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300-FF-5 Operable Unit Remedy Implementation Sampling and Analysis Plan

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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APPROVED
By Ashley R Jenkins at 7:26 am, May 28, 2015

Release Approval   Date

Signature Sheet

Title DOE/RL-2014-42, *300-FF-5 Operable Unit Remedy Implementation Sampling and Analysis Plan*

Ray Corey

U.S. Department of Energy, Richland Operations Office

Signature _______________________ Date _______________

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U.S. Environmental Protection Agency

Signature _______________________ Date _______________

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Terms

AEA	*Atomic Energy Act of 1954*
ALARA	as low as reasonably achievable
ASTM	ASTM International, formerly American Society for Testing and Materials
AWLN	Automated Water Level Network
bgs	below ground surface
BTR	Buyer's Technical Representative
CAS	Chemical Abstracts Service
CCU	Cold Creek unit
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
CO_2	carbon dioxide
COC	contaminant of concern
CUL	cleanup level
DCE	dichloroethene
DO	dissolved oxygen
DOE	U.S. Department of Energy
DOE-RL	DOE-Richland Operations Office
DOT	U.S. Department of Transportation
DQA	data quality assessment
DQI	data quality indicator
DQO	data quality objective
DWS	drinking water standard
DUP	field duplicate
EA	enhanced attenuation
EB	equipment blank
ECO	Environmental Compliance Officer
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency

ERT	electrical resistivity tomography
FSO	Field Sampling Operations
FTB	full trip blank
FWS	Field Work Supervisor
FXR	field transfer blank
GC/MS	gas chromatography/mass spectrometry
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68)
HEIS	Hanford Environmental Information System
HDPE	high-density polyethylene
IC	ion chromatography
ICP	inductively coupled plasma
ICP/AES	inductively coupled plasma/atomic emission spectroscopy
ICP/MS	inductively coupled plasma/mass spectrometry
LCS	laboratory control sample
LRA	lead regulatory agency
MB	method blank
MDL	method detection limit
MNA	monitored natural attenuation
MS	matrix spike
MSD	matrix spike duplicate
NCO	Nuclear Chemical Operator
O&M	operations and maintenance
ORP	oxidation reduction potential
OU	operable unit
PPE	personal protective equipment
PQL	practical quantitation limit
PRZ	periodically rewetted zone
PSQ	principal study question
PVC	polyvinyl chloride

QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RAO	remedial action objective
RDR/RAWP	remedial design report/remedial action work plan
RCRA	*Resource Conservation and Recovery Act of 1976*
RCT	Radiological Control Technician
RDR	request for data review
RI/FS	remedial investigation/feasibility study
ROD	record of decision
RPD	relative percent difference
SAF	sample authorization form
SAP	sampling and analysis plan
SMR	Sample Management and Reporting
SPLIT	field split
SUR	surrogate
TCE	trichloroethene
TPA	Tri-Party Agreement
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
VFD	variable frequency drive
VOA	volatile organic analysis
VOC	volatile organic compound
WAC	*Washington Administrative Code*

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1 Introduction

This sampling and analysis plan (SAP) presents the plans for 300-FF-5 groundwater operable unit (OU) (Figure 1-1) remedy implementation, performance monitoring, and groundwater monitoring. The SAP is prepared in accordance with the groundwater remedial actions presented in Environmental Protection Agency (EPA) and Department of Energy (DOE), 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1* (hereinafter the 300 Area Record of Decision [ROD]/ROD Amendment). This SAP supplements information provided in the following documents:

- DOE/RL-2014-13, *Integrated Remedial Design Report/Remedial Action Work Plan for the 300 Area* (hereinafter the Integrated Remedial Design Report/Remedial Action Work Plan [RDR/RAWP])[1]
- DOE/RL-2014-13-ADD2, *Remedial Design Report/Remedial Action Work Plan for the 300 Area Groundwater*[1]

The 300-FF-5 OU comprises groundwater contaminated by releases from facilities and waste sites associated with past operation of uranium fuel production, research, and development in the 300 Area Industrial Complex. The 300 Area ROD/ROD Amendment (EPA and DOE, 2013) identifies uranium, gross alpha, nitrate, tritium, trichloroethene (TCE), and *cis*-1,2-dichloroethene (DCE) as the groundwater contaminants of concern (COCs). Table 1-1 summarizes the groundwater remedy implementation components covered in this SAP.

Table 1-1. Major Components of the Selected Groundwater Remedy

300-FF-1 and 300-FF-2 OUs	300-FF-5 OU
EA of uranium source mass using sequestration by phosphate application in the vadose zone and PRZ, and enhanced attenuation of uranium using sequestration by phosphate application at the top of the aquifer	MNA for nitrate and tritium downgradient of the 618-11 Burial Ground, and TCE and *cis*-1,2-DCE at the 300 Area Industrial Complex
	Groundwater monitoring for TCE, *cis*-1,2-DCE, uranium, and gross alpha at the 300 Area Industrial Complex, uranium and gross alpha downgradient of the 618-7 Burial Ground, and tritium and nitrate downgradient of the 618-11 Burial Ground
	EA of uranium using sequestration by phosphate application at the top of aquifer
	Institutional controls*

* Details are provided in Section 2.1 of the Integrated RDR/RAWP (DOE/RL-2014-13, *Integrated Remedial Design Report/ Remedial Action Work Plan for the 300 Area*).

DCE	= dichloroethene	OU	= operable unit
EA	= enhanced attenuation	PRZ	= periodically rewetted zone
MNA	= monitored natural attenuation	TCE	= trichloroethene

This SAP supersedes the following documents or document sections:

- DOE/RL-2002-11, *300-FF-5 Operable Unit Sampling and Analysis Plan* (modified by TPA-CN-611, *Tri-Party Agreement Change Notice Form: DOE/RL-2002-11, Rev 2, 300-FF-5 Operable Unit Sampling and Analysis Plan*)

[1] Documents have been completed as Draft A but have undergone EPA review and comment resolution.

- DOE/RL-2000-59, *Sampling and Analysis Plan for Aquifer Sampling Tubes* (modified by TPA-CN-612, *Tri-Party Agreement Change Notice Form: DOE/RL-2000-59, Sampling and Analysis Plan for Aquifer Sampling Tubes, Rev 1*), relevant sections
- DOE/RL-95-73, *Operation and Maintenance Plan for the 300-FF-5 Operable Unit*

Contaminated groundwater that migrates into the 300 Area from other areas, including offsite and the 200-PO-1 OU on the Central Plateau, is not part of the 300-FF-5 OU and is not addressed in this SAP. *Resource Conservation and Recovery Act of 1976* (RCRA) and *Atomic Energy Act of 1954* (AEA) monitoring within this geographic area is also not addressed in this SAP. These other programs are addressed as follows:

- RCRA monitoring at the 300 Area Process Trenches, currently performed through WHC-SD-EN-AP-185, *Groundwater Monitoring Plan for the 300 Area Process Trenches*
- Sitewide AEA and surveillance groundwater monitoring, including monitoring of the offsite nitrate contamination southwest of the 300 Area, currently performed via DOE/RL-2012-59, *Surveillance Groundwater Monitoring on the Hanford Site*
- 200-PO-1 OU groundwater monitoring, currently performed via DOE/RL-2003-04, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* (as modified by TPA-CN-205, *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: DOE/RL-2003-4, Revision 1, Sampling and Analysis Plan for the 200-PO-1 Operable Unit*)

1.1 Project Scope and Objective

This SAP provides quality assurance (QA) requirements, operational procedures, and sampling and analysis requirements to meet the following remedial action objectives (RAOs) set forth in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013):

- RAO 1—Prevent human exposure to groundwater containing COC concentrations above cleanup levels (CULs).
- RAO 7—Restore groundwater impacted by Hanford Site releases to CULs, which include drinking water standards (DWSs), within a time frame that is reasonable given the particular circumstances of the site.

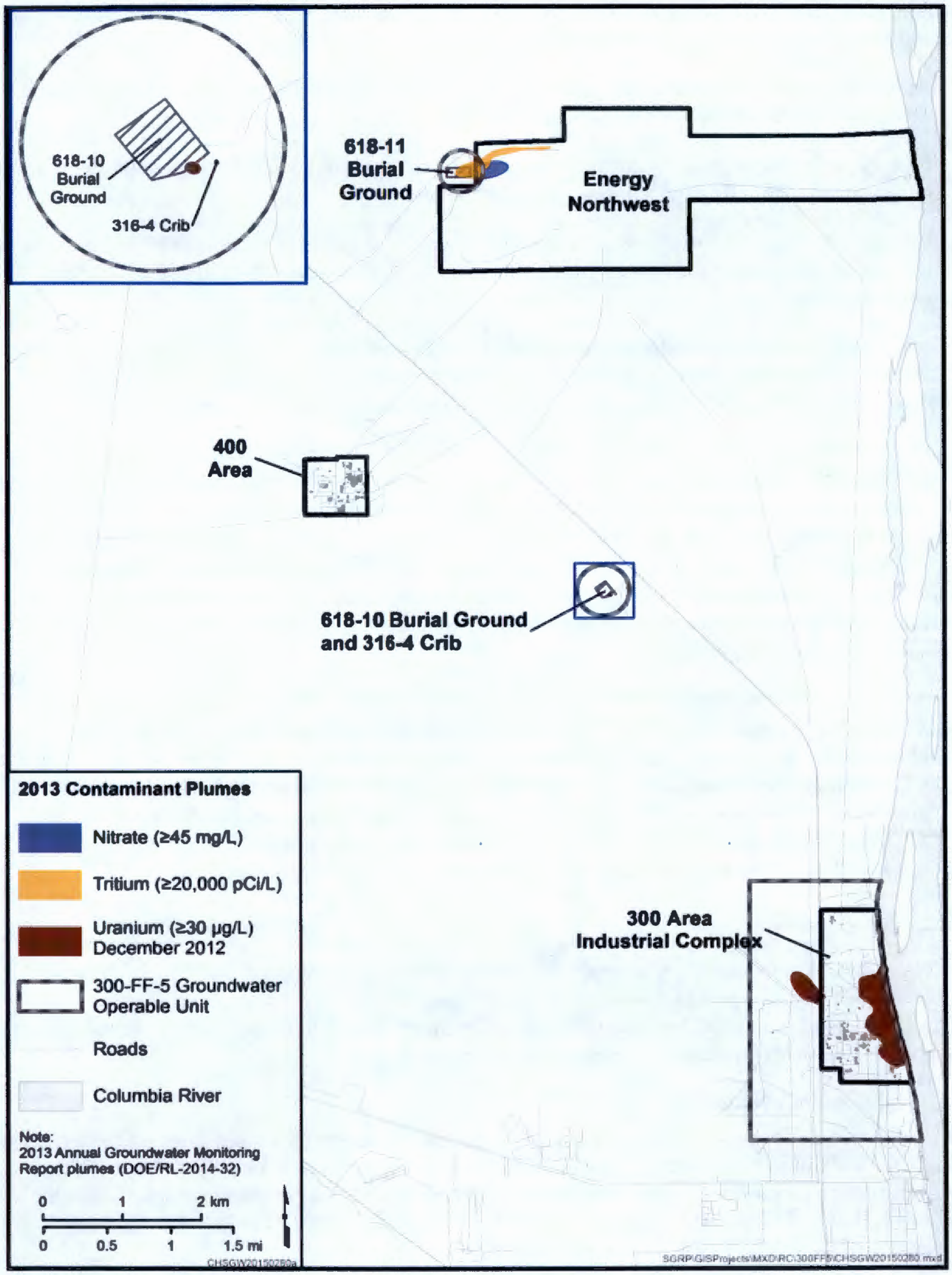


Figure 1-1. 300-FF-5 OU

The following remediation elements, implemented through this SAP, will result in the measurements necessary to gauge performance of the remedy:

- Implementation of the enhanced attenuation (EA) remedy to sequester uranium in the vadose zone, periodically rewetted zone (PRZ), and aquifer within the 1 ha (3 ac) EA area
- Remedy performance groundwater monitoring for the EA remedy implemented to sequester uranium in the vadose zone, PRZ, and aquifer within the EA area
- Remedy performance groundwater monitoring for monitored natural attenuation (MNA) of nitrate and tritium downgradient of the 618-11 Burial Ground, and TCE and *cis*-1,2-DCE at the 300 Area Industrial Complex
- Remedy performance groundwater monitoring for attainment of CULs of TCE, *cis*-1,2-DCE, uranium, and gross alpha at the 300 Area Industrial Complex; uranium and gross alpha downgradient of the 618-7 Burial Ground; and tritium and nitrate downgradient of the 618-11 Burial Ground

As part of the data quality objective (DQO) process, described in Appendix A, historical sampling locations and analytical results generated from the 300-FF-5 OU monitoring network from 2004 through 2014 were reviewed in conjunction with this SAP. Locations of monitoring wells with respect to the 2013 plume configurations were analyzed with the objective of optimizing the current well network and sampling requirements. The analysis was directed at defining those wells needed for contaminant monitoring and determination of an appropriate sampling frequency. The DQO provides the criteria applied to identify the wells needed for monitoring of contaminant conditions and the selection of an appropriate sampling frequency.

The monitoring network wells identified in this SAP are designed to collect groundwater data sufficient to monitor the effectiveness of the 300-FF-5 OU groundwater remedy in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013). These data will be reported annually. Performance monitoring data for the EA remedy implementation will be reported in EA performance report(s). The data gathered under this plan satisfy *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) requirements (40 CFR 300.430(b), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy").

1.2 Background

Hydrogeology, groundwater flow, groundwater contamination, and sources of contamination are presented in Chapters 3 and 4 of the Remedial Investigation/Feasibility Study (RI/FS) Report (DOE/RL-2010-99, Remedial Investigation/Feasibility Study for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units). Relevant items are summarized in this section.

1.2.1 Site Geology/Hydrology

The ground surface in the 300 Area Industrial Complex is flat, except for a steep slope on the eastern edge down to the Columbia River, which is the only surface water feature in the area. For the rest of the 300 Area, surface elevations change from approximately 137 m (449 ft) above mean sea level at the inland 618-11 Burial Ground to approximately 115 m (377 ft) at the 300 Area Industrial Complex (Section 3.1 of DOE/RL-2010-99, the RI/FS Report).

The vadose zone comprises backfill materials and unconsolidated gravels and sand of the Hanford formation. In the 300 Area Industrial Complex, the average thickness of the vadose zone is 10 m (33 ft). The thicknesses of the vadose zone at the 618-10 and 618-11 Burial Grounds are 21 and 19 m (68 and 63 ft), respectively. However, the vadose zone thickness varies with the seasonal stages of the Columbia

River and distance inland from the river. Rising groundwater elevations resulting from higher Columbia River stages seasonally saturate deeper portions of the vadose zone, while lower river stages result in falling groundwater elevations that de-water these same deeper portions of the vadose zone. These fluctuating groundwater elevations create the PRZ shown in Figure 1-2. Generally, wells adjacent to the river within the 300 Area Industrial Complex show higher variation in response to river stage changes than wells located at increasing distance from the shoreline (Section 2.4.3 of PNNL-22048, *Updated Conceptual Model for the 300 Area Uranium Groundwater Plume*). Wells at the 618-10 and 618-11 Burial Grounds typically do not show a response to river stage changes.

The unconfined aquifer occurs in the highly permeable, gravel-dominated Hanford formation and in the underlying, less permeable sands and gravels of the Ringold Formation unit E (Figure 1-2). A finer grained interval with very low permeability occurs within the Ringold Formation unit E in the 300 Area Industrial Complex. Although this finer-grained interval is saturated, it does not yield significant groundwater (Section 2.1 of PNNL-17666, *Volatile Organic Compound Investigation Results, 300 Area, Hanford Site, Washington*). Paleochannels carved into Ringold Formation unit E sediments are filled with Hanford formation gravels and act as preferential pathways for groundwater flow and for intrusion of river water during periods of high river stage (Section 4.4.4.3 of DOE/RL-2010-99, the RI/FS Report). The Ringold Formation lower mud unit is a confining layer (i.e., aquitard at the base of the unconfined aquifer) and is characterized by very low-permeability fine-grained sediment. This hydrologic unit prevents further downward movement of groundwater contamination to the deeper aquifers. The thickness of the unconfined aquifer along the Columbia River shoreline is about 25 m (80 ft).

An additional gravelly interval referred to as the Cold Creek unit (CCU) lies between the Hanford formation and underlying Ringold Formation unit E sediments in some areas near the 618-11 Burial Ground. The CCU is less permeable than Hanford formation sediment but more permeable than Ringold Formation sediment (Section 3.6.3 of DOE/RL-2010-99, the RI/FS Report).

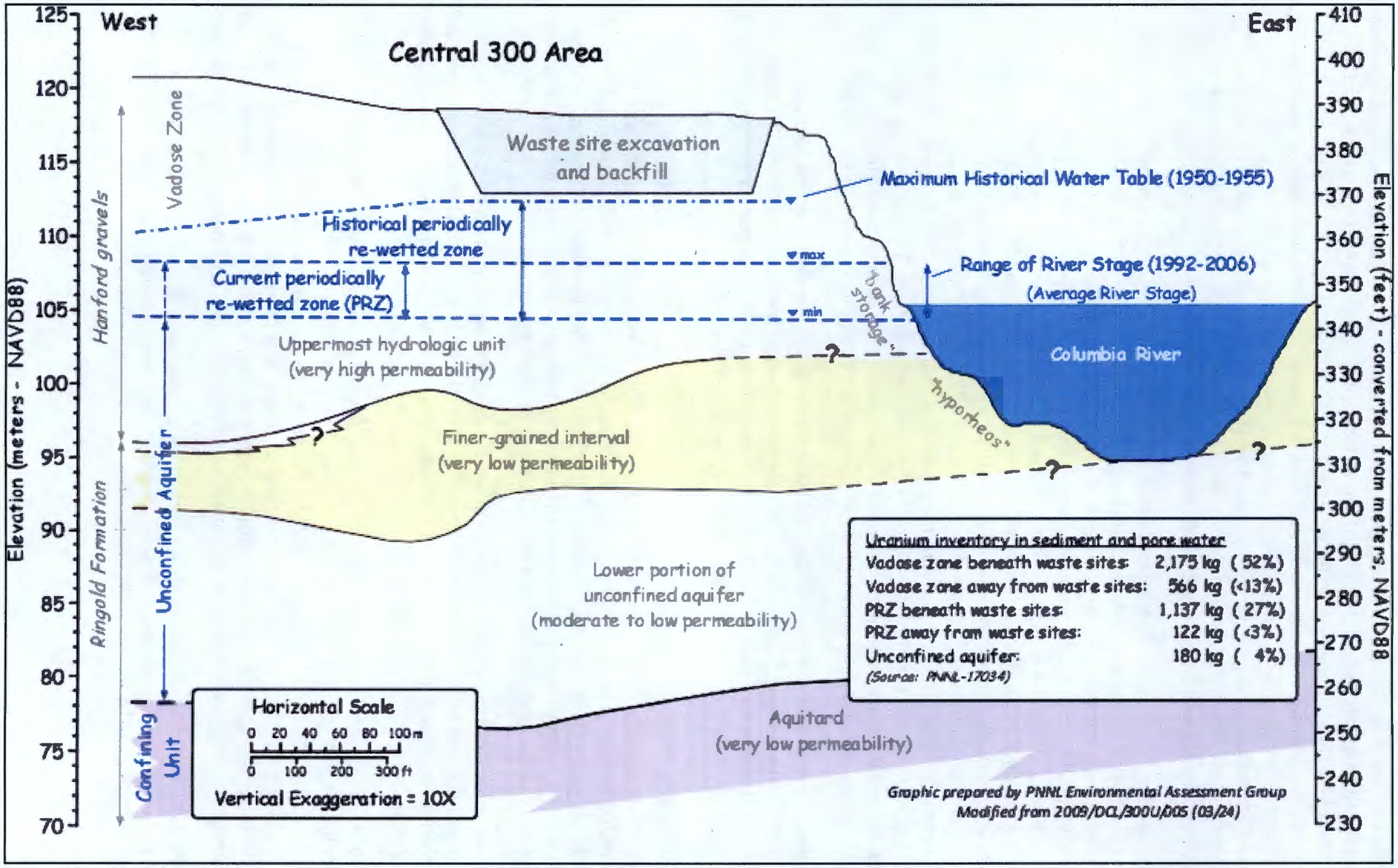
1.2.2 Groundwater Flow

Groundwater in the unconfined aquifer discharges to the Columbia River via upwelling through the riverbed and riverbank seeps. The flux from the unconfined aquifer is very low, compared to the flow of the river. Because the river stage regularly fluctuates up and down, flow beneath the shoreline oscillates back and forth, with river water intruding into the unconfined aquifer and mixing with groundwater at times. When the river stage drops quickly to a low elevation, riverbank seeps appear.

Groundwater flow velocities beneath the 300 Area in the Hanford formation portion of the aquifer are rapid, with observed rates up to 18 m/day (59 ft/day). However, the hydraulic gradients change direction in response to river stage, which fluctuates on seasonal and multiyear cycles. Consequently, groundwater flow is not always directed toward the river.

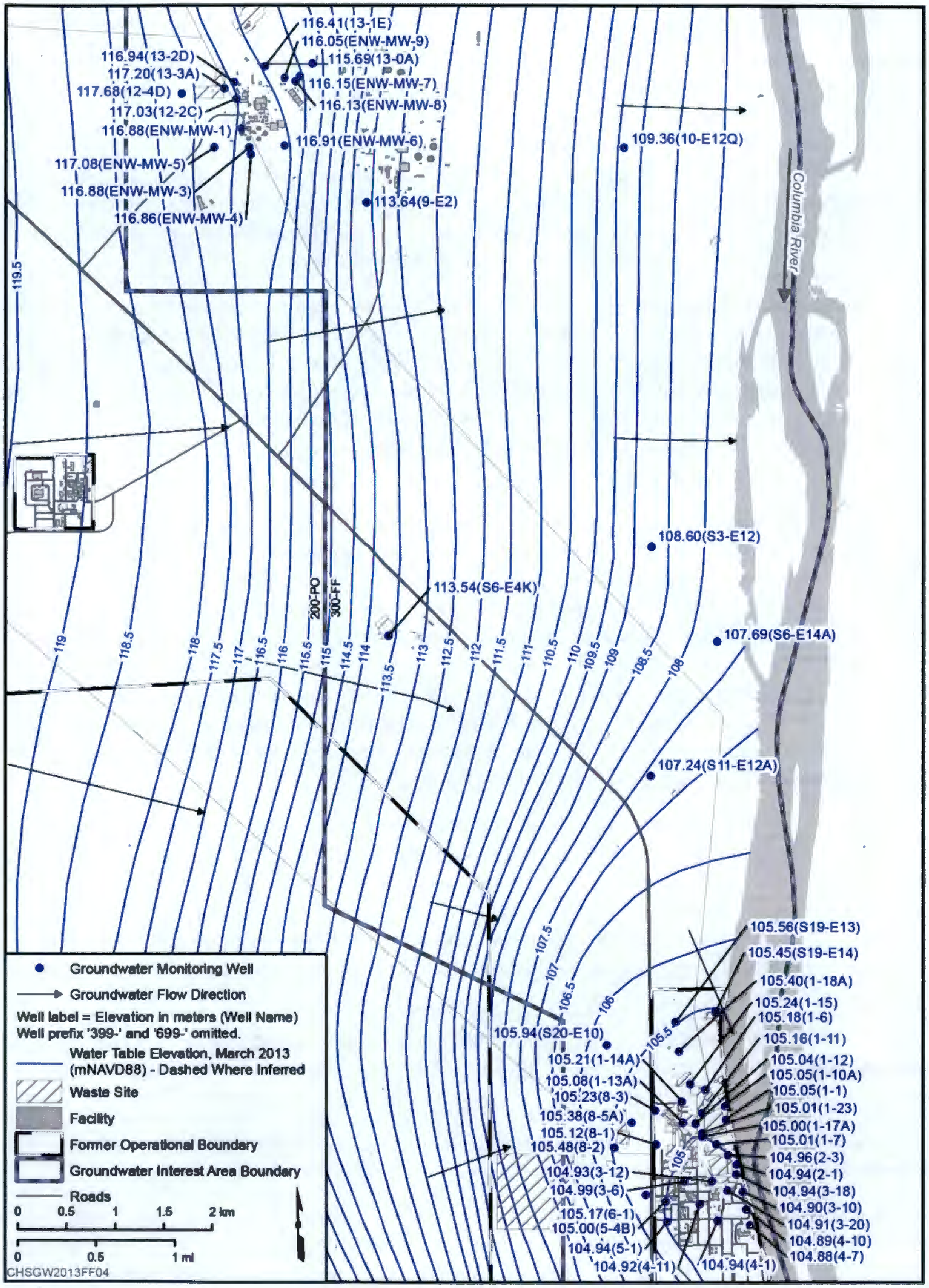
In general, regional groundwater flow converges on the 300 Area from the northwest, west, and southwest, inducing an east-southeast flow direction in the 300 Area (Figure 1-3). During periods of extended high river stage (typically March through June), water flows from the river into the aquifer. The rise and fall of the river stage create a dynamic zone of interaction between groundwater and river water (Figure 1-2) affecting groundwater flow patterns, contaminant transport rates (e.g., uranium in groundwater), groundwater geochemistry, contaminant concentrations, and contaminant attenuation rates.

At the 618-11 Burial Ground, groundwater flow is primarily to the east (Figure 1-3). The migration pathway of the tritium plume appears to be closely related to the lateral variability in aquifer permeability (Section 3.6.3 of DOE/RL-2010-99, the RI/FS Report).



Sources: DOE/RL-2011-47, *Proposed Plan for Remediation of the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units.*
Uranium inventory in the figure inset is from PNNL-17034, *Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington.*
NAVD88, *North American Vertical Datum of 1988.*

Figure 1-2. Principal Subsurface Features with PRZ and Uranium Inventory Estimates



Sources: DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*.
NAVD88, *North American Vertical Datum of 1988*.

Figure 1-3. Water Table Map for the 300-FF-5 OU (2013)

1.2.3 Sources of Groundwater Contamination

Groundwater contamination observed in the 300-FF-5 OU resulted from activities that occurred in the past, especially during the peak nuclear fuels and plutonium production years of the 1950s and 1960s. High-volume waste effluents resulting from fabrication of nuclear fuel assemblies were sent to ponds and trenches for infiltration into the soil column and formed groundwater mounds beneath the disposal sites. Effluents were typically acidic, which promoted movement through the vadose zone, and contained significant quantities of uranium. Volatile organic compounds (VOCs), such as TCE, were used and present in the effluent. Solid wastes from 300 Area Industrial Complex activities were buried at locations within the complex or sent to outlying burial grounds within the 300 Area.

Contaminants retained in the vadose zone at most of the disposal facilities, including solid waste burial grounds, have been removed and disposed via interim remedial actions. Residual contamination currently observed in soil and groundwater beneath the 300 Area persists for a variety of reasons. Attenuation of these contaminants is dependent on contaminant properties and continues to occur by natural processes along environmental pathways away from the source locations. Contamination that has entered the groundwater ultimately discharges to the Columbia River via upwelling through the riverbed and occasionally through riverbank seeps.

Contaminants can remain in the vadose zone following active liquid waste discharge as dissolved fractions within pore water or sorbed to soil until sufficient moisture is available for transport. Uranium is present in the lower vadose zone. The form uranium takes in solution is influenced by alkalinity, which affects uranium mobility. Uranium tends to sorb to aquifer matrix mineral surfaces and be less mobile when alkalinity in the aquifer is lowered. Columbia River water is low in alkalinity. At high river levels, river water infiltrates inland, and portions of the lower vadose zone become periodically rewetted (PRZ) by a mix of groundwater and river water that is lower in alkalinity than pure groundwater. As a result, uranium in this zone of mixed river water/groundwater is sorbed to a large degree on the mineral surfaces. The combination of uranium sorption and dilution results in diminished uranium concentrations in the river water/groundwater mixing zone during high river stage.

Further inland from the river water/groundwater mixing zone, the river stage creates an interruption of the natural groundwater gradient towards the river, causing groundwater levels to rise into the PRZ. In these inland areas, the relatively high-alkalinity groundwater comes in contact with uranium in the PRZ (in the form of both entrained vadose zone pore water and mineral-sorbed forms). Under these conditions, uranium takes the form of a negative ion carbonate complex, which has less tendency to sorb. The overall effect is that in the inland areas, uranium concentrations rise in groundwater as the water table rises during high river stages.

The 618-7 Burial Ground was the source of uranium detected in groundwater at this site. Uranium contamination in groundwater developed in 2008 as a result of infiltration of dust-control water during implementation of interim remedial actions.

The 618-11 Burial Ground was the source of nitrate and tritium gas that interacted with vadose zone moisture and eventually entered groundwater downgradient of this waste site.

The 618-10 Burial Ground and 316-4 Crib were the sources of uranium detected in groundwater at the 618-10 Burial Ground. Uranium concentrations in nearby downgradient wells increased in 2004, and again in 2012, following application of dust-control water during implementation of interim remedial actions.

1.2.4 Groundwater Contamination

Groundwater contaminants that exceed CULs specified in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013) for the 300-FF-5 OU are uranium, gross alpha, tritium, nitrate, TCE, and *cis*-1,2-DCE. Groundwater contaminants are not present at concentrations that are of ecological concern or pose an ecological risk to populations and communities in riparian, near shore, and river environments (Section 7.5 of DOE/RL-2010-99, the RI/FS Report; DOE/RL-2011-47, *Proposed Plan for Remediation of the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units*).

Uranium contamination in groundwater that exceeds the 30 µg/L CUL covers approximately 0.5 km^2 (0.2 mi^2) in the 300 Area Industrial Complex. There are smaller areas of uranium groundwater contamination downgradient of the 618-7 and 618-10 Burial Grounds. The volume of the main uranium plume is approximately 1,000,000 m^3 (35 million ft^3), with a dissolved uranium mass of approximately 60 kg (132 lb). Figure 1-4 presents the groundwater uranium plumes for January 2014 (low river stage) and May 2013 (high river stage).

Tritium in groundwater that exceeds the 20,000 pCi/L CUL occurs downgradient from the 618-11 Burial Ground. Tritium concentrations from the 618-11 Burial Ground (Figure 1-5) do not, and are not predicted to, affect the Columbia River above the CUL.

Nitrate concentrations exceed the 45 mg/L CUL downgradient from the 618-11 Burial Ground (Figure 1-6).

Nitrate in the 300 Area Industrial Complex exceeds the CUL in areas where groundwater has been affected by offsite activities. Elevated nitrate concentrations are detected in the southern portion of the 300 Area and result from onsite migration of nitrate-contaminated groundwater from sources to the southwest. Nitrate from offsite is not part of the 300-FF-5 OU.

VOCs that exceed the CUL in the 300 Area Industrial Complex groundwater are TCE and *cis*-1,2-DCE. TCE concentrations that exceed the CUL of 4 µg/L are detected sporadically. *cis*-1,2-DCE has been detected consistently at concentrations exceeding the CUL of 16 µg/L at a well (399-1-16B) that is screened in Ringold Formation gravelly sediment in the lower portion of the unconfined aquifer. In 2011, *cis*-1,2-DCE was also detected above the CUL at a new well (399-1-57), located approximately 80 m (262 ft) further downgradient and screened at mid-depth in the unconfined aquifer in the Ringold Formation unit E sandy gravel; the lowest extent of the screen just enters the top of the finer-grained interval within the Ringold Formation unit E (page 4-221 of DOE/RL-2010-99, the RI/FS Report). The origin for *cis*-1,2-DCE is attributed to degradation of TCE and tetrachloroethene historically disposed of to nearby liquid waste sites.

Natural attenuation through biodegradation is evident in historical monitoring results from Well 399-1-16B, where TCE has degraded to *cis*-1,2-DCE. Over the past 20 years, TCE concentrations from this well have decreased to below the CUL, whereas *cis*-1,2-DCE concentrations have remained fairly stable. *cis*-1,2-DCE can then further degrade anaerobically to vinyl chloride, which then degrades either anaerobically or aerobically to carbon dioxide (CO_2). *cis*-1,2-DCE can also degrade directly to CO_2 under aerobic conditions. The absence of vinyl chloride in downgradient wells indicates that these contaminants are degrading aerobically. The limited areal and vertical extent of VOCs in groundwater shows that these natural attenuation processes are preventing the persistence and significant migration of VOCs (Sections 4.8.4, 5.6, and 5.9 of DOE/RL-2010-99; Sections 1.2 and 3.3 of PNNL-17666).

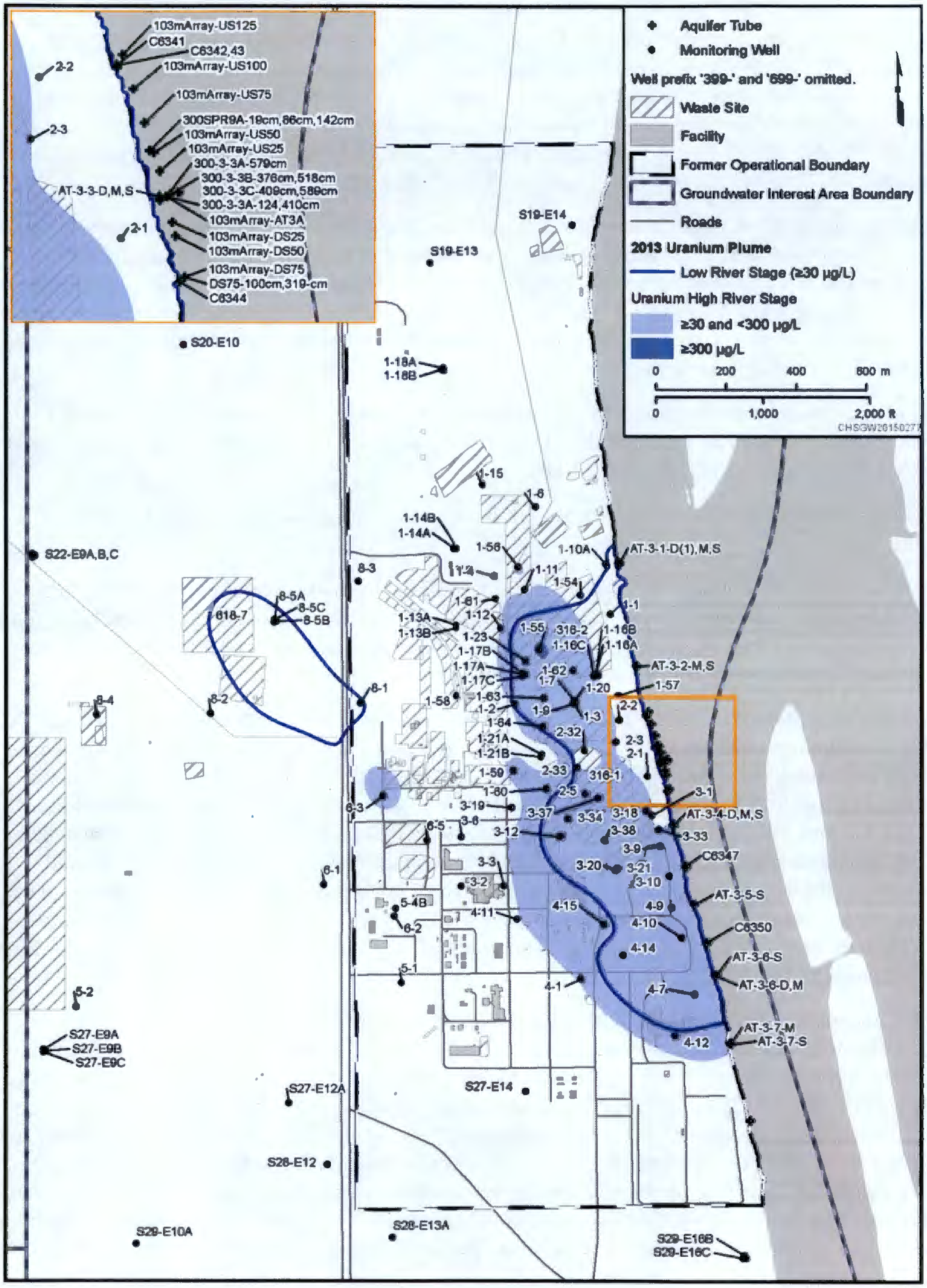


Figure 1-4. Uranium Plume in Groundwater (2013)

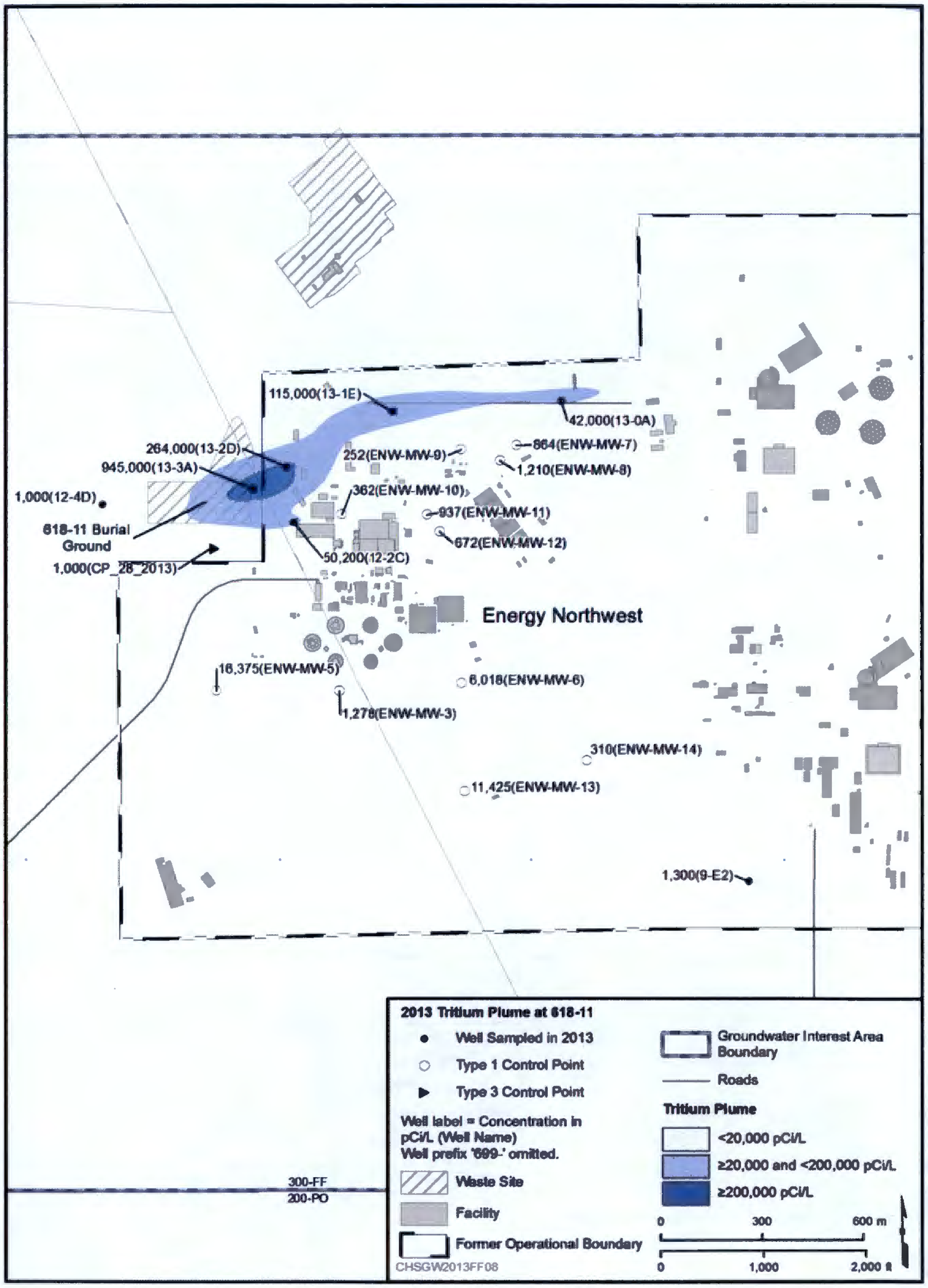


Figure 1-5. Tritium Plume from 618-11 Burial Ground (2013)

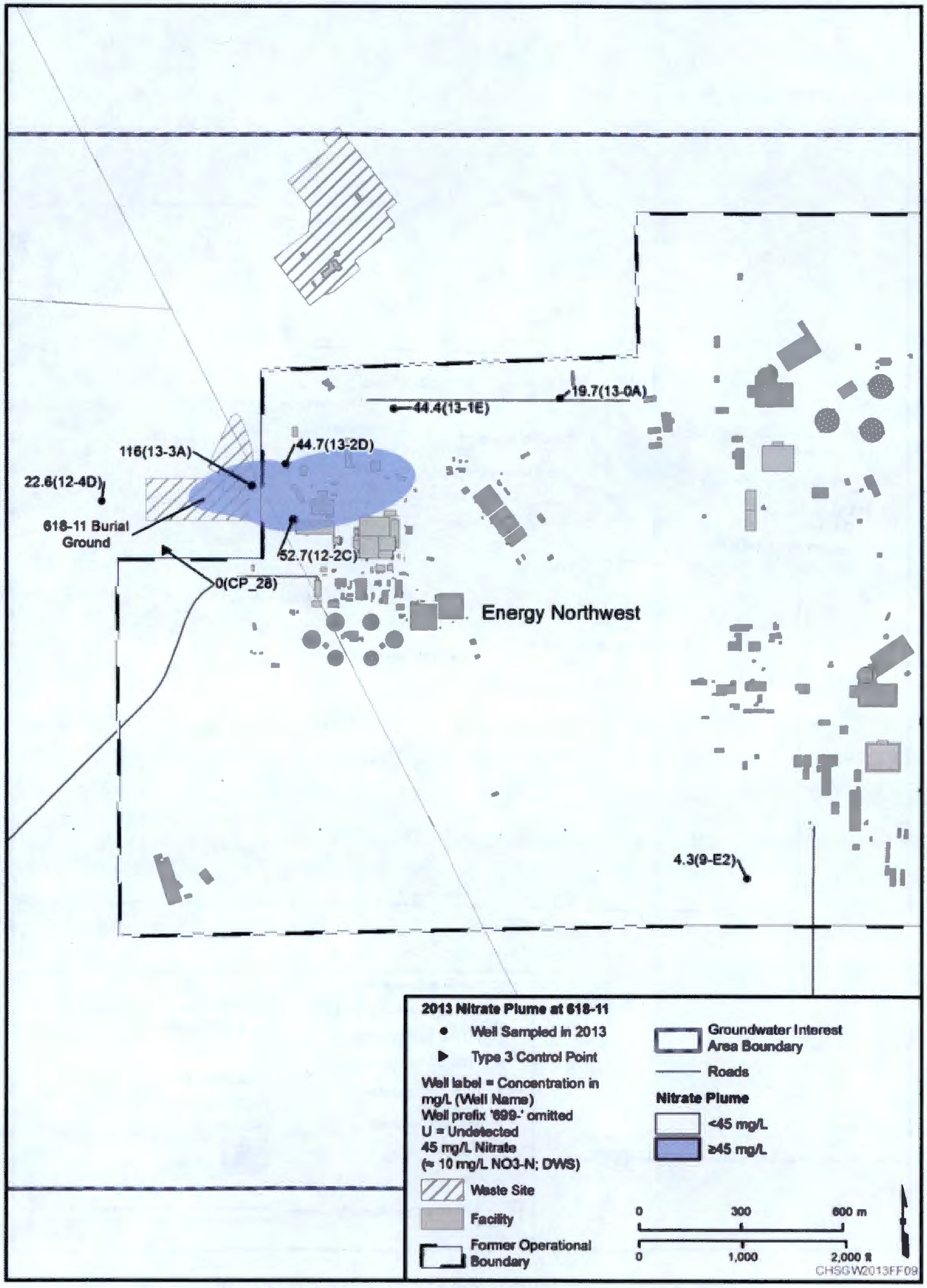


Figure 1-6. Nitrate Plume from 618-11 Burial Ground (2013)

TCE and *cis*-1,2-DCE concentrations exceeding CULs occur in the finer-grained sediment interval, within Ringold Formation unit E (Figure 1-2), with less capacity to yield or transmit groundwater. The greatly restricted hydraulic flow in these fine-grained sediments has contained the VOCs that migrated into this interval following their disposal decades ago, and has minimized migration of the VOCs into the more transmissive portions of the aquifer overlying or adjacent to the finer-grained interval. Monitoring wells are not screened in this interval because it has a very low permeability and does not readily yield groundwater.

1.2.5 Selected Remedy

The elements of the remedy for the 300-FF-5 OU are summarized in the following subsections.

1.2.5.1 Enhanced Attenuation of Uranium

Attenuation of uranium will be enhanced by sequestering uranium in the vadose zone and PRZ. Uranium sequestration will also be used in the top of the aquifer to reduce the mobility of uranium that may be mobilized during the vadose zone treatment process. Uranium sequestration involves infiltrating/injecting phosphate solutions to the vadose zone and PRZ to sequester, or bind, residual mobile uranium to form insoluble minerals. The target area for application of the phosphate solutions is a 1 ha (3 ac) area containing a persistent source of uranium contamination to groundwater. Uranium sequestration in the vadose zone and PRZ is anticipated to reduce the mass of soluble uranium entering the groundwater in this area and, thereby, reduce the restoration time frame for uranium in the groundwater.

Uranium sequestration will be implemented using a staged approach. Stage A will consist of performing infiltration/injection in one section of the EA area, covering approximately 0.3 ha (0.75 ac). The treatment effectiveness of the Stage A phosphate application will be evaluated by comparing the overall decrease in uranium leachability in vadose zone and PRZ soil samples, taking into consideration that a fate and transport model assumes that 50 percent of the mobile uranium will be reduced from phosphate treatment. Treatment effectiveness will also be evaluated based on other factors from the implementation of Stage A, such as phosphate distribution efficiency, the degree of uranium mobilization to groundwater, and changes to hydraulic conductivity of the aquifer due to precipitation of phosphate minerals.

The enhanced attenuation RA for the 300 Area is considered complete upon implementation of Stage A and Stage B infiltration and injection in the EA area unless otherwise agreed to by DOE and EPA following the Stage A performance delivery report. Stage B will be performed if a high likelihood of treatment effectiveness can be expected, based upon all the considerations from the Stage A evaluation. If Stage B is performed, the Stage A results will be used to refine the Stage B approach for the remaining untreated portions of the EA area. On treatment completion, an infiltration/injection completion report will be prepared and submitted to the regulatory agencies. The infiltration/injection completion report will include a comparison of the pre- and post-treatment attenuation time frames for achieving the CUL for uranium. Figure 2-1 presents the Stage A EA area, infiltration area, injection wells, and monitoring locations based on the post-ROD field investigation results presented in SGW-58736, *300-FF-5 Enhanced Attenuation Area Location Selection.* Figure 2-2 presents the preliminary Stage B EA area.

Preliminary data collected during the supplemental post-ROD field investigation (SGW-56993, *Sampling Instruction for the 300-FF-5 Operable Unit Supplemental Post ROD Field Investigation*) has provided additional delineation of the highest concentrations of total uranium in soil in the vicinity of the North Process Pond (316-2) and Process Trenches (316-5). The location and layout of the EA area has been revised to provide optimum coverage of these higher uranium concentrations. The updated model will be rerun to estimate the times required to achieve the CUL for uranium in the groundwater following completion of Stages A and B uranium sequestration and under a no-action scenario.

1.2.5.2 Monitoring Natural Attenuation

MNA will be used for nitrate and tritium, downgradient of the 618-11 Burial Ground, and TCE and *cis*-1,2-DCE at the 300 Area Industrial Complex.

Natural attenuation of nitrate and tritium in groundwater downgradient of the 618-11 Burial Ground will occur through a combination of dispersion during transport and natural radiological decay for tritium. Computer modeling predicts that tritium concentrations will decrease to below the CUL by 2031 and will not impact the river above CULs.

Natural attenuation of TCE and *cis*-1,2-DCE in groundwater from the 300 Area Industrial Complex will occur primarily through physical attenuation (diffusion and dispersion) and biodegradation.

1.3 Data Quality Objective Summary

The EPA's seven-step DQO process (EPA/240/B-06/001, *Guidance on Systematic Planning Using the Data Quality Objectives Process*) was used to guide development of remedy implementation for the 300-FF-5 OU. The remedy implementation for MNA was designed consistent with EPA guidance on monitoring programs for natural attenuation remedies (EPA 600/R-11/204, *An Approach for Evaluating the Progress of Natural Attenuation in Groundwater*). The report summarizing the output of the DQO process is provided as Appendix A.

The purpose of the DQO process was to support the optimization of the remedy performance monitoring networks for the 300-FF-5 Groundwater OU until CULs are attained. As described in Appendix A, the DQO process for the 300-FF-5 groundwater OU established a framework to answer four main questions:

1. Are the COCs attenuating according to expectations?
2. Does the EA using phosphate treatment reduce leachable uranium in the vadose zone and PRZ as expected?
3. Has contaminated groundwater been restored to CULs for each COC?
4. Have the lateral extents of the uranium, tritium, and nitrate groundwater contamination plumes above CULs changed?

1.4 Contaminants

The COCs for CERCLA groundwater monitoring are provided in Table 1-2. The CERCLA contaminants listed are those identified in the 300-FF-5 ROD/ROD Amendment (EPA and DOE, 2013).

Table 1-2. 300-FF-5 Groundwater OU COCs

COC	CAS Number	Location
Uranium	7440-61-1	300 Area Industrial Complex and 618-7 Burial Ground
Tritium	10028-17-8	618-11 Burial Ground
Nitrate (as NO_3)	14797-55-8	618-11 Burial Ground
TCE	79-01-6	300 Area Industrial Complex
cis-1,2-DCE	156-59-2	300 Area Industrial Complex
Gross Alpha	12587-46-1	300 Area Industrial Complex and 618-7 Burial Ground

CAS = Chemical Abstracts Service
COC = contaminant of concern
DCE = dichloroethene
TCE = trichloroethene

1.5 Project Schedule

This SAP will direct CERCLA remedy performance monitoring activities needed for the 300-FF-5 OU until CULs are attained. The yearly sampling schedule will be established by the Sample Management and Reporting (SMR) organization using processes and software applications, such as *Sample Management Integrated Lifecycle Environment*, which optimizes the overall number of well sampling trips and limits schedule redundancy. SMR tracks overlapping requirements, so single sampling well events can co-sample wells and optimize schedules.

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2 Enhanced Attenuation System Installation Plan

This chapter describes the installation of infrastructure required for the Stage A implementation of the EA remedy to sequester uranium in the vadose zone, PRZ, and aquifer. The Stage A EA area, shown in Figure 2-1, is used as the basis for the installation plan.

The preliminary Stage B EA area is presented in Figure 2-2 and is based on the post-ROD field investigation results presented in SGW-58736. The enhanced attenuation RA for the 300 Area is considered complete upon implementation of Stage A and Stage B infiltration and injection in the EA area unless otherwise agreed to by DOE and EPA following the Stage A performance delivery report. Stage B will be performed if a high likelihood of treatment effectiveness can be expected, based on all the considerations from the Stage A evaluation, such as overall decrease in uranium leachability in vadose zone and PRZ soil samples, phosphate distribution efficiency, degree of uranium mobilization to groundwater, and changes to hydraulic conductivity of the aquifer due to precipitation of phosphate minerals. If Stage B is performed, the Stage A results will be used to refine the Stage B infrastructure design.

An ecological and cultural resources review (MSA-1403636, *Ecological and Cultural Clearance for Sequestration Remedial Activities in the 300 Area of the Hanford Site (HCRC# 2014-300-004, ECR-2014-302)*) for the EA area project activities and infrastructure installation was conducted in August 2014.

2.1 Infiltration System Installation

A phosphate infiltration system will be installed within the Stage A EA area (Figure 2-1). The infiltration network will consist of high-density polyethylene (HDPE) liquid distribution lines (irrigation drip line or perforated tubing) installed below ground using horizontal directional drilling methods (or equivalent) or trenching. The liquid distribution lines will be installed approximately 1.8 m (6 ft) below ground surface (bgs) to prevent accumulation and wicking of sodium and phosphate up into the surficial soil, which would inhibit the establishment and growth of vegetation.

The specification of liquid distribution lines will be selected to achieve a liquid application rate of at least 511 lpm (135 gpm) over the 0.3 ha (0.75 ac) Stage A EA area. The spacing of the perforations will be no greater than 3 m (10 ft). The final specifications for the liquid distribution lines will be determined based on the limitations imposed by the installation methods achievable in the field and recommendations from the infiltration system installation subcontractor. For the purpose of this SAP, it is assumed that an Ore-Max™ Max-Emitterline irrigation drip line will be used for the liquid distribution lines. Specifications for the infiltration network using these drip lines are summarized as follows:

- Drip lines will consist of continuous HDPE tubing with emitters installed internally and welded to the inside of the tubing. Emitters will be rated at 8 lpm (2 gpm) each and spaced 0.36 m (14 in.) apart along drip lines.
- For the 0.3 ha (0.75 ac) Stage A EA area, drip lines will be spaced 1.98 m (78 in.) apart, resulting in a total of 36 lines aligned southeast to northwest.

™ Ore-Max is a trademark of the Ore-Max Division of Wade Rain Inc., Portland, Oregon.

2.2 Injection Well Installation

Nine combination PRZ/aquifer injection wells will be installed within the Stage A EA area (Figure 2-1). Injection well boreholes will be drilled with resonant sonic drilling equipment. Alternative drilling methods may be used with approval of the OU Technical Lead in consultation with the well maintenance and drilling manager. To avoid potential impact to the representativeness of vadose zone and PRZ soil, all efforts must be made to drill without the use of slurry makeup water. In the event that drilling slurry makeup water is needed, the situation must be discussed with project technical staff before proceeding.

Well boreholes will be drilled with a 25 cm (10 in.) diameter outer casing to allow construction of a 15 cm (6 in.) diameter injection well (i.e., the boreholes will be drilled to maintain a minimum 5 cm [2 in.] annular space around the permanent well, per WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"). The boreholes will be drilled approximately 5 m (18 ft) deeper than the seasonally low water table. Assuming a water table depth of 9.8 m (32 ft), boreholes will be drilled to a depth of approximately 15 m (48 ft). The final total depth of the boreholes will be confirmed by the drilling Buyer's Technical Representative (BTR) and site geologist and may change depending on the actual water stage, ground surface elevation, and/or subsurface conditions encountered. In the event that subsurface conditions prevent completion of the borehole to its intended depth, the OU Project Manager will be consulted to determine the path forward (e.g., re-drill the borehole at another location or accept the modified final depth for that borehole).

Table 2-1 presents construction details for the injection wells. Each well will have two screened intervals: one in the vadose zone and the other below the water table, with blank casing in between. The wells will be built with Schedule 80 polyvinyl chloride (PVC), reverse V-slot, continuous wire-wrap screen, with a 0.9 m (3 ft) long, PVC sump with end cap below the lower screen. A Schedule 80 PVC casing will extend from the top of the upper well screen to the ground surface. Colorado silica sand or an approved equivalent will be used for the sand packs, and sodium bentonite pellets and/or natural sodium bentonite chunks, crumbles, or powdered bentonite will be used for bentonite sealing material; Type I/II Portland cement will be used for cement grout.

Surface construction will consist of a protective casing, protective guard posts, and cement pad. The protective casing shall be a minimum of 5.1 cm (2 in.) larger in diameter than the permanent casing. Protective casing shall rise approximately 0.9 m (3 ft) above the ground surface. Permanent casing shall rise to approximately 0.3 m (1 ft) below the top of the protective casing. Protective casing shall have a lockable well cap extending approximately 38 cm (15 in.) above the top of the protective casing.

The functionality of the well is dependent on the well design and development of the well during completion activities. Overpumping the well will assist in obtaining maximum flow rates. Well development will be performed for the PRZ screens when adequate water levels allow. Well development will be limited to overpumping to the extent practicable, and surging will not be performed.

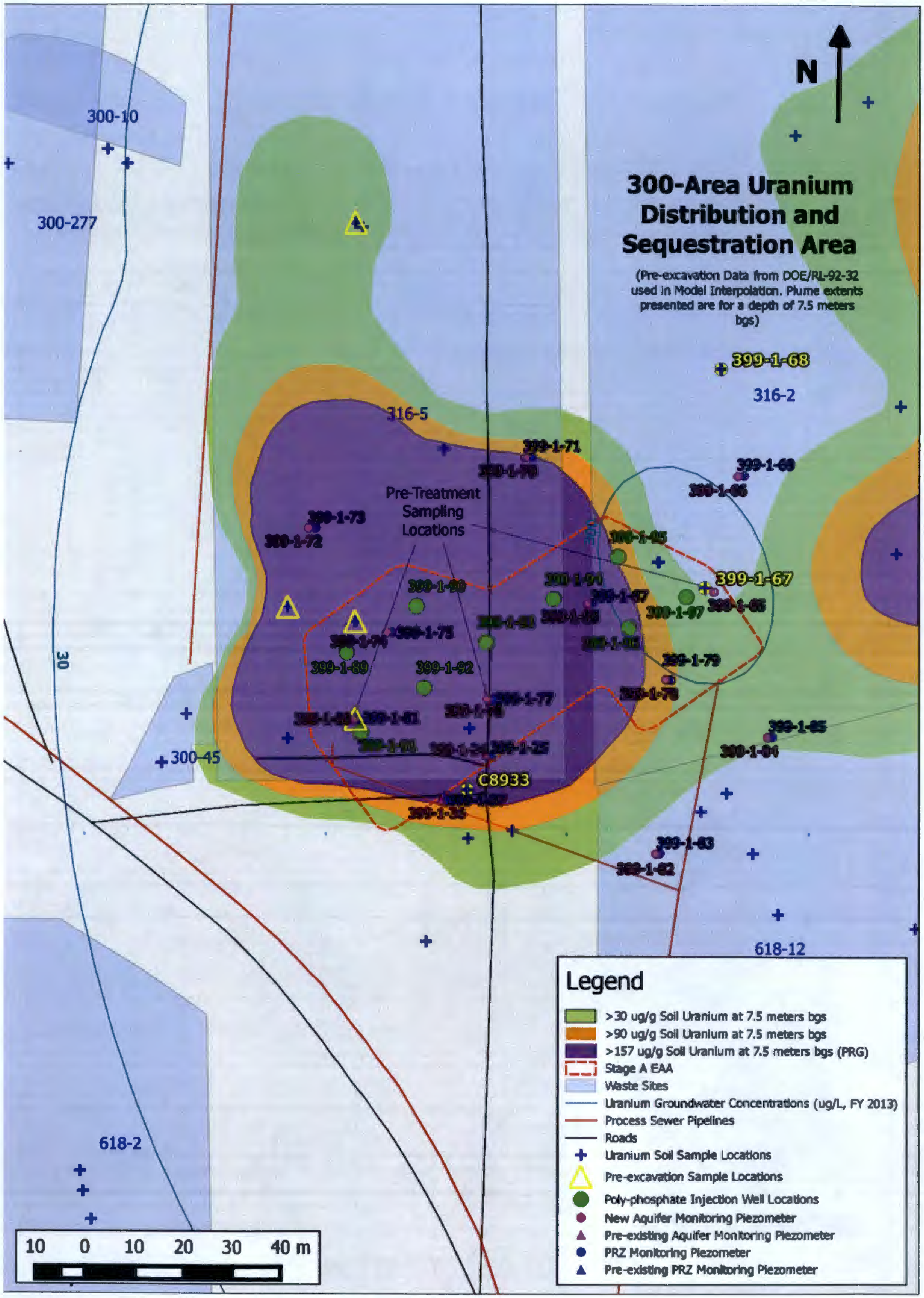

Figure 2-1. Stage A EA Area

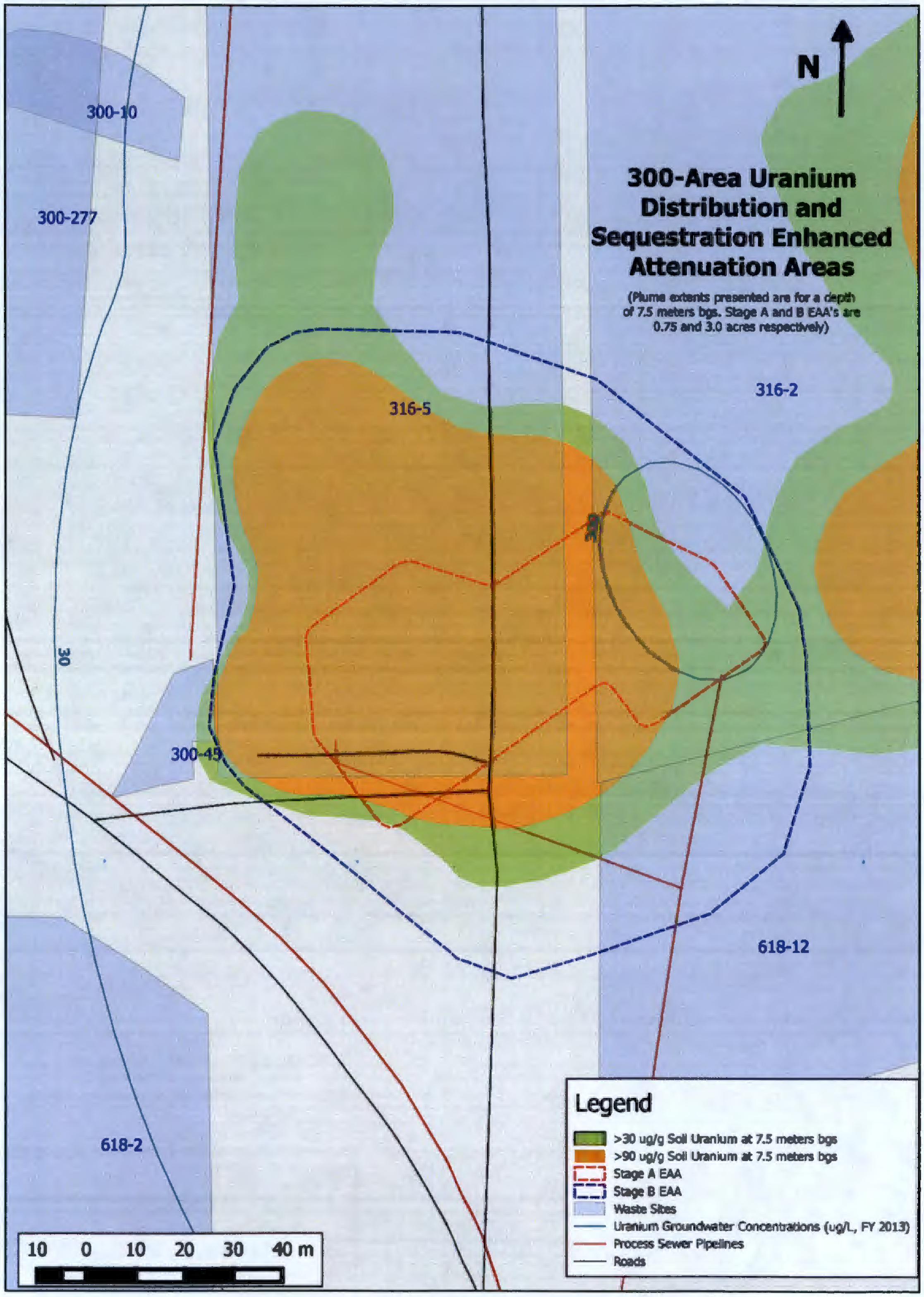

Figure 2-2. Preliminary Stage B EA Area

Table 2-1. PRZ/Aquifer Injection Well Construction Details

Construction Details	Depth
Estimated Depth to Water, Low River Stage (bgs)	9.8 m (32 ft)
Estimated Drill Depth (bgs)	15.2 m (50 ft)
Screen and Casing Diameter	15 cm (6 in)
Cement Grout Surface Seal (bgs)	0 to 4.9 m (0 to 16 ft)
Bentonite Crumbles Interval (bgs)	4.9 to 5.8 m (16 to 19 ft)
Bentonite Pellet Seal Interval (bgs)	5.8 to 6.7 m (19 to 22 ft)
PRZ Filter Pack Interval (bgs)*	6.7 to 10.1 m (22 to 33 ft)
PRZ Screen Interval (bgs)	7 to 10.1 m (23 to 33 ft)
Bentonite Pellet Seal Interval (bgs)	10.1 to 11 m (33 to 36 ft)
Blank Casing Interval (bgs)	10.1 to 11 m (33 to 36 ft)
Aquifer Filter Pack Interval (bgs)*	11 to 15.2 m (36 to 50 ft)
Aquifer Screen Interval (bgs)	11 to 14 m (36 to 46 ft)
Sump Interval (bgs)	14 to 14.9 m (46 to 49 ft)

Note: The information presented in Table 2-1 is estimated. Final drill depth, position of well screen, backfill interval, filter pack interval, and bentonite seal intervals will be determined based upon actual borehole conditions. All wells have a 15 cm (6 in.) dieameter PVC casing and screen.

* Filter pack interval, mesh size, and screen slot size are subject to change depending on field conditions.

bgs = below ground surface

PRZ = periodically rewetted zone

2.3 Piezometer Installation

Twenty-four individual piezometers consisting of 12 well pairs screened across the PRZ (approximately 9 to 10.7 m [30 to 35 ft] bgs) and across the top of the aquifer (approximately 12 to 13.7 m [40 to 45 ft] bgs) will be installed for Stage A. Piezometer installations will include 3 piezometer pairs upgradient of the Stage A EA area, 6 piezometer pairs within the Stage A EA area, and 3 piezometer pairs downgradient of the Stage A EA area (Figure 2-1).

Piezometers will be drilled with resonant sonic drilling equipment. Alternative drilling methods may be used with approval of the OU Technical Lead in consultation with the well maintenance and drilling manager. To avoid potential impact to the representativeness of vadose zone and PRZ soil, all efforts must be made to drill without the use of slurry makeup water. In the event that drilling slurry makeup water is needed, the situation must be discussed with project technical staff before proceeding.

Piezometer boreholes will be drilled with a 15 to 20 cm (6 to 8 in.) diameter outer casing to allow construction of a 5 cm (2 in.) diameter piezometer (i.e., the boreholes will be drilled to maintain a minimum 5 cm [2 in.] annular space around the permanent well, per WAC 173-160). Boreholes will be drilled to a depth of approximately 11.6 m (38 ft) for PRZ piezometers and 15 m (48 ft) for aquifer piezometers. The final total depth of the boreholes will be confirmed by the drilling BTR and site geologist and may change depending on the actual water stage, ground surface elevation, and/or subsurface conditions encountered. In the event that subsurface conditions prevent completion of the borehole to its intended depth, the OU Project Manager will be consulted to determine the path forward (e.g., re-drill the borehole at another location, or accept the modified final depth for that borehole).

Table 2-2 presents construction details for the piezometers. The piezometers will be built with 5 cm (2 in.) diameter Schedule 40 PVC casing, and slotted PVC screen sections on top of a 0.9 to 1.5 m (3 to 5 ft) long PVC sump with end cap. Colorado silica sand or an approved equivalent will be used for the sand pack; sodium bentonite pellets and/or natural sodium bentonite chunks, crumbles, or powdered bentonite will be used for bentonite sealing material; Type I/II Portland cement will be used for cement grout.

Table 2-2. Piezometer Well Construction Details

Piezometer Type	Planned Drill Depth (bgs)	Screen Length	Screen Interval (bgs)	Filter Pack Interval (bgs)[a]	Bentonite Pellet Interval (bgs)	Bentonite Crumbles Interval (bgs)	Cement Seal Interval (bgs)
PRZ	11.6 m (38 ft)	1.5 m (5 ft)	9 to 10.7 m (30 to 35 ft)	8.8 to 11 m (29 to 36 ft)	7.9 to 8.8 m (26 to 29 ft)	7 to 7.9 m (23 to 26 ft)	0 to 7 m (0 to 23 ft)
Aquifer	15 m (48 ft)	1.5 m (5 ft)	12 to 13.7 m (40 to 45 ft)	11.9 to 14 m (39 to 46 ft)	11 to 11.9 m (36 to 39 ft)	10.1 to 11 m (33 to 36 ft)	0 to 10.1 m (0 to 33 ft)

Note: The information presented in Table 2-2 is estimated. Final drill depth, position of well screen, backfill interval, filter pack interval, and bentonite seal intervals will be determined based upon actual borehole conditions. All piezometers have a 5 cm (2 in.) diameter PVC casing and screen.

a. Filter pack interval, mesh size, and screen slot size are subject to change depending on field conditions.

bgs = below ground surface

PRZ = periodically rewetted zone

PVC = polyvinyl chloride

Surface construction will consist of a protective casing, protective guard posts, and cement pad. The protective casing shall be a minimum of 5.1 cm (2 in.) larger in diameter than the permanent casing. Protective casing shall rise approximately 0.9 m (3 ft) above the ground surface. Permanent casing shall rise to approximately 0.3 m (1 ft) below the top of the protective casing. Protective casing shall have a lockable well cap extending approximately 38 cm (15 in.) above the top of the protective casing.

Piezometers will be developed by overpumping. Piezometer development will be performed for the PRZ screens when adequate water levels allow. Piezometer development will be limited to overpumping to the extent practicable, and surging will not be performed.

Soil samples for total uranium and uranium leachability testing were collected as part of the piezometer drilling to supplement the data collected during the supplemental post-ROD field investigation (SGW-56993). Details on soil sampling intervals, methodologies, and analyses are presented in Section 2.3 of SGW-56993.

2.4 Remediation Skid Modifications

Two remediation skids were designed (Figure 2-3) and constructed (Figure 2-4) as part of the apatite permeable reactive barrier remedy for the for the 100-NR-2 Groundwater OU, as specified in EPA, 2010, *U.S. Department of Energy 100-NR-1 and 100-NR-2 Operable Units Hanford Site – 100 Area Benton County, Washington Amended Record of Decision, Decision Summary and Responsiveness Summary.* These remediation skids will be used at the 300 Area for blending phosphate concentrate solutions with feed water and for distributing diluted phosphate solutions to the infiltration network and injection wells.

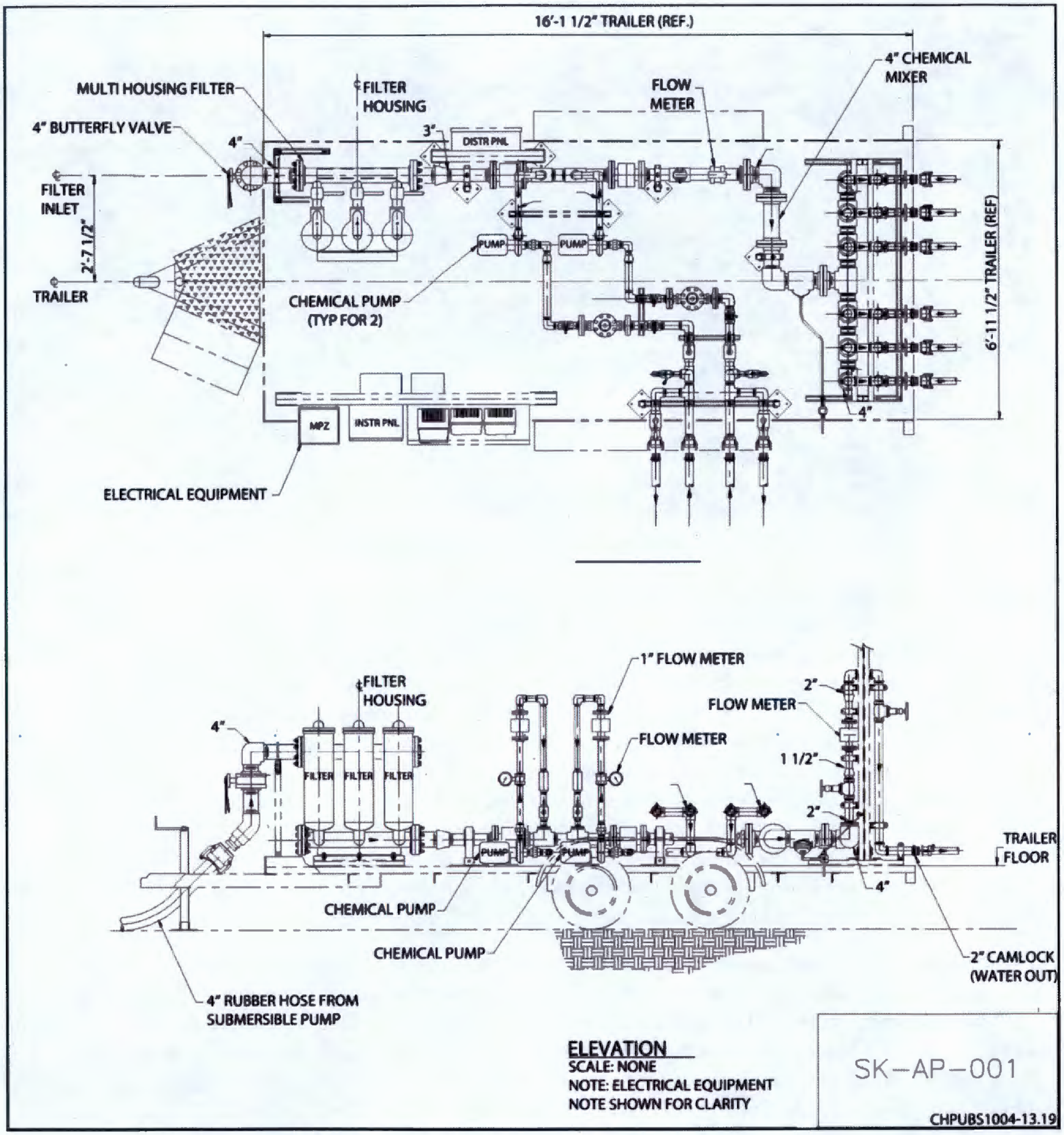

Figure 2-3. Generalized Schematic of Remediation Skid

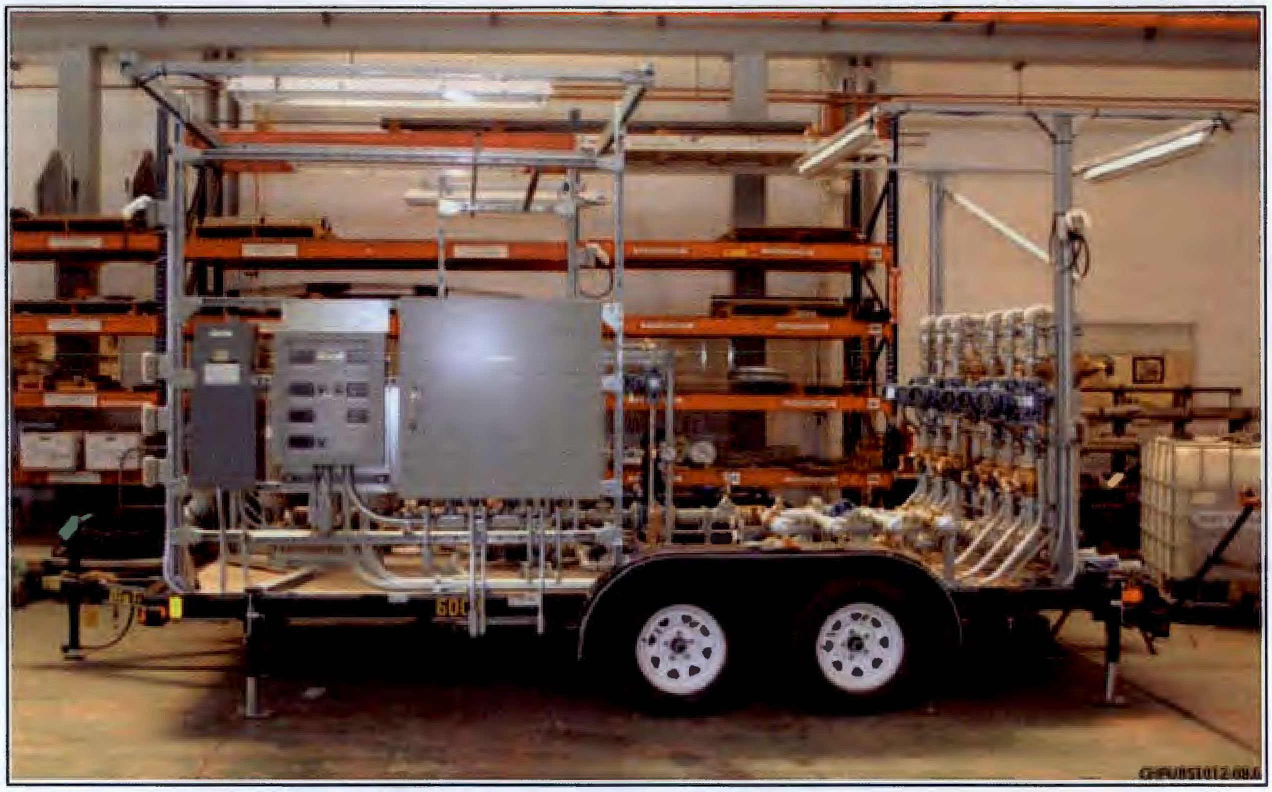

Figure 2-4. Photograph of Constructed Remediation Skid

The remediation skids are capable of delivering phosphate solution at a flow rate of up to 1,136 lpm (300 gpm). Each remediation skid is capable of pumping phosphate concentrate solutions from tanker trucks or stationary tanks, and metering the concentrate solutions into feed water streams from the river or a hydrant, to form phosphate solutions for distribution to the infiltration network or injection wells. Flowmeters and sample ports are provided on each injection skid to monitor and collect samples of diluted phosphate solution. Feed water from the river or a hydrant will be transferred via aboveground piping to the remediation skids, where it will be blended with the phosphate concentrate in a static inline mixing chamber. When river water is used as feed water, the feed water will be filtered through filter housings on the skids prior to blending with the phosphate concentrate solutions. Following mixing, a manifold will distribute the diluted phosphate solutions to transfer hoses or piping for distribution to up to six infiltration distribution lines or injection wells simultaneously. Flowmeters and pressure gauges are provided on each manifold to monitor the phosphate solution delivery stream.

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The following minor modifications will be made to the remediation skids to facilitate the Stage A chemical blending requirements and the infiltration/injection manifolding strategy:

- The chemical feed pumps will be modified or replaced to accommodate the chemical dosing rates specified in Section 3.2. The pumps are currently set up to dose at a rate of 1 part concentrate solution to 10 parts feed water (1:10).
- The variable frequency drives (VFDs) on the chemical feed pumps will be modified so they can be controlled from the remediation skids rather than slaved to VFDs on the river water pump.
- The manifold will be modified, as needed.

2.5 Water Supply Infrastructure

Feed water will be piped to the injection skids from the Columbia River as a primary source and a nearby hydrant as a backup supply. A 10 cm (4 in.) water conveyance pipe will be run from the water source to the EA area (anticipated to be approximately 457 m [1,500 ft]).

A platform-mounted submersible pump with a fish screen will be placed in the Columbia River. Shoreline access to the pump will be limited to foot traffic via a predetermined route designated with rope barriers to ensure that there is no impact to the nearby culturally sensitive shoreline areas.

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3 Groundwater Remedy Implementation and Field Sampling Plan

This chapter describes the implementation and performance monitoring plan for the Stage A EA remedy to sequester uranium in the vadose zone, PRZ, and aquifer. The Stage A EA area shown in Figure 2-1 is used as the basis for the implementation and performance monitoring plan. The plan specifies the groundwater and soil sampling locations, sampling frequency, and constituents to be analyzed as part of the EA remedy.

The preliminary Stage B EA area is presented in Figure 2-2 and is based on the post-ROD field investigation results presented in SGW-58736. The enhanced attenuation RA for the 300 Area is considered complete upon implementation of Stage A and Stage B infiltration and injection in the EA area unless otherwise agreed to by DOE and EPA following the Stage A performance delivery report. Stage B will be performed if a high likelihood of treatment effectiveness can be expected, based on all the considerations from the Stage A evaluation, such as overall decrease in uranium leachability in vadose zone and PRZ soil samples, phosphate distribution efficiency, degree of uranium mobilization to groundwater, and changes to hydraulic conductivity of the aquifer due to precipitation of phosphate minerals. If Stage B is performed, the Stage A results will be used to refine the Stage B infrastructure design.

This chapter also lists the groundwater sampling locations, sampling frequency, and constituents to be analyzed for the 300-FF-5 OU groundwater remedy.

3.1 Baseline Sampling for the Stage A Enhanced Attenuation Remedy

Baseline sampling of soils will be conducted to measure pretreatment uranium concentrations and leachability. Baseline sampling and analysis of groundwater will be conducted to measure pretreatment concentrations of selected parameters.

3.1.1 Pretreatment Uranium Concentration and Leachability Characterization

As part of the supplemental post-ROD field investigation (SGW-56993), pretreatment uranium concentration and leachability data were collected from three borings. These data were used to optimize the location and orientation of the Stage A EA area. Two additional borings located with the Stage A EA area will be drilled to collect uranium concentration and leachability data. Soil samples will be collected from at least two depth intervals in each of these borings. Data from Boring 399-1-67 (Figure 2-1) and these two additional borings will provide baseline conditions representing pretreatment uranium leaching characteristics in soil from the vadose zone and PRZ.

3.1.2 Baseline Groundwater Sampling and Analysis

Groundwater samples will be collected at the 24 piezometers for analyses of uranium, phosphate, and other anions (chloride and sulfate), carbonate and bicarbonate alkalinity, and cations (calcium, magnesium, sodium, and potassium) before application of phosphate to establish a baseline prior to phosphate application. Water levels and field parameters, including specific conductance, temperature, pH, dissolved oxygen (DO) and oxidation reduction potential (ORP), will also be collected. During low river stage conditions, the 12 piezometers screened in the PRZ are expected to be dry prior to phosphate application. Dry piezometers will not be sampled. Downhole instruments will be installed to provide hourly measurements of water level, specific conductance, and temperature at wells needed to assess uranium and phosphate migration.

Additional details for groundwater sampling procedures and laboratory analyses are presented in Section 5.1.1.

3.2 Phosphate Infiltration and Injection Operations for the Stage A Enhanced Attenuation Remedy

Stage A phosphate infiltration and injection operations include delivery and storage of the phosphate chemical solutions, blending of the phosphate chemical solutions, and injection and infiltration of the blended solution.

3.2.1 Phosphate Solution Delivery and Storage

Phosphate chemicals will be delivered to the site in concentrated liquid form, buffered to a pH of 7. Two concentrated phosphate solutions will be prepared: one at a concentration of 103,208 mg/L monosodium phosphate, and one at a concentration of 20,012 mg/L pyrophosphate. At these concentrations, the estimated volumes of concentrated phosphate solutions required for Stage A are 501,344 L (132,441 gal) of monosodium phosphate and 301,595 L (79,673 gal) of pyrophosphate. Concentrated phosphate solutions will be delivered to the 300 Area in tanker trucks. The concentrate solutions will be temporarily stored in holding tanks and fed to the remediation skids during infiltration and injection operations.

Each batch of concentrate solution will be sampled and analyzed for phosphate to verify the concentration of the delivered solution.

3.2.2 Chemical Blending for Phosphate Infiltration and Injection

The phosphate solution formulation for vadose zone infiltration, selected based on laboratory-scale treatability studies (PNNL-21733, *Use of Polyphosphate to Decrease Uranium Leaching in Hanford 300 Area Smear Zone Sediment*), is summarized in Table 3-1. The phosphate solution formulation for PRZ and aquifer injections is summarized in Table 3-2. The phosphate formulation for PRZ and aquifer injections is identical to that for the vadose zone infiltration, with an overall increase in compound concentrations to account for the groundwater dilution associated with injecting into the PRZ and aquifer under saturated conditions.

3.2.3 Phosphate Infiltration and Injection Schedule

The Stage A infiltration and injection schedule and flow rates are summarized in Table 3-3. Infiltration and injection will be performed in September through October, the time of year when the river stage is low and groundwater flow direction at the EA area will be to the southeast. For historical reference, Figure 3-1 presents the hydrographs from 2009 through 2013 from wells near the EA area.

Both remediation skids will be used during Stage A: one for mixing and pumping phosphate solution for infiltration and the other for mixing and pumping phosphate solution for injection.

The estimated Stage A operation period is 10 days (3 days of intermittent aquifer injection during the first 7 days, 5 days of infiltration during the first 7 days, followed by 3 days of PRZ injection during days 8, 9, and 10 per Table 3-3). The infiltration duration of 5 days is based on an estimated wetting front advancement rate of 1 m/day (3.4 ft/day) and a wetting distance of 5.8 m (19 ft) from the application depth of 1.8 m (6 ft) to the top of the PRZ at a depth of 7.6 m (25 ft). The estimated wetting front advancement rate is based on the advancement rate observed during infiltration studies at 100-NR-2 (PNNL-20322, *100-NR-2 Apatite Treatability Test: Fall 2010 Tracer Infiltration Test*), scaled up to account for a proposed Stage A infiltration rate of 1 cm/hr (0.39 in./hr) versus what was performed at 100-NR-2 (0.7 cm/hr [0.28 in./hr]). The estimated Stage A aquifer injection duration of 7 days is estimated based on the objective of injecting phosphate into the aquifer at least 1 day before, during, and after the phosphate infiltration period.

The planned mix proportions and blending ratios for preparing the infiltration and injection phosphate solutions are summarized in Tables 3-4 and 3-5.

Table 3-1. Phosphate Reagent Formulation for Uranium Sequestration in the Vadose Zone

Reagents	Molecular Weight (g/mole)	Formulation (Phosphate wt%)	Infiltration Concentration (mM)	Infiltration Concentration (mg/L)
NaH_2PO_4 (Monosodium Phosphate)	119.98	90	48	5,699
$Na_4P_2O_7$ (Pyrophosphate)	265.9	10	3	665
	Total	100	50	6,364

Table 3-2. Phosphate Reagent Formulation for Uranium Sequestration in the PRZ and Aquifer

Reagents	Molecular Weight (g/mole)	Formulation (Phosphate wt%)	Injection Concentration (mM)	Injection Concentration (mg/L)
NaH_2PO_4 (Monosodium Phosphate)	119.98	90	78	9,409
$Na_4P_2O_7$ (Pyrophosphate)	265.9	10	4	1,097
	Total	100	83	10,507

Table 3-3. Stage A Phosphate Infiltration and Injection Schedule

Day	Aquifer Injection (wells)	PRZ Injection (wells)	Infiltration (ha/ac)	Injection Flow Rate 8 Hours/Day (lpm/gpm)	Infiltration Flow Rate 24 Hours/Day (lpm/gpm)	Injection Volume (L/gal)	Infiltration Volume (L/gal)	Total Volume (L/gal)
1	6	--	--	1,135/300	--	545,000/ 144,000	--	545,000/ 144,000
2	--	--	0.3/0.75	--	511/135	--	736,000/ 194,400	736,000/ 194,400
3	--	--	0.3/0.75	--	511/135	--	736,000/ 194,400	736,000/ 194,400
4	6	--	0.3/0.75	1,135/300	511/135	545,000/ 144,000	736,000/ 194,400	1,281,000/ 338,400
5	--	--	0.3/0.75	--	511/135	--	736,000/ 194,400	736,000/ 194,400
6	--	--	0.3/0.75	--	511/135	--	736,000/ 194,400	736,000/ 194,400
7	6	--	--	1,135/300	--	545,000/ 144,000	--	545,000/ 144,000

Table 3-3. Stage A Phosphate Infiltration and Injection Schedule

Day	Aquifer Injection (wells)	PRZ Injection (wells)	Infiltration (ha/ac)	Injection Flow Rate 8 Hours/Day (lpm/gpm)	Infiltration Flow Rate 24 Hours/Day (lpm/gpm)	Injection Volume (L/gal)	Infiltration Volume (L/gal)	Total Volume (L/gal)
8	--	6	--	1,135/300	--	545,000/ 144,000	--	545,000/ 144,000
9	--	6	--	1,135/300	--	545,000/ 144,000	--	545,000/ 144,000
10	--	6	--	1,135/300	--	545,000/ 144,000	--	545,000/ 144,000

-- = not applicable

PRZ = periodically rewetted zone

Table 3-4. Stage A Chemical Blending for Phosphate Infiltration

Reagents	Concentration in Buffered Concentrate (mg/L)	Target Infiltration Concentration (mg/L)	Total Infiltration Rate* (lpm/gpm)	Concentrate Feed Rate (lpm/gpm)	Makeup Water Feed Rate (lpm/gpm)	Concentrate: Makeup Water Ratio
NaH_2PO_4 (Monosodium phosphate)	103,208	5,699	511/135	38/10	621/164	1:17
$Na_4P_2O_7$ (Pyrophosphate)	20,012	665	511/135	23/6	621/164	1:27

* Total infiltration rate for 0.3 ha (0.74 ac).

Table 3-5. Stage A Chemical Blending for Phosphate Injection

Reagents	Concentration in Buffered Concentrate (mg/L)	Target Injection Concentration (mg/L)	Total Injection Rate* (lpm/gpm)	Concentrate Feed Rate (lpm/gpm)	Makeup Water Feed Rate (lpm/gpm)	Concentrate: Makeup Water Ratio
NaH_2PO_4 (Monosodium Phosphate)	103,208	9,409	1,135/300	102/27	969/256	1:9
$Na_4P_2O_7$ (Pyrophosphate)	20,012	1,097	1,135/300	61/16	969/256	1:16

* Total injection rate for six wells.

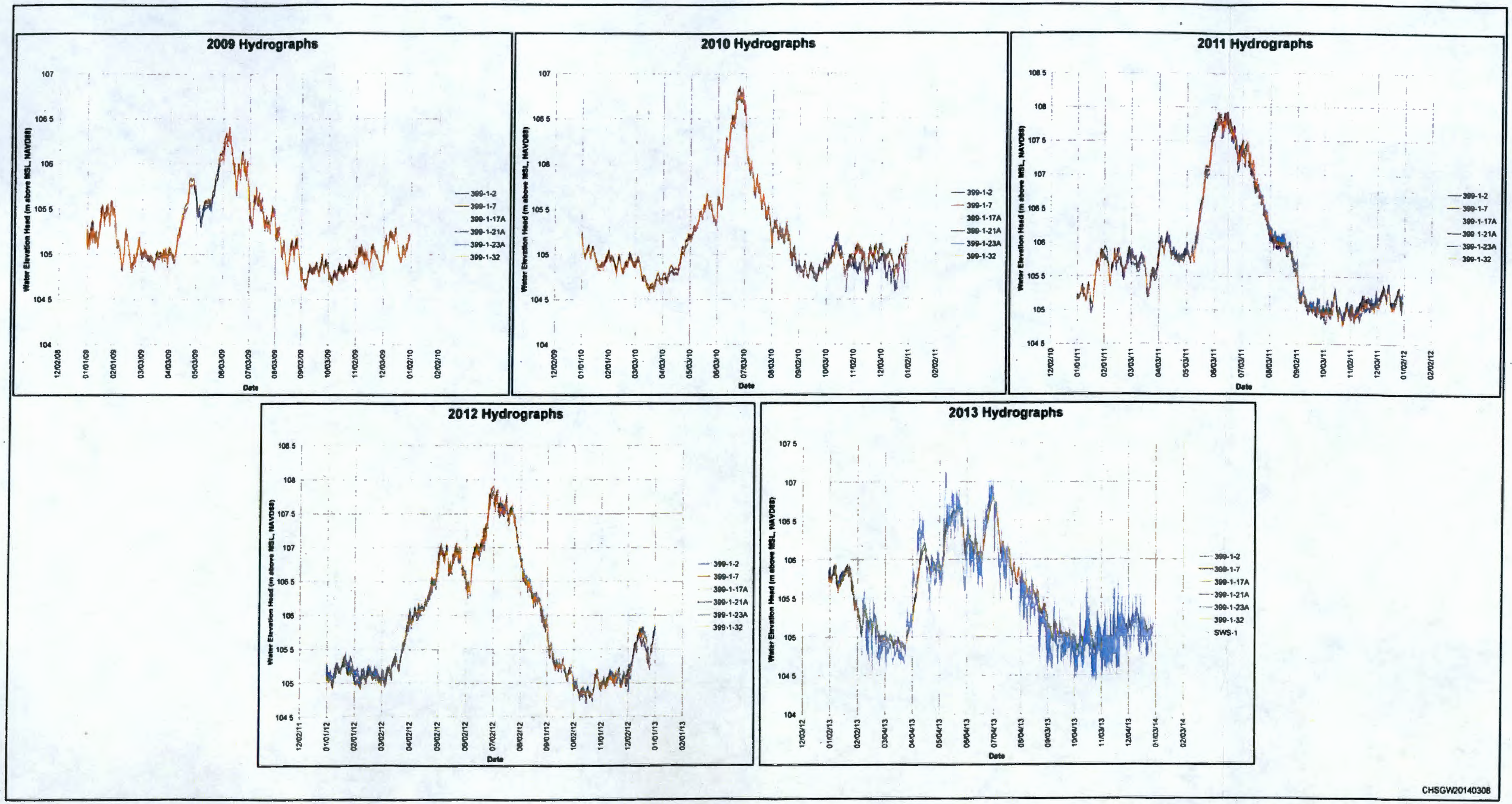

Figure 3-1. Hydrographs from 2009 to 2013

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Phosphate infiltration will be conducted continuously (24 hr/day operation) over the 0.3 ha (0.75 ac) Stage A EA area for approximately 5 days. Advancement of the infiltration wetting front will be real-time monitored using electrical resistivity tomography (ERT), as further described in Section 3.3.2. Infiltration rates will be adjusted, as needed, to maximize the contact time of phosphate solution in the vadose zone during the estimated 5-day infiltration period, while minimizing the potential for flushing phosphate solution too quickly through the vadose zone and PRZ, potentially mobilizing uranium to groundwater.

Phosphate injections into the nine Stage A aquifer injection well screens (lower screens isolated with a packer) will be conducted intermittently over approximately the first 7 days. Injections will be initiated the day before the start of phosphate infiltration, resume during infiltration, and conclude the day after completion of phosphate infiltration, in order to establish a layer of phosphate in groundwater below the infiltration area to remediate uranium that may be flushed to groundwater during infiltration operations. Injections will be conducted into at least six wells at a time during daytime hours, while varying the location of the six wells being injected during the 7-day period to maximize the distribution of phosphate in groundwater below the infiltration area.

Phosphate injections into the nine Stage A PRZ injection well screens (upper screens isolated with a packer) will be conducted over approximately 3 days after the completion of infiltration, when moisture content in the PRZ will be maximized from infiltration activities. Injecting into the PRZ when moisture content is highest will maximize the injection radius of influence in the PRZ during low river stage. Injections will be conducted into at least six wells at a time during daytime hours.

3.3 Phosphate Infiltration and Injection Operations Monitoring for the Stage A Enhanced Attenuation Remedy

Monitoring during Stage A phosphate infiltration and injection includes sampling chemical solutions at the skids, measuring skid system parameters, ERT, and sampling groundwater.

3.3.1 Remediation Skid Sampling, Flow Rate, and Volume

The remediation skids will be monitored to ensure that appropriate flow rates are maintained. Infiltration and injection monitoring includes the following process:

- Measurements of system parameters (flow rate and pressure for the main line and each leg of the manifold) will be made for each skid hourly, and field parameters (conductivity, temperature, pH, DO, and ORP) of the blended injection and infiltration solutions will be measured and recorded every 4 hours.
- Samples will be collected from the effluent stream for each skid at the start of the infiltration and injections (once flow rates have stabilized) and once daily thereafter (approximately three samples total over the duration of each injection round per skid). One sample of river water and/or hydrant water will be collected for each skid prior to mixing with the chemicals.
- Samples will be submitted to the laboratory for analyses of phosphate, anions (chloride and sulfate), carbonate and bicarbonate alkalinity (carbonate ion and hydrogen carbonate ion), and cations (calcium, magnesium, sodium, and potassium).
- Measurements of wellhead injection pressures and flow rates will be made for each injection well on an hourly basis. Maintenance may be needed on the flowmeters if the combined injection flow rate to each well differs by more than 10 percent from the total injection flow rate from the skid.

During aquifer injection, formation pressure will be maintained at a level where the packers remain sealed in the wells. Pressure monitoring will be conducted by recording pressure readings from pressure gauges at the injected well heads. Excessive pressure buildup in an injection well could push the entire well injection apparatus (packers, injection piping, and landing plates) up out of the well casing. Excessive pressure buildup could also cause a short-circuit upwelling of the injection fluid, as well as the formation of fines (very fine silt), along the outside of the casing to the surface. Although injection well pressures are not expected to increase significantly with the EA phosphate solution formulations, injection flow rates will be reduced, as needed, to mitigate pressure buildup.

3.3.2 Electrical Resistivity Tomography

ERT will be used to monitor the advancement of the phosphate infiltration wetting front through the vadose zone and PRZ. Phosphate infiltration is expected to increase vadose zone/PRZ electrical conductivity significantly by increasing both saturation and pore fluid specific conductance, thereby enabling the use of time-lapse ERT to remotely monitor polyphosphate transport. The 0.3 ha (0.75 ac) Stage A EA area will be monitored along a two-dimensional section bisecting the length of the infiltration area (Figure 3-2). This section will be monitored with a line of 73 electrodes at 1.5 m (5 ft) spacing (113 m [370 ft] in total), extending beyond the treatment area approximately 11.3 m (37 ft) in each direction. This extension is necessary to provide adequate imaging resolution at the boundary of the treatment area. The electrodes will be buried in a shallow 0.2 to 0.3 m (8 to 12 in.) deep trench for safety purposes.

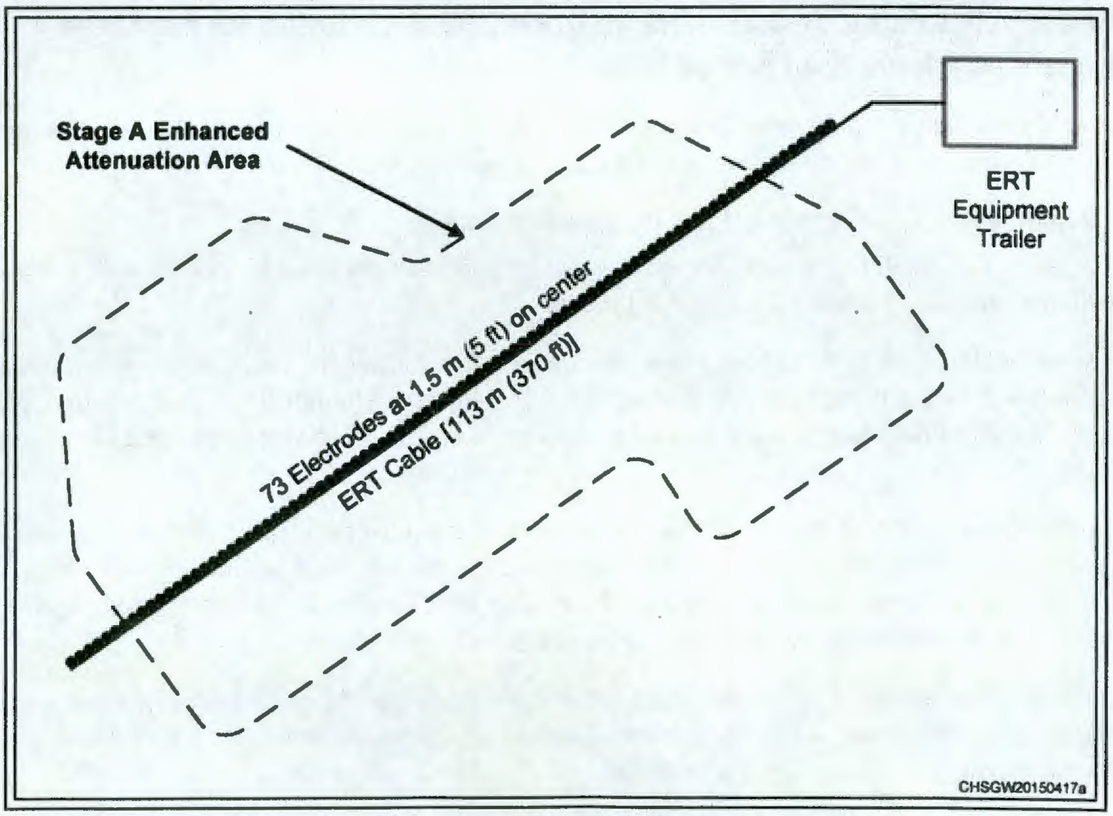


Figure 3-2. Plan View of Two-Dimensional Electrical Resistivity Tomography Array for Stage A

Baseline surveys will be collected prior to phosphate infiltration in order to image pre-infiltration subsurface structure, establish baseline conditions, and optimize the time-lapse imaging protocol. Time-lapse imaging with be performed during infiltration to monitor the advancement of the infiltration wetting front. During time-lapse imaging, ERT data will be autonomously collected, transferred via wireless internet, archived, filtered, and processed on high-performance computing resources; results will be transferred to site operators. The expected turnaround time from the beginning of a survey until time-lapse images are available is expected to be less than 30 minutes.

3.3.3 Groundwater and Pore Water Field Parameter Monitoring

Water levels and field parameters (conductivity, temperature, pH, and ORP) will be measured using downhole instruments in all piezometers at least every 4 hours during daytime hours to monitor the rate of solution distribution in the aquifer. Data-logging downhole instruments will also be deployed in select aquifer piezometers to continuously monitor conductivity, temperature, pH, and ORP. For preliminary planning, the data-logging instruments will be deployed in aquifer piezometers upgradient of the EA treatment area (399-1-70), downgradient of the EA treatment area (399-1-82 and 399-1-84), and within the footprint of the EA treatment area (399-1-76, 399-1-80, and 399-1-86) (Figure 2-1).

The Automated Water Level Network (AWLN) is an array of remote monitoring stations connected by a telemetry network to a central base station (SGW-53543, *Automated Water Level Network Functional Requirements Document*). Each monitoring station consists of a pressure transducer connected to a data collection telemetry unit. Eleven wells (399-1-10A, 399-1-15, 399-1-16A, 399-1-32, 399-3-18, 399-3-19, 399-4-7, 399-6-1, 399-8-1, 399-8-5A, and 699-S27-E14) in the AWLN will monitor water levels hourly to provide data to assess migration (Figure 3-3). Additional details for groundwater monitoring procedures are presented in Section 5.1.1.

3.3.4 Remediation Skid Flushing

Each remediation skid and connected chemical and injection lines will be flushed with river water or hydrant water following completion of the infiltration and injection operations. Once the chemical lines and injection skid have been flushed with water, the residual water can be drained to the ground. The flush water may be discarded to the ground within the EA area. The skids will then be prepared for storage and transported to and stored in a protected, covered area.

3.4 Performance Monitoring for the Stage A Enhanced Attenuation Remedy

This section lists the soil, groundwater, and PRZ pore water sampling to be conducted during implementation of the EA remedy for uranium in the 300 Area Industrial Complex. Long-term remedy performance groundwater monitoring is described in Section 3.5.

3.4.1 Performance Monitoring Objectives

The objectives of the EA performance monitoring at the EA area are to evaluate the effectiveness of phosphate application in sequestering uranium and reducing uranium leachability in the vadose zone and PRZ, the short-term impacts to uranium concentrations in groundwater, and changes to hydraulic conductivity of the aquifer due to precipitation of phosphate minerals.

3.4.2 Post-treatment Uranium Concentration and Leachability Characterization

Soil samples for total uranium and uranium leachability testing will be collected after the Stage A phosphate application to determine the post-treatment uranium leaching characteristics in soil from the vadose zone and PRZ. Soil samples will be collected from the borings drilled adjacent to the supplemental investigation borings drilled for the collection of pretreatment soil samples, at the same depth intervals selected for the pretreatment soil samples (Section 3.1.1). Borings will be drilled and abandoned using the same methodologies described for piezometer boring installation (Section 2.3). Additional details for soil sampling procedures and laboratory analyses are presented in Section 5.1.2.

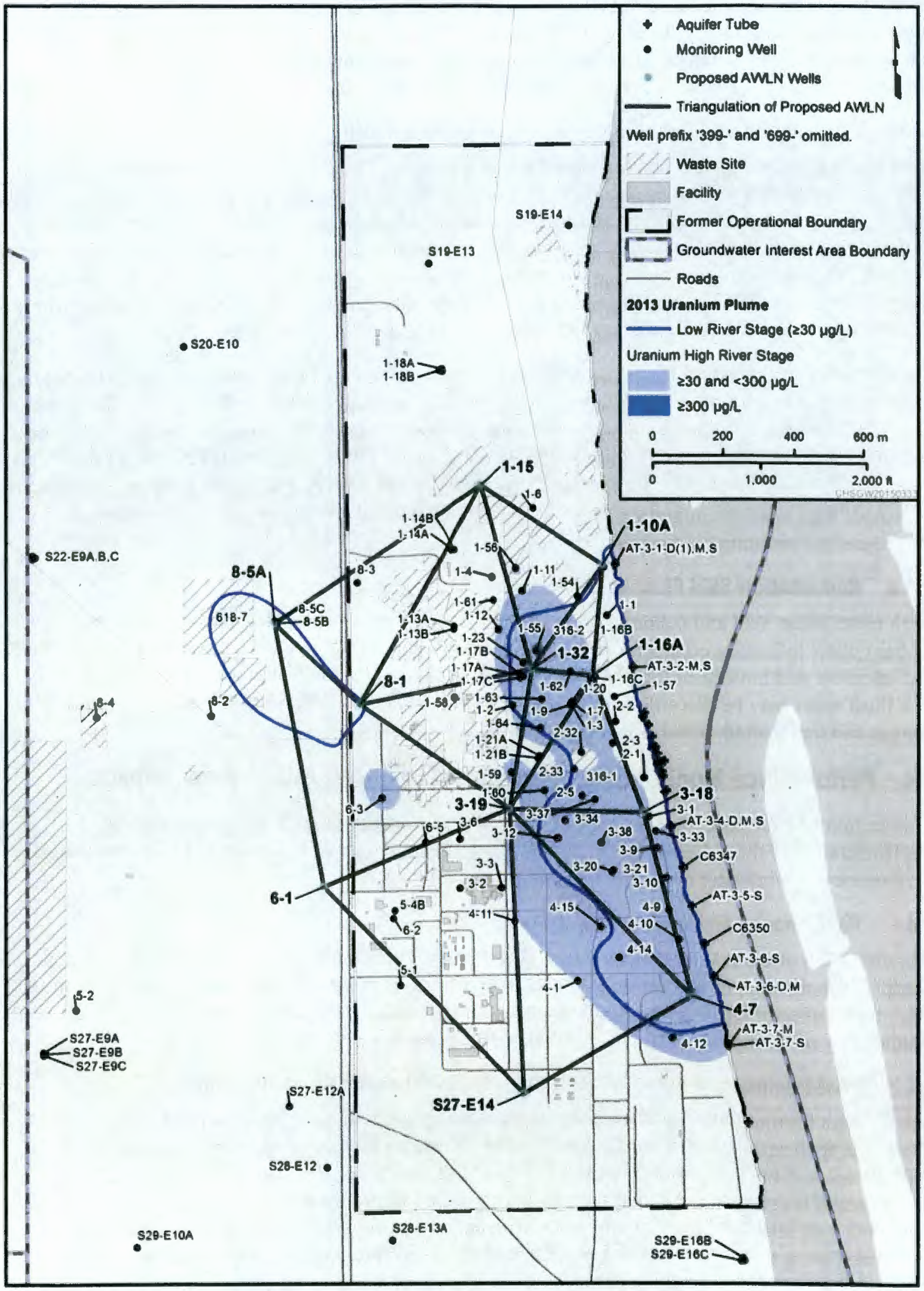


Figure 3-3. AWLN in the 300 Area Industrial Complex

3.4.3 Groundwater and Pore Water Sampling and Analysis

Groundwater samples will be collected at the 24 piezometers for analyses of uranium, phosphate, anions (chloride and sulfate), carbonate and bicarbonate alkalinity (carbonate ion and hydrogen carbonate ion), and cations (calcium, magnesium, sodium, and potassium) at least four times within 1 month after phosphate application to evaluate uranium and phosphate concentrations in groundwater after completion of the Stage A phosphate application. Water levels and field parameters including specific conductance, pH, temperature, DO, and ORP will also be collected. During low river stage conditions, it is expected that the 12 piezometers screened in the PRZ will be dry prior to phosphate application. Dry piezometers will not be sampled. Automated sensors deployed in select aquifer piezometers during the phosphate application will remain in operation to continuously monitor water levels, conductivity, and temperature.

Additional details for groundwater sampling procedures and laboratory analyses are presented in Section 5.1.1.

3.5 Performance Monitoring for the 300-FF-5 OU Groundwater Remedy

This section lists the groundwater wells and aquifer tubes to be monitored, sampling frequency, and constituents to be analyzed for remedy performance monitoring for the 300-FF-5 OU.

3.5.1 Performance Monitoring Objectives

The objectives of remedy performance monitoring in the 300-FF-5 OU are to evaluate the effectiveness of the following:

- EA to achieve the CULs for uranium in the 300 Area Industrial Complex
- MNA to achieve the CULs for nitrate and tritium downgradient from the 618-11 Burial Ground and for TCE and *cis*-1,2-DCE at the 300 Area Industrial Complex

Following evaluation of EA and MNA effectiveness, performance monitoring results are used to demonstrate attainment of CULs for TCE, *cis*-1,2-DCE, uranium, and gross alpha at the 300 Area Industrial Complex, and tritium and nitrate downgradient from the 618-11 Burial Ground.

These objectives are accomplished by sampling groundwater at designated wells and aquifer tubes and analyzing the samples for the COCs. Monitoring results will be used to demonstrate attainment of the CULs using the methodology described in Appendix B.

3.5.1.1 Phases of Performance Monitoring

EA and MNA include performance monitoring to assess the effectiveness of EA and MNA to meet CULs. Performance monitoring will continue until COCs have attained the CULs and are expected to continue to meet CULs, and EPA approves termination of the monitoring.

As discussed in OSWER 9355.0-129, *Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions*, performance monitoring consists of two phases: remediation monitoring and attainment monitoring. The first phase (remediation monitoring) refers to the phase of the remedy where remedial activities are being implemented to reach groundwater CULs. During this phase, groundwater sampling and monitoring data are collected to evaluate contaminant migration and changes in COC concentrations over time. Progress towards attaining the CUL is evaluated during the remediation phase on a well-by-well basis for each COC. Remediation monitoring for a specific monitoring well and COC is complete when the data evaluation demonstrates that the groundwater has reached the CUL. Some wells will monitor for multiple COCs. In these cases, conclusions may be made, at any time during groundwater remediation, to remove certain COCs from the monitoring program because the data indicate that they have met their CUL before other, more recalcitrant, COCs in the well (OSWER 9355.0-129).

The attainment monitoring phase occurs after the remediation monitoring phase is complete. Once the groundwater concentration for a COC is observed to have reached the CUL, data are collected and evaluated to confirm that attainment has indeed been achieved. The attainment monitoring phase at a monitoring well is complete when the data support both of the following conclusions:

- The contaminant CUL for each COC has been met.
- Groundwater will continue to meet the contaminant CUL for each COC in the future (OSWER 9355.0-129).

3.5.1.2 Evaluation of Performance Monitoring

Evaluation methods that will be used to assess progress toward CUL attainment are summarized in Table A-2 (Appendix A) and discussed in detail in Appendix B. These evaluation methods are based on the general guidance and recommendations discussed in EPA 600/R-11/204 as part of a general framework for implementation of MNA.

The primary evaluation method for MNA and EA is statistical analysis. Statistical analysis is summarized in Table A-2 (Appendix A) as follows:

> COC concentrations will be evaluated on a well-by-well basis based on statistical analyses of monitoring data. Fundamental tests will be applied to the remediation and attainment monitoring phases to evaluate performance and determine whether additional actions are required. The strategy for completing site closure is implemented in two phases: remediation monitoring phase and attainment monitoring phase. Attainment monitoring for each COC will commence on a well-by-well basis, as soon as concentrations of a COC have met the CUL at a well, as part of the analyses performed during the remediation monitoring phase.

Progress monitoring evaluation reports will be prepared every 5 years throughout the EA and MNA remedy duration. These reports will be the vehicle by which the well-by-well evaluations for each COC are documented and, ultimately, will support documenting remedial action completion for the 300-FF-5 OU. The performance monitoring reports will be prepared to support the sitewide 5-year review schedule.

3.5.1.3 Time Frames for Restoring Groundwater to Cleanup Levels

The time frame in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013) for restoring uranium to CULs using EA is between 22 and 28 years from 2012. As discussed in Section 1.2.5, the time to achieve the CUL for uranium in the groundwater will be re-evaluated following completion of the uranium sequestration application.

The time frame in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013) for restoring tritium to CULs using MNA is 18 years from 2012. Time frames for restoring nitrate, TCE, and *cis*-1,2-DCE to CULs using MNA were not defined in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013).

3.5.2 Sample Location, Frequency, and Constituents To Be Monitored

The sampling requirements and groundwater monitoring wells comprising the 300-FF-5 OU network for each COC are summarized in this section and also described in more detail in Appendix A. Monitoring locations are shown in Figures 3-4, 3-5, 3-6, 3-7, and 3-8. The AWLN is shown in Figure 3-3. Table 3-6 lists the specific constituents to be analyzed and the sampling frequency for the first 5 years for those wells that have been selected for monitoring. After the first 5 years, remediation monitoring will continue at the frequencies being used for sampling at the end of the first 5 years (Table 3-6). Sampling frequencies for each COC are summarized in Table 3-7.

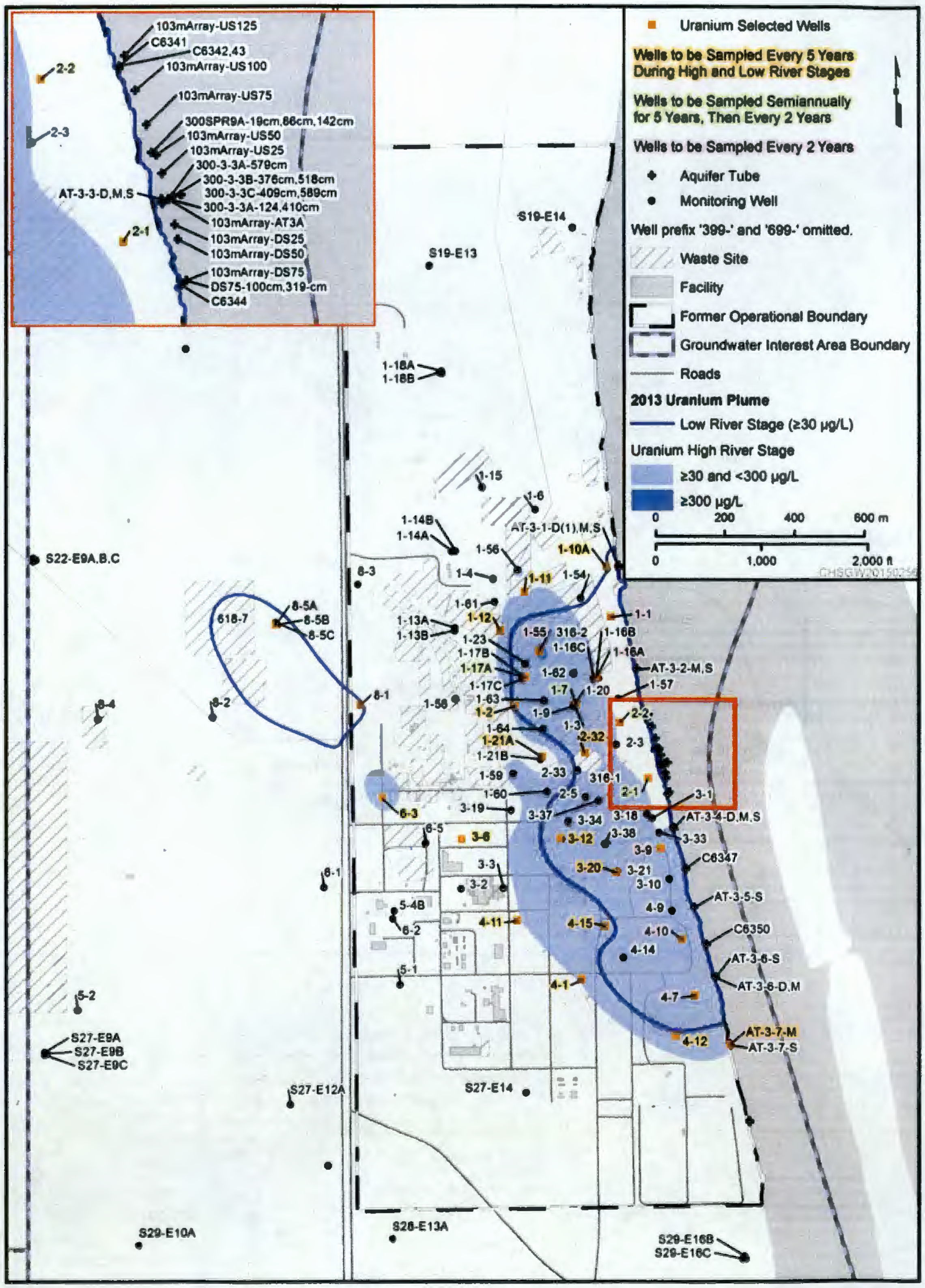


Figure 3-4. Groundwater Sampling Network for Uranium in the 300 Area Industrial Complex and at the 618-7 Burial Ground

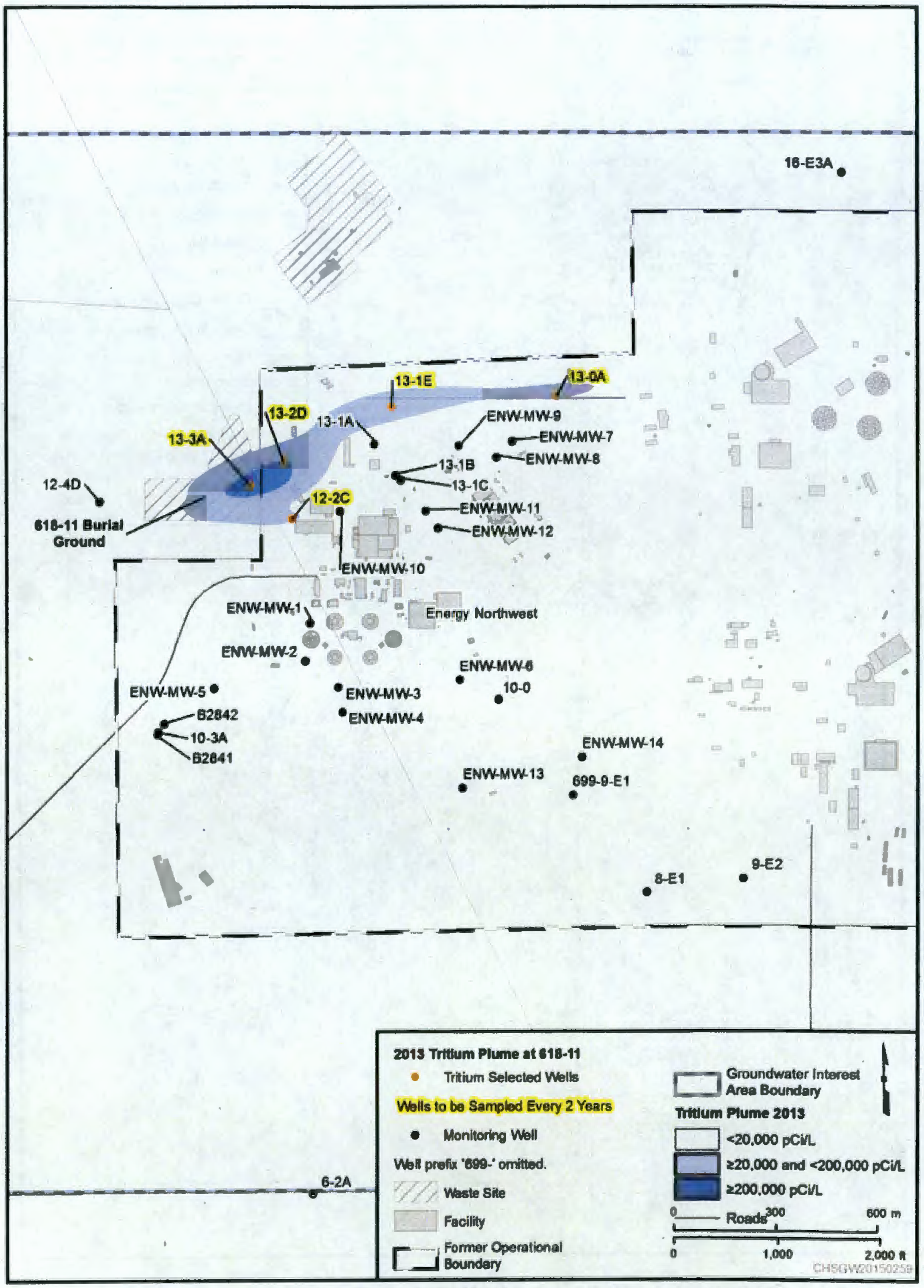
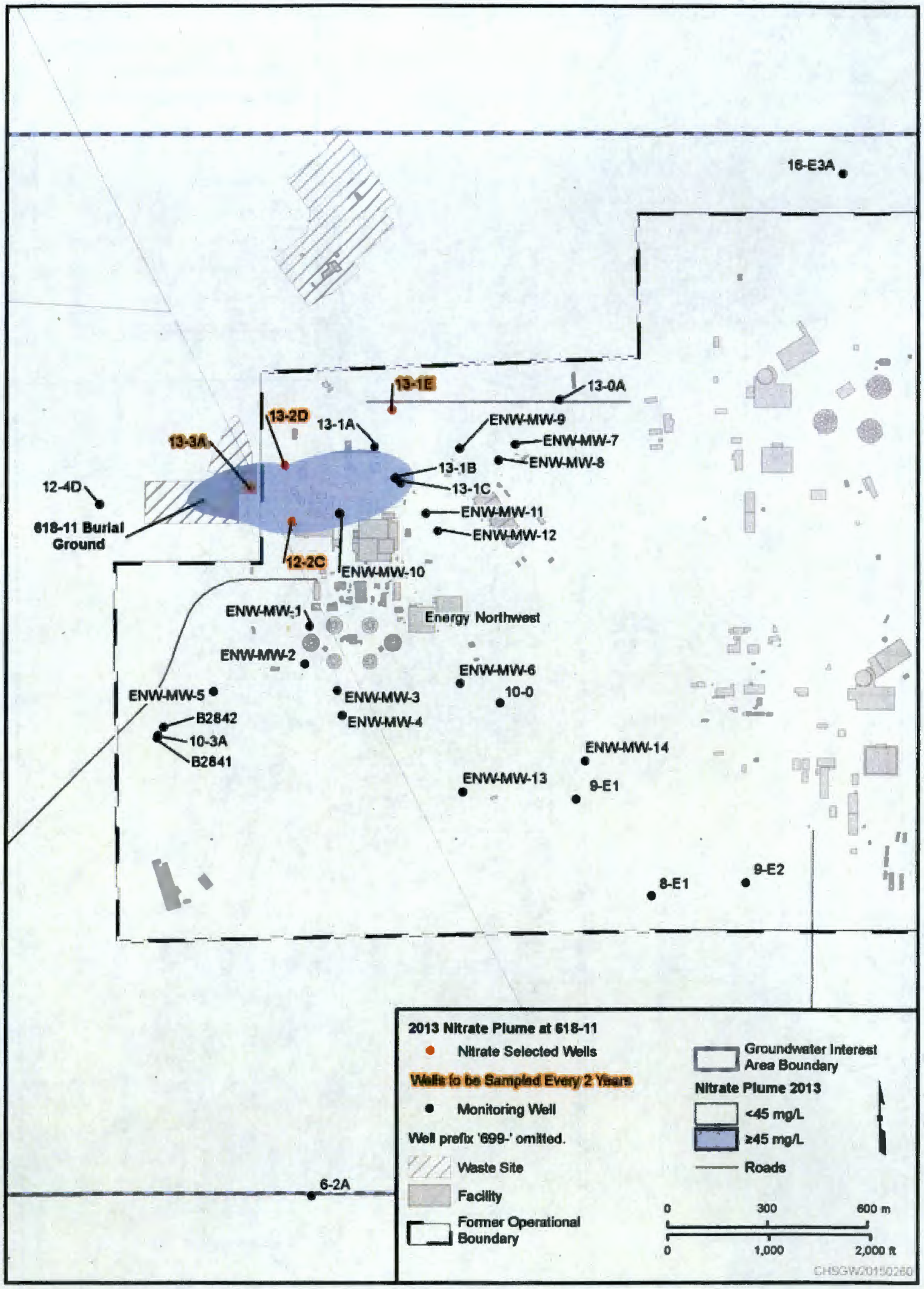


Figure 3-5. Groundwater Sampling Network for Tritium at the 618-11 Burial Ground



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2 **Figure 3-6. Groundwater Sampling Network for Nitrate at the 618-11 Burial Ground**

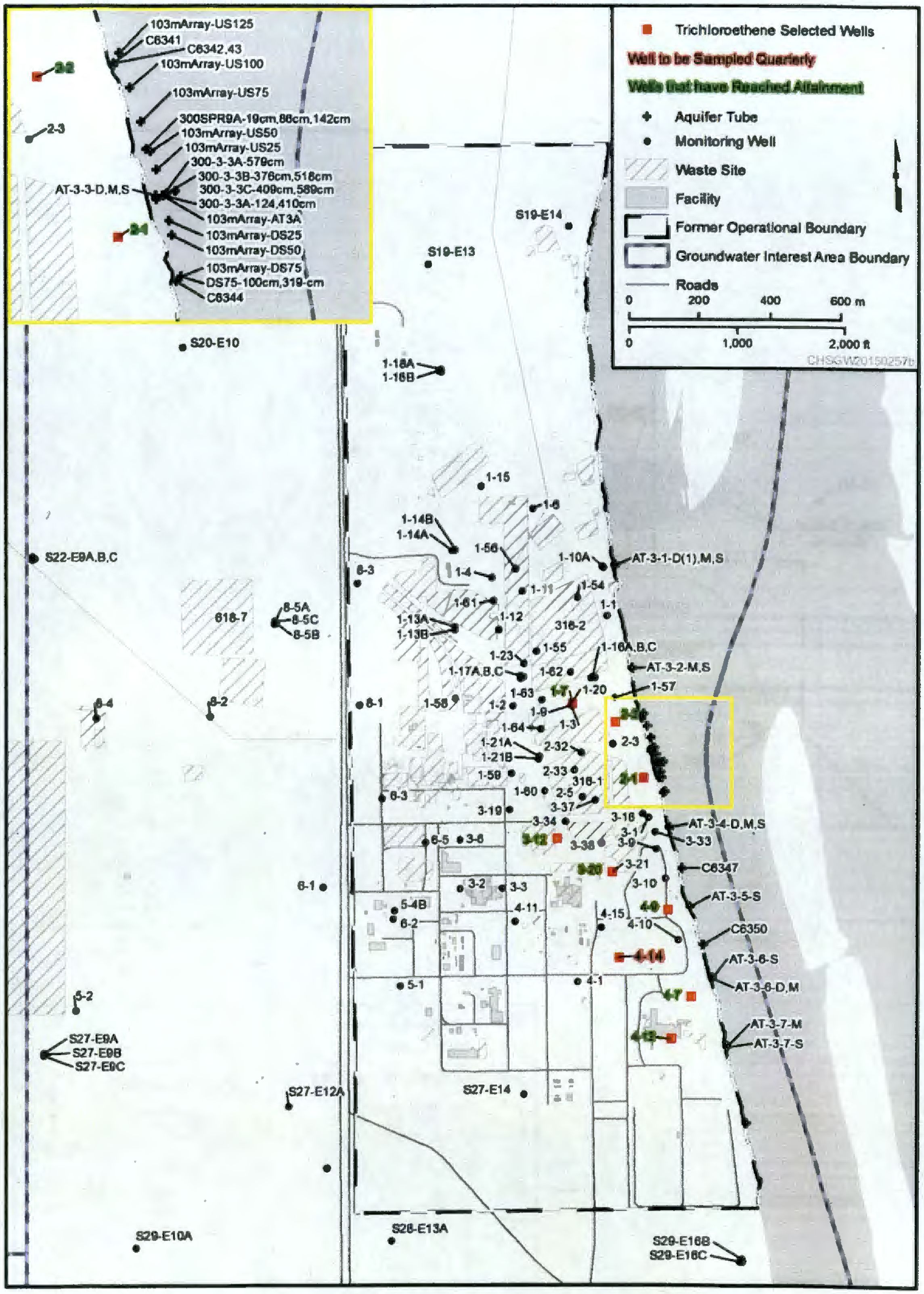

Figure 3-7. Groundwater Monitoring Network for TCE in the 300 Area Industrial Complex

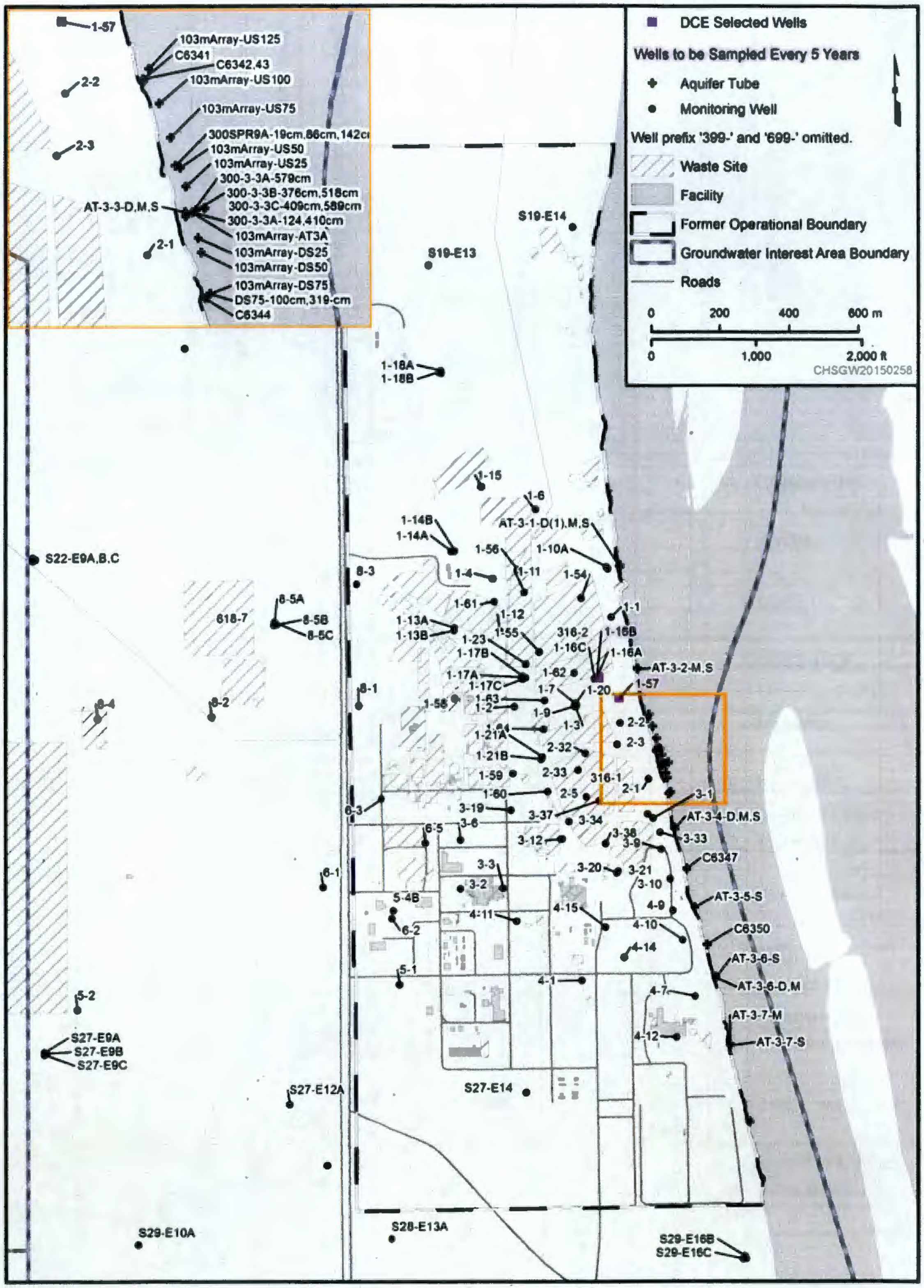

Figure 3-8. Groundwater Monitoring Network for *cis*-1,2-DCE in the 300 Area Industrial Complex

Table 3-6. Sample Locations, Frequencies, and Analytes

Well Name	Type	Screened Unit	Year Constructed	Uranium Sample/ River Stage	PSQ	Water Level		Years 1 through 5 Frequency						Comment/Rationale
						Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
399-1-1	Groundwater Well	TU	1948	Low	1		B	B					B	U: Define north extent of uranium plume near river.
399-1-10A	Groundwater Well	TU	1986	Low	2, 4	X	5	5					5	U: Define north extent of uranium plume near river.
399-1-11	Groundwater Well	TU	1986	High	4		5	5					5	U: Define north extent of uranium plume inland.
399-1-12	Groundwater Well	UU	1986	High	4		5	5					5	U: Delimit inland edge of plume.
399-1-15	Groundwater Well	TU	1986	N/A	2	X								No COC monitoring objective.
399-1-16A	Groundwater Well	TU	1986	Low	1, 2	X	B	B					B	U: Define north extent of uranium plume near river.
399-1-16B	Groundwater Well	LU	1987	N/A	1		5			5				U: No uranium in lower unconfined aquifer. *cis*-1,2-DCE: >CUL; TCE<CUL.
399-1-17A	Groundwater Well	TU	1986	Low and High	1, 2		SA B	SA B					SA B	U: Semiannually for 5 years for enhanced attenuation; also biennial for trends.
399-1-2	Groundwater Well	TU	1950	High	4		5	5					5	U: Define western extent of uranium plume near river.
399-1-21A	Groundwater Well	TU	1991	High	4		5	5					5	U: Monitor western part of uranium plume, concentration higher than 399-1-59.
399-1-32	Groundwater Well	TU	2006	N/A	2	X								No monitoring objective.
399-1-55	Groundwater Well	TU	2010	High	1		B	B					B	U: Maximum uranium concentration. TCE: Detections in characterization samples, but all nondetect after that.

Table 3-6. Sample Locations, Frequencies, and Analytes

Well Name	Type	Screened Unit	Year Constructed	Uranium Sample/ River Stage	PSQ	Water Level		Years 1 through 5 Frequency						Comment/Rationale
						Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
399-1-57	Groundwater Well	MU	2010	N/A	1		5			5				U: No uranium in middle unconfined. TCE: Detections during drilling and one routine sample >4 µg/L (flagged Q), but screened deep. Monitor 399-2-2 for TCE instead. *cis*-1,2-DCE: Persistent detections (>CUL).
399-1-7	Groundwater Well	TU	1985	Low and High	1, 2, 3		Q SA B	SA B					SA B	U: Semiannually for 5 years for enhanced attenuation; also biennial for uranium trends. TCE: Has demonstrated attainment.
399-2-1	Groundwater Well	TU	1948	Low and High	1, 2, 3		Q SA B	SA B					SA B	U: Semiannually for 5 years for enhanced attenuation; also biennial for uranium trends. TCE: Has demonstrated attainment.
399-2-2	Groundwater Well	TU	1976	Low and High	1, 2, 3		Q SA B	SA B					SA B	U: Semiannually for 5 years for enhanced attenuation; also biennial for uranium trends TCE: Has demonstrated attainment.
399-2-32	Groundwater Well	TU	2010	Low	4		5	5					5	U: Monitor central part of uranium plume
399-3-12	Groundwater Well	TU	1980	High	3, 4		Q 5	5					5	U: Monitor west part of uranium plume, central. TCE: Has demonstrated attainment.
399-3-18	Groundwater Well	TU	2006	N/A	2	X								No COC monitoring objective.
399-3-19	Groundwater Well	TU	2006	N/A	2	X								No COC monitoring objective.
399-3-20	Groundwater Well	TU	2006	High	3, 4		Q 5	5					5	U: Monitor south-central part of plume. TCE: Has demonstrated attainment.
399-3-6	Groundwater Well	TU	1943	Low	4		5	5					5	U: Downgradient of 618-7. TCE: Only one routine sample >4 µg/L; mostly nondetects.
399-3-9	Groundwater Well	TU	1976	Low	1		B	B					B	U: Monitor near river, central; among highest concentrations.

Table 3-6. Sample Locations, Frequencies, and Analytes

Well Name	Type	Screened Unit	Year Constructed	Uranium Sample/ River Stage	PSQ	Water Level		Years 1 through 5 Frequency						Comment/Rationale
						Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
399-4-1	Groundwater Well	TU	1951	Low or High	4		5	5					5	U: Delimit west edge of uranium plume, south. TCE: Only one routine sample >4 µg/L; monitor 399-4-14 instead.
399-4-10	Groundwater Well	TU	1976	Low	1		B	B					B	U: Monitor uranium near river, south. TCE: Only one routine sample >4 µg/L (flagged Q).
399-4-11	Groundwater Well	TU	1986	Low or High	4		5	5					5	U: Delimit west edge of plume, south.
399-4-12	Groundwater Well	TU	1980	Low	3, 4		Q 5	5					5	U: Delimit south part of uranium plume. TCE: Has demonstrated attainment.
399-4-14	Groundwater Well	TU	2007	N/A	3		Q				Q			U: Redundant with 399-4-15. TCE: Has not reached CUL.
399-4-15	Groundwater Well	TU	2011	High	4		5	5					5	U: Monitor in south part of uranium plume.
399-4-7	Groundwater Well	TU	1961	Low	1, 2, 3	X	Q B	B					B	U: Monitor uranium near river, south. TCE: Has reached attainment.
399-4-9	Groundwater Well	TU	1976	N/A	3		Q							U: Redundant with nearby wells. TCE: Has reached attainment.
399-6-1	Groundwater Well	TU	1950	N/A	2	X								No COC monitoring objective.
399-6-3	Groundwater Well	TU	2011	Low	4		5	5					5	U: Monitor downgradient 618-7 uranium plume.
399-8-1	Groundwater Well	TU	1950	Low	1, 2	X	B	B					B	U: Monitor 618-7 uranium plume.
399-8-5A	Groundwater Well	TU	1991	Low	1, 2	X	B	B					B	U: Monitor 618-7 uranium plume.
699-12-2C	Groundwater Well	TU	2001	N/A	1, 4		B		B			B		U: No monitoring objective for uranium. H3: In plume; monitor trends. NO3: In plume; monitor trends.

Table 3-6. Sample Locations, Frequencies, and Analytes

Well Name	Type	Screened Unit	Year Constructed	Uranium Sample/ River Stage	PSQ	Water Level		Years 1 through 5 Frequency						Comment/Rationale
						Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
699-13-0A	Groundwater Well	TU	2001	N/A	1, 4		B		B					U: No monitoring objective for uranium. H3: In plume; monitor trends.
699-13-1E	Groundwater Well	TU	2001	N/A	1, 4		B		B			B		U: No monitoring objective for uranium. H3: In plume; monitor trends. NO3: >DWS until 2014; monitor trend.
699-13-2D	Groundwater Well	TU	2001	N/A	1, 4		B		B			B		U: No monitoring objective for uranium. H3: In plume; monitor trends. NO3: At or above DWS; monitor trend.
699-13-3A	Groundwater Well	TU	1995	N/A	1, 4		B		B			B		U: No monitoring objective for uranium. H3: In plume; monitor trends. NO3: In plume; monitor trends.
699-S27-E14	Groundwater Well	TU	1948	N/A	2	X								No COC monitoring objective for uranium.
AT-3-7-M	Aquifer Tube	6.3*	2004	Low	4			5					5	U: Delimit southern extent of the plume.

Table 3-6. Sample Locations, Frequencies, and Analytes

Well Name	Type	Screened Unit	Year Constructed	Uranium Sample/ River Stage	PSQ	Water Level		Years 1 through 5 Frequency						Comment/Rationale
						Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	

* Screen depth (meters below ground surface)

AWLN = Automated Water Level Network

DCE = dichloroethene

CUL = cleanup level

DWS = drinking water standard

N/A = not applicable

PSQ = principal study question

TCE = trichloroethene

TU = (top unconfined) Screened across or within 1.5 m (5 ft) of the water table with less than 10.7 m (35 ft) of the open interval extending below the water table.

MU = (middle unconfined) Open interval begins at greater than 15 m (50 ft) below the water table and does not extend below the middle coarse unit of the Ringold Formation (unit 7) or to within 15 m (50 ft) of the top of basalt.

LU = (lower unconfined) Open interval begins at greater than 15 m (50 ft) below the water table and below the middle coarse unit of the Ringold Formation (unit 7) or within 15 m (50 ft) of the top of basalt and does not extend more than approximately 3 m (10 ft) below the top of basalt.

UU = (upper unconfined) Screened more than 1.5 m (5 ft) below the water table and with the open interval extending no more than 15 m (50 ft) below the water table.

X = included in the AWLN

Sampling frequency during Years 1 through 5:

5. Once every 5 years. For *cis*-1,2-DCE, sample during December. For uranium, sample during June and December.

B. Biennially (once every 2 years). For uranium in the 300 Area Industrial Complex, sample when highest concentrations are anticipated based on correlation of concentrations to river stage. For uranium downgradient of the 618-7 Burial Ground, sample in December. For tritium and nitrate downgradient of the 618-11 Burial Ground, sample in October.

SA. Semiannually (twice each year) for 5 years during June and December.

Q. Quarterly for up to 2 years. If attainment has not been achieved, monitoring may be continued at a reduced frequency. For TCE, collect the quarterly samples in March, June, September, and December.

Sampling frequency during Year 6+:

cis-1,2-DCE: Once every 5 years during December.

Uranium: Wells in the 300 Area Industrial Complex that were sampled semiannually or biennially during the first 5 years will be sampled biennially when highest concentrations are anticipated based on correlation of concentrations to river stage. Wells that were sampled every 5 years during June and December will continue to be sampled at that frequency. Wells downgradient of the 618-7 Burial Ground will continue to be sampled biennially in December.

Tritium and nitrate: Wells will continue to be sampled biennially in October.

Table 3-7. Summary of Sampling Frequencies for 300-FF-5 OU Long-Term Performance Monitoring

COC	Remedy Monitoring Network	Number of Locations	Sampling Frequency Years 1 through 5	Sampling Frequency Years 6+
Uranium	MNA: 300 Area Industrial Complex	10	Biennially in June or December	Biennially in June or December
		14	Once every 5 years in June and December	Once every 5 years in June and December
Uranium	EA: 300 Area Industrial Complex	4	Semiannually in June and December	Biennially in June or December
Uranium	MNA: 618-7 Burial Ground	2	Biennially in December	Biennially in December
cis-1,2-DCE	MNA: 300 Area Industrial Complex	2	Once every 5 years in December	Once every 5 years in December
TCE	MNA: 300 Area Industrial Complex	1	Quarterly for up to 2 years in March, June, September, and December	TBD
Tritium	MNA: 618-11 Burial Ground	5	Biennially in October	Biennially in October
Nitrate	MNA: 618-11 Burial Ground	4	Biennially in October	Biennially in October

DCE = dichloroethene
COC = contaminant of concern
EA = enhanced attenuation
MNA = monitored natural attenuation
TBD = to be determined
TCE = trichloroethene

When the concentration of a COC at a well achieves the CUL, attainment monitoring will begin. During attainment monitoring, wells will be sampled quarterly for up to 2 years to detect seasonal variability (Appendix A). If attainment has not been achieved, monitoring may be continued at a reduced frequency.

The criteria that were used to identify the wells to be monitored to answer each of the principal study questions (PSQs) of the DQO, and to determine the sampling frequency to be employed, are provided in Appendix A. Some wells are co-sampled with other monitoring programs (e.g., monitored to meet RCRA requirements). Monitoring requirements for those programs are described in separate plans. The reported data from those networks is supplementary to information gathered under this SAP. The breakdown of the well networks to answer individual PSQs is discussed in Section 3.5.2.1.

3.5.2.1 Monitoring Network

This SAP organizes the wells according to the relevant PSQ. An analysis of the well network to identify those wells needed for performance monitoring is presented in the DQO report in Appendix A.

PSQ 1: Are the COCs attenuating according to expectations?

The monitoring wells for PSQ 1 were selected based on location to evaluate the extent of contamination, migration pathways, contaminant trends, and contaminant concentration relative to CULs.

The sampling locations and frequency for each COC are provided as follows. The sampling frequencies for each COC monitoring network are summarized in Table 3-7.

1. **TCE:** Eight wells (399-1-7, 399-2-1, 399-2-2, 399-3-12, 399-3-20, 399-4-12, 399-4-7, and 399-4-9) in the 300 Area Industrial Complex are in the TCE monitoring network (Figure 3-7, Table 3-6) and have reached the CUL for TCE; one well (399-4-14) has not reached the CUL. Well 399-4-14 will be sampled quarterly during March, June, September, and December.

2. ***cis*-1,2-DCE:** Two wells (399-1-16B and 399-1-57) in the 300 Area Industrial Complex will be monitored every 5 years during December to be consistent with the historical monitoring period, 2 years before the 5-year review timeframe (Figure 3-8, Table 3-6).

3. **Uranium and gross alpha:** Ten wells in the 300 Area Industrial Complex (399-1-1, 399-1-16A, 399-1-17A, 399-1-55, 399-1-7, 399-2-1, 399-2-2, 399-3-9, 399-4-7, and 399-4-10) will be monitored biennially in June or December, when highest concentrations are anticipated based on correlation of concentrations to the river stage (Figure 3-4, Table 3-6). Two wells (399-8-1 and 399-8-5A) downgradient of the 618-7 Burial Ground will be monitored biennially during December to be consistent with the historical monitoring period. Additional wells will be sampled for uranium as part of PSQ 2 and PSQ 4.

4. **Tritium:** Five wells (699-12-2C, 699-13-2D, 699-13-0A, 699-13-1E, and 699-13-3A) downgradient of the 618-11 Burial Ground will be monitored biennially during October to be consistent with the historical monitoring period (Figure 3-5, Table 3-6). If concentrations increase in the furthest downgradient well (699-13-0A), installation of an additional well(s) further downgradient will be considered.

5. **Nitrate:** Four wells (699-12-2C, 699-13-2D, 399-13-1E, and 699-13-3A) downgradient of the 618-11 Burial Ground will be monitored biennially during October to be consistent with the historical monitoring period (Figure 3-6, Table 3-6).

6. **Environmental conditions impact to natural attenuation:** Water level measurements will be collected manually during sampling events and during the sitewide March synoptic event (Figure 1-3, Figures 3-4 through 3-8, Table 3-6). Field parameters (pH, specific conductance, ORP for TCE and

cis-1,2-DCE samples, and temperature) will be collected during each sampling event. The automated river gauge will collect river level, specific conductance, and temperature data hourly. The data will be used to determine whether there are changes in environmental conditional (e.g., hydraulic conditions) that may impact the evaluation of natural attenuation and migration.

7. **New contaminant releases:** Selected wells at and downgradient of active remediation locations (i.e., waste sites and belowgrade buildings in contaminated vadose zone sediments) will be monitored prior to, during, and after remediation. At least one sampling event during each phase will be during low water, if possible.

PSQ 2: Does the EA using phosphate treatment reduce leachable uranium in the vadose zone and PRZ as expected?

1. **EA operation and performance monitoring:** The operations and performance monitoring plans for the Stage A EA phosphate application are summarized in Sections 3.3 and 3.4, respectively.

2. **EA long-term monitoring**: Four wells (399-1-17A, 399-1-7, 399-2-1, and 399-2-2) within and downgradient of the EA area will be monitored for uranium and gross alpha twice a year for 5 years in June (high river stage) and December (low river stage) for comparison with historical data trends to evaluate whether the leachable uranium in the PRZ was reduced (Figure 3-4, Table 3-6). Prior to phosphate treatment, uranium concentrations show a dependence on water level. Following treatment, uranium concentrations are expected not to fluctuate with water level if the leachable uranium has been sequestered. These are the wells used for the two-dimensional uranium modeling in Appendix F of the RI/FS Report (DOE/RL-2010-99).

PSQ 3: Has contaminated groundwater been restored to CULs for each COC?

Each COC was evaluated for CUL attainment on a well-by-well basis using the methods described in Section 3.5.1.2 and Appendix B.

1. **TCE:** Eight wells (399-1-7, 399-2-1, 399-2-2, 399-3-12, 399-3-20, 399-4-12, 399-4-7, and 399-4-9) in the 300 Area Industrial Complex monitoring network have reached the demonstrated attainment for TCE (Figure 3-7 and Table 3-6). Well 399-4-14 will be monitored quarterly (March, June, September, and December) for up to 2 years to detect seasonal variability. If attainment has not been achieved, monitoring may be continued at a reduced frequency.

PSQ 4: Have the lateral extents of the uranium, tritium, and nitrate groundwater contamination plumes above CULs changed?

1. **Uranium:** Fourteen wells (399-1-2, 399-1-10A, 399-1-11, 399-1-12, 399-1-21A, 399-2-32, 399-3-6, 399-3-12, 399-3-20, 399-4-1, 399-4-11, 399-4-12, 399-4-15, and 399-6-3) and one aquifer tube (AT-3-7-M) in the 300 Area Industrial Complex will be monitored every 5 years during high (June) and low (December) river stage (Figure 3-4, Table 3-6). Concentrations in these wells, and in the wells monitored in the uranium monitoring networks for PSQ 1 and PSQ 2, will be used to track and communicate changes in the lateral extent of the uranium plume above the CUL in the 300 Area Industrial Complex.

2. **Tritium:** Concentrations in the five wells monitored in the tritium monitoring network for PSQ 1 will be used to track and communicate changes in the lateral extent of the tritium plume above the CUL downgradient of the 618-11 Burial Ground.

3. **Nitrate:** Concentrations in the four wells monitored in the nitrate monitoring network for PSQ 1 will be used to track and communicate changes in the lateral extent of the nitrate plume above the CUL downgradient of the 618-11 Burial Ground.

4 Quality Assurance Project Plan

A quality assurance project plan (QAPjP) establishes the quality requirements for environmental data collection. It includes planning, implementation, and assessment of sampling tasks, field measurements, laboratory analysis, and data review. This chapter describes the applicable environmental data collection requirements and controls based on the QA elements found in EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R-5), and DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD). Sections 6.5 and 7.8 of the Tri-Party Agreement (TPA) Action Plan (Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan*) require QA/quality control (QC) and sampling and analysis activities to specify the QA requirements for treatment, storage, and disposal units, as well as for past practice processes. Where appropriate, this QAPjP also describes the applicable requirements and controls based on guidance found in Ecology Publication No. 04-03-030, *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies*, and EPA/240/R-02/009, *Guidance for Quality Assurance Project Plans* (EPA QA/G-5). This QAPjP is intended to supplement the contractor's environmental QA program plan.

This QAPjP is divided into the following four sections, which describe the quality requirements and controls applicable to Hanford Site OU groundwater monitoring and soil sampling activities: Project Management, Data Generation and Acquisition, Assessment and Oversight, and Data Validation and Usability.

4.1 Project Management

This section addresses project goals, management approaches planned, and planned output documentation.

4.1.1 Project/Task Organization

The contractor, or its approved subcontractor, is responsible for planning, coordinating, sampling, and shipping samples to the laboratory. The project organization is described in the following subsections and is illustrated in Figure 4-1.

4.1.1.1 Regulatory Lead Agency

The lead regulatory agency (LRA) is responsible for regulatory oversight of cleanup projects and activities. The LRA has SAP approval authority for the OUs it manages. The LRA works with the U.S. Department of Energy-Richland Operations Office (DOE-RL) to resolve concerns over the work described in this SAP in accordance with the TPA (Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order*).

4.1.1.2 DOE-RL Project Manager

The DOE-RL Project Manager is responsible for the following:

- Monitoring the contractor's performance of activities under CERCLA, RCRA, AEA, and the TPA (Ecology et al., 1989a) for the Hanford Site
- Approving the SAP and serving as the primary interface with the LRA
- Obtaining LRA approval of the SAP
- Authorizing field sampling activities

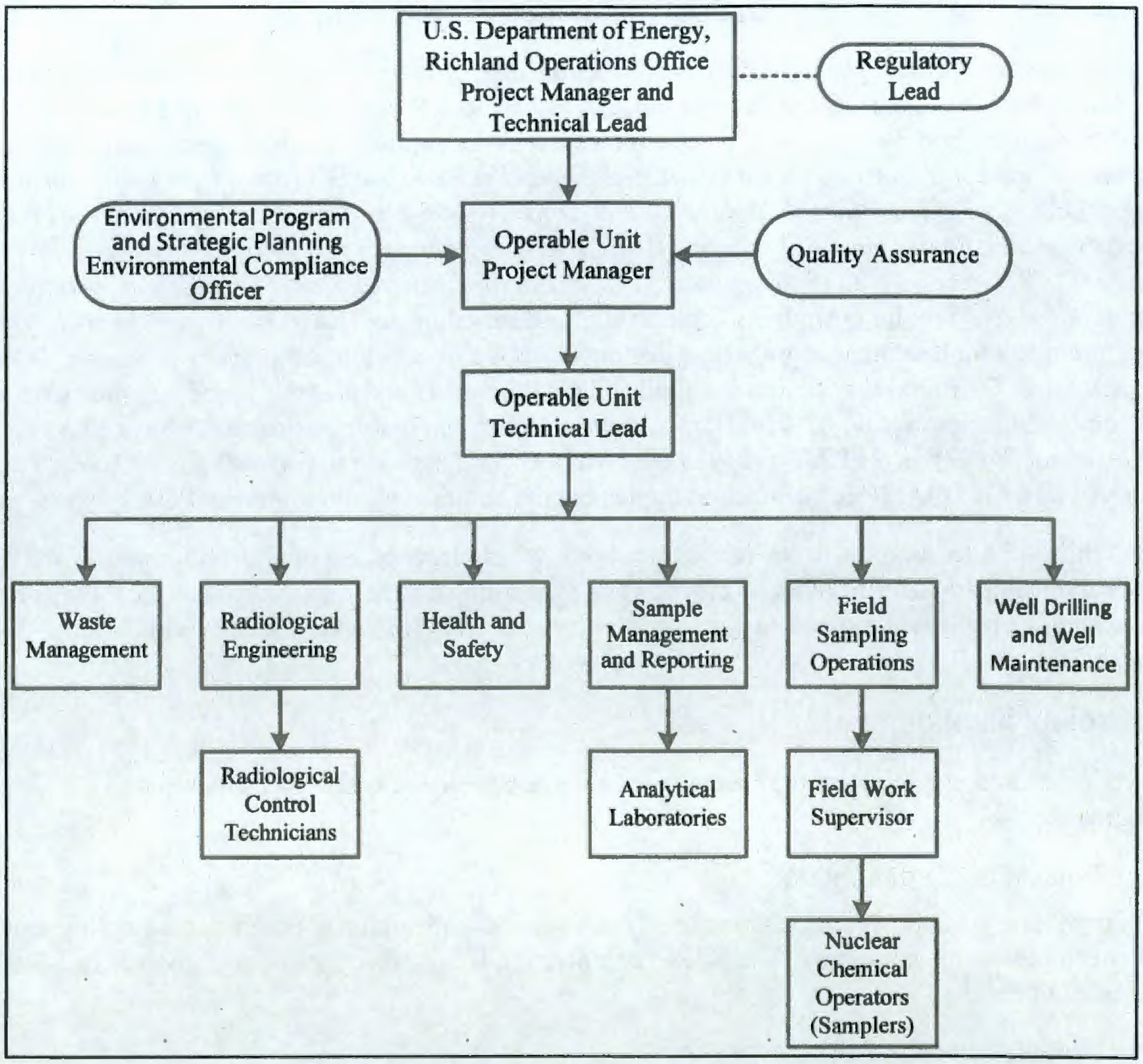

Figure 4-1. Project Organization

4.1.1.3 DOE-RL Technical Lead

The DOE-RL Technical Lead is responsible for the following:

- Providing day-to-day oversight of the contractor's work scope performance and working with the contractor and the regulatory agencies to identify and resolve technical issues
- Providing technical input to the DOE-RL Project Manager

4.1.1.4 Operable Unit Project Manager

The OU Project Manager (or designee) is responsible and accountable for the following:

- Project-related activities
- Coordinating with DOE-RL, regulators, and contactor management in support of sampling activities to ensure work is performed safely and cost effectively
- Managing sampling documents and requirements, field activities, and subcontracted tasks, and ensuring the project file is properly maintained

4.1.1.5 Operable Unit Technical Lead

The OU Technical Lead is responsible for the following:

- Developing specific sampling design, analytical requirements, and QC requirements, either independently or as defined through a systematic planning process
- Ensuring that sampling and analysis activities as delegated by the OU Project Manager are carried out in accordance with the SAP
- Working closely with the Environmental Compliance Officer (ECO), QA, the Health and Safety organization, the Field Work Supervisor (FWS), and the SMR organization to integrate these and other technical disciplines in planning and implementing the work scope

4.1.1.6 Environmental Compliance Officer

The ECO is responsible for the following:

- Providing technical oversight, direction, and acceptance of project and subcontracted environmental work
- Developing appropriate mitigation measures to minimize adverse environmental impacts
- Overseeing project implementation for compliance with applicable internal and external environmental requirements

4.1.1.7 Quality Assurance

The QA point-of-contact is responsible for the following:

- Addressing QA issues on the project
- Overseeing implementation of the project QA requirements
- Reviewing project documents (including the DQO summary report, QAPjP, and SAP)
- Reviewing data validation reports from third-party data validation contractors, as appropriate
- Participating in QA assessments on sample collection and analysis activities, as appropriate

4.1.1.8 Health and Safety Organization

The Health and Safety organization is responsible for the following:

- Coordinating industrial safety and health support within the project, in accordance with the health and safety program, job hazard analyses, and other pertinent federal regulation
- Assisting project personnel in complying with the applicable health and safety program
- Coordinating with the Radiological Engineering organization to determine personal protective equipment (PPE) requirements

4.1.1.9 Radiological Engineering Organization

The Radiological Engineering organization is responsible for the following:

- Radiological engineering and project health physics support
- Conducting as low as reasonably achievable (ALARA) reviews, exposure and release modeling, and radiological controls optimization

- Identifying radiological hazards and ensuring appropriate controls are implemented to maintain worker exposures to hazards at ALARA levels
- Interfacing with the project Health and Safety representative and other appropriate personnel, as needed, to plan and direct project Radiological Control Technician (RCT) support

4.1.1.10 Sample Management and Reporting Organization

The SMR organization is responsible for the following activities:

- Interfacing between the OU Technical Lead, Field Sampling Operations (FSO), the Well Maintenance Organization, and the analytical laboratories
- Generating field sampling documents, labels, and instructions for field sampling personnel
- Monitoring the entire sample and data process
- Coordinating laboratory analytical work, and ensuring that the laboratories conform to Hanford Site QA requirements (or their equivalent), as approved by DOE, EPA, and the Washington State Department of Ecology (Ecology)
- Resolving sample documentation deficiencies or issues associated with FSO, laboratories, or other entities to ensure that project needs are met
- Receiving the analytical data from the laboratories
- Ensuring data is uploaded into the Hanford Environmental Information System (HEIS)
- Arranging for, and overseeing, data validation, as requested
- Informing the OU Project Manager and/or OU Technical Lead of any issues reported by the analytical laboratory
- Developing the sample authorization form (SAF), which provides information and instruction to the analytical laboratories
- Providing instructions to the FSO samplers on the collection of samples as specified in a SAP

4.1.1.11 Analytical Laboratories

Analytical laboratories are responsible for the following:

- Analyzing samples in accordance with established methods
- Providing data packages containing analytical and QC results in compliance with contractual requirements
- Providing explanations in response to resolution of analytical issues
- Meeting requirements of this plan
- Being on the Mission Support Alliance Evaluated Suppliers List
- Being accredited by Ecology for the analyses performed for the Soil and Groundwater Remediation Project

4.1.1.12 Waste Management Organization

The Waste Management organization is responsible for the following:

- Communicating policies and protocols
- Ensuring compliance for waste storage, transportation, disposal, and tracking in a safe and cost-effective manner
- Identifying waste management sampling/characterization requirements to ensure regulatory compliance
- Interpreting data to determine waste designations and profiles
- Preparing and maintaining other documents confirming compliance with waste acceptance criteria

4.1.1.13 Field Sampling Organization

The FSO is responsible for the following:

- Planning, coordinating, and conducting field sampling activities
- The FWS ensuring that samplers are appropriately trained and available
- Ensuring that sampling design is understood and can be performed as specified by the Nuclear Chemical Operators (NCOs) (this is achieved by directing NCO training, performing mock-ups, and holding practice sessions with field personnel)
- The FWS directing the NCOs
- The NCOs collecting all salient samples in accordance with sampling documentation
- Completing field logbook entries, chain-of-custody forms, and shipping paperwork, and ensuring delivery of the samples to the analytical laboratory
- The FWS acting as a technical interface between the OU Project Manager and the field crew supervisors (such as the drilling BTR and geologist BTR) and ensuring technical aspects of the field work are met
- The FWS reviewing the SAP for field sample collection concerns, analytical requirements, and special sampling requirements
- Resolving issues regarding implementing technical requirements to field operations and coordinating resolution of sampling issues through consultation with the OU Project Manager and SMR

4.1.1.14 Well Drilling/Maintenance Manager

The Well Maintenance Manager is responsible for the following:

- Well drilling/maintenance activities
- Coordinating with the OU Technical Lead to identify field constraints that could affect groundwater sampling

4.1.1.15 Groundwater Remediation Contractor

The groundwater remediation contractor (not included on the organization chart) will implement the following activities associated with uranium sequestration for the vadose zone, PRZ, top of aquifer, and MNA:

- Installation of phosphate infiltration system
- Installation of injection wells and piezometers
- Well development
- Remediation skid modifications
- Installation of water supply conveyance pump and piping
- Phosphate solution delivery and storage
- Phosphate infiltration and injection operations monitoring

4.1.2 Quality Objectives and Criteria

The QA objective of this plan is to ensure the generation of analytical data of known and appropriate quality that are acceptable and useful for decision making. In support of this objective, statistics and data descriptors known as data quality indicators (DQIs) help determine the acceptability and utility of data to the user. The principal DQIs are precision, accuracy, representativeness, comparability, completeness, bias, and sensitivity. These are defined for the purposes of this document in Table 4-1.

Data quality is defined by the degree of rigor in the acceptance criteria assigned to the DQIs. Typically, acceptance criteria are set by the analytical method itself; however, project-specific requirements as indicated by DQOs may result in more stringent acceptance criteria. The applicable QC guidelines, DQI acceptance criteria, and levels of effort for assessing data quality are dictated by the intended use of the data and the requirements of the analytical method. DQIs are evaluated during the data quality assessment (DQA) process (Section 4.4).

4.1.3 Special Training/Certification

A graded approach is used to ensure that workers receive a level of training commensurate with their responsibilities and compliant with applicable DOE orders and government regulations. The FWS, in coordination with line management, will ensure special training requirements for field personnel are met.

Typical training requirements or qualifications have been instituted by the contractor management team to meet training and qualification programs to satisfy multiple training drivers imposed by the applicable *Code of Federal Regulations* (CFR) and *Washington Administrative Code* (WAC) requirements. For example, the environmental, safety, and health training program provides workers with the knowledge and skills necessary to execute assigned duties safely.

Training records are maintained for each employee in an electronic training record database. The contractor's training organization maintains the training records system. Line management confirms that an employee's training is appropriate and up-to-date prior to performing any field work.

4.1.4 Documents and Records

The OU Project Manager (or delegate) is responsible for ensuring the current version of the SAP is being used and providing updates to field personnel. Version control is maintained by the administrative document control process. Changes to the sampling document are handled consistent with HASQARD (DOE/RL-96-68) and the TPA Action Plan (Ecology et al., 1989b). The OU Project Manager is responsible for tracking all SAP changes, obtaining appropriate review, and alerting DOE-RL of these changes. Appropriate documentation will follow, in accordance with the requirements for the type of change. Table 4-2 summarizes the changes that may be made and their documentation requirements.

Table 4-1. DQIs

DQI	Definition	Determination Methodologies	Corrective Actions
Precision	Precision measures the agreement among a set of replicate measurements. Field precision is assessed through the collection and analysis of DUPs. Analytical precision is estimated by duplicate/replicate analyses, usually on LCSs, spiked samples, and/or field samples. The most commonly used estimates of precision are the relative standard deviation and, when only two samples are available, the RPD.	Use the same analytical instrument to make repeated analyses on the same sample. Use the same method to make repeated measurements of the same sample within a single laboratory. Acquire replicate field samples for information on sample acquisition, handling, shipping, storage, preparation, and analytical processes and measurements.	If duplicate data do not meet the objective: • Evaluate the apparent cause (e.g., sample heterogeneity). • Request reanalysis or re-measurement. • Qualify the data before use.
Accuracy	Accuracy is the closeness of a measured result to an accepted reference value. Accuracy is usually measured as a percent recovery. QC analyses used to measure accuracy include standard recoveries, LCSs, spiked samples, and surrogates.	Analyze a reference material or reanalyze a sample to which a material of known concentration or amount of pollutant has been added (a spiked sample).	If recovery does not meet the objective: • Qualify the data before use. • Request reanalysis or re-measurement.
Representativeness	Sample representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. It is dependent on the proper design of the sampling program and will be satisfied by ensuring the approved plans were followed during sampling and analysis.	Evaluate whether measurements are made and physical samples collected in such a manner that the resulting data appropriately reflect the environment or condition being measured or studied.	If results are not representative of the system sampled: • Identify the reason for them not being representative. • Flag the results for further review. • Review the data for usability. • If data are usable, qualify the data for limited use and define the portion of the system that the data represent. • If data are not usable, flag as appropriate. • Redefine sampling and measurement requirements and protocols. • Resample and reanalyze, as appropriate.

Table 4-1. DQIs

DQI	Definition	Determination Methodologies	Corrective Actions
Comparability	Comparability expresses the degree of confidence with which one data set can be compared to another. It is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the approved plans are followed and that proper sampling and analysis techniques are applied.	Use identical or similar sample collection and handling methods, sample preparation and analytical methods, holding times, and QA protocols.	If data are not comparable to other data sets: • Identify appropriate changes to data collection and/or analysis methods. • Identify quantifiable bias, if applicable. • Qualify the data as appropriate. • Resample and/or reanalyze if needed. • Revise sampling/analysis protocols to ensure future comparability.
Completeness	Completeness is a measure of the amount of valid data collected compared to the amount planned. Measurements are considered to be valid if they are unqualified or qualified as estimated data during validation. Field completeness is a measure of the number of samples collected versus the number of samples planned. Laboratory completeness is a measure of the number of valid measurements compared to the total number of measurements planned.	Compare the number of valid measurements completed (samples collected or samples analyzed) with those established by the project's quality criteria (DQOs or performance/ acceptance criteria).	If data set does not meet the completeness objective: • Identify appropriate changes to data collection and/or analysis methods. • Identify quantifiable bias, if applicable. • Resample and/or reanalyze if needed. • Revise sampling/analysis protocols to ensure future completeness.
Bias	Bias is the systematic or persistent distortion of a measurement process that causes error in one direction (e.g., the sample measurement is consistently lower than the sample's true value). Bias can be introduced during sampling, analysis, and data evaluation. Analytical bias refers to deviation in one direction (i.e., high, low, or unknown) of the measured value from a known spiked amount.	Sampling bias may be revealed by analysis of replicate samples. Analytical bias may be assessed by comparing a measured value in a sample of known concentration to an accepted reference value or by determining the recovery of a known amount of contaminant spiked into a sample (matrix spike).	For sampling bias: • Properly select and use sampling tools. • Institute correct sampling and subsampling procedures to limit preferential selection or loss of sample media. • Use sample handling procedures, including proper sample preservation, that limit the loss or gain of constituents to the sample media. Analytical data that are known to be affected by either sampling or analytical bias are flagged to indicate possible bias.

Table 4-1. DQIs

DQI	Definition	Determination Methodologies	Corrective Actions
			Laboratories that are known to generate biased data for a specific analyte are asked to correct their methods to remove the bias as best as practicable. Otherwise, samples are sent to other labs for analysis.
Sensitivity	Sensitivity is an instrument's or method's minimum concentration that can be reliably measured (i.e., instrument detection limit or limit of quantitation).	Determine the minimum concentration or attribute to be measured by an instrument (instrument detection limit) or by a laboratory (limit of quantitation). The lower limit of quantitation is the lowest level that can be routinely quantified and reported by a laboratory.	If detection limits do not meet the objective: • Request reanalysis or re-measurement using methods or analytical conditions that will meet required detection or limit of quantitation. • Qualify/reject the data before use.

Source: SW-846, Pending, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*, as amended.

DQI = data quality indicator

DQO = data quality objective

DUP = field sample

LCS = laboratory control sample

QA = quality assurance

QC = quality control

RPD = relative percent difference

Table 4-2. Change Control for Sampling Projects

Type of Change[a]	Type of Change (TPA Action Plan[b])	Action	Documentation
Minor Change. Change has no impact on the sample or field analytical result, and little or no impact on performance or cost. Further, the change does not affect the DQOs specified in the SAP.	**Minor Field Change.** Changes that have no adverse effect on the technical adequacy of the job or the work schedule.	The field personnel recognizing the need for a field change will consult with the OU Project Manager prior to implementing the field change.	Minor field changes will be documented in the field logbook. The logbook entry will include the field change, the reason for the field change, and the names and titles of those approving the field change.
Significant Change. Change has a considerable effect on performance or cost but still allows for meeting the DQOs specified in the SAP.	**Minor Change.** Changes to approved plans that do not affect the overall intent of the plan or schedule.	The OU Project Manager will inform the DOE-RL Project Manager and the Regulatory Lead of the change and seek concurrence at a Unit Manager's Meeting or comparable forum. The LRA determines there is no need to revise the document.	Documentation of this change approval would be in the Unit Manager's Meeting minutes or comparable record such as a CN.[c]
Fundamental Change. Change has a significant effect on the sample or the field analytical result, performance, or cost, and the change does not meet the requirements specified in the DQOs in the sampling document.	**Revision Necessary.** LRA determines changes to approved plans require revision to the sampling document.	If it is anticipated that a fundamental change will require the approval of the Regulatory Lead, the applicable DOE-RL Project Manager will be notified by the OU Project Manager and will be involved in the decision prior to implementation of a fundamental change. The LRA determines the change requires a revision to the document.	Formal revision of the sampling document.

a. Consistent with DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD).

b. Consistent with Sections 9.3 and 12.4 of the TPA Action Plan (Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan*).

c. The TPA Action Plan, Section 9.3, defines the minimum elements of a change notice.

CN	= change notice
DOE-RL	= U.S. Department of Energy-Richland Operations Office
DQO	= data quality objective
LRA	= lead regulatory agency
OU	= operable unit
SAP	= sampling and analysis plan
TPA	= Tri-Party Agreement

The FWS, SMR, and appropriate BTR are responsible for ensuring that the field instructions are maintained and aligned with any revisions or approved changes to the SAP. The SMR will ensure that any deviations from the SAP are reflected in revised paperwork for the samplers and the analytical laboratory. The FWS or appropriate BTR will ensure that deviations from the SAP or problems encountered in the field are documented appropriately (e.g., in the field logbook or on nonconformance report forms) in accordance with corrective action protocols.

The OU Project Manager, FWS, or designee is responsible for communicating field corrective action requirements and ensuring immediate corrective actions are applied to field activities. The OU Project Manager is also responsible for ensuring that project files are maintained. The project files will contain project records or references to their storage locations. Project files may include, as appropriate, the following information:

- Operational records and logbooks
- Data forms
- Global positioning system data (a copy will be provided to SMR)
- Inspection or assessment reports and corrective action reports
- Field summary reports
- Interim progress reports
- Final reports
- Forms required by WAC 173-160 and the master drilling contract

The following records are managed and maintained by SMR personnel:

- Field sampling logbooks
- Sample reports and field sample reports
- Chain-of-custody forms
- Sample receipt records
- Laboratory data packages
- Analytical data verification and validation reports
- Analytical data "case file purges" (i.e., raw data purged from laboratory files) provided by the offsite analytical laboratories

The laboratory is responsible for maintaining, and having available upon request, the following:

- Analytical logbooks
- Raw data and QC sample records
- Standard reference material and/or proficiency test sample data
- Instrument calibration information

Records may be stored in either electronic or hardcopy format. Documentation and records, regardless of medium or format, are controlled in accordance with work requirements and processes to ensure stored records are accurate and can be retrieved. Records required by the TPA (Ecology et al., 1989a) will be managed in accordance with the requirements therein.

4.2 Data Generation and Acquisition

The following sections present the requirements for analytical methods, measurement and analysis, data collection or generation, data handling, and field and laboratory QC. The requirements for instrument calibration and maintenance, supply inspections, and data management are also addressed.

4.2.1 Analytical Methods Requirements

Analytical method performance requirements for samples collected are presented in Table 4-3. Project-specific criteria identified in Table 4-3 may be more stringent than criteria specified in HASQARD (DOE/RL-96-68), in which case, Table 4-3 takes precedence over similar criteria in HASQARD (DOE/RL-96-68). In consultation with the laboratory and the OU Project Manager, SMR can approve changes to analytical methods provided that the new method is based upon a nationally recognized standard method (e.g., EPA, ASTM International, formerly American Society for Testing and Materials [ASTM]), and provided that the new method delivers analytical data that are comparable to those provided by the old method. The new method must achieve project DQOs as well or better than the replaced method, and must be required due to the nature of the sample (e.g., high radioactivity). The laboratory using the new method must be accredited by Ecology to perform that method.

Table 4-3. Performance Requirements for Analysis

Constituent	CAS Number	CUL	Analytical Method[a]	Highest Allowable PQL[b]	Precision	Accuracy[c]
Radionuclides, Groundwater (pCi/L)						
Tritium	10028-17-8	20,000	Tritium by LSC	400	≤20% RPD	70–130% recovery
Gross Alpha	12587-46-1	15	Total Alpha by GPC	3	≤20% RPD	70–130% recovery
Organics – VOCs, Groundwater (µg/L)						
TCE	79-01-6	4	EPA 8260	1	% recovery statistically derived[c]	Statistically derived[c]
cis-1,2-DCE	156-59-2	16	EPA 8260	5	% recovery statistically derived[c]	Statistically derived[c]
Inorganics – Cations/Metals, Groundwater (µg/L)						
Uranium	7440-61-1	30	EPA 6020	15	≤20% RPD	80–120% recovery
Calcium (Ca^{2+})	7440-70-2	--	SW-846 6010	1,000	≤20% RPD	80–120% recovery
Magnesium (Mg^{2+})	7439-95-4	--	SW-846 6010	750	≤20% RPD	80–120% recovery
Sodium (Na^{+})	7440-23-5	--	SW-846 6010	500	≤20% RPD	80–120% recovery
Potassium (K^{+})	7440-09-7	--	SW-846 6010	4,000	≤20% RPD	80–120% recovery

Table 4-3. Performance Requirements for Analysis

Constituent	CAS Number	CUL	Analytical Method[a]	Highest Allowable PQL[b]	Precision	Accuracy[c]
Inorganics – Anions, Groundwater (µg/L)						
Nitrate (as NO_3)	14797-55-8	45,000	EPA 300 or SW-846 9056	250	≤20% RPD	80–120% recovery
Phosphate (PO_4^{3-})	14265-44-2	--	EPA 300 or SW-846 9056	500	≤20% RPD	80–120% recovery
Chloride (Cl^-)	16887-00-6	--	EPA 300 or SW-846 9056	400	≤20% RPD	80–120% recovery
Sulfate (SO_4^{2-})	14808-79-8	--	EPA 300 or SW-846 9056	550	≤20% RPD	80–120% recovery
Carbonate (CO_3^{2-})	3812-32-6	--	EPA 310.1 or SM 2320	5,000	≤20% RPD	80–120% recovery
Bicarbonate (HCO_3^-)	71-52-3	--	EPA 310.1 or SM 2320	5,000	≤20% RPD	80–120% recovery
Inorganics – Metals, Soil (µg/kg)						
Uranium (Total)	7440-61-1	--	ICP/MS 6020	150	≤30% RPD	70–130% recovery
Uranium using semiselective chemical extraction (<2 mm grain-size fractions)	7440-61-1	--	ICP/MS	--	--	--
Labile uranium using sodium bicarbonate/ carbonate extraction (<2 mm grain-size fractions)	7440-61-1	--	ICP/OES ICP/MS	--	--	--
Inorganics – Miscellaneous, Soil						
pH	--	--	EPA Method 150.1 or EPA 9040	N/A	≤20% RPD	90–110% recovery
Grain size	--	--	ASTM D422-63(2007)	--	--	--
Predominant uranium-bearing mineral phase (<2 mm grain-size fractions)	--	--	SEM/EDS	--	--	--

Table 4-3. Performance Requirements for Analysis

Constituent	CAS Number	CUL	Analytical Method[a]	Highest Allowable PQL[b]	Precision	Accuracy[c]
Field Parameters						
Temperature	TEMPERATURE	N/A	Field measurement/probe	N/A	N/A	N/A
Specific Conductance	CONDUCT	N/A	Field measurement/probe	1 µS/cm	N/A	N/A
pH Measurement	PH	N/A	Field measurement/probe	N/A	N/A	N/A
Turbidity	TURBIDITY	N/A	Field measurement/probe	0.1 NTU	N/A	N/A
Dissolved Oxygen	DO	N/A	Field measurement/probe	N/A	N/A	N/A
Oxidation/ Reduction	REDOX	N/A	Field measurement/probe	N/A	N/A	N/A

Source: ASTM D422-63(2007), *Standard Test Method for Particle-Size Analysis of Soils*.

a. Equivalent methods may be substituted.

b. Highest allowable PQLs are specified in contracts with analytical laboratories. Actual PQLs vary by laboratory and may be lower than required contractually. MDLs are generally three to five times lower than PQLs. For radionuclides, values in this column are the highest allowable minimum detectable concentrations.

c. Determined by the laboratory based on historical data or statistically derived control limits. Limits are reported with the data. Where specific acceptance criteria are listed, those acceptance criteria may be used in place of statistically derived acceptance criteria.

For EPA Methods 335.2 and 300.0, see EPA-600/4-79-020, *Methods for Chemical Analysis of Water and Wastes*.
For four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*.

ASTM = ASTM International
CAS = Chemical Abstracts Service
DCE = dichloroethene
CUL = cleanup level
EPA = U.S. Environmental Protection Agency
GPC = gas proportional counting
ICP = inductively coupled plasma
ICP/MS = inductively coupled plasma/mass spectrometry
LSC = liquid scintillation counting
MDL = method detection limit
OES = optical emission spectroscopy
PQL = practical quantitation limit
RPD = relative percent difference
SEM/EDS = scanning electron microscopy/energy dispersive spectroscopy
VOC = volatile organic compound

4.2.2 Field Analytical Methods

Chemical field screening and radiological field survey data used for site characteristics will be measured in accordance with HASQARD (DOE/RL-96-68), as applicable, or with the manufacturers' manuals. Chapter 3 provides the parameters identified for field survey analyses.

4.2.3 Quality Control

The QC requirements specified in this SAP must be followed in the field and analytical laboratory to ensure that reliable data are obtained. Field QC samples will be collected to evaluate the potential for cross-contamination and provide information pertinent to sampling variability. Laboratory QC samples estimate the precision, bias, and matrix effects of the analytical data. Field and laboratory QC sample requirements are summarized in Table 4-4. Acceptance criteria for laboratory QC elements are shown in Table 4-5.

Data will be qualified and flagged in HEIS, as appropriate.

Table 4-4. Project QC Requirements

Sample Type	Frequency	Characteristics Evaluated
Field QC		
DUPs	1 in 20 well trips 1 for every borehole (soil samples)	Precision, including sampling and analytical variability
SPLITs	As needed. When needed, the minimum is one for every analytical method, for analyses performed where detection limit and precision and accuracy criteria have been defined in the Analytical Performance Requirements table.	Precision, including sampling (analytical and interlaboratory)
FTBs	1 per 20 well trips	Cross-contamination from containers or transportation
Field Transfer Blanks	1 each day VOCs are sampled.	Contamination from sampling site
EBs	As needed. If only disposable equipment is used, or equipment is dedicated to a particular well, then an EB is not required. Otherwise, 1 for every 20 samples for each media, or 1 for every borehole for soil samples.[a,b]	Adequacy of sampling equipment decontamination and contamination from nondedicated equipment
Analytical QC[c]		
MBs	1 per analytical batch[d]	Laboratory contamination
Laboratory Duplicates	1 per analytical batch[d]	Laboratory reproducibility and precision
MSs	1 per analytical batch[d]	Matrix effect/laboratory accuracy
MSDs	1 per analytical batch[d]	Laboratory accuracy and precision

Table 4-4. Project QC Requirements

Sample Type	Frequency	Characteristics Evaluated
Surrogates	1 per analytical batch[d]	Recovery/yield
Tracers	1 per analytical batch[d]	Recovery/yield
LCSs	1 per analytical batch[d]	Evaluate laboratory accuracy

a. For portable pumps, EBs are collected 1 for every 10 well trips. Whenever a new type of nondedicated equipment is used, an EB will be collected every time sampling occurs until it can be shown that less frequent collection of EBs is adequate to monitor the decontamination methods for the nondedicated equipment.
b. Vendor-provided borehole equipment is considered dedicated equipment, and EBs are not typically performed.
c. Batching across projects is allowed for similar matrices (e.g., all Hanford Site groundwater).
d. Unless not required by, or different frequency is called out in, laboratory analysis methods.

DUP	= field duplicate	MS	= matrix spike
EB	= equipment blank	MSD	= matrix spike duplicate
FTB	= full trip blank	QC	= quality control
LCS	= laboratory control sample	SPLIT	= field split
MB	= method blank	VOC	= volatile organic compound

Table 4-5. Field and Laboratory QC Elements and Acceptance Criteria

Analyte[a]	QC Element	Acceptance Criteria	Corrective Action
General Chemical Parameters			
Alkalinity	MB[b]	<MDL <5% sample concentration	Flagged with "C"
	LCS	80 to 120% recovery[c]	Data reviewed[d]
	Laboratory duplicate	≤20% RPD[e]	Data reviewed[d]
	Post-preparation spike	75 to 125% recovery[c]	Flagged with "N"
	EB	<2 × MDL	Flagged with "Q"
	Field duplicate	≤20% RPD[e]	Flagged with "Q"
Anions			
Nitrate Chloride Phosphate Sulfate (Preceding Anions by IC)	MB	<MDL <5% sample concentration	Flagged with "C"
	LCS	80 to 120% recovery[c]	Data reviewed[d]
	Laboratory duplicate or MS/MSD	≤20% RPD[e]	Data reviewed[d]
	MS	75 to 125% recovery[c]	Flagged with "N"
	EB, FTB	<2 × MDL	Flagged with "Q"
	Field duplicate	≤20% RPD[e]	Flagged with "Q"

Table 4-5. Field and Laboratory QC Elements and Acceptance Criteria

Analyte[a]	QC Element	Acceptance Criteria	Corrective Action
Metals			
Uranium Calcium Magnesium Sodium Potassium (Preceding Cations/ Metals by ICP)	MB	<RDL <5% sample concentration	Flagged with "C"
	LCS	80 to 120% recovery[c]	Data reviewed[d]
	MS	75 to 125% recovery[c]	Flagged with "N"
	MSD	75 to 125% recovery[c]	Flagged with "N"
	MS/MSD	≤20% RPD[e]	Data reviewed[d]
	EB, FTB	<2 × MDL	Flagged with "Q"
	Field duplicate	≤20% RPD[e]	Flagged with "Q"
Volatile Organic Compounds			
TCE and *cis*-1,2-DCE by GC/MS	MB	<MDL[f] <5% sample concentration	Flagged with "B"
	LCS	Statistically derived[c]	Data reviewed[d]
	MS	% recovery statistically derived[c]	Flagged with "T" if analyzed by GC/MS; otherwise, "N" based on FEAD
	MSD	% recovery statistically derived[c]	Flagged with "T" if analyzed by GC/MS; otherwise, "N" based on FEAD
	MS/MSD	% RPD statistically derived[c]	Data reviewed[d]
	SUR	Statistically derived[c]	Data reviewed[d]
	EB, FTB, FXR	<MDL[f]	Flagged with "Q"
	Field duplicate	≤20% RPD[e]	Flagged with "Q"
Radiochemical Analyses			
Gross Alpha Tritium	MB	<MDC <5% sample concentration	Flagged with "B"
	LCS	70 to 130% recovery	Data reviewed[d]
	Laboratory duplicate	≤20% RPD[e]	Data reviewed[d]
	MS (where applicable)	60 to 140% recovery	Flagged with "N"
	Tracer (where applicable)	20 to 105% recovery	Data reviewed[d]
	Carrier (where applicable)	30 to 105% recovery	Data reviewed[d]
	EB, FTB	<2 × MDA	Flagged with "Q"
	Field duplicate	≤20% RPD[e]	Flagged with "Q"

Table 4-5. Field and Laboratory QC Elements and Acceptance Criteria

Analyte[a]	QC Element	Acceptance Criteria	Corrective Action

a. Specific analytes and method for determination are available from the SMR organization.

b. Does not apply to pH, conductivity, total residue, total suspended solids, total dissolved solids, or alkalinity.

c. Determined by the laboratory based on historical data or statistically derived control limits. Limits are reported with the data. Where specific acceptance criteria are listed, those acceptance criteria may be used in place of statistically derived acceptance criteria.

d. After review, corrective actions are determined on a case-by-case basis.

e. Applies only in cases where both results are greater than 5 times the MDC.

f. For common laboratory contaminants such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the acceptance criteria is greater than 5 times the MDL.

Data Flags:

B (organics)/C (inorganics/wetchem) = Analyte was detected in both the associated QC blank and the sample.

N = all except GC/MS – MS outlier

Q = estimated maximum concentration

T = VOA and semi-VOA GC/MS – MS outlier

DCE = dichloroethene

EB = equipment blank

FEAD = format for electronic analytical data

FTB = full trip blank

FXR = field transfer blank

GC/MS = gas chromatography-mass spectrometry

IC = ion chromatography

ICP = inductively coupled plasma

LCS = laboratory control sample

MB = method blank

MDA = minimum detectable activity

MDC = maximum detectable concentration

MDL = method detection limit

MS = matrix spike

MSD = matrix spike duplicate

QC = quality control

RDL = required detection limit

RPD = relative percent difference

SMR = Sample Management and Reporting

SUR = surrogate

TCE = trichloroethene

VOA = volatile organic analysis

4.2.3.1 Field QC Samples

Field QC samples are collected to evaluate the potential for cross-contamination and provide information pertinent to field sampling variability and laboratory performance to help ensure reliable data are obtained. Field QC samples include field duplicates (DUPs), split samples (SPLITs), and three types of field blanks (full trip blanks [FTBs], field transfer blanks [FXRs], and equipment blanks [EBs]). Field blanks are typically prepared using high-purity reagent water. Field QC samples and their required frequency for collection are described as follows:

DUPs: independent samples collected as close as possible to the same time and same location as the schedule sample, and intended to be identical. DUPs are placed in separate sample containers and analyzed independently. DUPs are used to determine precision for both sampling and laboratory measurements.

SPLITs: two samples collected as close as possible to the same time and same location, and intended to be identical. SPLITs will be stored in separate containers and analyzed by different laboratories for the same analytes. SPLITs are interlaboratory comparison samples used to evaluate comparability between laboratories.

FTBs: bottles prepared by the sampling team prior to traveling to the sampling site. The preserved bottle set is either for volatile organic analysis (VOA) only or identical to the set that will be collected in the field. It is filled with high-purity reagent water (or dead water from Well 699-S11-E12AP for low-level tritium FTBs[2]), and the bottles are sealed and transported, unopened, to the field in the same storage containers used for samples collected that day. Collected FTBs are typically analyzed for the same constituents as the samples from the associated sampling event. FTBs are used to evaluate potential contamination of the samples attributable to the sample bottles, preservative, handling, storage, and transportation.

FXRs: preserved VOA sample vials filled with high-purity reagent water at the sample collection site where VOC samples are collected. The samples will be prepared during sampling to evaluate potential contamination attributable to field conditions. After collection, FXR sample vials will be sealed and placed in the same storage containers with the samples collected the same day for the associated sampling event. FXR samples will be analyzed for VOCs only.

EBs: reagent water passed through or poured over the decontaminated sampling equipment identical to the sample set collected and placed in sample containers, as identified on the SAF. EB sample bottles are placed in the same storage containers with the samples from the associated sampling event. EB samples will be analyzed for the same constituents as the samples from the associated sampling event. EBs are used to evaluate the effectiveness of the decontamination process. EBs are not required for disposable sampling equipment.

4.2.3.2 Laboratory QC Samples

Internal QA/QC programs are maintained by the laboratories utilized by the project. Laboratory QA includes a comprehensive QC program that includes the use of matrix spikes (MSs), matrix duplicates, matrix spike duplicates (MSDs), post-preparation spike, laboratory control samples (LCSs), surrogates (SURs), tracers, and method blanks (MBs). These QC analyses are required by EPA methods (e.g., those in SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*, as amended). QC checks outside of control limits are documented in analytical laboratory reports during DQAs. Laboratory QC samples and their typical frequencies are listed in Table 4-4. Acceptance criteria are shown in Table 4-5. Laboratory QC samples are described as follows:

MS: an aliquot of a sample spiked with a known concentration of target analyte(s). The MS is used to assess the bias of a method in a given sample matrix. Spiking occurs prior to sample preparation and analysis.

Matrix Duplicate: an intralaboratory replicate sample that is used to evaluate the precision of a method in a given sample matrix.

MSD: a replicate spiked aliquot of a sample that is subjected to the entire sample preparation and analytical process. MSD results are used to determine the bias and precision of a method in a given sample matrix.

Post-preparation Spike: the same as an MS; however, the spiking occurs after sample preparation.

LCS: a control matrix (e.g., reagent water) spiked with analytes representative of the target analytes or a certified reference material that is used to evaluate laboratory accuracy.

SUR: a compound added to all samples in the analysis batch prior to preparation. The SUR is typically similar in chemical composition to the analyte being determined, yet is not normally encountered. SURs are expected to respond to the preparation and measurement systems in a manner similar to the analytes

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2 Because of the low detection levels achieved in the low-level tritium analysis, special low-level tritium water must be used. This low-level tritium water, known as "dead water," is collected yearly, or as needed, from Well 699-S11-E12AP or another approved source.

of interest. Because SURs are added to all standards, samples, and QC samples, they are used to evaluate overall method performance in a given matrix. Surrogates are used only in organic analyses.

Tracer: a known quantity of radioactive isotope that is different from that of the isotope of interest but is expected to behave similarly and is added to an aliquot of a sample. Sample results are generally corrected based on tracer recovery.

MB: an analyte-free matrix to which all reagents are added in the same volumes or proportions as used in the sample processing. The MB is carried through the complete sample preparations and analytical procedure, and is used to quantify contamination resulting from the analytical process.

Laboratories are required to analyze samples within the holding time specified in Table 4-6. In some instances, constituents in the samples not analyzed within the holding times may be compromised by volatilizing, decomposing, or by other chemical changes. Data from samples analyzed outside the holding times are flagged in the HEIS database with an "H."

Table 4-6. Preservation, Container, and Holding Time Guidelines

Constituent/Parameter	Minimum Volume/Mass	Container Type	Preservation[a]	Holding Time[b]
Organic Analyses (Groundwater)				
Volatile Organics	4 × 40 mL	40 mL amber glass VOA vial with Teflon®-lined septum lid	Store at ≤6°C (if free Cl2, add 4 drops of 10% sodium thiosulfate), adjust pH to <2 with HCl.	14 days
Metals (Groundwater)				
ICP/MS (with/without Mercury)	250 mL	Narrow-mouth poly or glass	Adjust pH to <2 with nitric acid.	28 days/ 6 months[b]
ICP/AES (with/without Mercury)	250 mL	Narrow-mouth poly or glass	Adjust pH to <2 with nitric acid.	28 days/ 6 months[b]
Miscellaneous Inorganic (Groundwater)				
Alkalinity	500 mL	Narrow-mouth poly or glass	Store at ≤°6C.	14 days
Inorganic Ions (Groundwater)				
Anions (Chloride, Nitrate, Phosphate, and Sulfate)	60 mL	Narrow-mouth poly or glass	Store at ≤°6C.	48 hours
Radiochemical Analyses (Groundwater)				
Gross Alpha (Plate Count)	500 mL	Narrow-mouth poly or glass	Adjust pH to <2 with HNO3.	6 months
Tritium	250 mL	Narrow-mouth glass	None	6 months
Metals (Soil)				
Total Uranium	20 g	60 mL glass/plastic	None	6 months

Table 4-6. Preservation, Container, and Holding Time Guidelines

Constituent/Parameter	Minimum Volume/Mass	Container Type	Preservation[a]	Holding Time[b]
Uranium using semiselective chemical extraction (<2 mm grain-size fractions)	Split-spoon liner sediment that remains in stainless steel bowl after removal of 20 g total uranium sample	1,000 mL glass/plastic	None	6 months
Labile uranium using sodium bicarbonate/carbonate extraction (<2 mm grain-size fractions)				
Miscellaneous (Soil)				
pH	Split-spoon liner sediment that remains in stainless steel bowl after removal of 20 g total uranium sample	1,000 mL glass/plastic	None	6 months
Grain size				
Predominant uranium-bearing mineral phase (<2 mm grain-size fractions)				

Source: SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B* (Table 4.1).

Note: In the Container Type column, the term poly stands for EPA clean polyethylene bottles.

The information in this table does not represent an EPA requirement but is intended solely as guidance. Selection of container, preservation techniques, and applicable holding times should be based on the stated project-specific DQOs.

Teflon is a registered trademark of E.I. DuPont Nemours and Company, Wilmington, Delaware.

TDSs and TSSs can both be analyzed from a 1 L (0.3 gal) sample.

All metals for a sample of water (both ICP/MS and ICP/AES) can be analyzed from the same 500 mL samples.

a. For preservation identified as store at ≤6°C, the sample should be protected against freezing unless it is known that freezing will not impact the sample integrity.

b. For metals analysis, 28 days/6 months holding time defines 28 days for mercury, 6 months for all other metals.

EPA = U.S. Environmental Protection Agency
ICP/AES = inductively coupled plasma/atomic emission spectroscopy
ICP/MS = inductively coupled plasma/mass spectrometry
TDS = total dissolved solids
TSS = total suspended solids
VOA = volatile organic analysis

4.2.4 Measurement Equipment

Each user of the measuring equipment is responsible to ensure that equipment is functioning as expected, properly handled, and properly calibrated at required frequencies in accordance with methods governing control of the measuring equipment. Onsite environmental instrument testing, inspection, calibration, and maintenance will be recorded in accordance with approved methods. Field screening instruments will be used, maintained, and calibrated in accordance with the manufacturer's specifications and other approved methods.

4.2.5 Instrument and Equipment Testing, Inspection, and Maintenance

Collection, measurement, and testing equipment should meet applicable standards (e.g., ASTM) or have been evaluated as acceptable and valid in accordance with instrument-specific methods, requirements, and specifications. Software applications will be acceptance tested prior to use in the field.

Measurement and testing equipment used in the field or laboratory will be subject to preventive maintenance measures to ensure minimization of downtime. Laboratories must maintain and calibrate their equipment. Maintenance requirements (e.g., documentation of routine maintenance) will be included in the individual laboratory and onsite organization's QA plan or operating protocols, as appropriate. Maintenance of laboratory instruments will be performed in a manner consistent with applicable Hanford Site requirements.

4.2.6 Instrument/Equipment Calibration and Frequency

Specific field equipment calibration information is provided in Section 5.3. Analytical laboratory instruments and measuring equipment are calibrated in accordance with the laboratory's QA plan and applicable Hanford Site requirements.

4.2.7 Inspection/Acceptance of Supplies and Consumables

Consumables, supplies, and reagents will be reviewed in accordance with SW-846 requirements and will be appropriate for their use. Supplies and consumables used in support of sampling and analysis activities are procured in accordance with internal work requirements and processes. Responsibilities and interfaces necessary to ensure that items procured/acquired for the contractor meet the specific technical and quality requirements must be in place. The procurement system ensures purchased items comply with applicable procurement specifications. Supplies and consumables are checked and accepted by users prior to use.

4.2.8 Nondirect Measurements

Data obtained from sources such as computer databases, programs, literature files, and historical databases will be technically reviewed to the same extent as the data generated as part of any sampling and analysis QA/QC effort. All data used in evaluations will be identified by source.

4.2.9 Data Management

The SMR organization, in coordination with the OU Project Manager, is responsible for ensuring that analytical data are appropriately reviewed, managed, and stored in accordance with the applicable programmatic requirements governing data management methods.

Electronic data access, when appropriate, will be through a Hanford Site database (e.g., HEIS) or a project-specific database, whichever is applicable for the data being stored. Where electronic data are not available, hardcopies will be provided in accordance with Section 9.6 of the TPA Action Plan (Ecology et al., 1989b).

Laboratory errors are reported to the SMR organization on a routine basis. For reported laboratory errors, a sample issue resolution form will be initiated in accordance with applicable methods. This process is used to document analytical errors and to establish their resolution with the OU Project Manager. The sample issue resolution forms become a permanent part of the analytical data package for future reference and for records management.

4.3 Assessment and Oversight

The elements in assessment and oversight address the effectiveness of project implementation and associated QA/QC activities. The purpose of assessment is to ensure that the QAPjP is implemented as prescribed.

4.3.1 Assessments and Response Actions

Random surveillances and assessments verify compliance with the requirements outlined in this SAP, project field instructions, the project quality management plan, methods, and regulatory requirements. Deficiencies identified by these assessments will be reported in accordance with existing programmatic requirements. The project's line management chain coordinates the corrective actions/deficiencies resolutions in accordance with the QA program, the corrective action management program, and associated methods implementing these programs. When appropriate, corrective actions will be taken by the OU Project Manager (or designee).

Oversight activities in the analytical laboratories, including corrective action management, are conducted in accordance with the laboratories' QA plans. The contractor oversees offsite analytical laboratories and verifies the laboratories are qualified for performing Hanford Site analytical work.

4.3.2 Reports to Management

Management will be made aware of deficiencies identified by self-assessments, corrective actions from ECOs, and findings from QA assessments and surveillances. Issues reported by the laboratories are communicated to the SMR organization, which then initiates a sample issue resolution form. This process is used to document analytical or sample issues and to establish resolution with the OU Project Manager.

4.4 Data Review and Usability

This section addresses QA activities that occur after data collection. Implementation of data review, and verification and validation activities in an objective and consistent manner, determines whether the data will be accepted, rejected, or qualified and will, therefore, conform to the specified criteria, thus satisfying the project objectives.

4.4.1 Data Review and Verification

Data review and verification are performed to confirm that sampling and chain-of-custody documentation are complete. This review includes linking sample numbers to specific sampling locations, reviewing sample collection dates and sample preparation and analysis dates to assess whether holding times have been met, and reviewing QC data to determine whether analyses have met the data quality requirements specified in this SAP.

The criteria for verification include but are not limited to review for contractual compliance (samples were analyzed as requested), use of the correct analytical method, transcription errors, correct application of dilution factors, appropriate reporting of dry weight versus wet weight, and correct application of conversion factors.

Errors identified by the laboratories are reported to the SMR organization's project coordinator, who initiates a sample issue resolution form. This process is used to document analytical errors and to establish resolution with the OU Technical Lead.

Relative to analytical data in sample media, field screening results are of lesser importance in making inferences regarding risk. Field QA/QC results will be reviewed to ensure they are usable.

The OU Technical Lead data review will help determine if observed changes reflect improved/degraded groundwater quality or potential data errors and may submit a request for data review (RDR) on questionable data. The laboratory may be asked to check calculations or reanalyze the sample, or the well may be resampled. Results of the RDR process are used to flag the data appropriately in the HEIS database and/or to add comments.

4.4.2 Data Validation

Data validation activities will be performed at the discretion of the OU Project Manager and under the direction of SMR.

4.4.3 Reconciliation with User Requirements

The DQA process compares completed field sampling activities to those proposed in corresponding sampling documents and provides an evaluation of the resulting data. The purpose of the DQA is to determine whether quantitative data are of the correct type and are of adequate quality and quantity to meet the project DQOs. For routine groundwater monitoring undertaken through this integrated SAP, the DQA is captured in QC associated with the annual groundwater monitoring report, evaluating field and lab QC and the usability of data relative to the principal DQIs (Table 4-1) and acceptance criteria for laboratory QC elements (Table 4-5). Further DQAs will be performed at the discretion of the OU Project Manager and documented in a report overseen or reviewed by SMR.

5 Field Sampling Plan

This chapter described the field sampling plan and methodologies for the 300-FF-5 OU groundwater remedy.

5.1 Sampling Methods

Sampling methods may include but are not limited to the following:

- Field screening measurements
- Groundwater sampling
- Aquifer tube sampling
- Soil sampling
- Radiological screening
- Water level measurements

5.1.1 Groundwater Sampling

Groundwater samples will be collected according to the current, applicable sampling methods. Groundwater samples are collected after field measurements of purged groundwater have stabilized:

- pH – two consecutive measurements agree within 0.2 pH units.
- Temperature – two consecutive measurements agree within 0.2°C.
- Specific conductance – two consecutive measurements agree within 10 percent of each other.
- DO and ORP readings will also be collected, but stabilization of readings is not required prior to sampling.

For groundwater samples collected from piezometers screened in the PRZ, there may be insufficient pore water present to perform the previously described purging and stabilization method. In this scenario (if water is present), field parameters will be measured using a downhole instrument, and a grab sample will be collected using a low-flow pump or bailer.

For field parameter monitoring in groundwater and PRZ pore water during phosphate application, the purging and stabilization method will not be required. Field parameters will be measured using a downhole instrument.

For certain types of samples, preservatives are required. While the preservatives may be added to the collection bottles before their use in the field, it is allowable to add the preservatives at the sampling vehicles immediately after collection. Samples may require filtering in the field, based on field conditions.

To ensure sample and data usability, sampling associated with this SAP will be performed according to HASQARD (DOE/RL-96-68) pertaining to sample collection, collection equipment, and sample handling.

Required sample container, preservation, and holding time requirements are specified in Table 4-6 for groundwater samples. These requirements are in accordance with the analytical method specified. The container type and volumes will be identified on the field paperwork.

Holding time is the elapsed time period between sample collection and analysis. Exceeding required holding times could result in changes in constituent concentrations due to volatilization, decomposition, or other chemical alterations. Required holding times depend on the analytical method, as specified for appropriate EPA methods (e.g., EPA-600/4-79-020, *Methods for Chemical Analysis of Water and Wastes*, and SW-846). This SAP defines a sample as a filled sample bottle for starting the clock for holding time restrictions.

5.1.2 Soil Sampling

Soil from borings will be sampled in order to conduct post-treatment uranium concentration and leachability characterization. Sampling will be performed using a 10.2 cm (4 in.) diameter, 0.76 m (2.5 ft) long split-spoon sampler. Split-spoon samplers will be equipped with four separate polycarbonate liners that are each 15.2 cm (6 in.) long. If sufficient sample recovery is not achieved, soil from the split-spoon drive shoe may be used to supplement the sample mass of the split-spoon liners. Site personnel will not overdrive the sampling device.

Upon retrieval of the split-spoon sampler, each split-spoon liner will be labeled at the top and bottom with the appropriate depths and labeled according to well or borehole identification. A continuous line will be drawn the length of the split-spoon liner with an arrow pointing to the shallowest end of the liner (i.e., with an up arrow indicating core orientation). The site geologist will provide a lithologic description of each split-spoon liner, noting the soil size fractions and capturing a sample photo log. The ends of each split-spoon liner will be photographed in the field prior to capping or transfer to the stainless steel bowl.

Soil from the split-spoon liner will be transferred (while in the field) to a clean, stainless steel mixing bowl and homogenized. A 20 g grab sample (<2 mm sediment size) from the homogenized soil in the bowl will be collected and containerized, as described in Table 4-6, for total uranium analysis. The remaining homogenized soil (approximately 1 L [0.3 gal]) will be collected and containerized for uranium leachability characteristic tests, which include a semiselective sequential uranium leach test, labile uranium leach test, pH analysis, and a grain-size analysis.

5.1.3 Decontamination of Sampling Equipment

Sampling equipment will be decontaminated in accordance with the sampling equipment decontamination methods. To prevent potential contamination of the samples, care should be taken to use decontaminated equipment for each sampling activity.

Special care should be taken to avoid the following common ways in which cross-contamination or background contamination may compromise the samples:

- Improperly storing or transporting sampling equipment and sample containers
- Contaminating the equipment or sample bottles by setting the equipment/sample bottle on or near potential contamination sources (e.g., uncovered ground)
- Handling bottles or equipment with dirty hands or gloves
- Improperly decontaminating equipment before sampling or between sampling events

5.1.4 Radiological Field Data

Alpha and beta/gamma data collection in the field will be used, as needed, to support sampling and analysis efforts. Radiological screening will be performed by the RCT or other qualified personnel. The RCT will record field measurements, noting the depth of the sample and the instrument reading. Measurements will be relayed to the field geologist (for boreholes and wells) for daily inclusion in the field logbook or operational records, as applicable.

The following information will be distributed to personnel performing work in support of this SAP:

- Instructions to RCTs on the methods required to measure sample activity and media for gamma, alpha, and/or beta emissions, as appropriate.
- Information regarding the portable radiological field instrumentation including a physical description of the instruments, radiation and energy response characteristics, calibration/maintenance and performance testing descriptions, and the application/operation of the instrument. These instruments are commonly used on the Hanford Site to obtain measurements of removable surface contamination measurements and direct measurements of the total surface contamination.
- Instructions regarding the minimum requirements for documenting radiological controls information in accordance with 10 CFR 835, "Occupational Radiation Protection."
- Instructions for managing the identification, creation, review, approval, storage, transfer, and retrieval of radiological information.
- The minimum standards and practices necessary for preparing, performing, and retaining radiological-related information.
- The requirements associated with preparing and transporting regulated material.
- Daily reports of radiological surveys and measurements collected during conduct of field investigation activities. Data will be cross-referenced between laboratory analytical data and radiation measurements to facilitate interpreting the investigation results.

5.1.5 Water Levels

Groundwater levels are measured annually across the Hanford Site to construct water table maps that are used to determine the direction and rate of groundwater flow in the unconfined aquifer (SGW-38815, *Water-Level Monitoring Plan for the Hanford Site Soil and Groundwater Remediation Project*). Water levels are also measured in wells that are screened in confined or partially confined aquifers to help determine horizontal and vertical hydraulic gradients.

A measurement of depth to water is also recorded in each well prior to sampling, using calibrated depth measurement tapes. Two consecutive measurements are taken that agree within 6 mm (0.02 ft); these are recorded along with the date, time, measuring tape number, and so forth. The depth to groundwater is subtracted from the elevation of a reference point (usually the top of casing) to obtain the water level elevation. Tops of casings are known elevation reference points because they have been surveyed to local reference data.

The AWLN is an array of remote monitoring stations connected by a telemetry network to a central base station (SGW-53543). Each monitoring station consists of a pressure transducer connected to a data collection telemetry unit. AWLN data are used to collect data at multiple locations at the same times and frequency to establish migration pathways and changes in migration pathways. Use of AWLNs enables water level changes in response to river stage fluctuations to be recorded simultaneously at multiple locations. Eleven AWLN stations will be installed in 300-FF-5 OU wells listed in Table 3-6 and shown in Figure 3-3. These stations will be maintained for the first 5 years of monitoring, and then re-evaluated.

5.2 Documentation of Field Activities

Logbooks or data forms are required for field activities. A logbook must be identified with a unique project name and number. The individual(s) responsible for logbooks will be identified in the front of the logbook, and only authorized persons may make entries in logbooks. Logbook entries will be reviewed by the FWS, cognizant scientist/engineer, or other responsible manager; the review will be documented with a signature and date. Logbooks will be permanently bound, waterproof, and ruled with sequentially numbered pages. Pages will not be removed from logbooks for any reason. Entries will be made in indelible ink. Corrections will be made by marking through the erroneous data with a single line, entering the correct data, and initialing and dating the changes.

Data forms may be used to collect field information; however, the information recorded on data forms must follow the same requirements as those for logbooks. The data forms must be referenced in the logbooks.

A summary of information to be recorded in logbooks is as follows:

- Purpose of activity
- Day, date, time, and weather conditions
- Names, titles, and organizations of personnel present
- Deviations from the QAPjP
- All site activities, including field tests
- Materials quality documentation (e.g., certifications)
- Details of samples collected (e.g., preparation, splits, DUPs, MS, and EBs)
- Location and types of samples
- Chain-of-custody details and variances relating to chain-of-custody
- Field measurements
- Field calibrations testing, inspections, maintenance and surveys, and equipment identification numbers, as applicable
- Equipment decontaminated, number of decontaminations, and variations to decontamination methods
- Equipment failures or breakdowns and descriptions of any corrective actions
- Telephone calls relating to field activities

5.2.1 Corrective Actions and Deviations for Sampling Activities

The Project Manager, FWS, appropriate BTR (or designee), and SMR personnel must document deviations from protocols, and problems pertaining to sample collection, chain-of-custody forms, target analytes, contaminants, sample transport, or noncompliant monitoring. Examples of deviations include samples not collected because of field conditions, changes in sample locations because of physical obstructions, or additions of sample depths.

As appropriate, such deviations or problems will be documented in the field logbook or on nonconformance report forms in accordance with internal corrective action methods. The Project Manager, FWS, appropriate BTR (or designee), or SMR personnel will be responsible for communicating field corrective action requirements and for ensuring that immediate corrective actions are applied to field activities.

Changes in sample activities that require notification, approval, and documentation will be performed as specified in Table 4-2.

5.3 Calibration of Field Equipment

Construction management, the appropriate BTR, or the FWS is responsible for ensuring that field equipment is calibrated appropriately. Onsite environmental instruments will be calibrated in accordance with the manufacturer's operating instructions, internal work requirements and processes, and/or field instructions that provide direction for equipment calibration or verification of accuracy by analytical methods. Results from all instrument calibration activities will be recorded according to HASQARD (DOE/RL-96-68).

Field instrumentation, calibration, and QA checks will be performed as follows:

- Prior to initial use of a field analytical measurement system.
- At the frequency recommended by the manufacturer or methods, or as required by regulations.
- Upon failure to meet specified QC criteria.
- Calibration of radiological field instruments on the Hanford Site is performed by the Mission Support Alliance prime contractor, as specified by its calibration program.
- Daily calibration checks will be performed and documented for each instrument used to characterize areas under investigation. These checks will be made on standard materials sufficiently like the matrix under consideration for direct comparison of data. Analysis times will be sufficient to establish detection efficiency and resolution.
- Standards used for calibration will be traceable to nationally or internationally recognized standard agency source or measurement system, if available.

5.4 Sample Handling

Sample handling and transfer will be in accordance with established methods to preclude loss of identity, damage, deterioration, and loss of sample. Custody seals or custody tape will be used to verify that sample integrity has been maintained during sample transport. The custody seal will be inscribed with the sampler's initials and date.

A sampling and tracking database is used to track the samples from the point of collection through the laboratory analysis process.

5.4.1 Containers

Precleaned sample containers, with certificates of analysis denoting compliance with EPA specifications (EPA 540/R-93/051, *Specifications and Guidance for Contaminant-Free Sample Containers*) for the intended analyses, will be used for samples collected for chemical analysis. Container sizes may vary depending on laboratory-specific volumes/requirements for meeting analytical detection limits.
The Radiological Engineering organization will measure both the contamination levels and the dose rates associated with the filled sample containers. This information, along with other data, will be used to select proper packaging, marking, labeling, and shipping paperwork and to verify that the sample can be received by the analytical laboratory in accordance with the laboratory's radioactivity acceptance criteria. If the dose rate on the outside of a sample container or the curie content exceeds levels acceptable by an

offsite laboratory, the FWS (in consultation with the SMR organization) can send smaller volumes to the laboratory. Container types and sample amounts/volumes are identified in Table 4-6.

5.4.2 Container Labeling

Each sample container will be labeled with the following information on firmly affixed, water-resistant labels:

- SAF
- HEIS number
- Sample collection date and time
- Analysis required
- Preservation method (if applicable)
- Chain-of-custody number
- Bottle type and size
- Laboratory performing the analyses
- Sample location

In addition, sample records must include the following information:

- Analysis required
- Source of sample
- Matrix (water or soil)
- Field data (pH, temperature, conductivity, DO, and ORP)
- Radiological readings

DO and ORP may be specified by the project.

5.4.3 Sample Custody

Sample custody will be maintained in accordance with existing protocols to ensure the maintenance of sample integrity throughout the analytical process. Chain-of-custody protocols will be followed throughout sample collection, transfer, analysis, and disposal to ensure that sample integrity is maintained. A chain-of-custody record will be initiated in the field at the time of sampling and will accompany each set of samples shipped to any laboratory.

Shipping requirements will determine how sample shipping containers are prepared for shipment. The analyses requested for each sample will be indicated on the accompanying chain-of-custody form. Each time the responsibility for the custody of the sample changes, the new and previous custodians will sign the record and note the date and time. The sampler will make a copy of the signed record before sample shipment and will transmit the copy to the SMR organization within 48 hours of shipping.

The following information is required on a completed chain-of-custody form:

- Project name
- Signature of sampler
- Unique sample number
- Date and time of collection
- Matrix

- Preservatives
- Signatures of individual involved in sample transfer
- Requested analyses (or reference thereto)

Samplers should note any anomalies with the samples that would prevent batching. If anomalies are found, samplers should inform SMR before adding any information regarding batching on the chain-of-custody form.

5.4.4 Sample Transportation

All packaging and transportation instructions shall be in compliance with applicable transportation regulations and DOE requirements. Regulations for classifying, describing, packaging, marking, labeling, and transporting hazardous materials, hazardous substances, and hazardous wastes are enforced by the U.S. Department of Transportation (DOT) as described in 49 CFR 171, "General Information, Regulations, and Definitions," through 177, "Carriage by Public Highway." Carrier specific requirements defined in the International Air Transportation Association Dangerous Goods Regulations (IATA, 2013) shall also be used when preparing sample shipments conveyed by air freight providers.

Samples containing hazardous constituents shall be considered hazardous material in transportation and transported according to DOT/IATA requirements. If the sample material is known or can be identified, then it will be packaged, marked, labeled, and shipped according to the specific instructions for that material.

Materials are classified by DOT/IATA as radioactive when the isotope specific activity concentration and the exempt consignment limits described in 49 CFR 173, "Transportation," "Shippers—General Requirements for Shipments and Packagings," are exceeded. Samples shall be screened, or relevant historical data will be used, to determine if these values are exceeded. When screening or historical data indicate samples are radioactive, they shall be properly classified, described, packaged, marked, labeled, and transported according to DOT/IATA requirements.

Prior to shipping radioactive samples to the laboratory, the organization responsible for shipping shall notify the laboratory of the approximate number of and radiological levels of the samples. This notification is conducted through the SMR project coordinator. The laboratory is responsible for ensuring that the applicable license limits are not exceeded. The laboratory shall provide SMR with written acceptance for samples with elevated radioactive contamination or dose.

5.5 Operations and Maintenance

Operations and maintenance (O&M) will be performed to maintain the performance monitoring network as a necessary component of the groundwater remedy. O&M activities encompass monitoring wells and aquifer tubes within the performance monitoring network for the 300-FF-5 OU.

5.5.1 Operations

The operational goal is to sample at designated monitoring wells and aquifer tubes during the groundwater remedy performance monitoring period. An AWLN will be operated continuously through at least the initial 5 years of monitoring. As concentrations of COCs are reduced, and the plume sizes reduce, the monitoring network will be adjusted. Wells and aquifer tubes will not be arbitrarily removed from service unless they are determined to be no longer needed in the groundwater monitoring network due to decreasing COC plume size. Wells taken out of service due to shrinking of the COC plumes will be scheduled for future decommissioning if it is determined that they are not potentially needed for future monitoring.

5.5.2 Monitoring Network Maintenance

Well maintenance will be necessary for some wells during the time frame of the groundwater remedy. Maintenance includes wellhead inspection and maintenance. Well maintenance will be performed on an as needed basis. During scheduled sample collection events, sampling crews will inspect the wells. If problems with the wellhead are observed, or if there is a problem obtaining samples (e.g., excessive drawdown or high turbidity), well maintenance will be performed. Well maintenance may also be performed based on unusual sampling results. The following activities may be initiated if a well is determined to require maintenance:

- Removal and inspection of all downhole well components (e.g., level transducer and wiring)
- Downhole camera inspection (includes recording the inspection)
- Swabbing the well to loosen any accumulated solids from the well casing and screen
- Surging (with a dual-plate surge block) and pumping to redevelop the well screen and filter pack and remove accumulated solids from the well (continue surging the well until no more than 30 cm [0.1 ft] infill during 15 minutes surge is achieved)
- Final camera survey (includes recording the inspection)

During the performance monitoring period, it is highly likely that some wells will require replacement. If the condition of a well has deteriorated and is not repairable, DOE-RL and the LRA will determine if the well should be replaced.

An AWLN will be installed at selected monitoring locations identified in Section 3.3.3. After 5 years, the project will evaluate the need for continued AWLN operation. AWLN data will be checked against manual water level measurements at least once per year, and instruments will be recalibrated when necessary. Stations within AWLN will undergo installation, maintenance, upgrades, removal, and replacement in accordance with specific maintenance procedures. Maintenance may include troubleshooting, component change-outs, and upgrades to station telemetry equipment in support of AWLN. At the end of the AWLN monitoring period, system components will be removed from the monitoring wells.

During scheduled sample collection events, sampling crews will inspect the aquifer tubes. Repairs to the aquifer tubes will be performed, as needed.

5.5.3 Monitoring Network Maintenance Reporting

Any well maintenance activities that affect sample quality will be summarized in the Hanford Site annual groundwater monitoring report (e.g., DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*). Performance monitoring results will be included as part of the annual groundwater monitoring report following each sample collection year.

6 Management of Waste

Waste materials are generated during well drilling, phosphate injection/infiltration activities, sample collection, processing, and subsampling activities. Waste will be managed in accordance with DOE/RL-2000-56, *Waste Management Plan for the 300-FF-5 Operable Unit*, and must be characterized to the extent necessary to meet the requirements of DOE/RL-2011-41, *Hanford Site Strategy for Management of Investigation Derived Waste*. For waste designation purposes, the maximum concentration in 5 years of historical data from HEIS for the analytes and wells listed in Table 3-6, as applicable, will comprise a complete analytical data set.

Offsite analytical laboratories are responsible for the disposal of unused sample quantities. Pursuant to 40 CFR 300.440, "National Oil and Hazardous Substances Pollution Contingency Plan," "Procedures for Planning and Implementing Off-Site Response Actions," approval from DOE Remedial Project Manager is required before returning unused samples or waste from offsite laboratories.

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7 Health and Safety

The hazardous waste operations safety and health program was established to ensure the safety and health of workers involved in hazardous waste site activities. The program was developed to comply with the requirements of 29 CFR 1910.120, "Occupational Safety and Health Standards," "Hazardous Waste Operations and Emergency Response," and 10 CFR 835. The health and safety program defines the chemical, radiological, and physical hazards and specifies the controls and requirements for day-to-day work activities on the overall Hanford Site. Personal training, control of industrial safety and radiological hazards, PPE, site control, and general emergency response to spills, fire, accidents, injury, site visitors, and incident reporting are governed by the health and safety program.

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8 References

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Appendix A

Data Quality Objectives Report for 300-FF-5 Operable Unit Remedy Implementation

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Contents

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Terms

2-D	two-dimensional
AWLN	Automated Water Level Network
bgs	below ground surface
COC	contaminant of concern
CSM	conceptual site model
CUL	cleanup level
DCE	dichloroethene
DO	dissolved oxygen
DOE	U.S. Department of Energy
DQO	data quality objective
DWS	drinking water standard
D4	deactivation, decommission, decontamination, and demolition
EA	enhanced attenuation
EPA	U.S. Environmental Protection Agency
ERT	electrical resistivity tomography
HEIS	Hanford Environmental Information System
IC	institutional control
MNA	monitored natural attenuation
ORP	oxidation reduction potential
OU	operable unit
PMP	performance monitoring plan
PRZ	periodically rewetted zone
PVC	polyvinyl chloride
PSQ	principal study question
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RAO	remedial action objective
RI/FS	remedial investigation/feasibility study
RDR/RAWP	remedial design report/remedial action work plan
ROD	record of decision

SI	sampling instruction
TCE	trichloroethene

A1 Introduction

The 300-FF-5 Groundwater Operable Unit (OU) comprises groundwater contaminated by releases from facilities and waste sites associated with past operation of the 300 Area fuel fabrication facilities. The U.S. Environmental Protection Agency (EPA) issued the 300 Area record of decision (ROD)/ROD Amendment for the 300-FF-1, 300-FF-2, and 300-FF-5 OUs in November 2013 (EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1*), which specifies enhanced attenuation (EA), monitored natural attenuation (MNA), groundwater monitoring, and institutional controls (ICs) to restrict groundwater use as the final 300-FF-5 OU remedial actions. The remedy will be implemented for uranium, trichloroethene (TCE), *cis*-1,2-dichloroethene (DCE), gross alpha, nitrate, and tritium in 300-FF-5 OU groundwater. Performance monitoring of these contaminants of concern (COCs) in the groundwater is a component of the EA and MNA remedies. Performance monitoring includes two phases:

- The *remediation monitoring phase* occurs while remedial activities (in this case, enhanced and natural attenuation processes) are being implemented to reach groundwater cleanup levels (CULs).
- The *attainment monitoring phase* occurs after the remediation phase is complete. Data are collected and evaluated to confirm that the CUL for each COC has been met, and that groundwater will continue to meet the CULs in the future.

The EPA seven-step data quality objective (DQO) process (EPA/240/B-06/001, *Guidance on Systematic Planning Using the Data Quality Objectives Process*) was used to guide development of remedy implementation for the 300-FF-5 OU. DQO workshops were conducted on October 15, 2014, November 18, 2014, December 1, 2014, and January 29, 2015, to support design of the remedy implementation performance monitoring plan (PMP). The third and fourth workshops included review and contribution from the U.S. Department of Energy (DOE) sampling and analysis panel. This report summarizes the output of the DQO process.

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A2 Step 1: State the Problem

Step 1 provides a concise description of the problem, identifies the DQO planning team, presents the conceptual site model (CSM), and determines resources.

A2.1 Background

The remedy and location for each COC in groundwater are provided in Table A-1. The locations are shown on Figure A-1. EA will use uranium sequestration in the vadose zone and periodically rewetted zone (PRZ) to reduce the mobility of uranium that is the primary source of contamination in groundwater. Uranium sequestration will also be used in the top of the aquifer to reduce the mobility of uranium that may be mobilized during the vadose zone treatment process. MNA will be used for nitrate, TCE, and *cis*-1,2-DCE in groundwater.

Uranium sequestration will be implemented using a staged approach. Stage A will consist of performing infiltration/injection of phosphate solutions in one quadrant of the EA area, covering approximately 0.3 ha (0.75 ac). The Stage A results will be used to refine the Stage B approach for the remaining three quadrants (0.9 ha [2.25 ac]). Additional information on implementation of the EA remedy is provided in DOE/RL-2014-13-ADD2, *Remedial Design Report/Remedial Action Work Plan Addendum for the 300 Area Groundwater*, hereinafter called the remedial design report/remedial action work plan (RDR/RAWP).

A supplemental post-ROD field investigation will be completed to refine the location of the EA area before implementing the vadose zone infiltration and PRZ and aquifer injections. This field investigation is being conducted according to SGW-56993, *Sampling Instruction for the 300-FF-5 Operable Unit Supplemental Post ROD Field Investigation* (hereinafter the Post-ROD Field Investigation Sampling Instruction [SI]). Refinements will be made to Stage A design based on the results of the supplemental post-ROD field investigation.

Table A-1. Required Monitoring Constituents and Locations

Location	EA and Monitoring Constituents (300 Area ROD/ ROD Amendment, Sections 12.2.6 and 12.2.7)	MNA Constituents (300 Area ROD/ ROD Amendment, Section 12.2.8)	Groundwater Monitoring Constituents (300 Area ROD/ ROD Amendment, Section 12.2.9)
Enhanced Attenuation Area (1 ha [3 ac]) in 300 Area Industrial Complex	Uranium		
300 Area Industrial Complex		TCE and *cis*-1,2-DCE	TCE, *cis*-1,2-DCE, gross alpha, and uranium
618-7 Burial Ground			Uranium and gross alpha
618-11 Burial Ground		Nitrate and tritium	Nitrate and tritium

Source: EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1.*

Note: Section 12.2.9 of the 300 Area ROD/ROD Amendment (EPA and DOE, 2013) identifies monitoring for nitrate at the 300 Area Industrial Complex; however, Section 5.1.3 of the ROD/ROD Amendment states that this nitrate plume is not part of the 300-FF-5 OU.

DCE	=	dichloroethene	OU	=	operable unit
EA	=	enhanced attenuation	ROD	=	record of decision
MNA	=	monitored natural attenuation	TCE	=	trichloroethene

Remedy implementation for MNA was designed consistent with EPA guidance on monitoring programs for natural attenuation remedies (EPA 600/R-11/204, *An Approach for Evaluating the Progress of Natural Attenuation in Groundwater*). This guidance identifies the following steps to accomplish performance monitoring:

1. Demonstrate that natural attenuation is occurring according to expectations.
2. Detect changes in environmental conditions (e.g., hydrogeologic, geochemical, microbiological, or other changes) that may reduce the efficacy of any of the natural attenuation processes.
3. Identify any potentially toxic and/or mobile transformation products.
4. Verify that the plume(s) is not expanding downgradient, laterally, or vertically.
5. Verify that there is no unacceptable impact to downgradient receptors.
6. Detect new releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy.
7. Demonstrate the efficacy of ICs that were put in place to protect potential receptors.
8. Verify attainment of remediation objectives.

Evaluation methods that will be used to assess progress toward the groundwater remedial action objectives (RAOs) and CUL attainment are summarized in Table A-2 and discussed in detail in Appendix B. These evaluation methods are based on the general guidance and recommendations discussed in EPA 600/R-11/204 as part of a general framework for implementation of MNA.

Table A-2. Evaluation Methods for Progress Assessment of RAO Attainment

Evaluation Method	Description
Plume Mapping	Numerically interpolated piece-wise continuous COC distributions will be developed that allow estimating contaminant mass, plume center of mass, and spread of the contaminant across the plume area for each COC plume. Plume mapping will assist with monitoring potential expansion of the contaminant plume downgradient, vertically, or laterally.
Water Level Mapping	Synoptic and continuous groundwater level data will be mapped to depict patterns of groundwater flow and corresponding directions of contaminant migration throughout the groundwater OU. Water level mapping will assist with determining whether adverse conditions are being developed that could impact plume migration and might reduce the efficacy of the attenuation processes. Changes in hydrologic conditions could also indicate required refinements of the CSM.
Groundwater Modeling	Groundwater flow and contaminant transport modeling will be used for projecting the likely time required to attain the RAO for uranium following uranium sequestration in the EA area. The results will be reported in terms of a best estimate together with one or more measures of uncertainty that accompany the best estimate projection.
Statistical Analysis	COC concentrations will be evaluated on a well-by-well basis based on statistical analyses of monitoring data. Fundamental tests will be applied to the remediation and attainment monitoring

	phases to evaluate performance and determine whether additional actions are required. The strategy for completing site closure is implemented in two phases: remediation monitoring phase and attainment monitoring phase. Attainment monitoring for each COC will commence on a well-by-well basis, as soon as concentrations of a COC have met the CUL at a well as part of the analyses performed during the remediation monitoring phase.
EA Treatment Performance	The performance of the Stage A EA treatment will be evaluated though collection of uranium leachability data before and after phosphate application; fate and transport modeling to assess the decrease in the time frame to achieve the uranium CUL in groundwater; groundwater sampling prior to, during, and after phosphate application to evaluate mobilization of uranium to groundwater and phosphate distribution efficiency; and real-time sensing of phosphate solution movement in vadose zone, PRZ, and aquifer to evaluate phosphate distribution. Impacts to aquifer permeability will also be evaluated. Based on the overall effectiveness of the treatment, DOE and EPA will make the decision to proceed with implementing Stage B or to conclude EA treatment.

COC = contaminant of concern
CSM = conceptual site model
CUL = cleanup level
DOE = U.S. Department of Energy
EA = enhanced attenuation
EPA = U.S. Environmental Protection Agency
OU = operable unit
PRZ = periodically rewetted zone
RAO = remedial action objective

A2.2 300-FF-5 OU Problem Statements

The 300-FF-5 OU problem statements, presented in Table A-3, are based on groundwater RAOs in the 300 Area ROD/ROD Amendment (DOE and EPA, 2013).

Table A-3. Problem Statements for 300-FF-5 OU Performance Monitoring

	Problem Statement	RAO in 300 Area ROD/ ROD Amendment, Section 8.1
1	There is a need to prevent human exposure to groundwater containing COC concentrations above CULs.[a]	RAO 1
2	There is a need to restore groundwater impacted by Hanford Site releases to CULs, which include DWSs, within a time frame that is reasonable given the particular circumstances of the site.[b]	RAO 7

a. The 300 Area ROD/ROD Amendment (EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1*) states "Institutional Controls (ICs) are used to control access to residual contaminants in soil and groundwater as long as they exceed the CULs." Problem Statement 1 will be achieved through these ICs. This DQO addresses the data needs associated with Problem Statement 2.

b. Time frames consistent with the 300 Area ROD/ROD Amendment (EPA and DOE, 2013) and DOE/RL-2011-47, *Proposed Plan for the Remediation of 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units*, for the 300-FF-5 OU are considered reasonable. Time frames are provided in Table A-8.

COC = contaminant of concern
CUL = cleanup level
DQO = data quality objective
DWS = drinking water standard
IC = institutional control
RAO = remedial action objective
ROD = record of decision

A2.3 300-FF-5 OU DQO Planning Team

Table A-4 identifies the planning team members and their respective roles.

Table A-4. 300-FF-5 OU DQO Planning Team

Name	Organization	Role
Virginia Rohay	CHPRC	300-FF-5 OU Project Scientist (MNA Lead)
Gene Ng	CH2M HILL	Project Engineer (EA Monitoring)
Amy Lange	CH2M HILL	Performance Monitoring Plan Lead
Sunil Mehta	INTERA	Groundwater Modeling Lead
Leland Scantlebury	SSPA	Groundwater Data Support
Alex Spiliotopoulos	SSPA	Automated Water Level Network and Evaluation Methods Support
Bert Day	CHPRC	CHPRC 300-FF-5 OU Project Manager
Randy Hermann	CHPRC	300-FF-5 OU Project Field Remediation Lead
John Sands	DOE-RL	DOE-RL 300-FF-5 OU Project Manager
Ben Simes	EPA	EPA 300-FF-5 OU Project Manager

CHPRC = CH2M HILL Plateau Remediation Company
DOE-RL = U.S. Department of Energy-Richland Operations Office
DQO = data quality objective
EA = enhanced attenuation
EPA = U.S. Environmental Protection Agency
MNA = monitored natural attenuation
OU = operable unit
SSPA = S.S. Papadopulos and Associates, Inc.

A2.4 Conceptual Site Model

The CSM is described in Section 4.8 of DOE/RL-2010-99, *Remedial Investigation/Feasibility Study for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units* (hereinafter the 300 Area remedial investigation/feasibility study [RI/FS]), and supplemented by data in the Hanford Environmental Information System (HEIS). Figure A-2 illustrates a water table map for the region. Figures A-3 through A-5 show contaminant plumes for uranium, tritium, and nitrate.

A2.5 Resources

Budgetary and/or resource issues may impact sampling efforts. Sampling efforts will be implemented following PMP approval.

A3 Step 2: Identify the Goals of the Study

Step 2 identifies the principal study questions (PSQs), lists alternative outcomes as a result of addressing the PSQs, and lists the decision statements that address the PSQs.

A3.1 300-FF-5 OU Principal Study Questions

The data collection goal is to evaluate remedy performance associated with RAOs. A series of PSQs has been developed based on Problem Statement 2 presented in Step 1. The PSQs are identified as follows:

1. Are the COCs attenuating according to expectations?
2. Does the EA using phosphate treatment reduce leachable uranium in the vadose zone and PRZ as expected?
3. Has contaminated groundwater been restored to CULs for each COC?
4. Have the lateral extents of the uranium, tritium, and nitrate groundwater contamination plumes above CULs changed?

A3.2 Alternative Outcomes

Alternative outcomes that could result from addressing the PSQs are as follows:

- Continue monitoring program with no change.
- Modify monitoring program.
- Reconsider the EA response strategy.

A3.3 Decision Statements

The decision statements that address the study questions are as follows:

- Determine whether COC concentrations are decreasing, as expected, so that remediation monitoring may continue, or if remedy implementation should be assessed during the 5-year review.
- Determine whether COC concentrations are below CULs, and attainment monitoring may be initiated, or if remediation monitoring should continue.
- Determine whether leachable uranium was reduced as expected, phosphate was well distributed, and a reasonable/acceptable pulse of uranium was realized, so that Stage B may be implemented in accordance with the RDR/RAWP (DOE/RL-2014-13-ADD2), or if the response strategy and associated monitoring should be reconsidered.
- Determine whether the COC concentration at a well has reached attainment, so that the well may be eliminated from the monitoring network for that COC, or if attainment monitoring should continue.
- Determine whether the lateral extents of the uranium, tritium, and nitrate plumes above CULs have changed, so that monitoring location changes may be considered, or if current monitoring should continue.

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A4 Step 3: Identify Information Inputs

Step 3 lists the environmental measurements and observations needed to resolve the decisions, the locations of potential sources of measurements and observations, and the sampling and analysis methods for each measurement.

A4.1 Environmental Measurements and Observations

Answering PSQs requires collection of measurements and observations associated with the COCs and their respective contamination areas. Data needs may be filled through use of direct data (i.e., data collected specifically for this purpose) or indirect data (i.e., data collected by other programs or for other specific purposes that can provide representative information to describe conditions in this study area). Information inputs include data resulting from the monitoring of both physical and chemical parameters within the aquifer system. Typical physical measurements include groundwater elevation in wells and river stage elevation in the adjacent Columbia River. Inputs needed to support the decision statements include the following data and information:

- Groundwater CULs for COCs (Table A-5)
- Groundwater sample data from wells and aquifer tubes (COCs and supporting parameters)
- EA treatment application schedule
- Groundwater data from new EA treatment area piezometer locations (uranium, phosphate, and supporting parameters)
- Electrical resistivity tomography of the EA treatment area
- Soil core data (total uranium and uranium leachability) from the EA treatment area
- Historical chemistry and water level data
- Groundwater levels
- River stage

Table A-5. COC CULs

COC	CUL*	Units
Uranium	30	µg/L
Tritium	20,000	pCi/L
Nitrate (as NO_3)	45,000	µg/L
TCE	4	µg/L
cis-1,2-DCE	16	µg/L
Gross Alpha	15	pCi/L

Note: The CUL for total uranium metal of 30 µg/L is also protective for the uranium isotopes (U-233/234, U-235, and U-238).

* CULs are based on EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1* (Table A-5).

Media: Groundwater

OU: 300-FF-5

CUL	= cleanup level	OU	= operable unit
DCE	= dichloroethene	TCE	= trichloroethene

Table A-6 identifies the data needs associated with each PSQ and their related evaluation methods, data uses, measurement descriptions, measurement locations, and MNA guidance steps.

A4.2 Locations of Potential Sources of Measurements

Required data may come from the following sources:

- All available groundwater monitoring locations (wells and aquifer tubes) in the unconfined aquifer were identified within the 300 Area plus a 100 m (328 ft) wide buffer area. The buffer area includes nearby wells in the 1100-EM Area and 200-PO-1 OU.
- Locations for groundwater measurements needed during EA implementation were identified based on the Post-ROD Field Investigation SI (SGW-56993).
- Locations for soil samples needed during EA implementation are provided in the Post-ROD Field Investigation SI (SGW-56993).

A4.3 Sampling and Analysis Methods

- Continue current methods of sampling monitoring wells and aquifer tubes per project procedures.
- Implement EA in accordance with the RDR/RAWP (DOE/RL-2014-13-ADD2).
- Analytical methods will be selected in the PMP to meet required action levels. Acceptable analytical methods are provided in Table A-7.

Table A-6. Data Needs to Address PSQs

DQO Step 2	DQO Step 3	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Step 1
PSQ	**Data Need[a]**	**Data Uses**	**Measurement Type**	**Measurement Location**	**Measurement Frequency**	**MNA Guidance Step[b]**
1. Are the COCs attenuating according to expectations?	a. TCE and *cis*-1,2-DCE concentrations in the 300 Area Industrial Complex	Determine whether TCE and *cis*-1,2-DCE concentrations in the 300 Area Industrial Complex are attenuating as expected, and assess whether concentrations have reached the CUL (i.e., remediation monitoring has been completed). Evaluation Method: • Statistical analysis	Representative unfiltered groundwater samples submitted for quantitative analysis of TCE and *cis*-1,2-DCE using methods in Table A-7	TCE: 8 wells (399-1-7, 399-2-1, 399-2-2, 399-3-12, 399-3-20, 399-4-12, 399-4-7, and 399-4-9) in the TCE monitoring network have reached the CUL for TCE; 1 well (399-4-14) has not reached the CUL (Figures A-6 and A-7, Table A-12). *cis*-1,2-DCE: 2 wells (399-1-16B and 399-1-57) (Figures A-8 and A-9, Table A-12). *cis*-1,2-DCE is detected above the CULs in Wells 399-1-16B and 399-1-57.	TCE: Quarterly during March, June, September, and December. *cis*-1,2-DCE: Every 5 years during December to be consistent with the historical monitoring period, 2 years before the 5-year review time frame.	1, 4, and 5
	b. Uranium and gross alpha concentrations in the 300 Area Industrial Complex	Determine whether uranium and gross alpha concentrations in the 300 Area Industrial Complex are attenuating as expected, and assess whether concentrations have reached the CUL (i.e., remediation monitoring has been completed). Evaluation Methods: • Statistical analysis. • Consider PSQ 2 evaluations.	Representative unfiltered groundwater samples submitted for quantitative analysis of uranium and gross alpha using methods in Table A-7	10 wells (399-1-1, 399-1-16A, 399-1-17A, 399-1-55, 399-1-7, 399-2-1, 399-2-2, 399-3-9, 399-4-7, 399-4-10) that define contamination trends (Figures A-10 and A-11, Table A-12)	Biennial when highest concentrations are anticipated based on correlation of concentrations to river stage	1, 3, 4, and 5

Table A-6. Data Needs to Address PSQs

DQO Step 2	DQO Step 3	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Step 1
PSQ	Data Need[a]	Data Uses	Measurement Type	Measurement Location	Measurement Frequency	MNA Guidance Step[b]
		• Consider 5-year updates to monitoring program based on PSQ 4 evaluations.				
	c. Uranium and gross alpha concentrations downgradient of 618-7 Burial Ground	Determine whether uranium and gross alpha concentrations downgradient of 618-7 are attenuating as expected, and assess whether concentrations have reached the CUL (i.e., remediation monitoring has been completed). Evaluation Methods: • Statistical analysis. • Consider 5-year updates to monitoring program based on PSQ 4 evaluations.	Representative unfiltered groundwater samples submitted for quantitative analysis of uranium and gross alpha using methods in Table A-7	2 wells (399-8-1 and 399-8-5A) that define contamination trends (Figures A-10 and A-11, Table A-12)	Biennial during December to be consistent with the historical monitoring period	1, 3, 4, and 5
	d. Tritium and nitrate concentrations downgradient of 618-11 Burial Ground	Determine whether tritium and nitrate concentrations downgradient of 618-11 are attenuating as expected, and assess whether concentrations have reached the CUL (i.e., remediation monitoring has been completed).	Representative unfiltered groundwater samples submitted for quantitative analysis of the nitrate and tritium using methods in Table A-7	Tritium: 5 wells (699-12-2C, 699-13-0A, 699-13-1E, 699-13-2D, and 699-13-3A) (Figures A-12 and A-13, Table A-12). If concentrations increase in the farthest downgradient well (699-13-0A), during the 5-year review consider installing an additional	Biennial during October to be consistent with historical monitoring period	1, 3, 4, and 5

Table A-6. Data Needs to Address PSQs

DQO Step 2	DQO Step 3	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Step 1
PSQ	Data Need[a]	Data Uses	Measurement Type	Measurement Location	Measurement Frequency	MNA Guidance Step[b]
		Evaluation Methods: • Statistical analysis. • Consider 5-year updates to monitoring program based on PSQ 4 evaluations.		well(s) farther downgradient. Uncertainty regarding the northern extent of the plume does not impact attenuation evaluation. Nitrate: 4 wells (699-12-2C, 699-13-1E, 699-13-2D, and 699-13-3A,) (Figures A-14 and A-15, Table A-12).		
	e. Environmental conditions impact to natural attenuation	Determine whether there are changes in environmental conditions (e.g., hydraulic conditions) that may impact the evaluation of natural attenuation and migration. Evaluation Method: • Water level mapping • Statistical analysis	Water level measurements collected manually Field parameters (pH, specific conductance, ORP for TCE and *cis*-1,2-DCE samples, and temperature) using methods in Table A-7 Automated measurements of river level, specific conductance, and temperature	Selected groundwater wells monitored for COCs and wells necessary to confirm expected contaminant migration characteristics River data collected using the automated river gauge	Water levels concurrently with groundwater sampling events and during the sitewide March synoptic event Field parameters during each sampling event River data collected hourly	2
	f. New contaminant releases	Determine whether there is evidence of new contaminant releases to the environment that	Representative unfiltered groundwater samples, submitted	Selected groundwater wells at and downgradient of active remediation locations[c]	Prior to, during, and after remediation of waste sites and belowgrade buildings in	6

Table A-6. Data Needs to Address PSQs

DQO Step 2	DQO Step 3	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Step 1
PSQ	**Data Need[a]**	**Data Uses**	**Measurement Type**	**Measurement Location**	**Measurement Frequency**	**MNA Guidance Step[b]**
		could impact the effectiveness of the MNA remedy (e.g., as a result of source remediation activities). Evaluation Method: • Statistical analysis	for quantitative analysis of the contaminants using approved methods[c]		contaminated vadose zone sediments, with at least one sampling event during each phase during low water, if possible	
2. Does the EA using phosphate treatment reduce leachable uranium in the vadose zone and PRZ as expected?	a. EA operation and performance monitoring • Total uranium and uranium leachability in soil. • Movement and migration of infiltrated phosphate and mobilized uranium to groundwater • Phosphate distribution efficiency in vadose zone and PRZ • Changes in hydraulic conductivity of aquifer due to plugging	Determine the decrease in predicted time to achieve the uranium CUL in groundwater, due to uranium leachability decreases. Evaluate other factors from the implementation of Stage A, such as phosphate distribution efficiency and the degree of uranium mobilization to groundwater. Evaluation Methods: • Statistical analysis • Groundwater modeling • EA treatment performance	• Representative soil samples collected from boreholes prior to and after treatment analyzed for total uranium and uranium leaching characteristics described in the Post-ROD Field Investigation SI (SGW-56993) • Representative unfiltered groundwater samples, submitted for quantitative analysis of total uranium, phosphate, and ions using methods in Table A-7	• Soil samples from the vadose zone and PRZ from 3 boreholes within the EA treatment area prior to treatment and from 3 adjacent boreholes after treatment • Selected groundwater piezometers within and downgradient of the EA treatment area • Vadose zone, PRZ, and top of aquifer underlying footprint of the EA • Automated water level monitoring in wells	• Soil samples collected once before and once after phosphate application • Groundwater sampled before phosphate application, and during at least 4 events conducted within 1 month after phosphate application to measure any pulses of uranium and phosphate into groundwater after phosphate application • ERT and automated sensor monitoring during phosphate application • AWLN at hourly frequency for those wells needed to assess migration	1, 2, and 3

Table A-6. Data Needs to Address PSQs

DQO Step 2	DQO Step 3	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Step 1
PSQ	**Data Need[a]**	**Data Uses**	**Measurement Type**	**Measurement Location**	**Measurement Frequency**	**MNA Guidance Step[b]**
			• Field parameters collected during sampling of select monitoring locations (temperature, pH, DO, and ORP) • ERT testing in vadose zone and PRZ during phosphate infiltration • Automated water level sensor deployment to measure water level • Slug tests, constant rate tests, tracer tests, and/or pressure recovery tests before and after phosphate application		• Slug tests, constant rate tests, tracer tests, and/or pressure recovery tests conducted once before and once after phosphate application	
	b. Long-term uranium concentrations in groundwater before and after treatment	Determine whether the EA using phosphate has reduced the uranium concentration dependence on seasonal water level fluctuation.	Representative unfiltered groundwater samples, submitted for quantitative analysis of uranium and gross alpha using	4 wells (399-1-17A, 399-1-7, 399-2-2, and 399-2-1) within and downgradient of the EA area (Figures A-10 and A-11, Table A-12). Prior to phosphate treatment, the uranium concentrations at	Semiannual for 5 years during June (high river stage) and December (low river stage) for comparison with historical data trends	1 and 4

Table A-6. Data Needs to Address PSQs

DQO Step 2	DQO Step 3	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Step 1
PSQ	Data Need[a]	Data Uses	Measurement Type	Measurement Location	Measurement Frequency	MNA Guidance Step[b]
		Evaluation Methods: • Statistical analysis • Groundwater modeling	methods in Table A-7	the EA treatment area show a dependence on water level. Following treatment, uranium concentrations are expected not to fluctuate any longer with water level if leachable uranium has been sequestered. These 4 wells were used for the 2-D uranium modeling in Appendix F of 300 Area RI/FS (DOE/RL-2010-99).		
3. Has contaminated groundwater been restored to CULs for each COC?	TCE, *cis*-1,2-DCE, nitrate, tritium, uranium, and gross alpha concentrations	Perform the fundamental test for attainment monitoring (Appendix B, Section 2.4.2). Evaluation Method: • Statistical analysis	Representative unfiltered groundwater samples, submitted for quantitative analysis of TCE, *cis*-1,2-DCE, nitrate, tritium, uranium, and gross alpha using methods in Table A-7	Groundwater wells identified in PSQ 1 that define the COC contamination above the CUL and attenuation of COC contamination. TCE: 8 wells (399-1-7, 399-2-1, 399-2-2, 399-3-12, 399-3-20, 399-4-12, 399-4-7, and 399-4-9) in the TCE monitoring network have reached the demonstrated attainment for TCE (Figures A-6 and A-7, Table A-12).	At least 8 samples will be used to make this determination at each well for each COC (EPA 600/R-11/204). Sampling frequency will be quarterly (e.g., March, June, September, and December if sampled in June or December; January, April, July, and October if sampled in October) for up to 2 years to detect seasonal variability. If attainment has not been achieved, monitoring may be continued at a reduced frequency.	8

Table A-6. Data Needs to Address PSQs

DQO Step 2	DQO Step 3	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Steps 3 through 7	DQO Step 1
PSQ	**Data Need[a]**	**Data Uses**	**Measurement Type**	**Measurement Location**	**Measurement Frequency**	**MNA Guidance Step[b]**
4. Have the lateral extents of the uranium, tritium, and nitrate groundwater contamination plumes above CULs changed?	a. Uranium concentrations in the 300 Area Industrial Complex and nitrate and tritium concentrations downgradient of 618-11	Track and communicate changes in the lateral extents of the uranium, tritium, and nitrate plumes above the CULs. Evaluation Method: • Plume mapping	Representative unfiltered groundwater samples, submitted for quantitative analysis of uranium, tritium, and nitrate using methods in Table A-7	Uranium: Groundwater wells identified for PSQs 1c and 2b, plus an additional 14 wells (399-1-2, 399-1-10A, 399-1-11, 399-1-12, 399-1-21A, 399-2-32, 399-3-6, 399-3-12, 399-3-20, 399-4-1, 39-4-11, 399-4-12, 399-4-15, 399-6-3) and 1 aquifer tube (AT-3-7-M) that define the lateral extent of the uranium plume above the CUL in the 300 Area Industrial Complex (Figures A-10 and A-11, Table A-12). Tritium and nitrate: Groundwater wells identified for PSQ 1e (Figures A-12 through A-15, Table A-12).	Uranium: Consistent with PSQs 1c and 2b, plus an additional set of wells at least once before each 5-year review period during high (June) and low (December) river stage. Nitrate and tritium: Consistent with PSQ 1e.	4

Note: Complete reference citations are provided in Chapter 9.

a. All nitrate measurements should be reported as NO_3 for consistency with the CUL.

b. From EPA 600/R-11/204, *Approach for Evaluating the Progress of Natural Attenuation in Groundwater*.

c. Source remediation projects will be responsible for monitoring new or continuing releases of contaminants to the environment resulting from source remediation that could impact the effectiveness of the MNA remedy.

2-D = two-dimensional
AWLN = Automated Water Level Network
CUL = cleanup level
DCE = dichloroethene
DO = dissolved oxygen
DQO = data quality objective
EPA = U.S. Environmental Protection Agency
ERT = electrical resistivity tomography
MNA = monitored natural attenuation
ORP = oxidation reduction potential
PRZ = periodically rewetted zone
PSQ = principal study question
SAP = sampling and analysis plan
TCE = trichloroethene

Table A-7. Analytical Methods for Groundwater Analyses

Constituent	CAS Number	CUL	Analytical Method[a]	Highest Allowable PQL[b]	Precision	Accuracy[c]
Radionuclides (pCi/L)						
Tritium	10028-17-8	20,000	Tritium by LSC	400	≤20% RPD	70 to 130% recovery
Gross Alpha	12587-46-1	15	Total Alpha by GPC	3	≤20% RPD	70 to 130% recovery
Organics – VOCs (µg/L)						
TCE	79-01-6	4	EPA 8260	1	% recovery statistically derived[c]	Statistically derived[c]
cis-1,2-DCE	156-59-2	16	EPA 8260	5	% recovery statistically derived[c]	Statistically derived[c]
Inorganics – Metals (µg/L)						
Calcium	7440-70-2	N/A[d]	SW-846 6010	1,000	≤20% RPD	80 to 120% recovery
Magnesium	7439-95-4	N/A[d]	SW-846 6010	750	≤20% RPD	80 to 120% recovery%
Potassium	7440-09-7	N/A[d]	SW-846 6010	4,000	≤20% RPD	80 to 120% recovery
Sodium	7440-23-5	N/A[d]	SW-846 6010	500	≤20% RPD	80 to 120% recovery
Uranium	7440-61-1	30	EPA 6020	15	≤20% RPD	80 to 120% recovery

Table A-7. Analytical Methods for Groundwater Analyses

Constituent	CAS Number	CUL	Analytical Method[a]	Highest Allowable PQL[b]	Precision	Accuracy[c]
Inorganics – Anions (μg/L)						
Chloride	16887-00-6	N/A[d]	EPA 300.0 or SW-846 9056	400	≤20% RPD	80 to 120% recovery
Nitrate (as NO_3)	14797-55-8	45,000	EPA 300.0 or SW-846 9056	250	≤20% RPD	80 to 120% recovery
Phosphate	14265-44-2	N/A[d]	EPA 300.0 or SW-846 9056	500	≤20% RPD	80 to 120% recovery
Sulfate	14808-79-8	N/A[d]	EPA 300.0 or SW-846 9056	550	≤20% RPD	80 to 120% recovery
Alkalinity (μg/L)						
Alkalinity (as Calcium Carbonate)	ALKALINITY	N/A[d]	EPA 310.1 or SM 2320	5,000	≤20% RPD	80 to 120% recovery
Carbonate[e]	CO3ALKALINITY	N/A[d]	EPA 310.1 or SM 2320	5,000	≤20% RPD	80 to 120% recovery
Bicarbonate[e]	HCO3ALKALINITY	N/A[d]	EPA 310.1 or SM 2320	5,000	≤20% RPD	80 to 120% recovery
Field Parameters						
Temperature	TEMPERATURE	N/A	Field measurement/probe	N/A	N/A	N/A
Specific Conductance	CONDUCT	N/A	Field measurement/probe	1 μS/cm	N/A	N/A
pH Measurement	PH	N/A	Field measurement/probe	N/A	N/A	N/A
Turbidity	TURBIDITY	N/A	Field measurement/probe	0.1 NTU	N/A	N/A
Dissolved Oxygen	DO	N/A	Field measurement/probe	N/A	N/A	N/A
Oxidation/Reduction	REDOX	N/A	Field measurement/probe	N/A	N/A	N/A

Table A-7. Analytical Methods for Groundwater Analyses

Constituent	CAS Number	CUL	Analytical Method[a]	Highest Allowable PQL[b]	Precision	Accuracy[c]

Note: For EPA Methods 335.2 and 300.0, see EPA-600/4-79-020, *Methods for Chemical Analysis of Water and Wastes*. For four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*.

a. Equivalent methods may be substituted.

b. Highest allowable PQLs are specified in contracts with analytical laboratories. Actual PQLs vary by laboratory and may be lower than required contractually. MDLs are generally three to five times lower than PQLs. For radionuclides, values in this column are the highest allowable minimum detectable concentrations.

c. Determined by the laboratory based on historical data or statistically derived control limits. Limits are reported with the data. Where specific acceptance criteria are listed, those acceptance criteria may be used in place of statistically derived acceptance criteria.

d. Required for evaluation of enhanced attenuation implementation.

e. Carbonate and bicarbonate concentrations will be calculated from the alkalinity result.

CAS = Chemical Abstracts Service

CUL = cleanup level

DCE = dichloroethene

EPA = U.S. Environmental Protection Agency

GPC = gas proportional counting

LSC = liquid scintillation counting

MDL = method detection limit

N/A = not applicable

PQL = practical quantitation limit

VOC = volatile organic compound

A5 Step 4: Define the Boundaries of the Study

Step 4 defines the target population and its spatial boundaries, the temporal boundaries and other practical constraints associated with data collection, and the scale of inference (i.e., the smallest unit on which decisions will be made).

A5.1 Target Population and Spatial Boundaries

The monitoring program spatial boundaries constrain the data collection in three dimensions. The lateral limits are the extent of the 300-FF-5 Groundwater OU contaminated by COCs above CULs. Table A-8 identifies the figures showing the spatial boundaries associated with each contaminant and defines the target population.

Groundwater from the 300-FF-5 Groundwater OU discharges to the Columbia River through the hyporheic zone. The vertical boundary is the base of the unconfined aquifer, which is bounded by Ringold Formation lower mud. Table A-12 (in Step 7) identifies wells screened in the unconfined aquifer and aquifer tubes that are relevant to monitoring locations.

Measurement sampling locations are identified in Table A-6 for soil cores, groundwater data, water levels, and river stage.

A5.2 Temporal Boundaries and Practical Constraints

Temporal boundaries are related to timing, frequency, and duration of measurements and observations. Timing is driven by river stage seasonal variation and the associated changes in groundwater flow direction and flow velocity. The areal extent requiring monitoring will decrease over time, commensurate with groundwater restoration to CULs. As RAOs are achieved and verified, monitoring needs will change. Table A-8 identifies expected time frames established in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013) for restoring groundwater to CULs.

Table A-8. Time Frames for Restoring Groundwater to CULs for the 300-FF-5 OU

COC	Location	Figure	Years from 2012
Uranium	300 Area Industrial Complex	3	28
Uranium	618-7 Burial Ground	3	Not defined in the 300 Area ROD/ROD Amendment[a]
Tritium	618-11 Burial Ground	4	18
Nitrate (as NO_3)	618-11 Burial Ground	5	Not defined in the 300 Area ROD/ROD Amendment[a]
TCE	300 Area Industrial Complex	N/A[b]	Not defined in the 300 Area ROD/ROD Amendment[a]
cis-1,2-DCE	300 Area Industrial Complex	1	Not defined in the 300 Area ROD/ROD Amendment[a]
Gross Alpha	300 Area Industrial Complex	3	28
Gross Alpha	618-7 Burial Ground	3	Not defined in the 300 Area ROD/ROD Amendment[a]

Source: 300 Area ROD/ROD Amendment (EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1*).

a. The time frame for degradation to CULs has not been estimated.

b. TCE concentrations did not exceed the CUL in 2013.

COC = contaminant of concern
CUL = cleanup level
DCE = dichloroethene
N/A = not applicable
OU = operable unit
ROD = record of decision
TCE = trichloroethene

The following known and potential constraints may interfere with implementation of the groundwater monitoring program:

- Resource availability for well installation, sample collection, and laboratory analysis (funding)
- Cultural and ecological constraints on new well locations
- Seasonal variability of river stage and water table

A5.3 Scale of Inference

The scale of inference for groundwater monitoring is an individual well. Decisions about reaching attainment will be made on a well-by-well basis for each COC.

The scale of inference for EA implementation is the Stage A EA area and associated monitoring piezometers outside of the EA area. The decision about future remedy implementation will be made based on Stage A results.

A6 Step 5: Develop the Analytic Approach

Step 5 identifies the population parameters of interest for making decisions and provides decision rules based on chosen action levels.

A6.1 Population Parameters of Interest

The following parameters of interest, identified in Table A-6, were used to evaluate the principal lines of evidence:

- Concentrations/trends for each COC (as expressed by statistical parameters [e.g., 95 percent upper confidence limit])
- Extent of contamination (area) or quantity of contamination (mass) for each COC (changes with time [e.g., biennial])
- Comparison of observations to expectations of COC attenuation

A6.2 Decision Rules (If/Then)

The decision rules presented in Table A-9 were developed to guide the approach for analyzing measurements and observations collected under this DQO. Progress toward achieving RAOs and associated CULs will be evaluated using the following principal lines of evidence:

- Existing baseline information
- Monitoring to evaluate current conditions and determine rates of change in conditions
- Statistical analysis of both the monitoring data and groundwater model projections to assess conformance with expectations for ultimate attainment of and compliance with RAOs

Table A-9. PSQs and Corresponding Decision Rules

PSQ 1. Are the COCs attenuating according to expectations?		
IF the weight of evidence indicates COC concentrations are decreasing as expected…	…THEN continue remediation monitoring and associated evaluations…	…OTHERWISE, assess remedy implementation during the 5-year review.
IF the weight of evidence indicates COC concentrations are below CULs…	…THEN initiate attainment monitoring…	…OTHERWISE, continue remediation monitoring and associated evaluations.
PSQ 2. Does the EA using phosphate treatment reduce leachable uranium in the PRZ as expected?		
IF the weight of evidence indicates leachable uranium was reduced as expected, the phosphate was well distributed, and a reasonable/acceptable pulse of uranium was realized…	…THEN perform Stage B in accordance with the RDR/RAWP (DOE/RL-2014-13-ADD2)…	…OTHERWISE, reconsider response strategy and associated monitoring.
PSQ 3. Has contaminated groundwater been restored to CULs for each COC?		
IF the fundamental test demonstrates that the COC concentration at a well	…THEN eliminate the well from monitoring network for that COC,	…OTHERWISE, continue attainment monitoring and associated evaluations.

has reached attainment…	and prepare information in support of remedial action completion documentation…	
PSQ 4. Have the lateral extents of the uranium, tritium, and nitrate groundwater contamination plumes above CULs changed?		
IF the weight of evidence indicates that the lateral extents of the uranium, tritium, and nitrate plumes above CULs have changed…	…THEN consider monitoring location changes…	…OTHERWISE, continue with current monitoring.

COC = contaminant of concern
CUL = cleanup level
EA = enhanced attenuation
PRZ = periodically rewetted zone
PSQ = principal study question
RDR/RAWP = remedial design report/remedial action work plan

A7 Step 6: Specify Performance or Acceptance Criteria

Step 6 presents the acceptance criteria that data should achieve in order to minimize the possibility of making a decision error and examines the consequences of making incorrect decisions.

A7.1 300-FF-5 OU Acceptance Criteria

Judgmental sampling designs (rather than traditional statistical sampling designs) were identified for the 300-FF-5 OU groundwater monitoring and Stage A EA evaluation. Therefore, tables defining the null hypothesis, alpha and beta error, and width of gray region have been excluded from this DQO process. Although statistical sampling designs are not being used, statistical evaluations of the data collected to address PSQs will be used to support future decisions (e.g., RAO achievement or treatment performance).

Resolving PSQs is dependent on evaluating historical and current analytical data plus field measurements. Criteria for evaluating data with respect to PSQs will employ both statistical and nonstatistical methods. The evaluation methods to be used for each PSQ are identified in Table A-6. The limits on analytical data are specified within the analytical method quality assurance (QA)/quality control (QC) criteria, as identified in the quality assurance project plan (QAPjP) in the PMP.

The evaluation methods, derived from sources such as OSWER 9283.1-44, *Recommended Approach for Evaluating Completion of Groundwater Restoration Remedial Actions at a Groundwater Monitoring Well*, are summarized in Table A-2, with additional details provided in Appendix B.

The consequences of inadequate sampling design may affect the time it takes to achieve cleanup approval, the ability to demonstrate convincing RAO achievement, and the ability to demonstrate sufficient progress to substantiate continuation or indicate the need to discontinue. All of the monitoring wells are expected to be accessible for resampling, but resampling times will differ and may introduce data set variability. Table A-10 summarizes potential data variability, uncertainty, and errors that could affect PSQ decisions and actions that could mitigate their effects.

Table A-10. Data Variability, Uncertainty, or Error and Mitigating Measures

Source of Variability, Uncertainty, or Error	Mitigating Measures
Soil leachability data variability causing uncertainty in model parameters and cleanup time frame estimates	Collect multiple soil samples in vadose zone and PRZ; run sensitivity analyses to evaluate impact of variability in soil leaching data; conduct flow-through column experiments on select soil samples to derive desorption parameters that will help constrain the range of variability in soil leaching data.
Groundwater concentration variability causing inaccurate attenuation rate estimates (e.g., variability due to seasonal or longer-term changes in water table)	Consistent schedule for sampling to increase comparability; more frequent monitoring in wells with variable concentrations
Uncertainty in estimates of plume size or mass (interpretation, extrapolation)	Robust monitoring network to reduce uncertainty in plume or mass interpretations. Use geo-statistical methods to evaluate plume size.
Analytical (laboratory errors)	Robust QA/QC program to minimize analytical uncertainties

PRZ = periodically rewetted zone

QA = quality assurance

QC	=	quality control

A7.2 Decision Errors and Mitigating Measures

This section describes possible errors for each of the decision rules. The sources of errors that lead to those decision errors, and factors to mitigate them, are listed in Table A-10.

Decision Rule 1a: If the weight of evidence indicates that COC concentrations are decreasing as expected, then continue remediation monitoring and associated evaluations; otherwise, assess remedy implementation during the 5-year review:

- Decision Error 1a a: COC concentrations are determined to be decreasing as expected but, in fact, they are not. Consequence: Continued remediation monitoring would reveal the error, remedy implementation would be assessed during the 5-year review, and the remediation time frame would likely be longer than predicted. Severity: low.
- Decision Error 1a b: COC concentrations are determined not to be decreasing as expected but, in fact, they are. Consequence: Funding could be diverted from higher-priority projects to implement a more aggressive remedy. Severity: low to moderate.

Decision Rule 1b: If the weight of evidence indicates COC concentrations are below the CULs, then initiate attainment monitoring; otherwise, continue remediation monitoring and associated evaluations:

- Decision Error 1b a: COC concentrations are determined to be below the CULs but, in fact, they are not. Consequence: Attainment monitoring would reveal the error, and remediation monitoring would resume. Severity: low.
- Decision Error 1b b: COC concentrations are determined not to be below CULs but, in fact, they are. Consequence: Continued remediation monitoring would reveal the error, and attainment monitoring would be initiated. Severity: low.

Decision Rule 2: If the weight of evidence indicates that leachable uranium was reduced as expected, the phosphate was well distributed, and a reasonable/acceptable pulse of uranium was realized, then perform Stage B in accordance with the RDR/RAWP (DOE/RL-2014-13-ADD2); otherwise, reconsider the response strategy and associated monitoring:

- Decision Error 2a: It is determined that leachable uranium is reduced as expected, phosphate is well distributed, and/or the pulse of uranium is acceptable but, in fact, at least one of these components is not. Consequence: Funding for Stage B could be diverted from higher-priority projects, and a potentially unacceptable release of uranium to the aquifer could lengthen the time for remediation. Severity: low to moderate.
- Decision Error 2b: It is determined that leachable uranium is not reduced as expected, phosphate is not well distributed, and/or the pulse of uranium is unacceptable but, in fact, at least one of these components is. Consequence: Remediation timeline is longer than predicted. Severity: low.

Decision Rule 3: If the fundamental test demonstrates that the COC concentration at a well has reached attainment, then eliminate the well from the monitoring network for that COC and prepare information in support of remedial action completion documentation; otherwise, continue attainment monitoring and associated evaluations:

- Decision Error 3a: A COC at a well is determined to have reached attainment but, in fact, it has not. Consequence: Concentration of a COC at a well may have a short-term exceedance that is not monitored. Severity: low.
- Decision Error 3b: A COC at a well is determined to have not reached attainment but, in fact, it has. Consequence: Continued monitoring would reveal that the concentration of a COC at a well had reached attainment. Severity: low.

Decision Rule 4: If the weight of evidence indicates that the lateral extents of the uranium, tritium, and nitrate plumes above CULs have changed, then consider monitoring changes; otherwise, continue with current monitoring:

- Decision Error 4a: The lateral extents of the uranium, tritium, and/or nitrate plumes above CULs are determined to have changed but, in fact, they have not. Consequence: Continued monitoring would reveal the error. Severity: low.
- Decision Error 4b: The lateral extents of the uranium, tritium, and/or nitrate plumes above CULs are determined not to have changed but, in fact, they have. Consequence: Continued monitoring would reveal the error. Severity: low.

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A8 Step 7: Develop the Plan for Obtaining Data

Step 7 presents the final sampling and analysis design based on all of the information generated in Step 1 through Step 6.

The methodology used to select the final list of groundwater monitoring locations and sampling frequencies that adequately meet the data needs associated with the PSQs is provided in the following subsections.

A8.1 300-FF-5 OU Enhanced Attenuation Operations and Performance Monitoring

The EA operations and PMP consist of piezometer installation, baseline sampling, monitoring during phosphate application, and EA performance monitoring.

For Stage A EA treatment, 24 piezometers consisting of 12 well pairs screened across the PRZ (approximately 9 to 10.7 m [30 to 35 ft] below ground surface [bgs]) and across the top of the aquifer (approximately 12 to 13.7 m [40 to 45 ft] bgs) will be installed. Piezometer installations will include three piezometer pairs upgradient of the Stage A EA treatment area, six piezometer pairs within the Stage A EA treatment area, and three piezometer pairs downgradient of the Stage A EA treatment area (Figure A-16).

Piezometers will be drilled with resonant sonic drilling equipment. Alternative drilling methods may be used with approval of the OU Technical Lead in consultation with the well maintenance and drilling manager. To avoid potential impact to the representativeness of vadose zone and PRZ soil, all efforts must be made to drill without the use of slurry makeup water. In the event that drilling slurry makeup water is needed, the situation must be discussed with project technical staff before proceeding.

Piezometer boreholes will be drilled with a 15 to 20 cm (6 to 8 in.) diameter outer casing to allow construction of a 5 cm (2 in.) diameter piezometer (i.e., the boreholes will be drilled to maintain a minimum 5 cm [2 in.] annular space around the permanent well, per WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"). Boreholes will be drilled to a depth of approximately 11.6 m (38 ft) for PRZ piezometers and 15 m (48 ft) for aquifer piezometers. The final total depth of the boreholes will be confirmed by the drilling buyer's technical representative and site geologist and may change depending on the actual water stage, ground surface elevation, and/or subsurface conditions encountered. In the event that subsurface conditions prevent completion of the borehole to its intended depth, the OU Project Manager will be consulted to determine the path forward (e.g., re-drill the borehole at another location or accept the modified final depth for that borehole).

Table A-11 presents construction details for the piezometers. The piezometers will be built with 5 cm (2 in.) diameter Schedule 40 polyvinyl chloride (PVC) casing and slotted PVC screen sections on top of a 0.9 to 1.5 m (3 to 5 ft) long PVC sump with end cap. Colorado silica sand or an approved equivalent will be used for the sand pack; sodium bentonite pellets and/or natural sodium bentonite chunks, crumbles, or powdered bentonite will be used for bentonite sealing material; Type I/II Portland cement will be used for cement grout.

Surface construction will consist of a protective casing, protective guard posts, and cement pad. The protective casing will be a minimum of 5.1 cm (2 in.) larger in diameter than the permanent casing. Protective casing will rise approximately 0.9 m (3 ft) above the ground surface. Permanent casing will rise to approximately 0.3 m (1 ft) below the top of the protective casing. Protective casing will have a lockable well cap extending approximately 38 cm (15 in.) above the top of the protective casing.

Table A-11. Piezometer Well Construction Details

Piezometer Type	Planned Drill Depth (bgs)	Screen Length	Screen Interval (bgs)	Filter Pack Interval (bgs)*	Bentonite Pellet Interval (bgs)	Bentonite Crumbles Interval (bgs)	Cement Seal Interval (bgs)
PRZ	11.6 m (38 ft)	1.5 m (5 ft)	9 to 10.7 m (30 to 35 ft)	8.8 to 11 m (29 to 36 ft)	7.9 to 8.8 m (26 to 29 ft)	7 to 7.9 m (23 to 26 ft)	0 to 7 m (0 to 23 ft)
Aquifer	15 m (48 ft)	1.5 m (5 ft)	12 to 13.7 m (40 to 45 ft)	11.9 to 14 m (39 to 46 ft)	11 to 11.9 m (36 to 39 ft)	10.1 to 11 m (33 to 36 ft)	0 to 10.1 m (0 to 33 ft)

Note: All piezometers have a 5 cm (2 in.) diameter PVC casing and screen. Drill depth, screened interval, and bentonite seal intervals may vary slightly due to location-specific conditions.

* The filter pack interval will consist of 10 to 20 mesh Colorado silica sand, or an equivalent material based on lithology.

bgs = below ground surface

PRZ = periodically rewetted zone

PVC = polyvinyl chloride

Piezometers will be developed by surging and pumping. Surging will continue until there is less than 3 cm (0.1 ft) of screen infill per 15 minutes of surge time. Surging will continue until the piezometer ceases to exceed this rate of settling; turbidity has decreased to ≤5 nephelometric turbidity units; and temperature, pH, and conductivity measurements have stabilized (i.e., at least three consecutive measurements within 10 percent of each other). Development will be performed for the piezometers screened in the PRZ when adequate water levels allow.

A8.1.1 Baseline Sampling

Baseline sampling will be conducted to measure pretreatment uranium concentrations and leachability, and baseline groundwater sampling and analysis.

A8.1.1.1 Pretreatment Uranium Concentration and Leachability Characterization

Uranium concentration and leachability data from three borings will provide baseline conditions representing the pretreatment uranium leaching characteristics in soil from the vadose zone and PRZ. The three borings will be comprised of a combination of borings drilled during the supplemental post-ROD field investigation (SGW-56993, Post-ROD Field Investigation SI) and borings drilled for the piezometers, based on the final location of the Stage A EA treatment area.

For initial planning purposes, soil samples will be collected from two depth intervals in each of the three borings: approximately 4.9 m (16 ft) to 5.1 m (16.5 ft) in the vadose zone and 7.9 m (26 ft) to 8.1 m (26.5 ft) in the PRZ. Depth intervals of the soil samples may be changed based on the results of the supplemental post-ROD field investigation (SGW-56993, Post-ROD Field Investigation SI), groundwater levels, radiological field screening data, visual observation of lithology, or site geologist professional judgment.

A8.1.1.2 Baseline Groundwater Sampling and Analysis

Groundwater samples will be collected at the 24 piezometers for analyses of uranium, phosphate and other anions (chloride, sulfate, carbonate, and bicarbonate), and cations (calcium, magnesium, sodium, and potassium) before application of phosphate to establish a baseline prior to phosphate application. Water levels and field parameters, including conductivity, temperature, pH, dissolved oxygen (DO), and oxidation reduction potential (ORP), will also be collected. During low river stage conditions, 12 piezometers screened in the PRZ are expected to be dry prior to phosphate application. Dry piezometers will not be sampled.

A8.1.2 Monitoring during Phosphate Application Operations

Monitoring during phosphate application consists of electrical resistivity tomography (ERT) and groundwater monitoring.

A8.1.2.1 Electrical Resistivity Tomography

ERT will be used to monitor advancement of the phosphate infiltration wetting front through the vadose zone and PRZ. Phosphate infiltration is expected to increase vadose zone/PRZ electrical conductivity significantly by increasing both saturation and pore fluid specific conductance, thereby enabling the use of time-lapse ERT for remote monitoring of polyphosphate transport. The 0.3 ha (0.75 ac) Stage A EA treatment area will be monitored along a two-dimensional section spanning between the upgradient (northeast) and downgradient (southwest) corners (Figure A-17). This section will be monitored with a line of 64 electrodes at 1.5 m (5 ft) spacing (96 m [315 ft] total), extending beyond the treatment area approximately 11.3 m (37 ft) in each direction. This extension is necessary to provide adequate imaging resolution at the boundary of the treatment area. The electrodes will be buried in a shallow 0.2 to 0.3 m (8 to 12 in.) deep trench for safety purposes.

Baseline surveys will be collected prior to phosphate infiltration in order to image pre-infiltration subsurface structure, establish baseline conditions, and optimize the time-lapse imaging protocol. Time-lapse imaging with be performed during infiltration to monitor advancement of the infiltration wetting front. During time-lapse imaging, ERT data will be autonomously collected, transferred via wireless internet, archived, filtered, and processed on high-performance computing resources, with results transferred to site operators. The expected turnaround time from the beginning of a survey until time-lapse images are available is expected to be less than 30 minutes.

A8.1.2.2 Groundwater and Pore Water Field Parameter Monitoring

Water levels and field parameters (conductivity, temperature, pH, and ORP) will be measured in all 24 piezometers at least every 4 hours during daytime hours to monitor the rate of solution distribution in the aquifer. Automated sensors will also be deployed in seven select aquifer piezometers for continuous monitoring of water levels, conductivity, and temperature. For preliminary planning, the automated sensors will be deployed in aquifer piezometers upgradient of the EA treatment area (1-69), downgradient of the EA treatment area (1-83, 1-85, and 1-87), and within the footprint of EA treatment area (1-75, 1-77, and 1-79) (Figure A-16).

A8.1.3 Enhanced Attenuation Performance Monitoring

EA performance monitoring will be conducted to measure post-treatment uranium concentrations and leachability, and groundwater and pore water sampling and analysis.

A8.1.3.1 Post-treatment Uranium Concentration and Leachability Characterization

Soil samples for total uranium and uranium leachability testing will be collected after the Stage A phosphate application to determine post-treatment uranium leaching characteristics in soil from the vadose zone and PRZ. Soil samples will be collected from the borings drilled, adjacent to the borings selected for pretreatment soil samples and at the same depth intervals selected for pretreatment soil samples (Figure A-18).

A8.1.3.2 Groundwater and Pore Water Sampling and Analysis

Groundwater samples will be collected at the 24 piezometers for analyses of uranium, phosphate and other anions (chloride, sulfate, carbonate, and bicarbonate), and cations (calcium, magnesium, sodium, and potassium) at least four times within 1 month after phosphate application to evaluate uranium and phosphate concentrations in groundwater after completion of the Stage A phosphate application. Water levels and field parameters, including conductivity, pH, temperature, DO, and ORP, will also be collected. During low river stage conditions, 12 piezometers screened in the PRZ are expected to be dry prior to phosphate application. Dry piezometers will not be sampled. Automated sensors deployed in 7 select aquifer piezometers (1-69, 1-75, 1-77, 1-79, 1-83, 1-85, and 1-87) (Figure A-16) during the phosphate application will remain in operation for continuous monitoring of water levels, conductivity, and temperature.

A8.2 Long-Term Groundwater Sampling and Analysis Plan

The long-term groundwater monitoring network, analyte list, and sampling frequencies are summarized in the following subsections. Table A-12 lists all of the wells and aquifer tubes considered for sampling and which (if any) PSQs they address. Plume maps with available well locations are shown in Figures A-3 through A-5. Figures A-6 through A-15 show locations of the monitoring networks for each COC and trend plots for the wells in each monitoring network.

A8.2.1 Identification of Available Long-Term Monitoring Locations

The list of wells and aquifer tubes that can be used to collect measurements and observations is provided in Table A-12 (located at the end of this appendix after Figure A-19). Locations of 300-FF-5 OU wells and aquifer tubes relative to the contaminant plumes are shown on Figure A-1 and Figures A-3 through A-5. Locations of the 300-FF-5 OU wells, relative to the water table contours, are shown on Figure A-2. Contaminant plume maps and the water table map were generated based on DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*.

To facilitate identification of wells for long-term monitoring, the list of wells and aquifer tubes was divided into A and B lists. The A list (strong candidates for future use) contained those wells, with a status of in use, that are screened at the top of the unconfined or upper unconfined aquifer and have been sampled since 2004 (i.e., within the last 10 years). Wells monitored in the mid- or lower unconfined aquifer were added to the A list on a case-by-case basis (e.g., those used to monitor *cis*-1,2-DCE). Wells on the B list have more unknowns and require additional research. The B list wells would have been considered if the DQO concluded that they met a data need not filled by the A list wells. However, no B list wells were needed.

Well status and well construction information (e.g., relative position of screened intervals) were extracted from the Well Information Document Lookup. Measurements of specific conductance maintained in HEIS were reviewed through the Hanford Virtual Library to determine when the well was last sampled.

A8.2.2 Evaluation of Available Locations to Meet Data Needs

Each A list well and aquifer tube was evaluated for the data needs for each PSQ (with the exception of PSQ 2a, "Does the EA using phosphate treatment reduce leachable uranium in the vadose zone and PRZ as expected?, EA operation and performance monitoring") to identify locations that potentially fulfill the data need. The following rationale is generally used for identifying potential monitoring locations:

- Monitoring point location relative to contaminant plume
- Monitoring point location relative to contaminant source or elevated concentration or mass

- Monitoring point location relative to inferred contaminant migration pathway(s)
- Monitoring point location relative to the Columbia River
- Monitoring point location relative to other monitoring point locations
- Trends in contaminant concentrations at existing monitoring locations
- Expected representativeness of monitoring point based on well construction, configuration, and position of screened interval in the unconfined aquifer (top or lower portions)
- Dependence of contaminant concentrations on water level

Historical measurements and observations recorded in HEIS were used to identify concentration trends for COCs and water level measurements.

Maps were generated that showed the following:

- Groundwater water level contours
- Groundwater contaminant plumes
- Potential monitoring locations available for the 300-FF-5 OU

Two approaches were used initially to identify proposed locations for monitoring. One approach used plume maps, trend plots, and locations for all wells to select the monitoring networks. The other approach used plume maps, trend plots, and locations for those wells with concentrations that, on average, exceeded the applicable standard. Results of the two approaches were compared to develop the final list of wells.

Selected monitoring locations for each COC were then highlighted on the corresponding plume maps (Figures A-6, A-8, A-10, A-12, and A-14). The resulting figures were used to provide a spatial depiction of monitoring locations that could address each individual PSQ.

The systematic planning process for PSQ 2a ("Does the EA using phosphate treatment reduce leachable uranium in the vadose zone and PRZ as expected?, EA operation and performance monitoring") was conducted during development of the supplemental Post-ROD Field Investigation SI (SGW-56993) and the RDR/RAWP (DOE/RL-2014-13-ADD2).

A8.2.3 300-FF-5 OU Long-Term Groundwater Monitoring

Based on the evaluation, the COC-specific long-term groundwater monitoring networks were selected for TCE, *cis*-1,2-DCE, uranium, tritium, and nitrate. The selected wells are highlighted on the groundwater long-term monitoring network maps (Figures A-6 through A-15). The comment/rationale column on Table A-12 provides the basis for retaining and, for uranium, excluding specific monitoring locations.

The available monitoring locations to collect measurements and observation for each data need are included in Tables A-6 and A-12.

The following groundwater contaminants will not be monitored as part of the 300-FF-5 OU remedy implementation:

- Groundwater contaminants from the 200-PO-1 OU. The 300 Area ROD/ROD Amendment (EPA and DOE, 2013) states: "Because several of the 300-FF-5 groundwater COCs are also contaminants in 200-PO-1 that move through the 300 Area, monitoring of 300-FF-5 COC plumes will include lateral extent sufficient to distinguish contamination that is part of 300-FF-5 versus 200-PO-1." Plumes originating from the 200-PO-1 OU are assumed to be monitored by the 200-PO-1 OU project.

- Additional releases of contamination during remediation of waste sites and deactivation, decommission, decontamination, and demolition (D4) of buildings (PSQ 1g). Monitoring of additional releases of uranium or other COCs to the aquifer resulting from remediation of waste sites and D4 of buildings is not part of the 300-FF-5 OU scope in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013). Monitoring of groundwater for additional releases during and following remediation is assumed to be the responsibility of the source OUs.
- Groundwater at the 618-10 Burial Ground. Remediation of the 618-10 Burial Ground has released uranium to groundwater at concentrations above CULs. Monitoring that plume is neither included in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013) nor in this DQO.

A8.2.4 Water Level Monitoring

Water levels will be monitored manually and automatically. Manual measurements will be collected when groundwater wells in the COC-specific long-term monitoring networks are sampled. In March of each year, water levels will be measured in a comprehensive, sitewide network of wells monitoring the unconfined aquifer and used to prepare water table contour maps (e.g., Figure A-2) (SGW-38815, *Water-Level Monitoring Plan for the Hanford Site Soil and Groundwater Remediation Project*). In 2013, water levels were monitored in 53 wells in the 300 Area (Figure A-2).

The Automated Water Level Network (AWLN) will be an array of 11 monitoring stations connected by a telemetry network to a central base station (SGW-53543, *Automated Water-Level Network Functional Requirements Document*). Each monitoring station will consist of a pressure transducer connected to a data collection telemetry unit. The AWLN will be used to collect data at multiple locations hourly to establish migration pathways and changes in migration pathways. AWLN data obtained simultaneously from wells that form triangles will be used to calculate hydraulic gradients (Figure A-19). AWLN data will be used to evaluate water level changes in response to river stage fluctuations. The AWLN stations will be maintained for the first 5 years of monitoring, and then re-evaluated. The manual water level data will be used to verify the automated data (e.g., evaluate drift). The automated river gauge will collect river level, specific conductance, and temperature data at the same times and frequency as the AWLN.

A8.2.5 Analytes

COCs specific to each groundwater monitoring location are provided in Tables A-6 and A-12. Field parameters (specific conductance, pH, DO, turbidity, and temperature) will be collected each time a groundwater sample is collected.

A8.2.6 Sampling Frequency

The sampling frequency for each COC at each well is indicated on each monitoring network map (Figures A-6, A-8, A-10, A-12, and A-14) and provided on Tables A-6 and A-12. Sampling for uranium is specified for either June (high river stage) or December (low river stage), depending on when the highest concentration is anticipated, or both. Sampling for *cis*-1,2-DCE and TCE is specified for December, and sampling for tritium and nitrate is specified for October, to be consistent with the historical monitoring periods for these COCs.

The uranium and gross alpha monitoring network has three components corresponding to PSQ 1, PSQ 2, and PSQ 4. Four wells in the 300 Area Industrial Complex will be monitored semiannually (high and low river stage) for 5 years to evaluate the impact of the phosphate application on concentration dependence on water table elevation (PSQ 2b). After 5 years, the monitoring frequency for these four wells will change to every 2 years. An additional eight wells in the 300 Area Industrial Complex will be monitored every 2 years (PSQ 1). Biennial monitoring at these wells will be conducted when the highest uranium concentrations are anticipated based on correlation of concentrations to the river stage. Two wells, downgradient of the 618-7 Burial Ground, will be monitored every 2 years in December to be consistent with the historical monitoring period (PSQ 1). An additional 14 wells and 1 aquifer tube in the 300 Area Industrial Complex will be monitored every 5 years during high and low river stage (PSQ 4). Concentrations in these wells, and in the wells monitored in the uranium monitoring networks for PSQ 1 and PSQ 2, will be used to track and communicate changes in the lateral extent of the uranium plume above the CUL in the 300 Area Industrial Complex.

The TCE monitoring network has one component corresponding to PSQ 1. Eight of the nine wells in the TCE network have reached the CUL and demonstrated attainment. These eight wells require no additional monitoring. One well has not reached the CUL and will be monitored quarterly (March, June, September, and December) for up to 2 years. This well has a shorter TCE data record than the other eight wells. Quarterly monitoring will extend the data record and may demonstrate achievement of the CUL more quickly than monitoring biennially. If attainment has not been achieved, monitoring may be continued at a reduced frequency.

The *cis*-1,2-DCE monitoring network has one component corresponding to PSQ 1. Two wells in the 300 Area Industrial Complex will be monitored every 5 years during December, to be consistent with the historical monitoring period, 2 years before the 5-year review time frame.

The tritium monitoring network has two components corresponding to PSQ 1 and PSQ 4. Five wells downgradient of the 618-11 Burial Ground will be monitored biennially during October to be consistent with the historical monitoring period (PSQ 1). Concentrations in these five wells will be used to track and communicate changes in the lateral extent of the tritium plume above the CUL downgradient of the 618-11 Burial Ground (PSQ 4).

The nitrate monitoring network has two components corresponding to PSQ 1 and PSQ 4. Four wells downgradient of the 618-11 Burial Ground will be monitored biennially during October to be consistent with the historical monitoring period (PSQ 1). Concentrations in these four wells will be used to track and communicate changes in the lateral extent of the nitrate plume above the CUL downgradient of the 618-11 Burial Ground (PSQ 4).

A8.2.7 Quality Assurance and Quality Control Program

QA/QC will be implemented as specified in the QAPjP (Chapter 4 in the main text of this document).

A8.2.8 Rationale for Wells and Aquifer Tubes Not Sampled

Additional existing wells and aquifer tubes were considered and excluded from the monitoring networks. Table A-12 lists the rationale for not sampling these locations.

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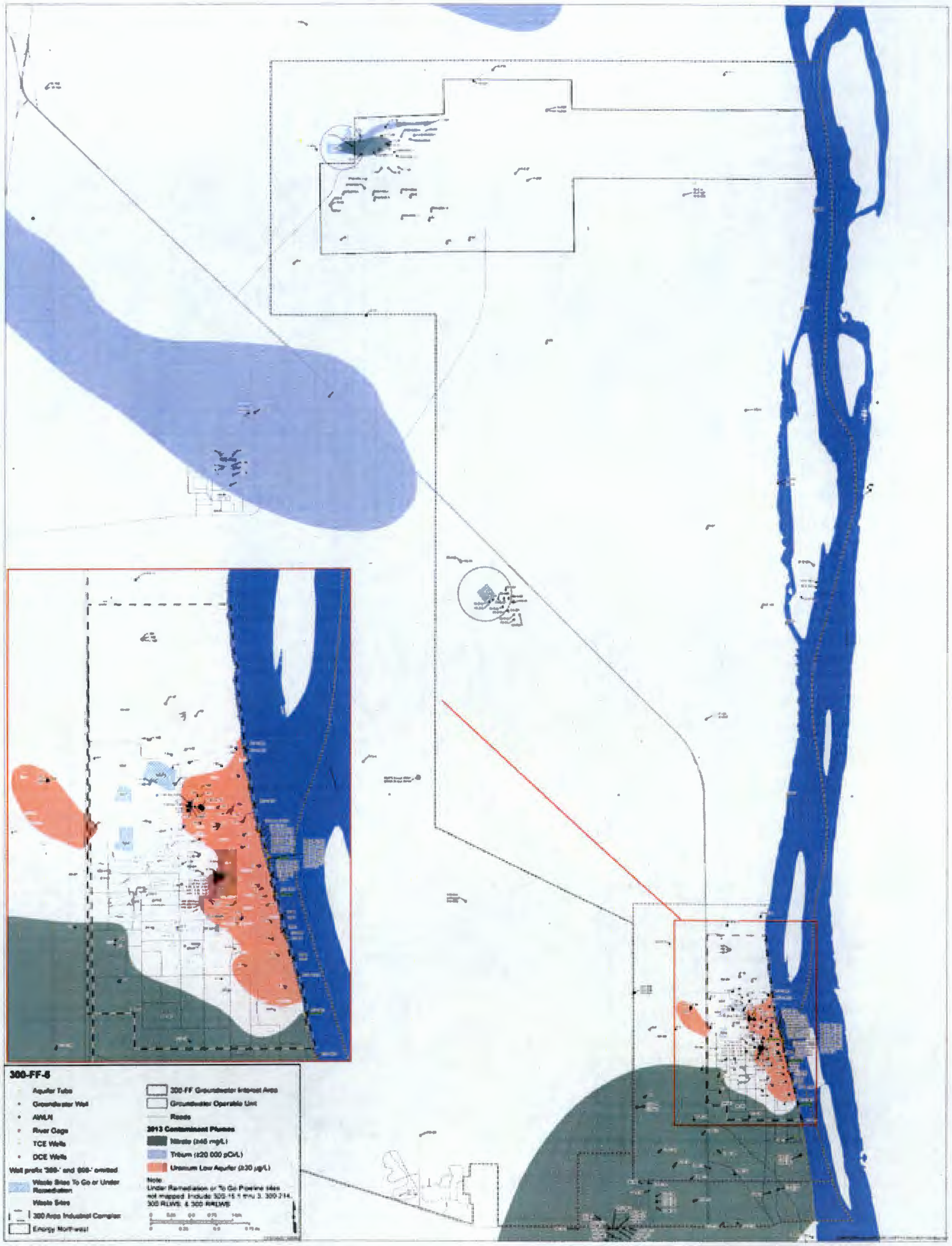
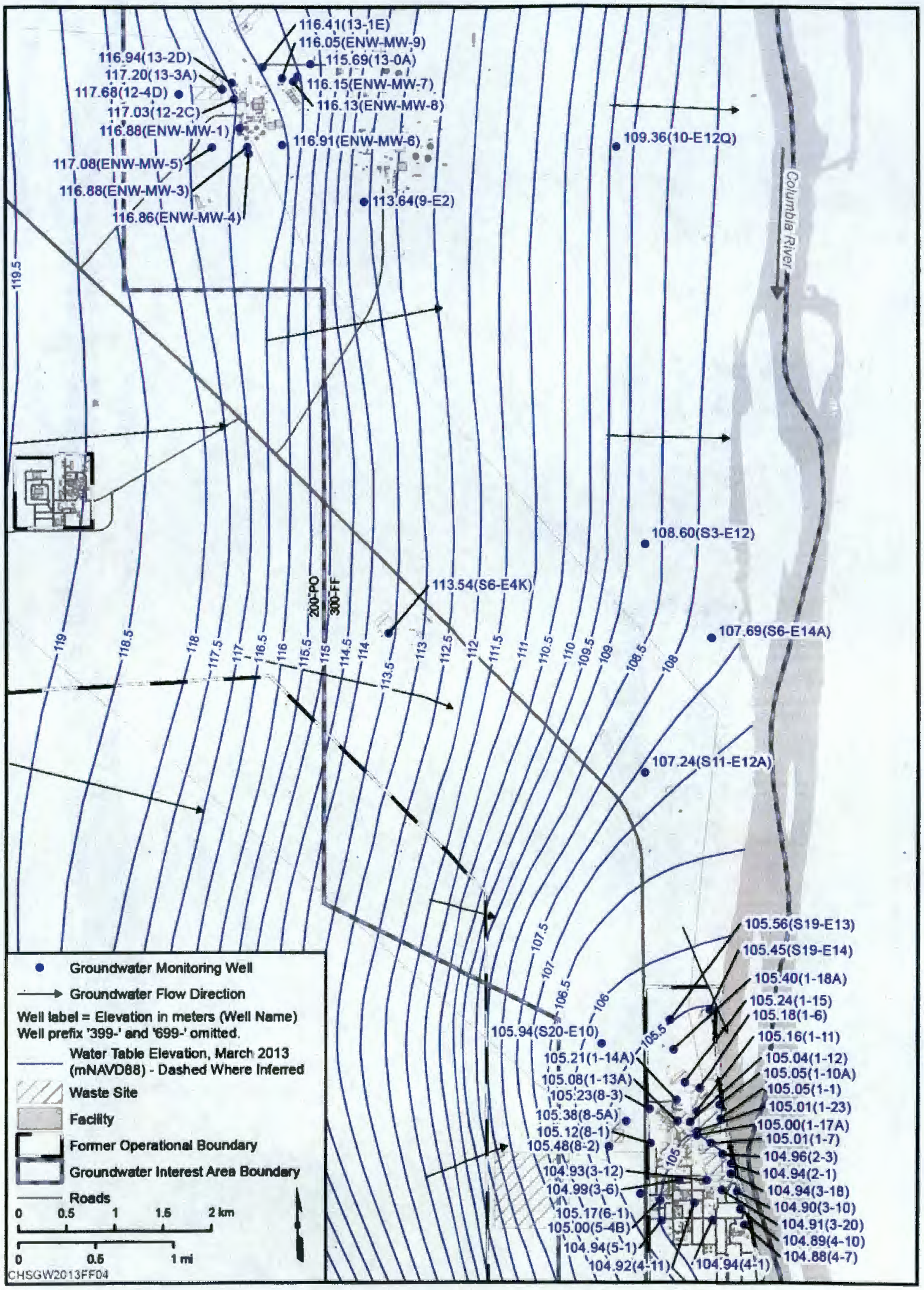


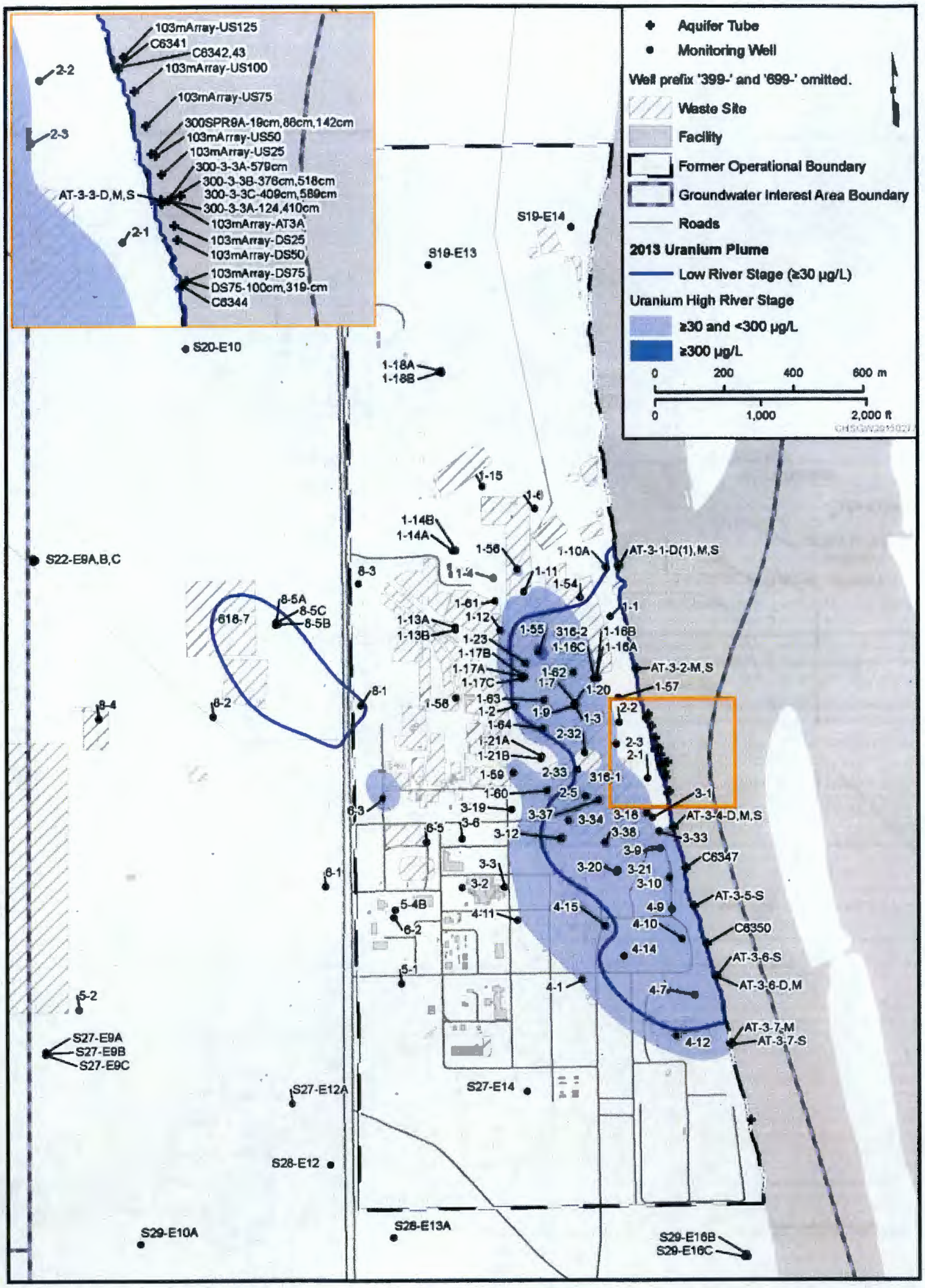
Figure A-1. Map of Groundwater Contamination in the 300-FF-5 OU



Sources: DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*.

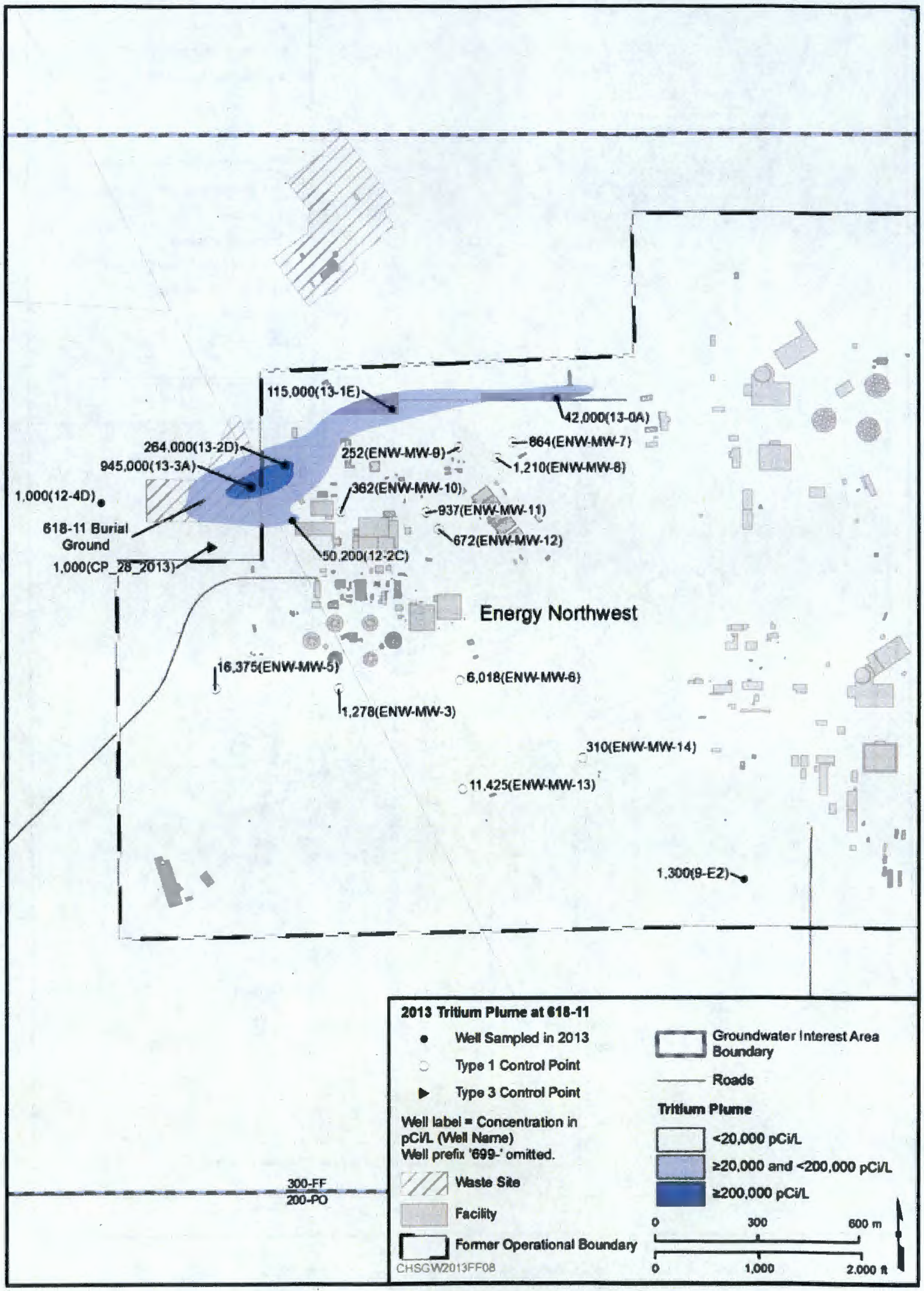
NAVD88, *North American Vertical Datum of 1988*.

Figure A-2. Water Table Map for the 300 Area



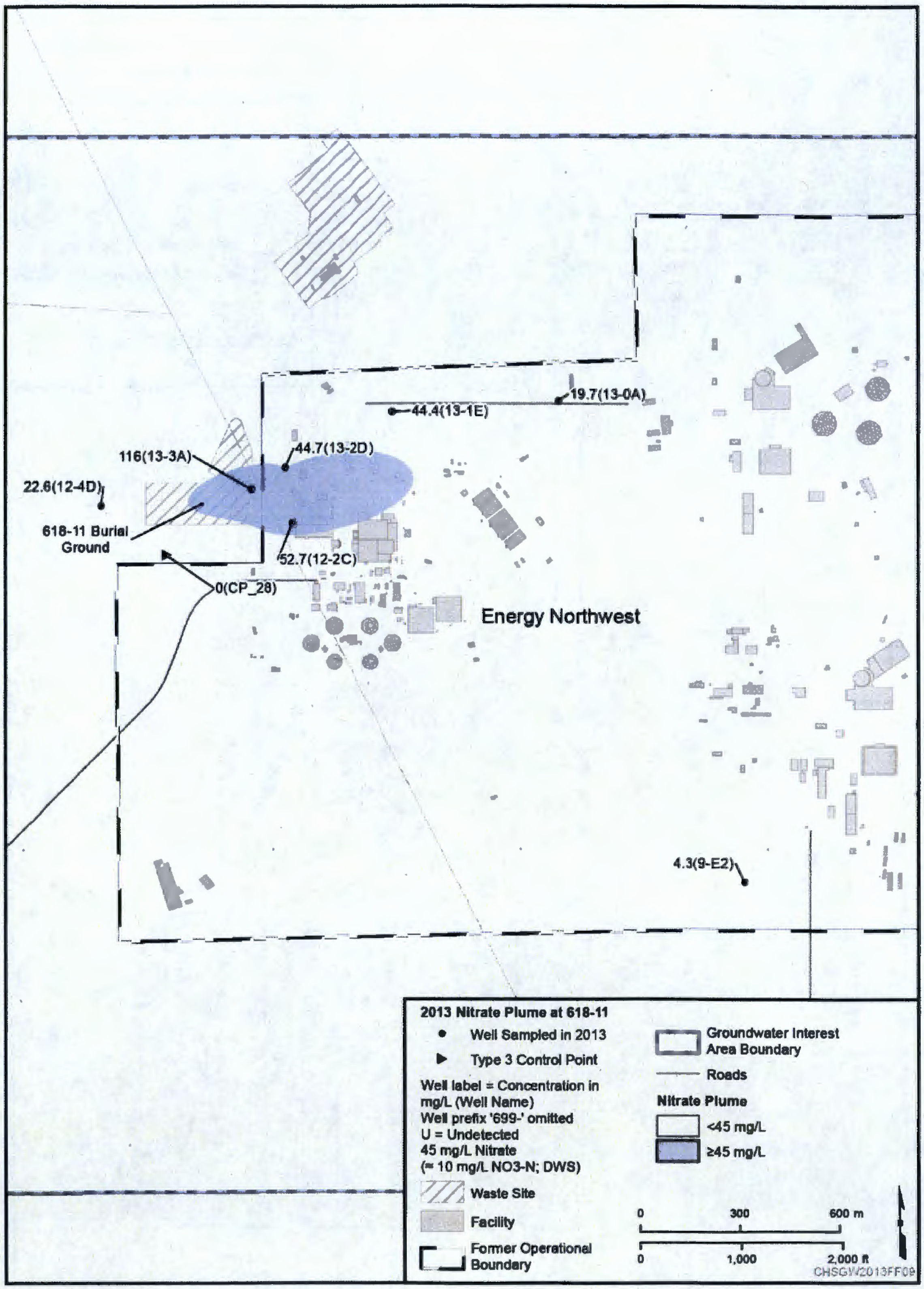
Sources: DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013.*

Figure A-3. Map of Uranium Contamination in the 300 Area Industrial Complex and at the 618-7 Burial Ground



Source: DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*.

Figure A-4. Map of Tritium Contamination at the 618-11 Burial Ground



Source: DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013.*

Figure A-5. Map of Nitrate Contamination at the 618-11 Burial Ground

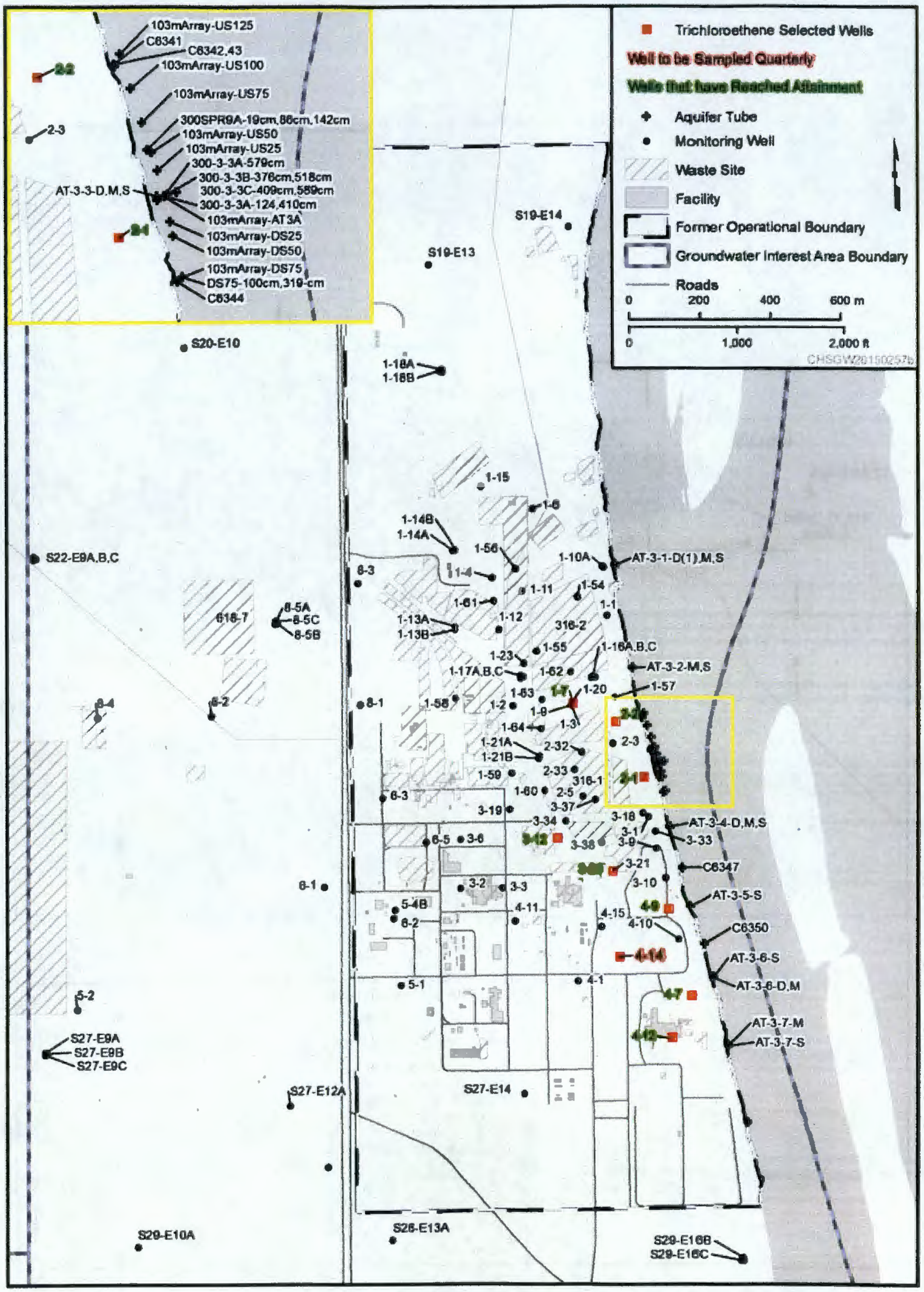
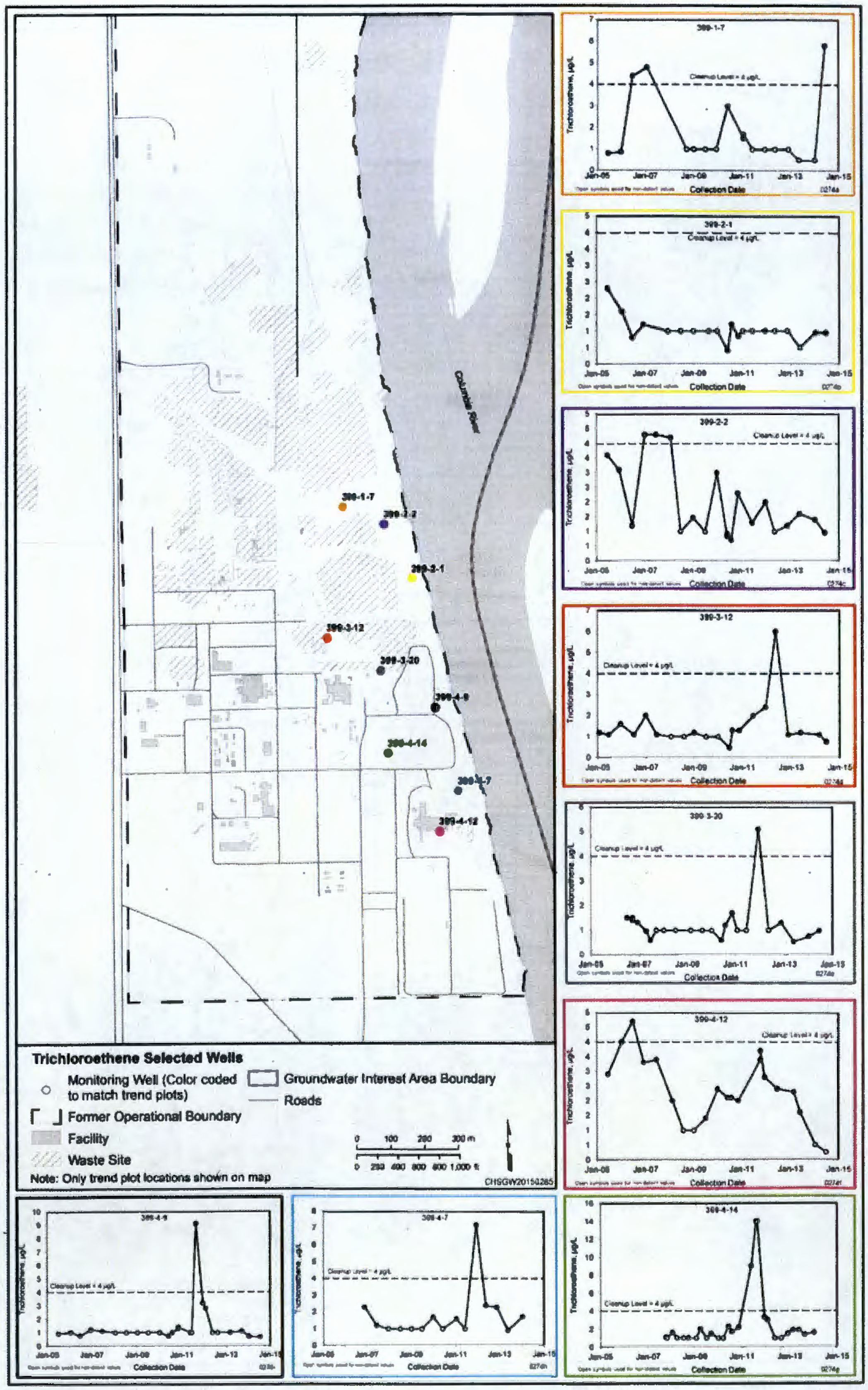


Figure A-6. Long-Term Groundwater Monitoring Network for TCE in the 300 Area Industrial Complex



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2 Figure A-7. Trend Plots for Wells in the TCE Monitoring Network

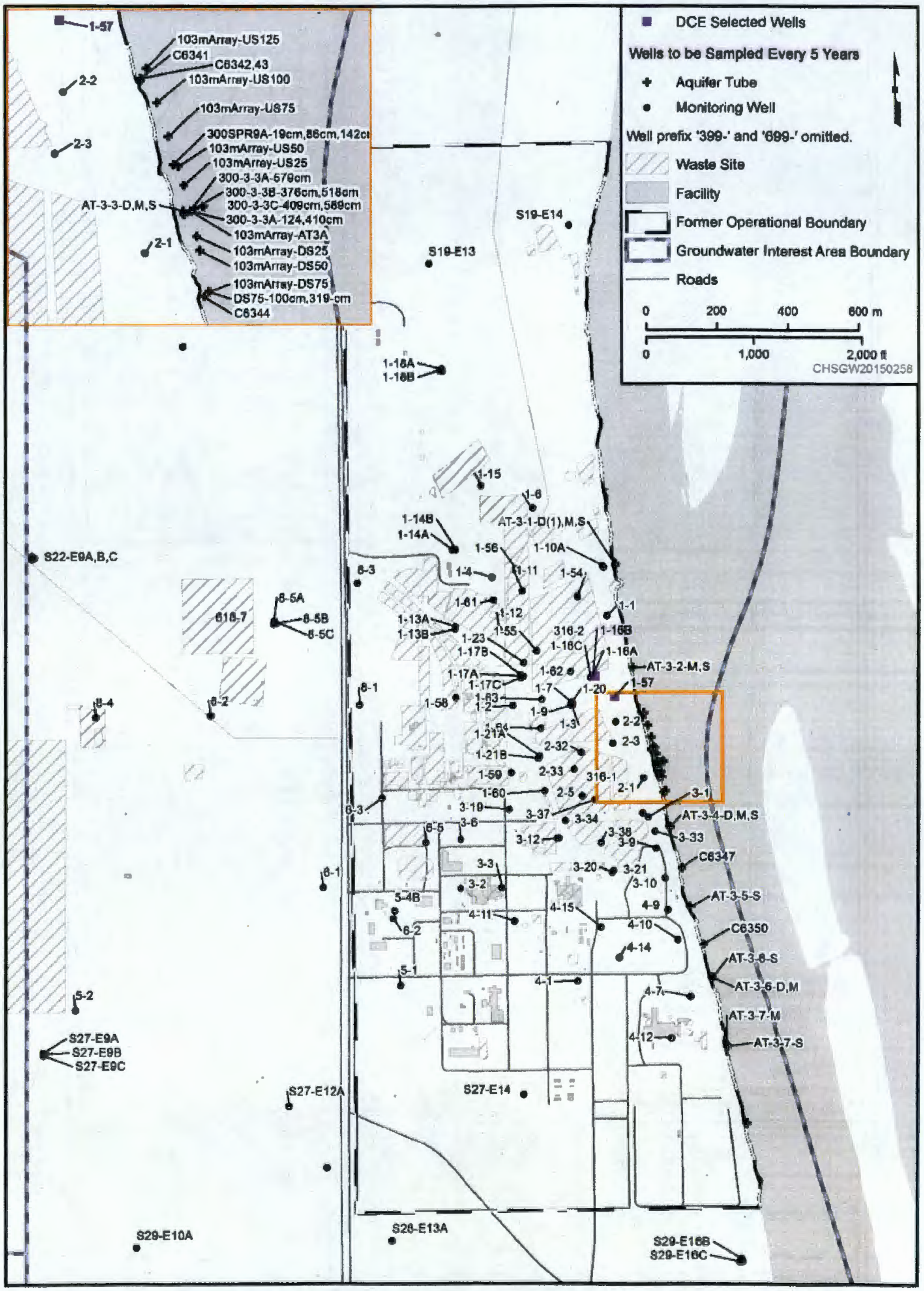

Figure A-8. Long-Term Groundwater Monitoring Network for *cis*-1,2-DCE in the 300 Area Industrial Complex

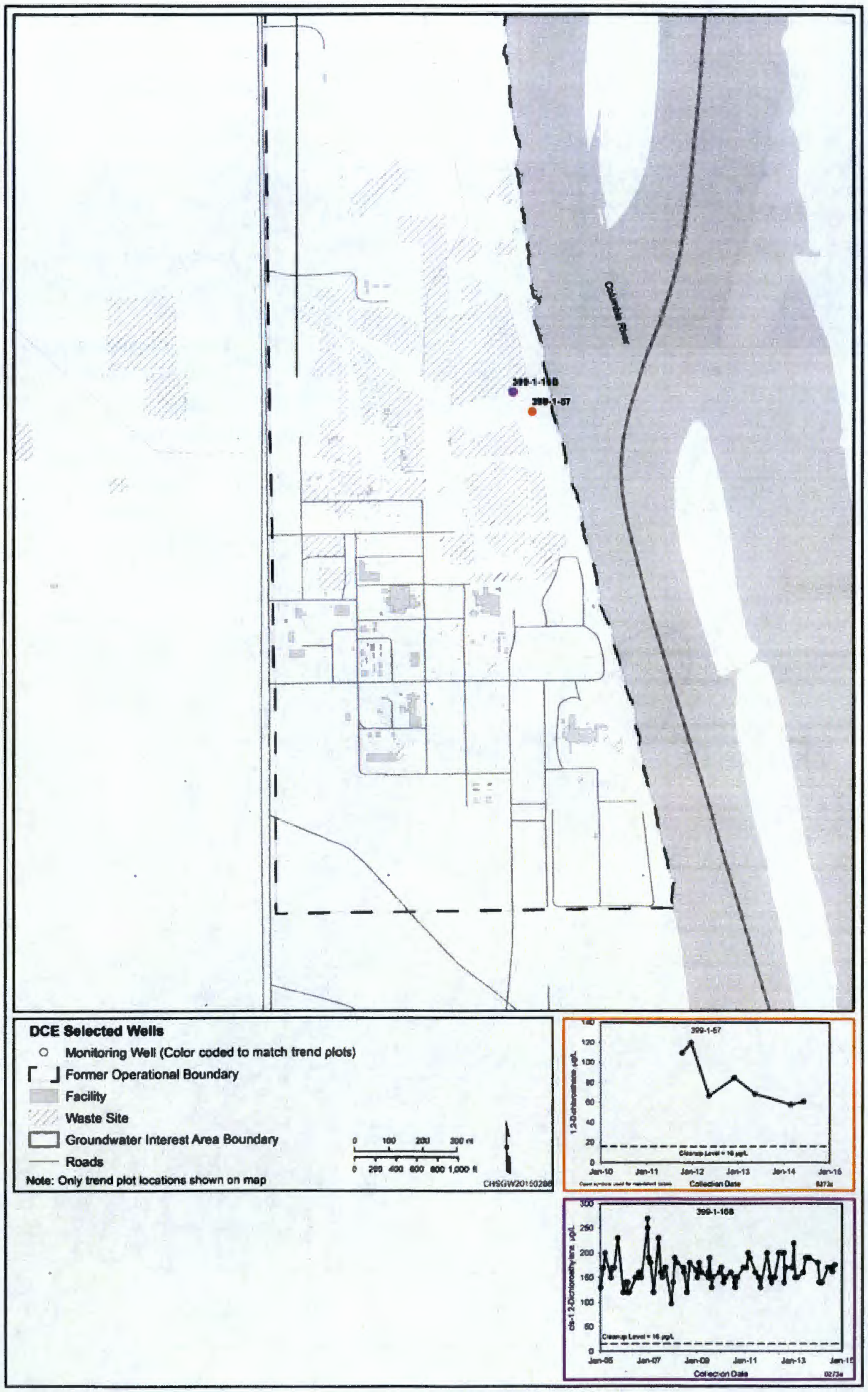

Figure A-9. Trend Plots for Wells in the *cis*-1,2-DCE Monitoring Network

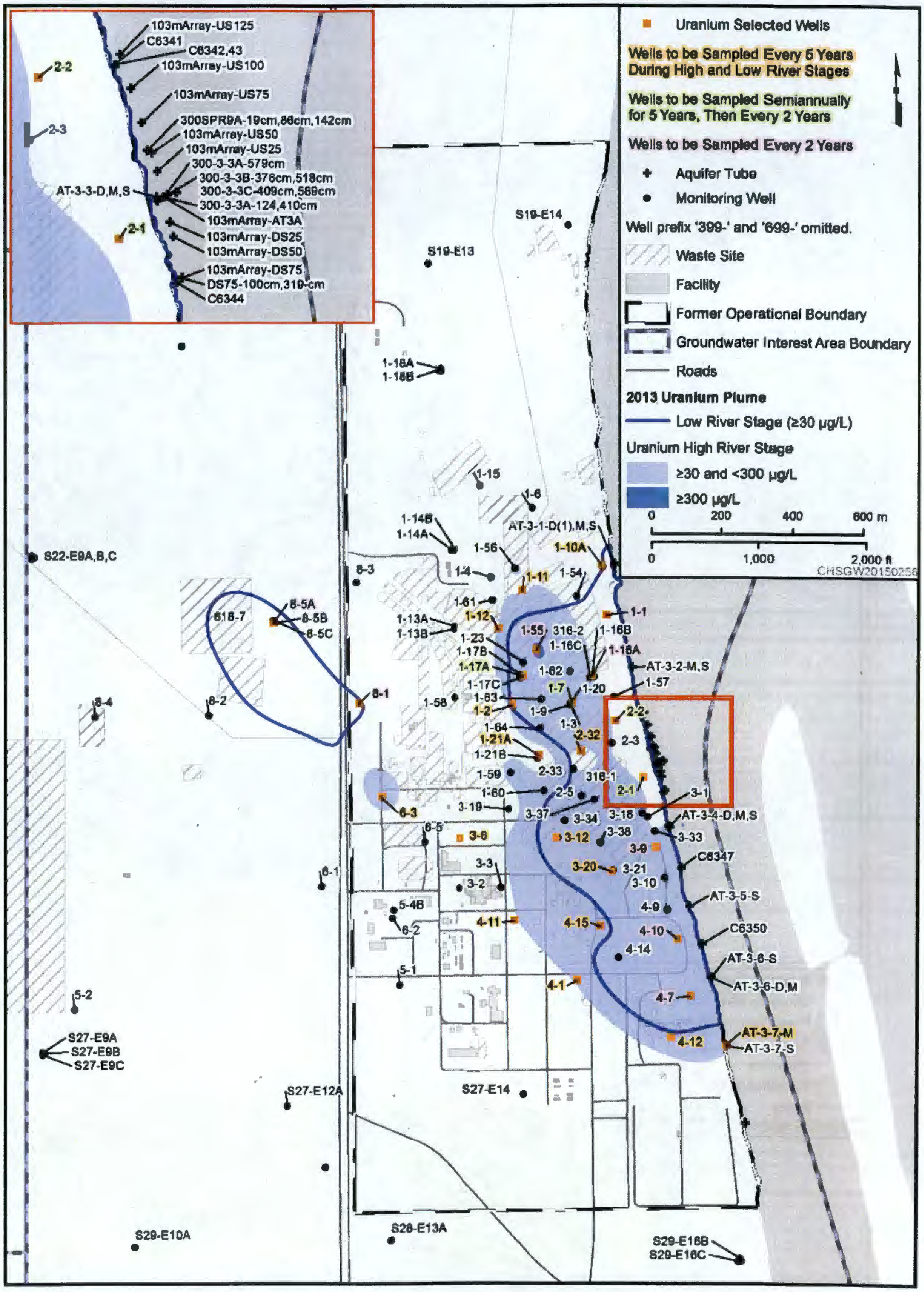

Figure A-10. Proposed Groundwater Sampling Network for Uranium in the 300 Area Industrial Complex and at the 618-7 Burial Ground

1

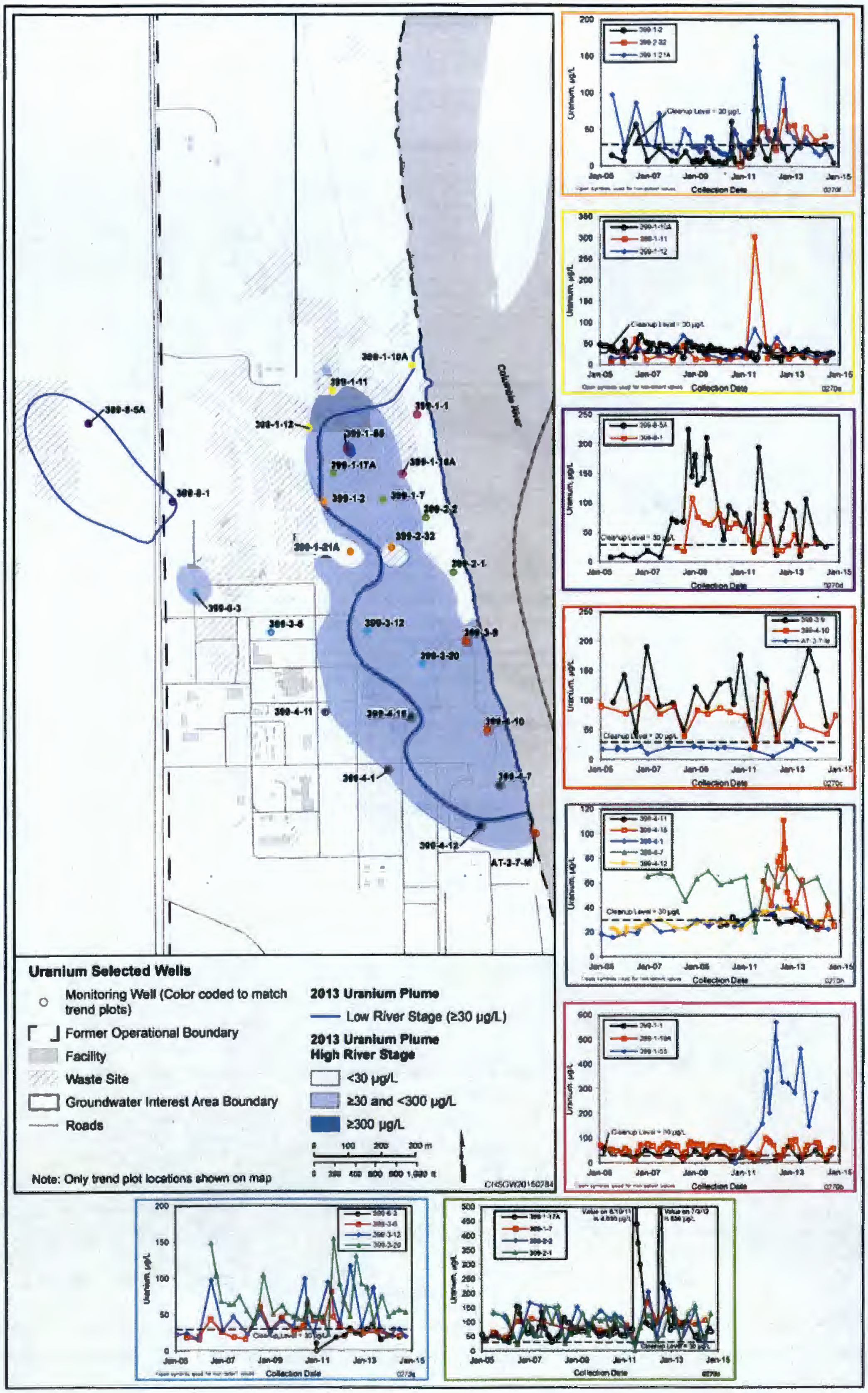

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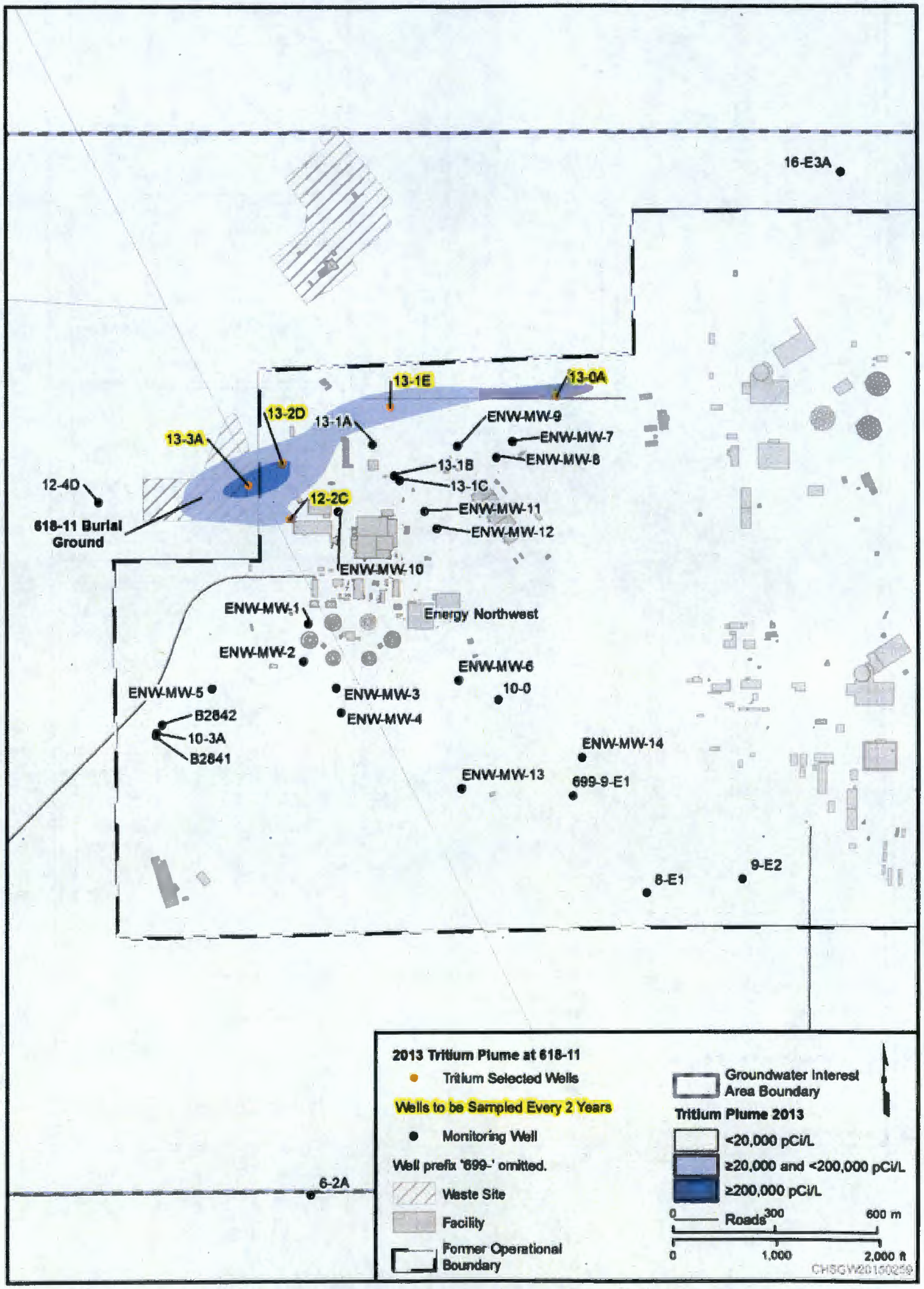
Figure A-11. Trend Plots for Wells in the Uranium Monitoring Network



1
2 Figure A-12. Proposed Groundwater Sampling Network for Tritium at the 618-11 Burial Ground

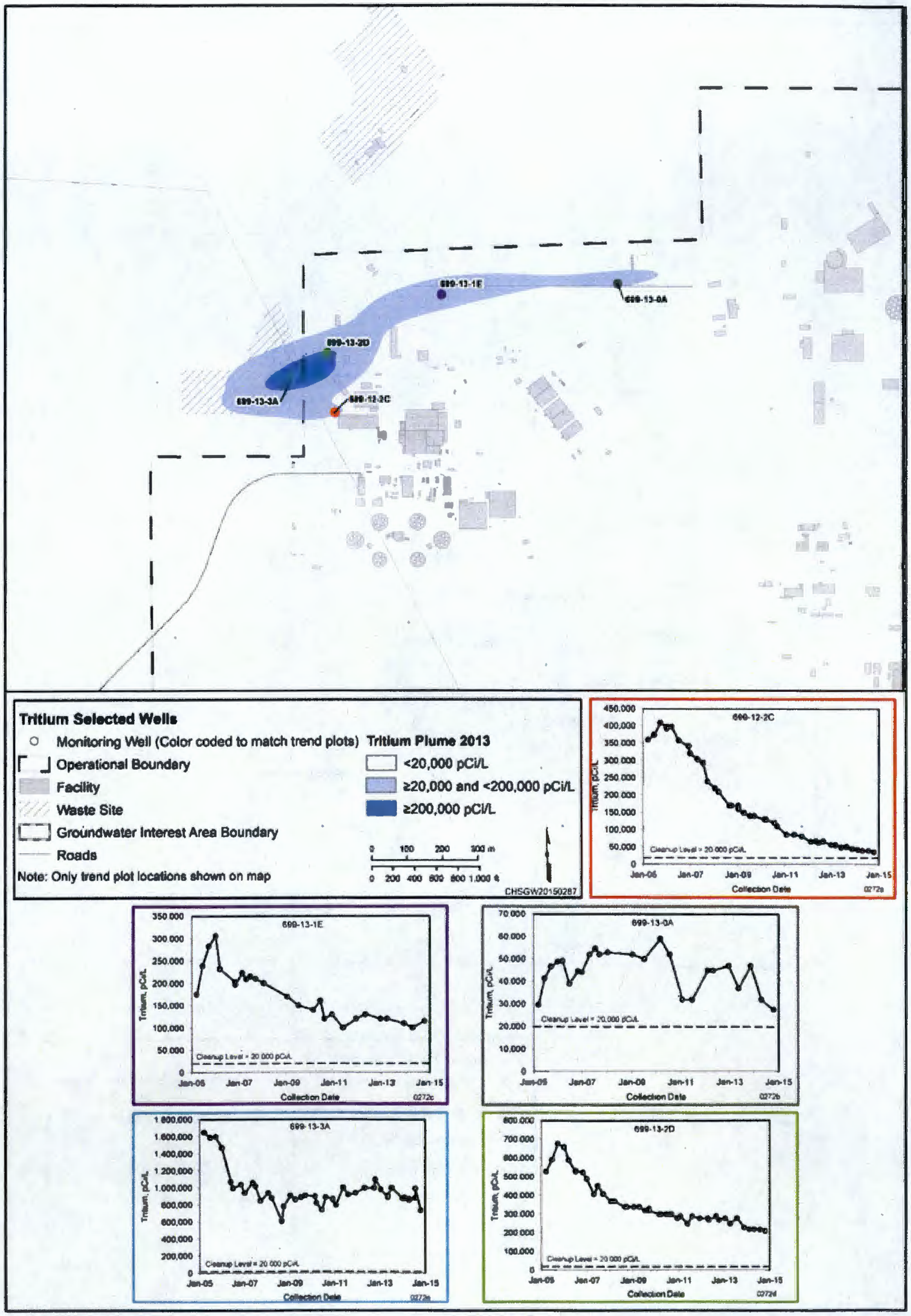
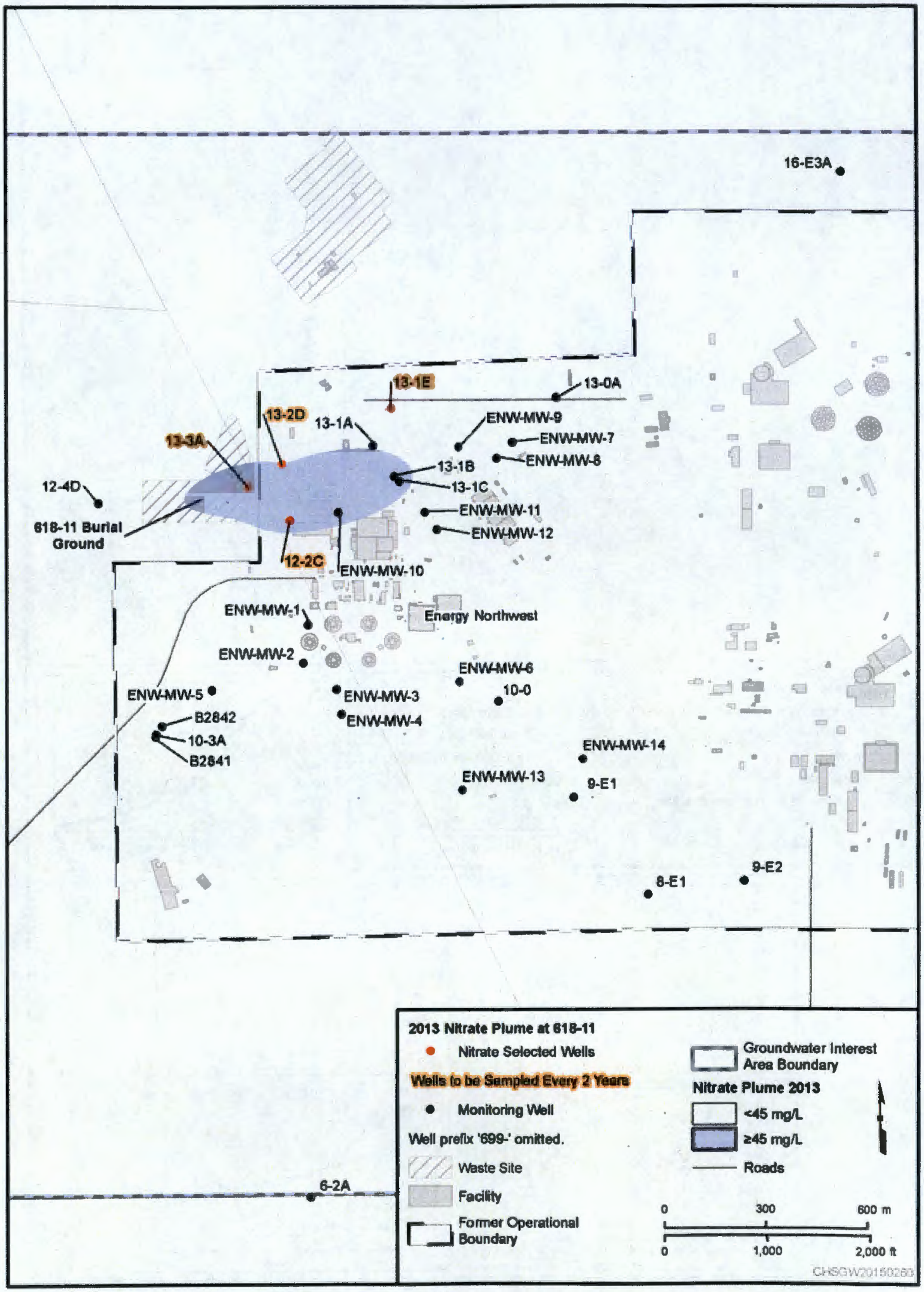


Figure A-13. Trend Plots for Wells in the Tritium Monitoring Network



1

2 **Figure A-14. Proposed Groundwater Sampling Network for Nitrate at the 618-11 Burial Ground**

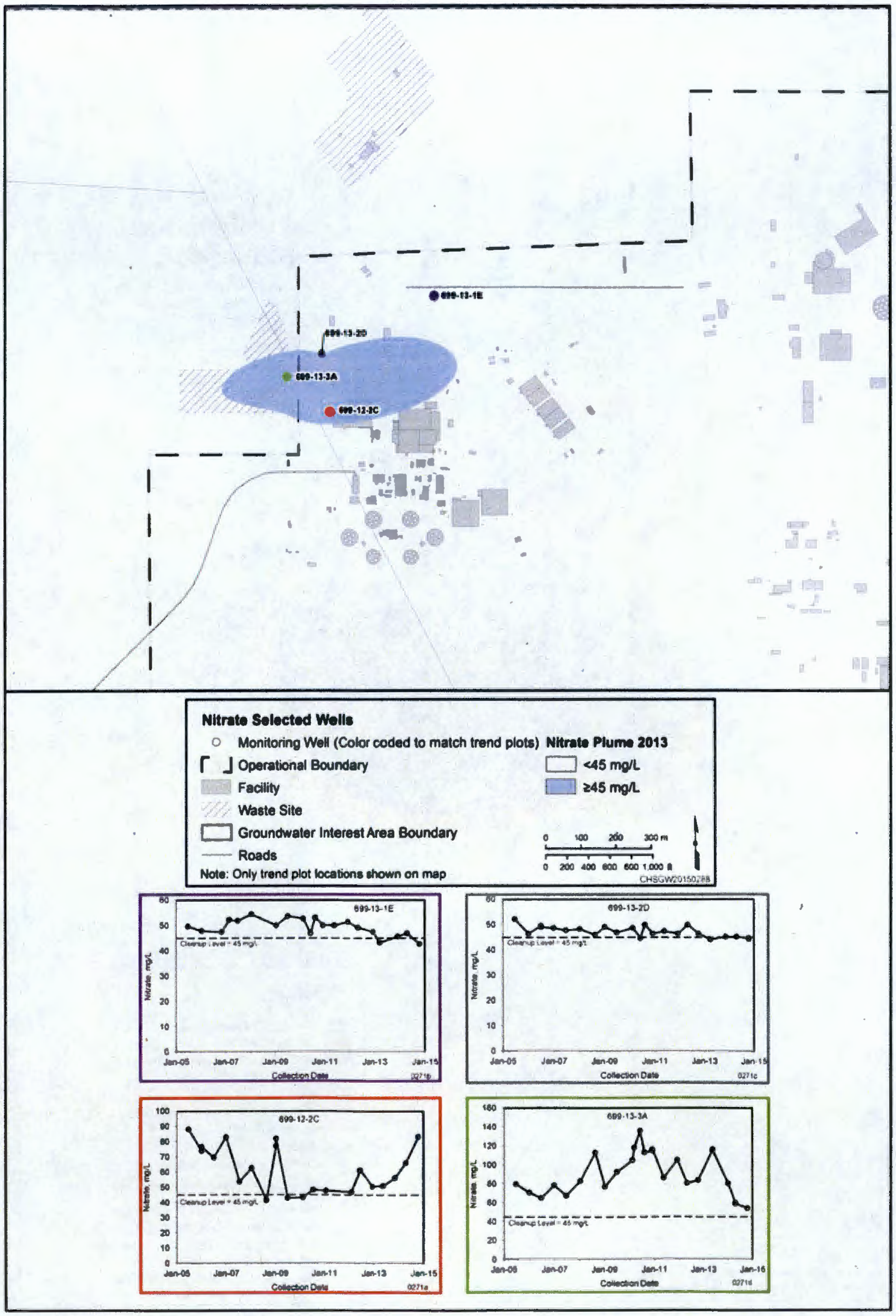


Figure A-15. Trend Plots for Wells in the Nitrate Monitoring Network

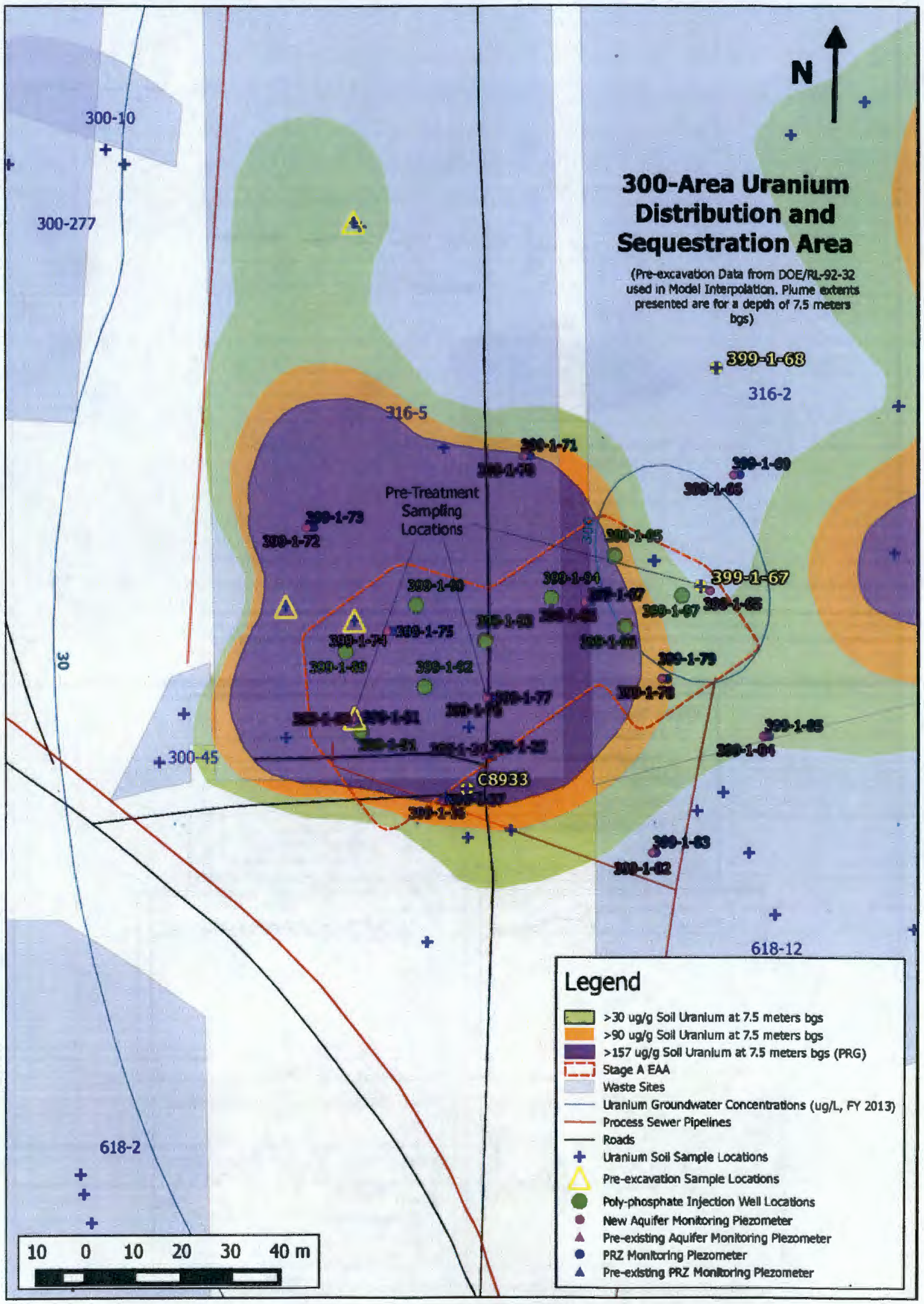


Figure A-16. Monitoring Piezometers for Stage A of the EA Treatment

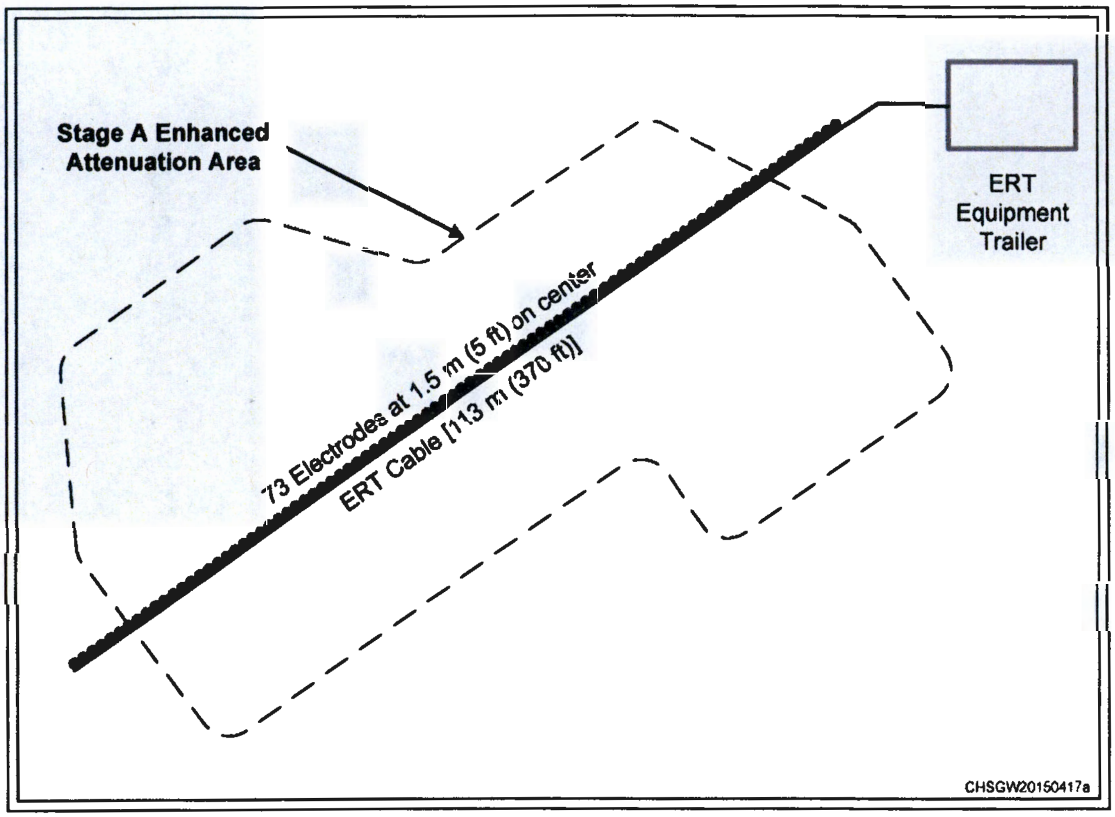
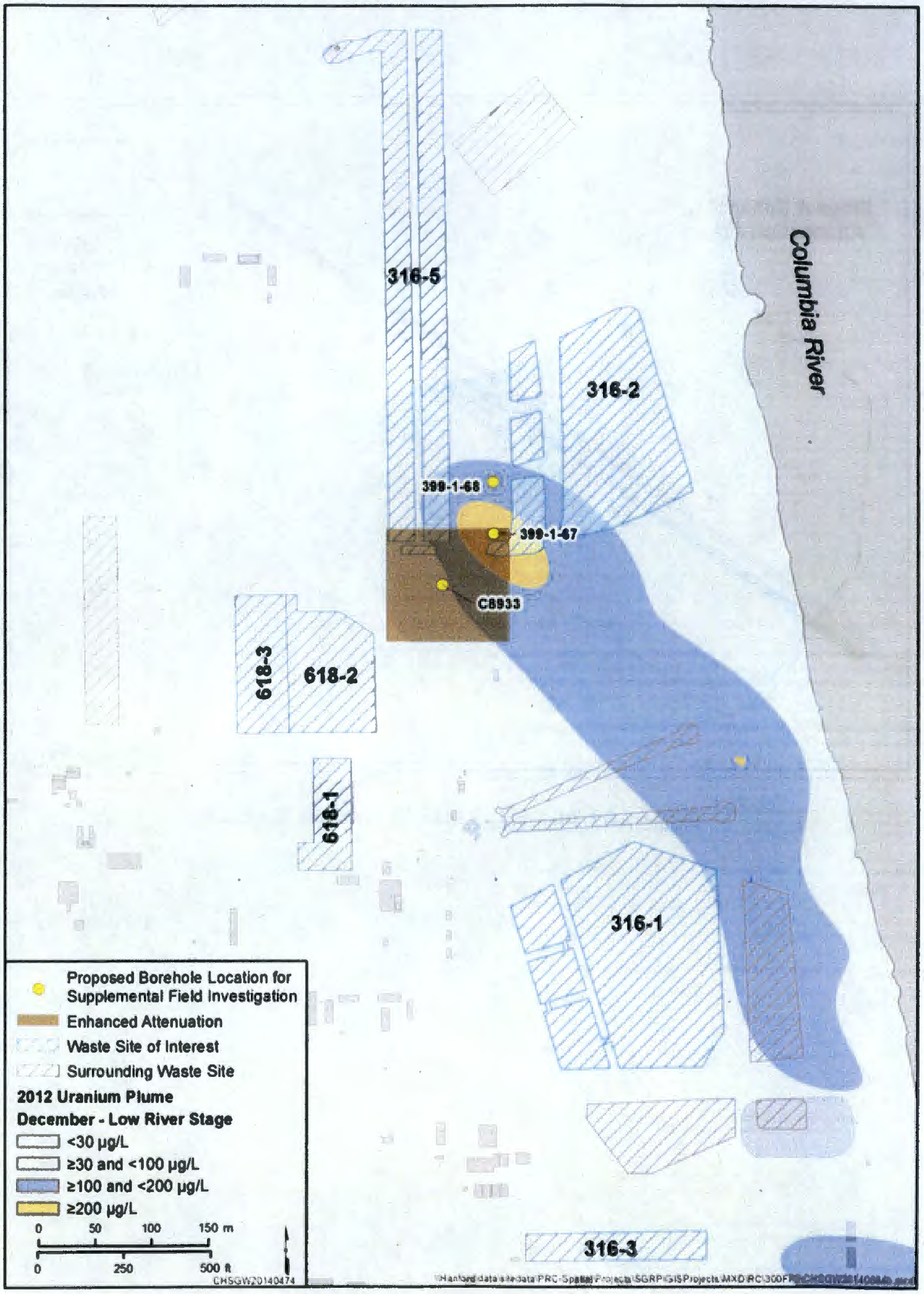


Figure A-17. Plan View of 2-D ERT Array for Stage A



Note: Three additional boreholes will be drilled, at locations near these three boreholes, and sampled following phosphate application.

Figure A-18. Proposed Boreholes for Post-ROD Supplemental Field Investigation prior to Phosphate Application for EA

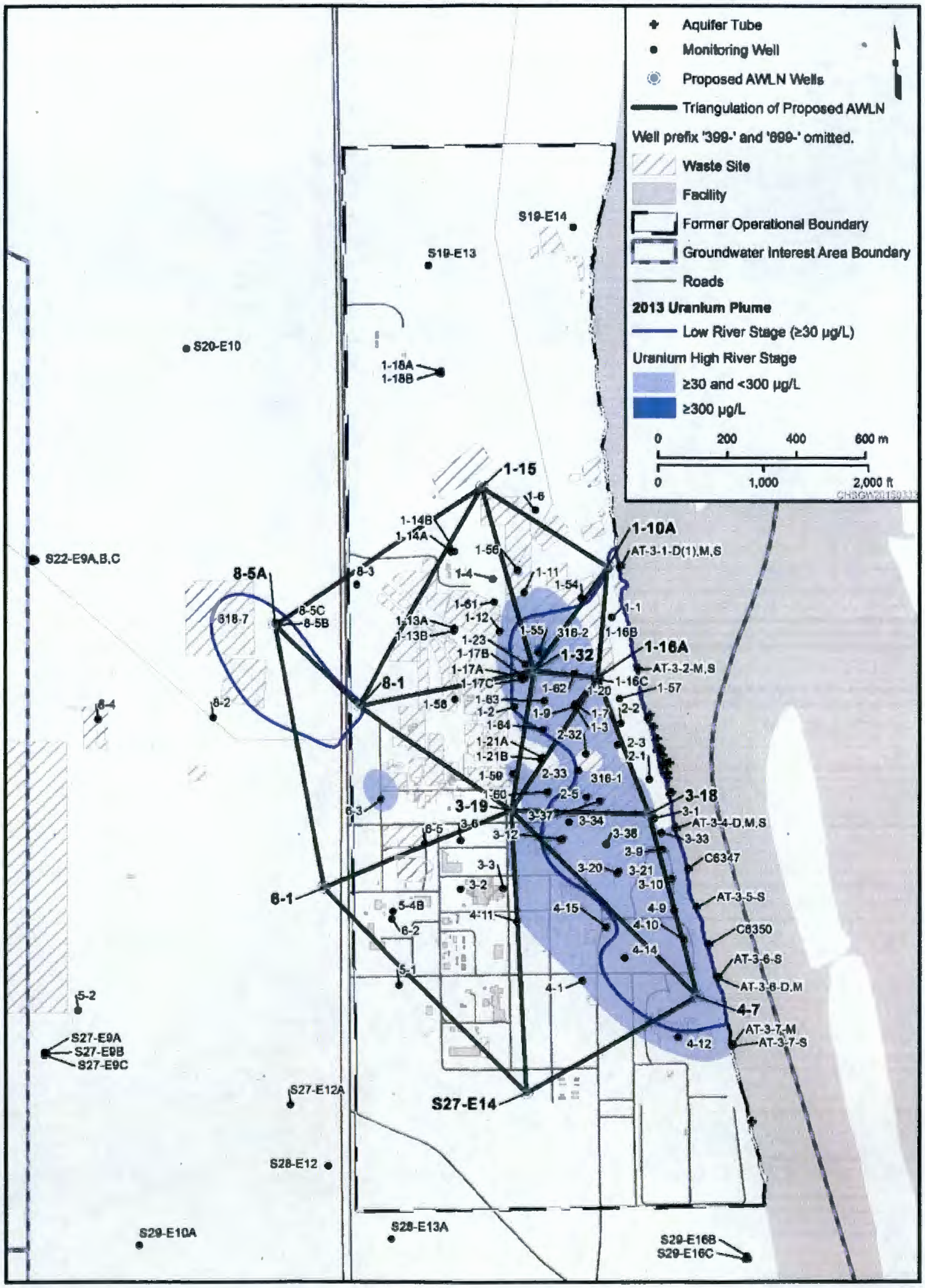


Figure A-19. AWLN in the 300 Area Industrial Complex

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Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	Rationale[b]										Water Level		Years 1 through 5 Frequency						Comment/Rationale
						PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
399-1-1	Groundwater well	TU	1948	A	Low		X			X							B	B					B	U: Define north extent of uranium plume near river
399-1-10A	Groundwater well	TU	1986	A	Low					X		X			X	X	5	5					5	U: Define north extent of uranium plume near river
399-1-10B	Groundwater well	LU	1991	A	N/A																			No monitoring objective
399-1-11	Groundwater well	TU	1986	A	High					X					X		5	5					5	U: Define north extent of uranium plume inland
399-1-12	Groundwater well	UU	1986	A	High					X					X		5	5					5	U: Delimit inland edge of plume
399-1-13A	Groundwater well	TU	1986	A	N/A																			No monitoring objective
399-1-13B	Groundwater well	MU	1992	B	N/A																			No monitoring objective
399-1-14A	Groundwater well	TU	1986	B	N/A																			No monitoring objective
399-1-14B	Groundwater well	LU	1991	B	N/A																			No monitoring objective
399-1-15	Groundwater well	TU	1986	A	N/A							X				X								No COC monitoring objective
399-1-16A	Groundwater well	TU	1986	A	Low		X			X		X				X	B	B					B	U: Define north extent of uranium plume near river
399-1-16B	Groundwater well	LU	1987	A	N/A	X											5			5				U: No uranium in lower unconfined aquifer *cis*-1,2-DCE: >CUL; TCE: <CUL
399-1-17A	Groundwater well	TU	1986	A	Low and High		X			X			X				SA B	SA B					SA B	U: Semiannually for 5 years for enhanced attenuation; also biennial for trends
399-1-17B	Groundwater well	MU	1986	A	N/A																			No monitoring objective
399-1-18A	Groundwater well	TU	1986	A	N/A																			No monitoring objective
399-1-18B	Groundwater well	MU	1987	A	N/A																			No monitoring objective
399-1-18C	Groundwater well	LU	1987	A	N/A																			No monitoring objective
399-1-2	Groundwater well	TU	1950	A	High					X					X		5	5					5	U: Define western extent of uranium plume near river
399-1-20	Unclassified	U	1988	B	N/A																			Contains multiple piezometer string
399-1-21A	Groundwater well	TU	1991	A	High					X					X		5	5					5	U: Monitor western part of uranium plume, concentration higher than 399-1-59
399-1-21B	Groundwater well	LU	1991	A	N/A																			No monitoring objective
399-1-23	Groundwater well	TU	2006	A	N/A																			U: Redundant with 399-1-17A
399-1-24	Groundwater well	TU	2006	B	N/A																			1.5 m (5 ft) long screen
399-1-25	Groundwater well	UU	2006	B	N/A																			1.5 m (5 ft) long screen
399-1-26	Groundwater well	TU	2006	B	N/A																			No monitoring objective
399-1-27	Groundwater well	UU	2006	B	N/A																			1.5 m (5 ft) long screen
399-1-28	Groundwater well	TU	2006	B	N/A																			1.5 m (5 ft) long screen
399-1-29	Groundwater well	TU	2006	B	N/A																			No monitoring objective
399-1-3	Groundwater well	TU	1950	B	N/A																			No monitoring objective
399-1-30	Groundwater well	TU	2006	B	N/A																			No monitoring objective

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	Rationale[b]										Water Level		Years 1 through 5 Frequency						Comment/Rationale
						PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
399-1-31	Groundwater well	TU	2006	B	N/A																			No monitoring objective
399-1-32	Groundwater well	TU	2006	B	N/A							X				X								No COC monitoring objective
399-1-33	Groundwater well	TU	2007	B	N/A																			No monitoring objective
399-1-34	Groundwater well	TU	2007	B	N/A																			No monitoring objective
399-1-35	Groundwater well	TU	2007	B	N/A																			No monitoring objective
399-1-36	Groundwater well	UU	2007	B	N/A																			1.5 m (5 ft) long screen
399-1-37	Groundwater well	TU	2007	B	N/A																			1.5 m (5 ft) long screen
399-1-38	Groundwater well	Unk	2007	B	N/A																			No monitoring objective
399-1-39	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-4	Groundwater well	TU	1950	B	N/A																			No monitoring objective
399-1-40	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-41	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-42	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-43	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-44	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-45	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-46	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-47	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-48	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-49	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-50	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-51	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-52	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-53	Groundwater well	TU	2009	B	N/A																			0.8 m (2.5 ft) long screen
399-1-54	Groundwater well	TU	2010	A	N/A																			No monitoring objective
399-1-55	Groundwater well	TU	2010	A	High		X			X							B	B					B	U: Maximum uranium concentration TCE: Detections in characterization samples, but all nondetect after that
399-1-56	Groundwater well	TU	2010	A	N/A																			No monitoring objective
399-1-57	Groundwater well	MU	2010	A	N/A	X				X							5			5				U: No uranium in middle unconfined TCE: Detections during drilling and one routine sample >4 µg/L (flagged Q), but screened deep; monitor 399-2-2 for TCE instead *cis*-1,2-DCE: Persistent detections >CUL
399-1-58	Groundwater well	TU	2010	A	N/A																			No monitoring objective

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	Rationale[b]										Water Level		Years 1 through 5 Frequency						Comment/Rationale
						PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
399-1-59	Groundwater well	TU	2010	A	N/A																			No monitoring objective
399-1-6	Groundwater well	TU	1975	A	N/A																			No monitoring objective
399-1-60	Groundwater well	TU	2011	A	N/A																			No monitoring objective
399-1-61	Groundwater well	TU	2011	A	N/A																			0.6 m (2 ft) long screen
399-1-62	Groundwater well	TU	2011	A	N/A																			0.6 m (2 ft) long screen
399-1-63	Groundwater well	TU	2011	A	N/A																			0.6 m (2 ft) long screen
399-1-64	Groundwater well	TU	2011	A	N/A																			0.6 m (2 ft) long screen
399-1-65	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-66	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
C8933	Drilled, sampled, decommissioned	N/A	2015	N/A	N/A							X												Soil sample for uranium leachability tests
399-1-67	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate Soil sample collected for uranium leachability tests
399-1-68	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate Soil sample for uranium leachability tests
399-1-69	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-7	Groundwater well	TU	1985	A	Low and High		X			X			X				Q SA B	SA B					SA B	U: Semiannually for 5 years for enhanced attenuation; also biennial for uranium trends TCE: Has demonstrated attainment
399-1-70	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-71	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-72	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-73	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-74	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-75	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-76	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-77	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-78	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-79	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-8	Groundwater well	LU	1985	A	N/A																			No monitoring objective
399-1-80	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-81	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-82	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-83	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

						Rationale[b]										Water Level		Years 1 through 5 Frequency						
Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	Comment/Rationale
399-1-84	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-85	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-86	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-87	Piezometer	TU	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-88	Piezometer	PRZ	2015	N/A	N/A							X						P						Will also be monitored for phosphate
399-1-9	Groundwater well	CR	1987	N/A	N/A																			No monitoring objective
399-2-1	Groundwater well	TU	1948	A	Low and High		X			X			X				Q SA B	SA B					SA B	U: Semiannually for 5 years for enhanced attenuation; also biennial for uranium trends TCE: Has demonstrated attainment
399-2-10	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-11	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-12	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-13	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-14	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-15	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-16	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-17	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-18	Groundwater well	UU	2008	B	N/A																			No monitoring objective
399-2-19	Groundwater well	UU	2008	B	N/A																			No monitoring objective
399-2-2	Groundwater well	TU	1976	A	Low and High		X			X			X				Q SA B	SA B					SA B	U: Semiannually for 5 years for enhanced attenuation; also biennial for uranium trends TCE: Has demonstrated attainment
399-2-20	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-21	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-22	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-23	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-24	Groundwater well	UU	2008	B	N/A																			No monitoring objective
399-2-25	Groundwater well	Unk	2008	B	N/A																			No monitoring objective
399-2-26	Groundwater well	TU	2008	B	N/A																			1.5 m (5 ft) screen with 7.6 m (25 ft) long sump
399-2-27	Groundwater well	Unk	2008	B	N/A																			0.6 m (2 ft) long screen; not clear where screen is relative to water table
399-2-28	Groundwater well	UU	2008	B	N/A																			0.6 m (2 ft) screen with 3.7 m (12 ft) long sump
399-2-29	Groundwater well	TU	2008	B	N/A																			1.5 m (5 ft) long screen
399-2-3	Groundwater well	TU	1976	B	N/A																			No monitoring objective

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

						Rationale[b]										Water Level		Years 1 through 5 Frequency						
Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	cis-1,2-DCE	TCE	Nitrate	Gross Alpha	Comment/Rationale
399-2-30	Groundwater well	UU	2008	B	N/A																			0.6 m (2 ft) long screen
399-2-31	Groundwater well	UU	2008	B	N/A																			0.6 m (2 ft) long screen
399-2-32	Groundwater well	TU	2010	A	Low					X					X		5	5					5	U: Monitor central part of uranium plume
399-2-33	Groundwater well	TU	2011	A	N/A																			U: Redundant with 399-2-32, which has more uranium data
399-2-34	Groundwater well	TU	2010	B	N/A																			No monitoring objective
399-2-37	Groundwater well	TU	2010	B	N/A																			No monitoring objective
399-2-5	Groundwater well	TU	2007	A	N/A																			No monitoring objective
399-2-7	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-8	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-2-9	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-3-1	Groundwater well	TU	1984	A	N/A																			No monitoring objective
399-3-10	Groundwater well	TU	1976	A	N/A																			No monitoring objective
399-3-12	Groundwater well	TU	1980	A	High					X					X		Q 5	5					5	U: Monitor west part of uranium plume, central TCE: Has demonstrated attainment
399-3-18	Groundwater well	TU	2006	A	N/A					X						X								No COC monitoring objective
399-3-19	Groundwater well	TU	2006	A	N/A					X						X								No COC monitoring objective
399-3-2	Groundwater well	TU	1947	A	N/A																			No monitoring objective
399-3-20	Groundwater well	TU	2006	A	High					X					X		Q 5	5					5	U: Monitor south-central part of plume TCE: Has demonstrated attainment
399-3-21	Groundwater well	LU	2007	A	N/A																			No monitoring objective
399-3-22	Groundwater well	LU	2007	A	N/A																			No monitoring objective
399-3-23	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-3-24	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-3-25	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-3-26	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-3-27	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-3-28	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-3-29	Groundwater well	TU	2008	B	N/A																			No monitoring objective
399-3-3	Groundwater well	TU	1948	B	N/A																			No monitoring objective
399-3-30	Groundwater well	TU	2008	B	N/A																			1.5 m (5 ft) long screen with 6.1 m (20 ft) long sump
399-3-31	Groundwater well	UU	2008	B	N/A																			0.6 m (2 ft) long screen
399-3-32	Groundwater well	UU	2008	B	N/A																			0.6 m (2 ft) long screen with 3.7 m (12 ft) long sump

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	Rationale[b]										Water Level		Years 1 through 5 Frequency						Comment/Rationale
						PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
399-3-33	Groundwater well	TU	2010	A	N/A																			No monitoring objective
399-3-34	Groundwater well	TU	2011	A	N/A																			No monitoring objective
399-3-35	Groundwater well	TU	2010	B	N/A																			No monitoring objective
399-3-37	Groundwater well	TU	2011	A	N/A																			No monitoring objective
399-3-38	Groundwater well	TU	2011	A	N/A																			0.6 m (2 ft) long screen
399-3-6	Groundwater well	TU	1943	A	Low					X					X		5	5					5	U: Downgradient of 618-7 TCE: Only one routine sample >4 µg/L; mostly nondetects
399-3-9	Groundwater well	TU	1976	A	Low		X			X							B	B					B	U: Monitor near river, central; among highest concentrations
399-4-1	Groundwater well	TU	1951	A	Low or High					X					X		5	5					5	U: Delimit west edge of uranium plume, south TCE: Only one routine sample >4 µg/L; monitor 399-4-14 instead
399-4-10	Groundwater well	TU	1976	A	Low		X			X							B	B					B	U: Monitor uranium near river, south TCE: Only one routine sample >4 µg/L (flagged Q)
399-4-11	Groundwater well	TU	1986	A	Low or High					X					X		5	5					5	U: Delimit west edge of plume, south
399-4-12	Groundwater well	TU	Unk	A	Low					X					X		Q 5	5					5	U: Delimit south part of uranium plume TCE: Has demonstrated attainment
399-4-14	Groundwater well	TU	2007	A	N/A	X											Q	Q			Q			U: Redundant with 399-4-15. TCE: Has not reached CUL
399-4-15	Groundwater well	TU	2011	A	High					X					X		5	5					5	U: Monitor in south part of uranium plume
399-4-7	Groundwater well	TU	1961	A	Low		X			X		X				X	Q B	B					B	U: Monitor uranium near river, south TCE: Has demonstrated attainment
399-4-9	Groundwater well	TU	1976	A	N/A					X		X					Q							U: Redundant with nearby wells TCE: Has demonstrated attainment
399-5-1	Groundwater well	TU	1951	A	N/A																			No monitoring objective
399-5-2	Groundwater well	UC	1954	A	N/A																			No monitoring objective
399-5-4B	Groundwater well	TU	1993	A	N/A																			No monitoring objective
399-6-1	Groundwater well	TU	1950	B	N/A							X				X								No COC monitoring objective
399-6-2	Groundwater well	TU	1993	A	N/A																			No monitoring objective
399-6-3	Groundwater well	TU	2011	A	Low					X					X		5	5					5	U: Monitor downgradient of 618-7 uranium plume
399-6-5	Groundwater well	TU	2011	A	N/A																			No monitoring objective
399-8-1	Groundwater well	TU	1950	A	Low			X		X		X				X	B	B					B	U: Monitor 618-7 uranium plume
399-8-2	Groundwater well	TU	1950	B	N/A																			No monitoring objective
399-8-3	Groundwater well	TU	1951	A	N/A																			No monitoring objective
399-8-4	Groundwater well	TU	1979	B	N/A																			No monitoring objective
399-8-5A	Groundwater well	TU	1991	A	Low			X		X		X				X	B	B					B	U: Monitor 618-7 uranium plume
399-8-5B	Groundwater well	LU	1991	B	N/A																			No monitoring objective

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	Rationale[b]										Water Level		Years 1 through 5 Frequency						Comment/Rationale
						PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
499-S0-7	Groundwater well	MU	Unk	A	N/A																			Perforated for 53 m (175 ft), unknown plug No monitoring objective
499-S0-8	Groundwater well	MU	Unk	A	N/A																			Perforated for 30 m (100 ft), unknown plug No monitoring objective
499-S1-7B	Groundwater well	U	Unk	B	N/A																			Perforated for 46 m (150 ft), open for another 82 m (270 ft)
499-S1-7C	Groundwater well	U	Unk	B	N/A																			7.6 m (25 ft) long screen
499-S1-8C	Groundwater well	U	Unk	B	N/A																			Unknown construction, 45 m (149 ft) deep
499-S1-8H	Groundwater well	U	Unk	B	N/A																			Unknown construction, depth of 559 m (1,835 ft)
499-S1-8J	Groundwater well	LU	Unk	A	N/A																			No information; monitored for 200-PO-1 U: No monitoring objective for uranium
499-S1-8K	Groundwater well	U	Unk	B	N/A																			6 m (20 ft) perforated, 55 m (180 ft) deep
699-10-0	Groundwater well	Unk	Unk	B	N/A																			No information; 18 m (59.9 ft) total depth; depth to water 13 m (42 ft) in 1996
699-10-3A	Groundwater well	Unk	1972	N/A	N/A																			No monitoring objective
699-10-E12	Piezometer host	TU	1962	A	N/A																			No monitoring objective
699-10-E12P	Hosted piezometer	Unk	1962	N/A	N/A																			No monitoring objective
699-10-E12Q	Hosted piezometer	UU	1962	B	N/A																			No monitoring objective
699-11-1A	Unclassified	U	Unk	B	N/A																			No monitoring objective
699-11-1B	Unclassified	U	1972	B	N/A																			No monitoring objective
699-11-1H	Unclassified	U	1972	B	N/A																			No monitoring objective
699-1-18	Groundwater well	TU	1958	A	N/A																			Partially filled? No monitoring objective
699-11-E4F	Groundwater well	MU	1975	B	N/A																			No information No monitoring objective
699-11-E5A	Groundwater well	MU	1975	B	N/A																			No information No monitoring objective
699-12-1B	Unclassified	Unk	1971	B	N/A																			No monitoring objective
699-12-2C	Groundwater well	TU	2001	A	N/A				X	X					X		B		B			B		U: No monitoring objective for uranium H3: In plume; monitor trends NO3: In plume; monitor trends
699-12-4D	Groundwater well	TU	1982	A	N/A																			Screened into Ringold formation No monitoring objective
699-13-0A	Groundwater well	TU	2001	A	N/A				X	X					X		B		B					U: No monitoring objective for uranium H3: In plume; monitor trends
699-13-1A	Groundwater well	MU	1973	A	N/A																			75 m (245 ft) deep, multiple screens, filled? No monitoring objective
699-13-1B	Groundwater well	U	1973	B	N/A																			71 m (234 ft) deep, multiple screens No monitoring objective
699-13-1C	Groundwater well	UC	1978	A	N/A																			No information No monitoring objective

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	Rationale[b]										Water Level		Years 1 through 5 Frequency						Comment/Rationale
						PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
699-13-1E	Groundwater well	TU	2001	A	N/A				X	X					X		B		B			B		U: No monitoring objective for uranium H3: In plume; monitor trends NO3: >DWS until 2014; monitor trend
699-13-2D	Groundwater well	TU	2001	A	N/A				X	X					X		B		B			B		U: No monitoring objective for uranium H3: In plume; monitor trends NO3: At or above DWS; monitor trend
699-13-3A	Groundwater well	TU	1995	A	N/A				X	X					X		B		B			B		U: No monitoring objective for uranium H3: In plume; monitor trends NO3: In plume; monitor trends
699-14-E6S	Independent piezometer	LU	1966	B	N/A																			91 m (300 ft) deep No monitoring objective
699-14-E6T	Independent piezometer	UU	1966	B	N/A																			No monitoring objective
699-15-15A	Piezometer host	TU	1961	B	N/A																			No monitoring objective
699-15-15AP	Hosted piezometer	MU	Unk	B	N/A																			No monitoring objective
699-15-15B	Groundwater well	TU	1972	A	N/A																			No monitoring objective
699-15-E13	Groundwater well	Unk	1981	N/A	N/A																			No monitoring objective
699-15-E3A	Unclassified	U	1974	B	N/A																			No given depth (used to be very deep but was filled) No monitoring objective
699-16-E3A	Groundwater well	U	1974	A	N/A																			No monitoring objective
699-2-3	Groundwater well	TU	1950	A	N/A																			No monitoring objective
699-2-6A	Groundwater well	TU	1997	A	N/A																			No monitoring objective
699-2-7	Groundwater well	MU	1978	A	N/A																			No monitoring objective
699-2-E14	Groundwater well	Unk	1981		N/A																			No monitoring objective
699-4-E6	Groundwater well	TU	1976	B	N/A																			No monitoring objective
699-6-2A	Groundwater well	U	1974	B	N/A																			No monitoring objective
699-8-17	Groundwater well	TU	1950	A	N/A																			No monitoring objective
699-8-5	Unclassified	Unk	Unk	B	N/A																			No monitoring objective
699-8-E1	Groundwater well	TU	Unk	B	N/A																			No information No monitoring objective
699-9-3	Unclassified	Unk	Unk	B	N/A																			No monitoring objective
699-9-E1	Groundwater well	TU	Unk	B	N/A																			No information No monitoring objective
699-9-E2	Groundwater well	TU	1958	A	N/A																			No monitoring objective
699-S11-E12A	Piezometer host	U	1960	B	N/A																			18 m (60 ft) nominal hole No monitoring objective
699-S11-E12AP	Hosted piezometer	UC	1960	A	N/A																			No monitoring objective
699-S12-3	Groundwater well	TU	1950	A	N/A																			No monitoring objective

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	Rationale[b]										Water Level		Years 1 through 5 Frequency						Comment/Rationale
						PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
699-S14-20A	Groundwater well	UU	1958	B	N/A																			No monitoring objective
699-S14-20C	Unclassified	UU	1976	B	N/A																			No monitoring objective
699-S18-E2A	Piezometer host	MU	1961	B	N/A																			No monitoring objective
699-S18-E2AP	Hosted piezometer	Unk	1964	B	N/A																			No information No monitoring objective
699-S18-E2B	Groundwater well	TU	1977	A	N/A																			Open for 46 m (150 ft) under perforations? No monitoring objective
699-S19-11	Groundwater well	TU	1968	A	N/A																			No monitoring objective
699-S19-E13	Groundwater well	TU	1971	A	N/A																			No monitoring objective
699-S19-E14	Groundwater well	TU	1991	A	N/A																			No monitoring objective
699-S20-E10	Groundwater well	TU	2005	A	N/A																			No monitoring objective
699-S22-E9A	Groundwater well	TU	1991	A	N/A																			No monitoring objective
699-S22-E9B	Groundwater well	LU	1991	A	N/A																			No monitoring objective
699-S22-E9C	Groundwater well	CR	1991	N/A	N/A																			No monitoring objective
699-S24-19	Piezometer host	N/A	1949	B	N/A																			No monitoring objective
699-S24-19P	Hosted piezometer	UC	1949	A	N/A																			No information No monitoring objective
699-S24-19Q	Hosted piezometer	TU	1949	A	N/A																			No information No monitoring objective
699-S27-E12A	Groundwater well	TU	1995	A	N/A																			No monitoring objective
699-S27-E14	Groundwater well	TU	1948	A	N/A							X				X								No COC monitoring objective
699-S27-E9A	Groundwater well	TU	1991	A	N/A																			No monitoring objective
699-S27-E9B	Groundwater well	LU	1991	A	N/A																			55 m (178.7 ft) deep No monitoring objective
699-S27-E9C	Groundwater well	CR	1991	N/A	N/A																			No monitoring objective
699-S28-E0	Groundwater well	MU	1981	A	N/A																			27 m (90 ft) perforated No monitoring objective
699-S28-E12	Groundwater well	TU	1991	A	N/A																			No monitoring objective
699-S28-E13A	Groundwater well	TU	1995	A	N/A																			No monitoring objective
699-S29-E10A	Groundwater well	TU	1991	A	N/A																			No monitoring objective
699-S29-E11	Groundwater well	TU	1991	A	N/A																			No monitoring objective
699-S29-E12	Groundwater well	UU	1971	A	N/A																			No monitoring objective
699-S29-E13A	Groundwater well	TU	1995	A	N/A																			No monitoring objective
699-S29-E16A	Groundwater well	TU	1991	A	N/A																			No monitoring objective

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	Rationale[b]										Water Level		Years 1 through 5 Frequency						Comment/Rationale
						PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
699-S29-E16B	Groundwater well	MU	1991	A	N/A																			No monitoring objective
699-S29-E16C	Groundwater well	CR	1991	N/A	N/A																			No monitoring objective
699-S30-E10A	Groundwater well	TU	1989	A	N/A																			No monitoring objective
699-S30-E10B	Groundwater well	TU	1989	A	N/A																			No monitoring objective
699-S30-E11A	Groundwater well	TU	1995	A	N/A																			No monitoring objective
699-S30-E14	Groundwater well	LC	1970		N/A																			No monitoring objective
699-S30-E15A	Groundwater well	TU	1971	A	N/A																			No monitoring objective
699-S30-E15B	Unclassified	U	1971	B	N/A																			No known perforations/screen No monitoring objective
699-S31-1	Piezometer host	UU	1951	A	N/A																			No monitoring objective
699-S31-1P	Hosted piezometer	TB	1951		N/A																			No monitoring objective
699-S31-E10A	Groundwater well	TU	1990	A	N/A																			No monitoring objective
699-S31-E10B	Groundwater well	TU	1990	A	N/A																			No monitoring objective
699-S31-E10C	Groundwater well	UU	1990	A	N/A																			No monitoring objective
699-S31-E10D	Groundwater well	TU	1989	A	N/A																			No monitoring objective
699-S31-E10E	Groundwater well	MU	1991	A	N/A																			No monitoring objective
699-S31-E11	Groundwater well	TU	1991	A	N/A																			No monitoring objective
699-S31-E8A	Groundwater well	TU	1989	A	N/A																			No monitoring objective
699-S32-E13A	Groundwater well	UU	1979	A	N/A																			No monitoring objective
699-S32-E13B	Groundwater well	UU	1979	A	N/A																			No monitoring objective
699-S32-E8	Groundwater well	MU	1990	A	N/A																			No monitoring objective
699-S3-E12	Groundwater well	TU	1960	A	N/A																			No monitoring objective
699-S5-E2	Groundwater well	LU	2010	A	N/A																			No monitoring objective
699-S5-E2B	Groundwater well		2010	B	N/A																			No monitoring objective
699-S6-E14A	Groundwater well	TU	1962	A	N/A																			No monitoring objective
699-S6-E4A	Groundwater well	TU	1997	A	N/A																			No monitoring objective
699-S6-E4B	Groundwater well	TU	1953	A	N/A																			No monitoring objective
699-S6-E4C	Piezometer host	U	1996	B	N/A																			Complicated decommission and remediation activity list on as-built No monitoring objective
699-S6-E4CS	Hosted piezometer	MU	1996	B	N/A																			No monitoring objective
699-S6-E4CT	Hosted piezometer	MU	1996	B	N/A																			No monitoring objective
699-S6-E4D	Groundwater well	TU	1953	A	N/A																			No monitoring objective

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

						Rationale[b]										Water Level		Years 1 through 5 Frequency						
Well Name	**Type**	**Screened Unit**	**Year Constructed**	**List[a]**	**Uranium Sample/ River Stage**	**PSQ 1a**	**PSQ 1b**	**PSQ 1c**	**PSQ 1d**	**PSQ 1e**	**PSQ 1f[c]**	**PSQ 2a**	**PSQ 2b**	**PSQ 3**	**PSQ 4**	**Automated**	**Manual**	**Uranium**	**Tritium**	***cis*-1,2-DCE**	**TCE**	**Nitrate**	**Gross Alpha**	**Comment/Rationale**
699-S6-E4E	Groundwater well	TU	1953	A	N/A																			No monitoring objective
699-S6-E4F	Groundwater well	TU	1954	B	N/A																			No monitoring objective
699-S6-E4G	Groundwater well	TU	1954	B	N/A																			No monitoring objective
699-S6-E4H	Groundwater well	TU	1954	B	N/A																			No monitoring objective
699-S6-E4J	Groundwater well	TU	1954	A	N/A																			No monitoring objective
699-S6-E4K	Groundwater well	TU	2003	A	N/A																			No monitoring objective
699-S6-E4L	Groundwater well	TU	2003	A	N/A																			No monitoring objective
699-S8-19	Groundwater well	TU	1950	A	N/A																			No monitoring objective
ANF #14	Unclassified	Unk	Unk	B	N/A																			No monitoring objective
ANF #15	Unclassified	Unk	Unk	B	N/A																			No monitoring objective
ANF #16	Unclassified	Unk	Unk	B	N/A																			No monitoring objective
B2841	Groundwater well	Unk	Unk	B	N/A																			No monitoring objective
B2842	Groundwater well	Unk	Unk	B	N/A																			No monitoring objective
C3783	Unclassified	N/A	2001	B	N/A																			No monitoring objective
ENW-MW-1	Groundwater well	TU	1995	B	N/A																			No monitoring objective
ENW-MW-10	Groundwater well	TU	2008	B	N/A																			No monitoring objective
ENW-MW-11	Groundwater well	TU	2008	B	N/A																			No monitoring objective
ENW-MW-12	Groundwater well	TU	2008	B	N/A																			No monitoring objective
ENW-MW-13	Groundwater well	TU	2008	B	N/A																			No monitoring objective
ENW-MW-14	Groundwater well	TU	2008	B	N/A																			No monitoring objective
ENW-MW-2	Groundwater well	TU	1995	B	N/A																			No monitoring objective
ENW-MW-3	Groundwater well	TU	1995	B	N/A																			No monitoring objective
ENW-MW-4	Groundwater well	TU	1995	B	N/A																			No monitoring objective
ENW-MW-5	Groundwater well	TU	1995	B	N/A																			No monitoring objective
ENW-MW-6	Groundwater well	TU	1997	B	N/A																			No monitoring objective
ENW-MW-7	Groundwater well	TU	1997	B	N/A																			No monitoring objective
ENW-MW-8	Groundwater well	TU	1997	B	N/A																			No monitoring objective
ENW-MW-9	Groundwater well	TU	1997	B	N/A																			No monitoring objective
SPC-GM-10	Groundwater well	Unk	Unk	B	N/A																			No monitoring objective
SPC-GM-11	Groundwater well	Unk	Unk	B	N/A																			No monitoring objective
SPC-GM-12	Groundwater well	Unk	Unk	B	N/A																			No monitoring objective

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	Rationale[b]										Water Level		Years 1 through 5 Frequency						Comment/Rationale
						PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	
SPC-GM-9	Groundwater well	Unk	Unk	B	N/A																			No monitoring objective
SPC-P-2	Groundwater well	Unk	1992	B	N/A																			No monitoring objective
SPC-TW-14	Groundwater well	Unk	1993	B	N/A																			No monitoring objective
SPC-TW-15	Groundwater well	Unk	Unk	B	N/A																			No monitoring objective
SPC-TW-16	Groundwater well	Unk	Unk	B	N/A																			No monitoring objective
SPC-TW-17	Groundwater well	Unk	Unk	B	N/A																			No monitoring objective
SPC-TW-18	Groundwater well	Unk	Unk	B	N/A																			No monitoring objective
C6368	Aquifer tube	2.0*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6371	Aquifer tube	2.3*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6374	Aquifer tube	2.1*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6375	Aquifer tube	2.7*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6378	Aquifer tube	1.5*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6380	Aquifer tube	0.5*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-1-S	Aquifer tube	3.5*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-1-M	Aquifer tube	5.1*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-1-D(1)	Aquifer tube	6.4*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-2-S	Aquifer tube	3.3*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-2-M	Aquifer tube	5.1*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
103mArray-US125	Aquifer tube	0.8*	2005	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6341	Aquifer tube	3.6*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6342	Aquifer tube	5.3*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6343	Aquifer tube	6.3*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
103mArray-US100	Aquifer tube	1.8*	2005	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
103mArray-US75	Aquifer tube	1.9*	2005	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
103mArray-US50	Aquifer tube	1.9*	2005	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
103mArray-US25	Aquifer tube	1.7*	2005	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
300-3-3B-376cm	Aquifer tube	3.8*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
300-3-3B-518cm	Aquifer tube	5.2*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
300-3-3C-409cm	Aquifer tube	4.1*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
300-3-3C-589cm	Aquifer tube	5.9*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
300-3-3A-124cm	Aquifer tube	1.2*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

						Rationale[b]										Water Level		Years 1 through 5 Frequency						
Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	Comment/Rationale
300-3-3A-410cm	Aquifer tube	4.1*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
300-3-3A-579cm	Aquifer tube	5.8*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
103mArray-AT3A	Aquifer tube	2.1*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-3-S	Aquifer tube	2.1*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-3-M	Aquifer tube	4.6*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-3-D	Aquifer tube	8.9*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
103mArray-DS25	Aquifer tube	1.7*	2005	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
103mArray-DS50	Aquifer tube	1.6*	2005	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6344	Aquifer tube	2.2*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
103mArray-DS75	Aquifer tube	2.0*	2005	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-4-S	Aquifer tube	2.1*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-4-M	Aquifer tube	2.8*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-4-D	Aquifer tube	2.9*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6347	Aquifer tube	3.0*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6348	Aquifer tube	3.1*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-5-S	Aquifer tube	2.3*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6350	Aquifer tube	2.6*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
C6351	Aquifer tube	4.3*	2008	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-6-S	Aquifer tube	2.9*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-6-M	Aquifer tube	6.7*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-6-D	Aquifer tube	11.8*	2004	A	N/A																			Aquifer tubes not needed; sufficient near-river wells
AT-3-7-S	Aquifer tube	2.6*	2004	A	N/A																			Uranium concentrations higher in mid-depth tube
AT-3-7-M	Aquifer tube	6.4*	2004	A	Low										X			5					5	Delimit southern extent of uranium plume and look for downstream migration
AT-3-7-D	Aquifer tube	11.4*	2004	A	N/A																			Uranium concentrations higher in mid-depth tube
AT-3-8-S	Aquifer tube	2.4*	2004	A	N/A																			No monitoring objective
AT-3-8-M	Aquifer tube	4.3*	2004	A	N/A																			No monitoring objective

Table A-12. Monitoring Wells and Aquifer Tubes Considered for 300-FF-5 OU Monitoring Networks

Well Name	Type	Screened Unit	Year Constructed	List[a]	Uranium Sample/ River Stage	Rationale[b]										Water Level		Years 1 through 5 Frequency						Comment/Rationale
						PSQ 1a	PSQ 1b	PSQ 1c	PSQ 1d	PSQ 1e	PSQ 1f[c]	PSQ 2a	PSQ 2b	PSQ 3	PSQ 4	Automated	Manual	Uranium	Tritium	*cis*-1,2-DCE	TCE	Nitrate	Gross Alpha	

a. To facilitate identification of wells for long-term monitoring, the A list of wells (strong candidates for future use) are those wells with a well status of in use, that are screened at the top of the unconfined (TU) or upper unconfined (UU) aquifer, and have been sampled relatively recently. Wells on the B list of wells have more unknowns and require additional research. The B wells could be considered if the DQO concludes that they are in a useful location.

b. Relationship to MNA guidance elements provided in Table A-6.

c. Monitoring, if needed, will use wells that are at and downgradient of waste site remediation locations.

*Top of screen (m below grade)

AWLN = Automated Water Level Network
CUL = cleanup level
DCE = dichloroethene
DQO = data quality objective
DWS = drinking water standard
MNA = monitored natural attenuation
N/A = not applicable
OU = operable unit
PSQ = principal study question
PRZ = periodically rewetted zone
TCE = trichloroethene
Unk = unknown

Screened Unit:
C: (undifferentiated basalt-confined)
CR: (confined Ringold) open interval does not extend more than approximately 3 m (10 ft) below the top of basalt. Typically open to the lower mud (unit 8) and basal gravel (unit 9) of the Ringold Formation.
TU: (top unconfined) screened across or within 1.5 m (5 ft) of the water table with less than 10.7 m (35 ft) of the open interval extending below the water table.
MU: (middle unconfined) open interval begins at greater than 15 m (50 ft) below the water table and does not extend below the middle coarse unit of the Ringold Formation (unit 7) or to within 50 ft of the top of basalt.
LC: (lower basalt-confined) open to the basalt and interflow zones below the Pomona Member of the Saddle Mountains Basalt.
LU: (lower unconfined) open interval begins at greater than 15 m (50 ft) below the water table and below the middle coarse unit of the Ringold Formation (unit 7) or within 15 m (50 ft) of the top of basalt and does not extend more than approximately 3 m (10 ft) below the top of basalt.
TB: (top basalt) open to less than 9.1 m (30 ft) above and below the top of basalt.
UC: (upper basalt confined) open to the basalt and/or interflow zones but does not extend below the Pomona Member of the Saddle Mountains Basalt.
U: (undifferentiated unconfined) open to more than 15 m (50 ft) of the unconfined aquifer.
UU: (upper unconfined) screened more than 1.5 m (5 ft) below the water table and with the open interval extending no more than 15 m (50 ft) below the water table.

X = In Rationale column, indicates which PSQ(s) is addressed by monitoring at the well; in Water Level column, indicates that the well is included in the AWLN.

Sampling frequency during years 1 through 5:
5. Once every 5 years. For *cis*-1,2-DCE, sample during December, 2 years before the 5-year review time frame. For uranium, sample during June and December.
B. Biennially (once every 2 years). For uranium in the 300 Area Industrial Complex, sample when highest concentrations are anticipated based on correlation of concentrations to river stage. For uranium downgradient of the 618-7 Burial Ground, sample in December. For tritium and nitrate downgradient of the 618-11 Burial Ground, sample in October.
SA. Semiannually (twice each year) for 5 years during June and December.
Q. Quarterly for up to 2 years. If attainment has not been achieved, monitoring may be continued at a reduced frequency. For TCE, collect the quarterly samples in March, June, September, and December.
P. Before phosphate application, and four events within first month after phosphate application.

Sampling frequency during year 6+:
cis-1,2-DCE: Once every 5 years during December, 2 years before the 5-year review time frame.
Uranium: Wells in the 300 Area Industrial Complex that were sampled semiannually or biennially during the first 5 years will be sampled biennially when highest concentrations are anticipated based on correlation of concentrations to river stage. Wells that were sampled every 5 years during June and December will continue to be sampled at that frequency. Wells downgradient of the 618-7 Burial Ground will continue to be sampled biennially in December.
Tritium and nitrate: Wells will continue to be sampled biennially in October.

Appendix B

Remedial Action Performance Evaluation and Completion

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Contents

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Terms

CI	confidence interval
COC	contaminant of concern
CL	confidence level
CSM	conceptual site model
CUL	cleanup level
EA	enhanced attenuation
LCL	lower confidence limit
MNA	monitored natural attenuation
OU	operable unit
PRZ	periodically rewetted zone
RAO	remedial action objective
ROD	record of decision
UCL	upper confidence limit

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B1 Introduction

This appendix describes the evaluation methods that will be used to accomplish the following:

- Assess progress toward the attainment of the remedial action objectives (RAOs).
- Determine when site closure can be implemented.
- Determine when remediation can end.
- Demonstrate attainment of cleanup level (CULs) in groundwater.

The strategy for completing site closure is based on the general guidance and recommendations discussed in EPA 600/R-11/204, *An Approach for Evaluating the Progress of Natural Attenuation in Groundwater*, as part of a general framework for the implementation of monitored natural attenuation (MNA).

The evaluation methods for progress assessment are as follows:

- Plume mapping
- Water level mapping and refining the conceptual site model (CSM)
- Groundwater modeling
- Statistical analysis
- Enhanced attenuation (EA) treatment performance

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B2 Evaluation Methods

This chapter provides a brief description of the evaluation methods.

B2.1 Plume Mapping

Contaminant plume mapping will be performed following the integrated numerical interpolation procedure implemented as part of the annual Hanford Site Groundwater Monitoring Report (e.g., DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*). The systematic plume mapping approach is based on implementing an integrated procedure of compiling and aggregating data sets in a comprehensive database, developing input files, and executing batch processes using the open-source statistical computing/programming language R (The R Development Core Team, 2012, *The R Project for Statistical Computing*) to develop piece-wise continuous contaminant distributions.

The numerically interpolated piece-wise continuous contaminant of concern (COC) distributions allow for estimating contaminant mass, plume center of mass, and spread of the contaminant across the plume area for each COC plume. As a result, the area and spread of contamination, as well as the migration of contamination, can be evaluated over time to monitor potential downgradient, vertical, or lateral expansion of the contaminant plume. Plume mass may be estimated based on estimates of plume thickness and aquifer porosity.

B2.2 Water Level Mapping and Refining the CSM

Mapping of synoptic and continuous groundwater level data will be performed to assist in the evaluation of groundwater flow patterns and MNA remedy performance.

First, hydraulic gradients are calculated for triangular elements developed from a focused subset of the complete network of monitoring wells. Next, groundwater elevation contours are constructed to depict the patterns of groundwater flow and corresponding directions of contaminant migration throughout the groundwater operable unit (OU). A Hanford Site water level map that encompasses the 300 Area is prepared on an annual basis for the Hanford Site Groundwater Monitoring Report (e.g., DOE/RL-2014-32); additional water level maps focused on the 300 Area will be prepared when necessary. The calculated hydraulic gradients and groundwater elevation contours, together, provide the basis for evaluating flow patterns and determining whether adverse conditions are being developed that could impact plume migration. Seasonal river stage variations will also be evaluated to determine their influence on flow patterns and the region of river-aquifer interaction.

Water level data from paired monitoring wells screened at different depths will provide the basis for calculating vertical gradients in the aquifer, thereby allowing for evaluating the potential for significant vertical migration patterns.

Implementation of this activity also addresses the detection of any changes in hydrologic conditions that may reduce the efficacy of the attenuation processes. Such changes in hydrologic conditions could also indicate required refinements of the CSM.

B2.3 Groundwater Modeling

Groundwater modeling will evaluate the fate and transport of uranium derived from the periodically rewetted zone (PRZ) and vadose zone located above the PRZ. A three-dimensional, variably saturated flow and transport model will be developed to evaluate the influence of the Columbia River on mixing with the groundwater and resulting changes in alkalinity that influence aqueous complexation of uranium and desorption kinetics. The fate and transport model will incorporate the capability to model planned injection of polyphosphate at the scale of the study in order to evaluate sequestration of uranium. An updated kinetic sorption-desorption model reflecting uranium-phosphate mineral formation, based on an estimated contact time period and assuming amorphous monocalcium phosphate continues to convert to the hydroxyapatite mineral phase, will be developed consistent with the results of the laboratory leaching tests on samples collected in the pre-injection and post-injection phase.

Modeling will be performed using the flow and transport simulator Subsurface Transport Over Multiple Phases, developed by Pacific Northwest National Laboratory, in the water operational mode and the water-reactive transport operational mode. The initial uranium mass distribution within the vadose zone, PRZ, and aquifer will be based on the depth-dependent concentration results from the recent drilling campaign reported in PNNL-22032, *Uranium in Hanford Site 300 Area: Extraction Data on Borehole Sediments*, and the 2014 post-record of decision (ROD) field investigation (SGW-56993, *Sampling Instruction for the 300-FF-5 Operable Unit Supplemental Post ROD Field Investigation*). The observed results from the monitoring wells during the injection phase and post-injection phase (in terms of polyphosphate concentrations and residence time) will be used to calibrate the reactive transport model. The calibrated groundwater flow and transport model will then be used to predict the fate of uranium within the EA treatment zone.

B2.4 Statistical Analysis

OSWER 9355.0-129, *Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions*, recommends evaluating COC concentration levels on a well-by-well basis separately for each COC to assess aquifer restoration. As discussed in OSWER 9283.1-44, *Recommended Approach for Evaluation Completion of Groundwater Restoration Remedial Actions at a Groundwater Monitoring Well*, it may be appropriate to conclude that the remediation phase is complete at a monitoring well based on a nonstatistical or visual analysis of the data if the groundwater COC concentrations are all nondetect, or a combination of nondetect sampling results, and all detected COC concentrations are below the CUL. If these conditions do not apply, COC concentrations will be evaluated on a well-by-well (i.e., intra-well) basis, based on statistical analyses of monitoring data and supporting modeling projections.

The strategy for completing site closure is implemented in two phases: remediation monitoring and attainment monitoring. Certain key statistical tests, referred to as fundamental tests, are applied during the remediation and attainment monitoring phases to evaluate performance and determine whether additional actions are required, as detailed in Sections B2.4.1 through B2.4.3. Consistent with the recommendations of OSWER 9283.1-44, data obtained during the remediation monitoring phase can be employed to assess the status of attainment of RAOs (i.e., CULs). Herein, it is proposed that attainment monitoring statistics be calculated simultaneously with the calculation of the remediation monitoring statistics because the statistics are calculated using the same, or similar, data sets and because calculation of the attainment statistics, in many cases, rests upon the results of the remediation monitoring statistical calculations. As a result, attainment monitoring statistics will, at a minimum, be calculated for *each* COC at each well on an annual basis as part of regular data processing and reporting. However, attainment monitoring statistics may also be calculated as soon as data collected from one or more wells suggest that concentrations for *any* COC may have met the CUL at that well. This calculation of attainment statistics during the remediation monitoring phase to determine if CULs are being achieved is detailed in Section B2.4.1.

This appendix emphasizes the use of quantitative methods of data analysis. Assessment of the attainment of CULs is almost entirely a quantitative procedure, implemented through the application of statistical tests as detailed in the following subsections. However, the assessment of MNA performance and progress toward the attainment of CULs during the remediation monitoring phase can be substantiated by additional qualitative interpretation of data—such as geochemical data, indicator parameters, groundwater flow and contaminant migration rates and directions, and other factors—in addition to the application of the statistical tests detailed in the following subsections.

B2.4.1 Remediation Monitoring Phase: Fundamental Tests

As recommended in OSWER 9283.1-44, for each combination of COC and monitoring well, a statistical analysis of groundwater water sample data will be performed to evaluate if MNA progress is consistent with expectations and also to assess the attainment of cleanup goals. During the remediation monitoring phase, the fundament test is the *trend test*. The trend test evaluates the time-dependent sample concentrations for each COC at each well, using parametric or nonparametric methods: if a trend is identified, then the slope of the trend can be calculated, together with confidence limits around this slope. However, during the remediation monitoring phase, a *mean test* will also be implemented in addition to the trend test. During the remediation monitoring phase, the mean test is based on calculating a sample statistic representing the mean contaminant concentration for the particular COC at the particular well, as well as upper confidence limits (UCLs) and lower confidence limits (LCLs), around this sample statistic to account for variability around the mean. During the remediation phase, the sample statistic calculated for the mean will incorporate the underlying concentration trend, where one is identified.

These statistical analyses will be used during the remediation monitoring phase to evaluate MNA progress toward, and potentially attainment of, cleanup goals. The outcomes of these calculations provide the basis for MNA progress evaluation by considering the following:

- If the mean test indicates that the COC/well combination has attained the CUL, then remediation monitoring is complete for this COC/well combination, and attainment monitoring can commence.
- If the slope of the trend indicates that the mean will fall below CULs sooner than the estimated time frame presented in the ROD, MNA progress is on target to meet the cleanup goals.
- If the slope of the trend indicates that the mean will fall below CULs later than the estimated time frame presented in the ROD, but the LCL indicates that CULs will be met sooner than the estimated time frame, then this may indicate that (a) the trend method being used does not adequately explain variations in the data, or (b) the confidence interval (CI) must be narrowed through the collection of additional data.
- If the slope of the trend indicates that the LCL will fall below CULs later than the estimated time frame presented in the ROD, then this may indicate that (a) the trend method being used does not adequately explain variations in the data, or (b) the CI must be narrowed through the collection of additional data. If the CI is acceptable, and the trend method adequately explains variations in the data, further investigation is required to identify the cause of the unanticipated time to cleanup.

Application of these tests during the remediation monitoring phase will assist in demonstrating that natural attenuation is occurring according to expectations. Evaluation of monitoring data for trends may reveal unexpected increases in COC contamination that may indicate new or continuing releases of contaminants that will require further investigation.

B2.4.2 Attainment Monitoring Phase: Fundamental Tests

Similarly to the remediation monitoring phase, a statistical analysis of the groundwater sample data for each combination of COC and monitoring well network will be performed to evaluate whether the CULs have been attained for the particular COC/well combination.

The fundamental test during the attainment monitoring phase comprises the following:

- If the UCL is at or below the CUL

  and

- The time-dependent slope of the trend is zero or statistically significantly negative

  then

- It is appropriate to conclude that the attainment monitoring phase has been completed for that COC/well combination.

Evaluation of CUL attainment will be performed on a COC and well-by-well basis following the previously described approach. Monitoring wells, where it is determined that the CUL for a COC has been attained, will be removed from the monitoring network for that COC. Application of these fundamental tests during the attainment monitoring phase will assist in verifying attainment of RAOs. Similar tests will be applied to evaluate changes in concentration of contamination entering the 300-FF-5 OU from upgradient locations.

B2.4.3 Methods for Calculating Means and Confidence Levels

UCLs and LCLs for the mean value for a sample data set can be calculated using a wide variety of statistical methods, each of which relies upon a set of assumptions. For example, some methods for calculating confidence limits (CLs) are strictly applicable only for certain sample data distributions—such as Gaussian (normal), or log-normal. In addition, some CL calculation methods are not suitable when there is a large number of nondetect (i.e., censored) sample results. For this reason, the sample data distribution will be tested prior to calculating CLs, and the most suitable statistical technique for computing the CLs will be used in accordance with the adherence of the data to a sample data distribution. Where appropriate, calculation of the mean value sample statistic and corresponding UCL will incorporate any statistically significant trend, as determined using the trend test. This is appropriate because the majority of contaminants are anthropogenic and, as such, do not exhibit a background (i.e., stationary) mean concentration. During the attainment monitoring phase, calculation of the mean value sample statistic and corresponding UCL may also be completed assuming a stationary population (i.e., no trend) using ProUCL for information purposes in accordance with EPA/600/R-07/041, *ProUCL Version 5.0.00 Technical Guide*.

B2.4.4 Methods for Trend Testing and Slope Estimation

For each COC/well combination, the analysis of concentration trends is important to both the remediation and attainment monitoring phases. In most cases, common nonparametric methods will be used to test for the presence of a trend and to quantify the slope of the trend: these methods comprise the Mann-Kendall (standard or seasonal) trend test, which identifies the presence of a trend but does not quantify the slope, and the Theil-Sen trend estimator (standard or seasonal), which calculates the slope value. These tests are typically conducted on the logarithm of the concentration value, rather than the native concentration value.

These trend test and slope estimation methods are strictly applicable in the case of a monotonic trend either in the entire data set or within seasonal subsets. In some instances, however, trends may not be monotonic in either the entire data set or within seasonal subsets; this occurs when changes in concentration are related to other factors, such as the impact of remediation or changes in groundwater levels. In such cases, the influence of these other factors may be incorporated in the trend estimation by presenting them as an independent variable using a parametric multiple regression technique. Depending on the variability of COC concentrations at each monitoring well, global application of a single slope estimation technique or regression equation for every COC/well combination may result in the calculation of misleading trends and slopes. Therefore, the dependency of COC concentrations on river stage variations and/or other hydrological factors will be evaluated in order to determine the most suitable methods for trend and slope estimation.

With regard to the selection of the number of samples required to estimate the slope, as presented in OSWER Directive 9200.4-17P, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*, the first line of evidence regarding the use of MNA requires that "regression analysis provides rate constants for attenuation that provide a precise definition of a "clear and meaningful trend of decreasing contaminant concentration over time." In Wilson, 2008, "Extracting rate constants for MNA from long-term monitoring data," a clear and meaningful trend is defined as the first order rate constant for attenuation over time that is greater than zero at some predetermined level of confidence. Although using eight sample dates is an efficient criterion for a minimal data set to evaluate natural attenuation, Wilson's (2008) examples concluded that eight sample dates would have failed to detect successful attenuation at 6 of 14 sites. Therefore, it may be necessary to use more than eight data points to be able to clearly identify statistically significant trends, particularly because short data sets can potentially lead to false positives.

Finally, there are cases when a statistically significant rate of attenuation can be calculated based on short-term data, but rates calculated based on longer-term data sets may not be statistically significant: this usually occurs following a substantial change in the system being monitored, such as active remediation. Therefore, it is important to determine the appropriate data set to perform any statistical analysis in order to calculate meaningful attenuation rates and evaluate the efficacy of the natural attenuation processes. For that reason, pre- and post-source removal trends will be analyzed to discern the right starting point in time to conduct the statistical analysis for the fundamental tests.

B2.5 Enhanced Attenuation Treatment Performance

Performance of Stage A EA treatment will be evaluated through collection of uranium leachability data before and after phosphate application; fate and transport modeling (Section B2.3); groundwater sampling prior to, during, and after phosphate application; and real-time sensing of phosphate solution movement in the vadose zone, PRZ, and aquifer.

Prior to phosphate application, baseline uranium concentration and leachability data will be collected from three borings within the EA area. The three borings will comprise a combination of borings drilled during the supplemental post-ROD field investigation (SGW-56993) and/or borings drilled for the EA performance monitoring piezometers, depending on the final location of the EA. Two samples from each boring selected from the vadose zone and/or PRZ will be collected and analyzed for total uranium analyses and semi-selective sequential uranium leach tests. One or two of the samples from each boring will also be run through labile uranium column leach tests. After the Stage A phosphate application, soil samples will be collected from the borings drilled adjacent to the borings selected for the pretreatment soil samples to determine the post-treatment uranium leaching characteristics in soil from the vadose zone and PRZ. Sample intervals and analyses will be identical to the pretreatment samples.

Soil uranium leachability data collected prior to and after phosphate application will be used to re-run the fate and transport model (Section B2.3) to estimate the decrease in times to achieve the CUL for uranium in the groundwater as compared to the no action scenario.

Groundwater samples prior to, during, and after Stage A phosphate treatment will be collected from a subset of the 12 PRZ piezometers and 12 aquifer piezometers installed within and proximal to the EA area. Samples will be analyzed for total uranium, phosphate, and ions. Groundwater field parameters (temperature, pH, dissolved oxygen, and oxidation-reduction potential) will also be collected during piezometer sampling. At least four sampling events conducted within 1 month after phosphate application will be conducted. The pre- and post-treatment data will be used to evaluate short-term changes in uranium due to sequestration and/or mobilization from the vadose zone and PRZ, and the distribution efficiency of phosphate across the EA area groundwater.

Real-time sensing of phosphate solution movement in the vadose zone, PRZ, and aquifer will also be conducted during phosphate application. Movement of infiltrated fluid in the vadose zone and PRZ will be evaluated using electrical resistance tomography, while automated sensors will be deployed in select aquifer piezometers to measure water levels, specific conductance, and temperature, which are indicators of phosphate solution distribution in the aquifer during phosphate infiltration and injection.

Reduction of aquifer permeability, due to the precipitation of phosphate minerals, will also be assessed before and after phosphate application. Slug tests are the preferred method to evaluate permeability reduction in the aquifer because there are no additional water handling issues. Other field methods including constant rate tests, tracer tests, and/or pressure recovery tests may also by used to verify results.

Based on the effectiveness of phosphate application in reducing uranium leachability and decreasing the modeled time frame to achieve the uranium CUL in groundwater, and other factors such as mobilization of uranium to groundwater and phosphate distribution efficiency, the U.S. Department of Energy and U.S. Environmental Protection Agency will make the decision to proceed with implementing Stage B or to conclude EA treatment.

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