DOE/RL-2019-24
Revision 0

SAMPLING AND ANALYSIS PLAN FOR BIOVENTING CONFIRMATION SAMPLING BOREHOLES

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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Title: *Sampling and Analysis Plan for Bioventing Confirmation Sampling Boreholes*

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Terms

ALARA	as low as reasonably achievable
bgs	below ground surface
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
DOECAP-AP	DOE Consolidated Audit-Accreditation Program
DOE-RL	U.S. Department of Energy, Richland Operations Office
DOT	U.S. Department of Transportation
DQA	data quality assessment
DQI	data quality indicator
DQO	data quality objective
ECO	Environmental Compliance Officer
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FSO	Field Sample Operations
FTB	full trip blank
FWS	Field Work Supervisor
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Document*
HEIS	Hanford Environmental Information System
IATA	International Air Transportation Association
IDLH	immediately dangerous to life or health
NAPL	nonaqueous phase liquid
OU	operable unit
PRZ	periodically rewetted zone
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RCT	radiological control technician
ROI	radius of influence

RUM	Ringold Formation upper mud
Rwie	Ringold Formation member of Wooded Island – unit E
S&GRP	Soil and Groundwater Remediation Project
SAP	sampling and analysis plan
SMR	Sample Management and Reporting
SPLIT	field split
TPH	total petroleum hydrocarbon
TPH-D	total petroleum hydrocarbon-diesel
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
WIDS	Waste Information Data System

1 Introduction

This sampling and analysis plan (SAP) directs activities required to evaluate the performance of in-situ bioremediation of petroleum hydrocarbon[1] in the vadose zone. From 2010 to 2019 (inclusive of pilot testing), a method of in-situ bioremediation called bioventing has been used in the 100-NR-1 Operable Unit (OU) to clean up deep vadose zone petroleum contamination at accepted waste site UPR-100-N-17. Bioventing supplies oxygen within the screen interval of injection wells 199-N-167 and 199-N-172 to enhance natural microbiological degradation of petroleum hydrocarbon in the deep vadose zone approximately 16.1 to 23.3 m (52.8 to 76.5 ft) below ground surface (bgs). Indirect measurements of remediation success in this zone currently suggest reductions in the rate of biodegradation at the site as indicated by oxygen, carbon dioxide, methane, and total organic hydrocarbon concentrations.
The calculated petroleum hydrocarbon biodegradation rates from vapor measurements taken during respirometry tests over the last 2 years are generally below literature values for recommending bioventing as a cost-effective remedial option. As such, direct measurements (soil sampling and analysis) are needed to determine existing levels of petroleum hydrocarbon throughout the vadose zone and the effectiveness of in-situ bioremediation after 10 years of system operation. Vadose zone characterization above the screen interval of injection wells is also within the scope of planned efforts.

The characterization described in this document will provide data to evaluate the effectiveness of bioventing and determine the population of biodegrading bacteria in the subsurface. Characterization will be accomplished by drilling three boreholes and sampling and analyzing vadose zone soils. Soil samples will be collected and analyzed for contaminants of potential concern (COPCs), the presence and population of total petroleum hydrocarbon (TPH) biodegrading bacteria present in the subsurface, and physical properties. Geologic and geophysical logging are also within the scope of activities. Characterization activities described in this plan are based on implementation of the data quality objective (DQO) process provided in Appendix A. Appendix B contains optional instructions for converting borehole D0072 to a deep injection well to replace deep injection well 199-N-172. Use of Appendix B may be implemented if deep injection well 199-N-172 is not repairable as the screen has separated from the casing.

1.1 Background

Information in this section is mainly summarized from Appendix H in DOE/RL-2005-93, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*.

1.1.1 Location

The UPR-100-N-17 waste site is located on the Hanford Site in the 100-N Area approximately 192 m (630 ft) northeast of the 105-N Reactor. The site is an unplanned release of diesel that occurred sometime between August 1965 and September 1966 at the 166-N Tank Farm. The diesel release was from a 10 cm diameter pipeline in the tank farm located approximately 140 m (460 ft) from the Columbia River. The presence of light, nonaqueous-phase liquid was discovered beneath the facility in March 1967, when evidence of oil was observed at the bank of the Columbia River (100-N-65 waste site) approximately 100 m (328 ft) northwest of the 166-N Tank Farm. Additional releases of both diesel and Bunker C fuel occurred during operations. Figure 1-1 shows the location of the Hanford Site and 100-N Area. Figure 1-2 shows the pipeline associated with the UPR-100-N-17 releases in the Waste Information Data System (WIDS) site and related petroleum hydrocarbon waste sites (accepted and remediated). Figure 1-3 provides an interpretation of the UPR-100-N-17 waste site based on excavations performed and pipelines

[1] Petroleum hydrocarbon/petroleum is synonymous with one or more of the following: diesel, Bunker C fuel, gasoline as well as of TPH-diesel, TPH-gasoline, TPH-motor oil, oil and grease, and related organic compounds.

removed within and adjacent to the site. Identified as 100-N-107 in WIDS, Figures 1-3 and 1-4 also show the Bioventing Island. Administratively in WIDS, the 100-N-107 Bioventing Island is soil contamination adjacent to the bioventing wells. The site is two separate but proximal areas of contaminated soils. One area surrounds wells 199-N-166, 199-N-167, 199-N-168, and 199-N-169. The second area is located adjacent to well 199-N-172. The 100-N-84:10 and remaining portion of the 100-N-84:2 pipeline are consolidated within the boundary of the Bioventing Island. A conceptual model of the petroleum contamination at the site is shown in Figure 1-5.

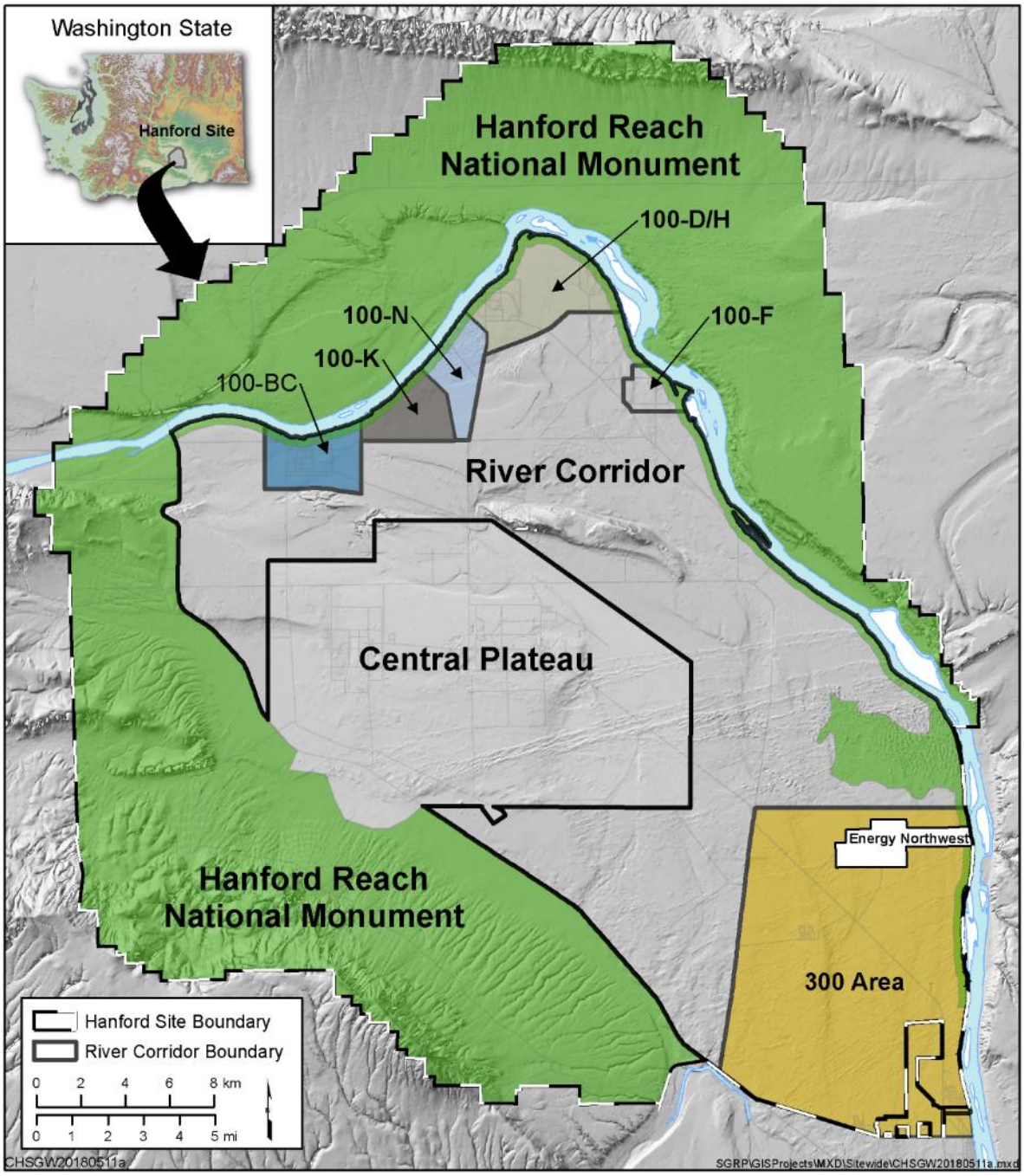


Figure 1-1. Hanford Site Location Map

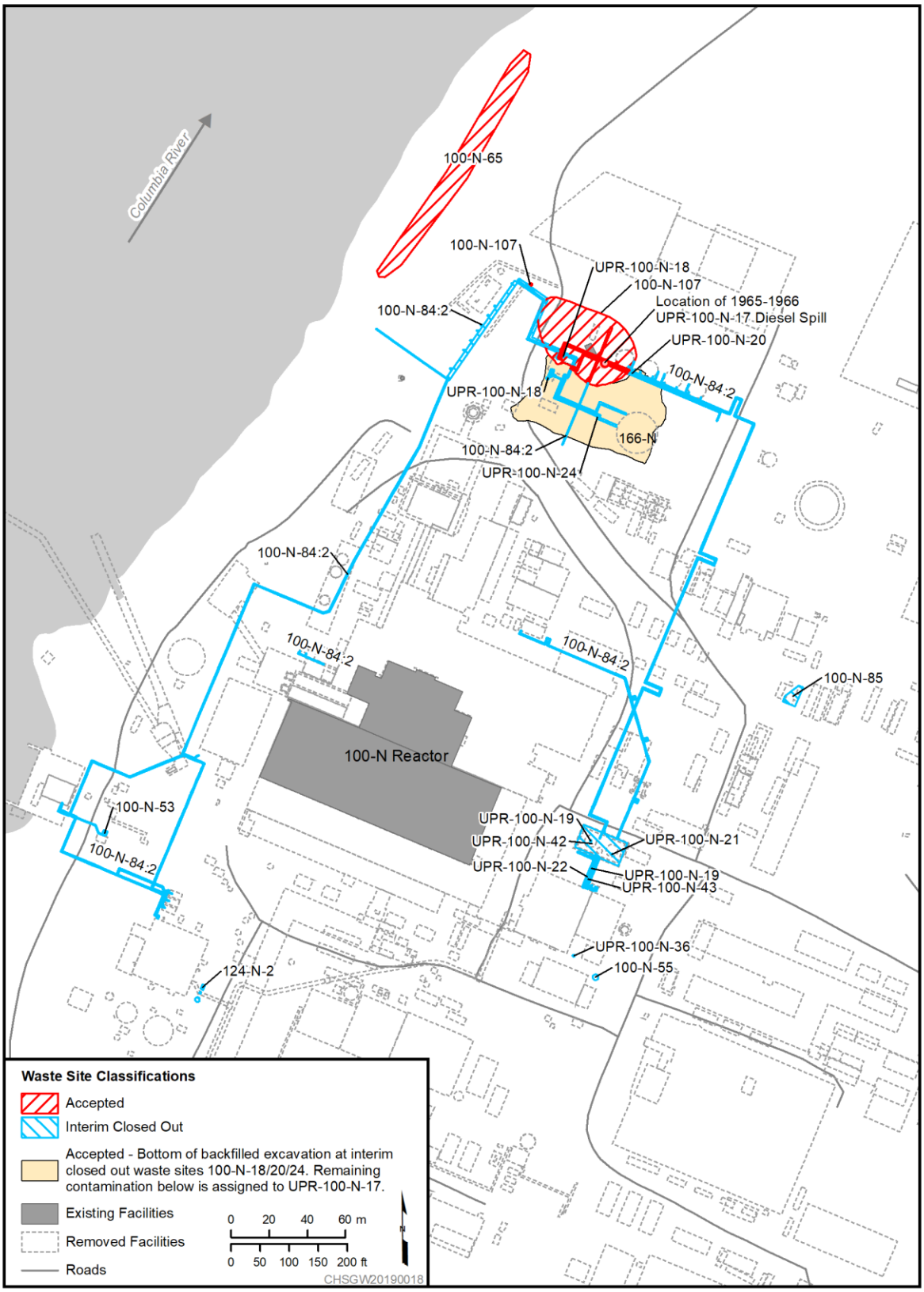


Figure 1-2. 105-N Reactor, WIDS Waste Site UPR-100-N-17, and Related Petroleum Sites Location Map

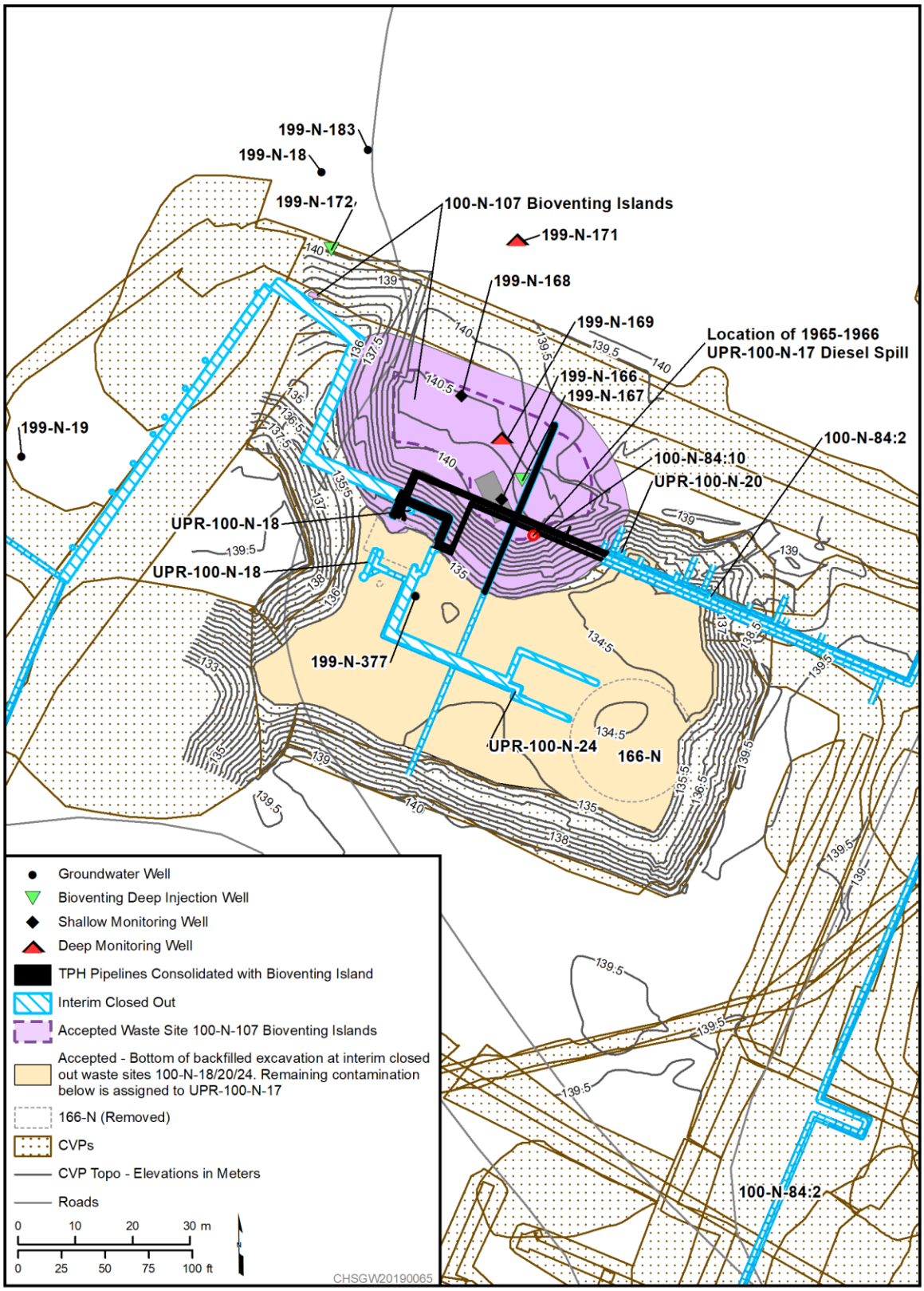


Figure 1-3. UPR-100-N-17 and 100-N-107 Bioventing Island Location Map

Figure 1-4. Aerial View of Bioventing Island

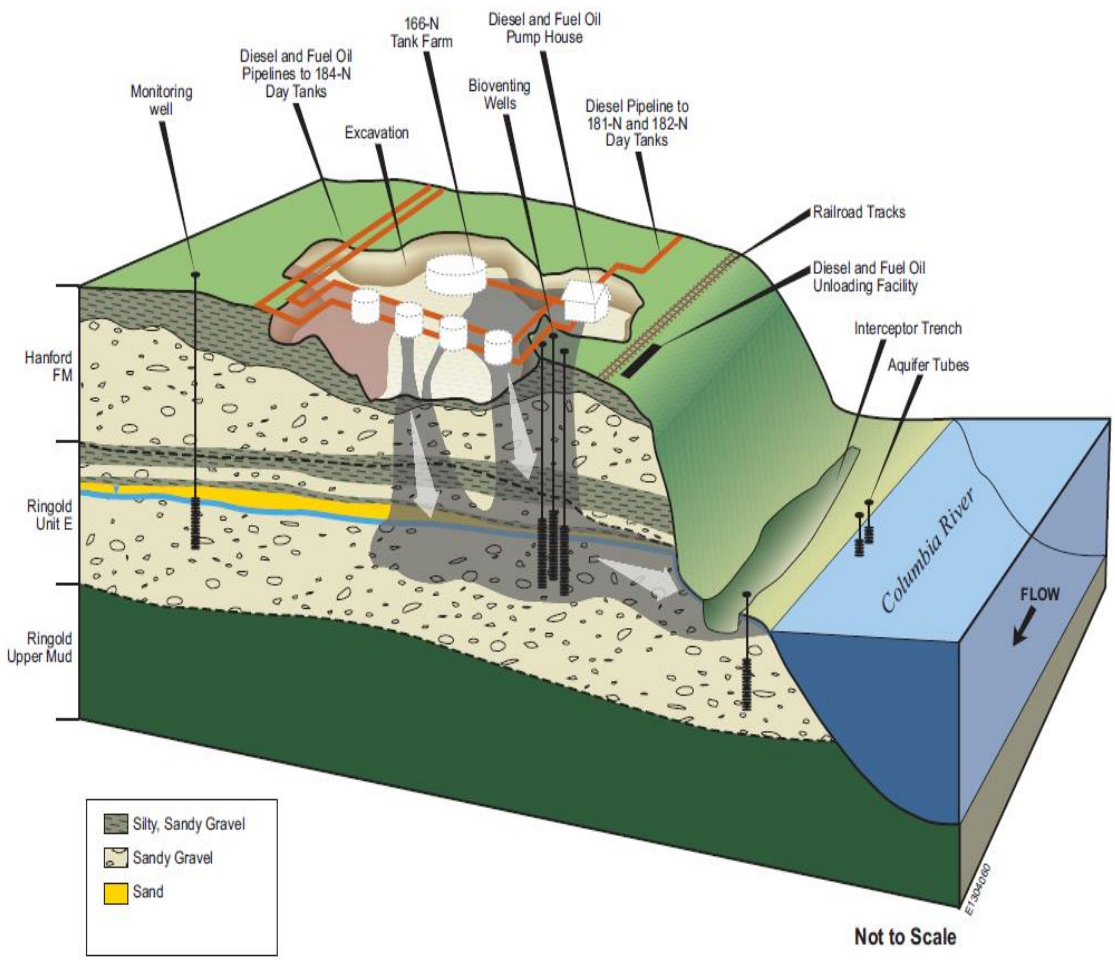


Figure 1-5. Conceptual Model of Petroleum Contamination in the 100-N Area

1.1.2 166-N Tank Farm

Corrosion of the transfer pipelines connecting the 166-N Tank Farm and associated facilities (i.e., 184-N) resulted in several incidents that released approximately 303,000 L (82,000 gal) of diesel between 1965 and 1985. Occasional releases of petroleum products from corrosion of piping systems, overfilling of tanks, and spills during transfers have been documented. A brief discussion of events is provided below.

An estimated 301,832 L (80,000 gal) of diesel oil leaked from an oil transfer line near the 166-N facility in August 1966. This release is identified in WIDS as UPR-100-N-17. The line was excavated and repaired in September 1966. Sometime later, diesel was observed entering the river at the shoreline. To alleviate this problem, a trench was excavated (in 1967) along the shoreline to intercept and accumulate the migrating diesel (GE, 1967, "Oil Leak - 100-N Area"). The trench was approximately 12.2 m (40 ft) in width, 27.4 m (90 ft) long, and was excavated approximately 9.1 m (30 ft) deep to a point beneath the prevailing water table.

The completed trench contained water at approximately river level. Periodically, the fuel in the trench was ignited and allowed to burn to remove as much of the diesel as possible before it could enter the river. The UPR-100-N-17 release extended through the deep vadose zone, at depths greater than 4.6 m (15 ft) bgs to groundwater. Based on reports estimated during the time of operation, the release may have resulted in up to 39,000 m^3 (1,377,272 ft^3) of soil contaminated with diesel.

An estimated 757 L (200 gal) of diesel oil leaked from a transfer line between the 166-N and 184-N facilities in August 1973. This release is identified in WIDS as UPR-100-N-18.

In June 1985, an estimated 757 L (200 gal) of diesel oil leaked from a transfer line near Tank 1 in the 166-N facility. This release is identified in WIDS as UPR-100-N-20.

On February 1, 1987, a line leak was reported. This release is identified as UPR-100-N-24.

1.1.3 Demolition and Remediation

Demolition of the 166-N facilities included removal of the fuel oil tank in January 2006 and removal of the 166-N Pump House and the 166-N Unloading Station in April 2006 (WCH, 2006, *Post-Demolition Summary Report for the 166-N Fuel Oil Pump House, 166-N Fuel Oil Unloading Station, and 1715-N Fuel Oil Storage Tanks 1-5*). Four 1715-N diesel tanks were removed approximately 10 years prior during demolition work, leaving the tank foundations to be removed during the 2006 demolition. Figure 1-6 is a photograph showing the 166-N Tank Farm after removal of the four diesel storage tanks and prior to the 2006 demolition activities.

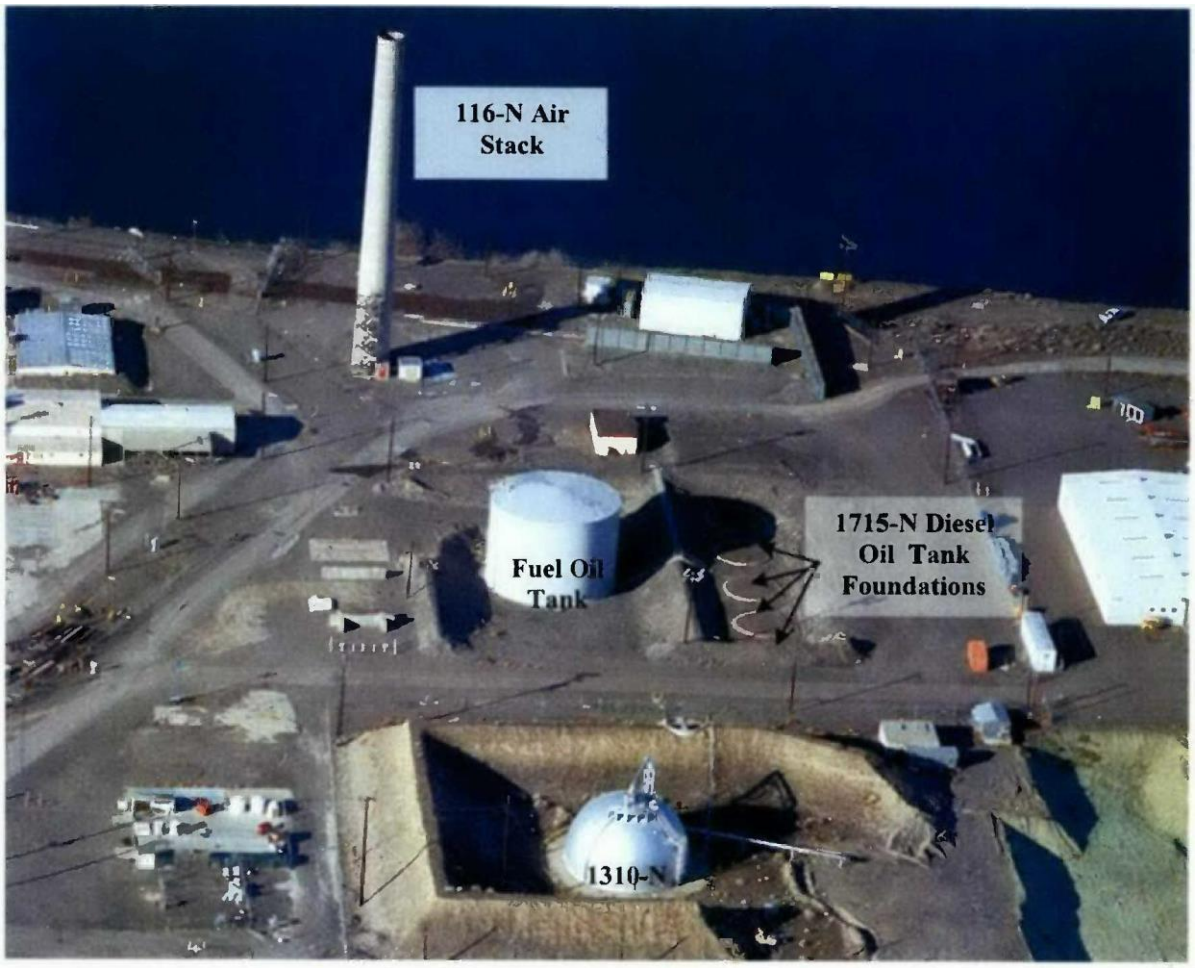


Figure 1-6. 166-N Tank Farm After Removal of Diesel Storage Tanks

Remediation of the UPR-100-N-18, UPR-100-N-20, and UPR-100-N-24 (collectively called UPR-N-18/20/24) waste sites was performed between June 27, 2011, and March 26, 2013 (WSRF-2013-055, *Waste Site Reclassification Form*, Operable Unit 100-NR-1, Waste Site Code UPR-100-N-18, with attachment, "Remaining Sites Verification Package for the UPR-100-N-18, UPR-100-N-20, and UPR-100-N-24 Waste Sites"). These sites are adjacent to and above UPR-100-N-17. Contaminated soil and debris removed from the combined UPR-N-18/20/24 excavation was disposed at the Environmental Restoration Disposal Facility. The UPR-N-18/20/24 waste sites excavation removed the contaminated soil to a depth of 4.6 m (15 ft) bgs. Potentially contaminated soil remaining below 4.6 m (15 ft) is part of the UPR-100-N-17 waste site.

The locations of petroleum waste sites near UPR-100-N-17 are also shown in Figure 1-2. Petroleum waste sites UPR-100-N-18, UPR-100-N-19, UPR-100-N-20, UPR-100-N-21, UPR-100-N-22, UPR-100-N-24, UPR-100-N-36, UPR-100-N-42, UPR-100-N-43, UPR-100-N-84:2, 100-N-85, 100-N-53, 100-N-55, and 124-N-2 have been cleaned up according to interim action records of decisions, with exception of deep zone (>4.6 m [15 ft]) contamination beneath UPR-100-N-18, UPR-100-N-20, and UPR-100-N-24. The deep zone beneath these three sites is a part of UPR-100-N-17 according to WSRF-2013-055.

1.1.4 History of Bioventing

The bioventing system, described in Section 1.1.5, was installed at the UPR-100-N-17 waste site to remediate deep vadose zone petroleum-contaminated soils identified within the 100-NR-1 OU. Pilot testing began in February 2010 and continued through May 2011. The pilot test included collection of baseline measurements at the seven bioventing wells, a respirometry test and air injection, and a 6-month operational test. Pilot testing indicated the following:

- Bioventing appears to be an effective and efficient method of promoting in-situ bioremediation in the deep zone soils in conjunction with naturally occurring microbes in the subsurface.
- Depressed baseline oxygen levels were clearly a key rate-limiting factor.
- At moderate airflow rates, bioventing affects a large area around injection wells, suggesting that soils are relatively permeable to airflow. The radius of influence (ROI) for each injection well is up to 61 m (200 ft).

The bioventing system became operational on November 27, 2012, and has continued to operate in the deep vadose zone since that time.

1.1.5 Bioventing System

The bioventing system consists of a blower system housed within a Conex container that can operate continuously. Figures 1-7 and 1-8 are photographs of the bioventing system. The airflow induced by the blower system enhances the biodegradation of the petroleum-contaminated soils. Details on the design criteria and equipment selection are provided in WCH-576, *Operation and Maintenance Manual: Phase II Testing – Bioremediation Design for Deep Zone Petroleum Contamination (UPR-100-N-17) at the 100-N Area*.

Three blowers supply air to the two injection wells. Each blower is a 7.5 HP 208–230/480 V AC regenerative blower. Each blower is connected to a header pipeline that connects to a main airline leading to each of the treatment wells, 199-N-167 and 199-N-172. The injection wells are constructed of 4 in. Schedule 40 polyvinyl chloride and are screened from approximately 16.8 to 22.9 m (55 to 75 ft).

Figure 1-7. Bioventing System Conex Box

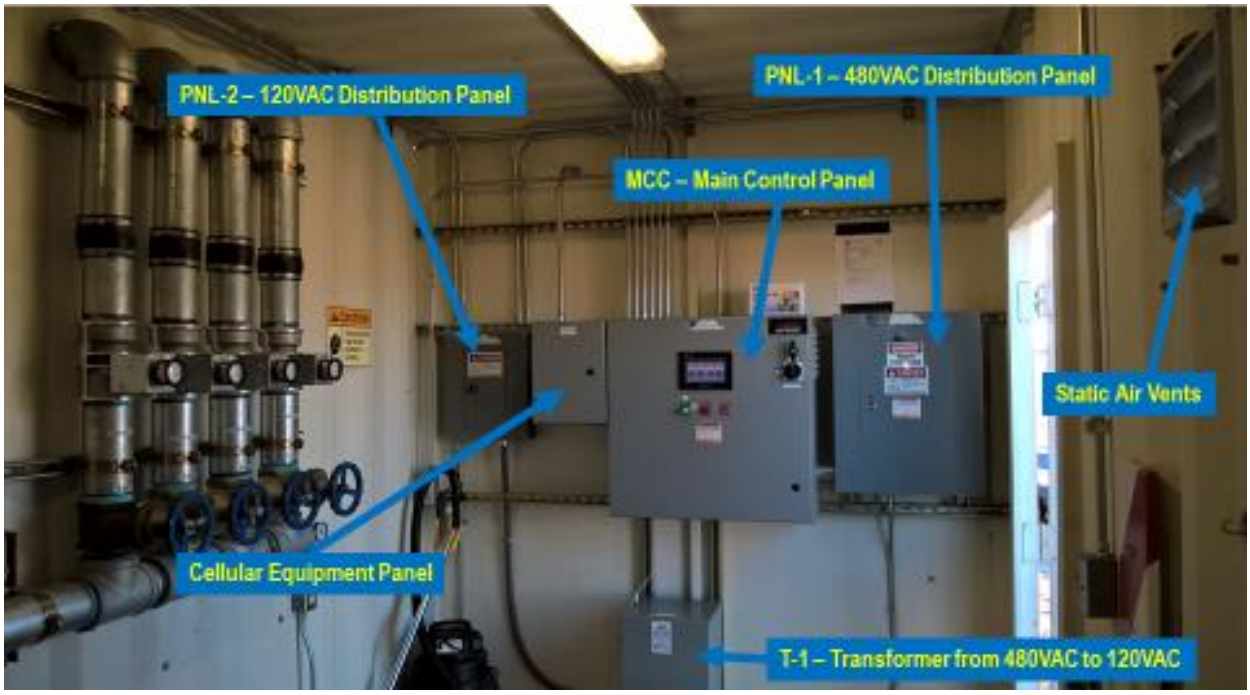


Figure 1-8. Interior of Bioventing System Conex Box

Other system components include the following:

- Pressure, vacuum, and temperature gauges
- In-line air filters
- A remote telemetry and alarm messaging system
- A 480-V control panel

Seven bioventing wells were drilled and constructed in 2009. Five of the wells were drilled to a depth of approximately 25 m (82 ft) bgs and completed as deep vadose zone wells, with well screens from approximately 16.1 to 24.4 m (53 to 80 ft). Two of the wells were drilled to a 10.1 m (33 ft) depth and completed as shallow wells, with well screens from 3 to 10 m (10 to 33 ft) (WCH-370, *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project [UPR-100-N-17]*). Table 1-1 provides a summary of the bioremediation well construction details. Figure 1-9 shows the locations of the bioventing wells, the ROI, and groundwater monitoring wells. The bioventing system uses wells 199-N-167 and 199-N-172 for air injection, and two other wells (199-N-169 and 199-N-171) are used for soil gas monitoring. Two additional groundwater monitoring wells (199-N-183 and 199-N-377) were drilled in 2011 and 2016, respectively, to support monitoring and characterization efforts within the ROI.

Table 1-1. Bioventing Well Network Information

Well Name and Type	Depth (ft bgs)	Screen (ft bgs/elevation ft)		Low River Stage Depth to Groundwater 2018 (ft bgs)	2018 Low River Stage Elevation (ft)
		Top	Bottom		
199-N-166-SMP	33	10/451.8	30/431.8	N/A	N/A
199-N-167-DIW[a]	83	53/408.6	78/383.6	72.9	388.7
199-N-168-SMP	33	10/452.3	30/432.2	N/A	N/A
199-N-169-DMP	83	53/408.8	78/383.8	73.4	388.4
199-N-170-DMP[b]	83.5	54/407.9	79/382.9	N/A	N/A
199-N-171-DMP	82.4	55/407.5	80/382.5	73.9	388.6
199-N-172-DIW[a]	82	57/404.2	77/384.2	72.6	388.6
199-N-183	117.3	62.6/397.5	91.9/368.2	74.8	385.3
199-N-377[c]	109.3	69.1/389.2	89.1/369.2	72.3	386

a. Well is also used for groundwater monitoring.

b. Well is decommissioned.

c. Groundwater monitoring well was drilled in 2016. Provides information on nature and extent of vadose zone contamination.

bgs = below ground surface
DIW = deep injection well
DMP = deep monitoring well
N/A = not applicable
SMP = shallow monitoring well

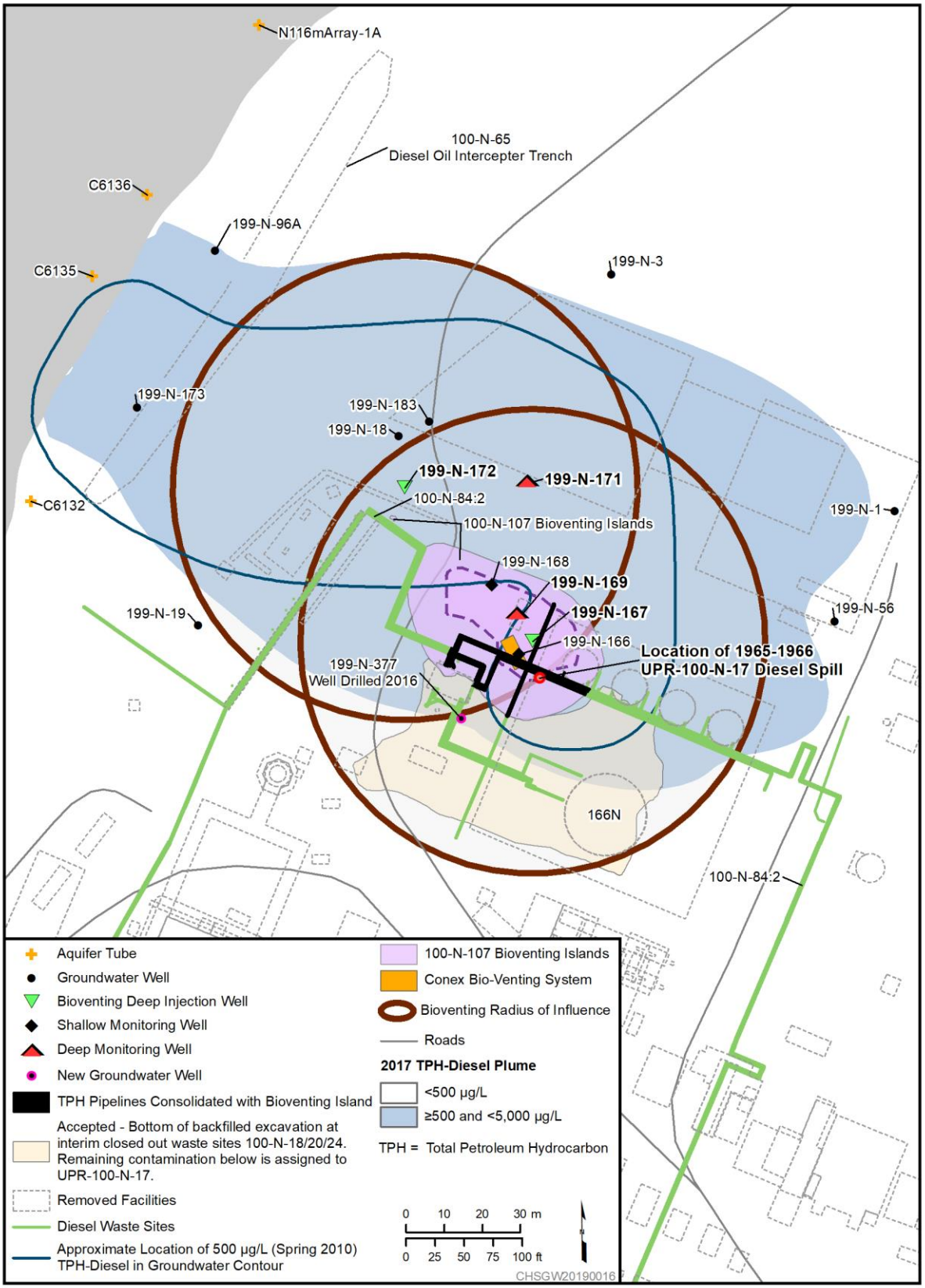


Figure 1-9. Bioventing System, Monitoring Wells, and Radius of Influence

1.1.6 Topography

The surface elevation at the bioventing site is approximately 140.6 m (461 ft). Surface elevations decrease toward the river to approximately 124 m (407 ft) on a lower terrace adjacent to the river.

1.1.7 Geology

The 166-N Tank Farm and UPR-100-N-17 are on a bluff approximately 16 m (53 ft) above the Columbia River. The geology in this area consists of the Miocene age Columbia River Basalt Group and late Miocene to Pleistocene age sediments that overlie the basalts. These suprabasalt sediments are over 125 m (400 ft) thick and consist of the late Miocene to Pliocene age Ringold Formation and the Pleistocene age Hanford formation. Holocene deposits of silt and sand are also present sporadically on the surface. Figure 1-10 provides a generalized geologic stratigraphic section for the 100-N Area.

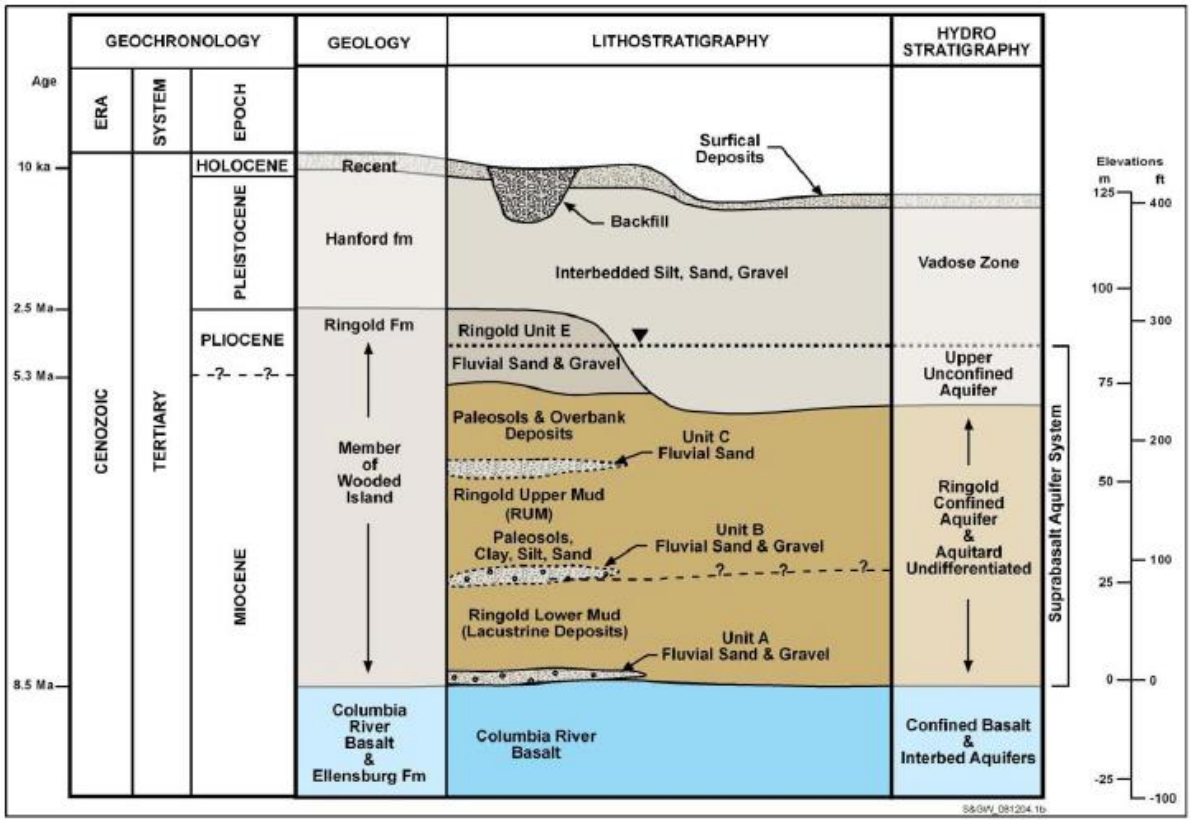


Figure 1-10. Generalized Stratigraphic Column

The Hanford formation is composed mainly of unconsolidated basaltic cobble and boulder-sized clasts and is up to 15.2 m (50 ft) thick. Within this gravel dominated sequence cobbles as large as 15 cm (6 in.) and boulders up to 0.9 m (3 ft) are common. A sand-dominated sequence of the Hanford formation common to the 100-N Area does not appear to be present at the site.

Underlying the Hanford formation throughout the study area, the Ringold Formation consists of a mix of fluvial gravels, fluvial sands, overbank deposits, paleosols, and lake deposits. Within the 100-N Area, the top of the Ringold Formation ranges from 6 m (19 ft) to approximately 23 m (77 ft) bgs. At UPR-l00-N-17, the top of the Ringold Formation is encountered at approximately 13.7 m (45 ft) to 15.2 m (50 ft) bgs and is up to 19.8 ft (65 ft) thick. The Ringold Formation member of Wooded Island – unit E (Rwie), which is the uppermost Ringold stratum, consists of variably cemented

pebble-to-cobble gravel with a fine- to coarse-grained sand matrix with interbedded layers of sand and sandy-silt gravel as noted in the bioventing borehole logs (WCH-370). Within the Rwie, a 1.5 to 2.1 m (5 to 7 ft) thick bed of fine to coarse grain sand is also present 19.2 to 21.5 m (63 ft to 70.5 ft) bgs (WHC-370). This continuous sand layer is present in wells199-N-167, 199-N-169, 199-N-170, and 199-N-172 and associated with TPH concentrations up to 4,400 mg/kg. The Rwie exhibits a more felsic (quarzitic) composition than the underlying Ringold subunits and can be differentiated from the overlying Hanford formation based on the composition of the sand. The Rwie has tan sands derived from primarily metamorphic rocks, while the Hanford formation has black sands derived primarily from basalt. In addition, the Rwie is more compact than the Hanford formation. The contact between the Hanford formation and the Ringold Formation is sometimes difficult to determine because a transition zone of reworked Ringold Formation is often present. However, beneath the UPR-100-N-17 waste site, the Hanford formation and Ringold Formation contact is clear.

The Ringold Formation upper mud (RUM) underlies the Rwie about 33.5 m (110 ft) bgs based on the geology in borehole 199-N-183. Silt-rich paleosols and lacustrine deposits of this undifferentiated unit are over 122 m (394 ft) thick and uncomfortably overlies the basalt of the Saddle Mountain Basalt Formation. Top of basalt is about 152 m (500 ft) bgs. Hydraulic and transport parameters for the Hanford formation and Ringold Formation are reported in ECF-100NR1-12-0056, *Vadose Zone Transport Modeling to Calculate Strontium-90 Flux to Groundwater and Preliminary Remediation Goal in Support of the 100-N Remedial Investigation/Feasibility Study*.

1.1.8 Hydrogeology

The vadose zone is the unsaturated area above the water table. In the project area, the vadose zone is 19.7 to 23.3 m (64.7 to 76.5 ft) thick, and varies with changes in the elevation of the water, which is influenced by the Columbia River stage. The vadose zone consist predominantly of the Hanford formation gravel sequence, while the Rwie makes up the lower, approximate third of vadose zone.

The uppermost aquifer beneath the site is unconfined and completely contained within the Rwie. From the surface of the water table to the RUM (base of unconfined aquifer), the aquifer is approximately 12 to 15 m (40 to 50 ft) thick.

The surface of unconfined aquifer is relatively flat; however, groundwater flows predominantly to the north in the 100-N Area toward the Columbia River (Figure 1-11) and is dominated by changes in Columbia River stage in the study area. The elevation of the river can fluctuate more than 2.4 m/d (8.0 ft/d) because of upriver discharges from Priest Rapids Dam. During high river stage, the river level may be higher than inland groundwater levels, initiating a temporary reversal of hydraulic gradient and the flow of river water into the unconfined aquifer. Figure 1-12 shows a comparison of annual fluctuations in groundwater elevations for well 199-N-3 located near the UPR-100-N-17 waste site, upgradient well 199-N-34, and Columbia River elevations. Automated Water Level Network data collected from groundwater monitoring well 199-N-3 indicate that water table elevation varied from 117.3 and 120.9 m (384.8 and 396.7 ft) between 2009 to 2018. This difference in elevation (3.6 m [11.8 ft]) defines the periodically rewetted zone (PRZ) in this report. The PRZ is predominantly unsaturated from November to March and less exposed (i.e., saturated) during other times of the year. The depths to groundwater in the PRZ range from 19.7 to 23.3 m (64.7 to 76.5 ft) bgs (elevation of 117.3 to 120.9 m [384.8 to 396.7 ft]). Historically, the thickness and elevation of the PRZ has changed over time because of past discharges of liquids to the soil column and river stage, so characterization is also needed above this zone to account for potential impacts.

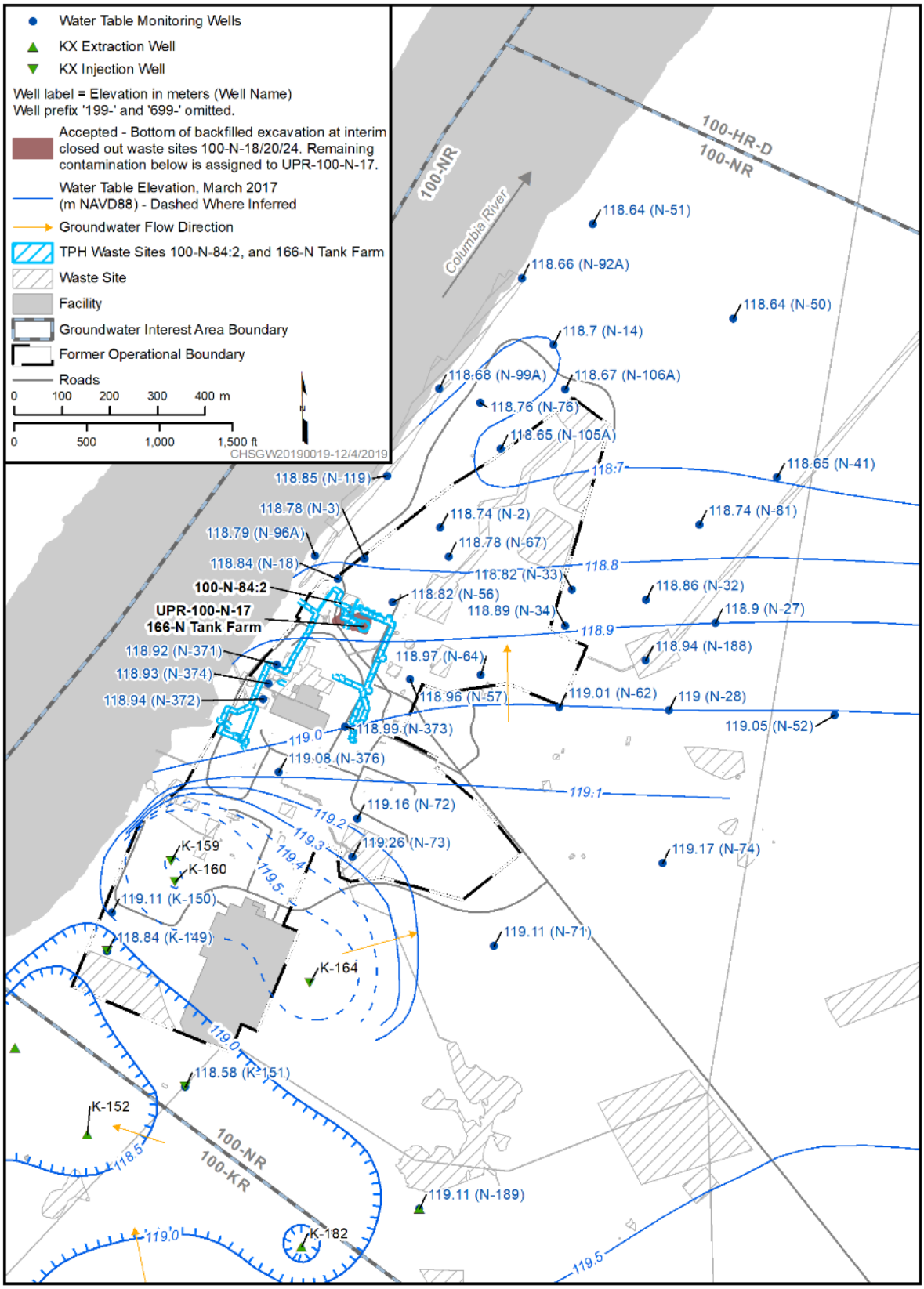
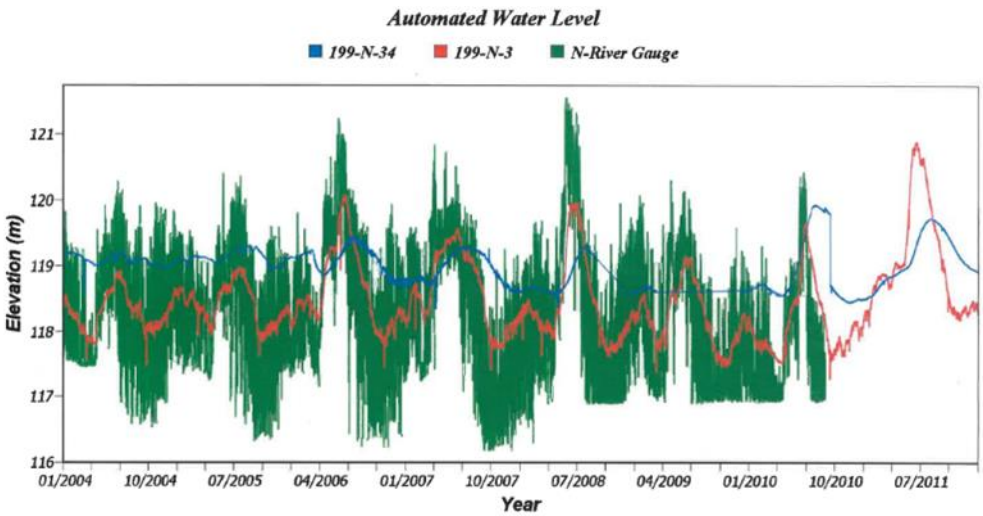
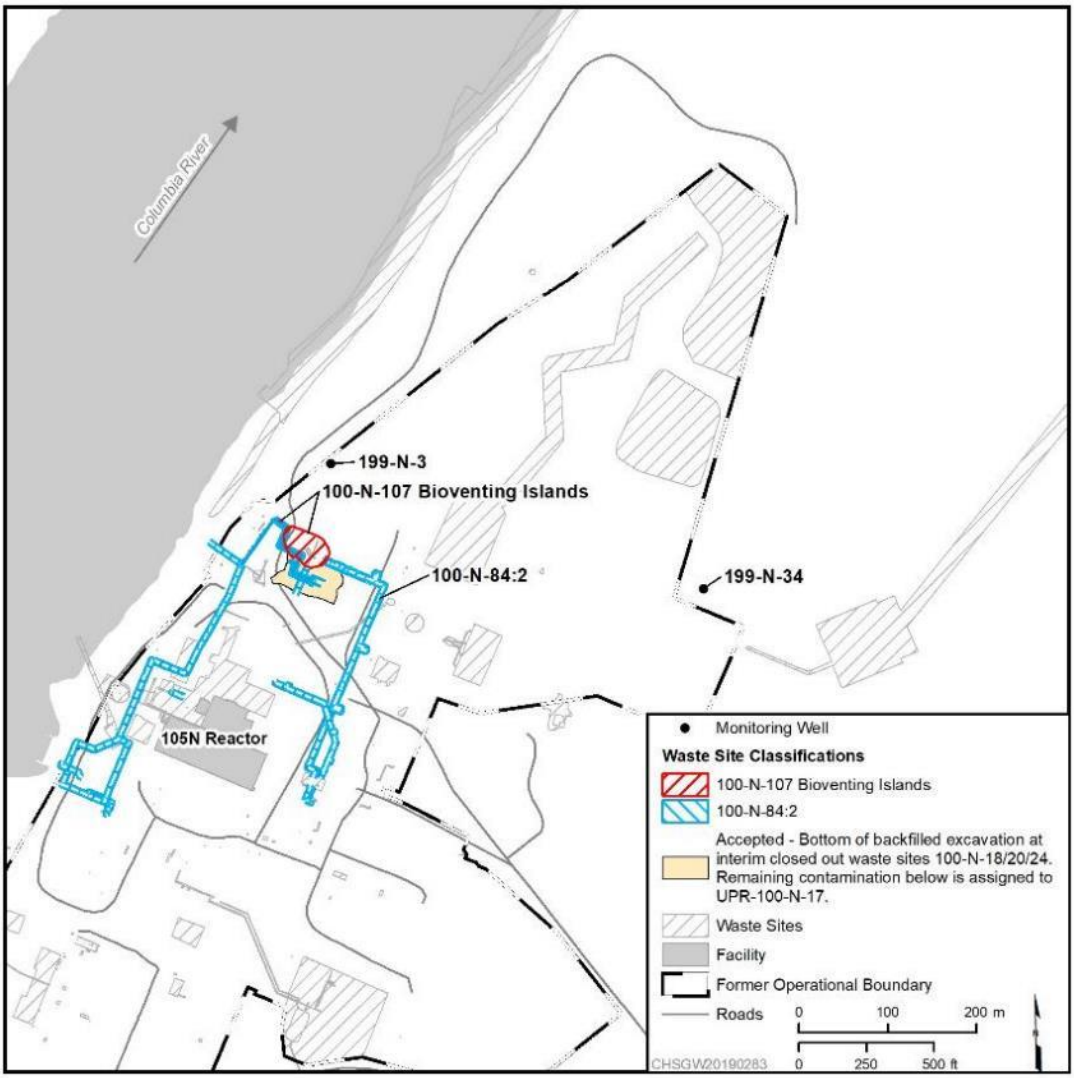


Figure 1-11. 100-N Area 2017 Groundwater Map





Source: Appendix H of DOE/RL-2005-93, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*.

Figure 1-12. Groundwater Elevation Fluctuations Near UPR-100-N-17

1.1.9 Petroleum Contamination

The distribution of petroleum contamination at the bioventing site is based on verification data collected during interim remedial action in 2013 within the shallow zone (0 to 4.6 m [15 ft bgs]) above UPR-100-N-17. Data are also available from seven wells (199-N-166, 199-N-167, 199-N-168, 199-N-169, 199-N-170, 199-N-171, and 199-N-172) drilled in 2009 and wells 199-N-183 and 199-N-377 drilled in 2011 and 2016, respectively.

Verification samples collected after remediation of waste sites within the shallow zone indicates that TPH concentration ranges from 2.7 to 320 mg/kg (75.5 mg/kg equals the 95% upper confidence limit) to a depth of 4.6 m (15 ft). These shallow zone concentrations remaining above the deep zone at UPR-100-N-17 are below the 200 mg/kg[2] cleanup level. The nature and extent of petroleum contamination (TPH-diesel [TPH-D] and TPH-motor oil) in the deep zone (>4.6 m [15 ft] bgs) at the bioventing site is shown in Figure 1-13. The concentrations of TPH in the deep zone ranged from 1.45 to 4,400 mg/kg with the highest concentrations present at injection wells 199-N-167 and 199-N-172 associated with a sand layer within the Rwie. As shown in the illustration, most of the significant contamination (>200 mg/kg) is within the deep vadose zone associated with Rwie. However, limited information on TPH-D is available from the Hanford formation. Elevated levels of contaminations were also detected in soil samples higher in the geologic section within the Hanford formation at borehole 199-N-377. The contamination generally decreased below the Hanford Ringold contact. Higher concentrations in the Hanford formation at this well indicate that contamination resulted from smaller releases, such as UPR-100-N-18/20/24 or other pipeline releases. Oil and grease data are also available to define the nature and extent of petroleum. The data suggest that elevated oil and grease concentrations are typically correlative with elevated TPH-D and TPH-motor oil concentrations. The concentration of oil and grease ranges from 88 to 4,400 mg/kg and generally increased with depth toward the water table. However, 18,000 mg/kg of oil and grease was in 199-N-169 about 10.7 m (35 ft) bgs within the Hanford formation. Deep zone TPH contamination 4.6 m (15 ft) bgs at UPR-100-N-17 can be seen in Figure 1-14.

TPH-D migrated vertically through the subsurface soil (Hanford formation). Lateral spreading of the diesel as nonaqueous-phase liquid (NAPL) or free product and possibly some dissolved fraction occurred when it encountered either the Ringold Formation or the water table. Diesel is less dense than water, and the NAPL stayed near the water table surface, slowly dissolving into the aquifer. The less dense diesel remained and moved along the groundwater flow path toward the Columbia River. As the water table subsided, some residual NAPL and dissolved petroleum products remained in the previously saturated portion of the Rwie within the PRZ.

The residual petroleum within the PRZ above the water table will continue to be a source to the groundwater plume during high river stage events, and any remaining groundwater NAPL will continue to introduce contamination into the vadose zone during high water table conditions. The magnitude of the petroleum contribution to the groundwater plume is expected to decrease over time as the periodically rewetted zone residual source is depleted.

1.1.10 Groundwater Contamination

A small, relatively narrow groundwater plume of TPH-D extends downgradient from the UPR-100-N-17 waste site to the river (Figure 1-15). The two highest TPH-D concentrations in 2017 were detected in wells 199-N-18 and 199-N-167 (16.6 and 13.0 mg/L, respectively). In 2017, the maximum aquifer concentration was detected in tube C6135 (4.43 mg/L). The concentration of TPH-D in shoreline seep 100-N SPRING 89-1 was less than detection.

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[2] The cleanup level for TPH is 200 mg/kg in the interim action record of decision; 2,000 mg/kg is the anticipated cleanup level for final actions based on changes to the *Model Toxics Control Act*.

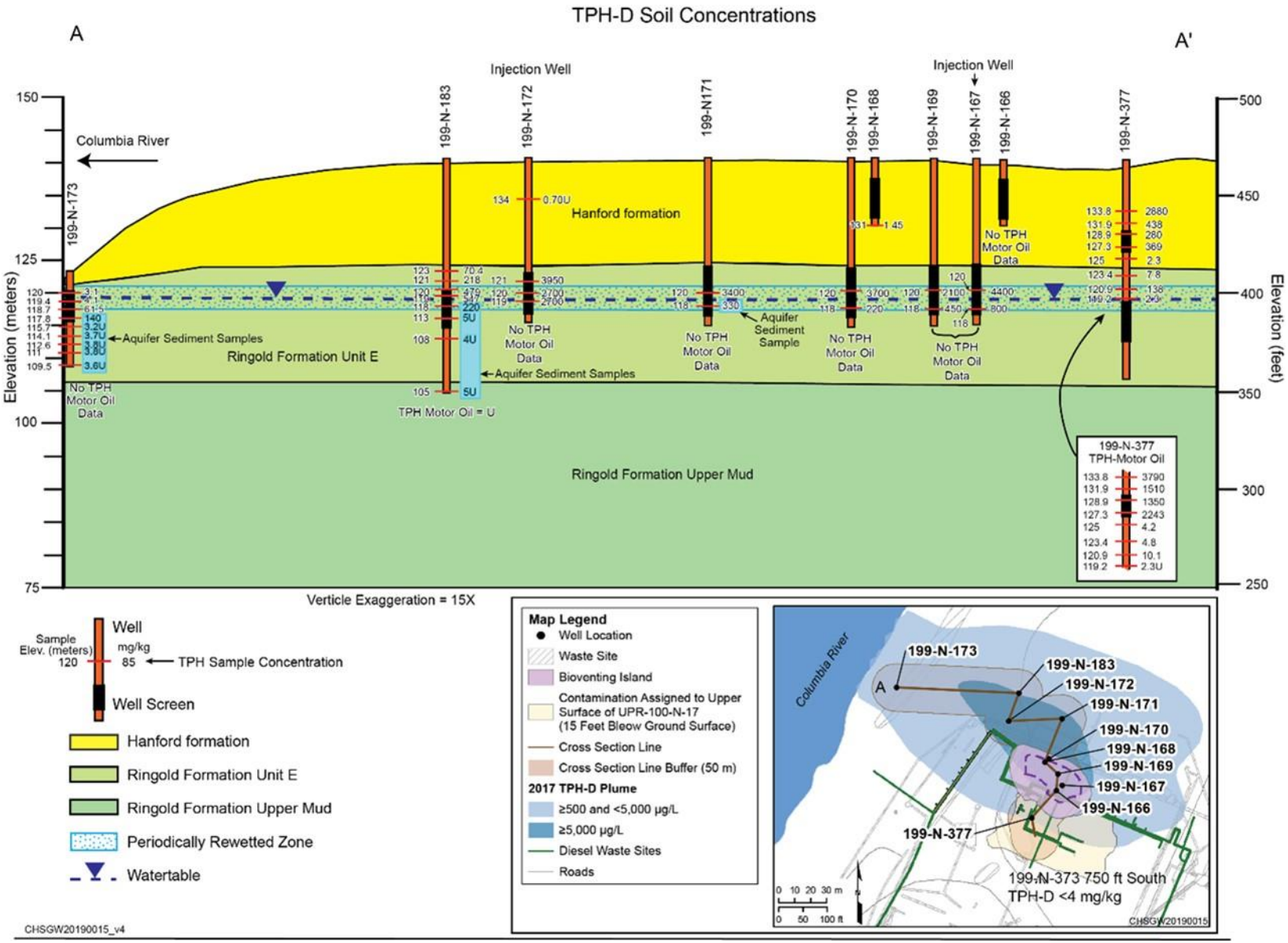

Figure 1-13. Distribution of TPH-D and TPH-Motor Oil

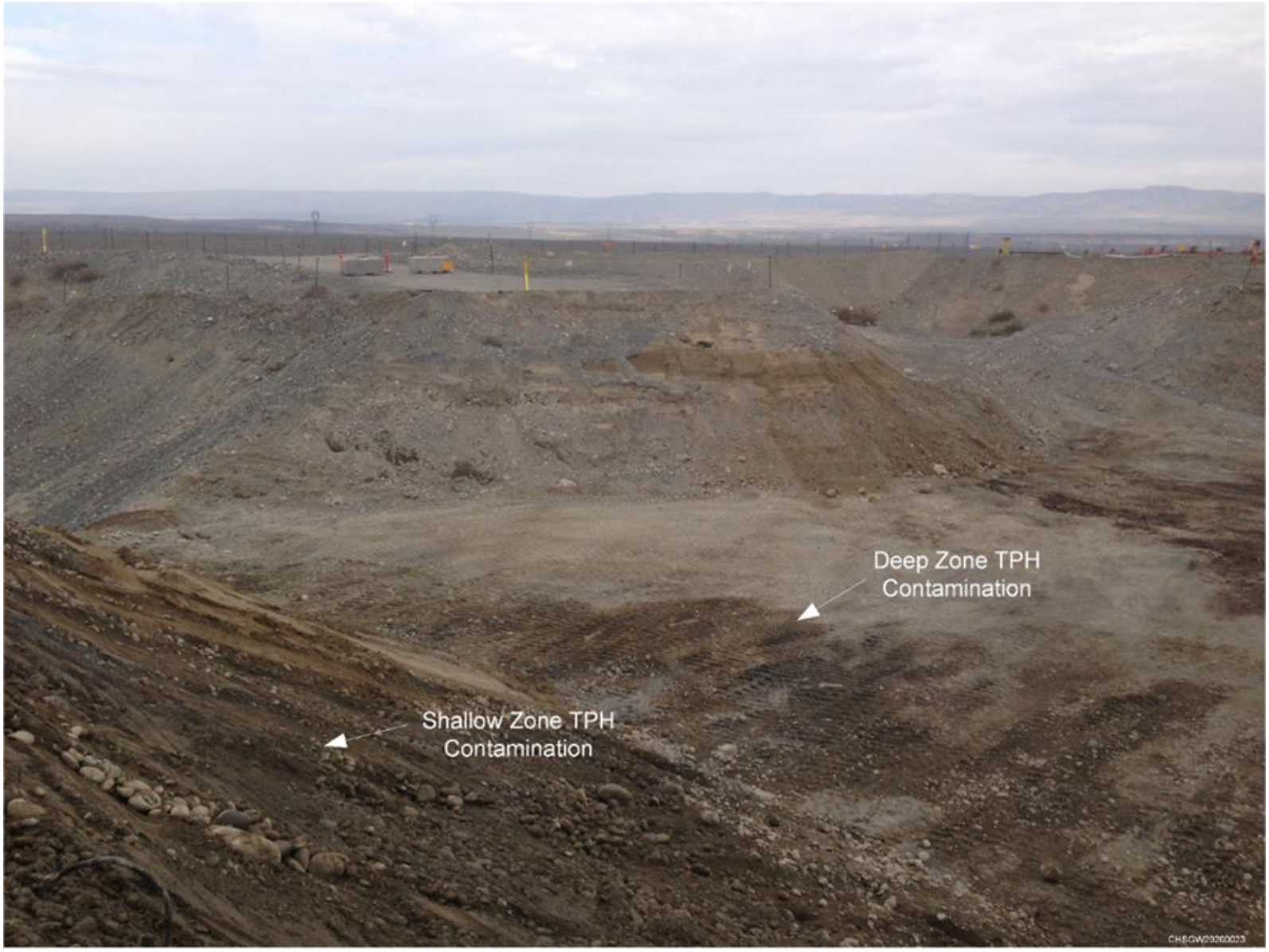

Figure 1-14. Deep Zone TPH Contamination at UPR-100-N-17

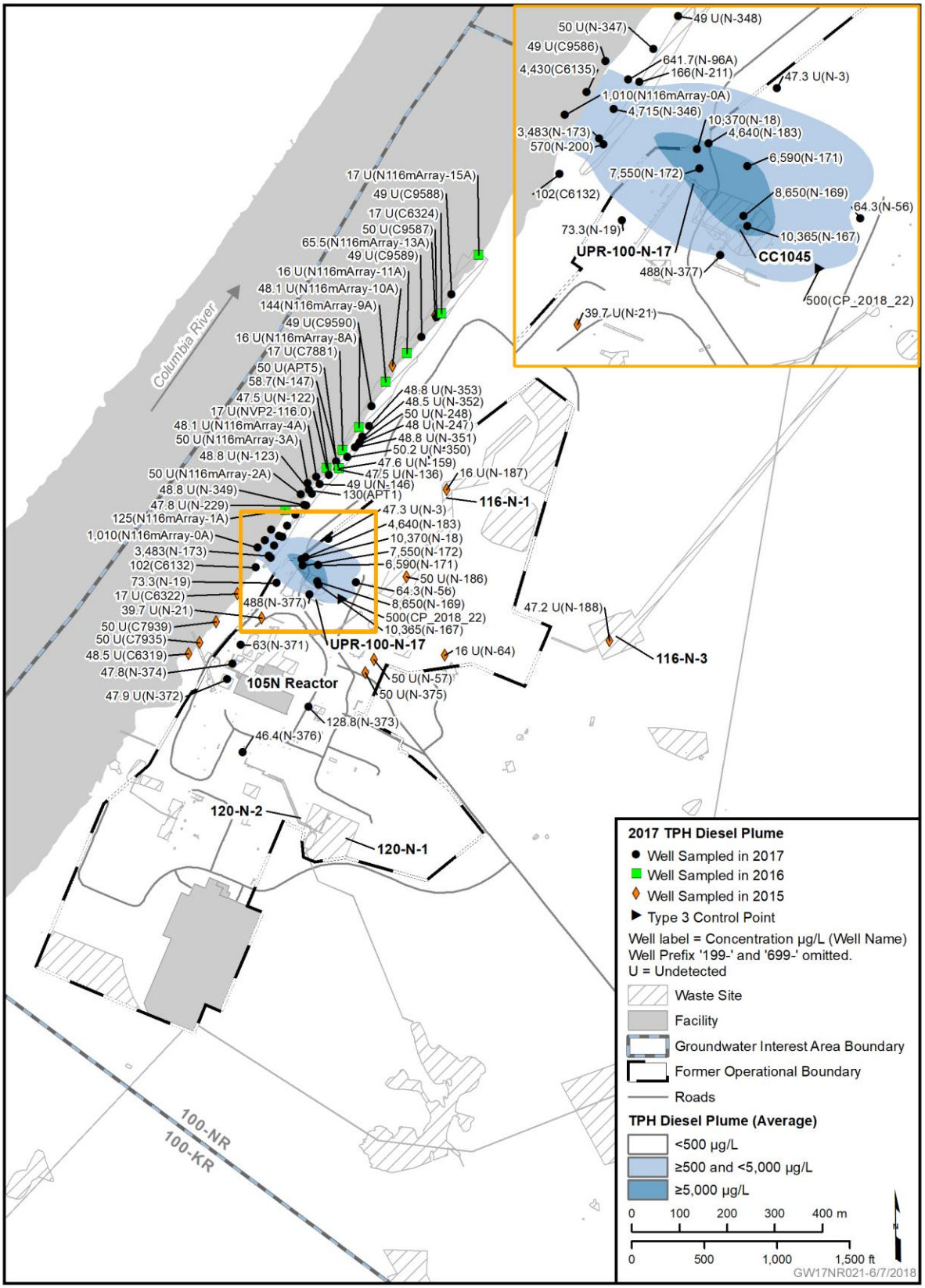

Figure 1-15. 100-N Area TPH-D Groundwater Plume 2017

1.1.11 Summary of TPH-D Removal

The quantity of TPH-D removed during bioventing at UPR-100-N-17 is estimated from measurements collected during respirometry testing. Since operation of the system began in 2012, respirometry testing is performed two times a year. Microbial respiration measurements collected during shut down of the bioventing system are used to estimate biodegradation rates of TPH-D. Higher levels of carbon dioxide and lower levels of oxygen are typical indicators of the biodegradation of TPH-D and cleanup progress. Other geochemical indicators of TPH-D biodegradation also include nitrate/sulfate depletion, lower reduction and oxidation potential and elevated manganese ferrous, methane, and alkalinity (DOE/RL-2005-93). Lower alkalinity is due to the production of carbon dioxide. Biodegradation rates calculated from respirometry testing exhibited a declining trend from the initial rates calculated in March 2010 of approximately 0.97 to 0.22 mg/kg per day. Biodegradation rates have been relatively stable since July 2014. This trend may indicate a reduction in the bio-available hydrocarbon food source in the treatment zone to levels that no longer support significant biological activity. On a sediment mass basis, calculations using the respirometry data indicate that the petroleum hydrocarbon concentrations have been reduced by approximately 790 mg/kg since startup of the bioventing system in November 2012. Table 1-2 shows the biodegradation rates over time, and the data are shown graphically in Figure 1-16.

Table 1-2. Comparison of Biodegradation Rates Over Time Calculated From In-Situ Respiration Testing

Monitoring Point	Biodegradation Rate (mg/kg per day)										
	2017		2016			2015		2014		2012	2010
	Nov	Jul	Dec	Aug	Feb	Aug	Jan	Jul	Jan	Dec	Mar
199-N-167	-0.14	-0.08	-0.06	-0.06	-0.07	-0.05	-0.05	-0.06	-0.01	-0.15	-0.99
199-N-169	-0.19	-0.11	-0.14	-0.07	-0.12	-0.12	-0.23	-0.09	-0.07	-0.28	-0.97
199-N-171	-0.11	-0.07	-0.22	-0.08	-0.19	-0.14	-0.23	-0.09	-0.05	-9.82	-0.37
199-N-172	-0.07	-0.08	-0.03	-0.02	-0.04	-0.04	-0.05	-0.02	-0.01	-0.14	-0.54
199-N-183	-0.06	-0.02	N/A	N/A	N/A	N/A	N/A	NA	-0.09	-0.05	Not tested

N/A = not applicable; oxygen depletion insignificant and biodegradation rate not calculated

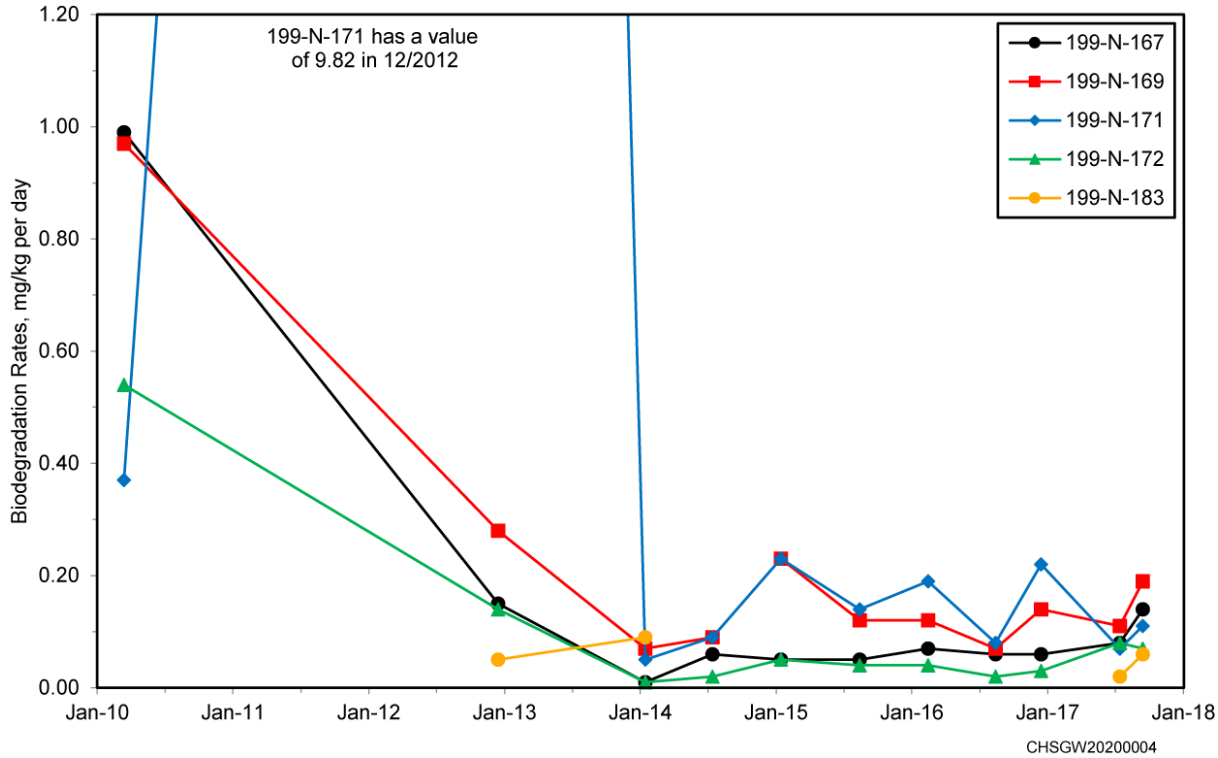

Figure 1-16. Plot of Biodegradation Rates (2010 to 2017)

1.1.12 Microbial Testing

The summary of microbial testing in this section is mainly from Appendix H in DOE/RL-2005-93 and PNNL-18645, *Summary of TPH Monitoring Conducted at 100-NR-2- 2008 through 2010*.

Microbial testing was performed on TPH-contaminated soils from the study area to determine the presence of diesel-degrading bacteria and the rate of diesel degradation by bacteria. Soil samples were collected in 2009 from borehole 199-N-173 and sent to Washington State University. TPH-D soil concentrations in the borehole ranged from the detection limited to a maximum of 140 mg/kg at the vadose zone-groundwater interface 5.3 to 6.1 m (17.4 to 20 ft) bgs. All concentrations detected were below the soil concentrations (2,000 mg/kg) protective of groundwater and the Columbia River. TPH-D was not detected in five soil samples collected below the water table at a depth of 5.6 m (18.5 ft).

Using a modified most probable number method, the population of diesel degrading bacteria was determined from samples collected 4.6 to 5.0 m (15 to 16.4 ft) bgs and 5.3 to 6.1 m (17.4 to 20 ft) bgs. The population of microorganisms was determined based on the growth on mini agar plates as compared to standard tables used by the food and drug administration (Blodgett, 2010, "BAM Appendix 2: Most Probable Number from Serial Dilutions"). In the two samples, the most probable number of bacteria per gram of soil was 5,400 in the vadose zone and 35,000 in the sample at the groundwater vadose zone interface.

Additional testing was also performed on regular agar plates containing 0.05 g of diesel to determine the presence of bacteria. Numerous plates indicated the presence of bacteria. Figure 1-8 in PNNL-18645 shows agar plates with bacteria growing. Diesel fuel was the sole carbon source of bacteria growing from sediments collected 4.6, 5.2, 5.3 to 6.1, and 10.7 m (15, 17, 17.5 to 20, and 35 ft) bgs on the agar plates.

Biological slurry reactors were used to determine the rate TPH-D degradation by bacteria from a sample collected 6.1 m (20 ft) bgs, which is below the water table as outlined in PNNL-18645. Various reactors were prepared to include controls, and containers with added nutrients (ammonia and phosphate), no-nutrients, nutrient, and molasses. Reactors from different groups were sacrificed and total concentration of soil-phased diesel range organics were determined by extraction/concentration in methylene chloride with quantification by gas chromatography/flame ionization (PNNL-18645). After 17 days of incubation, the reactors were analyzed for diesel. Initial results demonstrate a reduction in diesel concentration with nutrient relative to the control and the no-nutrient amendment. Repeat analysis showed that the small apparent benefit of nutrient addition was not statistically significant relative to the no-nutrient test. Results suggest that natural attenuation of diesel by microbial activity in the subsurface is occurring. Enhanced degradation with nutrients was not considered successful.

1.1.13 Contaminants of Potential Concern

COPCs for the 100-NR-1 OU were identified through an evaluation of both historical and limited field investigation data (EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*). The list of COPCs for petroleum sites were further refined in part based on in-process sampling data collected during remedial actions (excavation) at TPH waste sites and as documented in remaining sites verification packages (i.e., WSRF-2013-055 and WSRF-2014-088, *Waste Site Reclassification Form*, Operable Unit 100-NR-1, Waste Site Code 100-N-84:2, with attachment, "Remaining Sites Verification Package for the UPR-100-N-84:2, 100-N Area Fuel and Foam Pipelines Subsite") used to interim close out the waste sites and data presented in Appendix H of DOE/RL-2005-93. Table 1-3 and Appendix A identify the COPCs for this investigation. While not all contaminants of potential concern are necessary for the stated purposes of this sampling and analysis plan, data collected may be used to inform future remedial investigation/ feasibility study decision making. Testing methods used to determine the presence and population of petroleum-degrading bacteria are also included with the sample priority.

Table 1-3. Laboratory Analytical Methods and Microbial Needs

Contaminant of Potential Concern	Analytical Method	Sample Priority[a]
Total petroleum hydrocarbons – diesel	Method WTPH-diesel range (Ecology Publication No. ECY 97-602)	1
Total petroleum hydrocarbons – motor oil	Method WTPH-motor oil range (Ecology Publication No. ECY 97-602)	3
Total petroleum hydrocarbon fraction	Method WTPH aliphatic/aromatic fraction (Ecology Publication No. ECY 97-602)	5
Oil and grease	EPA Method 1664 OIL/GREASE (EPA-821-R-98-002)	4
Polycyclic aromatic hydrocarbons	SW-846 Method 8270 PAH	6
Polychlorinated biphenyls	SW-846 Method 8082 PCB	8
ICP metals[b]	SW-846 Method 6010 ICP Metals[b]	7
Mercury	SW-846 Method 7470 or7471 Mercury	12
Soil Properties		
Bulk Density (Dry Unit weight)	ASTM D2937-17e2	11
Porosity	ASTM D4404-18	10
Moisture Content	ASTM D2216-19	9

Table 1-3. Laboratory Analytical Methods and Microbial Needs

Contaminant of Potential Concern	Analytical Method	Sample Priority[a]
Microbial Count		
Microbial Count	Determination of petroleum-degrading bacteria on 0.05 g petroleum source (PNNL-18645)	2
	Determination of petroleum-degrading bacteria population by most probable number (Brown and Braddock, 1990; Blodgett, 2010)	

Note: Complete reference citations are provided in Chapter 6.

a. Sample priorities 1 through 8 are important for decision making.

b. The expanded list of ICP metals was performed and included antimony, arsenic, barium, beryllium, boron, cadmium, chromium (total), cobalt, copper, lead, manganese, molybdenum, nickel, selenium, silver, vanadium, and zinc.

EPA = U.S. Environmental Protection Agency

ICP = inductively coupled plasma

PAH = polycyclic aromatic hydrocarbons

PCB = polychlorinated biphenyl

WTPH = northwest total petroleum hydrocarbons

1.2 Borehole Drilling and Logging

Borehole drilling will be performed in accordance with the substantive standards of WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells." Each borehole will be drilled to the water table and backfilled after sample collection is complete. Backfilling will be performed with bentonite or grout, and all temporary casing shall be removed from the borehole. Appendix B of this SAP describes the option to complete borehole D0072 as a deep injection well.

1.2.1 Geologic Logging

Soil samples shall be logged throughout the borehole by the field geologist according to CH2M HILL Plateau Remediation Company (CHPRC) procedures. The field geologist will collect drill cuttings every 1.5 m (5 ft) and at changes in lithology from surface to total depth for storage. Archive samples will be collected in pint-sized glass jars, and representative interval samples will be saved in chip trays. If representative samples cannot be collected, notes describing the condition of the samples will be entered into the field geologist's log. Archive samples will not be collected if contamination is encountered. The field geologist will collect grab samples for archives and examine material from the boreholes.

1.2.2 Geophysical Logging

Boreholes will be logged with the high-resolution spectral gamma logging system, and neutron moisture logging system to determine the vertical distribution and concentration of gamma-emitting radionuclides, soil moisture variations, and borehole lithology changes. The boreholes will be geophysically logged before downsizing each temporary casing string and/or at total drill depth and prior to well construction. The driller will assist the logging engineer by providing borehole access, depth to current water table, and hoisting support, as appropriate, to access the borehole when the logging crew is onsite. Logging is performed according to CHPRC procedures.

1.2.3 Field Screening

Field screening (radiological and industrial hygiene) will be performed by the radiological control technician (RCT), industrial hygiene technician, and other qualified personnel in accordance with approved methods and the applicable site health and safety plan. The RCTs will record field measurements, noting the depth of the sample and the instrument reading on a radiological survey report. Measurements will be communicated to the field geologist for inclusion in the field logbook or operational records daily, or as applicable. Coverage is typically provided twice a day in uncontaminated areas. More frequent coverage is provided in contaminated areas.

2 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 quality assurance (QA) elements found in EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans*, and DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD). DoD/DOE QSM, 2018, *Department of Defense (DoD) Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories*, is also discussed. Section 7.8 of the *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b; hereinafter called the Tri-Party Agreement Action Plan) requires the QA/quality control (QC) and sampling and analysis activities to specify the QA requirements for past-practice processes. This QAPjP also describes applicable requirements and controls based on guidance in Washington State Department of Ecology (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*. This QAPjP supplements the contractor's environmental QA program plan.

The QAPjP references are included in Chapter 6. The QAPjP includes the following sections, which describe the quality requirements and controls applicable to Hanford Site OU sampling activities:

- Section 2.1, "Project Management"
- Section 2.2, "Data Generation and Acquisition"
- Section 2.3, "Assessment and Oversight"
- Section 2.4, "Data Review and Usability"

2.1 Project Management

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

2.1.1 Project/Task Organization

Project organization is described in the following sections and illustrated in Figure 2-1.

2.1.1.1 Regulatory Agencies

The lead regulatory agency for the 100-NR-1 OU is Ecology. They are responsible for regulatory oversight of cleanup projects and activities. The U.S. Environmental Protection Agency (EPA) retains approval authority for all SAPs. Ecology works with EPA and 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 *Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989a; hereinafter called the Tri-Party Agreement).

2.1.1.2 DOE-RL Project Manager

Hanford Site cleanup in the 100-NR-1 OU is the responsibility of DOE-RL. The DOE-RL Manager is responsible for authorizing the contractor to perform activities at the Hanford Site under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*; *Resource Conservation and Recovery Act of 1976*; *Atomic Energy Act of 1954*; and the Tri-Party Agreement (Ecology et al., 1989a).

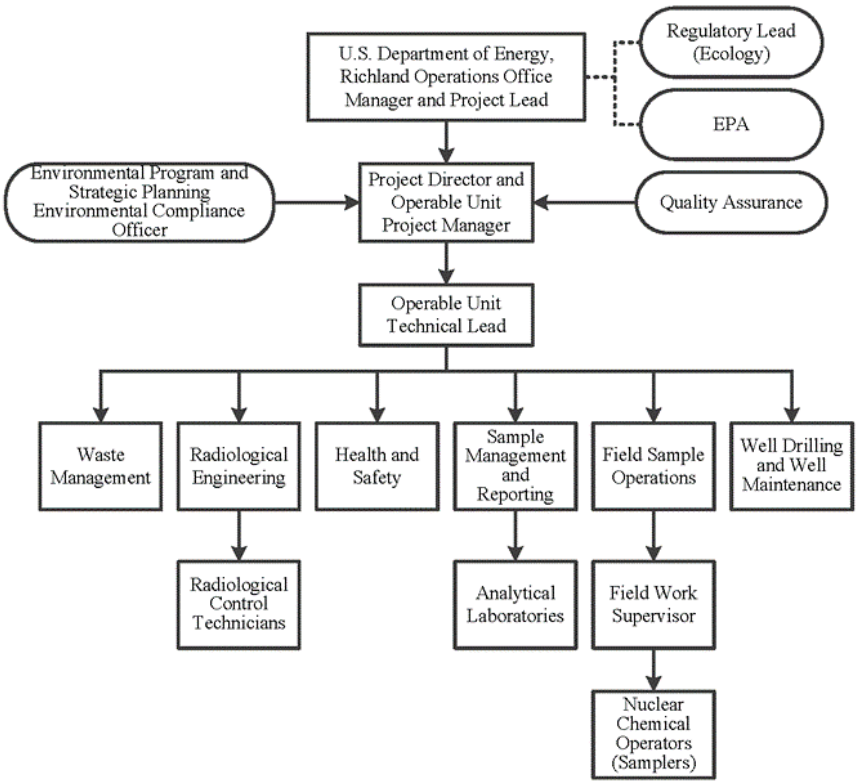

Figure 2-1. Project Organization

2.1.1.3 DOE-RL Project Lead

The DOE-RL Project Lead is responsible for providing day-to-day oversight of the contractor's performance of the work scope, working with the contractor to identify and work through issues, and providing technical input to the DOE-RL management.

2.1.1.4 S&GRP Remedy Selection & Implementation Director

The Soil and Groundwater Remediation Project (S&GRP) Remedy Selection & Implementation Director provides oversight and coordinates with DOE-RL and primary contractor management in support of sampling and reporting activities. The S&GRP Remedy Selection & Implementation Director also provides support to the OU Project Manager to ensure that work is performed safely and cost effectively.

2.1.1.5 Operable Unit Project Manager

The OU Project Manager (or designee) is responsible and accountable for the project-related activities including coordinating with DOE-RL, regulators, and contactor management in support of sampling activities to ensure work is performed safely, compliantly, and cost effectively. In addition, the OU Project Manager (or designee) is also responsible for managing sampling documents and requirements, field activities, subcontracted tasks, and for ensuring the project file is properly maintained.

2.1.1.6 Operable Unit Technical Lead

The OU Technical Lead is responsible for developing specific sampling design, analytical requirements, and QC requirements, either independently or as defined through a systematic planning process. The OU Technical Lead ensures that sampling and analysis activities, as delegated by the OU Project Manager, are carried out in accordance with the SAP and works closely with the Environmental

Compliance Officer (ECO), QA, Health and Safety, the Field Work Supervisor (FWS), and the Sample Management and Reporting (SMR) group to integrate these and other technical disciplines in planning and implementing the work scope.

2.1.1.7 Sample Management and Reporting

The SMR group oversees offsite analytical laboratories, coordinates laboratory analytical work to ensure that laboratories conform to the requirements of this plan, and verifies that laboratories are qualified for performing Hanford Site analytical work. The SMR group generates field sampling documents, labels, and instructions for field sampling personnel and develops the sample authorization form, which provides information and instruction to the analytical laboratories. The SMR group ensures that field sampling documents are revised to reflect approved changes. The SMR group receives analytical data from the laboratories, ensures the data are appropriately reviewed, performs data entry into the Hanford Environmental Information System (HEIS) database, and arranges for data validation and recordkeeping. The SMR group is responsible for resolving sample documentation deficiencies or issues associated with Field Sample Operations (FSO), laboratories, or other entities. The SMR group is responsible for informing the OU Project Manager of any issues reported by the analytical laboratories.

2.1.1.8 Field Sampling Operations

FSO is responsible for planning and coordinating field sampling resources. The FWS directs the nuclear chemical operators (samplers), who collect samples in accordance with this sampling plan and corresponding standard methods and work packages. The FWS ensures that deviations from field sampling documents or issues encountered in the field are documented appropriately (e.g., in the field logbook). The FWS ensures that samplers are appropriately trained and available. Samplers collect samples in accordance with sampling requirements. Samplers also complete field logbooks, data forms, and chain-of-custody forms, including any shipping paperwork, and enable delivery of the samples to the analytical laboratory.

Pre-job briefings are conducted by FSO, in accordance with work management and work release requirements, to evaluate activities and associated hazards by considering the following factors:

- Objective of the activities
- Individual tasks to be performed
- Hazards associated with the planned tasks
- Controls applied to mitigate the hazards
- Environment in which the job will be performed
- Facility where the job will be performed
- Equipment and material required

2.1.1.9 Quality Assurance

The QA point of contact provides independent oversight and is responsible for addressing QA issues on the project, overseeing implementation of the project QA requirements. Responsibilities include reviewing project documents including the QAPjP, and participating in QA assessments on sample collection and analysis activities, as appropriate.

2.1.1.10 Environmental Compliance Officer

The ECO provides technical oversight, direction, and acceptance of project and subcontracted environmental work and develops appropriate mitigation measures with the goal of minimizing adverse environmental impacts.

2.1.1.11 Health and Safety

The Health and Safety organization is responsible for coordinating industrial safety and health support within the project as carried out through health and safety plans, job hazard analyses, and other pertinent safety documents required by federal regulation or internal primary contractor work requirements.

2.1.1.12 Radiological Engineering

Radiological Engineering 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 RCT support

2.1.1.13 Waste Management

Waste Management is responsible for identifying waste management sampling/characterization requirements to ensure regulatory compliance and for interpreting data to determine waste designations and profiles. Waste Management communicates policies and practices and ensures project compliance for storage, transportation, disposal, and waste tracking in a safe and cost-effective manner.

2.1.1.14 Analytical Laboratories

The analytical laboratories analyze samples in accordance with established methods and the requirements of their subcontract, and provide necessary data packages containing analytical and QC results. Laboratories provide explanations of results to support data review and in response to resolution of analytical issues. Laboratory quality requirements are consistent with HASQARD (DOE/RL-98-68). The laboratories are evaluated under the U.S. Department of Energy (DOE) Consolidated Audit-Accreditation Program (DOECAP-AP) or its successor programs to DoD/DOE QSM, 2018 requirements. HASQARD requirements, beyond those within the DoD/DOE QSM, are also evaluated under the DOECAP-AP. Laboratories are accredited by Ecology for the analyses performed for CH2M HILL Plateau Remediation Company.

2.1.1.15 Well Drilling and Well Maintenance

The well drilling and maintenance and well coordination planning managers are responsible for the following:

- Planning, coordinating, and executing drilling construction
- Well maintenance activities
- Coordinating with the OU Technical Lead about field constraints that could affect sampling design
- Coordinating well decommissioning with DOE-RL in accordance with the substantive standards of WAC 173-160, “Minimum Standards for Construction and Maintenance of Wells”

2.1.2 Quality Objectives and Criteria

The QA objective of this plan is to ensure the generation of analytical data of known and appropriate quality is acceptable and useful in order to meet the evaluation requirements stated in the sampling plan. Data descriptors known as data quality indicators (DQIs) help determine the acceptability and usefulness of data to the user. The principal DQIs (precision, accuracy, representativeness, comparability, completeness, bias, and sensitivity) are defined for the purposes of this document in Table 2-1.

Table 2-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Precision (field duplicates, laboratory sample duplicates, and matrix spike duplicates)	Precision measures the agreement among a set of replicate measurements. Field precision is assessed through the collection and analysis of field duplicates. Analytical precision is estimated by duplicate/replicate analyses, usually on laboratory control samples, 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 relative percent difference.	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 objective: • Evaluate apparent cause (e.g., sample heterogeneity). • Request reanalysis or remeasurement. • Qualify the data before use.
Accuracy (laboratory control samples, matrix spikes, surrogates, tracers)	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, laboratory control samples, 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 objective: • Qualify the data before use. • Request reanalysis or remeasurement.
Representativeness (field duplicates)	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 that 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 results not being representative. • Flag for further review. • Review 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 2-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Comparability (field duplicate, field splits, laboratory control samples, matrix spikes, and matrix spike duplicates)	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 (no QC element; addressed in data quality assessment)	Completeness is a measure of the amount of valid data collected compared to the amount planned. Measurements are considered 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 (data quality objectives 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 (equipment blanks, full trip blanks, laboratory control samples, matrix spikes, and method blanks)	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 practices to limit preferential selection or loss of sample media. • Use sample handling practices, 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. • 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 laboratories for analysis.

Table 2-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Sensitivity (method detection limit, practical quantitation limit, and relative percent difference)	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 [b] is the lowest level that can be routinely quantified and reported by a laboratory.	If detection limits do not meet objective: • Request reanalysis or remeasurement using methods or analytical conditions that will meet required detection or limit of quantitation. • Qualify/reject the data before use.

Source: SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods Compendium*.

a. Acceptance criteria for QC elements are provided in Table 2-5.

b. For purposes of this sampling plan, the lower limit of quantitation is interchangeable with the practical quantitation limit.

QA = quality assurance

QC = quality control

Data quality is defined by the degree of rigor in the acceptance criteria assigned to the DQIs. 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 a data usability assessment process (Section 2.4.3).

2.1.3 Methods-Based Analysis

Laboratory testing for analytes described in Section 2.2.1 may include nontarget analytes that are part of the analytical method (i.e., methods-based reporting). The additional constituents that are part of the method and reported by the laboratory are for informational purposes. Analytical performance requirements will be applicable only to the analytes specific to this SAP. Poor QC related to nontarget analyte results would not result in any required corrective action by the laboratory, except for the application of proper result qualification flags.

2.1.4 Analytical Priority

If sample volume is insufficient to analyze for all analytes, the highest priority analytes critical for supporting waste site decisions are required to be analyzed. Lowest priority analytes not critical for supporting waste site decisions will be analyzed only if sufficient sample volumes are collected. Sample priority is identified in Table 1-3. Sample priorities 1 through 8 are important for decision making.

2.1.5 Special Training/Certification

Workers receive a level of training that is commensurate with their responsibility for collecting and transporting samples and compliant with applicable DOE orders and government regulations. The FWS, in coordination with line management, will ensure that special training requirements for field personnel are met.

Training has been instituted by the contractor management team to meet training and qualification programs that satisfy multiple training drivers imposed by applicable DOE, *Code of Federal Regulations*, and *Washington Administrative Code* requirements.

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 fieldwork.

2.1.6 Documentation and Records

The OU Project Manager (or designee) is responsible for ensuring the current version of the SAP is being used and providing any updates to field personnel. Version control is maintained by the administrative document control process. Table 2-2 defines the types of changes that may impact the sampling and the associated approvals, notifications, and documentation requirements.

Table 2-2. Change Control for Sampling Projects

Type of Change [a]	Action	Documentation
Minor Field Change. Changes that have no adverse effect on the technical adequacy of the sampling activity or the work schedule.	The field personnel recognizing the need for a field change will consult with the OU Project Manager (or designee) 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.
Minor Change. Changes to approved plans that do not affect the overall intent of the plan or schedule.	The OU Project Manager will inform DOE-RL and the Regulatory Lead of the change. The Ecology and EPA determine if there is no need to revise the document.	Documentation of this change approval would be in the Project Manager's Meeting minutes and comparable Tri-Party Agreement Change Notice.[b]
Revision Necessary. Lead regulatory agency determines if changes to approved plans require revision to document.	If it is anticipated that a revision is necessary, the OU Project Manager will inform DOE-RL and the Regulatory Lead (Ecology). EPA determine if the change requires a revision to the document.	Formal revision of the sampling document.

References: DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Documents*.

Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement).

Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan*.

a. Consistent with DOE/RL-96-68 and Sections 9.3 and 12.4 of Ecology et al., 1989b.

b. Section 9.3 of the Tri-Party Agreement Action Plan (Ecology et al., 1989b) defines the minimum elements of a change notice.

DOE-RL = U.S. Department of Energy, Richland Operations Office

Ecology = Washington State Department of Ecology

EPA = U.S. Environmental Protection Agency

OU = operable unit

Logbooks and data forms are required for field activities. The logbook must be identified with a unique project name and number. Only authorized individuals may make entries into the logbooks. Logbooks will be controlled in accordance with internal work requirements and processes.

The FWS, SMR, and any field crew supervisor 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 field sampling documents for the samplers and the analytical laboratory. The FWS or appropriate field crew supervisor will ensure that deviations from the SAP or problems encountered in the field are documented appropriately (e.g., in the field logbook).

The OU Project Manager, FWS, or designee, is responsible for communicating field corrective action requirements and ensuring that immediate corrective actions are applied to field activities. The OU Project Manager is also responsible for ensuring that project files are appropriately set up and maintained. The following are examples of documents and information that shall be included in the project file:

- 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
- Photographs

The following records are managed and maintained by SMR personnel:

- Completed field sampling logbooks
- Field drilling and analytical data
- Field equipment calibration data
- Groundwater sample reports and field sample reports
- Completed 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

Convenience copies of laboratory analytical results are maintained in the HEIS database. Records may be stored in either electronic (e.g., in the managed records area of the Integrated Document Management System) or hard copy format (e.g., DOE Records Holding Area). Documentation and records, regardless of medium or format, are controlled in accordance with internal work requirements and processes that ensure accuracy and retrievability of stored records. Records required by the Tri-Party Agreement (Ecology et al., 1989a) will be managed per Tri-Party Agreement requirements.

2.2 Data Generation and Acquisition

This section addresses data generation and acquisition to ensure that the project's methods for sampling measurement and analysis, data collection and generation, data handling, and QA/QC activities are appropriate and documented. Requirements for instrument calibration and maintenance, supply inspections, and data management are also addressed.

2.2.1 Analytical Methods Requirements

Table 2-3 provides information regarding analytical method requirements for samples collected. Updated EPA methods and nationally recognized standard methods may be substituted for the analytical methods identified in Table 2-3 in order to follow changed requirements in the method update. The new method shall achieve project DQOs as well or better than the replaced method, and is required due to the nature of the sample (e.g., high radioactivity).

Table 2-3. Performance Requirements for Soil Analysis

Constituent/Parameter	CAS Number	Analytical Method	Highest Allowable PQL (µg/kg)*
Petroleum			
Total petroleum hydrocarbons – diesel range	TPHDIESEL	Method WTPH-diesel range (Ecology Publication No. ECY 97-602)	25,000
Total petroleum hydrocarbons – motor oil	TPHMOTOR OIL	EPA Method WTPH-motor oil range (Ecology Publication No. ECY 97-602)	25,000
Oil and grease	OIL/GREASE	EPA Method 1664 (EPA-821-R-98-002)	200,000
Total extractable hydrocarbon fractions	Aliphatic fraction	EPA Method WTPH-aliphatic fraction (Ecology Publication No. ECY 97-602)	1,330
	Aromatic fraction	EPA Method aromatic fraction (Ecology Publication No. ECY 97-602)	1,300
Polycyclic Aromatic Hydrocarbons			
Anthracene (PAH)	120-12-7	SW-846 Method 8270 (SIM)	50
Benzo(a)anthracene (PAH)	56-55-3	SW-846 Method 8270 (SIM)	15
Benzo(a)pyrene (PAH)	50-32-8	SW-846 Method 8270 (SIM)	15
Benzo(b)fluoranthene (PAH)	205-99-2	SW-846 Method 8270 (SIM)	15
Benzo(ghi)perylene (PAH)	191-24-2	SW-846 Method 8270 (SIM)	30
Benzo(k)fluoranthene (PAH)	207-08-9	SW-846 Method 8270 (SIM)	15
Chrysene (PAH)	218-01-9	SW-846 Method 8270 (SIM)	40
Dibenz[a,h]anthracene (PAH)	53-70-3	SW-846 Method 8270 (SIM)	30
Fluoranthene (PAH)	206-44-0	SW-846 Method 8270 (SIM)	40
Fluorene (PAH)	86-73-7	SW-846 Method 8270 (SIM)	30
Indeno(1,2,3-cd)pyrene (PAH)	193-39-5	SW-846 Method 8270 (SIM)	30
Naphthalene (PAH)	91-20-3	SW-846 Method 8270 (SIM)	40
Phenanthrene (PAH)	85-01-8	SW-846 Method 8270 (SIM)	10
Pyrene (PAH)	129-00-0	SW-846 Method 8270 (SIM)	40
Inorganics and Mercury			
Aluminum	7429-90-5	SW-846 Method 6010/6020	20,000
Antimony	7440-36-0	SW-846 Method 6010/6020	1,200
Arsenic	7440-38-2	SW-846 Method 6010/6020	10,000
Barium	7440-39-3	SW-846 Method 6010/6020	5,000
Beryllium	7440-41-7	SW-846 Method 6010/6020	500
Bismuth	7440-69-9	SW-846 Method 6010/6020	20,000
Boron	7440-42-8	SW-846 Method 6010/6020	5,000
Cadmium	7440-43-9	SW-846 Method 6010/6020	500
Calcium	7440-70-2	SW-846 Method 6010/6020	100,000
Chromium	7440-47-3	SW-846 Method 6010/6020	1,000

Table 2-3. Performance Requirements for Soil Analysis

Constituent/Parameter	CAS Number	Analytical Method	Highest Allowable PQL (µg/kg)*
Cobalt	7440-48-4	SW-846 Method 6010/6020	5,000
Copper	7440-50-8	SW-846 Method 6010/6020	2,500
Iron	7439-89-6	SW-846 Method 6010/6020	25,000
Lead	7439-92-1	SW-846 Method 6010/6020	5,000
Lithium	7439-93-2	SW-846 Method 6010/6020	5,000
Magnesium	7439-95-4	SW-846 Method 6010/6020	100,000
Manganese	7439-96-5	SW-846 Method 6010/6020	5,000
Molybdenum	7439-98-7	SW-846 Method 6010/6020	4,000
Nickel	7440-02-0	SW-846 Method 6010/6020	4,000
Potassium	7440-09-7	SW-846 Method 6010/6020	500,000
Phosphorus	7723-14-0	SW-846 Method 6010/6020	50,000
Selenium	7782-49-2	SW-846 Method 6010/6020	10,000
Silicon	7440-21-3	SW-846 Method 6010/6020	40,000
Silver	7440-22-4	SW-846 Method 6010/6020	1,000
Sodium	7440-23-5	SW-846 Method 6010/6020	100,000
Strontium (elemental)	7440-24-6	SW-846 Method 6010/6020	1,000
Sulfur	7704-34-9	SW-846 Method 6010/6020	200,000
Thallium	7440-28-0	SW-846 Method 6010/6020	5,000
Tin	7440-31-5	SW-846 Method 6010/6020	10,000
Titanium	7440-32-6	SW-846 Method 6010/6020	2,000
Vanadium	7440-62-2	SW-846 Method 6010/6020	5,000
Zinc	7440-66-6	SW-846 Method 6010/6020	5,000
Mercury	7439-97-6	SW-846 Method 7470 or 7471	200
Polychlorinated Biphenyls			
Aroclor-1016	12674-11-2	SW-846 Method 8082	33 (1,000 for oil)
Aroclor-1221	11104-28-2	SW-846 Method 8082	33 (1,000 for oil)
Aroclor-1232	11141-16-5	SW-846 Method 8082	33 (1,000 for oil)
Aroclor-1242	53469-21-9	SW-846 Method 8082	33 (1,000 for oil)
Aroclor-1248	12672-29-6	SW-846 Method 8082	33 (1,000 for oil)
Aroclor-1254	11097-69-1	SW-846 Method 8082	33 (1,000 for oil)
Aroclor-1260	11096-82-5	SW-846 Method 8082	33 (1,000 for oil)
Aroclor-1262	37324-23-5	SW-846 Method 8082	33 (1,000 for oil)
Aroclor-1268	11100-14-4	SW-846 Method 8082	33 (1,000 for oil)

Table 2-3. Performance Requirements for Soil Analysis

Constituent/Parameter	CAS Number	Analytical Method	Highest Allowable PQL (µg/kg)*
Microbial Testing			
N/A	N/A	Determination of petroleum degrading bacteria on 0.05 g petroleum source (PNNL-18645)	N/A
N/A	N/A	Determination of petroleum degrading bacteria population by most probable number (Brown and Braddock, 1990; Blodgett, 2010)	N/A
Physical Properties			
Bulk Density	N/A	ASTM D2937-17e2	N//A
Porosity	N/A	ASTM D4404-18	NA
Moisture Content	N/A	ASTM D2216-19	N/A

Note: Complete reference citations are provided in Chapter 6.

*Highest allowable PQLs are specified in contracts with analytical laboratories. Actual quantitation limits vary by laboratory and may be lower. Method detection limits are three to five times lower than PQLs. Where project-specific action levels are greater than contract-specified HAPQLs, the contract-specified HAPQL is given. Where project-specific action levels are less than contract-specified HAPQLs, a HAPQL that is lower than the action level is given, provided that the lower HAPQL is technically achievable under routine operating conditions by laboratories under contract.

CAS = Chemical Abstracts Service
EPA = U.S. Environmental Protection Agency
HAPQL = highest allowable PQL
N/A = not applicable
PQL = practical quantitation limit
SIM = selected ion monitoring

2.2.2 Field Analytical Methods

Field screening and survey data will be measured consistent with HASQARD (DOE/RL-96-68). Field analytical methods are performed in accordance with the manufacturers' manuals.

2.2.3 Quality Control Requirements

The QC requirements specified in the 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 to provide information pertinent to sampling variability. Laboratory QC samples estimate the precision, bias, and matrix effects of the analytical data. Field and laboratory QC samples are summarized in Table 2-4. Acceptance criteria for field and laboratory QC are shown in Table 2-5. Data will be qualified and flagged in HEIS, as appropriate.

2.2.3.1 Field Quality Control 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, field split (SPLIT) samples, and two types of field blanks (equipment blanks and full trip blanks [FTBs]). Field blanks are typically prepared using high-purity reagent water.[3] QC sample definitions and their required frequency for collection are described below.

[3] Reagent water is high-purity water that is generally defined as water that has been distilled, deionized, or any combination of distillation, deionization, reverse osmosis, activated carbon filtration, ion exchange, particulate filtration, or other polishing techniques (HASQARD; DOE/RL-96-68).

Table 2-4. Quality Control Samples

Sample Type	Primary Characteristics Evaluated	Frequency
Field Quality Control		
Equipment Blanks	Contamination from nondedicated sampling equipment	As needed[a,b]
Full Trip Blanks	Contamination from containers, preservative reagents, storage, or transportation	1 in 20 sampling event (well trips[c] or other media samples)
Field Transfer Blank	Contamination from sampling site	1 each day VOCs are sampled; additional field transfer blanks are collected if VOC samples are acquired on the same day for multiple laboratories (wells or other media samples)
Field Duplicate Samples	Reproducibility/sampling precision	1 in 20 sampling events (well trips or other media samples[c])
Field Splits Samples	Inter-laboratory comparability	As needed When needed, the minimum is one for every analytical method, for analyses performed.
Laboratory Batch Quality Control[d]		
Method Blanks	Laboratory contamination	1 per analytical batch[e]
Laboratory Sample Duplicates	Laboratory reproducibility and precision	1 per analytical batch[e]
Matrix Spikes	Matrix effect/laboratory accuracy	1 per analytical batch[e]
Matrix Spike Duplicates	Laboratory reproducibility, and method accuracy and precision	1 per analytical batch[e]
Surrogates	Recovery/yield for organic compounds	Added to each sample and quality control
Laboratory Control	Method accuracy	1 per analytical batch[e]

Note: The information in this table does not represent U.S. Environmental Protection Agency or Washington State Department of Ecology requirements; it is intended solely as guidance.

a. For portable Grundfos® pumps, equipment blanks are collected 1 per 10 well trips. Whenever a new type of nondedicated equipment is used, an equipment blank shall be collected every time sampling occurs until it can be shown that less frequent collection of equipment blanks is adequate to monitor the decontamination procedure for the nondedicated equipment.

b. Vendor-provided borehole equipment is considered dedicated equipment and equipment blanks are not typically acquired in this instance.

c. A "well trip" is defined as any time a well is accessed for sampling. For groundwater monitoring, field duplicates and full trip blanks are run at a frequency of 1 in 20 well trips (i.e., 5% of the well trips) for all groundwater monitoring wells sampled within any given month (not just those restricted to a single TSD unit). For example, if a month has 181 wells scheduled, then 10 field duplicates will be collected.

d. Batching across projects is allowed for similar matrices (e.g., Hanford Site groundwater).

e. Unless not required by or different frequency is called out in laboratory analysis method.

®Grundfos is a registered trademark of Grundfos Corporation, Bjerringbro, Denmark.

TSD = treatment, storage, and disposal

VOC = volatile organic compound

Table 2-5. Field and Laboratory Quality Control Elements and Acceptance Criteria

Analyte[a]	Quality Control Element	Acceptance Criteria	Corrective Action
Petroleum			
Total Petroleum Hydrocarbons – by GC	MB	<MDL <5% sample concentration	Flag with "B"
	LCS	70% to 130% recovery or % recovery statistically derived[f]	Flag with "o"[b]
	DUP[c] or MS/MSD[d]	≤30% RPD	Review data[e]
	MS/MSD[d]	70% to 130% recovery	Flag with "N"
	SUR	60% to 140% recovery	Review data[e]
Extractable Petroleum Hydrocarbons by GC (aliphatic and aromatic hydrocarbon fractions)	MB	<MDL <5% sample concentration	Flag with "B"
	LCS	70% to 130% recovery or % recovery statistically derived[f]	Flag with "o"[b]
	DUP[c] or MS/MSD[d]	≤20% RPD	Review data[e]
	MS/MSD[d]	70% to 130% recovery	Flag with "N"
	SUR	60% to 140% recovery	Review data[e]
Oil and Grease			
Oil and Grease	MB	<MDL <5% sample concentration	Flag with "C"
	LCS	70% to 130% recovery	Flag with "o"[b]
	DUP[c] or MS/MSD[d]	≤35% RPD[d]	Review data[e]
	MS/MSD[d]	75% to 125% recovery	Flag with "N"
Polycyclic Aromatic Hydrocarbon			
Polycyclic Aromatic Hydrocarbon by GC-MS	MB	<MDL <5% sample concentration	Flag with "B"
	LCS	70% to 130% recovery or % recovery statistically derived[f]	Flag with "o"[b]
	DUP[c] or MS/MSD[d]	≤30% RPD	Review data[e]
	MS/MSD[d]	% recovery statistically derived[f]	Flag with "T"
	SUR	% recovery statistically derived[f]	Review data[e]
Inorganics			
Metals by ICP-MS/AES	MB	<MDL <5% sample concentration	Flag with "C"
	LCS	80% to 120% recovery	Flag with "o"[b]
	DUP[c] or MS/MSD[d]	≤35% RPD	Review data[e]
	MS/MSD[d]	75% to 125% recovery	Flag with "N"

Table 2-5. Field and Laboratory Quality Control Elements and Acceptance Criteria

Analyte[a]	Quality Control Element	Acceptance Criteria	Corrective Action
Polychlorinated Biphenyls			
Polychlorinated Biphenyls by GC	MB	<MDL <5% sample activity concentration	Flag with "B"
	LCS	70% to 130% recovery or % recovery statistically derived[f]	Flag with "o"[b]
	DUP[c] or MS/MSD[d]	≤30% RPD[d]	Review data[e]
	MS/MSD[d]	% recovery statistically derived[f]	Flag with "N"
	SUR	<% recovery statistically derived[f]	Review data[e]

References: DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document*.

SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods Compendium*.

Notes: The table is consistent with SW-846 and DOE/RL-96-68.

This table applies only to laboratory analyses. Depth to groundwater, dissolved oxygen, oxidation-reduction potential, pH, specific conductance, temperature, and turbidity are not listed because they are measured in the field.

a. Specific analytes and methods for determination are available from the SMR group.

b. Apply with SMR concurrence.

c. Applies when at least one result is greater than the laboratory PQL (chemical analyses) or over five times the MDC (radiochemical analyses).

d. Either a sample duplicate or a matrix spike duplicate is to be analyzed to determine measurement precision (if there is insufficient sample volume, an LCSD is analyzed with the acceptance criteria defaulting to the DUP/MSD criteria).

e. After review, corrective actions are determined on a case-by-case basis. Corrective actions may include a laboratory recheck or flagging data.

f. Laboratory determined statistically derived control limits based on historical data are used here. Control limits are reported with the data.

Data Flags:

B, C = possible laboratory contamination: analyte was detected in the associated method blank – laboratory applied.

o = result may be biased: associated laboratory control sample result was outside the acceptance limits – laboratory applied.

N = result may be biased: associated matrix spike result was outside the acceptance limits – laboratory applied.

T = result may be biased: associated matrix spike result was outside the acceptance limits (GC-MS only) – laboratory applied.

DUP = duplicate
GC = gas chromatography
GC-MS = gas chromatography – mass spectrometry
ICP-MS/AES = inductively coupled plasma – mass spectrometry/atomic emission spectroscopy
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MB = method blank
MDC = minimum detectable concentration
MDL = method detection limit
MS = matrix spike
MSD = matrix spike duplicate
PQL = practical quantitation limit
QC = quality control
RPD = relative percent difference
SMR = Sample Management and Reporting
SUR = surrogate

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

Field 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.

Equipment blanks: High-purity water passed through or poured over decontaminated sampling equipment identical to the sample set collected and placed in sample containers, as identified on the sample authorization form. Equipment blank sample bottles are placed in the storage containers with samples from the associated sampling event and are analyzed for the same constituents as samples from

the sampling event. Equipment blanks are used to evaluate decontamination process effectiveness; these samples are not required for disposable sampling equipment.

Full trip blanks: Bottles prepared by the sampling team before travel to the sampling site. The preserved bottle set is either for volatile organic analysis only or identical to the set that will be collected in the field. It is filled with high-purity water or silica sand 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 sample contamination from the sample bottles, preservative, handling, storage, and transportation.

2.2.3.2 Laboratory QC Samples

Internal QA/QC programs are maintained by laboratories used by the project. Laboratory QA includes a comprehensive QC program that includes the use of laboratory control samples, laboratory sample duplicates, matrix spikes, matrix spike duplicates, and method blanks. These QC analyses are required by EPA methods (e.g., those in SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods Compendium*), and will be run at the frequency specified in the respective references unless superseded by agreement. QC checks outside of control limits are documented in analytical laboratory reports during data usability assessments, if performed. Laboratory QC checks and their typical frequencies are listed in Table 2-4. Acceptance criteria are shown in Table 2-5. Descriptions of the various types of laboratory QC samples are provided below.

- **Laboratory control sample**: A control matrix (e.g., reagent water) spiked with analytes representing the target analytes or certified reference material used to evaluate laboratory accuracy.
- **Laboratory sample duplicate**: An intra-laboratory replicate sample that is used to evaluate the precision of a method in a given sample matrix.
- **Matrix spike**: An aliquot of a sample spiked with a known concentration of target analyte(s). The matrix spike is used to assess the bias of a method in a given sample matrix. Spiking occurs prior to sample preparation and analysis.
- **Matrix spike duplicate**: A replicate spiked aliquot of a sample that is subjected to the entire sample preparation and analytical process. Matrix spike duplicate results are used to determine the bias and precision of a method in a given sample matrix.
- **Method blank**: An analyte-free matrix to which the same reagents are added in the same volumes or proportions as used in the sample processing. The method blank is carried through the sample preparations and analytical procedure and is used to quantify contamination resulting from the analytical process.
- **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 generally added to an aliquot of sample prior to the sample preparation step. A tracer does not chemically interfere with the target radioisotope during radiochemical preparation, separation, and counting. Sample results are generally corrected based on tracer recovery.
- **Hold time**: Laboratories are required to analyze samples within the holding times specified in Table 2-6. In some instances, constituents in the samples not analyzed within the holding times may be compromised by volatilization, decomposition, or by other chemical changes. Data from samples analyzed outside of the holding times are flagged in the HEIS database with an “H.”

Table 2-6. Soil Holding Time Guidelines for Laboratory Analytes

Constituent/Parameter	Preservation*	Holding Time
Hydrocarbons		
Total petroleum hydrocarbons – diesel range	Store ≤6°C (43°F)	14/40 14 days to extraction 40 days post-extraction
Total petroleum hydrocarbons – motor oil		14/40 14 days to extraction 40 days post-extraction
Oil and grease		28 days
Polycyclic aromatic hydrocarbons		14/40 14 days to extraction 40 days post-extraction
Inorganics		
Mercury	None	28 days
Metals		6 months
Polychlorinated Biphenyls		
Polychlorinated biphenyls	Store ≤6°C (43°F)	1 year
Microbial Testing		
Microbial counts	Store ≤6°C (43°F)	Immediately – 24 hours
Physical Properties		
Bulk density	None	Not applicable
Porosity		
Moisture content	Store ≤6°C (43°F)	14 days

Notes: The information in this table does not represent U.S. Environmental Protection Agency requirements but is intended solely as guidance. Selection of containers, preservation techniques, and applicable holding times should be based on the stated project-specific data quality objectives.

Container types and volumes will be identified on the chain-of-custody form.

*For preservation identified as stored at ≤6°C (43°F), the sample should be protected against freezing unless it is known that freezing will not impact the sample integrity. Bottle requirements shall be identified by the Sample Management and Reporting group.

2.2.4 Measurement Equipment

Each measuring equipment user is responsible to ensure the equipment is functioning as expected, properly handled, and properly calibrated at required frequencies per methods governing control of the 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.

2.2.5 Instrument and Equipment Testing, Inspection, and Maintenance

Collection, measurement, and testing equipment should meet applicable standards (e.g., ASTM International, formerly the American Society for Testing and Materials) 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 in the 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.

2.2.6 Instrument/Equipment Calibration and Frequency

Field equipment calibration is discussed in Section 3.5. Analytical laboratory instruments are calibrated in accordance with the laboratory's QA plan and applicable Hanford Site requirements.

2.2.7 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.

2.2.8 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 data generated as part of any sampling and analysis QA/QC effort. Data used in evaluations will be identified by data source.

2.2.9 Data Management

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

Electronic data access, when appropriate, will be through a Hanford Site database (e.g., HEIS). Where electronic data are not available, hard copies will be provided in accordance with Section 9.6 of the Tri-Party Agreement Action Plan (Ecology et al., 1989b).

Laboratory errors are reported to the SMR group through an established process. 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.

2.3 Assessment and Oversight

Assessment and oversight activities 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.

2.3.1 Assessments and Response Action

Management assessments and/or independent assessments may be performed to verify compliance with the SAP (e.g., project field instructions, the QAPjP, and analytical methods). Deficiencies identified by these assessments will be reported in accordance with existing programmatic requirements. The project line management chain coordinates the corrective actions/deficiency resolutions in accordance with the QA program, 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 SMR group oversees offsite analytical laboratories and verifies the laboratories are qualified to perform Hanford Site analytical work.

2.3.2 Reports to Management

Program and project management (as appropriate) will be made aware of deficiencies identified by management assessments, corrective actions from ECOs, and findings from independent assessments and surveillances. Issues reported by the laboratories are communicated to the SMR group, 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. If an assessment finding results in sampling issues that affect a regulatory requirement, DOE will be informed and the matter discussed with the regulatory agencies.

2.4 Data Review and Usability

This section addresses QA activities that occur after data collection. Implementation of these activities determines whether the data conform to the specified criteria, thus satisfying the project objectives.

2.4.1 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, and reviewing sample collection dates and sample preparation and analysis dates to assess whether holding times, if any, have been met. Furthermore, review of QC data is used 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. Field QA/QC results will be reviewed to ensure they are usable.

The OU Technical Lead performs data reviews to help determine if observed changes reflect potential data errors, which may result in submitting a request for data review on questionable data. The laboratory may be asked to check calculations or reanalyze the sample. In extreme cases, another sample may be collected. Results of the request for the data review process are used to flag the data appropriately in the HEIS database and/or to add comments.

2.4.2 Data Validation

Data validation is an independent, third-party assessment to ensure the reliability of the data. Analytical data validation provides a level of assurance that an analyte is present or absent. Validation may also include the following:

- Verification of instrument calibrations
- Evaluation of analytical results based on method blanks
- Recovery of various internal standards
- Correctness of uncertainty calculations
- Correctness of identification and quantification of analytes
- The effect of quality deficiencies on data reliability

The contractor follows the data validation process described in EPA/240/R-02/004, *Guidance on Environmental Data Verification and Data Validation*; EPA-540-R-2017-001, *National Functional Guidelines for Inorganic Superfund Methods Data Review*; and EPA-540-R-2017-002, *National Functional Guidelines for Organic Superfund Methods Data Review*, adjusted for use with SW-846, HASQARD (DOE/RL-96-68), and radiochemistry methods. The criteria for data validation are based on a graded approach, using five levels of validation: Levels A through E. Level A is the lowest level and is the same as verification. Level E is a 100% review of all data (e.g., calibration data and calculations of representative samples from the data set). Data validation will be performed to Level C, which is a review of the QC data. Level C validation consists of a review of the QC data and specifically requires verification of deliverables; requested versus reported analytes; and qualification of the results based on evaluation of analytical holding times, method blank results, MS/MSD results, surrogate recoveries, and duplicate sample results. Level C data validation is generally equivalent to Level 2A in EPA 540-R-08-005, *Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use*. Level C data validation will be performed on at least 5% of the data by matrix and analyte group under the direction of SMR. Analyte group refers to categories such as radionuclides, volatile chemicals, semivolatiles, metals, and anions. The goal is to include each of the various analyte groups and matrices during the data validation process. The DOE-RL Project Lead or OU Project Manager may specify a higher percentage of data to be validated or that data validation be performed at higher levels.

2.4.3 Reconciliation with User Requirements

The purpose of reconciliation with user requirements is to determine if quantitative data are of the correct type and are of adequate quality and quantity to meet the project data needs. The data quality assessment (DQA) process is the scientific and statistical evaluation of previously verified and validated data to determine if information obtained from environmental data operations are of the right type, quality, and quantity to support their intended use (usability). The DQA process uses the entirety of the collected data to determine usability for decision making. If a statistical sampling design was utilized during field sampling activities, then the DQA will be performed following guidance in EPA/240/B-06/003, *Data Quality Assessment Statistical Methods for Practitioners*. When judgmental (focused) sampling designs are implemented in the field, DQIs such as precision, accuracy, representativeness, comparability, completeness, and sensitivity for the specific data sets (individual data packages) will be evaluated in accordance with EPA/240/R-02/004. Data verification and data validation are integral to both the statistical DQA data evaluation process and the DQI evaluation process. Results of the DQA or DQI processes generated by the SMR group will be used by the contractor OU Project Manager to interpret the data and determine if the DQOs for this activity have been met. DQAs and DQIs are documented in DQA and data usability reports.

3 Field Sampling Plan

This field sampling plan directs the sampling and analysis of vadose soils in the 100-NR-1 OU. In this OU, an in-situ bioremediation bioventing system is being used to clean up petroleum contamination in the vadose zone. The system supplies oxygen within the deep vadose zone to enhance natural microbiological degradation of petroleum contamination associated with the screen interval in two deep injection wells over a radius of 61 m (200 ft). This plan describes the sampling and analysis of soil to determine the effectiveness of the bioventing system to clean up petroleum contamination 16.1 to 23.3 m (52.8 to 76.5 ft) bgs, as well as confirm the nature and extent of petroleum contamination throughout the deep zone (4.6 to 23.3 m [15 to 76.5 ft]) bgs. A limited number of samples will also be collected in the shallow part of the vadose zone 0 to 4.6 m (15 ft) bgs to assess contamination in an unexcavated area called the bioventing islands (formally identified in WIDS as 100-N-107; Figure 1-3). Soil samples will also be collected periodically throughout the vadose zone to determine the population of biodegrading bacteria. Sampling shall be performed with lined split spoon samplers in conjunction with a drilling method that minimizes volatilization of organic compounds. Although split spooning works best in fine-grained sediments and is more difficult in the gravels, this method of sampling has been very successful on the Hanford Site, and sample recovery can be quite good. A sample priority list is identified in Table 1-3 to address insufficient sample recovery.

3.1 Sampling Objectives

The objectives of sampling and analysis are to provide data to evaluate the effectiveness of bioventing and determine the population of biodegrading bacteria in the subsurface. Characterization will be accomplished by drilling three boreholes and sampling and analyzing vadose zone soils. Soil samples will be collected and analyzed for COPCs, selected physical properties and to determine the population of TPH biodegrading bacteria present in the subsurface. Geologic and geophysical logging shall also be performed to better define stratigraphic relationship in the subsurface.

3.2 Sampling Design

The sampling design for this SAP is based on judgmental sampling. In judgmental sampling, the selection of sampling units (i.e., the number and location and/or timing of collecting samples) is based on knowledge of the feature or condition under investigation (i.e., previous sampling) and on professional judgment. Judgmental sampling is distinguished from probability-based sampling in that inferences are based on professional judgment, not statistical scientific theory. Therefore, conclusions about the target population are limited and depend entirely on the validity and accuracy of professional judgment. Probabilistic statements about parameters are not possible.

3.3 Sample Location Frequency and Constituents

Three boreholes (D0070, D0071, and D0072) will be drilled and sampled to evaluate chemical and microbial conditions in the subsurface at the bioventing site. The boreholes are positioned within 7.6 m (25 ft) of injection and monitoring wells where detected TPH-D concentrations in the deep vadose zone exceeded 3,000 mg/kg (Figure 1-13) in the year 2009 prior to bioventing. Figure 3-1 shows the location of each borehole.

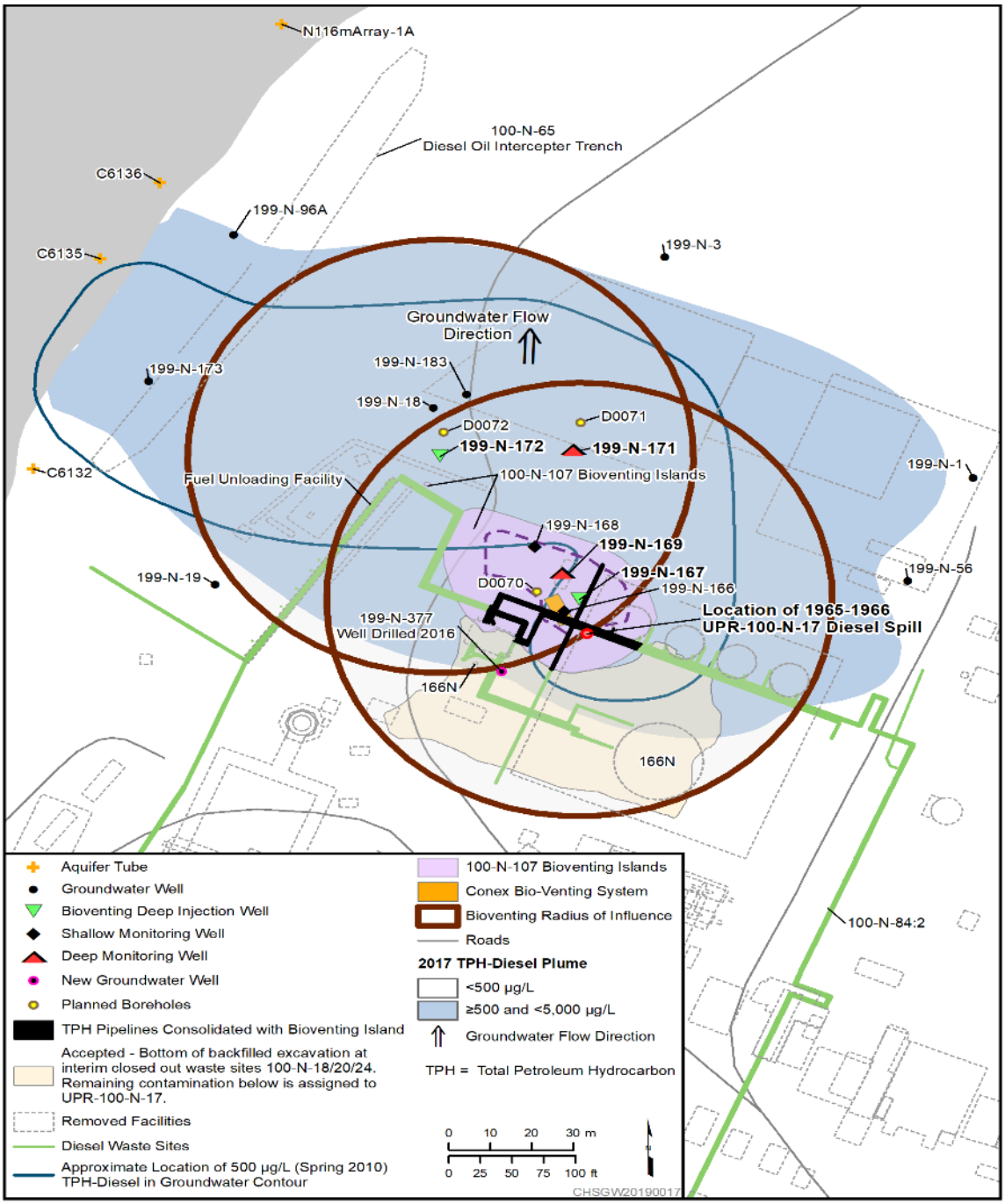

Figure 3-1. Location Map of Boreholes D0070, D0071, and D0072

3.3.1 Sampling and Analysis for Contaminants of Potential Concern

All soil samples collected for chemical analysis will be collected with a lined split-spoon sampler that shall not be overdriven. The liners shall consist of stainless steel or Lexan. Soil samples shall be homogenized and packaged according to procedure. With exception of borehole D0070, chemical sampling will commence at the top of the deep zone 4.6 m (15 ft) bgs. Samples shall be collected every 3 m (10 ft) to the top of the Ringold Formation (13.7 to 15.2 m [45 to 50 ft] bgs). Once the Ringold Formation is encountered, samples will be collected continuously to the water table. Additional samples will also be

collected 1.5 and 3.1 m (5 and 10 ft) bgs in borehole D0070, located within the Bioventing Island. At the discretion of the project scientist, additional samples may be collected based on field screening results and observations such as odor, discoloration, or elevated moisture content. Samples shall be analyzed in the laboratory for the COPCs identified in Table 3-1. Analytical methods are identified in Table 1-3. The generic sample design for the three boreholes are shown in Figure 3-2 and summarized in Table 3-1.

3.3.2 Sampling and Analysis for Petroleum Degrading Bacteria

Three soil samples shall be collected in each borehole for petroleum-degrading bacteria. In each borehole, one sample shall be collected from the Hanford formation, the Rwie above the PRZ, and within the PRZ of the Rwie. The presence and population of petroleum degrading bacteria shall be determined according to the methods in Table 1-3. The generic sample design for the three boreholes are shown in Figure 3-2 and summarized in Table 3-1.

3.4 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. Only authorized persons may make entries in logbooks. Logbooks 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. The following information is to be recorded in logbooks or on the data forms:

- 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, duplicates, matrix spikes, and blanks)
- 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

Table 3-1. Soil Sample Schedule

Sample Collection Method	Sample Location	Sample Interval (ft) for Chemical Analysis		Contaminants of Potential Concern	Sample Interval (ft) for Microbial Analysis/ Physical Properties	Microbial Count and Physical Properties
Drill rig with split spoon	D0070 E571290: N149701	5 to 7.5 10 to 12.5 15 to 17.5 25 to 27.5 35 to 37.5 45 to 47.5 50 to 52.5 52.5 to 55 55 to 57.5	57.5 to 60 60 to 62.5 62.5 to 65 65 to 67.5 67.5 to 70 70 to 72.5 72.5 to 75 75 to 77.5	Total petroleum hydrocarbon-diesel, total petroleum hydrocarbon-motor oil, oil and grease, total extractable hydrocarbon-aliphatic and aromatic fractions, metals, polyaromatic hydrocarbons, polychlorinated biphenyls	35 to 37.5 50 to 52.5 65 to 67.5	Determination of petroleum degrading bacteria on 0.05 g petroleum source, determination of petroleum-degrading bacteria population by most probable number, bulk density, porosity, moisture content
Drill rig with split spoon	D0071 E571297: N149748	15 to 17.5 25 to 27.5 35 to 37.5 45 to 47.5 50 to 52.5 52.5 to 55 55 to 57.5 57.5 to 60	60 to 62.5 62.5 to 65 65 to 67.5 67.5 to 70 70 to 72.5 72.5 to 75 75 to 77.5		35 to 37.5 50 to 52.5 65 to 67.5	
Drill rig with split spoon	D0072 E571264.3: N149745.3	15 to 17.5 25 to 27.5 35 to 37.5 45 to 47.5 50 to 52.5 52.5 to 55 55 to 57.5 57.5 to 60	60 to 62.5 62.5 to 65 65 to 67.5 67.5 to 70 70 to 72.5 72.5 to 75 75 to 77.5		35-37.5 50-52.5 65-67.5	

Summary	
Number of Samples	47
Approximate Number of Field Quality Control Samples	9
Approximate Total Number of Samples	56

Note: Samples depths may be adjusted based on the elevation of the water table. Quality control samples are not required for microbial testing.

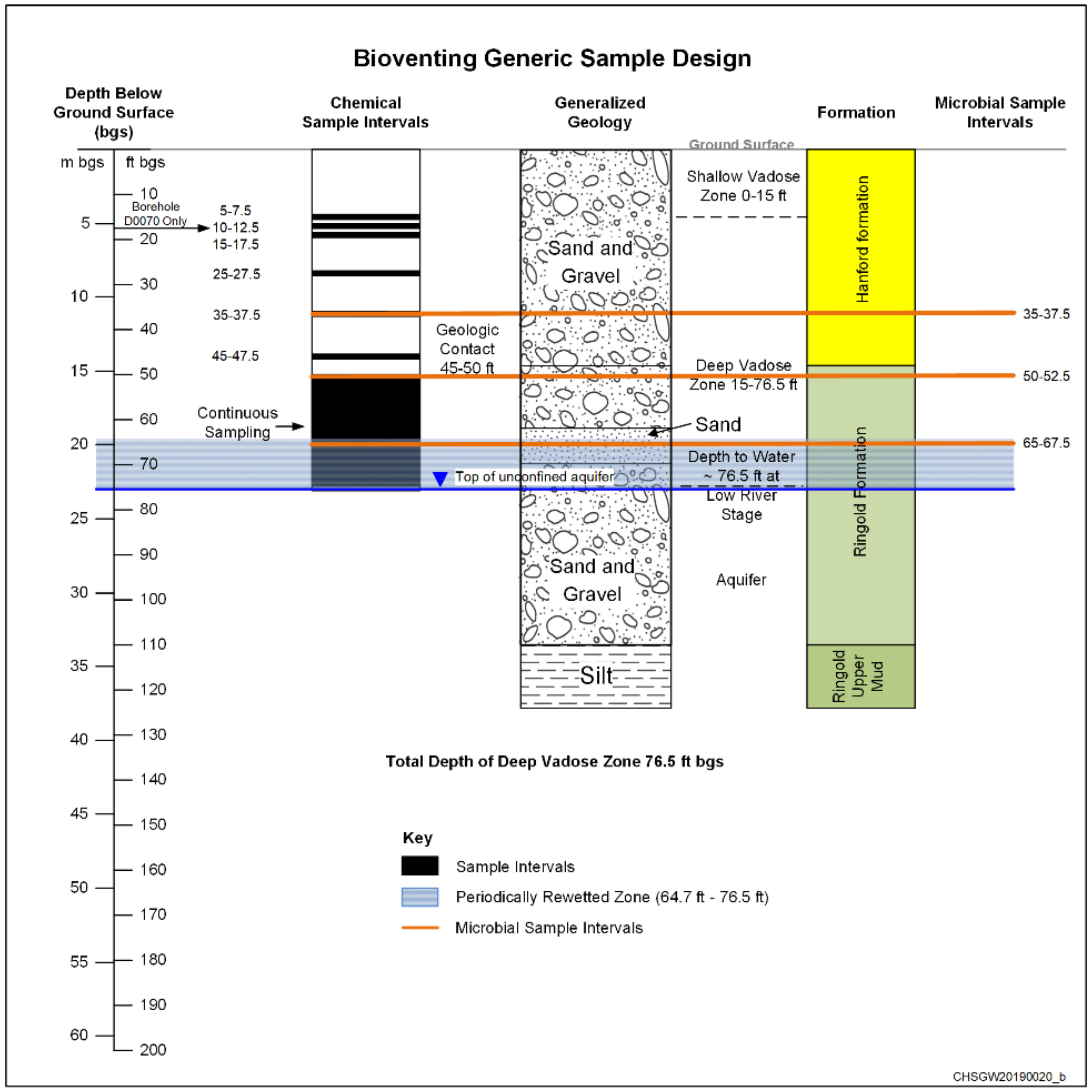

Figure 3-2. Generic Sample Design for Boreholes D0070, D0071, and D0072

3.4.1 Decontamination of Sampling Equipment

Sampling equipment shall 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 specific 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

Decontamination of sampling equipment is performed using high-purity water in each step. In general, three rinse cycles are performed to decontaminate sampling equipment: a detergent rinse, an acid rinse, and a water rinse. During the detergent rinse, the equipment is washed in a phosphate-free detergent solution, followed by rinsing with high-purity water in three sequential containers. After the third high-purity water rinse, equipment that is stainless steel or glass is rinsed in a 1 M nitric acid solution (pH <2). Equipment is then rinsed with high-purity water in three sequential containers (the high-purity water rinses following the acid rinse are conducted in separate water containers that are not used for detergent rinse). Following the final high-purity water rinse, equipment is rinsed in hexane and then placed on a rack to dry. Dry equipment is loaded into a drying oven. The oven is set at 50°C (122°F) for items that are not metal or glass or at 100°C (212°F) for metal or glass. Once reaching temperature, equipment is baked for 20 minutes and then cooled. The equipment is then removed from the oven, and the equipment is wrapped in clean, unused aluminum foil using surgeon's gloves. The wrapped equipment is stored in a custody locked, controlled access area.

3.4.2 Corrective Actions and Deviation for Sampling Activities

The Project Manager, FWS, and SMR personnel must document deviations from protocols, problems pertaining to sample collection, chain-of-custody forms, target analytes, contaminants of potential concern, 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 depth(s).

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, or SMR personnel will be responsible for communicating field corrective action requirements and for ensuring immediate corrective actions are applied to field activities.

3.4.3 Radiological Field Data

The RCT or other qualified personnel will perform radiological screening in accordance with approved methods and HASQARD (DOE/RL-96-68), as applicable. The RCT will record field measurements, noting the depth of the sample and the instrument reading. Measurements will be relayed to the FWS or site analytical lead for inclusion in the field logbook or daily 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 (instruments are commonly used on the Hanford Site to obtain measurements of removable surface contamination measurements and direct measurements of 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
- Minimum standards and practices necessary for preparing, performing, and retaining radiological related information

- Requirements associated with preparing and transporting regulated material
- Daily reports of radiological surveys and measurements collected during field investigation activities (data will be cross-referenced between laboratory analytical data and radiation measurements to facilitate interpreting the investigation results)

3.5 Calibration of Field Equipment

The FWS, or designated personnel, is responsible for ensuring that field equipment is calibrated appropriately. Onsite environmental instruments are calibrated in accordance with the manufacturer operating instructions, internal work requirements and processes, and/or work packages that provide direction for equipment calibration or verification of accuracy by analytical methods. Results from all instrument calibration activities are recorded in logbooks and/or work packages, in accordance with HASQARD (DOE/RL-96-68). Either hard copy or electronic calibration activity records are acceptable.

The following field instrumentation, calibration, and QA checks will be performed:

- Calibration of radiological field instruments on the Hanford Site is performed by the Mission Support Alliance prime contractor, as specified in their program documentation.
- 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.

The following field equipment requires calibrations:

- Field radiological survey instruments (e.g., alpha, beta and gamma detectors)
- Nonradiological field screening equipment (e.g., photo-ionization and multi-gas detectors)

3.6 Sample Handling

Sample handling and transfer shall be in accordance with established methods to preclude loss of identity, damage, deterioration, and loss of sample. Custody seals or custody tape shall 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. If during the chain-of-custody process it is discovered that the custody tape has been tampered with or broken on the sample bottle, SMR personnel will be notified, the sample will be analyzed but the results will include a flag to indicate that custody was broken. If the custody tape has been tampered with or is broken on the cooler, this condition will be documented in the data package. If the sample data did not trend with other data or is not as expected, the sample data will be flagged accordingly.

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

3.6.1 Containers

Samples shall be collected, where and when appropriate, in break-resistant containers. The field sample collection record shall indicate the laboratory lot number of the bottles used in sample collection. When commercially pre-cleaned containers are used in the field, the name of the manufacturer, lot identification, and certification shall be retained for documentation.

Containers shall be capped and stored in an environment that minimizes the possibility of sample container contamination. If contamination of the stored sample containers occurs, corrective actions shall be implemented to prevent reoccurrences. Contaminated sample containers cannot be used for a sampling event. Container sizes may vary depending on laboratory specific volumes/requirements for meeting analytical detection limits. Container types and sample amounts/volumes are identified on the chain-of-custody form.

The Radiological Control organization will measure both contamination levels and dose rates associated with the filled sample containers. Along with other data, this information will be used to select proper packaging, marking, labeling, and shipping paperwork and to verify that the analytical laboratory can receive sample 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 group) can send smaller sample volumes to the laboratory.

3.6.2 Container Labeling

Each sample is identified by affixing a standardized label or tag to the container. This label or tag shall contain the sample identification number and identify or provide reference to associate the sample with the date and time of collection, preservative used (if applicable), analysis required, and collector's name or initials. Sample labels may be either pre-printed or handwritten in indelible or waterproof ink.

3.6.3 Sample Custody

Sample custody will be maintained in accordance with existing protocols to ensure that sample integrity is maintained throughout the analytical process. Chain-of-custody protocols will be followed throughout sample collection, transfer, analysis, and disposal to ensure sample integrity is maintained.
A chain-of-custody record will be initiated in the field at the time of sampling and will accompany each sample or 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, new and previous custodians will sign the record and note the date and time. The field sampling team will make a copy of the signed record before sample shipment and transmit the copy to the SMR group.

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

- Project name
- Collectors' names
- Unique sample number
- Date, time, and location (or traceable reference thereto) of sample collection
- Matrix
- Preservatives
- Chain-of-possession information (i.e., signatures and printed names of each individual involved in the transfer of sample custody and storage locations, and dates/times of receipt and relinquishment)
- Requested analyses (or reference thereto)
- Number of sample containers per unique sample identification number
- Shipped-to information (i.e., analytical laboratory performing the analysis)

Samplers should note any anomalies with the samples. If anomalies are found, samplers should inform the SMR group so special direction for analysis can be provided to the laboratory if deemed necessary.

3.6.4 Sample Transportation

Packaging and transportation instructions shall comply 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, "Transportation," "General Information, Regulations, and Definitions," through 49 CFR 177, "Carriage by Public Highway."[4] Carrier-specific requirements defined in the current edition of International Air Transportation Association (IATA), 2019, *Dangerous Goods Regulations*, shall also be used when preparing sample shipments conveyed by air freight providers.

Samples containing hazardous constituents above regulated amounts 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. Appropriate laboratory notifications will be made, if necessary, through the SMR project coordinator.

Materials are classified by DOT/IATA as radioactive when the isotope specific activity concentration and the exempt consignment limits described in 49 CFR 173, "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. Prior to sample receipt, the laboratory shall provide SMR with written acceptance for samples with elevated radioactive contamination or dose.

[4] Transportation regulations 49 CFR 174, "Carriage by Rail," and 49 CFR 176, "Carriage by Vessel," are not applicable, as these two transportation methods are not used.

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4 Management of Waste

Waste materials are generated during sample collection, processing, and subsampling activities. Wastes from the three boreholes will be managed in accordance with DOE/RL-2000-41, *Interim Action Waste Management Plan for the 100-NR-2 Operable Unit*, because the waste generated under this SAP is similar to 100-NR-2 well drilling waste. DOE/RL-2000-41 will also need to be updated via Tri-Party Agreement change notice to include waste generated from these boreholes. For waste designation purposes, wells near those listed in Table 3-1 may be surveyed in HEIS, and the maximum concentration for each analyte will be evaluated for use in creating a waste profile, if required.

Miscellaneous solid waste that has contacted suspect dangerous waste will be managed as dangerous waste. Purgewater and decontamination fluids will be collected and managed in accordance with DOE/RL-2000-41. Packaging and labeling during waste storage and transportation will meet the applicable substantive federal and/or state requirements. Waste materials requiring collection will be placed in containers appropriate for the material and the receiving facility in accordance with the applicable waste management or waste control plan and applicable substantive federal and/or state requirements.

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5 Health and Safety

DOE established the hazardous waste operations safety and health program pursuant to the *Price-Anderson Amendments Act of 1988* to ensure the safety and health of workers involved in mixed-waste site activities. The program was developed to comply with the requirements of 10 CFR 851, "Worker Safety and Health Program," which incorporates the standards of 29 CFR 1910.120, "Occupational Safety and Health Standards," "Hazardous Waste Operations and Emergency Response"; 10 CFR 830, "Nuclear Safety Management"; and 10 CFR 835. The health and safety program defines the chemical, radiological, and physical hazards and specifies the controls and requirements for daily work activities on the overall Hanford Site. Personnel training; control of industrial safety and radiological hazards; personal protective equipment; site control and general emergency response to spills, fire, accidents, injury, site visitors; and incident reporting are governed by the health and safety program. Compliance of site-specific health and safety plans will be used to supplement the general health and safety program for field activities.

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Appendix A

DQO Systematic Planning Record

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A1 Introduction

On February 5, 2019, the U.S. Department of Energy, Richland Operations Office, Washington State Department of Ecology, and CH2M HILL Plateau Remediation Company met to conduct the Data Quality Objective (DQO) process for the purpose of determining the quality and quantity of data required to evaluate performance of a bioventing system. An in-situ bioremediation technology in the 100-N Area is in place to cleanup total petroleum hydrocarbon contamination in the deep vadose zone. The parties jointly reviewed and discussed the available data and information, as well as the proposed investigation. The decisions, action items, and key points of discussion were documented in a meeting summary and distributed for review by all parties. The process resulted in the attached Systematic Planning Record (SPR).

Major elements of the DQO process and reference to relevant information are identified as follows:

1. Statement of the Problem (Statement of the Problem in attached SPR)
2. Identification of the Goals of the Study (Chapter 3 in the main text of this Sampling and Analysis Plan (SAP) and the attached SPR)
3. Identification of Information Inputs (Chapters 1 and 2 in the main text of this SAP and the attached SPR)
4. Definition of the Boundaries of the Study (Attached SPR)
5. Development of the Analytical Approach (Sections 1.1.13, 3.2, and 3.3; Tables 2-3, 2-4, 2-5 and 3-1; Figure 3-2 in the main text of this SAP)
6. Specification of Performance or Acceptance Criteria (Sections 2.1.2 through 2.4 in the main text of this SAP and Performance or Acceptance Criteria in the attached SPR)
7. Development of the Plan for Obtaining Data (Chapter 3 in the main text of this SAP and Plan for Obtaining the Data in the attached SPR)

In some instances, entries in the SPR refer to components of the SAP to avoid duplication of information discussed in the DQO workshop but formally documented in the SAP.

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Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.

Project Summary

Project Name: 100-NR-1	Date: 2-5-2019
Name of Person Completing Record: Art Lee	Position: 100-N Area Project Lead
Name of Responsible Manager: William Faught	

Project Background:

The bioventing system was installed at the UPR-100-N-17 waste site to remediate deep vadose zone petroleum-contaminated soils identified within the 100-NR-1 Operable Unit (OU). Pilot testing began in February 2010 and continued through May 2011. The bioventing system was operational on November 27, 2012 and continues to remediate petroleum in the deep vadose zone.

This data quality objective (DQO) process is designed to provide data necessary to evaluate the effectiveness of the 100-N bioventing interim measure (IM) to address total petroleum hydrocarbon (TPH) in the vadose zone. Current data demonstrate a potential reduction in the effectiveness of the interim measure (sampling and analysis plan [SAP] Section 1.1.11). The potential causes to be evaluated through this DQO are a reduction in available TPH for biodegradation and a reduction in the number of bacteria capable of degrading TPH.

The area impacted by the bioventing system is a horizontal area with a radius of roughly 61 m (200 ft) from each injection well with a vertical range roughly equal to minimum and maximum depths of the bioventing well screens. This range of influence includes the current periodically rewetted zone (PRZ) and the deep vadose zone which was impacted by higher water table elevations during 100-N Area operations. Shallower areas of the vadose zone were previously determined to have sufficient oxygen naturally available to allow for degradation of TPH. Each of these vertical sections will be evaluated through the DQO process.

Planning Type:

(If systematic planning is not required, state the reason)

This planning activity will utilize an external planning approach. CH2M HILL Plateau Remediation Company (CHPRC) project personnel with review and concurrence by U.S. Department of Energy (DOE-RL) and Washington State Department of Ecology (Ecology) project staff conducted planning.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

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Organization, Schedule, and Goal

(State the problem, requirements, schedule, PSQs, and outcomes)

State the Problem

(Describe the reason/need for data collection and project goals/objectives)

Direct measurements (soil sampling and analysis) of current concentrations of petroleum hydrocarbons and the populations of bacteria capable of degrading TPH in the deep vadose zone (4.6 m [15 ft] below ground surface [bgs] to water table) are needed to evaluate the effectiveness of in-situ bioremediation (bioventing system of oxygen injection) and TPH degradation without the additional of oxygen in the 100-NR-1 OU.

Principal Study Questions *(What questions are data needed to answer?)*	**PSQ 1**	Has in-situ bioremediation reduced total petroleum hydrocarbon-diesel (TPH-D) concentrations within the region of influence associated with the screen interval in 199-N-167 and 199-N-172?	**PSQ 3**	Is the population of bacteria in the deep vadose zone sufficient for biodegradation of TPH-D (i.e., 5,400 to 35,000 bacteria per gram)?
	PSQ 2	Have TPH-D concentrations naturally declined in the deep vadose zone (i.e., below 4.6 m [15 ft]) above the area influenced by injection of oxygen?		
Define alternative outcomes or actions that can occur upon answering PSQs	**AA 1(a)**	New data compared to baseline indicate TPH concentrations have been reduced AND are now below cleanup levels. Discontinue bioremediation.	**AA 2(b)**	New data indicate TPH concentrations are below cleanup levels. Document current state in a remedial investigation/ feasibility study (RI/FS) or related document.
	AA 1(b)	New data compared to baseline indicate TPH concentrations have been reduced, BUT values remain above cleanup levels. Evaluate time to achieve cleanup levels and decide whether or not to continue bioremediation. Note: Residual concentrations in the PRZ may be best managed as part of groundwater plume (e.g., biosparging).	**AA 2(c)**	New data compared to baseline indicate TPH concentrations are not being reduced AND are still above cleanup levels. Define alternate response strategy.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

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	AA 1(c)	New data compared to baseline indicate TPH concentrations are not being reduced. Cease bioremediation and define alternate response strategy.	**AA 2(d)**	New data indicate concentrations in the "unexcavated islands" are above cleanup levels. Evaluate response in an RI/FS or related document.
	AA 2 (a)	New data compared to baseline indicates TPH concentrations have been reduced BUT are still above cleanup levels. Evaluate (model) time to achieve cleanup levels by natural attenuation.	**AA 3 (a)**	Bacteria populations are <5,400 bacteria per gram of soil in the vadose zone or 35,000 bacteria per gram at the vadose zone-groundwater interface. Reevaluate response strategy.
			AA 3 (b)	Bacteria population >5,400 bacteria per gram of soil in the vadose zone or 35,000 bacteria per gram at the vadose zone-groundwater interface. Continue remediation if contaminant concentrations are declining.

Identify the decision statements or estimation statements needed to address the PSQs.	AA 1(a)	Determine whether bioremediation should discontinue.
	AA 1(b)	Determine whether bioremediation should continue.
	AA 1(c)	Determine whether bioremediation should discontinue and evaluate alternate cleanup technologies, if applicable.
	AA 2(a)	Determine whether cleanup timeline (based on the rate of biodegradation) is practical.
	AA 2(b)	Determine whether bioremediation should discontinue.
	AA 2(c)	Determine whether bioremediation should discontinue.
	AA 2(d)	Determine whether bioventing island should be cleaned up.
	AA 3 (a, b)	Determine whether current biodegrading bacteria population support bioremediation.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.

Data Needs

(Define the spatial and temporal boundaries of the study)

Define what constitutes a sampling unit:

For the purposes of this study, a sampling unit consists of an individual borehole.

DOE-RL and Ecology agreed to the following spatial and temporal boundaries:

- Spatial
  - Vertical: The area to be evaluated by the DQOs is comprised of four sections:
    - The current PRZ [1] 19.5 to 23.3 m (64.5 to 76.5 ft bgs[2]).
    - Screened zone above the PRZ which is influenced by the bioventing IM (top of the Ringold Formation to 64.5 ft bgs.)
    - Hanford formation deep vadose soils (15 ft bgs to the bottom of the Hanford formation)
    - Shallow vadose zone soils (0-15 ft bgs.) for sampling locations that were not previously excavated and backfilled (near 199-N-167).
  - Horizontal: Radius of influence of air injection at 119-N-167 and 199-N-172 (approximately 200 ft).
- Temporal
  - Sampling would occur only when air injection system is not operating and after equilibration (approximately 1 month after shutdown.
  - Sampling would occur during low river stage (September to February) to have maximum access to the PRZ.

What is the smallest unit upon which decisions or estimates will be made?

The smallest unit for decision/estimation is the split-spoon sample interval (0.76 m [2.5 ft]) within a borehole.

[1] The attendees acknowledged that TPH contamination in groundwater is likely affecting contaminant levels in the PRZ. This impact will need to be considered while evaluating the effectiveness of the IM in this area.

[2] All bgs measurements are based on ground surface at 199-N-3.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.

Data Needs Summary

(Information inputs to answer PSQs: target population, characteristics of interest, spatial and temporal limits, scale of inference)

PSQ	Data Need	Media of Interest	Location	Sampling Method	Action Level	Frequency	Practical Constraints	Analytical Method	Potential Source of Data
1,2	TPH-D, TPH-motor oil and oil and grease concentrations	Soil	Within 25 ft of 199-N-172; borehole D0072 shall be drilled.	Split spoon	2,000 mg/kg of TPH	15	See constraints in "Plan for Obtaining Data" below.	EPA Method WTPH-diesel range and EPA Method WTPH-motor oil range (Ecology Publication ECY 97-602), EPA Method 1664 (EPA-821-R-98-002)	Site-specific sampling
1,2	TPH-D, TPH-motor oil and oil and grease concentrations	Soil	Within 25 ft of 199-N-171; borehole D0071 shall be drilled	Split spoon	2,000 mg/kg of TPH	15	See constraints in "Plan for Obtaining Data" below.	EPA Method WTPH-diesel range and EPA Method WTPH-motor oil range, EPA Method 1664	Site-specific sampling
1,2	TPH-D, TPH-motor oil and oil and grease concentrations	Soil	Within 25 ft of 199-N-167; borehole D0070 shall be drilled.	Split spoon	2,000 mg/kg of TPH	17	See constraints in "Plan for Obtaining Data" below.	EPA Method WTPH-diesel range and EPA Method WTPH-motor oil range, EPA Method 1664	Site-specific sampling
3	Bacteria Populations	Soil	Within 25 ft of 199-N-172; borehole D0072 shall be drilled.	Split spoon	Populations <5,400/g in soil or <35,000/g in vadose/ groundwater interface	3	See constraints in "Plan for Obtaining Data" below.	Determination of petroleum degrading bacteria and population, Brown et al., 1990; Blodgett, 2003; and PNNL-18645.	Site-specific sampling

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.

3	Bacteria Populations	Soil	Within 25 ft of 199-N-171; borehole D0071 shall be drilled.	Split spoon	Populations <5,400/g in soil or <35,000/g in vadose/ groundwater interface	3	See constraints in "Plan for Obtaining Data" below.	Determination of petroleum degrading bacteria and population, Brown et al., 1990; Blodgett, 2003; and PNNL-18645.	Site-specific sampling
3	Bacteria Populations	Soil	Within 25 ft of 199-N-167; borehole D0070 shall be drilled.	Split spoon	Populations <5,400/g in soil or <35,000/g in vadose/ groundwater interface	3	See constraints in "Plan for Obtaining Data" below.	Determination of petroleum degrading bacteria and population, Brown et al., 1990; Blodgett, 2003; and PNNL-18645.	Site-specific sampling

Performance or Acceptance Criteria

(Determine the quality of data needed and analytical approach)

Specify the population parameter (e.g., mean, median, or percentile), appropriate for making decisions or estimates:

Concentrations of analytes and bacteria populations at sample locations. Judgmental sampling will be used to identify sampling units (i.e., the number and location and/or timing of collecting samples) based on knowledge of the feature under investigation (i.e., previous sampling) and on professional judgment (Sections 2.1.2 through 2.4 in the main text of this SAP.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.

Decision Problem	Provide a decision rule related to the Action Level identified above that includes a clear "if…then…else" statement: If new data from the screen interval indicate that concentrations have been reduced and are now below cleanup levels, then stop bioremediation, else continue bioremediation. If new data from the screen interval indicate that concentrations have been reduced but are still above cleanup levels, then continue bioremediation, else optimize system. If new data from the screen interval indicate that concentrations have not been reduced, then stop bioremediation, else consider alternative cleanup technologies. If new data above the screen interval indicate that concentrations have been reduced but are still above cleanup levels, then continue natural bioremediation, else evaluate time required to cleanup site and optimize system. If new data above the screen interval indicate concentrations are below cleanup levels, then cease sampling and analysis, else discontinue monitoring. If new data above the screen interval indicate that concentrations are not being reduced and are still above cleanup levels, then consider alternative cleanup technologies, else continue monitoring. If concentrations in the unexcavated "islands" are above cleanup levels, then evaluate cleanup technologies, else clean up the site. If bacteria populations are below minimum thresholds necessary to degrade TPH, then consider methods of introducing bacteria across the vadose zone, else consider other cleanup technologies.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.

What are the consequences of making an incorrect decision and what is the tolerance for an incorrect decision?

If new data from the screen interval indicate that concentrations have been reduced and are now below cleanup levels, when in fact concentrations are high, then bioremediation would cease and unacceptable risk to human health and the environment would remain.

If new data from the screen interval indicate that concentrations have been reduced but are still above cleanup levels, when in fact concentrations are not being reduced, then bioremediation would continue, and unacceptable risk to human health and the environment would remain.

If new data from the screen interval indicate that concentrations have not been reduced, when in fact concentrations are reduced, then bioremediation would cease unnecessarily.

If new data above the screen interval indicate that concentrations have been reduced but are still above cleanup levels, when in fact concentrations are not being reduced, then bioremediation would continue and unacceptable risk to human health and the environment would remain.

If new data above the screen interval indicate concentrations are below cleanup levels, when in fact concentrations remain high, then bioremediation would cease and unacceptable risk to human health and the environment would remain.

If new data above the screen interval indicate that concentrations are not being reduced and are still above cleanup levels, when in fact concentrations are not being reduced, then bioremediation would continue, cleanup resources would be wasted and unacceptable risk to human health and the environment would remain.

If data indicates that concentrations in the unexcavated “islands” are above cleanup levels, when concentration are in fact below clean levels, then would resources would be used to cleanup an uncontaminated waste site.

If data indicate that bacteria populations are below minimum thresholds necessary to degrade TPH, when populations are above the threshold, then resources would be potentially be wasted injecting on bacteria into the treatment zone.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.

Estimation Problem	Develop the specification of the estimator by combining the true value of the selected population parameter with the scale of estimation and other boundaries: No estimation specification is established for this study.
	What are the acceptable limits on uncertainty? No limits of uncertainty are established for this study.

Plan for Obtaining the Data

(Specify the general plan of obtaining the needed data and explain where and how the information in this Planning Record will be formalized in a data collection plan)

Characterization data necessary to evaluate the principle study questions identified in this DQO will be collected by drilling three boreholes and sampling and analyzing vadose zone soils. Soils will be analyzed for contaminants of concern (TPH) and the presence and population of TPH biodegrading bacteria in the subsurface soils. Further detail has been documented in the SAP based on the decisions, action items, and key points of discussion from the February 5, 2019 meeting with DOE-RL, Ecology, and CHPRC.

Practical considerations to be accounted for during the planning of sample collection include the following:

1. Cultural site restrictions may affect drilling site locations

2. Sampling will occur when the air injection system is not operating and after equilibration (1 one month after shutdown)

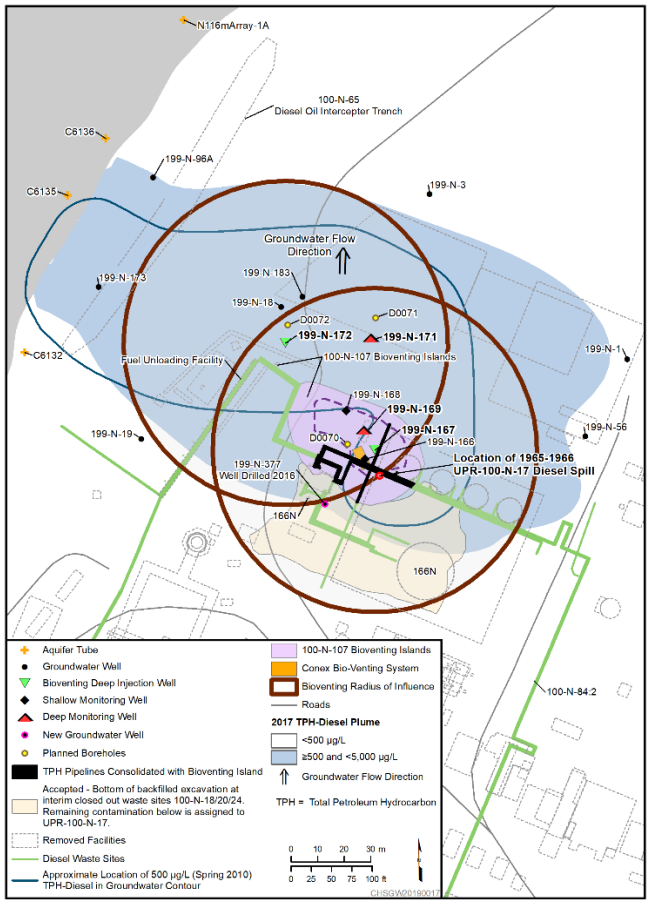
3. Sampling will occur during the low river stage (September to February) to maximize access to the PRZ.

Soil samples collected from three boreholes shall provide sufficient data to address principle study questions. While not directly related to the principle study questions, additional data (e.g., moisture content) will also be collected and analyzed in support of potential future site-specific fate and transport modeling. Borehole sample locations D0070, D0071, and D0072 are described in Section 3.3 in the main text of this SAP and shown in the following figure.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.



Drilling locations may be subject to change pending the identified practical considerations.

Appendix B

Option for Completion of Borehole D0072 as a Deep Injection Well

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Terms

bgs	below ground surface
OU	operable unit
PVC	polyvinyl chloride

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B1 Introduction

Borehole D0072 shall be located on the Hanford Site in the 100-N Area to support the bioremediation (bioventing) of total petroleum hydrocarbon-diesel (TPH-D). Vadose zone characterization and drilling of borehole D0072 is described in the main body of this sampling and analysis plan. This appendix describes the option for drilling ~3 m (~10 ft) into the aquifer at low river stage and completing borehole D0072 as a deep vadose zone injection well to replace injection well 199-N-172.

B2 Background

From 2010 to 2019 (inclusive of pilot testing), a method of in situ bioremediation called bioventing has been used in the 100-NR-1 Operable Unit (OU) to clean up deep vadose zone petroleum contamination at accepted waste site UPR-100- N-17. Bioventing supplies oxygen within the screen interval of injection wells 199-N-167 and 199-N-172 to enhance natural microbiological degradation of petroleum hydrocarbon in the deep vadose zone approximately 16.1 to 23.3 m (52.8 to 76.5 ft) below ground surface (bgs). Well 199-N-172 is one of two injection wells in the 100-N Area that supplies oxygen to the deep vadose zone to enhance natural microbiological degradation of petroleum hydrocarbon. The top of the injection well screen has separated from the casing, allowing filter pack material to fall into the well and accumulate to level above the water table. The well is still functional as a bioventing air injection well, but not for groundwater monitoring. Well remediation is being planned/implemented. If well remediation efforts fail to repair 199-N-172, this appendix provides the option, with regulator approval, to complete borehole D0072 as a replacement to well 199-N-172 for deep vadose zone air injection and groundwater monitoring.

The location of D0072 and other wells/boreholes in the vicinity of TPH-D contamination are shown in Figure B-1.

B3 Well Drilling and Construction

Well drilling and construction will be performed in accordance with the substantive standards of WAC 173-160, “Minimum Standards for Construction and Maintenance of Wells.” The deep injection well will be constructed as a 10.2 cm (4 in.) diameter monitoring well with polyvinyl chloride (PVC) casing and screen and will based on the design of well 199-N-172.

The screened interval in the well shall be ~17.4 to 23.5 m (57 to 77 ft) bgs with about 4.6 m (15 ft) of screen above the water table and 1.5 m (5 ft) of screen into the aquifer at low river stage (nominally 22.1 m [72.5 ft] bgs). In consultation with the OU project technical lead, buyer’s technical representative, and field geologist/hydrogeologist, the well design technical lead will determine the final well design details prior to construction based on the geologic and geophysical logs, sieve analyses, and contaminant data. The generic design of the PVC deep injection well at low river stage is shown in Figure B-2. Preliminary details about the design of the groundwater monitoring wells is presented in Table B-1.

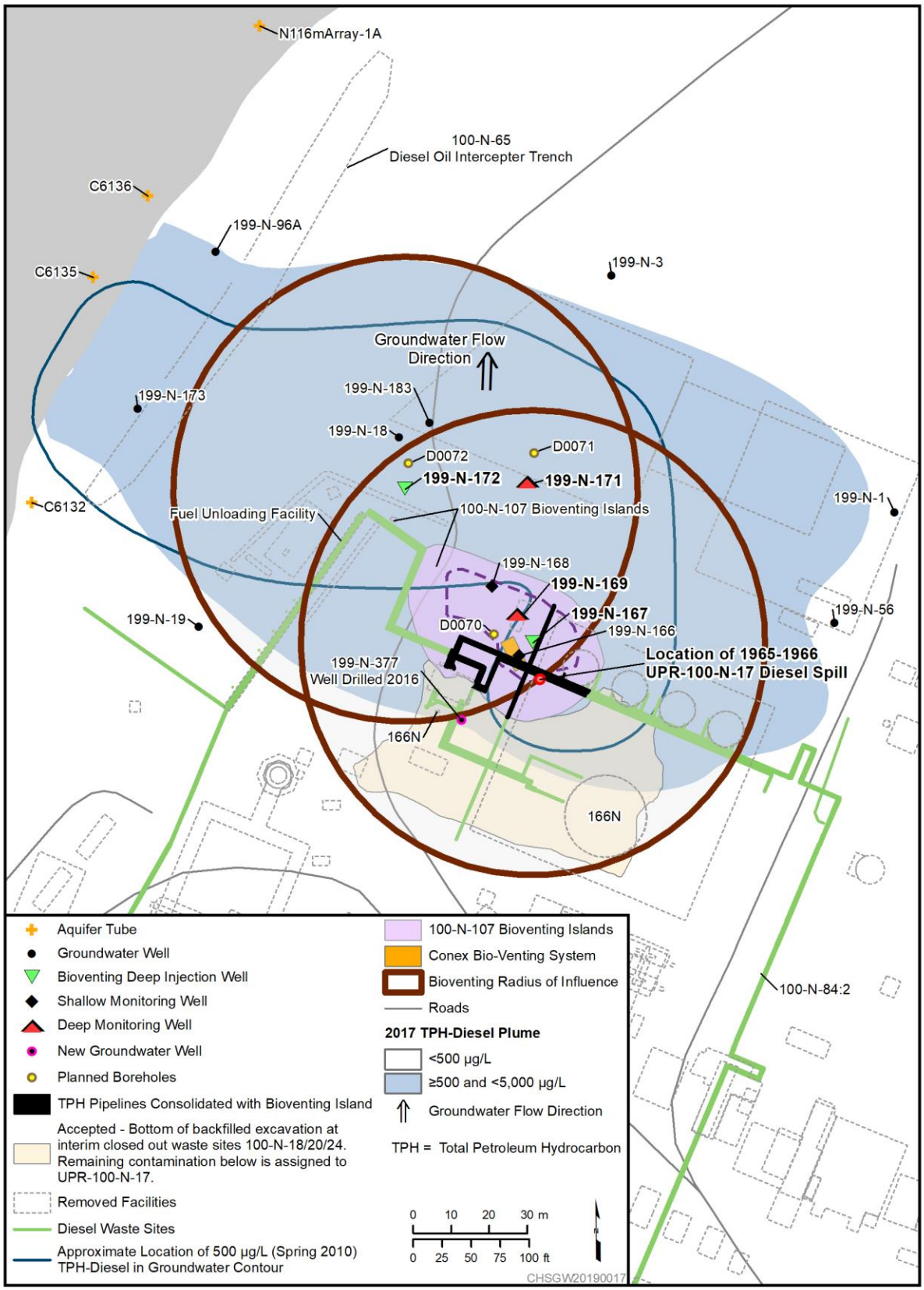

Figure B-1. Well Location Map

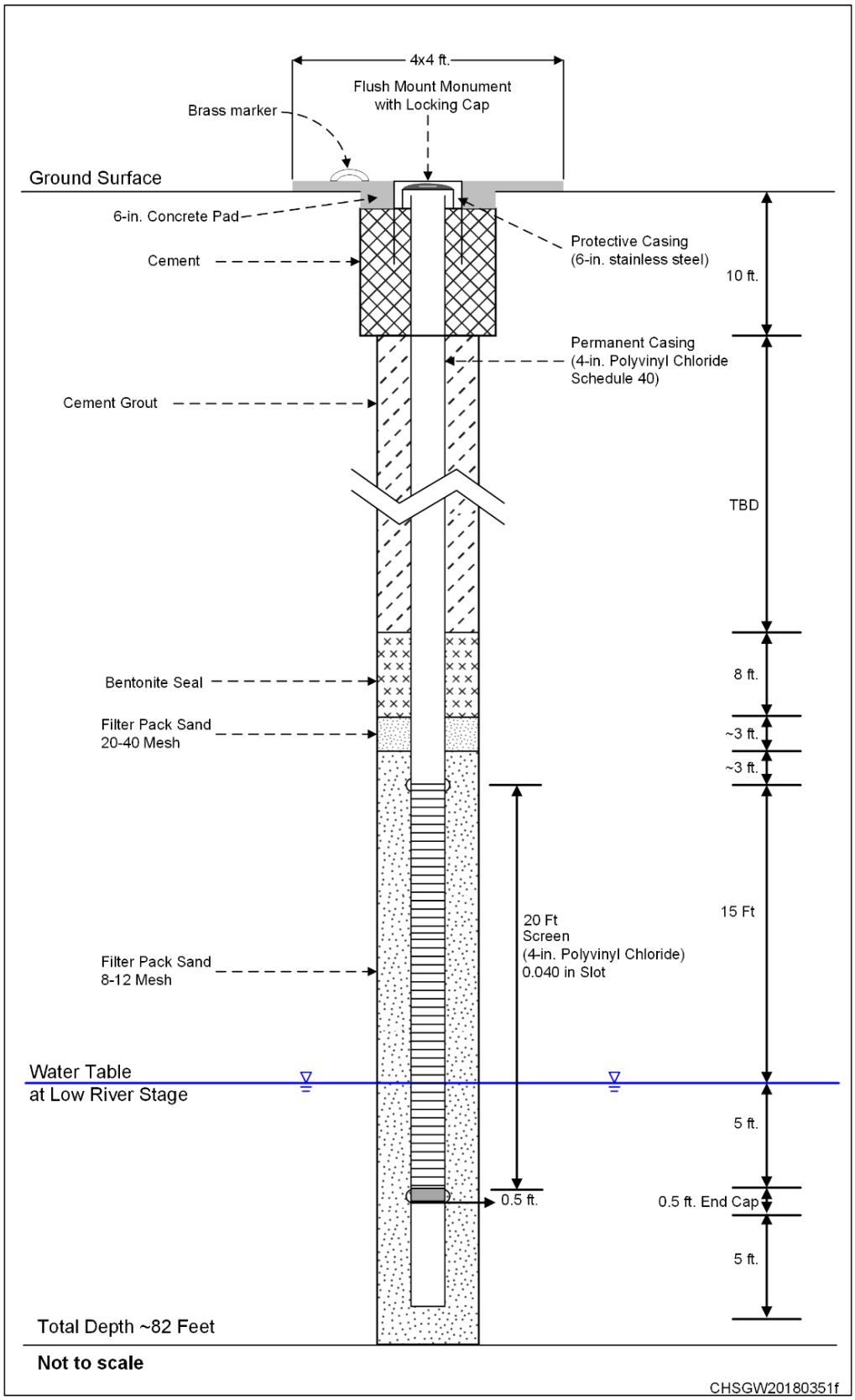

Figure B-2. Generic Deep Injection Monitoring Well

Table B-1. Well Construction Information

Well Name	Facility	Northing (m)	Easting (m)	Surface Elevation (m)	Depth to Water (ft bgs)	Drill Depth (ft bgs)	Perm. Well Diameter (in.)	PVC Screen Interval (ft bgs)	End Cap Interval (ft bgs)
D0072	100-N	149745.3	571264.3	461	72	82	4	57-77	77-77.5

bgs = below ground surface
PVC = polyvinyl chloride

B3.1 Sediment Sieve Analysis

Sediment samples for sieve analyses will be collected during drilling at 1.5 m (5 ft) intervals below the water table and composited into a single sample for analysis. Sieve analyses will be performed to support the selection of the correct filter pack mesh size and corresponding screen slot size. The field geologist will collect grab samples and conduct sieve analyses in accordance with contractor procedures.

B3.2 Geophysical Logging

The well within the saturated portion of the aquifer will be logged with the high-resolution spectral gamma logging system and neutron moisture logging system to determine the vertical distribution and concentration of gamma-emitting radionuclides, soil moisture variations, and borehole lithology changes. The boreholes will be geophysically logged before downsizing each temporary casing string and/or at total drill depth and prior to well construction. The driller will assist the logging engineer by providing borehole access, depth to current water table, and hoisting support, as appropriate, to access the borehole when the logging crew is onsite. Logging is performed according to CH2M HILL Plateau Remediation Company procedures.

B3.3 Well Development

The objectives of well development are to settle the filter pack, prevent uncontrolled infiltration of fines, and ensure communication of the well with the surrounding formation. Well development will be conducted during well construction and final development after the wells are completed. Initial development will be performed during well construction in conjunction with placement of the filter pack with the use of a dual surge block to both settle the filter pack and to develop communication across the borehole wall.

Final development is performed after well completion. Final well development with a submersible pump will occur after the fines are removed.

Water samples will be collected for analysis of turbidity, temperature, pH, and conductivity using field instruments. Development will continue until the well produces clear water (<5 nephelometric turbidity units) and the temperature, pH, and conductivity have stabilized (at least three consecutive measurements within 10% of each other). The field geologist will determine when development is complete. Performance requirements for field instrumentation/measurements is provided in Table B-2.

Analysis for general water chemistry will not be performed during development to evaluate changes throughout the purging process. The locations of the proposed wells have been characterized with regards to geology and water elevations allowing for placement of the well in the uppermost aquifer.

Table B-2. Performance Requirements for Field Measurements

CAS Number	Analyte	Matrix	Analytical Method
pH – 150.1	pH	Water	150.1 – pH – Field
Temp – 170.1	Temperature (°C)	Water	170.1 – Temperature – Field
Cond – 120.1	Specific conductance (µS/cm)	Water	120.1 – Conductivity – Field
TURBIDITY – 180.1	Turbidity	Water	TURBIDITY_FLD

CAS = Chemical Abstracts Service

B4 Reference

WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," *Washington Administrative Code*, Olympia, Washington. Available at: https://apps.leg.wa.gov/WAC/default.aspx?cite=173-160.

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