100-BC

This page intentionally left blank.

100-BC Overview

The 100-BC groundwater interest area includes the 100-BC-5 operable unit (OU) and surrounding region. Two nuclear reactors formerly operated in 100-BC. The B Reactor was the first of its kind, and it 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 100-BC is mainly associated with waste produced by the reactors and related processes. Table BC.1 summarizes key facts about 100-BC. Additional details about 100-BC history and waste sites are provided in DOE/RL-2010-96. Figure BC.1 shows the locations of groundwater monitoring wells and aquifer sampling tubes.

The U.S. Department of Energy (DOE) monitors 100-BC groundwater to meet *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) and *Atomic Energy Act of 1954* (AEA) requirements. Groundwater contaminants of concern are hexavalent chromium, strontium-90, and tritium (DOE/RL-2010-96). Previous assessments have not resulted in any interim remedial measures for groundwater. Figure BC.2 shows how estimated plume areas (in the upper part of the unconfined aquifer) have changed since 2003.

Nearly all of the waste sites in 100-BC have been remediated or are classified as not requiring remediation. The last site to undergo remediation under the interim action record of decision (ROD) (EPA/ROD/R10-95/126; EPA/ROD/R10-99/039; EPA/ROD/R10-00/121) was 100-C-7:1. The excavation to remove contaminated soil from this site was very large, extending to the water table at a depth of approximately 24 meters. Workers backfilled the hole in 2013 and revegetated the surface in 2014. With the completion of this remediation, there are no known remaining sources of significant contamination that could migrate to groundwater.

The vadose zone in 100-BC is comprised of Hanford formation sand and gravel (Figure BC.3). The water table is at a depth of approximately 18 to 24 meters. The upper portion of the unconfined aquifer beneath most of 100-BC is in the highly permeable sediments of the Hanford formation. The lower portion of the aquifer, and the entire aquifer near the Columbia River, is within the Ringold unit E sands and gravels. The unconfined aquifer is 32 to 48 meters thick, and the base of the aquifer is a silt/clay-rich unit commonly called the Ringold upper mud unit (RUM) (DOE/RL-2010-96).

Figure BC.4 illustrates water-table contours based on data collected in late February 2013. The hydraulic gradient is steepest in the north near the Columbia River, where the water table is in Ringold unit E. The gradient is very low in southern 100-BC where the water table is in the highly permeable Hanford formation. Table BC.2 summarizes the results of trend surface analysis of water-level data for various time periods in 2013 in the form of hydraulic gradients and flow direction for the southern and northern 100-BC areas.

In northern 100-BC, flow is primarily to the north during periods of low and moderate river stage. When river stage is very high, river water flows into the aquifer. A reversed gradient was not observed in 2013, similar to observations in the other river corridor areas. In July when the river stage was high, trend surface analysis showed the potential for flow toward the northwest.

The water table is very flat in southern 100-BC. Trend surface analysis of available data in 2013 indicated flow in southern 100-BC was toward the north-northeast in January and July, and northeast in late February. The water table dipped toward the northwest in October 2013 at a very low gradient. The results of the analyses in February and October have greater uncertainty than the others because the difference in water-table elevations was only about 2 cm across a distance of more than 1 km. Tracer tests conducted in the 100-C-7:1 excavation in spring and summer 2012 indicated flow toward the northeast (PNNL-21845). Recent movement of groundwater contaminants in the shallow aquifer also indicates that flow primarily is toward the northeast.

Table BC.1 100-BC at a Glance

Reactor Operations: B 1944–1968; C 1952–1969				
2013 Groundwater Monitoring				
Contaminant	**Water Quality Standard**	**Maximum Concentration**	**Plume Area[a] (km^2)**	**Shoreline Impact (m)**
Hexavalent Chromium	48 µg/L[b]/ 10 µg/L[c]	62 µg/L (199-B4-8)	0.2[b] / 1.6[c]	0[b] / 1,500[c]
Strontium-90	8 pCi/L	53 pCi/L (199-B3-46)	0.60	270
Tritium	20,000 pCi/L	19,000 pCi/L (199-B8-9)	0	0
Remediation				
Waste Sites (interim action): 92% complete[d]. Groundwater (interim action): None. Final Record of Decision anticipated in 2017.				

a. Estimated area at a concentration greater than the listed drinking water standard.
b. 48 µg/L MTCA groundwater cleanup standard
c. 10 µg/L surface water standard.
d. Sites with status of closed, interim closed, no action, not accepted, or rejected.

Table BC.2 Hydraulic Gradient and Groundwater Flow Directions in 100-BC

	Southern 100-BC		**Northern 100-BC**	
Date	**Magnitude**	**Deg E of N**	**Magnitude**	**Deg E of N**
1/3/2013	9.5E-05	30	1.06E-03	9.1
2/27/2013	2.6E-05*	57*	2.4E-03	6.0
7/18/2013	2.6E-04	12	5.2E-03	321
10/23/2013	2.2E-05*	331*	2.5E-03	6.7

*Little difference in water levels during these time periods. Results uncertain.

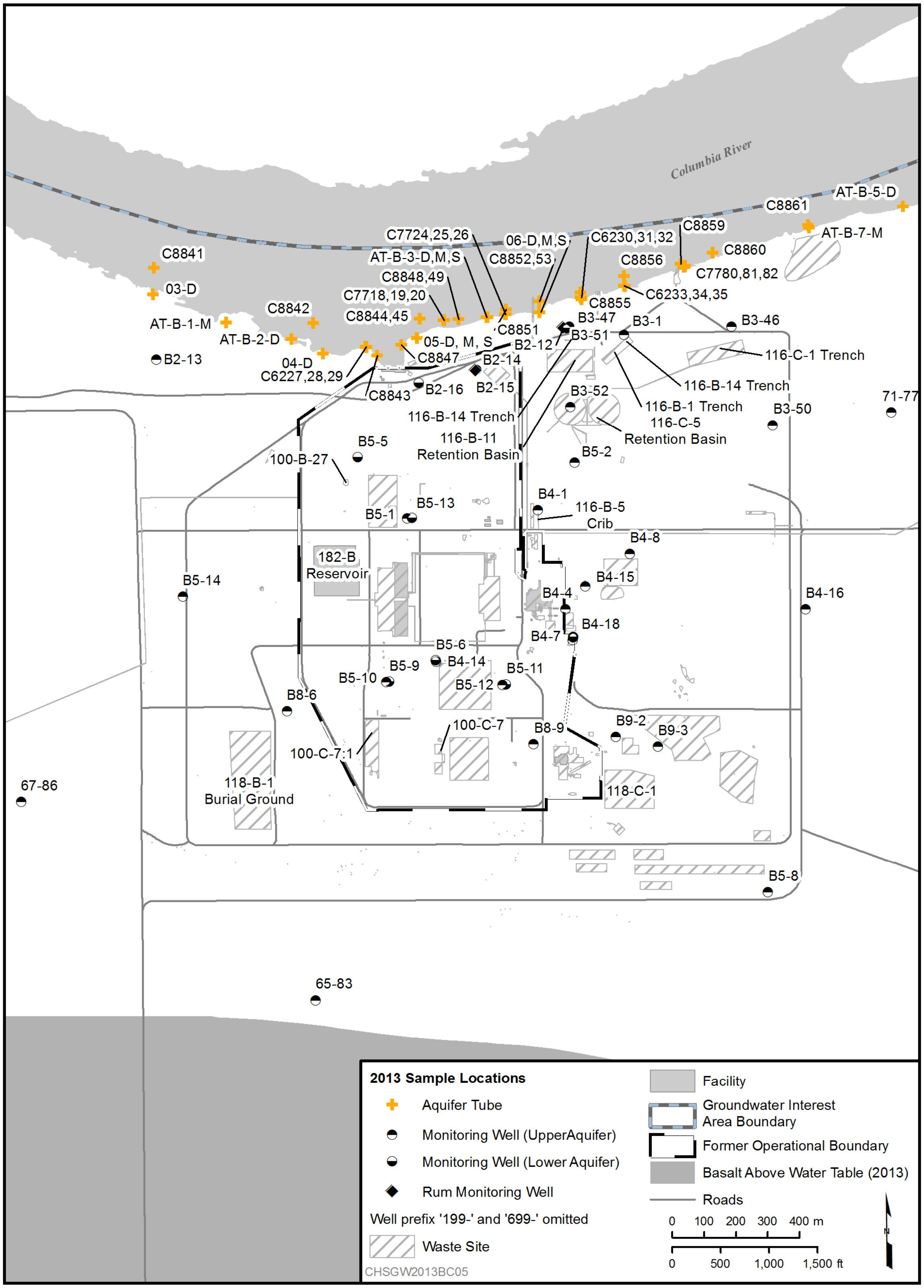

Figure BC.1 100-BC 2013 Sampling Locations

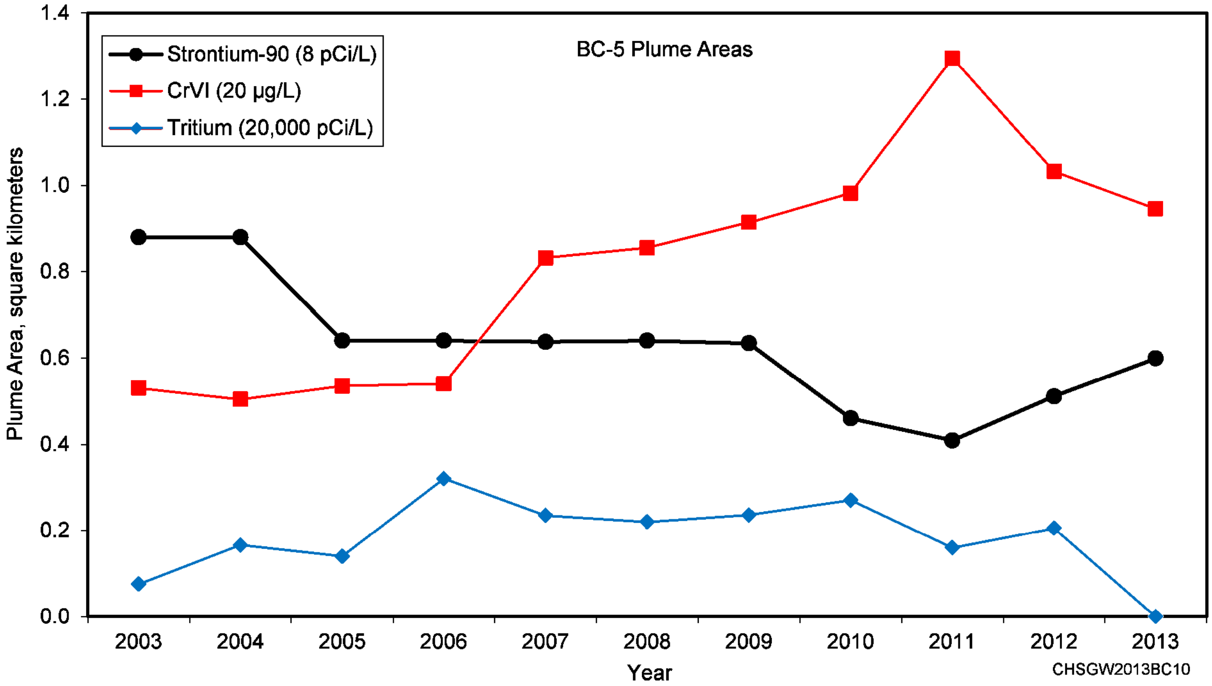

Figure BC.2 100-BC Plume Areas

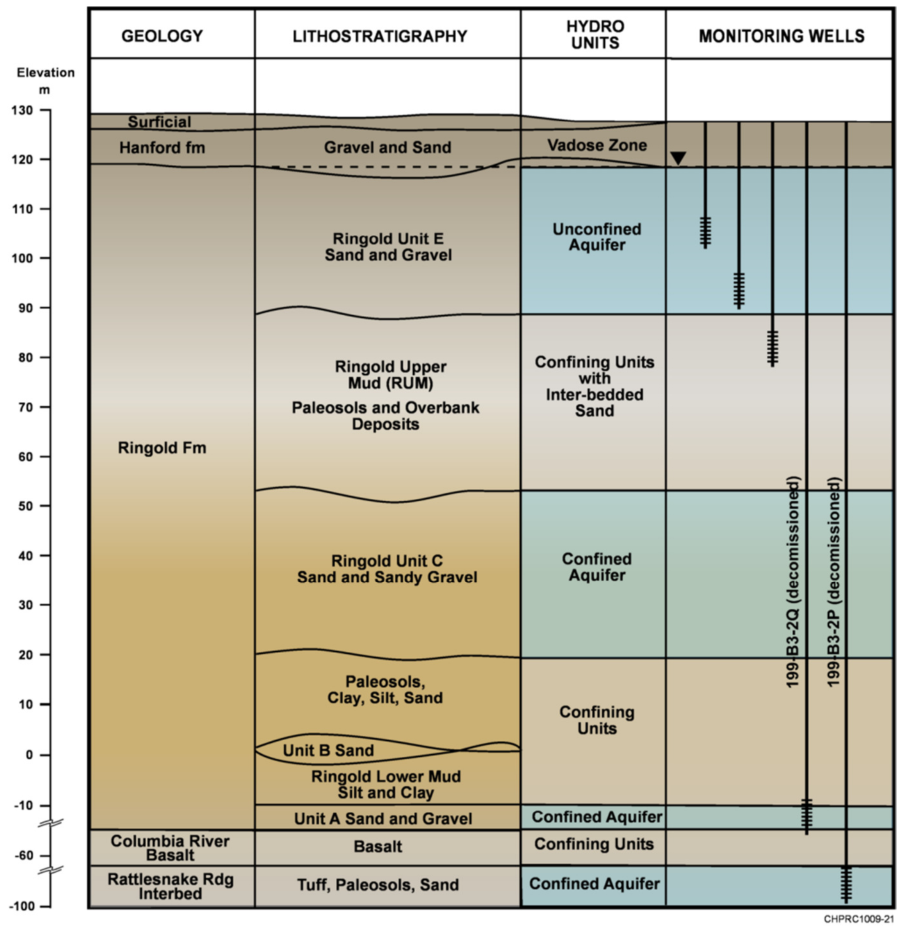

Figure BC.3 100-BC Geology

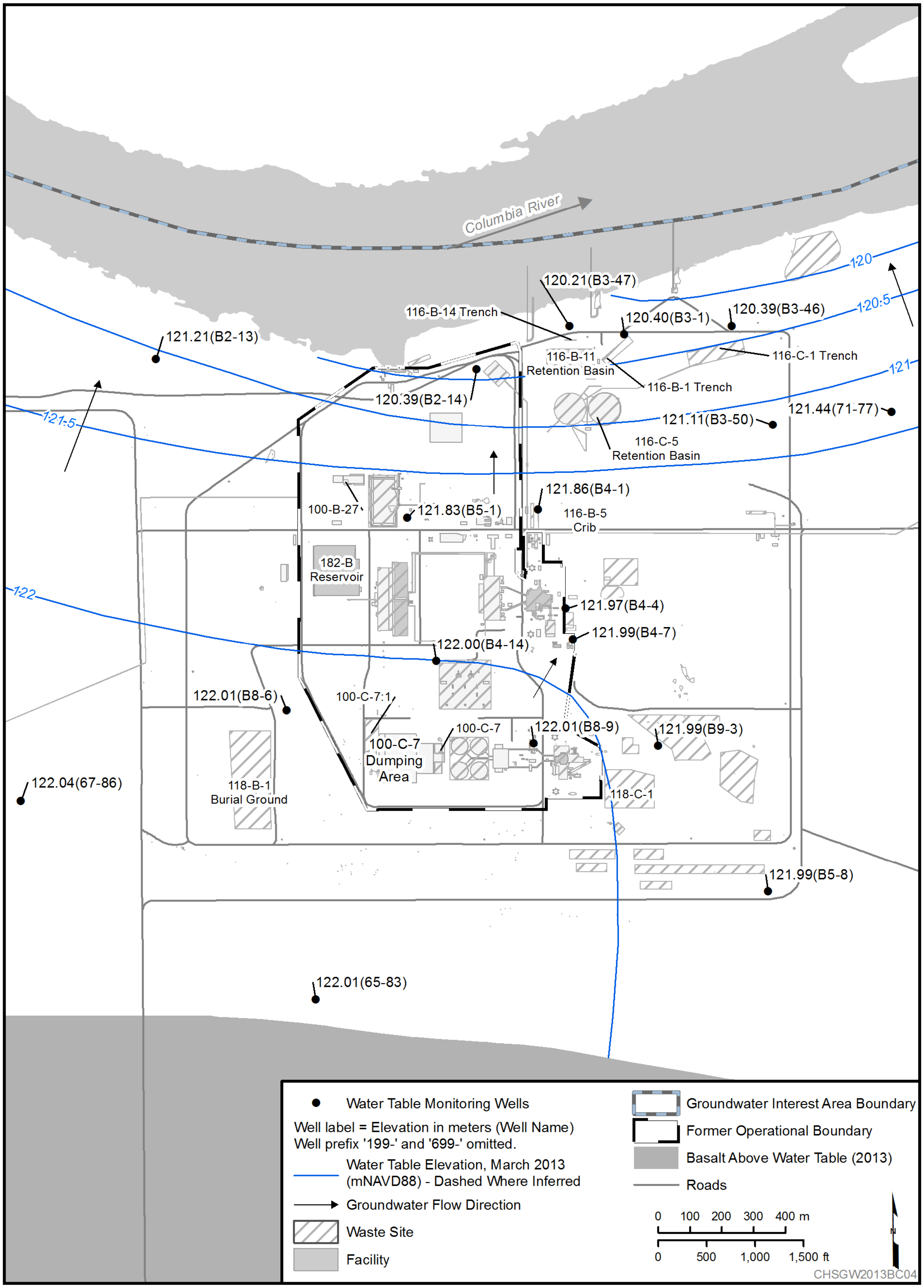

Figure BC.4 100-BC 2013 Water Table

100-BC CERCLA Activities

In 2013, CERCLA activities in 100-BC included routine groundwater monitoring and the beginning of additional remedial investigation (RI) studies.

Groundwater Monitoring. Routine groundwater monitoring is described in the sampling analysis plan for the area (DOE/RL-2003-38 Rev. 1, as modified by TPA-CN-522). Groundwater monitoring wells in 100-BC are sampled at frequencies ranging from biennial to monthly. The schedule for the comprehensive annual sampling event changed during 2013, so wells were sampled in January (the old schedule) and October (the new schedule). Table A.1 of Appendix A lists the wells and constituents monitored. Aquifer tubes in 100-BC were sampled September through December 2013 (Appendix C).

Remedial Investigation. DOE is conducting additional studies in 100-BC between 2013 and 2015 to reduce uncertainties relating to (1) the completion of waste site remediation; (2) short term changes in groundwater contaminants related to waste site remediation; (3) modeling results predicting that it will take a long time for the hexavalent chromium plume to attenuate; and (4) the level of risk associated with variable contaminant concentrations in Columbia River pore water. To address these uncertainties, a change was initiated in TPA Milestone M-015-74 and the RI/Feasibility Study (FS) Work Plan and Sampling Analysis Plan (SAP) were amended (TPA-CN-558, TPA-CN-559, TPA-CN-592, TPA-CN-593, and TPA-CN-602).

In 2013, workers installed a series of shallow aquifer tubes called hyporheic sampling points (HSP) to monitor Columbia River pore water. Their locations are shown on Figure BC.1. The HSPs will be monitored for hexavalent chromium monthly for 2 years to identify seasonal changes and characterize the level of risk to aquatic receptors. Tritium, strontium-90, and additional parameters will be analyzed semiannually.

The revised work plan called for installation of between 7 and 10 new groundwater monitoring wells to characterize the geology and vertical distribution of contaminants in areas of uncertainty. The wells were planned in pairs to increase vertical monitoring capability. Drilling began in fall 2013 and eight wells were completed before the end of February 2014 (Table BC.3). Two contingency wells were determined not to be needed, based on results of characterization sampling of groundwater during drilling.

The new wells and older wells will be monitored for two years to evaluate (a) the nature and extent of hexavalent chromium contamination (and co-contaminants), (b) groundwater model input parameters, and (c) which natural attenuation processes are occurring. Monitoring frequency is quarterly for the new wells and older wells with rapid changes in chromium concentration, and semiannually or annually for wells with less variability.

Results of the RI studies conducted in 2013 are discussed in the sections below.

Table BC.3 Monitoring Wells Installed in 2013-2014 for 100-BC Remedial Investigation

Well Name	Well ID	Location	Purpose
199-B4-16	C8776	East of 100-BC	Characterize full aquifer thickness. Monitor top of aquifer to define hexavalent chromium plume
199-B4-18	C8778	Central 100-BC	Characterize full aquifer thickness. Monitor lower portion of aquifer to define contaminant distribution; paired with shallow well 199-B4-7.
199-B5-9	C8779	Northeast of 100-C-7:1 waste site	Characterize full aquifer thickness. Monitor lower portion of aquifer downgradient of former hexavalent chromium sources (paired with 199-B5-10).
199-B5-10	C8780	Northeast of 100-C-7:1 waste site	Monitor top of aquifer downgradient of former hexavalent chromium sources (paired with 199-B5-9)
199-B5-11	C8781	Northeast of 100-C-7 waste site	Characterize full aquifer thickness. Monitor lower portion of aquifer downgradient of former hexavalent chromium sources (paired with 199-B5-12).
199-B5-12	C8782	Northeast of 100-C-7 waste site	Monitor top of aquifer downgradient of former hexavalent chromium sources (paired with 199-B5-11).
199-B5-13	C8783	Northwestern 100-BC	Characterize full aquifer thickness. Monitor lower portion of aquifer in western 100-BC; paired with shallow well 199-B5-1.
199-B5-14	C8784	West of 100-BC	Characterize full aquifer thickness. Monitor top of aquifer to define extent of hexavalent chromium.

100-BC Hexavalent Chromium

Sources of hexavalent chromium included cribs near the reactor buildings, trenches and retention basins near the Columbia River, and pipelines from the reactor buildings to the near-river facilities. Other chromium sources were the 100-C-7 and 100-C-7:1 sites in southern 100-BC and the 100-B-27 sodium dichromate spill site in the northwest.

Movement of chromium in 100-BC groundwater is influenced by differences in permeability in the Hanford formation and the underlying Ringold unit E. In most of 100-BC, the top of the aquifer includes 1 to 12 meters of the Hanford formation. The chromium plume moves rapidly through these highly permeable sediments. In northern 100-BC, the Hanford formation is unsaturated and the aquifer is entirely within Ringold unit E. Chromium concentrations in the upper aquifer in this location are more stable.

The hexavalent chromium plume with concentrations greater than 10 µg/L covers a large area at relatively low concentrations (Figure BC.5). The plume map illustrates distribution in the upper part of the aquifer, based on data collected September through December 2013 (most of the wells were sampled in October). The following changes are evident when comparing the 2013 and 2012 plume maps:

- Concentrations have declined immediately downgradient of 100-C-7:1 as contamination that was mobilized during site remediation migrates. Figure BC.6 shows variable concentrations in 199-B4-14, with declining peaks. New well 199-B5-9, slightly farther downgradient, had low concentrations in characterization samples.
- The 48-µg/L contour in southern 100-BC (with sources at 100-C-7:1 and 100-C-7) has migrated approximately 500 meters toward the northeast. As a result, concentrations in wells in central 100-BC have increased (Figure BC.7).
- The eastern boundary of the plume has moved toward the east in northern 100-BC. Concentrations have increased in wells 199-B3-46 and 199-B3-50 in this region (Figure BC.8).
- The 10 µg/L contour is shown as more extensive in southeastern 100-BC in 2013. This is based on a slight increase in concentrations in well 199-B9-3.

In recent years, chromium concentrations have declined in water-table wells in western 100-BC, such as 199-B5-1 and 199-B8-6. This change indicates clean groundwater moving into 100-BC from the west and south. The low concentrations in these wells persisted in 2013.

Chromium concentrations are relatively stable in wells screened in Ringold unit E, which is less permeable than the Hanford formation. Figure BC.9 illustrates chromium trends in wells 199-B5-5 and 199-B5-6, which are screened in the lower part of Ringold unit E, and 199-B3-47, which is screened at the top of the aquifer where the water table is in the Ringold Formation. Ringold unit E is not as permeable as the Hanford formation in 100-BC, so groundwater moves more slowly.

Vertical Distribution of Chromium. Beneath most of 100-BC chromium concentrations are highest near the top of the unconfined aquifer and decline with depth. In some locations, however, concentrations are elevated in the lower part of the aquifer. Characterization data collected during well drilling in 2009, 2010, and 2013 aided interpretation of vertical distribution. Several wells are screened in the lower part of the aquifer, providing ongoing monitoring opportunities.

Figure BC.10 shows chromium data from monitoring wells and characterization samples representing the lower part of the unconfined aquifer in fall 2013. Characterization data from 199-B2-16, 199-B5-5, and 199-B5-6 (in 2009 and 2010), and 199-B5-11 (2013) all showed bimodal distribution patterns, with concentrations highest near the top and bottom of the aquifer, and lower in between. The shallow contamination in the Hanford formation has migrated out of the region monitored by 199-B5-5, as evidenced by recent concentrations in shallow wells nearby. Concentrations in the Hanford formation are variable in 199-B4-14 (adjacent to 199-B5-6), but have declined overall between 2012 and 2013 (Figure BC.6).

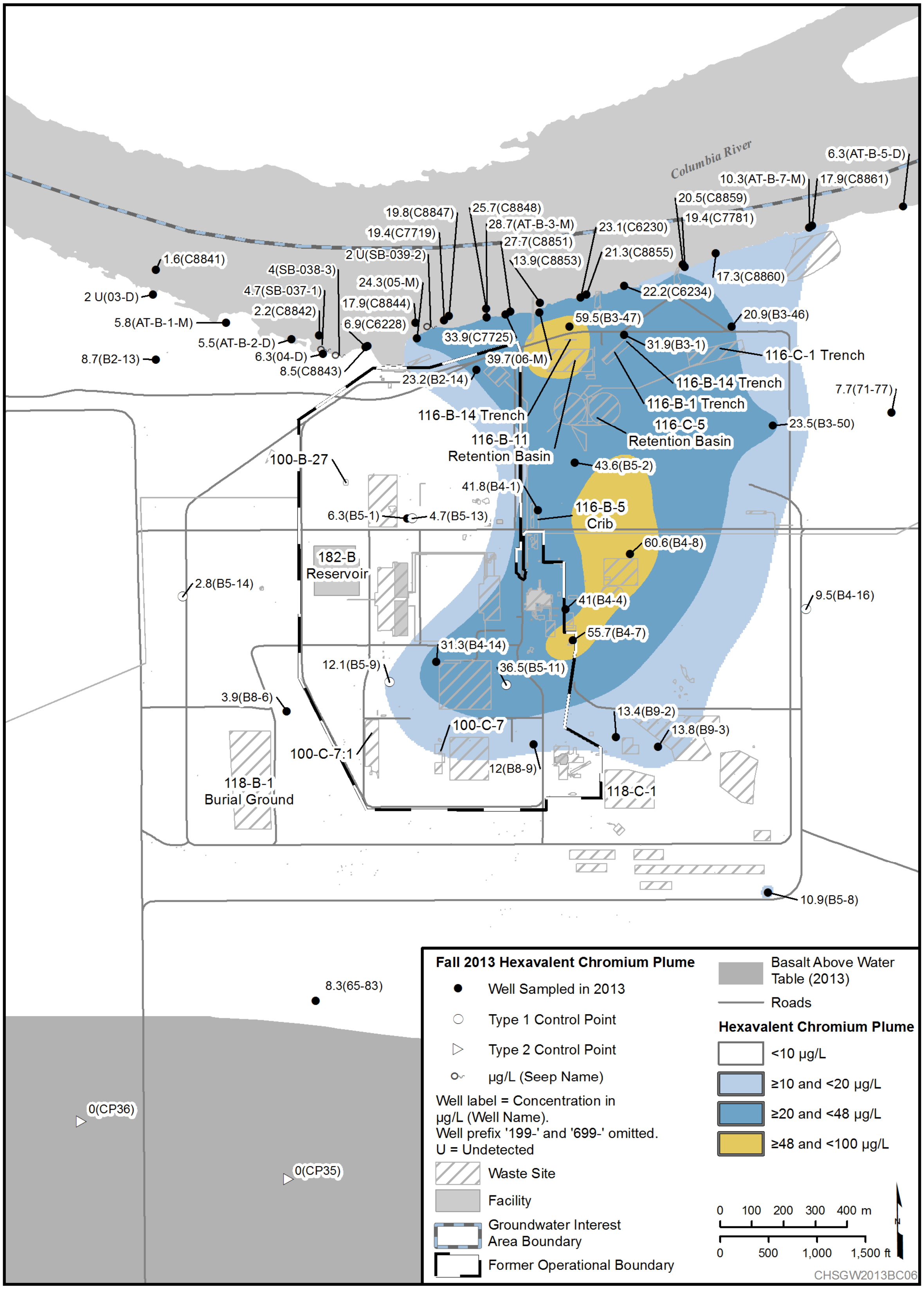

Figure BC.5 100-BC 2013 Hexavalent Chromium Plume

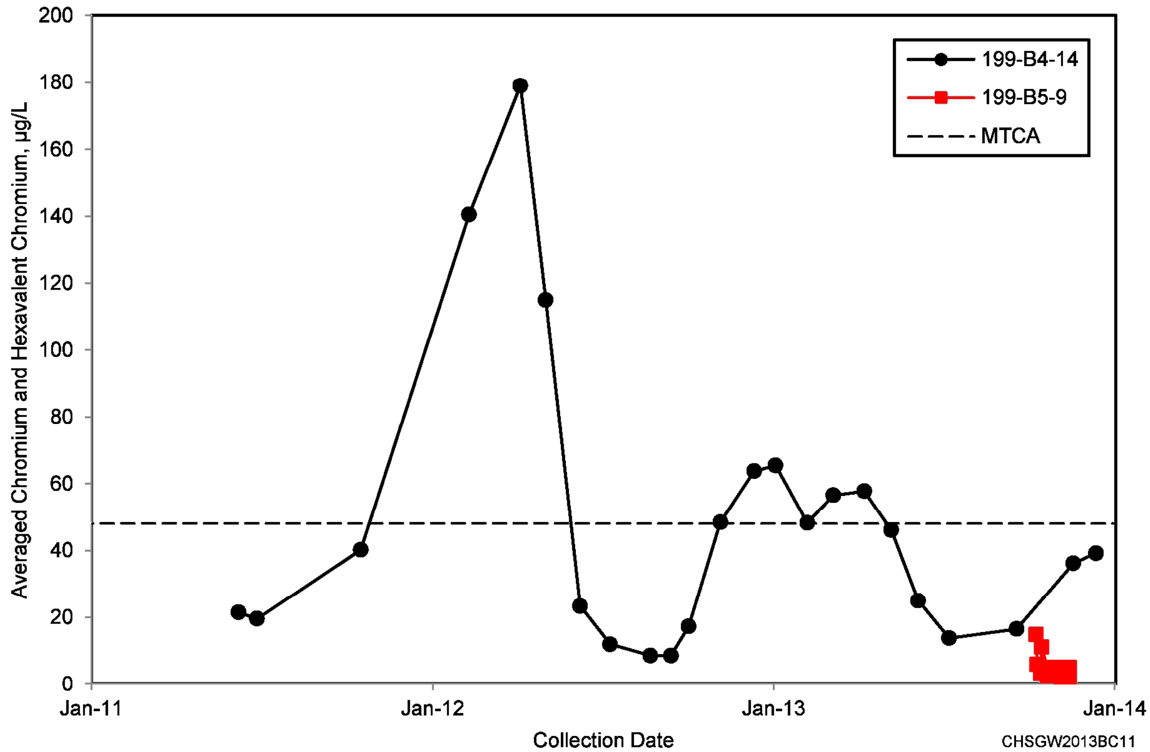

Figure BC.6 100-BC Hexavalent Chromium Data for Wells 199-B4-14 and 199-B5-9 in Southern 100-BC

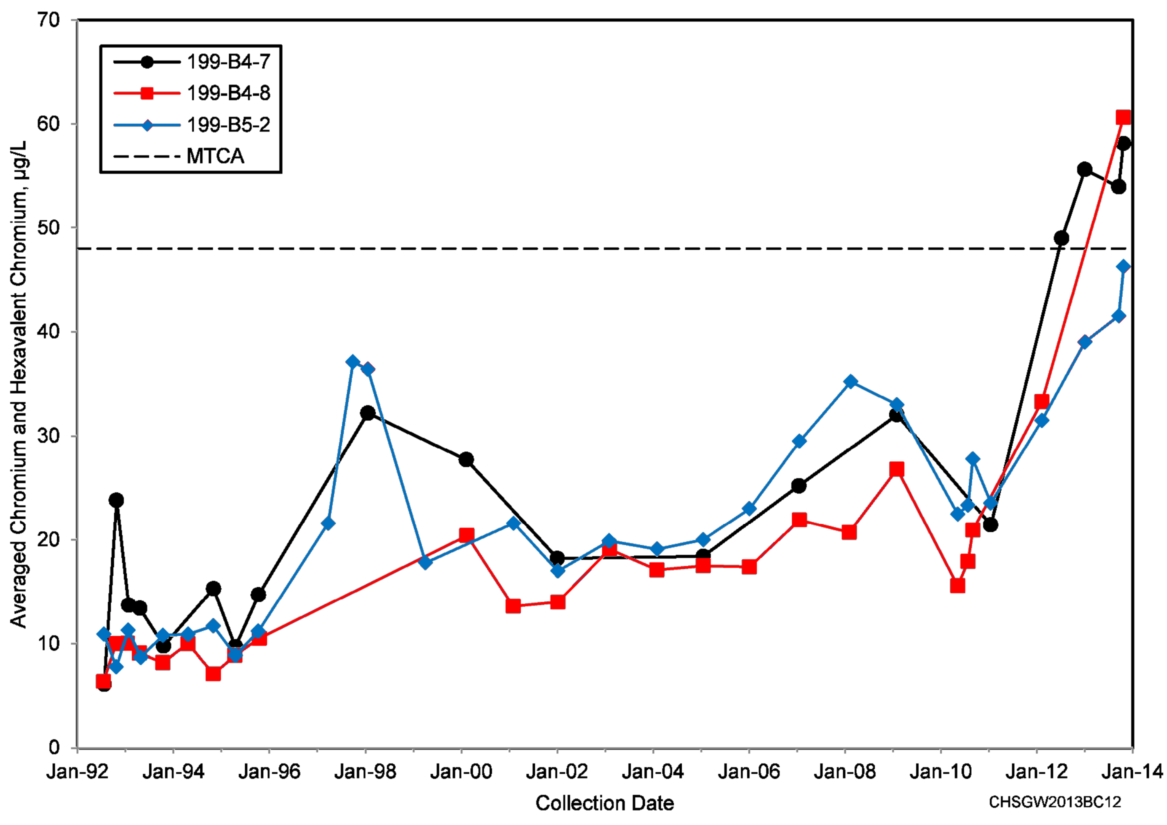

Figure BC.7 100-BC Hexavalent Chromium Data in Wells 199-B4-7, 199-B4-8, and 199-B5-2 in Central 100-BC

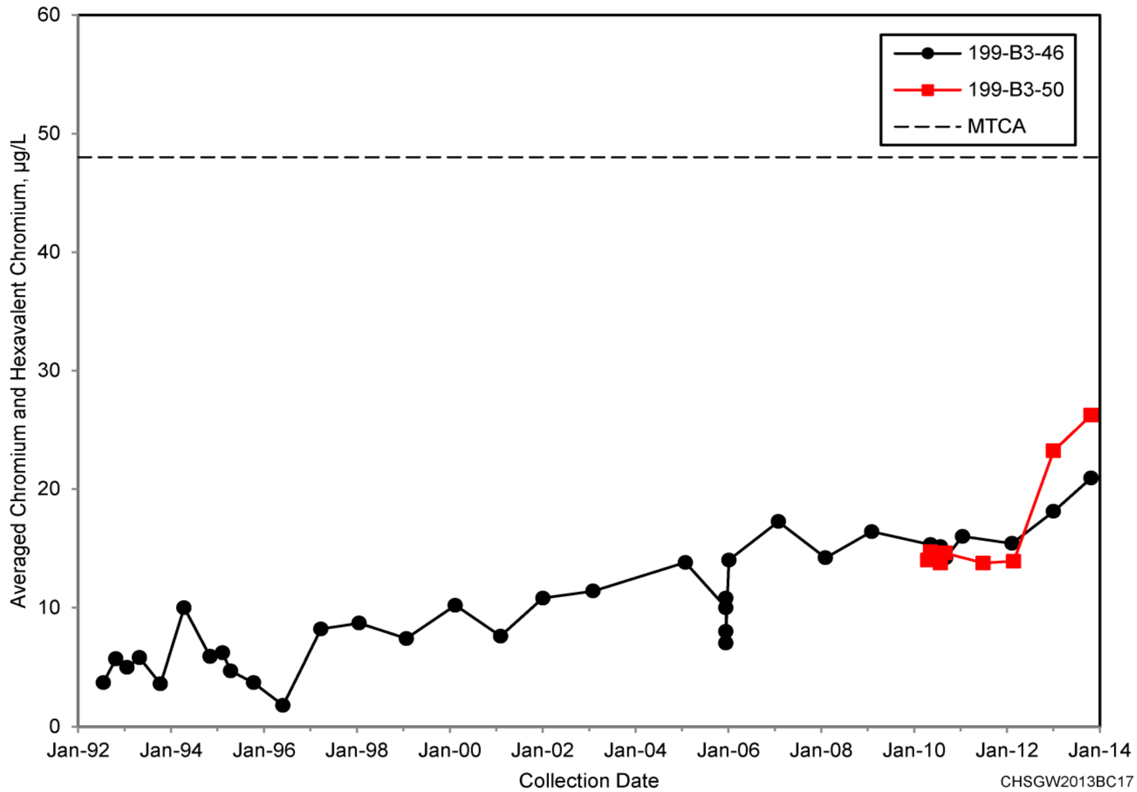

Figure BC.8 100-BC Hexavalent Chromium Data in Wells 199-B3-46 and 199-B3-50 in Northeastern 100-BC

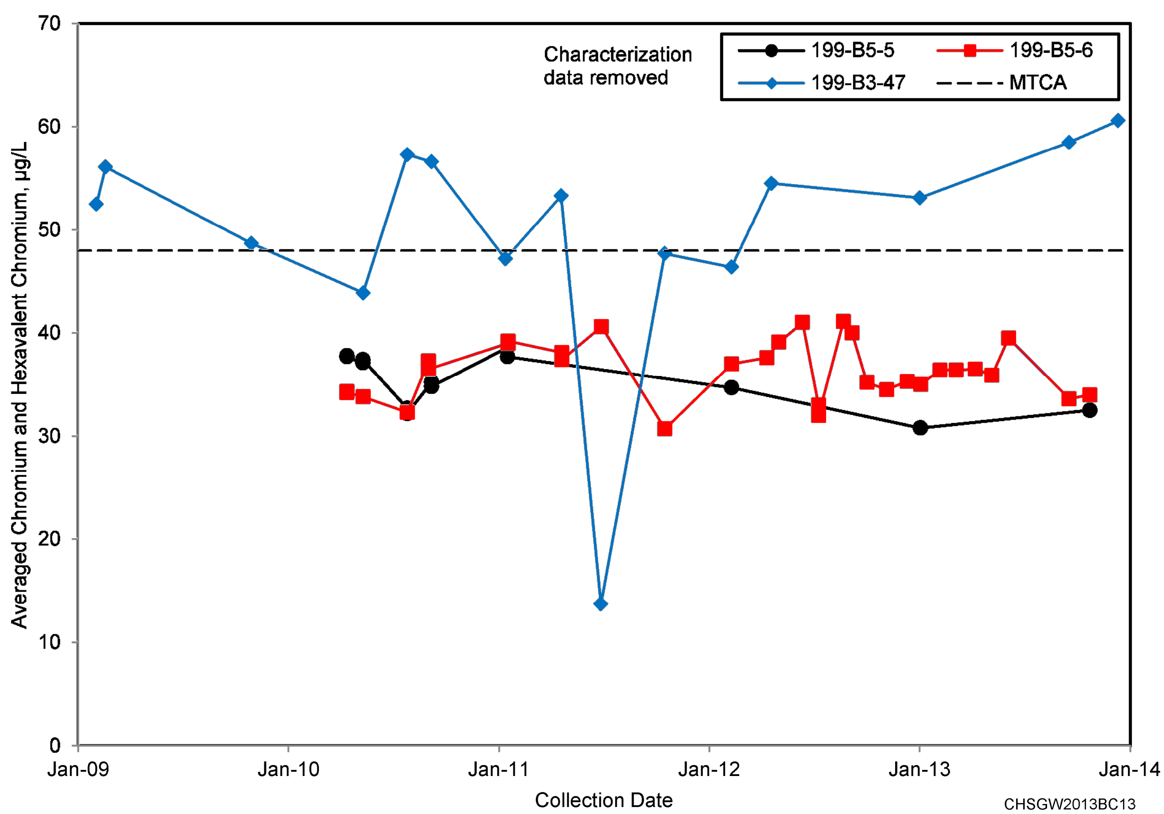

Figure BC.9 100-BC Hexavalent Chromium Data in Wells Screened in Ringold Unit E

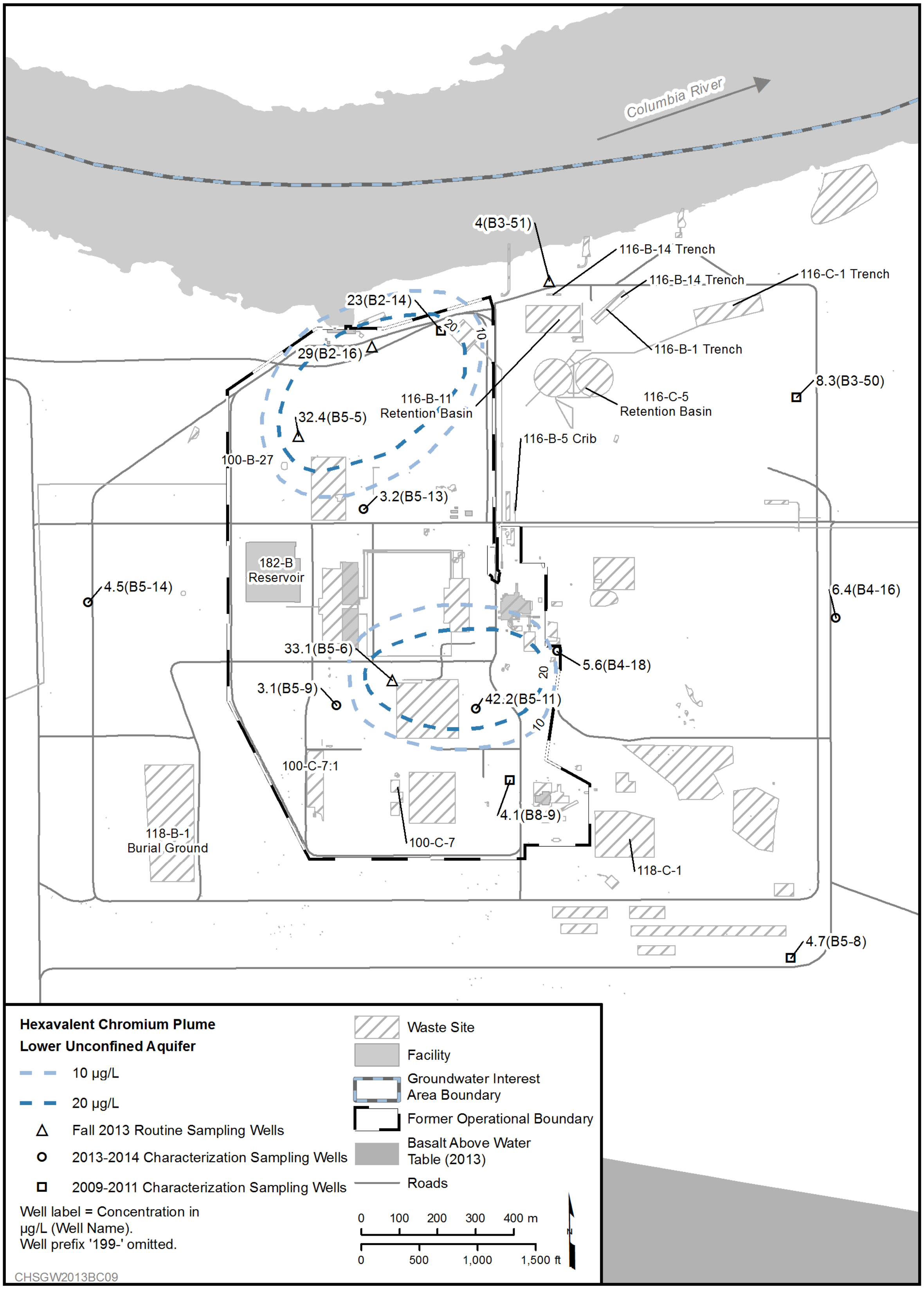

Figure BC.10 100-BC Hexavalent Chromium in the Lower Part of the Unconfined Aquifer

Figure BC.11 is a south-to-north cross section illustrating the geology and chromium distribution in the unconfined aquifer in the western part of 100-BC. Wells 199-B5-6, 199-B5-5, and 199-B2-16 consistently detect chromium at ~30 µg/L. However, nearby new wells 199-B5-9 and 199-B5-13 showed little chromium contamination at any depth. Ongoing monitoring will show if these patterns persist.

The cross section in Figure BC.12 is oriented along the axis of the chromium plume, i.e., along the approximate groundwater flow path from 100-C-7:1 to the Columbia River. In this region, the chromium plume is primarily within the upper half of the unconfined aquifer. The only exceptions are wells 199-B5-6 and 199-B5-11 in the south, where a zone of deeper contamination is observed. This contamination is believed to move much more slowly than that in the Hanford formation. New well 199-B4-18 will be monitored to detect potential movement of the deeper plume downgradient.

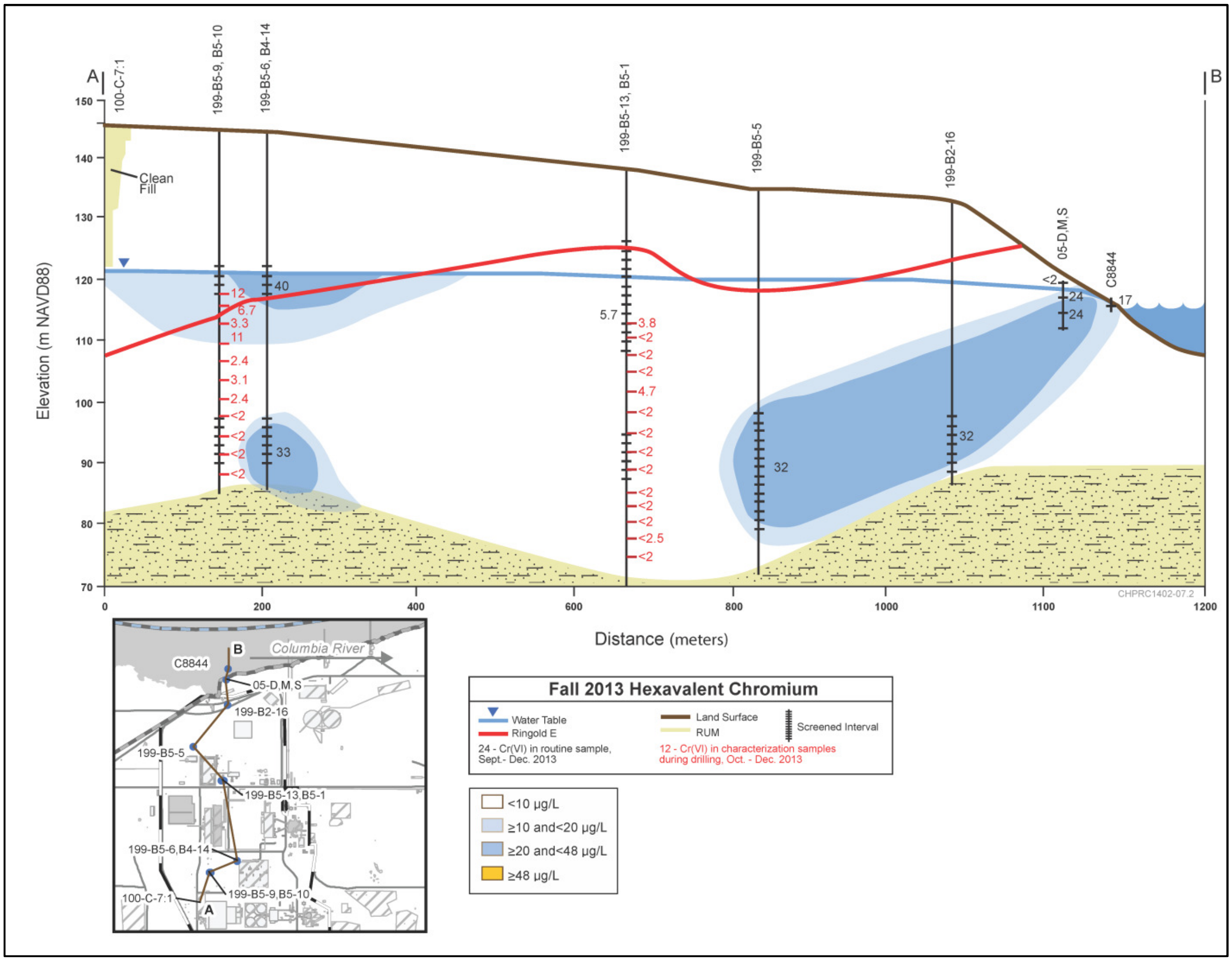

Figure BC.11 100-BC Cross Section Showing Hexavalent Chromium Distribution, South to North in Western 100-BC

Aquifer Tubes and Hyporheic Sampling Points (HSPs). Thirty-five aquifer sampling tubes in 100-BC are monitored annually (Appendix C). These aquifer tubes range from 2 to 8 meters in depth, and provide an indication of groundwater quality approaching its point of discharge to the Columbia River. Fourteen new aquifer tubes (HSPs) installed in 2013 are just 0.5 meter in depth, and are more indicative of concentrations in the accessible river environment. Four additional HSPs are 1 or 2 meters deep. Aquifer tube and HSP data are included in the plume maps of this report.

The first round of HSP monitoring (fall 2013) included high-frequency sampling of eight HSPs for four days each. The purpose of high-frequency sampling was to determine short-term variability of chromium concentration over the period applicable to the 10 µg/L aquatic standard, which is based on chronic exposure over 4 days (WAC 173-201A-240). Pumping rates were limited to reduce the potential for artificially drawing river water into the hyporheic zone. Between 28 and 48 samples were collected from each HSP.

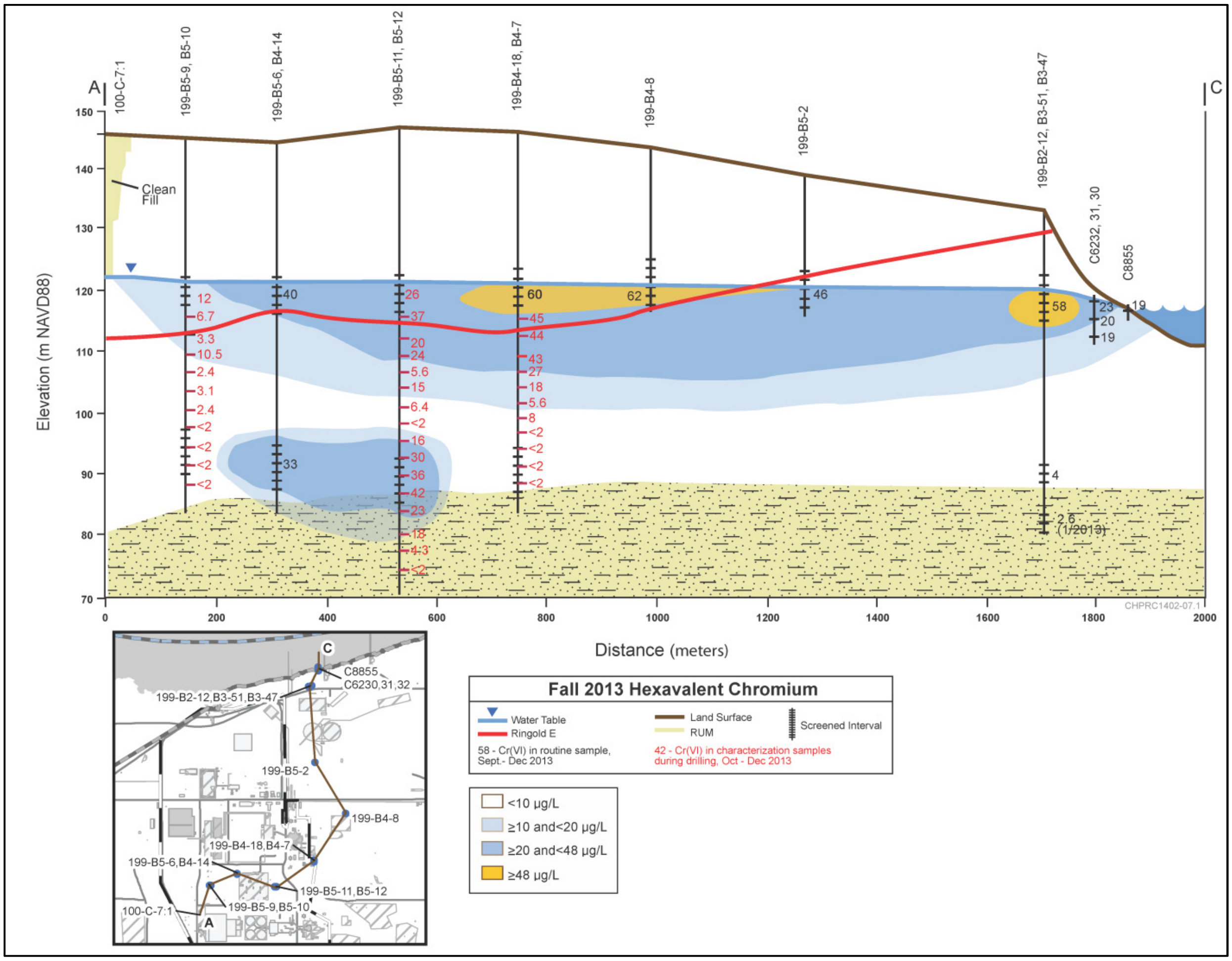

Figure BC.12 100-BC Cross Section Showing Hexavalent Chromium Distribution, Southwest to Northeast

Maximum and minimum river stage varied between 2.5 and 3.6 meters during sampling, but in general, specific conductance and chromium concentrations did not vary with river stage. Results were generally comparable to data from conventional aquifer tubes and near-river wells. Based on the results, the frequency of HSP sampling was reduced for the following months.

In addition to the high-frequency sampling of eight HSPs, grab samples are collected monthly from the full array of fourteen shallow HSPs and analyzed for hexavalent chromium. Semiannually (including December 2013), the entire network of eighteen HSPs are sampled for a more extensive list of analytes.

Figure BC.13 illustrates chromium concentrations from grab samples collected in December 2013. With two exceptions, concentrations from HSPs within the chromium plume ranged from 14 to 24 µg/L, exceeding the aquatic standard. The low chromium concentrations in samples from HSP C8852 and C8856 may not be representative because these HSPs showed evidence of inducing river flow into the hyporheic zone, despite care taken during sampling. Previous studies have shown that chromium concentrations in the water column of the river at 100-BC are below the aquatic standard (WCH-380 Rev. 1).

DOE will continue to sample the HSPs monthly in 2014 and 2015 to study the effects of seasonal river stage changes and plume migration.

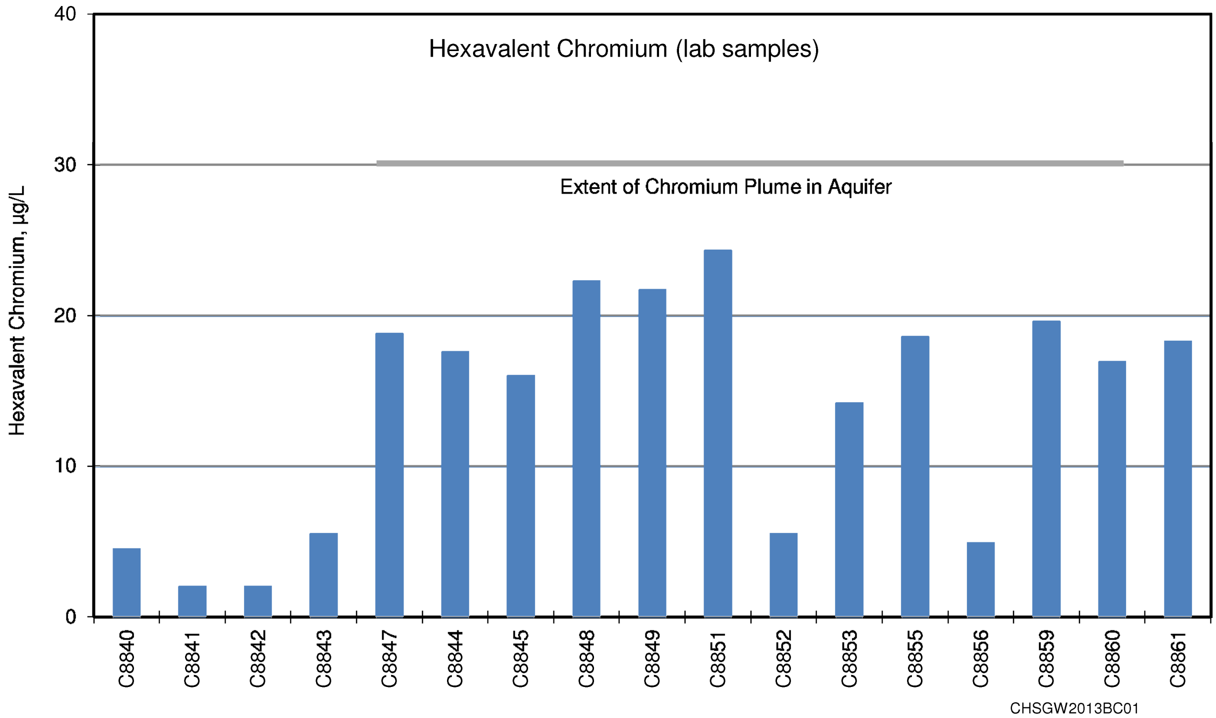

Figure BC.13 100-BC Hexavalent Chromium in Hyporheic Sampling Points, December 2013

100-BC Strontium-90

Liquid effluent containing strontium-90 was disposed to cribs near the reactor buildings and to cribs, trenches, and retention basins in northeastern 100-BC. Figure BC.14 shows an interpretation of the plume based on fall 2013 data. Concentrations ranged from below detection limits to 53 pCi/L, similar to previous years.

Figure BC.15 shows the strontium-90 trends in northern 100-BC near some of the former contaminant sources: 199-B3-47 near the 116-B-11 Retention Basin and 116-B-14 Trench; 199-B3-1 near the 116-B-1 Trench; and 199-B3-46 near the 116-C-1 Trench. These sites have been remediated; although a borehole near the 116-B-14 Trench detected low levels of strontium-90 in the vadose zone. This site is not considered significant as a source of strontium-90 to groundwater relative to other waste sites that received larger volumes of liquid waste (Section 4.2 of DOE/RL-2010-96). The concentrations in groundwater have declined since the 1990s.

Groundwater samples collected during drilling in 2009 and 2010 indicated that strontium-90 contamination in 100-BC groundwater is limited to the upper portion of the unconfined aquifer. Strontium-90 concentrations in well 199-B3-51, screened at the bottom of the aquifer, are below detection limits, while adjacent well 199-B3-47, screened at the water table, has concentrations above the drinking water standard.

Strontium-90 concentrations in several 100-BC aquifer tubes continued to exceed the drinking water standard in 2013. The highest concentrations are in the shallow or mid-depth tubes, reflecting the distribution in the aquifer. Strontium-90 was analyzed in five of the HSPs in December, with one detection: 3.9 pCi/L in HSP C8847.

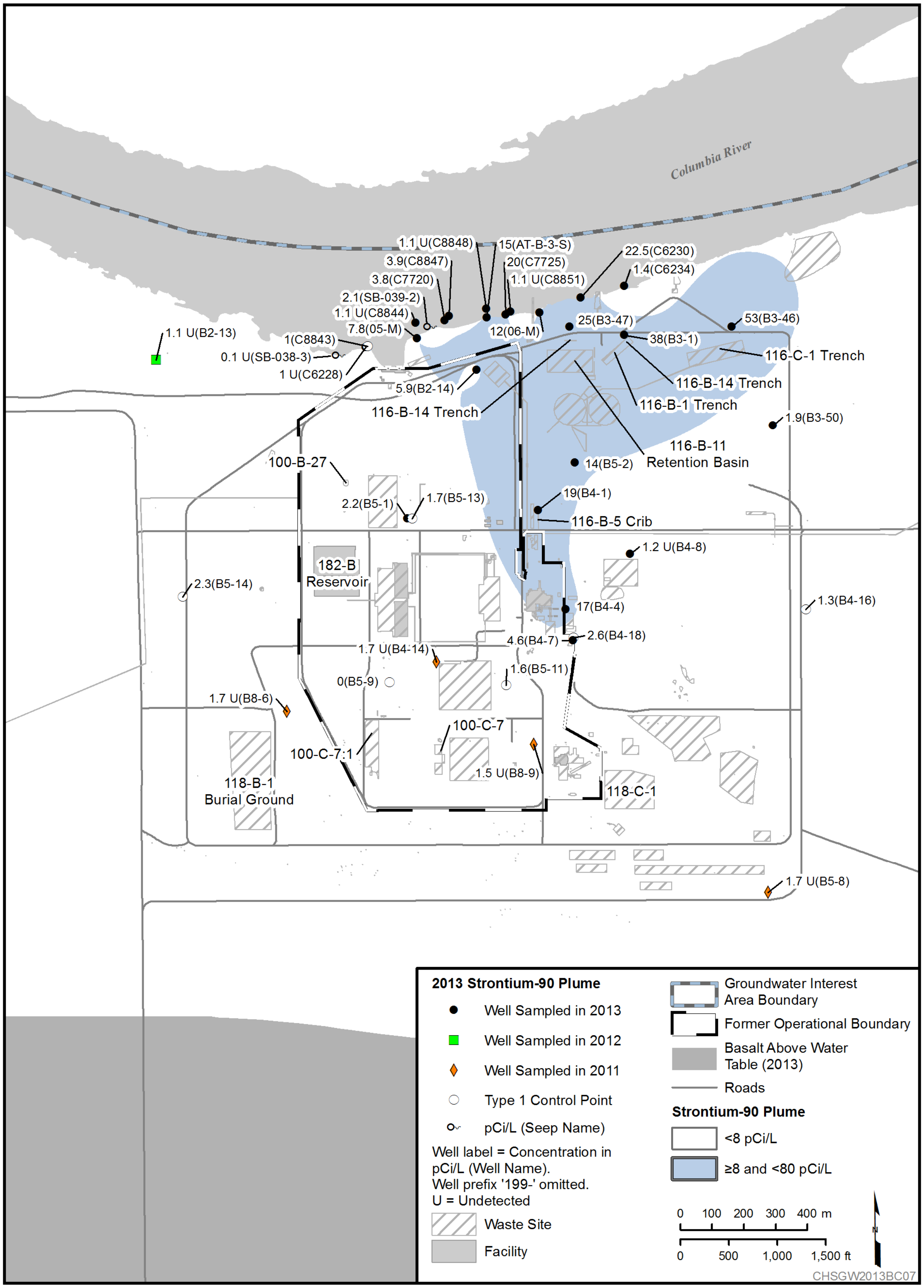

Figure BC.14 100-BC 2013 Strontium-90 Plume

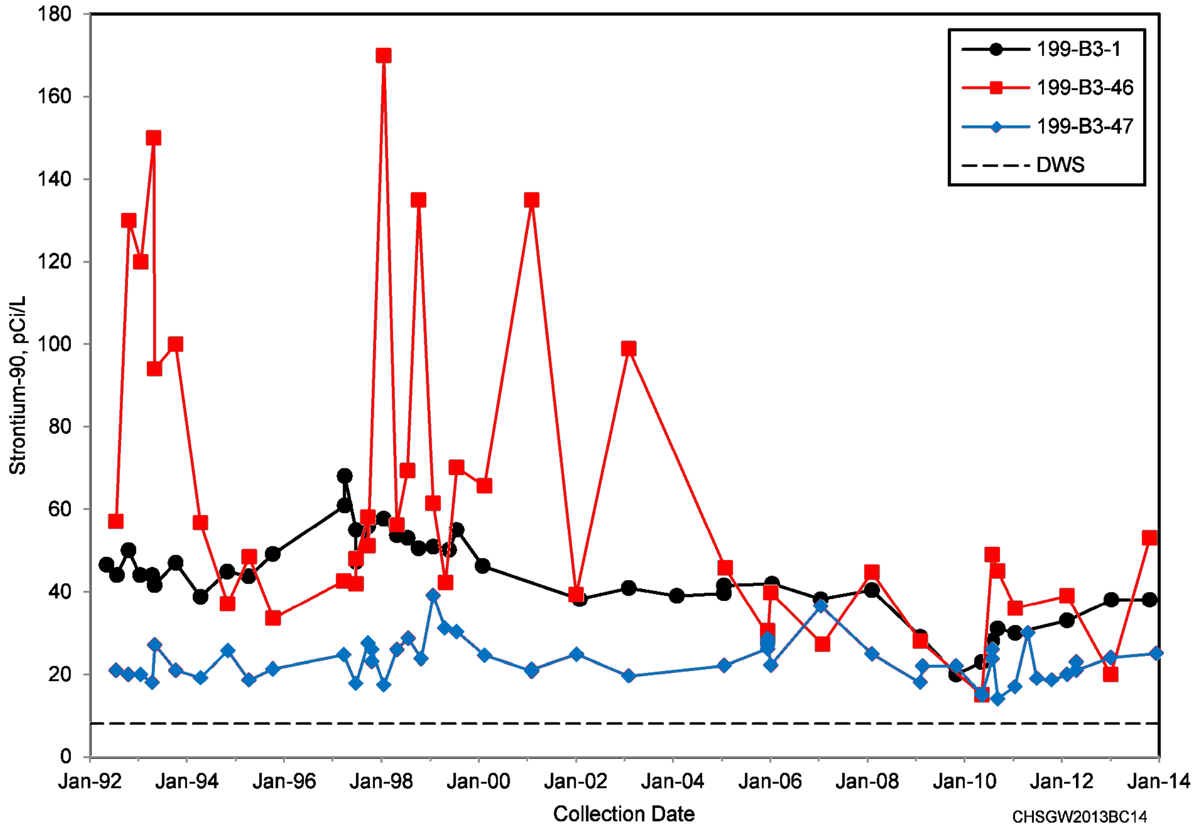

Figure BC.15 100-BC Strontium-90 Data in Wells 199-B3-1, 199-B3-46, and 199-B3-47

100-BC Tritium

Tritium was present in effluent discharged to former cribs near the B Reactor and near the Columbia River. The former 118-B-1 Burial Ground in southwestern 100-BC was another source of contamination. All of these waste sites have been remediated.

In 2013 no tritium concentrations exceeded the drinking water standard in 100-BC monitoring wells or aquifer tubes (Figure BC.16). In 2012, two portions of 100-BC had tritium concentrations slightly above the drinking water standard: one in northern 100-BC and one in southern 100-BC. The northern plume dissipated in 2013 as concentrations declined in well 199-B3-47 and aquifer tube 06-D (Figure BC.17). The southern plume has migrated into central 100-BC (Figure BC.18), where concentrations rose between 2007 and 2012 and declined in 2013, remaining below the drinking water standard.

Vertical characterization data from wells drilled in 2009, 2010, and 2013 indicated that tritium concentrations are generally highest near the top or middle of the aquifer, and lower at the bottom of the aquifer.

Tritium was analyzed in five of the HSPs in December 2013. Concentrations ranged from 1,400 to 6,300 pCi/L.

In the past, tritium contamination that originated in the 200 Areas migrated between Gable Butte and Gable Mountain to the region between 100-BC and 100-KR. The concentration peaked at 21,300 pCi/L in well 699-72-73 in 2000 and subsequently declined. In 2013 the maximum tritium concentration between 100-BC and 100-KR was 7,000 pCi/L in aquifer tube 12-D. With the decline of the water table in the 200 Areas, there is little potential for continued migration of contamination through Gable gap.

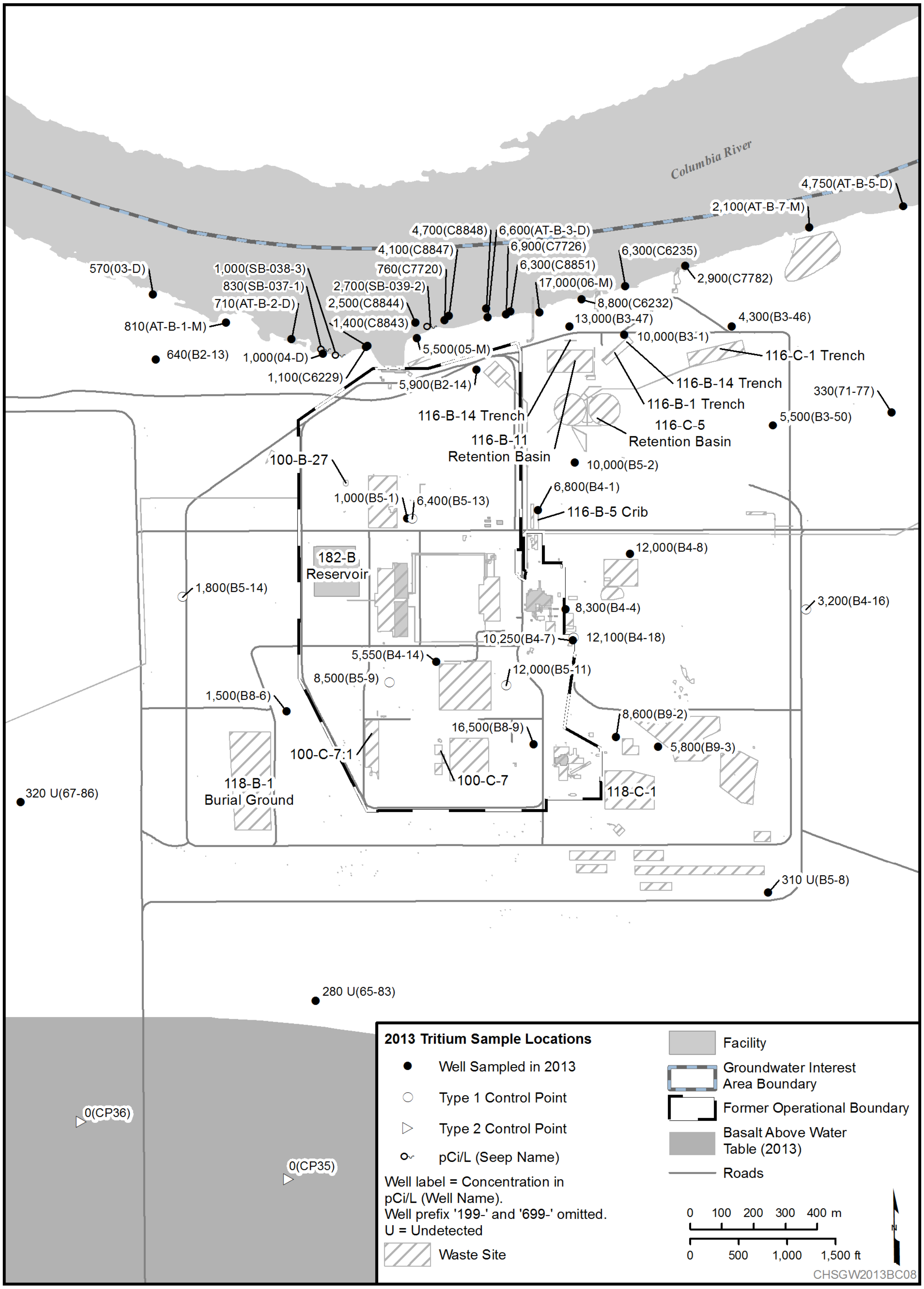

Figure BC.16 100-BC 2013 Tritium Plume

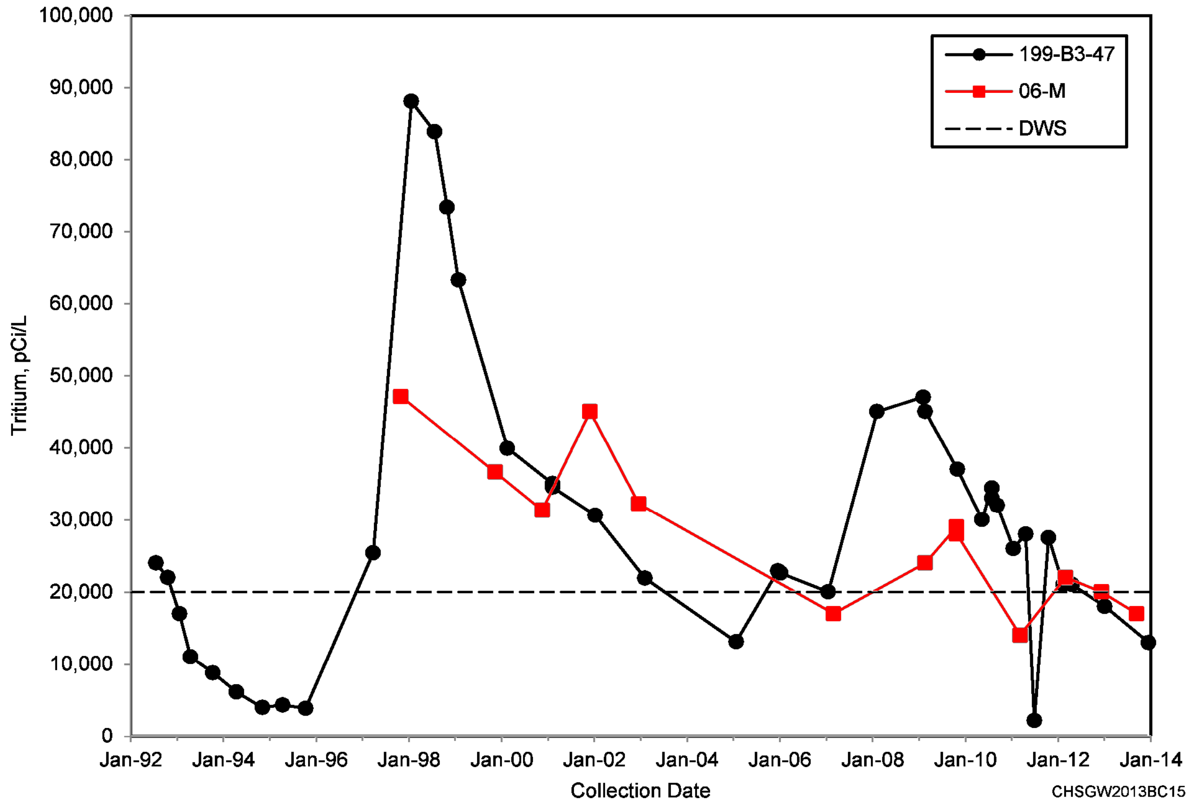

Figure BC.17 100-BC Tritium Data for Well 199-B3-47 and Aquifer Tube 06-M in Northern 100-BC

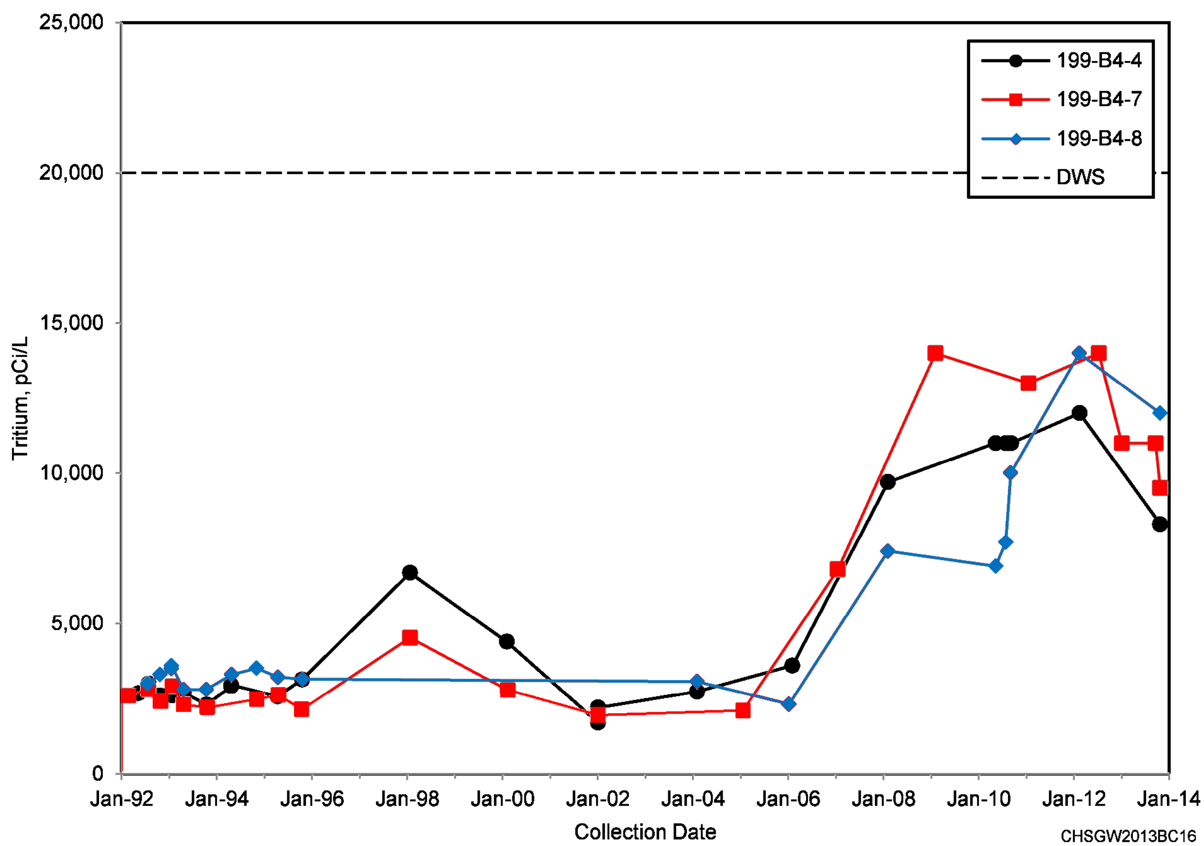

Figure BC.18 100-BC Tritium Data for Wells 199-B4-4, 199-B4-7, and 199-B4-8 in Central 100-BC

This page intentionally left blank.