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Assessment of Aquifer Baseline Conditions at the Idaho National Laboratory Remote-Handled Low-Level Waste Disposal Facility

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ACRONYMS

ATR	Advanced Test Reactor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy Idaho Operations Office
EPA	Environmental Protection Agency
INL	Idaho National Laboratory
LLW	low-level waste
NRF	Naval Reactors Facility
RH	remote-handled
RI/FS	remedial investigation and baseline risk assessment
SRPA	Snake River Plain Aquifer
USGS	United States Geological Survey
WAG	waste area group

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1. INTRODUCTION

This document provides an analysis of radiologic concentrations in the aquifer and vadose zone near Idaho National Laboratory's (INL's) Remote-Handled Low-Level Waste (RH-LLW) disposal facility. This document identifies pre-existing sources of radiologic contaminants that could be transported to the aquifer near the RH-LLW disposal facility based on releases from nearby facility operations. It contains a summary of radionuclide concentration data in the upstream perched water and in the aquifer upstream and downstream of the RH-LLW disposal facility in order to establish known variability from these pre-existing radiologic sources. Using this historical data allows meaningful aquifer monitoring targets to be established for the RH-LLW disposal facility monitoring system (i.e., vadose zone wells and aquifer wells) to allow potential releases from the RH-LLW disposal facility to be distinguished from the pre-existing sources of contaminants that are likely to be detected in the monitoring system.

1.1 Remote-Handled Low-Level Waste Disposal Facility Description

The RH-LLW disposal facility has been constructed at the INL Site 0.3 miles southwest of the Advanced Test Reactor (ATR) Complex (Figure 1-1 and Figure 1-2). This location is 5 miles southwest of the Naval Reactors Facility (NRF) (see Figure 1-1) and is 1.7 miles west of the Idaho Nuclear Technology and Engineering Center, 3.5 miles northwest of the Central Facilities Area, and 6.5 miles north of the Radioactive Waste Management Complex.

The RH-LLW disposal facility will accept RH-LLW radioactive waste in the form of activated metals, ion-exchange resins, and a small amount of miscellaneous contaminated debris. RH-LLW is radioactive waste that requires shielding to protect people from external radiation exposure. By definition, RH-LLW is LLW waste that has a radiation exposure rate at the outer surface of the container that is greater than 200 mR/hour. Gamma-emitting radionuclides that contribute to high external exposure rates are typically from activated metals and fission products produced in nuclear reactors. Activated metals are generated by operations at the ATR Complex and NRF and are contained in waste stored in the Radioactive Scrap and Waste Facility at the Materials and Fuels Complex. Activated metals are typically reactor core components replaced during core internal changeouts and are made of stainless steel, inconel (nickel-chromium-based alloys), zircaloy (high-zirconium alloys), or aluminum. The ion-exchange resins (e.g., ceramic or organic beads) are used to purify reactor cooling water as part of routine operations at NRF and the ATR Complex. In addition to the metals and resins, a relatively small amount of miscellaneous surface-contaminated materials will be included. Surface-contaminated materials include cuttings and grindings, polishing discs, tools, cable, wiring, glassware, rags, teri-towels, plastic bags, and gaskets.

The RH-LLW disposal facility includes a vault system and monitoring system (described below) that were designed to protect the environment from radiologic releases:

- **Vault System:** The vault system includes steel waste containers, precast concrete vaults, and a hydraulic drainage system. The waste will be contained in containers made of either carbon or stainless steel. The steel waste containers will be transported to the disposal facility in a shielded shipping cask. Vaults receiving carbon steel waste containers will be pre-lined with stainless steel overpack/liner and a stainless steel cap will be placed over the liner. Vaults receiving stainless steel waste containers are not required to be pre-lined with stainless steel.

The waste containers/liners will be placed in concrete disposal vaults constructed as precast concrete cylinders (i.e., pipe sections) stacked on end and placed in a close-packed array. The lower riser section of each vault is supported by an integral reinforced-concrete base plate that is hexagonal in shape. The base plate with integral lower riser section is placed atop a gravel drainage layer. The upper riser section sits on the lower riser section. It is covered with a removable hexagonal precast concrete plug. The plugs serve as a radiation shield for emplaced waste, as a barrier to water ingress into the vaults, and as a final intruder barrier.

Hydraulic drainage is provided beneath the vaults, between the vault riser sections, and around the perimeter of each vault array. The highly permeable drainage gravels provide stability and are designed to promote water drainage away from the vaults. The vault system has been designed to limit the release of waste from the vault system; virtually no aqueous releases are expected to occur for the first 500 years.

- **Monitoring System**. The monitoring system has been designed to confirm the overall vault system performance, to allow detection of radiologic contaminants in the event of a facility release, and to provide confirmation of facility compliance in the aquifer. The system performance and radiologic detection system is described in the As-Built Characterization and Monitoring System for the RH-LLW Disposal Facility (INL 2017). The focus of this document is on the aquifer monitoring system. Three aquifer monitoring wells are installed to detect releases from the RH-LLW disposal facility (i.e., USGS-136, USGS-140, and USGS-141) and to distinguish these potential releases from pre-existing sources of groundwater contamination by supplementing the existing monitoring well network. Aquifer well USGS-136 is located upgradient of the facility, and aquifer wells USGS-140 and USGS-141 are located approximately 100 m downgradient of the facility. Pre-existing sources of contamination exist at the upgradient ATR Complex and NRF. The monitoring wells installed to detect releases from the closer of these facilities (i.e., the ATR Complex) and those installed at the RH-LLW disposal facility are shown in Figure 1-2.

If a radiologic release were to occur from the RH-LLW disposal facility, it could allow radionuclides to migrate from the base of the vaults that are placed approximately 10 m below the top of the surficial alluvium. The alluvium is approximately 15-m thick and is underlain by a series of sedimentary interbed and basalt layers. The sedimentary interbed-basalt sequence forms the vadose zone. It is underlain by the Eastern Snake River Plain Aquifer. The base of the vault system is located about 140 m above the aquifer.

The Eastern Snake River Plain aquifer is one of the largest and most productive groundwater resources in the United States. It is listed as a Class I aquifer and has been designated by the U.S. Environmental Protection Agency (EPA) to be a sole-source aquifer (56 FR 50634 1991). Groundwater from this aquifer supplies most of the water for the area surrounding the INL Site and essentially all drinking water consumed within the Eastern Snake River Plain aquifer. Aquifer flow direction is generally from the northeastern recharge areas to the southwestern discharge areas (see arrow shown in Figure 1-2).

1.2 Purpose

The purposes of this document are to do the following:

1. Identify sources of pre-existing (i.e., pre-disposal of radionuclides in the RH-LLW disposal facility) radiologic contaminants released into the environment at INL facilities near the RH-LLW disposal facility and their arrival times in the aquifer at the RH-LLW disposal facility. These pre-existing releases could potentially be detected using the RH-LLW disposal facility aquifer monitoring wells. These sources include radionuclides still near land surface at the ATR Complex at NRF in the upper vadose zone, those in the perched water within the vadose zone, and those in the aquifer.
2. Summarize the relevant perched water and aquifer concentration data upstream and downstream of the RH-LLW disposal facility. This summary provides the historical statistical variability observed in

the pre-existing sources of radionuclide contaminants. The summary will allow determination of action levels (see PLN-5501) that could trigger additional data evaluation in order to determine if releases from the RH-LLW disposal facility have occurred.

3. Determine meaningful perched water and aquifer monitoring targets in order to allow detection of radionuclide releases from the RH-LLW disposal facility using wells that monitor the sedimentary interbed layers (see INL 2017) and aquifer monitoring wells (i.e., USGS-136, USGS-140, and USGS-141). Monitoring of target radionuclides will be selected from those disposed of in the RH-LLW disposal facility, allowing delineation from those from the pre-existing sources.
4. Develop response levels in the event radionuclides are detected in the RH-LLW disposal facility's monitoring system wells.

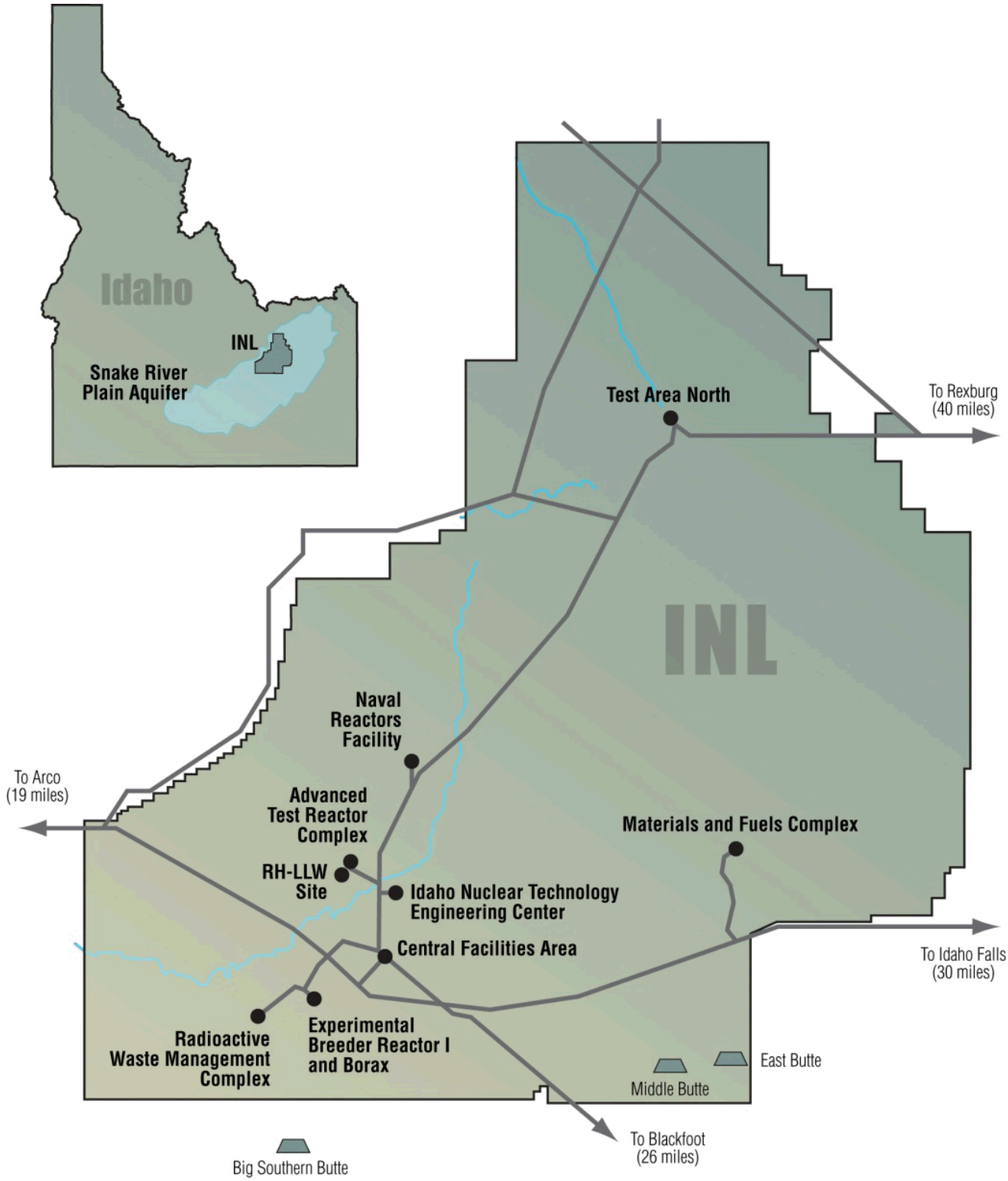

Figure 1-1. Map of INL showing the locations of major facilities.

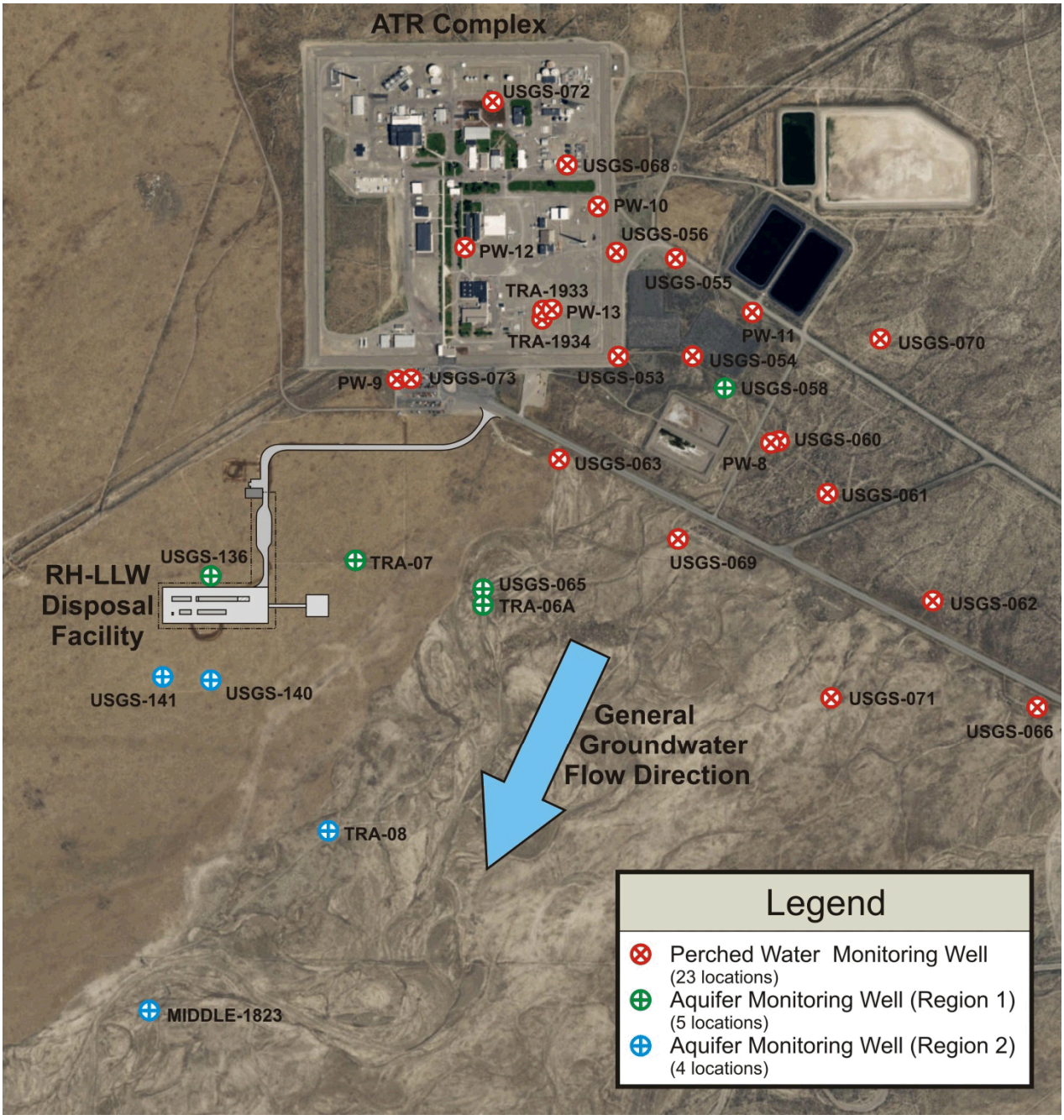

Figure 1-2. Locations of perched water and aquifer wells routinely monitored near the RH-LLW disposal facility.

2. SOURCES POTENTIALLY CONTRIBUTING TO AQUIFER CONCENTRATIONS BENEATH THE REMOTE-HANDLED LOW-LEVEL WASTE DISPOSAL FACILITY

Flow paths in the Snake River Plain aquifer (SRPA) have been inferred from measured water levels, existing groundwater concentration data, and flow paths calculated using a calibrated flow and transport model developed to address cumulative source releases from INL Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites. These flow paths have been used to identify specific source areas that could potentially contribute radionuclides to the aquifer beneath the RH-LLW disposal facility and be detected by the RH-LLW disposal facility's monitoring wells. These potential sources of contamination are limited to the upgradient sources at NRF and the ATR Complex. Supporting information is summarized as follows:

- **Measured Water Levels:** Measured water levels indicate that groundwater in the SRPA on the INL Site generally flows from northeast to southwest as indicated in Figure 2-1. This water level map was created from measurements in 274 wells collected over 1 week in 2005 and supplemented by an additional 114 water level measurements from the United States Geological Survey's (USGS) National Water Information Storage Database (DOE-ID 2008).
- **Plume Boundaries:** Figure 2-2 shows select aquifer plumes in this area, along with water table measurements from 2005 (DOE-ID 2008). As shown in Figure 2-2, given the proximity of the RH-LLW disposal facility to the ATR Complex and its downgradient location of NRF, it is reasonable to conclude that plumes from the ATR Complex and NRF could be detected using the RH-LLW disposal facility's monitoring wells.
- **Model Predicted Path lines:** Figure 2-3 shows flow path lines based on the Operable Unit (OU) 10-08 INL sitewide groundwater flow and contaminant transport model (DOE-ID 2008). This model was calibrated to the 2005 water level data, groundwater velocities interpreted from stable isotope disequilibrium studies, and movement of anthropogenic contaminants in the SRPA from facilities at INL. The model attempted to match observed tritium transport in the region between the ATR Complex and Idaho Nuclear Technology and Engineering Center facilities to the southern boundary of the INL Site, because commingling of plumes from INL Site facilities is most likely to occur in this region (see Figure 2-2).

  When considering groundwater flow paths, it is important to keep in mind that (1) they do not represent streamlines delineating equal volumes and (2) contaminants will mix and disperse as they migrate with the groundwater, creating wider more diffuse plumes than are indicated by the path lines shown in Figure 2-3. It also is important to recognize that they are based on a steady-state flow field. However, the plumes shown in Figure 2-2 include the effects of transient inflow and surface infiltration, including inflow from the mountains to the west and the Big Lost River for the range of conditions occurring during the roughly 60-year use of injection well and surface ponds for discharge of tritium at the ATR Complex. Therefore, model calibration to these data accounted for that range of transient conditions.

Specific radionuclide release sites at the ATR Complex and NRF are discussed in the following sections.

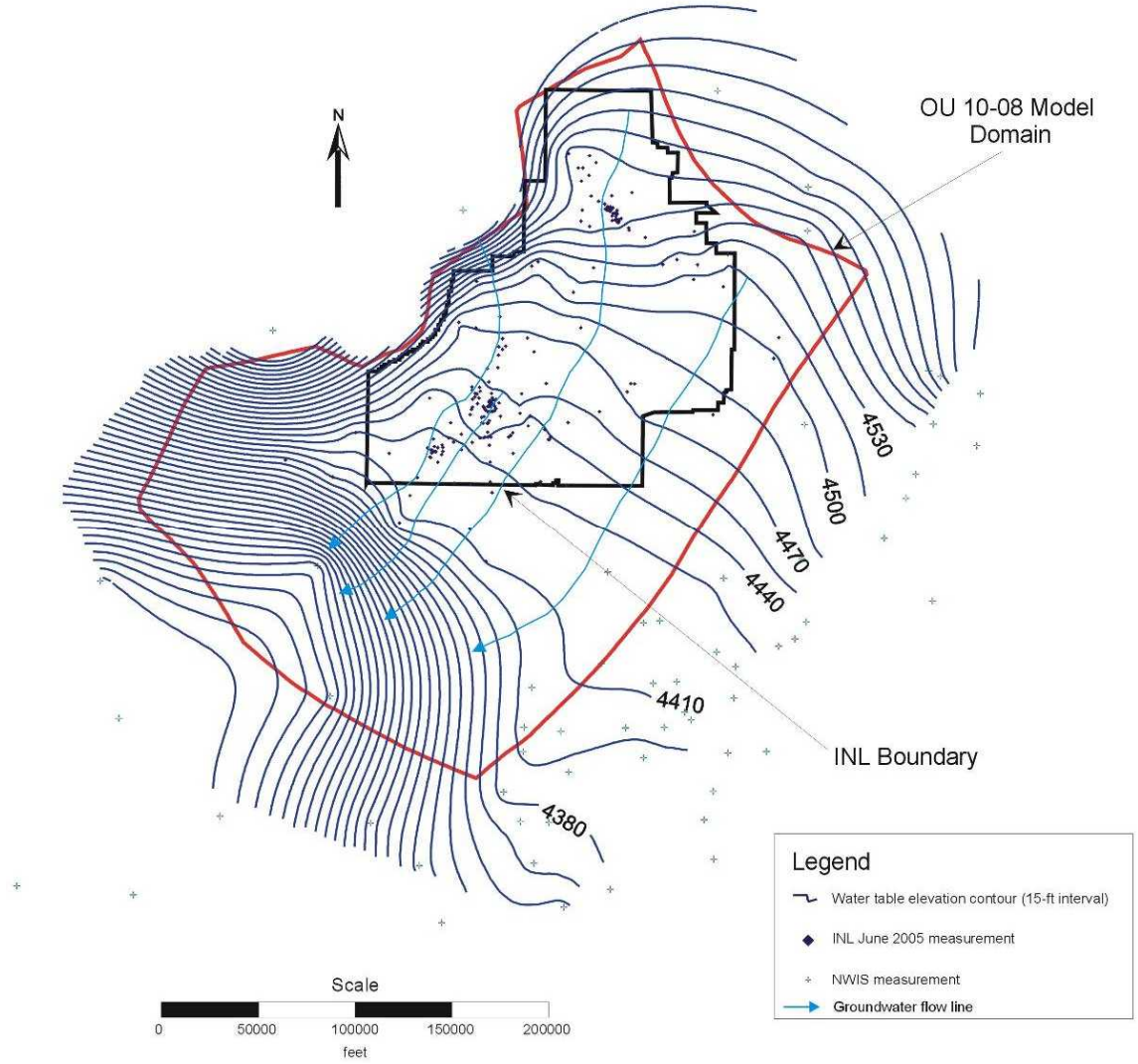

Figure 2-1. Water table map based on June 2005 water levels (from DOE-ID 2008, Figure 7-2) (OU = operable unit, NWIS = National Water Information System [USGS]).

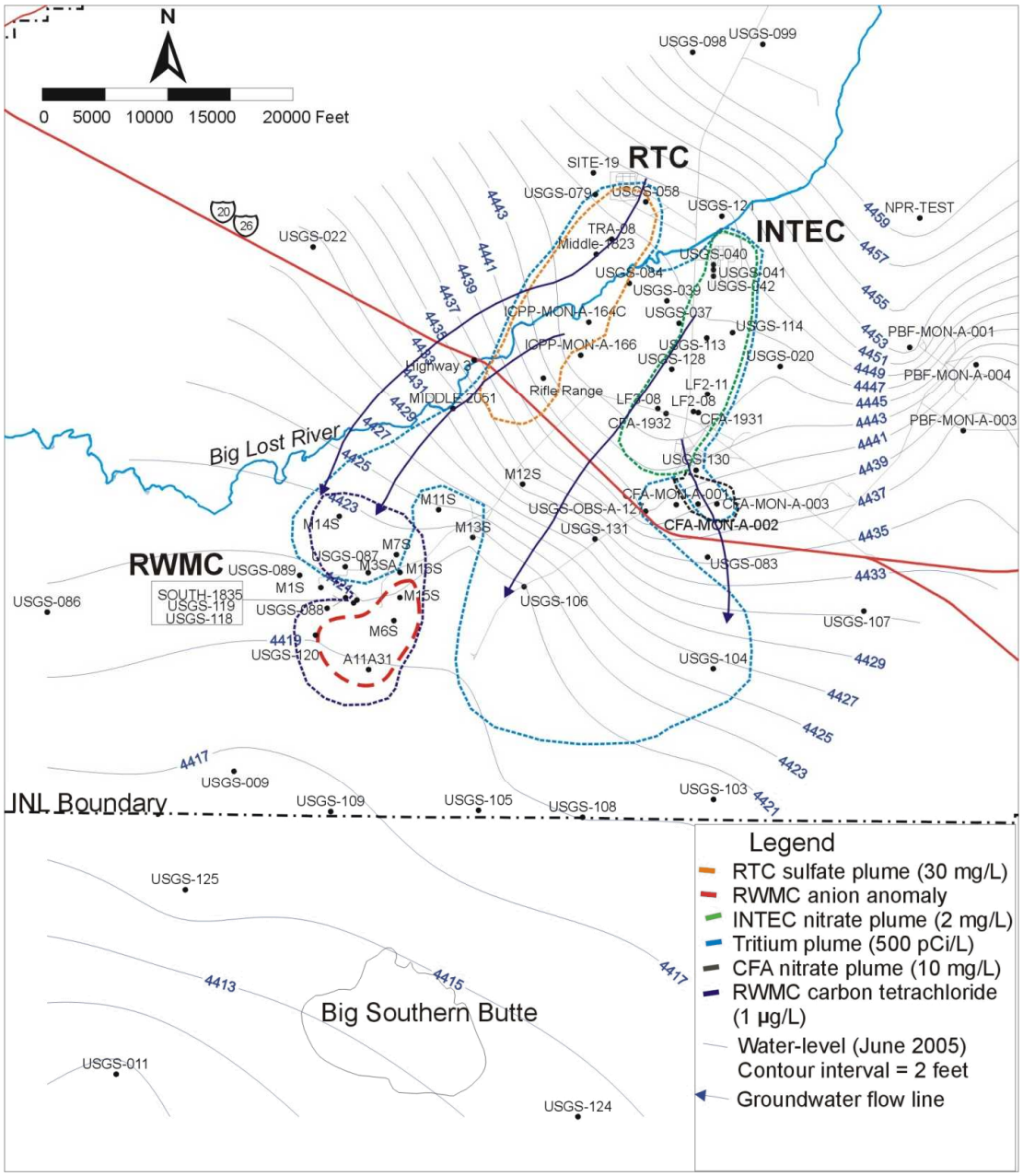

Figure 2-2. Approximate boundaries of select aquifer plumes based on concentrations in 2003 (from DOE-ID 2008, Figure 7-7). Note: RTC in the figure is currently named the ATR Complex.

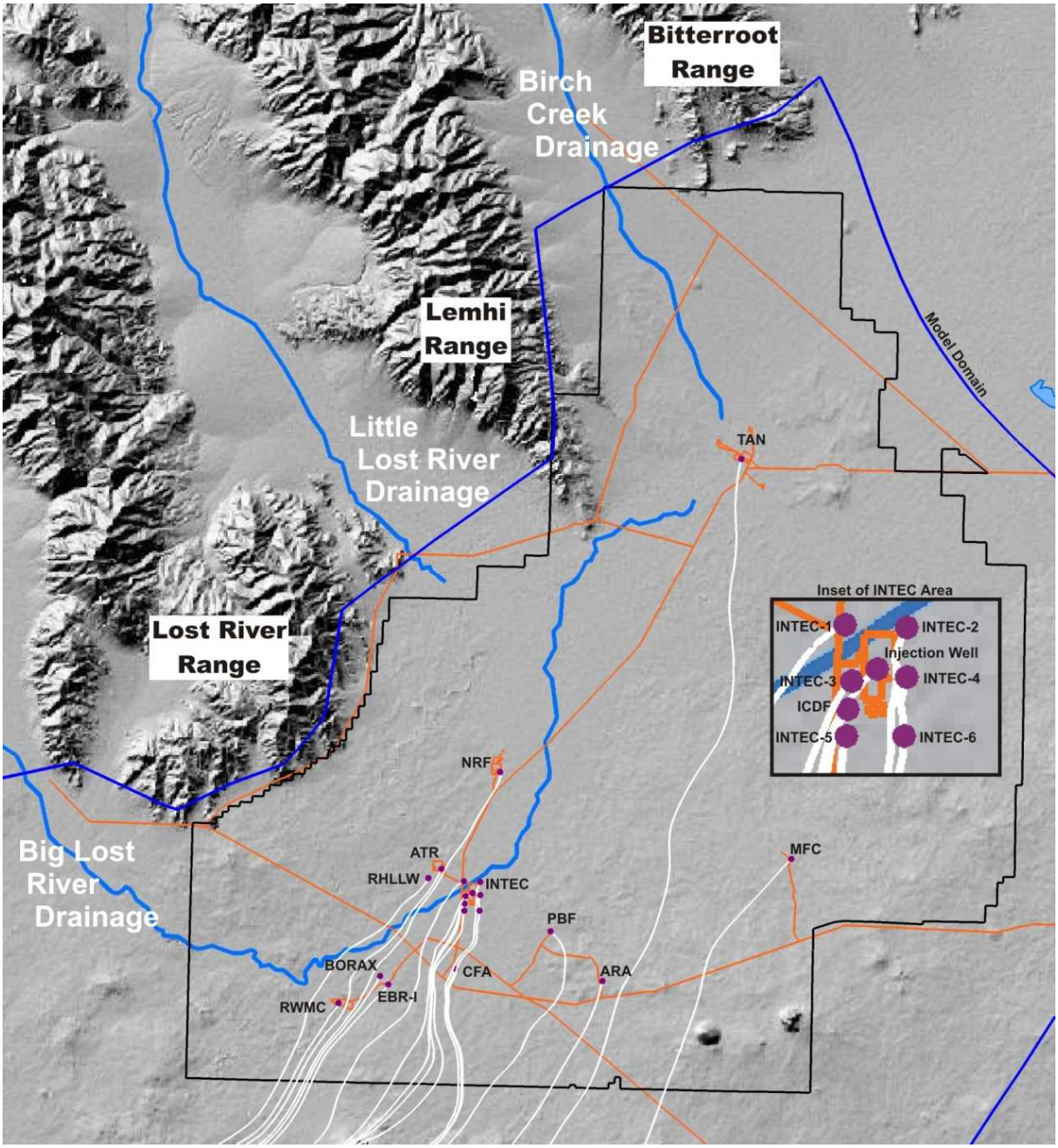

Figure 2-3. Aquifer flow path lines from major facilities at INL based on the OU 10-08 groundwater flow model (DOE-ID 2008).

2.1 Advanced Test Reactor Complex

The ATR Complex is located in the southwest portion of INL. The major mission of the ATR Complex has been to study the effects of radiation on materials, fuels, and equipment. The ATR Complex has been the site of three major test reactors: (1) the Materials Test Reactor (1952 through 1970), (2) the Engineering Test Reactor (1957 through 1982), and (3) ATR (1967 to the present). Current major programs at the ATR Complex are focused on use of ATR.

The ATR Complex is being remediated as Waste Area Group (WAG)-2 under CERCLA. The CERCLA cleanup actions for WAG-2 are being implemented in accordance with the associated record of decision (DOE-ID 1997b with status documented in DOE-ID 2005b). These remediation actions have left residual radionuclide sources in soils and perched water. In addition, after the comprehensive remedial investigation/feasibility study was conducted for WAG-2 (DOE-ID 1997b), additional non-time critical closures of facilities have been conducted and new contaminated soil sites have been identified. The following sections focus on sites investigated and reported in DOE-ID 1997b. The other closure sites will be addressed as part of the RH-LLW composite analysis.

2.1.1 CERCLA Site Investigations at the Advanced Test Reactor Complex

Under WAG-2, 55 sites were investigated under CERCLA, including pits, tanks, rubble piles, ponds, cooling towers, wells, French drains, spills, and perched water (DOE-ID 1997b) (Figure 2-4). The bulk of the inventory evaluated under CERCLA actions at the ATR Complex is associated with the Warm Waste Ponds, perched water, or has migrated into the aquifer.

- Of the 55 investigated release sites, 47 were either determined to present acceptable risk to human health or the environment; therefore, no further action was required; or they were part of a record of decision preceding the comprehensive OU 2-13 (WAG 2) record of decision.
- Eight sites had actual or threatened releases of hazardous substances, which, if not addressed by implementing the response actions specified in the OU 2-13 record of decision could have presented unacceptable risk to human health or the environment. These sites included the following:
  - Four disposal ponds: Warm Waste Pond-1952, 1957, and 1964 cells (TRA-03); Chemical Waste Pond (TRA-06); Cold Waste Pond (TRA-08); and the Sewage Leach Pond (TRA-13)
  - Three subsurface contaminant release sites: soil surrounding Hot Waste Tanks at Building 613 (TRA-15); Tanks 1 and 2 at Building 630 (TRA-19); and the Brass Cap Area
  - One area of surficial windblown contamination (i.e., the sewage leach pond berms and soil contamination area). Details of these areas are provided in INL 2012a.
- Perched water at the ATR Complex was formed as a result of historical discharges of water into the Warm Waste Pond, Chemical Pond, and Sewage Treatment Pond. Discharges to the ponds occurred from 1952 through 1980, with volumes on the order of 200 Mgal/year. Direct aquifer discharges of similar volumes during this time also occurred in the TRA Disposal Well. After 1980, the bulk of the discharges to the Warm Waste Pond and the disposal well were diverted to the Cold Waste Pond, reducing the Warm Waste Pond volumes to about 50 Mgal/year with discharges to the Cold Waste Pond maintained at about 250 Mgal/year. Downward infiltration of surface-discharged water was impeded by a fine silt-clay layer above the first basalt contact that formed the laterally extensive shallow perched water body in the alluvium. In addition to shallow perched water, there is a deeper perched water body that also formed as the infiltrating water reached another low-permeability layer about 110 ft below land surface.

  In the deep perched water, analyzed alpha-emitting radionuclides have historically included Am-241, Ra-226, U-234, U-235, U-238, Pu-238, Pu-239/240, and Cm-244. All but Pu-238, Pu-239/240, and Cm-244 have been detected at the 2-sigma level, but only Am-241, Ra-226, and U-234 have been detected at the 3-sigma level. In perched water, the sum of U-234 and U-238 concentrations is about 0.006 pCi/mL, excluding well PW-14, which recorded 0.0222 pCi/mL. The natural background concentration for total uranium ranges from 0 to 9 pCi/L, suggesting that the uranium detected in the deep perched water is natural and not anthropogenically derived.

Residual radionuclide contaminants in the perched water were evaluated under the Comprehensive Remedial Investigation and Feasibility Study (RI/FS) for WAG-2 (DOE-ID 1997a). Contaminants in the perched water were predicted to attenuate/decay to acceptable levels when assisted by control of water discharges to the disposal ponds.

- Aquifer contamination is a result of migration from the surface sites and/or direct deep injection into the SRPA. Groundwater contamination was evaluated under the Comprehensive RI/FS Study for WAG-2 (DOE-ID 1997a) and WAG-10 (OU 10-08) (DOE-ID 2005a).

2.1.2 Residual Radionuclide Sources at the Advanced Test Reactor Complex

The radionuclides evaluated in the Comprehensive OU 2-13 RI/FS (DOE-ID 1997a) are shown in Table 2-1 for each of the individual contaminated areas evaluated. The inventory shown in Table 2-1 contains the total activity estimated from measurements of contaminated soils and perched water.

Soil inventories at each of the eight retained sites and subareas are listed in Columns 2 through 12 of Table 2-1. The total activity across all contaminated soils sites is listed in Column 13. The table indicates the radionuclides not screened out as having insignificant potential to contribute to groundwater cancer risk (i.e., radionuclides in bold: Pu-239, Th-230, U-238, and U-234) that were carried forward into a dose/risk evaluation.

Table 2-1 also contains the radionuclides detected through soil sampling that were screened out because they pose an insignificant dose/risk contribution. Although these radionuclides are relatively benign from a human risk standpoint, they still have potential of being detected in the perched water or groundwater at some point in the future.

Perched water inventories are listed in Column 14 of Table 2-1. These radionuclides were considered to be contaminants of concern in the OU 2-13 Comprehensive RI/FS (DOE-ID 1997a) and Attachment IX of the OU 2-13 Work Plan (DOE-ID 1998). They were also evaluated in INL 2012a. Radionuclides in bold (i.e., Co-60, H-3, Sr-90, Am-241, and Np-237 from Am-241) were not screened out as having an insignificant potential to contribute to groundwater risk and were carried forward into a dose evaluation. However, even though the other radionuclides in the perched water were screened out because they pose an insignificant dose contribution, they have potential of being detected in groundwater at some point in the future.

Tritium in the SRPA resulting from direct injection and infiltration from the ATR Complex ponds was determined to remain above detectable quantities in the SRPA at least through the year 2097 (see the OU 2-13 Comprehensive RI/FS, DOE-ID 1997a), falling below the maximum contaminant level (i.e., 20,000 pCi/L) within that time period.

2.1.3 Expected Arrival Times in the Aquifer at the Advanced Test Reactor Complex for Parent and Progeny Radionuclides

The predicted activity fluxes for radionuclides shown in bold in Table 2-1 are provided at the vadose zone-aquifer interface for the re-analysis of the contaminated soils in the ATR Complex in Figure 2-5 (INL 2012a). Predicted peak radionuclide groundwater concentrations and an all-pathways dose for the contaminated soils in the ATR Complex are shown in Table 2-2.

The radionuclide fluxes shown in Figure 2-5 suggest that only U-238 and U-234 originating in the contaminated soils at the ATR Complex have any potential of being detected in the aquifer wells at the RH-LLW disposal facility location based on low fluxes and timing. The timing of the peak fluxes for the other soil contaminants is well after monitoring of the facility ends (i.e., 50 years after start of disposals). If Pu-239 and Th-230 were detected in the RH-LLW disposal facility aquifer monitoring wells, it could provide an indication of releases from the RH-LLW disposal facility.

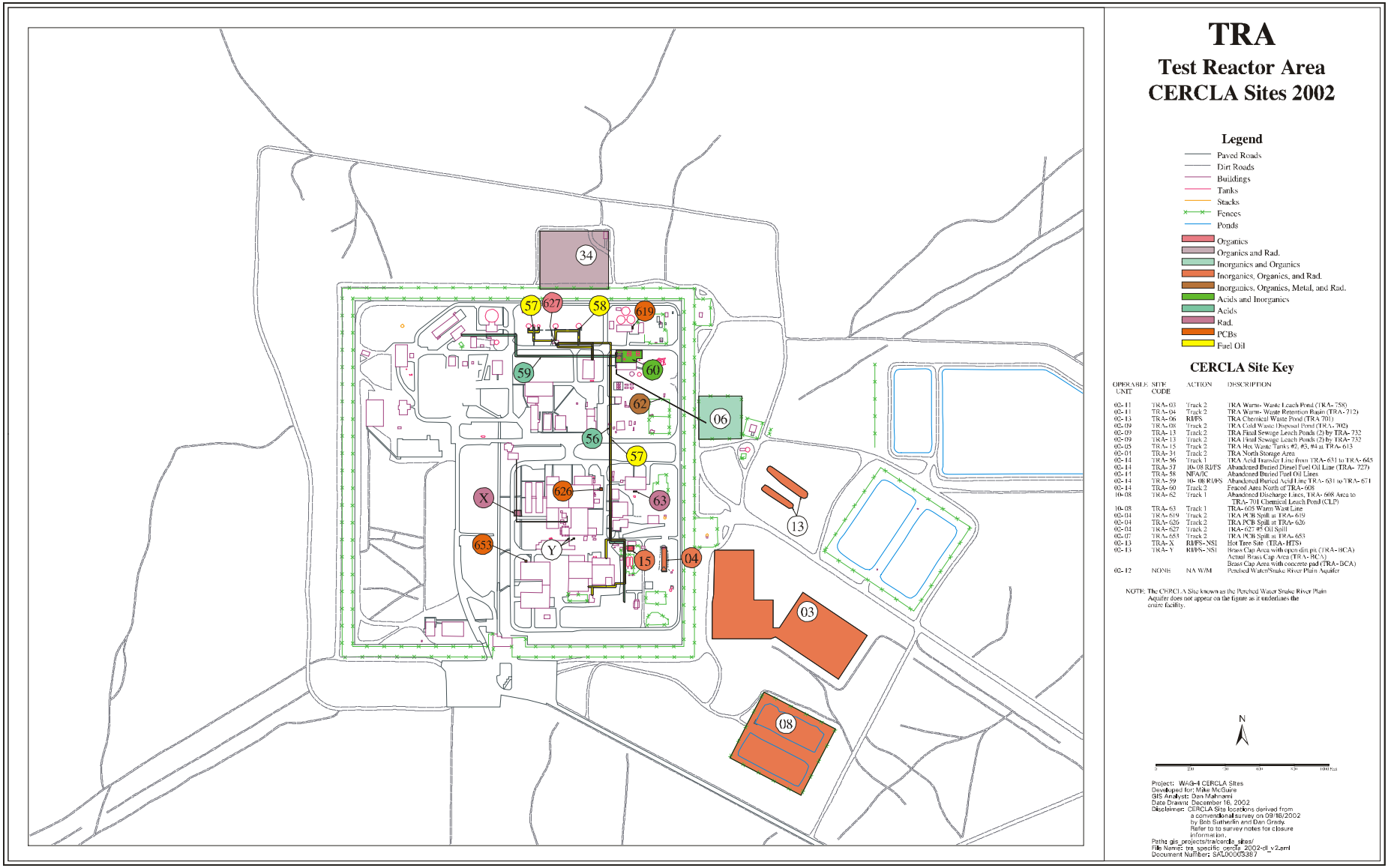

Figure 2-4. Map of the OU 2-13 CERCLA sites. Note: The Test Reactor Area (TRA) is currently called the ATR Complex.

Table 2-1. Inventory by radionuclide in surficial soils and perched water at the ATR Complex.

	TRA-34	TRA-15	TRA-19	TRA-08	TRA-13	TRA-03 (Cells 52, 57)	TRA-03 (Cell 64)	TRA-04/05	Brass Cap	SLP Windblown	Hot Tree	Total Activity (Ci)	
	North Storage Area	Hot Waste Tanks 2 to 4 at TRA-613	Rad Tanks 1 and 4 at TRA-630	Cold Waste Pond	Sewage Leach Pond	Warm Waste Pond		Warm Waste Retention Basin and Disposal Well				Soils	Alluvium Perched Water
Nuclide	Activity in Curies												
Ag-108m	1.94E-03				1.25E-02	3.12E-02	8.22E-03			1.24E-03		5.5E-02	
Am-241		1.91E-04			1.65E-03	5.74E+00				2.85E-03		**5.7E+00**	**3.0**
Cm-244						5.02E-01						5.0E-01	
Co-60	1.59E-03	5.12E-02	2.12E-05	3.04E-03	2.01E-01	2.05E+00	1.91E-01	1.90E-02	1.00E-03	1.97E-02	1.78E-04	2.5E+00	**480**
Cs-l34		3.20E-04	8.94E-03	7.74E-04	2.24E-03	3.30E-03	1.54E-02		4.00E-01			4.3E-01	
Cs-137	5.98E-03	2.04E+00	4.97E-02	5.05E-02	6.84E-01	7.54E+01	1.13E+00	6.56E-03	2.34E+00	4.58E-02	2.45E-03	8.2E+01	
Eu-152	8.14E-03				1.33E-02	5.74E+00	1.60E-02					5.8E+00	
Eu-l54		1.10E-03		2.02E-03	7.00E-03	1.44E+00	6.60E-03					1.5E+00	
Eu-l55						8.26E-02						8.3E-02	
H-3													**9,881**
Pu-238		3.97E-05				5.74E-01						5.7E-01	
Pu-239/240		4.78E-05			2.57E-03	6.10E+00						**6.1E+00**	
Sr-90	6.83E-03	1.87E+00	2.12E-03		1.60E-02	1.22E+02			1.00E-01	7.14E-03	1.02E-03	1.2E+02	**111**
Th-228						9.33E-03						9.3E-03	
Th-230						2.23E-02						**2.2E-02**	
Th-232						8.97E-03						9.0E-03	
U-234					1.28E-02	9.33E-02		3.57E-03				**1.1E-01**	
U-235						1.18E-03						1.2E-03	
U-238						4.31E-02		4.19E-03				**4.7E-02**	

Soils inventory was taken from Table B-28 of DOE/ID-10531 (DOE-ID 1997a). The larger inventory by percent is represented by grey-shaded cells.

Total surface area (m^2) = 8.14E-04; total volume (m^3) = 4.19E-04; average depth of contamination (m) = 5.20E-01.

Radionuclides in bold were not screened out as having an insignificant potential to contribute to groundwater risk and were carried forward into a dose evaluation.

Predicted peak aquifer concentrations, an all-pathways effective dose equivalent, and the time of peak for the radionuclides contained in the perched water are shown in Table 2-3 (from INL 2012a). Based on the model-predicted radionuclide fluxes, it is unlikely that Co-60, Sr-90, Am-241, and Np-237 originating in the perched water beneath the ATR Complex could be detected in the RH-LLW disposal facility's groundwater monitoring wells because the flux rates are extremely low and dilution in the aquifer would reduce concentrations to below-detection levels. However, it is very likely that H-3 originating in the ATR Complex perched water will be detected in the RH-LLW disposal facility monitoring wells. Based on the arrival times of Co-60, Sr-90, and Am-241, these radionuclides could be used as indicators of releases from the RH-LLW disposal facility as could the progeny of Am-241 (i.e., Np-237, U-233, and Th-229).

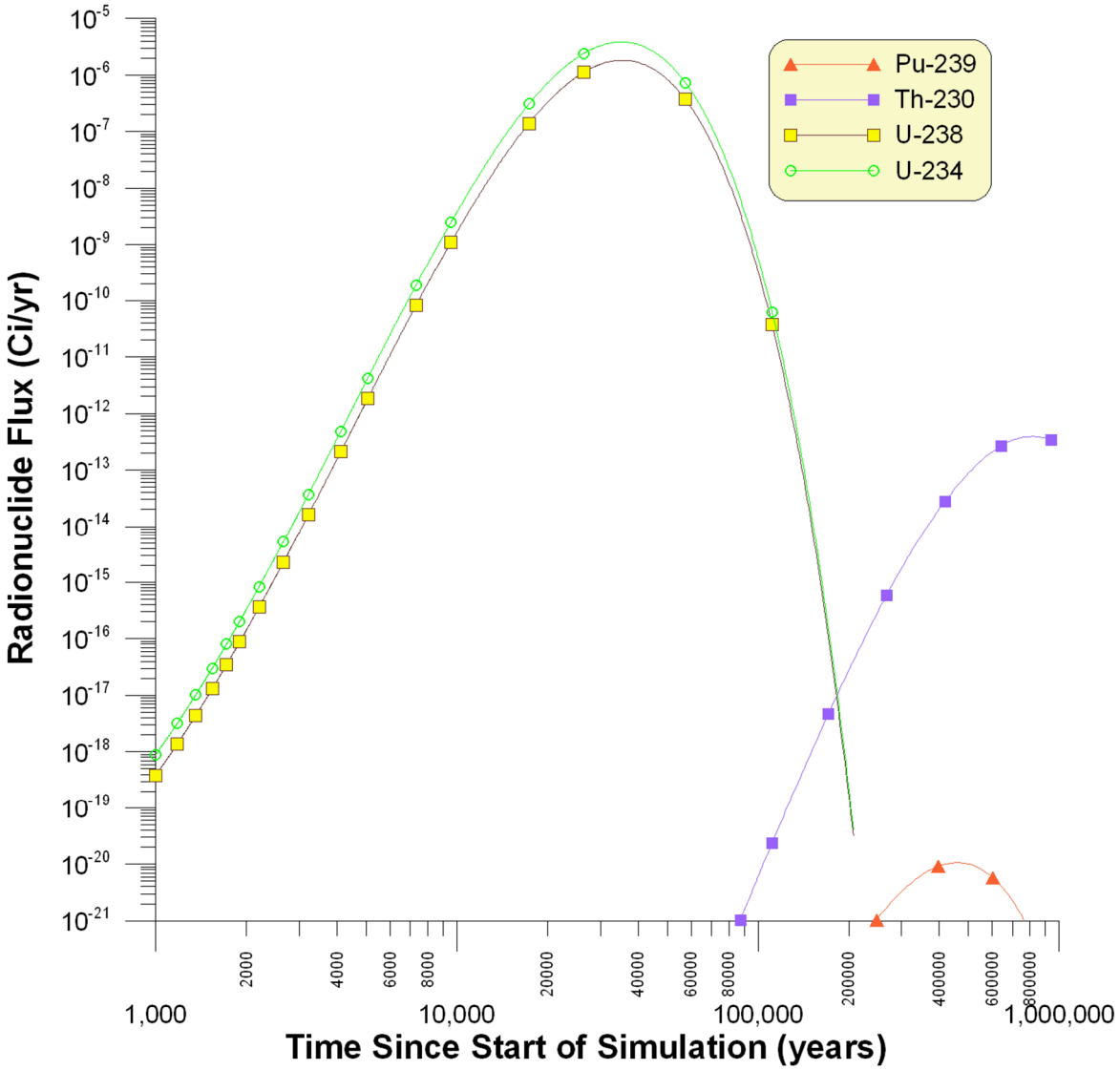

Figure 2-5. Predicted radionuclide activity fluxes at the water table from surface-contaminated soil sources at the ATR Complex (from INL 2012a).

Table 2-2. Predicted peak radionuclide groundwater concentrations and an all-pathways dose for re-analysis of ATR Complex surface soil contamination (from INL 2012a).

Radionuclide (Progeny on Right)	Peak Groundwater Concentration (pCi/L)	Time of Peak After Start of Simulation (years)	Peak All-Pathways Dose (mrem/year effective dose equivalent)
U-238	1.85E-02	37,815	3.13E-03
U-234	1.83E-03	39,815	3.13E-04
Th-230	7.41E-06	61,815	5.27E-06
Ra-226	7.30E-06	65,815	9.49E-06
Pb-210	1.04E-05	65,815	8.21E-05
U-238 Total	**NA**	**37,815**	**3.47E-03**
U-234	3.90E-02	36,815	6.67E-03
Th-230	1.53E-04	57,815	1.09E-04
Ra-226	1.51E-04	61,815	1.96E-04
Pb-210	2.15E-04	61,815	1.70E-03
U-234 Total	**NA**	**38,815**	**7.56E-03**
Th-230	2.78E-11	316,065	1.98E-11
Ra-226	2.84E-11	316,065	3.69E-11
Pb-210	4.04E-11	316,065	3.20E-10
Th-230 Total	**NA**	**316,065**	**3.76E-10**
Pu-239	4.20E-17	316,065	3.40E-17
U-235	3.54E-05	53,815	5.77E-06
Pa-231	3.54E-07	80,815	5.55E-07
Ac-227	4.88E-07	80,815	8.39E-07
Pu-239 Total	**NA**	**55,815**	**6.64E-06**

Table 2-3. Predicted peak radionuclide aquifer concentrations and all-pathways effective dose equivalent for the re-analysis of the ATR Complex perched water contamination (from INL 2012a).

Radionuclide	Peak Groundwater Concentration (pCi/L)	Peak All-Pathways Dose (mrem/year effective dose)	Time of Peak After Start of Simulation (years)
Am-241	1.85E-11	1.24E-11	51
Np-237	1.27E-08	4.48E-09	9,910
U-233	6.11E-09	1.09E-09	9,910
Th-229	2.65E-11	6.68E-11	9,910
Am-241 Total		4.86E-09	9,910
Co-60	6.93E-11	1.83E-12	51
Sr-90	9.66E-05	1.13E-05	51
Total		1.13E-05	51

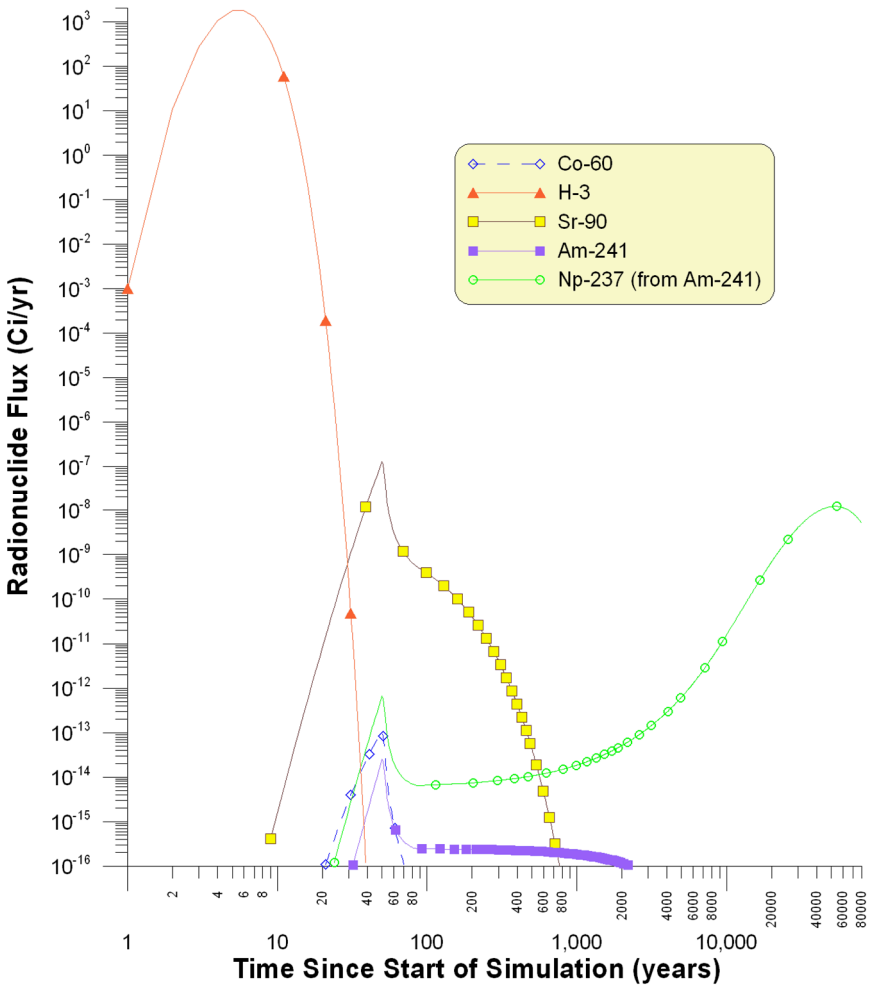

Figure 2-6. Predicted radionuclide activity fluxes at the water table for inventory contained in contaminated perched water at the ATR Complex (from INL 2012a).

2.2 Naval Reactors Facility

NRF is roughly 5 miles north of the RH-LLW disposal facility and 4.55 miles north of the ATR Complex. NRF is a government-owned, contractor-operated research and development facility operated by Bechtel Bettis, Inc. and supports the Naval Nuclear Propulsion Program. Materials and equipment research and development at NRF are directed by the National Nuclear Security Administration's Office of the Deputy Administrator for Naval Reactors (NNSA 2010).

Since its inception, NRF has built and operated three naval nuclear reactor prototype plants. The Submarine Thermal Reactor prototype was constructed beginning in 1951 and operations ceased in 1989. The Large Ship Reactor prototype was constructed in 1958 and operations were completed in 1994. The Submarine Reactor Plant Prototype was built in 1965 and operations ended in 1995. These prototypes were used to train sailors and for research and development programs (Willie and Sierra 2004).

NRF also includes the expended core facility and dry storage overpack facility. Built in 1958, the expended core facility receives, inspects, and conducts research on naval nuclear fuel and is expected to continue operating until at least 2035. The dry storage overpack facility was built in 2001 and provides storage for expended naval nuclear fuel in a non-aqueous environment until a permanent national repository becomes available (Willie and Sierra 2004). To fulfill the continuing long-term mission of the NRF, it is expected that additional facilities will be built and/or expanded.

2.2.1 CERCLA Investigations at the Naval Reactors Facility

Under CERCLA, NRF is designated as WAG 8 at INL. As documented in the WAG-8 Comprehensive RI/FS (Westinghouse 1997) and final record of decision (DOE-NR 1998), the radiologic inventory evaluated under CERCLA actions at NRF is primarily associated with surface-contaminated soils and groundwater. Unlike the ATR Complex, there is no perched water beneath NRF, even though NRF conducted controlled discharges of approximately 1.5 billion (1,500,000,000) liters (417,000,000 gal) of water contaminated with low-level radionuclide concentrations (total of 345.51 Ci) between 1953 and 1979. These discharges were primarily released into wastewater disposal systems such as ponds, ditches, basins, drains, drain fields, pits, and beds with other operational activities impacting landfills, surface soils, and storage areas. Remedial actions for WAG 8 are being implemented in accordance with the associated records of decision (DOE-NR 1998, Willie and Sierra 2004).

2.2.2 Residual Radionuclide Inventories at the Naval Reactors Facility

Radiologic constituents remaining after applying the screening criteria in the WAG 8 Comprehensive RI/FS included C-14, Np-237, Pu-239, Pu-244, U-234, and U-235. These radionuclides were reported for contaminated surface soils in the S1W Seepage Basin Leaching Pit (8-08-12), S1W Seepage Basin #4 (8-08-14), S1W Radiography Building Collection Tanks (8-08-16), A1W Leaching Bed (8-08-19), Old Sewage Treatment Plant (8-08-21), Seepage Basin Pump Out Area (8-08-43), and the A1W Processing Building Area Soils (8-08-81) (Figure 2-7). Radionuclide activities at each location are given in Table 2-4.

Table 2-4. Radionuclide inventories by OU for the NRF RI/FS.

Radionuclide	Source Unit*	Activity (Ci)
C-14	8-08-14/8-08-12B	7.35E-01
C-14	8-08-12A	2.37E-02
C-14	8-08-19	3.96E-02
C-14	8-08-43	4.62E-01
C-14	8-08-81	6.28E-02
C-14 Total		1.32E+00
Np-237	8-08-14/8-08-12B	6.67E-02
Np-237 Total		6.67E-02
Pu-239	8-08-14/8-08-12B	4.22E-02
Pu-239	8-08-12A	5.44E-04
Pu-239	8-08-19	6.95E-03
Pu-239	8-08-43	1.18E-02
Pu-239	8-08-81	1.61E-03
Pu-239 Total		6.31E-02
Pu-244	8-08-21B	1.77E-05
Pu-244	8-08-12A	6.53E-04
Pu-244 Total		6.71E-04
U-234	8-08-19	2.77E-02
U-234 Total		2.77E-02
U-235	8-08-16	1.54E-03
U-235	8-08-21B	3.13E-05
U-235	8-08-81	3.08E-04
U-235 Total		1.88E-03

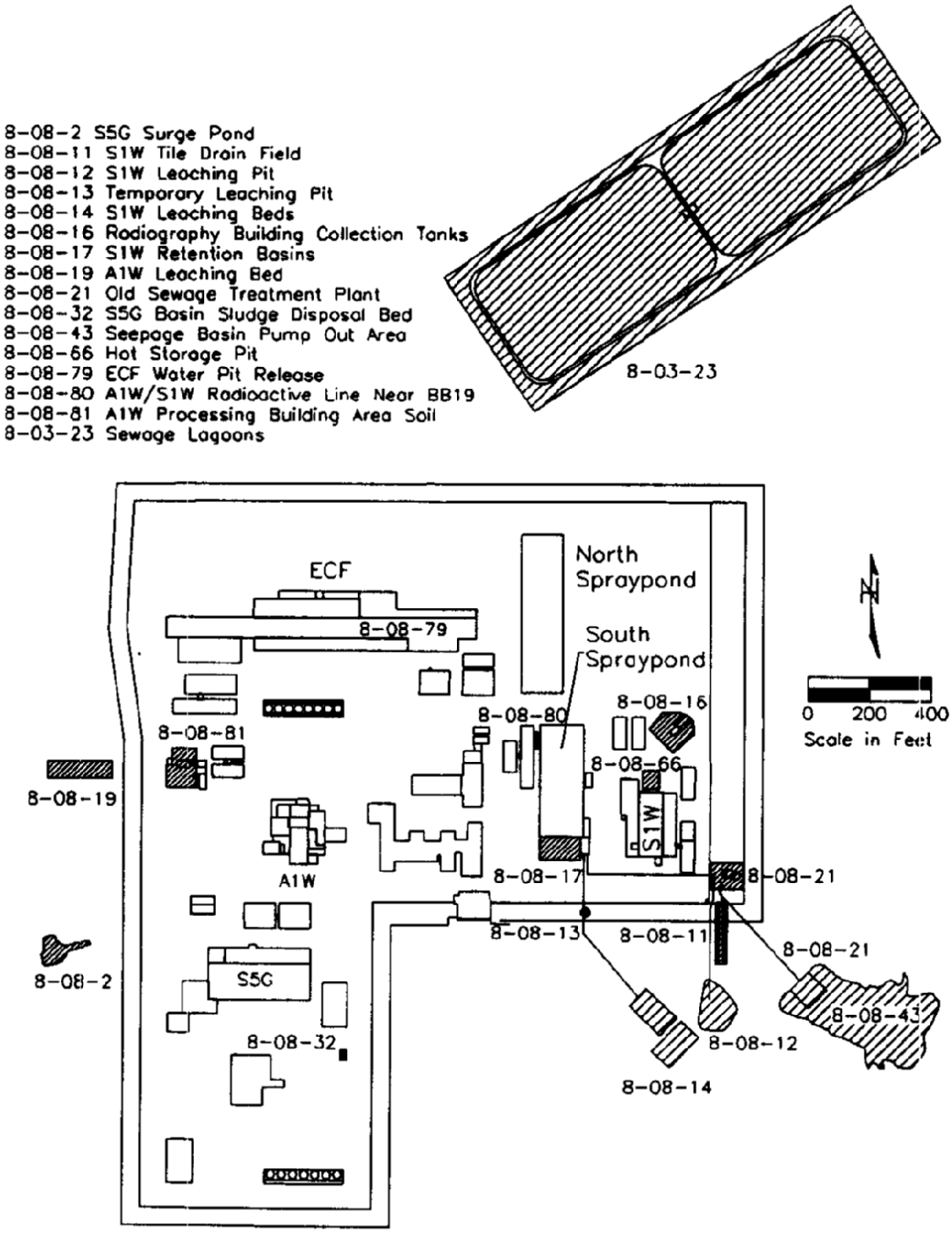

Figure 2-7. Distribution of contaminated sites with long-term groundwater ingestion risk greater than 1×10^{-7} at NRF (DOE-NR 1998).

2.2.3 Expected Arrival Times in the Aquifer at the Naval Reactors Facility for Parent and Progeny Radionuclides

The predicted radionuclide activity fluxes given in Table 2-4 are provided at the vadose zone-aquifer interface in Figure 2-8 (from INL 2012a). The activity flux for Pu-244 is less than 1E-16 Ci/year; therefore, it does not appear on the figure. With the exception of C-14, the potential for surficial soil releases at NRF to be detected in the groundwater wells at the RH-LLW disposal facility during the 100-year institutional control period is negligible.

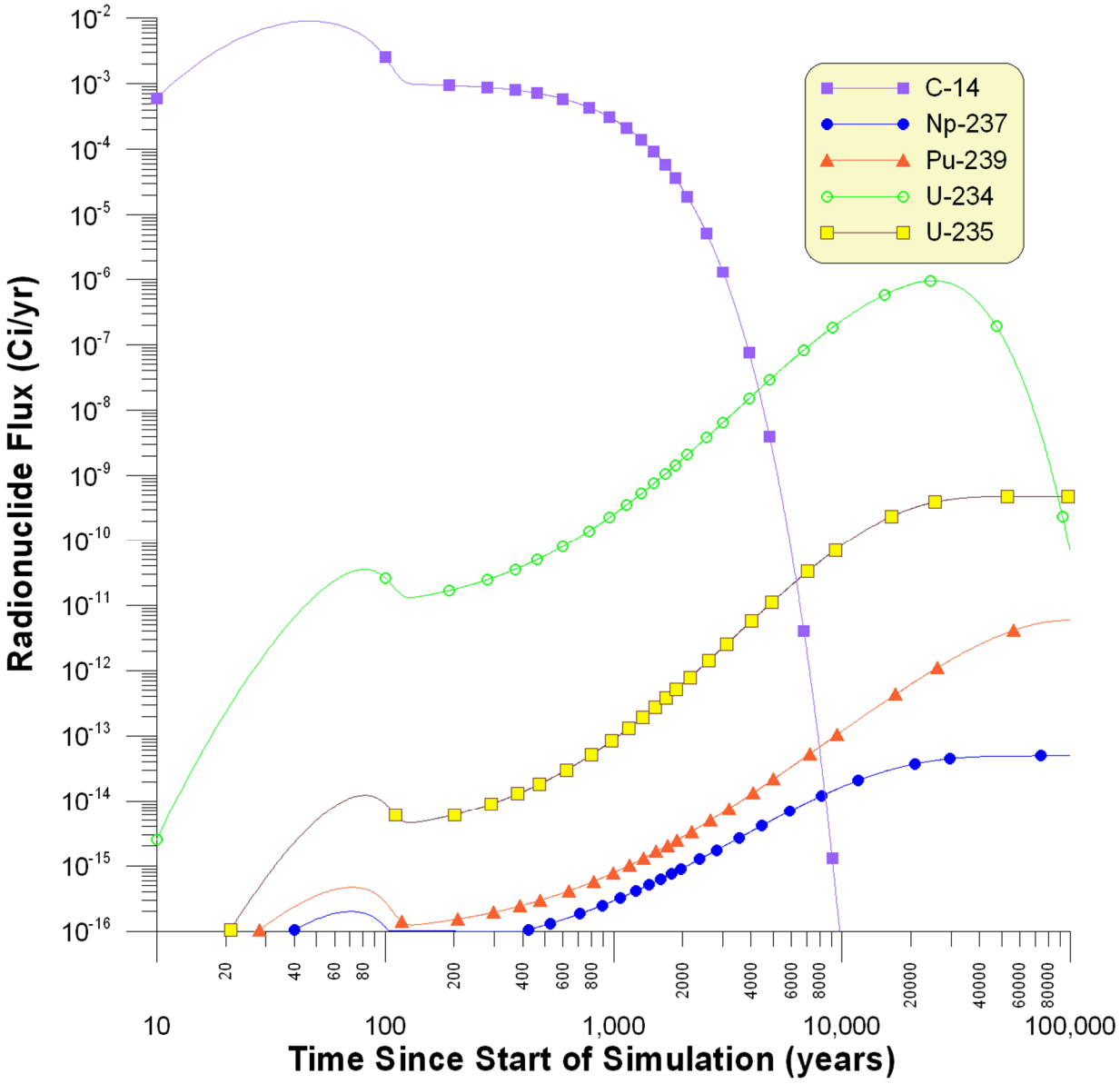

Figure 2-8. Predicted radionuclide activity fluxes at the vadose zone-aquifer interface for historical NRF releases for radionuclides shown in Table 2-4. Pu-244 fluxes were less than 1E-16 Ci/year and do not appear on the figure (from INL 2012a).

3. SUMMARY OF PERCHED WATER AND AQUIFER CONCENTRATION DATA AT THE ADVANCED TEST REACTOR COMPLEX AND RH-LLW DISPOSAL FACILITY

In this section, current water concentration data near the RH-LLW disposal facility is summarized. To this end, the INL Environmental Data Warehouse was queried to obtain radiologic concentration histories in perched water and the aquifer at the RH-LLW disposal facility. Water concentration data are summarized in this section in order to establish the baseline aquifer concentrations at the RH-LLW disposal facility prior to acceptance of waste and to provide a basis for expected variability in observable concentration data.

The water concentration data discussed in this section are limited to data obtained using wells near the ATR Complex. As discussed in Section 2, only the residual radiologic sources at the ATR Complex have the potential of impacting aquifer concentrations near the RH-LLW disposal facility. As shown in Tables 2-1, 2-2, 2-3, and 2-4, the same radionuclides in soils at NRF exist either in the perched water or soils at the ATR Complex. These radionuclides in NRF soils could migrate through the vadose zone and aquifer toward the ATR Complex and RH-LLW disposal facility. However, the NRF surficial soil contamination is insufficient to result in fluxes to the aquifer high enough to have a significant impact to groundwater at NRF; they would be diluted further upon transport to the ATR Complex and RH-LLW disposal facility; and they would be indistinguishable from the radionuclides originating at the ATR Complex. Therefore, this section focuses on radionuclide concentrations in the perched water, in the aquifer immediately south of the ATR Complex, and in the aquifer south of the RH-LLW disposal facility as discussed in the following subsections.

3.1 Perched Water Concentrations

Concentrations in perched water at the ATR Complex have been predominantly influenced by discharge practices to the warm, cold, and chemical waste ponds as discussed in Section 2. As influenced by CERLCA remediation actions and changes to operational practices, the radiologic concentrations were significantly reduced. Including data prior to the late 1990s (i.e., pre-record of decision and remedial actions) in this analysis would bias the interpretation of current variability in concentration data and would lead to erroneous conclusions. Therefore, the query for perched water data was limited to the time period extending from January 2000 through May 2016. These data are shown in Table 3-1.

The data shown in Table 3-1 were compiled from historical sampling of the perched water using Wells TRA-1933, TRA-1934, PW-8, PW-9- PW-10, PW-11, PW-12, PW-13, USG-053, USGS-054, USGS-055, USGS-056, USGS-060, USGS-061, USGS-062, USGS-063, USGS-066, USGS-068, USGS-069, USGS-070, USGS-071, USGS-072, and USGS-073. It does not include shallow perched water Wells CWP-01 to CWP-09. These wells were selected because they are regularly sampled for a full suite of radionuclides and are all completed in the deep perched water influenced by the historical radiologic releases at the ATR Complex.

Radionuclides in the deep perched water are predicted to influence the groundwater at the RH-LLW disposal facility within the 150-year period that spans the 50-year operational and 100-year institutional control periods of the RH-LLW disposal facility. Although these wells are not all directly upgradient of the facility, they are influenced by transport from the ponds at land surface and potentially by contaminated soil sites. Therefore, as a whole, their response can be used as an indicator of statistical trends, including the mean, variance, and coefficient of variation (CV) for perched water concentrations.

The data shown in Table 3-1 represent a statistical compilation from the queried wells that are compiled by radionuclide. Column 1 of the table indicates that in addition to the nuclides shown in Table 2-1 and discussed in Section 2, there have been historical positive detections of Sb-125, C-14, Ce-144, Co-58, I-129, Nb-95, Ra-226, Ru-103, Ru-106, Ag-110m, Zn-65, and Zr-95 in the deep perched

water between January 1, 2000, and June 1, 2016. Cl-36, Pu-238, Pu-239/240, and Ra-228 were not analyzed for, but were included in the table for completeness, because they have been analyzed for in nearby aquifer wells (see Tables 3-3 and 3-4). All radionuclides that were analyzed for and represented in the table have been detected at least once (see Column 5) above the 2-sigma (97.72%) positive detection level, with the exception of I-131 and Tc-99. Also shown in this table are the number of 3σ (99.87%) positive detects (Column 6) and the percentage of sample analyses resulting in either a 2σ or 3 σ-detection level (Columns 7 and 8, respectively). In these data, a true positive is defined as a result that is statistically positive (i.e., result greater than 2σ), greater than its minimum detectable activity, and defensible (i.e., the photopeak is properly fit or resolved and contains no interference or is interference corrected; the radionuclide has a half-life that is long enough to ensure and support a positive detection; and the parent-daughter relationships demonstrate that equilibrium conditions exist).

The contract-required detection limits (CRDLs) specified by the quality assurance project plan for the Idaho Cleanup Project WAGs 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10; removal actions (DOE-ID 2016) are given in Table 3-2. The CRDLs correspond to the CRDLs for Contract Laboratory Program inorganics (EPA 2015). They are 10 times lower than all 10^{-4} and most 10^{-6} residential 100-year, risk-based limits. However, the actual detection limits achieved by the laboratory may vary depending on radionuclide concentrations, sample matrix, sample size, counting times, and the detection system. Therefore, each measurement has its own combined sample uncertainty and its own σ; therefore, σs are not provided.

To establish the range of concentrations observed in the recent perched water at the ATR Complex, Columns 9 through 11 of Table 3-1 provide the minimum observed concentration, maximum observed concentration, and mean concentration for each radionuclide. Variability is established using sample standard deviation and the coefficient of variation (standard deviation/mean). Table 3-1 shows the following:

- The range of concentrations observed in the perched water during the time period assessed for each of the radionuclides is consistently broad as indicated by the standard deviation of the assessed concentrations. For example, Am-241 has not been detected in some of the perched water wells, but has been detected with concentrations as high as 71.3 pCi/L with a mean concentration among the 181 analyzed samples of 6.0 pCi/L. This indicates that there were a few samples collected and analyzed with relatively high concentrations compared to the mean value, $\bar{C}$. The overall standard deviation (σ_{pw}) of the 181 perched water samples analyzed was 10.6 pCi/L, yielding a CV of 1.8 where CV is calculated as: $CV = {}^{\sigma_{pw}}/_{\bar{C}}$). A CV greater than one indicates that there is a wide range of reported concentrations. This range of values between wells and within a single well where multiple samples have been analyzed for implies, for example, that if Am-241 were detected in the RH-LLW disposal facility monitoring wells, all upgradient wells at the ATR Complex would have to be assessed prior to determining the Am-241 originated at the RH-LLW disposal facility. This is true for most of the radionuclides observed in the ATR Complex deep perched water.
- Radionuclides other than those being tracked as significant groundwater risk contributors by WAG 2 are routinely measured in perched water at the ATR Complex. Migration from the perched water into the aquifer and, ultimately, detectability in the RH-LLW disposal facility monitoring wells is a very real possibility. Therefore, selection of indicator radionuclides to be used for the purpose of detecting releases from the RH-LLW disposal facility must consider all radionuclides currently in the perched water at the ATR Complex.

3.2 Aquifer Concentrations Between the Advanced Test Reactor Complex and the Remote-Handled-Low-Level Waste Disposal Facility

At the time of report generation, the aquifer upgradient of the RH-LLW disposal facility has been impacted by a combination of direct injection, leaching from the perched water, leaching from surface

disposal ponds, and leaching from soils at the ATR Complex. The resultant radiologic concentrations are summarized in Table 3-3 for aquifer wells shown in Figure 1-2. This table contains similar information as provided for the perched water in Table 3-1 and includes a summary of sample analyses results for the January 2000 through May 2016 time period. Radionuclides reported include those included in the final Comprehensive RI/FS for the ATR Complex listed in Table 2-1 and Ra-226 as a daughter product as given in Table 2-2. In addition, the aquifer sampling results report positive detections of Sb-125, C-14, Ce-144, Co-58, gross alpha, gross beta, I-129, Nb-95, Ra-228, Ru-103, Ru-106, Ag-110m, Tc-99, Zn-65, and Zr-95.

The data summarized in Table 3-3 include the number of positive detects (i.e., greater than 2σ) using the CRDLs shown in Table 3-2 for perched water and the number of positive detects at the 3σ level. The minimum, maximum, mean, and standard deviation in concentrations based on Wells TRA-06A, TRA-07, USGS-058, SGS-065, and USGS-136 are also provided with the resultant radionuclide-specific CV. The data indicates the following:

- The variation in aquifer sampling results mimics that observed in the perched water. A positively detected radionuclide concentration from the list of radionuclides shown in Table 3-3 observed in one of the RH-LLW disposal facility's downgradient aquifer monitoring wells would be very difficult to attribute to a release from the RH-LLW disposal facility unless (1) a significant upward trend were established for each radionuclide observed or correlated with analysis data from a RH-LLW disposal facility vadose zone monitoring well, (2) the upward trend persisted over a time-period longer than 8 years (i.e., longer than the record analyzed in Table 3-3), and (3) the trending values exceeded the CV shown in Table 3-3 for the radionuclide being investigated.
- Selection of specific target radionuclides that could be used as indicators of facility releases will be difficult and should not be based on the CERCLA radionuclides of interest from a groundwater perspective. The radionuclides of interest at the ATR Complex were evaluated and shown in Table 2-3. Indicator radionuclides should be based on the list of radionuclides contained in Tables 3-1 and 3-3 in order to avoid false positive detects.

3.3 Aquifer Concentrations Downgradient of the Remote-Handled Low-Level Waste Disposal Facility

Wells downgradient of the RH-LLW disposal facility include TRA-08, USGS-140, USGS-141, and Middle-1823. TRA-08 may not be directly downgradient, but was deemed close enough to include in this analysis. The list of radionuclides regularly sampled in these wells is shown in Table 3-4 with the number of positive detects (i.e., 2σ) and the number of 3σ detects. These data indicate the following:

- These wells are far enough downgradient of the ATR Complex that dilution reduces the concentrations for many of the radionuclides below the 2σ level. For example, there are no positive detects for Am-241, Sb-125, I-131, Pu-238, Pu-239/240, and Tc-99. Lack of positive detects in these wells in the presence of positive detects in upstream wells will make it difficult to establish a spatial trend when determining if any releases from the RH-LLW disposal facility have occurred. For low-concentration releases from the RH-LLW disposal facility, similar dilution would occur; therefore, using wells downgradient of USGS-140 and USGS-141 for release detection from the RH-LLW disposal facility is not recommended.
- The CV for positively detected radionuclides in these downgradient wells still exceeds 1.5 in most cases. This is expected given the variation observed in the upgradient aquifer wells and in the perched water wells. If these downgradient wells are to be used for release detection, very long-term upward trends would have to be established with concentrations approaching and/or exceeding the maximum observed concentration values shown in Table 3-4 in order to attribute the radionuclide concentrations to releases from the RH-LLW disposal facility.

Table 3-1. Summary of radionuclide sample analyses data for deep perched water near the ATR Complex from January 2000 through May 2016.

Constituent	Min Date	Max Date	# Samples/ Analyses[a]	# 2-Sigma Detects	# 3-Sigma Detects	% 2-Sigma Detects	% 3-Sigma Detects	Min Conc[b] (pCi/L)	Max Conc (pCi/L)	Mean Conc (pCi/L)	Std Dev (pCi/L)	Coeff Variation
Am-241	6/21/2000	10/20/2015	181	7	1	4%	1%	0	71.3	6.0	10.6	1.8
Sb-125	6/21/2000	10/20/2015	175	6	0	3%	0%	0	22.1	3.1	4.7	1.5
C-14	3/19/2003	3/19/2003	1	1	1	100%	100%	13.6	13.6	13.6	NA[c]	NA[d]
Ce-144	6/21/2000	10/20/2015	175	8	0	5%	0%	0	41.6	7.4	10.9	1.5
Cs-134	6/21/2000	10/20/2015	175	7	2	4%	1%	0	27.2	1.3	2.8	2.2
Cs-137	4/3/2000	10/20/2015	400	49	5	12%	1%	0	56	8.2	11.2	1.4
Cl-36			0									
Co-58	6/21/2000	10/20/2015	175	5	0	3%	0%	0	13.9	1.3	2.3	1.7
Co-60	6/21/2000	10/20/2015	175	27	13	15%	7%	0	330	7.97	31.9	4.0
Eu-152	6/21/2000	10/20/2015	175	5	0	3%	0%	0	104	5.4	13.8	2.5
Eu-154	6/21/2000	10/20/2015	175	4	0	2%	0%	0	34	3.8	7.0	1.8
Eu-155	6/21/2000	10/20/2015	175	10	0	6%	0%	0	61.1	4.6	7.5	1.6
Gross alpha	6/21/2000	4/1/2015	64	39	23	61%	36%	0	15.3	3.5	2.8	0.8
Gross beta	6/21/2000	4/1/2015	62	59	56	95%	90%	0.20	232	56.4	59.9	1.1
I-129	3/19/2003	10/29/2003	8	1	0	13%	0%	0	0.067	0.033	0.024	0.7
I-131	6/21/2000	11/27/2000	9	0	0	0%	0%	0	60.7	11.9	20.7	1.7
Nb-95	6/21/2000	10/20/2015	175	12	3	7%	2%	0	21.7	1.9	2.9	1.5
Pu-238			0									
Pu-239/240			0									
Ra-226	6/21/2000	10/20/2015	176	41	22	23%	13%	0	412	34.9	61.0	1.7
Ra-228			0									
Ru-103	6/21/2000	10/20/2015	175	4	0	2%	0%	0	11.7	1.1	2.3	2.1
Ru-106	6/21/2000	10/20/2015	175	6	1	3%	1%	0	81.6	13.1	16.8	1.3
Ag-108m	6/21/2000	10/20/2015	175	8	3	5%	2%	0	31.3	1.5	3.6	2.4
Ag-110m	6/21/2000	10/20/2015	175	4	1	2%	1%	0	12.4	1.11	1.9	1.7
Sr-90	1/26/2000	10/20/2015	449	309	279	69%	62%	0	113	21.1	27.2	1.3
Tc-99	3/19/2003	10/29/2003	8	0	0	0%	0%	0	2.5	0.31	0.88	2.8
H-3	1/26/2000	10/20/2015	459	300	268	65%	58%	0	70,100	6,207	12,607	2.0
U-234	5/14/2001	5/14/2001	1	1	1	100%	100%	1.4	1.4	1.4	N/A[c]	NA[d]
U-235	6/21/2000	10/20/2015	175	11	0	6%	0%	0	61.2	10.2	12.5	1.2
U-238	5/14/2001	5/14/2001	1	1	0	100%	0%	0.52	0.52	0.52	N/A[c]	NA[d]
Zn-65	6/21/2000	10/20/2015	175	3	1	2%	1%	0	27.4	2.0	4.3	2.1
Zr-95	6/21/2000	10/20/2015	175	10	2	6%	1%	0	23.7	2.9	4.5	1.6

a. Number of samples includes field duplicates. Includes data from wells TRA-1933, TRA-1934, PW-8, PW-9- PW-10, PW-11, PW-12, PW-13, USG-053, USGS-054, USGS-055, USGS-056, USGS-060, USGS-061, USGS-062, USGS-063, USGS-066, USGS-068, USGS-069, USGS-070, USGS-071, USGS-072, and USGS-073. Does not include shallow perched water wells CWP-01 to CWP-09.
b. Concentrations reported less than 0 were assumed to be 0 for statistical calculations.
c. Standard deviation not defined for one sample.
d. Coefficient of variation not defined without standard deviation.

Table 3-2. Radionuclide contract-required detection limits (DOE-ID 2016).

Radionuclides[b]		CRDLs[a,c] Soil (pCi/g)	CRDLs[a,c] Water (pCi/L)
Alpha Spectrometry			
Americium	(Am-241)	0.05	0.2[d]
Curium	(Cm-242 and Cm-244)	0.05	0.2
Neptunium	(Np-237)	0.05[d]	0.2[d]
Plutonium	(Pu-238, Pu-239/240, and Pu-242)	0.05	0.2[d]
Thorium	(Th-228, Th-230, and Th-232)	0.05	0.5[d]
Uranium	(U-234, U-235, and U-238)	0.05[d]	0.5[d]
Gamma Spectrometry[e]			
Antimony	(Sb-125)	~0.1	~30
Cerium	(Ce-144)	~0.1	~30
Cesium	(Cs-134 and Cs-137)	0.1[d,e]	30[d,e]
Cobalt	(Co-60)	~0.1	~30
Europium	(Eu-152, Eu-154, and Eu-155)	~0.1	~30
Manganese	(Mn-54)	~0.1	~30
Ruthenium	(Ru-106)	~0.1	~30
Silver	(Ag-108m and Ag-110m)	~0.1[d]	~30[d]
Zinc	(Zn-65)	~0.1	~30
Other[f]	(Results >2σ and > minimum detectable activity)[f]	~0.1	~30
Specific Analyses			
Carbon	(C-14)	3	3
Iodine	(I-129)	1d	1[d]
Iron	(Fe-55)	5	5
Nickel	(Ni-59)	5	5
Nickel	(Ni-63)	5	5
Plutonium	(Pu-241)	1	10[d]
Radium	(Ra-226)[g]	0.5[d]	1[d]
Radium	(Ra-228)	0.5	1
Strontium	(Sr-89)	0.5	1
Strontium	(Sr-90)	0.5	1
Strontium	(Sr-89 and Sr-90) total	0.5	1
Technetium	(Tc-99)	1	10[d]

Radionuclides[b]		CRDLs[a,c] Soil (pCi/g)	Water (pCi/L)
Tritium	(H-3)	20	400
Chlorine	(Cl-36)	10	100
Indicator Analyses			
Gross alpha	(gross α)	10	4
Gross beta	(gross β)	10	4

a. These are the CRDLs imposed by the Idaho Cleanup Project documented in DOE/ID-10587 (2016).

b. The analysis may include radionuclides not on this table.

c. All listed CRDLs are sufficiently low to meet most sample analysis needs. They are 10 times lower than all 10^{-4} and most 10^{-6} residential 100-year, risk-based limits. The CRDLs are based on ideal sample and analysis conditions. Actual detection limits achieved by the laboratory may vary depending on the radionuclide concentrations, sample matrix, sample size, counting times, and detection system.

d. These CRDLs are higher than one-tenth of the 10^{-6} risk-based limits (i.e., they are not 10 times lower than an activity that corresponds to the 10^{-6} risk-based limit); therefore, they may not meet project or program requirements for making 10^{-6} risk-based decisions. See footnote c above. The option to request lower CRDLs is possible for some radionuclides.

e. The CRDL applied to all gamma-emitting radionuclides is based on Cs-137. The detection limits of other gamma radionuclides will differ from that of Cs-137 (i.e., 0.1 pCi/g and 30 pCi/L); however, they are commensurate with that for Cs-137, taking into account differences in gamma-ray energies and branching ratios (gamma emission probabilities).

f. Naturally occurring radionuclides are not reported unless the measured concentrations are notably greater than what would normally be expected for the particular sample matrix.

g. A separate, specific analysis is required for Ra-226, which is not included in the standard target analyte list for gamma-emitting radionuclides.

Table 3-3. Summary of radionuclide sample analyses data for groundwater (aquifer) region near ATR Complex from January 2000 through May 2016. Region is downgradient of ATR Complex, but upgradient from the RH-LLW disposal facility.

Constituent	Min Date	Max Date	# Samples/ Analyses[a]	# 2-Sigma Detects	# 3-Sigma Detects	% 2-Sigma Detects	% 3-Sigma Detects	Min Conc[b] (pCi/L)	Max Conc (pCi/L)	Mean Conc (pCi/L)	Std Dev (pCi/L)	Coeff Variation
Am-241	4/6/2000	5/11/2016	132	5	0	4%	0%	0	61.2	3.1	7.7	2.5
Sb-125	6/21/2000	5/11/2016	103	6	1	6%	1%	0	106	5.1	14.0	2.7
C-14	3/11/2003	9/1/2011	5	3	3	60%	60%	0	1,747	373	769	2.1
Ce-144	6/21/2000	5/11/2016	103	2	0	2%	0%	0	41.5	5.3	9.5	1.8
Cs-134	6/21/2000	5/11/2016	103	3	0	3%	0%	0	6.0	0.9	1.5	1.6
Cs-137	1/13/2000	5/11/2016	152	13	2	9%	1%	0	60	6.2	11.3	1.8
Cl-36			0									
Co-58	6/21/2000	5/11/2016	103	2	0	2%	0%	0	9.1	1.0	1.7	1.7
Co-60	6/21/2000	5/11/2016	103	6	3	6%	3%	0	7.3	0.8	1.4	1.7
Eu-152	6/21/2000	5/11/2016	103	3	0	3%	0%	0	45.8	3.9	8.3	2.1
Eu-154	6/21/2000	5/11/2016	103	1	1	1%	1%	0	125	4.0	13.7	3.4
Eu-155	6/21/2000	5/11/2016	103	3	0	3%	0%	0	29.0	2.9	5.0	1.7
Gross alpha	6/21/2000	5/11/2016	70	45	24	64%	34%	0	14.0	2.6	2.2	0.8
Gross beta	6/21/2000	5/11/2016	68	65	58	96%	85%	0.87	15.3	5.4	2.8	0.5
I-129	3/11/2003	10/25/2011	8	1	1	13%	13%	0	0.048	0.017	0.019	1.1
I-131	6/21/2000	11/22/2000	6	0	0	0%	0%	0	140	44.6	55.6	1.2
Nb-95	6/21/2000	5/11/2016	103	8	2	8%	2%	0	12.1	1.7	2.5	1.5
Pu-238	4/6/2000	4/2/2015	21	0	0	0%	0%	0	0.007	0.001	0.002	2.3
Pu-239/240	4/6/2000	4/2/2015	21	0	0	0%	0%	0	0.014	0.004	0.002	1.0
Ra-226	6/21/2000	5/11/2016	104	12	3	12%	3%	0	318	36.8	58.4	1.6
Ra-228	10/8/2013	10/8/2013	1	1	0	100%	0%	0.29	0.29	0.29	NA[c]	NA[d]
Ru-103	6/21/2000	5/11/2016	103	1	0	1%	0%	0	16.5	1.1	2.6	2.5
Ru-106	6/21/2000	5/11/2016	103	2	0	2%	0%	0	81.6	8.5	17.6	2.1
Ag-108m	6/21/2000	5/11/2016	103	3	0	3%	0%	0	39.6	1.5	5.3	3.5
Ag-110m	6/21/2000	5/11/2016	103	1	0	1%	0%	0	8.1	0.9	1.7	1.9
Sr-90	1/13/2000	5/11/2016	149	26	9	17%	6%	0	44.3	0.7	3.6	5.1
Tc-99	3/11/2003	10/27/2003	7	2	0	29%	0%	0	4.8	1.4	2.3	1.7
H-3	1/13/2000	5/11/2016	169	166	166	98%	98%	0	18,800	5,702	5,125	0.9
U-234	9/1/2011	9/1/2011	1	1	1	100%	100%	1.4	1.4	1.4	NA[c]	NA[d]
U-235	6/21/2000	5/11/2016	104	4	0	4%	0%	0	45.1	7.1	10.1	1.4
U-238	9/1/2011	9/1/2011	1	1	1	100%	100%	0.42	0.42	0.42	NA[c]	NA[d]
Zn-65	6/21/2000	5/11/2016	103	3	0	3%	0%	0	26.2	2.2	4.6	2.1
Zr-95	6/21/2000	5/11/2016	103	6	1	6%	1%	0	33.7	2.5	5.4	2.2

a. Number of samples includes field duplicates. Includes data from Wells TRA-06A, TRA-07, USGS-058, USGS-065, and USGS-136.
b. Concentrations reported less than 0 were assumed to be 0 for statistical calculations.
c. Standard deviation not defined for one sample.
d. Coefficient of variation not defined without standard deviation.

Table 3-4. Summary of radionuclide sample analyses data for the groundwater (aquifer) region near the ATR Complex from January 2000 through May 2016. Region is downgradient of the RH-LLW disposal facility.

Constituent	Min Date	Max Date	# Samples/ Analyses[a]	# 2-Sigma Detects	# 3-Sigma Detects	% 2-Sigma Detects	% 3-Sigma Detects	Min Conc[b] (pCi/L)	Max Conc (pCi/L)	Mean Conc (pCi/L)	Std Dev (pCi/L)	Coeff Variation
Am-241	6/28/2000	5/10/2016	73	0	0	0%	0%	0	35.4	4.0	7.3	1.8
Sb-125	6/28/2000	5/10/2016	69	0	0	0%	0%	0	11.5	2.0	3.0	1.5
C-14	3/12/2003	3/12/2003	1	1	1	100%	100%	8.2	8.2	8.2	NA[c]	NA[d]
Ce-144	6/28/2000	5/10/2016	69	1	0	1%	0%	0	37.2	4.7	8.8	1.9
Cs-134	6/28/2000	5/10/2016	69	3	1	4%	1%	0	10.5	1.3	2.3	1.8
Cs-137	6/28/2000	5/10/2016	73	6	0	8%	0%	0	48.5	2.1	6.5	3.1
Cl-36	6/7/2005	6/7/2005	1	1	1	100%	100%	0.027	0.027	0.027	NA[c]	NA[d]
Co-58	6/28/2000	5/10/2016	69	2	0	3%	0%	0	12.4	0.8	2.1	2.6
Co-60	6/28/2000	5/10/2016	69	2	1	3%	1%	0	9.3	0.9	1.6	1.8
Eu-152	6/28/2000	5/10/2016	69	2	0	3%	0%	0	40.8	2.7	5.8	2.1
Eu-154	6/28/2000	5/10/2016	69	1	0	1%	0%	0	38.8	2.9	6.4	2.2
Eu-155	6/28/2000	5/10/2016	69	3	0	4%	0%	0	28.7	1.6	4.2	2.7
Gross alpha	6/28/2000	5/10/2016	47	29	19	62%	40%	0	26.4	3.7	5.2	1.4
Gross beta	6/28/2000	5/10/2016	47	39	33	83%	70%	0.40	43.5	7.6	10.3	1.3
I-129	3/12/2003	9/25/2013	6	1	1	17%	17%	0	0.032	0.008	0.012	1.4
I-131	6/28/2000	11/22/2000	2	0	0	0%	0%	0	0.56	0.28	0.40	1.4
Nb-95	6/28/2000	5/10/2016	69	3	0	4%	0%	0	8.4	1.3	2.1	1.5
Pu-238	7/31/2013	9/25/2013	2	0	0	0%	0%	0	0	0	0	NA[d]
Pu-239/240	7/31/2013	9/25/2013	2	0	0	0%	0%	0.003	0.009	0.006	0.004	0.7
Ra-226	6/28/2000	5/10/2016	71	8	3	11%	4%	0	287	26.5	48.0	1.8
Ra-228	4/18/2012	10/8/2012	2	2	1	100%	50%	0.7	3.2	2.0	1.8	0.9
Ru-103	6/28/2000	5/10/2016	69	2	0	3%	0%	0	18.8	1.4	3.1	2.3
Ru-106	6/28/2000	5/10/2016	69	3	0	4%	0%	0	63.2	7.8	14.3	1.8
Ag-108m	6/28/2000	5/10/2016	69	1	1	1%	1%	0	25.1	0.9	3.4	3.6
Ag-110m	6/28/2000	5/10/2016	69	1	0	1%	0%	0	12.5	0.6	1.8	2.8
Sr-90	11/22/2000	5/10/2016	73	17	10	23%	14%	0	7,280	178	1,071	6.0
Tc-99	3/12/2003	9/25/2013	5	0	0	0%	0%	0	3.2	0.7	1.4	2.2
H-3	6/28/2000	5/10/2016	75	75	75	100%	100%	638	8,040	2,054	1,631	0.8
U-234	7/31/2013	9/25/2013	2	2	2	100%	100%	1.5	1.6	1.5	0.08	0.1
U-235	6/28/2000	5/10/2016	71	4	0	6%	0%	0	78.4	6.9	12.5	1.8
U-238	7/31/2013	9/25/2013	2	2	2	100%	100%	0.51	0.6	0.6	0.07	0.1
Zn-65	6/28/2000	5/10/2016	69	3	0	4%	0%	0	29.3	1.2	4.0	3.3
Zr-95	6/28/2000	5/10/2016	69	2	0	3%	0%	0	22.8	1.7	4.0	2.3

a. Number of samples includes field duplicates. Includes data from Wells TRA-08, USGS-140, USGS-141, and Middle-1823.
b. Concentrations reported less than 0 were assumed to be 0 for statistical calculations.
c. Standard deviation not defined for one sample.
d. Coefficient of variation not defined without standard deviation.

4. SUMMARY OF AQUIFER CONCENTRATION DATA AT THE REMOTE-HANDLED LOW-LEVEL WASTE DISPOSAL FACILITY

This section summarizes aquifer concentration data collected in Well USGS-136, which is approximately 40 m upgradient of the RH-LLW disposal facility vault system, and for wells USGS-140 and USGS-141, which are located approximately 130 m downgradient of the vault system. These wells were drilled to provide performance confirmation of the facility, and water concentration data are summarized in this section in order to establish baseline aquifer concentrations prior to disposal of waste into the RH-LLW disposal facility. The time period for data collection is indicated in the column headings of Table 4-1. This table provides water quality data and radiologic data for nuclides predicted to either arrive in the aquifer earliest or to contribute significantly to the predicted facility dose (DOE/ID 2012). These data were extracted from Environmental Data Warehouse in January 2017.

- **Water quality data** provided in Table 4-1 include pH, constituents of concrete (i.e., cement containing predominantly lime-CaCO, silica-SiO_2, Alumina-Al_2O_3, Iron-Fe_2O_3, and Gypsum-$CaSO_4$ $2H_2O$), and those comprising carbon steel (i.e., iron and carbon), stainless steel (i.e., iron, carbon, nickel, chromium, and manganese), and aluminum metal. Monitoring these constituents and large changes in them will provide an indication of vault system performance, because the vault system contains a significant mass of lime and carbon steel and can be used to provide an indication of early corrosion of the stainless steel waste container/liners and activated metals (i.e., Inconel, zirconium, stainless steel, and aluminum) contained in them. Data provided in Table 4-1 should be maintained throughout the operational and institutional control periods of the RH-LLW disposal facility in order to establish overall performance of the facility and to determine appropriate vault closure systems. Collecting this data in the vadose zone beneath the facility would be much more informative that collecting it in the aquifer (see PLN-5501 2017)
- **Radionuclides** were selected for presentation in Table 4-1, in part, because of their potential to be released from the RH-LLW disposal facility (DOE-ID 2012). These radionuclides were also selected because they are present in upgradient sources at the ATR Complex and at NRF (see Sections 2 and 3). Of the radionuclides disposed of in the RH-LLW disposal facility and/or found in the upgradient sources, the most mobile are C-14, Cl-36, H-3, I-129, Mo-93, Tc-99, and U-xxx as indicated in the distribution coefficients provided in Table 4-2. These radionuclides will be transported to the aquifer after release into the environment with a rate inversely proportional to the vadose zone sediment distribution coefficient. The earlier arrival and relative abundance of these radionuclides would make them the ideal candidates for early vault system failure detection. However, as noted in Tables 3-1 and 3-3, there is a statistically positive presence of all of these radionuclides in the perched water and groundwater upgradient of the RH-LLW disposal facility as a result of historical operational practices at the ATR Complex.

Table 4-1. Baseline data collected in the RH-LLW disposal facility aquifer monitoring wells prior to start of disposal operations.

		USGS-136							USGS-140			USGS-141
Constituent or Measurement	Units	May-11	Sep-11	Oct-11	12-Oct	Oct-13	Oct-14	Oct-15	13-Jul	Dec-14	Oct-15	Sep-13
Temperature	Degrees C	13.7	13.5	13.1	13.3	13.6	13.7	13.29	13.4	13	13.27	13
pH	mg/L	0.000011	0.000012	0.000012	0.000111	0.000018	0.000015	NA	0.000018	0.000017	NA	0.000016
Conductivity	µS/cm	376	428	429	460	416	424	426	443	433	435	428
Dissolved Oxygen	mg/L	9.8	9.0	7.7	7.8	8.1	8.2	7.9	8.2	7.7	5.1	9.2
Alkalinity	mg/L	NA	163.7	NA	NA	NA	NA	NA	170	NA	NA	171
Hardness	mg/L	NA	196.8	NA	NA	NA	NA	NA	213.7	NA	NA	205.7
Calcium	mg/L	NA	50.0	NA	NA	NA	NA	NA	55.9	NA	NA	54.0
Magnesium	mg/L	NA	17.38	NA	NA	NA	NA	NA	17.94	NA	NA	17.13
Potassium	mg/L	NA	1.95	NA	NA	NA	NA	NA	1.98	NA	NA	1.99
Silica	mg/L	NA	22.24	NA	NA	NA	NA	NA	20.75	NA	NA	21.09
Sodium	mg/L	8.78	10.99	11	11.55	11.19	11.76	11.43	12.55	12.1	12.64	11.41
Bromide	mg/L	NA	0.027	NA	NA	NA	NA	NA	0.039	NA	NA	0.039
Chloride	mg/L	10.6	12.9	13.0	13.5	13.0	13.9	14.0	12.6	12.9	13.2	12.1
Fluoride	mg/L	NA	0.143	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate	mg/L	21.5	32.4	32.8	34.7	35.9	36.2	36.0	41.0	38.8	39.7	38.6
Ammonia	mg/L	0.011	<.01	<.01	<.01	<.01	<.0129	<.0129	<.0129	<.0129	<.0129	<.0129
Nitrite	mg/L	<.001	<.001	<.001	0.0042	<.0033	<.001	<.001	<.0033	<.0033	<.0033	<.0033
Nitrate	mg/L	0.911	1.13	1.09	1.13	1.125	1.082	1.138	1.087	1.055	1.085	4.725
Orthophosphate	mg/L	0.024	0.070	0.022	0.069	0.065	0.065	0.070	0.066	0.083	0.069	0.069
Aluminum	µg/L	NA	6.84	6.35	NA	NA	NA	NA	5.34	NA	NA	6.03
Antimony	µg/L	NA	0.088	0.094	NA	NA	NA	NA	0.088	NA	NA	0.087
Arsenic	µg/L	NA	1.55	1.69	NA	NA	NA	NA	1.62	NA	NA	1.40
Barium	µg/L	NA	48.1	57.6	NA	NA	NA	NA	54.9	NA	NA	54.4
Beryllium	µg/L	NA	<.1	<.006	NA	NA	NA	NA	0.166	NA	NA	<.1
Boron	µg/L	NA	21.9	N/A	NA	NA	NA	NA	21.6	NA	NA	22.1
Cadmium	µg/L	NA	<.016	<.016	NA	NA	NA	NA	<.016	NA	NA	<.016
Chromium	µg/L	3.93	13.3	15.1	15.9	13.9	15.0	15.8	18.1	15.0	16.0	15.9
Cobalt	µg/L	NA	0.031	0.047	NA	NA	NA	NA	0.049	NA	NA	0.078
Copper	µg/L	NA	<.5	<.8	NA	NA	NA	NA	<.8	v	NA	<.8

Constituent or Measurement	Units	USGS-136							USGS-140			USGS-141
		May-11	Sep-11	Oct-11	12-Oct	Oct-13	Oct-14	Oct-15	13-Jul	Dec-14	Oct-15	Sep-13
Iron	µg/L	NA	4.97	NA	NA	NA	NA	NA	<4	NA	NA	4.30
Lead	µg/L	NA	<.015	0.032	NA	NA	NA	NA	<.025	NA	NA	<.025
Lithium	µg/L	NA	2.04	NA	NA	NA	NA	NA	2.41	NA	NA	2.28
Manganese	µg/L	NA	0.404	0.399	NA	NA	NA	NA	0.192	NA	NA	0.367
Mercury	µg/L	NA	<.005	<.005	NA	NA	NA	NA	<.005	NA	NA	<.005
Molybdenum	µg/L	NA	1.165	1.243	NA	NA	NA	NA	1.17	NA	NA	1.084
Nickel	µg/L	NA	0.154	0.425	NA	NA	NA	NA	0.335	NA	NA	0.577
Selenium	µg/L	NA	1.2	1.4	NA	NA	NA	NA	1.1	NA	NA	1.1
Silver	µg/L	NA	<.005	<.005	NA	NA	NA	NA	<.005	NA	NA	<.005
Strontium	µg/L	NA	240.7	NA	NA	NA	NA	NA	230.6	NA	NA	222.3
Thallium	µg/L	NA	<.01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tungsten	µg/L	NA	0.18	N/A	NA	NA	NA	NA	0.10	NA	NA	0.07
Uranium	µg/L	NA	1.53	1.76	NA	NA	NA	NA	1.62	NA	NA	1.50
Vanadium	µg/L	NA	3.79	NA	NA	NA	NA	NA	4.48	NA	NA	4.19
Zinc	µg/L	NA	<1.4	2.9	NA	NA	NA	NA	NA	NA	NA	NA
Total Organic Carbon	mg/L	NA	0.472	<0.5	NA	NA	NA	NA	NA	NA	NA	NA
Tritium	pCi/L	50	2260	1910	2030	1550	1830	1720	2010	1820	1690	1920
Strontium-90	pCi/L	1.3	0.1	0.5	0.8	1.1	0.9	0.5	0.3	1.5	1.7	0.9
Technetium-99	pCi/L	NA	0	NA	NA	NA	NA	NA	N/A	NA	NA	NA
Iodine-129	pCi/L	NA	0.01	NA	NA	NA	NA	NA	-0.2	NA	NA	0.01
Carbon-14	pCi/L	NA	-20	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	pCi/L	8	13	18	29	6	24	30	21	48.5	19	2
Gross alpha	pCi/L	NA	-2	3	NA	NA	NA	NA	1.7	NA	NA	2
Gross beta	pCi/L	NA	3.8	2	NA	NA	NA	NA	2.1	NA	NA	1.1
Americium-241	pCi/L	NA	0.003	-0.003	NA	NA	NA	NA	0.003	NA	NA	0.012
Plutonium-238	pCi/L	NA	-0.003	-0.006	NA	NA	NA	NA	-0.003	NA	NA	-0.003
Plutonium-239/240	pCi/L	NA	0.003	-0.003	NA	NA	NA	NA	0.009	NA	NA	0.003
Uranium-234	pCi/L	NA	1.37	NA	NA	NA	NA	NA	1.59	NA	NA	1.48
Uranium-235	pCi/L	NA	0.047	NA	NA	NA	NA	NA	0.019	NA	NA	0.0066
Uranium-238	pCi/L	NA	0.423	NA	NA	NA	NA	NA	0.614	NA	NA	0.512

Constituent or Measurement	Units	USGS-136							USGS-140			USGS-141
		May-11	Sep-11	Oct-11	12-Oct	Oct-13	Oct-14	Oct-15	13-Jul	Dec-14	Oct-15	Sep-13
Carbon-13	per mil	NA	-8.33	NA	NA	NA	NA	NA	-8.38	NA	NA	NA
Carbon-14	(Pct Modern)	NA	1746.82	NA	NA	NA	NA	NA	N/A	NA	NA	NA
Deuterium/Protium Isotopic ratio	per mil	NA	-136.9	NA	NA	NA	NA	NA	-137.4	NA	NA	-136.52
Oxygen-18/Oxygen-16 Isotopic ratio	per mil	NA	-17.9	NA	NA	NA	NA	NA	-17.9	NA	NA	-17.9

Table 4-2. Distribution coefficients recommended for use by the RH-LLW disposal facility for key radionuclides also present in upgradient sources at the ATR Complex and NRF.

Element	Distribution Coefficients (mL/g) (INL 2012a)
Ac	300
C	0.5
Cl	0
H	0
I	6.1
Mo	10
Nb	160
Ni	100
No	17.5
Pa	550
Pb	270
Pu	1,250
Ra	500
Tc	0.1
Th	500
U	10

5. CONCLUSIONS

Aquifer concentrations upgradient of the RH-LLW disposal facility are currently being impacted by historical operational practices at the ATR Complex that have left residual low-level contamination in soil, perched water, and the aquifer. Residual contaminants in the soil will eventually migrate into the perched water, be diluted, and will ultimately arrive in the aquifer at concentrations predicted to be below regulatory imposed levels. A similar process will occur for radionuclides disposed of in the RH-LLW disposal facility. The waste disposed of in the RH-LLW disposal facility is primarily activated metals, resins, and surface-contaminated debris. The waste will be initially contained in stainless steel waste containers/liners that are placed in reinforced concrete vaults. In order for the waste to be released into the environment, the vaults must allow the stainless steel waste containers/liners to mechanically fail or the stainless steel waste containers/liners must corrode. The robust design was selected to provide significant protection to the environment and is expected to result in no releases to the environment during the first 500 years post-facility closure. However, monitoring of facility performance is required in order to ensure it meets the dose standards set by EPA (65 FR 21575 2000), the State of Idaho (IDAPA 58.01.08 and IDAPA 58.01.11), and DOE Order 435.1.

Prior releases of radionuclides to the environment at the upgradient ATR Complex will make early detection of vault system failure and premature releases to the environment at the RH-LLW disposal facility problematic due to the following:

- Perched water and the aquifer near the ATR Complex contain the primary candidates that would be used to indicate early vault system failure. Concentrations in perched water and the aquifer are relatively low compared to regulatory limits. In addition, although there is a general downward trend in perched water and aquifer concentrations, the variability in perched water and aquifer concentrations is significant (see Section 3). The reported concentrations and high variability would be expected to mask the anticipated smaller impacts that would occur if waste containers/liners failed at the RH-LLW disposal facility.
- Radionuclides reported above positive detection limits (i.e., greater than 2σ) in perched water and the aquifer at the ATR Complex include not only those being tracked and reported for CERCLA compliance, but also those that will be disposed of and could be used for early detection from the RH-LLW disposal facility. Therefore, selection of indicator radionuclides to be used for detecting releases from the RH-LLW disposal facility must consider all radionuclides currently in the perched water and aquifer at the ATR Complex.
- A positively detected radionuclide concentration from the list of radionuclides shown in Table 3-3 observed in one of the RH-LLW disposal facility monitoring wells would be very difficult to attribute to a release from the RH-LLW disposal facility unless the following:
  - A significant upward trend was established for each radionuclide observed and if it was correlated to data from the vadose zone monitoring wells
  - The upward trend persisted over a time-period longer than 8 years (i.e., longer than the record analyzed in Table 3-3)
  - The trending values exceeded the CV shown in Table 3-3 for the radionuclide being investigated.
- Wells downgradient of Wells USGS-140 and USGS-141 are far enough away that dilution and subsequent lack of positive detects in these wells will make it difficult to establish a spatial trend when determining if any releases from the RH-LLW disposal facility have occurred.

- The CV for positively detected radionuclides in the downgradient wells is greater than 1.5 – If the wells downgradient of USGS-140 and USGS-141 are to be used for release detection, very long-term upward trends would have to be established, with concentrations approaching and/or exceeding the maximum observed concentration values shown in Table 3-3 in order to attribute the radionuclide concentrations to releases from the RH-LLW disposal facility.

- For the purposes of early detection, data from the sedimentary interbed and vault array wells installed as part of the RH-LLW disposal facility monitoring system should be used to provide confirmatory information.

6. REFERENCES

56 FR 50634, 1991,"Sole Source Designation of the Eastern Snake River Plain Aquifer, Southern Idaho: Final Determination," *Federal Register*, U.S. Environmental Protection Agency, October 7, 1991.

65 FR 21575, 2000, "*National Primary Drinking Water Regulations; Radionuclides*; Notice of Data Availability; Proposed Rule," *Federal Register*, U.S. Environmental Protection Agency, April 2000.

DOE-ID, 1997a, *Comprehensive Remedial Investigation/Feasibility Study for the Idaho Test Reactor Area Operable Unit 2-13 at the Idaho National Engineering and Environmental Laboratory*, DOE/ID-10531, U.S. Department of Energy Idaho Operations Office.

DOE-ID, 1997b, *Final Record of Decision, Test Reactor Area, Operable Unit 2-13, Idaho National Engineering and Environmental Laboratory*, DOE/ID-10586, U.S. Department of Energy Idaho Operations Office, December 1997.

DOE-ID, 1998, Comprehensive Remedial Design/Remedial Action Work Plan for the Test Reactor Area, Operable Unit 2-13, DOE/ID-10643, Revision 0, U.S. Department of Energy Idaho Operations Office, September 1998.

DOE-ID, 2005a, *Waste Area Group 10, Operable Unit 10-08, Remedial Investigation/Feasibility Study Annual Status Report for Fiscal Year 2004*, DOE/NE-ID-11198, U.S. Department of Energy Idaho Operations Office, March 2005.

DOE-ID, 2005b, *Five-Year Review of CERCLA Response Actions at the Idaho National Laboratory,* DOE/NE-ID-11201, U.S. Department of Energy Idaho Operations Office, October 2005.

DOE-ID, 2008, *Operable Unit 10-08 Sitewide Groundwater and Miscellaneous Sites Remedial Investigation /Baseline Risk Assessment*, DOE/ID-11332, U.S. Department of Energy Idaho Operations Office, April 2008.

DOE-ID, 2012, *Performance Assessment for the Idaho National Laboratory Remote-Handled Low-Level Waste Disposal Facility*, DOE/ID-11421, Revision 1, U.S. Department of Energy Idaho Operations Office, May 2012.

DOE-ID, 2016, Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 7, 9, and 10 and Removal Actions, DOE/ID-10587, Revision 11. U.S. Department of Energy Idaho Operations Office, June 2016.

DOE-NR, 1998, *Final Record of Decision, Naval Reactors Facility, Operable Unit 8-08, Idaho National Engineering and Environmental Laboratory*, Idaho Falls, Idaho, Administrative Record No. AR5.1-10544, DOE Naval Reactors Idaho Branch Office; EPA, Region 10; Idaho Department of Health and Welfare, Division of Environmental Quality, September 1998.

DOE Order 435.1, Change 1, 2001, *"Radioactive Waste Management,"* U.S. Department of Energy.

EPA, 2015 "EPA Contract Laboratory Program Statement of Work for Organic Superfund Methods Multi-Media, Multi-Concentration SOM02.3," U.S. Environmental Protection Agency, September 2015.

IDAPA § 58.01.08, 2003, *"Idaho Rules for Public Drinking Water Systems,"* Idaho Administrative Procedures Act, Idaho Department of Environmental Quality.

IDAPA § 58.01.11, 1997, *"Ground Water Quality Rule,"* Idaho Administrative Procedures Act, Idaho Department of Environmental Quality.

INL, 2012a, *Evaluation of Radiological Sources with Potential to Contribute to Composite Groundwater Effects for the INL Remote-Handled Low-Level Waste Disposal Facility (DRAFT)*, INL/EXT-12-27909, Idaho National Laboratory, December 2012.

INL, 2017, *As-Built Characterization and Monitoring System for the RH-LLW Disposal Facility*, INL/EXT-17-43081, Idaho National Laboratory.

NNSA, 2010, "Powering the Nuclear Navy," http://nnsa.energy.gov/ourmission/poweringnavy, web page visited September 10, 2011.

PLN-5501, 2017, "Monitoring Plan for the Idaho National Laboratory Remote-Handled Low-Level Waste Disposal Facility", Idaho National Laboratory, October, 2017.

Willie, K. D. and A. Sierra, 2004, *Five-Year Review Document for the Naval Reactors Facility OU 8-08 Sites,* U.S. Department of Energy, Pittsburgh Naval Reactors Office, Idaho Branch Office, June 2004.

Westinghouse, 1997, *Final NRF Comprehensive Remedial Investigation/Feasibility Study, Waste Area Group 8, Naval Reactors Facility*, Idaho Falls, Idaho, DOE/ID-10432, Volumes 1 through 3, October 1997.