L31567

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AIRBORNE EXPRESS

21G-02-0124
GOV-01-55-04
ACF-02-0088

April 12, 2002

Director
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

References: 1) Docket No. 70-143; SNM License 124
2) Letter from NRC to B.M. Moore, Nuclear Fuel Services, Inc., (TAC NO. L31567) Blended Low-Enriched Uranium Project Environmental Report, Request for Additional Information, dated March 1, 2002
3) Letter from B.M. Moore to NRC, NFS Responses to NRC's Request for Additional Information to Support an Environmental Review for the BLEU Project, dated March 15, 2002 (21G-02-0087)

Subject: Clarification of NFS' Responses to the RAI Supporting NRC's Environmental Review for the BLEU Project

Dear Sir:

Nuclear Fuel Services, Inc. (NFS) hereby submits information to clarify certain NFS responses to the Nuclear Regulatory Commission's (NRC) March 1, 2002, Request for Additional Information (RAI) (Reference 2). A few of the NFS responses (Reference 3) were identified during a teleconference held on April 1, 2002, as needing further clarification to complete the NRC's ongoing Environmental Assessment (EA) for the Blended Low-Enriched Uranium (BLEU) Project. Following this teleconference, a list of the specific issues that required clarification was received via facsimile from your staff. In addition, further information was requested during a telephone discussion on April 2, 2002 between M.T. Adams (NRC) and J.S. Kirk (NFS) to support completion of this EA. NFS is providing the attached information to address each of these requests.

Also, please find enclosed (Attachment V) a letter to NFS from the Tennessee Department of Environment and Conservation, Tennessee Historical Commission, which states that no National Register of Historic Places listed or eligible properties will be affected by the BLEU Project. NFS is

NMSS01 Public

providing this information to fulfill commitments specified in response to Comment No. 17 of Reference 3.

NFS appreciates the progress made thus far by your staff and the Center for Nuclear Waste Regulatory Analysis to complete this phase of the BLEU Project.

If you or your staff have any questions, require additional information, or wish to discuss this, please contact me, or Mr. Rik Droke, Licensing and Compliance Director at (423) 743-1741. Please reference our unique document identification number (21G-02-0124) in any correspondence concerning this letter.

Sincerely,

NUCLEAR FUEL SERVICES, INC.

B. Marie Moore

B. Marie Moore
Vice President
Safety and Regulatory

JSK/lsn

cc:
Regional Administrator
U.S. Nuclear Regulatory Commission
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Mr. William Gloersen
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Mr. Dan Rich
Senior Resident Inspector
U.S. Nuclear Regulatory Commission

Attachment I

Clarification of NFS' Responses to the Request for Additional Information Supporting NRC's Environmental Review for the BLEU Project

(4 pages to follow)

NRC Comment 1: (RAI 7b) Some existing wells are missing from the current chart of groundwater monitoring wells. Even though NFS will propose new monitoring locations in the future (post EA), for the EA we requested an updated chart with the correct information. They [NFS] agreed to provide.

NFS Response to Comment 1: Attachment V of the RAI Responses[1] provided a drawing that depicted monitoring wells locations at the NFS site including the BLEU Complex. There had been two wells, SC-7 and 82, on the land for the BLEU Complex. They were abandoned in August 2001 and, thus, were not included on the drawing. This drawing has been amended to show the former locations for wells SC-7 and 82 and is Attachment II of this submittal.

NRC Comment 2: (RAI 9) NFS did not provide an update of the environmental monitoring program table (4.5), presumably because they have not made any changes since the renewal EA. NFS will provide clarification if the information in Table 4.5 of the renewal EA is still current or provide an updated table if not.

NFS Response to Comment 2: The only change to Table 4.5 of the license renewal environmental assessment[2] (EA) is a decrease in the number of sampling stations for groundwater. The license renewal EA indicates 16 wells are routinely monitored; the current NRC License SNM-124 indicates 11 wells are required to be routinely monitored. If additional detail is needed on the environmental monitoring program, Chapter 5 of NRC License SNM-124 provides details on the current program at NFS.

NRC Comment 3: (RAI 21) Information on the hydrology at the proposed BLEU Complex location that was discussed during the last meeting was not included in the RAI package. This includes zone depths, water levels, brief info generally describing that a baseline characterization would be done. NFS agreed to provide.

NFS Response to Comment 3: Attachment III of this submittal provides boring logs, well installation diagrams, and water level data for wells SC-7 and 82 that were located on the proposed BLEU Complex site. A description of the baseline characterization is provided in the response to Comment 5.

NRC Comment 4: (RAI 27b) NFS response provided soil sampling results for one sampling period but text of the response describes 3 sampling periods. Just asked for clarification which sampling period results was the table referring to and whether results were before or after remediation. NFS agreed to clarify.

NFS Response to Comment 4: Attachment IV of the RAI Responses[1] was titled "ISA Source Term Data and Radioactive Effluent Estimates for the TVA Project". Attachment

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[1] Nuclear Fuel Services, Inc., "NFS Responses to NRC's Request for Additional Information to Support an Environmental Review for the BLEU Project," Docket 70-143, March 15, 2002.

[2] U.S. Nuclear Regulatory Commission, "Finding of No Significant Impact and Environmental Assessment (TAC No. L30873)," Docket No. 70-143, January 29, 1999.

J of that document includes a table titled "Summary of NFS Ball Field Soil Sample Results Associated with Transmittal Letter EAS-01-119". Data presented in the table were collected on November 16, 2001, after remediation of the northwest corner of the site was complete. The data represent the final and current status of the excavated area.

NRC Comment 5: (RAI 27d) Requested the text describing the construction worker dose scenario from the North Site decommissioning since no information was provided and the reference could not be located. NFS agreed to provide the pages. We asked for additional clarification on the "sum of fractions" statements in the NFS response that were used in place of actual soil concentrations. NFS agreed to clarify. I also indicated that NFS' "additional characterization" of the contaminated construction site area need not be more detailed than that necessary to ensure compliance with worker protection requirements in 10 CFR Part 20 (i.e. they should do what they would normally do in accordance with their procedures/ Part 20).

NFS Response to Comment 5: Additional information on the dose calculation for the Construction Worker scenario and the associated RESRAD inputs is provided as Attachment IV of this submittal.

The sum-of-fractions (SOFs) described in NFS Response No. 27 (d) were calculated using derived concentration guideline levels (DCGLs) based on a Construction Worker land-use scenario at 25 mrem per year. The DCGLs are presented in the NFS document titled "Potential Dose Due to Radiological Contaminants in North Site Soil and Groundwater" (Appendix D, page D-327)[3].

As discussed in the teleconference, NFS will collect additional characterization data at the proposed BLEU Complex site. These data will come from a complete gamma scan to identify any radionuclide contamination that could result in a total effective dose equivalent to an individual member of the public exceeding 100 mrem per year (per 10 CFR 20.1301 (a) (1)).

As part of the baseline characterization, three monitoring wells will be installed, one at an upgradient location and two at downgradient locations. Soil samples will be obtained at various depths during well drilling. One sample from each boring will be analyzed for chemical and radiological constituents. After the wells are installed, groundwater samples will be obtained and analyzed for gross alpha/gross beta and gamma isotopic analysis.

NRC Comment 6: (RAI 27e) Asked NFS to clarify their statements regarding the contaminated construction area as not being considered a "radiation control area." While Part 20 defines "radiation area", "restricted area" and "controlled area" there is no definition for "radiation control area". NFS was asked to clarify what they mean

[3] The NRC reviewed the radiological dose assessment developed in support of the North Site Decommissioning Plan, which was subsequently approved as Amendment 27 to NRC License SNM-124 on June 19, 2000.

by the statement and to use the terms in Part 20 to be clear. NFS was informed that construction workers should be trained/informed of existing contamination/radiation safety pursuant to the requirements in 10 CFR Part 19 which NRC generally applies to all restricted areas.

NFS Response to Comment 6: The location where the BLEU Complex will be constructed is currently classified as an "Unrestricted Area" as defined in 10 CFR 20.1003. Radiation exposures to members of the general public are limited by NFS to levels significantly less than 100 millirem per year at this location and all other "unrestricted areas" of the site, in accordance with 10 CFR 20.1301 and Chapter 1, Section 1.7.18 of NRC License SNM-124. Based on a recent radiological assessment performed specifically for construction activities at the BLEU Complex site, the annual radiation effective dose to workers performing these types of activities will be less than 3 millirem per year.

This dose assessment was based on information (i.e., dose-to-source ratios for a construction worker) contained in the report titled "Potential Dose Due to Radiological Contaminants in North Site Soil and Groundwater" that supported the North Site Decommissioning Plan[3]. Radiological exposures pathways that were evaluated for this critical group include external radiation sources, soil ingestion, and inhalation associated with activities of construction workers at the BLEU Complex site. Attachment IV of this submittal contains a narrative summary of this radiological dose assessment that was reviewed by the NRC in support of the North Site Decommissioning Plan.

Individuals that may occupy land areas during construction of the BLEU Complex will not be exposed to radiation sources at levels exceeding 10 CFR 20.1301 "Dose Limits for Individual Members of the Public". Therefore, employing additional radiation protection measures, including those specified in 10 CFR 19.12 "Instruction to Workers", during the construction phase of this project is not necessary.

NRC Comment 7: Surface water data were not provided for 1996-1997. The former license renewal assessment Table 4-5 goes from 1990-1995 and the RAI Responses provide 1998-2001 data. Provide surface water data for 1996 and 1997.

NFS Response to Comment 7: The requested data are being provided in the updated table below. During further review of the data, the value previously presented for 2001 surface water (17.12 pCi/l) is actually 17.19 pCi/l which is the value stated in the updated table.

Table 1:
Environmental monitoring for gross alpha emitters in downstream surface water samples and stream sediment samples

Onsite		
WS-2 Banner Spring Branch		
Year	Surface Water (pCi/L)[a]	Sediment (pCi/g)[b]
1996	15.70	36.76
1997	17.52	NA
1998	22.25	92.0
1999	13.14	95.9
2000	15.43	60.70
2001	17.19	55.10

a. Average of monthly composite results
b. Average of quarterly samples
NA – Gross alpha for sediment was not analyzed in 1997.
Note: Gross alpha data presented in Table 24 of the Supplemental Environmental Report was derived from isotopic analysis with exception of year 2000.

Source: Nuclear Fuel Services, Inc. Environmental Database Management System, 3/06/02

NRC Comment 8: Banner Spring Branch Sediment data provided on Page 23 of the RAI Response show different values for 1998 and 1999 when compared with a similar table in the Supplemental Environmental Report Table 24; however, there is agreement between the RAI Response and Table 24 of the Supplemental Environmental Report for some data in year 2000. The difference is only about 10 pCi/g, but it's possible that the data were not summarized the same way (perhaps different averaging approach).

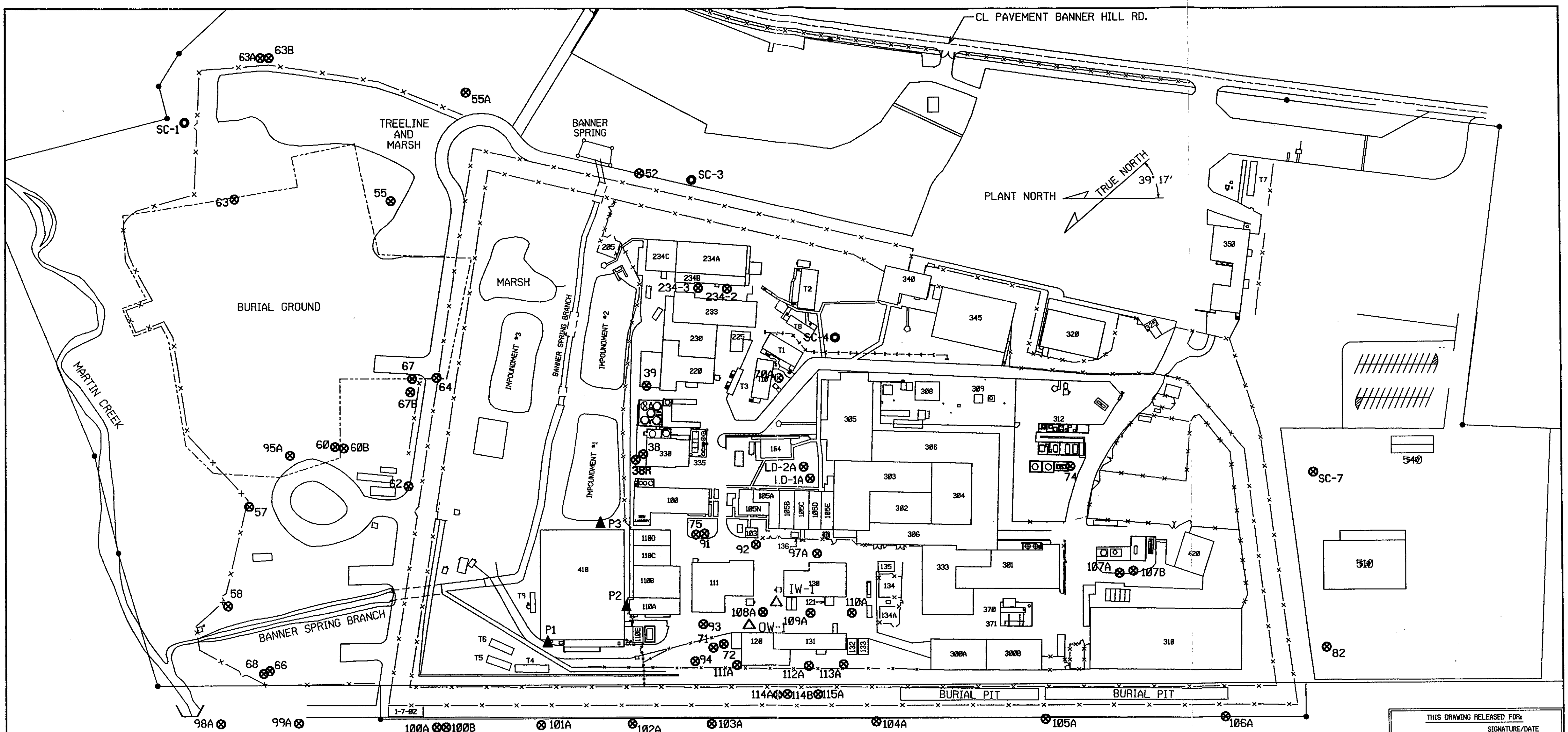
NFS Response to Comment 8: The data in Table 24 of the Supplemental Environmental Report[4] are gross alpha values derived from isotopic results. The data provided on page 23 of the RAI Responses[1] are the results from actual gross alpha analysis. In 2000, isotopic analysis of sediment was discontinued and gross alpha results are now used.

[4] Nuclear Fuel Services, Inc., "Supplemental Environmental Report for Licensing Actions to Support the BLEU Project," Docket 70-143, November 9, 2001.

Attachment II

Updated Drawing Including Locations for Former Wells SC-7 and 82

(1 page to follow)



THIS DRAWING RELEASED FOR:

SIGNATURE/DATE

WR# ____________

PR# ____________

☐ CONSTRUCTION

☐ INFORMATION ONLY

☐ BID

☐ PURCHASE/FAB

LEGEND

⊗ - MONITORING WELL LOCATION

○ - PIEZOMETER LOCATION

▲ - POND 4 PIEZOMETER LOCATION

△ - INJECTION WELL AND OBSERVATION WELL LOCATION

BY	DATE	REVISION	LET
		ADDED WELLS SC-7 & 82 NEAR BLDG. 510	A
WGH JG	2-20-02	ORIGINAL ISSUE	—

TOLERANCE UNLESS SPECIFIED

FRACTIONAL ± 1/64″

ANGULAR ± 1/2°

DECIMAL

XX ± .01

XXX ± .001

NFS

REVIEWED BY

PROPOSED COMPLETION DATE: 6-5-03

DRAFTER WG HENSLEY

PROPOSED APPROVALS

REQ.

DRAFTER

AS-BUILT APPROVALS

REQ.

OWNER

NUCLEAR FUEL SERVICES, INC.

ERWIN, TENNESSEE

MONITORING WELL AND PIEZOMETER LOCATIONS WITH PROPOSED BLEU FACILITY

SCALE 1″= 150′

DATE 4-2-02

DRAWING NO. 000-C0281-B1

CONFIGURATION CONTROL YES ________ NO ☒

Attachment III

Boring Logs, Well Installation Diagrams, and Water Level Data For Former Wells SC-7 and 82

(11 pages to follow)

Nuclear Fuel Services, Inc.
Well SC-7
Monitoring Well

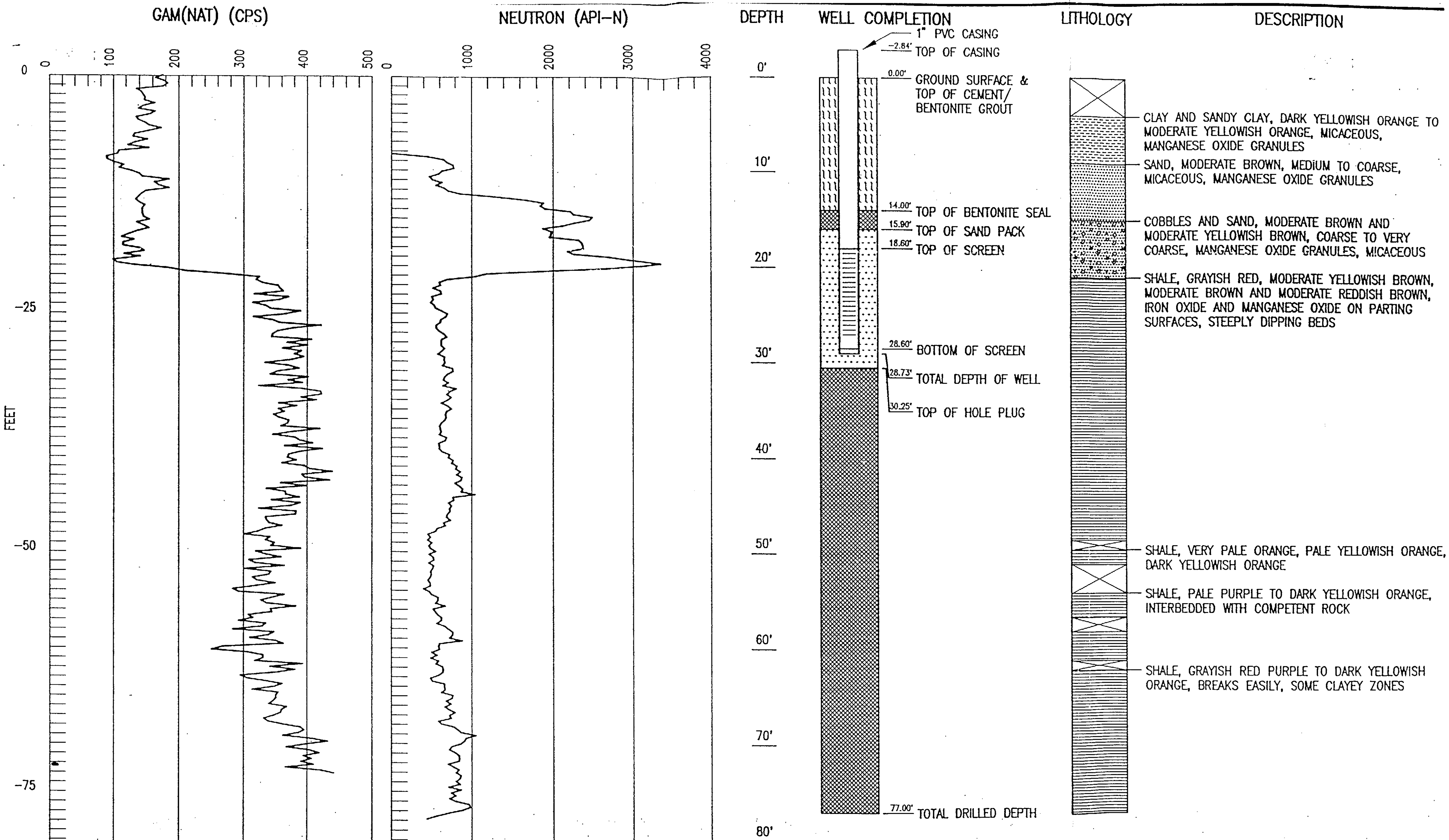
Coordinates: Northing / Easting

Ground Elevation: 1653.33 feet
Total Hole Depth: 77 feet

NFS Site Grid: Northing / Easting

Sampling Technique: Drill Rig
Drilling Method: Fluid Rotary/Wireline
Drilling Diameter: inches

Interval Type	Lithology Code and Description	Depth Range (Start - End)
Alluvium	SC - Clayey sands, poorly graded sand-clay mixtures	5 - 10
Alluvium	SP - Poorly graded sands, gravelly sands; little or no fines	10 - 15
Alluvium	CB - Cobbles	15 - 20
Bedrock	SH - Shale	20 - 77



SC-7

EcoTek	ECOTEK, INC. 1219 BANNER HILL ROAD ERWIN, TENNESSEE 37650			
NFS 1992/1993 DRILLING PROGRAM				
VERT. SCALE	DATE	JOB NO.	DRAWING NO.	SHEET
1" = 10'-0"	6-11-93	NFS027	NFSG037	1 OF 1

Potentiometric Surface Map
Source Data for Well SC-7
Reference Elevation 1656.43

Date	Depth to Water	Groundwater Elevation
January-94	No collection for this quarter.	
February-94	21.99	1634.44
March-94	20.61	1635.82
April-94	19.54	1636.89
May-94	19.32	1637.11
June-94	20.66	1635.77
July-94	21.74	1634.69
August-94	21.81	1634.62
September-94	21.46	1634.97
October-94	22.55	1633.88
November-94	23.2	1633.23
December-94	23.7	1632.73
January-95	23.94	1632.49
February-95	22.01	1634.42
March-95	20.9	1635.53
April-95	21.04	1635.39
May-95	22.2	1634.23
June-95	21.9	1634.53
July-95	21.82	1634.61
August-95	21.9	1634.53
September-95	22.74	1633.69
October-95	23.2	1633.23
November-95	23.1	1633.33
December-95	22.48	1633.95
January-96	21.66	1634.77
February-96	20.06	1636.37
March-96	19.71	1636.72
April-96	20.53	1635.9
May-96	20.88	1635.55
June-96	21.02	1635.41
July-96	21.9	1634.53
August-96	21.66	1634.77
September-96	22.88	1633.55
October-96	22.46	1633.97
November-96	23.3	1633.13
December-96	21.82	1634.61
January-97	21.22	1635.21
February-97	21.7	1634.73
March-97	19.9	1636.53
April-97	19.36	1637.07
May-97	19.88	1636.55
June-97	20.5	1635.93

Potentiometric Surface Map
Source Data for Well SC-7
Reference Elevation 1656.43

Date	Depth to Water	Groundwater Elevation
July-97	21.68	1634.75
August-97	22.28	1634.15
September-97	23.18	1633.25
October-97	23.52	1632.91
November-97	23.46	1632.97
December-97	23.77	1632.66
January-98	21.76	1634.67
June-98	19.96	1636.47
September-98	22.4	1634.03
November-98	23.76	1632.67
March-99	22.34	1634.09
June-99	No collection for this quarter.	
September-99	23.18	1633.25
December-99	24.24	1632.19
March-00	21.98	1634.45
June-00	22.38	1634.05
September-00	22.38	1634.05
December-00	24.58	1631.85
March-01	22.2	1634.23
June-01	23.46	1632.97
September-01	No collection for this quarter.	

Nuclear Fuel Services, Inc.
Well 82
Monitoring Well

Coordinates: 651596.8185 Northing
3053093.0098 Easting

Ground Elevation: 1653.73 feet
Total Hole Depth: 113 feet
Sampling Technique: Drill Rig
Drilling Method: Air Rotary
Drilling Diameter: 6 inches

NFS Site Grid: 150.1 Northing
102.9 Easting

Interval Type	Lithology Code and Description	Depth Range (Start - End)
Alluvium	CL - Inorganic clays of low to medium plasticity	0 - 16
Alluvium	GP - Poorly graded gravels, gravel-sand mixtures; little or no fines	16 - 18
Bedrock	SS - Sandstone	18 - 21
Bedrock	SH - Shale	21 - 113

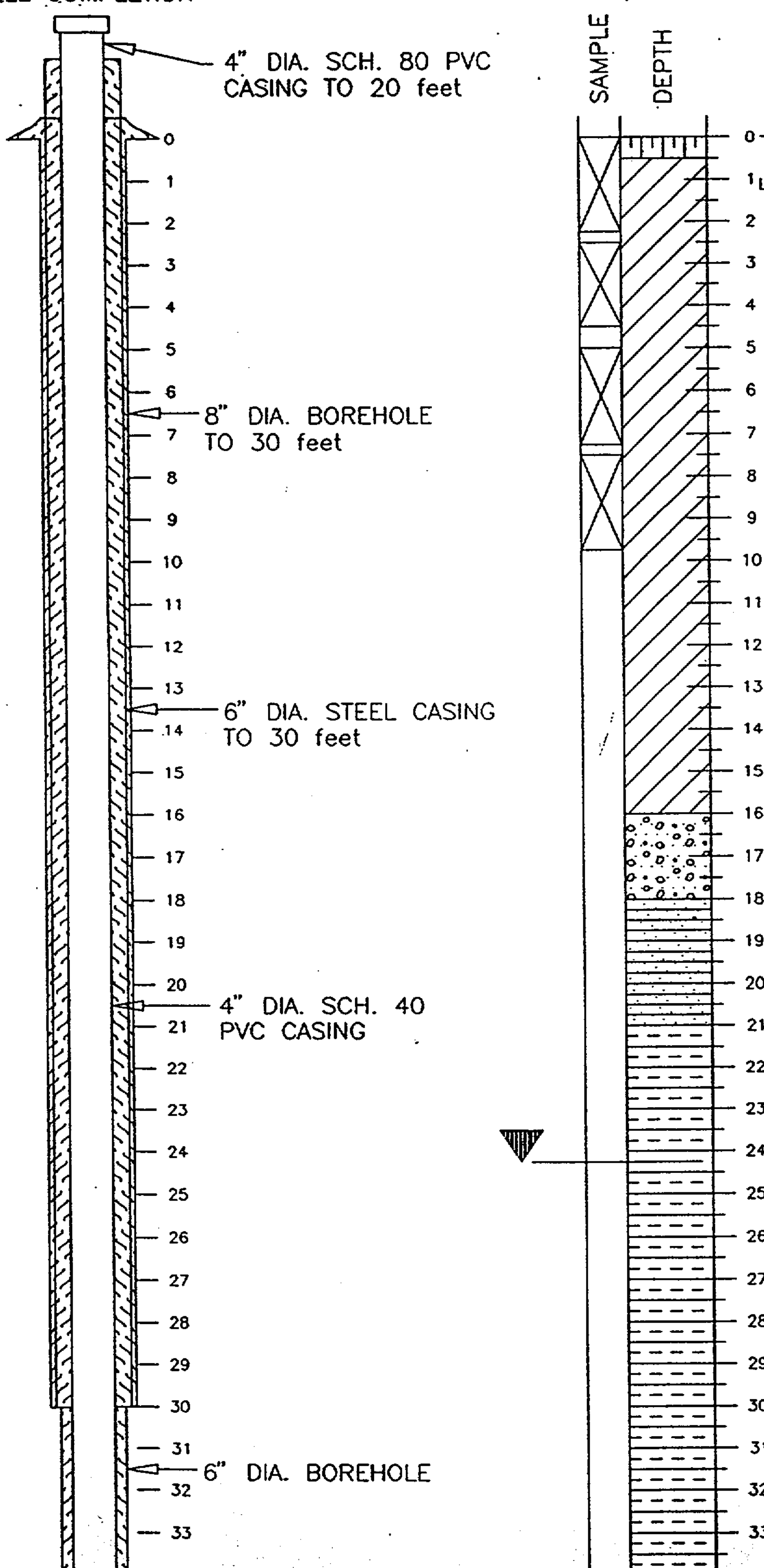
LOG OF BORING

Figure A–33a

Well Number: 82
Date: 7/6–8/88
Equipment: AIR ROTARY

TOC Elevation: 1657.12
Ground Elevation: 1653.50
Page Number: 1 OF 4

WELL COMPLETION



0 – BROWN–ORANGE ORGANIC SILTY CLAY
dry

1 – ORANGE–BROWN SILTY CLAY
dry, some sand and trace gravel

16 – GRAY SANDY GRAVEL
dry, limonite stain

18 – GRAY SANDSTONE
medium grain, some feldspar

21 – TAN AND WHITE SHALE
occasional thin limestone lenses,
some purple layers

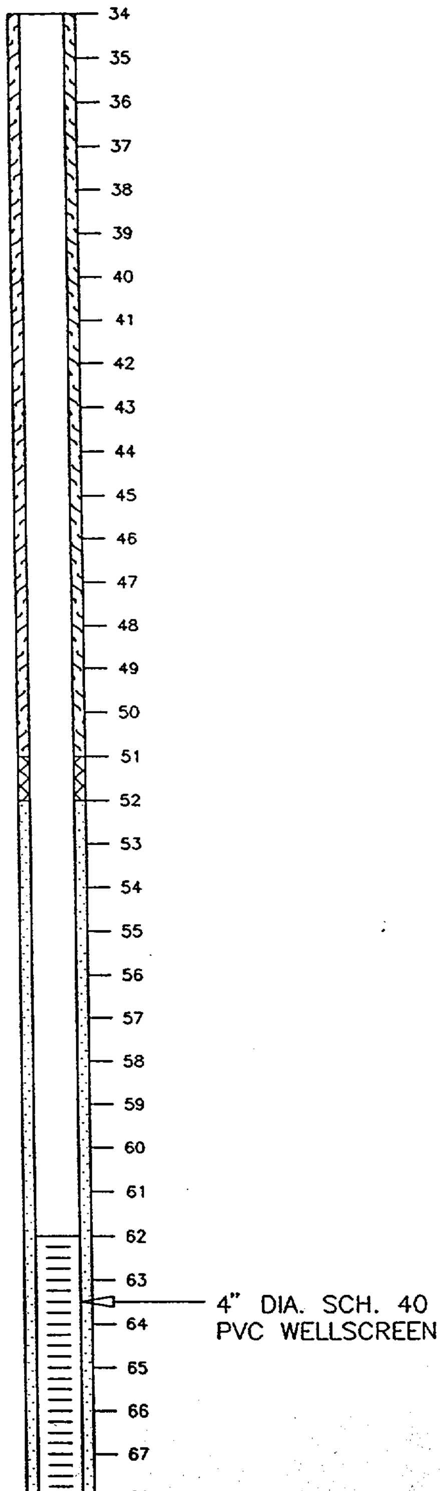
30 – tan and purple below 30 feet
very competent

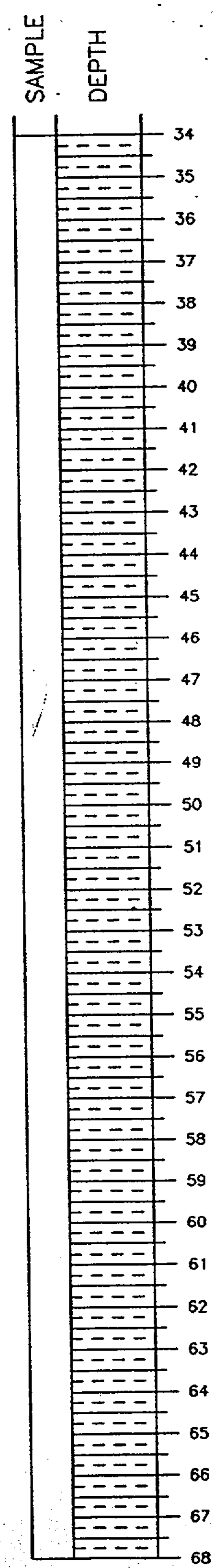
CONT. ON NEXT PAGE

LOG OF BORING

Figure A–33b

Well Number	82	TOC Elevation	1657.12
Date	7/6–8/88	Ground Elevation	1653.50
Equipment	AIR ROTARY	Page Number	2 OF 4





dark brown, gray and tan below 67 feet

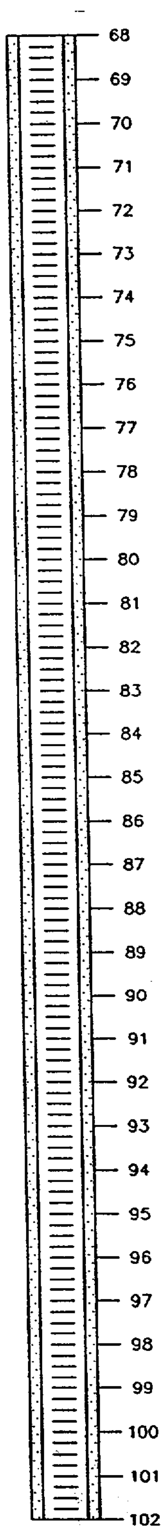
CONT. ON NEXT PAGE

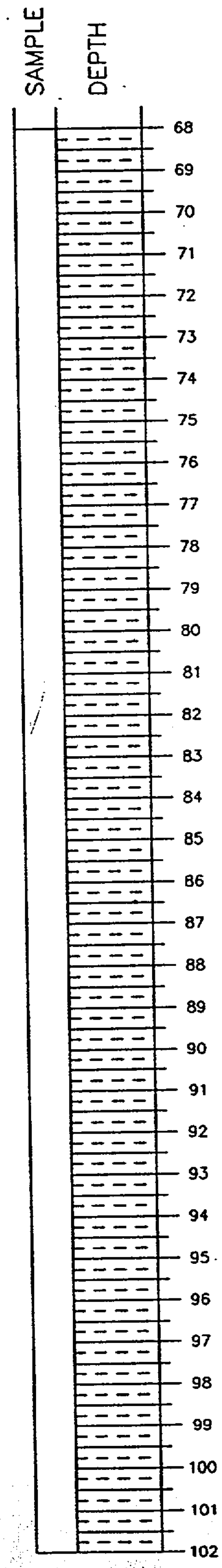
LOG OF BORING

Figure A–33c

Well Number 82
Date 7/6–8/88
Equipment AIR ROTARY JRW

TOC Elevation 1657.12
Ground Elevation 1653.50
Page Number 3 OF 4





major fractures below 82 feet

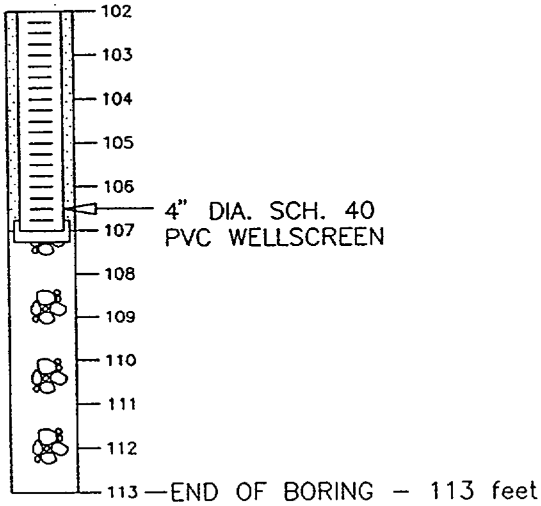
CONT. ON NEXT PAGE

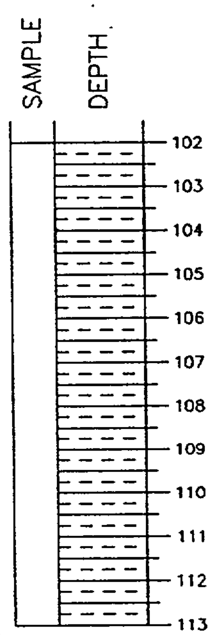
LOG OF BORING

Figure A–33d

Well Number	82	TOC Elevation	1657.12
Date	7/6–8/88	Ground Elevation	1653.50
Equipment	AIR ROTARY	Page Number	4 OF 4

JRW





Potentiometric Surface Map
Source Data for Well 82
Reference Elevation 1657.13

Date	Depth to Water	Groundwater Elevation
January-94	26.66	1630.47
February-94	25.71	1631.42
March-94	24.77	1632.36
April-94	23.25	1633.88
May-94	23.84	1633.29
June-94	25.38	1631.75
July-94	25.87	1631.26
August-94	26.05	1631.08
September-94	25.92	1631.21
October-94	26.84	1630.29
November-94	26.92	1630.21
December-94	27.04	1630.09
January-95	27.28	1629.85
February-95	25.73	1631.4
March-95	24.88	1632.25
April-95	25.43	1631.7
May-95	26.1	1631.03
June-95	25.98	1631.15
July-95	24.81	1632.32
August-95	26.17	1630.96
September-95	26.62	1630.51
October-95	26.9	1630.23
November-95	26.7	1630.43
December-95	26.04	1631.09
January-96	25.86	1631.27
February-96	24	1633.13
March-96	24.55	1632.58
April-96	25.1	1632.03
May-96	25.16	1631.97
June-96	25.5	1631.63
July-96	26.1	1631.03
August-96	20.88	1636.25
September-96	25.84	1631.29
October-96	26.26	1630.87
November-96	27.08	1630.05
December-96	25.6	1631.53
January-97	25.26	1631.87
February-97	25.2	1631.93
March-97	24.16	1632.97
April-97	19.7	1637.43
May-97	24.52	1632.61
June-97	25.2	1631.93

Potentiometric Surface Map
Source Data for Well 82
Reference Elevation 1657.13

Date	Depth to Water	Groundwater Elevation
July-97	26.06	1631.07
August-97	26.2	1630.93
September-97	27	1630.13
October-97	22.52	1634.61
November-97	27	1630.13
December-97	26.92	1630.21
January-98	25.44	1631.69
June-98	24.64	1632.49
September-98	26.56	1630.57
November-98	27.03	1630.1
March-99	26.04	1631.09
June-99	No collection for this quarter.	
September-99	26.72	1630.41
December-99	27.02	1630.11
March-00	25.86	1631.27
June-00	26.28	1630.85
September-00	26.54	1630.59
December-00	27.4	1629.73
March-01	25.4	1631.73
June-01	26.56	1630.57
September-01	No collection for this quarter.	

Attachment IV

Additional Information on the Dose Calculation for Construction Worker Scenario and RESRAD Inputs

(29 pages to follow)

1. INTRODUCTION

To support decommissioning of the northern portion of the Erwin, TN plant site (Figure 1, Appendix A), Nuclear Fuel Services, Inc. (NFS) conducted a study to determine the potential dose from radioactive contaminants in soil and groundwater. This study included a pathways analysis to determine the potential uptake and exposure to site contaminants. The study provides dose-to-source factors for use in developing site specific release criteria for residual radioactivity in soil and justification for excluding the groundwater pathway as a route of exposure.

1.1. Purpose

The purpose of this assessment was to determine site specific dose-to-source factors and estimate the potential dose to site inhabitants/users based on the current level of contamination in soil and groundwater.

1.2. Scope

This document discusses the development of site specific dose-to-source factors for radioactive contaminants in soil and groundwater at the NFS north plant site. The methods used to model the site and identify the critical groups and applicable exposure pathways are described. Dose-to-source factors were applied to site characterization results to estimate the potential dose due to radioactive contaminants in soil. Similarly, the methods used to develop dose-to-source factors for radioactive contaminants in groundwater are described. These factors were applied to site characterization data and groundwater modeling results to determine the potential dose due to the use of contaminated groundwater.

This evaluation used existing characteristics of soil and contaminants at the site and is applicable for NFS' preferred soil remediation option (remove and dispose). Other remediation options which may alter soil characteristics would require additional evaluation (e.g., soil washing).

The potential dose that may occur from exposure to materials in the burial trenches was not evaluated. NFS is currently excavating the contaminated soil, waste, and debris from the North Site Burial Ground.

1.3. Objectives

The objectives of this study were to:

1. identify the most probable future uses of the NFS North Site by evaluating local area development trends and plans and assessing existing and anticipated sources of drinking water,

2. define the average member of the critical group for applicable land-use scenarios,

3. describe the modeling methods used to evaluate potential exposure to site contaminants,

4. discuss the routes of exposure (pathways) and the inputs to the modeling code which apply to the various land-use scenarios;

5. determine site specific dose-to-source factors for radioactive contaminants in soil and groundwater, and

6. determine the potential dose to site inhabitants/users based on the current level of radioactive contamination found in soil and water on the north NFS site.

2. LOCAL SITE/AREA INFORMATION

Local land uses, development trends, and existing and anticipated sources of drinking water were evaluated to develop scenarios which are appropriate for NFS' North Site. The probability of a farm being erected on the north plant site was specifically evaluated although it was ruled at as being an appropriate land use scenario. The potential for exhumation of contaminated soil was assessed in order to evaluate dose due to residual contaminants in subsurface soil.

2.1. Area Farming and Development Trends

The industry which became NFS was established in 1957 on land previously utilized for farming and was incorporated into the Town of Erwin in Unicoi County in the late 1980's. Erwin (population approximately 5,600) currently encompasses a land area of roughly 2.8 square miles while Unicoi County (population approximately 17,200) encompasses roughly 186 square miles. Forty-seven percent of Unicoi County is national forest which limits the amount of land available for development. The number of households in Unicoi County has increased 345% from 1950 to 1990[4]. During the same time period, the number of farms in Unicoi County has decreased approximately 78% from 1945 to 1992[5]. The number of farming acres has decreased 72% during this time. A summary of local census data assessing agricultural trends from 1940 to 1996 is presented in Table 1.

[4] U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census. *County and City Data Books*. 1950-1990.

[5] U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census. *Census of Agriculture*. 1945-1992.

Table 1. Population and Agricultural Census Data for Unicoi and Washington Counties

Unicoi County								
Year	Number of Households	Percent Change	Year	Number of Farms	Percent Change	Year	Acres of Land in Farms	Percent Change
1950	1487	+345	1945	1,068	-78	1945	41,106	-72
1990	6,621		1992	237		1992	11,292	
Washington County								
Year	Number of Households	Percent Change	Year	Number of Farms	Percent Change	Year	Acres of Land in Farms	Percent Change
1950	14,993	+138	1945	3,975	-53	1945	175,843	-33
1996	35,823		1992	1,858		1992	117,808	

Land use trends within a 50 square mile radius of the NFS site were considered to determine the most applicable land use scenario. Unicoi County and Washington County are the only counties which fall within the 50 square mile radius. Land use and population trends for Washington County are similar to Unicoi County. In Washington County, the number of households has increased 138% from 1950 to 1990. During the same time period, the number of farms in Washington County has decreased 53% from 1945 to 1992. The number of farming acres has also decreased 33% during this time.

Within just the past three years, several new industries such as Studsvik, Inc., Georgia Pacific, Inc., and Erwin Modular Structures, Inc. have established themselves in the industrial zoned area where NFS is located. The development trends at NFS' plant site and surrounding area over the past ~40 years are evident in aerial photos taken in 1953 and 1990 (Figures 2 and 3, Appendix A).

Development trends in Unicoi County are also reflected in census data for the Town of Erwin. According to 1990 census information, Erwin had 19 households out of 2,118 whose main income was due to farming. This may be due to the proximity of several farms in the county which employ Erwin residents. As part of the same census, there were 13 Erwin residents out of 2,062 employed residents who had occupations in the farming, forestry, and fishing category. This category is believed to consist primarily of individuals employed by the two fish hatcheries in Erwin (7 employees)[6], support personnel for the national forest (10 employees)[7], and State wildlife management personnel (2 employees)[7]. In any case, the information for household

[6]Personal communication between Greg Chapman (NFS) and Frank Higgins (Tennessee State Fish Hatchery in Erwin) regarding number of employees in the fishing/wildlife industry in Erwin. May 16, 1996.

[7]Personal communication between Greg Chapman (NFS) and Olan Mason (District Ranger) regarding number of employees in the forestry industry in Erwin. May 16, 1996.

income and occupations in Erwin indicate that less than 1 percent of Erwin residents are involved in farming activities.

NFS staff visually surveyed the Erwin area and determined that there were few areas where farming activities (i.e., raising crops and livestock for consumption and/or sale and excluding small gardens) could occur within the town limits. Several hay/livestock fields (greater than five acres in size) were identified at the perimeter of the city limits; however, these fields are generally adjoining industrialized or suburban areas and will likely be incorporated into these developed areas in the future. The typical lot size in Erwin is approximately 100' by 150'[8] which is not large enough to support farming activities such as raising crops and livestock. During the visual survey, it was noted that there are many residences with small vegetable gardens in Erwin.

Mr. Kenneth Miller, a Regional Planning Commissioner, was contacted for his views on future development of the NFS plant site. He indicated that the most likely future development of the NFS property would be for industrial use[9]. This agrees with current zoning of the area and Town of Erwin plans[10]. However, a significant portion of the north plant site is within a 100 year floodplain and industrial (or residential) development of this portion of the property may be limited unless fill is brought to the site to raise grade above the floodplain.

The other development options Mr. Miller discussed were to use some of the NFS property for residences and/or to convert that portion of the site located in the floodplain into a public park similar to the park existing in north Erwin. Mr. Miller elaborated that some areas of the NFS site adjacent to existing residences may be used for residential development. Areas adjacent to Banner Hill Road may be used for commercial development, and areas adjacent to industrial areas of the plant site or the industrial park would most likely continue to be used for industry. The use of the North Site as a public park is a reasonable option because of the lack of recreational facilities on the south side of Erwin and because the natural beauty of the area with creeks and spring enhance the area's development potential. Also, there should be minimal impact to the facilities if the area were to flood.

NFS' staff contends that current trends for land use in the Erwin/Unicoi area where NFS is located is toward industrial or suburban development. Because the likelihood of a farm being built on the NFS site is minimal, the residential scenario that is most appropriate for the NFS site

[8]Personal communication between Shannon Dechert (NFS) and Bill Gaines (Assessor of Properties for Unicoi County) regarding local demographic data. April 12, 1996.

[9]Personal communication between Shannon Dechert (NFS) and Kenneth Miller (Regional Planning Commission) regarding potential future uses of the NFS plant site. April 12, 1996.

[10]Personal communication between Michelle Nichols (NFS) and Doris Hensley, City Recorder (Town of Erwin). August 1996.

reflects a typical residence within the town limits of Erwin. One other potential use for the North Site which appears likely is as a recreational park.

2.2. Potential Groundwater Use

Potential sources of drinking water identified by NFS include municipal utilities, surface water bodies on, or convenient to, the North Site, and domestic wells. Assessing the probable water supply sources involved identification of: 1) available drinking water sources; 2) enforceable local and state regulations concerning municipal and domestic water supply sources; 3) civil engineering and well installation practices; 4) costs for well installation; and 5) hydrogeological characterization data. It was concluded from this assessment that the most likely source of water for a future site occupant would be from municipal utilities. The probability of installing a domestic well into groundwater in the unconsolidated sediments underlying the North Site (where the majority of groundwater contaminants are present) is minimal considering the availability of city water. Table 2 presents a summary of the technical basis and the dose-based consequences of using each drinking water source evaluated.

2.2.1. Municipal Water Supply Sources

Under normal conditions, it is most probable that any new residence or business would utilize municipal utilities because existing water and sewer lines installed for NFS run through the north plant site and would be available for new development. This expectation is supported by a local ordinance (Title 13, Erwin Municipal Code) that requires connection of all industries and residences to the municipal sewer system; because an inlet water meter is generally used to determine sewer usage, a water service connection is implied.

Assuming practices at NFS are typical of industry, use of municipal utilities is expected should the site be developed for industry. The NFS plant obtains drinking and most of its process water from Erwin Utilities, a public water supply system. Also, a recent comparison of costs for municipal versus private water supply for Hoover Ball, Inc., a nearby industry, indicated that use of the public water supply was less expensive[11]. The most recent industry to locate in the adjacent industrial park included the availability of city water as a prerequisite.

[11]Personal communication between Sarah Barron (NFS) and Scott Street (Erwin Utilities). January, 1996.

Table 2. Impact of Using Various Drinking Supply Sources

Drinking Water Supply Source	Technical Basis: Supporting Basis	Technical Basis: Opposing Basis	Predicted Dose
Municipal Sources	• Utilities present at the Site • Common Practice • Economical • City Ordinance	• Subjective Bias	~0 mrem/y
Banner Spring	• Previously Used • On-site Location • No Treatment Required	• Municipal Supply Available	~0 mrem/y
Other Surface Water Sources	• Sufficient Yield • Location • Availability	• Requires Treatment	~3 mrem/y maximum
Domestic Well: Deep Groundwater Source	• Sufficient Yield • Water Quality Acceptable	• Municipal/Surface Water Sources Available • Cost • Majority of North Site located in the Flood Plain	~0 mrem/y maximum*
Domestic Well: Shallow Bedrock Source	• Groundwater present	• Municipal/Surface Water Sources Available • Cost • Majority of North Site located in the Flood Plain • Mud seams present • Good Civil Engineering Practices Would Tap Other Sources	5 to 23 mrem/y at 1% of North Site* 0 mrem/y for the remaining 99% of North Site
Domestic Well: Unconsolidated Sediments	• Sufficient Yield	• Other Sources Available • Cost • Requires Treatment • Uncommon in Region • Good Civil Engineering Practices Would Tap Other Sources • State Regulations • Majority of North Site located in the Floor Plain	62 to 157 mrem/y at 3% of North Site* 0.02 to 62 mrem/y for the remaining 97% of the North Site

* Predicted dose based on fate and transport modeling described in Sections 4 and 5.

Six public supply wells were identified within a five mile radius of the NFS site through review of well drilling and groundwater withdrawal records obtained from Erwin Utilities and the United States Geological Survey (USGS) water supply publications[12]. All were bedrock wells

[12] Geraghty & Miller, Inc. Table 2-1. *Final Project Report Groundwater Flow and Constituent Transport Modeling at the Nuclear Fuel Services Facility Erwin, Tennessee.* April 25, 1996.

with an average depth of 332 feet below grade and ranging from 240 feet to 606 feet below grade. Groundwater contaminants underlying NFS' north site primarily occur in the unconsolidated sediments which typically range from 0' to ~29' below land surface.

In April 1996, Geraghty and Miller, Inc., completed a groundwater modeling project for the NFS site[12]. One modeling objective was to predict uranium concentrations and transport in groundwater over the next 1,000 years. It was found that the extent of predicted contamination did not encroach on the capture zone of the nearest Erwin Utilities production well even after 1,000 years of migration from the site. It can be concluded that contaminants in groundwater underlying the North Site will not impact the quality of existing municipal supply wells.

2.2.2. Surface Water Supply Sources

Use of surface water bodies to obtain drinking water is most likely when site occupants would not have access to municipal utilities due to extenuating circumstances. Under those conditions, drinking water could most easily be obtained from either Banner Spring, Banner Spring Branch, Martin Creek, or the Nolichucky River. Banner Spring is a uncontaminated natural spring located on the North Site and hydraulically upgradient of contaminated areas. The spring rarely has storm related turbidity, signifying a deep groundwater source. Banner Spring has been utilized in the past as a drinking water source and, while currently owned by NFS, was listed as a potential water supply source in the Survey of Public Groundwater Supplies published by the First Tennessee Development District in March 1987. Its discharge in Banner Spring Branch is currently used by NFS for non-process cooling water. Based on its past use and availability, it is most likely that Banner Spring would be the source for drinking water if municipal water is not used.

Other surface water sources (Banner Spring Branch, Martin Creek, or the Nolichucky River) would typically require water treatment for pathological microorganisms and other water quality constituents prior to human consumption. Both Banner Spring Branch and Martin Creek have flow rates capable of providing ample water for domestic use. The Nolichucky River is the source for municipal water supply for the Town of Jonesborough, Tennessee which is located approximately 8 miles west of Erwin. Because these bodies of water originate off-site, the level of contamination present in them will be minimal (Banner Spring Branch runs through the plant site and typically contains less than 20 pCi/L uranium[13]) and use by a farmer as livestock and irrigation water supply would result in minimal dose. For the same reason, there would be minimal dose[14] to a subsistence farmer (unlikely land use scenario) choosing to utilize these

[13] Nuclear Fuel Services, Inc. *Safety Department Semi-Annual Report for the Second Half of 1997, Table 8*. March 25, 1998.

[14] A concentration of 20 pCi/L uranium in water coincides with a potential dose of ~ 3mrem/y when using the effluent limits in 10 CFR 20, Appendix B as the basis for the conversion from concentration to potential dose.

surface water bodies for drinking water. However, because Banner Spring Branch would not be used for these purposes considering other land use scenarios, the more likely potential dose to a future resident would be zero.

2.2.3. Domestic Well Utilization and Considerations

Installation of a domestic well in the North Site is unlikely because of the presence of alternative and more cost effective water sources. Should a domestic supply well be installed, it would be installed in the deeper bedrock where sufficient volume and clarity of water exist. Groundwater contamination present in unconsolidated sediments would not be expected to impact the water quality in a well because state regulations mandate installation of watertight casing through the unconsolidated sediments. Based on the groundwater model, the maximum dose predicted over the 1000 year period for groundwater present in the shallow bedrock is estimated at between 5 mrem/y to 23 mrem/y for only 1% of the area comprising the North Site. Groundwater present in shallow bedrock underlying the remaining 99% of the North Site is not expected to be impacted over the next 1000 years.

As shown in Figure 4, the majority of the North Site is located in the 100 year flood plain. Installation of domestic wells in a flood plain is undesirable and would be contrary to good civil engineering practice. Wells located in a flood plain may be contaminated by pathological microorganisms caused by the influx of surface flood waters. Because of potential failures of the watertight seal and flood damage to the well housing, good civil engineering practices preclude installation of a domestic well in a flood plain.

Listed below are several State of Tennessee regulations that impact well siting and installation efforts by a future site occupant and would inhibit an individual from siting a well in the flood plain. These regulations are applicable to anyone (private citizen or driller) that installs a well for drinking water supplies in the state of Tennessee.

- Rule 1200-4-9.10(1)(a) requires anyone (private citizen or driller) to comply with the TN Water Well Act of 1993, with respect to the construction, reconstruction, and repair of any water well, pump, pumping equipment, water filter or waste treatment device.
- Rule 1200-4.9.07 states that any person's license shall be revoked and prohibited from performing the duties of a well driller or pump installer that willfully violates any provision of the TN Water Well Act of 1993.
- Rule 1200-4-9-.10(1)(b) requires every driller to submit a report to the Tennessee Department of Environment and Conservation on the construction or reconstruction of a well.
- Rule 1200-4-9-.10(2)(b) states that the watertight casing on a well shall extend a minimum of two feet above the maximum recorded flood elevation.

- Rule 1200-4-9-.10(3)(a) states the source of water for any well shall be at least twenty feet below the surface of the ground.
- Rule 1200-4-9-.10(3)(b) states that the driller shall develop the most favorable water-bearing zone(s) and seal off any source(s) of less desirable quality.
- Rule 1200-4-9-.10(5)(a) states that a watertight casing shall extend from at least 6 inches above to at least twenty feet below the land surface.
- Rule 1200-4-9-.10(5)(a)(1) states that the watertight casing in wells constructed to obtain water from a consolidated rock formation shall be firmly seated and sealed below all crevices that release inferior quality water or mud into the well or to a depth of at least five feet below the top of the consolidated rock, whichever is greater.

The majority of contamination underlying the North Site occurs in the shallow groundwater present in unconsolidated sediments. The zone of unconsolidated sediments typically range from 0 ft along the eastern plant perimeter road, to ~29 ft. at the northeast corner of the burial ground, and averages approximately 16 ft[15]. State regulations require that a watertight casing be installed to a depth of 20 feet in wells. Because the depth from ground surface to bedrock at most all locations at the North Site is less than 20 feet, use of shallow groundwater sources is effectively excluded by this regulation.

State regulations mandate that wells be constructed to seal off sources of less desirable quality to a depth below all crevices and a minimum of five feet below the top of the consolidated rock. Implementation of this regulation at the North Site would require installation of a domestic well in bedrock (Rome Formation) sufficiently below the mud seams present in the upper bedrock. The typical depth required to obtain ample volumes of potable water from the Rome Formation is estimated at between 120 to 150 feet below the land surface[16].

Installation of a domestic well would not be cost effective when compared to inexpensive and abundant municipal water supply sources. The cost of installing a domestic well into the consolidated bedrock underlying the North Site is estimated at $3500. This cost includes use of the drill rig, equipment, supplies, and installation of the well to a depth of 120-150 feet and a pump house. The cost of water usage charged by Erwin Utilities for residential consumption is approximately $8.00 per month[17]. A resident that chooses to install a domestic water well would not regain their initial investment for approximately 36 years, excluding routine maintenance and operating costs.

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[15] Geraghty & Miller, Inc. *Final Project Report Groundwater Flow and Constituent Modeling at the Nuclear Fuel Services Facility Erwin, Tennessee.* p. 2-3. April 25, 1996.

[16] Personal communication between Scott Kirk (NFS) and J.J. Hollars, P.G. (SAIC) regarding typical domestic well installation depth to obtain viable water supply. January 5, 1999.

[17] Personal communication between Scott Kirk (NFS) and Marsha Edwards (Erwin Utilities). December 8, 1998.

An area survey of existing domestic water supply wells identified approximately 12 wells within a five mile radius of the NFS site[18]. None of the wells identified were installed in unconsolidated sediments or in a flood plain. The average depth of the 6 wells for which data were available was 119 feet below grade. The most shallow well was installed in bedrock (Honaker Formation) at a depth of 24 feet below grade. Geological surveys of the area indicate that the Honaker is located adjacent to and slightly west of the Nolichucky River and is not present directly beneath the NFS site.

2.3. Potential Exhumation of Soil

Homes constructed in the Erwin area have basements, half-basements, slabs, or crawl spaces so there is a possibility that residential construction may bring subsurface soil to the surface. However, much of the North Site is located within the 100 year flood plain and there is an Erwin ordinance (Ordinance No. 467, Article 5, Section B) which requires a minimum one foot elevation above the 100 year flood plain before erecting a structure. Therefore, it is unlikely that the habitable portion of a residential, commercial, or industrial structure will extend below the current land surface. Additional fill will probably be required before a structure is placed on the north NFS site.

Swimming pools are relatively common in the Erwin/Unicoi area, and it is possible that their construction may unearth buried contaminated soil. However, pools seldom extend beneath the water table because of the maintenance and special construction requirements. Because the water table is relatively shallow across most of the NFS site, pool construction is not considered a strong possibility that may result in exhuming contaminated soil.

Industrial development of the site may result in exhumation of contaminated soil due to footer installation, water/sewer installation, or through specific industry needs. Because these activities could extend below the water table, subsurface soil may potentially become surface soil and contribute to dose.

The Draft Environmental Impact Statement developed for 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste" (NUREG-0782), contains information concerning the dilution of waste caused by exhumation of a building foundation. Appendix G of NUREG-0782 discusses the inadvertent intruder scenario and provides a basis for reducing the waste concentration by a factor of 0.25 to account for dilution during excavation (i.e., the contaminated material would be mixed with the clean cover material as well as the clean soil surrounding the

[18] Geraghty & Miller, Inc. *Final Project Report Groundwater Flow and Constituent Transport Modeling at the Nuclear Fuel Services Facility Erwin, Tennessee.* Table 2-1. April 25, 1996.

burial). Dilution of the contaminant concentrations in subsurface soil should be evaluated when determining the potential dose due to exhumation of contaminated soil.

3. DOSE ASSESSMENT STRATEGY/METHODS

This assessment of the potential dose due to exposure to contaminants present in North Site soil and groundwater was directed at deriving dose-to-source factors appropriate for an *average* member of the critical group as discussed in the NRC's final decommissioning rule[19]. The NRC has recently released a computer code, DandD version 1.0, to implement the modeling methods outlined in NUREG/CR-5512 in conjunction with the final decommissioning rule. However, RESRAD version 5.82 was used to model the land use scenarios that were applied to the NFS plant site because of its availability during this project, versatility, and substantiation (benchmarking).

Because many of the default parameters in both the RESRAD and NUREG/CR-5512 models are intended to be conservative and generic, a review of the parameters was performed and site-specific values substituted when appropriate. The site model uses average soil characteristics from across the NFS site when appropriate. This was done due to the large area of contaminated soil being evaluated and the potential for past earth movement and placement of soil in the area. Average characteristics were determined through site characterization efforts or literature references.

The land-use scenarios modeled using RESRAD best represent the critical groups likely to use the site in the future. Consideration was given to utilities available at the site, existing recreational facilities in Erwin, and "average" diet, activities, etc., as specified by the U.S. Environmental Protection Agency[20] (EPA) and in the RESRAD support manuals[21]. For example, the residential use scenario reflects a suburban setting, and the recreational scenario reflects activities associated with maintaining an Erwin city park.

In addition to the scenarios which reflect the most probable future use of the site, the NRC has expressed an interest in more conservative scenarios which NFS has included for reference purposes only. These reference scenarios are the subsistence farming and the drinking water scenarios.

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[19]Final Rule, 10 Code of Federal Regulations (CFR) 20, Subpart E - Radiological Criteria for Decommissioning. Published in the Federal Register July 21, 1997.

[20]U.S. Environmental Protection Agency, Office of Health and Environmental Assessment. *Exposure Factors Handbook*. EPA/600/8-89/043. July 1989.

[21]Yu, C., et al. *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil*. Environmental Assessment and Information Sciences Division, Argonne National Laboratory. ANL/EAIS-8. April 1993.

3.1. Potential Site-Uses Evaluated

The scenarios evaluated include residential, industrial, and recreational use of the site as well as two reference scenarios of interest to the NRC. Best estimates of the critical groups' activities and the use of site resources have been incorporated into the scenario descriptions. The construction scenario is an additional consideration for scenarios that include development (e.g., industrial and residential land use). The subsistence farming and drinking water scenarios are included for reference purposes only. Assessments indicate that the subsistence farming and drinking water scenarios are not reasonable representations of future site use.

Table 3 summarizes the pathways evaluated for each scenario. Pathways were excluded from evaluation if preliminary modeling resulted in less than one percent of the total dose through that pathway. The radon pathway was not evaluated for any scenario for reasons cited by the NRC[22]. The following sections discuss the scenarios and related pathways that were evaluated for the final assessment.

3.1.1. Suburban Residential Land Use Scenario

The most reasonable estimation of a future residence on the north NFS property is a suburban dwelling typical of those found within the Town of Erwin. Because homes may be built with either a crawl space or slab floor, average external gamma shielding factors[23] were used to correct the external dose rate during the time spent inside the home. Typical lot sizes are 100' by 150'. However, because sampling of the North Site indicated that a relatively large area is contaminated, the external gamma shape factor[24] in RESRAD was conservatively set to unity. Utilities available to the site would likely be connected to new residential construction and potable water would likely be obtained from Erwin Utilities. Because of the high probability that municipal water supplies would be used by future site residents, the drinking water pathway was excluded. Consequently, no distinction was made between soil contamination located above and below the water table. The RESRAD default diet was used for the average resident with 25 percent of all plant foods being grown on the site. Neither the milk nor meat ingestion pathways were evaluated because raising livestock on a small residential lot within the town limits is not an anticipated activity.

[22]In the Federal Register, Vol. 59, No. 161, Monday, August 22, 1994, p. 43210, *Comments from Workshops; Radon*. The NRC noted that radon would not be evaluated when developing release criteria due to: the ubiquitous nature of radon in the general environment; the large uncertainties in the models used to predict radon concentrations; and the inability to distinguish between naturally occurring radon and that which occurs due to licensed activities.

[23]The external gamma shielding factor is the ratio of the exposure rate with flooring material acting as a shield to the rate that would exist if no shielding materials were present (i.e., the exposure rate inside the home divided by the exposure rate outside the home).

[24]The shape factor is used to correct for a noncircular-shaped contaminated area on the basis of an ideally circular contaminated zone.

Table 3. Exposure Pathways Evaluated for Each Scenario

Available RESRAD Pathways	Scenario					
	Suburban Resident	**Industrial Worker**	**Recreational Use**	**Construction Worker**	**Subsistence Farming** (reference only)	**Drinking Water** (reference only)
Meat Ingestion					X	X
Milk Ingestion					X	X
Water Ingestion					X	X
Plant Ingestion	X				X	X
Aquatic Food Ingestion					X	X
Soil Ingestion	X	X	X	X	X	
Dust Inhalation	X	X	X	X	X	
Direct Exposure from Ground Sources	X	X	X	X	X	
Radon						

Similarly, Banner Spring Branch is too small to support fish that could be considered a significant part of an individual's diet. Martin Creek may support sufficient fish life to merit evaluation of the aquatic food pathway but preliminary modeling using RESRAD indicated that negligible dose results through this pathway. Only the soil ingestion, plant ingestion, direct exposure, and inhalation pathways were included in the suburban residential user scenario. An

EPA study, *Time Spent in Activities, Locations, and Microenvironments*[25] was used to determine average time spent indoors vs. outdoors at the site under this scenario.

3.1.2. Industrial Land Use Scenario

It was assumed that an industrial worker would be primarily involved in indoor work activities at the site. The worker was assumed to be present at the site for a typical work year (assuming the worker gets two weeks per year as vacation and two weeks per year as holidays) with 90 percent of the time spent indoors and 10 percent outdoors. The building in which the worker spends his time was assumed to have a minimal 4" thick concrete slab as flooring. All food and water ingested by the worker originate off-site. Three pathways were included for the industrial worker: the inhalation pathway, the direct exposure pathway, and the soil ingestion pathway. Inclusion of the soil ingestion pathway was based on review of documented studies outlined in the RESRAD Data Collection Handbook.

3.1.3. Recreational Land Use Scenario

Recreational facilities, if constructed at the site, are expected to be similar to those existing in northern Erwin. Facilities may include basketball courts, tennis courts, softball fields, play areas for children, and picnic areas. All water at the site can be assumed to originate from Erwin Utilities and the user would not be expected to consume any food originating from the site. The critical group for this scenario is represented by a grounds keeper who works at the site 46-hours a week from mid-March to mid-November[26]. During the remainder of the year, this individual works at the site approximately five hours per week so that, in total, the worker spends 1,695 hrs/y at the site. The grounds keeper would have a slightly higher than normal breathing and soil ingestion rate. Additionally, the dust loading was marginally increased because work includes activities such as ballfield preparation and mowing.

3.1.4. Construction Worker Scenario

The construction worker scenario represents intrusion that occurs in conjunction with construction of facilities (e.g., residences or industrial buildings). A typical construction worker involved in erecting a structure was assumed to spend approximately three months of the year (50 hrs/week) at the site. This individual does not consume any food or water originating from the site. The breathing rate and soil ingestion rate were increased due to the physical nature of

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[25]Robinson, John P., J. Thomas. *Time Spent in Activities, Locations, and Microenvironments: A California-National Comparison.* EPA/600/4-91/006. January, 1991.

[26]Personal communication between Gina Craig (NFS) and Carl Lee Scott (Fishery Park Maintenance Supervisor) regarding activities associated with maintenance of the park. May 9, 1996.

the work. The direct exposure, inhalation, and soil ingestion pathways were included in this scenario.

3.1.5. Subsistence Farming Reference Scenario

The subsistence farming scenario reflects a person who lives on the contaminated site, grows most of his/her diet on the site, and drinks water from a well placed on the downgradient edge of the site. This person spends approximately 76 percent of their time on the site. All pathways are applicable in this instance; only the radon pathway was excluded. This scenario is the default setting in the RESRAD code and relatively few of the parameters were changed. This scenario is considered unlikely but was included for reference purposes.

3.1.6. Groundwater Use Reference Scenario

The groundwater use scenario assumes that a future site occupant would drink and otherwise be exposed to contaminated groundwater. This scenario does not consider non-water related pathways (e.g., inhalation and direct exposure pathways). A relative source contribution (RSC) factor was determined to account for water dependent pathways other than drinking by evaluating the subsistence farming scenario summary reports. Consistently in these reports, the drinking water pathway contributed 90 percent of the uranium water dependent dose[27]. Non-drinking water dependent pathways (i.e., the water-dependent component of the ingestion of plants, meats, milk, and seafood) contribute approximately ten percent of the water dependent dose for uranium. The spreadsheet used to make this determination is provided at the end of Appendix D.

Based on studies cited in the Exposure Factor Handbook[28], an average adult ingests 1.4 liters of tap water a day which is consistent with the RESRAD default assumption. NFS used this 1.4 L/d ingestion rate, dose per unit intake factors presented in Federal Guidance Report 11, Table 2.2, and a RSC factor of 0.9 to develop dose-per-unit-concentration factors. Other than the development of the RSC factor, RESRAD was not utilized to develop dose-to-source factors for groundwater contaminants.

[27] NFS acknowledges that the RSC factor may vary among site contaminants depending on many variables which affect uptake of a contaminant through water dependent pathways; however, uranium is the only contaminant currently detected in groundwater at potential dose levels greater than 10% of the 25 mrem/y criteria. The RSC factor for uranium was applied to all potential radionuclides in groundwater primarily to provide consistency in the development of the dose-to-source factors.

[28] Environmental Protection Agency (EPA). *Exposure Factors Handbook, Review Draft.* EPA/600/P-95/002A. June 1995.

3.2. Site Definition/Source Term

A generic site model was established which is conservative for the depth and extent of soil contamination typical in the north NFS plant site. The surface area used in the model was based on the maximum contiguous area of detected contamination in the North Site (approximately 55,000 m^2). The thickness of the contaminated zone was set at one meter. Contaminants below this depth have negligible contribution to the dose because the one meter of shielding/cover material practically eliminates exposure to the contaminants. Exposure through water-dependent (leachate) pathways is still possible, but the dose through these pathways is negligible for all probable scenarios because they exclude use of groundwater for drinking purposes.

Soil characteristics vary across the contaminated area(s). This occurs because the north NFS plant site is located at the junction of three different soil types[29] and past earth moving activities have mixed the soil. Modeling efforts incorporated soil characteristics as determined through site sampling and characterization efforts when available. Values available in literature were used when site specific data were unavailable. All soil characteristics used in the modeling effort were reviewed by the NFS staff geologist/hydrogeologist to verify the appropriateness of the values.

All contaminant concentrations were input at 1 pCi/g and appropriate daughter products were included in the initial source term. By using unit concentrations as inputs, the individual radionuclide dose results are equivalent to dose-to-source factors. Selection of the maximum dose result for each site contaminant over a 1,000 year modeled period provided conservative dose-to-source factors. The site specific dose-to-source factors were then applied to the contaminant concentrations in soil and water across the site to determine the potential dose for leaving the site "as is." All site specific and literature inputs to RESRAD are listed in Appendix B to this report.

3.3. Inputs to RESRAD

Because the NRC's final rule specifies that dose is predicted for the *average* member of the critical group, each RESRAD input parameter was reviewed to determine if it reflected the best estimate given the scenario being modeled. Many of the inputs used in RESRAD were revised based on site specific data and/or literature references. In each instance, a report was generated and the reference or methods used to revise these parameters were documented. Appendix C includes all reports relating to the modification of RESRAD input parameters.

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[29]United States Department of Agriculture and Soil Conservation Service, *Soil Survey of Unicoi County Tennessee*, September 1985

The RESRAD input parameters were adjusted to reflect the most appropriate values for distribution coefficients, plant-to-soil concentration ratios, inhalation dose conversion factors, and ingestion dose conversion factors based on knowledge of the NFS site. Because data were available on the solubility of uranium, averaging of the RESRAD output was required to generate appropriate dose-to-source factors for the various chemical forms of this contaminant.

Distribution Coefficients: NFS analyzed several samples using ASTM methods[30] to determine site-specific distribution coefficients for adsorption and desorption processes in soil. Adsorption processes are consistent with the processes occurring in the RESRAD model saturated zone while desorption processes are consistent with processes occurring in the contaminated zone. A total of 13 samples were collected; nine were run for adsorption processes and four for desorption processes. These data were used to determine suitable site-specific distribution coefficients (desorption) for uranium and thorium (10% Lower Confidence Limit of the mean). Other radionuclides and daughter products were assigned default values referenced in NUREG/CR 5512.

Plant-to-Soil Concentration Ratios: The default plant-to-soil concentration ratios used in RESRAD are generally the most conservative ratios developed for the various plants found on a farm. This may include dietary plants (leafy vegetables, root vegetables, fruit, grain, etc.) and plants used as fodder for livestock. However, all plants do not have the same ratio nor are they ingested in equal amounts. The use of only the most conservative ratio results in an overestimation of the dose through the plant ingestion pathway. NUREG/CR-5512 lists plant-to-source concentration ratios for each type of plant in the average individual's diet. By using a weighted average of these ratios based on the relative percentage of one's diet, an appropriate value was derived for estimating the uptake of contaminants through plant ingestion.

Dose Conversion Factors: The dose factors for only two site contaminants, uranium and thorium, were changed from the most conservative default. Uranium lung solubility class data are available through analysis of air samples obtained over the past decade. The majority of uranium on-site (~60.5 percent) is class "Y" while the remainder is primarily class "D". This division of soluble and insoluble uranium was applied in the evaluation of the ingestion and inhalation pathways. Ingestion dose conversion factors corresponding to the soluble and

[30] Three references were used in developing the analysis methodology for distribution coefficient: ASTM Method 4319-83 "Standard Test Method for Distribution Ratios by the Short-Term Batch Method;" ASTM Method 4646-87 "Standard Test Method for 24-h Batch-Type Measurement of Contaminant Sorption by Soils and Sediments;" and "Methods for Determining Radionuclide Retardation Factors: Status Report" by J.F. Relyea, et. al.

insoluble f1 values were determined from Federal Guidance Report 11[31]. RESRAD was run twice for each scenario to generate dose-to-source factors associated with exposure to purely soluble or insoluble forms of uranium. The final dose-to-source factors for scenarios which do not include ingestion of water, plants, or meats, are weighted averages based on the mixture of uranium solubility classes found on-site (i.e., 60.5 percent class "Y"/insoluble and 39.5 percent class "D"/soluble). If a scenario included ingestion of water, plants, or meat, then the dose-to-source factors were determined separately for each pathway and summed to obtain an overall dose-to-source factor. Generally, the doses through the soil ingestion and inhalation pathways were weighted based on the site uranium solubility while the doses through the remaining ingestion pathways were attributed solely to soluble forms of uranium. Dose through the direct exposure pathway is unaffected by solubility considerations other than how quickly a contaminant is transported away from the site.

Thorium-232, a contaminant which is present above background in soil, was assigned a class "Y" dose factor for inhalation. This is appropriate because the form of thorium primarily utilized onsite was an oxide which is designated Class "Y" in 10 CFR 20, Appendix B. Also, despite the abundant presence of thorium in soil, there is no indication that thorium has leached into groundwater—another reason for considering that the primary form of thorium in the environment is insoluble.

3.4. Developing Scenario-Specific Dose Maps

After determining dose-to-source factors for each scenario, the factors were applied to soil sampling results from the North Site characterization. The potential dose (mrem/y maximum over 1,000 yrs) associated with each scenario was determined for each sample location based on the concentration of contamination (background concentrations were subtracted from the gross measured concentrations of each contaminant). These dose values were categorized and plotted on a map of the site using a commercially available graphing program, SURFER[32]. Plots were generated for the surface and the uppermost subsurface soil layers and each land use scenario. Isopleths of the potential dose were also generated using the default kriging settings available in the SURFER program. The resulting maps provide an estimate of the dose relative to each land-use scenario for each sample location across the site.

A weighted average of the groundwater dose-to-source factors for uranium were developed using an isotopic percentage activity of 73.4% U-234, 6.1% U-235, and 20.5% U-238. These percentages are based on the average isotopic activity in all wells for which data were reported in

[31]U.S. Environmental Protection Agency. *Limiting Values of Radionuclide Intake and Air concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion. Federal Guidance Report No. 11.* EPA 520/1-88-020. September 1988.

[32]Golden Software, Inc., SURFER for Windows, Version 6. July 1995.

the North Site Characterization Report. The resulting dose-to-source factor for total uranium (0.157 mrem/y per pCi/L) was then applied to isopleths of uranium activity concentrations presented in groundwater modeling reports[33].

4. RESULTS

Pathways analysis modeling was conducted using RESRAD, version 5.82. RESRAD output reports are presented in Appendix D. Generally, two reports were generated for each evaluated scenario in order to determine weighted averages of the uranium dose-to-source factors (based on lung solubility data). Spreadsheets used to perform the weighted average calculations are presented at the end of Appendix D. The dose-to-source factors derived for each contaminant and scenario are presented in Table 4.

Maps were generated for the various land-use scenarios which show the potential dose due to existing levels of contamination (with background subtracted) in soil across the north plant site. Similar maps were generated for the drinking water scenario showing the potential dose due to contamination in groundwater based on modeling of groundwater flow and constituent transport. Maps showing the potential dose associated with soil contamination include posting symbols to indicate sample locations. These maps illustrating predicted doses for land use scenarios are presented in Appendix A, Figures 5 through 14. Maps correlating dose from groundwater modeling (Geraghty & Miller (1996) and Arcadis (1999)) results are presented as Appendix A, Figures 15 through 21.

Typically, dose due to soil contaminants prior to remediation is predicted to range from ~0 mrem/y to over 500 mrem/y for all scenarios depending on the location within the North Site. The greatest concentration of contaminants, and also the greatest potential dose, occurs within the NFS plant protected area. After remediation is completed at the site, the dose for land use scenario other than the subsistence farmer are expected to be less than 1 mrem/y. The maximum post remediation dose for the subsistence farmer is estimated at approximately 8 mrem/y. The post remediation dose for each land use scenario considered is presented in Table 5.

As stated previously, use of groundwater underlying the North Site as drinking water source is unlikely. Based on groundwater data from Well 67[34], which is screened from 100-120 feet,

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[33] Uranium Concentration Isopleth maps were developed and presented in two reports. The report "Final Project Report Groundwater Flow and Constituent Transport Modeling at the Nuclear Fuel Services Facility Erwin, Tennessee" (Prepared by Geraghty & Miller, Inc. April 25, 1996) was the source of Figures 15 -18 which depict uranium concentrations in groundwater assuming no remediation of contamination sources occur other than the burial grounds. Figures 19 - 21 were taken from the report "Revised Groundwater Flow and Solute-Transport Modeling Report" (Prepared by Arcadis/Geraghty & Miller, February 1999).

[34] Locations of groundwater monitoring wells for the North Site are depicted in Appendix A, Figure 22.

Table 4. Dose-to-Source Factors for all Scenarios

Radionuclide	Residential Use (mrem/y)/(pCi/g)	Industrial Use (mrem/y)/(pCi/g)	Recreational Use (mrem/y)/(pCi/g)	Construction (mrem/y)/(pCi/g)	Subsistence Farming Reference Scenario* (mrem/y)/(pCi/g)
Am-241	0.134	0.0405	0.192	0.0551	0.186
Pu-238	0.0968	0.0316	0.161	0.0457	0.138
Pu-239	0.107	0.0349	0.178	0.0505	0.389
Pu-240	0.107	0.0349	0.178	0.0505	0.360
Pu-241	0.00397	0.00121	0.00573	0.00165	0.00565
Pu-242	0.102	0.0332	0.169	0.048	0.379
Tc-99	0.0604	0.000025	0.0000745	0.0000282	0.467
Th-230	1.43	0.313	0.649	0.237	2.50
Th-232	6.81	1.71	3.34	1.23	9.17
U-233	0.0638	0.0124	0.0418	0.0104	0.607
U-234	0.0389	0.00231	0.0153	0.00253	0.556
U-235	0.338	0.0809	0.157	0.0572	0.912
U-238	0.0816	0.0163	0.0398	0.0123	0.584

*Includes use of contaminated groundwater for purposes other than drinking water. The potential dose from the drinking water pathway is zero assuming the domestic well is installed using good civil engineering practices at a depth of 120 to 150 below grade.

Table 5. Estimated Average Residual Soil Contamination and Potential Dose to Critical Groups After License Termination

Radionuclide	Average Contaminant Conc. (pCi/g)	Average Background Conc. (pCi/g)	Potential Dose Due to Residual Contamination Above Background (mrem/y)				
			Subsistence Farmer*	Suburban Resident	Park Groundskeeper	Industrial Worker	Construction Worker
Am-241	0.13	~0	0.02	0.02	0.02	0.01	0.01
Pu-238	.05	~0	0.01	0.00	0.01	0.00	0.00
Pu-239/240	.62	~0	0.24	0.07	0.11	0.02	0.03
Pu-241	1.50	~0	0.01	0.01	0.01	0.00	0.00
Pu-242	0.00	~0	0.00	0.00	0.00	0.00	0.00
Tc-99	1.31	~0	0.61	0.08	0.00	0.00	0.00
Th-230	0.96	1.45	0.00	0.00	0.00	0.00	0.00
Th-232	1.42	1.49	0.00	0.00	0.00	0.00	0.00
U-234	12.91	1.14	6.41	0.45	0.18	0.03	0.03
U-235	0.48	0.063	0.38	0.14	0.06	0.03	0.02
U-238	2.13	1.12	0.58	0.08	0.04	0.02	0.01
Total Dose (mrem/y) Above Bkg:			8.26	0.85	0.43	0.11	0.10

*Includes use of contaminated groundwater for purposes other than drinking water. The potential dose from the drinking water pathway is zero assuming the domestic well is installed using good civil engineering practices at a depth of 120 to 150 below grade.

uranium contamination is not believed to be present in bedrock sources at a depth where installation of a domestic well (120-150 ft) is expected. The highest uranium concentrations present in shallow bedrock are located in the vicinity of Well 60B (screened from 26-31 feet) and Pond 4 (Figures 15 and 17). The maximum potential dose over the next 1000 years to a future resident that installed a domestic well in the shallow bedrock at these locations ranges from approximately 5 mrem/y to 23 mrem/y at only 1% of the area comprising the North Site (Figure 19). Groundwater present in shallow bedrock for the remaining 99% of the North Site is not expected to be impacted. Should a future resident tap groundwater present in the unconsolidated sediments, the maximum potential dose ranges from approximately 62 to 157 mrem/y (Figures 16, 18, 20 and 21). This occurs in an area which comprises 3% of the North Site. The potential dose from groundwater present in the unconsolidated sediments for the remaining 97% of the North Site ranges from 0.02 to 62 mrem/y.

5. DISCUSSION

Dose-to-source factors were developed to aid in the evaluation of site contamination and development of decommissioning criteria. These factors reflect the best estimate of dose due to exposure to site radioactive contaminants. Dose maps were generated for the uppermost layers of soil and sediment using the dose-to-source factors and the data available from the North Site characterization effort.

The results presented in this document are conservative in that only the maximum dose-to-source factors are stated for each contaminant over the 1,000 year period under consideration. For example, Tc-99 has its maximum dose at t = 0 years while Th-230 has its maximum dose at t = 1,000 years. The dose-to-source factors used to evaluate contamination levels were generated for each individual contaminant's time of maximum dose and do not consider that Tc-99 and Th-230 contribute differently over the time period of concern. Therefore, soil containing a mixture of these two contaminants would likely generate less dose than estimated using the dose-to-source factors in Table 4.

Potential exposure to lower layers of contaminated soil is not easily evaluated because decommissioning plans call for covering residual radioactivity with clean soil. Excavation is necessary to expose contaminated soil and will result in mixing of the contaminated and clean soil. The NRC's Draft EIS for Land Disposal of Radioactive Waste (NUREG-0782) states that a dilution factor of 0.25 could be applied to excavated contaminated soil. Therefore, the potential dose due to contaminated soil in lower depths represents approximately one fourth the dose calculated for surface soils at the same level of contamination.

A conservatism was also introduced by the method used to evaluate the distribution of contaminants in soil. The contaminated soil area modeled to develop the dose-to-source factors was 55,000 m^2 with contamination distributed homogeneously to a depth of one meter. However, contamination over the North Site is heterogeneously distributed. Because the dose-to-source factors assume a large homogeneous area of contamination, the potential dose associated with heterogeneously distributed contamination is over estimated. This conservatism is accepted because there is not an effective way of modeling heterogeneously contaminated soil.

Assuming the dose-to-source factors in Table 4 were used to develop decommissioning criteria, conservatism will be present because dose-to-source factors from more than one scenario will be selected to develop the decommissioning criteria. For example, the Th-232 dose-to-source factor is highest for the residential scenario while most of the dose-to-source factors for transuranic radionuclides are highest for the recreational scenario. Therefore, the criteria will be conservative (i.e., would result in less dose than the dose basis) for any one scenario which may occur.

Two scenarios were evaluated for reference purposes only--the subsistence farming and the drinking water scenarios. The drinking water scenario was included to allow evaluation of existing and predicted contamination in groundwater. While a dose value was estimated for using contaminated groundwater in the unconsolidated sediments, and the shallow and deep bedrock, it should be noted that utilization of groundwater is considered unlikely.

Groundwater modeling (Geraghty & Miller (1996) and Arcadis (1999)) studies simulated uranium concentrations in hydrostratigraphic zones underlying the North Site over the next 1,000 years. These simulations predict uranium contaminant concentrations in groundwater based on a groundwater flow and transport model (MODFLOW and MT3D) that considers groundwater monitoring data.

Predicted simulations considered the effects of source depletion (i.e., removing contaminated soil) on groundwater contamination. Modeling results indicate that the predicted concentrations in groundwater are not correlated to the level of contaminated soil detected during the site characterization. This was a consideration for not using codes such as DandD and RESRAD for determining dose through the groundwater pathway. These pathway analysis codes only model groundwater contamination originating as leachate from residual soil contamination. Contamination in groundwater underlying the North Site is primarily attributable to either waste disposal practices or leaching of contaminated waste rather than soil. Therefore contaminant levels in groundwater will not agree with levels predicted using "standard" decommissioning codes.

As stated, dose due to use of groundwater was estimated from concentrations predicted using groundwater monitoring data and the groundwater flow and transport model. The average groundwater concentrations at wells located near the three surface impoundments, Pond 4 and the Radiological Burial Ground, vary considerably. The average uranium groundwater concentrations[35] in wells located in the unconsolidated sediments at the three surface impoundments, Pond 4 and the Radiological Burial Ground range from no detectable activity to approximately 3,556 pCi/L. The average mean uranium concentrations at these locations were approximately 135 pCi/L, 592 pCi/L and 917 pCi/L, respectively. A subset of this data[36] provided the basis for the fate and transport model. The isopleths predicted in the groundwater model are currently NFS' best method of estimating the contaminant concentrations (and potential dose) in a particular region of the North Site at a given time.

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[35] Groundwater monitoring data collected from June 1989 through October 1996 and cited in the NFS North Site Characterization Report.

[36] As reported in the 1996 Geraghty & Miller and 1999 Arcadis, the fate and transport models used routine groundwater monitoring data collected in the 4th quarter of 1993 and 3rd quarter 1997, respectively.

As cited in the 1996 Geraghty & Miller report, the highest dose from these sources over the next 1000 years was estimated at 157 mrem/y at one location. However, the surface area of the nearest 400 pCi/L contour (surface impoundments) encompasses approximately 1,642 m^2. This contaminant isopleth (>400 pCi/L) represents approximately 1.5% of the entire North Site (Figure 16). Simulated uranium contaminant isopleths exceeding 400 pCi/L (~62 mrem/y) do not affect significant portions (never more than 2% of the total surface area) of the North Site over the next 1000 years (Figure 18). The surface area of these affected areas are negligible with respect to the surface area of the North Site. Therefore, the estimated dose of 62 mrem/y to 157 mrem/y is most representative of the maximum dose from drinking contaminated groundwater present in the unconsolidated sediments.

The groundwater model predicted the highest dose from groundwater sources present in the shallow bedrock using concentrations detected at Well 60B[37] (199.47 pCi/L). The nearest 30 pCi/L contour encompasses (730 m^2) an area less than 1% of the North Site. Without considering groundwater remediation, uranium concentrations attributable to this source (in the vicinity of Well 60B) will attenuate over the next 1000 years. The potential dose to a future site resident installing a domestic well in the shallow bedrock area is expected to range from 5 mrem/y to 23 mrem/y at only 1% of the entire North Site area over this time period. Groundwater present in shallow bedrock for the remaining 99% of the North Site is not expected to be impacted.

Uranium groundwater contamination has not been detected during limited sampling of the deepest well located at the North Site (i.e., Well 67 installed in the Radiological Burial ground at a depth of 119 feet below grade). Therefore, no dose would result should a future site resident install a domestic well. This expectation is supported by groundwater modeling results which indicate that uranium concentrations do not significantly affect more than 1% of the entire North Site in the overlying shallow bedrock.

Groundwater remediation will be conducted at the North Site. Groundwater remediation is expected to reduce uranium concentrations in the unconsolidated sediment thus preventing downward migration into the bedrock. While on-site installation of a domestic well by a future resident is considered unlikely, groundwater remedial actions will ensure that potential dose from the drinking water pathway is maintained ALARA.

6. CONCLUSIONS

The dose-to-source factors developed through this assessment are more appropriate for the NFS site than generic dose-to-source factors available by running the default model in DandD, version 1.0. This is primarily due to the revision of RESRAD input parameters to reflect the most

[37] Groundwater modeling simulations used uranium concentrations cited in Arcadis 1998, Table 4-4.

reasonable and probable future land-use scenarios and average activities of the critical group. The dose-to-source factors presented in Table 4 are generally applicable to the entire NFS plant site although soil characteristics may vary slightly from one area to the next.

While the dose-to-source factors listed in Table 4 were used to develop site-specific dose based CGLs for decommissioning, consideration should be given to the potential exhumation of buried contaminated soil as that activity results in dilution of the contaminants (assuming a clean soil cover). Consideration should also be given as to the inapplicability of the subsistence farming and drinking water scenarios which are considered improbable and included primarily for reference purposes in this document.

The potential dose due to existing levels of contamination across the NFS site varies due to the heterogeneous distribution of contamination in soil and water. Overall, because the level of contamination inside the plant protected area is much greater and widely dispersed than that outside the protected area, the potential doses are highest inside the protected area.

Use of drinking water obtained from a domestic well installed by a future site resident is not considered likely because of available municipal sources. However, if installed, a domestic well would be expected to be drilled to a depth of between 120 and 150 feet. Uranium contamination at this depth is not expected to be present over the next 1000 years. If a future site resident installed a domestic well in the shallow bedrock and consumed groundwater, a maximum potential dose of between 5 mrem/y to 23 mrem/y may occur in only 1% of the area comprising the North Site. Groundwater present in the shallow bedrock would not be impacted for the remainder of the North Site. Installation of a domestic well in the unconsolidated sediments by a future site resident would be counter to good civil engineering practices and noncompliant with state regulations in most areas of the North Site. However, should a future site resident ignore these issues, install a domestic well in the unconsolidated sediments, and consume groundwater, a maximum potential dose ranging from 62 to 157 mrem/y could occur in approximately 3% of the area comprising the North Site. The potential dose from groundwater present in the unconsolidated sediments for the remaining 97% of the North Site ranges from 0.02 to 62 mrem/y. Groundwater remediation activities planned for the North Site will reduce uranium groundwater concentrations in the unconsolidated sediments and reduce the potential for contamination in the bedrock. These ALARA measures are expected to result in doses to future site residents (considering all exposure pathways) below 25 mrem/y. Since the dose to a future site user would be far below 25 mrem/y, exclusive of the groundwater pathway (particularly the worst-case well location assumption), and since the groundwater pathway is not considered a realistic future land use scenario, NFS considers the site conditions existing following completion of planned soil remedial activities should support release of the North Site for future unrestricted use. ALARA actions for groundwater would likely continue beyond the point of unrestricted site release.

APPENDIX B
SITE SPECIFIC INPUTS TO RESRAD

RESRAD Input Parameter	Units	Source	RESRAD Default	Subsistence Farming (reference only)	Residential Use Scenario	Industrial Use Scenario	Recreational Use Scenario	Const. Worker	Conserv Value?
Area of contaminated zone	m²		10,000	55,000	55,000	55,000	55,000	55,000	yes
Thickness of contaminated zone	m		2	1	1	1	1	1	no
Length Parallel to Aquifer Flow	m		100	260	260	n/a	n/a	n/a	yes
Time since placement of material	y		0	0	0	0	0	0	n/a
Initial Soil Concentration of Radionuclides									
Am-241	pCi/g		0	1	1	1	1	1	yes
Pu-238	pCi/g		0	1	1	1	1	1	yes
Pu-239	pCi/g		0	1	1	1	1	1	yes
Pu-240	pCi/g		0	1	1	1	1	1	yes
Pu-241	pCi/g		0	1	1	1	1	1	yes
Pu-242	pCi/g		0	1	1	1	1	1	yes
Tc-99	pCi/g		0	1	1	1	1	1	yes
Th-230	pCi/g		0	1	1	1	1	1	yes
Th-232	pCi/g		0	1	1	1	1	1	yes
U-233	pCi/g		0	1	1	1	1	1	yes
U-234	pCi/g		0	1	1	1	1	1	yes
U-235	pCi/g		0	1	1	1	1	1	yes
U-236	pCi/g		0	1	1	1	1	1	yes
U-238	pCi/g		0	1	1	1	1	1	yes
Cover depth	m		0	0	0	0	0	0	n/a
Density of contaminated zone	g/cm³		1.5	1.5	1.5	1.5	1.5	1.5	n/a
Contaminated zone erosion rate	m/y	SS, Lit²	0.001	1.23E-06	1.23E-06	1.23E-06	1.23E-06	1.23E-06	yes
Contaminated zone total porosity			0.4	0.4	0.4	0.4	0.4	0.4	n/a
Contaminated zone effective porosity			0.2	0.2	0.2	0.2	0.2	0.2	n/a
Contaminated zone hydraulic conductivity	m/y	SS	10	641.8	641.8	641.8	641.8	641.8	no
Contaminated zone b parameter			5.3	5.3	5.3	5.3	5.3	5.3	n/a
Evapotranspiration Coefficient			0.5	0.5	0.5	0.5	0.5	0.5	n/a
Precipitation	m/y	SS	1	1.16	1.16	1.16	1.16	1.16	no
Irrigation	m/y		0.2	0.2	0.2	0.2	0.2	0.2	n/a
Irrigation mode			overhead	overhead	overhead	overhead	overhead	overhead	n/a
Runoff Coefficient		Lit¹	0.2	0.35	0.35	0.35	0.35	0.35	no
Watershed area	m²		1E+6	1E+6	1E+6	n/a	n/a	n/a	n/a
Density of saturated zone	g/cm³		1.5	1.5	1.5	1.5	1.5	1.5	n/a
Saturated zone total porosity			0.4	0.4	0.4	0.4	0.4	0.4	n/a
Saturated zone effective porosity			0.2	0.2	0.2	0.2	0.2	0.2	n/a
Saturated zone hydraulic conductivity	m/y	SS	100	641.8	641.8	641.8	641.8	641.8	no
Saturated zone hydraulic gradient		SS	0.02	0.013	0.013	0.013	0.013	0.013	yes
Water table drop rate	m/y	SS	0.001	0	0	0	0	0	yes

RESRAD Input Parameter	Units	Source	RESRAD Default	Subsistence Farming (reference only)	Residential Use Scenario	Industrial Use Scenario	Recreational Use Scenario	Const. Worker	Conserv Value?
Number of unsaturated zone strata			1	0	0	n/a	n/a	n/a	yes
Distribution coefficients									
Americium (CZ)	cm^3/g	Lit[5]	20	1,900	1,900	1,900	1,900	1,900	*
Americium (SZ)	cm^3/g	Lit[5]	20	1,900	1,900	1,900	1,900	1,900	*
Plutonium (CZ)	cm^3/g	Lit[5]	2,000	550	550	550	550	550	*
Plutonium (SZ)	cm^3/g	Lit[5]	2,000	550	550	550	550	550	*
Radium (CZ)	cm^3/g	Lit[5]	70	500	500	500	500	500	*
Radium (SZ)	cm^3/g	Lit[5]	70	500	500	500	500	500	*
Technetium (CZ)	cm^3/g	Lit[5]	0	0.1	0.1	0.1	0.1	0.1	*
Technetium (SZ)	cm^3/g	Lit[5]	0	0.1	0.1	0.1	0.1	0.1	*
Thorium (CZ)	cm^3/g	SS	60,000	3,144.5	3,144.5	3,144.5	3,144.5	3,144.5	*
Thorium (SZ)	cm^3/g	Lit[5]	60,000	3,200	3,200	3,200	3,200	3,200	*
Uranium (CZ)	cm^3/g	SS	50	280.1	280.1	280.1	280.1	280.1	*
Uranium (SZ)	cm^3/g	Lit[5]	50	15	15	15	15	15	*
Actinium (CZ)	cm^3/g	Lit[5]	20	420	420	420	420	420	*
Actinium (SZ)	cm^3/g	Lit[5]	20	420	420	420	420	420	*
Neptunium (CZ)	cm^3/g	Lit[5]	-1	-1	-1	-1	-1	-1	*
Neptunium (SZ)	cm^3/g	Lit[5]	-1	-1	-1	-1	-1	-1	*
Protactinium (CZ)	cm^3/g	Lit[5]	50	510	510	510	510	510	*
Protactinium (SZ)	cm^3/g	Lit[5]	50	510	510	510	510	510	*
Lead (CZ)	cm^3/g	Lit[5]	100	270	270	270	270	270	*
Lead (SZ)	cm^3/g	Lit[5]	100	270	270	270	270	270	*
Inhalation Rate	m^3/y	Lit[4]	8,400	8,400	6,431	7,582	11,570	11,570	*
Mass loading for inhalation	g/m^3	Lit[1]	0.0001	0.0001	0.0001	0.0001	0.0003	0.0006	yes
Shielding factor, external gamma			0.7	0.62	0.62	0.43	0.62	0.43	yes
Fraction of time spent indoors		SS,Lit[5],Lit[6]	0.5	0.55	0.637	0.1971	0	0	*
Fraction of time spent outdoors		SS,Lit[5],Lit[6]	0.25	0.21	0.026	0.0219	0.1934	0.07415	no
Shape Factor flag, external gamma			1	1	1	1	1	1	n/a
Fruits, veg., and grain consumption	kg/y		160	160	160	n/a	n/a	n/a	n/a
Leafy veg. consumption	kg/y		14	14	14	n/a	n/a	n/a	n/a
Milk consumption	l/y		92	92	n/a	n/a	n/a	n/a	n/a
Meat and poultry consumption	kg/y		63	63	n/a	n/a	n/a	n/a	n/a
Fish consumption	kg/y		5.4	5.4	n/a	n/a	n/a	n/a	n/a
Other seafood consumption	kg/y		0.9	0.9	n/a	n/a	n/a	n/a	n/a
Soil ingestion rate	g/y	Lit[1]	36.5	36.5	36.5	36.5	175.2	175.2	yes
Drinking water intake	l/y		510	510	n/a	n/a	n/a	n/a	n/a
Contaminated fraction of:									
Drinking water			1	1	n/a	n/a	n/a	n/a	n/a

RESRAD Input Parameter	Units	Source	RESRAD Default	Subsistence Farming (reference only)	Residential Use Scenario	Industrial Use Scenario	Recreational Use Scenario	Const. Worker	Conserv Value?
Household water			1	n/a	n/a	n/a	n/a	n/a	n/a
livestock water			1	1	n/a	n/a	n/a	n/a	n/a
Irrigation Water			1	1	1	n/a	n/a	n/a	n/a
Aquatic Food			0.5	0.5	n/a	n/a	n/a	n/a	n/a
Plant Food		Lit[1]	-1	-1	0.25	n/a	n/a	n/a	yes
Meat			-1	-1	n/a	n/a	n/a	n/a	n/a
Milk			-1	-1	n/a	n/a	n/a	n/a	n/a
Drinking water, fraction from groundwater			1	1	1	1	1	1	n/a
Household water, fraction from groundwater			1	1	n/a	n/a	n/a	n/a	n/a
Livestock water, fraction from groundwater			1	n/a	n/a	n/a	n/a	n/a	n/a
Irrigation fraction from groundwater			1	1	n/a	n/a	n/a	n/a	n/a
Plant/soil concentration ratio									
Actinium		Lit[5]	2.5E-03	2.09E-04	2.09E-04	2.09E-04	2.09E-04	2.09E-04	no
Americium		Lit[5]	1.0E-03	6.94E-05	6.94E-05	6.94E-05	6.94E-05	6.94E-05	no
Neptunium		Lit[5]	2.0E-02	2.26E-03	2.26E-03	2.26E-03	2.26E-03	2.26E-03	no
Protactinium		Lit[5]	1.0E-02	1.49E-04	1.49E-04	1.49E-04	1.49E-04	1.49E-04	no
Lead		Lit[5]	1.0E-02	2.39E-03	2.39E-03	2.39E-03	2.39E-03	2.39E-03	no
Plutonium		Lit[5]	1.0E-03	3.06E-05	3.06E-05	3.06E-05	3.06E-05	3.06E-05	no
Radium		Lit[5]	4.0E-02	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	no
Technetium		Lit[5]	5.0E+00	9.55E-01	9.55E-01	9.55E-01	9.55E-01	9.55E-01	no
Thorium		Lit[5]	1.0E-03	1.07E-04	1.07E-04	1.07E-04	1.07E-04	1.07E-04	no
Uranium		Lit[5]	2.5E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	no
Dose Conversion Factors for Inhalation									
Th-232	mrem/pCi	SS	1.64	1.15	1.15	1.15	1.15	1.15	no
U-233 (insoluble)[3]	mrem/pCi		0.135	0.135	0.135	0.135	0.135	0.135	n/a
U-234 (insoluble)**	mrem/pCi		0.132	0.132	0.132	0.132	0.132	0.132	n/a
U-235 (insoluble)**	mrem/pCi		0.123	0.123	0.123	0.123	0.123	0.123	n/a
U-236 (insoluble)**	mrem/pCi		0.125	0.125	0.125	0.125	0.125	0.125	n/a
U-238 (insoluble)**	mrem/pCi		0.118	0.118	0.118	0.118	0.118	0.118	n/a

* Conservatism of input value is land use scenario dependent.

** RESRAD was run twice for all scenarios using the dose factors for inhalation and ingestion applicable for both soluble and insoluble forms of uranium. Runs for insoluble uranium consisted of using the default (most conservative) inhalation dose factor and the lowest (least conservative) f1 dose factor. Runs for soluble uranium consisted of using the default (most conservative) ingestion dose factor and the Class "D" (least conservative) inhalation dose factor.

SS = site specific data

Lit[1] = U.S. Dept. of Energy. Data Collection Handbook to Support Modeling of the Impacts of Radioactive Material in Soil. Argonne, IL. April 1993.

Lit[2] = U. S. Dept. of Agriculture. Erosion Prediction Guide. Rev 2. March 1995.

Lit[3] = Sheppard and Thibault. Default Soil Solid/Liquid Partition Coefficients, K_ds, For Four Major Soil Types: A Compendium. *Health Physics Society*. Volume 59, Number 4. October 1990.

Lit[4] = U.S. EPA. Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments.

Lit[5] = NRC guidance document NUREG/CR-5512.

Lit[6] = U.S. EPA. Time Spent in Activities, Locations, and Microenvironments: A California-National Comparison. Table 6-6.

Attachment V

Tennessee Historical Commission Letter Regarding the BLEU Complex Construction Site

(1 page to follow)

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G0V05
BLEU PROJ

TENNESSEE HISTORICAL COMMISSION
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
2941 LEBANON ROAD
NASHVILLE, TN 37243-0442
(615) 532-1550

March 14, 2002

Ms. Janice Green
Nuclear Fuel Services, Inc.
1205 Banner Hill Road
Erwin, Tennessee 37650

RE: NRC, BLEU COMPLEX CONSTRUCTION PLANT SITE, ERWIN, UNICOI COUNTY

Dear Ms. Green

The Tennessee State Historic Preservation Office has reviewed the above-referenced undertaking received on Tuesday, March 12, 2002 for compliance by the participating federal agency or applicant for federal assistance with Section 106 of the National Historic Preservation Act. The Procedures for implementing Section 106 of the Act are codified at 36 CFR 800 (Federal Register, December 12, 2000, 77698-77739).

After considering the documentation submitted, it is our opinion that there are no National Register of Historic Places listed or eligible properties affected by this undertaking. This determination is made either because of the location, scope and/or nature of the undertaking, and/or because of the size of the area of potential effect; or because no listed or eligible properties exist in the area of potential effect; or because the undertaking will not alter any characteristics of an identified eligible or listed property that qualify the property for listing in the National Register or alter such property's location, setting or use. Therefore, this office has no objections to your proceeding with the project.

If you are applying for federal funds, license or permit, you should submit this letter as evidence of compliance with Section 106 to the appropriate federal agency, which, in turn, should contact this office as required by 36 CFR 800. If you represent a federal agency, you should submit a formal determination of eligibility and effect to this office for comment. You may direct questions or comments to Jennifer M. Bartlett (615) 741-1588, ext. 17. This office appreciates your cooperation.

Sincerely,

Herbert L. Harper

Herbert L. Harper
Executive Director and
Deputy State Historic
Preservation Officer

HLH/jmb