4.0 RADIOLOGICAL STATUS OF FACILITY

PURPOSE OF THIS SECTION

The purpose of this section and the related Appendix B is to provide summary information on the radiological status of the facilities and environmental media within the scope of the plan. This information is intended to enable readers to understand the types, levels, and general extent of radioactive contamination in the WVDP facilities and in soil, sediment, groundwater, and surface water on the project premises.

INFORMATION IN THIS SECTION

This section focuses mainly on facilities and areas within the scope of the plan.

- Section 4.1.1 discusses sources of available radiological data, background radioactivity, the origin of site radioactivity, and the mode of contamination in facilities.
- Section 4.1.2 identifies facilities impacted by radioactivity.
- Section 4.1.3 identifies facilities not impacted by radioactivity as of 2008.
- Section 4.1.4 provides information on radionuclide distributions in facilities.
- Section 4.1.5 summarizes the radiological status of the facilities of interest.
- Section 4.2 addresses the radiological status of surface soil, sediment, sub-surface soil, surface water, and groundwater and identifies impacted and non-impacted areas of the project premises. It also provides data on environmental radiation levels.

Additional radiological characterization would be performed where appropriate as described in Section 7 and Section 9.

RELATIONSHIP TO OTHER PLAN SECTIONS

To put into perspective the information in this section, one must consider:

- The information in Section 1 on the project background and those facilities and areas within the scope of the plan;
- The information in Section 2 on site history, processes, previous decommissioning activities, and spills; and
- The facility descriptions, photographs, and illustrations in Section 3.

The radiological status information in this section provides the context for information provided in later sections, such as the dose modeling described in Section 5, the decommissioning activities in Section 7, and facility radiation surveys in Section 9.

4.1 Radiological Status of Facilities, Systems, and Equipment

This section summarizes existing data on radiological conditions in WVDP facilities, systems, and equipment. To fully define the radiological status of facilities and equipment within the scope of this plan, additional characterization would be performed in connection with proposed decommissioning activities as described in Sections 7 and 9.

4.1.1 Sources of Available Data

Radiological data on facilities, systems, and equipment are available from the Facility Characterization Project, which focused on the Process Building and the Vitrification Facility, and from several other sources.

Facility Characterization Project

The Facility Characterization Project, as described in the *Characterization Management Plan for the Facility Characterization Project* (Michalczak 2004a), produced conservative estimates of radionuclide inventories in various areas of the Process Building and in the 01-14 Building and the Vitrification Facility. These estimates are documented in a series of radioisotope inventory reports issued between 2002 and 2005.[1]

The Facility Characterization Project focused on the following radionuclides of interest:

Am-241	Cs-137	Pu-239	Tc-99	U-235
C-14	I-129	Pu-240	U-232	U-238
Cm-243	Np-237	Pu-241	U-233	
Cm-244	Pu-238	Sr-90	U-234	

Sixteen of these radionuclides (all except Sr-90 and Cs-137) were determined to be of interest because of their impacts in dose analyses associated with long-term performance assessment of the partially remediated site (Michalczak 2004a). Strontium-90 and Cs-137 were included because they are among the dominant radionuclides in site radioactive contamination and because they could have significant dose impacts in the near term.[2]

The process used to compile total activity estimates was inherently conservative for several reasons. These reasons include (1) assuming in dose rate-to-activity modeling that all measured gamma radiation was due to a single surrogate radionuclide (Cs-137 or Am-241), even though other gamma-emitting radionuclides may have also been present, and (2) use of the most conservative radionuclide distribution data for estimating scaling factors relating amounts of other radionuclides to Cs-137 in cases where multiple sets of radionuclide distribution data were available (Michalczak 2004a).

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[1]The Facility Characterization Project focused on source term estimates because when it was initiated the decommissioning approach was expected to entail in-place closure of a portion of the upper structure of the Process Building, as well as the underground portions of the structure and the Vitrification Facility.

[2] Additional information about selection of the radionuclides of primary interest for the Facility Characterization Project and in developing DCGLs for soil and sediment contamination appears in Section 5.2.

In addition to the source term estimates, the radioisotope inventory reports contain information on radiological history, radionuclide distributions, contamination levels, and radiation levels.

Characterization of the Underground Waste Storage Tanks

The four waste storage tanks have undergone detailed characterization. Data collection and analysis for Tanks 8D-1 and 8D-2 were performed in accordance with an approved data collection and analysis plan (Fazio 2001). The characterization results appear in three radioisotope inventory reports (Fazio 2002a, Fazio 2002b, and Fazio 2004c). These reports were provided to NRC in connection with preparation of the Decommissioning EIS.

In response to comments on the radioisotope inventory reports from NRC and other agencies, DOE prepared a supplemental report (WVNSCO and Gemini 2005) to clarify information on radionuclides of significance, address uncertainty in the inventory estimates, and provide additional information on the technical basis for scaling factors and on the mobile inventory estimate for Tank 8D-4.

Other Facility Residual Radioactivity Estimates

In 2008, the site contractor, West Valley Environmental Services (WVES), developed additional estimates for residual radioactivity in the Process Building, the Vitrification Facility, and underground waste storage Tanks 8D-3 and 8D-4 in the interim end state, i.e., at the beginning of the Phase 1 proposed decommissioning activities (WVES 2008a, WVES 2008b, and WVES 2008c, respectively). These estimates utilized the previous characterization results combined with projections based on additional decontamination to be performed in certain areas in connection with work to achieve the interim end state.

Analytical Data

The results of analyses of numerous liquid and solid samples performed by both onsite and offsite laboratories are available. These data, most of which are summarized in the radioisotope inventory reports, have been used to define radionuclide distributions in various areas of the Process Building and in the Vitrification Facility, the underground waste tanks, and other WVDP areas.

Routine Radiological Survey Data for Facilities

Routine radiological status surveys are performed in WVDP facilities in support of the WVDP radiation protection program. Data from these surveys, which typically include general area gamma radiation levels and removable beta contamination levels, reflect the current radiological status in accessible areas of most WVDP facilities.

Scoping Data

Available radiological data on facilities, systems, and equipment are generally considered to be scoping data, with the exception of data on the underground waste tanks, which have been appropriately characterized. As defined in the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (NRC 2000), scoping survey data

identify radionuclide contaminants, relative radionuclide ratios, general levels, and the extent of contamination, yet may not comprise definitive characterization data. In some areas, available data are insufficient to meet the definition of scoping data, especially in cases where radionuclide ratios are not available or where the extent of contamination is not defined. (As noted previously, additional characterization would be performed in connection with proposed decommissioning activities as described in Sections 7 and 9.)

Background Radioactivity

Limited data are available on background radioactivity in facilities, although there are data from areas with a low potential for contamination. For example, typical routine surveys show gamma radiation levels <0.1 mR/h in the Solvent Storage Terrace and Acid Handling Area of the Process Building (Michalczak 2004b) and measurements taken with sodium-iodide detectors recorded in μR/h are available in some low-potential areas. During the characterization program outlined in Section 9, sufficient data would be acquired to establish background levels in facilities within the scope of the Phase 1 proposed decommissioning activities.

Origin of Site Radioactivity

Radioactivity associated with the project premises originated in irradiated nuclear fuel reprocessed in the Process Building. Analytical data on radioactivity in the fuel are available as described below. With the exception of one batch of thorium-uranium fuel, all fuel reprocessed was uranium based, as noted in Section 2.

Information on how the facilities became contaminated is contained in Section 2.

Mode of Contamination in Facilities

In many cases, radioactive contamination associated with facilities is located only on facility surfaces, and does not penetrate into the surfaces, and inside contaminated systems and equipment. In some cases contamination is also located on the outside of systems and equipment.

Exceptions primarily involve contamination of Process Building facility surfaces in depth from spills of radioactive acid on painted concrete surfaces and where radioactive water stood in the fuel pools. This conclusion is generally based on radiation level measurements on decontaminated surfaces that have minimal removable contamination. Quantitative information on the depth of penetration is available only in a single case: one sample from a wall of the Chemical Process Cell that showed contamination had penetrated approximately two inches into the concrete (URS 2001).

Data Provided in this Section

Section 4.1 provides estimates of residual radioactivity for the Process Building and the Vitrification Facility, which are within the scope of this plan, and for information and perspective, the underground waste storage tanks, and the NRC-Licensed Disposal Area (NDA). Data on radiation levels in representative areas of the Process Building, in the

Vitrification Facility, and in other areas are provided. Residual radioactivity in other areas is also discussed.

4.1.2 Impacted Facilities

The following facilities where licensed activities and/or WVDP activities have taken place are known or suspected to contain residual radioactive material in excess of background levels. Figures 4-1, 4-2, 4-3, 4-4, and 4-5 show the locations of these facilities. This list does not include facilities existing in 2008 that will be removed before the proposed decommissioning activities begin, which are addressed in Section 2.2.2. However, it does include for information and perspective some facilities that are not within the scope of Phase 1 of the proposed decommissioning.

WMA 1, Process Building and Vitrification Facility Area

- Process Building
- Utility Room and Utility Room Expansion
- Plant Office Building
- 01-14 Building
- Load-In/Load-Out Facility
- Vitrification Facility
- Vitrification off-gas trench lines
- Underground wastewater Tanks 35104, 7D-13, and 15D-6
- Underground lines

WMA 2, Low-Level Waste Treatment Facility Area

- LLW2 Building
- Old Interceptor
- New Interceptors (2)
- Neutralization Pit
- Lagoon 1 (deactivated)
- Lagoon 2
- Lagoon 3
- Lagoon 4
- Lagoon 5
- Solvent Dike

- Underground wastewater lines[3]
- French drain
- Maintenance Shop leach field
- North Plateau Groundwater Pump and Treat Facility (not in plan scope)
- Pilot permeable treatment wall (not in plan scope)
- Full-scale permeable treatment wall (to be installed, not in plan scope)

WMA 3, Waste Tank Farm Area

- Underground waste Tanks 8D-1 and 8D-2 and associated vaults[4]
- Underground waste Tanks 8D-3 and 8D-4 and their common vault[3]
- Con-Ed Building
- Equipment Shelter and Condensers
- HLW Transfer Trench piping
- Permanent Ventilation System Building (not in plan scope)
- Supernatant Treatment System Support Building (not in plan scope)
- Underground lines (not in plan scope)

WMA 4, Construction and Demolition Debris Landfill Area

- Construction and Demolition Debris Landfill (not in plan scope)
- Permeable reactive barrier (to be installed, not in plan scope)

WMA 5, Waste Storage Area

- Lag Storage Area 4 and Shipping Depot
- Remote Handled Waste Facility

WMA 6, Central Project Premises

- Demineralizer sludge ponds (2)
- Cooling Tower basin
- Rail Spur (because of nearby soil contamination, not within plan scope)

WMA 7, NDA and Associated Facilities

- Entire area (only the hardstand is within plan scope)

WMA 9, Radwaste Treatment System Drum Cell Area

- Radwaste Treatment System Drum Cell

[3] Only those lines within planned excavations to remove facilities are within plan scope.
[4] Only the tank mobilization and transfer pumps and their support structures are with the scope of this plan.

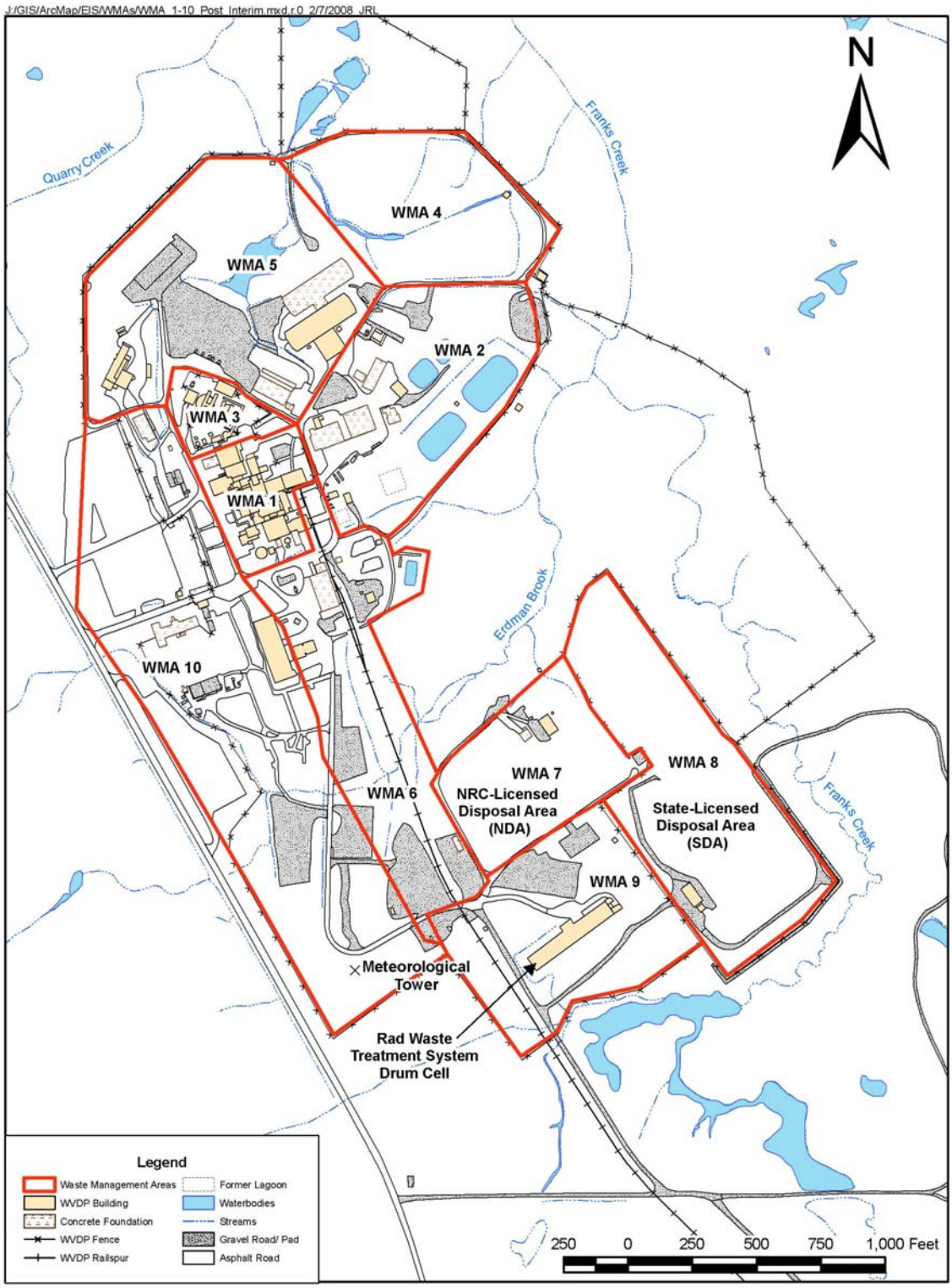

Figure 4-1. Location of Impacted and Non-Impacted Facilities

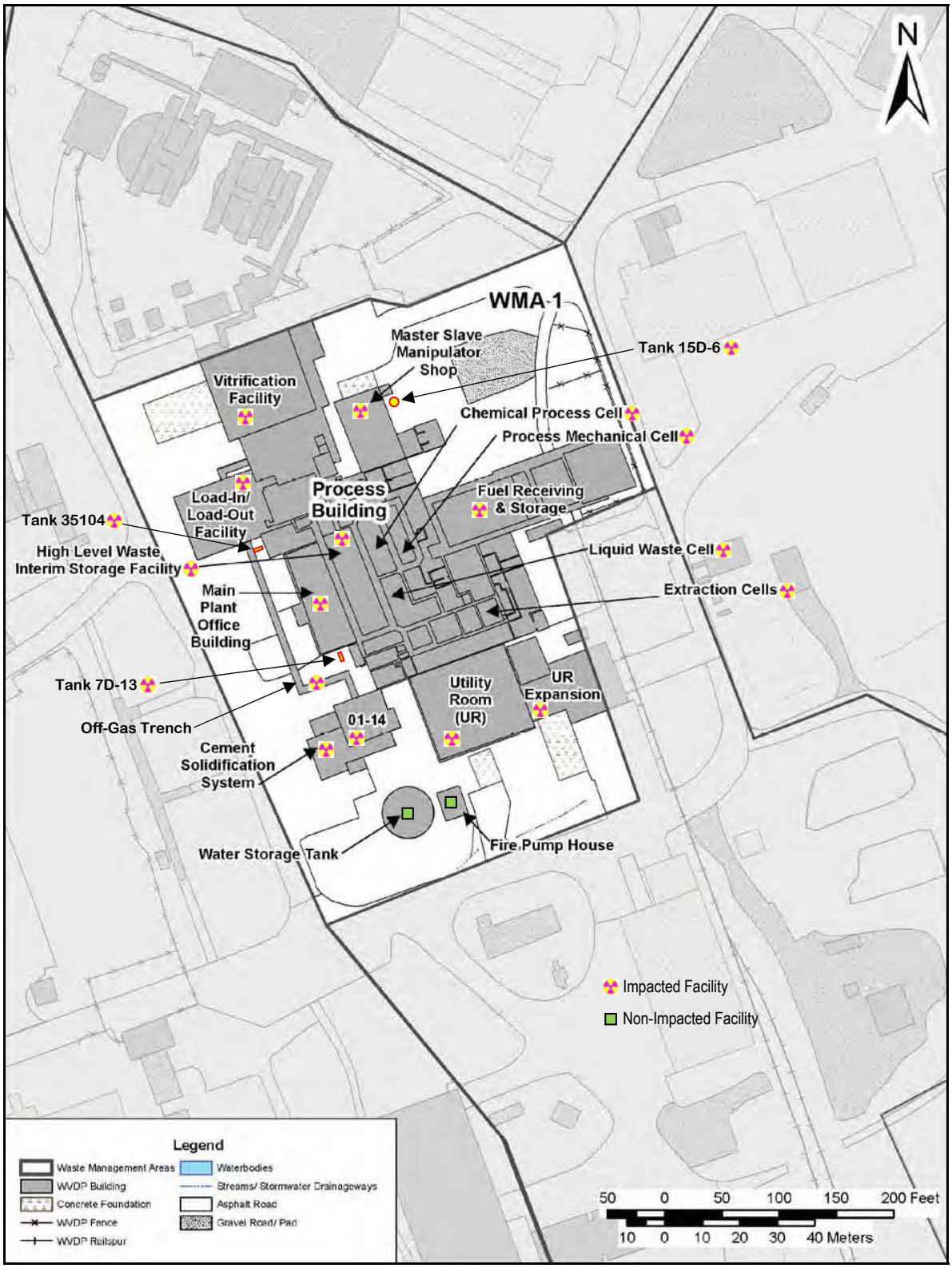

Figure 4-2. Impacted and Non-Impacted Facilities in WMA 1

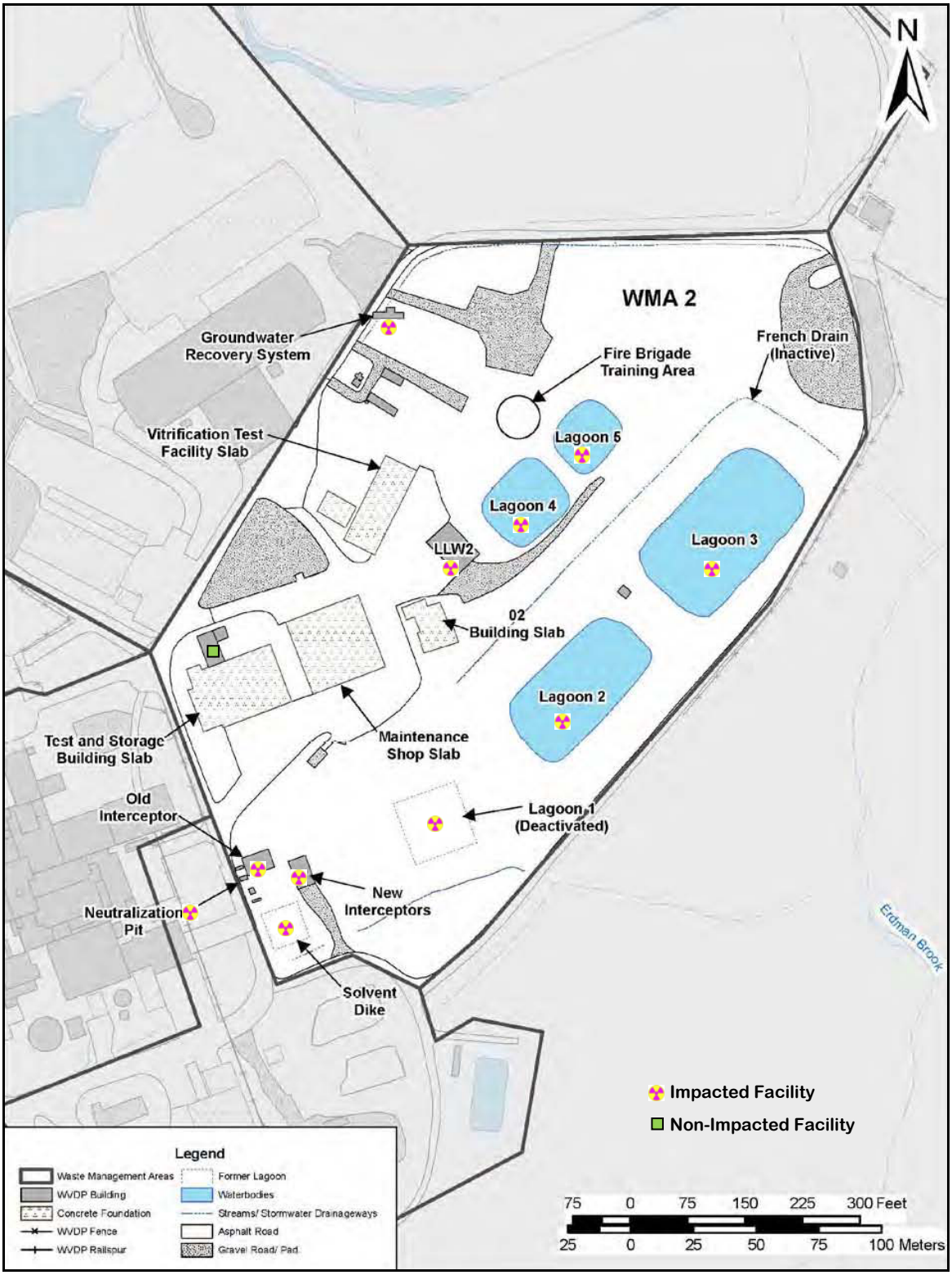

Figure 4-3. Impacted and Non-Impacted Facilities in WMA 2

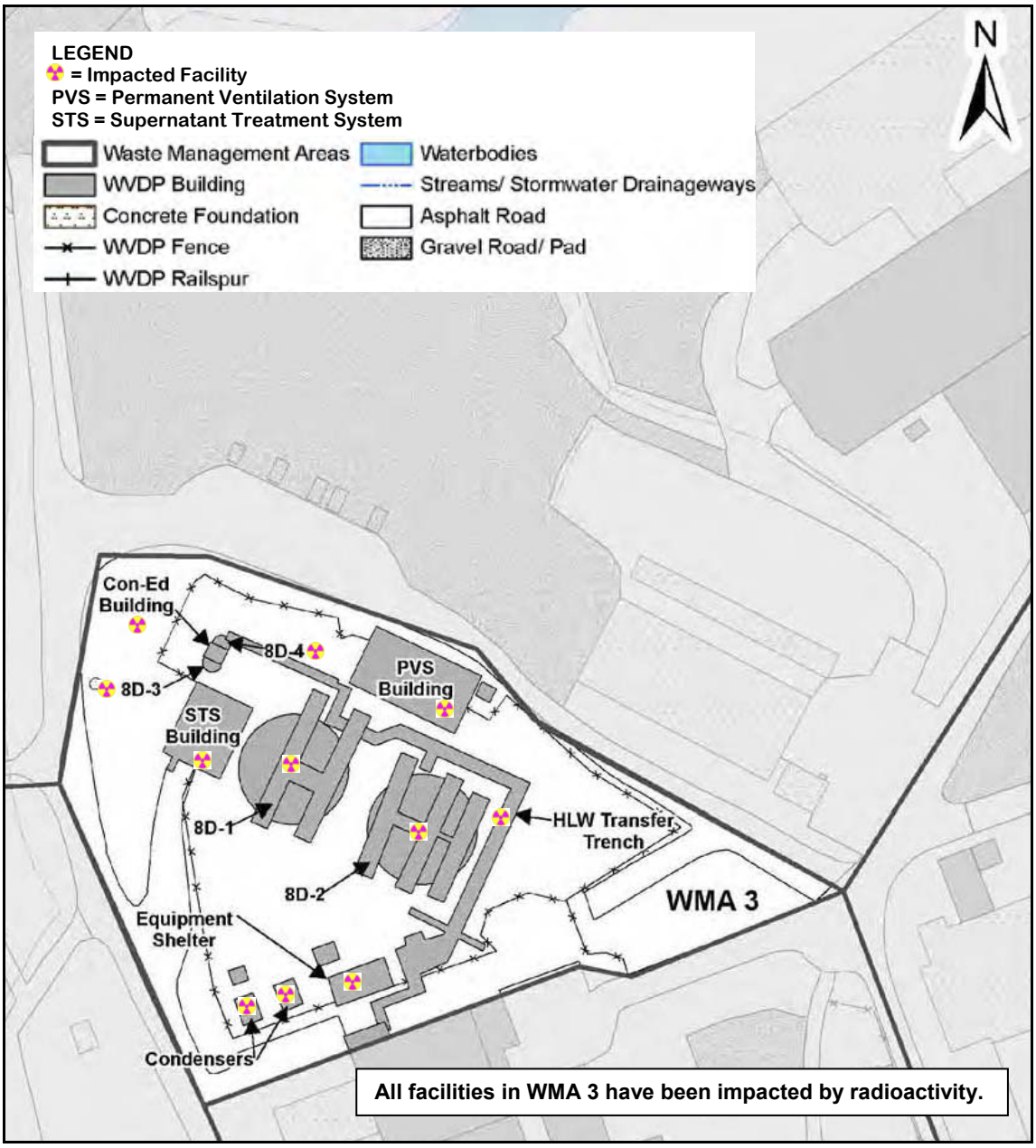

Figure 4-4. Impacted Facilities in WMA 3

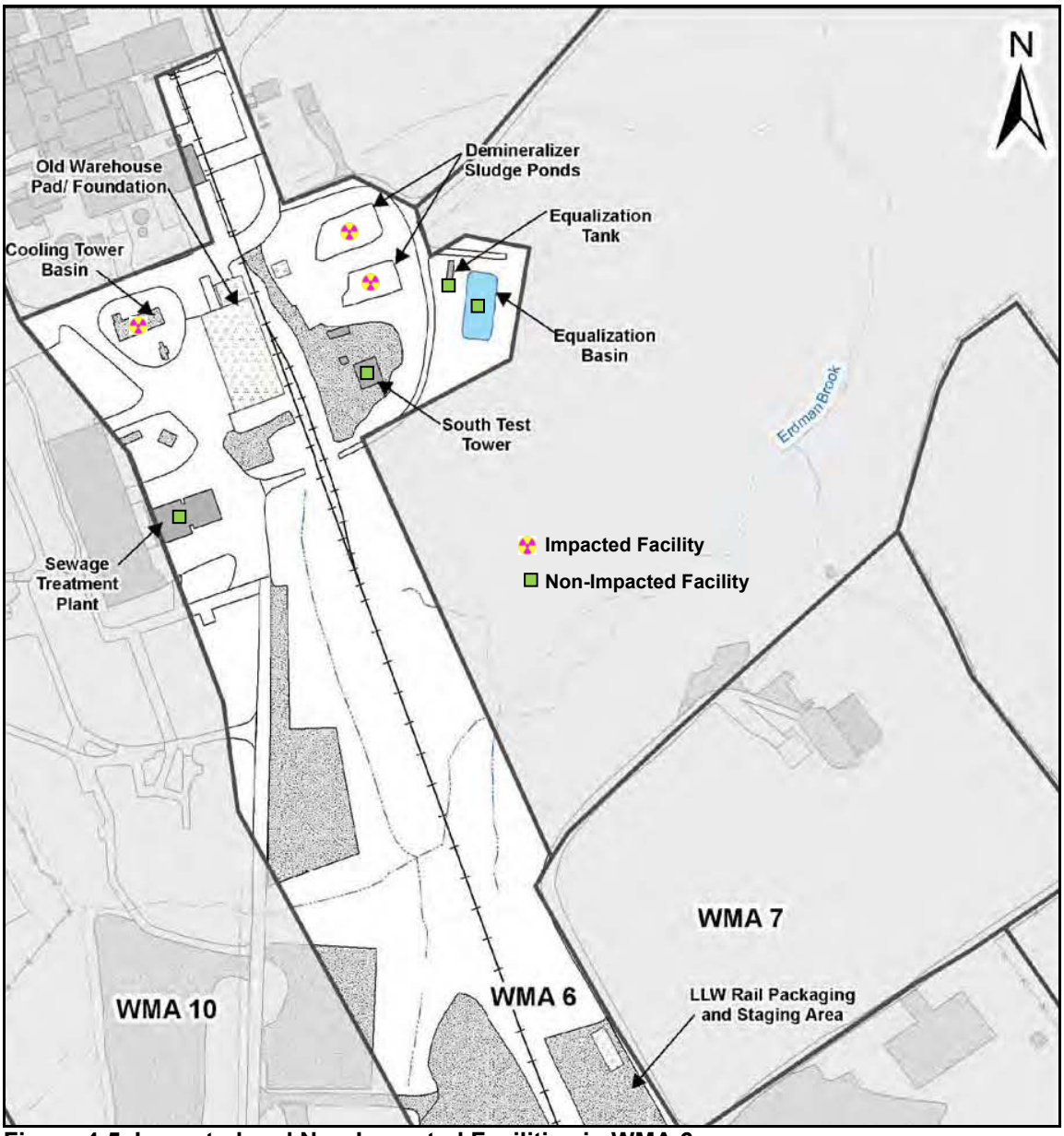

Figure 4-5. Impacted and Non-Impacted Facilities in WMA 6

4.1.3 Non-Impacted Facilities

The following structures and locations have not been impacted by radioactivity associated with licensed activities or WVDP activities as of 2008, based on process history, the results of routine radiological surveys, and the results of the WVDP environmental monitoring program (WVES and URS 2008). These facilities are shown in Figures 4-1, 4-2, or 4-5.

WMA 1, Process Building Area

- Fire Pump House
- Water Storage Tank
- Electrical Substation

WMA 6, Central Project Premises

- Sewage Treatment Plant
- South Waste Tank Farm Test Tower
- Equalization Basin
- Equalization Tank

WMA 10, Support and Services Area

- New Warehouse
- Meteorological Tower (not within plan scope)
- Security Gatehouse and Fences (not within plan scope)

Even though the Sewage Treatment Plant is considered not to have been impacted by radioactivity associated with licensed activities or the WVDP as of 2008, the excavation dug for its removal would be considered in Phase 1 final status surveys because of the potential buildup of naturally-occurring radioactivity in sewage sludge, as explained in Section 7.

Some WMAs also contain concrete floor slabs and foundations and gravel pads that would be removed during Phase 1. Some of the concrete slabs have been impacted by radioactivity as explained in Section 2 and may contain low levels of residual radioactivity.

> Note that conditions in the non-impacted facilities are subject to change. DOE or its decommissioning contractor would reevaluate the conclusion that these facilities have not been impacted before decommissioning activities begin.

4.1.4 Radionuclide Distributions

Owing to the nature of spent fuel separation and purification processes, radionuclide distributions vary inside different areas of the Process Building and in other facilities of interest depending on the point in the reprocessing cycle where the contamination originated. Other factors discussed below also influenced radionuclide distributions inside the Process Building.

During the Facility Characterization Project, available analytical data and data from samples obtained and analyzed during this project were utilized to establish bounding radionuclide scaling factors. These scaling factors, which relate the concentrations of other radionuclides of interest to the concentration of Cs-137 or Am-241, were chosen to ensure that concentrations of radionuclides important to the dose evaluation were not underestimated[5].

The two principal radionuclide distributions that were available before the beginning of the Facility Characterization Project are known as the spent fuel distribution and the Batch 10 distribution. These distributions are discussed below.

Spent Fuel Distribution

Information on the radionuclide distribution associated with spent nuclear fuel has been derived primarily from the results of modeling of fuel processed by Nuclear Fuel Services (NFS) that was performed by Pacific Northwest National Laboratory using the ORIGEN2 computer code (Jenquin, et al. 1992). These data were used for all radionuclides of interest in spent fuel except U-235 and U-238, which were derived from NFS records for recovered and unaccounted for losses of uranium, and U-232, U-233, U-234, and U-236, which were established based on analytical results showing the U-232 to U-235/236 ratio from samples collected in the Acid Recovery Pump Room of the Process Building. The resulting scaling factors relating concentrations of other radionuclides of interest to the concentration of Cs-137 were determined to be conservative (Mahoney 2002). These scaling factors are shown in Table 4-1.

Table 4-1. Scaling Factors for Spent Fuel Reprocessed(1)

Nuclide	Ratio(2)	Nuclide	Ratio(2)	Nuclide	Ratio(2)
Am-241	8.58E-02	Np-237	4.5E-06	U-232	6.9E-01
C-14	1.3E-04	Pu-238	1.69E-02	U-233	1.40E+00
Cm-242	2.0E-04	Pu-239	2.84E-02	U-234	9.0E-02
Cm-243	5.9E-05	Pu-240	1.48E-02	U-235	1.5E-06
Cm-244	1.52E-03	Pu-241	9.10E-01	U-236	1.39E-01
I-129	6.3E-07	Tc-99	2.7E-04	U-238	2.6E-05

Notes: (1) From Mahoney 2002, Tables 1 and 2, reference date January 1, 1993

(2) All are scaled to Cs-137, except for U-232, U-233, U-234, and U-236, which are scaled to U-238. Sr-90 does not appear in the tables of calculated scaling factors in Mahoney, 2002. The Sr-90 to Cs-137 ratio was determined to be 9.5E-01 (WVNSCO 1989).

Note that in compiling estimates during the Facility Characterization Project, the reference date was adjusted to September 30, 2004 and the values for U-232, U-233, U-234, and U-236 were scaled to Cs-137 rather than U-238.

[5]Where multiple data sets were available, the highest values among radionuclide ratios from the different data sets were selected for each radionuclide for conservatism (Michalczak 2004a).

Batch 10 HLW Distribution

The vitrification Batch 10 distribution was used to establish bounding scaling factors related to Cs-137 for HLW. The Batch 10 sample analyzed was obtained from the first HLW transfer from underground waste Tank 8D-2 to the Vitrification Facility in 1996. It was representative of the waste in its most concentrated form when the highest ratios of alpha-emitting transuranic radionuclides to Cs-137 were present. Later batches contained relatively higher concentrations of Cs-137 (and lower ratios of alpha-emitting transuranics to Cs-137) because Cs-137 captured in zeolite resin was returned to Tank 8D-2 for subsequent transfer to the Vitrification Facility.

The Batch 10 sample was analyzed in May 1997 by the Radiological Processing Laboratory at Pacific Northwest National Laboratory. The analysis results are shown in Table 4-2.

Table 4-2. Batch 10 Sample Data(1)

Nuclide	µC/g	Nuclide	µC/g	Nuclide	µC/g
Am-241	3.21E+01	Np-237	2.00E-02	Tc-99	8.45E-02
C-14	4.90E-04	Pu-238	3.96E+00	U-232	(2)
Cm-243	2.58E-01	Pu-239	1.09E+00	U-233	3.60E-03
Cm-244	6.72E+00	Pu-240	7.70E-01	U-234	1.30E-03
Cs-137	2.85E+03	Pu-241	3.43E+01	U-235	3.80E-05
I-129	3.90E-07	Sr-90	2.75E+03	U-238	3.40E-04

Notes: (1) From Pacific Northwest National Laboratory results corrected for decay and ingrowth to May 15, 1997, included in Michalczak 2003b.
(2) No analysis was performed for U-232.

Process Building Distributions

During the Facility Characterization Project, the spent fuel distribution and the Batch 10 distribution were used in conjunction with sample analytical data to determine the appropriate radionuclide distribution for various representative areas of the Process Building.

Contamination in most areas of the building resulted primarily from spills and leaks of materials in the reprocessing feed and waste process streams. This feed and waste contamination is associated with reactor fuel before fission products have been separated or with the separated fission products. Until the point where the fuel was dissolved in the Chemical Process Cell, radionuclide ratios remained characteristic of the feed and waste process streams, typified by the Batch 10 distribution in Table 4-2.

Downstream of the dissolution process that took place in the Chemical Process Cell, radionuclide ratios began to change in the extraction cells, where the dissolved fuel underwent a solvent extraction process that separated uranium and plutonium from the

fission products. The uranium and plutonium products achieved their purest forms in the Product Purification Cell.

Contamination in other areas of the building came primarily from spills or leaks of the reprocessed products. These other areas are the Product Purification Cell, the Lower Warm Aisle, the Product Packaging and Handling Area, and the Extraction Sample Aisle.

There are substantial variations among distributions in different areas. One particular spill during reprocessing that affected radionuclide distributions in several areas was the release of highly radioactive nitric acid from an acid recovery line in the southwest corner of the building, as described in Section 2.

The dominant radionuclides in the Process Building contamination are typically Cs-137, Pu-241, Sr-90, Am-241, and Pu-238. The relative fractions of dominant radionuclides in the two basic distributions can be calculated based on the geometric means of the distributions in the various Process Building areas. Table 4-3 shows the results of these calculations. However, there are significant variations from these relative fractions in the different areas for which data were compiled.

Table 4-3. Relative Fractions of Process Building Dominant Radionuclides(1)

Relative Fractions of Dominant Radionuclides in Feed and Waste Contamination					
Radionuclide	**Pu-241**	**Cs-137**	**Sr-90**	**Am-241**	**Pu-238**
Fraction	0.404	0.281	0.216	0.065	0.035
Relative Fractions of Dominant Radionuclides in Product Contamination					
Radionuclide	**Pu-241**	**Am-241**	**Pu-238**	**Pu-239**	**Pu-240**
Fraction	0.754	0.133	0.045	0.039	0.029

NOTE: (1) Based on geometric means of radionuclides in the differently impacted areas using data from the Facility Characterization Project radioisotope inventory reports . These were the ratios on September 30, 2004, the reference date for the data used.

The information on radionuclide distributions for different Process Building areas found in the radioisotope inventory reports produced by the Facility Characterization Project would be used for planning decommissioning activities in the building and for waste management purposes.

The relative fractions of the dominant radionuclides in the Vitrification Facility are shown in Table 4-4.

Table 4-4. Relative Fractions of Vitrification Facility Dominant Radionuclides(1)

Radionuclide	**Cs-137**	**Sr-90**	**Am-241**	**Pu-241**	**Cm-244**
Fraction	0.506	0.482	0.007	0.005	0.001

NOTE: (1) Based on data in Radioisotope Inventory Report RIR-403-010 (Lachapelle 2003) as of December 31, 2006 as given in WVES 2008b.

4.1.5 Radiological Status of Facilities

Most of the residual radioactivity in facilities within the scope of this plan resides in two areas: the Process Building and the Vitrification Facility. Significant amounts of radioactivity are also located in Lagoon 1, Lagoon 2, the piping in the HLW transfer trench, the vitrification off-gas line that runs to the 01-14 Building, and underground piping in the Process Building area.

Radioactivity in WMA 1, the Process Building

The Facility Characterization Project provided residual inventory estimates for 33 different areas of the Process Building, including a group of "low ranking" areas. However, additional decontamination work is being accomplished in the Off-Gas Cell, the General Purpose Cell, and the Process Mechanical Cell.

Table 4-5 provides an estimate of the total amount of residual radioactivity that will be in the building when the interim end state is reached, that is, at the beginning of Phase 1 proposed decommissioning activities. The estimates account for the expected effectiveness of the planned decontamination work, which will include removal of certain equipment and two decontamination cycles for the floors and walls of the General Purpose Cell, the Process Mechanical Cell, and the Off-Gas Cell (WVES 2008a).

Table 4-5. Estimated Process Building Residual Activity at Start of Decommissioning(1)

Nuclide	Estimate (Ci)	Nuclide	Estimate (Ci)	Nuclide	Estimate (Ci)
Am-241	260	Np-237	0.57	Tc-99	4.9
C-14	13	Pu-238	200	U-232	0.75
Cm-243	0.27	Pu-239	63	U-233	0.41
Cm-244	6.3	Pu-240	47	U-234	0.19
Cs-137	2550	Pu-241	1100	U-235	0.03
I-129	0.63	Sr-90	1900	U-238	0.09

(1) From WVES, 2008a, not including the amounts for "yard" (i.e., the three underground wastewater tanks) and the 01-14 Building, with the estimates rounded to two significant figures or the nearest integer. These estimates were corrected for decay and ingrowth to 2011. They do not include activity associated with the HLW canisters or approximately 110 curies in embedded piping in the Process Building (McNeil 2005a).

Table 4-6 shows the total estimated residual radioactivity in different areas of the Process Building as of 2004.

Table 4-6. Estimated Total Activity in Representative Process Building Areas(1)

Area	Curies	Area	Curies
Analytical Decontamination Aisle	<1	Main Plant Stack	88
Acid Recovery Cell(1)	60	Miniature Cell	9
Acid Recovery Pump Room	31	Off-Gas/Acid Recovery Aisle	40

Table 4-6. Estimated Total Activity in Representative Process Building Areas(1)

Area	Curies	Area	Curies
Analytical Hot Cells	39	Off-Gas Blower Room	72
Building Roof	1	Off-Gas Cell(1)	250
Chemical Crane Room	6	Process Mechanical Cell(1)	1000
Chemical Process Cell	130	Process Sample Cells, 1C Sample Station	6
Equipment Decontamination Rm	36	Product Purification Cell	43
Extraction Cell 1(1)	47	Sample Storage Cell	17
Extraction Cell 2	2	Scrap Removal Room	<1
Extraction Cell 3(1)	11	Southwest Stairwell	5
Fuel Receiving and Storage	290	Upper Warm Aisle	18
General Purpose Cell(1)	3000	Uranium Load-Out Area	<1
GPC Crane Room and Extension	7	Uranium Product Cell	45
Head-End Ventilation Cell	610	Ventilation Exhaust Cell	67
Hot Acid Cell	<1	Ventilation Wash Room	74
Liquid Waste Cell	1000	Low Ranking Areas (31 areas)	25
Lower Warm Aisle	84	Embedded Piping	110

(1) From WVES, 2008a, with estimates corrected for decay and ingrowth to September 30, 2004 and here rounded to two significant figures or the nearest whole number, with the exception of the embedded piping estimate, which is taken from McNeil 2005a. These estimates assume that the work to achieve the interim end state will include additional decontamination of the floors and walls in three areas: the General Purpose Cell, the Off-Gas Cell, and Process Mechanical Cell. The estimates also assume that the vessels in the Acid Recovery Cell, the Hot Acid Cell, Extraction Cell 1, and Extraction Cell 3 will be removed.

Despite decontamination efforts, radiation levels remain relatively high in some areas of the building. Table 4-7 shows the highest radiation levels measured in representative areas.

Table 4-7. Measured Maximum Gamma Radiation Levels in Process Building Areas

Area	mR/h	Remarks	Source
Chemical Process Cell	15,000	At south sump in 1994	Michalczak 2003a
Equipment Decontamination Room	50	On floor in 1997	Michalczak 2003b
Fuel Receiving and Storage Area	8.5	Fuel Storage Pool, 2002	Fazio 2004a
	500	Cask Unloading Pool, 2002	Fazio 2004a
General Purpose Cell	200,000	3 feet above floor(1)	Choroser 2005a
	32,000	9 feet above floor(1)	Choroser 2005a
Head-End Ventilation Cell	50,000	On pre-filters in 2002	Michalczak 2003c
Liquid Waste Cell	1,800	In 2002	Choroser 2004
Miniature Cell	80	In 1998	Michalczak 2002a
Off-Gas Blower Room	700	In 2003	Michalczak 2002b

Table 4-7. Measured Maximum Gamma Radiation Levels in Process Building Areas

Area	mR/h	Remarks	Source
Process Mechanical Cell	40,000	In 2004, 3 feet above floor(1)	Choroser 2005b
Product Purification Cell	53	Hot spot on wall in 2003	Choroser 2003
Sample Storage Cell	1,950	On floor in 2001	Drobot 2003
Ventilation Wash Room	1,500	On ventilation duct	URS 2001

(1) Before planned additional decontamination described in report WVES 2008a.

Radiation levels on the vitrified HLW canisters measured in the 1996 to 2002 period during vitrification ranged from 1,770 to 7,460 R/h (Michalczak 2003a). The total activity in the average canister is approximately 37,000 curies, including approximately 13,600 curies of Sr-90 and approximately 23,400 curies of Cs-137, based on data in the waste form qualification report (WVNSCO 2007). The canisters remain stored in the HLW Interim Storage Facility in the former Chemical Process Cell, as noted previously.

Radioactivity in WMA 1, the Vitrification Facility

Table 4-8 shows the estimated residual radioactivity in the Vitrification Facility at the beginning of Phase 1 proposed decommissioning activities. Essentially all of this radioactivity is in the Vitrification Cell.

Table 4-8. Estimated Total Activity in the Vitrification Facility(1)

Nuclide	Estimate (Ci)	Nuclide	Estimate (Ci)	Nuclide	Estimate (Ci)
Am-241	14	Np-237	0.01	Tc-99	0.04
C-14	<0.01	Pu-238	1.6	U-232	<0.01
Cm-243	0.09	Pu-239	0.49	U-233	<0.01
Cm-244	1.9	Pu-240	0.35	U-234	<0.01
Cs-137	960	Pu-241	8.7	U-235	<0.01
I-129	<0.01	Sr-90	910	U-238	<0.01

(1) From WVES 2008b, corrected for decay and ingrowth to 2011 and rounded to two significant figures or the nearest integer.

Gamma radiation levels in the Vitrification Cell process pit in 2004 after equipment removal and decontamination ranged from 3.1 to 50.5 R/h, with levels in other parts of the cell in the 1.2 to 18.1 R/h range (WVNSCO 2004b).

Radioactivity in Other WMA 1 Facilities

The 01-14 Building together with the vitrification off-gas line that runs to the building from the Vitrification Facility is estimated to contain in 2011 approximately 340 curies, due principally to Sr-90 and Cs-137. Almost the entire amount is expected to be inside the off-gas line. The only place within the building itself where a significant amount of radioactivity is expected, besides the portion of the off-gas line in the building, is in the ventilation exhaust system filters (if these filter remain in place). (Michalczak 2004c)

While the Plant Office Building, the Utility Room, the Utility Room Expansion, and the Load-In Facility have been impacted, they are expected to contain insignificant amounts of radioactivity. Radiation levels in these structures are expected to be <1 mR/h with no removable surface contamination above the minimum detectable concentration (Michalczak 2004b).

Three underground wastewater tanks are located below grade outside of the Process Building: Tank 7D-13, Tank 15D-6, and Tank 35104 as shown in Figure 4-2. Tank 7D-13 has been estimated to contain 150 to 300 gallons of solids containing up to 84 curies in 2011, with the dominant radionuclide being Cs-137, Sr-90, Pu-241, Am-241, and Pu-239 (Michalczak 2004c). The other two tanks are not expected to contain significant amounts of radioactivity.

Most of the underground lines in WMA 1 are expected to be radioactively contaminated. A single line – HLW transfer line 7P120-3 – was estimated to contain more than 90 percent of the total activity. This line runs from under the Chemical Process Cell to Tanks 8D-3 and 8D-4 in WMA 3 and is expected to contain residual radioactivity of approximately 0.4 curie per linear foot in 2011, with almost all of this activity associated with Sr-90 and Cs-137. Several of the underground lines within WMA 1 are known to have leaked as discussed in Section 2. (Luckett, et. al 2004)

Radioactivity in WMA 2 Low-Level Waste Treatment Facility Area Facilities

Low levels of radioactivity are expected to be present in the LLW2 Building. Lagoon 1 is expected to contain a substantial amount of radioactivity, with more than 90 percent in the remaining sediment. Table 2-19 shows the estimated amounts in 2011.

Lagoon 2 is expected to contain residual radioactivity of the same order of magnitude as Lagoon 1 with a similar radionuclide distribution.[6] Lagoon 3 is expected to contain less radioactivity in its sediment than Lagoons 1 and 2. Lagoons 4 and 5 are expected to contain relatively low levels of radioactivity in sediment both above and below their liners. Table 4-14 shows the maximum measured concentrations of radioactivity in sediment samples obtained from each of the lagoons.

The Old Interceptor is expected to contain a significant amount of radioactivity based on available data, which include a gamma radiation level of 408 mR/h measured near the tank bottom in 2003 (WVNSCO 2003). As noted in Section 2, 12 inches of concrete was poured on the tank floor by NFS as radiation shielding. The New Interceptors and the Neutralization Pit are both expected to contain low levels of radioactive contamination.

The three septic tanks and other equipment in the Maintenance Shop leach field may have been impacted by the north plateau groundwater plume, but any resulting contamination levels are expected to be low.

[6] This conclusion is based on primarily on records showing that 22,400 cubic feet of sediment was pumped from Lagoon 1 to Lagoon 2 in 1984, with this sediment containing approximately 107 curies of total alpha activity and 1162 curies of total beta activity (Passuite and Monsalve-Jones 1993). Table 4-14 shows maximum measured radionuclide concentrations in the two lagoons, with Cs-137 concentrations being the same order of magnitude.

The contaminated underground wastewater lines within WMA 2 were estimated to contain a total of approximately 0.3 curies of residual radioactivity in 2004 (Luckett, et al. 2004). The French drain is expected to contain very low levels of residual radioactivity.

Radioactivity in the WMA 3 Waste Tank Farm Area Facilities

As explained in Section 1, only certain facilities and equipment within WMA 3 are within the scope of this plan. However, all WMA 3 facilities are briefly addressed here for perspective.

Table 2-5 in Section 2 provides estimates for the residual radioactivity in the underground waste tanks at the conclusion of reprocessing. Table 4-9 provides conservative estimates for residual radioactivity in the four underground waste tanks at the start of Phase 1 proposed decommissioning activities. These estimates were based on a comprehensive characterization program that made use of sample analytical data and radiation level measurements (WVNSCO and Gemini 2005)[7].

Table 4-9. Estimated Radioactivity in the Underground Waste Tanks(1)

Nuclide	Estimate (Ci)	Nuclide	Estimate (Ci)	Nuclide	Estimate (Ci)
Am-241	380	Np-237	0.55	Tc-99	12
C-14	0.036	Pu-238	170	U-232	0.90
Cm-243	3.6	Pu-239	39	U-233	0.34
Cm-244	80	Pu-240	28	U-234	0.14
Cs-137	310,000	Pu-241	630	U-235	0.005
I-129	0.018	Sr-90	33,000	U-238	0.039

NOTE: (1) From WVNSCO and Gemini 2005 and from WVES 2008c, corrected for decay and ingrowth to 2011 and rounded to two significant figures or a single integer.

The tank mobilization and transfer pumps are expected to contain significant amounts of radioactive contamination. Radiation levels near the bottom of Pump 55-G-003 exceeded 50 R/hr when this pump was removed in 1998 (WVNSCO 1998a). An order-of-magnitude estimate of the residual radioactivity in this removed pump was approximately 220 curies (WVNSCO 2001). The mobilization pumps remaining in the tanks will likely be similarly contaminated. The transfer pumps in Tanks 8D-1 and 8D-2 will likely have more contamination, since HLW passed through the entire length of the pump, rather than impacting only the lower portion as with the mobilization pumps. The other suction pumps in Tanks 8D-1 and 8D-2 that are described in Section 3 will likely have somewhat lower contamination levels than the mobilization and transfer pumps.

[7] These estimates addressed NRC comments provided on earlier characterization reports (NRC 2003). The characterization report (WVNSCO and Gemini 2005) included three different estimates: best case, conservative cases, and worst case. The conservative case on which Table 4-9 is based is considered to be conservative because it provides adequate safety margins, yet it is also considered to be realistic. The best and worst case estimates provide the lower and upper bounds on the realistic conservative case.

As explained in Section 3, the transfer pumps in Tanks 8D-3 and 8D-4 will be removed before Phase 1 of the proposed decommissioning and replaced with small submersible pumps. These submersible pumps are expected to contain much lower levels of contamination than the other transfer pumps.

The piping and equipment in the HLW transfer trench also contains significant amounts of residual radioactivity. Radiation levels measured in the trench in 2004 ranged from 0.6 to 9.6 mR/hr. Levels in the pump pits in 2003 ranged from background at the top of Pit 8Q-1 to 33.5 R/hr inside Pit 8Q-2. Conservative estimates indicated that the pump pits and the diversion pit contained approximately 440 curies and the transfer piping approximately 234 curies in 2004, with the dominant radionuclides being Cs-137, Sr-90, Am-241, Pu-241, and Cm-244, in that order. The transfer trench itself is not expected to be radiologically contaminated. (Fazio 2004b)

The equipment in the M-8 pump pit for Tank 8D-2 was estimated to contain approximately seven curies in 2004. Radiation levels up to 1.2 R/h were measured in the pit in 2000. (Fazio 2004b)

The Permanent Ventilation System Building is expected to contain a significant amount of activity inside the ventilation filter housing, but most other areas in the building typically show no removable contamination above minimum detectable concentrations.

In the Supernatant Treatment System Support Building, radiation levels as high as 8.2 R/hr were measured in the valve aisle in 2003. The valve aisle was conservatively estimated to contain 213 curies of residual radioactivity in 2004 (Fazio 2002c). Other areas of the building are not expected to contain significant radioactive contamination.

In the Equipment Shelter, most of the radiological inventory is expected to be located inside the ventilation system equipment. Radiation levels measured in 2003 ranged from 0.1 to 2.8 mR/hr. (Fazio, 2004b).

The Con-Ed Building is also radiologically contaminated, with the majority of the radiological inventory located inside the piping and equipment. Radiation levels measured in 2003 were typically 0.1 mR/hr. (Fazio, 2004b).

The total activity in the 40 underground lines in the immediate vicinity of the Waste Tank Farm has been estimated to be approximately 117 curies in 2004, with more than 99 percent of this activity associated with Cs-137 and Sr-90 (Luckett, et al. 2004).

Radioactivity in the Construction and Demolition Debris Landfill in WMA 4

Much of the buried waste in the landfill, which was not radioactive when it was emplaced, is now expected to have low-levels of radioactive contamination, mostly Sr-90, from the north plateau groundwater plume, which is addressed in Section 4.2.

Radioactivity in the Facilities in WMA 5, the Waste Storage Area

In WMA 5, Lag Storage Addition 4 and the attached shipping depot are expected to contain only low levels of radioactive contamination, if any. The Remote-Handled Waste

Facility is expected to contain only low levels of contamination after it is deactivated. Most of the residual radioactivity is expected to be in the Work Cell where high activity waste and equipment are being packaged for disposal.

Radioactivity in the Facilities in WMA 6, the Central Project Premises

The only facilities in WMA 6 that had been impacted by licensed radioactivity or the WVDP as of 2008 are the two demineralizer sludge ponds, which are addressed in Section 4.2, and the Cooling Tower basin. However, portions the Sewage Treatment Plant may contain radioactivity concentrations above background from sewage sludge which tends to concentrate naturally occurring radionuclides (ISCORS 2005).

Radioactivity in the NDA in WMA 7

The buried waste in the NDA is known to contain a large amount of radioactivity which has been estimated to total approximately 180,000 curies in 2011 as shown in Table 4-10.[8]

Table 4-10. Estimated Radioactivity in the NDA(1)

Nuclide	Estimate (Ci)	Nuclide	Estimate (Ci)	Nuclide	Estimate (Ci)
Am-241	2,000	Np-237	0.62	Tc-99	10
C-14	520	Pu-238	350	U-233	11
Co-60	7,000	Pu-239	580	U-234	0.71
Cs-137	29,000	Pu-240	400	U-235	0.13
H-3	35	Pu-241	9,100	U-238	1.5
I-129	0.022	Ra-226	0.039	-	-
Ni-63	110,000	Sr-90	22,000	-	-

NOTE: (1) From URS 2000, corrected for decay and ingrowth to 2011 and rounded to two significant figures.

Radioactivity in the Radwaste Treatment System Drum Cell in WMA 9

The Drum Cell – the only facility in WMA 9 and which is to be removed during Phase 1 – is expected to contain only low levels of residual radioactivity, if any.

WMA 10, the Support and Services Area

None of the facilities to remain within WMA 10 at the time the Phase 1 proposed decommissioning activities begin had been impacted by site radioactivity as of 2008.

[8] This table, which is the same as Table 2-21 in Section 2, is included here for completeness.

4.2 Radiological Status of Environmental Media

Section 4.2 describes the radiological status of surface soil, sediment, subsurface soil, surface water, and groundwater within the project premises as compared with background.

NOTE

Environmental media have not been fully characterized and, as a result, certain information normally included in decommissioning plans is not available. Additional characterization is planned in connection with the Phase 1 decommissioning work as described in Sections 7 and 9.

Additional characterization of subsurface soil is also being undertaken in 2008. This characterization is focusing on hazardous contaminants and radionuclides in the area of the north plateau groundwater plume (Michalczak 2007). DOE plans to provide a copy of the summary report of this characterization program to NRC and other involved agencies and to revise this plan to incorporate key data from this program.

The information provided below represents a compilation of environmental radiological data collected as part of the routine WVDP Environmental Monitoring and Groundwater Monitoring programs. It also includes data from nonroutine investigations designed to satisfy regulatory requirements (e.g., RCRA facility investigations) and other focused sampling activities.

Section 2.3 contains information on documented spills of radioactivity that have impacted environmental media on the project premises. These spills include the 1968 airborne radioactivity releases that produced the widespread area of surface contamination northeast of the Process Building known as the cesium prong and the release of radioactive acid under the southwest corner of the Process Building that resulted in the area of subsurface soil and groundwater contamination known today as the north plateau groundwater plume. This section focuses on environmental media conditions that exist today and duplicates information in Section 2.3 only where necessary for clarity.

Information in Section 4.2 is organized as follows:

- Section 4.2.1 identifies data sources used for this evaluation.
- Section 4.2.2 summarizes background levels of (1) radionuclide concentrations in surface soil, subsurface soil, stream sediment, surface water, and groundwater; and (2) environmental radiation.
- Section 4.2.3 summarizes radiological status of surface soil and sediment within the project premises.
- Section 4.2.4 provides the same information on subsurface soil.
- Section 4.2.5 summarizes maximum radionuclide concentrations at locations in each WMA where background levels were exceeded in soil, sediment, and subsurface soil.

- Section 4.2.6 provides information on environmental radiation levels on the project premises.
- Section 4.2.7 provides information on the radiological status of surface water on the project premises.
- Section 4.2.8 addresses the radiological status of groundwater on the project premises and, in particular, the north plateau groundwater plume.

Appendix B, *Environmental Radioactivity Data*, provides the following information:

- A description of how background radionuclide concentrations and environmental radiation levels were estimated;
- Maps showing locations where background data were taken;
- Summary statistics applicable to each medium;
- A description of how data from onsite sampling programs were evaluated to determine if radiological concentrations or environmental radiation levels were above background;
- Tables summarizing the ratios of above-background concentrations of radionuclides with Cs-137 in surface soil, sediment, and subsurface soil;
- Additional summary information about radiological concentrations from routine onsite sampling locations;
- Descriptions both impacted and non-impacted locations; and
- Tables that list the coordinates and descriptions of groundwater sampling locations, along with the depths and geologic units at which samples were collected.

4.2.1 Data Sources

Radiological data on surface soil, sediment, subsurface soil, surface water, groundwater, and environmental radiation levels were taken from the WVDP Laboratory Information Management System controlled database, which contains environmental data from 1991 through the present. This system is used to manage data from the WVDP Environmental Monitoring and Groundwater Monitoring Programs, as well as data from special sampling activities (e.g., RCRA facility investigations, north plateau groundwater plume investigations).

If necessary (i.e., if only pre-1991 data were available for an area), data were drawn from historical sources or summaries included in reports from previous evaluations.

Previous Evaluations

Radiological data from environmental media have been presented in formal reports, for example:

(1) WVDP Annual Site Environmental Reports (years 1982 through 2006 available on the Internet at www.wv.doe.gov);

(2) Groundwater trend analysis reports;

(3) Reports of RCRA facility investigations of various areas of the WVDP (WVNSCO 1995, WVNSCO 1996, WVNSCO 1997a, WVNSCO 1997b, WVNSCO and Dames & Moore [D&M] 1996a, WVNSCO and D&M 1996b, WVNSCO and D&M 1997a, WVNSCO and D&M 1997b, and WVNSCO and D&M 1997c); and

(4) Results from north plateau groundwater plume investigations (Carpenter and Hemann 1995, WVNSCO 1998, and URS 2002). The RCRA Facility Investigations and the north plateau investigations produced a substantial body of soil characterization data, most associated with nonradiological constituents.

Data Quality

WVDP environmental samples evaluated in this plan were collected in accordance with formal sampling plans. Samples were analyzed by onsite and offsite laboratories in accordance with controlled procedures as required by the WVDP quality assurance (QA) program. QA requirements applicable to the sampling programs include documented training of field personnel; controlled collection procedures; using appropriate containers, preservatives, and storage methods to protect samples from contamination and degradation; following appropriate field and analytical quality control guidelines; maintaining and documenting chain-of-custody; and conducting assessments and audits of field and analytical processes to verify compliance.

Data were validated by a separate data validation group, and validation and approval status of sample results were documented in the LIMS.

4.2.2 Background Levels

This subsection addresses background radioactivity in environmental media on the project premises and provides information on background radiation levels.

Background Radionuclide Concentrations in Environmental Media

Radionuclides for which backgrounds were estimated were selected with consideration of (1) radionuclides of interest from the Facility Characterization Project, listed in Section 4.1.1, and (2) radionuclides that are routinely monitored in environmental media at the WVDP, for which sufficient data were available to develop a reliable estimate of background.

Background radionuclide concentrations were estimated for soil, sediment, subsurface soil, surface water, and groundwater for the following radionuclides:

Sr-90	U-232	U-235/236	Pu-238	Am-241
Cs-137	U-233/234	U-238	Pu-239/240	

Pu-241, Cm-243, Cm-244, and Np-237, which are radionuclides of interest in the Facility Characterization Project, are not routinely measured in environmental media at the WVDP so were not included in background estimates.

In addition, background concentrations were estimated for surface water and groundwater for the following nuclides that were not routinely analyzed in soil and sediment:

H-3 C-14 Tc-99 I-129

Although tritium (H-3) is not identified in Section 4.1.1 as a radionuclide of interest, it is commonly found in surface water and groundwater samples at the WVDP and so was included in the nuclide listing for environmental media. In addition, gross alpha and gross beta measurements are routinely used as screening (i.e., "surrogate" or "indicator") parameters for other nuclides, so background concentrations were estimated for gross alpha and gross beta activity. (For instance, gross beta measurements are used as a surrogate for Sr-90 measurements in the WVDP Groundwater Monitoring Program.)

Appendix B provides maps showing locations from which background data were taken and a description of how background concentrations were estimated. Appendix B also includes a table of summary statistics (e.g., number of samples, percentage of nondetect values, average concentrations, medians) for each constituent in each medium.[9] Median and maximum background concentrations are summarized in Table 4-11.

Table 4-11. Median and Maximum(1) Background Concentrations for Environmental Media at the WVDP

Constituent	Surface soil(2) (pCi/g dry)	Sediment (pCi/g dry)	Surface water (pCi/L)	Groundwater (pCi/L)
Gross alpha	1.3E+01 (2.7E+01)	9.2E+00 (2.2E+01)	<9.6E-01 (5.4E+00)	<2.6E+00 (2.2E+01)
Gross beta	2.0E+01 (4.0E+01)	1.6E+01 (2.7E+01)	2.3E+00 (2.0E+01)	4.6E+00 (2.8E+01)
H-3	NA	NA	<8.2E+01 (6.3E+02)	<8.6E+01 (9.4E+02)
C-14	NA	NA	<1.3E+01 (4.1E+02)	<2.7E+01 (7.4E+00)
Sr-90	9.5E-02 (3.1E+00)	<3.4E-02 (1.6E-01)	9.0E-01 (1.2E+01)	2.4E+00 (7.4E+00)
Tc-99	NA	NA	<1.8E+00 (7.3E+00)	<1.8E+00 (4.0E+00)
I-129	NA	NA	<7.9E-01	<6.0E-01

[9] Note that if a data set is symmetric, the average (i.e., mean) and the median will be the same. However, if the distribution is skewed to the right (i.e., contains a large number of low values and a few high values), the average will usually be higher than the median. For this reason, the median may be the more reliable estimator of central tendency. In this evaluation, both were estimated and are presented in Appendix B.

Table 4-11. Median and Maximum(1) Background Concentrations for Environmental Media at the WVDP

Constituent	Surface soil(2) (pCi/g dry)	Sediment (pCi/g dry)	Surface water (pCi/L)	Groundwater (pCi/L)
			(2.0E+00)	(1.6E+00)
Cs-137	4.2E-01 (1.2E+00)	3.8E-02 (7.8E-02)	<4.2E+00 (1.0E+01)	<2.2E+01 (1.9E+01)
U-232	<2.4E-02 (1.9E-02)	<3.1E-02 (3.9E-02)	<4.3E-02 (2.6E-01)	<4.9E-02 (3.8E-01)
U-233/234	7.9E-01 (9.4E-01)	6.6E-01 (8.6E-01)	9.9E-02 (3.0E-01)	1.6E-01 (8.2E+00)
U-235/236	5.2E-02 (2.2E-01)	4.6E-02 (2.8E-01)	<3.3E-02 (1.0E-01)	<5.0E-02 (1.9E-01)
U-238	7.9E-01 (9.3E-01)	6.5E-01 (9.0E-01)	5.7E-02 (4.0E-01)	1.2E-01 (5.3E+00)
Pu-238	<1.2E-02 (4.0E-02)	<1.4E-02 (1.3E-01)	<3.1E-02 (1.0E-01)	<4.6E-02 (2.2E-01)
Pu-239/240	1.6E-02 (2.3E-01)	<1.2E-02 (6.1E-02)	<2.7E-02 (2.0E-01)	<5.3E-02 (2.7E-01)
Am-241	<1.6E-02 (1.9E-01)	<1.4E-02 (8.6E-02)	<3.3E-02 (2.2E+00)	<3.8E-02 (1.8E-01)

NOTE: (1) Maxima are in parentheses. Maxima were selected from samples in which the radionuclide was detected (i.e., a "nondetect" result, indicated by a "<" sign, was used only if no detectable results were available).

(2) Data from only two subsurface locations sampled in 1993 were available for calculation of subsurface soil background concentrations. Therefore, surface soil backgrounds were used to evaluate subsurface soil data. (For comparability, data from the subsurface soil samples are summarized in Appendix B.)

LEGEND: NA = Not analyzed in this medium

Data on radionuclide concentrations in environmental media on the project premises were evaluated to determine the locations where radionuclide concentrations in excess of site background levels were found. Methods for evaluating sample data with respect to background were dependent on the type of data available for comparison (e.g., a single sample result, a data set encompassing several years). Methods for each are described in Appendix B.

Data evaluated in Section 4.2 were taken from samples collected over several years. While the majority of data points were from 1991 through the present, the earliest was from

a sample collected in 1967.[10] In Section 4.1, radionuclide activities in facilities on the project premises were decay-corrected to the year 2011. However, in Section 4.2 no attempt was made to decay-correct results from environmental samples because, unlike process cells or tanks, environmental media are not closed, static systems.

Media such as surface soil, sediment, subsurface soil, surface water, and groundwater are all subject to forces (aside from radioactive decay) with the potential to modify their radionuclide concentrations. Forces such as weathering, biological activity, atmospheric fallout, surface water runoff, wind erosion, and evaporation may act to deposit or remove radionuclides from a medium. Also, radionuclides are affected differentially by these mechanisms (e.g., Sr-90 is more mobile in water than Cs-137, which is more likely to bind to clay particles in soil and sediment).

Many of the radionuclides considered in this section are long-lived and it is unlikely that decay-correction would have affected the determination of whether or not background concentrations were exceeded. However, it is possible that estimates of radiological concentrations of the shorter-lived radionuclides (i.e., tritium [half-life of 12.3 years], Sr-90 [half-life of 28.9 years], and Cs-137 [half-life of 30 years]) are conservatively high, that is, overestimates.

NOTE

A soil characterization program will be undertaken in 2008. One of the goals will be to establish background soil concentrations. The interpretations in the following sections may be revised based on the results of this sampling program.

Background Environmental Radiation Levels

Radiation levels have been measured at the WVDP from 1986 through the present with a network of environmental thermoluminescent dosimeters (TLDs).[11] Average quarterly exposure measurements from four background locations over this time period was 19.3 mR per quarter (about 8.8E-03 mR/h). The maximum for any single quarter was 35 mR/quarter (about 1.6E-02 mR/h).

Background environmental radiation levels were used to evaluate measurements from onsite TLDs near process facilities, waste storage areas, and burial areas. (See Appendix B for a map showing the locations of background TLDs. See Section 4.2.6 for a discussion of onsite exposure measurements.)

[10] Note that historical and current data, which were generated over more than 40 years of NFS and WVDP operations, may not be directly comparable because different sampling and analytical methodologies have been used over the years. Historical and current data were compared with background concentrations using different statistical methods, as described in Appendix B.

[11] While radiation levels were measured at the WVDP prior to 1986, the current methodology has been used only since 1986. Therefore, for comparability, only data generated from 1986 through the present were used in the background calculation.

4.2.3 Radiological Status of Surface Soil and Sediment

Since the facility has operated, numerous soil sampling studies have been conducted on site, not as part of a formal site-wide soil program, but rather as area-specific investigations in response to specific circumstances or events (WVNSCO 1994). In 1993, a site-wide soil sampling program was conducted to obtain additional data to support the EIS and RCRA processes. As part of this program, surface soil, sediment, and subsurface soil samples were collected. Results were summarized in WVNSCO 1994.

NUREG-1757 (NRC 2006) defines surface soil as the soil within the top 15 to 30 cm (six to 12 inches) of the soil column. That definition has been broadened in this plan to include soil within the top 60 cm (0 to two feet) of the soil column. This was done so that available data from the top interval (0 to two-foot depth) from onsite soil-borings collected as part of the 1993 program could be used to assess the radiological status of surface soil. Data from the subsurface portions of the boreholes (i.e., at depths greater than two feet) are discussed in Section 4.2.5.

Areas With Radionuclide Concentrations in Excess of Site Background Levels

Figure 4-6 shows locations at which radiological concentrations exceeding background were noted in surface soil and sediment for (1) gross alpha or alpha-emitting radionuclides and (2) gross beta or beta-gamma emitting radionuclides.[12]

- The highest radionuclide concentrations were found in sediment from the lagoons in the WMA 2 Low-Level Waste Treatment Facility. See Table 4-14 for a listing of maximum radionuclide concentrations above background noted in the lagoon and drainage system. The highest radionuclide concentrations were noted in sediment from Lagoon 2. (Although higher concentrations are listed for Lagoon 1, the Lagoon 1 sediment was transferred to Lagoon 2 when Lagoon 1 was deactivated in 1984.)
- Cs-137 concentrations in excess of background were found in surface soil samples from all waste management areas at which samples had been collected. Although no surface soil data were available from WMA 1 (the Process Building and Vitrification Facility area), it is suspected that radionuclide concentrations in excess of background would be found here based on proximity to the Process Building and the elevated concentrations observed in adjoining WMAs. The highest levels noted in surface soil from other areas (i.e., 2.8E+02 pCi/g in WMA 2 near the Interceptors, 1.6E+02 pCi/g in WMA 6 near the Fuel Receiving and Storage Area and 2.3E+01 pCi/g in WMA 3 near the Waste Tank Farm) were all from areas in closest proximity to WMA 1. Elevated Cs-137 concentrations are thought to be largely attributable to historical releases and continuing low-level airborne releases from the main stack of the Process Building.

[12] WMA 12 is not labeled on the figures in this section because it extends to the boundaries of the Center. Areas on the project premises (i.e., within the security fence) that are considered to be part of WMA 12 include (1) the area between the north and south plateaus, which contains much of the drainage for Erdman Brook and Franks Creek, and (2) a small area north of WMA 4.

- Surface soil concentrations of Sr-90 exceeding background were noted in several areas, most notably in areas affected by the north plateau groundwater plume, such as WMA 2 (the Low-Level Waste Treatment Facility area) and WMA 4 (the area of the Construction and Demolition Debris Landfill).
- Radionuclide concentrations exceeding background, primarily from Sr-90 and Cs-137, were found in sediment samples from streams and drainage ditches in several waste management areas (WMAs 2, 4, 5, 6, 7, 10, and 12). Concentrations of alpha-emitting radionuclides (i.e., U-232, Pu-238, Pu-239/240, and/or Am-241) in excess of background were also noted in WMAs 2, 4, 5, 7, and 12 downgradient of liquid release points or waste burial areas.
- High radionuclide concentration levels were also associated with soil and sediment from the area of the Old Interceptors, the Solvent Dike, and inactive (filled-in) Lagoon 1 in WMA 2.
- South plateau areas with radionuclide concentrations exceeding background in surface soil include the two former shallow land burial disposal facilities, the NDA (WMA 7) and SDA (WMA 8). Elevated radiological concentrations in the surface and near-surface soils in the vicinities of those facilities is expected due to the nature of their operations. (As noted previously, WMA 8 is not within plan scope.)

Levels at which radionuclide concentrations in excess of background were found in surface soil and sediment are listed by WMA in the tables in Section 4.2.5. As shown in Figure 4-6, only one surface soil sampling location (SS-11) had no concentrations exceeding background. All sediment sampling locations had at least one constituent exceeding background.

4.2.4 Radiological Status of Subsurface Soil

Figure 4-7 shows locations at which concentrations of radiological constituents above background were noted in subsurface soil for (1) gross alpha or alpha-emitting radionuclides and (2) gross beta or beta-gamma emitting radionuclides. All subsurface soil samples had at least one constituent that exceeded background concentrations.

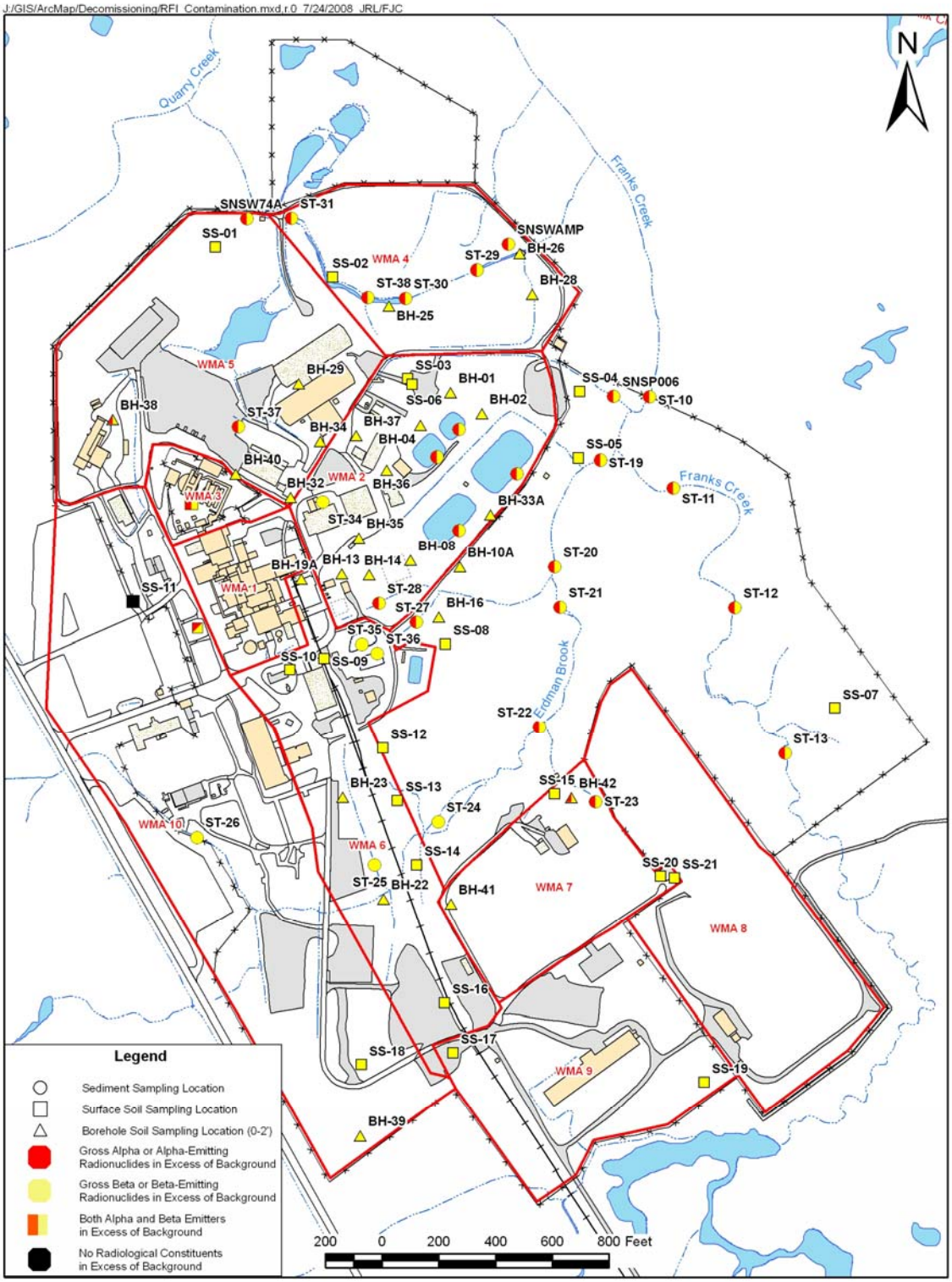

Figure 4-6. Surface Soil and Sediment Locations With Radionuclide Concentrations in Excess of Background

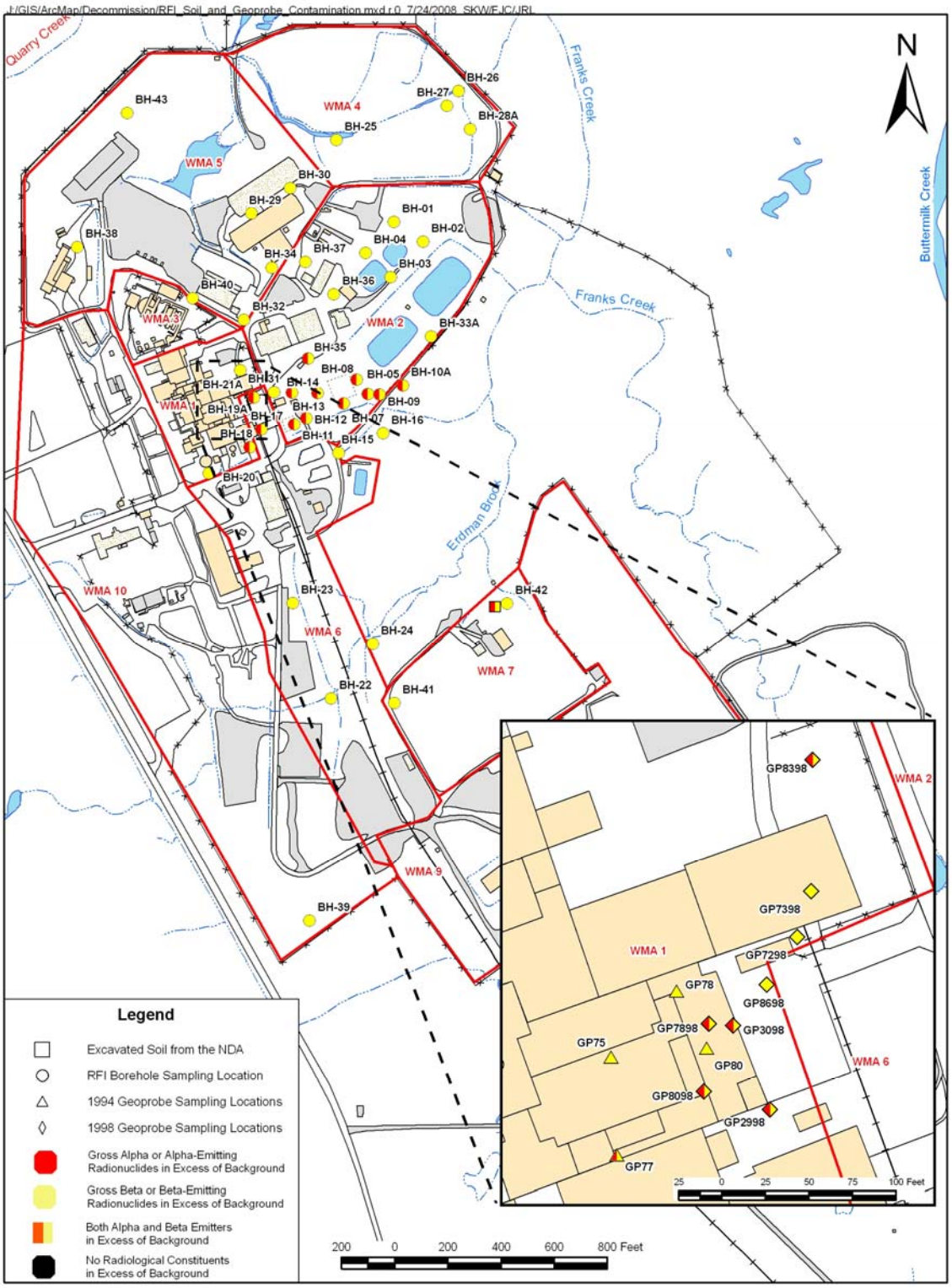

Figure 4-7. Subsurface Soil Locations With Radionuclide Concentrations in Excess of Background

Most subsurface soil data were taken from the 1993 RCRA Facility Investigation sampling program and two Geoprobe® sampling efforts (one in 1994 and one in 1998) to better define the origin and extent of the north plateau groundwater plume.

The highest subsurface radiological concentrations on the north plateau were observed in WMA 1 (the Process Building and Vitrification Facility area), WMA 2 (the Low-Level Waste Treatment Facility area), and WMA 6 (the Central Project Premises), downgradient of the Process Building. On the south plateau, highest concentrations were from WMA 7 (the NDA). Subsurface soil concentrations exceeding background were primarily associated with the north plateau groundwater plume (see Section 2) or with former waste processing or burial activities. Figure 4-8 presents a cross-section of Sr-90 concentrations in subsurface soil with depth in the north plateau below the Process Building. Data from this cross-section were taken from samples collected in 1993, 1994, and 1998 from WMAs 1, 2, and 6. The highest concentrations of Sr-90 were observed in the sand and gravel unit below the water table.

In WMA 1, high levels of Sr-90 were measured during the Geoprobe® investigations near the Process Building. In WMA 2, the highest levels of both beta-gamma and alpha-emitting radionuclides in subsurface soil were observed in sediments from borings taken near the Solvent Dike, the interceptors, and the Maintenance Shop leach field. In WMA 6, elevated subsurface soil concentrations were noted near the Utility Room and the Fuel Receiving and Storage Building. Data from WMA 7 were taken from rolloffs and boxes of excavated soil removed from “special holes” during NDA burial activities and from the Interceptor Trench, immediately downgradient of the NDA, when it was installed in 1990. Although the packaged soil has since been shipped offsite, it is likely that radionuclide concentrations in subsurface soil remaining in the NDA would be similar to those from the excavated soil.

Concentrations of radionuclides observed in excess of background levels in subsurface soils are summarized in Section 4.2.5.

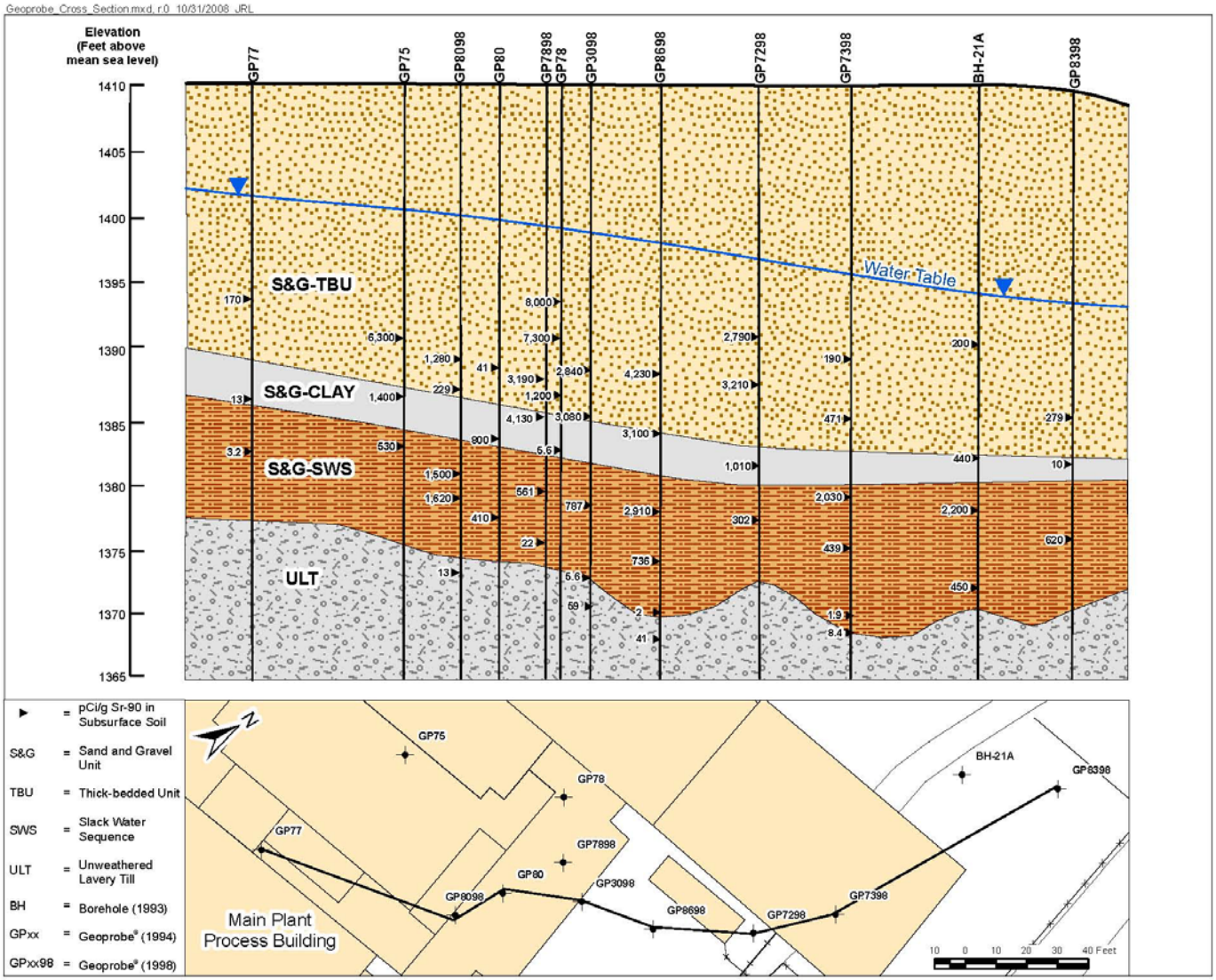

Figure 4-8. Cross-section of Sr-90 Concentrations Versus Depth in Subsurface Soil on the North Plateau

4.2.5 Radionuclide Concentrations Exceeding Background in Surface Soil, Sediment, and Subsurface Soil By WMA

The following tables summarize locations in each WMA where radionuclide concentrations were noted in excess of background. (See Table 4-11 and Appendix B for background radionuclide concentrations used to evaluate soil, sediment, and subsurface soil.) Data from surface soil, sediment, and subsurface soil are combined into one table for each WMA, except for WMA 2, where data are presented in three tables due to the large volume of information.

For each area, the maximum concentration at which the radionuclide was found is listed, together with source and location (i.e., reference or specific sample identifier). Identifiers from the 1993 RCRA Facility Investigation sampling program are specified as boreholes ("BH-"), surface soil ("SS-") or stream sediment ("ST-"). For subsurface soil, the depth at which the maximum was noted (if available) is also provided. Gross alpha and gross beta measurements are not presented because the measurements represent a mix of radionuclides (including those naturally occurring), and because data for specific alpha- and beta-emitting radionuclides were available. Ratios of above-background radionuclide concentrations to Cs-137 are presented in Appendix B in Tables B-9 (Surface Soil), B-10 (Sediment), and B-11 (Subsurface Soil).

WMA 1, Process Building and Vitrification Facility Area

Limited data are available for WMA 1, none for surface soil or sediment. Most subsurface soil data were taken from the 1994 and 1998 Geoprobe® investigations. Data from the Fuel Receiving and Storage Building subsurface soil and from near the Laundry were taken from the 1993 RCRA Facility Investigation sampling. Additional data were taken from one sample collected in 2004 near a breach in an underground wastewater line near the Laundry. The maximum Sr-90 value at the Fuel Receiving and Storage Building borehole (BH-21A) was observed in saturated soil from a depth of 30 to 32 feet. All maxima from the Geoprobe® samples were found at depths between 19 and 29 feet. Records from the 1998 sampling noted that this depth was in the saturated area. The ratio of the maximum Sr-90 to Cs-137 concentrations noted from the Geoprobe® samples was about 1600 to 1, reflecting the influence of the north plateau groundwater plume.

Table 4-12. Above-Background Concentrations of Radionuclides in Subsurface Soil at WMA 1[(1)]

Location	Maximum Concentration (pCi/g dry)			
	Cs-137	Sr-90	Pu-238	Am-241
Subsurface soil near Laundry (BH-18, Laundry line breach)	3.3E+03	≤Bkg	7.1E-02	8.7E+01
Subsurface soil north of FRS (BH-21A at a depth of 30-32')	≤Bkg	2.2E+03	≤Bkg	≤Bkg

Table 4-12. Above-Background Concentrations of Radionuclides in Subsurface Soil at WMA 1(1)

Location	Maximum Concentration (pCi/g dry)			
	Cs-137	Sr-90	Pu-238	Am-241
Subsurface soil from Geoprobe® sampling near Process Building (GP-72 [Cs-137 at 27-29' depth in 1998] ; GP-78 [Sr-90 at 19-23' depth in 1994]; GP-77 [Am-241 at 19-23' depth in 1994])	3.1E+01	8.0E+03	≤Bkg	9.8E-02

LEGEND: FRS = Fuel Receiving and Storage Building. "≤Bkg" = Background was not exceeded.

NOTE: (1) See Figure 4-2 for a map of facilities in WMA 1. The Laundry (not labeled in Fig. 4-2), is located adjacent to the Utility Room Expansion.

WMA 2, Low-Level Waste Treatment Facility Area

Extensive data, available both electronically and from historical reports, were available for WMA 2. The maximum concentrations observed at each location within WMA 2 are listed below. Due to the large volume, data are presented in three tables: Table 4-13 (surface soil), Table 4-14 (sediment), and Table 4-15 (subsurface soil).

The radionuclides observed above background in surface soil (Table 4-13) were Cs-137 and Sr-90. The maximum ratio of Sr-90 to Cs-137 (about 1.4 to 1) was observed in surface soil north of Lagoons 4 and 5, which is affected by the north plateau groundwater plume. No gross alpha concentrations or concentrations of alpha-emitting radionuclides were observed at concentrations above background in surface soil from WMA 2.

Table 4-13. Above-Background Concentrations of Radionuclides in Surface Soil From WMA 2(1)

Location	Maximum Concentration (pCi/g dry)	
	Cs-137	Sr-90
Surface soil near the Old and New Interceptors (BH-13)	2.8E+02	4.1E+00
Surface soil between the Interceptors and inactive Lagoon 1 (WVNSCO 1994 [Table 3-2] and BH-14)	1.4E+01	1.4E+00
Surface soil between inactive Lagoon 1 and active Lagoon 2 (BH-08)	4.8E+00	1.1E+00
Surface soil from Maintenance Shop Leach Field (WVNSCO 1994 [Table 3-2] and BH-35)	2.1E+01	1.3E+00
Surface soil near the LLW2 Facility (BH-36)	≤Bkg	3.2E-01
Surface soil near the Vitrification Test Facility (BH-37)	6.6E-01	≤Bkg

Table 4-13. Above-Background Concentrations of Radionuclides in Surface Soil From WMA 2(1)

Location	Maximum Concentration (pCi/g dry)	
	Cs-137	Sr-90
Surface soil north of Lagoons 4 and 5 (BH-04)	8.5E-01	1.2E+00
Surface soil between the lagoons and WMA 4 (SS-03, SS-06)	3.6E+00	3.6E-01
Surface soil between the road and Lagoon 2 (BH-33A)	8.9E-01	≤Bkg

LEGEND: "≤Bkg" = Background was not exceeded.

NOTE: (1) See Figure 4-3 for a map of facilities in WMA 2. Facilities not labeled in Fig. 4-3 include the former Maintenance Shop (which was located southwest of the LLW2 Facility), and the Vitrification Test Facility (located northwest of the LLW2 Facility). See Figure 4-6 for a map with the above sampling locations.

Radionuclides observed above background in sediment (Table 4-14) were Cs-137, Sr-90, U-232, U-233/234, U-235/236, U-238, Pu-238, Pu-239/240, and Am-241. Maximum ratios to Cs-137 for each were: Sr-90 (144 to 1), U-232 (0.0054 to 1), U-233/234 (0.056 to 1), U-235/236 (0.011 to 1), U-238 (0.057 to 1), Pu-238 (0.018 to 1), Pu-239/240 (0.019 to 1), and Am-241 (4.2 to 1). (See Appendix B, Table B-10, for a summary of radionuclide ratios in sediment from WMA 2.)

Maximum ratios to Cs-137 were found in sediment from (or downgradient of) the Solvent Dike (Sr-90, U-233/234, U-235/236, Pu-239/240, and Am-241), sediment from Lagoon 3 (U-232 and U-238), and sediment from the Lagoon 2 shoreline (Pu-238). The highest Am-241 to Cs-137 ratio (4.2 to 1) was from one Solvent Dike sediment sample collected in 1986. For comparison, the median Am-241 to Cs-137 ratio in WMA 2 was 0.0019 to 1.

Table 4-14. Above-Background Concentrations of Radionuclides in Sediment From WMA 2

Location	Maximum Concentration (pCi/g dry)								
	Cs-137	Sr-90	U-232	U-233/234	U-235/236	U-238	Pu-238	Pu-239/240	Am-241
Sediment from drainage north of Test and Storage Building (ST-34)	2.0E+00	3.5E-01	NA	NA	NA	NA	NA	NA	NA
Sediment from Solvent Dike (WVNSCO 1994, Table 3-12, 1986 samples)	3.1E+02	1.6E+03	NA	NA	NA	NA	NA	NA	1.1E+03
Sediment from drainage downgradient of Solvent Dike (ST-28)	1.7E+01	2.9E+00	≤Bkg	9.5E-01	≤Bkg	≤Bkg	2.9E-01	3.2E-01	7.1E-01

Table 4-14. Above-Background Concentrations of Radionuclides in Sediment From WMA 2

Location	Maximum Concentration (pCi/g dry)								
	Cs-137	Sr-90	U-232	U-233/ 234	U-235/ 236	U-238	Pu-238	Pu-239/ 240	Am-241
Sediment from Lagoon 1 (Passuite and Monsalve-Jones 1993, Tables 3-2 [1982 data] and 3-3 [1984 data])	4.7E+05	1.5E+05	NA	NA	NA	NA	3.9E+04	1.8E+04	1.9E+04
Sediment from Lagoon 2(1) (WVNSCO 1994, Tables 3-5 [1982 data] and 3-8 [1990 data])	2.7E+05	3.6E+04	NA	NA	6.5E-01	6.2E+00	8.0E+02	6.4E+02	8.3E+02
Sediment from Lagoon 3 (WVNSCO 1994, Tables 3-11 [1990 data], 3-9 [1967 data]; and 1994 Lagoon 3 sampling)	1.1E+04	7.7E+02	7.6E+00	4.5E+00	1.3E+00	8.8E+00	3.1E+00	1.4E+00	5.1E+00
Sediment from Lagoon 4 (1994 sampling)	3.2E+01	7.3E+00	NA	NA	NA	NA	NA	NA	NA
Sediment from Lagoon 5 (1994 sampling)	5.2E+01	4.1E+01	NA	NA	NA	NA	NA	NA	NA

NOTE: (1) In 1984, an estimated 22,400 cubic feet of sediment were pumped from Lagoon 1 to Lagoon 2 (Passuite and Monsalve-Jones 1993) so the 1982 sample results are not necessarily representative of the of the activity in Lagoon 2 sediment.

(2) See Figure 4-3 for a map of facilities in WMA 2. The Test and Storage Building (which was located near the southwestern boundary of WMA 2) is not labeled in Fig. 4-3. See Figure 4-6 for a map with the above sampling locations.

LEGEND: NA = No analysis. "≤Bkg" = Background was not exceeded.

Radionuclides observed above background in subsurface soil (Table 4-15) were Cs-137, Sr-90, U-232, U-233/234, U-235/236, U-238, Pu-238, Pu-239/240, and Am-241. The highest concentrations were noted downgradient of inactive Lagoon 1, near the Old and New Interceptors, near the Solvent Dike, and near the Maintenance Shop Leach Field.

All maxima downgradient of inactive Lagoon 1 were found in saturated soil from the six to eight foot depth. Near the Solvent Dike, the Cs-137 maximum was found in moist soil at the four to six foot depth, while maxima of the other radionuclides were found in saturated soil from the eight to ten foot depth. Near the Old and New Interceptors, maxima were located in saturated soil from the eight to ten foot depth.

The maximum ratios to Cs-137 for each were: Sr-90 (78 to 1), U-232 (0.081 to 1), U-233/234 (5.0 to 1), U-235/236 (0.74 to 1), U-238 (3.1 to 1), Pu-238 (0.089 to 1), Pu-239/240 (0.10 to 1), and Am-241 (0.15 to 1).

The maximum ratios to Cs-137 were found in subsurface soil near the Solvent Dike at the eight to 10 feet depth (Sr-90, U-233/234, U-235/236, U-238, Pu-239/240, and Am-241), from the Maintenance Shop leach field at the six to eight feet depth (U-232), and from between the interceptors and inactive Lagoon 1 at the 14-16' depth (Pu-238).

Table 4-15. Above-Background Concentrations of Radionuclides in Subsurface Soil From WMA 2(1)

Location	Maximum Concentration (pCi/g dry)								
	Cs-137	Sr-90	U-232	U-233/ 234	U-235/ 236	U-238	Pu-238	Pu-239/ 240	Am-241
Downgradient of inactive Lagoon 1 (BH-08 at 6-8' depth)	3.6E+04	1.5E+04	5.8E+02	2.7E+02	4.2E+00	6.8E+01	6.8E+02	1.2E+03	1.7E+03
Near Solvent Dike (BH-11 at 8-10' depth, Cs-137 max at 2-4' depth)	1.8E+02	5.6E+01	≤Bkg	3.6E+00	5.3E-01	2.2E+00	≤Bkg	7.5E-02	1.1E-01
Near the Old and New Interceptors (BH-13, 8-10' depth)	5.2E+03	1.9E+02	5.1E+01	2.4E+01	2.0E-01	3.7E+00	6.6E+01	5.1E+01	5.3E+01
Between the Interceptors and inactive Lagoon 1 (4-6' depth, Pu-238 at 14-16' depth)	6.1E+00	2.8E+01	1.0E-01	≤Bkg	≤Bkg	≤Bkg	1.7E-01	1.9E-01	2.8E-01
Maintenance Shop Leach Field (BH-35, 6-8' depth)	1.6E+01	3.9E+02	1.3E+00	≤Bkg	≤Bkg	≤Bkg	4.6E-01	7.4E-02	1.3E+00
Near Lagoon 4 (BH-03, 12-14' depth)	≤Bkg	2.3E+00	NA	NA	NA	NA	NA	NA	NA
North of Lagoons 4 and 5 (BH-04, 16-18' depth)	≤Bkg	3.5E+00	NA	NA	NA	NA	NA	NA	NA
Near Old Interceptor (BH-31, 10-12' depth)	≤Bkg	1.0E+01	≤Bkg	≤Bkg	≤Bkg	≤Bkg	≤Bkg	≤Bkg	≤Bkg
Between the Vitrification Test Facility and LSA 4 (BH-37, 8-10' depth)	≤Bkg	1.1E+02	≤Bkg	≤Bkg	≤Bkg	≤Bkg	≤Bkg	≤Bkg	≤Bkg
Near LLW2 facility (BH-36, 20-22' depth)	≤Bkg	2.9E+01	≤Bkg	≤Bkg	≤Bkg	≤Bkg	≤Bkg	≤Bkg	≤Bkg

LEGEND: NA = No analysis. "≤Bkg" = Background was not exceeded.

NOTE: (1) See Figure 4-3 for a map of facilities in WMA 2. Facilities not labeled in Figure 4-2 include the former Maintenance Shop (which was located southwest of the LLW2 Facility), and the Vitrification Test Facility (located northwest of the LLW2 Facility). See Figure 4-7 for a map with the above sampling locations.

WMA 3. High-level Waste Tank Farm

Minimal data were available for the Waste Tank Farm. Table 4-16 lists maximum concentrations of radionuclides found in surface soil at levels above background. Data were from a 1990 sampling, as summarized in Table 3-2 of WVNSCO 1994. Concentrations in excess of background levels were noted for Cs-137, U-238, and Am-241. The ratios of U-238 and Am-241 to Cs-137 in surface soil from the Waste Tank Farm were 0.047, and 0.011, respectively. No sediment or subsurface soil data were available, although subsurface soil concentrations exceeding background are expected because of leaks or breaches in transfer lines (see Section 2) and because of elevated radionuclide concentrations found in groundwater as discussed below.

Table 4-16. Above-Background Concentrations of Radionuclides in Surface Soil at WMA 3(1)

Location	Maximum Concentration (pCi/g dry)		
	Cs-137	U-238	Am-241
Surface soil at the Waste Tank Farm (WVNSCO 1994, Table 3-2 [1990 data])	2.3E+01	1.1E+00	2.5E-01

NOTE: (1) See Figure 4-4 for a map of facilities in WMA 3 and Figure 4-6 for a map showing areas with above-background levels of radionuclides in surface soil.

WMA 4, Construction and Demolition Debris Landfill Area

Concentrations of radiological constituents measured at levels in excess of background in surface soil, sediment, and subsurface soil from WMA 4 are listed in Table 4-17. Surface soil from WMA 4, a portion of which includes the landfill, was found to contain concentrations of Cs-137 and Sr-90 in excess of background. The maximum ratio of Sr-90 to Cs-137 in surface soil was about 9.5 to 1.

Table 4-17. Above-Background Concentrations of Radionuclides in Surface Soil, Sediment, and Subsurface Soil From WMA 4(1)

Location	Maximum Concentration (pCi/g dry)						
	Cs-137	Sr-90	U-233/ 234	U-238	Pu-238	Pu-239/ 240	Am-241
Surface soil along drainage though CDDL (SS-02 and WVNSCO 1994, Table 3-2 [1990 data])	9.1E+00	1.2E+01	NA	NA	NA	NA	NA
Sediment from drainage through CDDL (ST-31, ST-38)	7.0E+00	8.4E+01	NA	NA	7.3E-02	7.4E-02	1.3E-01
Sediment from Northeast Swamp drainage (SNSWAMP)	3.1E+01	3.0E+01	1.1E+00	1.1E+00	4.3E-01	6.4E-01	1.3E+00
Subsurface soil in CDDL (BH-27 [Cs-137 max at 2-4'], BH-25 [Sr-90 max at 12-14'])	7.3E-01	4.1E+00	NA	NA	NA	NA	NA

LEGEND: CDDL = Construction and Demolition Debris Landfill; NA = No analysis.

NOTE: (1) See Figures 4-6 and 4-7 for maps showing locations with radionuclide concentrations in excess of background.

Sediment from drainage locations on WMA 4 also contained Sr-90 and Cs-137 at levels exceeding background. However, it also contained above-background levels of the alpha-emitting radionuclides U-233/234, U-238, Pu-238, Pu-239/240, and Am-241. Maximum radionuclide ratios to Cs-137 were: Sr-90 (16 to 1), U-233/234 (1.4 to 1), U-238 (1.3 to 1) Pu-238 (0.057 to 1), Pu-239/240 (0.21 to 1), and Am-241 (0.22 to 1).

The maximum Sr-90 to Cs-137 ratio in sediment was noted from drainage through WMA 4 north of the landfill. The north plateau groundwater plume surfaces near ST-38 where this sample was taken (see Figure 4-6). Maximum ratios for the remaining nuclides were noted at the routine monitoring point SNSWAMP, which is located where drainage from WMA 4 leaves the site. Sediment (or soil, depending upon annual rainfall and drainage flow patterns) is collected at this location as part of the WVDP Environmental Monitoring Program. (See Appendix B for average and median radionuclide concentrations at the SNSWAMP location from 1995 through 2007.)

The comparatively high Sr-90 to Cs-137 ratios observed for surface soil and sediment in WMA 4 reflect the presence of Sr-90 in the north plateau groundwater plume.

Both Cs-137 and Sr-90 concentrations exceeding background were noted in subsurface soil from WMA 4. Because the landfill located on WMA 4 was not used for radioactive waste disposal, it was not thought to be the origin of the radionuclides. Cs-137 in subsurface soil is most likely leached from the overlying surface soil (the concentration of Cs-137 at the two to four feet depth was roughly one-tenth of the concentration at the surface). As seen in other areas, elevated levels of Cs-137 in surface soil were most likely attributable to airborne deposition (see Section 2). The maximum ratio of Sr-90 to Cs-137 for subsurface soil was about 0.73 to 1. As with the surface soil and sediment media, the north plateau groundwater plume is thought to be the origin of Sr-90 in subsurface soil in WMA 4.

WMA 5, Waste Storage Area

Concentrations of radiological constituents measured at levels in excess of background in surface soil, sediment, and subsurface soil from WMA 5 are listed in Table 4-18. Cs-137 and Sr-90 concentrations exceeding background were found in surface soil and sediment. Concentrations of the alpha-emitting radionuclides Pu-238, Pu-239/240, and Am-241 exceeding background were also found, possibly attributable to residual activity from the old/new hardstand, on which contaminated vessels and equipment from the Process Building had been stored when NFS was operating. Historical site surveys have noted elevated gamma radiation readings and soil contamination in the area of the old/new hardstand (Marchetti, 1982). Material from the hardstand was excavated and used to fill Lagoon 1 when it was closed in 1984. (See Section 2.)

Maximum ratios to Cs-137 in soil and/or sediment were: Sr-90 (3.3 to 1), Pu-238 (0.015 to 1), Pu-239/240 (0.096 to 1), and Am-241 (0.087 to 1). The maximum ratios were all found in sediment from the North Swamp drainage point SNSW74A.

No concentrations exceeding background of Cs-137 or alpha-emitting radionuclides were noted in subsurface soil samples from WMA 5. However, Sr-90 concentrations above background were found six to eight feet below-ground at a point between Lag Storage Addition 3 and Lag Storage Addition 4 and 22 to 24 feet below the surface at the southernmost point of WMA 5 near the Lag Storage Building.

Table 4-18. Above-Background Concentrations of Radionuclides in Surface Soil, Sediment, and Subsurface Soil at WMA 5(1)

Location	Maximum Concentration (pCi/g dry)				
	Cs-137	Sr-90	Pu-238	Pu-239/ 240	Am-241
Surface soil on north plateau near security fence (SS-01)	2.0E+01	3.7E-01	NA	NA	NA
Surface soil near Remote-Handled Waste Facility location (BH-38)	1.1E+01	8.2E-01	3.6E-02	1.6E-01	3.7E-01
Surface soil from footers for LSA 3 and LSA 4 (WVNSCO 1994, Table 3-15 [1990 data])	2.8E+01	NA	NA	NA	9.1E-01
Surface soil from the Lag Storage Building (BH-32)	7.8E-01	≤Bkg	≤Bkg	≤Bkg	≤Bkg
Sediment near old LSA 2 (ST-37)	6.1E+01	8.3E+00	≤Bkg	≤Bkg	6.5E-02
Sediment from north swamp drainage (SNSW74A)	8.8E+00	2.1E+00	≤Bkg	1.9E-01	2.6E-01
Subsurface soil between LSA 3 and 4 (BH-29, 6-8' depth)	≤Bkg	2.8E+00	NA	NA	NA
Subsurface soil by the lag storage building (BH-32, 22-24' depth)	≤Bkg	5.8E-01	≤Bkg	≤Bkg	≤Bkg

LEGEND: LSA = Lag Storage Addition. NA = No analysis. "≤Bkg" = Background was not exceeded.

NOTE: (1) See Figures 4-6 and 4-7 for maps showing locations with radionuclide concentrations in excess of background.

WMA 6, Central Project Premises

Concentrations of radionuclides measured at levels in excess of background in surface soil, sediment, and subsurface soil from WMA 6 are listed in Table 4-19. Cs-137 and Sr-90 were the only radionuclides found in concentrations exceeding background in surface soil and sediment from WMA 6. The highest concentrations of both Cs-137 and Sr-90 were found in surface soil collected near the Fuel Receiving and Storage Building.

The highest Sr-90 to Cs-137 ratio in surface soil (1.7 to 1) was also found in soil near the rail spur by the Fuel Receiving and Storage Building. The highest Sr-90 to Cs-137 ratio in sediment (0.59 to 1) was found in sediment from the south Demineralizer Sludge Pond.

The highest radionuclide concentrations in surface soil and sediment were from the northern portion of WMA 6, closest to the Process Building. However, elevated concentrations were also found along the rail spur south of the Sewage Treatment Plant. These elevated concentrations may be attributable to events in the 1960s and 1970s (e.g., increased radioactivity in treated effluents or possible line leaks [see further detail in Section 2.3.2]).

Subsurface soil samples – one from near the Utility Room and one from near the Fuel Receiving and Storage Building – contained Cs-137, Sr-90, Pu-238, Pu-239/240, and Am-241 concentrations exceeding background. The highest concentrations were found near the Fuel Receiving and Storage Building at a depth of 22 to 24 feet in the sand and gravel unit below the water table. (See Figure 4-8.) The maximum concentrations near the Utility Room were from 16 to 18 feet below the surface.

Ratios to Cs-137 for Pu-238, Pu-239/240, and Am-241 were similar for subsurface soil samples taken near the Utility Room and the Fuel Receiving and Storage Building (about 0.03 to 1, 0.04 to 1, and 0.2 to 1, respectively). However, the Sr-90 to Cs-137 ratios for each were strikingly different. Near the Utility Room, the ratio was about 1 to 1, but near the Fuel Receiving and Storage Building the ratio was 133 to 1, suggesting that the Fuel Receiving and Storage Building subsurface location was more central to the north plateau groundwater plume.

Table 4-19. Above-Background Concentrations of Radionuclides in Surface Soil, Sediment, and Subsurface Soil at WMA 6[(1)]

Location	Maximum Concentration (pCi/g dry)				
	Cs-137	Sr-90	Pu-238	Pu-239/240	Am-241
Surface soil along rail spur south of STP (BH-23, SS-13)	1.8E+00	3.2E-01	NA	NA	NA
Sediment along drainage by rail spur south of STP (ST-25)	2.1E+00	1.3E-01	NA	NA	NA
Surface soil by FRS (1994 sampling near rail spur)	1.6E+02	1.2E+01	NA	NA	NA
Surface soil by Cooling Tower (SS-10)	1.3E+01	1.4E+00	NA	NA	NA
Surface soil by Old Incinerator (WVNSCO 1994, Table 3-2 [1990 data])	1.9E+01	2.3E+00	NA	NA	NA
Surface soil by Old Warehouse (SS-09)	1.3E+01	9.3E-01	NA	NA	NA
Sediment from North Demineralizer Sludge Pond (WVNSCO 1994 Table 3-18 [1988 data], ST-35)	1.3E+01	7.7E-01	NA	NA	NA

Table 4-19. Above-Background Concentrations of Radionuclides in Surface Soil, Sediment, and Subsurface Soil at WMA 6(1)

Location	Maximum Concentration (pCi/g dry)				
	Cs-137	Sr-90	Pu-238	Pu-239/ 240	Am-241
Sediment from South Demineralizer Sludge Pond (WVNSCO 1994 Table 3-19 [1988 data], ST-36)	3.8E+01	3.5E-01	NA	NA	NA
Subsurface soil near the Utility Room (BH-17, 14-16' depth)	2.4E+00	2.7E+00	6.1E-02	9.7E-02	4.9E-01
Subsurface soil near the FRS (BH-19A, 22-24' depth)	4.3E+00	5.7E+02	1.5E-01	2.0E-01	8.0E-01

LEGEND: FRS = Fuel Receiving and Storage Building, STP = Sewage Treatment Plant

NOTE: (1) See Figure 4-5 for a map showing facilities in the northern portion of WMA 6. See Figures 4-6 and 4-7 for maps showing locations with radionuclide concentrations in excess of background.

WMA 7, NDA and Associated Facilities

Concentrations of radiological constituents measured at levels in excess of background in surface soil and sediment from WMA 7 are listed in Table 4-20. Cs-137, Sr-90, and Am-241 were found in concentrations exceeding background in surface soil. Sediment samples collected near the Interceptor Trench contained concentrations of Cs-137, Sr-90, Pu-238, and Am-241 in excess of background. Ratios of Sr-90 to Cs-137 in surface soil ranged from 0.11 to 1 to 8.2 to 1. The Sr-90 to Cs-137 ratio for sediment was about 3.7 to 1. Maximum ratios to Cs-137 for Pu-238, Pu-239/240, and Am-241 in surface soil and sediment were, respectively: 0.096 (sediment), 0.022 (surface soil), and 0.046 (sediment). All were found near the Interceptor Trench.

No concentrations above background were found in boreholes of subsurface soil taken in 1993 at WMA 7. (Note that the two subsurface soil borings done at this location in 1993 were taken from the edges of the burial area, one upgradient of the buried waste and the other on the opposite side of the Interceptor Trench downgradient of the area.) However, analytical results from boxes and rolloffs filled with subsurface soil excavated from “special holes” during burial activities on the NDA or during construction of the Interceptor Trench contained Am-241 concentrations well in excess of background. Ratios of Am-241 to Cs-137 ranged from 0.024 to 0.077 to 1. The excavated soil has been shipped offsite, however, results suggest that subsurface soil remaining in the NDA contains radionuclide concentrations exceeding background.

Table 4-20. Above-Background Concentrations of Radionuclides in Surface Soil, Sediment, and Subsurface Soil at WMA 7[1]

Location	Maximum Concentration (pCi/g dry)				
	Cs-137	Sr-90	Pu-238	Pu-239/ 240	Am-241
Surface soil by the NDA Interceptor Trench (SS-15, BH-42)	4.7E+00	3.3E+00	8.5E-02	9.2E-02	1.5E-01
Surface soil by the NDA Hardstand (SS-20)	6.8E+01	7.7E+00	NA	NA	NA
Surface soil at remainder of NDA (1994 data from special sampling)	3.2E+00	2.1E+01	NA	NA	NA
Sediment from drainage near Interceptor Trench (ST-23)	9.0E-01	3.3E+00	8.6E-02	≤Bkg	4.1E-02
Subsurface soil excavated from "special holes" or Interceptor Trench (1997 sampling of excavated soil in boxes and rolloffs)	3.5E+01	NA	NA	NA	1.8E+00

NOTE: (1) See Figures 4-6 and 4-7 for maps showing locations with radionuclide concentrations in excess of background. Not shown on the map, the Interceptor Trench borders the northeast and northwest boundaries of the NDA. The Trench was installed in 1990 to intercept and collect leaching from the NDA. The NDA Hardstand (not shown on the map) was located at the easternmost point of WMA 7.

WMA 9, Radwaste Treatment Drum Cell Area

Data from only two surface soil samples were available for WMA 9. Although gross beta concentrations exceeded background for both, data for specific beta-emitting radionuclides did not. (See Figure 4-6.) No subsurface soil or sediment data were available for WMA 9.

WMA 10, Support and Services Area

Concentrations of radiological constituents measured at levels in excess of background in surface soil and sediment from WMA 10, the Support and Services Area, are listed in Table 4-21. This area includes support facilities (e.g., administrative buildings, offices, parking lots, the Environmental Laboratory) that are not known to be radiologically contaminated. Note that only one surface soil sample shown on Figure 4-6 did not have concentrations exceeding background: SS-11 on the north plateau, located on the western side of the project premises in WMA 10.

Low-level concentrations of Cs-137 exceeding background were found in surface soil near support trailers close to the Process Building and in sediment from a drainage ditch south of the Environmental Laboratory. Elevated Cs-137 in surface soil is thought to be attributable to airborne releases. Elevated Cs-137 in the drainage ditch could be

attributable to runoff from WMA 6 (i.e., possibly related to historical releases or leaks from the old Sewage Treatment Plant that released radionuclides to drainage by the railroad bed, as discussed in Section 2). Although gross alpha and gross beta concentrations slightly above background were noted for certain surface soil samples from WMA 10 (as shown on Figure 4-6), no other concentrations of specific radionuclides above background have been reported.

Table 4-21. Above-Background Concentrations of Radionuclides in Surface Soil and Sediment at WMA 10(1)

Location	Maximum Concentration (pCi/g dry)
	Cs-137
Surface soil by former Trailer City (1998 special soil sampling)	1.0E+00
Sediment samples by drainage south of Environmental Laboratory (ST-26)	1.7E-01

NOTE: (1) See Figure 4-6 for a map showing locations with radionuclide concentrations in excess of background. Not shown on maps, the former Trailer City was located directly opposite the western entrance to the Process Building. The Environmental Laboratory (shown, but not labeled, on Figure 4-6) is located immediately north of sampling point ST-26.

WMA 12, Remainder of the Site

Concentrations of radiological constituents measured at levels in excess of background in surface soil and sediment from WMA 12 are listed in Table 4-22. Only the portion of WMA 12 within the project premises, which includes the onsite segments of Franks Creek and Erdman Brook, is addressed in this evaluation.

Surface soil concentrations of both Cs-137 and Sr-90 were noted in excess of background in WMA 12 (see Figure 4-6). Cs-137 and Sr-90 exceeding background concentrations were also found in sediment samples from both Franks Creek and Erdman Brook, as well as in drainage downgradient of the demineralizer sludge ponds. Sediment samples collected along the lengths of both Franks Creek and Erdman Brook also contained alpha-emitting radionuclides at concentrations in excess of background, although the radionuclides varied in relationship to the stream segment.

In Erdman Brook downstream of drainage from the NDA (locations ST-22 and ST-21), Am-241 and Pu-238 were observed in concentrations greater than background. Further downstream, at point ST-20, after the stream receives inflow from via a drainage from WMA 2, Am-241, Pu-238, and Pu-239/240 concentrations were all above background. At point ST-19, located downstream where the stream receives effluent from Lagoon 3, U-232 (in addition to the other nuclides) was also found above background.

Similarly, sediment at the southernmost segments of Franks Creek (points ST-13, ST-12, and ST-11) contained gross alpha concentrations in excess of background. However, at point ST-10, located downstream of its junction with Erdman Brook, concentrations of Am-241, Pu-238, and Pu-239/240 were found in its sediment in excess of background.

Table 4-22. Above-Background Concentrations of Radionuclides in Surface Soil and Sediment at WMA 12(1)

Location	Maximum Concentration (pCi/g)					
	Cs-137	Sr-90	U-232	Pu-238	Pu-239/240	Am-241
Surface soil near borders with WMA 2 and WMA 6 (SS-08 [Cs-137], BH-16 [Sr-90])	8.1E+00	1.3E+00	NA	NA	NA	NA
Surface soil near eastern fence line (SS-07)	1.6E+00	4.4E+00	≤Bkg	≤Bkg	≤Bkg	≤Bkg
Sediment from drainage downgradient of Demineralizer Sludge Ponds (ST-27)	6.0E+00	8.5E-01	≤Bkg	≤Bkg	7.3E-02	1.4E-01
Sediment from Erdman Brook (ST-19 [Cs-137, Sr-90, U-232], ST-20 [Pu-238, Pu-239/240], ST-22 [Am-241])	3.5E+01	1.6E+00	1.1E-01	2.5E-01	7.3E-02	1.4E-01
Sediment from Franks Creek (ST-10 [Cs-137 only], SNSP006)	1.0E+02	1.0E+01	1.4E-01	1.4E-01	1.1E-01	2.4E-01

NOTES: (1) See Figure 4-6 for a map showing locations with radionuclide concentrations in excess of background. The location of the Demineralizer Sludge Ponds is shown in Figure 4-5.

LEGEND: NA = No analysis. "≤Bkg" = Concentrations did not exceed background.

The highest concentrations of all radionuclides (except Pu-238, for which the maximum was found at point ST-20 on Erdman Brook) were observed in sediment from Franks Creek at location SNSP006, where it flows off site at the security fence.[13] As was found with sediment from Erdman Brook, sediment from Franks Creek collected downgradient of the controlled effluent water release point WNSP001 contained U-232 at concentrations exceeding background. (Effluent water discharged from lagoon 3 through WNSP001 often contains measureable quantities of U-232.) Summary statistics for radionuclide concentrations at SNSP006 are presented in Appendix B.

The highest ratio of Sr-90 to Cs-137 (about 3 to 1) in surface soil from WMA 12 was noted for one sample collected near the eastern edge of the fenced area. In sediment, the maximum ratios to Cs-137 for Sr-90 (0.1 to 1), Pu-239/240 (0.012 to 1), and Am-241 (0.023

[13] In 1990, a sample from a hot spot in Erdman Brook that measured 3000 μR/h during the ground-level survey showed 0.01 μCi/g (10,000 pCi/g) Cs-137. (This was a screening analysis that may have been performed on a wet sample; it was not validated.) This area of localized contamination was described as about six inches by six inches located one meter from the edge of the water. Limited investigation indicated that the contamination extended more than seven inches below the streambed surface. (Passuite and Monsalve-Jones 1993, Appendix C)

to 1) were all found downgradient of the Demineralizer Sludge Ponds. The highest ratios to Cs-137 of U-232 (0.003 to 1) and U-238 (0.007 to 1) were found in sediment from Erdman Brook, immediately after the point where it receives Lagoon 3 effluent.

4.2.6 Environmental Radiation Levels

As part of the WVDP Environmental Monitoring Program, since 1986 thermoluminescent dosimeters (TLDs) have been placed in the field to measure levels of integrated gamma radiation exposure. TLDs are placed:

(1) At background locations far from the Center,

(2) At communities near the Center,

(3) At a ring of perimeter locations around the Center, and

(4) At onsite locations near process areas, waste storage areas, and waste burial locations.

Figure 4-9 shows the locations of onsite TLDs.

Note that not all areas on the project premises have environmental TLD monitoring locations, therefore, data are not available for these areas. Average results over the last ten years, in mR/quarter and in mR/h, are summarized in Table 4-23. Onsite results are presented by waste management area. For comparison, measurements from background are included.

Exposure measurements from the ring of TLDs around the perimeter of the Center and at the community locations are evaluated each year as part of preparing the Annual Site Environmental Report. Values from offsite TLDs have consistently been indistinguishable from background.

Results from all onsite TLDs, with the single exception of DNTLD27 located on the eastern border of the security-fenced area, were in excess of background levels. Note that exposure levels in the above table may not be indicative of radionuclides in soil, but of radiation from the wastes being processed and/or stored nearby.

The on-site monitoring point with the highest dose readings was location DNTLD24 on the north plateau (Figure 4-9). Sealed containers of radioactive components and debris from the plant decontamination work are stored nearby in the Chemical Process Cell Waste Storage Area. Exposure rates at this location have been generally decreasing over time because the radioactivity in the materials stored nearby is decaying. This storage area is well within the Center boundary, just inside the WVDP fenced area, and is not accessible by the public.

The maximum quarterly exposure level (1298 mR/qtr [0.59 mR/hr]) was noted at DNTLD35, near the rail spur by the Drum Cell in the second quarter of 2007. This high reading was associated with waste storage and with staging and shipping drums of cement-stabilized waste from the Drum Cell. All remaining drums were shipped from the Drum Cell in 2007, and in the fourth quarter of 2007 the exposure level at DNTLD35 had dropped to 23 mR/qtr (0.011 mR/hr).

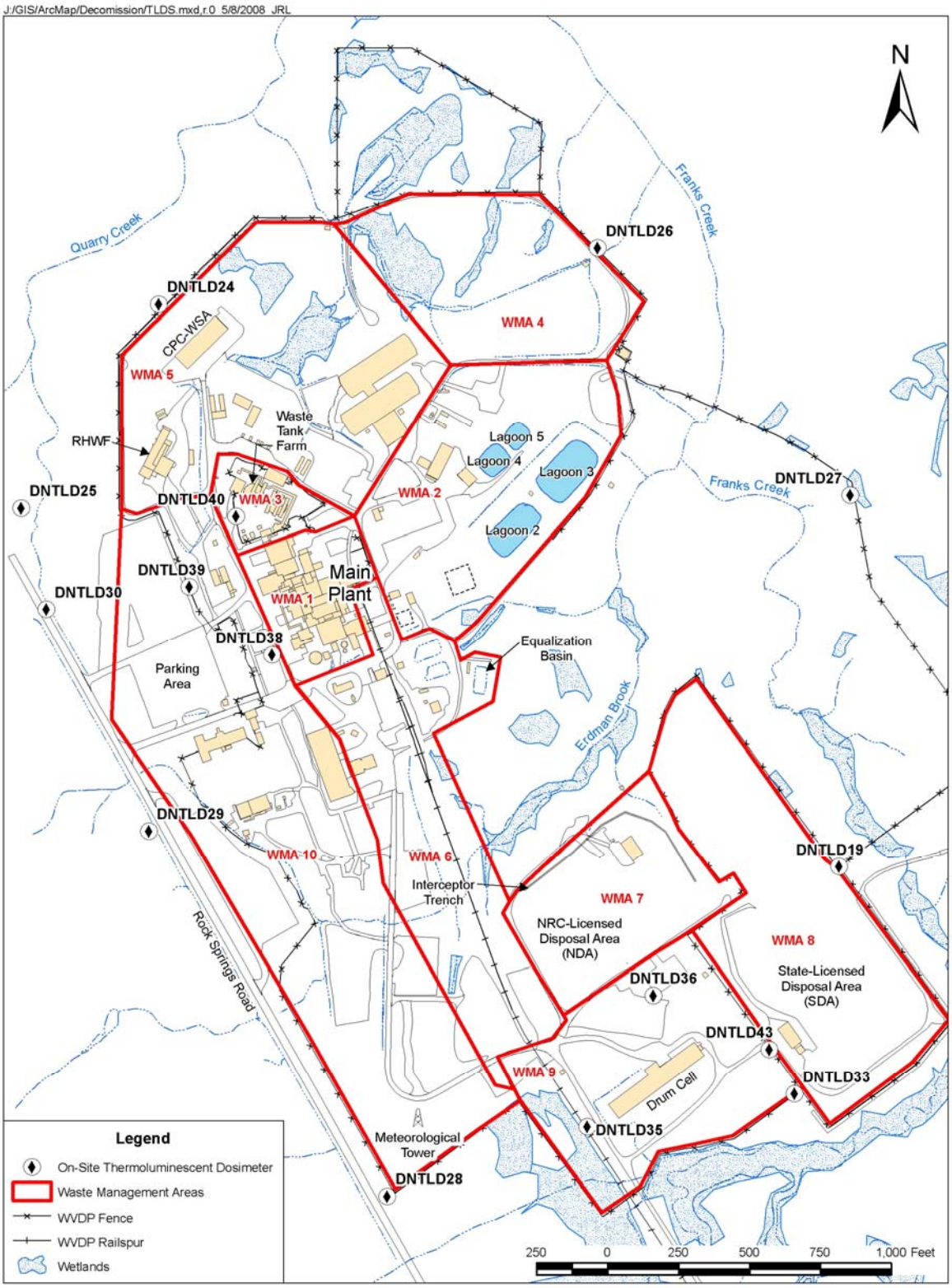

Figure 4-9. Onsite Environmental TLD Locations

Table 4-23. Environmental Radiation Levels on the WVDP Site (1998-2007 data)

TLD (s)	Location	Average mR/qtr	Average mR/h	Maximum mR/qtr	Maximum mR/h	(1)Exceeds Background?
DNTLD40	Waste Tank Farm (WMA 3)	119	0.054	268	0.122	Yes
DNTLD26	Construction and Demolition Debris Landfill fence line (WMA 4)	23	0.011	30	0.014	Yes
DNTLD24	Chemical Process Cell Waste Storage Area fence line (WMA 5)	523	0.239	717	0.327	Yes
DNTLD25	Quarry Creek, between security fence and public road (WMA 5)	23	0.011	31	0.014	Yes
DNTLD30	Northwest parking lot, near public road (WMA 10)	23	0.010	32	0.015	Yes
DNTLD39	On fence between parking lot and Process Building (WMA 10)	49	0.022	70	0.032	Yes
DNTLD38	Nurse's office across Process Building (WMA 10)	34	0.015	55	0.025	Yes
DNTLD29	On fence near Environmental Laboratory (WMA 10)	22	0.010	29	0.013	Yes
DNTLD28	Southwestern corner of Project Premises (WMA 10)	22	0.010	38	0.018	Yes
DNTLD35	(2)Near rail spur by Drum Cell (WMA 9)	109	0.050	1298	0.592	Yes
DNTLD36	(2)Drum Cell north fence (WMA 9)	61	0.028	458	0.209	Yes
DNTLD43	Drum Cell northeastern fence (WMA 9)	31	0.014	69	0.031	Yes
DNTLD33	Drum Cell southeastern corner (WMA 9)	32	0.014	54	0.025	Yes
DNTLD19	Western fence line near waste burial areas (WMA 12)	22	0.010	39	0.018	Yes
DNTLD27	Eastern fence line farthest from process and waste storage areas (WMA 12)	20	0.009	27	0.012	No
Background	Four background locations (map in Appendix B)	19	0.009	35	0.016	NA

NOTE: (1) Data sets from each location were compared with background data sets using one-way analysis of variance (see Appendix B).

(2) Exposure measurements near the Drum Cell have been elevated in the last several years because the area is being used as a storage area for vessels removed from the Process Building and for staging waste for shipping. Waste drums formerly stored in the Drum Cell itself were removed in 2007.

As summarized in WVNSCO 1994, two aerial radiation surveys of the WNYNSC in 1969 and 1979 identified above-background gamma radiation extending from the reprocessing plant in a northwest direction along Buttermilk Creek (1969) and in a prong extending westward offsite across Rock Springs Road (1979). Cs-137 was determined to be the source of the gamma activity. (See Section 2.)

Soil sampling by NYSDEC in 1971 and by WVNSCO in 1982 determined that Cs-137 activity was greater in soil northwest of the plant and that activity was greatest at the soil surface and decreased with depth (WVNSCO 1994). Activity in the cesium prong is attributed to airborne releases from a filter blow-out in 1968, as indicated in Section 2. Elevated radionuclide concentrations in the Buttermilk Creek drainage are attributed to routine radioactive liquid releases.

Posted Radiation Areas

At the WVDP Site, radiation areas are posted if exposure can exceed 5 mrem/hr at 30 centimeters (WVNSCO 2006). Posted radiological control areas on the project premises are shown in Figure 4-10. Posted radiation levels are generally indicative of surface and/or near surface contamination, storage of radioactive waste, and proximity to radiological process areas. Posted areas are delineated in accordance with 10 CFR 835, *Occupational Radiation Protection*.

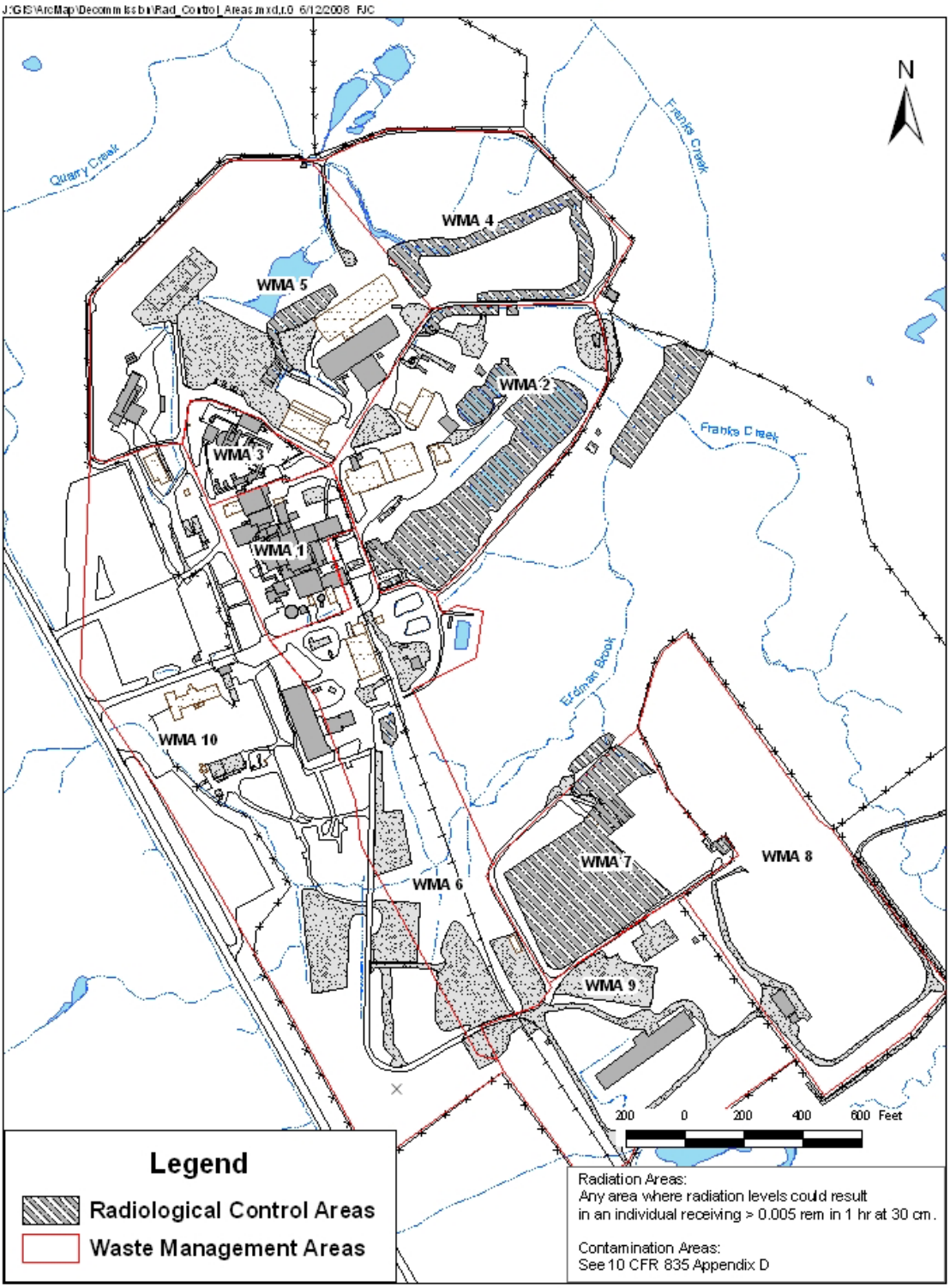

Figure 4-10. WVDP Radiological Control Areas. (Facilities with radiological controlled areas are outlined in black. Radiological Control Areas are current as of June 2008.)

4.2.7 Radiological Status of Onsite Surface Water

The WVDP Environmental Monitoring Program routinely collects surface water samples from the following locations on the project premises:

(1) Two controlled effluent discharges (releases from lagoon 3 through the weir at point WNSP001 and from the Sanitary Waste Treatment Facility at point WNSP007);

(2) Two drainages where water from the North Swamp and the Northeast Swamp leave the site (points WNSW74A and WNSWAMP, respectively);

(3) Facility cooling water from the Cooling Tower (WNCOOLW);

(4) Two drainage ditches (facility drainage [point WNSP005] and NDA surface drainage [point WNNDADR]); and

(5) Three locations on two streams (point WNERB53 on Erdman Brook, point WNFRC67 on Franks Creek, and point WNSP006 where Franks Creek leaves the project premises at the security fence).

Figure 4-11 shows the location of these routine surface water monitoring locations and indicates those with gross alpha (or alpha-emitting radionuclide) concentrations and gross beta (or beta/gamma-emitting radionuclide) concentrations in excess of background. All surface water locations had at least one constituent exceeding background (i.e., no non-impacted locations were noted).

Table 4-24 summarizes median, average, and maximum concentrations of those radionuclides observed to exceed background in surface water over the ten-year period 1998-2007. (For a complete summary of radionuclide concentrations in surface water, including those not detected above background, see Table B-13 of Appendix B.) Note that concentrations of the beta-emitting radionuclide Sr-90 exceeding background were observed in surface water throughout the project premises. (See Appendix B for comparable summary statistics for each radionuclide in surface water from background locations.) The highest Sr-90 concentrations were observed at location WNSWAMP, which is downstream of the point where the leading edge of the north plateau groundwater plume surfaces.

The full suite of radionuclides monitored in surface water was detected at above-background concentrations at the Lagoon 3 discharge point WNSP001. Tritium was detected downstream of the Low-Level Waste Treatment Facility (points WNSP001 and WNSP006), at the Northeast Swamp Discharge Point (WNSWAMP), at a point immediately downstream of the NDA on the south plateau (WNNDADR), and in Erdman Brook and Franks Creek on the south plateau (locations WNERB53 and WNFRC67, respectively).

Alpha-emitting radionuclides at concentrations exceeding background were noted only in surface water from the north plateau, primarily at locations downstream of the Low-Level Waste Treatment Facility discharge, but also at the North (WNSW74A) and Northeast Swamp (WNSWAMP) discharge points.

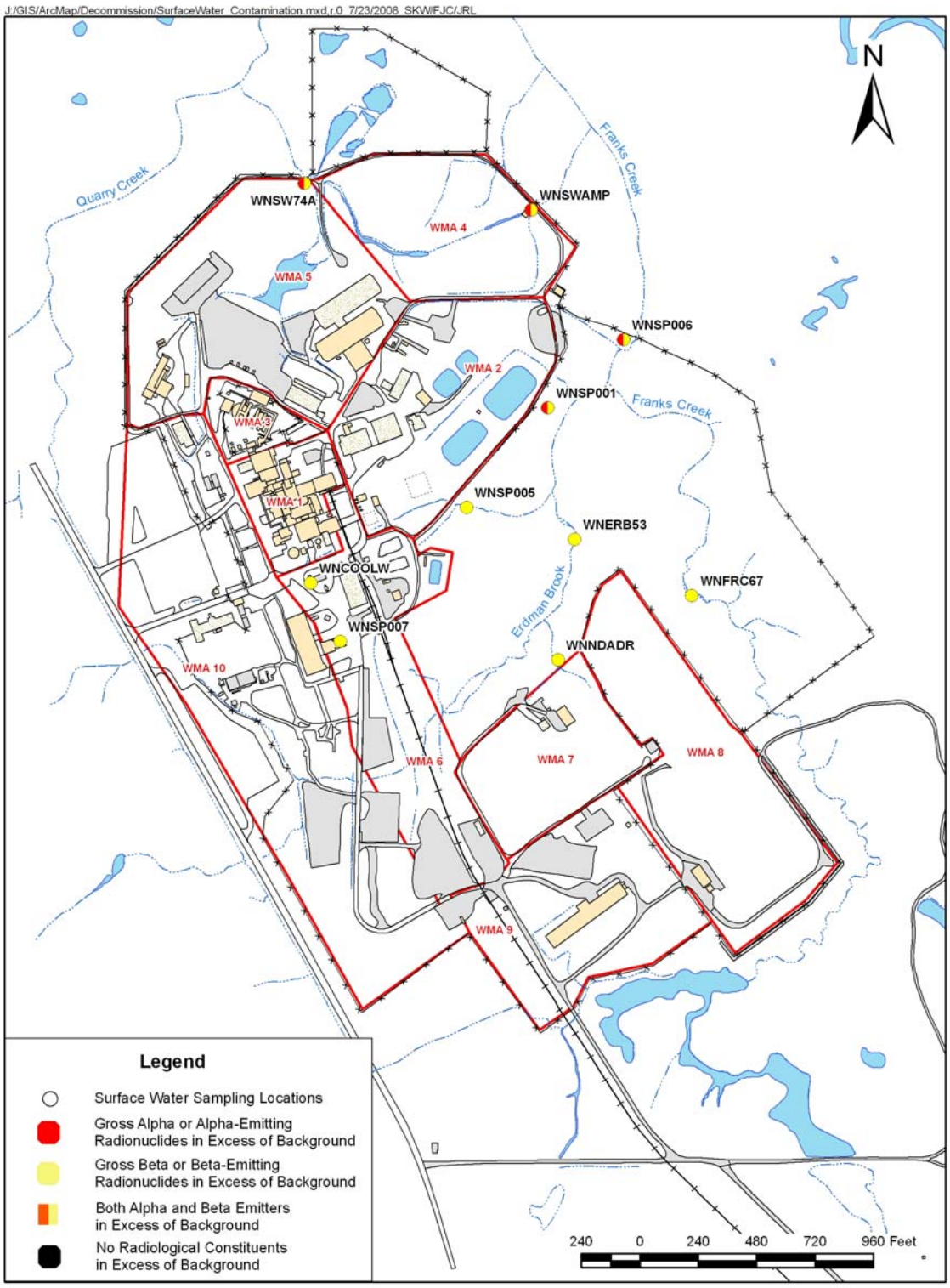

Figure 4-11. Surface Water Locations with Radionuclide Concentrations in Excess of Background

Table 4-24. Radionuclide Concentrations (pCi/L)[1] in Excess of Background in Surface Water[2]

Location	Median	Average			Maximum
		Result	±	Uncertainty	
Lagoon 3 discharge weir (WNSP001), WMA 2					
H-3	2.5E+03	2.8E+03	±	1.4E+02	7.2E+03
C-14	< 2.8E+01	1.4E+01	±	2.2E+01	4.8E+01
Sr-90	9.9E+01	1.2E+02	±	7.4E+00	3.2E+02
Tc-99	6.5E+01	7.9E+01	±	4.8E+01	3.4E+03
I-129	2.1E+00	2.4E+00	±	1.5E+00	1.0E+01
Cs-137	6.1E+01	7.6E+01	±	1.9E+01	3.3E+02
U-232	8.0E+00	9.0E+00	±	9.9E-01	2.1E+01
U-233/234	5.0E+00	5.5E+00	±	6.2E-01	1.4E+01
U-235/236	2.6E-01	2.8E-01	±	1.2E-01	5.8E-01
U-238	3.8E+00	3.8E+00	±	4.9E-01	7.6E+00
Pu-238	6.5E-02	1.5E-01	±	6.8E-02	1.6E+00
Pu-239/240	5.2E-02	1.3E-01	±	6.2E-02	1.4E+00
Am-241	6.8E-02	1.2E-01	±	6.0E-02	9.7E-01
Northeast swamp drainage (WNSWAMP), WMA 4					
H-3	1.1E+02	1.1E+02	±	8.2E+01	5.2E+02
Sr-90	1.5E+03	1.7E+03	±	3.1E+01	5.2E+03
U-233/234	1.7E-01	2.0E-01	±	1.4E-01	9.3E-01
U-238	1.0E-01	1.2E-01	±	1.1E-01	7.2E-01
North swamp drainage (WNSW74A), WMA 5					
Sr-90	5.5E+00	5.5E+00	±	1.8E+00	1.2E+01
U-233/234	1.5E-01	1.6E-01	±	8.4E-02	3.5E-01
U-238	1.0E-01	1.0E-01	±	6.6E-02	2.0E-01
Sanitary waste discharge (WNSP007), WMA 6					
Sr-90	3.1E+00	3.4E+00	±	1.9E+00	1.2E+01
Franks Creek at security fence (WNSP006), WMA 12					
H-3	< 8.5E+01	1.4E+02	±	8.3E+01	2.2E+03
Sr-90	1.9E+01	2.0E+01	±	3.0E+00	5.0E+01
Tc-99	< 2.1E+00	3.3E+00	±	2.1E+00	5.2E+01
Cs-137	< 8.0E+00	6.3E+00	±	9.5E+00	7.3E+01
U-232	3.2E-01	3.2E-01	±	1.3E-01	7.5E-01
U-233/234	3.7E-01	3.7E-01	±	1.3E-01	6.9E-01
U-238	2.5E-01	2.8E-01	±	1.1E-01	7.4E-01

Table 4-24. Radionuclide Concentrations (pCi/L)[1] in Excess of Background in Surface Water[2]

Location	Median	Average			Maximum
		Result	±	Uncertainty	
Pu-238	< 3.4E-02	2.1E-02	±	3.4E-02	1.4E-01
Facility yard drainage (WNSP005), WMA 12					
H-3	< 8.3E+01	3.8E+01	±	8.2E+01	1.2E+03
Sr-90	9.6E+01	1.0E+02	±	6.5E+00	2.0E+02
Drainage between NDA and SDA (WNNDADR), WMA 12					
H-3	1.0E+03	1.1E+03	±	1.0E+02	4.0E+03
Sr-90	8.5E+01	8.4E+01	±	5.4E+00	1.2E+02
Erdman Brook north of disposal areas (WNERB53), WMA 12					
H-3	< 8.3E+01	3.9E+01	±	8.0E+01	4.9E+02
Sr-90	8.2E+00	8.0E+00	±	2.0E+00	9.9E+00
Franks Creek East of SDA (WNFRC67), WMA 12					
H-3	< 8.3E-01	3.1E+01	±	8.1E+01	3.5E+02

NOTES: (1) 1 pCi/L = 3.7E-02 Bq/L
(2) Refer to Table 4-11 for median and maximum background values and to Appendix B for summary statistics of background radionuclide concentrations in surface water.

4.2.8 Radiological Status of Groundwater

Groundwater at the WVDP is routinely monitored in accordance with the WVDP Groundwater Monitoring Program. Although the primary focus of the program is on nonradiological constituents, all wells are monitored for radiological indicator parameters (gross alpha, gross beta, and H-3). Several wells, especially those impacted by the north plateau groundwater plume, are sampled for Sr-90. Select wells are monitored for a full suite of radionuclides. Table 4-25 lists routine groundwater monitoring locations at which radiological concentrations were found at levels exceeding background. Medians, averages, and maximum concentrations (in pCi/L) are presented for each.

For groundwater (unlike the other environmental media discussed in this section), gross alpha and gross beta concentrations exceeding background are presented. This is because limited radionuclide data are available for routinely monitored groundwater locations, and gross alpha and gross beta measurements, taken at all wells, may indicate the presence of other alpha- or beta-emitting radionuclides. For instance, gross beta measurements are used as a surrogate measurement for Sr-90 at monitoring points where the Sr-90-to-gross beta ratio has been determined to be approximately 0.5 to 1.

Locations at which gross alpha (or alpha-emitting radionuclide) concentrations and/or gross beta (or beta-emitting radionuclide, including H-3) concentrations exceeded background are shown on Figure 4-12. Locations at which no radiological constituents were found to exceed background are also shown. For a complete summary of

radionuclide data from both impacted and non-impacted routine groundwater monitoring locations, see Appendix B, Table B-14. A listing of supplementary information for each point (e.g., geographical coordinates, well construction, screened interval, geologic unit) is provided in Appendix B, Table B-15.

Table 4-25. Routine Groundwater Monitoring Locations With Radionuclide Concentrations (pCi/L)[(1)] in Excess of Background[(2)]

WMA	Monitoring Point	Constituent	Median	Average			Maximum
				Result	±	Uncertainty	
WMA 1	WP-A	Gross beta	2.4E+01	3.1E+01	±	4.6E+00	5.4E+01
		H-3	1.2E+04	1.1E+04	±	6.2E+02	1.3E+04
WMA 2	WP-C	Gross beta	2.4E+01	4.2E+01	±	5.5E+00	1.2E+02
		H-3	4.9E+04	4.7E+04	±	1.6E+03	6.6E+04
	WP-H	Gross alpha	6.1E+00	7.9E+01	±	2.3E+01	7.4E+02
		Gross beta	7.0E+03	7.2E+03	±	1.9E+02	1.2E+04
		H-3	3.0E+03	3.4E+03	±	5.0E+02	7.4E+03
	WNW0103	Gross beta	1.4E+02	1.8E+02	±	1.9E+01	5.5E+02
	WNW0104	Gross beta	5.9E+04	5.6E+04	±	1.6E+03	1.0E+05
		H-3	3.7E+02	3.9E+02	±	8.6E+01	7.5E+02
	WNW0105	Gross beta	3.9E+04	3.3E+04	±	1.5E+03	1.0E+05
		H-3	3.6E+02	3.7E+02	±	9.1E+01	7.1E+02
	WNW0106	Gross beta	1.6E+01	8.2E+01	±	8.0E+00	5.8E+02
		H-3	9.6E+02	1.0E+03	±	1.0E+02	1.8E+03
	WNW0107	Gross beta	7.0E+00	8.2E+00	±	2.6E+00	2.2E+01
		H-3	3.7E+02	4.8E+02	±	9.0E+01	9.9E+02
	WNW0108	Gross alpha	1.6E+00	1.5E+00	±	1.5E+00	4.3E+00
		H-3	1.2E+02	1.1E+02	±	8.4E+01	2.5E+02
	WNW0110	H-3	1.3E+03	1.3E+03	±	1.1E+02	1.7E+03
	WNW0111	Gross alpha	<4.4E+00	3.2E+00	±	5.1E+00	1.0E+01
		Gross beta	5.6E+03	5.9E+03	±	1.4E+02	1.2E+04
		H-3	2.0E+02	2.3E+02	±	8.4E+01	8.0E+02
	WNW0116	Gross beta	8.7E+02	2.0E+03	±	1.6E+02	9.5E+03
		H-3	1.7E+02	1.9E+02	±	8.2E+01	4.7E+02
	WNW0205	Gross beta	1.6E+01	1.7E+01	±	8.4E+00	4.1E+01
	WNW0408	Gross beta	4.0E+05	4.0E+05	±	3.0E+03	6.3E+05
		H-3	1.5E+02	1.9E+02	±	1.1E+02	2.2E+03
		Sr-90	1.5E+05	1.5E+05	±	1.7E+02	2.5E+05
		Tc-99	1.6E+01	1.7E+01	±	3.3E+00	2.5E+01

Table 4-25. Routine Groundwater Monitoring Locations With Radionuclide Concentrations (pCi/L)[1] in Excess of Background[2]

WMA	Monitoring Point	Constituent	Median	Average			Maximum
				Result	±	Uncertainty	
WMA 2		U-233/234	4.5E-01	5.3E-01	±	2.2E-01	1.3E+00
		U-238	2.9E-01	3.1E-01	±	1.6E-01	4.8E-01
	WNW0501	Gross beta	1.9E+05	1.9E+05	±	2.6E+03	3.2E+05
		H-3	1.4E+02	1.2E+02	±	8.4E+01	3.2E+02
		Sr-90	9.2E+04	9.3E+04	±	2.4E+02	1.5E+05
	WNW0502	Gross beta	1.7E+05	1.6E+05	±	2.8E+03	2.3E+05
		H-3	1.3E+02	1.4E+02	±	8.4E+01	5.0E+02
		Sr-90	8.4E+04	8.3E+04	±	2.1E+02	1.2E+05
	WNW8603	Gross beta	5.7E+04	4.8E+04	±	1.2E+03	9.0E+04
		H-3	3.4E+02	3.4E+02	±	8.8E+01	5.8E+02
	WNW8604	Gross beta	4.1E+04	4.6E+04	±	1.1E+03	1.0E+05
		H-3	3.5E+02	3.8E+02	±	8.4E+01	6.4E+02
	WNW8605	Gross alpha	9.1E+00	8.5E+00	±	7.7E+00	2.1E+01
		Gross beta	1.1E+04	1.1E+04	±	1.7E+02	1.6E+04
		H-3	3.7E+02	4.2E+02	±	8.7E+01	1.3E+03
WMA 3	WNW8609	Gross beta	1.5E+03	1.4E+03	±	4.2E+01	2.3E+03
		H-3	4.5E+02	4.7E+02	±	9.1E+01	7.9E+02
		Sr-90	8.0E+02	7.2E+02	±	2.1E+01	1.1E+03
WMA 4	WNW0801	Gross beta	8.0E+03	8.6E+03	±	2.7E+02	1.5E+04
		H-3	1.5E+02	1.6E+02	±	8.2E+01	3.8E+02
		Sr-90	4.1E+03	4.3E+03	±	4.7E+01	8.0E+03
	WNW0802	Gross beta	9.9E+00	3.5E+01	±	5.1E+00	2.8E+02
		H-3	<1.1E+02	9.0E+01	±	8.0E+01	4.2E+02
	WNW0803	Gross beta	1.5E+01	1.5E+01	±	4.7E+00	2.5E+01
		H-3	1.8E+02	1.6E+02	±	8.5E+01	3.4E+02
	WNW0804	Gross beta	2.6E+02	2.9E+02	±	1.1E+01	6.9E+02
		H-3	1.2E+02	1.1E+02	±	8.0E+01	3.6E+02
	WNW8612	H-3	4.2E+02	4.3E+02	±	8.9E+01	8.5E+02
WMA 5	WNW0406	Gross beta	7.4E+00	8.1E+00	±	3.5E+00	1.7E+01
		H-3	1.2E+02	1.1E+02	±	8.4E+01	4.4E+02
		Tc-99	2.2E+00	2.5E+00	±	1.9E+00	8.5E+00
	WNW0409	Gross alpha	<1.0E+00	9.4E-01	±	9.9E-01	2.3E+00
	WNW0602A	Gross beta	1.2E+01	1.3E+01	±	2.9E+00	3.5E+01

Table 4-25. Routine Groundwater Monitoring Locations With Radionuclide Concentrations (pCi/L)(1) in Excess of Background(2)

WMA	Monitoring Point	Constituent	Median	Average			Maximum
				Result	±	Uncertainty	
WMA 5		H-3	2.2E+02	2.2E+02	±	8.9E+01	4.9E+02
	WNW0604	Gross beta	6.1E+00	6.3E+00	±	3.0E+00	1.3E+01
	WNW0605	Gross beta	4.8E+01	5.1E+01	±	4.0E+00	8.8E+01
	WNW0704	Gross beta	8.0E+00	8.2E+00	±	3.0E+00	1.3E+01
	WNW8607	Gross beta	2.6E+01	2.7E+01	±	5.3E+00	7.6E+01
	WNW1304	U-233/234	2.7E-01	2.9E-01	±	1.3E-01	5.6E-01
		U-238	1.9E-01	2.2E-01	±	1.0E-01	5.8E-01
WMA 7	WNW0902	Gross alpha	1.5E+00	1.3E+00	±	1.3E+00	5.4E+00
	WNW0909	Gross beta	3.7E+02	3.7E+02	±	1.4E+01	6.4E+02
		H-3	8.2E+02	1.5E+03	±	1.2E+02	3.9E+03
		Sr-90	1.9E+02	1.8E+02	±	8.3E+00	2.2E+02
		Tc-99	<1.9E+00	1.3E+00	±	1.8E+00	5.0E+00
		I-129	6.2E+00	6.3E+00	±	1.9E+00	9.7E+00
		U-233/234	6.0E-01	7.4E-01	±	2.4E-01	1.3E+00
		U-238	4.7E-01	5.4E-01	±	2.0E-01	1.0E+00
	WNW0910	Gross alpha	<2.5E+00	1.9E+00	±	2.3E+00	3.4E+00
		Gross beta	3.8E+01	1.5E+02	±	8.5E+01	1.5E+03
	WNNDATR	Gross alpha	2.2E+00	2.1E+00	±	2.1E+00	1.1E+01
		Gross beta	1.5E+02	1.8E+02	±	8.4E+00	5.5E+02
		H-3	3.6E+03	5.0E+03	±	2.3E+02	2.0E+04
		Sr-90	5.8E+01	7.8E+01	±	5.5E+00	2.8E+02
		I-129	<9.1E-01	8.4E-01	±	9.4E-01	7.0E+00
		U-233/234	1.7E+00	1.5E+00	±	2.8E-01	2.1E+00
		U-235/236	1.1E-01	1.4E-01	±	9.5E-02	3.0E-01
		U-238	1.3E+00	1.2E+00	±	2.5E-01	1.7E+00
WMA 9	WNW1006	Gross alpha	<5.1E+00	4.2E+00	±	5.5E+00	1.0E+01

NOTES: (1) 1 pCi/L = 3.7E-02 Bq/L

(2) Refer to Table 4-11 for median and maximum background values and to Appendix B for summary statistics of background radionuclide concentrations in groundwater (Table B-7) and at non-impacted groundwater monitoring locations (Table B-14). Data sets from each location were compared with background data sets using the nonparametric Mann-Whitney "U" test, as described in Appendix B, section 4.3.

As shown in Figure 4-12, elevated gross beta concentrations are evident in groundwater northeast of the Process Building (WVNSCO and URS 2005). The beta activity is primarily found in the surficial sand and gravel unit, and the general direction of flow in this unit is to the northeast. Elevated gross beta concentrations are largely

attributed to Sr-90 in the north plateau plume. While concentrations of gross alpha or alpha-emitting radionuclides exceeding background were found at only a few locations, the locations were associated with (or downgradient of) historical waste processing or waste burial activities (i.e., WMAs 1, 2, and 7).

In December 1993, elevated gross beta concentrations were detected in surface water at a former sampling location near the edge of the north plateau. This discovery initiated a subsurface groundwater and soil Geoprobe® investigation in 1994 (Carpenter and Hemann 1995). Two additional Geoprobe® investigations were conducted in 1997 (Hemann and Fallon 1998) and 1998 (Hemann and Steiner 1999). A listing of the Geoprobe® locations, sample depths, and geologic units from which the groundwater was sampled is provided in Appendix B, Table B-16. (NOTE: For completeness, Appendix B, Table B-17, provides a listing of groundwater points — in addition to the routine groundwater monitoring and Geoprobe® locations included in this evaluation — that have been sampled over the years. Table B-17 presents information on the locations and depths of these points, and summarizes the reasons that the points were not included in the current evaluation [dry wells, wells dropped from program, unvalidated data, located in areas outside the scope of the Phase 1 DP, etc.].)

The principal source of the north plateau groundwater plume is believed to be a release of radioactively contaminated acid from the NFS acid recovery system in the 1960s when NFS was reprocessing fuel, during 10 CFR Part 50 licensed activities. A detailed description of the release is provided in Section 2, subsection 2.3.1. See also Table 2-15 for an estimate of radionuclide activity from this release expected to remain in the plume in 2011.

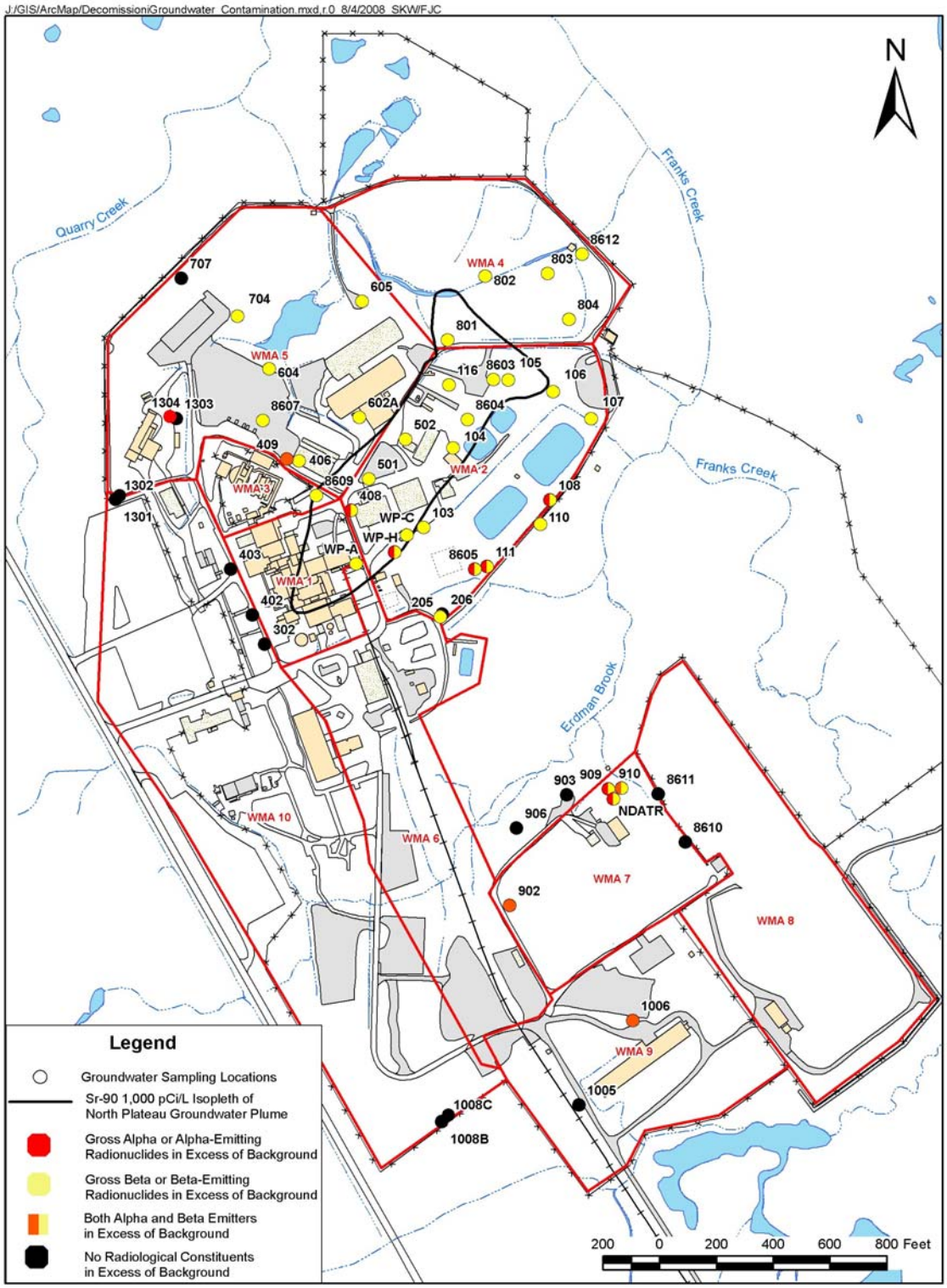

Figure 4-12. Routine Groundwater Monitoring Locations with Radionuclide Concentrations in Excess of Background

The Geoprobe® investigation results were used to estimate the extent of the north plateau groundwater plume beneath and downgradient of the Process Building. As part of the Geoprobe® investigations, a more extensive suite of radionuclides was analyzed in groundwater than was done for routine monitoring. Because the Geoprobe® groundwater samples differed from those taken from routine monitoring locations in that Geoprobe® samples may have been taken from several depths (and even from different geologic units) at a single location, the sample results were not directly comparable and have not been presented in the same table. However, results from the Geoprobe® investigations provide supplemental information about the presence of radionuclides in groundwater on the north plateau.

Geoprobe® locations at which concentrations of gross alpha (or alpha-emitting radionuclides) or gross beta (or beta/gamma-emitting radionuclides, including H-3) exceeded background are shown on Figure 4-13. The maximum measured radionuclide concentrations are summarized by WMA in Table 4-26. Since radionuclide data were available for these sampling locations, gross alpha and gross beta data were not included in this table.

As can be seen in Figure 4-13, concentrations of gross beta or beta/gamma-emitting radionuclides exceeding background are evident at all locations, with the exception of the four non-impacted points in WMA 5 northwest of the north plateau groundwater plume. Gross alpha or alpha-emitting radionuclide concentrations exceeding background were found immediately downgradient of the Process Building and downgradient of the Interceptors.

Table 4-26. Geoprobe® Groundwater Points with Radionuclide Concentrations (pCi/L) in Excess of Background[(1)]

WMA	Point	Constituent	Maximum	Point	Constituent	Maximum
WMA 1	GP8098	H-3	6.4E+04	GP76	Cs-137	8.5E+01
	GP29	C-14	2.3E+03	GP30	U-232	1.5E-01
	GP30	Sr-90	1.2E+06	GP73	U-233/234	1.2E+00
	GP72	Tc-99	1.2E+04	GP73	U-238	8.6E-01
	GP29	I-129	3.0E+01	GP76	Am-241	4.7E-01
WMA 2	GP47	H-3	3.4E+04	GP44	U-233/234	3.7E+01
	GP66	C-14	4.0E+02	GP44	U-235/236	6.2E-01
	GP8298	Sr-90	2.8E+05	GP60	U-238	1.5E+01
	GP68	Tc-99	5.8E+01	GP59	Pu-238	4.5E+00
	GP47	I-129	8.2E+01	GP59	Pu-239/240	7.9E+00
	GP46	Cs-137	1.5E+02	GP59	Am-241	5.9E+00
	GP44	U-232	7.8E+01	-	-	-
WMA 3	GP20	H-3	1.5E+03	GP20	I-129	2.5E+00
	GP2097	Sr-90	1.2E+04	-	-	-

Table 4-26. Geoprobe® Groundwater Points with Radionuclide Concentrations (pCi/L) in Excess of Background(1)

WMA	Point	Constituent	Maximum	Point	Constituent	Maximum
WMA 4	GP32A	H-3	1.3E+03	GP0397	Sr-90	8.6E+03
WMA 5	GP43	H-3	2.0E+04	GP53	Tc-99	8.0E+01
	GP40	Sr-90	3.8E+03	GP43	I-129	4.6E+00
WMA 6	GP70	H-3	6.8E+03	GP70	Tc-99	3.1E+01
	GP70	C-14	1.4E+02	GP70	I-129	1.1E+01
	GP70	Sr-90	2.8E+04	-	-	-
WMA 12	GP48	H-3	1.5E+03	GP50	U-238	7.2E-01
	GP50	Sr-90	1.3E+01	-	-	-

NOTE: (1) Points ending with "97" or "98" were collected in 1997 or 1998, respectively. The remaining points were collected in 1994. Sample results were compared with average background values as described in Appendix B, section 4.2.

The north plateau plume, as delineated by the 1,000 pCi/L isopleth, was approximately 300 feet wide and 800 feet long in 1994. By 2004, the plume area had expanded to approximately 350 feet by 1050 feet, and by 2007 to about 540 feet (at its widest point near the leading edge) by 1300 feet (WVES and URS 2008). (See Figure 4-14.)

The highest gross beta concentrations in groundwater and soil were found near the southeast corner of the Process Building. In the 1994 study, the maximum concentration in groundwater was 3.6E+06 pCi/L, and the maximum concentration in subsurface soil was 2.4E+04 pCi/g. Sr-90 and its progeny, Y-90, were determined to be the isotopes responsible for most of the elevated gross beta activity (WVNSCO and URS 2007).

As a result of recommendations from a 1997 external review of WVDP response actions on the north plateau, more attention was given in 1998 to the core area of the plume, determined to be beneath and immediately downgradient of the Process Building. Results from the 1998 investigation were presented in a summary report (Hemann and Steiner 1999) that compared groundwater and soil sampling data with the 1994 data. Concentrations detected in 1998 samples were generally lower than those in the 1994 samples due to radioactive decay and continuing migration and dispersion of the plume. The study also concluded that Lagoon 1 was a possible contributor of gross beta activity to groundwater downgradient of the Lagoon.

Figure 4-14 shows the 1E+03 pCi/L gross beta contour lines defining the extent of the plume in 1994, 2001, and 2007. (This figure, which duplicates Figure 2-6 in Section 2, is provided here for the sake of completeness.) Figure 4-14 also shows gross beta concentrations at the 12 routine groundwater monitoring locations that define the plume as of the fourth quarter of 2007. Contour lines show a gradual lengthening and expansion of the plume toward the northeast, with the highest concentration (i.e., well 408 at 3.9E+05

pCi/L) near the Process Building and lower concentrations near the leading edge. Further downgradient, the plume appears to be diverging – one prong moving to the north toward the surface drainage north of the CDDL and the other toward the east. Figure 4-14 also shows 1E+03 pCi/L contour lines of gross beta activity in groundwater over time near inactive Lagoon 1. This smaller area of elevated activity, likely associated with contamination remaining in Lagoon 1 sediment and backfill, appears to be migrating slightly eastward over time.

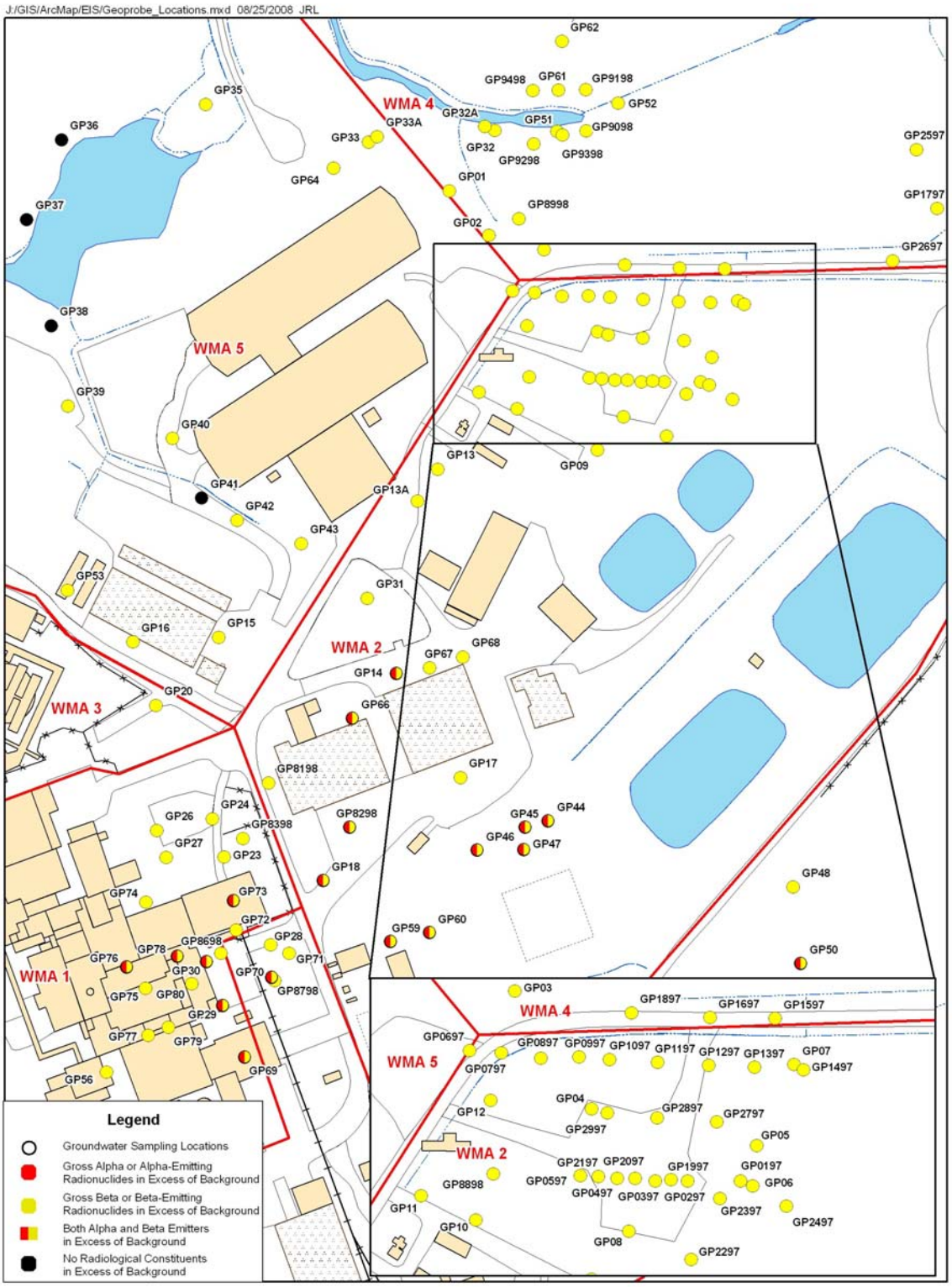

Figure 4-13. Geoprobe® Groundwater Locations with Radionuclide Concentrations in Excess of Background

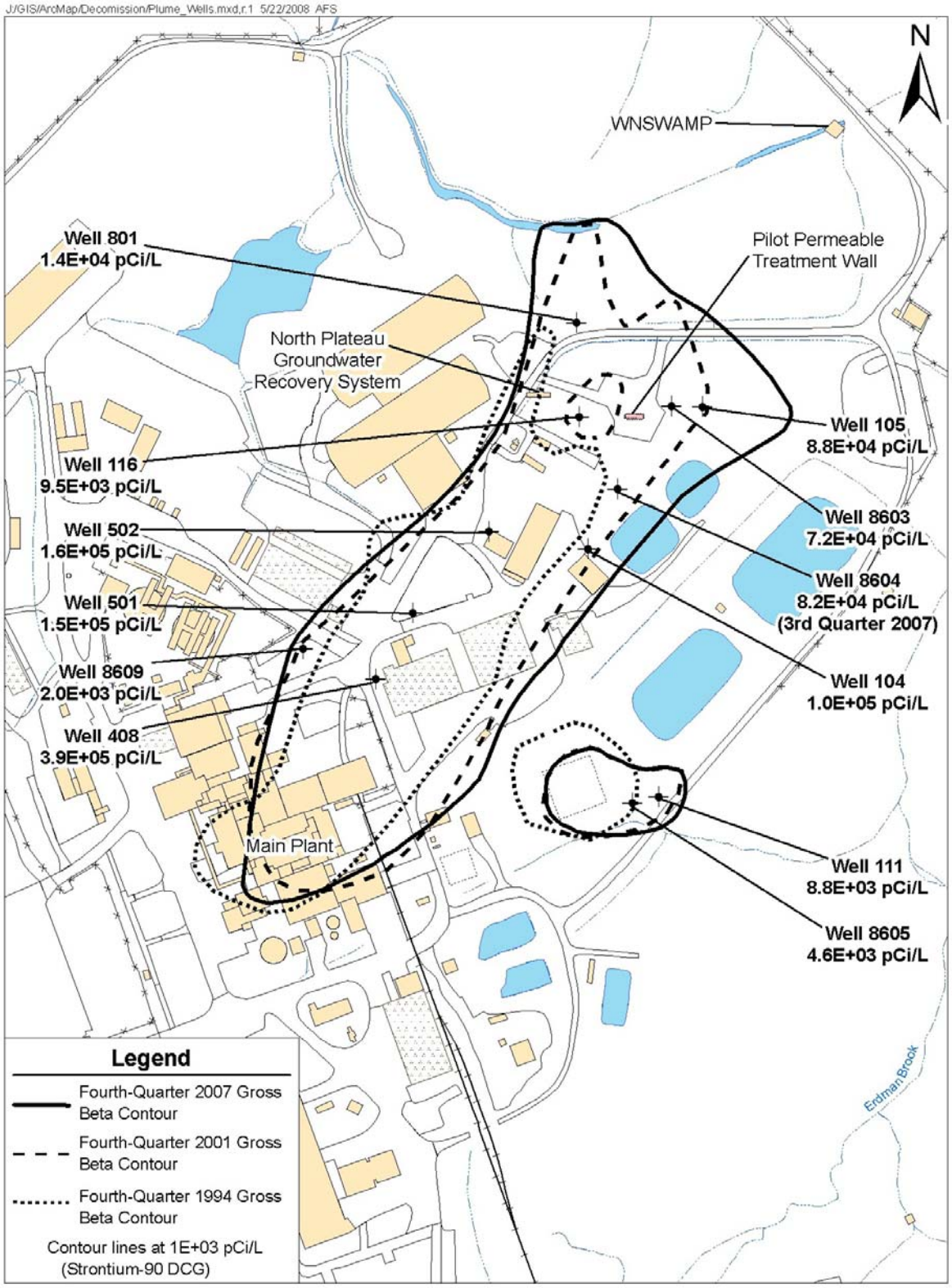

Figure 4-14. North Plateau Groundwater Plume

4.3 References

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