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Dominion®

March 22, 2011

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

Serial No. NA3-10-035RA
Docket No. 52-017
COL/DWL

DOMINION VIRGINIA POWER
NORTH ANNA UNIT 3 COMBINED LICENSE APPLICATION
SRP 02.05.02: SUPPLEMENTAL RESPONSE TO RAI LETTER 53

On December 21, 2010, the NRC requested additional information to support the review of certain portions of the North Anna Unit 3 Combined License Application (COLA). Dominion letter NA3-10-035R, dated January 28, 2011, provided a complete response to Request for Additional Information (RAI) Question 02.05.02-1, but deferred the submittal of the proposed COLA revision to a later date. The proposed COLA revision associated with this RAI response is provided in Enclosure 1.

This information will be incorporated into a future submission of the North Anna Unit 3 COLA, as described in the enclosure.

Please contact Regina Borsh at (804) 273-2247 (regina.borsh@dom.com) if you have questions.

Very truly yours,

Eugene S. Grecheck

D089
NRO

Enclosure:

1. Proposed COLA Markups for RAI Letter Number 53, RAI 5198, Question 02.05.02-1

Commitments made by this letter:

1. Incorporate proposed changes in a future COLA submission.

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 Development of Virginia Electric and Power Company (Dominion Virginia Power). He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of the Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 22nd day of March, 2011

My registration number is 310847 and my

Commission expires: 4/30/13

Ginger L Melton

Notary Public

GINGER LYNN MELTON
Notary Public
Commonwealth of Virginia
310847
My Commission Expires Apr 30, 2013

I was commissioned a notary as Ginger L. Alligood.

cc: U. S. Nuclear Regulatory Commission, Region II
C. P. Patel, NRC
T. S. Dozier, NRC
J. T. Reece, NRC

ENCLOSURE 1

Supplement 1 to Response to NRC RAI Letter 53

RAI 5198 Question 02.05.02-1

SUPPLEMENTAL RESPONSE TO
REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 5198 (RAI Letter 53)

SRP SECTION: 02.05.02 – VIBRATORY GROUND MOTION

QUESTIONS for Geosciences and Geotechnical Engineering Branch 2 (RGS2)

DATE OF RAI ISSUE: 12/21/2010

QUESTION NO.: 02.05.02-1

FSAR Section 2.5.2.5 states that the GMRS is defined at a site elevation of 135 ft below finished grade at the hard rock interface (Vs = 9200 ft/sec). Justify that this location for the GMRS is consistent with the description of the SSE found in 10 CFR 100.23(d)(1) and the location of the GMRS as specified in ISG-17 and RG 1.208, which states that

> The horizontal and vertical GMRS are determined in the free-field on the ground surface. For sites with soil layers near the surface that will be completely excavated to expose competent material, the GMRS are specified on the outcrop or hypothetical outcrop that will exist after excavation.

As the weathered rock above the hard rock interface has a Vs less than 9200 ft/sec, please provide the base Vs profile along with a complete description of the site response analysis to determine the GMRS for the site.

<u>Dominion Supplemental Response</u>

On December 21, 2010, the NRC requested additional information for the justification of the GMRS determination in Letter No. 53, RAI 5198, Question 02.05.02-1. In Letter No. NA3-10-035R, dated January 28, 2011, Dominion provided a response to this question, however, the expected COLA revisions were not yet completed. This supplemental response provides the markups of COLA pages with the proposed revisions.

Proposed COLA Revision

The sections, tables, and figures in COLA Part 2 (FSAR) and Part 7 (Departures Report) listed below will be revised as indicated on the attached markups.

1. FSAR Table 1.8-201, "Resolution of Combined License Items for Chapters 1-19"
2. FSAR Table 1.8-202, "Departures from the Referenced Certified Design"
3. FSAR Table 1.8-203, "Variances from the ESP and ESPA SSAR"
4. FSAR Table 1.9-202, "Conformance with Regulatory Guides"
5. FSAR Table 2.0-201, "Vibratory Ground Motion" Evaluation
6. FSAR Section 2.5.2, "Vibratory Ground Motion"
7. FSAR Table 2.5-201, "Selected Horizontal Ground Motion Response Spectrum Amplitudes, V/H Spectral Ratios, and Resulting Vertical Ground Motion Response Spectrum Amplitudes"
8. FSAR Figure 2.5-201, "Horizontal and Vertical Ground Motion Response Spectra (GMRS)"
9. FSAR Figure 2.5-202, "High-Frequency and Low-Frequency Hard Rock Horizontal Response Spectra"
10. FSAR Section 3.7, "Seismic Design"
11. FSAR Figure 3.7-203, "GMRS and Geologic Outcrop FIRS at Bottom of Basemat – Horizontal"
12. FSAR Figure 3.7-204, "GMRS and Geologic Outcrop FIRS at Bottom of Basemat – Vertical"
13. FSAR Appendix 3OO, "Site Response Analysis and Development of SSI Analysis Input"
14. Departures Report, Departure NAPS DEP 3.7(2), "Site Amplification Functions and Site Response Analysis"
15. Departures Report, Variance NAPS ESP VAR 2.0-4, "Vibratory Ground Motion"

Markup of North Anna COLA

The attached markup represents Dominion's good faith effort to show how the COLA will be revised in a future COLA submittal in response to the subject RAI. However, the same COLA content may be impacted by revisions to the DCD, responses to other COLA RAIs, other COLA changes, plant design changes, editorial or typographical corrections, etc. As a result, the final COLA content that appears in a future submittal may be somewhat different than as presented herein.

NAPS COL 1.8(2)

Table 1.8-201 Resolution of Combined License Items for Chapters 1–19

COL Item No.	COL Item	FSAR Section	Resolution Category
COL 3.7(4)	To prevent non-conservative results, the COL Applicant is to review the resulting level of seismic response and determine appropriate damping values for the site-specific calculations of ISRS that serve as input for the seismic analysis of seismic category I and seismic category II subsystems.	3.7.1.2 3.7.2.4.1	3a
COL 3.7(5)	The COL Applicant is to assure that the horizontal FIRS defining the site-specific SSE ground motion at the bottom of seismic category I or II basemats envelope the minimum response spectra required by 10 CFR 50, Appendix S, and the site-specific response spectra obtained from the response analysis.	3.7 3.7.1.1 Appendix 3OO Tables 3.7-201 through 3.7-203 Tables 3.7-201 through 3.7-204	3a
COL 3.7(6)	The COL Applicant is to develop site-specific GMRS and FIRS by an analysis methodology, which accounts for the upward propagation of the GMRS. The FIRS are compared to the CSDRS to assure that the US-APWR standard plant seismic design is valid for a particular site. If the FIRS are not enveloped by the CSDRS, the US-APWR standard plant seismic design is modified as part of the COLA in order to validate the US-APWR for installation at that site.	2.5.2 3.7 Figure 3.7-201	3a
COL 3.7(7)	The COL Applicant is to determine the allowable dynamic bearing capacity based on site conditions, and to evaluate the bearing load to this capacity.	3.7.1.3	3a
COL 3.7(8)	The soil properties may be considered strain-independent for subgrade materials with initial shear wave velocities of 3.500 ft/s or higher, to be confirmed by the COL Applicant as part of the site-specific subsurface material investigations discussed in Section 2.5.4. However, the COL Applicant must institute dynamic testing to evaluate the strain-dependent variation of the material dynamic properties for site materials with initial shear wave velocities below 3,500 ft/s.	3.7.2.4.1	3a
COL 3.7(9)	The COL Applicant is to assure that the design or location of any site-specific seismic category I SSCs, for example pipe or duct banks, will not expose those SSCs to possible impact due to the failure or collapse of non-seismic category I structures, or with any other SSCs that could potentially impact, such as heavy haul route loads, transmission towers, non safety-related storage tanks, etc.	3.7.2.8	3a

NAPS COL 1.8(2)

Table 1.8-201 Resolution of Combined License Items for Chapters 1–19

COL Item No.	COL Item	FSAR Section	Resolution Category
COL 3.7(20)	The COL Applicant is to validate the site-independent seismic design of the standard plant for site-specific conditions, including geological, seismological, and geophysical characteristics, and to develop the site-specific GMRS as free-field outcrop motions on the uppermost in-situ competent material.	2.5.2 3.7 3.7.2.2 3.7.2.4.1 Appendix 3NN	3a
COL 3.7(21)	The COL Applicant is responsible for the seismic design of those seismic category I and seismic category II SSCs that are not part of the US-APWR standard plant.	3.7 Appendix 3LL	3a
COL 3.7(22)	The COL Applicant is required to perform site-specific seismic analyses, including SSI analysis which considers seismic wave transmission incoherence and analysis of the CAV of the seismic input motion, in order to determine if high-frequency exceedances of the CSDRS could be transmitted to SSCs in the plant superstructure with potentially damaging effects.	3.7.1.1	3a
COL 3.7(23)	The COL Applicant is to verify that the results of the site-specific SSI analysis for the broadened ISRS and basement walls lateral soil pressures are enveloped by the US-APWR standard design.	3.7 Appendix 3NN	3a
COL 3.7(24)	The COL Applicant is to verify that the site-specific ratios V/A and AD/V^2 (A, V, D, are PGA, ground velocity, and ground displacement, respectively) are consistent with characteristic values for the magnitude and distance of the appropriate controlling events defining the site-specific uniform hazard response spectra.	3.7.1.1 Appendix 3OO	3a
COL 3.7(25)	The COL Applicant referencing the US-APWR standard design is required to perform a site-specific SSI analysis for the R/B-PCCV-containment internal structure utilizing the program ACS-SASSI (Reference 3.7-17R) which contains time history input incoherence function capability. The SSI analysis using SASSI is required in order to confirm that site-specific effects are enveloped by the standard design. After the SASSI analysis is first performed for a specific unit, subsequent COLAs for other units may be able to forego SASSI analyses if the FIRS and GMRS derived for those subsequent units are much smaller than the US-APWR standard plant CSDRS, and if the subsequent unit can also provide justification through comparison of site-specific geological and seismological characteristics.	3.7 Appendix 3NN	3a

NAPS COL 1.8(3)

Table 1.8-202 Departures from the Referenced Certified Design

	Number	Subject	FSAR Section
	NAPS DEP 02.0(1)	Maximum Non-Coincident Wet Bulb Temperature	2.0
RAI 02.03.04-2 S1 R1	~~NAPS DEP 02.3(1)~~	~~Main Control Room Atmospheric Dispersion Factors, Source to Receptor Distance Determination~~	~~2.3~~
	NAPS DEP 03.7(1)	Seismic Spectra Exceedance	2.0, 3.7, 3.8, Appendix 3NN, Appendix 3OO, 6.2, 19.1
RAI 02.05.02-1	NAPS DEP 03.7(2)	~~Site Amplification Functions and~~ Site Response Analysis	~~2.5,~~ 3.7
	NAPS DEP 03.7(3)	MNES Improvements to Seismic Analysis Methods	3.7, 3.8, Associated Appendices
	NAPS DEP 08.2(1)	Clarification of GDC 2 and 4 Applicability for Offsite Power	1.9, 8.1, 8.2
	NAPS DEP 09.2(1)	Replacement of Boron Recycle System with a Degasifier Subsystem	1.2, 3.2, Appendix 3E, 7.4, 9.2, 9.3, Appendix 9A, 10.4, 11.2, 11.3, 11.4, 11.5, 12.2, 12.3, 14.2
	NAPS DEP 09.2(2)	Non-Essential Service Water System, Design Service Water Temperature	9.2
	NAPS DEP 09.5(1)	Power Source Fuel Storage Vault Elevation	1.2, 1.9, 3.5, 3.7, 3.8, 8.3, 9.5, Appendix 19A; COLA Part 4, Section A
	NAPS DEP 10.2(1)	Main Turbine Type Change	1.2, 3.5, Appendix 9A, 10.1, 10.2, 10.4, 11.5, 12.3
	NAPS DEP 10.4(1)	Main Condenser Type Change	1.2, Appendix 9A, 10.1, 10.4, 11.5, 12.3
	NAPS DEP 14.2(1)	Initial Test Program (ITP) Administration	14.2
	NAPS DEP 14.2(2)	Separation of Startup Organization into Preoperational and Startup Testing Organizations	14.2, Appendix 14AA
	NAPS DEP 14.2(3)	Initial Test Program Scope	3.9, 6.2, 6.3, 6.5, 14.2

NAPS COL 1.8(2)

Table 1.8-203 Variances from the ESP and ESPA SSAR

Number	Subject	FSAR Section
NAPS ESP VAR 2.0-1a-I	Long-Term Dispersion Estimates (χ/Q and D/Q)	2.0 2.3
NAPS ESP VAR 2.0-2	Hydraulic Conductivity	2.4.12
NAPS ESP VAR 2.0-3	Hydraulic Gradient	2.4.12
RAI 02.05.02-1 NAPS ESP VAR 2.0-4	Vibratory Ground Motion	2.0 2.5.2 3.7.1
NAPS ESP VAR 2.0-5	Distribution Coefficients (K_d)	2.4.12
NAPS ESP VAR 2.0-6	DBA Source Term Parameters and Doses	2.0 15.9
NAPS ESP VAR 2.0-7	Coordinates and Abandoned Mat Foundations	2.0
RAI 02.03.01-5 NAPS ESP VAR 2.3-1	Tornado Site Characteristics	2.3.1.3.2
NAPS ESP VAR 2.4-1	Void Ratio, Porosity, and Seepage Velocity	2.4.12
NAPS ESP VAR 2.4-2	NAPS Water Supply Well Information	2.4.12
NAPS ESP VAR 2.4-3	Well Reference Point Elevation	2.4.12
NAPS ESP VAR 2.4-4	Lake Anna Normal Pool Level	2.4
NAPS ESP VAR 2.5-1	Stability of Slopes	2.5.5
NAPS ESP VAR 11.2-1	Annual Liquid Effluent Releases	11.2
NAPS ESP VAR 11.3-1	Annual Gaseous Effluent Releases	11.3
NAPS ESP VAR 11.3-2	Total Doses from Site	11.3

NAPS COL 1.9(1)

Table 1.9-202 Conformance with Regulatory Guides

RG Number	Title	Revision	Date	RG Position	Evaluation
1.208	A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion	Rev. 0	Mar-07	C.1 C.2.1 C.2.3 C.3 C.3.1 C.3.2 C.3.3 C.4 C.4.1 C.4.2 C.5.2 C.5.3 C.5.4	Conforms. RG 1.165, NUREG/CR-6728, and DC/COL-ISG-1 are mainly used instead of RG 1.208 to define the GMRS and develop the FIRS. See Sections 2.5.2 and 3.7, and SSAR Section 2.5.2.
				~~C.1~~ ~~C.2~~ ~~C.3~~ C.2.2 C.3.4 C.3.5 ~~C.4.1~~ C.4.3 C.5.1 ~~C.5.3~~ ~~C.5.4~~	Not Applicable
1.209	Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants	Rev. 0	Mar-07	General	Conforms. Operational program implementation is described in Section 13.4.
1.210	Qualification of Safety-Related Battery Chargers and Inverters for Nuclear Power Plants	Rev. 0	Jun-08	General	Exception. See DCD Section 8.1.
1.211	Qualification of Safety-Related Cables and Field Splices for Nuclear Power Plants	Rev. 0	Apr-09	General	Exception. The requirements are defined by the DCD which implements RG 1.131.

Table 2.0-201 Evaluation of Site/Design Parameters and Characteristics

	Parameter Description (15)	DCD Site Parameter Value (15)	Site Characteristic	Evaluation
NAPS SUP 2.0(2)	**Part 2 – Evaluation of ESP Site Characteristics and Design Parameters For Which There is No Corresponding DCD Site Parameter**			
	Vibratory Ground Motion			
	Design Response Spectra	No value provided	**ESP** ESP, Appendix A, Figure 2	The ESP site characteristic values are the horizontal and vertical response spectra provided in ESP, Appendix A, Figure 2. SSAR Table 1.9-1 states that the site-specific response spectra are provided in SSAR Section 2.5.2.6. That section includes SSAR Figure 2.5-48A which is the same as ESP, Appendix A, Figure 2.
NAPS ESP VAR 2.0-4			**Unit 3** Figure 2.5-201	The Unit 3 site characteristic values are the horizontal and vertical ground motion response spectra (GMRS) defined at ~~the hard rock horizon~~ Elevation 250 ft NAVD88 (250.86 ft NGVD29) (as tabulated in Table 2.5-201 and plotted in Figure 2.5-201). ~~rather than at the top of competent rock (Zone III-IV) as in the ESP spectra (SSAR Figure 2.5-48A). Although the Unit 3 values at the hard rock horizon fall within (are the same as) the ESP and SSAR values at the hard rock horizon, the change in control point is considered a variance~~ The Unit 3 site characteristic values at Elevation 250 ft NAVD88 (250.86 ft NGVD29) (response spectra) do not fall within (are not lower than) the ESP site characteristic values (response spectra) at a few frequencies less than 6 Hz. Figure 2.0-206 and Table 2.0-202 compare the ESP and Unit 3 horizontal response spectra. Figure 2.0-207 and Table 2.0-203 compare the ESP and Unit 3 vertical response spectra. While the figures are essentially overlapping curves at low frequencies, the tables show where the Unit 3 spectra exceed the ESP spectra.

NAPS ESP VAR 2.0-4

Table 2.0-202 Comparison of Horizontal Spectra for ESP Top of Zone III-IV SSE and Unit 3 GMRS at Elevation 250 feet NAVD88

Freq. (Hz)	Unit 3 SA (g)[a]	ESP SA (g)[b][c]	Controlling ESP or Unit 3[c]
0.1	0.00414	0.00382	Unit 3 Spectrum
0.125	0.00598	—	—
0.15	0.00807	—	—
0.2	0.01295	0.01298	ESP Spectrum
0.3	0.0230	0.0233	ESP Spectrum
0.4	0.0339	0.0343	ESP Spectrum
0.5	0.0451	0.0429	Unit 3 Spectrum
0.6	0.0502	0.0488	Unit 3 Spectrum
0.7	0.0545	—	—
0.8	0.0585	0.0576	Unit 3 Spectrum
0.9	0.0622	—	—
1	0.0659	0.0677	ESP Spectrum
1.25	0.0833	—	—
1.5	0.1026	—	—
2	0.1499	0.142	Unit 3 Spectrum
2.5	0.1821	0.179	Unit 3 Spectrum
3	0.210	0.214	ESP Spectrum
4	0.284	0.287	ESP Spectrum
5	0.382	0.376	Unit 3 Spectrum
6	0.453	0.481	ESP Spectrum
7	0.522	—	—
8	0.595	0.717	ESP Spectrum
9	0.667	—	—
10	0.744	0.945	ESP Spectrum
12.5	0.935	—	—
15	1.116	—	—

NAPS ESP VAR 2.0-4 **Table 2.0-202 Comparison of Horizontal Spectra for ESP Top of Zone III-IV SSE and Unit 3 GMRS at Elevation 250 feet NAVD88**

Freq. (Hz)	Unit 3 SA (g)[a]	ESP SA (g)[b][c]	Controlling ESP or Unit 3[c]
20	1.337	1.446	ESP Spectrum
25	1.328	1.476	ESP Spectrum
30	1.233	1.470	ESP Spectrum
35	1.143	—	—
40	1.101	—	—
45	1.077	—	—
50	1.049	1.195	ESP Spectrum
60	0.886	—	—
70	0.752	—	—
80	0.648	—	—
90	0.579	—	—
100	0.535	0.555	ESP Spectrum

(a) Values from Table 2.5-201
(b) Values from SSAR Table 2.5-27A
(c) "—" denotes not applicable: SA(g) value was not calculated for the ESPA SSAR

NAPS ESP VAR 2.0-4 **Table 2.0-203 Comparison of Vertical Spectra for ESP Top of Zone III-IV SSE and Unit 3 GMRS at Elevation 250 feet NAVD88**

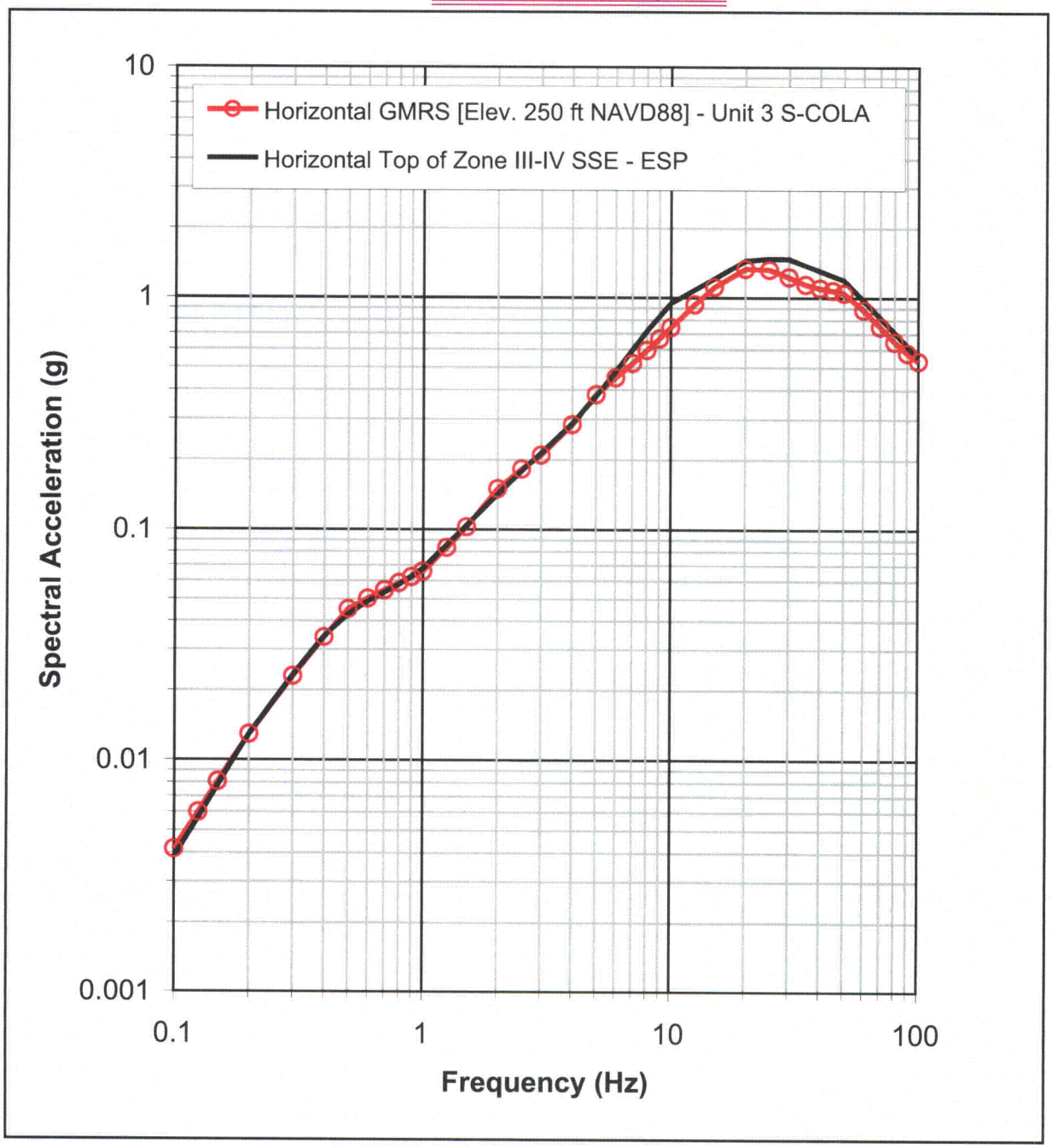
Freq. (Hz)	Unit 3 SA (g)[a]	ESP SA (g)[b][c]	Controlling ESP or Unit 3[c]
0.1	0.00311	0.00286	Unit 3 Spectrum
0.125	0.00448	—	—
0.15	0.00605	—	—
0.2	0.00971	0.00973	ESP Spectrum
0.3	0.01727	0.0174	ESP Spectrum
0.4	0.0254	0.0257	ESP Spectrum
0.5	0.0339	0.0321	Unit 3 Spectrum
0.6	0.0376	0.0366	Unit 3 Spectrum
0.7	0.0409	—	—
0.8	0.0439	0.0432	Unit 3 Spectrum
0.9	0.0467	—	—
1	0.0494	0.0507	ESP Spectrum
1.25	0.0625	—	—
1.5	0.0769	—	—
2	0.1124	0.106	Unit 3 Spectrum
2.5	0.1366	0.134	Unit 3 Spectrum
3	0.1574	0.160	ESP Spectrum
4	0.213	0.215	ESP Spectrum
5	0.286	0.282	Unit 3 Spectrum
6	0.340	0.360	ESP Spectrum
7	0.391	—	—
8	0.446	0.537	ESP Spectrum
9	0.500	—	—
10	0.558	0.708	ESP Spectrum
12.5	0.721	—	—
15	0.879	—	—

NAPS ESP VAR 2.0-4 **Table 2.0-203 Comparison of Vertical Spectra for ESP Top of Zone III-IV SSE and Unit 3 GMRS at Elevation 250 feet NAVD88**

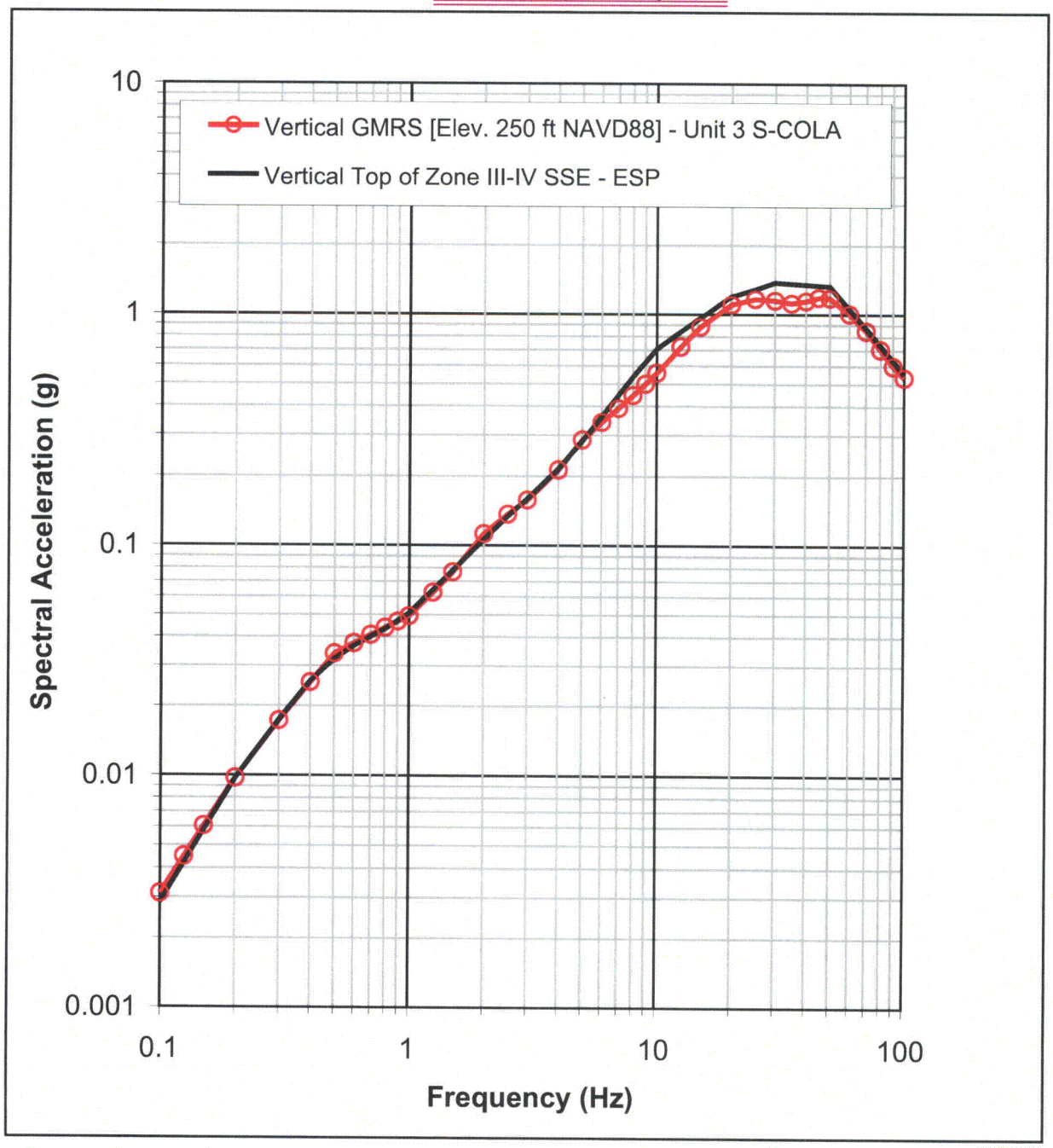
Freq. (Hz)	Unit 3 SA (g)[a]	ESP SA (g)[b][c]	Controlling ESP or Unit 3[c]
20	1.104	1.20	ESP Spectrum
25	1.169	1.29	ESP Spectrum
30	1.155	1.38	ESP Spectrum
35	1.121	—	—
40	1.148	—	—
45	1.187	—	—
50	1.180	1.33	ESP Spectrum
60	1.007	—	—
70	0.848	—	—
80	0.706	—	—
90	0.600	—	—
100	0.535	0.555	ESP Spectrum

(a) Values from Table 2.5-201
(b) Values from SSAR Table 2.5-27A
(c)"—" denotes not applicable: SA(g) value was not calculated for the ESPA SSAR

NAPS ESP VAR 2.0-4 **Figure 2.0-206** Comparison of Horizontal ESP SSE and Unit 3 GMRS Design Response Spectra



NAPS ESP VAR 2.0-4 **Figure 2.0-207** Comparison of Vertical ESP SSE and Unit 3 GMRS Design Response Spectra



2.5.2 Vibratory Ground Motion

NAPS COL 2.5(1)
NAPS COL 3.7(6)
NAPS COL 3.7(20)

Replace the content of DCD Section 2.5.2 with the following.

The information needed to address DCD COL Item 2.5(1) is included in SSAR Section 2.5.2, which is incorporated by reference with the following variances and supplements.

NAPS ESP VAR 2.0-4

The second paragraph in this SSAR section is supplemented as follows.

SSAR Sections 2.5.2.1 through 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 Unit 3 site with reference to more detailed discussion of the engineering aspects of the shallow subsurface in Section 2.5.4, and also indicates the depth ~~to the hard rock horizon~~ at which the ground motion response spectra (GMRS) are defined for Unit 3. ~~This depth is based on the results in Section 2.5.4 which provide the engineering aspects of the shallow subsurface above the hard rock horizon.~~ The engineering properties of the subsurface materials are used to develop the GMRS as described in Section 2.5.2.6 and the foundation input response spectra (FIRS) as described in Section 3.7.1.

The last paragraph in this SSAR section is supplemented as follows with information to address the Operating Basis Earthquake (OBE).

The ~~derivation~~ derivations of the selected vertical ~~GMRS is~~ SSE spectra are described in Section 2.5.2.6.7. The derivation of the OBE is described in Section 3.7.1.

2.5.2.5 Seismic Wave Transmission Characteristics of the Site

~~**NAPS DEP 3.7(2)**~~
NAPS ESP VAR 2.0-4

This SSAR section is supplemented as follows with information to address the GMRS control point.

~~As presented in Section 2.5.4, hard rock conditions (with a shear wave velocity of 9200 ft/sec or greater) consistent with the ground motion attenuation relations used in the site-specific probabilistic seismic hazard analysis (PSHA), presented in SSAR Subsection 2.5.2.6.6, are at a depth of about 145 feet from finished grade, as described in Section 2.5.4.7.1.a. Figure 2.5-237 illustrates the variability across the site of lower shear wave velocities above this depth horizon. This hard~~

~~NAPS ESP VAR 2.0-4~~

~~rock horizon, which is below the foundation levels of the various safety-related structures, is used as the control point in defining the GMRS. Therefore, for the purpose of defining the GMRS, the seismic wave transmission characteristics of the site up to shallower horizons are not required.~~

~~The seismic wave transmission characteristics of the site are considered in Section 3.7.1 in the development of the amplification of the GMRS hard rock ground motions at the higher elevations. This is necessary to obtain the FIRS required as inputs to the analysis and the design of each seismic category I structure in Section 3.7.~~

As described in Section 2.5.4.2, the upper in situ soil is characterized as residual clays and clayey silts (Zone I) which is scarce across the site and will be removed. This zone is followed by saprolite (Zone IIA and Zone IIB), followed by rock which is classified into three zones: Zone III (weathered rock), Zone III-IV (moderately weathered to slightly weathered rock) and Zone IV (slightly weathered to fresh rock, including 9200 fps hard rock).

For the purpose of defining the GMRS, Elevation 250 ft is used as the control point which closely corresponds to the bottoms of the foundations of the R/B Complex and PS/Bs which are at the lowest foundation elevation of the Seismic Category I structures. At this elevation, the top layer of the rock column is Zone III-IV material with a best estimate (BE) shear wave velocity of 4250 fps. The design grade elevation for Unit 3 is Elevation 290 ft. Vertical datum is with reference to NAVD88 throughout Section 2.5.2, unless stated otherwise.

The seismic wave transmission characteristics of the site materials are defined in Section 2.5.4.7 including shear wave velocity profiles, soil and rock layer thicknesses, unit weights, Poisson's ratios, as well as strain-dependent property curves and damping ratios. The properties of the different soil and rock layers provide the BE properties and an estimate of the variation of these properties. Profile simulation accounts for the variation of the shear wave velocities, damping ratios, strain-dependent property curves, as well as the thicknesses of the different layers to generate the simulated profile sets for the considered structures.

The analyses of seismic wave transmission characteristics of the site are presented in Sections 2.5.2.6.7 and 3.7.1 in the rock and soil column

amplification analyses required for the development of the GMRS and for the FIRS for each Seismic Category I structure, respectively.

2.5.2.6.7 Selected SSE Ground Motion

c. Selection of Enveloping Horizontal SSE Spectrum

NAPS ESP VAR 2.0-4

Item c in this SSAR section is supplemented as follows with information to address the definition of the selected GMRS.

Horizontal Hard Rock SSE Spectrum

SSAR Figure 2.5-54A shows four horizontal ground spectra - the mean 5×10^{-5} annual hazard RG 1.165 (SSAR Reference 2) high- and low-frequency scaled spectra (from SSAR Figure 2.5-51), the performance-based spectrum (from SSAR Figure 2.5-53) and the selected hard rock SSE spectrum (shown in SSAR Figure 2.5-48), which is the envelope of the other three spectra. As shown in SSAR 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 envelope both the mean 5×10^{-5} annual hazard RG 1.165 spectra and the performance-based spectrum. ~~The selected horizontal hard rock SSE spectrum defines the horizontal GMRS, as tabulated in Table 2.5-201 and plotted in Figure 2.5-201 (which is the same as SSAR Table 2.5-27 and Figure 2.5-48, respectively, for only 21 frequencies).~~

For further perspective, SSAR Figure 2.5-54B compares three spectra and available discrete spectral values from the 1989 EPRI and LLNL studies recognized in SSAR Reference 2:

1. The mean 5×10^{-5} annual hazard RG 1.165 envelope spectrum (from SSAR Figure 2.5-51).
2. The performance-based spectrum (from SSAR Figure 2.5-53).
3. The selected SSE spectrum GMRS, 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 SSAR Reference 115.

5. "1989 LLNL" spectral values, which are estimated median 10^{-5} spectral values calculated using a parabolic extrapolation from results published in SSAR 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 SSAR Reference 129).

SSAR Figure 2.5-54B shows that all spectra and spectral values are similar, giving further credibility to the selected hard rock SSE spectrum ~~(GMRS)~~.

The spectra shown in SSAR Figure 2.5-48, SSAR Figure 2.5-51, SSAR Figure 2.5-53, SSAR Figure 2.5-54A, and SSAR 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. ~~These response spectra do not include any effects such as structure, embedment, or incoherence of seismic waves due to base mat size. Such effects are considered in Section 3.7 in the development of structure specific seismic design motions for appropriate design and analysis of seismic category I SSCs at the Unit 3 site.~~

~~Section 2.5.4.7 describes subsurface shear wave velocity and related material property information for the site, including the materials above the hard rock horizon at which the GMRS is defined. Based on these data, site shear wave velocity profiles have been developed for the locations of the new unit including all seismic category I structures. Section 3.7 uses these Section 2.5.4 profiles and the GMRS rock motions, presented in this section, as input to site response analyses to develop FIRS for seismic category I structures. Following site response analysis Approach 2 in NUREG/CR-6728 (SSAR Reference 119), the controlling earthquakes and spectral content that comprise design response spectra in the high frequency range differ from that in the low frequency range and were considered. The high- and low frequency response spectra, developed from consideration of the corresponding controlling earthquakes (see SSAR Table 2.5-25) and implementation of the modified RG 1.165 Reference Probability Approach, shown in SSAR Figure 2.5-54A, are adapted to develop the required rock input response spectra for the Unit 3 site response analyses in Section 3.7.~~

For the purpose of developing the horizontal GMRS at Elevation 250 feet, as described below, as well as the FIRS in

Section 3.7.1, it is necessary to consider the specification of the hard rock ground motions as input to site response analyses. Following site response analysis Approach 2 in NUREG/CR-6728 (SSAR Reference 119), the controlling earthquakes and spectral content that comprise design response spectra in the high-frequency range differ from those in the low-frequency range and need to be considered. The high- and low-frequency rock response spectra, developed from consideration of the corresponding controlling earthquakes (see SSAR Table 2.5-25) and implementation of the modified RG 1.165 Reference Probability Approach, shown in SSAR Figure 2.5-54A, are adapted to develop the required input rock response spectra for the Unit 3 site response analyses both in the development of the GMRS below and in the development of FIRS in Section 3.7.1.

High- and low-frequency rock response spectra are defined, in composite, to match the horizontal ~~GMRS~~ enveloping hard rock SSE spectrum in SSAR Figure 2.5-48, but individually, are based on the high- and low-frequency reference probability response spectra shapes. Considering SSAR Figure 2.5-54A, the low-frequency (LF) horizontal hard rock response spectrum is defined by the horizontal ~~GMRS~~ enveloping hard rock 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. Similarly, the high-frequency (HF) horizontal hard rock response spectrum is defined by the horizontal ~~GMRS~~ enveloping hard rock 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 HF and LF hard rock horizontal response spectra are plotted in ~~Figure 2.5-202~~ Figure 2.5-202a.

As presented below in the development of the horizontal GMRS, as well as in the development of FIRS presented in Section 3.7.1, the site response analysis method employed does not require the input of earthquake time histories, but rather the specification of the HF and LF horizontal hard rock response spectra, presented above. Earthquake time histories spectrally-matched to the HF and LF horizontal hard rock spectra are, however, used in site response analyses for liquefaction hazard analyses, as described in Sections 2.5.4.7.4 and 2.5.4.8.

SSAR Figure 2.5-54B(1) shows the HF horizontal hard rock response spectrum-compatible time history that was developed, and SSAR

Figure 2.5-54B(2) shows the LF horizontal hard rock response spectrum-compatible time history. The average magnitude and distance (M-bar and D-bar) values for the HF and LF target spectra are given in SSAR 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 (CEUS) time histories given in SSAR 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 HF and LF target spectra, respectively, satisfying the spectral matching criteria of SSAR Reference 171.

These hard rock spectra and time histories do not include any effects such as structure, embedment, or incoherence of seismic waves due to basemat size.

Horizontal GMRS

Section 2.5.4.7 describes the subsurface shear wave velocity and related material property information for the site. The GMRS soil and rock profile is developed based on the provided data in the power block area which is characteristic of the entire site. The BE shear-wave velocity profile is determined from log-mean of profiles 1 and 2, as defined in Section 2.5.4.7. The rock profile considered for the GMRS calculation consists entirely of Zone III-IV and IV rock material which behave linearly and are supported on the 9200 fps hard rock at BE Elevation of 145 ft. Due to the linear characteristics of the considered rock column, there are no confining effects from the soils above and the calculation of the GMRS as a free field geologic outcrop is carried out by removing the top layers above Elevation 250 ft consistent with the requirements of DC/COL-ISG-17 (Reference 3OO-8). Figure 2.5-202b presents the site-specific BE shear-wave velocity profile for the GMRS.

The computer program SPS is used to generate site-specific simulated (randomized) soil profiles to represent the dynamic properties of the site while considering the uncertainty associated with each of these properties. The generation of the low-strain simulated soil profiles uses

the input BE properties and their associated uncertainty. The uncertainty is expressed in terms of statistical distribution, standard deviation (SD), and correlation among engineering parameters.

Figure 2.5-202c presents the set of 60 shear-wave velocity simulated profiles before including thickness variation, i.e., based on the BE thicknesses provided for each soil layer. Note that this figure also provides the randomized shear-wave velocities above Elevation 250 ft which correspond to the structural fill described in Section 3.7.1 and are removed before use for the purpose of GMRS calculation. Also note that the log-average (simulated median) profile matches the input BE profile very closely. Maximum and minimum bounds of twice the SD around the BE are imposed to prevent unrealistic shear-wave velocity realizations. Figure 2.5-202d presents the set of 60 shear-wave velocity simulated profiles, including thickness variation, characteristic of the site conditions. Note that while the simulated median profile matches the input BE profile, it shows smoother transitions between the consecutive strata, which is the result of the combination of shear-wave velocity and thickness variation in the simulated profiles. For the purpose of site response analysis, halfspace bedrock, where the input hard rock motion is applied, is defined by a minimum shear-wave velocity of 9200 fps. Bedrock depth varies across the site and is generally found at a depth of around 145 ft from finished grade (refer to Section 2.5.4). The Zone III-IV and IV strata are assigned strain-independent damping ratios, based on BE damping ratios of 1 percent with a log-standard deviation of 0.6. This amounts to damping values with one standard deviation range of 0.5 percent to 1.5 percent. The resulting low-strain damping ratio profiles are presented in Figure 2.5-202e. This figure also provides the randomized damping ratios above Elevation 250 ft which correspond to the structural fill described in Section 3.7.1 and are removed before use for the purpose of GMRS calculation.

The LF and HF input hard rock spectra are presented in Figure 2.5-202a. The hard rock spectra are applied at bedrock having a shear wave velocity of 9200 fps, and are propagated upward from bedrock to Elevation 250 ft, through the set of 60 simulated profiles, representing the site-specific conditions using the computer program P-SHAKE (Reference 2.5-222).

P-SHAKE implements an equivalent-linear iterative approach similar to SHAKE (References 3OO-2 and 3OO-9), where a number of iterations is

needed to reach a converged solution. Since the rock profile considered for GMRS calculation is entirely described by linear properties, the free field 5 percent damping Acceleration Response Spectra (ARS), at the GMRS control point (Elevation 250 ft) are computed without iterations at the top of the truncated soil and rock columns as a geologic outcrop motion consistent with the truncated soil column response (TSCR) described in DC/COL-ISG-17 (Reference 3OO-8).

As input for site response analysis, the duration of the input motion is specified as a parameter in P-SHAKE. The strong motion durations are determined as a function of the magnitudes (M) of the LF and HF input hard rock motions from Table 2.3-1 in ASCE 4-98 (Reference 3OO-1). The magnitudes and corresponding durations are reported in Table 3OO-202. An additional parameter required for P-SHAKE is the effective strain ratio (equivalent uniform strain divided by maximum strain), which is calculated as a function of earthquake magnitude, as shown in Equation 3OO-1 (Reference 3OO-2). The resulting effective strain ratios used in site response analysis are reported in Table 3OO-202.

All spectra are calculated at 301 points equally spaced in log-scale in the frequency range from 0.1 to 100 Hz (a period range of 0.01 to 10 seconds). The cut-off frequency of the P-SHAKE runs is 100 Hz. The set of 60 simulated profiles results in a set of ARS at the selected horizons. ARS amplification functions are calculated at the GMRS level, by dividing the computed horizontal ARS at the GMRS horizon by the ARS of the input hard rock motion. The natural logarithmic average of the resulting ARS is calculated and that average is referred to as log-mean ARS. Log-mean ARS amplification functions are calculated in the same manner.

Figures 2.5-202f and 2.5-202g present the geologic outcrop ARS amplification functions calculated at the GMRS horizon for the LF and HF motions, respectively. In these figures, the thin gray lines designate the response of the 60 individual profiles, while the thick red line designates the log-mean response. The LF and HF log-mean ARS amplification functions are presented together in Figure 2.5-202h. The resulting 5 percent damped geologic outcrop log-mean ARS at the GMRS horizon along with the input bedrock HF and LF motions are presented in Figure 2.5-202i.

Finally, the horizontal GMRS is calculated by enveloping the LF and HF 5 percent damped log-mean ARS at the GMRS elevation and is presented in Figure 2.5-202j along with the input bedrock HF and LF motions. The response spectral values for the horizontal GMRS are interpolated for a selected set of 38 frequency points as presented in Figure 2.5-201 and tabulated in Table 2.5-201.

d. **Development of Vertical SSE Spectra**

NAPS ESP VAR 2.0-4

The first three paragraphs of Item d. in this SSAR section ~~is~~ are supplemented as follows with information to address the use of the V/H ratios.

~~**Hard Rock SSE Spectrum**~~

~~The applicable V/H ratios from SSAR Reference 171 used to develop the selected vertical GMRS (5 percent of critical damping) are listed in Table 2.5-201. The vertical GMRS is calculated by multiplying the horizontal GMRS amplitude at each frequency by the applicable V/H ratio for that frequency. The selected horizontal and vertical GMRS are plotted in Figure 2.5-201 and tabulated in Table 2.5-201.~~

Vertical 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 SSAR Table 2.5-27. The vertical hard rock SSE spectrum is calculated by multiplying the selected horizontal hard rock SSE spectral amplitude at each frequency by the applicable V/H ratio for that frequency. The selected horizontal and vertical spectra are plotted in SSAR Figure 2.5-48 for the hard rock SSE.

Vertical GMRS

The horizontal GMRS spectral accelerations, V/H ratios, and vertical GMRS spectral accelerations for the Elevation 250 ft hypothetical rock outcrop control point are listed in Table 2.5-201. The vertical GMRS is calculated by multiplying the selected horizontal GMRS spectral amplitude at each frequency by the applicable V/H ratio for that frequency from NUREG/CR-6728 (SSAR Reference 171). The horizontal and vertical GMRS are plotted in Figure 2.5-201.

NAPS COL 2.5(1)
NAPS ESP VAR 2.0-4

Table 2.5-201 ~~Selected~~ Horizontal Ground Motion Response Spectrum Amplitudes, V/H Spectral Ratios, and Resulting Vertical Ground Motion Response Spectrum Amplitudes at Selected Frequencies

~~Frequency (Hz)~~	~~Horizontal GMRS SA (g)~~	~~V/H Spectral Ratio[a]~~	~~Vertical GMRS SA (g)~~
~~0.1~~	~~0.00412~~	~~0.75~~	~~0.00309~~
~~0.125~~	~~0.00595~~	~~0.75~~	~~0.00446~~
~~0.15~~	~~0.00803~~	~~0.75~~	~~0.00602~~
~~0.2~~	~~0.0129~~	~~0.75~~	~~0.00968~~
~~0.3~~	~~0.0229~~	~~0.75~~	~~0.0172~~
~~0.4~~	~~0.0337~~	~~0.75~~	~~0.0253~~
~~0.5~~	~~0.0450~~	~~0.75~~	~~0.0338~~
~~0.6~~	~~0.0498~~	~~0.75~~	~~0.0374~~
~~0.7~~	~~0.0541~~	~~0.75~~	~~0.0406~~
~~0.8~~	~~0.0581~~	~~0.75~~	~~0.0436~~
~~0.9~~	~~0.0617~~	~~0.75~~	~~0.0463~~
~~1~~	~~0.0651~~	~~0.75~~	~~0.0488~~
~~1.25~~	~~0.0824~~	~~0.75~~	~~0.0618~~
~~1.5~~	~~0.100~~	~~0.75~~	~~0.0750~~
~~2~~	~~0.145~~	~~0.75~~	~~0.109~~
~~2.5~~	~~0.175~~	~~0.75~~	~~0.131~~
~~3~~	~~0.200~~	~~0.75~~	~~0.150~~
~~4~~	~~0.266~~	~~0.75~~	~~0.200~~
~~5~~	~~0.351~~	~~0.75~~	~~0.263~~
~~6~~	~~0.405~~	~~0.75~~	~~0.304~~
~~7~~	~~0.453~~	~~0.75~~	~~0.340~~
~~8~~	~~0.499~~	~~0.75~~	~~0.374~~
~~9~~	~~0.539~~	~~0.75~~	~~0.404~~
~~10~~	~~0.578~~	~~0.75~~	~~0.434~~

NAPS COL 2.5(1)
NAPS ESP VAR 2.0-4

Table 2.5-201 ~~Selected~~ Horizontal Ground Motion Response Spectrum Amplitudes, V/H Spectral Ratios, and Resulting Vertical Ground Motion Response Spectrum Amplitudes at Selected Frequencies

~~Frequency (Hz)~~	~~Horizontal GMRS SA (g)~~	~~V/H Spectral Ratio[a]~~	~~Vertical GMRS SA (g)~~
~~12.5~~	~~0.659~~	~~0.77[b]~~	~~0.508~~
~~15~~	~~0.734~~	~~0.79[b]~~	~~0.578~~
~~20~~	~~0.869~~	~~0.83[b]~~	~~0.717~~
~~25~~	~~0.930~~	~~0.88~~	~~0.818~~
~~30~~	~~0.924~~	~~0.94[b]~~	~~0.866~~
~~35~~	~~0.878~~	~~0.98[b]~~	~~0.861~~
~~40~~	~~0.840~~	~~1.04[b]~~	~~0.875~~
~~45~~	~~0.808~~	~~1.10[b]~~	~~0.890~~
~~50~~	~~0.780~~	~~1.12[b]~~	~~0.877~~
~~60~~	~~0.643~~	~~1.14[b]~~	~~0.731~~
~~70~~	~~0.546~~	~~1.13[b]~~	~~0.616~~
~~80~~	~~0.474~~	~~1.09[b]~~	~~0.517~~
~~90~~	~~0.418~~	~~1.04[b]~~	~~0.434~~
~~100~~	~~0.374~~	~~1.00~~	~~0.374~~
Frequency [Hz]	**Horizontal GMRS [g]**	**V/H Spectral Ratio[a]**	**Vertical GMRS[g]**
0.1	0.00414	0.75	0.00311
0.125	0.00598	0.75	0.00448
0.15	0.00807	0.75	0.00605
0.2	0.01295	0.75	0.00971
0.3	0.0230	0.75	0.01727
0.4	0.0339	0.75	0.0254
0.5	0.0451	0.75	0.0339
0.6	0.0502	0.75	0.0376

NAPS COL 2.5(1)
NAPS ESP VAR 2.0-4

Table 2.5-201 ~~Selected~~ Horizontal Ground Motion Response Spectrum Amplitudes, V/H Spectral Ratios, and Resulting Vertical Ground Motion Response Spectrum Amplitudes at Selected Frequencies

~~Frequency (Hz)~~	~~Horizontal GMRS SA (g)~~	~~V/H Spectral Ratio[a]~~	~~Vertical GMRS SA (g)~~
0.7	0.0545	0.75	0.0409
0.8	0.0585	0.75	0.0439
0.9	0.0622	0.75	0.0467
1	0.0659	0.75	0.0494
1.25	0.0833	0.75	0.0625
1.5	0.1026	0.75	0.0769
2	0.1499	0.75	0.1124
2.5	0.1821	0.75	0.1366
3	0.210	0.75	0.1574
4	0.284	0.75	0.213
5	0.382	0.75	0.286
6	0.453	0.75	0.340
7	0.522	0.75	0.391
8	0.595	0.75	0.446
9	0.667	0.75	0.500
10	0.744	0.75	0.558
12.5	0.935	0.77[b]	0.721
15	1.116	0.79[b]	0.879
20	1.337	0.83[b]	1.104
25	1.328	0.88	1.169
30	1.233	0.94[b]	1.155
35	1.143	0.98[b]	1.121
40	1.101	1.04[b]	1.148
45	1.077	1.10[b]	1.187

NAPS COL 2.5(1)
NAPS ESP VAR 2.0-4

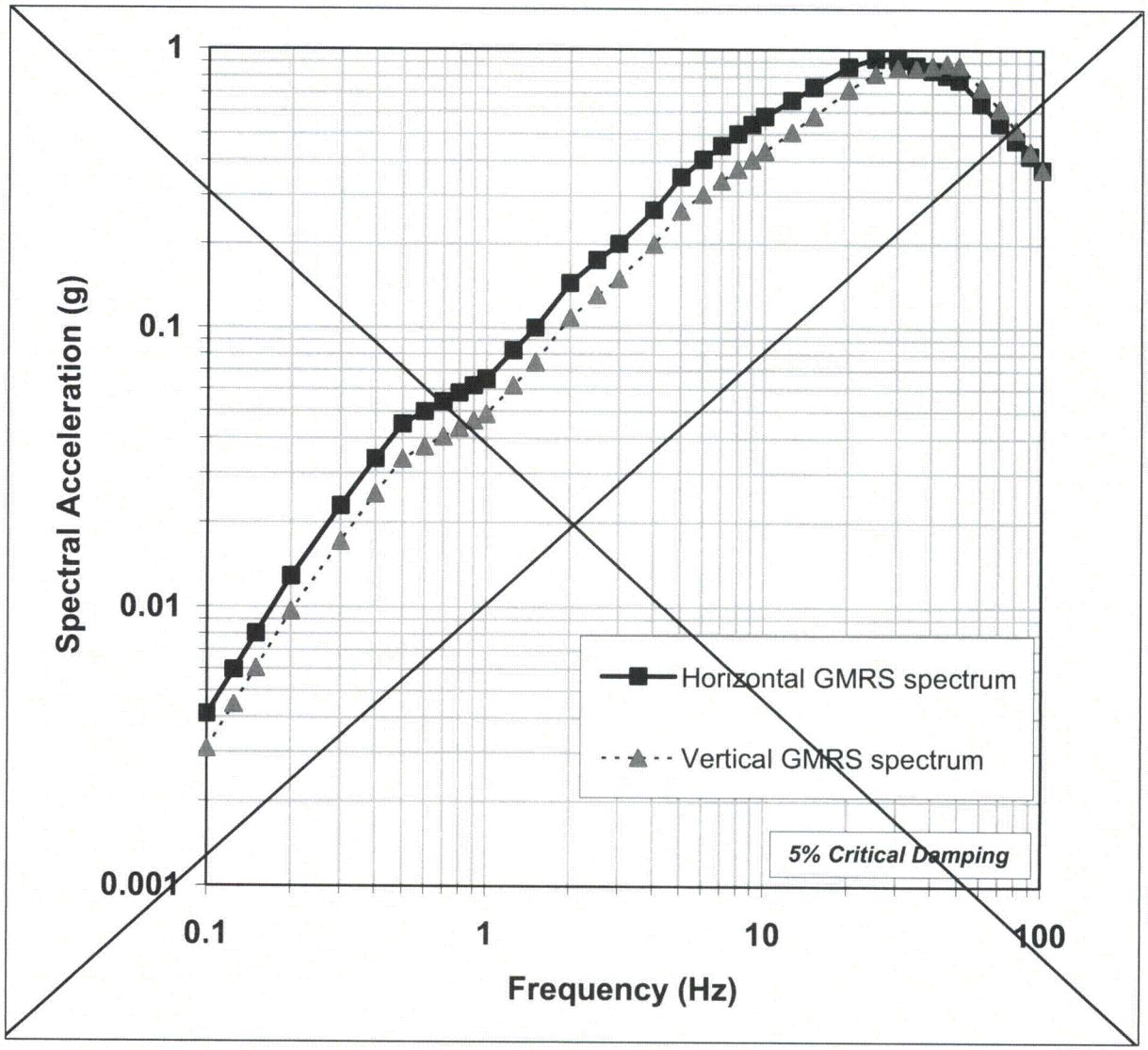
Table 2.5-201 ~~Selected~~ Horizontal Ground Motion Response Spectrum Amplitudes, V/H Spectral Ratios, and Resulting Vertical Ground Motion Response Spectrum Amplitudes at Selected Frequencies

~~Frequency (Hz)~~	~~Horizontal GMRS SA (g)~~	~~V/H Spectral Ratio[a]~~	~~Vertical GMRS SA (g)~~
50	1.049	1.12[b]	1.180
60	0.886	1.14[b]	1.007
70	0.752	1.13[b]	0.848
80	0.648	1.09[b]	0.706
90	0.579	1.04[b]	0.600
100	0.535	1.00	0.535

a. From SSAR Reference 171
b. V/H ratios calculated by log-log interpolation

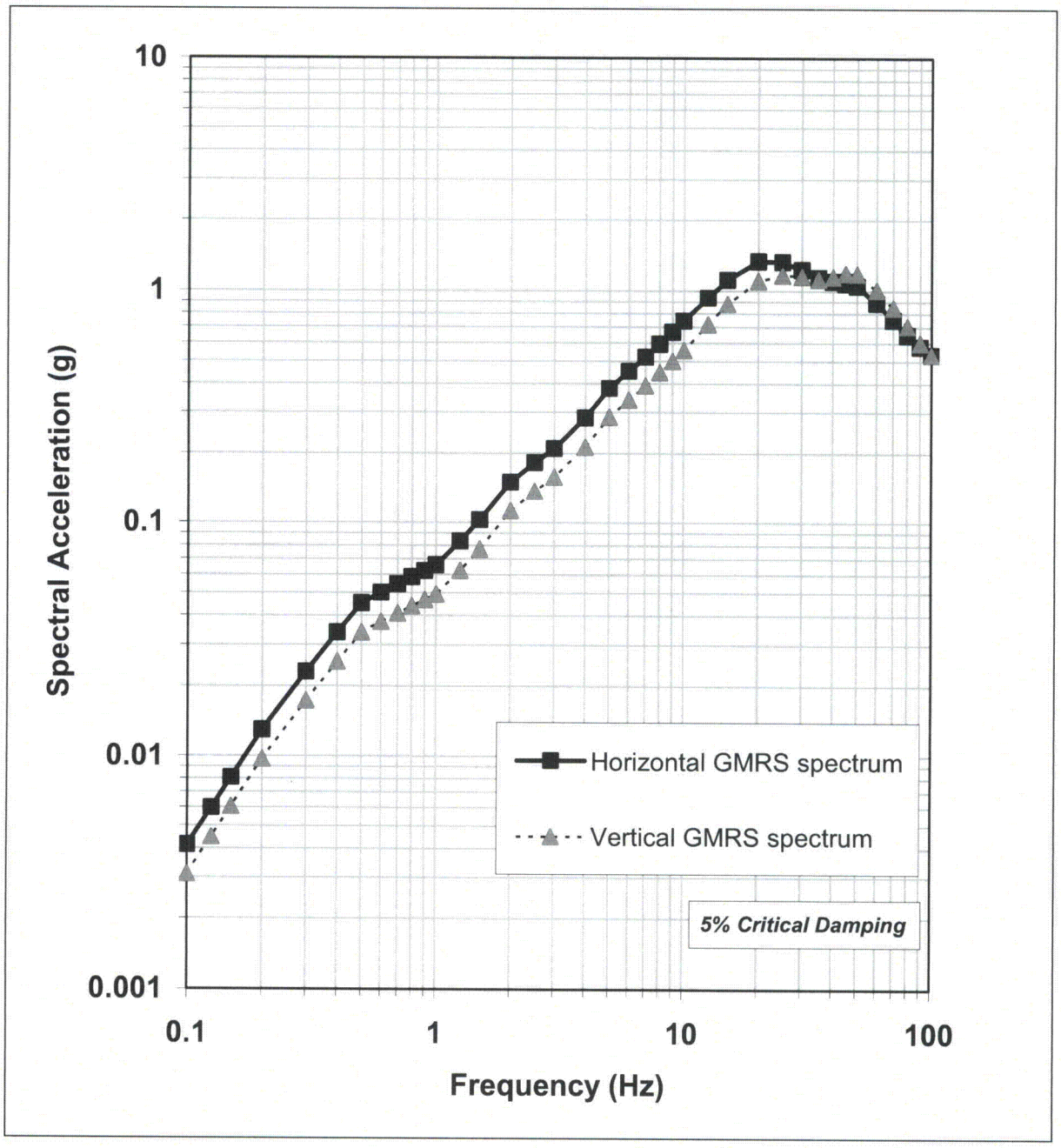
NAPS COL 2.5(1)
NAPS ESP VAR 2.0-4

Figure 2.5-201 Horizontal and Vertical Ground Motion Response Spectra (GMRS)



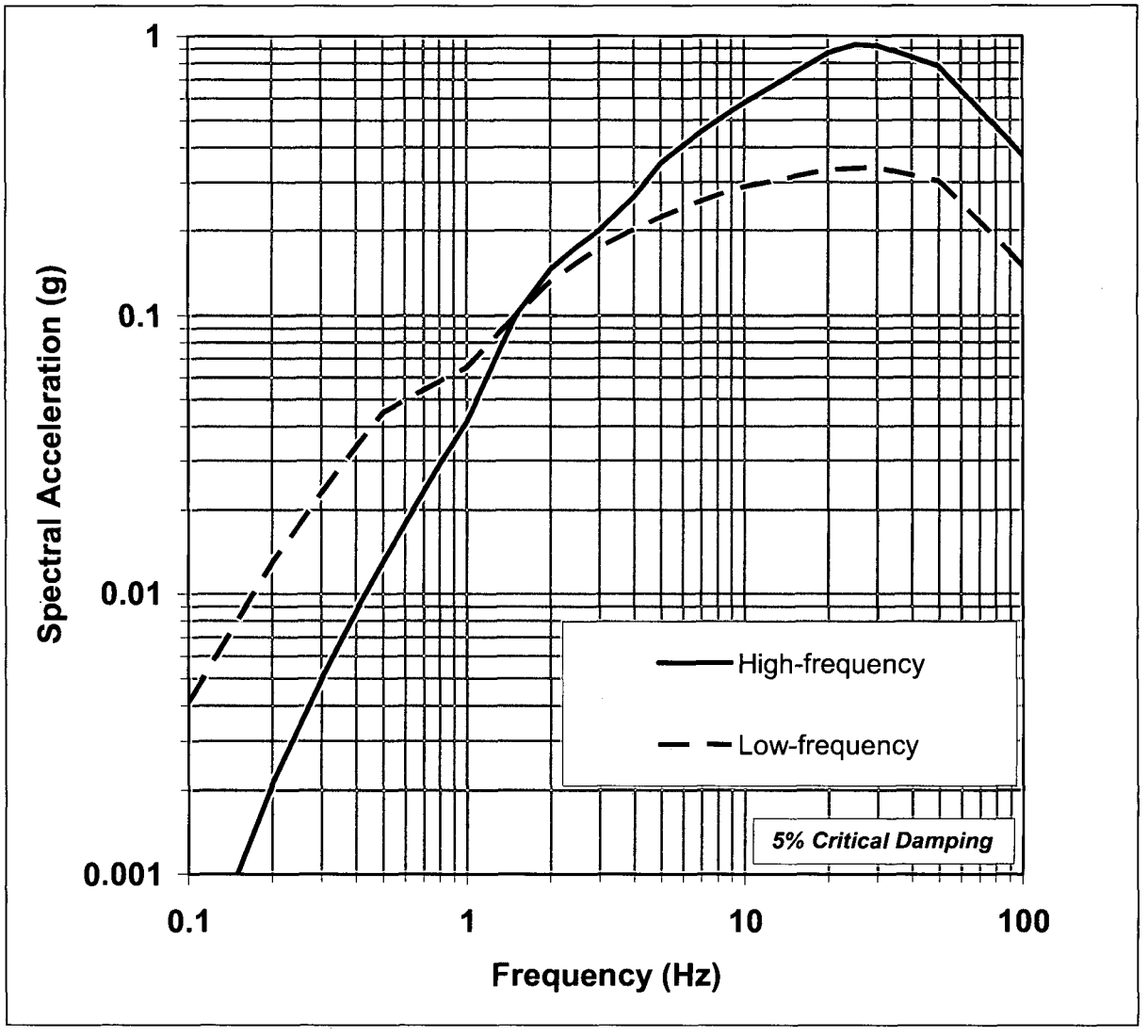
NAPS COL 2.5(1)
NAPS ESP VAR 2.0-4

Figure 2.5-201 Horizontal and Vertical Ground Motion Response Spectra (GMRS)



NAPS COL 2.5(1)
NAPS ESP VAR 2.0-4

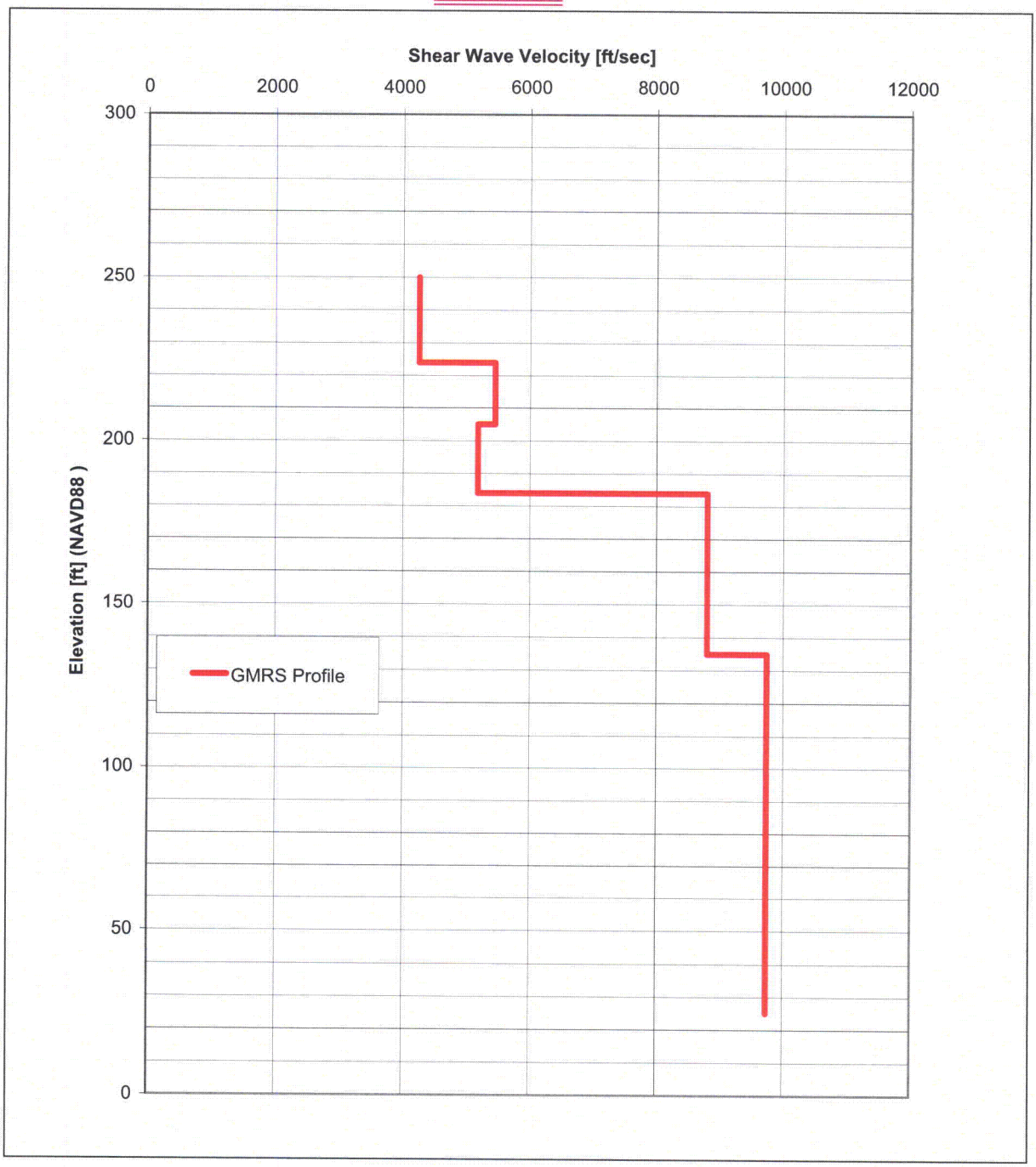
Figure 2.5-202a ~~Figure 2.5-202~~ High-Frequency and Low-Frequency Hard Rock Horizontal Response Spectra



Note: The envelope of these response spectra gives the horizontal GMRS in Figure 2.5-201.

NAPS COL 2.5(1)

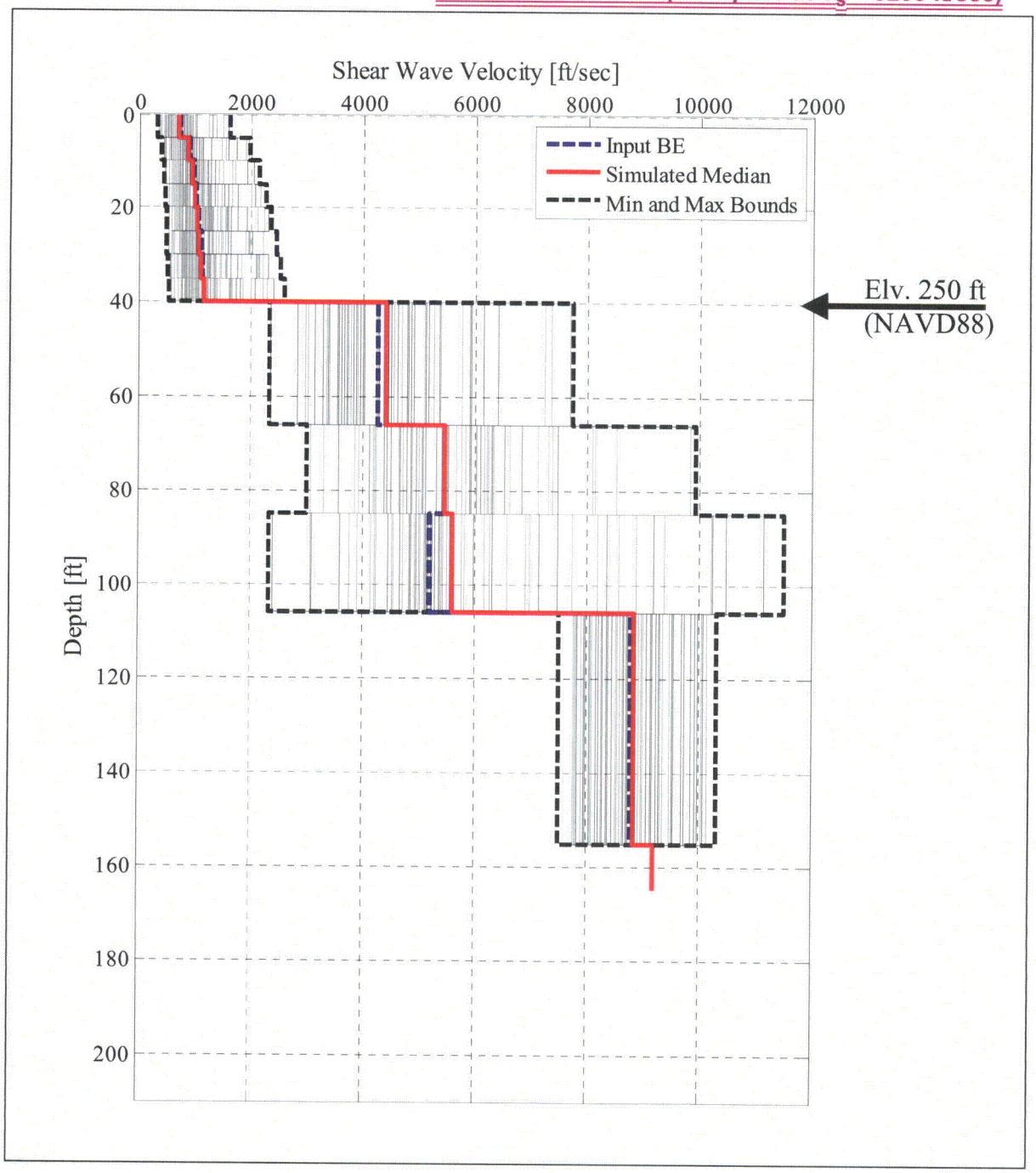
Figure 2.5-202b Best Estimate Shear Wave Velocity Profile for GMRS Calculation



Note: The conversion from NAVD88 Datum elevations to NGVD29 datum elevations is +0.86 ft.

NAPS COL 2.5(1)

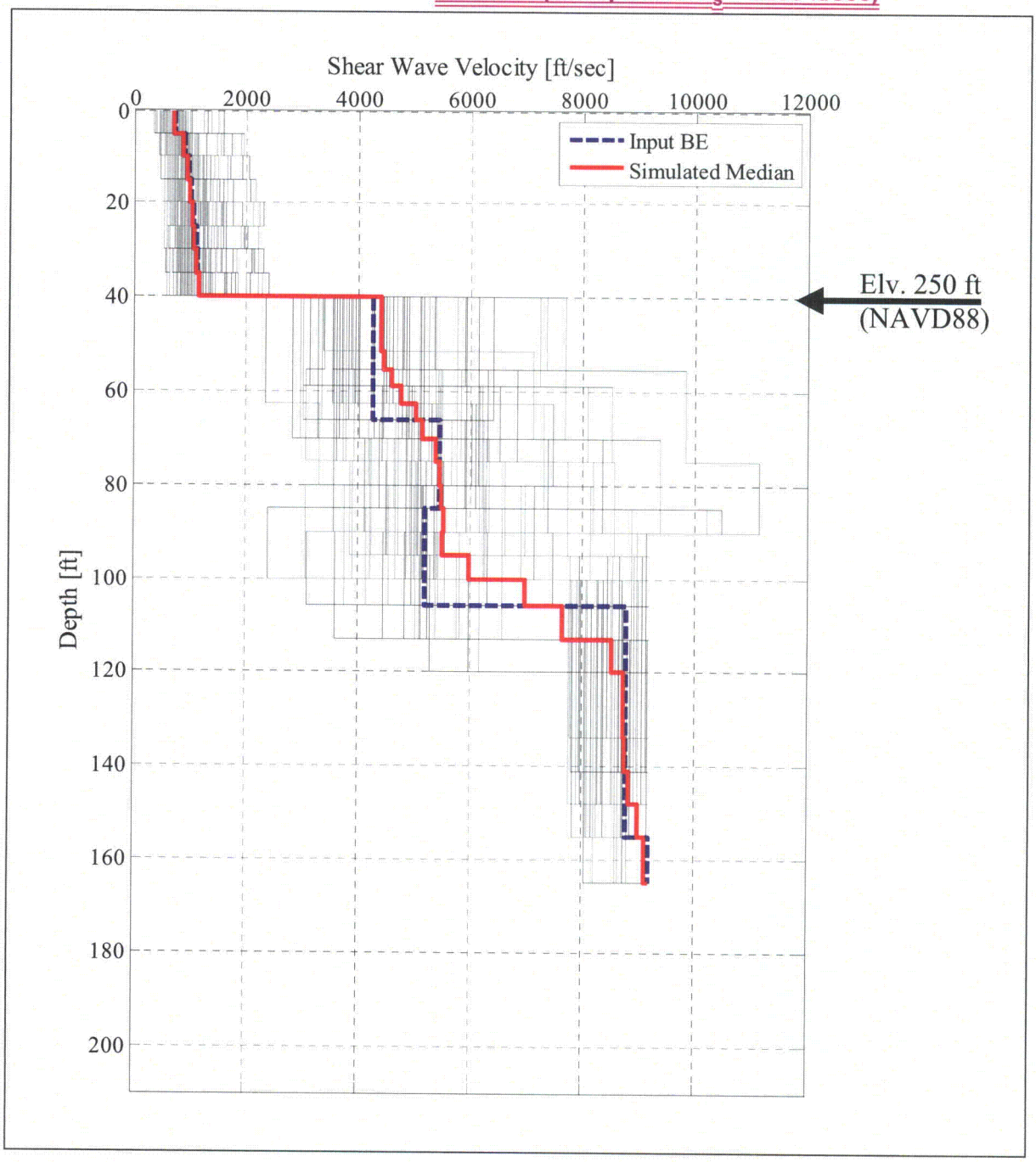
Figure 2.5-202c Low-Strain Shear-Wave Velocity for 60 Simulated Profiles for GMRS Calculation Not Including Thickness Variation (Halfspace at V_s = 9200 ft/sec)



Note: The top 40 ft of backfill is removed in the TSCR analysis performed for calculation of GMRS.

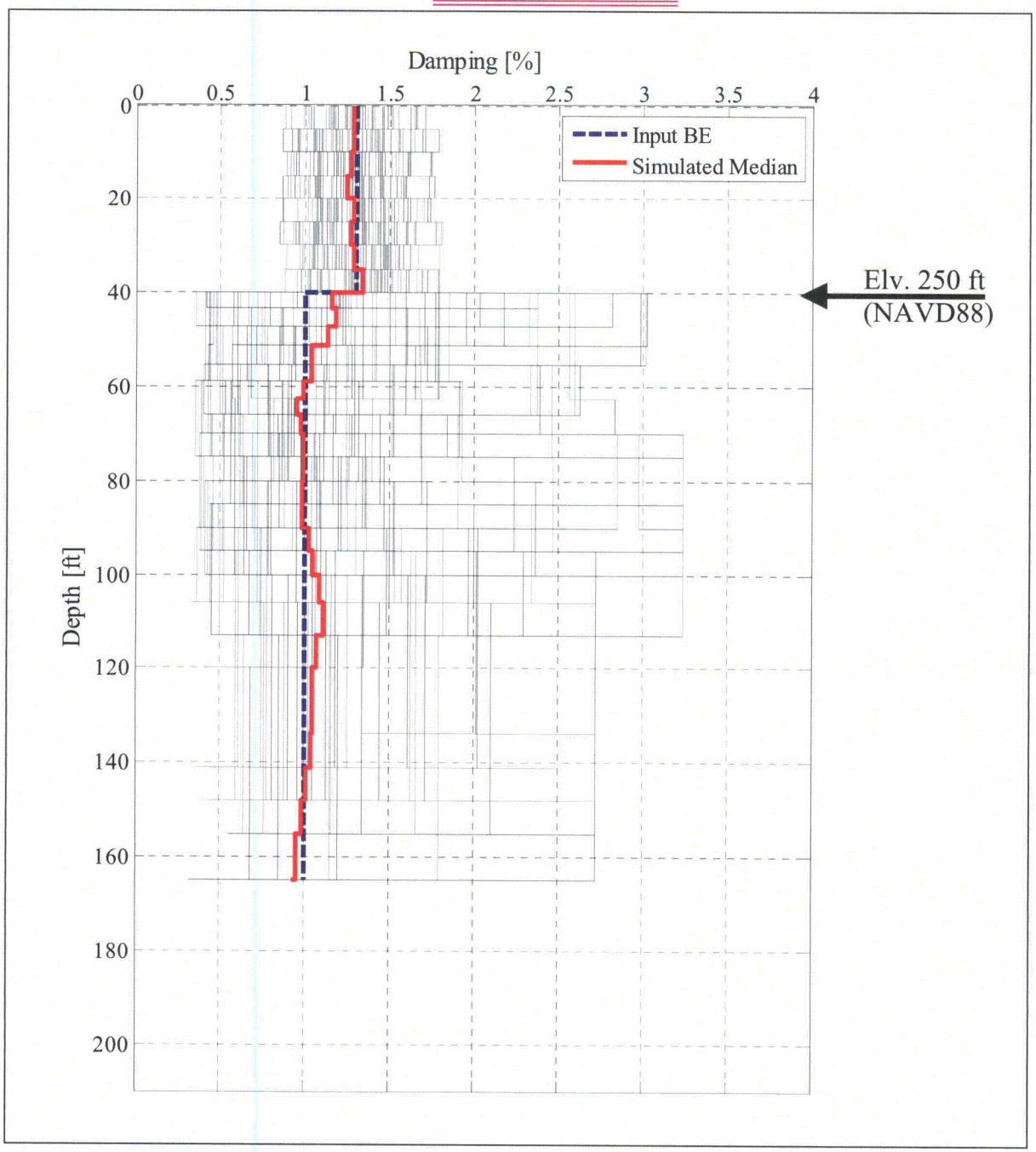
NAPS COL 2.5(1)

Figure 2.5-202d **Low-Strain Shear-Wave Velocity for 60 Simulated Profiles for GMRS Calculation Including Thickness Variation (Halfspace at V_s = 9200 ft/sec)**



Note: The top 40 ft of backfill is removed in the TSCR analysis performed for calculation of GMRS.

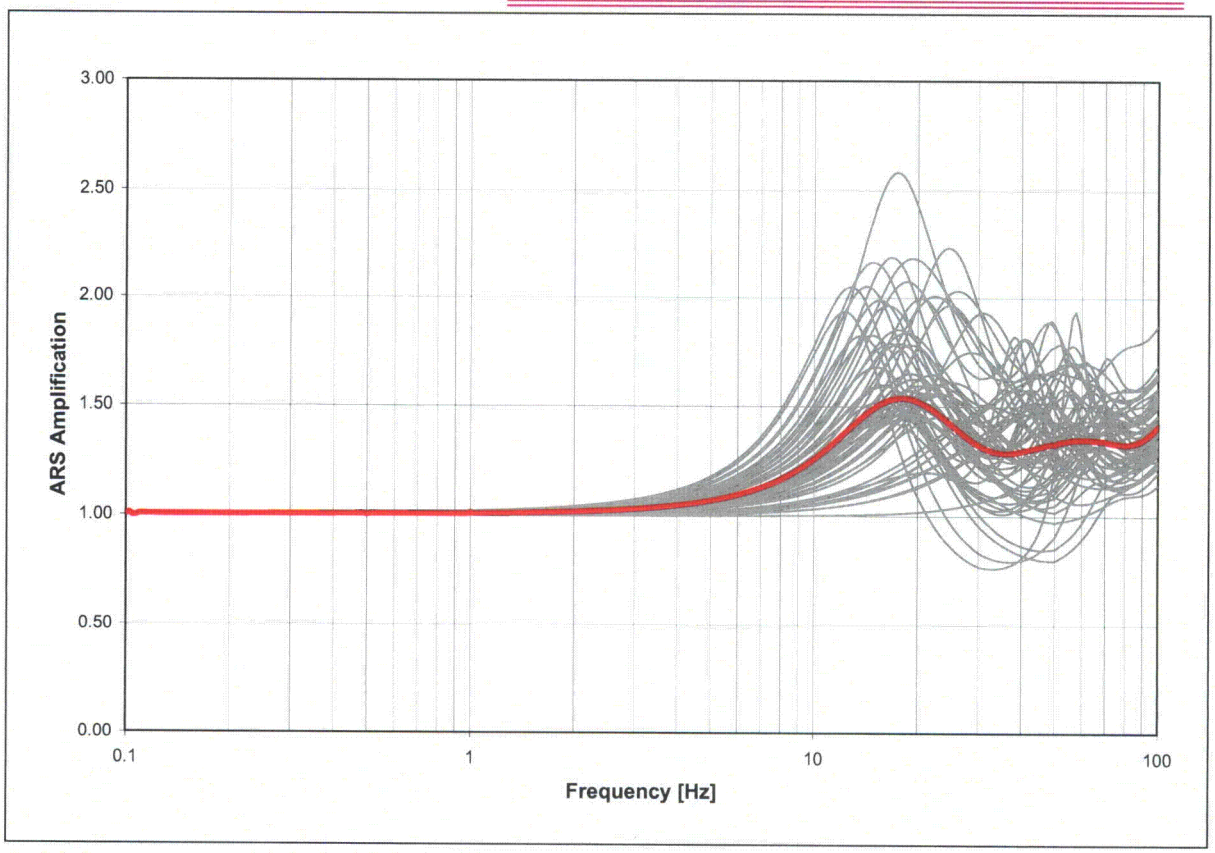
NAPS COL 2.5(1) **Figure 2.5-202e** Low-Strain Damping Ratio for 60 Simulated Profiles for GMRS Calculation



Note: The top 40 ft of backfill is removed in the TSCR analysis performed for calculation of GMRS.

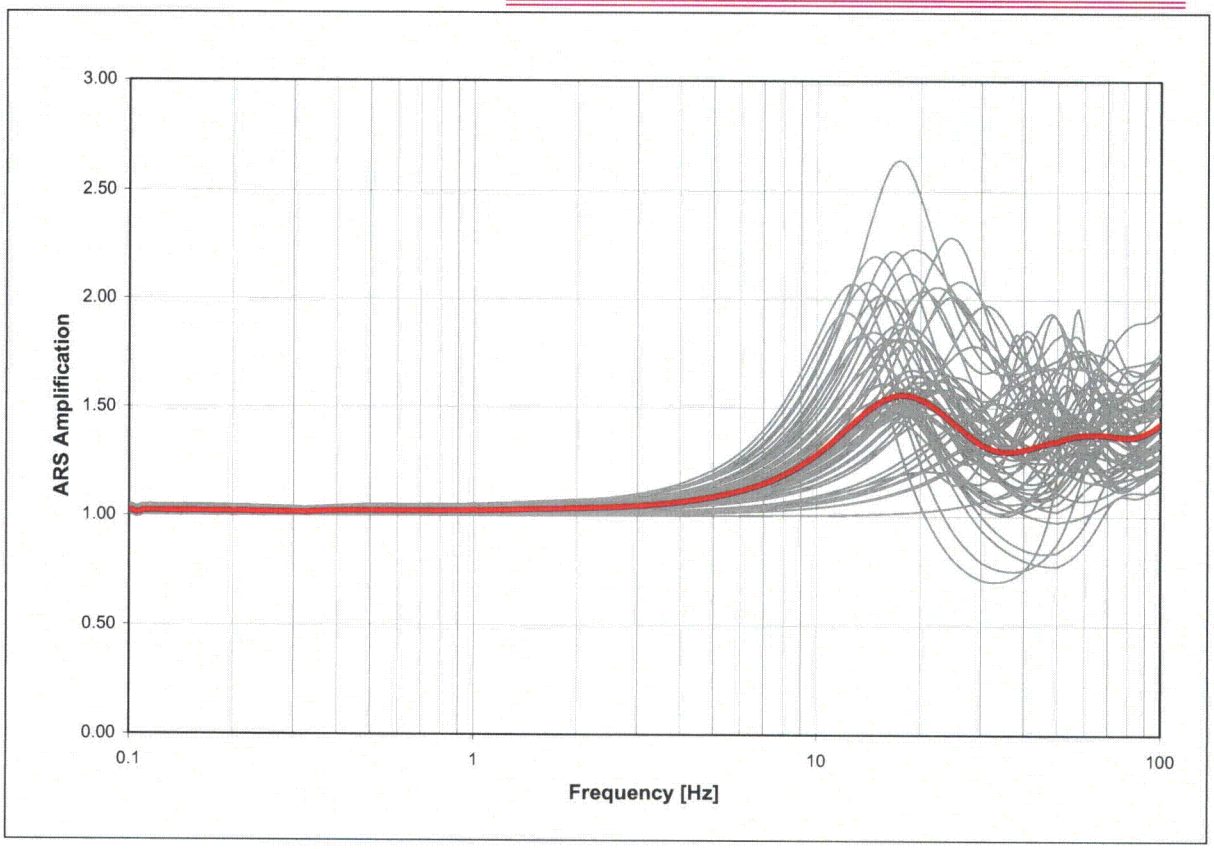
NAPS COL 2.5(1)

Figure 2.5-202f Geologic Outcrop ARS Amplification Functions at Elevation 250 ft NAVD88 for GMRS Calculation - LF



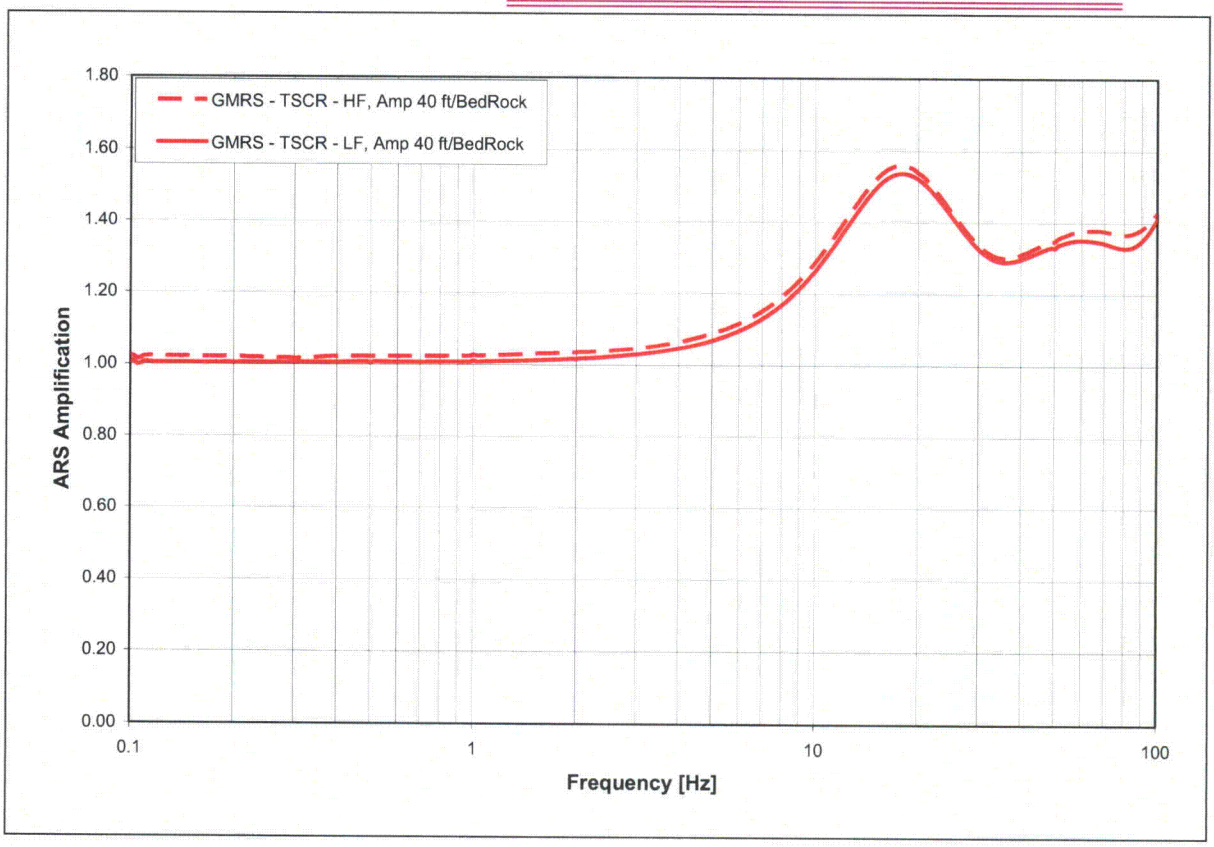
NAPS COL 2.5(1)

Figure 2.5-202g Geologic Outcrop ARS Amplification Functions at Elevation 250 ft NAVD88 for GMRS Calculation - HF



NAPS COL 2.5(1)

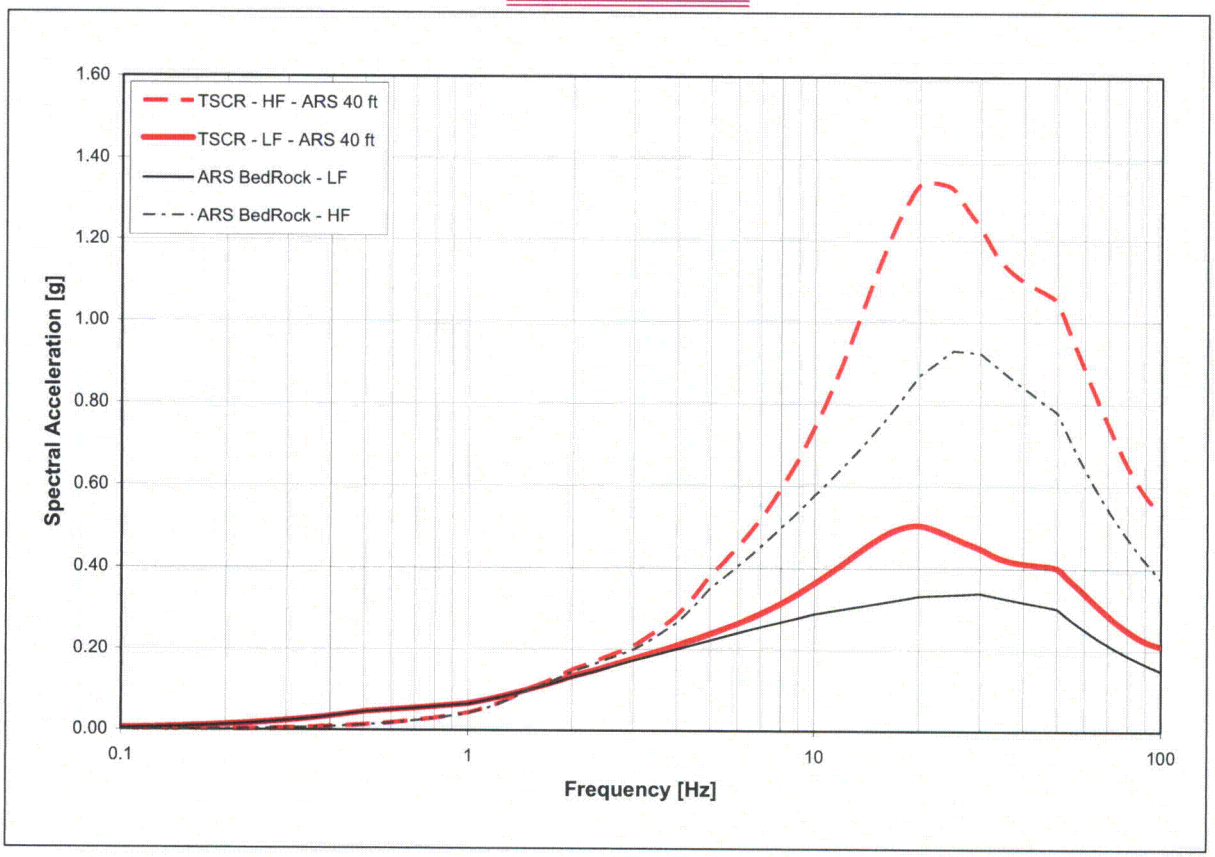
Figure 2.5-202h Geologic Outcrop (TSCR) Log-Mean 5% Damped ARS Amplification Functions for GMRS Calculation



Note: In the legend, 40 ft refers to the depth with respect to the finished ground surface (Elevation 290 ft NAVD88) at which the ARS amplification is calculated and it corresponds to Elevation 250 ft NAVD88.

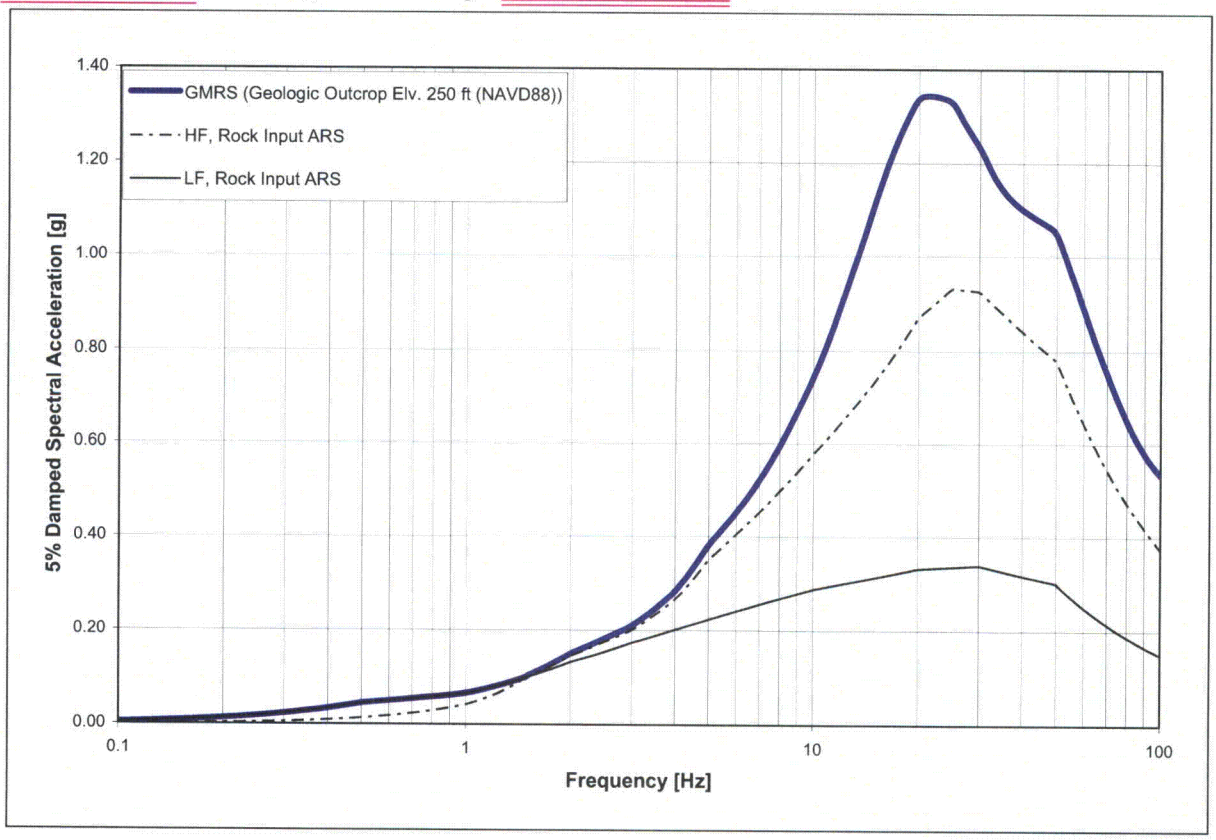
NAPS COL 2.5(1)

Figure 2.5-202i Geologic Outcrop Log-Mean 5% Damped ARS for GMRS Calculation



Note: In the legend, 40 ft refers to the depth with respect to the finished ground surface (Elevation 290 ft NAVD88) at which the ARS amplification is calculated and it corresponds to Elevation 250 ft NAVD88.

NAPS COL 2.5(1) **Figure 2.5-202j** Horizontal GMRS



3.7 Seismic Design

This section of the referenced DCD is incorporated by reference with the following departures and/or supplements.

NAPS COL 3.7(20)
NAPS COL 3.7(6)
NAPS COL 3.7(5)

Replace the third paragraph in DCD Section 3.7 with the following.

The validity of the site-independent seismic design of the standard plant structures for the site-specific seismic conditions is addressed in this Section 3.7 and in Appendix 3NN. Foundation input response spectra (FIRS), presented in Appendix 3OO and Section 3.7.1.1, are developed for the site-specific US-APWR plant configuration. SSI Input motions are developed considering both the minimum response spectra that are defined in Subsection 3.7.1.1 and the response spectra obtained from the site-specific SSE ground motion response analyses. The FIRS are derived by an analysis methodology which accounts for the upward propagation of the SSE ground motion. The site-dependent (also referred to herein as site-specific) GMRS, defined as a free-field hypothetical outcrop at ~~a horizon~~ Elevation 250 ft NAVD88 (250.86 ft NGVD29) corresponding to ~~hard~~ Zone III-IV rock with a shear wave velocity of ~~9,200~~ 4250 ft/s as discussed in Section 2.5.2, is developed following the intent of Regulatory Guide 1.165 and Regulatory Guide 1.208. The site-specific design SSE motions are defined in Subsection 3.7.1.1.

NAPS COL 3.7(21)

Replace the ~~third~~ fourth paragraph in DCD Section 3.7 with the following.

For the site-specific seismic design of seismic category I and seismic category II SSCs that are not part of the US-APWR standard plant, FIRS included in Appendix 3OO are derived from the site-specific SSE ground motion in the same manner as the site-specific FIRS used for validation of the standard plant structures.

NAPS COL 3.7(1)
NAPS COL 3.7(6)

Replace the fifth paragraph in DCD Section 3.7 with the following.

The PGA and spectral shapes of the site-specific FIRS are not enveloped by the US-APWR standard plant CSDRS. Exceedances of the CSDRS are present in the mid- to high-frequency range. To confirm the suitability of the US-APWR standard plant seismic designs for the site, validation analyses compare the standard plant seismic design to the site-specific seismic responses. The site-specific seismic responses are derived from site-specific soil-structure interaction (SSI) analyses which use the

site-specific soil properties and SSI Input motions. The analyses results demonstrate that the standard plant seismic design of structural components envelopes the responses from the site-specific seismic analyses. The analyses are discussed further in Section 3.7.2.4.1.

NAPS COL 3.7(23)

The site-specific SSI analyses show that the broadened in-structure response spectra (ISRS) derived from the site-specific input motion are not enveloped by the US-APWR standard plant ISRS. The evaluation approach for the spectral exceedances in the mid- to high-frequency range is discussed further in Sections 3.7.2.4.1 and 3.7.2.5, and Sections 3.10 and 3.12.

3.7.1 Seismic Design Parameters

3.7.1.1 Design Ground Motion

NAPS SUP 3.7(1)

Add the following before the first paragraph in DCD Subsection 3.7.1.1.

The site-specific seismic design ground motions are developed, as described in detail in Appendix 3OO, for the following seismic category I structures:

- Reactor Building Complex (R/B Complex); this includes the R/B, the PCCV and the containment internal structure, which all rest on a common basemat.
- East and West Power Source Buildings (PS/Bs)
- East and West Power Source Fuel Storage Vaults (PSFSVs)
- Ultimate Heat Sink Related Structures (UHSRS) A, B, C and D; each of the four are composed of a basin, pump house cooling tower and pipe room. The UHSRS Pipe Chase extends between UHSRS B and C
- East and West Essential Service Water Pipe Tunnels (ESWPTs)

Note that while the R/B Complex and PS/B are included in the US-APWR standard plant design, the PSFSV, UHSRS and ESWPT are site-specific structures.

NAPS COL 3.7(1)
NAPS DEP 3.7(1)

Replace the second sentence of the first paragraph in DCD Subsection 3.7.1.1 with the following.

The applicable site-specific PGA is greater than 0.3g for the horizontal and vertical directions (refer to Figure 3.7-201 through Figure 3.7-208).

NAPS COL 3.7(22)

Replace the last sentence of the third paragraph in DCD Subsection 3.7.1.1 "CSDRS" with the following.

Unit 3 seismic category I structures are founded on rock or concrete fill on rock, and the ground motion at Unit 3 is characterized by a high frequency content. The site-specific seismic GMRS and FIRS demonstrate that there are high frequency exceedances of the CSDRS. Site-specific seismic analyses, including SSI analyses, which consider seismic wave transmission incoherence and analysis of the cumulative absolute velocity (CAV) of the seismic input motion are described in Section 3.7.2. The site-specific SSI analyses determine if high-frequency exceedances of the CSDRS could be transmitted to SSCs in the plant superstructure with potentially damaging effects.

~~**NAPS DEP 3.7(2)**~~

~~Replace the second and third paragraphs in DCD Subsection 3.7.1.1 "Site-Specific GMRS" with the following.~~

~~Site-specific GMRS are developed at a sufficient number of frequencies (at least 25) that adequately represent the local and regional seismic hazards using the site-specific geological, seismological, and geophysical input data (Refer to Table 2.5-201 and Figure 2.5-201). A probabilistic seismic hazard analysis considering horizontal ground motion models for central and eastern US generic hard rock (shear wave velocity of at least 9,200 ft/s) is performed conforming to guidance in RG 1.165. The horizontal GMRS is developed as the free surface motion at the hypothetical outcrop of the hard rock horizon, as presented in Subsection 2.5.2.6.7. The vertical GMRS is developed by combining the horizontal GMRS and the vertical/horizontal response spectral ratios from NUREG/CR-6728 (Reference 3.7-14).~~

Replace the last two sentences of the first paragraph in DCD Subsection 3.7.1.1 "FIRS" with the following.

Free-field outcrop spectra of site-specific horizontal ground motions are derived from the hard rock SSE spectra consistent with the horizontal GMRS using site response analyses that consider the wave propagation effects in the materials representing the Unit 3 site-specific conditions. The methodology is described in detail in Appendix 3OO.

vertical directions, respectively. The comparisons show that the site-dependent GMRS and FIRS exceed the CSDRS in all cases in the high frequency range of the spectrum. Note that the FIRS for the site-specific seismic category I structures are also shown in **Figure 3.7-201** and **Figure 3.7-202** for full-column outcrop motions, and in **Figure 3.7-203** and **Figure 3.7-204** for the geologic outcrop motions.

A site-specific verification analysis of US-APWR standard plant seismic category I structures is performed considering SSI effects, as described in Section 3.7.2, and using the site-specific SSI Input motions, based on the site-specific FIRS, which are described in detail in **Appendix 3OO**. One set of full-column outcrop SSI Input motions (horizontal and vertical) is developed for each of the R/B Complex, and the PS/B (based on the envelope FIRS for the East and West units) for their analysis with embedded foundations. The full-column outcrop SSI Input motions are presented in **Figure 3.7-205** and **Figure 3.7-206** in the horizontal and vertical directions, respectively. A second set for each of the R/B Complex and the PS/B (based on the envelope FIRS for the East and West units) is shown in **Figure 3.7-207** and **Figure 3.7-208** for the geologic outcrop SSI Input motion in the horizontal and vertical directions, respectively. The geologic outcrop SSI input motions are used for the SSI analysis of the structures with surface foundations. Note that, since the design of the R/B Complex and PS/B is covered by the standard plant design, the minimum design response spectra required by 10 CFR 50, Appendix S, are not included in these motions, and are considered in a separate SSI analysis, as described in Section 3.7.2.

NAPS SUP 3.7(2)
NAPS ESP VAR 2.0-4

Add the following before the first paragraph in DCD Subsection 3.7.1.1 "OBE."

For the design of seismic category I SSCs that are not part of the US-APWR standard plant, the site-specific SSI Input motions, including minimum requirements, are developed based on the site-specific FIRS for the ESWPT and UHSRS. **Figure 3.7-209** and **Figure 3.7-210** present the SSI Input motions in the horizontal and vertical directions, respectively. Note that the site-specific SSI Input motions for the PS/B are adopted for the SSI analysis of the PSFSV, due to their proximity and similar site conditions. As described in **Appendix 3LL** and **Reference 3.7-201**, the minimum design response spectra required by 10 CFR 50, Appendix S for PSFSV is satisfied through SSI analysis of

site-specific SSI Input motion for each structure is used and the incoherency of the input motion is not considered. The SSI analyses and results for the UHSRS, ESWPT, and PSFSVs are addressed in further detail in Appendix 3LL.

NAPS COL 3.7(20)

Site-specific SSI analyses are required to confirm that the seismic designs of the A/B and T/B are suitable for the site-specific seismic input motion and the range of site-specific subgrade conditions, in accordance with the guidance given in SRP 3.7.2.

NAPS COL 3.7(25)

Replace the first sentence of the third paragraph in DCD Subsection 3.7.2.4.1 with the following.

The site-specific seismic response analyses address factors that affect the response of the combined soil-structure dynamic system that include, but are not limited to, the following.

Replace the last two sentences of the fifth paragraph in DCD Subsection 3.7.2.4.1 with the following.

The value of C_V used to determine bounding values for all subgrade and backfill shear moduli in the SSI analyses is at least 0.5, corresponding to a well investigated site.

NAPS COL 3.7(8)
NAPS COL 3.7(25)
NAPS COL 3.7(26)
NAPS DEP 3.7(1)
NAPS DEP 3.7(2)

Replace the sixth, seventh, and eighth paragraphs with the following.

The SSI analyses use stiffness and damping properties of the subgrade materials that are compatible with the strains generated by the site-specific design earthquake which is based on the FIRS discussed in Section 3.7.1.1. In accordance with guidance of SRP 3.7.2, the soil material damping considered in Appendices 3OO and 3NN does not exceed 15%.

All standard plant and site-specific seismic category I and II buildings and structures are founded on sound rock or on a layer of fill concrete placed on the sound rock (Zone III and/or Zone III-IV rock as described in Section 2.5.4 and SSAR (R9) Subsection 2.5.1.2.3). The R/B complex, the PSFSVs, and the PS/Bs are founded completely on Zone III-IV bedrock or on fill concrete placed on Zone III-IV bedrock.

The fill concrete has a minimum design compressive strength of 2,500 psi as stated in Section 2.5.4 and a best estimate shear wave velocity of 7,000 ft/s as stated in Appendix 3OO. The fill concrete is installed as a leveling layer and to fill the space between the basemat

NAPS COL 3.7(4)

3.7(4) ***Damping values for site-specific ISRS***

This COL item is addressed in Subsections 3.7.1.2 and 3.7.2.4.1.

NAPS COL 3.7(5)

3.7(5) ***Horizontal FIRS, Vertical FIRS, and Minimum Response Spectra***

This COL item is addressed in Subsections 3.7 and 3.7.1.1, and Appendix 3OO.

NAPS COL 3.7(6)

3.7(6) ***Site-specific GMRS and FIRS***

This COL item is addressed in Sections 2.5.2, 3.7, 3.7.1.1, ~~2.5.2,~~ and Appendix 3OO.

NAPS COL 3.7(7)

3.7(7) ***Allowable dynamic bearing capacity***

This COL item is addressed in Subsections 3.7.1.3, 2.5.4.10, and Table 3.8-202.

NAPS COL 3.7(8)

3.7(8) ***Strain-dependent variation of material dynamic properties***

This COL item is addressed in Subsection 3.7.2.4.1.

NAPS COL 3.7(9)

3.7(9) ***Failure or collapse of non-seismic category I structures***

This COL item is addressed in Subsection 3.7.2.8.

NAPS COL 3.7(10)

3.7(10) ***Structure-to-structure interaction***

This COL item is addressed in Subsection 3.7.2.8.

3.7(11) ***Deleted from the DCD***

NAPS COL 3.7(12)

3.7(12) ***Liquid-retaining metal tanks***

This COL item is addressed in Subsection 3.7.3.9 and Appendix 3LL.

NAPS COL 3.7(13)

3.7(13) ***Value of OBE to define criteria for shutdown***

This COL item is addressed in Subsection 3.7.1.1.

NAPS COL 3.7(14)

3.7(14) ***Seismic instrumentation at multiple-unit site***

This COL item is addressed in Subsection 3.7.4.3.

3.7(15) ***Deleted from the DCD***

NAPS COL 3.7(16) *3.7(16)* ***Seismic monitors and need for free-field motion sensors***

This COL item is addressed in Subsections 3.7.4.1 and 3.7.4.2.

3.7(17) ***Deleted from the DCD.***

3.7(18) ***Deleted from the DCD.***

NAPS COL 3.7(19) *3.7(19)* ***Site-specific details of seismic instrumentation implementation plan***

This COL item is addressed in Subsection 3.7.4.6.

NAPS COL 3.7(20) *3.7(20)* ***Standard plant for site-specific conditions***

This COL item is addressed in Sections 2.5.2, 3.7, 3.7.2.2, 3.7.2.4.1, Appendix 3NN, and Appendix 3OO.

NAPS COL 3.7(21) *3.7(21)* ***Seismic design of non-standard plant SSCs***

This COL item is addressed in Subsection 3.7 and Appendix 3LL.

NAPS COL 3.7(22) *3.7(22)* ***High seismic areas***

This COL item is addressed in Subsections 3.7, 3.7.2.4.1 and 3.7.2.5, and Appendix 3NN.

NAPS COL 3.7(23) *3.7(23)* ***Broadened ISRS and lateral soil pressure***

This COL item is addressed in Subsection 3.7.2.4.1 and Appendix 3NN.

NAPS COL 3.7(24) *3.7(24)* ***Site-specific uniform hazard response spectra***

This COL item is addressed in Subsection 3.7.1.1.

NAPS COL 3.7(25) *3.7(25)* ***SSI analysis of R/B-PCCV-containment internal structure***

This COL item is addressed in Subsection 3.7.2.4.1 and Appendix 3NN.

NAPS COL 3.7(26) *3.7(26)* ***SSI effects for non-standard plant structures***

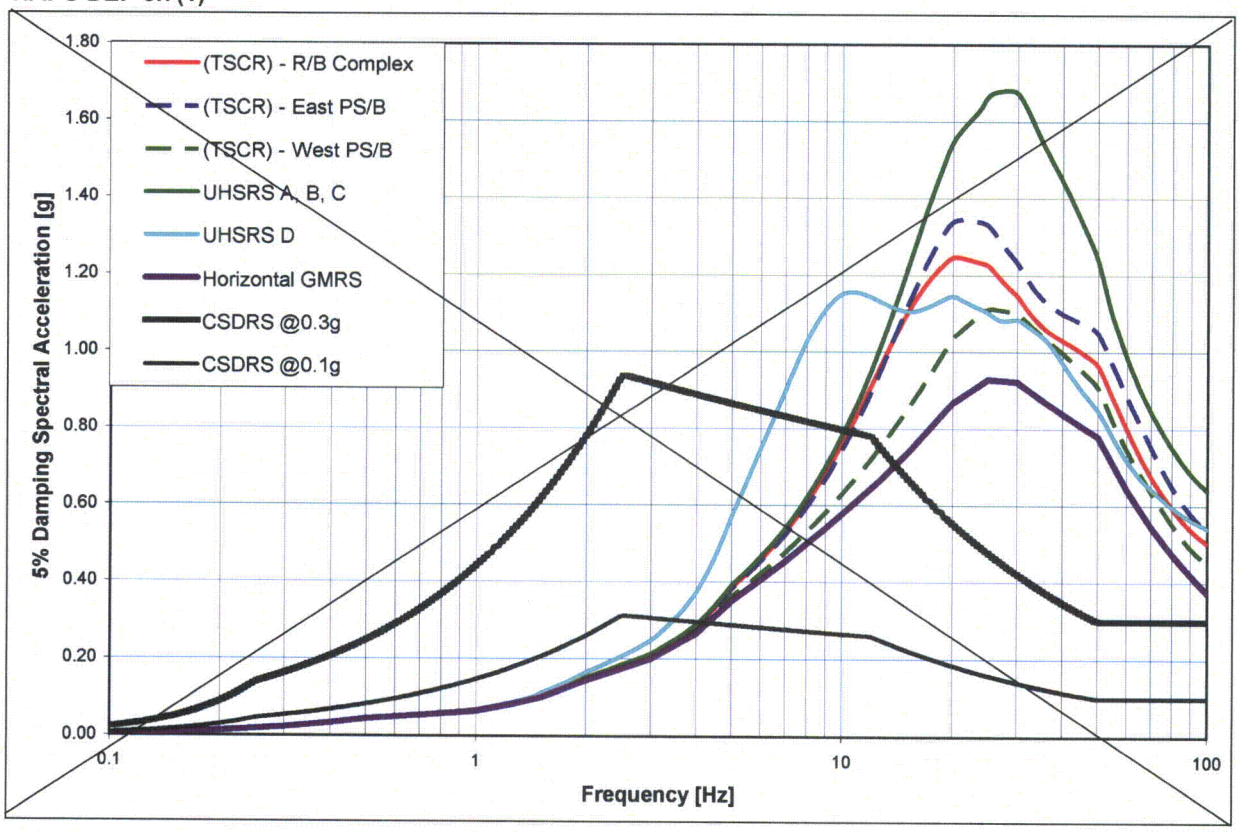
This COL item is addressed in Subsection 3.7.2.4.1 and Appendix 3LL.

NAPS COL 3.7(27) *3.7(27)* ***Seismic analysis of dams***

This COL item is addressed in Subsections 3.7.2.13 and 3.7.3.8.

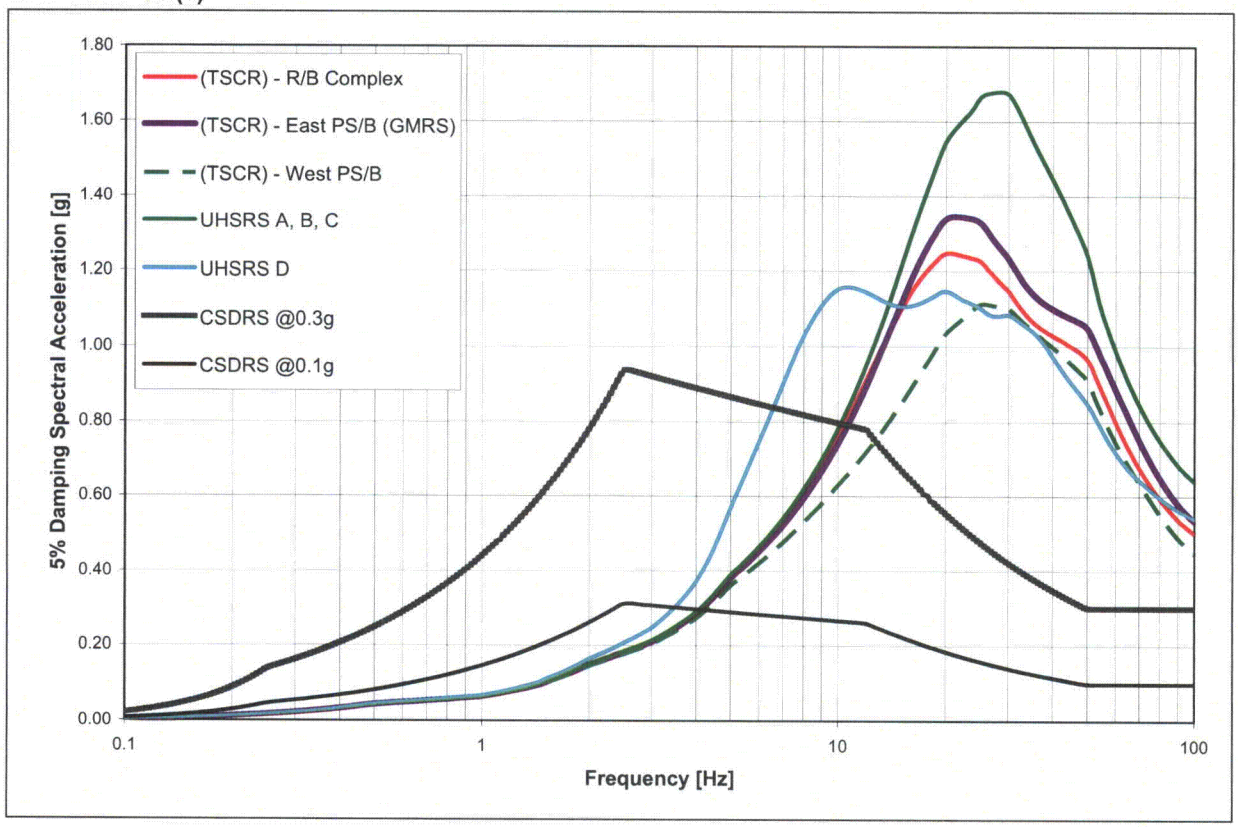
NAPS COL 3.7(2)
NAPS COL 3.7(5)
NAPS DEP 3.7(1)

Figure 3.7-203 GMRS and Geologic Outcrop FIRS at Bottom of Basemat - Horizontal



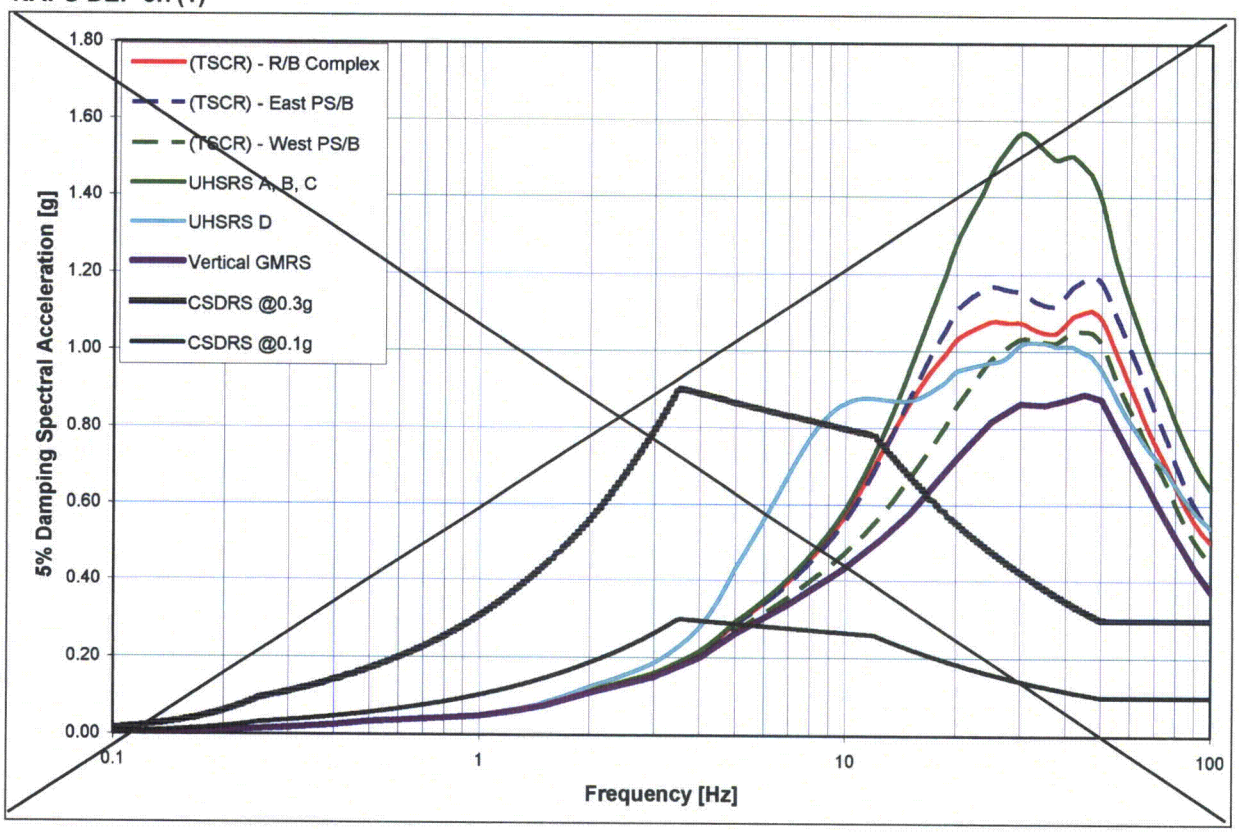
NAPS COL 3.7(2)
NAPS COL 3.7(5)
NAPS DEP 3.7(1)

Figure 3.7-203 GMRS and Geologic Outcrop FIRS at Bottom of Basemat - Horizontal



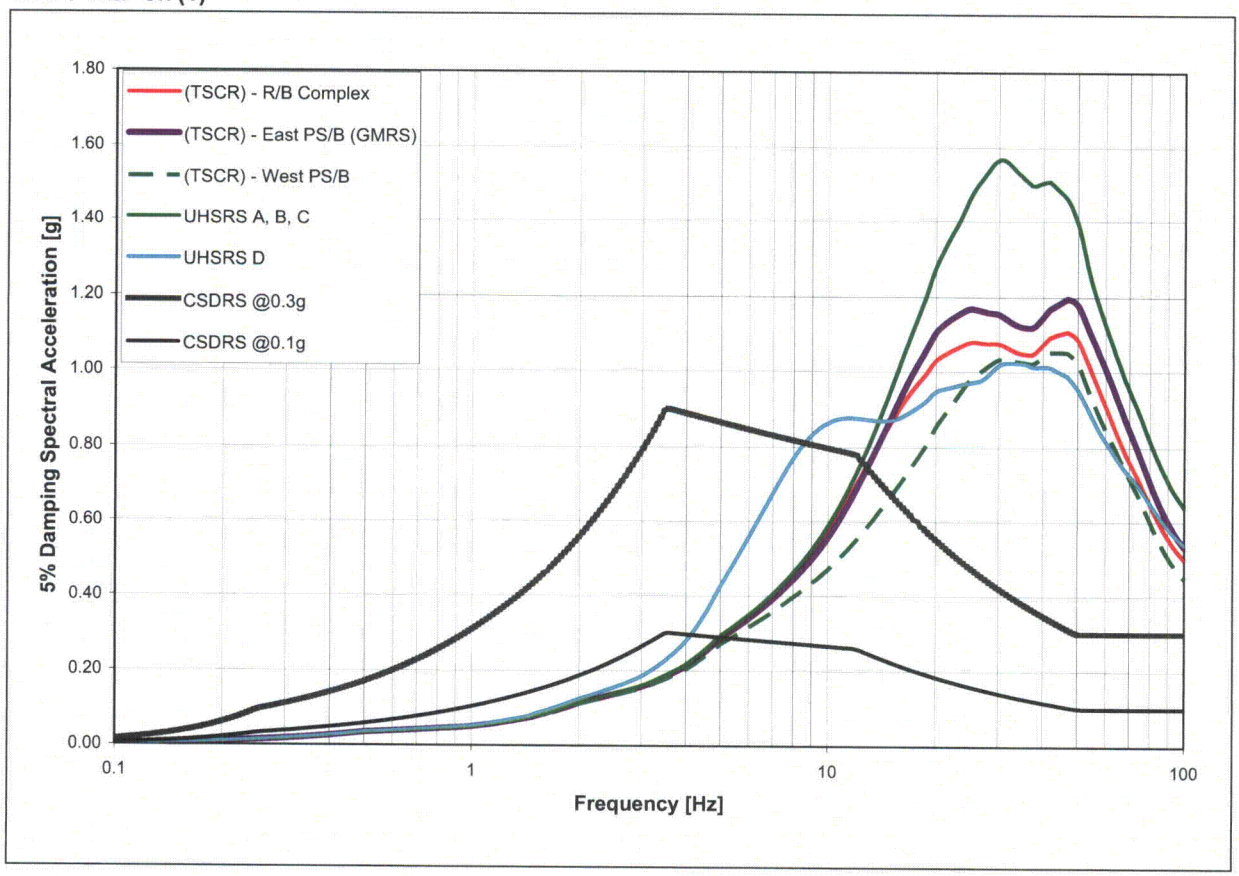
NAPS COL 3.7(2)
NAPS COL 3.7(5)
NAPS DEP 3.7(1)

Figure 3.7-204 GMRS and Geologic Outcrop FIRS at Bottom of Basemat - Vertical



NAPS COL 3.7(2)
NAPS COL 3.7(5)
NAPS DEP 3.7(1)

Figure 3.7-204 GMRS and Geologic Outcrop FIRS at Bottom of Basemat - Vertical



NAPS COL 3.7(5)
NAPS COL 3.7(24)
NAPS COL 3.7(30)
NAPS DEP 3.7(1)
NAPS SUP 3.7(2)
NAPS SUP 3.7(3)

Appendix 3OO Site Response Analysis and Development of SSI Analysis Input

This appendix describes the development of the seismic design ground motions and the strain-compatible soil profile properties, which are used in the Soil-Structure Interaction (SSI) analysis of the following seismic category I structures:

- Reactor Building Complex (R/B Complex); this includes the R/B, the PCCV and the containment internal structure, which all rest on a common basemat
- East and West PS/B
- East and West PSFSV
- UHSRS A, B, C and D
- East and West ESWPT

Note that while the R/B Complex and PS/B are included in the US-APWR standard plant design, the PSFSV, UHSRS and ESWPT are site-specific structures.

Section 3OO.1 describes the development of the Foundation Input Response Spectra (FIRS) and the resulting SSI Input motions, and SSI soil profiles. The soil amplification functions are developed in accordance with Approach 2 in NUREG/CR-6728 (Reference 3OO-6), through seismic site response analysis using the Low Frequency (LF) and High Frequency (HF) hard rock motions, presented in Section 2.5.2.6, and the soil profile properties, presented in Section 2.5.4.2. The LF and HF hard rock spectra are ~~derived from the Ground Motion Response Spectra (GMRS),~~ defined in Section 2.5.2.6.

The development of the SSI soil property profiles is described in Section 3OO.2. The acceleration time histories that are applied at the foundation of the structures in the SSI analysis are presented in Section 3OO.3. Section 3OO.4 presents a list of the references.

3OO.1 FIRS and SSI Input Motions

The Unit 3 site includes several seismic category I structures founded at different elevations. Table 3OO-201 presents the embedment elevations and depths of these structures. Note that all elevations are based on the NAVD88 datum with design plant grade at Elevation +290 ft (+290.86 ft

based on NGVD29). The design ground water table information is provided in Section 2.4.12.

The generation of low-strain, site-specific, simulated soil property profiles is described in Section 3OO.1.1, the site response analysis is described in Section 3OO.1.2, and the calculation of FIRS is presented in Section 3OO.1.3. For site-specific structures, the FIRS are augmented with the Certified Seismic Design Response Spectra (CSDRS) scaled to a Peak Ground Acceleration (PGA) of 0.1g. The CSDRS scaled to a PGA of 0.1g satisfies the minimum design response spectra requirements as described in 10 CFR 50, Appendix S (Reference 3OO-5). The SSI Input motions are obtained from the FIRS following the guidance of ISG-017 (References 3OO-8 and 3OO-4).

The development of the smooth SSI Input motions, satisfying 10 CFR 50, Appendix S, is described in Section 3OO.1.4.

3OO.1.1 Dynamic Soil Profile and Stochastic Simulation

As described in Section 2.5.4.2, the upper in situ soil is characterized as residual clays and clayey silts (Zone I) which is scarce across the site and will be removed. This zone is followed by saprolite (Zone IIA and Zone IIB), followed by rock which is classified into three zones: Zone III (weathered rock), Zone III-IV (moderately weathered to slightly weathered rock) and Zone IV (slightly weathered to fresh rock). The extent of excavation at the location of each structure is described in detail in Section 2.5.4.5. Structural backfill is used on the sides of all the Seismic Category I structures.

The computer program SPS is used to generate site-specific simulated (randomized) soil profiles to represent the dynamic properties of the site while considering the uncertainty associated with each of these properties. The generation of the low-strain simulated soil profiles uses the input Best Estimate (BE) properties and their associated uncertainty. The uncertainty is expressed in terms of statistical distribution, standard deviation (SD), and correlation among engineering parameters.

Section 2.5.4.2 provides the static and dynamic soil properties including shear wave velocity profiles, soil layer thicknesses, unit weights, Poisson's ratios, as well as strain-dependent property curves and damping ratios. The properties of the different soil, rock and concrete layers under each structure provide the BE properties and an estimate of the variation of these properties. Profile simulation accounts for the

variation of the shear wave velocities, damping ratios, strain-dependent property curves, as well as the thicknesses of the different layers to generate the simulated profile sets for the considered structures.

In the case of the R/B Complex, profiles 1 and 2, as defined in Section 2.5.4.2, are combined by taking their log-mean and augmenting it with backfill properties for the top 40 ft to develop the BE profile. Figure 3OO-201 presents the site-specific BE shear-wave velocity profile for the R/B Complex. Note that the concrete fill, starting at a depth of 40 ft, has a BE shear-wave velocity of 7000 ft/sec, while backfill properties are used in the top 40 ft. Figure 3OO-202 presents the set of 60 shear-wave velocity simulated profiles before including thickness variation, i.e. based on the BE thicknesses provided for each soil layer. Note that the log-average (simulated median) profile matches the input BE profile very closely. Maximum and minimum bounds of twice the SD around the BE are imposed to prevent unrealistic shear-wave velocity realizations. Figure 3OO-203 presents the set of 60 shear-wave velocity simulated profiles, including thickness variation, representing the site conditions under the R/B Complex. Note that while the simulated median profile matches the input BE profile, it shows smoother transitions between the consecutive strata, which is the result of the combination of shear-wave velocity and thickness variation in the simulated profiles. For the purposes of site response analysis, halfspace bedrock, where the input hard rock motion is applied, is defined by a minimum shear-wave velocity of 9200 ft/sec. Bedrock depth varies across the site and is generally found at a depth of around 145 ft from finished grade (refer to Section 2.5.4).

As described in Section 2.5.4.2, the structural backfill, in situ saprolite, and Zone III rock are each assigned a set of strain-dependent property curves (shear modulus degradation and damping), while concrete fill, Zone III-IV rock, and Zone IV rock are assigned linear properties (strain-independent shear modulus and damping). Figure 3OO-204 presents the simulated strain-dependent property curves for the top structural backfill layer of the R/B Complex site (referred to as Fill1). In these plots, the BE and simulated median are compared, as well as the input log-standard deviation (Input SD) and simulated log-standard deviation (Simulated SD). Maximum and minimum bounds of twice the SD around the BE are imposed on the strain-dependent property curves. Note that damping curves, in Figure 3OO-204, are truncated at a

maximum of 15 percent as described by SRP Section 3.7.1 (Reference 3OO-7), which explains the discrepancy between input and simulated properties once that upper limit is reached. The damping truncation at 15 percent is a conservative measure with respect to the subsequent use of the curves in site response analysis. The remaining strata (concrete fill, Zone III-IV rock, and Zone IV rock) are assigned strain-independent damping ratios, based on BE damping ratios of 1 percent with a log-standard deviation of 0.6. This amounts to damping values with one standard deviation range of 0.5 percent to 1.5 percent. The resulting low-strain damping ratio profiles are presented in Figure 3OO-205.

The soil profile simulation is conducted in the same manner to represent the site conditions under the other considered structures. As in the case of the R/B Complex, each set of simulated profiles is based on the site-specific BE profile for that particular structure, including the site-specific thicknesses of the different strata. The strain-independent and strain-dependent damping ratios are assigned for each stratum based on the soil classification of the stratum.

Figure 3OO-206 presents the BE shear-wave velocity profiles for the East and West PS/B, which are taken to represent the site conditions under the PSFSV given the proximity and similar conditions of the two structures. Note that the foundation elevation of the east PS/B is modeled at a depth of 40 ft, compared to a depth of 39 ft for the west PS/B, as described in Table 3OO-201. The BE shear-wave velocity profile for the East PS/B below Elevation 250 ft NAVD88 (250.86 ft NGVD29) (40 ft depth) exactly matches the GMRS shear wave velocity profile described in Section 2.5.2.5. Figure 3OO-207 presents the BE shear wave velocity profiles for the four UHSRS, and Figure 3OO-208 presents the BE shear wave velocity profiles for the East and West ESWPT. The South segment of the ESWPT is modeled as part of or using the same input to the SSI analysis of the PS/B, or the PSFSV according to the locations of various parts of that segment, as described in Section 3.7.2, therefore alleviating the need for the generation of the corresponding simulated soil profile sets. The BE shear wave velocity profile for the UHSRS Pipe Chase is presented in Figure 3OO-208. Note that the UHSRS Pipe Chase is the only structure which includes in situ soils (saprolite) near the sides of the chase as part of its BE profile, due to the limited excavation/backfill

around the UHSRS Pipe Chase. The in situ soils are there fore modeled for the free-field site response analysis (refer to Section 3.7.2).

3OO.1.2 Site Response Analysis

The LF and HF input hard rock spectra are presented in Section 2.5.2.6.7, ~~Figure 2.5-202~~ Figure 2.5-202a. The hard rock spectra are applied at bedrock having a shear wave velocity of 9,200 ft/sec, and are propagated from bedrock to the ground surface, through the sets of 60 simulated profiles, representing the site-specific conditions under each structure, using the computer program P-SHAKE.

As input for site response analysis, the duration of the input motion is specified as a parameter in P-SHAKE. The strong motion durations are determined as a function of the magnitudes (M) of the LF and HF input hard rock motions, from Table 2.3-1 in ASCE 4-98 (Reference 3OO-1). The magnitudes and corresponding durations are reported in Table 3OO-202. An additional parameter required for P-SHAKE is the effective strain ratio (equivalent uniform strain divided by maximum strain), which is calculated as a function of earthquake magnitude, as shown in Equation 3OO-1 (Reference 3OO-2). The resulting effective strain ratios used in site response analysis are reported in Table 3OO-202.

Effective Strain Ratio = $(M-1)/10$ Equation (3OO-1)

P-SHAKE implements an equivalent-linear iterative approach similar to SHAKE (References 3OO-2 and 3OO-9), where a number of iterations is needed to reach a converged solution. The free field 5 percent damping Acceleration Response Spectra (ARS), at the ground surface and at the bottom of foundation elevations, are computed as *full-column outcrop* motions through analysis of the full soil column up to the ground surface. The *full-column outcrop* motions are suitable for developing the SSI Input motion when the considered structure is modeled in the SSI analysis as embedded.

It should be noted that the R/B Complex, PS/B and PSFSV are analyzed assuming both embedded and surface foundations. The UHSRS are analyzed as surface founded structures, except for the UHSRS Pipe Chase which is analyzed with embedded foundation; while the east and west segments of the ESWPT are analyzed as embedded structures.

LF rock motions are used for the site response analysis for all considered structures.

The PS/B ARS at the foundation level are calculated in the same manner and the log-mean *full-column outcrop* and *geologic outcrop* ARS are presented in **Figure 3OO-217** and **Figure 3OO-218**, respectively for the east PS/B. **Figure 3OO-219** and **Figure 3OO-220** present the corresponding plots for the west PS/B. Note that the ARS developed for PS/B are also applicable to the PSFSV (including the adjacent ESWPT segment) due to their proximity and similar soil column profiles, and given the SSI analysis approach for PSFSV, which includes the concrete fill below PSFSV basemat extended to the foundation elevation of PS/B.

In the case of the four UHSRS, only *geologic outcrop* ARS are calculated, to be consistent with their SSI analysis as surface founded structures. The developed ARS for the four UHSRS are presented in **Figure 3OO-221**.

For the ESWPT, the *full-column outcrop* ARS at foundation level and at round surface are presented in **Figures 3OO-222** and **3OO-223** for the East and West ESWPT segments, respectively. **Figure 3OO-224** presents the *full-column outcrop* ARS at foundation level and at ground surface for the UHSRS Pipe Chase.

The P-SHAKE runs provide the strain-compatible shear wave velocities and damping ratio profiles (presented in **Section 3OO.2**) as well as the maximum strains within each soil layer. **Figure 3OO-225** presents the log-mean maximum strain profiles for the R/B Complex. With the exception of the backfill layers (above the foundation elevation), the computed maximum strains are small (less than 0.002 percent) which confirms the adequacy of the strain-independent properties for the concrete fill and in situ rock layers. Similarly small strain levels, with the exception of backfill and saprolite layers, are computed for all considered structures.

3OO.1.3 FIRS Calculation

The horizontal performance-based surface response spectra (PBSRS) are calculated by enveloping the LF and HF log-mean 5 percent damping ARS at finished grade. Similarly, the horizontal Foundation Input Response Spectra (FIRS) are calculated by enveloping the LF and HF log-mean 5 percent damping ARS for the horizon of interest.

The horizontal PBSRS and FIRS are scaled by an appropriate V/H scaling function to obtain the corresponding vertical PBSRS and FIRS. For this calculation, the V/H function is that presented in Section 2.5.2.6 (Table 2.5-201).

Figure 3OO-226 presents the horizontal FIRS calculated as full-column outcrop motions for the R/B Complex, as well as the East and West PS/B, while Figure 3OO-227 presents the corresponding vertical spectra. Similarly, Figure 3OO-228 and Figure 3OO-229 present the horizontal and vertical FIRS, respectively, for these structures calculated as geologic outcrop motions. The horizontal and vertical geological outcrop FIRS calculated for the East PS/B are exactly the same as the horizontal and vertical GMRS described in Section 2.5.2.6.7. The CSDRS, which is also shown in these figures, is clearly exceeded by the site-dependent FIRS in the high frequency range. A site-specific SSI analysis is therefore performed, as documented in Section 3.7.2, in order to validate the US-APWR for installation at the Unit 3 site.

In the case of the UHSRS, which are analyzed as surface founded structures, only *geologic outcrop* FIRS are needed, except for the UHSRS Pipe Chase which is analyzed with embedded foundation. The responses of UHSRS A, B and C are enveloped to yield one set of FIRS, in addition to another set for UHSRS D. Figure 3OO-230 presents the *geologic outcrop* FIRS for the UHSRS in the horizontal and vertical directions, in addition to the horizontal and vertical CSDRS scaled to a PGA of 0.1g representing the minimum requirements for the design ground motion response spectra.

In the case of the ESWPT and the UHSRS Pipe Chase, which are analyzed with embedded foundations, only *full-column outcrop* FIRS are needed. Figure 3OO-231 presents the *full-column outcrop* FIRS for the East and West ESWPT, and the UHSRS Pipe Chase in the horizontal direction, in addition to the horizontal CSDRS scaled to a PGA of 0.1g representing the minimum requirements for the design ground motion. Figure 3OO-232 presents the corresponding vertical spectra.

The PBSRS at the location of the considered structures are presented in Figure 3OO-233 and Figure 3OO-234.

3OO.1.4 **SSI Input Motions**

To develop the SSI Input motions starting from the calculated FIRS, the "NEI check" described below is performed for all *full-column outcrop*

1 Departures

Introduction

A *departure* is a plant-specific deviation from design information in a standard design certification rule. Departures from the reference US-APWR Design Control Document (DCD) are identified and evaluated consistent with regulatory requirements and guidance. Each departure is examined in accordance with 10 CFR 52 requirements. Although the US-APWR Design Certification Application is currently under review with the NRC, departures are evaluated using the guidance in Regulatory Guide (RG) 1.206, Section C.IV.3.3.

It is anticipated that the final certification rulemaking for the US-APWR would have the same change process requirements as that in the current appendices to 10 CFR 52. References in this Part to the Design Certification Rule are understood to mean Appendix "X" to 10 CFR 52 once the US-APWR rulemaking is final, where "X" refers to the appendix number assigned by the NRC at the time of rulemaking.

The departure evaluation summaries provided in this Part refer to both DCD Tier 1 and Tier 2 content. Unless otherwise noted, "DCD" refers to US-APWR DCD Tier 2 information. References in this Part to Tier 1 information are noted explicitly as "DCD Tier 1."

The following departures are summarized in this report:

NAPS DEP 2.0(1): Maximum Non-Coincident Wet Bulb Temperature

RAI 02.03.04-2 S1 R1 ~~NAPS DEP 2.3(1): Main Control Room Atmospheric Dispersion Factors, Source to Receptor Distance Determination~~

NAPS DEP 3.7(1): Seismic Spectra Exceedance

RAI 02.05.02-1 NAPS DEP 3.7(2): ~~Site Amplification Functions and~~ Site Response Analysis

NAPS DEP 3.7(3): MNES Improvements to Seismic Analysis Methods

NAPS DEP 8.2(1): Clarification of GDC 2 and 4 Applicability for Off-Site Power

NAPS DEP 9.2(1): Replacement of Boron Recycle System with a Degasifier Subsystem

NAPS DEP 9.2(2): Non-Essential Service Water Temperature, Design Service Water Temperature

NAPS DEP 9.5(1): Power Source Fuel Storage Vault Elevation

NAPS DEP 10.2(1): Main Turbine Type Change

NAPS DEP 10.4(1): Main Condenser Type Change

NAPS DEP 14.2(1): Initial Plant Test Program (ITP) Administration

Departure: NAPS DEP 3.7(2) - ~~Site Amplification Functions and~~ Site Response Analysis

1. Summary of Departure

The DCD specifies how a ~~site amplification function must be determined and how~~ the site response analysis must be performed. The Unit 3 FSAR clarifies that certain DCD requirements do not apply to ~~development of the Unit 3 GMRS or to~~ the derivation of the free-field outcrop spectra of site-specific horizontal ground motions. This clarification requires a departure from DCD Tier 2 information.

2. Scope/Extent of Departure

This departure is identified in ~~FSAR Sections 2.5 and~~ FSAR Section 3.7.

3. Departure Justification

~~a. *Use of Hard Rock Conditions to define Unit 3 GMRS.* DCD Section 3.7.1.1, under *Site Specific GMRS*, indicates that horizontal GMRS are developed using a site amplification function obtained from site response analyses performed on site specific soil profiles that include the layers of soil and rock over the generic rock defined as the rock with shear wave velocity exceeding 9200 ft/s. This DCD section anticipates that COL applicants would perform this portion of the seismic analysis only in the manner specified in the DCD. However, as described in FSAR Section 2.5.2 and in the Request for Variance from the ESP, VAR 2.0 4 (Section 3), hard rock conditions (with a shear wave velocity exceeding 9200 ft/sec) are at a depth of about 145 feet from finished grade. In addition, the hard rock conditions are consistent with the ground motion attenuation relations used in the site specific probabilistic seismic hazard analysis (PSHA). This hard rock horizon, which is well below the foundation levels of all safety related structures, is used to define the Unit 3 GMRS. Therefore, for the purpose of defining the GMRS, the site amplification analysis was not required. However, as described in FSAR Section 3.7, the seismic wave transmission characteristics of the site were considered in the development of the amplification of the GMRS hard rock ground motions at the higher elevations to obtain the site specific foundation input response spectra (FIRS).~~

~~b.~~ *Considerations of Material Relative to the Control Point.* DCD Section 3.7.1.1 ~~also~~ identifies (under *FIRS*) that the free-field outcrop spectra of site-specific horizontal ground motion are derived from the horizontal GMRS using site response analyses that consider only the wave propagation effects in materials that are below the control point elevation at the bottom of the basemat. Derivation of horizontal FIRS, as described in FSAR Section 3.7.1, is consistent with the development of the horizontal GMRS, where both FIRS and GMRS are derived from hard rock Safe Shutdown Earthquake (SSE) spectra described in FSAR Section 2.5.2, using site response analyses that consider the vertical wave propagation effects. This DCD section does not allow that material present above the control point elevation to be included in the site response analysis. In soil-structure interaction (SSI) analysis, structures can be analyzed with surface or embedded

foundations. As described in FSAR Section 3.7.2, the site-specific SSI analyses of the different Seismic Category I structures consider one or both of the SSI modeling approaches. In the case where the structures are analyzed as embedded, the free-field outcrop spectra are developed at the foundation level from site response analysis of the full height soil column, which requires consideration of the material above the bottom of the basemat. In the case where the structures are analyzed as surface founded, the free-field outcrop spectra are developed as geologic outcrop spectra from truncated soil column response (TSCR) analysis. The TSCR analysis approach, as described in NRC Interim Staff Guidance DC/COL-ISG-017, requires the consideration of the effects of the material above the bottom of the basemat. The methodology is described in detail in FSAR Appendix 3OO.

4. Departure Evaluation

This departure provides clarification that certain DCD requirements do not apply to ~~development of the Unit 3 GMRS or to~~ the derivation of the free-field outcrop spectra of site-specific horizontal ground motions. This departure has been evaluated and determined to require prior NRC approval in accordance with the Design Certification Rule, Section VIII.B.5.

This departure does not affect resolution of an ex-vessel severe accident design feature identified in the DCD.

This departure does not modify design features and functional capabilities that are supported in a required assessment of a DCD design regarding aircraft impact hazards (i.e., as required by 10 CFR 50.150(a)(1)).

Departure: NAPS DEP 3.7(3) - MNES Improvements to Seismic Analysis Methods

1. Summary of Departure

Certain changes have been made in the methodology and models used for the USAPWR standard plant seismic analyses, which affect the NRC review of the USAPWR application for design certification. These changes, applicable to the standard plant design analysis, including soil-structure interaction analysis, were submitted to the NRC in MHI Technical Report MUAP-10001 (Reference 1). The associated analysis results for the standard plant seismic design were provided to the NRC in MHI Technical Report MUAP-10006 (Reference 2).

The changes described in the above referenced technical reports will serve as the basis for a subsequent DCD revision as stated in MHI responses to NRC Requests for Additional Information[1] on the seismic design basis analyses. The analysis methods described in these reports are applicable to the Unit 3 FSAR analyses. In that the DCD has not yet been revised to incorporate the changes addressed in the referenced reports, the use of these improved analyses methods

1. Relevant NRC questions are identified, along with MHI resolutions, in MUAP-10001.

Variance: NAPS ESP VAR 2.0-3 – Hydraulic Gradient

Request

This is a request to use the Unit 3 hydraulic gradient value provided in FSAR Section 2.4.12.1.2 rather than the corresponding ESP value in FSER Supplement 1, Appendix A and in SSAR Table 1.9-1. The Unit 3 value does not fall within (is larger than) the ESP and SSAR value.

SSAR Section 2.4.12.1.2 states that there is a hydraulic gradient toward Lake Anna of about 3 m per 100 m (3 ft per 100 ft). The corresponding Unit 3 hydraulic gradient in FSAR Section 2.4.12.1.2 is calculated to be 5 ft per 100 ft.

The variance in hydraulic gradient results from the use of additional groundwater data collected from the Unit 3 subsurface investigation.

Justification

The variance in hydraulic gradient is acceptable because compliance with 10 CFR 20 is demonstrated in FSAR Section 2.4.13 with the use of the higher hydraulic gradient of 5 ft per 100 ft to evaluate radionuclide concentrations as a result of a postulated accidental release of liquid effluents in the groundwater pathways.

Variance: NAPS ESP VAR 2.0-4 – Vibratory Ground Motion

Request

This is a request to use the Unit 3 horizontal and vertical spectral acceleration (g) values for the ground motion response spectra (GMRS) ~~for Unit 3 defined at the hard rock horizon (with a shear wave velocity of 9200 ft/sec or greater)~~ at the top of a hypothetical outcrop under the reactor building (R/B) complex and power source buildings (PS/Bs rather than ~~at the top of competent rock (Zone III-IV) as in the ESP and SSAR. FSAR Section 2.5.4 discusses the variability of subsurface materials and corresponding shear wave velocities across the Unit 3 site, warranting the re-defining of the GMRS at the hard rock horizon, consistent with the SRP 2.5.2~~ hypothetical rock outcrop control point safe shutdown earthquake (SSE) spectrum at the top of Zone III-IV as presented in the ESP and SSAR. The Unit 3 ~~SSE values at the hard rock horizon~~ values do not fall within (are ~~the same as~~ slightly larger than) the ESP and SSAR values at ~~the hard rock horizon. However, the change in definition for the control point for defining the GMRS is a variance from the ESP Figure 2 and SSAR Figure 2.5-48A~~ frequencies less than 6 Hz for both the horizontal and vertical spectra, as shown in FSAR Tables 2.0-202 and 2.0-203.

~~The variance to change the control point results from the need to use the engineering properties of the subsurface materials above the hard rock horizon to develop the foundation input response spectra (FIRS), as described in FSAR Section 3.7, consistent with the GMRS. As it is now not needed to define the GMRS in FSAR Section 2.5.2, information provided in SSAR Section 2.5.2.5,~~

~~related to seismic analysis of subsurface materials above the hard rock horizon, is moved from SSAR Section 2.5.2 to FSAR Section 3.7.~~

The Unit 3 site-specific horizontal and vertical GMRS at ~~the hard rock horizon at a depth of about 145 feet from finished grade, as described in FSAR Section 2.5.4.7.1.a,~~ Elevation 250 feet (NAVD88) are plotted in FSAR Figure 2.5-201. The corresponding ESP SSE spectra at Elevation 250 feet (NAVD88) are provided in ~~SSAR Figure 2.5-48~~ FSER Supplement 1 (NUREG-1835, Supplement 1), Appendix A, Figure 2, and in SSAR Figure 2.5-48A. ~~The Unit 3 FSAR and ESP/SSAR response spectra are the same, except that the Unit 3 figure provides 38 frequencies while the ESP figure provides 21 frequencies.~~ FSAR Figure 2.0-206 compares the Unit 3 and ESP horizontal response spectra. FSAR Figure 2.0-207 compares the Unit 3 and ESP vertical response spectra. FSAR Tables 2.0-202 and 2.0-203 show that some Unit 3 values below 6 Hz exceed the corresponding ESP values by a small amount. There are 38 frequencies used for the Unit 3 spectra while 21 frequencies were used for the ESP spectra.

This variance in spectral acceleration (g) values results from the use of the additional data from the Unit 3 subsurface investigation which provided the seismic wave transmission characteristics of the materials specifically applied to the Unit 3 Seismic Category I R/B complex and PS/Bs.

The development of the Unit 3 horizontal and vertical spectral acceleration (g) values for the GMRS at a hypothetical outcrop at elevation 250 feet (NAVD88) used the site response analysis program P-SHAKE, rather than SHAKE2000, which was used in the SSAR evaluations. Operating exclusively in the frequency domain, P-SHAKE uses power spectral density functions derived from input rock response spectra in lieu of earthquake time histories matched to those same rock response spectra and then used as input to SHAKE2000 as was done in the SSAR analysis. Simulating the effect of numerous input spectrally-matched time histories, the methodology used in P-SHAKE derives a more robust consideration of the variability of input ground motions, and the resulting smooth output ground motions did not require a post-process fitting function as was used to smooth the ground motions for the top of Zone III-IV SSE in the SSAR analysis.

This variance also includes moving the definition of the operating basis earthquake (OBE) from SSAR Section 2.5.2 to FSAR Section 3.7 in order to facilitate compatibility with OBE instrumentation which records free-field ground motions at grade.

Justification

~~The variance in the GMRS control point location is justified given the additional subsurface information obtained after the SSAR was prepared, as well as the identification and specification of the various Seismic Category I structures above and below the depth of the top of Zone III-IV, a horizon of competent material considered in the SSAR. FSAR Section 2.5.4 discusses notable variability across the Unit 3 site of the shear wave velocities above and below the top of Zone III-IV - e.g., see FSAR Figure 2.5-237. Redefining the GMRS horizon at the hard rock horizon below all Seismic Category I structure foundations not only facilitates consistent definition of input reference~~

~~ground motions for development of the FIRS in FSAR Section 3.7, but is also consistent with the SRP 2.5.2 that specifies that the GMRS be defined on an outcrop or a hypothetical outcrop that will exist after excavation.~~

~~The variance in GMRS control point location is acceptable because the US APWR certified seismic design response spectra (CSDRS) cannot be used for analysis of the seismic design of Unit 3 Seismic Category I structures at higher frequencies. The seismic response at the Unit 3 site has high frequency exceedances of the CSDRS. Due to the spatial variation of the input ground motion, FSAR Section 3.7 provides the results of site specific soil structure interaction (SSI) analyses which consider the incoherence of the input control motion. The site specific SSI analyses use the site specific FIRS which are based on site specific soil properties as input. The suitability of the US APWR standard plant Seismic Category I structures for use at the Unit 3 site is confirmed by the validation analyses which compare the standard plant designs to the site specific seismic loadings. The SSI analyses also demonstrate the seismic design adequacy of the site specific Seismic Category I structures. See FSAR Section 3.7.2 for the results of the site specific SSI analyses.~~

The variance in the Unit 3 horizontal and vertical spectral acceleration (g) values for the ground motion response spectra (GMRS) is justified given the GMRS control point location is changed from the top of competent rock for the SSAR to a hypothetical outcrop under the R/B Complex and PS/Bs for Unit 3. This location is representative of the Unit 3 site for the Seismic Category I structures in the power block area.

The number of frequencies was increased to 38 frequencies based on the minimum number of points specified in the DCD, Regulatory Guide 1.206, and Regulatory Guide 1.208. The SSAR which, presents 21 points, was written before these documents were issued ~~or referenced~~. Therefore, the COLA FSAR was updated to conform to the DCD and existing guidance.

The specification of OBE in SSAR Section 2.5.2.7 is moved to FSAR Section 3.7 because neither the SRP 2.5.2 nor the DCD requests the OBE information to be described in FSAR Section 2.5.2. Further, given that OBE instrumentation is likely to be at a surface location, the definition of the OBE ground motions should consider the site response of possible surface or *at grade* locations, which is not assessed in FSAR Section 2.5.2, but is in FSAR Section 3.7. Therefore, the OBE is defined in FSAR Section 3.7.

Variance: NAPS ESP VAR 2.0-5 – Distribution Coefficients (K_d)

Request

This is a request to use the Unit 3 distribution coefficient (K_d) values provided in FSAR Table 2.4-206 rather than the corresponding values in SSAR Table 1.9-1 and SSAR Table 2.4-20. Some of the values provided in FSAR Table 2.4-206 do not fall within (are