DOE/RL-2010-40
Revision 0

Report on Investigation of Hexavalent Chromium Source in the Northern 100-D Area

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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Executive Summary

Groundwater beneath much of the Hanford Site's 100-D area is contaminated with hexavalent chromium, most likely through spills and/or leaks of high-concentration sodium dichromate used to control corrosion in the reactors' cooling systems. The chromium occurs in two distinct plumes: one in the southwest and the other in the north. The purpose of this report is to present and discuss results of an investigation to identify vadose zone sources in the northern plume and better define the high-concentration area in the groundwater. This work involved drilling and installing three groundwater monitoring wells and collecting vadose zone samples in nine locations. Two different compact drilling technologies (hydraulic hammer and compact sonic drilling) were tested to evaluate alternative methods of vadose zone sample collection.

During installation of the groundwater wells and boreholes, subsurface geology was described and vadose zone samples were collected. Most of these samples were analyzed for hexavalent and total chromium. Elevated chromium levels were found near the surface at three borehole locations located in the 100-D-30 waste site, with hexavalent chromium concentrations up to 34 mg/kg and total chromium concentrations up to 265 mg/kg. Groundwater samples were collected and analyzed during and after drilling. All three wells contained elevated levels of hexavalent chromium, with the highest concentration being 2,350 µg/L.

The following summarizes the findings of this investigation with respect to the overall objectives:

- Objective 1: *Identify potential vadose zone hexavalent chromium sources*:
  - Only two locations, approximately 5.5 m (18 ft) below ground surface in the 100-D-104 waste site, yielded significantly high levels of chromium. This waste site is approximately 250 m (820 ft) from the highest groundwater concentration in the northern plume, so it is unlikely that this area provides a source to the plume. Concentrations in this area decreased with depth.
  - Total and hexavalent chromium concentrations in other borehole samples were at least an order of magnitude less than the concentrations in samples from boreholes in 100-D-104. It is not likely that these scattered and discontinuous

hexavalent chromium sources are major contributors to the 100-D northern hexavalent chromium plume.

- Objective 2: *Provide a definition of the hexavalent chromium plume boundary and refine the location of the source*:
  - Groundwater samples from the three new wells resulted in a more complete understanding of chromium concentration in the proximal part of the northern plume.
  - Even though the three groundwater wells drilled as part of this project helped to refine the location of the highest concentration portion of the plume, these data do not help identify potential source areas. There are two known potential source areas downgradient from the highest-concentration well, so it is unlikely that these facilities are groundwater sources. Potential source areas upgradient of the hot spot are over 300 m (984 ft) away. If these upgradient sites were the source of the northern chromium plume, they are probably not actively contributing to groundwater contamination at this time, as groundwater between these sites and the highest concentration area of the plume contains only small amounts of chromium.
- Objective 3: *Evaluate the effectiveness of the hydraulic hammer direct and compact sonic drilling methods in emplacing borings and collecting sediment samples in the coarse Hanford formation sediments typical of 100-D*:
  - The hydraulic hammer rig was able to penetrate about 14.6 m (47.9 ft) below ground surface in one location, but there were numerous operational problems including sheared off drill rods and casing and stuck drill rods and drive shoes. These problems were likely due to the coarse nature of the Hanford formation sediments.
  - The compact sonic drill rig, utilizing a combination of rotation and vibration, was able to complete three boreholes, but was not successful in advancing past approximately 18 m (55 ft) below regional ground surface, which is the likely depth of the Ringold Unit E sediments in this area. The major problem with this method, other than difficulty advancing through dense and/or cemented

sediments, was that the samples were disturbed by the intense heat created during drilling. This heat could also be a safety consideration.

One working hypothesis to explain high persistent chromium concentrations in 100-D plumes is that one or more active sources of contamination are present in the vadose zone. Neither this study nor the previous southern chromium source investigation discovered significant levels of hexavalent chromium in the deep vadose zone.
An alternative explanation for groundwater contamination is that the zones of persistent high chromium concentrations represent contamination collected in portions of the aquifer that have relatively low flow rates. This explanation suggests that much of the hexavalent chromium present in the vadose zone has migrated downward, carried by deep percolation that recharges the aquifer. Under this scenario, chromium remaining in the higher portions of the vadose zone would tend to be low-concentration remnants or non-leachable (i.e., Cr(III)). Continued measurement and examination of seasonal head data and chromium concentration in the northern plume may help elucidate groundwater flow conditions and lead to a more refined conceptual model of the source area. An effort such as this would yield less accurate results than in the southern hot spot due to the paucity of groundwater wells and lower hexavalent chromium concentrations in the northern plume.

While this chromium source investigation did not identify a specific vadose zone source contributing to the northern plume hot spot, several potential source areas have been identified in the nearby area through development of the remedial investigation work plan and the design of remediation activities. These other potential sources will be investigated during one of two phases: (1) remedial investigation conducted under the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 1: 100-D/H Decision Unit*, which covers the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units (DOE/RL-2008-46-ADD1), or (2) the interim remedial 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-N-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington* (EPA/ROD/R10-96/134).

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Terms

bgs	below ground surface
brgs	below regional ground surface
CERCLA	*Comprehensive Environmental Response, Compensations, and Liability Act of 1980*
CHPRC	CH2M HILL Plateau Remediation Company
CPT	cone penetrometer technology
CSDR	Compact Sonic Drill Rig
HHR	Hydraulic Hammer Rig
OU	operable unit
ROD	Record of Decision
RUM	Ringold Formation Upper Mud
WCH	Washington Closure Hanford

1 Introduction

This report summarizes the results of a field investigation to identify the potential source(s) of contamination associated with the 100-D northern hexavalent chromium groundwater plume. The investigation approach is documented in *Field Investigation Plan for the Source of the Northern Chromium Plume in the 100-D Area* (DOE/RL-2008-09). This project was performed in two phases: (1) a groundwater investigation phase to better define the hexavalent chromium plume boundaries and refine the location of the source, and (2) a vadose zone phase focused on testing innovative technologies to improve subsurface access. An additional objective was to identify contaminant sources in the vadose zone that could contribute to groundwater contamination.

This report discusses the geologic and hydrogeologic data collected during well drilling and sampling and compares the aquifer properties obtained during well development to results collected during prior investigations. In addition, the positive and negative aspects of the innovative drilling method are discussed with respect to their use in the coarse Hanford formation sediments characteristic of 100-D.

1.1 Background and Objectives

The 100-D area is located along the southern shore of the Columbia River in the north-central portion of the Hanford Site and contains the former 105-D and 105-DR Reactor Buildings and their associated support facilities. During the reactors' operation, sodium dichromate was added to reactor coolant water to prevent system corrosion. An unknown amount of the chemical, which contained up to 25-wt. percent hexavalent chromium, was spilled and/or leaked from pipelines and migrated through the vadose zone, resulting in two hexavalent chromium groundwater plumes beneath 100-D. The two plumes, shown in Figure 1-1, are referred to as the southern plume and the northern plume.

Hexavalent chromium could have been released to the subsurface in a number of locations. Sodium dichromate was handled in 50 locations within the 100-D area (129547, *Sodium Dichromate Investigation for the 105-D/105-DR Reactor Area Report*). Eleven of these locations received sodium dichromate in pure (approximately 70-wt. percent) form, six handled it in 10-wt. percent concentration, and the rest received it in 2 mg/L concentration, which was the typical concentration in reactor cooling water. Within the area investigated in this study, the two more concentrated forms were handled in the 185-D and 190-D buildings (now the 100-D-30 waste site) and the 108-D building. Significant amounts of hexavalent chromium, up to 5,000 mg/kg, were associated with the 190-D complex at the time of its demolition (BHI-01185, *100-D Area Chromium Study Summary Report*). Adding to the uncertainties of where, when, and how much sodium dichromate may have been released to the vadose zone is the paucity of records of spills or intentional discharges. A rare example is recorded in "Irradiation Processing Department Monthly Report" for March 1964 (HW-81001), where the environmental release of a significant amount of chromium was described in two sentences:

> *A sodium dichromate transfer line failed at a weld at a location near the Main Pump House. Approximately 1,000 gallons of the chemical were lost to the soil before discovery of the leak.*

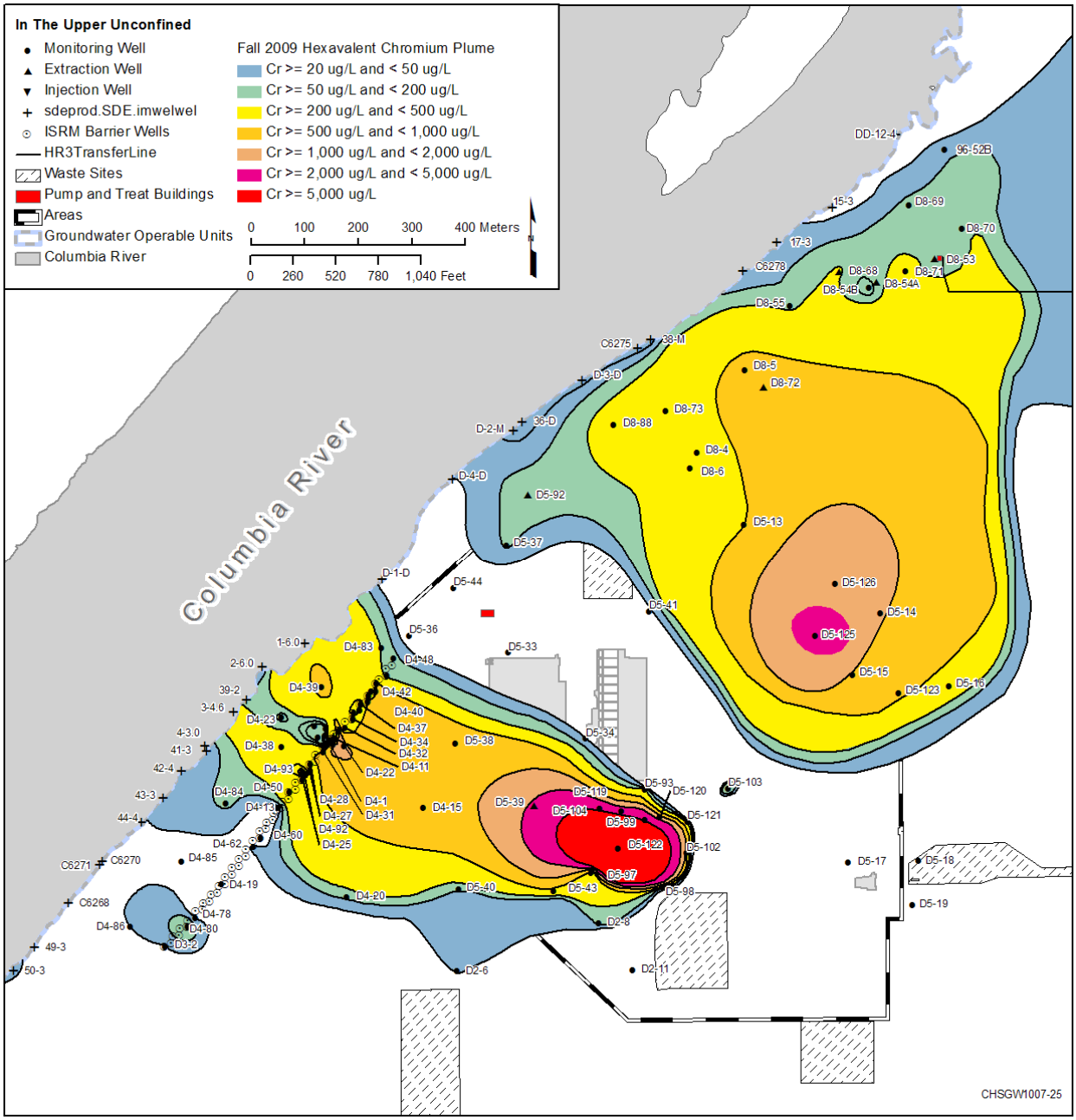


Figure 1-1. North and South Hexavalent Chromium Plumes at 100-D Area

An interim remedial action Record of Decision (ROD) for the 100-HR-3 groundwater Operable Unit (OU) was issued in April 1996 (EPA et al., 1996) pursuant to the Hanford Site's 1989 listing on the National Priorities List for the *Comprehensive Environmental Response, Compensations, and Liability Act of 1980* (CERCLA). The goal of the resulting interim remedial action is to prevent discharge of harmful concentrations of hexavalent chromium into the Columbia River. The 100-D area groundwater cleanup and investigation activities, including work described in this report, are primarily being conducted to meet requirements and objectives of the interim ROD. However, the information generated in support of this work will also support the remedial investigation and feasibility study process being conducted to develop a final ROD for cleanup of this groundwater OU.

Three Tri-Party Agreement target milestones guide the implementation of groundwater cleanup in 100-D. The first (M-016-110-T01) includes taking the actions necessary to remediate hexavalent chromium plumes such that ambient water quality standards for hexavalent chromium are achieved in the hyporheic zone and river water column by December 31, 2012. The second target milestone (M-016-110-T04) specifies that by December 31, 2016, no other contaminants enter the Columbia River above drinking water standards or ambient water quality standards unless otherwise specified in a CERCLA decision document. The third (M-016-110-T02) states that actions necessary to remediate hexavalent chromium groundwater plumes shall be taken to meet drinking water standards in the 100 Area OUs by December 31, 2020. The ability to achieve this 2020 milestone is dependent on the presence of a vadose zone source. If there are sources of hexavalent chromium that continue to contaminate the aquifer, groundwater treatment may have to continue beyond 2020.

Two projects funded by the U.S. Department of Energy's EM-22 program have helped to delineate the source area of each plume. The southern plume investigation completed in fiscal year 2009 (DOE/RL-2009-92) included installing 11 new wells and monitoring groundwater for two years. This report summarizes work performed on the northern plume, which has a central area of contamination that is less well defined because of the limited number of groundwater monitoring wells within the region. The plans for performing the northern plume source investigation activities are described in DOE/RL-2008-09 (Rev. 0 and Rev. 1).

1.2 Project Description

The purpose of this investigation was to (1) collect information supporting evaluation of potential sources of chromium contamination contributing to the northern chromium groundwater plume in 100-D, and (2) evaluate the application and limitations of using compact drilling methods in the 100 Area of the Hanford Site. The initial field investigation plan (DOE/RL-2008-09, Rev. 0) separates the investigation into two phases: a vadose zone phase and a groundwater phase. The vadose zone phase involved collecting vadose zone sediments to determine the presence and distribution of chromium and identify potential sources of groundwater contamination. As part of the investigation, two innovative drilling and sampling technologies were demonstrated. The demonstration assessed the capabilities of a hydraulic hammer rig (HHR) and a compact sonic drill rig (CSDR) to penetrate deep into the vadose zone and collect sediment samples in the difficult drilling conditions of 100-D. The groundwater phase consisted of drilling and constructing three wells in the vicinity of the proximal (source) end of the existing northern groundwater plume. This document summarizes the activities and results of each investigation phase. Figure 1-2 shows the location of the project boreholes and wells within 100-D. Boreholes and wells are presented in Table 1-1 along with the associated drilling dates.

Three groundwater wells were drilled and completed between August 29 and October 28, 2008 under the direction of Fluor Hanford and CH2M HILL Plateau Remediation Company (CHPRC). The *Description of Work for the Installation of Three Groundwater Wells at the for the 100-D North Plume Chromium Investigation, FY 2008 (*SGW-37994) was the controlling document for drilling and construction of the three wells. Drilling and sampling activities are documented in *Borehole Summary Report for the Installation of Three Groundwater Wells for the 100-D North Plume Chromium Source Investigation, CY 2008* (SGW-39730). The borehole summary report includes the field notes and forms produced during drilling and soil sampling. The summary report also includes subsurface geologic descriptions, photographs of lithologic samples and drill cuttings, an explanation of how drilling-derived waste was managed, and civil survey results.

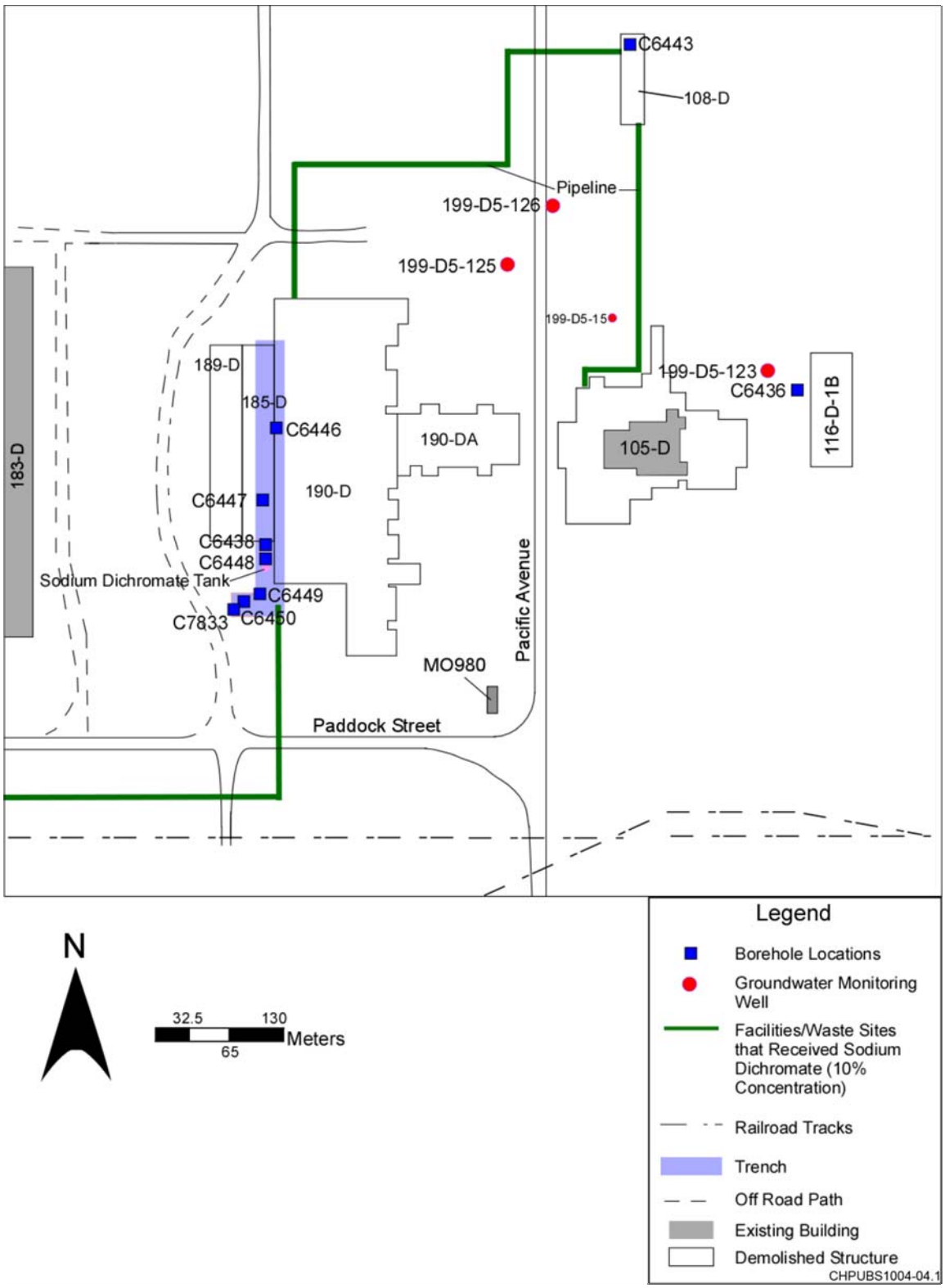


Figure 1-2. 100-D Borehole and Well Locations

Table 1-1. Project Borehole Identification and Drilling Dates Summary

Borehole ID	Well Name/ Project Borehole ID*	Drilling Date	
		Start	Finish
C6387	199-D5-123	9/19/08	10/14/08
C6389	199-D5-125	8/29/08	9/16/08
C6390	199-D5-126	10/14/08	10/28/08
C6436	CSDR-1	6/19/09	7/6/09
C6443	CSDR-8	6/5/09	6/9/09
C6446	CSDR-11	6/15/09	6/18/09
C6447	CSDR-12	6/3/09	6/11/09
C6448	HHR-13	2/19/09	2/23/09
C6438	CSDR-13	6/10/09	6/11/09
C6449	HHR-14	2/17/09	2/19/09
C6450	HHR-15	1/26/09	2/17/09
C7833	--	2/17/09	2/17/09

* Project Borehole ID corresponds to temporary identification of borehole listed in DOE/RL-2008-09, *Field Investigation Plan for the Source of the Northern Chromium Plume in the 100-D Area*, Rev. 1.

CSDR = compact sonic drill rig

HHR = hydraulic hammer rig

2 Northern Chromium Plume Investigation Results

The purpose of this investigation was to collect information supporting evaluation of potential sources of chromium contamination contributing to the northern chromium groundwater plume in 100-D. Figure 2-1 depicts the May 2009 100-D northern hexavalent chromium plume. The locations of the vadose investigation boreholes and groundwater monitoring wells installed for this investigation are also shown in Figure 1-2. Results of each phase of the investigation are presented in the sections that follow the summary of geologic and hydrogeologic conditions below.

2.1 Geology and Hydrogeology of the 100-D Area

This section describes the geology and hydrogeology relevant to the 100-D northern chromium plume. The major stratigraphic units underlying 100-D include the Hanford formation, the Ringold Formation, and the Columbia River Basalt Group (WHC-SD-EN-TI-011 and WHC-SD-EN-TI-132*n*). It is estimated that excavation disturbance or demolition backfill in 100-D may extend deeper than 4.6 m (15 ft) below ground surface (bgs) in some locations.

The Hanford formation is the uppermost stratigraphic unit in the project area. It is an informal designation for Pleistocene cataclysmic flood and inter-flood deposits comprised of clast-supported, unconsolidated sandy gravels to gravelly sands, with occasional intercalated silt and sand stringers. In the project area it consists predominantly of unconsolidated sandy gravel, gravelly sand, or sand generally composed of over 40 percent basalt. Individual beds are typically shallow-dipping, but moderately dipping foreset beds have been observed in excavation side-slopes. The Hanford formation maximum thickness is approximately 23 m (75 ft) in central 100-D, thinning toward the Columbia River to the north and east toward 100-H.

Hanford formation sediments disconformably overlie the fluvially-derived, late Miocene to Pliocene Ringold Formation. In most of 100-D, the uppermost Ringold Formation is predominantly coarse-grained sand and gravel designated the Ringold Unit E. Ringold Unit E sediments are generally differentiated from the Hanford formation on the basis of lower basalt content in the sand fraction, increased iron oxide staining, and increased cementation. Locally, the contact between the Hanford formation and Ringold Unit E may be gradational with gradually increasing cementation and quartz content and decreasing basalt. The Ringold Formation Upper Mud (RUM) unit, a fine-grained facies of the Ringold Formation underlies the Ringold Unit E. The lower part of the Ringold Unit E is locally silty and, therefore, the contact between the Ringold Unit E and RUM may be gradational.

The RUM is a paleosol/overbank deposit, which is composed of pale brown to brown silt and clay with minor lenses of sand. The RUM forms the confining layer for the aquifer, which is entirely contained within the overlying Ringold Unit E, except in the northern part of 100-D, where the Hanford formation directly overlies the RUM. The unconfined aquifer in this part of 100-D is within the Hanford formation. Geologic cross sections have been prepared both parallel to (A-A’) and perpendicular to (B-B’) the Columbia River. Section locations are displayed on Figure 2-1, and the sections are displayed on Figures 2-2 and 2-3.

No wells drilled in 100-D have penetrated through the total thickness of the Ringold Formation and reached the Columbia River Basalt Group. However, based on 100-H and 100-N wells drilled to basalt, the Ringold Formation total thickness is estimated at 90 to 107 m (300 to 350 ft) in 100-D (WHC-SD-EN-TI-132).

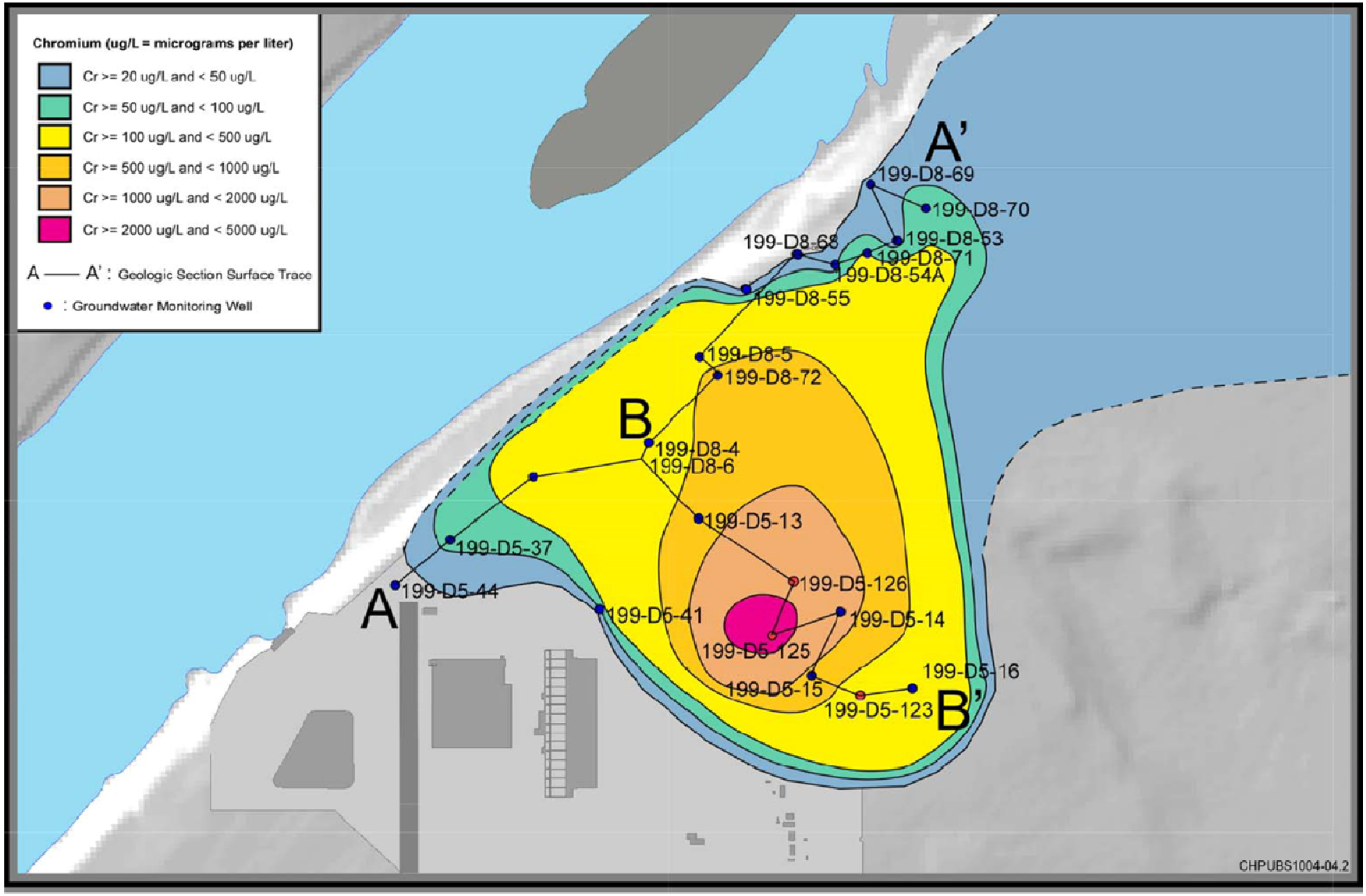


Figure 2-1. May 2009 100-D Area Northern Hexavalent Chromium Plume

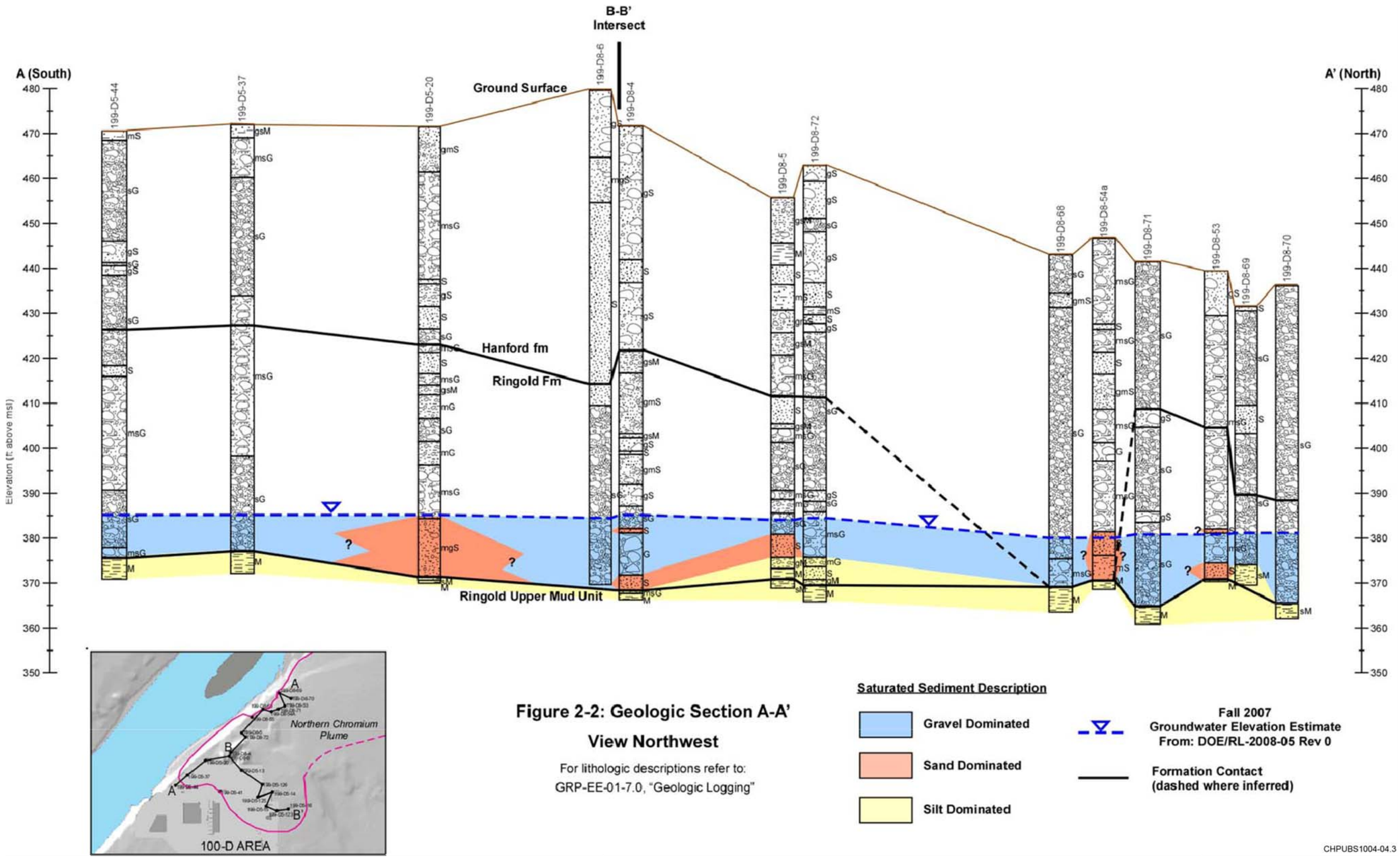


Figure 2-2: Geologic Section A-A'

View Northwest

For lithologic descriptions refer to:
GRP-EE-01-7.0, "Geologic Logging"

Figure 2-2. 100-D Area—Geologic Section A-A'

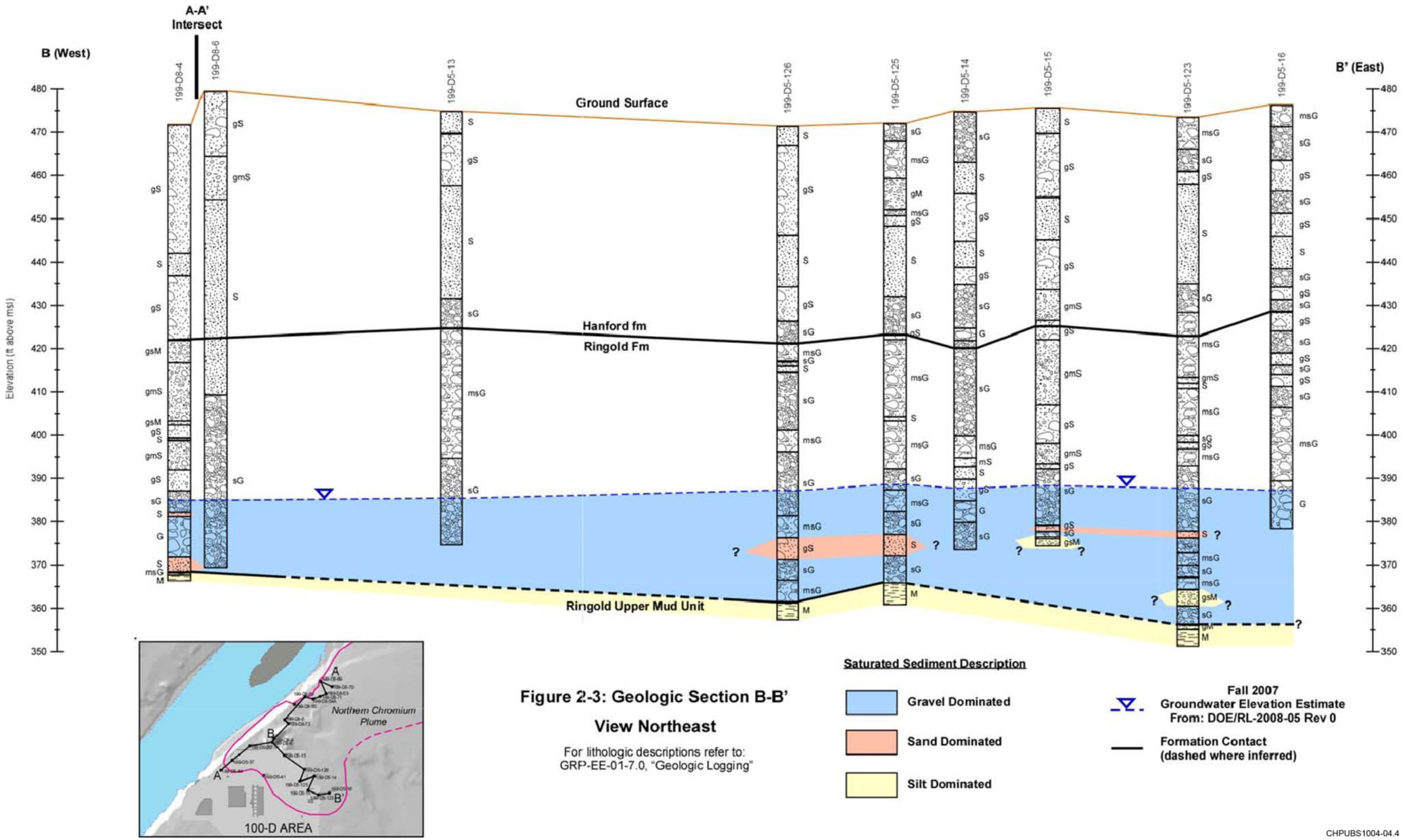


Figure 2-3.100-D Area—Geologic Section B-B'

2.1.1 Geology in the Vicinity of the Northern Chromium Plume

The three groundwater wells constructed as part of the northern plume investigation were drilled through the entire extent of the unconfined aquifer, terminating within the RUM. The Hanford formation and Ringold Formation sediments observed during well drilling and sampling operations were sand and gravel dominated, with variable lithology and cementation. The upper surface of the RUM varied as much as 4 m (13 ft) in elevation from east to west as shown in Section B-B'. The nature of the Ringold Unit E and RUM contact varied from sharp to gradational as describe above. The contact between the Ringold Unit E and the RUM was sharp in Wells 199-D5-125 and 199-D5-126. The silt content of the Ringold Unit E sediments encountered near the bottom of Well 199-D5-123 increased significantly until grading to the silt dominated sediment typical of the RUM in 100-D. Well-specific descriptions can be found in the project borehole summary report (SGW-39730).

2.1.2 Hydrogeology in the Vicinity of the Northern Chromium Plume

The vadose zone at the project location is composed of excavation and demolition backfill material near the surface and the sands, gravels, and boulders of the Hanford formation and Ringold Unit E below. The unconfined aquifer beneath the project area is found mostly within the Ringold Unit E and locally within the lower Hanford formation where the Ringold Unit E has been eroded away. The bottom of the unconfined aquifer is defined as the first occurrence of a fine-grained facies of the Ringold Formation, the RUM.

The groundwater flow direction beneath the 100-D north plume area moves generally from the river inland in the spring during high river stage and then back toward the river in the fall and winter during low river stages. Near the southwestern edge of the north plume, the natural flow system has been affected by historic leakage from the 182-D Reservoir creating mounding, injection of treated groundwater into Well 199-D5-42, and a potential pipe leak south of the 183-D Building. In addition, there are two pump-and-treat systems that are withdrawing groundwater from 10 wells in the northern chromium plume. The most recent spring (high river stage) and fall (low river stage) water table maps may be found in the 2008 annual summary report. This report, *Calendar Year 2008 Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operation* (DOE/RL-2009-15), describes 100-HR-3 OU pump-and-treat operations. The unconfined aquifer in 100-D ranges from 4.5 to 9.1 m (15 to approximately 30 ft) in thickness.

2.1.3 Aquifer Properties

Drawdown data collected during development of each of the three new wells completed in the Ringold Unit E were used to estimate the well transmissivity and local unconfined aquifer hydraulic conductivity using the following expressions (Cooper and Jacob, 1946):

$$T = \frac{264Q}{\Delta s}$$

and

$$k = \frac{T}{7.48b}$$

where:

T = transmissivity (gpd/ft)

Q = the pumping rate (gpm)

Δs = the slope of the straight-line portion of a plot of drawdown (ft) *versus* $\log_{10} t$ (t = time in minutes)

k = hydraulic conductivity (ft/d)

b = the screened interval (ft)

The screened interval, b, is also the aquifer thickness, because each of the three new wells fully penetrates the Ringold Unit E aquifer with the well screen extending from the aquifer base to above water table.

These equations were also used to estimate aquifer hydraulic conductivities for wells completed in the Ringold Unit E during the recent investigation of the southern 100-D hexavalent chromium plume (DOE/RL-2009-92) so results may be directly compared. The three new wells drilled for the present investigation yielded hydraulic conductivities ranging from 13.4 to 79.8 m/d (44 to 262 ft/d), with a mean value of 43.6 m/d (143 ft/d). For the southern plume, calculated hydraulic conductivity ranged from 8.4 to 72.2 m/d (28 to 237 ft/d), with a mean value of 51.5 m/d (169 ft/d).

Thus, evidence gathered to date reveals no significant difference in aquifer hydraulic properties for the two plumes.

Table 2-1 is a summary of test parameters and calculated results (including specific capacity) for the new wells in the northern plume and for four wells drilled in 1991 and 1992. These older wells are of interest because of their locations along the main plume axis. In addition, slug test data are available for three of the older wells. Note that the four older wells only penetrate the top half of the aquifer and so are partially penetrating (Figure 2-3). Therefore, the estimated hydraulic conductivities of the older, partially penetrating wells may not be directly comparable to results for the new, fully penetrating wells due to heterogeneity of the aquifer, or from vertical flow gradients in the vicinity of the partially penetrating wells during pumping tests (Freeze and Cherry, 1979; Domenico and Schwartz, 1990).

The hydraulic gradients in 100-D and vicinity are very shallow, as shown by March 2008 head data (DOE/RL-2008-66). Currently available head data in the vicinity of the northern plume are insufficient to estimate seasonal groundwater flow rates or directions. However, continuous local head data will become available as wells within the northern plume vicinity are added to the Hanford Site automated water level measurements system.

Table 2-1. Estimated Aquifer Hydraulic Properties

Well	Screened Interval (ft)	Pumping Rate (gpm)	Pump Duration (min)	Hydraulic Conductivity ([ft/d] from Drawdown Test)[a]	Hydraulic Conductivity ([ft/d] from Slug Test)[b]	Specific Capacity (gpm/ft)
New Wells						
199-D5-123	36.15	12.5/11.5[c]	84/60[c]	111/132[c]	--	10.96/11.5[c]
199-D5-125	26.75	5.0	75	44	--	3.70
199-D5-126	27.43	14.28	69	262	--	9.65

Table 2-1. Estimated Aquifer Hydraulic Properties

Well	Screened Interval (ft)	Pumping Rate (gpm)	Pump Duration (min)	Hydraulic Conductivity ([ft/d] from Drawdown Test)[a]	Hydraulic Conductivity ([ft/d] from Slug Test)[b]	Specific Capacity (gpm/ft)
Previously-Existing Wells						
199-D5-13	14.39	12.5	42	102	--	3.99
199-D5-14	14.69	12.5	--	--	41	--
199-D5-15	15.11	12.5	14	177	--	3.12
199-D5-16	12.77	1.8	--	--	11	0.42

a. Cooper and Jacob, 1946, "A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-Field History."

b. Bouwer, 1989, "The Bouwer and Rice Slug Test—An Update."

c. First and second of two drawdown tests, respectively.

2.2 Vadose Zone Investigation Phase Results

Vadose zone sediment samples were collected in 100-D during the demonstration of HHR and CSDR drilling technologies pursuant to the field investigation plan (DOE/RL-2008-09). Fifteen boreholes were originally planned, however only nine boreholes were drilled. Of these nine boreholes, samples were obtained from eight boreholes. Sampling methods carried out while using both the HHR and CSDR technologies are described in Sections 3.2 and 3.3, respectively.

The vicinity of the 100-D-30 waste site (Figure 2-4), referred to as the sodium dichromate trench, was a primary focus of this phase of the project. A suspected chromium contamination source (a sodium dichromate storage tank) was formerly located there and the waste site has been excavated to remove contaminated sediments to a depth of about 4.6 m (15 ft) below grade. Seven boreholes were drilled in this excavated area, with locations shown in Figure 2-4. Two of these boreholes were located in a pit in the southwest corner of 100-D-30 that had been excavated to a total depth of 5.9 m (19.6 ft). Stained sediment samples in the bottom of this pit (recently designated 100-D-104) were found to be high in hexavalent chromium (maximum value of 286 mg/kg).

Two other boreholes were drilled in waste sites suspected to contain potential residual sources of chromium in the vadose zone. Borehole C6436 was drilled through the former 116-D-1B storage basin trench, which was remediated in 2000. Site remediation work had not included sediment sampling and analysis for chromium. Borehole C6443 was drilled on a slant beneath the remaining foundation of the razed 108-D Building to determine if the 100-D-56 pipelines within the former building had leaked chromium contamination to the soil.

Hexavalent chromium and total chromium analytical results are summarized in Table A-1 (Appendix A) and are illustrated by the vertical profiles in Figure 2-5. The profiles for Boreholes C6443, C6446, C6447, and C6449 show total chromium concentrations that are comparable to or slightly in excess of Hanford Site expected background concentrations (DOE/RL-92-24). Boreholes C6450, C7833, and C6448/C6438, on the other hand, show significantly elevated total chromium and hexavalent chromium concentrations. Given that there is no known historic use of trivalent chromium compounds, it is reasonable to conclude that the elevated total chromium was originally hexavalent chromium that was subsequently reduced.

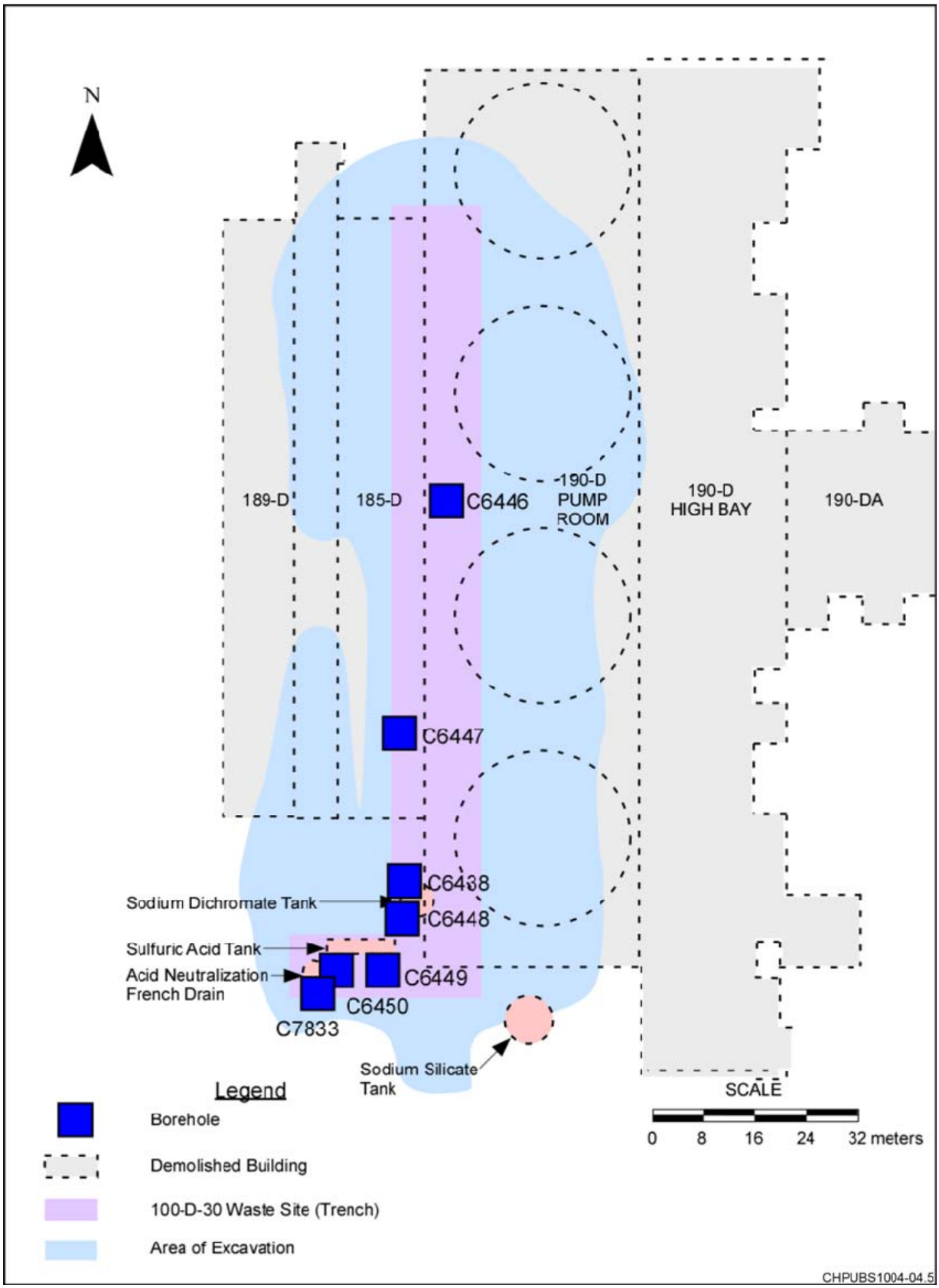


Figure 2-4. Vadose Zone Investigation Locations in the 100-D-30 Excavation

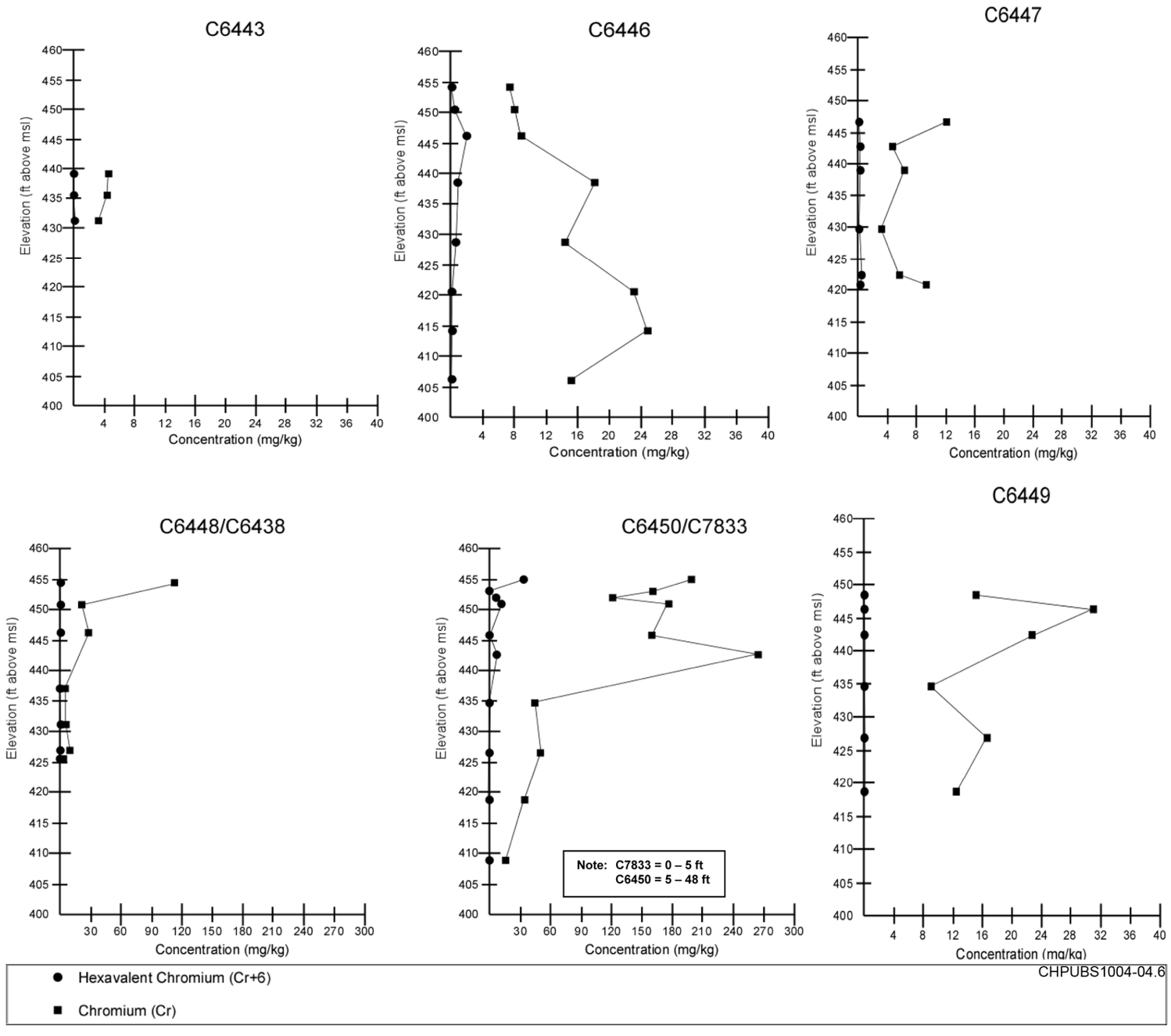


Figure 2-5. Vadose Zone Concentration Profiles, 100-D Area

Shallow sediment samples collected from Boreholes C6450 and C7833 contained the highest hexavalent chromium concentrations found in borehole samples, specifically 33.6 mg/kg at 0.6 to 0.9 m bgs (2 to 3 ft bgs) in C7833 and 14.6 mg/kg at 1.2 to 1.8 m (4 to 6 ft) bgs in C6450. These two boreholes were located within a foot of each other and Figure 2-5 includes the C7833 results from 0 to 1.5 m (0 to 5 ft) bgs and the C6450 results from 1.5 to 14.6 m (5 to 48 ft) bgs. The hexavalent chromium concentration in Borehole C6450 decreased to 0.7 mg/kg at 6.1 to 6.7 m (20 to 22 ft) bgs and below detection (less than 0.38 mg/kg) at the deepest sampling interval of 14 to 14.6 m (46 to 48 ft) bgs. It should be noted that boring C6449 was located 11 m (36 ft) east of Borehole C6450, and hexavalent chromium concentrations in all samples collected were undetected (less than 0.5 mg/kg). The hexavalent chromium concentration at 1.5 m (5 ft) bgs, the maximum depth of Borehole C7833, was 7.16 mg/kg.

Washington Closure Hanford (WCH), which excavated 100-D-30 during the period June 2006 through May 2007, is in the process of completing the Remaining Sites Verification Package for waste site 100-D-30. A comparison of preliminary results from grab samples collected during site remediation of the southwest corner of waste site 100-D-30 and borehole sample results from this study follows.

- Borehole C6450 was located approximately 0.3 m (1 ft) southwest of WCH samples J16J17 and J16J18. The WCH samples contained 286 mg/kg and 243 mg/kg of hexavalent chromium, respectively. The borehole sample at approximately the same depth as the WCH sample (6 m [20 ft] below original ground surface) had a maximum hexavalent chromium concentration of 14.2 mg/kg.
- Samples from borehole C7833 collected approximately 5.5 m, 5.8 m, and 6 m (18, 19, and 20 ft) below regional ground level contained hexavalent chromium concentrations of 33.6 mg/kg, less than detection, and 7.16 mg/kg, respectively.
- Based on the borehole sample results and the excavated grab sample results, it appears that the distribution of hexavalent chromium laterally and vertically in the sediment column under the 100-D-30 waste site is irregular and difficult to predict, as shown in Figure 2-6.
- Samples from Borehole C6446, located near the 185-D sump associated with the 100-D-30 waste site, had hexavalent chromium concentrations of up to 2.03 mg/kg 3.7 m (12 ft) below the drilling surface.
- Within Boreholes C6446, C6450, and C7833, concentrations decreased with depth.

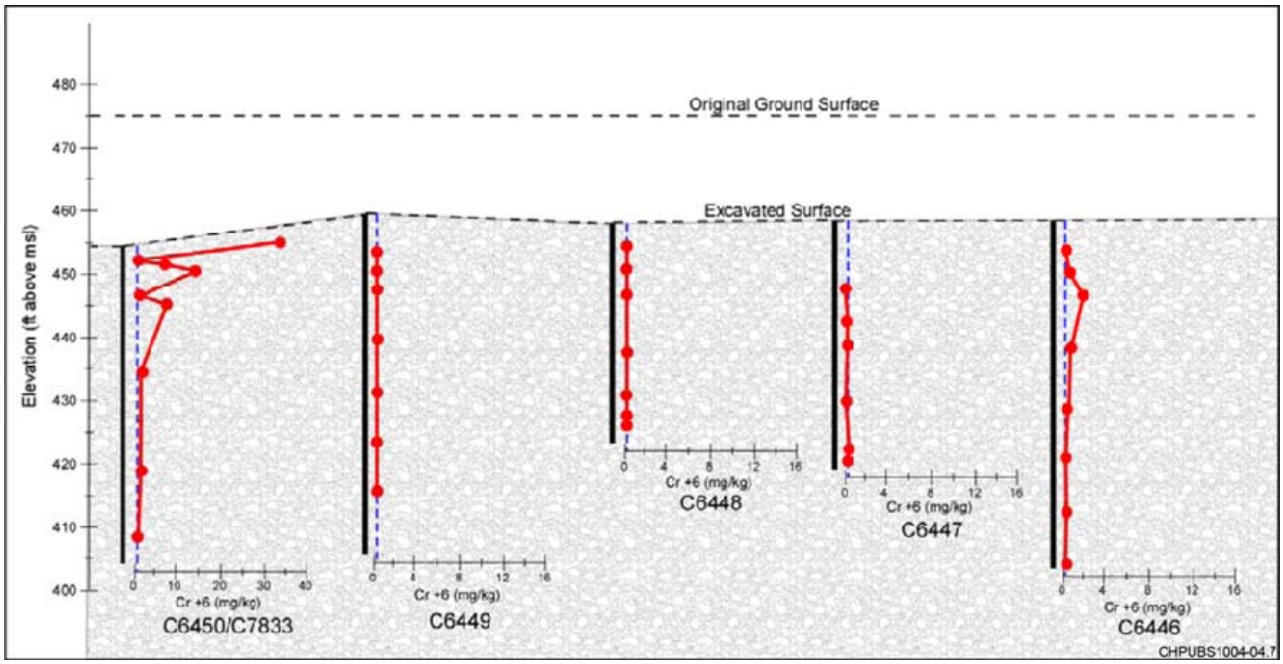


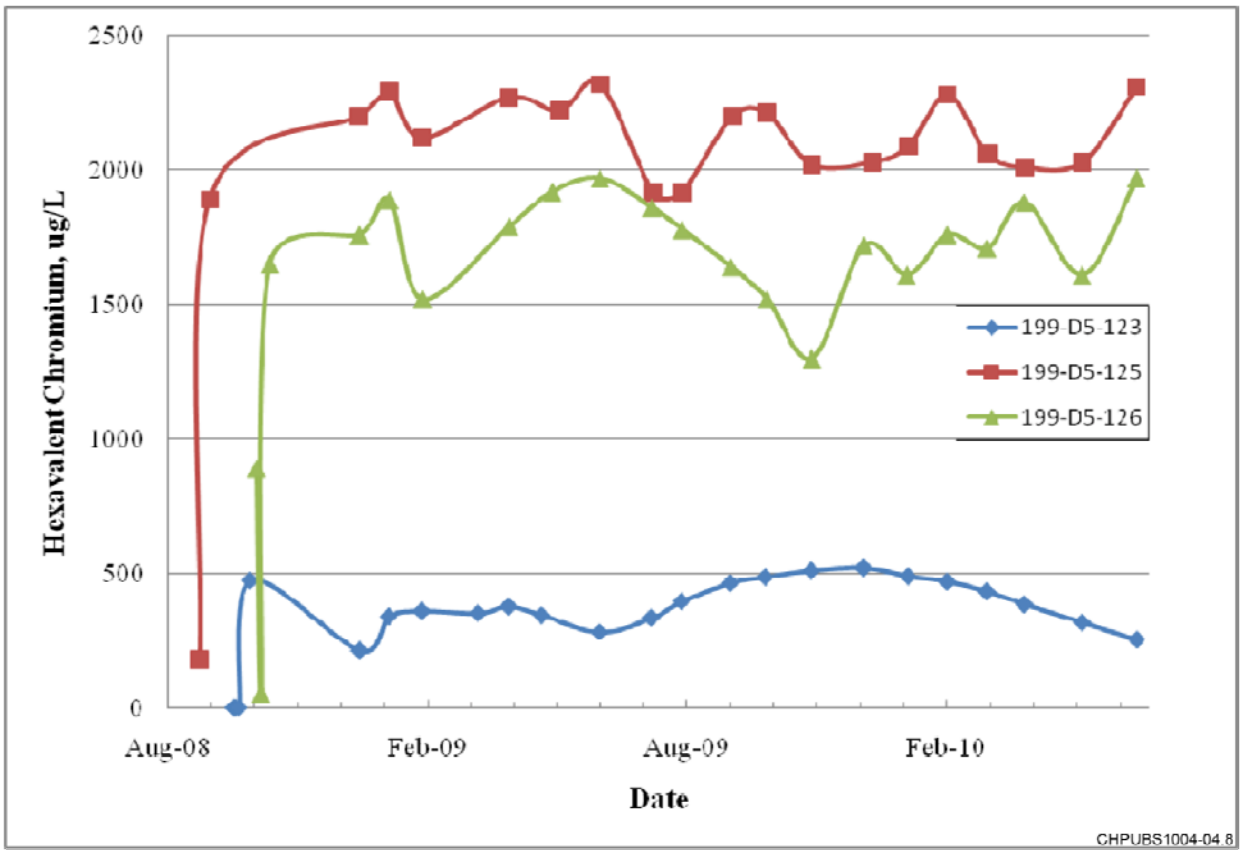
Figure 2-6. Fence Diagram (100-D-30 Trench Boreholes) Showing Hexavalent Chromium Profiles

2.3 Groundwater Investigation Phase Results

The groundwater phase consisted of drilling and constructing three wells near the proximal (source) end of the existing northern groundwater plume (Figure 2-1). Initial findings from the first wells drilled were used to finalize the locations of the subsequent wells (DOE/RL-2008-09, Appendix A). The wells were drilled beginning with Well 199-D5-123, on the east side of 105-D Reactor, near the 116-D-1A and 116-D-1B Trenches. This well is located about 100 m (330 ft) upgradient (southeast) of Well 199-D5-15, which had the highest historical groundwater hexavalent chromium concentration in the northern plume (2,450 µg/L in May 2007). Based upon the preliminary groundwater concentration of hexavalent chromium sampled from Well 199-D5-123, Well 199-D5-125 was installed northwest of Well 199-D5-15 to provide better control in defining the western edge of the high-concentration portion of the hexavalent chromium plume. The third well, 199-D5-126, is located west-northwest of Well 199-D5-14 to gather data on the central region of the plume and better define the northern edge of the high-concentration area (DOE/RL-2008-09).

During drilling, split-spoon samples of aquifer sediments were collected at various depths and analyzed for chromium. In addition, groundwater samples were collected when drilling penetration reached the top of the aquifer for all three wells, and at additional depth intervals in Wells 199-D5-123 and 199-D5-126. Groundwater samples were collected during the development of all three completed wells. These data are presented in Table A-2 (Appendix A).

Monthly sampling of the wells as part of the 100-HR-3 OU monitoring well network began following well completion. These data are presented in Table A-3 (Appendix A) and are plotted in Figure 2-7 through June 2010.



Note: The first few samples were collected while drilling; the low hexavalent chromium values are a result of drilling-induced reduction, as discussed in the text.

Figure 2-7. Groundwater Data Hexavalent Chromium Versus Time

Depth-discrete groundwater samples were collected at 0.6 m (2-ft) intervals from each of the three new wells in December 2008, after the wells were completed and developed. The results are shown in Table A-4 (Appendix A) and are illustrated in Figure 2-8.

Monthly groundwater sampling reveals hexavalent chromium reaching concentrations over 500 µg/L in Well 199-D5-123, which is the furthest of the three wells from the higher concentration portion of the hexavalent chromium plume. Well 199-D5-125, which was placed to better define the width of the plume, contained hexavalent chromium concentrations up to 2,350 µg/L. Well 199-D5-126, also placed to further define plume geometry, contained hexavalent chromium concentration up to 1,970 µg/L. The highest hexavalent chromium concentrations for both of these wells were for samples collected on June 15, 2009. The results of groundwater analysis of hexavalent chromium for samples collected during drilling (i.e., a drill-and-test sequence) show little correlation with the results of subsequent monthly sampling. This has been observed in previous investigations and has been attributed to local reduction of hexavalent chromium during drilling (Bjornstad et al., 1994).

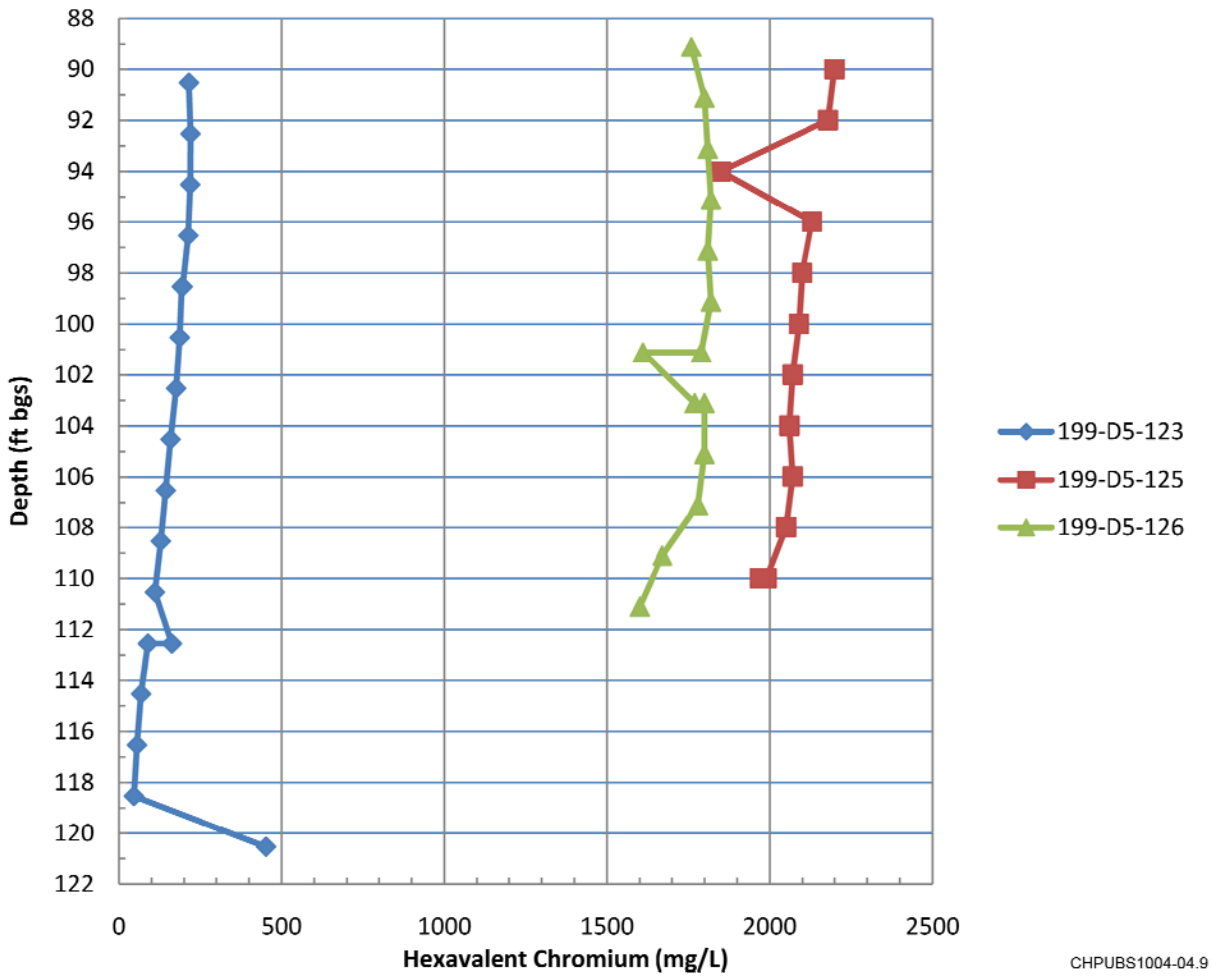


Figure 2-8. Vertical Distribution of Hexavalent Chromium in the Three New 100-D Northern Plume Wells

Figure 2-9 illustrates the northern plume interpreted and contoured both before and after inclusion of data from the three new wells. Although, in the central area of the plume the hexavalent chromium concentration in Well 199-D5-125 slightly exceeds the 2,000 µg/L contour, it is clear that the new data do not significantly alter understanding of the shape, extent, and contaminant burden of the plume.

The highest concentrations of hexavalent chromium found in the northern plume are more than an order of magnitude less than the highest concentrations found to date in the southern chromium plume at 100-D (DOE/RL-2009-92), which are over 60,000 µg/L. However, like the southern plume, relatively high concentrations of hexavalent chromium have persisted at the proximal end of the plume compared to concentrations nearer the river.

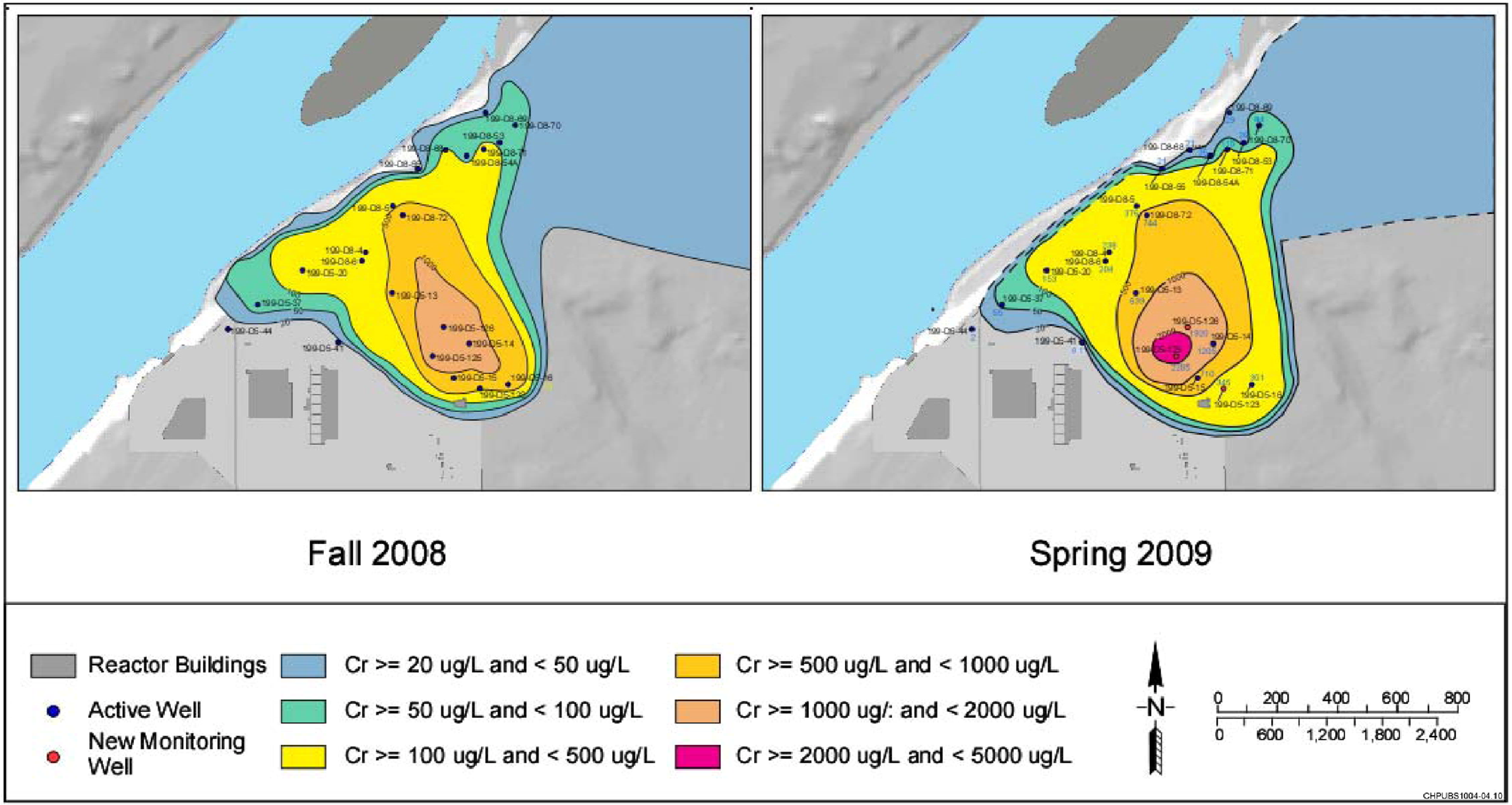


Figure 2-9. Northern Hexavalent Chromium Plume Comparison

3 Drilling Technology Demonstration for Vadose Zone Investigation Phase

This section summarizes the results of the hydraulic hammer direct push and compact sonic drilling technology demonstrations for the vadose zone investigation phase of work conducted between January and July 2009. This section also summarizes the successes and limitations of each technology. Additionally, this section provides a brief description of the history of various direct push methods used on the Hanford Site.

Drilling in 100-D is difficult and challenging to most drilling and sampling technologies because of the area's subsurface characteristics. These characteristics include coarse and locally cemented sediments and a relatively thick vadose zone. Drilling and sampling at 100-D are typically performed using robust cable tool and air rotary drilling methods. The larger cable tool and rotary drill rigs require a relatively large and flat area to conduct drilling operations and are not easily deployed in excavated areas or along the steeply sloped river shoreline present at 100-D.

The Phase I technology demonstration associated with this report was designed to field test compact direct push technologies that are principally designed for rapid borehole emplacement and sampling. Direct push drilling methods are commonly used in the environmental industry because:

- The equipment is generally less expensive to deploy than traditional drilling technologies.
- Minimal to no investigative derived waste is generated during borehole advancement.
- The equipment is generally compact in size and can be mobilized into difficult terrain or limited space.
- Sample collection can be performed rapidly.

Direct push drilling methods include the cone penetrometer, which pushes small-diameter cone-tipped rods using hydraulic rams, hydraulic hammers, rotary drives, and sonic technology. These latter enhancements to direct push methods are designed to enable drilling in more difficult geologic conditions, such as 100-D.

The technologies demonstrated during this project were the hydraulic hammer direct push and compact sonic drilling methods. Of the 15 borings originally planned for the technology demonstration (DOE/RL-2008-09), eight boreholes were successfully emplaced and abandoned. Of the eight boreholes, two were drilled between January 26 and February 22, 2009 using the hydraulic hammer direct push method. A third borehole using this method began during this time, but could not be completed due to equipment failure. After the hydraulic hammer direct push method demonstrated to be inadequate for 100-D geologic conditions, the field investigation plan (DOE/RL-2008-09) was revised to include plans for drilling and sampling with a CSDR. Using this method, five boreholes were drilled between June 3 and July 6, 2009.

The borehole summary report (SGW-39730) documents field notes and forms produced during drilling and soil sampling as well as subsurface geologic descriptions, management of drilling-derived waste, and civil survey results.

3.1 History of Cone Penetrometer Technology on the Hanford Site

Cone penetrometer technology (CPT) has been tested on the Hanford Site with varying degrees of success since 1991. The first test took place in the 200 West Area in 1991 with a 20-ton Push-CPT drill rig. Of the 13 penetrations, 6 reached a depth greater than 6.1 m (20 ft) bgs, and only 2 reached a depth greater than

12.2 m (40 ft) bgs. The remaining five pushes reached refusal between 1.8 and 2.4 m (6 and 8 ft) bgs. For comparison, in 1992, a 30-ton CPT drill rig was brought into the 200 West Area and depths of up to 44.8 m (147 ft) bgs were reached, a significant improvement over the previous year.

The 30-ton CPT drill rig was also used in the 3000, 300, and 200 East Areas. In the 3000 Area, CPT was successful at approximately half of the locations. Success was reduced in the 300 Area due to refusal from cobbles and boulders. In the 200 East Area, the CPT was able to reach depths of 15 and 29 m (50 and 95 ft) bgs. In 1993, CPT was tested at McGee Ranch on the Hanford Site, where penetrations were terminated in a cemented sand (caliche) layer. In 1996, six electrical resistivity tomography strings were installed successfully at the Mock Tank Site in the 200 East Area to a depth of 30 to 36 m (100 to 120 ft) bgs. Between 1991 and 1996, the depth capabilities of the Push-CPT method in the 200 Areas increased to up to 45.7 m (150 ft) as 30-ton and greater units were utilized.

The Sonic-CPT, tested in April 1999, used a 25-ton CPT unit to reach depths of 15.5 to 40.8 m (51 to 134 ft) bgs in 100-D and the 200 East Area and 19.8 m (65 ft) bgs in the 200 West Area. This drilling method was moderately successful when in very gravely to cobbly soils but capabilities were reduced when penetrating silt and clay layers.

3.2 Hydraulic Hammer Rig Demonstration

Three boreholes were drilled using a Geoprobe®[1] 8040DT HHR shown in Figure 3-1. All three boreholes were located at the bottom of the excavated 100-D-30 waste site, which was 4.6 to 5.1 m (15 to 17 ft) below regional ground surface (brgs).

The HHR is a direct push technology that uses a GH80 Hammer to drive a 5.7 or 8.2 cm (2.25- or 3.25-in.) diameter stainless steel casing equipped with a tapered drive shoe. An inner drill rod equipped with a cone-shaped bit prevents sediment from entering the casing during borehole advancement. Once the specified sample depth is reached the inner drill rod and bit are tripped out and the bit is replaced with a 5.1 cm (2-in.) diameter by 1.5 m (5-ft) long sampling tube. The sampling tube is equipped with two 0.76 m (2.5-ft) long Lexan®[2] liners to preserve sample integrity and for easy sample removal. The soil samples are collected by driving the sampling tube ahead of the casing.

The Geoprobe is equipped with a two-speed hydraulic top head used to rotate the casing while pushing. Using both push and rotational methods improves advancement through boulders and tightly packed gravels.

Boreholes C6449 and C6450 (Figure 1-2) were successfully drilled and abandoned using the HHR drilling method. However, there were difficulties experienced with this method. The first borehole (C6450) was drilled using only direct push technology. At approximately 1.8 m (6 ft) bgs (approximately 7 m [23 ft] brgs) the shoe became lodged in the formation and warped. Replacement of the shoe required removal of the casing. The drive-shoe was replaced twice to continue advancement of the casing. Once drilling successfully resumed, borehole advancement continued steadily to approximately 13.7 m (45 ft) brgs where formation conditions apparently changed and the drilling rate slowed. During sampling at 13.7 m (45 ft) brgs, excessive downward hammering on the sampling tube (required to advance sampling tube) resulted in failure of the drill rod and the sampling tube broke off. After the sampling tube was recovered from the borehole, drilling resumed. At approximately 14.6 m (48 ft) brgs, 6.1 m (20 ft) of drill rod sheared off. This equipment was successfully retrieved from the borehole.

[1] Geoprobe is a registered trademark of Geoprobe Systems, Salina, Kansas.
[2] Lexan is a trademark of SABIC Innovative Plastics, Pittsfield, Massachusetts.

Figure 3-1. Geoprobe 8040DT Hydraulic Hammer Rig Deployed at 100-D Area

Following the initial difficulties using only direct push methods, CHPRC project leads directed the drilling company to incorporate the rotational capabilities of the Geoprobe along with push methods to advance the borehole. The larger-diameter casing was removed from the borehole and replaced with the smaller diameter casing. The smaller-diameter casing was advanced to approximately 15 m (50 ft) brgs before refusal occurred.

During abandonment of borehole C6450, approximately 1.5 m (5 ft) of drill rod and 7.6 m (25 ft) of casing broke off during casing removal. The breakage occurred while attempting to free the threaded joints which had become tightly bound from the drilling rotation. The broken casing and rod fell back into the borehole and the formation collapsed over the top. This prevented removal of the casing. The project lead instructed the driller to abandon the borehole by leaving the irretrievable equipment in place, and backfilling with a seal of bentonite crumbles, in accordance with, “Minimum Standards for Construction and Maintenance of Wells” (WAC 173-160).

Borehole C6449 was emplaced using a combination of rotation and direct push methods. The 5.7 cm (2.25-in.) diameter casing was successfully advanced to 15 m (50 ft) brgs. Frequent overheating of the drill rod and casing made it necessary to stop drilling to wait for the equipment to cool. Refusal was met at a 16.5 m (54.1 ft) bgs, a similar depth as Borehole C6450, which was located approximately 11 m (36 ft) away. It is unclear whether refusal was a result of change in formation conditions (i.e., increased sediment size or cementation) or represents an equipment limitation. Difficulties again arose while

retrieving the casing. The threaded joints on the casing were tightly bound and it took considerable effort and time to break them apart. All casing and drill rods were removed from borehole and it was properly abandoned.

A third borehole (C6448) was attempted using the HHR drilling method. The same push-and-rotate method with 5.7 cm (2.25-in.) casing was used, similar to that used for Borehole C6449. The casing advanced to 17 ft bgs (32 ft brgs) when the top 1.5 m (5-ft) section of casing broke off, leaving 4.6 m (15 ft) of casing in the borehole from 2 to 17 ft bgs. A spear was used to retrieve the drill rod and casing. At this juncture, further drilling was terminated, all casing was removed and the borehole was properly abandoned.

3.3 Compact Sonic Drill Rig Demonstration

Five boreholes were drilled using a Layne Christensen SCR-13 CSDR as shown in Figure 3-2. The SCR-13 is equipped with a Compact Roto-Sonic head that provides simultaneous rotation and vibration to advance a core barrel and drill casing. This combination provides much greater cutting action down-hole, and facilitates drilling in more competent, semi-consolidated geologic formations. One significant drawback of the combination rotary and sonic drill motion is that the core barrel heats up excessively. This requires cooling the hot barrel, which is typically done by pouring water into the borehole. This was not done during the test because of the concern that hexavalent chromium would be mobilized, so the barrel was cooled using a water spray after it was brought to the surface.

Figure 3-2. Layne Christensen SCR-13 Compact Sonic Drill Rig Deployed in the 100-D-30 Excavation

For this project, a 1.5 m (5-ft) long by 15 cm (6-in.) diameter stainless steel core barrel was advanced ahead of the 19.4 cm (7.6 in.) diameter stainless steel casing. Upon driving the full length of the core barrel, the drilling tools were tripped out of the borehole. The sediments inside the barrel were extracted using the sonic vibration and discharged into a Teflon®[3] bag. Samples for geologic description or for chemical analysis were collected from the Teflon bag. Following sample extraction the casing was advanced to the core barrel sample depth. The core barrel was then used to remove the slough from inside the casing. After removing the slough, the drilling advancement and sampling process was repeated.

Three boreholes were successfully drilled using the CSDR method before complications arose. Boreholes C6447 and C6438 were located in the 100-D-30 waste site, approximately 4.6 m (15 ft) below the regional ground surface. Both boreholes reached the target depth of approximately 0.6 m (2 ft) into the Ringold Unit E, approximately 4.5 m (15 ft) bgs. Borehole C6443 was a slant borehole drilled at a 45 degree angle beneath the site of the 108-D Building pipelines. This borehole was advanced to 55 linear ft (39 ft true vertical depth) and then reached refusal.

Borehole C6446, also located in the 100-D-30 waste site excavation, was designed to be drilled to groundwater. Advancement of the borehole was terminated at 16.7 m (55 ft) brgs (approximately 7.6 m [25 ft] above groundwater) due to problems with sediment recovery from the core barrel. Attempts to improve sediment recovery included adding water and reducing the core barrel diameter (10 cm rather than 15.2 cm diameter [4-in. rather than 6-in. diameter]). The drill bit, core barrel, and a portion of the drill rod also were lost down hole due to failure from metal fatigue from the high heat generated during drilling. Most of the lost tooling was recovered by running a smaller-diameter casing (6-in.-diameter) casing inside the 19.4 cm (7.6 in.) diameter casing. The borehole was advanced with the smaller diameter casing and core barrel until final refusal at 16.7 m (55 ft) brgs.

Borehole C6436 was drilled with 8-in. nominal casing and a 6-in. core barrel. The borehole was located east of the 105-D Reactor in an area of known backfill and near a high-traffic service road (frequented by large equipment and trucks). The primary problems identified during drilling at this borehole were the alteration of the sample due to pulverization and high temperatures. In one instance, soil moisture inside the sample barrel heated to the point of releasing steam when the sample was retrieved from the barrel. The released steam and hot sediments came in flash contact with the driller's helper resulting in a reportable safety incident and mandatory review and corrective action. Following this incident, water was used to cool down the sampling equipment prior to retrieving the sample.

3.4 Technology Demonstration Summary

This section provides a summary of the HHR and CSDR technology demonstration performed between January and July 2009. Table 3-1 lists drilling information and drilling observations for each of the boreholes. Table 3-2 lists both positive and negative results for both drilling technologies.

[3] Teflon is a registered trademark of E.I. du Pont de Nemours and Company.

Table 3-1. Drilling Summary

Borehole ID	Drill Method	Total Depth Drilled (ft bgs)	Combined Sampling and Drilling Time	Borehole Advancement Rate[a] (ft/hour)	Samples Collected	Reason for Terminating Drilling	Observations
C6436	CSDR	10.0	0:37	16.2	0	Safety Incident	• Moderate drilling rate 0 m to 3.1 m (0 ft to 10 ft) bgs through backfill material • Driller helper injured as a consequence of the extremely hot drive barrel, which caused the project to be terminated
C6438[b]	CSDR	35.0	2:56	11.9	4	Target Depth Reached	• Moderate drilling rate 0 to total depth
C6443[c]	CSDR	40.0	4:03	9.8	3	Target Depth Reached	• Moderate drilling rate 0 m to 1.5 m (0 ft to 5 ft) • Concrete foundation and refusal encountered, rig moved 10 ft from original location to re-drill • Moderate drilling rate 0 to total depth
C6446[b]	CSDR	55.0	12:57	4.2	8	Refusal	• Moderate drilling rate 0 m to 6.1 m (0 ft to 20 ft) bgs • Slow drilling rate 6.1 m to 7.6 m (20 ft to 25 ft) bgs • Very slow drilling rate 7.6 m (25 ft) bgs • Core barrel stuck down hole • Begin using a 10.2-cm (4-in.) core barrel for better recovery • Slow drilling rate 7.6 m to 11.3 m (25 ft to 37 ft) bgs • Very slow drilling 11.3 m to 11.6 m (37 ft to 38 ft) bgs • Core barrel stuck down hole, drill bit broke off and remains down hole • Very slow drilling rate 11.6 m to 16.8 m (38 ft to 55 ft) bgs • Run 15.2-cm (6-in.) casing down borehole to prevent collapse • No further advancement of borehole
C6447[b]	CSDR	40.0	6:14	6.4	6	Target Depth Reached	• Moderate drilling rate 0 m to 7.6 m (0 ft to 25 ft) bgs • Slow drilling rate 7.6 m (25 ft) to total depth
C6448[b]	HHR	17.0	0:32	31.8	3	Equipment Failure	• Fast drilling rate to total depth • Casing broke off and HHR project was terminated

Table 3-1. Drilling Summary

Borehole ID	Drill Method	Total Depth Drilled (ft bgs)	Combined Sampling and Drilling Time	Borehole Advancement Rate[a] (ft/hour)	Samples Collected	Reason for Terminating Drilling	Observations
C6449[b]	HHR	54.1	1:44	31.1	8	Refusal	• Rapid drilling rate 0 m to 6 m (0 ft to 19 ft) bgs • Moderate drilling rate 6 m to 11.6 m (19 ft to 38 ft) bgs • Slow drilling rate 11.6 m to 13.4 m (38 ft to 44 ft) bgs • Moderate drilling rate 13.4 m to 14.3 m (44 ft to 47 ft) bgs • Slow drilling rate 14.3 m (47 ft) to total depth
C6450[d]	HHR	50.0	1:42	29.4	7	Refusal	• Rapid drilling rate 0 m to 3.4 m (0 ft to 11 ft) bgs • Drill rig seal broke, project down for the day • Rapid drilling rate 3.4 m to 11.6 m (11 ft to 38 ft) bgs • Slow drilling rate 11.6 m to 14 m (38 ft to 46 ft) bgs • Sampling tube broke off down borehole at 14 m (46 ft) bgs • Slow drilling rate 14 m to 14.6 m (46 to 48 ft) bgs • 7 m (20 ft) of drill rod broke off down the borehole • Casing downsized from 8.9 cm to 5.7 cm (3.5 in. to 2.25 in.), re-drill to 14.6 m (48 ft) bgs • Slow drilling rate 14.6 m to 15.2 m (48 ft to 50 ft) bgs • Refusal hit at 15.2 m (50 ft) bgs
C7833[d]	HHR	5			3		• Near surface sampling completed

a. Total borehole advancement rate calculated using the combined sampling and drilling time divided by the total depth drilled. The combined drilling and sampling rate was used since the sampling process for direct push methods typically involve advancement of the borehole. Down time for equipment repair and other non-drilling or sampling activities was not included.

b. Located 4.6 m (15 ft) bgs in 100-D-30 trench. Measurements from drilling surface.

c. Because this borehole was drilled on a 45-degree slant, measurements are by rod length.

d. Located approximately 5.2 m (17 ft) bgs in the 100-D-104 waste site.

bgs = below ground surface
CSDR = compact sonic drill rig
HHR = hydraulic hammer rig

Table 3-2. Technology Demonstration Summary

PROS	HHR Method	CSDR Method
Drilling	• Remote handling capability • Fast drilling rate • No drilling cuttings generated • Compact size allowed deployment in narrow 4.6 m (15-ft) deep trench • Easy access kill switches for increased safety	• Fast drilling rate • Simple and safe rod handling apparatus • Compact size allowed deployment in narrow 4.6 m (15-ft) deep trench
Sampling	• Easy collection of split-spoons or drive tubes with inner liner capability	• Easy collection of drive barrel samples • Representative samples collected
CONS	**HHR Method**	**CSDR Method**
Drilling	• Drill bit bound and warped within gravelly formation • Drill rods break down borehole due to extreme force • Large gravels or consolidated sediments result in refusal	• Drill cuttings generated • Drill rods and core barrel become extremely hot during drilling
Sampling	• In situ view of sample not possible due to a size distribution of sediment as the sampler is removed from the borehole	• No inner liner for drive barrel • Sampled sediments exposed to high temperatures potentially affecting sample integrity • Sampled sediments frequently pulverized potentially affecting sample integrity

CSDR = compact sonic drill rig
HHR = hydraulic hammer rig

3.4.1 Hydraulic Hammer Rig

The HHR drilling method encountered delays and equipment failure over the course of this project. Drilling progress was relatively rapid in the top 6.1 m (20 ft) bgs in sand and gravel. For example, Borehole C6450 was able to advance approximately 13 m (40 ft) while collecting multiple soil samples in four days, and Borehole C6449 reached its total depth in two days of drilling. However, when boulders or tight formations were encountered it was necessary to apply greater force and the increased stress to the HHR equipment caused casing, rods, and sampling tubes to break. The total time required for equipment recovery during the HHR test (including down-time for approvals, fishing for down-hole tools, and repair) was over 100 hours.

The HHR method was able to drill without producing large amounts of waste. As the sampling tube was brought to the surface, sediments tended to sort by size. This prevented accurate lithologic observations in some cases (e.g., the 13.4 to 14 m (44 ft to 46 ft) bgs interval in Borehole C6449), although chemical analyses could still be performed on the sample. Grab samples for geologic archiving were successfully collected from the sampling tube.

The Geoprobe HHR proved to be very maneuverable, and was guided by wireless control that allowed the operator to stay well clear of the machine while repositioning it. The three boreholes attempted with this technology were located in a 4.6 m (15-ft) trench and an approximately 4.8 m (16-ft) deep pit (Figure 3-1) on the southwest end of the 100-D-30 waste site. Access to the borehole was on the north side of the trench down an approximately 30-degree incline. The drill rig moved over uneven, gravelly terrain with relative ease.

Decisions regarding future use of HHR technology at the Hanford Site should carefully consider the site-specific geologic conditions that will be encountered. For 100-D, most of the complications with the HHR method occurred when drilling at a depth greater than 12 m (40 ft) bgs, or approximately 17 m (55 ft) brgs. Where boulder-obstructed formation and consolidated gravels are absent, less damage to the equipment would be incurred and samples might be collected more readily.

3.4.2 Compact Sonic Drill Rig

The CSDR, like the HHR, provided fast drilling for vadose zone sample collection in unconsolidated sediments. However, drilling became very difficult when the more consolidated formation was reached. The primary problem with this drilling method was the generation of heat in the core barrel and drill rods. During intervals of increased drilling resistance, the core barrel and drill rods became extremely hot (occasionally turning a dark blue color), resulting in unsafe handling conditions at the surface. In one instance, soil moisture inside the sample barrel heated to the point of releasing steam when the sample was retrieved from the barrel. The released steam and hot sediments came in contact with the driller’s helper, resulting in a safety incident and mandatory review and corrective action.

Even after attempting to cool the sample barrel, the sediments inside the barrel were so hot that sample integrity was questioned and samples were not collected. Sample integrity was also questioned when sediments inside the barrel sleeve were observed to be pulverized to rock flour. It is speculated that the combined effects of elevated temperatures and the sonic vibration increased the amount of pulverization in the samples.

In order for the CSDR technology to be successful, it should be used where consolidated gravels and unconsolidated backfill with large cobbles are absent. Sample collection could then be performed more effectively. This technology could also be used to install wells in situations where sediment sampling is not necessary. If continuous addition of water is allowed, the tools would be cooled and lubricated while drilling within formations that are difficult to penetrate.

4 Discussion

The following discussion summarizes the findings of the investigation with respect to the overall objectives.

- Objective 1: *Identify potential vadose zone hexavalent chromium sources*:
  - The maximum hexavalent chromium concentration was 33.6 mg/kg in a sample from 0.6 to 0.9 m (2 to 3 ft) bgs in Borehole C7833, located about a foot southwest of Borehole C6450. The total chromium concentration in this sample was 200 mg/kg. The maximum hexavalent chromium concentration in a sample from Borehole C6450 was 14.6 mg/kg at a depth of 1.2 to 1.8 m (4 to 6 ft) bgs. Hexavalent chromium concentrations were as great as 286 mg/kg in grab samples collected in a previous study near the present ground surface and up to 243 mg/kg within a radius of about a meter from the C6450 site. This large range in hexavalent chromium concentration is indicative of the discontinuous nature of the contaminated sediments. Hexavalent and total chromium concentrations in both these boreholes decreased to background levels at depth (14.6 m [48 ft] brgs).
  - Total and hexavalent chromium concentrations in other borehole samples were at least an order of magnitude less than the concentrations in samples from Boreholes C6450 and C7833. It is not likely that these scattered and discontinuous hexavalent chromium sources are major contributors to the 100-D northern hexavalent chromium plume.
- Objective 2: *Provide a better definition of the hexavalent chromium plume boundary and refine the location of the source*:
  - Groundwater samples from the three new wells resulted in a more complete understanding of chromium concentration in the proximal part of the northern plume. For Well 199-D5-123, the fall 2008 groundwater sample was characterized by a hexavalent chromium concentration of 473 µg/L; subsequent concentrations ranged between 214 and 520 µg/L. Previous plume maps had estimated a chromium concentration of 1,000 to 2,000 µg/L in this portion of the plume. Groundwater samples from Wells 199-D5-125 and 199-D5-126 range from 1,300 to 2,300 µg/L, confirming that a high concentration portion of the plume is present west of Well 199-D5-14.
  - Even though the three groundwater wells drilled as part of this project helped to refine the location of the highest concentration portion of the plume, these data do not help identify potential source areas. Known potential source areas near Wells 199-D-125 and 199-D5-126 are the 108-D building and the 100-D-56 pipeline, which carried sodium dichromate from 108-D to 185-D. These facilities are approximately 230 m (755 ft) northeast and 140 m (460 ft) north, respectively, of Well 199-D5-125, which contains the highest groundwater concentrations. It is unlikely that either of these facilities are the source as they are downgradient of the northern plume hot spot. Potential source areas upgradient of the hot spot are the 116-D-1A and -1B cribs (300 m [985 ft] southeast of Well 199-D5-125) and the site of the former 185-D and 190-D buildings (350 m [1,150 ft] southwest of Well 199-D5-125). The 185-D building occupied what is now the 100-D-30 and 100-D-104 waste sites, where hexavalent chromium has been detected in near-surface soil. If these upgradient waste sites were the source of the northern chromium plume, they are probably not actively contributing to groundwater contamination at this time, as groundwater between these sites and the highest concentration area of the plume contains only small amounts of chromium.

- Objective 3: *Evaluate the effectiveness of the hydraulic hammer direct push and compact sonic drilling methods in emplacing borings and collecting sediment samples in the coarse Hanford formation sediments typical of 100-D*:
  - The Geoprobe 8040DT HHR advanced boring C6450 to about 14.6 m (48 ft) brgs, but there were numerous operational problems including sheared off drill rods and casing and stuck drill rods and drive shoes. These problems were likely due to the coarse nature of the Hanford formation sediments.
  - The Lane Christiansen SCR-13 CSDR, utilizing a combination of rotation and vibration, was able to complete three boreholes but was not successful in advancing past approximately 18 m (55 ft) brgs, which is the likely depth of the Ringold Unit E sediments in this area. The major problem with this method, other than difficulty advancing through dense and/or cemented sediments, was that the samples were disturbed by the intense heat created during drilling. This heat could also be a safety consideration.
  - These methods would likely be more successful in sediments composed of loose to unconsolidated sand-sized materials. It should be noted that even very robust drilling methods such as a cable tool rig could only advance some of the 100-D wells through the Ringold Unit E materials using a hard tool rather than a drive barrel.

One working hypothesis to explain high persistent chromium concentrations in 100-D plumes is that one or more active sources of contamination are present in the vadose zone. Neither this study nor the previous southern chromium source investigation discovered significant levels of hexavalent chromium in the deep vadose zone. However, any contaminant source to the plumes could be restricted to a small area and thus very difficult to find using surface drilling technologies. Contaminant sources may also migrate laterally to some extent due to stratigraphic control in the vadose zone. Lateral migration of contamination of a few meters has been observed at waste site 100-D-104, which is also the site of Boreholes C6450 and C7833. Waste site 100-D-104 is located at the southwest corner of 100-D-30 at the site of the former Acid Neutralization French Drain. Soil samples collected from this area yielded hexavalent chromium values up to 286 mg/kg and total chromium concentrations as high as 303 mg/kg. Historical samples from this area prior to remediation were greater than 5,000 mg/kg (the highest values were scraped from demolition debris including concrete, clay pipe, and tile [BHI-01185]). This evidence leaves open the possibility that hexavalent chromium contamination in proximity to 100-D-104 and 100-D-30 waste sites may have contributed to groundwater contamination in 100-D. These waste sites are approximately 250 m (820 ft) from the groundwater with the highest concentration in the northern hexavalent chromium plume (Figure 1-2) so it is unlikely to be a source for this plume. There are no groundwater wells directly between the waste site and the known northern plume hot spot, so this hypothesis cannot be evaluated owing to the lack of data.

An alternative explanation for groundwater contamination is that the zones of persistent high chromium concentrations represent contamination collected in portions of the aquifer that have relatively low flow rates. This is consistent with the low gradients observed between the area south of 100-D and the Columbia River in the south part of the Horn. In the southern plume, evaluation of long-term water level measurements and periodic groundwater sampling and analysis indicates that groundwater in the east side of the hot spot is nearly stagnant, and little net movement of groundwater from the highly contaminated proximal portion of the plume has occurred. This explanation suggests that much of the hexavalent chromium present in the vadose zone has migrated downward, carried by deep percolation that recharges the aquifer. Under this scenario, chromium remaining in the higher portions of the vadose zone would tend to be low-concentration remnants or non-leachable (i.e., Cr(III)). Continued measurement and examination of seasonal head data and chromium concentration in the northern plume may help elucidate

groundwater flow conditions and lead to a more refined conceptual model of the source area. An effort such as this would yield less accurate results than in the southern hot spot due to the paucity of groundwater wells in the northern plume.

While this chromium source investigation did not identify a specific vadose zone source contributing to the northern plume hot spot, several potential source areas have been identified in the nearby area through development of the remedial investigation work plan and the design of remediation activities. These other potential sources of hexavalent chromium will be investigated during one of two phases: (1) remedial investigation conducted under the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 1: 100-D/H Decision Unit* (DOE/RL-2008-46-ADD1), which covers the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 OUs, or (2) the interim remedial action ROD 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-N-2, 100-IU-2, 100-IU-6, and 200-CW-3 OUs (*Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington* [EPA/ROD/R10-96/134]). Additional excavation will also be conducted by the River Corridor Contractor at 100-D-104 to remove residual chromium from the vadose zone in this area.

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Appendix A

Data Summary

Table A-1. Vadose Zone Sample Data

Borehole ID	Date of Collection	Sample Depth[c] (ft)	HEIS Number	Sample Result Cr+6 (mg/kg)	Sample Result Cr (Total) (mg/kg)
C6443[a]	6/9/09	32.0	B1YKB6	0.2(U)	4.7
C6443[a]	6/9/09	36.0	B1YKB7	0.19(U)	4.33
C6443[a]	6/9/09	40.0	B1YKB8	0.39(U)	3.28
C6446[b]	6/15/09	4.0	B1YKD1	0.12(U)	7.42
C6446[b]	6/15/09	8.0	B1YKD2	0.62	8.09
C6446[b]	6/15/09	12.0	B1YKD3	2.03	8.93
C6446[b]	6/15/09	20.0	B1YKD4	0.93	18.3
C6446[b]	6/16/09	30.0	B1YKD5	0.68	14.2
C6446[b]	6/17/09	38.0	B1YKD6	0.2(U)	23.1
C6446[b]	6/17/09	44.0	B1YKD7	0.34(U)	24.8
C6446[b]	6/17/09	52.0	B1YKD8	0.2(U)	15.4
C6447[b]	6/4/09	11.0	B1YK71	0.12(U)	12.0
C6447[b]	6/4/09	16.0	B1YK72	0.21(U)	4.99
C6447[b]	6/4/09	20.0–22.0	B1YK74	0.21(U)	6.51
C6447[b]	6/4/09	29.0	B1YK75	0.14(U)	3.24
C6447[b]	6/10/09	36.0[d]	B1YK76	0.33(U)	5.26
C6447[b]	6/10/09	38.0[e]	B1YK77	0.22(U)	9.15
C6448[b]	2/19/09	4.0–6.0	B1YK82	0.21(U)	112
C6448[b]	2/19/09	8.0–10.0	B1YK83	0.21(U)	19.7
C6448[b]	2/19/09	12.0–14.0	B1YK84	0.21(U)	28.1
			B1YK85	0.21(U)	15.6
C6438[b]	6/11/09	21.0	B20XX8	0.15(U)	4.96
C6438[b]	6/11/09	28.0	B20XX9	0.21(U)	5.2
C6438[b]	6/11/09	31.0[c]	B20XY0	0.19(U)	12.2
C6438[b]	6/11/09	33.0[d]	B20XY1	0.14(U)	3.39
C6449[b]	2/17/09	6.0–8.0	B1YK58	0.2(U)	15.7
C6449[b]	2/17/09	6.0–8.0	B1YK59	0.155(U)	6.13
C6449[b]	2/17/09	8.0–10.0	B1YK60	0.2(U)	31
C6449[b]	2/17/09	12.0–14.0	B1YK61	0.21(U)	22.9
C6449[b]	2/18/09	20.0–22.0	B1YK62	0.21(U)	9.01
C6449[b]	2/18/09	28.0–30.0	B1YK63	0.2(U)	16.5

Table A-1. Vadose Zone Sample Data

Borehole ID	Date of Collection	Sample Depth[c] (ft)	HEIS Number	Sample Result Cr+6 (mg/kg)	Sample Result Cr (Total) (mg/kg)
C6449[b]	2/18/09	36.0–38.0	B1YK64	0.2(U)	12.6
C6449[b]	2/18/09	44.0–46.0	B1YK65	0.21(U)	34.8
C6450[b]	1/26/09	4.0–6.0	B1YK94	14.2	178
C6450[b]	1/26/09	8.0–10.0	B1YK95	0.607	159
C6450[b]	1/28/09	12.0–14.0	B1YK96	8.42	265
C6450[b]	1/28/09	20.0–22.0	B1YK97	0.7	43.6
C6450[b]	1/28/09	28.0–30.0	B1YK98	0.56	51.2
C6450[b]	1/28/09	36.0–38.0	B1YK99	0.78	31.3
C6450[b]	1/29/09	46.0–48.0	B1YKB0	0.38	15.8
C7833[b]	2/17/09	2.0–3.0	B1YKY2	33.6	200
C7833[b]	2/17/09	3.0–4.0	B1YKY3	0.6	162
C7833[b]	2/17/09	4.0–5.0	B1YKY4	7.16	121

Source:

DOE/RL-2008-09, 2009, *Field Investigation Plan for the Source of the Northern Chromium Plume in the 100-D Area*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

a. Slant borehole with slope length provided as rod length.

b. Located in bottom of excavation 15 ft below ground surface in 100-D-30 trench. Measurements from drilling surface.

c. Sample depth below relative ground surface.

d. Sample collected at Ringold Formation contact as requested by the Project Scientist.

e. Sample collected 2 ft into the Ringold Formation as described in DOE/RL-2008-09.

HEIS = Hanford Environmental Information System

Laboratory Qualifier:

(U) = Value reported is less than the contract required detection limit.

Table A-2. Chromium Results for Sediments and Groundwater Sampled During Monitoring Well Drilling

Well Name	Date of Collection	Sample Type	Sample Depth (ft)	HEIS Number	Sample Result Cr+6 (mg/kg or as noted)	Sample Result Cr (Total) (mg/kg or as noted)
199-D5-123	9/22/08	Soil: Split-Spoon	15–17.5	B1WXB2	0.3(U)	4.15
199-D5-123	9/22/08	Soil: Split-Spoon	19.5–22.0	B1WXB3	0.3(U)	3.72
199-D5-123	9/22/08	Soil: Split-Spoon	24.6–27.1	B1WXB4	0.3(U)	6.11
199-D5-123	9/22/08	Soil: Split-Spoon	29.6–32.1	B1WXB5	0.3(U)	5.32

Table A-2. Chromium Results for Sediments and Groundwater Sampled During Monitoring Well Drilling

Well Name	Date of Collection	Sample Type	Sample Depth (ft)	HEIS Number	Sample Result Cr+6 (mg/kg or as noted)	Sample Result Cr (Total) (mg/kg or as noted)
199-D5-123	9/22/08	Soil: Split-Spoon	35.4–37.9	B1WXB6	0.3(U)	9.78
199-D5-123	9/23/08	Soil: Split-Spoon	39.6–42.1	B1WXB7	--	--
199-D5-123	9/23/08	Soil: Split-Spoon	44.3–46.8	B1WXB8	--	--
199-D5-123	9/23/08	Soil: Split-Spoon	49.4–50.9	B1WXB9	--	--
199-D5-123	9/24/08	Soil: Split-Spoon	54.7–56.2	B1WXC0	--	--
199-D5-123	9/24/08	Soil: Split-Spoon	60.2–62.2	B1WXC1	--	--
199-D5-123	9/25/08	Soil: Split-Spoon	64.6–66.6	B1WXC2	--	--
199-D5-123	9/25/08	Soil: Split-Spoon	69.4–71.4	B1WXC3	--	--
199-D5-123	9/26/08	Soil: Split-Spoon	74.5–76.0	B1WXC4	--	--
199-D5-123	9/29/08	Soil: Split-Spoon	80–82.5	B1WXC5	--	--
199-D5-123	10/2/08	Soil: Split-Spoon	84.5–86	B1WXC6	--	--
199-D5-123	10/3/08	Soil: Split-Spoon	87.9–89.0	B1WXC7	0.3(U)	11.3
				B1WXC8	--	--
				B1WXK8(S)	0.21(U)	63.9(N)
				B1WXL0(S)	0.22(U)	
199-D5-123	10/6/08	Groundwater: KABIS®	92.4	B1X1H4	2 µg/L(U)	--
				B1X1J6	--	0.5 µg/L(U)
				B1X1K9(S)	--	3.1 µg/L(U)
				B1X1K8(S)	--	2.0 µg/L
199-D5-123	10/3/08	Soil: Split-Spoon	89.5–91.5	B1WXC9	0.3(U)	15.8
				B1WXD0		
199-D5-123	10/6/08	Soil: Split-Spoon	92.2–94.9	B1WXD1	0.3	11.3
				B1WXD2		
199-D5-123	10/6/08	Soil: Split-Spoon	94.5–96.5	B1WXD3	0.3	10.5
				B1WXD4		
199-D5-123	10/6/08	Soil: Split-Spoon	97.7–98.7	B1WXD5	0.3	8.6
				B1WXD6	--	--
199-D5-123	10/7/08	Soil: Split-Spoon	99.4–102.1	B1WXD7	0.3	11.5
				B1WXD8	--	--

Table A-2. Chromium Results for Sediments and Groundwater Sampled During Monitoring Well Drilling

Well Name	Date of Collection	Sample Type	Sample Depth (ft)	HEIS Number	Sample Result Cr+6 (mg/kg or as noted)	Sample Result Cr (Total) (mg/kg or as noted)
199-D5-123	10/7/08	Soil: Split-Spoon	101.8–103.3	B1WXD9	0.3	11.7
				B1WXF0	--	--
199-D5-123	10/7/08	Soil: Split-Spoon	104.6–107.1	B1WXF1	0.3	23.6
				B1WXF2	--	--
199-D5-123	10/8/08	Soil: Split-Spoon	107.1–109.6	B1XF82	0.3(U)	17.1
				B1XF83	0.3(U)	--
199-D5-123	10/8/08	Groundwater: Submersible Pump	107	B1X1H5	2 µg/L(U)	--
				B1X1H6	473 µg/L	--
				B1X1J7	--	0.5 µg/L(U)
				B1X1J8	--	452 µg/L
199-D5-123	10/8/08	Soil: Split-Spoon	108.9–111.1	B1XF90	0.3(U)	11.3
				B1XF91	0.3(U)	--
199-D5-123	10/9/08	Soil: Split-Spoon	112.4–114.4	B1FX93	0.3(U)	19.7
				B1FX94	0.3(U)	--
199-D5-123	10/10/08	Soil: Split-Spoon	114.7–116.7	B1XFB8	0.3(U)	28.5
				B1XFB9	--	--
199-D5-123	10/10/08	Soil: Split-Spoon	120.0–122.0	B1XFD6	0.3	35.1
				B1XFD7	0.3	--
199-D5-123	10/16/08	Groundwater: Submersible Pump	Collected after development; intake at 93.71	B1X1J8	--	452 µg/L
				B1X1H6	473 µg/L	--
199-D5-125	9/10/08	Soil: Split-Spoon	83.5–85.5	B1WXH2	0.1(U)	10.1
199-D5-125	9/11/08	Groundwater: KABIS	95.1	B1X1K2	--	153 µg/L
				B1X1J0	181 µg/L	--
199-D5-125	9/10/08	Soil: Split-Spoon	89.8–92.0	B1WXH3	0.1(U)	8.04
				B1WXH4	0.22(U)	--
199-D5-125	9/11/08	Soil: Split-Spoon	94.8–97.0	B1WXH5	0.1(U)	8.67
				B1WXH6	0.22(U)	--
199-D5-125	9/11/08	Soil: Split-Spoon	99.4–101.9	B1WXH7	0.1(U)	9.77
				B1WXH8	0.22(U)	--

Table A-2. Chromium Results for Sediments and Groundwater Sampled During Monitoring Well Drilling

Well Name	Date of Collection	Sample Type	Sample Depth (ft)	HEIS Number	Sample Result Cr+6 (mg/kg or as noted)	Sample Result Cr (Total) (mg/kg or as noted)
199-D5-125	9/12/08	Soil: Split-Spoon	104.8–107.3	B1WXH9	0.1	8.44
				B1WXJ0	0.21(U)	--
199-D5-125	9/12/08	Soil: Split-Spoon	106.8–109.1	B1X515	0.2	17.0
				B1X516	0.25(U)	--
199-D5-125	9/18/08	Groundwater: Submersible Pump	Collected after development; intake at 92.8	B1X1K4	--	1,820 µg/L
				B1X1J2	1,890 µg/L	--
199-D5-126	10/20/08	Soil: Split-Spoon	45.23	--	0.3(U)	20.1
199-D5-126	10/17/08	Soil: Split-Spoon	83.3–85.7	B1WXJ1	0.3(U)	8.36
199-D5-126	10/17/08	Soil: Split-Spoon	85.7–87.2	B1WXJ2	0.3(U)	7.35
				B1WXJ3	0.3(U)	--
				B1WXK9(S)	0.23(U)	9.1
				B1WXL1(S)	0.22(U)	--
199-D5-126	10/20/08	Groundwater: KABIS	87.5	B1X1J3	891 µg/L	--
				B1X1K5	--	718 µg/L
199-D5-126	10/20/08	Soil: Split-Spoon	87.0–89.0	B1WXJ4	0.3(U)	18.1
				B1WXJ5	0.3(U)	--
199-D5-126	10/20/08	Soil: Split-Spoon	90.5–91.0	B1WXJ6	0.3(U)	20.1
				B1WXJ7	0.3(U)	--
199-D5-126	10/21/08	Soil: Split-Spoon	92.1–94.1	B1WXJ8	0.3(U)	43.3
				B1WXJ9	0.3(U)	--
199-D5-126	10/21/08	Soil: Split-Spoon	95.0–97.2	B1WXK0	0.3(U)	23.1
				B1WXK1	0.3(U)	--
199-D5-126	10/21/08	Soil: Split-Spoon	96.9–99.4	B1WXK2	0.3(U)	11.5
				B1WXK3	0.3(U)	--
199-D5-126	10/21/08	Soil: Split-Spoon	99.6–102.2	B1WXK4	0.3(U)	8.31
				B1WXK5	0.3(U)	--
199-D5-126	10/21/08	Soil: Split-Spoon	102.0–104.9	B1WXK6	0.3(U)	18.4
				B1WXK7	0.3(U)	--
199-D5-126	10/22/08	Soil: Split-Spoon	104.6–106.2	B1XN78	0.3(U)	8.83
				B1XN83	0.3(U)	--

Table A-2. Chromium Results for Sediments and Groundwater Sampled During Monitoring Well Drilling

Well Name	Date of Collection	Sample Type	Sample Depth (ft)	HEIS Number	Sample Result Cr+6 (mg/kg or as noted)	Sample Result Cr (Total) (mg/kg or as noted)
199-D5-126	10/22/08	Soil: Split-Spoon	107.0–109.5	B1XN79	0.3(U)	7.43
				B1XN84	0.3(U)	--
199-D5-126	10/22/08	Soil: Split-Spoon	110.0–112.0	B1XN80	0.3(U)	20.1
				B1XN85	0.3(U)	--
199-D5-126	10/23/08	Groundwater: KABIS	110.0	B1X1J4	56.1 µg/L	--
				B1X1K6	--	52.4 µg/L
199-D5-126	10/29/08	Groundwater: Submersible Pump	Sample collected after well development; intake at 93.68	B1X1J5	1,650 µg/L	--
				B1X1K7	--	1,290 µg/L

Note:

KABIS is a registered trademark of Sibak Industries.

HEIS = Hanford Environmental Information System

Laboratory Qualifiers:

(N) = Sample spike recovery is outside control limits

(U) = Value reported is less than the contract required detection limit.

Table A-3. Monthly Groundwater Sampling

Well	Date Sampled	Cr+6 (UF) (µg/L)	Cr+6 (F) (µg/L)	Total Cr (F) (µg/L)	Total Cr (UF) (µg/L)
199-D5-123	10/5/2008	2(U)	--	--	--
199-D5-123	10/6/2008	2(N)	--	--	0.5(U)
199-D5-123	10/16/2008	473	--	--	452
199-D5-123	1/20/2009	340	--	--	--
199-D5-123	2/12/2009	360	--	--	--
199-D5-123	3/23/2009	352	--	--	--
199-D5-123	4/13/2009	377	376	--	--
199-D5-123	5/6/2009	345	344	--	--
199-D5-123	6/15/2009	273	282	--	--
199-D5-123	7/21/2009	320	335	--	--
199-D5-123	8/11/2009	397	396	--	--
199-D5-123	9/14/2009	461	464	--	--

Table A-3. Monthly Groundwater Sampling

Well	Date Sampled	Cr+6 (UF) (µg/L)	Cr+6 (F) (µg/L)	Total Cr (F) (µg/L)	Total Cr (UF) (µg/L)
199-D5-123	10/8/2009	485	486	--	--
199-D5-123	11/9/2009	522	510	--	--
199-D5-123	12/5/2009	515	520	--	--
199-D5-123	1/15/2010	488	489	--	--
199-D5-123	2/11/2010	463	469	--	--
199-D5-123	3/11/2010	398	432	--	--
199-D5-123	4/6/2010	382	385	--	--
199-D5-123	5/16/2010	317	318	--	--
199-D5-123	6/23/10	266	268	--	--
199-D5-125	9/11/2008	181	--	--	153
199-D5-125	9/18/2008	1,890	--	--	1,820
199-D5-125	1/20/2009	2,290	--	--	--
199-D5-125	2/12/2009	2,120	--	--	--
199-D5-125	4/13/2009	2,270	2,270	--	--
199-D5-125	5/18/2009	2,190	2,220	--	--
199-D5-125	6/15/2009	2,350	2,320	--	--
199-D5-125	7/22/2009	1,920	1,920	--	--
199-D5-125	8/11/2009	1,940	1,920	--	--
199-D5-125	9/15/2009	2,180	2,200	--	--
199-D5-125	10/9/2009	2,250	2,210	--	--
199-D5-125	11/9/2009	2,140	2,020	--	--
199-D5-125	12/21/2009	2,060	2,030	--	--
199-D5-125	1/15/2010	2,100	2,090	--	--
199-D5-125	2/11/2010	2,280	2,280	--	--
199-D5-125	3/11/2010	2,170	2,160	--	--
199-D5-125	4/6/2010	2,050	2,010	--	--
199-D5-125	5/16/2010	2,070	2,030	--	--
199-D5-125	6/23/2010	2,110	2,110	--	--
199-D5-126	10/20/2008	891	--	--	718
199-D5-126	10/23/2008	56.1	--	--	52.4
199-D5-126	10/29/2008	1,650	--	--	1,290
199-D5-126	1/20/2009	1,890	--	--	--

Table A-3. Monthly Groundwater Sampling

Well	Date Sampled	Cr+6 (UF) (µg/L)	Cr+6 (F) (µg/L)	Total Cr (F) (µg/L)	Total Cr (UF) (µg/L)
199-D5-126	2/12/2009	1,520	--	--	--
199-D5-126	2/12/2009	1,670	--	--	--
199-D5-126	4/13/2009	1,790	1,810	--	--
199-D5-126	5/13/2009	1,920	1,920	--	--
199-D5-126	6/15/2009	1,940	1,970	--	--
199-D5-126	7/21/2009	1,890	1,860	--	--
199-D5-126	8/11/2009	1,790	1,780	--	--
199-D5-126	9/14/2009	1,720	1,640	--	--
199-D5-126	10/9/2009	1,520	1,520	--	--
199-D5-126	11/9/2009	1,660	1,300	--	--
199-D5-126	12/15/2009	1,710	1,720	--	--
199-D5-126	1/14/2010	1,710	1,610	--	--
199-D5-126	2/11/2010	1,790	1,760	--	--
199-D5-126	3/11/2010	1,730	1,710	--	--
199-D5-126	4/6/2010	1,810	1,880	--	--
199-D5-126	5/16/2010	1,710	1,610	--	--
199-D5-126	6/23/10	1,910	1,920	--	--

Laboratory Qualifiers:

(F) = filtered

(N) = spike sample recovery outside control limits

(U) = value reported less than contract required detection limits

(UF) = unfiltered

Table A-4. Depth Discrete Groundwater Data

Well Name	Date of Collection	Sample Depth (ft bgs)*	Cr+6 Concentration (µg/L)*
199-D5-123	12/31/2008	90.53	214
199-D5-123	12/31/2008	92.53	219
199-D5-123	12/31/2008	94.52	218
199-D5-123	12/31/2008	96.53	212
199-D5-123	12/31/2008	98.53	195
199-D5-123	12/31/2008	98.53	192

Table A-4. Depth Discrete Groundwater Data

Well Name	Date of Collection	Sample Depth (ft bgs)*	Cr+6 Concentration (µg/L)*
199-D5-123	12/31/2008	100.52	186
199-D5-123	12/31/2008	104.53	158
199-D5-123	12/31/2008	106.53	143
199-D5-123	12/31/2008	108.53	128
199-D5-123	12/31/2008	110.53	110
199-D5-123	12/31/2008	112.54	162
199-D5-123	12/31/2008	112.54	88.6
199-D5-123	12/31/2008	114.53	67.6
199-D5-123	12/31/2008	116.53	55.2
199-D5-123	12/31/2008	118.53	45.7
199-D5-123	12/31/2008	120.53	452
199-D5-123	12/31/2008	102.53	175
199-D5-125	12/30/2008	90.00	2,200
199-D5-125	12/30/2008	91.99	2,180
199-D5-125	12/30/2008	95.99	2,130
199-D5-125	12/30/2008	97.99	2,100
199-D5-125	12/30/2008	99.99	2,090
199-D5-125	12/30/2008	101.99	2,070
199-D5-125	12/30/2008	103.99	2,060
199-D5-125	12/30/2008	105.98	2,070
199-D5-125	12/30/2008	107.98	2,050
199-D5-125	12/30/2008	109.98	1,990
199-D5-125	12/30/2008	109.98	1,970
199-D5-125	12/30/2008	111.98	*2*
199-D5-125	12/30/2008	*6*	2,150
199-D5-125	12/30/2008	94.00	1,850
199-D5-126	12/30/2008	89.12	1,760
199-D5-126	12/30/2008	91.12	1,800
199-D5-126	12/30/2008	93.12	1,810
199-D5-126	12/30/2008	95.11	1,820
199-D5-126	12/30/2008	97.11	1,810
199-D5-126	12/30/2008	99.11	1,820

Table A-4. Depth Discrete Groundwater Data

Well Name	Date of Collection	Sample Depth (ft bgs)*	Cr+6 Concentration (µg/L)*
199-D5-126	12/30/2008	101.11	1,790
199-D5-126	12/30/2008	101.11	1,610
199-D5-126	12/30/2008	103.11	1,770
199-D5-126	12/30/2008	103.11	1,800
199-D5-126	12/30/2008	105.10	1,800
199-D5-126	12/30/2008	107.10	1,780
199-D5-126	12/30/2008	109.10	1,670
199-D5-126	12/30/2008	111.10	1,600

* Italic font denotes a result less than the 10 µg/L RDL for Cr+6 in water samples.
bgs = below ground surface
RDL = reliable detection limit

Distribution

	MS	Quantity
U.S. Department of Energy, Richland Operations Office		
DOE Public Reading Room	H2-53	1
J. P. Hanson	A5-11	1
J. G. Morse	A6-38	1
T. C. Post	A3-04	1
K. M. Thompson	A6-38	2
CH2M HILL Plateau Remediation Company		
M. R. Adams	E6-35	3
F. H. Beibesheimer	R3-60	1
J. G. Blount	R3-50	1
J. A. Eluskie	R3-50	1
S. W. Petersen	E6-35	3
J. L. Smoot	R3-50	1
J. A. Winterhalder	E6-35	1
C. S. Wright	E6-35	1
Hanford Technical Library	P8-55	1
Washington Closure Hanford, LLC		
M. A. Buckmaster	X9-08	1
J. M. Capron	H4-23	1
E. T. Fiest	H4-22	1
W. S. Thompson	H4-23	1
Administrative Record	H6-08	1
Document Clearance	H6-08	1