DOE/RL-2003-38
Revision 2 Draft A

100-BC-5 Operable Unit Sampling and Analysis Plan

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

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Signature Sheet

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M.W. Cline

U.S. Department of Energy, Richland Operations Office

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L.C. Buelow

U.S. Environmental Protection Agency

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Terms

ALARA	as low as reasonably achievable
ASTM	ASTM International, formerly the American Society for Testing and Materials
AWLN	automated water level network
BTR	Buyer's Technical Representative
CAS	Chemical Abstracts Service
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	contaminant of concern
CSM	conceptual site model
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DOT	U.S. Department of Transportation
DQA	data quality assessment
DQO	data quality objective
DWS	drinking water standard
EB	equipment blank
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FS	feasibility study
FTB	full trip blank
FWS	Field Work Supervisor
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68)
HEIS	Hanford Environmental Information System
HSP	hyporheic sampling point
IATA	International Air Transportation Association
ID	identification
LCS	laboratory control sample
MB	method blank
MDA	minimum detectable activity

MDL	method detection limit
MNA	monitored natural attenuation
MS	matrix spike
MSD	matrix spike duplicate
OU	operable unit
PQL	practical quantitation limit
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RCRA	*Resource Conservation and Recovery Act of 1976*
RI	remedial investigation
ROD	record of decision
RPD	relative percent difference
SAP	sampling and analysis plan
SMR	Sample Management and Reporting
TPA	Tri-Party Agreement
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*

1 Introduction

This document presents the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) sampling and analysis plan (SAP) for groundwater monitoring of the 100-BC-5 Groundwater Operable Unit (OU) (Figure 1-1). The OU is located adjacent to the Columbia River on the U.S. Department of Energy (DOE) Hanford Site.

The B Reactor was the first of its kind and operated from 1944 to 1968. Its primary mission was plutonium production for the development of an atomic bomb during World War II. The C Reactor operated from 1952 to 1969. Groundwater contamination in the 100-BC-5 OU is mainly associated with waste produced by these reactors and related processes. DOE has remediated waste sites under an interim record of decision (ROD) (EPA/ROD/R10-99/039, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites*)), and there are no known remaining sources of significant contamination that could migrate to groundwater.

DOE is conducting a remedial investigation (RI) of the 100-BC-5 groundwater OU, along with the 100-BC-1 and 100-BC-2 source OUs (DOE/RL-2009-44, *Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study*). DOE and the U.S. Environmental Protection Agency (EPA) agreed that completion of the RI/feasibility study (FS) report and decisions about remedial action should be delayed in order to conduct additional RI studies to reduce various uncertainties. The uncertainties relate to the completion of waste site remediation, short-term changes in groundwater contaminants related to waste site remediation, modeling results predicting that it will take a long time for the hexavalent chromium (Cr(VI)) plume to attenuate, and the level of risk associated with variable contaminant concentrations in Columbia River pore water. Those additional studies, described in DOE/RL-2009-44 and related change notices, began in 2013 and will conclude around January, 2016. After that, DOE will revise the Working Draft A RI/FS report (DOE/RL-2010-96, *Remedial Investigation/Feasibility Study for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*) and prepare a proposed plan for remediation, and EPA will issue a ROD selecting a preferred alternative.

Monitoring under this SAP will begin after the conclusion of the RI studies in early 2016 and will remain in effect until a performance monitoring plan is implemented following implementation of the groundwater remediation alternative selected under the ROD. This SAP supersedes other groundwater SAPs listed in Table 1-1.

The remainder of this chapter addresses the project scope and objectives, conceptual site model (CSM), summary of data quality objectives (DQOs), contaminants of concern (COCs), and project schedule. Chapter 2 discusses quality assurance (QA) requirements, and Chapter 3 provides the field sampling plan. Chapters 4 and 5 address waste management and health and safety requirements. Appendix A contains the DQO documentation, which includes construction information for wells and aquifer tubes.

1.1 Project Scope and Objective

The objective of this SAP is to present the requirements for monitoring groundwater in the 100-BC-5 OU during the period of time after the supplemental RI studies are completed (fall 2015) and before implementation of remedial actions under the final ROD.

Section 8.1.1 of the draft RI/FS report (DOE/RL-2010-96) identified Cr(VI), strontium-90, and tritium as COCs for groundwater. This SAP will also monitor those three contaminants.

As part of the DQO process described in Appendix A, historical sampling locations and analytical results were reviewed. The locations of monitoring wells and aquifer tubes were analyzed with respect to the 2013 and 2014 contaminant plume configurations with the objective of optimizing the well network and sampling requirements. The analysis was directed at defining those wells and aquifer tubes needed for contaminant monitoring and determining appropriate sampling frequencies.

The monitoring network identified in this SAP is designed to collect groundwater data sufficient to determine whether contaminants and discharges to the Columbia River are changing as expected in accordance with the CSM. Resulting data will be reported in the Hanford Site annual groundwater reports (e.g., DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*) and will support design of the groundwater remedial action selected in the final ROD. Monitoring under this plan will continue until a groundwater remedial action is selected, and related groundwater monitoring begins. Data gathered under this plan help satisfy the requirements of CERCLA (40 CFR 300.430(b), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy").

Table 1-1 identifies the existing documents that currently have groundwater sampling requirements associated with the 100-BC-5 OU and identifies which existing documents are completely or partially superseded by this SAP. There are no *Resource Conservation and Recovery Act of 1976* (RCRA) facilities in the 100-BC Area.

1.2 Conceptual Site Model

This section summarizes hydrogeology, groundwater flow, contaminant plumes, and sources of contamination. It also summarizes supplemental RI studies and describes expectations based on the CSM.

1.2.1 Site Geology and Hydrogeology

The unconfined aquifer in the 100-BC-5 OU is 32 to 48 m (105 to 157 ft) thick, comprising Hanford formation and Ringold unit E gravel and sand (Figures 1-2 and 1-3). The upper part of the aquifer in most of 100-BC-5 is in the Hanford formation, which is much more transmissive than Ringold unit E. Ringold unit E comprises the greatest thickness of the aquifer; the thickness of the saturated Hanford formation ranges from zero near the river to more than 30 m (98 ft) in the southern part of the 100-BC-5 OU (Figure 1-4). The portion of the aquifer without saturated Hanford formation (striped fill in Figure 1-4) influences groundwater flow, creating a steeper hydraulic gradient and slowing contaminant migration.

1.2.2 Groundwater Flow and Discharge to the Columbia River

In the northern 100-BC-5 OU, groundwater flow is to the north. In southern 100-BC-5, the water table is very flat (gradient 10^{-4} to 10^{-5}), and the direction of flow appears to vary from northward to northeastward (Figure 1-5). The plume shows overall movement to the northeast from southern 100-BC-5. Chromium and tritium trends in wells on the west side of the 100-BC-5 OU suggest that clean groundwater is migrating in from that direction.

The hyporheic zone is located in the riverbed sediments and pore spaces where groundwater and river water mix. This zone has a strong influence on aquatic communities and, for the purposes of this SAP, is defined as the upper 0.5 m (1.6 ft) of the riverbed. Studies in 2009 and 2010 identified a broad region of groundwater upwelling in the hyporheic zone adjacent to the 100-BC Area (Section 1.2.5).

1.2.3 Sources of Groundwater Contamination

Groundwater contamination in 100-BC-5 is mainly associated with waste produced by reactors and related processes. Waste sites, which included cribs, basins, pipelines, unplanned releases, and burial grounds, have been remediated under interim action RODs. This remediation typically involved excavation of contaminated material, eliminating significant ongoing sources of groundwater contamination.

Remediation of liquid effluent sites began in the 1990s and was completed by 2000. Remediation of other sites, including pipelines, unplanned releases, and burial grounds, continued for another 15 years. The largest excavations were the 100-C-7 and 100-C-7:1 sites in southern 100-BC Area. These sites were sources of Cr(VI) contamination, and the excavations in 2012 extended to the water table.

Figure 1-6 shows the locations of Cr(VI) waste sites. Many of these same sites, particularly in the eastern part of 100-BC Area, were also strontium-90 sources.

1.2.4 Groundwater Contaminants

This subsection describes groundwater COCs.

1.2.4.1 Contaminants of Concern

Section 8.1.1 of the draft RI/FS report (DOE/RL-2010-96) identified Cr(VI), strontium-90, and tritium as COCs in groundwater. Figure 1-7 shows chromium in the upper part of the aquifer in 2012, 2013, and 2014. Chromium is present in the lower part of the aquifer in some locations (Figures 1-2 and 1-3). Contamination is present in both the Hanford formation and the thicker Ringold unit E.

Excavation of waste sites 100-C-7 and 100-C-7:1 mobilized chromium in 2012, seen as a spike in concentration in a downgradient well (Figure 1-8). The inverse relationship with water levels indicates that concentrations vary seasonally, as the direction of groundwater flow changes, but peaks have declined each year. The 48 µg/L contour of this chromium plume migrated toward the northeast during 2012, 2013, and 2014 (Figure 1-7). The southernmost tail of the 48 µg/L contour migrated approximately 1,000 m (3,280 ft) between fall 2012 and fall 2014, which equates to an average flow rate of approximately 1.4 m/day (4.6 ft/day). The eastern boundary of the chromium plume (at 10 µg/L) appears to have migrated eastward ~300 m (984 ft) between 2013 and 2014, based on trends in wells and aquifer tubes.

In the northern 100-BC Area, another region of contamination at concentrations above 48 µg/L is observed around a single well (199-B3-47 [Figures 1-2 and 1-7], where the aquifer is all in Ringold unit E). This contamination has been present since 1995, and concentrations are not declining.

Figure 1-9 shows the distribution of strontium-90. In some wells, concentrations are not attenuating as rapidly as expected due to radioactive decay with a 29-year half-life. Strontium-90 concentrations decline with depth in the aquifer.

Tritium concentrations are >10,000 pCi/L in a narrow plume in eastern 100-BC-5. Levels were below the 20,000 pCi/L drinking water standard (DWS) in 2013 and 2014. Tritium likely will remain a groundwater COC when the RI/FS report is written in 2016 because concentrations were above the DWS in 2012 and earlier.

Fate and transport models, as described in Chapter 5 of the draft RI/FS, estimated that Cr(VI) may persist in 100-BC groundwater for between 100 and 150 years, and strontium-90 may persist for between 50 and 100 years.

1.2.5 Supplemental RI Studies

Supplemental RI studies were undertaken between fall 2013 and fall 2015 (DOE/RL-2009-44, as revised). These studies were designed to reduce uncertainties relating to the hyporheic zone and groundwater contamination. The following subsections summarize those results, and additional details are provided in SGW-58308, *100-BC-5 Remedial Investigation: 2014 Status Report*.

1.2.5.1 Hyporheic Zone Studies

100-BC-5 hyporheic zone samples collected in 2009 and 2010 showed elevated concentrations of Cr(VI) in some locations. Of 29 samples collected in fall 2009, 14 had concentrations above the 10 µg/L aquatic standard, with results ranging from 15 to 112 µg/L. Chromium concentrations at the same locations were lower during two subsequent sampling events, with maxima of 46 µg/L in January and February 2010 and 12.6 µg/L in November 2010. These subsequent events resampled some of the same sites with the highest concentrations in the first round. The inconsistent results of pore water sampling were a prime reason for additional 100-BC RI studies of the hyporheic zone in 2013 through 2015.

Eighteen hyporheic sampling points (HSPs) were installed in fall 2013 to monitor and characterize spatial and temporal variations in Cr(VI) concentrations (Figure 1-1). Most of the HSPs are 0.5 m (1.5 ft) deep. An additional six shallower HSPs were installed in fall 2014. High-frequency sampling in the early months of the study (multiple samples per day for 4 days) investigated chromium concentrations in relation to short-term variability in river stage. Monthly sampling continued for the remainder of the study to investigate seasonal variability and longer-term trends in chromium concentration.

Most of the HSPs within the extent of the plume in the aquifer had average concentrations above the aquatic standard (10 µg/L, Figure 1-10). Typical concentrations were in the teens and low twenties of µg/L, and the maximum concentration in a single sample was 36 µg/L. Cr(VI) concentrations in the hyporheic zone did not show a distinct relationship to short-term (daily) changes in river stage. Longer-term (seasonal) rises in river stage suppressed chromium concentrations in the HSPs. The duration of this suppression appears to be limited to 2 or 3 months during the highest river stage. During the rest of the year, concentrations were relatively steady.

Some locations have HSP clusters at depths of 15 cm (6 in.), 0.5 m (1.6 ft), and 1 m (3.2 ft). Chromium concentrations do not increase with depth.

1.2.5.2 Groundwater Studies

As part of the supplemental RI studies in 2013 and 2014, DOE installed eight new wells and sampled groundwater through the full aquifer thickness. The wells were monitored quarterly during the study period.

Wells were installed as shallow/deep well pairs to monitor vertical distribution of Cr(VI). Data from the new wells enabled the creation of geologic cross sections and maps, such as those presented in Figures 1-2 and 1-3. The new wells also provided additional monitoring points for Cr(VI) in southern 100-BC-5, along the flow path from the 100-C-7 waste sites, as shown in Figure 1-7.

Isotopic chromium analyses were performed to seek evidence of natural attenuation due to reduction of Cr(VI) to trivalent chromium. Other parameters are being monitored to evaluate natural attenuation: dissolved oxygen, sulfide, divalent iron, and organic carbon. Results to date do not provide clear evidence for reduction of Cr(VI).

1.2.6 Conceptual Site Model Expectations

Given the CSM presented in Sections 1.2.1 through 1.2.5, contaminants in groundwater and the hyporheic zone are expected to exhibit the following patterns over the duration of monitoring covered by this SAP:

- The center of the 100-C-7 chromium plume will continue to migrate through central 100-BC, into northern 100-BC, and into the hyporheic zone. This may result in concentrations temporarily rising (to no more than 60 µg/L) in some wells and HSPs. After this time, the overall chromium plume is expected to diminish because of the source reduction actions. If chromium concentrations remain stable around well 199-B3-47 (where the aquifer is all in Ringold unit E), while the remainder of the plume declines. This information may indicate that the well is sampling an isolated lower-permeability zone, or there is a continuing source in that area.

- Chromium concentrations in the upper part of the aquifer in southern 100-BC will continue to decline overall due to source reduction actions and inflow of clean upgradient groundwater.
- Chromium concentrations in the lower part of the unconfined aquifer will remain stable or change slowly. Concentrations in some wells may decline slowly due to slow movement of the groundwater. Concentrations in downgradient wells may increase slowly as the deep plume migrates.
- The eastward migration of the chromium plume east of 100-BC will slow because of regional groundwater flow patterns, and dispersion of the plume will reduce concentrations as it spreads.
- Because strontium-90 has low mobility, distribution of the plume will not change significantly, although concentrations will decline due to radioactive decay.
- Strontium-90 samples collected during high river stage will not show increases in concentrations because no vadose zone sources remain.
- Tritium concentrations will remain below the action level and will continue to decline gradually due to radioactive decay and dispersion.
- Strontium-90 concentrations in HSPs will remain below action levels.

1.3 Data Quality Objective Summary

In association with development of this SAP, the DQO process (EPA/240/B-06/001 *Guidance on Systematic Planning Using the Data Quality Objectives Process* [EPA QA/G-4]) was applied to support identification of appropriate sampling requirements. Appendix A provides the outcome of the DQO process which is summarized in this section.

The DQO identified the following problem statement: Due to recently completed source remediation and plume dynamics, continued monitoring is necessary to confirm the CSM used for the RI/FS evaluations. Data collected will be used to support the design of remedial alternatives, such as monitored natural attenuation (MNA), pump and treat technology, or other alternatives considered in the FS.

This SAP addresses a single principal study question: Are Cr(VI), strontium-90, and tritium plumes and discharges to the Columbia River changing as expected in accordance with the CSM? The following parameters will be evaluated:

- Spatial distribution of contaminants
- Concentration trends of contaminants
- Hydraulic gradients
- River stage

The decision rule is as follows: If the body of evidence indicates that Cr(VI), strontium-90, and tritium plumes and discharges to the Columbia River are not changing as expected in accordance with the CSM, then refine the CSM and incorporate the new information into design of remedial action alternatives, or consider new alternatives. Otherwise, proceed with the design as indicated by the established CSM.

Evaluation methods for this decision rule include contaminant plume maps, contaminant cross sections, concentration graphs, hydraulic gradient calculations, water table maps, groundwater model simulations, and river stage graphs.

1.4 Groundwater Contaminants

Table 1-2 provides specific contaminants for CERCLA groundwater monitoring in the 100-BC-5 OU. CERCLA COCs are those identified in the draft RI (DOE/RL-2010-96).

1.5 Project Schedule

This SAP will direct CERCLA groundwater monitoring activities needed for the 100-BC-5 OU until it is replaced by a monitoring plan for the remedial action identified in an upcoming ROD. Sampling of wells, conventional aquifer tubes, and HSPs under this SAP will begin according to the schedule indicated in Table 1-1.

The Sample Management and Reporting (SMR) organization will establish the yearly sampling schedule, consistent with the requirements and data quality objectives described in this SAP. SMR uses processes and software applications such as *Sample Management Integrated Lifecycle Environment*, which optimizes the overall number of sampling trips and limits schedule redundancy. SMR tracks overlapping requirements, so single sampling events can co-sample wells and optimize schedules.

Table 1-1. Groundwater SAPs Applicable to 100-BC-5

Document Number (date)	Title	Scope	Status and Schedule
DOE/RL-2003-38, Rev. 1 (September 2004) as modified by TPA-CN-522 (May 2012)	*100-BC-5 Operable Unit Sampling and Analysis Plan*	Routine groundwater monitoring (wells only); modified by TPA-CN-522 and replaced by Revision 2. TPA-CN-522 added wells installed 2009 through 2011 and incorporated changes made under previous TPA (Ecology et al., 1989a) change notices.	Replaced by Revision 2 after the October 2015 sampling event for annual wells and after January 2016 for quarterly wells.
DOE/RL-2009-44 (2010), Rev. 0 as modified by TPA-CN-559 (May 2013), TPA-CN-593 (September 2013), and TPA-CN-602 (November 2013)	*Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/ Feasibility Study*	Described studies conducted in 2009 through 2011. TPA-CN-559 added a new appendix to describe additional studies of groundwater and the hyporheic zone. TPA-CN-593 and TPA-CN-602 removed the requirement for one of the wells proposed by TPA-CN-559, modified the proposed design of HSPs, and made other minor changes.	Studies will conclude in January, 2016, and the SAP will be retired.
DOE/RL-2000-59, Rev. 1 (February 2009)	*Sampling and Analysis Plan for Aquifer Sampling Tubes*	Presented sampling requirements for conventional aquifer tubes for the entire River Corridor.	Requirements for 100-BC aquifer tubes will be superseded by this SAP (2003-38 Rev 2) beginning in fall 2016.
DOE/RL-2012-59 (November 2013)	*Surveillance Groundwater Monitoring on the Hanford Site*	Included monitoring of Ringold Formation confined aquifers (one well in 100-BC-5).	The surveillance SAP is not replaced by this SAP

Note: Complete reference citations are provided in Chapter 6.

HSP = hyporheic sampling point

SAP = sampling and analysis plan

TPA = Tri-Party Agreement

Table 1-2. Analytes for 100-BC-5 OU Groundwater Monitoring

Contaminant	CAS Number
COC	
Chromium (Hexavalent)	18540-29-9
Strontium-90	10098-97-2
Tritium	10028-17-8
Field Measurements	
Dissolved Oxygen	Not applicable
pH	Not applicable
Specific Conductance	Not applicable
Temperature	Not applicable
Turbidity	Not applicable
Depth to Groundwater	Not applicable

CAS = Chemical Abstracts Service
COC = contaminant of concern
OU = operable unit

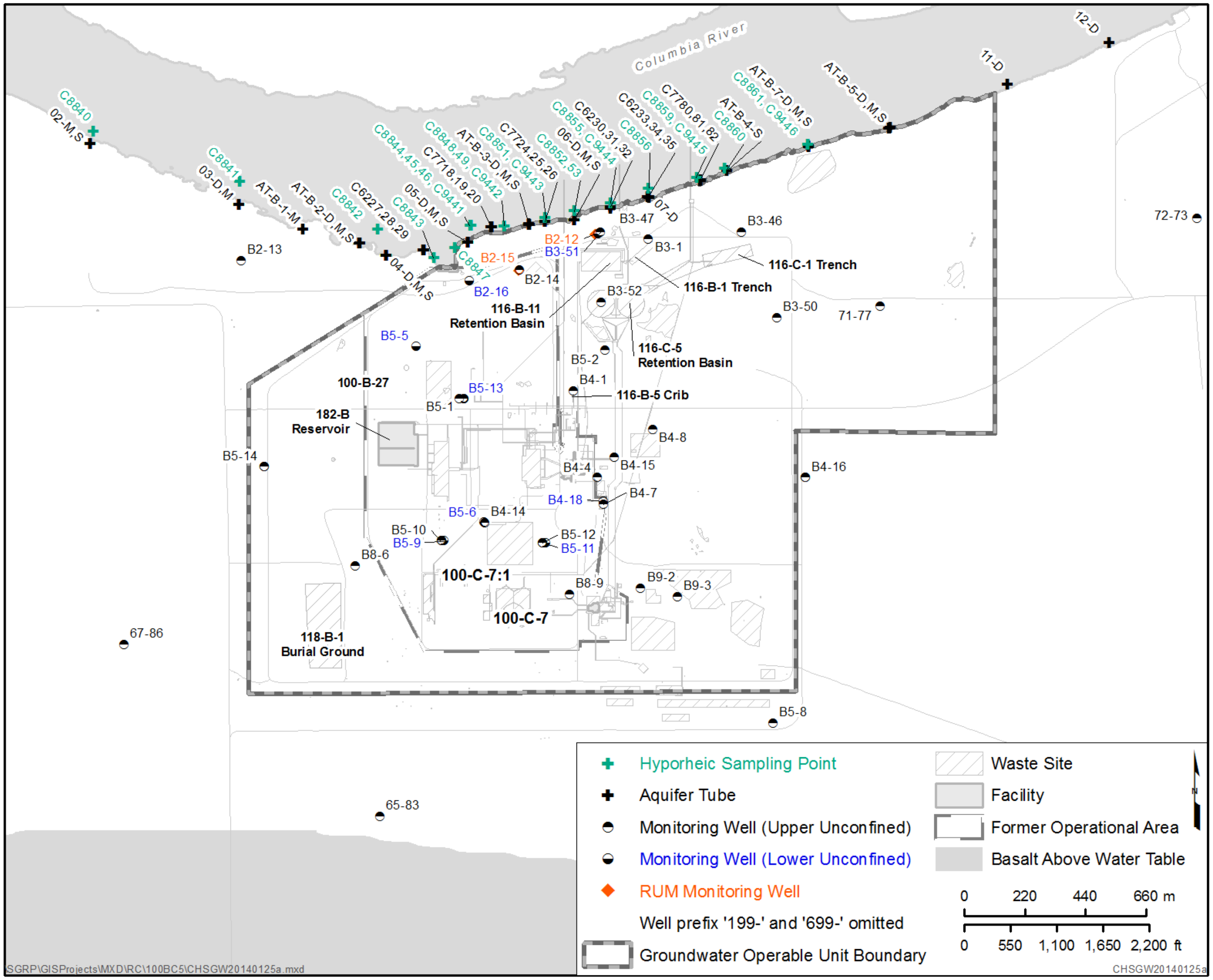


Figure 1-1. Locations of Wells, Conventional Aquifer Tubes, and Hyporheic Sampling Points in 100-BC-5

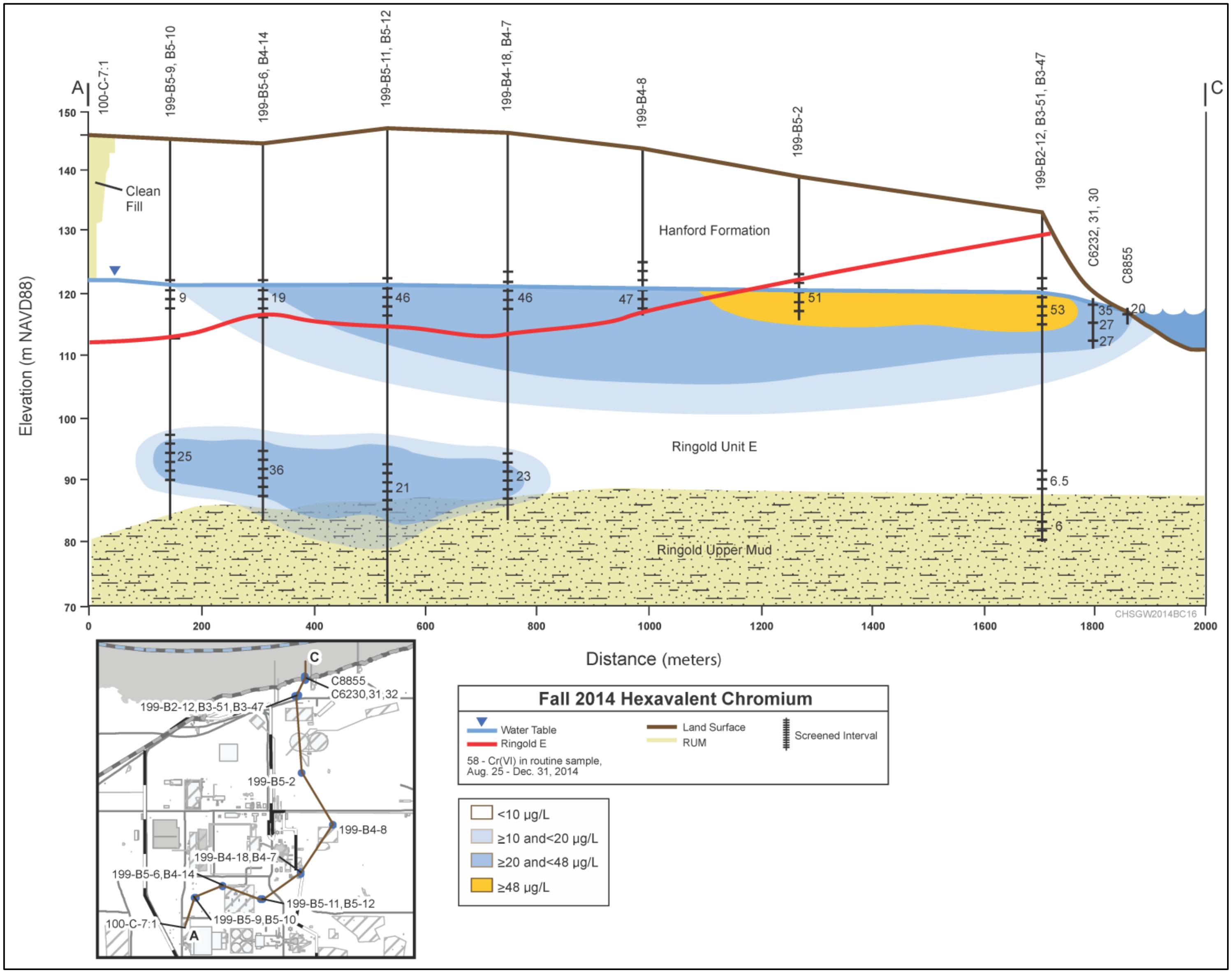


Figure 1-2. Geologic Cross Section A-C (Southwest to Northeast) with Fall 2014 Hexavalent Chromium

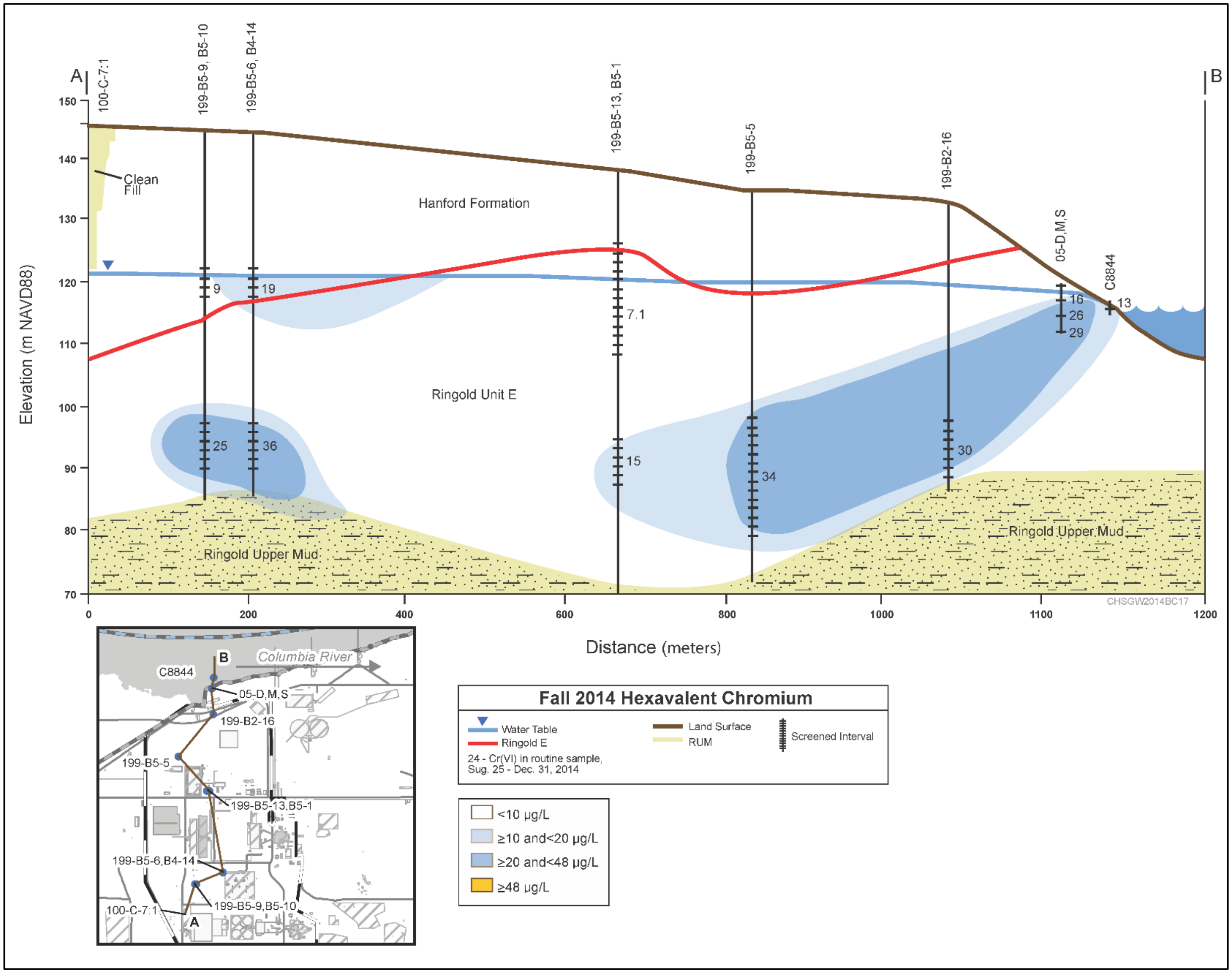


Figure 1-3. Geologic Cross Section A-B (South to North) with Fall 2014 Hexavalent Chromium

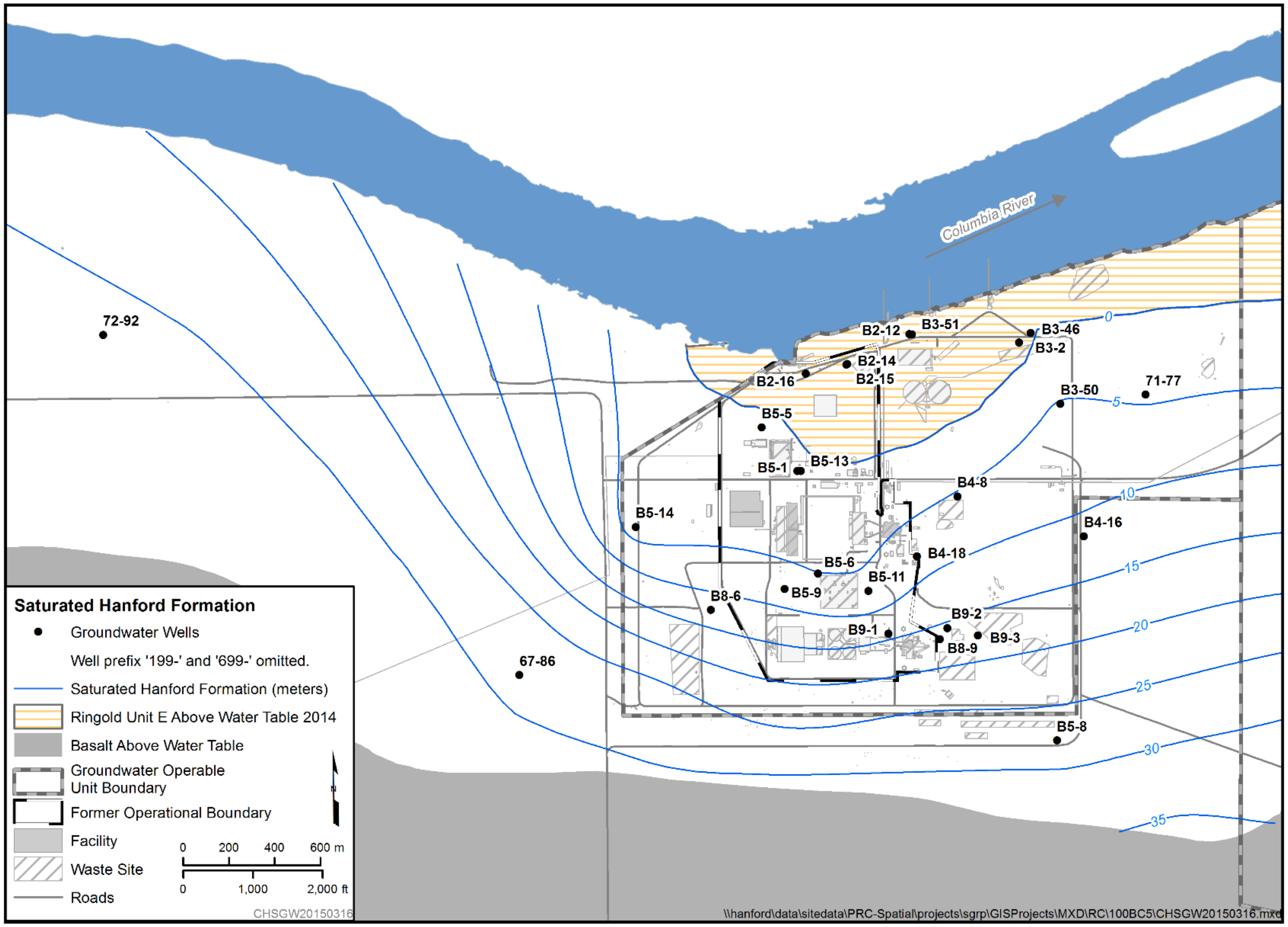
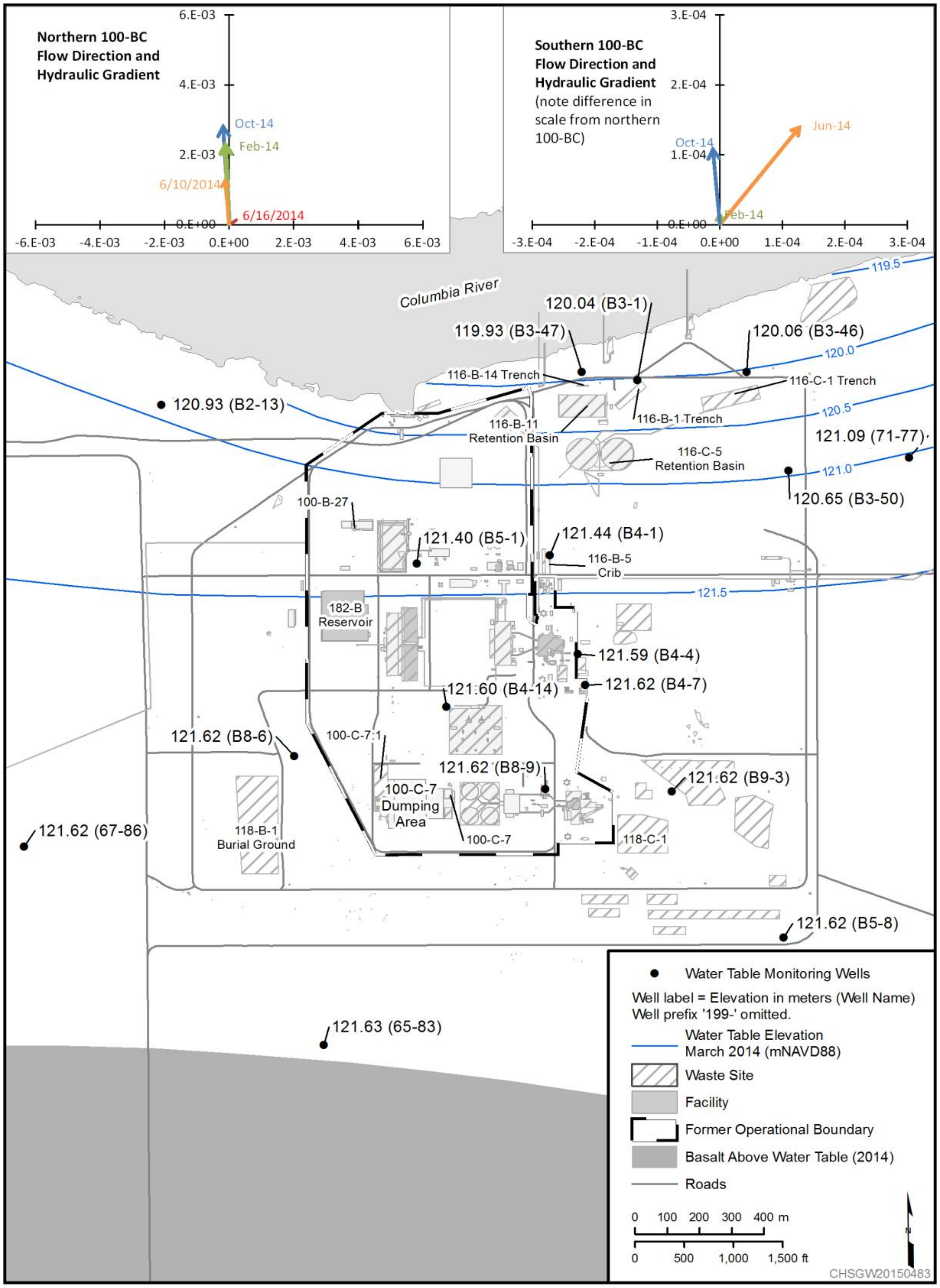
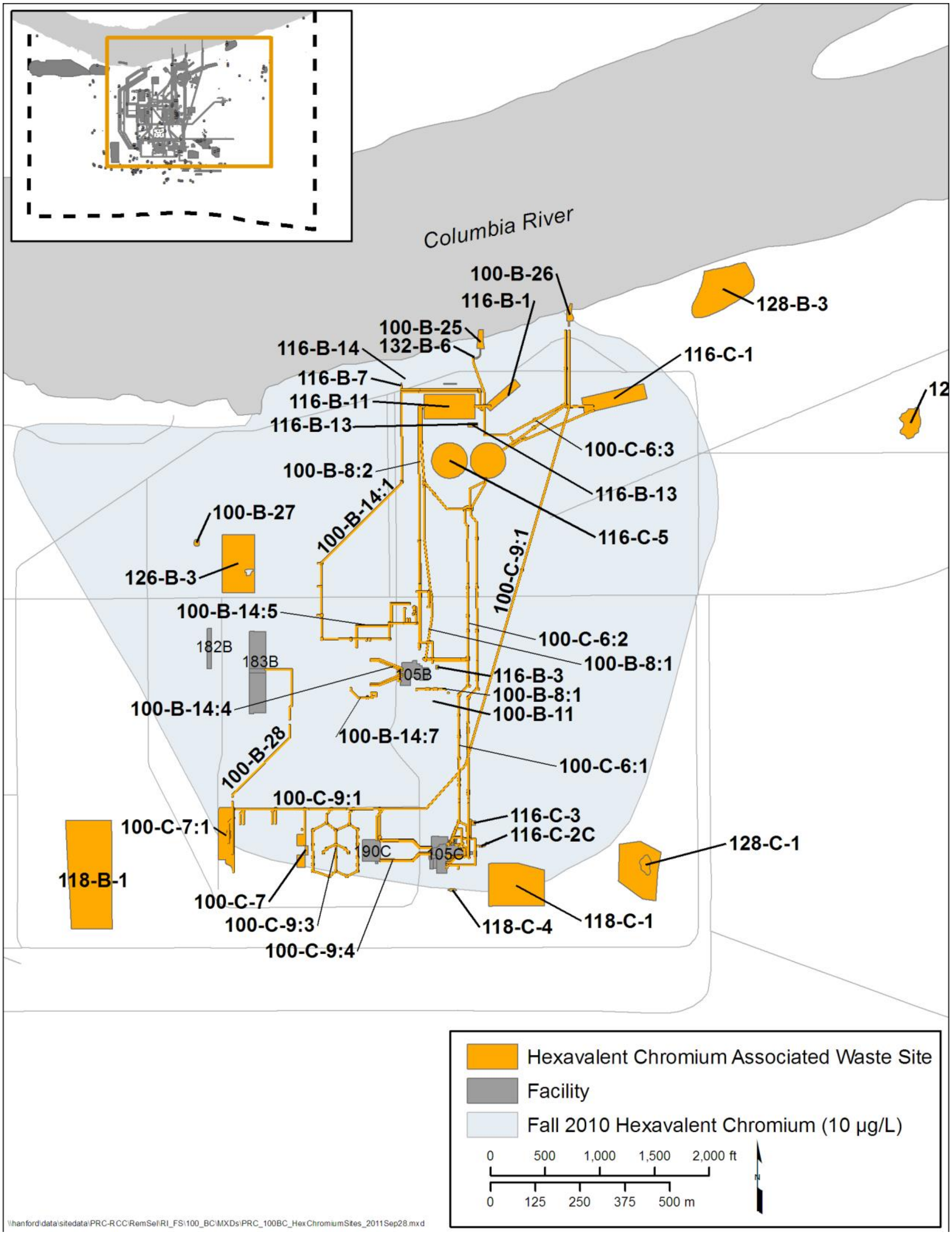


Figure 1-4. Thickness of Saturated Hanford Formation Sediments beneath the 100-BC-5 OU



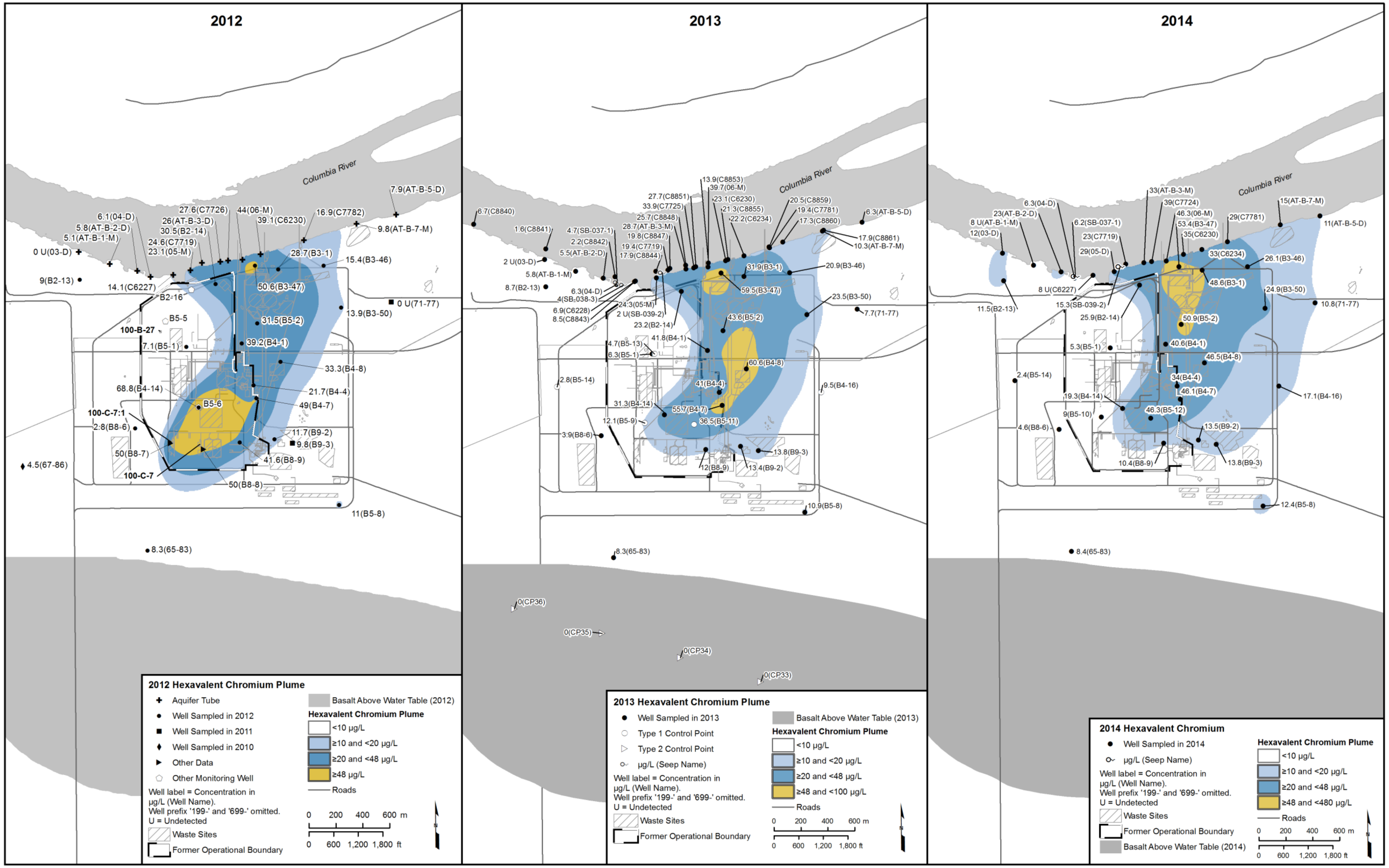
Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 1-5. Water Table and Hydraulic Gradients in the 100-BC-5 OU



Reference: DOE/RL-2010-96, *Remedial Investigation/Feasibility Study for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units.*

Figure 1-6. Hexavalent Chromium Waste Sites in the 100-BC Area



1
2
Figure 1-7. Hexavalent Chromium in the Upper Part of the Unconfined Aquifer in 2012, 2013, and 2014

3

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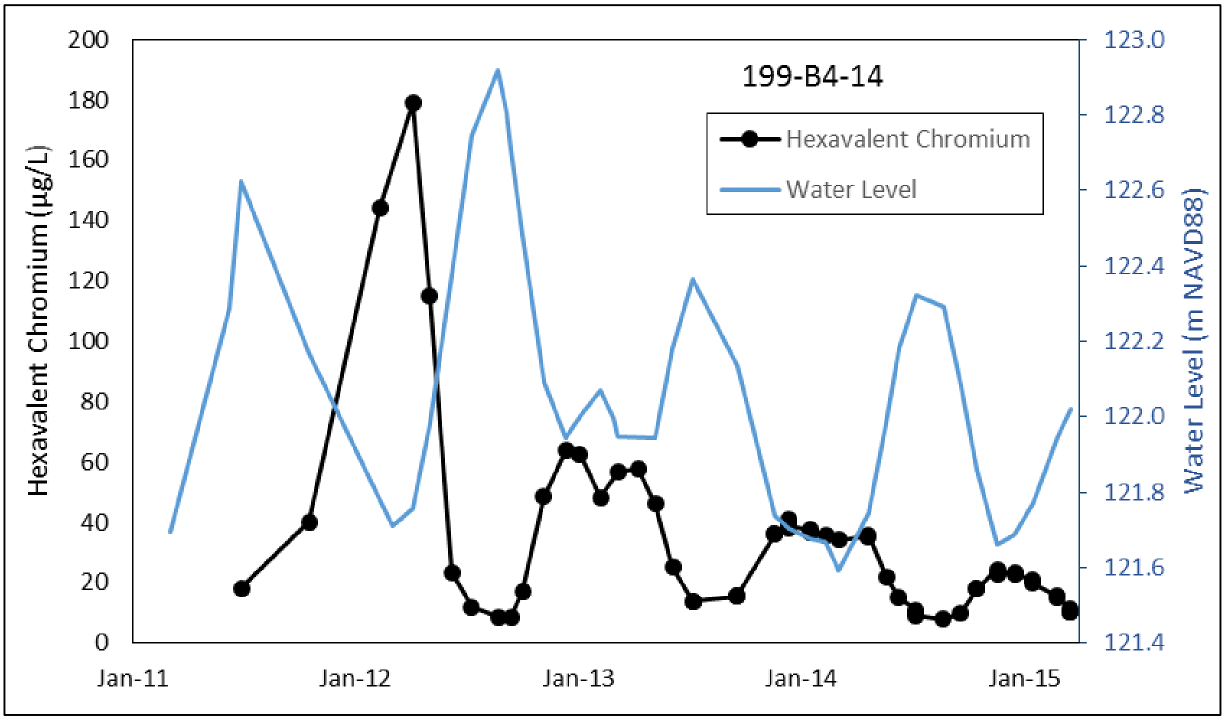

Figure 1-8. Hexavalent Chromium and Water Levels in Well 199-B4-14, Downgradient of the 100-C-7:1 Waste Site

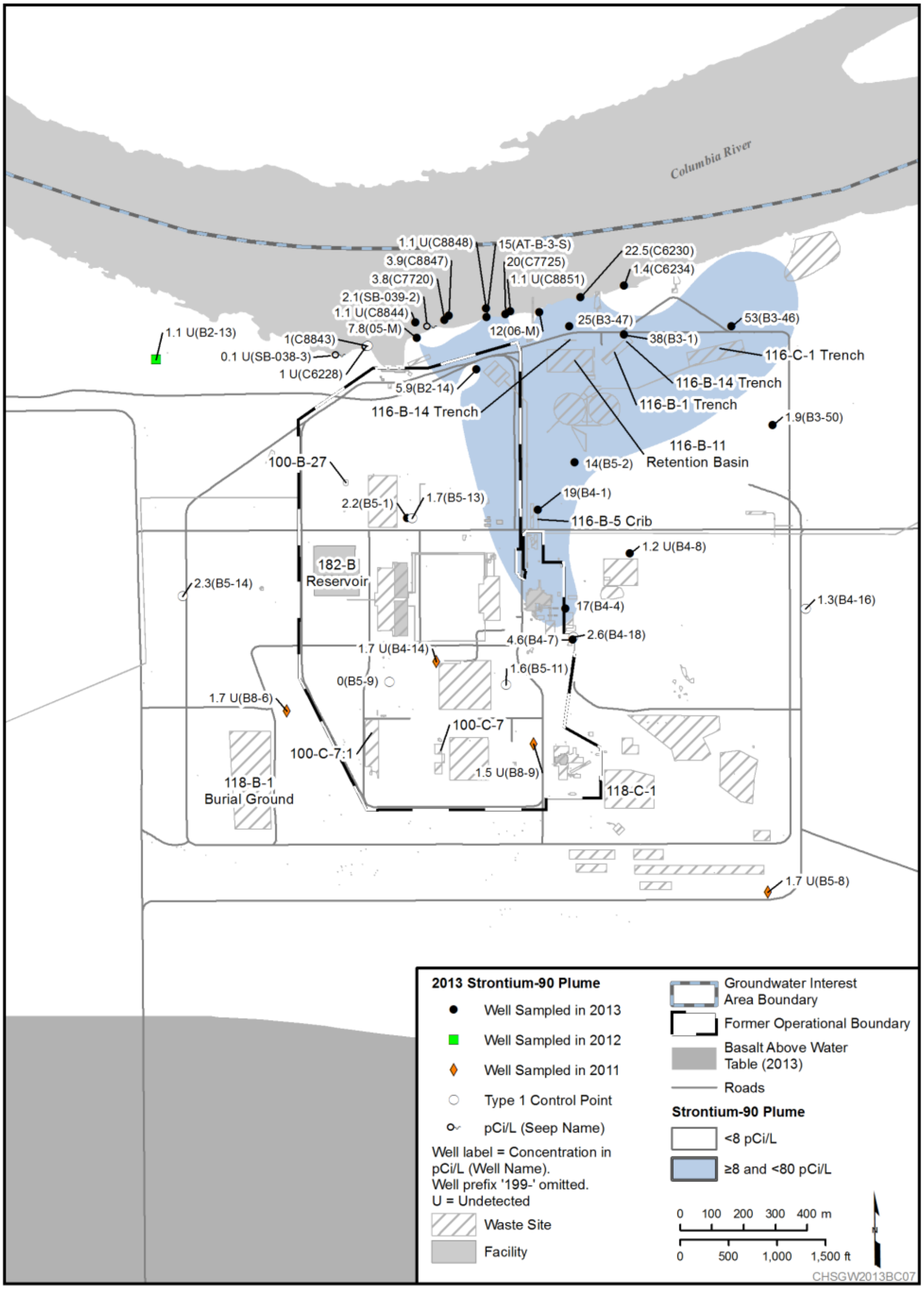

Figure 1-9. Strontium-90 in the Upper Part of the Unconfined Aquifer

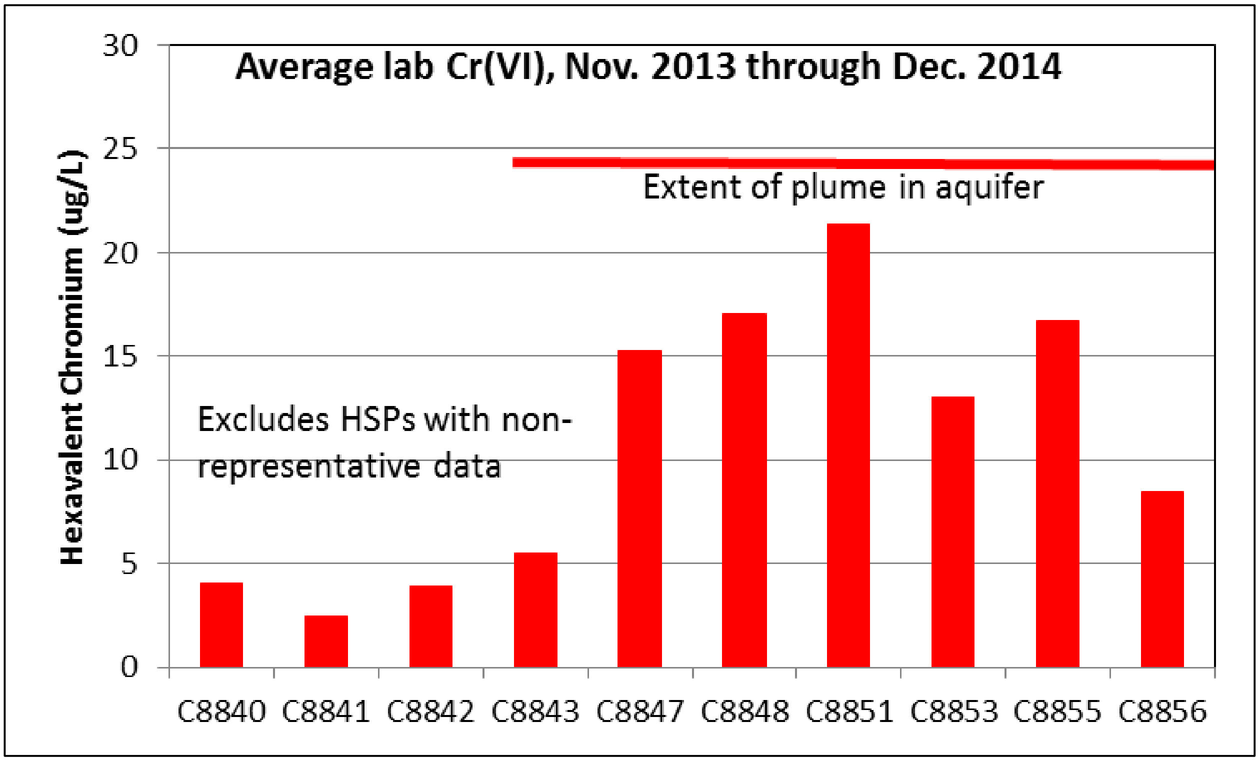

Figure 1-10. Average Hexavalent Chromium in 10 HSPs with Representative Results for the Entire Period, November 2013 through December 2014

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

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

2.1 Project Management

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

2.1.1 Project/Task Organization

The contractor, or its approved subcontractor, is responsible for planning, coordinating, sampling, and shipping samples to the laboratory. The contractor is also responsible for preparing and maintaining configuration control of the SAP and assisting the DOE Richland Operations Office (DOE-RL) project manager in obtaining approval of the SAP and future proposed revisions. The project organization (regarding routine groundwater monitoring) is described in the following subsections and is illustrated in Figure 2-1.

2.1.1.1 Regulatory Lead

The lead regulatory agency is responsible for regulatory oversight of cleanup projects and activities. EPA manages the 100-BC-5 OU and has SAP approval authority. EPA works with DOE-RL to resolve concerns over the work described in this SAP, in accordance with the TPA (Ecology et al., 1989a).

2.1.1.2 DOE-RL Project Manager

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

- Monitoring the contractor's performance of activities under CERCLA, RCRA, *Atomic Energy Act of 1954*, and the TPA (Ecology et al., 1989a) for the Hanford Site
- Obtaining EPA approval of this SAP
- Authorizing field sampling activities
- Approving the SAP
- Functioning as primary interface with regulators

2.1.1.3 DOE-RL Technical Lead

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

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

2.1.1.4 Operable Unit Project Manager

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

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

2.1.1.5 Operable Unit Technical Lead

The OU Technical Lead is responsible for the following tasks:

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

2.1.1.6 Environmental Compliance Officer

The Environmental Compliance Officer is responsible for the following tasks:

- Providing technical oversight, direction, and acceptance of project and subcontracted environmental work
- Developing appropriate mitigation measures to minimize adverse environmental impacts
- Reviewing plans, protocols, and technical documents to ensure that environmental requirements have been addressed
- Identifying environmental issues affecting operations, and developing cost-effective solutions
- Responding to environmental/regulatory issues or concerns
- Overseeing project implementation for compliance with applicable internal and external environmental requirements

2.1.1.7 Quality Assurance

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

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

2.1.1.8 Health and Safety

The Health and Safety organization is responsible for the following tasks:

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

2.1.1.9 Radiological Engineering

Radiological Engineering is responsible for the following tasks:

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

2.1.1.10 Sample Management and Reporting Organization

The SMR organization is responsible for the following activities:

- Interfacing between the OU Technical Lead, Field Sampling Operations, the Well Maintenance Organization, and analytical laboratories
- Generating field sampling documents, labels, and instructions for field sampling personnel
- Developing the sample authorization form, which provides information and instructions to the analytical laboratories
- Providing instructions to the Nuclear Chemical Operators (samplers) on the collection of samples, as specified in a SAP
- Monitoring the entire sample and data process
- Coordinating laboratory analytical work, and ensuring that the laboratories conform to Hanford Site QA requirements (or their equivalent), as approved by DOE, EPA, and the Washington State Department of Ecology (Ecology)

- Resolving sample documentation deficiencies or issues associated with Field Sampling Operations, laboratories, or other entities to ensure that project needs are met
- Receiving analytical data from the laboratories
- Ensuring that data are uploaded into the Hanford Environmental Information System (HEIS)
- Arranging for, and overseeing, data validation, as requested
- Informing the OU Project Manager and/or OU Technical Lead of any issues reported by the analytical laboratory

2.1.1.11 Analytical Laboratories

Analytical laboratories are responsible for the following tasks:

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

2.1.1.12 Waste Management

Waste Management is responsible for the following tasks:

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

2.1.1.13 Field Sampling Operations

Field Sampling Operations is responsible for the following tasks:

- Planning, coordinating, and conducting field sampling activities
- FWS directing the samplers, and ensuring they are appropriately trained and available
- FWS reviewing the SAP for field sample collection concerns, analytical requirements, and special sampling requirements
- Ensuring that the sampling design is understood by the samplers and can be performed as specified; this is achieved by performing mockups and holding practice sessions with field personnel
- Samplers collecting all salient samples in accordance with sampling documentation

- Completing field logbook entries, chain-of-custody forms, and shipping paperwork, and ensuring delivery of samples to the analytical laboratory
- FWS acting as a technical interface between the OU Project Manager and field crew supervisors (such as the Drilling Buyer's Technical Representative [BTR] and Geologist-BTR), and ensuring that technical aspects of the fieldwork are met
- In consultation with the OU Project Manager and SMR, resolving issues regarding translation of technical requirements to field operations, and coordinating resolution of sampling issues

2.1.1.14 Well Maintenance

The Well Maintenance Manager is responsible for the following tasks:

- Completing well maintenance activities
- Coordinating with the OU Technical Lead to identify field constraints that could affect groundwater sampling

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 that are acceptable and useful for decision making. In support of this objective, statistics and data descriptors, known as data quality indicators help determine the acceptability and utility of data to the user. Principal data quality indicators are precision, accuracy, representativeness, comparability, completeness, bias, and sensitivity. These are defined for the purposes of this document in Table 2-1.

Data quality is defined by the degree of rigor in the acceptance criteria assigned to data quality indicators. Applicable QC guidelines, acceptance criteria, and levels of effort for data quality assessment (DQA) are dictated by the intended use of data and the requirements of the analytical method. Data quality indicators are evaluated during the DQA process (Section 2.4.3).

2.1.3 Special Training/Certification

A graded approach is used to ensure that workers receive a level of training commensurate with their responsibilities and compliant with applicable DOE orders and government regulations. The FWS, in coordination with line management, will ensure that special training requirements for field personnel are met. Pre-job briefings, in accordance with work management and work release requirements, document the following evaluation activities and associated hazards:

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

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

2.1.4 Documents and Records

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

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

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 maintained. The project files will contain project records or references to their storage locations. Project files may include, as appropriate, the following information:

- Operational records and logbooks
- Data forms
- GPS data (a copy will be provided to SMR)
- Inspection or assessment reports and corrective action reports
- Field summary reports
- Interim progress reports
- Final reports
- Forms required by WAC 173-160, “Minimum Standards for Construction and Maintenance of Wells,” and the master drilling contract

The following records are managed and maintained by SMR personnel:

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

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

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

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

2.2 Data Generation and Acquisition

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

2.2.1 Analytical Methods Requirements

Analytical method performance requirements for samples collected are presented in Table 2-3. In consultation with the laboratory and the OU Project Manager, SMR can approve changes to analytical methods as long as the new method is based upon a nationally recognized standard method (e.g., EPA or ASTM International, formerly the American Society for Testing and Materials [ASTM]), and the new method delivers analytical data that are comparable to those provided by the old method. The new method must achieve project DQOs, as well or better than the replaced method, and is required due to the nature of the sample (e.g., high radioactivity). The laboratory using the new method must be accredited by Ecology to perform that method. Issues that may affect analytical results are resolved by SMR in coordination with the OU Project Manager.

2.2.2 Field Analytical Methods

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

2.2.3 Quality Control

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 provide information pertinent to sampling variability. Laboratory QC samples estimate precision, bias, and matrix effects of analytical data. Field and laboratory QC sample requirements 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 that reliable data are obtained. Field QC samples include field duplicates, split samples, and two types of field blanks: full trip blanks (FTBs) and equipment blanks (EBs). Field blanks are typically prepared using high-purity reagent water. QC sample definitions and their required frequency for collection are described in this section.

Field duplicates are independent samples collected as close as possible to the same time and same location as the schedule sample and are 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 are two samples collected as close as possible to the same time and same location and are intended to be identical. Field splits will be stored in separate containers and analyzed by different laboratories for the same analytes. Field splits are interlaboratory comparison samples used to evaluate comparability between laboratories.

FTBs are bottles prepared by the sampling team prior to traveling to the sampling site. The preserved bottle set is identical to the set that will be collected in the field. It is filled with high-purity reagent water (or dead water from well 699-S11-E12AP for low-level tritium FTBs[1]), 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 samples from the associated sampling event. FTBs are used to evaluate potential contamination of samples attributable to the sample bottles, preservative, handling, storage, and transportation.

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

2.2.3.2 Laboratory Quality Control Samples

Internal QA/QC programs are maintained by laboratories utilized by the project. Laboratory QA includes a comprehensive QC program that includes the use of matrix spikes, matrix spike duplicates, laboratory control samples (LCSs), tracers, carriers, and method blanks (MBs). These samples are recommended in guidance documents, are required by EPA protocol (e.g., EPA-600/4-79-020, *Methods for Chemical Analysis of Water and Wastes*), 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 DQAs, if performed. Laboratory QC and typical frequencies are listed in Table 2-4. Acceptance criteria are shown in Table 2-5. The following descriptions define the various laboratory QC samples.

Laboratory duplicate is an intralaboratory replicate sample that is used to evaluate the precision of a method in a given sample matrix.

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

Matrix spike is 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.

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

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

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

Carriers are typically nonradioactive (e.g., natural strontium) substances added in known quantities to samples to determine the overall chemical yield for the analytical preparation steps. As with a tracer, carrier recovery is a measure of the amount of analyte lost in performing the method.

Laboratories are required to analyze samples within the holding time specified in Table 2-6. In some instances, constituents in the samples not analyzed within the holding times may be compromised by volatilizing, decomposing, or other chemical changes. Data from samples analyzed outside the holding times are flagged in the HEIS database with an “H.”

2.2.4 Measurement Equipment

Each user of the measuring equipment is responsible to ensure that the equipment is functioning as expected, properly handled, and properly calibrated at required frequencies in accordance with methods governing control of the measuring equipment. Onsite environmental instrument testing, inspection, calibration, and maintenance will be recorded in accordance with approved methods. Field screening instruments will be used, maintained, and calibrated in accordance with manufacturer 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) or have been evaluated as acceptable and valid in accordance with instrument-specific methods, requirements, and specifications. Software applications will be acceptance tested prior to use in the field.

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

2.2.6 Instrument/Equipment Calibration and Frequency

Specific field equipment calibration information is provided 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 analytical methods 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 must be in place to ensure that items procured/acquired for the contractor meet the specific technical and quality requirements. The procurement system ensures that 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 the data generated as part of any sampling and analysis QA/QC effort. All data used in evaluations will be identified by source.

2.2.9 Data Management

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

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

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

2.3 Assessment and Oversight

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

2.3.1 Assessments and Response Actions

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

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

2.3.2 Reports to Management

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

2.4 Data Review and Usability

This section addresses QA activities that occur after data collection. Implementation of these activities determines whether 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, reviewing sample collection dates and sample preparation and analysis dates to assess whether holding times, if any, have been met, and reviewing QC data to determine whether analyses have met the data quality requirements specified in this SAP.

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

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

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

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

2.4.2 Data Validation

Data validation activities will be performed at the discretion of the OU Project Manager and under the direction of SMR. If performed, data validation activities will be based on EPA functional guidelines.

2.4.3 Reconciliation with User Requirements

The DQA process compares completed field sampling activities to those proposed in corresponding sampling documents and provides an evaluation of the resulting data. The purpose of the DQA is to determine whether quantitative data are of the correct type and are of adequate quality and quantity to meet the project DQOs. For routine groundwater monitoring undertaken through this integrated SAP, the DQA is captured in QC associated with the annual groundwater report (e.g., DOE/RL-2014-32), which evaluates field and laboratory QC and the usability of data. Further DQAs will be performed at the discretion of the OU Project Manager and documented in a report overseen by SMR.

Table 2-1. Data Quality Indicators

Data Quality Indicator	Definition	Determination Methodologies	Corrective Actions
Precision	Precision measures the agreement among a set of replicate measurements. Field precision is assessed through the collection and analysis of 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 the objective: • Evaluate the apparent cause (e.g., sample heterogeneity). • Request reanalysis or re-measurement. • Qualify the data before use.
Accuracy	Accuracy is the closeness of a measured result to an accepted reference value. Accuracy is usually measured as a percent recovery. QC analyses used to measure accuracy include standard recoveries, 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 the objective: • Qualify the data before use. • Request reanalysis or re-measurement.
Representativeness	Sample representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. It is dependent on the proper design of the sampling program and will be satisfied by ensuring the approved plans were followed during sampling and analysis.	Evaluate whether measurements are made and physical samples collected in such a manner that the resulting data appropriately reflect the environment or condition being measured or studied.	If results are not representative of the system sampled: • Identify the reason for them not being representative. • Flag data 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	Definition	Determination Methodologies	Corrective Actions
Comparability	Comparability expresses the degree of confidence with which one data set can be compared to another. It is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the approved plans are followed and that proper sampling and analysis techniques are applied.	Use identical or similar sample collection and handling methods, sample preparation and analytical methods, holding times, and QA protocols.	If data are not comparable to other data sets: • Identify appropriate changes to data collection and/or analysis methods. • Identify the quantifiable bias, if applicable. • Qualify the data as appropriate. • Resample and/or reanalyze if needed. • Revise sampling/analysis protocols to ensure future comparability.
Completeness	Completeness is a measure of the amount of valid data collected compared to the amount planned. Measurements are considered to be valid if they are unqualified or qualified as estimated data during validation. Field completeness is a measure of the number of samples collected versus the number of samples planned. Laboratory completeness is a measure of the number of valid measurements compared to the total number of measurements planned.	Compare the number of valid measurements completed (samples collected or samples analyzed) with those established by the project's quality criteria (DQOs or performance/ acceptance criteria).	If the data set does not meet the completeness objective: • Identify appropriate changes to data collection and/or analysis methods. • Identify the quantifiable bias, if applicable. • Resample and/or reanalyze if needed. • Revise sampling/analysis protocols to ensure future completeness
Bias	Bias is the systematic or persistent distortion of a measurement process that causes error in one direction (e.g., the sample measurement is consistently lower than the sample's true value). Bias can be introduced during sampling, analysis, and data evaluation. Analytical bias refers to deviation in one direction (i.e., high, low, or unknown) of the measured value from a known spiked amount.	Sampling bias may be revealed by analysis of replicate samples. Analytical bias may be assessed by comparing a measured value in a sample of known concentration to an accepted reference value or by determining the recovery of a known amount of contaminant spiked into a sample (matrix spike).	For sampling bias: • Properly select and use sampling tools. • Institute correct sampling and subsampling procedures to limit preferential selection or loss of sample media. • Use sample handling procedures, including proper sample preservation, that limit the loss or gain of constituents to the sample media.

Table 2-1. Data Quality Indicators

Data Quality Indicator	Definition	Determination Methodologies	Corrective Actions
			• 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 labs for analysis.
Sensitivity	Sensitivity is an instrument's or method's minimum concentration that can be reliably measured (i.e., instrument detection limit or limit of quantitation).	Determine the minimum concentration or attribute to be measured by an instrument (instrument detection limit) or by a laboratory (limit of quantitation). The lower limit of quantitation* is the lowest level that can be routinely quantified and reported by a laboratory.	If detection limits do not meet the objective: • Request reanalysis or re-measurement using methods or analytical conditions that will meet the required detection or limit of quantitation. • Qualify/reject the data before use.

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

* For the purposes of this SAP, the lower limit of quantitation is the same as the PQL.

DQO = data quality objective
PQL = practical quantitation limit
QA = quality assurance
QC = quality control
SAP = sampling and analysis plan

Table 2-2. Change Control for Sampling Projects

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

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

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

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

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

DQO = data quality objective

OU = operable unit

SAP = sampling and analysis plan

TPA = Tri-Party Agreement

Table 2-3. Performance Requirements for Groundwater Analysis

Constituent	CAS Number	Action Level[a]	Analytical Method	Highest Allowable PQL[b]	Precision	Accuracy
Radionuclides (pCi/L)						
Strontium-90	10098-97-2	8	Gas proportional counting	2	≤20% RPD	70 to 130%
Tritium	10028-17-8	20,000	Tritium liquid scintillation (mid-level)	400		
Inorganics – Metals (µg/L)						
Hexavalent Chromium (Low Level)	18540-29-9	10/48[c]	EPA 7196[d]	5[e]	≤20% RPD	80 to 120%

a. See Appendix A for action level basis.

b. 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 quantitation limits. For radionuclides, values in this column are the highest allowable minimum detectable concentrations.

c. 10 µg/L where groundwater discharges to surface water; 48 µg/L in upland areas.

d. SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*. Equivalent methods may be substituted.

e. A low-level hexavalent chromium PQL of 5 µg/L is applicable to River Corridor where groundwater discharges to surface water.

CAS = Chemical Abstracts Service

EPA = U.S. Environmental Protection Agency

PQL = practical quantitation limit

RPD = relative percent difference

Table 2-4. Project QC Requirements

Sample Type	Frequency	Characteristics Evaluated
Field QC		
Field Duplicates	1 in 20 well trips	Precision, including sampling and analytical variability
Field Splits	As needed When needed, the minimum is one for every analytical method, for analyses performed where detection limit and precision and accuracy criteria have been defined in the analytical performance requirements table (Table 2-3).	Precision, including sampling, analytical, and interlaboratory
FTBs	1 in 20 well trips	Cross-contamination from containers or transportation
EBs	As needed If only disposable equipment is used, or equipment is dedicated to a particular well, then an EB is not required; otherwise, 1 for every 20 samples.[a]	Adequacy of sampling equipment decontamination and contamination from nondedicated equipment
Analytical QC[b]		
Laboratory Duplicates	1 per analytical batch[c]	Laboratory reproducibility and precision
MSs	1 per analytical batch[c]	Matrix effect/laboratory accuracy
LCSs	1 per analytical batch[c]	Evaluate laboratory accuracy
MBs	1 per analytical batch[c]	Laboratory contamination
Tracers/Carriers	1 per analytical batch[c]	Recovery/yield

a. For portable pumps, EBs are collected 1 for every 10 well trips. Whenever a new type of nondedicated equipment is used, an EB will be collected every time sampling occurs until it can be shown that less frequent collection of EBs is adequate to monitor the decontamination methods for the nondedicated equipment.

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

c. Unless not required by, or different frequency is called out in, laboratory analysis methods.

EB = equipment blank
FTB = full trip blank
LCS = laboratory control sample
MB = method blank
MS = matrix spike
QC = quality control

Table 2-5. Field and Laboratory QC Elements and Acceptance Criteria

Analyte[a]	QC Element	Acceptance Criteria	Corrective Action
General Chemical Parameters			
Hexavalent Chromium	MB	<MDL <5% Sample Concentration	Flagged with “C”
	LCS	80 to 120% Recovery	Data reviewed[b]
	Laboratory Duplicate	≤20% RPD[c]	Data reviewed[b]
	MS	75 to 125% Recovery	Flagged with “N”
	EB	<2 × MDL	Flagged with “Q”
	Field Duplicate	≤20% RPD[e]	Flagged with “Q”
Radiochemical Analyses			
Strontium-89/90 Tritium	MB	<MDA <5% Sample Concentration	Flagged with “B”
	LCS	70 to 130% Recovery	Data reviewed[b]
	Laboratory Duplicate	≤ 20% RPD[c]	Data reviewed[b]
	MS[d]	60 to 140% Recovery	Flagged with “N”
	Tracer (where applicable)	20 to 105% Recovery	Data reviewed[b]
	Carrier (where applicable)	30 to 105% Recovery	Data reviewed[b]
	EB, FTB	<2 × MDA	Flagged with “Q”
	Field Duplicate	≤20% RPD[c]	Flagged with “Q”

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

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

c. Applies only in cases where both results are greater than 5 times the minimum detectable concentration.

d. Applies only to tritium.

EB = equipment blank
FTB = full trip blank
LCS = laboratory control sample
MB = method blank
MDA = minimum detectable activity
MDL = method detection limit
MS = matrix spike
MSD = matrix spike duplicate
QC = quality control
RPD = relative percent difference
SMR = Sample Management and Reporting

Data Flags:

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

N = MS outlier

Q = associated QC sample is out of limits

Table 2-6. Preservation, Container, and Holding Time Guidelines

Constituent/ Parameter	Minimum Volume	Container Type[a]	Preservation[b]	Holding Time
Miscellaneous Inorganic				
Hexavalent Chromium	500 mL	Poly or glass	Store ≤6°C	24 hours
Radiochemical Analyses				
Strontium-90 (Total Beta Radiostrontium)	2 × 1 L	Wide-mouth poly or glass	Adjust pH to <2 with HNO_3	6 months
Tritium	250 mL	Narrow-mouth glass	None	6 months

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

a. Under the Container Type heading, the term poly stands for EPA clean polyethylene bottles.

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

DQO = data quality objective

EPA = U.S. Environmental Protection Agency

HNO_3 = nitric acid

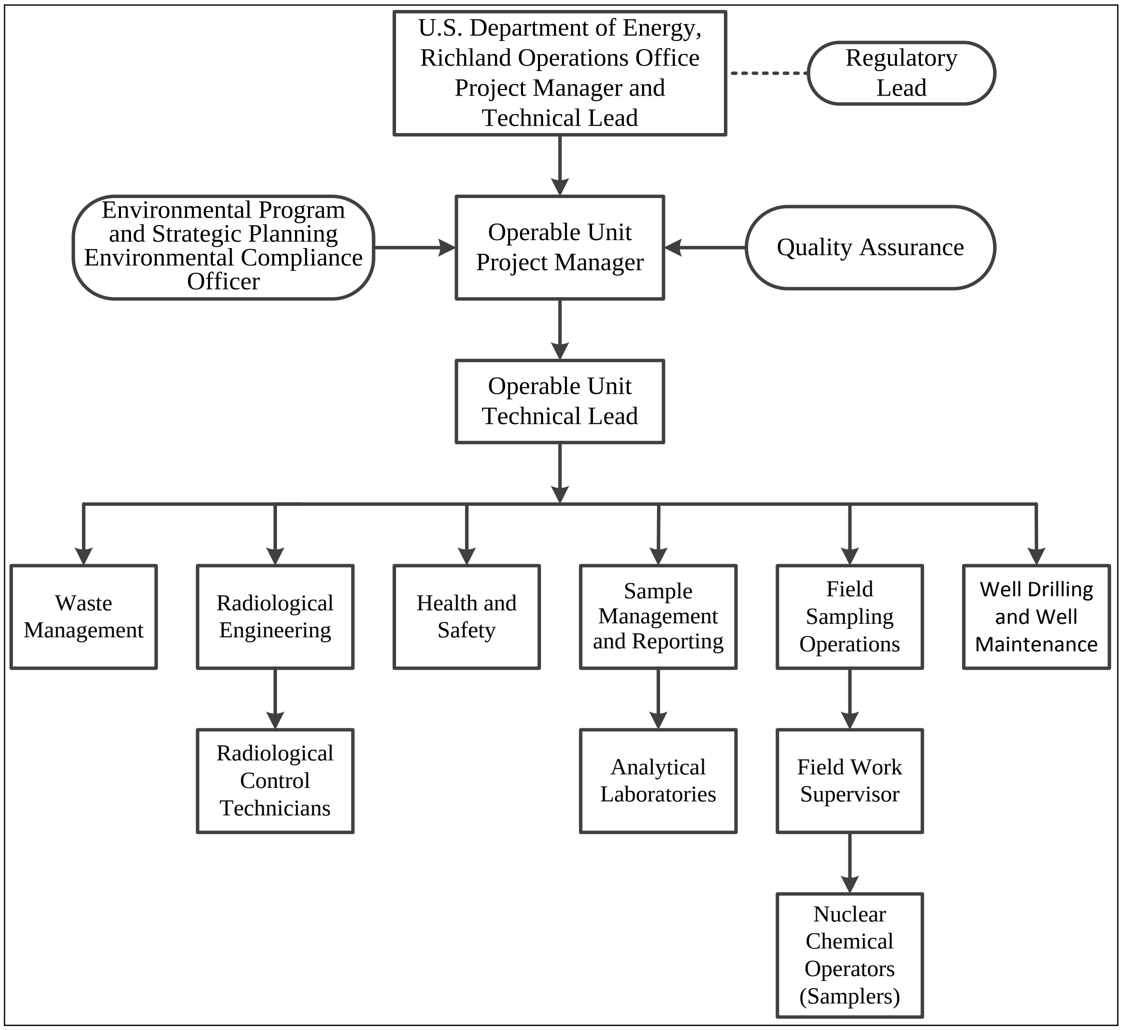

Figure 2-1. Project Organization

3 Field Sampling Plan

This chapter lists the groundwater wells and aquifer tubes to be monitored, the sampling frequency, and the constituents to be analyzed.

3.1 Sampling Objectives

Due to recently completed source remediation and plume dynamics, continued monitoring is necessary to confirm the CSM used for the RI/FS evaluations. Data collected under this SAP will be used to support the design of remedial alternatives such as MNA, pump and treat, or other alternatives considered in the FS. Appendix A provides details of sampling objectives, goals of the study, and the analytical approach.

3.2 Sample Location, Frequency, and Constituents To Be Monitored

Table 3-1 lists the monitoring wells, aquifer tubes, and HSPs selected for the 100-BC-5 monitoring network. It also specifies analytes and sampling frequency. The monitoring network includes 28 wells, 14 conventional aquifer tubes, and 9 HSPs (Figure 3-1). Appendix A contains the criteria used to identify the wells and aquifer tubes needed to answer the principal study question and to determine the sampling frequency to be employed. Table A-4 of Appendix A provides information on the hydrogeologic unit monitored by the wells, aquifer tubes, and HSPs. Table 3-2 lists wells for water level monitoring.

3.3 Sampling Methods

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

- Field screening measurements
- Groundwater sampling
- Aquifer tube and HSP sampling
- Water level measurements

Water samples will be collected according to the current revision of applicable operating methods. Water samples are collected after field measurements of purged groundwater have stabilized:

- pH – two consecutive measurements agree within 0.2 pH units
- Temperature – two consecutive measurements agree within 0.2°C
- Conductivity – two consecutive measurements agree within 10 percent of each other
- Turbidity – less than 5 nephelometric turbidity units prior to sampling (or project scientist's recommendation)

Dissolved oxygen also will be measured in the field, but stabilization of dissolved oxygen is not required under sampling procedures.

For certain types of samples, preservatives are required. While the preservative may be added to the collection bottles before their use in the field, it is allowable to add the preservative at the sampling vehicle immediately after collection. Hexavalent samples require filtering in the field, as noted on the chain-of-custody forms.

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

Suggested sample container, preservation, and holding time requirements are specified in Table 2-6. These requirements are in accordance with the analytical method specified in Table 2-3. The final container type and volumes will be identified on the sample authorization and chain-of-custody forms. This SAP defines a sample as a filled sample bottle for starting the clock for holding time restrictions.

Holding time is the elapsed time period between sample collection and analysis. Exceeding required holding times could result in changes in constituent concentrations due to volatilization, decomposition, or other chemical alterations. Required holding times are specified in appropriate EPA analytical methods (e.g., EPA-600/4-79-020 or SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*).

3.3.1 Decontamination of Sampling Equipment

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

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

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

3.3.2 Radiological Field Data

The 100-BC-5 wells and aquifer tubes do not currently require radiological screening. If conditions change, alpha and beta/gamma data collection in the field will be used, as needed, to support sampling and analysis efforts. Radiological screening will be performed by the Radiological Control Technician or other qualified personnel. The Radiological Control Technician will record field measurements, noting the depth of the sample and the instrument reading. Measurements will be relayed to the field geologist (for aquifer tubes and wells) for daily inclusion in the field logbook or operational records, as applicable.

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

- Instructions to Radiological Control Technicians on the methods required to measure sample activity and media for gamma, alpha, and/or beta emissions, as appropriate.
- Information regarding portable radiological field instrumentation, including a physical description of the instruments; radiation and energy response characteristics; calibration/maintenance and performance testing descriptions; and application/operation of the instrument. These instruments are commonly used on the Hanford Site to obtain measurements of removable surface contamination and direct measurements of the total surface contamination.
- Instructions regarding the minimum requirements for documenting radiological controls information in accordance with 10 CFR 835, "Occupational Radiation Protection."
- Instructions for managing the identification, creation, review, approval, storage, transfer, and retrieval of radiological information.

- 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 conduct of field investigation activities. Data will be cross-referenced between laboratory analytical data and radiation measurements to facilitate interpreting the investigation results.

3.3.3 Water Levels

An existing automated water level network (AWLN) in 100-BC-5 will be modified under this SAP (Table 3-2 and Figure 3-2). Manual measurements will be made periodically in a broader network of wells (Table 3-2) according to the following schedule:

- March (moderate river stage; in conjunction with Hanford Sitewide measurements [SGW-38815, *Water-Level Monitoring Plan for the Hanford Site Soil and Groundwater Remediation Project*])
- June (high river stage)
- September (low river stage)

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

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

Data forms may be used to collect field information; however, 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 the logbooks:

- 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, and other QC samples)
- Locations and types of samples
- Chain-of-custody details and variances relating to the chain-of-custody
- Field measurements
- Field calibrations testing, inspections, maintenance, 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

3.4.1 Corrective Actions and Deviations for Sampling Activities

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

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

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

3.5 Calibration of Field Equipment

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

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

- Prior to initial use of a field analytical measurement system.
- At the frequency recommended by the manufacturer or methods, or as required by regulations.
- Upon failure to meet specified QC criteria.
- Calibration of radiological field instruments on the Hanford Site is performed by the Mission Support Alliance prime contractor, as specified by their calibration program.
- Daily calibration checks will be performed and documented for each instrument used to characterize areas under investigation. These checks will be made on standard materials sufficiently like the

matrix under consideration for direct comparison of data. Analysis times will be sufficient to establish detection efficiency and resolution.

- Standards used for calibration will be traceable to a nationally recognized standard agency source or measurement system.

3.6 Sample Handling

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

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

3.6.1 Containers

Precleaned sample containers with certificates of analysis denoting compliance with EPA specifications (EPA 540/R-93/051, *Specifications and Guidance for Contaminant-Free Sample Containers*) for the intended analyses will be used for samples collected for chemical analysis. Container sizes may vary depending on laboratory-specific volumes/requirements for meeting analytical detection limits. The Radiological Engineering organization will measure both the contamination levels and dose rates associated with filled sample containers. This information, along with other data, will be used to select proper packaging, marking, labeling, and shipping paperwork and to verify that the sample can be received by the analytical laboratory in accordance with the laboratory's radioactivity acceptance criteria. If the dose rate on the outside of a sample container or the curie content exceeds levels acceptable by an offsite laboratory, the FWS (in consultation with the SMR organization) can send smaller volumes to the laboratory. However, based upon historical data, it is unlikely that water samples from 100-BC-5 will have sufficient radionuclide levels or dose rates to pose problems for shipping or laboratory acceptance. Container types and sample amounts/volumes are identified in Table 2-6.

3.6.2 Container Labeling

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

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

Sample records must include the following information:

- Analysis required
- Source of sample

- Matrix (water)
- Field data (pH, temperature, turbidity, and conductivity)
- Radiological readings

3.6.3 Sample Custody

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

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

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

- Project name
- Signature of sampler
- Unique sample number
- Date and time of collection
- Matrix
- Preservatives
- Signatures of individual involved in sample transfer
- Requested analyses (or reference thereto)

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

3.6.4 Sample Transportation

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

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

Materials are classified by DOT/IATA as radioactive when the isotope-specific activity concentration and the exempt consignment limits described in 49 CFR 173, "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 that 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 applicable license limits are not exceeded. The laboratory shall provide SMR with written acceptance for samples with elevated radioactive contamination or dose.

Table 3-1. 100-BC-5 Groundwater Monitoring Network

Well, Aquifer Tube, or HSP	Zone Monitored	Monitoring Rationale	Field	Cr(VI)[a]	Sr-90	Tritium
Monitoring Wells						
199-B2-13	Top unconfined	Northwest of 100-BC; Cr(VI) >ambient water quality criterion 2014; confirm general attenuation of Cr(VI).	A	A		
199-B2-14	Top unconfined	Define Cr(VI) plume and delimit Sr-90.	A	A	A	
199-B2-16	Bottom unconfined	Monitor deep Cr(VI).	A	A		
199-B3-1	Top unconfined	Monitor passage of Cr(VI) plume and Sr-90 variability; tritium is elevated and increasing.	S	S	S	S
199-B3-46	Top unconfined	Monitor passage of Cr(VI) plume and Sr-90 variability.	S	S	S	
199-B3-47	Top unconfined	Monitor passage of Cr(VI) plume and Sr-90 variability; tritium is elevated.	S	S	S	S
199-B3-50	Top unconfined	Cr(VI) >20 µg/L and increasing; monitor eastward migration; Sr-90 is consistently low.	A	A		
199-B3-51	Bottom unconfined	Monitor deep Cr(VI).	A	A		
199-B3-52	Top unconfined	Monitor passage of southern Cr(VI) plume and Sr-90 variability.	S	S	S	
199-B4-1	Top unconfined	Monitor Cr(VI) plume; redundant for Sr-90.	A	A		
199-B4-4	Top unconfined	Monitor Cr(VI) plume; southern extent Sr-90 plume.	A	A	A	
199-B4-7	Top unconfined	Monitor migration of Cr(VI); tritium is elevated; Sr-90 is consistently <DWS.	A	A		A
199-B4-8	Top unconfined	Monitor migration of Cr(VI); tritium is elevated; Sr-90 is consistently <DWS.	A	A		A
199-B4-14	Top unconfined	Monitor Cr(VI) plume near 100-C-7:1.	S[b]	S[b]		
199-B4-16	Top unconfined	Monitor east part of Cr(VI) plume.	A	A		

Table 3-1. 100-BC-5 Groundwater Monitoring Network

Well, Aquifer Tube, or HSP	Zone Monitored	Monitoring Rationale	Field	Cr(VI)[a]	Sr-90	Tritium
199-B4-18	Bottom unconfined	Monitor deep Cr(VI).	A	A		
199-B5-2	Top unconfined	Monitor passage of southern Cr(VI) plume; in Sr-90 plume; elevated tritium.	S	S	A	S
199-B5-5	Middle/bottom unconfined	Monitor deep Cr(VI).	A	A		
199-B5-6	Bottom unconfined	Monitor deep Cr(VI).	A	A		
199-B5-9	Bottom unconfined	Monitor deep Cr(VI).	A	A		
199-B5-10	Top unconfined	Monitor Cr(VI) adjacent to 100-C-7:1.	A	A		
199-B5-11	Bottom unconfined	Monitor deep Cr(VI).	A	A		
199-B5-12	Top unconfined	Monitor Cr(VI) adjacent to 100-C-7; tritium is redundant with nearby wells.	A	A		
199-B5-13	Middle unconfined	Monitor deep Cr(VI).	A	A		
199-B8-9	Top unconfined	Monitor southern edge of Cr(VI) plume; elevated tritium.	A	A		A
199-B9-3	Top unconfined	Monitor southern edge of Cr(VI) plume; tritium is increasing.	A	A		A
699-71-77	Top unconfined	Monitor eastward migration Cr(VI).	A	A		
699-72-73	Top unconfined	Monitor eastward migration Cr(VI).	A	A		
Conventional Aquifer Tubes						
03-D	Upper unconfined	Monitor upstream deep hyporheic zone.	A	A		
05-M	Upper unconfined	Define upstream edge of Sr-90; monitor Cr(VI).	A	A	A	
06-M	Upper unconfined	Monitor Cr(VI), Sr-90 (>DWS), and tritium (formerly >DWS).	A	A	A	
11-D	Upper unconfined	Delimit downstream edge of plume; has not been sampled since 2007 and may no longer be useable.	A	A		
12-D	Upper unconfined	Delimit downstream edge of plume.	A	A		
AT-B-2-D	Upper unconfined	2014 data point is anomalously high; monitor for trend.	A	A		
AT-B-3-S	Upper unconfined	Cr(VI) and Sr-90 are elevated and rising.	A	A	A	
AT-B-5-D	Upper unconfined	Monitor downstream migration of Cr(VI).	A	A		
AT-B-7-M	Upper unconfined	Monitor Cr(VI); Sr-90 is historically undetected.	A	A		

Table 3-1. 100-BC-5 Groundwater Monitoring Network

Well, Aquifer Tube, or HSP	Zone Monitored	Monitoring Rationale	Field	Cr(VI)[a]	Sr-90	Tritium
C6230	Upper unconfined	Highest Sr-90 in aquifer tube; Cr(VI) is also elevated.	A	A	A	
C6234	Upper unconfined	Monitor Cr(VI).	A	A		
C7719	Upper unconfined	Maximum Cr(VI) in this cluster; no significant Sr-90.	A	A		
C7725	Upper unconfined	Monitor Cr(VI) and Sr-90.	A	A	A	
C7781	Upper unconfined	Monitor Cr(VI) and Sr-90.	A	A	A	
Hyporheic Sampling Points						
C8841	Hyporheic zone	Monitor upstream shallow hyporheic zone	A	A		
C8842	Hyporheic zone	Monitor hyporheic zone near AT-B-2-D.	A	A		
C8847	Hyporheic zone	Upstream edge of Cr(VI) in shallow hyporheic zone	A	A	A	
C8851	Hyporheic zone	Monitor shallow hyporheic zone.	A	A	A	
C8853	Hyporheic zone	Monitor shallow hyporheic zone adjacent to 06-M; flow is too low for Sr-90.	A	A		
C8855	Hyporheic zone	Monitor Cr(VI) in shallow hyporheic zone; flow is too low for Sr-90.	A	A		
C8859	Hyporheic zone	Monitor shallow hyporheic zone.	A	A		
C8861	Hyporheic zone	Monitor shallow hyporheic zone.	A	A		
C9442	Hyporheic zone	Monitor Cr(VI) in shallow hyporheic zone.	A	A		

Note: Field column indicates specific conductance, pH, temperature, turbidity, and dissolved oxygen.

a. Filtered samples

b. Semiannual on a different schedule from others (low river stage and January or February)

Cr(VI) = hexavalent chromium

DWS = drinking water standard

HSP = hyporheic sampling point

Sr-90 = strontium-90

Sampling frequencies:

A = annual (low river stage, September to October)

S = semiannual (low and high river stage, mid-May to early July)

Table 3-2. Water Level Network for 100-BC-5

Well Name	Well ID	Comment	Manual	AWLN	Status of AWLN as of April 2015
199-B2-13	A4551		Y		
199-B2-14	C7665		Y	Y	Not yet installed
199-B2-16	C7784	Deep	Y		
199-B3-1	A4552		Y		
199-B3-46	A4553		Y	Y	Not yet installed
199-B3-47	A4554		Y	Y	AWLN operating
199-B3-50	C7506		Y	Y	AWLN operating
199-B3-51	C7785	Deep	Y	Y	AWLN operating
199-B3-52	C7843		Y		
199-B4-1	A4555		Y		
199-B4-4	A4557		Y		
199-B4-7	A5541		Y	Y	AWLN operating
199-B4-8	A4559		Y	Y	Not yet installed
199-B4-14	C7786		Y	Y	AWLN operating
199-B4-16	C8776		Y	Y	AWLN operating
199-B4-18	C8778	Deep	Y	Y	AWLN operating
199-B5-1	A4561		Y	Y	AWLN operating
199-B5-2	A4562		Y		
199-B5-5	C7505	Deep	Y		
199-B5-6	C7507	Deep	Y	Y	AWLN operating
199-B5-8	C8244		Y	Y	AWLN operating
199-B5-9	C8779	Deep	Y		
199-B5-10	C8780		Y		
199-B5-11	C8781	Deep	Y		
199-B5-12	C8782		Y		
199-B5-13	C8783	Deep	Y	Y	AWLN operating
199-B5-14	C8784		Y		
199-B8-6	A4563		Y	Y	AWLN operating
199-B8-9	C7508		Y	Y	Not yet installed

Table 3-2. Water Level Network for 100-BC-5

Well Name	Well ID	Comment	Manual	AWLN	Status of AWLN as of April 2015
199-B9-3	A4566		Y	Y	Not yet installed
699-65-72	A5302		Y		
699-65-83	A5303		Y		
699-67-86	A5313		Y		
699-71-77	A5322		Y	Y	Not yet installed
699-72-73	A5323		Y	Y	Not yet installed
Total			35	19	

Note: Manual water levels are to be measured three times per year (September, March, and June).

AWLN = automated water level network (data recorded at 1-hour intervals)

ID = identification

Y = well used for automated or manual water levels

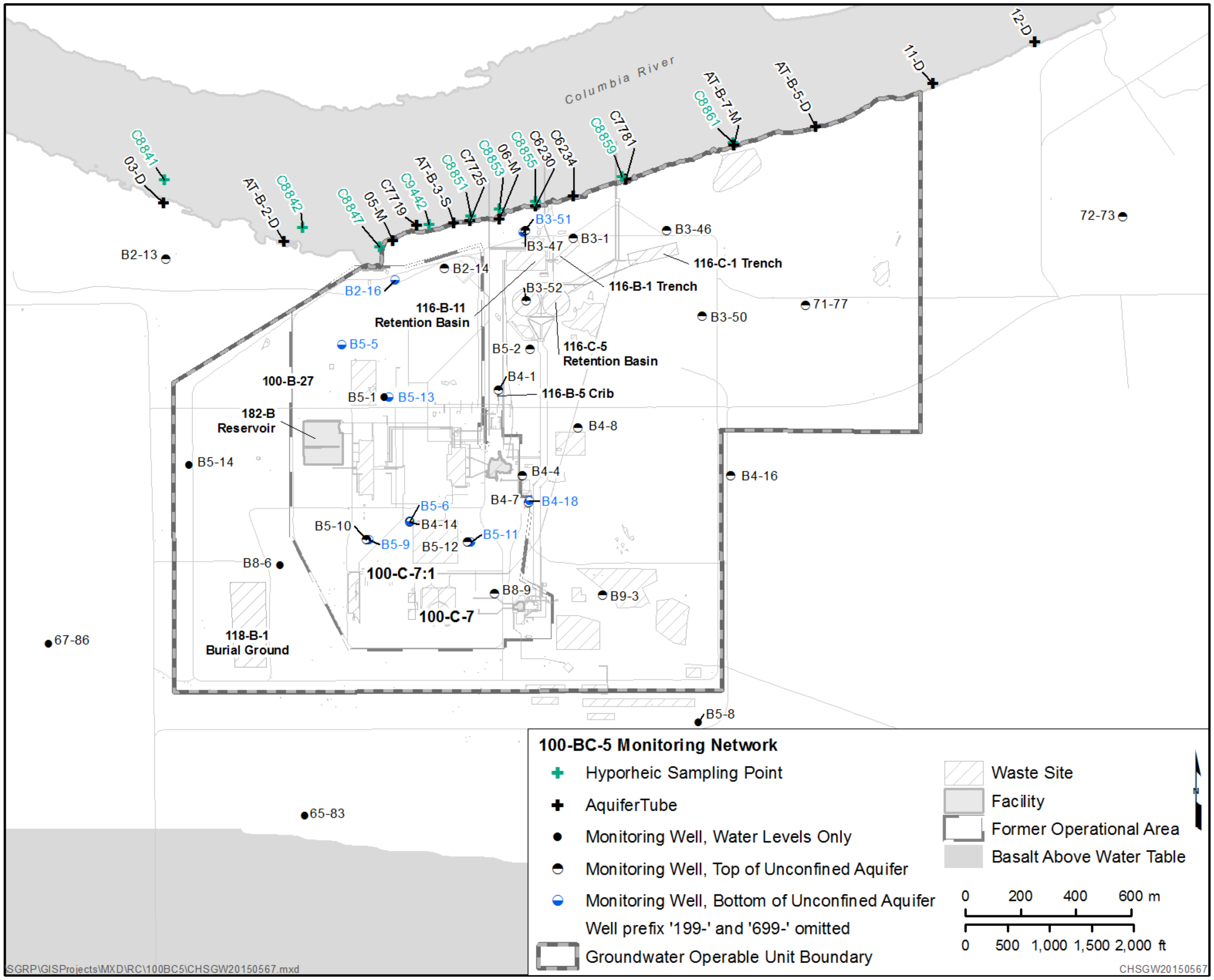

Figure 3-1. 100-BC-5 Monitoring Network

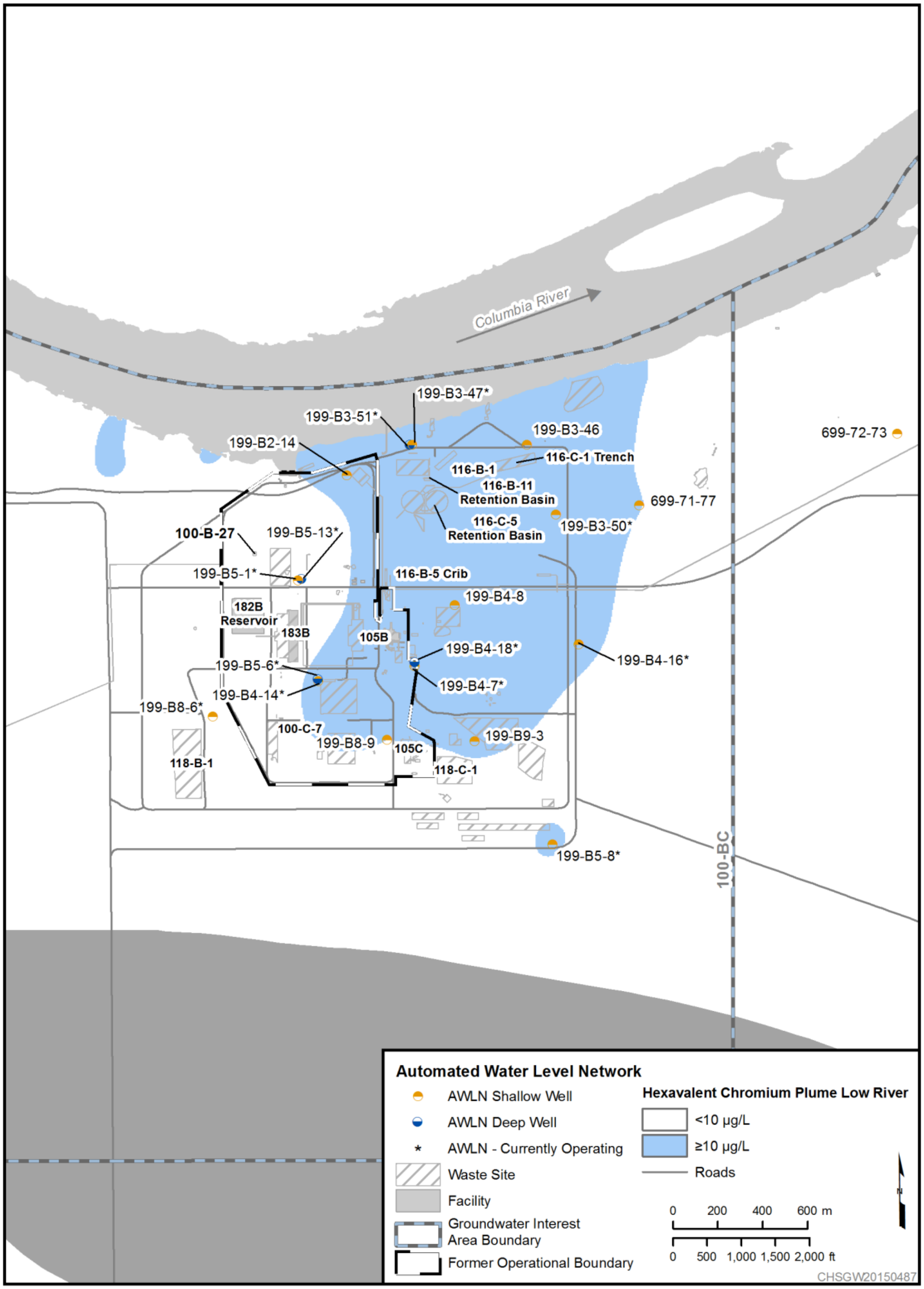

Figure 3-2. Automated Water Level Network for 100-BC-5

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4 Management of Waste

Waste materials are generated during sample collection, processing, and subsampling activities. Waste will be managed in accordance with DOE/RL-2004-30, *Waste Control Plan for the 100-BC-5 Operable Unit*, as revised by TPA Change Notices. For waste designation purposes, the maximum concentration in 5 years of historical data from HEIS for the analytes and wells listed in Table 3-1, as applicable, will comprise a complete analytical data set.

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

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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 to ensure the safety and health of workers involved in mixed hazardous 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,” and 10 CFR 830, “Nuclear Safety Management,” through 10 CFR 835, concerning nuclear safety. The health and safety program defines the chemical, radiological, and physical hazards and specifies the controls and requirements for day-to-day work activities on the overall Hanford Site. Personal training, control of industrial safety and radiological hazards, 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.

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Appendix A

Data Quality Objectives Documentation

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1 # Terms

AWLN	automated water level network
AWQC	ambient water quality criterion
CHPRC	CH2M HILL Plateau Remediation Company
COC	contaminant of concern
COPC	contaminant of potential concern
Cr(VI)	hexavalent chromium
CS	carbon steel (casing)
CSM	conceptual site model
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DQO	data quality objective
DWS	drinking water standard
EPA	U.S. Environmental Protection Agency
FS	feasibility study
HSP	hyporheic sampling point
ID	identification
MNA	monitored natural attenuation
MSA	Mission Support Alliance
MTCA	"Model Toxics Control Act—Cleanup" (WAC 173-340)
ND	not determined
Not ID'd	not identified
OU	operable unit
PNNL	Pacific Northwest National Laboratory
PQL	practical quantitation limit
PVC	polyvinyl chloride (casing/screen)
RI	remedial investigation
RUM	Ringold Formation upper mud
SAP	sampling and analysis plan

SS	stainless steel (casing/screen)
U	undetected

A1 Introduction

A1.1 Purpose and Scope

The purpose of this data quality objective (DQO) process is to support optimization of the groundwater monitoring network for the 100-BC-5 Operable Unit (OU).

This document follows the DQO guidance identified in EPA/240/B-06/001, *Guidance on Systematic Planning Using the Data Quality Objective Process* (EPA QA/G-4). The following steps are used for DQO development:

1. State the problem.
2. Identify the goal of the study.
3. Identify information inputs.
4. Define the boundaries of the study.
5. Develop the analytic approach.
6. Specify performance or acceptance criteria.
7. Develop the plan for obtaining data.

DQO workshops were held on March 25 and 26, 2015; Table A-1 lists the DQO team. Participants provided additional input following the workshops. Results of the seven-step process are presented in Chapters A2 through A8.

Workshop participants discussed the following questions:

- When is the cutoff date for incorporating data into the remedial investigation (RI)/feasibility study (FS)?
  - Project staff stated that a cutoff date of fall 2015 is needed (after the comprehensive October sampling campaign). At that point, staff will be preparing the RI/FS document. However, “game changing” data collected after could be worked in. The proposed plan might be a logical place to incorporate new data.
- Why does monitoring need to continue during the “gap?” Why not just call the RI/FS done and wait until the remedy is implemented to monitor again?
  - If something changes unexpectedly, it is better to know it sooner rather than after the remedy is implemented.
  - The public wants to know current conditions.
  - The hexavalent chromium (Cr(VI)) plume is migrating rapidly. The recent 100-C-7 remediation should have a direct, positive impact on groundwater. Migration and trends need to be tracked to confirm or refute this expectation.
- What remedial actions are tentatively being considered for 100-BC groundwater?
  - Monitored natural attenuation (MNA) for all three contaminants of concern (COCs)
  - Pump and treat or other active remedy for Cr(VI) and possibly strontium-90 (focused or aggressive)

Tritium is to remain a COC because concentrations have been below the drinking water standard (DWS) in 2013 and 2014 but above the DWS during the RI studies; MNA is the logical choice for tritium (attainment monitoring may be able to start immediately).

Table A-1. 100-BC-5 DQO Participants

Name	Affiliation or Role	Present Day 1	Present Day 2
Workshop Participants			
Joe Axtell	DOE-RL	X	X
Laura Buelow	EPA	X	X
Phil Burke	CHPRC cost account manager	X	X
Mary Hartman	CHPRC project scientist	X	X
Kevin Kytola	DOE Headquarters liaison	X	X
Rob Mackley	PNNL		X
Ken Moser	MSA portfolio management	X	X
Jessica Ni	CHPRC		X
Greg Sinton	DOE/RL	X	X
Mike Truex	PNNL	X	X
Other Invitees			
Ron Brunke	CHPRC		
Bruce Ford	CHPRC		
John Morse	DOE-RL		

CHPRC = CH2M HILL Plateau Remediation Company
DOE = U.S. Department of Energy
DOE-RL = DOE, Richland Operations Office
DQO = data quality objective
EPA = U.S. Environmental Protection Agency
MSA = Mission Support Alliance
PNNL = Pacific Northwest National Laboratory

A2 Step 1: State the Problem

During the period between completion of RI studies and implementation of remedial actions at 100-BC-5, there is a need to add to the body of knowledge about 100-BC groundwater. The additional data gathered during this period may show changes to groundwater conditions that will add to the conceptual site model (CSM) and influence remediation.

The DQO team developed a single problem statement to focus the scope of data collection:

Due to recently completed source remediation and plume dynamics, continued monitoring is necessary to confirm the CSM used for the RI/FS evaluations. Data collected will be used to support the design of remedial alternatives such as MNA, pump and treat, or other alternatives considered in the FS.

The team also discussed whether it would be useful to keep monitoring MNA parameters but concluded that MNA groundwater parameters are unlikely to change in the period of monitoring under this DQO, so there is no objective to continue monitoring after the RI studies are complete.

The team also considered cobalt as a contaminant of potential concern (COPC). The draft RI report (DOE/RL-2010-96, *Remedial Investigation/Feasibility Study for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*) concluded that cobalt could not be entirely ruled out as a COPC because some exceedances of action levels were observed, and some detection limits were high compared to action levels. The team discussed collecting cobalt data during the next few years that could be used to exclude cobalt from further monitoring during the period of groundwater remediation.

Further evaluation of cobalt data after the DQO workshops led to the conclusion that there are sufficient data to exclude it from this sampling and analysis plan (SAP). In the initial data window (January 5, 2006, through January 26, 2011), the following four wells had at least one exceedance of the 2.6 µg/L action level (Figures A-1 through A-4); no additional exceedances were detected through the end of 2014:

- 199-B3-50: A single exceedance in 2010 (5 µg/L by Method 6010, flagged "B" because it was less than the practical quantitation limit [PQL]) will remain in the data set. However, an unfiltered sample from the same date analyzed by the same method was a nondetect. Six subsequent sample dates had no detections, including samples analyzed by the more sensitive methods (200.8 or 6020).
- 199-B4-1: Two exceedances were reported, one in 2006 and another in 2008, both by Method 6010. These will both fall out of the RI data set when it is updated to 2010 through 2015. Five subsequent sample dates had no detections, including samples analyzed by the more sensitive methods (200.8 or 6020).
- 199-B8-8: There were three exceedances reported, all before 2010 and all by Method 6010. Two of them were flagged by the laboratory as being associated with an out-of-range quality control blank. The other exceedance was in a filtered sample; the unfiltered sample was a nondetect. This well was decommissioned in 2010.
- 699-67-86: A single exceedance was reported in 2010 (8 µg/L by Method 6010, flagged "B") and will remain in the updated data set. Three samples collected the same day (unfiltered by 6010 and a filtered/unfiltered pair by 200.8) were either nondetects or detections below the action level. This well has not been sampled for cobalt since 2010, it is located west of 100-BC, and it is not associated with any waste sites.

In summary, the updated RI data set (2010 through 2015) will include only two cobalt data points exceeding the action level. These are from two different wells, neither of which has a pattern of detection or trend. During preparation of the RI/FS, a formal risk assessment will be performed, and cobalt is unlikely to remain a COPC. Therefore, the DQO did not include a problem statement for cobalt.

A3 Step 2: Identify the Goal of the Study

Step 2 of the DQO process involves identifying principal study questions that the study attempts to address. Each question corresponds to a problem statement identified in Step 1. The DQO team developed the following single principal study question for this study:

Are Cr(VI), strontium-90, and tritium plumes and discharges to the Columbia River changing as expected in accordance with the CSM?[2] The following parameters will be evaluated:

- Spatial distribution of contaminants
- Concentration trends of contaminants
- Hydraulic gradients
- River stage

A4 Step 3: Identify Information Inputs

Step 3 of the DQO process identifies the types and sources of information needed to resolve the principal study question developed in Step 2. Data may already exist or may be derived from computational or sampling and analysis methods. Chapter 1 of the main text of this SAP includes a description of the CSM for 100-BC-5 and provides references for additional information.

This chapter identifies action levels for COCs, types of groundwater data needed, and study methods. Table A-2 lists action levels for COCs as determined in the RI work plan (DOE/RL-2008-46-ADD3, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*).

Table A-2. 100-BC-5 Action Levels

Contaminant	Category	Action Level	Type
Hexavalent Chromium	COC	10 µg/L at river, 48 µg/L inland	AWQC/MTCA
Stronium-90	COC	8 pCi/L	DWS
Tritium	COC	20,000 pCi/L	DWS

AWQC = ambient water quality criterion
COC = contaminant of concern
DWS = drinking water standard
MTCA = "Model Toxics Control Act—Cleanup" (WAC 173-340)

Information input to the study potentially includes the following types of data:

- Groundwater sample data from wells and conventional aquifer tubes
- Sample data from hyporheic sampling points (HSPs)
- Groundwater levels from wells (automated and manual measurements)
- River stage data (derived from the U.S. Geological Survey gauging station downstream of Priest Rapids Dam using the method described in ECF-Hanford-13-0028, "Columbia River Stage Correlation for the Hanford Area")

This study will continue to use current methods of sampling monitoring wells, aquifer tubes, and HSPs (per project procedures). Analytical methods will be selected, so PQLs are less than or equal to required action levels.

[2] Expectations are in accordance with the CSM as described in Section 1.2.6 of the SAP main text.

A5 Step 4: Define the Boundaries of the Study

Step 4 of the DQO process identifies spatial and temporal features pertinent for decision making and practical constraints. Spatial boundaries include the following:

- Unconfined aquifer in the 100-BC-5 OU, which ranges from 32 to 48 m (105 to 157 ft) thick
- Hyporheic zone adjacent to 100-BC

Spatial boundaries delimit plumes at the following levels:

- Cr(VI) plume boundaries at >10 µg/L
- Strontium-90 plume boundaries at >8 pCi/L
- Tritium concentrations in area formerly >20,000 pCi/L

The DQO team discussed whether there is a need to monitor Cr(VI) in the lower part of the unconfined aquifer where concentrations are stable. The team concluded that it would be of value to continue monitoring because no monitoring wells were in this unit until 2009 with very few until 2014. Early results from some 2014 wells showed changes that are related to either (a) migration of the deep plume, or (b) the chemistry of the new wells settling in as drilling effects dissipate. There is a need to continue monitoring these wells to see if the deep contamination is really changing or not and to verify the CSM.

The time period for this study begins when RI monitoring concludes (October 2015 for HSPs and annual wells; January 2016 for quarterly wells) and ends when performance monitoring for the groundwater remedial action begins (3 to 5 years).

The following practical constraints are identified:

- Resource availability for sample collection and laboratory analysis (funding)
- Analytical detection limits
- Seasonal variability of river stage and water table
- Limitations on pumping rates of HSPs (Table A-3)
- Aquifer tubes that must be sampled when river stage is low because some of them become submerged when the river is higher

Table A-3. Recommended Maximum Pumping Rates for 100-BC HSPs

HSP	Flow Rate (mL/min)	HSP	Flow Rate (mL/min)
C8840	60	C8855	10
C8841	10	C8856	10
C8842	40	C8859	30
C8843	50	C8860	10
C8844	30	C8861	10
C8845	30	C9441	30
C8847	40	C9442	30

Table A-3. Recommended Maximum Pumping Rates for 100-BC HSPs

HSP	Flow Rate (mL/min)	HSP	Flow Rate (mL/min)
C8848	30	C9443	30
C8849	30	C9444	30
C8851	50	C9445	10
C8852	10	C9446	30
C8853	10		

HSP = hyporheic sampling point

A6 Step 5: Develop the Analytic Approach

Step 5 of the DQO process involves developing an analytic approach that will guide analysis of the study results. This is accomplished by developing a decision rule for each principal study question. Decision rules can be formed as “If-Then” statements. The 100-BC-5 DQO team identified the following decision rule:

If the body of evidence indicates that Cr(VI), strontium-90, and tritium plumes and discharges to the Columbia River are not changing as expected in accordance with the CSM, then refine the CSM and incorporate the new information into design of remedial action alternatives, or consider new alternatives. Otherwise, proceed with the design as indicated by the established CSM.

Evaluation methods for the decision rule include the following:

- Contaminant plume maps
- Contaminant cross sections
- Concentration versus time graphs
- Seasonal hydraulic gradient calculations
- Seasonal water table maps
- Groundwater model simulations
- Concentrations versus river stage

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A7 Step 6: Specify Performance or Acceptance Criteria

This step is intended to specify performance or acceptance criteria that the collected data will need to achieve in order to minimize the possibility of either making erroneous conclusions or failing to keep uncertainty in decisions to within acceptable levels. Primary decisions for the monitoring DQOs involve the adequacy of spatial and temporal coverage of the monitoring network. Analytical data and field measurements can only estimate the true condition of the site under investigation, and decisions that are made based on measurement data could potentially be in error (i.e., decision error).

Methods of plume mapping, trending, calculating gradients, and water table mapping will remain the same as currently used for routine monitoring.

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A8 Step 7: Develop the Plan for Obtaining Data

The goal of Step 7 is to develop a resource-effective design for collecting data to address the identified problems. This section provides the methodology used to select the final list of groundwater monitoring locations and sampling frequencies that adequately meet the data needs associated with the principal study question.

A8.1 Analytes

Water samples will be analyzed for the following elements:

- Cr(VI)
- Strontium-90
- Tritium
- Field parameters (specific conductance, pH, turbidity, temperature, and dissolved oxygen)

A8.2 Monitoring Network

Table A-4 lists monitoring wells in and around 100-BC. It includes wells monitored under the previous routine plan, some of which lie west of the 100-BC Area and some in 100-BC that are not currently monitored. It also includes a few wells in the adjacent 200-BP-5 OU to the east of 100-BC-5. Most of the wells monitor the upper part of the unconfined aquifer and are screened across the water table. Eight wells are screened at the base of the unconfined aquifer or elsewhere in the lower part of the unconfined aquifer. Two wells are screened in water-bearing units of the Ringold Formation upper mud (RUM) unit. The cross sections in Chapter 1 of the SAP illustrate screen depths of the wells. Well locations are illustrated on Figure 1-1 in the SAP main text.

Table A-5 lists aquifer tubes and HSPs, which monitor various depths in the aquifer near or under the Columbia River. The top panel of Figure A-5 shows the screen depths plotted versus distance along the shoreline, west to east. The bottom panel of the figure shows the same screen information adjusted for differences in surface elevation at the aquifer tube or HSP location. These elevations all equate to the upper part of the unconfined aquifer (compare to cross sections in Chapter 1 of the SAP). Locations of aquifer tubes and HSPs are illustrated on Figure 1-1 in Chapter 1 of the SAP main text.

A8.3 Rationale for Well Selection

The well network was selected to define plumes at the following action levels and other levels of interest:

- Cr(VI) at 10, 20, and 48 µg/L
- Strontium-90 at 8, 20, and 40 pCi/L
- Tritium at 10,000 and, if present, 20,000 pCi/L

Additional wells were selected to monitor groundwater downgradient of plumes.

Figures A-6, A-7, and A-8 show 2014 contaminant plumes with wells in the proposed networks highlighted. Table A-4 provides rationale for sampling or not sampling each well.

The network to be analyzed for Cr(VI) (Figure A-6) includes most wells in the 100-BC Area screened at the top of the aquifer and all of the wells completed in the lower part of the unconfined aquifer. The western extent of the plume has previously been defined by wells 199-B8-6 and 199-B5-1. Contamination is migrating to the northeast, so these wells, along with 199-B5-14, 699-67-86, and

699-65-83, are not needed and will no longer be monitored. Deep, unconfined aquifer wells will be monitored to track trends and migration of the deep plume. Wells screened in the RUM are not needed because previous characterization has shown contamination does not extend into water-bearing units within the RUM.

A smaller network of wells will be monitored for strontium-90 (Figure A-7). Wells outside the plume (e.g., 199-B5-1, 199-B3-50, 199-B4-7, and 199-B4-8) are not needed to help define the plume because it is reasonable to assume that concentrations of this low-mobility contaminant will remain below detection limits in those wells. No deep wells are needed because strontium-90 concentrations are below detection limits in the lower part of the unconfined aquifer and in the RUM.

Tritium concentrations above the DWS were most recently observed in 199-B3-47 (2012) and 199-B4-1 (2011) in northern 100-BC, and 199-B8-9 (2012) in southern 100-BC. The southern tritium plume was observed to migrate east and north, similar to the chromium plume. Figure A-8 shows the tritium plume contoured at 10,000 pCi/L and highlights wells in the proposed network. If concentrations increase to levels above the DWS in wells on the eastern side of the plume, additional wells farther east may be added to the network. No deep wells are needed because tritium concentrations above the DWS have never been detected in the lower part of the unconfined aquifer or in the RUM.

A8.4 Rationale for Conventional Aquifer Tubes and HSPs

Aquifer tubes and HSPs were selected using the following general rationale:

- Select sites to define plumes laterally and monitor for downstream migration.
- Preferentially pick sites with an aquifer tube and an HSP; single depth for each.
- From each site, pick the aquifer tube that typically has the highest concentration, to provide a conservative estimate of contamination approaching the river. Pick the 0.5 m HSP (for consistency) unless it has nonrepresentative data (then choose 0.15 or 1 m HSP).
- Exclude HSPs that frequently have nonrepresentative data.
- For strontium-90, select HSPs with sufficient flow rates to obtain required sample volumes.

Table A-5 provides rationale for sampling or not sampling each aquifer tube or HSP.

Figure A-9 shows all of the fall 2014 Cr(VI) data on the top panel (58 data points). The bottom panel shows a subset of 14 aquifer tubes and 9 HSPs proposed for ongoing sampling. Though fewer points are sampled, the proposed network still allows delineation of the plume and monitoring of the highest concentrations.

Figure A-10 shows all of the fall 2014 strontium-90 data on the top panel (30 data points). The bottom panel shows a subset of 6 aquifer tubes and 2 HSPs proposed for ongoing sampling. The proposed network allows delineation of the plume and monitoring of the highest concentrations. It also includes 2 HSPs for confirmation that strontium-90 is not at levels of concern in the shallow hyporheic zone.

Tritium concentrations have been below the DWS in wells and aquifer tubes in 2013 and 2014. No aquifer tubes or HSPs are needed for ongoing sampling.

A8.5 Sample Frequency and Schedule

During RI studies in 2010, wells were sampled at high, low, and transitional river stage. The plume maps from the three events showed little difference. One well adjacent to the river (199-B3-47) showed signs of mixing with river water when it was sampled during high river stage. The objectives of determining how the plumes are changing can be met by annual sampling during relatively low river stage, with the following exceptions:

- Semiannual for Cr(VI) in near-river wells to watch for (a) passage of the pulse of chromium released during excavation of the 100-C-7:1 Waste Site, and (b) potentially continuing sources in the vicinity of 199-B3-47.
- Semiannual (low and high river) for strontium-90 in wells where a variable water table might mobilize contamination from the lower vadose zone if there are vadose zone sources remaining.
- Semiannual sampling for tritium if the well is being sampled semiannually for other constituents, and the well is needed for tritium. The extra data can be used later to show attainment of tritium cleanup goals.

The annual sampling campaigns should be scheduled for periods of low river stage (September or October; Section B3.5.1.2 of TPA-CN-593). Wells, aquifer tubes, and HSPs should be sampled concurrently, as much as practical. The high river stage sampling campaigns should be scheduled for periods of high river stage (between mid-May and early July).

Well 199-B4-14 will be sampled on a different semiannual frequency. One sample will be collected during low river stage, concurrent with the other wells. A second sample will be collected in January or February, when seasonal peak concentrations have been observed in the past.

A8.6 Water Levels

An automated water level network (AWLN) was established for the 2013 through 2015 RI studies. Staff recently evaluated the network and recommended additional stations to cover the chromium plume. Wells 199-B3-50 and 699-72-73 were added to the list to create the AWLN listed in Table 3-2 of the main text of this SAP.

Manual measurements will be made periodically in a broader network of wells at the following schedule:

- March (moderate river stage; in conjunction with Hanford Sitewide measurements)
- June (high river stage)
- September (low river stage)

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A9 References

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Table A-4. Groundwater Monitoring Wells in 100-BC and Vicinity

Well Name	Well ID	Installed	Construction	Diameter (in.)	Elev. Top Screen or Perf. (m)	Elev. Bottom Screen or Perf. (m)	Water Level (m)	Water Level Date	Effective Open Interval (m)	Elev. Ringold E (m)	Elev. RUM (m)	Thickness Upper Aquifer (m)	Saturated Hanford (m)	Construction Comments	Monitoring Rationale	Sample?	Cr(VI)	Sr-90	Tritium
199-B2-12	A4550	1992	SS, screen	4	83.6	80.6	120.50	2/28/2014	3.0	130.1	88.4	32.1	-9.6	Screened in RUM	No monitoring objective for RUM	N			
199-B2-13	A4551	1992	SS, screen	4	123.3	116.9	120.93	2/28/2014	4.1	Not ID'd	<115.5	ND	ND		Northwest of 100-BC; Cr(VI) >2014 AWQC; confirm general attenuation of Cr(VI).	Y	A		
199-B2-14	C7665	2010	SS, screen	6	121.5	113.9	120.75	12/12/2013	6.8	124.2	92.2	28.5	-3.5		Define Cr(VI) plume and delimit Sr-90.	Y	A	A	
199-B2-15	C7783	2011	SS, screen	4	86.0	82.9	120.53	2/28/2014	3.1	124.8	90.5	30.1	-4.3	Screened in RUM	No monitoring objective for RUM	N			
199-B2-16	C7784	2011	SS, screen	6	99.2	88.5	120.27	10/23/2013	10.7	123.6	88.6	31.7	-3.3	Bottom of unconfined	Monitor deep Cr(VI).	Y	A		
199-B3-1	A4552	1953	CS, perf	8	123.9	114.8	120.04	2/28/2014	3.6	Not ID'd	<114.8	ND	ND		Monitor passage of Cr(VI) plume and Sr-90 variability; tritium is elevated and increasing.	Y	S	S	S
199-B3-46	A4553	1992	SS, screen	4	121.2	114.7	120.06	2/28/2014	5.3	119.5	<114.4	ND	0.6		Monitor passage of Cr(VI) plume and Sr-90 variability.	Y	S	S	
199-B3-47	A4554	1992	SS, screen	4	122.2	115.8	119.93	2/28/2014	4.1	Not ID'd	<115.3	ND	ND		Monitor passage of Cr(VI) plume and Sr-90 variability; tritium is elevated.	Y	S	S	S
199-B3-50	C7506	2010	SS, screen	6	121.9	115.8	120.65	2/28/2014	4.8	115.3	89.1	31.6	5.4		Cr(VI) >20 µg/L and increasing; monitor eastward migration; Sr-90 is consistently low.	Y	A		
199-B3-51	C7785	2011	SS, screen	6	91.7	88.6	120.77	12/12/2013	3.0	128.6	88.5	32.3	-7.8	Bottom of unconfined	Monitor deep Cr(VI).	Y	A		
199-B3-52	C7843	2010	PVC	4	121.7	117.1	118.75	9/21/2010	1.6	Not ID'd	<116.4	ND	ND		Monitor passage of southern Cr(VI) plume and Sr-90 variability; tritium is elevated.	Y	S	S	S
199-B4-1	A4555	1949	CS, perf	8	126.0	113.8	121.44	2/28/2014	3.5	Not ID'd	<113.8	ND	ND		Monitor Cr(VI) plume; redundant for Sr-90.	Y	A		
199-B4-4	A4557	1960	CS, perf	8	129.7	117.2	121.59	2/28/2014	4.4	Not ID'd	<112.6	ND	ND		Monitor Cr(VI) plume; southern extent of Sr-90 plume.	Y	A	A	
199-B4-5	A5540	1990	SS, screen	4	123.8	117.5	141.42	1/3/2002	6.3	Not ID'd	<117.4	ND	ND		Redundant with nearby wells	N			
199-B4-6	A4558	1990	SS, screen	4	123.7	117.4	121.77	2/2/2004	4.3	Not ID'd	<117.3	ND	ND		Redundant with nearby wells	N			
199-B4-7	A5541	1990	SS, screen	4	123.9	117.7	121.62	2/28/2014	4.0	Not ID'd	<117.7	ND	ND		Monitor migration of Cr(VI); tritium is elevated; Sr-90 is consistently <DWS.	Y	A		A
199-B4-8	A4559	1992	SS, screen	4	124.7	118.3	121.57	2/28/2014	3.3	117.6	<116.9	ND	3.9		Monitor migration of Cr(VI); tritium is elevated; Sr-90 is consistently <DWS.	Y	A		A
199-B4-14	C7786	2010	SS, screen	6	123.0	116.9	121.60	2/28/2014	4.7	<115.8	<115.8	ND	>5.9		Monitor Cr(VI) plume near 100-C-7:1.	Y	S		
199-B4-15	C7846	2010	PVC	4	122.9	119.2	121.34	11/5/2010	2.1	<118.6	<118.6	ND	>2.7		Redundant with nearby wells	N			
199-B4-16	C8776	2013	SS, screen	4	123.0	116.9	121.61	3/24/2014	4.7	110.5	89.5	32.1	11.1		Monitor eastern part of the Cr(VI) plume.	Y	A		

Table A-4. Groundwater Monitoring Wells in 100-BC and Vicinity

Well Name	Well ID	Installed	Construction	Diameter (in.)	Elev. Top Screen or Perf. (m)	Elev. Bottom Screen or Perf. (m)	Water Level (m)	Water Level Date	Effective Open Interval (m)	Elev. Ringold E (m)	Elev. RUM (m)	Thickness Upper Aquifer (m)	Saturated Hanford (m)	Construction Comments	Monitoring Rationale	Sample?	Cr(VI)	Sr-90	Tritium
199-B4-18	C8778	2013	SS, screen	4	95.6	88.0	121.61	3/24/2014	7.6	113.1	87.8	33.8	8.5	Bottom of unconfined	Monitor deep Cr(VI).	Y	A		
199-B5-1	A4561	1962	CS, perf	8	127.0	108.7	121.40	2/28/2014	3.6	123.9	<93.0	ND	ND		Cr(VI) and Sr-90 are consistently low and unlikely to migrate west.	N			
199-B5-2	A4562	1992	SS, screen	4	123.3	117.2	121.33	2/28/2014	4.1	<117.2	<116.9	ND	ND		Monitor passage of southern Cr(VI) plume; in Sr-90 plume; elevated tritium.	Y	S	A	S
199-B5-5	C7505	2010	SS, screen	6	99.1	79.3	120.78	2/28/2014	19.8	119.3	74.8	46.0	1.5	Middle/bottom of unconfined	Monitor deep Cr(VI).	Y	A		
199-B5-6	C7507	2010	SS, screen	6	94.7	87.1	121.46	2/28/2014	7.7	116.6	88.6	32.9	4.8	Bottom of unconfined	Monitor deep Cr(VI).	Y	A		
199-B5-8	C8244	2011	SS, screen	6	123.1	117.0	121.62	2/28/2014	4.6	94.2	86.9	34.7	27.4		Cr(VI) >AWQC, but that standard is not applicable so far inland.	N			
199-B5-9	C8779	2013	SS, screen	4	96.3	88.7	121.64	3/24/2014	7.6	113.4	86.6	35.1	8.3	Bottom of unconfined	Monitor deep Cr(VI).	Y	A		
199-B5-10	C8780	2014	SS, screen	4	122.6	116.5	121.58	3/24/2014	5.1	<114.7	<114.7	ND	ND		Monitor Cr(VI) adjacent to 100-C-7:1.	Y	A		
199-B5-11	C8781	2013	SS, screen	4	92.2	86.1	121.67	3/24/2014	6.1	115.6	87.3	34.4	6.0	Bottom of unconfined	Monitor deep Cr(VI).	Y	A		
199-B5-12	C8782	2014	SS, screen	4	122.8	116.7	121.34	3/24/2014	4.6	<115.7	<115.7	ND	ND		Monitor Cr(VI) adjacent to 100-C-7; tritium is redundant with nearby wells.	Y	A		
199-B5-13	C8783	2013	SS, screen	4	95.3	87.7	121.49	3/24/2014	7.6	121.2	76.7	44.8	0.3	Middle of unconfined	Monitor deep Cr(VI).	Y	A		
199-B5-14	C8784	2013	SS, screen	4	122.5	116.4	121.64	3/24/2014	5.3	118.8	71.6	50.0	2.8		No monitoring objective	N			
199-B8-6	A4563	1992	SS, screen	4	124.1	118.0	121.62	2/28/2014	3.6	<117.3	<117.3	ND	>4.3		Cr(VI) is consistently low and unlikely to migrate west.	N			
199-B8-9	C7508	2010	SS, screen	6	123.5	117.4	121.62	2/28/2014	4.2	107.1	86.5	35.1	14.5		Monitor southern edge of Cr(VI) plume; elevated tritium.	Y	A		A
199-B9-2	A4565	1992	SS, screen	4	124.2	118.1	121.86	10/23/2013	3.8	<115.8	<115.8	ND	>5.5		Redundant with B9-3	N			
199-B9-3	A4566	1992	SS, screen	4	124.4	118.3	121.62	2/28/2014	3.3	<117.2	<117.2	ND	>4.4		Monitor southern edge of Cr(VI) plume; tritium is increasing.	Y	A		A
699-63-90	A5293	1948	CS, perf	8	127.3	111.5	122.20	2/28/2014	10.7	115.1	113.3	ND	7.1		Far west; no monitoring objective	N			
699-63-92	A5294	1973	CS, open	6	106.1	95.1	122.18	3/2/2009	9.4	Not ID'd	Absent	ND	ND	46 m (150 ft) to basalt	No monitoring objective for basalt	N			
699-63-95	A8958	1973	CS, open	3	-11.4	-67.2	121.99	2/28/2014		Not ID'd	Absent	ND	ND	Deep basalt well	No monitoring objective for basalt	N			
699-65-72	A5302	?	CS, perf	12	110.6	104.5	121.64	3/13/2014	6.1	Not ID'd	No log	ND	ND		No monitoring objective	N			
699-65-83	A5303	1967	CS, perf	6	129.8	112.5	121.63	2/28/2014	7.8	<112.5	<111.2	ND	ND		Cr(VI) occasionally >10 AWQC, but that level is not applicable so far inland.	N			

Table A-4. Groundwater Monitoring Wells in 100-BC and Vicinity

Well Name	Well ID	Installed	Construction	Diameter (in.)	Elev. Top Screen or Perf. (m)	Elev. Bottom Screen or Perf. (m)	Water Level (m)	Water Level Date	Effective Open Interval (m)	Elev. Ringold E (m)	Elev. RUM (m)	Thickness Upper Aquifer (m)	Saturated Hanford (m)	Construction Comments	Monitoring Rationale	Sample?	Cr(VI)	Sr-90	Tritium
699-66-91	A5311	1973	CS, open	6	112.8	84.7	122.25	3/2/2009	25.7	Not ID'd	Absent	ND	ND	30 m (98 ft) to basalt	Far west; no monitoring objective	N			
699-67-86	A5313	1962	CS, perf	8	126.2	114.0	121.62	2/28/2014	7.6	Not ID'd	69.2	52.4	ND	Piezometers P, Q, R, and S decommissioned	No monitoring objective	N			
699-68-105	A5315	1952	CS, perf	8	125.2	112.1	121.48	2/28/2014	8.7	Not ID'd	<110.3	ND	ND		Far west; no monitoring objective	N			
699-71-77	A5322	1962	CS, perf	8	125.9	106.1	121.09	2/28/2014	13.7	116.8	92.4	28.7	4.3		Monitor eastward migration of Cr(VI).	Y	A		
699-72-73	A5323	1961	CS, perf	8	129.3	106.4	121.08	2/28/2014	14.5	120.1	96.6	24.4	1.0		Monitor eastward migration of Cr(VI).	Y	A		
699-72-92	A5325	1961	CS, perf	8	123.8	109.8	121.28	2/28/2014	11.0	90.0	<76.2	ND	31.3	Piezometers O, P, and Q decommissioned	Far west; no monitoring objective	N			
Totals																28[a]	34[b]	11[b]	12[b]

Construction:
CS = carbon steel casing
perf = perforated casing
SS = stainless steel casing/screen
PVC = polyvinyl chloride casing/screen
Effective open interval: Thickness of wetted screened (or perforated) interval
ND = not determined
Not ID'd = not identified
RUM = Ringold Formation upper mud
Saturated Hanford: Difference between water table elevation and Hanford/Ringold contact, where identified. Negative values indicate how far below the contact the water table lies.
Sampling frequencies:
A = annual
S = semiannual
a. Number of wells to be sampled
b. Number of samples per year
AWQC = ambient water quality criterion
Cr(VI) = hexavalent chromium
Sr-90 = strontium-90

Table A-5. Aquifer Sampling Tubes and HSPs

Tube Name	Year Installed	Type	Elevation at Grade (m)	Depth to Top of Screen (ft)	Elevation at Top of Screen (m)	Hanford River Mile	Fall 2014 Cr(VI) (μg/L)	Fall 2014 Sr-90 (pCi/L)	Monitoring Rationale	Cr(VI)	Sr-90
01-D	1997	AT-N	122.68	24.0	115.4	2.6			No monitoring objective		
01-M	1997	AT-N	122.68	16.0	117.8	2.6	8 U		No monitoring objective		
01-S	1997	AT-N	122.68	7.0	120.5	2.6			No monitoring objective		
02-M	1997	AT-N	122.27	14.9	117.7	3.13			No monitoring objective		
02-S	1997	AT-N	122.27	6.0	120.4	3.13			No monitoring objective		
C8840	2013	HSP-0.5	118.37	1.1	118.0	3.13	8 U		No monitoring objective		
03-D	1997	AT-N	121.15	13.0	117.2	3.45	12		Monitor upstream deep hyporheic zone.	A	
03-M	1997	AT-N	121.15	7.0	119.0	3.45			Mid-depth is not needed.		
C8841	2013	HSP-0.5	118.21	1.1	117.9	3.45	8 U		Monitor upstream shallow hyporheic zone.	A	
AT-B-1-M	2004	AT	121.27	13.3	117.2	3.57	8 U		No monitoring objective		
AT-B-1-S	2004	AT	121.24	8.0	118.8	3.57			No monitoring objective		
AT-B-2-D	2004	AT	120.92	19.0	115.1	3.66	23		2014 data point anomalously high; monitor for trend.	A	
AT-B-2-M	2004	AT	120.86	14.0	116.6	3.66			No monitoring objective		
AT-B-2-S	2004	AT	120.90	8.6	118.3	3.66			No monitoring objective		
04-D	1997	AT	122.48	25.0	114.9	3.73	16		Redundant with other upstream tubes		
04-M	1997	AT	122.49	13.0	118.5	3.73			Redundant with other upstream tubes		
04-S	1997	AT	122.41	8.3	119.9	3.73			Redundant with other upstream tubes		
C8842	2013	HSP-0.5	117.96	1.1	117.6	3.73	8 U		Monitor hyporheic zone near AT-B-2-D.	A	
C6227	2008	AT	120.00	11.2	116.6	3.81	8 U	0.04 U	Redundant with other upstream tubes		
C6228	2008	AT	119.93	17.5	114.6	3.81	8 U	0.64 U	Redundant with other upstream tubes		
C6229	2008	AT	119.96	23.4	112.8	3.81	8 U	0.12 U	Redundant with other upstream tubes		
C8843	2013	HSP-0.5	116.84	1.1	116.5	3.81	8 U	0 U	Redundant with other upstream tubes		
05-D	1997	AT-N	121.99	25.5	114.2	3.89	29	0.13 U	Redundant with mid-depth AT for Cr(VI); no Sr-90 this depth		
05-M	1997	AT-N	121.99	17.0	116.8	3.89	25.6	7.15	Define upstream edge of Sr-90; monitor Cr(VI).	A	A
05-S	1997	AT-N	121.99	8.5	119.4	3.89	16	3.92	Shallow depth is not needed.		
C8847	2013	HSP-0.5	116.90	1.1	116.6	3.89	15	3.9	Upstream edge of Cr(VI) in shallow hyporheic zone	A	A
C8844	2013	HSP-0.5	117.27	1.1	116.9	3.91	12	0.07 U	Redundant with nearby HSPs		
C8845	2013	HSP-1	117.28	2.8	116.4	3.91	18		Redundant with nearby HSPs		
C9441	2014	HSP-0.15	117.17	0.5	117.0	3.91	19.2		Redundant with nearby HSPs		
C7718	2010	AT	119.39	7.1	117.2	3.95	9	0.05 U	Shallow depth is not needed.		
C7719	2010	AT	119.40	12.5	115.6	3.95	23	0.05 U	Maximum Cr(VI) in this cluster; no significant Sr-90	A	

Table A-5. Aquifer Sampling Tubes and HSPs

Tube Name	Year Installed	Type	Elevation at Grade (m)	Depth to Top of Screen (ft)	Elevation at Top of Screen (m)	Hanford River Mile	Fall 2014 Cr(VI) (μg/L)	Fall 2014 Sr-90 (pCi/L)	Monitoring Rationale	Cr(VI)	Sr-90
C7720	2010	AT	119.38	18.3	113.8	3.95	8 U	1.31 U	Deep depth is not needed.		
C8848	2013	HSP-0.5	118.20	1.1	117.9	3.95	17	0.73 U	Specific conductance is frequently low.		
C8849	2013	HSP-1	118.20	2.8	117.4	3.95	19		Redundant with C9442		
C9442	2014	HSP-0.15	118.13	0.5	118.0	3.95	19.6		Monitor Cr(VI) in shallow hyporheic zone.	A	
AT-B-3-D	2004	AT	120.62	23.2	113.6	4.02	35	0 U	Redundant with nearby tubes		
AT-B-3-M	2004	AT	120.51	14.2	116.2	4.02	33	4.06	Redundant with nearby tubes		
AT-B-3-S	2004	AT	120.74	8.1	118.3	4.02	33	21.2	Cr(VI) and Sr-90 are elevated and rising.	A	A
C7724	2010	AT	119.34	6.3	117.4	4.08	39	24.9	Shallow depth is not needed.		
C7725	2010	AT	119.47	10.6	116.2	4.08	37	14.2	Monitor Cr(VI) and Sr-90.	A	A
C7726	2010	AT	119.45	15.6	114.7	4.08	31	0.2 U	Deep depth is not needed.		
C8851	2013	HSP-0.5	117.68	1.1	117.3	4.08	22	0.19 U	Monitor shallow hyporheic zone.	A	A
C9443	2014	HSP-0.15	117.57	0.5	117.4	4.08	25.4		Redundant with C8851		
06-D	1997	AT	122.12	23.0	115.1	4.12	30	0.26	Deep tube is not needed.		
06-M	1997	AT	122.12	15.5	117.4	4.12	47	10.4	Monitor Cr(VI), Sr-90 (>DWS), and tritium (formerly >DWS).	A	A
06-S	1997	AT	122.12	8.8	119.4	4.12	8 U	5.35	Shallow tube is not needed.		
C8852	2013	HSP-0.5	117.61	1.1	117.3	4.12	13		Specific conductance is frequently low.		
C8853	2013	HSP-1	117.61	2.8	116.9	4.12	21		Monitor shallow hyporheic zone adjacent to 06-M; flow is too low for Sr-90.	A	
C6230	2008	AT	119.84	9.2	117.0	4.2	35	32.1	Highest Sr-90 in aquifer tube; Cr(VI) is also elevated.	A	A
C6231	2008	AT	119.72	13.0	115.8	4.2	27	3.54	Mid-depth is not needed.		
C6232	2008	AT	120.09	26.5	112.0	4.2	27	0.56 U	Deep depth is not needed.		
C8855	2013	HSP-0.5	117.60	1.1	117.2	4.2	22		Monitor Cr(VI) in shallow hyporheic zone; flow is too low for Sr-90.	A	
C9444	2014	HSP-0.15	117.58	0.5	117.4	4.2	19.6		Redundant with C8855		
C6233	2008	AT	120.23	9.6	117.3	4.29	19	0.03 U	Redundant with nearby tubes		
C6234	2008	AT	120.17	15.3	115.5	4.29	33	0.07 U	Monitor Cr(VI).	A	
C6235	2008	AT	120.31	19.2	114.5	4.29	33	0.1 U	Redundant with nearby tubes		
C8856	2013	HSP-0.5	116.93	1.1	116.6	4.29	16		Tends to have low conductivity		
C7780	2010	AT	119.44	5.7	117.7	4.39	24		Shallow depth is not needed.		
C7781	2010	AT	119.40	8.5	116.8	4.39	29	No data since 2010	Monitor Cr(VI) and Sr-90.	A	A
C7782	2010	AT	119.04	11.3	115.6	4.39	29		Deep depth is not needed.		

Table A-5. Aquifer Sampling Tubes and HSPs

Tube Name	Year Installed	Type	Elevation at Grade (m)	Depth to Top of Screen (ft)	Elevation at Top of Screen (m)	Hanford River Mile	Fall 2014 Cr(VI) (µg/L)	Fall 2014 Sr-90 (pCi/L)	Monitoring Rationale	Cr(VI)	Sr-90
C8859	2013	HSP-0.5	118.60	1.1	118.3	4.39	21		Monitor shallow hyporheic zone.	A	
C9445	2014	HSP-0.15	118.27	0.5	117.4	4.39	1.5 U		Specific conductance is low.		
C8860	2013	HSP-0.5	118.83	1.1	118.5	4.45	18		Redundant with nearby HSPs		
AT-B-7-D	2004	AT	119.55	18.1	114.0	4.62			Deep depth is not needed.		
AT-B-7-M	2004	AT	119.34	13.3	115.3	4.62	15		Monitor Cr(VI); Sr-90 is historically undetected.	A	
AT-B-7-S	2004	AT	119.49	6.8	117.4	4.62			Shallow depth is not needed.		
C8861	2013	HSP-0.5	117.75	1.1	117.4	4.62	19		Monitor shallow hyporheic zone.	A	
C9446	2014	HSP-0.15	117.90	0.5	117.4	4.62	19.2		Redundant with C8861		
AT-B-5-D	2004	AT	119.32	24.0	112.0	4.77	11		Monitor downstream migration of Cr(VI).	A	
AT-B-5-M	2004	AT	119.34	16.2	114.4	4.77			Mid-depth is not needed.		
AT-B-5-S	2004	AT	119.35	9.6	116.4	4.77			Shallow depth is not needed.		
11-D	1997	AT	119.00	10.5	115.8	5.07			Delimit downstream edge of plume. Has not been sampled since 2007; may no longer be useable.	A	
12-D	1997	AT	119.50	10.0	116.5	5.33	10		Delimit downstream edge of plume.	A	
Total										23	8

Notes: Tubes are listed in order of Hanford River Mile, upstream to downstream.

Shading groups multiple tubes at a single site.

Type: AT = conventional aquifer tube; AT-N = nested aquifer tube; HSP-xx = HSP screened at xx meter depth

Cr(VI) = hexavalent chromium HSP = hyporheic sampling point Sr-90 = strontium-90 U = undetected

Sampling frequency:

A = annual

S = semiannual

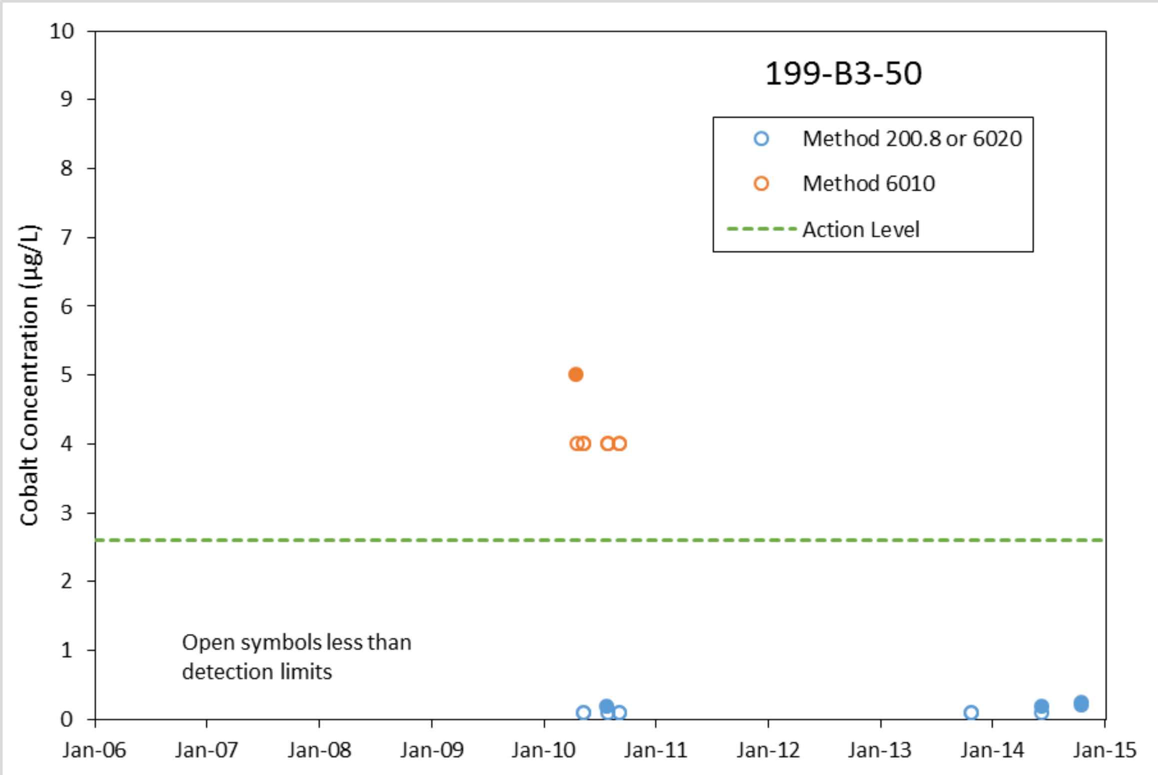


Figure A-1. Cobalt in Well 199-B3-50

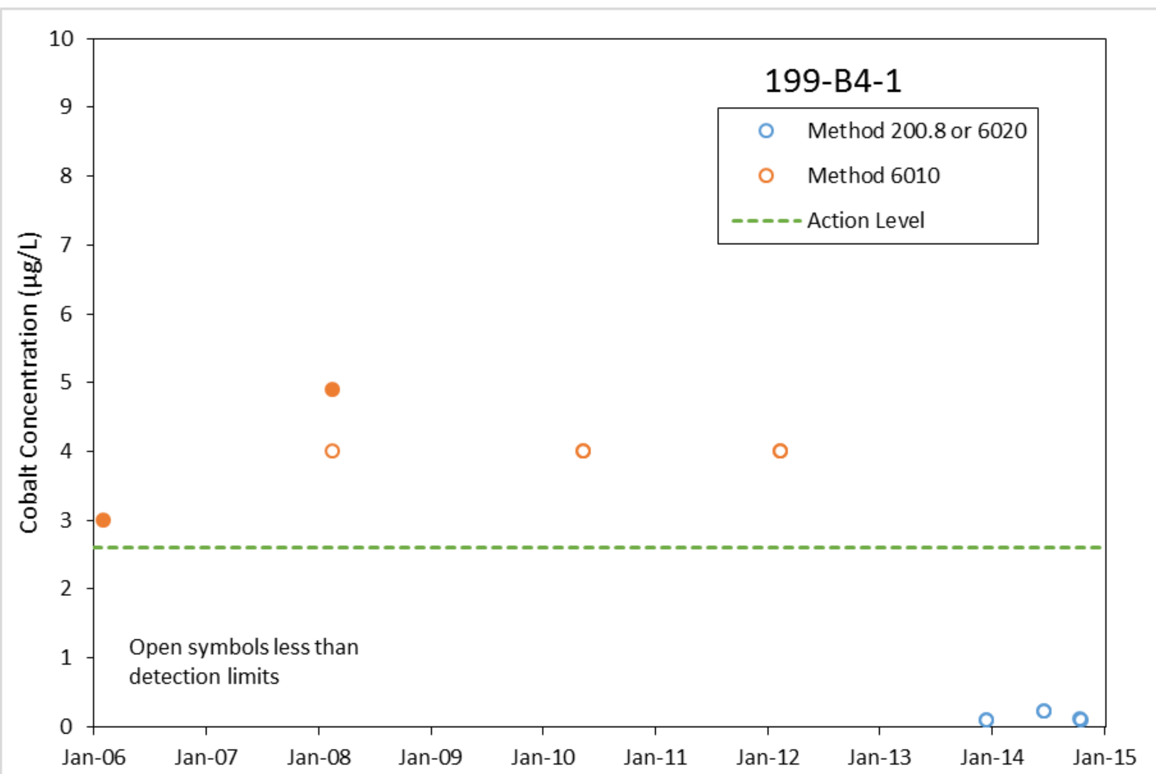


Figure A-2. Cobalt in Well 199-B4-1

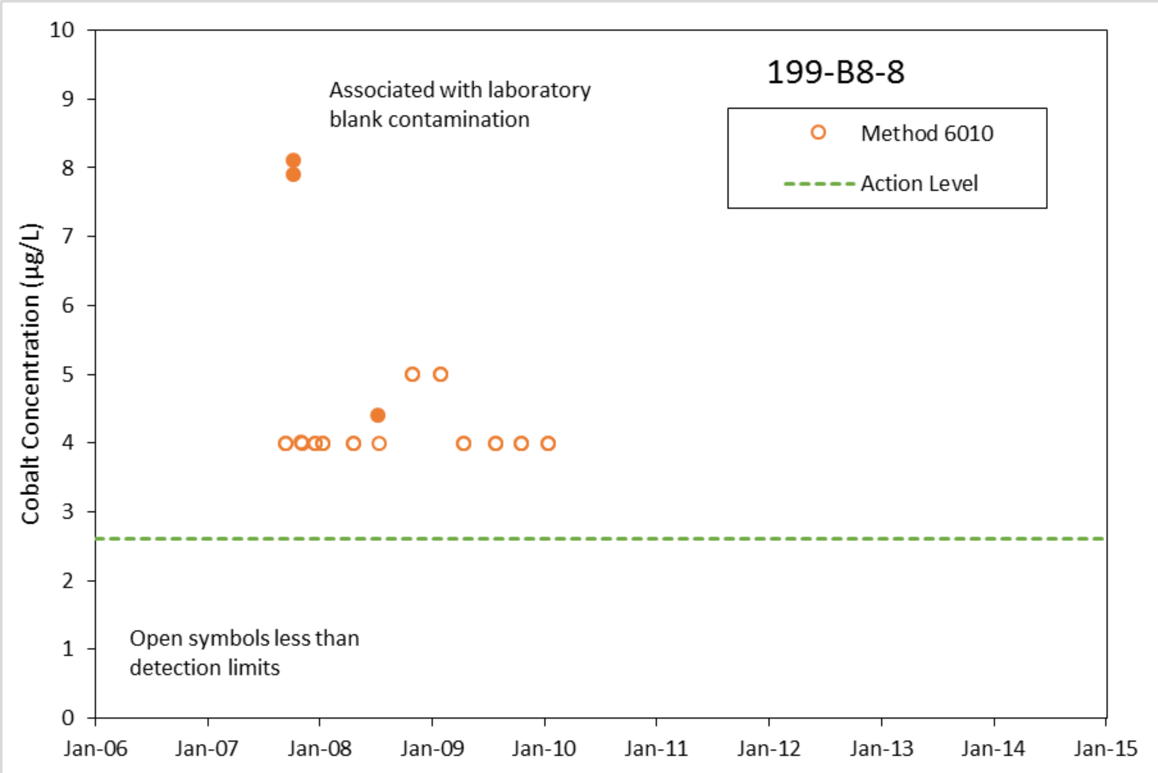


Figure A-3. Cobalt in Well 199-B8-8

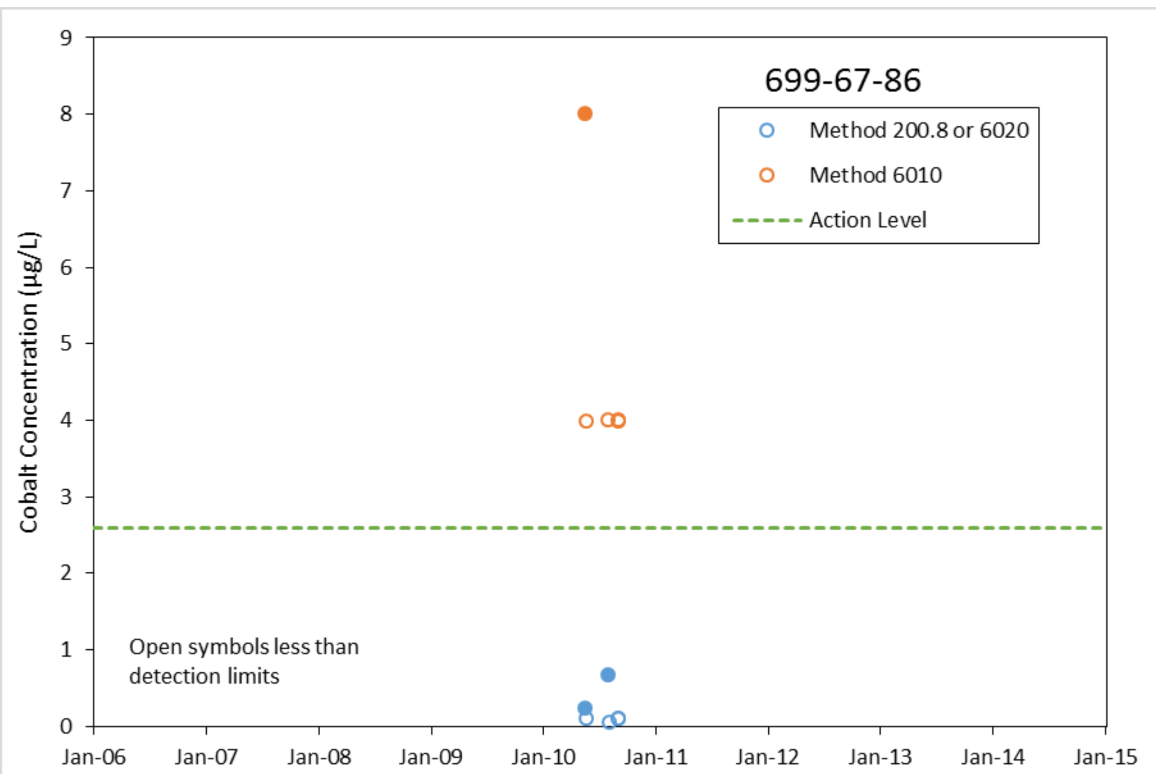


Figure A-4. Cobalt in Well 699-67-86

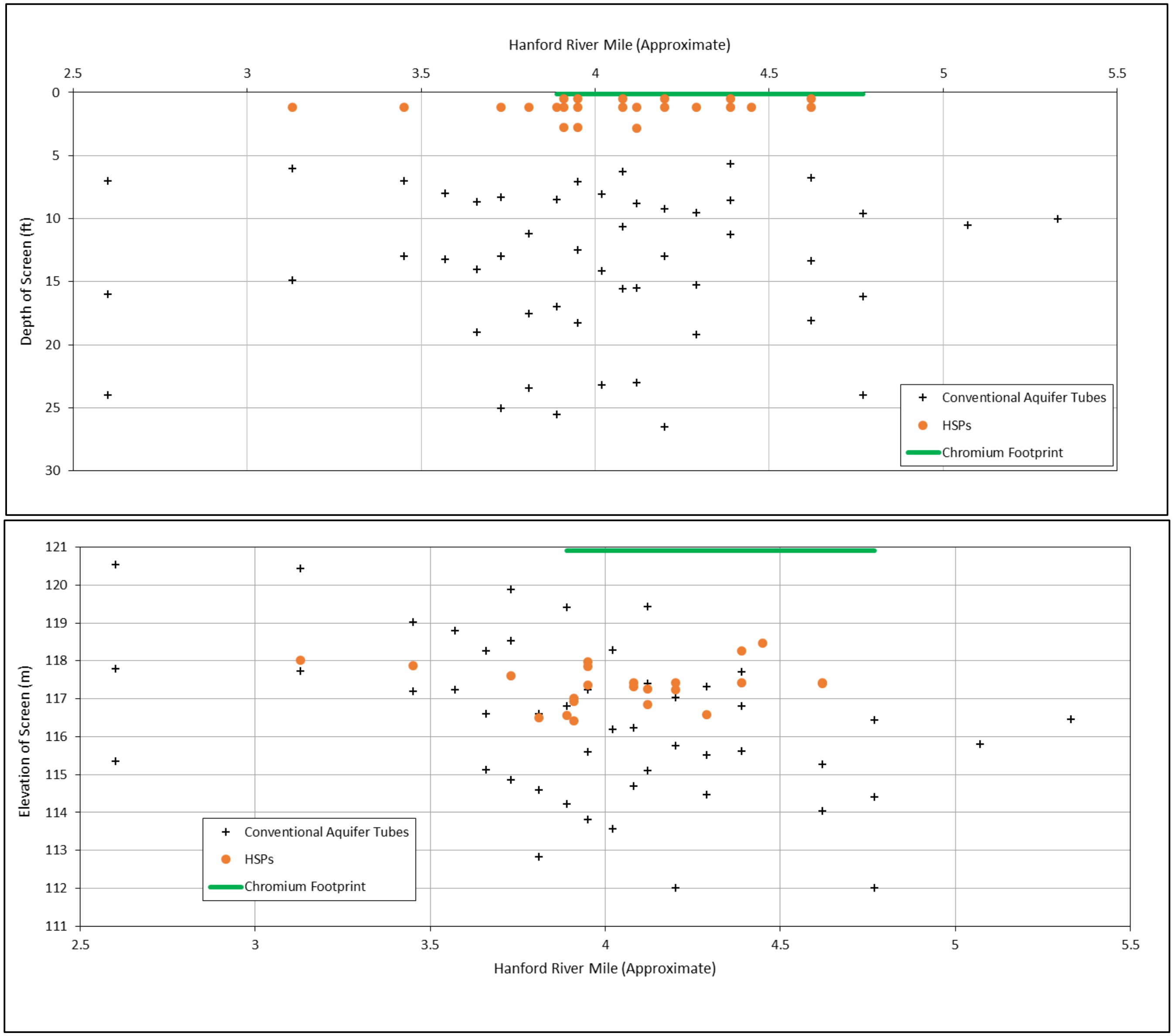


Figure A-5. Depths (Top Panel) and Elevation (Bottom Panel) of Screens in 100-BC Aquifer Tubes and HSPs

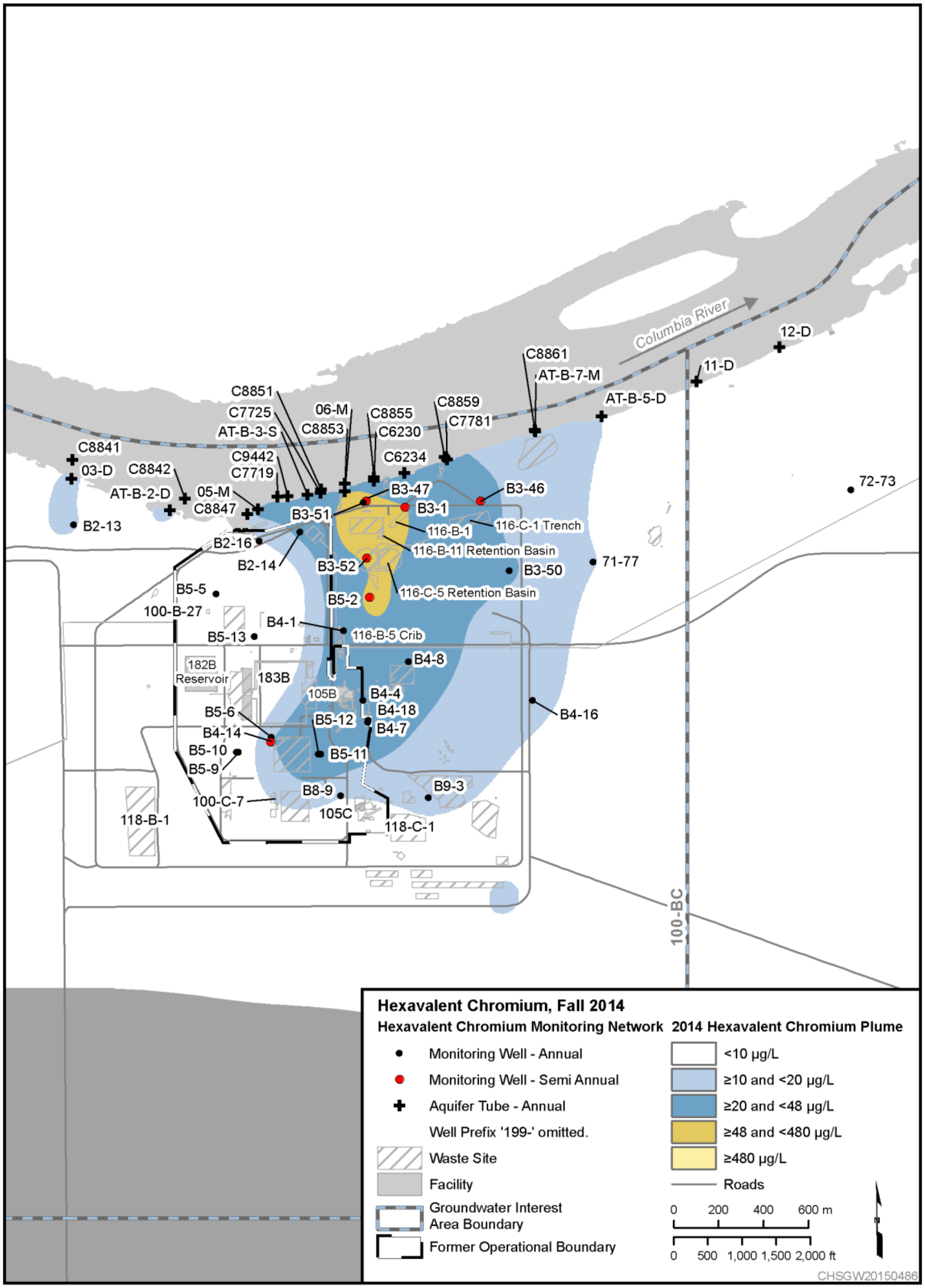


Figure A-6. Proposed Monitoring Network for Hexavalent Chromium

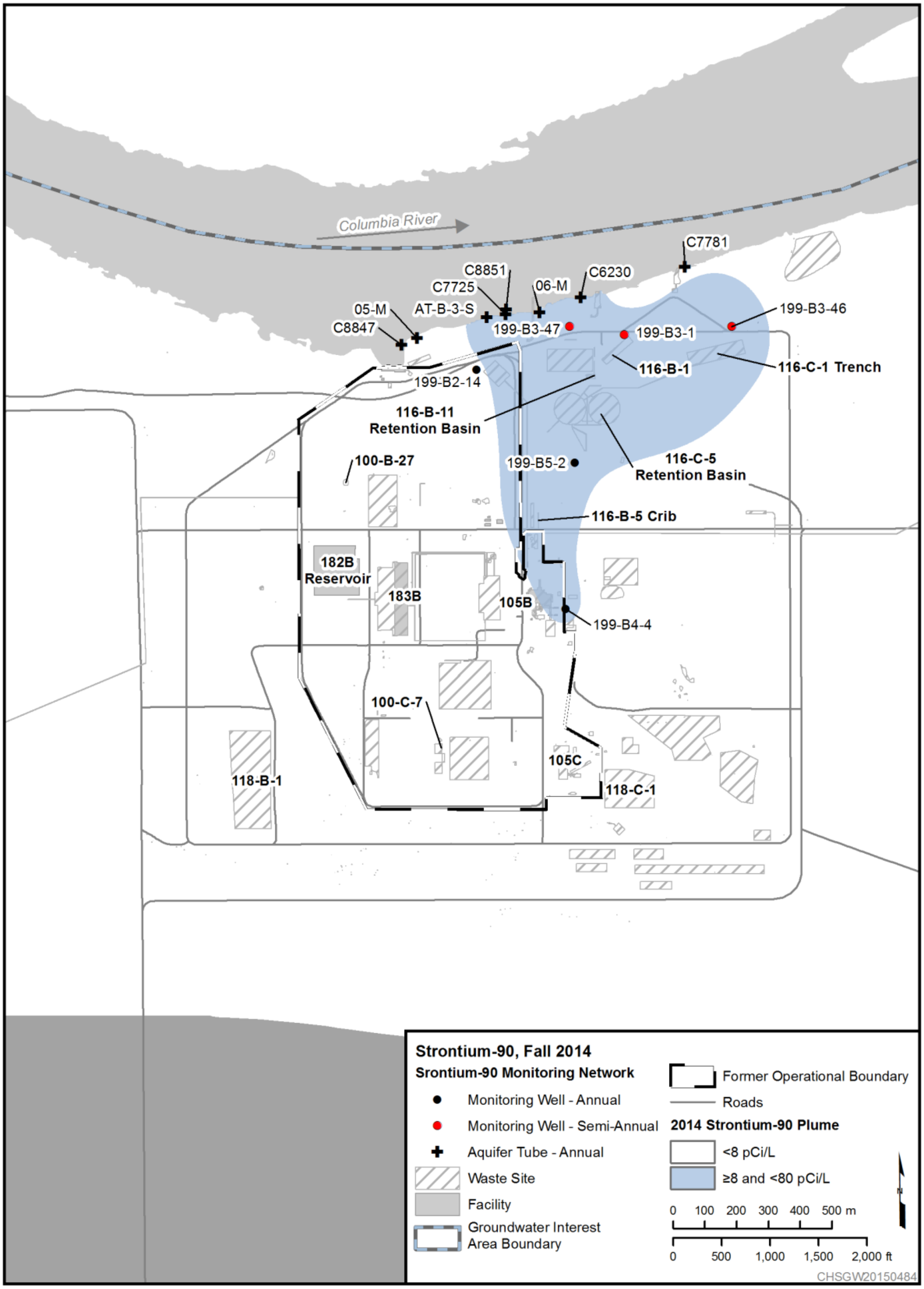
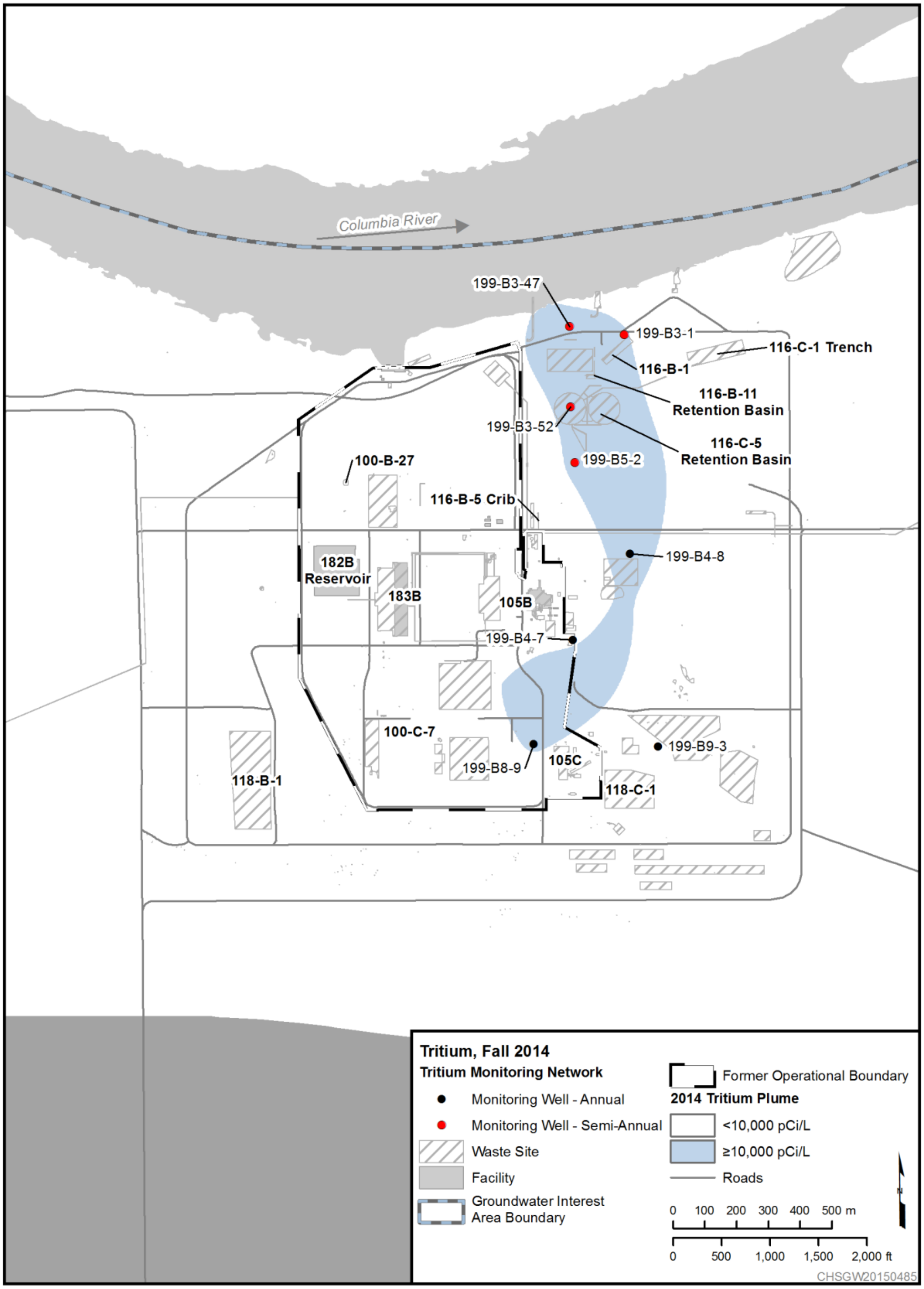


Figure A-7. Proposed Monitoring Network for Strontium-90

1



2 **Figure A-8. Proposed Monitoring Network for Tritium**

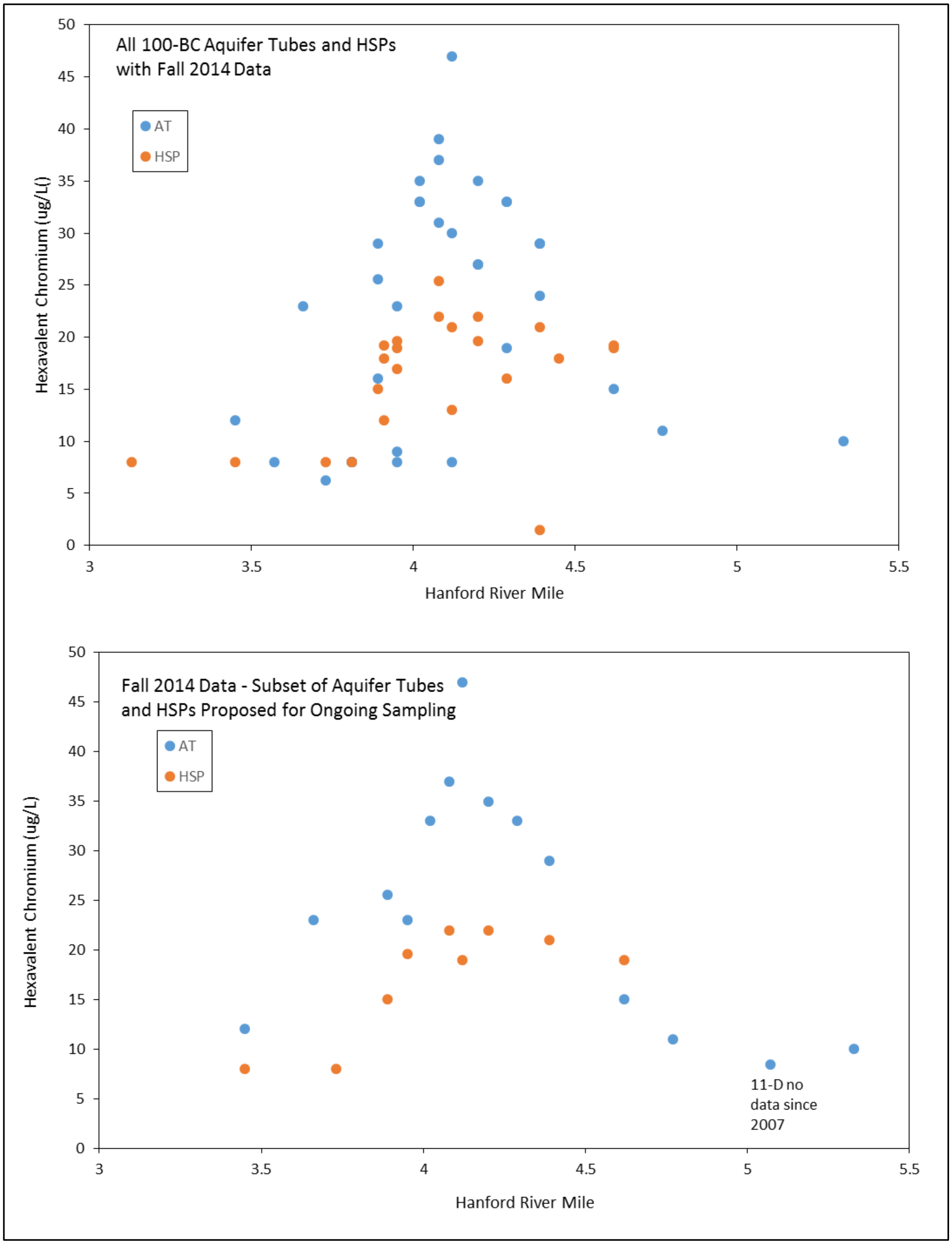
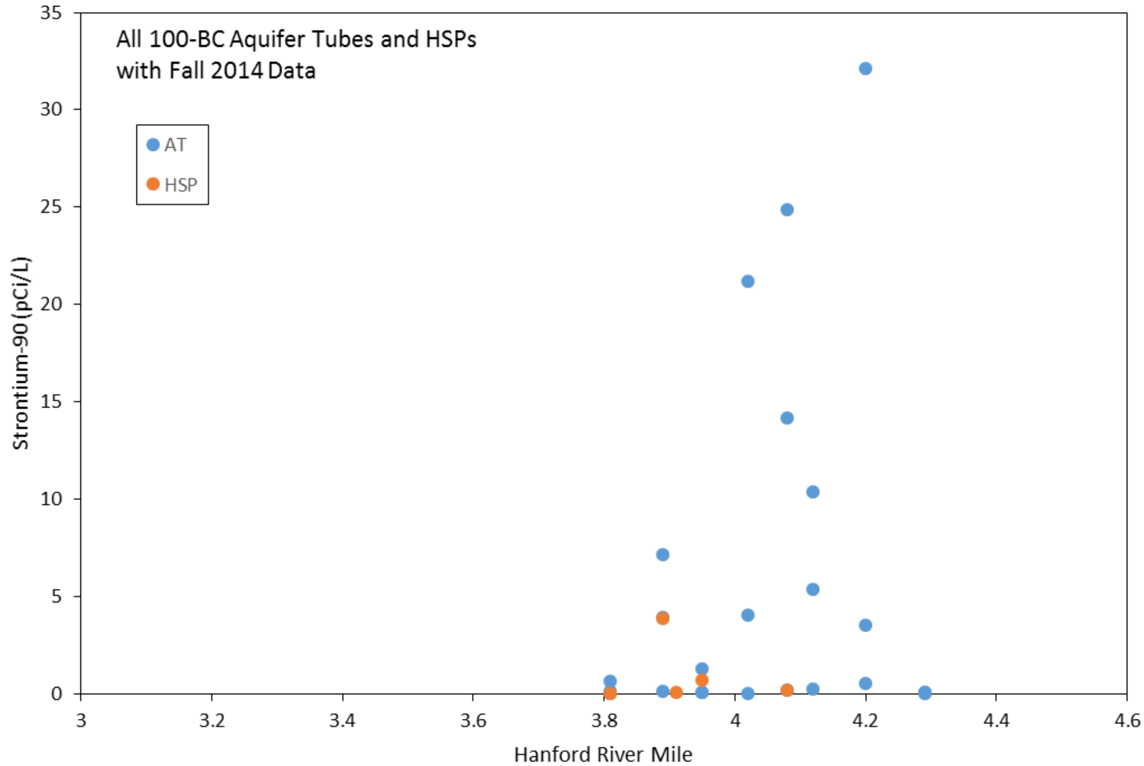


Figure A-9. Fall 2014 Hexavalent Chromium Concentrations in 100-BC Aquifer Tubes and HSPs



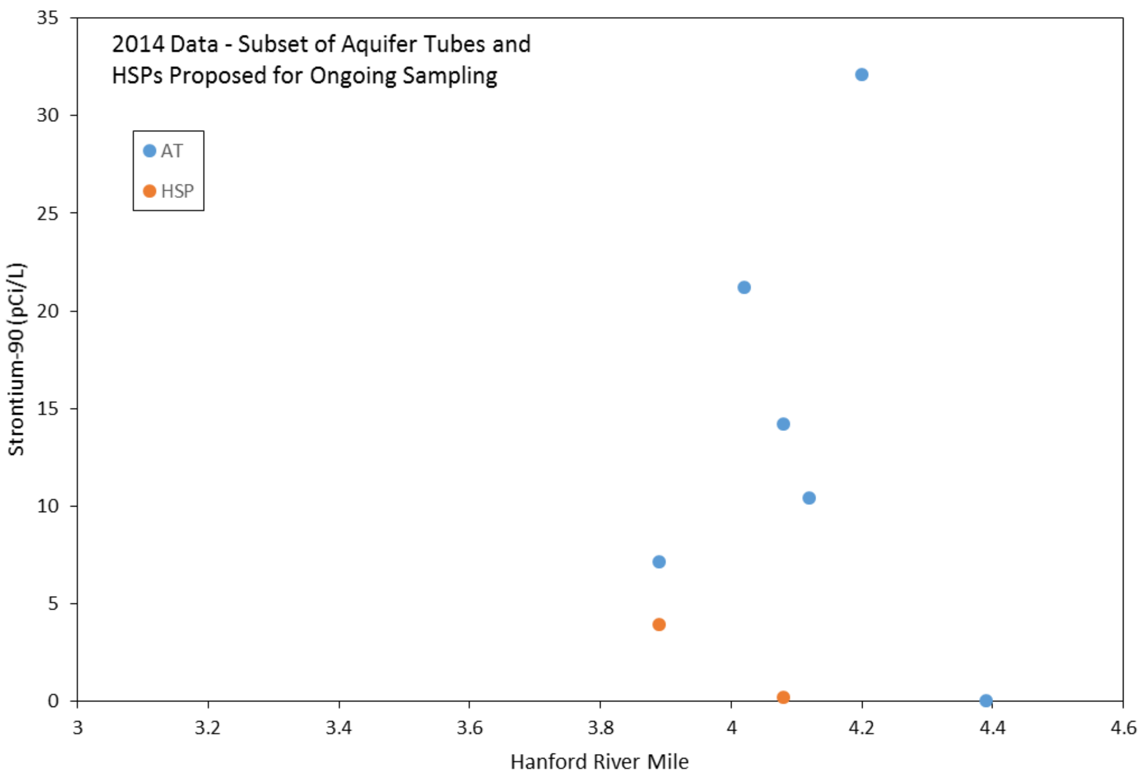


Figure A-10. Fall 2014 Strontium-90 Concentrations in 100-BC Aquifer Tubes and HSPs