

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. In 2016, trichloroethene and chloroform were identified as contaminants of potential concern in deep wells 199-B3-51, 199-B5-5 and 199-B5-6. This SAP will also monitor those ~~three~~ five contaminants.

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, Cr(VI), strontium-90, and tritium. Appendix B describes chloroform and trichloroethene contamination in groundwater.

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.

(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. Appendix B provides DQO information for trichloroethene and chloroform.

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

Contaminant	CAS Number
Laboratory Analyses COC	
Chromium (Hexavalent)	18540-29-9
Strontium-90	10098-97-2
Tritium	10028-17-8
<u>Chloroform</u>	<u>67-66-3</u>
<u>Trichloroethene</u>	<u>79-01-6</u>
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

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		
Organics (µg/L)						
<u>Chloroform</u>	<u>67-66-3</u>	<u>TBD</u>	<u>EPA 8260</u>	<u>1</u>	<u>≤20% RPD</u>	<u>80 to 120%</u>
<u>Trichloroethene</u>	<u>79-01-6</u>	<u>TBD</u>	<u>EPA 8260</u>	<u>1</u>	<u>≤20% RPD</u>	<u>80 to 120%</u>
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 Appendices A and B 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

TBD = to be determined

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 ^c	Flagged with "Q"
<u>Volatile Organic Compounds</u>			
<u>Chloroform</u> <u>Trichloroethene</u>	<u>MB</u>	<u><MDL</u> <u><5% Sample Concentration</u>	<u>Flagged with "B"</u>
	<u>LCS</u>	<u>Statistically Derived^c</u>	<u>Data reviewed^b</u>
	<u>Laboratory Duplicate</u>	<u>< 20% RPD^c</u>	<u>Data reviewed^b</u>
	<u>MS, MSD</u>	<u>% Recovery Statistically Derived^c</u>	<u>Flagged with "T" if analyzed by GC/MS, otherwise "N" based on FEAD</u>
	<u>Surrogate</u>	<u>Statistically Derived^c</u>	<u>Data reviewed^b</u>
	<u>EB, FTB, FXR</u>	<u><2 × MDL</u>	<u>Flagged with "Q"</u>
	<u>Field Duplicate</u>	<u><20% RPD^c</u>	<u>Flagged with "Q"</u>
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

MDA = minimum detectable activity

FEAD = format for electronic analytical data

MDL = method detection limit

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

Analyte ^a	QC Element	Acceptance Criteria	Corrective Action
FTB = full trip blank		<u>MS</u> = matrix spike	
<u>FXR</u> = field transfer blank		<u>MSD</u> = matrix spike duplicate	
<u>GC/MS</u> = gas chromatography/mass spectrometry		<u>QC</u> = quality control	
LCS = laboratory control sample		<u>RPD</u> = relative percent difference	
MB = method blank		<u>SMR</u> = Sample Management and Reporting	
MDA = minimum detectable activity			
MDL = method detection limit			
Data Flags:			
B (radionuclides)/C (inorganics/wetchem) = analyte was detected in both the associated QC blank and the sample).		N = <u>MS outlier Spike or spike duplicate sample recover out of limits</u>	
		Q = associated QC sample is out of limits	

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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 $\leq 6^{\circ}\text{C}$	24 hours
Radiochemical Analyses				
<u>Volatile Organic Compounds by EPA 8260</u>	<u>40 mL</u>	<u>Amber glass volatile organic analysis vial with Teflon® lined septum</u>	<u>Cool $\leq 6^{\circ}\text{C}$, hydrochloric acid to pH ≤ 2</u>	<u>14 Days</u>
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 $\leq 6^{\circ}\text{C}$, 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

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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.

1.6 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~~ Appendices A and B provides details of sampling objectives, goals of the study, and the analytical approach.

1.7 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.

HSPs are subject to breakage, and can only be repaired by divers during periods of low river flow. If an HSP is found to be broken when sampling is attempted, another HSP (either a different depth in the same cluster, or a nearby HSP) may be sampled instead and EPA will be informed of the change. If no nearby HSP is available, the sample will be skipped. DOE will consult with EPA to determine if repair or replacement is required at a later date. Conventional aquifer tubes are less prone to breakage, but also occasionally cannot be sampled. A similar process will be followed.

1.8 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.

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	VOCs
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) <u>and VOCs</u> .	A	A			<u>A</u>
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) <u>and VOCs</u> .	A	A			<u>A</u>
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			

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

Well, Aquifer Tube, or HSP	Zone Monitored	Monitoring Rationale	Field	Cr(VI)	Sr-90	Tritium	VOCs
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			
199-B4-18	Bottom unconfined	Monitor deep Cr(VI), <u>possible VOCs</u> .	A	A			<u>A</u>
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) <u>and VOCs</u> .	A	A			<u>A</u>
199-B5-6	Bottom unconfined	Monitor deep Cr(VI) <u>and VOCs</u> .	A	A			<u>A</u>
199-B5-9	Bottom unconfined	Monitor deep Cr(VI), <u>possible VOCs</u> .	A	A			<u>A</u>
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), <u>possible VOCs</u> .	A	A			<u>A</u>
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), <u>possible VOCs</u> .	A	A			<u>A</u>
<u>199-B8-6</u>	<u>Top unconfined</u>	<u>Monitor tritium downgradient of 118-B-1</u>	<u>A</u>			<u>A</u>	
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		

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	VOCs
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			
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			
C8860	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

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	VOCs
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Sr-90 = strontium-90

VOC = volatile organic compounds (chloroform and trichloroethene)

Sampling frequencies:

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

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

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 $>10 \mu\text{g/L}$
- Strontium-90 plume boundaries at $>8 \text{ pCi/L}$
- Tritium concentrations in area formerly $>20,000 \text{ pCi/L}$ and downgradient of the 118-B-1 Burial Ground, a potential residual source

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

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 or potential residual sources.

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

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. <u>Downgradient of potential residual tritium source.</u>	Y N			A
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			

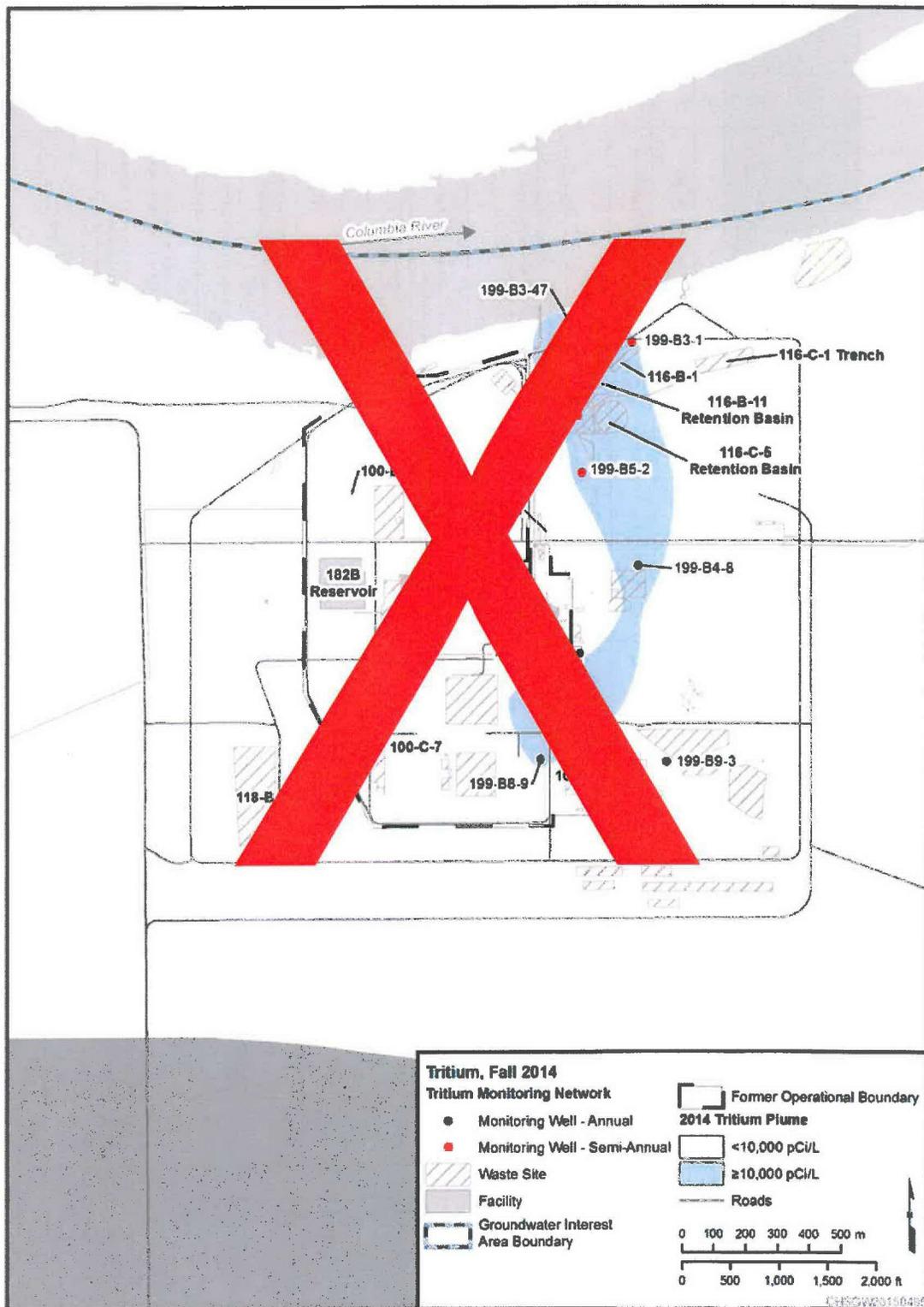


Figure A-8. Proposed Monitoring Network for Tritium

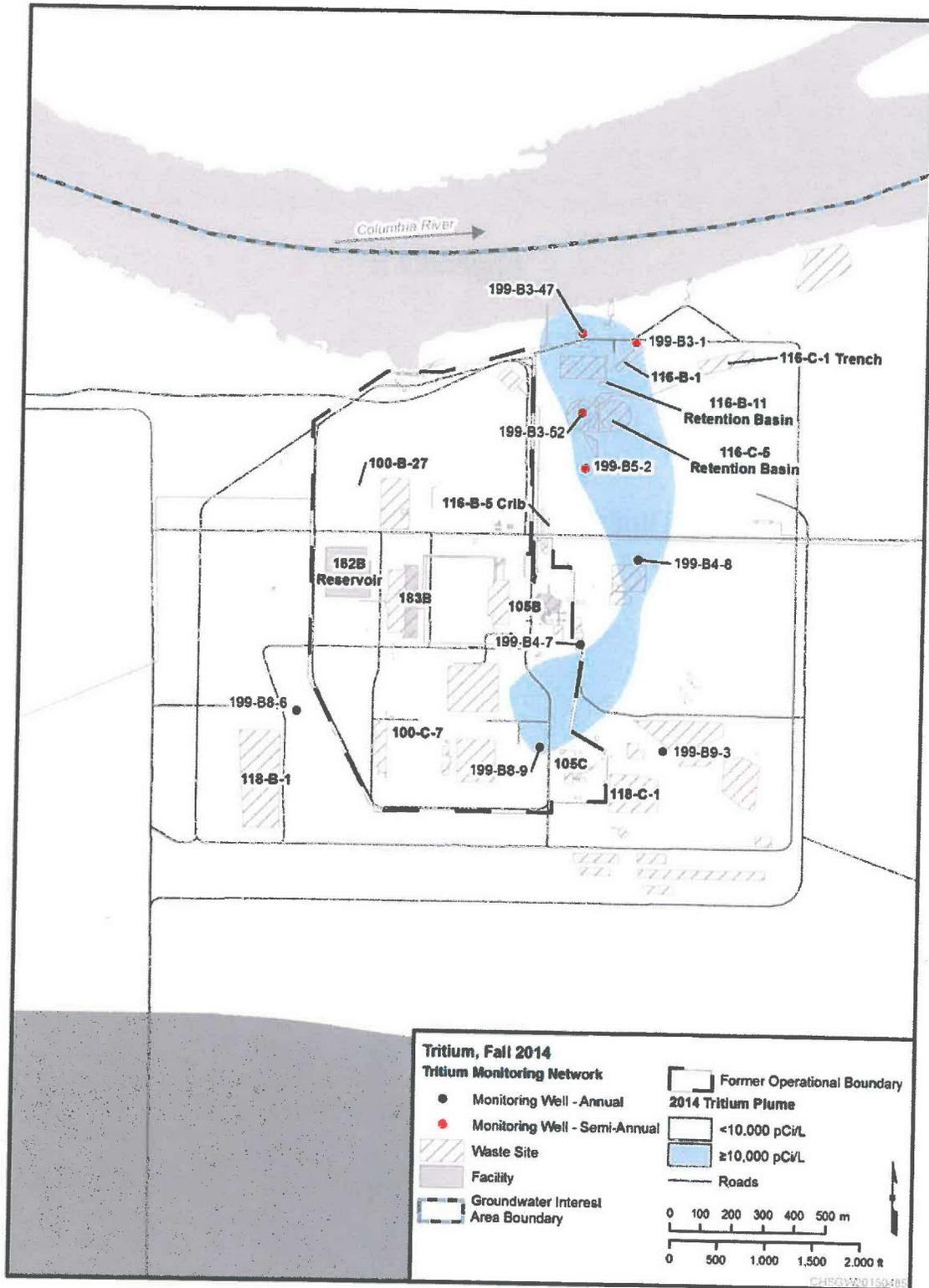


Figure A-8. Proposed Monitoring Network for Tritium [replacement figure]

Appendix B

Data Quality Objectives for Chloroform and Trichloroethene

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B1 Introduction

An updated groundwater risk assessment in 2016 identified chloroform and trichloroethene as additional groundwater contaminants of potential concern (COPCs) in deep wells 199-B3-51, 199-B5-5, and 199-B5-6. An abbreviated data quality objectives (DQO) process was applied to determine appropriate monitoring for the additional contaminants.

B2 Available Data

Wells were analyzed for volatile organic compounds (VOCs) during spatial and temporal sampling in 2010; the detection limit for most of these analyses was 1 µg/L for both trichloroethene and chloroform.

In the upper part of the unconfined aquifer, most results were near or below detection limits for chloroform and trichloroethene. Of 25 shallow wells with volatile organic compound (VOC) data, 7 wells had trichloroethene detections greater than 1 µg/L in at least one sample with the highest concentration of TCE estimated as 2.2 µg/L at well 199-B5-8. (Table B-1). Chloroform concentrations were less than 1 µg/L in the upper part of the unconfined aquifer. The highest chloroform detection (excluding those associated with out-of-range a quality control results) was an estimated 0.59 µg/L in well 199-B2-13.

Characterization samples were collected through the entire aquifer thickness in 8 wells installed in between 2009 and 2011. These characterization data were not included in the risk assessment to determine contaminants of concern (COCs). In the lower part of the unconfined aquifer, trichloroethene concentrations above 1 µg/L were detected in 7 wells and chloroform concentrations above 1 µg/L were detected in 5 wells (Table B-1).

Four of the wells installed in 2009-2011 were completed with screens in the lower part of the aquifer and were sampled at least once for VOCs after completion (Figure B-1). Those data were included in the risk assessment for the RI/FS. The combined concentrations of trichloroethene and chloroform in wells 199-B5-5, 199-B5-6, and 199-B3-51 exceeded the cumulative risk threshold of 10^{-5} . Well 199-B3-51 had a single sample and the results were not consistent with characterization data, which were nondetects. Trichloroethene and chloroform also were detected in routine samples from 199-B2-16, but levels did not exceed the cumulative risk threshold.

Wells installed in 2013 through 2014 were not sampled for VOCs during or after drilling.

B3 DQO Steps

B3.1 Step 1: State the Problem

The problem statement is as follows:

Chloroform and trichloroethene have been identified as groundwater COPCs in three wells screened in the lower part of the unconfined aquifer. One additional deep well had detections but levels were not high enough to make these COPCs in that well. Other deep wells have not been sampled for chloroform and trichloroethene. Monitoring is necessary to confirm the CSM used for the RI/FS evaluations.

B3.2 Step 2: Identify the Goal of the Study

The principal study question is as follows:

Are concentrations of chloroform and TCE in the lower part of the aquifer consistent with the CSM?

B3.3 Step 3: Identify Information Inputs

The primary source of information will be groundwater samples from wells screened in the lower part of the aquifer, which will be analyzed for chloroform and trichloroethene.

Chloroform and trichloroethene are COPCs because the cumulative risk level is greater than 1×10^{-5} . Detection limits of 1 µg/L or less will provide data to meet this cumulative action level.

B3.4 Step 4: Define the Boundaries of the Study

The 2016 risk assessment concluded that chloroform and trichloroethene are COPCs only in the lower part of the unconfined aquifer. Although the assessment identified these as COPCs in only three wells, four other deep wells lack chloroform and trichloroethene data. Given the widespread detections of these contaminants beneath 100-BC during characterization, study boundaries will include all 8 wells screened in the deep part of the aquifer (Table B-2).

The time period for this study begins with the planned fall 2016 sampling event and ends when performance monitoring for the groundwater remedial action begins.

B3.5 Step 5: Develop the Analytic Approach

The decision rule for this study is as follows:

If chloroform and trichloroethene concentrations are not within or near previously established ranges in the lower part of the unconfined aquifer, then incorporate the new information into the 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 distribution maps
- Concentration versus time graphs

B3.6 Step 6: Specify Performance or Acceptance Criteria

Analytical criteria for chloroform and trichloroethene will be consistent with established criteria for the groundwater project.

B3.7 Step 7: Develop the Plan for Obtaining Data

Analytes include chloroform and trichloroethene. The monitoring network includes 8 wells screened in the lower part of the unconfined aquifer (Table B-2). These wells are also sampled for the COCs hexavalent chromium, strontium-90, and tritium, as described in the main body of this document and in Appendix A. Sampling frequency will be annual in the fall of the year, as defined for the COCs.

Table B-1. Maximum Chloroform and Trichloroethene Concentrations in Selected Wells

Well Name	Maximum Shallow TCE, µg/L	Maximum Deep TCE, 1 µg/L	Maximum Shallow Chloroform, µg/L	Maximum Deep Chloroform, µg/L
199-B2-14	0.84 J (C)	0.37 J (C)	0.36 J (C)	1.4 J (C)
199-B2-16	1.3 J (C)	2.1 J (C)	Not detected (C)	4.8 J (C)
199-B3-46	1.2 (R)	No data	0.39 J (R)	No data
199-B3-50	1.7 J (C)	4.2 J (C)	0.39 J (R)	Not detected (C)
199-B3-51	Not detected (C)	4.0 Y (R) ^b	Not detected (C)	1.9 J (R)
199-B5-5	Not detected (C)	2.5 J (R)	Not detected (C)	4.8 J (C)
199-B5-6	Not detected (C)	3.3 (R)	Not detected (C)	2.2 J (C)
199-B5-8	2.2 J (R)	2.0 J (C)	Not detected (R)	Not detected (C)
199-B8-9	1.3 J (C) ^a	1.1 J (C)	Not detected (R)	Not detected (C)
199-B9-3	1.4 (R)	No data	0.47 (R) ^a	No data
699-65-72	1.3 (R)	No data	0.15 J (R)	No data

Notes:

Maximum values in shallow and deep parts of unconfined aquifer (above or below 100 m elevation), 2009 to 2015

Wells are listed only if at least one detected value of chloroform or trichloroethene was >1 µg/L

C = sample collected during characterization

J = estimated value (result is above detection limit but below quantitation limit)

R = sample collected from completed well during routine monitoring

Y = suspect

a. Excludes T flagged values (T = spike and/or spike duplicate sample recovery out of limits)

b. Flagged as suspect because it was inconsistent with characterization samples; however, there is insufficient evidence to reject the value

Table B-2. Monitoring Network for Chloroform and Trichloroethene

Well Name	Location*	Rationale
199-B2-16	Near river, Northwestern 100-BC	Chloroform and trichloroethene were routinely detected 2010-2014 but the cumulative risk level was below the threshold. Continue to monitor because the well is downgradient of other wells with higher concentrations.
199-B3-51	Near river, Northeastern 100-BC	Chloroform and trichloroethene were undetected during drilling, but exceeded the risk threshold in a single sample after well completion (2010). Continue to monitor to determine whether the detections are repeatable.
199-B4-18	Inland; Southeastern 100-BC	No VOC data collected to date. Monitor to determine if concentrations are within ranges observed in other deep wells.
199-B5-5	Inland, Northwestern 100-BC	Chloroform and trichloroethene routinely detected 2010-2014 at levels that exceed the cumulative risk threshold.
199-B5-6	Inland, Southwestern 100-BC	Chloroform and trichloroethene routinely detected 2010-2014 at levels that exceed the cumulative risk threshold.
199-B5-9	Inland, Southwestern 100-BC	No VOC data collected to date. Monitor to determine if concentrations are within ranges observed in other deep wells.
199-B5-11	Inland, South-central 100-BC	No VOC data collected to date. Monitor to determine if concentrations are within ranges observed in other deep wells.
199-B5-13	Inland, between 199- B5-5 and 199-B5-6	No VOC data collected to date. Monitor to determine if concentrations are within ranges observed in other deep wells.
*Well locations are illustrated in Figure 1-1 of the main text		

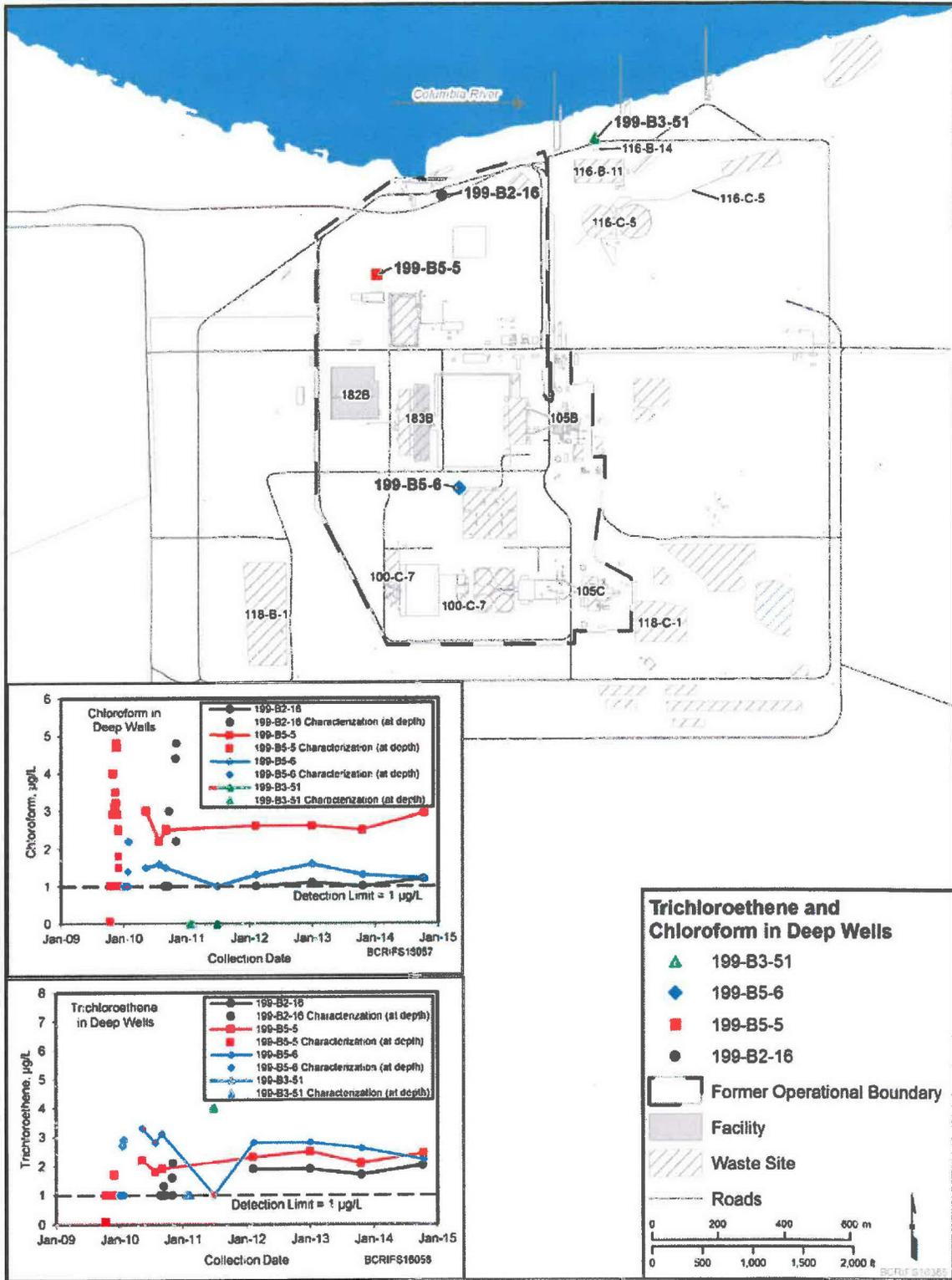


Figure B-1. Chloroform and Trichloroethene Trends in Deep Wells