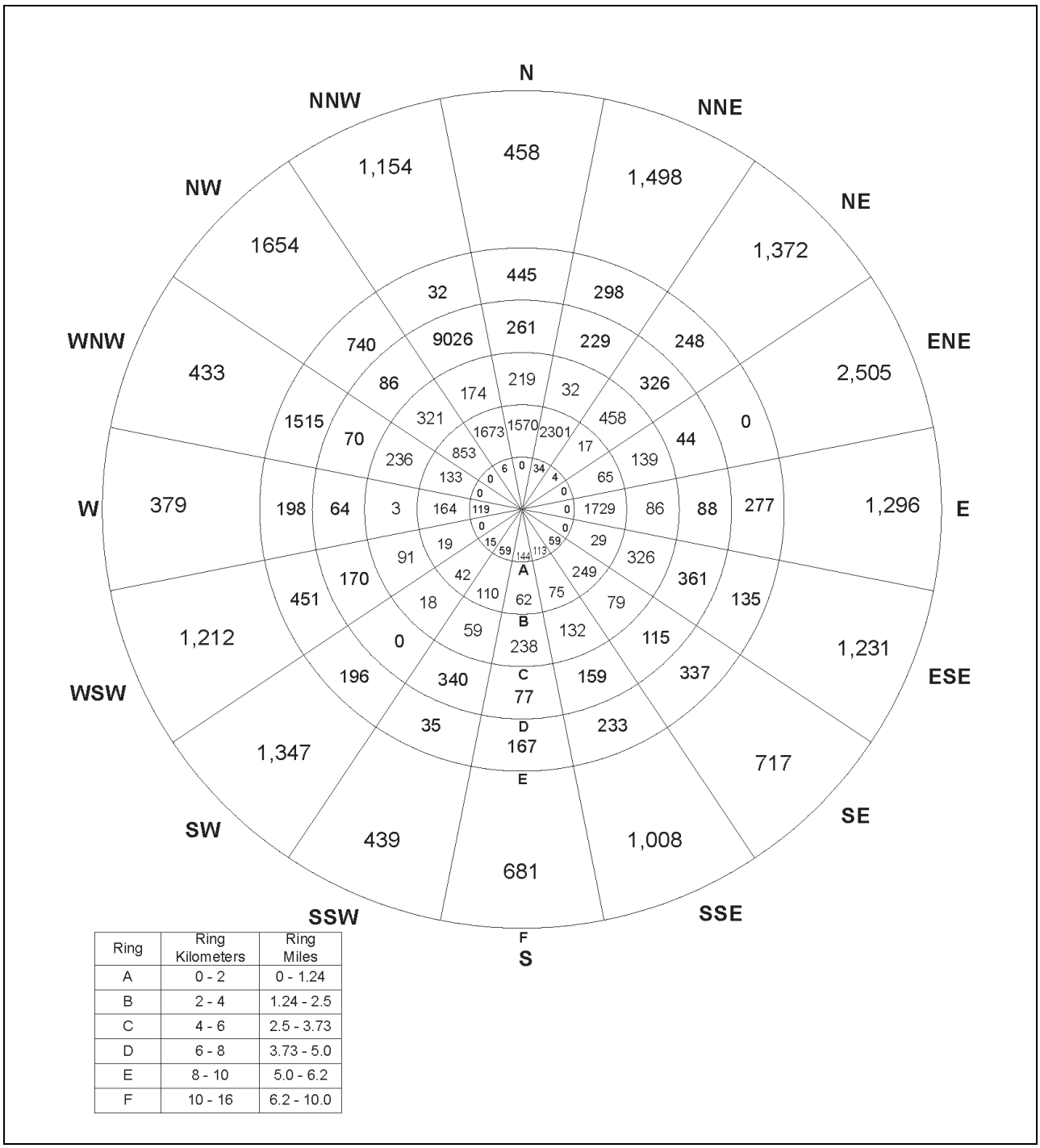


Figure 2.5-4 16-Kilometer (10-Mile) Resident and Transient Population Distribution–2010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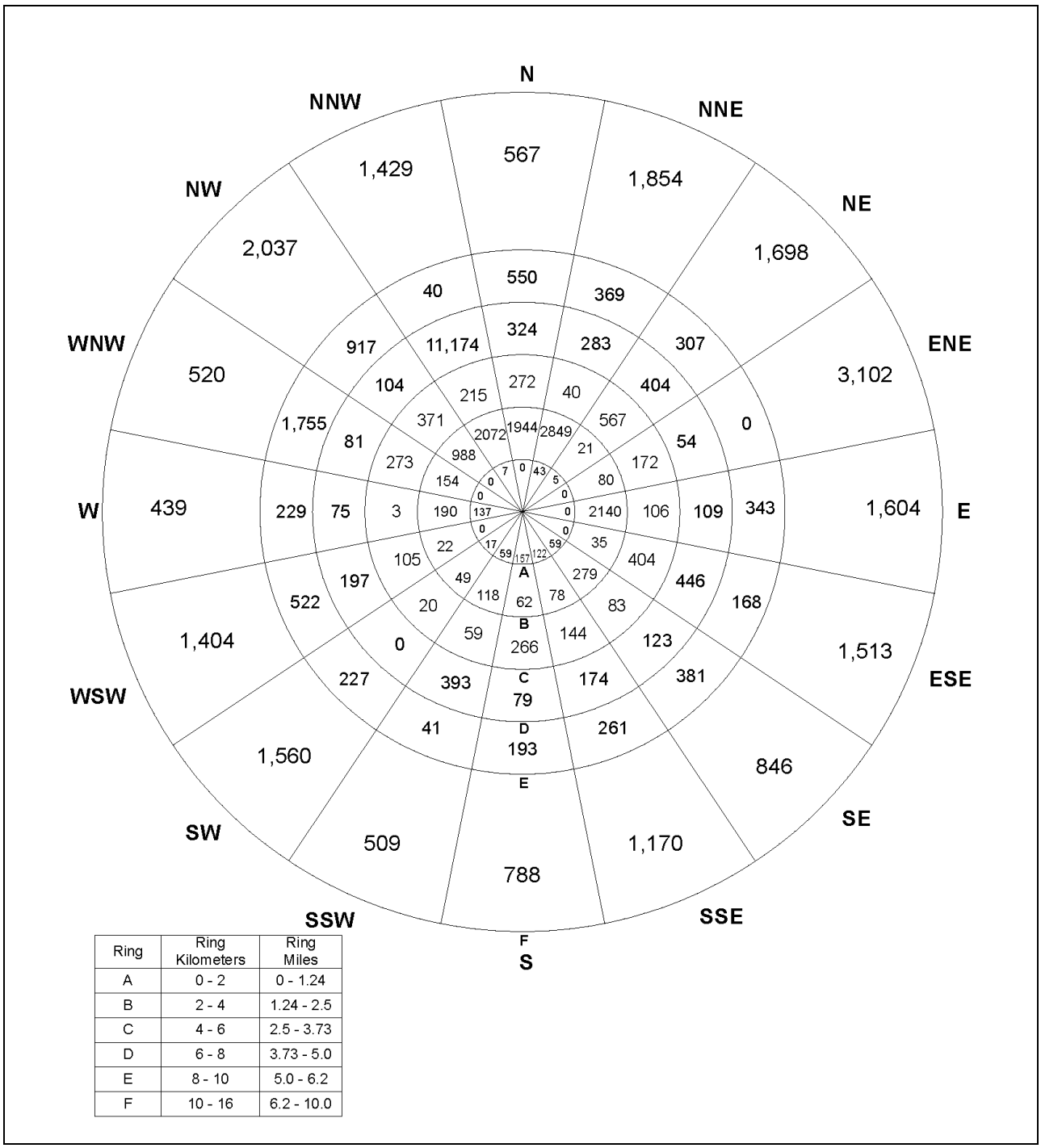
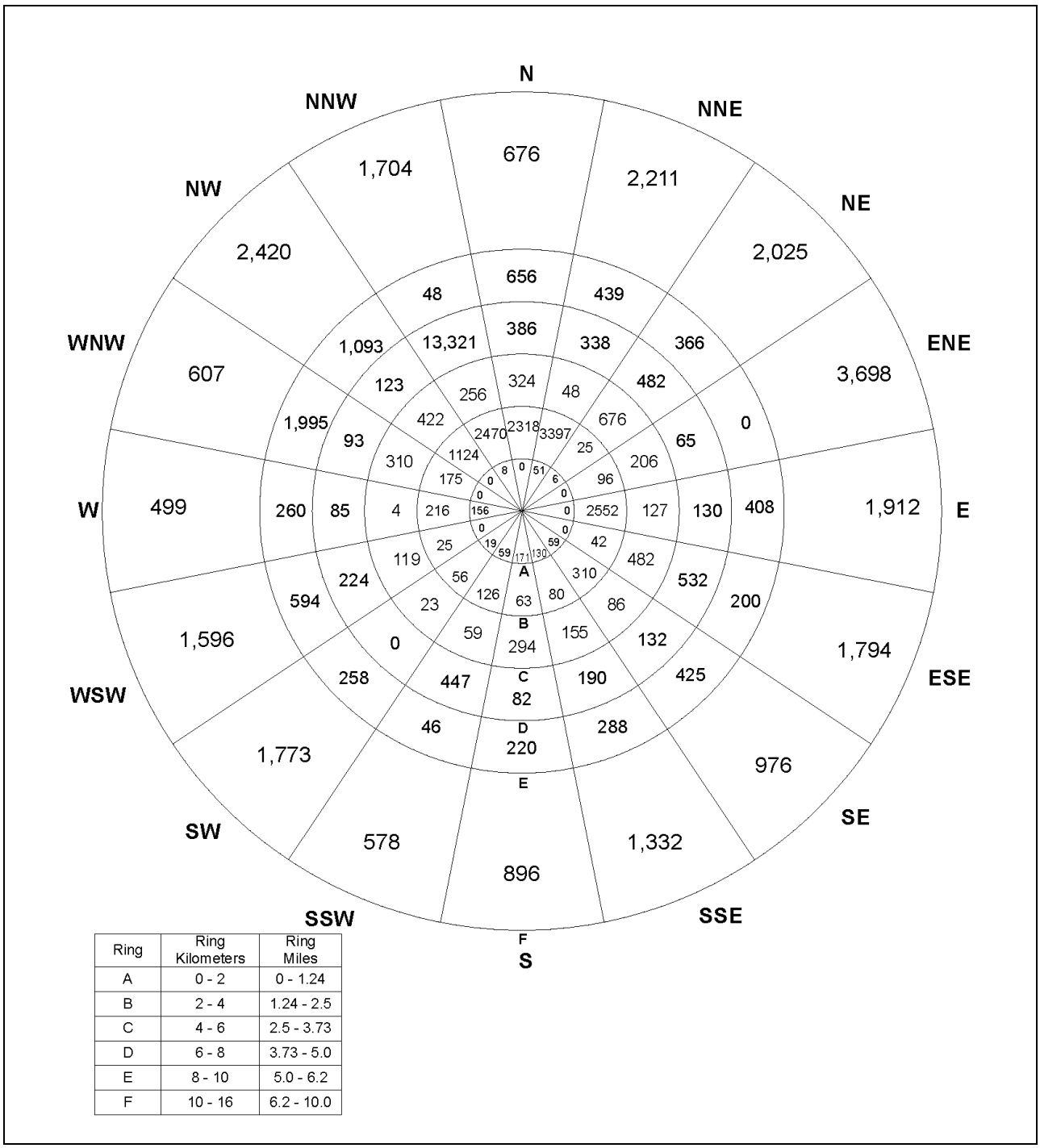


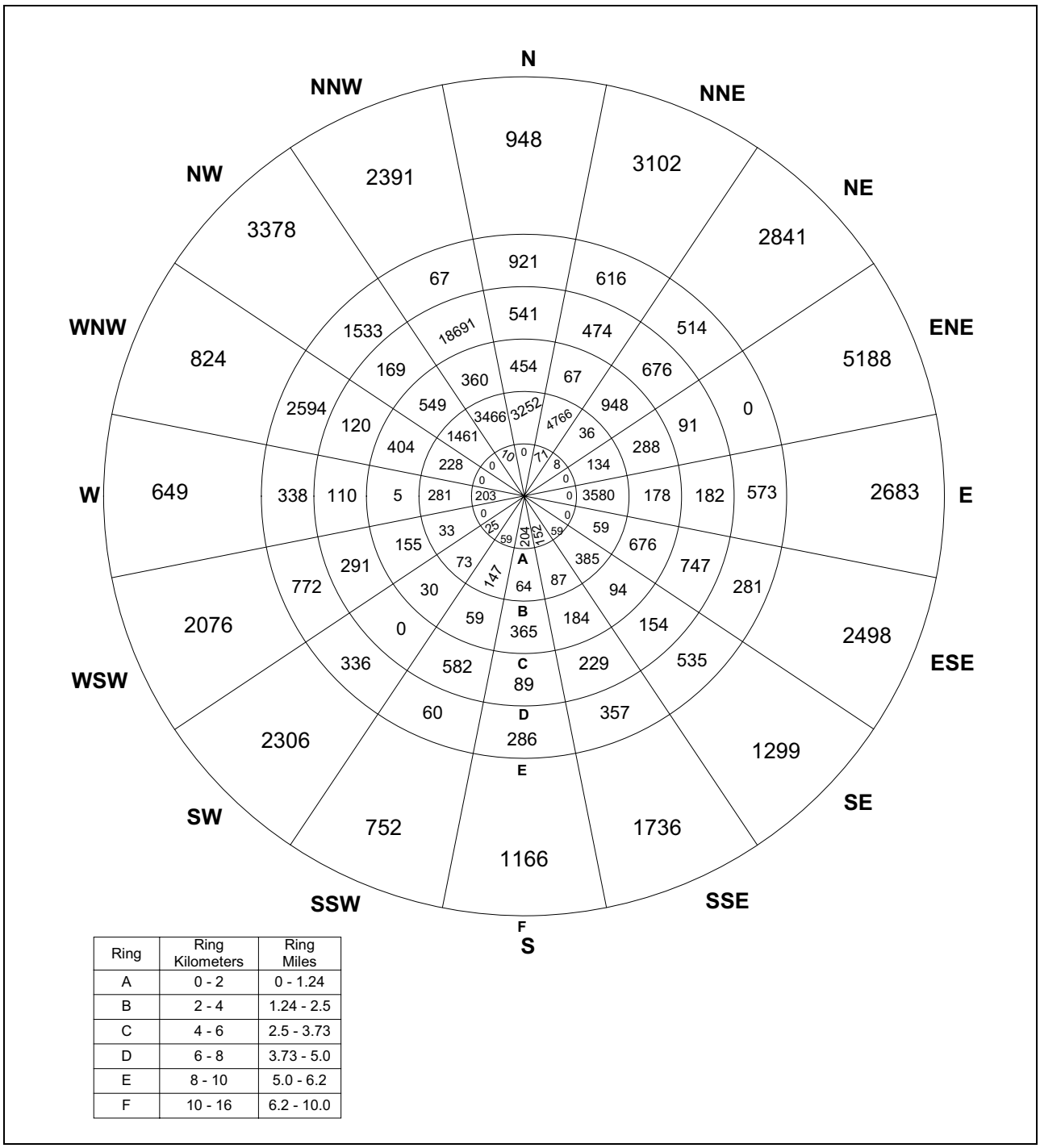
Ring	Ring Kilometers	Ring Miles
A	0 - 2	0 - 1.24
B	2 - 4	1.24 - 2.5
C	4 - 6	2.5 - 3.73
D	6 - 8	3.73 - 5.0
E	8 - 10	5.0 - 6.2
F	10 - 16	6.2 - 10.0

Figure 2.5-6 16-Kilometer (10-Mile) Resident and Transient Population Distribution–2030



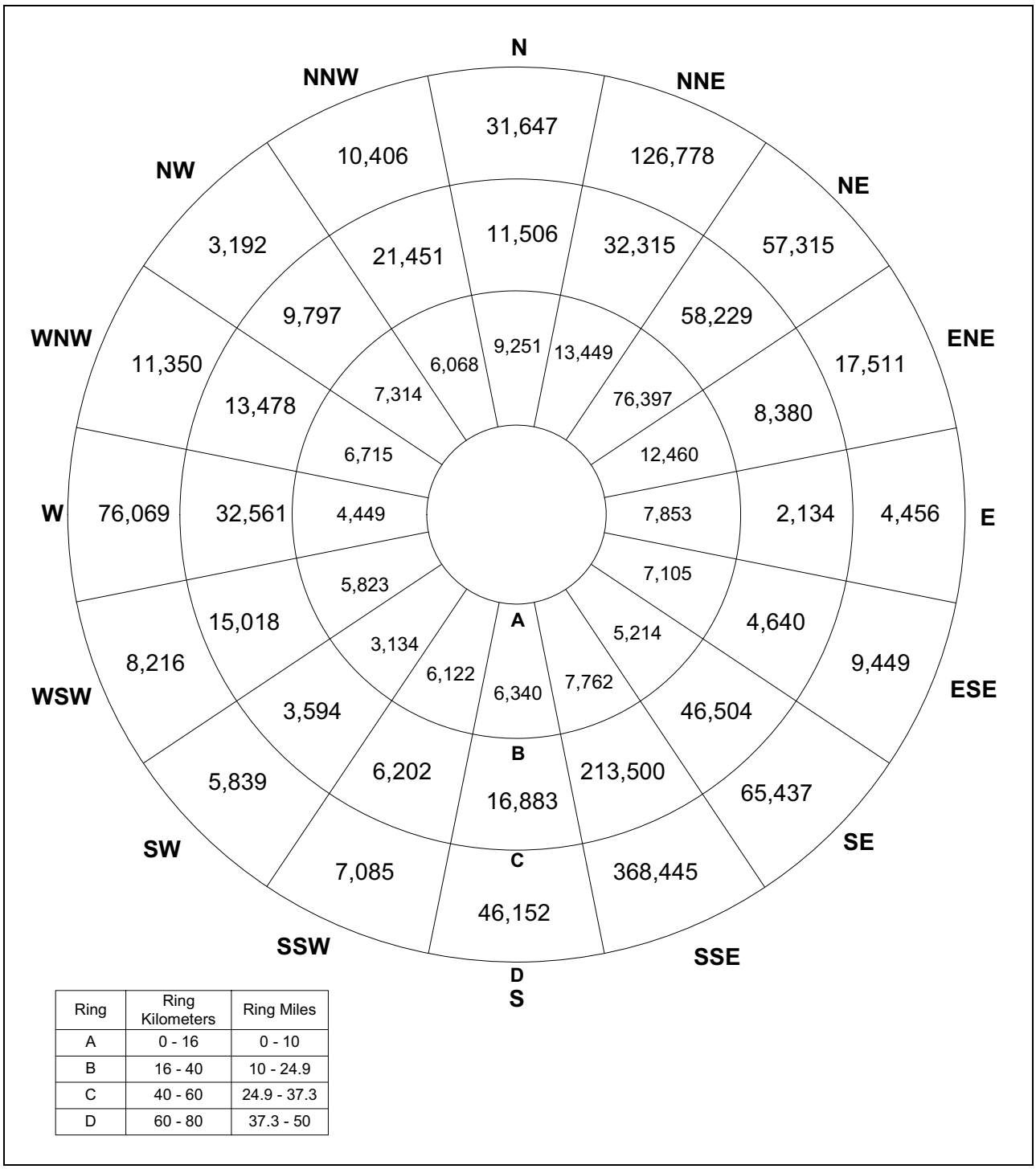
Ring	Ring Kilometers	Ring Miles
A	0 - 2	0 - 1.24
B	2 - 4	1.24 - 2.5
C	4 - 6	2.5 - 3.73
D	6 - 8	3.73 - 5.0
E	8 - 10	5.0 - 6.2
F	10 - 16	6.2 - 10.0

Figure 2.5-7 16-Kilometer (10-Mile) Resident and Transient Population Distribution–2040



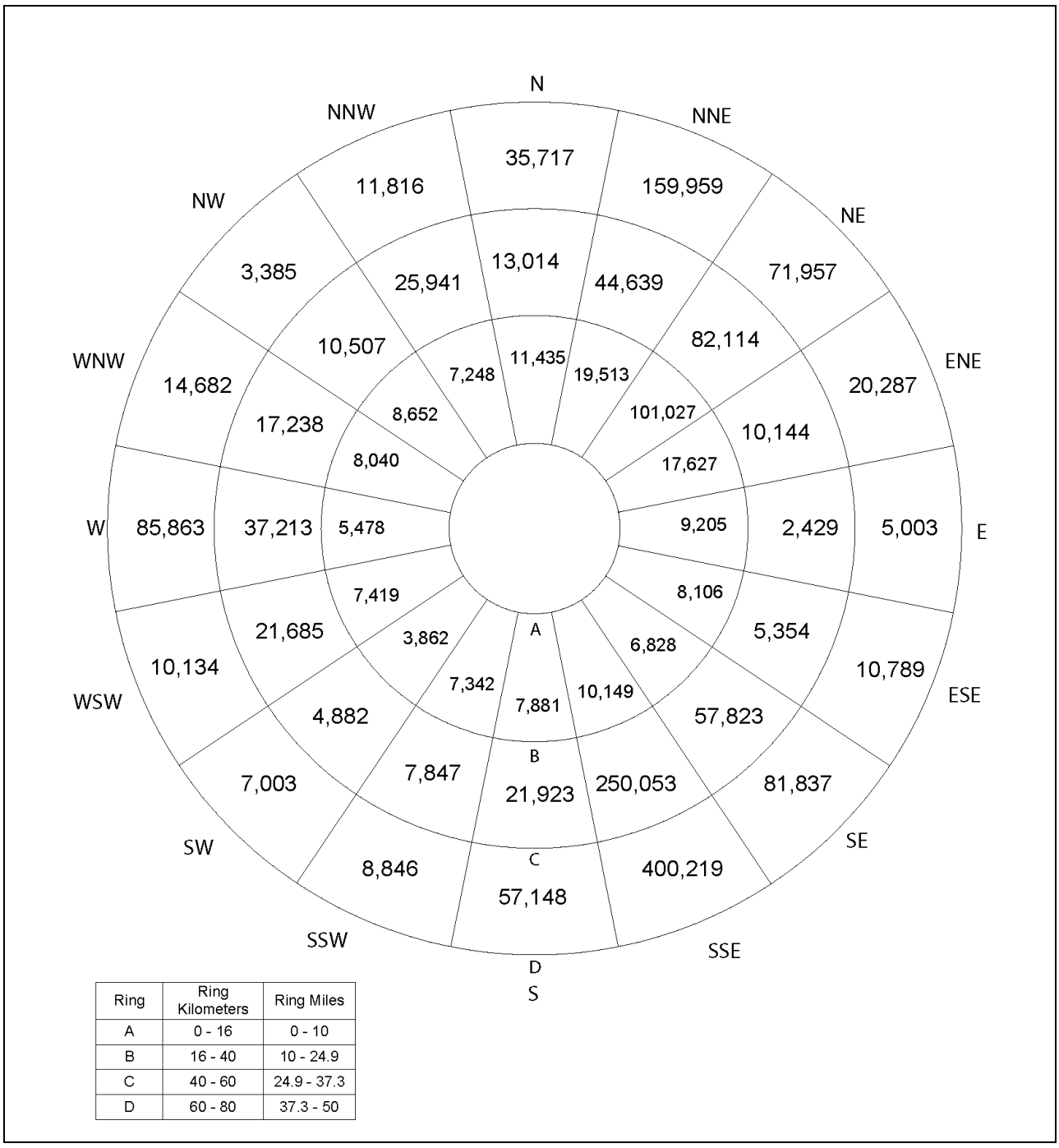
Ring	Ring Kilometers	Ring Miles
A	0 - 2	0 - 1.24
B	2 - 4	1.24 - 2.5
C	4 - 6	2.5 - 3.73
D	6 - 8	3.73 - 5.0
E	8 - 10	5.0 - 6.2
F	10 - 16	6.2 - 10.0

Figure 2.5-7A 16-Kilometer (10-Mile) Resident and Transient Population Distribution–2065



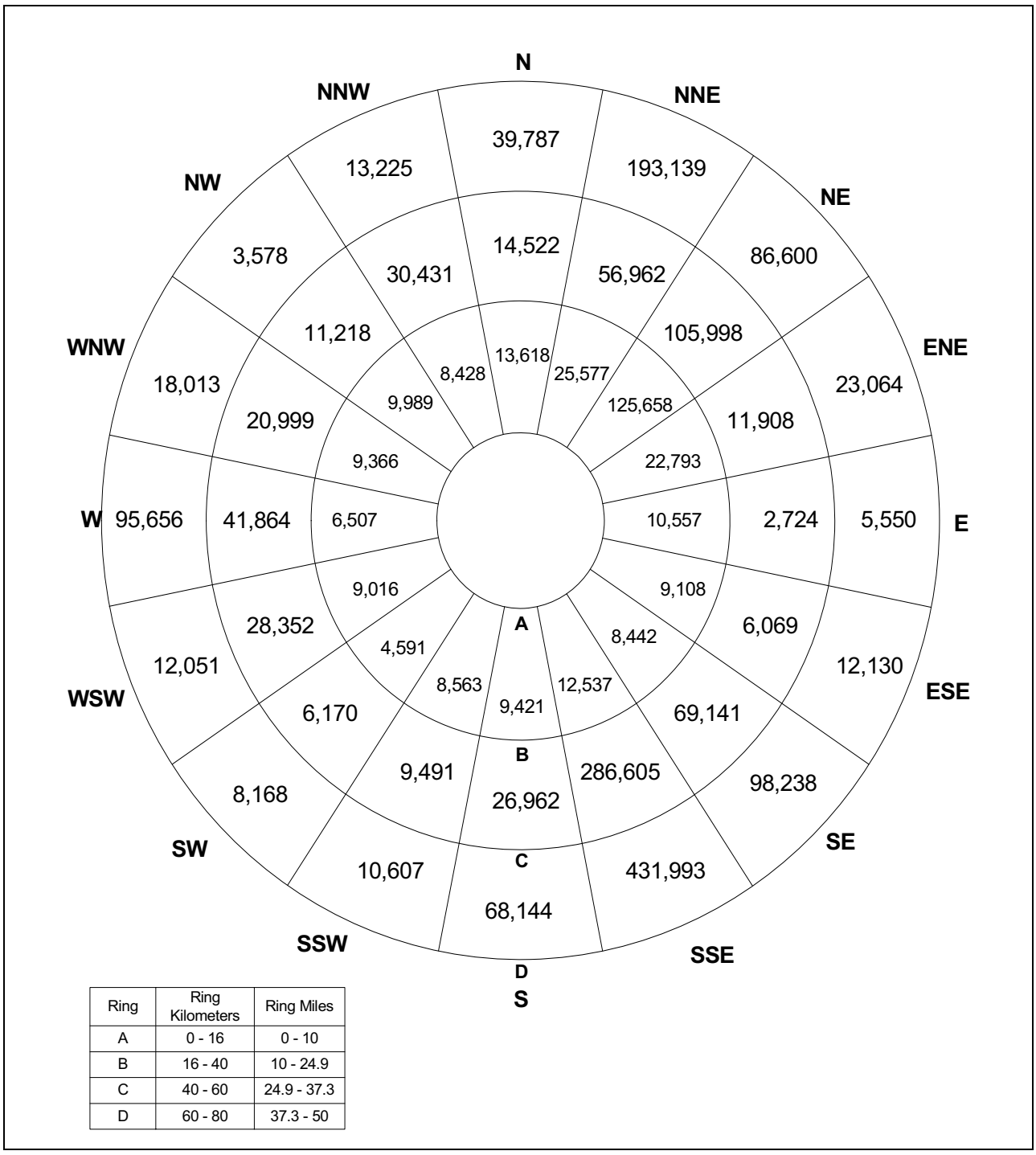
Ring	Ring Kilometers	Ring Miles
A	0 - 16	0 - 10
B	16 - 40	10 - 24.9
C	40 - 60	24.9 - 37.3
D	60 - 80	37.3 - 50

Figure 2.5-8 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2000



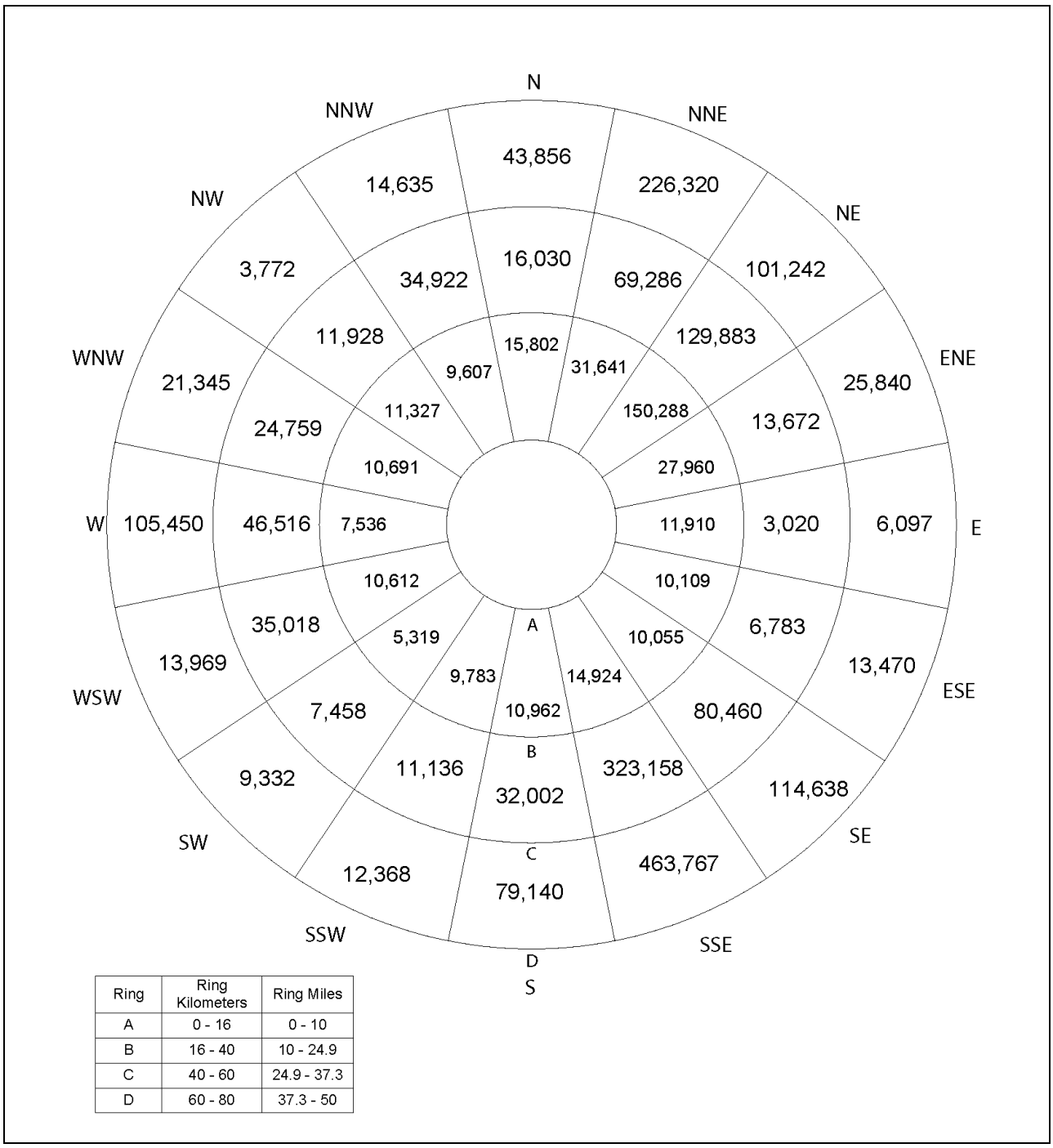
Ring	Ring Kilometers	Ring Miles
A	0 - 16	0 - 10
B	16 - 40	10 - 24.9
C	40 - 60	24.9 - 37.3
D	60 - 80	37.3 - 50

Figure 2.5-9 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2010



Ring	Ring Kilometers	Ring Miles
A	0 - 16	0 - 10
B	16 - 40	10 - 24.9
C	40 - 60	24.9 - 37.3
D	60 - 80	37.3 - 50

Figure 2.5-10 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2020



Ring	Ring Kilometers	Ring Miles
A	0 - 16	0 - 10
B	16 - 40	10 - 24.9
C	40 - 60	24.9 - 37.3
D	60 - 80	37.3 - 50

Figure 2.5-11 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2030

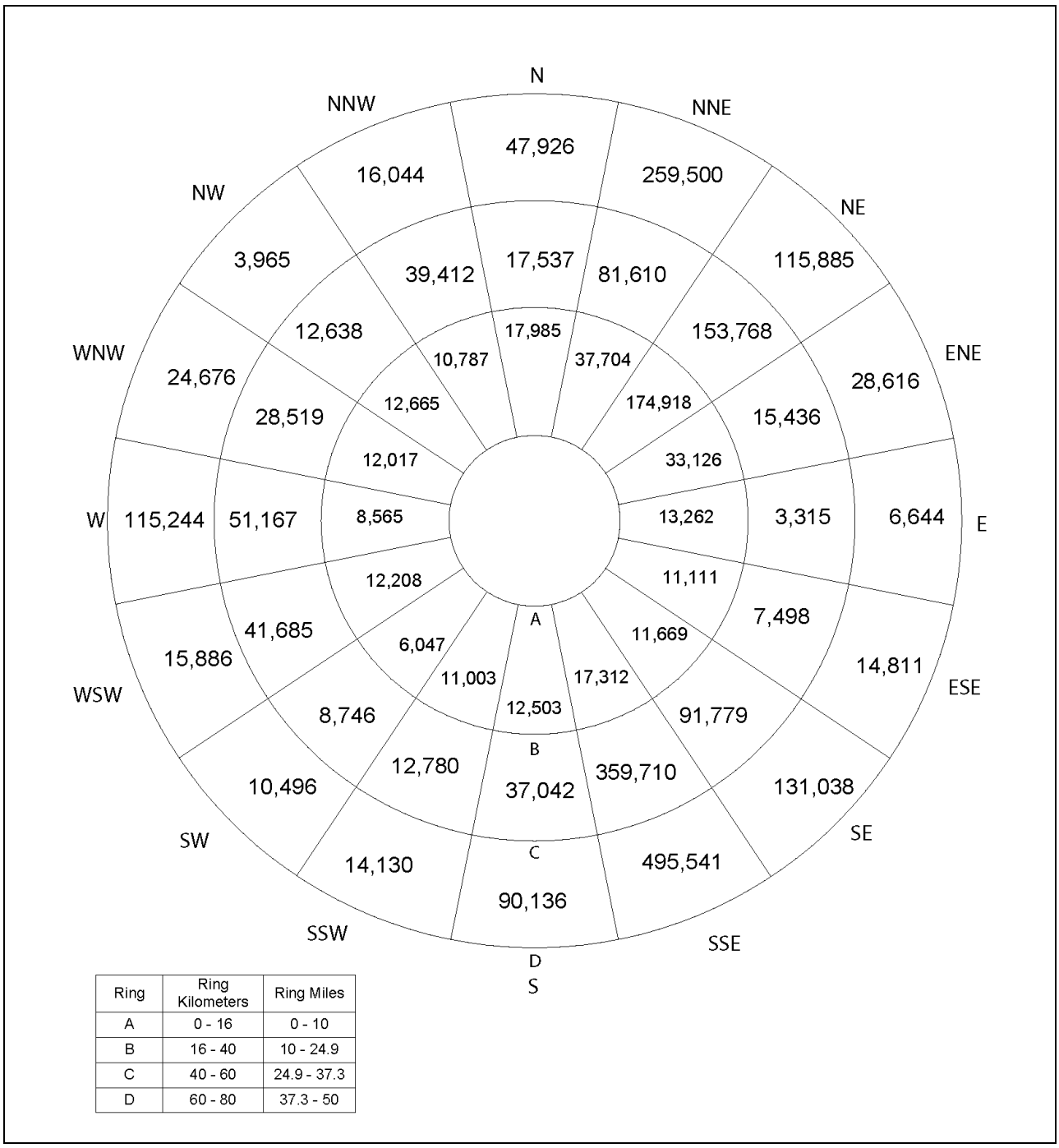


Figure 2.5-12 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2040

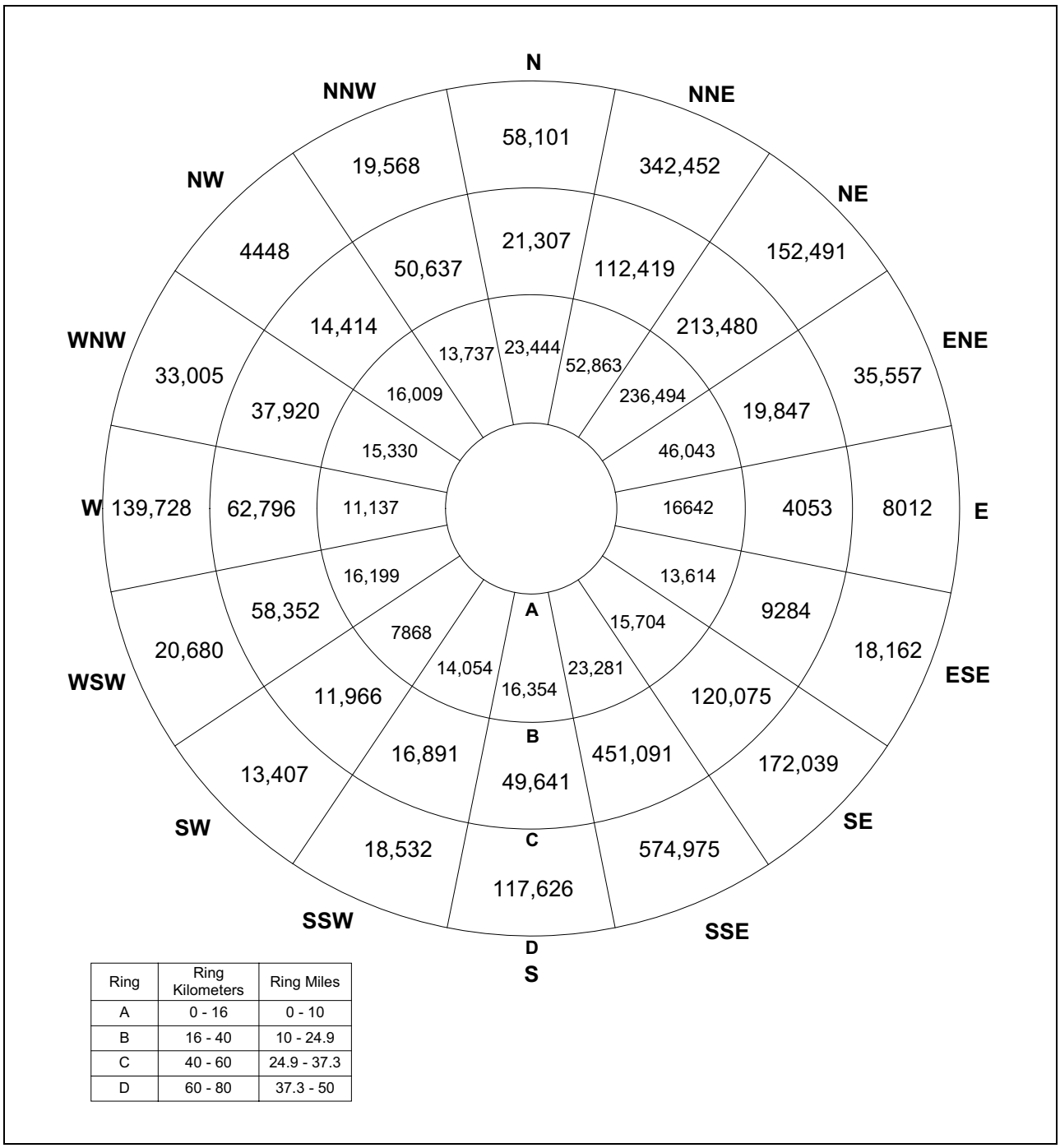


Figure 2.5-12A 80-Kilometer (50-Mile) Resident and Transient Population Distribution–2065

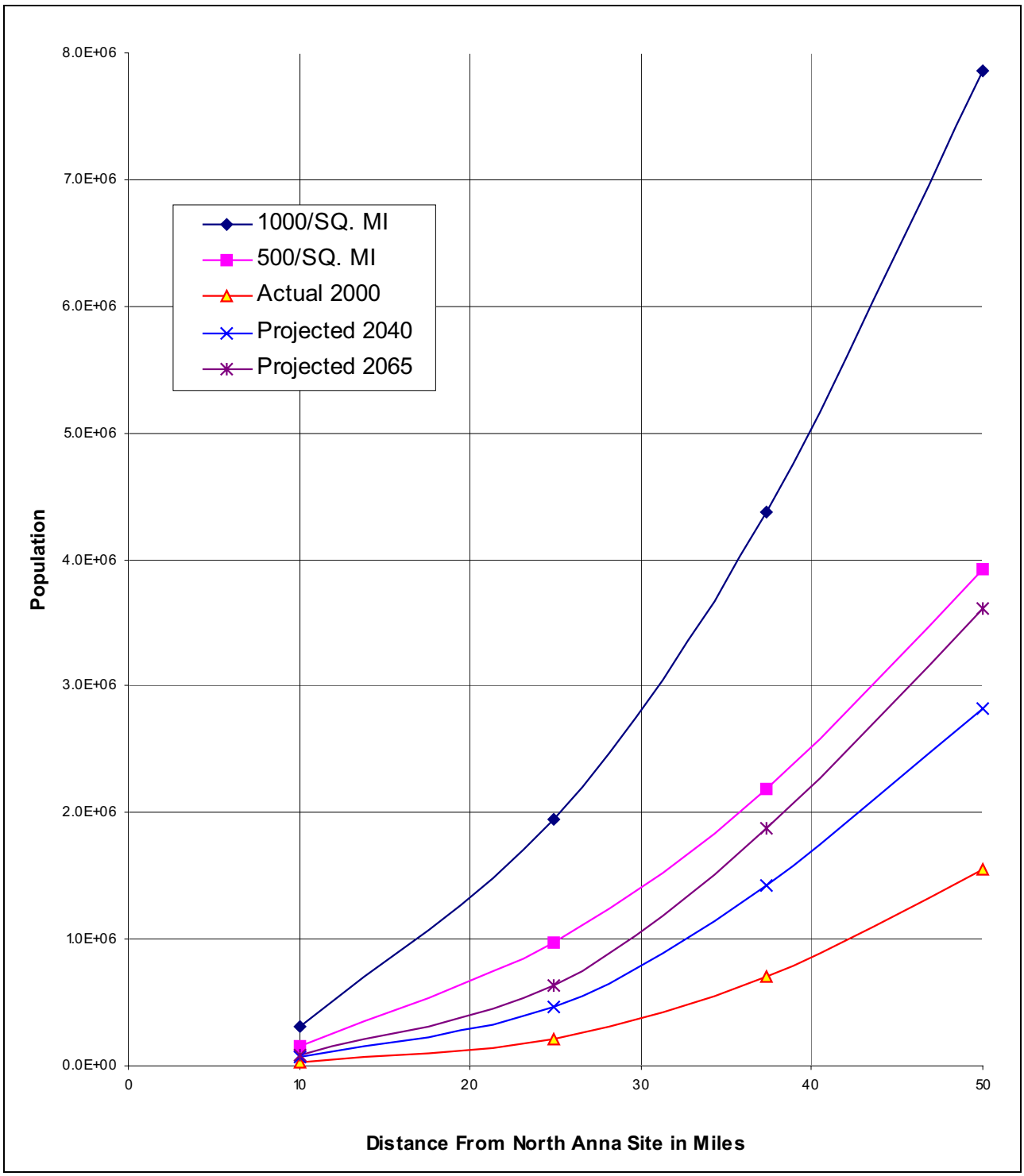


Figure 2.5-13 Population Density

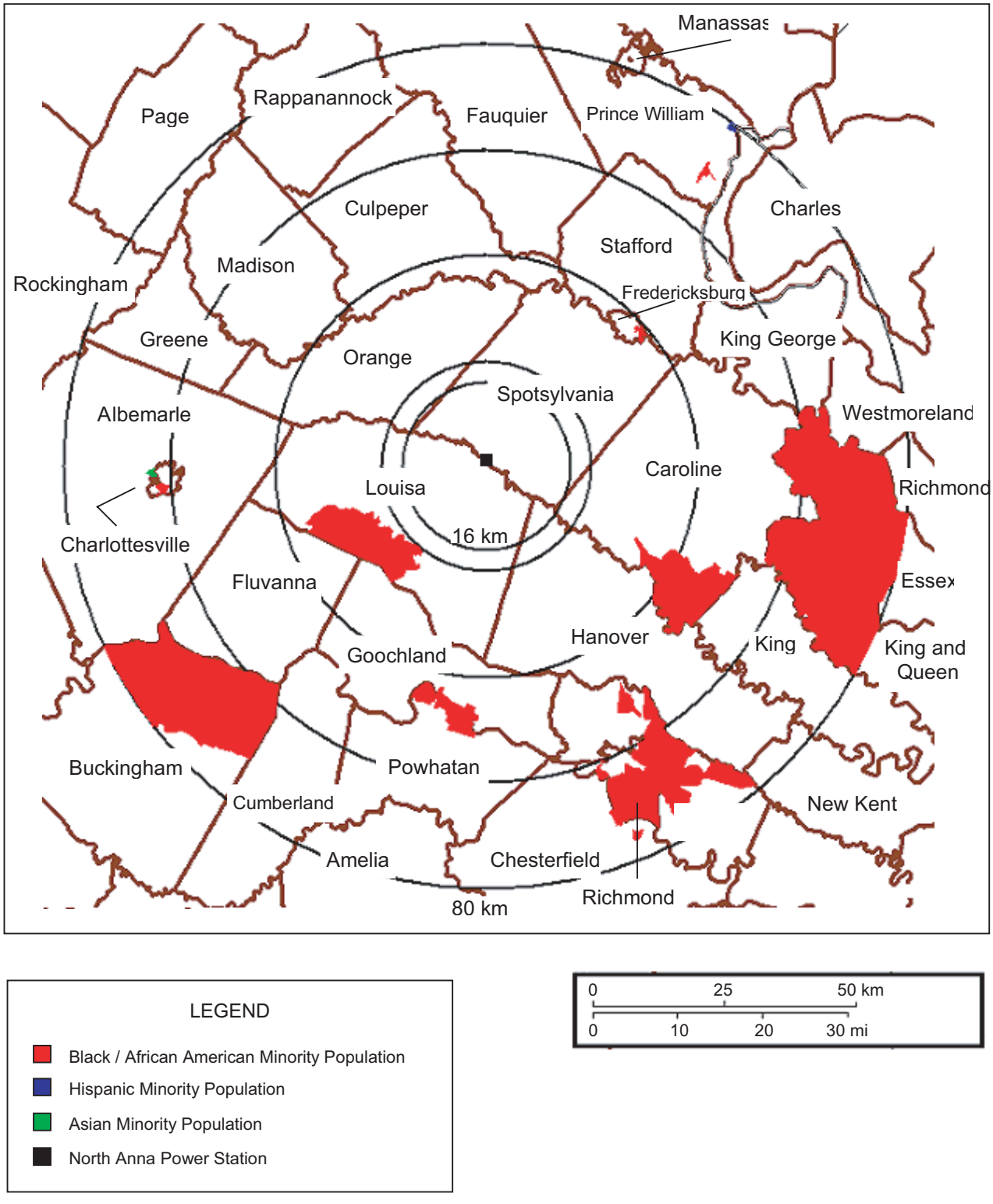


Figure 2.5-14 Minority Population

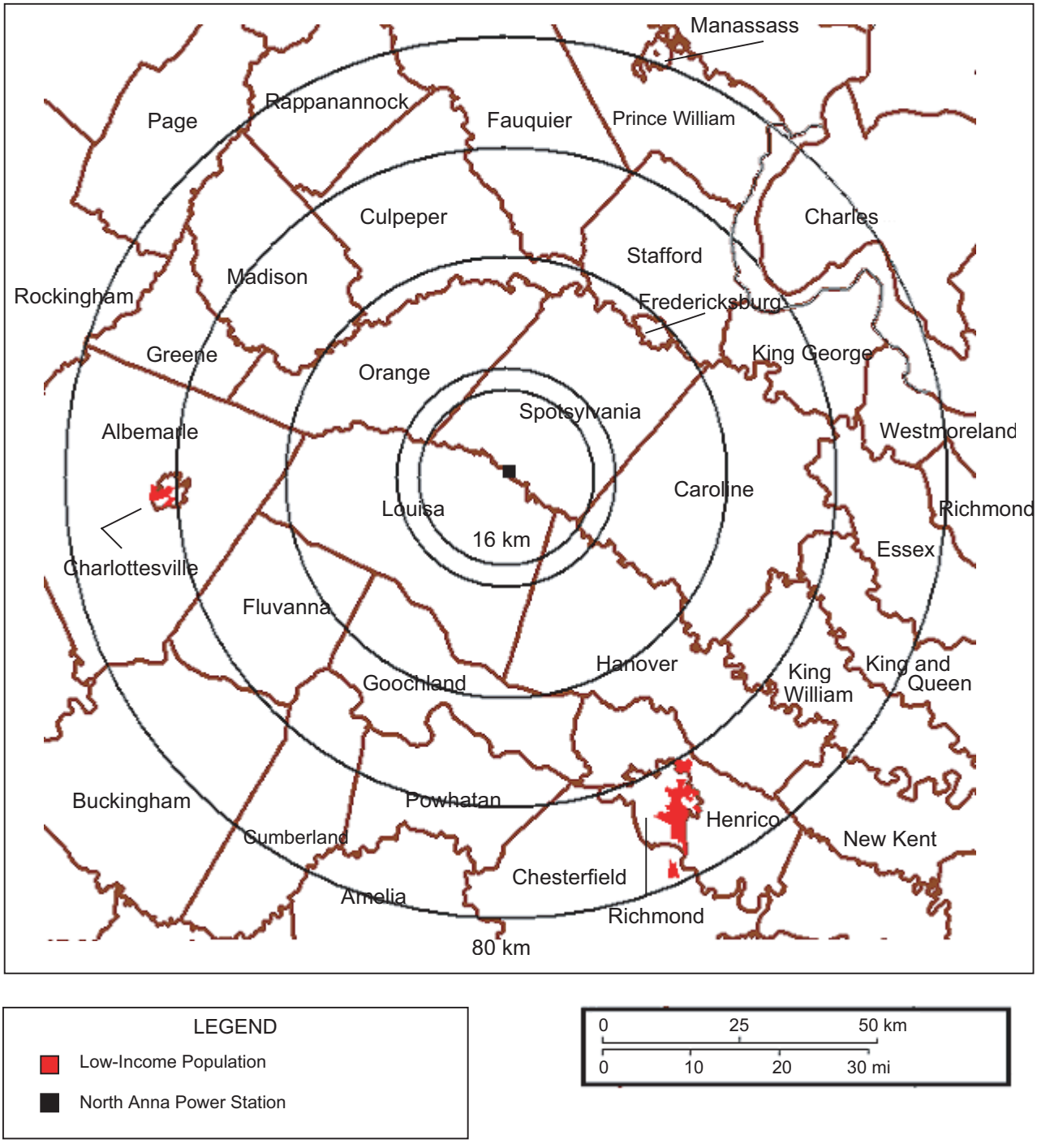


Figure 2.5-15 Low-Income Population

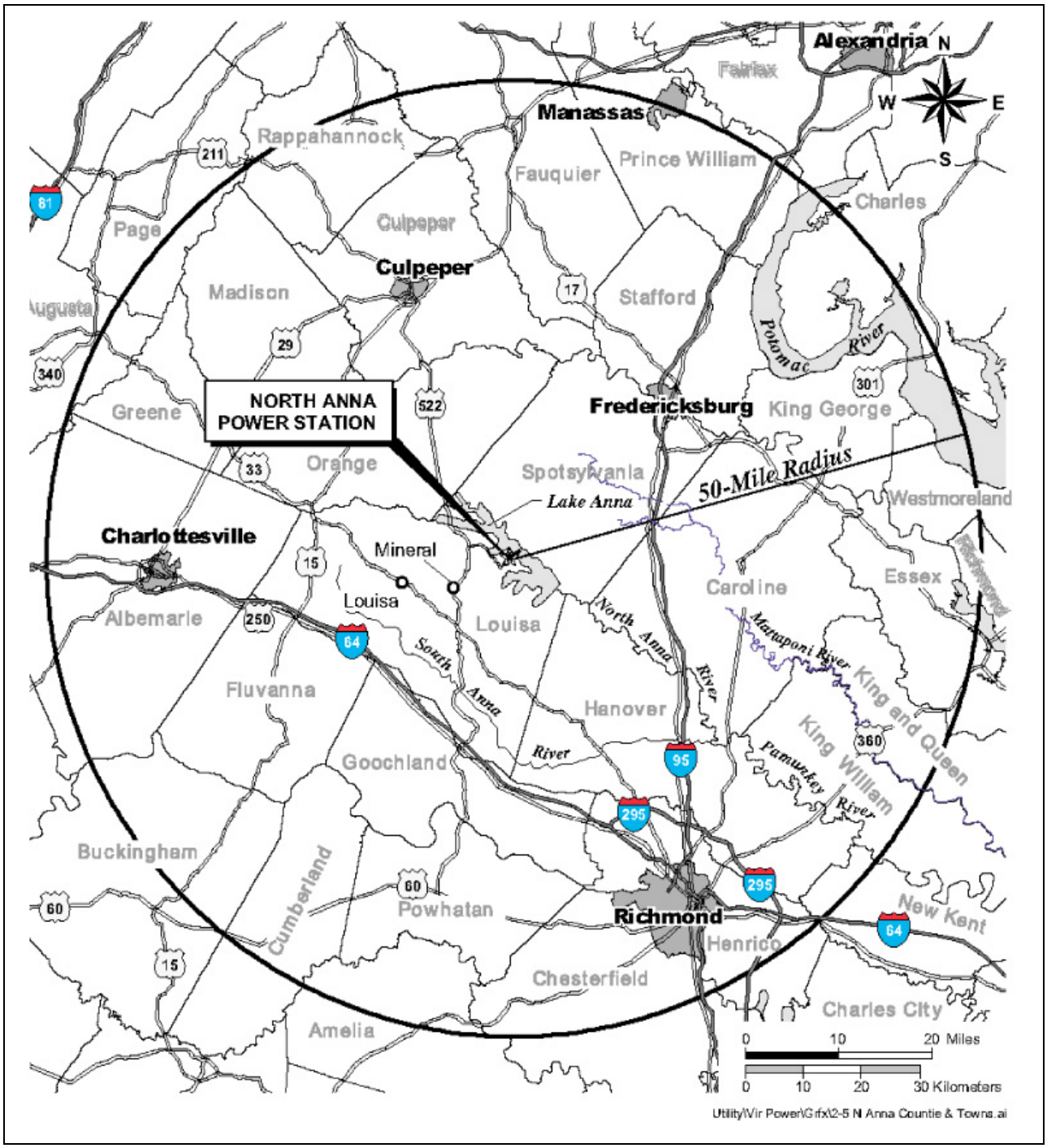


Figure 2.5-16 50-Mile Vicinity Map Showing Counties and Important Towns and Cities

Source: North Anna Power Station, Units 1 and 2 Application for Renewed Operating Licenses Appendix E – Environmental Report, Figure 2-5

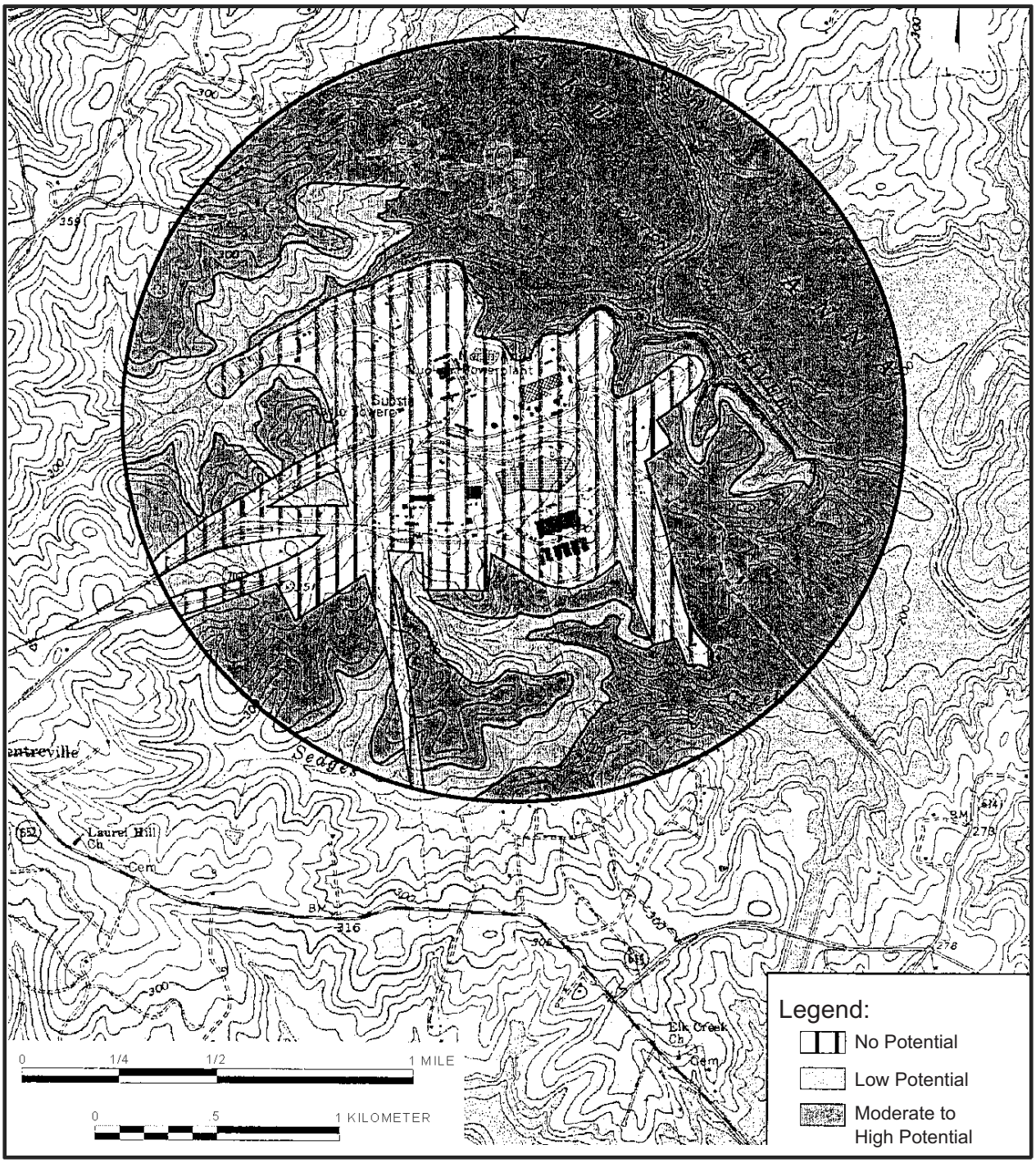


Figure 2.5-17 Area Potentials for Yielding Archeological Resources Within the Study Area

Source: Cultural Resources Assessment, Louis Berger Group, 2001 (Reference 21)

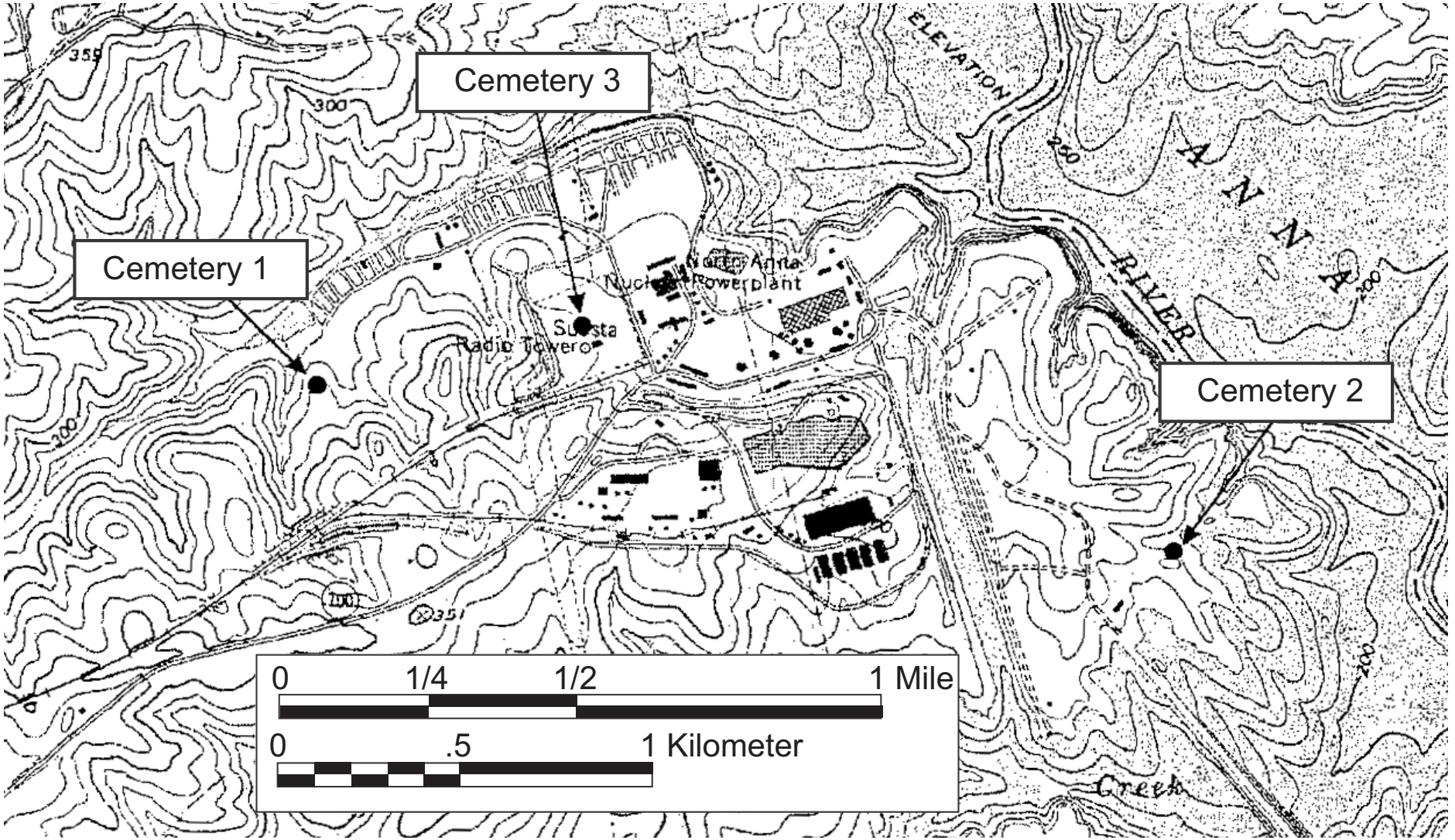


Figure 2.5-18 Cemeteries Within the NAPS Site Boundary

Source: Cultural Resources Assessment, Louis Berger Group, 2001 (Reference 21)

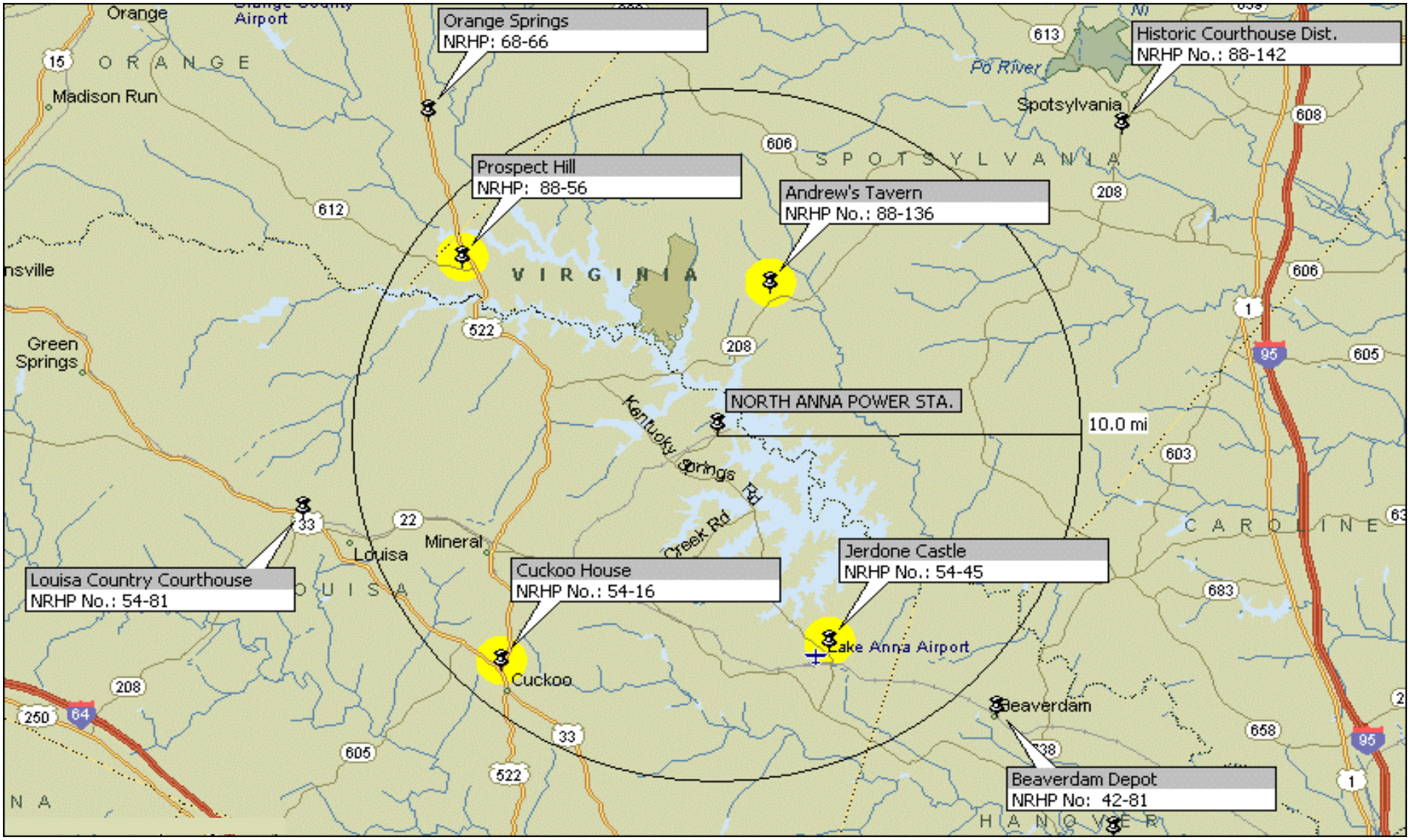


Figure 2.5-19 Location of Historic Sites in the Vicinity of NAPS

2.6 Geology

The following sections summarize geological, seismological, and geotechnical conditions at the ESP site. These conditions and utilization of the ESP site for new units are then evaluated for potential environmental impacts. The information is subdivided into three categories, corresponding to the subject conditions. The geological, seismological, and geotechnical information has been developed in accordance with the guidance provided in RG 4.2 (Reference 1).

The geological, seismological, and geotechnical information presented in this section is based on reviews of previous reports prepared for the existing units and the abandoned Units 3 and 4, geologic literature, and the results of a subsurface investigation performed in late 2002 (Part 2: Appendix 2.5.4B) as part of the ESP application activities. Previous NAPS site-specific reports reviewed include the UFSAR for the existing units (Reference 2) and the ISFSI Safety Analysis Report (Reference 3). Reports prepared by Dames and Moore for licensing of the existing units (Reference 4) and the abandoned Units 3 and 4 (Reference 5) (Reference 6) were also reviewed.

Geological and geotechnical investigations conducted for the existing units and for the abandoned Units 3 and 4 included over 100 borings to depths ranging from 20 to 175 feet (Reference 4) (Reference 5). Test pits were excavated in the area of abandoned Units 3 and 4, and detailed field geologic mapping was performed (Reference 6). During the foundation excavation for abandoned Units 3 and 4, the rock comprising the excavation walls and floor was mapped (Reference 7). As part of the ESP subsurface investigation program, seven borings, eight cone penetrometer tests, two seismic cone penetrometer tests, and cross-hole and down-hole seismic tests were performed. The data obtained by the ESP investigation are presented in Part 2: Appendix 2.5.4B. Field and aerial reconnaissance geologic mapping was also performed as part of the ESP seismicity investigation program.

2.6.1 Geological Conditions

2.6.1.1 Physiography

The ESP site lies within the Piedmont Physiographic Province (Figure 2.6-1). The Piedmont Province is a rolling hilly area that extends from its boundary with the Coastal Plain Province on the east to the Blue Ridge Province on the west. Elevations range from about 800 to 1500 feet along the western border of the Province and slope eastward to elevations of about 200 feet at its eastern border (Reference 8).

The ESP site is located within the Piedmont Upland section (referred to as subprovince in some publications) of the Piedmont Province, approximately 15 miles west of the Coastal Plain Province (Figure 2.6-1). Topography in the vicinity of the ESP site is characteristic of the Piedmont Upland section with a gently undulating surface varying in elevation from about 200 to 500 feet (Figure 2.6-2). The ESP site is surrounded by forest and brushwood-covered land interspersed with

an occasional farm and is well dissected by streams (Reference 2). Slopes in the region typically range from 2 to 5 percent with steeper slopes ranging from 7 to 10 percent along the lower tributaries of some of the larger streams.

2.6.1.2 **Stratigraphy**

The Piedmont Upland section is underlain by Late Precambrian and Paleozoic age crystalline rocks, which are overlain by Cenozoic age residual soils. The crystalline rocks consist of deformed and metamorphosed sedimentary, igneous, and volcanic rocks, intruded by mafic dikes and granitic plutons (Reference 9). The rocks belong to a number of northeast trending lithotectonic belts, bounded by low-angle thrust faults (Paleozoic in age), and are interpreted to have formed along the shore and offshore of ancestral North America. The lithotectonic belts are: the Goochland-Raleigh belt; the Carolina and Eastern Slate belts; the Charlotte, Milton and Chopawamsic belts; and the Western/Inner Piedmont belt (Reference 10) (Figure 2.6-3).

The ESP site is located in the Chopawamsic belt. The Chopawamsic belt is bounded on the west and east by the Chopawamsic and Spotsylvania thrust faults, respectively, and is interpreted to be a volcanic-arc that was accreted to ancestral North America. The belt is comprised of the Chopawamsic Formation and the Ta River Metamorphic Suite, which are overlain unconformably by the Quantico Formation and intruded by rocks of the Falmouth Intrusive Suite (Figure 2.6-4 and Figure 2.6-5). The Chopawamsic Formation and Ta River Metamorphic suite have been assigned to the Cambrian and/or Ordovician Periods (Reference 11) and the Quantico Formation and Falmouth Intrusive Suite have been assigned to the Ordovician and Carboniferous Periods, respectively (Reference 12).

The ESP site is underlain by rocks of the Ta River Metamorphic Suite, which extend thousands of feet below the ground surface (Reference 13). The main rock encountered in borings completed during previous subsurface investigations at the NAPS site and in borings completed as part of the ESP subsurface investigation is a gneiss. The gneiss is generally described as a gray to dark gray:

- quartz gneiss with some biotite quartz gneiss, and
- hornblende gneiss, biotite quartz gneiss, and quartz gneiss.

The gneiss is moderately to intensely jointed and contains layers of quartz, pegmatite, chlorite, and clay. The upper part of the gneiss (averaging about 30 feet thick) is highly weathered and fractured, becoming less weathered and fractured with increasing depth.

Residual soil overlying the gneiss consists predominantly of saprolite. The saprolite is derived from weathering of the underlying bedrock and retains many of the structural and mineraological features of the bedrock. The saprolite extends to the top of the rock from which it was derived; however, the contact between the saprolite and sound rock may be gradational and not well defined. The saprolite at the site generally consists of micaceous clayey, silty, fine to coarse sand

with some to many relict rock fragments and in some areas of the site it extends to a depth of about 100 feet below the ground surface.

2.6.1.3 Faults

Seven bedrock faults (Paleozoic in age) have been mapped within 5 miles of the ESP site (Figure 2.6-4 and Figure 2.6-5). Two of the faults, the Spotsylvania and Chopawamsic, are major thrust faults that separate lithotectonic belts within the Piedmont Province. The Long Branch and Sturgeon Creek faults are thrust faults, and the remaining three unnamed faults are designated as faults “a”, “b”, and “c” on Figure 2.6-4 and Figure 2.6-5.

2.6.2 Seismological Conditions

2.6.2.1 Tectonic Setting

The northeast trending, fault-bounded belts comprising the Piedmont Physiographic Province (Paleozoic in age) are defined essentially on the basis of rock type and metamorphic grade. The faults that separate the belts are low-angle thrust faults created by large-scale detachment and northwest thrusting of rocks along a basal decollement. Below the decollement are rocks that form the North American basement complex. The basal decollement is a nearly horizontal blind thrust fault that dips gently southeast and is at a depth of approximately 3 to 6 miles below the ground surface (Reference 14) (Reference 15). The low-angle thrust faults rise from the basal decollement and either terminate in the subsurface or extend to the ground surface. Also located in the Piedmont Province are a number of Mesozoic age grabens and half-grabens (“Triassic basins”) that are bounded on their western side by normal faults. The normal faults are considered to be either listric into the Paleozoic thrust faults or penetrate into the North American basement complex (Reference 16).

2.6.2.2 Seismic Sources

Seismic activity in the Piedmont Province is generally considered to originate in the North American basement. Geologic structures considered to be responsible for earthquake activity in the province are the basal decollement and associated thrust structures and the normal faults and intrusions associated with rifting that occurred during Mesozoic time (Reference 17).

2.6.2.2.1 Seismic Source Zones

The region (200-mile radius) encompasses two areas where seismic sources have been delineated. These areas have been designated as seismic source zones and consist of the Central Virginia seismic source zone and the Giles County seismic source zone (Reference 18) (Figure 2.6-6).

The CVSZ is an area of persistent, low-level seismicity. The zone is about 75 miles long and 90 miles wide and seismicity ranges in depth from about 2 to 11 miles below the ground surface

(Reference 19). The ESP site lies within the zone, near its northern boundary (Reference 18). Seismic sources within the CVSZ vary from place to place. In the central and western parts of the zone, seismicity is considered to be attributed to west-dipping reflectors (interfaces between media of different elastic properties that reflect seismic waves) that form the roof of a detached antiform. In the eastern part of the zone, seismicity is considered to be related to intrusions that have created an extensive near-vertical dike swarm (Reference 20). Given the depth distribution of 2 to 11 miles and broad spatial distribution of seismicity, however, it is difficult to uniquely attribute the seismicity to any known geologic structure, and earthquakes are considered to occur within the upper portion of the North American basement complex or within thrust fault bounded crust above the basal decollement. The largest historical earthquake to occur in this zone occurred in Goochland County on December 23, 1875, about 30 miles southwest of the ESP site. It had a body-wave magnitude (m_b) of 5 (Reference 21) and a Modified Mercalli Intensity (MMI) of VII. Isoseismal maps indicate that the ESP site would have experienced a shaking intensity of MMI V (Reference 22).

The Giles County seismic zone is located in Giles County, Virginia, near its southwestern border with West Virginia. The zone is about 25 miles long, 6 miles wide and seismicity ranges in depth from 3 to 16 miles below the ground surface (Reference 23) (Reference 24). The ESP site is about 150 miles northeast of this zone (Reference 18). The source of seismicity within the Giles County seismic zone is considered to be due to normal faulting within the North American basement complex (Reference 16) (Reference 24). The largest known earthquake to occur in Virginia and the second largest earthquake to occur in the southeastern United States occurred in this zone on May 31, 1897. It had a magnitude m_b of 5.8 and an intensity MMI of VIII (Reference 25). Isoseismal maps indicate that the ESP site would have experienced a shaking intensity of MMI V (Reference 22) from this earthquake.

2.6.2.2.2 Tectonic Sources (Faults)

The Spotsylvania and Chopawamsic thrust faults bound the eastern and western margins of the Chopawamsic belt, respectively. They have been mapped over significant distances within the Piedmont Province (Reference 12). The Spotsylvania thrust fault is about 4.5 miles southeast of the site and juxtaposes rocks of the Ta River Metamorphic Suite against rocks of the Goochland belt. It is a fault zone, rather than a single fault, having a width of approximately 1.5 miles (Reference 13) (Reference 26) and a length of over 300 miles (Reference 11). The Chopawamsic thrust fault is about 4.5 miles northwest of the site and separates rocks of the Chopawamsic Formation from rocks of the Western Piedmont belt. Interpretations indicate that this structure extends for a distance of over 45 miles (Reference 27).

The Long Branch thrust fault is about 2 miles west of the site and separates rocks of the Quantico Formation from rocks of the Chopawamsic Formation and Ta River Metamorphic Suite. The fault has been mapped for over 45 miles and along its length it is locally displaced by smaller faults (Reference 12) (Reference 13).

The Sturgeon Creek fault is about 1 mile west of the site and displaces the fault contact between the Quantico Formation and the Ta River Metamorphic Suite. It has been mapped for a distance of about 10 miles (Reference 13).

Unnamed fault ("a") extends directly through the NAPS site. The fault was found in the Ta River Metamorphic Suite during the foundation excavation for abandoned Units 3 and 4. The fault was investigated by Dames and Moore (Reference 6) and the results were presented to the U.S. Atomic Energy Commission (Reference 28). The results of the investigation indicate that movement occurred along the fault approximately 200 million years ago and that movement has not occurred since, or at least not within the last one million years, given the relatively undisturbed thickness of residual soil overlying the fault. The results of the investigation also concluded that the fault is of limited extent (Reference 6), although subsequent interpretation has extended the fault north and south for a total distance of about 7 miles (Reference 26) (Reference 29). Aerial reconnaissance, field reconnaissance and air photo interpretation carried out for this ESP application, however, did not reveal any evidence for existence of the fault over this distance. Bedrock exposures that are poor to non-existent along the entire 7-mile length of the postulated fault trace, and a lack of geomorphic expression do not support this extension of the fault.

Unnamed faults "b" and "c" are located east of the Long Branch thrust fault, approximately 1 and 4 miles west and north of the ESP site, respectively Figure 2.6-4. The longer of the two faults ("b") juxtaposes rocks of the Quantico Formation against rocks of the Ta River Metamorphic and Falmouth Intrusive Suites. It is about 16 miles long, is offset by the Sturgeon Creek fault and is truncated at its northern end by the unnamed fault "c." This fault juxtaposes rocks of the Quantico Formation against rocks of the Falmouth Suite.

2.6.3 **Geotechnical Conditions**

For geotechnical purposes, the subsurface materials at the NAPS site were initially classified into the following five categories (Reference 4):

- I Residual clays and clayey silts
- IIA Saprolite (rock fragments less than 10 percent of volume of overall mass)
- IIB Saprolite (rock fragments 10 to 50 percent of soil mass)
- III Weathered Rock (rock fragments more than 50 percent of volume of mass)
- IV Parent Rock (slightly weathered to fresh rock below zone of soil and rock fragments)

In addition to these five categories, a sixth category termed Zone III-IV, representing a slightly to moderately weathered rock, was subsequently added to further describe the soil and rock with regard to engineering properties (Reference 2) (Reference 4) (Reference 5). The engineering properties for Zones IIA, IIB, III, III-IV, and IV, based on the previous and ESP field investigation and laboratory testing programs, are presented in Table 2.6-1.

Bedrock at the ESP site exhibits various degrees of weathering that affects its engineering behavior and properties. Zone III bedrock is generally a poor quality rock, with an average rock quality designation (RQD) value of 20 percent, while Zone III-IV and IV bedrock is typically a good to excellent quality rock, with average RQD values of 50 and 95 percent, respectively.

While the saprolite at the ESP site has the relict structure of the parent bedrock, its engineering properties typically resemble those of a soil. It exhibits certain aspects that are characteristic of both cohesive and cohesionless soils. Zone IIA saprolite has been classified as silty sand (SM), clayey sand (SC), and high and low plasticity silt and clay (MH, ML, CH, and CL). Zone IIB saprolite has been classified as mainly silty sand (SM). Standard penetration test (SPT) N-values for the Zone IIA saprolite indicates medium dense conditions, while SPT N-values for the Zone IIB saprolite indicates very dense conditions. The presence of mica in the saprolite (about 5 to 20 percent) contributes to high void ratios, high compressibilities, and low compacted densities (Reference 30). Therefore, due to the potential for excessive settlement of the Zone IIA saprolite, as occurred beneath the Units 1 and 2 SWR, no safety-related structures would be founded on the Zone IIA saprolite without ground improvement.

2.6.4 Environmental Impact Evaluation

2.6.4.1 Geological Impacts

2.6.4.1.1 Zones of Alteration, Weathering, and Structural Weakness

Occasional zones of severely weathered and fractured rock have been identified in the weathered and unweathered gneiss at the ESP site (Reference 4) (Reference 5) (Reference 7) (Part 2: Appendix 2.5.4B). The zones are typically 0.5 to 1 foot thick and contain quartz, clay, and iron oxides. Because of the tendency for zones of severely weathered rock to weather further upon exposure, where encountered in excavations for plant structures and judged to have a potential for impact on the stability of the foundation, they would be removed from the face of the excavation and replaced with cement grout. As a result, no adverse environmental impacts due to the effects of inadequate bearing capacity of the foundation rock mass resulting from the presence of weathered and fractured rock are anticipated for the ESP site.

2.6.4.1.2 Effects of Human Activity

Massive sulfide and gold deposits have been mined from rocks of the Chopawamsic belt in the vicinity of the ESP site. The deposits have been mined predominantly in and around the town of Mineral, approximately 7 miles west of the site. Mined deposits within a 5-mile radius of the site have been designated the Allah Cooper, Sulfur, Cofer and Old Dominion (Reference 31) (Reference 32) (Reference 33) (Reference 34). Published documentation of these mining activities indicate that the ESP site has not been nor would it be affected by these mining activities. As a result, no adverse environmental impacts due to the effects of mining activities are anticipated for the ESP site.

2.6.4.1.3 Construction Groundwater Control

Groundwater at the ESP site generally occurs at depths ranging from about 6 to 58 feet below the present day ground surface, with the exception of the area of the abandoned Units 3 and 4 excavation where groundwater is within about 2 feet of the ground surface. Groundwater levels at the site are such that foundation excavations extending below the water table during plant construction are likely to require temporary dewatering. Any dewatering that may be required would be performed in a manner that minimizes drawdown effects on the surrounding environment. As a result, no adverse environmental impacts due to dewatering are anticipated for the ESP site.

2.6.4.1.4 Unforeseen Geologic Features

Evaluation of the ESP site's geology indicates that no conditions are present that could potentially produce an adverse environmental impact associated with plant construction or operation. The ESP site has not been adversely affected by human activity with respect to the development of natural resources or groundwater withdrawal, nor are any such future activities expected to produce adverse effects at or beyond the site.

2.6.4.2 Seismological Impacts

2.6.4.2.1 Ground Shaking

The upper-bound maximum earthquake magnitude estimate, developed for the Central Virginia and Giles County Seismic Source Zones, ranges from m_b 6.6 to 7.2 (Reference 18). The two largest earthquakes to occur in the ESP site region are the 1875 Goochland County and 1897 Giles County earthquakes with intensities of MMI VII and VIII, respectively. Isoseismal maps indicate that the ESP site would have experienced a shaking intensity of MMI V from these two earthquakes (Reference 22). There is no physical evidence at the site, such as fissuring, liquefaction, landsliding, or lurching, to suggest that the surficial sediments or the underlying bedrock were disturbed by ground shaking during these events.

Damaging earthquake ground shaking is not expected to occur at the ESP site during the life of the new units. However, safety-related structures, systems, and components would be designed to accommodate the maximum horizontal ground accelerations determined for the ESP site. Therefore, adverse environmental impacts resulting from the effects of ground shaking on plant structures would be small.

2.6.4.2.2 Surface Fault Rupture

The seven bedrock faults mapped within the vicinity of the ESP site are not considered to be capable tectonic sources, as defined in RG 1.165, Appendix A (Reference 35). The faults are considered to be old structures that formed during Pre-Cambrian and Paleozoic time, and no deformational or geomorphic features indicative of potential Quaternary activity have been associated with them. No historical seismic activity has been reported as being associated with any

of the faults (Reference 23) (Reference 36). Therefore, the resulting environmental impacts of potential surface fault rupture would be small.

2.6.4.3 Geotechnical Impacts

2.6.4.3.1 Settlement

Settlement at the ESP site is only a consideration for structures founded directly on the Zone IIA saprolite. Larger than expected settlement was initially recorded beneath the existing units SWR pumphouse, which is founded on about 65 feet of Zone IIA saprolite, mainly micaceous sand and silt. The settlement was considered to be a result of the weight of the pumphouse itself and the 30 feet of embankment fill built up around it.

The potential for excessive settlement of the Zone IIA saprolite makes it unsuitable, in its natural state, for the support of any safety-related structures due to the possibility of adverse environmental impacts that could result from damage to the structure during plant operation. The Zone IIA saprolite may be used to support safety-related structures if ground improvement methods are used and assuming adequate bearing capacity strengths can be achieved.

2.6.4.3.2 Slope Stability

The only existing slope at the NAPS site with a potential to affect the safety of the new units is the 55-foot high, 2H:1V slope that presently exists between abandoned Units 3 and 4 and the existing units SWR. Static long-term analyses of modification of the existing slope using the computer program SLOPE/W produced a factor of safety in excess of the minimum 1.5 required. Pseudo-static analyses using horizontal and vertical seismic accelerations developed in support of this ESP application produced a factor of safety less than the minimum acceptable value of 1.1. However, when the pseudo-static analyses were run with the seismic input modified to conform to the reductions given by Seed (Reference 37), the computed factor of safety against slope failure is in excess of 1.1.

The Seed reductions are considered reasonable and valid, and the slope is considered to have an adequate factor of safety against failure during the ESP design seismic event.

A new slope may be excavated to the west of the existing SWR to accommodate ultimate heat sinks for the new units. This slope would have the same configuration and composition as the existing slope. The analytical conclusions for the existing slope would apply to the new slope, i.e., the new slope would be stable under seismic and long-term static conditions. If analysis during detailed engineering indicates unacceptable factors of safety against slope failure, modifications would be employed to ensure adequate slope stability.

Based on the preceding discussion, slope failure and the potential environmental implications associated with damage to the facility are not an issue for the new units.

2.6.4.3.3 Liquefaction

Liquefaction of site soils during an earthquake event could affect the safety of the new units by causing foundation bearing failures and excessive settlement and slope failure. Liquefaction can occur when all of the following criteria are met:

- Design ground acceleration is high.
- Soil is saturated.
- Soils are sands or silty sands in a loose to medium dense condition.

At the ESP site, the first criterion is met, and the second criterion applies in many areas of the ESP site. However, the third criterion, involving the type and density of the soil, is less clearly applicable. The Zone IIB soils are extremely dense and the Zone III weathered rock has over 50 percent rock fragments. Neither of these materials meets the loose or medium dense criterion and neither has liquefaction potential.

The only soil at the NAPS site with the gradation and relative density attributes than can potentially result in liquefaction is the Zone IIA saprolite. However, the structure, fabric, and mineralogy of this saprolite substantially reduces its potential for liquefaction. No evidence of liquefaction has been reported at the NAPS site. The possibility of isolated liquefaction effects in localized zones at the site may exist, although the fabric and structure of the soil are considered to minimize such effects. To avoid these zones, structures associated with the new units would not be sited above them, or ground improvement measures would be implemented to mitigate any liquefaction effects. As a result, no adverse environmental impacts associated with possible liquefaction effects at the ESP site are anticipated.

2.6.4.3.4 Excavation

a. **Excavation in Soil and Rock**

   Temporary excavations in soil would have slopes no steeper than 1.5H:1V and would be performed in accordance with OSHA regulations. Where there is insufficient space to slope the excavations, vertical cuts would be supported with sheet pile, soldier piles and lagging or other suitable methods. For large excavations, this support may be supplemented by the use of tiebacks that are angled down and anchored, where possible, into bedrock. Temporary excavations into bedrock would be vertical, except where the structure of the rock dips into the excavation, in which case the excavation would be carried out parallel to the dip of the structure (about 1H:1V). The potential for the failure of temporary excavation slopes and walls during construction at the ESP site would be minimized and, therefore, environmental impacts associated with the failure of temporary excavation slopes are anticipated.

b. **Excavation Techniques**

   Excavations in the soils at the ESP site are expected to be achieved using conventional excavating equipment. Excavation in the Zone III rock would likely require the use of powerful

but conventional earthmoving equipment. Excavation in Zone III-IV and Zone IV rock would likely require the use of blasting techniques followed by removal using appropriate earthmoving equipment. To ensure the integrity of the foundation rock, the stability of the excavated slopes, and to limit the blasting impact on surrounding structures and the environment, controlled blasting techniques, such as pre-splitting use of delays, minimizing blast size, etc., would be utilized. Monitoring of the blast vibrations would be performed to determine blast magnitudes on existing structures and equipment in and around the NAPS site. No adverse environmental impacts resulting from excavation methods or the use of heavy construction equipment are anticipated during construction at the ESP site.

Alternatives to blasting for the excavation of rock at the ESP site would be reviewed and considered prior to selection of the final excavation method. The alternative excavation methods to be considered would likely include thermal lance, plasma gun, pile driver and expandable metal slug, drilling and expansive grout, hydraulic splitter, hoe ram, diamond wire saw, trenching machine, and water jet.

c. **Disposal of Excavated Material**

Excavated material would be disposed of either within the NAPS site boundary or at an offsite disposal area. Whether at or off the site, the disposal area would be identified and approval for the intended purpose obtained in advance of the start of construction. The area would be a stable area, not prone to slumping or sliding, and isolated from waterways or streams. Methods such as re-vegetation and erosion control measures would be used to mitigate the potential for the erosion of material at the disposal site. The topsoil would be removed to accommodate disposal of the material and would be used to cover and re-vegetate the stockpile at the completion of construction. No adverse environmental impacts from the disposal of excavated material are anticipated at or in the area or vicinity of the ESP site.

2.6.4.3.5 Backfill

a. **Backfill Material**

Backfill at the ESP site would be a sound, well-graded granular material – either a sandy gravel or a gravelly sand – with less than 10 percent passing the No. 200 sieve. Although a large amount of saprolite would be excavated for the project, the saprolite would not be used as structural fill to support plant structures. An onsite testing laboratory would be established and operated by qualified soils technicians under the direction of a civil or geotechnical engineer to control the quality of the backfill. As a result, no adverse environmental impacts due to the use of poor quality backfill material or the improper placement and compaction of backfill are anticipated at the ESP site.

b. **Source of Backfill**

Backfill material would either be imported or produced at the ESP site. If imported, materials such as dense graded Aggregate (e.g. Size 21A or 21B, as specified by the Virginia

Department of Transportation Road and Bridge Specifications (Reference 38)) would be considered suitable. If the material is produced at the ESP site, a crushing, screening and blending plant would be set up to produce crushed rock to the required gradation specifications for use as structural fill. This would not adversely affect natural resources at or in the vicinity of the ESP site and as a result, no environmental impacts are anticipated.

Section 2.6 References

1. Regulatory Guide 4.2, *Preparation of Environmental Report for Nuclear Power Stations*, Revision 2, U.S. Nuclear Regulatory Commission, July 1976.

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Table 2.6-1 Summary of Geotechnical Engineering Properties

Stratum	IIA		IIB	III	III-IV	IV
	Coarse-grained	Fine-grained		Moderately to Highly Weathered Quartz Gneiss w/Biotite	Slightly to Moderately Weathered Quartz Gneiss w/Biotite	Fresh to Slightly Weathered Quartz Gneiss w/Biotite
Description	**Saprolite**	**Saprolite**	**Saprolite w/10 to 50% Core Stone**			
Rock properties						
Recovery,%	-	-	-	60	90	100
RQD,%	-	-	-	20	50	95
Unconfined compressive strength, ksi	-	-	-	0.6	4	12
USCS symbol	SP, SM, SC	ML, CL, MH, CH	Mainly SM	-	-	-
Range of fines content,%	15 to 45	-	-	-	-	-
Natural moisture content, w,%	-	26	-	-	-	-
Undrained shear strength, c_u, ksf	-	2.0	-	-	-	-
Effective cohesion, c′, ksf	0.25	0.5	-	-	-	-
Effective friction angle, ϕ', degrees	30	25	40	-	-	-
Total unit weight, γ, pcf	125		130	145	163	163
SPT N-value, N_{60}, blows/ft	20		100	-	-	-
Shear and compression wave velocity						
Shear wave velocity range, ft/sec	600 to 1350		-	-	-	4000 to 8000
Shear wave velocity average, ft/sec	950		1600	2000	3300	6300
Compression wave velocity average, ft/sec	2100		3500	4500	7400	14,000
Elastic and shear moduli						
Elastic modulus (high strain), E_{hs}	1200 ksf		3500 ksf	120 ksi	1000 ksi	3750 ksi
Elastic modulus (low strain), E_{ls}	9500 ksf		28,000 ksf	300 ksi	1000 ksi	3750 ksi
Shear modulus (high strain), G_{hs}	450 ksf		1300 ksf	50 ksi	375 ksi	1400 ksi

Table 2.6-1 Summary of Geotechnical Engineering Properties

Stratum	IIA		IIB	III	III-IV	IV
	Coarse-grained	Fine-grained				
Description	Saprolite	Saprolite	Saprolite w/10 to 50% Core Stone	Moderately to Highly Weathered Quartz Gneiss w/Biotite	Slightly to Moderately Weathered Quartz Gneiss w/Biotite	Fresh to Slightly Weathered Quartz Gneiss w/Biotite
Shear modulus (low strain), G_{ls}	3500 ksf		10,000 ksf	125 ksi	375 ksi	1400 ksi
Consolidation characteristics						
Recompression ratio, RR	0.015		-	-	-	-
Coeff. of secondary compression, C_α	0.0008		-	-	-	-
Coeff. of subgrade reaction, k_1, kcf	230		1,500	-	-	-
Coefficient of sliding against concrete	0.35		0.45	0.6	0.65	0.7
Poisson's ratio, μ (high strain)	0.35		0.3	0.33	0.33	0.33
Static earth pressure coefficients						
Active, K_a	0.33		0.22	-	-	-
Passive, K_p	3.0		4.6	-	-	-
At-rest, K_o	0.5		0.36	-	-	-
Hydraulic conductivity, cm/sec	5×10^{-4}		-	-	-	-

Note:"-" denotes no design parameter given.

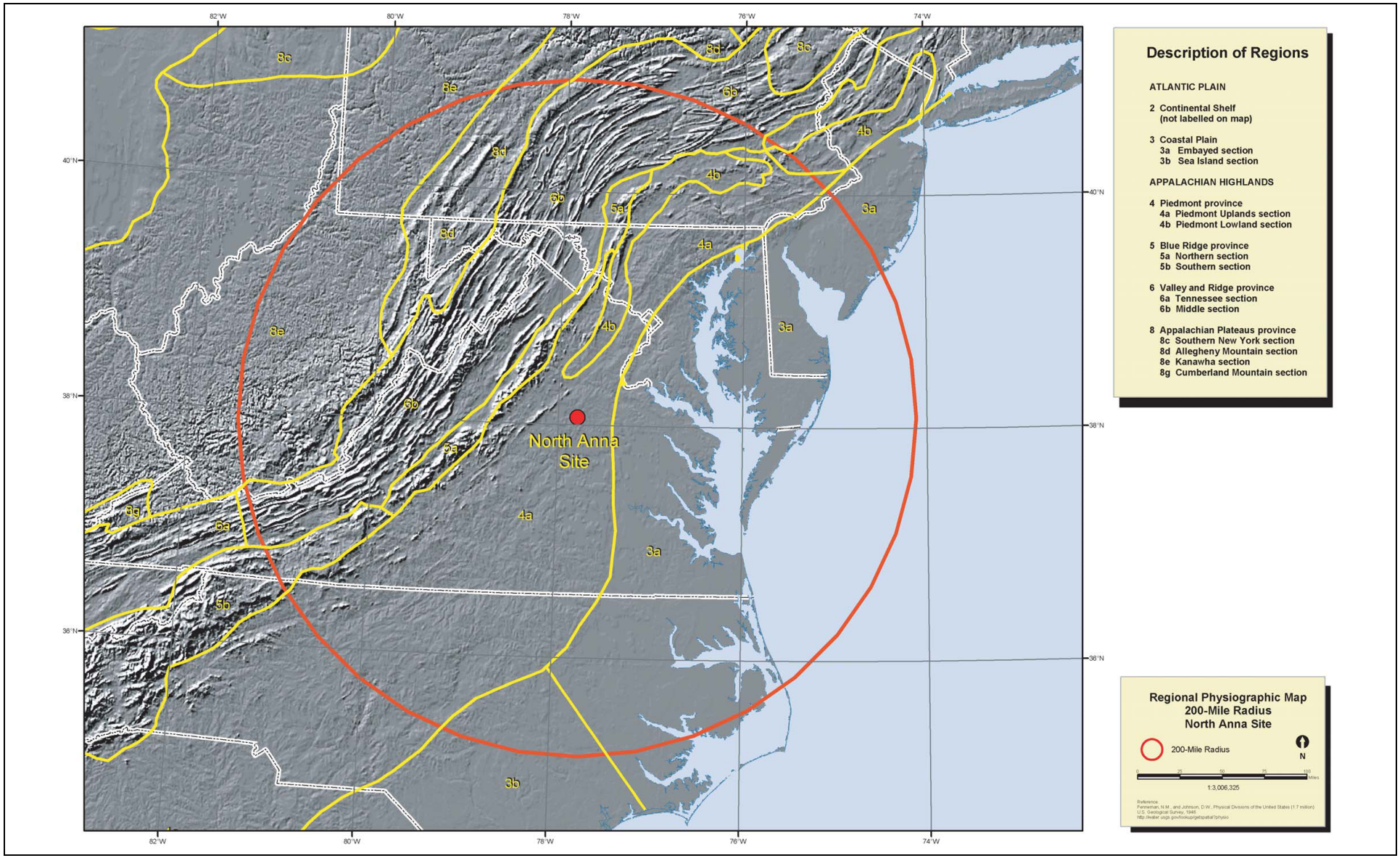

Figure 2.6-1 Regional Physiographic Map (200-Mile Radius)

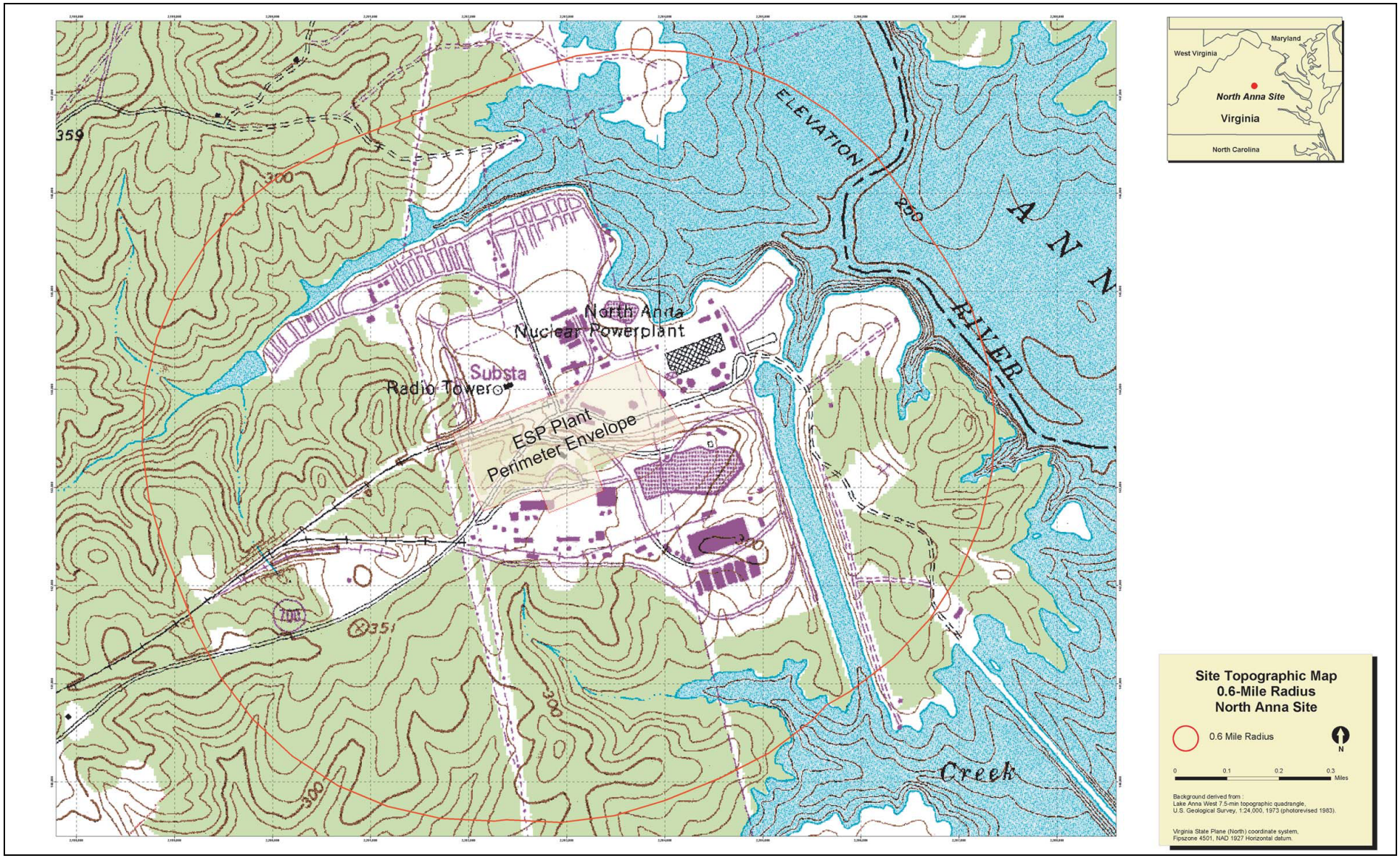

Figure 2.6-2 Site Topographic Map (0.6-Mile Radius)

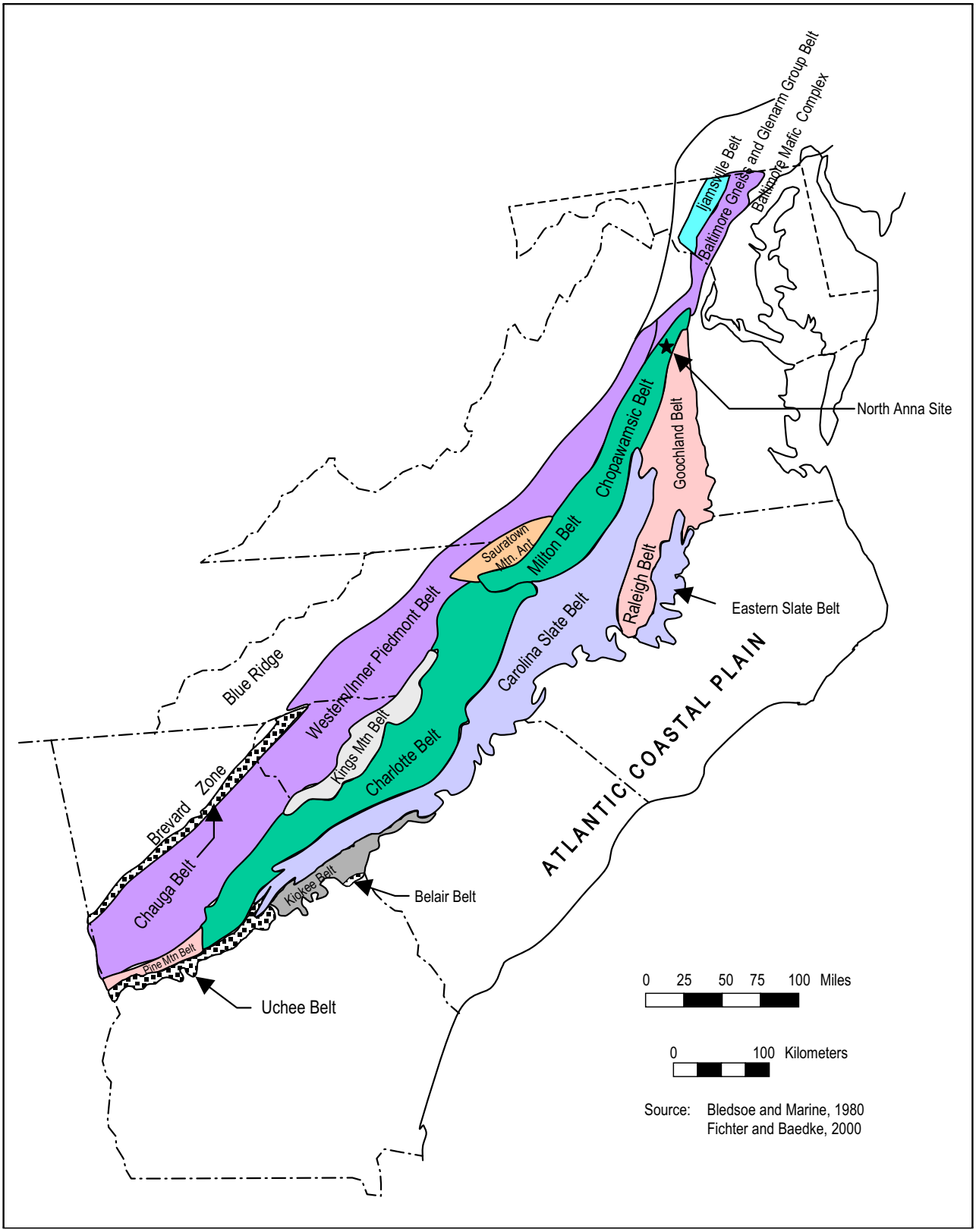

Figure 2.6-3 Lithotectonic Belts of the Piedmont Province

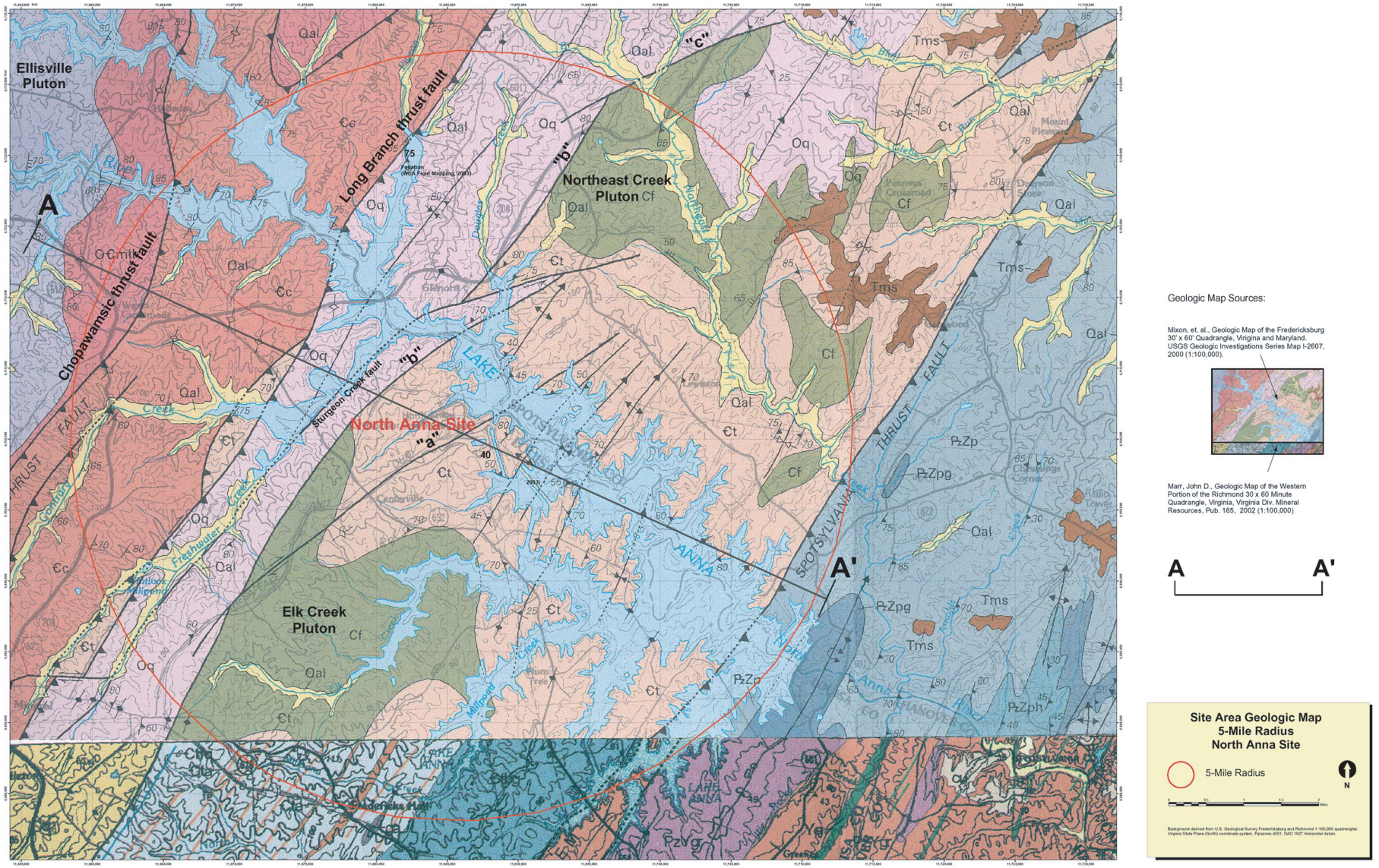

Figure 2.6-4 Site Area Geologic Map (5-Mile Radius) (Sheet 1 of 2)

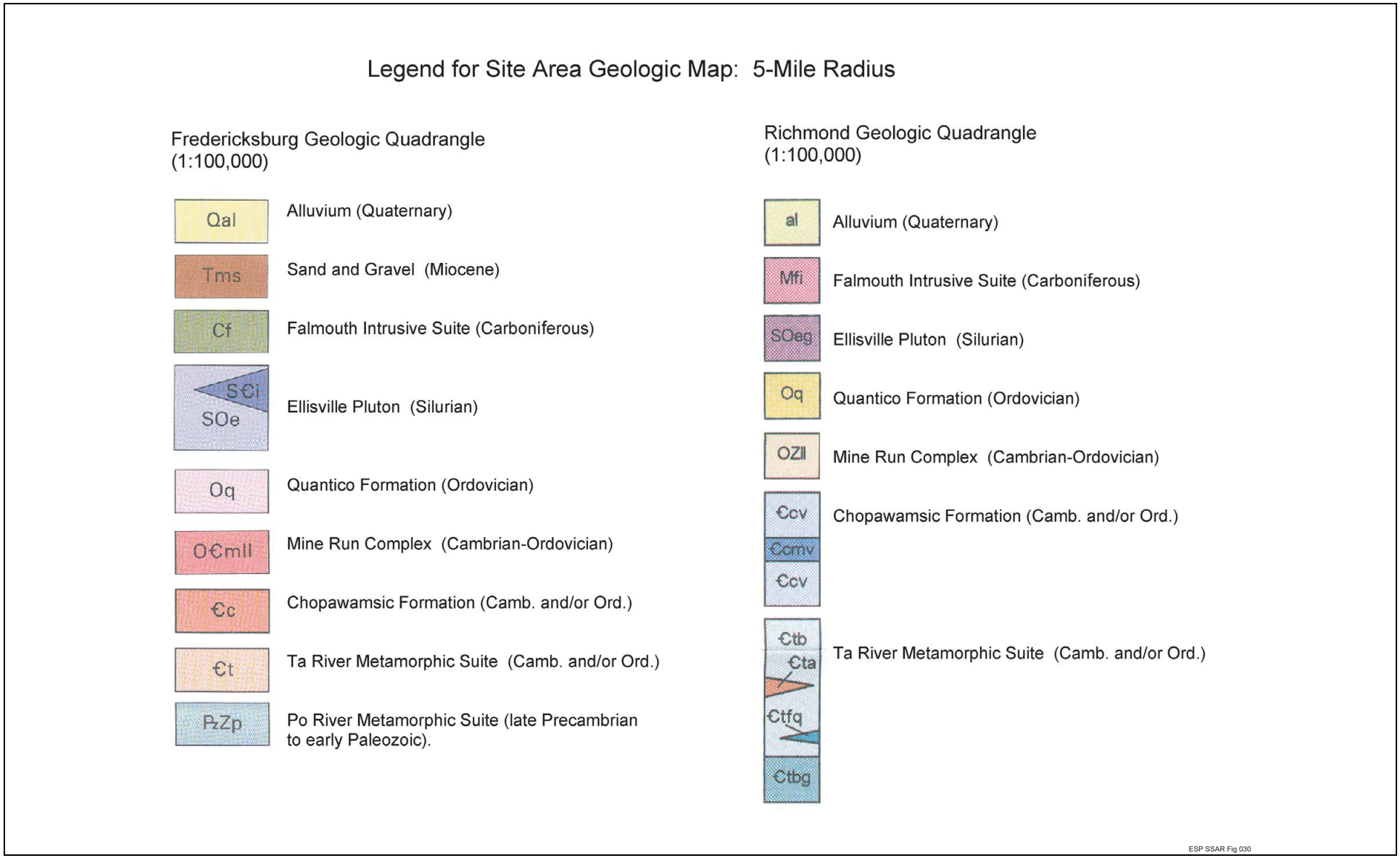

Figure 2.6-4 Site Area Geologic Map (5-Mile Radius) (Sheet 2 of 2)

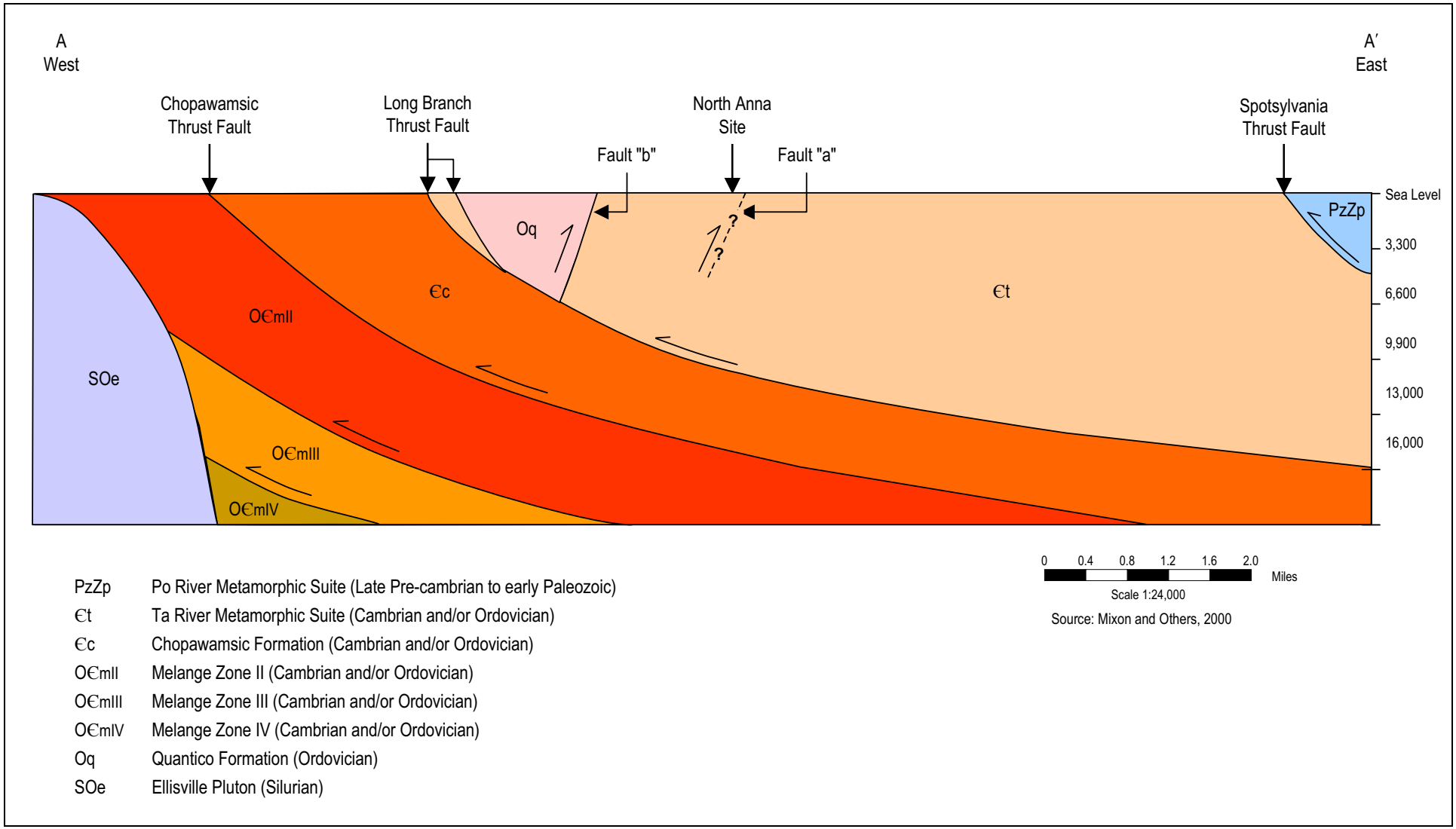

Figure 2.6-5 Site Area Geologic Cross Section (5-Mile Radius)

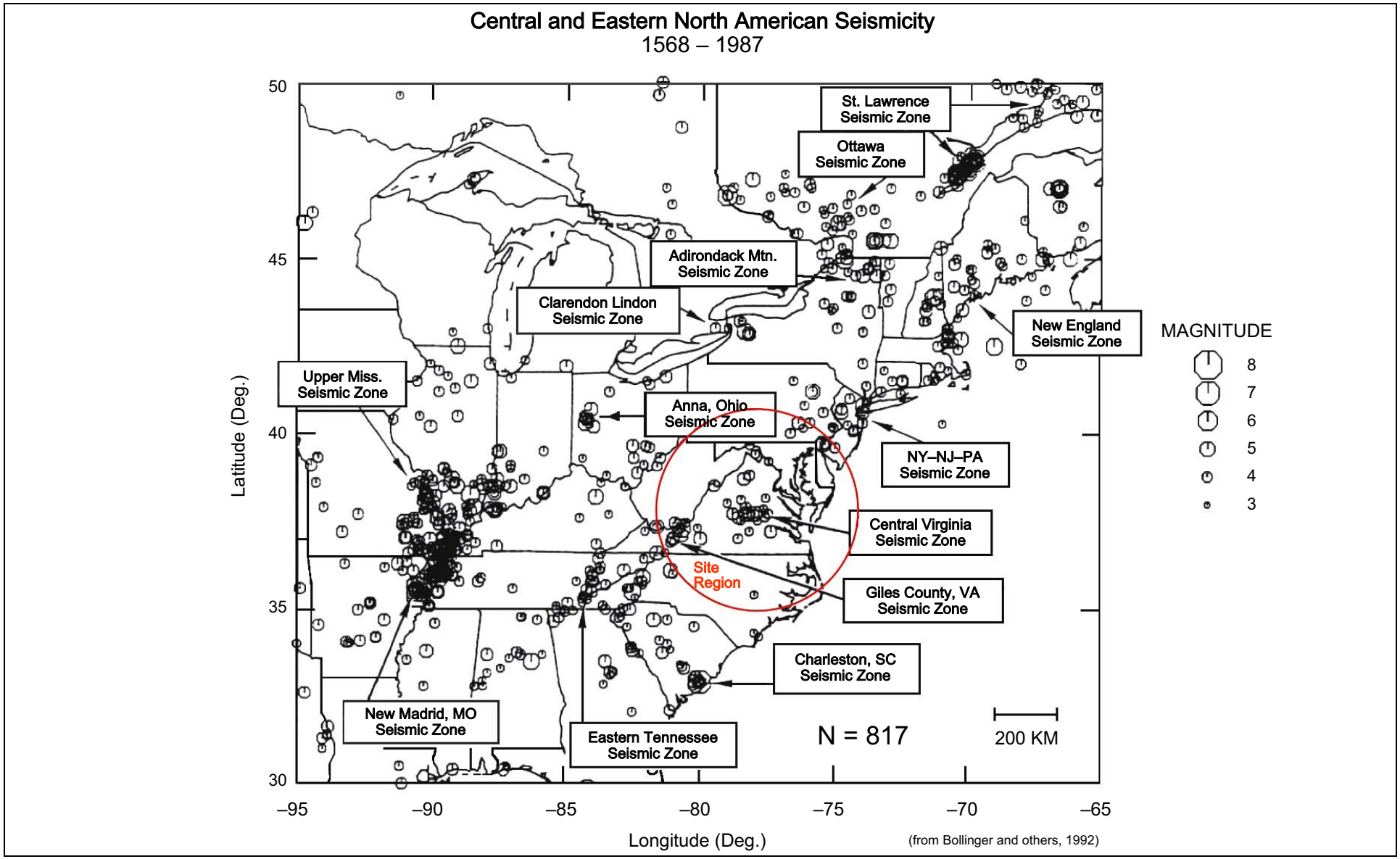

Figure 2.6-6 Seismic Source Zones and Seismicity in Central and Eastern North America

2.7 Meteorology and Air Quality

This section describes the general climate of the ESP site and the regional meteorological conditions used as the basis for design and operational conditions of the new units. This section also provides meteorological information that has been used to evaluate construction and operational impacts.

2.7.1 General Climate

The description of the site general climate is based on regional climatological and meteorological information primarily collected for Richmond, Virginia, and supplemented by the meteorological information collected at the NAPS site. In addition, observations taken at NWS cooperative network stations in the ESP site have been used to supplement the data from Richmond and the NAPS site.

2.7.1.1 General Description

The climate in the Piedmont region of Virginia, where the ESP site is located, is classified as modified continental. Summers are warm and humid and winters are generally mild. The Blue Ridge Mountains to the west act as a partial barrier to outbreaks of cold, continental air in winter. The mountains also tend to channel winds along a general north-south orientation. Temperatures in the site region rarely exceed 100°F or fall below 0°F. (Reference 1)

Based on 30 years of data (1961–1990), the area around the site receives an annual average rainfall of approximately 43.2 inches. Rainfall is fairly well distributed throughout the entire year, with the exception of July and August, when thunderstorm activity raises monthly totals to about 5.0 inches (Reference 1). Tropical cyclones can also contribute substantially to the precipitation totals and to extreme precipitation events.

The 60-year climatological records show that the monthly average snowfall of 4 inches or more occurs only in January. Snow usually remains on the ground only 1 or 2 days at a time. Richmond averages about 16.3 inches of snow a year (Reference 1).

In general, during light wind conditions, the local environmental conditions predominate, resulting in a channeling effect of winds such that the airflow patterns follow the topographical contour lines of the region. Lake Anna has a moderating effect with respect to extreme temperatures in the immediate vicinity of the site. During periods of temperature inversions or light wind conditions, the local dispersion conditions can be somewhat restricted (Reference 2, Section 2.3.1.2.1).

The existing units' Meteorological Monitoring Program began operations in 1971. The system was upgraded in 1978 in accordance with the criteria of RG 1.23 (Reference 2, Section 2.3.3.2.5.1). Data collected by the existing units' meteorological monitoring system is representative of long-term site meteorological conditions. However, long-term regional climatological data are considered more suitable for use for estimates of climatological extremes. Therefore, design and operating

basis conditions (probable maximum precipitation, tornado parameters, snow load, ice thickness, etc.) are based primarily on regional climatological data.

2.7.1.2 Winds

The climatological data indicate that while Richmond's prevailing wind is southerly on an annual basis, there are 6 months when the prevailing wind direction is northerly. The annual average wind speed is 7.9 mph. The monthly average wind speed is slightly lower during the summer season. The monthly average wind speed is highest during late winter and early spring. The maximum 2-minute average wind speed is 46 mph, while the maximum 5-second wind speed is 60 mph.

Based on the data collected from 1974 to 1987 (see Table 2.7-7), the average wind speed is 6.3 mph. Similar to Richmond, the average onsite summer wind speed (5.4 mph) is also lower than those during other seasons (Reference 2, Section 2.3).

2.7.1.3 Temperature

Annual average temperature is 58.2°F in Richmond, based on an 81-year period of record for that station, while the monthly average temperature ranges from the high 30s in January to the high 70s in July. Extreme temperatures recorded in Richmond range from a maximum of 105°F to a minimum of –12°F (Reference 1).

The annual average temperature onsite is 55.8°F, the monthly average temperature ranges from 33.6°F in February to 75.0F° in July (Reference 2, Section 2.3).

2.7.1.4 Atmospheric Moisture

Annual average relative humidity in Richmond is 70 percent. The early morning relative humidity is highest during August and September, with an average of 90 percent. Heavy fog conditions with visibility less than 0.25 mile are infrequent, on average occurring 27.2 days per year (Reference 1).

2.7.1.5 Precipitation

Annual precipitation in Richmond is about 43 inches, based on the 1961 to 1990 period. For the 64-year period (1938–2001), the maximum annual precipitation of 61.3 inches was measured in 1975. During the same period, the minimum annual precipitation of 22.9 inches occurred in 1941 (Reference 1) (Reference 3).

On average, about 48 percent of the annual precipitation at Richmond occurs from May through September each year. Generally, July has the highest amount of precipitation. The normal monthly totals range from about 3 to 5 inches. On average, there are about 11 days per year with precipitation greater than 1.0 inch. The maximum 24-hour precipitation was about 8.8 inches (August 1955). This event was associated with the remnants of Hurricane Connie as presented in Section 2.7.3.4.

Snowfall normally occurs from November through March, with an annual average of 16.3 inches for the 1961 to 1990 period. The monthly maximum snowfall measured in the region was 29.8 inches in Charlottesville in March 1960 (Reference 21). The maximum 24-hour snowfall observed in Richmond was 21.6 inches in January 1940. Annually, there are 4.3 days with snowfall greater than 1.0 inch. (Reference 1)

2.7.2 Regional Air Quality

2.7.2.1 Background Air Quality

The ESP site is in Louisa County, Virginia, which is within the Northeastern Virginia Intrastate AQCR. This region is designated as in attainment or unclassified for all criteria pollutants except $PM_{2.5}$ as noted below. The City of Richmond is within the State Capital Intrastate AQCR. This AQCR is also designated as attainment or unclassified for all criteria pollutants (40 CFR 81.347). Criteria pollutants are those for which NAAQSs have been established, such as SO_2, PM_{10}, $PM_{2.5}$, CO, Ozone, NO_2, and lead (Reference 42). Attainment areas are areas where the ambient air quality levels are better than EPA-designated ambient air quality standards.

The Commonwealth of Virginia is also subject to a revised 8-hour ozone standard and a new ambient air quality standard for $PM_{2.5}$, both promulgated by the EPA in July 1997 (Reference 5) (Reference 6). $PM_{2.5}$ refers to particles with an aerodynamic diameter less than or equal to 2.5 nominal micrometers. The EPA is taking steps to implement the new standard but has not yet designated the non-attainment areas for $PM_{2.5}$. Currently, Louisa County is designated as in attainment for both the ozone 1-hour and 8-hour standards.

The EPA has designated Class I Areas as areas with pristine air quality, such as wilderness areas, national parks, and Indian Reservations. There are two Class I Areas in Virginia: James River Face Wilderness and Shenandoah National Park, in which visibility is an important issue (Reference 7). The Shenandoah National Park is located closer to the ESP site (42 miles away) than is the James River Face Wilderness.

2.7.2.2 Projected Air Quality

VDEQ regulates airborne emissions at the NAPS site. Virginia Power holds an Exclusionary General Permit from VDEQ under Title 9 of the Virginia Administrative Code for all non-radiological airborne emissions resulting from plant operations. These emission sources at the NAPS site include two auxiliary boilers, four emergency diesel generators (3840 HP each), and a blackout generator (4640 HP). No air emission monitoring is performed at the site. Compliance under the Exclusionary General Permit is based on fuel sulfur content and fuel consumption records. Annual operation of the auxiliary boilers and the diesel generators is limited under the permit to 3000 and 500 hours, respectively. Under the terms of the permit, Virginia Power provides VDEQ with emissions update information and compliance certification annually (Reference 8).

The number of new unit-related non-radiological emission sources (i.e., auxiliary boilers, emergency diesel generators or station blackout generators, and cooling towers) on the ESP site is unknown at this time. However, these new emission sources would be regulated under the VDEQ air regulations. If Dominion decides to build the new units, Dominion would provide the required emissions update information to VDEQ. These future non-radiological emission sources would not be expected to cause significant impacts to ambient air quality or to visibility in Class I areas. New unit sources such as emergency and station blackout generators would only be operated for short time periods during tests or in the event of a loss of station power. In addition, the distances between the ESP site and the Class I areas are relatively long.

2.7.2.3 Inversion and High Air Pollution Potential

In the ESP site region, the annual frequency of occurrence of low-level inversions or isothermal layers based at or below 500 feet in elevation is approximately 30 percent according to Hosler (Reference 9). Seasonally, the greatest frequencies of inversions occur during the fall and winter (34 percent and 33 percent, respectively). Spring and summer have the lowest inversion frequencies (about 28 percent of the time for each season). Most of these inversions are nocturnal in nature, generated through nighttime cooling.

The mean maximum mixing height depth (MMMD) is another indication of the restriction to atmospheric dilution at a site. The mixing depth is the distance above the ground in which relatively free vertical mixing occurs in the atmosphere (Reference 10). According to Holzworth, the annual afternoon MMMD value for the ESP site region is about 4900 feet (Reference 11). The seasonal afternoon MMMD values for the ESP site during fall and winter are about 4600 feet and 3300 feet, respectively. Shallow mixing depths have a greater frequency of occurrence during the fall and winter seasons: fall and winter have a higher frequency of inversions. The actual effect of the mixing height on pollutants emitted within the mixing depth is determined by the actual hourly mixing heights.

2.7.3 Severe Weather

2.7.3.1 Thunderstorms, Hail, and Lightning

Based on a 65-year period of record, Richmond averages 36 thunderstorm-days per year. July has the highest frequency of occurrence, about 8 days, on average (Reference 1).

Hail can occur at any time of the year and is associated with well-developed thunderstorms, but has been observed primarily during the spring and summer months. The latest version of the Climate Atlas of the United States (Reference 40), published by the NCDC in 2002 and developed from observations made over the 30-year period of record from 1961 to 1990, indicates that Louisa and Spotsylvania Counties can expect, on average, hail with diameters greater than or equal to 0.75 inch about one day per year. The occurrence of hailstorms with hail greater than or equal to 1.0 inch in diameter averages less than one day per year.

However, the annual mean number of days with hail 0.75 inch or greater is slightly higher in nearby southern and eastern Hanover County (just to the southeast of the ESP site), eastern Goochland County (south of the ESP site) and Henrico County (also southeast of the ESP site), ranging from one to two days per year. Similarly, hailstorms with hail 1.0 inch or greater occur about one day per year on average. The NCDC cautions that hailstorm events are point observations and somewhat dependent on population density.

While no hailstorms of note have been recorded in some years, multiple events have been observed in other years including four in Louisa County during 1998 and three in Spotsylvania County during 1993, both with diameters up to 1.75 inches (Reference 41). Therefore, the slightly higher annual mean number of hail days may be a more representative frequency for the relatively less-populated ESP site area.

In terms of extreme hailstorm events, softball size hail (about 4.5 inches in diameter) has been observed in recent years at two locations in the general ESP site area (Reference 41) - on June 4, 2002 at Free Union, just northwest of Charlottesville in Albemarle County (about 42 miles west of the ESP site) and on May 4, 1996 at Lignum in central Culpeper County (about 28 miles north-northwest of the ESP site).

The mean frequency of lightning strikes to earth can be estimated using a method reported by EPRI (Reference 13). The EPRI formula assumes a relationship between the average number of thunderstorm-days per year (T) and the number of lightning strikes to earth per square mile per year (N).

$$N = 0.31\ T$$

As indicated previously, there are 36 thunderstorm-days per year, on average, at Richmond (Reference 1). Consequently, the number of lightning strokes to earth per square mile is about 11.2 per year. The ESP site plant envelope area is approximately 0.068 mi^2. Using this area as the potential reactor area, the annual average number of lightning strokes in the reactor area can be calculated as follows:

$$11.2/mi^2/year \times 0.068\ mi^2 = 0.76 \text{ lightning strokes per year at the ESP site}$$

2.7.3.2 Tornadoes and Severe Winds

Based on the period of record, 1953-1999 (Reference 14), Virginia ranks 28th in the U.S. for average annual number of tornadoes.

During the period from January 1950 through December 2003, a total of 235 tornadoes were reported within a 2-degree square area around the ESP site (Reference 12). This averages 4.35 tornadoes per year within this area, which includes counties in Virginia, West Virginia, and Maryland, and the District of Columbia. Among those 235 tornadoes, 204 occurred in Virginia, 29 in Maryland, 2 in the District of Columbia, and none in West Virginia. For the same period of record,

the tornado intensities, based on the Fujita-Pearson Tornado Scale, and the number of tornado occurrences in the entire Commonwealth of Virginia are presented in Table 2.7-2.

During the 54-year period (1950–2003), 433 tornadoes were reported in Virginia (Reference 12). This is equivalent to about 8 tornadoes per year. In Louisa County and the immediately adjacent four-county area (Hanover, Spotsylvania, Caroline, and Orange counties), 7 tornadoes were reported in Louisa County, 5 in Hanover County, 5 in Spotsylvania County, 8 in Orange County, and 5 in Caroline County. No F3 or higher intensity tornadoes were reported in Louisa or Spotsylvania counties.

As discussed in the Technical Basis for Regional Tornado Criteria (WASH-1300) (Reference 36), according to statistical methods proposed by Thom, the probability of a tornado striking a point within a given area may be estimated as follows (Reference 15):

$$P = \frac{z \times t}{A}$$

where:

P = the mean probability per year
z = the mean path area of a tornado
t = the mean number of tornadoes per year
A = the area of concern

The Event Record Details provided in the Storm Events report list the path length and path width of each specific tornado (Reference 12). For tornado events within the 2-degree square area around the ESP site, according to the available recorded data, the calculated mean tornado path length is 3.1 miles and the calculated mean path width is 116.7 yards. These values yield a z value of 0.2056 square mile. Using a 2-degree square area as a basis for A and a value of 4.35 tornadoes per year yields an annual probability of 5.94×10^{-5}, or a recurrence interval of 16,835 years. The strike probability, multiplied by the intensity probability yields the total probability that a tornado of a certain strength will strike a certain area.

According to American National Standard ANSI A58.1-1982, the operating basis wind velocity at 33 feet (10 meters) above ground level in the ESP site area associated with a 100-year return period is 64 miles per hour (Reference 38). Values for other recurrence intervals are listed in Table 2.7-3 (Reference 38). The fastest-mile-wind speed is defined as the passage of one mile of wind with the highest speed for the day. The fastest-mile-wind speed at Richmond (68 miles per hour) was recorded at that station in October 1954 (Reference 17). The 3-second gust wind speed that represents a 100-year return period is 96 mph at 10 meters above ground. This wind speed was determined in accordance with the guidance in Reference 37.

2.7.3.3 Heavy Snow and Ice Storms

Frozen precipitation typically occurs in the form of hail (already discussed in Section 2.7.3.1), snow, sleet and freezing rain. The frequency of occurrence of these types of weather events in the ESP site area are based on the latest version of the Climate Atlas of the United States (Reference 40).

The data indicate that the occurrence of snowfalls greater than or equal to 1 inch in the ESP site area ranges from about three to five days per year. However, the frequency of such snow events increases to the west and northwest of the ESP site in far western Louisa County, north-central Fluvanna County, and much of Albemarle and Orange Counties, ranging between 6 and 10 days per year. In general, these differences can be attributed to topographic effects.

On the other hand, the frequency of snowstorms of greater magnitude is similar over the ESP site area because the weather systems that produce such events often affect fairly large areas. On average, the data indicate that daily snowfall totals greater than or equal to thresholds of 5 and 10 inches occur less than one day per year.

Freezing rain falls as a liquid but freezes upon impact forming a glaze on the ground or other exposed objects whose temperature is typically near or below 32°F (0°C). It frequently occurs during the transition from winter rains to ice pellets (sleet) or snow and vice versa depending on the characteristics of the air mass. The Climate Atlas indicates that freezing precipitation events occur, on average, about six to ten days per year in the ESP site area.

2.7.3.4 Tropical Cyclones

On average, a tropical cyclone, or its remnants, can be expected to impact some part of the Commonwealth of Virginia each year (Reference 20). Tropical cyclones include not only hurricanes and tropical storms, but systems classified as tropical depressions, sub-tropical depressions and extra-tropical storms, among others.

This characterization considers all “tropical cyclones” (rather than systems classified only as hurricanes or tropical storms) because storm classifications are generally downgraded once landfall occurs and the system weakens although it may still result in significant rainfall events as it travels through the site region.

A comprehensive database of historical tropical cyclone tracks (i.e., currently extending from 1851 through 2003), available through the NOAA’s Coastal Services Center and based on information compiled by the National Hurricane Center (Reference 39), indicates that a total of 55 tropical cyclone centers or storm tracks have passed within a 100-nautical mile radius of the North Anna ESP site. Storm classifications and respective frequencies of occurrence over this period of record are as follows:

- Hurricanes - Category 3 (1), Category 2 (1), and Category 1 (5)
- Tropical Storms - 27

- Tropical Depressions - 13
- Subtropical Depressions - 1
- Extra-Tropical Storms - 7

Tropical cyclones are responsible for at least two separate record rainfall events in the North Anna ESP site area. In August 1969, Hurricane Camille, a tropical depression by the time it passed through the area within 100-nautical miles of the site, resulted in a record 24-hour (daily) rainfall total of 11.18 inches at the nearby Louisa observation station (see Section 2.7.4.1.5). The Louisa station is part of the National Weather Service's cooperative climatological network.

In August 1955, Hurricane Connie passed within about 120 nautical miles of the site at its closest approach. Although not included in the count of tropical cyclones above, Connie, then classified as a tropical storm, was responsible for the current record 24-hour (daily) rainfall total at Richmond Byrd International Airport (i.e., 8.79 inches) (see Section 2.7.1.5).

2.7.4 Local Meteorology

Data acquired from the NCDC (in Asheville, NC) have been used to determine the normal, means, and extremes of temperature, precipitation, relative humidity, and fog applicable to the ESP site. The 2001 Richmond Local Climatological Data (Reference 1) provides detailed climatological data for this first-order station. Climatological summaries for other stations in the area also provide supplemental information (Reference 21 through Reference 25).

The approximate distance and direction of the Richmond NWS station and at other nearby locations in the NWS' network of cooperative observing stations in the ESP site area are provided in Table 2.7-1:

Table 2.7-1 NWS and Cooperative Observing Stations Near the ESP Site

Station	Distance (miles)	Direction
Partlow 3WNW	5	East
Louisa	12	West
Piedmont Research Station	21	Northwest
Fredericksburg Nat'l Park	26	Northeast
Charlottesville 2W	40	West
Richmond	46	Southeast

The closest station, Partlow 3WNW, was closed on December 31, 1976 (Reference 26); therefore, recent data are not available from this station.

Besides using data from the nearby meteorological and climatological observing stations, data collected from the existing units' meteorological monitoring system was also used to characterize local meteorological conditions. The onsite primary meteorological tower is about 1750 feet east-northeast from the Unit 1 containment building (see Figure 2.7-1 and Figure 2.7-2). Based on proximity, the meteorological parameters (i.e., wind speed and wind direction) collected by the tower are representative of the ESP site. Consequently, they are appropriate for use in describing local meteorological conditions.

2.7.4.1 Normal and Extreme Values of Meteorological Parameters

A summary of normal and extremes of available temperature, precipitation, relative humidity, and fog are presented for Richmond in Table 2.7-4. Climatological means for Richmond and stations in the site region are presented in Table 2.7-5. Monthly temperature means for other applicable stations are presented in Table 2.7-6.

2.7.4.1.1 Wind Direction, Wind Speed and Wind Persistence

The distribution of wind direction and speed is an important consideration when evaluating transport conditions relevant to site diffusion climatology. The topographic features of the site region and/or the general circulation of the atmosphere (i.e., movement of pressure systems and location of semi-permanent zones) are factors in influencing the wind direction within the site region. For the ESP site, the prevailing wind is from the south-southwest during the summer season and from the northwest and north during the winter season. These wind directions are due primarily to the location of the Bermuda High off the eastern coast of the United States during the summer season, and the development of a cold high-pressure zone over the eastern portion of the United States during the winter season.

However, the topographic features of the ESP site region, in conjunction with the movement of pressure systems and the location of the semi-permanent pressure zones, have a definite influence on the wind direction distribution. The Blue Ridge Mountains, which are oriented in a south-southwest to north-northeast direction, are approximately 40 to 50 miles northwest of the ESP site. Consequently, the prevailing winds during the summer season are from the south and south-southwest because of the channeling effect created by the presence of the Blue Ridge Mountains. Additionally, the Blue Ridge Mountains act as a barrier to the prevailing westerly winds at the surface; but even more so, they act as a barrier to the movement of low-pressure cells from the Gulf of Mexico region to the northeast portion of the United States. Consequently, low-pressure cells that are generated in the Gulf are frequently forced to move toward the east on the back (west) side of the Blue Ridge Mountains, therefore, resulting in a southerly flow of air in the ESP site region instead of a southeasterly or easterly wind.

Topographic features also have a definite influence with respect to the wind direction during periods of light winds. Usually, during episodes of near calm, the pressure gradient is weak and there is no organization in the general circulation. However, due to topographic effects such as the presence of

Lake Anna, the airflow typically follows the contour lines of the land. Air is channeled along Lake Anna and the North Anna River Valley during light wind conditions. If there is a sufficient temperature gradient between the ambient air over the lake and surrounding land, a weak lake breeze could form. However, the lake breeze would affect only the area in the immediate vicinity of the lake (less than 1 mile) (Reference 2, Section 2.3.2.2.1.1).

The seasonal and annual average distributions of wind direction based on data collected at the existing units' primary tower are presented in Figure 2.7-3 through Figure 2.7-12 for the lower (33 ft) and upper (159 ft) levels (Reference 2). Winds occur on an annual basis along a north-south orientation with a general westerly component. Wind direction distributions based on the lower level data are similar to those based on the upper level data. However, the upper level data indicate a more distinct north-south orientation of wind flows. Wind data at Richmond show a south-southwest/north orientation that is similar to the general wind flow at the ESP site (Reference 1).

Wind direction distributions show seasonal variations. The frequencies of northerly and southerly winds are generally equivalent during the fall season. Winds from the northwest and south-southwest sectors characterize wind flows during the winter. During the spring season, the wind flow is predominantly from the northwest at the lower level. During the summer months, the predominant wind is from the south-southwest.

Atmospheric dilution is directly proportional to the wind speed (other factors remaining constant). The seasonal and annual mean wind speeds for the ESP site are presented in Table 2.7-7. As indicated in the table, mean wind speeds show seasonal variations.

The mean annual wind speeds at the ESP site are 6.3 mph and 8.6 mph at the lower and upper tower level, respectively. The annual frequencies of calm are 0.37 and 0.75 percent for the lower and upper tower levels, respectively (Reference 2, Section 2.3.2.2.1.1).

Wind persistence is important when considering potential effects of a radiological release. It is defined as a continuous flow from a given direction or range of directions. Wind persistence roses for meteorological data collected at the NAPS site are presented in Figure 2.7-13 through Figure 2.7-22. The maximum 22.5-degree range direction persistence episodes recorded at NAPS during the period of record from the data for the lower level was a 26-hour wind from the north. The maximum persistence period at the upper level was 33 hours from the west-northwest. In general, extreme persistence periods (greater than 18 hours) at the ESP site are associated with moderately high winds and relatively low or moderate turbulence (Reference 2, Section 2.3.2.2.1.2).

2.7.4.1.2 **Atmospheric Stability**

Atmospheric stability, as applied in this report, is determined by the delta T method defined by the NRC (Reference 2, Section 2.3.3.2).

The seasonal and annual frequencies of stability classes and associated wind speeds for the ESP site are presented in Table 2.7-8. The vertical stability data, based on delta T site measurements, indicate the predominance of neutral and slightly stable conditions (Reference 2, Section 2.3.2.2.1.1).

Extremely unstable conditions (Stability Class A) are more frequent and extremely stable conditions (Stability Class G) are less frequent during the summer than during the winter. This situation is attributed to the greater solar heating of the surface during the summer and the large-scale restrictive dilution conditions (presented in Section 2.7.2.3) that generally occur during the winter. Also, ground snow cover is conducive to the formation of stable (or inversion) conditions.

Instrumentation is available in the main control room of the existing units by which personnel can identify atmosphere stability. The existing units' Emergency Plan Implementing Procedures identify station-specific instructions and appropriate temperature values for determining RG 1.23, Table 2 atmospheric stability classifications. This stability classification method allows for the rapid assessment of pertinent meteorological parameters by control room personnel in the event of an accidental release of radioactive material to the atmosphere.

2.7.4.1.3 Temperature

Ambient temperature at the ESP site is measured by the primary tower at the 33-foot level, and differential temperature is measured between the 33-foot and 158.9-foot levels. The annual onsite average temperature, as reported in Reference 2, is 55.8°F, while the annual average temperature in Richmond is 58.3°F, based on the period of record from September 16, 1971 to September 15, 1972. A higher annual average for Richmond is expected because the ESP site is in a rural area, which tends to have slightly lower average temperature than large cities that are influenced by the heat-island effect. In addition, the presence of Lake Anna would also moderate the site temperature.

The annual average temperature measured in Louisa (Reference 23) is 56.1°F, based on the long-term climatological record for that station. Similarly, the nearby Partlow 3WNW station, located in southern Spotsylvania County, has a long-term annual average temperature of 55.2°F. (Reference 25)

2.7.4.1.4 Atmospheric Moisture

The relative humidity data collected in Richmond is described in Section 2.7.1.4. These data are representative of the ESP site area due to its similar exposure to the Atlantic shore.

Based on 24-year (1973–1996) records, the 0.4 percent, 1 percent, and 2 percent wet-bulb temperatures measured in Richmond are 79°F, 78°F, and 77°F, respectively (Reference 43). Wet bulb temperature is used for cooling system-modeling studies.

2.7.4.1.5 Precipitation

As stated in Section 2.7.1.5, the annual precipitation in Richmond is about 43 inches. This annual total is representative of conditions at the ESP site. Based on a 30-year (1951–1980) period, the annual precipitation recorded in Louisa averages 42.08 inches (Reference 23). The annual precipitation in Partlow 3WNW (1952–1971) is about 42.2 inches (Reference 25). In Louisa, the maximum 24-hour precipitation is 11.18 inches (August 1969), while the maximum monthly precipitation is about 16.3 inches (August 1969). The Richmond monthly average precipitation ranges from about 3 to 5 inches (Reference 1), while in Louisa, the monthly averages range from about 3 to 4.5 inches (Reference 23).

In Louisa, the annual snowfall averages about 20 inches (Reference 23). The Partlow 3WNW annual snowfall averages 18.6 inches (Reference 25). These values are slightly higher than the average value of 16.3 inches measured in Richmond. The maximum monthly snowfall measured in Louisa (32.2 inches) is also slightly higher than 28.5 inches measured in Richmond (Reference 1) or 29.8 inches measured in Charlottesville 2W (Reference 21).

2.7.4.1.6 Fog

The closest available fog data for the ESP site area are from the NWS observations at Richmond International Airport in Richmond. The local climatological data for Richmond through 2001 indicate an average of 27.2 days per year of heavy fog based on 73 years of records (Reference 1). Heavy fog is defined by the NWS as fog that reduces visibility to one-quarter of a mile or less. The frequency of fog conditions at the ESP site would be expected to be somewhat different from Richmond. The ESP site is characterized by gentle rolling terrain that rises to an average height of 50 to 150 feet above Lake Anna's level. Low regions at the site and in the vicinity of the lake would be expected to have a higher frequency of fog occurrences attributed to the accumulation of relatively cool surface air due to drainage flows from higher elevations when compared to the relatively flat region of the Richmond airport.

2.7.4.1.7 Topographical Description and Potential Modifications

The ESP site and exclusion area (approximately 1803 acres) is in the northeastern portion of Virginia in Louisa County along the North Anna River. The site region is characterized by gently rolling terrain that rises to an average height of 50 to 150 feet above Lake Anna's level and is cut by the North Anna River. The topography in the site region is characteristic of the Central Piedmont Plateau, which has a gently undulating surface that varies from 200 to 500 feet above sea level. Figure 2.7-23 and Figure 2.7-24 present the topographic features of the site. Section 2.7.4.1.1 presents how the topographic features of the site influence wind direction distribution.

Lake Anna, which extends approximately 17 miles along the old North Anna riverbed, was formed by damming up the North Anna River about 5 miles southeast of the site. As described in Section 2.3.1, the North Anna Reservoir and the WHTF, which together form Lake Anna, cover a surface area of about 13,000 acres and contain approximately 305,000 acre-feet of water.

Because of the gently rolling terrain, there is cold air drainage into low-lying areas at night. Some wind channeling along Lake Anna is expected during low-wind-speed conditions. This same effect also occurred in the natural lowland area before the lake was developed.

The ESP site for the new Units 3 and 4 is immediately west of the existing units. The primary topographic influences on local meteorological conditions at the ESP site are Lake Anna and the North Anna River Valley. During construction of the new units, a portion of the currently undeveloped area of the ESP site would be cleared of existing vegetation and subsequently graded to accommodate the new units and their ancillary structures. No large-scale cut and fill activities would be needed in the area of the ESP Plant Parameter Envelope to accommodate the new units since a large portion of the area to be developed is already relatively level. Undulating surfaces in the area of the planned cooling towers would be leveled to accommodate the towers. Therefore, the expected terrain modifications associated with development of the new nuclear power plant(s) at the ESP site would be limited to the existing NAPS site and would not significantly impact terrain features around the Lake and/or Valley, nor significantly alter the site's existing gently undulating surface that is characteristic of its location in the Piedmont region of Virginia.

2.7.5 Short-Term Diffusion Estimates

2.7.5.1 Basis

To evaluate potential health effects for DBAs, NUREG-1555, Section 7.1 requires the applicant to account for the 50 percentile χ/Q values at appropriate distances from the effluent release points (Reference 27). The NRC-sponsored PAVAN computer code (Reference 28) was used to generate these overall site, 50 percentile χ/Q values.

Recent readily available site meteorological data (1996–1998) were used for a quantitative evaluation of the hypothetical accident at the ESP site. Onsite data provide representative measurements of local dilution conditions appropriate to the ESP site and are reasonable representative of long-term conditions. The use of the recent 3-year data for dispersion analyses involving accidental releases in this ESP application is consistent with the approach used in the license renewal application for the existing units (Reference 29) and also satisfies the requirement of RG 4.7 (Reference 30). These 3-year combined joint frequency distributions of wind direction, wind speed, and atmospheric stability recorded at the NAPS site are presented in Table 2.7-9.

The PAVAN program implements the guidance provided in RG 1.145 (Reference 31) and performs the following calculation procedures. The code computes χ/Q values at the EAB and LPZ for each combination of wind speed and atmospheric stability for each of the 16 downwind direction sectors. Because the ground level release scenario provides a bounding case, elevated releases were not evaluated. The χ/Q values for each sector are then ranked in descending order, and an associated cumulative frequency distribution is derived based on the frequency distribution of wind speed and

stabilities for that sector. The χ/Q values are also ranked independent of wind direction into a cumulative frequency distribution for the entire site.

The PAVAN model was configured to calculate offsite χ/Q values assuming both wake-credit allowed and wake-credit not-allowed. As described in Section 2.1, the EAB is the perimeter of a 5000-foot-radius circle from the center of the abandoned Unit 3 containment. There are no residential areas in the EAB. The PPE indicates that the highest expected structure would be about 234 feet above grade level. Therefore, the closest EAB is more than 10 building heights away from the boundary of the plant envelope developed for the ESP site. As a result, the entire EAB is located beyond the wake influence zone that would be induced by a containment building. The LPZ is a 6-mile-radius circle centered at the Unit 1 containment building. Because it is located further away from the plant site than the EAB, the "wake-credit not allowed" scenario of the PAVAN results was used for the χ/Q analysis at the EAB and LPZ.

To be conservative, the shortest distances between the ESP plant envelope boundaries to the 5000-ft-radius circle for each downwind sector were entered as input to calculate the χ/Q values at the EAB (see Table 2.7-10). Similarly, the shortest distance from the ESP plant envelope area boundary to the LPZ was entered as input to calculate the X/Q values at the LPZ. With respect to the ESP site, the shortest distance between the ESP site plant envelope boundary and the LPZ is 8843 m (about 5.5 mi.) measured from the southwest of the plant envelope area.

2.7.5.2 PAVAN Modeling Results

Based on the PAVAN-generated ordered χ/Q values (see Table 2.7-11 and Table 2.7-12), the 50-percentile overall site χ/Q values calculated by the model at the EAB and LPZ are 3.34E-05 and 2.17E-06, respectively.

2.7.6 Long-Term (Routine) Diffusion Estimates

2.7.6.1 Basis

The NRC-sponsored, computer code designated XOQDOQ (Reference 32) was used to estimate χ/Q values due to routine releases. The XOQDOQ model implements the assumptions outlined in RG 1.111 (Reference 33). A straight-line trajectory was assumed between the release point and all receptors by the XOQDOQ model.

The primary function of the XOQDOQ computer code, obtained from RSICC (Reference 34), is to calculate annual χ/Q values and annual average relative deposition D/Q values, at interested receptors (i.e., EAB, LPZ, nearest milk cow, residence, garden, meat animal, etc.). The program assumes the material released to the atmosphere to be a Gaussian distribution around the plume centerline. In estimating concentrations for longer time periods, the Gaussian distribution is assumed to be evenly distributed within the directional sector.

Input data and assumptions used in the XOQDOQ modeling are presented below.

- Meteorological Data: Three-year combined (1996–1998) onsite joint frequency distribution of wind speed, wind direction and atmospheric stability.
- Type of Release: Ground level
- Wind Sensor Height: 33 ft
- Vertical Temperature Difference: 33 ft–158.9 ft
- Number of Wind Speed Categories: 7
- Release Height: 33 ft (default height)
- Minimum Building Cross-Sectional Area: 2250 m^2
- Distances from the release point to the site boundary, and the nearest milk cow, vegetable garden, milk goat, and meat animal: See Table 2.7-13.

For dispersion analysis, a smaller cross-sectional area usually results in higher ground level concentrations. To be conservative, the minimum building cross-sectional area of 2250 m^2 was used to evaluate building downwash effect.

When compared to the elevated releases, ground level releases usually produce higher pollutant concentrations for receptors located at ground level. Therefore, ground level releases were conservatively assumed in the χ/Q analysis. Distances from the Unit 1 containment building to various interested receptors (nearest residence, garden, meat animal, site boundary, and vegetable garden) for each directional sector are provided in Reference 35, Appendix C. Because the plant envelope area for the ESP site is an area (not a point), the shortest distances from any point of the plant envelope to the interested receptors were re-calculated for each directional sector. The results are presented in Table 2.7-13. The maximum annual χ/Q (no decay) value at the EAB (0.88 mile to the ESE of the plant envelope) is 3.70×10^{-6} sec/m^3. The maximum annual average χ/Q value calculated for the nearest residence (0.96 mile to the NNE of the plant envelope) is 2.4×10^{-6} sec/m^3. The maximum annual χ/Q for the nearest vegetable garden (0.94 mile to the NE of the plant envelope) is 2.0×10^{-6} sec/m^3. Finally, the maximum annual χ/Q for the nearest meat animal (1.37 miles to the SE of the plant envelope) is 1.4×10^{-6} sec/m^3.

Table 2.7-14 summarizes the maximum χ/Q and D/Q values predicted by the XOQDOQ model for the sensitive receptors due to routine releases. Table 2.7-15 summarizes the maximum annual average χ/Q and D/Q values at distances between 0.25 and 50 miles and for various segment boundaries.

Detailed annual average χ/Q and D/Q estimates generated by the XOQDOQ model for the interested receptors and at distances between 0.25 mile to 50 miles, as well as for various segment boundaries, are also presented. Table 2.7-16 represents χ/Q estimates at the specific points of interest. Table 2.7-17 lists χ/Q estimates at downwind distances between 0.25 and 50 miles. Table 2.7-18 contains χ/Q estimates that include radioactive decay with a half-life of 2.26 days for short-lived noble gases. Table 2.7-19 contains χ/Q estimates that include radioactive decay with a

half-life of 8 days for all iodines released to the atmosphere. Finally, Table 2.7-20 contains estimates of long-term average D/Q at downwind distances between 0.25 and 50 miles.

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Table 2.7-2 Summary of Virginia Tornado Intensities

Tornado Intensity (Fujita Tornado Scale)	**Number of Occurrences** (January 1950–December 2003)
F0	120
F1	184
F2	72
F3	29
F4	2
F5	0
Non-Classified	26
Total	433

Notes: Scale	Wind Speed (mph)
F0	40–72
F1	73–112
F2	113–157
F3	158–206
F4	207–260
F5	261–318

Source: Storm Events for Virginia, 01/01/1950 through 12/31/2003, NCDC, NOAA. (Reference 12)

Table 2.7-3 Extreme 1-Mile Wind Passage at Richmond, Virginia

Probability	**Speed (mph)**	**Recurrence Interval (years)**
0.04	56	25
0.02	60	50
0.01	64	100

Source: ANSI A58.1, American National Standard: Minimum Design Loads for Building and Other Structures, ANSI, 1982. (Reference 38)

Table 2.7-4 Richmond Climatological Data

NORMALS, MEANS, AND EXTREMES

RICHMOND, VA

LATITUDE: 37° 30' 40" N LONGITUDE: 77° 19' 24" W ELEVATION (FT): GRND: 164 BARO: 167 TIME ZONE: EASTERN (UTC + 5) WBAN: 13740

	ELEMENT	WBAN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F	NORMAL DAILY MAXIMUM	30	45.7	49.2	59.5	70.0	77.8	85.1	88.4	87.1	80.9	70.7	61.3	50.2	68.8
	MEAN DAILY MAXIMUM	81	47.4	50.3	58.9	69.3	77.6	85.1	88.3	86.5	80.8	70.6	60.4	50.0	68.8
	HIGHEST DAILY MAXIMUM	72	80	83	93	96	100	104	105	102	103	99	86	81	105
	YEAR OF OCCURRENCE		1950	1932	1938	1990	1941	1952	1977	1983	1954	1941	1993	1998	JUL 1977
	MEAN OF EXTREME MAXS.	81	69.4	71.2	80.2	87.8	91.1	96.0	97.5	95.9	93.1	85.5	77.8	70.1	84.6
	NORMAL DAILY MINIMUM	30	25.7	28.1	36.3	44.6	54.2	62.7	67.5	66.4	59.0	46.5	37.9	29.9	46.6
	MEAN DAILY MINIMUM	81	28.4	30.0	36.6	45.4	54.7	63.5	68.0	66.6	60.1	47.8	38.4	30.9	47.5
	LOWEST DAILY MINIMUM	72	-12	-10	11	23	31	40	51	46	35	21	10	-1	-12
	YEAR OF OCCURRENCE		1940	1936	1960	1985	1956	1967	1965	1934	1974	1962	1933	1942	JAN 1940
	MEAN OF EXTREME MINS.	81	10.2	14.2	21.6	30.9	41.0	51.1	57.8	55.6	45.4	32.4	22.7	14.6	33.1
	NORMAL DRY BULB	30	35.7	38.7	48.0	57.3	66.0	73.9	78.0	76.8	70.0	58.6	49.6	40.1	57.7
	MEAN DRY BULB	81	38.0	40.1	47.8	57.4	66.2	74.3	78.2	76.6	70.5	59.2	49.5	40.4	58.2
	MEAN WET BULB	17	34.0	36.7	41.9	50.5	59.4	67.3	71.5	66.0	63.6	53.7	44.9	36.8	52.2
	MEAN DEW POINT	17	27.0	29.1	33.9	43.0	54.3	63.2	68.1	63.1	59.9	48.7	38.6	30.0	46.6
	NORMAL NO. DAYS WITH:														
	MAXIMUM ≥ 90°	30	0.0	0.0	0.1	0.8	2.3	8.7	13.8	11.0	4.1	0.3	0.0	0.0	41.1
	MAXIMUM ≤ 32°	30	4.3	1.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	7.6
	MINIMUM ≤ 32°	30	23.0	19.5	10.8	2.3	0.1	0.0	0.0	0.0	0.0	2.1	9.4	19.2	86.4
	MINIMUM ≤ 0°	30	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
H/C	NORMAL HEATING DEG. DAYS	30	908	736	527	241	61	0	0	0	23	233	462	772	3963
	NORMAL COOLING DEG. DAYS	30	0	0	0	10	92	270	403	366	173	34	0	0	1348
RH	NORMAL (PERCENT)	30	68	66	63	61	70	72	75	77	77	74	69	69	70
	HOUR 01 LST	30	75	73	72	73	83	86	88	90	90	86	79	76	81
	HOUR 07 LST	30	79	78	78	76	81	83	86	90	90	89	84	80	83
	HOUR 13 LST	30	56	53	49	45	52	54	57	58	57	52	51	55	53
	HOUR 19 LST	30	65	62	57	53	63	66	69	74	77	75	68	68	66
S	PERCENT POSSIBLE SUNSHINE	46	54	58	62	66	65	69	68	66	65	63	59	54	62
W/O	MEAN NO. DAYS WITH:														
	HEAVY FOG(VISBY≤1/4 MI)	73	2.7	2.1	1.7	1.6	1.8	1.5	2.0	2.4	2.9	3.3	2.3	2.8	27.1
	THUNDERSTORMS	65	0.2	0.4	1.6	2.4	5.3	6.6	8.2	6.2	2.9	1.0	0.6	0.2	35.6
CLOUDINESS	MEAN:														
	SUNRISE-SUNSET (OKTAS)	1			5.6		5.6	3.2							
	MIDNIGHT-MIDNIGHT (OKTAS)	1			5.6										
	MEAN NO. DAYS WITH:														
	CLEAR	1	2.0	1.0	9.0		9.0	10.0							
	PARTLY CLOUDY	1		1.0	5.0		4.0	8.0							
	CLOUDY	1	7.0	4.0	10.0		8.0	1.0							
PR	MEAN STATION PRESSURE(IN)	28	29.91	29.89	29.85	29.81	29.81	29.81	29.83	29.86	29.89	29.92	29.92	29.93	29.87
	MEAN SEA-LEVEL PRES. (IN)	17	30.12	30.11	30.05	29.99	30.00	29.99	30.01	30.04	30.08	30.12	30.14	30.14	30.07
WINDS	MEAN SPEED (MPH)	43	8.3	8.7	9.3	9.2	7.9	7.5	7.1	6.6	7.0	7.2	7.7	7.9	7.9
	PREVAIL.DIR(TENS OF DEGS)	26	01	01	36	19	19	20	19	19	36	36	19	36	19
	MAXIMUM 2-MINUTE:														
	SPEED (MPH)	6	38	39	37	46	41	45	33	44	40	37	36	40	46
	DIR. (TENS OF DEGS)		31	23	22	33	30	26	29	36	01	10	16	15	33
	YEAR OF OCCURRENCE		2000	1997	1996	1999	1997	2000	1999	1996	1999	1996	1999	1996	APR 1999
	MAXIMUM 5-SECOND:														
	SPEED (MPH)	6	48	49	49	56	60	55	44	59	53	46	46	48	60
	DIR. (TENS OF DEGS)		31	26	22	25	28	27	29	32	08	10	16	16	28
	YEAR OF OCCURRENCE		2000	1997	1996	1998	1996	2000	1999	2000	1996	1996	1999	1996	MAY 1996
PRECIPITATION	NORMAL (IN)	30	3.24	3.16	3.61	2.96	3.84	3.62	5.03	4.40	3.34	3.53	3.17	3.26	43.16
	MAXIMUM MONTHLY (IN)	64	7.97	5.97	8.65	7.31	8.87	9.24	18.87	14.10	16.60	9.39	7.64	7.07	18.87
	YEAR OF OCCURRENCE		1978	1979	1984	1987	1972	1938	1945	1955	1999	1971	1959	1973	JUL 1945
	MINIMUM MONTHLY (IN)	64	0.64	0.48	0.94	0.64	0.87	0.38	0.51	0.52	0.26	0.01	0.17	0.40	0.01
	YEAR OF OCCURRENCE		1981	1978	1966	1963	1965	1980	1983	1943	1978	2000	2001	1980	OCT 2000
	MAXIMUM IN 24 HOURS (IN)	64	3.31	2.67	3.43	2.97	3.08	4.61	5.73	8.79	6.52	6.50	4.07	3.16	8.79
	YEAR OF OCCURRENCE		1962	1979	1992	1987	1981	1963	1969	1955	1999	1961	1956	1958	AUG 1955
	NORMAL NO. DAYS WITH:														
	PRECIPITATION ≥ 0.01	30	10.4	9.4	10.2	9.0	10.7	9.6	10.4	9.5	7.6	7.0	8.0	9.1	110.9
	PRECIPITATION ≥ 1.00	30	0.8	0.7	0.8	0.6	1.0	0.9	1.4	1.3	1.0	1.2	0.8	0.7	11.2
SNOWFALL	NORMAL (IN)	30	5.8	5.5	2.4	0.1	0.0	0.0	0.0	0.0	0.0	T	0.3	2.2	16.3
	MAXIMUM MONTHLY (IN)	62	28.5	21.4	19.7	2.0	T	0.0	0.0	0.0	0.0	T	7.3	12.5	28.5
	YEAR OF OCCURRENCE		1940	1983	1960	1940	1994					1979	1953	1958	JAN 1940
	MAXIMUM IN 24 HOURS (IN)	62	21.6	16.8	12.1	2.0	T	0.0	0.0	0.0	0.0	T	7.3	7.5	21.6
	YEAR OF OCCURRENCE		1940	1983	1962	1940	1994					1979	1953	1966	JAN 1940
	MAXIMUM SNOW DEPTH (IN)	77	18	20	13	1	0	0	0	0	0	0	6	9	20
	YEAR OF OCCURRENCE		1922	1922	1980	1964							1938	1958	FEB 1922
	NORMAL NO. DAYS WITH:														
	SNOWFALL ≥ 1.0	30	1.5	1.4	0.6	0.*	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	4.3

Source: Richmond, Virginia, Local Climatological Data, Annual Summary with Comparative Data 2001, NCDC, NOAA.

Table 2.7-5 Mean Annual Meteorological Data for Stations in the Site Region

Location	Mean Annual Temperature (°F)	Mean Annual Precipitation (in.)	Mean Annual Snowfall (in.)
Charlottesville	56.8	45.72	24.2
Fredericksburg	56.2	40.99	17.7
Louisa	56.3	41.62	19.9
Piedmont Research Station	55.9	38.68	22.0
Partlow	55.2	42.24	18.6

Source: Reference 21 through Reference 25.

Table 2.7-6 Comparison of Mean Temperature Data for North Anna, Richmond, Partlow, and Louisa (°F) (September 16, 1971–September 15, 1972)

Month	North Anna	Richmond	Partlow	Louisa
January (1972)	36.6	40.7	37.6	39.5
February (1972)	33.6	37.6	35.5	36.2
March (1972)	43.0[a]	47.2	45.1	46.3[a]
April (1972)	54.7[a]	56.2	54.1	55.0
May (1972)	62.4	64.6	62.4	62.1
June (1972)	68.3	70.1	69.5	68.1
July (1972)	75.0	77.1	77.0	74.8
August (1972)	72.9	75.2	73.1	72.8
September (16-30, 1971; 1-15, 1972)	68.2[a]	69.6	([b])	([b])
October (1971)	62.8	64.6	63.9	63.0[a]
November (1971)	45.8[a]	48.5	46.6[a]	47.1
December (1971)	46.3[a]	48.0	46.8	46.2

Source: Reference 2

a. One or more days of data missing.

b. Data not available.

Table 2.7-7 North Anna Mean Wind Speeds (mph) 1974-1987

Elevation	Spring (Mar, Apr, May)	Summer (Jun, Jul, Aug)	Fall (Sept, Oct, Nov)	Winter (Dec, Jan, Feb)	Annual
Upper Level	9.6	7.5	8.3	9.2	8.6
Lower Level	7.1	5.4	5.9	6.6	6.3

Source: Reference 2

Table 2.7-8 North Anna Vertical Stability (ΔT) and Low-Level Wind Speed Distribution 1974-1987

	Vertical Stability Categories						
Period	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Spring							
Frequency (%)	20.04	5.41	4.86	29.87	24.18	7.92	7.71
Wind Speed (mph)	(8.6)	(8.4)	(8.6)	(7.9)	(6.3)	(4.0)	(2.9)
Summer							
Frequency (%)	25.33	5.38	5.10	29.52	27.21	6.42	1.44
Wind Speed (mph)	(6.1)	(6.2)	(6.2)	(5.7)	(4.3)	(3.2)	(2.9)
Fall							
Frequency (%)	21.28	4.16	4.25	28.71	25.57	10.26	6.14
Wind Speed (mph)	(6.9)	(7.1)	(7.4)	(6.8)	(4.9)	(3.4)	(3.2)
Winter							
Frequency (%)	13.39	4.82	4.85	35.10	27.55	8.09	6.60
Wind Speed (mph)	(7.6)	(7.8)	(8.2)	(7.4)	(5.6)	(3.5)	(2.8)
Annual							
Frequency (%)	20.00	4.91	4.74	30.69	26.08	8.22	5.46
Wind Speed (MPH)	(7.2)	(7.4)	(7.6)	(7.0)	(5.2)	(3.5)	(3.0)

Source: Reference 2

Table 2.7-9 1996–1998 NAPS Meteorological Data (33-ft Level)

Sector	Class	Wind Speed (m/s)												
Frequency	**Calm**	0.34-0.50	0.51-0.75	0.76-1.0	1.01-1.25	1.26-1.5	1.51-2.0	2.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-8.0	8.01-10	>10.0	Total
Stability Class A – by ΔT															
N	0	0	2	2	5	3	6	17	19	19	12	5	0	0	90
NNE	0	0	0	0	2	3	5	6	14	4	1	2	0	0	37
NE	0	0	0	2	2	1	4	5	8	3	6	2	0	0	33
ENE	0	0	0	0	2	3	1	10	16	3	0	1	0	0	36
E	0	0	1	2	3	2	22	15	4	5	1	0	0	0	55
ESE	0	0	0	2	4	7	19	26	6	5	0	0	0	0	69
SE	0	0	0	0	1	4	18	26	2	0	0	0	0	0	51
SSE	0	0	0	2	6	2	18	39	1	0	0	0	0	0	68
S	0	0	0	2	3	8	33	113	10	1	0	0	0	0	170
SSW	0	0	0	0	5	5	24	107	73	12	0	1	0	0	227
SW	0	0	0	0	3	3	15	35	50	20	9	1	0	0	136
WSW	0	0	0	0	0	1	11	40	40	12	3	4	0	0	111
W	0	0	0	0	1	4	7	52	55	28	8	3	0	0	158
WNW	0	0	0	1	4	4	19	46	39	36	30	7	0	0	186
NW	0	0	1	2	13	8	41	78	54	26	16	11	3	0	253
NNW	0	0	0	3	12	14	24	20	22	13	18	14	3	0	143
Total	0	0	4	18	66	72	267	635	413	187	104	51	6	0	1823

Table 2.7-9 1996–1998 NAPS Meteorological Data (33-ft Level)

Sector	Class	Wind Speed (m/s)													
Frequency	**Calm**	0.34-0.50	0.51-0.75	0.76-1.0	1.01-1.25	1.26-1.5	1.51-2.0	2.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-8.0	8.01-10	>10.0	Total
Stability Class B – by ΔT															
N	0	0	0	0	0	1	3	22	10	3	8	9	0	0	56
NNE	0	0	0	1	0	1	5	8	8	3	1	0	0	0	27
NE	0	0	0	0	0	1	4	9	8	5	1	1	0	0	29
ENE	0	0	0	0	1	4	6	10	4	3	0	0	0	0	28
E	0	0	0	1	2	4	12	12	6	2	0	0	0	0	39
ESE	0	0	0	1	1	3	20	30	2	1	1	0	0	0	59
SE	0	0	0	0	0	1	10	13	4	0	0	0	0	0	28
SSE	0	0	0	0	1	0	7	18	1	0	0	0	0	0	27
S	0	0	0	0	2	3	18	39	6	3	0	0	0	0	71
SSW	0	0	0	1	0	2	16	48	40	15	15	8	0	0	145
SW	0	1	0	0	1	1	4	18	26	11	4	3	0	0	69
WSW	0	0	0	0	0	0	4	16	16	9	3	4	0	0	52
W	0	0	0	0	0	1	2	14	11	7	6	1	0	0	42
WNW	0	0	0	0	1	1	5	20	21	13	9	4	2	0	76
NW	0	0	0	2	3	6	18	14	19	25	21	8	8	8	132
NNW	0	0	0	1	4	3	8	23	16	20	19	14	5	0	113
Total	0	1	0	7	16	32	142	314	198	120	88	52	15	8	993

Table 2.7-9 1996–1998 NAPS Meteorological Data (33-ft Level)

Sector	Class	Wind Speed (m/s)													
Frequency	**Calm**	0.34-0.50	0.51-0.75	0.76-1.0	1.01-1.25	1.26-1.5	1.51-2.0	2.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-8.0	8.01-10	>10.0	Total
Stability Class C– by ΔT															
N	0	0	0	5	5	1	14	17	28	28	28	11	1	0	138
NNE	0	0	0	0	3	1	7	9	9	10	8	0	0	0	47
NE	0	0	0	2	5	3	3	8	5	3	4	0	0	0	33
ENE	0	0	0	1	3	1	10	17	12	6	0	0	0	0	50
E	0	0	0	0	6	7	13	18	8	3	1	0	0	0	56
ESE	0	0	0	3	3	12	31	48	13	3	5	1	0	0	119
SE	0	0	0	0	2	9	20	22	4	0	0	0	0	0	57
SSE	0	0	0	1	0	3	10	10	1	0	0	0	0	0	25
S	0	0	0	0	4	5	34	30	7	1	0	0	0	0	81
SSW	0	0	0	0	0	5	18	72	28	17	11	4	0	0	155
SW	0	0	0	1	1	4	8	35	28	18	14	10	0	0	119
WSW	0	0	0	0	0	0	7	17	8	6	6	4	0	0	48
W	0	0	0	1	4	3	5	14	17	7	4	3	0	0	58
WNW	0	0	0	4	6	2	10	21	17	15	11	1	2	0	89
NW	0	0	1	1	7	2	14	28	26	29	9	19	5	12	153
NNW	0	0	1	0	7	10	22	32	32	39	15	18	2	3	181
Total	0	0	2	19	56	68	226	398	243	185	116	71	10	15	1409

Table 2.7-9 1996–1998 NAPS Meteorological Data (33-ft Level)

Sector	Class	Wind Speed (m/s)													
Frequency	**Calm**	0.34-0.50	0.51-0.75	0.76-1.0	1.01-1.25	1.26-1.5	1.51-2.0	2.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-8.0	8.01-10	>10.0	Total
Stability Class D– by ΔT															
N	2	0	10	33	51	57	176	460	406	263	86	56	6	2	1608
NNE	0	0	6	23	55	53	173	358	233	122	42	16	5	0	1086
NE	0	0	5	14	52	56	139	290	179	87	23	5	7	1	858
ENE	0	1	7	28	45	54	119	227	138	66	21	7	4	0	717
E	0	2	11	31	60	41	138	230	171	63	20	9	11	0	787
ESE	0	0	6	12	34	32	98	185	115	43	21	2	1	0	549
SE	0	2	7	9	22	21	79	224	59	14	4	0	0	0	441
SSE	0	2	6	13	25	25	56	89	15	2	1	0	0	0	234
S	0	1	5	32	55	75	167	199	38	14	2	0	0	0	588
SSW	1	2	9	39	64	63	176	352	175	91	48	12	0	0	1032
SW	1	2	17	36	51	47	140	266	176	64	41	32	2	0	875
WSW	0	1	13	20	16	21	44	100	102	63	18	4	0	0	402
W	0	4	7	28	31	16	40	67	55	36	17	3	0	0	304
WNW	1	0	3	22	31	32	70	107	74	69	34	25	8	2	478
NW	0	2	2	25	48	59	96	158	119	92	43	27	15	3	689
NNW	0	0	8	25	46	49	147	264	221	141	76	58	7	3	1045
Total	5	19	122	390	686	701	1858	3576	2276	1230	497	256	66	11	11693

Table 2.7-9 1996–1998 NAPS Meteorological Data (33-ft Level)

Sector	Class	Wind Speed (m/s)													
Frequency	**Calm**	0.34-0.50	0.51-0.75	0.76-1.0	1.01-1.25	1.26-1.5	1.51-2.0	2.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-8.0	8.01-10	>10.0	Total
Stability Class E– by ΔT															
N	2	3	14	27	16	16	31	62	28	24	6	9	3	0	241
NNE	1	7	10	21	23	11	29	54	29	9	3	4	3	0	204
NE	1	6	17	20	23	18	31	41	16	9	2	4	3	4	195
ENE	0	9	11	20	19	20	23	43	7	2	0	0	0	1	155
E	2	8	11	13	26	21	53	38	13	1	1	3	0	1	191
ESE	1	6	13	22	35	24	53	72	21	6	6	0	0	0	259
SE	0	4	17	36	28	31	96	131	21	1	1	1	1	0	368
SSE	0	5	17	39	38	50	96	58	10	5	5	0	0	0	323
S	1	14	54	94	115	117	244	185	58	22	1	0	0	0	905
SSW	4	11	67	132	125	85	157	280	145	33	8	1	0	0	1048
SW	1	9	45	102	101	72	133	229	120	50	12	5	0	0	879
WSW	1	11	39	69	56	40	46	97	69	10	1	2	0	0	441
W	1	13	45	81	111	80	105	141	38	18	5	0	0	0	638
WNW	0	11	30	85	99	93	143	107	45	24	10	10	1	0	658
NW	1	9	26	50	80	49	69	51	18	15	6	1	1	0	376
NNW	0	3	22	30	34	25	42	44	21	7	2	7	1	0	238
Total	16	129	438	841	929	752	1351	1633	659	236	69	47	13	6	7119

Table 2.7-9 1996–1998 NAPS Meteorological Data (33-ft Level)

Sector	Class	Wind Speed (m/s)													
Frequency	**Calm**	0.34-0.50	0.51-0.75	0.76-1.0	1.01-1.25	1.26-1.5	1.51-2.0	2.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-8.0	8.01-10	>10.0	Total
Stability Class F– by ΔT															
N	1	3	5	4	1	5	1	0	0	0	0	0	0	0	20
NNE	0	1	7	3	6	0	3	2	1	0	0	0	0	0	23
NE	1	4	7	3	4	3	2	0	0	1	0	0	0	0	25
ENE	2	2	7	9	4	2	4	0	0	0	0	0	0	0	30
E	1	6	15	15	4	3	10	2	0	0	0	0	0	2	58
ESE	1	4	5	7	10	5	9	5	1	0	1	0	0	3	51
SE	0	6	8	8	6	5	8	3	0	0	1	0	0	0	45
SSE	0	1	10	12	6	10	4	1	0	0	2	0	0	0	46
S	0	7	10	36	31	20	12	1	0	0	0	0	0	0	117
SSW	1	4	17	55	55	30	28	10	0	0	0	0	0	0	200
SW	0	8	23	37	26	21	27	20	5	0	0	0	0	0	167
WSW	1	8	20	49	36	8	9	10	2	2	0	0	0	0	145
W	2	12	38	75	85	74	109	26	0	0	0	0	0	0	421
WNW	2	12	37	99	101	66	62	36	1	0	3	0	0	0	419
NW	0	6	24	37	44	20	16	10	1	0	0	0	0	0	158
NNW	2	7	14	7	5	4	5	5	0	0	0	0	0	0	49
Total	14	91	247	456	424	276	309	131	11	3	7	0	0	5	1974

Table 2.7-9 1996–1998 NAPS Meteorological Data (33-ft Level)

Sector	Class	Wind Speed (m/s)													
Frequency	**Calm**	0.34-0.50	0.51-0.75	0.76-1.0	1.01-1.25	1.26-1.5	1.51-2.0	2.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-8.0	8.01-10	>10.0	Total
Stability Class G – by ΔT															
N	3	7	5	5	3	2	0	0	0	0	0	0	0	0	25
NNE	1	6	5	3	1	0	0	0	0	0	0	0	0	0	16
NE	2	5	4	4	1	0	0	0	0	0	0	0	0	0	16
ENE	0	4	5	3	3	0	0	0	0	0	0	0	0	0	15
E	1	6	11	9	2	0	0	0	0	0	0	0	0	0	29
ESE	0	1	7	7	4	0	0	0	0	0	0	0	0	0	19
SE	0	1	2	5	6	4	1	0	0	0	0	0	0	0	19
SSE	0	2	1	2	1	2	0	1	0	0	0	0	0	0	9
S	0	0	1	2	1	3	0	0	0	0	0	0	0	0	7
SSW	0	1	1	1	4	2	5	0	0	0	0	0	0	0	14
SW	1	1	6	6	4	4	5	1	0	0	0	0	0	0	28
WSW	1	2	10	7	6	1	0	0	0	0	0	0	0	0	27
W	0	6	16	31	27	8	9	2	0	0	0	0	0	0	99
WNW	0	5	39	120	117	57	40	5	0	0	0	0	0	0	383
NW	3	15	45	89	86	38	17	3	1	0	0	0	0	0	297
NNW	4	14	25	19	10	3	0	0	0	0	0	0	0	0	75
Total	16	76	183	313	276	124	77	12	1	0	0	0	0	0	1078

Table 2.7-9 1996–1998 NAPS Meteorological Data (33-ft Level)

Sector	Class	Wind Speed (m/s)													
Frequency	**Calm**	0.34-0.50	0.51-0.75	0.76-1.0	1.01-1.25	1.26-1.5	1.51-2.0	2.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-8.0	8.01-10	>10.0	Total
Total Observations – All Stability Categories															
N	8	13	36	76	81	85	231	578	491	337	140	90	10	2	2178
NNE	2	14	28	51	90	69	222	437	294	148	55	22	8	0	1440
NE	4	15	33	45	87	82	183	353	216	108	36	12	10	5	1189
ENE	2	16	30	61	77	84	163	307	177	80	21	8	4	1	1031
E	4	22	49	71	103	78	248	315	202	74	23	12	11	3	1215
ESE	2	11	31	54	91	83	230	366	158	58	34	3	1	3	1125
SE	0	13	34	58	65	75	232	419	90	15	6	1	1	0	1009
SSE	0	10	34	69	77	92	191	216	28	7	8	0	0	0	732
S	1	22	70	166	211	231	508	567	119	41	3	0	0	0	1939
SSW	6	18	94	228	253	192	424	869	461	168	82	26	0	0	2821
SW	3	21	91	182	187	152	332	604	405	163	80	51	2	0	2273
WSW	3	22	82	145	114	71	121	280	237	102	31	18	0	0	1226
W	3	35	106	216	259	186	277	316	176	96	40	10	0	0	1720
WNW	3	28	109	331	359	255	349	342	197	157	97	47	13	2	2289
NW	4	32	99	206	281	182	271	342	238	187	95	66	32	23	2058
NNW	6	24	70	85	118	108	248	388	312	220	130	111	18	6	1844
Total	51	316	996	2044	2453	2025	4230	6699	3801	1961	881	477	110	45	26089

Table 2.7-10 Shortest Distances from the ESP Plant Envelope Boundary to the EAB

Downwind Direction	Distance (ft)	Distance (m)
N	4521	1378
NNE	4589	1399
NE	4697	1432
ENE	4835	1474
E	4707	1435
ESE	4660	1420
SE	4266	1300
SSE	3562	1086
S	3131	954
SSW	2877	877
SW	2860	872
WSW	2838	865
W	2860	872
WNW	2959	902
NW	3242	988
NNW	3822	1165

Table 2.7-11 PAVAN Results for χ/Q Values at the EAB

Plant Name: North Anna ESP
Data Period: 1996–1998 JFD
Type of Release: Ground-Level Release
Source of Data: Onsite
Comments: Data period: 1/1/96 - 12/31/98
Program: PAVAN, 10/76, 8/79 Revision, Implementation of RG 1.145
Site Exclusion Boundary Calculations:
Five Percent Overall Site Limit.
Building wake credit is not included.
Correction factors used in the annual average calculations.

Meteorological Instrumentation
Wind Sensors Height: 32.8 ft
ΔT Heights: 32.8 ft–158.9 ft

Below are printed the ordered values of χ/Q and the frequency with which that value is reached or exceeded.
The top number is the χ/Q. The middle number is the frequency normalized to this sector.
The third number is the frequency with respect to all time.

0	9.211E-04	9.140E-04	9.090E-04	8.847E-04	8.381E-04	8.101E-04	7.256E-04	6.790E-04	6.263E-04	6.215E-04
	0.001	0.004	0.005	0.006	0.007	0.008	0.013	0.013	0.029	0.071
	0.00095	0.00360	0.00454	0.00574	0.00713	0.00827	0.01275	0.01325	0.02858	0.07075
0	6.181E-04	6.142E-04	6.099E-04	6.050E-04	6.016E-04	6.016E-04	5.848E-04	5.832E-04	5.755E-04	5.699E-04
	0.094	0.111	0.112	0.114	0.118	0.119	0.120	0.120	0.121	0.148
	0.09374	0.11097	0.11183	0.11413	0.11796	0.11857	0.11969	0.12013	0.12070	0.14753
0	5.680E-04	5.639E-04	5.628E-04	5.527E-04	5.508E-04	5.499E-04	5.334E-04	4.934E-04	4.808E-04	4.617E-04
	0.169	0.170	0.176	0.176	0.180	0.182	0.183	0.237	0.238	0.246
	0.16885	0.17018	0.17573	0.17638	0.18021	0.18185	0.18304	0.23670	0.23803	0.24569
0	4.471E-04	4.177E-04	4.175E-04	4.147E-04	4.143E-04	4.121E-04	4.114E-04	4.091E-04	4.011E-04	4.002E-04
	0.247	0.305	0.324	0.331	0.389	0.408	0.446	0.450	0.477	0.482
	0.24709	0.30459	0.32376	0.33142	0.38892	0.40808	0.44641	0.45025	0.47708	0.48178

Table 2.7-11 PAVAN Results for χ/Q Values at the EAB

0	3.977E-04	3.913E-04	3.863E-04	3.834E-04	3.827E-04	3.799E-04	3.776E-04	3.758E-04	3.739E-04	3.720E-04
	0.497	0.501	0.520	0.524	0.547	0.566	0.570	0.581	0.589	0.595
	0.49711	0.50095	0.52011	0.52395	0.54694	0.56611	0.56984	0.58134	0.58901	0.59479
0	3.672E-04	3.665E-04	3.635E-04	3.627E-04	3.627E-04	3.590E-04	3.560E-04	3.539E-04	3.533E-04	3.437E-04
	0.602	0.614	0.618	0.628	0.651	0.653	0.656	0.657	0.662	0.664
	0.60246	0.61377	0.61790	0.62810	0.65110	0.65267	0.65591	0.65734	0.66168	0.66367
0	3.290E-04	3.269E-04	3.240E-04	3.132E-04	3.123E-04	3.107E-04	3.090E-04	3.078E-04	3.041E-04	3.008E-04
	0.759	0.786	0.788	0.799	0.802	0.851	0.863	0.867	0.871	0.897
	0.75949	0.78633	0.78783	0.79933	0.80164	0.85147	0.86296	0.86680	0.87063	0.89746
0	2.850E-04	2.833E-04	2.785E-04	2.765E-04	2.754E-04	2.743E-04	2.727E-04	2.721E-04	2.651E-04	2.644E-04
	0.917	0.919	1.091	1.118	1.137	1.222	1.249	1.272	1.291	1.295
	0.91663	.91889	1.09138	1.11821	1.13737	1.22170	1.24853	1.27153	1.29070	1.29453
0	2.620E-04	2.609E-04	2.601E-04	2.575E-04	2.575E-04	2.568E-04	2.557E-04	2.556E-04	2.552E-04	2.529E-04
	1.297	1.301	1.303	1.452	1.455	1.482	1.483	1.506	1.567	1.583
	1.29749	1.30132	1.30267	1.45216	1.45487	1.48171	1.48307	1.50607	1.56740	1.58273
0	2.506E-04	2.505E-04	2.493E-04	2.492E-04	2.486E-04	2.472E-04	2.472E-04	2.469E-04	2.467E-04	2.467E-04
	1.602	1.613	1.652	1.698	1.709	1.713	1.744	1.745	1.817	1.863
	1.60190	1.61340	1.65173	1.69772	1.70922	1.71306	1.74372	1.74456	1.81739	1.86338
0	2.441E-04	2.421E-04	2.418E-04	2.407E-04	2.406E-04	2.402E-04	2.337E-04	2.321E-04	2.309E-04	2.302E-04
	1.898	1.952	1.982	1.998	2.024	2.055	2.078	2.082	2.090	2.091
	1.89788	1.95154	1.98221	1.99754	2.02437	2.05504	2.07803	2.08228	2.08995	2.09146

Table 2.7-11 PAVAN Results for χ/Q Values at the EAB

0	2.280E-04	2.203E-04	2.203E-04	2.203E-04	2.180E-04	2.177E-04	2.142E-04	2.123E-04	2.107E-04	2.088E-04
	2.103	2.114	2.137	2.138	2.192	2.200	2.208	2.223	2.230	2.571
	2.10296	2.11446	2.13745	2.13806	2.19173	2.19955	2.20789	2.22322	2.22953	2.57067
0	2.088E-04	2.083E-04	2.074E-04	2.057E-04	2.045E-04	2.027E-04	2.023E-04	1.988E-04	1.983E-04	1.974E-04
	2.577	2.584	2.618	2.687	2.699	2.737	2.741	2.768	2.776	2.814
	2.57721	2.58376	2.61825	2.68725	2.69875	2.73708	2.74135	2.76818	2.77584	2.81417
0	1.962E-04	1.957E-04	1.931E-04	1.927E-04	1.917E-04	1.914E-04	1.900E-04	1.879E-04	1.870E-04	1.847E-04
	2.815	2.819	3.279	3.291	3.314	3.433	3.440	3.456	3.482	3.486
	2.81545	2.81929	3.27925	3.29075	3.31375	3.43257	3.44024	3.45557	3.48240	3.48623
0	1.836E-04	1.814E-04	1.813E-04	1.799E-04	1.782E-04	1.768E-04	1.751E-04	1.712E-04	1.686E-04	1.671E-04
	3.502	3.594	3.624	3.625	3.644	3.648	3.656	3.694	3.759	4.089
	3.50157	3.59356	3.62422	3.62493	3.64410	3.64793	3.65560	3.69393	3.75909	4.08873
0	1.662E-04	1.659E-04	1.648E-04	1.646E-04	1.645E-04	1.644E-04	1.636E-04	1.635E-04	1.627E-04	1.614E-04
	4.231	4.246	4.334	4.365	4.376	4.522	4.545	4.572	4.614	4.721
	4.23055	4.24589	4.33404	4.36471	4.37621	4.52186	4.54486	4.57169	4.61386	4.72118
0	1.604E-04	1.602E-04	1.591E-04	1.586E-04	1.578E-04	1.571E-04	1.565E-04	1.558E-04	1.545E-04	1.539E-04
	4.760	4.836	4.875	4.878	4.913	4.914	4.930	4.979	5.428	5.435
	4.75951	4.83617	4.87450	4.87834	4.91283	4.91419	4.92952	4.97935	5.42782	5.43548
0	1.534E-04	1.531E-04	1.520E-04	1.503E-04	1.498E-04	1.496E-04	1.481E-04	1.469E-04	1.461E-04	1.456E-04
	5.451	5.554	5.600	5.604	5.612	5.635	5.688	5.742	5.744	5.786
	5.45082	5.55431	5.60031	5.60414	5.61180	5.63480	5.68846	5.74213	5.74381	5.78597

Table 2.7-11 PAVAN Results for χ/Q Values at the EAB

0	1.451E-04	1.434E-04	1.433E-04	1.420E-04	1.416E-04	1.416E-04	1.408E-04	1.407E-04	1.393E-04	1.392E-04
	5.809	5.811	5.853	5.887	5.937	6.002	6.006	6.007	6.009	6.154
	5.80897	5.81074	5.85290	5.88740	5.93723	6.00239	6.00622	6.00710	6.00863	6.15428
0	1.389E-04	1.382E-04	1.377E-04	1.376E-04	1.375E-04	1.371E-04	1.361E-04	1.343E-04	1.326E-04	1.322E-04
	6.155	6.163	6.167	6.209	6.213	6.236	6.377	6.378	6.397	6.409
	6.15514	6.16281	6.16664	6.20881	6.21264	6.23564	6.37746	6.37817	6.39733	6.40883
0	1.308E-04	1.304E-04	1.288E-04	1.284E-04	1.284E-04	1.278E-04	1.276E-04	1.265E-04	1.253E-04	1.253E-04
	6.428	6.436	6.654	6.738	6.876	6.892	6.922	7.133	7.137	7.156
	6.42800	6.43566	6.65415	6.73847	6.87646	6.89179	6.92246	7.13328	7.13711	7.15627
0	1.250E-04	1.246E-04	1.246E-04	1.236E-04	1.233E-04	1.224E-04	1.223E-04	1.221E-04	1.216E-04	1.210E-04
	7.168	7.172	7.551	7.693	7.980	7.984	7.992	8.069	8.092	8.218
	7.16777	7.17161	7.55108	7.69290	7.98038	7.98421	7.99187	8.06853	8.09153	8.21802
0	1.209E-04	1.203E-04	1.201E-04	1.191E-04	1.188E-04	1.179E-04	1.168E-04	1.167E-04	1.159E-04	1.147E-04
	8.237	8.318	8.506	8.509	8.574	8.601	8.686	8.747	8.770	8.774
	8.23719	8.31768	8.50550	8.50933	8.57450	8.60133	8.68565	8.74698	8.76998	8.77381
0	1.139E-04	1.129E-04	1.129E-04	1.126E-04	1.121E-04	1.119E-04	1.102E-04	1.090E-04	1.088E-04	1.085E-04
	8.793	8.801	8.804	8.812	8.820	8.843	8.946	8.962	9.130	9.149
	8.79298	8.80064	8.80448	8.81214	8.81981	8.84280	8.94630	8.96163	9.13028	9.14945
0	1.068E-04	1.062E-04	1.052E-04	1.052E-04	1.044E-04	1.044E-04	1.037E-04	1.029E-04	1.027E-04	1.023E-04
	9.157	9.295	9.395	9.399	9.464	9.502	9.517	9.563	9.682	9.694
	9.15711	9.29510	9.39476	9.39859	9.46376	9.50209	9.51742	9.56341	9.68224	9.69374

Table 2.7-11 PAVAN Results for χ/Q Values at the EAB

0	1.014E-04	1.012E-04	9.988E-05	9.969E-05	9.942E-05	9.935E-05	9.887E-05	9.871E-05	9.866E-05	9.784E-05
	9.732	9.943	9.970	10.357	10.391	10.395	10.495	10.702	11.028	11.047
	9.73207	9.94288	9.96972	10.35685	10.39135	10.39518	10.49484	10.70182	11.02763	11.04680
0	9.765E-05	9.758E-05	9.750E-05	9.709E-05	9.683E-05	9.657E-05	9.633E-05	9.626E-05	9.609E-05	9.586E-05
	11.120	11.131	11.139	11.396	11.583	11.737	11.852	11.940	12.078	12.097
	11.11962	11.13112	11.13879	11.39560	11.58342	11.73674	11.85173	11.93989	12.07788	12.09705
0	9.568E-05	9.552E-05	9.470E-05	9.465E-05	9.445E-05	9.443E-05	9.396E-05	9.348E-05	9.171E-05	9.134E-05
	12.132	12.247	12.254	12.427	12.442	12.615	12.618	12.752	12.902	12.906
	12.13155	12.24654	12.25420	12.42669	12.44202	12.61451	12.61834	12.75250	12.90198	12.90582
0	9.070E-05	9.067E-05	8.908E-05	8.894E-05	8.842E-05	8.814E-05	8.755E-05	8.693E-05	8.663E-05	8.558E-05
	12.982	13.013	13.163	13.193	13.301	13.362	13.534	13.623	13.642	13.718
	12.98248	13.01314	13.16263	13.19330	13.30062	13.36195	13.53444	13.62259	13.64176	13.71842
0	8.493E-05	8.431E-05	8.395E-05	8.308E-05	8.239E-05	8.222E-05	8.173E-05	8.157E-05	8.137E-05	8.069E-05
	13.826	13.941	13.987	14.240	14.320	14.604	14.623	14.646	14.723	14.872
	13.82575	13.94074	13.98673	14.23971	14.32021	14.60385	14.62302	14.64602	14.72268	14.87216
0	8.022E-05	8.008E-05	7.965E-05	7.947E-05	7.892E-05	7.828E-05	7.790E-05	7.706E-05	7.602E-05	7.491E-05
	14.914	14.945	14.949	14.956	15.148	15.275	15.367	15.497	15.512	15.547
	14.91433	14.94499	14.94882	14.95649	15.14814	15.27463	15.36662	15.49695	15.51228	15.54678
0	7.403E-05	7.345E-05	7.282E-05	7.164E-05	7.126E-05	7.121E-05	7.098E-05	7.082E-05	7.078E-05	7.074E-05
	15.907	15.968	16.474	16.800	16.946	16.953	17.344	17.655	17.774	17.946
	15.90708	15.96841	16.47437	16.80018	16.94583	16.95350	17.34447	17.65494	17.77377	17.94625

Table 2.7-11 PAVAN Results for χ/Q Values at the EAB

0	7.060E-05	7.004E-05	6.999E-05	6.977E-05	6.954E-05	6.878E-05	6.803E-05	6.716E-05	6.674E-05	6.670E-05
	17.954	18.383	18.422	18.425	18.636	18.901	18.962	19.092	19.104	19.200
	17.95392	18.38322	18.42155	18.42538	18.63620	18.90068	18.96201	19.09233	19.10383	19.19966
0	6.623E-05	6.540E-05	6.500E-05	6.426E-05	6.422E-05	6.419E-05	6.380E-05	6.336E-05	6.323E-05	6.316E-05
	19.219	19.223	19.257	19.295	19.391	19.437	19.449	19.453	19.560	19.698
	19.21882	19.22266	19.25715	19.29548	19.39131	19.43731	19.44880	19.45264	19.55996	19.69795
0	6.314E-05	6.313E-05	6.297E-05	6.262E-05	6.255E-05	6.244E-05	6.240E-05	6.231E-05	6.211E-05	6.179E-05
	20.005	20.070	20.097	20.292	20.369	20.376	20.476	20.714	20.718	20.821
	20.00459	20.06976	20.09659	20.29207	20.36873	20.37640	20.47606	20.71370	20.71754	20.82103
0	6.166E-05	6.143E-05	6.117E-05	6.103E-05	6.089E-05	6.052E-05	6.050E-05	6.031E-05	6.016E-05	6.006E-05
	21.239	21.258	21.308	21.396	21.446	21.768	21.806	21.971	22.082	22.117
	21.23883	21.25800	21.30783	21.39598	21.44581	21.76779	21.80612	21.97094	22.08210	22.11659
0	5.993E-05	5.973E-05	5.961E-05	5.938E-05	5.933E-05	5.923E-05	5.915E-05	5.897E-05	5.895E-05	5.893E-05
	22.201	22.504	22.531	22.722	22.929	23.370	23.378	23.489	23.696	23.703
	22.20092	22.50373	22.53056	22.72221	22.92920	23.37000	23.37766	23.48882	23.69580	23.70347
0	5.872E-05	5.852E-05	5.842E-05	5.836E-05	5.825E-05	5.822E-05	5.795E-05	5.788E-05	5.773E-05	5.750E-05
	23.715	23.826	24.029	24.401	24.880	24.919	25.122	25.133	25.168	25.179
	23.71497	23.82613	24.02928	24.40108	24.88021	24.91854	25.12169	25.13319	25.16769	25.17919
0	5.737E-05	5.731E-05	5.703E-05	5.697E-05	5.679E-05	5.666E-05	5.635E-05	5.597E-05	5.591E-05	5.537E-05
	25.455	25.835	25.842	25.854	26.241	26.666	26.747	26.870	26.873	26.896
	25.45517	25.83464	25.84231	25.85381	26.24094	26.66641	26.74690	26.86956	26.87339	26.89639

Table 2.7-11 PAVAN Results for χ/Q Values at the EAB

0	5.509E-05	5.502E-05	5.442E-05	5.363E-05	5.341E-05	5.336E-05	5.308E-05	5.304E-05	5.261E-05	5.225E-05
	27.015	27.230	27.253	27.491	27.586	27.763	28.131	28.150	28.338	28.445
	27.01522	27.22987	27.25286	27.49051	27.58634	27.76266	28.13063	28.14979	28.33761	28.44494
0	5.218E-05	5.140E-05	5.093E-05	5.069E-05	4.995E-05	4.994E-05	4.982E-05	4.969E-05	4.968E-05	4.943E-05
	28.663	29.166	29.258	29.269	29.311	29.392	29.472	29.495	29.618	29.629
	28.66342	29.16555	29.25754	29.26904	29.31120	29.39170	29.47219	29.49519	29.61785	29.62935
0	4.936E-05	4.894E-05	4.875E-05	4.855E-05	4.834E-05	4.816E-05	4.785E-05	4.776E-05	4.735E-05	4.732E-05
	30.078	30.174	30.323	30.649	30.653	30.814	30.898	31.255	31.393	31.669
	30.07781	30.17364	30.32313	30.64893	30.65277	30.81376	30.89808	31.25455	31.39254	31.66852
0	4.723E-05	4.722E-05	4.698E-05	4.694E-05	4.596E-05	4.585E-05	4.567E-05	4.454E-05	4.447E-05	4.421E-05
	31.776	32.082	32.094	32.098	32.266	32.420	32.496	32.864	33.052	33.508
	31.77584	32.08249	32.09398	32.09782	32.26647	32.41979	32.49645	32.86442	33.05224	33.50837
0	4.395E-05	4.378E-05	4.347E-05	4.313E-05	4.273E-05	4.273E-05	4.243E-05	4.224E-05	4.211E-05	4.204E-05
	33.589	34.651	35.314	35.341	35.525	35.540	35.559	35.563	35.590	35.812
	33.58886	34.65061	35.31373	35.34056	35.52454	35.53988	35.55904	35.56287	35.58971	35.81202
0	4.198E-05	4.162E-05	4.120E-05	4.078E-05	4.042E-05	4.034E-05	3.982E-05	3.981E-05	3.974E-05	3.946E-05
	36.188	36.226	36.230	36.326	36.333	36.337	36.345	36.383	36.594	36.858
	36.18766	36.22599	36.22982	36.32565	36.33332	36.33715	36.34482	36.38315	36.59396	36.85844
0	3.915E-05	3.914E-05	3.900E-05	3.828E-05	3.788E-05	3.780E-05	3.778E-05	3.768E-05	3.746E-05	3.727E-05
	36.904	37.579	37.824	37.943	38.139	38.158	38.277	39.147	39.450	41.443
	36.90444	37.57906	37.82437	37.94320	38.13868	38.15784	38.27667	39.14677	39.44958	41.44276

Table 2.7-11 PAVAN Results for χ/Q Values at the EAB

0	3.727E-05	3.702E-05	3.698E-05	3.692E-05	3.662E-05	3.654E-05	3.641E-05	3.599E-05	3.582E-05	3.561E-05
	41.477	42.413	43.785	43.789	43.984	44.045	44.647	44.666	45.214	45.441
	41.47725	42.41251	43.78474	43.78857	43.98406	44.04539	44.64717	44.66634	45.21446	45.44061
0	3.558E-05	3.549E-05	3.541E-05	3.536E-05	3.521E-05	3.450E-05	3.439E-05	3.418E-05	3.416E-05	3.405E-05
	46.150	46.660	47.062	47.066	47.070	47.081	47.257	47.269	47.338	48.047
	46.14972	46.65952	47.06199	47.06582	47.06965	47.08115	47.25747	47.26897	47.33796	48.04708
0	3.358E-05	3.354E-05	3.341E-05	3.335E-05	3.319E-05	3.319E-05	3.312E-05	3.294E-05	3.291E-05	3.279E-05
	48.576	48.603	49.676	50.240	50.274	51.616	51.903	53.666	54.559	54.970
	48.57603	48.60287	49.67612	50.23957	50.27407	51.61563	51.90311	53.66631	54.55940	54.96954
0	3.250E-05	3.245E-05	3.237E-05	3.201E-05	3.190E-05	3.178E-05	3.168E-05	3.157E-05	3.156E-05	3.152E-05
	55.211	56.089	56.629	56.687	56.809	56.813	56.852	57.032	57.473	57.695
	55.21102	56.08878	56.62924	56.68674	56.80939	56.81323	56.85156	57.03171	57.47251	57.69483
0	3.148E-05	3.138E-05	3.136E-05	3.130E-05	3.122E-05	3.090E-05	3.087E-05	3.068E-05	3.059E-05	3.045E-05
	57.756	58.615	58.634	59.006	59.067	59.094	59.650	59.903	60.117	60.198
	57.75616	58.61476	58.63392	59.00573	59.06705	59.09388	59.64967	59.90265	60.11730	60.19780
0	3.031E-05	3.029E-05	3.026E-05	3.024E-05	3.012E-05	3.002E-05	2.989E-05	2.981E-05	2.980E-05	2.936E-05
	60.225	60.800	60.803	60.976	60.999	61.467	61.926	61.938	62.084	62.202
	60.22463	60.79958	60.80342	60.97590	60.99890	61.46653	61.92649	61.93799	62.08365	62.20247
0	2.934E-05	2.904E-05	2.873E-05	2.871E-05	2.868E-05	2.847E-05	2.817E-05	2.809E-05	2.805E-05	2.795E-05
	62.287	63.843	64.107	64.272	64.399	64.479	64.483	64.648	64.740	64.778
	62.28680	63.84301	64.10749	64.27231	64.39880	64.47929	64.48312	64.64793	64.73993	64.77826

Table 2.7-12 PAVAN Results for χ/Q Values at the LPZ

Plant Name: North Anna ESP
Data Period: 1996–1998 JFD
Type of Release: Ground-Level Release
Source of Data: Onsite
Comments: Data period: 1/1/96 - 12/31/98
Program: PAVAN, 10/76, 8/79 Revision, Implementation of RG 1.145
Low Population Zone Calculations:
Five Percent Overall Site Limit.
Building wake credit is not included.
Correction factors used in the annual average calculations.

Meteorological Instrumentation
Wind Sensors Height: 32.8 ft
ΔT Heights: 32.8 ft–158.9 ft

Below are printed the ordered values of χ/Q and the frequency with which that value is reached or exceeded.
The top number is the χ/Q. The middle number is the frequency normalized to this sector.
The third number is the frequency with respect to all time.

0	1.237E-04	8.410E-05	5.981E-05	5.607E-05	4.205E-05	4.067E-05	3.364E-05	2.803E-05	2.711E-05	2.701E-05
	.061	.353	.406	1.108	2.307	2.656	3.714	4.190	5.136	5.198
	.06133	.35264	.40630	1.10775	2.30749	2.65629	3.71421	4.18951	5.13627	5.19759
0	2.102E-05	2.033E-05	1.837E-05	1.776E-05	1.627E-05	1.492E-05	1.356E-05	1.256E-05	1.225E-05	1.017E-05
	5.493	7.241	7.735	7.781	9.406	9.410	10.468	10.487	12.166	13.350
	5.49274	7.24060	7.73506	7.78106	9.40626	9.41009	10.46801	10.48718	12.16604	13.35045
0	9.185E-06	8.543E-06	7.847E-06	7.348E-06	6.341E-06	6.123E-06	5.695E-06	5.303E-06	4.592E-06	4.550E-06
	16.574	16.647	17.149	20.710	20.752	23.634	24.102	24.114	29.292	29.319
	16.57403	16.64686	17.14898	20.70987	20.75204	23.63448	24.10211	24.11361	29.29204	29.31887
0	4.271E-06	3.417E-06	3.375E-06	2.848E-06	2.668E-06	2.482E-06	2.206E-06	2.136E-06	1.880E-06	1.493E-06
	30.814	33.443	39.703	42.390	44.915	44.935	45.839	52.961	53.226	66.932
	30.81375	33.44321	39.70255	42.38952	44.91549	44.93466	45.83926	52.96103	53.22552	66.93244

Table 2.7-12 PAVAN Results for χ/Q Values at the LPZ

0	1.410E-06	1.245E-06	1.151E-06	1.128E-06	1.026E-06	9.388E-07	9.339E-07	7.932E-07	7.471E-07	6.366E-07
	67.113	67.120	75.844	75.894	75.917	80.632	80.705	82.610	82.824	82.828
	67.11259	67.12025	75.84424	75.89405	75.91705	80.63168	80.70450	82.60951	82.82416	82.82799
0	6.226E-07	5.949E-07	4.759E-07	4.670E-07	4.327E-07	4.244E-07	3.183E-07	3.113E-07	2.546E-07	2.335E-07
	83.089	84.070	84.323	85.189	85.231	85.247	85.342	86.868	87.182	88.114
	83.08863	84.06989	84.32287	85.18914	85.23130	85.24663	85.34245	86.86799	87.18228	88.11370
0	2.122E-07	1.868E-07	1.592E-07	1.557E-07	1.167E-07	1.061E-07	9.339E-08	8.490E-08	7.958E-08	6.366E-08
	88.512	89.221	90.789	91.234	91.506	95.143	95.182	95.239	97.581	98.758
	88.51231	89.22141	90.78912	91.23375	91.50589	95.14342	95.18176	95.23925	97.58121	98.75794
0	5.305E-08	3.979E-08	3.183E-08	2.894E-08						
	99.494	99.889	99.969	100.000						
	99.49386	99.88866	99.96915	99.99981						

Table 2.7-13 ESP Application Nearby Sensitive Receptors

	Nearest Resident		Nearest Site Boundary		Milk* Cow	Meat Animal		Milk* Goat	Veg. Garden 500 ft^2	
Sector	(mile)	(km)	(mile)	(km)		(mile)	(km)		(mile)	(km)
N	1.48	2.38	0.87	1.40		2.18	3.51		1.78	2.86
NNE	0.96	1.54	0.88	1.42		1.56	2.51		1.66	2.67
NE	0.94	1.51	0.90	1.45		1.44	2.32		0.94	1.51
ENE	2.18	3.51	0.91	1.47		2.58	4.15		2.18	3.51
E	1.38	2.22	0.89	1.43		3.58	5.76		1.38	2.22
ESE	1.77	2.85	0.88	1.42		None	None		3.57	5.74
SE	1.37	2.20	0.83	1.34		1.37	2.20		1.37	2.20
SSE	0.91	1.46	0.73	1.17		2.71	4.36		1.21	1.95
S	1.01	1.63	0.62	0.99		None	None		1.11	1.79
SSW	1.1	1.77	0.57	0.92		1.90	3.06		1.50	2.41
SW	2.78	4.47	0.54	0.87		None	None		2.78	4.47
WSW	1.22	1.96	0.55	0.88		1.22	1.96		1.52	2.45
W	1.30	2.09	0.54	0.87		4.20	6.76		4.80	7.72
WNW	0.98	1.58	0.56	0.90		3.98	6.40		None	None
NW	0.88	1.42	0.62	0.99		None	None		0.98	1.58
NNW	0.93	1.50	0.72	1.16		1.93	3.11		1.13	1.82

Note: No milk cow or goats within a 5-mile radius of the NAPS.
Source: Reference 35.

Table 2.7-14 XOQDOQ Predicted Maximum χ/Q and D/Q Values at Specific Points of Interest

Type of Location	Direction from Site	Distance (miles)	χ/Q (No Decay)	χ/Q (2.26 Day Decay)	χ/Q (8 Day Decay)	D/Q
Residence	NNE	0.96	2.4E-06	2.4E-06	2.1E-06	7.2E-09
EAB	ESE	0.88	3.7E-06	3.7E-06	3.3E-06	1.2E-08 [a]
Meat Animal	SE	1.37	1.4E-06	1.4E-06	1.2E-06	3.1E-09 [b]
Veg. Garden	NE	0.94	2.0E-06	2.0E-06	1.8E-06	6.0E-09

Notes:
χ/Q – sec/m^3
D/Q – $1/m^2$

a. direction = south

b. direction = north-northeast

Table 2.7-15 XOQDOQ Predicted Maximum Annual Averages (Ground-Level Release)

No Decay Undepleted

	Distance in Miles From the Site										
ESE	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
χ/Q (s/m^3)	2.685E-5	8.740E-6	4.697E-6	3.103E-6	1.742E-6	1.163E-6	8.527E-7	6.634E-7	5.373E-7	4.482E-7	3.822E-7
	Distance in Miles From the Site										
ESE	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00
χ/Q (s/m^3)	3.317E-7	1.934E-7	1.325E-7	7.833E-8	5.418E-8	4.079E-8	3.239E-8	2.668E-9	2.257E-8	1.948E-8	1.709E-8
	Segment Boundaries in Miles From the Site										
ESE	0.5 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 10	10 – 20	20 - 30	30 - 40	40 - 50	
χ/Q (s/m^3)	4.887E-6	1.787E-6	8.596E-7	5.394E-7	3.831E-7	1.971E-7	7.964E-8	4.100E-8	2.675E-8	1.951E-8	

2.26 Day Decay, Undepleted

	Distance in Miles From the Site										
ESE	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
χ/Q (s/m^3)	2.681E-5	8.712E-6	4.674E-6	3.083E-6	1.725E-6	1.148E-6	8.388E-7	6.504E-7	5.251E-7	4.365E-7	3.711E-7
	Distance in Miles From the Site										
ESE	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00
χ/Q (s/m^3)	3.210E-7	1.841E-7	1.241E-7	7.095E-8	4.750E-8	3.462E-8	2.662E-8	2.124E-8	1.740E-8	1.455E-8	1.237E-8
	Segment Boundaries in Miles From the Site										
ESE	0.5 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 10	10 – 20	20 - 30	30 - 40	40 - 50	
χ/Q (s/m^3)	4.864E-6	1.770E-6	8.458E-7	5.272E-7	3.719E-7	1.878E-7	7.233E-8	3.485E-8	2.131E-8	1.459E-8	

Table 2.7-15 XOQDOQ Predicted Maximum Annual Averages (Ground-Level Release)

8.0 Day Decay, Depleted

	Distance in Miles From the Site										
ESE	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
χ/Q (s/m^3)	2.540E-5	7.974E-6	4.180E-6	2.711E-6	1.475E-6	9.592E-7	6.875E-7	5.240E-7	4.166E-7	3.415E-7	2.866E-7
	Distance in Miles From the Site										
ESE	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00
χ/Q (s/m^3)	2.450E-7	1.344E-7	8.739E-8	4.735E-8	3.047E-8	2.153E-8	1.614E-8	1.261E-8	1.015E-8	8.357E-9	7.007E-9
	Segment Boundaries in Miles From the Site										
ESE	0.5 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 10	10 - 20	20 - 30	30 - 40	40 - 50	
χ/Q (s/m^3)	4.370E-6	1.521E-6	6.945E-7	4.187E-7	2.874E-7	1.381E-7	4.874E-8	2.176E-8	1.268E-8	8.388E-9	
Relative Deposition/Area											
	Distance in Miles from Site										
NNE	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
D/Q ($1/m^2$)	6.2570E-8	2.116E-8	1.086E-8	6.671E-9	3.326E-9	2.017E-9	1.364E-9	9.882E-10	7.514E-10	5.920E-10	4.793E-10
	Distance in Miles from Site										
NNE	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00
D/Q ($1/m^2$)	3.964E-10	1.943E-10	1.219E-10	6.161E-11	3.729E-11	2.500E-11	1.792E-11	1.345E-11	1.046E-11	8.355E-12	6.820E-12
	Segment Boundaries in Miles From the Site										
NNE	0.5 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 10	10 - 20	20 - 30	30 - 40	40 - 50	
D/Q ($1/m^2$)	1.129E-8	3.487E-9	1.388E-9	7.583E-10	4.820E-10	2.070E-10	6.420E-10	2.544E-11	1.359E-11	8.410E-12	

Table 2.7-16 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Specific Points of Interest (1996-98 Meteorological Data)

Ground-Level Release - No Purge Releases

Dir. From Site	Type of Location	Dist. (Mile)	χ/Q (sec/m^3) No Decay Undepleted	2.26 Day Decay Undepleted	8.0 Day Decay Depleted	D/Q (1/m^2)	Type of Location	Dist. (Mile)	χ/Q (sec/m^3) No Decay Undepleted	2.26 Day Decay Undepleted	8.0 Day Decay Depleted	D/Q (1/m^2)
S	Residences	1.01	1.10E-06	1.10E-06	9.40E-07	5.00E-09	S. B.	0.62	2.40E-06	2.40E-06	2.10E-06	1.20E-08
SSW	Residences	1.1	7.50E-07	7.50E-07	6.50E-07	2.90E-09	S. B.	0.57	2.10E-06	2.10E-06	1.90E-06	8.70E-09
SW	Residences	2.78	1.60E-07	1.60E-07	1.30E-07	4.80E-10	S. B.	0.54	2.10E-06	2.10E-06	1.90E-06	7.80E-09
WSW	Residences	1.22	5.40E-07	5.30E-07	4.60E-07	1.70E-09	S. B.	0.54	1.90E-06	1.90E-06	1.70E-06	6.70E-09
W	Residences	1.3	6.00E-07	5.90E-07	5.10E-07	1.80E-09	S. B.	0.54	2.30E-06	2.30E-06	2.10E-06	8.00E-09
WNW	Residences	0.98	8.00E-07	7.90E-07	7.00E-07	2.70E-09	S. B.	0.56	1.90E-06	1.90E-06	1.80E-06	7.00E-09
NW	Residences	0.88	9.70E-07	9.70E-07	8.60E-07	3.00E-09	S. B.	0.61	1.70E-06	1.70E-06	1.50E-06	5.40E-09
NNW	Residences	0.93	7.70E-07	7.70E-07	6.80E-07	2.00E-09	S. B.	0.72	1.10E-06	1.10E-06	1.00E-06	3.00E-09
N	Residences	1.48	9.70E-07	9.60E-07	8.20E-07	2.30E-09	S. B.	0.87	2.20E-06	2.20E-06	1.90E-06	5.80E-09
NNE	Residences	0.96	2.40E-06	2.40E-06	2.10E-06	7.20E-09	S. B.	0.88	2.70E-06	2.70E-06	2.40E-06	8.30E-09
NE	Residences	0.94	2.00E-06	2.00E-06	1.80E-06	6.00E-09	S. B.	0.9	2.10E-06	2.10E-06	1.90E-06	6.40E-09
ENE	Residences	2.18	3.50E-07	3.50E-07	2.90E-07	7.50E-10	S. B.	0.92	1.30E-06	1.30E-06	1.10E-06	3.40E-09
E	Residences	1.38	1.30E-06	1.30E-06	1.10E-06	2.30E-09	S. B.	0.89	2.60E-06	2.50E-06	2.30E-06	5.00E-09
ESE	Residences	1.77	1.40E-06	1.40E-06	1.20E-06	2.00E-09	S. B.	0.88	3.70E-06	3.70E-06	3.30E-06	6.70E-09
SE	Residences	1.37	1.40E-06	1.40E-06	1.20E-06	2.90E-09	S. B.	0.83	2.80E-06	2.80E-06	2.50E-06	6.70E-09
SSE	Residences	0.91	1.30E-06	1.30E-06	1.20E-06	5.10E-09	S. B.	0.72	1.90E-06	1.90E-06	1.70E-06	7.50E-09

Note: S. B. – Site Boundary; M. A. – Meat Animal; V. G. – Vegetable Garden

Table 2.7-16 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Specific Points of Interest (1996-98 Meteorological Data)

	Ground-Level Release - No Purge Releases										
			χ/Q (sec/m^3)						χ/Q (sec/m^3)			
Dir. From Site	Type of Location	Dist. (Mile)	No Decay Undepleted	2.26 Day Decay Undepleted	8.0 Day Decay Depleted	D/Q (1/m^2)	Type of Location	Dist. (Mile)	No Decay Undepleted	2.26 Day Decay Undepleted	8.0 Day Decay Depleted	D/Q (1/m^2)
S	M. A.	-	-	-	-	-	V. G.	1.11	9.30E-07	9.20E-07	8.10E-07	4.30E-09
SSW	M. A.	1.9	3.20E-07	3.20E-07	2.70E-07	1.10E-09	V. G.	1.5	4.60E-07	4.60E-07	3.90E-07	1.70E-09
SW	M. A.	-	-	-	-	-	V. G.	2.78	1.60E-07	1.60E-07	1.30E-07	4.80E-10
WSW	M. A.	1.22	5.40E-07	5.30E-07	4.60E-07	1.70E-09	V. G.	1.52	3.80E-07	3.80E-07	3.20E-07	1.20E-09
W	M. A.	4.2	1.00E-07	1.00E-07	7.70E-08	2.30E-10	V. G.	4.8	8.40E-08	8.20E-08	6.20E-08	1.80E-10
WNW	M. A.	3.98	9.50E-08	9.30E-08	7.30E-08	2.40E-10	V. G.	None	-	-	-	-
NW	M. A.	None	-	-	-	-	V. G.	0.98	8.20E-07	8.20E-07	7.20E-07	2.50E-09
NNW	M. A.	1.93	2.50E-07	2.50E-07	2.10E-07	5.60E-10	V. G.	1.13	5.70E-07	5.70E-07	4.90E-07	1.40E-09
N	M. A.	2.18	5.40E-07	5.30E-07	4.40E-07	1.20E-09	V. G.	1.78	7.30E-07	7.30E-07	6.10E-07	1.70E-09
NNE	M. A.	1.56	1.10E-06	1.10E-06	9.50E-07	3.10E-09	V. G.	1.66	1.00E-06	1.00E-06	8.60E-07	2.80E-09
NE	M. A.	1.44	1.00E-06	1.00E-06	8.90E-07	2.90E-09	V. G.	0.94	2.00E-06	2.00E-06	1.80E-06	6.00E-09
ENE	M. A.	2.58	2.80E-07	2.70E-07	2.20E-07	5.60E-10	V. G.	2.18	3.50E-07	3.50E-07	2.90E-07	7.50E-10
E	M. A.	3.58	3.40E-07	3.40E-07	2.70E-07	4.40E-10	V. G.	1.38	1.30E-06	1.30E-06	1.10E-06	2.30E-09
ESE	M. A.	None	-	-	-	-	V. G.	3.57	5.20E-07	5.10E-07	4.10E-07	5.90E-10
SE	M. A.	1.37	1.40E-06	1.40E-06	1.20E-06	2.90E-09	V. G.	1.37	1.40E-06	1.40E-06	1.20E-06	2.90E-09
SSE	M. A.	2.71	2.60E-07	2.50E-07	2.10E-07	7.70E-10	V. G.	1.21	8.60E-07	8.60E-07	7.40E-07	3.10E-09

Note: S. B. – Site Boundary; M. A. – Meat Animal; V. G. – Vegetable Garden

Table 2.7-17 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Distances Between 0.25 to 50 Miles No Decay, Undepleted

Ground Level Release - No Purge Releases

Annual Average χ/Q (sec/m^3) **Distance in Miles from the Site**

Sector	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	9.892E-06	3.343E-06	1.737E-06	1.099E-06	5.804E-07	3.710E-07	2.630E-07	1.990E-07	1.573E-07	1.285E-07	1.076E-07
SSW	7.733E-06	2.642E-06	1.380E-06	8.743E-07	4.630E-07	2.965E-07	2.105E-07	1.594E-07	1.262E-07	1.031E-07	8.641E-08
SW	6.892E-06	2.360E-06	1.235E-06	7.838E-07	4.158E-07	2.667E-07	1.896E-07	1.437E-07	1.139E-07	9.320E-08	7.815E-08
WSW	6.435E-06	2.194E-06	1.149E-06	7.299E-07	3.879E-07	2.491E-07	1.773E-07	1.346E-07	1.067E-07	8.740E-08	7.334E-08
W	7.894E-06	2.665E-06	1.399E-06	8.926E-07	4.777E-07	3.083E-07	2.203E-07	1.678E-07	1.335E-07	1.096E-07	9.221E-08
WNW	6.843E-06	2.320E-06	1.217E-06	7.739E-07	4.128E-07	2.660E-07	1.899E-07	1.446E-07	1.150E-07	9.437E-08	7.937E-08
NW	6.822E-06	2.367E-06	1.253E-06	7.999E-07	4.290E-07	2.776E-07	1.988E-07	1.517E-07	1.209E-07	9.942E-08	8.374E-08
NNW	5.763E-06	2.029E-06	1.080E-06	6.897E-07	3.706E-07	2.402E-07	1.723E-07	1.316E-07	1.050E-07	8.641E-08	7.284E-08
N	1.469E-05	5.213E-06	2.778E-06	1.771E-06	9.494E-07	6.142E-07	4.399E-07	3.357E-07	2.675E-07	2.200E-07	1.853E-07
NNE	1.868E-05	6.567E-06	3.500E-06	2.234E-06	1.198E-06	7.757E-07	5.558E-07	4.242E-07	3.382E-07	2.782E-07	2.344E-07
NE	1.523E-05	5.352E-06	2.854E-06	1.826E-06	9.817E-07	6.364E-07	4.564E-07	3.487E-07	2.782E-07	2.290E-07	1.930E-07
ENE	9.350E-06	3.256E-06	1.748E-06	1.126E-06	6.118E-07	3.995E-07	2.881E-07	2.211E-07	1.771E-07	1.463E-07	1.237E-07
E	1.774E-05	6.092E-06	3.305E-06	2.154E-06	1.188E-06	7.835E-07	5.696E-07	4.400E-07	3.543E-07	2.940E-07	2.497E-07
ESE	2.685E-05	8.740E-06	4.697E-06	3.103E-06	1.742E-06	1.163E-06	8.527E-07	6.634E-07	5.373E-07	4.482E-07	3.822E-07
SE	1.932E-05	6.168E-06	3.268E-06	2.151E-06	1.202E-06	8.001E-07	5.855E-07	4.548E-07	3.678E-07	3.064E-07	2.611E-07
SSE	1.049E-05	3.458E-06	1.807E-06	1.158E-06	6.243E-07	4.053E-07	2.910E-07	2.225E-07	1.776E-07	1.463E-07	1.234E-07

Table 2.7-17 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Distances Between 0.25 to 50 Miles No Decay, Undepleted

Ground Level Release - No Purge Releases

Annual Average χ/Q (sec/m^3)	Distance in Miles from the Site										
Sector	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	9.185E-08	5.021E-08	3.285E-08	1.820E-08	1.203E-08	8.748E-09	6.752E-09	5.430E-09	4.499E-09	3.814E-09	3.291E-09
SSW	7.380E-08	4.043E-08	2.649E-08	1.469E-08	9.713E-09	7.062E-09	5.450E-09	4.381E-09	3.629E-09	3.076E-09	2.653E-09
SW	6.680E-08	3.671E-08	2.412E-08	1.342E-08	8.899E-09	6.484E-09	5.013E-09	4.037E-09	3.348E-09	2.841E-09	2.453E-09
WSW	6.274E-08	3.459E-08	2.277E-08	1.272E-08	8.461E-09	6.180E-09	4.788E-09	3.863E-09	3.209E-09	2.727E-09	2.358E-09
W	7.905E-08	4.398E-08	2.916E-08	1.646E-08	1.103E-08	8.108E-09	6.314E-09	5.116E-09	4.267E-09	3.638E-09	3.156E-09
WNW	6.805E-08	3.789E-08	2.514E-08	1.422E-08	9.558E-09	7.041E-09	5.493E-09	4.458E-09	3.723E-09	3.177E-09	2.759E-09
NW	7.188E-08	4.017E-08	2.672E-08	1.515E-08	1.018E-08	7.497E-09	5.847E-09	4.743E-09	3.960E-09	3.379E-09	2.932E-09
NNW	6.257E-08	3.506E-08	2.336E-08	1.327E-08	8.922E-09	6.572E-09	5.126E-09	4.158E-09	3.471E-09	2.961E-09	2.570E-09
N	1.591E-07	8.890E-08	5.911E-08	3.347E-08	2.246E-08	1.652E-08	1.286E-08	1.042E-08	8.691E-09	7.407E-09	6.422E-09
NNE	2.012E-07	1.126E-07	7.492E-08	4.248E-08	2.854E-08	2.100E-08	1.637E-08	1.327E-08	1.108E-08	9.446E-09	8.194E-09
NE	1.658E-07	9.287E-08	6.186E-08	3.512E-08	2.362E-08	1.739E-08	1.357E-08	1.101E-08	9.187E-09	7.837E-09	6.802E-09
ENE	1.065E-07	6.033E-08	4.050E-08	2.325E-08	1.575E-08	1.167E-08	9.148E-09	7.451E-09	6.242E-09	5.342E-09	4.650E-09
E	2.158E-07	1.239E-07	8.400E-08	4.888E-08	3.344E-08	2.496E-08	1.968E-08	1.611E-08	1.356E-08	1.165E-08	1.017E-08
ESE	3.317E-07	1.934E-07	1.325E-07	7.833E-08	5.418E-08	4.079E-08	3.239E-08	2.668E-08	2.257E-08	1.948E-08	1.709E-08
SE	2.264E-07	1.317E-07	9.011E-08	5.318E-08	3.676E-08	2.767E-08	2.198E-08	1.810E-08	1.531E-08	1.322E-08	1.160E-08
SSE	1.061E-07	5.969E-08	3.991E-08	2.281E-08	1.545E-08	1.144E-08	8.972E-09	7.312E-09	6.130E-09	5.250E-09	4.573E-09

Table 2.7-17 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Distances Between 0.25 to 50 Miles No Decay, Undepleted

Ground Level Release - No Purge Releases

χ/Q (sec/m^3) for each segment	**Segment Boundaries in Miles from the Site**									
Direction From Site	0.5–1	1–2	2–3	3–4	4–5	5–10	10–20	20–30	30–40	40–50
S	1.810E-06	6.025E-07	2.662E-07	1.583E-07	1.080E-07	5.175E-08	1.871E-08	8.825E-09	5.453E-09	3.823E-09
SSW	1.436E-06	4.804E-07	2.130E-07	1.269E-07	8.669E-08	4.165E-08	1.510E-08	7.124E-09	4.400E-09	3.083E-09
SW	1.285E-06	4.313E-07	1.918E-07	1.145E-07	7.841E-08	3.780E-08	1.379E-08	6.540E-09	4.053E-09	2.848E-09
WSW	1.195E-06	4.022E-07	1.794E-07	1.073E-07	7.358E-08	3.559E-08	1.306E-08	6.232E-09	3.878E-09	2.733E-09
W	1.455E-06	4.946E-07	2.228E-07	1.342E-07	9.249E-08	4.519E-08	1.687E-08	8.170E-09	5.135E-09	3.646E-09
WNW	1.265E-06	4.278E-07	1.921E-07	1.156E-07	7.962E-08	3.893E-08	1.458E-08	7.093E-09	4.473E-09	3.184E-09
NW	1.299E-06	4.441E-07	2.010E-07	1.215E-07	8.399E-08	4.124E-08	1.551E-08	7.553E-09	4.760E-09	3.386E-09
NNW	1.117E-06	3.836E-07	1.741E-07	1.055E-07	7.306E-08	3.598E-08	1.358E-08	6.620E-09	4.173E-09	2.967E-09
N	2.872E-06	9.831E-07	4.447E-07	2.689E-07	1.859E-07	9.126E-08	3.428E-08	1.664E-08	1.046E-08	7.422E-09
NNE	3.619E-06	1.241E-06	5.618E-07	3.399E-07	2.351E-07	1.155E-07	4.349E-08	2.116E-08	1.332E-08	9.465E-09
NE	2.952E-06	1.016E-06	4.613E-07	2.796E-07	1.936E-07	9.529E-08	3.595E-08	1.752E-08	1.104E-08	7.854E-09
ENE	1.807E-06	6.318E-07	2.910E-07	1.779E-07	1.240E-07	6.179E-08	2.375E-08	1.175E-08	7.475E-09	5.353E-09
E	3.413E-06	1.223E-06	5.748E-07	3.558E-07	2.503E-07	1.266E-07	4.982E-08	2.511E-08	1.616E-08	1.167E-08
ESE	4.887E-06	1.787E-06	8.596E-07	5.394E-07	3.831E-07	1.971E-07	7.964E-08	4.100E-08	2.675E-08	1.951E-08
SE	3.416E-06	1.234E-06	5.904E-07	3.693E-07	2.617E-07	1.343E-07	5.409E-08	2.782E-08	1.815E-08	1.324E-08
SSE	1.885E-06	6.456E-07	2.941E-07	1.785E-07	1.238E-07	6.122E-08	2.334E-08	1.152E-08	7.336E-09	5.260E-09

Table 2.7-18 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Distances Between 0.25 to 50 Miles 2.260-Day Decay, Undepleted

Ground Level Release - No Purge Releases

Annual Average χ/Q (sec/m^3) **Distance in Miles from the Site**

Sector	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	9.882E-06	3.336E-06	1.732E-06	1.094E-06	5.768E-07	3.679E-07	2.603E-07	1.964E-07	1.550E-07	1.263E-07	1.055E-07
SSW	7.724E-06	2.636E-06	1.375E-06	8.704E-07	4.598E-07	2.938E-07	2.081E-07	1.572E-07	1.241E-07	1.013E-07	8.462E-08
SW	6.884E-06	2.355E-06	1.231E-06	7.800E-07	4.128E-07	2.641E-07	1.873E-07	1.417E-07	1.120E-07	9.140E-08	7.644E-08
WSW	6.427E-06	2.189E-06	1.145E-06	7.262E-07	3.849E-07	2.466E-07	1.750E-07	1.325E-07	1.048E-07	8.560E-08	7.164E-08
W	7.884E-06	2.658E-06	1.394E-06	8.880E-07	4.739E-07	3.051E-07	2.174E-07	1.651E-07	1.310E-07	1.073E-07	9.001E-08
WNW	6.834E-06	2.315E-06	1.213E-06	7.700E-07	4.097E-07	2.633E-07	1.875E-07	1.423E-07	1.129E-07	9.244E-08	7.754E-08
NW	6.814E-06	2.361E-06	1.248E-06	7.960E-07	4.258E-07	2.748E-07	1.963E-07	1.494E-07	1.187E-07	9.741E-08	8.183E-08
NNW	5.755E-06	2.023E-06	1.075E-06	6.859E-07	3.675E-07	2.375E-07	1.698E-07	1.294E-07	1.029E-07	8.446E-08	7.099E-08
N	1.467E-05	5.198E-06	2.767E-06	1.762E-06	9.415E-07	6.074E-07	4.338E-07	3.301E-07	2.623E-07	2.151E-07	1.807E-07
NNE	1.866E-05	6.550E-06	3.486E-06	2.222E-06	1.189E-06	7.675E-07	5.484E-07	4.175E-07	3.319E-07	2.723E-07	2.288E-07
NE	1.521E-05	5.339E-06	2.843E-06	1.816E-06	9.740E-07	6.298E-07	4.505E-07	3.432E-07	2.731E-07	2.242E-07	1.885E-07
ENE	9.337E-06	3.247E-06	1.741E-06	1.120E-06	6.065E-07	3.949E-07	2.840E-07	2.173E-07	1.735E-07	1.429E-07	1.205E-07
E	1.772E-05	6.073E-06	3.289E-06	2.140E-06	1.177E-06	7.738E-07	5.608E-07	4.318E-07	3.466E-07	2.868E-07	2.427E-07
ESE	2.681E-05	8.712E-06	4.674E-06	3.083E-06	1.725E-06	1.148E-06	8.388E-07	6.504E-07	5.251E-07	4.365E-07	3.711E-07
SE	1.929E-05	6.149E-06	3.253E-06	2.137E-06	1.191E-06	7.898E-07	5.761E-07	4.460E-07	3.595E-07	2.985E-07	2.535E-07
SSE	1.048E-05	3.450E-06	1.800E-06	1.152E-06	6.194E-07	4.010E-07	2.871E-07	2.189E-07	1.743E-07	1.432E-07	1.204E-07

Table 2.7-18 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Distances Between 0.25 to 50 Miles 2.260-Day Decay, Undepleted

Ground Level Release - No Purge Releases

Annual Average χ/Q (sec/m^3)	Distance in Miles from the Site										
Sector	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	8.989E-08	4.859E-08	3.144E-08	1.702E-08	1.100E-08	7.823E-09	5.903E-09	4.641E-09	3.760E-09	3.117E-09	2.630E-09
SSW	7.211E-08	3.904E-08	2.528E-08	1.368E-08	8.832E-09	6.268E-09	4.723E-09	3.707E-09	2.999E-09	2.481E-09	2.091E-09
SW	6.518E-08	3.538E-08	2.295E-08	1.245E-08	8.048E-09	5.717E-09	4.310E-09	3.384E-09	2.737E-09	2.265E-09	1.908E-09
WSW	6.112E-08	3.325E-08	2.160E-08	1.175E-08	7.604E-09	5.407E-09	4.078E-09	3.203E-09	2.591E-09	2.144E-09	1.806E-09
W	7.696E-08	4.223E-08	2.761E-08	1.516E-08	9.882E-09	7.064E-09	5.351E-09	4.219E-09	3.423E-09	2.840E-09	2.398E-09
WNW	6.631E-08	3.644E-08	2.386E-08	1.314E-08	8.600E-09	6.169E-09	4.688E-09	3.706E-09	3.015E-09	2.508E-09	2.122E-09
NW	7.006E-08	3.865E-08	2.537E-08	1.401E-08	9.174E-09	6.583E-09	5.003E-09	3.955E-09	3.218E-09	2.677E-09	2.265E-09
NNW	6.081E-08	3.359E-08	2.206E-08	1.217E-08	7.957E-09	5.697E-09	4.320E-09	3.408E-09	2.766E-09	2.295E-09	1.938E-09
N	1.547E-07	8.524E-08	5.588E-08	3.077E-08	2.008E-08	1.436E-08	1.088E-08	8.579E-09	6.961E-09	5.774E-09	4.873E-09
NNE	1.959E-07	1.081E-07	7.096E-08	3.916E-08	2.561E-08	1.835E-08	1.392E-08	1.099E-08	8.934E-09	7.421E-09	6.272E-09
NE	1.614E-07	8.924E-08	5.865E-08	3.242E-08	2.122E-08	1.522E-08	1.157E-08	9.140E-09	7.433E-09	6.179E-09	5.226E-09
ENE	1.035E-07	5.772E-08	3.818E-08	2.128E-08	1.400E-08	1.007E-08	7.667E-09	6.067E-09	4.938E-09	4.107E-09	3.473E-09
E	2.091E-07	1.182E-07	7.888E-08	4.449E-08	2.950E-08	2.135E-08	1.632E-08	1.296E-08	1.058E-08	8.819E-09	7.474E-09
ESE	3.210E-07	1.841E-07	1.241E-07	7.095E-08	4.750E-08	3.462E-08	2.662E-08	2.124E-08	1.740E-08	1.455E-08	1.237E-08
SE	2.191E-07	1.253E-07	8.436E-08	4.816E-08	3.222E-08	2.348E-08	1.805E-08	1.440E-08	1.180E-08	9.866E-09	8.385E-09
SSE	1.032E-07	5.726E-08	3.774E-08	2.096E-08	1.379E-08	9.931E-09	7.568E-09	5.995E-09	4.886E-09	4.069E-09	3.446E-09

Table 2.7-18 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Distances Between 0.25 to 50 Miles 2.260-Day Decay, Undepleted

Ground Level Release - No Purge Releases

χ/Q (sec/m^3) for each segment	Segment Boundaries in Miles from the Site									
Direction From Site	0.5–1	1–2	2–3	3–4	4–5	5–10	10–20	20–30	30–40	40–50
S	1.805E-06	5.989E-07	2.634E-07	1.559E-07	1.059E-07	5.015E-08	1.755E-08	7.903E-09	4.666E-09	3.127E-09
SSW	1.431E-06	4.773E-07	2.106E-07	1.249E-07	8.492E-08	4.027E-08	1.410E-08	6.334E-09	3.727E-09	2.490E-09
SW	1.280E-06	4.284E-07	1.895E-07	1.126E-07	7.670E-08	3.647E-08	1.283E-08	5.776E-09	3.402E-09	2.272E-09
WSW	1.191E-06	3.993E-07	1.771E-07	1.054E-07	7.188E-08	3.426E-08	1.209E-08	5.461E-09	3.220E-09	2.151E-09
W	1.450E-06	4.909E-07	2.199E-07	1.317E-07	9.029E-08	4.345E-08	1.558E-08	7.130E-09	4.239E-09	2.849E-09
WNW	1.261E-06	4.247E-07	1.897E-07	1.135E-07	7.780E-08	3.748E-08	1.350E-08	6.225E-09	3.723E-09	2.515E-09
NW	1.295E-06	4.409E-07	1.985E-07	1.194E-07	8.209E-08	3.973E-08	1.439E-08	6.642E-09	3.974E-09	2.685E-09
NNW	1.113E-06	3.805E-07	1.717E-07	1.034E-07	7.121E-08	3.451E-08	1.250E-08	5.749E-09	3.424E-09	2.302E-09
N	2.860E-06	9.753E-07	4.386E-07	2.637E-07	1.813E-07	8.762E-08	3.160E-08	1.450E-08	8.621E-09	5.792E-09
NNE	3.605E-06	1.231E-06	5.544E-07	3.336E-07	2.295E-07	1.111E-07	4.020E-08	1.851E-08	1.105E-08	7.444E-09
NE	2.941E-06	1.008E-06	4.554E-07	2.745E-07	1.890E-07	9.169E-08	3.327E-08	1.536E-08	9.183E-09	6.198E-09
ENE	1.800E-06	6.265E-07	2.869E-07	1.744E-07	1.208E-07	5.920E-08	2.180E-08	1.016E-08	6.094E-09	4.118E-09
E	3.397E-06	1.212E-06	5.660E-07	3.482E-07	2.433E-07	1.209E-07	4.547E-08	2.151E-08	1.301E-08	8.842E-09
ESE	4.864E-06	1.770E-06	8.458E-07	5.272E-07	3.719E-07	1.878E-07	7.233E-08	3.485E-08	2.131E-08	1.459E-08
SE	3.401E-06	1.223E-06	5.810E-07	3.610E-07	2.541E-07	1.280E-07	4.912E-08	2.364E-08	1.445E-08	9.890E-09
SSE	1.878E-06	6.407E-07	2.902E-07	1.752E-07	1.208E-07	5.880E-08	2.150E-08	1.002E-08	6.022E-09	4.081E-09

Table 2.7-19 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Distances Between 0.25 to 50 Miles 8.000-Day Decay, Depleted

Ground Level Release - No Purge Releases

Annual Average χ/Q (sec/m^3)	Distance in Miles from the Site										
Sector	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	9.360E-06	3.051E-06	1.547E-06	9.606E-07	4.921E-07	3.065E-07	2.124E-07	1.575E-07	1.223E-07	9.819E-08	8.091E-08
SSW	7.316E-06	2.411E-06	1.228E-06	7.643E-07	3.924E-07	2.448E-07	1.699E-07	1.261E-07	9.799E-08	7.876E-08	6.495E-08
SW	6.521E-06	2.154E-06	1.100E-06	6.851E-07	3.524E-07	2.202E-07	1.530E-07	1.137E-07	8.845E-08	7.115E-08	5.872E-08
WSW	6.088E-06	2.002E-06	1.023E-06	6.380E-07	3.287E-07	2.057E-07	1.431E-07	1.064E-07	8.285E-08	6.670E-08	5.508E-08
W	7.468E-06	2.432E-06	1.245E-06	7.802E-07	4.048E-07	2.546E-07	1.778E-07	1.327E-07	1.036E-07	8.364E-08	6.924E-08
WNW	6.474E-06	2.117E-06	1.083E-06	6.764E-07	3.498E-07	2.196E-07	1.533E-07	1.143E-07	8.924E-08	7.202E-08	5.962E-08
NW	6.454E-06	2.160E-06	1.115E-06	6.992E-07	3.636E-07	2.292E-07	1.605E-07	1.200E-07	9.385E-08	7.588E-08	6.290E-08
NNW	5.452E-06	1.851E-06	9.612E-07	6.028E-07	3.140E-07	1.983E-07	1.390E-07	1.040E-07	8.145E-08	6.591E-08	5.468E-08
N	1.390E-05	4.756E-06	2.473E-06	1.548E-06	8.044E-07	5.070E-07	3.549E-07	2.653E-07	2.076E-07	1.678E-07	1.391E-07
NNE	1.767E-05	5.993E-06	3.115E-06	1.952E-06	1.015E-06	6.404E-07	4.485E-07	3.354E-07	2.625E-07	2.123E-07	1.760E-07
NE	1.441E-05	4.884E-06	2.541E-06	1.596E-06	8.319E-07	5.254E-07	3.683E-07	2.757E-07	2.159E-07	1.747E-07	1.450E-07
ENE	8.845E-06	2.971E-06	1.556E-06	9.843E-07	5.183E-07	3.297E-07	2.324E-07	1.748E-07	1.374E-07	1.116E-07	9.283E-08
E	1.679E-05	5.558E-06	2.941E-06	1.882E-06	1.006E-06	6.465E-07	4.594E-07	3.477E-07	2.748E-07	2.241E-07	1.873E-07
ESE	2.540E-05	7.974E-06	4.180E-06	2.711E-06	1.475E-06	9.592E-07	6.875E-07	5.240E-07	4.166E-07	3.415E-07	2.866E-07
SE	1.828E-05	5.628E-06	2.909E-06	1.879E-06	1.018E-06	6.601E-07	4.721E-07	3.592E-07	2.852E-07	2.335E-07	1.958E-07
SSE	9.928E-06	3.156E-06	1.608E-06	1.012E-06	5.291E-07	3.346E-07	2.348E-07	1.759E-07	1.379E-07	1.116E-07	9.268E-08

Table 2.7-19 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Distances Between 0.25 to 50 Miles 8.000-Day Decay, Depleted

Ground Level Release - No Purge Releases

Annual Average χ/Q (sec/m^3)	Distance in Miles from the Site										
Sector	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	6.805E-08	3.507E-08	2.180E-08	1.110E-08	6.849E-09	4.687E-09	3.426E-09	2.620E-09	2.071E-09	1.679E-09	1.389E-09
SSW	5.465E-08	2.822E-08	1.756E-08	8.952E-09	5.520E-09	3.776E-09	2.758E-09	2.108E-09	1.665E-09	1.349E-09	1.115E-09
SW	4.945E-08	2.561E-08	1.597E-08	8.170E-09	5.050E-09	3.461E-09	2.531E-09	1.937E-09	1.532E-09	1.242E-09	1.027E-09
WSW	4.642E-08	2.411E-08	1.507E-08	7.733E-09	4.793E-09	3.291E-09	2.411E-09	1.848E-09	1.463E-09	1.188E-09	9.832E-10
W	5.848E-08	3.065E-08	1.929E-08	9.997E-09	6.243E-09	4.312E-09	3.175E-09	2.443E-09	1.941E-09	1.581E-09	1.313E-09
WNW	5.036E-08	2.642E-08	1.664E-08	8.645E-09	5.416E-09	3.751E-09	2.768E-09	2.134E-09	1.698E-09	1.385E-09	1.152E-09
NW	5.319E-08	2.801E-08	1.769E-08	9.211E-09	5.771E-09	3.996E-09	2.949E-09	2.272E-09	1.808E-09	1.475E-09	1.226E-09
NNW	4.627E-08	2.442E-08	1.544E-08	8.051E-09	5.043E-09	3.491E-09	2.574E-09	1.983E-09	1.577E-09	1.285E-09	1.067E-09
N	1.176E-07	6.193E-08	3.908E-08	2.032E-08	1.270E-08	8.781E-09	6.467E-09	4.976E-09	3.953E-09	3.219E-09	2.672E-09
NNE	1.489E-07	7.846E-08	4.956E-08	2.581E-08	1.616E-08	1.118E-08	8.243E-09	6.348E-09	5.048E-09	4.113E-09	3.417E-09
NE	1.227E-07	6.473E-08	4.094E-08	2.135E-08	1.338E-08	9.264E-09	6.834E-09	5.267E-09	4.190E-09	3.416E-09	2.839E-09
ENE	7.876E-08	4.200E-08	2.676E-08	1.410E-08	8.894E-09	6.191E-09	4.586E-09	3.546E-09	2.829E-09	2.312E-09	1.925E-09
E	1.595E-07	8.619E-08	5.543E-08	2.959E-08	1.884E-08	1.320E-08	9.835E-09	7.639E-09	6.119E-09	5.017E-09	4.191E-09
ESE	2.450E-07	1.344E-07	8.739E-08	4.735E-08	3.047E-08	2.153E-08	1.614E-08	1.261E-08	1.015E-08	8.357E-09	7.007E-09
SE	1.672E-07	9.154E-08	5.941E-08	3.214E-08	2.067E-08	1.461E-08	1.095E-08	8.553E-09	6.884E-09	5.669E-09	4.753E-09
SSE	7.849E-08	4.159E-08	2.639E-08	1.385E-08	8.732E-09	6.079E-09	4.505E-09	3.485E-09	2.783E-09	2.276E-09	1.897E-09

Table 2.7-19 Long-Term Average χ/Q (sec/m^3) for Routine Releases at Distances Between 0.25 to 50 Miles 8.000-Day Decay, Depleted

Ground Level Release - No Purge Releases

χ/Q (sec/m^3) for each segment	Segment Boundaries in Miles from the Site									
Direction From Site	0.5–1	1–2	2–3	3–4	4–5	5–10	10–20	20–30	30–40	40–50
S	1.620E-06	5.137E-07	2.155E-07	1.231E-07	8.127E-08	3.650E-08	1.159E-08	4.759E-09	2.641E-09	1.688E-09
SSW	1.285E-06	4.095E-07	1.724E-07	9.870E-08	6.523E-08	2.936E-08	9.340E-09	3.834E-09	2.125E-09	1.356E-09
SW	1.150E-06	3.676E-07	1.552E-07	8.907E-08	5.897E-08	2.663E-08	8.518E-09	3.513E-09	1.952E-09	1.248E-09
WSW	1.070E-06	3.428E-07	1.451E-07	8.343E-08	5.531E-08	2.505E-08	8.057E-09	3.340E-09	1.862E-09	1.193E-09
W	1.302E-06	4.214E-07	1.802E-07	1.043E-07	6.952E-08	3.179E-08	1.039E-08	4.372E-09	2.461E-09	1.588E-09
WNW	1.132E-06	3.645E-07	1.554E-07	8.985E-08	5.986E-08	2.739E-08	8.987E-09	3.802E-09	2.149E-09	1.391E-09
NW	1.163E-06	3.784E-07	1.626E-07	9.447E-08	6.315E-08	2.902E-08	9.566E-09	4.050E-09	2.289E-09	1.481E-09
NNW	9.996E-07	3.267E-07	1.408E-07	8.198E-08	5.489E-08	2.528E-08	8.356E-09	3.538E-09	1.997E-09	1.291E-09
N	2.569E-06	8.375E-07	3.596E-07	2.089E-07	1.397E-07	6.416E-08	2.111E-08	8.902E-09	5.012E-09	3.234E-09
NNE	3.238E-06	1.057E-06	4.544E-07	2.642E-07	1.767E-07	8.126E-08	2.680E-08	1.133E-08	6.394E-09	4.132E-09
NE	2.642E-06	8.654E-07	3.732E-07	2.173E-07	1.455E-07	6.703E-08	2.216E-08	9.389E-09	5.304E-09	3.432E-09
ENE	1.616E-06	5.381E-07	2.353E-07	1.382E-07	9.317E-08	4.340E-08	1.460E-08	6.269E-09	3.570E-09	2.322E-09
E	3.052E-06	1.041E-06	4.646E-07	2.763E-07	1.879E-07	8.880E-08	3.055E-08	1.336E-08	7.687E-09	5.037E-09
ESE	4.370E-06	1.521E-06	6.945E-07	4.187E-07	2.874E-07	1.381E-07	4.874E-08	2.176E-08	1.268E-08	8.388E-09
SE	3.055E-06	1.050E-06	4.771E-07	2.866E-07	1.964E-07	9.408E-08	3.311E-08	1.476E-08	8.602E-09	5.690E-09
SSE	1.687E-06	5.500E-07	2.379E-07	1.388E-07	9.304E-08	4.303E-08	1.436E-08	6.157E-09	3.509E-09	2.286E-09

Table 2.7-20 Long-Term Average D/Q (1/m^2) for Routine Releases at Distances Between 0.25 to 50 Miles

Ground Level Release - No Purge Releases

********** Relative Deposition per Unit Area (M**-2) at Fixed Points By Downwind Sectors **********

Distances in Miles

Direction From Site	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	4.819E-08	1.630E-08	8.367E-09	5.138E-09	2.561E-09	1.553E-09	1.050E-09	7.611E-10	5.787E-10	4.559E-10	3.691E-10
SSW	3.194E-08	1.080E-08	5.546E-09	3.405E-09	1.698E-09	1.030E-09	6.961E-10	5.045E-10	3.836E-10	3.022E-10	2.446E-10
SW	2.633E-08	8.902E-09	4.571E-09	2.807E-09	1.399E-09	8.486E-10	5.738E-10	4.158E-10	3.161E-10	2.491E-10	2.016E-10
WSW	2.286E-08	7.732E-09	3.970E-09	2.438E-09	1.215E-09	7.371E-10	4.983E-10	3.611E-10	2.746E-10	2.163E-10	1.751E-10
W	2.691E-08	9.101E-09	4.673E-09	2.869E-09	1.430E-09	8.676E-10	5.866E-10	4.251E-10	3.232E-10	2.546E-10	2.061E-10
WNW	2.495E-08	8.438E-09	4.333E-09	2.660E-09	1.326E-09	8.044E-10	5.439E-10	3.941E-10	2.997E-10	2.361E-10	1.911E-10
NW	2.242E-08	7.583E-09	3.893E-09	2.391E-09	1.192E-09	7.229E-10	4.887E-10	3.542E-10	2.693E-10	2.122E-10	1.718E-10
NNW	1.628E-08	5.504E-09	2.826E-09	1.735E-09	8.652E-10	5.247E-10	3.548E-10	2.571E-10	1.955E-10	1.540E-10	1.247E-10
N	4.309E-08	1.457E-08	7.481E-09	4.594E-09	2.290E-09	1.389E-09	9.391E-10	6.805E-10	5.175E-10	4.077E-10	3.300E-10
NNE	6.257E-08	2.116E-08	1.086E-08	6.671E-09	3.326E-09	2.017E-09	1.364E-09	9.882E-10	7.514E-10	5.920E-10	4.793E-10
NE	5.046E-08	1.706E-08	8.761E-09	5.379E-09	2.682E-09	1.627E-09	1.100E-09	7.969E-10	6.059E-10	4.774E-10	3.865E-10
ENE	2.720E-08	9.199E-09	4.723E-09	2.900E-09	1.446E-09	8.769E-10	5.929E-10	4.296E-10	3.267E-10	2.574E-10	2.084E-10
E	3.824E-08	1.293E-08	6.640E-09	4.077E-09	2.033E-09	1.233E-09	8.335E-10	6.040E-10	4.593E-10	3.618E-10	2.929E-10
ESE	5.097E-08	1.724E-08	8.849E-09	5.434E-09	2.709E-09	1.643E-09	1.111E-09	8.050E-10	6.121E-10	4.822E-10	3.904E-10
SE	4.574E-08	1.547E-08	7.942E-09	4.877E-09	2.431E-09	1.475E-09	9.970E-10	7.225E-10	5.493E-10	4.328E-10	3.504E-10
SSE	4.085E-08	1.381E-08	7.092E-09	4.355E-09	2.171E-09	1.317E-09	8.902E-10	6.451E-10	4.905E-10	3.865E-10	3.129E-10

Table 2.7-20 Long-Term Average D/Q ($1/m^2$) for Routine Releases at Distances Between 0.25 to 50 Miles

Ground Level Release - No Purge Releases

********** Relative Deposition per Unit Area (M**-2) at Fixed Points By Downwind Sectors **********

Direction From Site	Distance in Miles										
	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	3.053E-10	1.496E-10	9.388E-11	4.745E-11	2.872E-11	1.926E-11	1.380E-11	1.036E-11	8.056E-12	6.435E-12	5.252E-12
SSW	2.024E-10	9.917E-11	6.222E-11	3.145E-11	1.904E-11	1.276E-11	9.145E-12	6.867E-12	5.339E-12	4.265E-12	3.481E-12
SW	1.668E-10	8.174E-11	5.129E-11	2.592E-11	1.569E-11	1.052E-11	7.538E-12	5.660E-12	4.401E-12	3.515E-12	2.869E-12
WSW	1.449E-10	7.099E-11	4.454E-11	2.251E-11	1.363E-11	9.136E-12	6.547E-12	4.916E-12	3.822E-12	3.053E-12	2.492E-12
W	1.705E-10	8.356E-11	5.243E-11	2.650E-11	1.604E-11	1.075E-11	7.706E-12	5.786E-12	4.499E-12	3.594E-12	2.933E-12
WNW	1.581E-10	7.748E-11	4.861E-11	2.457E-11	1.487E-11	9.971E-12	7.145E-12	5.365E-12	4.171E-12	3.332E-12	2.720E-12
NW	1.421E-10	6.962E-11	4.369E-11	2.208E-11	1.336E-11	8.961E-12	6.421E-12	4.821E-12	3.749E-12	2.994E-12	2.444E-12
NNW	1.031E-10	5.054E-11	3.171E-11	1.603E-11	9.701E-12	6.504E-12	4.661E-12	3.500E-12	2.721E-12	2.174E-12	1.774E-12
N	2.730E-10	1.338E-10	8.394E-11	4.243E-11	2.568E-11	1.722E-11	1.234E-11	9.264E-12	7.203E-12	5.754E-12	4.697E-12
NNE	3.964E-10	1.943E-10	1.219E-10	6.161E-11	3.729E-11	2.500E-11	1.792E-11	1.345E-11	1.046E-11	8.355E-12	6.820E-12
NE	3.197E-10	1.567E-10	9.830E-11	4.968E-11	3.007E-11	2.016E-11	1.445E-11	1.085E-11	8.435E-12	6.738E-12	5.500E-12
ENE	1.724E-10	8.446E-11	5.300E-11	2.679E-11	1.621E-11	1.087E-11	7.789E-12	5.849E-12	4.548E-12	3.633E-12	2.965E-12
E	2.423E-10	1.187E-10	7.451E-11	3.766E-11	2.279E-11	1.528E-11	1.095E-11	8.223E-12	6.393E-12	5.107E-12	4.168E-12
ESE	3.229E-10	1.583E-10	9.929E-11	5.019E-11	3.038E-11	2.037E-11	1.459E-11	1.096E-11	8.520E-12	6.806E-12	5.555E-12
SE	2.898E-10	1.420E-10	8.912E-11	4.504E-11	2.726E-11	1.828E-11	1.310E-11	9.835E-12	7.647E-12	6.108E-12	4.986E-12
SSE	2.588E-10	1.268E-10	7.957E-11	4.022E-11	2.434E-11	1.632E-11	1.170E-11	8.782E-12	6.828E-12	5.454E-12	4.452E-12

Table 2.7-20 Long-Term Average D/Q ($1/m^2$) for Routine Releases at Distances Between 0.25 to 50 Miles

Ground Level Release - No Purge Releases

********** Relative Deposition per Unit Area (M**-2) at Fixed Points By Downwind Sectors **********

Direction From Site	Segment Boundaries in Miles									
	0.5–1	1–2	2–3	3–4	4–5	5–10	10–20	20–30	30–40	40–50
S	8.694E-09	2.686E-09	1.069E-09	5.841E-10	3.712E-10	1.594E-10	4.944E-11	1.960E-11	1.046E-11	6.477E-12
SSW	5.762E-09	1.780E-09	7.084E-10	3.871E-10	2.460E-10	1.057E-10	3.277E-11	1.299E-11	6.936E-12	4.293E-12
SW	4.749E-09	1.467E-09	5.839E-10	3.191E-10	2.028E-10	8.710E-11	2.701E-11	1.071E-11	5.717E-12	3.538E-12
WSW	4.125E-09	1.274E-09	5.071E-10	2.771E-10	1.761E-10	7.565E-11	2.346E-11	9.298E-12	4.965E-12	3.073E-12
W	4.855E-09	1.500E-09	5.969E-10	3.262E-10	2.073E-10	8.905E-11	2.761E-11	1.094E-11	5.844E-12	3.617E-12
WNW	4.502E-09	1.391E-09	5.534E-10	3.024E-10	1.922E-10	8.256E-11	2.560E-11	1.015E-11	5.419E-12	3.354E-12
NW	4.045E-09	1.250E-09	4.973E-10	2.718E-10	1.727E-10	7.420E-11	2.301E-11	9.119E-12	4.870E-12	3.014E-12
NNW	2.937E-09	9.072E-10	3.610E-10	1.973E-10	1.254E-10	5.386E-11	1.670E-11	6.619E-12	3.535E-12	2.188E-12
N	7.773E-09	2.402E-09	9.557E-10	5.222E-10	3.319E-10	1.426E-10	4.421E-11	1.752E-11	9.357E-12	5.792E-12
NNE	1.129E-08	3.487E-09	1.388E-09	7.583E-10	4.820E-10	2.070E-10	6.420E-11	2.544E-11	1.359E-11	8.410E-12
NE	9.103E-09	2.812E-09	1.119E-09	6.115E-10	3.887E-10	1.669E-10	5.177E-11	2.052E-11	1.096E-11	6.782E-12
ENE	4.908E-09	1.516E-09	6.033E-10	3.297E-10	2.095E-10	9.001E-11	2.791E-11	1.106E-11	5.907E-12	3.656E-12
E	6.899E-09	2.132E-09	8.482E-10	4.635E-10	2.946E-10	1.265E-10	3.924E-11	1.555E-11	8.305E-12	5.140E-12
ESE	9.195E-09	2.841E-09	1.130E-09	6.177E-10	3.926E-10	1.686E-10	5.230E-11	2.073E-11	1.107E-11	6.851E-12
SE	8.252E-09	2.550E-09	1.015E-09	5.544E-10	3.524E-10	1.514E-10	4.693E-11	1.860E-11	9.934E-12	6.149E-12
SSE	7.369E-09	2.277E-09	9.059E-10	4.950E-10	3.146E-10	1.351E-10	4.191E-11	1.661E-11	8.870E-12	5.490E-12

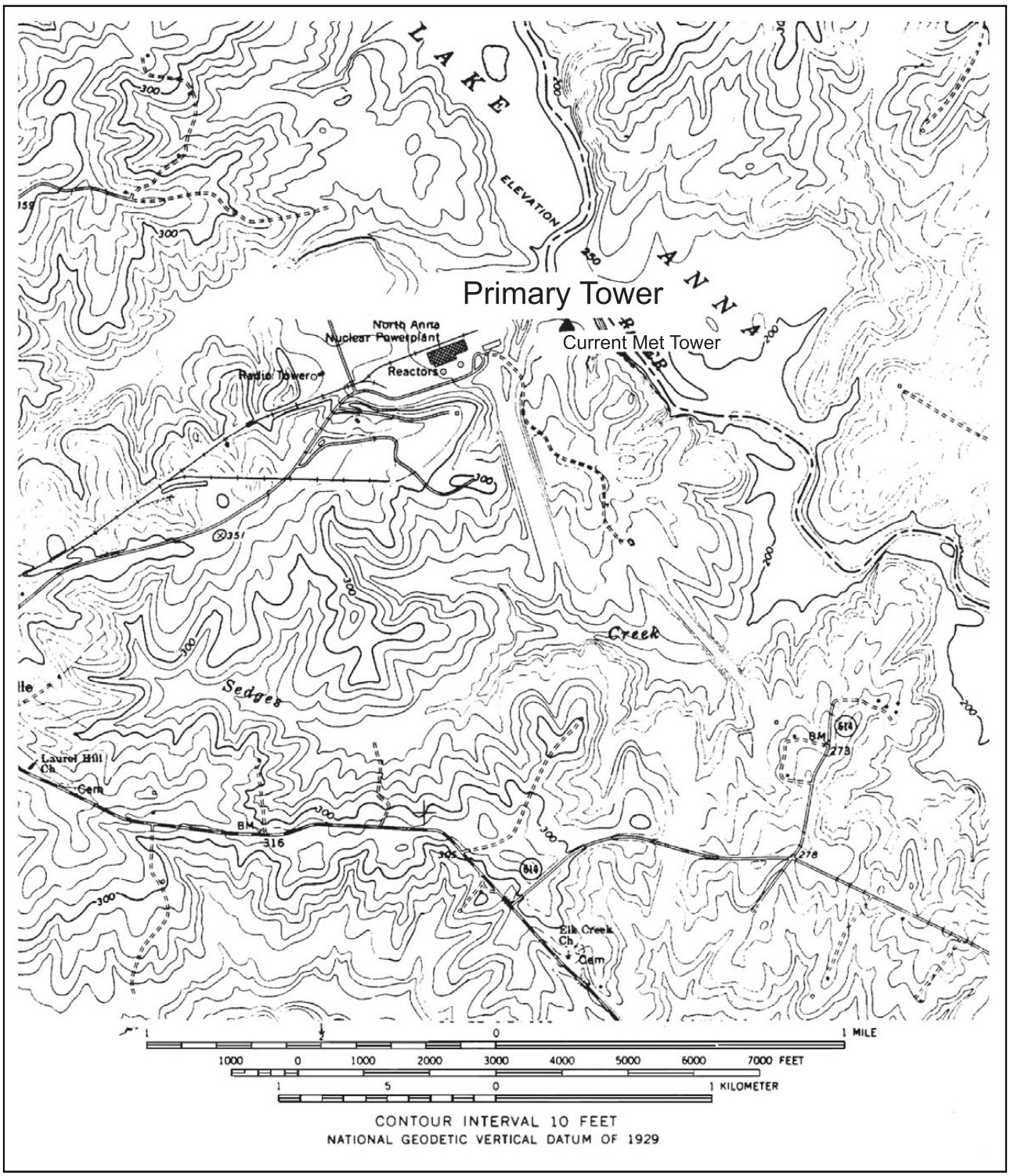
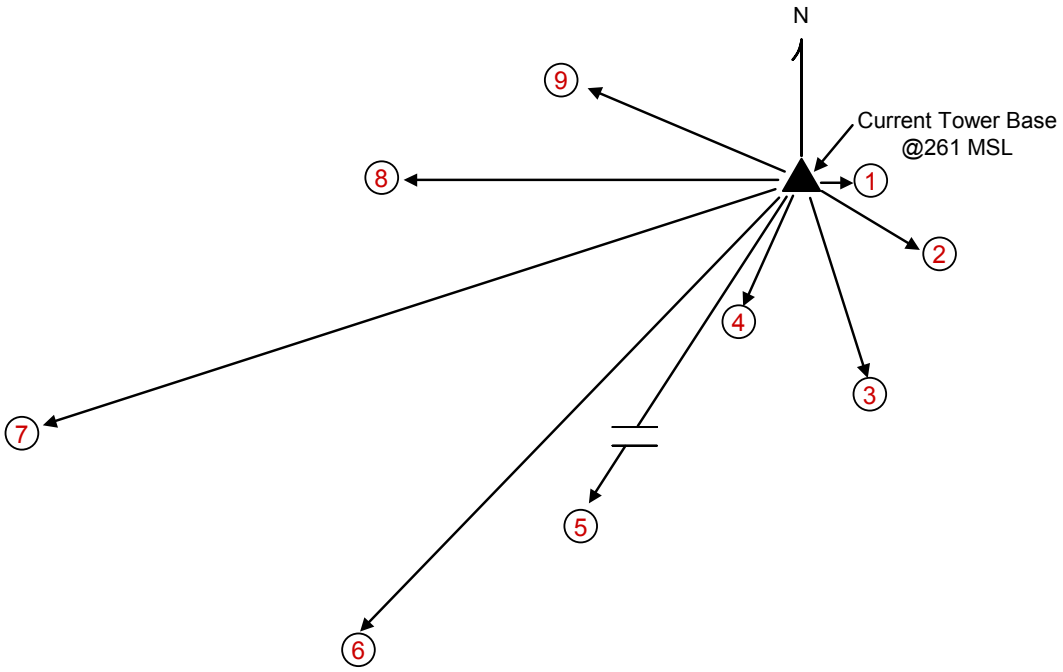


Figure 2.7-1 Location of Meteorological Tower



Approximated Directions and Distances

1	Basketball Backboard	095°	100'
2	30 x 50 Pavilion	122°	222'
3	20 x 30 Pavilion	160°	294'
4	Softball Backstop	200°	203'
5	Nearest Contiguous Tree Line		>500'
6	Training Center	205°	740'
7	Unit 1 Containment	250°	1750'
8	Original Tower	272°	1020'
9	Back-up Tower	–	–

Figure 2.7-2 Location of Meteorological Tower Relative to Local Ground Features

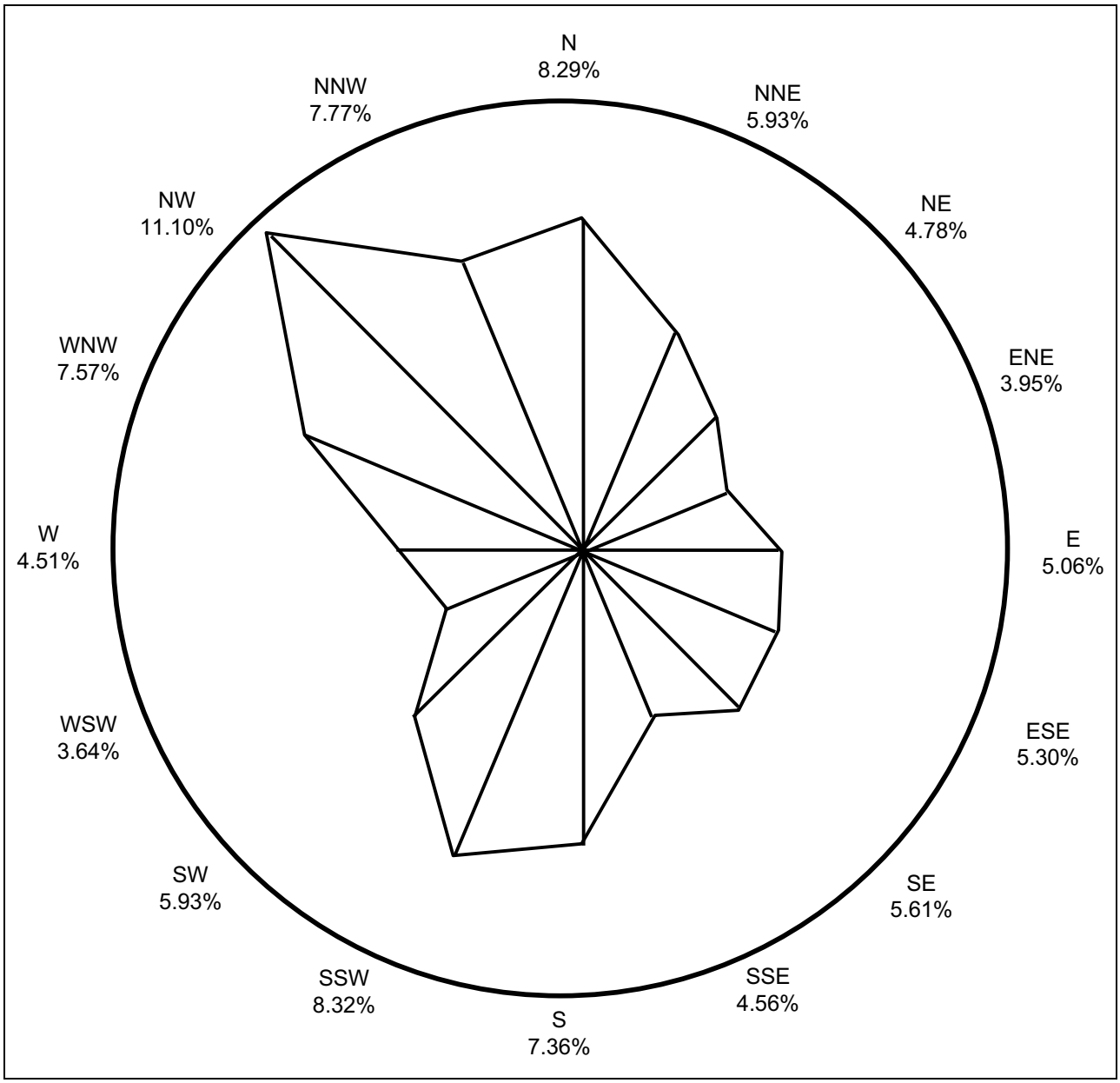


Figure 2.7-3 North Anna Seasonal Wind Direction Roses: Low-Level Winds: 1974–1987: Season = Spring

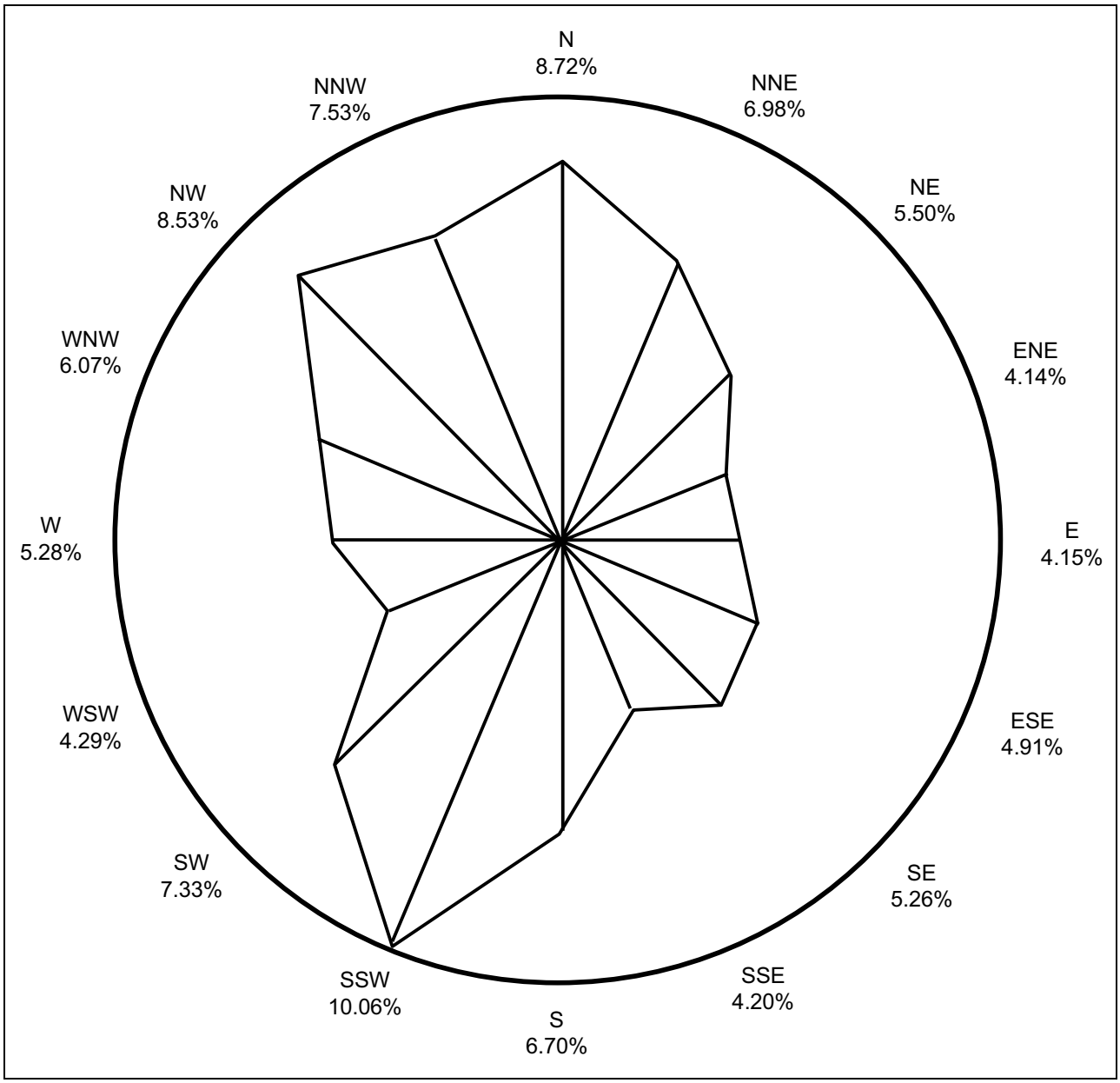


Figure 2.7-4 North Anna Seasonal Wind Direction Roses: High-Level Winds: 1974–1987: Season = Spring

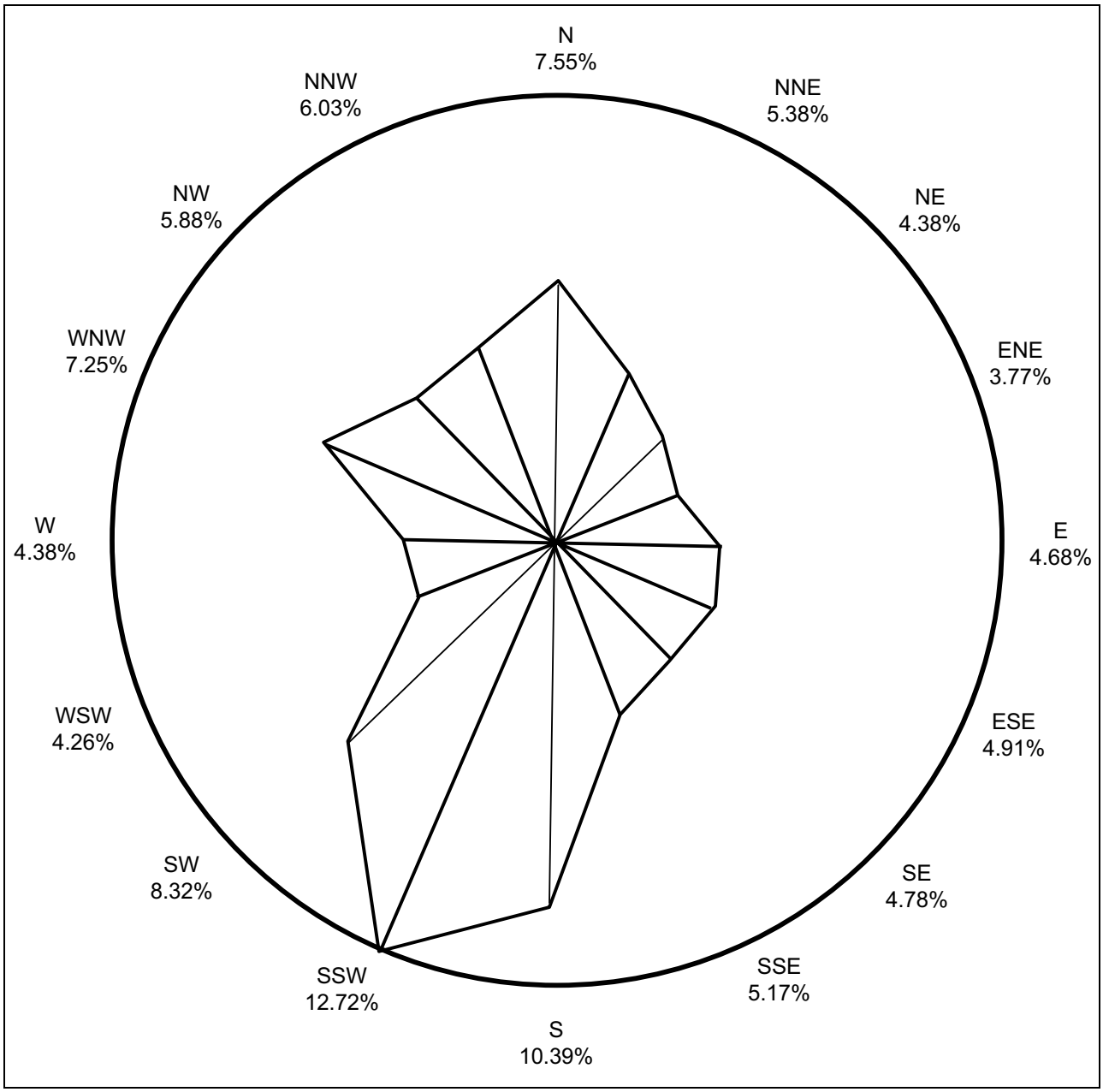


Figure 2.7-5 North Anna Seasonal Wind Direction Roses: Low-Level Winds: 1974–1987: Season = Summer

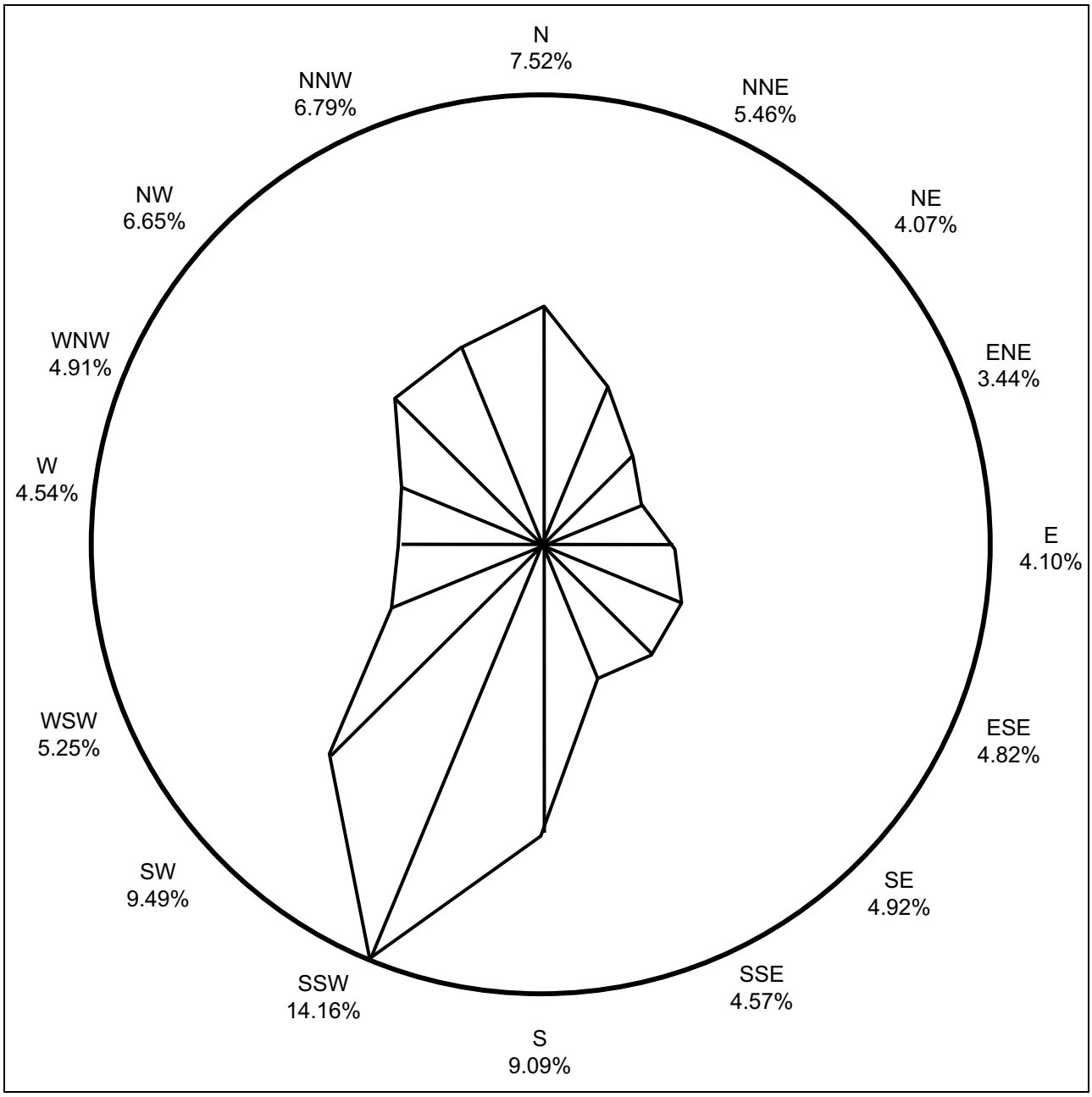


Figure 2.7-6 North Anna Seasonal Wind Direction Roses: High-Level Winds: 1974–1987: Season = Summer

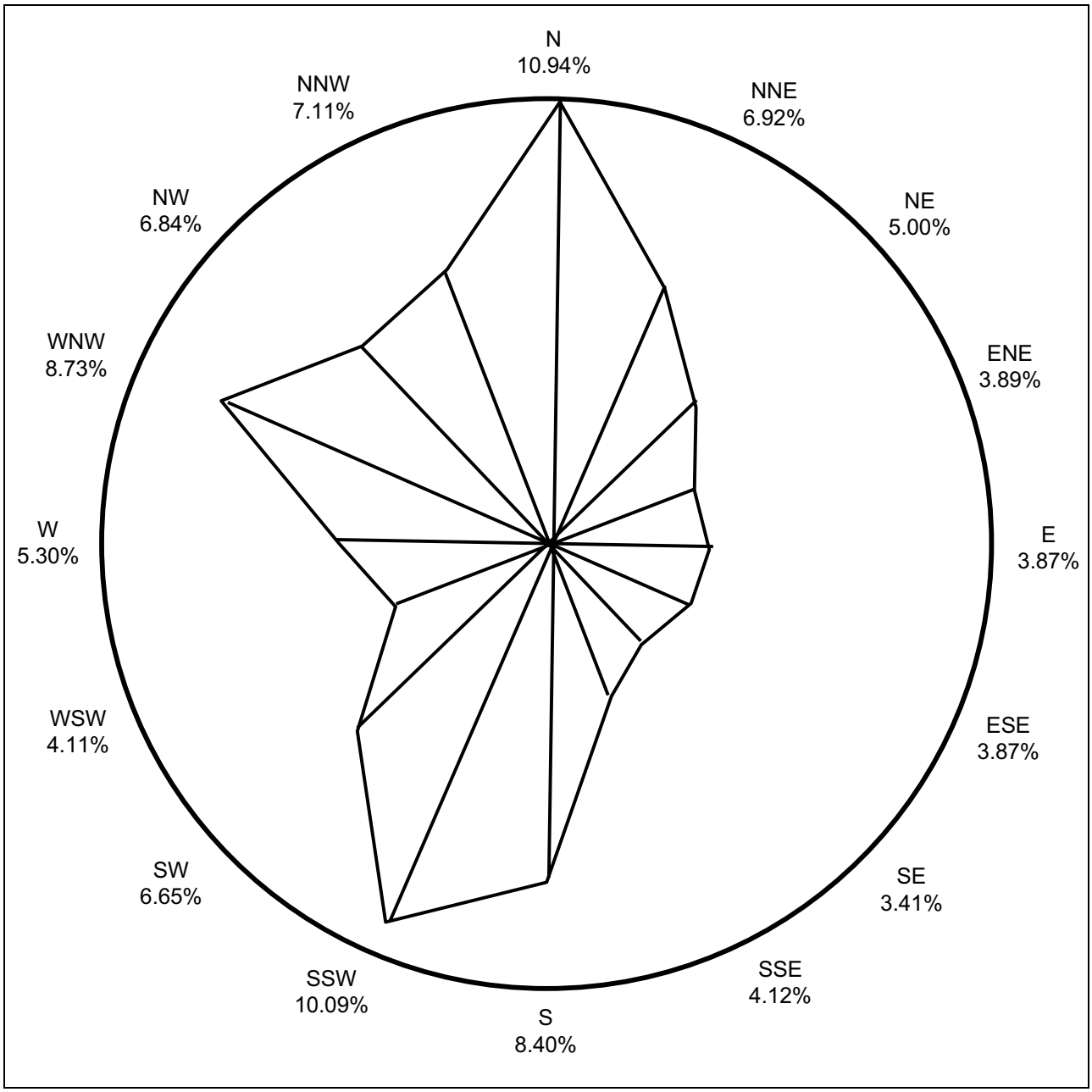


Figure 2.7-7 North Anna Seasonal Wind Direction Roses: Low-Level Winds: 1974–1987: Season = Fall

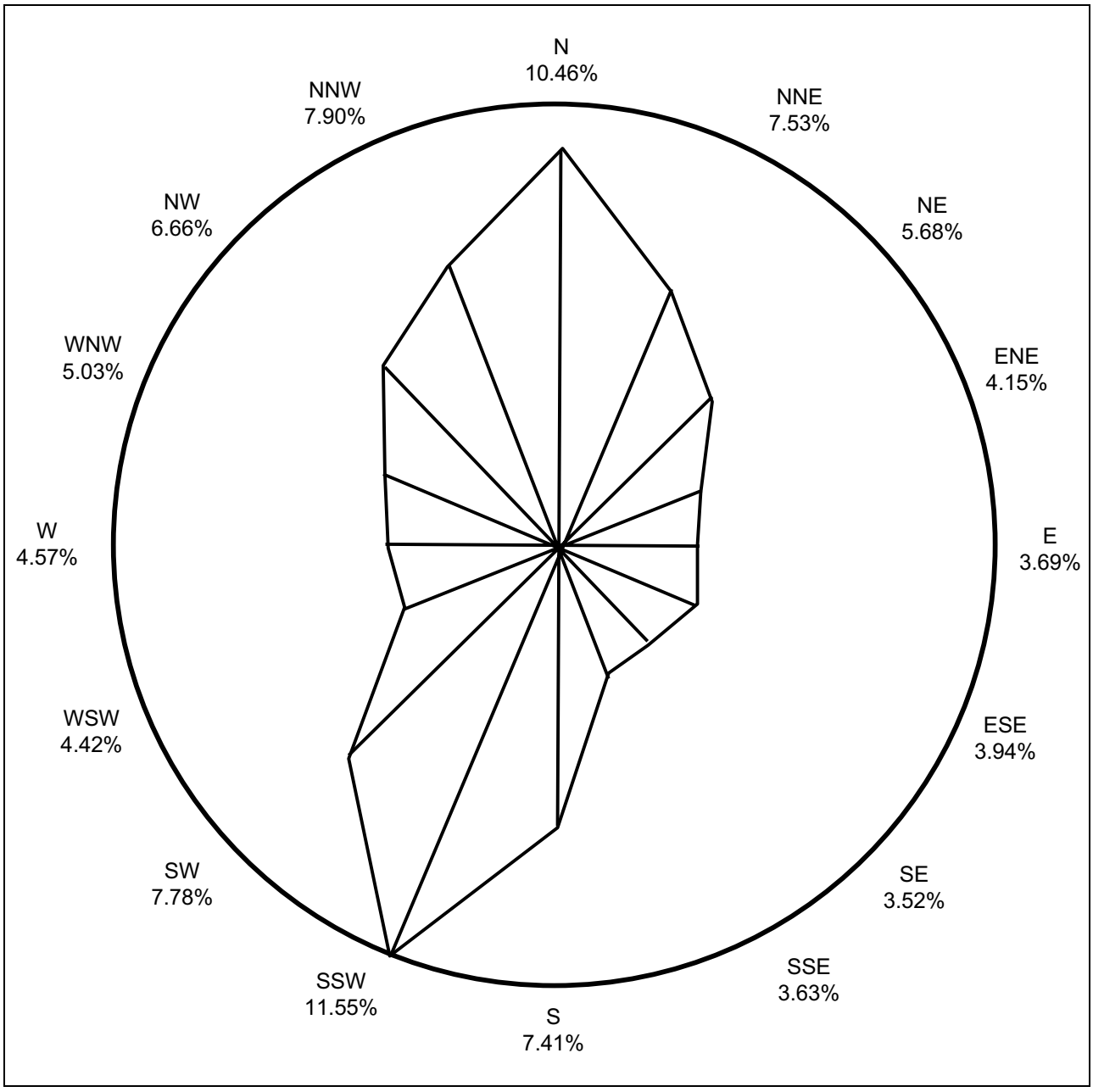


Figure 2.7-8 North Anna Seasonal Wind Direction Roses: High-Level Winds: 1974–1987: Season = Fall

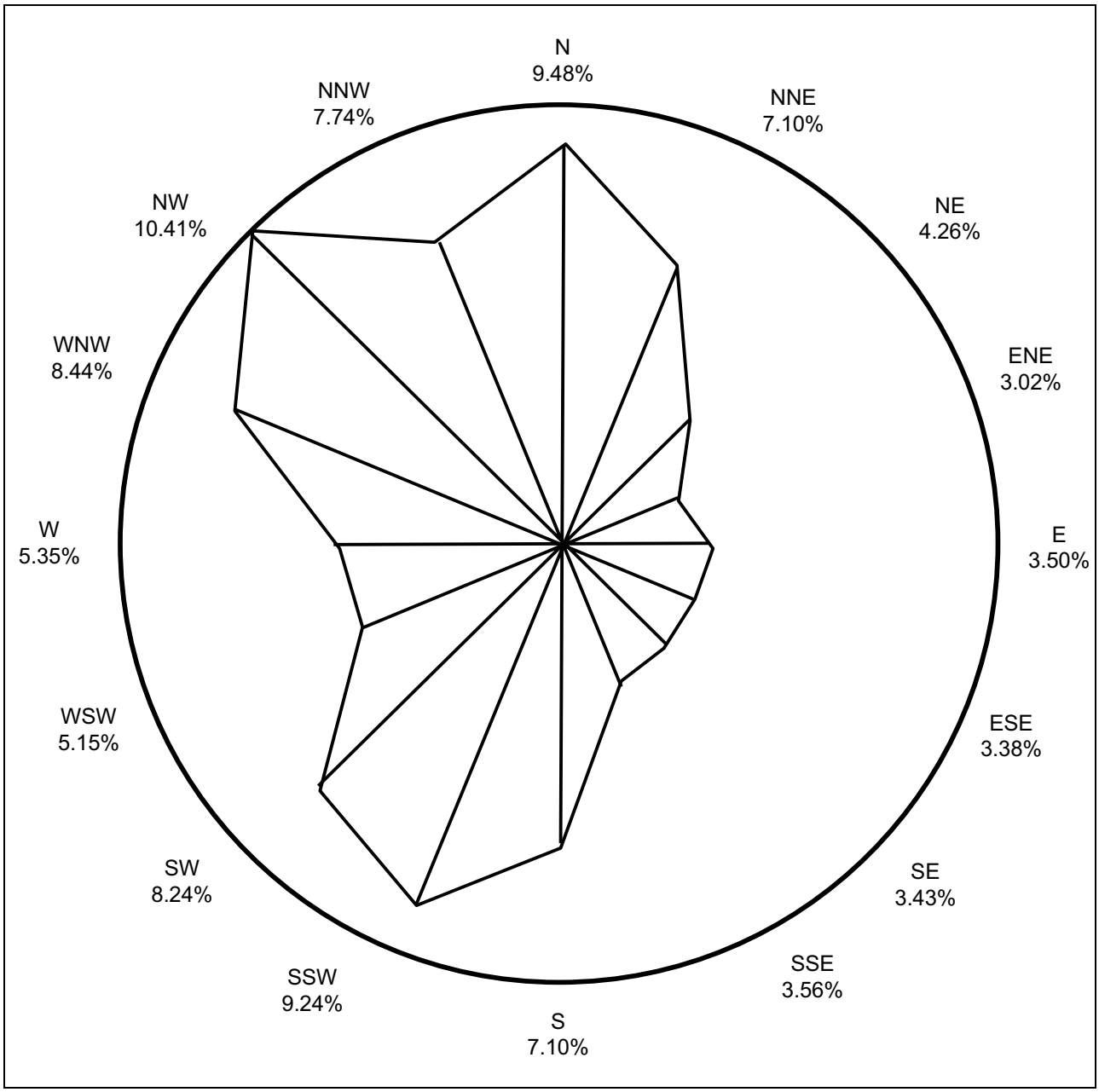


Figure 2.7-9 North Anna Seasonal Wind Direction Roses: Low-Level Winds: 1974–1987: Season = Winter

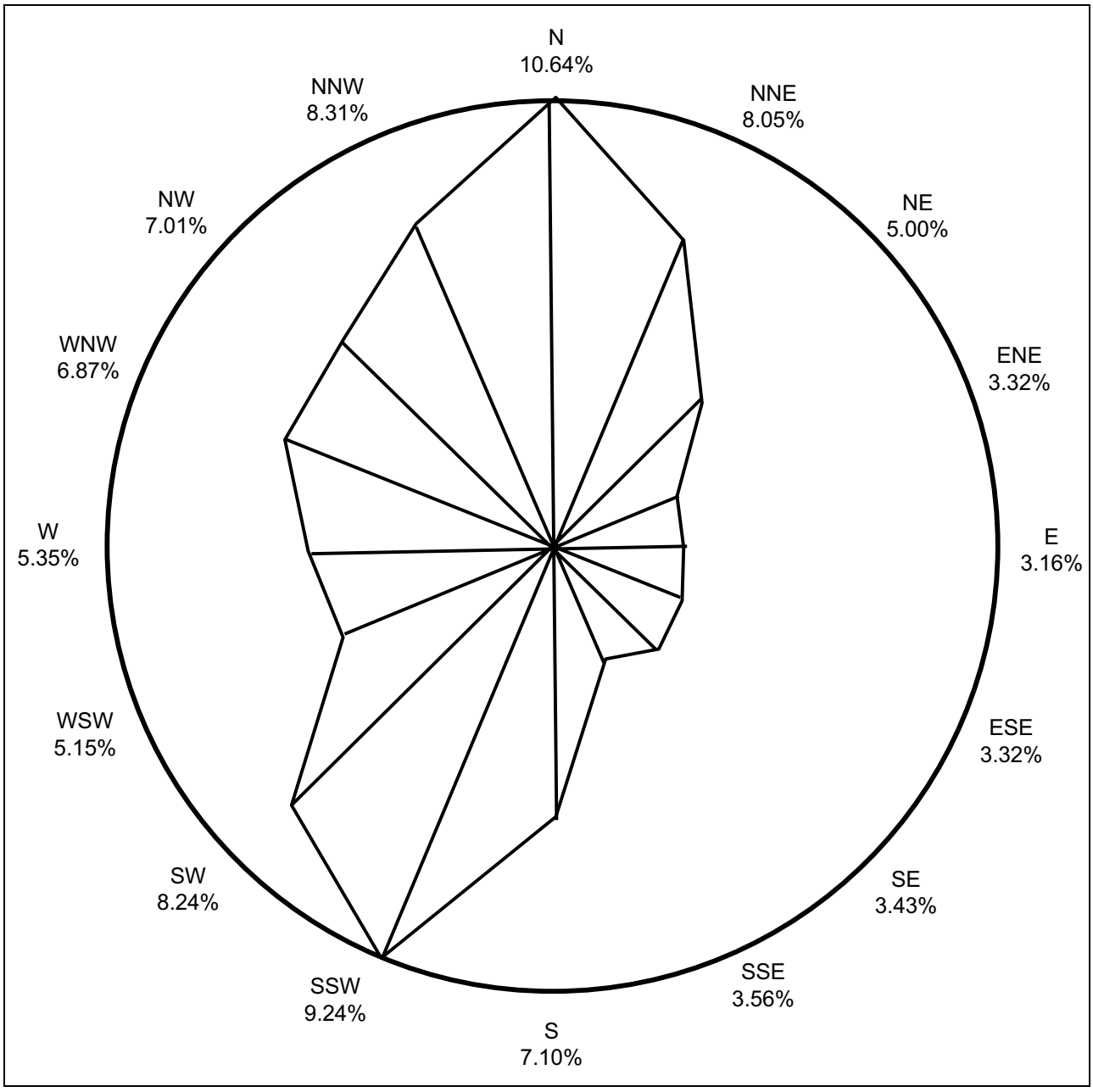


Figure 2.7-10 North Anna Seasonal Wind Direction Roses: High-Level Winds: 1974–1987: Season = Winter

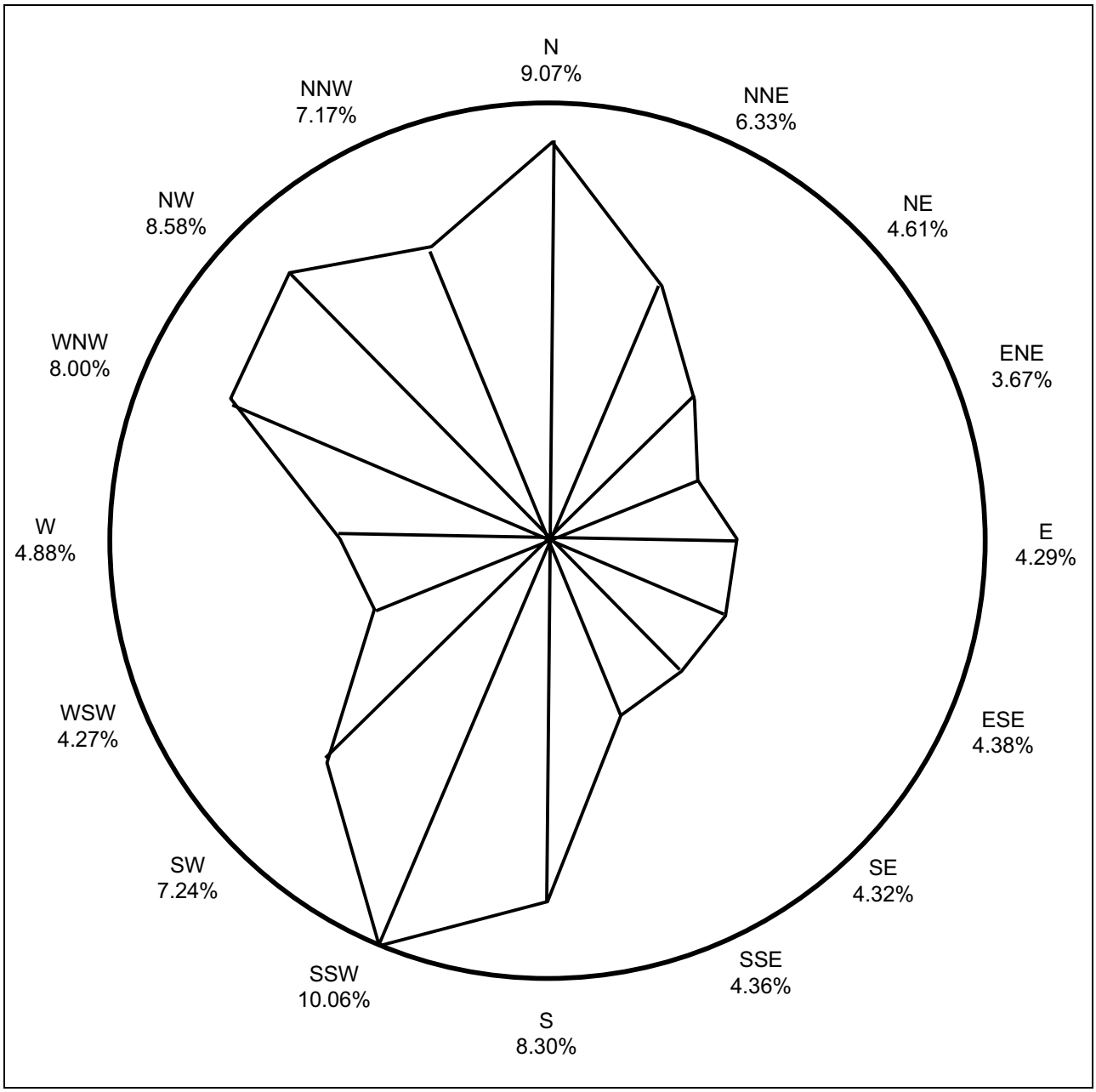


Figure 2.7-11 North Anna Seasonal Wind Direction Roses: Low-Level Winds: 1974–1987: Season = Overall

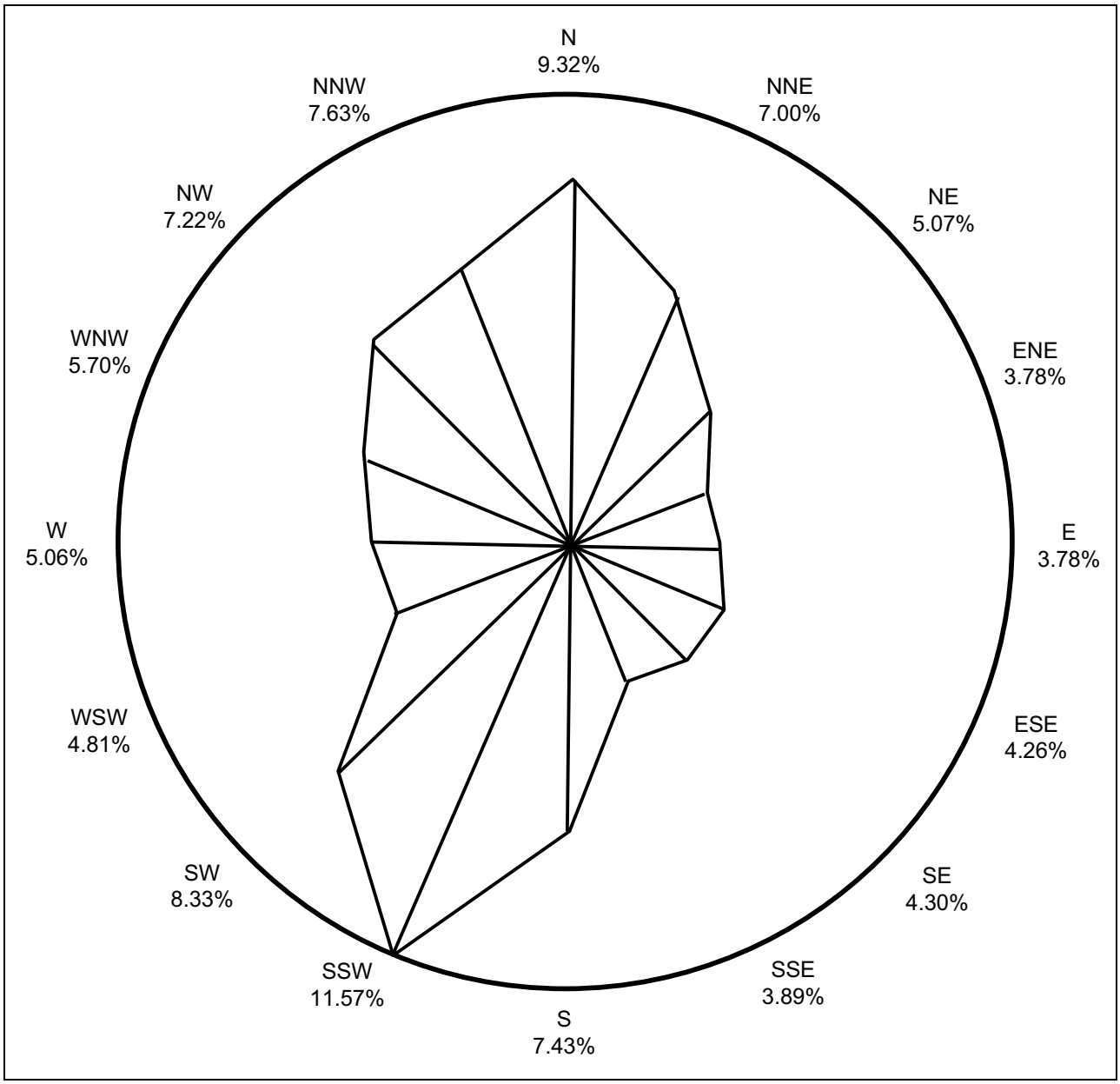


Figure 2.7-12 North Anna Seasonal Wind Direction Roses: High-Level Winds: 1974–1987: Season = Overall

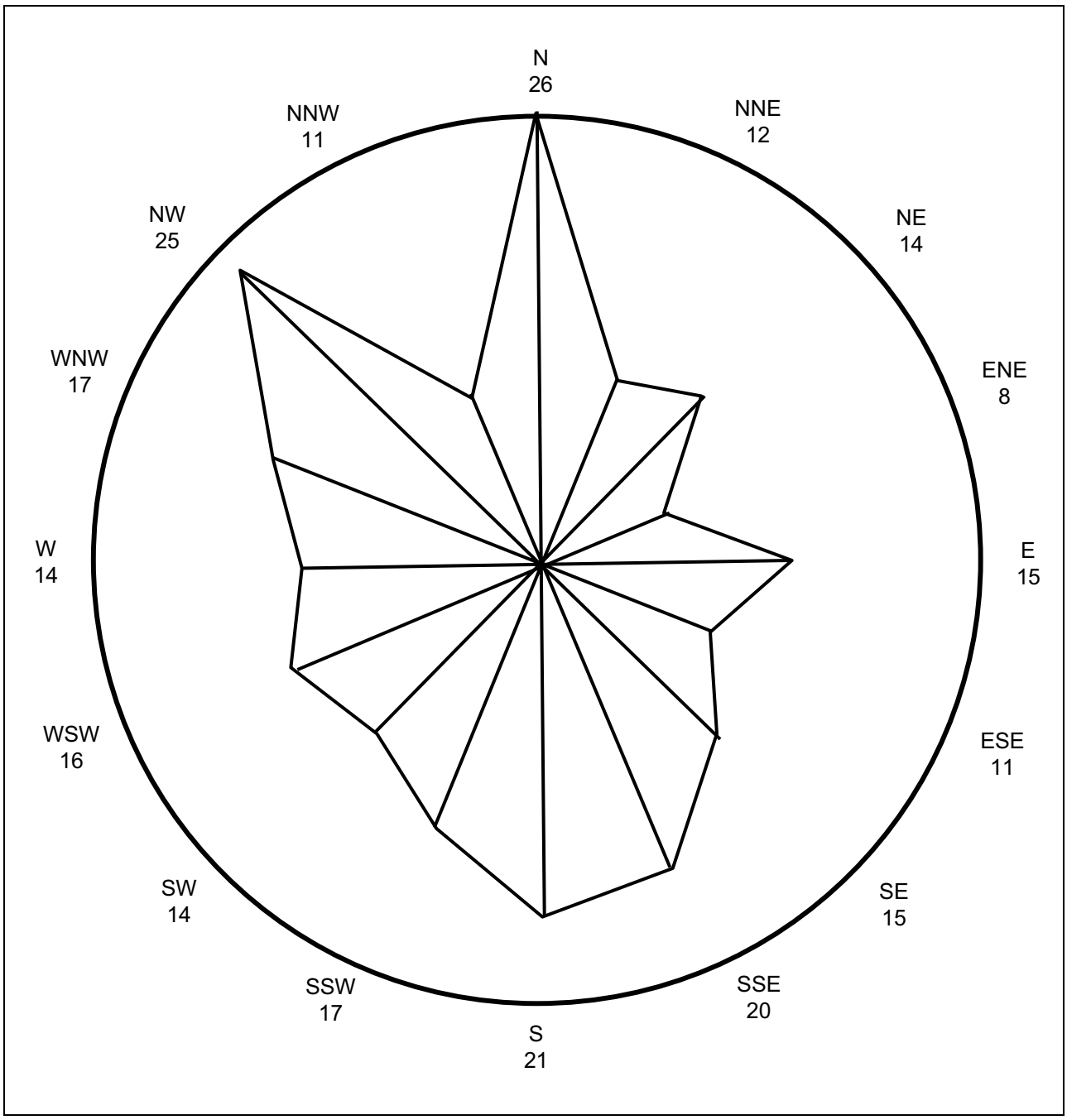


Figure 2.7-13 North Anna Seasonal Wind Persistence Roses: Low-Level Winds: 1974–1987: Season = Spring

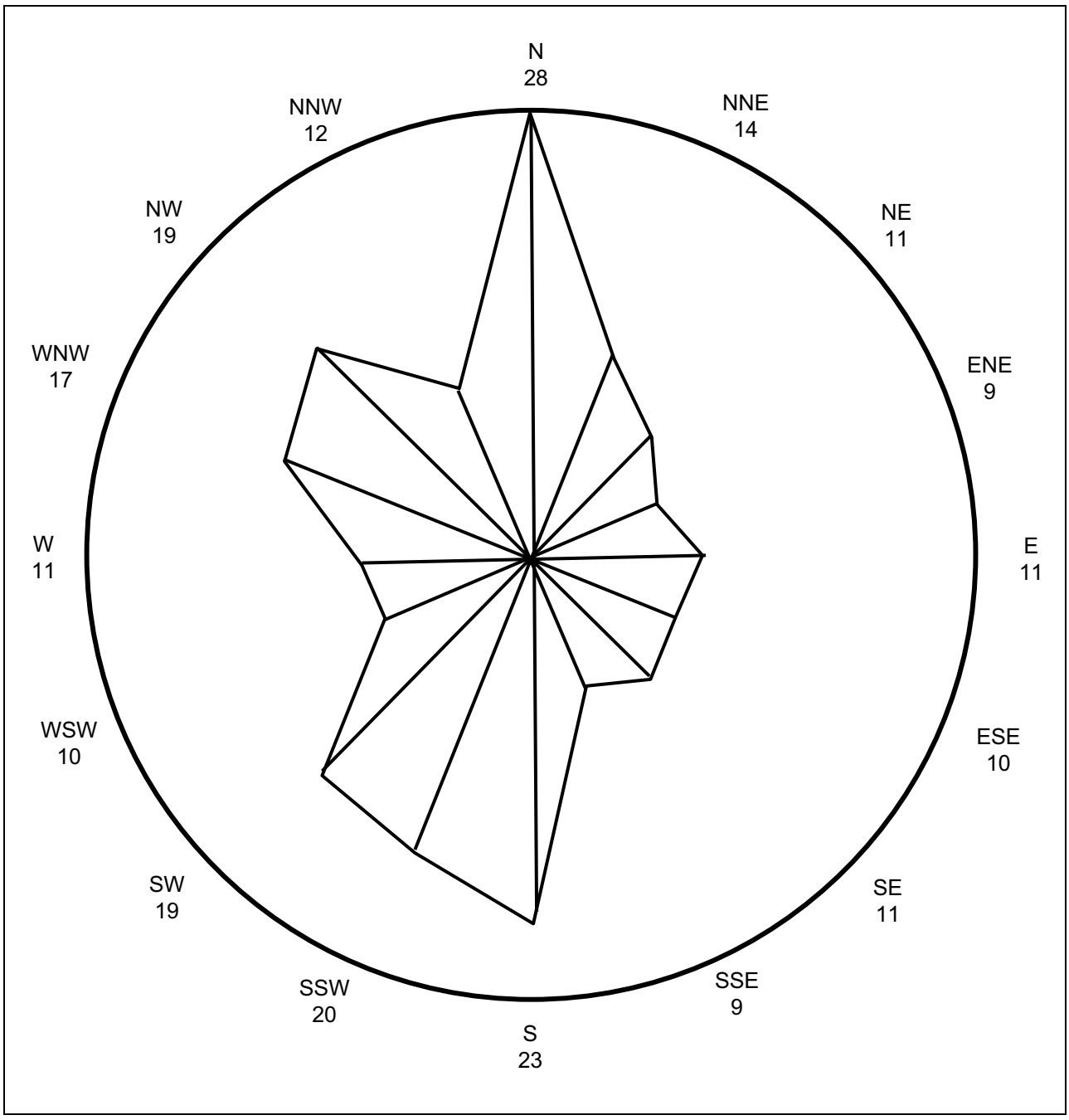


Figure 2.7-14 North Anna Seasonal Wind Persistence Roses: High-Level Winds: 1974–1987: Season = Spring

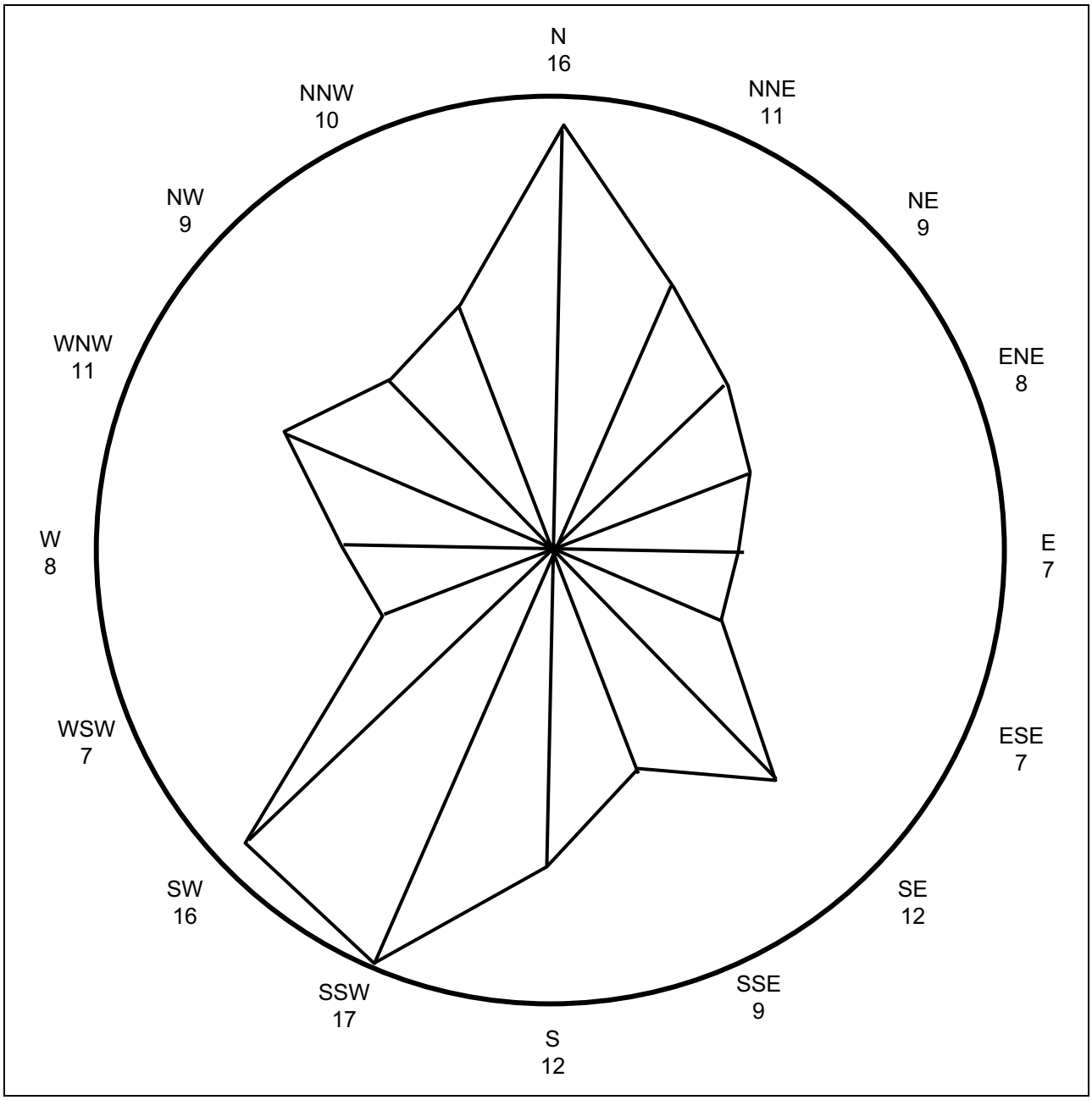


Figure 2.7-15 North Anna Seasonal Wind Persistence Roses: Low-Level Winds: 1974–1987: Season = Summer

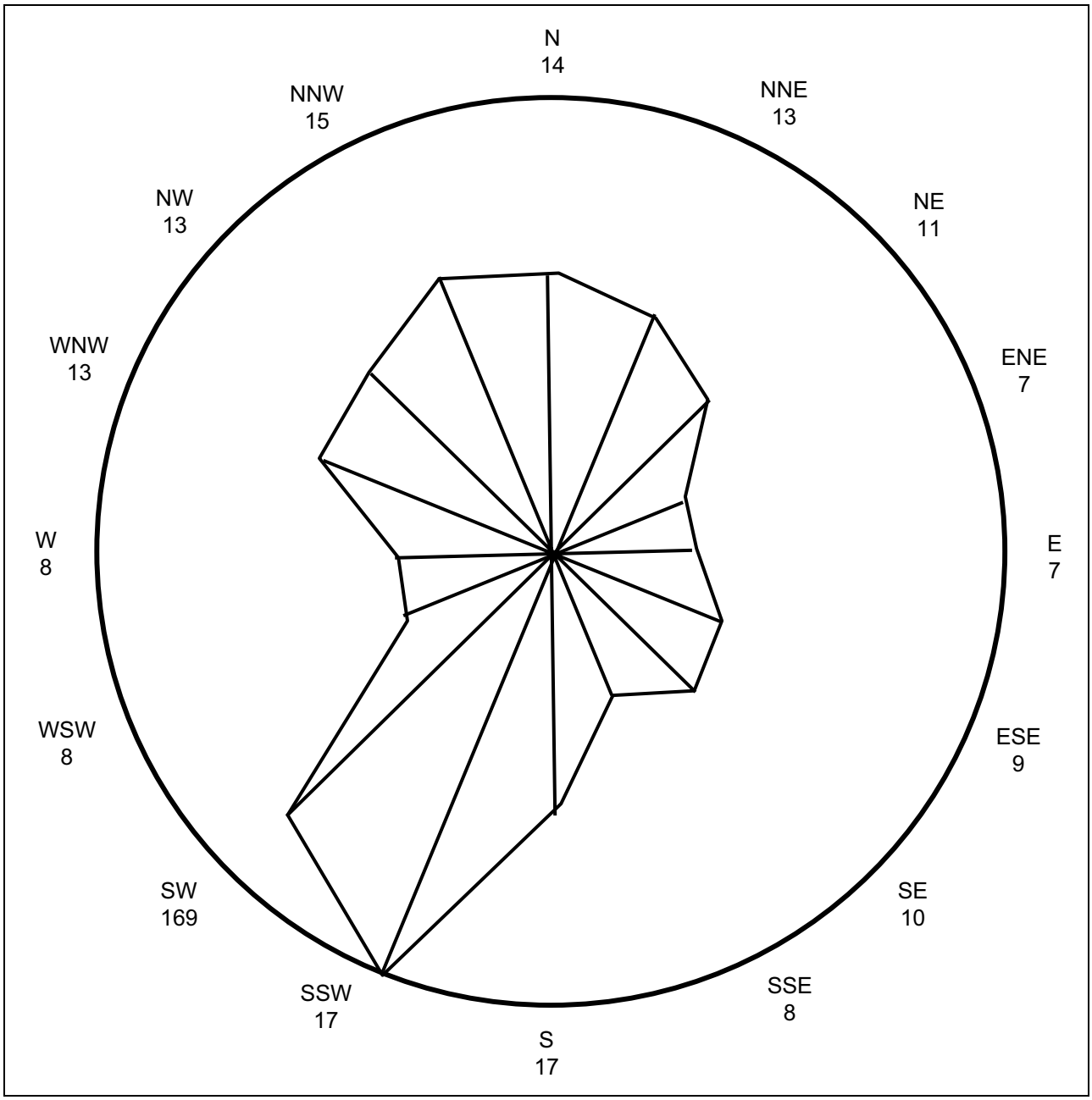


Figure 2.7-16 North Anna Seasonal Wind Persistence Roses: High-Level Winds: 1974–1987: Season = Summer

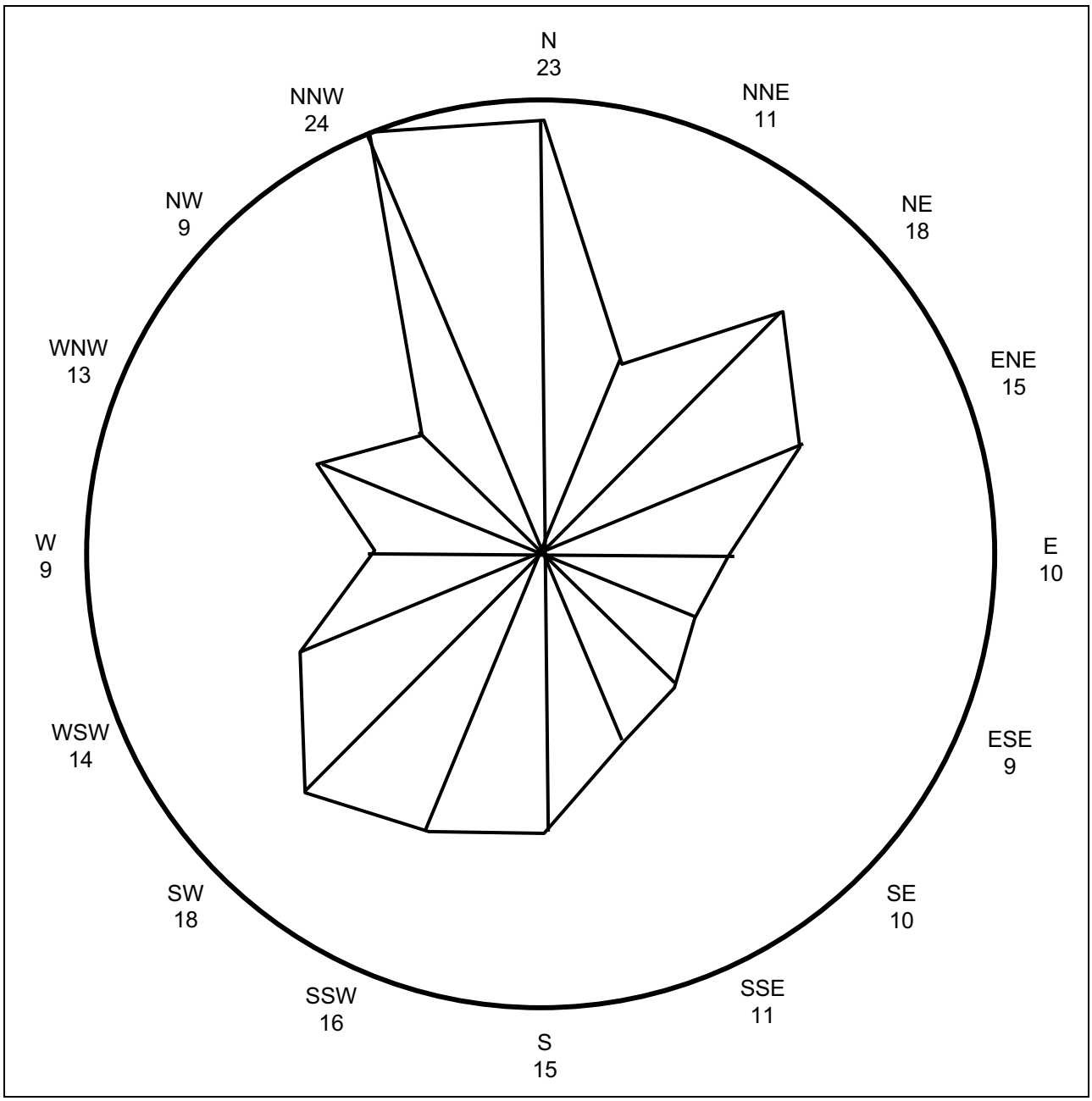


Figure 2.7-17 North Anna Seasonal Wind Persistence Roses: Low-Level Winds: 1974–1987: Season = Fall

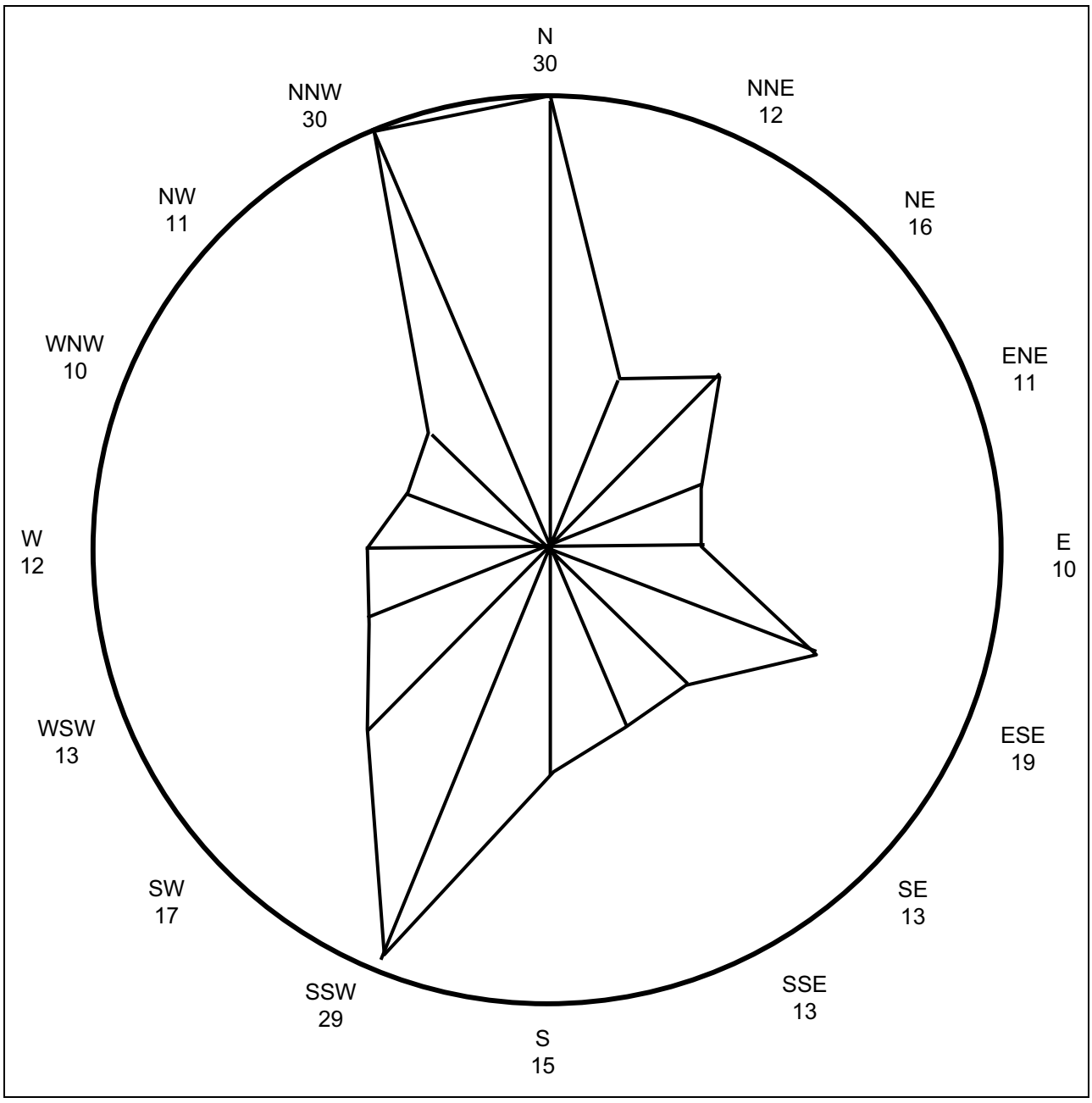


Figure 2.7-18 North Anna Seasonal Wind Persistence Roses: High-Level Winds: 1974–1987: Season = Fall

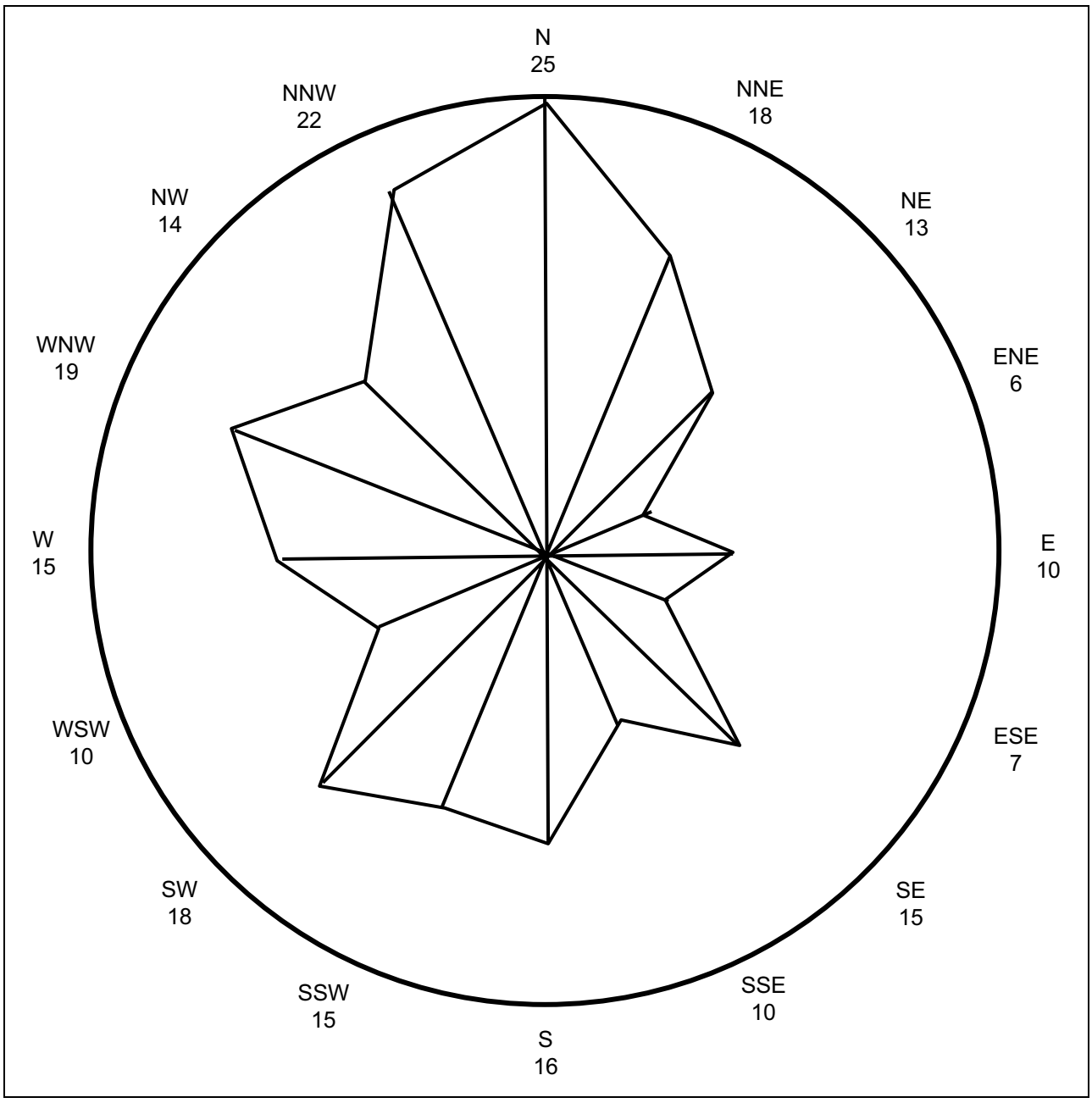


Figure 2.7-19 North Anna Seasonal Wind Persistence Roses: Low-Level Winds: 1974–1987: Season = Winter

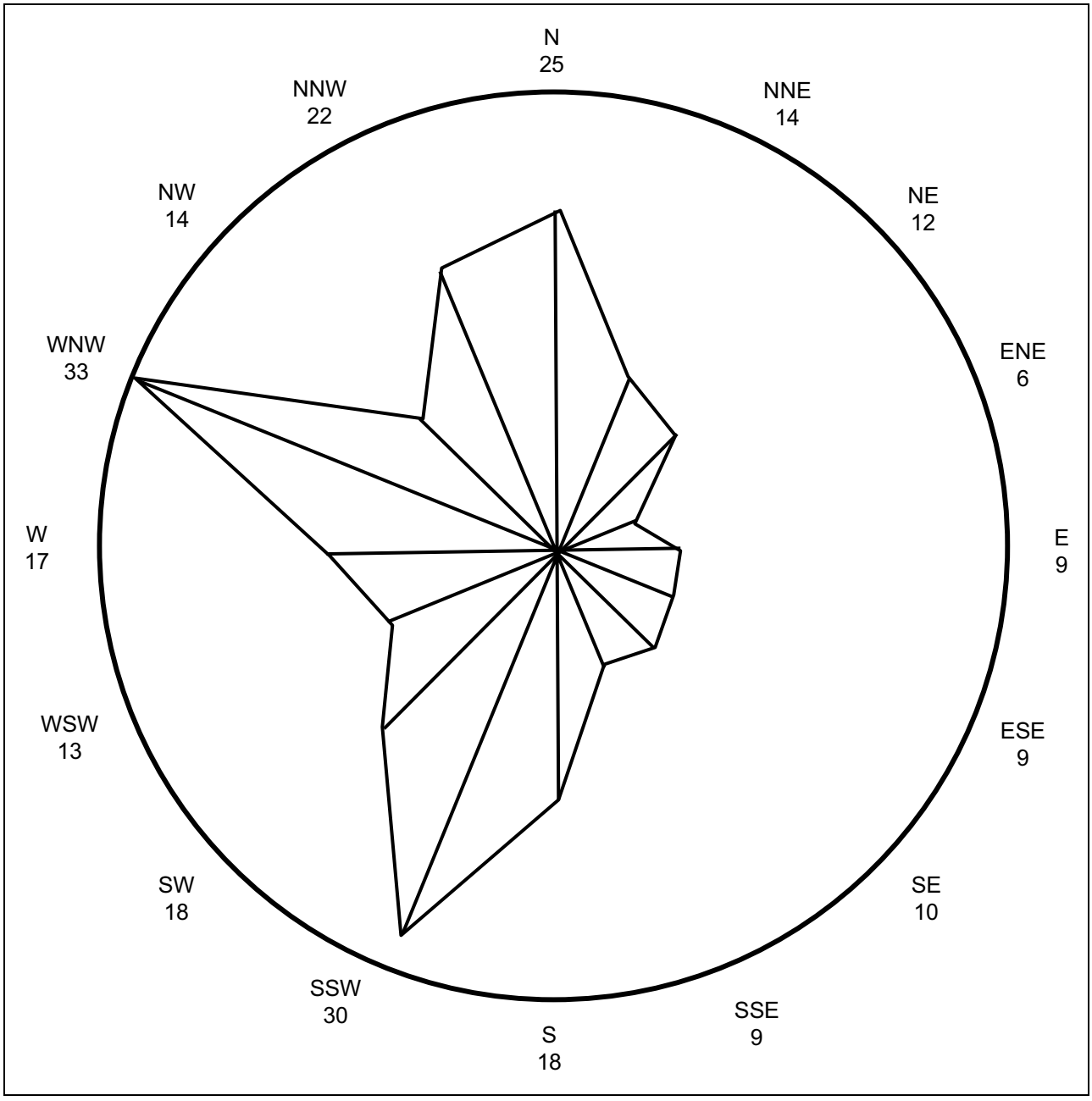


Figure 2.7-20 North Anna Seasonal Wind Persistence Roses: High-Level Winds: 1974–1987: Season = Winter

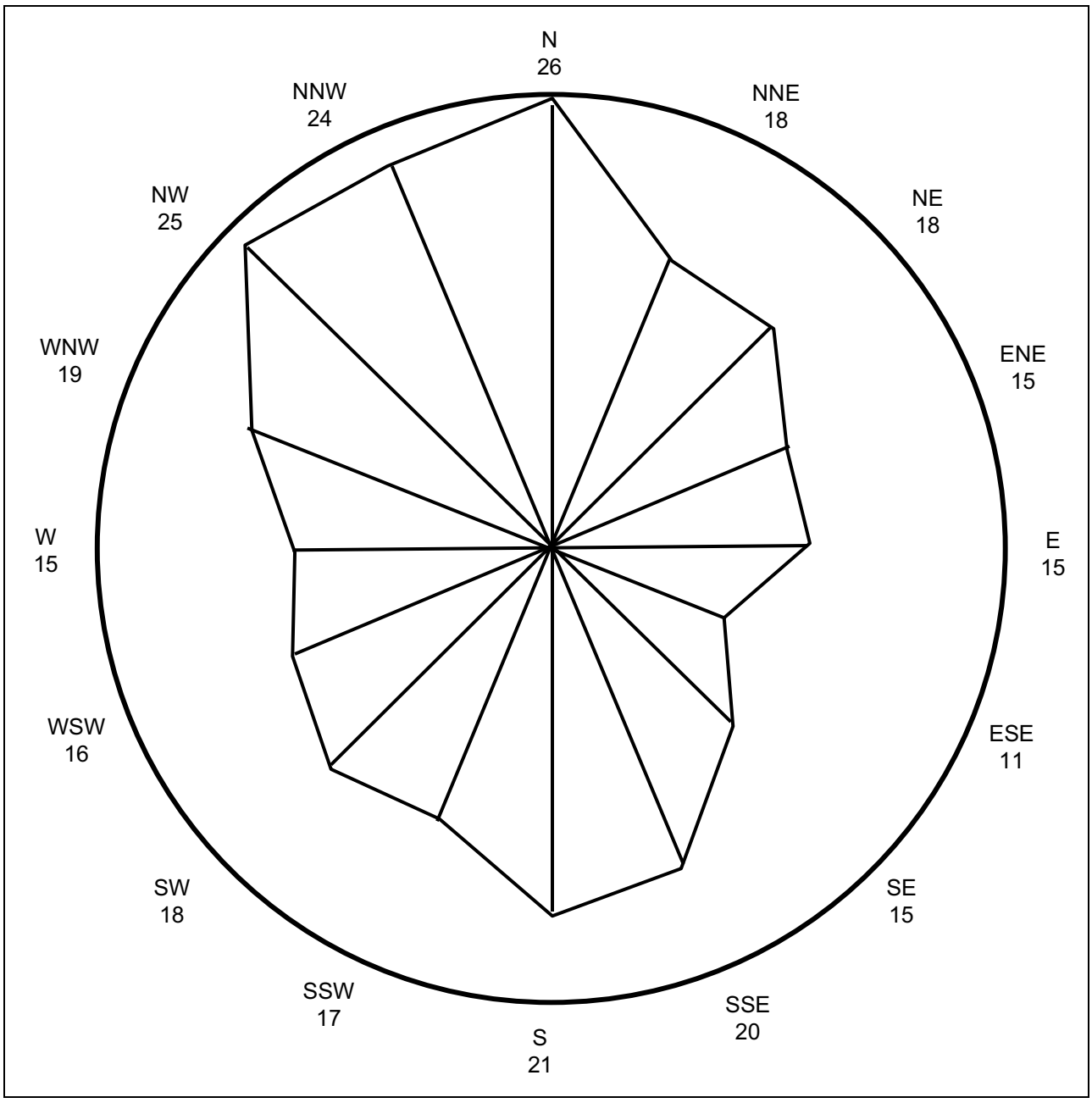


Figure 2.7-21 North Anna Seasonal Wind Persistence Roses: Low-Level Winds: 1974–1987: Season = Overall

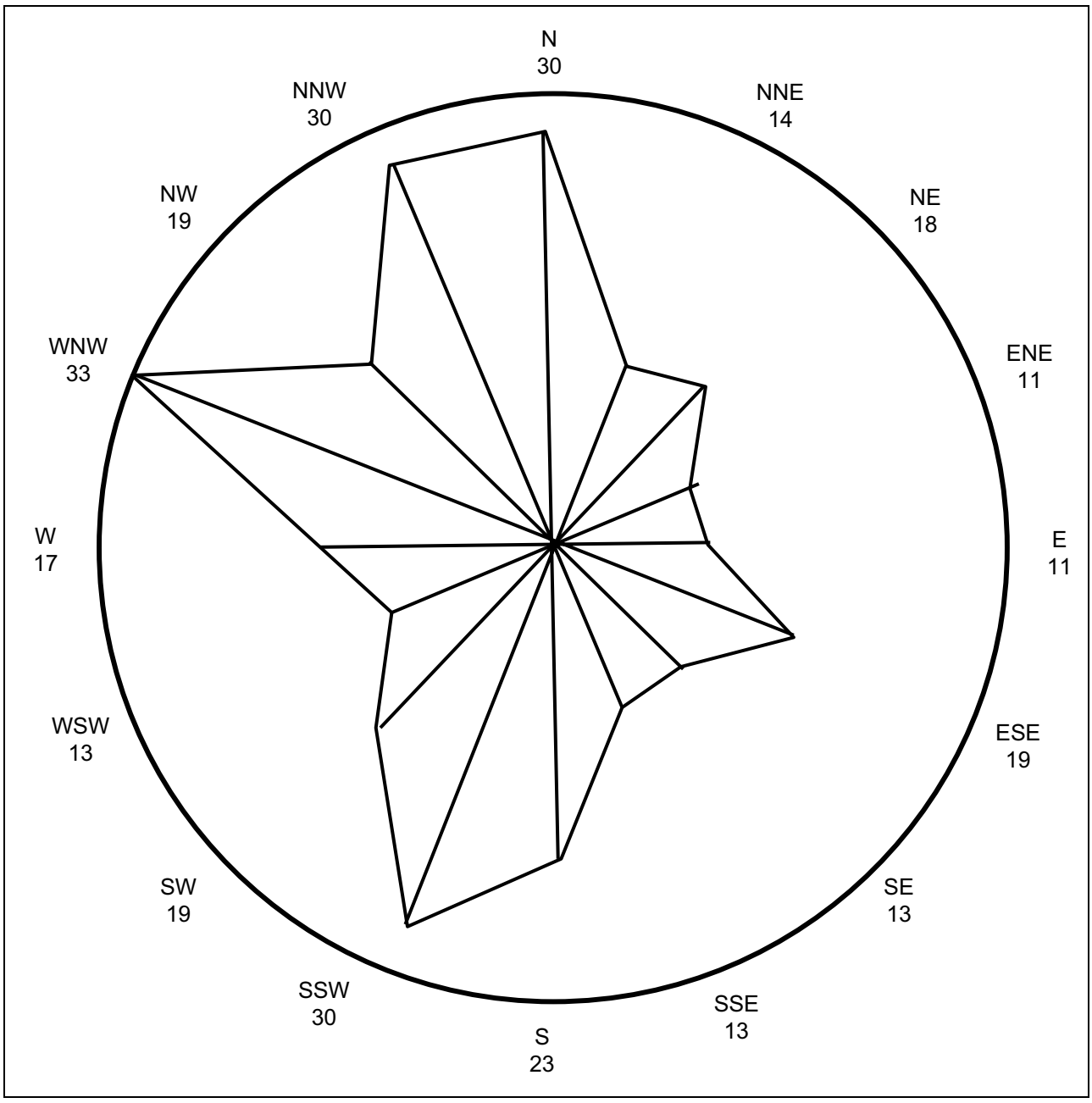


Figure 2.7-22 North Anna Seasonal Wind Persistence Roses: High-Level Winds: 1974–1987: Season = Overall

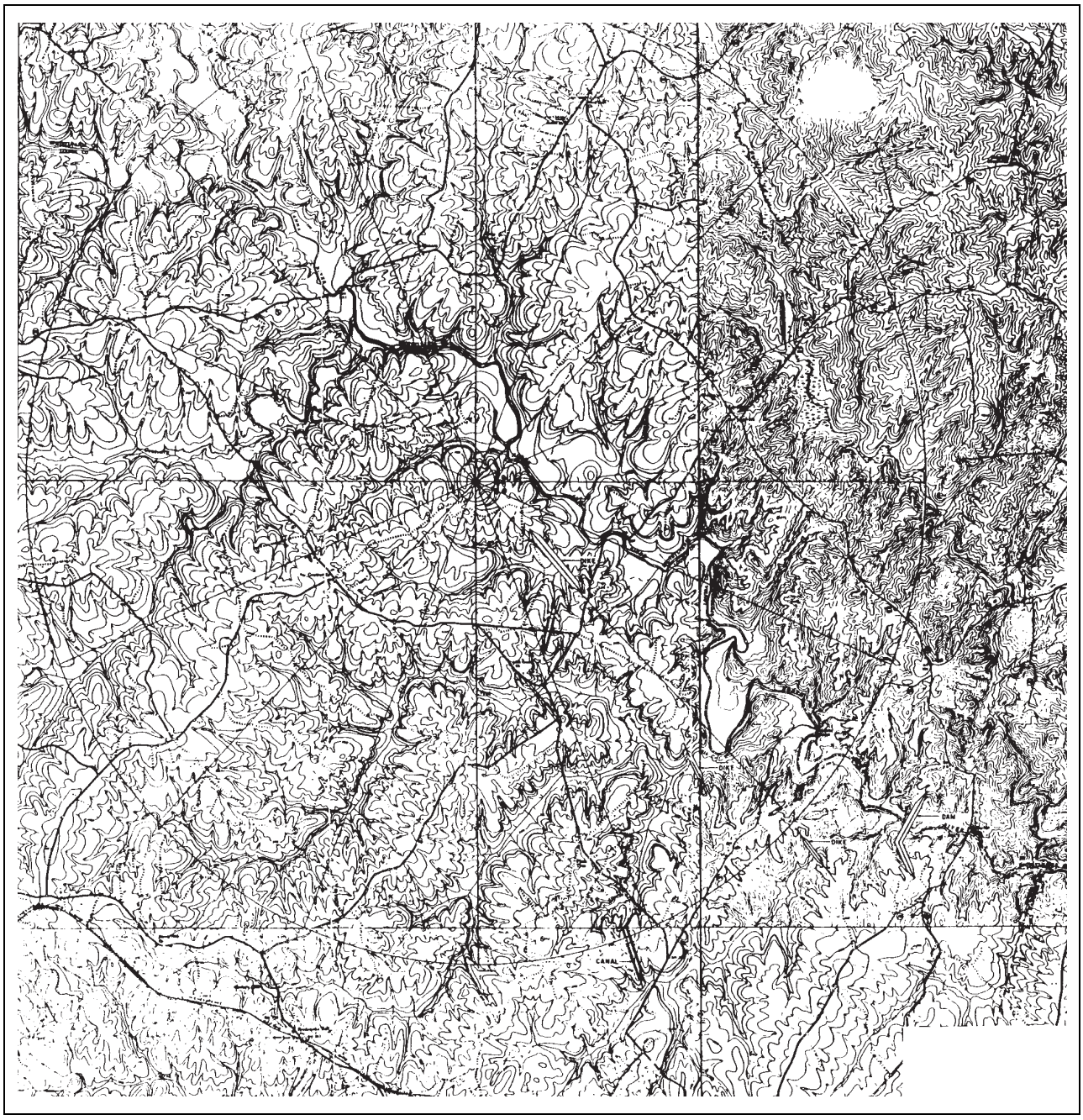
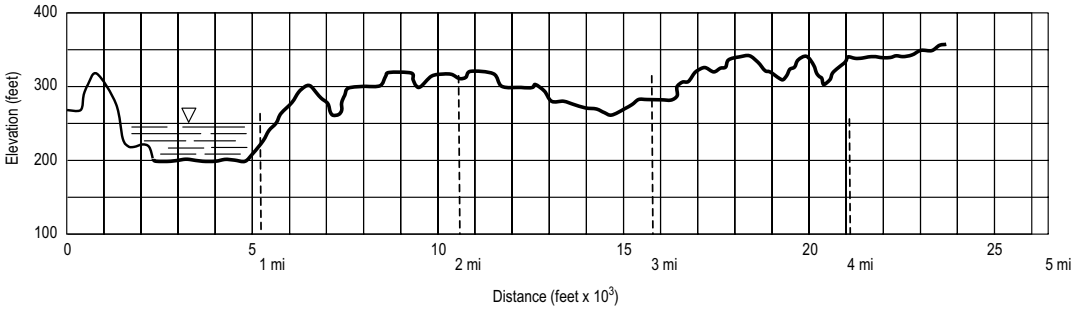
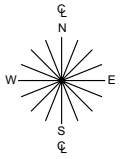
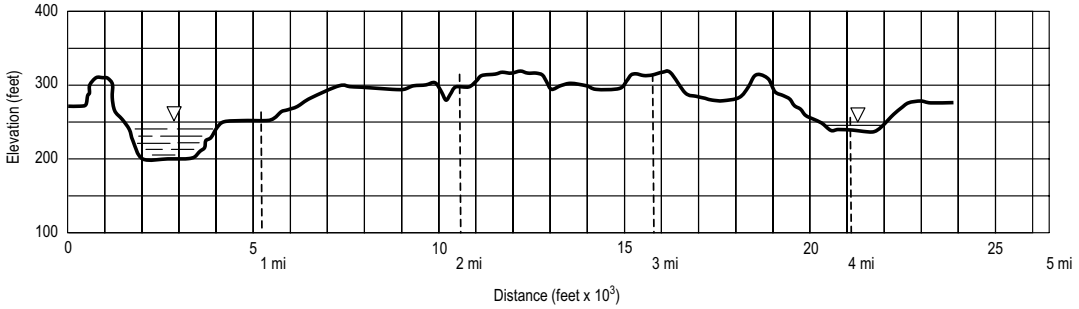


Figure 2.7-23 Topographic Map
Source: Reference 2





From Reactor 3 to Reference Point (Lat. 38°-07'-12", Long. 77°-04'-20")



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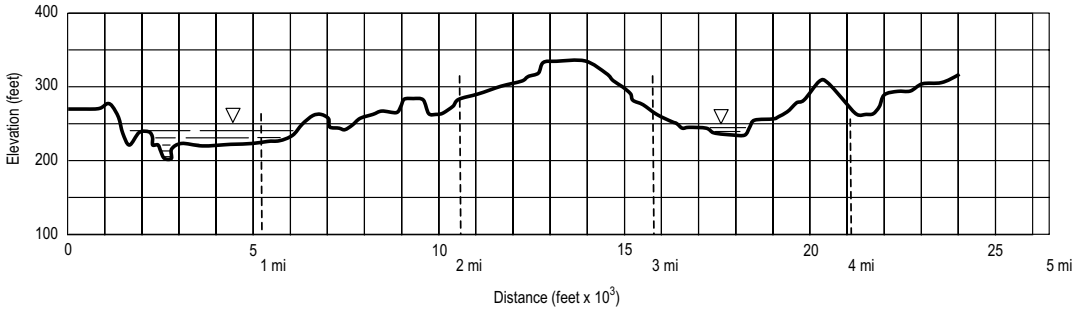
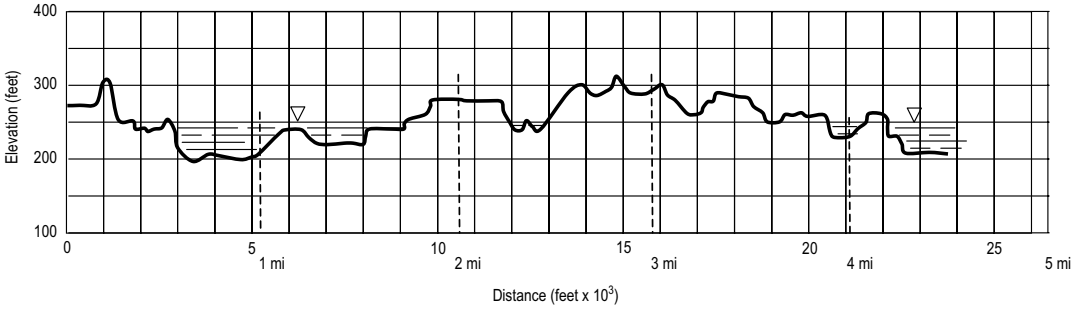
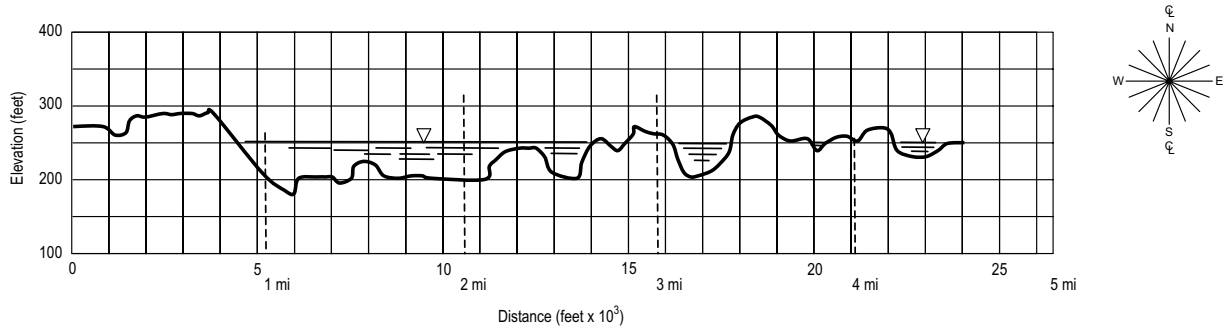


From Reactor 3 to Reference Point (Lat. 38°-03'-02", Long. 77°-42'-51")

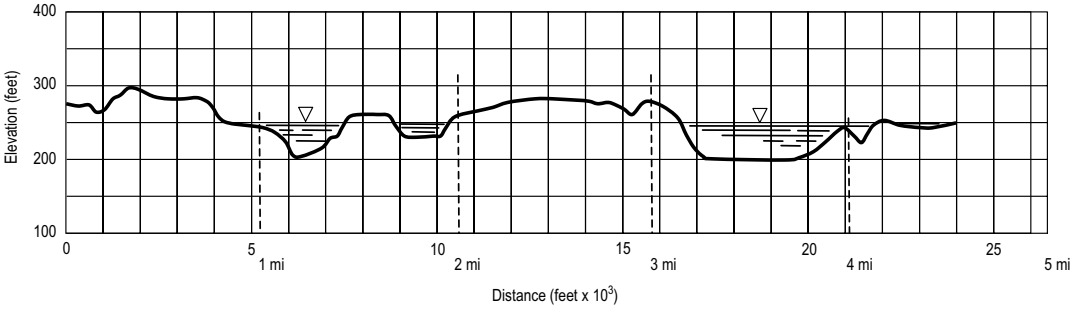


From Reactor 3 to Reference Point (Lat. 38°-03'-03", Long. 77°-42'-30")

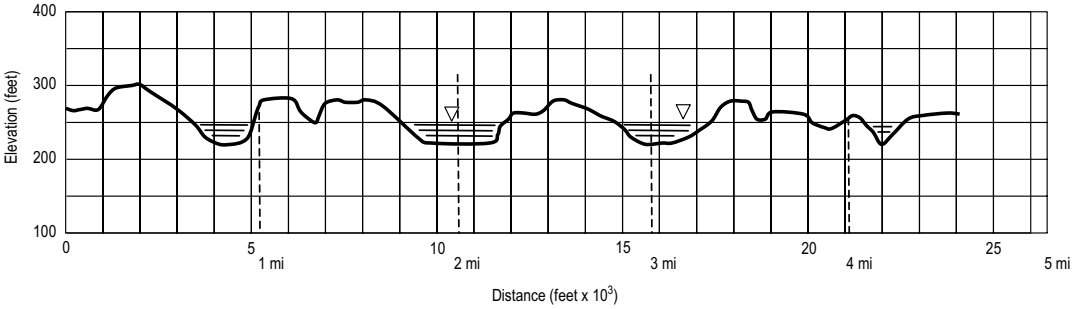
Figure 2.7-24 Vertical Profiles (Sheet 1 of 4)
Source: Reference 2



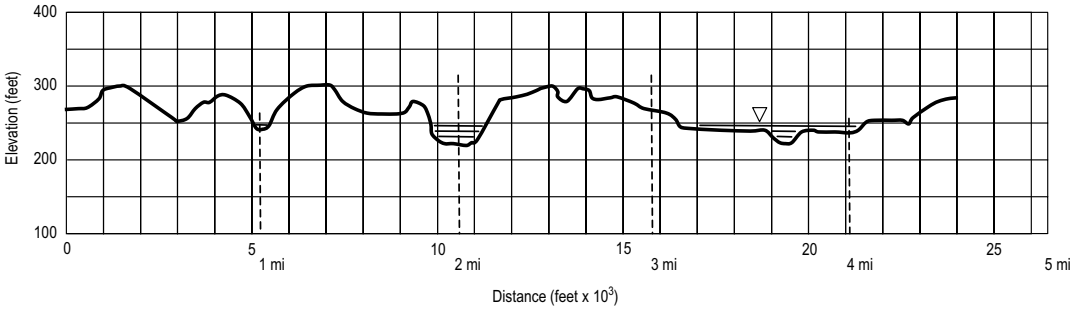
From Reactor 3 to Reference Point (Lat. 38°-01'-37", Long. 77°-42'-51")



From Reactor 3 to Reference Point (Lat. 38°-00'-40", Long. 77°-43'-57")



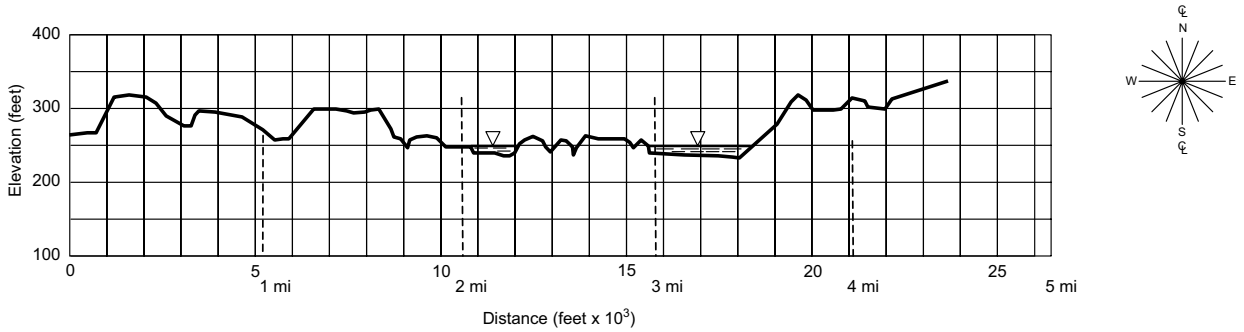
From Reactor 3 to Reference Point (Lat. 38°-00'-00", Long. 77°-45'-30")



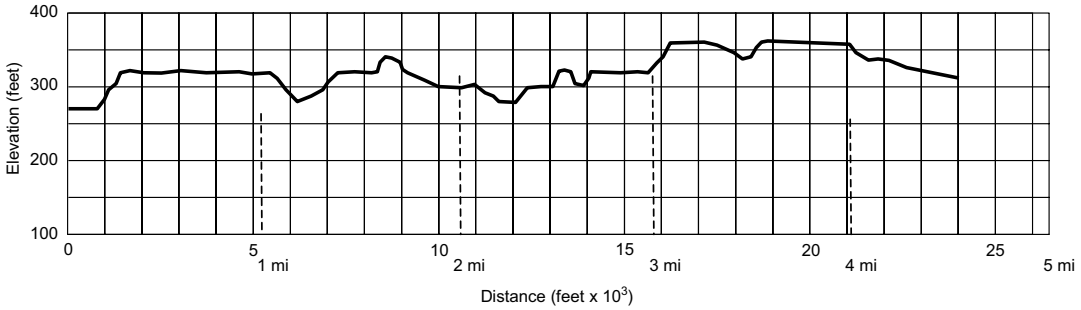
From Reactor 3 to Reference Point (Lat. 37°-59'-59", Long. 77°-47'-28")

Figure 2.7-24 Vertical Profiles (Sheet 2 of 4)

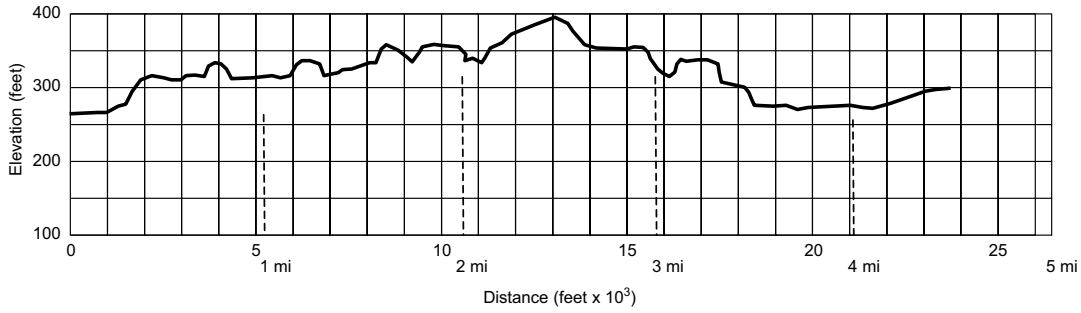
Source: Reference 2



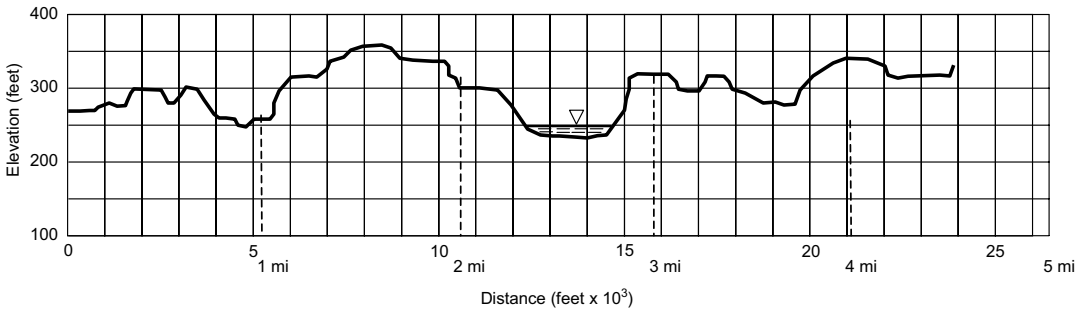
From Reactor 3 to Reference Point (Lat. 38°-00'-00", Long. 77°-49'-28")



From Reactor 3 to Reference Point (Lat. 38°-00'-00", Long. 77°-30'-39")



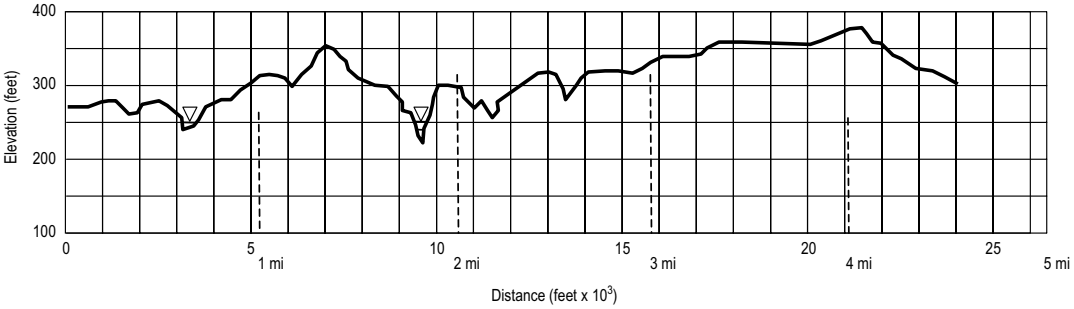
From Reactor 3 to Reference Point (Lat. 38°-01'-37", Long. 77°-32'-03")

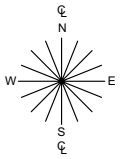


From Reactor 3 to Reference Point (Lat. 38°-03'-30", Long. 77°-52'-28")

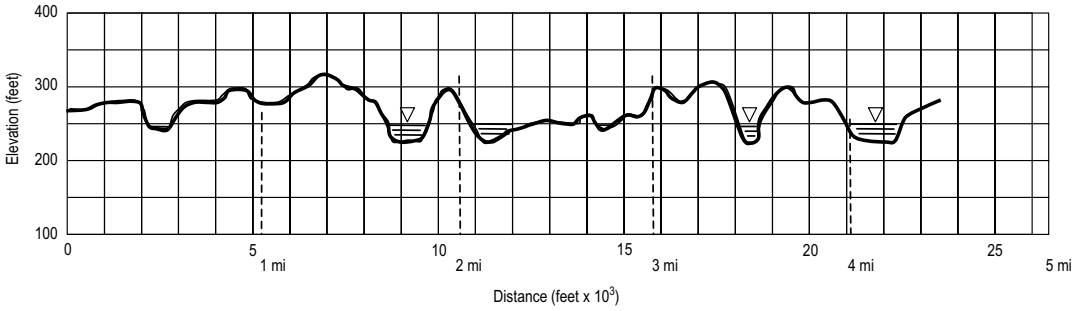
Figure 2.7-24 Vertical Profiles (Sheet 3 of 4)

Source: Reference 2

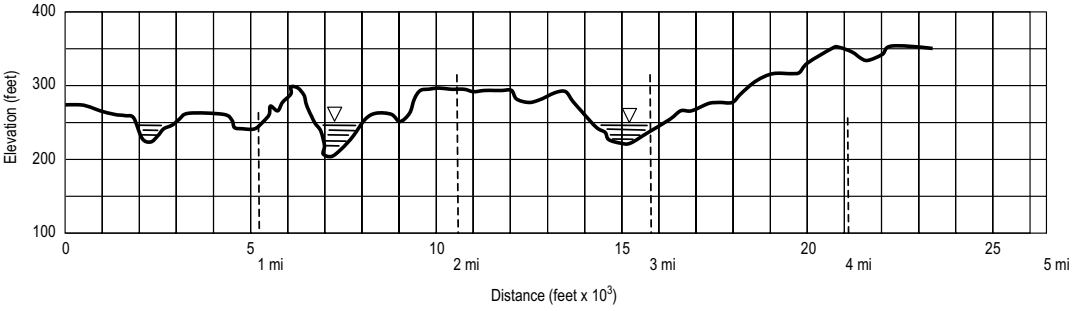




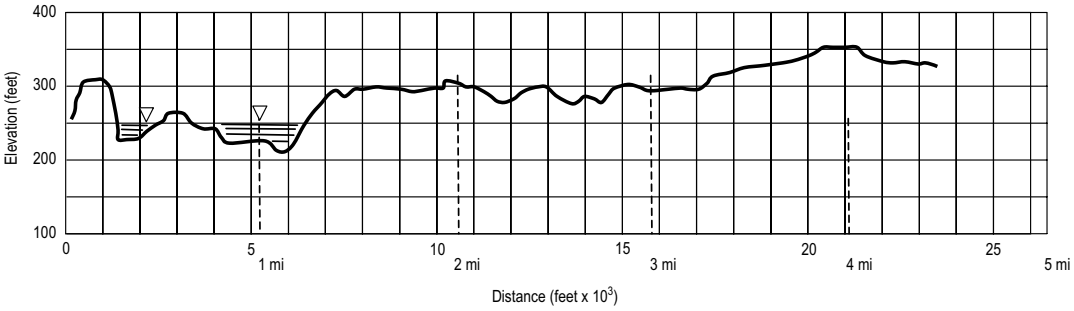
From Reactor 3 to Reference Point (Lat. 38°-05'-02", Long. 77°-52'-05")



From Reactor 3 to Reference Point (Lat. 38°-06'-20", Long. 77°-50'-59")



From Reactor 3 to Reference Point (Lat. 38°-07'-12", Long. 77°-47'-23")



From Reactor 3 to Reference Point (Lat. 38°-07'-30", Long. 77°-47'-23")

Figure 2.7-24 Vertical Profiles (Sheet 4 of 4)

Source: Reference 2

2.8 Related Federal Project Activities

The purpose of this section is to identify any federal activities related to this ESP application and to highlight the possible need for federal agencies to participate in the preparation of the environmental impact statement as cooperating agencies.

In summary, there are no known federal activities or projects associated with early site permitting at the ESP site.

Specifically:

- No known federal projects (e.g., water supply pipelines) are planned that would provide additional cooling water for the new units.
- No known federal actions are planned regarding the acquisition and/or use of the ESP site.
- No known federal projects are planned that must be completed as a condition of construction or operation of the new units.
- No known federal projects are contingent on construction or operation of the new units at the ESP site.

Section 2.8 References

None

Chapter 3 Plant Description

This chapter describes the plant design and the potential impacts of that design on the ESP site. The specific plant type to be constructed at the site has not been selected, and in its place a list of parameters describing a bounding plant design, the PPE, has been provided. The PPE is a comprehensive list of plant data developed from a variety of plant types available or proposed for the U.S. market. Section 3.1 provides details on the development of the PPE and the PPE data itself.

New units for which the site might be used, to be designated Units 3 and 4, would be located adjacent to the existing units. The site design would make the maximum use of existing permanent site support structures. Detailed information about the new units is presented in this section.

This chapter is organized into the following sections:

- External Appearance and Plant Layout (Section 3.1)
- Reactor Power Conversion System (Section 3.2)
- Plant Water Use (Section 3.3)
- Cooling System (Section 3.4)
- Radioactive Waste Management System (Section 3.5)
- Nonradioactive Waste Systems (Section 3.6)
- Power Transmission System (Section 3.7)
- Transportation of Radioactive Materials (Section 3.8)

3.1 External Appearance and Plant Layout

3.1.1 Existing Site Development

The existing NAPS site development consists of two operational pressurized water reactors (PWRs) furnished by Westinghouse, a shared turbine building, and other supporting structures. These structures include a switchyard, intake and discharge structures, and support buildings. The site is located on the shore of Lake Anna. Lake Anna is divided into the North Anna Reservoir, which serves as the source for cooling water for the existing units, and the WHTF, which receives their heated discharge. The existing units use a spray pond for an ultimate heat sink (UHS). A radioactive waste disposal system, a fuel handling system, and the auxiliaries, structures, and other onsite facilities required for a complete nuclear power station also exist on the NAPS site. The tallest existing structures on the NAPS site are each existing units' containment building, rising 157 feet, 6 inches above grade.

The NRC issued operating licenses in April 1978 and August 1980 for Units 1 and 2, respectively. Unit 1 started commercial operation in June 1978 and Unit 2 in December 1980. In April 2003, the NRC renewed the operating licenses for Units 1 and 2. A complete description of the power station is provided in the NAPS UFSAR, NRC Dockets 50-338/339. (Reference 1)

An ISFSI is also located on the NAPS site. A complete description of the ISFSI is provided in the North Anna ISFSI Safety Analysis Report, NRC Docket 72-16. (Reference 2)

The existing NAPS site development is shown in Figure 3.1-1.

With the exception of a few support buildings that may be relocated, the existing NAPS site development would remain as is.

3.1.2 Power Plant Design

No specific plant design has been chosen for the new units. Instead, a set of bounding plant parameters is presented to envelop ESP site development. This PPE is based on the addition of power generation in two distinct units, designated North Anna Units 3 and 4.

Each new unit would represent a portion of the total generation capacity to be added and may consist of one or more reactors or reactor modules. These multiple reactors or modules (the number of which may vary depending on the reactor type selected) would be grouped into distinct operating units. Each new unit would be a stand-alone plant, with its own support systems and structures. These new units would share ancillary support structures such as maintenance facilities, office centers or waste and water treatment plants. Section 3.1.3 provides a description of the PPE and describes its development.

3.1.2.1 **Module Description**

Depending on the reactor type selected, new units would be developed and constructed in a conventional style as individual large capacity reactors, or in modules, with each module being a small, self-contained reactor and power conversion unit. These modules would be grouped together around a single common support building, containing multi-unit support systems and a control area. This common support building would provide a means for controlling access to the individual modules. The individual modules would be constructed as needed, with much of the fabrication and construction work performed at a central location. The individual modules could then be easily integrated into the common support building and supporting systems.

The module sizes may vary, depending on the reactor type. Some gas-cooled reactors have a thermal output of as little as 400 MWt while other pressurized water module designs may be as large as 1000 MWt. Multiple modules would be grouped into units around the common support building to provide an economical single source of electricity.

3.1.2.2 **New Unit Description**

Not all of the reactor types are designed as modules. Some of the possible designs are conventional style plants, based on single-reactor or dual-reactor construction. These plants are designed with individual turbine buildings and reactor buildings for each unit, and some of the designs share some systems and facilities. The layout of these plants is such that the numbers of secondary structures is minimized and overall land area of the plant is controlled to the extent practical.

The unit sizes of these conventional plants also vary, with some individual units having reactor ratings of as much as 4500 MWt. The conventional style plants that are based on dual-reactor construction have individual power ratings significantly less than that stated above, and the 4500 MWt rating bounds these dual-reactor designs.

The common support buildings for both the modular and the conventional plants would be designed to integrate into the overall station design. Each support building and associated modules would be called an operating unit, with a single control room and operating staff.

An operating unit or group of modules typically has a maximum total thermal power rating of not greater than 4500 MWt, with a maximum electrical capacity of about 1520 MWe. The structure would consist of between 1 and 8 reactors or reactor modules structured around a common support building and/or conventional turbine building. The ESP site can accommodate construction and operation of various numbers of new reactors and/or modules, configured as two operating units, up to a total of 9000 MWt or about 3040 MWe.

Structure height would vary depending upon the reactor design chosen. The PPE states that the highest expected structure for the power plant itself (excluding any potential cooling towers) would be approximately 234 feet above grade level. Buildings for the new facility would generally be

shorter than 234 feet, and constructed of concrete, metal with metal siding, or, in a few cases, wood with metal, vinyl, or other aesthetically acceptable siding.

Figure 3.1-2 provides an artist's conception of the ESP site, with the new units superimposed.

Unit 3 would use closed-cycle, combination dry and wet cooling towers that would be placed on the ESP site in the area shown for cooling towers on Figure 3.1-3. Unit 3 dry and wet cooling towers would be less than 180 feet high. Make-up water for Unit 3 wet cooling towers would be provided from Lake Anna. To extract make-up water from the Lake, a new intake structure would be constructed near the existing Unit 1 and 2 intake structure. Unit 4 would use dry cooling towers, with finned-fan air coolers that would be placed on the ESP site in the area shown for cooling towers on Figure 3.1-3. The dry towers would be approximately 150 feet high, and would consist of a series of modules, each containing air-circulating fans. The Unit 3 and 4 cooling towers would be located with the approximately 55-acre cooling tower area.

3.1.3 Generic Plant Parameters Envelope

The Generic PPE was developed to characterize the installation of new nuclear generating units at the site without specifying a specific design. The PPE parameters were selected to provide an overall and thorough technical description of the bounding plant; that is, a combination of design parameters that, taken together, encompasses the addition of a maximum amount of generation of various reactor types.

Section 1.3 of the Site Safety Analysis Report (SSAR) includes technical data characterizing the installation of one or two new units. The values presented are for a single unit addition (where a unit may be made up of multiple modules or reactors). The ESP site can accommodate two of these units.

This Generic PPE was developed from reviews of technical data from seven designs. These designs included five water-cooled reactors: the single-unit Westinghouse AP1000; the dual-unit Atomic Energy Canada, Ltd., ACR-700; the single-unit General Electric ABWR; the single-unit General Electric ESBWR; and the three-unit design of the Westinghouse-led International Reactor Innovative and Secure (IRIS). Two gas-cooled reactors were also included in the reviewed designs: the four-module General Atomics Gas Turbine Modular Helium Reactor (GT-MHR) and the eight-module Pebble Bed Modular Reactor (PBMR) Pty (LTD). The Generic PPE is not intended to be limited to these designs, but rather to provide a broad overall outline of a design concept and to include other potential designs if they can be demonstrated to fall within the parameter values provided in the Generic PPE.

The Generic PPE is reproduced from the SSAR beginning with Table 3.1-1.

Table 3.1-9, Bounding Site-Specific Plant Parameters Envelope, which contains the bounding site characteristics and design parameters for assessing the environmental impacts of constructing and operating nuclear power plants at the proposed ESP site, is described in Section 3.1.6.

3.1.4 Plant Appearance

The reactor type that would be constructed at the ESP site has not been selected, but a general description of the new units can be presented. Figure 3.1-3 shows the location where Units 3 and 4 would be installed.

The current NAPS site has two operating units with concrete containment buildings next to a steel and siding common turbine building. These are connected by a common concrete auxiliary building and a steel- and metal-sided fuel building.

The new units at the ESP site would be designed to emphasize the two-power-unit concept. The new units, along with their support structures, would be kept separate from each other and from the existing units. Each new unit would have its own control room and structure, but could share radwaste and other waste handling facilities. Paved site roadways would connect the new units to the rest of the NAPS site, providing routine and non-routine access to current and new plants with minimal disturbance of the area. Cooling towers for the new units would be located on a nearly 55-acre portion of the site, which has been specifically designated for them.

The modules and multi-unit designs would be fully integrated into the design of each new unit. Where possible, building lines would be blended to minimize the visual effect and reduce the multiple module visual images. This aesthetically pleasing visual effect would be accomplished by connecting turbine and support buildings and blending multiple containment structures together where possible. A separate control area for each unit would be used to further enhance the single unit concept. The use of common and shared support systems would reduce the number of ancillary buildings and connecting structures.

3.1.5 Site Development and Improvements

A combination of dry and wet cooling towers would provide cooling for Unit 3. Dry cooling towers use water-to-air finned-fan coolers to transfer heat through the finned tubes to the atmosphere. The dry tower would comprise fans that pass air through finned tubes and discharge the air to the atmosphere. A series of tower modules would provide the needed cooling surface area for approximately one-third of Unit 3 heat duty at design ambient conditions. The dry towers themselves do not allow circulating water evaporation since the water is fully contained inside the tubes. The wet cooling towers would remove the heat by spraying the water into a forced air or induced stream. The wet towers would have the capacity to meet all of Unit 3 condenser cooling requirements. The existing capacity of Lake Anna would allow the Unit 3 (up to 4500 MWt) wet cooling tower system to draw make-up water from the lake. Cooling capacity of the lake and operating modes of dry and wet cooling towers are presented in Section 3.4. To extract make-up water from the lake, a new intake structure would be constructed near the existing intake structure for the operating units. All cooling system discharges for both the existing units and the new Unit 3 cooling tower blowdown would be sent to the WHTF via the existing discharge canal. The new intake structure would be designed to be complementary in appearance to the existing structures.

Dry cooling towers would provide cooling for Unit 4. Dry cooling towers utilize water-to-air finned fan coolers to transfer heat through the finned tubes to the atmosphere. The tower would be comprised of fans passing air through finned tubes and discharging the air to the atmosphere. A series of tower modules would provide the needed cooling surface area for Unit 4. The towers themselves do not allow circulating water evaporation since the water is fully contained inside the tubes.

Operation of the cooling fans in the towers would create an audible noise. By using standard design techniques, the noise contribution from the dry tower and wet tower systems would produce impacts below 60 dBA at the EAB. Tower height is presented in Section 3.1.2.2. The proposed tower locations, indicated in Figure 3.1-3, are west of the proposed locations for new units.

Some plant designs require additional cooling space for safety systems, sometimes called UHS cooling. These cooling requirements are small compared to normal heat rejection requirements and are met through the use of mechanical draft towers. The area required for these towers is approximately 0.5 acres per unit (see Table 3.1-1) and the towers are no more than 60 feet high. Ample space exists near Units 3 and 4 to locate these towers.

Since the ESP site has some distinct elevation changes, use of topographical elements to shield and screen the site structures would be encouraged. The grade elevation for the new units would approximate the grade of the existing units where possible. This positioning would provide a single station visual effect and promote a more consistent overall aesthetic view of the station. These topographical elements would also serve to reduce noise impacts on the surrounding area.

Some services and support structures that are suited to support multiple units, including the current operating plant facilities - such as office facilities, warehouse space, switchyard, and water and sewage treatment - would be at locations on the NAPS site. To the extent practical, efforts would be made to use and expand the existing facilities, including the training center, for these functions. Expansion of these facilities to support the additional generation and plant population would reduce the overall impact to the site, compared to the construction of new and separate stand-alone facilities. Figure 3.1-3 shows the integration of the new and existing units as well as site roadways and access.

After the completion of new unit construction, areas used for construction support would be landscaped and planted where appropriate to match the overall site appearance. Previously forested areas would be planted with seedlings and harsh topographical features created during construction would be contoured to match the surrounding areas. These areas include equipment laydown and module fabrication areas, areas around completed structures, and construction parking that is not required following the completion of construction.

Construction of Units 3 and 4 could occur in a single time frame (back to back) or could be separated by a significant amount of time. In the event of a time separation, efforts would be made to landscape and plant the unused portion of the site to control erosion and restore those disturbed

areas to green space. The interim plantings would consist of not less than grass seeding with a mix appropriate for the area.

3.1.6 Bounding Site-Specific Plant Parameters Envelope

Table 3.1-9, Bounding Site-Specific Plant Parameters Envelope, provides a summary listing of site characteristics that have been established by analyses presented throughout the ER. This list provides a summary of bounding site characteristics that are important for assessing the environmental impacts of constructing and operating nuclear power plants at the proposed ESP site. This listing is intended to support development of Table 2, “Site Characteristics and Plant Design Parameters for the Early Site Permit,” as defined by Reference 3. Table 3.1-9 also provides a listing of design parameters and assumptions about the design of a nuclear power plant that might in the future be constructed on the ESP site. It was necessary to assume certain design parameters in order to assess site characteristics.

Section 3.1 References

1. *North Anna Power Station UFSAR*, Revision 38.

2. *North Anna ISFSI Safety Analysis Report*, Revision 3.

3. NRC letter to Dominion, J. E. Lyons to D. A. Christian, "Early Site Permit Template," June 22, 2004.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
1. Structures			c	
1.1 Building Characteristics				
1.1.1 Height	234 ft-0 in. [Same for 2nd unit/group]	1		The height from finished grade to the top of the tallest power block structure, excluding cooling towers.
1.1.2 Foundation Embedment	140 ft [Same for 2nd unit/group]	2		The depth from finished grade to the bottom of the basemat for the most deeply embedded power block structure.
1.2 Precipitation (for Roof Design)				
1.2.1 Maximum Rainfall Rate	19.4 in/hr (6.2 in/5 min) [Same for 2nd unit/group]	2, 3, 4, 5		The probable maximum precipitation (PMP) value that can be accommodated by a plant design. Expressed as maximum precipitation for 1 hour in 1 square mile with a ratio for five minutes to the 1 hour PMP of 0.32 as found in National Weather Service Publication HMR No. 52.
1.2.2 Snow and Ice Load	50 lb/sq ft [Same for 2nd unit/group]	2, 3, 4		The maximum load on structure roofs due to the accumulation of snow and ice that can be accommodated by a plant design.
1.3 Safe Shutdown Earthquake (SSE)				
1.3.1 Design Response Spectra	RG 1.60 [Same for 2nd unit/group]	6		The assumed design response spectra used to establish a plant's seismic design.
1.3.2 Peak Ground Acceleration	0.30g [Same for 2nd unit/group]	6		The maximum earthquake ground acceleration for which a plant is designed; this is defined as the acceleration which corresponds to the zero period in the response spectra taken in the free field at plant grade elevation.
1.3.3 Time History	Envelope SSE Response Spectra [Same for 2nd unit/group]	6		The plot of earthquake ground motion as a function of time used to establish a plant's seismic design.
1.3.4 Capable Tectonic Structures or Sources	No fault displacement potential within the investigative area [Same for 2nd unit/group]	1		The assumption made in a plant design about the presence of capable faults or earthquake sources in the vicinity of the plant site (e.g., no fault displacement potential within the investigative area).

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
1.4 Site Water Level (Allowable)				
1.4.1 Maximum Flood (or Tsunami)	1 ft below plant grade [Same for 2nd unit/group]	2, 3, 4		Design assumption regarding the difference in elevation between finished plant grade and the water level due to the probable maximum flood and probable maximum precipitation (defined in ANSI/ANS 2.8-1992) used in the plant design.
1.4.2 Maximum Ground Water	1 meter below grade (i.e., 3.3 feet below grade) [Same for 2nd unit/group]	7		Design assumption regarding the difference in elevation between finished plant grade and the maximum site ground water level used in the plant design.
1.5 Soil Properties Design Bases				
1.5.1 Liquefaction	None at Site-Specific SSE [Same for 2nd unit/group]	6		Design assumption regarding the presence of potentially liquefying soils at a site (e.g., none at Site-Specific SSE).
1.5.2 Minimum Bearing Capacity (Static)	15 ksf [Same for 2nd unit/group]	2, 3		Design assumption regarding the capacity of the competent load-bearing layer required to support the loads exerted by plant structures used in the plant design.
1.5.3 Minimum Shear Wave Velocity	≥3,500 fps [Same for 2nd unit/group.]	1		The assumed limiting propagation velocity of shear waves through the foundation materials used in the plant design.
1.6 Tornado (Design Bases)				
1.6.1 Maximum Pressure Drop	2.0 psi [Same for 2nd unit/group]	6		The design assumption for the decrease in ambient pressure from normal atmospheric pressure due to the passage of the tornado.
1.6.2 Maximum Rotational Speed	240 mph [Same for 2nd unit/group]	6		The design assumption for the component of tornado wind speed due to the rotation within the tornado.
1.6.3 Maximum Translational Speed	60 mph [Same for 2nd unit/group]	6		The design assumption for the component of tornado wind speed due to the movement of the tornado over the ground.
1.6.4 Maximum Wind Speed	300 MPH [Same for 2nd unit/group]	6		The design assumption for the sum of maximum rotational and maximum translational wind speed components.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
1.6.5 Missile Spectra	Spectrum II from NUREG-0800 SRP Section 3.5.1.4 [Same for 2nd unit/group]	4, 8		The design assumptions regarding missiles that could be ejected either horizontally or vertically from a tornado. The spectra identify mass, dimensions and velocity of credible missiles.
1.6.6 Radius of Maximum Rotational Speed	150 ft [Same for 2nd unit/group]	6		The design assumption for distance from the center of the tornado at which the maximum rotational wind speed occurs.
1.6.7 Rate of Pressure Drop	1.2 psi/sec [Same for 2nd unit/group]	6		The assumed design rate at which the pressure drops due to the passage of the tornado.
1.7 Wind				
1.7.1 Basic Wind Speed	110 mph [Same for 2nd unit/group]	2, 3, 4		The design wind, or “fastest mile of wind” with a 100-year return period (NUREG-0800, Sections 2.3.1 and 3.3.1) for which the facility is designed.
1.7.2 Importance Factors	1.0 (non-safety related)/ 1.11 (safety related) [Same for 2nd unit/group]	2, 3		Multiplication factors (as defined in ANSI A58.1-1982) applied to basic wind speed to develop the plant design.
2. Normal Plant Heat Sink				
2.1 Ambient Air Requirements				
2.1.1 Normal Shutdown Max Ambient Temp (1% Exceed)	100°F db / 77°F wb coincident [Same for 2nd unit/group]	6		Assumption used for the maximum ambient temperature that will be exceeded no more than 1% of the time, to design plant systems capable of effecting normal shutdown under the assumed temperature condition.
2.1.2 Normal Shutdown Max Wet Bulb Temp (1% Exceed)	80°F wb non-coincident [Same for 2nd unit/group]	6		Assumption used for the maximum wet bulb temperature that will be exceeded no more than 1% of the time – used in design of plant systems that must be capable of effecting normal shutdown under the assumed temperature condition.
2.1.3 Normal Shutdown Min Ambient Temp (1% Exceed)	-10°F [Same for 2nd unit/group]	6		Assumption used for the minimum ambient temperature that will be exceeded no more than 1% of the time to design of plant systems that must be capable of effecting normal shutdown under the assumed temperature condition.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
2.1.4 Rx Thermal Power Max Ambient Temp (0% Exceed)	115°F db/80°F wb coincident [Same for 2nd unit/group]	6		Assumption used for the maximum ambient temperature that will never be exceeded – used in design of plant systems that must be capable of supporting full power operation under the assumed temperature condition.
2.1.5 Rx Thermal Power Max Wet Bulb Temp (0% Exceed)	81°F wb non-coincident [Same for 2nd unit/group]	6		Assumption used for the maximum wet bulb temperature that will never be exceeded – used in design of plant systems that must be capable of supporting full power operation under the assumed temperature condition.
2.1.6 Rx Thermal Power Min Ambient Temp (0% Exceed)	-40°F [Same for 2nd unit/group]	6		Assumption used for the minimum ambient temperature that will never be exceeded – used in design of plant systems that must be capable of supporting full power operation under the assumed temperature condition.
2.2 Condenser				
2.2.1 Max Inlet Temp Condenser/Heat Exchanger	100°F [Same for 2nd unit/group]	2, 3, 4		Design assumption for the maximum acceptable circulating water temperature at the inlet to the condenser or cooling water system heat exchangers.
2.2.2 Condenser/Heat Exchanger Duty	1.03 E10 Btu/hr [Additional 1.03 E10 Btu/hr for 2nd unit/group]	11		Design value for the waste heat rejected to the circulating water and service water systems.
2.3 Mechanical Draft Cooling Towers			d	
2.3.1 Acreage	50 acres [100 acres]	3, 5	e	The land required for cooling towers or ponds, including support facilities such as equipment sheds, basins, canals, or shoreline buffer areas.
2.3.2 Approach Temperature	10°F [Same for 2nd unit/group]	1, 4, 7		The difference between the cold water temperature and the ambient wet bulb temperature.
2.3.3 Blowdown Constituents and Concentrations	See Table 3.1-3 [Twice that shown in table]		f	The maximum expected concentrations for anticipated constituents in the cooling water systems blowdown to the receiving water body.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section		Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
2.3.4	Blowdown Flow Rate	6400 gpm expected (24,500 gpm max) [12,800 gpm expected (49,000 gpm max)]	1, 5	g	The normal (and maximum) flow rate of the blowdown stream from the cooling water systems to the receiving water body for closed system designs.
2.3.5	Blowdown Temperature	100°F [Same for 2nd unit/group]	1, 2, 3, 4, 5	g	The maximum expected blowdown temperature at the point of discharge to the receiving water body.
2.3.6	Cycles of Concentration	4 [Same for 2nd unit/group]	6	f	The ratio of total dissolved solids in the cooling water blowdown streams to the total dissolved solids in the make-up water streams.
2.3.7	Evaporation Rate	17,550 gpm expected (19,500 gpm max) [35,100 gpm expected (39,000 gpm max)]	3	h	The expected (and maximum) rate at which water is lost by evaporation from the cooling water systems.
2.3.8	Height	60 ft [Same for 2nd unit/group]	1, 3, 4, 5, 7	c	The vertical height above finished grade of either natural draft or mechanical draft cooling towers associated with the cooling water systems.
2.3.9	Make-up Flow Rate	23,950 gpm expected (44,000 gpm max) [47,900 gpm expected (88,000 gpm max)]	9	g	The expected (and maximum) rate of removal of water from a natural source to replace water losses from closed cooling water system.
2.3.10	Noise	55 dBA at 1000 ft [Same for 2nd unit/group]	6	i	The maximum expected sound level produced by operation of cooling towers, measured at 1000 feet from the noise source.
2.3.11	Cooling Tower Temperature Range	23°F [Same for 2nd unit/group]	7		The temperature difference between the cooling water entering and leaving the towers or ponds.
2.3.12	Cooling Water Flow Rate	800,000 gpm [1,600,000 gpm]	5		The total cooling water flow rate through the condenser/heat exchangers.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
2.3.13 Heat Rejection Rate (Blowdown)	6,400 gpm expected (19,500 gpm max) @100°F [12,800 gpm expected (39,000 gpm max)]	3, 5		The expected heat rejection rate to a receiving water body, expressed as flow rate in gallons per minute at a temperature in degrees Fahrenheit.
2.3.14 Maximum Consumption of Raw Water	30,000 gpm [60,000 gpm]	1		The expected maximum short-term consumptive use of water by the cooling water systems (evaporation and drift losses).
2.3.15 Monthly Average Consumption of Raw Water	23,000 gpm [46,000 gpm]	10		The expected normal operating consumption of water by the cooling water systems (evaporation and drift losses).
2.3.16 Stored Water Volume	11,800,000 gal [23,600,000 gal]	5		The quantity of water stored in cooling water system impoundments, basins, tanks and/or ponds.
2.4 Natural Draft Cooling Towers			d	
2.4.1 Acreage	34.5 acres [69 acres]	7	e	The land required for cooling towers or ponds, including support facilities such as equipment sheds, basins, canals, or shoreline buffer areas.
2.4.2 Approach Temperature	10°F [Same for 2nd unit/group.]	1, 4, 7		The difference between the cold water temperature and the ambient wet bulb temperature.
2.4.3 Blowdown Constituents and Concentrations	See Table 3.1-3 [Twice that shown in table]		f	The maximum expected concentrations for anticipated constituents in the cooling water systems blowdown to the receiving water body.
2.4.4 Blowdown Flow Rate	6,400 gpm expected (24,500 gpm max) [12,800 gpm expected (49,000 gpm max)]	1, 5	g	The normal (and maximum) flow rate of the blowdown stream from the cooling water systems to the receiving water body for closed system designs.
2.4.5 Blowdown Temperature	100°F [Same for 2nd unit/group]	1, 3, 4, 5	g	The maximum expected blowdown temperature at the point of discharge to the receiving water body.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section		Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
2.4.6	Cycles of Concentration	4 [Same for 2nd unit/group]	1, 3, 4, 5, 7	f	The ratio of total dissolved solids in the cooling water blowdown streams to the total dissolved solids in the make-up water streams.
2.4.7	Evaporation Rate	17,550 gpm expected (19,500 gpm max) [35,100 gpm expected (39,000 gpm max)]	3	h	The expected (and maximum) rate at which water is lost by evaporation from the cooling water systems.
2.4.8	Height	550 ft [Same for 2nd unit/group]	3, 5, 7	j	The vertical height above finished grade of either natural draft or mechanical draft cooling towers associated with the cooling water systems.
2.4.9	Make-up Flow Rate	23,950 gpm expected (44,000 gpm max) [47,900 gpm expected (88,000 gpm max)]	9	g	The expected (and maximum) rate of removal of water from a natural source to replace water losses from closed cooling water systems.
2.4.10	Noise	55 dBA at 1000 ft [Same for 2nd unit/group]	1, 3, 4, 5, 7	i	The maximum expected sound level produced by operation of cooling towers, measured at 1000 feet from the noise source.
2.4.11	Cooling Tower Temperature Range	23°F [Same for 2nd unit/group]	7		The temperature difference between the cooling water entering and leaving the towers or ponds.
2.4.12	Cooling Water Flow Rate	800,000 gpm [1,600,000 gpm]	5		The total cooling water flow rate through the condenser/heat exchangers.
2.4.13	Heat Rejection Rate (Blowdown)	6,400 gpm expected (19,500 gpm max) @ 100°F [12,800 gpm expected (39,000 gpm max) @ 100°F	3, 5		The expected heat rejection rate to a receiving water body, expressed as flow rate in gallons per minute at a temperature in degrees Fahrenheit.
2.4.14	Maximum Consumption of Raw Water	33,720 gpm [67,440 gpm]	4		The expected maximum short-term consumptive use of water by the cooling water systems (evaporation and drift losses).

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
2.4.15 Monthly Average Consumption of Raw Water	23,000 gpm [46,000 gpm]	10		The expected normal operating consumption of water by the cooling water systems (evaporation and drift losses)
2.4.16 Stored Water Volume	11,800,000 gal [23,600,000 gal]	5		The quantity of water stored in cooling water system impoundments, basins, tanks and/or ponds
2.5 Once-Through Cooling			d	
2.5.1 Cooling Water Discharge Temperature	127°F [Same for 2nd unit/group.]	2	g	Expected temperature of the cooling water at the exit of the condenser/heat exchangers
2.5.1.1 Deleted				
2.5.2 Cooling Water Flow Rate	1,140,000 gpm [2,280,000 gpm]	5	g	Total cooling water flow rate through the condenser (also the rate of withdrawal from and return to the water source)
2.5.3 Cooling Water Temperature Rise	18°F [Same for 2nd unit/group]	1, 3, 5	g	Temperature rise across the condenser (temperature of water out minus temperature of water in)
2.5.4 Evaporation Rate	10,550 gpm expected (11,700 gpm max) [21,100 gpm expected (23,400 gpm max)]	3	h	The expected (and maximum) rate at which water is lost by evaporation from the receiving water body as a result of heating in the condenser
2.5.4.1 Deleted				
2.5.5 Heat Rejection Rate	1.03 E10 Btu/hr [2.06 E10 Btu/hr]	11		The expected heat rejection rate

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
3. Ultimate Heat Sink			k	
3.1 Ambient Air Requirements				
3.1.1 Maximum Ambient Temp (0% Exceedance)	115°F db/80°F wb coincident [Same for 2nd unit/group]	2, 3, 5, 7		Assumption used for the maximum ambient temperature in designing the UHS system to provide heat rejection for 30 days under the assumed temperature condition.
3.1.2 Maximum Wet Bulb Temp (0% Exceedance)	81°F wb (non-coincident) [Same for 2nd unit/group]	2, 3, 5, 7		Assumption used for the maximum wet bulb temperature in designing the UHS system to provide heat rejection for 30 days under the assumed temperature condition.
3.1.3 Minimum Ambient Temp (0% Exceedance)	-40°F [Same for 2nd unit/group]	2, 3, 5, 7		Assumption used for the minimum ambient temperature in designing the UHS system to provide heat rejection for 30 days under the assumed temperature condition.
3.2 CCW Heat Exchanger				
3.2.1 Maximum Inlet Temp to CCW Heat Exchanger	95°F [Same for 2nd unit/group]	3, 5, 7		The maximum temperature of safety-related service water at the inlet of the UHS component cooling water heat exchanger.
3.2.2 CCW Heat Exchanger Duty	420 E6 Btu/hr (shutdown) [Additional 420 E6 Btu/hr (shutdown) for 2nd unit]	3		The heat transferred to the safety-related service water system for rejection to the environment in UHS heat removal devices.
3.3 Mech Draft Cooling Towers				
3.3.1 Acreage	0.5 acre [1.0 acre]	3, 5	k	The land required for UHS cooling towers or ponds, including support facilities such as equipment sheds, basins, canals, or shoreline buffer areas.
3.3.2 Approach Temperature	15°F [Same for 2nd unit/group]	3, 5		The difference between the cold water temperature and the ambient wet bulb temperature.
3.3.3 Blowdown Constituents and Concentrations	See Table 3.1-3 [Twice that shown in table]		k	The maximum expected concentrations for anticipated constituents in the UHS blowdown to the receiving water body.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section		Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
3.3.4	Blowdown Flow Rate	144 gpm expected (850 gpm max) [288 gpm expected (1700 gpm max)]	3, 7	k	The normal (and maximum) flow rate of the blowdown stream from the UHS system to receiving water body for closed system designs.
3.3.5	Blowdown Temperature	95°F [Same for 2nd unit/group]	3, 5	k	The maximum expected UHS blowdown temperature at the point of discharge to the receiving water body.
3.3.6	Cycles of Concentration	4 (2 Minimum) [Same for 2nd unit/group]	3, 5, 7	k	The ratio of total dissolved solids in the UHS system blowdown streams to the total dissolved solids in the make-up water streams.
3.3.7	Evaporation Rate	411 gpm normal 850 gpm shutdown [822 gpm normal 1700 gpm shutdown]	3, 7	k	The expected (and maximum) rate at which water is lost by evaporation from the UHS system.
3.3.8	Height	60 ft [Same for 2nd unit/group]	3, 5, 7	k	The vertical height above finished grade of mechanical draft cooling towers associated with the UHS system.
3.3.9	Make-up Flow Rate	555 gpm 1700 gpm max [1,110 gpm, 3,400 gpm max]	3, 7, 9	k	The expected (and maximum) rate of removal of water from a natural source to replace water losses from the UHS system
3.3.10	Noise	55 dBA at 1000 ft [Same for 2nd unit/group]	2, 3, 5, 7	k	The maximum expected sound level produced by operation of mechanical draft UHS cooling towers, measured at 1000 feet from the noise source.
3.3.11	Cooling Tower Temperature Range	16°F [Same for 2nd unit/group]	5		The temperature difference between the cooling water entering and leaving the UHS system.
3.3.12	Cooling Water Flow Rate	26,125 gpm (normal) 52,250 gpm (shutdown/ accident) [52,250 gpm (normal), 104,500 (shutdown/ accident)]	3		The total cooling water flow rate through the UHS system.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
3.3.13 Heat Rejection Rate (Blowdown)	100 gpm expected (850 gpm max) @ 95°F [200 gpm expected (1,700 gpm max) @ 95°F]	3		The expected heat rejection rate to a receiving water body, expressed as flow rate in gallons per minute at a temperature in degrees Fahrenheit.
3.3.14 Maximum Consumption of Raw Water	900 gpm [1800 gpm]	7		The expected maximum short-term consumptive use of water by the UHS system (evaporation and drift losses).
3.3.15 Monthly Average Consumption of Raw Water	533 gpm [1066 gpm]	10		The expected normal operating consumption of water by the UHS system (evaporation and drift losses).
3.3.16 Stored Water Volume	30,600,000 gal [61,200,000 gal]	3		The quantity of water stored in UHS impoundments, basins, tanks and/or ponds.
4. Containment Heat Removal System (Post-Accident)				
4.1 Ambient Air Requirements				
4.1.1 Maximum Ambient Air Temperature (0% Exceedance)	115°F db/80°F wb coincident [Same for 2nd unit/group]	1, 7		Assumed maximum ambient temperature used in designing the containment heat removal system.
4.1.2 Minimum Ambient Temperature (0% Exceedance)	-40°F [Same for 2nd unit/group]	1, 7		Assumed minimum ambient temperature used in designing the containment heat removal system.
5. Potable Water/Sanitary Waste System				
5.1 Discharge to Site Water Bodies				
5.1.1 Flow Rate	60 gpm expected (105 gpm max) [120 gpm expected (210 gpm max)]	7	I	The expected (and maximum) effluent flow rate from the potable and sanitary waste water systems to the receiving water body.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
5.2 Raw Water Requirements				
5.2.1 Maximum Use	120 gpm [240 gpm]	5	I	The maximum short-term rate of withdrawal from the water source for the potable and sanitary waste water systems.
5.2.2 Monthly Average Use	90 gpm [180 gpm]	5	I	The average rate of withdrawal from the water source for the potable and sanitary waste water systems.
6. Demineralized Water System				
6.1 Discharge to Site Water Bodies				
6.1.1 Flow Rate	110 gpm expected (150 gpm max) [220 gpm expected (300 gpm max)]	5, 7	I	The expected (and maximum) effluent flow rate from the demineralized system to the receiving water body.
6.2 Raw Water Requirements				
6.2.1 Maximum Use	720 gpm [1440 gpm]	5	I	The maximum short-term rate of withdrawal from the water source for the demineralized water system.
6.2.2 Monthly Average Use	550 gpm [1100 gpm]	5	I	The average rate of withdrawal from the water source for the demineralized water system.
7. Fire Protection System				
7.1 Raw Water Requirements				
7.1.1 Maximum Use	2,500 gpm [5,000 gpm]	11	I	The maximum short-term rate of withdrawal from the water source for the fire protection water system.
7.1.2 Monthly Average Use	675,000 gal/mo [1,350,000 gal/mo]	7	I	The average rate of withdrawal from the water source for the fire protection water system.
7.1.3 Stored Water Volume	2,325,000 gallons [4,650,000 gallons]	7		The quantity of water stored in fire protection system impoundments, basins or tanks.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
8. Miscellaneous Drain				
8.1 Discharge to Site Water Bodies				
8.1.1 Flow Rate	100 gpm expected (150 gpm max) [200 gpm expected (300 gpm max)]	3, 7	l	The expected (and maximum) effluent flow rate from miscellaneous drains to the receiving water body.
9. Unit Vent/Airborne Effluent Release Point				
9.1 Atmospheric Dispersion (CHI/Q) (Accident)			m	The atmospheric dispersion coefficients used in the design safety analysis to estimate dose consequences of accident airborne releases.
9.1.1 0–2 hr @EAB	0.61 E-3 sec/m^3 [Same for 2nd unit/group]	1		
9.1.2 0–8 hr @LPZ	1.30 E-4 sec/m^3 [Same for 2nd unit/group]	5		
9.1.3 8–24 hr @LPZ	1.0 E-4 sec/m^3 [Same for 2nd unit/group]	1, 5		
9.1.4 1–4 day @LPZ	3.36 E-5 sec/m^3 [Same for 2nd unit/group]	3		
9.1.5 4–30 day @LPZ	7.42 E-6 sec/m^3 [Same for 2nd unit/group]	3		
9.2 Atmospheric Dispersion (χ/Q) (Annual Average)	1.17 E-6 sec/m^3 [Same for 2nd unit/group]	3	m	The atmospheric dispersion coefficients used in the safety analysis for the dose consequences of normal airborne releases.
9.3 Dose Consequences			n	
9.3.1 Normal	10 CFR 20, 10 CFR 50 App I [Same for 2nd unit/group]	6		The estimated design radiological dose consequences due to gaseous releases from normal operation of the plant.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
9.3.2 Post-Accident	10 CFR 100 [Same for 2nd unit/group]	1, 3, 4, 5, 7		The estimated design radiological dose consequences due to gaseous releases from postulated accidents.
9.3.3 Severe Accidents	25 rem wb in 24 hr 0.5 mi <1 E-6/rx-yr [Same for 2nd unit/group]	1, 3, 7		
9.4 Release Point			o	
9.4.1 Configuration (Horiz vs. Vert)	Horizontal	2		The orientation of the release point discharge flow.
9.4.2 Elevation (Normal)	95.5 ft [Same for 2nd unit/group]	2		The elevation above finished grade of the release point for routine operational releases.
9.4.3 Elevation (Post Accident)	Ground level [Same for 2nd unit/group]	1, 2, 3, 5, 7		The elevation above finished grade of the release point for accident sequence releases.
9.4.4 Minimum Distance to Site Boundary	0.5 mi exclusion area [Same for 2nd unit/group]	1, 3, 7		The minimum lateral distance from the release point to the site boundary.
9.4.5 Temperature	No value bounds, overall range is 35-120°F [Same for 2nd unit/group]			The temperature of the airborne effluent stream at the release point.
9.4.6 Volumetric Flow Rate	118,000 scfm for 2 units (normal operation) [for 2 units]	5		The volumetric flow rate of the airborne effluent stream at the release point.
9.5 Source Term			p	
9.5.1 Gaseous (Normal)	15,000 Ci/yr [30,000 Ci/yr] See Table 5.4-7 for isotopic breakdown	12		The annual activity, by isotope, contained in routine plant airborne effluent streams, excluding tritium.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
9.5.2 Gaseous (Post-Accident)	See Chap 15 Tables RG 1.70 [Same for 2nd unit/group]	1, 3	q	The activity, by isotope, contained in post-accident airborne effluents.
9.5.3 Tritium	3500 Ci/yr [7000 Ci/yr]	5		The annual activity of tritium contained in routine plant airborne effluent streams.
10. Liquid Radwaste System				
10.1 Dose Consequences			r	
10.1.1 Normal	10 CFR 50, Appendix I, 10 CFR 20	1, 3, 4, 5		The estimated design radiological dose consequences due to liquid effluent releases from normal operation of the plant.
10.1.2 Post-Accident	10 CFR 20, 10 CFR 100 [Same for 2nd unit/group]	1, 3, 4, 5		The estimated design radiological dose consequences due to liquid effluent releases from postulated accidents.
10.2 Release Point			s	
10.2.1 Flow Rate	100 gpm + 10,000 gpm dilution [200 gpm + 20,000 gpm dilution]	3		The discharge (including minimum dilution flow, if any) of liquid potentially radioactive effluent streams from plant systems to the receiving water body.
10.3 Source Term			t	
10.3.1 Liquid	0.37 Ci/yr [0.74 Ci/yr] See Table 5.4-6 for isotopic breakdown	13		The annual activity, by isotope, contained in routine plant liquid effluent streams, excluding tritium.
10.3.2 Tritium	3100 Ci/yr [6200 Ci/yr]	5		The annual activity of tritium contained in routine plant liquid effluent streams.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
11. Solid Radwaste System			u	
11.1 Acreage				
11.1.1 Low Level Radwaste Storage	2 years in radwaste building @ expected generation rate [Same for 2nd unit/group]	1		The land usage required to provide onsite storage of low level radioactive wastes.
11.2 Solid Radwaste				
11.2.1 Activity	2700 Ci/yr [5400 Ci/yr]	3		The annual activity contained in solid radioactive wastes generated during routine plant operations.
11.2.2 Volume	9041 cu ft/yr [18,646 cu ft/yr]	4		The expected volume of solid radioactive wastes generated during routine plant operations.
12. Auxiliary Boiler System				
12.1 Exhaust Elevation	110 ft above plant grade [Same for 2nd unit/group]	5	v	The height above finished plant grade at which the flue gas effluents are released to the environment.
12.2 Flue Gas Effluents	See Table 3.1-4 [Twice that shown in table]		v	The expected combustion products and anticipated quantities released to the environment due to operation of the auxiliary boilers, diesel engines and gas turbines.
12.3 Fuel Type	No. 2 [Same for 2nd unit/group]	1, 3, 5, 7	v	The type of fuel oil required for proper operation of the auxiliary boilers, diesel engines and gas turbines.
12.4 Heat Input Rate (btu/hr)	156,000,000 Btu/hr [312,000,000 Btu/hr]	1		The average heat input rate due to the periodic operation of the auxiliary boilers.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section		Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
13. Heating, Ventilation and Air Conditioning System					
13.1 Ambient Air Requirements					
13.1.1	Non-safety HVAC max ambient temp (1% Exceed)	100°F db/77°F wb coincident [Same for 2nd unit/group]	6		Assumption used for the maximum ambient temperature that will be exceeded no more than 1% of the time, to design the non-safety HVAC systems.
13.1.2	Non-safety HVAC min ambient temp (1% Exceed)	–10°F [Same for 2nd unit/group]	6		Assumption used for the minimum ambient temperature that will be exceeded no more than 1% of the time, to design the non-safety HVAC systems.
13.1.3	Safety HVAC max ambient temp (0% Exceed)	115°F db/80°F wb coincident [Same for 2nd unit/group]	1, 3, 5, 7		Assumption used for the maximum ambient temperature that will never be exceeded, to design the safety-related HVAC systems.
13.1.4	Safety HVAC min ambient temp (0% Exceed)	–40°F [Same for 2nd unit/group]	1, 3, 5, 7		Assumption used for the minimum ambient temperature that will never be exceeded, to design the safety-related HVAC systems.
13.1.5	Vent System max ambient temp (5% Exceed)	95°F dry bulb/ 77°F wb coincident), 79°F wb (non-coincident) [Same for 2nd unit/group]	3, 5		Assumption used for the maximum ambient temperature that will be exceeded no more than 5% of the time to design the non-HVAC ventilation systems.
13.1.6	Vent System min ambient temp (5% Exceed)	– 5°F [Same for 2nd unit/group]	3		Assumption used for the minimum ambient temperature that will be exceeded no more than 5% of the time to design the non-HVAC ventilation systems.
14. Onsite/Offsite Electrical Power System					
14.1 Acreage					
14.1.1	Switchyard	15 acres [30 acres]	7	e	The land usage required for the high voltage switchyard used to connect the plant to the transmission grid.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
15. Standby Power System				
15.1 Diesels				
15.1.1 Diesel Capacity	2 × 15,000 kW [4 × 15,000 kW]	11		The capacity of diesel engines used for generation of standby electrical power.
15.1.2 Diesel Exhaust Elevation	30 ft [Same for 2nd unit/group]	4	v	The elevation above finished grade of the release point for standby diesel exhaust releases.
15.1.3 Diesel Flue Gas Effluents	See Table 3.1-5 [Twice that shown in table]		v	The expected combustion products and anticipated quantities released to the environment due to operation of the emergency standby diesel generators.
15.1.4 Diesel Noise	55 dBA at 1000 ft [Same for 2nd unit/group.]	1, 3, 4, 5, 7	i	The maximum expected sound level produced by operation of diesel engines turbines, measured at 1000 feet from the noise source.
15.1.5 Diesel Fuel Type	No. 2 per ASTM D975-1974 [Same for 2nd unit/group]	1, 3, 4, 5, 7		The type of fuel oil required for proper operation of the diesel engines.
15.2 Gas Turbines				
15.2.1 Gas Turbine Capacity (kw)	20 MWe at limiting site conditions [40 MWe at limiting site conditions]	3		The capacity of gas turbines used for generation of standby electrical power.
15.2.2 Gas Turbine Exhaust Elevation	60 ft [Same for 2nd unit/group]	3	v	The elevation above finished grade of the release point for standby gas turbine exhaust releases.
15.2.3 Gas Turbine Flue Gas Effluents	See Table 3.1-6 [Twice that shown in table]		v	The expected combustion products and anticipated quantities released to the environment due to operation of the emergency standby gas-turbine generators.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
15.2.4 Gas Turbine Noise	55 dBA at 1000 ft [Same for 2nd unit/group]	2, 3	i	The maximum expected sound level produced by operation of gas turbines, measured at 1000 feet from the noise source.
15.2.5 Gas Turbine Fuel Type	Distillate [Same for 2nd unit/group]	2, 3	v	The type of fuel oil required for proper operation of the gas turbines.
16. Plant Characteristics				
16.1 Access Routes				
16.1.1 Heavy Haul Routes	7 acres [Same for 2nd unit/group]	3, 7	e	The land usage required for permanent heavy haul routes to support normal operations and refueling.
16.1.2 Spent Fuel Cask Weight	150 tons [Same for 2nd unit/group]	3	w	The weight of the heaviest expected shipment during normal plant operations and refueling.
16.2 Acreage	87 acres [174 acres]	2	x	The land area required to provide space for plant facilities.
16.2.1 Office Facilities	1.8 acres [2.18 acre (95,200 sq ft)]	2		
16.2.2 Parking Lots	3.86 acres [7.72 acres]	3		
16.2.3 Permanent Support Facilities	12 acres [8.4 acres]	2		
16.2.4 Power Block	11.64 acres [23.3 acres]	7		
16.2.5 Protected Area	40 acres [80 acres]	7		

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
16.3 Megawatts Thermal	4500 MWt [9000 MWt]	11		The thermal power generated by one unit (may be the total of several modules).
16.4 Plant Design Life	60 years [Same for 2nd unit/group]	1, 2, 3, 5, 7	y	The operational life for which the plant is designed.
16.5 Plant Population				
16.5.1 Operation	580 people [1160 people]	5	y	The number of people required to operate and maintain the plant
16.5.2 Refueling / Major Maintenance	1000 people [Same for 2nd unit/group]	1	y	The additional number of temporary staff required to conduct refueling and major maintenance activities
16.6 Station Capacity Factor	96% [Same for 2nd unit/group]	2		The percentage of time that a plant is capable of providing power to the grid
17. Construction				
17.1 Access Routes				
17.1.1 Construction Module Dimensions	90' (H) x 82' (W) x 93' (L) or 130' (Dia) x 51' (H) [Same for 2nd unit/group]	1, 7	w	The maximum expected length, width, and height of the largest construction modules or components and delivery vehicles to be transported to the site during construction.
17.1.2 Heaviest Construction Shipment	2,200,000 lb [Same for 2nd unit/group]	2	w	The maximum expected weight of the heaviest construction shipment to the site
17.2 Acreage				The land area required to provide space for construction support facilities
17.2.1 Laydown Area	29 acres [58 acres]	3	e	
17.2.2 Temporary Construction Facilities	52 acres [104 acres]	3	e	
17.3 Construction				

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition
17.3.1 Noise	76–101 db @ 50 ft [Same for 2nd unit/group]	1, 3, 4, 5, 7	i	The maximum expected sound level due to construction activities, measured at 50 feet from the noise source
17.4 Plant Population				
17.4.1 Construction	3150 people max [5,355 for unit simultaneous construction]	3, 14	y	Peak employment during plant construction.
17.5 Site Preparation Duration	18 months [Same for 2nd unit/group]	1, 3, 7	y	Length of time required to prepare the site for construction.

Table 3.1-1 Generic Plant Parameters Envelope

PPE Section	Bounding Value [a] [Value for 2 Units in brackets] [b]	Bound Notes See Table 3.1-2	Comments	Definition

Comments:

a. PPE values should be based on plant designs being considered. The Bounding PPE values provide an envelope (most restrictive values selected) for the ABWR, ESBWR, AP1000, IRIS, GT-MHR, PBMR and ACR-700 designs. A composite PPE should be used for the actual set of plant designs under consideration for the site.

b. The values in brackets reflects the values corresponding to a plant that is twice the vendor's specified standard size plant, i.e., two ABWR units, two ESBWR units, two AP1000 units, six IRIS units, two sets of four GT-MHR modules, two sets of eight PBMR modules and two ACR-700 twin unit plants.

c. Visual resources impacts.

d. Applicants must identify main condenser cooling system alternatives (e.g., mechanical or natural draft cooling towers, cooling ponds, or once-through cooling). To maintain multiple options, the most restrictive value for each cooling system PPE section should be used in the ESP application (e.g., 550-foot cooling tower height selected if both mechanical and natural draft towers are being considered).

e. Construction impacts on ecological resources.

f. Operational impacts on water quality and ecological resources.

g. Operational impacts on water quality and ecological resources. An NPDES permit must be obtained for this blowdown rate, blowdown temperature, withdrawal rate or temperature rise.

h. Operational impacts on water quality and local climatology.

i. Noise impacts.

j. Visual impacts.

k. Impacts of the main condenser cooling system will usually bound impacts from operation of the Ultimate Heat Sink.

l. Operational impacts on water quality and aquatic ecological resources.

m. The atmospheric dispersion values presented in PPE Sections 9.1 and 9.2 represent typical site parameter values assumed by reactor vendors.

n. Values listed for Section 9.3 are regulatory standards for effluent concentrations, doses from routine operations, and doses from postulated accidents. The applicant must demonstrate that the plant is capable of meeting these standards considering the plant design and, for the dose standards, dilution and dispersion conditions at the site.

o. Release point characteristics (Section 9.4.1 - Section 9.4.6) are used to calculate atmospheric dispersion factors used: S - In the Site SAR to demonstrate compliance with requirements listed in Section 9.3, and, E - In the ER to estimate impacts from routine and accident-scenario atmospheric releases.

p. Source term data (Section 9.5.1 -Section 9.5.3) are used to calculate dose consequences used: S - In the Site SAR to demonstrate compliance with requirements listed in Section 9.3, and, E - In the ER to estimate impacts from routine and accident-scenario atmospheric releases.

q. See Section 9.5. Tables in Chapter 15 of RG 1.70 list the design and accident sequence parameters necessary to derive these source terms. Applicants must obtain calculated release values from the vendor/A-E for designs under consideration.

r. Values listed for Section 10.1 are regulatory standards for effluent concentrations, doses from routine operations, and doses from postulated accidents. The applicant must demonstrate that the plant is capable of meeting these standards considering the plant design and, for the dose standards, dilution and dispersion conditions at the site.

s. Flow rate and dilution characteristics (Section 10.2) are used to calculate dilution factors used: S - In the Site SAR to demonstrate compliance with requirements listed in Section 10.1, and, E - In the ER to estimate impacts from liquid effluents.

t. Liquid discharge data (Section 10.3.1 - Section 10.3.2) are used to calculate dose consequences used: S - In the Site SAR to demonstrate compliance with requirements listed in Section 10.1, and, E - In the ER to estimate impacts from liquid effluents.

u. Environmental effects of the uranium fuel cycle, including solid waste management, are set forth in Table S-3 of 10 CFR 51.20. Reference to this Table is made in the applicant's ER.

v. Operational impacts of non-radiological atmospheric emissions.

w. Transport requirements for component delivery.

x. Total acreage footprint for site facilities is used to estimate construction impacts on ecological resources.

y. Socio-economic impacts of plant construction and operation.

Table 3.1-2 Bounding Value Notes for Table 3.1-1

1. Bounding value from AP1000 criteria.
2. Bounding value from GT-MHR criteria.
3. Bounding value from ABWR/ESBWR criteria.
4. Bounding value from PBMR criteria.
5. Bounding value from ACR-700 criteria.
6. Bounding value common for the seven designs.
7. Bounding value from IRIS criteria.
8. The Spectrum A missiles were for plants that used the November 24, 1975 version of the SRP; for all plants since, the Spectrum I or II of the July 1981 version of the SRP was to be used.
9. The bounding Make-up Flow Rate is a calculated value based on the sum of the bounding Evaporation rate plus the bounding Blowdown Flow Rate.
10. The bounding value for the Monthly Average Consumption of Raw Water is a calculated value based on the maximum bounding make-up flow rate times the bounding capacity factor (PPE Section 16.6).
11. Bounding value from ESBWR criteria.
12. The Gaseous (Normal) source term bounding value is the sum of the bounding values of the yearly released activity for each nuclide type for each reactor (ABWR, AP1000, ACR-700, ESBWR). These were the only reactor types with adequate information available. See Table 5.4-7.
13. The liquid waste source term bounding value is the sum of the bounding values of the yearly released activity for each nuclide type for each reactor (ABWR, AP1000, ACR-700, ESBWR). These were the only reactor types with adequate information available. The PBMR value was not supported by isotopic data and was not used in the evaluation. See Table 5.4-6.
14. Two-unit simultaneous construction staffing is based on 170% of single unit build. This assumes optimum timing between units and is based on rough estimates by Bechtel. Refined information will be contingent upon type of plant built, and plant location.

Table 3.1-3 Blowdown Constituents and Concentrations[a]

Constituent	Bounding Value			
	Concentration (ppm)[b]			
	River Source	Well/ Treated Water	Envelope	Notes
Chlorine demand	10.1	—	10.1	c, d, e
Free available chlorine	0.5	—	0.5	f
Chromium	—	—	—	
Copper	—	6	6	f
Iron	0.9	3.5	3.5	f
Zinc	—	0.6	0.6	f
Phosphate	—	7.2	7.2	c, d, e
Sulfate	599	3500	3500	f
Oil and grease	—	—	—	
Total dissolved solids	—	17,000	—	c, d, e
Total suspended solids	49.5	150	150	f
BOD, 5-day	—	—	—	

a. See PPE Section 2.3.3, 2.4.3, and 3.3.3.
b. Assumed cycles of concentration equals 4.
c. Bounding value from ABWR/ESBWR criteria.
d. Bounding value from AP1000 criteria.
e. Bounding value from PBMR criteria.
f. Bounding value common for the seven designs.

Table 3.1-4 Yearly Emissions Auxiliary Boilers[a]

	Bounding Value	
Pollutant Discharged[b]	**Quantity (lb.)**	**Notes**
Particulates	9,900	c
Sulfur oxides	31,703	d
Carbon monoxide	1749	d
Hydrocarbons	50,100	e
Nitrogen oxides	19,022	d

a. See PPE Section 12.2.
b. Emissions are based on 30 days/yr operation for each of the generators.
c. Bounding value from ABWR/ESBWR criteria.
d. Bounding value from ACR-700 criteria.
e. Bounding value from AP1000 criteria.

Table 3.1-5 Yearly Emissions From Standby Diesel Generators[a]

	Bounding Value	
Pollutant Discharged[b]	**Quantity (lb.)**	**Notes**
Particulates	<1,230	c
Sulfur oxides	4,608	d
Carbon monoxide	4,600	e
Hydrocarbons	3,070	e
Nitrogen oxides	28,968	d

a. See PPE Section 15.1.
b. Emissions are based on 4 hrs/month operation for each of the generators.
c. Bounding value from IRIS criteria.
d. Bounding value from ABWR/ESBWR criteria.
e. Bounding value from ACR-700 criteria.

Table 3.1-6 Standby Power System Gas Turbine Flue Gas Effluents[a]

Fuel: Distillate 20°F Ambient
9,890 Btu/kWH (LHV)
10,480 Btu/kWH (HHV)

Bounding Value		
Fuel Consumption Rate	**121,200 lb/hr [b]**	
Effluent	**Quantity[c] (lb.)**	**Notes**
NO_X (PPMVD @15% O_2)	42	d
NO_x as NO_2	2016	d
CO (PPMVD)	31	d
CO	912	d
UHC (PPMVD)	3	d
UHC	48	d
VOC	10	b
SO_2	1882	d
$S0_3$	30	b
Sulfur Mist	50	b
Particulates	22	b
Exhaust Analysis	**% Vol**	
Argon	0.87	d
Nitrogen	72.56	b
Oxygen	12.52	d
Carbon Dioxide	5.19	b
Water	9.87	b

a. See PPE Section 15.2.
b. Bounding value from GT-MHR criteria.
c. Emissions are based on 4 hrs/month operation for each of the generators.
d. Bounding value from ABWR criteria.

Table 3.1-7 Deleted
Table 3.1-8 Deleted

Table 3.1-9 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Part 1 - Site Characteristics		
Atmospheric Dispersion (χ/Q) (Accident)		• Atmospheric dispersion coefficients used to estimate dose consequences of accident airborne releases. • Refer to Section 2.7.5; Tables 2.7-11 & 2.7-12.
• EAB	3.34E-5 sec/m^3 [Same for 2nd unit/group]	
• LPZ	2.17E-6 sec/m^3 [Same for 2nd unit/group]	
Gaseous Effluents Dispersion, Deposition (Annual Average)		
• Atmospheric Dispersion (χ/Q)	χ/Q values in Table 2.7-14 [Same for 2nd unit/group]	• The atmospheric dispersion coefficients used to estimate dose consequences of normal airborne releases. • Refer to Section 2.7.6; Table 2.7-14.
• Ground Deposition (D/Q)	D/Q values in Table 2.7-14 [Same for 2nd unit/group]	• The ground deposition coefficients used to estimate dose consequences of normal airborne releases. • Refer to Section 2.7.6; Table 2.7-14.
Dose Consequences		
• Normal	10 CFR 20, 10 CFR 50 Appendix I, and 40 CFR 190 dose limits [Same for 2nd unit/group]	• Radiological dose consequences due to gaseous releases from normal operation of the plant. • Refer to Section 5.4.3; Tables 5.4-10 & 5.4-11.
• Post-Accident	10 CFR 50.34(a)(1) and 10 CFR 100 dose limits [Same for 2nd unit/group]	• Radiological dose consequences due to gaseous releases from postulated plant accidents. • Refer to Sections 7.1.2 & 7.1.4.
• Minimum Distance to Site Boundary	2854.9 ft [Same for 2nd unit/group]	• Minimum lateral distance from the ESP Plant Parameter Envelope boundaries to the Exclusion Area Boundary • Refer to Figure 3.1-3.
Liquid Radwaste System		
• Normal Dose Consequences	10 CFR 50 Appendix I, 10 CFR 20, and 40 CFR 190 dose limits [Same for 2nd unit/group]	• The radiological dose consequences due to liquid effluent releases from normal operation of the plant. • Refer to Section 5.4.3; Tables 5.4-10 & 5.4-11.

Table 3.1-9 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Part 1 - Site Characteristics (continued)		
Population Density		
• Population density at the time of initial site approval and within about 5 years thereafter	Population density meets the guidance of RS-002, Section 2.1.3 for RG 4.7, Regulatory Position C.4 [Both units/groups]	• At the time of initial site approval and within about 5 years hereafter, the population densities, including weighted transient population, averaged over any radial distance out to 20 miles (cumulative population at a distance divided by the circular area at that distance), would not exceed 500 persons per square mile. • Refer to Section 2.5.1.5; Figure 2.5-13.
• Population density at the time of initial operation	Population density meets the guidance of RS-002, Section 2.1.3 [Both units/groups]	• The population densities, including weighted transient population, averaged over any radial distance out to 30 miles (cumulative population at a distance divided by the area at that distance), would not exceed 500 persons per square mile at the time of initial operation. • Refer to Section 2.5.1.5; Figure 2.5-13.
• Population density over the lifetime of the new units until 2065	Population density meets the guidance of RS-002, Section 2.1.3 [Both units/groups]	• The population densities, including weighted transient population, averaged over any radial distance out to 30 miles (cumulative population at a distance divided by the area at that distance), would not exceed 1000 persons per square mile over the lifetime of new units. • Refer to Section 2.5.1.5; Figure 2.5-13.
Population Center Distance	10 CFR 100.21(b) Meets requirement [Both units/groups]	• The distance from the ESP plant parameter envelope to the nearest boundary of a densely populated center containing more than about 25,000 residents is not less than one and one-third times the distance from the ESP plant parameter envelope to the outer boundary of the LPZ. • Refer to Section 2.5.1.2.
Exclusion Area Boundary (EAB)	10 CFR 100.21(a) Meets requirement [Both units/groups]	• The exclusion area boundary is the perimeter of a 5000-ft-radius circle from the center of the abandoned Unit 3 containment. • Refer to Sections 2.7.5, 2.7.6, 3.1.5, 4.1.1, 4.4.1.3, 5.1.1, 5.3.3.2.3, 5.3.4, 5.3.4.2, 5.4.1.3, 5.4.2.2, 5.5.1.3, 5.8.1.1, 5.8.1.2, 5.8.1.4, 5.8.3.1, 7.1.2, 7.1.4; Tables 2.7-10, 2.7-11, 2.7-14, 4.4-2, 7.1-1, 7.1-2, 7.1-4, 7.1-6, 7.1-8, 7.1-10, 7.1-11, 7.1-13, 7.1-15, 7.1-17, 7.1-19, 7.1-20, 7.1-22, 7.1-24, 7.1-26, & 7.1-28; Figures 1.1-1 & 2.1-2.
Low Population Zone (LPZ)	10 CFR 100.21(a) Meets requirement [Both units/groups]	• The LPZ is a 6-mile-radius circle centered at the Unit 1 containment building. • Refer to Sections 2.7.5, 2.7.6, 5.8.3.1, 7.1.2, 7.1.4; Tables 2.7-12, 7.1-1, 7.1-2, 7.1-4, 7.1-6, 7.1-8, 7.1-10, 7.1-11, 7.1-13, 7.1-15, 7.1-17, 7.1-19, 7.1-20, 7.1-22, 7.1-24, 7.1-26, & 7.1-28.

Table 3.1-9 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
	Part 2 - Design Parameters	
Structure Height	≤234 ft [Same for 2nd unit/group]	• The height from finished grade to the top of the tallest power block structure, excluding cooling towers • Refer to Sections 2.7.5, 3.1.2.2, & 6.4.1.1.
Structure Foundation Embedment	≤140 ft [Same for 2nd unit/group]	• The depth from finished grade to the bottom of the basemat for the most deeply embedded power block structure • Refer to Section 4.2.1.2.
Normal Plant Heat Sink		
• Condenser/Heat Exchanger Duty	≤1.03 E10 Btu/hr [Additional 1.03 E10 Btu/hr for 2nd unit/group]	• Waste heat rejected from the main condenser and the auxiliary heat exchangers during normal plant operation at full station load • Refer to Sections 3.4.1.1, 3.4.1.3, 3.4.2.3, 5.3.2.1, & 5.3.2.1.2.
• Maximum Inlet Temperature Condenser/ Heat Exchanger	100°F [Same for 2nd unit/group]	• Maximum water temperature at condenser and heat exchanger inlet • Refer to Section 3.4.1.3.2.
• Unit 3 Closed-Cycle, Dry and Wet Tower		
Height	≤180 ft	• The height above finished grade of the cooling towers • Refer to Sections 3.1.2.2, 5.3.3.2.4, & 5.8.1.5.
Make-Up Flow Rate	15,384 gpm, maximum (MWC mode) 22,268 gpm, maximum (EC mode)	• The expected rate of removal of water from Lake Anna to replace water losses from the closed-cycle cooling water system • Refer to Sections 3.4.1.1, 3.4.2.1, 3.4.2.2, 5.2.1.1, 5.2.2.1.2, 5.3.1, 5.3.1.1, 5.3.1.1.2, 5.3.2.1.2, & 5.3.2.1.3; Table 3.3-1; Figure 3.3-1.
Evaporation Rate	8707 gpm, average (96% plant capacity factor with wet tower cooling) 11,532 gpm, maximum (MWC mode) 16,695 gpm, maximum (EC mode)	• Expected rates at which water is lost by evaporation resulting from operation of the plant cooling towers. • Refer to Section 5.2.1.1; Tables 3.3-1 & 5.2-1; Figure 3.3-1.
Drift Rate	8 gpm, maximum (MWC mode) 8 gpm, maximum (EC mode)	• Expected rates at which water is lost by drift resulting from operation of the plant cooling towers based on 0.001% of cooling water flow. • Refer to Table 3.3-1; Figure 3.3-1.

Table 3.1-9 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Part 2 - Design Parameters (continued)		
Normal Plant Heat Sink (continued)		
• Unit 3 Closed-Cycle, Dry and Wet Tower (continued)		
Blowdown Flow Rate	3844 gpm, maximum (MWC mode) 5565 gpm, maximum (EC mode)	• Flow rate of the blowdown stream from the closed-cycle cooling water system to the WHTF • Refer to Sections 3.4.1.1, 3.4.2.1, 3.4.2.2, 5.2.1.1, 5.2.2.1.2, 5.3.1, 5.3.1.1, 5.3.1.1.2, 5.3.2.1.2, & 5.3.2.1.3; Table 3.3-1; Figure 3.3-1.
Blowdown Temperature	100°F	• The maximum expected temperature of the cooling tower blowdown stream to the WHTF • Refer to Sections 3.4.1.1 & 5.3.2.2.2
Blowdown Constituents and Concentrations • Free Available Chlorine • Copper • Iron • Sulfate • Total Dissolved Solids	 <0.3 ppm <1 ppm <1 ppm <300 ppm <3000 ppm	• The maximum expected concentrations for anticipated constituents in the cooling water system blowdown to the WHTF • Refer to Section 5.5.1.1.
Heat Rejection Rate	≤1.03 E10 Btu/hr	• The expected maximum heat rejection rate to the atmosphere during normal operation at full station load • Refer to Sections 3.4.1.1, 3.4.1.3.1, 3.4.2.3, 5.3.2.1 & 5.3.2.1.2.
Noise	<65 dbA at EAB	• Maximum expected sound level produced by operation of the cooling towers • Refer to Sections 3.1.5, 5.3.3.2.3, 5.3.4.2, & 5.8.1.2.
• Unit 4 Dry Cooling Towers		
Evaporation Rate	None or negligible (on the order of 1 gpm, average)	• The expected rate at which water is lost by evaporation from the cooling water system • Refer to Sections 1.1.4, 2.3.1.1, 3.1.5, 3.3.1, 3.4.1.1, 5.2.1, 5.2.2.1.2, 5.3.3.1, & 5.3.3.2.1; Table 3.3-2; Figure 3.3-2.
Height	≤150 ft	• The vertical height above finished grade of the cooling towers • Refer to Sections 3.1.2.2, 5.3.3.2.4, & 5.8.1.5.
Make-Up Flow Rate	None or negligible (on the order of 1 gpm, average)	• The expected rate of removal of water from Lake Anna to replace evaporative water losses from the cooling water system • Refer to Sections 2.3.1.1, 2.3.3.1, 3.3.1, 3.4.1.1, 3.4.2.1, 5.2.1, 5.2.1.1, 5.2.1.4, 5.3.1, 5.3.1.1, 5.3.1.2.2 & 5.3.3.1; Table 3.3-2; Figure 3.3-2.

Table 3.1-9 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Part 2 - Design Parameters (continued)		
Normal Plant Heat Sink (continued)		
• Unit 4 Dry Cooling Towers (continued)		
Noise	<60 dbA at EAB	• Maximum expected sound level produced by operation of the cooling towers • Refer to Sections 3.1.5, 5.3.3.2.3, 5.3.4.2 & 5.8.1.2.
Heat Rejection Rate	≤1.03 E10 Btu/hr	• Waste heat rejected to the atmosphere from the cooling water system, during normal plant operation at full station load • Refer to Sections 3.4.1.1, 3.4.1.3.1, & 3.4.2.3.
Ultimate Heat Sink Mechanical Draft Cooling Towers		
• Blowdown Constituents and Concentrations • Free Available Chlorine • Copper • Iron • Sulfate • Total Dissolved Solids	[Values same for both units/group] <0.3 ppm <1 ppm <1 ppm <300 ppm <3000 ppm	• The maximum expected concentrations for anticipated constituents in the UHS blowdown to the WHTF • Refer to Section 5.5.1.1.
• Blowdown Flow Rate	144 gpm expected, 850 gpm maximum [288 gpm expected, 1700 gpm maximum]	• The normal expected and maximum flow rate of the blowdown stream from the UHS system to the WHTF • Refer to Sections 3.4.1.2, 3.4.2.2, & 5.3.2.1; Tables 3.3-1 & 3.3-2; Figures 3.3-1 & 3.3-2.
• Evaporation Rate	411 gpm normal, 850 gpm shutdown [822 gpm normal, 1700 gpm shutdown]	• The expected (and maximum) rate at which water is lost by evaporation from the UHS system • Refer to Section 3.4.1.2; Tables 3.3-1 & 3.3-2; Figures 3.3-1 & 3.3-2.
• Height	≤60 ft [Same for 2nd unit/group]	• The vertical height above finished grade of mechanical draft cooling towers associated with the UHS system. • Refer to Section 3.1.5.
• Maximum Consumption of Raw Water	850 gpm, nominal [1700 gpm]	• The expected maximum short-term consumptive use of water from Lake Anna by the UHS system (evaporation and drift losses) • Refer to Tables 3.3-1 & 3.3-2; Figures 3.3-1 & 3.3-2.
• Monthly Average Consumption of Raw Water	411 gpm [822 gpm]	• The expected normal operating consumption of water from Lake Anna by the UHS system (evaporation and drift losses) • Refer to Tables 3.3-1 & 3.3-2; Figures 3.3-1 & 3.3-2.

Table 3.1-9 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Part 2 - Design Parameters (continued)		
Release Point		
▪ Elevation	Ground Level	• The elevation above finished grade of the release point for routine operational and accident sequence releases
Source Term		
• Gaseous (Normal)	Values in Table 5.4-7 (maximum values) [Double values in Table 5.4-7]	• The annual activity, by isotope, contained in routine plant airborne effluent streams • Refer to Section 5.4.2.2; Table 5.4-7.
• Gaseous (Post-Accident)	Values in Section 7.1 tables (maximum values) [Same for 2nd unit/group]	• The activity, by isotope, contained in post-accident airborne effluents • Refer to Section 7.1.4; Tables 7.1-3, 7.1-5, 7.1-7, 7.1-9, 7.1-12, 7.1-14, 7.1-16, 7.1-18, 7.1-21, 7.1-23, 7.1-25, & 7.1-27.
▪ Tritium	3530 Ci/y [7060 Ci/yr] (maximum values)	• The annual activity of tritium contained in routine plant airborne effluent streams • Refer to Section 5.4.2.2; Table 5.4-7.
Liquid Radwaste System		
• Release Point Dilution Factor	10 (minimum) [Same for 2nd unit/group]	• The ratio of liquid potentially radioactive effluent streams to liquid non-radioactive effluent streams from plant systems to the WHTF through the discharge canal used for NAPS Units 1 and 2 • Refer to Section 5.4.1.1; Table 5.4-1.
• Liquid	Values in Table 5.4-6 (maximum values) [Double the values in Table 5.4-6]	• The annual activity, by isotope, contained in routine plant liquid effluent streams • Refer to Section 5.4.2.1; Table 5.4-6.
• Tritium	≤3100 Ci/yr [≤6200 Ci/yr]	• The annual activity of tritium contained in routine plant liquid effluent streams • Refer to Section 5.4.2.1; Table 5.4-6.
Solid Radwaste System		
• Activity	≤2700 Ci/yr [≤5400 Ci/yr]	• The annual activity contained in solid radioactive wastes generated during routine plant operations • Refer to Section 3.5.3.
• Volume	≤9041 cu ft/yr [≤18,646 cu ft/yr]	• The expected volume of solid radioactive wastes generated during routine plant operations • Refer to Section 3.5.3.

Table 3.1-9 Bounding Site-Specific Plant Parameters Envelope

Item	Single Unit/Group Value [Second Unit/Group Value]	Description and References
Part 2 - Design Parameters (continued)		
Plant Characteristics		
• Acreage	Approximately 128.5 acres [Both units/groups]	• Approximate area on the NAPS site that would be affected on a long-term basis as a result of additional permanent facilities • Refer to Section 4.1.1.4.
• Megawatts Thermal	≤4500 MWt [≤9000 MWt]	• The thermal power generated by one unit (may be the total of several modules) • Refer to Sections 1.1.3, 3.1.2.2, 3.1.5, 3.2.1, 3.8.1, 5.7.1, 7.1.3 & 7.1.4; Tables 3.8-1, 5.4-6, & 5.4-7.
• Plant Population – Operation	Approximately 720 permanent employees [Both units/groups]	• Anticipated number of new employees that would be required for operation of the new units • Refer to Sections 2.5.2, 5.8.2, & 5.8.2.2.
• Plant Population – Refueling / Major Maintenance	Approximately 700–1,000 temporary workers during planned outages [Same for 2nd unit/group]	• Anticipated number of additional workers onsite during planned outages of the new units • Refer to Sections 2.5.2 & 5.8.2.1.2.
• Plant Population – Construction	5,000 people maximum [simultaneous construction]	• Peak workforce of 5,000 for construction of both new units/groups • Refer to Sections 2.5.2, 4.4.2, 4.4.2.2.1, 4.5.4, 5.8.2.2, & 5.8.2.2.2.
• Maximum Fuel Enrichment for Light-Water-Cooled Reactors	5% [Same for 2nd unit/group]	• Concentration of U-235 in fuel • Refer to Sections 3.2.1 & 3.8; Table 3.8-1.
• Maximum Fuel Burn-up for Light-Water-Cooled Reactors	62,000 MWd/MTU [Same for 2nd unit/group]	• The value derived by calculating the reactor thermal power multiplied by the time of irradiation divided by fuel mass (expressed as megawatt-days per metric ton of irradiated fuel) • Refer to Sections 3.2.1 & 3.8; Table 3.8-1.
• Maximum Fuel Enrichment for Gas-Cooled Reactors	19.8% [Same for 2nd unit/group]	• Concentration of U-235 in fuel • Refer to Sections 3.2.1 & 3.8; Table 3.8-2.
• Maximum Fuel Burn-up for Gas-Cooled Reactors	133,000 MWd/MTU [Same for 2nd unit/group]	• The value derived by calculating the reactor thermal power multiplied by the time of irradiation divided by fuel mass (expressed as megawatt-days per metric ton of irradiated fuel) • Refer to Sections 3.2.1 & 3.8; Table 3.8-2.



Figure 3.1-1 Existing North Anna Power Station Site



Figure 3.1-2 Artist's Conception of New Units Adjacent to Existing Units

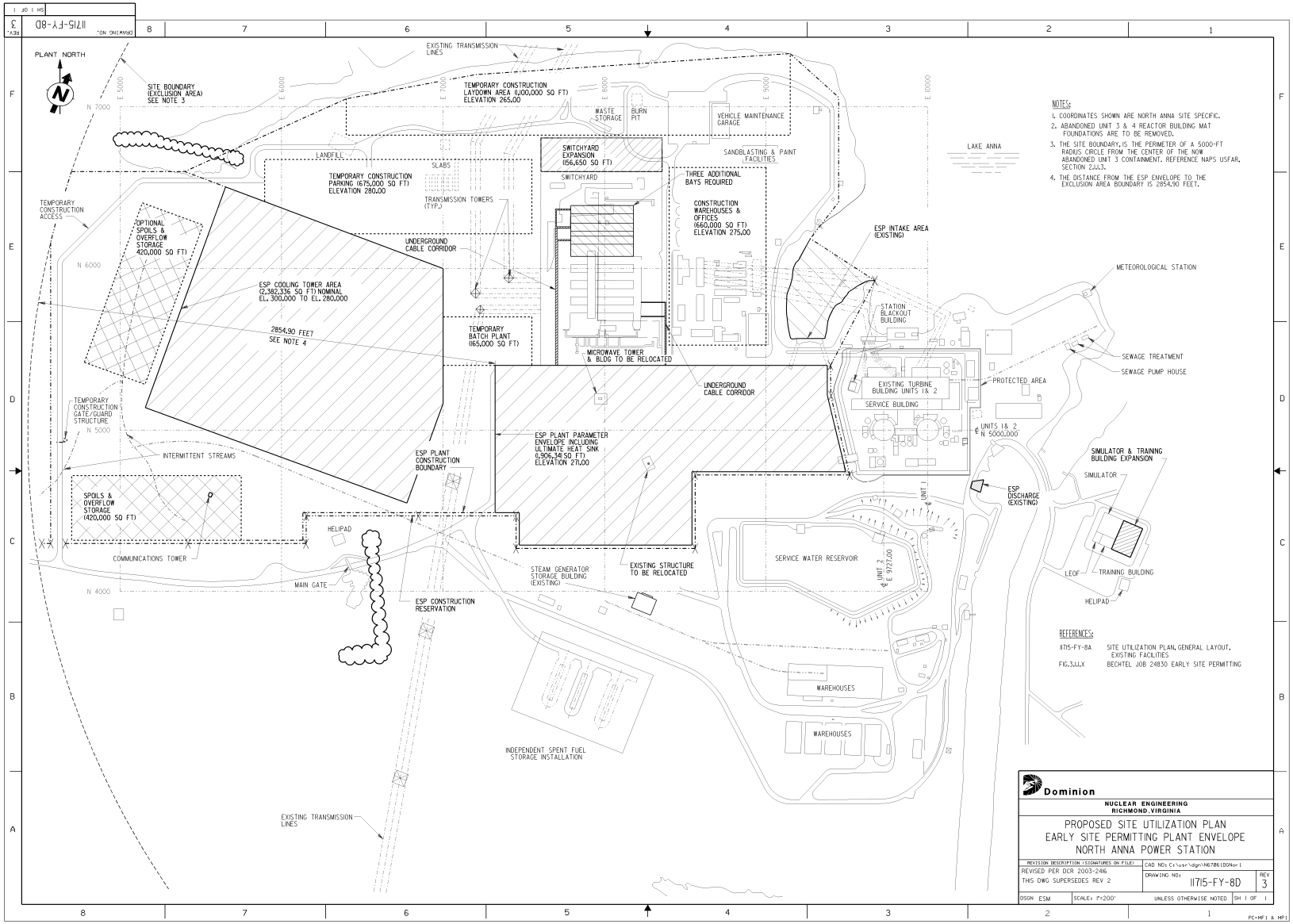


Figure 3.1-3 ESP Site Utilization Plan

3.2 Reactor Power Conversion System

For the ESP site, the selection of the reactor and power conversion system has not been made. In its place, a detailed, Generic PPE was developed to describe the maximum potential impacts. This Generic PPE is described in Section 3.1.3. The site has a potential development of up to approximately 3040 MWe (gross), which would be achieved with two power blocks to be called Units 3 and 4. Each unit could consist of several reactors or modules, perhaps as many as eight, depending on the reactor technology selected.

3.2.1 Reactor Description

The ESP site has been designed to allow incremental addition of new units. Figure 3.1-3 shows the location for new units. This location, west-southwest of the existing units, is sized to allow construction of two new units.

Each unit would consist of a maximum 4500 MWt reactor(s) and associated turbines and power conversion equipment. The gross electrical output of each unit of approximately 1520 MWe is dependent on circulating water inlet temperature and condenser design. Plant and site equipment would require approximately 30–100 MWe, resulting in an approximate maximum net 1420–1490 MWe output.

All of the proposed reactors use uranium as their fissile material. Enrichment of the uranium would vary based on the reactor type deployed, ranging from 2 percent enriched U-235 to 19.8 percent enriched U-235. Discharged fuel burn-up is based on the specific plant design, but would be in the range of 20,500 to 133,000 megawatt-days per metric ton of uranium (MWd/MTU). The enrichment limits for light-water-cooled reactors and gas-cooled reactors are 5 percent and 19.8 percent U-235, respectively. The burn-up limits for light-water-cooled reactors and gas-cooled reactors are 62,000 MWd/MTU and 133,000 MWd/MTU, respectively.

Fuel design and total quantity of uranium is specific to the reactor design selected. The larger, single-unit-type plants could contain as much as 157 MTU. Smaller modular units would contain considerably less, depending on their size.

3.2.2 Engineered Safety Features

Depending on the plant type selected, a wide range of engineered safety systems could be used. Potential plant designs for the ESP site currently employ both active and passive types of engineered safety features (ESF) systems. Active systems rely on active components, such as pumps, to move coolant to the needed locations, while passive systems use gravity and thermal convection to attain the same result. Active systems are typically powered by redundant power sources, such as an emergency diesel generator or a gas turbine. The passive system designs are based on using gravity to move water, and valves are typically actuated by safety-related dc power sources.

Some designs rely on an UHS to remove heat from safety-related systems and discharge it to the atmosphere. If required for the reactor design selected, the UHS cooling would be by small mechanical draft cooling towers. The towers would require no more than half an acre per unit.

3.2.3 **Power Conversion Systems**

The type of power conversion system used would depend upon the type of reactor deployed. The gas-cooled reactor uses a gas turbine system to convert the heat energy to mechanical energy, while the water-cooled reactor uses a steam turbine for the same purpose. Waste heat from Unit 3 would be rejected from either turbine type to the closed-cycle, combination dry and wet cooling towers and from Unit 4 to dry cooling towers. The tube material for the condenser or turbine exhaust cooling heat exchangers (depending on reactor type) has not been selected.

Section 3.2 References

None

3.3 Plant Water Use

Since no specific design has been selected for the ESP site, plant water use is defined in broad terms, using as a basis the Generic PPE information from Section 3.1.3. This Generic PPE describes a bounding plant design that is intended to accommodate current and future plants. This Generic PPE outlines the water consumption requirements for the bounding plant and is based on representative plant designs that would result in the highest water consumption values.

Plant cooling for the first new unit at the ESP site would use closed-cycle, combination dry and wet cooling towers. The second unit would use dry cooling towers. Cooling tower make-up water necessary to replace the water lost to evaporation would be obtained from the North Anna Reservoir. Plant water sources would come from two sources—Lake Anna and local wells—depending on the quantity and quality of make-up water required.

3.3.1 Water Consumption

Two new units at the ESP site would require the use of additional water for both plant cooling and internal consumption. Unit 3 would use closed-cycle, combination dry and wet cooling towers with make-up water from the North Anna Reservoir. Unit 4 would use dry cooling towers, with make-up from the North Anna Reservoir, if needed. Dry cooling towers prevent evaporation of the cooling water and significantly reduce the need for make-up water. In the event that the cooling water loop would use an open sump pump configuration with a free surface, a small amount of evaporation loss would occur, estimated to be on the order of 1 gpm. This small quantity of make-up water would be drawn from Lake Anna. The lake would also be used as a source of operating water supply for the fire protection system and the plant demineralized water supply for both units. Potable water supplies would be drawn from groundwater wells. The data listed in Table 3.3-1 and Table 3.3-2 reflect this arrangement.

Hydrological impacts of this arrangement are provided in Section 5.2.1 and water use impacts are provided in Section 5.2.2.

Figure 3.3-1 through Figure 3.3-3 outline the water use for the new units. As stated earlier (Section 3.3), the water balance for the new units is based on data from the Generic PPE and on site-specific parameters. Evaporation estimates for Unit 3 wet cooling towers and the Unit 4 dry cooling tower collection basin are based on site-specific data (see Section 5.2.1 and Section 5.2.2). Any future development would be bounded by the information in this table.

3.3.1.1 Plant Water Use

The total water use for new units for which the ESP site may be used is shown in tabular form in Table 3.3-1 and Table 3.3-2. This includes make-up water for the cooling towers, water supply for the potable water system, water supply for the demineralized water system, and the fire protection system requirements. As indicated in the tables, water use for the site would depend on the number of units constructed. Except as noted for plant cooling towers, the normal values listed are expected

limiting values for normal plant operation. Except as noted for plant cooling towers, the maximum values are those expected for upset or abnormal conditions. Figure 3.3-3 is typical for both new units and illustrates water requirements for the potable water systems, demineralized water supplied systems and the fire protection system. It should be noted that fire protection water consumption maximums are based on system actuation, which is an event-based activity. Normal water consumption is that required to maintain system availability. Figure 3.3-1 and Figure 3.3-2 illustrate water use for the cooling systems of Units 3 and 4, respectively.

3.3.1.2 Plant Water Releases

The water release estimates for the new units are provided in Table 3.3-1 and Table 3.3-2 as well as in Figure 3.3-1, Figure 3.3-2, and Figure 3.3-3. These estimates include evaporation and blowdown from both the circulating water cooling towers (where needed) and the UHS cooling towers (if needed). The radiological waste, sanitary waste, miscellaneous drains, and demineralizer discharges are also included. The normal values listed are the expected limiting values for normal plant operation. The maximum values are those expected for upset or abnormal conditions.

The release location for the new units would be in the same vicinity as the existing units. Site drainage points would remain largely in place. The majority of the release points are to the discharge canal or the WHTF. There may be some releases to the North Anna Reservoir, depending on service or plant location. Specific release points and quantities would be determined once the plant design has been finalized, and described in the COL application.

3.3.2 Water Treatment

There are several water treatment systems that are used in the existing units' operations. Similarly designed water systems for the new units would exercise similar treatment technologies and methods for generating or replenishing the necessary water supplies. The expected water treatment systems are described in the following subsections.

3.3.2.1 Raw Water

Cooling tower make-up water for Unit 3 would be from the North Anna Reservoir. Make-up water necessary for Unit 3 cooling towers would need treatment for biofouling, scaling, and suspended matter, with acceptable biocides, antiscalants, and dispersants, respectively.

Raw water from the North Anna Reservoir that could be used to provide make-up for various station secondary systems would also require treatment.

Any make-up water necessary for cooling towers, including the towers supporting Unit 4, would need treatment for biofouling, scaling, and suspended matter, with acceptable biocides, antiscalants, and dispersants, respectively.

3.3.2.2 Make-up Water

Make-up water from the North Anna Reservoir for other systems would be treated systematically and thoroughly with a process that includes ultra-filtration, reverse osmosis (RO), and electro-deionization, which results in highly purified water for various plant systems. In the final stages of the purification process, the treated water passes through ion exchange beds and is then de-oxygenated by gaseous hydrogen passing over a catalytic bed (palladium) (Reference 1). Once purified, the make-up water would most likely to be directed to the following water supplies:

- Condensate
- Primary
- Closed cooling (for various subsystems)

3.3.2.3 Condensate System

Treated condensate water would serve as a source of feedwater. Condensate water would also provide component cooling for the removal of residual heat from primary systems during the shutdown mode and recirculates air cooling water from a chilled water subsystem. With the existing units, component cooling water is treated by the chemical addition of chromates for corrosion inhibition and pH control. For the new units, the use of an alternative to chromates (such as molybdate) would be evaluated for treatment and environmental benefit. Chilled water could need additional treatment depending on piping materials.

3.3.2.4 Domestic Water System

The domestic water system provides a safe and approved potable water supply (Reference 1). For the new units, the domestic water system would consist of supply from ground water wells, a storage facility, pressure maintenance equipment, and a distribution system. Water treatment would be provided through filtration and disinfection as needed.

Section 3.3 References

1. Updated Final Safety Analysis Report, Revision 38, North Anna Power Station.

Table 3.3-1 Unit 3 Water Consumption

Service	Normal (gpm/cfs)[a]	Maximum (gpm/cfs)[a]	Reference (PPE Section)[b]
Water Supplies[c]			
Plant Cooling Tower Make-Up[d,e]	15,384/34.3	22,268/49.6	
UHS Cooling Tower Make-Up	555/1.24	1700/3.79	3.3.9
Potable Water Supply	90/0.2	120/0.27	5.2.1 and 5.2.2
Demineralized Water Supply	550/1.23	720/1.60	6.2.1 and 6.2.2
Fire Protection Water Supply	15/0.03	2500/5.57	7.1.1 and 7.1.2
Water Releases			
Evaporation Rate[e]			
Plant Cooling Tower[d,e]	11,532/25.7	16,695/37.2	
UHS Tower	411/0.92	850/1.89	3.3.7
Blowdown			
Plant Cooling Tower[d,e]	3844/8.57	5565/12.4	
UHS Tower	144/0.32	850/1.89	3.3.4
Drift Rate			
UHS Tower	negligible	negligible	
Plant Cooling Tower[d,e]	<8.0/0.018	<8.0/0.018	
Sanitary Waste Discharge	60/0.13	105/0.23	5.1.1
Radwaste Discharge	100/0.22	--	10.2.1
Misc. Drains Discharge	100/0.22	150/0.33	8.1.1
Demineralized Water Discharge	110/0.25	150/0.33	6.1.1

a. Flow rates were converted from gpm to cfs.
b. Reference refers to the line entry on the Generic PPE, Table 3.1-1.
c. Make-up water for Plant Cooling Towers, UHS Tower, Demineralized Water, and Fire Protection Water would be from Lake Anna. The potable water supply would be from area wells.
d. Normal for Plant Cooling Tower Make-Up, Evaporation, Drift, and Blowdown is “Maximum Water Conservation” (MWC) mode (two-thirds heat dissipated in wet cooling towers and one-third heat dissipated in dry cooling towers) and Maximum is “Energy Conservation” (EC) mode (all heat dissipated in the wet cooling towers).
e. The “Plant Cooling Tower” reference has contributions from circulating water wet and dry cooling towers and service water wet towers. Values are expected maximums at design 0.4% exceedance atmospheric conditions.

Table 3.3-2 Unit 4 Water Consumption

Service	Normal (gpm/cfs)[a]	Maximum (gpm/cfs)[a]	Reference (PPE Section)[b]
Water Supplies[c]			
Plant Cooling Tower Make-Up[d,e]	1.0/0.002	1.0/0.002	
UHS Cooling Tower Make-Up	555/1.24	1700/3.79	3.3.9
Potable Water Supply	90/0.2	120/0.27	5.2.1 and 5.2.2
Demineralized Water Supply	550/1.23	720/1.60	6.2.1 and 6.2.2
Fire Protection Water Supply (Lake Water)	15/0.03	2500/5.57	7.1.1 and 7.1.2
Water Releases			
Evaporation Rate			
Plant Cooling Towers[d,e]	1.0/0.002	1.0/0.002	See ER Section 5.2.1
UHS Tower	411/0.92	850/1.89	3.3.7
Blowdown			
Plant Cooling Towers[d,e]	0	0	See ER Section 5.2.1
UHS Tower	144/0.32	850/1.89	3.3.4
Drift Rate			
UHS Tower	negligible	negligible	
Plant Cooling Tower[d,e]	0.0/0.0	0.0/0.0	
Sanitary Waste Discharge	60/0.13	105/0.23	5.1.1
Radwaste Discharge	100/0.22	—	10.2.1
Misc. Drains Discharge	100/0.22	150/0.33	8.1.1
Demineralized Water Discharge	110/0.25	150/0.33	6.1.1

a. Flow rates were converted from gpm to cfs.
b. Reference refers to the line entry on the Generic PPE, Table 3.1-1.
c. Make-up water for Plant Cooling Towers, UHS Tower, Demineralized Water, and Fire Protection Water would be from Lake Anna. The potable water supply would be from area wells.
d. Unit 4 would use dry cooling towers. If an open sump pump configuration is used, a maximum 1 gpm evaporation rate would occur. There would be no drift loss associated with the dry cooling towers.
e. The “Plant Cooling Tower” reference has contributions from circulating water cooling tower and the service water cooling tower.

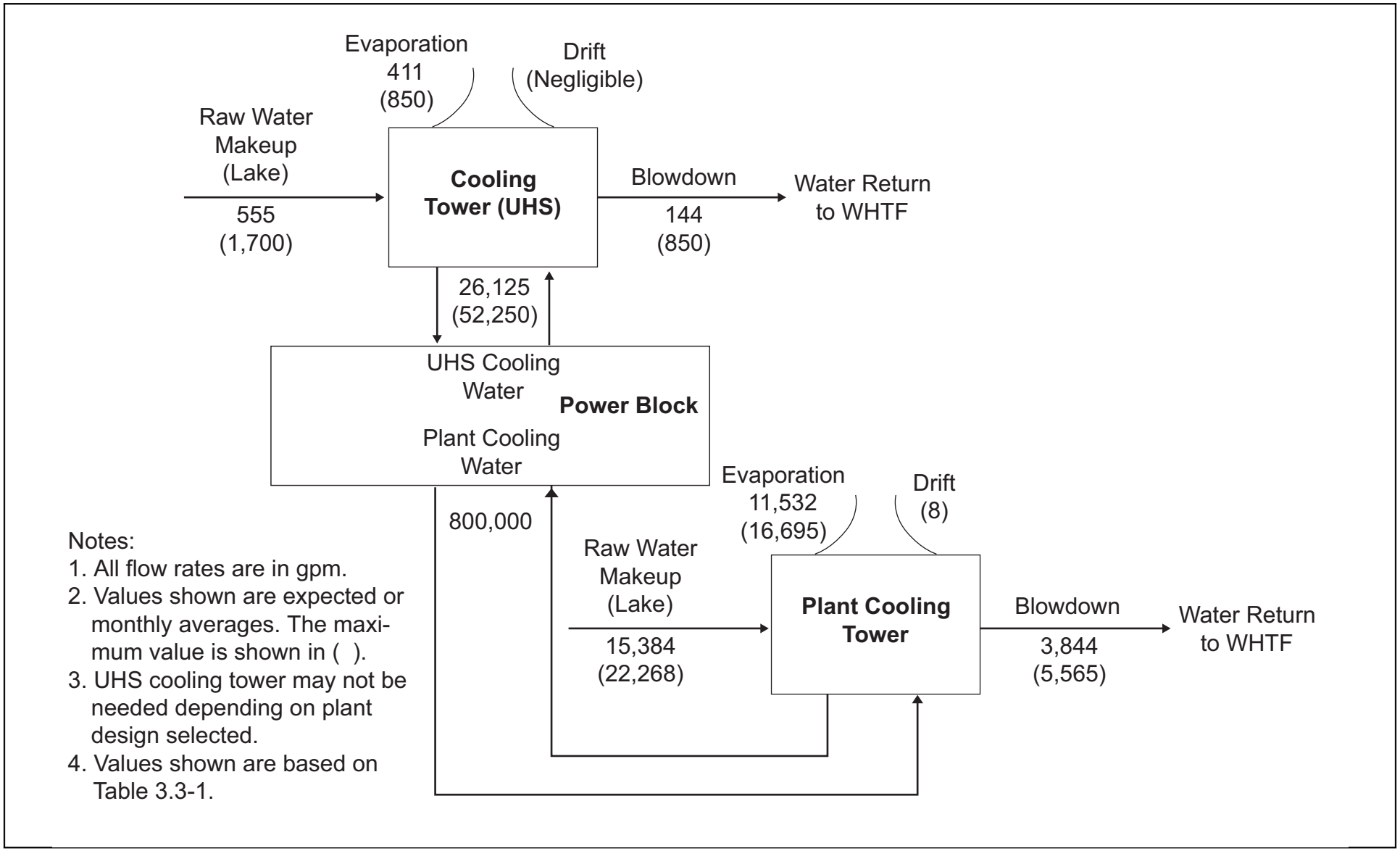


Figure 3.3-1 Unit 3 Cooling Water Use

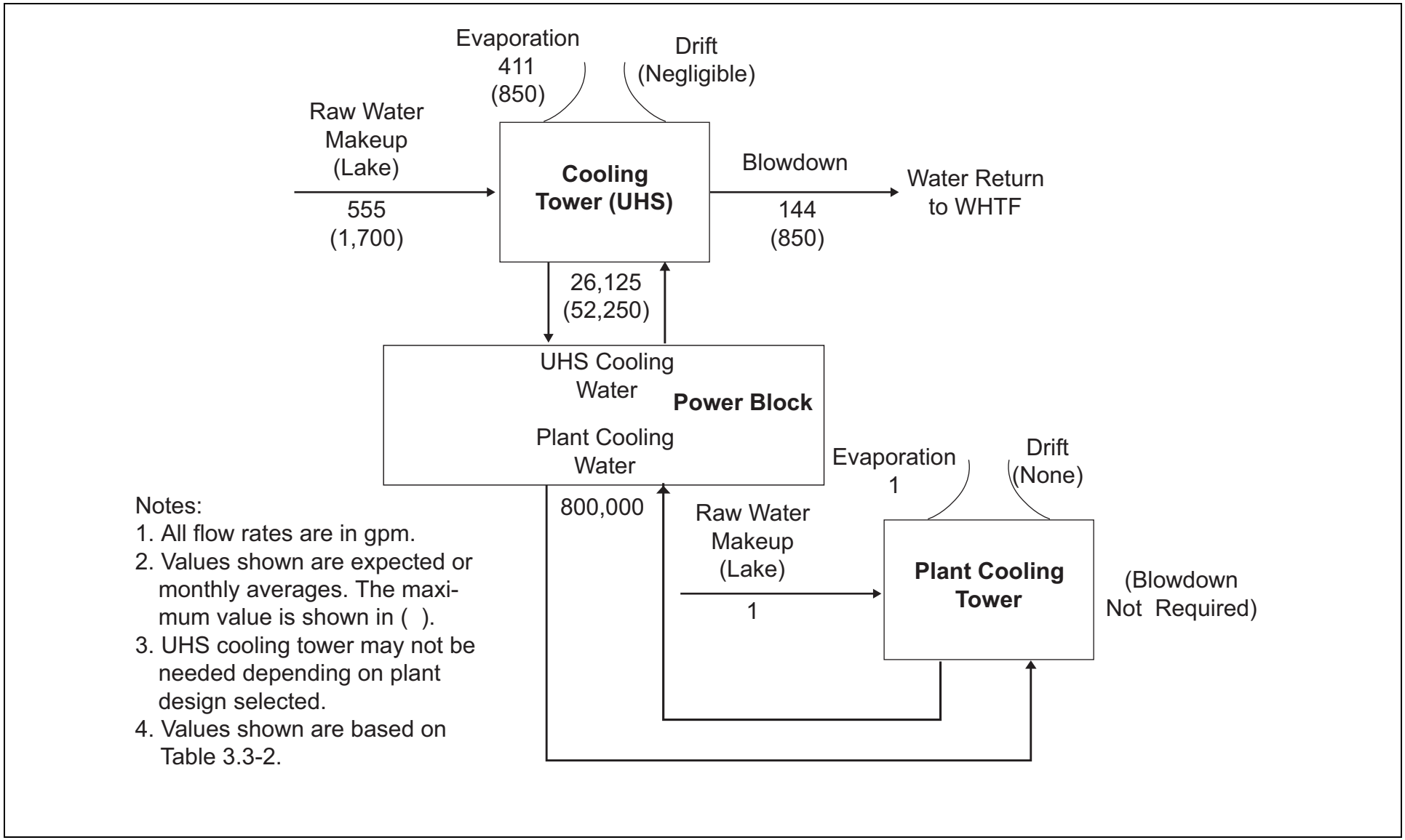


Figure 3.3-2 Unit 4 Cooling Water Use

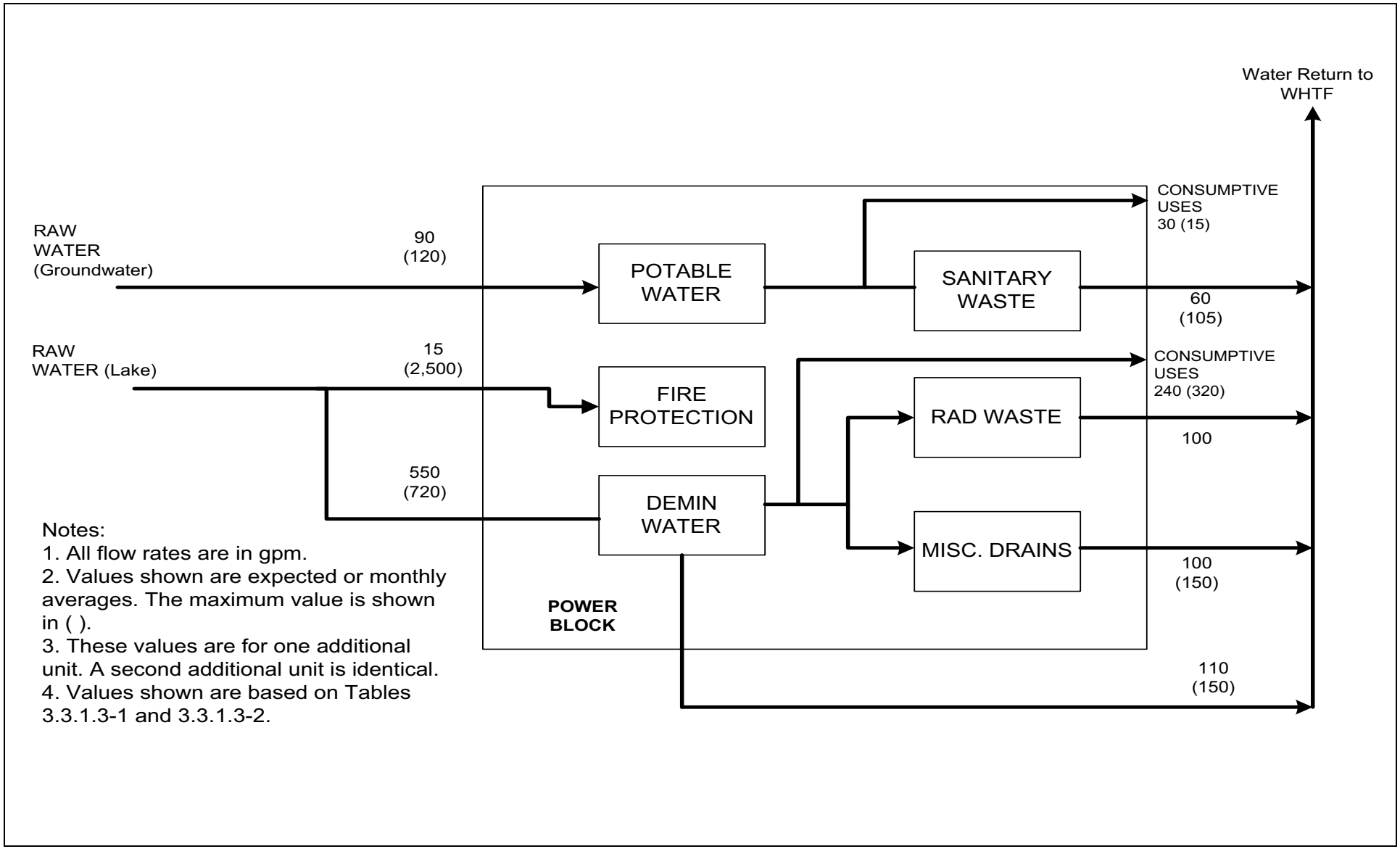


Figure 3.3-3 Power Block Water Use

3.4 Cooling System

The plant cooling system for new units and the anticipated modes of operation of the cooling system are described in Section 3.4.1. The design data of the cooling system components; specifically, the intake, the discharge, and the heat dissipation system, and their performance characteristics for the anticipated operational modes are presented in Section 3.4.2. The parameters provided are used to evaluate the physical, chemical, and biological impacts to the environment that would result from the operation of the cooling system.

3.4.1 Description and Operational Modes

The selection of the type of cooling system for new units requires consideration of the total amount of waste heat that would be generated as a byproduct of the proposed electricity generation, as well as the impacts of the waste heat to the environment. The amount of waste heat rejected from the steam-electric system varies, depending on the reactor type, because the core thermal output and the gross electrical output are different among the reactor types being evaluated. Unless site-specific data are available to generate a more realistic and appropriate estimate of the design parameters, bounding values from the Generic PPE (described in Section 3.1.3) were used to provide the basis for evaluation and selection of the types of cooling system best suited for the ESP site. Dominion would apply for the required environmental permits to support the construction of the new cooling system(s), including permits for the discharge and intake structures under the EPA CWA 316(a) and 316(b) regulations after a decision is made to proceed with development of the new units.

3.4.1.1 Normal Plant Cooling

Each new unit would require cooling systems to dissipate up to 1.03×10^{10} Btu/hr of waste heat rejected from the main condenser and the unit's auxiliary heat exchangers during normal plant operation at full station load. The primary normal plant cooling system, hereafter referred to as the circulating water system, would dissipate heat from the main condenser and potentially other auxiliary heat exchangers. A closed-cycle, combination dry and wet cooling tower arrangement would be used for the circulating water system of the new Unit 3, and a closed-cycle dry cooling tower would be used for the new Unit 4. Dissipation of waste heat from auxiliary heat exchangers not cooled by the plant circulating water system is typically performed by the plant service water system. The typical plant service water system water flows, heat dissipation, and losses are included in the plant cooling water system values for each unit. The service water cooling system would use a closed-cycle, wet cooling tower system for Unit 3 and a dry cooling tower system for Unit 4.

Unit 3's circulating water system would use both dry cooling towers and wet cooling towers for heat dissipation. Figure 3.4-11 shows a diagram of the conceptual closed loop system for Unit 3. Exhaust from the plant's steam turbines would be directed to a surface condenser where the heat of

vaporization would be rejected to the cooling water in a closed loop. The heated cooling water would be circulated first to the finned tubes of the dry cooling towers where heat content of the cooling water would be transferred to the ambient air. To increase heat rejection to the atmosphere, electric motor-driven fans would be used to force airflow across the finned tubes. No water loss would occur in the dry cooling towers. Cooling water leaving the dry towers would then pass through the wet towers to remove the balance of condenser/heat exchanger rejected heat by spraying the water into a forced or induced air stream. The wet towers would incorporate water-saving features to help reduce evaporative water losses.

Water saving features for wet cooling towers can include incorporation of a dry cooling section in the wet tower to reduce the amount of evaporative cooling required or use of heat exchange surfaces in the upper section of the wet tower where water is condensed from the exhaust stream before it leaves the tower. Other features such as variable speed fans and pumps and adjustable louvers may also be used to more efficiently match cooling capacity to heat load and ambient conditions. Further, although the system described uses wet and dry towers, it is possible to incorporate both wet and dry cooling sections in the same tower design. The performance characteristics of the cooling towers analyzed for Unit 3 are based on considerations of a model that incorporates such features.

After passing through the cooling towers, the cooled water would be recirculated back to the surface condenser to complete the closed-cycle cooling water loop. Make-up water to the circulating water system and service water cooling system would be obtained from the North Anna Reservoir. Blowdown from the cooling systems would be discharged to the existing plant WHTF discharge canal.

The Unit 3 circulating water system would operate in either of two operating modes:

- Energy Conservation (EC) – Dry cooling would be turned off, with reliance on wet towers for heat removal.
- Maximum Water Conservation (MWC) – A minimum of one-third[1] of the heat would be removed by the dry towers. The remainder would be removed, as required, by the wet towers.

When North Anna Reservoir level is at or above 250 ft msl and adequate reservoir discharge is being maintained, the EC mode would be used. However, if reservoir level falls below 250 ft msl and if the level is not restored within a reasonable period of time, the MWC mode would be used. The period of time before switching to the MWC mode was assumed to be 7 days for analysis of

1. In the MWC mode, the dry towers would have the capacity to remove one-third of the design condenser heat duty at a design dry bulb temperature (DBT) of 95°F (the 0.4 percent exceedance DBT for the site). As the DBT decreases, the percentage of heat which can be removed by the dry towers would increase proportionately until, at some lower DBT, the dry towers would have the capability of removing the entire condenser heat duty.

water level and downstream flows. The actual time frame would be established with the appropriate State agencies at the time of permitting.

The Unit 4 system would use dry cooling towers for heat dissipation in which the exhaust from the plant's steam turbines would be directed to a surface condenser where the heat of vaporization would be rejected to a closed loop of cooling water. The heated cooling water would be circulated to the finned tubes of the dry cooling towers where heat content of the cooling water would be transferred to the ambient air. To increase heat rejection to the atmosphere, electric motor driven fans would be used to force airflow across the finned tubes. After passing through the dry cooling towers, the cooled water would be recirculated back to the surface condenser to complete the closed-cycle cooling water loop. Except for the initial filling of the cooling water loop, Unit 4's circulating water and service water cooling systems would have no make-up water need since dry tower systems typically have no evaporative water losses and would have no continuous blowdown discharge to the WHTF. In the event that the cooling water loop would use an open pump sump configuration with a free surface, a small amount of evaporation losses, estimated to be on the order of 1 gpm (0.002 cfs), will occur. Any make-up water necessary to replenish the small evaporative losses for Unit 4's circulating water system and service water cooling system would be obtained from the North Anna Reservoir. Since there would be a minimal, if any, make-up water requirement and no blowdown discharge to the WHTF from the Unit 4 dry cooling systems, impacts to Lake Anna would be minimal.

In the closed-cycle, wet and dry cooling system for new Unit 3, pumps would circulate water in a closed loop of cooling water at an expected rate of about 3.355×10^8 lb/hr (approximately 1500 cfs at a maximum temperature of 100°F). The circulating water flow rate may vary depending on the final selected parameters of the unit condenser. Make-up water to the circulating water and service water cooling systems would be taken from the North Anna Reservoir by make-up water pumps at a maximum instantaneous rate of 2.23×10^4 gpm (49.6 cfs) when not operating in the MWC mode. The make-up water is required to compensate for the water lost from the closed-cycle cooling system due to evaporation, blowdown, and drift. In the EC mode, these losses would be no greater than 1.67×10^4 gpm for evaporation, 5.57×10^3 gpm for blowdown, and 8 gpm for drift. In the MWC mode, these losses would be no greater than 1.15×10^4 gpm for evaporation, 3.84×10^3 gpm for blowdown, and 8 gpm for drift. The make-up water pumps would be installed inside a new shoreline intake structure located in a cove west of the intake structure for the existing units. Blowdown from the circulating water and service water cooling systems of Unit 3 would be discharged to an outfall structure located at the head of the WHTF discharge canal at a temperature no greater than 100°F and a flow rate no greater than 5.57×10^3 gpm (12.4 cfs). At the maximum blowdown flow rate of 12.4 cfs at 100°F discharge temperature, the heat rejected from the closed cycle cooling systems of Unit 3 to the WHTF would be on the order of 4.2×10^7 Btu/hr during the extreme summer months when the wet-bulb temperature is close to 80°F and the average lake temperature is in the mid-80°F range. Compared to the once-through cooling system discharge of the existing units,

which have a combined maximum heat content of up to 1.35×10^{10} Btu/hr, the heat load in the blowdown discharge of Unit 3 would be about 0.3 percent of the heat load from the existing units during the summer months, when thermal impact would be most critical. Figure 2.1-1 shows the location of the cooling towers for normal plant cooling on the ESP site. Figure 3.4-1 shows the proposed location of the intake structure and discharge structures for the new units. Figure 3.4-2 shows the general layout of the WHTF and North Anna Reservoir. Within the discharge channel, the blowdown discharge from Unit 3 would mix with the circulating water discharge from Units 1 and 2. The combined effluent streams would travel through the main ponds, connecting canals and side arms of the WHTF, while dissipating the excess heat through surface heat exchange to the atmosphere. Because of the significantly lower flow rate and heat content, the blowdown discharge from Unit 3 would have negligible effect on the thermal structure and heat dissipation capacity of WHTF. At the end of the WHTF, the combined flow, after losing a substantial amount of heat via heat exchange with the atmosphere, would return to the North Anna Reservoir through a six-bay adjustable skimmer wall discharge structure at Dike 3 as described in Section 3.4.2. Upon entering the reservoir, most of the discharged cooling water would flow up-lake and would re-enter the intake structures after releasing more heat to the atmosphere.

The closed-cycle dry cooling tower system for new Unit 4 would consist of pumps that circulate cooling water in a closed loop at a rate of about 8.00×10^5 gpm (1782 cfs). The cooling water would be pumped through the main condenser and auxiliary heat exchangers, and then to the finned tubes of the dry cooling towers for heat dissipation to the atmosphere. Figure 2.1-1 shows the location of the cooling towers for normal plant cooling on the ESP site. The closed-cycle dry towers for the circulating water and service water systems would be designed to dissipate the heat load of up to 1.03×10^{10} Btu/hr anticipated during full station load operation. During the heat transfer process, no water would be lost to the atmosphere since there would be typically no evaporation losses in a dry tower system. A small amount of make-up water on the order of 1 gpm (0.002 cfs) would be needed and would be obtained from North Anna Reservoir to replenish the evaporative loss only if an open pump sump with a free surface would be used to recirculate water in the circulating water system cooling water loop or the service water cooling loop. Water use impacts to Lake Anna would therefore be minimal. Since the dry cooling system would produce no continuous blowdown discharge, new Unit 4 would have no thermal impact on Lake Anna.

3.4.1.2 Ultimate Heat Sink

For safety-related cooling, the UHS would provide cooling water to the reactor cooling systems and safety-related components that are necessary for the safe shutdown and cool-down of the plant under normal operations, anticipated operational events, and DBAs. Some reactor designs use a passive system and stored water for safety-related cooling and do not require an external UHS system to reach safe shutdown. For other reactor designs, a dedicated closed-cycle system with mechanical draft towers is proposed for the UHS. The UHS for each new unit would dissipate the decay heat of up to 1.2×10^8 Btu/hr during normal conditions and 4.2×10^8 Btu/hr during shutdown

or accident conditions. The UHS system would consist of a pump house that circulates cooling water to the safety-related cooling systems and components at a rate of 58 cfs during normal conditions or 116 cfs during shutdown or accident conditions. Then the cooling water would flow to the UHS cooling towers where the excess heat would be dissipated to the atmosphere by evaporation and conduction. The UHS cooling towers would be designed for a temperature range of 16°F. The evaporation water loss of each new unit is expected to be about 0.9 cfs during normal conditions and 1.9 cfs during upset or abnormal conditions. The blowdown flow from the UHS towers would be discharged to the new outfall at the head of the discharge canal and would have a flow rate varying from 0.3 cfs per unit during normal conditions to 1.9 cfs per unit during upset or abnormal conditions. An underground basin beneath each UHS tower, with a potential storage of 3.06×10^7 gallons of water, equivalent to 4.1×10^6 ft^3, would provide the 30-day supply of make-up water flow at 1.2 cfs to 3.8 cfs. Water supply to the storage basin would be pumped directly from the UHS make-up water pumps or other water supply pumps installed in the new intake structures.

3.4.1.3 Other Operational Modes

3.4.1.3.1 Station Load Factor

The new units are expected to operate with a maximum load factor of 96 percent (annualized) considering scheduled outages and other plant maintenance. On a long-term basis, an average heat load of 9.9×10^9 Btu/hr per each new unit, that is 96 percent of the rated unit heat load of 1.03×10^{10} Btu/hr, would be dissipated to the atmosphere via wet and dry cooling towers for Unit 3 and dry cooling towers for Unit 4.

3.4.1.3.2 Condenser Inlet and Lake Water Temperature

The new units' cooling systems would be designed for a maximum condenser inlet temperature limit of 100°F. This temperature is higher than the maximum allowable intake water temperature of 95°F for Units 1 and 2, specified in the existing units' Technical Requirements Manual. However, as the new units' closed-loop cooling systems operate independently of lake water temperature, no mandatory shutdown of the new units would be required if intake water temperature exceeded the 95°F limit.

Since the existing units began operation, ice blockage has not been encountered that rendered the cooling system inoperable. Historical water temperatures in the lake show that the minimum temperature near the intake area has not gone below 37°F. De-icing operations are, therefore, not expected to be necessary at the intake structures of the new units.

3.4.1.3.3 Minimum Operating Lake Level

The water level in Lake Anna is currently regulated by the North Anna dam to maintain a normal lake level of 250 ft msl to support operation of the existing units. Fluctuations of the inflows to the lake cause the lake level to temporarily go above or below the normal design level of 250 ft msl.

According to the existing units' Technical Requirements Manual, 242 ft msl is the minimum lake level for the Unit 1 and 2 circulating water systems to continue operation. With the additional water supply demand from the new units, the water budget analysis in Section 5.2.2 indicates that the lake level will not drop below 242 ft msl during severe drought conditions. For the future concurrent operation, the normal lake level would be maintained at 250 ft msl.

3.4.1.3.4 Anti-Fouling Treatment

Bio-fouling control using thermal or chlorination treatment has not been used for the once-through cooling system (circulating water) of the existing units. Cooling tower make-up water for Unit 3 would come from the North Anna Reservoir and would require treatment for bio-fouling, scaling, and suspended matter, with acceptable biocides, antiscalants, and dispersants, respectively.

If an open pump sump configuration would be selected for the cooling water loop of Unit 4's dry cooling tower system, make-up water would be obtained from the North Anna Reservoir to replenish the small evaporative losses. Pre-treatment of the dry cooling tower make-up would be required.

3.4.2 Component Descriptions

The design data of the cooling system components and their performance characteristics during the anticipated system operation modes are described in this section. Bounding site-specific estimates, if available, are used as the basis for discussion. If site-specific estimates are not available, bounding values of the parameters from the Generic PPE are used.

3.4.2.1 Intake System

The intake structure for new units at the ESP site would meet Section 316(b) of the CWA and the implementing regulations, as applicable.

The new intake structure for Unit 3 would withdraw make-up water for the normal plant circulating water and service water cooling systems from the North Anna Reservoir at a flow rate up to 2.23×10^4 gpm (49.6 cfs). As presented in Section 3.4.1.1, make-up water for the closed-cycle dry cooling tower system of Unit 4 would not be required normally. However, if an open pump sump configuration would be used in the closed cooling water loop, a small amount of make-up water estimated to be on the order of 1 gpm (0.002 cfs) would be needed to replace the evaporative losses through the free surface of the sump. This make-up water for Unit 4 would be obtained from the North Anna Reservoir.

The intake system of the new units would consist of a compartmented intake structure with a common screen well and separate pump bays dedicated to each unit, and a common approach channel in a cove on the south shore of the North Anna Reservoir near Harris Creek and immediately west of the cove that houses the existing intake structure. In addition to the make-up water pumps for Unit 3's closed-cycle cooling towers, the new intake structure would also house a

number of smaller service water pumps with a total capacity of up to 11 cfs per unit to supply other plant water uses, including 1.2 to 3.8 cfs of make-up water for the UHS storage system, 1.2 cfs to 1.6 cfs of demineralized water, and a maximum of 5.6 cfs of fire protection water. Screen wash pumps with a total capacity of about 1.1 cfs per unit will be installed in the screenwell to clean the traveling water screens during operation of the intake pumps. The screen wash flow would not be a consumptive water use as it would be recirculated back to intake flow upstream of the traveling water screens. The miscellaneous water supply pumps in the Unit 4 pump bays would also supply the make-up water as needed to the closed cooling water loop of the Unit 4 dry cooling tower system. The location of the new intake is shown in Figure 3.4-1. Figure 3.4-3 is a schematic drawing showing the approximate footprint and dimensions of the new intake structure and the intake channel.

As shown in Figure 3.4-3, the intake channel and new combined intake structure are in the cove originally planned for the intake of the abandoned Units 3 and 4. In the early 1980s, a cofferdam was installed across the cove to facilitate the construction of the now-abandoned intake system. To bring water from the reservoir to the new intake structure via the approach channel, the cofferdam, or a portion of it, would be removed. Because of the limited quantity of water to be supplied from the North Anna Reservoir, no major modification to the existing shoreline or dredging in the approach channel would be necessary. The approach channel has a typical side slope of 3:1 (horizontal to vertical) on both sides and a bottom width varying from about 300 feet at the lake end to 230 feet at the entrance to the screenwells and pump bays. The invert elevation of the channel is approximately 220 ft msl. At the minimum lake operating level (242 ft msl) for the future combined operation of the new and existing units, the flow velocity in the approach channel would be about 0.01 ft/sec, based on the intake flow rate of 61 cfs for Unit 3 and 11 cfs for Unit 4. If a partial opening at the cofferdam would be constructed to connect the reservoir with the approach channel of the intake structure of Units 3 and 4, the through flow velocity at the opening would be designed to be about 0.1 fps, similar to the current velocity in the reservoir, to minimize entrainment of debris, aquatic life, and sediment.

At the end of the approach channel, lake water would flow into the common screen well and the pump bays of either Unit 3 or Unit 4 at a velocity of less than 1 fps. A skimmer wall, extending to just below Elevation 242 ft msl, would be installed at the entrance of the screen well to reduce the amount of floating debris carried into the intake. The screenwell would also be equipped with automatically raking trash racks, traveling water screens, debris basin, and screen wash pumps. The traveling water screens would be designed to have the capability to operate continuously.

Debris collected by the trash racks and the traveling water screens would be collected in a debris basin for cleanout and disposal as solid waste. Downstream of the common screen well, multiple pump bays would house the make-up water pumps for Unit 3. Other smaller capacity water supply pumps and firewater pumps of Unit 3 would also share the space in some of these pump bays. The make-up water pumps and firewater pumps for Unit 4 would be located in separate pump bays

dedicated to Unit 4. To enhance the performance of the debris-filtering system and minimize fish mortality due to impingement and entrainment, the intake structure would be sized so that the designed approach velocity to the screen well, trash racks, and traveling water screens would be less than 1 fps at the minimum operating lake level of 242 ft msl. The total width of the intake structure would be about 70 feet, with approximately 50 feet allocated for Unit 3 and 20 feet for Unit 4. A bottom sill would be installed at the entrance of the common screenwell to reduce entrainment of bed sediment. Figure 3.4-4 is a schematic section view of the arrangement of the intake structure. The shoreline area disturbed by construction of the new intake structure would be stabilized and rip-rap protected against erosion. The intake systems for the new units would be located inside a restricted area marked by no-boat buoys to prohibit public access, as are the existing units.

3.4.2.2 Discharge System

Blowdown flow from the Unit 3 closed-cycle cooling towers would be released into the discharge channel of the WHTF via a new outfall. The temperature of the blowdown discharge would be no greater than 100°F. Figure 3.4-5 shows the location of the future outfall in relation to the existing outfall of Units 1 and 2. In accordance with Table 3.3-1, the maximum blowdown flow rate from the Unit 3 circulating water and service water cooling towers would be no greater than 12.4 cfs. As presented in Section 3.4.1.1, there would be no blowdown discharge from the Unit 4 closed-cycle, dry cooling tower system.

With all four units operating, the 12.4 cfs of blowdown effluent from Unit 3 would mix in the discharge channel with 4246 cfs of circulating water from Units 1 and 2. During the UHS cooling mode, a very small blowdown flow of about 0.3 to 1.9 cfs per new unit would be discharged to the outfall. Other plant discharges and miscellaneous drains from each new unit to the WHTF would total about 0.8 cfs to 1.1 cfs.

The discharge canal is 3850 feet long with a bottom width of 100 feet and side slopes of 2.5:1 (horizontal to vertical) as shown in Figure 3.4-6. The invert elevation of the canal is at Elevation 227 ft msl with an intermediate berm of 15 feet width at Elevation 255 ft. For the existing units, the water level in the WHTF is designed to be 1 to 1.5 feet above the water level in the North Anna Reservoir. At the normal pool level of 250 ft msl in the reservoir, the water level at the discharge canal would be about 251.5 ft msl with the new units on line.

The WHTF, which was formed by diking off a portion of Lake Anna, consists of three cooling ponds interconnected by canals with dimensions similar to the discharge canal. When filled to Elevation 251.5 ft, these ponds have a combined volume of about 2.66×10^9 ft^3, a total surface area of about 3400 acres, and an average depth of 18 ft (Reference 1). A major characteristic of the WHTF is the existence of the long narrow side arms that comprise about 1530 acres or 45 percent of the total WHTF area. The maximum depth is 50 feet in the vicinity of the dikes. The three dikes separating the WHTF from the North Anna Reservoir consist mostly of compacted earthen

materials. Each has a crest width of 26 feet and a side slope of 2.5:1 (horizontal to vertical). Rip-rap protection against erosion is provided on both slopes from Elevation 242 ft msl to Elevation 250 ft msl.

As shown in Figure 3.4-2, Figure 3.4-7, and Figure 3.4-8, the plant discharge would flow through the various ponds and connecting canals of the WHTF and enters the North Anna Reservoir at Dike 3 through a 6-bay skimmer wall discharge structure. Each discharge bay is 16.7 feet wide and 15 feet high from Elevation 212 ft msl to Elevation 227 ft msl, as shown in Figure 3.4-9 and Figure 3.4-10. Stop-log gates adjust the effective area of the openings to achieve the design exit velocity of 7 to 8 fps for mixing the WHTF outflow with the North Anna Reservoir. To minimize localized erosion at the discharge, the discharge outlet is provided with a 12.5-foot-long concrete apron.

The bottom topography at the exit to the Dike 3 discharge is shown in Figure 3.4-8. A 700-foot-long section of Dike 3 is constructed to Elevation 253.5 ft msl; whereas, the crests of the other dikes are at Elevation 260 ft msl. The 700-foot long section of Dike 3 forms an emergency spillway between the WHTF and North Anna Reservoir during periods of high flood flow equal to the return period of 100 years or worse. (Reference 1)

After entering the North Anna Reservoir, most of the cooling water flows up-lake toward the intake for recirculating back to the plant cooling system. A small portion of the discharge flow is released at the dam into the North Anna River downstream. As presented in Section 5.3.1.1, the long-term average flow released at the dam is estimated to be 276 cfs during the operation of the existing units. The lake receives inflow estimated to be about 369 cfs on a long-term average basis. At the normal pool level of 250 ft msl, the North Anna Reservoir has a surface area of 9600 acres, a volume of 1.06×10^{10} ft^3, and an average depth of 25 feet (Reference 1). The maximum depth is 70 feet near the dam.

3.4.2.3 Heat-Dissipation System

The cooling system described in Section 3.4.1 would provide the normal heat sink for Unit 3. A closed-cycle, combination dry and wet cooling tower arrangement would be used for the circulating water system. A separate service water cooling system would use a closed-cycle, wet cooling tower for dissipation of waste heat from auxiliary heat exchangers not cooled by the plant circulating water system. Mechanical draft type dry towers with electric motor-driven fans would be used to force airflow across the finned tubes to increase heat rejection to the atmosphere. Similarly, mechanical draft type wet towers with electric motor-driven fans would be used to force or induce airflow through the sprayed water to increase heat rejection to the atmosphere. The closed-cycle cooling towers would be designed to dissipate up to 1.03×10^{10} Btu/hr of waste heat at full station load.

For the closed-cycle cooling system of Unit 4, dry cooling towers with finned tubes would be used as the normal heat sink. Mechanical draft type dry towers with electric motor-driven fans would be

used to force airflow across the finned tubes to increase heat rejection to the atmosphere. The dry cooling towers would be designed to dissipate a maximum waste heat load of up to 1.03×10^{10} Btu/hr.

The location of the cooling towers is shown in Figure 2.1-1.

Section 3.4 References

1. Final Environmental Statement, related to the continuation of construction and the operation of Units 1 & 2 and the construction of Units 3 & 4, North Anna Power Station, Virginia Electric and Power Company, Docket Nos. 50-338 & 50-339 and Docket Nos. 50-404 & 50-405, United States Atomic Energy Commission, Directorate of Licensing, April 1973.

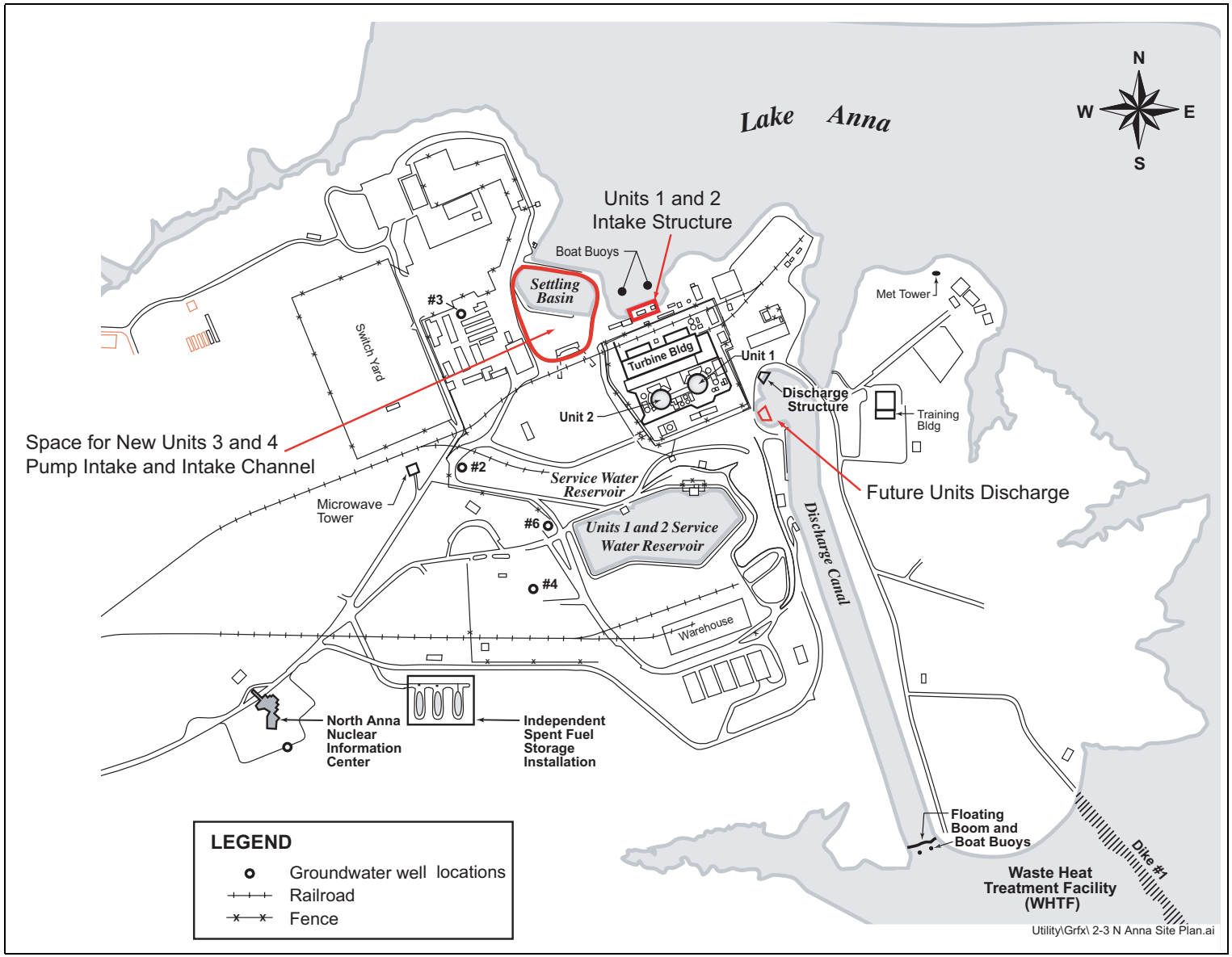


Figure 3.4-1 Proposed Location of the Intake Structure and Discharge Structures for the New Units 3 and 4

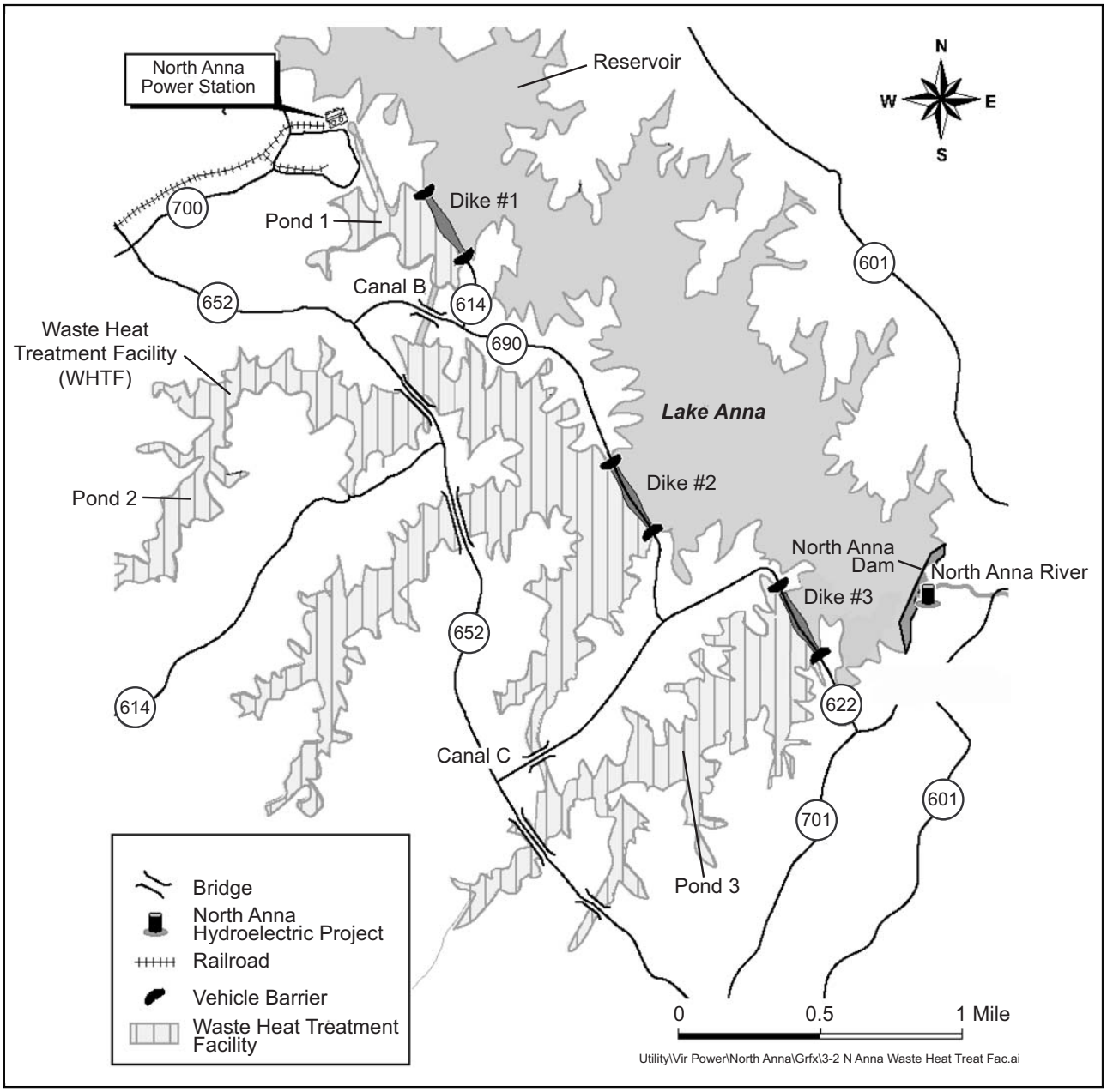


Figure 3.4-2 North Anna Plant - Reservoir and WHTF of Lake Anna

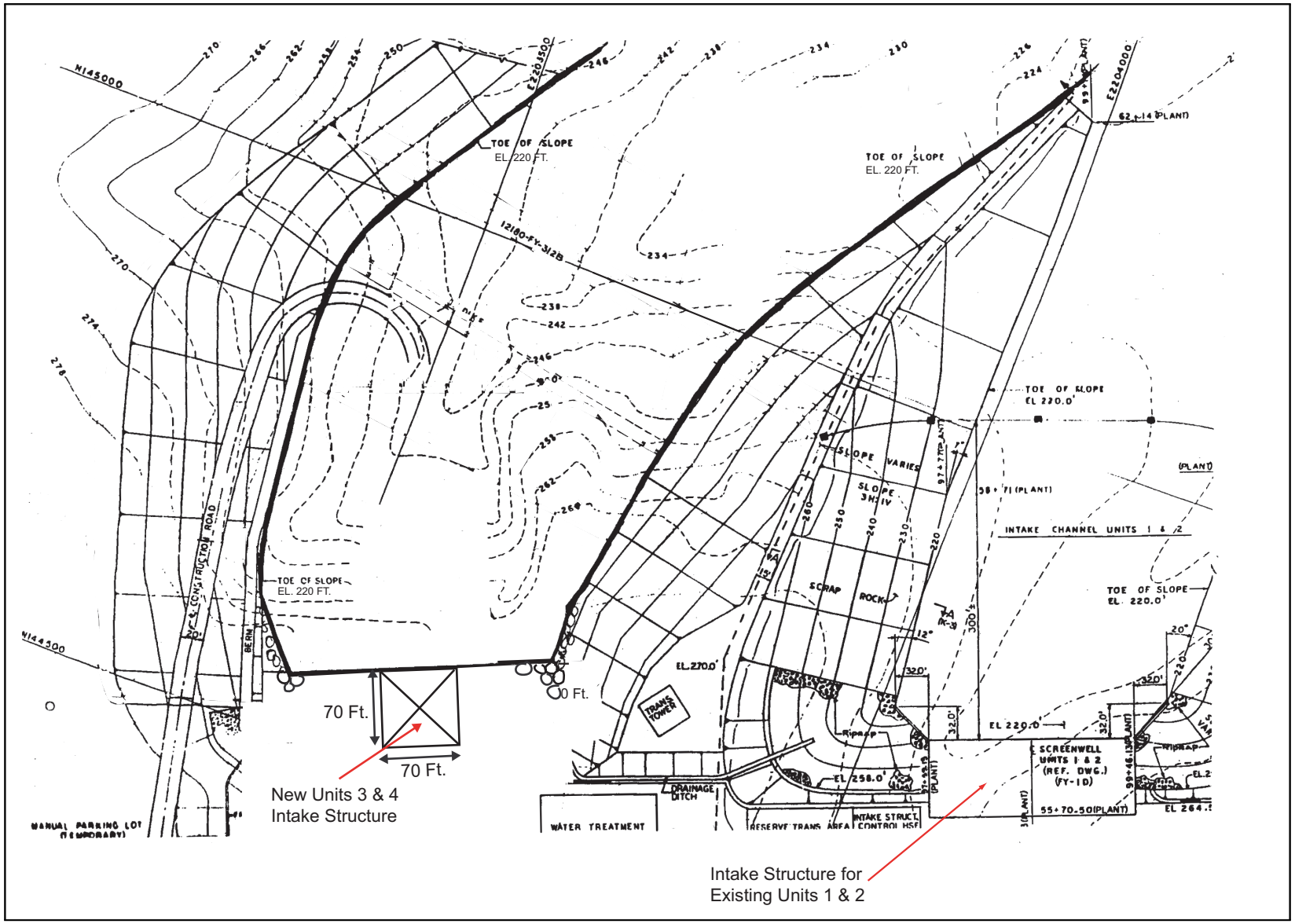


Figure 3.4-3 Layout of Screenwell/Pump Intake for New Units 3 and 4

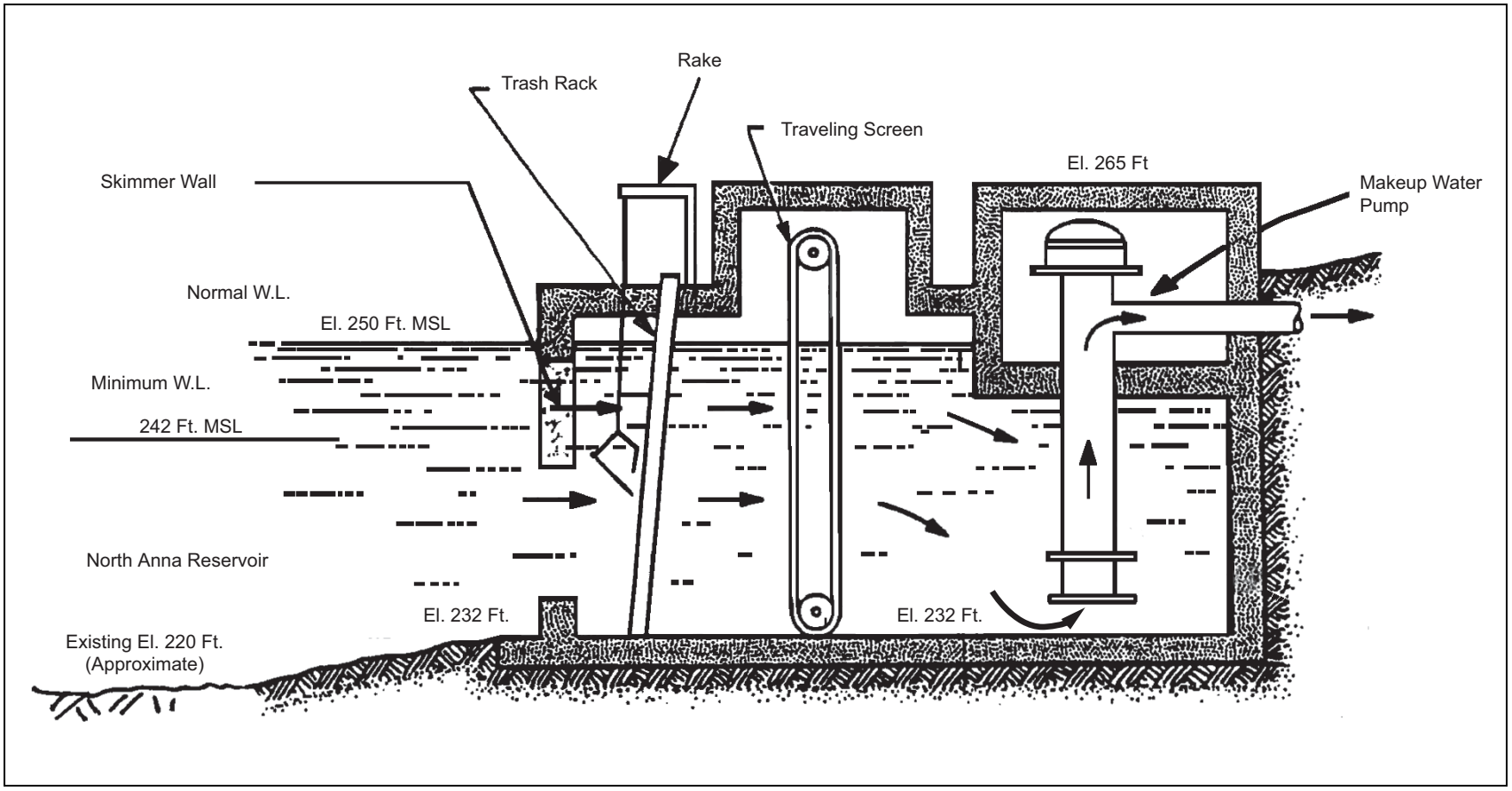


Figure 3.4-4 Schematic View of Pump Intake

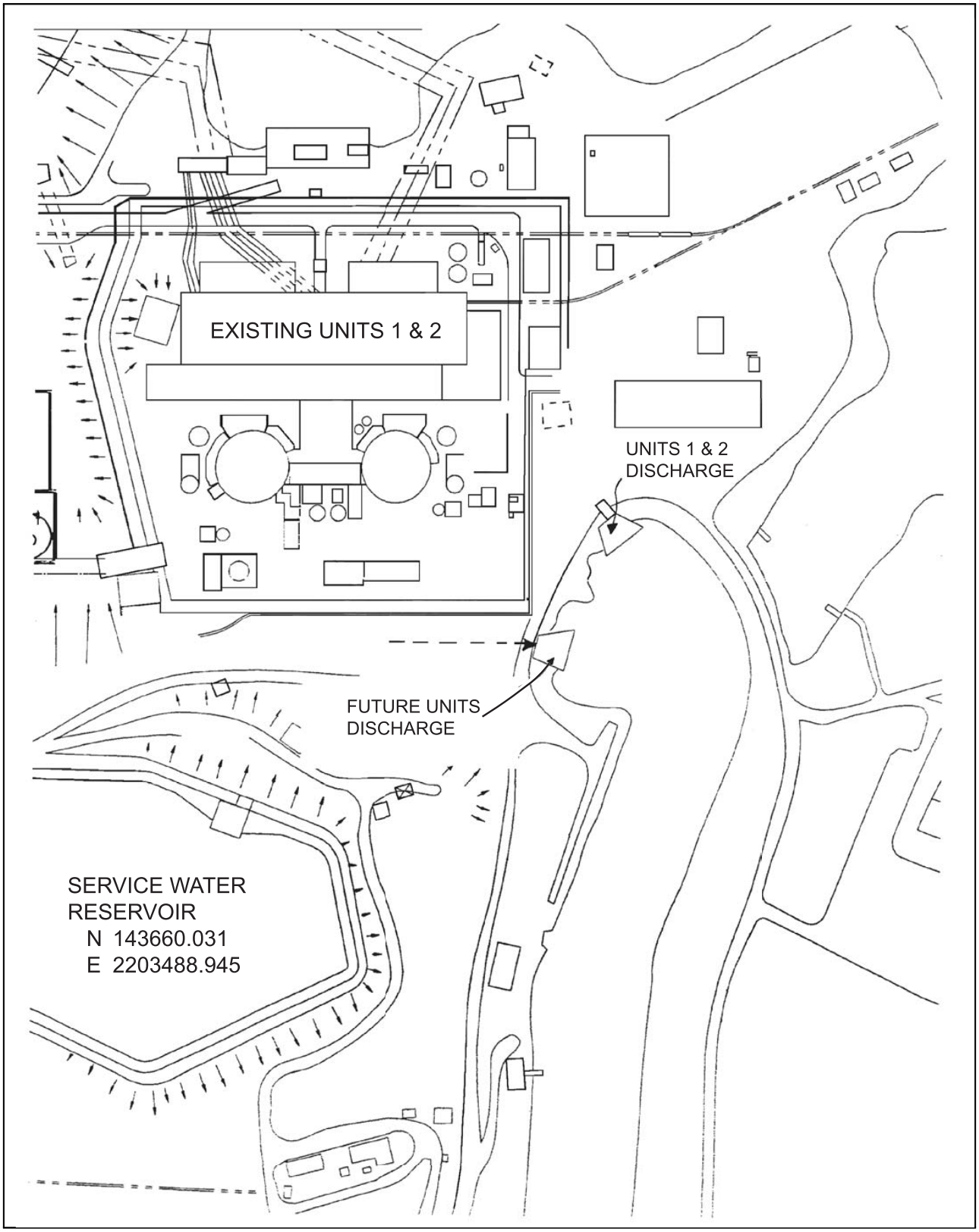


Figure 3.4-5 Discharge Outfall at Head of the Discharge Canal for New Units 3 and 4

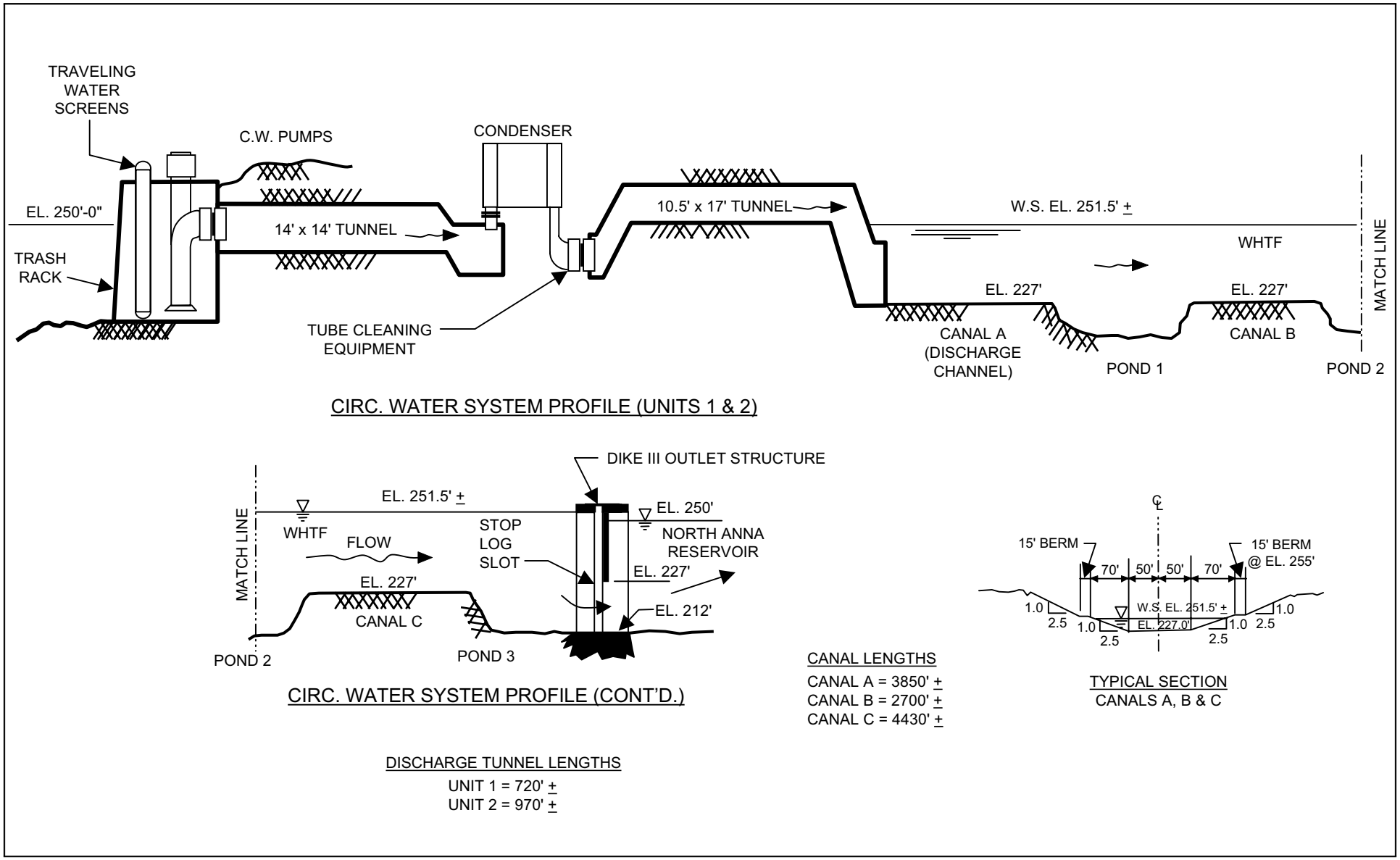


Figure 3.4-6 Discharge Channel and Dike 3 Outlet Structure

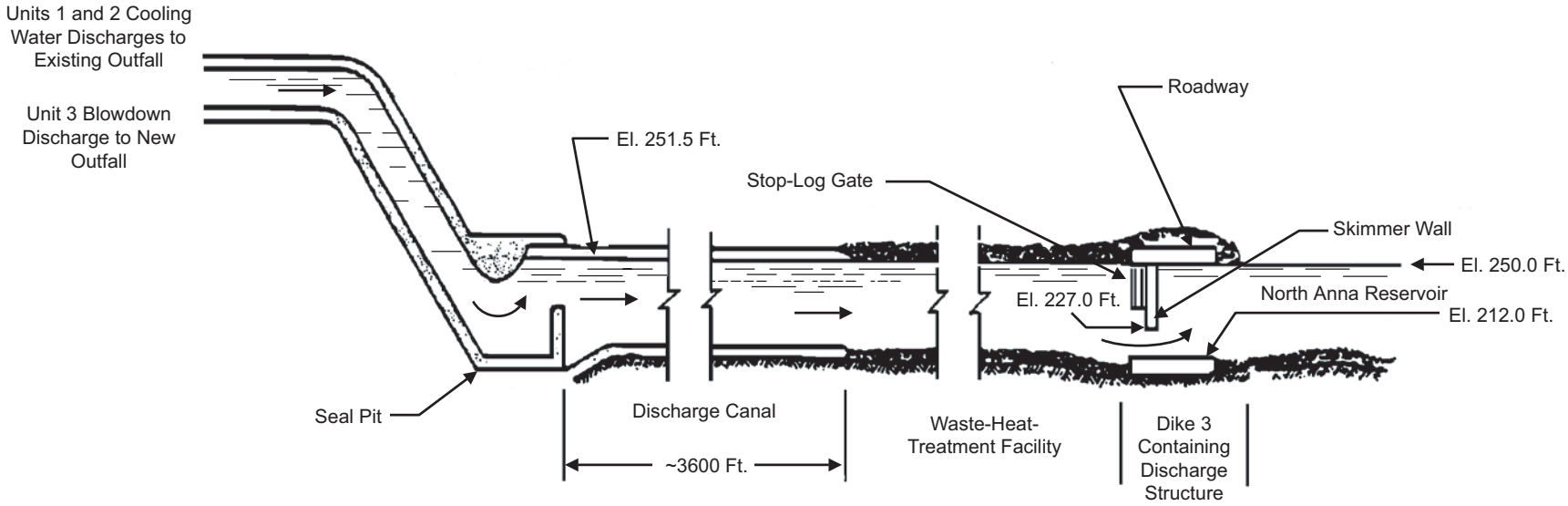


Figure 3.4-7 Schematic Diagram of the Discharge System

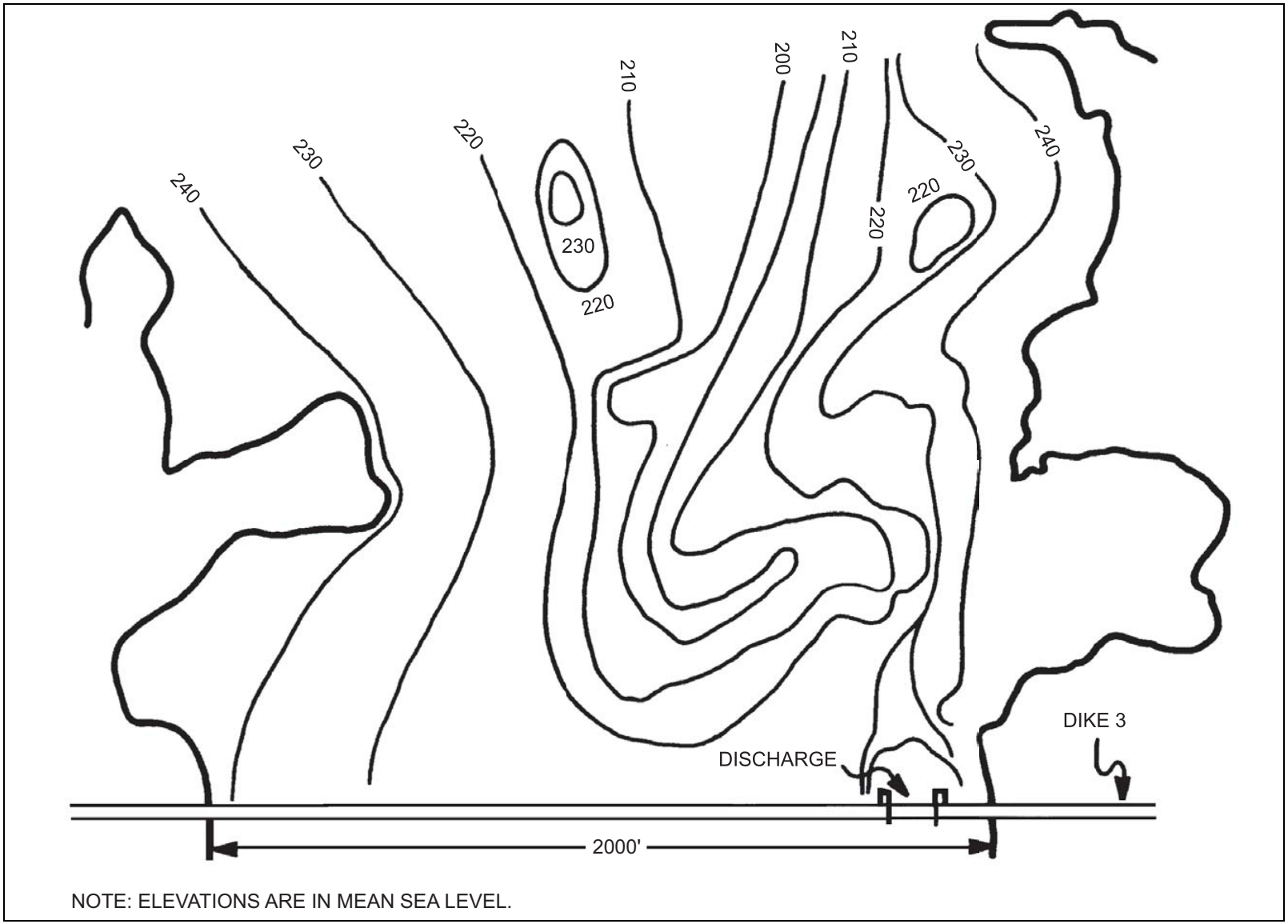


Figure 3.4-8 Location of Discharge Structure in Dike 3 and Bottom Topography of the North Anna Reservoir

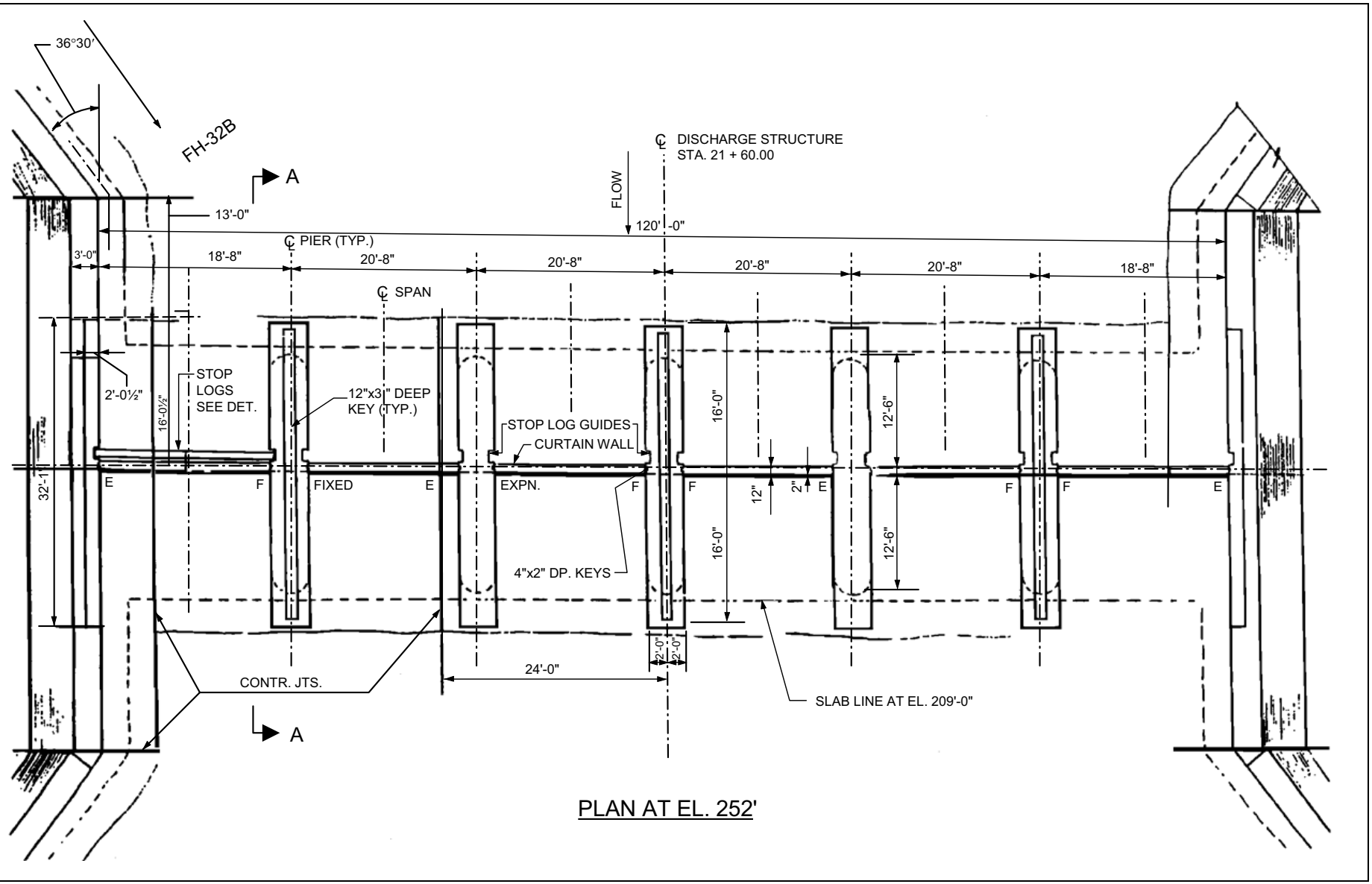


Figure 3.4-9 Water Discharge System from WHTF to North Anna Reservoir

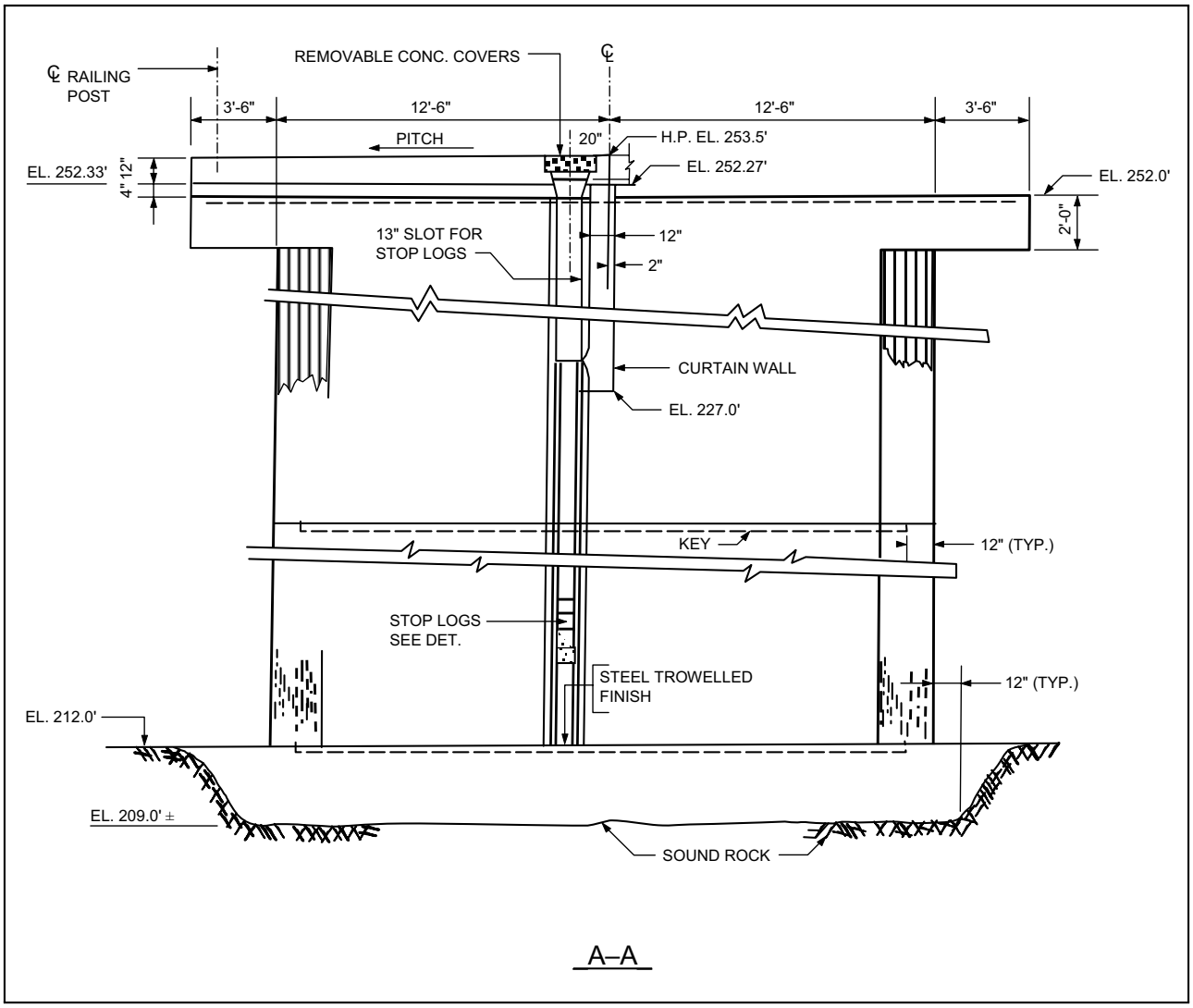


Figure 3.4-10 Water Discharge System from WHTF to North Anna Reservoir

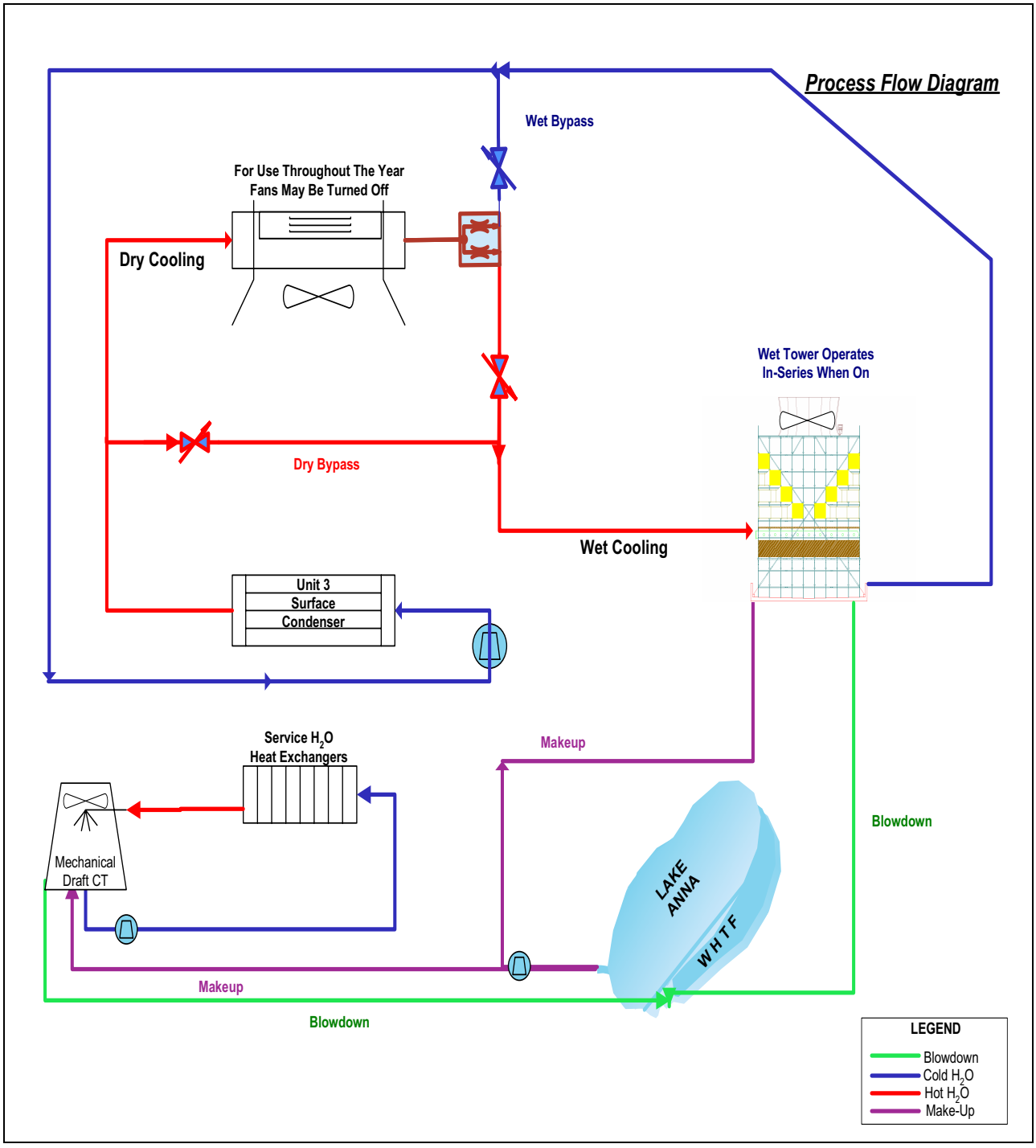


Figure 3.4-11 Conceptual Closed Loop Cooling Water Diagram

3.5 Radioactive Waste Management System

Because a reactor design has not been chosen for the ESP site, a Generic PPE was developed to characterize the generic bounding conditions for which the ESP site is suitable for development (See Section 3.1.3 and Table 3.1-1).

From the Generic PPE, a Bounding Site-Specific PPE was developed (Table 3.1-9). This site-specific PPE provides a bounding quantity of radioactive wastes that are projected to be generated and processed and then stored or released annually as liquid or gaseous effluents or as solid waste. Radioactive waste management systems would be designed to minimize releases from reactor operations to values as low as reasonably achievable (ALARA). These systems would be designed and maintained to meet the requirements of 10 CFR 20 and 10 CFR 50, Appendix I. Based on the design of these systems, the plant effluents provided in the PPE have been used to determine the maximum individual and population doses for normal plant operations.

3.5.1 Liquid Radioactive Waste Management System

Radioisotopes are produced during the normal operation of nuclear reactors. The source of production varies by reactor type, but the primary liquid sources for light water reactors include activation of non-radioactive water-borne materials normally present as the water, used for cooling the reactor, circulates through the reactor core.

Because impurities in water are mostly removed prior to its introduction into a reactor, the activated materials in the water are corrosion products and other leached materials, such as iron, cobalt, and manganese. Additionally, small amounts of activated material may enter the coolant by diffusing through the fuel containment, leaching from the fuel itself, or by escaping through fuel cladding leaks, if they occur.

Commercial nuclear reactors have effective liquid waste management systems. These systems are designed to gather liquids that may leak from radioactive and potentially radioactive sources and to store those liquids for further processing. The sources of liquid waste in a water-cooled reactor include controlled and uncontrolled leakage from the reactor coolant systems, cleanup and purification systems, rod control systems in boiling water reactors (BWRs) and other similar sources. In addition, other related plant systems, such as cooling systems, can contain radioactive materials in the event of a minor component or system-based leak, such as a heat exchanger leak, or they can contain contaminants as part of their design, such as station laundry systems.

During the design phase of the new units, these sources and potential sources would be identified and collection systems designed such that any leakage would be contained and either returned to the system or transported to a liquid waste management system collection point for treatment or disposal. The system would be designed to store and process those wastes to maintain radiation exposure ALARA.

Following processing, the liquid waste systems may release small qualities of radioactive effluents to the environment at defined release points. These release points, typically in the cooling water discharge stream, would be monitored to measure the activity released.

The expected releases from water-cooled reactors are well known. Table 5.4-6 lists expected isotopic releases from a bounding single unit reactor design. Note that a single unit is defined in Section 3.1.2.2.

Gas-cooled reactors have fewer sources of liquid waste because no direct activation of impurities is likely. For this reason, Table 5.4-6 presents a bounding set of data for expected liquid releases.

3.5.2 Gaseous Radioactive Waste Management System

Gaseous radioisotopes are produced during the normal operation of nuclear reactors. The sources vary by reactor type and include fuel leakage, activation, and radioactive dissociation. These gases are typically retained in the plant systems and are removed in a controlled fashion through a gaseous waste collection system.

Gaseous waste collection systems collect waste from multiple sources, compress the gas to reduce its volume, and then store the gas for a predetermined time to allow short-lived isotopes to decay. The remaining activity is released in a controlled manner to the environment through a monitored release point.

The system would be designed to store and process those released wastes to maintain radiation exposure as low as reasonably achievable.

Some small gaseous fraction would leak from the plant systems into the plant atmosphere. Monitoring systems are designed to detect and quantify the leakage. In addition, plant design features route building ventilation flows through monitored release points, or in some cases, through filtration systems to remove particulates and selected isotopes. The release points for both the plant ventilation systems and the gaseous waste management systems are designed to dilute the waste stream and release the gas at an elevated location. The bounding plant's normal release point is a 95.5-foot horizontal stack.

Gaseous releases of water-cooled plants are well known, and studies of gas-cooled plant operation have indicated that their gaseous releases would be bounded by the water-cooled data. Table 5.4-7 lists expected gaseous isotopic releases from a bounding single unit reactor design. Note that a single unit is defined in Section 3.1.2.2.

3.5.3 Solid Radioactive Waste Management System

Solid radioactive wastes are produced by multiple methods in a nuclear power station. The waste can be either dry or wet solids, and depends on whether the source is from an operational activity, or based on maintenance or other function. The solid radioactive waste management system is

designed to receive, collect, and store solid radioactive wastes prior to their onsite storage or their shipment off site.

Since the NAPS site already has two existing units, low-level solid waste storage from the new units would be coordinated with that from the existing units. The system would be designed to store and process those wastes to maintain radiation exposure ALARA. Radiation monitors would be used to monitor the area as well as the waste to ensure that applicable requirements are met.

The system design would ensure that the solid radioactive wastes are collected, monitored, segregated, stored, and packaged for shipment (if required) in a manner that minimizes exposure to plant personnel and the public in accordance with 10 CFR 20 and 10 CFR 50, Appendix I.

The total yearly activity and yearly generated volume of solid radwaste is listed in the Bounding Site-Specific PPE, Table 3.1-9.

Section 3.5 References

None

3.6 Nonradioactive Waste Systems

The following sections provide descriptions and scopes of service for non-radioactive waste systems for the new units. Typical non-radioactive waste systems need to address: 1) waste streams with effluents containing chemicals or biocides, 2) sanitary effluents, and 3) miscellaneous or other effluents. Descriptions in this section are based on best available information from operating experience and regulatory guidance.

3.6.1 Effluents Containing Chemicals or Biocides

Proper water chemistry for plant operation incorporates the treatment of water used in various secondary systems. Consequently, effluents from these water systems in the new units would be treated, but might still contain some low-level chemicals and/or biocides, similar to effluents from the existing units. These effluents would be treated according to regulations, as current discharges. The following list identifies some typical chemicals that may be present in the plant's permitted discharge:

- Iron
- Chlorides
- Ammonia or Amines
- Hydrazine
- Chlorine (sodium hypochlorite)
- Phosphates or dispersants used in cooling towers
- Low levels of oil and grease
- Corrosion inhibitors used in cooling systems
- Suspended solids

Discharges would occur from domestic water treatment, dry and wet cooling tower treatment, and plant blowdown. Regardless of the water systems' sources or constituents, each constituent discharged to the environment would be limited (i.e., volume and concentration) by the VPDES permit (Reference 1).

3.6.2 Sanitary System Effluents

A sanitary waste system, with expected effluents in compliance with acceptable industry design standards, the CWA, and state regulatory authority (through the VPDES permit), would be maintained onsite during the new units' construction and operation. The waste treatment system would be a permanent, self-contained system: its wastes would not be addressed through a municipal system.

The waste treatment system would be monitored and controlled by trained operators. If there was a need during peak construction or outage support activities for additional provisions, approved supplemental means of handling sanitary wastes would be employed.

Approved technology for processing wastes would include laboratory testing of effluents to ensure proper treatment. Monitoring would be implemented to ensure compliance with regulatory limits.

3.6.3 Other Effluents

This section describes miscellaneous gaseous, liquids, or solid effluents not addressed in Section 3.6.1 and Section 3.6.2.

3.6.3.1 Gaseous Effluents

Non-radioactive gaseous effluents created during plant operation from back-up power plant supply sources, such as diesel generators, would be permitted by state and federal regulatory authorities. The permits would specify operation frequency parameters and allowable quantities.

There are no other planned sources of gaseous emissions from the new units.

3.6.3.2 Liquid Effluents

Non-radioactive liquid effluents that could potentially drain to Lake Anna would be limited under the VPDES permit. A list of permitted outfalls for the existing units would be expanded to include any additional locations, adjusted flowpaths, or volumes created by the construction and operation of the new units (Reference 2).

3.6.3.3 Solid Effluents

Non-radioactive solid wastes are addressed by local regulation under “truck and haul” permitting. These solid effluents include typical industrial wastes such as metal, wood, and paper, as well as process wastes such as non-radioactive resins and sludge. Hazardous wastes are handled by permitted contractors and are addressed on site in compliance with federal regulation. It is anticipated that there would be no change to the method for handling solid wastes created by the new units.

Section 3.6 References

1. VPDES Permit No. VA0052451, Authorization to Discharge Under the Virginia Pollutant Discharge Elimination System and the Virginia State Water Control Act, Commonwealth of Virginia, Department of Environmental Quality, permit’s effective date, January 11, 2001; expiration date, January 11, 2006.

2. VPDES Application (Part 1), VPDES Outfall Descriptions and Sampling Points, North Anna Power Station, Dominion, March 30, 2000.

3.7 Power Transmission System

3.7.1 Switchyard Interfaces

The 500 kV switchyard at the NAPS site is an air-insulated, breaker-and-a-half switchyard with two full bays and two half bays. One full bay is for an existing unit and a transmission line; the other full bay is for the other existing unit and a 500/230 kV transformer; and two half bays, are each for a transmission line and two breaker open positions.

New units would be connected to the existing 500 kV switchyard by overhead or underground conductor circuits in accordance with the final plant configuration. The need for breaker-and-a-half bays varies depending on the reactor design selected. The existing switchyard may require extension to the north and the possible construction of additional bays, depending on the reactor design selected. This extension could be accommodated within the existing space at the site. The interface with the transmission system would occur at the connections to the bay of the existing switchyard, which interconnects with the outgoing transmission lines.

Depending on the final configuration selected, some existing plant buildings in the vicinity of the switchyard would be relocated so that they would not interfere with the connections to the generator step-up transformers.

The existing high-voltage equipment in the bay is rated for 3000A and 40 kA, and the 5-inch tubular bus is rated for 3676A and a 2 fps wind. The addition of the new units would require the upgrading of both the existing equipment and the bus, due to an increased output of approximately 3040 MWe. The specific upgrading would be determined based on detailed system studies and would be described in the COL application.

Each of the 500 kV switchyard buses is connected to a 500/36.5 kV, 60/80/100/112 MVA transformer to feed station service loads in a double-ended, single bus configuration. A voltage drop study would be performed to verify the acceptability of using these transformers.

Additional bays would require new control and relay protection systems in the control house, and the control house could require expansion, if room is not available for the new units. The existing relay protection system for the lines and buses may not be able to accommodate the scheme for the new units. Therefore, the existing relay system may need to be upgraded.

The addition of the new units would also require the modification and/or expansion of some service systems, such as grounding, raceway, lighting, AC/DC station service, and switchyard lightning protection.

3.7.2 Transmission System

The NAPS site is interconnected with the power grid system by three 500 kV transmission lines from the 500 kV switchyard and by one 230 kV transmission line from the 230 kV switchyard. These transmission interconnections are as follows:

- A 500 kV line to the east to a 500 kV switching station near Ladysmith, Virginia, provides a connection to the 500 kV system. This line normally delivers the power generated at the NAPS site to loads. This line can deliver power to the NAPS site, if desired.
- A 500 kV line to the north to a substation near Morrisville, Virginia, provides a second connection to the 500 kV system. This line can deliver power to the NAPS site, if desired.
- A 500 kV line to the south to a substation near Midlothian, Virginia, provides a third connection to the 500 kV system. This line can deliver power to the NAPS site, if desired.
- A 230 kV line to the west to the South Anna non-utility generator substation near Gordonsville, Virginia, provides power to the 230 kV substation, a non-utility generator.

Each transmission line, constructed between 1973 and 1984, occupies a separate right-of-way. The rights-of-way range in width from 37 to 84 meters (120 to 275 ft) and from 24 to 66 km (15 to 41 miles) in length, covering a total of approximately 1174 ha (2900 acres) (Reference 1). The capacity of the 500 kV transmission lines is such that the output of the existing units can be carried by any of the 500 kV lines. Units 1 and 2 were uprated in 1986 to a gross electrical output of 1964 MWe, with a net electrical output of approximately 1884 MWe (Reference 2). The net electrical output of the new units is estimated to be 3040 MWe. The existing 500 kV transmission line utilizes 2 x 2500 ACAR (aluminum conductor aluminum reinforced) 84/7 conductors per phase and is rated 2292 MWe with a 2 fps wind. The 230 kV line can carry approximately 571 MWe due to the size of the transformer.

Total output of the existing units and the new units would be:

1884 MWe + 3040 MWe = 4924 MWe

Capacity of any two 500 kV lines and a 230 kV line is:

$(2 \times 2292$ MWe) + 571 MWe = 5155 MWe

Thus, based on this initial evaluation, any two 500 kV transmission lines and the 230 kV transmission line are expected to have sufficient capacity to carry the total output of the existing units and the new units. However, detailed system load flow studies for the new units cannot be performed until an in-service date for the new units is established.

Section 3.7 References

1. NUREG-1437, Supplement 7, Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding North Anna Power Station, Units 1 and 2, U.S. Nuclear Regulatory Commission.

2. North Anna Power Station Updated Final Safety Analysis Report, Revision 38.

3.8 Transportation of Radioactive Materials

This section addresses the transportation issues associated with siting and operating a new reactor and is divided into two main subsections. The first subsection addresses the light-water-cooled reactor (LWR) designs presently being considered. The second subsection addresses the gas-cooled reactor designs also being considered. This split addresses the regulatory distinction made in 10 CFR 51.52 for LWRs.

3.8.1 Light-Water-Cooled Reactors

As required by 10 CFR 51.52, every environmental report prepared for the construction permit stage of an LWR, and submitted on or after February 4, 1975, is to utilize Table S-4, “Environmental Impact of Transportation of Fuel and Waste To and From One Light-Water-Cooled Nuclear Power Reactor,” and shall contain a statement concerning transportation of fuel and radioactive wastes to and from the reactor.

Table S-4 (as provided in 10 CFR 51.52(c) and repeated in Table 3.8-3) is a summary impact statement concerning transportation of fuel and radioactive wastes to and from a reactor. The table is divided into two categories of environmental considerations: 1) normal conditions of transport and 2) accidents in transport. The normal conditions of transport consideration are further divided into environmental impact, exposed population, and range of doses to exposed individuals per reactor reference year. The “accidents in transport” consideration is concerned with environmental risk. Under “normal conditions of transport,” the environmental impacts of the heat of the fuel cask in transit, weight, and traffic density are described. Also the number and range of radioactive doses to transportation workers and the general public are described. Under “accidents in transport,” the environmental risk from radiological effects and common non-radiological causes such as fatal and nonfatal injuries and property damage are described.

To indicate that Table S-4 adequately describes the environmental effects of the transportation of fuel and waste to and from the reactor, the reactor licensee must state that the reactor and this transportation either meet all of the conditions in paragraph (a) of 10 CFR 51.52 or all of the conditions in paragraph (b) of 10 CFR 51.52. Subparagraphs 10 CFR 51.52(a)(1) through (5) delineate specific conditions the reactor must meet to use Table S-4 as part of its environmental report. Subparagraph 10 CFR 51.52(a)(6) states, “The environmental impacts of transportation of fuel and waste to and from the reactor, with respect to normal conditions of transport and possible accidents in transport, are as set forth in Summary Table S-4 in paragraph (c) of this section; and the values in the table represent the contribution of the transportation to the environmental costs of licensing the reactor.” For reactors not meeting the conditions of 10 CFR 51.52(a) paragraph 10 CFR 51.52(b) requires a further analysis of the transportation effects. As accepted in other licensing proceedings, a sensitivity analysis may be used to show that the transportation effects for such reactors remain bounded by Table S-4.

The LWR technologies being considered have characteristics that fall within the conditions of 10 CFR 51.52, for use of Table S-4, with the minor exceptions of 1) rated core thermal power level for two of the reactors, and 2) average fuel irradiation. As presented below, the rated core thermal power level for these reactors does not translate into a greater amount of fuel than that assumed in Table S-4, and because average fuel irradiation is within the bounds of sensitivity analyses performed by the NRC, the environmental impacts of transporting fuel and wastes for these five types of LWRs are all bounded by Table S-4.

The LWR technologies being considered are the ABWR, the ESBWR, the AP1000 (Advanced Passive PWR), the IRIS, and the ACR-700 (Advanced CANDU Reactor). The standard configuration for each of these reactor technologies is as follows. The ABWR is a single unit, 4300 MWt, nominal 1500 MWe reactor. The ESBWR is a similar BWR: single unit, 4500 MWt, nominal 1520 MWe. The AP1000 is a single unit, 3400 MWt, nominal 1117–1150 MWe PWR. The IRIS is a three module PWR configuration for a total of 3000 MWt and nominal 1005 MWe. And the ACR-700 is a twin unit, 3964 MWt, nominal 1462 MWe, LWR with a heavy water moderator.

These conditions establishing the applicability of Table S-4 are reactor core thermal power; fuel form; fuel enrichment; fuel encapsulation; average fuel irradiation; time after discharge of irradiated fuel before shipment; waste form and packaging; mode of transport for unirradiated fuel; mode of transport for irradiated fuel; and mode of transport for radioactive waste other than irradiated fuel. Table 3.8-1 was prepared to succinctly show the reference conditions along with the bounding values for the new reactor technologies. The information to complete the table was supplied by the reactor vendors.

10 CFR 51.52(a)(1) requires that the reactor have a core thermal power level not exceeding 3800 MW. Of the considered LWR technologies, only the two BWRs, the ABWR and the ESBWR, exceed this value. The ABWR has a core thermal power level of 4300 MW thermal (MWt) while the ESBWR reactor power level is 4500 MWt. The core power level was established as a condition because, for the LWRs being licensed when Table S-4 was promulgated, higher power levels typically indicated the need for more fuel and therefore more fuel shipments than was evaluated in Table S-4. This is not the case for the new LWR designs due to the higher unit capacity and higher burnup for these reactors. The annual fuel loading for the reference reactor was 35 MTU while the annual fuel loading for both the ABWR and ESBWR is only 34 MTU. In fact, the annual MTU of fuel normalized to equivalent electrical generation is significantly less that of the reference LWR, 21.9 for ABWR and 22.4 for the ESBWR versus 35 MTU per year for the reference case. This reduced annual MTU of fuel would mean fewer shipments and less environmental impact. Also, WASH-1238 states: “The analysis is based on shipments of fresh fuel to and irradiated fuel and solid waste from a boiling water reactor or a pressurized water reactor with design ratings of 3,000 to 5,000 MW thermal (MWt) or 1,000 to 1,500 MW electrical (MWe).” Both the ABWR and the ESBWR fall within these bounds for thermal rating. The ESBWR deviates slightly from the maximum listed electrical

output due to a higher thermal efficiency. This higher thermal efficiency has no impact on the analysis.

10 CFR 51.52(a)(2) requires that the reactor fuel be in the form of sintered uranium dioxide ($UO_{2)}$ pellets. The LWR technologies being considered have a sintered UO_2 pellet fuel form.

10 CFR 51.52(a)(2) requires that the reactor fuel have a U-235 enrichment not exceeding 4 percent by weight. The NRC has subsequently concluded that enrichment up to 5 percent is also bounding by the environmental impacts considered in Table S-4. These evaluations are documented in the "NRC Assessment of the Environmental Effects of Transportation Resulting From Extended Fuel Enrichment and Irradiation" as provided in 53 FR 30555 and 53 FR 32322, and in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*. The LWR technologies being considered meet this subsequent evaluation condition. The enrichment limit for LWRs at the ESP site is 5 percent U-235.

10 CFR 51.52(a)(2) requires that the reactor fuel pellets be encapsulated in Zircaloy rods. 10 CFR 50.44 also allows use of ZIRLO™. License amendments approving use of ZIRLO™ rather than Zircaloy have not involved a significant increase in the amounts or significant change in the types of any effluents that may be released offsite, or significant increase in individual or cumulative occupational radiation exposure. Based on this assessment, the LWR technologies being considered meet this subsequent evaluation condition.

10 CFR 51.52(a)(3) requires that the average burnup is not to exceed 33,000 MWd/MTU. The NRC has subsequently concluded that average burnup up to 62,000 MWd/MTU for the peak rod is also bounded by the environmental impacts considered in Table S-4. These evaluations are also documented in the "NRC Assessment of the Environmental Effects of Transportation Resulting From Extended Fuel Enrichment and Irradiation" as provided in 53 FR 30555 and 53 FR 32322, and in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*. The LWR technologies being considered meet this subsequent evaluation condition. The burnup limit for LWRs at the ESP site is 62,000 MWd/MTU.

10 CFR 51.52(a)(3) requires that no irradiated fuel assemblies be shipped until at least 90 days after it is discharged from the reactor. Table S-4 assumes 150 days of decay time prior to shipment of any irradiated fuel assemblies. The sensitivity analysis performed by the NRC to extend Table S-4 to burnups of up to 62,000 MWD/MTU assumes a minimum of five years between removal from the reactor and shipment. For the LWR technologies being considered, five years is the minimum decay time expected before shipment of irradiated fuel assemblies. U.S. Department of Energy's (DOE's) contract for acceptance of spent fuel, as set forth in 10 CFR 961, Appendix E, requires a five year minimum cooling time. In addition, the NRC specifies five years as the minimum cooling period when they issue certificates of compliance for casks used for shipment of power reactor fuel (NUREG-1437, Addendum 1, pp 26). Further, all of the LWR technologies considered have a design storage capacity well exceeding that needed to accommodate five-year cooling.

10 CFR 51.52(a)(5) requires that unirradiated fuel be shipped to the reactor by truck. Unirradiated fuel is currently transported to the North Anna site by truck, and Dominion would do the same.

10 CFR 51.52(a)(5) allows for truck, rail, or barge transport of irradiated fuel. This condition would be met for all the LWR technologies being considered. Three of the reactor vendors identified rail as the shipment mode, two reactor vendors specified truck as the shipment mode, and the vendor for the ABWR and the ESBWR stated either rail or truck. Of note, the DOE is responsible for transport from reactor sites to the repository and DOE would make the decision on transport mode.

10 CFR 51.52(a)(5) requires that the mode of transport of low-level radioactive waste is either truck or rail. Dominion would ship its radioactive waste by truck.

Finally, 10 CFR 51.52(a)(4) requires that with the exception of spent fuel, radioactive waste shipped from the reactor is to be packaged and in a solid form. The LWR technologies being considered would solidify and package their radioactive waste. Additionally, existing NRC (10 CFR 71) and DOT (49 CFR 173,178) packaging and transportation regulations specify requirements for the shipment of radioactive material. The LWR technologies being considered are also subject to these regulations.

In conclusion, since the LWR technologies being considered either satisfy the conditions for use of Table S-4 or have impacts shown by sensitivity analysis to be bounded by Table S-4, the environmental impacts of transportation of fuel and radioactive wastes are represented by the values given in 10 CFR 51.52(c), Table S-4. Thus, the radiological and non-radiological environmental impacts of transportation of fuel to and from, and waste from, an LWR are small.

3.8.2 Gas-Cooled Reactors

3.8.2.1 Introduction and Background

The following assessment of the environmental impacts of the transportation of fresh and spent fuel to and from, and low-level waste from, the reactor for gas-cooled reactor technologies is based on a comparison of the key parameters and conditions that were used to generate the impacts listed in 10 CFR 51.52(c), Table S-4. This comparison can then demonstrate that the environmental impacts of these gas-cooled reactor technologies are no greater than the impacts previously identified in Table S-4 for the LWR technologies. The premise is that if the values of the major contributors to the health and environmental impacts that were used for the reference LWR are greater than those comparable values for the gas-cooled reactor technologies, then the subsequent impacts would also be greater and therefore bounding. It is important to point out that even though the contributors are being examined individually, it is the overall cumulative impact that is of concern. That is, for purposes of comparing/evaluating cumulative impacts, there may be increases in select individual contributors if offset by decreases in other contributors.

The parameters that have been chosen for purposes of comparison include not only the major contributors to the health and environmental impacts but also the conditions listed in 10 CFR 51.52.

The major contributor to transportation risk is the number of shipments. Basically, the more shipments, the more risk; if there are no shipments, there is no risk. The Table S-4 shipments include fresh fuel for both initial core loading and reloads, irradiated fuel, and low-level waste (LLW) from operations. The second main contributor to the transportation risk would be the mode of shipment. In this case, only trucks and trains are considered. The last important risk factor relates to what kind of material is being shipped. In the category for irradiated fuel fission product inventory, krypton inventory, actinide inventory, total radioactivity, decay heat, and weight of shipment were compared. For radioactive waste, the volume was used to determine the number of shipments. Radioactivity was also estimated to verify that the assumption about the percentage of LLW that might require shielding was reasonable.

The 10 CFR 51.52 conditions are: reactor core thermal power; fuel form; fuel enrichment; fuel encapsulation; average fuel irradiation; time after discharge of irradiated fuel before shipment; mode of transport for unirradiated fuel; mode of transport for irradiated fuel; and mode of transport for radioactive waste other than irradiated fuel. In addition, there are two other conditions that require that all radioactive waste with the exception of irradiated fuel be packaged and in solid form. Since existing packaging and transportation regulations already address those items and these regulations would also apply to these new reactor technologies, no further discussion is needed for these two conditions.

Before proceeding with the evaluation, it is important to note that the NRC has an ongoing review of the safety of spent fuel transportation. One recent evaluation is NUREG/CR-6672, “Reexamination of Spent Fuel Shipment Risk Estimates,” published in March 2000. The NRC in their document “An Updated View of Spent Fuel Transportation Risk,” concluded that the NUREG/CR-6672 study confirmed that: 1) earlier risk estimates (NUREG-0170, “Final Environmental Statement on the Transport of Radioactive Materials by Air and Other Modes”) to the public remain conservative by factors of 2 to 10 or more; 2) existing regulations governing the shipment of spent fuel are adequate; and 3) no unreasonable risk is posed to the public by the continued shipment of spent fuel. The range of conservative risk factors covers differences in mode of transport (rail or truck) and either accident or accident-free scenarios.

These same NRC conclusions support the position that environmental assessments of the transport casks do not have to be done for the Part 71 cask certifications because they meet the categorical exclusion criteria in 10 CFR 51.22(c)(13) that package designs used for the transportation of licensed materials do not require an environmental review. As presented in 10 CFR 51.22(a), the NRC has determined that certain categories of licensing and regulatory actions have already been determined individually or cumulatively to not have a significant effect on the human environment; thus, a separate environmental assessment is not required. As mentioned in the previous paragraph, a generic assessment of the environmental effects associated with transportation of all radioactive material, including spent fuel, has already been done as provided in NUREG-0170, “Final Environmental Statement on the Transportation of Radioactive Material by Air

and Other Modes," dated December 1977. This environmental impact statement (EIS) provided the regulatory basis for continued issuance of general licenses for transportation of radioactive material under 10 CFR 71. In addition, the NRC has conducted a reexamination of the risks associated with spent fuel shipments as documented in NUREG/CR-6672. This reexamination concluded that the estimated risks for future shipments are well below those in the 1977 study. Thus, NUREG-0170 remains valid as the baseline report on which NEPA analyses of transportation risk are based.

Table 3.8-2 captures the major features of the reference LWR that were used to develop Table S-4 and compares these same features with the gas-cooled reactor technologies being considered. The reference LWR pertains to the typical 1100 MWe LWR as described in WASH-1238. The information to construct the worksheet was taken from the "Normal Conditions of Transport" portion of the 10 CFR 51.52, Summary Table S-4 "Environmental Impact of Transportation of Fuel and Waste to and from One Light-Water-Cooled Nuclear Power Reactor," WASH-1238, *Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants* and Supplement 1 to WASH-1238 (NUREG-75/038) for the reference LWR. The information for the reactor technologies was provided by the reactor vendors.

3.8.2.2 **Analysis**

This section provides a detailed description of the comparison of the individual characteristics supporting Table S-4 against the corresponding parameters for the gas-cooled reactor technologies. The value for the reference reactor is given along with the corresponding values or range of values for the gas-cooled reactor technologies. As appropriate, additional information and/or observations are provided. Table 3.8-2 provides additional details regarding the reactor technology specific values.

There are two gas-cooled reactor technologies presently being considered. These reactor technologies are the GT-MHR (Gas Turbine-Modular Helium Reactor), and the PBMR. The standard configuration for each of these reactor technologies is as follows. The GT-MHR is a four module, 2400 MWt, nominal 1140 MWe gas-cooled reactor. The PBMR is an eight module, 3200 MWt, nominal 1320 MWe gas-cooled reactor. The unit capacities for these reactors are as follows: 88 percent for the GT-MHR; 95 percent for the PBMR. These values are contrasted with the reference LWR, a single unit, 1100 MWe plant with a unit capacity factor of 80 percent.

The enrichment and burnup limits for the gas-cooled reactors analyzed in this section are 19.8 percent U-235 and 133,000 MWd/MTU, respectively.

It is important to note that the plants being considered are a different physical size, have a different electrical rating, and have a different capacity factor from the reference LWR. In order to make proper comparisons, we need to evaluate the characteristics based on equivalent criteria. In this case, electrical generation is the metric of choice. Electrical generation is why the plants are being built, and we want to know if these new reactor technologies, for the same electrical output, have a greater or lesser impact on the health and environment. The reference LWR is a nominal

1100 MWe plant with a capacity factor of 80 percent. Based on this, the reactor technologies should be normalized to 880 MWe using their plant specific electrical rating and capacity factor. For many of the characteristics being examined, this adjustment is not necessary. But in a few cases, specifically those dealing with the number of shipments of fuel and waste, an adjustment is appropriate. The amount of this adjustment ranges from minus 12 percent for the GT-MHR to minus 30 percent for the PBMR.

The risk to the environment associated with the transportation of fuel is a function of the number of shipments and the contents of the shipments. Thus, a detailed analysis of these risk contributors is provided in the following sections.

3.8.2.3 **Risk Contributors – Shipments**

This section discusses the type and number of shipments for the gas-cooled reactor technologies and the values used for the reference LWR.

The reference LWR assumed an initial core loading of 100 MTU for a PWR and 150 MTU for a BWR. These quantities resulted in 18 truck shipments. For the new gas-cooled reactor technologies, the numbers of shipments were 44 for the PBMR and 51 for the GT-MHR. If normalized to the equivalent electrical output, the number of shipments would be 31 and 45 respectively.

The reference LWR assumed an annual reload of 30 MTU. This quantity resulted in 6 truck shipments. For the new gas-cooled reactor technologies, the numbers of reload shipments was 20 for both the PBMR and GT-MHR. The number of shipments normalized to the electrical generation changes to 14 for the PBMR and 18 for the GT-MHR.

With respect to the number of spent fuel shipments by truck, the reference LWR assumed 60 shipments annually. For the two gas-cooled reactor technologies, the number of shipments is considerably less. The PBMR requires 16 annual shipments while the GT-MHR requires 38 truck shipments annually. Normalizing to the electrical generation lowers these numbers to 12 to 34, respectively.

The reference LWR assumed 10 rail shipments annually of spent fuel. Since the gas-cooled reactor technologies are not planning to ship their spent fuel by rail, no comparison is needed. However, based on the comparison for truck shipments, fewer than 10 rail shipments annually would be expected if DOE decided to use larger and higher capacity rail transport casks for gas-reactor spent fuel.

The reference LWR also considered transporting spent fuel by barge and assumed 5 shipments annually. Since the gas-cooled reactor technologies are not planning to ship their spent fuel by barge, no comparison is needed.

The reference LWR assumes 46 shipments annually of low-level radioactive waste. The gas-cooled reactor technologies would make far fewer shipments. The GT-MHR would need only six shipments

while the PBMR would require nine shipments annually. These results assume that 90 percent of the LLW can be shipped at 1000 ft^3 per truck, and the remaining 10 percent can be shipped at 200 ft^3 per truck. If the numbers are normalized to electrical generation, the numbers of shipments range from six to seven.

The Table S-4 value, traffic density in trucks per day, for the reference LWR is given as less than one per day. Both the gas-cooled reactor technologies would also have less than one per day. In fact, the new gas-cooled reactor technologies would have far fewer shipments per year. The reference LWR bounding annual value for truck shipments is 113 based on a 40-year period, while the normalized number of truck shipments for the gas-cooled reactor technologies would require as few as 31 for the PBMR and only 53 for the GT-MHR.

The rail density in cars per month for the reference LWR is given as less than three per month. Since the gas-cooled reactor technologies are not planning to make any shipments by rail, no comparison is needed. However, as noted above, if DOE decided to use rail transport for spent fuel instead of truck, fewer than three shipments per month would be expected based on the expected larger capacity of rail spent fuel casks compared to truck casks.

3.8.2.4 **Risk Contributors - Contents**

This section addresses the radioactive contents of the shipments and their thermal loading and compares them to the reference LWR. The radioactive and decay heat values are based on the earliest time of shipment. For the gas-cooled reactor technologies, the five-year time was selected because it is the current minimum allowed time before shipment per DOE contract. These values are compared with the reference LWR that used a 90-day decay time. Ninety days was the minimum allowed time before shipment for Table S-4. Since we are evaluating the transportation impacts, it is the inventory and associated decay heat at the time of shipment that is of interest, not the inventory and decay heat at any other particular time.

The fission product inventory at the time of shipment for the reference LWR was 6.19×10^6 curies (Ci) per MTU. The values for the fission product inventory at the time of shipment for the gas-cooled reactor technologies were both much lower, from 3.5 to 4 times lower.

The actinide inventory at the time of shipment in Ci per MTU for the reference LWR was 1.42×10^5. Because of the longer burnup times for the new gas-cooled new reactor technologies, both of these reactor technologies have values that exceed the reference LWR. The GT-MHR and the PBMR, exceed the reference LWR by $\approx$64 percent and $\approx$59 percent, respectively. This comparison changes significantly for the GT-MHR if one considers the Ci per shipment, which is really what is of concern. The reference LWR ships 0.5 MTU per truck cask while the GT-MHR ships about a third less 0.16044 MTU per truck cask. Based on this comparison, the actinide inventory per shipment is about half (53 percent) for the GT-MHR versus the reference LWR. Since the PBMR plans to ship 0.495 MTU per cask, there is essentially no difference from the comparison per MTU.

The total radioactive inventory in Ci per MTU at the time of shipment for the reference LWR was 6.33×10^6. The new gas-cooled reactor technologies have much lower total radioactivity at time of shipment. The differences are from three to almost four times lower.

The krypton-85 inventory in Ci per MTU at the time of shipment for the reference LWR was 1.13×10^4. Both the GT-MHR and the PBMR exceed the reference LWR by about a factor of 2.3. As before, if one considers the Ci per shipment, the Kr-85 inventory for the GT-MHR would be about 71 percent of the Kr-85 reference LWR inventory. The PBMR comparison remains essentially the same.

The kilowatts per MTU at the time of shipment for the reference LWR were 27.1. This value is considerably higher than for the gas-cooled reactor technologies. At the time of shipment, the decay heat for the gas-cooled reactor technologies being considered ranges from 6.36 kilowatts per MTU for the GT-MHR to 3.91 kilowatts per MTU for the PBMR.

The decay heat (per irradiated fuel truck cask in transit) in kilowatts for the reference LWR was 10. Both the gas-cooled reactor truck casks generate much less heat (5 to 10 times lower) per truck cask than the reference LWR.

The decay heat (per irradiated fuel rail cask in transit) in kilowatts for the reference LWR was 70. Since the gas-cooled reactor technologies are not planning to ship their spent fuel by rail, no comparison is needed. However, should DOE elect to transport by rail, the expected decay heat would be less than 70 based on the comparison for truck shipment.

At the time of the reference LWR evaluation, the road limit was 73,000 lb. This has changed slightly through the years. 23 CFR 658.17 “Weight” states that for the interstate and defense highways the maximum gross vehicle weight shall be 80,000 pounds. In all cases for the gas-cooled reactor technologies, the road limit is governed by state and federal regulations.

3.8.2.5 **Discussion**

Of the close to 30 characteristics/conditions that were examined, there are only 8 that were exceeded by the gas-cooled reactor technologies being considered. Three of these characteristics have no direct transportation impact on the health and the environment: fuel form, U_{235} enrichment, and fuel rod cladding. There are operational issues and fuel cycle impact issues associated with these characteristics that are addressed as part of the operating license and as part of the evaluation of Table S-3 “Uranium fuel cycle data,” respectively. Two of these characteristics (number of shipments for initial core loading and number of reload shipments) are really a part of the overall truck transportation picture. When one considers the total number of truck shipments (fresh fuel, spent fuel, and radioactive waste), the new reactor technologies have many fewer total shipments. For example, on an average annual basis, the new reactor technologies require 60 to 82 fewer truck shipments. Comparing the total number of shipments is appropriate since the radiological impacts from fresh fuel are negligible. One characteristic, burnup, manifests its impact

through other characteristics, fuel inventory and decay heat at time of shipment, which are addressed separately. In the case of decay heat, both of the gas-cooled reactor technologies would generate fewer watts per MTU at time of shipment, and fewer kW per truck cask at time of shipment. The fuel inventory would be discussed as part of the remaining two characteristics that were exceeded: actinide inventory and krypton-85 inventory.

That the actinide inventory per metric ton of spent fuel is greater for the majority of the new gas-cooled reactor technologies is not surprising, since actinide activity tends to increase with increasing burnup and both of the gas-cooled reactor technologies plan a higher burnup than the reference LWR. The increase in the actinide activity for the new reactor technologies ranges from 59 percent to 65 percent. And as presented in the previous section, if one considers the actinide inventory per shipment, only the PBMR exceeds the reference LWR by 59 percent. From NUREG/CR-6703 "Environmental Effects of Extending Fuel Burnup Above 60 GWd/MTU," we learn that "none of the actinides contributes more than one percent of the external dose from an iron transportation cask, and as a group, the actinides do not contribute significantly to the dose from transportation accidents. In fact, increasing the activities of Pu-238, Pu-239, Pu-240, Pu-241, Am-241, Cm-242 and Cm-244 by more than a factor of 1000 only increased the cumulative dose for a transportation accident during shipment of 43 GWd/MTU spent fuel from the northeast to Clark County, NV from 0.0358 to 0.0359 person-mSv/shipment (3.58×10^{-3} to 3.59×10^{-3} person-rem/shipment)." There is one other area where the increased actinide activity needs to be considered and that is the corresponding increase in neutron source term. NUREG/CR-6703 states "because neutrons are effectively attenuated by low-density materials such as plastics and water, it is believed that minor modifications can be made to shipping casks to allow them to transport the higher burnup fuel at full load."

Based on the analysis performed and the conclusions drawn in NUREG/CR-6703 which show that actinides are not major contributors to the transportation risk, either incident free or accident, and with the actinide activity only 59 percent greater, the environmental impacts would still be bounded even for these higher burnups.

This leaves the Kr-85 inventory as the final characteristic to be addressed. The increase of Kr-85, a long-lived noble gas, would suggest an increase of the consequences associated with an accident that resulted in a breach of the fuel cask and fuel rods. The range of increase for the gas-cooled technologies being considered is from 121 percent to 133 percent. And as presented in the previous section, if one considers the Kr-85 inventory per shipment, only the PBMR exceeds the reference LWR. These amounts are based on a 5-year cooling time. If this decay time were increased by about 11 years, slightly greater than the half-life of Kr-85 (10.6 years), not an unlikely scenario by the way, this increase would for the most part decay away. Another factor to consider is that transportation risk is a function of both consequences and likelihood. Because the new reactor technologies require fewer truck shipments, the likelihood would decrease approximately 37 percent for the reactor with the greatest Kr-85 inventory. Another factor to consider is that the

accident rate for large trucks has steadily declined for more than the past 25 years and is less than half the rate in 1975. Thus, the likelihood has decreased to about 37 percent (0.63×0.5) of the 1975 likelihood. A final and major factor to consider is that the cask regulations are based on allowable releases independent of the inventory. Thus, regardless of the initial source term, if the cask releases more than a specific acceptable amount, it would not be licensed. Based on these considerations, the 5-year Kr-85 quantities would still be bounded by the overall transportation risk profile provided by Table S-4.

3.8.2.6 **Conclusion**

In conclusion, this detailed comparison of the underpinnings of Table S-4 show that the existing environmental and health effects are also conservative for the gas-cooled reactor technologies being considered. Of close to 30 characteristics examined, only eight were exceeded by the new technologies. In these instances, either they are independent of any impact or there are mitigating factors and controls to demonstrate that these slight increases are bounded by the impacts specified in Table S-4. This conclusion is also borne out by the observation that these new reactor technologies would be using the same transportation modes and subject to the same NRC and DOT regulations for packaging and transportation as the original analysis that was used to develop Table S-4. Thus, the new reactor technologies under consideration and the transportation of radioactive material associated with them meet the conditions in 10 CFR 51.52(b).

3.8.3 **Methodology Assessment**

The selection of a reactor design to be used for the ESP Facility is still under consideration. Selection of a reactor to be used at the ESP site may not be limited to those considered above. However, the methodology utilized above is appropriate to evaluate the final selected reactor. Further, should the selected design be shown to be bounded by the above evaluation, then the selected design would be considered to be within the acceptable fuel cycle environmental impacts considered for this ESP.

Section 3.8 References

1. 10 CFR 50.44, Standards for combustible gas control system in light-water-cooled power reactors.

2. 10 CFR 51.22, Criterion for categorical exclusion; identification of licensing and regulatory actions eligible for categorical exclusion or otherwise not requiring environmental review.

3. 10 CFR 51.52, Table S-4 Environmental Impact of Transportation of Fuel and Waste.

4. 10 CFR 71, Packaging and Transportation of Radioactive Material.

5. 49 CFR 173, Shippers – General Requirements for Shipments and Packagings.

6. 49 CFR 178, Specifications for Packagings.

7. Docket No. 50-400, 53 FR 30355, *NRC Assessment of the Environmental Effects of Transportation Resulting From Extended Fuel Enrichment and Irradiation*, August 11, 1988, and 53 FR 32322, August 24, 1988.

8. NUREG-0170, *Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes*, Vols. 1 and 2, December 1977.

9. NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Volumes 1 & 2, May 1996.

10. NUREG-1555 *Standard Review Plans for Environmental Reviews for Nuclear Power Plants*, October 1999.

11. NUREG/CR-6672, *Reexamination of Spent Fuel Shipment Risk Estimates*, March 2000.

12. NUREG/CR-6703 *Environmental Effects of Extending Fuel Burnup Above 60 Gwd/MTU*, January 2001.

13. WASH-1238, *Environmental Survey Of Transportation Of Radioactive Materials To And From Nuclear Power Plants*, December 1972.

14. Supplement 1 to WASH-1238 (NUREG-75/038), *Environmental Survey Of Transportation Of Radioactive Materials To And From Nuclear Power Plants*, April 1975.

Table 3.8-1 LWR-S4 Transportation Impact Evaluation

Reactor Technology	Table S-4 Condition	ESBWR (Single unit) (4500 MWt) (1520 MWe)	ABWR (Single unit) (4300 MWt) (1500 MWe)	AP1000 (Single Unit) (3400 MWt) (1117–1150 MWe)	IRIS (3 Reactors) (3000 MWt total) (1005 MWe total)	ACR-700 (Twin Unit) (3964 MWt total) (1462 Mwe total)
Characteristic						
Reactor Power Level (MWt)	not exceeding 3800 per reactor	4500	4300	3400	3000 (1000 per reactor, 3 reactors per plant)	3964 (1982 per reactor, 2 reactors per plant)
Fuel Form	sintered UO_2 pellets	sintered UO_2 pellets	sintered UO_2 pellets	sintered UO_2 pellets	sintered UO_2 pellets	sintered UO_2 pellets
U235 Enrichment (%)	Not exceeding 4; NRC has also accepted 5 as bounded	Initial Core <3.5; Reload average <4.5	Initial Core <3.5; Reload average <4.5	Initial Core Load Region 1: 2.35 Region 2: 3.40 Region 3: 4.45 Reload Average 4.51	fuel cycle average ≈4.85; maximum assembly 4.95; reload 4.75–4.95	2
Fuel Rod Cladding	Zircaloy rods; NRC has also accepted ZIRLO per 10 CFR 50.44	Zircaloy	Zircaloy	Zircaloy or ZIRLO™	ZIRLO™	Zircaloy-4
Average burnup (MWd/MTU)	Not exceeding 33,000; NRC has also accepted 62,000 for peak rod as bounded	45,000–55,000	46,000	48,700	55,200	20,500

Table 3.8-1 LWR-S4 Transportation Impact Evaluation

Reactor Technology	Table S-4 Condition	ESBWR (Single unit) (4500 MWt) (1520 MWe)	ABWR (Single unit) (4300 MWt) (1500 MWe)	AP1000 (Single Unit) (3400 MWt) (1117–1150 MWe)	IRIS (3 Reactors) (3000 MWt total) (1005 MWe total)	ACR-700 (Twin Unit) (3964 MWt total) (1462 Mwe total)
Characteristic						
Unirradiated fuel						
Transport mode	truck	truck	truck	truck	truck	truck
Irradiated fuel						
Transport mode	truck, rail or barge	truck, rail	truck, rail	rail	rail	rail
Decay time prior to shipment	Not less than 90 days is a condition for use of Table S-4; 5 years is per contract with DOE	five years	five years	ten years	five years	ten years
Radioactive waste						
Transport mode	truck or rail	truck	truck	truck	truck	truck
Waste form	solid	solid	solid	solid	solid	solid
Packaged	yes	yes	yes	yes	yes	yes

Yellow indicates a value larger than or different from Table S-4.

Table 3.8-2 Gas-cooled Reactor Transportation Impact Evaluation

Reactor Technology	Reference LWR (Single unit) (1100 MWe)	GT-MHR (4 Modules) (2400 MWt total) (1140 MWe total)	PBMR (8 Modules) (3200 MWt total) (1320 MWe total)	Comments
Characteristic				
Capacity (%)	80	88	95	
Normalization factor	1	0.88	0.7	
Reactor Power Level (MWt)	≈3400	2400 (600 per module, 4 modules per plant)	3200 (400 per module, 8 modules per plant)	Not exceeding 3800 per reactor is a condition for use of Table S-4
Fuel Form	sintered UO_2 pellets	TRISO coated particle fuel with uranium oxycarbide (UCO) kernal	Sphere of TRISO Coated UO_2 fuel kernels	Sintered UO_2 pellets is a condition for use of Table S-4.
U235 Enrichment (%)	1–4	fissile particle 19.8; fertile particle natural uranium	initial 4.9; equilibrium 12.9	Not exceeding 4 is a condition for use of Table S-4; NUREG-1437 concludes that 5 is bounded.
Fuel Rod Cladding	zircaloy	Graphite	Graphite	Zircaloy rods are a condition for use of Table S-4; 10 CFR 50.44 allows use of ZIRLO).
Average burnup (MWd/MTU)	33,000	112,742	133,000	Not exceeding 33,000 is a condition for use of Table S-4; NUREG-1437 concludes 62,000 for peak rod is bounded.

Table 3.8-2 Gas-cooled Reactor Transportation Impact Evaluation

Reactor Technology	Reference LWR (Single unit) (1100 MWe)	GT-MHR (4 Modules) (2400 MWt total) (1140 MWe total)	PBMR (8 Modules) (3200 MWt total) (1320 MWe total)	Comments
Characteristic				
Unirradiated fuel				
Unirradiated fuel transport mode	truck	truck	truck	Shipment by truck is a condition for use of Table S-4
No. of shipments for initial core loading	18	51 shipments (1020 fuel elements per module × 4 modules; 80 elements per truck)	44 shipments (260,000 fuel spheres per module × 8 modules, 48,000 spheres per truck)	100 MTU for PWR; 150 MTU for BWR
No. of reload shipments/year	6	20 shipments (520 elements per reload per 1.32 years × 4 modules; 80 elements per truck)	20 shipments (120,000 fuel spheres per module × 8 modules; 48,000 spheres per truck)	30 MTU annual reload
Irradiated fuel				
Irradiated fuel transport mode	truck, rail or barge	truck	truck	Shipment by truck, rail or barge is a condition for use of Table S-4.
Decay time prior to shipment	150 days	five years	five years	Not less than 90 days is a condition for use of Table S-4; 5 years is per contract with DOE
Fission product inventory in Ci per MTU after 5-year decay	6.19×10^6	1.55×10^6	1.78×10^6	The value for the LWR is for a 90-day decay time.
Actinide inventory in Ci per MTU after 5-year decay	1.42×10^5	2.33×10^5	2.26×10^5	The value for the LWR is for a 90-day decay time.

Table 3.8-2 Gas-cooled Reactor Transportation Impact Evaluation

Reactor Technology	Reference LWR (Single unit) (1100 MWe)	GT-MHR (4 Modules) (2400 MWt total) (1140 MWe total)	PBMR (8 Modules) (3200 MWt total) (1320 MWe total)	Comments
Characteristic				
Irradiated fuel (continued)				
Total radioactivity inventory in Ci per MTU after 5 year decay	6.33×10^6	1.78×10^6	2.01×10^6	The value for the LWR is for a 90 day decay time.
Krypton-85 inventory in Ci per MTU after 5 year decay	1.13×10^4	2.50×10^4	2.63×10^4	The value for the LWR is for a 90 day decay time.
Watts per MTU after 5 year decay	2.71×10^4	6.36×10^3	3.91×10^3	The value for the LWR is for a 90 day decay time.
No. of spent fuel shipments by truck	60	38 shipments (520 elements per module $\times$ 4 modules per 1.32 years, 42 elements per truck)	16 shipments (12 shipments for 1000 Mwe)	0.5 MT of irradiated fuel per cask
Heat (per irradiated fuel truck cask in transit) (kW)	10	1.02 (6.356 kW/MTU x 0.16044 MTU/shipment)	1.9 (3.9 kw/MTU $\times$ 0.495 MTU/shipment)	
No. of spent fuel shipments by rail	10	0	0	Appendix B, Table 1 says 3.2 MT of irradiated fuel per cask, Appendix B, Table 3 says 3.5
Heat (per irradiated fuel rail cask in transit) (kW)	70	NA	NA	
No. of spent fuel shipments by barge	5	0	0	

Table 3.8-2 Gas-cooled Reactor Transportation Impact Evaluation

Reactor Technology	Reference LWR (Single unit) (1100 MWe)	GT-MHR (4 Modules) (2400 MWt total) (1140 MWe total)	PBMR (8 Modules) (3200 MWt total) (1320 MWe total)	Comments
Characteristic				
Radioactive Waste				
Radioactive waste transport mode	truck or rail	truck	truck	Shipment by truck or rail is a condition for use of Table S-4.
No. of radwaste shipments by truck	46	6 (1100 Ci/yr; 98 m^3/yr)	9 (800 drums)	Assumed 90% of the waste shipped at 1000 ft^3 per truck, 10% at 200 ft^3 per truck.
Weight per truck (lb.)	73,000	governed by state and federal regulations	governed by state and federal regulations	Current interstate gross vehicle limit is 80,000 lb. (23 CFR 658.17)
No. of radwaste shipments by rail	11	0	0	
Weight per cask per rail car tons	100	100	100	
Transport totals				
Traffic density, trucks per day	less than 1	less than 1	less than 1	
Rail density, cars per month	less than 3	0	0	

Yellow indicates a value larger than or different from the reference LWR.

Reference: 10 CFR 51.52, Table S-4 Environmental Impact of Transportation of Fuel and Waste.

Note: The results for the reactor technologies have not been adjusted for their larger electrical generation or increased capacity factor.

Table 3.8-3 Summary Table S-4: Environmental Impact of Transportation of Fuel and Waste to and from One Light-Water-Cooled Nuclear Power Reactor[a]

Normal Conditions of Transport			
Condition	**Value**		
Heat (per irradiated fuel cask in transit)	250,000 Btu/hr		
Weight (governed by Federal or State restrictions)	73,000 lb. Per truck; 100 tons per cask per rail car.		
Traffic density Truck Rail	 Less than 1 per day. Less than 3 per month.		
Exposed Population	**Estimated Number of Persons Exposed**	**Range of Doses to Exposed Individuals[b] (per reactor year)**	**Cumulative Dose to Exposed Population (per reactor year)[c]**
Transportation workers	200	0.01 to 300 millirem	4 man-rem
General public:			
Onlookers	1,100	0.003 to 1.3 millirem	3 man-rem
Along Route	600,000	0.0001 to 0.06 millirem	
Accidents in Transport			
Types of Effects	**Environmental Risk**		
Radiological effects Common (non-radiological) causes	Small[d] 1 fatal injury in 100 reactor years; 1 nonfatal injury in 10 reactor years; $475 property damage per reactor year.		

a. Data supporting this table are given in the Commission's "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants," WASH-1238, December 1972, and Supp. 1 NUREG-75/038 April 1975.

b. The Federal Radiation Council has recommended that the radiation doses from all sources of radiation other than natural background and medical exposures should be limited to 5,000 millirem per year for individuals as a result of occupational exposure and should be limited to 500 millirem per year for individuals in the general population. The dose to individuals due to average natural background radiation is about 130 millirem per year.

c. Man-rem is an expression for the summation of whole body doses to individuals in a group. Thus, if each member of a population group of 1,000 people were to receive a dose of 0.001 rem (1 millirem), or if 2 people were to receive a dose of 0.5 rem (500 millirem) each, the total man-rem dose in each case would be 1 man-rem.

d. Although the environmental risk of radiological effects stemming from transportation accidents is currently incapable of being numerically quantified, the risk remains small regardless of whether it is being applied to a single reactor or a multi-reactor site.

Chapter 4 Environmental Impacts of Construction

Chapter 4 presents the potential impacts of the construction of the new units. In accordance with 10 CFR 51, impacts are analyzed, and a single significance level of potential adverse impacts (i.e., small, moderate, or large) has been assigned to each analysis. This is noted in respective topic discussions. Mitigation of adverse impacts is also presented, where appropriate. Construction activities would take place within a clearly-defined and access-controlled area designated as the construction site. This chapter is divided into six subsections which address the following topics:

- Land use impacts
- Water-related impacts
- Ecological impacts
- Socioeconomic impacts
- Radiation exposure to construction workers
- Measures and controls to limit adverse impacts during construction

The environmental description, where referenced, includes the following definitions:

- NAPS site - the property within the NAPS site boundary, or fence line, including the EAB.
- ESP site - the property within the NAPS site intended for the construction and operation of new units.
- Vicinity - the area within a 6-mile radius of the ESP site.
- Region - the area within a 50-mile radius of the ESP site.

4.1 Land-Use Impacts

This section discusses the potential land use impacts associated with construction of the new units. Construction activities would not require any current, or planned, land uses to be changed or modified from the existing NAPS site or vicinity land uses, either temporarily or permanently. The land use areas considered include those that have the potential to be directly impacted by construction activities (e.g., the site, the vicinity, along transmission corridors, and offsite areas). Additionally, land use considerations include those historic properties identified in the NRHP, as well as those properties that have the potential to hold potential historically significant items such as artifacts and human remains. This section is divided into three subsections: 1) site and vicinity, 2) transmission corridors and offsite areas, and 3) historic properties.

4.1.1 **The Site and Vicinity**

This section describes the construction impacts on land use of the NAPS site and vicinity. The NAPS site is located in Louisa County, Virginia. The area identified as the NAPS site, which includes the EAB extending out 5000 feet from the reactors, creates an entire site area of

approximately 730 hectares (1803 acres). The ESP site is located entirely within the NAPS site. The ESP vicinity is defined as the area approximately within 6 miles of the existing units, making the entire vicinity area approximately 29,300 hectares (72,400 acres). The vicinity surrounding the ESP site contains parts of Louisa and Spotsylvania counties. Each county has different designations and definitions for land-use categories. Unless otherwise referenced, the information used in this section was taken from the Final Supplement 7 to the Generic Environmental Impact Statement (GEIS) Regarding License Renewal for the NAPS, Units 1 and 2 (Reference 1) as well as from contacts with applicable county-level agencies.

4.1.1.1 Louisa County Land Use

Louisa County lies on the southern shore of Lake Anna. During the 30 years since the existing units were constructed, Louisa County has experienced substantial growth in population but relatively little growth in industry. The predominant land use in the county remains forestry. Forestry activities are a major contributor to the county's economy through employment, the sale of timber and forest products, and the generation of forest-related support activities. Other land uses include: agricultural lands occupy 23.5 percent, developed land uses occupy 6 percent (i.e., residential development predominates with 5.5 percent of the county land area) and water resources about 3 percent. Residential land use has increased 3.7 percent since 1979.

Louisa County land-use changes have been generally consistent with changes in the region as a whole. The county's proximity to metropolitan areas (i.e., Richmond, Charlottesville, and Fredericksburg, Virginia), combined with regional population growth trending away from metropolitan areas toward less developed areas like Louisa County, are the predominant forces resulting in county land-use changes.

4.1.1.2 Spotsylvania County Land Use

Spotsylvania County lies on the northern shore of Lake Anna. Historically, agriculture and forestry have been important components of the county's economy. Currently, 11 percent of the total county land is in agriculture and 64 percent is in forest. Developed lands (e.g., residential, industrial, commercial, public lands) cover 25 percent of the county, with residential use representing 22 percent of the developed land.

4.1.1.3 Vicinity Land Use Areas

Land use maps of the NAPS site and the vicinity have been prepared by the County of Louisa, Department of Planning and Zoning, and the Spotsylvania Planning Department (Reference 2) (Reference 3). Within the vicinity of the ESP site, the predominant land use is forestry and agricultural, followed by residential. Table 4.1-1 identifies the land areas developed for major uses within the ESP site boundary and vicinity.

Table 4.1-1 Land Use within the ESP Site and Vicinity

Land Use	Area[a] (Hectares)
Forestry	15,000
Industrial	2,700
Agriculture	5,600
Residential	2,200
Recreational	3,200
Other	600
Total Area	29,300

a. Areas shown are approximated based on zoning maps provided by Louisa and Spotsylvania counties (Reference 2) (Reference 3).

4.1.1.4 NAPS Land Use

The entire NAPS site is zoned for industrial use by Louisa County. All construction activities for the new units, including ground-disturbing activities, would occur within the NAPS site boundary. The area that would be affected on a long-term basis as a result of permanent facilities is approximately 52 hectares. The additional areas that would be disturbed on a short-term basis (e.g., as a result of temporary facilities, lay down areas) is approximately 27.5 hectares. Table 4.1-2 lists the general construction zones and their expected areas within the NAPS site boundary.

Table 4.1-2 Construction Areas

Construction Zone	Area (Hectares)
Material Lay Down	10
Parking Lot	6
Temporary Offices and Warehouses	6
Spoil Stockpile and Overflow	4
Batch Plant	1.5
Total Area	27.5

A site redress plan has been developed (see Part 4: Chapter 1, Site Redress) that addresses the need to stabilize and/or restore lands disturbed by pre-construction activities. Locations that are permanently disturbed would be stabilized and contoured in accordance with design specifications to meet the surrounding areas. Re-vegetation of disturbed lands would be compliant with site maintenance and safety requirements. Methods used to stabilize and restore areas would be

compliant with applicable laws and regulations, permit requirements, good engineering and construction practices, and recognized environmental best management practices. Methods that may be used to restore and stabilize disturbed areas are as follows:

- Re-contour with heavy equipment
- Mulch, seed, and plant
- Re-vegetate
- Provide permanent stabilization (e.g., pavement, rock, and gravel)
- Install permanent and/or temporary storm water management and erosion and sediment controls

4.1.1.5 Highways, Railroads, and Rights-of-Way

Figure 4.1-1 illustrates the existing highways, railroads, and transmission rights-of-way that cross the NAPS site and vicinity. No new or modified (e.g., widened) highways or railroads are planned to support the new units. As described in Section 2.2.2 and Section 3.7, based on an initial evaluation, the existing transmission lines have sufficient capacity to carry the total output of the existing units and the new units. A system study (load flow) modeling these lines with the new units' power contribution would be performed, if and when Dominion decided to proceed with the development of new units at the ESP site to confirm this conclusion.

4.1.1.6 Other Land Uses Considered

4.1.1.6.1 Recreational Areas

Lake Anna extends along the northern border of the NAPS site. Recreational use of the North Anna Reservoir is controlled by VDCR and is open to the public. Construction of a new water intake system would generally be limited to activity along a small portion of the North Anna Reservoir shoreline. Any work conducted immediately adjacent to the lake would be performed in accordance with applicable federal, Virginia, and local laws and regulations, permits, and authorizations. Therefore, construction-related impacts would not affect the recreational uses of the lake. See Section 2.4.1 and Section 2.4.2 for potential ecological impacts and Section 4.4.1 for physical impacts associated with the new units.

Another recreational area within the vicinity of the ESP site is Lake Anna State Park. The park is across the lake from the ESP site and to the northeast in Spotsylvania County. No construction-related impacts would affect recreation at the park.

4.1.1.6.2 Water Courses and Wetlands

A few small wetland areas and two intermittent streams exist on the ESP site (refer to Section 2.4.1). Watercourses and wetlands would be avoided to the extent possible during any construction. Any work that has the potential to impact a wetland would be performed in

accordance with the applicable regulatory requirements and necessary mitigation strategy. Therefore, construction-related impacts would be small.

4.1.1.6.3 Floodplains

The floodplain along the Lake Anna shoreline has been determined using the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (Reference 4). Any flooding that might occur during construction of the new units would be limited to areas adjacent to the lake shoreline (i.e., below elevations of 255 feet above msl). Limited construction activity would occur within the lake floodplain for the construction and installation of a new water intake structure. Any construction work conducted within the floodplain would be performed in accordance with the applicable regulatory requirements. Therefore, no construction-related impacts are expected to affect current land uses within floodplains.

4.1.1.6.4 Forested Areas

Forested land does exist within the ESP site. Clearing and removal of trees within the ESP site would be required. The removal of the trees would not create land-use impacts on the existing (industrial) site or vicinity. Section 4.3.1 describes the removal of trees and ecological impacts resulting from such removal.

4.1.1.6.5 Agriculture

There are no agricultural lands within or adjacent to the ESP site. Therefore, no farmlands would be impacted by proposed construction activities.

4.1.1.7 Significant Cumulative or Other Impacts

Since construction activities would be limited to the ESP site, the new units would not impact federal, Virginia, regional, local, or Native American tribal land-use plans. Additionally, the new units would not significantly impact any future local or regional land-use plans (see Section 2.2.1 and Section 2.2.3). There are no known federally-sponsored actions that would have cumulatively significant impacts on construction activities, either at the ESP site or within the vicinity. Land or other similarly designated areas that may be considered for development (other than industrial) would be addressed through local county jurisdiction. All construction impacts on land use would be small and would not warrant mitigation.

4.1.2 Transmission Corridors and Offsite Areas

Based on an initial evaluation, the existing transmission lines have sufficient capacity to carry the total output of the existing units and the new units. A system study (load flow) modeling these lines with the new units' power contribution would be performed, if and when Dominion decided to proceed with the development of new units at the ESP site, to confirm this conclusion. Additional transmission system information is provided in Section 3.7.

No new routes of access corridors would be necessary to serve operation of the new units. No offsite land uses would be affected by operation of the new units.

4.1.3 Historic Properties and Cultural Resources

This section provides information on potential impacts from new unit construction activities on historic properties in the NAPS site and vicinity, along transmission corridors, and offsite areas.

Historic properties listed in the NRHP that exist within the vicinity of the ESP site are identified in Section 2.5.3. There are no known historic properties listed in the NRHP that exist within the NAPS site boundary or within the existing transmission corridors. No offsite areas would be impacted by construction activities associated with the new units.

Virginia Power has maintained communications with the Virginia Division of Historic Resources (VDHR) regarding the management of the NAPS site and the potential ground-disturbing activities in areas that have the potential for containing historic and/or archaeological artifacts.

Prior to any activities that would disturb existing ground conditions, Dominion would assess the need, in coordination with VDHR, to undertake subsurface investigations for the identification of potentially significant historic or cultural resources in the area(s) to be disturbed. The investigations would be conducted in accordance with professional archeological practices and recommendations as developed in coordination with VDHR.

Additionally, Dominion would implement the necessary administrative steps to make proper notifications in the event of any unanticipated discovery (including human remains). These steps would include stop-work, assessment, and notification protocol.

The primary controls to be used to minimize impacts in the event of an unanticipated discovery would include: ongoing coordination with VDHR with regards to the potential presence of historic and cultural resources within planned disturbed areas, adherence to Dominion administrative procedures regarding activities to be implemented in the event of an unanticipated discovery, and adherence to specific permit requirements through their integration into construction scheduling and work practices.

Section 4.1 References

1. Final Supplement 7 to the Generic Environmental Impact Statement (GEIS) Regarding License Renewal for the North Anna Power Station, Units 1 and 2, November 2002.

2. *Land Use Classifications for Louisa County, Virginia (Site and Vicinity),* Louisa County Department of Planning/Zoning, Louisa County (Virginia), 2002.

3. *Land Use Classifications for Spotsylvania County, Virginia (Site and Vicinity),* Spotsylvania County Planning Department, Spotsylvania County (Virginia), 2002.

4. *Flood Insurance Rate Map, Louisa County, VA and Incorporated Areas*, Federal Emergency Management Agency (FEMA), U.S. Department of Interior, November 1997.

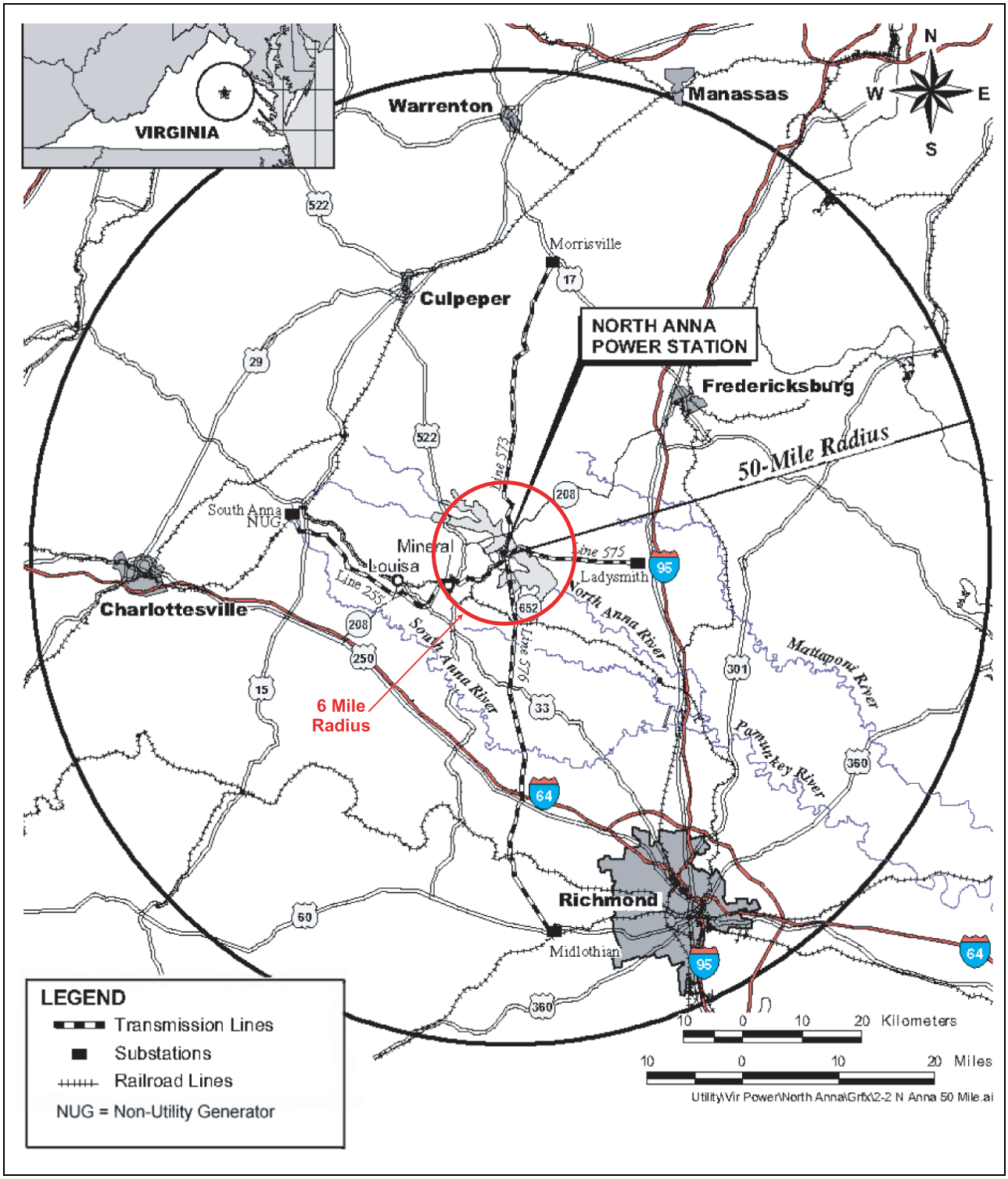


Figure 4.1-1 Vicinity Highways, Railroads, and Utility Rights-of-Way

Source: Reference 1, Figure 2-5

4.2 Water-Related Impacts

This section addresses hydrologic alterations and water-use impacts that would result from new unit construction activities at the ESP site. The discussion includes mitigation measures that would be incorporated to reduce adverse impacts from hydrologic alterations and water-use. Compliance with applicable regulatory requirements is also addressed.

4.2.1 Hydrologic Alterations

During construction of new units at the ESP site, hydrologic alterations would occur to two small ephemeral streams, the North Anna Reservoir, and groundwater. Mitigation measures would be implemented to reduce adverse impacts. This section addresses each of the alterations and the mitigation measures that would be used to reduce the adverse impacts.

4.2.1.1 Surface Water

Currently, the ESP site area slopes gently north toward the North Anna Reservoir. Runoff from the majority of the site reaches the North Anna Reservoir as sheet flow or shallow concentrated overland flow. In the cooling tower area that is west of the power block area, two small ephemeral streams discharge to the North Anna Reservoir. These streams are designated Stream A and Stream B on Figure 4.2-1. The drainage areas for Streams A and B are about 74 and 56 acres, respectively (Reference 1). Should dry cooling towers be constructed, portions of these ephemeral steams would be filled to level the site. Approximately 1500 feet of stream channel would require filling.

The ESP site drainage system design would incorporate measures to convey streamflows to Lake Anna. Construction activities would comply with the applicable regulatory requirements governing the filling of these ephemeral streams. All required permits would be obtained prior to the commencement of construction.

During construction of the new units, the potential would exist for sediment from the construction site to be eroded and conveyed to Lake Anna by storm water runoff until the ESP site drainage system is installed and construction is completed. Best management practices (BMPs) described in the Virginia Erosion and Sediment Control Handbook (Reference 2) would be used to control erosion and minimize the sediment load to Lake Anna in accordance with an approved erosion and sediment control plan. Best management practices may include sediment basins, sediment barriers, vegetative stabilization and filter strips, rip rap, rock filter berms, mulching, etc. Other than the two ephemeral streams, there are no other existing defined drainage channels or streams in the proposed area of construction.

Once construction is completed and the ESP site has been stabilized, the risk of increased sediment loading to the lake would be minimal. Given the volume of Lake Anna and the use of state-approved BMPs, the adverse impacts from sediment loading to Lake Anna would be small.

The small amount of sediment that could reach Lake Anna during construction would settle out in the vicinity of the ESP site.

The make-up water intake for the new Unit 3 would be located along the shoreline of the North Anna Reservoir west of the intakes for the existing units. A cofferdam installed in the early 1980s for the construction of the intake for the abandoned Units 3 and 4 exists at this location. Construction of the intake for the new Unit 3 would require dewatering. Because of the cofferdam, the intake location is not in contact with the North Anna Reservoir. Therefore, construction of the shoreline intake could proceed without any hydrologic impacts to the North Anna Reservoir. State-approved BMPs would be implemented prior to construction of the intake to reduce the impacts of erosion and sedimentation.

After construction of the intake, the cofferdam would be removed. Removal of the cofferdam would temporarily create the potential for increased sediment loading to the North Anna Reservoir in the vicinity of the new intake. The increased sediment loading would be mitigated by the installation of approved mitigation measures, such as silt curtains or similar methods, and BMPs. Federal, state, and local permits associated with the removal of material from the cofferdam area and/or lake would be obtained prior to construction of the new units. By implementing the mitigation measures, any adverse impacts to the reservoir would be small, and limited to the duration of the cofferdam removal. Removing the cofferdam would also permanently increase the North Anna Reservoir surface area and shoreline as the lake fills in the void behind the cofferdam and reaches the original shoreline.

4.2.1.2 **Groundwater**

Depending on the reactor type selected, excavations for foundations could reach depths of up to 140 feet below the final grade elevation. The final grade elevation is anticipated to be at or near the grade at the existing units at Elevation 271.0 ft. Therefore, the foundation excavations could reach approximately Elevation 130 ft msl. Based on measurements in observation wells at the site, groundwater is present at depths as shallow as about 5 feet below existing grade (Section 2.3.1.2). Dewatering would be required to a greater or lesser extent in excavations extending below the water table to permit construction of foundations. Dewatering for individual excavations would continue until construction is raised to a point above the water table and backfill is placed in the excavation.

The dewatering process would draw down the water table in the excavated area and the area surrounding the excavation. Subsurface investigations indicate that the subsurface materials underlying the ESP site consist of residual soils and metamorphic bedrock. Based on the experience gained from the construction of the existing units and abandoned Units 3 and 4, the drawdown created by dewatering would be localized to the area of the ESP site.

Impacts of the dewatering drawdown would be temporary and small.

Groundwater extracted from the excavations would be monitored and, if necessary, treated to remove sediment before discharging it to the North Anna Reservoir. The additional flow to the North Anna Reservoir resulting from dewatering activities would be temporary and small. Groundwater at the ESP site is generally of good quality, as presented in Section 2.3.3.2, and its discharge to the North Anna Reservoir would not have an adverse affect on the quality of the water in the lake.

4.2.2 **Water-Use Impacts**

This section identifies construction activities or construction-related alterations that could impact water use. Proposed practices to minimize adverse impacts are also presented.

Construction activities for the new units would be limited to the ESP site adjacent to Lake Anna.

In addition to the existing units, there are three known industrial water users (Bear Island Paper Co., St. Laurent Paper Products, and the Doswell Water Treatment Plant) that take water from the affected hydrologic system. The existing units use lake water for their circulating water systems. The general public uses the lake for recreational boating and fishing. Impacts of construction activities to the lake and the North Anna River would be temporary and limited to the area near the construction site. The only impact would be a small increase in sediment loading in the lake near the new units. Other than increased sediment loading near the site, no other water quality impacts to surface waters are anticipated.

In addition to the Erosion and Sediment Control Plan, an approved construction storm water pollution prevention plan (SWPPP) would be implemented for the duration of construction activities at the ESP site. The SWPPP would provide approved measures to prevent fuel, oil, and other chemicals associated with construction from contaminating the surface water or the groundwater. Applicable federal, state, and local permits would be obtained prior to the commencement of construction. Because any impacts would be limited to the area adjacent to the lake, no impacts to the recreational water use of Lake Anna are anticipated. Additionally, there would be no water quality impacts to the North Anna River upstream or downstream of the ESP site.

The private groundwater user nearest to the ESP site is about one mile south-southeast. Because the impacts of dewatering would be confined to the area around the ESP site, private groundwater uses would not be affected. There are also existing potable water wells at the NAPS site. Some of the existing potable water supply wells at the site could be affected by the resulting drawdown.

The combined production capacity of the water supply wells of the existing units is greater than the water use requirements (Section 2.3.2.2.2). Because not all of the water supply wells would be affected by construction dewatering, the excess capacity of the unaffected wells would be sufficient to supply the needs for the existing units. However, if additional water is needed, a temporary supply of potable water could be obtained from an offsite source.

4.2.3 Future Growth and Development Impacts

As shown in Figure 2.3-9, the watershed draining to Lake Anna upstream of the North Anna Dam, referred to as the "upstream watershed," lies within three counties: Louisa, Spotsylvania and Orange Counties. Downstream of the North Anna Dam, the North Anna River becomes part of the Pamunkey River Basin, which lies within the land of Hanover County, Caroline County, New Kent County and King William County. Further downstream, the Pamunkey River joins with the Mattaponi River to form the York River, which is tidal and its flow availability will not be affected by the inflow from the North Anna River and the Pamunkey River.

In the consideration of regional water use and water budget, future growth and development will impact a watershed in three ways:

1. Increase withdrawal from surface water and/or groundwater resources to meet the rising water demand from population, commercial and industrial growth.

2. Increase impervious area due to urbanization and land development will reduce groundwater recharge and affect the local and regional water budget.

3. Increase impervious area due to urbanization and land development will increase runoff volume and/or peak runoff intensity.

Anticipated changes in the upstream land-use and downstream water demand are described below.

4.2.3.1 Future Upstream Land-Use Changes

The upstream watershed lies in three counties in Virginia: Louisa, Spotsylvania and Orange. The watershed is predominantly rural with residential areas in the immediate surrounding of Lake Anna. Of the acreage in the Lake Anna watershed, 57 percent is forest, 38 percent is covered with cropland and pasture. Only 3 percent of the land is developed for residential use (Reference 3). The comprehensive plan for each county (Reference 4, Reference 5, and Reference 6) indicates that future growth and land use changes are expected in all three counties.

The following examines the projected growth and impact in each of the three upstream counties.

4.2.3.1.1 Louisa County

Louisa County has projected a population increase of about 36 percent over the 20-year period from 2000 to 2020. The Comprehensive Plan proposes the designation of growth centers to guide future growth and development to preserve and protect the rural character of the county as well as provide for efficient delivery of public services. Most of the growth will center around existing towns in the county. Of these towns, parts of Louisa, Mineral, and Gordonsville lie within the Lake Anna watershed. The town of Gordonsville is actually in Orange County, but portions of the growth area for this town are in Louisa County. Most of the area adjacent to Lake Anna has been designated as

low density residential with smaller portions designated as village residential (see Map 24 of Comprehensive Plan). (Reference 4)

The Plan recognizes that water resources in Louisa County are somewhat limited, and careful planning for allocation of scarce and costly water resources is required to support the projected growth. Historically, Louisa has been a county of individual well and septic systems with 89 percent of the county's residents relying on groundwater for their drinking water. Public water and sewer are provided for the towns of Louisa and Mineral and the adjoining areas. The Northeast Creek Reservoir just north of Route 33 between the towns of Louisa and Mineral, outside the Lake Anna watershed, serves the water needs of the two towns and would provide water for the future development in that area. Future growth and development in the areas not supported by the reservoir would increase groundwater withdrawal rate. However, impact to both the groundwater and surface water resources in the Lake Anna watershed is not expected to be extensive since future land use outside the towns is planned to be low density development.

According to Louisa County website (Reference 7), about 71 percent of County's land is in natural and planted forest land, 16 percent in crop, pasture and open land, 10 percent developed as urban, residential and industrial, and 3 percent in water bodies. With growth projected for these areas, the percentage of developed land is expected to increase slightly in future years leading to more impervious areas. To minimize the impacts of this growth on storm water runoff and downstream water resources, the Comprehensive Plan recommends implementation of policies to encourage the use of storm water management measures that promote infiltration and discourage the use of impervious surfaces. Since the majority of the Lake Anna watershed within Louisa County is not designated as growth centers and future development is expected to be primarily of the low-density residential type, the impact to groundwater recharge and surface runoff are expected to be small.

4.2.3.1.2 Spotsylvania County

Spotsylvania County's population has increased rapidly at an annual growth rate of 4.5 percent from 1990 to 2000. The rapid growth in the county has been primarily concentrated in the northern and central portions of the county in a concentric pattern around the City of Fredericksburg as well as along Route 3, Route 17, and Route 208, outside of the Lake Anna watershed. There has also been significant growth around Lake Anna, primarily recreational and retirement living. In the remainder of Spotsylvania County, a rural settlement pattern predominates even though growth is occurring. One of the goals of the 2002 Comprehensive Plan of Spotsylvania County (Reference 5) is to implement policies to limit the growth rate to 2 percent annually and achieve a 70/30 mix of residential to commercial/industrial development. The Plan recommends that the residential growth continue within the settlement areas of the county in proportion to existing development patterns. Most of the county's residential, commercial, office and industrial development has occurred and will continue in the "Primary Settlement District" near Fredericksburg. To discourage growth outside the designated areas, a Primary Development Boundary has been established to define the area

within which public utilities would be provided. Both the Primary Settlement District and the Primary Development Boundary are outside the Lake Anna watershed. In the Lake Anna District, there is a plan to allow for development of a village center and to allow public water and sewer services within the boundaries of the village center. The rest of the Lake Anna watershed in Spotsylvania County would remain largely low-density residential area and would rely on private groundwater wells. (Reference 5)

Water supply for the county mainly comes from surface water. The county's water supply system consists of the Ni Reservoir, the Motts Run Reservoir, an intake on the Rappahannock River, and the Hunting Run Side-Stream Storage Reservoir with an intake on the Rapidan River, all of which are outside the Lake Anna watershed.

Groundwater is not considered a viable public water source for Spotsylvannia County. Currently, approximately one-third of Spotsylvania County residents use small private wells that withdraw from the Piedmont aquifers, which are generally low yielding and highly variable in thickness and hydrologic characteristics. Because of this, groundwater is dedicated for residential use only, and withdrawals for commercial and industrial purposes are denied. (Reference 8)

Several alternatives have been considered to meet future water supply demands including expanding existing reservoirs and adding new impoundments. The Rappahannock River is considered a promising source of water for domestic and industrial consumption. It has been determined that Lake Anna, on the other hand, would be unavailable as a significant water resource for Spotsylvania County (Reference 8). Future growth in the County is therefore not expected to impact the water budget of the Lake Anna watershed.

The Plan recommends implementation of land use and best management practices to limit the increase of impervious areas created due to future growth to reduce their impact on groundwater recharge and runoff increases.

4.2.3.1.3 **Orange County**

Orange County is a rural community whose economic base is primarily agricultural. The future land-use plan is built around the goal of striving to protect the farm and forest land. In the next decade (2000-2010), the population growth is projected at 2.25 percent per year, which is somewhat above the normally accepted highest level for orderly growth rate of 2 percent. The Comprehensive Plan (Reference 6) advises that the County should limit growth to those areas that can support it: places where water supply, sewage disposal, transportation and other public facilities and services can be provided at low cost. Development is encouraged in the existing growth areas: the Towns of Orange, Gordonsville, Unionville, and Rhoadesville, the area around the Orange County Airport, and the Germanna Highway Corridor. Among these areas, parts of the towns of Orange, Gordonsville, Unionville, and Rhoadesville border on the Lake Anna watershed. According to the future land use map 2000-2020, a majority of the county lying within the Lake Anna watershed would remain agricultural. (Reference 6)

The county lies between the headwaters of York and Rappahannock Rivers, with its northern limit bounded by the Rapidan River and the southern limit bounded by the North Anna River. The primary sources of water for the near term are the Rapidan River and domestic wells. Impoundments have yet to be exploited as a source of water except on a few farms. In most parts of the county, an adequate supply of water is obtained from springs, streams, and wells. Farm ponds are used to supply water for livestock. A total of 300 to 370 farm ponds have been inventoried in the county. The North Anna River and its tributaries are small and supply only a small amount of water. As the county's population continues to grow, new development would be encouraged where it can be supplied from surface water sources. The flow of the Rapidan River is limited, but the water supply can be augmented through impoundments. The Comprehensive Plan recommends that the county should look well into the future when planning for impoundments due to the lengthy permitting processes. (Reference 6)

Under the current Riparian Rule, Orange County has little control over how much water is withdrawn upstream on the Rapidan River. Construction of impoundments in the county has been considered for several decades. It does not appear that North Anna River and its tributaries would be considered as future water source for the county due to their small flow. Groundwater offers several advantages compared to river withdrawal and surface reservoirs. The Plan recommends investigating groundwater conjunctively or independently, with surface water sources. The area of the county appearing most suited for groundwater resource is the northern tip of the Triassic Barboursville Basin. (Reference 6)

Over 58 percent of Orange County's 355 square miles land area is in commercial farms and forestland, areas that are critical to groundwater recharge. Residential, commercial, industrial and public uses occupy about 5 percent. The Plan also recognizes that the location of new development has an impact on groundwater. It is a goal of the Comprehensive Plan to protect the groundwater resources by implementing policies to identify and protect groundwater recharge areas as well as to minimize impact on surface runoff. (Reference 6)

4.2.3.2 Future Downstream Water Withdrawal Changes

The North Anna and Pamunkey River are both potential water sources for industrial and potable use in the downstream counties. These rivers pass through Hanover, Caroline, King William, and New Kent Counties in Virginia. Counties downstream along the York River will not be discussed further since the river is tidal and inflows from the Pamunkey River would not affect the availability of the York River water.

The comprehensive plan for each of these counties (Reference 9, Reference 10, Reference 11, and Reference 12) indicates that growth is anticipated and that additional water resources would be needed. The Hanover County Comprehensive Plan (Reference 9) describes an alternative that includes water withdrawal from the North Anna River. Additionally, the Comprehensive Plan for Caroline County (Reference 10) and New Kent County (Reference 11) list the Pamunkey River as a

possible source for future water needs. The King William County plan, while indicating future water needs, does not list the Pamunkey River as a possible source.

Use of the North Anna/Pamunkey River by the downstream counties for future water use would further reduce the overall water volume in the Pamunkey River in addition to the reduction from the addition of the new units at North Anna Power Station.

The following examines the projected growth and impact in each of the four downstream counties that will affect the flow in the North Anna River or Pamunkey River:

4.2.3.2.1 **Hanover County**

The Hanover County Comprehensive Plan adopted in June 2003 (Reference 9) states that the long-range population growth should be maintained at an average rate of 2.5 percent, and that suburban development should be concentrated in those sections of the county with an existing infrastructure so that suburban services can be most economically provided within the 2022 suburban boundary.

The need for future water supplies has been recognized since the 1970s. The findings of numerous studies agree that the groundwater resources of Hanover County are restricted by quantity and quality and are not viable for meeting the county's long-term water resource requirements.

Currently, the county provides water service from 11 wells and 2 surface water treatment plants. In addition, the county has water supply contracts to purchase water from Henrico County and from the City of Richmond. Of the two water treatment plants, Doswell Water Treatment Plant has a capacity of 4 million gallons per day (MGD) (6.1 cfs) and uses the North Anna River as its source. Through its contract with the City of Richmond, the county would have 20 MGD of water available to it through 2010. Currently, 10 MGD of water is available from Richmond. It is estimated that the 20 MGD capacity of this contract, when combined with other supply sources available to the county, would meet the county's average and peak day demands to sometime during 2020–2025 period, depending on growth within the Suburban Service Area (Reference 9).

Among the various water supply alternatives proposed, two are being retained for incorporation into the Comprehensive Plan, one of which would require a new river intake of 30 MGD (46 cfs) estimated capacity at the North Anna River. The minimum instantaneous release from the North Anna Dam under normal conditions is 25.8 MGD (40 cfs) when lake level is at or above 248 ft MSL in accordance with the Lake Level Contingency Plan operating rules (Reference 13). During drought condition, when the lake level reaches 248 ft MSL, the Lake Level Contingency Plan operating rules requires a minimum instantaneous release limit of 12.9 MGD (20 cfs). Although the Hanover County Comprehensive Plan does not specify the location of the North Anna River intake, it does not appear feasible to plan for a new intake at the North Anna River with a capacity of 30 MGD as the river may not be able to support this flow in addition to the existing Doswell WTP intake with a 4 MGD of capacity given the Lake Level Contingency Plan operating rules as defined

for the North Anna dam. The addition of Unit 3 at the North Anna site would have no impact on these operating rules and there would be no changes in the minimum instantaneous release values.

4.2.3.2.2 Caroline County

During the period of 2000 to 2010, the population of Caroline County is projected to grow by 14 percent to 36 percent, depending on the growth scenario. The Comprehensive Plan (Reference 10) recognizes the need to conduct a long range water supply planning for the county as a whole to sustain anticipated growth, inclusive of surface water, groundwater, flood hazards, and regular potable water quality. Currently, groundwater is the primary source of potable water in Caroline County. Only Lake Caroline is served by surface water withdrawal for its water requirements. The county anticipates that groundwater supplies are probably sufficient to meet the water needs in the near future. To avoid depletion of the groundwater supply, the Virginia Water Control Board regulates withdrawals from wells in the Groundwater Management Area. The county also has an abundant supply of surface water resources available. The Rappahannock, Mattaponi, and Pamunkey Rivers are considered as potential water supply sources for the county, however, no definite plan or study has yet been developed. (Reference 10)

4.2.3.2.3 New Kent County

The New Kent County Planning Department projects continued population growth of 33.7 percent during the period of 2000 to 2010, and another 30.6 percent from 2010 to 2020 (Reference 11). The county's residents have relied primarily on groundwater to provide their potable water needs. The continued withdrawal of groundwater has caused a lowering of the water levels throughout the aquifer system creating problems for existing shallow wells and raising concerns about the long-term viability of groundwater as a dependable, safe source of water. The county lies within two major river basins: the York in the northeast and the James in the south. Approximately one-third of the county lies in the Pamunkey River basin, which is part of the York basin. The county's rivers, streams, and water bodies provide opportunities for a variety of surface water users, but difficulties in federal and state permitting severely restrict the county's ability to develop its own surface water resources. Although permitting issues would need to be evaluated, considerations have been given to develop a future reservoir or reservoirs to be used for the collection of both surface runoff and as a storage site for pump-over from the upper, freshwater portion of Pamunkey River. Future water resource plans for New Kent County would be developed based on the preliminary state water resource plan which would include criteria for development of local and regional plans. No defined study or plan has yet been developed. (Reference 11)

4.2.3.2.4 King William County

The 2003 Comprehensive Plan Update of King William County (Reference 12) on population projections indicates that the county would continue to experience accelerated population growth

during the planning period. It is estimated that the county's population would grow from 2000 to 2010 by over 20 percent, twice the rate projected for Virginia as a whole. The vast majority of King William County residents are served by private wells, though the county does have three small water systems that have specific service areas. Within Virginia, King William ranks in the second highest category for groundwater withdrawal. A reservoir is being planned by damming Cohoke Creek near its confluence with the Pamunkey River. However, water would be taken from the Mattaponi River at Scotland Landing and pumped to the proposed Cohoke Reservoir. It would provide the county with an alternate surface water supply. There is no plan of using North Anna or Pamunkey Rivers or their tributaries as future water sources. (Reference 12)

4.2.3.3 Impacts of Future Development on Inflow and on Low Water Condition of the Lake

Most of the upstream counties do not rely on the North Anna River or its tributaries for their current or future water supply. Groundwater withdrawal would increase with the rising demand from the projected growth of the counties, but impact on the inflow to the lake is expected to be small due to the relatively low percentage of overall development and the low density of the projected development in the majority of the watershed.

Due to the increase in impervious area, increased growth and urbanization in the watershed would generally increase runoff volume and peak discharges in local streams and rivers, and reduce groundwater recharge. Through storm water management measures that promote stormwater retention and infiltration, these impacts can be reduced significantly. The growth and development projected for the upstream counties would tend to increase the runoff volume into Lake Anna. Increased flow into the lake could reduce the impacts of increased evaporation that would result from the operation of Unit 3. However, current development in the counties located in the watershed is small relative to the size of the watershed and even with the projected growth, the increase in the runoff to the lake is expected to be small.

During periods of low runoff, the lake could receive less inflow because of the higher groundwater withdrawal and the potentially lower groundwater recharge as a result of increased impervious area from future development. But the effect should be small due to the relatively small percentage of current and projected future development relative to the size of the watershed.

4.2.3.4 Impacts of Future Development on Downstream River Flow

The future growth in the upstream counties is not likely to have a significant impact on the watershed's surface and groundwater resources, and on the inflow to Lake Anna. Consequently, the impact of future development of the upstream counties would have small impact on the release from the North Anna Dam to the downstream river.

Three of the counties downstream of the dam are considering using the North Anna River or Pamunkey River as future water sources to support their projected growth. No firm estimate or definite water use plans have been developed to this date, but detailed state water resource studies

would be required to demonstrate the feasibility of using these downstream rivers as potential water sources for the downstream counties. The operation of Unit 3 would have no effect on the instantaneous minimum releases from Lake Anna and would not affect the minimum flows available for any future downstream development. The duration of the minimum flow release rates would increase with the addition of Unit 3 as presented in Section 5.2.2.2.

Section 4.2 References

1. 38077-A7-TF-024, *Lake Anna West, VA*, 7.5 Minute Series Topographic Map, U.S. Department of Interior, U.S. Geological Survey, Photorevised 1983.

2. *Virginia Erosion and Sediment Control Handbook,* 3rd Edition, Virginia Department of Conservation, Division of Soil and Water Conservation, 1992.

3. Lake Anna Special Plan Committee, “Lake Anna Special Area Plan,” March, 2000.

4. County of Louisa, Virginia, “Louisa County Comprehensive Plan,” September 4, 2001.

5. County of Spotsylvania, Virginia, “Comprehensive Plan,” 2002.

6. County of Orange, Virginia, “Comprehensive Plan,” adopted on September 14, 1999.

7. Website of County of Louisa, Virginia, “Louisa County At a Glance,” www.louisacounty.com/glance.htm, accessed on April 15, 2004

8. County of Spotsylvania, Virginia, “Water and Sewer Master Plan,” Revisions 2002.

9. County of Hanover, Virginia, “Hanover County Comprehensive Plan - Vision 2022,” adopted June 2003.

10. County of Caroline, Virginia, “2001 - 2004 Caroline County Comprehensive Plan,” adopted on February 27, 2001.

11. New Kent County, Virginia, “Vision 2020, New Kent County Comprehensive Plan,” adopted August 4, 2003.

12. King William County, Virginia, “2003 Comprehensive Plan Update,” adopted June 23, 2003

13. Commonwealth of Virginia, Department of Environmental Quality, Authorization to Discharge Under the Virginia Pollutant Discharge Elimination System and the Virginia Water Control Law, Virginia Electric & Power Company, North Anna Nuclear Power Station, Permit No. VA0052451.

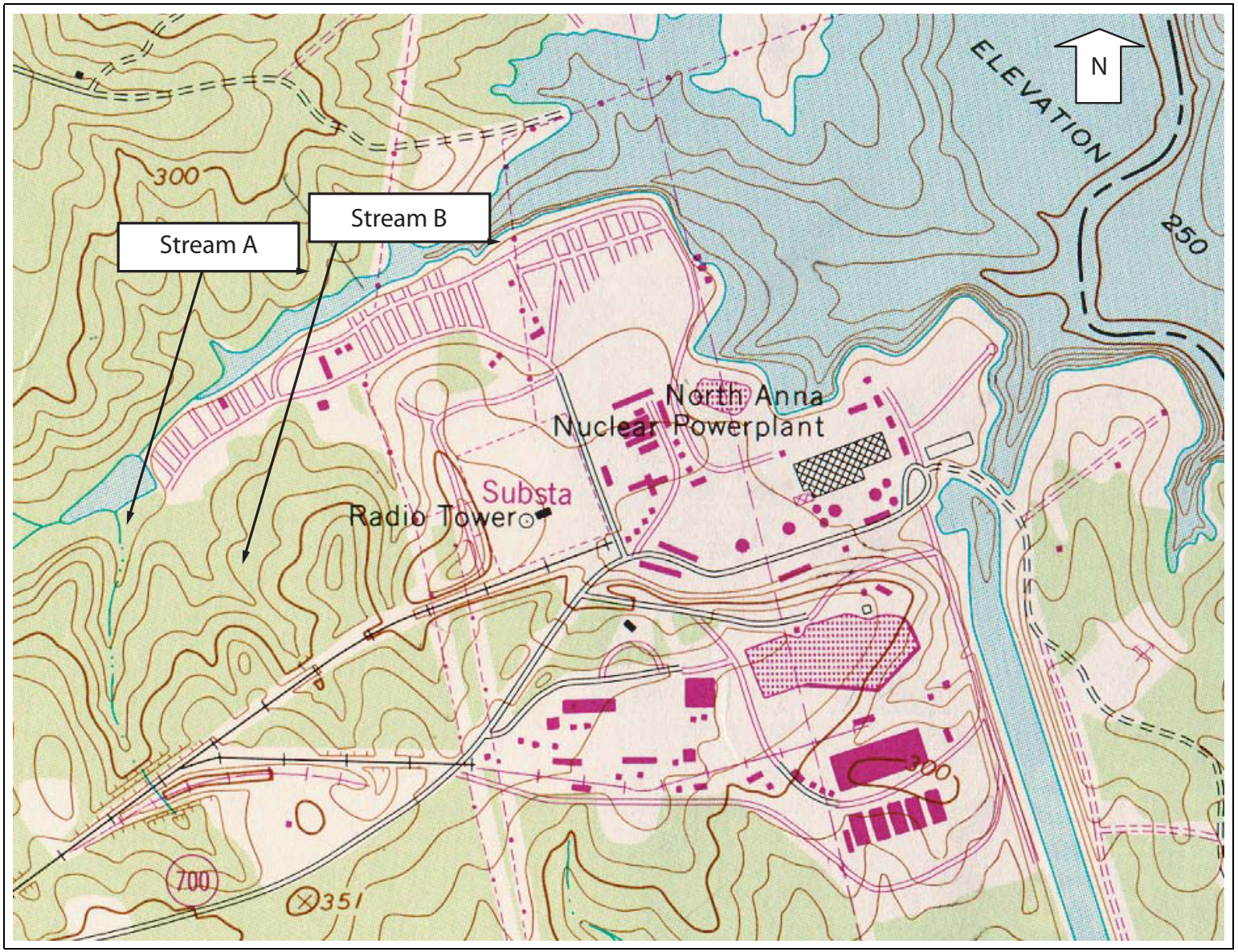


Figure 4.2-1 Ephemeral Steam Locations

4.3 Ecological Impacts

This section describes the potential impacts to the ecological resources that could result from construction activities. This section is divided into two subsections: 1) Terrestrial ecosystems, and 2) Aquatic ecosystems. Each subsection provides sufficient detail to assess the nature and magnitude of potential impacts on the identified resources.

4.3.1 Terrestrial Ecosystems

4.3.1.1 Transmission Corridors

Section 3.7 discusses assessment of the power transmission system. No impacts on transmission corridors, transmission towers, transmission-tower configurations, or transmission tower access roads are anticipated.

4.3.1.2 ESP Site

Section 2.4.1 discusses terrestrial ecological habitats at the ESP site. The approximate area of the ESP site is 200 acres. Natural habitats are absent from the industrial/developed portions (approximately 120 acres) of the ESP site (Figure 2.1-1). As a result, construction activity would have no impact on ecological resources within these portions of the ESP site.

Construction of the new units would result in the removal of essentially all forested habitat (approximately 80 acres) within the ESP site (Figure 2.1-1). The ESP site does not contain any old growth timber, unique or sensitive plants, or unique or sensitive plant communities. Therefore, construction activities would not noticeably reduce the local or regional diversity of plants or plant communities. There are no “important” species or habitats on the ESP site. No areas designated by the USFWS as “critical habitat” for endangered species exist at or near the ESP site, nor are threatened or endangered plants or animals known to exist there. Therefore, construction would have no impact on any threatened or endangered species, or other “important” species or habitats. Section 2.4.1 discusses the results of consultation with agencies regarding protected species.

A few small wetland areas and two intermittent streams exist on the ESP site (refer to Section 2.4.1). Watercourses and wetlands would be avoided to the extent possible during any construction. Any work that has the potential to impact a wetland would be executed in accordance with the applicable laws, regulations, permits, and authorizations. Therefore, construction-related impacts would be small.

Land clearing associated with construction would be conducted according to federal and state regulations, permit conditions, existing procedures, good construction practices, and established best management practices (e.g., directed drainage ditches, silt fencing). Fugitive dust would be minimized by watering the access roads and construction site as necessary. Thus, impacts from dust would be small and mitigation would be unwarranted. Emissions from heavy construction equipment would be minimized through scheduled equipment maintenance procedures.

Section 4.1.1 describes the physical impacts of construction at the site. To minimize construction-related impacts, Dominion would adhere to permit conditions that may restrict the timing of certain construction activities. As the site undergoes clearing and grading, disturbance and forested habitat loss would displace mobile animals such as birds and larger mammals. Species that can adapt to disturbed or developed areas (e.g., raccoon, opossum, mockingbird, Northern cardinal) may recolonize portions of the site where grasses and other vegetation are undisturbed or are replanted following construction activities. Species more dependent on forested habitat may be permanently displaced. Clearing and grading activities may directly result in the loss of some individuals, particularly the less mobile animals such as toads, lizards, snakes, moles, and mice.

Construction activities would involve movement of workers and construction equipment, and would be associated with noisy activities from construction equipment (e.g., earth-moving equipment, portable generators, pile drivers, pneumatic equipment, and hand tools). Although short-term noise levels from construction activities could be as high as approximately 110 dBA, (e.g., impulse noise during pile driving activities), these noise levels would not extend far beyond the boundaries of the ESP site. Table 4.3-1 illustrates the rapid attenuation of construction noise over relatively short distances.

Construction noises would range from approximately 60 to 80 dBA 120 meters (400 feet) from the construction site. These noise levels are below the 80 to 85 dBA threshold at which birds and small mammals are startled or frightened (Reference 1). Thus, noise from construction activities would not disturb wildlife beyond 120 meters from the construction site. After initial land clearing, wildlife such as mammals and songbirds that are associated with uplands would be impacted only by the construction noise in the area to the west of the ESP site. In addition, only a narrow lake inlet immediately north of the laydown area and a small wet area near the existing units comprise portions of Lake Anna that are within 120 meters of the ESP site. Furthermore, it is noted that construction would occur adjacent to the existing units, where wildlife have presumably become accustomed to typical existing operating facility noise levels of approximately 50 to 60 dBA at the security fence.

Avian collisions with man-made structures are a result of numerous factors related to species' characteristics such as flight behavior, age, habitat use, seasonal habits, and diurnal habitats; and to environmental characteristics such as weather, topography, land use, and orientation of the structures. Most authors on the subject of avian collisions with utility structures agree that collisions are not a biologically significant source of mortality for thriving populations of birds with good reproductive potential (Reference 2). The number of construction-related bird collisions with structures has not been quantitatively assessed; however, because no avian collisions with existing structures at the NAPS site have been noted, such collisions during the construction phase would also be negligible.

Table 4.3-1 Peak and Attenuated Noise (in dBA) Levels Expected from Operations of Construction Equipment[a]

Source	Nose Level (peak in dBA)	Distance from Source			
		50 feet[b]	100 feet	200 feet	400 feet
Heavy trucks	95	84-89	78-83	72-77	66-71
Dump trucks	108	88	82	76	70
Concrete mixer	105	85	79	73	67
Jackhammer	108	88	82	76	70
Scraper	93	80-89	74-82	68-77	60-71
Dozer	107	87-102	81-96	75-90	69-84
Generator	96	76	70	64	58
Crane	104	75-88	69-82	63-76	55-70
Loader	104	73-86	67-80	61-74	55-68
Grader	108	88-91	82-85	76-79	70-73
Dragline	105	85	79	73	67
File driver	105	95	89	83	77
Fork lift	100	95	89	83	77

a. Source: (Reference 1)

b. To convert feet to meters, multiply by 0.3048.

In summary, while the construction-related impacts of forested habitat loss to local wildlife populations cannot be quantitatively assessed because population data for species on and adjacent to the NAPS site are not available, relatively large tracts of forest to the north, west, and south of the NAPS site are available to displaced animals. Given the fact that approximately 80 acres of forested habitat at the site represents a small portion of the available undeveloped land in the vicinity, the construction-related mortality and temporary displacement of wildlife would be minimal, relative to wildlife populations in the region. In addition, construction activities would not reduce the local or regional diversity of plants or plant communities, and would not impact endangered or threatened species. Noise-related impacts and bird collisions during construction would be negligible.

4.3.2 Aquatic Ecosystems

Construction of an intake structure would be the primary source of construction impacts on the aquatic environment. Construction would involve major modifications to an existing intake structure. Section 3.4.2 provides a description of the proposed construction activities.

The new intake structure would be approximately 70 feet long and 70 feet wide, and would house the trash racks, traveling screens, and intake pumps (Figure 3.4-3 and Figure 3.4-4). No major modifications to the shoreline or short intake channel are expected, except that the existing cofferdam would be removed to allow reservoir water access to the new intake through the intake channel that is now behind the cofferdam.

Approximately 84,000 cubic yards of material would be moved from the cofferdam. All of the material would be properly disposed of in accordance with regulatory requirements and permit conditions.

In anticipation of construction, topsoil would be removed from the construction footprint, stored, rolled, and seeded as necessary, to minimize erosion. Some disturbed areas may be graveled, paved, or compacted to prevent erosion. These soil preparation procedures and others would minimize impacts to the aquatic environment from earth-moving activities. Following the cessation of construction activities, areas that are disturbed temporarily would be graded and contoured, covered with topsoil, and seeded with native vegetation.

Degraded water quality (e.g., increased turbidity and siltation) as a result of cofferdam removal and intake construction would pose the greatest potential for impacts on the North Anna Reservoir ecosystem in the immediate vicinity of the construction activities. Construction activities would result in the temporary loss of benthic habitat and the displacement or loss of benthic organisms, which provide food for other animals such as fish and shorebirds. After construction, the intake channel and cove would be re-colonized by benthic organisms available to predators. To minimize impacts to benthic populations in the reservoir, intake construction and protection activities would be conducted in accordance with state regulations and permit requirements. The benthic habitat lost would be temporary and a small percentage of the available benthic habitat. The loss of this habitat would not have a long-term impact on the aquatic ecosystem.

Some fishery habitat may be changed as well. Fish inhabiting the intake channel and the lake near the intake channel would likely leave the area temporarily during construction activities. After construction is completed, fish would re-populate those areas. Temporary habitat loss would be a small percentage of the total fishery habitat available in the North Anna Reservoir. To minimize impacts to fish populations in the reservoir, intake construction and protection activities would be conducted in accordance with state regulations and permit requirements. Construction impacts on the reservoir's fishery would be small and temporary.

Construction activities in the new intake channel could re-suspend heavy metals from the Contrary Creek area (see Section 2.4.2) that may be in the bottom sediments of the old North Anna River channel in the lake. Should heavy metals be present in the re-suspended sediments they could result in impacts to aquatic biota. Any environmental concerns would be addressed through the permitting process for the new units.

Increased turbidity also could result in a temporary reduction in primary productivity due to reduced light penetration and smothering of periphyton and aquatic macrophytes in the intake channel. After construction, primary productivity would be expected to increase to previous levels and macrophyte re-colonization would occur. A barrier (e.g., turbidity curtain, sheet piling) may be installed between the ESP site and the lake to reduce the potential for silt and soil entrainment through the existing units to the WHTF, where it could adversely affect primary production.

The potential for fuel or other fluid spills exists throughout the construction phase. To prevent contaminants from entering the aquatic system any spills would be handled according to an approved Spill Prevention Control and Countermeasure (SPCC) Plan.

As stated in Section 2.4.2, Virginia Power has monitored fish populations in Lake Anna and the North Anna River since the early 1970s, to evaluate the response of these populations to the operations of the existing units. No federal or state-listed protected fish species has been collected in any of these monitoring studies, nor has any listed species been observed in creel surveys or special studies conducted by Virginia Power biologists and affiliated researchers. Refer also to the discussion in Section 2.4.2 for other field and database searches regarding threatened, endangered, or state-listed aquatic species. Based on the absence of federal and state-listed protected fish species, construction impacts to threatened, endangered, or important aquatic species in Lake Anna, its tributary streams or the North Anna River would be unlikely.

Construction of cooling towers could be near an intermittent stream (Figure 2.1-1). See Section 4.3.1 for additional discussion. Construction could result in soil erosion and silt entry into the stream.

Refurbishment of an existing rail spur or construction of a new one also could occur near the stream. Intermittent streams in this area are not known to provide key fishery habitat for any important species. However, sedimentation and erosion control BMPs and/or effective stormwater management would be used to protect aquatic resources in the construction area.

In summary, construction activities would affect the North Anna Reservoir and its aquatic communities in the vicinity of the intake channel. These impacts would be small and temporary and would be mitigated through adherence to applicable laws, regulations, and permit conditions, and the use of good construction and BMPs to minimize impacts on aquatic resources. No critical habitats or protected aquatic species exist in the area, so none would be adversely affected by construction activities.

4.3.2.1 **Deleted**

Section 4.3 References

1. Golden, J., Ouellette, R. P., Saari, S, and Cheremisinoff, P. N.; *Environmental Impact Data Book* (Second Printing), Chapter 8, “Noise.” Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1980.

2. Brown, W. M., *Proceedings: Avian Interactions with Utility Structures International Workshop*, Miami, Florida, September 13-16, 1992, “Avian Collisions with Utility Structures: Biological Prospectives.” Prepared by EPRI, Palo Alto, California, December 1993.

4.4 Socioeconomic Impacts

This section discusses the socioeconomic impacts of construction activities, including those impacts that could result from the construction-related activities at the ESP site, and from the activities and demands of the workforce on the surrounding region. Evaluated socioeconomic impacts include potential effects on individual communities, the surrounding region, and minority and low-income populations.

This section has three subsections:

- Physical impacts,
- Social and economic impacts,
- Environmental justice impacts.

4.4.1 Physical Impacts

Construction activities can cause temporary and localized physical impacts such as noise, odor, vehicle exhaust, and dust. Vibration and shock impacts are not expected, due to the strict restriction or control of such activities onsite. This section addresses those potential impacts that may affect people, buildings, roads, and recreational facilities (e.g., Lake Anna). The physical impacts would be small and, therefore, are presented qualitatively.

The NAPS site is located in an area zoned for industrial use. The site is bounded by light industrial and commercial zones to the north and west, a recreational area (Lake Anna) to the east, and residential housing to the south. All construction activities would occur within the NAPS site boundary. Offsite areas that would support construction activities (e.g., borrow pits, quarries, disposal sites) would already be permitted and operational. Therefore, impacts on those facilities from constructing new units would be small incremental impacts associated with their normal operation. The use of public roadways and railways would be necessary to transport construction materials and equipment. The roadways could require some minor repairs or upgrading, such as patching and filling potholes, to allow safe equipment access. However, no extensive work is planned to the existing roads or railways and no new routes would be required.

4.4.1.1 Groups Vulnerable to Physical Impacts

4.4.1.1.1 People

The area within 10 miles of the ESP site is estimated to be populated by approximately 15,500 people (See Section 2.5). This area is predominately rural and characterized by farmland and wooded tracts (Reference 1). No significant industrial or commercial facilities exist or are planned for this area. Population distribution details are given in Section 2.5.1.1.

People who could be vulnerable to noise, fugitive dust, and gaseous emissions resulting from construction activities are listed below in order of most vulnerable to least vulnerable:

- Construction workers and personnel working onsite
- People working or living immediately adjacent to the site
- Transient populations (i.e., temporary employees, recreational visitors, tourists)

Construction workers would have adequate training and personal protective equipment to minimize the risk of potentially harmful exposures. Services would be provided for emergency first-aid care, and regular health and safety monitoring would be conducted during construction.

People working onsite or living near the ESP site would not experience any physical impacts greater than those that would be considered an annoyance or nuisance. In the event that atypical or noisy construction activities would be necessary (e.g., pile driving), public announcements and/or notifications would be provided. These activities would be performed in compliance with local, state, and federal regulations, and site-specific permit conditions.

Fugitive dust and odors could be generated as a result of normal construction activities. Mitigation measures (e.g., paving disturbed areas, water suppression, reduced material handling) would be in place to prevent or reduce such occurrences Additional mitigation control measures would address any nuisance issues on a case-by-case basis.

Noise and exhaust emissions from construction equipment would have no discernible impact on the local noise level and air quality. All equipment would be operated in accordance with local, state, and federal emission requirements (see Section 4.4.1.2).

Reasonable efforts would be made to ensure that transient populations are aware of the potential impacts of construction activities. Signs would be posted at or near construction site entrances and exits to make the public aware of potentially high construction traffic areas.

4.4.1.1.2 **Buildings**

Construction activities would not impact any offsite buildings. In the event that pile driving would be necessary, the building(s) most vulnerable to shock and vibration would be those within the NAPS site boundary. Onsite buildings have been constructed to safely withstand any possible impacts, including shock and vibration, from construction activities associated with the proposed activity. (No historically significant buildings (see Section 2.5.3) exist near the ESP site.

4.4.1.1.3 **Roads**

The transportation network in Louisa County and at the ESP site already a well-developed system, would not be significantly impacted as a result of construction activities. Material transportation routes (haul routes) would be selected based on equipment accessibility, existing traffic patterns, and noise restrictions, logistics, distance, costs, and safety. Methods to mitigate potential impacts include: 1) avoiding routes that could adversely affect sensitive areas (e.g., housing, hospitals,

schools, retirement communities, businesses) to the extent possible and 2) restricting activities during daylight hours and delivery times.

No new public roads would be required as a result of construction activities. No public roads would be altered (e.g., widened) as a result of construction activities. Some minor road repairs and improvements (e.g., patching cracks and potholes, adding turn lanes, re-enforcing soft shoulders) would be necessary to enable equipment accessibility and reduce safety risks.

Construction site exits onto public roads would be marked clearly with signs and maintained such that they are clear of debris and markings are visible. Any damage to public roads, markings, or signs caused by construction activities would be repaired to pre-existing conditions or better.

A new access road on the NAPS site would support construction activities. The new road would be private and fully contained within the existing NAPS site boundary. The road would be maintained by Virginia Power personnel as needed.

4.4.1.1.4 **Recreational Facilities**

Lake Anna was created in 1971 on the main stem of the North Anna River to supply cooling water for the power station. The lake has public access, and its resource use includes recreational boating, fishing, camping and picnicking. People live along its shoreline. Virginia Power and ODEC own, and Virginia Power controls, the land that forms Lake Anna, both above and beneath water surfaces, up to the expected high-water marks (i.e., Elevation 255 ft msl). The aquatic resources of Lake Anna are managed cooperatively by Virginia Power and state natural resource agencies, including the VDGIF and the VDCR.

Construction activities would include limited in-water activity to construct the intake structure, remove a portion of the existing cofferdam and local dredging. The work would be executed in accordance with applicable regulations such as the CWA and permit conditions such as CWA Section 404 administered by the U.S. Army Corps of Engineers. Fugitive dust would be generated during site construction activities; however, quantities would not have any discernible impact on Lake Anna or adjacent environs. Water turbidity could be temporarily degraded in the immediate construction area during cofferdam removal and localized dredging. Measures to control turbidity include permit conditions, use of best management practices and, if necessary, installing a barrier (e.g. silt curtain) to prevent the migration of a turbid water plume into the lake.

4.4.1.2 **Applicable Standards**

Applicable local, state, and federal standards for noise, fugitive dust, and equipment emissions are described in these subsections.

4.4.1.2.1 Noise

The Commonwealth of Virginia has no state regulations nor guidelines for noise limits and provides no model noise ordinance for municipalities. Additionally, the state does not provide guidelines or limitations for impulse noise like a sharp sound pressure peak occurring in a short interval of time.

Within the County of Louisa, “it shall be unlawful to create any unreasonable loud, disturbing and unnecessary noise in the county, and noise of such character, intensity and duration as to be detrimental to the life or health of any person or to unreasonably disturb or annoy the quiet comfort or repose of any person is hereby prohibited. This prohibition shall not be construed to apply to any livestock, domesticated animal, fowl, or agricultural operation.” (Reference 2) No guidelines or ordinances have been identified that are written specifically to address construction activities.

Within the County of Spotsylvania, “The creation of any unreasonably loud, disturbing, and unnecessary noise in the county is prohibited. Noise of such character, intensity, and duration as to be detrimental to the life or health of any individual is prohibited.” (Reference 3) Construction activities are exempt from this ordinance between the hours of 6:00 a.m. and 10:00 p.m.

The Noise Control Act of 1972 gives authority to the EPA to determine the limits of noise and to set noise emission standards for major sources of noise in the environment, including construction equipment. Federal regulations exist for noise emitted from construction (40 CFR 204, Noise Emission Standards for Construction Equipment).

4.4.1.2.2 Fugitive Dust

Virginia Administrative Code (VAC) 9 VAC 5-50 establishes standards for visible emissions and fugitive/dust emissions. 9 VAC 5-50 defines “fugitive dust” as particulate matter composed of soil or other materials of natural origin, or both. Fugitive dust may include emissions from haul roads, wind erosion of exposed surfaces and storage piles, and other activities in which the material (dust) is removed, stored, transported, or redistributed.

4.4.1.2.3 Gaseous Pollutants

Virginia Administrative Code 9 VAC 5-40-5680 establishes emission standards for mobile sources.

4.4.1.3 Predicted Noise Levels

The impacts from noise would be small; therefore, no modeling was undertaken for of this analysis. As presented previously, Louisa and the surrounding counties are predominantly farmland and wooded tracts. Areas that are subject to farming are prone to seasonal noise-related events such as planting and harvesting. Wooded areas provide natural noise abatement control to reduce noise propagation. Table 4.4-1 identifies expected noise levels in the immediate vicinity (less than 10 feet) of operating pieces of construction equipment. (Reference 4)

Table 4.4-1 Equipment and Approximate Noise Level

Equipment	Noise Level (dB)
Pneumatic chip hammer	103-113
Earth Tamper	90-96
Jackhammer	102-111
Crane	90-96
Concrete joint cutter	99-102
Hammer	87-95
Skilsaw	88-102
Gradeall	87-94
Front-end loader	86-94
Bulldozer	93-96
Backhoe	84-93

Noise level attenuates with distance. The noise from a gradeall earth mover can be as high as 94 decibels (dB) from 10 feet away, and from 70 feet away can be 82 dB. A 10-dB decrease is perceived as roughly halving loudness; a 10-dB increase doubles the loudness. A crane lifting a load can make 96 dB of noise; at rest, it may make less than 80 dB. Moderate auto traffic at a distance of 100 feet (30 m) rates about 50 dB. To a driver with a car window open or a pedestrian on the sidewalk, the same traffic rates about 70 dB; that is, it sounds four times louder. The level of normal conversation is about 50 to 60 dB.

The EAB extends 5000 feet from the center line of the abandoned Unit 3 containment building. No major roads, public buildings or residences are located within the exclusion area. Distances from the construction site to the EAB are shown in Table 4.4-2 (See Section 4.1.1.4). As presented in Section 4.1.1, the land adjacent to the ESP site along the western boundary is zoned light industrial.

Table 4.4-2 Distances from Construction Site to EAB

Direction	Approximate Distance (feet)
North	2650
South	4450
East	4680
West	70

In addition to the local ordinances and permitted noise restrictions that would be adhered to by construction activities to reduce potential noise impacts, the following controls could also be incorporated into activity planning:

- Regular inspection and maintenance of equipment to include noise aspects
- Restrict noise-related activities (e.g., pile driving) to daylight hours
- Restrict delivery times

4.4.1.4 Predicted Air Pollutant Levels

Physical impacts from air pollutants such as engine exhaust and fugitive dust would be small; therefore, no modeling was undertaken for this analysis. Temporary and minor impacts to local ambient air quality occur as a result of normal construction activities. Fugitive dust and fine particulate matter emissions – including those less than 10 microns (PM10) in size, are generated during earth-moving and material-handling activities. Construction equipment and offsite vehicles used for hauling debris, equipment, and supplies also produce emissions during construction. The pollutants of primary concern include PM10 fugitive dust, reactive organic gases, oxides of nitrogen, carbon monoxide, and, to a lesser extent, sulfur dioxides. Because the variables affecting construction, emissions (e.g. type of construction vehicles, timing and phasing of construction activities, and haul routes) cannot be determined until the project is ready for construction; no reasonable estimate of construction emissions can be undertaken. However, construction would be conducted in accordance with all federal, state and local regulations that govern construction activities and emissions from construction vehicles.

Specific mitigation measures to control fugitive dust would be identified in a dust control plan, or similar document, prepared prior to project construction. These mitigation measures would include any or all of the following:

- Stabilize construction roads and spoil piles
- Limit speeds on unpaved construction roads
- Perform housekeeping (e.g., remove dirt spilled onto paved roads daily)
- Cover haul trucks when loaded or unloaded
- Minimize material handling (e.g., drop heights, double-handling)
- Cease grading and excavation activities during high wind speeds and during extreme air pollution episodes
- Phase grading to minimize the area of disturbed soils
- Phase construction to minimize daily emissions
- Perform proper maintenance of construction vehicles to maximize efficiency and minimize emissions

- Re-vegetate road medians and slopes in accordance with the site redress plan (see, Part 4: Chapter 1, Site Redress)

While emissions from construction activities and equipment would be unavoidable, a mitigation plan would minimize impacts to local ambient air quality and the nuisance impacts to the public in proximity to the project. Other mitigation measures would include temporary storm water management and erosion and sediment control strategies.

4.4.2 Social and Economic Impacts

The social and economic impacts on the immediate vicinity and surrounding region during construction of new units at the ESP site are evaluated in this section. This evaluation assesses both the potential impacts that could result from the construction-related activities at the ESP site and the activities and demands of the workforce on the surrounding region.

Construction of a new unit is estimated to occur over a 5-year period. Construction of the second unit may lag the first by a year or more. Because a specific reactor design has not been selected, the peak workforce estimate does not include consideration of reactor-specific approaches which could reduce the types and lengths of activities onsite.

The peak workforce is estimated to be about 5,000 people, which would be maintained for a large part of the construction period(s). If such a large workforce were introduced into the region, it could affect traffic, taxes, housing, and public services. Most of the workforce would probably come from the 50-mile region. This peak workforce estimate and the assumption that most of the workforce would be local are consistent with experience during prior construction projects at NAPS.

The magnitude of impacts is dependent on two considerations:

- The percentage of the workforce that would come from the region and, therefore, be expected to commute
- Where those who have to relocate to the region would reside

4.4.2.1 Economic Impacts

The impacts of construction of the new units on the local and regional economy of the ESP region are based on the region's current and projected economy and population. The projected economy is based on information developed internally by Virginia Power and from Comprehensive Land Use plans for applicable localities. Because the ESP would be in effect for 20 years after approval, construction could start anytime within that 20-year timeframe, once a COL authorizing construction has been issued. The issuance of an ESP allows, under certain regulatory conditions, the start of limited early construction activities (see Part 4). Therefore, the positive economic benefits of construction could begin some time before the start of major construction.

4.4.2.1.1 Potential Non-Income Taxes Related to Construction of New Units

The actual monetary value of the revenues generated because of the construction of the new units cannot be estimated with precision because the type of reactor has not been selected. This decision would affect the size of the work force and the percentage of the work force that could come from outside the region. Therefore, at this time it is not possible to estimate the value of taxes that could be paid to the regional governments nor expenditures that the regional governments would have to incur to accommodate the workforce.

a. **Sales and Use Taxes**

   The Commonwealth of Virginia and counties surrounding the ESP site would experience an increase in the amount of sales and use taxes collected from construction materials and supplies purchased for the project. Additional sales and use taxes would be generated by retail expenditures (restaurants, hotels, merchant sales) of construction workers. It is estimated that about half of the day-to-day expenditures during construction would occur in the region.

   The current combined sales and use tax rate for Louisa County is 4.5 percent; 3.5 percent would be paid to the Commonwealth of Virginia and 1 percent to the locality, Louisa County.

b. **Property Taxes**

   Louisa County would benefit from additional property tax revenue from two sources. The first source would be tangible personal property taxes paid by contractors during construction of the additional units. The tax would be based on the value of property owned by the contractors that acquire taxable status in Louisa County during the construction period. Currently, the county calculates the assessed value of the property at ten percent of the original cost, which is then taxed at the rate of $1.90 per $100 of value.

   The second source would be the property taxes levied for the incremental increase in value to the entire site from the additional units. During the construction phase, tax would be levied only on the value of the tangible personal property to become part of the additional units. Currently, the Virginia State Corporation Commission is responsible for the valuation of the property both during construction and following completion of the additional units. The current tax rate for this property is $0.67 per $100 of value.

4.4.2.1.2 Housing

If the entire construction workforce came from within a 50-mile radius of the ESP site, there would be no impact on housing. However, based on prior experience on projects of similar size, up to 20 percent of the workforce could come from beyond the 50-mile region. Most, if not all, of these workers from outside the region would be expected to relocate to the region at least during the workweek.

If up to 1000 workers were to come from outside the region, there would be a demand for up to that many housing units, mainly apartments, although, some single-family residences might be required if construction workers decide to relocate with their families. A review of the vacant housing available in the year 2000, shows that there were sufficient numbers of rentals (5,884 units) and permanent housing units (2,656 units) in the region to accommodate the expected workforce. Most of these were in the City of Richmond and Henrico County. Very few rental properties were available in Louisa, Hanover, Spotsylvania, or Orange Counties.

There is also the possibility that some relocated construction workers would bring trailers for the duration of their employment. For purposes of this ER, it is assumed that the number of such workers who bring trailers would be low. If this is not the case, an influx of construction workers into the local area could compete with recreational users for spaces at existing trailer/RV parks.

Alternatively, if the incoming construction force were to generate demand for additional private trailer parks, this demand could lead to an increase in spaces being made available. However, there are no public water or sewer systems in the vicinity of the ESP site except for those of the incorporated towns. It is not likely that new trailer/RV parks would be constructed within the boundaries of these towns. New trailer/RV parks would most likely be located in Henrico County, nearer to the City of Richmond where public water and sewer systems are in place and where expansion of infrastructure is currently planned.

Neither Henrico County nor the City of Richmond would benefit directly from property taxes paid by Dominion. However, both should benefit from increased sales taxes and rents for housing units.

It is assumed that the number of housing units for rent or sale in the nearby counties would remain at or near the Year 2000 levels in future years. Under this assumption, an in-migration of up to 1000 construction workers should be able to find housing without creating issues for the region regardless of when construction is initiated.

4.4.2.2 **Social Impacts**

Under the assumption that the construction workforce would come from the region, the main social impact of the proposed construction would be most related to the transportation network in the vicinity of the ESP site. It is assumed that workers who relocate would settle in the City of Richmond, or, Henrico County. The relative social impact of such an in-migration to these two areas should be small, given the population of the areas. Impacts on the fire, police, school systems, recreational facilities, medical facilities, and the sewer and water systems would be small.

The installation of the new units would not displace families, because housing is not allowed on the NAPS site and construction activities would be entirely on site.

Most of the larger pieces of equipment or structures would probably be brought in to the site by rail. However, the transport of such large pieces of equipment would be an infrequent occurrence.

4.4.2.2.1 Transportation-Related Impacts

Impacts of construction of new units at the ESP site could be associated with transportation-related activities offsite, such as the delivery of major pieces of equipment.

Construction-related impacts on the transportation network in the region would arise from an additional 5,000 people commuting to the NAPS site.

a. **Federal Highways**

Construction workers traveling south on Interstate 95 (I-95) (Figure 2.1-3) from Spotsylvania or further north would take the Virginia Route 606 west exit, or the Spotsylvania Turnpike exit to the Route 208 Bypass (under construction in 2003), and then south on Route 208 (Courthouse Road) to reach the site.

The Route 606 - Interstate 95 interchange is congested, generally at a level of service D (LOS D) or better (Table 4.4-3). A VDOT I-95 interchange study has determined that this interchange would become more congested with time (Reference 5). The addition of commuting construction workers would increase this congestion.

The VDOT I-95 study includes an analysis of traffic patterns for the Route 606 – I-95 interchanges out to the Year 2025. The study identifies an existing congestion issue and relates it to the ongoing rapid growth in western Spotsylvania County. Upgrading the access to I-95 has been delayed due to funding. This study also identifies the need for widening the western section of Route 606 to alleviate the existing congestion that affects traffic trying to access I-95 north and south.

I-95 north from Richmond would not be adversely impacted by commuting construction workers coming from the Greater Richmond area, because the more likely commuting routes would be Virginia Route 33 through Hanover County or I-64 through northwest Henrico County and along the southern boundary of Louisa County.

I-64 west from Richmond has a LOS no worse than B. Commuting construction workers from the Greater Richmond Area to Virginia Route 208 or Route 522 would not cause congestion problems.

b. **Virginia Roadway System**

The Louisa-Orange-Spotsylvania Advisory's 3-county planning group, the Lake Anna Advisory Committee (LAAC), has recommended that planners in each of the three counties upgrade their local roads around Lake Anna. This recommended upgrade would provide a circumferential roadway system around the lake with adequate lanes for towed boats and bicycles (Reference 6). Such upgrades would alleviate congestion on local roads due to the influx of construction workers.

The Louisa County draft Comprehensive Plan of 2001 recognizes the need to improve roadways around Lake Anna. The draft Comprehensive Plan of 2001 recommends

improvement of the roads within Louisa County, but provides no information on funding or the timing of the road improvements. (Reference 7)

Spotsylvania County plans to widen Route 606 west of I-95 to four lanes and has included this project in their Comprehensive Plan (Reference 8). This project should be completed in the near-term and should reduce additional impacts of large number of construction workers commuting on Route 606 to the site. Additionally, the Route 208 Bypass around the historic Courthouse District is currently under construction and should be completed in the near-term. When completed, the 208 Bypass would connect the Spotsylvania Parkway (Route 208 north), with Courthouse Road (Route 208) south of its intersection with Route 606. Route 208 south is a minor road with a bridge over the North Anna Reservoir west of the ESP site. Spotsylvania County plans to upgrade the 2-lane roads around Lake Anna by widening them to include shoulders to accommodate larger vehicles such as motor homes. This upgrade is in line with the 3-county planning group's plans for the Lake Anna area.

In Hanover County, U.S. Route 33 links Richmond with Louisa and points north and west. This 2-lane road in the northern part of the County is subject to congestion and needs to be widened according to the Hanover Comprehensive Plan of 1998. No time frame has been set because the source of funding has not been identified. If the widening does not occur before the start of construction of the new units, U.S. Route 33 congestion could increase from construction workers commuting from Richmond. The magnitude of the impact would depend to some extent on the shift schedule for the construction of the new units relative to the normal commuting schedule of other road users. Traffic congestion would be considered in developing a traffic management plan as a mitigation measures. (Reference 9)

c. **Local Roads**

According to the North Anna License Renewal Environmental Report, the major commuting routes in the immediate vicinity of the ESP site are local roads Routes 700, 652, 208, 522, and 618 (Figure 2.1-2). These roads carry a LOS designation of B. (Reference 4)

Table 4.4-3 Level-of-Service Designation Characteristics

Level of Service	Conditions
A	Free flow of the traffic stream; users are unaffected by the presence of others.
B	Stable flow in which the freedom to select speed is unaffected, but the freedom to maneuver is slightly diminished.
C	Stable flow that marks the beginning of the range of flow in which the operation of individual users is significantly affected by interactions with the traffic stream.

Table 4.4-3 Level-of-Service Designation Characteristics

Level of Service	Conditions
D	High-density stable flow, in which the freedom to maneuver are severely restricted; small increases in traffic will generally cause operational problems.
E	Operating conditions at or near capacity level, causing low but uniform speeds and extremely difficult maneuvering that is accomplished by forcing another vehicle to give way; small increases in flow or minor perturbation will cause breakdowns.
F	Defines forced or breakdown flow that occurs whenever the amount of traffic approaching a point exceeds the amount that can traverse the point. This situation causes the formation of queues characterized by stop-and-go waves and extreme instability.

Source: Environmental Report (Reference 4), Appendix E of the North Anna Power Station Unit 1 and 2 Applications for Renewed Operating Licenses, Page 2-39, May 2001.

d. **Route 700 East of Route 652**

Route 700 is the only road that leads directly into the ESP site, and the traffic east of the intersection with Route 652 is normally related only to the power station site. This would be true during the construction of the new units.

Construction worker access to the ESP site would be via a construction access road that would be built on the north side of Route 700 on Virginia Power property and would intersect with Route 700 several hundred yards west of the access road to the existing units. Therefore, the potential exists for congestion to develop on site access roads and on Route 700, if the construction shifts and the plant shifts are not synchronized. To avoid congestion, a traffic management plan would be developed in cooperation with VDOT as a construction mitigation measure.

Beginning at the intersection of Route 700 with Route 652, the increased construction traffic would start to disperse onto local roads. However, congestion could develop at the 700/652 intersection during construction shift changes even if the shift changes for construction and operation are synchronized.

Currently, about 850 employees commute to NAPS. These workers are spread over three 8-hour shifts. Planned outages of 4 to 6 weeks occur at each existing unit on a staggered basis. The workforce onsite doubles during these outages (Reference 4). Outage workers are also spread over three 8-hour shifts. Route 700 has historically been able to handle the peak demands of around 2,000 workers without creating a major traffic problem on the local road system. Assuming an average of 1.8 workers per vehicle, this represents about 1100 cars per day traveling this road into and out of the site.

The construction of the new units would add a maximum of approximately 5,000 workers over two 10-hour shifts. These workers would travel the section of Route 700 between Route 652 and the access road to the ESP site on a daily basis. Assuming the same average of 1.8 workers per vehicle, this would represent 2800 additional vehicles, for a total of about 3300 vehicles per day. This would be a major increase in Route 700 traffic. Implementation of a traffic management plan for construction would alleviate the traffic increase to some extent.

At least four outages at the existing units would occur during the 5-year period when the peak construction workforce of 5,000 workers would be onsite. This would create short-term periods when the total onsite workforce (for construction of the new units and work at the existing units) would be about 7,000. Of these, 5,000 would be working two 10-hour shifts and 2,000 would be spread over three 8-hour shifts. During outages, the number of vehicles could rise to 3900 per day unless the use of multi-person vans is strongly encouraged by both the construction and the outage workforces.

e. **Proposed Mitigation Measures**

Currently, Route 700 into the NAPS site has a LOS B. The objective of any traffic mitigation measures would be to maintain LOS on Route 700 at D or better.

To avoid congestion on Route 700 that could congest the Route 700-652 intersection and the construction access road-Route 700 intersection, a construction management traffic plan would be developed prior to the start of construction. This plan would include approaches to increase the number of workers per vehicle above the average of 1.8. The traffic management plan would include methods for enhancing the use of multi-person vans by the construction workforce. Typically, such a plan involves providing offsite parking areas from which workers can be bused to the site and ways to encourage the use of vanpools and carpools.

Concurrently, Dominion would implement measures that enhance the use of vanpools for use by the outage workforce. Additionally, schedules for shift changes for operating personnel, outage workers, and construction workforce would be coordinated to reduce the number of vehicles on the road at any one time. The need to hand-off work from the outgoing to the incoming shift workers may complicate this scheduling effort for the construction workforce and, possibly, for the outage workforce.

Currently, traffic control at the intersection of the Routes 700 and 652 consists of a blinking red light for traffic exiting the NAPS site. Upgrades to Route 700 may be necessary to reduce congestion during shift changes that could develop at the intersection of Routes 652 and 700 due to construction traffic. Upgrades may include construction of turning lanes, and, possibly traffic lights, including green arrows for left-turning vehicles. These options would be assessed after the type of reactor is selected and a better definition of the size of the required workforce can be determined.

4.4.2.2.2 Impacts on Lake Anna Recreational Area

Lake Anna is a recreational area that attracts visitors during the summer and early fall months, as well as year-round residents. Therefore, any construction impacts that would substantially reduce the number of visitors could have adverse socioeconomic impacts on the local area. Most impacts that would affect local residents would be related to traffic, and would be confined to discrete times of day when worker shifts were changing.

4.4.2.2.3 Conclusion

Analyses of potential impacts of construction activities on the surrounding vicinity and region, presented in Section 4.1, Section 4.2, Section 4.3, and Section 4.4.1, concluded that most impacts would be small. Impacts from traffic would be moderate and would be mitigated with a construction management traffic plan.

4.4.3 Environmental Justice Impacts

This section addresses the potential for disproportionately high and adverse human health or environmental impacts on minority and low-income populations that reside within an 80-km (50-mile) radius of the NAPS site during construction of the new units at the ESP site.

The potential for environmental impacts associated with the installation of new units at the ESP are based on the following findings:

- Construction impact analyses presented in Section 4.4.1 and Section 4.4.2 conclude that the physical and socioeconomic impacts would be small to moderate.
- The ESP site is located in an area that does not raise environmental justice concerns. There are relatively few minority and low-income populations in the environmental impact area. The nearest minority or low-income populations are 20 km (about 12 miles) from the ESP site and most types of impacts associated with construction of the new units decrease rapidly with distance from the construction site.
- As described in Section 4.4.2, the only potential moderate impact from construction of the new units would be associated with traffic congestion created by the large workforce. However, these traffic issues would affect all drivers in the impacted areas equally. That is, there would not be a disproportionately high and adverse impact on minorities and low-income populations within the 80-km (50-mile) radius of the ESP site.

Based on the above, it can be concluded that there would be no disproportionately high and adverse human health or environmental impacts on minority and low-income populations due to construction of new units. There are potential beneficial impacts for these populations related to increased direct employment.

Section 4.4 References

1. NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Supplement 7, Regarding North Anna Power Station, Units 1 and 2, U.S. Nuclear Regulatory Commission (SEIS), November 2002.

2. Louisa County Ordinance, Section 51-3, Unnecessary and disturbing noise prohibited.

3. Spotsylvania County Ordinance, Section 14-14, Unreasonably loud, disturbing, and unnecessary noise.

4. *Environmental Report* (ER) as Appendix E of the North Anna Power Station, Units 1 and 2 Application for Renewed Operating Licenses, Dominion Energy, May 2001.

5. *I-95 Collector-Distribution Access Feasibility Study Final Report*, prepared by BMI et al. for Virginia Department of Transportation, March 2002.

6. *Lake Anna Special Area Plan* by the Lake Anna Special Area Plan Committee appointed by the Boards of Supervisors of Louisa, Orange and Spotsylvania Counties, March 2000.

7. *The County of Louisa Tomorrow – The Plan*, The County of Louisa, Virginia, Comprehensive Plan, Chapter V, September 4, 2001.

8. *Spotsylvania County Approved 2002 Comprehensive Plan*, Transportation Plan, February 12, 2002.

9. *Hanover County Comprehensive Plan – Vision 2017*, Transportation Plan, adopted September 1998.

4.5 Radiation Exposure to Construction Workers

4.5.1 Site Layout

The physical location of the new units relative to the existing units at the NAPS site is presented on Figure 2.1-1. As shown, the new units would be located west of the protected area for the existing units. Hence, construction activity would take place outside the protected area for the existing units, but inside the restricted area boundary.

4.5.2 Radiation Sources

During the construction of the new units, the construction workers may be exposed to radiation sources from the routine operation of the existing units as described in the following paragraphs.

4.5.2.1 Direct Radiation

The boron recovery tanks and the low-level contaminated storage area are among the existing units' principal sources contributing to direct radiation exposure at the construction site. The design basis radiation source term for the boron recovery tank is listed in the North Anna UFSAR, Table 11.2-4. The UFSAR also estimates that the low-level contaminated storage area contains the equivalent of less than 1 Ci of Co-60 (Reference 1).

Another source of direct radiation is the ISFSI, which is located south of the construction site. The source terms for the ISFSI are provided in the ISFSI Safety Analysis Report (SAR), Tables 7-1 to 7-4 (Reference 2).

4.5.2.2 Gaseous Effluents

Sources of gaseous releases include the waste decay tanks, boron recovery and high-level waste tanks, containment purge system, auxiliary building vent, main condenser air ejector vents, auxiliary steam drain receiver, turbine building ventilation exhaust, and gland seal ejector vent. The annual releases for 2001 have been reported as 270 Ci of fission and activation gases, 2.1E-3 Ci of I-131, 4.0E-5 Ci of particulates with half-lives greater than eight days, and 82 Ci of tritium (Reference 3). The annual releases for 2001 are typical for the existing units.

4.5.2.3 Liquid Effluents

Effluents from the liquid waste disposal system produce small amounts of radioactivity in the North Anna Reservoir and the WHTF. The annual liquid radioactivity releases for 2001 have been reported as 0.49 Ci of fission and activation products, 810 Ci of tritium, and 1.2E-2 Ci of dissolved and entrained gases (Reference 3). The annual releases for 2001 are typical for the existing units.

4.5.3 Measured and Calculated Dose Rates

The measured or calculated dose rates used to estimate worker dose are presented below.

4.5.3.1 Direct Radiation

Table 4.5-1 provides thermo-luminescent dosimeter (TLD) measurements at the west protected area fence of the existing units from 1996 to 2002. The average annual dose for this period is 56 mrem. It should be noted that the TLD measurements include background radiation. A radiological survey taken at the same location in April 2003 shows a dose rate of 0.02 mrem/hr.

The average distance from the ISFSI pads to the construction area for the new units is about 1600 feet. The dose rate at 1600 feet from a fully loaded ISFSI has been previously calculated using the MCNP computer program as 4.7E-3 mrem/hr.

4.5.3.2 Gaseous Effluents

The Annual Radioactive Effluent Release Report for 2001 (Reference 3) indicates a total body dose of 4.6E-2 mrem, a skin dose of 1.1E-1 mrem, and a critical organ dose of 1.5E-1 mrem to the maximally exposed member of the public due to the release of gaseous effluents from the existing units, calculated in accordance with the existing units' Offsite Dose Calculation Manual (Reference 4).

4.5.3.3 Liquid Effluents

The Annual Radioactive Effluent Release Report for 2001 (Reference 3) reports a whole body dose of 0.308 mrem and a critical organ dose of 0.352 mrem to the maximally exposed member of the public due to the release of liquid effluents from the existing units, calculated in accordance with the existing units' Offsite Dose Calculation Manual (Reference 4).

4.5.4 Construction Worker Doses

Construction worker doses were conservatively estimated using the following information (see Section 4.4.2):

- The estimated maximum dose rate for each pathway
- An exposure time of 2080 hours per year
- A peak loading of 5000 construction workers per year

The estimated maximum annual dose for each pathway as well as the total dose are shown below.

4.5.4.1 Direct Radiation

At the west protected area fence, Section 4.5.3 indicates an average annual dose of 56 mrem based on TLD measurements and a dose rate of 0.02 mrem/hr based on a radiological survey. The latter reading reflects the sensitivity of the instrument in measuring such low instantaneous dose rates. TLD measurements, however, are more accurate as they reflect continuous exposures for long periods of time. The average measured dose rate over a seven-year period of 56 mrem/yr is based on continuous exposure at the protected area fence between the existing and new units.

Since the construction workers would spend most of their time west of this fence, further away from the existing units, using this dose rate for the workers is conservative. Adjusting for an exposure time of 2080 hr/yr yields an annual worker whole body or total effective dose equivalent (TEDE) dose of 13 mrem.

Although the TLD reading includes the dose contribution from the ISFSI loading at the time of the measurement, the dose from a fully loaded ISFSI is conservatively added to the TLD dose. The ISFSI dose rate of 4.7E-3 mrem/hr with an exposure time of 2080 hr/yr is equivalent to an annual dose of 9.8 mrem. Adding the two contributions results in a total annual dose of 23 mrem.

4.5.4.2 Gaseous Effluents

The annual gaseous effluent doses to the maximally exposed member of the public (Section 4.5.3.2) are based on continuous occupancy. Adjusted for an exposure time of 2080 hr/yr and multiplying by a factor of 10 to account for the fact that the worker is located closer to the effluent release point than is the maximally exposed member of the public, the estimated worker doses are 1.1E-1 mrem for the total body, 2.7E-1 mrem for the skin, and 3.5E-1 mrem for the critical organ. Applying a weighting factor of 0.3 to the critical organ dose (Reference 5) and adding to the total body dose, a TEDE of 2.1E-1 mrem is estimated.

4.5.4.3 Liquid Effluents

As the annual liquid effluent doses to the maximally exposed member of the public in Section 4.5.3 are based on continuous occupancy, they are adjusted for an exposure time of 2080 hr/yr. Although the liquid effluent dose rates to which the workers would be exposed are expected to be no higher than those to the maximally exposed member of the public, the doses are multiplied by a factor of 10 for conservatism and consistency with the gaseous dose factor above. The resulting doses are 7.3E-1 mrem for the whole body and 8.4E-1 mrem for the critical organ. Applying a weighting factor of 0.3 to the organ dose and adding to the whole body dose, a TEDE of 9.8E-1 mrem is estimated.

4.5.4.4 Total Doses

The annual doses from all three pathways are summarized in Table 4.5-2 and compared to the public dose criteria in 10 CFR 20.1301 (Reference 6) and 40 CFR 190 (Reference 7) in Table 4.5-3 and Table 4.5-4, respectively. The unrestricted area dose rate in Table 4.5-3 was estimated by rounding up the 0.02 mrem/hr reading (Section 4.5.3) to 0.1 mrem/hr. Since the calculated doses meet the public dose criteria of 10 CFR 20.1301 and 40 CFR 190, the workers would not need to be classified as radiation workers. Table 4.5-5 shows that the doses also meet the design objectives of 10 CFR 50, Appendix I, for gaseous and liquid effluents (Reference 8).

The maximum annual collective dose to the construction work force (5000 workers) is estimated to be 120 person-rem.

The calculated doses are based on available dose rate measurements and calculations. It is possible that these dose rates would increase in the future as site conditions change. However, the ESP site would be continually monitored during the construction period and appropriate actions would be taken as necessary to ensure that the construction workers are protected from radiation.

Section 4.5 References

1. *Updated Final Safety Analysis Report,* North Anna Power Station, Revision 38.

2. *Independent Spent Fuel Storage Installation Safety Analysis Report,* North Anna Power Station, Revision 3.

3. *Annual Radioactive Effluent Release Report, North Anna Power Station (January 01, 2001 to December 31, 2001),* Virginia Electric and Power Company, 2002.

4. Procedure No. VPAP-2103N, *Offsite Dose Calculation Manual,* Revision 2, Administrative Procedure, Dominion.

5. ICRP Publication 30, *Limits for Intakes of Radionuclides by Workers*, Part 1, Published for the International Commission on Radiological Protection by Pergamon Press, 1979.

6. 10 CFR 20.1301, *Code of Federal Regulations*, “Dose Limits for Individual Members of the Public.”

7. 40 CFR 190, *Code of Federal Regulations*, “Environmental Radiation Protection Standards for Nuclear Power Operations.”

8. 10 CFR 50, Appendix I, *Code of Federal Regulations*, “Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion ‘As Low As is Reasonably Achievable’ for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents.”

Table 4.5-1 TLD Dose Measurements at West Protected Area Fence of Existing Units

	Dose (mrem)				
Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total
1996	25	0	16	18	59
1997	13	9	12	14	48
1998	14	13	12	13	52
1999	1	9	8	15	32
2000	16	22	0	17	55
2001	16	19	13	21	69
2002	18	15	15	26	74
Average					56

Note: The west protected area fence represents the closest approach to the existing units for construction workers working on the new units; see Section 4.5.1.

Table 4.5-2 Annual Construction Worker Doses

	Annual Dose (mrem)		
	Whole Body	Critical Organ	TEDE
Direct radiation	2.3E+01	-	2.3E+01
Gaseous effluents	1.1E-01	3.5E-01	2.1E-01
Liquid effluents	7.3E-01	8.4E-01	9.8E-01
Total	2.4E+01	1.2E+00	2.4E+01

Table 4.5-3 Comparison with 10 CFR 20.1301 Criteria for Doses to Members of the Public

Criteria	Dose Limit	Estimated Dose
Annual TEDE (mrem)	100	24
Unrestricted area dose rate (mrem/hr)	2	0.1

Table 4.5-4 Comparison with 40 CFR 190 Criteria for Doses to Members of the Public

	Annual Dose (mrem)	
Organ	**Limit**	**Estimated**
Whole body	25	24
Thyroid	75	1.2
Other organ	25	1.2

Note: The estimated whole body dose conservatively includes background radiation whereas the dose limit applies to exposures from plant operation only.

Table 4.5-5 Comparison with 10 CFR 50, Appendix I Criteria for Effluent Doses

	Annual Dose (mrem)	
	Limit	**Estimated**
Total body dose from liquid effluents	3	0.73
Organ dose from liquid effluents	10	0.84
Total body dose from gaseous effluents	5	0.11
Skin dose from gaseous effluents	15	0.27
Organ dose from radioactive iodine and radioactive material in particulate form	15	1.2

4.6 Measures and Controls to Limit Adverse Impacts During Construction

The following measures and controls would limit adverse environmental impacts:

- Compliance with applicable federal, Virginia, and local laws, ordinances, and regulations intended to prevent or minimize adverse environmental impacts (e.g., solid waste management, erosion and sediment control, air emissions, noise control, storm water management, spill response and cleanup, hazardous material management).
- Compliance with applicable requirements of existing permits and licenses (e.g., VPDES Permit, Operating License) for the existing units and other permits or licenses required for construction of the new units (e.g., U.S. Army Corps of Engineers Section 404 Permit, VDEQ wetlands permit).
- Compliance with existing Virginia Power processes and/or procedures applicable to construction environmental compliance activities for the NAPS site (e.g., solid waste management, hazardous waste management, spill prevention and response).
- Incorporation of environmental requirements into construction contracts.
- Identification of environmental resources and potential impacts during the development of this Environmental Report and the Early Site Permitting process.

The Potential Impact Significance columns in Table 4.6-1 list the elements identified in NUREG-1555, Section 4.6, (Reference 1) that relate to the construction issues. The significance levels – (S)mall, (M)oderate, or (L)arge – provided for each element in the table are determined by evaluating the potential impacts after any controls or mitigation measures are implemented.

Section 4.6 References

1. NUREG-1555, *Standard Review Plans for Environmental Reviews of Nuclear Power Plants,* Section 4.6, “Measures and Controls to Limit Adverse Impacts During Construction,” Office of Reactor Regulation, U.S. Nuclear Regulatory Commission (USNRC), October 1999.

Table 4.6-1 Summary of Measures and Controls to Limit Adverse Impacts During Construction

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Specific Measures and Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
4.1 Land-Use Impacts																
4.1.1 The Site and Vicinity		S				S				S	S				• Ground disturbing activities including grading and re-contouring • Removal of existing trees and vegetation. Potential impacts to wetlands and intermittent streams. • Stockpiling of soils onsite. • Construction of new buildings and impervious surfaces (e.g., parking lots).	• Conduct ground disturbing activities in accordance with regulatory and permit requirements. Use adequate erosion controls and stabilization measures to minimize impacts. • Limit tree and vegetation removal to the existing NAPS site, which is zoned “industrial.” • Minimize potential impacts to wetlands and intermittent streams through avoidance and compliance with applicable permitting requirements. • Restrict soil stockpiling and re-use to the NAPS site. • Restrict construction activities to the NAPS site.

Table 4.6-1 Summary of Measures and Controls to Limit Adverse Impacts During Construction

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Specific Measures and Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
4.1.2 Transmission Corridors and Offsite Areas															Based on an initial evaluation, the existing transmission lines have sufficient capacity to carry the total output of the existing units and the new units. A system study modeling these lines with the new units' power contribution would be performed to confirm this conclusion. This evaluation would be conducted at a suitable time after a decision is made by Dominion to proceed with the new capacity.	None
4.1.3 Historic Properties and Cultural Resources														S	• Ground disturbing activities including grading, excavation, and re-contouring.	• Conduct sub-surface testing prior to initiating ground disturbing activities to identify buried historic or archeological resources. • Take appropriate actions (e.g., stop work) following discovery of potential historic or archeological resources. • Use existing Virginia Power procedures that require contacting the appropriate regulatory agencies following a discovery of potential historic or archeological resources.

Table 4.6-1 Summary of Measures and Controls to Limit Adverse Impacts During Construction

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Specific Measures and Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
4.2 Water-Related Impacts																
4.2.1 Hydrologic Alterations		S				S	S		S		S	S			• Removal of existing cofferdam for the construction of new water intake on Lake Anna. • Impact to intermittent streams. • Erosion, sediment, and storm water runoff from construction site to Lake Anna prior to permanent stabilization, and installation of storm water drainage system • Potential impact to some potable water wells at the NAPS site from construction dewatering activities.	• Design and install appropriate barrier (e.g., turbidity curtain in Lake Anna near cofferdam work location) to prevent turbid water from migrating into the Lake. • Adhere to applicable regulations and permit requirements with regard to seasonal restrictions for in-water work, installation of appropriate erosion control measures, drainage controls to convey stream flow, and construction storm water management. • Use Best Management Practices (BMP) described in the Virginia Erosion and Sediment Control Handbook to control erosion and minimize the sediment load from the construction zone. • Use wells unaffected by dewatering activities to maintain needed capacity for the NAPS site. Not all wells are expected to be affected by dewatering activities.

Table 4.6-1 Summary of Measures and Controls to Limit Adverse Impacts During Construction

Section Reference	Potential Impact Significance [a, b]													Impact Description or Activity	Specific Measures and Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)	
4.2.2 Water-Use Impacts		S			S	S	S		S		S	S			• Potential impacts from releases of fuel, oils, or other chemicals associated with construction to surface or ground water. • Potential impacts from increased sediment loading in storm water runoff to North Anna Reservoir. • Potential impact to the local water table due to construction dewatering activities.	• Develop and implement a construction Storm Water Pollution Prevention Plan (SWPPP) and spill response plan during construction at the NAPS site. • Implement an Erosion and Sediment Control Plan that describes use of approved/recognized Best Management Practices (BMP). • Limit dewatering activities to only those necessary for construction. • Use offsite sources of potable water, if necessary, to temporarily supplement onsite water resources.

Table 4.6-1 Summary of Measures and Controls to Limit Adverse Impacts During Construction

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Specific Measures and Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
4.3 Ecological Impacts (i.e., impacts on the physical environment)																
4.3.1 Terrestrial Ecosystems	S		S					S		S					• Clearing and grading activities and habitat loss would displace existing mobile animals such as birds and larger mammals from construction zone. • Wildlife (e.g., birds and small mammals) may be startled or frightened away by noisy construction activities. • Potential impacts from avian collisions with man-made structures (e.g., cranes, buildings) during construction.	• No measures and controls are necessary because impacts would be small.

Table 4.6-1 Summary of Measures and Controls to Limit Adverse Impacts During Construction

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Specific Measures and Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
4.3.2 Aquatic Ecosystems		S	S			S			S		S				• Potential impacts on surface water from releases of fuel, oils, or other chemicals associated with construction to surface water. • Potential impacts on the North Anna Reservoir from increased sediment loading in storm water runoff to the North Anna Reservoir. • Temporarily degraded water quality due to in-water and shoreline work near the cofferdam. • Temporary loss of benthic habitat and organisms near cofferdam. • Potential impact from re-entrainment of contaminated sediments into the water column.	• Develop and implement a construction Storm Water Pollution Prevention Plan (SWPPP) and spill response plan during construction at the site. • Implement an Erosion and Sediment Control Plan that describes use of approved/recognized BMPs. • Design and install appropriate barrier (e.g., turbidity curtain in the North Anna Reservoir near cofferdam work location) to prevent turbid water from migrating into the lake. • Adhere to seasonal restrictions on in-water construction activities. Following temporary construction disturbance, intake channel cove would likely be re-colonized by benthic organisms and fish.

Table 4.6-1 Summary of Measures and Controls to Limit Adverse Impacts During Construction

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Specific Measures and Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
4.4 Socioeconomic Impacts (i.e., Impacts on the Human Community)																
4.4.1 Physical Impacts	S		S	S		S			S		S	S			• Potential temporary and limited impact to sensitive populations due to noise, fugitive dust, and gaseous emissions resulting from construction activities. • Potential for traffic accidents with increased construction traffic near the NAPS site. • Limited in-water construction activity to remove the existing cofferdam.	• Train and appropriately protect NAPS site and temporary construction personnel (i.e., those most directly and frequently affected by construction noise, dust and gaseous emissions) to reduce the risk of potential harmful exposures from noise, dust, and gaseous emissions. • Provide onsite services for emergency first aid care and conduct regular health and safety monitoring for affected personnel on site. • In the event of atypical or noisy construction activities are necessary (e.g., pile driving), make public announcements and/or notifications prior to undertaking such activities. • Use normal dust control measures (e.g., watering, stabilizing disturbed areas, covering truck loads). • Manage concerns from adjacent residents, business owners, or landowners, on a case-by-case basis through a Dominion prepared concern resolution process. • Post signs at or near construction site entrances and exits to make the public aware of potentially high construction traffic areas. • Design and install appropriate barrier (e.g., turbidity curtain in the North Anna Reservoir near cofferdam work location) to prevent turbid water from migrating into the lake.

Table 4.6-1 Summary of Measures and Controls to Limit Adverse Impacts During Construction

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Specific Measures and Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
4.4.2 Social and Economic Impacts				M								S			• Potential impact on existing transportation network in the vicinity of the ESP site due to increased construction workforce traffic. • General increase in construction equipment and material deliveries affecting local and regional roadways.	• Develop a construction traffic management plan prior to construction to address potential impacts on local roadways. • Encourage the use of shared (e.g., carpooling) and multi-person transport (e.g., buses) of construction personnel to the ESP site. • Coordinate schedules during work force shift changes to limit impacts on local roads. • Schedule delivery of larger pieces of equipment or structures on off-peak traffic hours (e.g., at night) or through other transportation modes (e.g., rail). • If necessary, consider/coordinate with local planning authorities the upgrading of local roads, intersections, and signals to handle increased traffic loads.
4.4.3 Environmental Justice Impacts															No impacts identified	No mitigation measure or controls proposed
4.5 Radiation Exposure to Construction Workers															No impacts identified	No mitigation measure or controls proposed

a. The assigned significance levels [(S)mall, (M)oderate, or (L)arge are based on the assumption that for each impact, the associated proposed mitigation measures and controls (or equivalents) would be implemented.

b. A blank in the elements column denotes “no impact” on that specific element due to the assessed impacts.

Chapter 5 Environmental Impacts of Station Operation

This chapter presents the potential environmental impacts from the operations of new units on the ESP site. In accordance with 10 CFR 51, impacts are analyzed, and a single significance level of potential adverse impacts (i.e., small, moderate, or large) has been assigned to each analysis. This is noted in respective topic discussions. Mitigation of adverse impacts is also presented, where appropriate. This chapter is divided into ten subsections:

- Land use impacts
- Water-related impacts
- Cooling system impacts
- Radiological impacts of normal operation
- Environmental impacts of waste
- Transmission system impacts
- Uranium fuel cycle impacts
- Socioeconomic impacts
- Decommissioning
- Measures and controls to limit adverse impacts during operation

These subsections also present potential ways to avoid, minimize, or mitigate environmental impacts to the extent possible, including complying with the applicable sections of the following laws, regulations, guidelines, or procedures:

- Federal, Virginia, and local laws and regulations that minimize or prevent adverse environmental impacts (e.g., waste management, air emissions, noise control, storm water management, spill response and cleanup, hazardous material management)
- Recognized industry-standard codes and practices
- Site permits and licenses (e.g., VPDES Permit, Operating License) and other permits that would be required if/when operation and maintenance activities commence
- Existing Virginia Power policies and/or procedures that address environmental compliance requirements

The environmental description, where referenced, includes the following definitions:

- NAPS site - the property within the NAPS site boundary, or fence line, including the EAB.
- ESP site - the property within the NAPS site intended for the construction and operation of new units.
- Vicinity - the area within a 6-mile radius of the ESP site.
- Region - the area within a 50-mile radius of the ESP site.

5.1 Land-Use Impacts

This section discusses the potential land-use impacts associated with operations of the new units. The operational activities of the new units would not require any current or planned land-uses to be changed or modified either temporarily or permanently. The land use areas considered include those that have the potential to be impacted by operational activities (e.g., the site, the vicinity, the area along transmission corridors, and offsite areas). Additionally, land-use considerations include those historic properties that have been identified in the NRHP, as well as those properties that have the potential to hold historic significance, such as artifacts and human remains. The section is further segregated into the following subsections:

- Site and vicinity
- Transmission corridors and offsite areas
- Historic properties

5.1.1 The Site and Vicinity

Section 2.2.1 describes the NAPS site and vicinity. The NAPS site (including the EAB) has been zoned by Louisa County for industrial use. Land-use impacts to the ESP site as a result of operating the new units would not be significant to the region. Potential land-use impacts to the vicinity from the new units may occur as a result of the following:

- Additional discharges through the WHTF
- Heat dissipation from the dry towers
- Heat, salt deposition, and moisture dissipation (from evaporation and drift) from the wet towers
- Increased traffic loads on the existing local transportation network

5.1.1.1 Waste Heat Treatment Facility Discharges

A detailed description of the WHTF is provided in Section 3.3. The WHTF discharges to the North Anna Reservoir through the Virginia Power owned and operated Dike 3. The North Anna Reservoir has public access and is used for recreational boating, swimming, fishing, camping, and picnicking, and has residential (vacation and year-round) housing along its shores.

All discharges to the WHTF due to operations would continue to be in accordance with federal, state, and local laws and regulations and applicable permit requirements (e.g., VPDES Permit). State agencies (e.g., VDEQ) conduct regular inspections and advise Virginia Power of any concerns or problems that require resolution. The expected increase in discharge water volume from Unit 3 wet cooling tower system blowdown would be negligible when compared with the discharge water volume from the existing units. The change in temperature at the discharge point of the WHTF due to operation of the new units would be negligible and would not impact the current or future recreational uses of the lake.

Section 5.3.2.2, provides an assessment of the potential operational impacts to aquatic ecosystems in Lake Anna due to anticipated increases in discharge volume and temperature resulting from the new units.

5.1.1.2 Heat and Moisture Dissipation for Dry and Wet Towers

Potential impacts on land use would be related to possible increases in local temperatures due to heat dissipation to the atmosphere from the new dry and wet towers. A closed-cycle, combination dry and wet tower cooling system would be used for Unit 3 and a dry tower cooling system would be used for Unit 4. Section 3.4.1.1 contains a detailed description of the operation of the wet and dry towers. As ambient air is drawn over sealed piping containing heated water in dry towers, excess heat is transferred to the air through conduction and convection. In wet towers, heat from the water is transferred to the air by allowing a small portion of the water to evaporate thus raising the air temperature and relative humidity. The heated air from the dry and wet towers is then released to the atmosphere where it mixes and is entrained into the surrounding air mass. Any increases in overall atmosphere temperature would be very localized to the NAPS site, and would not affect the atmospheric or ground temperatures beyond the NAPS site boundary. Therefore, there would be no impacts to offsite land use due to heat dissipation to the atmosphere from the new dry and wet towers for Units 3 and 4. Fogging, icing, and salt deposition, which could result from the moisture dissipation (from evaporation and/or drift) from the wet towers, are discussed in Section 5.3.3.

5.1.1.3 Increased Use of the Existing Local Transportation Network

The impact on the transportation network accessing the ESP site would be small as a result of operational activities associated with the new units. During the operation of the new units there could be minor increases in traffic on existing public roads leading to and from the NAPS site due to an increase in operations personnel. However, any increases would be small.

5.1.2 Transmission Corridors and Offsite Areas

Based on an initial evaluation, the existing transmission lines have sufficient capacity to carry the total output of the existing units and the new units. If Dominion decides to proceed with development of new units at the ESP site, a system study (load flow) modeling these lines with the new units' power contribution would be performed at that time, to confirm this conclusion. Additional information regarding the existing transmission system is provided in Section 3.7.

No new routes of access corridors would be necessary to serve operation of the new units. No offsite land uses would be affected by operation of the new units.

5.1.3 Historic Properties

Impacts of operations on historic properties or cultural resources would be small. (See Section 4.1.3)

Section 5.1 References

None

5.2 Water-Related Impacts

This section describes the hydrological alterations, plant water supply, and water-use impacts associated with the operation of new units at the ESP site. The following topics are covered.

- Hydrologic alterations resulting from station operations and the effects of these alterations on other water users
- Adequacy of water supplies to meet plant water needs
- Water quality changes and possible effects on water use
- Practices that would minimize or avoid hydrologic alterations having adverse impacts
- Identification and compliance with federal, state, regional, and local regulations applicable to water use and water quality

The evaluation of hydrologic alterations and water quality changes considers both surface water and groundwater uses, including domestic, municipal, industrial, mining, recreation, navigation, and hydroelectric power uses.

5.2.1 Hydrologic Alterations and Plant Water Supply

This section describes the hydrological alterations resulting from plant operation and the adequacy of the water sources to supply water needs to the new units. The following topics are covered.

- Identification and description of proposed operational activities that could result in hydrologic alterations
- Identification, description, and analysis of the resulting hydrologic alterations and the effects of these alterations on other water users
- Analysis of proposed practices to minimize hydrologic alterations having adverse impacts.
- Analysis and comparison of plant water needs and the availability of water supplies to meet the plant water needs
- Conclusions with respect to the adequacy of water supplies to meet plant water needs

As described in Section 3.3.1, the North Anna Reservoir would supply most water needs during operation of the new units, which include plant cooling, the initial fill and make-up water for the UHS cooling tower, water supply to the demineralized water system, and fire protection water. Most of the water needs would be for plant cooling. Unit 3 would use a closed-cycle system for plant cooling and a combination of dry and wet cooling towers for heat dissipation. Make-up water to replace the water lost due to evaporation in the wet cooling towers would be supplied from the North Anna Reservoir. Unit 4 would use a closed-cycle system for plant cooling and dry cooling towers for heat dissipation. There would typically be no make-up water needs since the cooling water would be circulated in a closed loop from the surface condenser to the dry towers of Unit 4. In the event that the Unit 4 cooling water loop would use an open pump sump configuration with a free surface, a

small amount of make-up water estimated to be on the order of 1 gpm (0.002 cfs) would be needed to replenish the evaporative loss. This make-up water would be obtained from the North Anna Reservoir. There would be no blowdown discharge from the Unit 4 dry cooling towers.

Water needs other than for plant cooling would be required on an intermittent, short-term basis and would be small relative to the long-term plant water use for normal cooling of Unit 3. The water needs supplied by Lake Anna would include UHS cooling tower make-up, demineralized water supply, and fire protection water supply, as described Section 3.3.1. Based on information provided in Table 3.3-1 and Table 3.3-2, withdrawals would total 2.5 cfs during normal plant operation and 11.0 cfs during abnormal or upset conditions for each unit. Plant water releases back to the lake via the WHTF are described in Section 3.3.1. These releases would total 1.1 cfs during normal plant operation and 3.0 cfs during abnormal or upset conditions for each unit, based on information provided in Table 3.3-1 and Table 3.3-2. Considering these withdrawals and returns, the net use of Lake Anna water for each of the new units would be 1.4 cfs during normal plant operation and up to 8.0 cfs during upset or abnormal conditions. Because the 1.4 cfs value (2.8 cfs for two new units) is small relative to the other terms in the Lake Anna water balance and because water consumption at this rate would occur on an intermittent, short-term basis, this water usage would have no impact on the adequacy of the water supplies to meet plant water needs.

5.2.1.1 Operational Activities That Could Result in Hydrologic Alterations

The operational activity that could result in the most significant hydrologic alterations is the use of water from the North Anna Reservoir for plant cooling. The associated hydrologic alterations are presented below.

The operation of Unit 3 would result in evaporative losses from the wet cooling towers used for plant cooling. Table 3.3-1 indicates MWC mode and EC mode evaporation rates of 25.7 and 37.2 cfs, respectively. To maintain the water balance in the closed-cycle cooling system, water supplied from the North Anna Reservoir would be used to make up the water lost to evaporation. Table 3.3-1 indicates the maximum make-up water withdrawal rate of 34.3 cfs when in the MWC mode and 49.6 cfs when in the EC mode, which includes evaporation, drift losses, and blowdown requirement. These make-up withdrawal rates are in addition to the 4246 cfs of cooling water withdrawn currently by the existing units (Reference 1). Blowdown from the wet cooling towers would be returned to the North Anna Reservoir via the WHTF. MWC mode and EC mode blowdown rates are 8.6 and 12.4 cfs, respectively, as indicated in Table 3.3-1. The rates expressed for evaporation, make-up, and blowdown are maximums for the defined modes of operation, and would occur on an instantaneous basis only when maximum dry and wet bulb ambient conditions are at their defined 0.4 percent exceedence condition. The average evaporative loss during normal plant operation is expected to be 19.4 cfs based on the operating plan described in Section 3.4.1.1.

Operation of Unit 4 would increase the quantity of water withdrawn from the North Anna Reservoir by a small amount to supply for the other plant water uses, as presented in Section 5.2.1. An

additional, negligible amount (0.002 cfs) of make-up water may also be necessary for normal plant cooling. There would also be a small increase in plant water releases discharged to the WHTF for return to the North Anna Reservoir. The Unit 4 closed-cycle dry cooling system would have no blowdown discharge and therefore would have no impact on Lake Anna water temperatures.

5.2.1.2 Hydrologic Alterations and Effects on Other Water Users

The additional water use would reduce the volume of water available for release from the North Anna Dam. Evaporation from Unit 3's wet cooling towers would decrease the water available to be released from the dam by a maximum of 25.7 cfs during MWC mode operating conditions and 37.2 cfs during EC mode operating conditions on an instantaneous basis. Operation of the Unit 4 closed-cycle dry cooling system would have no measurable impact on the quantity of water available for dam release. No reductions in the minimum releases specified in the Lake Level Contingency Plan (Reference 2) would occur.

Additional effects of the hydrologic alterations would be reductions in the Lake Anna water levels during periods of extended drought, due to the additional evaporative losses associated with the operation of Unit 3's wet cooling towers. The impacts on lake level from the operation of the new units are presented in Section 5.2.2.

No hydrologic alterations in addition to those identified and analyzed above are anticipated.

5.2.1.3 Proposed Practices to Minimize Hydrologic Alterations Having Adverse Impacts

As described in Section 3.4.1.1, the closed-cycle, dry and wet tower cooling system for normal plant cooling of Unit 3 would be operated to conserve water when lake inflows are insufficient to maintain a pool level of 250 ft or above. When lake level falls below 250 ft msl and the level is not restored within a reasonable period of time, the cooling system would be operated in the MWC mode. The period assumed was 7 days; however, the actual time frame from switching to the MWC mode would be established with State agencies at the time of permitting. In this mode, only the dry towers would be used to dissipate the entire heat load from the surface condenser when the ambient DBT is sufficiently low. When the ambient DBT is above the temperature where the dry tower can reject the plant waste heat on its own, the necessary capacity of wet tower cells required to assist in the dissipation of condenser heat load would be placed in operation in series with the dry towers. Using the MWC mode would reduce adverse impacts on lake levels and reservoir releases during sustained dry periods.

5.2.1.4 Comparison of Plant Water Needs to the Availability of Water Supplies

The available water supplies are compared to plant water needs on a time-averaged basis in Table 5.2-1. The available water supply is estimated from the water balance equation:

Available Water Supply = Net Inflow – Evaporation – Minimum Release (Equation 5.2-1)

where:

Net Inflow = average net inflow to Lake Anna from tributary inflow, groundwater discharge, and direct precipitation;

Evaporation = average pre-operational evaporation, including natural evaporation and forced evaporation from the existing units; and

Minimum Release = minimum amount of flow that must be released from the North Anna Dam.

Table 5.2-1 summarizes the results for the combined operation of the existing units plus new Unit 3 using a closed-cycle, combination dry and wet cooling tower system. The results would be similar to the combined operation of the existing units plus new Unit 3 using a closed-cycle, combination dry and wet cooling tower system along with new Unit 4 using a closed-cycle, dry cooling tower system with no or negligible make-up water needs. The average evaporative loss from Unit 3's wet cooling towers is used to define the plant water needs on a long-term operating basis. The results provided in Table 5.2-1 indicate that the available water supply (236 cfs) exceeds the plant water needs (19.4 cfs).

Table 5.2-1 Available Water Supply Versus Plant Water Needs

	Flow Rate (ft^3/s)
Quantity	**Existing Units Plus Units 3 & 4**
Net Inflow[a]	369
Pre-Operational Evaporation[b]	93
Minimum Release[c]	40
Available Water Supply[d]	236
Plant Water Needs[e]	19.4

a. Average net inflow derived from water balance model described in Section 5.2.2.

b. Natural evaporation from Lake Anna plus forced evaporation from the existing units on a time-averaged basis; derived from the thermal model described in Section 5.3. Forced evaporation is based on a 93% plant capacity factor.

c. Minimum release for Lake Anna water levels in excess of 248 ft above mean sea level (Reference 2).

d. Equation 5.2-1

e. Average evaporation associated with Unit 3's wet cooling towers based on a 96% plant capacity factor; the evaporation rate was derived from the water balance model described in Section 5.2.2. Unit 4's dry towers incur no to negligible evaporative losses.

5.2.1.5 Adequacy of Water Supplies to Meet Plant Water Needs

The analysis presented in Section 5.2.1.4 demonstrates that the available water supply from the Lake Anna watershed is adequate to meet plant water needs for the existing units plus Unit 3 alone, or the existing units plus new Units 3 and 4, on a long-term average basis.

5.2.2 Water-Use Impacts

This section analyzes and assesses the impacts of plant operation on water use. The following topics are covered in the section:

- Analysis of hydrologic alterations that could have impacts on water use, including water availability
- Analysis of water-quality changes that could affect water use
- Analysis and evaluation of impacts resulting from hydrologic alterations and changes
- Analysis and evaluation of proposed practices to minimize or avoid water-use impacts
- Evaluation of compliance with federal, state, regional, local, and affected Native American tribal regulations applicable to water use and water quality

As described in Section 5.2.1, the primary hydrologic alterations resulting from the operation of new units at the ESP site include:

- reductions in the volume of water available for release from the North Anna Dam, and
- reductions in Lake Anna water levels during periods of drought.

A water balance model for Lake Anna was developed to quantitatively assess the impacts of adding the new units. This model considers the evaporation of cooling water associated with the operation of Unit 3. Unit 4 is not represented in the model because operation of its cooling system would have no measurable impacts. The model formulation, input data, and results, in terms of lake outflow and lake level, are described below. Analysis and evaluation of impacts are described subsequently.

5.2.2.1 Water Balance Model

5.2.2.1.1 Model Formulation

Figure 5.2-1 illustrates the conceptual model used to represent the Lake Anna water balance. The continuity equation for this control volume may be expressed as (Reference 3):

$$\frac{dS}{dt} = I - O, \quad S(0) = S_0 \qquad \text{(Equation 5.2-2)}$$

where:

S is the storage
t is time

I is the inflow rate
O is the outflow rate
S_0 is the initial storage

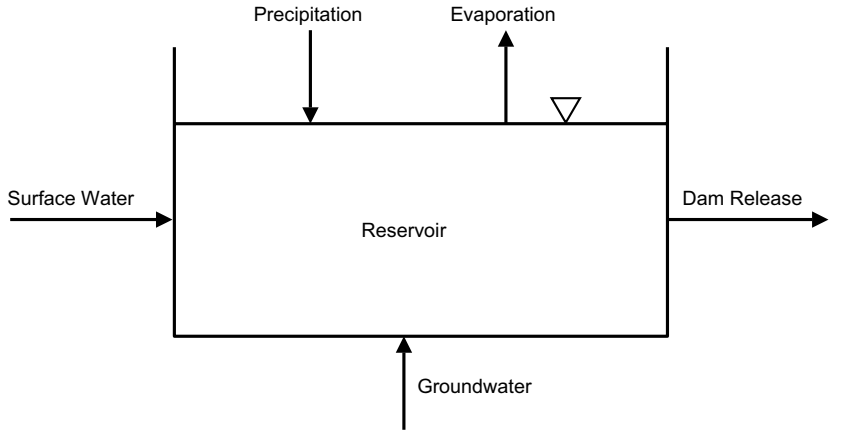


Figure 5.2-1 Lake Anna Water Balance Model

In this analysis, S includes the combined storage of the North Anna Reservoir and the WHTF. The inflow rate to Lake Anna, I, is defined as:

$$I \equiv I_{SW} + I_{GW} + I_P \qquad \text{(Equation 5.2-3)}$$

where:

I_{SW} is the surface water inflow to the lake from contributing tributaries
I_{GW} is the groundwater inflow to lake
I_P is the inflow from precipitation falling directly on the lake

Because data are not available to characterize I_{SW} and I_{GW} adequately, the total inflow rate to Lake Anna, I, is unknown. The basis for estimating this time series will be described subsequently.

The outflow rate from Lake Anna, O, is defined as

$$O \equiv O_{Preop\text{-}Evap} + O_{Unit3\text{-}Evap} + O_R \qquad \text{(Equation 5.2-4)}$$

where:

$O_{Preop\text{-}Evap}$ is the pre-operational outflow due to evaporation
$O_{Unit3\text{-}Evap}$ is the evaporative loss associated with Unit 3's wet cooling towers
O_R is the outflow from dam releases

Note that $O_{Preop\text{-}Evap}$ includes the natural evaporation from the lake plus the forced evaporation from operating the once-through cooling systems of the existing units.

The initial value problem defined by Equation 5.2-2 is solved by the finite-difference method. Using subscript *n* and *n+1* to represent the beginning and end of any given time period, Equation 5.2-2 can be written:

$$\frac{S_{n+1} - S_n}{\Delta t} = I_n - O_n \qquad \text{(Equation 5.2-5)}$$

and rearranged to yield:

$$S_{n+1} = (I_n - O_n)\Delta t + S_n \qquad \text{(Equation 5.2-6)}$$

Note that S_{n+1} is a function of reservoir elevation, *h*, which can be obtained from the reservoir's elevation-storage relationship. Equation 5.2-6 is solved first for S_1 given the initial conditions at $t = 0$. The computation is then repeated for succeeding time steps.

5.2.2.1.2 Model Input Data

Required model input includes the relationship between water surface elevation and lake storage, the relationship between water surface elevation and lake outflow, the inflow time history to Lake Anna, and the time histories of evaporative losses from the lake and the wet cooling towers. The bases for assigning these input data are described below.

The relationship between water surface elevation and storage is derived from the elevation-volume curves for the North Anna Reservoir and the WHTF, which are reported in the UFSAR for the existing units (Reference 1, Appendix 2A). These curves have been added to yield a single elevation-storage curve for the entire Lake Anna for the purpose of this water balance study. Table 5.2-2 summarizes the storage volumes determined at Elevations 240, 250 and 260 ft msl. A quadratic equation was fitted to the values for interpolating between elevations. The estimated storage volume of 305,100 acre-ft at 250 ft msl lake level used in the water budget model is slightly higher (by 0.03 percent) than the 305,000 acre-ft volume reported in UFSAR Section 2.4.1.2 (Reference 1) or Part 2: Table 2.4-1. This small difference would have no impact on any of the hydrologic and water use evaluations.

Table 5.2-2 Data Input for Water Balance Model

Elevation (ft msl)	Storage (acre-feet)		
	North Anna Reservoir	WHTF	Total Lake Anna
240	161,900	33,300	195,200
250	244,300	60,800	305,100
260	352,750	105,300	458,050

The operating rule curve implemented in the model, which relates water surface elevation to dam releases, has been developed as follows. For lake levels less than or equal to the normal pool elevation of 250 ft above msl, the Lake Level Contingency Plan is followed (Reference 2). This plan requires a minimum instantaneous release from the Lake Anna impoundment of 40 cfs. When lake level drops to or below 248 ft msl, releases can be incrementally reduced to a 20 cfs minimum. For lake levels greater than or equal to 250.1 ft msl, it is assumed that any inflow in excess of the evaporative losses is released, provided the minimum release requirements are met.

The inflow time history to Lake Anna has been calculated by a reverse routing procedure using observed Lake Anna releases and water levels and estimated pre-operational evaporation. This procedure has been adopted because only a small fraction of the Lake Anna watershed is gauged, as is described in Section 2.3.1. The inflow to Lake Anna is calculated by solving Equation 5.2-5 for I_n, or:

$$I_n = \frac{S_{n+1} - S_n}{\Delta t} + O_n \qquad \text{(Equation 5.2-7)}$$

This calculation requires the time histories for storage, S, and outflow, O. The storage time history has been determined using the available period of record for lake level observation, which extends from October 1, 1978, through April 10, 2003. Lake levels, h, have been related to S through quadratic interpolation of the values summarized in Table 5.2-2. According to Equation 5.2-4, O includes the historical releases from the North Anna Dam, and the historical rate of Lake Anna evaporation associated with operation of the existing units. Historical releases from the dam from October 1, 1978, through October 9, 1995, have been derived from the Partlow stream gauging station, which is located approximately one-half mile downstream of the dam. Stream gauging at this station was discontinued on October 10, 1995. Releases from October 10, 1995, through April 10, 2003 have, therefore, been estimated from the historical gate openings and associated rating curves for the North Anna Dam. The determination of historical lake evaporation is described below.

Historical evaporation from Lake Anna has been estimated using the Lake Anna Cooling Pond Model developed by the Massachusetts Institute of Technology (Reference 4) (Reference 5). This model calculates, as part of the heat balance, the heat lost to the atmosphere due to evaporation and the associated evaporation rate on a daily basis for the control volumes used to represent the main ponds in the WHTF and the North Anna Reservoir. The model assumed a constant lake level at 250 ft msl. The thermal model also includes a number of side arms for which the model does not provide the evaporation rates directly. To determine these evaporation rates, an exponentially decreasing function is used to represent the temperature distribution in the surface layer of each side arm based on the entrance and return flow temperatures predicted by the thermal model. Using the mean value of this function to assign a characteristic temperature for the entire side arm, side arm evaporation is calculated using the Ryan-Harleman function (Reference 6). The pre-operational evaporative loss, $O_{Preop\text{-}Evap}$, is then determined as the sum of the values calculated directly by the thermal model for the ponds and those calculated for the side arms. Note that this time series has been estimated using the historical waste heat load from the existing units.

For predictive purposes, the evaporative losses associated with the existing units, which use once-through cooling systems, have been determined on a daily basis using the thermal model following the methodology described above. The calculated evaporation rates have been corrected to reflect a 93 percent plant capacity factor for the existing units and averaged to obtain weekly values for use in the water budget model. The corresponding waste heats loads are 1.26×10^{10} Btu per hour for the existing units combined.

Evaporative losses from the new units were determined as follows:

Evaporation rates from Unit 3's wet cooling towers were calculated on a daily basis as a function of air temperature and relative humidity, using performance data supplied by a cooling tower vendor, and a waste heat load of 1.03×10^{10} Btu/hour from the circulating and plant service water systems. Evaporation rates were determined for plant operation in the EC and MWC modes, as described in Section 3.4.1.1. In the EC mode, which applies when lake levels are at or above Elevation 250 ft msl, Unit 3's circulating water system wet cooling towers would be used to dissipate 100 percent of the waste heat from the main condenser. When lake levels fall below Elevation 250 ft msl for seven successive days, the plant is assumed to be operated in the MWC mode, wherein the dry towers would be used to dissipate a minimum of about one-third of the waste heat and the wet towers would be used to dissipate the remaining waste heat. For any given time step, the determination of whether Unit 3 would be in an EC or MWC mode of operation was made based on the lake elevation from the previous time step. The circulating water system cooling tower evaporation rates were combined with those from the service water cooling towers, corrected to reflect a 96 percent plant capacity factor for Unit 3, and averaged to obtain weekly values for use in the water budget model. The closed-cycle dry cooling systems of Unit 4 would introduce negligible additional evaporative losses.

5.2.2.1.3 Model Results

The water balance model described above has been used to predict releases from the North Anna Dam and water levels in Lake Anna on a weekly basis for the 24-year period extending from October 1, 1979, through April 10, 2003 considering the addition of Unit 3 as described above. For comparative purposes, the existing units running at a plant capacity factor of 93 percent, which exceeds their historical operating experience, have been simulated as well. An assumption inherent to this analysis is that the climatic conditions and variations during this historical period would be representative of future conditions. Figure 5.2-2 and Table 5.2-3 summarize the results for water releases from the North Anna Dam. Figure 5.2-3 and Table 5.2-4 summarize the results for Lake Anna water levels. The water releases used in the following analyses are determined by the computed lake level at the beginning of each model time step. The lake levels shown below correspond to the end of each time step. As a result of this difference, the percentage of time when the outflow is less than or equal to 20 cfs would be similar, but not necessarily identical, to the percentage of time when the lake level is less than or equal to 248 ft msl. A discussion of these results is provided below.

Table 5.2-3 Lake Anna Low Outflow Frequency

	Percent of Time Outflow is Less Than or Equal to Indicated Values	
Outflow (ft^3/s)	**Existing Units**	**Existing Units plus Unit 3**
100	50.6%	56.1%
80	48.2%	53.4%
60	46.5%	51.1%
40	44.6%	49.6%
20	5.2%	7.3%

Figure 5.2-2 illustrates the variation in the flow released from the North Anna Dam as a function of time for the 24-year period as simulated by the water balance model for the existing units, and the existing units with the addition of Unit 3. These results indicate that outflows from the dam vary seasonally and annually. Typically, flow rates are relatively high in the wetter fall and winter months due to the need to release water in order to maintain the normal pool elevation of 250 ft msl. Releases in the drier summer months are typically limited to the minimum releases required by the Lake Level Contingency Plan. With the onset of wetter conditions in the fall months, inflows to the lake increase, and releases typically increase above the minimum values. Exceptions to this pattern

would have occurred during the droughts of 1980–1981 and 2001–2002 during which the minimum release was maintained over the winter months due to diminished lake inflow.

Table 5.2-3 summarizes the outflow frequency for the low flows of interest. Results for the existing units indicate that water would have been released from the dam at a rate of 40 cfs or less for 44.6 percent of the time and at a rate of 20 cfs for 5.2 percent of the time. These frequencies increase with the increasing plant water needs associated with the addition of Unit 3 to 49.6 percent and 7.3 percent of the time, respectively.

Figure 5.2-3 illustrates the variation in Lake Anna water level as a function of time, as simulated by the water balance model for the two cases under consideration. These results indicate that the water level in Lake Anna varies seasonally and annually in response to climatic conditions. The typical seasonal pattern is as follows. Water levels are normally at their minimum values in October, the beginning of the water year. In response to runoff from fall and winter precipitation, water levels then normally increase to the normal operating pool level of 250 ft msl. This normal pool level is usually maintained over the winter months. With the reduction in precipitation beginning in April, decreased tributary inflows, and increased lake evaporation, water levels in the lake are typically drawn down during the summer months such that the maximum annual drawdown occurs near the end of the water year in September. The magnitude of the lake drawdown varies year to year in response to annual variations in surface water and groundwater inflow, which are caused by annual variations in climate conditions. In particular, the maximum annual drawdown during drought years, such as 1980–1981 and 2001–2002, is substantially greater than in other years.

Table 5.2-4 provides the water level frequency for the low water levels of interest to Lake Anna users and the minimum water level for the 24-year simulation period. These results demonstrate that the percent of time that the water level is less than or equal to a given elevation increases with the increasing plant cooling water needs associated with the addition of Unit 3. The results also indicate that the minimum water level for the simulation period decreases with increasing plant cooling water needs of Unit 3. The minimum water levels are above Elevation 242 ft msl, which is the minimum operating elevation specified in the Technical Requirements Manual for Units 1 and 2 (Reference 11) and the minimum operating elevation proposed for Units 3 and 4. The reduction in the lake level due to the future operation of Unit 3's cooling system would have negligible impact on the water temperature and evaporative loss from the lake. On a long-term basis, the average lake temperature has been estimated to increase less than 0.1°F. The corresponding lake evaporation has been estimated to have a small savings of the order of 0.1 cfs due to a reduction in natural evaporation from the reduced lake area. These variations are not expected to affect the results of the water use impact analysis.

Table 5.2-4 Lake Anna Low Water Level Frequency

	Percent of Time Water Level is Less Than or Equal to Indicated Values	
Elevation (ft msl)	**Existing Units**	**Existing Units plus Unit 3**
248	5.2%	7.0%
246	1.1%	1.4%
244	0%	0%
242	0%	0%
Minimum Water Level	245.1 feet	244.2 feet

5.2.2.2 Analysis and Evaluations of Impacts on Water Use

The results described in Section 5.2.2.1 indicate there would be water-use impacts associated with the operation of Unit 3. These impacts include reductions in the volume of water available for release from the North Anna Dam, which would decrease the volume of water available for downstream users. Impacts also include increases in lake drawdown during the summer months, which could impact other lake users. These impacts are analyzed and evaluated below. Section 5.2.2.1 indicates that the operation of Unit 4 would have no or negligible water-use impacts.

Results included in Figure 5.2-2 and Table 5.2-3 quantify the impact of the releases from the North Anna Dam that would occur with the addition of Unit 3. Given that the minimum releases would comply with the existing VPDES permit Lake Level Contingency Plan (Reference 2), there would be no impact on downstream water users in terms of the minimum flow rate in the North Anna River. The duration of the minimum flow release rates would increase with the addition of Unit 3, however. For the existing units, the duration for which the minimum release is less than or equal to 40 cfs would be 44.6 percent of the time; and the duration for which the minimum release is 20 cfs would be 5.2 percent of the time. Comparable durations with the addition of Unit 3 are 49.6 percent of the time for flows less than or equal to 40 cfs, and 7.3 percent of the time for a flow of 20 cfs. Potential impacts would be greatest in the reach of the North Anna River extending from below the North Anna Dam to its confluence with the South Anna River.

To better quantify impacts to instream flows in the North Anna River, Indicators of Hydrologic Alteration (IHA) have been calculated for the outflow from the North Anna Dam under both pre- and post-impact conditions, and the Range of Variability Approach (RVA) has been applied to assess hydrologic alteration. These analyses have been performed using the methodology proposed by Richter et al. (Reference 8, Reference 9, Reference 10), which calculates statistical descriptions of

the streamflow record and changes in these statistics for 33 hydrologic parameters. These parameters are organized into five groups that are intended to characterize the following:

- Magnitude of monthly water conditions
- Magnitude and duration of annual extreme water conditions
- Timing of annual extreme water conditions
- Frequency and duration of high and low pulses
- Rate and frequency of water condition changes

The IHA software package (Reference 11) has been used to perform the IHA and RVA analyses. The current release of the IHA software (Version 7) calculates some parameter values differently than those computed by earlier versions of the software. In particular, the monthly flow values determined for non-parametric analysis are now medians, whereas in previous versions of the software, these values were means. Any statistics subsequently derived from these sub-annual data also would be affected. The application of this methodology to the North Anna River and associated results are described below.

IHA were calculated for the Lake Anna weekly outflows as predicted by the water balance model described in Section 5.2.2.1. The period of record for this simulation includes water years 1979–2002 (24 years). Daily outflows, required as input to the IHA software package, were obtained through linear interpolation of the weekly time series. The pre-impact condition is defined to be Lake Anna in its current, impounded condition with the existing Units 1 and 2 utilizing the lake for condenser cooling. The post-impact condition assumes the addition of Unit 3 with a closed-cycle, dry and wet cooling tower system, and the addition of Unit 4 with a closed-cycle dry tower system. The heat dissipation system selected for Unit 4 will have negligible impacts to lake levels or outflows.

Results of the statistical analyses are summarized in Table 5.2-5, Table 5.2-6, and Table 5.2-7. Table 5.2-5 includes the 10 percent, 25 percent, 50 percent, 75 percent, and 90 percent quantiles for each of the 33 hydrologic parameters for pre- and post-impact conditions. Table 5.2-6 summarizes the results of the IHA analysis, provides the medians and coefficients of dispersion for each hydrologic parameter in a “scorecard” format, and quantifies changes in the IHA between the pre-impact and post-impact water regimes. Table 5.2-7 provides the results of the RVA analysis. In each of these tables, the IHA statistics have been calculated non-parametrically as recommended in the IHA User’s Manual (Reference 11). Note that post-impact period is assumed to extend from 2003–2026 for the purpose of comparing pre- and post-impact streamflow statistics. Also note that several IHA are associated with durations of less than 7 days (e.g., 1-day minimum flow). Because the daily outflows were obtained through linear interpolation of the weekly values, any of the IHA associated with durations of less than 7 days may not be representative.

The results in Table 5.2-5, Table 5.2-6, and Table 5.2-7 indicate that there are no changes in the median 7-day, 30-day, and 90-day minimum flows as a consequence of adding Unit 3. The results do indicate greater variability in the minimum flows with the addition of Unit 3. Results included in Table 5.2-5, Table 5.2-6, and Table 5.2-7 also demonstrate that the Julian date of the annual maximum does not change significantly with the addition of Unit 3.

Because of interest in striped bass spawning and early life stage rearing, the Pamunkey River flows in April and May at the Hanover gauge were analyzed for two-unit and three-unit operation. The low flow (5 percent occurrence frequency, as 7-day running average) was diminished from 207 to 206 cfs (0.5 percent difference), while the median flow was reduced from 851 cfs to 824 cfs (3 percent difference). Across all flows, the flow reduction ranged from 0.5 to 5 percent. Mandated minimum flows would be highly unlikely in April and May. This would indicate that the spring spawning regime in the North Anna River below the North Anna Dam would not be impacted by operation of a new Unit 3 on Lake Anna.

The Pamunkey River in the vicinity of striped bass spawning is accustomed to wide variations of freshwater inflow during April and May, as shown by the Hanover gage data. The variations of freshwater inflow in the spawning areas are attenuated, however, by the tidal flows in the freshwater tidal reach. There are wide temperature variations and considerable variation in timing of spawning episodes in the Pamunkey River (Reference 13). Thus, it would seem reasonable that the spawning fish or their developing eggs, larvae and early juveniles would not detect the small changes in freshwater inflow caused by 25 to 35 cfs reduction of North Anna flows. The adjacent Mattaponi River, with a considerably lower springtime average flow of 961 cfs, also has excellent striped bass spawning and early life rearing (Reference 12).

The abundance in rearing areas for juvenile striped bass is unlikely to be influenced by the changes in freshwater inflow on the order of 1–5 percent, especially when the dynamics of the estuary are largely governed by tidal flows. This conclusion is bolstered by recognition that the adjacent Mattaponi River, with much lower freshwater flow than the Pamunkey, is also a major striped bass spawning river.

Dominion concludes that there will be indistinguishable biological impacts to the general aquatic community of the North Anna River and the striped bass spawning and early rearing areas of the Pamunkey River from changes in flows from the additional evaporative water loss from a new Unit 3 that uses evaporative wet-dry cooling towers. Therefore impacts would be small.

Results presented in Figure 5.2-3 and Table 5.2-4 quantify the impact on lake levels that would occur with the addition of Unit 3. Figure 5.2-3 indicates that the maximum annual drawdown in most years would not differ greatly from the current operation of the existing units. This figure also shows that the minimum lake levels occur in the latter half of the calendar year. To further quantify the impact on lake levels associated with the addition of Unit 3, the minimum lake elevation for the latter half of each year in the 1978–2002 period simulated along with the date on which the minimum lake

elevation would have occurred have been summarized in Table 5.2-8. Data are provided for both pre-impact (existing units by themselves) and post-impact (existing units plus Unit 3) conditions. The last column in Table 5.2-8 represents the difference between post- and pre-impact minimum lake elevations for each year.

The Table 5.2-8 results indicate that annual minimum lake elevations under post-impact conditions are 0.01 to 0.89 feet lower than for pre-impact conditions, with this difference averaging 0.26 feet. The greatest difference occurs during drought years, such as those that occurred in 1981 (0.79 feet) and 2002 (0.89 feet). During non-drought years, the differences in minimum lake elevations are significantly less. The Table 5.2-8 results further indicate that the minimum lake elevation occurs most frequently in October for the existing units by themselves and for the existing units plus Unit 3 (9 out of 25 years in both cases). With respect to the recreational impact due to the additional drawdown from operation of Unit 3, the analysis of the effects in non-drought years shows that the overall impacts on the lake levels are relatively small, with the minimum lake levels averaging 248.6 ft msl (versus 248.9 ft currently), mainly in the fall months. Throughout the summer months, the lake levels would be higher than these minimum levels. Although the recreational use of the lake would still be high in the early fall, the greatest use would be during the summer months. Therefore, the impacts on the recreational use of the lake due to decreases in lake level during these non-drought years would be small.

Lake drawdown to Elevation 244.2 ft msl would not impact the existing units. The Technical Requirements Manual for the existing units requires plant shutdown when the lake level drops below Elevation 242 ft msl (Reference 7). Results included in Table 5.2-4 indicate that lake levels would not fall to Elevation 242 ft msl when Unit 3 is added.

No other water-use impacts on surface water or groundwater users due to the normal operation of a new unit or units at the ESP site are anticipated other than those described above.

5.2.2.3 **Analysis of Water-Quality Changes**

The primary impact on water quality from operating new units at the ESP site would be the discharge of cooling tower blowdown from Unit 3's wet cooling towers to the WHTF for return to the North Anna Reservoir. The cooling tower blowdown would contain elevated levels of dissolved solids, concentrated by evaporation, and various anti-fouling chemicals as described in Section 3.4.1.3.4. The blowdown would also add a small amount of waste heat to the WHTF. Section 5.3.2 details and quantifies the thermal and chemical impacts.

As presented in Section 5.2.1, Unit 4 would not add any waste heat to Lake Anna since there would be no blowdown discharges from its closed-cycle dry cooling tower system.

Other than the water-quality changes identified above, no other water-quality impacts on either surface-water or groundwater users would result from the normal operation of new units at the ESP site.

5.2.2.4 Proposed Practices to Minimize or Avoid Impacts

As described in Section 3.4.1.1, the closed-cycle, dry and wet tower cooling system for normal plant cooling of Unit 3 would be operated to conserve water when lake inflows are insufficient to maintain a pool level of 250 ft or above. When lake level falls below 250 ft msl and the level is not restored within a reasonable period of time, the cooling system could be operated in an MWC mode. The time period was assumed to be 7 days; however, the actual time frame would be established with State agencies at the time of permitting. In the MWC mode, only the dry tower would be used to dissipate the entire heat load from the surface condenser when the ambient dry bulb temperature is sufficiently low. When the ambient dry bulb temperature is above the temperature where the dry tower can reject the plant waste heat on its own, the necessary capacity of wet tower cells required to assist in the dissipation of condenser heat load would be placed in operation in series with the dry tower. The use of the MWC mode would reduce adverse impacts on lake levels and reservoir releases during sustained dry periods.

5.2.2.5 Compliance With Regulations Applicable to Water Use and Water Quality

The new units at the ESP site would comply with all regulations applicable to water use and water quality. Compliance would be demonstrated in the COL application. Modification of the existing units' VPDES permit (Reference 2) to include discharges from the new units would be required. See Section 5.3.4 for a discussion of potential chemical additives to cooling tower water. The discharge of heated water to the North Anna Reservoir via the WHTF would be subject to CWA Section 316(a) regulations which require that the thermal discharges assure the maintenance of a balanced, indigenous population of shellfish, fish, and wildlife in and on the receiving body of water. The withdrawal of cooling water from the North Anna Reservoir would meet Section 316(b) of the CWA and the implementing regulations, as applicable.

Section 5.2 References

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Table 5.2-5 IHA Percentile Data North Anna River

	Pre-Impact Period: 1979-2002 (24 years)						Post-Impact Period: 2003-2026 (24 years)					
	10%	25%	50%	75%	90%	(75-25)/50	10%	25%	50%	75%	90%	(75-25)/50
Parameter Group #1												
October	40	40	40	79	259	0.97	21	40	40	58	221	0.44
November	30	40	104	273	365	2.25	20	40	48	217	312	3.71
December	30	40	196	332	525	1.50	30	40	161	269	501	1.43
January	40	98	380	529	780	1.14	40	43	359	506	759	1.29
February	40	165	344	592	1147	1.24	40	140	321	570	1122	1.34
March	107	199	480	713	1256	1.07	93	173	455	687	1231	1.13
April	46	146	300	448	1111	1.01	40	119	274	422	1083	1.11
May	40	76	152	318	501	1.59	40	53	123	288	472	1.92
June	40	40	49	111	274	1.47	40	40	46	80	243	0.86
July	40	40	40	63	331	0.58	40	40	40	40	300	0.00
August	40	40	40	90	208	1.24	36	40	40	43	177	0.07
September	40	40	40	40	227	0.00	30	40	40	40	199	0.00
Parameter Group #2												
1-day minimum	30	40	40	40	40	0.00	20	25	40	40	40	0.38
3-day minimum	30	40	40	40	40	0.00	20	25	40	40	40	0.38
7-day minimum	30	40	40	40	40	0.00	20	25	40	40	40	0.38
30-day minimum	26	40	40	40	40	0.00	20	27	40	40	40	0.33
90-day minimum	27	40	40	49	94	0.23	20	27	40	42	77	0.36

Table 5.2-5 IHA Percentile Data North Anna River

	Pre-Impact Period: 1979-2002 (24 years)						Post-Impact Period: 2003-2026 (24 years)					
	10%	**25%**	**50%**	**75%**	**90%**	**(75-25)/50**	**10%**	**25%**	**50%**	**75%**	**90%**	**(75-25)/50**
1-day maximum	269	1086	1642	2846	3961	1.07	257	926	1615	2817	3936	1.17
3-day maximum	262	1042	1614	2534	3681	0.92	249	890	1588	2505	3656	1.02
7-day maximum	250	976	1572	2067	3240	0.69	236	853	1545	2038	3215	0.77
30-day maximum	202	601	873	1317	1650	0.82	187	570	847	1290	1626	0.85
90-day maximum	121	411	598	796	1168	0.64	104	381	572	769	1143	0.68
Number of zero days	0	0	0	0	0	0	0	0	0	0	0	0
Base flow	0.08	0.10	0.15	0.25	0.65	0.98	0.08	0.10	0.15	0.23	0.46	0.83
Parameter Group #3												
Date of minimum	165	275	275	275	288	0.00	205	275	275	275	284	0.00
Date of maximum	339	38	85	170	275	0.36	339	33	82	143	275	0.30
Parameter Group #4												
Low pulse count	0	0	0	0	1	0.00	0	0	0	0	1	0.00
Low pulse duration	55	55	204	352	352	1.46	27	34	76	304	373	3.55
High pulse count	0.5	3	4	6	8	0.75	1	3	4	6	8	0.69
High pulse duration	9	12	18	22	29	0.52	9	11	15	20	28	0.55

Table 5.2-5 IHA Percentile Data North Anna River

	Pre-Impact Period: 1979-2002 (24 years)						Post-Impact Period: 2003-2026 (24 years)					
	10%	**25%**	**50%**	**75%**	**90%**	**(75-25)/50**	**10%**	**25%**	**50%**	**75%**	**90%**	**(75-25)/50**
Parameter Group #5												
Rise rate	10.21	15.45	21.91	31.13	38.49	0.72	12.67	16.44	22.54	30.52	36.43	0.62
Fall rate	–35.83	–30.68	–14.76	–10.09	–6.36	–1.39	–35.82	–31.39	–16.18	–10.01	–4.48	–1.32
Number of reversals	3	14	19	21	25	0.41	3	13	16	21	24	0.48

Table 5.2-6 Non-Parametric IHA Scorecard, North Anna River

	Pre-impact period: 1979-2002 (24 years)	Post-impact period: 2003-2026 (24 years)
Watershed area	343	343
Mean annual flow	283	257
Mean flow/area	0.82	0.75
Annual C. V.	0.84	0.95
Flow predictability	0.45	0.45
Constancy/predictability	0.71	0.70
% of floods in 60d period	0.26	0.26
Flood-free season	3	3

(continued on next page)

Table 5.2-6 Non-Parametric IHA Scorecard, North Anna River

	Medians		Coeff. of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.V.	Medians	C.V.
Parameter Group #1								
October	40	40	0.97	0.44	0.00	0.54	0.00	0.74
November	104	48	2.25	3.71	0.54	0.65	0.73	0.48
December	196	161	1.50	1.43	0.18	0.05	0.66	0.88
January	380	359	1.14	1.29	0.06	0.14	0.76	0.69
February	344	321	1.24	1.34	0.07	0.08	0.91	0.83
March	480	455	1.07	1.13	0.05	0.06	0.83	0.88
April	300	274	1.01	1.11	0.09	0.10	0.78	0.84
May	152	123	1.59	1.92	0.19	0.21	0.49	0.52
June	49	46	1.47	0.86	0.04	0.42	0.99	0.33
July	40	40	0.58	0.00	0.00	1.00	0.00	0.20
August	40	40	1.24	0.07	0.00	0.94	0.00	0.55
September	40	40	0.00	0.00	0.00		0.00	0.00
Parameter Group #2								
1-day minimum	40	40	0.00	0.38	0.00		0.00	0.00
3-day minimum	40	40	0.00	0.38	0.00		0.00	0.00
7-day minimum	40	40	0.00	0.38	0.00		0.00	0.00
30-day minimum	40	40	0.00	0.33	0.00		0.00	0.00
90-day minimum	40	40	0.23	0.36	0.00	0.57	0.01	0.59
1-day maximum	1642	1615	1.07	1.17	0.02	0.09	0.96	0.79
3-day maximum	1614	1588	0.92	1.02	0.02	0.10	0.94	0.77
7-day maximum	1572	1545	0.69	0.77	0.02	0.11	0.85	0.81
30-day maximum	873	847	0.82	0.85	0.03	0.04	0.78	0.90
90-day maximum	598	572	0.64	0.68	0.04	0.05	0.60	0.92
Number of zero days	0	0	0.00	0.00			0.00	0.00
Base flow	0.15	0.15	0.98	0.83	0.02	0.15	0.96	0.76

Table 5.2-6 Non-Parametric IHA Scorecard, North Anna River

	Medians		Coeff. of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.V.	Medians	C.V.
Parameter Group #3								
Date of minimum	275	275	0.00	0.00	0.00		0.00	0.00
Date of maximum	85	82	0.36	0.30	0.02	0.16	0.72	0.82
Parameter Group #4								
Low pulse count	0	0	0.00	0.00			0.00	0.00
Low pulse duration	204	76	1.46	3.55	0.63	1.43	0.75	0.09
High pulse count	4	4	0.75	0.69	0.00	0.08	0.47	0.79
High pulse duration	18	15	0.52	0.55	0.16	0.06	0.38	0.87
The low pulse threshold is 40								
The high pulse level is 348								
Parameter Group #5								
Rise rate	21.91	22.54	0.72	0.62	0.03	0.13	0.84	0.61
Fall rate	–14.76	–16.18	–1.39	–1.32	0.10	0.05	0.83	0.89
Number of reversals	19	16	0.41	0.48	0.16	0.19	0.37	0.53

Table 5.2-7 IHA Non-Parametric RVA Scorecard, North Anna River

	Pre-impact period: 1979-2002				Post-impact period: 2003-2026				RVA Categories		Hydrologic Alteration (Middle Category)
	Medians	Coeff. Disper-sion	Range Limits		Medians	Coeff. Disper-sion	Range Limits		RVA Categories		Hydrologic Alteration (Middle Category)
			Min	Max			Min	Max	Low	High	
Parameter Group #1											
October	40	0.97	34	290	40	0.44	20	255	40	40	-0.13
November	104	2.25	20	702	48	3.71	20	675	40	233	0.14
December	196	1.50	20	658	161	1.43	20	634	45	259	0.13
January	380	1.14	20	836	359	1.29	20	812	151	465	0.00
February	344	1.24	20	2688	321	1.34	20	2664	241	485	0.13
March	480	1.07	20	1353	455	1.13	20	1328	271	644	0.25
April	300	1.01	20	1388	274	1.11	20	1360	172	388	0.25
May	152	1.59	20	648	123	1.92	20	618	92	255	0.00
June	49	1.47	20	561	46	0.86	20	531	40	104	0.27
July	40	0.58	20	486	40	0.00	20	455	40	43	0.20
August	40	1.24	20	331	40	0.07	20	318	40	40	–0.06
September	40	0.00	20	483	40	0.00	20	454	40	40	–0.06
Parameter Group #2											
1-day minimum	40	0.00	20	40	40	0.38	20	40	40	40	–0.18
3-day minimum	40	0.00	20	40	40	0.38	20	40	40	40	–0.18
7-day minimum	40	0.00	20	40	40	0.38	20	40	40	40	–0.18
30-day minimum	40	0.00	20	173	40	0.33	20	145	40	40	–0.25

Table 5.2-7 IHA Non-Parametric RVA Scorecard, North Anna River

	Pre-impact period: 1979-2002				Post-impact period: 2003-2026				RVA Categories		Hydrologic Alteration (Middle Category)
	Medians	Coeff. Disper-sion	Range Limits		Medians	Coeff. Disper-sion	Range Limits		RVA Categories		Hydrologic Alteration (Middle Category)
			Min	Max			Min	Max	Low	High	
90-day minimum	40	0.23	20	270	40	0.36	20	240	40	42	–0.08
1-day maximum	1642	1.07	40	4756	1615	1.17	20	4733	1283	2376	–0.13
3-day maximum	1614	0.92	40	4692	1588	1.02	20	4669	1233	2219	0.00
7-day maximum	1572	0.69	40	4577	1545	0.77	20	4554	1136	1930	0.13
30-day maximum	873	0.82	40	3432	847	0.85	20	3408	657	1185	0.00
90-day maximum	598	0.64	40	1931	572	0.68	20	1906	449	679	0.00
Number of zero days	0	0	0	0	0	0	0	0	0	0	0
Base flow	0.15	0.98	0.07	1.00	0.15	0.83	0.04	1.00	0.12	0.20	0.25
Parameter Group #3											
Date of minimum	275	0	153	313	275	0	153	292	275	275	0.00
Date of maximum	85	0.36	13	343	82	0.30	13	343	81	218	0.00
Parameter Group #4											
Low Pulse Count	0	0.00	0	1	0	0.00	0	2	0	0	–0.09
Low Pulse Duration	204	1.46	55	352	76	3.55	27	373	55	352	0.00
High Pulse Count	4	0.75	0	10	4	0.69	0	9	3	6	0.18
High Pulse Duration	18	0.52	5	36	15	0.55	4	36	13	18	0.00
The low pulse threshold is 40											

Table 5.2-7 IHA Non-Parametric RVA Scorecard, North Anna River

	Pre-impact period: 1979-2002				Post-impact period: 2003-2026				RVA Categories		Hydrologic Alteration (Middle Category)
	Medians	Coeff. Disper-sion	Range Limits		Medians	Coeff. Disper-sion	Range Limits		Low	High	
			Min	Max			Min	Max			
The high pulse level is 348											
Parameter Group #5											
Rise rate	21.91	0.72	4.38	47.15	22.54	0.62	2.86	57.71	16.08	28.33	0.22
Fall rate	–14.76	–1.39	–36.47	–2.86	–16.18	–1.32	–37.78	–2.86	–24.11	–10.90	0.11
Number of reversals	19	0.41	0	25	16	0.48	0	24	15	21	–0.08

Table 5.2-7 IHA Non-Parametric RVA Scorecard, North Anna River

	Assessment of Hydrologic Alteration								
	Middle RVA Category			High RVA Category			Low RVA Category		
	Expected	Observed	Alter.	Expected	Observed	Alter.	Expected	Observed	Alter.
Parameter Group #1									
October	16	14	-0.13	7	6	–0.14	1	4	3.00
November	14	16	0.14	8	5	–0.38	2	3	0.50
December	8	9	0.13	8	6	–0.25	8	9	0.13
January	8	8	0.00	8	7	–0.13	8	9	0.13
February	8	9	0.13	8	7	–0.13	8	8	0.00
March	8	10	0.25	8	6	–0.25	8	8	0.00
April	8	10	0.25	8	6	–0.25	8	8	0.00
May	8	8	0.00	8	7	–0.13	8	9	0.13
June	15	19	0.27	8	4	–0.50	1	1	0.00
July	15	18	0.20	8	5	–0.38	1	1	0.00
August	16	15	–0.06	7	7	0.00	1	2	1.00
September	18	17	–0.06	5	5	0.00	1	2	1.00
Parameter Group #2									
1-day minimum	22	18	–0.18	0	0	0.00	2	6	2.00
3-day minimum	22	18	–0.18	0	0	0.00	2	6	2.00
7-day minimum	22	18	–0.18	0	0	0.00	2	6	2.00
30-day minimum	20	15	–0.25	1	1	0.00	3	8	1.67

Table 5.2-7 IHA Non-Parametric RVA Scorecard, North Anna River

	Assessment of Hydrologic Alteration								
	Middle RVA Category			High RVA Category			Low RVA Category		
	Expected	Observed	Alter.	Expected	Observed	Alter.	Expected	Observed	Alter.
90-day minimum	12	11	–0.08	8	6	–0.25	4	7	0.75
1-day maximum	8	7	–0.13	8	8	0.00	8	9	0.13
3-day maximum	8	8	0.00	8	7	–0.13	8	9	0.13
7-day maximum	8	9	0.13	8	7	–0.13	8	8	0.00
30-day maximum	8	8	0.00	8	7	–0.13	8	9	0.13
90-day maximum	8	8	0.00	8	7	–0.13	8	9	0.13
Number of zero days	24	24	0.00	0	0	0.00	0	0	0.00
Base flow	8	10	0.25	8	7	–0.13	8	7	–0.13
Parameter Group #3									
Date of minimum	17	17	0.00	4	3	–0.25	3	4	0.33
Date of maximum	8	8	0.00	8	7	–0.13	8	9	0.13
Parameter Group #4									
Low Pulse Count	22	20	–0.09	2	4	1.00	0	0	0.00
Low Pulse Duration	2	2	0.00	22	1	–0.95	0	1	0.00
High Pulse Count	11	13	0.18	8	6	–0.25	5	5	0.00
High Pulse Duration	9	9	0.00	9	6	–0.33	6	7	0.17

Table 5.2-7 IHA Non-Parametric RVA Scorecard, North Anna River

	Assessment of Hydrologic Alteration								
	Middle RVA Category			High RVA Category			Low RVA Category		
	Expected	Observed	Alter.	Expected	Observed	Alter.	Expected	Observed	Alter.
	Parameter Group #5								
Rise rate	9	11	0.22	8	7	–0.13	7	4	–0.43
Fall rate	9	10	0.11	8	6	–0.25	7	7	0.00
Number of reversals	13	12	–0.08	5	4	–0.20	6	8	0.33

Table 5.2-8 Minimum Lake Elevation for the Latter Half of Years 1978–2002

Year[a]	Existing Units		Existing Units + Unit 3		Difference in Minimum Lake Elevation (ft)
	Minimum Lake Elevation (ft MSL)	Date of Minimum Lake Elevation	Minimum Lake Elevation (ft MSL)	Date of Minimum Lake Elevation	
1978	248.44	11/05/1978	248.43	11/05/1978	–0.01
1979	250.07	07/29/1979	249.95	07/29/1979	–0.12
1980	248.48	10/26/1980	248.07	10/26/1980	–0.41
1981	248.04	10/11/1981	247.25	10/11/1981	–0.79
1982	249.48	10/10/1982	249.36	10/10/1982	–0.12
1983	248.56	10/02/1983	248.27	10/02/1983	–0.29
1984	249.87	09/16/1984	249.78	09/16/1984	–0.09
1985	249.64	08/04/1985	249.44	08/04/1985	–0.19
1986	248.69	10/12/1986	248.27	10/19/1986	–0.42
1987	248.99	08/23/1987	248.68	08/23/1987	–0.30
1988	248.87	10/23/1988	248.65	10/23/1988	–0.22
1989	249.94	08/27/1989	249.87	08/27/1989	-0.07
1990	249.67	09/30/1990	249.49	09/30/1990	-0.18
1991	248.83	11/10/1991	248.66	11/10/1991	–0.17
1992	249.63	09/13/1992	249.49	10/18/1992	–0.14
1993	248.33	11/14/1993	248.01	11/14/1993	–0.32
1994	249.91	10/02/1994	249.84	07/03/1994	-0.07
1995	249.27	09/17/1995	249.08	09/17/1995	–0.19
1996	250.04	09/22/1996	250.01	09/22/1996	–0.03
1997	249.31	10/05/1997	248.95	10/05/1997	–0.36
1998	247.81	11/22/1998	247.56	12/20/1998	–0.25
1999	248.34	08/15/1999	248.01	08/22/1999	–0.33
2000	249.48	11/12/2000	249.25	11/12/2000	-0.23
2001	247.33	12/30/2001	247.04	12/30/2001	–0.28
2002	245.06	10/13/2002	244.17	10/13/2002	-0.89

a. Minimum lake elevations identified from July-December period of each year to ensure independence of events.

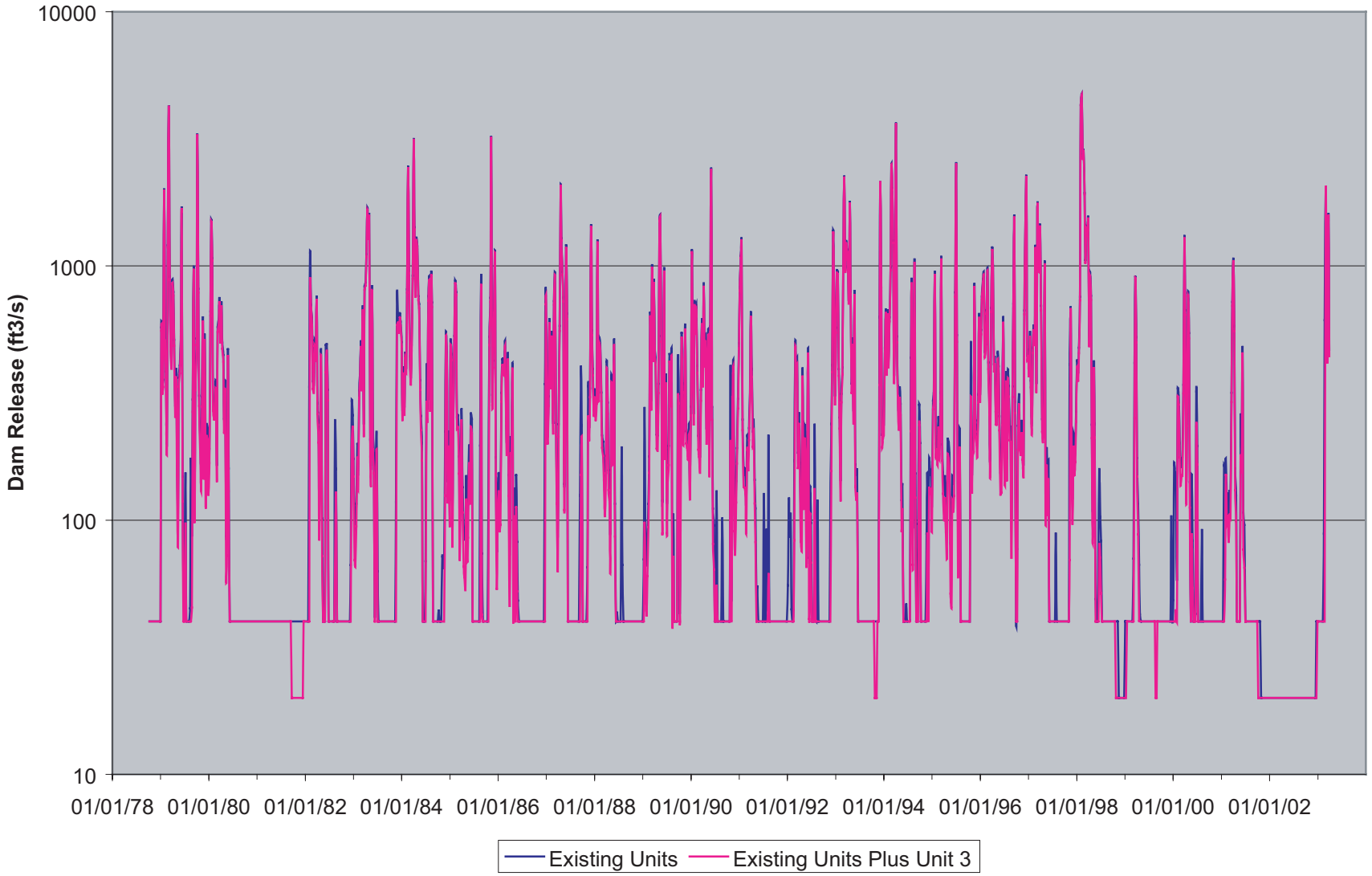

Figure 5.2-2 Lake Anna Outflow Hydrographs

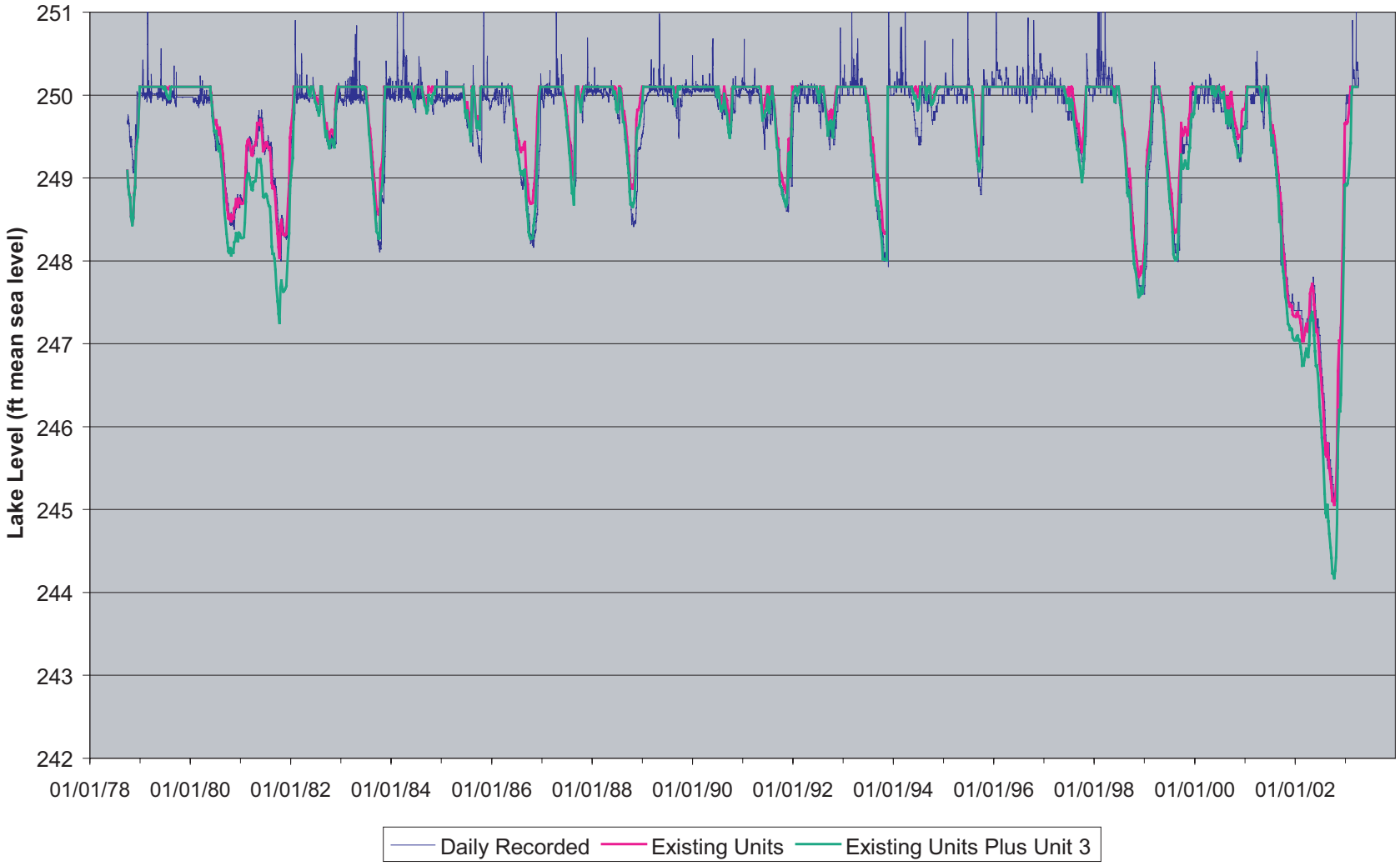

Figure 5.2-3 Lake Anna Water Level Hydrographs

5.3 Cooling System Impacts

This section discusses the impacts on Lake Anna of the cooling systems associated with operation of new units at the ESP site. As described in Section 3.3, and Section 3.4, the lake would be the main source of cooling water make-up for the new units.

For normal plant operation, Unit 3 would use a closed-cycle, combination dry and wet cooling tower system for the circulating water system and closed-cycle wet towers for the service water system, both with cooling water make-up supply from the lake. Unit 4 would use closed-cycle dry cooling towers for the circulating water system and for the service water system cooling during normal plant operation. As presented in Section 3.4.1.1, there would be negligible impacts to Lake Anna from the closed-cycle dry cooling tower systems that would be used for Unit 4. For those reactor designs that require an UHS, safety-related cooling would be provided by mechanical draft cooling towers. Those cooling towers would have a separate basin to provide a minimum 30-day water supply. The lake would provide make-up to this 30-day storage basin as necessary. Make-up water would be withdrawn from the North Anna Reservoir through a new intake structure located in a cove adjacent to the intake structure for the existing units. All cooling system discharges for the new units, including the UHS tower blowdown, would be sent to the WHTF via a new outfall at the head of the existing discharge canal.

The different aspects of cooling system impacts are addressed separately in the following sections:

- Intake system
- Discharge system
- Heat-discharge system
- Impacts to members of the public

5.3.1 Intake System

This section describes the impacts of the intake system for the new units, including the physical impacts of the projected hydrodynamic condition induced by the new intake flow and the potential impacts on the aquatic community of Lake Anna.

As described in Section 3.4.2, the new units' intake system would consist of an intake structure at the end of an approach channel located in a cove on the south shore of the North Anna Reservoir near Harris Creek. The area that would be occupied by this intake system, originally planned for the intake of the abandoned Units 3 and 4, is adjacent to the cove that houses the intake structure for the existing units.

During normal plant operation, the new intake would supply make-up water at a maximum flow rate of 2.23×10^4 gpm (49.6 cfs) to the Unit 3 closed-cycle wet cooling towers, and up to 1 gpm (0.002 cfs) of make-up water to the Unit 4 closed-cycle dry cooling towers. The new intake structure

would also supply lake water as make-up water to the underground storage basins of the UHS cooling towers.

Other water use for the new units, including demineralized water and fire protection water, would be supplied through the new intake structure as well. According to Section 3.3.1, the total of the maximum incidental plant water usage would be an additional 4920 gpm (11 cfs) of intermittent intake flow per each new unit. The new intake structure would be equipped with screen wash pumps that would withdraw up to 1.1 cfs per unit of lake water to clean the traveling water screens. The screen wash flow would be returned back to the intake upstream of the traveling water screens after cleaning and would result in no water loss.

5.3.1.1 Hydrodynamic Descriptions and Physical Impacts

The intake hydrodynamics and the potential alteration of the ambient flow field induced by the intake system operation are presented in this section. The physical hydrological impacts to the lake during operation of the new units, including shoreline erosion, bottom scouring, induced turbidity and silt buildup, have been assessed. Unless site-specific data are available, bounding parameters from the Generic PPE are used to characterize the cooling water flow and other plant water uses for the new units. As demonstrated in the following analysis, adverse impacts would be small. This section also identifies and evaluates design considerations, engineering practices, and operating procedures that would increase stability of the shore and lakebed.

Currently, the North Anna Reservoir is the principal water source for the existing units, providing circulating water for the once-through cooling system and other plant water needs during normal plant operation. Up to 4310 cfs of lake water is withdrawn from an existing intake structure located on the south shore of the North Anna Reservoir in a cove about 5 miles upstream of the dam (Reference 1). Of the 4310 cfs withdrawn, a maximum flow of 4246 cfs is used for the normal plant cooling of the existing units and is discharged at an elevated temperature to the WHTF via a common outfall at the head of the discharge canal. The remaining 64 cfs is for incidental plant use.

As described in Section 3.3 and Section 3.4, the North Anna Reservoir would also be a main source of cooling water make-up for Unit 3 during normal station operation. Unit 4 plant cooling would be provided by dry cooling towers, which require no or a negligible amount of make-up water.

The lake would also provide make-up water to maintain the separate 30-day supply of emergency cooling water needed for the UHS for both new units, as presented in Section 3.4.2. However, during any shutdown requiring the UHS, no cooling or make-up water from the lake would be needed for any of the affected reactors to reach safe shutdown.

The new intake system would consist of a compartmented intake structure with a common screenwell, separate pump bays dedicated to each unit, and an approach channel in the cove adjacent to the intake for the existing units. During normal plant operation, the new intake system would supply up to 49.6 cfs of cooling water make-up to the Unit 3 closed-cycle wet cooling towers

and zero to 0.002 cfs of make-up water to the Unit 4 closed-cycle dry cooling towers. Additional plant water needs of up to 2.5 cfs (during normal conditions), 11 cfs (during upset or abnormal conditions) for each new unit, including water to supply the demineralized water system, fire protection water, and the make-up water for the 30-day storage of UHS cooling tower, would also be withdrawn from the lake through the new intake structure. An additional 1.1 cfs of screen wash water per new unit would be withdrawn from the intake but would be returned back to the intake flow upstream of the traveling water screens, resulting in zero net water use. These incidental plant water needs would be intermittent and small compared to the once-through cooling water flow of the existing units. They would have no adverse physical impact to the lake.

At the downstream end of the plant cooling system, a new outfall would discharge up to 12.4 cfs of blowdown effluent from the Unit 3 wet towers. The Unit 4 closed-cycle dry cooling towers would have no blowdown discharges. Other permitted plant discharges, including discharges from the demineralized water and sanitary waste systems, would be released to the new outfall, but their volume would be small and would have no physical impact on the lake. The new outfall structure would be next to the outfall of the existing units at the head of the discharge canal in the WHTF. From the discharge canal, the Unit 3 cooling tower blowdown and the cooling water discharge from the existing units would flow through the WHTF's various canals, ponds, and side-arms to dissipate heat, and would eventually re-enter the North Anna Reservoir at Dike 3 via six adjustable, submerged skimmerwall gates. The physical impacts of the operation of the discharge system are presented in Section 5.3.2.1.

5.3.1.1.1 Lake Hydrologic Characteristics

Section 2.3.1 describes the hydrologic characteristics of the Lake Anna watershed and the impoundment that was created by the construction of the North Anna Dam. Figure 5.3-1 is a map of Lake Anna showing the upper lake, mid-lake and lower lake reaches of the North Anna Reservoir, the WHTF, as well as the relative location of the existing station intake, the new intake, and the discharge canal.

Lake Anna is about 17 miles long with a shoreline length of approximately 272 miles. At the normal operating lake level of 250 ft msl, the reservoir and the WHTF have a combined volume of about 305,000 acre-feet and a surface area of approximately 13,000 acres. The watershed area above the dam draining into Lake Anna is 343 square miles. Based on the water budget analysis described in Section 5.2.1, the long-term average inflow to the lake including surface water runoff, direct precipitation, and ground water flow is estimated to be about 369 cfs. The average outflow at the dam varies, depending on various water uses on the lake, including water loss due to evaporation. The outflow is estimated to be about 276 cfs during the operation of the existing units.

The hydrologic characteristics of the North Anna Reservoir gradually change from riverine upstream to lacustrine downstream. The upper lake is primarily riverine, shallow (average depth of 4 m (13 ft)) and slightly stratified in summer. The mid-lake is more lacustrine and stratified. The

lower lake is deeper (average depth of 11 m (36 ft)) and displays lacustrine characteristics (e.g., more vertical gradients of light, temperature, and decomposition). Both the lower lake and mid-lake reaches tend to be stratified in summer and mixed in winter. (Reference 2)

Because the additional waste heat from the new units discharged to the North Anna Reservoir through the WHTF would be very small, there would be no perceptible impact on the temperature or stratification in Lake Anna as discussed in Section 5.3.2.1.

According to the Lake Anna Special Area Plan (Reference 3), the primary cause of lakeshore erosion is wave action induced by wind and wakes from boats. The additional units would have no impact on lakeshore erosion due to the small intake and discharge flow rates associated with their proposed operation.

5.3.1.1.2 Intake Hydrodynamics and Physical Impacts

The hydrodynamics of the North Anna Reservoir are different from those of most other lakes and reservoirs, in that during station operation, the mid-lake and lower lake reaches, where the intakes and the Dike 3 skimmer gates are located, have a circulation pattern induced by the plant circulating water flow. Most of the cooling water from the existing plant, which discharges at a rate of up to 4246 cfs into the reservoir via Dike 3, is drawn uplake by the cooling water and service water pumps in the existing intake structure. Since the circulating water flow is very large compared to the average inflows to the lake and the average release flow at the dam, the plant's cooling system flow dominates the circulation in the lake except during periods of high inflows from the tributaries upstream.

As shown in Figure 5.3-1, the width of the reservoir perpendicular to the main flow direction varies from less than 1600 feet near Dike 1 to over 7000 feet near Dike 2 in the lower lake reach. With a typical epilimnion thickness of 26 feet to 33 feet in the lower lake region during the operation of the existing units (Reference 2), the induced surface current is estimated to be flowing in a general uplake direction at 0.1 fps or less on the average during the normal lake level of 250 ft msl. The colder return flow from the upper lake toward the dam occurs in the lower part of the water column (the hypolimnion) and is predicted to have a lower velocity. A conservative estimate has been made based on the assumption that the return flow would be the same as the total inflows to the lake. In the lower lake reach upstream of the Dike 3 discharge, the velocity of the bottom current is predicted to be less than 0.1 fps on a long-term average basis. The flow near Dike 3 is more complicated and is dominated by the mixing process at the skimmer gates. The outfall hydrodynamics and the physical impacts to the lake are presented in Section 5.3.2.1. With operation of the new units, the additional blowdown discharge of 12.4 cfs from Unit 3 flowing through Dike 3 to the reservoir would not have any measurable impact on the lake hydrodynamics. Operation of the new intake system would not increase the lake current by any detectable extent and would have no adverse impact on the scouring of the lakebed or erosion of the shoreline.

Water quality parameters in the lake and the WHTF were measured as part of the 316(a) demonstration study for the existing units (Reference 2). Measured turbidity levels were reported as generally low, except during periods of heavy inflows from the tributary streams. According to the 316(a) demonstration study, the mean annual turbidities from 1981 to 1986 ranged from 6 to 10 NTUs in the upper lake, and 2 to 5 NTUs in the lower lake reaches. Most of the turbidity measurements greater than 15 NTUs were taken in February, March, and April, months with higher runoff. The combined operations of the existing and new units would not increase turbidity in the lake.

The intake channel for the existing units has a bottom width of approximately 320 feet at the mouth of the cove opening to the North Anna Reservoir, and narrows down to 185 feet wide just in front of the screen well. The channel banks have a typical side slope of 3:1 (horizontal to vertical) and the bottom of the channel has been dredged to Elevation 220 ft msl. At a proposed minimum operating lake level of Elevation 242 ft msl and the existing intake flow rate of up to 4310 cfs, the flow velocity in the channel is estimated to be about 0.5 fps at the mouth to less than 1 fps at the approach to the screen well. At the normal lake level of 250 ft msl, the velocity in the existing channel is slightly lower, in the range of 0.3 fps to 0.8 fps. The approach channel of the new intake would have a bottom width that varies from approximately 300 feet near the mouth to 230 feet upstream of the screen well and pump house. As shown in Figure 5.3-2, the channel bottom is at approximately Elevation 220 ft msl and the channel banks have a side slope of about 3:1 (horizontal to vertical). At the proposed minimum lake operating level of Elevation 242 ft msl, the flow velocity in the channel would be about 0.01 fps, based on the maximum combined intake flow of 72 cfs (which includes 49.6 cfs of cooling water make-up for Unit 3, 0.002 cfs of cooling water make-up potentially required for Unit 4, and 11 cfs of miscellaneous plant water uses per new unit for upset or abnormal conditions) for the new units. At the normal operating lake level of 250 ft msl, the velocity in the approach channel to the new intake would be further reduced. Because there is no indication of scour or erosion at the existing intake, and because the new units would have lower approach velocities than the existing units, neither intake channel is expected to have any scouring and erosion concerns on the bottom or shoreline. In the event that a partial opening, instead of a full opening, would be constructed at the cofferdam to connect the reservoir and the approach channel to the new intake, the flow velocity at the opening would be designed to be no greater than 0.1 fps, similar to the average current velocity in the reservoir, to reduce impact to the lake hydrodynamics and entrainment of debris, aquatic life, and sediment.

Lake Anna in general does not have a sediment problem. Siltation in the approach channel to the new intake would not be a concern during normal lake conditions as the coarse and medium sediment would settle out in the reservoir where the current velocity is typically small, on the order of 0.1 fps or less. Sediment could come into the approach channel during floods and deposit there due to the low channel velocity. Operation of the new intake, however, would not be affected because the channel bottom is 12 feet deeper than the design invert of the new intake, allowing

room for occasional sediment deposition and buildup. Any suspended sediment entrained into the intake structure would remain in suspension as the flow velocity increased downstream of the screen well and pump house, and would either be filtered out during the water treatment process or carried through the plant cooling system and discharged to the WHTF.

The banks of the approach channels to the new intake and the existing intake are stabilized with riprap to protect against erosion due to wind waves. Any areas that would be disturbed during construction of the new intake would be stabilized in a similar fashion. The design approach velocity to the traveling water screens and trash racks would be less than 1.0 fps at the lowest estimated operating lake level of 242 ft msl, and would enhance the performance of the debris filtering system and create a non-eroding environment. The new intake structure would have a sill at the entrance to avoid the entrainment of bed sediment into the screen well and pump house. Regular maintenance dredging during operation of the new units would not be necessary.

Section 5.3.1.2 discusses in further detail the impact of the operation of the intake system on the aquatic ecosystem of the lake.

5.3.1.2 **Aquatic Ecosystems**

Cooling water intake systems (CWIS) can potentially impact aquatic communities by either impingement or entrainment. The first mechanism by which a CWIS may adversely impact aquatic organisms is through impingement. Traveling screens in the front of the cooling water pumps filter the water and provide protection to the cooling water pumps from damage and clogging. Impingement occurs when swimming organisms are not strong enough to escape the cooling water intake flow and are driven into the screens (i.e., impinged). Impinged organisms are generally fish, but can include other semi-aquatic animals such as amphibians (e.g., frogs and salamanders), waterfowl (e.g., ducks and coots), or mammals (e.g., muskrats). The screens are periodically cleaned using a spray wash system from which the impinged organisms are collected and disposed.

The second mechanism that may cause adverse impact is entrainment (i.e., the intake of organisms into the cooling water system). Entrained organisms are generally small in size and include phytoplankton, zooplankton, and fish eggs and larvae. As these entrained organisms pass through the cooling water system, they are subjected to stresses that may result in mortality. Impacts to the entrained organisms include physical damage from contact with pumps, pipes, and condensers; pressure damage from passage through pumps; shear damage from complex water flows; thermal damage from elevated temperatures in the condenser passage; and toxicity damage from the addition of chemicals to the cooling water system.

In May 1985, Virginia Power published *Impingement and Entrainment Studies for North Anna Power Station, 1978-1983* (Reference 4). This study was conducted in accordance with Section 316(b) and in compliance with the NAPS Environmental Technical Specifications and the existing VPDES Permit under Special Conditions: Environmental Studies. The objective of the study

was to examine the effects of impingement and entrainment at the CWIS and determine if they adversely affect the fish populations in Lake Anna.

When the existing units are operating, there is a maximum total withdrawal capacity of 1,934,300 gpm, or about 2.8 percent of the total Lake Anna volume per day (305,000 acre-feet at 250 ft msl). In addition, the existing units operate in a once-through mode and all water withdrawn is returned to the lake, but at a higher temperature. Each unit uses four circulating water pumps to withdraw condenser cooling water from Lake Anna. The cooling water is withdrawn through two screenwells (one for each unit) located in a cove north of the station (see Figure 5.3-1). Each screenwell contains four individual bays and each bay is equipped with a trash rack, a traveling screen, and a vertical, motor-driven, circulating water pump. The trash racks consist of 1.3 centimeters (cm) wide by 8.9 cm thick vertical bars spaced 10.2 cm on center. The flow through the trash racks is about 0.2 meters per second (0.69 fps) (Reference 4). The traveling screens, constructed of 14-gauge wire with 9.5 mm square openings, are designed to rotate once every 24 hours or whenever a predetermined pressure differential exists across the screens. Debris collected at the trash racks is removed by mechanical rakes and collected in hoppers that discharge the debris into wire baskets. Debris and fish collected in the wire baskets are disposed of as solid waste (Reference 4). The existing units also withdraw a small volume of water for a variety of other uses (e.g., backup service water, bearing cooling; Section 3.3.1). These additional uses contribute less than 3 percent of the total water withdrawal and are included in the total withdrawal capacity presented earlier.

5.3.1.2.1 Impingement

Impingement studies were conducted at NAPS from April 1978 through December 1983 in compliance with Section 316(b) of the CWA (Reference 4). An average of just over 47,400 fish representing 34 species was collected annually during each full year of the study. 1978 was not included because sampling was not conducted for the entire year (Reference 4).

For each sample collection the screens were washed to ensure that all fish were removed. The fish were washed into a catch basket at the end of a sluiceway and were removed and transported to the laboratory. Decayed fish that obviously had been dead for longer than 24 hours were excluded from the impingement sample. In the laboratory, up to 50 individuals of each species were measured and weighed. Those species numbering over 50 were counted and weighed in bulk (Reference 4).

To determine the total estimated number of fish impinged over a given time period, daily impingement values (number per gallon withdrawn) were multiplied by the average volume of intake cooling water withdrawn on that sample day, which provides the number of fish impinged per day per gallon of water withdrawn. Period estimates were computed using daily estimates and the number of days in each period. Totaling period estimates by species results in estimates of total fish impinged by month; yearly estimates are the sum of the months.

Six species accounted for 99 percent of all fish impinged during the study. The most commonly impinged fish were gizzard shad (61 percent), followed by black crappie (16 percent), yellow perch (16 percent), bluegill (4 percent), white perch (1 percent), and striped bass (1 percent). No other species comprised more than 1.0 percent of the total number impinged (Reference 4). Based on the estimation process outlined above, an average of 182,000 fish was impinged each year from 1979 through 1983 (Table 5.3-1), 114,000 of which were gizzard shad. These impingement estimates represent a maximum number based on the withdrawal capacity for the existing units on the specific sample collection date. A comparison of impingement numbers to standing crop estimates based on cove rotenone data from Lake Anna indicates that the percentage of the fish population affected by impingement is very low. Gizzard shad impingement losses represent 0.38 percent by number and 0.32 percent by weight of the total standing crop for Lake Anna. For black crappie, the percentages were 3.1 percent by number and 3.8 percent by weight. Values for all other species were 1.4 percent or less (Reference 4).

Table 5.3-1 Mean Number of Representative Important Fish Species Estimated Impinged per Month at the Existing Units from 1979–1983

Month	Striped Bass	Black Crappie	Bluegill	Gizzard Shad	White Perch	Yellow Perch	Total All Species
January	213	929	134	14,600	92	44	16,012
February	265	2,360	235	26,459	162	1,392	30,873
March	381	9,734	465	58,314	625	24,436	93,955
April	87	4,347	636	8,407	471	1,754	15,702
May	10	1,643	630	1,607	390	84	4,364
June	0	480	839	57	135	49	1,560
July	0	372	392	67	164	39	1,034
August	3	426	985	84	159	23	1,680
September	12	845	644	485	161	19	2,166
October	30	3,449	574	236	160	5	4,454
November	357	2,143	1,944	714	176	26	5,360
December	682	1,211	293	2,827	231	36	5,280
Yearly Totals	2,040	27,939	7,771	113,857	2,926	27,907	182,440

Source: Reference 4.

During the study period, total impingement rates declined; the decline appeared to be associated with the reduction in gizzard shad impingement after 1979. On a yearly basis, the majority of the

fish impinged were gizzard shad during 1979, 1981, and 1983. However, black crappie were impinged most often in 1980 and 1982 (Reference 4). Most fish were impinged during the winter (75 percent, January–March), followed by spring (13 percent, April-June), fall (9 percent, October–December), and summer (3 percent, July–September). Lower water temperatures during the winter months tend to make fishes lethargic and thus more susceptible to impingement. During 1979, gizzard shad accounted for over 78 percent of the impingement total: 64 percent of these shad (290,000) were impinged between February 20 and March 20. This large gizzard shad impingement occurred when water temperature (1.18°C, February 20, 1979) was the lowest recorded during the study period (Reference 4). Winter kills are common for gizzard shad when water temperatures fall below 3.3°C (Reference 5). This suggests that impingement rates may have been inflated by winter-killed or cold-stunned shad that float into the intake area and are "impinged." In subsequent years of the study impingement levels for gizzard shad never reached the levels of 1979.

a. **Impingement Estimate for Unit 3 Using Dry and Wet Cooling Towers**

Data from the 1978–1983 sampling study (Reference 4) were used to estimate the impacts of adding a new CWIS with a maximum intake flow of 27,309 gpm on the impingement of fish in the North Anna Reservoir. The following assumptions were used to extrapolate fish impingement rates for a new cooling tower make-up system:

- Fish distribution and composition has remained generally the same as in the 1978–1983 study,
- A new CWIS would operate at 100 percent pumping capacity, and
- The intake screen mesh size and approach flow velocity of the new units would be the same as that of the existing units.

These assumptions were used to provide a very conservative estimate that results in bounding impingement estimates that are considerably higher than expected.

Based on the impingement rate for the six representative important fish species from the 1978–1983 study and assuming the maximum flow rate of 27,309 gpm and 100 percent pumping capacity, an estimate was calculated of the total number of fish that could be impinged. Mean monthly impingement estimates for the six representative important fish species were calculated for the same five full years of operation (Table 5.3-2). It was determined that using the mean of the five representative years would give the most accurate estimate for annual fish impingement. As expected, gizzard shad dominated the impingement estimates for the new system with an estimated annual impingement of approximately 3460 fish. This estimate is about 97 percent less than the yearly estimate for the existing units (Table 5.3-1), and is primarily due to significantly less cooling water intake flow for the new unit.

Table 5.3-2 Mean Number of Representative Important Fish Species Estimated Impinged per Month at NAPS With a Cooling Tower Water Make-up Intake System for Unit 3

Month	Striped Bass	Black Crappie	Bluegill	Gizzard Shad	White Perch	Yellow Perch	Total All Species
January	6	21	3	277	2	1	310
February	8	57	6	696	4	40	811
March	11	304	14	2123	18	788	3258
April	3	150	17	233	15	62	480
May	0	39	15	46	14	3	117
June	0	12	18	2	3	2	37
July	0	7	7	2	3	1	20
August	0	7	19	1	3	0	30
September	0	15	11	7	3	1	37
October	1	79	13	4	4	0	101
November	8	58	39	14	3	1	123
December	15	34	6	55	5	1	116
Yearly Totals	52	783	168	3460	77	900	5440

Estimated impingement for the other representative important species would be proportional to those of the existing units. In addition, seasonal impingement would be highest during the winter and lowest during the summer; all reflective of the 1985 study (Table 5.3-2).

Cumulatively, based on the maximum flow rate and 100 percent pumping capacity, impingement would increase by less than 3 percent with the addition of Unit 3. Total estimated impingement for the six representative important species would be approximately 188,000 fish annually. Approximately 94 percent of the annual impingement would be gizzard shad (63 percent), yellow perch (16 percent), and black crappie (15 percent) (Table 5.3-3).

Table 5.3-3 Mean Number of Representative Important Fish Species Estimated Impinged per Month with Existing Units and With a Unit 3 Cooling Tower Make-Up Water Intake System.

Month	Striped Bass	Black Crappie	Bluegill	Gizzard Shad	White Perch	Yellow Perch	Total All Species
January	219	950	137	14,877	94	45	16,322
February	273	2417	241	27,155	166	1432	31,684
March	392	10,038	479	60,437	643	25,224	97,213
April	90	4497	653	8640	486	1816	16,192
May	10	1682	645	1653	404	87	4481
June	-	492	857	59	138	51	1597
July	-	379	399	69	167	40	1054
August	3	433	1004	85	162	23	1710
September	12	860	655	492	164	20	2203
October	31	3528	587	240	164	5	4555
November	365	2201	1983	728	179	27	5483
December	697	1245	299	2882	236	37	5396
Yearly Totals	2092	28,722	7939	117,857	3003	28,807	187,880

b. **Impingement Estimates for Unit 3 Plus Unit 4**

Because Unit 4 would use a dry cooling tower system, there would be no regular withdrawal of water from Lake Anna and therefore no additional impingement impacts beyond those associated with Unit 3.

Table 5.3-4 Deleted

5.3.1.2.2 Impingement Discussion

Gizzard shad are the major forage fish in Lake Anna (Section 2.4.2). Threadfin shad, which were introduced by VDGIF in 1983, were collected in impingement samples only in late summer and fall of 1983, and were not included in the impingement estimates due to lack of data. Threadfin shad contribute to the forage base, but the population is cyclic and subject to die-offs during cold winters (Section 2.4.2).

The percentage of the total reservoir population that is impinged is very low. Based on cove rotenone sampling in Lake Anna, the average annual standing crop of gizzard shad over a five year period (1979–1983) was 121 kg per hectare and the average annual impingement weight of gizzard shad was 2200 kg (Reference 4). Therefore, the average percentage of gizzard shad standing crop

in the North Anna Reservoir that was removed annually by impingement was 0.32 percent by weight. Similarly, values for black crappie were 3.8 percent, yellow perch 1.4 percent, bluegill 0.02 percent, and white perch 0.1 percent (Reference 4). Using the assumptions presented earlier, the addition of Unit 3 would increase the number of fish impinged by less than 3 percent. Therefore, a new CWIS for Unit 3 in combination with the current once-through system for Units 1 and 2 would remove approximately 0.33 percent by weight of gizzard shad annually, 3.9 percent of black crappie, just over 1.4 percent of yellow perch, 0.02 percent of bluegill, and 0.1 percent of white perch. Adding Unit 4 with a new dry tower system would not increase these numbers because no regular water withdrawals would be made from Lake Anna for the new system.

Gizzard shad have a high reproductive potential because they grow rapidly, mature quickly, and produce a large number of eggs per female. As reported in Carlander (Reference 6), gizzard shad can reproduce at 2 years of age and each age-2 female can produce from 211,000 to 543,000 eggs. The average yearly combined impingement estimates for the existing units, and towers for Units 3 and 4, is approximately 115,000 gizzard shad, considerably less than the maximum egg production of one average size age-2 female gizzard shad. Likewise, black crappie become sexually mature at age-2 or age-3 and a mature female can produce from 11,000 to 188,000 eggs annually (Reference 7). The average yearly impingement estimates for black crappie from all existing and new units combined would be approximately 29,000 fish; well below the maximum egg production of one mature female. These trends hold true for the other representative important species.

There are a number of factors that directly influence recruitment in fish populations. Growth rates, survival rates, and age at maturity are critical elements in determining recruitment success in fish populations. Fish that grow and mature quickly are more likely to be added to the population than those that grow and mature slowly. Growth, survival, and age at maturity are in turn influenced by an array of interrelated factors that include water quality, disease, competition, predator-prey relationships, and genetics. Generally speaking, high mortality rates are associated with low rates of recruitment. Fish can be preyed on by larger fish, by wading birds, and by fishermen. Power plants can function as predators, and like predators, tend to be more “successful” as prey populations expand and densities increase. The theory of natural compensation relies on the principle that fish populations would grow when the population density (standing crop) is low and would likewise decline when the density is high. In other words, compensation is the capacity of a population to offset, to some extent, reductions in numbers caused by some disturbance. This is a natural compensation process that works to ensure that population size remains relatively stable over time. The assessment presented in Section 2.4.2 concludes that the Lake Anna fish population is balanced and has remained balanced is an indication that natural compensation is occurring. Therefore, natural compensation would offset fishery losses from impingement in Lake Anna.

Generally, new reservoirs exhibit high initial productivity followed by a decline in productivity, and finally a period of stability, but at a productivity level below the initial level. The initial surge in productivity is primarily due to high nutrient levels from freshly inundated vegetation and soil and thus cannot be maintained (Reference 8) (Reference 9). Environmental conditions tend to stabilize 5–10 years after impoundment, and fish biomass stabilization follows. Lake Anna exhibited high initial fish abundance during 1973 and 1974 followed by a decline in succeeding years. Since 1978, the mean standing crop of fishes has remained relatively stable, with the exception of 1985 when the standing crop increased significantly due to the introduction of threadfin shad in 1983 and concurrently an excellent year-class for gizzard shad. Lake Anna appears to support a standing crop of fish higher than most reservoirs in the United States, with thriving populations of several forage and gamefish species (see Section 2.4.2).

The 1985 Section 316(b) study showed no significant impacts due to impingement, a conclusion validated by 20-plus years of monitoring in Lake Anna. In addition, the Section 316(a) demonstration (Reference 2) and more recent monitoring data and annual reports (Reference 10) indicate that Lake Anna fish populations are healthy and diverse. Operating new cooling towers for Units 3 and 4 would not change this conclusion. This conclusion is supported because the fish impinged most frequently are prolific, exhibit a high reproductive potential, and compensatory responses of the fish population would occur to offset losses due to impingement, and therefore would not require mitigation.

5.3.1.2.3 **Entrainment**

During the 1978–1983 study referenced earlier, entrainment samples were collected once a week in front of the intake forebays from March through July of each year, which represents the spawning period of Lake Anna fish (Reference 4). During this six-year study, an average of 1318 fish larvae were collected annually in the entrainment samples. No fish eggs were collected. Most of the fish species in Lake Anna produce demersal (sinking), adhesive eggs, which reduces their potential for entrainment. For purposes of the study and as a conservative estimate, 100 percent entrainment and 100 percent mortality were assumed for all larval fish collected (Reference 4).

During the study, five larval fish taxa dominated the collections; with gizzard shad (65.7 percent) being the most commonly entrained larvae followed by white perch (15 percent), sunfishes (*Lepomis* sp.) (13.3 percent), yellow perch (4.9 percent), and black crappie (1.0 percent). All of the larvae collected were representatives of common, widely distributed species found across Virginia and the southeast (Reference 11) (Reference 12). As noted in Section 2.4.2, no threatened or endangered fish species have been recorded from Lake Anna. Seasonal differences in the sample collections of the various species reflected the spawning characteristics of the individual species (Reference 4).

More sunfish (*Lepomis* sp.) and yellow perch larvae were collected in the first year of the study (1978) than in subsequent years. Gizzard shad were collected in relatively greater numbers in 1979

and 1981. White perch exhibited a general increase in samples over the study period. Collections of black crappie were considered too low to make any meaningful comparison between years. With the exception of 1978, when sunfish and yellow perch dominated the collections, trends in total numbers of larvae entrained from year to year were generally reflected in the number of gizzard shad, sunfishes, and white perch collected. The percentage of the total larvae collected represented by gizzard shad remained high (between 43 and 88 percent) and stable each year of the study, whereas the percentage of white perch increased each year from 0.3 percent in 1978 to 31 percent in 1983 (Reference 4).

Seasonally, yellow perch larvae were the first to appear each year in collections, generally in early April, when water temperatures approached 12°C. White perch appeared in April when temperatures approached 14°C, peaked in numbers in mid-May, and were collected into July. Gizzard shad larvae generally were first collected in late April to early May at water temperatures between 14°C and 18°C and peaked in numbers in mid-May to early June. Sunfishes were the last group to appear in samples (May-June) and were first collected when water temperatures rose to 19°C. Both gizzard shad and sunfish larvae were collected in relatively fewer numbers in July (Reference 4).

To determine the total estimated number of larvae entrained over a time period, daily entrainment values (number per gallon withdrawn) were multiplied by the average volume of intake cooling water withdrawn on that sample day. Period estimates were computed using daily estimates and the number of days in each period. Totaling period estimates by species results in estimates of total numbers of larvae entrained by month; yearly estimates are the sum of the months (Reference 4).

Based on the estimation method outlined above, an average of 149,400,000 fish larvae was entrained each year from 1978 through 1983 (Table 5.3-5). During this period, gizzard shad had an average yearly entrainment of approximately 95,500,000 or about 63 percent of the total entrainment, while white perch represented 15.4 percent; sunfish 14.9 percent; yellow perch 4.6 percent and black crappie 1.2 percent.

On a seasonal basis, highest estimated larval fish entrainment occurred in May (47.6 percent) when all representative important species were present (Table 5.3-5). June estimates were the second highest with collections dropping dramatically in July.

Table 5.3-5 Mean Number of Representative Important Fish Species Estimated Entrained per Month From 1979-1983 With Existing Units Operating

Taxa	March	April	May	June	July	Yearly Totals
Black Crappie	-	-	1,144,967	598,711	-	1,743,678
Lepomis sp.	-	-	892,255	12,326,144	9,031,991	22,250,390
Gizzard Shad	-	367,705	51,580,191	41,131,018	2,396,247	95,475,161
White Perch	-	3,923,856	17,157,903	1,818,796	92,820	22,993,375
Yellow Perch	223,513	6,309,313	384,800	10,400	-	6,928,026
Monthly Totals	223,513	10,600,874	71,160,116	55,885,069	11,521,058	149,390,630

Source: Reference 4.

a. **Entrainment Estimates for Unit 3 Using Dry and Wet Cooling Towers**

In order to estimate the impacts of the addition of a new CWIS with a maximum intake flow of 27,309 gpm on the entrainment of fish from the North Anna Reservoir, data from the 1978–1983 sampling study (Reference 4) were used. The following assumptions were used to extrapolate fish entrainment rates for a new cooling tower make-up system:

- Fish distribution and composition has remained generally the same as in the 1978–1983 study,
- A new CWIS would operate at 100 percent pumping capacity, and
- The intake screen mesh size and approach flow velocity of the new unit would remain the same as that of the existing units.

These assumptions were used to provide a very conservative estimate that results in bounding entrainment estimates that are considerably higher than expected.

Based on the entrainment rate (number per gallon) for the five representative important fish species from the 1978–1983 study and the maximum flow rates for the new CWIS, an estimate of the total number of these species' larvae entrained was calculated. As noted earlier in this section, the maximum cooling water withdrawal rate from the North Anna Reservoir for Unit 3 towers would be 27,309 gpm. Combined with current usage of 1,934,300 gpm for the existing Units 1 and 2, this would result in 3.6 percent of Lake Anna's volume being used each day. Entrainment rates were calculated for the following representative important species: gizzard shad, sunfishes, white perch, yellow perch, and black crappie.

Mean monthly and yearly entrainment estimates for Unit 3 were calculated for the five representative important fish species for each of the six years of the study (Table 5.3-6). Because the sampling period was similar in all six years, all data were used and an average

yearly estimate was calculated. As expected, the entrainment estimates for Unit 3 follow those of the existing Units 1 and 2 very closely.

Entrainment estimates for Unit 3 averaged approximately 3,350,000 larvae annually, with gizzard shad dominating the estimates. Estimated entrainment for the other representative important species also would be proportional to those of the existing units on an annual and monthly basis.

Table 5.3-6 Mean Number of Representative Important Fish Species Estimated Entrained per Month With Cooling Tower Make-Up Water Intake System for Unit 3

Taxa	March	April	May	June	July	Yearly Totals
Black Crappie	—	—	29,547	11,595	—	41,143
Lepomis sp.	—	—	31,170	256,714	178,893	466,577
Gizzard Shad	—	8809	1,153,671	904,014	49,889	2,114,381
White Perch	—	100,812	418,854	31,791	1634	553,091
Yellow Perch	5251	162,714	10,865	199	—	179,029
Monthly Totals	5251	272,335	1,644,107	1,204,313	230,416	3,354,224

Cumulatively, entrainment would increase by less than 3 percent (Table 5.3-7) with the addition of a CWIS for Unit 3. As noted earlier, this is based on a maximum intake flow rate and 100 percent pumping capacity. Total estimated entrainment with the old and new units operating for the five representative important species would be approximately 152,000,000 fish larvae annually. Once again, gizzard shad would account for approximately 63 percent of all larvae entrained (Table 5.3-7).

Table 5.3-7 Mean Number of Representative Important Fish Species Estimated Entrained per Month With Existing Units and a Cooling Tower Make-Up Water Intake System for Unit 3

Taxa	March	April	May	June	July	Yearly Totals
Black Crappie	-	-	1,174,514	611,306	-	1,784,821
Lepomis sp.	-	-	923,425	887,392	17,079,735	22,716,967
Gizzard Shad	-	376,514	52,733,862	42,035,032	2,446,136	97,589,545
White Perch	-	4,024,668	17,567,757	1,850,587	94,454	23,546,466
Yellow Perch	228,764	6,472,027	395,665	10,599	-	7,107,055
Monthly Totals	228,764	10,873,209	72,804,223	57,089,382	11,751,474	152,744,854

b. **Entrainment Estimate for Unit 3 Plus Unit 4 Cooling**

Because Unit 4 would use a dry cooling tower system, there would be no regular withdrawals of water from Lake Anna and therefore no additional entrainment impacts beyond those associated with the Unit 3 CWIS.

Table 5.3-8 Deleted

5.3.1.2.4 Entrainment Discussion

Reproductive strategies vary among fish species. In general, the strategy is to produce large numbers of eggs but provide little protection thereafter. Therefore, mortality rates are extremely high, with generally less than 1 percent of the larvae surviving to one year of age (Reference 13). Survival rates are higher in species (e.g., sunfish, salmonids) that build nests and provide protection until the larvae swim away from the nest, but are still generally 10 percent or less (Reference 13). To assess the impact of the loss of fish larvae due to entrainment on the fisheries of Lake Anna, the adult equivalent model of Goodyear (Reference 14) was used (Reference 4). Assumptions used included:

- There is 100 percent mortality of entrained larvae,
- The stock populations are at equilibrium and the total lifetime fecundity produces two adults,
- No compensatory mechanisms are operating, and
- 75 percent of the eggs produced by the entrained species survive to the larval stage.

This model estimates the number of adult fish that would have resulted from the entrained larvae had they not been lost to entrainment. It also provides an estimate of the potential percent reduction in the adult fish population as a consequence of entrainment. Values ranged from 0.01 percent for black crappie in 1978 and 1979 and sunfishes in 1982, to 4.13 percent for gizzard shad in 1980. Percent reductions of this magnitude would not have a significant adverse effect on the Lake Anna fishery, especially when viewed in concert with other population mechanisms such as compensation (see Section 5.3.1.2.2) (Reference 4).

The analysis from the adult equivalent model provided a conservative estimate of entrainment impact, primarily as a result of assumptions used in the analysis (Reference 4). Applying the adult equivalent model analysis to a CWIS for Unit 3 would increase the entrainment losses for the existing units by less than 3 percent (Reference 4). Losses of this magnitude would not impact the Lake Anna fishery. Adding Unit 4, with a dry cooling tower system, would not increase these entrainment numbers because no regular water withdrawals from Lake Anna would be required for this system.

The information summarized in Section 2.4.2 and in the *Environmental Study of Lake Anna and the Lower North Anna River Annual Report for 2000 including summary for 1998–2000* (Reference 10) indicates that the fish population in Lake Anna represents a balanced community. Over the years, the fishery of Lake Anna has matured and changed to meet the demands for public fishing through

species additions (threadfin shad) and annual stockings of striped bass. Overall, the abundance and quality of the fishery has remained healthy and balanced despite increased fishing pressure and shoreline development. Therefore, based on the information presented in Section 2.4.2 that summarizes the Lake Anna fish community and its thriving populations of gamefish and the forage species that support them, the additional entrainment resulting from the operation of a new CWIS for Unit 3 would have a small impact on the fishery community and would not require mitigation.

5.3.2 Discharge System

This section describes the impacts on Lake Anna of the discharge system during operation of the units at the ESP site. The existing temporal and spatial temperature distributions in Lake Anna and the potential physical impacts resulting from the new units' cooling water discharges are described in Section 5.3.2.1. Potential thermal, physical, and chemical stresses to aquatic organisms that may occur as a result of plant cooling system discharges to the North Anna Reservoir via the WHTF are described and assessed in Section 5.3.2.2.

5.3.2.1 Thermal Description and Physical Impacts

This section discusses the thermal distribution in Lake Anna and potential physical impacts, including increased turbidity, scouring, erosion, and sedimentation in the lake resulting from the new units' cooling system discharges, noting that only Unit 3 would have blowdown discharge from its wet cooling towers during normal plant operation. Section 5.3.2.2 evaluates the aquatic impact on the lake's ecosystem. Section 5.2.1 and Section 5.2.2 describe the water use impacts of the new cooling systems. Unless site-specific data were available, the bounding design parameter values from the Generic PPE were used as the basis for the analysis and evaluation of the new units' discharge system. Section 3.4.2 describes the physical attributes of the new discharge system.

Each new unit would generate, during normal full load operation, up to 10.3×10^9 Btu/hr of waste heat that needs to be dissipated. This heat load is in addition to the 13.54×10^9 Btu/hr of waste heat currently permitted for discharge to the WHTF from the existing units (Reference 15). Three alternative systems are identified as technically viable options for normal plant cooling of the new units:

- A once-through system using Lake Anna as the heat sink
- A closed-cycle system with wet evaporative-type cooling towers
- A closed-cycle system with a combination of dry and wet evaporative-type cooling towers
- A closed-cycle system with air-cooled condensers or dry cooling towers

As noted in Section 3.4, Unit 3 would use a closed-cycle, dry and wet cooling tower system, whereas Unit 4 would use a closed-cycle system with dry cooling towers for the circulating water system during normal station operation. A separate, service water cooling system would use a closed-cycle wet cooling tower system for Unit 3 and a dry cooling tower system for Unit 4 for

dissipation of waste heat from auxiliary heat exchangers not cooled by the unit's circulating water system. The blowdown effluent from Unit 3's wet cooling towers of both the circulating water and service water systems would discharge to the WHTF, but Unit 4 would have no cooling system discharges and therefore no associated heat load released to the WHTF. Due to the small discharge flow rate of no greater than 12.4 cfs and small heat load on the order of 4.2×10^7 Btu/hr during extreme summer months (See Section 3.4.1.1) that would be associated with the blowdown discharge from the wet towers, the circulating water and service water cooling systems of Unit 3 would have very small, if not imperceptible, physical, chemical, biological or ecological impacts to Lake Anna.

The UHS for each unit would dissipate decay heat of up to 1.2×10^8 Btu/hr during normal conditions, and 4.2×10^8 Btu/hr during shutdown or accident conditions. A blowdown flow of 0.3 cfs (normal) to 1.9 cfs (maximum) per unit would be discharged to the WHTF if a plant was in UHS mode, but the heat load associated with this discharge would be very small, with its impact bounded by the normal plant cooling discharge of Unit 3. No thermal analysis was conducted specifically for the UHS discharge. The following discussion pertains to the thermal impacts on the lake due to normal plant cooling only.

5.3.2.1.1 Existing Hydrothermal Condition

The existing units each have a reactor core power level of 2893 MWt (uprated in 1986) and an expected gross electrical output of about 982 MWe (Reference 1), rejecting a waste heat load of about 1911 MW (6.5×10^9 Btu/hr) per unit to the condenser cooling system for dissipation. The total heat load to the existing heat dissipation system is, therefore, below the current VPDES permit limit of 13.54×10^9 Btu/hr (Reference 15). The existing units use a once-through cooling system to dissipate the waste heat from the turbine condensers and from the auxiliary cooling systems. When both units are operating, eight circulating water pumps draw water to the plant from the North Anna Reservoir at a design rate of 4246 cfs (2123 cfs per unit). The cooling water, at a design temperature rise of about 14°F above the water temperature at the intake, is discharged through rectangular tunnels to an outfall structure at the head of the WHTF discharge channel. The actual temperature rise across the condensers may be greater or less than 14°F, depending on the power station load and the number of circulating water pumps operating. For instance, at lower condenser flow rates with three circulating water pumps running per unit rather than four, the temperature increase across the condenser averages approximately 18.3°F. A minimum of three circulating water pumps is required for each operating unit in the summer months when the intake temperature exceeds 75°F. (Reference 16)

In the WHTF, the heated effluent flows through a series of ponds and connecting canals, and returns to the North Anna Reservoir via a 6-bay skimmer wall submerged structure at Dike 3. Each discharge bay can be adjusted to maintain the discharge velocity at about 7 fps to promote mixing with the receiving water. Although the discharge is submerged, the slope of the reservoir bottom

immediately adjacent to the Dike 3 discharge structure directs the discharge to the surface. (Reference 16)

Circulation in Lake Anna results from four mechanisms:

- Station pumping, which produces a forced horizontal surface flow through the WHTF and the North Anna Reservoir
- Wind stresses, which produce currents in the direction of the wind
- Water temperature differences, which produce natural convective flows into the sidearms of the WHTF and the main reservoir
- Inflows and outflows to and from the reservoir

Station pumping normally dominates the flow pattern and forces the majority of the cooling water flow to circulate back to the intake, because the cooling water flow rate is much higher than the average inflow to the lake and outflow at the dam. The average inflow to the lake including surface runoff, direct precipitation, and groundwater flow is estimated to be about 369 cfs (Section 5.2.1). The average outflow at the dam varies and is estimated to be about 276 cfs when the existing units are in operation (see Section 5.3.1.1). Waste heat is transferred to the atmosphere mostly by evaporation, conduction, and back radiation. Only a small percentage of waste heat is released downstream via the North Anna Dam. It is estimated that, with the existing units operating, the cooling water's residence time in the WHTF is approximately 7 days, where about half of the waste heat is dissipated. The remaining waste heat is dissipated to the atmosphere from the North Anna Reservoir surface.

As presented in Section 5.3.1.1, the natural hydrologic characteristics of Lake Anna gradually change from riverine upstream to lacustrine downstream. Figure 5.3-1 shows the three different reaches of the lake: the upper, middle, and lower. The upper lake is primarily riverine, shallow (average depth of 4 m (13 ft)) and slightly stratified in summer. The mid-lake is more lacustrine and stratified. The lower lake is deeper (average depth of 11 m (36 ft)) and displays lacustrine characteristics (e.g., more vertical gradients of light, temperature, and decomposition). It is stratified in summer and mixed in winter.

Table 5.3-10 identifies physical attributes of the North Anna Reservoir and WHTF.

With the additional waste heat from the new units discharged to Lake Anna, the lower North Anna Reservoir reach near Dike 3 and the North Anna Dam would be strongly stratified in summer and mixed or weakly stratified in winter. As in a typical cooling lake, one of the defining features is the temperature differential that exists between the discharge and the intake. If transient fluctuations are averaged, this differential is equal to the condenser temperature rise. As density changes are associated with temperature changes, buoyancy forces arise, which tend to cause the spreading of lighter (warmer) water over heavier (cooler) water. The discharge of heated effluent into the lower lake at Dike 3 causes the surface water to become warmer and lighter than the bottom water. Thus,

the lower lake tends to be more stratified. Turnover of the hypolimnion (deeper, colder water) of the lower lake occurs through vertical entrainment of the hypolimnion by the horizontally circulating warmer cooling water. Fresh water from the upper lake, which is cooler and denser than the heated surface water, tends to sink to the bottom of the lake, or to some intermediate depth, and thus reinforces stratification in the reservoir, especially in the lower lake. (Reference 17)

The stratification pattern in the lake would not change with the addition of new units. The thermal plume and the hypolimnion would be the same as a consequence of the very small flow and heat load added to WHTF by the new units.

Temperature data collected prior to the operation of the existing units indicated that the more shallow upper lake warmed more quickly than the lower lake water in the spring. The water in the upper lake reach was also warmer into the early summer, and it reached a higher maximum temperature than the water in the lower lake reach. The large volume of the water in the lower lake retained heat longer, as the natural heat inputs decreased in the fall. In 1976, the lower lake temperature changes lagged about 2-3 weeks behind the temperature changes in the upper lake from February through July, and surface temperatures were warmer in the lower lake from mid-July through December. In 1983, a year when the existing units were operating at close to full load capacity, the surface temperature in the lower lake exceeded the upper lake temperature, except during the spring and early summer. Hence, station operation apparently causes the following lake temperature changes:

- The lower lake is more closely aligned with the upper lake temperature in spring.
- Peak summer temperatures of both lake reaches are similar (whereas the lower lake was cooler pre-operation).
- Heat retention of the lower lake is prolonged. (Reference 2)

Quarterly field temperature surveys have been conducted since 1983 to characterize the thermal plume entering the reservoir via the discharge structure at Dike 3. The data show that in the hottest months of the year (July and August), near-maximum operating conditions have not produced a distinct thermal plume in the lower lake reach. In fact, results show nearly uniform temperatures across the reservoir. There is also no clearly defined thermal plume in the lower lake in the fall, winter, or spring. The results of recent quarterly plume studies (1994 to 1998) are similar. Typically, no thermal plume is evident in spring and summer surveys. In cooler months, differences between upper lake, mid-lake, and lower lake temperatures have been noticeable, both at the surface and at depth. However, seasonal cooling and warming trends of surface waters in the shallow upper lake and in the deeper lower lake have made it difficult to identify or precisely define a thermal plume. (Reference 16) (Reference 2)

Table 5.3-11 shows the observed maximum, average, and minimum daily temperature at four monitoring stations: NALDISC1 near the end of the discharge channel in the WHTF; NALST10 near Dike 3 in the WHTF side; NALBRPT near Burrus Point, which is about one-third of the way up the

North Anna Reservoir from the dam; and NALINT, near the intake. In this context, daily temperature refers to the 24-hour average temperature. The temperature summary is based on the continuous surface temperature measurements at the monitoring stations since 1978. Surface temperatures are taken in the top 1 m of the water column. Figure 6.1-1 shows the relative locations of the continuous temperature monitoring stations. Table 5.3-12 summarizes the time exceedence of the measured surface temperatures at the same four locations. Table 5.3-13 shows the seasonal trend of the monthly maximum and average surface temperature observed near the intake (monitoring station NALINT), and near Burrus Point (monitoring station NALBRPT). The temperature at the intake monitoring station is considered to be representative of the mid-lake condition, whereas the temperature of the Burrus Point monitoring station is representative of the lower lake condition. During the spring months, the monthly maximum temperature near the intake is warmer than the temperature at the Burrus Point. This temperature difference is due to the effect of the warmer inflows from the shallower upper lake reach and the potentially more pronounced natural stratification near the sheltered area around the intake monitoring station. During the summer months, the monthly maximum temperatures at the two locations are more similar due to the effect of the station heat load, as stated previously.

Figure 5.3-3 and Figure 5.3-4 show the observed seasonal average vertical temperature profiles near the dam (monitoring station A) and near the intake (monitoring station I). These profiles have been generated from plume survey data measured quarterly since 1983. The location of the plume survey monitoring stations is illustrated in Figure 6.1-2. The seasonal warming and cooling trend in the lower lake and mid-lake reaches can easily be identified in the observed temperature profiles.

5.3.2.1.2 Thermal Impact

The maximum heat load associated with the new units for release to WHTF during normal operation would be very small, on the order of 4.2×10^7 Btu/hr during the extreme summer months when the wet-bulb temperature is close to 80°F, and the average lake temperature is in the mid-80°F range. Compared to the total heat load of 1.35×10^{10} Btu/hr from the normal plant once-through cooling system of Units 1 and 2, the new units would add about 0.3 percent of heat content to the WHTF during these summer months. As the cooling tower blowdown from Unit 3 exits through the new outfall at the beginning of the discharge canal, it will mix with the cooling water discharge of Units 1 and 2 from the existing outfall nearby. Using a maximum blowdown flow rate of 12.4 cfs and discharge temperature of 100°F for Unit 3, and a total circulating water discharge flow rate of 4246 cfs and a condenser temperature rise of 14°F for the existing units, the average water temperature increase due to the new units is estimated to be less than a hundredth of a degree Fahrenheit at the end of the discharge canal where fully mixed condition of the two flow streams would be expected. This is based on an average ambient lake temperature of 85°F during the summer months when the thermal impact would be most critical. In the cooler months when the average lake temperature is lower in the 60°F range, a conservative estimate of the heat load associated with the new units would increase to about 1.1×10^8 Btu/hr due to the potentially higher

temperature difference between the ambient lake water and the blowdown flow. The corresponding water temperature increase at the end of the discharge canal due to the new units would be less than a tenth of a degree Fahrenheit in the cooler months. The small water temperature increase due to the new units would dissipate to an undetectable level within a short distance of travel in the WHTF. The North Anna Reservoir would, therefore, experience no thermal impact as a result of the proposed operation of the new units.

Section 5.3.2.2 presents the potential impact on the aquatic ecological system of the North Anna Reservoir due to the additional heat load from the new units.

5.3.2.1.3 Other Physical Impacts

Section 5.3.1.1 discusses the hydrodynamics and the flow distribution induced in the North Anna Reservoir with the addition of new units. The conclusion is that, with the small water demand from the new units, the impacts such as increased shoreline erosion, lakebed scouring, and turbidity levels due to operation of the new intake system would be negligible.

The flow velocity in the discharge channel, the connecting canals, and the main ponds of the WHTF would be slightly higher than in the North Anna Reservoir due to their smaller dimensions. Unit 3 would release a maximum of 12.4 cfs of blowdown discharge to the WHTF and Unit 4 would use a closed-cycle system with dry cooling towers that would have no blowdown discharges. Including the cooling water discharge of 4246 cfs from the existing units, the total maximum plant cooling discharge to the WHTF would be 4258 cfs, which represents an increase in the velocity in the WHTF of about 0.3 percent. During the existing operation of Units 1 and 2, scouring and erosion have not been a concern in the WHTF where the flow velocity is typically less than 1 fps. The small increase in flow and velocity due to the new units would therefore not cause any scouring or erosion problems in the lake.

Banks of the connecting canals are currently protected by rip-rap from 242 ft msl to 250 ft msl to protect against erosion. The flow velocity decreases substantially in the main ponds of the WHTF beyond the entrance-mixing zone near the end of the connecting canals. At the Dike 3 discharge to the reservoir, the exit velocity is designed to be about 7 fps. The bottom of the discharge structure is protected by a concrete apron to minimize local erosion at the discharge, as shown in Figure 3.4-9. No adverse impact due to scouring from the existing plant discharge has occurred, and none would occur as a result of the future combined operation of four units.

There is limited record of turbidity level measurements in the WHTF, but based on the projected discharge flow velocity, the range of the turbidity level in the WHTF would be approximately the same as current turbidity.

Siltation would be minimal, because the medium to coarse sediment would settle before reaching the intake approach channel during normal lake conditions. Sediment could come into the approach channel during floods and deposit there due to the low channel velocity. Operation of the new

intake, however, would not be affected because the channel is 12 feet deeper than the design invert of the new intake, allowing room for occasional sediment deposition. A small amount of fine, suspended sediment could be entrained into the new intake structure and would either be filtered out during water treatment processes or be returned to the North Anna Reservoir via the WHTF as part of the plant effluent from the cooling systems. Regular maintenance dredging would not be necessary for the operation of the new units.

5.3.2.2 Aquatic Ecosystems

5.3.2.2.1 Overview

Nuclear power plant heat dissipation systems can affect aquatic communities in receiving waters in a number of ways. High flows associated with circulating water systems have the potential for scouring discharge substrates and transporting sediment to downstream locations, potentially harming benthic organisms and damaging fish spawning habitats. Chemicals used in circulating water systems to control biofouling and corrosion can be harmful to aquatic organisms. Heated effluent from once-through cooling systems can affect the distribution and abundance of aquatic organisms in receiving waters. For example, fish may avoid a heated discharge area in summer and be attracted to the same area in winter and spring.

5.3.2.2.2 Aquatic Ecosystem Impacts: Unit 3 Dry and Wet Cooling Towers

a. **Physical effects**

The NRC has queried utilities and regulatory agencies and reviewed operational monitoring reports of more than 100 nuclear power plants in the course of preparing the Generic Environmental Impact Statement for License Renewal of Nuclear Plants (GEIS). With regard to physical effects (scouring, sediment transport, and siltation), the NRC has observed in the GEIS that sediment scouring has caused “minor localized effects” at three operating plants, but has not been a problem at most plants. (Reference 19)

The addition to the existing once-through units at NAPS of a new Unit 3 that uses a closed-cycle, dry and wet cooling tower system would have almost no effect on circulating water discharge flows. The increase in discharge flow would range from 0.2 percent (the MWC mode maximum blowdown rate of 3844 gpm added to two-unit, open-cycle flow of approximately 1,900,000 gpm) to 0.6 percent (maximum blowdown rate of 5565 gpm added to one-unit, open-cycle flow of approximately 950,000 gpm). Discharge flow would range from 3844 gpm (Units 1 and 2 off-line; Unit 3 operating and discharging blowdown at maximum MWC mode rate) to 1,905,565 gpm (Units 1, 2, and 3 operating; Unit 3 discharging blowdown at maximum rate). An increase in circulating water flow of this magnitude would have no discernible effect on the substrate of the discharge canal or WHTF, and would have no impact at the Dike 3 discharge, the VPDES point of compliance. Impacts to aquatic organisms would be negligible. Mitigation would not be warranted.

b. **Chemical effects**

Nuclear power plants use a variety of chemicals, including biocides, corrosion inhibitors, and dispersants to control biofouling, corrosion, and scale formation in circulating and service water systems. For North Anna, the use of these chemicals is regulated and monitored under the VPDES permit, which prescribes their use (i.e., frequency, concentrations, and limits) and their monitoring frequency (i.e., continuous, daily, or monthly monitoring). Because of continuing efforts of utilities to reduce the use of these chemicals and required National Pollutant Discharge Elimination System (NPDES) monitoring and reporting, water quality degradation from cooling water system chemicals used in once-through cooling systems at nuclear power plants has not been a major regulatory concern. The GEIS notes that "…water quality effects of [the] discharge of chlorine and other biocides are considered to be of small significance for all plants" (Reference 19). NAPS submits monthly discharge monitoring reports to the VDEQ, which administers the Commonwealth's VPDES program. In addition, on a 5-year cycle, VDEQ conducts an extensive review of the effectiveness of existing VPDES programs, ensuring that water treatment systems in place adequately protect aquatic communities.

The GEIS notes (p 4-11) that discharges of sanitary wastes are regulated by NPDES permit, and discharges that do not violate the permit limits "are of small significance." Similarly, the GEIS notes (p 4-11) that water quality impacts of minor chemical discharges and spills do not have a significant impact on aquatic biota for all plants and have been mitigated as needed. NAPS has not had a pattern of permit exceedances or violations, and there is no basis for predicting that operation of an additional unit with cooling towers would increase the frequency or severity of VPDES permit exceedances.

Sewage treatment capacity may increase to accommodate additional on-site personnel. Any modification or expansion of existing sewage treatment facilities would be made in consultation with VDEQ, and any discharges from new or expanded facilities would comply with VPDES permit limits.

Adding a new Unit 3 with wet cooling towers to the two existing units would result in the discharge of cooling tower blowdown with concentrations of chemical constituents and solids that are up to approximately five times higher than those in water withdrawn from Lake Anna for make-up. However, this blowdown would mix with circulating water flow in the discharge canal and be further diluted downstream in the WHTF.

Based on five cycles of concentration in the cooling towers and the design blowdown flow, concentrations of lake water chemicals and solids would approach equilibrium (i.e., their concentration in circulating water) at the point at which the discharge canal enters the first pond of the WHTF. Concentrations of chemicals and solids would be below applicable VPDES permit limits at the Dike 3 discharge, the point of compliance. Impacts of chemicals in cooling

tower blowdown on Lake Anna's aquatic communities would be small and would not warrant mitigation.

Metals such as copper and zinc, leached from condenser tubing and other heat exchangers, have accumulated in some water bodies receiving discharges from nuclear plants (Reference 19). Concentrations of metals in the discharges of once-through nuclear power plants are normally within NPDES permit limits, because the metals are quickly flushed from the area by the large volumes of cooling water or diluted by the receiving water (Reference 19). Concentrations of metals in the NAPS discharge are regulated by VPDES permit. There has been no pattern of exceedances or permit violations at NAPS.

Notwithstanding the fact that mining operations discharging to the Contrary Creek drainage have resulted in elevated concentrations of metals in some Lake Anna surface water and sediment samples in the past, there is no evidence of adverse impacts to aquatic communities. An additional unit with wet cooling towers would not result in additional impacts because discharges would continue to be regulated by the VPDES permit and thus be protective of aquatic biota. The impacts of chemicals associated with the operation of an additional unit with wet cooling towers on aquatic resources of Lake Anna would be small, regulated by VPDES permit, and would not warrant mitigation.

c. **Thermal effects**

1. **Thermal effects on important species**

Cold shock occurs when aquatic organisms that have been acclimated to warm water, such as fish in a power plant's discharge canal, are exposed to a sudden temperature decrease. This sometimes occurs when single-unit power plants shut down suddenly in winter. It is less likely to occur at a multiple-unit plant, because a sudden temperature decrease is moderated by the heated discharge from the unit or units that continue to operate. Cold shock mortalities at U.S. nuclear power plants are "relatively rare" and typically involve small numbers of fish (Reference 19).

There have been "winter kills" of fish in Lake Anna associated with cold weather and unusually cold water temperatures, but plant operations were not a factor. In February and March 1979, large numbers of gizzard shad were killed or stunned when Lake Anna water temperatures fell below 36°F (Reference 4). These fish drifted into the existing units' intake, and were observed in impingement samples. Limited threadfin shad kills have occurred during severe winters. The susceptibility of gizzard shad and threadfin shad to winter kills is well known.

The temperature of cooling tower blowdown from Unit 3 would be approximately the same as the temperature of the circulating water entering the WHTF from the two existing once-through units during the summer months. As noted previously, a new Unit 3 using a closed-cycle, dry and wet cooling tower system would contribute very little to discharge

flow (less than one percent of total, when discharging blowdown) and would have almost no effect on discharge temperatures. The maximum temperature of cooling tower blowdown entering the discharge canal would be 100°F (Table 3.1-9). Over a recent three-year period that encompassed a severe drought, maximum temperatures recorded at the discharge canal with once-through units in operation ranged from 98.6°F in July 2000 (Reference 10) to 102.4°F in August 2002 (See Table 5.3-9). Based on the fact that blowdown from new Unit 3 would have negligible effect on temperatures in the WHTF, thermal impacts to aquatic organisms in the WHTF from operation of a third unit would be negligible, and would not warrant mitigation. Similarly, blowdown from Unit 3 would have no effect on temperature in Lake Anna and no impact on aquatic communities.

2. **Thermal effects on nuisance species**

   Densities of the introduced Asiatic clam (*Corbicula fluminea*) in Lake Anna increased from 1979 (when first discovered) to the late 1980s, and declined in the 1990s (see Section 2.4.2). As discussed in the previous sections, operation of a third unit with a closed-cycle, dry and wet cooling tower system would have negligible effect on discharge temperatures, and thus there would be no thermal impact on nuisance species, including the introduced Asiatic clam.

5.3.2.2.3 Aquatic Ecosystem Impacts: Unit 3 Using Dry and Wet Cooling Towers and Unit 4 Using Dry Towers

a. **Physical effects**

Adding a new Unit 4, that uses dry cooling towers, to the two existing units and a new unit (Unit 3) with a combination of dry and wet towers would contribute very little to circulating water discharge flows. Such an addition would have no appreciable effect on substrate in the discharge area or the Dike 3 discharge beyond those described in Section 5.3.2.2.2.a for two once-through units and one unit with a combination of dry and wet cooling towers. Physical impacts to aquatic communities would be small, and would not warrant mitigation.

b. **Chemical effects**

The dry cooling tower system proposed for Unit 4 would employ a closed loop of cooling water and, unlike wet cooling towers, would not require regular blowdown of water treatment chemicals and solids. Consequently, there would be no appreciable discharges of water treatment chemicals, biocides, salts, or other solids from the Unit 4 cooling systems, and no chemical effects on the aquatic communities of the WHTF and Lake Anna beyond those described in Section 5.3.2.2.2.b for two once-through units and one unit with a combination of dry and wet cooling towers. Chemical impacts would be small and would not warrant mitigation.

c. **Thermal effects**

As noted previously, a new unit (Unit 4), using dry towers would have no regular discharges (i.e., blowdown) and would have no appreciable affect on discharge temperatures beyond those already described in Section 5.3.2.2.2.c for the two existing units (Units 1 and 2) with once-through cooling systems and the new unit (Unit 3) with a closed-cycle, cooling tower-based system.

5.3.3 Heat-Discharge System

This section describes the impacts of the heat-discharge system during operation of the new units, including the impacts of heat dissipation on the atmosphere and on terrestrial ecosystems. Impacts of the heat-discharge system have been assessed assuming that Unit 3 would use a closed-cycle, dry and wet cooling tower system. All cooling system discharges for both the existing units and the new Unit 3 cooling tower system blowdown would be sent via the discharge canal to the existing WHTF and the North Anna Reservoir for heat dissipation, while Unit 4 would use closed-cycle, dry cooling towers for heat dissipation. Consideration is given to potential atmospheric phenomena resulting from operation of these types of heat-dissipation systems and the significance of their potential environmental impacts on terrestrial ecosystems and human activities in the ESP site vicinity.

5.3.3.1 Heat Dissipation to the Atmosphere

The cooling system options that have been evaluated for the new units would transfer waste heat from the plant components to the atmosphere and to surface water. A closed-cycle, dry and wet cooling tower system is the primary cooling process evaluated for Unit 3. Lake Anna would provide the make-up water to wet cooling towers. Unit 4 cooling would be provided by closed-cycle dry towers to transfer heat to the atmosphere.

Specifically, new Unit 3 would use the existing North Anna Reservoir as the make-up water supply source and the wet cooling tower blowdown would be discharged to the WHTF. A cooling system analysis was performed as described in Section 3.4. The WHTF dissipates the rejected heat from the plant by heat transfer to the atmosphere and through internal mixing within the water body itself. Under extreme humidity conditions during fall, winter, and spring, cool moist air above the WHTF could turn to fog (i.e., steam fog) and drift to adjacent areas. Based on informal observations from plant personnel, with Units 1 and 2 operating (with once-through cooling systems), this type of atmospheric phenomenon is infrequent and is very localized. Since the additional heat dissipated from the blowdown from the Unit 3 cooling towers would be negligible when compared to the heat dissipated from the existing units, any additional steam fog on and around the WHTF due to Unit 3 would be negligible. Additionally, the results from screening 5 years (1996–2000) of hourly meteorological data collected at Richmond, Virginia, indicate that there were no hours concurrently having relative humidity greater than 90 percent and ambient temperature below 32°F. Therefore,

steam-fog-induced icing conditions are very infrequent at the site. Consequently, ice buildup on transmission lines, switchyard, insulators and structures due to steam fog would not be anticipated.

A combination of dry and wet towers would be used to dissipate plant rejected heat for Unit 3. Dry towers alone would be used to dissipate all of plant rejected heat for Unit 4. Except for the initial filling of the cooling water loop, there will be no appreciable additions of make-up water for the dry towers since a closed-cycle dry cooling system typically has no evaporative losses or need for continuous blowdown. Therefore, the operation of closed-cycle dry towers for Unit 3 and Unit 4 would not produce a visible plume, salt drift, or steam fog. Operation of the wet cooling towers may produce a visible plume, salt drift and steam fog, and warm, moist air would be discharged from the top of the towers. This would tend to cause the atmosphere to be saturated in the immediate vicinity of the tower discharge. As the vapor plume mixes with the cooler surrounding air, some of the water vapor may condense and fall to the ground in the area close to the towers. The remaining water vapor would dissipate into the atmosphere. Due to the buoyancy of water vapor and the natural movement of air (e.g., currents and breezes), the mixing of the water vapor in the plume with the atmosphere would cause any increase in the overall humidity due to the towers to be transient and very localized. Certain components located outdoors and in the proximity of the Unit 3 wet cooling towers could potentially be affected by fogging or by salt deposition from drift from towers. In the COL application, when specific cooling tower and power plant designs are selected, a confirmatory evaluation of the fogging and salt deposition will be performed to show that the analysis conducted for the ESP Application remains bounding. Most of the fogging from the wet cooling towers would occur within the site boundary in winter and spring. No icing would be anticipated within or beyond the site boundary. A description of the evaluation of the fogging, icing, salt deposition, and visible plume from the wet towers is provided in Section 5.3.3.2.1.

Section 3.4.1.1 contains a detailed description of the operation of the closed-cycle, dry and wet cooling towers. As ambient air is drawn over sealed piping containing heated water, excess heat is transferred to the air through conduction and convection. In wet towers, heat from the water is transferred to the air by allowing a small portion of the water to evaporate, thus raising the water temperature and relative humidity. The heated air from the dry and wet towers is then released to the atmosphere where it mixes and is entrained into the surrounding air mass. The mixture of heated air would continue to rise while it is transported downwind. Additional mixing with cooler air outside would further lower the temperature of the mixture. Therefore, any increases in overall atmosphere temperature would be localized to the NAPS site, and would not affect the atmospheric or ground temperatures beyond the NAPS site boundary.

5.3.3.2 **Terrestrial Ecosystems**

Heat dissipation systems associated with nuclear power plants have the potential to impact terrestrial ecosystem resources through salt drift, vapor plumes, icing, atmospheric temperature

increases, noise, or avian collisions with surface structures (e.g., dry towers). Each of these topics is presented in later subsections.

No important terrestrial species or habitats exist within the vicinity of the closed-cycle, dry and wet towers for Unit 3 and the closed-cycle dry towers for Unit 4. Important species are defined as follows:

- State- or federally-listed (or proposed for listing) threatened or endangered species
- Commercially or recreationally valuable species
- Species that are essential to the maintenance and survival of species that are rare and commercially or recreationally valuable
- Species that are critical to the structure and function of the local terrestrial ecosystem
- Species that may serve as biological indicators to monitor the effects of the facilities on the terrestrial environment

Important habitats include any wildlife sanctuaries, refuges, preserves, or habitats identified by state or federal agencies as unique, rare, or of priority for protection; wetlands and floodplains; and land areas identified as critical habitat for species listed by the USFWS (Reference 40) as threatened or endangered.

5.3.3.2.1 Salt Drift, Vapor Plumes, and Icing

The environmental impact of the operation of the wet cooling towers is evaluated using the SACTI computer model, a suite of programs developed by Argonne National Laboratories to describe fogging, icing, salt deposition, and visible plumes from traditional (e.g., non plume-abated) wet cooling towers. The programs were written specifically for the Electric Power Research Institute (EPRI) for use in licensing power plants with mechanical- or natural-draft cooling tower systems. Using the local meteorological conditions and operating characteristics of the cooling tower, the program predicts the potential seasonal and annual environmental effects of the plumes and drift. The programs that comprise SACTI and the models for cooling tower effects have been validated with field and laboratory data. The cooling tower characteristics used in this analysis were vendor-supplied and are representative of a typical wet tower system given the following as input:

- Cooling water flow rate 674,600 gpm
- Cooling water temperature (cold) 100F
- Range 29.87F
- Design wet bulb temperature 79F

The meteorological conditions used in the analysis were a combination of North Anna site data and data from the National Weather Service for Richmond, Virginia for the years 1998 through 2000. The site data was used for hourly wind speed and direction, station barometric pressure, relative humidity, dry bulb temperature, and dew point temperature. The site wet bulb temperature was

calculated using the site dry bulb temperature, dew point temperature and station barometric pressure. The National Weather Service data for Richmond was used to compliment the site data and to complete the input requirements for SACTI, providing information on cloud cover, general description of weather conditions and visibility, and sea level barometric pressure. The combined data set was selected as representative of site conditions.

The SACTI program calculates the fogging, icing, salt deposition, and plume height and length without consideration of water-saving techniques or features that would be part of the design of the towers and would result in a reduction of the vapor plume as a consequence. As described in Section 3.4.1.1, these features can include incorporation of a dry cooling section in the wet tower or the use of heat exchange surfaces in the upper section of the wet tower, or the use of variable speed fans and pumps and adjustable louvers. However, for the analysis performed for the ESP application, to conservatively maximize the prediction of environmental impact due to visible plume, fogging, icing, and salt deposition, a lower profile (74 feet) non-plume-abated wet cooling tower was modeled. Seventy-four feet is the maximum expected non-plume-abated wet tower height.

The results of the SACTI analysis are presented in Table 5.3-22 through Table 5.3-41. The seasonal and annual fogging and icing results are presented in Table 5.3-22 through Table 5.3-26. The seasonal and annual salt deposition results are presented in Table 5.3-27 through Table 5.3-31, and the seasonal and annual plume height and length results are presented in Table 5.3-32 through Table 5.3-41. As may be seen from the tables, most fogging would occur in the winter. The number of hours of plume fogging is greatest at a distance of 300 m from the towers, mainly in the NNW direction. The SACTI calculated annual plume fogging hours due to the cooling towers is about 70 hours (excluding hours of natural fog). Therefore, the impact of the cooling tower induced fogging frequency is small. No cooling tower induced icing is predicted to occur at any distance from the cooling towers. Salt deposition, from drift from the cooling towers would be below 1 kg/ha/month at ground level at any distance from the tower within and beyond the site boundary. (Values for salt deposition in Table 5.3-27 through Table 5.3-31 are presented in terms of $kg/km^2/mo$.) The visible plume frequency is greatest during the winter. For all seasons, the plume can extend out to a maximum length of 4900 m and to a height of 980 m from the tower. The following table estimates by season, the approximate percentage of time that the plume would extend above the tallest structure in the PPE (234 feet/71 m) or would extend more than 0.5 mile (800 m) from the towers. The top of the tallest structure in the PPE is approximately 160 ft (49 m) above the top of the cooling towers in the model. The frequency results reported below are for 131 ft (40 m) and 164 ft (50 m). These results are based on the wet cooling towers operating 100 percent of the time in the energy conservation (EC) mode.

Season	Plume height >40 m above top of towers	Plume height >50 m above top of towers	Plume length >0.5 mile from towers
Winter	89	49	20
Spring	77	29	11
Summer	78	20	4
Fall	79	27	7

As stated in Section 5.3.3.1, steam fog formation and steam-fog-induced icing conditions resulting from operation of the Waste Heat Treatment Facility (WHTF) are very localized and infrequent at the NAPS site. The contribution of Unit 3 (from cooling tower blowdown) to the steam fog formation or steam-fog induced icing conditions would be negligible.

Since no important terrestrial species or habitats exist in the vicinity of Unit 3, any steam fog, drift and icing impacts resulting from operation of the WHTF and wet cooling towers on the local terrestrial ecosystems would be small.

As presented in Section 5.3.3.1, there are no evaporative losses associated with the operation of closed-cycle dry cooling systems. Therefore, dry cooling tower operation for Units 3 and 4 would pose no impacts from salt drift, salt deposition, vapor plumes, or icing.

5.3.3.2.2 Local Temperature Increases

Based on general industry experience, sensible atmospheric temperature increases resulting from operation of dry or wet cooling towers are typically small and are very localized near the tower location. Therefore, there are no expected impacts, adverse or beneficial, to terrestrial ecosystems beyond the NAPS site boundary from atmospheric temperature increases due to operation of the dry towers for Unit 3 or Unit 4.

5.3.3.2.3 Noise

Noise from the operation of the heat dissipation systems would be similar to current noise levels to which local species are adapted. Current noise levels at NAPS are occasionally as high as 100 dBA (measured at the security fence during outages), but they are typically less than 80 to 85 dBA, which is the threshold at which birds and small mammals are startled or frightened (Reference 41). As presented in Section 5.3.4, noise levels from cooling tower operation would be less than 65 dBA at the EAB. No important terrestrial species or important habitats are found in the vicinity of the heat dissipation systems. Noise impacts would be small.

5.3.3.2.4 Avian Collisions

A combination of dry and wet cooling towers with an overall height of less than 180 feet would be used for the Unit 3 heat dissipation system. Dry towers with an overall height of less than 150 feet would be used for the Unit 4 heat dissipation system. Use of these maximum cooling tower heights in the evaluation of avian collisions conservatively maximizes the prediction of that environmental

impact. Since no avian collisions with existing NAPS structures have been noted, it is likely that bird collisions with the new towers would be rare. Therefore, the new towers would not adversely affect flying birds. Impacts to birds from collisions with heat dissipation structures would be small and would not warrant mitigation. The GEIS conclusion that impacts from bird collisions would be minimal (Reference 19) is valid for new units at the ESP site.

5.3.3.2.5 Aesthetics

Aesthetic impacts are addressed in Section 5.8.1.

5.3.3.2.6 Conclusions

Heat dissipation systems associated with new units at the ESP site would have small impacts on terrestrial ecosystem resources and mitigation would not be warranted.

5.3.4 Impacts to Members of the Public

This section describes the potential health impacts associated with the cooling system for the new units. Specifically, impacts to human health from thermophilic micro-organisms and from noise resulting from operation of the cooling system are addressed. (Reference 40) (Reference 19)

The existing units use an open-cycle cooling system which withdraws cooling water from the North Anna Reservoir and returns heated effluent to the WHTF. The WHTF discharges to the North Anna Reservoir through Dike 3 (Reference 38). Virginia Power considers the WHTF to be an integral part of the power station, and as such it has never been operated as an extension of the North Anna Reservoir for the purposes of public recreational use. However, with Virginia Power's permission, homeowners on the shoreline of the WHTF have access to it for recreational use (boating, fishing, swimming). This limited access and use would remain unchanged following the addition of the cooling systems for the new units. The WHTF would be one of the areas possibly affected by the noise from the new cooling systems. The thermal effects on the WHTF due to the new cooling systems would be negligible.

Although the WHTF is a private treatment facility rather than state or federal waters under the VPDES program, given the use of the WHTF for recreation and has aquatic life, Dominion has evaluated the potential impact of chemical constituents discharged to the WHTF against EPA's water quality criteria for these constituents. A review of historical impacts and current modeling results for the WHTF are presented in this section.

Public usage of the lake is transient and therefore less sensitive to noise impacts. Typically, noise limits apply at permanent residences or similar sensitive locations, as opposed to open ground where the public may have transient access. The noise impacts in this assessment were evaluated at the EAB, which is 5000 feet from the existing units.

As described in Section 3.4, the cooling needs of the new units would be provided by a closed-cycle, dry and wet tower system for Unit 3 and a closed-cycle dry tower system for Unit 4.

The Unit 3 closed-cycle wet tower cooling system would have a negligible thermal impact on the WHTF. The Unit 3 closed-cycle wet towers would generate more noise. The evaluations of thermophilic organisms and noise on the public are based on the composite cooling system (i.e., -closed-cycle wet tower system operating in tandem with dry towers).

The chemistry of the circulating water in wet cooling towers is typically controlled through the use of additives. For example, typical treatment includes biocides to prevent fouling of heat exchanger surfaces by algae and other macroscopic organisms. Cooling tower water pH is adjusted with acid to discourage corrosion and the formation of scale. Other organic and inorganic corrosion inhibitors may be used in combination with an acid for pH control. Dispersants are commonly used to prevent the formation of deposits on the heat exchange surfaces.

Dominion would use treatment chemicals that have been tested for toxicity and determined to be protective of the environment and human health. The chemicals are added to the cooling tower water circulation system in concentrations in accordance with manufacturer's recommendations to ensure that they are below toxicity thresholds as defined by each chemical's Material Safety Data Sheet. Discharge limits are administratively controlled through the NPDES permitting process which prescribes the concentrations which can be released to surface waters.

Although Dominion has not selected which chemicals would be added to the proposed cooling towers to control water chemistry, the following are common additives which are typically used:

- Biocides
  - Sodium Hypochlorite
  - Sodium Bromide (in combination with Sodium Hypochlorite)
  - Bromonated Hydantoins (typically 1-bromo-3-chloro-5,5,-dimethylhydantoin, but others may be used)
  - Isothiazolin (typically 5-chloro-2-methyl-4-isothiazoline, but others may also be used)
- Corrosion Inhibitors
  - Organic and Inorganic Phosphates
  - Tolytriazole (and potentially other azoles)
  - Zinc Chloride or Zinc Sulfate
- Dispersants
  - Polyelectrolytes & Organophosphates
- Acid
  - Sulfuric Acid

The chemicals in these potential additives would be modeled against applicable EPA human health and aquatic life criteria to demonstrate that the concentrations of these chemicals in the WHTF

would not exceed the criteria, and thus would not pose any risks to human health for the environment. None of the listed additives are identified priority pollutants defined in 40 CFR 423 with the exception of chlorine. The Total Residual Chlorine concentration of the cooling tower blowdown would be maintained to meet permit limits. Dominion would provide adequate flow to ensure that the water quality in the WHTF would not differ significantly from water quality of the North Anna Reservoir.

5.3.4.1 Thermophilic Micro-Organism Impacts

NUREG-1555 and NUREG-1437 state that consideration of the impacts of thermophilic micro-organisms on public health are important for facilities using cooling ponds, lakes, canals, or small rivers, because use of such water bodies may significantly increase the presence and numbers of thermophilic micro-organisms. These micro-organisms could be causative agents of potentially serious human infections such as primary amoebic meningoencephalitis (PAM). (Reference 48).

Thermophilic micro-organisms (e.g., *Naegleria fowleri*) generally exist in water bodies with ambient temperatures between 77°F to 176°F. However, such organisms begin to thrive especially well (compared to their competitors) at ambient temperatures above 95°F (Reference 48) and maximum growth generally occurs when ambient temperatures are maintained between 122°F and 140°F (Reference 16, Section 4.12). Since 1975, Virginia Power has monitored water temperatures at various locations in the North Anna Reservoir, the WHTF, and the discharge canal. The highest temperatures recorded are summarized in Table 5.3-9:

While ambient summer water temperatures in the sampled locations were found to be within the range of those known to permit the reproduction and growth of pathogenic micro-organisms, the temperatures measured at all locations beyond the plant discharge to the WHTF were below those considered optimal for the growth of thermophilic forms. Temperatures in the WHTF downstream of the discharge structure were several degrees cooler than those in the immediate area of the discharge outfall, and under normal circumstances, would not create an environment especially conducive to the reproduction and growth of pathogenic micro-organisms.

Because the existing units currently discharge heated cooling water into the WHTF, and then into the North Anna Reservoir and the North Anna River, the potential impacts of thermophilic organisms have been investigated since the 1970s (Reference 16). The thermophilic pathogen amoeba *Naegleria fowleri*, found in freshwater throughout the United States, was found in the WHTF following start up of North Anna Unit 1 in June 1978. In 1981, VEPCO environmental personnel met with the Virginia Epidemiologist to determine whether *N. fowleri* at North Anna represented a public health risk. Following consultation with other state and federal agencies, the risk of contracting primary amoebic meningoencephalitis was determined to be too low to justify any action by VEPCO or state agencies. (Reference 38, Section 4.1.4; Reference 16, Section 4.12 & Appendix F) In 2002, the NRC concluded that the potential impacts of microbiological organisms on

Table 5.3-9 Lake Anna Reservoir Temperature Measurements

Date	Monitoring Station	Temperature
	Pre-Operation Period (Units 1 & 2)	
July 1977	North Anna Reservoir – Pamunkey Arm	92.7°F (hourly average)
August 1980	North Anna Reservoir – Lower Lake Station	91.6°F (hourly average)
	Operational Period (Units 1 & 2)	
Summer 1983	North Anna Reservoir	92.3°F (hourly average)
June 1984	North Anna Reservoir – Upper Lake Station	91.8°F (hourly average)
Summer Seasons 1983-1985	Dike 3 – Discharge of WHTF to North Anna Reservoir	88.2°F (monthly mean)
July 1993	Dike 3 – Discharge of WHTF to North Anna Reservoir	95.0°F (hourly average)
July 1993	Lake Anna – inlet structure	90.1°F (hourly average)
Summer Season 1997	North Anna Reservoir	86.4°F (max. recorded)
Summer Season 1997	Discharge Canal	97.7°F (max. recorded)
Summer Season 1997	WHTF	94.3°F (max. recorded)
August 2002	Discharge Canal	102.4°F (hourly average)

Data Source: Reference 15 and Reference 16, Section 4.12

public health resulting from the continued operation of the existing units is small. (Reference 38, Section 4.1.4)

There have been no known occurrences of PAM at Lake Anna or the WHTF. Recent correspondence with Virginia Department of Health (VDH, September 2005) (Reference 48) indicates PAM is rare, with only one death in Virginia due to PAM during the period 1979 to 2002. Nevertheless, the VDH suggests that to reduce risk of PAM, swimmers might wish to avoid swimming in freshwater venues when surface water temperatures are greater than or equal to 95°F, should avoid shallow stagnant areas and minimize forceful entry of water up nasal passages during jumping or diving activities, and should avoid digging in sediment while under water (Reference 48). In response to this suggestion, Dominion has been working with state agencies (VDH, VDEQ) to establish how such information should be communicated to residents around the WHTF. Postal mail, signage, or internet are methods that Virginia agencies have employed at other times for public notifications.

The addition of Unit 3 wet towers would require a small amount of continuous blowdown from the closed-cycle system to the WHTF, but the blowdown would not have any significant effect on the temperature of the WHTF. Further, there is no concern with thermophilic micro-organisms in the

Unit 3 cooling tower basins because the makeup water to the cooling towers would be treated with a biocide (such as sodium hypochlorite) to prevent their growth. Therefore, the blowdown from the Unit 3 wet cooling towers would not contribute to an environment conducive to the growth of thermophilic organisms in the WHTF. Unit 3 and Unit 4 dry tower operation would pose no significant additional thermal impact to the North Anna Reservoir to support thermophilic micro-organisms. The downstream North Anna River temperatures would be unaffected by the negligible increase in thermal discharge. The maximum hourly average discharge canal and WHTF water temperatures would remain below the optimal range for thermophilic micro-organism growth (see Section 5.3.2).

Another component of the risk evaluation is the source of pathogenic materials; that is, the seeds or inoculants for such organisms. Wastewater (e.g., domestic sewage from the existing units case) represents the primary potential source of water-borne pathogens. Virginia Power recently upgraded the onsite sewage treatment plant to include disinfection processes that reduce coliform bacteria and other micro-organisms to levels that meet state water quality standards (see Section 3.6.2). The addition of personnel to support operation of the new units would not adversely impact the performance of this upgraded treatment facility.

In summary, the thermal and wastewater discharges from the addition of new units at the ESP site would result in the following:

- No significant alteration of the existing ambient temperature regime of the WHTF and the North Anna Reservoir
- No significant seeds or inoculants of pathogenic organisms would be present
- No significant increases to the population of naturally occurring micro-organisms

5.3.4.2 **Noise Impacts**

NUREG-1555, Section 5.3.4, mandates that the day-night average level of noise at the site boundary (dB[A-scale]) from the operation of the cooling system comply with applicable state limits. Because neither the Commonwealth of Virginia nor the counties surrounding the ESP site prescribe specific noise limitations, the noise evaluation compared potential offsite noise impacts with noise levels that the NRC considers to be at the threshold of significance: 65 dB(A) (Reference 40) (Reference 42) (Reference 43).

Using the CADNA/A Program, a ray-tracing noise model based on ISO 9613, Part 1 & 2, Noise Propagation Outside, predicted peak noise levels along the EAB from operation of the new composite cooling system would be below the applicable NRC-defined significance levels. Thus, the new units' cooling system would not produce adverse noise impacts to the public, and consequently, no noise mitigation measures would be required.

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15. VPDES Permit No. VA0052451, *Authorization to Discharge Under the Virginia Pollutant Discharge Elimination System and the Virginia State Water Control Act,* Commonwealth of Virginia, Department of Environmental Quality, permit's effective date, January 11, 2001; expiration date, January 11, 2006.

16. Appendix E – Applicant's Environmental Report - Operating License Renewal Stage, North Anna Power Station Units 1 and 2, License Nos. NPF-4 and NPF-7, Virginia Electric & Power Company, May 2001.

17. Final Environmental Statement, Related to the Continuation of Construction and the Operation of Units 1 & 2 and the Construction of Units 3 & 4, North Anna Power Station, Docket Nos. 50-338 & 50-339, and 50-404 & 50-405, United States Atomic Energy Commission, April 1973.

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Table 5.3-10 Physical Attributes of North Anna Reservoir and WHTF

North Anna Reservoir	
Surface Area[a]	9600 acres
Downstream from NAPS[b]	4998 acres
Upstream from NAPS	4602 acres
Volume	10.6×10^9 ft^3
Mean Depth	25 ft
Downstream from NAPS	36 ft
Upstream from NAPS	13 ft
Maximum Depth	80 ft
Downstream from NAPS	46 ft
Upstream from NAPS	46 ft
Length	17 miles
Shoreline Length	272 miles
Waste Heat Treatment Facility	
Surface Area[c]	3400 acres
Volume	2.66×10^9 ft^3
Mean Depth	18 ft
Maximum Depth	50 ft
Side-Arm Areas	1530 acres

a. Reservoir area at the design pool level of 250 ft msl

b. From NAPS to the North Anna Dam

c. WHTF area at design water level of 251.5 ft msl

Table 5.3-11 Maximum, Minimum, and Average Daily Observed Surface Temperatures at Four Monitoring Stations in WHTF and North Anna Reservoir from 7/26/1978 to 4/10/2003

Discharge[a]	Dike 3[a]	Burrus Point[a]	Intake[a]
Maximum Daily Temperature[b] (°F)			
102.4	95.0	89.4	90.1
Average Daily Temperature[b] (°F)			
77.1	69.6	65.5	63.8
Average July-August Daily Temperature[b] (°F)			
95.0	88.9	84.3	83.8
Minimum Daily Temperature[b] (°F)			
39.4	36.1	34.7	34.2

a. Refer to Section 6.1 and Figure 6.1-1 for the location of the monitoring stations.

b. Daily temperature refers to the 24-hour average temperature.

Table 5.3-12 Exceedence Frequency of Observed Daily Surface Temperatures at Four Monitoring Stations in WHTF and North Anna Reservoir from 7/26/1978 to 4/10/2003

Daily Temperature[a]	Number of Days Equal to Or Exceeding (% of Total[b])			
	Discharge	Dike 3	Burrus Point	Intake
100°F	129 (1.5%)	0 (0%)	0 (0%)	0 (0%)
95.0°F	1186 (14%)	2 (0.02%)	0 (0%)	0 (0%)
90.0°F	2085 (24%)	527 (6.0%)	0 (0%)	1 (0.01%)
87.0°F	2588 (30%)	1346 (15%)	197 (2.4%)	109 (1.3%)

a. Daily temperature refers to the 24-hour average temperature.

b. Total number of days with observations: 8251 days for Burrus Point, 8449 days for Intake, 8766 days for Dike 3 and 8640 days for Discharge.

Table 5.3-13 Monthly Maximum and Average Observed Surface Temperature Near Intake from 7/26/1978 to 4/10/2003

	Monthly Maximum Temperature (°F)		Monthly Average Temperature (°F)	
Month	**Burrus Point**	**Intake**	**Burrus Point**	**Intake**
January	56.3	52.7	47.0	43.6
February	54.5	52.5	46.4	42.8
March	59.7	60.6[a]	51.0	48.5
April	71.4	72.1[a]	59.6	58.4
May	82.8	84.2[a]	69.8	69.5
June	86.5	86.9[a]	78.7	78.8[a]
July	89.2	90.1[a]	84.2	84.0
August	89.4	89.4	84.3	83.6
September	87.4	86.5	79.9	78.7
October	79.7	78.8	70.6	68.7
November	69.8	68.5	61.5	58.8
December	64.0	62.2	53.2	50.2

a. Higher temperature at intake during spring months due to effects of in-flows from the shallower upper reach and potentially more pronounced natural stratification in the sheltered area of the intake monitoring station.

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Table 5.3-22 Winter SACTI Fogging and Icing Results

Hours of Plume Fogging Table

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Winter

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	0.0	0.0	0.0	1.5	3.1	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9	0.9	8.8
200	0.0	0.0	0.3	8.0	7.3	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	7.6	34.2
300	3.5	0.0	0.5	8.1	7.5	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	5.5	22.1	56.3
400	4.5	0.0	0.5	7.1	7.5	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	6.5	19.9	53.8
500	4.5	0.0	0.5	6.3	7.5	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	6.5	19.5	51.5
600	4.5	0.0	0.3	4.9	7.3	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	6.5	19.1	47.7
700	4.5	0.0	0.3	4.5	7.3	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	6.5	19.0	46.5
800	0.0	0.0	0.1	2.8	7.1	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.0	18.7	33.2
900	0.0	0.0	0.0	2.3	7.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	18.5	31.6
1000	0.0	0.0	0.0	0.9	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	18.5	28.9
1100	0.0	0.0	0.0	0.5	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	18.5	28.5
1200	0.0	0.0	0.0	0.5	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	18.5	26.7
1300	0.0	0.0	0.0	0.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	18.0	24.0
1400	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	18.0	23.5
1500	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	11.2	16.7
1600	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	9.0	14.5

Table 5.3-22 Winter SACTI Fogging and Icing Results

Hours of Rime Icing Table

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Winter

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.3-23 Spring SACTI Fogging and Icing Results

Hours of Plume Fogging Table

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Spring

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	0.0	0.0	0.0	0.4	0.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
200	0.0	0.0	0.3	3.0	2.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	8.5
300	0.6	0.0	0.5	3.1	2.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	3.4	12.6
400	0.8	0.0	0.5	2.7	2.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	3.0	12.0
500	0.8	0.0	0.5	2.5	2.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	3.0	11.5
600	0.8	0.0	0.3	2.1	2.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	3.0	10.3
700	0.8	0.0	0.3	2.0	2.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	3.0	10.0
800	0.0	0.0	0.1	1.5	2.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	7.2
900	0.0	0.0	0.0	1.4	2.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	6.7
1000	0.0	0.0	0.0	0.9	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	5.9
1100	0.0	0.0	0.0	0.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	5.5
1200	0.0	0.0	0.0	0.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	5.0
1300	0.0	0.0	0.0	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	4.5
1400	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	4.0
1500	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	2.9
1600	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.5

Table 5.3-23 Spring SACTI Fogging and Icing Results

Hours of Rime Icing Table

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Spring

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.3-24 Summer SACTI Fogging and Icing Results

Hours of Plume Fogging Table

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Summer

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.3-24 Summer SACTI Fogging and Icing Results

Hours of Rime Icing Table

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Summer

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.3-25 Fall SACTI Fogging and Icing Results

Hours of Plume Fogging Table

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Fall

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	0.0	0.0	0.0	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.9	0.4	2.6
200	0.0	0.0	0.0	0.4	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.0	0.8	5.4
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.3-25 Fall SACTI Fogging and Icing Results

Hours of Rime Icing Table

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Fall

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1100.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1200.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1300.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1400.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1500.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1600.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.3-26 Annual SACTI Fogging and Icing Results

Hours of Plume Fogging Table

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Annual

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	0.0	0.0	0.0	2.2	4.4	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.8	1.3	13.1
200	0.0	0.0	0.6	11.4	10.6	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	4.0	9.4	48.1
300	4.1	0.0	1.0	11.2	10.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	6.1	25.5	69.0
400	5.3	0.0	1.0	9.8	10.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	7.3	22.9	65.8
500	5.3	0.0	1.0	8.8	10.0	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	7.3	22.5	63.0
600	5.3	0.0	0.6	7.0	9.6	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	7.3	22.1	58.0
700	5.3	0.0	0.5	6.5	9.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	7.3	22.0	56.5
800	0.0	0.0	0.2	4.3	9.2	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.0	21.7	40.5
900	0.0	0.0	0.0	3.7	9.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	21.5	38.3
1000	0.0	0.0	0.0	1.7	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	21.5	34.7
1100	0.0	0.0	0.0	1.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	21.5	34.0
1200	0.0	0.0	0.0	1.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	21.5	31.7
1300	0.0	0.0	0.0	1.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	21.0	28.5
1400	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	21.0	27.5
1500	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	13.1	19.6
1600	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	10.5	17.0

Table 5.3-26 Annual SACTI Fogging and Icing Results

Hours of Rime Icing Table

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Annual

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.3-27 Winter SACTI Salt Deposition Results

Plume Salt Deposition Table (Kg./(Km.2-Mo.))**

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Winter

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	2.40	0.00	0.19
125	0.14	0.14	0.06	0.00	0.00	0.00	0.00	0.00	2.07	1.34	1.52	0.00	0.00	0.85	3.45	0.00	0.60
150	0.29	0.25	0.15	0.18	0.00	0.00	0.00	0.43	4.85	3.37	3.56	0.35	0.00	0.85	3.24	0.40	1.12
175	1.96	1.05	1.08	0.46	0.00	0.00	0.00	0.81	9.54	9.38	7.29	0.74	0.00	7.06	23.06	0.87	3.96
200	2.07	1.12	1.17	0.07	0.00	0.00	0.00	0.07	4.01	5.77	3.91	0.19	3.17	7.83	23.36	0.12	3.30
250	1.22	0.54	0.62	0.07	0.00	0.00	0.00	0.07	2.60	3.71	2.43	0.19	0.69	5.31	17.03	0.12	2.16
300	1.67	0.89	0.76	0.07	0.33	0.30	0.69	0.07	2.36	3.02	2.29	0.19	3.53	6.78	14.07	0.12	2.32
350	1.57	0.94	0.69	0.07	0.12	0.17	0.11	0.07	1.60	1.70	1.58	0.19	1.72	1.85	2.73	0.12	0.95
400	1.58	0.94	0.70	0.07	0.15	0.18	0.18	0.07	1.60	1.71	1.58	0.19	1.36	1.45	1.94	0.12	0.86
450	1.38	0.84	0.61	0.05	2.27	1.05	1.44	0.06	1.36	1.46	1.36	0.15	4.60	5.26	4.91	0.10	1.68
500	1.04	0.63	0.44	0.08	0.78	0.38	0.59	0.06	0.90	1.03	0.95	0.26	2.24	2.30	2.11	0.23	0.88
550	0.95	0.57	0.39	0.52	0.23	0.15	0.19	0.45	0.71	0.89	0.82	1.07	1.30	1.37	0.89	1.61	0.76
600	0.66	0.42	0.27	0.51	0.23	0.15	0.19	0.37	0.53	0.65	0.60	0.75	1.30	1.37	0.89	1.39	0.64
800	0.68	0.43	0.29	0.15	0.43	0.46	0.34	0.09	0.59	0.76	0.67	0.19	4.50	4.88	2.64	0.35	1.09
900	1.82	1.14	0.93	0.08	0.55	0.64	0.43	0.05	1.94	2.90	2.23	0.14	6.34	6.90	3.65	0.17	1.87
1000	1.77	1.11	0.90	0.26	0.33	0.31	0.27	0.14	1.88	2.79	2.16	0.49	2.88	3.11	1.76	0.47	1.29
1250	0.86	0.52	0.40	0.33	0.31	0.30	.250	0.18	0.83	1.18	0.95	0.63	2.85	3.08	1.72	0.59	0.94
1400	0.83	0.49	0.39	0.16	0.14	0.16	0.11	0.09	0.80	1.15	0.93	0.30	1.60	1.74	0.93	0.31	0.63
1525	0.72	0.42	0.33	0.16	0.10	0.10	0.07	0.09	0.67	0.94	0.78	0.30	0.94	1.03	0.57	0.31	0.47

Table 5.3-28 Spring SACTI Salt Deposition Results

Plume Salt Deposition Table (Kg./(Km.2-Mo.))**

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Spring

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
125	0.63	0.57	0.19	0.00	0.00	0.00	0.00	0.00	1.45	0.58	0.80	0.00	0.00	0.00	0.00	0.00	0.26
150	1.58	1.43	0.62	0.15	0.00	0.00	0.00	0.32	4.16	2.71	2.84	0.53	0.00	0.00	0.00	0.31	0.92
175	3.41	3.30	2.20	0.27	0.00	0.00	0.00	0.70	11.23	12.92	9.93	1.09	0.00	0.00	.00	0.75	2.86
200	3.35	1.66	1.39	0.10	2.47	0.57	0.34	0.10	4.83	6.62	4.33	0.11	3.14	3.26	4.83	0.15	2.33
250	3.35	1.27	1.32	0.10	0.99	0.11	0.06	0.10	4.41	6.25	4.12	0.11	1.29	0.97	1.56	0.15	1.64
300	2.50	1.05	0.97	0.10	0.81	0.41	0.64	0.10	2.76	3.57	2.47	0.11	1.41	2.67	1.68	0.15	1.34
350	1.18	0.62	0.44	0.10	0.16	0.14	0.21	0.10	0.74	0.51	0.49	0.11	0.64	1.37	0.73	0.15	0.48
400	1.18	0.62	0.44	0.10	0.46	0.45	0.68	0.10	0.74	0.51	0.49	0.11	1.52	2.26	1.25	0.15	0.69
450	0.99	0.53	0.38	0.10	1.47	1.19	1.08	0.10	0.62	0.44	0.41	0.11	2.95	4.41	2.90	0.13	1.11
500	0.64	0.35	0.26	0.06	0.44	0.31	0.25	0.09	0.39	0.29	0.24	0.14	0.88	1.50	0.93	0.20	0.44
550	0.56	0.30	0.21	0.36	0.13	0.09	0.07	0.39	0.31	0.25	0.19	0.68	0.34	0.81	0.41	0.88	0.37
600	0.41	0.24	0.17	0.34	0.13	0.09	0.07	0.25	0.25	0.19	0.17	0.56	0.34	0.81	0.41	0.88	0.33
800	0.40	0.25	0.16	0.07	0.23	0.19	0.17	0.03	0.26	0.20	0.17	0.08	1.00	2.72	1.42	0.17	0.47
900	0.75	0.66	0.30	0.05	0.29	0.25	0.22	0.02	0.53	0.40	0.24	0.04	1.38	3.83	2.00	0.10	0.69
1000	0.73	0.64	0.30	0.11	0.18	0.14	0.12	0.04	0.52	0.39	0.24	0.04	0.67	1.76	0.91	0.27	0.44
1250	0.41	0.31	0.16	0.13	0.17	0.14	0.11	0.06	0.26	0.21	0.15	0.04	0.66	1.74	0.90	0.35	0.36
1400	0.39	0.31	0.16	0.07	0.07	0.06	0.06	0.03	0.24	0.21	0.15	0.04	0.35	0.97	0.52	0.18	0.24
1525	0.36	0.27	0.14	0.07	0.05	0.04	0.04	0.03	0.21	0.19	0.14	0.04	0.22	0.58	0.31	0.18	0.18

Table 5.3-29 Summer SACTI Salt Deposition Results

Plume Salt Deposition Table (Kg./(Km.2-Mo.))**

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Summer

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
125	0.43	0.27	0.21	0.00	0.00	0.00	0.00	0.00	1.92	1.73	2.02	0.00	0.00	0.00	0.00	0.00	0.41
150	1.65	0.93	0.65	0.29	0.00	0.00	0.00	0.55	5.64	5.41	5.54	0.74	0.00	0.00	0.00	0.67	1.38
175	6.76	3.76	2.17	0.56	0.00	0.00	0.00	1.11	16.40	17.76	14.84	1.38	0.00	0.00	0.00	1.36	4.13
200	6.84	3.69	3.31	0.20	2.21	1.71	0.60	0.29	9.05	12.22	7.72	0.42	0.12	0.43	0.48	0.25	3.10
250	6.91	3.69	3.61	0.20	0.52	0.37	0.11	0.29	8.47	11.61	6.29	0.42	0.02	0.11	0.09	0.25	2.68
300	4.04	2.16	2.02	0.20	0.23	0.22	0.29	0.29	4.75	6.40	3.73	0.42	2.64	1.98	0.85	0.25	1.90
350	0.73	0.37	0.23	0.20	0.27	0.10	0.31	0.29	0.61	0.67	0.79	0.42	1.22	0.94	0.36	0.25	0.48
400	0.74	0.37	0.23	0.20	1.08	0.40	1.14	0.29	0.61	0.67	0.79	0.42	3.06	2.80	1.09	0.25	0.88
450	0.61	0.33	0.20	0.19	1.04	0.42	0.27	0.28	0.52	0.57	0.70	0.40	2.55	2.19	0.66	0.25	0.70
500	0.38	0.25	0.14	0.15	0.20	0.05	0.05	0.12	0.35	0.38	0.53	0.25	0.80	0.66	0.27	0.15	0.30
550	0.34	0.23	0.12	0.48	0.04	0.01	0.00	0.26	0.24	0.31	0.45	0.52	0.42	0.25	0.10	0.53	0.27
600	0.25	0.15	0.07	0.24	0.04	0.01	0.00	0.22	0.18	0.24	0.35	0.37	0.42	0.25	0.10	0.42	0.21
800	0.23	0.15	0.06	0.08	0.04	0.01	0.00	0.04	0.21	0.28	0.41	0.07	1.42	0.70	0.25	0.05	0.25
900	0.58	0.36	0.06	0.05	0.04	0.01	0.00	0.04	0.69	1.04	1.65	0.06	1.99	0.96	0.34	0.02	0.49
1000	0.56	0.35	0.06	0.17	0.04	0.01	0.00	0.15	0.66	1.00	1.59	0.23	0.91	0.47	0.18	0.02	0.40
1250	0.29	0.19	0.06	0.21	0.04	0.01	0.00	0.20	0.30	0.43	0.68	0.30	0.90	0.47	0.17	0.02	0.27
1400	0.29	0.19	0.06	0.10	0.01	0.00	0.00	0.09	0.30	0.42	0.67	0.14	0.51	0.25	0.09	0.02	0.20
1525	0.26	0.17	0.06	0.10	0.01	0.00	0.00	0.09	0.25	0.35	0.55	0.14	0.30	0.16	0.05	0.02	0.16

Table 5.3-30 Fall SACTI Salt Deposition Results

Plume Salt Deposition Table (Kg./(Km.2-Mo.))**

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Fall

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.11
125	0.98	0.59	0.13	0.00	1.67	0.00	0.00	0.00	2.22	2.04	1.59	0.00	0.00	0.00	0.42	0.00	0.60
150	2.72	1.59	0.36	0.12	1.67	0.00	0.00	0.57	5.46	4.96	3.91	1.08	0.00	0.00	0.42	1.04	1.49
175	7.50	4.27	1.08	0.29	13.94	0.00	0.00	1.07	9.90	10.15	8.68	2.04	0.00	0.00	3.48	2.05	4.03
200	4.19	2.05	1.24	0.04	10.77	0.12	0.25	0.13	5.58	7.66	4.60	0.28	1.99	2.69	5.33	0.21	2.95
250	4.01	1.77	1.21	0.04	8.56	0.02	0.05	0.13	5.58	6.73	3.32	0.28	0.37	0.68	3.03	0.21	2.25
300	2.90	1.22	0.81	0.04	7.29	0.36	0.21	0.13	3.61	4.22	2.49	0.28	4.67	2.20	3.01	0.21	2.10
350	1.20	0.44	0.29	0.04	0.08	0.08	0.14	0.13	1.12	1.22	1.28	0.28	1.98	0.75	0.46	0.21	0.61
400	1.20	0.44	0.29	0.06	0.21	0.18	0.53	0.13	1.12	1.22	1.28	0.28	2.59	1.45	0.92	0.22	0.76
450	1.03	0.38	0.23	0.06	1.17	1.05	1.84	0.13	0.92	1.04	1.07	0.25	6.18	4.87	2.13	0.20	1.41
500	0.69	0.26	0.14	0.10	0.35	0.27	0.52	0.12	0.54	0.67	0.68	0.25	2.57	1.63	0.67	0.24	0.61
550	0.59	0.24	0.10	0.43	0.12	0.08	0.09	0.47	0.38	0.47	0.51	0.98	1.34	0.55	0.27	1.04	0.48
600	0.47	0.19	0.09	0.26	0.12	0.08	0.09	0.37	0.24	0.37	0.44	0.76	1.34	0.55	0.27	1.04	0.42
800	0.44	0.20	0.09	0.04	0.22	0.18	0.14	0.04	0.24	0.44	0.50	0.14	4.49	1.52	0.83	0.21	0.61
900	0.79	0.48	0.23	0.02	0.28	0.24	0.17	0.01	0.45	1.63	1.76	0.10	6.30	2.07	1.15	0.15	0.99
1000	0.77	0.46	0.23	0.05	0.17	0.13	0.11	0.01	0.44	1.57	1.70	0.36	2.90	1.03	0.55	0.41	0.68
1250	0.42	0.22	0.12	0.06	0.16	0.13	0.11	0.01	0.25	0.66	0.73	0.46	2.86	1.00	0.54	0.52	0.52
1400	0.39	0.21	0.12	0.04	0.07	0.06	0.06	0.01	0.24	0.65	0.70	0.22	1.59	0.54	0.30	0.27	0.34
1525	0.36	0.18	0.10	0.04	0.05	0.04	0.05	0.01	0.22	0.53	0.58	0.22	0.95	0.34	0.18	0.27	0.26

Table 5.3-31 Annual SACTI Salt Deposition Results

Plume Salt Deposition Table (Kg./(Km.2-Mo.))**

North Anna, Richmond (1998-2000), 52-Cell MDCT

Season = Annual

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.68	0.00	0.08
125	0.54	0.39	0.14	0.00	0.42	0.00	0.00	0.00	1.92	1.42	1.48	0.00	0.00	0.21	0.95	0.00	0.47
150	1.56	1.05	0.44	0.19	0.42	0.00	0.00	0.47	5.03	4.12	3.97	0.67	0.00	0.21	0.90	0.60	1.23
175	4.91	3.10	1.64	0.39	3.48	0.00	0.00	0.92	11.79	12.59	10.21	1.31	0.00	1.74	6.55	1.26	3.74
200	4.12	2.13	1.78	0.10	3.85	0.60	0.30	0.15	5.88	8.08	5.15	0.25	2.13	3.56	8.44	0.18	2.92
250	3.89	1.82	1.69	0.10	2.51	0.13	0.05	0.15	5.28	7.09	4.05	0.25	0.60	1.77	5.37	0.18	2.18
300	2.78	1.33	1.14	0.10	2.16	0.33	0.45	0.15	3.38	4.31	2.75	0.25	3.06	3.39	4.86	0.18	1.91
350	1.17	0.59	0.41	0.10	0.16	0.12	0.19	0.15	1.01	1.02	1.03	0.25	1.39	1.22	1.06	0.18	0.63
400	1.17	0.59	0.41	0.11	0.48	0.30	0.64	0.15	1.01	1.02	1.03	0.25	2.14	1.99	1.30	0.19	0.80
450	1.00	0.52	0.35	0.10	1.49	0.93	1.15	0.14	0.85	0.88	0.88	0.23	4.06	4.17	2.63	0.17	1.22
500	0.69	0.37	0.24	0.10	0.44	0.25	0.35	0.10	0.54	0.59	0.60	0.22	1.62	1.52	0.99	0.21	0.55
550	0.61	0.34	0.20	0.45	0.13	0.08	0.09	0.39	0.41	0.48	0.49	0.81	0.85	0.74	0.41	1.01	0.47
600	0.45	0.25	0.15	0.34	0.13	0.08	0.09	0.30	0.30	0.36	0.39	0.61	0.85	0.74	0.41	0.93	0.40
800	0.44	0.26	0.15	0.08	0.23	0.21	0.16	0.05	0.32	0.42	0.44	0.12	2.84	2.44	1.28	0.20	0.60
900	0.98	0.66	0.38	0.05	0.29	0.28	0.21	0.03	0.90	1.48	1.47	0.08	3.99	3.42	1.77	0.11	1.01
1000	0.95	0.64	0.37	0.15	0.18	0.15	0.12	0.09	0.87	1.43	1.42	0.28	1.83	1.59	0.84	0.29	0.70
1250	0.49	0.31	0.18	0.18	0.17	0.14	0.12	0.11	0.41	0.62	0.63	0.36	1.81	1.56	0.83	0.36	0.52
1400	0.48	0.30	0.18	0.09	0.07	0.07	0.06	0.06	0.39	0.61	0.61	0.17	1.01	0.87	0.45	0.19	0.35
1525	0.42	0.26	0.16	0.09	0.05	0.05	0.04	0.06	0.34	0.50	0.51	0.17	0.60	0.52	0.28	0.19	0.27

Table 5.3-32 Winter SACTI Plume Length Frequency Results

Plume Length Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Winter

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	10.32	5.70	3.76	2.59	4.18	2.28	2.51	1.94	8.87	10.59	8.62	4.46	8.76	9.44	8.78	7.21	100.00
200	4.72	2.54	1.49	0.77	1.71	0.67	0.98	0.43	1.82	2.35	1.82	1.09	4.76	5.58	4.52	2.61	37.85
300	4.72	2.54	1.49	0.44	0.77	0.30	0.35	0.15	1.82	2.35	1.82	0.53	1.63	2.17	1.80	1.45	24.33
400	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
500	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
600	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
700	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
800	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
900	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
1000	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
1100	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
1200	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
1300	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
1400	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
1500	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
1600	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
1700	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
1800	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
1900	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
2000	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
2100	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
2200	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
2300	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
2400	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
2500	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
2600	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
2700	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
2800	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15

Table 5.3-32 Winter SACTI Plume Length Frequency Results

Plume Length Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Winter

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
2900	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
3000	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
3100	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
3200	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
3300	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
3400	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
3500	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
3600	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
3700	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
3800	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
3900	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
4000	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
4100	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
4200	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
4300	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
4400	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
4500	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
4600	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
4700	3.03	1.48	1.03	0.44	0.77	0.30	0.35	0.15	.68	1.10	0.87	0.53	1.62	2.10	1.69	1.45	17.60
4800	0.36	0.27	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.27	1.13
4900	0.36	0.27	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.27	1.13
5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.3-33 Winter SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Winter

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
10	10.32	5.70	3.76	2.59	4.18	2.28	2.51	1.94	8.87	10.59	8.62	4.46	8.76	9.44	8.78	7.21	100.00
20	10.32	5.70	3.76	2.59	4.18	2.28	2.51	1.94	8.87	10.59	8.62	4.46	8.76	9.41	8.65	7.21	99.85
30	10.21	5.69	3.76	2.59	4.18	2.28	2.51	1.94	8.86	10.37	8.15	4.30	8.76	9.41	8.65	7.16	98.82
40	10.17	5.67	3.76	2.52	3.00	1.27	1.80	1.91	8.86	10.28	8.06	4.08	6.53	7.54	6.73	7.00	89.19
50	6.89	4.01	2.47	1.19	1.71	0.67	0.98	0.89	3.86	4.34	3.59	1.45	4.34	5.24	4.20	3.53	49.37
60	6.61	3.93	2.39	0.82	1.71	0.67	0.98	0.52	3.12	3.61	3.10	1.16	4.33	5.16	4.13	2.70	44.94
70	5.35	2.99	1.78	0.77	1.71	0.67	0.98	0.43	2.37	2.94	2.30	1.09	4.33	5.16	4.13	2.61	39.60
80	4.72	2.54	1.49	0.77	1.71	0.67	0.98	0.43	1.82	2.35	1.82	1.09	4.33	5.16	4.13	2.61	36.61
90	4.72	2.54	1.49	0.60	1.45	0.58	0.77	0.30	1.82	2.35	1.82	0.97	3.83	4.75	3.67	1.97	33.62
100	4.72	2.54	1.49	0.60	1.22	0.53	0.70	0.30	1.82	2.35	1.82	0.97	3.32	4.22	3.11	1.97	31.68
110	4.72	2.54	1.49	0.53	1.22	0.53	0.70	0.19	1.82	2.35	1.82	0.72	3.32	4.22	3.11	1.61	30.89
120	4.72	2.54	1.49	0.44	1.06	0.48	0.51	0.15	1.82	2.35	1.82	0.53	3.00	3.82	2.56	1.45	28.73
130	4.72	2.54	1.49	0.44	0.84	0.40	0.40	0.15	1.82	2.35	1.82	0.53	2.58	3.16	2.22	1.45	26.90
140	4.72	2.54	1.49	0.44	0.84	0.40	0.40	0.15	1.82	2.35	1.82	0.53	2.58	3.16	2.22	1.45	26.90
150	3.93	2.22	1.33	0.44	0.84	0.40	0.40	0.15	1.51	1.95	1.47	0.53	2.58	3.16	2.22	1.45	24.57
160	3.93	2.22	1.33	0.44	0.84	0.40	0.40	0.15	1.51	1.95	1.47	0.53	2.58	3.16	2.22	1.45	24.57
170	3.93	2.22	1.33	0.44	0.84	0.40	0.40	0.15	1.51	1.95	1.47	0.53	2.58	3.16	2.22	1.45	24.57
180	3.93	2.22	1.33	0.44	0.77	0.30	0.35	0.15	1.51	1.95	1.47	0.53	1.62	2.10	1.69	1.45	21.81
190	3.93	2.22	1.33	0.44	0.77	0.30	0.35	0.15	1.51	1.95	1.47	0.53	1.62	2.10	1.69	1.45	21.81
200	3.93	2.22	1.33	0.44	0.77	0.30	0.35	0.15	1.51	1.95	1.47	0.53	1.62	2.10	1.69	1.45	21.81
210	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
220	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
230	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
240	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
250	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
260	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
270	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
280	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15

Table 5.3-33 Winter SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Winter

Distance From Tower	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Wind From																
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
290	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
300	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
310	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
320	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
330	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
340	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
350	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
360	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
370	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
380	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
390	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
400	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
410	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
420	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
430	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
440	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
450	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
460	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
470	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
480	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
490	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
500	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
510	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
520	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
530	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
540	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
550	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
560	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15

Table 5.3-33 Winter SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Winter

Distance From Tower	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Wind From																
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
570	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
580	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
590	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.10	1.69	1.45	20.15
600	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
610	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
620	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
630	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
640	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
650	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
660	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
670	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
680	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
690	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
700	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
710	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
720	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.45	20.09
730	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.82
740	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.82
750	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.82
760	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.82
770	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.82
780	3.68	2.06	1.19	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.82
790	3.32	1.80	1.01	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.02
800	3.32	1.80	1.01	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.02
810	3.32	1.80	1.01	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.02
820	3.32	1.80	1.01	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.02
830	3.32	1.80	1.01	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.02
840	3.32	1.80	1.01	0.44	0.77	0.30	0.35	0.15	1.22	1.48	1.12	0.53	1.62	2.08	1.64	1.18	19.02

Table 5.3-33 Winter SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Winter

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
850	1.46	1.00	0.56	0.44	0.40	0.19	0.24	0.15	0.78	0.73	0.62	0.53	1.14	1.49	0.71	1.18	11.62
860	1.46	1.00	0.56	0.08	0.40	0.19	0.24	0.03	0.78	0.73	0.62	0.19	1.14	1.49	0.71	0.32	9.94
870	1.46	1.00	0.56	0.08	0.40	0.19	0.24	0.03	0.78	0.73	0.62	0.19	1.14	1.49	0.71	0.32	9.94
880	1.46	1.00	0.56	0.08	0.40	0.19	0.24	0.03	0.78	0.73	0.62	0.19	1.14	1.49	0.71	0.32	9.94
890	1.46	1.00	0.56	0.08	0.40	0.19	0.24	0.03	0.78	0.73	0.62	0.19	1.14	1.49	0.71	0.32	9.94
900	0.65	0.58	0.16	0.08	0.40	0.19	0.24	0.03	0.54	0.38	0.25	0.19	1.14	1.49	0.71	0.32	7.35
910	0.65	0.58	0.16	0.00	0.09	0.08	0.13	0.00	0.54	0.38	0.25	0.00	0.52	0.58	0.36	0.00	4.32
920	0.65	0.58	0.16	0.00	0.09	0.08	0.13	0.00	0.54	0.38	0.25	0.00	0.52	0.58	0.36	0.00	4.32
930	0.65	0.58	0.16	0.00	0.09	0.08	0.13	0.00	0.54	0.38	0.25	0.00	0.52	0.58	0.36	0.00	4.32
940	0.65	0.58	0.16	0.00	0.09	0.08	0.13	0.00	0.54	0.38	0.25	0.00	0.52	0.58	0.36	0.00	4.32
950	0.65	0.58	0.16	0.00	0.09	0.08	0.13	0.00	0.54	0.38	0.25	0.00	0.52	0.58	0.36	0.00	4.32
960	0.65	0.58	0.16	0.00	0.09	0.08	0.13	0.00	0.54	0.38	0.25	0.00	0.52	0.58	0.36	0.00	4.32
970	0.65	0.58	0.16	0.00	0.09	0.08	0.13	0.00	0.54	0.38	0.25	0.00	0.52	0.58	0.36	0.00	4.32
980	0.65	0.58	0.16	0.00	0.09	0.08	0.13	0.00	0.54	0.38	0.25	0.00	0.52	0.58	0.36	0.00	4.32
990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.3-34 Spring SACTI Plume Length Frequency Results

Plume Length Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Spring

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	10.02	5.12	4.72	3.89	6.10	4.57	3.15	2.30	7.36	9.32	7.79	4.35	7.10	9.18	8.12	6.93	100.00
200	2.79	1.37	1.26	1.08	2.09	0.86	0.44	0.25	0.41	0.45	0.45	0.19	1.81	3.25	2.56	1.20	20.46
300	2.79	1.37	1.26	0.77	1.11	0.42	0.20	0.16	0.41	0.45	0.45	0.08	0.53	0.93	0.72	0.78	12.44
400	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
500	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
600	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
700	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
800	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
900	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
1000	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
1100	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
1200	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
1300	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
1400	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
1500	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
1600	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
1700	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
1800	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
1900	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
2000	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
2100	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
2200	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
2300	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
2400	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
2500	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
2600	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
2700	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
2800	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76

Table 5.3-34 Spring SACTI Plume Length Frequency Results

Plume Length Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Spring

Distance From Tower	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	********** Wind From **********																
	********** Plume Headed **********																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
2900	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
3000	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
3100	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
3200	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
3300	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
3400	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
3500	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
3600	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
3700	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
3800	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
3900	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
4000	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
4100	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
4200	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
4300	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
4400	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
4500	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
4600	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
4700	1.71	.82	0.84	0.77	1.05	0.42	0.20	0.16	0.19	0.27	0.24	0.08	0.48	0.87	0.69	0.78	9.57
4800	0.46	0.10	0.15	0.10	.10	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.03	0.21	1.19
4900	0.46	0.10	0.15	0.10	.10	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.03	0.21	1.19
5000	0.00	0.00	0.00	0.00	.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.3-35 Spring SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Spring

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
10	10.02	5.12	4.72	3.89	6.10	4.57	3.15	2.30	7.36	9.32	7.79	4.35	7.10	9.18	8.12	6.93	100.00
20	10.02	5.12	4.72	3.89	6.10	4.57	3.15	2.30	7.36	9.32	7.79	4.35	7.10	9.18	8.12	6.93	100.00
30	9.34	4.86	4.47	3.28	6.10	4.57	3.15	2.28	7.23	8.52	6.92	3.77	7.10	9.18	8.12	6.14	95.02
40	9.16	4.80	4.33	3.25	3.08	2.01	1.67	2.17	7.22	8.35	6.74	3.66	3.88	6.15	4.26	5.98	76.72
50	4.57	2.34	1.83	1.45	1.83	0.78	0.39	0.56	2.20	2.31	1.96	.60	1.44	2.82	1.98	2.10	29.16
60	4.25	2.09	1.63	1.11	1.77	0.78	0.39	0.33	1.20	0.98	1.01	0.31	1.40	2.79	1.95	1.28	23.26
70	3.32	1.66	1.34	1.08	1.77	0.78	0.39	0.25	0.70	0.70	0.64	0.19	1.40	2.79	1.95	1.20	20.14
80	2.79	1.37	1.26	1.08	1.77	0.78	0.39	0.25	0.41	0.45	0.45	0.19	1.40	2.79	1.95	1.20	18.52
90	2.79	1.37	1.26	0.95	1.64	0.70	0.36	0.24	0.41	0.45	0.45	0.16	1.24	2.51	1.79	1.09	17.42
100	2.79	1.37	1.26	0.95	1.47	0.62	0.31	0.24	0.41	0.45	0.45	0.16	1.12	2.31	1.51	1.09	16.51
110	2.79	1.37	1.26	0.80	1.47	0.62	0.31	0.17	0.41	0.45	0.45	0.08	1.12	2.31	1.51	0.87	16.00
120	2.79	1.37	1.26	0.77	1.24	0.51	0.27	0.16	0.41	0.45	0.45	0.08	0.96	1.90	1.25	0.78	14.64
130	2.79	1.37	1.26	0.77	1.08	0.45	0.23	0.16	0.41	0.45	0.45	0.08	0.68	1.45	1.00	0.78	13.41
140	2.79	1.37	1.26	0.77	1.08	0.45	0.23	0.16	0.41	0.45	0.45	0.08	0.68	1.45	1.00	0.78	13.41
150	2.26	1.15	1.14	0.77	1.08	0.45	0.23	0.16	0.34	0.39	0.30	0.08	0.68	1.45	1.00	0.78	12.25
160	2.26	1.15	1.14	0.77	1.08	0.45	0.23	0.16	0.34	0.39	0.30	0.08	0.68	1.45	1.00	0.78	12.25
170	2.26	1.15	1.14	0.77	1.08	0.45	0.23	0.16	0.34	0.39	0.30	0.08	0.68	1.45	1.00	0.78	12.25
180	2.26	1.15	1.14	0.77	1.05	0.42	0.20	0.16	0.34	0.39	0.30	0.08	0.48	0.87	0.69	0.78	11.08
190	2.26	1.15	1.14	0.77	1.05	0.42	0.20	0.16	0.34	0.39	0.30	0.08	0.48	0.87	0.69	0.78	11.08
200	2.26	1.15	1.14	0.77	1.05	0.42	0.20	0.16	0.34	0.39	0.30	0.08	0.48	0.87	0.69	0.78	11.08
210	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
220	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
230	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
240	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
250	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
260	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
270	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
280	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76

Table 5.3-35 Spring SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Spring

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
290	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
300	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
310	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
320	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
330	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
340	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
350	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
360	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
370	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
380	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
390	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
400	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
410	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
420	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
430	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
440	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
450	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
460	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
470	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
480	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
490	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
500	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
510	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
520	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
530	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
540	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
550	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
560	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76

Table 5.3-35 Spring SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Spring

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
570	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
580	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
590	2.18	1.06	1.10	0.77	1.05	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.69	0.78	10.76
600	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
610	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
620	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
630	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
640	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
650	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
660	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
670	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
680	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
690	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
700	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
710	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
720	2.18	1.06	1.10	0.77	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.08	0.48	0.87	0.66	0.78	10.63
730	2.18	1.06	1.10	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.05	0.48	0.87	0.66	0.57	10.29
740	2.18	1.06	1.10	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.05	0.48	0.87	0.66	0.57	10.29
750	2.18	1.06	1.10	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.05	0.48	0.87	0.66	0.57	10.29
760	2.18	1.06	1.10	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.05	0.48	0.87	0.66	0.57	10.29
770	2.18	1.06	1.10	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.05	0.48	0.87	0.66	0.57	10.29
780	2.18	1.06	1.10	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.28	0.05	0.48	0.87	0.66	0.57	10.29
790	1.72	0.96	.96	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.27	0.05	0.48	0.87	0.66	0.57	9.57
800	1.72	0.96	.96	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.27	0.05	0.48	0.87	0.66	0.57	9.57
810	1.72	0.96	.96	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.27	0.05	0.48	0.87	0.66	0.57	9.57
820	1.72	0.96	.96	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.27	0.05	0.48	0.87	0.66	0.57	9.57
830	1.72	0.96	.96	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.27	0.05	0.48	0.87	0.66	0.57	9.57
840	1.72	0.96	.96	0.67	.95	0.42	0.20	0.16	0.28	0.34	0.27	0.05	0.48	0.87	0.66	0.57	9.57

Table 5.3-35 Spring SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Spring

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
850	0.98	0.51	0.51	0.67	0.70	0.26	0.12	0.16	0.14	0.19	0.15	0.05	0.40	0.68	0.34	0.57	6.43
860	0.98	0.51	0.51	0.41	0.70	0.26	0.12	0.02	0.14	0.19	0.15	0.03	0.40	0.68	0.34	0.11	5.55
870	0.98	0.51	0.51	0.41	0.70	0.26	0.12	0.02	0.14	0.19	0.15	0.03	0.40	0.68	0.34	0.11	5.55
880	0.98	0.51	0.51	0.41	0.70	0.26	0.12	0.02	0.14	0.19	0.15	0.03	0.40	0.68	0.34	0.11	5.55
890	0.98	0.51	0.51	0.41	0.70	0.26	0.12	0.02	0.14	0.19	0.15	0.03	0.40	0.68	0.34	0.11	5.55
900	0.47	0.24	0.27	0.41	0.70	0.26	0.12	0.02	0.09	0.08	0.05	0.03	0.40	0.68	0.34	0.11	4.27
910	0.47	0.24	0.27	0.00	0.33	0.08	0.08	0.00	0.09	0.08	0.05	0.00	0.19	0.30	0.09	0.00	2.26
920	0.47	0.24	0.27	0.00	0.33	0.08	0.08	0.00	0.09	0.08	0.05	0.00	0.19	0.30	0.09	0.00	2.26
930	0.47	0.24	0.27	0.00	0.33	0.08	0.08	0.00	0.09	0.08	0.05	0.00	0.19	0.30	0.09	0.00	2.26
940	0.47	0.24	0.27	0.00	0.33	0.08	0.08	0.00	0.09	0.08	0.05	0.00	0.19	0.30	0.09	0.00	2.26
950	0.47	0.24	0.27	0.00	0.33	0.08	0.08	0.00	0.09	0.08	0.05	0.00	0.19	0.30	0.09	0.00	2.26
960	0.47	0.24	0.27	0.00	0.33	0.08	0.08	0.00	0.09	0.08	0.05	0.00	0.19	0.30	0.09	0.00	2.26
970	0.47	0.24	0.27	0.00	0.33	0.08	0.08	0.00	0.09	0.08	0.05	0.00	0.19	0.30	0.09	0.00	2.26
980	0.47	0.24	0.27	0.00	0.33	0.08	0.08	0.00	0.09	0.08	0.05	0.00	0.19	0.30	0.09	0.00	2.26
990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.3-36 Summer SACTI Plume Length Frequency Results

Plume Length Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Summer

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	9.77	5.78	4.36	4.39	8.13	4.20	3.85	3.24	9.79	11.79	8.69	3.97	7.10	5.88	3.85	5.20	100.00
200	0.77	0.59	0.46	0.43	1.18	0.62	0.31	0.18	0.53	0.43	0.50	0.17	1.16	0.89	0.45	0.20	8.88
300	0.77	0.59	0.46	0.22	0.64	0.22	0.14	0.08	0.53	0.43	0.50	0.03	0.23	0.22	0.16	0.03	5.24
400	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
500	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
600	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
700	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
800	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
900	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
1000	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
1100	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
1200	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
1300	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
1400	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
1500	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
1600	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
1700	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
1800	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
1900	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
2000	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
2100	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
2200	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
2300	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
2400	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
2500	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
2600	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
2700	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
2800	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95

Table 5.3-36 Summer SACTI Plume Length Frequency Results

Plume Length Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Summer

Distance From Tower	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	********** Wind From **********																
	********** Plume Headed **********																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
2900	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
3000	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
3100	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
3200	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
3300	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
3400	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
3500	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
3600	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
3700	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
3800	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
3900	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
4000	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
4100	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
4200	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
4300	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
4400	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
4500	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
4600	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
4700	0.36	0.27	0.22	0.22	0.64	0.20	0.14	0.08	0.28	0.20	0.12	0.03	0.23	0.20	0.16	0.03	3.37
4800	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
4900	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.3-37 Summer SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Summer

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
10	9.77	5.78	4.36	4.39	8.13	4.20	3.85	3.24	9.79	11.79	8.69	3.97	7.10	5.88	3.85	5.20	100.00
20	9.77	5.78	4.36	4.39	8.13	4.20	3.85	3.24	9.79	11.79	8.69	3.97	7.10	5.88	3.85	5.20	100.00
30	9.04	5.29	4.18	4.28	8.13	4.20	3.85	3.24	9.79	11.78	8.66	3.92	7.10	5.88	3.85	4.91	98.10
40	8.88	5.26	4.15	4.22	2.46	0.98	1.11	3.18	9.79	11.78	8.66	3.89	4.18	3.51	1.51	4.80	78.34
50	2.07	1.43	0.93	0.86	0.90	0.39	0.23	0.81	2.69	2.83	2.64	1.08	1.14	0.82	0.39	0.89	20.13
60	1.37	1.10	0.73	0.49	0.90	0.38	0.23	0.31	1.25	1.21	1.43	0.32	1.14	0.82	0.39	0.36	12.43
70	0.91	0.81	0.57	0.43	0.90	0.38	0.23	0.18	0.98	0.79	0.90	0.17	1.14	0.82	0.39	0.20	9.81
80	0.77	0.59	0.46	0.43	0.90	0.38	0.23	0.18	0.53	0.43	0.50	0.17	1.14	0.82	0.39	0.20	8.13
90	0.77	0.59	0.46	0.39	0.87	0.36	0.23	0.15	0.53	0.43	0.50	0.14	0.99	0.70	0.30	0.13	7.54
100	0.77	0.59	0.46	0.39	0.79	0.28	0.23	0.15	0.53	0.43	0.50	0.14	0.89	0.60	0.25	0.13	7.14
110	0.77	0.59	0.46	0.28	0.79	0.28	0.23	0.14	0.53	0.43	0.50	0.12	0.89	0.60	0.25	0.03	6.90
120	0.77	0.59	0.46	0.22	0.73	0.25	0.18	0.08	0.53	0.43	0.50	0.03	0.78	0.46	0.23	0.03	6.27
130	0.77	0.59	0.46	0.22	0.64	0.20	0.14	0.08	0.53	0.43	0.50	0.03	0.54	0.34	0.20	0.03	5.70
140	0.77	0.59	0.46	0.22	0.64	0.20	0.14	0.08	0.53	0.43	0.50	0.03	0.54	0.34	0.20	0.03	5.70
150	0.69	0.47	0.36	0.22	0.64	0.20	0.14	0.08	0.38	0.38	0.41	0.03	0.54	0.34	0.20	0.03	5.10
160	0.69	0.47	0.36	0.22	0.64	0.20	0.14	0.08	0.38	0.38	0.41	0.03	0.54	0.34	0.20	0.03	5.10
170	0.69	0.47	0.36	0.22	0.64	0.20	0.14	0.08	0.38	0.38	0.41	0.03	0.54	0.34	0.20	0.03	5.10
180	0.69	0.47	0.36	0.22	0.64	0.20	0.14	0.08	0.38	0.38	0.41	0.03	0.23	0.20	0.16	0.03	4.62
190	0.69	0.47	0.36	0.22	0.64	0.20	0.14	0.08	0.38	0.38	0.41	0.03	0.23	0.20	0.16	0.03	4.62
200	0.69	0.47	0.36	0.22	0.64	0.20	0.14	0.08	0.38	0.38	0.41	0.03	0.23	0.20	0.16	0.03	4.62
210	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
220	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
230	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
240	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
250	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
260	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
270	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
280	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95

Table 5.3-37 Summer SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Summer

Distance From Tower	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	********** Wind From **********																
	********** Plume Headed **********																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
290	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
300	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
310	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
320	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
330	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
340	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
350	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
360	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
370	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
380	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
390	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
400	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
410	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
420	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
430	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
440	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
450	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
460	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
470	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
480	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
490	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
500	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
510	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
520	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
530	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
540	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
550	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
560	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95

Table 5.3-37 Summer SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Summer

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
570	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
580	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
590	0.62	0.42	0.36	0.22	0.64	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.95
600	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
610	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
620	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
630	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
640	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
650	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
660	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
670	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
680	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
690	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
700	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
710	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
720	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
730	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
740	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
750	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
760	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
770	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
780	0.62	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.92
790	0.60	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.91
800	0.60	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.91
810	0.60	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.91
820	0.60	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.91
830	0.60	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.91
840	0.60	0.42	0.36	0.22	0.61	0.20	0.14	0.08	0.28	0.22	0.14	0.03	0.23	0.20	0.16	0.03	3.91

Table 5.3-37 Summer SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Summer

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
850	0.46	0.26	0.16	0.22	0.22	0.16	0.02	0.08	0.00	0.03	0.02	0.03	0.11	0.09	0.08	0.03	1.96
860	0.46	0.26	0.16	0.02	0.22	0.16	0.02	0.00	0.00	0.03	0.02	0.00	0.11	0.09	0.08	0.02	1.64
870	0.46	0.26	0.16	0.02	0.22	0.16	0.02	0.00	0.00	0.03	0.02	0.00	0.11	0.09	0.08	0.02	1.64
880	0.46	0.26	0.16	0.02	0.22	0.16	0.02	0.00	0.00	0.03	0.02	0.00	0.11	0.09	0.08	0.02	1.64
890	0.46	0.26	0.16	0.02	0.22	0.16	0.02	0.00	0.00	0.03	0.02	0.00	0.11	0.09	0.08	0.02	1.64
900	0.25	0.16	0.14	0.02	0.22	0.16	0.02	0.00	0.00	0.02	0.02	0.00	0.11	0.09	0.08	0.02	1.30
910	0.25	0.16	0.14	0.00	0.17	0.14	0.02	0.00	0.00	0.02	0.02	0.00	0.09	0.09	0.08	0.00	1.19
920	0.25	0.16	0.14	0.00	0.17	0.14	0.02	0.00	0.00	0.02	0.02	0.00	0.09	0.09	0.08	0.00	1.19
930	0.25	0.16	0.14	0.00	0.17	0.14	0.02	0.00	0.00	0.02	0.02	0.00	0.09	0.09	0.08	0.00	1.19
940	0.25	0.16	0.14	0.00	0.17	0.14	0.02	0.00	0.00	0.02	0.02	0.00	0.09	0.09	0.08	0.00	1.19
950	0.25	0.16	0.14	0.00	0.17	0.14	0.02	0.00	0.00	0.02	0.02	0.00	0.09	0.09	0.08	0.00	1.19
960	0.25	0.16	0.14	0.00	0.17	0.14	0.02	0.00	0.00	0.02	0.02	0.00	0.09	0.09	0.08	0.00	1.19
970	0.25	0.16	0.14	0.00	0.17	0.14	0.02	0.00	0.00	0.02	0.02	0.00	0.09	0.09	0.08	0.00	1.19
980	0.25	0.16	0.14	0.00	0.17	0.14	0.02	0.00	0.00	0.02	0.02	0.00	0.09	0.09	0.08	0.00	1.19
990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.3-38 Fall SACTI Plume Length Frequency Results

Plume Length Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Fall

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	10.55	4.37	2.96	2.84	4.38	3.35	4.03	2.87	8.63	9.28	7.51	4.65	11.90	8.65	6.47	7.54	99.98
200	1.54	0.78	0.60	0.40	0.75	0.32	0.60	0.09	0.54	0.69	0.90	0.50	4.83	2.57	1.72	0.88	17.70
300	1.54	0.78	0.60	0.21	0.16	0.10	0.19	0.03	0.54	0.69	0.90	0.24	1.27	0.64	0.46	0.32	8.67
400	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
500	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
600	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
700	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
800	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
900	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
1000	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
1100	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
1200	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
1300	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
1400	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
1500	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
1600	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
1700	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
1800	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
1900	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
2000	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
2100	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
2200	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
2300	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
2400	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
2500	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
2600	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
2700	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
2800	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98

Table 5.3-38 Fall SACTI Plume Length Frequency Results

Plume Length Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Fall

Distance From Tower	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Wind From								Plume Headed								
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
2900	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
3000	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
3100	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
3200	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
3300	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
3400	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
3500	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
3600	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
3700	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
3800	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
3900	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
4000	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
4100	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
4200	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
4300	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
4400	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
4500	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
4600	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
4700	1.02	0.39	0.32	0.21	0.16	0.10	0.19	0.03	0.24	0.23	0.32	0.24	1.27	0.62	0.44	0.32	6.10
4800	0.08	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.15
4900	0.08	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.15
5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.3-39 Fall SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Fall

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
10	10.55	4.37	2.96	2.84	4.38	3.35	4.03	2.87	8.63	9.28	7.51	4.65	11.90	8.65	6.47	7.54	99.98
20	10.55	4.37	2.96	2.84	4.32	3.35	4.03	2.87	8.63	9.28	7.51	4.65	11.90	8.65	6.45	7.54	99.91
30	9.67	4.22	2.76	2.69	4.32	3.35	4.03	2.87	8.58	9.08	7.43	4.52	11.90	8.65	6.45	6.45	96.95
40	9.52	4.22	2.76	2.61	1.73	1.06	1.84	2.81	8.58	9.08	7.43	4.41	8.55	5.14	3.03	6.21	78.97
50	3.66	1.59	0.87	0.60	0.63	0.30	0.57	0.58	2.37	2.31	2.58	1.28	4.56	2.21	1.38	1.95	27.43
60	2.92	1.23	0.73	0.41	0.63	0.30	0.57	0.22	1.47	1.55	1.89	0.74	4.56	2.20	1.37	1.10	21.87
70	2.09	0.98	0.63	0.38	0.63	0.30	0.57	0.09	0.99	1.02	1.26	0.50	4.56	2.20	1.37	0.87	18.44
80	1.54	0.78	0.60	0.38	0.63	0.30	0.57	0.09	0.54	0.69	0.90	0.50	4.56	2.20	1.37	0.87	16.51
90	1.54	0.78	0.60	0.33	0.49	0.22	0.46	0.09	0.54	0.69	0.90	0.44	3.96	1.73	1.21	0.66	14.65
100	1.54	0.78	0.60	0.33	0.32	0.17	0.39	0.09	0.54	0.69	0.90	0.44	3.47	1.46	0.99	0.66	13.39
110	1.54	0.78	0.60	0.22	0.32	0.17	0.39	0.03	0.54	0.69	0.90	0.38	3.47	1.46	0.99	0.46	12.95
120	1.54	0.78	0.60	0.21	0.25	0.17	0.28	0.03	0.54	0.69	0.90	0.24	2.92	1.15	0.80	0.32	11.43
130	1.54	0.78	0.60	0.21	0.19	0.13	0.21	0.03	0.54	0.69	0.90	0.24	2.23	0.91	0.61	0.32	10.12
140	1.54	0.78	0.60	0.21	0.19	0.13	0.21	0.03	0.54	0.69	0.90	0.24	2.23	0.91	0.61	0.32	10.12
150	1.31	0.59	0.49	0.21	0.19	0.13	0.21	0.03	0.44	0.58	0.74	0.24	2.23	0.91	0.61	0.32	9.23
160	1.31	0.59	0.49	0.21	0.19	0.13	0.21	0.03	0.44	0.58	0.74	0.24	2.23	0.91	0.61	0.32	9.23
170	1.31	0.59	0.49	0.21	0.19	0.13	0.21	0.03	0.44	0.58	0.74	0.24	2.23	0.91	0.61	0.32	9.23
180	1.31	0.59	0.49	0.21	0.16	0.10	0.19	0.03	0.44	0.58	0.74	0.24	1.27	0.62	0.44	0.32	7.73
190	1.31	0.59	0.49	0.21	0.16	0.10	0.19	0.03	0.44	0.58	0.74	0.24	1.27	0.62	0.44	0.32	7.73
200	1.31	0.59	0.49	0.21	0.16	0.10	0.19	0.03	0.44	0.58	0.74	0.24	1.27	0.62	0.44	0.32	7.73
210	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
220	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
230	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
240	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
250	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
260	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
270	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
280	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98

Table 5.3-39 Fall SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Fall

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
290	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
300	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
310	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
320	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
330	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
340	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
350	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
360	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
370	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
380	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
390	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
400	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
410	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
420	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
430	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
440	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
450	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
460	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
470	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
480	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
490	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
500	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
510	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
520	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
530	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
540	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
550	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
560	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98

Table 5.3-39 Fall SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Fall

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
570	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
580	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
590	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.44	0.32	6.98
600	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
610	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
620	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
630	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
640	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
650	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
660	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
670	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
680	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
690	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
700	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
710	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
720	1.23	0.53	0.46	0.21	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.32	6.94
730	1.23	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.91
740	1.23	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.91
750	1.23	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.91
760	1.23	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.91
770	1.23	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.91
780	1.23	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.91
790	1.15	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.83
800	1.15	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.83
810	1.15	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.83
820	1.15	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.83
830	1.15	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.83
840	1.15	0.53	0.46	0.19	0.16	0.10	0.19	0.03	0.40	0.32	0.46	0.24	1.27	0.62	0.40	0.31	6.83

Table 5.3-39 Fall SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Fall

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
850	0.62	0.30	0.22	0.19	0.08	0.10	0.09	0.03	0.17	0.19	0.19	.24	1.05	0.46	0.21	0.31	4.46
860	0.62	0.30	0.22	0.08	0.08	0.10	0.09	0.00	0.17	0.19	0.19	0.03	1.05	0.46	0.21	0.18	3.97
870	0.62	0.30	0.22	0.08	0.08	0.10	0.09	0.00	0.17	0.19	0.19	0.03	1.05	0.46	0.21	0.18	3.97
880	0.62	0.30	0.22	0.08	0.08	0.10	0.09	0.00	0.17	0.19	0.19	0.03	1.05	0.46	0.21	0.18	3.97
890	0.62	0.30	0.22	0.08	0.08	0.10	0.09	0.00	0.17	0.19	0.19	0.03	1.05	0.46	0.21	0.18	3.97
900	0.20	0.14	0.14	0.08	0.08	0.10	0.09	0.00	0.16	0.09	0.14	0.03	1.05	0.46	0.21	0.18	3.15
910	0.20	0.14	0.14	0.00	0.08	0.03	0.08	0.00	0.16	0.09	0.14	.00	0.52	0.24	0.14	0.00	1.96
920	0.20	0.14	0.14	0.00	0.08	0.03	0.08	0.00	0.16	0.09	0.14	.00	0.52	0.24	0.14	0.00	1.96
930	0.20	0.14	0.14	0.00	0.08	0.03	0.08	0.00	0.16	0.09	0.14	.00	0.52	0.24	0.14	0.00	1.96
940	0.20	0.14	0.14	0.00	0.08	0.03	0.08	0.00	0.16	0.09	0.14	.00	0.52	0.24	0.14	0.00	1.96
950	0.20	0.14	0.14	0.00	0.08	0.03	0.08	0.00	0.16	0.09	0.14	.00	0.52	0.24	0.14	0.00	1.96
960	0.20	0.14	0.14	0.00	0.08	0.03	0.08	0.00	0.16	0.09	0.14	.00	0.52	0.24	0.14	0.00	1.96
970	0.20	0.14	0.14	0.00	0.08	0.03	0.08	0.00	0.16	0.09	0.14	.00	0.52	0.24	0.14	0.00	1.96
980	0.20	0.14	0.14	0.00	0.08	0.03	0.08	0.00	0.16	0.09	0.14	.00	0.52	0.24	0.14	0.00	1.96
990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.3-40 Annual SACTI Plume Length Frequency Results

Plume Length Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Annual

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
100	10.14	5.24	3.95	3.43	5.71	3.60	3.39	2.59	8.67	10.26	8.17	4.36	8.71	8.29	6.80	6.70	100.00
200	2.44	1.31	0.95	0.67	1.43	0.62	0.58	0.24	0.82	0.97	0.91	0.48	3.13	3.07	2.30	1.21	21.15
300	2.44	1.31	0.95	0.41	0.67	0.26	0.22	0.10	0.82	0.97	0.91	0.22	0.91	0.99	0.78	0.64	12.62
400	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
500	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
600	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
700	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
800	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
900	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
1000	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
1100	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
1200	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
1300	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
1400	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
1500	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
1600	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
1700	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
1800	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
1900	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
2000	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
2100	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
2200	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
2300	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
2400	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
2500	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
2600	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
2700	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
2800	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42

Table 5.3-40 Annual SACTI Plume Length Frequency Results

Plume Length Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Annual

Distance From Tower	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	********** Wind From **********																
	********** Plume Headed **********																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
2900	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
3000	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
3100	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
3200	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
3300	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
3400	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
3500	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
3600	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
3700	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
3800	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
3900	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
4000	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
4100	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
4200	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
4300	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
4400	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
4500	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
4600	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
4700	1.52	0.73	0.60	0.41	0.66	0.26	0.22	0.10	0.35	0.45	0.39	0.22	0.89	0.94	0.74	0.64	9.12
4800	0.23	0.09	0.08	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.12	0.63
4900	0.23	0.09	0.08	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.12	0.63
5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.3-41 Annual SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Annual

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
10	10.14	5.24	3.95	3.43	5.71	3.60	3.39	2.59	8.67	10.26	8.17	4.36	8.71	8.29	6.80	6.70	100.00
20	10.14	5.24	3.95	3.43	5.69	3.60	3.39	2.59	8.67	10.26	8.17	4.36	8.71	8.28	6.76	6.70	99.94
30	9.55	5.01	3.79	3.21	5.69	3.60	3.39	2.58	8.62	9.94	7.79	4.13	8.71	8.28	6.76	6.16	97.22
40	9.42	4.98	3.75	3.15	2.57	1.33	1.60	2.52	8.61	9.87	7.72	4.01	5.78	5.58	3.87	5.99	80.76
50	4.28	2.33	1.52	1.03	1.27	0.54	0.54	0.71	2.78	2.94	2.69	1.10	2.86	2.76	1.98	2.11	31.43
60	3.77	2.08	1.37	0.71	1.25	0.53	0.54	0.34	1.76	1.83	1.85	0.63	2.85	2.73	1.95	1.35	25.53
70	2.90	1.61	1.08	0.67	1.25	0.53	0.54	0.24	1.26	1.35	1.27	0.48	2.85	2.73	1.95	1.21	21.91
80	2.44	1.31	0.95	0.67	1.25	0.53	0.54	0.24	0.82	0.97	0.91	0.48	2.85	2.73	1.95	1.21	19.86
90	2.44	1.31	0.95	0.57	1.11	0.46	0.45	0.20	0.82	0.97	0.91	0.42	2.49	2.41	1.73	0.96	18.23
100	2.44	1.31	0.95	0.57	0.95	0.40	0.41	0.20	0.82	0.97	0.91	0.42	2.19	2.14	1.46	0.96	17.11
110	2.44	1.31	0.95	0.46	0.95	0.40	0.41	0.13	0.82	0.97	0.91	0.32	2.19	2.14	1.46	0.74	16.61
120	2.44	1.31	0.95	0.41	0.82	0.35	0.31	0.10	0.82	0.97	0.91	0.22	1.91	1.82	1.20	0.64	15.20
130	2.44	1.31	0.95	0.41	0.69	0.29	0.24	0.10	0.82	0.97	0.91	0.22	1.50	1.46	1.00	0.64	13.97
140	2.44	1.31	0.95	0.41	0.69	0.29	0.24	0.10	0.82	0.97	0.91	0.22	1.50	1.46	1.00	0.64	13.97
150	2.03	1.10	0.83	0.41	0.69	0.29	0.24	0.10	0.67	0.82	0.73	0.22	1.50	1.46	1.00	0.64	12.73
160	2.03	1.10	0.83	0.41	0.69	0.29	0.24	0.10	0.67	0.82	0.73	0.22	1.50	1.46	1.00	0.64	12.73
170	2.03	1.10	0.83	0.41	0.69	0.29	0.24	0.10	0.67	0.82	0.73	0.22	1.50	1.46	1.00	0.64	12.73
180	2.03	1.10	0.83	0.41	0.66	0.26	0.22	0.10	0.67	0.82	0.73	0.22	0.89	0.94	0.74	0.64	11.26
190	2.03	1.10	0.83	0.41	0.66	0.26	0.22	0.10	0.67	0.82	0.73	0.22	0.89	0.94	0.74	0.64	11.26
200	2.03	1.10	0.83	0.41	0.66	0.26	0.22	0.10	0.67	0.82	0.73	0.22	0.89	0.94	0.74	0.64	11.26
210	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
220	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
230	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
240	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
250	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
260	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
270	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
280	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42

Table 5.3-41 Annual SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Annual

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
290	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
300	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
310	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
320	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
330	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
340	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
350	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
360	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
370	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
380	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
390	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
400	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
410	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
420	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
430	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
440	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
450	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
460	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
470	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
480	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
490	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
500	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
510	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
520	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
530	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
540	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
550	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
560	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42

Table 5.3-41 Annual SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Annual

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
570	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
580	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
590	1.91	1.01	0.78	0.41	0.66	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.74	0.64	10.42
600	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
610	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
620	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
630	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
640	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
650	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
660	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
670	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
680	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
690	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
700	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
710	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
720	1.91	1.01	0.78	0.41	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.22	0.89	0.94	0.71	0.64	10.35
730	1.91	1.01	0.78	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	10.19
740	1.91	1.01	0.78	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	10.19
750	1.91	1.01	0.78	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	10.19
760	1.91	1.01	0.78	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	10.19
770	1.91	1.01	0.78	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	10.19
780	1.91	1.01	0.78	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	10.19
790	1.69	0.92	0.70	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	9.79
800	1.69	0.92	0.70	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	9.79
810	1.69	0.92	0.70	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	9.79
820	1.69	0.92	0.70	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	9.79
830	1.69	0.92	0.70	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	9.79
840	1.69	0.92	0.70	0.38	0.63	0.26	0.22	0.10	0.54	0.59	0.50	0.21	0.89	0.94	0.71	0.52	9.79

Table 5.3-41 Annual SACTI Plume Height Frequency Results

Plume Height Frequency Table
North Anna, Richmond (1998-2000), 52-Cell MDCT
Season = Annual

Distance From Tower	Wind From																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	All
	Plume Headed																
(M)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	SUM
850	0.88	0.51	0.36	0.38	0.35	0.18	0.12	0.10	0.27	0.28	0.24	0.21	0.67	0.68	0.33	0.52	6.09
860	0.88	0.51	0.36	0.15	0.35	0.18	0.12	0.01	0.27	0.28	0.24	0.06	0.67	0.68	0.33	0.15	5.25
870	0.88	0.51	0.36	0.15	0.35	0.18	0.12	0.01	0.27	0.28	0.24	0.06	0.67	0.68	0.33	0.15	5.25
880	0.88	0.51	0.36	0.15	0.35	0.18	0.12	0.01	0.27	0.28	0.24	0.06	0.67	0.68	0.33	0.15	5.25
890	0.88	0.51	0.36	0.15	0.35	0.18	0.12	0.01	0.27	0.28	0.24	0.06	0.67	0.68	0.33	0.15	5.25
900	0.39	0.28	0.18	0.15	0.35	0.18	0.12	0.01	0.20	0.14	0.11	0.06	0.67	0.68	0.33	0.15	4.00
910	0.39	0.28	0.18	0.00	0.17	0.08	0.07	0.00	0.20	0.14	0.11	0.00	0.33	0.30	0.17	0.00	2.42
920	0.39	0.28	0.18	0.00	0.17	0.08	0.07	0.00	0.20	0.14	0.11	0.00	0.33	0.30	0.17	0.00	2.42
930	0.39	0.28	0.18	0.00	0.17	0.08	0.07	0.00	0.20	0.14	0.11	0.00	0.33	0.30	0.17	0.00	2.42
940	0.39	0.28	0.18	0.00	0.17	0.08	0.07	0.00	0.20	0.14	0.11	0.00	0.33	0.30	0.17	0.00	2.42
950	0.39	0.28	0.18	0.00	0.17	0.08	0.07	0.00	0.20	0.14	0.11	0.00	0.33	0.30	0.17	0.00	2.42
960	0.39	0.28	0.18	0.00	0.17	0.08	0.07	0.00	0.20	0.14	0.11	0.00	0.33	0.30	0.17	0.00	2.42
970	0.39	0.28	0.18	0.00	0.17	0.08	0.07	0.00	0.20	0.14	0.11	0.00	0.33	0.30	0.17	0.00	2.42
980	0.39	0.28	0.18	0.00	0.17	0.08	0.07	0.00	0.20	0.14	0.11	0.00	0.33	0.30	0.17	0.00	2.42
990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

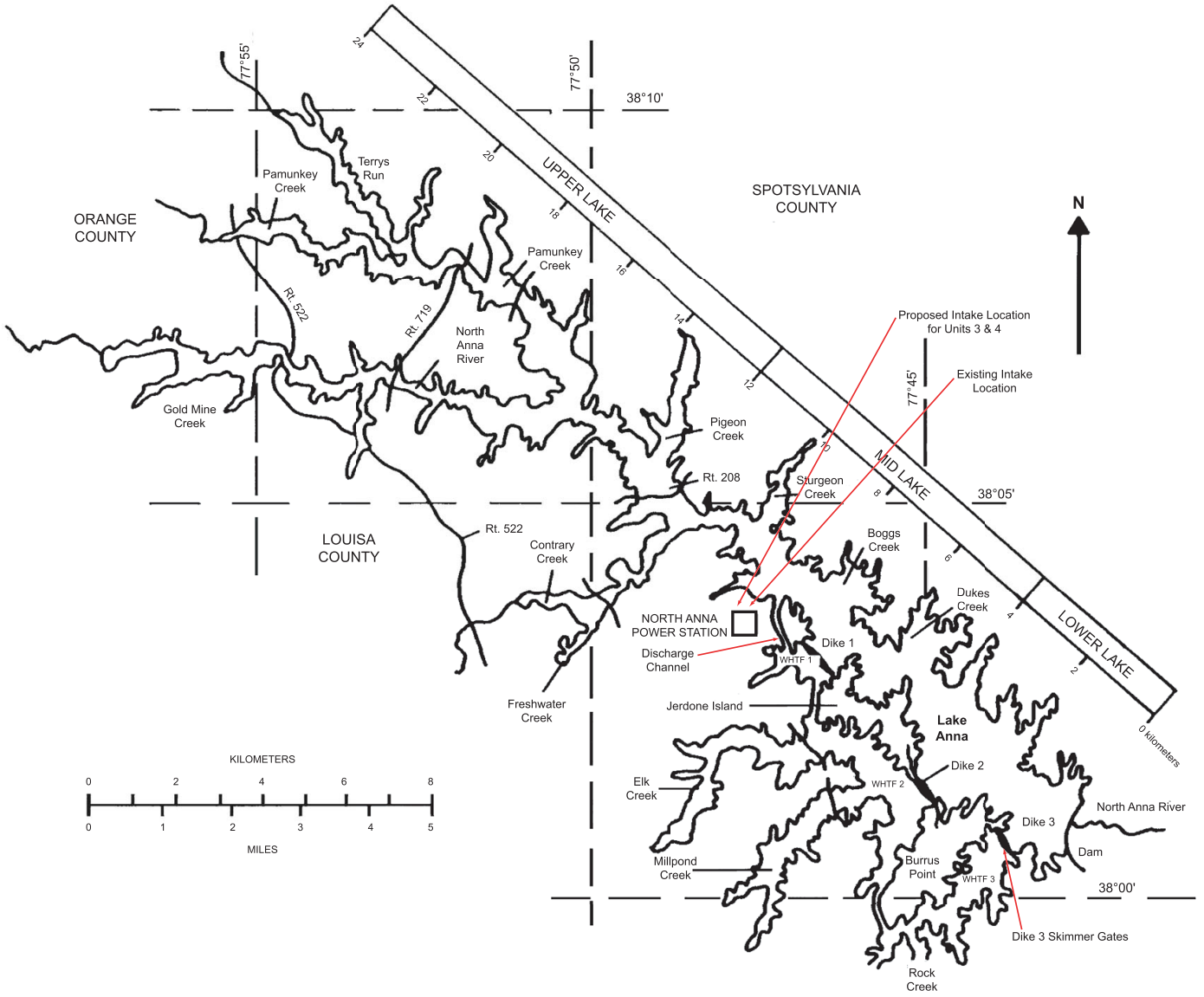

Figure 5.3-1 Generalized Map of North Anna Power Station Environs

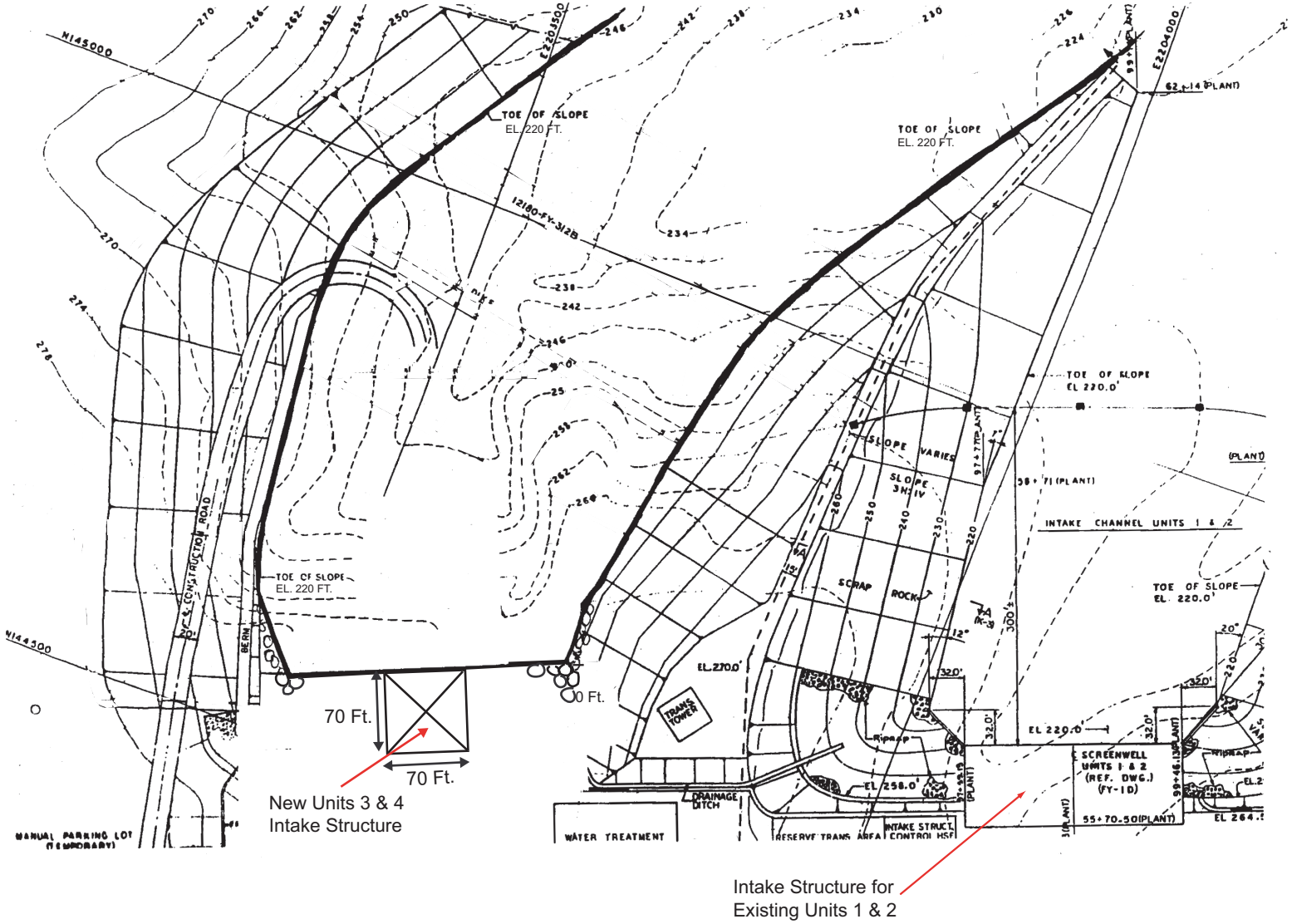

Figure 5.3-2 Intake Structure and Approach Channel for the New Units and the Existing Units

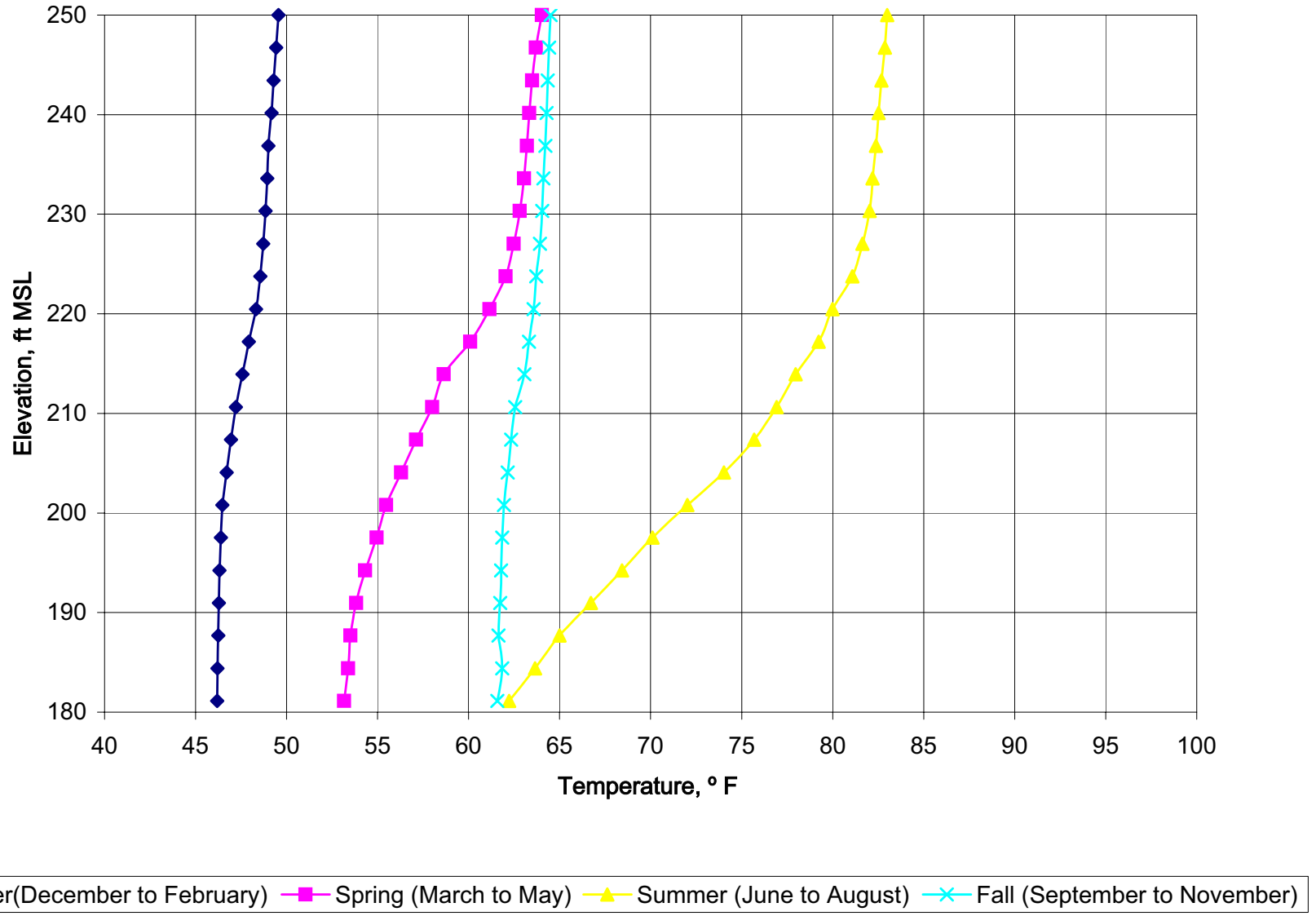

Figure 5.3-3 Observed Seasonal Average Vertical Temperature Profiles at Monitoring Station A Near North Anna Dam

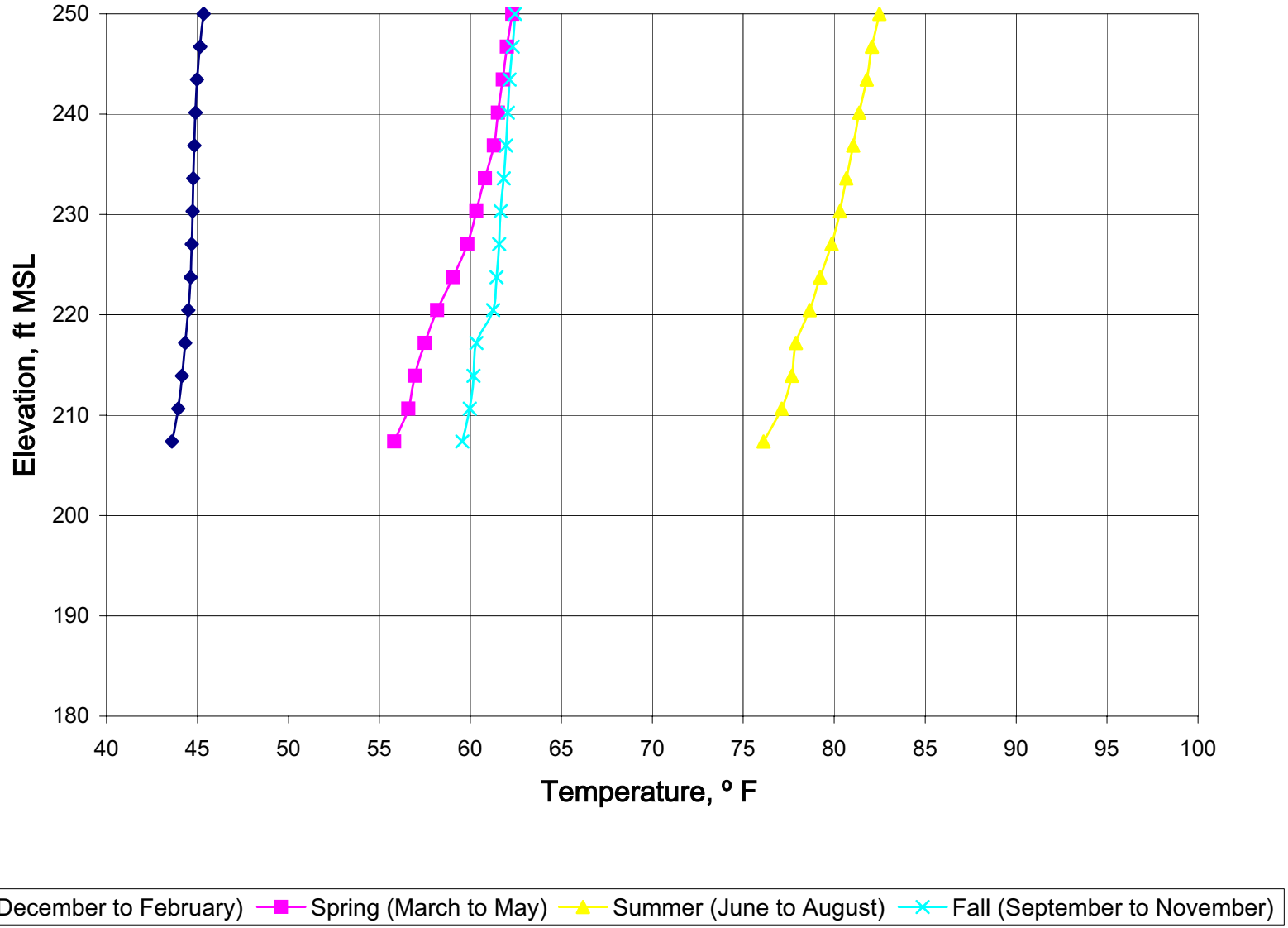

Figure 5.3-4 Observed Seasonal Average Vertical Temperature Profiles at Monitoring Station I Near the Intake

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5.4 Radiological Impacts of Normal Operation

This section describes the radiological impacts of normal plant operation on members of the public and biota. Section 5.4.1 describes the exposure pathways by which radiation and radioactive effluents can be transmitted from the new units to organisms living near the plant. Section 5.4.2 estimates the maximum doses to the public from the operation of one new unit. Section 5.4.3 evaluates the impacts of these doses by comparing them to regulatory limits for one unit. In addition, the impact of two new units in conjunction with the two existing units is compared to the corresponding regulatory limit. Finally, Section 5.4.4 considers the impact to biota that appear along the exposure pathways or that are on endangered species lists.

5.4.1 Exposure Pathways

Small quantities of radioactive liquids and gases would be discharged to the environment during normal operation of the new units. The impact of these releases and any direct radiation to individuals, population groups, and biota in the vicinity of the new units was evaluated by considering the most important pathways from the release to the receptors of interest. The major pathways are those that could yield the highest radiological doses for a given receptor. The relative importance of a pathway is based on the type and amount of radioactivity released, the environmental transport mechanism, and the consumption or usage factors of the receptor.

The exposure pathways considered and the analytical methods used to estimate doses to the maximally exposed individual (MEI) and to the population surrounding the new units are based on RGs 1.109 and 1.111 (Reference 1 and Reference 2, respectively). A MEI is a hypothetical member of the public located to receive the maximum possible calculated dose. The MEI allows dose comparisons with established criteria for the public.

5.4.1.1 Liquid Pathways

The new units would release effluents to the WHTF through the discharge canal used for Units 1 and 2.

The LADTAP II computer program (Reference 3) was used to calculate the doses to the MEI, population groups, and biota. This program implements the radiological exposure models described in RG 1.109 for radioactivity releases in liquid effluent. The following exposure pathways are considered in LADTAP II:

- Ingestion of aquatic foods
- Ingestion of drinking water
- External exposure to shoreline sediments
- External exposure to water through boating and swimming

Irrigation was not considered as a pathway because the use of the water from Lake Anna for this purpose is negligible (Reference 4).

The input parameters for the liquid pathway are presented in Table 5.4-1 and Table 5.4-2. It should be noted that the dilution factor is a conservative low value of 10 with no credit taken for the transit time from the release point to the receptors. Furthermore, an impoundment reconcentration model is not used because Lake Anna serves as an impoundment as well as the receiving water body.

5.4.1.2 Gaseous Pathways

The GASPAR II computer program (Reference 5) was used to calculate the doses to the MEI, population groups, and biota. This program implements the radiological exposure models described in RG 1.109 to estimate the radioactivity releases in gaseous effluent and the subsequent doses. The following exposure pathways are considered in GASPAR II:

- External exposure to airborne plume
- External exposure to contaminated ground
- Inhalation of airborne activity
- Ingestion of contaminated agricultural products

The input parameters for the gaseous pathway are presented in Table 5.4-3 and Table 5.4-5, and the receptor locations are shown in Table 5.4-4.

5.4.1.3 Direct Radiation from Station Operation

Contained sources of radiation at the new units would be shielded. An evaluation of all operating plants by the NRC states that:

> "…because the primary coolant of an LWR is contained in a heavily shielded area, dose rates in the vicinity of light water reactors are generally undetectable and are less than 1 mrem/year at the site boundary. Some plants [mostly BWRs] do not have completely shielded secondary systems and may contribute some measurable off-site dose."

The NRC concludes that the direct radiation from normal operation results in "small contributions at site boundaries" (Reference 6, Section 4.6.1.2). Since the advanced reactor designs being considered are expected to provide shielding that is at least as effective as existing light water reactors, direct dose contribution from the new units would be negligible

5.4.2 Radiation Doses to Members of the Public

In this section, doses to MEIs from liquid and gaseous effluents from one new unit are estimated using the methodologies and parameters specified in Section 5.4.1. Additionally, based on the available data on the reactor designs being considered, the maximum annual occupational dose is estimated to be 150 person-rem. This maximum dose would be verified in the COL application when a reactor design is selected.

5.4.2.1 Liquid Pathway Doses

Based on the parameters shown in Table 5.4-1 and Table 5.4-2, the LADTAP II computer program was used to calculate doses to the MEI via the following activities:

- Eating fish and invertebrates caught near the point of discharge
- Drinking water from Lake Anna
- Boating, swimming, and using the shoreline for recreational purposes

The liquid activity releases (source terms) are shown in Table 5.4-6. These are bounding, composite activities for a single new unit, obtained by taking the maximum activity for each isotope from multiple reactor designs. The activity concentrations of liquid effluents from the new units are calculated using the composite activity releases with the methodology presented in the NAPS Updated Final Safety Analysis Report (UFSAR) (Reference 10, Section 11.2.5.1). The concentrations from the existing units are obtained from UFSAR Table 11.2-14. Table 5.4-6 shows the total activity concentrations from the new and existing units and compares them to the effluent concentration limits (ECLs) in 10 CFR 20, Appendix B, Table 2, Column 2 (Reference 13). The sum of the fractions of ECLs is within unity, in conformance with 10 CFR 20. The calculated annual doses to the total body, the thyroid, and the maximally exposed organ are presented in Table 5.4-8. The maximum annual dose of 2.5 mrem would be received by the bone of the maximally exposed child. These calculations are conservative and do not represent actual doses near the ESP site.

5.4.2.2 Gaseous Pathway Doses

Based on the parameters in Table 5.4-3 and Table 5.4-5, the GASPAR II computer program was used to calculate doses to the maximally exposed adult, teenager, child, and infant at the following locations:

- Nearest site boundary
- Nearest vegetable garden
- Nearest residence
- Nearest meat cow

The gaseous activity releases (source terms) are shown in Table 5.4-7. These are bounding, composite activities for a single new unit, obtained by taking the maximum activity for each isotope from multiple reactor designs. Table 5.4-7 also shows the maximum activity concentrations at the site boundary from the new and existing units and compares them to the ECLs in 10 CFR 20, Appendix B, Table 2, Column 1 (Reference 13). The gaseous effluent concentrations are calculated based on the composite activity releases for the new units and the activity releases from the existing units from UFSAR Table 11.3-2 and the respective atmospheric dispersion factors at the site boundary. The sum of the fractions of ECLs is within unity, in conformance with 10 CFR 20.

The calculated annual total body, thyroid, and skin doses are presented in Table 5.4-9. These calculations are conservative and do not represent actual doses to individuals near the ESP site.

5.4.3 Impacts to Members of the Public

In this section, the radiological impacts to individuals and population groups from liquid and gaseous effluents are estimated using the methodologies and parameters specified in Section 5.4.1.

Table 5.4-10 shows the total body and organ doses to the MEI from liquid effluents and from gaseous releases from a new unit. The calculated doses for both sources are within the design objectives of 10 CFR 50, Appendix I (Reference 7). The total site liquid and gaseous effluent doses from the two existing units and two new units would be well within the regulatory limits of 40 CFR 190 (Reference 8), as shown in Table 5.4-11. As indicated in NUREG-1555 (Reference 9), demonstration of compliance with the limits of 40 CFR 190 is considered to be in compliance with 0.1 rem limit of 10 CFR 20.1301. Table 5.4-12 shows the population doses attributable to the new units for the population within 50 miles of the ESP site.

5.4.4 Impacts to Biota Other than Members of the Public

Radiation exposure pathways to biota were examined to determine if the pathways could result in doses to biota greater than those predicted for humans. This assessment used surrogate species that provide representative information about the various dose pathways potentially affecting broader classes of living organisms. Surrogates were used since important attributes of these species are well defined and are accepted as a method for judging doses to biota.

Important biota considered are federally- and state-listed species that are endangered or threatened, commercially and recreationally valuable species, and species important to the local ecosystem. Table 5.4-13 identifies the important species near the ESP site and the assigned surrogates employed in the assessment of radiation doses. The aquatic species listed in the table are those that may potentially exist in the counties immediately adjacent to Lake Anna, the North Anna River upstream or downstream of Lake Anna, and tributary streams crossed by transmission lines. The terrestrial species listed are those that exist or may potentially exist within the ESP site or the associated transmission line rights-of-way. The doses are calculated using pathway models adopted from RG 1.109.

5.4.4.1 Liquid Pathway

The LADTAP II computer program was used to calculate doses to the biota via the following exposure pathways:

- Fish, invertebrates – Internal exposure from bioaccumulation of radionuclides and external exposure from swimming and shoreline activities

- Algae – Internal exposure from bioaccumulation of radionuclides and external exposure from immersion in water
- Muskrat, duck – Internal exposure from ingestion of aquatic plants and external exposure from swimming and shoreline activities
- Raccoon – Internal exposure from ingestion of invertebrates and external exposure from shoreline activities
- Heron – Internal exposure from ingestion of fish and external exposure from swimming and shoreline activities

Food consumption rates, body masses, and effective body radii used in the dose calculations are shown in Table 5.4-14, while the residence times for swimming and shoreline exposure are shown in Table 5.4-15. In determining shoreline doses, adjustments were made for the fact that biota would be closer to any potential shoreline contamination than humans. Other biota parameters are taken from RG 1.109 and NUREG/CR-4013 (Reference 3).

5.4.4.2 Gaseous Pathway

Gaseous effluents contribute to the terrestrial doses. Immersion and ground deposition doses are largely independent of organism size, and the doses for the MEI, as described in Section 5.4.2, can be applied to biota. However, the external ground deposition doses, as calculated by GASPAR II, were increased by a factor of two to account for the closer proximity of terrestrial organisms to the ground, similar to the adjustments made for biota exposures to shoreline sediments in LADTAP II.

5.4.4.3 Biota Doses

Maximum calculated doses to biota from liquid and gaseous effluents are shown in Table 5.4-16. Assuming mrem and mrad to be approximately equivalent, the maximum calculated doses to all biota, except fish, exceed the regulatory limit (40 CFR 90) for humans of 25 mrem/yr. Although there are no regulatory limits specifically for biota, there is no scientific evidence that chronic dose rates below 100 mrad/day are harmful to plants and animals (Reference 9). The biota doses in Table 5.4-16 are all less than 1 mrad/day.

Section 5.4 References

1. Regulatory Guide 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I*, Revision 1, U. S. Nuclear Regulatory Commission, October 1977.

2. Regulatory Guide 1.111, *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors*, Revision 1, U. S. Nuclear Regulatory Commission, July 1977.

3. NUREG/CR-4013, *LADTAP II – Technical Reference and User Guide*, Prepared for the U. S. Nuclear Regulatory Commission by Pacific Northwest Laboratory, April 1986.

4. Virginia Agricultural Statistics Service website, www.nass.usda.gov/va/va.pdf.

5. NUREG/CR-4653, *GASPAR II – Technical Reference and User Guide*, Prepared for the U. S. Nuclear Regulatory Commission by Pacific Northwest Laboratory, March 1987.

6. NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, U. S. Nuclear Regulatory Commission, May 1996.

7. 10 CFR 50, Appendix I, *Code of Federal Regulations*, “Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion ‘As Low As is Reasonably Achievable’ for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents.”

8. 40 CFR 190, *Code of Federal Regulations*, “Environmental Radiation Protection Standards for Nuclear Power Operations.”

9. NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, October 1999.

10. *North Anna Power Station Updated Final Safety Analysis Report*, Revision 38.

11. *Annual Radioactive Effluent Release Report, North Anna Power Station (January 01, 2001 to December 31, 2001)*, Virginia Electric and Power Company, 2002.

12. NRP Report No. 94, *Exposure of the Population in the United States and Canada from Natural Background Radiation*, National Council on Radiation Protection and Measurements, 1987.

13. 10 CFR 20, Appendix B, *Code of Federal Regulations*, “Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage.”

Table 5.4-1 Liquid Pathway Parameters

Parameter	Value
Release source terms	Table 5.4-6
Effluent discharge rate	100 gpm with 10,000 gpm dilution
Dilution factor for discharge	10
Transit time to receptor	0
Impoundment reconcentration model	None
Population distribution	Table 2.5-8
Sport fishing harvest in 2040	2.7E+05 kg/yr

Table 5.4-2 Liquid Pathway Consumption Factors for Maximally Exposed Individual

	Annual Rate			
Consumption Factor	**Adult**	**Teen**	**Child**	**Infant**
Fish consumption (kg/yr)	21	16	6.9	0
Invertebrate consumption (kg/yr)	5	3.8	1.7	0
Drinking water consumption (l/yr)	730	510	510	330
Shoreline usage (hr/yr)	300	300	300	300
Swimming exposure (hr/yr)	200	200	200	200
Boating usage (hr/yr)	500	500	500	500

Source: Reference 1 (Table E-5) and Reference 10 (Section 11B.4.1).

Table 5.4-3 Gaseous Pathway Parameters

Parameter	Value
Release source terms	Table 5.4-7
Population distribution	Table 2.5-8
Milk production rate within 50 miles	7.2E+08 l/yr
Meat production rate within 50 miles	1.7E+09 kg/yr
Vegetable/fruit production rate within 50 miles	5.4E+08 kg/yr
Atmospheric dispersion factors	Table 2.7-17 to Table 2.7-19
Ground deposition factors	Table 2.7-20

Note: Production rates are projected for year 2040.

Table 5.4-4 Gaseous Pathway Receptor Locations

Receptor	Direction	Distance (miles)
Nearest site boundary	ESE	0.88
Nearest vegetable garden	NE	0.94
Nearest residence	NNE	0.96
Nearest meat animal	SE	1.37

Note: This data is taken from Table 2.7-14. There are no milk cows or goats within 5 miles of the plant (see Table 2.7-13).

Table 5.4-5 Gaseous Pathway Consumption Factors for Maximally Exposed Individual

	Annual Rate			
Consumption Factor	Adult	Teen	Child	Infant
Leafy vegetable consumption (kg/yr)	64	42	26	0
Meat consumption (kg/yr)	110	65	41	0
Milk consumption (l/yr)	310	400	330	330
Vegetable/fruit consumption (kg/yr)	520	630	520	0

Source: Reference 1, Table E-5.

Table 5.4-6 Release of Activities in Liquid Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
H-3	3.1E+03	5.8E-05	1.0E-03	5.8E-02
C-14	4.4E-04	7.7E-12	3.0E-05	2.6E-07
Na-24	3.5E-03	3.5E-11	5.0E-05	7.1E-07
P-32	6.6E-04	6.7E-12	9.0E-06	7.4E-07
Cr-51	2.1E-02	2.4E-10	5.0E-04	4.8E-07
Mn-54	2.8E-03	7.6E-11	3.0E-05	2.5E-06
Mn-56	4.2E-03	4.2E-11	7.0E-05	6.0E-07
Fe-55	6.4E-03	9.6E-11	1.0E-04	9.6E-07
Fe-59	2.0E-04	2.8E-11	1.0E-05	2.8E-06
Co-56	5.7E-03	6.1E-11	6.0E-06	1.0E-05
Co-57	7.9E-05	9.9E-13	6.0E-05	1.7E-08
Co-58	3.4E-03	7.8E-10	2.0E-05	3.9E-05
Co-60	1.0E-02	2.2E-10	3.0E-06	7.4E-05
Ni-63	1.5E-04	2.7E-12	1.0E-04	2.7E-08
Cu-64	8.2E-03	8.3E-11	2.0E-04	4.1E-07
Zn-65	7.5E-04	9.3E-12	5.0E-06	1.9E-06
Zn-69m	6.0E-04	6.0E-12	6.0E-05	1.0E-07
Br-83	7.5E-05	7.5E-13	9.0E-04	8.4E-10
Br-84	2.0E-05	2.0E-13	4.0E-04	5.0E-10
Rb-88	2.7E-04	2.7E-12	4.0E-04	6.8E-09
Rb-89	4.8E-05	4.8E-13	9.0E-04	5.4E-10
Sr-89	3.6E-04	1.1E-10	8.0E-06	1.4E-05
Sr-90	3.8E-05	1.3E-11	5.0E-07	2.5E-05
Sr-91	9.8E-04	2.9E-11	2.0E-05	1.4E-06
Sr-92	8.8E-04	8.8E-12	4.0E-05	2.2E-07
Y-90	3.4E-06	1.3E-11	7.0E-06	1.9E-06
Y-91m	1.0E-05	1.0E-13	2.0E-03	5.0E-11
Y-91	2.4E-04	1.3E-10	8.0E-06	1.7E-05

Table 5.4-6 Release of Activities in Liquid Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
Y-92	6.6E-04	6.6E-12	4.0E-05	1.6E-07
Y-93	9.8E-04	9.9E-12	2.0E-05	4.9E-07
Zr-95	1.0E-03	3.2E-11	2.0E-05	1.6E-06
Nb-95	1.9E-03	4.2E-11	3.0E-05	1.4E-06
Mo-99	3.9E-03	9.9E-08	2.0E-05	5.0E-03
Tc-99m	5.1E-03	8.5E-08	1.0E-03	8.5E-05
Ru-103	4.9E-03	5.1E-11	3.0E-05	1.7E-06
Ru-105	1.0E-04	1.0E-12	7.0E-05	1.4E-08
Ru-106	7.4E-02	9.7E-10	3.0E-06	3.2E-04
Rh-103m	4.9E-03	5.0E-11	6.0E-03	8.3E-09
Rh-106	7.4E-02	7.4E-10	—	—
Ag-110m	1.1E-03	1.3E-11	6.0E-06	2.2E-06
Ag-110	1.4E-04	1.4E-12	—	—
Sb-124	6.8E-04	7.2E-12	7.0E-06	1.0E-06
Te-129m	1.4E-04	1.4E-12	7.0E-06	2.0E-07
Te-129	1.5E-04	1.5E-12	4.0E-04	3.8E-09
Te-131m	1.0E-04	1.0E-12	8.0E-06	1.3E-07
Te-131	3.0E-05	3.0E-13	8.0E-05	3.8E-09
Te-132	2.4E-04	4.8E-09	9.0E-06	5.3E-04
I-131	1.4E-02	5.6E-08	1.0E-06	5.6E-02
I-132	2.8E-03	8.5E-09	1.0E-04	8.5E-05
I-133	2.4E-02	6.2E-08	7.0E-06	8.9E-03
I-134	1.9E-03	1.2E-09	4.0E-04	3.0E-06
I-135	8.2E-03	3.7E-09	3.0E-05	1.2E-04
Cs-134	9.9E-03	1.8E-08	9.0E-07	2.0E-02
Cs-136	1.2E-03	2.6E-09	6.0E-06	4.4E-04
Cs-137	1.3E-02	1.2E-07	1.0E-06	1.2E-01
Cs-138	2.1E-04	2.1E-12	4.0E-04	5.2E-09

Table 5.4-6 Release of Activities in Liquid Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
Ba-137m	1.2E-02	1.3E-10	—	—
Ba-139	2.5E-05	2.5E-13	2.0E-04	1.3E-09
Ba-140	5.5E-03	1.5E-10	8.0E-06	1.8E-05
La-140	7.4E-03	1.2E-10	9.0E-06	1.4E-05
La-142	2.5E-05	2.5E-13	1.0E-04	2.5E-09
Ce-141	1.3E-04	1.3E-12	3.0E-05	4.5E-08
Ce-143	1.9E-04	1.9E-12	2.0E-05	9.5E-08
Ce-144	3.2E-03	5.8E-11	3.0E-06	1.9E-05
Pr-143	1.4E-04	1.4E-12	2.0E-05	6.9E-08
Pr-144	3.2E-03	3.2E-11	6.0E-04	5.3E-08
W-187	2.1E-04	2.1E-12	3.0E-05	7.1E-08
Np-239	1.4E-02	1.4E-10	2.0E-05	6.9E-06
Total w/o H-3	3.7E-01	4.7E-07		2.1E-01
Total w/ H-3	3.1E+03	5.8E-05		2.7E-01

Note: The releases are composite, bounding values for a new single unit based on multiple reactor designs. In determining the composite values, ABWR activities were scaled up to 4300 MWt and ESBWR activities were increased by 25 percent. The concentrations are the total liquid effluents from the two new units and the two existing units. No ECLs are provided in 10 CFR 20 for Rh-106, Ag-110, and Ba-137m.

Table 5.4-7 Release of Activities in Gaseous Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
H-3	3.5E+03	8.3E-10	1.0E-07	8.3E-03
C-14	1.2E+01	2.8E-12	3.0E-09	9.3E-04
Na-24	4.4E-03	1.0E-15	7.0E-09	1.5E-07
P-32	1.0E-03	2.4E-16	5.0E-10	4.7E-07
Ar-41	3.0E+02	7.1E-11	1.0E-08	7.1E-03
Cr-51	3.8E-02	9.0E-15	3.0E-08	3.0E-07
Mn-54	5.9E-03	1.4E-15	1.0E-09	1.4E-06
Mn-56	3.8E-03	9.0E-16	2.0E-08	4.5E-08
Fe-55	7.1E-03	1.7E-15	3.0E-09	5.6E-07
Fe-59	8.9E-04	2.1E-16	5.0E-10	4.2E-07
Co-57	8.2E-06	1.9E-18	9.0E-10	2.1E-09
Co-58	2.3E-02	5.4E-15	1.0E-09	5.4E-06
Co-60	1.4E-02	3.3E-15	5.0E-11	6.7E-05
Ni-63	7.1E-06	1.7E-18	1.0E-09	1.7E-09
Cu-64	1.1E-02	2.6E-15	3.0E-08	8.6E-08
Zn-65	1.2E-02	2.8E-15	4.0E-10	7.1E-06
Kr-83m	1.3E-03	3.0E-16	5.0E-05	5.9E-12
Kr-85m	3.6E+01	7.9E-11	1.0E-07	7.9E-04
Kr-85	4.1E+03	2.2E-09	7.0E-07	3.2E-03
Kr-87	4.9E+01	5.1E-11	2.0E-08	2.6E-03
Kr-88	7.4E+01	1.4E-10	9.0E-09	1.6E-02
Kr-89	4.7E+02	1.1E-10	1.0E-09	1.1E-01
Kr-90	4.2E-04	9.9E-17	1.0E-09	9.9E-08
Rb-89	4.7E-05	1.1E-17	2.0E-07	5.6E-11
Sr-89	6.2E-03	1.5E-15	2.0E-10	7.3E-06
Sr-90	1.2E-03	2.8E-16	6.0E-12	4.7E-05
Sr-91	1.1E-03	2.6E-16	5.0E-09	5.1E-08
Sr-92	8.6E-04	2.0E-16	9.0E-09	2.2E-08

Table 5.4-7 Release of Activities in Gaseous Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
Y-90	5.0E-05	1.2E-17	9.0E-10	1.3E-08
Y-91	2.6E-04	6.2E-17	2.0E-10	3.1E-07
Y-92	6.8E-04	1.6E-16	1.0E-08	1.6E-08
Y-93	1.2E-03	2.8E-16	3.0E-09	9.5E-08
Zr-95	1.7E-03	4.1E-16	4.0E-10	1.0E-06
Nb-95	9.2E-03	2.2E-15	2.0E-09	1.1E-06
Mo-99	6.5E-02	1.5E-14	2.0E-09	7.6E-06
Tc-99m	3.3E-04	7.6E-17	2.0E-07	3.8E-10
Ru-103	3.8E-03	9.0E-16	9.0E-10	1.0E-06
Ru-106	7.8E-05	1.8E-17	2.0E-11	9.2E-07
Rh-103m	1.2E-04	2.8E-17	2.0E-06	1.4E-11
Rh-106	2.1E-05	4.9E-18	1.0E-09	4.9E-09
Ag-110m	2.2E-06	5.1E-19	1.0E-10	5.1E-09
Sb-124	2.0E-04	4.6E-17	3.0E-10	1.5E-07
Sb-125	6.1E-05	1.4E-17	7.0E-10	2.0E-08
Te-129m	2.4E-04	5.6E-17	3.0E-10	1.9E-07
Te-131m	8.3E-05	1.9E-17	1.0E-09	1.9E-08
Te-132	2.1E-05	4.9E-18	9.0E-10	5.4E-09
I-131	5.1E-01	3.5E-13	2.0E-10	1.7E-03
I-132	2.4E+00	6.1E-13	2.0E-08	3.0E-05
I-133	1.9E+00	7.2E-13	1.0E-09	7.2E-04
I-134	4.1E+00	9.9E-13	6.0E-08	1.6E-05
I-135	2.6E+00	7.3E-13	6.0E-09	1.2E-04
Xe-131m	1.8E+03	4.2E-10	2.0E-06	2.1E-04
Xe-133m	8.7E+01	1.2E-10	6.0E-07	2.0E-04
Xe-133	4.6E+03	1.0E-08	5.0E-07	2.1E-02
Xe-135m	7.7E+02	1.9E-10	4.0E-08	4.7E-03
Xe-135	8.2E+02	4.0E-10	7.0E-08	5.7E-03

Table 5.4-7 Release of Activities in Gaseous Effluent

Isotope	Release (Ci/yr)	Concentration (µCi/ml)	ECL (µCi/ml)	Fraction of ECL
Xe-137	9.8E+02	2.3E-10	1.0E-09	2.3E-01
Xe-138	7.8E+02	2.1E-10	2.0E-08	1.0E-02
Xe-139	5.3E-04	1.2E-16	1.0E-09	1.2E-07
Cs-134	6.8E-03	1.6E-15	2.0E-10	8.0E-06
Cs-136	6.5E-04	1.5E-16	9.0E-10	1.7E-07
Cs-137	1.0E-02	2.4E-15	2.0E-10	1.2E-05
Cs-138	1.9E-04	4.4E-17	8.0E-08	5.5E-10
Ba-140	3.0E-02	6.9E-15	2.0E-09	3.5E-06
La-140	2.0E-03	4.6E-16	2.0E-09	2.3E-07
Ce-141	1.0E-02	2.4E-15	8.0E-10	2.9E-06
Ce-144	2.1E-05	4.9E-18	2.0E-11	2.4E-07
Pr-144	2.1E-05	4.9E-18	2.0E-07	2.4E-11
W-187	2.1E-04	4.9E-17	1.0E-08	4.9E-09
Np-239	1.3E-02	3.1E-15	3.0E-09	1.0E-06
Total w/o H-3	1.5E+04	1.5E-08		4.2E-01
Total w/ H-3	1.8E+04	1.5E-08		4.2E-01

Note: The releases are composite, bounding values for a single new unit based on multiple reactor designs. In determining the composite values, ABWR activities were scaled up to 4300 MWt and ESBWR activities were increased by 25 percent. The concentrations are the total at the site boundary from the new units and the two existing units.

Table 5.4-8 Liquid Pathway Doses for Maximally Exposed Individuals at Lake Anna

	Dose (mrem/yr)		
Pathway	**Total Body**	**Thyroid**	**Bone**
Fish	5.3E-01	0.0E+00	2.3E+00
Invertebrate	6.9E-02	0.0E+00	1.5E-01
Drinking	6.9E-01	1.3E+00	2.7E-02
Shoreline	3.0E-02	3.0E-02	3.0E-02
Swimming	3.2E-04	3.2E-04	3.2E-04
Boating	4.0E-04	4.0E-04	4.0E-04
Total	1.3E+00	1.3E+00	2.5E+00
Age group receiving maximum dose	Adult	Infant	Child

Note: Doses are from one new unit. Bone of the child is the organ receiving the maximum dose.

Table 5.4-9 Gaseous Pathway Doses for Maximally Exposed Individuals

		Dose (mrem/yr)		
Location	**Pathway**	**Total Body**	**Thyroid**	**Skin**
Nearest Site Boundary (0.88 mi ESE)	Plume	2.1E+00	0.0E+00	6.2E+00
	Inhalation			
	Adult	3.0E-01	1.6E+00	0.0E+00
	Teen	3.1E-01	2.0E+00	0.0E+00
	Child	2.7E-01	2.3E+00	0.0E+00
	Infant	1.6E-01	2.0E+00	0.0E+00
Nearest Garden (0.94 mi NE)	Vegetable			
	Adult	4.4E-01	4.9E+00	0.0E+00
	Teen	5.7E-01	6.6E+00	0.0E+00
	Child	1.1E-00	1.3E+01	0.0E+00
Nearest Residence (0.96 mi NNE)	Plume	1.4E+00	0.0E+00	4.0E+00
	Inhalation			
	Adult	2.0E-01	1.0E+00	0.0E+00
	Teen	2.0E-01	1.3E+00	0.0E+00
	Child	1.8E-01	1.5E+00	0.0E+00
	Infant	1.0E-01	1.3E+00	0.0E+00
Nearest Meat Cow (1.37 mi SE)	Meat			
	Adult	6.7E-02	1.5E-01	0.0E+00
	Teen	4.9E-02	1.1E-01	0.0E+00
	Child	7.9E-02	1.7E-01	0.0E+00

Note: Doses are from one new unit. There are no milk cows or goats within 5 miles (SeeTable 2.7-13). There are no infant doses for the vegetable and meat pathways because infants do not consume these foods (See Table 5.4-5).

Table 5.4-10 Comparison of Maximally Exposed Individual Doses with 10 CFR 50, Appendix I Criteria

Type of Dose	Location	Annual Dose per Unit	
		Calculated	Limit
Liquid Effluent			
Total Body (mrem)	Lake Anna	1.3	3
Maximum Organ - Bone (mrem)	Lake Anna	2.5	10
Gaseous Effluent			
Gamma Air (mrad)	Site Boundary	3.2	10
Beta Air (mrad)	Site Boundary	4.8	20
Total Body (mrem)	Site Boundary	2.4	5
Skin (mrem)	Site Boundary	6.2	15
Iodines and Particulates (All Effluents)			
Maximum Organ - Thyroid (mrem)	Lake Anna/ Nearest Garden	13	15

Note: Doses are from one new unit.

Table 5.4-11 Comparison of Maximally Exposed Individual Doses with 40 CFR 190 Criteria

	Dose (mrem/yr)					
	Two New Units			Existing Units	Site Total	Regulatory Limit
	Liquid	Gaseous	Total			
Total Body	2.6E+00	4.8E+00	7.5E+00	3.2E-01	7.8E+00	2.5E+01
Thyroid	2.7E+00	2.5E+01	2.8E+01	4.6E-01	2.8E+01	7.5E+01
Other Organ - Bone	5.0E+00	6.5E+00	1.1E+01	4.6E-01	1.2E+01	2.5E+01

Note: Doses for existing units are from Reference 11.

Table 5.4-12 Collective Total Body Doses Within 50 Miles

	Dose (person-rem/yr)	
	Each New Unit	Both Units
Liquid	1.4E+01	2.9E+01
Noble Gases	3.5E+00	7.0E+00
Iodines and Particulates	1.4E+00	2.8E+00
H-3 and C-14	1.4E+01	2.9E+01
Total	3.4E+01	6.7E+01
Natural Background	9.2E+05	9.2E+05

Note: Natural background dose is based on a dose rate of 325 mrem/person-yr (Reference 10, Table 11B-8, and Reference 12, Table 9.7) and a population of 2.8E+06 (Table 2.5-8). Occupational workforce doses are not shown.

Table 5.4-13 Important Biota Species and Analytical Surrogates

Ecology	Specie Type	Species	Status	Surrogate Species
Terrestrial	Bird	Bald eagle	Federal threatened, State threatened	Heron
		Loggerhead shrike	State threatened	Heron
Aquatic	Invertebrate	Dwarf wedgemussel	Federal endangered, State endangered	Invertebrate
		Slippershell mussel	State endangered	Invertebrate
		Fluted kidneyshell mussel	Candidate for federal listing	Invertebrate
	Fish	Various	Recreationally valuable	Fish

Source: Section 2.4.1 and Section 2.4.2.

Table 5.4-14 Terrestrial Biota Parameters

Biota	Effective Body Radius (cm)	Body Mass (kg)	Consumption of Food (g/day)	Food Organism
Muskrat	6	1	100	Aquatic plants
Raccoon	14	12	200	Invertebrates
Heron	11	4.6	600	Fish
Duck	5	1	100	Aquatic plants

Source: NUREG/CR-4013 (Reference 3).

Table 5.4-15 Parameters for Shoreline and Swimming Exposure to Biota

	Exposure Time (hr/yr)	
Biota	Shoreline	Swimming
Fish	4380	8760
Invertebrates	8760	8760
Algae	NA	8760
Muskrat	2922	2922
Raccoon	2191	Not Applicable
Heron	2922	2920
Duck	4383	4383

Source: NUREG/CR-4013 (Reference 3).

Table 5.4-16 Biota Doses from Liquid and Gaseous Effluents

Biota	Dose (mrad/yr)			Dose (mrad/day)
	Liquid Effluent	Gaseous Effluent	Total	
Fish	9.9E+00	0.0E+00	9.9E+00	2.7E-02
Invertebrates	4.6E+01	0.0E+00	4.6E+01	1.3E-01
Algae	5.4E+01	0.0E+00	5.4E+01	1.5E-01
Muskrat	4.4E+01	3.4E+01	7.8E+01	2.1E-01
Raccoon	5.1E+00	3.4E+01	3.9E+01	1.1E-01
Heron	5.6E+01	3.4E+01	9.0E+01	2.5E-01
Duck	4.4E+01	3.4E+01	7.8E+01	2.1E-01

5.5 Environmental Impact of Waste

This section describes the environmental impacts that could result from the operation of the non-radioactive waste system and from storage and disposal of mixed wastes. As defined in the Atomic Energy Act (AEA) of 1954, as amended, (42 USC 2011 et seq.), mixed waste contains hazardous waste and a low-level radioactive source, special nuclear material, or byproduct material. Federal regulations governing generation, management, handling, storage, treatment, disposal, and protection requirements associated with these wastes are contained in 10 CFR (NRC regulations) and 40 CFR (EPA regulations). The section is divided into two subsections: non-radioactive waste system impacts and mixed waste impacts.

5.5.1 Nonradioactive-Waste-System Impacts

Descriptions of the existing units' waste systems and waste systems for the new units' non-radioactive wastes are presented in Section 3.6.

All non-radioactive wastes generated at the NAPS site, including those from the new units (i.e., solid wastes, liquid wastes, air emissions) would continue to be managed in accordance with applicable federal, Virginia, local laws and regulations, and permit requirements. Management practices would be the same as those implemented for the existing units and would include the following:

- Non-radioactive solid waste (e.g., office waste, glass bottles, scrap wood) would be collected temporarily on the NAPS site and disposed of at offsite licensed commercial waste disposal site(s).
- Debris (e.g., vegetation) collected on trash screens at the water intake structure(s) would be disposed of off site as solid waste, in accordance with the existing VPDES Permit. (Reference 1)
- Scrap metal would be collected temporarily on the NAPs site and transported to an offsite permitted recycling facility.
- Water from wet cooling tower blowdown and auxiliary systems would be discharged through the WHTF to the North Anna Reservoir via Dike 3.
- Wastewater treatment sludge would be taken to the Louisa County Sewage Treatment Plant for further processing and disposal.
- Used oil and antifreeze would be collected temporarily on the NAPS site and recycled through an offsite environmental services contractor.

For further descriptions of plant systems generating non-radioactive wastes, refer to Section 3.6. There would be no other site-specific waste disposal activities unique to the new units. The assessment of potential impacts resulting from the discharge of non-radioactive wastes is presented in the following subsections.

5.5.1.1 Discharge Constituents and Characteristics

Non-radioactive wastewater discharges to surface water would increase as a result of several aspects of new units' operation, such as blowdown from the Unit 3 wet cooling tower, new auxiliary systems, and storm water runoff from new impervious surfaces. The Bounding Site-Specific PPE (Table 3.1-9) lists typical constituents along with estimates of constituent concentrations in the cooling and auxiliary system discharges. The estimates of constituent concentrations are based on conservative assumptions of system operation (e.g., flow rates, cycles of concentration, chemical addition, etc.) and on historical data on water quality for the North Anna Reservoir (the source of cooling tower make-up). Suspended solids which may exist in the cooling tower make-up water would also be discharged by way of blowdown from Unit 3 at a higher concentration. Section 3.6 contains a list of some typical chemicals that may be present in the plant's permitted discharge, including chemicals used in the new units' cooling systems, and information regarding the engineering controls that would prevent or minimize the release of harmful levels of constituents to Lake Anna. Concentrations of constituents in the cooling tower blowdown water discharge would be diluted and would reach a concentration upon entering the North Anna Reservoir not significantly different from that in the reservoir (see Section 5.3.2.2). Cooling towers would be constructed of materials that would not have the potential for leaching of hazardous chemicals.

Smaller volume discharges associated with plant auxiliary systems would be discharged in accordance with the applicable VPDES water quality standards. Therefore, potential impacts from constituents in the cooling tower blowdown water and plant auxiliary systems' discharges from the new units would be small.

With regard to changes in volume and constituent concentrations in storm water discharge, Dominion would coordinate with Virginia Power to revise the existing units' SWPPP which is required by the VPDES permit to prevent or minimize the release of harmful levels of pollutants within the storm water discharge. Impacts from increases in volume or pollutants in the storm water discharge would be small.

5.5.1.2 Impacts of Discharges to Land

Operation of the new units would result in an increase in the total volume of solid waste generated at the NAPS site. However, no new solid waste streams would be generated. All applicable federal, Virginia, and local requirements and standards would be met with regard to the handling, transportation, and offsite land disposal of the solid waste. All non-radioactive solid waste would be reused or recycled to the extent possible. Solid wastes appropriate for recycling (e.g., used oil, antifreeze, scrap metal) would be managed through use of approved and appropriately licensed contractors. All non-radioactive solid waste destined for offsite land disposal would be disposed of at approved and licensed offsite commercial waste disposal site(s). Therefore, potential impacts from land disposal of non-radioactive solid wastes would be small.

5.5.1.3 Impacts of Discharges to Air

Operation of the new units would increase small amounts of gaseous emissions to the air, primarily from equipment associated with plant auxiliary systems (e.g., diesel engines). Dry and wet cooling tower impacts on terrestrial ecosystems are addressed in Section 5.3.3.2. Potential impacts associated with Unit 3 wet cooling towers and Units 3 and 4 dry cooling towers would be small and restricted within the NAPS site boundary. Other minor air emission sources associated with the new units would be operated in accordance with federal, Virginia, and local air quality control laws and regulations. Impacts to air would be small.

5.5.1.4 Sanitary Waste

The existing units' sanitary waste treatment system (see Section 3.6) would be modified to accommodate the increases in sanitary wastes generated as a result of the operation of the new units. Sanitary wastes would be managed on site and disposed of off site in compliance with applicable laws, regulations, and permit conditions imposed by federal, Virginia, and local agencies. Potential impacts associated with increases in sanitary waste from operation of the new units would be small.

5.5.2 Mixed Waste Impacts

The term "mixed waste" refers specifically to waste that is regulated as both radioactive and hazardous waste. Radioactive materials at nuclear power plants are regulated by the NRC under the Atomic Energy Act (AEA) (Reference 2). Hazardous wastes are regulated by the EPA or an Authorized State (a state authorized by the EPA to regulate those portions of the federal act) under the Resource Conservation and Recovery Act (RCRA) (Reference 3).

Mixed waste generated on site is assessed based on the following regulatory guidance. The radioactive component of mixed waste must satisfy the definition of low-level radioactive waste in the Low-Level Radioactive Waste Policy Amendments Act (LLRWPAA) of 1985 (Reference 4). The hazardous component must exhibit at least one of the hazardous waste characteristics identified in 40 CFR 261, Subpart C, or be listed as a hazardous waste in 40 CFR 261, Subpart D (Reference 5). Entities who generate, treat, store, or dispose of mixed wastes are subject to the requirements of the Atomic Energy Act, the Solid Waste Disposal Act of 1965 as amended by the RCRA in 1976, and the Hazardous and Solid Waste Amendments, which amended the RCRA in 1984. The federal agencies responsible for ensuring compliance with these statutes are the NRC and the EPA.

5.5.2.1 Plant Systems Producing Mixed Waste

Proper chemical handling techniques, pre-job planning, and compliance with an approved facility waste minimization plan would ensure that only small quantities of mixed waste would be generated by the new units. For example, the Westinghouse AP1000 would produce (Reference 6):

- Expected generation of 15 ft^3/yr mixed liquid waste and 5 ft^3/yr of mixed solid waste
- Maximum generation of 30 ft^3/yr mixed liquid waste and 10 ft^3/yr of mixed solid waste

These quantities represent less than 1 percent of the total waste generation for the AP1000 design, and they are consistent with the experience at existing operating plants, where the volume of mixed waste accounts for less than 3 percent of the annual low-level waste generated (Reference 7).

A 1990 survey by the NRC identifies the following types of mixed low-level waste at reactor facilities (Reference 8):

- Waste oil from pumps and other equipment
- Chlorinated fluorocarbons (CFC) resulting from cleaning, refrigeration, degreasing, and decontamination activities
- Organic solvents, reagents, and compounds, and associated materials such as rags and wipes
- Metals such as lead from shielding applications and chromium from solutions and acids
- Metal-contaminated organic sludges and other chemicals
- Aqueous corrosives consisting of organic and inorganic acids

Primary importance would be placed on source reduction efforts to prevent pollution and eliminate or reduce the generation of mixed waste. Potential pollutants and wastes that cannot be eliminated or minimized would be evaluated for recycling. Treatment for reducing the quantity, toxicity, or mobility of the mixed waste before storage or disposal would be considered only when prevention or recycling is not possible or practical. A waste minimization plan is described in Section 5.5.2.4.

5.5.2.2 Mixed Waste Storage and Disposal Plans

The volume of mixed waste could be reduced or eliminated by one or more of the following treatments prior to disposal: decay, stabilization, neutralization, filtration, or chemical or thermal destruction by an offsite vendor.

Some small quantities of mixed waste must be temporarily stored onsite due to the lack of treatment options or disposal sites. For this reason, impacts resulting from occupational exposure to chemical hazards and radiological doses could be higher than otherwise expected. Occupational chemical and radiological exposures could occur during the testing of mixed wastes to determine if the constituents are chemically hazardous.

Potential disposal facilities for mixed waste that would be shipped for treatment and disposal rather than stored would be identified. Dominion would identify one disposal facility as the primary facility and a second as an alternate.

5.5.2.3 Environmental Impacts

Minimal environmental impacts would result from storage or shipment of mixed wastes. In the event of a spill, emergency procedures would be implemented to limit any onsite impacts. Emergency

response personnel would be properly trained and would maintain a current facility inventory, which would include types of waste, volumes, locations, hazards, control measures, and precautionary measures to be taken in the event of a spill.

Generation and temporary storage of mixed waste could expose workers to hazards associated with the chemical component(s) of the mixed waste matrix from leaks and spills. Dominion would require appropriate procedures if it was necessary to store mixed wastes temporarily on the ESP site. These procedures would include proper labeling of containers, installation of fire detection and suppression equipment (if required), use of fences and locked gates, availability of emergency shower and eyewash facilities, posting of hazard signs, and regular inspections. Dominion would also develop and implement contingency plans, emergency preparedness plans, and spill prevention procedures that would be implemented in the event of a mixed waste spill. Personnel who are designated to handle mixed waste or to respond to mixed waste emergency spills would receive appropriate training to enable them to perform their work properly and safely.

Offsite shipment, treatment, and disposal options depend on the hazard levels and radiological characteristics of the mixed waste. Because personnel performing packaging and shipping could be exposed to radiation from the mixed waste, appropriate controls would be implemented to ensure that ALARA goals are not exceeded. EPA mandates that waste storage containers in temporary storage be inspected weekly and certain aboveground portions of waste storage tanks be inspected daily. The purpose of these inspections is to detect leakage from, or deterioration of, containers (Reference 9). The NRC recommends that waste in storage be inspected at least quarterly (Reference 10). Waste inspection methods could include direct visual monitoring or remote monitoring for detecting leakage or deterioration. Additionally, measures would be provided to promptly locate and segregate or mitigate leaking containers.

5.5.2.4 **Waste Minimization Plan**

A waste minimization program would be developed and implemented. The following would be some of the key elements of such a program:

- Inventory Management – Inventory management or control techniques would be used to reduce the amount of excess or out-of-date chemicals or hazardous substances. Techniques would be used to reduce the inventory of hazardous chemicals and the size of the containers, and also monitor inventory turnover.
- Maintenance Program – Equipment maintenance programs would be periodically reviewed to establish improvements in corrective and preventive maintenance that would reduce equipment failures that could generate mixed waste. Maintenance procedures would be reviewed to determine which were contributing to the production of waste in the form of process materials, scrap, and cleanup residue. In addition, the need for revising operational procedures, modifying equipment, and segregating and recovering the mixed waste source would be determined.

- Recycling and Reuse – Recycling of waste would be considered. Opportunities for reclamation and reuse of waste materials would be used whenever feasible. Tools, equipment, and materials would be decontaminated for reuse or recycle whenever possible to minimize the amount of waste for disposal. Impediments to recycling, whether regulatory or procedural, would be challenged to enable generators to recycle whenever possible.
- Segregation – If radiological or hazardous waste is generated, proper handling, containerization, and separation techniques would be employed. This would minimize cross contamination and the unnecessary generation of mixed waste.
- Decay in Storage – Some portion of the mixed waste would be radionuclides with relatively short half-lives. The NRC generally allows facilities to store waste containing radionuclides with half-lives of less than 65 days until 10 half-lives have elapsed and the radiation emitted from the unshielded surface of the waste is indistinguishable from background levels. The waste could then be disposed of as a nonradioactive waste. Radioactive waste could also be stored for decay under certain circumstances in accordance with 10 CFR 20. For mixed waste, storage for decay would be particularly advantageous, because the waste could be managed solely as a hazardous waste after the radionuclides decayed to background levels, thus simplifying the management and regulation of these wastes.
- Work Planning – Pre-job planning would be performed to determine what materials and equipment would be needed to perform the anticipated work. One objective of this planning would be to prevent pollution and minimize the amount of mixed waste that may be generated and to use only the resources necessary to accomplish the work. Planning would also prevent mixing of materials or waste types.
- Tracking Systems – A tracking system would be developed, if required, to identify waste generation data and waste minimization opportunities. This would provide essential feedback to successfully guide future efforts. The data collected by the system would be used for internal reporting. The tracking system would provide feedback on the progress of the waste minimization program, including the results of the implementation of pollution prevention technologies. In addition, it would facilitate reporting pollution prevention data to the NRC and EPA.
- Training and Awareness Programs – A successful waste minimization program requires employee commitment. By educating employees in the principles and benefits of such a program, solutions to current and potential environmental management problems would be found. The broad objective of the waste minimization program would be to educate employees in the environmental aspects of activities occurring at the plant and in their community.

5.5.3 **Conclusions**

Minimal chemical constituents would be discharged to the water or air from operation of the new units. Waste minimization programs would reduce the amount of wastes, including mixed wastes,

generated by operation of the new units. No new waste streams would be generated. Impacts of waste generation would be small and would not warrant mitigation.

Section 5.5 References

1. VPDES Permit. Permit Number: VA0052451. January 2001.

2. 42 USC 2011 et seq., *United States Code*, Title 42, Chapter 23, “Development and Control of Atomic Energy,” (Atomic Energy Act of 1954).

3. 42 USC 6901 et seq., *United States Code*, Title 42, Chapter 82, “Solid Waste Disposal,” (Resource Conservation and Recovery Act of 1976).

4. 42 USC 2021b et seq., *United States Code*, Title 42, Chapter 23, “Development and Control of Atomic Energy,” (Low-Level Radioactive Waste Policy Amendments Act of 1985).

5. 40 CFR 261, *Code of Federal Regulations*, “Identification and Listing of Hazardous Waste.”

6. AP1000 Document No. APP-GW-GL-700, *AP1000 Design Control Document*, Tier 2 Material, Westinghouse, Revision 2, 2002.

7. NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Vol. 1, U. S. Nuclear Regulatory Commission, April 1996.

8. NUREG/CR-5938, *National Profile on Commercially Generated Low-Level Radioactive Mixed Waste*, U. S. Nuclear Regulatory Commission, December 1992.

9. 40 CFR 264, *Code of Federal Regulations*, “Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities.”

10. 10 CFR 20, *Code of Federal Regulations*, “Standards for Protection Against Radiation.”

5.6 Transmission System Impacts

This section discusses the environmental impacts of the transmission system during operation of the new units. As described in Section 3.7, based on an initial evaluation, the current ESP site transmission lines and corridors appear to have sufficient capacity for the total output of the existing and new units.

The current corridor maintenance activities are in compliance with applicable federal, state, and local laws and regulations, and applicable permit requirements. Section 5.6.1 and Section 5.6.2 discuss the terrestrial and aquatic impacts associated with current maintenance activities. Current maintenance practices would continue if two new units were built at the ESP site. Section 5.6.3 discusses the current potential impacts to members of the public.

5.6.1 Terrestrial Ecosystems

Refer to Section 2.2.2 for a description of the terrestrial ecology along the existing units' transmission corridors. In addition to the information presented in this application, Section 2.4 and Section 2.5 of the ER prepared for the North Anna License Renewal application provide further detail of the activities summarized below and more detail regarding terrestrial ecosystems. (Reference 1)

5.6.1.1 Impacts of Routine Maintenance Practices

As part of a three-year cycle for maintenance, slow helicopter inspections are conducted to support more detailed surveys of facilities and rights-of-way (Reference 1, Sections 2.4 and 2.5). Impacts of helicopter inspections are primarily air emission and noise from the aircraft.

Aircraft engines emit carbon dioxide, oxides of nitrogen, oxides of sulphur, water vapor, hydrocarbons and particulates. Noise generated by the fly-overs may cause local fauna to become nervous, startled, or temporarily displaced. These impacts are short-term and limited to a localized area; there are no long-term impacts. Impact(s) associated with helicopter inspections would be small.

The transmission corridors are managed (e.g., brush cutting and tree trimming) to prevent woody growth from encroaching on the transmission lines and potentially causing disruption in service or be a general safety hazard. As part of a three-year maintenance cycle, transmission lines and corridors are inspected from the ground and monitored for clearance at locations of concern identified during fly-overs. These inspections involve the use of light equipment (e.g., saws, mowers), herbicides, and hand tools. Mowing is the primary method for maintaining the corridors. Tree and brush trimming is performed in accordance with the Commonwealth of Virginia's tree trimming policy (Reference 2). In areas where mowing is impractical or undesirable, hand cutting and/or non-restricted herbicides are used. In areas where the ground is saturated (e.g., wetlands or wet areas), hand-cutting is the preferred alternative. These activities are regulated by federal and

state laws as well as applicable permit conditions and landowner agreements and have been incorporated into corridor management plans. (Reference 1, Sections 2.4 and 2.5)

Keeping the corridors free of woody vegetation can provide suitable habitat for protected plant species (e.g., rare, threatened, endangered) that depend on open conditions. Virginia Power has cooperated with the VDCR Natural Heritage Program in rare plant surveys within transmission corridors. Although several rare plant species have been located along transmission corridors, no threatened or endangered plant species have been identified or recorded. Locations of rare or sensitive plant species are marked on cutting sketches that Virginia Power maintains for its transmission lines. These cutting sketches, along with specifications and guidelines regarding herbicide use and brush cutting, are provided to corridor maintenance contractors so that adverse impacts on the environment can be avoided. (Reference 1, Sections 2.4 and 2.5)

The bald eagle and the loggerhead shrike (*Lanius ludovicianus*), are known to exist in central Virginia Piedmont areas (see Section 2.4.1), however, no federally and/or state-listed species designated as endangered or threatened are known to exist along the transmission corridors. Therefore, no special protection measures for such species is incorporated in the existing corridor system maintenance procedures.

The use of light equipment (e.g., pick-up trucks, farm tractors with mower attachments, small-engine hand tools) could result in incidental spills of fuel and/or lubricants. Whenever these materials are taken into the field, adequate spill response materials are immediately available to clean-up any such occurrences. Additionally, personnel are trained in how to respond to, clean-up, and report a spill, if one should occur. Contaminated material is managed and disposed of in accordance with federal and state laws and regulations.

Herbicides are handled and applied by specialty contractors in accordance with manufacturer specifications and guidance from jurisdictional regulatory agencies. Contractors are appropriately trained and licensed to perform such work. Herbicide applications are scheduled at appropriate times of the year (e.g., late summer when plants senesce). Furthermore, to prevent environmental impacts from herbicides, their use is prohibited:

- within 100 feet of a river or highway crossing or within 50 feet of a stream crossing
- on protected flora or habitats identified as being environmentally or commercially sensitive to the use of herbicides
- on desirable groundcover (e.g., dogwood, redbud, holly, rhododendron, wax myrtle)
- during high or unfavorable winds, when the risk of an uncontrolled application is increased
- on wild cherry trees growing in pasture lands or areas where livestock may be present.

5.6.1.2 Impacts of Special Maintenance Practices

Special maintenance practices are sometimes necessary for important habitats or wildlife-management requirements not addressed by applicable laws, regulations, or permit requirements. No areas designated by the USFWS as "critical habitat" for endangered species have been identified along or adjacent to NAPS transmission lines. The transmission corridors do not cross state or federal parks, wildlife refuges, or wildlife management areas (Reference 1, Sections 2.4 and 2.5).

5.6.1.3 Conclusion

Potential impacts associated with corridor maintenance activities would be small.

5.6.2 Aquatic Ecosystems

Refer to Section 2.2.2 for a description of the aquatic ecology along the existing units' transmission corridors. In addition to the information presented in application, Section 2.4 and Section 2.5 of the ER prepared for the North Anna License Renewal application, provide further details of the activities summarized below and more detail regarding aquatic ecosystems. (Reference 1, Sections 2.4 and 2.5)

5.6.2.1 Impacts of Routine Maintenance Practices

Routine maintenance practices in and near wetlands and other water bodies are performed in accordance with the practices described in Section 5.6.1.1. As noted in Section 5.6.1.1, tree trimming and brush cutting is done by hand in aquatic resource areas. Herbicide applications are prohibited within 50 feet of a stream crossing or where winds are likely to increase the risk of misapplication to aquatic resources.

5.6.2.2 Impacts of Special Maintenance Practices

Special maintenance practices are sometimes necessary for important habitats or wildlife management requirements not addressed by applicable laws, regulations, or permit requirements. No threatened or endangered aquatic species have been identified in the water bodies crossed by the NAPS transmission corridors.

Based on the VDGIF Fish and Wildlife Information Service Database (Reference 3), two state- and federally-listed freshwater mussel species [i.e., green floater (*Lasmigona subviridis),* and yellow lance *(Elliptio lanceolata)*] could exist in watercourses that the transmission corridors cross. Neither of these mussel species has been observed in the watercourses crossed by the transmission corridors. They have, been collected from other locations in the counties through which the transmission corridors run.

A third mussel species, the fluted kidney shell mussel (*Ptychobranchus subtentum*), has been reported within the vicinity of the ESP site. This mussel is a candidate for federal listing, and the

database referenced above lists this species as existing in a stream or streams in Louisa County, but not on the ESP site. All confirmed accounts of this species are confined to mountain streams in southwestern Virginia. (Reference 3) These streams comprise part of the Tennessee River watershed, and it is unlikely that fluted kidney shell mussel populations in such streams would be impacted, either directly or indirectly, by maintenance practices on the transmission line corridors, most of which cross streams in watersheds flowing toward the Atlantic Ocean.

5.6.2.3 Conclusion

Impacts of routine and special maintenance procedures for transmission corridors on aquatic resources would be small.

5.6.3 Impacts to Members of the Public

This section discusses the potential impacts on members of the public from electrical shock, electromagnetic field (EMF) exposure, noise, and aesthetics associated with the existing NAPS site transmission lines. Four transmission lines currently originate from the NAPS site. Three of the lines are 500 kV-transmission lines designed and built in the late 1970s in accordance with the National Electrical Safety Code (NESC) and industry guidance that was current at the time. The fourth line is a 230 kV line to South Anna, designed and built in 1984 in accordance with the NESC and industry guidance that was current at the time. (Reference 1, Section 4.13)

5.6.3.1 Electrical Shock

Virginia Power analyzed the potential impacts of electrical shock for the transmission lines in its environmental report for the existing units operating licenses renewal application. This analysis would be unaffected by the new units. The analysis of the induced current along the transmission lines began with the identification of the limiting case for each transmission line. By definition, the limiting case is the configuration along each transmission line where the potential for current-induced shock would be greatest. Because transmission corridors leaving the NAPS site contain only one transmission line per corridor, the limiting case was defined primarily by ground clearance and tower configuration of a single-line corridor. (Reference 4)

Once the limiting case was identified, the electrostatic field strength and the associated induced current for each transmission line was calculated using a computer algorithm (ENG01814), developed by Cincinnati Gas & Electric Company, and used by Virginia Power since 1978. The input parameters for ENG01814 included the design features of the limiting-case scenario, a calculated line sag at 120°F conductor temperature (i.e., NESC requirement and based on design clearances), and an assumed maximum vehicle size under the lines of a tractor-trailer (i.e., 55 ft x 8 ft x 11 ft). Model results were then field-verified through actual electric field measurements under energized transmission lines.

The computer analysis, confirmed by field verification, concluded that none of the four transmission lines have the capacity to induce more than 5 milliamperes in a vehicle parked beneath the lines. Therefore, the four transmission line designs conform to the NESC provisions for preventing electric shock from induced current. The analysis results for each transmission line are provided in Table 5.6-1. Impacts to members of the public from existing transmission lines would be small.

Table 5.6-1 Results of Induced Current Analysis

Transmission Line	Voltage (kV)	Limiting Case Electric Field Strength (kV/meter)	Limiting Case Induced Current (mA)
South Anna NUG (255)	230	4.35	3.10
Morrisville (573)	500	6.95	4.95
Ladysmith (575)	500	6.40	4.56
Midlothian (576)	500	6.68	4.77

5.6.3.2 Electromagnetic Field Exposure

In 1996, after 17 years of research that examined more than 500 studies, the National Research Council released the results of a study that stated, “The findings to date do not support claims that EMFs are harmful to a person’s health.” Furthermore the report added there is no conclusive evidence that EMF plays a role in the development of cancer, or reproductive or other abnormalities in humans. (Reference 5) Impacts to members of the public attributable to EMF exposure would be small.

5.6.3.3 Noise

Noise emitted from high-voltage lines is caused by the discharge of energy that occurs when the electrical field strength on the conductor surface is greater than the breakdown strength (i.e., the field intensity necessary to start a flow of electric current) of the surrounding air. The energy loss is known as corona loss. The higher voltages at which modern transmission lines operate have increased the nuisance noise problem.

The intensity of the noise, is affected by two conditions:

- Ambient weather conditions (e.g., humidity, air density, wind, precipitation)
- Irregularities on the conductor surface (e.g., sharp points)

Aging or weathering of the conductor surface typically reduces the significance of these factors. To limit corona activity, transmission lines are constructed and maintained so that during dry weather they operate below the corona-inception voltage. However, during wet weather, the likelihood of corona loss increases, contributing to nuisance noise. Corona-induced noise levels along the

existing transmission system are low and do not pose a health risk to humans. Additionally, Virginia Power has not received any reports from the public of nuisance noise due to transmission lines. Impacts to members of the public attributable to noise from the transmission lines would be small.

5.6.3.4 Visual Impacts

Visual impacts to members of the public from the transmission system were addressed qualitatively during the development of the Final Environmental Impact Statement (FEIS) for the existing units (Reference 6). The FEIS notes that the visual impact of the transmission lines would be diminished by several techniques including use of russet-brown tower structures that blend with the rural landscape and gray-painted H-frame structures to support conductor spans over the North Anna reservoir. The FEIS also notes that the route of transmission lines would, in most locations, be along existing ground contours thereby partially concealing the lines and eliminating long views of the line through woods and up slopes. In addition, the FEIS recommended that natural vegetation be retained, where possible, at road crossings to help minimize ground-level visual impacts. This specific recommendation from the FEIS has been incorporated into transmission corridor routine maintenance practices for vegetation control. Contractors performing routine vegetation control activities on the transmission lines are instructed to maintain a screen of natural vegetation in the right-of-way on each side of major highways and rivers unless otherwise directed. Based on the design conditions and ongoing routine vegetation control practices, the visual impact to members of the public from the transmission system would be small.

5.6.3.5 Conclusions

Potential impacts from electric shock, EMF exposure, noise or visual impacts from the existing NAPS site transmission lines would be small.

Section 5.6 References

1. *North Anna Power Station, Units 1 and 2 Application for Renewed Operating Licenses Environmental Report*, (Appendix E) Dominion, May 2001.

2. Policy for Tree and Brush Trimming, Virginia Department of Transportation, as seen on the TLC for Trees Project, www.tlcfortrees.info/virginia_department_of_transport.htm, accessed July 29, 2003.

3. Virginia Department of Game & Inland Fisheries' Fish and Wildlife Information Service Database, Website address: vafwis.org/perl/vafwis.pl/vafwis Online database accessed on February 26, 2003.

4. *Transmission Line Electric Shock Analysis, Virginia Power Bulk Power Delivery Transmission Lines*, Donald Koonce, Director, Transmission O&M Support. Virginia Power, December 1999.

5. Possible Health Effects of Exposure to Residential Electric and Magnetic Fields, National Research Council, October 1996.

6. Atomic Energy Commission (AEC), Docket Nos. 50-338 and 50-339, Final Environmental Impact Statement (FEIS) Section 4.1, **"**Effect on Land Use," Virginia Electric and Power Company, April 1973.

5.7 Uranium Fuel Cycle Impacts

This section addresses the uranium fuel cycle environmental impacts and is divided into two main subsections. The first subsection addresses the LWR designs presently being considered. The second subsection addresses the gas-cooled reactor designs also being considered. This split addresses the regulatory distinction made in 10 CFR 51.51 for LWRs.

5.7.1 Light-Water-Cooled Reactors

10 CFR 51.51(a) states that "Every environmental report prepared for the construction permit stage of a light-water-cooled nuclear power reactor, and submitted on or after September 4, 1979 shall take Table S-3, *Table of Uranium Fuel Cycle Environmental Data*, as the basis for evaluating the contribution of the environmental effects of uranium mining and milling, the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, reprocessing of irradiated fuel, transportation of radioactive materials and management of low level waste and high level wastes related to uranium fuel cycle activities to the environmental costs of licensing the nuclear power plant. Table S-3 shall be included in the environmental report and may be supplemented by a discussion of the environmental significance of the data set forth in the table as weighed in the analysis for the proposed facility."

Table S-3 of 10 CFR 51.51 is reproduced in its entirety herein as Table 5.7-3. Specific categories of natural-resource use included in the table relate to land use, water consumption and thermal effluents, radioactive releases, burial of transuranic and high- and low-level wastes, and radiation doses from transportation and occupational exposures. The contributions in the table for reprocessing, waste management, and transportation of wastes are maximized for either of the two fuel cycles (uranium only and no recycle); that is, the cycle that results in the greater impact is used.

Dominion's analysis of environmental effects of the uranium fuel cycle for North Anna's ESP application included a review of impact considerations due to radon-222 (Ra-222) and technetium-99 (Tc-99). This assessment took advantage of previous analyses documented in NUREG-1437, Section 6.2, including Tables 6.1 through 6.4, as well as a review of known impacts from experience with these isotopes in the fuel cycle. The analysis in NUREG-1437, Section 6.2 is incorporated by reference in the North Anna ESP application.

As described in NUREG-1437, Chapter 6, the data on environmental impacts of the uranium fuel cycle presented in Table S-3 (which didn't address the impacts of Ra-222 and Tc-99) was supplemented to extend the coverage of assessed impacts to include those isotopes. In NUREG-1437 it states that "Principal radon releases occur during mining and milling operations and as emissions from mill tailings, whereas principal Tc-99 releases occur from gaseous diffusion enrichment facilities." In accordance with the guidance provided in NUREG-1555 (Section 5.7, Appendix A) and the NEPA evaluation process, Dominion determined that there was no new significant information relevant to the impacts of those isotopes for the North Anna ESP site. Since the principal fuel cycle and impact evaluations for new reactor technologies are bounded by the

existing LWR impact assessment, Dominion concluded that the overall significance of contribution from Ra-222 and Tc-99 would remain small. In addition, calculated operational aspects of the fuel cycle associated with supporting new units at the North Anna site would only contribute to an extremely low percentage of the natural total body dose to the public. Furthermore, the EPA has found that current emissions from power plants were at levels that provided an ample margin of safety. Therefore, since uranium fuel cycle facilities must comply with federal and state regulatory limits, dose contribution to the public would also be considered small. In addition, the non-radiological impacts of the uranium fuel cycle are acceptable.

The LWR technologies being considered to demonstrate site suitability include the ABWR, the ESBWR, the AP1000 (Advanced Passive PWR), the IRIS, and the ACR-700 (Advanced light-water-cooled version of the CANDU Reactor). The standard configuration for each of these reactor technologies is as follows. The ABWR is a single-unit, 4300 MWt, nominal 1500 MWe reactor. The ESBWR is a similar BWR: single-unit, 4500 MWt, nominal 1520 MWe. The AP1000 is a single-unit, 3400 MWt, nominal 1117–1150 MWe PWR. The IRIS is a three-module PWR configuration for a total of 3000 MWt and nominal 1005 MWe. And the ACR-700 is a twin-unit, 3964 MWt, nominal 1462 MWe, light-water-cooled CANDU reactor.

These reactor technologies are all LWRs with uranium dioxide fuel and therefore Table S-3 of 10 CFR 51.51(b) provides the basis for evaluating the environmental effects from the uranium fuel cycle for these reactor technologies. The Table S-3 values are normalized for a 1000 MWe reference LWR. Since the ESP site may be used for up to 3200 MWe, the fuel cycle impacts resulting from operation of new LWRs at the ESP site would be no more than 3.2 times the Table S-3 values.

5.7.2 Gas-cooled Reactors

5.7.2.1 Introduction and Background

This section provides an assessment of the environmental impacts of the fuel cycle, as related to the operation of the gas-cooled reactor technologies, based on a comparison of the key parameters that were used to generate the impacts listed in 10 CFR 51.51, Table S-3 (and repeated in Table 5.7-3). The key parameters are energy usage, material involved, number of shipments, etc. associated with the major fuel cycle activities. The major fuel cycle activities are mining and milling, uranium hexafluoride conversion, enrichment, fuel fabrication, and radioactive waste disposal. Basically, the premise is that if less energy is needed, if fewer shipments are required, and if less material is involved in the process, then with all other things being equal, the overall impacts are less.

There are two gas-cooled reactor technologies being considered at this time. The GT-MHR is a four-module, 2400 MWt, nominal 1140 MWe reactor that operates at a unit capacity of 88 percent.

The PBMR is an eight module, 3200 MWt, nominal 1320 MWe reactor operating at a 95 percent unit capacity.

A key reference is NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants,* May 1996, which provides a very detailed look at the impacts to the environment from the nuclear fuel cycle. The document also looks at the sensitivity of the changes to the nuclear fuel cycle on the impacts to the environment.

Table 5.7-1 was prepared to succinctly capture the major features of the reference LWR fuel cycle that were used to develop Table S-3 and compare these same features with the gas-cooled reactor technologies being considered. This comparison can then help to demonstrate that the previously accepted environmental impacts identified in Table S-3 are comparable to the impacts for these gas-cooled technologies. The premise is that if the values of the major contributors to the health and environmental impacts that were used for the reference LWR fuel cycle are greater than those comparable values for the gas-cooled reactor technologies, then the published, previously accepted impacts would also be greater than the impacts from the new reactor technologies. It is important to point out that even though the contributors are being examined individually, it is the overall impact that is of concern. As such, there can be increases in individual contributors, yet the total impacts can still be bounded, if offset by decreases in other contributors.

The information to conduct the comparison was taken from 10 CFR 51.51, Table S-3 “Uranium Fuel Cycle Environmental Data,” WASH-1248, *Environmental Survey of the Uranium Fuel Cycle*, and Supplement 1 to WASH-1248, (also known as NUREG-0116) *Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle*. The “reference LWR” refers to the model 1000 MWe LWR used as a basis for studying annual fuel related requirements as described in WASH-1248. For the gas-cooled reactor technologies, information was gathered from the reactor vendors, United States Enrichment Corporation (USEC) and ConverDyn.

5.7.2.2 **Analytic Approach**

The major activities of the reference LWR fuel cycle that were considered in the WASH-1248 report were uranium mining, uranium milling, uranium hexafluoride production, uranium enrichment, fuel fabrication, irradiated fuel reprocessing, radioactive waste management which includes decontamination and decommissioning, and transportation. Three comments pertinent to this analysis are: 1) the WASH-1248 report and this evaluation only address the uranium fuel cycle (other fuel cycles such as thorium and plutonium are not part of this effort), 2) irradiated fuel reprocessing is not being considered by any of the new reactor technologies and is not included in this analysis, and 3) the transportation impacts are addressed based on the following premise - if the quantity of material required by the new gas-cooled reactor technologies at each major step of the fuel cycle is less than the reference plant, then the transportation impacts are also less. Comparing only the number of shipments of material is appropriate since there is little if any radioactivity in the fuel cycle shipments considered by Table S-3.

The main features of the major activities of the reference LWR fuel cycle that were identified as being the primary contributors to the health and environmental impacts are as follows. For the mining operation, annual ore supply is the major determinant of environmental and health impacts. Less ore would necessitate less energy, fewer emissions, less water usage, and less land disturbed. Secondarily, the mining technique can play a significant role in any impacts. Open pit mining has by far the most environment impact, followed by underground mining, with *in situ* leaching being the most environmentally benign.

For the milling operation, annual yellowcake (U_3O_8) production is the metric of interest. If a plant requires less U_3O_8 than the reference plant, then there would be less energy needed, fewer emissions, and less water usage. This is especially true if *in situ* leaching was used to obtain the ore, because the major milling steps of crushing and grinding are not required.

For the uranium conversion process, annual uranium hexafluoride (UF_6) production is the primary determinant of environmental impacts. If the new technology requires less UF_6 than the reference plant, then there would be less energy required, fewer emissions and less water used. As with the mining step, the conversion process (wet versus dry) is also a consideration. However, NUREG-1437 states that in either case “the environmental releases are so small that changing from 100 percent use of one process to 100 percent of the other would make no significant difference in the totals given in Tables S-3 or S-4.”

For the enrichment operation, there are two quantities of interest. The first quantity is the separative work units (SWU) needed to enrich the fuel, and the second quantity is the amount of enriched UF_6. The SWU is a measure of energy required to enrich the fuel. More SWUs would indicate not only more energy required but also more emissions associated with the production of the energy needed and with that more water usage. However, this assumes the same technology is used to achieve the enrichment. As presented in NUREG-1437, the centrifuge process uses 90 percent less energy than the gaseous diffusion process. Since the major environmental impacts for the entire fuel cycle are from the emissions from the fossil fueled plants needed to supply the energy demands of the gaseous diffusion plant, this reduction in energy requirements results in a fuel cycle with much less environmental impact. With regard to the amount of enriched UF_6 produced, the major effect would be the number of shipments. More UF_6 would necessitate more shipments, while less UF_6 would require fewer shipments. Slight increases or decreases would probably result in the same number of shipments.

For the fuel fabrication process, the quantity of UO_2 produced is the value of interest. This is really equivalent to the annual fuel loading in MTU, which would also be evaluated. Here again, the production of more UO_2 would require more energy, greater emissions, and increased water usage. New reactor technologies with an annual fuel loading less than the reference LWR plant would have less environmental impact, requiring less energy, fewer emissions and less water usage.

The last activity to be addressed is radioactive waste management. There are two aspects of radioactive waste that are considered as part of Table S-3: operations and reactor decontamination and decommissioning (D&D). For these activities, curies of low-level waste (LLW) from annual operations and Ci of LLW from reactor (D&D) are the measures to consider. Curies by themselves are not a direct indicator of the potential environmental impacts. The radionuclide, its half-life and type of emission, and its physical and chemical form are the main contributors to risk. While we recognize this distinction, for this bounding analysis we will use curies as was done in the WASH-1248. More curies generally indicate the potential for greater impacts, while fewer curies indicate lesser impacts.

One of the clearest ways to conduct this comparison between the reference LWR and the gas-cooled reactor technologies is to start with the annual fuel loading in MTU for each of the reactor technologies. The other activities more accurately originate from the need for a certain amount of fuel. Using annual fuel loading as the starting point, the analysis will proceed in the reverse direction for the fuel cycle until the mining has been addressed, then the radioactive waste will be addressed. Before beginning this comparison, it is important to recognize that the plants being considered are a different size, have a different electrical rating and have a different capacity factor from the reference LWR. The reference LWR is a 1000 MWe plant with a capacity factor of 80 percent. In order to make a proper comparison, we need to evaluate the activities based on the same criterion. In this case, electrical generation is the metric of choice. Electrical generation is why the plants are being built and we want to know if these new reactor technologies, for the same electrical output, have a greater or lesser impact on human health and environment. Based on this, the reactor technologies will be normalized to 800 MWe using plant specific electrical rating and capacity factor.

5.7.2.3 Analysis and Discussion

5.7.2.3.1 Fuel Fabrication/Operations

The reference LWR required 35 MTU on an annual basis. This is equivalent to 40 MT of enriched UO_2, the annual output needed from the fuel fabrication plant. In comparison, the normalized annual fuel needs for the new gas-cooled reactor technologies ranged from 4.3 MTU to 5.3 MTU, approximately 88 percent to 85 percent lower than the reference plant. Similarly, the annual output needed from the fuel fabrication plant range from a low of 4.89 MT of UO_2 to 6.0 MT of UO_2, again approximately 88 percent to 85 percent lower than the reference plant. The specific breakdowns are shown on Table 5.7-1. One important distinction is that the fuel form for the gas-cooled reactors is also different. For the GT-MHR, the fuel is a two-phase mixture of enriched UO_2 AND UC_2, usually referred to as UCO. For the PBMR the fuel kernel is UO_2. Both fuels are then TRISO coated. For the GT-MHR these TRISO fuel particles are blended and bonded together with a carbonaceous binder. These fuel compacts are then stacked within a graphite block. For the PMBR, the fuel unit is a 6 cm diameter graphite sphere containing approximately 15000 fuel particles.

Before concluding the potential impacts from the fuel fabrication process are less, the gas-cooled reactors require a different fuel fabrication process altogether. The TRISO coated fuel kernel is quite different from the UO_2 sintered fuel pellet and as such would require a different type of facility. Ideally, to verify the environmental impacts of this change in fabrication process are bounded by the reference LWR fuel fabrication plant, a comparison of the land use, energy demand, effluents, etc., is in order. However, because there are no planned or currently operating plants in the United States, a direct comparison cannot be made at this time. Therefore, we have provided information on the reference fuel fabrication plant along with conceptual design information for a TRISO fabrication plant that was planned for the New Production Reactor and conceptual design information received from one of the gas-cooled reactor vendors.

From WASH-1248, the reference LWR fuel fabrication plant produced fuel for 26 plants (≈910 MTU), was located on a site of about 100 acres, required 5.2 million gallons of water per annual fuel requirement of 35 MTU, and required 1,700 MW-hours of electricity per 35 MTU. The WASH-1248 report also states that nearly all of the airborne chemical effluents resulted from the combustion of fossil fuels to produce electricity to operate the fabrication plant. These numbers represented a very small portion of the overall fuel cycle. For example, the electrical usage represented less than 0.5 percent of that needed for the enrichment process, and the water use was less than 2 percent of the overall fuel cycle.

The fuel fabrication facility for the New Production Reactor was for a modular high temperature gas reactor (MHTGR) design and was sized for just one plant, so the much larger reference LWR fuel fabrication plant are not readily comparable. The dimensions for the fuel fabrication building were 230 ft x 150 ft. The annual production was about 2 MTU. The plant required 960 kW of electrical power and 45 liters per minute of water. Effluents consisted of 60 m^3/yr of miscellaneous non-combustible solids and filters; 50 m^3/yr of combustible solids; 50 m^3/yr of process off-gas and HVAC filters; 2.0 m^3/yr of tools and failed equipment; and process off-gases of 900,000 m^3/yr. The process off-gases consisted of 74 percent N_2, 12 percent O_2, 7.2 percent Ar, 6.4 percent CO_2, 0.2 percent CO, and 0.02 percent CH_3CCl_3. The activity associated with this off-gas: 0.01 pCi alpha/m^3, and 0.01 pCi beta/m^3.

The information gathered from one of the current reactor vendors was for a plant producing 6.3 MTU, about 19 percent more than the annual reload of 5.31 MTU for its reactor. Again this plant was sized for just one reactor. This plant would require 10 MW of electrical power with an annual electrical usage of 35,000 MW-hr. The gaseous emissions consist of 80 MT of nitrogen, 52 MT of argon, 22.4 MT of CO, 22 MT of hydrogen and 3.7 MT of CO_2. The solid waste totals about 84 m^3 of LLW, 3 m^3 of intermediate level waste, and the remainder sanitary/industrial wastes. The liquid processing system would generate an additional 3.8 m^3 of LLW, would discharge about 3700 m^3 of low activity aqueous effluent, and would discharge about 45,000 m^3 of industrial cooling water.

Because of the differences in scale and the state of design of the facilities, it is not possible or appropriate to make a direct comparison of the impacts. Obviously, there are economies of scale

and design improvements that would occur for a plant comparable in size to the reference plant. Regardless, the projected impacts of a TRISO fuel plant based on the two conceptual designs are not inconsistent with the reference plant and would be operated within existing air, water, and solid waste regulations. Furthermore, like the impacts associated with the sintered UO_2 pellet plant, the impacts from a TRISO fuel plant would still be a minor contributor to the overall fuel cycle impacts. By characterizing the impacts as "not inconsistent," it is meant that while certain parameters such as electrical usage for fuel fabrication might be higher for the gas-cooled plants on an annual fuel loading basis, the environmental impacts from the TRISO plants as conceptualized would still be bounded by the overall LWR fuel cycle impacts.

5.7.2.3.2 Uranium Enrichment

In order to produce the 40 MT of enriched UO_2 for the reference LWR, the enrichment plant needed to produce 52 MT of UF_6, which required 127 MT of SWU. The normalized enriched UF_6 needs for the new gas-cooled reactor technologies ranged from 6.38 MT of UF_6 to 7.9 MT of UF_6, approximately 88 percent to 85 percent lower. To produce these quantities of UF_6 requires from 124 MT of SWU to 163 MT of SWU, slightly lower to 28 percent higher. The enrichment SWU calculation for the new reactor technologies was performed using the USEC SWU calculator and assumes a 0.30 percent tails assay, the same value as for the reference LWR. Using this calculator for the reference LWR plant yielded 126 MT of SWU versus the NUREG value of 127. This is very close indicating that this latest version of the USEC SWU calculator is appropriate for use in this computation. Table 5.7-2 gives the details of the computations.

The 28 percent increase in the MTU of SWU would by itself indicate greater environmental impacts. However, a close look at the original WASH-1248 analysis shows that the environmental impacts are almost totally from the electrical generation needed for the gaseous diffusion process. These impacts result from the emissions from the electrical generation that is assumed to be from coal plants and from the associated water to cool the plants. Today, and in the future, the enrichment process is and will be different. A significant fraction of the enrichment services to U.S. utilities today is provided from European facilities using centrifuge technology rather than the fifty-year-old gaseous diffusion technology. For the future, two private companies, United States Enrichment Corporation and Louisiana Energy Services, are planning to develop centrifuge technology in the U.S. In fact, NRC has just recently accepted United States Enrichment Corporation's centrifuge license application for technical review. Centrifuge technology requires less than 10 percent of the energy needed for the gaseous diffusion process and as such the environmental impacts associated with the electrical generation would be correspondingly less. This tremendous reduction in energy and the associated environmental impacts more than offsets a 28 percent increase in SWU.

5.7.2.3.3 Uranium Hexafluoride Production

In order to provide the feed needed for the reference LWR to the enrichment plant, the uranium hexafluoride plant needed to produce 360 MT of UF_6. The normalized feed needed for the new gas-cooled reactor technologies, the output from the uranium hexafluoride plant, ranged from 241 to 303 MT of UF_6, well below the reference plant. The feed calculations were performed using the USEC SWU calculator. Using this calculator for the reference LWR yielded 353 MT of UF_6 versus 360 MT specified for the reference LWR in NUREG-0166. Again this value is very close (<2 percent) to the published value.

5.7.2.3.4 Uranium Milling

To produce the 360 MT of UF_6 for the reference LWR, 293 MT of yellowcake (U_3O_8) from the mill was required. The normalized new gas-cooled reactor technologies needs ranged from 193 MT of U_3O_8 to 243 U_3O_8, well below the reference plant. These yellowcake numbers were generated using the relationship 2.61285 lb of U_3O_8 to 1 kg of UF_6. This conversion factor was obtained from ConverDyn.

5.7.2.3.5 Uranium Mining

The raw ore needed to produce the 293 MT of yellowcake (U_3O_8) for the reference LWR was 272,000 MT. Now assuming a 0.1 percent ore body and a 90 percent recovery efficiency, the normalized new gas-cooled reactor technologies ore requirements ranged from 215,000 to 270,000 MT of ore, both below the reference plant. Of note, the value of 272,000 MT specified for the reference LWR in NUREG-0116 should be about 325,600 using the same assumptions. In any case, the gas-cooled reactor technologies are below the published reference plant value.

Uranium mining completes the front end of the fuel cycle. However, there are two areas on the down stream cycle to be considered. These are the LLW generated by operations and the LLW generated as part of the D&D process. As mentioned earlier, spent fuel reprocessing is not germane to this analysis, and therefore, not discussed.

5.7.2.3.6 Solid Low-Level Radioactive Waste - Operations

For the reference LWR, 10 CFR 51.51, Table S-3, Table of Uranium Fuel Cycle Environmental Data, states that there are 9,100 Ci of LLW generated annually from operations. The range of activity of LLW generated annually projected by the new gas-cooled reactor technologies is 65.4 Ci to 1,100 Ci, far below the reference LLW. This decrease would also suggest many fewer shipments to the disposal facility and less worker exposure.

5.7.2.3.7 Solid Low-Level Radioactive Waste – Decontamination and Decommissioning

10 CFR 51.51, Table S-3, states 1,500 Ci per Reactor Reference Year (RRY) “comes from reactor decontamination and decommissioning – buried at land burial facilities.” Based on this small quantity and the modifying phrase “buried at land burial facilities” it is clear that only waste suitable for shallow land burial was being considered as a basis for the Table S-3 line item. At this time, only

general conclusions can be drawn to indicate these gas-cooled reactor technologies would generate less D&D LLW than the reference plant. The new plants would operate much cleaner than the reference LWR as evidenced by the annual generation of much less LLW. Improvements in fuel integrity and differences in fuel form as well as the use of the chemically and radiologically inert helium as the coolant are responsible for this reduction and also should contribute to both a lower level and less overall contamination to be managed during the D&D process. The plants higher thermal efficiency and higher fuel burnup would produce less heavy metal radioactive waste. Lastly, the plants, with the exception of the reactor core, are typically more compact than the reference LWR contributing to less D&D waste. For these reasons, it is expected that the D&D LLW generation from the gas-cooled reactor designs would be comparable or less than that associated with the reference LWR.

The key areas of impact from D&D LWR for the gas-cooled reactor are expected to be identical to those of the reference LWR, namely transportation and land use supporting waste disposal. As presented in WASH-1248, the contributions from the D&D LLW to the overall environmental impacts are relatively quite small. WASH-1248 points out that by far the major environmental impacts are dominated by the front end phases (mining, milling, enrichment) of the fuel cycle, e.g., land use from mining and power consumption to support enrichment, related water usage, and power plant emissions.

As noted above, the D&D LLW impacts related to the gas-cooled reactor designs are expected to be comparable or less than that of the reference LWR. However, even if the gas-cooled reactor D&D LLW activities and/or volumes were larger, the overall reference LWR fuel cycle impacts would continue to be bounding.

5.7.2.4 **Summary and Conclusion**

To recap, there are only two instances where any part of the uranium fuel cycle is/might be exceeded by the new gas-cooled reactor technologies. These fuel cycle steps are enrichment, a 28 percent increase and possibly D&D. As presented above, the enrichment requirement for SWU, while slightly larger, can be conducted in a much more environmentally benign manner, centrifuge versus gaseous diffusion, from current overseas sources or expected new domestic facilities. The net effect would be that the environmental and health impacts would be less than those identified in Table S-3. The second area, decontamination and decommissioning, is a minor contributor to the fuel cycle impacts. While definitive D&D LLW information was not readily available for the gas-cooled reactor technologies, for several qualitative reasons, the impacts are expected to be comparable or less than the reference LWR. However, even an increase in the D&D LLW impacts would be more than offset by the significant decreases in the impacts due to reduction in fuel needs and changes in the enrichment process and mining technique.

In conclusion, this detailed comparison of the underpinnings of Table S-3 show qualitatively that the existing WASH-1248 environmental and health effects are conservative and appropriate for use by

these new gas-cooled reactor technologies. Collectively, improvements in both past practices as well as changes in technology have resulted in a fuel cycle with lower environmental impact.

5.7.3 **Methodology Assessment**

The selection of a reactor design to be used for the ESP Facility is still under consideration. Selection of a reactor to be used at the ESP site may not be limited to those considered above. However, the methodology utilized above is appropriate to evaluate the final selected reactor. Further, should the selected design be shown to be bounded by the above evaluation, then the selected design would be considered to be within the acceptable fuel cycle environmental impacts considered for this ESP.

Section 5.7 References

1. 10 CFR 51.51, Table S-3, Table of Uranium Fuel Cycle Environmental Data.

2. NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants,* May 1996.

3. WASH-1248, *Environmental Survey of the Uranium Fuel Cycle*, April 1974.

4. Supplement 1 to WASH-1248, also known as NUREG-0116, *Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle*, October 1976.

5. EGG-NPR-8522, Rev. B, *NPR-MHTGR Generic Reactor Plant Description and Source Terms*, March 1991.

Table 5.7-1 Gas-Cooled Fuel Cycle Impact Evaluation

Reactor Technology Facility/Activity	Reference LWR (Single unit) (≈1000 MWe) 80% Capacity	GT-MHR (4 Modules) (2400 MWt total) (≈1150 MWe total) 88% Capacity	PBMR (8 Modules) (3200 MWt total) (≈1280 MWe total) 95% Capacity
Mining Operations			
Annual ore supply MT	272,000	337140	337140
Normalized annual ore supply MT	272,000	269712	214739
Fraction of reference LWR	1	0.99	0.79
Calculated number	314,011	269712	214739
Milling Operations			
Annual yellowcake MT	293	303	303
Normalized annual yellowcake MT	293	243	193
Fraction of reference LWR	1	0.83	0.66
Calculated number	283	243	193
UF_6 Production			
Annual UF_6 MT	360	379	379
Normalized annual UF_6 MT	360	303	241
Fraction of reference LWR	1	0.84	0.67
Calculated number	353	303	241
Enrichment Operations			
Enriched UF_6 (MT)	52	8.0	12.3
Normalized enriched UF_6 (MT)	52	6.38	7.9
fraction of reference LWR	1	0.12	0.15
Calculated number	52	6.38	7.9
Annual SWU (MT)	127	204	194
Normalized annual SWU (MT)	127	163	124
fraction of reference LWR	1	1.29	0.97
Calculated number	126	163	124

Table 5.7-1 Gas-Cooled Fuel Cycle Impact Evaluation

Reactor Technology Facility/Activity	Reference LWR (Single unit) (≈1000 MWe) 80% Capacity	GT-MHR (4 Modules) (2400 MWt total) (≈1150 MWe total) 88% Capacity	PBMR (8 Modules) (3200 MWt total) (≈1280 MWe total) 95% Capacity
Fuel Fabrication Plant Operations			
Enriched UO_2 (MT)	40	6.11	9.5
Normalized enriched UO_2 (MT)	40	4.89	6.0
fraction of reference LWR	1	0.12	0.15
Calculated number	40	4.89	6.0
Annual Fuel Loading (MTU)	35	5.39	8.34
Normalized annual fuel loading (MTU)	35	4.3	5.31
fraction of reference LWR	1	0.12	0.15
Reprocessing Plant Operations			
Annual spent fuel reprocessing MTU	35	0	0
Solid Radioactive Waste			
Annual LLW from reactor operations Ci	9,100	1100 Ci; 98 m^3	65.4 Ci; 800 drums
fraction of reference LWR	1	0.12	0.01
LLW from Reactor Decontamination & Decommissioning Ci per RRY	1,500	Data not available	Data not available
TRU and HLW Ci	1.1×10^7	Reprocessing is not considered in this evaluation.	Reprocessing is not considered in this evaluation.

Yellow indicates a value larger than Table S-3.

References:

1. 10 CFR 51.51, Table S-3 Table of Uranium Fuel Cycle Environmental Data
2. 10 CFR 51.51, Table S-3 Table of Uranium Fuel Cycle Environmental Data

Table 5.7-1 Gas-Cooled Fuel Cycle Impact Evaluation

Reactor Technology Facility/Activity	Reference LWR (Single unit) (≈1000 MWe) 80% Capacity	GT-MHR (4 Modules) (2400 MWt total) (≈1150 MWe total) 88% Capacity	PBMR (8 Modules) (3200 MWt total) (≈1280 MWe total) 95% Capacity

Notes:

1. The enrichment SWU calculation was performed using the USEC SWU calculator and assumes a 0.30% tails assay.
2. The information on the reference reactor (mining, milling, UF_6, enrichment, fuel fabrication values) taken from NUREG-0116, Table 3.2, no recycling.
3. The information on the reference reactor (solid radioactive waste) taken from 10 CFR 51.51, Table S-3.
4. The calculated information on the reference reactor uses the same methodology as for the reactor technologies.
5. The normalized information is based on 1000 MWe and the reactor vendor supplied unit capacity factor.
6. For the new reactor technologies, the annual fuel loading was provided by the reactor vendor.
7. The USEC SWU calculator also calculated the kgs of U feed. This number was multiplied by 1.48 to get the necessary amount of UF_6.
8. The annual yellowcake number was generated using the relationship 2.61285 lb. of U_3O_8 to 1 kg U of $UF_{6;}$ 1.185 kgs of U_3O_8 to 1.48 kg.
9. The annual ore supply was generated assuming an 0.1% ore body and a 90% recovery efficiency.
10. Co-60 with a 5.26 year half-life and Fe-55 with a 2.73 year half-life are the main nuclides listed for the PBMR D&D waste.

Table 5.7-2 SWU and Feed Calculation Results

Reactor Technology	kg Uranium Product	Weight Percent U_{235}	SWU Quantity	kg of U Feed Required	Tails Assay
ABWR	32,760	4.5	204,127.56	334,774.44	0.30%
ESBWR	32,760	4.5	204,127.56	334,774.44	0.30%
AP1000	24,400	4.51	152,500.00	249,929.20	0.30%
IRIS	18,800	4.85	129,851.60	208,134.8	0.30%
ACR-700	66,200	2.00	112,341.40	273,803.20	0.30%
GT-MHR	5,394	19.80	204373.27	255,918.33	0.30%
PBMR	8,340	12.90	194,413.74	255,679.38	0.30%
NUREG-0116	35,000	3.10	126,175	238,455	0.30%
WASH-1248	35,000	3.20	147,280	223,965	0.25%

Notes:

1. The reactor vendor supplied the kg uranium product and weight percent U_{235}.
2. The tails assay was assumed to be 0.3% to match NUREG-0116 with the exception of WASH-1248 which used a tail assay of 0.25%.
3. The SWU Quantity and kg Feed Required were calculated using the USEC SWU Calculator.
4. The results have not been normalized to equivalent electrical generation.

Table 5.7-3 10 CFR 51.51, Table S-3- of Uranium Fuel Cycle Environmental Data[a]

[Normalized to model LWR annual fuel requirement [WASH-1248] or reference reactor year [NUREG-0116]]
[See Footnotes at end of this table]

Environmental Considerations	Total	Maximum effect per annual fuel requirement or reference reactor year of model 1,000 MWe LWR
Natural Resource Use		
Land (acres)		
Temporarily committed[b]	100	
Undisturbed area	79	
Disturbed area	22	Equivalent to a 110 MWe coal-fired power plant.
Permanently committed	13	
Overburden moved (millions of MT)	2.8	Equivalent to 95 MWe coal-fired power plant.
Water (millions of gallons)		
Discharged to air	160	=2% of model 1,000 MWe LWR with cooling tower.
Discharged to water bodies	11,090	
Discharged to ground	127	
Total	11,377	<4% of model 1,000 MWe LWR with once through cooling.
Fossil Fuel:		
Electrical energy (thousands of MW-hour)	323	<5% of model 1,000 MWe output
Equivalent coal (thousands of MT)	118	Equivalent to the consumption of a 45 MWe coal-fired power plant.
Natural gas (millions of scf)	135	<0.4% of model 1,000 MWe energy output.
Effluents-Chemical (MT)		
Gases (including entrainment)[c]		
SO_x	4,400	
NO_x[d]	1,190	Equivalent to emissions from 45 MWe coal-fired plant for a year.
Hydrocarbons	14	
CO	29.6	
Particulates	1,154	

Table 5.7-3 10 CFR 51.51, Table S-3- of Uranium Fuel Cycle Environmental Data[a]

[Normalized to model LWR annual fuel requirement [WASH-1248] or reference reactor year [NUREG-0116]]
[See Footnotes at end of this table]

Environmental Considerations	Total	Maximum effect per annual fuel requirement or reference reactor year of model 1,000 MWe LWR
Other gases		
F	0.67	Principally from UF_6, production, enrichment, and reprocessing. Concentration within range of state standards- below level that has effects on human health.
HCl	0.014	
Liquids		
SO_4	9.9	From enrichment, fuel fabrication, and reprocessing steps. Components that constitute a potential for adverse environmental effect are present in dilute concentrations and receive additional dilution by receiving bodies of water to levels below permissible standards. The constituents that require dilution and the flow of dilution water are: NH_3-600 cfs., NO_3-20 cfs., Fluoride-70 cfs.
NO_3	25.8	
Fluoride	12.9	
CA^{++}	5.4	
Cl^-	8.5	
Na^+	12.1	
NH_3	10.0	
Fe	0.4	
Tailings Solutions (thousands of MT)	240	From mills only-- no significant effluents to environment.
Solids	91,000	Principally from mills-- no significant effluents to environment.
Effluents—Radiological (curies)		
Gases (including entrainment)		
Rn-222		Presently under reconsideration by the Commission.
Ra-226	0.02	
Th-230	0.02	
Uranium	0.034	

Table 5.7-3 10 CFR 51.51, Table S-3- of Uranium Fuel Cycle Environmental Data[a]

[Normalized to model LWR annual fuel requirement [WASH-1248] or reference reactor year [NUREG-0116]]
[See Footnotes at end of this table]

Environmental Considerations	Total	Maximum effect per annual fuel requirement or reference reactor year of model 1,000 MWe LWR
Tritium (thousands)	18.1	
C-14	24	
Kr-85 (thousands)	400	
Ru-106	0.14	Principally from fuel reprocessing plants.
I-129	1.3	
I-131	0.83	
Tc-99		Presently under consideration by the Commission
Fission products and transuranics	0.203	
Liquids		
Uranium and daughters	2.1	Principally from milling-- included tailings liquor and returned to ground -- no effluents; therefore, no effect on the environment.
Ra-226	0.0034	From UF_6 production.
Th-230	.0015	
Th-234	.01	From fuel fabrication plants-- concentration 10 percent of 10 CFR 20 for total processing 26 annual fuel requirements for model LWR.
Fission and activation products	5.9×10^{-6}	
Solids (buried on site)		
Other than high level (shallow)	11,300	9,100 Ci comes from low level reactor wastes and 1,5000 Ci comes from reactor decontamination and decommissioning -- buried at land burial facilities. 600 Ci comes from mills -- included in tailing returned to ground. Approximately 60 Ci comes from conversion and spent fuel storage. No significant effluent to the environment.
TRU and HLW (deep)	1.1×10^{7}	Buried at Federal Repository
Effluents-- thermal (billions of British thermal units)	4,063	<5 percent of model 1,000 MWe LWR.
Transportation (person-rem):		
Exposure of workers and general public	2.5	

Table 5.7-3 10 CFR 51.51, Table S-3- of Uranium Fuel Cycle Environmental Data[a]

[Normalized to model LWR annual fuel requirement [WASH-1248] or reference reactor year [NUREG-0116]]
[See Footnotes at end of this table]

Environmental Considerations	Total	Maximum effect per annual fuel requirement or reference reactor year of model 1,000 MWe LWR
Occupational exposure	22.6	From reprocessing and waste management.

[49FR9381, Mar. 12, 1984; 49FR10922, Mar. 23, 1984]

a. In some cases where no entry appears it is clear from the background documents that the matter was addressed and that, in effect, the Table, should be read as if a specific zero entry had been made. However there are other areas that are not addressed at all in the Table. Table S-3 does not include health effects from the effluents described in the Table, or estimates of releases of Radon-222 from the uranium fuel cycle or estimates of Technetium-99 released from waste management or reprocessing activities. These issues may be the subject of litigation in the individual licensing proceedings.

   Data supporting this table are given in the Environmental Survey of the Uranium Fuel Cycle," WASH-1248, April 1974; the "Environmental Survey of Reprocessing and Waste Management Portion of the LWR Fuel Cycle," NUREG-0116 (Supp. 1 to WASH-1248); the "Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle," NUREG-0216 (Supp. 2 to WASH-1248): and in the record of final rulemaking pertaining to Uranium Fuel Cycle Impacts from Spent Fuel Reprocessing and Radioactive Waste Management, Docket RM-50-3. The contributions from reprocessing, waste management and transportation of wastes are maximized for either of the two fuel cycles (uranium only and fuel recycle). The contribution from transportation excludes transportation of cold fuel to a reactor and of irradiated fuel and radioactive wastes from a reactor which are considered in Table S-4 of §51.20(g). The contributions from the other steps of the fuel cycle are given in columns A-E of Table S-3A of WASH-1248.

b. The contributions to temporarily committed land from reprocessing are not prorated over 30 years, since the complete temporary impact accrues regardless of whether the plant services one reactor for one year or 57 reactors for 30 years.

c. Estimated effluents based upon combustion of equivalent coal for power generation.

d. 1.2 percent from natural gas use and process.

5.8 Socioeconomic Impacts

Section 5.8 describes the socioeconomic impacts of operating the new units. For this ER, socioeconomic impacts include potential impacts on individual communities, the surrounding region, and minority and low-income populations. This section has been segregated into three subsections:

- Physical impacts
- Social and economic impacts
- Environmental justice impacts

5.8.1 Physical Impacts of Station Operation

This section describes the assessment of the potential physical impacts on the nearby communities due to operation of the new units. Potential impacts include noise, odors, exhausts, thermal emissions, and visual intrusions. These physical impacts would be managed to comply with applicable federal, state and local environmental regulations and would not significantly affect the ESP site and its vicinity.

5.8.1.1 Plant Site and Vicinity

There are no residential areas located within the NAPS site boundary. Lake Anna, which was created to meet the cooling supply needs of the station, has public access and is the nearest recreational facility to the ESP site.

The region surrounding the lake is covered with forest and brushwood interspersed with occasional farmland. The population immediately surrounding the lake is about 980 and about 2940 between 2.5 and 5 miles from the ESP site (see Section 2.5.1). The town of Mineral, located about 7 miles southwest of the ESP site, is a small rural community that includes small businesses, houses, and farm buildings. Mineral has a population of 424, according to the Year 2000 census. Because of Mineral's distance from the ESP site, its residents would not experience any physical impacts from operation of the new units.

5.8.1.2 Noise

The new units would produce noise from the operation of pumps, wet and dry cooling tower fans, water cascading down the wet cooling towers, transformers, turbines, generators, and switchyard equipment. The noise levels would be controlled in accordance with applicable local county regulations. As described in Section 5.3.4, Virginia has no state regulations or guidelines regarding noise limits. The nearby counties (Louisa and Spotsylvania) maintain county ordinances to prohibit unnecessary, unreasonable, or disturbing noise (Reference 1) (Reference 2).

Most equipment would be located inside structures reducing the outdoor noise level. Noise would be further attenuated by distance to the NAPS site boundary. Wet and dry cooling towers would be located outdoors and would generate more significant noise levels.

Closed-cycle, combination dry and wet cooling towers would be used for heat dissipation for Unit 3. Wet cooling towers would remove the heat by spraying the water into a forced or induced air stream. Motor-driven fans would be used to drive air flow. The noise level from the wet cooling towers would be most dominant and would be greater than the near-field noise from fans for the dry towers for Unit 3 and Unit 4. The sound level at the nearest point on the EAB, at approximately 700 feet to the west of proposed cooling tower location, would be less than 65 dBA.

The sound levels were evaluated using vendor-supplied data for typical wet and dry cooling towers. This data, along with an assumed physical configuration of the cooling towers, were modeled using the commercially available “CADNA/A” noise propagation software package. The noise propagation algorithm used in the CADNA/A software is based on ISO 9613, part 2, “Acoustics – Attenuation of sound during propagation outdoors”. Neutral atmospheric conditions were assumed, and with no credit taken for sound attenuation due to structures (other than the cooling towers themselves), vegetation, or changes in terrain. In general, a flat plane was assumed, with a moderate ground absorption coefficient of 0.5. Aside from the cooling tower fans, motors, and water noise, no other sources (e.g., plant pumps, motors, transformers) were modeled and no background noise was included in the evaluation. This is appropriate since, at the closest point on the EAB, the sound levels will be dominated by noise from the cooling towers. For the modeling of the dry cooling towers, the total free field sound power level of each fan was modeled, assuming that half of the power radiates downward from the bottom of the fan deck and most of the remainder radiating from the top of the units. Both the top and bottom of the towers were represented as horizontal area sources encompassing the combined noise from all the individual fans. For the wet cooling towers, the fan discharge power level for each fan was modeled as a point source located just above the top of the fan stack. The wet towers were modeled as three banks of cells, distributed within the area allocated for the cooling towers; two banks with 19 cells and one bank with 14 cells. The water noise from each side of each bank of cells is shown in the table below. The model considered the directional dependence of the source (with one side from each bank of cells facing the general direction of the EAB and the other side facing away from the EAB.) The following noise source sound power levels were used in the assessment:

	Sound Power Level relative to 1 Pico-Watt, dBA	Quantity	Total Sound Power Level relative to 1 Pico-Watt, dBA
Dry Tower Unit 3 Fan Intake	98.5	100	118.5
Dry Tower Unit 3 Fan Discharge	96.8	100	116.8
Dry Tower Unit 4 Fan Intake	83.2	100	103.2
Dry Tower Unit 4 Fan Discharge	81.4	100	101.4
Wet Tower Intake per side (for two 19-cell rows)	119.4	4 (2 sides facing the near-side EAB and 2 sides facing away from the near-side EAB)	—
Wet Tower Intake per side (for one 14-cell row)	118.1	2 (1 side facing toward the near-side EAB and 1 side facing away from the near-side EAB)	—
Wet Tower Discharge	102.6	52	119.8
Service Water Tower Intake per side	113.1	2 (1 side facing toward the near-side EAB and 1 side facing away from the near-side EAB)	—
Service Water Tower Fan Discharge	100.8	4	106.8

The result from this evaluation is lower than the NRC-defined significant level (65 dBA) at the EAB (See Section 5.3.4). The nearest residence is about 3000 feet to the north of the planned cooling tower location (see Figure 5.8-1). Noise levels below 65 dBA are considered to be of small significance (Reference 3). Therefore, the noise impact at the nearest residence would be small and no mitigation would be warranted.

Dry towers would be used for heat dissipation for the new Unit 3 and Unit 4. In order to dissipate enough heat and to minimize the generation of local air turbulence, fans used for dry towers are large and slow. As noted above, noise from the Unit 3 wet cooling towers would be most dominant. However, during operation of dry towers only, the fan noise will be the main noise source at the EAB. At the time of the COL (when design details are known), a confirmatory evaluation will be performed to show that the current analysis of cooling tower noise (conducted as part of this ESP application) remains bounding.

Ambient noise heard by recreational users of Lake Anna under normal conditions includes noise from the existing units. The noise level generated by the operation of the new units would not affect the recreational use of the lake (see Section 5.3.4).

Commuter traffic would be controlled by speed limits. The access roads to the ESP site would be paved. Good road conditions and appropriate speed limits would minimize the noise level generated by the work force commuting to the ESP site.

Section 2.7 of RG 4.2 requires an assessment of the ambient noise level within 5 miles of the ESP site. Particular attention is directed toward obtaining acoustic levels associated with high voltage transmission lines (Reference 4). As presented in Section 3.7.1, the evaluation of the need for noise impact from the transmission system would be completed at a suitable time within Dominion's future planning work and after a decision has been made to proceed with the new capacity. This evaluation would include assessment of noise impacts.

5.8.1.3 Air

The new units would have standby diesel generators and auxiliary power systems. Air permits acquired for these generators would ensure that air emissions comply with regulations. In addition, standby diesel generators would be operated on a limited short-term basis. The impact of the operation of the new units on air quality would be small, and would not warrant any mitigation.

Good access roads and appropriate speed limits would minimize the amount of dust generated by the commuting work force.

During normal plant operation, the new units would not use a large amount of chemicals that would generate odors exceeding the odor threshold value.

5.8.1.4 Thermal Emissions

Heat dissipation to the atmosphere from operation of the Unit 3 dry and wet cooling towers and Unit 4 dry towers is described in Section 5.3.3.1. Because any increase in overall atmosphere temperature would be very localized to the NAPS site, and there is no residential area within the NAPS site boundary, there would be no heat impacts on nearby communities.

5.8.1.5 Visual Intrusions

The nearest residential area is about 3000 feet north of the ESP site and is shielded by forested land. Further, the ESP and cooling tower site grade will be lower than the surrounding terrain, except in the direction of Lake Anna. Given this distance and relative elevations, residents near the site would not have a clear view of the new units. However, recreational users on the Lake Anna Reservoir and some residents along the lake would be able to see the new units in addition to the other developed areas of the NAPS site already in their view.

The existing units' Turbine Building is about 100 feet above grade and the existing units' containment buildings are about 130 feet above grade. Because the new units' containment building could be approximately 230 feet above grade, the Unit 3 wet and dry towers would be less than 180 feet tall and Unit 4 dry towers would be less than 150 feet tall, small visual impacts from the plant structures would result. Use of these maximum cooling tower structural heights in the

evaluation of the visual impacts conservatively maximizes the prediction of that environmental impact.

The use of wet cooling towers for Unit 3 may result in the generation of a vapor plume that would be visible above the height of the plant buildings and that could extend beyond the site boundary. The plume would be most prevalent during times when the ambient temperature is low and when the dry bulb and wet bulb temperatures are nearly equal. Typically this would be between late autumn and early spring. The evaluation shows that on an annual average basis, the plume would extend more than 650 feet above the tower, or extend more than 0.25 mile in length approximately 10 percent of the time the wet towers are operating. A description of the plume evaluation, including seasonal average frequency of visible plume, plume height, and plume length, is provided in Section 5.3.3.2.1. As is discussed in Section 5.3.3.2.1, for the plume analysis, in order to conservatively maximize the prediction of the environmental impact due to visible plume, fogging, icing, and salt deposition, a lower profile (74 feet) non-plume-abated wet cooling tower was modeled. Seventy-four feet is the maximum expected non-plume-abated wet tower height.

The reactor design and ancillary facilities have not yet been selected. Depending on the design selected, a visual impact study would be performed and described in the COL application.

5.8.1.6 Other Related Impacts

Water withdrawal and the associated discharge of heated water from the new Unit 3 would be conducted in accordance with federal, state and local regulations that govern water quality. As described in Section 3.4.1, new Unit 3 would use closed-cycle, combination dry and wet cooling towers with the North Anna Reservoir as the make-up water supply and the wet cooling tower blowdown would be discharged to the WHTF. The new Unit 4 would use a dry tower system for heat dissipation.

Roads within the vicinity of the ESP site would experience a temporary increase in traffic at the beginning and the end of the workday period. However, the current road network has sufficient capacity to accommodate the increase, as detailed in Section 5.1.1.1. Therefore, no significant congestion would result from operation of the new units.

5.8.2 Social and Economic Impacts of Station Operation

The social and economic impacts from the operation of new units at the ESP site would be associated with activities related to the daily operation of the new units, and with the social and economic demands on the surrounding region.

Approximately 720 workers would be required for the operation of the new units, about the same as currently required for the existing units. These 720 workers would relocate into the area with their families and, therefore, would represent both a source of income to the community and a potential demand on community services, such as schools and police protection. These 720 employees

would translate into an increase in population of about 2900 to the region, assuming each new employee represents a family of four and relocates into the region.

The expected number of permanent workers needed to operate the new units, and their families, would be a small fraction of the total projected population growth in the region. Assuming that the geographic distribution of new employees would be the same as for the existing units, about 200 would settle in Louisa County, 157 in Spotsylvania County, and 102 in Orange County. The remaining 261 would settle in Henrico and Hanover Counties and the City of Richmond.

5.8.2.1 Economic Impacts

The main economic impacts of the new workers and their families on the area would be related to taxes, housing, and purchase of goods and services. Economic impacts related to the operation of the new units would be associated mainly with payment of the plant property taxes.

5.8.2.1.1 Potential Non-Income Taxes related to Operation of New Unit(s)

In Virginia, counties and towns collect most of their tax revenue through property taxes and sales taxes.

The assessed value of the new units would exceed that of the existing units, which have depreciated with time. It is not possible to estimate the actual taxes that would be paid to the regional governments or of the expenditures that the regional governments would incur to accommodate the workforce, at this time. The expenditures by the regional governments would, in part, be related to the size and age distribution of the families of the new employees. Based on the assumption that the new employees would come from outside the region, the regional governments would experience both outflows and inflows of monies as a result of the operation of the new units. Expenditures would be related to the impacts on the local and regional infrastructure due to the increased usage of the school, recreational, medical, fire and police, and transportation systems. The types of non-income taxes and their bases can be addressed and are presented below.

a. **Sales and Use Taxes**

   The Commonwealth of Virginia and Louisa County would experience an increase in the amount of sales and use taxes associated with the operation of the new units, as will other, more developed counties, such as Spotsylvania.

   Additional sales and use tax revenues would also be generated by retail expenditures (restaurants, hotels, and merchant sales) by the new employees and by their families. It is estimated that about half of the day-to-day expenditures during operation would occur in the region.

   The current combined sales and use tax rate in counties adjoining the ESP site is 4.5 percent. Of the 4.5 percent tax rate, 3.5 percent would be paid to the Commonwealth, and 1 percent to the locality.

b. **Property Taxes**

The surrounding counties about the ESP site and the City of Richmond would benefit from additional property tax revenues from two sources associated with the new units: the new units and the new employees through their purchase of housing.

Property taxes would be levied for the increase in value of the NAPS site due to the new units. The property tax payments to Louisa County are presented in Section 2.5.2 and identified as a large beneficial impact for Louisa County. The addition of the new units to the NAPS site would substantially increase the property tax payments.

The existing units have contributed more than 50 percent of the property taxes paid to Louisa County over the past decade, which has allowed the property tax assessment rates within the county to remain substantially below those of neighboring counties. The construction and operation of the new units would serve to maintain the very high percent of the property taxes paid by the various DRI subsidiaries. Overall, the property taxes paid to Louisa County by Virginia Power amounted to about 22.5 percent of the total budget for the County during the 1995–2000 time period. Operation of the NAPS site will continue to be a major benefit to Louisa County when the new units start operating.

The GEIS (Reference 5) points out that the potential effects of electric utility deregulation within Virginia are not known. However, it is reasonable to conclude that the operation of new units should result in a substantial increase in property tax payments.

5.8.2.1.2 Housing

A review of Table 2.5-22 shows that the number of housing units for sale in the region could easily accommodate the expected permanent workforce of 720 new employees. Furthermore, as presented in Section 4.4.2.1.2, the counties in the vicinity of the NAPS site and within the region are addressing the needs of the projected increases in population in their Comprehensive Plans. Because the new workforce income would be good relative to other incomes in the region, it can be expected that the housing purchases would be on the high end of the price range. However, as is presented in more detail in Section 5.8.2.2, the new workers and their families are a small percentage of the populations that the VEC has projected for the Counties and the City of Richmond over the next thirty years. Therefore, the impact of the property taxes paid for housing by these families would be a positive, but not necessarily a very large, benefit to the Counties and the City of Richmond.

Currently, the planned outages of each existing unit (approximately every 18 months per unit) are staggered so that only about 700 to 1000 additional workers per unit would be onsite for a period of 30 to 40 days per outage. It is expected planned outages for each new unit could involve the same numbers of additional workers and would be scheduled so that multiple units would not be worked on simultaneously. This would also reduce the potential for demand exceeding the availability of short-term housing in the immediate vicinity of the NAPS site.

As presented in Section 4.4.2, within the region — particularly in the City of Richmond and Henrico County — there are sufficient numbers of housing units available for rent, if needed, to accommodate the total workforce required in the event there are simultaneous outages of two or more units.

5.8.2.2 Social Impacts

The communities with the greatest potential for social impact associated with the installation and operation of new units at the NAPS site are in Henrico, Hanover, Louisa, Orange, and Spotsylvania Counties, and in the City of Richmond. The permanent new employees, would relocate with their families to the region. Depending on the number of families that move into a given area and the number of children and their ages, it is possible that social impacts would be recognized locally.

The VEC has developed for the counties and some cities in Virginia preliminary local population projections for years 2000 to 2030. These projections are presented in Table 5.8-1 for the counties within a 50-mile radius around the ESP site and for the City of Richmond (Reference 6). The population of the City of Richmond is projected to remain flat from year 2000 to 2020 and then to increase by about 13,000 between 2020 and 2030, while Henrico County will grow about 15 percent over the 30-year period for a total increase in population of 41,900. Hanover and Spotsylvania Counties are projected to have the greatest sustained growth over this period with Spotsylvania doubling in population and Hanover increasing by 53,014, about a 60 percent increase in population. Louisa and Orange Counties are projected to grow by 10,587 (41 percent increase) and 12,723 (49 percent increase), respectively, over the thirty years, with fairly steady growth projected to occur over the entire time period.

Table 5.8-1 VEC Preliminary Local Population Projections, 2000–2030

County	2000	2010	2020	2030	Total Increase
Louisa County	25,627	29,123	32,565	36,214	10,587
Hanover County	86,320	105,934	122,751	139,334	53,014
Spotsylvania County	90,395	124,933	153,032	181,394	90,999
Orange County	25,881	30,414	34,384	38,604	12,723
Henrico County	262,300	271,632	281,059	304,200	41,900
Richmond City	197,790	198,390	199,329	212,337	14,547

If, as assumed, the distribution of the permanent work force would be about the same as the current distribution, then the increase in operating personnel would have a small impact on the infrastructure or social services in the vicinity or in the general region of the ESP site.

The estimated peak workforce of 5000 over a 5-year construction period would have a moderate effect on the transportation network in the vicinity and region. However, permanent mitigation measures to reduce or eliminate this effect would be implemented, as necessary, during, or prior to, construction. These permanent measures would also effectively reduce or eliminate any such impacts during operation because the total operating workforce for the existing and new units is not expected to exceed 1500 workers.

Implementation of the permanent transportation mitigation measures proposed for the construction of the new units would also result in small transportation-related impacts during operation of the new units.

5.8.2.2.1 Schools and Recreational Areas

a. **Schools**

As presented in Section 2.5.2, only Louisa and Orange Counties currently have potential limits to the number of students that could be assimilated by their systems into each grade level if a sudden large influx of families were to relocate into these areas. However, it is reasonable to conclude that the future updates to the County Comprehensive Plans for these counties would include funding for new schools, given the projected increases in their populations. Therefore, an increase of 200 families in Louisa County and about 157 families in Orange County should have a small impact on the school system.

b. **Recreational Areas**

Recreational areas are described in Section 2.5.2. By the year 2020, Louisa County population is projected to increase by about 7,000. Of these, only about 800 would be due to the new employees and their families (i.e., 200 workers and their families) relocating into the county. The numbers of new workers relocating with their families into the counties other than Louisa County or into the City of Richmond would be less than those relocating into Louisa County.

The population increase in the potentially impacted counties other than Louisa County is expected to be equal to or greater than that the increase in Louisa County. To accommodate these increases in population, the surrounding counties would need to address and fund new recreational areas as they update their Comprehensive Plans.

The GEIS concludes that impacts of the existing employees and their families on the parks and other recreational areas within the region are small. This would also apply to the employees of the new units and their families who would relocate to the area because they represent a small fraction of the projected population growth for the area.

5.8.2.2.2 Public Services

Public services addressed include water supply, sewer systems, transportation network, and police, fire and medical facilities. The baseline for these services is provided in Section 2.5.2.

a. **Water and Sewer Systems**

As presented in Section 2.5.2, water supply would not be a problem for Henrico County, the City of Richmond, Spotsylvania County, or Hanover County, because they currently have sufficient water sources and are expanding their water systems. Except for the towns in Louisa and Orange Counties, groundwater is the source of water for the residents and there is no concern about the availability of such groundwater for future growth in the two counties, as identified in the SEIS.

Sewer systems in the more urbanized counties and the City of Richmond are expected to accommodate their projected population growths. The residents in the more rural counties normally have individual septic systems, which are expected to be able to accommodate the projected population growth. Only a few towns in these rural counties have connections to a sewer system with a publicly-owned treatment works, and these towns are not currently planning major expansions of their sewer systems.

For Louisa County and Orange County, the projected growth in population between 2000 and 2010 is 3,496 and 4,533, respectively; values that greatly exceed the projected number of new employees and their families. These projections for population growth and their possible impacts on the local infrastructure, including water and sewer services, have been incorporated into the comprehensive land use plans for both counties. Although there are plans to construct new treatment plants or to expand existing facilities in the towns of Louisa County and Orange County, these are not expected to accommodate many new houses. The limited number of sewer and water hookups that will be available would serve to restrict the number of new homes that will be built in the existing towns.

Louisa County is planning for construction of about 300 houses per year for the foreseeable future. New employees who wish to relocate their families to Louisa County should have sufficient new housing in the County. However, because most of this housing would be outside the towns, the relocated families' impacts on these water and sewer systems would be small.

b. **Transportation Network**

Section 4.4.2 discusses a number of permanent changes to the regional and local transportation network that would reduce any potential adverse impacts generated by the influx of 5,000 construction workers during construction of the new units. These permanent changes would also reduce or eliminate any potential adverse impacts that could be generated by the operating workforce of about 720 for the new units who have relocated with their families into the region.

c. **Police, Fire, and Medical Facilities** Section 2.5.2

Section 2.5.2 addresses police, fire, and medical facilities.

The police and fire departments within ten miles of the NAPS site are part of the existing emergency response plan for the existing units. The police departments are responsible for the proper evacuation of the area in the event of an emergency at the NAPS site. This would continue to be the case when the new units become operational.

Medical facilities generally consist of local physicians' offices in the surrounding counties. However, there are major medical facilities in Fredericksburg, Charlottesville, Mechanicsville, and the City of Richmond that are readily accessible to the counties' residents.

A review of the Comprehensive Plans for the counties reveals that the need for additional medical, fire, and police facilities is being assessed. Where the planners assess that the demands of the growth in population would create a need, the intent of the various county plans is to add new facilities or expand existing facilities. The increase of 720 new employees and their families would represent a small fraction of the expected population growth in the vicinity and region around the NAPS site. Therefore, no unforeseen demands would result from the operation of the new units.

5.8.2.3 Impacts on Lake Anna Recreational Area

Lake Anna is a recreational area that attracts year-round residents (including both commuters and retirees) as well as visitors during the summer and early fall months. Any impacts that would reduce the number of visitors in the area due to the operation of the new units could have a socioeconomic impact on the local area.

Section 5.8.1 assesses the relative physical impacts on the environment created by the operation of the new units and concludes that these impacts would be small. Since the types of reactor and ancillary facilities have not yet been selected, there is the potential for an aesthetic impact on the users of Lake Anna. The potential heights of the containment (reactor) building and of cooling towers are larger than the sizes of the existing structures, which have the potential to result in a visual impact. The cooling system design would take into consideration the need to minimize the visual impact of any cooling towers to the extent reasonable and practicable. Based on the design selected, a visual impact study would be performed and described in the COL application. The study would assess the physical layout on the site of the reactor and ancillary facilities with respect to the existing facilities that would reduce the potential aesthetic impact of the new units on the users of the lake to the extent reasonable and practicable.

Although not expected to be a major issue, a noise study may be appropriate prior to final design of the cooling system. If a noise study determines that the incremental increase in noise created by the operation of the new units is intrusive to continued recreational enjoyment of the lake, then commonly applied mitigation measures would be considered to determine if they are effective in reducing the noise and if they are reasonable and practicable at the ESP site.

In addition to potential aesthetic and noise impacts on the ESP site, Dominion evaluated shoreline areas in an effort to assess, in general, various impacts of raising normal operating lake level 6 inches to 12 inches above 250 ft msl, if a Virginia permitting agency process determined the need for such an action. Raising normal operating lake level is not being proposed to demonstrate site suitability. VDEQ could require an increase in lake level to mitigate impacts on down-river flows. Increasing the lake level by approximately 7 inches would eliminate changes in the frequency and duration of the 20 cfs minimum instream flow.

Dominion's evaluations included:

- a review of the US FWS National Wetlands Inventory, and various Lake Anna topographical maps;
- a physical survey by boat of the best estimate of areas that could be impacted; and
- an aerial survey of uplake, low gradient tributaries.

Because of the generally steep shoreline topography, the conclusion is that a rise in water level of 6 inches to 12 inches would result in minimal changes to the types and amounts of wetlands other than to shift the prevailing vegetation in gradually sloping tributaries in an upland direction.

In many of the headwater lake tributaries, with gradually sloping shoreline, a successional shift, or movement in wetland vegetation in an upland direction with forest shrub/scrub transitioning to emergents, and emergents to submersed, would be expected. Typical vegetation included rushes and sedges with river birch grading to yellow poplar with increases in elevation. These shifts would likely develop over several years and depend on conditions such as soil type, water clarity and extent of canopy cover.

Rushes were observed intermittently in these areas. Due to the altered shoreline in some areas along Contrary Creek, the lateral extent of flooding and resulting changes to the types and amounts of wetlands appear to be less than in the neighboring headwater, Freshwater Creek.

Along the main lake channel toward the dam, both upstream and downstream, some shoreline topography had relatively steep banks. Some of these banks were nearly vertical gradients due to the effect of wind and wave action undercutting the banks. Several points and coves on either shoreline toward the dam confirmed that a lake level rise would likely result in little lateral or upland change within these areas. Much of the main lake shoreline is more exposed to wind and wave action and would unlikely contain rooted vegetation.

Uplake, near the southern shore about one mile above the Route 208 bridge, there is an elevated area of cleared and gently sloping land which would not be flooded by the postulated water level increase. There appeared to be dormant water willow in a protected area adjacent to this land.

A helicopter survey of the upper lake followed a boat survey, specifically to view the low gradient tributaries in both the North Anna and Pamunkey arms. The survey confirmed that changes associated with an increased water level would be most evident in these areas and result in the

likely shift of wetland vegetation in an upland direction. Beaver activity was observed throughout these upper tributaries, with their dams already acting to flood and alter the wetland landscape. A direct result of the aerial survey was an identification of about 15 areas, ranging in size of approximately one-half acre to 25 acres, which could be impacted as described.

As a result of the evaluations described above, including ground-truthing points around the lake, the conclusion is that a 6 inches to 12 inches water level increase above the normal 250 ft msl, depending on seasonal variation in precipitation and lake management, over time, would most likely result in little to no net loss of wetland areas impacted, with many areas remaining largely unchanged. Other areas, most notably the gradually sloping headwater tributaries, would exhibit an upland shift in the vegetation community concurrent with any sustained increase in normal water level.

In addition to wetland impacts, raising the lake level could increase localized flooding potential and downstream flows, and would likely affect usage of some residential and marina boat ramps and docks, including Lake Anna State Park. These might need some modification to avoid impacting the year-round and seasonal recreational usage of the lake.

5.8.3 Environmental Justice Impacts

This section addresses the potential for disproportionately high and adverse human health or environmental impacts during the operation of the new units on minority or low-income populations who reside within a 50-mile radius of the new units at the ESP site.

5.8.3.1 New Unit(s) at the North Anna Power Station Site

The geographic distribution of minority and low-income populations within 80 km (50 miles) of the NAPS site are those that were determined for Section 2.5.4, that is, for purposes of this section, the distribution of such populations within the region is assumed to remain the same as, or about the same as, that identified in the 2000 Census. The analysis for Section 2.5.4 is based on data from the 2000 Census and applies the following definitions:

A minority population or low-income population exists if either of the following criteria are met:

1. A “minority population” is considered to be present if: 1) the minority population in the census block group or environmental impact site exceeds 50 percent, or 2) the minority population percentage of the environmental impact area is significantly greater (typically at least 20 percentage points) than the minority population percentage in the geographic area chosen for the comparative analysis, for example, the county or State, or

2. A “low-income population” is considered to be present if: 1) the low-income population in the census block group or the environmental impact area exceeds 50 percent, or 2) the percentage of households below the poverty level in an environmental impact area is significantly greater (typically at least 20 percentage points) than the low-income population percentage in the geographic area chosen for the comparative analysis.

As presented in Section 2.5.4, the census tracts with at least 50 percent of their area within the 80-km (50-mile) distance from the NAPS site were included in the analysis. The distribution of minority and low-income populations is presented in the text and is graphically presented in Figure 2.5-14 and Figure 2.5-15.

The assessment of the potential for environmental justice impacts associated with the operation of the new units at the ESP site was based on the following information:

- The results of the analyses of the physical impacts of operation presented in Section 5.8.1 and the social and economic impact analyses presented in Section 5.8.2.
- The DBA analyses presented in Section 7.1.
- There are relatively few minority and low-income populations in the environmental impact area and none in proximity to the ESP site. The nearest minority or low-income populations are 20 km (about 12 miles) from the ESP site.

Section 5.8.1 identifies no large or moderate physical impacts from the operation of the new units at the ESP site. Therefore, there could be no large or moderate physical impacts on the minority or low-income populations.

Socioeconomic impacts identified in Section 5.8.2 would be beneficial throughout the region. The potential does exist for adverse visual and/or noise impacts related to the size of the new units and associated ancillary equipment. However, these potential adverse social impacts would be small and restricted to the immediate area of the site. Socioeconomic impacts would, therefore, not be an issue at the distance of the nearest minority or low-income populations.

The calculated environmental doses due to radiological impacts from DBAs are analyzed in Section 7.1. The analyses demonstrated that the evaluated dose consequences of such accidents would be within the regulatory limits. These doses are calculated at the EAB and the LPZ using NRC-approved methodology. The EAB is 5000 feet and the LPZ is six miles from the existing units, much closer to the ESP site than the nearest minority or low-income populations.

Given the distances to the nearest minority or low-income populations, the calculated low environmental doses from the DBA analyses at the EAB and LPZ, and the small potential socioeconomic impacts, no disproportionately high or adverse human health or environmental impacts on minority or low-income populations would arise from operation of the new units, alone or in combination with the existing units at the NAPS site.

Section 5.8 References

1. Louisa County Ordinance, Section 51-3, Louisa County, Virginia.

2. Spotsylvania County Ordinance, Section 14-14, Spotsylvania County, Virginia.

3. NUREG-1555, Standard Review Plan for Environmental Reviews for Nuclear Power Plants, U.S. Nuclear Regulatory Commission, October 1999.

4. Regulatory Guide 4.2, Preparation of Environmental Reports for Nuclear Power Stations, U.S. Nuclear Regulatory Commission, Revision 2, July 1976.

5. Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 7, Regarding North Anna Power Station, Units 1 and 2, NUREG-1437, U.S. Nuclear Regulatory Commission (SEIS), November 2002.

6. Virginia Employment Commission (VEC) Website, www.vec.state.va.us, accessed on March 28, 2003.

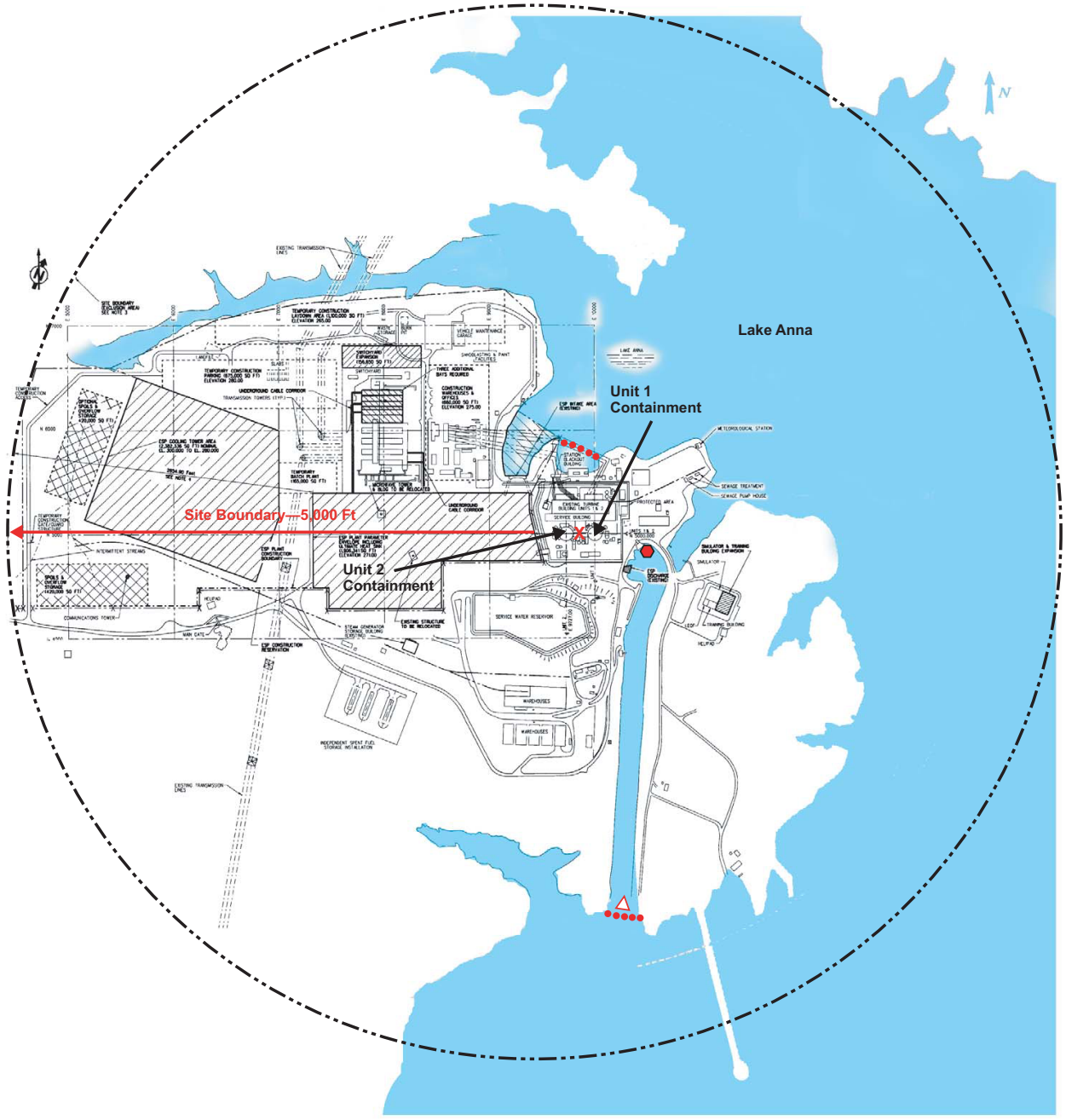

Figure 5.8-1 Site Boundary and Cooling Tower Envelope Area

5.9 Decommissioning

According to Section 5.9 of NUREG-1555 (Reference 1), studies of social and environmental effects of decommissioning large commercial power generating units have not identified any significant impacts beyond those considered in the Final Generic Environmental Impact Statement (GEIS) on decommissioning (Reference 2). The GEIS evaluates the environmental impact of the following three decommissioning methods:

- DECON – The equipment, structures, and portions of the facility and site that contain radioactive contaminants are removed or decontaminated to a level that permits termination of the license shortly after cessation of operations.
- SAFSTOR – The facility is placed in a safe stable condition and maintained in that state until it is subsequently decontaminated and dismantled to levels that permit license termination. During SAFSTOR, a facility is left intact, but the fuel has been removed from the reactor vessel and radioactive liquids have been drained from systems and components and then processed. Radioactive decay occurs during the SAFSTOR period, thus reducing the quantity of contaminated and radioactive material that must be disposed of during the decontamination and dismantlement.
- ENTOMB – This alternative involves encasing radioactive structures, systems, and components in a structurally long-lived substance, such as concrete. The entombed structure is appropriately maintained, and continued surveillance is carried out until the radioactivity decays to a level that permits termination of the license.

NRC regulations do not require an ESP applicant to select one of these decommissioning alternatives or to prepare definite plans for decommissioning. These plans are required by 10 CFR 50.82 after a decision has been made to cease operations. General decommissioning environmental impacts are summarized in this section, since detailed plans or a selection of alternatives is not required for an ESP.

Decommissioning of a nuclear facility that has reached the end of its useful life has a positive environmental impact (Reference 2). The major environmental impact, regardless of the specific decommissioning option selected, is the commitment of small amounts of land for waste burial in exchange for the potential re-use of the land where the facility is located (Reference 2).

Dominion would control radiological doses during decommissioning with appropriate work procedures, shielding, and other occupational dose control measures similar to those used during plant operation. Experience with decommissioned power plants has shown that the occupational exposures during the decommissioning period are comparable to those associated with refueling and plant maintenance when it is operational (Reference 2). Each potential decommissioning alternative would have radiological impacts from the transport of materials to their disposal sites. The expected impact from this transportation activity would not be significantly different from normal operations(Reference 1, Section 5.9).

NRC regulations do not require the establishment of decommissioning financial assurances to support an ESP application (Reference 1, Section 5.9). Therefore, this environmental report does not discuss decommissioning financial assurances.

Section 5.9 References

1. NUREG-1555, *Environmental Standard Review Plan*, U.S. Nuclear Regulatory Commission, March 2000.

2. NUREG-0586, *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities,* U.S. Nuclear Regulatory Commission, October 2001.

5.10 Measures and Controls to Limit Adverse Impacts During Operation

This section summarizes the potential adverse impacts, along with the measures and controls to be used to minimize those impacts as identified in Section 5.1 through Section 5.9.

The following measures and controls would be used in limiting adverse environmental impacts:

- Compliance with the applicable federal, Virginia, and local laws, ordinances, and regulations that prevent or minimize environmental impacts (e.g., solid waste management, erosion and sediment control, air emission control, noise control, storm water management, spill response and cleanup, hazardous material management).
- Compliance with applicable requirements of permits and licenses required for operation (e.g., VPDES Permit, Operating License).
- Compliance with Virginia Power procedures applicable to environmental control and management.

The measures and controls presented above would be implemented in concert with the specific measures and controls shown in Table 5.10-1. These measures and controls are considered feasible from both a technical and economic standpoint. In addition, they are expected to be adequate to avoid or mitigate the identified potential adverse impacts associated with operation of the new units.

The columns in Table 5.10-1 listed under the “Potential Impact Significance” are those elements listed in NUREG-1555, Section 5.10, relating to the various issues addressed in the operational impact assessment sections of the Environmental Report (i.e., Sections 5.1 – 5.9). The significance rating (i.e., [S]mall, [M]oderate, or [L]arge) provided for each element in the table has been determined by viewing the potential impact in terms of its significance following implementation of the associated mitigation measures and controls.

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section Reference		Potential Impact Significance [a, b]														
		Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)	Impact Description or Activity	Feasible and Adequate Measures/Controls
5.1	Land-Use Impacts																
5.1.1	The Site and Vicinity			S	S											• The NAPS site is zoned by Louisa County as “industrial.” This designation would not change due to operation of the new units. • The change in temperature at the discharge point of WHTF due to operation of new units would be negligible and would not impact recreational use. • The impact of heat and moisture dissipation from new wet and dry cooling towers on overall atmospheric temperature is limited to NAPS site boundary. • Increased traffic loads on existing network from workforce during operations	• Comply with VPDES permit requirements imposed on water discharges from operation of the new units. • No new public roads needed for operation of the new units. Potential increases in traffic would be mitigated through effective traffic management.
5.1.2	Transmission Corridors and Offsite Areas															• The existing transmission lines and corridors have sufficient capacity for the total output of the existing and new units.	None
5.1.3	Historic Properties														S	• No impacts identified beyond those associated with construction of the proposed new units.	None

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section Reference		Potential Impact Significance [a, b]														Impact Description or Activity	Feasible and Adequate Measures/Controls
		Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.2	Water-Related Impacts																
5.2.1	Hydrologic Alterations and Plant Water Supply									S						• Reduction in the volume of water available to be released from the North Anna Dam • Reductions in Lake Anna water levels from current values during periods of extended drought	• Practices to minimize the hydrologic alterations may be implemented. • During periods of extended drought, dry cooling towers would be put into service to dissipate a portion of waste heat from Unit 3 to minimize the make-up water requirements.
5.2.2	Water-Use Impacts									S						• Reduction in the volume of water available to be released from the North Anna Dam • Reductions in Lake Anna water levels from current values during periods of extended drought • There would be no appreciable water quality impacts due to blowdown from the Unit 3 wet cooling towers. There would be no blowdown from the Unit 3 and Unit 4 dry cooling towers.	• During periods of extended drought, dry cooling towers would be put into service to dissipate a portion of waste heat from Unit 3 to minimize the make-up water requirements.
5.3.1	Intake System															The make-up water intake system for Unit 3 would consist of a new intake structure and located in a cove on the south shore of Harris Creek to withdraw water from North Anna Reservoir. The area to be occupied by this intake system, originally planned for the intake of the previously abandoned Units 3 and 4, is adjacent to the cove that houses the intake of the existing units.	

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Feasible and Adequate Measures/Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.3.1.1 Hydrodynamic Descriptions and Physical Impacts															• Evaluation concludes that the potential for scouring of the lake bottom, erosion of the shoreline, increased turbidity, and increased siltation from operation of the new units would be small.	• Stabilizing the banks of the channel to the screen house and pump house would be considered.
5.3.1.2 Aquatic Ecosystems															• Increase in impingement of fish from new water intake system. Increases in impingement by important species would represent only a small percentage of the estimated standing crop in Lake Anna. Any increased impingement would be offset by natural compensation due to a stable, healthy, and diverse fish population. • Increase in entrainment of larval fish from new make-up water intake system would be very small. Mortality rates for eggs and larval fish of important species in Lake Anna due to natural causes are extremely high. In spite of this, the fishery in Lake Anna has remained stable, healthy, and productive. Any slight increases in mortality due to entrainment from the additional intake systems would have a negligible impact on the Lake Anna fishery.	• The intake structure for the new Unit 3 at the ESP site would meet Section 316(b) of the Clean Water Act and the implementing regulations, as applicable. • A fish return system based on the latest technology available during detailed engineering would be considered for incorporation into the intake system.

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Feasible and Adequate Measures/Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.3.2 Discharge System															Blowdown from Unit 3 wet cooling towers would be sent via the WHTF to the North Anna Reservoir for heat dissipation. The blowdown discharge volume from Unit 3 is very small when compared with the discharge volume from the existing Units. The increase in water temperature due to operation of new units would be negligible.	
5.3.2.1 Thermal Description and Physical Impacts															• The blowdown discharge volume from Unit 3 is very small when compared with the discharge volume from the existing units. The increase in water temperature due to operation of new units would be negligible. • Assuming new Unit 3 on closed-cycle, combination dry and wet cooling tower system and new Unit 4 on a closed-cycle dry tower system, there are no expected impacts such as scouring of the lakebed or erosion of the shoreline at the current discharge point (i.e., Dike 3) from operation of the existing units in combination with the new units. No mitigation measures or control are proposed beyond overall cooling system design. • Evaluation concludes that the potential for scouring of the lake bottom, erosion of the shoreline, increased turbidity, and increased siltation from operation of the new units would be very small.	None

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Feasible and Adequate Measures/Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.3.2.2 Aquatic Ecosystems															• Negligible impact from scouring and sediment transport due to increased water discharge flows.	• Maintain compliance with VPDES water quality standards and permitted discharge limits for cooling water discharges to the North Anna Reservoir.
															• The addition of new Unit 3 would cause no thermally-induced impact on the fish population in Lake Anna. Sudden changes in discharge temperature are typically minimal with a nuclear power facility since units do not come on and off-line regularly. This limits the potential for heat or cold shock to fish.	None

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Feasible and Adequate Measures/Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.3.3 Heat-Discharge System															N/A	
5.3.3.1 Heat Dissipation to the Atmosphere															• Operation of Unit 3 wet cooling towers may produce visible plume, salt drift and steam fog. Salt deposition rates would be below threshold value beyond the site boundary at ground levels. • Most of the fogging from the wet cooling towers would occur within site boundary in winter and spring. No icing would be anticipated within or beyond the site boundary • There would be no plume associated with the Unit 3 and Unit 4 dry cooling towers, and consequently no potential interaction with other permitted air emission sources at the existing units (e.g., standby diesel generators and auxiliary power systems) at the site.	None
5.3.3.2 Terrestrial Ecosystems	S													S	• Predicted noise from heat dissipation system would be similar to or less than NAPS site current operating levels. • Potential for avian collisions with dry and wet cooling towers would be small.	None

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Feasible and Adequate Measures/Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.3.4 Impacts to Members of the Public	S				S	S	S		S						• Thermal effluent discharge from Unit 3 wet cooling tower systems would not alter the temperature regime in Lake Anna. Assessed temperature increases due to addition of Units 3 and 4 would be insignificant and would not contribute to an environment conducive to the reproduction and growth of thermophilic micro-organisms in the WHTF or alter the recreational uses of Lake Anna. • The recently upgraded on-site sewage treatment plant at the NAPS site includes disinfection to reduce coliform bacteria and other micro-organism to levels that meet Virginia water quality standards. • Small potential for offsite noise impacts from wet and dry cooling tower system operation. Modeled peak noise levels from operation of the composite cooling system would be below threshold levels.	None

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section	Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Feasible and Adequate Measures/Controls
		Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.4	Radiological Impacts of Normal Operation																
5.4.1	Exposure Pathways			S			S	S	S	S	S	S	S	S		• Potential for small discharges of radioactive liquids and gases to the environment. • Direct dose contribution from the new units would be negligible.	• Sources of radiation at the new units would be contained similar to the existing units.
5.4.2	Radiation Doses to Members of the Public													S		See Section 5.4.3 for discussion of impacts to members of the public.	
5.4.3	Impacts to Members of the Public													S		• Potential doses to the public from liquid radwaste effluent releases to the discharge canal and WHTF and gaseous pathway releases. Calculated doses to public through liquid and gaseous pathways are within the design objectives of 10 CFR 50 Appendix I and within regulatory limits of 40 CFR 190.	None
5.4.4	Impacts to Biota Other than Members of the Public													S		• Potential doses to biota from liquid and gaseous effluents. Although there are no acceptance criteria specifically for biota, there is no scientific evidence that chronic dose rates below 100 mrad/day are harmful to plants and animals. The biota doses are all less than 1 mrad/day.	None

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section	Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Feasible and Adequate Measures/Controls
		Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.5	Environmental Impact of Waste																
5.5.1	Nonradioactive-Waste-System Impacts			S		S	S			S		S				• Increased volume of discharged effluent. • Increased chemicals and other pollutants in the discharge effluent. • Increased storm water discharge • Increase in total volume of solid waste generated. • Potential increase in gaseous emissions. • Increase in total volume of sanitary waste generated.	• Water availability issues regarding the North Anna River are addressed via regulated releases from the North Anna Dam. • Comply with applicable VPDES water quality standards for any discharge from Dike 3. • Prepare and implement a new operational Storm Water Pollution Prevention Plan to avoid and/or minimize releases of contaminated storm water. • Use approved transporters and offsite landfills for disposal of solid waste. Continue existing units' program for reuse and recycling of nonradwastes. • Operate any new minor air emission sources in accordance with applicable regulations and permits. • Modify (if necessary) existing sanitary waste treatment systems to accommodate increased volume.

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Feasible and Adequate Measures/Controls
	Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.5.2 Mixed Waste Impacts					S	S	S		S				S	S	• Expected annual generation of between 15–30 cubic feet of mixed liquid waste and 5–10 cubic feet of mixed solid waste. • Potential chemical hazardous and occupational exposure to radiological materials during handling and storage onsite. • Potential exposures to onsite workers and emergency response personnel during accidental releases and cleanup activities.	• Limit need to manage and dispose of mixed waste through: 1) source reduction; 2) recycling options; 3) treatment. • Develop a Waste Minimization Program, to address mixed waste inventory management; equipment maintenance; recycling and reuse; segregation; treatment (decay in storage); work planning; waste tracking; and awareness training. • Implement a program to manage wastes stored onsite in compliance with applicable EPA and NRC regulatory requirements. • Implement spill prevention and response plans and procedures to address hazards associated with managing mixed wastes. Include in plans and procedures measures for response personnel training and protective equipment.

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section	Reference	Potential Impact Significance [a, b]														Impact Description or Activity	Feasible and Adequate Measures/Controls
		Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.6	Transmission System Impacts																
5.6.1	Terrestrial Ecosystems	S		S							S					• Air emissions and nuisance noise from use of helicopter to maintain transmission corridors. Virginia Power's current maintenance activities for the transmission corridors are infrequent and limited to the localized areas of the corridor. No new maintenance practices are expected for the new units.	None
5.6.2	Aquatic Ecosystems											S				• Potential impacts to mussel species from maintenance of transmission corridors. Although some mussel species occur in Louisa County, there are no confirmed accounts of mussels in watercourses crossed by existing transmission lines. There are no mitigation measures since there are no planned changes to transmission corridor maintenance practices for the proposed new units.	None
5.6.3	Impacts to Members of the Public	S													S	• Based on an initial evaluation, the existing transmission lines and corridors have sufficient capacity for the total output of the existing and new units. Mitigation of potential impacts from electric shock, EMF exposure, noise, or visual impacts would be unchanged.	None

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section Reference		Potential Impact Significance [a, b]														
		Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)	Impact Description or Activity	Feasible and Adequate Measures/Controls
5.7	Uranium Fuel Cycle Impacts																
5.7	Uranium Fuel Cycle Impacts (i.e., relative to the reference LWR)			S			S							S		• Yellowcake production and uranium conversion impacts such as energy required, emissions, and water. • Air emissions from fossil fuel plants supplying the gaseous diffusion plant. • Production of UO_2 during fuel fabrication • Radioactive waste management from operations, and decontamination and decommissioning.	• Select mining techniques that minimize potential impacts. • Consider use of new technology that requires less uranium hexafluoride. • Consider use of centrifuge process over gaseous diffusion process, which can significantly reduce energy requirements and environmental impacts. • Consider use of new technologies with less fuel loading to reduce energy, emissions and water usage. Projected impacts of TRISO fuel plant would be less than existing air, water, and solid waste regulations. • Consider use of new gas-cooled reactor technologies that can result in generation of far less low-level wastes.

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section	Reference	Potential Impact Significance [a, b]													Impact Description or Activity	Feasible and Adequate Measures/Controls
		Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)	
5.8	Socioeconomic Impacts															
5.8.1	Physical Impacts of Station Operation	S		S	S				S						S	• Noise associated with dry and wet cooling towers would be below level considered nuisance to public at the nearest residence. • Potential impacts from air emissions associated with diesel generators and auxiliary power systems • Potential visual impacts to surrounding areas due to new buildings, and wet and dry cooling towers. • Local roads would experience increased operations traffic but have sufficient capacity without implementation of additional mitigation measures or controls.	• Comply with applicable VDEQ permit limits and regulations when installing and operating air emission sources. • Perform noise study as part of final design for dry cooling towers. • Perform visual impact study for new structures on site, including dry and wet cooling towers, as part of final design.

Table 5.10-1 Summary of Impacts and Measures and Controls to Limit Adverse Impacts During Operations

Section	Reference	Potential Impact Significance [a, b]													Impact Description or Activity	Feasible and Adequate Measures/Controls
		Noise	Erosion and Sediment	Air Quality	Traffic	Wastes	Surface Water	Groundwater	Land-Use	Water-Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomic	Radiation Exposure	Other (site-specific)		
5.8.2	Social and Economic Impacts of Station Operation												S		S	• Increase need for community services up to 2900 persons. Overall impact to services in the surrounding counties would be small. Predicted workforce is a small fraction of the total projected population growth in the region. • Revenue from sales and use taxes would be beneficial to Louisa County. • Property taxes paid by new workers in the region would be beneficial but small relative to those already obtained from the regional population. • Potential aesthetic impacts (e.g., visual, noise) to residences and recreational users of Lake Anna	• Perform noise study as part of final design for dry and wet cooling towers. • Perform visual impact study for new structures on site, including dry and wet cooling towers, as part of final design.
5.8.3	Environmental Justice Impacts															• No disproportionatly high impacts on minority or low-income populations resulting from operation of the proposed new units.	None
5.9	Decommissioning																
5.9	Decommissioning															• Potential radiation exposure related to decommissioning, including transportation of materials to disposal sites. • Decommissioning methods are expected to produce impacts equivalent to operations.	• The significance of the impacts is unknown because the decommissioning methods have not been chosen. No mitigation measures or controls are proposed at this time.

a. The assigned significance levels [(S)mall, (M)oderate, or (L)arge are based on the assumption that for each impact, the associated proposed mitigation measures and controls (or equivalents) would be implemented.

b. A blank in the elements column denotes “no impact” on that specific element due to the assessed impacts.

Chapter 6 Environmental Measurements and Monitoring Programs

This chapter describes the environmental measurement and monitoring programs for the new units. Some of the programs at the existing units would constitute the primary monitoring efforts that would be relied on if a decision to add additional capacity at the ESP site was made.

The discussion of environmental measurements and monitoring programs is divided into the following sections:

- Thermal Monitoring (Section 6.1)
- Radiological Monitoring (Section 6.2)
- Hydrological Monitoring (Section 6.3)
- Meteorological Monitoring (Section 6.4)
- Ecological Monitoring (Section 6.5)
- Chemical Monitoring (Section 6.6)
- Summary of Monitoring Programs (Section 6.7)

Monitoring details (e.g., sampling equipment, constituents, parameters, frequency, and locations) for each specific phase of the overall program are described in each of these sections.

6.1 Thermal Monitoring

This section describes the thermal monitoring program that would be implemented to monitor the effects of new units at the ESP site.

6.1.1 Existing Thermal Monitoring Program

Thermal monitoring is currently being conducted in Lake Anna in accordance with VPDES permit number VA-0052451, which was established by VDEQ for the existing units (Reference 1). The permit limits the total maximum rejected heat load from the existing units to 1.354×10^{10} Btu per hour and requires reporting of the daily rejected heat, measured as a percentage of the combined rated power level. The permit also prescribes a thermal monitoring program that consists of taking two sets of water temperature measurements in the cooling lake system: a) continuous water temperature monitoring; and b) water temperature profiling (thermal plume survey). The temperature monitoring program is described in more detail below.

Fixed water temperature recorders continuously record water temperatures at 11 locations: 10 in the North Anna Reservoir and WHTF areas, and one in the North Anna River downstream of the dam (Table 6.1-1 and Figure 6.1-1) (Reference 1). Temperature measurements at all stations, except NALST10, are taken near the water surface. At station NALST10, the water temperature measurement is taken at 3 m below the water surface. Temperature readings are reported in

degrees Celsius in accordance with the VPDES permit on the following basis: 1) monthly maximum daily temperature, and 2) monthly mean of daily high, daily mean, and daily low.

During water temperature profiling, water temperatures are recorded during daylight hours from the surface to the bottom at one-meter intervals at Stations A to N (Figure 6.1-2) (Reference 1). The temperature profiling is conducted during at least two quarters per year, such that one measurement quarter is always during the July-to-September quarter, and the remaining quarter is alternated every year.

6.1.2 Pre-Application, Pre-Operational, and Operational Thermal Monitoring

The current thermal monitoring plan has provided sufficient thermal data to establish baseline conditions prior to any construction. This program would be continued for pre-operational monitoring of the new units (while under construction) to establish a baseline for identifying and assessing the environmental impacts resulting from operation of the new units. The same program would continue to be used for operational monitoring of the new and existing units.

Section 6.1 References

1. VPDES Permit No. VA 0052451, *Authorization to Discharge Under the Virginia Pollutant Discharge Elimination System and The Virginia State Water Control Law*, Commonwealth of Virginia, Department of Environmental Quality, January 11, 2001.

Table 6.1-1 Water Temperature Recorder Station Locations

Station	Site Description	Monitoring Depth
NALST10	Lake Anna: Mid-level in Lake in the flow through Lake Anna Dike 3	At 3 m water depth
NALBRPT	Lake Anna: near Burruss Point	Surface
NALTHIS	Lake Anna: near Thurman Island	Surface
NALIN	Lake Anna: at North Station intakes	Surface
NAL208	Lake Anna: Route. 208 Bridge	Surface
NADISC1	At end of station discharge in Lagoon (Pond) 1	Surface
NAWHTF2	Lagoon (Pond) 2	Surface
NAWHTF3	Lagoon (Pond) 3	Surface
NAL719S	North Anna River arm of Lake Anna at Route 719 bridge	Surface
NAL719N	Pamunkey Creek arm of Lake Anna at Route 719 bridge	Surface
NARIV601	Route 601 crossing	Surface

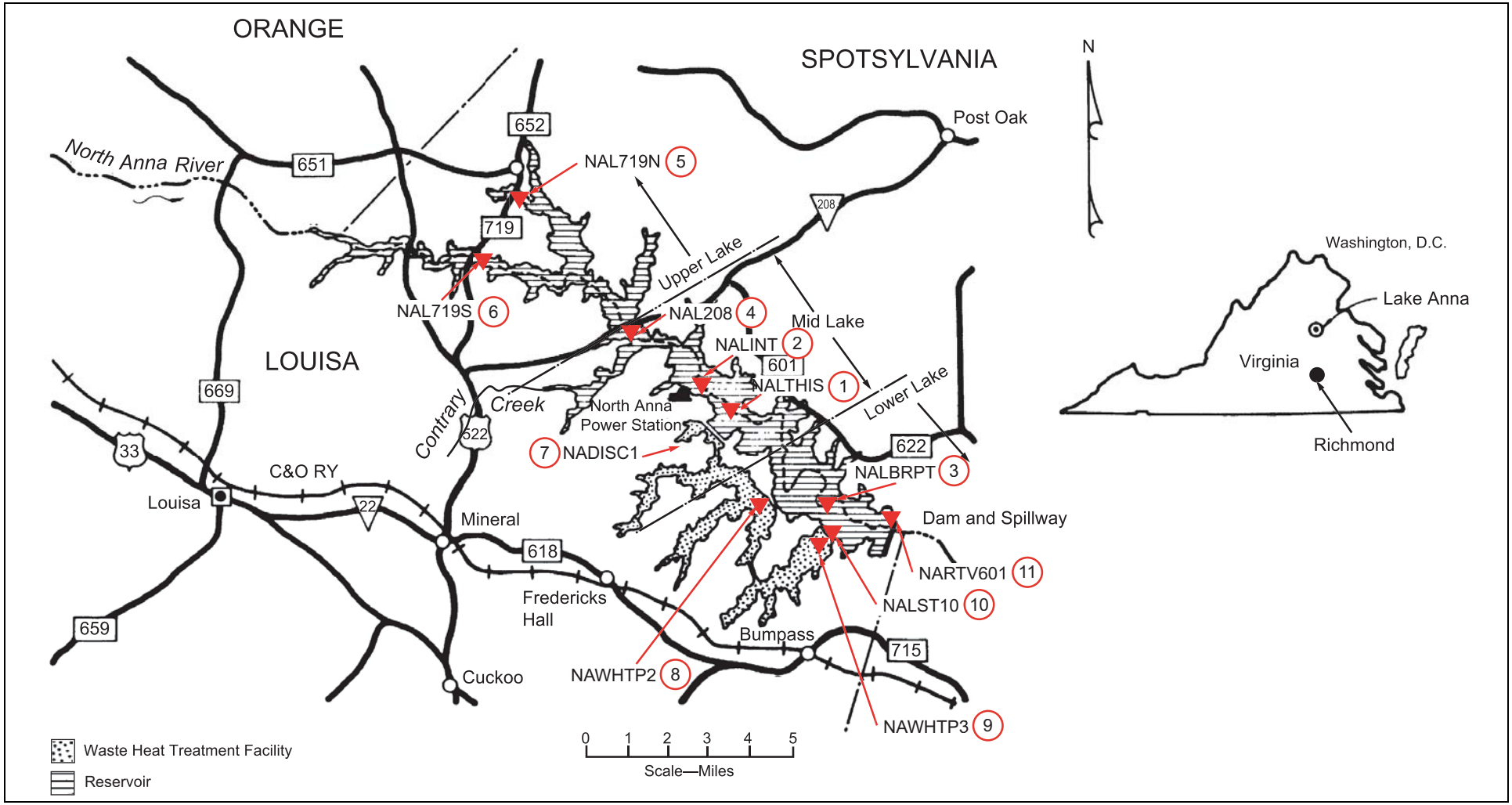

Figure 6.1-1 Locations of Water Temperature Monitoring Stations

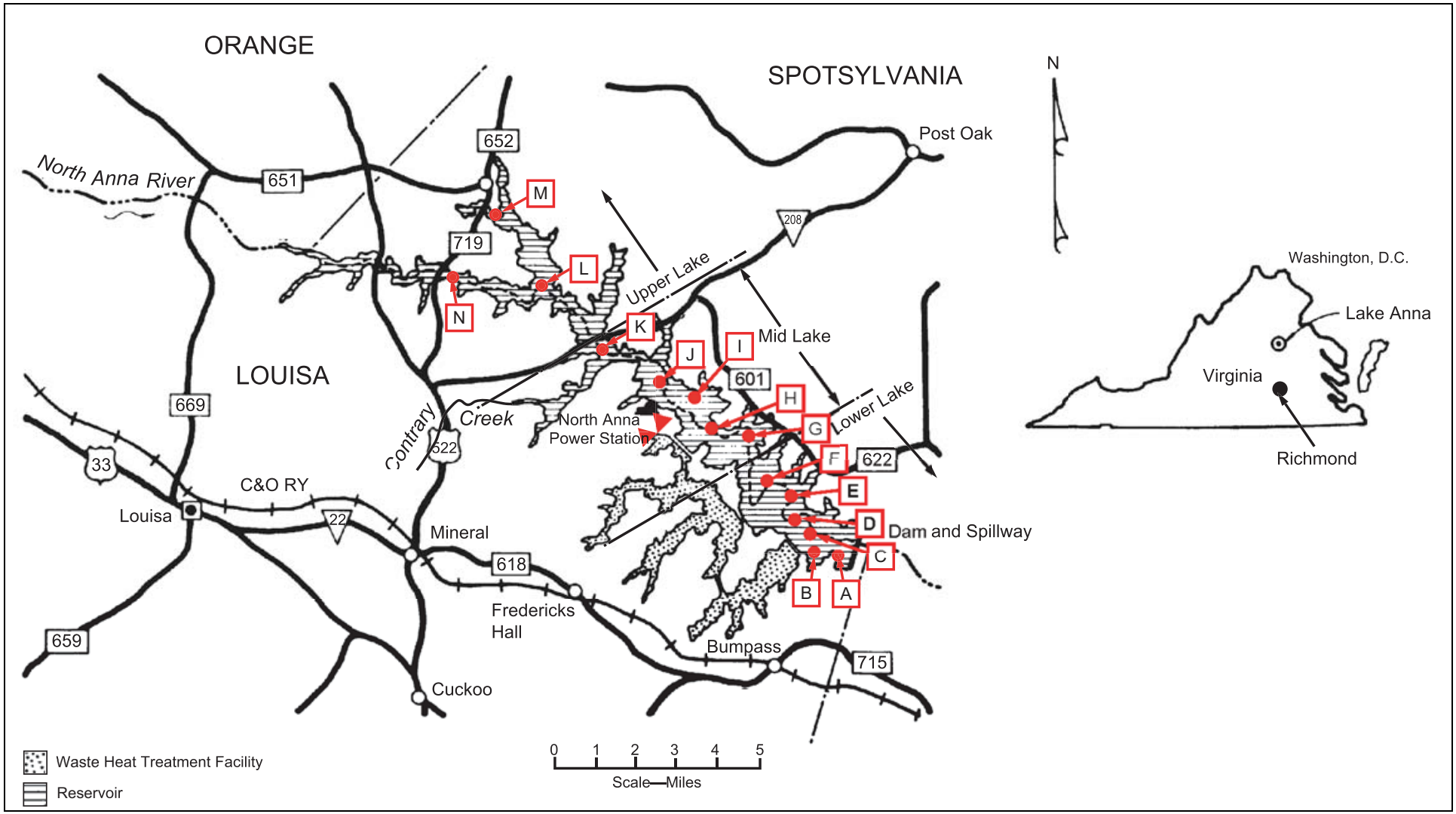

Figure 6.1-2 Temperature Profiling Stations A Through N

6.2 Radiological Monitoring

This section presents the basis, contents, reporting, and quality assurance of the ESP site Radiological Environmental Monitoring Program.

6.2.1 Radiological Environmental Monitoring Program Basis

The Radiological Environmental Monitoring Program (REMP) for the ESP site would be based on NUREG-0472 Revision 3 (Reference 1) and the NRC's Branch Technical Position Paper, *Acceptable Radiological Environmental Monitoring Program*, Revision 1 (Reference 2). The structure of the ESP site REMP would be based on the necessary components of the monitoring program established for the existing units, which encompasses the entire NAPS site and would be expanded to include radiological environmental monitoring for the new units. This expanded REMP would continue to be in accordance with the existing units' Technical Specifications and is described in the NAPS UFSAR Section 11.6 (Reference 2). It would be implemented through the existing units' Offsite Dose Calculation Manual (ODCM), and via administrative and technical procedures.

6.2.2 Radiological Environmental Monitoring Program Contents

The pre-operational and operational radiological monitoring program incorporates measurements to evaluate the possible effects from plant operation and to ensure that changes in environmental radioactivity can be detected. Pre-operational data provided a baseline for the existing units and the current REMP data would provide a baseline for the new units. The measurement of radiation levels, concentrations (including surface area), and/or other quantities of radioactive material, are used to evaluate potential exposures and doses to members of the public and the environment.

The following exposure pathways to radiation would be monitored.

- Direct (including dosimeters)
- Airborne (including iodine and particulates)
- Waterborne (including ground and precipitation)
- Aquatic (including tissue analysis)
- Ingestion (including milk and crops)
- Vegetation (including soil)

Sampling results and locations can be evaluated to determine effects from seasonal yields and variations. Figure 6.2-1 shows existing sampling locations for the REMP which would apply for the ESP site and expanded program. Table 6.2-1 provides details of the radiation exposure pathways monitored and the monitoring frequencies for those pathways. Sensitivity analyses provide information regarding changes in background levels and determine the adequacy of analysis techniques in light of program results and changes in technology, when compared to baseline

measurements. Changes in program implementation (including sampling techniques, frequencies and locations) may be added in response to monitoring results.

6.2.3 Radiological Environmental Monitoring Program Reporting

An annual Radiological Environmental Operating Report for the NAPS site would be written and submitted in accordance with the existing units Technical Specifications. Results from REMP implementation and evaluation would be compared to the previous years' results for measurement trends, methodology consistency, and indications that program changes are needed.

An Inter-laboratory Comparison Program exists to verify correctness of vendor results of samples sent for their analysis of radioactive materials. These results would be reported in an Annual Radiological Environmental Monitoring Report.

A land use census would be conducted within a designated distance of the NAPS site, currently 5 miles, to determine sampling yields and locations, and to ascertain if changes to the Radiological Environmental Monitoring Program are warranted. Parameters that have been reported include locations of nearest residence, milk production yield, and broad leaf vegetation.

6.2.4 Quality Assurance Program

Quality assurance is provided in the existing NRC-approved Radiological Environmental Monitoring Program through quality training, program implementation by periodic tests, the Inter-laboratory Comparison Program, and administrative and technical procedures. In addition, the existing units' Technical Specifications direct an audit of the REMP and its results under cognizance of the offsite Management Safety Review Committee.

Quality and credibility in the ESP Radiological Environmental Monitoring Program would be consistent with existing program components, regulatory guidance, and best management practices.

Section 6.2 References

1. NUREG-0472, Revision 3, *Standard Radiological Effluent Technical Specifications for Pressurized Water Reactors*, U.S. Nuclear Regulatory Commission, January 1983.

2. Branch Technical Position Paper, Revision 1, *Acceptable Radiological Environmental Monitoring Program*, U.S. Nuclear Regulatory Commission, November 1979.

3. Updated Final Safety Analysis Report, North Anna Power Station, Units 1 and 2, Revision 38.

Table 6.2-1 Radiation Pathway Monitoring

Radiation Exposure Pathways Monitored	Parameters	Frequency
Direct	Radiation Levels	Quarterly
Airborne, including Gaseous, Particulate, and Iodine	Radiation Levels Concentrations Radioactive Material Quantities	Continuous Weekly Quarterly
Waterborne, including Surface, Ground, and Sediment	Concentrations Radioactive Material Quantities	Monthly, Quarterly, Semi-annually
Ingestion, including Milk, Aquatic, Vegetation, and Food products	Concentrations Radioactive Material Quantities	Monthly Semi-annually

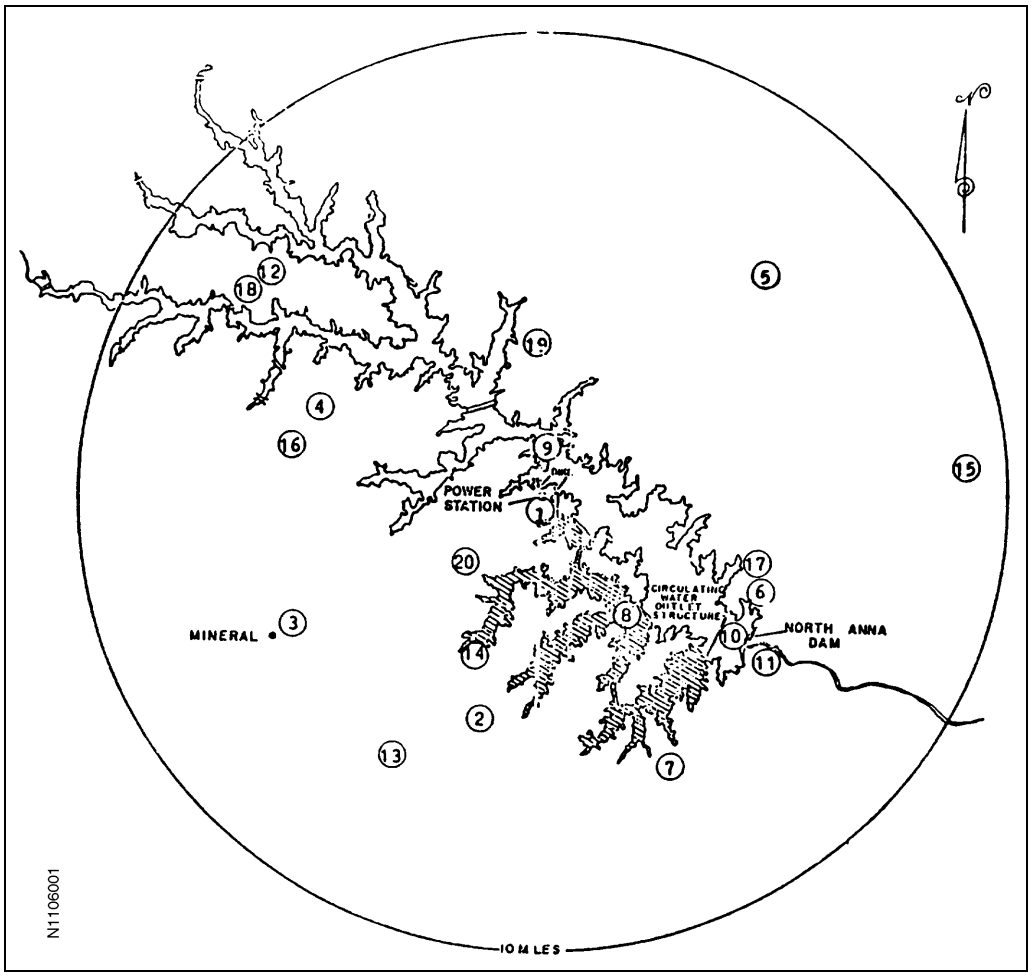

Figure 6.2-1 Preoperational Radiological Environmental Sampling Program Sample Station Locations

6.3 Hydrological Monitoring

This section discusses the hydrological monitoring program that would be implemented to monitor the effects of the new units at the ESP site, including monitoring of flow rates, water levels, sediment loads, and groundwater levels.

6.3.1 Existing Hydrological Monitoring

Presently, Virginia Power conducts hydrological monitoring in accordance with VPDES Permit No. VA0052451 (Reference 1). The hydrological measurements required by this permit are shown in Table 6.3-1. In addition to the flow measurements required for the VPDES permit, hourly lake water level readings are recorded at the North Anna Dam for use in regulating outflow from the dam.

Groundwater levels are the subject of an ongoing monitoring program at the ESP site. Nine groundwater observation wells were installed at the ESP site during November and December 2002 to determine groundwater levels, flow paths, and gradients. Tests were performed in these wells to determine the permeability of the subsurface materials. These wells, together with nine existing monitoring wells around the SWR for the existing units and one monitoring well at the ISFSI, are being used to measure groundwater levels on a quarterly basis to observe seasonal variations. Wells around the existing SWR are monitored every six months to evaluate the reservoir for leakage, assess the effectiveness of horizontal drains beneath the existing units pump house, and determine the flow rate and clarity of the associated discharge water.

6.3.2 Construction and Pre-Operational Monitoring

The VPDES Permit monitoring and lake water level monitoring would continue through the construction phase and prior to operation of the new units. This monitoring, in addition to the groundwater monitoring currently ongoing, would establish the baseline hydrological conditions for both Lake Anna and groundwater near the ESP site. Although no significant impacts to Lake Anna or groundwater aquifers are anticipated during construction, continual monitoring, as described in Section 6.3.1, would provide a means of detecting any unanticipated changes should they occur.

Also, prior to construction of the new units, an approved Erosion and Sediment Control Plan would be developed and implemented in accordance with state and local regulations (Reference 2). The Erosion and Sediment Control Plan would require periodic visual inspection of erosion and sediment control best management practices that have been implemented. If erosion or sediment deposition is discovered outside the defined limits of disturbance, measures would be implemented to correct the problem. Additionally, any hydrological monitoring required in conjunction with permits associated with construction of the make-up water intake structure or removal of the existing coffer dam at the intake location would be implemented via a specific construction monitoring plan, if necessary.

6.3.3 **Operational Monitoring**

An operational monitoring program would be developed in coordination with the VDEQ to establish a new or amended VPDES discharge permit. Since the permitted site is a nuclear power station, it is anticipated that the monitoring requirements of the new/amended permit would be similar to the existing permit. Monitoring of the Lake Anna water levels at North Anna Dam would continue during plant operation.

The NAPS site groundwater use is currently less than 100 gpm, and it is not expected to increase significantly after the addition of the new units. No changes to existing groundwater monitoring programs would be necessary.

Section 6.3 References

1. VPDES Permit No. VA0052451, *Authorization to Discharge Under the Virginia Pollutant Discharge Elimination System and The Virginia State Water Control Act, Effective January 11, 2002, Expiration January 11, 2006*, Department of Environmental Quality, Commonwealth of Virginia.

2. Virginia Erosion and Sediment Control Handbook, 3rd Edition, Division of Soil and Water Conservation, Virginia Department of Conservation, 1992.

Table 6.3-1 VPDES Hydrological Monitoring Program

Monitoring Location	Constituent (units)	Frequency	Sample Type
001 - Discharge of Condenser Cooling Water from Heat Treatment Facility at Dike 3	Flow (mgd)	1/month	Calculated
103 - Process Waste Clarifier	Flow (mgd)	2/month	Estimate
104 - Oil Water Separator and Storm Water	Flow (mgd)	2/month	Estimate
105 - Bearing Cooling Tower Blowdown	Flow (mgd)	1/month	Estimate
107 - Bearing Cooling Tower System Discharge-Lake to Lake Operation	Flow (mgd)	1/month	Estimate
108 - Service Water Overflow	Flow (mgd)	1/month	Estimate
109 & 110 - Hot Well Drains	Flow (mgd)	1/month	Estimate
111 - Sewage	Flow (mgd)	1/day	Estimate
112 & 113 - Steam Generator Blowdown Units 1 & 2	Flow (mgd)	1/month	Estimate
114 - Service Water Pipe Vault Drain	Flow (mgd)	1/month	Estimate
115 - Service Water System Blowdown	Flow (mgd)	1/month	Estimate
009 - Ground Water, Storm Water, Backwash from Sand Filters and RO Units	Flow (mgd)	1/month	Estimate
013 - Turbine Building Sump #1 and Storm Water	Flow (mgd)	1/month	Estimate
014 - Turbine Building Sump #2 and Storm Water	Flow (mgd)	1/month	Estimate
016 - Intake Screen Wash Water	Flow (mgd)	1/year	Estimate
020 - RO Reject	Flow (mgd)	2/month	Estimate
021 - RO Drain Line	Flow (mgd)	1/month	Estimate
022 – 026 - Storm Water Outfalls	Flow	1/storm event	Estimate

Data Source: Reference 1

6.4 Meteorological Monitoring

6.4.1 General Description – Onsite Meteorological Monitoring Program

Dominion plans to use the existing NAPS meteorological monitoring program for the ESP site. The existing program is described in the NAPS UFSAR, Section 2.3 (Reference 1). The existing program is suited for the ESP-required onsite meteorological measurements because the ESP site is adjacent to the existing units within the existing NAPS site. Additionally, the ESP site is relatively flat and free of elevated terrain features that generate complex airflows. Therefore, the airflow patterns throughout the site area would be similar.

The current onsite NAPS meteorological measurements program conforms to the requirements of 10 CFR 50.47 (Reference 2) and the guidance criteria set forth in NUREG-0696 (Reference 3), NUREG-0737 (Reference 4), NUREG-0654, Appendix 2 (Reference 5), Section C.4 of RG 1.111 (Reference 6), RG 1.21 (Reference 7), and RG 1.23 (Reference 10). System accuracy conforms to RG 1.23, Proposed Revision 1 (Reference 8).

The meteorological program has the following basic functions:

- Collecting meteorological data
- Generating real-time predictions of atmospheric effluent transport and diffusion
- Providing the appropriate organizations access (remote interrogation) to the atmospheric measurements and predictions

Meteorological measurements are available from both a primary tower and a backup tower, as required in 10 CFR 50, Appendix E (Reference 9). The backup system is designed to function even when the primary system is out of service, thus providing assurance that basic meteorological information would be available during and immediately following an accidental airborne radioactivity release.

Descriptions of the onsite meteorological monitoring program are from the NAPS UFSAR, unless otherwise indicated. The primary meteorological monitoring site at the NAPS site consists of a Rohn Model 80, guyed, 160-ft (48.8-m) tower, approximately 1750 ft (580 m) east of the Unit 1 containment building. Sensors are located at the 32.8-ft (10-m) level, the 158.9-ft (48.4-m) level, and ground level. Wind speed, wind direction, horizontal wind direction fluctuation, ambient temperature, one-half of differential temperature, and dew point temperature are measured at the 10-m elevation. Wind speed, wind direction, horizontal wind direction fluctuation, and one-half of the differential temperature are measured at the 48.4-m elevation. Precipitation is monitored at the ground level. Signal cables are routed through conduit from each location into the instrument shelter at the base of the tower. Inside the shelter, the signals are routed to the appropriate signal-conditioning equipment. The equipment outputs are directed to digital data recorders and to an interface with the intelligent remote multiplex system.

The backup meteorological monitoring site consists of a Rohn Model 25, freestanding 32.8-ft (10-m) tower. This tower is approximately 1300 ft (396 m) northeast of the Unit 1 containment building. A sensor at the top of the mast monitors wind speed, wind direction, and horizontal wind direction fluctuation. The signal path, instrument shelter and data recording are similar to those at the primary tower. All parameters are interfaced to the intelligent remote multiplexing system.

Because of the proximity of the ESP site to the existing units, meteorological parameters collected at the onsite primary and backup towers are representative of the dispersion conditions at the ESP site.

6.4.1.1 Location, Elevation, and Exposure of Instruments

The location of the primary meteorological tower is shown on the topographical map, Figure 2.7-1. Distances and bearings to ground features in the vicinity of the tower are shown on Figure 2.7-2. Onsite structures have been evaluated as having no adverse structural influence on the measurements taken at the tower. Trees in the immediate vicinity of the tower have been topped to heights of 10-15 ft (3-4.6 m). The nearest contiguous tree line is more than 500 ft (152 m) away from the tower and those tree heights are 40 to 50 ft (12 to 15 m).

Ground cover at the location is native grasses. Comparable cover is maintained at the base of the tower.

The Bounding Site-Specific PPE shows that the highest structure for new units at the ESP site would not be more than 234 ft (71.3 m) above grade level. Both the existing primary and backup towers are located more than 10 building heights away from the tallest expected structure within the ESP site plant envelope area. Therefore, these structures would not have any influence on the meteorological measurements.

6.4.1.2 Wind System

The wind sensors at both towers are positioned such that the tower does not influence the prevailing south-southwest wind flow detected by the sensors. The wind speed, wind direction, and horizontal wind direction fluctuation sensors are mounted on booms longer than the tower face width. Wind speed, wind direction, and horizontal wind direction fluctuation are measured at both the lower and upper tower levels. Electro-mechanical instruments are used to measure wind speed and wind direction. Horizontal wind direction fluctuation is calculated by the digital data acquisition system.

For the primary meteorological monitoring site, wind speed, wind direction, and horizontal wind direction fluctuation are measured at the 32.8-ft (10-m) level and at the 158.9-ft (48.4-m) level. The wind speeds are recorded with an accuracy of ±0.22 m/s (0.5 mph) for speeds less than 11.13 m/s (25 mph), with a starting threshold of less than 0.45 m/s (1 mph). The wind direction is measured with an accuracy of at least ±5 degrees of azimuth with a starting threshold of less than 0.45 m/s

(1.0 mph). Wind speed accuracy, wind direction, and starting threshold values conform to the guidance of RG 1.23, Proposed Revision 1.

The backup meteorological monitoring sensor at the top of the mast monitors wind speed, wind direction, and horizontal wind direction fluctuation to the same accuracy as the primary monitoring system.

6.4.1.3 **Temperature Systems**

At the primary meteorological monitoring site, temperature is measured at the 32.8-ft (10-m) level and differential temperature is measured between the 32.8-ft (10-m) and 158.9-ft (48.4-m) levels. The system consists of two temperature sensors. One single-element, high-precision, platinum resistance temperature sensor located at the 158.9-ft (48.4-m) level measures temperature in support of the differential temperature calculation. The other single-element, precision, platinum resistance sensor located at 32.8-ft (10-m) level measures ambient temperature and provides input to the differential temperature calculation. The sensors' signals are input into a temperature/delta temperature processor to provide output signals proportional to one ambient and one differential (ΔT) temperature. The temperature sensors record the data with an accuracy of at least ±0.5°C (0.9°F). The temperature difference is recorded with an accuracy of at least ±0.15°C (0.27°F) per 164 ft (50-m) height interval. These accuracy levels meet the guidance presented in RG 1.23, Proposed Revision 1.

Temperature and differential temperature sensors are housed in motor-aspirated shields to insulate them from thermal radiation. These shields support temperature measurement, which have less than 0.2°F (0.11°C) error, assuming maximum solar radiation of 1.6 gm-cal/cm^2/min). The backup tower does not measure differential temperature. The temperature sensor of the backup tower is also housed in a motor-aspirated shield.

6.4.1.4 **Dew Point Systems**

At the primary meteorological monitoring site, a lithium chloride dew point sensor measures dew point temperature at the 32.8-ft (10-m) level. The sensor signals are input into a dew point processor, which provides output signals proportional to the ambient dew point temperatures. The dew point levels are recorded to an accuracy of at least ±1.5°C (2.7°F), in accordance with RG 1.23, Proposed Revision 1.

Dew point temperature sensors are housed in motor-aspirated shields to insulate them from thermal radiation. These shields support temperature measurement with less than 0.2°F (0.11°C) error, assuming maximum solar radiation of 1.6 gm-cal/cm^2/min. The backup tower does not collect dew point temperature.

6.4.1.5 Precipitation Systems

At the primary meteorological monitoring site, precipitation is monitored at the ground level. The precipitation is measured with a recording rain gauge that has a resolution of 0.25 mm (0.01 in.). The accuracy is at least ±10 percent of the total accumulated catch, in accordance with RG 1.23, Proposed Revision 1. The backup tower does not collect precipitation.

6.4.2 Instrument Calibration and Maintenance

The meteorological monitoring system is calibrated at least semi-annually at both the primary and backup towers. Inspection, service, and maintenance are performed, as necessary, to ensure not less than 90 percent data recovery in accordance with the guidance of RG 1.23, Proposed Revision 1. Site-based instrument technicians have the requisite expertise to service and, in the event of a system failure, to repair the monitoring equipment.

In the event of a system outage, an inventory of spare sensors and parts is maintained for the replacement of major components. Redundant recording systems are incorporated into the program to further minimize data loss due to recorder failure. As an example, for this ESP application, the data recovery rates for more recent observations are presented in Table 6.4-1. Those data recovery rates for meteorological parameters (wind direction, wind speed, and atmospheric stability class) used for the dispersion analyses, as presented in Section 2.7, are very high and exceed the 90 percent guidance criteria in RG 1.23, Proposed Revision 1.

6.4.3 Data Recording Systems

6.4.3.1 Control Room Systems

Table 6.4-2 and Table 6.4-3 list each meteorological input parameter collected by the current system and the location to which the data are transmitted for the primary tower and backup tower, respectively. Parameters provided in Table 6.4-2 and Table 6.4-3 are available for remote interrogation at any time. During emergency conditions, selected meteorological parameters can be made available to the NRC through the ERF system.

6.4.3.2 Tower Base Shelter Systems

A nominally 8 ft x 8 ft x 18 ft (2.4 m x 2.4 m x 5.5 m) shelter is located at the primary and backup tower bases. The shelter is insulated. A thermostatically controlled heat and air conditioning system maintains the shelter interior temperature within a range appropriate for proper equipment operation. The enclosure is located so as to minimize any micrometeorological effects on the tower instrumentation. Equipment and circuitry for two separate data recording systems are housed in the shelter.

Microprocessor-based data acquisition systems are the primary method of data acquisition. The sensor analog signals are collected, processed, and telemetered to a system computer. The data

acquisition systems have a built-in battery, which maintains the time and date and initialized parameters. In addition to the power-up diagnostic checks, memory diagnostic tests are continually performed to insure data integrity. The instruments and data acquisition systems as detailed herein are consistent with the current level of technology for meteorological monitoring and the accuracy of the components meets the guidance of RG 1.23, Proposed Revision 1.

6.4.4 Meteorological Data Analysis Procedure

The collected data are used to generate a sequential file of 1-hour values for each parameter. The average values are calculated by the digital data collection system.

In addition to being transmitted real-time to the ERF system, the data are telemetered daily to a computer in the corporate office. Virginia Power personnel check the data for representativeness and reasonableness. The data are compared with data collected from other offsite meteorological towers as well as with the real-time data received at the Virginia Power Meteorological Operations Center. The data is maintained on computers and is used as the database for data summaries and historical calculations.

Routine data summaries are generated for each day, each calendar month, and each calendar year for certain meteorological parameters recorded on strip charts in the existing units control room. Annual summaries of this data are provided within Virginia Power.

The format of the onsite data summaries conforms to the recommended format found in Reference 10, Table 1, and RG 1.21. To facilitate comparison, these summaries include joint frequency distributions of wind speed and wind direction for each stability class, as defined by horizontal wind sigma and differential temperature.

6.4.5 Preoperational and Operational Monitoring

Per the guidance of NUREG-0654, Appendix 2 (Reference 5), all meteorological data systems should have the capability of being remotely interrogated. Also, the guidance of NUREG-1555, Section 6.4 (Reference 11) states that the meteorological monitoring program should establish a baseline for identifying and assessing environmental impacts during pre-operational and operational stages. As stated in NAPS UFSAR (Reference 1, Section 2.3.3.2.6), the meteorological data collected onsite are transmitted on real-time basis to the ERF, the data are telemetered daily to a computer in the corporate office. This satisfies the guidance provided in NUREG-0654.

In conclusion, the current NAPS meteorological monitoring program would serve as the preoperational monitoring program for the new units. The existing database adequately establishes a baseline for identifying and assessing environmental impacts that would result from operation of the new units. This database satisfies the guidance specified in RG 1.111, Section C.4, for providing representative meteorological data for evaluating environmental impacts.

Because the existing onsite meteorological monitoring program is conducted in accordance with the guidance criteria of RG 1.23 and the system accuracy specified in RG 1.23, Proposed Revision 1, the current system would serve as the basis for the operational monitoring program for any new units at the ESP site. Additional data links to the existing and new facilities would be required for the new units. After selection of a specific reactor design, actual data recording system designs would be defined in the COL application.

Section 6.4 References

1. *Updated Final Safety Analysis Report,* North Anna Power Station Units 1 and 2, Revision 38.

2. 10 CFR 50.47, *Emergency Plans,* January 19, 2001.

3. NUREG-0696, *Functional Criteria for Emergency Response Facilities, Final Report,* U.S. Nuclear Regulatory Commission, 1981.

4. NUREG-0737, *Clarification of TMI Plan Requirements,* U.S. Nuclear Regulatory Commission, 1980.

5. NUREG-0654, *FEMA-REP-1, Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants,* Rev. 1, U.S. Nuclear Regulatory Commission, 1996.

6. Regulatory Guide 1.111, *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors,* Rev. 1, U.S. Nuclear Regulatory Commission, 1977.

7. Regulatory Guide 1.21, *Measuring, Evaluating, and Reporting Radioactivity in Solid Waste and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants,* Rev. 1, U.S. Nuclear Regulatory Commission, 1974.

8. Regulatory Guide 1.23, *Meteorological Programs in Support of Nuclear Power Plants,* Proposed Revision 1, U.S. Nuclear Regulatory Commission, September 1980.

9. 10 CFR 50, Appendix E, *Emergency Planning and Preparedness for Production and Utilization Facilities (Integrated),* Code of Federal Regulations, June 14, 1996.

10. Regulatory Guide 1.23, *Onsite Meteorological Programs,* U.S. Nuclear Regulatory Commission, February 1972.

11. NUREG-1555, *Standard Review Plan for Environmental Reviews for Nuclear Power Plants,* U.S. Nuclear Regulatory Commission, October 1999.

Table 6.4-1 Meteorological Data Recovery Rates (percent) (North Anna, January 1, 1996–December 31, 2001)

	Delta T Included		Delta T Not Included	
Year	33-ft Wind Data	150-ft Wind Data	33-ft Wind Data	150-ft Wind Data
1996	98.88	99.30	98.92	99.48
1997	98.96	90.09	99.36	99.20
1998	99.12	99.34	99.21	99.43
1999	98.91	98.90	99.45	99.44
2000	98.73	98.76	99.23	99.24
2001	98.88	91.78	99.76	92.59

Note: Data in this table are for the primary site.

Table 6.4-2 Primary Tower Meteorological Parameters

	Transmitted Locations		
Parameter	ERF Data Base	Control Room	Remote Interrogation
Wind Direction (upper)	X	X	X
Wind Speed (upper)	X	X	X
Sigma theta (upper) (S_t)			X
Wind Direction (lower)	X	X	X
Wind Speed (lower)	X	X	X
Sigma theta (lower) (S_t)			X
Ambient Temperature (lower)	X	X	X
Dew point (lower)			X
Delta Ambient Temperature (upper-lower)	X	X	X
Precipitation			X

Note: All parameters going to the ERF database are available for printout in the existing TSC and EOF. The Units 1 & 2 control room parameters are hardwired.

Source: Reference 1

Table 6.4-3 Backup Tower Parameters

Parameter	ERF Data Base	Control Room	Remote Interrogation
Wind Speed	X	X	X
Wind Direction	X	X	X
Sigma Theta (S_t)	X	X	X

Note: All parameters going to the ERF database are available for printout in the existing TSC and EOF. The Units 1 & 2 control room parameters are hardwired.

Source: Reference 1

6.5 Ecological Monitoring

NUREG-1555 recommends that ecological monitoring programs encompass the elements of the ecosystems for which a causal relationship is established or strongly suspected between the construction or operation of a new unit and adverse change (Reference 1, Section 6.5).

Ecological monitoring programs have been conducted at the NAPS site on a periodic basis since the early 1970s. The data collected under these programs is summarized in Section 2.4. The existing ecological monitoring programs and associated databases would be supplemented, as necessary, to support new units.

6.5.1 Terrestrial Ecology and Land Use

The following sections describe the prescribed pre-application, construction/pre-operational, and operational monitoring programs for terrestrial ecology and land use of the ESP site and transmission corridors that may be impacted by the new units.

6.5.1.1 Pre-Application Monitoring

The pre-application monitoring program has two objectives: 1) to provide supplemental information that aids in assessing the suitability of the ESP site, and 2) to support the assessment of potential impacts on the terrestrial environment that could result from construction and operation of the new units. The pre-application monitoring program comprises the existing NAPS terrestrial ecological database and the ongoing NAPS-based ecological monitoring programs.

The existing units terrestrial monitoring program was initiated in 1973 to monitor the local wildlife and vegetation communities in response to the expected major changes in the terrestrial environment associated with the creation of Lake Anna and NAPS. The program was designed to provide baseline data about existing ecological communities. The program specifically identified vegetation types around Lake Anna, compiled an inventory of wildlife in the area, and evaluated local land use patterns. (Reference 2) Some of the terrestrial monitoring programs continued to monitor the variations within existing communities during the construction and operation of the existing units.

The following sections describe the vegetation, avian, and mammalian community monitoring programs performed to date, highlight the present status of “important” related ecological species and habitats, and identify the on-going related monitoring programs.

6.5.1.1.1 Vegetation

As described in Section 2.4.1, much of the NAPS site consists of existing generation and maintenance facilities, parking lots, roads, cleared areas, and mowed grass. Hardwood forests exist in areas that have not been cleared for the construction and operation of the existing units. These wooded areas are remnants of forests that were used for timber production, prior to the land acquisition by Virginia Power, and are dominated by a variety of oak, yellow poplar, sweet gum, and

red maples. Scattered loblolly pines, Virginia pines, and short-leaf pines exist in some wooded areas. (Reference 3, Sections 2.4 and 2.5) (Reference 4, Section 2.2.6)

The transmission corridors are regularly managed by Virginia Power to prevent woody growth from reaching the transmission lines. The removal of woody species can provide outstanding grassland and bog-like habitat for many rare plant species dependent on open conditions. No endangered or threatened plants have been recorded along the transmission corridors. (Reference 3, Sections 2.4 and 2.5)

Virginia Power currently conducts a transmission corridor rare plant survey program in cooperation with the VDCR's Natural Heritage Program (see Section 2.2.2 and Section 5.6.1). The Natural Heritage Program prepares annual reports from these surveys.

No additional monitoring would be performed for the new units.

6.5.1.1.2 **Avian Communities**

Common bird species recorded in upland areas on and near the ESP site include the American crow, blue jay, Carolina chickadee, mourning dove, black vulture, turkey vulture, European starling, song sparrow, white-throated sparrow, dark-eyed junco, Northern cardinal, house finch, tufted titmouse, red-bellied woodpecker, downy woodpecker, and Northern flicker.

Several species of residential and migratory wading birds and waterfowl use Lake Anna. Virginia Power biologists have documented breeding at Lake Anna by mallards, wood ducks, and Canada geese. Virginia Power, in association with the Louisa County Chapter of Ducks Unlimited, has placed wood duck nest boxes on Lake Anna and wood ducks have used several of these nest boxes. Belted kingfishers, great blue herons, and green-backed herons are present at Lake Anna throughout the year and presumably nest on or near the Lake Anna shoreline (see Section 2.4.1.4).

Even though the bald eagle and loggerhead shrike have been observed in the local area, terrestrial species that are listed by the federal and/or the Commonwealth of Virginia governments as endangered or threatened species are not known to exist at the NAPS site or along the transmission corridors. No areas designated by the USFWS as "critical habitat" for endangered species exist at or near the NAPS site or associated transmission lines. In addition, the transmission corridors do not cross any Commonwealth or federal parks, wildlife refuges, or wildlife management areas.

Virginia Power annually has participated with the National Audubon Society in conducting the "Christmas Bird Counts" during either December or January (see Section 2.4.1.3). Bird species were recorded in upland areas on and near the NAPS site during this count.

6.5.1.1.3 **Small Mammals**

Wildlife species resident in the forested portions of the NAPS site are typical of those found in upland Piedmont forests of north-central Virginia. As presented in Section 2.4.1.2, frequently observed mammals such as the white-tailed deer, raccoon, opossum, gray squirrel, and gray fox

occur on site, as do smaller mammals such as moles, shrews, and a variety of mice and voles. Woodchucks exist in grassy areas near the forest edges of the NAPS site, and beavers exist in Lake Anna and its tributaries. Various birds, reptiles (e.g., snakes, lizards), and amphibians (e.g., frogs, salamanders) exist in uplands and along the edge of Lake Anna.

No areas designated by the USFWS as "critical habitat" for endangered species exist at the NAPS site or along/adjacent to transmission corridors. In addition, the transmission corridors do not cross any Commonwealth or federal parks, wildlife refuges, or wildlife management areas.

No additional mammal-related monitoring would be performed for the new units.

6.5.1.2 Construction and Pre-Operational Monitoring

Construction of the new units would result in the removal of substantial portions of the existing forested habitat on the NAPS site. The construction site and support areas do not contain any old growth timber, unique or sensitive plants, or unique or sensitive plant communities. Therefore, construction would not significantly reduce the local or regional diversity of plants or plant communities. As the potentially impacted forested habitat on site represents a small portion of the available undeveloped land in the region of the NAPS site, the displacement and construction-related mortality of wildlife would be small, relative to wildlife populations in the region.

Noise-related impacts and bird collisions due to construction activities and equipment would be negligible. Section 2.4.1 and Section 4.3.1 conclude that while there is potential for bird collisions with the buildings and equipment during the facility construction phase, the additional impact of construction-related structures would be small, given the proximity of existing units structures and the relative absence of evidence of previous avian collisions with these structures. Finally, no federal or Commonwealth threatened or endangered plants or animals are known to exist in the construction site and support areas, and these areas do not contain any designated critical habitats. Thus, construction would not adversely impact any threatened or endangered species, or trigger the need to conduct additional terrestrial monitoring.

6.5.1.3 Operational Monitoring

Operation of the new units would not pose any additional impacts to areas outside those previously disturbed by NAPS site or new unit construction. New unit operation would not impact critical habitats, or important, threatened, or endangered species. Thus, additional terrestrial monitoring would not be warranted.

6.5.2 Aquatic Ecology

The following sections describe the pre-application, construction/pre-operational, and operational monitoring programs for aquatic ecology. These programs would support any required assessments of aquatic impacts associated with new unit construction and operation.

6.5.2.1 Pre-Application Monitoring

The objective of the pre-application aquatic monitoring program is to provide information that aids in the assessment of site suitability and supports the assessment of potential impacts on the aquatic environment that would result from the construction and operation of the new units. This monitoring program comprises the existing NAPS aquatic ecological database and the related ongoing NAPS aquatic monitoring programs. The following subsections summarize the previous aquatic monitoring programs, the current status of "important" aquatic species and habitats, and the nature of ongoing aquatic monitoring programs.

6.5.2.1.1 Previous Aquatic Ecology Monitoring Programs

The earliest aquatic monitoring program was initiated by Virginia Power in the early 1970s, prior to the creation of Lake Anna and the construction of the existing units. This program was designed to provide baseline data about the ecology of the North Anna River basin, to support the evaluation of impacts from dam construction on the North Anna River and the upper section of the Pamunkey River. This aquatic monitoring program was followed in the summer of 1972 by a more intensive post-impoundment aquatic ecological monitoring program. This program collected biological samples at 10 stations distributed upstream and downstream of the North Anna dam. Epiphytes, macrobenthic fauna, and fish were collected during the summer months of 1972. Later in the year, following the filling of Lake Anna, a new aquatic ecology monitoring program was initiated, which sampled phytoplankton, zooplankton, benthos, and fishes at stations in the Lake. Prior to the construction and operation of the existing units, this program generated a database that characterized the newly formed Lake Anna biota. (Reference 2, Section 6.1) Supplemental studies of phytoplankton, zooplankton, and benthic organisms followed from 1973 through 1985 (see Section 2.4.2.2).

Section 2.4.2.2 discusses fish community studies. From 1975 through 1985, Virginia Power evaluated the abundance and distribution of adult fish using a variety of sampling methods. Virginia Power also conducted larval fish studies, creel surveys, and a number of special studies, focusing on the reproduction and growth of important recreational species, such as largemouth bass (*Micropterus salmoides*). Using ultrasonic tags, Virginia Power investigated the seasonal movement and habitat preferences of striped bass (*Morone saxatilis*). (Reference 3, Sections 2.4 and 2.5)

6.5.2.1.2 Important, Threatened, and Endangered Species

As described in Section 2.4.2.2, from 1975 through 1985, 39 species of fish (representing 12 families) were found in Lake Anna. The species include those historically found in the North Anna River, those in local farm ponds inundated by the new lake, and nine species (four non-natives) introduced by the VDGIF. (Reference 4, Section 2.2.5) Section 2.4.2.2 also reports that fish monitoring conducted over a more recent six-year period (1995–2000) shows a balanced reservoir fish community of healthy top-of-the-food-chain predators (e.g., largemouth bass and

striped bass), the forage species on which they feed (e.g., threadfin shad, and gizzard shad), pan fish (e.g., bluegill, red ear sunfish, redbreast, crappie), and catfish.

No Commonwealth of Virginia or federally-listed (e.g., endangered, threatened, species of concern) fish species or critical habitats are found in Lake Anna or the North Anna River (see Section 2.4.2.2.5 and Section 2.4.2.3.5). No Commonwealth or federally-listed fish species have been collected in any surveys or operational monitoring studies. While VDGIF ecological databases indicate that three Commonwealth and federally-listed species – the Commonwealth freshwater mussel species dwarf wedge mussel *(Alasmidonta heterodon*), the Atlantic pig toe (*Fusonaia mason*), and James spiny mussel (*Pleurobema collina*) – could occur in local streams, none have been observed or collected in local streams. A fourth mussel species, the kidney mussel (*Ptychobranchus subtentum*), a candidate for federal listing, has been reported to have been observed in the vicinity of the ESP site. However, these observations may be in error, since confirmed observations limit this species to more western mountain streams that drain to the Gulf of Mexico. (Reference 3, Sections 2.4 and 2.5) (Reference 4, Section 2.2.5)

6.5.2.1.3 Current Monitoring Programs

Virginia Power has monitored fish populations in Lake Anna since 1986. Virginia Power conducts quarterly electro-fishing sampling at nine stations (five stations in the North Anna Reservoir, four in the WHTF, and six gillnetting stations (four in the reservoir and two in the WHTF). These surveys are designed to document: 1) the types of fish species present in Lake Anna, 2) their relative numbers by species, and 3) their size class distribution. In the North Anna River below the dam, Virginia Power biologists have also gathered abundance and distribution data on largemouth and smallmouth bass via direct (snorkel) observation. The biologists swim established transects, counting and categorizing (by size) all bass that are observed, and noting the type of cover being used. Other fish abundance and distribution information in the North Anna River is collected by electro-fishing at 4 stations, 3 times per year.

In response to NRC Generic Letter 89-13, Virginia Power initiated a semi-annual sampling program in the fall of 1990 to monitor Asiatic clams (*Corbicula flumenia)* in the North Anna Reservoir, the WHTF, and the SWR. Virginia Power continues to collect replicate samples at two North Anna Reservoir stations (i.e., Intake and Mid-Lake), two WHTF stations, and a single station in the SWR, and they report the total number and density of clams at the stations and discuss population trends in semi-annual reports. In the course of monitoring *Corbicula* populations, Virginia Power assesses the micro-fouling potential of Asiatic clams and looks for evidence that the exotic zebra mussel (*Dreissena polymorpha*) has invaded Lake Anna. As of the end of 2002, Virginia Power had observed no zebra mussels in Lake Anna.

Virginia Power biologists have also conducted studies in the North Anna River in response to reduced flow due to drought conditions. The studies included physical habitat measurements at different flows, dissolved oxygen, temperature, and collection of benthic macro-invertebrates. Each

fall, when warranted, an aerial and ground-based monitoring program that focuses on identifying the presence of a nuisance submerged aquatic macrophyte, Hydrilla verticillata is conducted.

As presented in Section 2.4.2.2.3, the VDGIF also conducts aquatic ecology monitoring as part of their management responsibilities for the fisheries of Lake Anna. VDGIF district biologists monitor and research the fishes of Lake Anna, annually, focusing primarily on the largemouth and striped bass, two species that are highly esteemed by local anglers. Other species, such as black crappie, walleye, channel catfish, and gizzard and threadfin shad, are monitored by VDGIF.

6.5.2.2 Construction and Pre-Operational Monitoring

Construction of the new units would result in minor temporary disruptions of some aquatic habitats. The addition of a new Lake Anna intake structure for Unit 3 wet cooling tower make-up and removal of the existing intake cofferdam would contribute to temporary increases in the turbidity of the water in these disturbed areas. The land clearing and earthwork associated with construction of the new units could similarly result in temporary increases in the turbidity in adjacent surface water bodies. As appropriate, soil erosion and sedimentation controls and construction-phase storm water management practices would be employed to minimize the sediment-related impacts to these surface water resources. Therefore, new unit construction would not reduce the local or regional diversity of aquatic species.

No federally or Commonwealth-listed threatened or endangered aquatic plants or important species are known to live in areas that would be impacted by construction of the new units, nor do these areas contain any designated critical habitats. Therefore, construction of the new units would not adversely impact any threatened or endangered aquatic species.

The Virginia Power aquatic ecology monitoring programs (i.e., quarterly fish surveys, semi-annual shellfish surveys, Hydrilla inspections) and the VDGIF-sponsored annual fish monitoring program would continue. Therefore, construction of the new units would not require additional aquatic ecology monitoring programs or efforts.

6.5.2.3 Operational Monitoring

While the addition of the new units would increase water withdrawal rates (to provide make-up water for the cooling towers) and, very slightly, the water discharge rates (due to cooling tower blowdown), operation with the new units would be fundamentally similar to operation with the existing units. The impact of these changes on lake temperature would be negligible. Therefore, operation with the new units is not predicted to have any impact or to cause habitat reductions for striped bass. Likewise, other aquatic species are predicted to not be affected. Consequently, the operational-phase aquatic ecological monitoring program for the new units would be an extension of the ongoing Virginia Power and VDGIF monitoring programs.

Section 6.5 References

1. NUREG-1555, *Standard Review Plans for Environmental Review for Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, October 1999.

2. *North Anna Power Station Final Environmental Statement,* United States Atomic Energy Commission, April 1973.

3. *North Anna Station Application for Renewed Operating Licenses (Appendix E – Environmental Report)*, Dominion Energy, May 2001.

4. NUREG-1437*, Generic Environmental Impact Statement for License Renewal of Nuclear Power Plants, Supplement 7*, U.S. Nuclear Regulatory Commission, November 2002.

6.6 Chemical Monitoring

The following section describes the chemical monitoring program for surface water and groundwater quality, which includes the following topics:

- Pre-application monitoring that supports the baseline environmental hydrologic and water quality descriptions in Chapter 2 and Chapter 3.
- Construction/pre-operational monitoring that would evaluate anticipated impacts from site preparation and new unit construction and that would establish a baseline for identifying and assessing environmental impacts from operation of the new units.
- Operational monitoring that would identify impacts from operation of the new units.

The proposed chemical monitoring programs contain the elements necessary to evaluate potential impacts on water quality in accordance with the guidance of NUREG-1555 (Reference 1, Section 6.6).

6.6.1 Pre-Application Monitoring

The objective of the pre-application monitoring program is to provide information that aids in the assessment of site suitability and supports the assessment of potential impacts that could result from the construction and operation of the new units. The pre-application monitoring program is composed of the existing NAPS water quality database and the ongoing VPDES permit-mandated surface water and NAPS groundwater monitoring programs

6.6.1.1 Surface Water Monitoring

A series of pre-operational water quality programs were initiated for the NAPS site in the early 1970s. Lake Anna was created to supply plant cooling water for the power station. The initial pre-impoundment program focused on evaluating the local water quality effects of pyrite-mine drainage from Contrary Creek and its tributaries. A post-impoundment water quality monitoring program began in the summer of 1971. During this monitoring period, temperature, total solids, turbidity, flow rate, dissolved oxygen (DO), salinity, biological oxygen demand (BOD), alkalinity, pH, iron, magnesium, manganese, copper, zinc, mercury, lead, nitrates, and sulfates were measured bi-monthly at 10 monitoring stations located downstream of the North Anna Dam and the upper Pamunkey River. A 3-year pre-operational water quality monitoring program was initiated in March 1972 to monitor temperature, DO, pH, conductivity, alkalinity, nutrients, iron, magnesium, copper, strontium, calcium, manganese, chromium, aluminum, zinc, and potassium at 12 locations in the recently fully developed Lake Anna. In addition, Secchi disk and radiological analyses were conducted at these stations. All of these measurements were conducted monthly, except during the summer months, when they were performed bi-weekly. (Reference 2, Section 6.1)

As part of the NAPS CWA Section 316(a) Demonstration in 1985, a revised temperature-monitoring program was initiated at seven local monitoring stations. Temperatures were recorded hourly at most of these stations through 1985 (Reference 3, Section 2.2).

Virginia Power continues to measure Lake Anna water temperatures at a number of monitoring stations in the Lake in accordance with VPDES permit conditions (Reference 4). Specific monitoring details (location, parameters, frequency) of this ongoing permit-based water quality and temperature monitoring program are provided in Table 6.6-1 and Figure 6.6-1, Figure 6.2-3, and Figure 6.6-2.

Dominion would continue to conduct the water quality monitoring program mandated by the VPDES permit.

6.6.1.2 Groundwater Monitoring

NAPS groundwater use is currently less than 100 gpm. Operation of the new units would not significantly increase groundwater use (see Section 2.3.2.2.1). Given the regular and small usage of groundwater at the NAPS site, the quality of the groundwater has not been the subject of any recent systematic monitoring efforts. Current groundwater use would not change during new unit construction, pre-operational periods, or operating periods. Therefore, groundwater impacts will continue to be viewed as minimal, and mitigation and related water quality monitoring measures are not warranted. (Reference 5, Section 4.5)

Groundwater levels have been, and continue to be, the subject of an on-going monitoring program. Nine groundwater observation wells were installed (November and December 2002) at the ESP site to determine water elevations, flow paths, and gradients. Tests have been performed in these wells to determine the permeability of the subsurface materials. These wells, together with 9 existing monitoring wells around the SWR and one monitoring well at the ISFSI, are used to measure groundwater elevations on a quarterly basis for one year to determine seasonal variations. Virginia Power would continue to monitor wells around the SWR to evaluate the SWR for leakage, to assess the effectiveness of horizontal drains beneath the existing units pump house, and to determine the flow rate and clarity of the water discharge. An existing well at the NAPS metrology lab is also being monitored quarterly for radiological purposes.

6.6.2 Construction and Pre-Operational Monitoring

The VPDES-mandated temperature and water quality monitoring program and the groundwater level monitoring program for the existing units would continue. Construction of the new units would require Dominion to seek a permit for storm water discharges from construction activities. This permit would not trigger the need to conduct additional storm water-related monitoring beyond that required for the existing units. The ongoing surface and groundwater monitoring programs for the existing units would provide the data necessary to assess potential changes in water quality associated with construction of the new units. These ongoing programs would also provide a

baseline for the identification and measurement of water quality impacts from operation of the new units.

6.6.3 **Operational Monitoring**

An operational monitoring program would be implemented to identify any changes in water quality that may result from the operation of the new units and to assess the effectiveness of the related effluent treatment systems. The specific elements of the operational monitoring program would be developed in consultation with the VDEQ during the process to revise the existing VPDES permit. Given that the new units would represent an expansion of the existing nuclear power generation facilities, any new monitoring would be similar to that described in the current VPDES-mandated program.

Section 6.6 References

1. NUREG-1555, *Environmental Standard Review Plan*, U.S. Nuclear Regulatory Commission, October 1999.

2. *North Anna Power Station Final Environmental Statement,* United States Atomic Energy Commission, April 1973.

3. *North Anna Station Application for Renewed Operating Licenses* (Appendix E – Environmental Report), Dominion Energy, May 2001.

4. Virginia Discharge Elimination System Permit No. VA0052451, Virginia Department of Environmental Quality, July 11, 2001.

5. NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Power Plants*, Supplement 7, U.S. Nuclear Regulatory Commission, November 2002.

Table 6.6-1 VPDES Water Quality Monitoring Program

Monitoring Location	Constituent (units)	Frequency	Sample Type
001 - Discharge of Condenser Cooling Water from Heat Treatment Facility at Dike 3 (Note 1)	Flow (mgd)	1/month	Calculated
	pH	1/year	Grab
	Heat Rejected ($\times 10^9$ Btu/hr)	1/day	Calculated
	Total Residual Chlorine (mg/l)	1/month	Grab
	Copper	1/5 years beginning 2004	Grab
	Nickel	1/5 years beginning 2004	Grab
	Acute and Chronic Toxicity Test	August/September 2004 or 2005 1/3 months if test fails for one year. Annually thereafter	48-hour static test using *Ceriodaphnia dubia* to determine No Observable Adverse Effects Concentration (NOAEC).
103 – Process Waste Clarifier (Note 1)	Flow (mgd)	2/month	Estimate
	pH	2/month	Grab
	Suspended Solids (mg/l)	1/3 months	Grab
	Oil and Grease (mg/l)	1/3 months	Grab
104 – Oil Water Separator and Storm Water (Note 1)	Flow (mgd)	2/month	Estimate
	pH	2/month	Grab
	Suspended Solids (mg/l)	1/3 months	Grab
	Oil and Grease (mg/l)	1/3 months	Grab

Data Source: Reference 4

Notes: 1. See Figure 6.6-2 for location.
2. See Figure 6.6-1 for location.
3. See Figure 6.2-3 for location.

Table 6.6-1 VPDES Water Quality Monitoring Program

Monitoring Location	Constituent (units)	Frequency	Sample Type
105 – Bearing Cooling Tower Blowdown (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
	Free Available Chlorine	1/month	Grab
	Priority Pollutants (mg/l) Note: 126 Priority Pollutants contained in cooling tower treatment chemicals except for total chromium and total zinc)	1/3 months	Grab
	Total Chromium (mg/l)	1/3 months	Grab
	Total Zinc (mg/l	1/3 months	Grab
107 - Bearing Cooling Tower System Discharge-Lake to Lake Operation (Note 1)	Flow (mgd)	1/month	Estimate
	Total Residual Chlorine (mg/l)	1/month	Grab
108 – Service Water Overflow (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
109 & 110 – Hot Well Drains (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
	Suspended Solids (mg/l)	1/month	Grab
	Oil and Grease (mg/l)	1/month	Grab
111 - Sewage (Note 1)	Flow (mgd)	1/day	Estimate
	pH	1/month	Grab
	BOD - 5-day (mg/l)	1/6 months	Grab
	Suspended Solids (mg/l)	1/3 months	Grab
	Total Residual Chlorine (mg/l) or Fecal Coliform (n/100 ml)	1/day 1/week	Grab Grab

Data Source: Reference 4

Notes: 1. See Figure 6.6-2 for location.
2. See Figure 6.6-1 for location.
3. See Figure 6.2-3 for location.

Table 6.6-1 VPDES Water Quality Monitoring Program

Monitoring Location	Constituent (units)	Frequency	Sample Type
112 & 113 – Steam Generator Blowdown Units 1 & 2 (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
	Suspended Solids (mg/l)	1/6 months	Grab
	Oil and Grease (mg/l)	1/6 months	Grab
114 – Service Water Pipe Vault Drain (Note 1)	Flow (mgd)	1/month	Estimate
115 – Service Water System Blowdown (Note 1)	Flow (mgd)	1/month	Estimate
009 – Groundwater, Storm Water, Backwash form Sand Filters and RO Units (Note 1)	Flow (mgd)	1/month	Estimate
	pH	2/month	Grab
	Suspended Solids (mg/l)	1/3 months	Grab
013 - Turbine Building Sump #1 and Storm Water (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
	Suspended Solids (mg/l)	1/month	Grab
	Oil and Grease (mg/l)	1/month	Grab
014 - Turbine Building Sump #2 and Storm Water (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
	Suspended Solids (mg/l)	1/month	Grab
	Oil and Grease (mg/l)	1/month	Grab
016 – Intake Screen Wash Water (Note 1)	Flow (mgd)	1/year	Estimate
020 – RO Reject (Note 1)	Flow (mgd)	2/month	Estimate
	pH	2/month	Grab
	Suspended Solids (mg/l)	1/3 months	Grab
	Total Residual Chlorine	2/month	Grab

Data Source: Reference 4

Notes: 1. See Figure 6.6-2 for location.
2. See Figure 6.6-1 for location.
3. See Figure 6.2-3 for location.

Table 6.6-1 VPDES Water Quality Monitoring Program

Monitoring Location	Constituent (units)	Frequency	Sample Type
021 – RO Drain Line (Note 1)	Flow (mgd)	1/month	Estimate
022 to 026 Storm Water Associated with Industrial Activities (Note 1)	Total Recoverable Iron	2/year for years 2005 and 2006, immediately after applicable storm event (> 0.1 inch)	Grab
	Visual Inspection	1/3 months immediately following applicable storm event (> 0.1 inch)	Visual observation
Station 1 – 9 & 11 (Note 2)	Temperature (°C)	Hourly during summer quarter and one other alternating quarter of year	Automated surface measurement
Station 10 (Note 2)	Temperature (°C)	Hourly during summer quarter and one other alternating quarter of year	Automated 3 meter deep measurement
Stations A – N (Note 3)	Temperature (°C)	Hourly measurements during daylight hours	Automated surface to bottom measurements at one meter intervals

Data Source: Reference 4
Notes: 1. See Figure 6.6-2 for location.
2. See Figure 6.6-1 for location.
3. See Figure 6.2-3 for location.

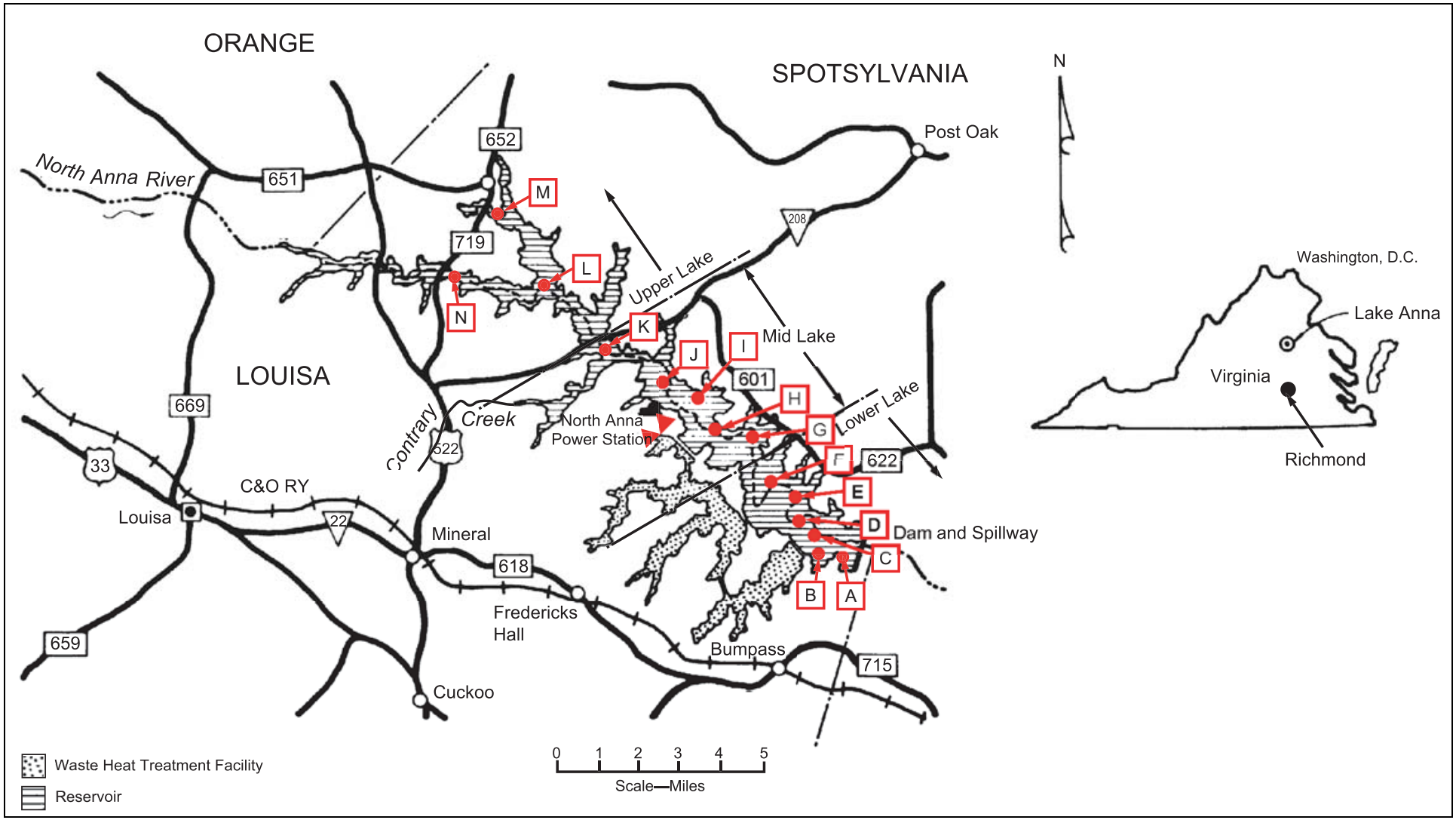

Figure 6.2-3 Location of Thermal Plume Sampling Stations – Lake Anna

Data source: Reference 4

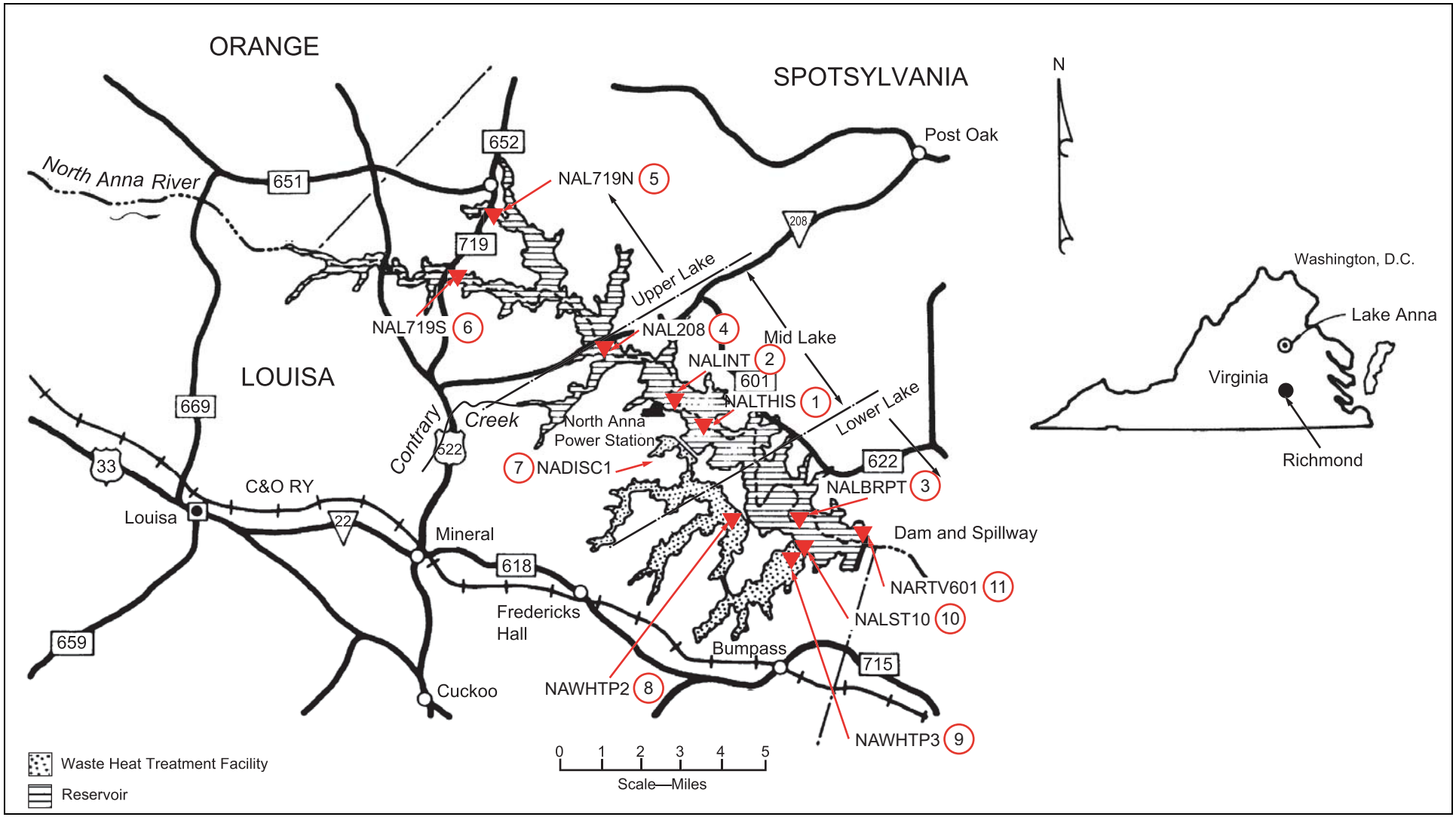

Figure 6.6-1 Location of Temperature Sensors – Lake Anna

Data source: Reference 4

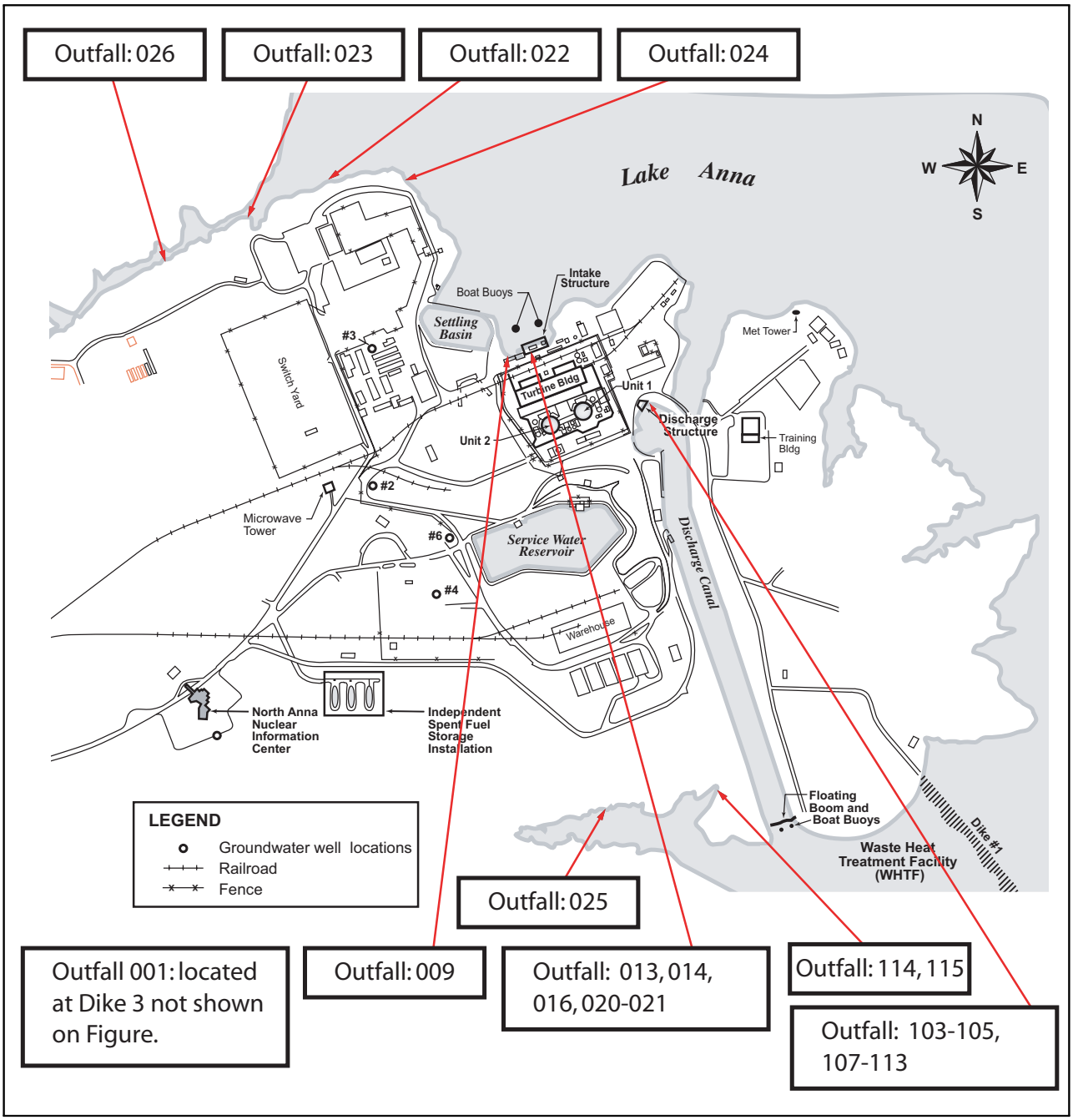

Figure 6.6-2 Location of Monitored VPDES Permit Outfalls

6.7 Summary of Monitoring Programs

This section summarizes all of the environmental monitoring programs described in Chapter 6. The summary is divided into three sections:

- Pre-application monitoring
- Construction and Pre-Operational monitoring
- Operational monitoring

6.7.1 Pre-Application Monitoring

Table 6.7-1 through Table 6.7-6 summarize the pre-application monitoring programs. These programs represent continuations of the thermal, radiological, hydrological, meteorological, ecological, and chemical monitoring programs currently being performed at the NAPS site.

6.7.2 Construction and Pre-Operational Monitoring

The current thermal, radiological, hydrological, meteorological, ecological, and chemical monitoring programs for the existing units would be continued through the construction and pre-operational phases of the new units. Table 6.7-1 through Table 6.7-6 reflect this continuation.

6.7.3 Operational Monitoring

While specific operational monitoring requirements and programs for the new units have not been established at this time, they would be similar to those monitoring programs outlined in Table 6.7-1 through Table 6.7-6. The operational monitoring programs may be modified as a result of future consultations with appropriate VDEQ and other Commonwealth of Virginia and municipal authorities. The need for further modifications (e.g., changes in monitoring locations, parameters, collection, or analytical procedures) would be assessed prior to and during the course of operation.

Section 6.7 References

None

Table 6.7-1 Pre-Application, Construction/Pre-Operational, and Operational Thermal Monitoring Program

Sites	Monitoring Location	Sampling Methodology	Sampling Frequency
NALST10	Lake Anna: Mid-level in Lake in the flow through Lake Anna Dike 3	Mid-level depth at 3 m water depth	2/year
NALBRPT	Lake Anna: near Burruss Point	Surface	2/year
NALTHIS	Lake Anna: near Thurman Island	Surface	2/year
NALIN	Lake Anna: at North Station intakes	Surface	2/year
NAL208	Lake Anna: Route. 208 Bridge	Surface	2/year
NADISC1	At end of station discharge in Lagoon (Pond) 1	Surface	2/year
NAWHTF2	Lagoon (Pond) 2	Surface	2/year
NAWHTF3	Lagoon (Pond) 3	Surface	2/year
NAL719S	North Anna River arm of Lake Anna at Route 719 bridge	Surface	2/year
NAL719N	Pamunkey Creek arm of Lake Anna at Route 719 bridge	Surface	2/year
NARIV601	Route 601 crossing	Surface, at Route 601 crossing	4/year

Table 6.7-2 Pre-Application, Construction/Pre-Operational, and Operational Radiological Monitoring Program

Radiation Exposure Pathways Monitored	Parameters	Frequency
Direct	Radiation Levels	Quarterly
Airborne, including Gaseous, Particulate, and Iodine	Radiation Levels Concentrations Radioactive Material Quantities	Continuous, Weekly, Quarterly
Waterborne, including Surface, Ground, and Sediment	Concentrations Radioactive Material Quantities	Monthly, Quarterly, Semi-annually
Ingestion, including Milk, Aquatic, Vegetation, and Food products	Concentrations Radioactive Material Quantities	Monthly, Semi-annually

Table 6.7-3 Pre-Application, Construction/Pre-Operational, and Operational Hydrological Monitoring Program

Monitoring Location	Constituent (units)	Frequency	Sample Type
001 - Discharge of Condenser Cooling Water from Heat Treatment Facility at Dike 3	Flow (mgd)	1/month	Calculated
103 - Process Waste Clarifier	Flow (mgd)	2/month	Estimate
104 - Oil Water Separator and Storm Water	Flow (mgd)	2/month	Estimate
105 - Bearing Cooling Tower Blowdown	Flow (mgd)	1/month	Estimate
107 - Bearing Cooling Tower System Discharge - Lake to Lake Operation	Flow (mgd)	1/month	Estimate
108 - Service Water Overflow	Flow (mgd)	1/month	Estimate
109 & 110 - Hot Well Drains	Flow (mgd)	1/month	Estimate
111 - Sewage	Flow (mgd)	1/day	Estimate
112 & 113 - Steam Generator Blowdown Units 1 & 2	Flow (mgd)	1/month	Estimate
114 - Service Water Pipe Vault Drain	Flow (mgd)	1/month	Estimate
115 - Service Water System Blowdown	Flow (mgd)	1/month	Estimate
009 - Ground Water, Storm Water, Backwash from Sand Filters and RO Units	Flow (mgd)	1/month	Estimate
013 - Turbine Building Sump #1 and Storm Water	Flow (mgd)	1/month	Estimate
014 - Turbine Building Sump #2 and Storm Water	Flow (mgd)	1/month	Estimate
016 - Intake Screen Wash Water	Flow (mgd)	1/year	Estimate
020 - RO Reject	Flow (mgd)	2/month	Estimate
021 - RO Drain Line	Flow (mgd)	1/month	Estimate
022 – 026 - Storm Water Outfalls	Flow	1/storm event	Grab

Table 6.7-4 Pre-Application, Construction/Pre-Operational, and Operational Meteorological Monitoring Program

Primary Tower Meteorological Parameters			
	Transmitted Locations		
Parameter	**ERF Data Base**	**Control Room**	**Remote Interrogation**
Wind Direction (upper)	X	X	X
Wind Speed (upper)	X	X	X
Sigma theta (upper)			X
Wind Direction (lower)	X	X	X
Wind Speed (lower)	X	X	X
Sigma theta (lower)			X
Ambient Temperature (lower)	X	X	X
Dew point (lower)			X
Delta Ambient Temperature (upper-lower)	X	X	X
Precipitation			X
Backup Tower Meteorological Parameters			
Wind Speed	X	X	X
Wind Direction	X	X	X
Sigma Theta	X	X	X

Note: All parameters are continuously monitored. All parameters going to the ERF database would be available for printout in the existing TSC and EOF. The Units 1 & 2 control room parameters are hardwired.

Table 6.7-5 Pre-Application, Construction/Pre-Operational, and Operational Ecological Monitoring Program

Category	Monitoring Location	Summary	Sampling Methodology	Sampling Frequency
Ecological (Terrestrial)	Site property and immediate vicinity	Bird count in December or January	Visual observation	Variable
Ecological (Terrestrial)	Transmission line corridors	Rare plant survey (National Heritage Program)	Ground-base inspection	Variable
Ecological (Aquatic)	Lake Anna, WHTF	Fish surveys (species, numbers, size distributions)	Electro-fishing, gillnetting	4/year
Ecological (Aquatic)	North Anna River	Smallmouth and largemouth bass abundance survey	Snorkel observations along transects	6/year
Ecological (Aquatic)	Lake Anna, WHTF, and Service Water Reservoir	Shellfish surveys	Virginia Power biologist collection of replicate samples	2/year
Ecological (Aquatic)	North Anna River	Benthic macro-invertebrate studies	Virginia Power biologist collection	Periodic in drought conditions
Ecological (Aquatic)	Lake Anna	Hydrilla inspections	Aerial and ground-based inspection	
Ecological (Aquatic)	Lake Anna	VDGIF-sponsored fish monitoring program		1/year
Ecological (Aquatic)	North Anna River	Monitor fin fish population	Electro-fishing	3/year

Table 6.7-6 VPDES Water Quality Monitoring Program

Monitoring Location	Constituent (units)	Frequency	Sample Type
001 - Discharge of Condenser Cooling Water from Heat Treatment Facility at Dike 3 (Note 1)	Flow (mgd)	1/month	Calculated
	pH	1/year	Grab
	Heat Rejected ($\times 10^9$ Btu/hr)	1/day	Calculated
	Total Residual Chlorine (mg/l)	1/month	Grab
	Copper	1/5 years beginning 2004	Grab
	Nickel	1/5 years beginning 2004	Grab
	Acute and Chronic Toxicity Test	August/September 2004 or 2005 1/3 months if test fails for one year. Annually thereafter.	48-hour static test using Ceriodaphnia dubia to determine No Observable Adverse Effects Concentration (NOAEC).
103 – Process Waste Clarifier (Note 1)	Flow (mgd)	2/month	Estimate
	pH	2/month	Grab
	Suspended Solids (mg/l)	1/3 months	Grab
	Oil and Grease (mg/l)	1/3 months	Grab
104 – Oil Water Separator and Storm Water (Note 1)	Flow (mgd)	2/month	Estimate
	pH	2/month	Grab
	Suspended Solids (mg/l)	1/3 months	Grab
	Oil and Grease (mg/l)	1/3 months	Grab
105 – Bearing Cooling Tower Blowdown (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
	Free Available Chlorine	1/month	Grab
	Priority Pollutants (mg/l) Note: 126 Priority Pollutants contained in cooling tower treatment chemicals except for total chromium and total zinc.	1/3 months	Grab
	Total Chromium (mg/l)	1/3 months	Grab
	Total Zinc (mg/l	1/3 months	Grab

Table 6.7-6 VPDES Water Quality Monitoring Program

Monitoring Location	Constituent (units)	Frequency	Sample Type
107 - Bearing Cooling Tower System Discharge-Lake to Lake Operation (Note 1)	Flow (mgd)	1/month	Estimate
	Total Residual Chlorine (mg/l)	1/month	Grab
108 – Service Water Overflow (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
109 & 110 – Hot Well Drains (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
	Suspended Solids (mg/l)	1/month	Grab
	Oil and Grease (mg/l)	1/month	Grab
111 - Sewage (Note 1)	Flow (mgd)	1/day	Estimate
	pH	1/month	Grab
	BOD _ 5day (mg/l)	1/6 months	Grab
	Suspended Solids (mg/l)	1/3 months	Grab
	Total Residual Chlorine (mg/l) or Fecal Coliform (n/100 ml)	1/day 1/week	Grab Grab
112 & 113 – Steam Generator Blowdown Units 1 & 2 (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
	Suspended Solids (mg/l)	1/6 months	Grab
	Oil and Grease (mg/l)	1/6 months	Grab
114 – Service Water Pipe Vault Drain (Note 1)	Flow (mgd)	1/month	Estimate
115 – Service Water System Blowdown (Note 1)	Flow (mgd)	1/month	Estimate
009 – Groundwater, Storm Water, Backwash form Sand Filters and RO Units (Note 1)	Flow (mgd)	1/month	Estimate
	pH	2/month	Grab
	Suspended Solids (mg/l)	1/3 months	Grab

Table 6.7-6 VPDES Water Quality Monitoring Program

Monitoring Location	Constituent (units)	Frequency	Sample Type
013 - Turbine Building Sump #1 and Storm Water (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
	Suspended Solids (mg/l)	1/month	Grab
	Oil and Grease (mg/l)	1/month	Grab
014 - Turbine Building Sump #2 and Storm Water (Note 1)	Flow (mgd)	1/month	Estimate
	pH	1/month	Grab
	Suspended Solids (mg/l)	1/month	Grab
	Oil and Grease (mg/l)	1/month	Grab
016 – Intake Screen Wash Water (Note 1)	Flow (mgd)	1/year	Estimate
020 – RO Reject (Note 1)	Flow (mgd)	2/month	Estimate
	pH	2/month	Grab
	Suspended Solids (mg/l)	1/3 months	Grab
	Total Residual Chlorine	2/month	Grab
021 – RO Drain Line (Note 1)	Flow (mgd)	1/month	Estimate
022 to 026 Storm Water Associated with Industrial Activities (Note 1)	Total Recoverable Iron	2/year for years 2005 and 2006, immediately after applicable storm event (>0.1 inch)	Grab
	Visual Inspection	1/3 months immediately following applicable storm event (>0.1 inch)	Visual observation
Station 1 – 9 & 11 (Note 2)	Temperature (°C)	Hourly during summer quarter and one other alternating quarter of year	Automated surface measurement.
Station 10 (Note 2)	Temperature (°C)	Hourly during summer quarter and one other alternating quarter of year	Automated 3 m deep measurement

Table 6.7-6 VPDES Water Quality Monitoring Program

Monitoring Location	Constituent (units)	Frequency	Sample Type
Stations A – N (Note 3)	Temperature (°C)	Hourly measurements during daylight hours	Automated surface to bottom measurements at one meter intervals

Data Source: VPDES Permit

Notes:
1. See Figure 6.6-2 for location.
2. See Figure 6.6-1 for location.
3. See Figure 6.2-3 for location.

Chapter 7 Environmental Impacts of Postulated Accidents Involving Radioactive Materials

The purpose of this section is to assess the environmental impacts of postulated accidents involving radioactive materials. Section 7.1 evaluates DBAs, Section 7.2 considers the impact of severe accidents, Section 7.3 addresses severe accident mitigation alternatives (SAMA), and Section 7.4 pertains to transportation accidents.

7.1 Design Basis Accidents

7.1.1 Selection of Accidents

The radiological consequences of accidents are assessed to demonstrate that new units could be constructed and operated at the ESP site without undue risk to the health and safety of the public. The assessment uses site-specific accident meteorology with the radiological analyses in selected reactor designs to analyze the suitability of the ESP site. The assessment uses a robust and conservative set of surrogate DBAs that is representative of the range of reactor designs being considered for the ESP site. The DBAs include a spectrum of events, including those of relatively greater probability of occurrence as well as those that are less probable but have greater severity.

The set of accidents selected focuses on three light water reactor (LWR) designs: AP1000, ABWR, and ESBWR. These three designs have been chosen because these are standard designs that have recognized bases for postulated accident analyses. The accidents for some of the newer reactor types being considered are not as well defined as those for these LWRs and, hence, the accepted analytical methodologies and assumptions applied to LWRs may not apply to these newer reactors. However, because of their greater potential for inherent safety, the accident radiological consequences of the other reactors being considered for the site are expected to be bounded by the AP1000, the ABWR, and the ESBWR. If one of these other designs is eventually selected for the ESP site, the COL application would verify that the AP1000, ABWR, and ESBWR doses are bounding or provide a complete evaluation of accident radiological consequences compared with regulatory limits.

The following LWR accidents are identified in NUREG-1555, Section 7.1, Appendix A (Reference 1), as those that should be considered for radiological consequences, based on the SRP, NUREG-0800 (Reference 2):

- SRP Section 15.1.5, PWR Main Steam Line Break
- SRP Section 15.2.8, Feedwater System Pipe Break
- SRP Section 15.3.3, Locked Rotor Accident
- SRP Section 15.3.4, Reactor Coolant Pump Shaft Break
- SRP Section 15.4.9, BWR Control Rod Drop Accident

- SRP Section 15.6.2, Failure of Small Lines Carrying Primary Coolant Outside Containment
- SRP Section 15.6.3, PWR Steam Generator Tube Failure
- SRP Section 15.6.5, Loss-of-Coolant Accident
- SRP Section 15.7.4, Fuel Handling Accident

RG 1.183 (Reference 3) includes the following additional accidents:

- PWR Rod Ejection Accident (corresponds to SRP Section 15.4.8)
- BWR Main Steam Line Break (corresponds to SRP Section 15.6.4)

In addition, a cleanup water line break is evaluated for the ABWR and the ESBWR. The radiological consequences from the above DBAs are analyzed. This set of accidents provides a reasonable basis for evaluating the suitability of the ESP site.

7.1.2 **Evaluation Methodology**

Doses for the representative DBAs are evaluated at the EAB and the LPZ. These doses must meet the site acceptance criteria in 10 CFR 50.34 and 10 CFR 100 (Reference 4 and Reference 5, respectively). Although the emergency safety features are expected to prevent core damage and mitigate releases of radioactivity, the loss-of-coolant accidents (LOCAs) analyzed presume substantial core melt with the release of significant amounts of fission products. The postulated LOCAs are expected to more closely approach 10 CFR 50.34 limits than the other DBAs of greater probability of occurrence but lesser magnitude of activity releases. For these accidents, the calculated doses are compared to the acceptance criteria in RG 1.183 and NUREG-0800, to demonstrate that the consequences of the postulated accidents are acceptable.

The evaluations use short-term accident atmospheric dispersion factors (χ/Q). The χ/Qs are calculated using the methodology of RG 1.145 (Reference 6) and site-specific meteorological data. The following site-specific 50th percentile χ/Q values from Section 2.7.5.2 are used in these evaluations, per NUREG-1555:

- EAB – 3.34E-5 sec/m^3
- LPZ – 2.17E-6 sec/m^3

The accident dose calculations are performed using the activity releases for the following time intervals:

- EAB – 0 to 2 hours
- LPZ – 0 to 8 hours, 8 to 24 hours, 24 to 96 hours, and 96 to 720 hours

The accident doses are expressed as TEDE, consistent with 10 CFR 50.34. The TEDE consists of the sum of the committed effective dose equivalent (CEDE) from inhalation and either the deep dose equivalent (DDE) or the effective dose equivalent (EDE) from external exposure. The CEDE is determined using the dose conversion factors in Federal Guidance Report 11 (Reference 7), while

the DDE and the EDE are based on dose conversion factors in Federal Guidance Report 12 (Reference 8).

7.1.3 Source Terms

Doses are calculated based on the time-dependent activities released to the environment during each DBA. The activities are based on the analyses used to support the reactor standard safety analysis reports. Different reactor technologies use different source terms and approaches in defining the activity releases. The ABWR source term is based on TID-14844 (Reference 9). Environmental releases are calculated using the guidance in the NUREG-0800 and RGs 1.3 and 1.25 (Reference 10 and Reference 11, respectively). The AP1000 and ESBWR source terms, methodologies, and assumptions are based on the alternative source term methods outlined in RG 1.183. The activity releases and doses for the AP1000, the ABWR, and the ESBWR are based on 102 percent of core thermal power.

The ABWR activity releases are scaled up from a power level of 4005 MWt (102 percent of 3926 MWt, as specified in the design certification) to 4386 MWt (102 percent of 4300 MWt, the power proposed for a new ABWR unit at the ESP site), an adjustment factor of 1.10. Because the ESBWR design has not yet been certified by the NRC, the ESBWR design control document activity releases are increased by 25 percent to allow for uncertainty.

The IRIS and ACR-700 source term information are preliminary, but the AP1000 LOCA is expected to bound the worst-case accident releases for these advanced reactor concepts.

The advanced gas reactor designs (GT-MHR and PBMR) use mechanistic accident source terms and postulate relatively small environmental releases, compared with the water reactor technologies. The activity releases to the environment are typically provided by the reactor vendors as part of their standard design packages.

7.1.4 Radiological Consequences

For the AP1000 and ABWR accidents identified in Section 7.1.1, site-specific doses are calculated by multiplying the design certification doses by the ratio of site χ/Qs to design certification χ/Qs. Using the EAB and LPZ site χ/Qs of 3.34E-5 and 2.17E-6 sec/m^3, respectively, from Section 7.1.2,

with the design certification χ/Qs (Reference 12 and Reference 13), the following ratios are obtained:

Table 7.1-1 Design Certification χ/Q Values and Ratios to Site χ/Q Values

		χ/Q (sec/m^3)		Ratio (Site/DC)	
	Time (hr)	**AP1000**	**ABWR**	**AP1000**	**ABWR**
EAB	0–2	6.00E-04	1.37E-03	5.57E-02	2.44E-02
LPZ	0–8	1.35E-04	1.56E-04	1.61E-02	1.39E-02
	8–24	1.00E-04	9.61E-05	2.17E-02	2.26E-02
	24–96	5.40E-05	3.36E-05	4.02E-02	6.46E-02
	96–720	2.20E-05	7.42E-06	9.86E-02	2.92E-01

Details about the methodology and assumptions pertaining to each of the accidents, such as activity release paths and the credited mitigation features, may be found in the design certification documents for the AP1000 (Reference 12), the ABWR (Reference 13), and the ESBWR (Reference 14).

As the ABWR design certification document presents whole body and thyroid doses, an equivalent TEDE value is estimated by multiplying the thyroid dose by 0.03 and adding the product to the whole body dose in accordance with RG 1.183. Also, consistent with the activity releases in Section 7.1.3, the ABWR doses are scaled up by a factor of 1.10 from a power level of 4005 MWt (102 percent of 3926 MWt, as specified in the design certification) to 4386 MWt (102 percent of 4300 MWt, the power proposed for a new ABWR unit at the ESP site).

As the ESBWR design has not yet been certified by the NRC, the doses are calculated based on activity releases, which include a margin of 25 percent to allow for uncertainty. The TEDE dose from an isotope for a given time period is calculated by adding the CEDE from inhalation and the EDE from external exposure. The CEDE is calculated by multiplying the isotopic activity by the site χ/Q value, the breathing rate of the individual located offsite, and the effective inhalation dose conversion factor from Federal Guidance Report 11. The EDE is calculated by multiplying the isotopic activity by the site χ/Q value and the effective submersion dose conversion factor from Federal Guidance Report 12.

A summary of the resulting accident doses is presented in Table 7.1-2. This table also compares the environmental doses to the recommended limits in RG 1.183 and NUREG-0800 and shows that the evaluated dose consequences are within the recommended limits.

The TEDE dose limits in Table 7.1-2 are taken from RG 1.183, Table 6, for all accidents except PWR Reactor Coolant Pump Shaft Break (SRP Section 15.3.4) and Failure of Small Lines Carrying Primary Coolant Outside Containment (SRP Section 15.6.2). For these two accidents,

NUREG-0800 indicates that the dose limit is a “small fraction” or 10 percent of the 10 CFR 100 guideline of 25 Rem, meaning a limit of 2.5 Rem.

The doses summarized in Table 7.1-2 are based on the time-dependent doses presented in Table 7.1-3 to Table 7.1-32 for each of the accidents. In addition to doses, the latter tables also show the activities released to the environment.

Section 7.1 References

1. NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants*, NRC, October 1999.

2. NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants*, NRC, 1987.

3. Regulatory Guide 1.183, *Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors*, NRC, July 2000.

4. 10 CFR 50.34, *Code of Federal Regulations*, “Contents of applications; technical information.”

5. 10 CFR 100, *Code of Federal Regulations*, “Reactor Site Criteria.”

6. Regulatory Guide 1.145, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, Revision 1, NRC, November 1982.

7. Federal Guidance Report 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, U. S. Environmental Protection Agency, EPA-520/1-88-020, 1988.

8. Federal Guidance Report 12, *External Exposure to Radionuclides in Air, Water, and Soil*, U. S. Environmental Protection Agency, EPA-402-R-93-081, 1993.

9. TID-14844, *Calculation of Distance Factors for Power and Test Reactor Sites*, U. S. Atomic Energy Commission, March 1962.

10. Regulatory Guide 1.3, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors*, Revision 2, NRC, June 1974.

11. Regulatory Guide 1.25 (Safety Guide 25), *Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors*, NRC, March 1972.

12. AP1000 Document No. APP-GW-GL-700, *AP1000 Design Control Document*, Tier 2 Material, Westinghouse, Revision 2, 2002.

13. Document 23A6100, *ABWR Standard Safety Analysis Report*, General Electric, Revision 8.

14. Document 26A6642, *ESBWR Design Control Document*, Tier 2 Material, General Electric, Revision 1.

Table 7.1-2 Summary of Design Basis Accident Doses

SRP Section	Accident	Reactor	TEDE (Rem) EAB	TEDE (Rem) LPZ	TEDE (Rem) Limit
15.1.5	PWR Main Steam Line Break				
	Pre-Existing Iodine Spike	AP1000	3.9E-02	1.1E-02	25
	Accident-Initiated Iodine Spike	AP1000	4.5E-02	4.5E-02	2.5
15.2.8	Feedwater System Pipe Break	AP1000	See Note 1		2.5
		ABWR	See Note 2		2.5
		ESBWR	6.8E-06	4.4E-07	2.5
15.3.3	Reactor Coolant Pump Rotor Seizure (Locked Rotor Accident)	AP1000	1.4E-01	9.6E-03	2.5
		ABWR/ESBWR	Not Postulated		2.5
15.3.4	Reactor Coolant Pump Shaft Break	AP1000	See Note 3		2.5
		ABWR/ESBWR	Not Postulated		2.5
15.4.8	PWR Rod Ejection Accident	AP1000	1.7E-01	3.1E-02	6.3
15.4.9	BWR Control Rod Drop Accident	ABWR/ESBWR	Not Postulated		6.3
15.6.2	Failure of Small Lines Carrying Primary Coolant Outside Containment	AP1000	7.2E-02	4.8E-03	2.5
		ABWR	6.4E-03	4.1E-04	2.5
		ESBWR	4.5E-03	6.8E-04	2.5
15.6.3	PWR Steam Generator Tube Rupture				
	Pre-Existing Iodine Spike	AP1000	1.7E-01	5.7E-03	25
	Accident-Initiated Iodine Spike	AP1000	8.4E-02	4.5E-03	2.5
15.6.4	BWR Main Steam Line Break				
	Pre-Existing Iodine Spike	ABWR	7.6E-02	4.9E-03	25
	Equilibrium Iodine Spike	ABWR	3.7E-03	2.4E-04	2.5
	Pre-Existing Iodine Spike	ESBWR	3.1E-01	2.0E-02	25
	Equilibrium Iodine Spike	ESBWR	1.6E-02	1.0E-03	2.5
15.6.5	Loss-of-Coolant Accident	AP1000	1.4E+00	2.0E-01	25
		ABWR	2.6E-01	1.7E+00	25
		ESBWR	2.1E-01	2.0E-01	25

Table 7.1-2 Summary of Design Basis Accident Doses

SRP Section	Accident	Reactor	TEDE (Rem) EAB	LPZ	Limit
15.7.4	Fuel Handling Accident	AP1000	1.3E-01	9.6E-03	6.3
		ABWR	9.2E-02	6.0E-03	6.3
		ESBWR	1.8E-01	1.2E-02	6.3
	Cleanup Water Line Break	ABWR	4.7E-04	3.0E-05	2.5
		ESBWR	2.6E-02	1.7E-03	2.5

Notes:

1. The AP1000 design certification indicates that the doses for the feedwater system pipe break are bounded by the main steam line break (Reference 12, Section 15.2.8.3).
2. The ABWR design certification indicates that the doses for the feedwater system pipe break are bounded by the cleanup water line break (Reference 13, Section 15.2.8).
3. The AP1000 design certification indicates that the doses for the reactor coolant pump shaft break are bounded by the reactor coolant pump rotor seizure (Reference 12, Section 15.3.4.2).
4. The ABWR design certification indicates that there are no radiological consequences for the reactor coolant pump rotor seizure, the reactor coolant pump shaft break, and the control rod drop accident (Reference 13, Sections 15.3.3.5, 15.3.4.5, and 15.4.10.6).
5. The ESBWR design certification indicates that there are no radiological consequences for the reactor coolant pump rotor seizure, the reactor coolant pump shaft break, and the control rod drop accident (Reference 14).

Table 7.1-3 Activity Releases for AP1000 Main Steam Line Break, Pre-Existing Iodine Spike

	Activity Release (Ci)				
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–72 hr**	**Total**
Kr-85m	2.30E-01	3.82E-01	2.26E-01	2.03E-02	8.58E-01
Kr-85	9.47E-01	2.83E+00	7.47E+00	2.17E+01	3.29E+01
Kr-87	9.24E-02	4.49E-02	1.76E-03	2.84E-07	1.39E-01
Kr-88	3.77E-01	4.59E-01	1.34E-01	2.72E-03	9.73E-01
Xe-131m	4.28E-01	1.27E+00	3.26E+00	8.78E+00	1.37E+01
Xe-133m	5.31E-01	1.51E+00	3.45E+00	6.69E+00	1.22E+01
Xe-133	3.95E+01	1.15E+02	2.87E+02	7.03E+02	1.14E+03
Xe-135m	1.02E-02	4.44E-05	0.00E+00	0.00E+00	1.02E-02
Xe-135	1.04E+00	2.31E+00	2.78E+00	1.11E+00	7.24E+00
Xe-138	1.34E-02	3.81E-05	0.00E+00	0.00E+00	1.34E-02
I-130	4.98E-01	4.74E-01	6.95E-01	4.36E-01	2.10E+00
I-131	3.37E+01	4.05E+01	1.03E+02	2.67E+02	4.44E+02
I-132	4.02E+01	1.39E+01	2.68E+00	2.16E-02	5.68E+01
I-133	6.03E+01	6.35E+01	1.17E+02	1.30E+02	3.71E+02
I-134	8.24E+00	5.47E-01	4.77E-03	1.50E-08	8.79E+00
I-135	3.56E+01	2.73E+01	2.51E+01	5.60E+00	9.36E+01
Cs-134	1.91E+01	6.52E-01	1.72E+00	5.00E+00	2.65E+01
Cs-136	2.84E+01	9.57E-01	2.47E+00	6.69E+00	3.85E+01
Cs-137	1.38E+01	4.70E-01	1.24E+00	3.61E+00	1.91E+01
Cs-138	1.02E+01	3.41E-03	1.48E-06	0.00E+00	1.02E+01
Total	2.93E+02	2.72E+02	5.58E+02	1.16E+03	2.28E+03

Table 7.1-4 Doses for AP1000 Main Steam Line Break, Pre-Existing Iodine Spike

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	7.00E-01		5.57E-02	3.90E-02	
0–8 hr		2.40E-01	1.61E-02		3.86E-03
8–24 hr		8.00E-02	2.17E-02		1.74E-03
24–96 hr		1.30E-01	4.02E-02		5.22E-03
96–720 hr		0.00E+00	9.86E-02		0.00E+00
Total	7.00E-01	4.50E-01		3.90E-02	1.08E-02
Limit				25	25

Table 7.1-5 Activity Releases for AP1000 Main Steam Line Break, Accident-Initiated Iodine Spike

	Activity Release (Ci)				
Isotope	**0-2 hr**	**2-8 hr**	**8-24 hr**	**24-72 hr**	**Total**
Kr-85m	2.30E-01	3.82E-01	2.26E-01	2.03E-02	8.58E-01
Kr-85	9.47E-01	2.83E+00	7.47E+00	2.17E+01	3.29E+01
Kr-87	9.24E-02	4.49E-02	1.76E-03	2.84E-07	1.39E-01
Kr-88	3.77E-01	4.59E-01	1.34E-01	2.72E-03	9.73E-01
Xe-131m	4.28E-01	1.27E+00	3.26E+00	8.78E+00	1.37E+01
Xe-133m	5.31E-01	1.51E+00	3.45E+00	6.69E+00	1.22E+01
Xe-133	3.95E+01	1.15E+02	2.87E+02	7.03E+02	1.14E+03
Xe-135m	1.02E-02	4.44E-05	0.00E+00	0.00E+00	1.02E-02
Xe-135	1.04E+00	2.31E+00	2.78E+00	1.11E+00	7.24E+00
Xe-138	1.34E-02	3.81E-05	0.00E+00	0.00E+00	1.34E-02
I-130	6.84E-01	3.33E+00	5.27E+00	3.30E+00	1.26E+01
I-131	3.92E+01	1.92E+02	5.18E+02	1.35E+03	2.10E+03
I-132	9.12E+01	3.26E+02	7.46E+01	6.00E-01	4.92E+02
I-133	7.75E+01	3.81E+02	7.54E+02	8.34E+02	2.05E+03
I-134	3.03E+01	6.23E+01	8.85E-01	2.78E-06	9.35E+01
I-135	5.57E+01	2.59E+02	2.61E+02	5.82E+01	6.34E+02
Cs-134	1.91E+01	6.52E-01	1.72E+00	5.00E+00	2.65E+01
Cs-136	2.84E+01	9.57E-01	2.47E+00	6.69E+00	3.85E+01
Cs-137	1.38E+01	4.70E-01	1.24E+00	3.61E+00	1.91E+01
Cs-138	1.02E+01	3.41E-03	1.48E-06	0.00E+00	1.02E+01
Total	4.09E+02	1.35E+03	1.92E+03	3.00E+03	6.68E+03

Table 7.1-6 Doses for AP1000 Main Steam Line Break, Accident-Initiated Iodine Spike

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	8.00E-01		5.57E-02	4.45E-02	
0–8 hr		6.40E-01	1.61E-02		1.03E-02
8–24 hr		4.20E-01	2.17E-02		9.11E-03
24–96 hr		6.30E-01	4.02E-02		2.53E-02
96–720 hr		0.00E+00	9.86E-02		0.00E+00
Total	8.00E-01	1.69E-00		4.45E-02	4.47E-02
Limit				2.5	2.5

Table 7.1-6a Activity Releases for ABWR Cleanup Water Line Break

	Activity Release (Ci)
Isotope	0–2 hr
I-131	2.40E+00
I-132	5.62E+00
I-133	6.80E+00
I-134	9.46E+00
I-135	7.39E+00
Total	3.17E+01

Table 7.1-6b Doses for ABWR Cleanup Water Line Break

	ABWR EAB Dose (S_v)			χ/Q Ratio	Site TEDE (Rem)	
Time	**W. Body**	**Thyroid**	**TEDE**	**(Site/ABWR)**	**EAB**	**LPZ**
0–2 hr	1.70E-04	1.70E-04	1.75E-04	2.44E-02	4.68E-04	
0–8 hr	1.70E-04	1.70E-04	1.75E-04	1.58E-03		3.04E-05
8–24 hr						0.00E+00
24–96 hr						0.00E+00
96–720 hr						0.00E+00
Total	1.70E-04	1.70E-04	1.75E-04		4.68E-04	3.04E-05
Limit					2.5	2.5

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. Since the ABWR design certification document does not include an LPZ dose for this accident, the site LPZ dose is obtained by multiplying the ABWR EAB dose by the ratio of site LPZ χ/Q to ABWR EAB χ/Q. The site doses include a multiplier of 1.10 for power adjustment.

Table 7.1-6c Activity Releases for ESBWR Feedwater System Pipe Break

	Activity Release (Ci)
Isotope	**0–2 hr**
I-131	4.39E-03
I-132	4.05E-02
I-133	2.94E-02
I-134	7.43E-02
I-135	4.05E-02
Total	1.89E-01

Table 7.1-6d Doses for ESBWR Feedwater System Pipe Break

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
0–2 hr	6.85E-06	
0–8 hr		4.45E-07
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	6.85E-06	4.45E-07
Limit	2.5	2.5

Table 7.1-7 Activity Releases for AP1000 Locked Rotor Accident

	Activity Release (Ci)
Isotope	**0–2 hr**
Kr-85m	4.09E+02
Kr-85	3.77E+01
Kr-87	6.05E+02
Kr-88	1.05E+03
Xe-131m	1.87E+01
Xe-133m	1.02E+02
Xe-133	3.33E+03
Xe-135m	1.63E+02
Xe-135	8.01E+02
Xe-138	6.48E+02
I-130	4.15E+00
I-131	1.83E+02
I-132	1.33E+02
I-133	2.31E+02
I-134	1.44E+02
I-135	2.04E+02
Cs-134	5.83E+00
Cs-136	1.85E+00
Cs-137	3.42E+00
Cs-138	3.05E+01
Rb-86	6.69E-02
Total	8.11E+03

Table 7.1-8 Doses for AP1000 Locked Rotor Accident

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	**EAB**	**LPZ**	**(Site/AP1000)**	**EAB**	**LPZ**
0–2 hr	2.50E+00		5.57E-02	1.39E-01	
0–8 hr		6.00E-01	1.61E-02		9.64E-03
8–24 hr		0.00E+00	2.17E-02		0.00E+00
24–96 hr		0.00E+00	4.02E-02		0.00E+00
96–720 hr		0.00E+00	9.86E-02		0.00E+00
Total	2.50E+00	6.00E-01		1.39E-01	9.64E-03
Limit				2.5	2.5

Table 7.1-9 Activity Releases for AP1000 Rod Ejection Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Kr-85m	2.85E+02	6.48E+01	3.87E+01	3.53E+00	5.01E-05	3.92E+02
Kr-85	1.24E+01	5.60E+00	1.49E+01	6.70E+01	5.71E+02	6.71E+02
Kr-87	4.86E+02	2.60E+01	1.03E+00	1.67E-04	0.00E+00	5.13E+02
Kr-88	7.49E+02	1.18E+02	3.49E+01	7.18E-01	1.68E-08	9.03E+02
Xe-131m	1.22E+01	5.46E+00	1.42E+01	5.72E+01	2.31E+02	3.20E+02
Xe-133m	6.62E+01	2.81E+01	6.49E+01	1.69E+02	1.06E+02	4.34E+02
Xe-133	2.18E+03	9.58E+02	2.40E+03	8.53E+03	1.68E+04	3.09E+04
Xe-135m	2.18E+02	5.30E-02	4.33E-09	0.00E+00	0.00E+00	2.18E+02
Xe-135	5.39E+02	1.72E+02	2.09E+02	8.69E+01	3.58E-01	1.01E+03
Xe-138	8.89E+02	1.38E-01	3.19E-09	0.00E+00	0.00E+00	8.89E+02
I-130	5.93E+00	7.28E+00	4.32E+00	4.06E-01	5.88E-04	1.79E+01
I-131	1.64E+02	2.45E+02	2.31E+02	6.20E+01	3.33E+01	7.35E+02
I-132	1.90E+02	9.94E+01	9.85E+00	1.65E-02	0.00E+00	2.99E+02
I-133	3.29E+02	4.40E+02	3.18E+02	4.56E+01	4.81E-01	1.13E+03
I-134	2.18E+02	2.85E+01	1.37E-01	8.96E-08	0.00E+00	2.47E+02
I-135	2.91E+02	2.97E+02	1.19E+02	4.79E+00	1.46E-04	7.12E+02
Cs-134	3.15E+01	6.22E+01	6.03E+01	1.55E+01	1.03E+01	1.80E+02
Cs-136	8.98E+00	1.75E+01	1.67E+01	4.10E+00	1.31E+00	4.86E+01
Cs-137	1.83E+01	3.62E+01	3.51E+01	9.04E+00	6.05E+00	1.05E+02
Cs-138	1.13E+02	7.05E+00	1.68E-03	0.00E+00	0.00E+00	1.20E+02
Rb-86	3.70E-01	7.27E-01	6.96E-01	1.73E-01	6.79E-02	2.03E+00
Total	6.81E+03	2.62E+03	3.57E+03	9.06E+03	1.78E+04	3.98E+04

Table 7.1-10 Doses for AP1000 Rod Ejection Accident

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	3.00E-00		5.57E-02	1.67E-01	
0–8 hr		1.40E+00	1.61E-02		2.25E-02
8–24 hr		2.60E-01	2.17E-02		5.64E-03
24–96 hr		4.60E-02	4.02E-02		1.85E-03
96–720 hr		1.20E-02	9.86E-02		1.18E-03
Total	3.00E-00	1.72E+00		1.67E-01	3.12E-02
Limit				6.3	6.3

Table 7.1-11 Doses for AP1000 Failure of Small Lines Carrying Primary Coolant Outside Containment

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	1.30E+00		5.57E-02	7.24E-02	
0–8 hr		3.00E-01	1.61E-02		4.82E-03
8–24 hr		0.00E+00	2.17E-02		0.00E+00
24–96 hr		0.00E+00	4.02E-02		0.00E+00
96–720 hr		0.00E+00	9.86E-02		0.00E+00
Total	1.30E+00	3.00E-01		7.24E-02	4.82E-03
Limit				2.5	2.5

Note: No activity release information is available for this accident.

Table 7.1-12 Activity Releases for ABWR Failure of Small Lines Carrying Primary Coolant Outside Containment

	Activity Release (Ci)		
Isotope	**0–2 hr**	**2–8 hr**	**Total**
I-131	2.01E+00	2.16E+00	4.17E+00
I-132	1.76E+01	1.76E+01	3.52E+01
I-133	1.36E+01	1.43E+01	2.79E+01
I-134	2.93E+01	2.69E+01	5.62E+01
I-135	1.95E+01	2.01E+01	3.96E+01
Total	8.20E+01	8.11E+01	1.63E+02

Table 7.1-13 Doses for ABWR Failure of Small Lines Carrying Primary Coolant Outside Containment

	ABWR EAB Dose (Sv)			χ/Q Ratio	Site TEDE (Rem)	
Time	**W. Body**	**Thyroid**	**TEDE**	**(Site/ABWR)**	**EAB**	**LPZ**
0–2 hr	9.40E-04	4.80E-02	2.38E-03	2.44E-02	6.36E-03	
0–8 hr	9.40E-04	4.80E-02	2.38E-03	1.58E-03		4.13E-04
8–24 hr						0.00E+00
24–96 hr						0.00E+00
96–720 hr						0.00E+00
Total	9.40E-04	4.80E-02	2.38E-03		6.36E-03	4.13E-04
Limit					2.5	2.5

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. Since the ABWR design certification document does not include an LPZ dose for this accident, the site LPZ dose is obtained by multiplying the ABWR EAB dose by ratio of site LPZ χ/Q to ABWR EAB χ/Q. The site doses include a multiplier of 1.10 for power adjustment.

Table 7.1-13a Activity Releases for ESBWR Failure of Small Lines Carrying Primary Coolant Outside Containment

	Activity Release (Ci)		
Isotope	**0–2 hr**	**2–8 hr**	**Total**
I-131	6.13E+00	1.05E+01	1.66E+01
I-132	8.03E+00	7.35E+00	1.54E+01
I-133	1.51E+01	2.35E+01	3.86E+01
I-134	8.78E+00	4.60E+00	1.34E+01
I-135	1.39E+01	1.85E+01	3.24E+01
Total	5.19E+01	6.45E+01	1.16E+02

Table 7.1-13b Doses for ESBWR Failure of Small Lines Carrying Primary Coolant Outside Containment

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
2–4 hr	4.49E-03	
0–8 hr		6.84E-04
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	4.49E-03	6.84E-04
Limit	2.5	2.5

Note: The maximum EAB dose occurs between 2 and 4 hours.

Table 7.1-14 Activity Releases for AP1000 Steam Generator Tube Rupture, Pre-Existing Iodine Spike

	Activity Release (Ci)			
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**Total**
Kr-85m	5.67E+01	1.91E+01	2.50E-02	7.58E+01
Kr-85	2.25E+02	1.07E+02	4.44E-01	3.32E+02
Kr-87	2.46E+01	3.56E+00	3.02E-04	2.82E+01
Kr-88	9.44E+01	2.61E+01	1.80E-02	1.21E+02
Xe-131m	1.02E+02	4.82E+01	1.96E-01	1.50E+02
Xe-133m	1.26E+02	5.83E+01	2.19E-01	1.85E+02
Xe-133	9.37E+03	4.41E+03	1.75E+01	1.38E+04
Xe-135m	3.61E+00	5.78E-03	0.00E+00	3.62E+00
Xe-135	2.51E+02	1.00E+02	2.35E-01	3.51E+02
Xe-138	4.78E+00	4.99E-03	0.00E+00	4.78E+00
I-130	1.81E+00	6.12E-02	2.90E-01	2.16E+00
I-131	1.22E+02	5.97E+00	3.32E+01	1.61E+02
I-132	1.43E+02	8.53E-01	2.08E+00	1.46E+02
I-133	2.19E+02	8.68E+00	4.41E+01	2.72E+02
I-134	2.78E+01	5.16E-03	4.57E-03	2.78E+01
I-135	1.28E+02	3.06E+00	1.26E+01	1.44E+02
Cs-134	1.65E+00	6.35E-02	2.27E-01	1.94E+00
Cs-136	2.45E+00	9.30E-02	3.30E-01	2.87E+00
Cs-137	1.19E+00	4.58E-02	1.64E-01	1.40E+00
Cs-138	5.71E-01	3.07E-06	6.00E-07	5.71E-01
Total	1.09E+04	4.79E+03	1.12E+02	1.58E+04

Table 7.1-15 Doses for AP1000 Steam Generator Tube Rupture, Pre-Existing Iodine Spike

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	3.00E-00		5.57E-02	1.67E-01	
0–8 hr		3.20E-01	1.61E-02		5.14E-03
8–24 hr		2.60E-02	2.17E-02		5.64E-04
24–96 hr		0.00E+00	4.02E-02		0.00E+00
96–720 hr		0.00E+00	9.86E-02		0.00E+00
Total	3.00E-00	3.46E-01		1.67E-01	5.71E-03
Limit				25	25

Table 7.1-16 Activity Releases for AP1000 Steam Generator Tube Rupture, Accident-Initiated Iodine Spike

	Activity Release (Ci)			
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**Total**
Kr-85m	5.67E+01	1.91E+01	2.50E-02	7.58E+01
Kr-85	2.25E+02	1.07E+02	4.44E-01	3.32E+02
Kr-87	2.46E+01	3.56E+00	3.02E-04	2.82E+01
Kr-88	9.44E+01	2.61E+01	1.80E-02	1.21E+02
Xe-131m	1.02E+02	4.82E+01	1.96E-01	1.50E+02
Xe-133m	1.26E+02	5.83E+01	2.19E-01	1.85E+02
Xe-133	9.37E+03	4.41E+03	1.75E+01	1.38E+04
Xe-135m	3.61E+00	5.78E-03	0.00E+00	3.62E+00
Xe-135	2.51E+02	1.00E+02	2.35E-01	3.51E+02
Xe-138	4.78E+00	4.99E-03	0.00E+00	4.78E+00
I-130	7.30E-02	1.19E-02	3.13E-02	1.16E-01
I-131	4.90E+00	1.15E+00	3.55E+00	9.60E+00
I-132	5.79E+00	1.75E-01	2.30E-01	6.20E+00
I-133	8.79E+00	1.68E+00	4.73E+00	1.52E+01
I-134	1.12E+00	1.18E-03	5.21E-04	1.12E+00
I-135	5.15E+00	6.01E-01	1.36E+00	7.11E+00
Cs-134	1.65E+00	6.35E-02	2.27E-01	1.94E+00
Cs-136	2.45E+00	9.30E-02	3.30E-01	2.87E+00
Cs-137	1.19E+00	4.58E-02	1.64E-01	1.40E+00
Cs-138	5.71E-01	3.07E-06	6.00E-07	5.71E-01
Total	1.03E+04	4.78E+03	2.93E+01	1.51E+04

Table 7.1-17 Doses for AP1000 Steam Generator Tube Rupture, Accident-Initiated Iodine Spike

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	1.50E+00		5.57E-02	8.35E-02	
0–8 hr		1.80E-01	1.61E-02		2.89E-03
8–24 hr		7.20E-02	2.17E-02		1.56E-03
24–96 hr		0.00E+00	4.02E-02		0.00E+00
96–720 hr		0.00E+00	9.86E-02		0.00E+00
Total	1.50E+00	2.52E-01		8.35E-02	4.46E-03
Limit				2.5	2.5

Table 7.1-18 Activity Releases for ABWR Main Steam Line Break

	Activity Release (Ci)	
Isotope	Pre-Existing	Equilibrium Activity
I-131	4.32E+01	2.16E+00
I-132	4.20E+02	2.10E+01
I-133	2.95E+02	1.48E+01
I-134	8.25E+02	4.14E+01
I-135	4.32E+02	2.16E+01
Kr-83m	7.22E-02	1.20E-02
Kr-85m	1.27E-01	2.12E-02
Kr-85	4.02E-04	6.68E-05
Kr-87	4.35E-01	7.22E-02
Kr-88	4.38E-01	7.27E-02
Kr-89	1.75E+00	2.92E-01
Kr-90	4.58E-01	7.54E-02
Xe-131m	3.13E-04	5.20E-05
Xe-133m	6.03E-03	1.00E-03
Xe-133	1.69E-01	2.80E-02
Xe-135m	5.15E-01	8.55E-02
Xe-135	4.79E-01	7.98E-02
Xe-137	2.19E+00	3.64E-01
Xe-138	1.67E+00	2.79E-01
Xe-139	7.66E-01	1.28E-01
Total	2.02E+03	1.02E+02

Table 7.1-19 Doses for ABWR Main Steam Line Break, Pre-Existing Iodine Spike

	ABWR EAB Dose (Sv)			χ/Q Ratio	Site TEDE (Rem)	
Time	W. Body	Thyroid	TEDE	(Site/ABWR)	EAB	LPZ
0–2 hr	1.30E-02	5.10E-01	2.83E-02	2.44E-02	7.56E-02	
0–8 hr	1.30E-02	5.10E-01	2.83E-02	1.58E-03		4.91E-03
8–24 hr						0.00E+00
24–96 hr						0.00E+00
96–720 hr						0.00E+00
Total	1.30E-02	5.10E-01	2.83E-02		7.56E-02	4.91E-03
Limit					25	25

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. Since the ABWR design certification document does not include an LPZ dose for this accident, the site LPZ dose is obtained by multiplying the ABWR EAB dose by the ratio of site LPZ χ/Q to ABWR EAB χ/Q. The site doses include a multiplier of 1.10 for power adjustment.

Table 7.1-20 Doses for ABWR Main Steam Line Break, Equilibrium Iodine Activity

	ABWR EAB Dose (Sv)			χ/Q Ratio	Site TEDE (Rem)	
Time	W. Body	Thyroid	TEDE	(Site/ABWR)	EAB	LPZ
0–2 hr	6.20E-04	2.60E-02	1.40E-03	2.44E-02	3.74E-03	
0–8 hr	6.20E-04	2.60E-02	1.40E-03	1.58E-03		2.43E-04
8–24 hr						0.00E+00
24–96 hr						0.00E+00
96–720 hr						0.00E+00
Total	6.20E-04	2.60E-02	1.40E-03		3.74E-03	2.43E-04
Limit					2.5	2.5

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. Since the ABWR design certification document does not include an LPZ dose for this accident, the site LPZ dose is obtained by multiplying the ABWR EAB dose by the ratio of site LPZ χ/Q to ABWR EAB χ/Q. The site doses include a multiplier of 1.10 for power adjustment.

Table 7.1-20a Activity Releases for ESBWR Main Steam Line Break

	Activity Release (Ci)	
Isotope	**Pre-Existing**	**Equilibrium Activity**
I-131	1.96E+02	9.79E+00
I-132	1.86E+03	9.45E+01
I-133	1.35E+03	6.75E+01
I-134	3.38E+03	1.72E+02
I-135	1.92E+03	9.45E+01
Kr-85m	1.72E-02	1.72E-02
Kr-85	6.75E-05	6.75E-05
Kr-87	5.74E-02	5.74E-02
Kr-88	5.74E-02	5.74E-02
Xe-133	2.46E-02	2.46E-02
Xe-135	6.75E-02	6.75E-02
Total	8.70E+03	4.39E+02

Table 7.1-20b Doses for ESBWR Main Steam Line Break, Pre-Existing Iodine Spike

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
0–2 hr	3.13E-01	
0–8 hr		2.03E-02
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	3.13E-01	2.03E-02
Limit	25	25

Table 7.1-20c Doses for ESBWR Main Steam Line Break, Equilibrium Iodine Activity

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
0–2 hr	1.57E-02	
0–8 hr		1.02E-03
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	1.57E-02	1.02E-03
Limit	2.5	2.5

Table 7.1-21 Activity Releases for AP1000 Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Kr-85m	6.31E+02	3.14E+03	1.87E+03	1.71E+02	2.43E-03	5.82E+03
Kr-85	3.22E+01	2.64E+02	7.05E+02	3.17E+03	2.70E+04	3.12E+04
Kr-87	6.87E+02	1.26E+03	4.97E+01	8.11E-03	0.00E+00	1.99E+03
Kr-88	1.50E+03	5.76E+03	1.70E+03	3.49E+01	8.16E-07	8.99E+03
Xe-131m	3.20E+01	2.62E+02	6.79E+02	2.74E+03	1.11E+04	1.48E+04
Xe-133m	1.74E+02	1.37E+03	3.15E+03	8.21E+03	5.15E+03	1.80E+04
Xe-133	5.71E+03	4.62E+04	1.16E+05	4.11E+05	8.10E+05	1.39E+06
Xe-135m	3.33E+01	2.62E+00	2.14E-07	0.00E+00	0.00E+00	3.59E+01
Xe-135	1.31E+03	8.33E+03	1.01E+04	4.21E+03	1.73E+01	2.40E+04
Xe-138	1.14E+02	6.83E+00	1.58E-07	0.00E+00	0.00E+00	1.20E+02
I-130	3.22E+01	4.58E+01	2.96E+00	1.11E+00	1.99E-02	8.21E+01
I-131	9.13E+02	1.45E+03	1.56E+02	3.74E+02	1.12E+03	4.01E+03
I-132	8.77E+02	7.93E+02	7.64E+00	2.29E-02	0.00E+00	1.68E+03
I-133	1.81E+03	2.70E+03	2.16E+02	1.63E+02	1.62E+01	4.91E+03
I-134	7.16E+02	3.04E+02	1.26E-01	1.07E-07	0.00E+00	1.02E+03
I-135	1.53E+03	1.97E+03	8.31E+01	9.55E+00	4.95E-03	3.59E+03
Cs-134	1.46E+02	2.16E+02	8.06E+00	1.88E-01	1.59E+00	3.72E+02
Cs-136	4.15E+01	6.13E+01	2.25E+00	4.72E-02	2.03E-01	1.05E+02
Cs-137	8.50E+01	1.26E+02	4.70E+00	1.10E-01	9.39E-01	2.17E+02
Cs-138	2.67E+02	5.25E+01	6.92E-04	0.00E+00	0.00E+00	3.19E+02
Rb-86	1.72E+00	2.54E+00	9.37E-02	2.03E-03	1.05E-02	4.37E+00
Sb-127	1.10E+01	2.01E+01	7.13E-01	1.16E-02	1.60E-02	3.18E+01
Sb-129	2.63E+01	3.65E+01	4.83E-01	1.01E-04	1.00E-09	6.33E+01
Te-127m	1.42E+00	2.64E+00	9.83E-02	2.27E-03	1.77E-02	4.18E+00
Te-127	9.83E+00	1.59E+01	3.65E-01	5.63E-04	2.72E-06	2.61E+01
Te-129m	4.85E+00	9.00E+00	3.33E-01	7.47E-03	4.79E-02	1.42E+01
Te-129	1.35E+01	9.71E+00	8.54E-03	7.27E-10	0.00E+00	2.32E+01
Te-131m	1.46E+01	2.60E+01	8.29E-01	6.86E-03	1.60E-03	4.14E+01

Table 7.1-21 Activity Releases for AP1000 Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Te-132	1.46E+02	2.68E+02	9.42E+00	1.44E-01	1.60E-01	4.24E+02
Sr-89	4.16E+01	7.74E+01	2.87E+00	6.54E-02	4.60E-01	1.22E+02
Sr-90	3.59E+00	6.68E+00	2.48E-01	5.82E-03	4.97E-02	1.06E+01
Sr-91	4.64E+01	7.52E+01	1.74E+00	2.76E-03	1.44E-05	1.23E+02
Sr-92	3.80E+01	4.50E+01	3.26E-01	1.06E-05	0.00E+00	8.33E+01
Ba-139	3.64E+01	2.98E+01	4.73E-02	2.03E-08	0.00E+00	6.63E+01
Ba-140	7.35E+01	1.36E+02	5.00E+00	1.05E-01	4.41E-01	2.15E+02
Mo-99	9.77E+00	1.78E+01	6.19E-01	8.79E-03	7.72E-03	2.82E+01
Tc-99m	7.30E+00	1.10E+01	1.94E-01	1.08E-04	2.73E-08	1.85E+01
Ru-103	7.82E+00	1.45E+01	5.38E-01	1.21E-02	8.11E-02	2.30E+01
Ru-105	4.19E+00	5.87E+00	7.97E-02	1.82E-05	2.40E-10	1.01E+01
Ru-106	2.57E+00	4.79E+00	1.78E-01	4.16E-03	3.46E-02	7.58E+00
Rh-105	4.71E+00	8.45E+00	2.76E-01	2.64E-03	8.48E-04	1.34E+01
Ce-141	1.76E+00	3.26E+00	1.21E-01	2.71E-03	1.72E-02	5.16E+00
Ce-143	1.59E+00	2.84E+00	9.20E-02	8.29E-04	2.34E-04	4.51E+00
Ce-144	1.32E+00	2.47E+00	9.19E-02	2.14E-03	1.77E-02	3.91E+00
Pu-238	4.13E-03	7.70E-03	2.86E-04	6.71E-06	5.73E-05	1.22E-02
Pu-239	3.63E-04	6.77E-04	2.52E-05	5.90E-07	5.04E-06	1.07E-03
Pu-240	5.34E-04	9.92E-04	3.69E-05	8.65E-07	7.39E-06	1.57E-03
Pu-241	1.19E-01	2.23E-01	8.30E-03	1.94E-04	1.66E-03	3.52E-01
Np-239	2.04E+01	3.72E+01	1.27E+00	1.67E-02	1.17E-02	5.89E+01
Y-90	3.68E-02	6.70E-02	2.32E-03	3.25E-05	2.75E-05	1.06E-01
Y-91	5.35E-01	9.94E-01	3.69E-02	8.43E-04	6.09E-03	1.57E+00
Y-92	4.18E-01	5.46E-01	5.77E-03	5.86E-07	0.00E+00	9.70E-01
Y-93	5.81E-01	9.48E-01	2.25E-02	4.05E-05	2.91E-07	1.55E+00
Nb-95	7.20E-01	1.34E+00	4.95E-02	1.11E-03	7.23E-03	2.12E+00
Zr-95	7.17E-01	1.33E+00	4.94E-02	1.13E-03	8.29E-03	2.11E+00
Zr-97	6.66E-01	1.15E+00	3.26E-02	1.38E-04	7.58E-06	1.84E+00

Table 7.1-21 Activity Releases for AP1000 Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
La-140	7.66E-01	1.38E+00	4.58E-02	4.84E-04	1.97E-04	2.19E+00
La-141	5.37E-01	7.26E-01	8.69E-03	1.31E-06	0.00E+00	1.27E+00
La-142	3.47E-01	3.06E-01	6.67E-04	6.96E-10	0.00E+00	6.53E-01
Nd-147	2.79E-01	5.16E-01	1.89E-02	3.88E-04	1.49E-03	8.16E-01
Pr-143	6.28E-01	1.16E+00	4.27E-02	9.01E-04	3.95E-03	1.84E+00
Am-241	5.40E-05	1.00E-04	3.74E-06	8.75E-08	7.48E-07	1.59E-04
Cm-242	1.27E-02	2.37E-02	8.81E-04	2.04E-05	1.64E-04	3.75E-02
Cm-244	1.56E-03	2.91E-03	1.08E-04	2.53E-06	2.16E-05	4.61E-03
Total	1.72E+04	7.52E+04	1.35E+05	4.30E+05	8.54E+05	1.51E+06

Table 7.1-22 Doses for AP1000 Loss-of-Coolant Accident

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	**EAB**	**LPZ**	**(Site/AP1000)**	**EAB**	**LPZ**
0–2 hr	2.48E+01		5.57E-02	1.38E+00	
0–8 hr		9.20E+00	1.61E-02		1.48E-01
8–24 hr		3.30E-01	2.17E-02		7.16E-03
24–96 hr		3.10E-01	4.02E-02		1.25E-02
96–720 hr		2.90E-01	9.86E-02		2.86E-02
Total	2.48E+01	1.01E+01		1.38E+00	1.96E-01
Limit				25	25

Table 7.1-23 Activity Releases for ABWR Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
I-131	2.84E+02	1.25E+02	1.01E+03	9.52E+03	6.80E+04	7.90E+04
I-132	3.85E+02	3.63E+01	3.55E+01	0.00E+00	0.00E+00	4.57E+02
I-133	5.92E+02	2.21E+02	1.29E+03	3.64E+03	7.39E+02	6.48E+03
I-134	5.62E+02	1.17E+00	0.00E+00	0.00E+00	0.00E+00	5.63E+02
I-135	5.62E+02	1.45E+02	3.63E+02	1.83E+02	0.00E+00	1.25E+03
Kr-83m	3.57E+02	5.09E+02	1.66E+02	0.00E+00	0.00E+00	1.03E+03
Kr-85	4.47E+01	3.38E+02	2.40E+03	2.38E+04	3.13E+05	3.40E+05
Kr-85m	9.24E+02	3.17E+03	4.78E+03	7.69E+02	0.00E+00	9.64E+03
Kr-87	1.31E+03	1.07E+03	1.01E+02	0.00E+00	0.00E+00	2.48E+03
Kr-88	2.32E+03	5.48E+03	3.76E+03	3.25E+02	0.00E+00	1.19E+04
Kr-89	1.98E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.98E+02
Xe-131m	2.33E+01	1.65E+02	1.22E+03	1.04E+04	6.80E+04	7.98E+04
Xe-133	8.35E+03	5.85E+04	4.12E+05	3.04E+06	9.20E+06	1.27E+07
Xe-133m	3.28E+02	2.38E+03	1.51E+04	8.31E+04	7.95E+04	1.80E+05
Xe-135	1.01E+03	5.02E+03	1.66E+04	1.28E+04	0.00E+00	3.55E+04
Xe-135m	5.33E+02	8.87E-02	0.00E+00	0.00E+00	0.00E+00	5.33E+02
Xe-137	5.62E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.62E+02
Xe-138	2.19E+03	1.48E-01	0.00E+00	0.00E+00	0.00E+00	2.19E+03
Total	2.05E+04	7.72E+04	4.59E+05	3.18E+06	9.73E+06	1.35E+07

Table 7.1-24 Doses for ABWR Loss-of-Coolant Accident

	ABWR EAB Dose (Sv)			ABWR LPZ Dose (Sv)			χ/Q Ratio (Site/ ABWR)	Site TEDE (Rem)	
Time	W. Body	Thyroid	TEDE	W. Body	Thyroid	TEDE		EAB	LPZ
0–2 hr	4.10E-02	1.90E+00	9.80E-02				2.44E-02	2.62E-01	
0–8 hr				1.00E-02	3.10E-01	1.93E-02	1.39E-02		2.94E-02
8–24 hr				8.00E-03	2.00E-01	1.40E-02	2.26E-02		3.46E-02
24–96 hr				1.10E-02	7.90E-01	3.47E-02	6.46E-02		2.45E-01
96–720 hr				9.00E-03	1.10E+00	4.20E-02	2.92E-01		1.35+00
Total	4.10E-02	1.90E+00	9.80E-02	3.80E-02	2.40E+00	1.10E-01		2.62E-01	1.65E+00
Limit								25	25

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. The site doses include a multiplier of 1.10 for power adjustment.

Table 7.1-24a Activity Releases for ESBWR Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	0–2 hr	2–8 hr	8–24 hr	24–96 hr	96–720 hr	Total
Co-58	2.28E-03	2.22E-02	3.89E-02	4.18E-02	2.61E-02	1.31E-01
Co-60	2.19E-03	2.16E-02	3.76E-02	4.10E-02	2.89E-02	1.31E-01
Kr-85	6.59E+00	3.23E+02	2.72E+03	2.08E+04	5.31E+04	7.70E+04
Kr-85m	1.14E+02	3.01E+03	5.21E+03	8.50E+02	0.00E+00	9.19E+03
Kr-87	1.17E+02	8.60E+02	1.08E+02	0.00E+00	0.00E+00	1.09E+03
Kr-88	2.68E+02	5.12E+03	4.30E+03	1.63E+02	0.00E+00	9.85E+03
Rb-86	1.38E-01	1.00E+00	1.72E+00	1.79E+00	8.25E-01	5.48E+00
Sr-89	3.53E+00	3.46E+01	6.01E+01	6.43E+01	3.88E+01	2.01E+02
Sr-90	3.48E-01	3.42E+00	5.98E+00	6.51E+00	4.63E+00	2.09E+01
Sr-91	3.95E+00	3.06E+01	2.63E+01	5.00E+00	0.00E+00	6.58E+01
Sr-92	3.18E+00	1.45E+01	2.88E+00	1.25E-01	0.00E+00	2.06E+01
Y-90	6.34E-03	1.70E-01	9.06E-01	2.51E+00	4.25E+00	7.84E+00
Y-91	4.59E-02	4.70E-01	8.96E-01	1.03E+00	6.38E-01	3.08E+00
Y-92	4.89E-01	1.01E+01	8.31E+00	3.75E-01	0.00E+00	1.93E+01
Y-93	4.94E-02	3.87E-01	3.45E-01	7.25E-02	0.00E+00	8.54E-01

Table 7.1-24a Activity Releases for ESBWR Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Zr-95	6.39E-02	6.26E-01	1.09E+00	1.18E+00	7.25E-01	3.68E+00
Zr-97	6.16E-02	5.28E-01	6.10E-01	2.25E-01	0.00E+00	1.43E+00
Nb-95	6.43E-02	6.30E-01	1.11E+00	1.20E+00	8.25E-01	3.83E+00
Mo-99	8.30E-01	7.86E+00	1.23E+01	9.88E+00	1.00E+00	3.19E+01
Tc-99m	7.46E-01	7.24E+00	1.19E+01	1.01E+01	8.75E-01	3.09E+01
Ru-103	6.66E-01	6.52E+00	1.13E+01	1.21E+01	6.88E+00	3.75E+01
Ru-105	3.48E-01	2.09E+00	8.88E-01	3.75E-02	0.00E+00	3.36E+00
Ru-106	2.33E-01	2.28E+00	3.99E+00	4.34E+00	3.04E+00	1.39E+01
Rh-105	4.05E-01	3.88E+00	5.85E+00	3.74E+00	1.25E-01	1.40E+01
Sb-127	9.09E-01	8.69E+00	1.40E+01	1.23E+01	1.75E+00	3.76E+01
Sb-129	2.18E+00	1.30E+01	5.25E+00	1.25E-01	0.00E+00	2.05E+01
Te-127	9.29E-01	8.96E+00	1.49E+01	1.39E+01	3.13E+00	4.18E+01
Te-127m	1.22E-01	1.20E+00	2.09E+00	2.29E+00	1.54E+00	7.24E+00
Te-129	2.41E+00	1.62E+01	1.15E+01	6.75E+00	3.50E+00	4.04E+01
Te-129m	4.09E-01	4.02E+00	6.98E+00	7.35E+00	4.13E+00	2.29E+01
Te-131m	1.22E+00	1.11E+01	1.53E+01	8.75E+00	2.50E-01	3.66E+01
Te-132	1.24E+01	1.19E+02	1.88E+02	1.59E+02	1.88E+01	4.96E+02
I-131	6.66E+01	5.13E+02	9.33E+02	1.44E+03	7.00E+02	3.65E+03
I-132	7.88E+01	3.44E+02	2.45E+02	1.89E+02	2.25E+01	8.79E+02
I-133	1.31E+02	9.10E+02	1.22E+03	7.63E+02	1.25E+01	3.04E+03
I-134	4.96E+01	5.10E+01	3.75E-01	0.00E+00	0.00E+00	1.01E+02
I-135	1.11E+02	6.07E+02	4.16E+02	5.38E+01	0.00E+00	1.19E+03
Xe-133	1.08E+03	5.19E+04	4.08E+05	2.51E+06	1.20E+06	4.18E+06
Xe-135	3.68E+02	1.40E+04	5.13E+04	3.80E+04	0.00E+00	1.04E+05
Cs-134	1.16E+01	8.50E+01	1.48E+02	1.63E+02	1.14E+02	5.21E+02
Cs-136	4.03E+00	2.92E+01	5.00E+01	5.05E+01	2.00E+01	1.54E+02
Cs-137	7.54E+00	5.52E+01	9.60E+01	1.05E+02	7.50E+01	3.39E+02
Ba-139	2.96E+00	7.50E+00	3.00E-01	0.00E+00	0.00E+00	1.08E+01

Table 7.1-24a Activity Releases for ESBWR Loss-of-Coolant Accident

	Activity Release (Ci)					
Isotope	**0–2 hr**	**2–8 hr**	**8–24 hr**	**24–96 hr**	**96–720 hr**	**Total**
Ba-140	6.26E+00	6.10E+01	1.04E+02	1.06E+02	4.00E+01	3.18E+02
La-140	1.40E-01	4.41E+00	2.37E+01	5.83E+01	4.35E+01	1.30E+02
La-141	4.50E-02	2.56E-01	9.13E-02	2.50E-03	0.00E+00	3.95E-01
La-142	2.84E-02	8.09E-02	4.50E-03	0.00E+00	0.00E+00	1.14E-01
Ce-141	1.49E-01	1.46E+00	2.54E+00	2.69E+00	1.46E+00	8.30E+00
Ce-143	1.35E-01	1.23E+00	1.75E+00	1.05E+00	2.50E-02	4.19E+00
Ce-144	1.21E-01	1.19E+00	2.08E+00	2.26E+00	1.55E+00	7.20E+00
Pr-143	5.46E-02	5.40E-01	9.68E-01	1.06E+00	4.63E-01	3.09E+00
Nd-147	2.38E-02	2.31E-01	3.94E-01	3.95E-01	1.39E-01	1.18E+00
Np-239	1.69E+00	1.59E+01	2.44E+01	1.88E+01	1.38E+00	6.21E+01
Pu-238	2.98E-04	2.93E-03	5.11E-03	5.54E-03	4.00E-03	1.79E-02
Pu-239	3.59E-05	3.53E-04	6.19E-04	6.80E-04	4.75E-04	2.16E-03
Pu-240	4.65E-05	4.56E-04	7.98E-04	8.75E-04	6.13E-04	2.79E-03
Pu-241	1.35E-02	1.33E-01	2.31E-01	2.53E-01	1.78E-01	8.08E-01
Am-241	6.08E-06	5.97E-05	1.06E-04	1.15E-04	9.25E-05	3.79E-04
Cm-242	1.43E-03	1.40E-02	2.44E-02	2.65E-02	1.76E-02	8.39E-02
Cm-244	6.91E-05	6.77E-04	1.19E-03	1.29E-03	9.13E-04	4.14E-03
Total	2.46E+03	7.82E+04	4.76E+05	2.58E+06	1.25E+06	4.39E+06

Table 7.1-24b Doses for ESBWR Loss-of-Coolant Accident

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
2–4 hr	2.08E-01	
0–8 hr		4.38E-02
8–24 hr		4.24E-02
24–96 hr		7.91E-02
96–720 hr		3.81E-02
Total	2.08E-01	2.03E-01
Limit	25	25

Note: The maximum EAB dose occurs between 2 and 4 hours.

Table 7.1-25 Activity Releases for AP1000 Fuel Handling Accident

	Activity Release (Ci)
Isotope	**0–2 hr**
Kr-85m	2.68E-03
Kr-85	1.10E+03
Xe-131m	5.36E+02
Xe-133m	1.29E+03
Xe-133	6.94E+04
Xe-135m	4.37E-01
Xe-135	1.32E+02
I-130	3.52E-02
I-131	2.90E+02
I-132	1.54E+02
I-133	1.91E+01
I-135	1.36E-02
Total	7.29E+04

Table 7.1-26 Doses for AP1000 Fuel Handling Accident

	AP1000 TEDE (Rem)		χ/Q Ratio	Site TEDE (Rem)	
Time	EAB	LPZ	(Site/AP1000)	EAB	LPZ
0–2 hr	2.40E+00		5.57E-02	1.34E-01	
0–8 hr		6.00E-01	1.61E-02		9.64E-03
8–24 hr		0.00E+00	2.17E-02		0.00E+00
24–96 hr		0.00E+00	4.02E-02		0.00E+00
96–720 hr		0.00E+00	9.86E-02		0.00E+00
Total	2.40E+00	6.00E-01		1.34E-01	9.64E-03
Limit				6.3	6.3

Table 7.1-27 Activity Releases for ABWR Fuel Handling Accident

	Activity Release (Ci)
Isotope	**0–2 hr**
I-131	1.35E+02
I-132	1.66E+02
I-133	1.39E+02
I-134	6.74E-06
I-135	2.25E+01
Kr-83m	7.04E+00
Kr-85m	9.34E+01
Kr-85	5.23E+02
Kr-87	1.35E-02
Kr-88	2.66E+01
Kr-89	8.90E-11
Xe-131m	9.14E+01
Xe-133m	1.20E+03
Xe-133	3.08E+04
Xe-135m	2.42E+02
Xe-135	6.98E+03
Xe-137	2.27E-10
Xe-138	4.70E-10
Total	4.04E+04

Table 7.1-28 Doses for ABWR Fuel Handling Accident

	ABWR EAB Dose (Sv)			χ/Q Ratio	Site TEDE (Rem)	
Time	W. Body	Thyroid	TEDE	(Site/ABWR)	EAB	LPZ
0–2 hr	1.20E-02	7.50E-01	3.45E-02	2.44E-02	9.21E-02	
0–8 hr	1.20E-02	7.50E-01	3.45E-02	1.58E-03		5.99E-03
8–24 hr						0.00E+00
24–96 hr						0.00E+00
96–720 hr						0.00E+00
Total	1.20E-02	7.50E-01	3.45E-02		9.21E-02	5.99E-03
Limit					6.3	6.3

Note: The ABWR TEDE is whole body dose plus 3% of thyroid dose. The site LPZ dose is obtained by multiplying ABWR EAB dose by ratio of site LPZ χ/Q to ABWR EAB χ/Q. The site doses include a multiplier of 1.10 for power adjustment.

Table 7.1-29 Activity Releases for ESBWR Fuel Handling Accident

	Activity Release (Ci)
Isotope	0–2 hr
I-131	3.00E+02
I-132	2.43E+02
I-133	1.92E+02
I-134	1.05E-05
I-135	3.17E+01
Kr-85m	2.77E+02
Kr-85	1.01E+03
Kr-87	4.39E-02
Kr-88	8.78E+01
Xe-133	8.10E+04
Xe-135	2.13E+04
Total	1.04E+05

Table 7.1-30 Doses for ESBWR Fuel Handling Accident

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
0–2 hr	1.84E-01	
0–8 hr		1.19E-02
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	1.84E-01	1.19E-02
Limit	6.3	6.3

Table 7.1-31 Activity Releases for ESBWR Cleanup Water Line Break

	Activity Release (Ci)
Isotope	**0–2 hr**
I-131	3.48E+01
I-132	7.05E+01
I-133	9.28E+01
I-134	1.22E+02
I-135	9.59E+01
Total	4.16E+02

Table 7.1-32 Doses for ESBWR Cleanup Water Line Break

	Site TEDE (Rem)	
Time	**EAB**	**LPZ**
0–2 hr	2.59E-02	
0–8 hr		1.68E-03
8–24 hr		0.00E+00
24–96 hr		0.00E+00
96–720 hr		0.00E+00
Total	2.59E-02	1.68E-03
Limit	2.5	2.5

7.2 Severe Accidents

This section describes the probabilities and consequences of accidents of greater severity than the DBAs. As a class, they are considered less likely to occur**,** but because their consequences could be more severe, they are considered important both in terms of impact to the environment and off-site costs. These severe accidents can be distinguished from DBAs in two primary respects:

1. They involve substantial physical deterioration of the fuel in the reactor core, including overheating to the point of melting.

2. They involve deterioration of the capability of the containment system to perform its intended function of limiting the release of radioactive materials to the environment.

In NUREG-1437 (NRC 1996), the Generic Environmental Impact Statement for License Renewal of Nuclear Plants (GEIS), the NRC generically assesses the impacts of severe accidents during license renewal periods, using the results of existing analyses and site-specific information to conservatively predict the environmental impacts of severe accidents for each plant during the renewal period (Reference 1). This methodology is used as a basis for evaluating the severe accident environmental impacts of new units at the ESP site.

7.2.1 Applicability of Existing Generic Severe Accident Studies

NUREG-1437, Section 5.3.3, presents a thorough assessment by the NRC staff of the impacts of severe accidents during the license renewal period. Methodologies are developed therein to evaluate each of the dose pathways by which a severe accident may result in adverse environmental impacts and to estimate the off-site costs of severe accidents. This assessment methodology and the resulting conclusions are considered, for reasons presented below, broadly applicable beyond the license renewal context, including evaluation of severe accident impacts associated with determining site suitability for a nuclear power plant. The three NUREG-1437 pathways for release of radioactive material to the environment from severe accidents (atmospheric, air to surface water, and groundwater to surface water) are presented in this section. The economic impacts from severe accidents are also comparatively evaluated in this section.

The GEIS evaluations and conclusions are based on existing assessments of severe accident impacts presented in numerous Final Environmental Statements (FES) published after 1980 and for a representative set of U.S. plants and sites in NUREG-1150 (Reference 2). The GEIS results are expressed as a range of values in terms of risk of severe accident impact per reactor-year of operation. The NRC confirms, in 61 FR 28480, that “the analyses performed for the GEIS represent adequate, plant-specific estimates of the impacts from severe accidents…” (Reference 3).

As described in the GEIS, the purpose of the evaluation of severe accidents is “to use, to the extent possible, the available severe accident results, in conjunction with those factors that are important to risk and that change with time to estimate the consequences of nuclear plant accidents for all

plants for a time period that exceeds the time frame of existing analyses." This estimation process is completed by predicting increases or decreases in consequences as the plant lifetime is extended past the normal license period by considering the projected changes in the risk factors. The primary assumption in this analysis is that regulatory controls ensure that the physical plant condition, which affects the predicted probability of and radioactive releases from an accident, is maintained at a constant level during the renewal period; therefore, the frequency and magnitude of a release remains relatively constant. In other words, significant changes in consequences would result only from changes in the plant's external environment. The logical approach, then, would be to incorporate the most significant environmental factors into calculations of consequences for subsequent correlation with existing analyses, which use the consequence computer codes.

The NRC staff concludes in NUREG-1437 that the primary factors affecting risk are the site population, which reflects the number of people potentially at risk to severe accident exposure, and wind direction, which reflects the likelihood of exposure. Secondary factors – such as terrain, rainfall, and wind stability – also have some effect on risk, but their impact is judged to be much smaller than the effects of population and wind direction. These factors are included in the FES analyses whose results are the bases for the GEIS analyses. Consequently, their effects are indirectly considered in the prediction of future risks and are reflected within the uncertainty bounds generated by the regression of the FES risk values. To ensure that the existing FES analyses cover a range of secondary factors representative of the total population of plants, the more significant secondary factors are also examined in the GEIS. Variations in these factors (precipitation, 50-mile population, 50-mile population in the direction of highest wind frequency, general terrain, and emergency planning) are found to be enveloped by the FES analyses and thus reasonably accounted for in the GEIS evaluation of severe accidents.

Detailed evaluations of severe accident consequences such as early and latent fatalities and total dose are not available for all plants considered in the GEIS. Therefore, a predictor for these consequences is developed using correlations based upon the calculated results from the existing FES severe accident analyses. This predictor is then used to infer the future consequence level of all individual nuclear plants. Correlations are developed using two environmental parameters that are available for all plants. This correlation process is well described in NUREG-1437.

While NUREG-1437 discussions deal with the environmental impacts of accidents during operation after license renewal, the primary assumption for this evaluation is that the frequency or likelihood of occurrence of an accident at a given plant would not increase during the plant lifetime, inclusive of the license renewal period, because regulatory controls ensure that the plant's licensing basis is maintained and improved, where warranted. The GEIS use of severe accident risk per reactor-year of operation as the principal metric for evaluating severe accident environmental impacts and the assumption that this risk remains constant over the life of the plant are equally applicable and appropriate in the license renewal context as in the ESP and COL contexts. Therefore, the

thorough generic analysis of severe accident impacts presented in the GEIS also provides an appropriate basis and method for evaluating severe accident impacts for early site permitting.

It is recognized, however, that the changing environment around the plant is not subject to regulatory controls and introduces the potential for changing risk. Consequently, the site-specific environmental considerations (population and meteorology) are evaluated in the GEIS and are considered in the following sections.

Specifically, the following evaluation of the significant factors associated with the environment shows these factors for the ESP site are not substantially different from those factors identified for previously analyzed sites. Thus, it follows that the environmental impacts for the ESP site would not be substantially different from the acceptable environmental impacts identified for the previously analyzed sites. Furthermore, the NRC's severe accident policy statement about new reactors (Reference 4) reinforces the concept that the results of the existing severe accident analyses would bound the consequences of the advanced reactor designs being considered for the ESP site.

7.2.2 Evaluation of Site-Specific Potential Severe Accident Releases

The significance of the impacts associated with each issue is identified as either small, moderate, or large, consistent with the criteria that the NRC established in Appendix B to Subpart A of 10 CFR 51, Table B-1, Footnote 3 as follows (Reference 4):

- Small – Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small.
- Moderate – Environmental effects are sufficient to alter noticeably, but not to destabilize, important attribute of the resource.
- Large – Environmental effects are clearly noticeable and are sufficient to destabilize any important attributes of the resource.

In accordance with NEPA practice, ongoing and potential additional mitigations are considered in proportion to the significance of the impact to be addressed, meaning that impacts that are small receive less mitigative consideration than impacts that are large.

Dominion bases its evaluation of potential environmental consequences of severe accidents on the evaluation of potential consequences of severe accidents for current generation reactors presented in NUREG-1437, and on source term parameters provided from the ABWR, AP1000, and ESBWR reactor designs. Three release pathways were considered: 1) the atmospheric pathway in which radioactive material is released to the air, 2) the surface water pathway in which airborne radioactive material falls out on open bodies of water, and 3) the groundwater pathway in which groundwater is contaminated by a basemat melt-through with subsequent contamination of surface water by the groundwater. The MACCS2 computer code was utilized to evaluate the potential

offsite consequences of severe accidents. Three types of consequences were assessed: 1) human health, 2) economic costs, and 3) land area affected by contamination.

7.2.2.1 Evaluation of Potential Releases via Atmospheric Pathway

The site-specific significant factors of demography and meteorology are considered in the evaluation of the atmospheric exposure pathway for new units at the ESP site. For this evaluation, NUREG-1437 calculates an exposure index (EI) for use in comparing the relative risk for the current fleet of nuclear power plants. NUREG-1437 provides the following discussion of EI:

> Population, which changes over time, defines the number of people within a given distance from the plant. Wind direction, which is assumed not to change from year to year, helps determine what proportion of the population is at risk in a given direction, because radionuclides are carried by the wind. Therefore, an EI relationship was developed by multiplying the wind direction frequency (fraction of the time per year) for each of 16 (22.5 degrees) compass sectors times the population in that sector for a given distance from the plant and summing all products. … Population varies with population growth and movement, and with the distance from any given plant. As the population changes for that plant, the EI also changes (the larger the EI, the larger the number of people at risk). Thus, EI is proportional to risk and an EI for a site for a future year can be used to predict the risk to the population around that site in that future year.

Thus, the EI is a function of population surrounding the site, weighted by the site-specific wind direction frequency, and is, therefore, a site-specific parameter. Because meteorological patterns, including wind direction frequency, tend to remain constant over time, the site meteorology would not be significantly different for the ESP site than that considered in NUREG-1437 for the NAPS site and only population can significantly affect the resulting risk in any given year of reactor operation.

Two EI values are evaluated in NUREG-1437. A 10-mile EI is found to best correlate with early fatalities and a 150-mile EI is found to best correlate with latent fatalities and total dose. Using these indices, it is determined that the risk of early and latent fatalities from individual nuclear power plants is small and represents only a small fraction of the risk to which the public is exposed from other sources.

NUREG-1437 indicates a 10-mile EI for the NAPS site of 704 for the year 2030, while the 10-mile EI for the current generation of nuclear power plant sites ranges from 96 to 18,959 (Reference 1, Table 5.7). Using the US Census Bureau population data (circa 2000) projected to years 2040 and 2065 with the best available wind direction frequency information (1996–1998), 10-mile EI values of 4200 and 5700 are calculated for the ESP site for the years 2040 and 2065, respectively. For both years, the ESP site 10-mile EI is within the range of risk calculated for the existing fleet of nuclear power plants.

NUREG-1437 indicates a 150-mile EI for the NAPS site of 876,587 for the year 2030, while the 150-mile EI for the current generation of nuclear power plant sites ranges from 132,195 to 2,863,844 (Reference 1, Table 5.8). Using the US Census Bureau population data (circa 2000) projected to years 2040 and 2065 with the best available wind direction frequency information (1996–1998), 150-mile EI values of 1.1E6 and 1.4E6 are calculated for the ESP site for the years 2040 and 2065, respectively. For both years, the ESP site 150-mile EI is within the range of risk calculated for the existing fleet of nuclear power plants.

Thus, the risks for new units at the ESP site for the atmospheric exposure pathway would be within the range of those considered in NUREG-1437 as “small.” NUREG-1437, Section 5.5.2.1, indicates that these predicted effects of a severe accident “are not expected to exceed a small fraction of that risk to which the population is already exposed.”

Results for dose and economic costs from MACCS2 runs for the atmospheric pathway are presented in Tables 7.2-1 and 7.2-2, respectively.

Table 7.2-1 ESBWR Population Dose

	Sieverts					
STC	**Case1A 98MET**	**Case2A 97MET**	**Case3A 96MET**	**Case4A 5500MWt**	**Case5B Plume = 1.0E6W**	**Category Frequency Prob/yr**
BOC	9.33E+04	8.55E+04	8.77E+04	9.79E+04	8.84E+04	<1E-12
BYP	8.68E+04	7.96E+04	8.22E+04	9.11E+04	8.28E+04	4E-12
CCID	7.17E+04	6.48E+04	6.65E+04	7.16E+04	6.71E+04	2.9E-11
CCIW	1.24E+04	1.09E+04	1.18E+04	1.30E+04	1.20E+04	2.9E-10
DCH	6.29E+04	5.74E+04	5.73E+04	6.41E+04	5.76E+04	<1E-12
EVE	7.72E+04	6.90E+04	7.18E+04	7.70E+04	7.27E+04	2.5E-10
FR	3.15E+02	2.64E+02	2.98E+02	3.60E+02	3.02E+02	2.3E-10
OPVB	3.12E+04	2.83E+04	2.91E+04	3.30E+04	2.93E+04	<1E-12
OPW1	5.52E+04	5.13E+04	5.21E+04	5.73E+04	5.27E+04	<1E-12
OPW2	2.87E+04	2.68E+04	2.76E+04	2.96E+04	2.78E+04	1.4E-11
TSL	2.43E+02	2.02E+02	2.29E+02	2.73E+02	2.32E+02	2.8E-8

Table 7.2-2 ESBWR Offsite Cost

	Cost, $					
STC	**Case1A 98MET**	**Case2A 97MET**	**Case3A 96MET**	**Case4A 5500MWt**	**Case5B Plume = 1.0E6W**	**Category Frequency Prob/yr**
BOC	1.36E+10	1.27E+10	1.41E+10	1.63E+10	1.43E+10	<1E-12
BYP	1.34E+10	1.25E+10	1.38E+10	1.58E+10	1.41E+10	4E-12
CCID	1.51E+10	1.36E+10	1.42E+10	1.62E+10	1.44E+10	2.9E-11
CCIW	8.19E+08	6.24E+08	7.54E+08	1.06E+09	7.80E+08	2.9E-10
DCH	9.46E+09	8.50E+09	9.20E+09	1.01E+10	9.37E+09	<1E-12
EVE	1.59E+10	1.44E+10	1.50E+10	1.70E+10	1.52E+10	2.5E-10
FR	2.48E+06	1.93E+06	2.51E+06	3.25E+06	2.47E+06	2.3E-10
OPVB	4.15E+09	3.45E+09	3.95E+09	4.38E+09	4.04E+09	<1E-12
OPW1	9.13E+09	8.11E+09	8.63E+09	9.63E+09	8.74E+09	<1E-12
OPW2	4.58E+09	3.84E+09	4.25E+09	4.93E+09	4.35E+09	1.4E-11
TSL	1.64E+06	1.47E+06	1.74E+06	2.60E+06	1.68E+06	2.8E-8

7.2.2.2 Evaluation of Potential Releases via Atmospheric Fallout onto Open Bodies of Water

This section examines radiation exposure risk for new reactors at the ESP site in the event of a severe reactor accident in which radioactive contaminants are released into the atmosphere and subsequently deposited onto open bodies of water. In the GEIS, the drinking water pathway is treated separately, while the aquatic food, swimming, and shoreline pathways are addressed collectively. Population dose estimates for both the drinking water and aquatic food pathways are then compared with estimates from the atmospheric pathway.

As reported in NUREG-1437, analyses for both the drinking water and aquatic food pathways are performed with and without considering interdiction. In the case of the drinking-water pathway, the Great Lakes and the estuarine sites are bound by a previous site evaluation (i.e., Fermi) while small river sites with relatively low annual flow rates, long residence times, and large surface-area-to-volume ratios may potentially not be bounded by a previous analysis. In all cases, however, interdiction can reduce relative risk to levels at or below that of the previous acceptable analysis and significantly below that for the atmospheric pathway. River sites that may have relatively high concentrations of contaminants, but which remove contaminants within short periods of time (hours to several days), are amenable to short-term interdiction. A similar level of reduced

risk can be achieved at those sites with longer residence times (months) by more extensive interdictive measures.

Lake Anna is the major surface water body in the vicinity of the North Anna ESP site, and is used for recreational activities including swimming and fishing. However, the North Anna ESP site is classified as being on a small river. NUREG-1437 provides an estimate of typical population exposure risk for the aquatic food pathway for power stations located on small rivers. In the event of a large release of radioactive material, access to Lake Anna could be controlled. This control would reduce human exposures through the surface water pathways.

Analysis of water-related exposure pathways at the Fermi reactor (NRC 1981) suggests that population exposures from swimming are significantly lower than exposures from the aquatic ingestion pathway. After considering the water ingestion dose estimates, the NUREG-1437 evaluations, and controlled access to Lake Anna, impacts as a result of the surface water exposure pathway would be expected to be small.

For the aquatic food pathway, the population dose and the population exposure per reactor-year are directly related to aquatic food harvest. For river sites, the population exposure for the un-interdicted pathway is lower than that for the atmospheric pathway by orders of magnitude. For Great Lakes sites, the un-interdicted population exposure is a substantial fraction of that predicted for the atmospheric pathway but is reduced significantly by interdiction. For estuarine sites with large annual aquatic food harvests, dose reduction of a factor of 2 to 10 through interdiction provides essentially the same population exposure estimates as the atmospheric pathway.

For these reasons, population dose for the drinking-water pathway is found to be a small fraction of that for the atmospheric pathway. Risk associated with the aquatic food pathway is found to be small relative to the atmospheric pathway for most sites and essentially the same as the atmospheric pathway for the few sites with large annual aquatic food harvests.

Environmental parameters important for input in performing the above analyses, and for use in analyses of additional sites, are: 1) the surface area of the receiving body, 2) the volume of water in the body, and 3) the flow rate. In the absence of rigorous site-specific analyses, these data can provide estimates of the extent of contamination in the receiving water body and the residence time of the contaminant in the affected water body. Comparing these estimates and site environmental parameters with those for the previously evaluated site (i.e., Fermi) can provide an indication of the comparative hazard associated with drinking contaminated surface water among sites and the need for site-specific analyses. Accounting for population and meteorological data in the comparison can provide further indication of relative risk among sites.

The environmental parameters listed above have been identified in the GEIS for the NAPS site (Reference 1, Table 5.14a). These parameters are applicable for new units at the ESP site, since these parameters are generally constant for a given site, and no major changes have been identified that would impact these parameters. Thus, the drinking-water pathway and the aquatic

food, swimming, and shoreline pathways for the ESP site are comparable to those considered in the GEIS evaluation. Therefore, the risk from air fallout to a water body exposure pathway generally compares favorably with the risk to the population from atmospheric releases. The risks for new units at the ESP site for the water body exposure pathway would also be within the range of those considered in NUREG-1437 as "small."

7.2.2.3 Evaluation of Potential Releases to Groundwater

This section discusses the potential for radiation exposure from the groundwater pathway as the result of postulated severe accidents for new units at the ESP site. Severe accidents are the only accidents capable of producing significant groundwater contamination.

As identified in NUREG-1437, groundwater contamination due to severe accidents has been evaluated generically in NUREG-0440, Liquid Pathway Generic Study (LPGS) (Reference 5). The LPGS evaluates the consequences assuming a core melt with subsequent basemat melt-through. The LPGS examines six generic sites using typical or comparative assumptions about geology, adsorption factors, etc.

According to NUREG-1437, "the LPGS results are believed to provide generally conservative uninterdicted population dose estimates in the six generic plant-site categories. Five of these categories are site groupings in common locations adjacent to small rivers, large rivers, the Great Lakes, oceans, and estuaries. In a severe accident, contaminated groundwater could reach nearby surface water bodies and the population could be exposed to this source of contamination through drinking of surface water, ingestion of finfish and shellfish, and shoreline contact. Exposure by drinking contaminated groundwater is considered to be minor or nonexistent in these five categories because of a limited number of drinking-water wells. The sixth category is a "dry" site located either at a considerable distance from surface water bodies or where groundwater flow is away from a nearby surface water body. In this case, the only population exposure results from drinking contaminated groundwater." (Reference 1, Section 5.3.3.4.1)

NUREG-1437 concludes that the risk from the groundwater exposure pathway generally contributes only a small fraction of that risk attributable to the population from the atmospheric pathway but in a few cases may contribute a comparable risk.

In the GEIS analysis, site-specific data of groundwater travel time; retention-adsorption coefficients; distance to surface water; and soil, sediment, and rock characteristics are compared with previous groundwater contamination analyses (Reference 1, Section 5.3.3.4). Previous analyses are contained in the LPGS and site-specific FESs. These environmental parameters have been identified in the GEIS for the NAPS site. These same parameters are applicable to new units at the ESP site, since these environmental parameters are generally constant for a given site, and no major changes have been identified that would impact these parameters. Thus, the groundwater pathway for the ESP site is comparable to that considered in the GEIS evaluation. Therefore, the risk from the groundwater exposure pathway generally compares favorably with the risk to the

population from atmospheric releases. The risks for new units at the ESP site for the groundwater exposure pathway would also be within the range of those considered in NUREG-1437 as “small.”

7.2.3 Evaluation of Economic Impacts of Severe Accidents

This section discusses the potential economic impact that could result from postulated severe accidents at the ESP site. Similar to Section 7.2.2.1, the EI is used as a predictor of cost because, as identified in the GEIS, the cost should be dependent on the economic impact in the same way and for the same reason that population dose estimates are dependent on the EI values.

As noted in NUREG-1437, FES analyses use the Calculation of Reactor Accident Consequences (CRAC) computer code to calculate off-site severe accident costs for the area contaminated by the accident. The off-site costs that are considered relate to avoidance of adverse health effects and are categorized as follows:

- Evacuation costs
- Value of crops contaminated and condemned
- Value of milk contaminated and condemned
- Costs of decontamination of property where practical
- Indirect costs resulting from the loss of use of property and incomes derived therefrom, including interdiction to prevent human injury

For those FES analyses that address severe accidents, the off-site accident costs are estimated to be as high as $6 billion to $8 billion in 1994 dollars; however, the accident probabilities are extremely low (1E-6 per year), as would be expected for this class of events. Because key variables used in the FES cost analyses are strongly related to population density, NUREG-1437 further evaluates the FES results using normalization techniques and the 150-mile EI values. This evaluation, which includes the NAPS site, demonstrates that the FES cost predictions remain valid, even considering population changes represented by the EI values.

In addition, NUREG-1437 generically predicts that conditional land contamination is small (10 acres per year at most). This is consistent with WASH-1400 (Reference 6) and NUREG/CR-2239 (Reference 7). NUREG/CR-2239 is a 1982 study on siting criteria that predicts small conditional land contamination values. The GEIS concludes that land contamination values for the evaluated plants can be considered representative of all plants, since they cover the major vendor and containment types and include sites at the upper end of annual rainfall. However, even considering that land contamination values can vary at other sites, predicted land contamination from plants at other sites are expected to vary more than one or two orders of magnitude from the values listed above and, therefore, there would still be a small impact.

Based on the evaluations of the expected economic costs and land contamination as a result of a severe accident, the GEIS concludes in Section 5.5.2.4 that the conditional impacts in both cases

are of small significance for all plants. As with other aspects of the GEIS evaluation of severe accident impacts, this evaluation and conclusion are broadly applicable beyond the license renewal context. Thus the economic impacts and land contamination resulting from postulated severe accidents at new units on the ESP site would be comparable as well, falling within the range of those considered in NUREG-1437 as having a "small" impact.

7.2.4 Consideration of Commission Severe Accident Policy

In 1985, the NRC adopted a Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants (Reference 8), which stated the following:

> "The Commission fully expects that vendors engaged in designing new standard (or custom) plants will achieve a higher standard of severe accident safety performance than their prior designs. This expectation is based on:
>
> - The growing volume of information from industry and government-sponsored research and operating reactor experience has improved our knowledge of specific severe accident vulnerabilities and of low-cost methods for their mitigation. Further learning on safety vulnerabilities and innovative methods is to be expected.
> - The inherent flexibility of this Policy Statement (that permits risk-risk trade-offs in systems and sub-systems design) encourages thereby innovative ways of achieving an improved overall systems reliability at a reasonable cost.
> - Public acceptance, and hence investor acceptance, of nuclear technology is dependent on demonstrable progress in safety performance, including the reduction in frequency of accident precursor events as well as a diminished controversy among experts as to the adequacy of nuclear safety technology."

Thus, based on the informed expectations of the Commission's Severe Accident Policy, it is reasonable to conclude that the environmental impact of new units at the ESP site would be within the range of risk previously determined to be "small."

A significant factor in the risk associated with plant design is the frequency of the considered accident sequences. As indicated above, the designs certified in accordance with 10 CFR 52 are expected to exhibit a "higher standard of severe accident safety performance than the prior designs." The ABWR is a currently certified design under 10 CFR 52, Appendix A (Reference 9), and is considered to be representative of advanced light water reactor standard designs. The NRC Safety Evaluation Report for the ABWR states, "the ABWR design and the submittals made for the ABWR in the SSAR meet the intent of the Commission's Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants." Similar findings have been made for the other currently certified designs, namely System 80+ and AP-600. Thus, the Severe Accident Policy Statement expectations have been met for each of the three advanced standard designs

considered to date by the NRC and are expected to continue to be met for future design certifications and COL application approvals.

7.2.5 Conclusion

The GEIS concludes, based on the generic evaluations presented, that the probability-weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to groundwater, and societal and economic impacts from severe accidents are “small” for all plants.

As described above, the methodology and evaluations of the GEIS are applicable to the consideration of new plants in the ESP and COL application context. Evaluation of site-specific factors for purposes of this application have shown that the ESP site is within the range of sites considered in the GEIS. Thus, the GEIS conclusion is applicable to the ESP site.

Use of pertinent site specific information to confirm the applicability of existing generic analyses is consistent with NRC staff plans for addressing severe accident environmental impacts at the ESP, as identified in SECY-91-041 (Reference 11).

In summary, the environmental impacts considered in NUREG-1437 evaluations include potential radiation exposures to individuals and to the population as a whole, the risk of near- and long-term adverse health effects that such exposures could entail, and the potential economic and societal consequences of accidental contamination of the environment. The consequences of these accidents could be severe, but due to their low likelihood of occurrence, the impacts are judged to be small. This conclusion is based on: 1) considerable experience gained with the operation of similar facilities without significant degradation of the environment, 2) the requirement that in order to obtain a license the applicant must comply with the applicable Commission regulations and requirements, and 3) a previously analyzed assessment of the risk of design-basis and severe accidents (Reference 10).

Specifically, based on the NRC and industry implementation of the 1985 policy statement, the generic NUREG-1437 risk evaluations, and the ESP site specific demography and meteorology, the radiological consequences and the societal and economic impacts of severe accidents for new units at the ESP site would be “small.”

Section 7.2 References

1. NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Vol. 1, U. S. Nuclear Regulatory Commission, April 1996.

2. NUREG-1150, *Severe Accident Risks: An Assessment for Five U. S. Nuclear Power Plants*, U. S. Nuclear Regulatory Commission, December 1990.

3. 61 FR 28467 – 28497, *Final Rule*, “Environmental Review for Renewal of Nuclear Power Plant Operating Licenses,” U. S. Nuclear Regulatory Commission, June 5, 1996.

4. 10 CFR 51, *Code of Federal Regulations*, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions,” U. S. Nuclear Regulatory Commission.

5. NUREG-0440, *Liquid Pathway Generic Study: Impacts of Accidental Radioactive Releases to the Hydrosphere from Floating and Land-Based Nuclear Power Plants*, U. S. Nuclear Regulatory Commission, February 1978.

6. WASH-1400 (NUREG-75/014), *Reactor Safety Study: An Assessment of the Accident Risks in U.S. Commercial Nuclear Power Plants*, U. S. Nuclear Regulatory Commission, October 1975.

7. NUREG/CR-2239, *Technical Guidance for Siting Criteria Development*, Prepared for U. S. Nuclear Regulatory Commission by Sandia National Laboratories, December 1982.

8. 50 FR 32138 – 32150, *Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants*, U. S. Nuclear Regulatory Commission, August 8, 1985.

9. 10 CFR 52, *Code of Federal Regulations*, “Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants,” U. S. Nuclear Regulatory Commission.

10. NUREG-1503, *Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design*, U. S. Nuclear Regulatory Commission, July 1, 1994.

11. SECY-91-0041, *Early Site Permit Review Readiness*, U. S. Nuclear Regulatory Commission, February 13, 1991.

7.3 Severe Accident Mitigation Alternatives

The purpose of SAMA is to review and evaluate plant-design alternatives that could significantly reduce the radiological risk from a severe accident by preventing substantial core damage or by limiting releases from containment in the event that substantial core damage does occur.

SAMAs depend on design issues evaluated during the development and review of standard design certifications and COL applications. The design of the reactor and analyses of projected severe accidents are major contributing factors in the determination of SAMAs. To determine whether mitigation alternatives are cost beneficial, severe accident analyses must be included in these evaluations. SAMA would be evaluated for the new units in the COL application.

Section 7.3 References

None

7.4 Transportation Accidents

The assessment of transportation accidents is provided in Section 3.8, Transportation of Radioactive Materials.

Section 7.4 References

None

Chapter 8 Need for Power

The need for power would be addressed in the COL application.

Chapter 9 Alternatives to the Proposed Action

This chapter assesses alternatives to siting and developing nuclear power plants at the North Anna ESP site.

9.1 No-Action Alternative

The no-action alternative on a proposed ESP is non-issuance of that permit (i.e., NRC declining to determine whether a proposed site is suitable for new nuclear plants). In this context, no-action would accomplish none of the benefits intended by the ESP process, which would include early resolution of siting issues prior to large investments with financial capital and human resources in new plant design and construction, early resolution of issues on the environmental impact of construction and operation of reactors that fall within the site parameters, and the ability to bank sites on which nuclear plants may be located, and the facilitation of future decisions on whether to build new nuclear plants. This no-action alternative would avoid no significant environmental impacts, because no such impacts are caused by a site suitability determination. The only activities that are permissible under an ESP are limited work activities allowed by 10 CFR 50.10(e)(1), and those activities are permissible only if the final environmental impact statement concludes that the activities will not result in any significant environmental impacts that cannot be redressed.

With respect to a future proposal to construct and operate new nuclear units, the no-action alternative at that stage would constitute denial of the construction permit and operating license (eliminating nuclear units as the source of generation to meet the power needs at that time. The alternative of not licensing the construction and operation of new units would obviously avoid the environmental impacts associated with such construction and operation. However, depending on the need for power and impacts associated with alternative energy sources at the time when construction of new nuclear units may be proposed, the alternative of not licensing the construction and operation of the new nuclear units might result in other site and area environmental impacts, such as the impacts of constructing and operating a large, base-load coal-fired plant. Consideration of the reasonableness of this alternative involves need for power and alternative energy sources, which are topics that would be addressed during the combined construction and operating license stage.

9.2 Energy Alternatives

This subject is not addressed in the ESP application.

9.3 Alternative Sites

This section presents the alternative site evaluation to determine whether there is any obviously superior site when compared to the ESP site. The ROI for the proposed action is defined, the

concept of candidate sites within the ROI is presented, the sites selected as reasonable alternatives are identified, and the preferred site, (i.e., the ESP site) is selected.

This section includes a description of the screening process for identifying candidate sites and the methodology used in evaluating alternative sites.

9.3.1 Technical Approach

The candidate site criteria described in NUREG-1555, Section 9.3, were used to screen for candidate sites (Reference 1, Section 9.3) in the ROI.

The alternative site evaluation was performed using 45 suitability criteria as part of a study that reviewed previous nuclear industry siting information and current power plant siting approaches (Reference 2). These suitability criteria were grouped into four major categories: economic, engineering, environmental and sociological. A ranking or score for each criterion was assigned (from 0 to 5, with 5 being the most favorable). The relative importance of each criterion to the overall evaluation was established by assigning weights that reflect the collective judgment of experts involved in the process. The sum of the weighted scores for all criteria represented a total site merit score. The preferred site (i.e., the ESP site) was chosen based on the highest site merit score.

9.3.2 Region Of Interest

Prior to deregulation of the power industry, alternative sites were typically located within a utility's ROI, usually its service territory. Under deregulation, power producers cannot recover construction and operation costs associated with development of a commercial power generation facility through the cost-of-service rates process. Instead, a newly completed power generation facility has to generate power for sale to consumers in a competitive marketplace. Dominion would only proceed with the development of such a new facility if it is economically viable.

As the parent company for Dominion, DRI's energy interests are to continue to operate and grow to a more substantial position as a natural gas and electric power provider serving customers in America's most energy-intense market: the Mid-Atlantic, Northeast, and Midwest. This energy-intense market region comprises approximately a quarter of the nation's land, but it accounts for 40 percent of the energy consumed. This market is home to DRI's ever-growing base of 4 million retail utility customers, and 1.1 million others served by DRI in the deregulated marketplace. DRI has defined its ROI for power generation to be the eastern quadrants of the United States, as shown in Figure 9.3-1. This defined ROI is based on the locations of the load centers to be supplied by the new units that would be constructed and operated at the ESP site.

9.3.3 Identification of Candidate Sites

In developing a list of reasonable candidate sites, multiple categories of sites were evaluated including federal facility sites and existing nuclear power plant sites within the identified ROI. The

federal sites were considered under the assumption that such sites could accommodate new reactor technologies. The use of existing nuclear power plant sites for new power generation has many environmental and cost benefits. Additionally, Dominion evaluated the relative impacts of construction and operation of a new nuclear plant at a generic greenfield site. The review of a greenfield site was made to ensure that there are no sites that are obviously superior.

9.3.3.1 Site Screening Criteria

The candidate site criteria described in NUREG-1555 were used to screen for candidate sites. By using the criteria, sites were selected that:

- Did not pose significant issues that would preclude the use of the site for a nuclear power plant
- Did not cause significant impacts or degradation of local natural resources on the site that would be created
- Did not pose significant impacts to surrounding terrestrial and aquatic ecosystems
- Were not located in proximity to major population centers
- Did not affect site development costs significantly, when compared to the proposed site

9.3.3.2 Federal Site Review

Two of the DOE sites within DRI's ROI – Portsmouth, Ohio, and Savannah River, South Carolina – were selected as candidate sites because:

- The sites represent valuable national assets with prior or existing nuclear energy potential.
- New nuclear power facilities would represent potentially promising new missions for these sites.
- The sites have the potential to support reactor demonstrations and/or commercial reactor development.
- There is extensive site information and an available infrastructure that could help to reduce site development costs.
- Because of the partially or fully developed site environment and the available infrastructure, the incremental environmental impacts associated with the new plant construction and operation on land use, ecological resources, aesthetic, and local transportation network are reduced.
- The sites are not in proximity to major population centers.

The Portsmouth site, which is a previously developed industrial site, is a 3700-acre parcel of DOE-owned land located in a sparsely populated, rural area about 65 miles south of Columbus, Ohio. A major portion of the site and existing facilities are leased to USEC, Inc. for the Portsmouth Gaseous Diffusion plant. The Portsmouth site has substantial site characterization information and available electrical transmission facilities that were used to support operation of the diffusion plant prior to the decision to cease operations at this facility.

The 198,000-acre Savannah River site is about 25 miles southeast of Augusta, Georgia, and 19.5 miles south of Aiken, South Carolina. Augusta is the largest city in the vicinity with a 2000 Census population of 195,182. The site is located in a generally rural area on the Savannah River in southwest South Carolina. The entire area within a 5-mile radius about the center of the site is government-owned property, with approximately 95 percent of the site undeveloped. The Savannah River site has an extensive history of nuclear facilities, with substantial site characteristic information and infrastructure available to support DOE and new nuclear-related missions.

9.3.3.3 Generic Greenfield Site Review

Consideration of the effects of replacing power generation from the existing units by construction of a new unit at a greenfield site was provided in Supplement 7 of the GEIS (Reference 3). Results of the Supplement 7 evaluation indicated that the associated environmental impacts for the replacement plant located at a greenfield site were worse than the extension scenario of the existing units (see Table 9.3-1). A generic greenfield site is not a reasonable candidate ESP site for the following environmental reasons:

- A large area would need to be disturbed to build new plants which would cause large impacts on land use, ecological resources, aesthetics, and the local transportation network.
- New transmission lines and corridors may be needed to connect the new plant to the power grid, and local transportation routes and access roads may need to be built or upgraded. Such improvements could lead to additional land use, ecological resource, and aesthetic impacts.
- It is unlikely that a site in a remote area with the water supply needed by a large power plant and an adequate local transportation network would be available in the ROI.
- For a site in a rural area, the socioeconomic impacts associated with plant construction and operation would be largely due to the number of workers that would have to move into the area.

In addition, the site development costs for a greenfield site are substantial, especially with regard to building the required infrastructure and conducting the site characterization.

Finally, community acceptance of a new nuclear power plant in an area that is not familiar with their operational record is an unknown factor. This would have an impact on the ability to finance a project.

Based on the above considerations, Dominion has concluded that a generic greenfield site is not an obviously superior alternative for siting new units. Therefore, no further evaluation of greenfield sites was performed.

9.3.3.4 Existing Nuclear Sites Review

9.3.3.4.1 Benefits of Existing Nuclear Power Plant Sites

There are obvious benefits offered by locating a new nuclear power plant at an existing nuclear site rather than a non-nuclear site. These benefits are summarized below:

- Environmental Benefits
  - The existing environmental conditions and the environmental impacts of an existing nuclear station are known from data collected during years of monitoring air, water, ecological, and other parameters. Based on the knowledge of the various reactors and ancillary facilities being considered in the Generic PPE, it is reasonable to assume that the impacts of additional units would be comparable to those of the operating units.
  - Construction of new transmission corridors may be avoided if the existing transmission system (lines and corridors) can accommodate the increased power generation. This could substantially reduce environmental impacts associated with construction of the new plant.
  - No additional land acquisitions would be necessary if a new transmission corridor can be avoided, and the resulting land use impacts of the new plant would be small.
  - The sites have already been subject to the alternative review process mandated by the NEPA.
  - The sites have extensive environmental studies performed during the original site selection process, which could be updated and used for new units.
- Constructability and Cost Benefits
  - Site physical criteria, including primarily geologic/seismic suitability, have been characterized at existing nuclear sites.
  - No additional land acquisitions would be necessary, if a new transmission corridor can be avoided and the site can accommodate the land requirements of the new units.
  - Plant construction, operation, and maintenance costs would be reduced because of existing site infrastructure (e.g., roads, transmission lines, water source, intake/discharge system) and its maintenance.
- Other Benefits
  - The existing sites have nearby power markets.
  - Existing nuclear plants are likely to have gained local community acceptance and support.
  - Existing nuclear sites have relevant nuclear experience.

9.3.3.4.2 **Nuclear Power Station Sites Owned by DRI Subsidiaries**

Existing nuclear power plants where Dominion could more readily obtain access and control are preferred over other nuclear sites. Sites that were originally designed for more generation than actually constructed also received preference.

Various DRI subsidiaries own and control three nuclear power stations within the ROI: NAPS and Surry Power Station in Virginia, and Millstone Power Station in Connecticut. The following paragraphs examine these sites for further consideration as alternative sites.

- North Anna Power Station
  - The 1803-acre NAPS site is located on Lake Anna in northeastern Virginia. Lake Anna, built to supply cooling water for the power station, is approximately 17 miles long and has 272 miles of shoreline. Two 944 MWe PWRs are currently in operation at North Anna. The site is located approximately 40 miles north-northwest of Richmond, 36 miles east of Charlottesville, and 22 miles southwest of Fredericksburg. The NAPS site was originally issued construction permits for two additional units.
- Surry Power Station
  - The 840-acre Surry site is located on the Gravel Neck Peninsula on the south side of the James River in Surry County, Virginia. The Hog Island Wildlife Management Area is situated on the tip of the peninsula. Two 855 MWe PWRs are currently in operation at Surry. The site is 7 miles south of two large tourist attractions: Colonial Williamsburg and Busch Gardens Amusement Park. Urban areas of Hampton Roads, Virginia, are 10 to 30 miles north and east of the site. The Surry site was originally issued construction permits for two additional units.
- Millstone Power Station
  - The 500-acre Millstone Power Station site sits on a peninsula on the eastern end of Long Island Sound, in Waterford, Connecticut. The station consists of three units. Unit 2, an 878 MWe PWR, and Unit 3, a 1152 MWe PWR, are currently in operation. Unit 1 is undergoing decommissioning. Parts of Connecticut, Rhode Island, and New York, including the major population centers of the Hartford and New Haven metropolitan areas in Connecticut and the Warwick and Newport areas in Rhode Island are within a 50-mile radius of the site. The east-west running portion of Interstate 95 along Long Island Sound in Connecticut passes within five miles of the site. Harkness Memorial State Park, three miles east of the site, is designed to accommodate and is used frequently as recreational facilities for persons with special needs. Rocky Neck State Park is 5 miles west of the site.

    This site was eliminated from further evaluation as an alternative site because of its proximity to a special recreational facility; an ongoing feasibility study that evaluates once-through cooling system impacts; and the potential for fogging and/or icing impacts associated with wet mechanical draft cooling towers. Furthermore, the site had not been licensed for additional units to those constructed.

9.3.4 Alternative Sites Evaluation

Four candidate sites: North Anna, Surry, Savannah River, and Portsmouth were identified as alternative sites. These four sites were further examined and evaluated to select the preferred site. The evaluation process and methodology used, and the findings of the evaluation are described in Reference 2.

9.3.4.1 A Summary of the Evaluation Process

Each site was evaluated against 45 suitability criteria, grouped into four major categories:

1. Environmental – Includes criteria (e.g., local population, groundwater, aquatic habitat and organisms) for assessing the potential adverse impacts of plant construction, operation, and decommissioning on the site, the surrounding environment, and the people.

2. Sociological – Includes criteria (e.g., socioeconomic benefits, present/planned land use, environmental justice) for assessing the potential impacts of plant construction, operation, and decommissioning on sociological issues.

3. Engineering – Includes regional, environmental, site, or other characteristics (e.g., cooling water source, site size, emergency planning requirements, site-specific seismic concerns, environmentally sensitive areas) that have the potential to impact the design, construction, operation, or decommissioning of a nuclear facility.

4. Economic – Includes criteria for assessing electricity and market projections, transmission line access, stakeholder support, and site development costs.

Table 9.3-2 provides a listing of these 45 criteria by category.

A ranking or score was assigned for each criterion. The sum of the weighted scores for all criteria is the total site merit score. In addition, a “bounding plant” was evaluated to establish a ranking score that would envelop the selected advanced reactor designs.

9.3.4.2 Discussion of Ranking Results

The bounding plant site merit scores are provided in Table 9.3-3. A “site merit” score of 500 is the maximum that can be achieved for the “total site merit” of any criteria subgroup. Results show a narrow total score spread (i.e., ranging from 351 to 377) with the North Anna ESP site ranking highest. These results further indicate that all four sites are suitable locations for additional nuclear generating units.

Based on the results of the evaluation, Dominion decided to locate the ESP site within the NAPS site. This basis included the special case provision noted in NUREG-1555, ESRP 9.3 (Subsection III(8)), that a new facility to be constructed can be located at an existing nuclear power plant site previously found acceptable from a NEPA review and/or demonstration of satisfactory environmental operating experience (Reference 1). Although the other sites were found to be environmentally acceptable, Dominion concluded that there are no obviously superior sites to the North Anna ESP site.

Subsequent to completion of the alternative site evaluation, additional evaluations of cooling water alternatives for the ESP site were conducted. Dominion decided to use a closed-cycle, combination wet and dry cooling tower approach for Unit 3 instead of the once-through cooling system originally

proposed. Due to the change in the cooling system design, a review of the alternative site evaluation was conducted to determine the impact, if any, on the North Anna site merit score and conclusions reached by this evaluation. Based on this review, it was determined that alternative approaches for the cooling system, including the use of dry or wet cooling towers, were considered as part of the rankings assigned to suitability criteria for the North Anna site. Therefore, the changes in the cooling system design have minimal impact on the North Anna site ranking versus the alternative sites, and do not affect the overall conclusion reached in the site evaluation that there are no obviously superior sites to the North Anna ESP site.

Section 9.3 References

1. NUREG-1555, *Environmental Standard Review Plan*, U.S. Nuclear Regulatory Commission (USNRC), October 1999.

2. *Study of Potential Sites for the Deployment of New Nuclear Plants in the United States,* U.S. Department of Energy Cooperative Agreement No. DE-FC07-02ID14313, Prepared by Dominion Energy, Inc. and Bechtel Power Corporation, September 2002. np2010.ne.doe.gov/ESP_Study/ESP_Study_Dominion.pdf

3. NUREG-1437, *Generic Environmental Impact Statement for License Renewal of a Nuclear Plant,* Supplement 7, Regarding North Anna Power Station, Units 1 and 2, Final Report, U.S. Nuclear Regulatory Commission, November 2002.

Table 9.3-1 Summary of Environment Impacts For New Nuclear Units

Impact Areas	Phase of Project	At Existing Nuclear Site	At Generic Greenfield Site
Land Use		Moderate	Moderate to Large
Water Quality		Small	Small to Moderate
Air Quality		Small	Small
Ecological Resources		Moderate	Moderate to Large
Human Health		Small	Small
Socioeconomic Non-Transportation	During Construction During Operation	Small to Moderate Small	Large Small to Moderate
Socioeconomic Transportation	During Construction During Operation	Moderate to Large Small	Moderate to Large Small to Moderate
Waste Management		Small	Small
Aesthetics		Small	Large
Cultural Resources: Historical & Archaeological Resources		Small	Small
Environmental Justice		Small	Small to Large

Source: Supplement 7 of GEIS, November 2002

Table 9.3-2 Suitability Criteria

Economic	Engineering	Environmental	Socioeconomic
Electricity Projections	Site Size	Terrestrial Habitat	Present/Planned Land Use
Transmission System	Site Topography	Terrestrial Vegetation	Demography
Stakeholder Support	Environmentally Sensitive Areas	Aquatic Habitat/ Organisms	Socioeconomic Benefits
Site Development Costs	Emergency Planning	Groundwater	Agricultural/ Industrial
	Labor Supply	Surface Water	Aesthetics
	Transportation Access	Population	Historic/ Archaeological
	Security		Transportation Network
	Hazardous Land Use		Environmental Justice
	Ease for Decommissioning		
	Water Rights and Air Permits		
	Regulatory		
	Schedule		
	Geologic Hazards		
	Site-Specific SSE		
	Capable Faults		
	Liquefaction Potential		
	Bearing Material		
	Near-Surface Material		
	Groundwater		
	Flooding Potential		
	Ice Formation		
	Cooling Water Source		
	Temperature & Moisture		
	Winds		
	Rainfall		
	Snow		
	Atmospheric Dispersion		

Source: Part 2, Table 6-2 of “Study of Potential Sites for the Deployment of New Nuclear Plants in the United States”, U.S. Department of Energy Cooperative Agreement No. DE-FC07-02ID14313, Prepared by Dominion Energy, Inc. and Bechtel Power Corporation, September 2002.

Table 9.3-3 Site Merit Scores for the Four Alternative Sites

Site	Economic	Engineering	Environmental	Sociological	Total
North Anna	392	326	359	418	377
Savannah River	323	382	344	489	372
Portsmouth	321	348	345	453	358
Surry	348	304	339	416	351

Source: Extract from Executive Summary, Table 2 of “Study of Potential Sites for the Deployment of New Nuclear Plants in the United States”, U.S. Department of Energy Cooperative Agreement No. DE-FC07-02ID14313, Prepared by Dominion Energy, Inc. and Bechtel Power Corporation, September 2002.

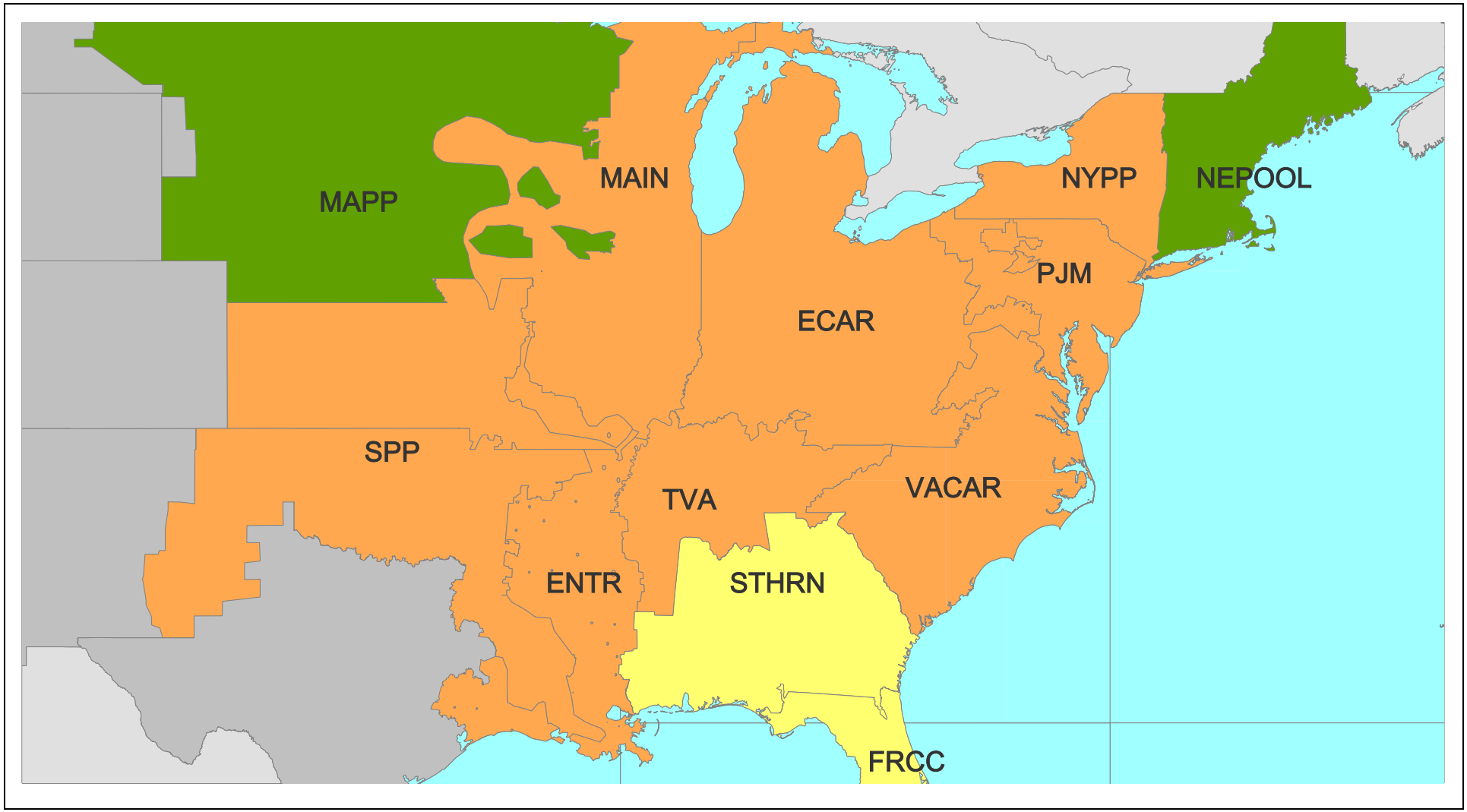

Figure 9.3-1 Region of Interest

9.4 Alternative Plant and Transmission Systems

This section describes the evaluation of the alternative plant and transmission systems for heat dissipation, circulating water, and power transmission, in accordance with NUREG-1555 (Reference 1, Section 9.4).

The evaluation of alternatives is segregated into the following topics:

- Heat dissipation systems
- Circulating water systems
- Transmission systems

9.4.1 Heat Dissipation Systems

This evaluation focuses on identifying alternative heat dissipation systems that are feasible, legislatively compliant, and environmentally preferable. In accordance with NUREG-1555, this evaluation first compares these alternatives with the proposed system using standardized criteria that include land use, water use, thermal and physical impacts, atmospheric effects, noise generation, aesthetics and recreational benefits, generating efficiency, and operating and maintenance experience with similar units. (Reference 1, Section 9.4.1)

The proposed system and alternatives that prove to be feasible, legislatively compliant, and environmentally preferable have been economically evaluated. This economic evaluation is limited to a comparison of the relative costs of these screened alternatives.

Heat from the new units would be dissipated by two independent systems: 1) a closed-cycle, dry and wet tower cooling system for Unit 3, and 2) a closed-cycle dry tower system for Unit 4. The “base case” for Unit 3 is a closed-cycle, with a combination of dry and wet mechanical draft towers. The dry cooling tower would consist of a series of moderate-profile, rectangular structures that house large fans and piping, and the wet cooling towers would consist of a series of multi-cell, rectangular cooling tower banks. Associated intake/discharge, pumping, and piping systems would be required. Cooled water from the towers would be pumped first through the condenser, where it would be heated. The heated water would then be circulated through the dry and wet towers where it would reject heat to ambient air. Make-up water would be obtained from the North Anna Reservoir, and wet cooling tower blowdown would be discharged to the head of the existing discharge canal. The Unit 3 base case system is compared with the following heat dissipation alternatives:

- Once-through system (Alternative 1): This alternative would include a once-through system with its intake and pumping system on the North Anna Reservoir, and discharges at the head of the discharge canal.

- Once-through system with helper tower (Alternative 2): This alternative would include the once-through system and a small multi-cell mechanical draft cooling tower system. The helper tower would operate on an as-needed basis during the warmest summer months to mitigate the peak temperatures in the WHTF and the North Anna Reservoir by transferring heat to the environment via evaporation, and directly to the atmosphere. Water would be withdrawn from the North Anna Reservoir and cooling tower blowdown would be returned to the discharge canal.
- Natural draft cooling tower system (Alternative 3): This alternative would consist of a number of free-standing, hyperbolic towers and associated intake/discharge, pumping, and piping systems. This closed-cooling system would withdraw water from the North Anna Reservoir and transfer heat to the environment via evaporation and directly to the atmosphere. Minor cooling tower blowdown discharges would be released to the existing discharge canal.
- Mechanical draft cooling tower system (Alternative 4): This alternative would consist of four multi-cell, rectangular cooling tower banks and associated intake/discharge, pumping, and piping systems. This closed-cooling system would withdraw water from the North Anna Reservoir and transfer heat to the environment via evaporation and directly to the atmosphere. Minor cooling tower blowdown discharges would be released to the existing discharge canal.
- Spray ponds (Alternative 5): This alternative would involve the addition of new surface water bodies on site and the addition of an extensive matrix of spray modules to promote evaporative cooling in the new ponds. Additional pumping and piping systems would be required.
- Dry tower system (Alternative 6): This alternative would consist of a series of moderate profile (150-foot high) rectangular structures that house large fans and piping. There would be little other resources required (e.g., water, wastewater) besides land.

The Unit 4 base case would consist of a dry tower system. The Unit 4 base case system is compared with the following heat dissipation alternatives:

- Once-through system (Alternative 7)
- Once-through system with helper tower (Alternative 8)
- Natural draft cooling tower system (Alternative 9)
- Mechanical draft cooling tower system (Alternative 10)
- Spray ponds (Alternative 11)

9.4.1.1 Technical, Regulatory, and Environmental Review of Heat Dissipation Systems – Unit 3

The Unit 3 base case and alternative heat dissipation systems are evaluated and compared in Table 9.4-1 through Table 9.4-3.

The Unit 3 evaluation concludes that the following heat dissipation systems are feasible, legislatively compliant, and environmentally preferable or equivalent to the base case:

- Natural draft cooling tower system (Alternative 3)
- Mechanical draft cooling tower system (Alternative 4)
- Dry towers (Alternative 6)

The once-through system (Alternative 1), once-through system with helper tower (Alternative 2) and the spray pond system (Alternative 5) posed regulatory approval barriers, as presented in Table 9.4-2, and therefore have been removed from further consideration.

9.4.1.1.1 Relative Economic Evaluation of Heat Dissipation Systems – Unit 3

The Unit 3 capital costs would be the highest for dry towers (Alternative 6). The capital cost for alternatives using wet cooling towers (Alternatives 3 and 4), including the base case, would be lower than dry towers. The operating costs of wet cooling tower alternatives, including the base case, are lower than dry towers (Alternative 6), primarily because dry tower fans use more power.

9.4.1.1.2 Alternative Heat Dissipation System Summary – Unit 3

Table 9.4-3 offers a summary comparison of the relative natural resource (i.e., land, water) requirements, environmental impacts, regulatory barriers, operating issues, and energy/economic considerations for the base case and the alternative heat dissipation systems for Unit 3. This table identifies the closed-cycle, dry and wet tower system (base case) as the preferred cooling system option because of its advantages from regulatory, water usage, and thermal impact perspectives. The once-through cooling systems (Alternatives 1 and 2) offers advantages with respect to land use, aesthetics (no visual impact or noise), superior operating experience, and low impact on generating efficiency. However, the once-through systems raised concerns involving discharge water temperature to the WHTF, resultant increase in lake water temperature, water usage from the North Anna Reservoir, potential impacts on striped bass population, and difficulty in obtaining regulatory approval. Therefore, the once-through systems were determined to be unacceptable alternatives for Unit 3. While the remaining wet and dry tower systems (Alternatives 3, 4 and 6) scored lower on key attributes than the base case, they did not present any fatal flaws, and thus, they were also deemed appropriate for further energy and economic review.

Subsequent cost comparisons show that the capital and operating costs of dry towers alone (Alternative 6) would be higher than wet towers or combination dry and wet towers. A 100 percent dry cooling tower system would require significantly more fans to dissipate condenser rejected heat. It is estimated that up to 80 MW would be required to power dry tower fans under design operating conditions. Even when compared to operation in the MWC mode (dry towers operating and removing at least one-third of condenser heat duty) under design conditions, the 100 percent dry cooling system fans require more than three times the power of the combination dry and wet cooling tower circulating water system fans. The lower efficiency of the dry tower system represents

a significant increase in fuel requirements over the lifetime of the plant. In addition, evaluations show that the all-dry system (three-thirds dry cooling capacity) material cost is more than 500 percent higher than a one-third minimum dry cooling capacity system and the dry system contains significantly more active components, which would increase maintenance costs. Also, the dry tower system alone is unable to produce the needed performance required during periods of high ambient dry bulb temperature (>95°F), which could occur during the summer season, without having periods of power reduction. Thus, a partially wet cooling tower system is required to lower the cooling water temperature sufficiently to operate the plant without a reduction in unit power output. Dry cooling towers can require as much as 10 times the area of a wet tower with a comparable cooling capacity, depending on the technology selected. Because of its thermal performance limitations when air ambient temperature is high, a dry tower array would become very large, using significant acreage, and could have a higher profile.

The capital and operating costs of wet tower systems would be lower than combination dry and wet tower systems. However, the natural-draft and mechanical-draft cooling towers (Alternatives 3 and 4) would not provide the operational flexibility of the base case with respect to water usage and reduced downstream water flow. When water usage has to be reduced during drought conditions and low lake levels, the base case, which has the dry towers, would afford the ability to continue to operate Unit 3 with a minimum of one-third of the heat dissipation achieved through the use of the dry towers and, depending on prevailing ambient conditions, a significantly higher than one-third of the heat dissipation could be achieved through the dry towers. Therefore, the combination wet and dry tower system is superior on the most important environmental factors essential for obtaining regulatory approval and preserving lake water under normal and severe drought conditions.

Thus, Table 9.4-3 illustrates that the Unit 3 base case is the preferable heat dissipation system.

9.4.1.1.3 Thermal Impact and Water Level Enhancements – Unit 3

As demonstrated in previous sections, Lake Anna would dissipate the negligible waste heat from the continuous blowdown of Unit 3 wet towers. Because blowdown is taken from water already cooled in the towers, any additional waste heat to Lake Anna would be negligible. From a water level perspective, operation of dry towers during the MWC mode of operation would reduce water consumption from Lake Anna. Therefore, Dominion has not considered any other supplemental options to mitigate decreases in lake level from operation of the preferred Unit 3 combination dry and wet tower cooling system.

9.4.1.2 Technical, Regulatory, and Environmental Review of Heat Dissipation Systems – Unit 4

The Unit 4 base case and alternative heat dissipation systems are evaluated and compared in Table 9.4-4 through Table 9.4-6.

This tabular evaluation (Table 9.4-4 and Table 9.4-5) indicates that once through options (Alternatives 7 and 8), wet cooling tower options (Alternatives 9 and 10), and the spray pond

system (Alternative 11) would have to overcome significant regulatory barriers with respect to water usage from the North Anna Reservoir. In particular, even with natural-draft or mechanical cooling towers, a supplemental source of cooling water would be required during drought conditions to maintain minimum lake levels and downstream flows. The need for a supplemental source of cooling water would result in additional impacts, such as consumption of water from remote supplies and the impacts of transporting the water (e.g., the impacts of building a pipeline). In the absence of any identifiable and readily available source, none of these alternatives is currently deemed feasible.

9.4.1.2.1 Relative Economic Evaluation of Heat Dissipation Systems – Unit 4

Because none of the alternatives to the base case currently appears feasible, energy and economic considerations are not relevant.

9.4.1.2.2 Alternative Heat Dissipation System Summary – Unit 4

Table 9.4-6 offers a summary comparison of the relative land and water resource needs, environmental impacts, regulatory barriers, operating issues, and economic considerations for the base case and the alternative heat dissipation systems for Unit 4. This comparison illustrates that the Unit 4 base case dry tower system is the preferable heat dissipation system.

9.4.2 Circulating Water Systems

As presented in Section 9.4.1, the proposed heat dissipation systems for the new units at the ESP site are a closed-cycle, dry and wet cooling tower system for the first new unit (Unit 3), and a closed-cycle dry tower system for the second new unit (Unit 4). Since the proposed systems for Units 3 and 4 do not comprise an open-loop circulating water system, there is no need to evaluate circulating water system alternatives. The closed-loop circulating water system for Unit 3 would, however, require continuous make-up water to the wet cooling tower basin to compensate for the evaporative losses and cooling tower blowdown when waste heat cannot be rejected via the dry towers alone. The quantity of make-up is only about 2 percent of what would be required to be withdrawn for a once-through system, so the intake water for Unit 3 would be very small compared to the existing units' intake. This evaluation focuses on identifying feasible make-up water intake systems that are legislatively compliant, environmentally preferable, and economically viable. In accordance with NUREG-1555 guidance, this evaluation first compares alternative intake water systems against the base case system using standardized criteria that include construction impacts, aquatic issues, water use, land use, and compliance with regulations (Reference 1, Section 9.4.2). As stated in NUREG-1555, the proposed system and alternatives that prove to be feasible, legislatively compliant, and environmentally preferable are then evaluated on an economic basis. In this case, a comparison of alternate intake water system components has not revealed alternatives that are preferable on an environmental basis. Therefore, further economic analysis of alternatives is not warranted.

The base case intake water system for Unit 3 comprises:

- Intake System: Shoreline
- Intake Location: Adjacent to existing intake structure on Lake Anna
- Discharge System: Shoreline
- Discharge Location: Existing discharge canal
- Water Supply: Lake Anna
- Water Treatment: Mechanical condenser cleaning and chemical biocide/corrosion/antiscalant treatment (cooling tower systems)

The following sections evaluate this base case against a list of potential alternative system components that address intake, discharge, water supply, and water treatment issues for Unit 3 only.

9.4.2.1 Intake System

While NUREG-1555 suggests that the intake system evaluation address alternative intake systems, locations, pumping arrangements, defouling processes and screens; the base case design has not matured sufficiently to support evaluation of alternative pumping, defouling and screen systems. Consequently, the evaluation of the intake base case and alternatives is limited to the intake system and intake location. Table 9.4-7 and Table 9.4-8 provide an evaluation or comparison of the following base case and alternative intake systems and locations:

- Systems
  - Shoreline Intake System (Base Case): Partially submerged concrete inlet structure positioned along the shoreline.
  - Offshore Intake (Alternative 1): Completely submerged intake structure(s) positioned just above the bottom of the body of water supply source, some distance from shore.
- Locations
  - Existing Intake location (Base Case): Intake location immediately adjacent to existing units intake on Lake Anna
  - Alternate intake location on Lake Anna (Alternative 2): Intake location at least several hundred feet away from the existing intake structure
  - Lower North Anna River (Alternative 3): Intake location downstream of the North Anna Dam along the North Anna River

This evaluation concludes that: 1) an offshore intake system or alternate intake locations would be difficult to permit, 2) the alternatives could generate larger environmental impacts relative to the base case intake system arrangement, and finally 3) they could trigger costly additional permitting,

stakeholder consultations, and environmental restoration. Therefore, further economic evaluation of the base case and alternative intake systems is unwarranted.

9.4.2.2 **Discharge System**

While NUREG-1555 also suggests that the discharge system evaluation address alternative discharge systems, locations, and discharge port technology, the incomplete base case discharge design can only support consideration of alternate discharge systems and locations. The discharge water quantity is smaller than the intake because the discharge comprises cooling tower blowdown only, whereas the intake comprises make-up for evaporative losses, drift losses, and blowdown. Table 9.4-9 and Table 9.4-10 provide comparisons of the following base and alternative discharge systems and locations.

- Discharge Systems
  - Shoreline Discharge (Base Case): Concrete, partially submerged, discharge structure along shoreline of receiving body of water
  - Offshore Discharge (Alternative 4): Completely submerged discharge structure(s) positioned just above the receiving water body bottom, some distance from shore
- Discharge Location
  - Existing discharge location (Base Case): Discharge location (shoreline) at the head of the Discharge Canal immediately adjacent to the existing units discharge structures
  - Waste Heat Transfer Facility (WHTF) Location (Alternative 5): Discharge location (shoreline) in a portion of the WHTF outside of the discharge canal
  - Lake Anna (Alternative 6): Discharge location (shoreline) in publicly accessible portion of Lake Anna

This evaluation concludes that: 1) the all of the discharge system alternatives may be more difficult to permit than the base case, and 2) they could generate larger adverse environmental impacts relative to the base case intake system arrangement. Further economic evaluation of the base case and alternative discharge systems is unwarranted.

9.4.2.3 **Water Supply**

The evaluation of alternative water supplies prescribed by NUREG-1555 is amended herein because of the certainty of water supply (Lake Anna) for the Unit 3 preferred closed-cycle, dry and wet cooling tower system and because of the application of the closed-cycle dry tower system for Unit 4.

9.4.2.4 **Water Treatment**

The evolving water treatment system design is not sufficiently mature to support all of the NUREG-1555 suggested water treatment evaluation processes: water treatment processes,

chemical additives, and operating mode. Consequently, the evaluation of the water treatment processes focuses herein only on water treatment system issues for Unit 3. Table 9.4-11 provides a tabularized evaluation of the following base case and alternative water treatment systems.

- Water Treatment Systems
  - Mechanical Treatment (Base Case): Periodic mechanical cleaning of condenser tubing
  - Chemical Treatment (Alternative 7): Cooling water biofouling, corrosion and pH control chemical additives
  - Non-chemical Treatment (Alternative 8): Ultraviolet light sterilization

This evaluation demonstrates that the Unit 3 base case mechanical condenser cleaning option poses smaller adverse environmental impacts than the other technically-feasible alternative treatment system—the chemical treatment system. The mechanical cleaning system represents the environmentally-preferred treatment system for the Unit 3 condenser. However the mechanical cleaning process is not practical for the cooling towers. Therefore, chemical treatment (Alternative 7) would be necessary. A chemical treatment system would be selected that meets environmental impact limits. The dry tower system for Unit 4 poses minimal water treatment requirements. Further economic evaluation of the base case and alternative water treatment systems is unwarranted.

9.4.2.5 Summary

The evaluation of the key components (excluding water supply) of the base case and alternative intake water systems for Unit 3 indicates that the following base case configuration collectively represents the only environmentally preferable circulating water system:

- Intake System: Shoreline
- Intake Location: Adjacent to existing intake structure on Lake Anna
- Discharge System: Shoreline
- Discharge Location: Adjacent to existing discharge structure on discharge canal
- Water Supply: Lake Anna
- Water Treatment: Mechanical condenser cleaning and chemical biocide/corrosion/pH adjustment treatment, as required for cooling towers

9.4.3 Transmission Systems

NUREG-1555, Section 9.4.3, provides guidelines for the preparation of a summary discussion that identifies the feasible and legislatively compliant alternative transmission systems. Based on an initial evaluation, the current ESP site transmission lines and corridors have sufficient capacity for the total output of the existing and new units. There are no environmentally equivalent or more advantageous alternatives to “no action.”

Section 9.4 References

1. NUREG-1555, *Environmental Standard Review Plan* U.S. Nuclear Regulatory Commission, October 1999.

2. *Platts Power Magazine*, “Cooling Options Change for a Hot, Thirsty Industry,” September 2002.

3. Vermeyen, T, “Use of Temperature Control Curtains to Control Reservoir Release Water Temperatures,” Report No. R-97-09, Water Resources Research Lab., Bureau of Reclamation, Denver, December 1997.

4. *New All Organic Chemistry for Treatment of Closed Cooling Tower Systems*, Paper No. TP-07, Cooling Tower Institute, 2002.

5. CWA §316(b), Technical Development Document for the Final Regulations (EPA-821-R-01-036), *Chapter 3: Energy Penalties, Air Emissions, and Cooling Tower Side Effects*, U.S. Environmental Protection Agency, http://www.epa.gov/waterscience/316b/technical/ch3.pdf, November 2001.

Table 9.4-1 Screening of Unit 3 Alternative Heat Dissipation Systems (Base Case & Alternatives 1–2)

Factors Affecting System Selection	Combination Dry and Wet Towers (Base Case)	Once-Through (Alternative 1)	Once-Through with Helper Tower (Alternative 2)
Land Use: Onsite Land Considerations	A combination dry and wet mechanical draft cooling tower (CDWMDCT) system would require more land (as compared to the OT system) to site widely spaced dry and wet towers. A CDWMDCT system could be placed within the confines of the existing NAPS site.	The once-through (OT) system would have the smallest land requirements. The OT system could be placed within the confines of the existing NAPS site.	A once-through and helper tower (OTHT) system would require marginally more land than is required by the OT system alone, but less than other cooling tower systems. The OTHT system could be placed within the confines of the existing NAPS site.
Land Use: Terrain Considerations	CDWMDCT system withdraws less water and so is less affected by significant terrain variations. Terrain features of the site are suitable for a CDWMDCT system.	OT systems require flat or gently rolling terrain to minimize pump head requirements. Terrain features of the site would not preclude the use of the OT system.	OTHT systems require flat or gently rolling terrain situations. Terrain features of the site are suitable for an OTHT system.
Water Use	The closed wet cooling tower system would have considerable evaporative losses to the atmosphere, but these losses could be reduced by operation of the dry towers in the MWC mode, thus reducing the water usage and conserving water during drought conditions.	An OT system would have an intake requirement of nearly 50 times more water than a mechanical draft wet cooling tower (MDCT) system. OT - 1,140,000 gpm Wet cooling systems - 23,950 gpm Despite this increased water intake requirement, the OT system would return most of the withdrawn water. However, the evaporative loss due to the increased temperature in the WHTF and the lake would exceed the consumption of the CDWMDCT (base case) in the MWC mode.	An OTHT system would require the second largest water supply. Although the helper tower system would reduce water intake requirements, its use would not reduce water usage to below the combined dry and wet tower operation.

Table 9.4-1 Screening of Unit 3 Alternative Heat Dissipation Systems (Base Case & Alternatives 1–2)

Factors Affecting System Selection	Combination Dry and Wet Towers (Base Case)	Once-Through (Alternative 1)	Once-Through with Helper Tower (Alternative 2)
Regulatory Restrictions	An intake structure for a CDWMDCT system would meet Section 316(b) of the CWA and the implementing regulations, as applicable. The VPDES discharge permit thermal discharge limitation to the WHTF would need to be modified to account for the minor additional thermal load rejected by the new CDWMDCT system. These regulatory restrictions would have small impacts on this heat dissipation system.	The intake structure for the OT system would meet Section 316(b) of the CWA and the implementing regulations, as applicable. Because of concerns with thermal impacts and water consumption, permitting would be difficult.	An intake structure for the OTHT systems would meet Section 316(b) of the CWA and the implementing regulations, as applicable. While the helper tower would temper the thermal loading to the WHTF during the hottest summer season periods, concerns with thermal impacts and water consumption would pose an impediment to permitting.
Atmospheric Effects	The CDWMDCT system would emit water droplets (drift) and intermittently produce a visible vapor plume. The drift droplets would be a minor source of particulate matter and salt deposition. The water vapor plume would result in minimal additional fogging but no icing conditions on local road systems. Aesthetic impacts from the visible plume would be small.	Since OT systems do not produce a visible plume and the associated pond-induced fogging (steam fog) is minimal, atmospheric effects would be small.	An OTHT system would emit water droplets (drift) and produce visible plumes during periods when the helper tower is in operation. The particulate, salt deposition and fogging and aesthetic impacts would not be significant from the infrequent/intermittent operation of this small cooling tower.
Thermal and Physical Effects	The CDWMDCT system would discharge a significantly smaller thermal load to the WHTF (compared to OT systems) because 65–85% of the heat removal in cooling towers is associated with evaporation (Reference 2). Most of the remaining heat is dissipated directly to the atmosphere. The small amount of heat from blowdown to the WHTF would be additive to the OT thermal load from the existing units. The VPDES permit thermal discharge criteria would need to be revised to reflect this minor addition.	The OT system would add thermal load to the WHTF, resulting in the greatest temperature increase to the WHTF and the lake. The VPDES permit thermal discharge criteria would need to be revised to reflect this addition of thermal load.	An OTHT system would add thermal load to the WHTF. The helper tower would temper the thermal loading to the WHTF during the hottest summer season periods, but the thermal impact would be greater than the base case. The VPDES permit thermal discharge criteria would need to be revised to reflect this addition of thermal load.

Table 9.4-1 Screening of Unit 3 Alternative Heat Dissipation Systems (Base Case & Alternatives 1–2)

Factors Affecting System Selection	Combination Dry and Wet Towers (Base Case)	Once-Through (Alternative 1)	Once-Through with Helper Tower (Alternative 2)
Noise Levels	CDWMDCT operation would generate noise from fan and pump operation and from cascading water in the towers. The results of the Section 5.3.4 noise evaluation for combination dry and wet tower system suggests that noise impacts for the CDWMDCT would also be below the NRC-defined significance levels (65 dBA) at the EAB. Construction related noise impacts would be small.	OT system operation would generate small noise impacts from pump operation. Construction-related noise impacts would be small.	OTHT operation would generate noise from fan and pump operation and from cascading water in the towers during the periods when the helper tower is needed. The associated noise impacts would be less than the dry tower system impacts, which were below the NRC-defined significance levels (65 dBA) at the EAB as described in Section 5.3.4. Construction-related noise impacts would be small.
Aesthetics and Recreational Benefits	The CDWMDCT system would be wholly situated on the existing NAPS site and the primary external impact would be the minor discharge of heated water to the North Anna Reservoir via the WHTF. Discharges to the North Anna Reservoir, a popular recreational resource, would produce no tangible aesthetic or recreational benefits.	The OT system would be wholly situated on the existing NAPS site and its primary external impact would be the discharge of a large quantity of heated water to the North Anna Reservoir via the WHTF. Discharges to the North Anna Reservoir, a popular recreational resource, would produce no tangible aesthetic or recreational benefits.	An OTHT system would be wholly situated on the existing NAPS site and its primary external impact would be the discharge of large quantity of heated water to the North Anna Reservoir via the WHTF. Discharges to the North Anna Reservoir, a popular recreational resource, would produce no tangible aesthetic or recreational benefits.
Operating and Maintenance Experience	Dry and wet tower systems are common to power plants (both fossil and nuclear) and are considered highly reliable.	OT systems are common to older power plants (both fossil and nuclear) and they are considered highly reliable.	While OTHT systems are less common than OT systems, they do not pose any greater operating and maintenance risks than other cooling tower systems.
Generating Efficiency Penalty	The energy penalty (% reduction in plant output) of CDWMDCT systems versus OT systems is 1.7 to 4 percent. (extrapolated from Reference 5, Tables 3-1 and 3.2).	The OT system has the least energy requirement. The energy penalty (% reduction in plant output) of wet tower systems versus OT systems is 1.7 to 1.9%. The energy penalty of dry tower systems versus OT systems is 8.5 to 11.4%. (Reference 5, Tables 3-1 and 3-2)	The additional energy requirements associated with cooling tower operation do not alter this system's energy efficiency advantages over wet cooling tower only systems.
Is this a suitable heat dissipation system?	Yes	No	No

Table 9.4-2 Screening of Unit 3 Alternative Heat Dissipation Systems (Alternatives 3–6)

Factors Affecting System Selection	Natural Draft Cooling Towers (Alternative 3)	Mechanical Draft Cooling Towers (Alternative 4)	Spray Ponds (Alternative 5)	Dry Towers (Alternative 6)
Land Use: Onsite Land Considerations	A natural draft cooling tower (NDCT) system would require less land (as compared to a CDWMDCT system) to accommodate the hyperbolic towers. An NDCT system could be placed within the confines of the existing NAPS site.	An MDCT system would require less land (as compared to the CDWMDCT system) to site the towers. An MDCT system could be placed within the confines of the existing NAPS site.	A spray pond-cooling alternative would involve the development of significant additional surface water impoundments and consequently pose the additional land requirements. It is unlikely that new spray ponds of sufficient size could be placed within the confines of the existing NAPS site.	A dry tower system would require more land than wet cooling tower systems. The dry tower system would require up to 10 times the land use area of the CDWMDCT system (base case). Dry towers could be situated within the confines of the existing NAPS site.
Land Use: Terrain Considerations	NDCT systems withdraw less water and so are less affected by substantial terrain variations. Terrain features of the site are suitable for an NDCT system.	MDCT systems withdraw less water and so are less affected by significant terrain variations. Terrain features of the site are suitable for a MDCT system.	Since spray pond construction involves substantial earthwork, such systems are most appropriate for flat or gently rolling terrain. Terrain features of the site are suitable for the addition of spray ponds.	Dry tower systems are unaffected by terrain considerations.
Water Use	The water intake requirements for the NDCT system and the CDWMDCT system are approximately the same when the unit is in the EC mode. However, when dry towers are in operation, the CDWMDCT system (base case) would have lower evaporative losses.	The water intake requirements for the MDCT system and the CDWMDCT system are approximately same. When dry towers are in operation, the CDWMDCT system (base case) would have lower evaporative losses	A spray pond would require large volumes of water and would likely require offsite sources of water.	A dry tower system would have no comparable evaporative water losses when compared with MDCTs or spray ponds. A dry tower system would require minimal service water.

Table 9.4-2 Screening of Unit 3 Alternative Heat Dissipation Systems (Alternatives 3–6)

Factors Affecting System Selection	Natural Draft Cooling Towers (Alternative 3)	Mechanical Draft Cooling Towers (Alternative 4)	Spray Ponds (Alternative 5)	Dry Towers (Alternative 6)
Regulatory Restrictions	An intake structure for an NDCT system would meet Section 316(b) of the CWA and the implementing regulations, as applicable. The VPDES discharge permit thermal discharge limitation to the WHTF would need to be modified to account for the small additional thermal load from NDCT blowdown.	An intake structure for an MDCT system would meet Section 316(b) of the CWA and the implementing regulations, as applicable. The VPDES discharge permit thermal discharge limitation to the WHTF would need to be modified to account for the minor additional thermal load from the MDCT blowdown.	Additional land would have to be obtained and developed to support the spray pond option. The development of this land may entail a substantial and lengthy federal, state, and local permit and approval process.	There would be little or no permit or approval-related impacts to the dry tower system alternative.
Atmospheric Effects	An NDCT system would emit water droplets (drift) and intermittently produce a visible plume. The drift droplets would be a minor source of particulate matter and salt deposition. The water vapor plume would not encourage any additional fogging or icing conditions on local road systems. Visible plume aesthetic impacts would be small.	The MDCT system would emit water droplets (drift) and intermittently produce a visible vapor plume. The drift droplets would be a minor source of particulate matter and salt deposition. The water vapor plume would result in minimal additional fogging but no icing conditions on local road systems. Aesthetic impacts from the visible plume would be small.	A spray pond system could produce a low-level visible water droplet plume and encourage formation of fog above the heated pond. These impacts would be localized and short-lived, and consequently small.	A dry tower system would not produce a visible plume or pose particulate emission or salt deposition impacts.

Table 9.4-2 Screening of Unit 3 Alternative Heat Dissipation Systems (Alternatives 3–6)

Factors Affecting System Selection	Natural Draft Cooling Towers (Alternative 3)	Mechanical Draft Cooling Towers (Alternative 4)	Spray Ponds (Alternative 5)	Dry Towers (Alternative 6)
Thermal and Physical Effects	An NDCT system would produce a small thermal load to the WHTF because 65–85% of the heat removal in these towers is associated with evaporation (Reference 2) and most of the remaining heat is dissipated directly to the atmosphere. The NDCT thermal load would be greater than the thermal load from the CDWMDCT system (base case) operating in the MWC mode. The small NDCT thermal load rejected to the WHTF would be additive to the OT thermal load from the existing units. The VPDES permit thermal discharge criteria would need to be revised to reflect this addition of thermal load.	The MDCT system would discharge a small thermal load to the WHTF because 65–85% of the heat removal in cooling towers is associated with evaporation (Reference 2). Most of the remaining heat is dissipated directly to the atmosphere. The MDCT thermal load would be greater than the thermal load from the CDWMDCT system (base case) operating in the MWC mode. The small MDCT thermal load rejected to the WHTF would be additive to the OT thermal load from the existing units. The VPDES permit thermal discharge criteria would need to be revised to reflect this small thermal load addition.	Since the thermal load would be rejected to the spray pond and that pond would be wholly dedicated to industrial use, the thermal impacts external to the pond would be none to small.	A dry tower system would direct an invisible heated plume of air into the atmosphere, and impacts would be small.
Noise Levels	An NDCT system would produce less noise than a wet and dry tower system because of the absence of fan-generated noise. Construction-related noise impacts would be small.	MDCT operation would generate noise from fan and pump operation and from cascading water in the towers. The results of the Section 5.3.4 noise evaluation suggests that noise impacts for the MDCT would also be below the NRC-defined significance levels (65 dBA) at the EAB. Construction-related noise impacts would be small.	Spray pond system operation would generate noise from the spray operations. Since the location of the spray ponds and associated receptor boundaries are presently undefined, the associated noise impacts cannot be evaluated at this time. Construction-related noise impacts would be small.	A dry tower system would generate operational noise from fan operation. The Section 5.3.4 noise evaluation for a dry tower system indicates that noise contributions from a dry tower system would produce impacts below the NRC-defined significance levels (65 dBA) at the EAB. Construction-related noise impacts would be small.

Table 9.4-2 Screening of Unit 3 Alternative Heat Dissipation Systems (Alternatives 3–6)

Factors Affecting System Selection	Natural Draft Cooling Towers (Alternative 3)	Mechanical Draft Cooling Towers (Alternative 4)	Spray Ponds (Alternative 5)	Dry Towers (Alternative 6)
Aesthetics and Recreational Benefits	An NDCT system would be wholly situated on the existing NAPS site and its primary external impact would be the discharge of heated water to the North Anna Reservoir via the WHTF. Discharges to the North Anna Reservoir, a popular recreational resource, would produce no tangible aesthetic or recreational benefits.	The MDCT system would be wholly situated on the existing NAPS site and the primary external impact would be the discharge of heated water to the North Anna Reservoir via the WHTF. Discharges to the North Anna Reservoir, a popular recreational resource, would produce no tangible aesthetic or recreational benefits.	The spray ponds would be at least partially situated on land outside of the NAPS site. The resulting commitment of previously undeveloped property to industrial use would produce no tangible aesthetic or recreational benefits.	A dry tower system would be wholly situated on the existing NAPS site and their primary external impact would be the discharge of heated air and noise to the atmosphere. These discharges would produce no tangible aesthetic or recreational benefits.
Operating and Maintenance Experience	NDCT systems are common to older power plants (both fossil and nuclear) and they are considered highly reliable.	MDCT systems are common to power plants (both fossil and nuclear) and are considered highly reliable.	Spray pond systems have been used on power plant sites and they pose no operational and maintenance constraints.	Dry tower systems are becoming more popular at power plants. Their more limited operating experience indicates that their reliability is similar to wet cooling towers. While dry tower systems are less common, they do not pose any greater operating and maintenance risks than other cooling systems.

Table 9.4-2 Screening of Unit 3 Alternative Heat Dissipation Systems (Alternatives 3–6)

Factors Affecting System Selection	Natural Draft Cooling Towers (Alternative 3)	Mechanical Draft Cooling Towers (Alternative 4)	Spray Ponds (Alternative 5)	Dry Towers (Alternative 6)
Generating Efficiency Penalty	Natural draft cooling tower energy requirements would be less than the CDWMDCT and the mechanical draft systems. (Reference 5, Tables 3-1 and 3-2)	The energy requirements for MDCTs would be more than the NDCT system, but less than the CDWMDCT system, because of the potential for operating the dry and wet towers together under certain conditions.	Spray ponds' efficiency penalty is greater than OT systems, but smaller than all the other cooling tower system based alternatives.	The energy penalty (% reduction in plant output) of dry tower systems would be approximately 7% greater than the CDWMDCT system (base case) (extrapolated from Reference 5, Tables 3-1 and 3-2). The dry tower system can not produce the needed performance required during periods of high ambient dry bulb temperature (>95°F) without periods of significant power output reduction.
Is this a suitable alternative heat dissipation system?	Yes	Yes	No	Yes

Table 9.4-3 Summary Comparison of Unit 3 Heat Dissipation Systems Impacts

	Base Case	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Criteria	**CDWMDCT**	**OT**	**OTHT**	**NDCT**	**MDCT**	**SD**	**Dry Tower**
Land Use	Medium	Low	Low	Low	Medium	High	High
Water Use	Medium	High	High	Medium	Medium	High	Low
Regulatory Barriers	Low	High	High	Low	Low	High	Low
Air Impacts	Medium	Low	Low	Medium	Medium	Low	Low
Thermal/Physical Impacts	Low	High	High	Medium	Medium	Medium	Low
Noise Impacts	Medium	Low	Low	Medium	Medium	Low	Medium
Aesthetics & Recreational Benefits	None	None	None	None	None	None	None
Operating and Maintenance Experience	High	High	Medium	High	High	Medium	Low
Generating Efficiency Penalty	Medium	Low	Low	Low	Medium	Low	High
Overall Environmental & Operability Ranking	Preferable	Unacceptable	Unacceptable	Acceptable	Acceptable	Unacceptable	Acceptable
Capital Costs	Medium	Not evaluated	Not evaluated	Medium	Medium	Not evaluated	High
Operating Costs	Medium	Not evaluated	Not evaluated	Low	Medium	Not evaluated	High
Costs Ranking	Acceptable	Not evaluated	Not evaluated	Acceptable	Acceptable	Not evaluated	Unacceptable
Overall Preference	X						

Table 9.4-4 Initial Screening of Alternative Heat Dissipation Systems - Unit 4 (Base Case & Alternatives 7–9)

Factors Affecting System Selection	Dry Towers (Base Case)	Once-Through (Alternative 7)	Once-Through with Helper Tower (Alternative 8)	Natural Draft Cooling Towers (Alternative 9)
Land Use: Onsite Land Considerations	A dry tower system would require more land than a wet cooling tower system. Since dry towers could be situated within the confines of the existing site, impacts would be none to small.	An OT system would have the smallest land requirements.	An OTHT system would require marginally more land than is required by the OT system alone, but less than other cooling tower system. The OTHT system could be placed within the confines of the existing NAPS site.	An NDCT system could be placed within the confines of the existing NAPS site.
Land Use: Terrain Considerations	Dry tower systems are unaffected by terrain considerations.	OT systems require flat or gently rolling terrain to minimize pump head requirements. Terrain features of the site would not preclude the use of an OT system.	OTHT systems require flat or gently rolling terrain situations to minimize pump head requirements. Terrain features of the site are suitable for a OTHT system.	NDCT systems withdraw less water than OT systems and are less affected by substantial terrain variations. Terrain features of the site are suitable for a NDCT system.
Water Use	Dry tower systems have no comparable evaporative water losses when compared with MDCTs or spray ponds. Dry tower systems require minimal service water.	A OT system would require nearly 50 times more water than the MDCT system. Despite this increased water intake requirement, a OT system would return most of the water withdrawn, while the MDCT system would lose a considerable portion of the lesser water withdrawal to the atmosphere through evaporation. Hydrological and thermal modeling results (Section 3.4.1) indicate that Lake Anna cannot support operation of Unit 4 with OT cooling.	A OTHT system would require less water than a pure OT system. Despite this reduction, hydrological/thermal modeling results (Section 3.4.1) indicate that Lake Anna cannot support operation of Unit 4 with this modified OT system.	A OT system would require nearly 50 times more water than a NDCT system. Despite the reduced water intake requirements, a NDCT system would lose a considerable portion of the lesser water withdrawal to the atmosphere through evaporation. The overall evaporative losses would be somewhat greater for closed wet cooling tower systems compared to open cooling systems.

Table 9.4-4 Initial Screening of Alternative Heat Dissipation Systems - Unit 4 (Base Case & Alternatives 7–9)

Factors Affecting System Selection	Dry Towers (Base Case)	Once-Through (Alternative 7)	Once-Through with Helper Tower (Alternative 8)	Natural Draft Cooling Towers (Alternative 9)
Regulatory Restrictions	There are little or no permit or approval-related impacts to the dry tower system alternative.	An intake structure for OT system would meet Section 316(b) of the CWA and the implementing regulations, as applicable. Since the thermal load contribution of a Unit 4 OT system could produce undesirably high temperatures in the WHTF, it is unlikely that an additional once-through system could be successfully permitted.	An intake structure for OTHT system would meet Section 316(b) of the CWA and the implementing regulations, as applicable. While the helper tower for Unit 4 would temper the thermal loading to the WHTF during the hottest summer season periods, it is unlikely that an additional once-through system could be successfully permitted.	Although the water withdrawal of the NDCT is moderate, Lake Anna does not have the capacity to provide a water source for this cooling option. A supplemental source of cooling water would be required during drought conditions to maintain minimum lake levels and downstream flows. The need for a supplemental source of cooling water would result in additional impacts, such as consumption of water from remote supplies and the impacts of transporting the water (e.g., the impacts of building a pipeline). In the absence of any identifiable and readily available source, this alternative is not deemed feasible.
Atmospheric Effects	Dry towers systems do not produce visible plume or pose particulate emission or salt deposition impacts.	Since OT systems do not produce a visible water droplet plume and the associated pond induced fogging (steam fog) would be minimal, atmospheric effects would be none to small.	An OTHT system would emit water droplets (drift) and produce visible plumes during periods when the helper tower is in operation. The particulate, salt deposition, and fogging and aesthetic impacts would not be significant from the infrequent/intermittent operation of this small cooling tower.	An NDCT system would emit water droplets (drift) and may intermittently produce a visible plume. The drift droplets would be a minor source of particulate matter and salt deposition. The water vapor plume would not encourage any additional fogging or icing conditions on local road systems. Visible plume aesthetic impacts would be small.

Table 9.4-4 Initial Screening of Alternative Heat Dissipation Systems - Unit 4 (Base Case & Alternatives 7–9)

Factors Affecting System Selection	Dry Towers (Base Case)	Once-Through (Alternative 7)	Once-Through with Helper Tower (Alternative 8)	Natural Draft Cooling Towers (Alternative 9)
Thermal and Physical Effects	A dry tower system would direct an invisible heated plume of air into the atmosphere, and impacts would be none to small.	Hydrological and thermal modeling results (Section 3.4.1) indicate that Lake Anna cannot support operation of Unit 4 with an OT system.	While an OTHT system would minimize the thermal loading to the WHTF during the hottest summer season periods, hydrological/thermal modeling results (Section 3.4.1) indicate that Lake Anna cannot support operation of Unit 4 with this modified OT system.	An NDCT system would produce a significantly smaller thermal load on the WHTF (compared to OT systems) because 65–85% of the heat removal in cooling towers is associated with evaporation (Reference 2). Most of the remaining heat is dissipated directly to the atmosphere. In this case the smaller NDCT thermal load rejected to the WHTF would be additive to the existing OT thermal load. The VPDES permit thermal discharge criteria would need to be revised to reflect this minor thermal addition.
Noise Levels	The Section 5.3.4 noise evaluation for a dry tower system indicates that noise contributions from this system would produce impacts below the NRC-defined significance levels (65 dBA) at the EAB. Construction-related noise impacts would be small.	OT system operation would generate minimal noise from pump operation. Construction-related noise impacts would be small.	OTHT operation would generate noise from fan and pump operation and from cascading water in the towers during the periods when the helper tower is needed. The associated noise impacts would be less than dry towers impacts which were below the NRC-defined significance levels (65 dBA) at the EAB as described in Section 5.3.4. Construction-related noise impacts would be small.	An NDCT system would produce less noise than a dry tower system because of the absence of fan generated noise. Dry tower noise levels were evaluated to be below NRC-defined significance levels (65 dBA) at the EAB (see Section 5.3.4). Construction-related noise impacts would be small.

Table 9.4-4 Initial Screening of Alternative Heat Dissipation Systems - Unit 4 (Base Case & Alternatives 7–9)

Factors Affecting System Selection	Dry Towers (Base Case)	Once-Through (Alternative 7)	Once-Through with Helper Tower (Alternative 8)	Natural Draft Cooling Towers (Alternative 9)
Aesthetics and Recreational Benefits	A dry tower system would be wholly situated on the existing NAPS site and its primary external impact would be the discharge of heated air and noise to the atmosphere. These discharges would not produce tangible aesthetic or recreational benefits.	An OT system would be wholly situated on the existing NAPS site and its primary external impact would be the discharge of heated water to the North Anna Reservoir via the WHTF. Discharges to the North Anna Reservoir, a popular recreational resource, would produce no tangible aesthetic or recreational benefits.	An OTHT system would be wholly situated on the existing NAPS site and its primary external impact would be the discharge of heated water to the North Anna Reservoir via the WHTF. Discharges to the North Anna Reservoir, a popular recreational resource, would produce no tangible aesthetic or recreational benefits.	An NDCT system would be wholly situated on the existing NAPS site and its primary external impact would be the discharge of heated water to the North Anna Reservoir via the WHTF. Discharges to the North Anna Reservoir, a popular recreational resource, would produce no tangible aesthetic or recreational benefits.
Operating and Maintenance Experience	Dry tower systems are becoming more popular at power plants. Their more limited operating experience indicates that their reliability is similar to wet cooling towers. While dry tower systems are less common, they do not pose any greater operating and maintenance risks than other cooling systems.	OT systems are common to power plants (both fossil and nuclear) and they are considered highly reliable.	While OTHT systems are less common than OT systems, they do not pose any greater operating and maintenance risks than other cooling tower systems.	NDCT systems are common to power plants (both fossil and nuclear) and they are considered highly reliable.
Generating Efficiency Penalty	The energy penalty (% reduction in plant output) of dry tower systems versus wet tower systems is 6.8 to 9.6%. The energy penalty of dry tower systems versus OT systems is 8.5 to 11.4%. (Reference 5, Tables 3-1 and 3-2)	The energy penalty (% reduction in plant output) of dry tower systems versus OT systems is 8.5 to 11.4%. (Reference 5, Tables 3-1 and 3-2)	The additional energy requirements associated with cooling tower operation do not alter this system's energy efficiency advantages over wet cooling tower only systems.	The energy penalty (% reduction in plant output) of dry tower systems versus wet cooling tower systems is 6.8 to 9.6%. (Reference 5, Tables 3-1 and 3-2)

Table 9.4-4 Initial Screening of Alternative Heat Dissipation Systems - Unit 4 (Base Case & Alternatives 7–9)

Factors Affecting System Selection	Dry Towers (Base Case)	Once-Through (Alternative 7)	Once-Through with Helper Tower (Alternative 8)	Natural Draft Cooling Towers (Alternative 9)
Is this a suitable heat dissipation system?	Yes	No	No	No

Table 9.4-5 Screening of Unit 4 Alternative Heat Dissipation Systems (Alternatives 9 & 10)

Factors Affecting System Selection	Mechanical Draft Cooling Towers (Alternative 10)	Spray Pond (Alternative 11)
Land Use: Onsite Land Considerations	An MDCT system would require more land to site widely spaced towers. An MDCT system could be placed within the confines of the existing NAPS site property.	The spray pond cooling alternative would involve the development of significant additional surface water impoundments and consequently pose the greatest new land requirements. It is unlikely that spray ponds of sufficient size could be placed within the confines of the existing site.
Land Use: Terrain Considerations	MDCT systems withdraw less water than OT systems and are less affected by substantial terrain variations. Terrain features of the site are suitable for an MDCT system.	Since spray pond construction involves substantial earthwork, such systems are most appropriate for flat or gently rolling terrain. Terrain features of the site are suitable for the addition of spray ponds.
Water Use	An OT system would require nearly 50 times more water than an MDCT system. Despite the reduced water intake requirements, an MDCT system would lose a considerable portion of the lesser water withdrawal to the atmosphere through evaporation. The overall evaporative losses are somewhat greater for closed wet cooling tower systems compared to open cooling systems.	Spray ponds would require large volumes of water and would likely require offsite sources of water.
Regulatory Restrictions	Although the water withdrawal of the MDCT is moderate, Lake Anna does not have the capacity to provide a water source for this cooling option. A supplemental source of cooling water would be required during drought conditions to maintain minimum lake levels and downstream flows. The need for a supplemental source of cooling water would result in additional impacts, such as consumption of water from remote supplies and the impacts of transporting the water (e.g., the impacts of building a pipeline). In the absence of any identifiable and readily available source, this alternative is not deemed feasible.	Additional land would have to be obtained and developed to support a spray pond option. The development of this land would entail a substantial and lengthy federal, state, and local permit and approval process.

Table 9.4-5 Screening of Unit 4 Alternative Heat Dissipation Systems (Alternatives 9 & 10)

Factors Affecting System Selection	Mechanical Draft Cooling Towers (Alternative 10)	Spray Pond (Alternative 11)
Atmospheric Effects	An MDCT system would emit water droplets (drift) and intermittently produce a visible plume. The drift droplets would be a minor source of particulate matter and salt deposition. The water vapor plume is expected to encourage some minor supplemental hours of fogging annually and no icing conditions on local roads would encourage some additional fogging. Visible plume aesthetic impacts would be small.	Spray pond systems could produce a low-level visible water droplet plume and encourage formation of fog above the heated pond. These impacts would be localized and short-lived, and consequently small.
Thermal and Physical Effects	An MDCT system would produce a significantly smaller thermal load on the WHTF (compared to OT systems) because 65–85% of the heat removal in cooling towers is associated with evaporation (Reference 2). Most of the remaining heat is dissipated directly to the atmosphere. In this case the smaller MDCT thermal load rejected to the WHTF would be additive to the existing OT thermal load. The VPDES permit thermal discharge criteria would need to be revised to reflect this minor thermal addition.	Since the thermal load would be rejected to the spray pond that would be wholly dedicated to industrial use, the thermal impacts external to the pond would be none to small.
Noise Levels	MDCT operation would generate noise from fan and pump operation and from cascading water in the towers. Results from a noise impact analysis of dry towers operation described in Section 5.3.4 suggest that MDCT impacts will be below the NRC-defined significance levels (65 dBA) at the EAB. Construction-related noise impacts would be small.	Spray pond system operation would generate noise from the spray operations. Since the location of the spray ponds and associated receptor boundaries are presently undefined, the associated noise impacts cannot be evaluated at this time. Construction-related noise impacts would be small.
Aesthetics and Recreational Benefits	An MDCT system would be wholly situated on the existing NAPS site and its primary external impact would be the discharge of heated water to the North Anna Reservoir via the WHTF. Discharges to the North Anna Reservoir, a popular recreational resource, would produce no tangible aesthetic or recreational benefits.	The spray ponds would be at least partially situated on land outside of the NAPS site. The resulting commitment of previously undeveloped land to industrial use would produce no tangible aesthetic or recreational benefits.
Operating and Maintenance Experience	MDCT systems are common to power plants (both fossil and nuclear) and they are considered highly reliable.	Spray pond systems have been used on power plant sites and they pose no operational or maintenance constraints.

Table 9.4-5 Screening of Unit 4 Alternative Heat Dissipation Systems (Alternatives 9 & 10)

Factors Affecting System Selection	Mechanical Draft Cooling Towers (Alternative 10)	Spray Pond (Alternative 11)
Generating Efficiency Penalty	The energy penalty (% reduction in plant output) of dry tower systems versus wet cooling tower systems is 6.8 to 9.6%. (Reference 5, Tables 3-1 and 3-2)	Spray ponds' efficiency penalty is greater than OT systems, but smaller than all the other cooling tower system based alternatives.
Is this a suitable heat dissipation system?	No	No

Table 9.4-6 Summary Comparison of Unit 4 Heat Dissipation Systems Impacts

	Base Case	Alternative 7	Alternative 8	Alternative 9	Alternative 10	Alternative 11
Criteria	**Dry Towers**	**OT**	**OTHT**	**NDCT**	**MDCT**	**SP**
Land Use	High	Low	Low	Medium	Medium	High
Water Use	Low	High	High	Medium	Medium	High
Regulatory Barriers	Low	High	High	High	High	High
Air Impacts	Low	None	Low	Medium	Medium	Low
Thermal/Physical Impacts	Low	High	High	Medium	Medium	Medium
Noise Impacts	Medium	Low	Low	Medium	Medium	Low
Aesthetics & Recreational Benefits	None	None	None	None	None	None
Operating and Maintenance Experience	Low	High	Medium	High	High	Medium
Generating Efficiency Penalty	High	Low	Low	Medium	Medium	Low
Overall Environmental & Operability Ranking	Preferable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
Capital Costs	High	Not Evaluated	Not Evaluated	Not Evaluated	Not Evaluated	Not Evaluated
Operating Costs	High	Not Evaluated	Not Evaluated	Not Evaluated	Not Evaluated	Not Evaluated
Costs Ranking	Preferable	Not Evaluated	Not Evaluated	Not Evaluated	Not Evaluated	Not Evaluated
Overall Preference	X					

Table 9.4-7 Screening of Alternatives to the Proposed Intake System (Base Case & Alternative 1)

Factors Affecting System Selection	Intake System - Base Case Addition of Shoreline Intake on Lake Anna	Intake System - Alternative 1 Offshore Intake System
Construction Impacts	Since development of the intake shoreline would result in disruptions of the littoral zone (i.e., area of more concentrated biological resources), there could be localized adverse impacts to this disturbed zone. Since previous development in this zone and the new intake would be adjacent to an operational water intake system, these impacts would be small. Experience has shown that impacts near shorelines (i.e., transportation of silt) are more readily controllable near the shoreline than offshore.	If the offsite intake system is installed using an open trench construction process, there could be large adverse impacts to both the littoral zone and to deeper areas of the lake. This process would result in greater lakebed disruptions and larger increases in the turbidity of Lake Anna water. The resulting adverse impact to the lake water quality could be large during the construction phase of work.
Aquatic Impacts	The potentially large adverse operational impacts to aquatic life could be mitigated by reducing intake velocities and using traveling screens to reduce impingement, entrapment and entrainment of aquatic life.	Situated in areas with relatively less abundant aquatic resources, submerged offsite intake systems generally pose fewer impacts to aquatic life during operation.
Land Use Impacts	Since the commitment of land for the shoreline intake is small and this development would occur on the NAPS site, land use impacts would not be an important differentiating factor for intake systems.	Through offshore intake systems have somewhat lesser land requirements then shoreline intake systems, land use impacts would not be an important differentiating factor.
Water Use Impacts	The relative position of the intake (shoreline or offshore) would have no differentiating impact on the water use requirements and therefore, it would not be an important factor.	The relative position of the intake (shoreline or offshore) would have no differentiating impact on the water use requirements, and therefore, it would not be an important factor.
Compliance with Regulations	The intake structure for the new units at the ESP site would meet Section 316(b) of the CWA and the implementing regulations, as applicable. The applicable VPDES permit and current Section 316(b) considerations (aquatic species entrainment-impingement-entrapment) issues would need to be modified in response to the additional intake. These regulatory restrictions would not be an important differentiating factor.	The intake structure for the new units at the ESP site would meet Section 316(b) of the CWA and the implementing regulations, as applicable. The applicable VPDES permit and current Section 316(b) considerations (aquatic species entrainment-impingement-entrapment) issues would need to be modified in response to the additional intake. These regulatory restrictions would not be an important differentiating factor.
Environmentally preferred or equivalent? (Yes/No)	Yes	No

Table 9.4-8 Screening of Alternatives to the Proposed Intake System (Base Case & Alternatives 2 & 3)

Factors Affecting Location Selection	Intake Location - Base Case	Intake Location - Alternative 2	Intake Location - Alternative 3
	Adjacent to Existing Intake	**Alternative Location on Lake Anna**	**Lower North Anna River**
Construction Impacts	Construction impacts would be minimized if the intake structure is located adjacent to the existing NAPS site intake. Already cleared and graded in support of the original intake system development, this area has less ecological resources than other shoreline locations. Proximity to shore would allow use of best management practices to control the movement of silt and minimize impact on North Anna Reservoir waters.	Construction impacts from the disruption of shoreline environment would be larger for alternative shoreline locations along Lake Anna, since these areas have not been impacted by previous construction activities.	Construction impacts would be more significant in the lower North Anna River, since the affected body of water is smaller and more prone to turbidity impacts. The adjacent river shoreline is less developed and likely offers more diverse ecosystems.
Aquatic Impacts	The potentially large adverse operational impacts to aquatic ecosystems could be mitigated and rendered small by applying management techniques in use at the existing intake (e.g., minimized intake velocity, screens).	The potentially large adverse operational impacts to aquatic ecosystems could be mitigated and rendered small by applying management techniques in use at the existing intake (e.g., minimized intake velocity minimization, screens).	The potentially large adverse operational impacts to aquatic ecosystems could be somewhat mitigated by applying management and screening techniques in use at the existing intake. The more confined, potentially richer biological environment along the river shoreline would make it more difficult to effectively mitigate adverse impacts relative to the base case.
Land Use Impacts	Since the new intake would reside totally within the confines of the NAPS site, its location adjacent to another intake, poses the smallest land use impacts.	Land use designations outside of the NAPS site do not support the installation or operation of industrial facilities. Thus, development of intake locations in these areas would trigger potentially onerous land use amendment processes, which would make this alternative less desirable than the base case.	Land use designations along the lower North Anna River do not support the installation and operation of industrial facilities. Thus, development of intake locations in these areas would trigger potentially onerous land use amendment processes.

Table 9.4-8 Screening of Alternatives to the Proposed Intake System (Base Case & Alternatives 2 & 3)

Factors Affecting Location Selection	Intake Location - Base Case	Intake Location - Alternative 2	Intake Location - Alternative 3
	Adjacent to Existing Intake	**Alternative Location on Lake Anna**	**Lower North Anna River**
Water Use Impacts	Since Lake Anna represents the largest source of water for industrial use in the NAPS site area, the related water use impacts of an adjacent intake system would be small relative to other potential locations.	Since Lake Anna represents the largest source of water for industrial use in the NAPS site area, the related water use impacts of a new adjacent intake system would be small relative to potential impacts from using other locations.	The lower North Anna River does not have sufficient water capacity to supply the proposed circulating water system. The alternative is not technically viable.
Compliance with Regulations	The intake structure for the new units at the ESP site would meet Section 316(b) of the CWA and the implementing regulations, as applicable. The applicable VPDES permit and current Section 316(b) issues (aquatic species entrainment-impingement-entrapment) issues would need to be modified in response to the additional intake. Thus, these regulatory restrictions would not be an important differentiating factor.	The intake structure for the new units at the ESP site would meet Section 316(b) of the CWA and the implementing regulations, as applicable. The applicable VPDES permit and current Section 316(b) issues (aquatic species entrainment-impingement-entrapment) issues would need to be modified in response to the additional intake. Thus, these regulatory restrictions would not be an important differentiating factor.	The intake structure for the new units at the ESP site would meet Section 316(b) of the CWA and the implementing regulations, as applicable. Since construction of the intake structure would likely impact wetland areas and other important habitats, additional federal and state-sponsored permitting processes would also be triggered. Consequently, the environmental permitting process for this intake structure location could represent a large barrier to this alternative.
Environmentally preferred or equivalent? (Yes or No)	Yes	No	No

Table 9.4-9 Screening of Alternatives to the Proposed Discharge System (Base Case & Alternative 4)

Factors Affecting System Selection	Discharge System – Base Case	Discharge System - Alternative 4
	Shoreline Discharge & Discharge Canal	Offshore Submerged Discharge System
Construction Impacts	Since development of the shoreline discharge would result in disruptions of the littoral zone (area of more concentrated biological resources), there could be localized moderate adverse impacts on this disturbed zone.	If the offsite discharge system is installed using an open trench system, there could be large adverse impacts on both the littoral zone and other areas of the lake. Open trench activities would result in greater lakebed disruptions and larger increases in the turbidity of Lake Anna water. The resulting adverse impact on the lake water quality could be large during the construction phase of work.
Aquatic Impacts	Situated in the more biologically important littoral zone areas, shoreline discharges would have the potential to disturb the local aquatic ecosystem. Such systems pose greater impacts than offshore discharge systems.	Situated in areas with relatively less abundant aquatic resources (outside of more ecologically abundant littoral zone), submerged offsite intake systems generally pose fewer impacts on the aquatic ecosystem.
Land Use Impacts	Since the commitment of land for the shoreline discharge is not significant, land use impacts would not be an important differentiating factor.	Through offshore discharge systems have somewhat lesser land requirements than shoreline intake systems, land use impacts would not be an important differentiating factor. Note that the submerged systems would likely be situated deep enough to avoid direct interference with recreational water uses.
Water Use Impacts	The relative position of the shoreline discharge would have little impact on the water use requirements and, therefore, it would not be an important differentiating factor.	The relative position of the discharge would have little impact on the water use requirements and, therefore, it would not be an important differentiating factor. Note that the submerged systems would likely be situated deep enough to avoid direct interference with recreational water uses.
Compliance with Regulations	The discharge system would meet the requirements of Section 316(a) of the CWA, and the implementing regulations, as applicable. The applicable VPDES permit and Section 316(a) thermal impact considerations would need to be evaluated in response to the additional discharge. These regulatory restrictions would not be an important differentiating factor.	The discharge system would meet the requirements of Section 316(a) of the CWA, and the implementing regulations, as applicable. The applicable VPDES permit and Section 316(a) thermal impact considerations would need to be evaluated in response to the additional discharge. These regulatory restrictions would not be an important differentiating factor.
Environmentally preferred or equivalent?	Yes	No

Table 9.4-10 Screening of Alternatives to the Proposed Discharge System Location (Base Case & Alternatives 5 & 6)

Factors Affecting Location Selection	Discharge Location Base Case	Discharge Location Alternative 5	Discharge Location Alternative 6
	Adjacent to Existing Discharge	**Discharge along WHTF**	**Discharge on Lake Anna**
Construction Impacts	Construction impacts would be minimized if the discharge structure is located adjacent to the existing discharge structure at the head of the discharge canal. Already cleared and graded in support of the original discharge system, this area boasts less ecological resources than other undeveloped areas.	Construction impacts (surface disruption and turbidity increases) would be more significant at less developed alternative discharge structure sites along the WHTF shoreline.	Construction impacts (surface disruption and turbidity increases) would be the greatest for the undeveloped or less developed alternative shoreline discharge structure sites along the shore of Lake Anna.
Aquatic Impacts	The thermal and chemical impacts of effluent discharges would be effectively mitigated (through mixing and dilution) in the discharge canal and downstream WHTF.	The thermal and chemical impacts of effluent discharges would be effectively mitigated (mixing and dilution) in the WHTF.	Effluent that is discharged directly to Lake Anna may significantly impact local aquatic resources, since the effluent would not be subject to the beneficial mixing and dilution actions from travel through the discharge canal and WHTF.
Land Use Impacts	Since the new discharge would reside totally within the confines of the NAPS site, its location adjacent to another discharge structure would pose the smallest land use impacts.	Although the new discharge would reside totally within the confines of the NAPS site, its location along a relatively undeveloped shoreline of the WHTF would require a greater commitment of land resources.	Land use designations along Lake Anna areas outside the NAPS site do not support the installation or operation of industrial facilities. The lake also offers substantial recreational benefits to the local community, which could be adversely impacted by the construction of a discharge structure. Thus, development of discharge systems in these more ecological important and community-valued areas would trigger potentially onerous land use amendment processes.

Table 9.4-10 Screening of Alternatives to the Proposed Discharge System Location (Base Case & Alternatives 5 & 6)

Factors Affecting Location Selection	Discharge Location Base Case	Discharge Location Alternative 5	Discharge Location Alternative 6
	Adjacent to Existing Discharge	**Discharge along WHTF**	**Discharge on Lake Anna**
Water Use Impacts	The additional effluent released through the discharge structure would pose the smallest water use and cumulative impacts since the release is consistent with current discharge practices into the WHTF; an industrial facility already designed and constructed to receive heat dissipation system discharges.	The additional effluent released to the WHTF in an alternate location would pose the smallest water use impacts, because this activity is consistent with current discharge practices into the WHTF; an industrial facility designed and constructed to receive heat dissipation system discharges.	The new discharge of effluent directly to Lake Anna could have moderate water use impacts to this receiving water body. Lake Anna is a multi-use water resource that is not compatible with direct industrial discharges. Note the thermal and chemical impacts of this discharge would not be subject to the beneficial dilution and mixing actions from travel through the discharge canal and WHTF.
Compliance with Regulations	The discharge system would meet the requirements of Section 316(a) of the CWA, and the implementing regulations, as applicable. The applicable VPDES permit and current associated 316(a) considerations would need to be modified in response to the additional discharge system. These regulatory restrictions would offer only small impacts to the design and operation of a new a discharge system sited with the existing discharge canal.	The discharge system would meet the requirements of Section 316(a) of the CWA, and the implementing regulations, as applicable. The applicable VPDES permit and current associated 316(a) considerations would need to be modified to respond to the additional discharge system. These regulatory restrictions would offer only small impacts to the design and operation of a new discharge system sited in the WHTF.	The discharge system would meet the requirements of Section 316(a) of the CWA, and the implementing regulations, as applicable. Since construction of the discharge structure is likely to impact wetland and important habitat areas, additional federal and state-sponsored permitting processes could also be triggered. The environmental permitting process for this discharge structure location could represent a barrier to development.
Environmentally preferred or equivalent?	Yes	No	No

Table 9.4-11 Screening of Alternatives to the Proposed Water Treatment System (Base Case & Alternatives 7 & 8)

Factors Affecting System Selection	Water Treatment Base Case Mechanical Condenser Cleaning	Water Treatment System Alternative 7 Chemical Treatment: Biocide, Corrosion Inhibitor, pH Adjustment	Water Treatment System Alternative 8 Non-chemical Treatment: Ultraviolet (UV) Treatment
Chemicals Used	Mechanical cleaning would involve periodic removal of organic and inorganic residue and debris on circulating system condenser piping and related equipment. No chemicals are used.	Biocide – chlorine, sodium-hypochlorite, ozone Corrosion inhibitors (cooling tower systems only) – oxidizer (nitrates, molybates), filming (nitrogen compounds), polymer (polymeric carboxylate). pH adjustment (cooling tower systems only) – acids (sulfuric acid) and caustics (sodium hydroxide) (Reference 4)	None
Construction Impacts	Periodic mechanical cleaning of the condenser system would not require any substantial construction activities and there would be no related environmental impacts.	Installation of the chemical treatment systems would result in additional commitments of land. Associated soil erosion and sediment impacts, however, would be small.	Installation of the UV treatment systems would result in additional commitments of land. Associated soil erosion and sediment impacts, however, would be small.
Aquatic Impacts	While mechanical cleaning measures would remove biological materials from condenser system surfaces, these measures would not pose systemic impacts on aquatic resources in Lake Anna.	Residual chemicals from this treatment process could impact aquatic resources in the WHTF and downstream North Anna Reservoir. Biocides, corrosion inhibitors, and pH adjustment chemicals are potentially toxic to aquatic life. Polymeric corrosion inhibitors are proposed and would represent a much less toxic option. (Reference 4)	The UV treatment would have no residual impacts on aquatic resources in the receiving body of water. UV systems, however, have not been proven effective on large-scale cooling systems; therefore, they may prove infeasible or unreliable.
Land Use Impacts	Mechanical cleaning measures would not require any additional commitment of land.	Since the chemical treatment systems do require additional land, these systems would be wholly-confined to the existing NAPS site. There would be no appreciable land use impacts.	While these UV treatment systems do require additional land, these systems would be wholly-confined to the existing NAPS site. There would be no appreciable land use impacts.
Water Use Impacts	Mechanical cleaning would not impact water withdrawal requirements.	Chemical treatment systems would not impact water withdrawal requirements.	UV treatment systems would not impact water withdrawal requirements.

Table 9.4-11 Screening of Alternatives to the Proposed Water Treatment System (Base Case & Alternatives 7 & 8)

Factors Affecting System Selection	Water Treatment Base Case Mechanical Condenser Cleaning	Water Treatment System Alternative 7 Chemical Treatment: Biocide, Corrosion Inhibitor, pH Adjustment	Water Treatment System Alternative 8 Non-chemical Treatment: Ultraviolet (UV) Treatment
Compliance with Regulations	Mechanical condenser cleaning is a continuation of current practice and fully compliant with the applicable regulations and existing and pending permit conditions.	The addition of chemical treatment systems would impact the current NAPS VPDES discharge permit. This permit would need to be revised in response to the revised characterization of the chemically-treated cooling system effluent.	The addition of UV treatment systems may impact the current NAPS VPDES discharge permit. This permit may need to be revised in response to the new characterization of the treated cooling system effluent.
Environmentally preferred or equivalent?	Yes	Yes	No

Chapter 10 Environmental Consequences of the Proposed Action

This chapter presents the potential environmental consequences of constructing and operating the new units at the ESP site. These potential consequences are presented in the following subsections:

Section 10.1 – Unavoidable Adverse Environmental Impacts. Unavoidable adverse environment impacts are those potential impacts of construction and operation of the new units that cannot be avoided and for which no practical means of mitigation are available.

Section 10.2 – Irreversible and Irretrievable Commitments of Resources. Irreversible commitments of resources applies to environmental resources that would be potentially impacted by the new units and that could not be altered at some later time to restore the current state of the resources. Irretrievable commitments of resources applies to material resources that would be used for the new units in such a way that they could not, by practical means, be recycled or restored for other uses.

Section 10.3 – Relationship Between Short-Term Uses and Long-Term Productivity of the Human Environment. Short-term uses and long-term productivity refer to the analyses of unavoidable adverse or beneficial environmental impacts of the construction and operation of the new units during the period of construction, operation, and through decommissioning.

Section 10.4 – Benefit -Cost Balance. This section contains a brief description explaining why cost-benefit information is not included in this ESP application.

10.1 Unavoidable Adverse Environmental Impacts

This section summarizes those adverse environmental impacts due to the construction and operation of the new units that cannot be avoided and for which no practical means of mitigation are available. Part of this summary includes identification of mitigation actions that have been proposed to reduce the impacts and would be reasonable and practical to implement. Information provided in Section 4.6 and Section 5.10 has been used in preparing this section.

10.1.1 Unavoidable Adverse Environmental Impacts During Construction

The potential adverse environmental impacts from construction of the new units are described in Chapter 4. The measures and controls to reduce or eliminate these impacts are identified in Section 4.6. The expected impacts and the mitigation measures that are practical to reduce these impacts are identified and summarized in Table 10.1-1. Those instances where adverse environmental impacts would remain after all reasonable means have been taken to avoid or mitigate them are also identified in Table 10.1-1, under the column labeled “Unavoidable Adverse Impacts”, where “Y” means there are such impacts and “N” means the specified mitigation measures are sufficient to reduce the impacts to insignificant or small. For many of the impacts related to construction activities, mitigation measures that would be applied are referred to as “best

management practices." Typically, their use is determined by the types of activities that are to be performed, and frequently, they are implemented through plans and procedures developed at the time of construction.

10.1.2 Unavoidable Adverse Environmental Impacts During Operation

The potential adverse environmental impacts from operation of the new units are described in Chapter 5. The measures and controls to reduce or eliminate these impacts are identified in Section 5.10. The expected impacts and the mitigation measures that are practical to reduce these impacts are identified and summarized in Table 10.1-2. Those instances where adverse environmental impacts would remain after all practical means to avoid or mitigate them have been applied are also identified in Table 10.1-2, under the column labeled "Unavoidable Adverse Impacts," where "Y" means there are such impacts, and "N" means the specified mitigation measures are sufficient to reduce the impacts to insignificant or small. Again, the environmental impacts and related mitigation measures identified in this ER are based on the PPE approach. Because the type of reactor and associated ancillary equipment have not yet been selected, the impacts and mitigation measures identified in Table 10.1-2 should be considered as bounding cases.

10.1.3 Summary of Adverse Environmental Impacts

As can be seen from Table 10.1-1 and Table 10.1-2, most of the adverse environmental impacts are reduced to insignificance or eliminated through the application of the listed mitigation measures. Those that are not entirely eliminated are discussed further in this section.

During construction, the primary adverse environmental impacts would be related to land use. Much of the NAPS site would undergo a change from unused property to industrial use associated with operation of the new units at the site. While these changes would result in the movement of wildlife from the NAPS site, the changes are in keeping with the current industrial use zoning. Furthermore, the original selection and review of the NAPS site was based on building four units at the site. Therefore, the changes, while small, are compatible with the long-term use of the site. Furthermore, Dominion and Virginia Power have the long-term intention of continuing energy production on the NAPS site into the foreseeable future, which is compatible with the industrial use zoning and the current use of the site.

Many of the expected construction impacts on the terrestrial ecology of the site would be short-term impacts. The numbers of wildlife, especially of the larger animals, and the amount of vegetation that would decrease because of the construction activities, would not fully recover, because the land used for new structures and operational activities, including parking, would effectively eliminate the possibility of restoring the acreage to its pre-construction condition. However, the conclusions of the ecological studies for this ER are that: 1) there are no important species currently on site, 2) some of the species would return to the areas of the site that are restored to their previous state, and

3) areas outside the site would be generally unaffected with regard to terrestrial wildlife and vegetation. Therefore, while there would be noticeable changes due to construction of the new units, the immediate area surrounding the site would not experience any long-term impacts due to the construction and operation of the new units.

Depending on the selected reactor design and its related ancillary equipment (e.g., use of dry cooling towers) there could be a noticeable visual change obvious to lake users and line-of-sight residences around the lake. Completion of a visual impact study once technologies and equipment are selected, however, would identify mitigation measures that could reduce visual impacts, through configuration of the structures on the ESP site. The conclusion is that visual impacts would not have any short- or long-term impacts to local residents or tourists, and are therefore small.

The use of new reactor technologies would reduce the amount of radioactive waste generated that would need to be disposed of when compared to the volume of waste currently generated at existing nuclear power plants.

10.1.4 Irreversible and Irretrievable Commitment of Resources

As presented in Section 10.2, during construction there would be very little commitment of significant resources that are irreversible or irretrievable. Those that would be committed are the typical construction resources of steel, piping, and concrete. The latter, while large, is not atypical of other types of power plants such as hydroelectric and coal-fired plants, nor of many large industrial facilities (e.g., refineries and steel plants) that are constructed throughout the United States.

During operation, as presented in Section 10.2, the main resource that is irreversibly and irretrievably committed is the uranium that is consumed in the power production process. However, the use of new, more efficient reactor technologies by the nuclear power industry would result in lower consumption of uranium in the form of enriched UF_6. This reduced demand for enriched UF_6 would result in a reduction in the amount of uranium ore that has to be mined for production of yellowcake that is subsequently converted into UF_6. Because the mining of uranium ore, the production of yellowcake and its conversion to UF_6, and the subsequent enrichment of the UF_6 so that it can be used as fuel, all require energy, a reduction in the amount of uranium ore required would also serve to reduce the amount of energy consumed in the production of the fuel.

Section 10.1 References

None

Table 10.1-1 Construction-Related Unavoidable Adverse Environmental Impacts

Category/ ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Land Use/ Section 4.1.1	Construction of new units and related parking	Comply with requirements of applicable federal, state and local construction permits/approvals and local ordinances.	Y
Section 4.1.1	Construction of power plant	Construct only in area approved by federal, state, and local agencies for installation of the power plant.	Y
Section 4.1.1	Earthmoving activities (e.g., grading, re-contouring of disturbed areas)	Restrict activities to actual construction site and construction access road from Route 700. Install fence along southern and eastern boundaries, which includes the boundary with the existing units.	N
Section 4.1.1	Construction and maintenance of soil stockpiles	Locate soil stockpiles on the construction site only.	N
Atmospheric/ Section 4.1.1	Fugitive dust and/or gaseous emissions from the operating vehicles and equipment	Apply measures from the fugitive dust control plan and maintain vehicles and equipment in good working order.	N
Historic, Cultural, and Archaeological Resources/ Section 4.1.3	Potential for destruction of archaeological, historic, or cultural resources in areas suspected or known to have artifacts	Conduct sub-surface testing prior to start of any onsite work to identify buried archaeological or cultural resources.	N
Section 4.1.3	Unanticipated discovery of archaeological or cultural resources or hazardous waste during construction	Require construction contractor and subcontractors to develop and follow procedures (or use applicable existing procedures) to handle potential unanticipated discoveries, including stopping work immediately and notifying appropriate agencies.	N
Hydrologic Alterations/ Section 4.2.1	Potential affect of dewatering on some existing NAPS potable water wells	Maintain flows required by existing units by using unaffected wells.	N

Table 10.1-1 Construction-Related Unavoidable Adverse Environmental Impacts

Category/ ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Section 4.2.1	Erosion and sedimentation impacts on Lake Anna due to storm water runoff from the construction site	Obtain Storm Water Construction General Permit, the VPDES permit. Apply Storm Water Pollution Prevention Plan developed as part of the Storm Water Construction General Permit application. Use best management practices (BMPs) described in Virginia Erosion and Sediment Control Handbook.	N
Section 4.2.1	Migration of turbid water into the lake due to removal of existing cofferdam after construction of new water intake	Design and install appropriate barrier (e.g., turbidity curtain in Lake Anna near cofferdam) to prevent migration of turbid water into Lake.	N
Section 4.2.1	Impacts to intermittent stream channel on site	Obtain and comply with VPDES permit. Adhere to seasonal restrictions for in-water work. Install erosion control measures. Install drainage controls to convey stream flow. Follow construction stormwater management requirements.	N
Water Use/ Section 4.2.2	Increased sediment loading to surface water due to dewatering activities	Limit dewatering activities to what is needed. Require application of erosion and sediment controls to such activities (e.g., bag filter, flow spreader, retention basin).	N
Section 4.2.2	Contamination of surface water or groundwater from releases of fuel, oils, or chemicals during construction.	Develop and implement a spill control and response plan in addition to the SWPPP.	N
Terrestrial Ecology/ Section 4.3.1	Removal of existing trees and vegetation	Restrict removal of trees and vegetation to the construction site. Leave greenbelt of trees along southern boundary of construction site. Avoid sensitive areas if any are protected by law, permit, or approval process.	Y
Section 4.3.1	Loss of habitat due to clearing and grading, which would result in movement of wildlife from area during construction	Re-establish areas, where possible, when construction is completed so that wildlife should return.	Y

Table 10.1-1 Construction-Related Unavoidable Adverse Environmental Impacts

Category/ ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Section 4.3.1	Migration of wildlife away from undisturbed areas onsite or close to site during time when there are high levels of noise generated by construction activities	Maintain vehicles and equipment as per manufacturer's requirements.	Y
Aquatic Ecology/ Section 4.3.2	Disturbance, or destruction, of wetlands by working in, over, or in proximity to these areas	Avoid, if possible. Otherwise minimize disturbance, and compensate for any destruction of wetlands as per VDEQ regulations. Compensation would require creation or expansion of another, larger, wetland area.	N
Section 4.3.2	Disturbance of intermittent streams by working in, over, or in proximity to these areas	Avoid, or else work in the dry season, if possible, and restore streambed. Divert stream around construction and use settling basins, as needed, to remove sediment prior to re-connecting downstream of construction. Reconnect original streambed after construction activities, if possible. Install permanent diversion to restore the streambed, if necessary. Minimize disturbance and compensate for any destruction of streambed as per VDEQ regulations. Compensating for the loss of the intermittent stream would replace the loss.	Y
Section 4.3.2	Degradation of water quality in lake during in-water and shoreline work	Design and install barrier (e.g., turbidity curtain) to prevent turbid water from entering lake.	N
Section 4.3.2	Temporary loss of benthic habitat and organisms during construction, as benthic organisms and fish should recolonize the intake channel cove after completion of construction activities	Adhere to any seasonal restrictions of working in-water if stipulated in approval of ER or of any required permits.	N

Table 10.1-1 Construction-Related Unavoidable Adverse Environmental Impacts

Category/ ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Socioeconomic/ Section 4.4.1	Relatively higher noise levels offsite in residential areas	Restrict noisier construction activities to daytime hours. Notify general public when activities with atypically loud noise levels would occur. Develop and implement a plan to manage and respond to concerns of citizens about noise.	N
Section 4.4.1	Offsite effects of gaseous emissions from vehicles and diesel -powered equipment which should be small due to distance to nearest residences	Proper maintenance of vehicles and equipment should be sufficient to avoid noticeable impacts. Respond to concerns of citizens about gaseous emissions from the construction site via the complaint management plan.	N
Section 4.4.1	Transport of high dust levels offsite into residential areas	Develop and apply dust control plan that includes the following: Speed controls for onsite vehicles, covers for truck loads; use of water or approved chemicals on soil stockpiles and disturbed areas. Stop work on dust-generating activities under high wind conditions. Respond to concerns of citizens about high dust levels via the complaint management plan.	N
Section 4.4.1, Section 4.4.2	Traffic congestion and/or accidents from increased commuting construction workers, especially on local roads	Develop and implement a construction traffic management plan to reduce the numbers of vehicles being used on the local roads through use of buses, increased carpooling and vanpooling. Post signs in the local area to make the public and passers-by aware of the high construction traffic associated with the site Perform a traffic study and implement recommendations with regard to upgrades needed to Route 700 between the NAPS and the intersection with Route 652. Coordinate work shifts so that the construction workers and the existing units personnel do not have simultaneous or overlapping shift changes.	N
Section 4.4.2	Traffic congestion due to slow moving construction equipment deliveries	Schedule such deliveries on off hours or via rail.	N

Table 10.1-1 Construction-Related Unavoidable Adverse Environmental Impacts

Category/ ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Aesthetics/ Section 4.4.2	Visual Impact	Leave a 50–100 foot greenbelt of trees along the southern boundary as a visual shield for the construction site.	N
Environmental Justice/ Section 4.4.3	No impacts predicted based on use of local workforce	None Required	N
Radiation Exposure/ Section 4.5	Increased exposure of workers to radiation from existing units	Less than the acceptable annual value for the general public, therefore, no mitigation needed.	N

Table 10.1-2 Operations-Related Unavoidable Adverse Environmental Impacts

Category/ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Land Use/ Section 5.1.1	Potential for additional waste heat to affect recreational use of Lake Anna	The change in temperature at the discharge point of WHTF due to operation of new units would be negligible. Design/operate cooling system to comply with VPDES permit requirements.	N
Section 5.1.1	Increased traffic could create need for changes to local road system	Effective traffic management should avoid need for changes.	N
Transmission Lines/ Section 5.1.2	Based on an initial evaluation, the existing transmission lines and corridors have sufficient capacity for the total output of the existing and new units.	None required.	N
Historic, Cultural, or Archaeological Resources/ Section 5.1.3	None expected	None required.	N
Hydrological Alterations and Water Supply/ Section 5.2.1	Potential reduction in available water released from the North Anna Dam from current values (permit limits maintained)	Assess practices to minimize the hydrologic alterations and their implementation.	Y
Section 5.2.1	Potential reduction in Lake Anna water levels from current values during periods of extended drought with existing and new units operating	During periods of extended drought, dry cooling towers would be put into service to dissipate a portion of waste heat from Unit 3 to minimize the make-up water requirements.	N
Water-Use Impacts/ Section 5.2.2	Discharge of dissolved solids above ambient levels	There would be no appreciable water quality impacts due to blowdown from the Unit 3 wet cooling towers. There would be no blowdown from the Unit 3 and Unit 4 dry cooling towers.	N

Table 10.1-2 Operations-Related Unavoidable Adverse Environmental Impacts

Category/ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Make-up Water Intake System Physical Impacts/ Section 5.3.1.1	Scouring of the lake bottom and erosion of shoreline due to operation of new unit(s)' intake system	As for existing units, construct new make-up water intake system and intake structure in a cove on the south shore of Harris Creek. Install intake system for new units in area planned for intake system of previously abandoned Units 3 and 4. Stabilize the banks of the channel to the screens and pump house during construction.	N
Make-up Water Intake System Aquatic Impacts/ Section 5.3.1.2	Increased impingement of fish and increased entrainment of larva	Predicted effects are minimal for increased impingement and small for increased entrainment due to stable, healthy, and diverse fish population in Lake Anna.	N
Blowdown Water Discharge System/ Thermal Description and Physical Impacts/ Section 5.3.2.1	Installation of Unit 3 dry and wet cooling system and Unit 4 dry cooling tower would result in negligible temperature increases in the North Anna Reservoir and the WHTF.	The cooling system for the new units will not have an adverse effect on the North Anna reservoir and the WHTF. Blowdown from the Unit 3 wet cooling towers will be discharged to the WHTF at the cold water temperature of the cooling tower.	N
Section 5.3.2.1	Potential for scouring of lake bed or erosion of shoreline at Dike 3 if multiple units are constructed with wet and dry cooling system would be very small.	The first new unit would use a combination wet and dry cooling system. The second unit would be designed with dry towers as the cooling system. The intake flow rate would be for wet cooling tower make-up and the velocity would be relatively low.	N
Section 5.3.2.1	Potential increased turbidity due to blowdown flows from discharges of new units would be very small.	Design new cooling systems' blowdown such that the flow velocities are low to minimize the potential for increased turbidity.	N
Aquatic Ecosystem Impacts/ Section 5.3.2.2	Scouring and sediment transport due to water discharge flows is very low due to combination wet and dry cooling towers.	None required. Flow velocities associated with cooling tower blowdown will be relatively low.	N
Section 5.3.2.2	Impacts due to increase in chemicals and other pollutants contained in discharge from new units	Maintain compliance with VPDES water quality standards and permitted discharge limits for cooling water discharges to Lake Anna.	N

Table 10.1-2 Operations-Related Unavoidable Adverse Environmental Impacts

Category/ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Section 5.3.2.2	Impacts due to increase in thermal discharges or sudden changes in discharge temperatures	Maintain compliance with VPDES water quality standards and permitted discharge limits for cooling water discharges to Lake Anna. No impact on overall fish population in Lake Anna. Most temperature-sensitive species, would be expected to move away from discharge area. Typical operations of a nuclear power plant would limit sudden changes in discharge temperatures as such units do not come on and off-line regularly.	N
Heat Discharge System/ Dissipation to Atmosphere/ Section 5.3.3.1	Visual impact of wet and dry towers, e.g., visible plumes and steam fog, and icing and salt deposition	Design and install the wet and dry towers incorporating industrial standard measures indicated from the visual impact study to be performed during the design phase of the project. Most of the fogging from the wet cooling tower would occur within the site boundary in winter and spring seasons No icing is anticipated within or beyond site boundary. Salt deposition rates would be below threshold value beyond the site boundary at ground levels.	N
Terrestrial Ecology/ Section 5.3.3.2	Noise from wet and dry cooling towers could cause some wildlife to avoid the site	Wildlife expected to adapt to normal operating noise variations as for existing units.	N
Section 5.3.3.2	Reduction in moisture content of the air due to the dry hot exhaust from cooling tower could result in dieback of vegetation	None. If there are any impacts, they would be close to the dry towers, and there are no important species near the cooling towers.	N
Section 5.3.3.2	Decreased local precipitation due to hot exhaust from dry towers	Any impacts from decreased precipitation would be localized to the NAPS site, which does not contain important species.	N
Section 5.3.3.2	Avian collisions with cooling towers	Negligible impacts from collisions with dry towers that would be lower in height than existing or proposed onsite structures.	N

Table 10.1-2 Operations-Related Unavoidable Adverse Environmental Impacts

Category/ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Impacts to Members of the Public/ Section 5.3.4	Increased thermal discharges from wet cooling towers could affect composition micro-organisms in Lake Anna, thereby also affecting recreational use of the lake	Analyses show that there would be no significant alteration of the temperature regime in the lake or the surrounding environment and that the additional units would not contribute to an environment conducive to the reproduction and growth of thermophilic micro-organisms.	N
Section 5.3.4	Discharge of pathogenic materials in wastewater and/or sanitary wastes	The recently upgraded onsite sewage treatment plant that includes disinfection to reduce coliform bacteria and other micro-organisms to levels that meet Virginia water quality standards, would prevent adverse impacts from sanitary wastes.	N
Section 5.3.4	Offsite noise impacts from cooling system operation	Modeled peak noise levels from operation of all of the cooling systems are below the applicable NRC-defined significance levels at the EAB	N
Radiological Impacts from Normal Operations/ Exposure Pathways/ Section 5.4.1	Direct dose to population and environment	Shielding of new units would be at least as effective of that of existing units so direct dose contribution from the new units is expected to be negligible compared to those from liquid and gaseous effluent pathways or from natural and artificial sources outside the NAPS site	N
Impacts to Members of the Public/ Section 5.4.3	Doses due to liquid effluent releases to the discharge canal and the WHTF and from gaseous pathway releases	Calculated doses to public via liquid and gaseous pathways are within the design objectives of 10 CFR 50 Appendix I and within regulatory limits of 40 CFR 190.	N
Impacts to Biota Other Than Members of the Public/ Section 5.4.4	Doses to biota from liquid radwaste effluent releases to the discharge canal, WHTF, and the North Anna Reservoir	There are no acceptance criteria specifically for biota. However, there is no scientific evidence that chronic dose rates below 100 mrad/day are harmful to plants and animals and all biota doses are calculated to be less than 1 mrad/day. No mitigation measures or controls are proposed.	N

Table 10.1-2 Operations-Related Unavoidable Adverse Environmental Impacts

Category/ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Environmental Impacts of Waste/ Nonradioactive Waste System Impacts/ Section 5.5.1	Potential impacts to Lake Anna and North Anna River from increased volume of effluent discharged and increased amounts of chemicals and other pollutants in the discharged effluent as well as increased storm water discharge	Comply with applicable VPDES water quality standards for discharges from Dike 3. Prepare and implement a Storm Water Pollution Prevention Plan for the operation of the existing and new units to avoid and/or minimize releases of contaminated storm water.	N
Section 5.5.1	Potential increase in impacts due to increase in gaseous and particulate emissions	Operate new minor air emission sources in accordance with applicable regulations and permits.	N
Section 5.5.1	Increase in total volume of solid and sanitary wastes	Continue use of approved transporters and offsite landfills for disposal of solid wastes. Continue existing units program for reuse and recycling of non-radwastes. Modify existing sanitary waste treatment systems, as required, to accommodate increased volume.	N
Mixed Wastes Impacts/ Section 5.5.2	Potential hazardous chemical and occupational exposure to radiological materials during handling and storage of 15-30 cubic feet of mixed liquid waste and 5-10 cubic feet of mixed solid waste generated by operation activities for new unit(s)	Limit amounts of mixed waste to be handled and disposed of through source reduction, recycling, and treatment, to the extent practical and feasible. Develop a Waste Minimization Program that includes new and existing units. Construct temporary onsite storage facilities, as needed, for mixed wastes and implement a waste management program in compliance with applicable EPA and NRC requirements. Identify a primary and an alternative offsite facilities for transportation, treatment and disposal of mixed wastes.	N
Section 5.5.2	Potential exposure of onsite workers and emergency response personnel during accidental releases and cleanup activities	Implement, or comply with existing, spill prevention and response plans and procedures that address hazards associated with managing/handling mixed wastes. Include measures for response personnel training and protective equipment.	N

Table 10.1-2 Operations-Related Unavoidable Adverse Environmental Impacts

Category/ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Transmission System Impacts/ Terrestrial Ecosystems/ Section 5.6.1	Air emissions and noise from use of helicopter to maintain transmission corridors	No new measures are required as current maintenance activities are sufficient.	N
Aquatic Ecosystems/ Section 5.6.2	Potential impacts to mussel species from maintenance of transmission corridors	No new measures are required as current maintenance practices would continue.	N
Impacts to Members of the Public/ Section 5.6.3	Dependent on design of transmission corridors and a determination whether any changes are required.	Based on an initial evaluation, the current ESP site transmission lines and corridors have sufficient capacity for the total output of the existing and new units.	N/A
Uranium Fuel Cycle Impacts (relative to reference LWR)/ Section 5.7	Energy required, emissions generated, and water usage during mining, yellowcake production and uranium conversion; and production of UO_2 during fuel fabrication.	Select mining techniques, where feasible and practical, that minimize impacts such as in situ leaching rather than open pit mining. Consider use of new technology that requires less UF_6. Consider use of new technologies with less fuel loading to reduce energy, emissions, and water usage	Y
Section 5.7	Emissions from fossil fuel plants supplying the gaseous diffusion plant	Consider use of new technology that requires less UF_6. Consider use of centrifuge process rather than gaseous diffusion process which significantly reduces energy requirements and environmental impacts. Fossil fuel plants must comply with air quality regulations.	N
Section 5.7	Radioactive waste to be managed from operations, and decontamination and decommissioning	Consider use of new gas-cooled reactor technologies that can result in generation of far less low-level wastes.	Y

Table 10.1-2 Operations-Related Unavoidable Adverse Environmental Impacts

Category/ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Physical Impacts of Station Operations/ Section 5.8.1	Potential noise impact from operating plant activities	Noise from cooling towers is expected to be below NRC-defined significance levels at the NAPS site EAB and nearest residence. Perform noise study as part of the design of the cooling system to confirm compliance with NRC-defined levels, and apply controls if necessary. Control noise levels in accordance with local noise regulations.	N
Section 5.8.1	Potential air quality impacts from emissions associated with diesel generators and auxiliary power systems	Comply with applicable VDEQ permit limits and regulations to install and operate such sources.	N
Section 5.8.1	Potential visual impacts to surrounding areas due to new structures, including wet and dry towers	Perform visual impact study during final plant design, and incorporate mitigation measures, as appropriate.	N
Section 5.8.1	Potential traffic impacts on local roads	Existing roads are expected to have sufficient capacity to handle increased traffic due to operation of new units.	N
Socioeconomic/ Section 5.8.2	Noise impacts at residences from operation of the new units and ancillary facilities, e.g., cooling tower	Due to distance to nearest residences, no noticeable increase in noise levels. A noise study would be performed for the area once the reactor and ancillary facilities are selected. If indicated, noise mitigation measures would be designed into facility.	N
Section 5.8.2	Visual impact of new units	Selection of cooling tower, reactor. Perform visual impact assessment prior to construction to assist in facility layout.	N
Section 5.8.2	Impact of increased operations traffic on local road network	Operations traffic management study plus any permanent upgrades for the construction phase should eliminate any adverse impact on the local road network.	N
Environmental Justice/ Section 5.8.3	None expected	None required.	N

Table 10.1-2 Operations-Related Unavoidable Adverse Environmental Impacts

Category/ESP ER Section	Adverse Impact	Mitigation Measure	Unavoidable Adverse Environmental Impacts
Decommissioning/ Section 5.9	Potential radiation exposure related to decommissioning, including transportation of materials to authorized disposal sites	No mitigation measures are proposed at this time as this would be part of the required decommissioning plan.	N/A

10.2 Irreversible and Irretrievable Commitments of Resources

This section describes the predicted irreversible and irretrievable environmental resource commitments used in the construction and operation of the new units. These environmental resource commitments are developed from information in Chapter 4 and Chapter 5, and are summarized in Section 10.1. Those areas that were assessed and determined to have unavoidable adverse environmental impacts, even after application of all practical means to mitigate or avoid the impacts, have been used to identify resources to be evaluated in this section.

10.2.1 Irreversible Environmental Commitments

The following categories have been assessed for their irreversible environmental commitments and are described in this section:

- Land Use
- Hydrology and Water Use
- Ecology (Terrestrial and Aquatic)
- Socioeconomics
- Radiological Releases
- Atmospheric Releases and Meteorological Changes

10.2.1.1 Land Use

The ESP site is within the NAPS site. The NAPS site is zoned industrial by Louisa County. The original permitting of the NAPS site was for the installation of four units. Lake Anna was created by damming up the North Anna River for the purpose of providing cooling water to the power station. Virginia Power and ODEC own all of the land under the lake as well as the NAPS site. Structures at the NAPS site that would be used by the new units include the partial construction of an intake structure originally intended to service the abandoned Units 3 and 4.

Based on an initial evaluation, the existing transmission lines have sufficient capacity to carry the total output of the existing units and the new units.

In summary, no new property is needed for the new units and an existing partially completed intake structure for the cooling water is available to support the new units.

Currently undeveloped portions of the NAPS site would be cleared to construct the new units. A large portion of the cleared area would contain the new units and ancillary equipment. That area would not be restored after completion of the new units until the new units are decommissioned. Much of the wildlife that currently utilizes the area where the new units would be constructed would move out into the areas surrounding the ESP site. There are no known special or protected species on the site. When the units are decommissioned, both the vegetation and the wildlife are eventually

expected to return naturally to current conditions. Therefore, there are no irreversible environmental commitments associated with the land that is to house the new units and ancillary equipment.

10.2.1.2 Hydrology and Water Use

Unit 3 would use a combination wet and dry cooling tower system for plant cooling, whereas Unit 4 would use a dry tower system. Make-up water for the wet cooling towers of Unit 3 would be taken from the North Anna Reservoir, consistent with the original permitting of the NAPS site. The amount of make-up water that is not returned as blowdown to the WHTF would be that evaporated in the wet towers, which is a small fraction of the amount of water in the lake. The evaporated water would be replaced by in-flowing water upstream of the dam. Once the site is decommissioned, the balance of water in the lake would be governed by the in-flowing water, evaporation from the surface of the lake, and the amount of water flowing over the dam.

Groundwater from existing wells would be sufficient for the potable water demands during operation of the new units.

10.2.1.3 Ecology (Terrestrial and Aquatic)

As presented in Section 10.2.1.1, there would be some anticipated loss of vegetation and relocation of terrestrial wildlife, respectively, due to construction of the new units. However, some of this would return once construction is completed and unused areas are restored. The decommissioning of the new units would eventually result in complete restoration, if left undisturbed. There would be no irreversible loss of terrestrial ecology.

Similarly, aquatic ecology in streams and wetlands on site would be affected by the construction of the new units, but there are no protected or special aquatic ecosystems on the ESP site. The discharge from the new units would not adversely affect the aquatic ecology in Lake Anna. There are no unique, special, or protected aquatic ecosystems on the ESP site or in Lake Anna. Once the new units are decommissioned, the aquatic ecology is eventually expected to return to its current levels. Therefore, there is no irreversible loss of aquatic ecology associated with installation of the new units at the ESP site.

10.2.1.4 Socioeconomics

The effect of the construction and operation of the new units would be to increase long-term employment and to provide positive input to the local community in the form of taxes and personal commitments to the community by the new employees and their families. The fact that the workforce during construction would be supplied primarily from the region means that there would not be major disruptions in the transition from construction to operation of the new units. Because the various DRI subsidiaries intend to maintain the NAPS site for power generation purposes for the foreseeable future, there would be no irreversible commitment of resources from a socioeconomic standpoint, once the decommissioning of the new units occurs.

10.2.1.5 Radiological Releases

The new units would operate under the limitations imposed by the NRC with respect to radioactive releases. Decommissioning would also be performed according to the requirements of the NRC, which would ultimately be expected to result in the unrestricted use of the site. The loss of radioactive material in the form of nuclear fuel due to operation of the new units, is addressed in Section 10.2.2 under Irretrievable Resources.

10.2.1.6 Atmospheric Releases and Meteorological Changes

There would be no major releases of pollutants to the atmosphere from operation of the new units, because only the testing of emergency generators and occasional use of large pieces of equipment that run on diesel fuel would generate such pollutants. The operation of a combination wet and dry tower system has the potential for making micro-level changes to the meteorology, but only in the immediate vicinity of the tower. Upon decommissioning of the new units, these changes would cease to be a factor. Therefore, the operation of ancillary equipment associated with the new units would not result in irreversible atmospheric or long-term meteorological changes to the area.

10.2.2 Irretrievable Commitments of Resources

Irretrievable commitments of resources during construction of the new units generally would be similar to that of any major, multi-year, construction project. Unlike the earlier generation of nuclear plants, asbestos and other materials considered hazardous would not be used, if possible, or would be used sparingly and in accordance with safety regulations and practices. Available information on materials used to construct earlier nuclear power plants has been reviewed and adjusted to a nominal 1000 MWe unit on the assumption that the usage is linear with energy output. That is, the usage of materials for each of the units is simply multiplied by the ratio of the actual energy output for each unit reviewed, divided by 1000. The conclusion is that each new 1000 MWe unit could require up to 200,000 cubic yards of concrete (not including cooling tower requirements) and up to 15,000 tons of structural steel.

The U.S. Defense National Stockpile centers, shut down since 1991, have been slowly selling off reserves since that time. A review by the federal government of the sources of available materials in the world, and their locations, has resulted in the determination of no material supply threat to the U. S., nor any real benefit to continuing to stockpile such materials. That is, the use of certain metals and materials on the list of strategic materials has been determined to no longer represent a significant impact on the country's defense (Reference 1). Therefore, use of such materials in the quantities associated with those expected for a 1000 MWe nuclear power plant, while irretrievable, would not be a large or moderate impact, with respect to the availability of such resources.

The main resource that would be irretrievably lost during operation of a new 1000 MWe nuclear unit would be uranium. This is best represented by the annual consumption of yellowcake, which is not expected to exceed the normalized value for the reference plant of 293 metric tons (MT) per year

for a 1000 MWe generating unit using current reactor technology as identified in Section 5.7.2.3.4, Uranium Milling. Depending on the actual reactor technology selected, this yellowcake consumption could be much lower. Studies performed by U.S. Government agencies, such as the National Defense Stockpile Impact Committee of the Bureau of Industry and Security (Reference 2), and entities such as the World Nuclear Association (Reference 3) (Reference 4), have concluded that there are easily accessible, rich deposits of uranium throughout the world and that existing stocks of highly enriched uranium (HEU) in the U.S. and Russia--formerly for military usage--could be converted to fuel for nuclear power plants. Also, the reduction in use of uranium by the newer reactors when compared to the existing reactors would serve to extend the current 50-year supply of uranium available to the nuclear power industry. Therefore, the uranium that would be used to generate power by the new units at the ESP site, while irretrievable, would not be a large or moderate impact with respect to the long-term availability of uranium worldwide.

Section 10.2 References

1. *National Defense Stockpile Market Impact Committee*, Bureau of Industry and Security, website www.bis.doc.gov/DefenseIndustrialBasePrograms/OSIES/StockpikeCommittee.html accessed 8/15/03.

2. *Effects of Imports of Uranium on the National Security* Summary, Bureau of Industry and Security, Document Number 003-009-00698-8, September 1989, website. www.bis.doc.gov/defenseindustrialbaseprograms/OSIES/2-3-2-Reports/Uranium89.html.

3. *Introduction to Nuclear Energy/Factsheets, Uranium Resources*, World Nuclear Association, website www.world-nuclear.org/factsheets/uranium.htm, accessed 8/15/03.

4. *Supply of Uranium, Information and Issue Briefs,* World Nuclear Association August 2002, website www.world-nuclear.org/info/inf75.htm, accessed 8/15/03.

10.3 Relationship Between Short-Term Uses and Long-Term Productivity of the Human Environment

This ER has focused on the analyses and resulting conclusions associated with the environmental and socioeconomic impacts arising from activities during the construction, operation, and decommissioning of new units at the ESP site. These activities are considered to be short-term uses for purposes of this section. For this section, the long-term is considered to start with the conclusion of decommissioning of the new units at the ESP site. This section includes an evaluation of the extent to which the short-term uses preclude any options for future use of the ESP site.

10.3.1 Construction of New Units at ESP Site and Long-Term Productivity

Section 10.1 summarizes the potential unavoidable adverse environmental impacts of construction of the new units and the measures proposed to reduce these impacts. There are adverse environmental impacts that would remain after all practical measures to avoid or mitigate the impacts have been taken. However, none of these impacts represent a long-term effect that would preclude any options for future use of the ESP site.

The new units would be constructed on the property adjacent to the existing units. The NAPS site was originally selected and reviewed to accommodate four units. As a consequence, the size of the site, the characterization of the Lake, and the transmission capacity are generally already acceptable for the new units.

While some changes may be made to the WHTF or the existing intake area to accommodate the new units, any disturbances to these areas would be temporary and would not change the long-term productivity of the ESP site.

The acreage disturbed during construction of the new units would be much larger than that required for the actual structures and other ancillary facilities because of the need for construction laydown areas and a parking area for the construction workforce. The clearance of this acreage, plus the noise of the construction of the new units, would displace some wildlife and remove vegetation. Once the new units are completed, the disturbed areas would be restored. Wildlife is expected to return to the restored area.

Noise emitted during some construction activities would increase the ambient noise levels in the vicinity of the site. However, upon completion of these activities, the ambient levels would return to the levels associated with the operation of the existing units. Because of the nature of the vicinity about the ESP site, no long-term effects would occur. Generally, the requirements of the local ordinance would be complied with during construction of the new units so that the local residents or visitors to Lake Anna would not be unduly impacted. Also, the workforce would be protected by adherence to the OSHA requirements for noise levels that are acceptable during specified time periods or through the use of protective equipment when excessive noise levels for a given time

period are unavoidable. There would be no effects on the long-term productivity of the ESP site as a result of these impacts.

Construction traffic has the potential to cause congestion in the immediate area of the ESP site. A construction traffic management plan would be developed and implemented in cooperation with VDOT to reduce the possibility of major congestion problems. It is likely that permanent upgrades would be made at both the intersection of the construction access road with Route 700 and at the intersection of Route 700 and Route 652. These upgrades to relieve congestion problems that could arise during shift changes would remain in place after construction ends and would be a benefit to the local area throughout the life of the new units.

The construction of the new units would be beneficial to the local area through the generation of new construction-related jobs, local spending by the construction workforce, and payment of taxes to the area.

No long-term adverse environmental impacts would result from the construction of new units at the ESP site.

10.3.2 **Operation of the New Units and Long-Term Productivity**

Section 10.1 summarizes the potential unavoidable adverse environmental impacts of operation of the new units and the measures proposed to reduce or eliminate these impacts. There are some adverse environmental impacts that could remain after all practical measures to avoid or mitigate the impacts have been taken. However, none of these impacts represent long-term effects that would preclude any options for future use of the ESP site.

The NAPS site has been developed by Virginia Power as a location for major energy generation facilities. The existing units have been operating for over twenty years. The various DRI subsidiaries intend to continue the use of the NAPS site for major energy generation facilities beyond the lifetime of the existing or new units. Therefore, the operation of the new units represents a continuation of the current and planned use of the land. For the foreseeable future, any options for future use of the ESP site, including operation of new energy generation facilities, are not precluded.

The type of reactor to be installed at the ESP site has not yet been selected, nor has the ancillary equipment related to the reactor. Unit 3 would use a combination wet and dry cooling tower system, whereas Unit 4 would use a dry tower system. Make-up water for Unit 3 would be taken from the North Anna Reservoir, consistent with the original permitting of the NAPS site. The amount of water that is not returned as blowdown to the WHTF would be that evaporated in the wet towers, which is a small fraction of the amount of water in the lake. The evaporated water would be replaced by in-flowing water upstream of the dam. Once the site is decommissioned, the balance of water in the lake would be governed by the in-flowing water, evaporation from the surface of the lake, and the

amount of water flowing over the dam. There would be no future long-term issues with regard to future uses of the ESP site.

The blowdown water discharge from Unit 3 would be to the existing WHTF. Although there would be a small increase in water temperature within the WHTF, there would be negligible to no increase in temperature within the North Anna Reservoir part of Lake Anna that is open to the public for recreational purposes. Additionally, the discharges to the existing WHTF are projected to remain within the limits of the wastewater discharge permit issued for the NAPS site (or, if needed, to the wastewater discharge permit as amended). Therefore, any long-term effects on the future usage of the lake, including the cessation of the heated discharge, would be small.

The daily volume of traffic on the section of Route 700 between Route 652 and the entrance to the NAPS site is expected to nearly double, once the new units become operational. However, any permanent upgrades that would be made for construction to eliminate or greatly reduce congestion, would remain in effect after construction is completed and the new units become operational. Normal maintenance of this half-mile section of road should allow the benefits of these upgrades to persist into the future.

The operation of the new units would slightly increase air emissions because of diesel engines that would be operated intermittently on site. However, these engines would be operated in accordance with applicable federal, state, and local regulations, and they would not create any noticeable impacts in the area. Additionally, no long-term impacts would result from salt deposition arising from salt drift from the cooling towers as the analysis has determined the amount deposited on a monthly basis would be minimal when compared to those levels at which ecological impacts might occur. Normal maintenance activities for the area within 300 feet of the cooling towers plus rain or snowfall would prevent the buildup of salt in the soil within this area. No future issues for the long-term uses of the site would result from the impacts of increased air emissions.

Impacts due to radiological emissions would be negligible to small, since the operation of the new units would be in accordance with the operating license and NRC regulations. Furthermore, radiological monitoring would be implemented to measure radiation levels from the operation of the new units and would initiate a timely response to reduce such emissions if elevated levels are detected. No future issues associated with the radiological emissions from operation of the new units would affect the long-term uses of the ESP site.

10.3.3 Summary of Relationship Between Short-Term Uses and Long-Term Productivity

The impacts from the local use of the human environment by the installation and operation of the proposed new units at the ESP site is presented in Section 10.1 and summarized in the preceding paragraphs in terms of the unavoidable adverse environmental impacts of construction and operation. Section 10.2 presents information on the irreversible and irretrievable commitments of resources. Except for consumption of non-renewable resources because of construction and operation of the new units, the uses may be classified as short-term. The principal short-term

benefit is the production of electrical energy, and the economic productivity of the ESP site is large compared with the productivity from agriculture or other probable uses for the site. Because the site would eventually be restored by decommissioning, there would be no significant impact on long-term productivity.

Section 10.3 References

None

10.4 Benefit – Cost Balance

In accordance with the 10 CFR 52.17(a)(2), an assessment of the benefits (need for power) of new units is not included in this report.

Section 10.4 References

None

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PART 4: PROGRAMS AND PLANS

Chapter 1 Site Redress

This chapter describes early site preparation (ESP) site preparation activities that might occur after U.S. Nuclear Regulatory Commission (NRC) issuance of an early site permit. The chapter also describes the site redress plan that would be implemented if those site preparation activities were performed, but the ESP then expired before it is referenced in a combined license (COL) application.

1.1 Description of Site Preparation Activities

The Site Redress Plan in Section 1.2 is submitted by Dominion Nuclear North Anna, LLC (Dominion) pursuant to 10 CFR 52.17(c) to allow Dominion to perform, after being granted the ESP, the site preparation activities for new nuclear units at the ESP site allowed by 10 CFR 50.10(e)(1). The site preparation activities that Dominion may perform include:

- Preparation of the site for construction of the facility (including such activities as clearing, grading, construction of temporary access roads, and preparation of borrow areas);
- Installation of temporary construction support facilities (including items such as warehouse and shop facilities, utilities, concrete mixing plants, docking and unloading facilities, and construction support buildings);
- Excavation for facility structures;
- Construction of service facilities (including items such as roadways, paving, railroad spurs, fencing, exterior utility and lighting systems, switchyard interconnects, and sanitary sewage treatment facilities);
- Construction of structures, systems and components which do not prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public, including but not limited to:
  - Cooling towers,
  - Intake and discharge structures,
  - Circulating water lines,
  - Fire protection equipment,
  - Switchyard and on-site interconnections,
  - Microwave towers,
  - Underground utilities.

Before commencing any of these activities, after the ESP is granted, Dominion would:

1. Create a record of the existing site conditions within the proposed ESP site by way of photographs, surveys, listings of existing facilities and structures, or other documentation. This record would serve as the baseline for redressing the site in the event ESP site preparation activities are terminated as a result of project cancellation or expiration of the ESP.

2. Obtain any state and local permits and authorizations necessary to perform the site preparation activities.

3. Obtain the appropriate regulatory approvals of an agreement between Virginia Power and Dominion. This agreement would authorize Dominion to conduct the pre-construction activities subject to Dominion's obligation to perform such site redress as may be required to comply with the Site Redress Plan approved by the NRC.

4. Provide to the NRC a guaranty by Dominion Resources, Inc. (DRI) of $10 million as financial assurance for Dominion's obligation to comply with the Site Redress Plan. Dominion is an indirect, wholly-owned subsidiary of DRI. DRI is the largest fully-integrated natural gas and electric provider in the United States with over $37 billion in assets, over $10 billion in annual revenue, and over $2 billion in annual operating cash flow.

1.2 Site Redress Plan

This section constitutes Dominion's plan for redress of the North Anna site in the event that activities allowed by 10 CFR 50.10(e)(1) are performed but the ESP then expires before it is referenced in an application for a combined license under 10 CFR 52, Subpart C. This Site Redress Plan provides reasonable assurance that redress carried out under the plan would achieve an environmentally stable and aesthetically acceptable site condition suitable for whatever non-nuclear use may conform with local zoning laws.

The following sections describe the objective of the Site Redress Plan and activities that would be considered to redress the site; a general description of proposed redress activities; and the procedure for NRC notification and final acceptance of the redressed site.

1.2.1 Site Redress Plan Objective and Considerations

The objective of the Site Redress Plan is to ensure that the site, should it not be fully developed for the intended purpose of new nuclear power generation, would be returned to an unattended, environmentally stable and aesthetically acceptable condition suitable for such non-nuclear use as is consistent with local zoning laws.

Site redress activities would be commensurate with the level of site modification created by the proposed site preparation activities. Redress activities would reflect applicable land use and/or zoning requirements of local, state and federal agencies. Redress activities would consider the following:

- Recontouring, revegetation, and replanting of cleared areas
- Restoration of sensitive water resource features disturbed for intake and/or discharge structures
- Habitat replacement
- Use of constructed facilities for alternative purposes, or their removal
- Remediation of contamination resulting from site preparation or site redress activities

In planning for site redress, two general categories of conceptual options would be considered:

1. Topographic approaches that accomplish the objective stated above as well as preserve the potential of the site for future industrial use

2. Completion or addition of site development features that enhance the value of the site for potential future industrial use.

Redress activities would begin (in concert with local and/or state land use agencies and industrial development authorities) either when the ESP has expired or reactor construction plans have been abandoned. The redress activities would include those actions necessary to terminate or transfer local and state permits and would identify site features or improvements that would remain and those that must be removed. A detailed redress scope and schedule consistent with this plan would

be implemented at that time. The schedule would include adequate preparation time to secure additional input from regulators and local municipalities. The redress activities would comply with applicable environmental requirements. If, prior to commencement of the redress activities, industrial or other acceptable uses for the site are identified that are consistent with its development, the redress would be performed in a manner that accommodates and is consistent with the alternative use. Dominion would carry out the Site Redress Plan to the greatest extent possible consistent with the alternative use.

Prior to the commencement of site redress activities, environmental control of local water quality, air quality, stormwater runoff, solid waste, and the protection of critical ecological elements, if any, would be maintained in compliance with approved permits and regulatory requirements.

1.2.2 **Description of Site Redress**

This section describes the site redress actions that would be taken should pre-construction work not proceed to full construction. The overall objective of site redress is to provide an environmentally stable, self-draining, self-maintaining, esthetically acceptable site that can be left unattended. The methods by which this would be accomplished are presented in the following subsections.

1.2.2.1 **Future Use of Constructed Facilities**

Any facilities or structures constructed as part of the site preparation activity that could have applicability to a future use of the site may be left in place to the extent that they are consistent with local zoning and provided that they pose no hazard to safety or the environment. Such facilities or structures would be evaluated at the time of site redress to assess their usefulness for potential or proposed site utilization. Should the facilities or structures be deemed to have a potential for future use, they would be preserved in a manner that would pose no threat to the environment or to activities on the site. However, should the facilities or structures be considered to be of no value to final disposition of the property, they would be removed as part of the overall site redress activities.

1.2.2.2 **Physical Restoration**

Changes to the site would be evaluated to assess their potential for future impact on the site and future site use. Any changes that are deemed to have no future value to the site and could not be dispositioned to a stable configuration would be redressed. No additional areas outside those already cleared would be disturbed. Final site redress would include regrading the area to conform with the surrounding land surface and to mitigate stormwater runoff and erosion potential. Revegetation and replanting would be performed to achieve the objective of environmental and

aesthetic site stabilization. Some or all of the following activities would be performed to redress the site to a suitable condition:

- Structures and facilities, unless deemed useful to the existing plant or for future industrial development, would be demolished and the resulting debris would be properly disposed of at the site or an approved disposal facility.
- Existing excavations would be backfilled and the areas regraded to conform with the surrounding land surface and to mitigate stormwater runoff and erosion potential. Backfill placement would be performed in accordance with specified procedures. Borrow materials to be used in the backfilling and contouring operations would be obtained from locations on the site that are within the existing cleared areas. The backfilled areas would be revegetated and/or replanted, or otherwise mitigated for erosion control.
- Perimeter fencing would be removed, unless it is considered necessary for liability and security purposes.
- Fire protection systems would be evaluated for removal or abandonment in place.
- Underground utilities and overhead lighting would be evaluated for removal or abandonment in place.
- All unneeded construction equipment would be removed from the site and dispositioned accordingly.
- If intake and discharge structures are removed, the shoreline would be restored to an acceptable long-term condition.
- If not needed, onsite transmission interconnects (towers, lines, etc.) would be deactivated at the switchyard and evaluated for removal or abandonment in place.
- Asphalt roadways would be evaluated for removal or abandonment in place. If removed, the materials would be disposed of at an approved disposal facility.
- Roadbeds would be evaluated for removal or abandonment in place. If removed, the roadbed areas would be recontoured to conform with the surrounding land surface and revegetated.
- Borrow areas would be regraded to conform with the surrounding land surface and to mitigate stormwater runoff and erosion potential, and the areas would be revegetated.
- Railroad spurs would be evaluated for removal or abandonment in place. If removed, the railbed areas would be recontoured to conform with the surrounding land surface, and the areas would be revegetated.

1.2.2.3 Restoration of Sensitive Water Resource Features

1.2.2.3.1 Lake Anna

Construction of the cooling water intake structure for the new units at the ESP site would not significantly affect the open water habitat of Lake Anna. The intake structure would be constructed in the vicinity of the existing units cooling water intake structure. The modification to open water habitat resulting from construction of the intake structure would not be considered significant in comparison to the amount of open water habitat found on Lake Anna. If the intake structure is removed as part of site redress activities, the shoreline would be redressed by grading and revegetation to control erosion. Any significant sediment deposition in the vicinity of the intake structure would be removed.

During site redress activities, erosion and sediment control best management practices would be used to contain eroded soil on the site and remove sediment from stormwater runoff prior to its leaving the site. Measures would be taken to avoid concentrated flows with a high potential to transport sediment. Visual inspections of erosion control measures would be performed to monitor the effectiveness of the control measures and to aid in determining if other mitigation measures are necessary. Where necessary, special erosion control measures would be implemented to further minimize impacts to the lake, lake users, and existing units operations. Site redress activities would include the use of appropriate stabilization methods to mitigate the long-term delivery of sediment into the lake.

1.2.2.3.2 Freshwater Streams

Portions of two small ephemeral streams that discharge to Lake Anna, designated Streams A and B on Figure 1.2-1, may be filled to level the area should the construction of cooling towers in that area become a part of the final plant design. It is estimated that about 1500 feet of stream channel would require filling. The site drainage system would be designed to incorporate the flow currently conveyed by these streams to the lake. By providing alternate drainage facilities to convey the stream flows, no short-term or long-term adverse hydrologic impacts on site drainage would result. Therefore, the need to redress the streams to their original condition, should construction be terminated, would be evaluated at that time to determine the best way to ensure long-term stability of the site. If considered necessary, the stream channels would be re-excavated and stabilized by vegetation and/or riprap to return the area to an acceptable long-term condition.

New onsite pipelines that cross freshwater streams would be constructed so that no permanent alteration to the streams occurs. Should site preparation activities be terminated, an evaluation would be made at that time regarding removal of these facilities as part of the site redress activities. Should removal be considered necessary, it would be accomplished in such a manner as to minimize disruption to the streams, and the streams would be redressed to an acceptable long-term condition.

1.2.2.3.3 **Groundwater**

Impacts to groundwater during site preparation activities may occur due to temporary dewatering of foundation areas or general lowering of the groundwater table in localized areas due to topographic alterations. Once the dewatering activities are terminated, the groundwater levels are expected to return to their previous levels. Groundwater levels that are altered due to topographic changes would be minor and of no significance to the overall flow of groundwater to Lake Anna. Should the topographic alterations be redressed to their original configuration, the groundwater would also likely return to its previous levels and flow direction in these areas. Therefore, no redress of groundwater levels is anticipated to be necessary.

1.2.2.4 **Habitat Replacement**

Site preparation activities would occur within the boundaries of the existing NAPS site, which has been designated an industrial zone. Areas outside the site would be generally unaffected with respect to habitat disturbance. The site contains no critical habitat areas that would require replacement as a result of ESP site preparation activities. Therefore, no habitat replacement would be necessary as part of the site redress activities. Some habitats would recover naturally when the site is redressed.

1.2.2.5 **Contamination**

Any areas on the ESP site that become contaminated as a result of site preparation or redress activities would be remediated in compliance with applicable local, state and federal regulations.

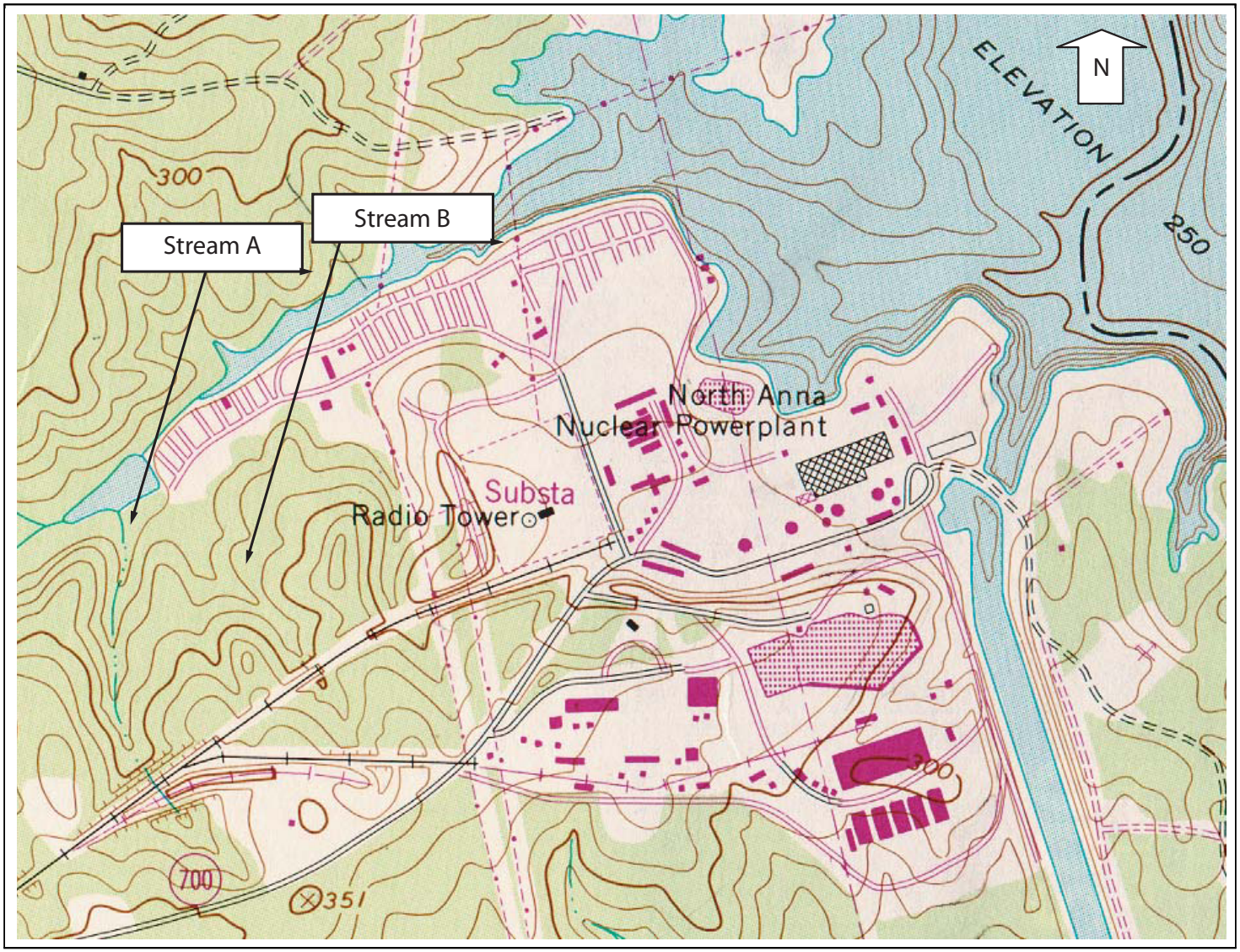

Figure 1.2-1 Ephemeral Steam Locations

Source: *Lake Anna West, VA*, USGS 7.5 Minute Topographic Map, 1983.

1.2.3 **NRC Notification Upon Completion**

Dominion Nuclear North Anna, LLC would notify the NRC upon completion of activities addressed by this Site Redress Plan. The site would be made available for inspection and any documentation that the NRC may require would be provided to confirm the satisfactory completion of the redress activities.