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Calendar Year 2014 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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Richland, Washington 99352

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Executive Summary

Interim groundwater treatment remedies are operating in the 100-HR-3, 100-KR-4, and 100-NR-2 Groundwater Operable Units (OUs). Hexavalent chromium (Cr(VI)), the primary contaminant of concern (COC) in the 100-HR-3 and 100-KR-4 OUs, is being addressed by pump and treat (P&T) systems under an interim remedial action. Strontium-90 is the primary COC in the 100-NR-2 OU and is being addressed using permeable reactive barrier (PRB) technology to immobilize the strontium.

The P&T systems in the 100-HR-3 and 100-KR-4 OUs extract groundwater and remove the Cr(VI) with ion-exchange resin in treatment plants before reinjecting the treated water into the aquifer. A total of 4,657 million L (1,230 million gal) of groundwater was extracted and treated by the active P&T systems during 2014. These actions removed 251.6 kg (554 lb) of hexavalent chromium from the aquifer, described as follows:

- At the 100-HR-3 OU, the combined DX and HX P&T systems processed approximately 2,352 million L (621 million gal) of groundwater and removed 201.5 kg (444 lb) of Cr(VI). Since startup of the 100-HR-3 P&T systems, the cumulative volume of groundwater treated is approximately 12,937 million L (3,415 million gal), with 2,240 kg (4,927 lb) of Cr(VI) removed.

- Concentrations of Cr(VI) in the 100-D Area have been decreasing significantly because of DX P&T system operations. In 2014, the maximum Cr(VI) concentration was 3,616 µg/L, compared to the maximum concentration in 2010 of 69,700 µg/L. This indicates a significant reduction in Cr(VI) mass from the unconfined aquifer. This reduction is the product of focused groundwater extraction from high-concentration plume segments, as well as soil remediation actions that removed substantial continuing source contributions. The areal extent of the plume at the remedial action target concentration of 20 µg/L Cr(VI) remains much the same; however, high-concentration areas of the plume continued to decline substantially in 2014. Removal of high-concentration plumes and elimination of continuing secondary sources is essential to achieving the ultimate groundwater cleanup goal.

- The 100-KR-4 OU P&T systems include the KR4, KW, and KX P&T systems. During calendar year 2014, a total of 2,305 million L (609 million gal) of groundwater was treated and 50.1 kg (110 lb) of Cr(VI) was removed. Since startup of the 100-KR-4 OU P&T systems, the cumulative volume of groundwater treated is

approximately 15,945 million L (4,209 million gal), with 786.3 kg (1,733 lb) of Cr(VI) removed. In 2014, high-capacity extraction wells were brought online in both 100-KE and 100-KW Head House areas to provide groundwater extraction in these areas of elevated groundwater chromium concentration. Increased extraction by installation of new wells and realignment of existing wells is providing enhanced plume control in near-river regions of the 100-K Area.

At the 100-HR-3 OU, in situ redox manipulation (ISRM) is used to produce a PRB for in situ treatment of Cr(VI). This passive system reduces Cr(VI) to the immobile, nontoxic, trivalent form as it flows through an aquifer zone treated with sodium dithionite. A notice of nonsignificant change to the Record of Decision was issued in 2010,[1] which indicated that the barrier would no longer be actively maintained and P&T system expansion (i.e., extraction wells downgradient of the PRB) would be used to address breakthrough and provide a protective interim remedy. The ISRM PRB at the 100-D Area continued to operate, supplemented by P&T system extraction wells. At the end of 2014, concentrations at barrier wells ranged from below detection to 160 µg/L, with an overall decrease in concentrations compared to 2013. The observed changes in Cr(VI) concentration are attributed to a combination of residual reduction activity of the ISRM PRB and to extraction and treatment of contaminated groundwater in areas where the PRB is no longer effective.

Protection of the Columbia River against discharge of chromium-contaminated groundwater continues to steadily improve. River protection is assessed against conditions that may cause the river interface area to exceed the 10 µg/L ambient water quality criterion. During 2014, only 500 m (1,640 ft) of the 2,800 m (9,186 ft) of affected shoreline in the 100-D Area was identified as not adequately protected. This reflected a substantial improvement in river protection along the northern portion of the 100-D Area. Of the 4,400 m (14,435 ft) of affected shoreline in the 100-H Area, 500 m (1,640 ft) was identified as not adequately protected in 2014. This is a reduction from 1,700 m (5,577 ft) identified as not adequately protected in the 100-H Area during 2013. In the 100-K Area,

[1] 11-AMCP-0002, 2010, "Non-Significant Change for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision, Hanford Site, Washington, July 2010, Memo to File Regarding: Supplemental Actions for the In-Situ Reduction/Oxidation Manipulation Barrier Performance for the 100-HR-3 Groundwater Operable Unit Interim Remedy" (letter to J.A. Hedges, Washington State Department of Ecology, and D.A. Faulk, U.S. Environmental Protection Agency, from R.A. Holten), U.S. Department of Energy, Richland Operations Office, Richland, Washington, October 26. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1011290677.

200 m (656 ft) of the 4,000 m (13,123 ft) of affected shoreline was identified as not adequately protected in 2014. This is a reduction from 400 m (1,312 ft) identified as not adequately protected in 2013. In both the 100-HR-3 and 100-KR-4 OUs, the improvements in river protection status are the direct result of ongoing improvements in capture and treatment of contaminated groundwater. Improvements in 2014 included increased extraction rates and placement of new extraction wells at locations selected to intercept targeted plume segments.

In the 100-NR-2 OU, the primary groundwater COC is strontium-90. A P&T system developed for the removal and treatment of strontium-90-contaminated groundwater proved ineffective; subsequently, a PRB was installed along the shoreline to treat the aquifer with the mineral apatite. Strontium-90 moving with groundwater through the barrier adsorbs to the apatite and is immobilized within the barrier, reducing the amount of contamination migrating to the Columbia River. Groundwater samples at the PRB monitoring points show that the concentrations in most of the monitoring wells in 2014 were lower than preinjection levels by nearly 90 percent. However, concentrations of strontium-90 have begun to increase slightly in some of the monitoring wells.

This annual summary report describes the operations and results of these groundwater treatment remedies during 2014. The goals of the remedies are to protect the Columbia River, protect human health and aquatic life, and provide information that will enhance remediation. Target *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement)[2] milestones have been established to ensure that the impact of Cr(VI) and other contaminants to the Columbia River and groundwater is remediated in a timely manner. The following four milestones are directly applicable to the 100 Area OUs:

- ***Milestone M-016-110-TO1 (December 31, 2012):*** *DOE shall take actions necessary to contain or remediate hexavalent chromium groundwater plumes in each of the 100 Area NPL [National Priorities List] Operable Units to ensure ambient water quality standards for hexavalent chromium are achieved in the hyporheic zone and river column water.*

[2] Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.hanford.gov/?page=81.

The U.S. Department of Energy (DOE) continues to optimize groundwater remedies in the 100 Areas. Groundwater P&T systems in the 100-HR-3 and 100-KR-4 OUs show continuing improvement in river protection. In 2014, the 100-D Area exhibited a 25 percent increase in protected shoreline length and the 100-H Area exhibited a 55 percent reduction in unprotected shoreline length. The 100-K Area exhibited a 50 percent reduction in unprotected shoreline length in 2014.

- ***Milestone M-016-110-TO2 (December 31, 2020):*** *DOE shall take actions necessary to remediate hexavalent chromium groundwater plumes to ensure hexavalent chromium will meet drinking water standards in each of the 100 Area NPL Operable Units.*

  DOE's operation and enhancement of Cr(VI) groundwater remedies in the 100 Areas continued to reduce overall groundwater chromium concentrations. Plume areas exceeding drinking water standards have been substantially diminished in the 100-HR-3 and 100-KR-4 OUs.

- ***Milestone M-016-110-TO3 (December 31, 2016):*** *DOE shall take actions to contain the strontium-90 plume at 100-NR-2 Operable Unit to ensure the default ambient water quality standard (8 pCi/L) is achieved in the hyporheic zone and river water column.*

  DOE has demonstrated the efficacy of a PRB to reduce strontium-90 releases to the river from contaminated groundwater at the 100-NR-2 OU. Plans are in place to expand the barrier treatment.

- **Milestone M-016-110-TO4 (December 31, 2016):** DOE shall implement remedial actions selected in all 100 Area Records of Decision for Groundwater OUs to ensure no contamination above drinking water standards enters the Columbia River unless otherwise specified in a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) decision.

  DOE will continue to address identified COCs in groundwater in the 100 Areas in records of decision. Final remedial actions are not limited to Cr(VI).

This report details the volume of water treated, the contaminant mass removed through the P&T systems, the efficiency of the P&T systems, the effectiveness of the PRBs, and the resulting effect on groundwater concentrations. These interim remedies were initially

implemented in the mid-1990s, based on the understanding of the nature and extent of contamination at that time. Since the interim remedies were implemented, additional characterization activities (i.e., the remedial investigations), along with information gained from continued operation of the remedial systems and expansion of well networks, have substantially increased the understanding of the nature and extent of Cr(VI) contamination in groundwater. Additional improvements have been made in interpretation of groundwater measurements and observations, including enhanced contaminant plume interpolation processes and development of a method to critically evaluate the degree of river protection afforded by the remedial systems in place.

In 2006, based on *The Second CERCLA Five-Year Review Report for the Hanford Site*,[3] plans were initiated to expand the remedial systems to provide comprehensive treatment of the plumes in the aquifer. Expanded system capacity has been installed at all three OUs. Expansion has included increased treatment capacity in the 100-HR-3 and 100-KR-4 OUs through construction of the 100-DX, 100-HX, and 100-KX treatment plants; incorporation of high-capacity ResinTech® SIR-700 ion-exchange resin into the treatment systems; and expansion of groundwater extraction through installation of new high-capacity extraction wells at selected locations and increasing extraction rates at existing locations.

Although the interim remedial actions are effective and have demonstrated improvement in both protection of the Columbia River and overall reduction of groundwater contaminant concentrations, remedies are not yet complete. Interim remedial action operations will continue, along with monitoring activities and remedial process optimization. Monitoring and optimization activities include the following:

- Regular evaluation of results of sampling and analysis of groundwater samples collected from wells, aquifer tubes, and treatment process locations
- Regular evaluation of individual extraction and injection well performance
- Regular evaluation of estimated hydraulic capture by remedial systems
- Regular evaluation of treatment process performance

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[3] DOE/RL-2006-20, 2006, *The Second CERCLA Five-Year Review Report for the Hanford Site*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA04570094.

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- Adjustment of P&T system operations to optimize system performance in response to observed conditions. System adjustments have included modification of the treatment plants in the 100-K Area to expand treatment capacity by reducing the number of resin vessels in each treatment train to use the high-capacity SIR-700™ ion-exchange resin more effectively.

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Terms

amsl	above mean sea level
AWLN	automated water-level network
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFM	capture frequency map
COC	contaminant of concern
Cr(VI)	hexavalent chromium
CSM	conceptual site model
CY	calendar year
DO	dissolved oxygen
DOE	U.S. Department of Energy
DOS	design optimization study
DWS	drinking water standard
Ecology	Washington State Department of Ecology
ESD	explanation of significant differences
FS	feasibility study
FSB	fuel storage basin
IC	institutional control
ICFM	interpolated capture frequency map
ID	identification
ISRM	in situ redox manipulation
IX	ion exchange
MCL	maximum contaminant level
NA	not available
N/A	not applicable
NAPL	nonaqueous-phase liquid
NC	not calculated
NR	not reported
NS	not sampled

NSD	not sufficient data
O&M	operations and maintenance
OU	operable unit
P&T	pump and treat
PLC	programmable logic controller
PRB	permeable reactive barrier
QA	quality assurance
QC	quality control
RAO	remedial action objective
RCRA	*Resource Conservation and Recovery Act of 1976*
RD/RAWP	remedial design report/remedial action work plan
RI	remedial investigation
ROD	Record of Decision
RPO	remedial process optimization
RUM	Ringold upper mud unit
SAP	sampling and analysis plan
SCFM	simulated capture frequency map
TCE	trichloroethene
TPH	total petroleum hydrocarbon
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
UK	universal kriging
UPR	unplanned release
USGS	U.S. Geological Survey
WIDS	Waste Information Data System

1 Introduction

The U.S. Department of Energy (DOE) currently operates and maintains five ion-exchange (IX) pump and treat (P&T) systems along the Columbia River Corridor. In addition, DOE maintains one permeable reactive barrier (PRB), and monitors a second PRB as part of ongoing efforts to remediate contaminated groundwater in the Hanford Site's 100-KR-4, 100-HR-3, and 100-NR-2 Operable Units (OUs) (Figure 1-1). The primary contaminant of concern (COC) in the 100-KR-4 and 100-HR-3 OUs is hexavalent chromium (Cr(VI)). The primary COC in the 100-NR-2 OU is strontium-90.

The DX and HX P&T systems operated throughout 2014 to remediate Cr(VI) in the 100-HR-3 OU, located within the combined 100-D and 100-H Areas and the Horn. These P&T systems replaced the DR-5 and HR-3 P&T systems, which were shut down in March 2011 and May 2011, respectively. An in situ redox manipulation (ISRM) PRB, located in the southwestern portion of the 100-D Area, continues to remove Cr(VI) contamination from groundwater. The remaining three P&T systems (KR4, KX, and KW) remediate Cr(VI) contamination within the 100-KR-4 Groundwater OU. Table 1-1 lists the design capacity and the number of extraction and injection wells that operated in 2014 and are connected to the five P&T systems. Additionally, Table 1-1 summarizes the average flow rate plus average influent and effluent Cr(VI) concentration, groundwater volume treated, and Cr(VI) mass removed in 2014 for each P&T system.

The interim actions conducted at the 100-HR-3 and 100-KR-4 OUs are part of the effort to achieve the following interim remedial action objectives (RAOs), as described in EPA/ROD/R10-96/134, *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington*:

- **RAO #1:** Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.
- **RAO #2:** Protect human health by preventing exposure to contaminants in the groundwater.
- **RAO #3:** Provide information that will lead to a final remedy.

The interim remedial action initially chosen for the 100-NR-2 OU was P&T using an IX medium to remove strontium-90. The RAOs were reviewed in 2005, and the P&T system was deemed ineffective in reducing the strontium-90 flux to the Columbia River. In accordance with the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) Milestone M-16-06-01 ("Complete a Permeable Reactive Barrier [PRB] at 100-N"), the 100-NR-2 P&T system was placed in cold-standby status on March 9, 2006. DOE began emplacement of a PRB along the 100-N Area shoreline in 2007 with the goal of sequestering strontium-90 in the aquifer (DOE/RL-2005-96, *Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit*).

The following four RAOs for the 100-NR-2 OU are described in the current interim Record of Decision (ROD) (EPA, 2010, *U.S. Department of Energy 100-NR-1 and NR-2 Operable Units Hanford Site - 100 Area Benton Country, Washington Amended Record of Decision, Decision Summary and Responsiveness Summary*) (the remedial technology implemented uses apatite as a reactive material to sequester strontium-90 from the groundwater):

- **RAO #1:** Protect the Columbia River from adverse impacts from the 100-NR-2 groundwater so designated beneficial uses of the Columbia River are maintained.
- **RAO #2:** Protect the unconfined aquifer by implementing remedial actions that reduce concentrations of radioactive and nonradioactive contaminants present in the unconfined aquifer.
- **RAO #3:** Obtain information to evaluate technologies for strontium-90 removal and evaluate ecological receptor impacts from contaminated groundwater.

- **RAO #4:** Prevent destruction of sensitive wildlife habitat. Minimize disruption of cultural resources and wildlife habitat in general and prevent adverse impacts to cultural resources and threatened or endangered species.

Target Tri-Party Agreement (Ecology et al., 1989) milestones have been established for remedial actions to protect the Columbia River and groundwater from further impact due to Cr(VI) and other contaminants resulting from Hanford Site operations. The following four milestones are directly applicable to the 100 Area OUs:

- ***Milestone M-016-110-T01 (December 31, 2012):*** *DOE shall take actions necessary to contain or remediate hexavalent chromium groundwater plumes in each of the 100 Area NPL Operable Units such that ambient water quality standards for hexavalent chromium are achieved in the hyporheic zone and river column water.*

  DOE continues to optimize groundwater remedies in the 100 Areas. Groundwater P&T systems in the 100-HR-3 and 100-KR-4 OUs show continuing improvement in river protection. In 2014, the 100-D Area exhibited a 25% increase in protected shoreline length and the 100-H Area exhibited a 55% reduction in unprotected shoreline length. The 100-K Area exhibited a 50% reduction in unprotected shoreline length in 2014.

  Milestone M-016-110-T02 (December 31, 2020): *DOE shall take actions necessary to remediate hexavalent chromium groundwater plumes such that hexavalent chromium will meet drinking water standards in each of the 100 Area NPL Operable Units.*

  DOE's operation and enhancement of Cr(VI) groundwater remedies in the 100 Areas continued to reduce overall groundwater chromium concentrations. Plume areas exceeding drinking water standards have been substantially diminished in the 100-HR-3 and 100-KR-4 OUs.

- ***Milestone M-016-110-T03 (December 31, 2016):*** *DOE shall take actions to contain the strontium-90 plume at 100-NR-2 Operable Unit such that the default ambient water quality standard (8 pCi/L) is achieved in the hyporheic zone and river water column.*

  DOE has demonstrated the efficacy of a permeable reactive barrier to reduce strontium-90 releases to the river from contaminated groundwater at the 100-NR-2 OU. Plans are in place to expand the barrier treatment.

- ***Milestone M-016-110-T04 (December 31, 2016):*** *DOE shall implement remedial actions selected in all 100 Area Records of Decision for Groundwater Operable Units so that no contamination above drinking water standards enters the Columbia River unless otherwise specified in a CERCLA decision.*

  DOE will continue to address identified contaminants of concern in groundwater in the 100 Areas in RODs. Final remedial actions are not limited to Cr(VI); for example, groundwater in the 100-KR-4 OU also includes elevated concentrations of trichloroethene, strontium-90, carbon-14, tritium, and nitrate in addition to chromium.

Remedial actions toward achieving Milestone M-016-110-T01 have been implemented in the 100-HR-3 and 100-KR-4 OUs (12-AMRP-0172, "Completion of Hanford Facility Agreement and Consent Order (Tri-Party Agreement) Target Milestone M-016-110-T01, DOE Shall Take Actions Necessary to Contain or Remediate Hexavalent Chromium Groundwater Plumes in Each of the 100 Area National Priority List Operable Units Such that Ambient Water Quality Standards for Hexavalent Chromium are Achieved in the Hyporheic Zone and River Water Column"). These remedial actions are not yet complete, but current estimates indicate that the P&T approach is capable of remediating the Cr(VI) contamination in the affected aquifer. Annual assessments of river protection status, presented in subsequent sections of this

report for the 100-HR-3 and 100-KR-4 OUs, indicate continuing improvement in river protection for these two OUs. DOE reviews remedial action progress regularly and annually evaluates recommendations for changes to the remedial action systems to improve system performance and shorten the time to remedy completion. Remedial investigations (RIs) and feasibility studies (FSs) currently being conducted for the 100 Area OUs address the other target milestones. Status of the RI/FS activities for the specific OUs in this report is presented in subsequent chapters.

This annual summary report discusses the groundwater remedial actions conducted during 2014 at the 100-HR-3 OU (Chapter 2), the 100-KR-4 OU (Chapter 3), and the 100-NR-2 OU (Chapter 4). A cost evaluation for each OU is presented in the respective chapters. The references cited in this report are included in Chapter 5.

1.1 Summary of Operable Unit Activities

Information on site history for the 100-HR-3, 100-KR-4, and 100-NR-2 OUs is provided in Appendix A of DOE/RL-2014-25, *Calendar Year 2013 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*. The appendix presents a chronology of the investigations and decisions for the interim remedial actions, and it summarizes the conceptual site models (CSMs) associated with groundwater contamination at the OUs.

Of particular interest to understanding the CSM for Cr(VI) in groundwater at the 100-HR-3 OU, and specifically within the 100-D Area, is the waste site remediation and subsequent aquifer characterization conducted at the 100-D-100 waste site during 2014. During early 2014, excavation of chromium-contaminated vadose zone soil was completed at the 100-D-100 and 100-D-30 waste sites. Conditions at both of these sites exhibited full-thickness vadose zone contamination by Cr(VI). The chromium entered the vadose zone from historical unplanned releases of high-concentration sodium dichromate dihydrate solution. These releases were of sufficient volume to cause the chromium solution to travel through the entire vadose zone thickness and enter the underlying unconfined aquifer. Some of the residual Cr(VI) within the vadose zone, as well as within the aquifer, was found as a chromate-substituted calcium carbonate mineral. This material is sparingly soluble in water and forms a persistent secondary source of groundwater contamination where it occurs in substantial quantities, as it did within the soil and aquifer volume underlying these two waste sites (SGW-58416, *Persistent Source Investigation at 100-D Area*).

A series of temporary groundwater monitoring wells was installed within the aquifer underlying the 100-D-100 waste site. Vertical profile soil/aquifer media samples were collected during drilling these wells and moderate-frequency (i.e., weekly to monthly) groundwater samples were collected from the wells to provide additional understanding of the secondary source contribution of these solid-phase minerals. The chromate-substituted calcite was found to present a persistent groundwater contamination source. As a result, additional removal of contaminated soil was initiated in November 2014, to remove contamination up to 3 m (10 ft) below the water table at the 100-D-100 waste site. This activity is planned to be completed in early 2015.

Based on the observations and measurements of the secondary vadose zone source at the 100-D Area, the opportunity is believed to exist for the presence of similar source material within the vadose and shallow aquifer at other locations where high-concentration sodium dichromate dihydrate solution was released to the ground. The potential source areas include the 183-KE and 183-KW Head House areas in the 100-KR-4 OU.

Active groundwater interim action remediation continued during 2014, in conjunction with preparing RI/FS reports that will support RODs for future implementation of final remedies. This chapter provides an overview of these activities, and Chapters 2 through 4 provide detailed discussions for each respective OU.

1.2 100-HR-3 Operable Unit Activities

The following subsections provide a brief summary of the activities at the 100-HR-3 OU for the reporting period.

1.2.1 100-HR-3 Operable Unit Pump and Treat Systems

The DX and HX P&T systems operated throughout 2014, with several wells realigned to improve capture and remove mass from the aquifer. As presented in DOE/RL-2014-25, areas along the Columbia River were classified as "protected," "not protected," or "action may be required." Those areas considered at risk for impacts from contamination were evaluated, and actions were initiated to improve river protection in those areas.

The 2014 system modifications included connecting new extraction wells (199-D5-146 and 199-D5-153) and new injection Well 199-D5-148 to the DX P&T system well network. No significant changes in the treatment system configuration were made in 2014. Well 199-D5-146 is located downgradient of the 100-D-100 waste site, an area of historically high Cr(VI) concentrations. Well 199-D5-146 has been operating at 94.6 L/min (25 gal/min) and has been drawing contaminants toward it. Concentrations increased from about 30 to 65 µg/L during 2014. Well 199-D5-153 targets high concentrations in the 100-D northern plume. As a result of extraction operations at Well 199-D5-153, the concentrations in downgradient wells have declined and capture has improved (see Section 2.2.6). Injection Well 199-D5-148 is upgradient of the 100-D-100 waste site and extraction Well 199-D4-146. This well accepts over 378.5 L/min (100 gal/min) and helps move the local groundwater towards the existing extraction well network to improve capture in this area.

Well 199-D8-55 was converted from an injection well to an extraction well and was operational for extraction by mid-2014. This well is located near the river along the 100-D northern plume. Evaluation of the flow regime near the river indicated that conversion of Well 199-D8-55 to an extraction well would potentially improve capture along the 100-D northern plume (see Section 2.2.4).The 2014 well network modifications included taking extraction Well 199-D8-6 out of service. This well had ongoing issues with calcite buildup causing the pump to become inoperable. Calcite in this location is directly related to the geochemistry of the groundwater below the coal ash waste site where the well is located.

As the observed maximum Cr(VI) concentration in groundwater at the 100-D Area decreases, the treatment system may be modified in the future to optimize operation. In the 100-K Area, operation of the treatment plants in a "split-train" configuration has been demonstrated in which the high-efficiency ResinTech®[4]SIR-700 IX resin is used in a two-vessel treatment train to remove the Cr(VI). This approach can effectively double the treatment capacity of the original treatment plants that were initially operated using four-vessel trains.

No configuration changes were made to the HX P&T system treatment or well network during 2014. As with the DX system, the HX P&T system alignment will evolve while groundwater remediation activities continue toward meeting Tri-Party Agreement (Ecology et al., 1989) remediation goals and the system optimization process is applied to meet RAOs.

Figure 1-2 shows the current 100-HR-3 P&T system layout, and Figure 1-3 highlights the well changes to the P&T system configuration during 2014. Modifications made to the P&T systems in 2014 have

[4] ResinTech is a registered trademark of RESINTECH INC., West Berlin, New Jersey.[5] Dowex® is a registered trademark of the Dow Chemical Company, Midland, Michigan.

improved capture along the river, although capture is not complete at the 100-D northern plume or along the southern boundary of the 100-D Area. Section 2.2 discusses these changes in detail.

Figures 1-4 and 1-5 show the annual and cumulative trends for groundwater volume treated and COC mass removed, respectively, from the 100-HR-3 P&T systems. In 2014, the 100-HR-3 P&T systems treated approximately 2,352 million L (621 million gal) and removed 201.5 kg (444 lb) of Cr(VI) from the groundwater. This is a 37 percent reduction in mass removal from 2013, due primarily to the large decrease in Cr(VI) concentrations in the 100-D southern plume area near the 100-D-100 waste site, which is a result of ongoing extraction by the DX P&T system and source area remediation.

1.2.2 In Situ Redox Manipulation

In 2000, additional cleanup action was taken using an in situ chemical treatment technology (i.e., ISRM). Use of this new technology was approved by the 1999 interim ROD amendment (EPA/AMD/R10-00/122, *Interim Remedial Action Record of Decision Amendment for the 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington*). Rather than pumping contaminated groundwater to the surface for treatment, this technology treats the groundwater in the aquifer by reducing Cr(VI) to trivalent chromium, which is a much less toxic and less mobile form. Due to breakthrough of contaminants at the ISRM barrier, a notice of nonsignificant change to the ROD was issued in 2010, which indicated that the barrier would no longer be actively maintained (11-AMCP-0002, "Non-Significant Change for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision, Hanford Site, Washington, July 2010, Memo to File Regarding: Supplemental Actions for the In-Situ Reduction/Oxidation Manipulation Barrier Performance for the 100-HR-3 Groundwater Operable Unit Interim Remedy"). The notice of nonsignificance shifted the groundwater remedy at the ISRM barrier to the P&T system.

The ISRM barrier is still monitored for effectiveness and continued to convert Cr(VI) to a nontoxic, immobile form (trivalent chromium) within a portion of the aquifer in 2014. Concentrations in some downgradient wells remained above the interim remedial action target of 20 µg/L since the northeast segment of the barrier does not work effectively. Groundwater in this area is captured by extraction wells installed for the DX P&T system. Sections 2.1.2 and 2.2.8 discuss the ISRM treatment technology and its effectiveness in detail.

1.2.3 Remedial Investigation/Feasibility Study Activities

An RI/FS is being conducted for the 100-D and 100-H Areas and the Horn. Characterization activities began in 2009, as described in DOE/RL-2008-46-ADD1, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 1: 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*, and implemented through DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*. The RI/FS addresses contaminant sources (e.g., site history), contaminant flow and transport, and exposure assessment. It also supports risk characterization, remedial action selection, performance monitoring, and site closure. DOE completed Rev. 0 of the RI/FS report (DOE/RL-2010-95, *Remedial Investigation/Feasibility Study for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*) in October 2014. The Washington State Department of Ecology (Ecology) is currently reviewing the Proposed Plan (DOE/RL-2011-111, *Proposed Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*), which will lead to a ROD for cleanup of contaminated soil and groundwater at the 100-D and 100-H Areas.

1.3 100-KR-4 Operable Unit Activities

The following subsections provide a brief summary of activities at the 100-KR-4 OU for the reporting period.

1.3.1 100-KR-4 Operable Unit Pump and Treat Systems

Three active systems continued operating in the 100-KR-4 OU during 2014. The KR4 P&T system treats groundwater downgradient from the 116-K-2 Trench, with a treatment capacity of 1,136 L/min (300 gal/min). The KX P&T system treats groundwater between the 116-K-2 Trench and the N Reactor area, as well as a plume downgradient of the KE Reactor. The KX P&T system has a 2,300 L/min (600 gal/min) design treatment capacity. The KW P&T system extracts groundwater around the KW Reactor facility and has a treatment capacity of 1,136 L/min (300 gal/min). Figure 1-6 shows the layout of the 100-KR-4 OU P&T systems.

Well realignments for the 100-KR-4 OU P&T systems in 2014 included the addition of two new extraction wells (199-K-198 and 199-K-199) to the KR4 P&T system to improve capture near the river shoreline. One new extraction well (199-K-205, located at the 183-KW Head House area) and one new injection well (199-K-206, located between injection Wells 199-K-158 and 199-K-175) were constructed and connected to the KW P&T system. These wells allowed increased water treatment rate at the KW P&T system, as well as providing high-capacity extraction at the head house vicinity.

Three new extractions wells were connected to the KX P&T system in 2014. Extraction Wells 199-K-210 and 199-K-212 were added to the KX P&T system to improve river protection by enhancing capture of the Cr(VI) plume in the near-river vicinity downgradient of the KE Reactor (199-K-210), and along the 116-K-2 Trench (199-K-212). Extraction Well 199-K-220 is installed near the 183-KE Head House to provide mass removal from that source area. KX P&T system modifications included loading the third and fourth vessels in the treatment trains with ResinTech IX SIR-700 resin to provide additional treatment capacity. This increased capacity was demonstrated during 2014 when the KX P&T system was operated at a maximum daily throughput rate of 2,926.1 L/min (773 gal/min). Figure 1-7 highlights the changes to the 100-KR-4 OU P&T system configuration during 2014, and Section 3.1 provides a detailed discussion of these changes.

During 2014, the combined systems treated 2,306 million L (608 million gal) and removed 50.2 kg (110.6 lb) of Cr(VI). Figures 1-8 and 1-9 show the annual and cumulative trends for volume treated and mass removed, respectively, from the 100-KR-4 OU P&T systems. The groundwater treatment systems at the 100-KR-4 OU are presently operating in a "split-train" configuration. With the implementation of high-efficiency, high-capacity SIR-700 IX resin, the systems were found to function effectively using a two-vessel treatment train. This allows the remaining two vessels of the original four-vessel train to be used for additional plan treatment capacity. Using this approach, the capacity of the KR4 and KW treatment plants has been effectively doubled. The KX treatment plant is also running on the two-vessel train configuration; the third and fourth vessels in each treatment train at KX were loaded with SIR-700 resin during 2014 in preparation for operation of the KX P&T system in full split-train mode.

1.3.2 Remedial Process Optimization Activities

Remedial process optimization (RPO) activities at the 100-KR-4 OU remedial systems have evolved over recent years and currently focus on the following system aspects:

- **Assessment of extraction and injection well performance:** This includes evaluation of individual well performance and the identification of wells that need maintenance. This also includes evaluation of individual pumping rates for extraction wells located within specific portions of contaminant plumes (e.g., at or near source areas, along the leading edge of plumes).

- **Evaluation of well network performance:** This includes evaluating the placement and pumping rates of wells with respect to the inferred contaminant plume distribution. Modeling tools are used to evaluate anticipated well field performance under selected pumping scenarios. Based on these assessments, additional extraction capability has been added to the 100-K remedial systems by realigning selected existing wells as extraction wells and by drilling and constructing new wells, focusing on enhancing contaminant capture and mass removal in source areas (e.g., the 183-KE and 183-KW Head House areas) and river protection by enhancing capture along the leading edges of plumes that approach or intersect the river.
- **Assessment of treatment process effectiveness:** This evaluation led to the changeover in 2011 to the current SIR-700 IX resin. This resin has continued to provide highly efficient removal of Cr(VI) from extracted groundwater. No resin changes have been required at any of the three 100-K Area treatment systems since the use of SIR-700 resin was initiated. An evaluation is under way to assess the potential need for, and alternative approaches to, management of pH of the treatment process effluent water in the 100-K Area P&T plants. The KR4, KW, and KX treatment systems are presently not configured for alkaline adjustment of the treated water effluent.

1.4 100-NR-2 Operable Unit Activities

The following subsections provide a brief summary of activities at the 100-NR-2 OU for the reporting period.

1.4.1 100-NR-2 Operable Unit Pump and Treat System

The 100-NR-2 P&T system was placed in cold-standby status in March 2006. Contaminant concentrations have been tracked to quantify the effect on groundwater and the recovery of the water table to pre-pumping conditions.

1.4.2 100-NR-2 Operable Unit Permeable Reactive Barrier

Under the existing interim action ROD (EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*) and Tri-Party Agreement (Ecology et al., 1989) Change Control Form M-16-06-01, DOE agreed to construct and evaluate the effectiveness of a PRB for strontium-90 using apatite sequestration technology as part of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) RI/FS process.

No additional injections were conducted in 2014. Wells and aquifer tubes downgradient of the treated segments of the PRB continued to be monitored. Treated segments of the PRB include the following:

- From 2006 through 2008, DOE installed the first apatite PRB along 90 m (300 ft) of the most contaminated section of 100-N Area shoreline. Since 2008, this section of the shoreline has been monitored to track the formation of apatite within the vadose zone and groundwater and to determine the effectiveness of the PRB in attenuating strontium-90 and reducing its release to the Columbia River. The PRB has shown a 90 percent reduction of strontium-90 concentrations at the river's edge (PNNL-19572, *100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization, Final Report*). In response to the success of the existing PRB, DOE installed 146 new injection wells and 25 new monitoring wells along the remainder of the 100-N Area shoreline in 2009 and 2010, both upriver and downriver of the existing PRB.
- Wells in two 90 m (300 ft) long PRB segments (one upriver and one downriver of the original 90 m [300 ft] long segment) were injected with apatite solutions in 2011 (DOE/RL-2010-29, *Design*

Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit), which expanded the original barrier upstream and downstream and increased the current treated portion of the 100-N Area shoreline to 270 m (900 ft) in length. The injections were performed using a two-step process, where the deeper Ringold Formation wells were injected first and then the overlying Hanford formation wells were injected. These staggered injections overlay each other and maximize the coverage in the upper unconfined aquifer and lower vadose zones. The formulation for these injections was the high-concentration, calcium-citrate-phosphate solution amendment that was tested in 2008 (PNNL-19572).

Figure 1-10 shows the location of the original PRB and the upstream and downstream extensions. Performance monitoring is ongoing along the entire treated portion of the barrier and is discussed further in Chapter 4. Future PRB expansion will increase the barrier along the entire length of the contaminated portion of the 100-N Area shoreline approximately 760 m (2,500 ft).

1.5 Quality Assurance/Quality Control

Discussions on quality assurance (QA) and quality control (QC) encompassing sampling and analysis of the wells are provided in Appendix F of DOE/RL-2015-07, *Hanford Site Groundwater Monitoring Report for 2014* (in publication). It includes an overall view of the QA/QC issues that may affect interpretation of the groundwater data.

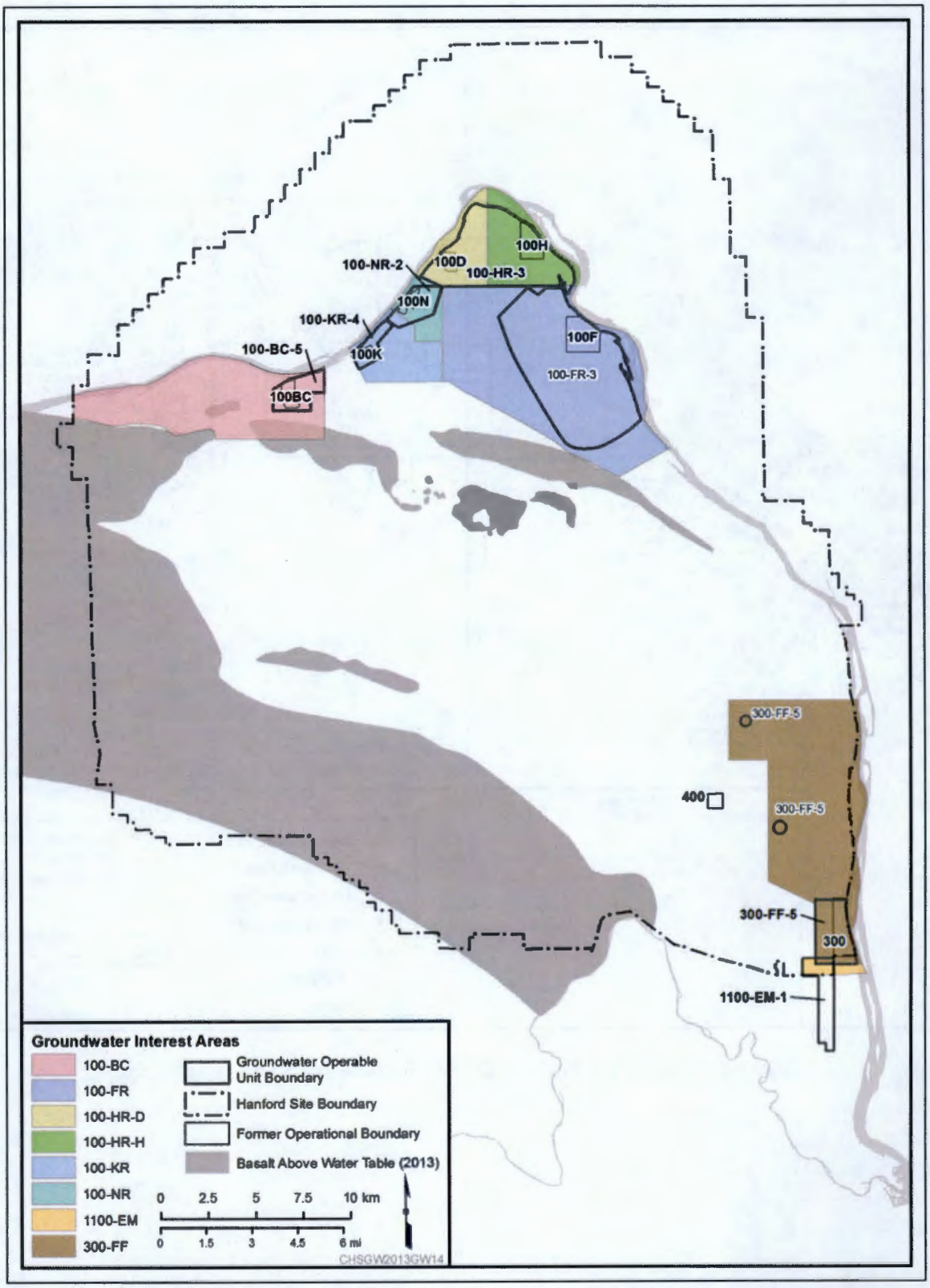

Figure 1-1. Locations of Groundwater OUs and Interest Areas along the Columbia River

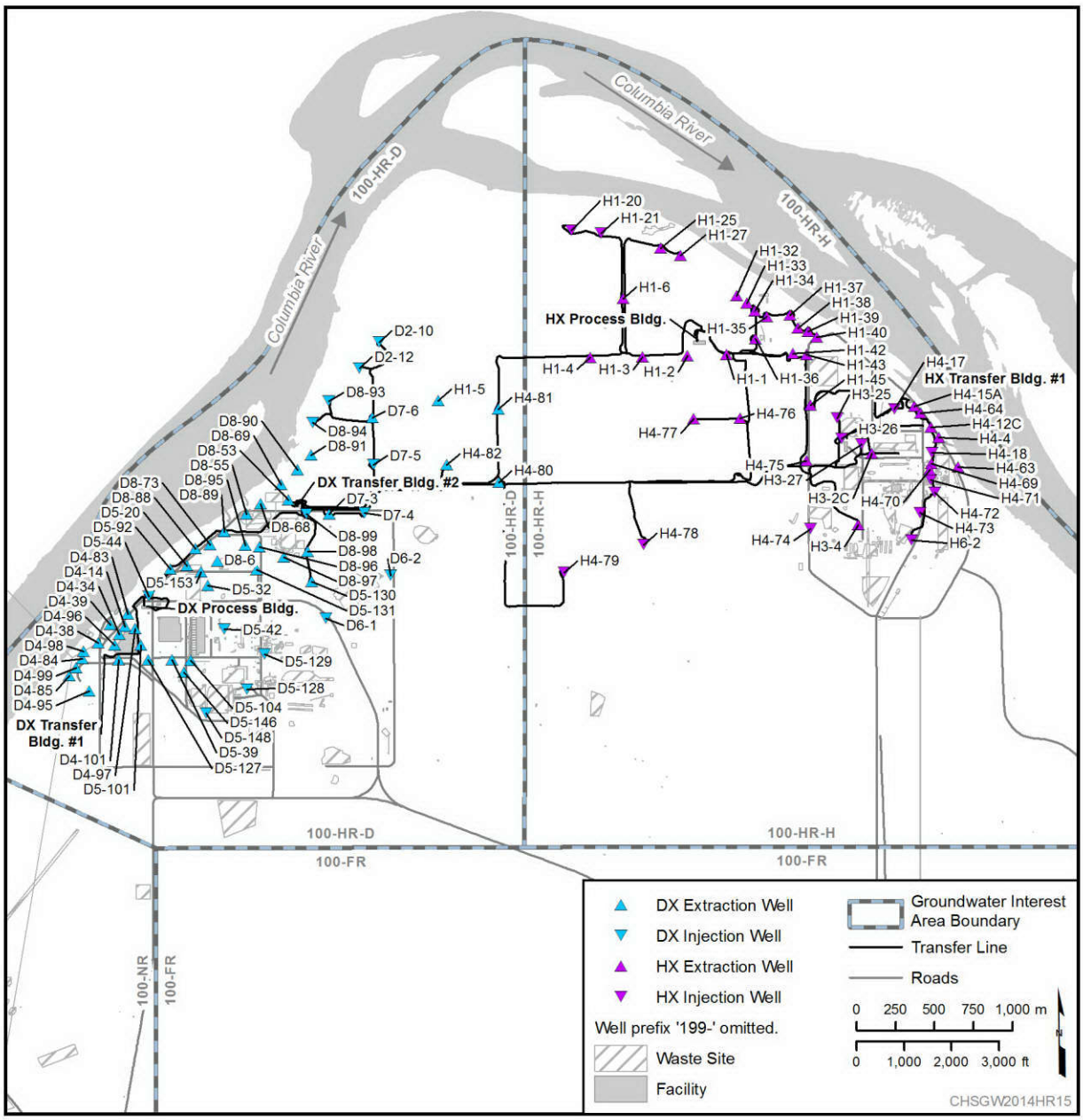

Figure 1-2. Layout of the 100-HR-3 OU P&T Systems (as of December 31, 2014)

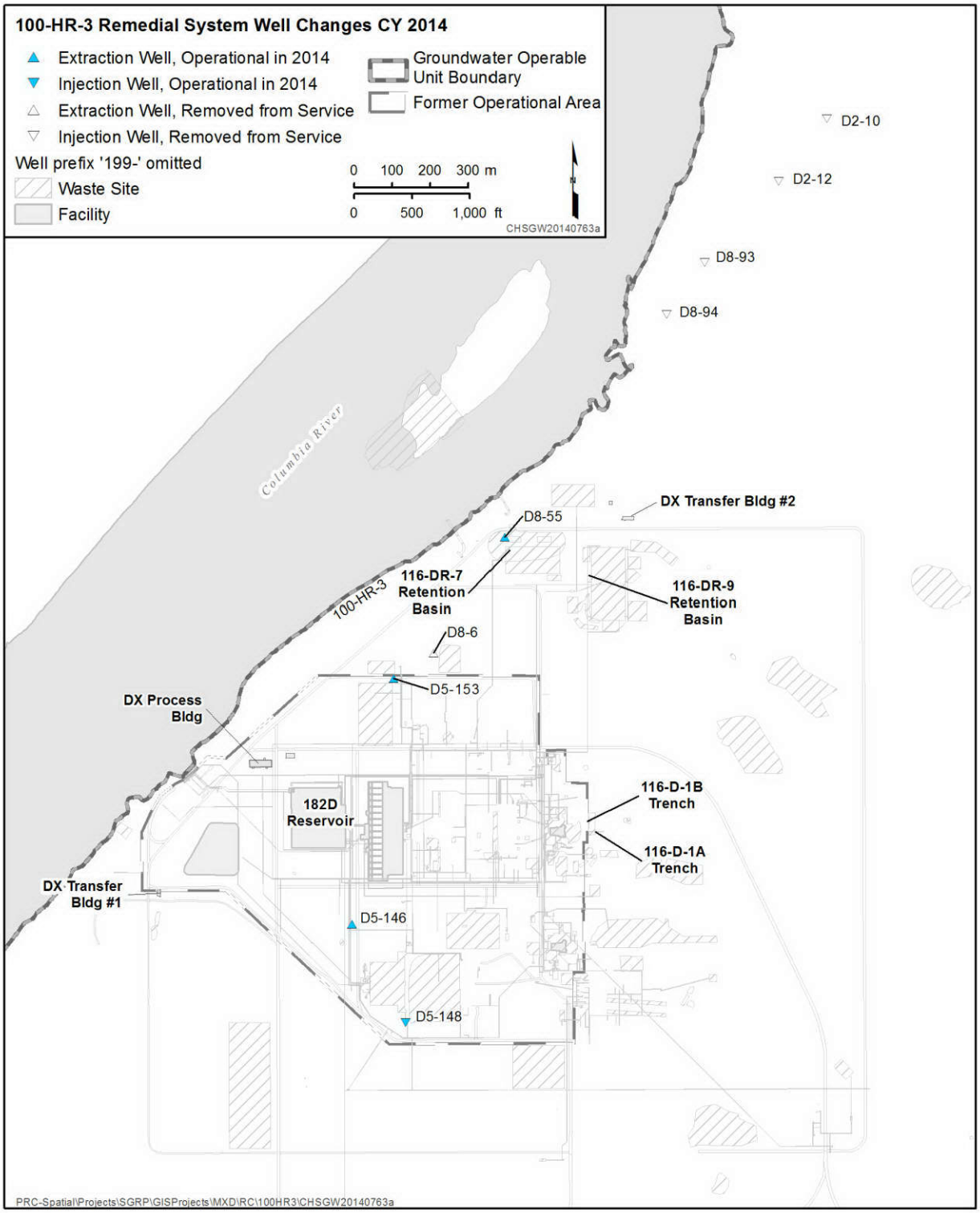

Figure 1-3. Well Changes to the 100-HR-3 OU P&T Systems in 2014

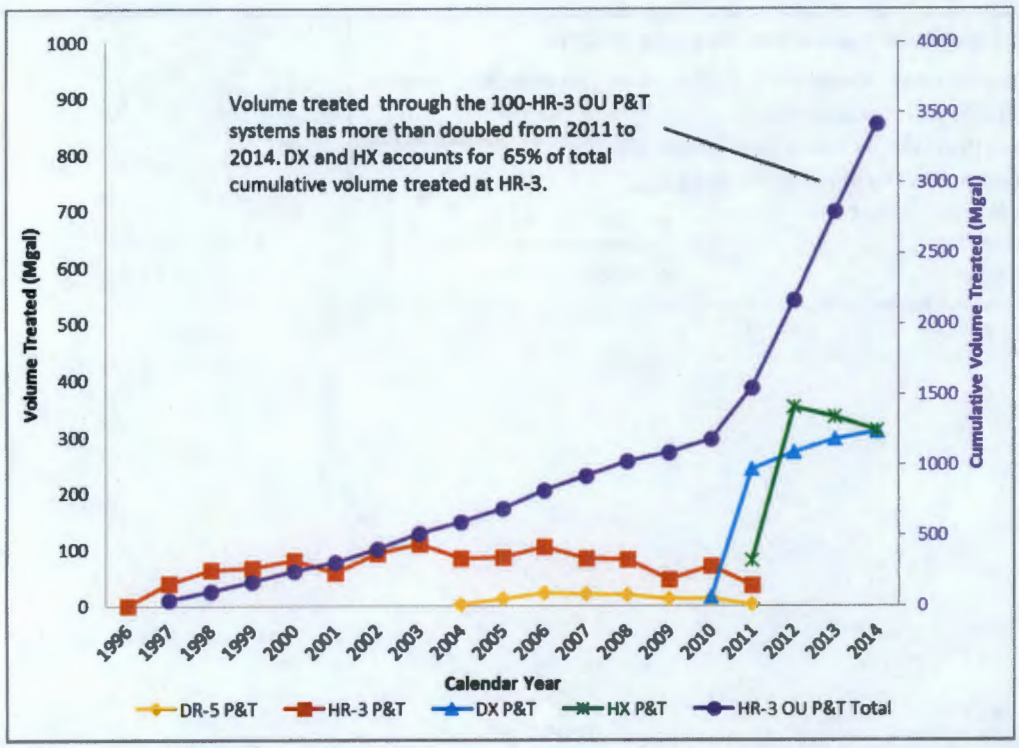

Figure 1-4. Volume Treated at the 100-HR-3 OU P&T Systems

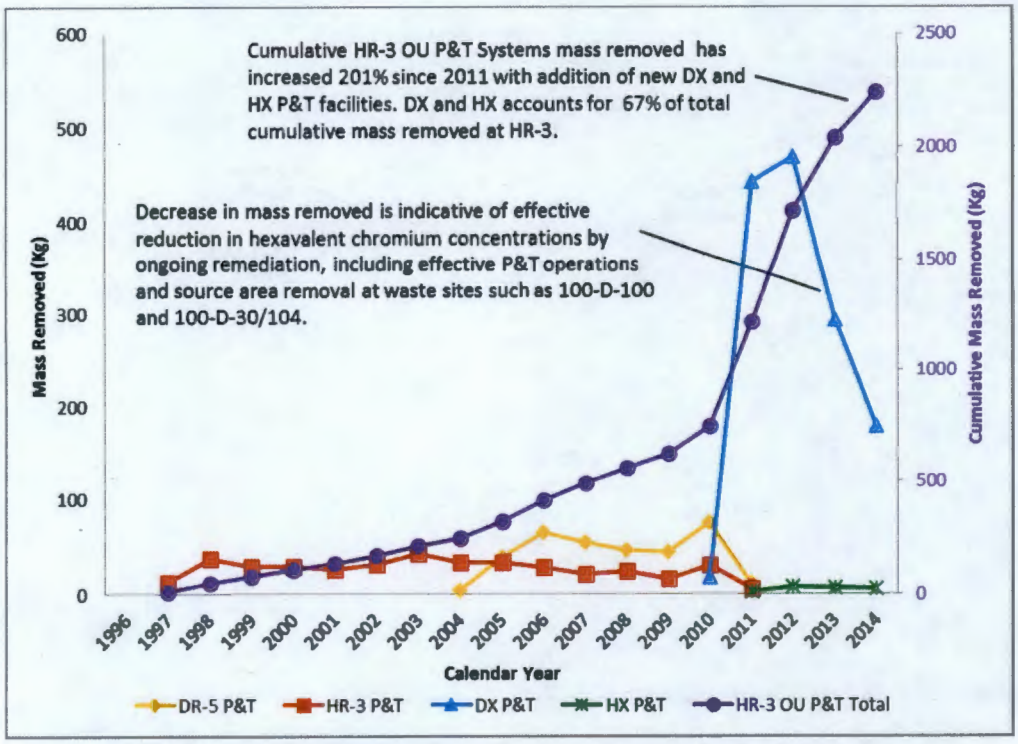

Figure 1-5. Cr(VI) Mass Removed by the 100-HR-3 OU P&T Systems

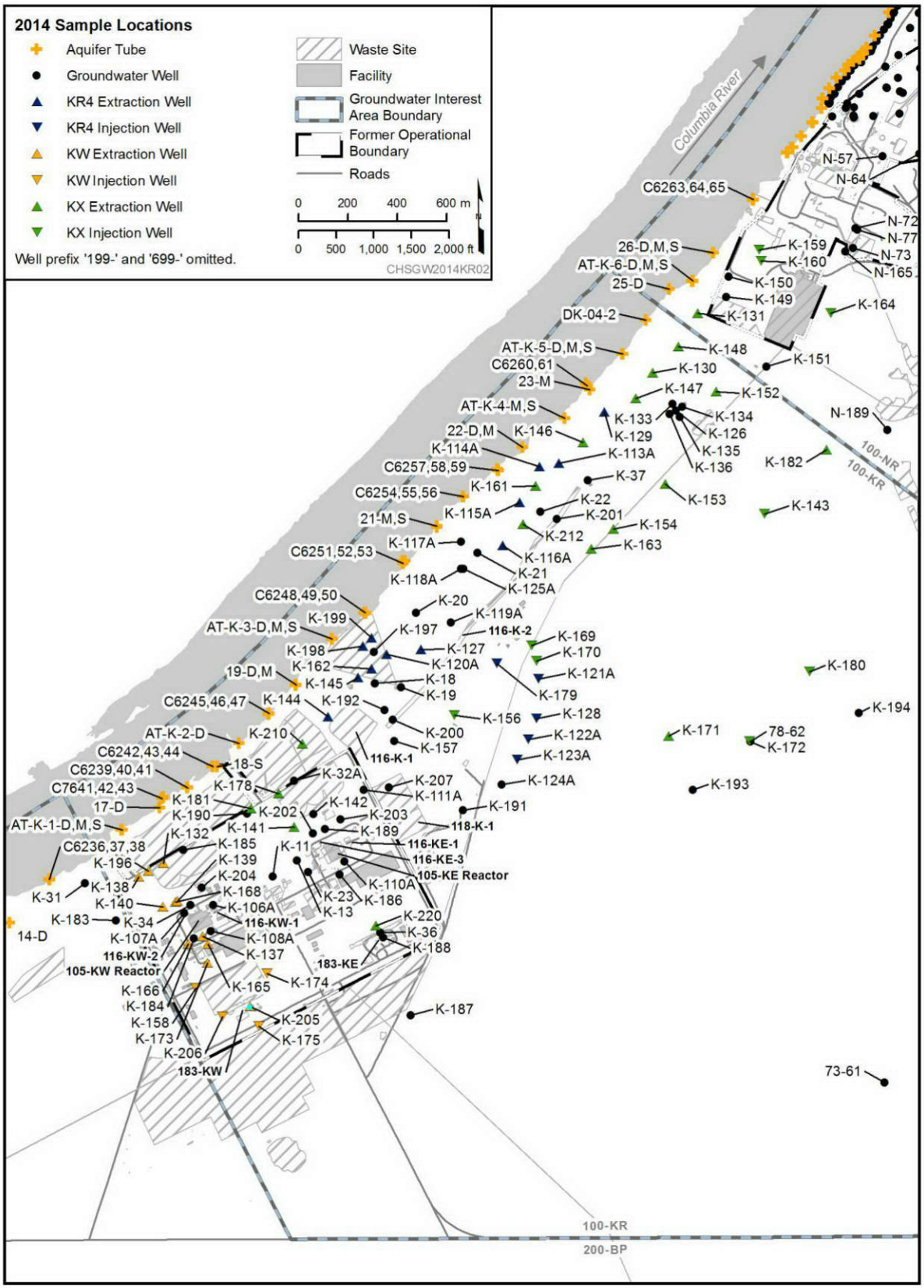

Figure 1-6. Layout of the 100-KR-4 OU P&T Systems

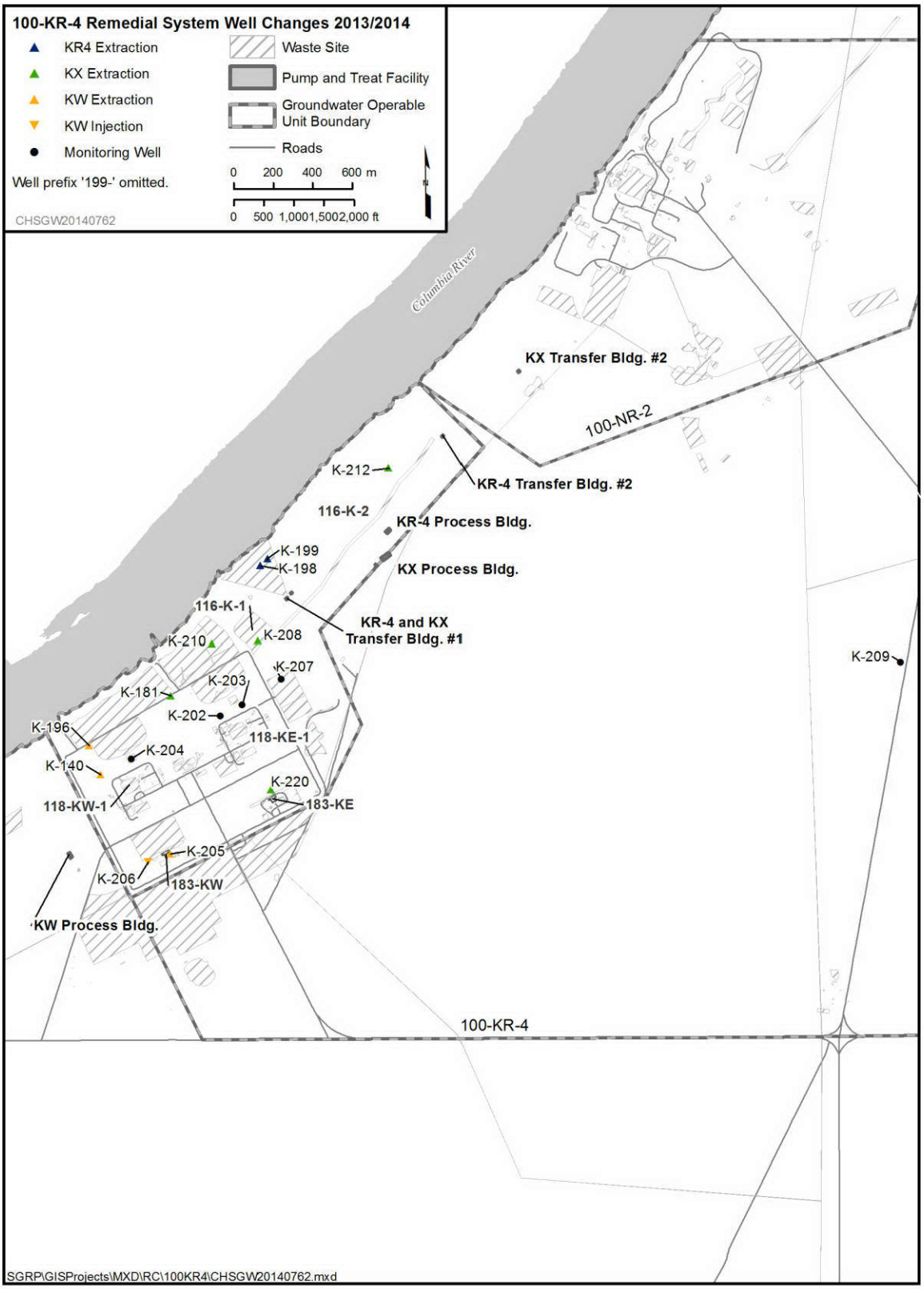

Figure 1-7. Extraction, Injection, and Monitoring Wells Added to the 100-KR-4 OU Well Network in 2014

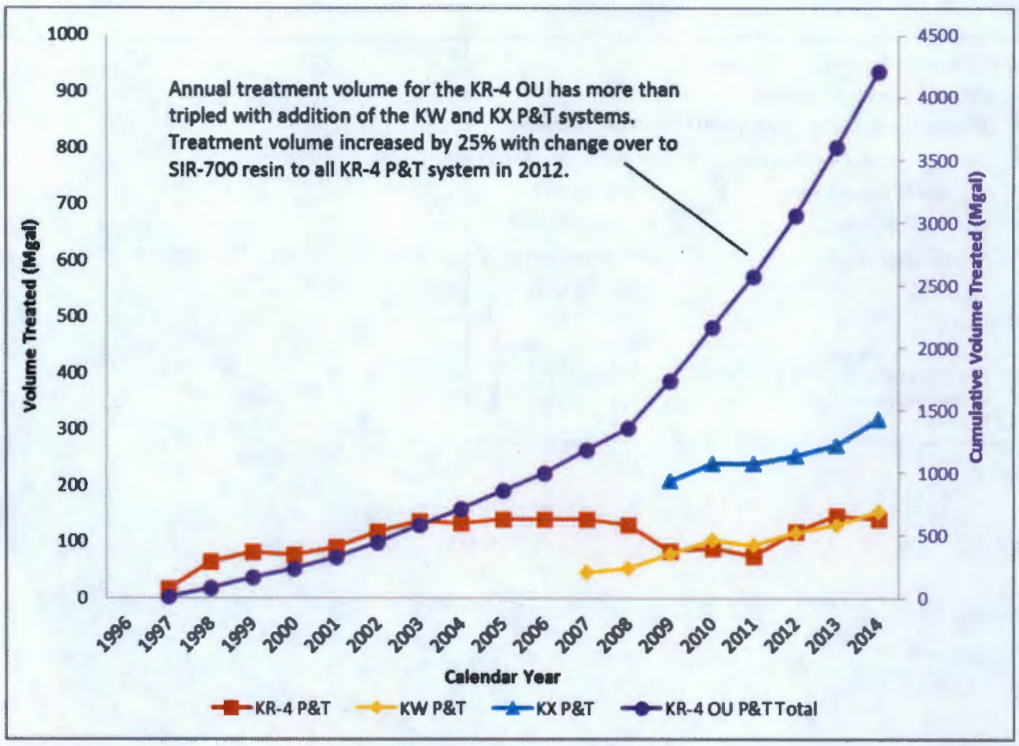

Figure 1-8. Volume Treated at the 100-KR-4 OU P&T Systems

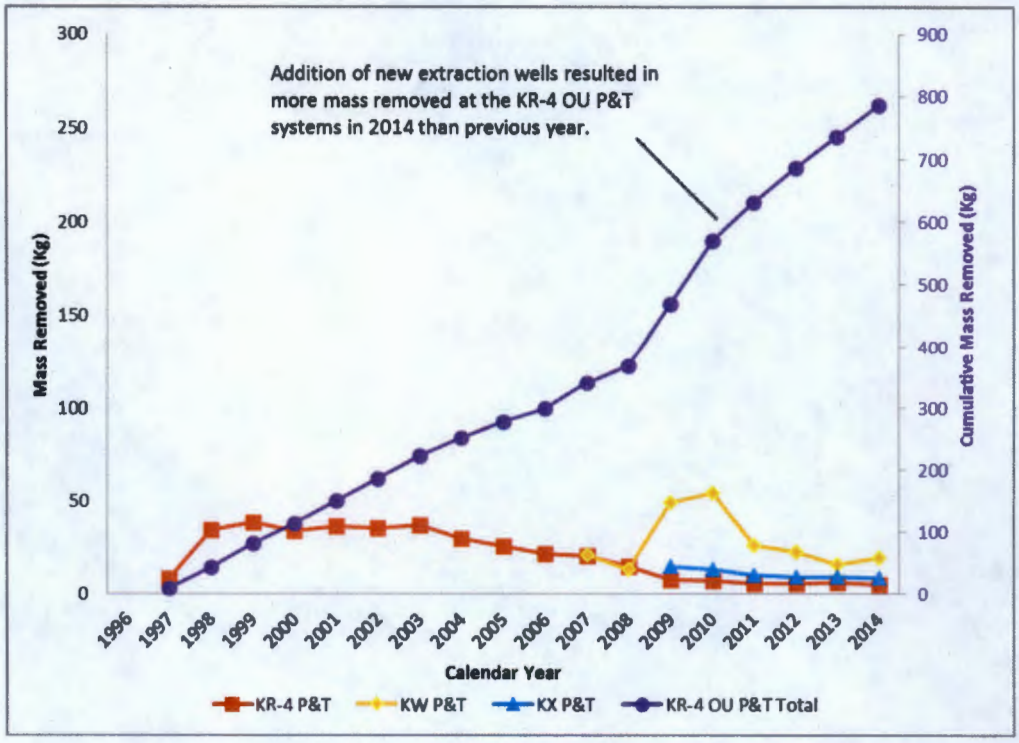

Figure 1-9. Cr(VI) Mass Removed by the 100-KR-4 OU P&T Systems

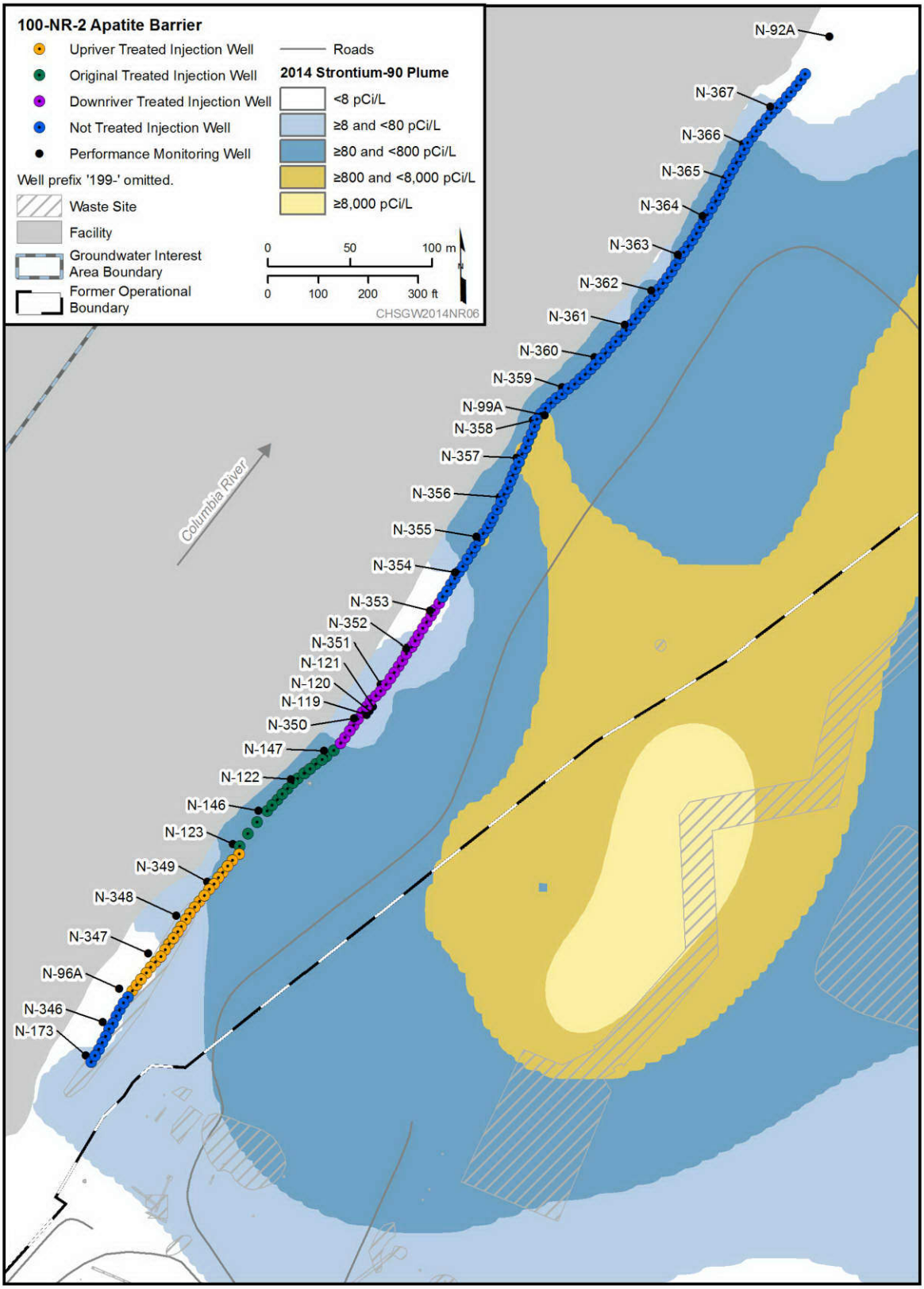

Figure 1-10. Original 100-NR-2 OU PRB with Upstream and Downstream Extensions

Table 1-1. 2014 P&T Performance Summary

Groundwater Operable Unit	100-HR-3		100-KR-4		
Pump and Treat System	**DX**	**HX**	**KW**	**KR4**	**KX**
Design capacity (L/min [gal/min])	2,273 (600)	3,030 (800)	758 (200)	1,136 (300)	2,273 (600)
Extraction wells	44	31	11	12	18
Injection wells	10	14	4	5	9
Average flow rate (L/min [gal/min])	2,233 (589)	2,240 (591)	1,105 (292)	1,002 (265)	2,278 (601)
Volume treated (million L [million gal])	1,174 (310)	1,178 (311)	580 (153)	527 (139)	1,199 (316)
Cr(VI) mass removed (kg)	178.7	22.8	19.4	5.0	25.8
Average Cr(VI) influent concentration (μg/L)	145	20.3	22.0	9.5	21.5
Average Cr(VI) effluent concentration (μg/L)	<2	<2	<2	<2	<2

Cr(VI) = hexavalent chromium

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2 100-HR-3 Operable Unit Remediation

This chapter describes the status of the interim remedies and other CERCLA activities for the 100-HR-3 Groundwater OU. The following discussion includes the interim remedy P&T system performance and ISRM barrier monitoring.

2.1 Summary of Operable Unit Activities

The 100-HR-3 OU consists of the groundwater contaminated by releases from facilities and waste sites associated with past operation of the D, DR, and H Reactors that underlie the 100-D Area, the 100-H Area, and the region between known as the Horn (Figure 2-1). The Cr(VI) released from facilities and waste sites poses a risk to human health and/or the environment and is the primary COC identified in the interim action ROD (EPA/ROD/R10-96/134) for groundwater in the 100-HR-3 OU. Groundwater co-contaminants identified in this interim remedial action scope are nitrate, strontium-90, and tritium. Uranium and technetium-99 are currently monitored as part of the *Resource Conservation and Recovery Act of 1976* (RCRA) permit for the 183-H Solar Evaporation Basins.

The interim remedial action ROD (EPA/ROD/R10-96/134) for the 100-HR-3 OU defined the cleanup goal for Cr(VI) in groundwater discharging to the Columbia River as the current ambient water quality criterion of 11 µg/L. Based in part on the expectation that contaminated groundwater (prior to discharging to the river) is mixed on a 1:1 basis with relatively uncontaminated water within a near-shore mixing zone along the river, attaining less than 22 µg/L of Cr(VI) in the compliance monitoring well network is consistent with achieving this RAO. The explanation of significant differences (ESD) for the 100-HR-3 and 100-KR-4 OUs (EPA et al., 2009, *Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision: Hanford Site, Benton County, Washington*) reduced the groundwater remediation target to 20 µg/L to meet the revised surface water quality criterion of 10 µg/L. Consequently, a compliance criterion of 20 µg/L for Cr(VI) in groundwater is currently applied to near-shore and compliance wells along the river. The drinking water standard (DWS) for total chromium remains at 100 µg/L. Ecology has established a Method B groundwater cleanup level of 48 µg/L for Cr(VI) under WAC 173-340, "Model Toxics Control Act—Cleanup."

To mitigate the risks associated with Cr(VI) contamination in groundwater discharging to the river, DOE initially installed a CERCLA interim action P&T system in the 100-HR-3 OU in 1997. The P&T interim remedial actions were implemented under DOE/RL-96-84, *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*, in accordance with the interim ROD (EPA/ROD/R10-96/134). A second P&T system, DR-5, was installed in 2004. In 2010, the two original systems were replaced with the larger DX and HX P&T systems, and both are currently operating. In addition, an ISRM barrier was installed in the southern portion of the 100-D Area starting in 2000. Due to breakthrough of contaminants at the ISRM barrier, a notice of nonsignificant change to the ROD was issued in 2010, which indicated that the barrier would no longer be actively maintained (11-AMCP-0002). The notice of nonsignificance change shifted the groundwater remedy at the ISRM barrier to the P&T system but maintained monitoring of the ISRM. The active interim action remedy in the 100-HR-3 OU is P&T and consists of the DX and HX P&T systems. The intent of the current interim remedial actions is to meet the RAOs described in Chapter 1.

Monitoring, data evaluation, and site characterization activities are conducted each year in an ongoing effort to determine the 100-HR-3 OU P&T systems' performance compared to design criteria, whether system design modifications or operating parameters will further optimize performance, and the measurable progress toward achieving plume cleanup and river protection RAOs. This chapter discusses the results of the 2014 100-HR-3 OU P&T evaluation and includes the following:

- Section 2.2 discusses the interim action groundwater-remediation activities, including the condition of ISRM.
- Section 2.3 provides the remedial action cost summary.
- Sections 2.4 and 2.5 include the conclusions and recommendations, respectively, for the 100-HR-3 OU.

2.1.1 100-HR-3 Operable Unit Pump and Treat Systems

This subsection describes the general operating status and notable modifications to the 100-HR-3 OU interim action P&T systems during 2014.

Changes to remedial systems during 2014 consisted primarily of constructing additional wells for extraction and injection as well as realigning an existing injection well for use as an extraction well. These actions were intended to enhance hydraulic plume capture, reduce Cr(VI) plume concentrations, and remove mass from source areas. In addition, one new well was constructed in 2014 and is planned for connection to the P&T system for extraction in early 2015. Changes to the remedial systems are shown in Table 2-1. The locations of the new and realigned wells in 2014 are shown in Figure 1-3.

Figures 2-2, 2-3, and 2-4 present the 2014 extraction, injection, and monitoring well locations for the 100-D Area, the ISRM portion of 100-D, and the 100-H Area, respectively. Figure 2-5 shows the well and aquifer tube locations in the Horn. The layouts of the P&T systems are shown in Figure 2-6.

2.1.2 In Situ Redox Manipulation Barrier

Prior to installation of the DX P&T system, additional cleanup action was deemed necessary in the southern portion of the 100-D Area. As approved by the 1999 interim ROD amendment (EPA/AMD/R10-00/122), an in situ chemical treatment technology was applied in 2000. The ISRM barrier (Figure 2-3) was installed to treat groundwater in the aquifer by reducing Cr(VI) to trivalent chromium, which is a much less toxic and less mobile form. However, due to breakthrough of contaminants at the ISRM barrier, Ecology issued a notice of nonsignificant change to the ROD in 2010, which indicated that the barrier would no longer be actively maintained (11-AMCP-0002). The notice of nonsignificance change shifted the groundwater remedy at the ISRM barrier to the P&T system. Groundwater at the ISRM site is still monitored for Cr(VI) and dissolved oxygen (DO) as part of CERCLA interim action monitoring, with Cr(VI) as the target contaminant. The DO is monitored along the barrier since the treatment process reduces oxygen content in the aquifer.

The DO levels along most of the ISRM barrier have returned to normal or near normal levels, with most wells indicating DO greater than 6 mg/L. An area of lower DO levels is present within the barrier, between Wells 199-D4-19 and 199-D4-36 (Figure 2-7). The oxygen levels on the downgradient side of the barrier are at normal levels. A second area of lower DO levels is located near the former treatability test wells (Wells 199-D5-107 and 199-D5-108). The low DO in this second area does not extend much beyond the two test areas, which are limited to the two clusters of wells as described in PNNL-18784 (*Hanford 100-D Area Biostimulation Treatability Test Results*).

The Cr(VI) concentrations in barrier wells in 2014 ranged from below detection limits to 160 µg/L at Well 199-D4-22, which is a reduction from previous years. The Cr(VI) concentration in groundwater flowing across the ISRM barrier trended downward throughout the year. The declining concentrations are attributed to the increased effectiveness of the P&T system with the conversion of Wells 199-D4-14 and 199-D4-34 from monitoring to extraction wells in August 2013 to increase protection in the northern portion of the barrier where most elevated Cr(VI) concentrations continue to be present.

2.2 CERCLA Operable Unit Interim Action Activities

This section discusses the CERCLA activities for the 100-HR-3 OU during the reporting period, including activities related to operation and performance monitoring of the DX and HX P&T systems during 2014. Specific activities and operational performance details for these systems include system configuration changes and availability, contaminant mass removed during operation, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, and waste generation.

2.2.1 DX Pump and Treat System

The DX P&T system (Figure 2-8) was designed to capture and treat the Cr(VI) plume located in the 100-D Area, which is typically discussed as the 100-D "northern" and "southern" plumes. Releases of highly concentrated stock solution of sodium dichromate to the environment through spills, washout of vehicles and containers, and leaks in the conveyance system resulted in a high concentrations of Cr(VI) in the groundwater in the southern plume of the 100-D Area. Disposal of large volumes of reactor cooling water to cribs and trenches and smaller releases of sodium dichromate solution resulted in Cr(VI) contamination of the groundwater in the northern portion of the 100-D Area. Since startup of the DX P&T system in 2010 to the end of 2014, the system has treated over 4,277 million L (1,130 million gal) of groundwater and has removed 1,400 kg (3,086 lb) of Cr(VI). During 2014, the DX process plant included 43 extraction wells, and 10 injection wells (Figure 2-9) treating up to 112 million L (29.5 million gal) in a single month. Treated water is returned to the aquifer through the injection wells.

The DX P&T system utilizes ResinTech SIR-700 resin to bind Cr(VI) as influent groundwater flows through tanks in the treatment facility. The new resin does not need to be replaced as often as the previous resin type, saving time and money. The resin changes for DX vessels started in August 2014 and were completed in April 2015. The DX P&T system improved the groundwater treatment capacity along the river and is a key component in DOE's strategy for keeping Cr(VI) from entering the Columbia River. Changes in concentrations and overall trends are discussed in Section 2.2.3.

2.2.1.1 DX Pump and Treat System Configuration and Changes

The annual evaluation of the plume capture from 2012 (DOE/RL-2013-13, *Calendar Year 2012 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*) was used to identify areas along the Columbia River where additional plume capture was needed. This evaluation guided the system changes during 2013. In 2013, the plume capture evaluation (DOE/RL-2014-25) identified areas for additional system modifications and assisted in the assessment of the previous changes. A summary of the 2013 system modifications and the effect of those changes to the 2014 plume are discussed below, as well as the changes conducted in 2014 and their effects (where realized).

Changes to the DX P&T system during 2013 and the resultant effect in 2014 are as follows:

- Two wells within the ISRM barrier (199-D4-14 and 199-D4-34) were connected to the DX P&T system as extraction wells in late 2013. The wells were converted to extraction wells primarily to increase capture from the area near the ISRM barrier. Capture appears to have improved in that area during 2014 as a result of this modification with the Cr(VI) plume being pulled back from the river as shown in Figure 2-17 and discussed in Section 2.2.5.
- Wells 199-D8-53 and 199-D8-68 were converted from monitoring to extraction wells to improve the hydraulic capture of the northern 100-D plume area. Capture in that area has improved, with flows in Well 199-D8-68 averaging 143.8 L/min (38 gal/min) year around.

The 2014 system changes (Figure 1-3) include the following:

- Injection Wells 199-D2-12, 199-D2-10, 199-D8-94, and 199-D8-93, which have limited injection capacity at high river stage, were taken out of service but remain connected.
- New extraction Well 199-D5-146 was placed in operation and began extracting groundwater for treatment in mid-2014. The well was installed in 2013 and is located downgradient of the 100-D-100 waste site, which is an area of increasing Cr(VI) concentrations. Well 199-D5-146 has been operating at 94.6 L/min (25 gal/min) and has been drawing contaminants toward this well. Concentrations increased from about 30 to 65 µg/L during 2014.
- Injection Well 199-D5-148 was also drilled during 2013, upgradient of the 100-D-100 waste site, and became operational in mid-2014. This well accepts over 378.5 L/min (100 gal/min) and increases the groundwater velocity towards the existing extraction well network due to a steepened gradient.
- Wells 199-D5-153 and 199-D5-154 were drilled in the 100-D north plume in 2012. Extraction operations began in Well 199-D5-153 in June 2014. Due to accessibility issues from waste site excavation activities, the connection of Well 199-D5-154 to the treatment system was postponed until early 2015. The new extraction wells are located in an area of high concentrations of Cr(VI) and downgradient extraction wells have low flow rates. As a result of extraction operations at Well 199-D5-153, the concentrations in downgradient wells have declined and capture has improved (Section 2.2.5). When Well 199-D5-154 comes on line, capture and mass removal are both expected to increase.
- Well 199-D8-55 was converted from injection to extraction use starting in 2013 and was operational for extraction by mid-2014. This well is located near the river along the 100-D northern plume, adjacent to extraction Wells 199-D8-68 and 199-D8-89 (Figure 2-2). Evaluation of the flow regime near the river indicated that conversion of Well 199-D8-55 to an extraction well would potentially improve capture along the 100-D north plume. As indicated by Figure 2-25 (and as discussed in Section 2.2.5), capture appears to have improved in this area. The well pumping rate is less than 37.9 L/min (10 gal/min); however, there has been an increase in capture efficiency of nearby extraction Wells 199-D8-68 and 199-D8-89 and, therefore, an overall increase in river protection in that area.
- The 2014 system modifications included taking extraction Well 199-D8-6 out of service. Calcite buildup in this well caused the pump to become inoperable. Calcite in this location is directly related to the geochemistry of the groundwater below the coal ash waste site where the well is located. Well 199-D5-159 is planned for installation in 2015 to replace Well 199-D8-6. The well will be placed slightly upgradient from the coal ash waste site in order to eliminate the concern of calcite in the new well.
- The caustic piping in the treatment system was rerouted in 2014 in an attempt to reduce calcite buildup in the effluent piping and tank. Modifications to the piping are ongoing. There were no other changes to the treatment system conducted in 2014.

The DX P&T system will be continue to be optimized using available source area data; groundwater monitoring data; updated contaminant fate and transport modeling results; and extraction/injection well performance data.

2.2.1.2 *Treatment System Performance*

The DX P&T system operated full time throughout 2014. Table 2-2 presents the summary of groundwater extracted, mass removed, and system performance for the DX P&T system. The DX P&T system extracted 1.17 billion L (310 million gal) of water in 2014, an increase of nearly 53 million L (14 million gal) from 2013. The system removed 179 kg (394 lb) of Cr(VI) during the reporting period, compared to 294 kg (648 lb) in 2013 and 469 kg (1,034 lb) in 2012. This reduction in total Cr(VI) mass removed is primarily a result of rapidly declining Cr(VI) concentrations in the high-concentration areas, such as the middle of the 100-D southern plume.

The influent and effluent concentrations for the treatment systems are shown in Figure 2-10. The average influent Cr(VI) concentration in 2014 was 145 µg/L. The high influent concentration of 694 µg/L (Figure 2-10) is suspect since this value is twice as high as the concentrations reported in prior and subsequent samples and is out of trend with Cr(VI) concentrations observed in the DX extraction wells. The effluent concentration was below the laboratory detection limit for effluent samples collected in 2014, with the maximum reported nondetect at 8 µg/L. The average reported effluent concentration was less than 2 µg/L. The average removal efficiency for 2014 was 99 percent, and the system operated at an average rate of approximately 2,233 L/min (589 gal/min). The influent concentration predominantly reflects the concentrations from extraction Wells 199-D5-39 and 199-D5-104, which extract from the southern plume hot spot. The declining influent concentration trend is a result of significant mass removal in that area.

Figure 2-11 shows the system availability for the reporting period. The system operated over 99 percent of the time in 2014, with short downtimes for corrective maintenance. As reflected in Figure 2-11, the total flow rate through the DX P&T system (in terms of percentage of system capacity) is reduced slightly during periods of system and well maintenance and reconfiguration of piping. Overall system throughput increased as a result of the various system modifications.

Table 2-3 presents the pumping flow rates and total run-time for the extraction and injection wells currently active in the DX P&T system. The flow rate was calculated by dividing the total volume extracted for the period by the hours of pumping. Figure 2-12 shows the hydrograph for the Columbia River at the 100-D and 100-H Areas. Operational downtime of extraction and injection wells due to downtime (e.g., low water in wells during low river stage, repair, and/or maintenance) is reflected in the yearly average flow rate calculations and the total run-time percentages for each extraction well.

Several wells have low operational run-time percentages. Three new wells were added to the system during 2014 and became operational in mid-2014: 199-D5-146, 199-D5-148, and 199-D5-153. Well 199-D8-55 was converted from injection to extraction use, and this transition resulted in some downtime during reconfiguration. Low river stage affected production at Well 199-D5-20. Well 199-D8-6, which had precipitate accumulation that fouled the pump, was removed from service. Injection Wells 199-D2-12, 199-D2-10, 199-D8-94, and 199-D-93, which have limited injection capacity at high river stage, were taken out of service.

2.2.2 HX Pump and Treat System

The HX P&T system (Figure 2-13) became fully operational in 2011 with a treatment capacity of 3,000 L/min (800 gal/min). The treatment capacity is currently being upgraded through splitting the treatment trains. The design of the HX P&T system is described in SGW-43616, *Functional Design Criteria for the 100-HX Pump and Treat System*. The design and operational philosophy optimizes containment along the river, and containment and removal of the mass in areas with higher contamination. During 2014, the HX P&T system included 31 extraction wells, 14 injections wells

(Figure 2-14), and over 87 km (54 mi) of piping to bring groundwater to the facility, treating as much as 129 million L (34.1 million gal) of water in a single month. There were no treatment system modifications during 2014.

ResinTech SIR-700 is used to treat the Cr(VI) as it flows through tanks in the HX treatment facility. This is the same technology that is used at the DX P&T system. The resin capacity at HX has not been exceeded and replacement of resin in the IX vessels has not been necessary since startup of the HX P&T.

2.2.2.1 System Configuration and Changes in 2014

Extraction Well 199-H1-3 had minimal flow during 2014 and was turned off late in the year, but remains connected to the system. No other configuration changes were made to the HX P&T system during 2014. System optimization is ongoing while groundwater remediation activities continue toward meeting Tri-Party Agreement (Ecology et al., 1989) remediation goals. Evaluation of areas of potential contaminant impact to the Columbia River were identified in 2014. As a result, several modifications are planned for 2015 to address these needs.

Up to 11 new wells are planned for installation in the Horn and the 100-H Area. These new wells will be primarily extraction wells. New extraction wells placed in the Horn will be constructed with larger diameters (25.4 cm [10 in.]) than previous extraction wells to increase flow rates. The new wells are being placed in areas with residual mass, with the intent of causing the overall plume to shrink and to remove the area of higher mass within the central Horn area.

Well realignments are focused on several goals: (1) isolating the H Reactor area from the plume migrating across the Horn, (2) shifting pumping areas to those with higher Cr(VI) concentrations, and (3) allowing rebound in the reactor area in order to determine if residual sources are present. Plans for realignment include turning several extraction and injection wells within the reactor area off and converting wells from injection to extraction or from extraction to injection, depending on the location.

2.2.2.2 Treatment System Performance

The HX P&T system extracted 1,177 million L (311 million gal) of groundwater from the 100-H Area in 2014, which is essentially the same volume of water treated in 2013 and 2012. The mass removed decreased slightly from 27 kg (59.5 lb) of Cr(VI) in 2013 to 23 kg (50.7 lb) in 2014. The decrease in mass removed is due to a slightly lower volume of water treated and removal of mass overall. A summary of operational parameters and total system performance for the HX P&T system is presented in Table 2-4.

The average influent Cr(VI) concentration in 2014 was 20 µg/L. The average effluent concentration for the reporting period was less than 2 µg/L. The influent and effluent concentrations for the treatment systems are shown in Figure 2-15. The average removal efficiency for 2014 was 96 percent. The system operated at an average rate of approximately 2,240 L/min (591 gal/min) during 2014. Slightly higher influent concentrations are observed during the winter and fall; this seasonal fluctuation is reflective of the decreased pumping rates at extraction wells closer to the river shoreline as water levels in the wells decline. In comparison, pumping rates from extraction Wells 199-H3-2C and 199-H4-12C, which extract groundwater from the first water-bearing unit in the Ringold upper mud unit (RUM), have relatively constant pumping rates and high Cr(VI) concentrations.

Figure 2-16 shows the system availability for the reporting period. The system operated nearly 99 percent of the time in 2014, with short downtimes for corrective maintenance. As reflected in Figure 2-16, the total flow rate through the HX P&T system (in terms of percentage of system capacity) was reduced during system outages, as well as during periods of low river stage, because pumping rates are reduced at extraction wells closer to the river shoreline as water levels in the wells decline with river stage.

Along the northern and eastern portions of the Horn, as well as in the 100-H Area, the aquifer thickness ranges from zero to about 6 m (0 to 20 ft), depending on the river stage. There is often less than 3 m (10 ft) of available water in extraction wells during large portions of the year. As a result, pumping from these wells is unreliable during low river stage since an insufficient amount of water over the top of the submersible pump is present to allow operation. Wells in this area that have lower run times include 199-H1-6, 199-H1-32 and 199-H1-33 (Table 2-5). Modifications to the system such as alternative well construction (e.g., using horizontal wells or larger diameter wells) and manipulation of the groundwater flow regime by using injection water to push contaminants toward extraction wells are being evaluated as an overall strategy to address low water periods.

Table 2-5 presents the pumping flow rates and total run-time for the extraction and injection wells currently active in the HX P&T system. The flow rate was calculated by dividing the total volume pumped by the hours of pumping. Operational downtime of extraction and injection wells (e.g., low water in wells during low river stage, repair, and/or maintenance) is reflected in the yearly average flow rate calculations and the total run-time percentages for each extraction well.

Several wells had low (less than 75 percent) operational run-time percentages in 2014, including Wells 199-H1-3, 199-H1-32, 199-H1-33, 199-H1-39, and 199-H4-4. These wells are located in areas that have a thin aquifer, low flows, and periods of nonoperation during low river stage. Other wells along the river also experienced periods of low flow rates, but the pumps were operating. Well 199-H1-3 was removed from service during 2014 due to low production rates. Well 199-H4-76, located in the Horn in an area with a thicker aquifer, also experienced reduced operational frequency during the year, primarily related to river stage. Older Well 199-H4-4 is located along the river but has low operational run-times due to the thin aquifer combined with apparent construction constraints.

2.2.3 Performance Monitoring

Control of Cr(VI) in groundwater remains the principal objective of the active groundwater interim remedial action at 100-HR-3 OU. Nitrate, strontium-90, tritium, uranium, and technetium-99 are listed in the interim action ROD for the OU (EPA/ROD/R10-96/134) as co-contaminants and are monitored as part of the remedial action. The ROD acknowledges that other nonchromium groundwater contaminants are not treated by the interim action remedy. Sulfate is a contaminant of interest because the secondary DWS (250 mg/L) has previously been exceeded in a limited number of wells, primarily due to sodium dithionite solution injections during the ISRM barrier installation.

Contaminant concentration data are collected each year from 100-HR-3 OU compliance wells, other monitoring and extraction wells, and aquifer tubes within the OU. The sampling data are used to update the status of the plumes and to evaluate the effectiveness of ongoing remedial activities. Particular emphasis is given to data collected during the fall of each year, when river levels are low and contaminant flux toward the river is highest. Tables 2-6 through 2-8 depict the highest 2014 concentrations for Cr(VI), total chromium, nitrate, strontium-90, tritium, technetium-99, sulfate, uranium, gross alpha, and gross beta emitters for the various areas within the 100-HR-3 OU that are described in the following subsections. This report focuses on evaluating the analytical results for Cr(VI) being remediated through the interim action P&T systems. Further summary and analysis of the other COCs and contaminants of interest are presented in the annual groundwater monitoring report (DOE/RL-2015-07).

Tables 2-9 through 2-11 present the fall 2014 monitoring results for Cr(VI) at the 100-HR-3 OU. Where data for the fall of 2012 and 2013 were previously collected at the locations monitored during the fall of 2014, the older data are included in these tables for comparison. In wells where sufficient data were available, the concentration trends between the fall of 2012 and 2014 were evaluated. Additionally, the data summary tables present percent increases or percent decreases in the concentrations between 2012 and 2013, and between 2013 and 2014. CERCLA system performance assessment addresses longer term changes in Cr(VI) concentrations at selected monitoring and extraction wells in the 100-HR-3 OU.

Figures 2-17 and 2-18 illustrate the Cr(VI) plumes during periods of low river-stage and high river-stage in 2014 for the 100-D and 100-H Areas, respectively. Contaminant plume maps in this report are based on average results for samples collected either during the low-river period or high-river period in 2014 for each well shown. During high river stage periods, many of the aquifer tubes become submerged and unable to sample, or samples would be mostly diluted with river water, so most aquifer tubes in the 100-HR-3 OU are only sampled during low river stage. Aquifer tube samples collected during the low river-stage period detected Cr(VI) at some locations along the length of river shore at the 100-HR-3 OU. The Cr(VI) values measured in the aquifer tubes at low river stage were assigned to the aquifer tube locations for both high and low river-stage plume map constructions (Figures 2-17 and 2-18)) because the high river elevation in 2014 was lower than the high river elevations measured in previous years by approximately 1.5 m (4.9 ft) resulting in a reduced river stage induced hydraulic head at the shoreline. Contaminant plume maps were constructed by computer programs using a method called quantile kriging to produce a continuous spatial illustration of the contaminant distribution as described in ECF-HANFORD-15-0001, *Description of Groundwater Modeling Calculations and Assessments of the River Protection Objective for the Calendar Year 2014 (CY2014) 100 Areas Pump-and-Treat Report.* Tables 2-6, 2-7, and 2-8 summarize the maximum 2014 contaminant and co-contaminant (including contaminants of interest) concentrations detected in the 100-D Area (Table 2-6), 100-H Area, and Horn area (Table 2-7) wells, aquifer tubes, and wells completed in the first water-bearing unit of the RUM (Table 2-8).

The following subsections present the contaminant monitoring results. Further summary and analysis of contaminants and co-contaminants is presented in the annual groundwater monitoring report (DOE/RL-2015-07).

2.2.3.1 River Stage Effects

During the period of low river stage, groundwater beneath the 100-HR-3 OU flows toward the Columbia River in the 100-D and 100-H Areas. High river stage in 2014 included the seasonal rising portion of the hydrograph and extended through the falling portion of the freshet. The 2014 high-river stage period exhibited the highest stage (about 121 m [397 ft] above mean sea level [amsl]) occurring at two periods during early and late-June, with a substantially lower point (i.e., about 119 m [390.4 ft]) occurring in mid-June. The observed high river stage in 2014 was similar in peak stage elevation to that observed in 2013.

The seasonal river stage increase began about 1 month earlier in 2014 than in 2013 (Figure 2-12). The change in river stage was due to a controlled response to a crack in Wanapum Dam, upstream from the Hanford Site. The problem was observed in late February 2014, and the pool level behind Wanapum Dam was immediately lowered, which resulted in increased downstream river flow and the observed rapid increase in stage along the Hanford Reach. This response appears to have affected only the timing of the early part of the freshet at the 100-HR-3 OU, not the peak river stage. As the river stage rises toward its peak level, the water table surface also rises in response to the change in boundary condition at the river shore. With peak river stage occurring in a manner similar to that observed in 2013, conditions

are expected to have exhibited only minimal (if any) bank storage during 2014 due to natural river water intrusion into the adjacent aquifer.

Increased pumping rates at extraction wells near the Columbia River influenced river water intrusion into the aquifer at one location within the 100-D Area. During 2014, system modifications resulted in increased pumping rates at 100-D extraction wells. Groundwater specific conductance was mapped to evaluate the potential for migration of river water into the aquifer due to capture by pumping (Figure 2-19).

A specific conductance level of less than 200 μS/cm is indicative of river water (i.e., the Columbia River exhibits a relative low dissolved solids load and, thus, a low specific conductance). Specific conductance of 300 μS/cm, or greater, is typical of groundwater in former industrial operating area of the 100-HR-3 OU. Specific conductance of 200 to 300 μS/cm indicates a likely mixing of groundwater with river water. Seven well locations in the northern end of the ISRM barrier exhibited specific conductance less than 300 μS/cm. As shown in Figure 2-19, Wells 199-D4-4, 199-D4-5, 199-D4-6, 199-D4-23, 199-D4-31, 199-D5-38, and 199-D4-39 all exhibited specific conductance of less than 300 μS/cm. This is consistent with the inferred water table map that illustrates an area of groundwater capture (as indicated by a definable groundwater depression) in that area (Section 2.2.4).

2.2.3.2 Hexavalent Chromium

As described in Section 2.1, the cleanup goal for Cr(VI) in groundwater discharging to the Columbia River is the current ambient water quality criterion of 10 μg/L. This is based in part on the expectation that contaminated groundwater (prior to discharging to the river) is mixed on a 1:1 basis with relatively uncontaminated water within a near-shore mixing zone along the river. Consequently, a compliance criterion of 20 μg/L for Cr(VI) in groundwater is currently applied to near-shore and compliance wells along the river.

The Cr(VI) concentrations are monitored in wells and aquifer tubes in the 100-HR-3 OU. Figures 2-17 and 2-18 show high and low river-stage comparison of the distribution of Cr(VI) in the unconfined aquifer in the 100-D and 100-H Areas, respectively. In wells near the Columbia River, maximum Cr(VI) levels generally coincide with low river conditions and occur in late fall to early spring. The exception is where monitoring wells are located within a source area; in this case, the contaminant concentrations increase at high river stage. Tables 2-9, 2-10, and 2-11 compare the fall 2014 Cr(VI) concentrations from extraction wells, compliance wells, monitoring wells, and aquifer tubes to previous years and the first water-bearing unit of the RUM. The tables also include the percent changes in concentration for the 100-HR-3 OU unconfined aquifer wells and the RUM wells from 2012 through 2014.

Hexavalent Chromium in the 100-D Area

The southern 100-D plume (Figure 2-17) continues to have high Cr(VI) concentrations. The highest concentrations in the 100-HR-3 OU were detected in extraction Well 199-D5-104 (3,616 μg/L in February 2014). Areas with elevated Cr(VI) concentrations in 2014 remain in the following locations: near the 100-D-100 waste site, near Well 199-D5-103, near Well 199-D4-20, and at the northern end of the ISRM barrier. Overall, high-concentration areas continued to decline during 2014 in response to continued groundwater and source area remediation.

The 100-D-100 and 100-D-104/30 waste sites were excavated to the water table during 2014, with the 100-D-100 waste site excavated a few feet into the aquifer material. The removal of high concentrations of Cr(VI) from the vadose zone and aquifer resulted in overall reductions in Cr(VI) within the groundwater in those areas.

At the 100-D-100 waste site, data indicate that chromium-substitute calcite was precipitated in the periodically rewetted zone and within the aquifer sediment. Most of the chromium mass associated with the precipitate is found in the vadose zone near the water table and in the upper portion of the aquifer material. The presence of chromium-substitute calcite provides a slow leaching source of Cr(VI) to the aquifer, resulting in a long-term secondary source (SGW-58416, *Persistent Source Investigation at 100-D Area*). The discovery of this mineral led DOE to remove this source material from below the water table at 100-D-100. Removal of this type of secondary source material, where present, has the potential to greatly decrease the duration and cost of groundwater remediation. In extraction Well 199-D5-104, which is directly downgradient from the 100-D-100 waste site, Cr(VI) concentrations dropped from 5,392 µg/L in April 2013 to 465 µg/L on December 29, 2014. Throughout the 100-D Area, Cr(VI) concentrations have declined by an order of magnitude and were below 500 µg/L by the end of 2014.

The areas of higher concentrations (greater than 100 µg/L) remaining within the northern 100-D plume are located in the vicinity of the 120-D-1, 100-D Ponds waste site, the 126-D-1 Coal Ash waste site, and in the area northeast of those waste sites near the 100-D-31 underground pipelines. In general, wells upgradient of those waste sites have decreasing concentrations (199-D5-131, 199-D5-130, and 199-D8-97). Those wells near the waste site (199-D8-95, 199-D5-153, 199-D5-32, and 199-D8-4) and downgradient (199-D8-73, 199-D8-88, and 199-D8-89) show the effects of seasonal variations but no pronounced downward trend (Figures 2-20 and 2-21) indicating a possible vadose source. The overall footprint of the northern plume (greater than 10 µg/L) remained similar in shape to that of 2013.

To further improve river protection and increase mass removal, alterations to the DX P&T system were initiated in 2013 and 2014 (Section 2.2.1.1). The system modifications resulted in increased capture along the ISRM barrier and at the river along the northern plume, and increased mass removal near the 100-D-100 waste site and the middle of the northern plume.

Hexavalent Chromium in the Horn and 100-H Area

A portion of the chromium plume originated at the 116-DR-1&2 Trench and extends across the Horn to the 100-H Area (Figures 2-17 and 2-18). This plume encompasses the largest area in the 100-HR-3 OU, but concentrations in the unconfined aquifer remain consistently less than 100 µg/L. Ongoing remediation activities continue to reduce the contaminant levels; however, the presence of a thin aquifer limits the effectiveness of the extraction wells.

The highest concentrations in the unconfined aquifer in the Horn are found in extraction Wells 199-H4-75, 199-H4-76, and 199-H4-77, located just west of the 100-H Area. Concentrations in these extraction wells ranged from 41 to 60 µg/L in 2014, representing little change from 2013 levels. The slow decline in concentrations is likely related to the thin aquifer, which results in extraction rates to less than 75.7 L/min (20 gal/min) in these wells. As previously discussed, the planned system modifications in 2015 are designed to increase extraction flow rates in the Horn. The general shape of the Cr(VI) plume and the areal footprint of Cr(VI) above 10 µg/L have changed little over the last year. The plume continues to migrate along the interpolated zone of higher hydraulic conductivity south of the 100-H Area.

Hexavalent Chromium in the Ringold Formation Upper Mud Unit

Concentrations near the river at the 100-H Area ranged from below detection limits (Wells 199-H3-10 and 199-H2-1) to a high of 141 µg/L (199-H3-9) during 2014. Extraction Wells 199-H4-12C and 199-H3-2C are connected to the HX P&T system. Concentrations in these wells remain fairly constant at 120 µg/L and 65 µg/L, respectively, with a slow decline over time. Since Well 199-H3-9 has concentrations greater than 100 µg/L, it will be connected to the HX P&T system during 2015 to improve mass removal from the RUM unit.

Across the Horn, the highest Cr(VI) concentrations in the RUM were detected in Well 699-97-48C at 78.2 µg/L, which is a decline from 105 µg/L in 2013. Approximately 1,100 m (3608.9 ft) to the east of Well 699-97-48C, however, the Cr(VI) concentrations in RUM Well 699-97-45B increased from below detection to 7.40 µg/L. While this is a small increase, it is potentially significant, and possibly indicates the front of the Cr(VI) plume as it moves from west to east across the Horn. New wells are planned for installation in 2015 to determine the extent of the Cr(VI) plume in the Horn. Figure 2-22 depicts the Cr(VI) concentrations in the RUM.

2.2.3.3 Sulfate

Sulfate is being detected at increasing levels in monitoring wells located near injection wells. Groundwater that has been treated by the DX P&T system is affected by the addition of sulfuric acid, which changes the sulfate concentrations. The acid is used to lower the pH in the influent groundwater because the SIR-700 IX resin treatment technology used to remediate Cr(VI) is more efficient at a lower pH. Sodium hydroxide is added to the treated groundwater prior to reinjection into the aquifer to neutralize the acid and return to pH to near neutral. However, sulfate concentrations in the effluent are near the DWS, altering the sulfate concentration of the aquifer near the injection wells. The aquifer sulfate concentrations now appear to be stabilizing in areas near injection wells at levels above 200 mg/L but below the secondary DWS of 250 mg/L.

Other changes related to the injection of acid/caustic treated water into the aquifer include lowering of pH from near 8 to between 6.5 and 7.5; increase in specific conductance from about 400 µs/cm to around 600 µs/cm; and some increases in concentrations in various other metals such as calcium, but with high variability. The effect from the injection wells, however, appears to be limited to the zone very near the injection wells and does not extend very far into the surrounding aquifer, presumably due to a buffering effect in the aquifer. In addition, this effect has not been noted in the 100-H Area to the same degree.

In Well 199-D2-11, for example, a sharp increase in sulfate concentrations was noted when DX started operations, as a result of injection at Well 199-D5-128, and later with the addition of injection Well 199-D5-148 in 2014 (Figure 2-23). This was mirrored with an increase in specific conductance and a lowering of pH.

During 2014, the highest concentrations of sulfate were in the four temporary wells installed at the base of the 100-D-100 waste site excavation: 199-D5-155, 199-D5-156, 199-D5-157, and 199-D5-158. These wells are located downgradient from injection Well 199-D5-148. At least one sample from a port in these wells exceeded the sulfate DWS in 2014. The wells are now decommissioned and the waste site is being backfilled in early 2015. Other wells with high sulfate concentrations are also located near or downgradient from an injection well. Those wells with concentrations over 210 mg/L are 199-D2-11, 199-D5-106, 199-D5-97, 199-D6-3, and 199-D8-101 (Figure 2-23).

2.2.4 Hydraulic Monitoring

Hydraulic monitoring (i.e., water-level monitoring) is performed to evaluate the effect of the P&T systems on the water table and to evaluate groundwater flow direction and gradient. The hydraulic effects of the P&T systems are superimposed on seasonal fluctuations in the river levels and inland groundwater elevation to evaluate the effectiveness of providing hydraulic containment and capture of Cr(VI) plumes.

Groundwater elevation is measured during regularly scheduled groundwater sampling events, during focused events to collect elevation measurements from many wells over a short period of time, and in selected wells by automated data-logging pressure transducers placed in the wells (the Automated Water Level Network [AWLN]). The 100-HR-3 AWLN system was refurbished and expanded during 2014 with the addition of 15 new measurement stations. By December 2014, the AWLN recorded data from

pressure transducers from 53 locations. The increase in number and location of monitoring wells increases certainty to the hydraulic monitoring system and, therefore, the ability to determine hydraulic capture. Additional localized dynamic water level data are collected at each of the P&T extraction and injection wells. Manual depth-to-groundwater measurements are collected routinely during groundwater sampling missions. All of the available data are used, where applicable, to assemble the groundwater elevation maps.

Under natural gradient conditions, groundwater in the southern portion of 100-D generally flows to the west toward the Columbia River. In northern 100-D, the gradient changes to a northwesterly direction, with groundwater flow inland being more westerly, moving across the Horn Area towards the 100-H Area. In the 100-H Area, the natural groundwater gradient is towards the east and southeast and the Columbia River on the eastern side of the Horn. In general, the groundwater velocity in the 100-D Area is lower than that of the 100-H Area (DOE/RL-2009-92, *Report on Investigation of Hexavalent Chromium in the Southwest 100-D Area*). Groundwater flow entering the southern portion of the 100-HR-3 OU tends to flow towards the 100-H Area. Figure 2-24 presents the March 2014 groundwater flow map that demonstrates a mid-period river stage when flow direction is changing. Hydraulic effects of the P&T systems at the 100-HR-3 OU (i.e., the formation of depressions at extraction wells and mounds at injection locations) are superimposed onto these broad seasonal fluctuations. Small groundwater mounds are due to the injection of treated groundwater from the P&T systems.

The groundwater gradients during low and high river stage are presented in Figures 2-17 and 2-18, along with the low and high river-stage Cr(VI) plume. The effect of the P&T system is more pronounced where groundwater depressions were observed around some DX P&T system extraction wells.

The effects of seasonal changes in river stage (and water table elevation) on contaminant concentrations in the aquifer and treatment system performance are discussed in Section 2.2.5. Increasing river stage was observed starting in late February 2014, with peak stage elevation observed in June. The river stage declined from late June through the end of August, returning to low-stage levels by September 1, 2014 (Figure 2-12).

During high river-stage periods, the local groundwater gradient magnitude is reduced near the river; the vicinity very near the river may actually exhibit a flow direction reversal, with river water intruding slowly into the aquifer (i.e., seasonal bank storage). In addition, this change (i.e., increased elevation) of the boundary condition causes the groundwater inland of the river to backup during high river stage, thus creating the seasonal rise in groundwater elevation typically observed inland of the river. As the river stage declines following the seasonal freshet, the boundary condition again adjusts, the groundwater gradient steepens toward the river, and velocity increases. This condition continues until the groundwater head again equilibrates with the low river-stage condition. Seasonal groundwater elevation transients are observed up to several kilometers from the river as the water table and river stage equilibrate, although the magnitude of the increase progressively decreases with distance from the river. Figure 2-24 presents a groundwater contour map of the area, which was developed using concurrent measurements collected on February 28, 2014 (near the end of the low river-stage period).

Groundwater elevations in the unconfined aquifer were measured in monitoring wells in the 100-D and 100-H Areas and the Horn on an hourly basis in 2014, using an AWLN. The automated measurements were supplemented by quarterly manual measurements using an electric tape. These measurements were then compared to known survey elevations. The height of the Columbia River is also monitored electronically at the 100-H river gauge location.

2.2.5 Hydraulic Containment

This section compares the estimated extent of hydraulic containment for the 100-HR-3 OU P&T systems with the estimated extent of chromium contamination in groundwater. The assessment is based upon a joint evaluation of groundwater levels, pumping rates (extraction and injection), and water quality data. The extent of hydraulic containment is estimated using two methods:

- Water-level mapping using an extension of the hybrid universal kriging (UK)/analytic element method technique detailed in SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*
- Groundwater modeling using the 100 Area groundwater model, which is documented in SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*

In each case, the estimated extent of hydraulic containment is depicted using a capture frequency map (CFM). The CFM constructed using the water-level mapping technique is referred to as an interpolated capture frequency map (ICFM), whereas the CFM constructed using the 100 Area groundwater model is referred to as a simulated capture frequency map (SCFM). In each case, the CFM depicts the frequency with which particles representing mobile groundwater and contaminants are captured at extraction wells, calculated over a series of mapped or simulated groundwater levels that represent conditions throughout the year. A frequency of 1.0 indicates that groundwater in the area is hydraulically contained under all conditions encountered during the period (i.e., groundwater is always moving toward extraction wells). A frequency of zero indicates that groundwater in the area was not hydraulically contained under any conditions encountered during the period (i.e., was at no time during the period moving toward extraction wells). Intermediate frequencies indicate that the groundwater was contained under some conditions but not all.

Water-level mapping using the ICFM approach was completed using monthly averaged groundwater elevations, pumping rates, and stage of the Columbia River, which resulted in 12 water-level maps encompassing the entire River Corridor, and correspondingly 12 individual depictions of the extent of hydraulic containment for use in constructing an ICFM. Groundwater modeling using the 100 Area groundwater model was completed using monthly averaged pumping rates, stage of the Columbia River, and other time-varying boundary conditions. This resulted in 12 simulated groundwater level and flow fields, and correspondingly, 12 individual depictions of the extent of hydraulic containment for use in constructing an SCFM.

The ICFM and SCFM are ensemble estimates for the monitoring period; emphasis is placed on regions of high frequency and on comparing areas where the ICFM and SCFM are similar or where they differ. Where the ICFM and SCFM are similar, confidence is relatively high that containment is being achieved (where both maps suggest that containment is achieved) or is not being achieved (where both maps suggest that containment is not achieved). Where the ICFM and SCFM differ substantially, confidence is lower in the assessment of containment because one method suggests that containment is being achieved whereas the other method suggests it is not.

Figures 2-25(a) through (f) compare the estimated extent of hydraulic containment and the estimated extent of chromium contamination in groundwater for both high and low river-stage conditions for the 100-D Area as follows:

- Figure 2-25(a) and Figure 2-25(b) depict chromium contamination under high river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.

- Figure 2-25(c) and Figure 2-25(d) depict chromium contamination under low river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-25(e) depicts the groundwater flow lines from particle tracking to estimate the aquifer capture zone of the DX P&T system over a 10-year period, and Figure 2-25(f) overlays the capture zone flow lines with the chromium plume contours under low river-stage conditions.

Figures 2-26(a) through (f) compare the estimated extent of hydraulic containment and the estimated extent of chromium contamination in groundwater for both high and low river-stage conditions for the 100-H Area as follows:

- Figure 2-26(a) and Figure 2-26(b) depict chromium contamination under high river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-26(c) and Figure 2-26(d) depict chromium contamination under low river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-26(e) depicts the groundwater flow lines from particle tracking to estimate the aquifer capture zone of the HX P&T system over a 10-year period, and Figure 2-26(f) overlays the capture zone flow lines with the chromium plume contours under low river-stage conditions.

The capture flow lines in some areas may undergo a more circuitous path to an extraction well, as observed in Figures 2-26(e) and (f), which reflects the effects of river stage fluctuations and aquifer hydraulic conditions on a particle flow path.

ECF-HANFORD-15-0001 presents details for the specific calculations used to produce these figures, including updates to and implementation of the 100 Area groundwater model; the methodology for water-level mapping; and the development of the ICFM and SCFM. Finally, although advanced interpolation techniques are used in developing water-level maps, confidence in these maps is heavily dependent on the density of the monitoring well network and the quality of the available data. During 2014, data from AWLN monitoring locations were not always available or deemed usable for the entire period. Due to station technology improvements and additional AWLN stations, the data network at the 100-HR-3 OU was improved in 2014 as compared to 2013; therefore, the data set was again not as extensive as in previous years. Although the interpolated water-level maps are consistent with observations and qualitative interpretations of aquifer conditions and resulting flow fields during the year, improvements to the monitoring network are required to increase confidence in these interpretations. Maintenance and data checks are being conducted on a regular basis to improve the system reliability and data quality.

2.2.6 River Protection Evaluation

The river protection status of conditions at the 100-HR-3 OU is based on assessment of the hydraulic effects of operation of the remedial action systems, along with evaluation of changes in the discharge boundary head conditions associated with the Columbia River and the inferred distribution of Cr(VI) in groundwater. Both a quantitative and a qualitative approach are used for this assessment. The assessment indicates that the river protection status improved in 2014 over the assessment for 2013.

This subsection describes the river protection evaluation process and presents the results of the 2014 analysis. SGW-54209, *Systematic Method for Evaluating the Length of the Hanford Reach of the Columbia River Shoreline that is Protected from Further Discharges of Chromium from the 100 Area Operable Units (OUs)*, describes a method for evaluating progress toward attaining RAO #1, referred to as the "river protection objective." Since RAO #1 emphasizes protection of aquatic receptors, the river

protection objective focuses on the performance of P&T (and other remedies) in protecting the Columbia River from further discharges of dissolved chromium from inland at concentrations above 10 µg/L. Use of this standard is consistent with Tri-Party Agreement (Ecology et al., 1989) Milestone M-016-110-T01. ECF-HANFORD-12-0078, *Assessment of the River Protection Objective: Calculation for Calendar Year 2011 (CY2011)*, demonstrates the methods described in SGW-54209 for evaluating the progress toward attaining the river protection objective using data obtained during (or prior to) 2011.

Assessment of progress toward attaining the river protection objective for 2014 is presented in Figures 2-27(a) and (b) and Figures 2-28(a) and (b). The technical methods and process that are used to complete the calculations necessary to prepare these figures are detailed in SGW-54209. ECF-HANFORD-15-0001 presents details for the specific calculations used to produce these two figures for 2014. The results of contaminant standard and trend tests described in SGW-54209 to identify low-, moderate-, and high-concern wells are presented in Figures 2-27(a) and (b) and Figures 2-28(a) and (b) using the following symbols:

Low Concern Wells			High Concern Wells			Moderate Concern Wells		
Symbol	**Standard**	**Trend**	**Symbol**	**Standard**	**Trend**	**Symbol**	**Standard**	**Trend**
▼	Less than	Down	▲	Exceed	Up	△	Less than	Up
■	Less than	None	■	Exceed	None	▽	Exceed	Down
●	Less than	NSD	●	Exceed	NSD			

NSD = not sufficient data to calculate trend

Shoreline lengths are calculated and reported in increments of 100 m (328 ft); the results of the assessment are presented in these figures as color-filled circles of radius equal to 100 m (328 ft). The color fill of each circle indicates the relative river protection objective status (i.e., green = protected; yellow = protected, but action may be required to ensure long-term protectiveness; and red = not protected) for the unconfined aquifer only. The following symbols depict the results of the river protection evaluation:

River Protection Objective - Status

● Protected ● Protected (Action May Be Required) ● Not Protected

Figures 2-27(a) and (b) depict the assessment of progress toward attaining the river protection objective for chromium in the 100-D Area. Figure 2-27(a) shows the results of the quantitative evaluation of the objective, which is determined based upon overlay and quantitative comparison of the extent of chromium contamination with the extent of hydraulic containment. Figure 2-27(b) depicts the results of the qualitative evaluation of the objective, which is based upon the quantitative evaluation but also incorporates qualitative considerations (e.g., the duration and magnitude of hydraulic gradients along the shoreline, the locations of pumping wells, and trends in concentrations). Based on these calculations, the river protection evaluation for the 100-D Area is as follows:

- Total length of shoreline adjacent to the 100-D Area: 2,800 m (9,180 ft)
- Length identified as protected: 1,500 m (4,920 ft)
- Length identified as protected (action may be required): 800 m (2,620 ft)
- Length identified as not protected: 500 m (1,640 ft)

Figures 2-28(a) and (b) depict the assessment of progress toward attaining the river protection objective for chromium in the 100-HR-3 OU/100-H Area. Figure 2-28(a) depicts the results of the quantitative evaluation of the objective, which is determined based upon overlay and quantitative comparison of the extent of chromium contamination with the extent of hydraulic containment. Figure 2-28(b) shows the results of the qualitative evaluation of the objective, which is based upon the quantitative evaluation but incorporates qualitative considerations (e.g., the duration and magnitude of hydraulic gradients along the shoreline). Based on these calculations, the river protection evaluation for the 100-H Area is as follows

- Total length of shoreline adjacent to the 100-H Area: 4,400 m (14,430 ft)
- Length identified as protected: 2,700 m (8,855 ft)
- Length identified as protected (action may be required): 1,200 m (3,935 ft)
- Length identified as not protected: 500 m (1,640 ft)

The results of the qualitative evaluations for the 100-D Area and the 100-H Area for 2014 are compared to those presented in DOE/RL-2014-25. Table 2-12 provides a comparison of the river protection evaluation for 2013 and 2014. The effect of river-stage fluctuations on groundwater flow, combined with the aquifer response to pumping, resulted in qualitative evaluations of the river protection objective for 2014 that indicate improved system performance compared to 2013.

Quantitative evaluations of the river protection objective provide a conservative assessment of shoreline protection; qualitative evaluations for 2014 incorporate the transient effects of hydraulic capture. The CFMs describe the aggregate fate of particles, under an ensemble of steady-state conditions, each reflecting a snapshot of hydraulic gradient magnitude and direction due to pumping and river stage. As a result, CFMs only indicate the relative strength of hydraulic containment and not a depiction of actual transient hydraulic capture patterns. CFMs provide an effective metric to evaluate the relative strength of the capture zone, but they should not be considered an absolute indicator of hydraulic containment success or failure. Even during months of steeper hydraulic gradients near the shoreline, groundwater flow velocities result in actual plume migration expected to occur over very short distances. Relative dissipation of hydraulic gradient magnitude in subsequent months results in even slower plume migration and transient hydraulic containment. Capture can, and does, occur in areas where CFMs indicate relatively low capture frequency.

The chromium plume depiction for 2014 illustrates that implementation of well realignments, combined with only moderate flow reversal during high river-stage conditions, has translated into increased hydraulic containment. Comparison of the chromium plume depictions for 2013 and 2014 indicates an increased number of shoreline segments in 2014 where chromium concentrations are below the aquatic standard despite the prolonged periods of low river stage, including in areas of lower capture frequency. Acknowledgement of these processes is reflected in the qualitative evaluation results.

2.2.7 Contaminant Mass Recovery

Comparison of the ICFM and SCFM provides comparative depiction of the hydraulic simulation capabilities of the flow component of the 100 Area groundwater model. A similar qualitative comparison can be made for the transport component of the 100 Area groundwater model by comparing simulated and measured rates of contaminant mass recovery.

Figure 2-29 presents a comparison of the monthly and cumulative mass of chromium that was recovered throughout 100-HR-3 OU at both the DX and HX P&T systems for 2014, as determined using actual influent concentrations and flow rates versus the mass recovery simulated using the 100 Area groundwater model. For the HX P&T system, mass recovery is presented showing the results the extraction from the RUM wells included in the plot and with the mass from the RUM wells excluded from the measured recovery plot, since the groundwater model addresses the presence of chromium in the unconfined aquifer only. As indicated in Figure 2-29, the majority of mass recovered at the HX P&T system originates in the RUM aquifer. For this simulation, the initial distribution of chromium in groundwater was assumed to be the low river-stage depiction of chromium for 2013, reflecting data collected during the period from September 1, 2013, to December 31, 2013, as presented in ECF-HANFORD-14-0034, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2013 (CY2013) Hanford Site Groundwater Monitoring Report*.

The model typically under-predicts the mass of chromium that was recovered by each system. ECF-HANFORD-15-0001 presents graphs comparing the simulated and measured mass recovery at each individual extraction well for the HX and DX P&T systems, which generally compare well to the simulated results presented in Figure 2-29. In each case, however, there are system-specific and systematic conditions that might lead to differences between the simulated and measured values, most notably the groundwater model assumption that no continuing sources are present.

At the DX P&T system, the mass of chromium immediately downgradient of the 100-D-100 waste site, as well as the area upgradient of Wells 199-D5-32 and 199-D8-73 in the 100-D northern plume, may be under-represented in the simulation initial conditions. This is likely since persistent sources have been identified in 100-D. For example, the investigation at the 100-D-100 waste site (SGW-58416, Rev.1) indicated that chromate-substituted calcite remaining in the periodically rewetted zone soil and aquifer sediment provides a potential source of ongoing release of Cr(VI) into groundwater. Since the simulated mass recovery reflects only the dissolved chromium distribution as delineated for low river-stage conditions in 2013, and does not include any contribution from continuing sources, the mass recovery may not correlate well in locations where a source remains. This condition may also affect the long-term model predictions of cleanup time since unaccounted for mass may remain in the soil and/or aquifer is isolated locations.

The HX P&T system has removed 22.8 kg (50.2 lb) of Cr(VI) during 2014 (Figure 2-29). Approximately 10.3 kg (22.7 lb) of the mass recovered by the HX P&T system was extracted from wells completed within the RUM (i.e., Wells 199-H3-2C and 199-H4-12C), which are not simulated by the 100 Area groundwater model. The remaining mass of approximately 12.5 kg (27.6 lb) that was recorded as being recovered by the HX P&T system originates from the unconfined aquifer that is simulated by the 100 Area groundwater model. In comparing the observed mass removed from the unconfined aquifer (12.5 kg [27.6 lb]) to the mass recovery simulated by the 100 Area groundwater model (11.3 kg [24.9 lb]), the comparison is more favorable (Figure 2-29). Comparison between simulated and measured concentrations at the extraction wells of the HX P&T system is presented in detail in ECF-HANFORD-15-0001. In general, the comparison between simulated and measured concentrations indicates patterns similar to those observed in the DX P&T system. Measured concentrations in the HX P&T system are much lower than those measured in the DX P&T system and, in most cases, about or below the groundwater cleanup standard of 48 μg/L.

From a systematic perspective, differences between the simulated and measured mass recovery could result from using contaminant transport parameters in the transport model that do not exactly reflect conditions encountered in the subsurface. The simulated mass recovery estimate, however, presents a useful tool for estimating the system performance over time and developing estimates of time

to remediation, but will tend to under-estimate remediation timeframes where a continuing source is present.

2.2.8 In Situ Redox Manipulation Barrier Compliance Monitoring

The reduction-oxidation treatment zone (Figure 2-3) is approximately 680 m (2,230 ft) long, aligned parallel to the Columbia River, and is approximately 100 to 200 m (330 to 660 ft) inland from the river. The barrier includes 65 wells spaced across almost the entire width of the southern Cr(VI) plume. The treatment zone was designed to reduce the Cr(VI) concentration in groundwater to below 20 µg/L at the compliance wells located between the treatment zone and the Columbia River. Figure 2-30 shows the nitrate and Cr(VI) concentrations along the barrier for 2014.

As discussed in Section 2.1.2, a notice of nonsignificance shifted the groundwater remedy at the ISRM barrier to the P&T system. Groundwater at the ISRM site continues to be monitored for Cr(VI) as part of CERCLA interim action and is discussed in this report in order to provide a consolidated discussion of all interim remedies being used in the River Corridor. DO is monitored since the treatment process reduces oxygen content in the aquifer, and groundwater with depleted DO levels could harm aquatic receptors. Other groundwater constituents and properties are monitored to provide better understanding of the chemical characteristics of the plume.

2.2.8.1 Hexavalent Chromium

The ISRM barrier initially had seven compliance wells. Of these, monitoring Wells 199-D4-86 and 199-D4-23 are the only remaining wells that have not been converted to extraction wells. Figure 2-31 provides Cr(VI) concentration plots for the seven compliance wells: 199-D4-23, 199-D4-38, 199-D4-39, 199-D4-83, 199-D4-84, 199-D4-85, and 199-D4-86. The 20 µg/L interim remedial action target was met at four of the seven ISRM compliance wells during 2014 (199-D4-23, 199-D4-83, 199-D4-85, and 199-D4-86).

The Cr(VI) concentrations in barrier wells during 2014 ranged from below detection limits to 160 µg/L at Well 199-D4-22, which is a reduction from previous years. The Cr(VI) concentration in groundwater at the ISRM barrier generally trended downward, with some seasonal fluctuation. Areas where lower concentrations are already present (less than 20 µg/L) remained stable, with little change in concentrations during the year. The declining overall concentrations are attributed to the increased effectiveness of the P&T system as a result of the conversion of Wells 199-D4-14 and 199-D4-34 from monitoring wells to extraction wells in August 2013. This system modification has also improved the hydraulic capture in that area. Most elevated Cr(VI) concentrations continue to be in the northeastern half of the barrier, near the former ISRM Pond. The remedial action target of 20 µg/L was exceeded in three wells (199-D4-38, 199-D4-39, and 199-D4-84) during 2014 in the northern part of the barrier, as shown in Figure 2-30. Remedial action monitoring is described in DOE/RL-99-51, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In-Situ Redox Manipulation.*

Figures 2-32 through 2-35 show the Cr(VI) concentrations in the ISRM barrier for the four quarters of 2014. Cr(VI) concentrations are the lowest in the summer (second and third quarters). The greatest number of wells had concentrations over the remedial action target of 20 µg/L in the fourth quarter (Figure 2-35). Since groundwater flow is predominantly toward the river during low river stage and the hydraulic gradient was the highest during this period, there is less time for groundwater to react with reduced sediments in the ISRM barrier. Conversely, when the river stage is high and groundwater gradients are reversed (i.e., groundwater flow is inland from the river), water has a longer residence time in the barrier and/or previously treated water flows back to the barrier. As a result, more Cr(VI) is reduced to trivalent chromium, and the concentrations of Cr(VI) decrease. The northeastern half of the barrier

continues to have a high number of wells with concentrations greater than 20 µg/L. However, in 2014 the southern end of the barrier also showed a high number of wells with concentrations greater than 20 µg/L. Overall concentrations in the barrier decreased during 2014, most likely due to extraction of contaminated groundwater in the ISRM area for treatment through the DX P&T system.

2.2.8.2 Dissolved Oxygen

The DO concentrations are monitored as required by the ROD amendment (EPA/AMD/R10-00/122) and the remedial design report/remedial action work plan (RDR/RAWP) (DOE/RL-99-51). The sodium dithionite injection process reduced DO in the groundwater at the barrier to low levels. Low levels of DO are monitored to assess changes in concentration as groundwater approaches the Columbia River. Low levels of DO in the river may pose a risk to aquatic organisms. Monitoring of DO will enable actions to take place to increase the oxygen in groundwater via air sparging, or other means, if significant low values persist. The DO profile near the ISRM treatment zone is generally characterized by relatively high DO concentrations upgradient of the treatment zone, decreasing significantly through the treatment zone, and recovering to higher DO concentrations as groundwater flow approaches the river (Figure 2-7).

The DO sampling results from fall 2014 were reviewed. A selection of wells trending in a northwest line perpendicular to the northern end of the ISRM barrier were compared: Well 199-D5-43 at 9,750 µg/L, Well 199-D4-15 at 410 µg/L, and Well 199-D4-23 at 9,240 µg/L. Perpendicular to the southern end of the ISRM barrier, a selection of three wells trending in a west line were compared: Well 199-D4-20 at 8,800 µg/L, Well 199-D4-19 at 3,930 µg/L, and Well 199-D4-86 at 9,490 µg/L. Both of these well groupings exhibit regional groundwater levels of DO upgradient of the ISRM barrier, significantly lower DO levels proximate to the barrier, and increased DO levels at or below the regional levels adjacent to the Columbia River. Based on these results, it is evident that the ISRM barrier continues to create favorable conditions for reducing Cr(VI) in a limited zone in the northern portion. This system, together with the downgradient DX P&T system extraction wells, will aid in meeting remedial action goals.

The DO concentrations near the ISRM barrier have been slowly returning to pre-treatment levels. Compared to levels in 2013, the areas of DO values below 3 mg/L have decreased slightly and are now limited to the area south of the ISRM barrier and in a small band along the southern portion of the barrier. The DO concentrations upgradient and downgradient of the ISRM barrier remain between 3 and 6 mg/L, indicating that the barrier continues to create a small zone of oxygen reduction. This zone continues to shrink over time, however, as the effectiveness of the barrier declines.

2.2.8.3 Sulfate

Sulfate is listed as a groundwater contaminant with a national secondary DWS of 250 mg/L (40 CFR 143, "National Secondary Drinking Water Regulations"). Sulfate is a byproduct of the sodium dithionite reaction used to establish the ISRM treatment zone. Sodium dithionite solution injections at the barrier can increased sulfate concentrations to levels above the secondary DWS of 250 mg/L in the ISRM barrier and in some downgradient wells and aquifer tubes. However, sulfate concentrations did not exceed the secondary DWS in wells associated with the ISRM barrier during 2014. The highest sulfate concentrations along the ISRM barrier were found at Well 199-D4-83, at 158 mg/L.

2.2.9 Remedial Process Optimization Activities

Contractors have developed a pumping optimization model, based on the 100 Area Groundwater Model that will be used by OU scientists along with a detailed simulation display interface to evaluate the relative performance of alternative well configurations. The OU scientists will evaluate pumping configurations throughout the year and provide adjustments to flow rates and recommendations for well

realignment and/or the installation of new wells. Specific remedial process activities performed at the 100-HR-3 OU during 2014 included the following:

- Installing new extraction wells at locations based on previous years' evaluation of plume capture and river protection analyses
- Designing and constructing new extraction and injection wells as high-performance wells (i.e., using high-capacity well screens and matching filter pack to screen and formation).
- Placing new and realigned extraction and injection wells in service to enhance plume capture
- Repairing and expanding the AWLN system to enhance hydraulic monitoring capacity
- Identifying low-performing extraction and injection wells for maintenance or removal from operations
- Identifying system infrastructure components to be changed to enhance groundwater extraction and injection performance
- Initially using the pumping optimization model to evaluate expected extraction/injection well effects on plume capture

2.3 100-HR-3 Operable Unit Pump and Treat Systems Costs

This section summarizes the actual costs for the 100-HR-3 OU P&T systems for 2014. The primary categories of expenditures are described as follows:

- **Capital design:** Includes design activities to construct the P&T systems, including wells, and designs for major system upgrades and modifications.
- **Capital construction:** Includes oversight labor, material, and subcontractor fees for capital equipment, initial construction, construction of new wells, redevelopment of existing wells, and modifications to the P&T systems.
- **Project support:** Includes project coordination-related activities and technical consultation, as required, during the course of the facility design, construction, acceptance testing, and operation.
- **Operations and maintenance (O&M):** Represents facility supplies, labor, and craft supervision costs associated with operating the facility. It also includes the costs associated with routine field screening and engineering support as required during the course of P&T operation and periodic maintenance.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis, as required in accordance with the 100-HR-3 and 100-KR-4 OUs interim action work plan (DOE/RL-96-84).
- **Waste management:** Includes the cost for management of spent resin at the 100-HR-3 OU in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes. Cost includes waste designation sampling and analysis, resin regeneration, and new resin purchase.

The costs include all activities associated with the interim remedial actions, including construction of new wells and interim action performance monitoring. The 100-HR-3 OU costs for 2014 are associated with four P&T systems: HR-3, DR-5, DX, and HX. The cost breakdowns for these P&T systems are shown in Tables 2-13 through 2-16. The HR-3 and DR-5 P&T systems were shut down in 2011; however,

historical costs for these systems are included as part of the overall cost of the interim action remedy (Tables 2-13 and 2-14). Costs for the HR-3 and DR-5 P&T systems after system shutdown in 2011 are associated with surveillance and maintenance pending decommissioning of the facilities. Costs are burdened and are based on actual operating costs incurred during 2014. Summaries of the costs for the DX and HX P&T systems are presented in the following subsections.

2.3.1 DX Pump and Treat System

The total cost for the DX P&T system during 2014 was approximately $2.96 million, which consists of the sum of the categories shown in Table 2-15. The largest single component of the total cost was $2.03 million spent during the year for O&M. The cost breakdown percentage for the DX P&T system (Figure 2-36) indicates that the majority of the costs, in decreasing order, were charged to O&M (68.5 percent), construction (19.1 percent), performance monitoring (7.7 percent), project support (4.5 percent), and design (0.2 percent). The costs for waste management and field studies during 2014 were negligible. The cost increase from 2013 to 2014 for the DX P&T system is associated with capital construction for well realignments described in Section 2.2.1, resin changeout, and increased performance monitoring associated with the additional wells in the P&T network.

Based on the total 2014 cost of $2,961,300, the yearly production rate of 1,174 million L (310 million gal), and 178.7 kg (394 lb) of Cr(VI) removed, the annual treatment costs equate to $0.0025/L, or $16.57/g of Cr(VI) removed.

2.3.2 HX Pump and Treat System

The total cost for the HX P&T system during 2014 was approximately $2.86 million, which consists of the sum of the categories shown in Table 2-16. The largest single component of the total cost was $1.96 million spent during the year for O&M. The cost breakdown for the HX P&T system for 2014 (Figure 2-37) indicates that the majority of the costs, in decreasing order, were charged to O&M (68.8 percent), construction (19.8 percent), performance monitoring (6.6 percent), and project support (4.5 percent). The costs for design, waste management, and field studies during 2013 were negligible. The cost increase from 2013 to 2014 for the HX P&T system is associated capital construction for well realignments described in Section 2.2.2.

Based on the total 2014 cost of $2,856,300, the yearly production rate of 1,178 million L (311 million gal), and 22.8 kg (50 lb) of Cr(VI) removed, the annual treatment costs equate to $0.0024/L, or $125.1/g of Cr(VI) removed.

2.4 Conclusions

The status of the 100-HR-3 OU illustrates that remedial progress has been achieved for the plume areas associated with each of the P&T systems currently active within the 100-HR-3 OU. The following conclusions for the OU are based on each of the RAOs.

During 2014, the DX and HX P&T systems removed a significant amount of Cr(VI) mass from the aquifer, The amount of mass removed on a year-by-year basis continues to decrease as the areas of high Cr(VI) concentrations are remediated. RPO will continue, and system modifications will be conducted to target the remaining mass, along with increasing river protection.

The combined hydraulic and water quality data evaluation suggest that the extent of hydraulic containment that was developed by the DX and HX P&T systems during 2014 is consistent with their design and is within expectations. Calculations suggest that the river protection objective is being achieved along the majority of the 100-HR-3 OU shoreline.

- **RAO #1:** Protect aquatic receptors in the river bottom substrate from contaminants in the groundwater entering the Columbia River.

  Results: Capture zone analysis suggests that operation of the P&T systems is resulting in a capture frequency of 70 to 90 percent over most of the 100-HR-3 OU Cr(VI) plume above 10 µg/L.

  The combined hydraulic and water quality data evaluation indicates that the extent of hydraulic containment developed by the DX and HX P&T systems during 2014 improved over that identified in 2013. This improvement is consistent with expectations from well locations and planned extraction rates. Calculations indicate that the river protection objective is being achieved along the majority of the 100-HR-3 OU shoreline The performance of remedial action systems currently in place at 100-HR-3 OU confirms that DOE has taken the necessary measures to control the discharge of Cr(VI) into the Columbia River (Tri-Party Agreement Milestone M-016-110-T01 [Ecology et al. 1989]). The increase in protection in the 100-D Area is mostly related to the addition of new wells to the P&T system, with the greatest change in the ISRM area and northern plume. For the 100-H Area, the increase in protection is primarily related to a higher certainty in groundwater flow directions and source area remediation.

  Based on the aquifer tube data for 2014, the concentrations of Cr(VI) discharged to the Columbia River within the 100-HR-3 OU declined from 2013. This appears directly related to the magnitude of river-stage elevation changes over the calendar year and better overall capture from improved system alignments. The locations where Cr(VI) discharged to the river remained generally the same, although the length of shoreline where the discharges occurred decreased. These are localized areas at the downgradient edge of the 100-D north plume, the north portion of the Horn, and south of the H Reactor area.

  The DX P&T system has largely attained the RAO for river protection along the ISRM barrier and 100-D northern plume. The improvements in these areas are directly related to well field modifications, as discussed above. South of the ISRM barrier, the RAO is not currently attained; however, additional extraction is planned for that area. In addition, the RAO is not attained in the far north portion of the 100-D Area. Additional extraction and well realignments are planned to address that area of concern. These areas are expected to be captured by 2016.

  The HX P&T system has largely attained the RAO for river protection at the 100-H Area, and the Horn. System modifications being conducted for fiscal year 2015 are planned to address the area of weaker protection to the south of the 100-H Area, within the reactor area, and in a small area to the north of the 100-H Area.

  The 100-HR-3 OU P&T systems have removed substantial amounts of Cr(VI) from the groundwater. Since the DX and HX P&T systems started operation, the systems have removed an estimated total of 1,496 kg (3,298 lb) of Cr(VI) from the shallow unconfined aquifer and RUM combined, with the DX P&T system alone removing 1,403 kg (3,093 lb) of that total.

  The observed concentrations of Cr(VI) in groundwater at both the DX and HX P&T systems are declining as remediation progresses.

- **RAO #2:** Protect human health by preventing exposure to contaminants in the groundwater.

  Results: The interim remedial ROD (EPA/ROD/R10-96/134) establishes a variety of institutional controls (ICs) that must be implemented and maintained throughout the interim action period. These provisions include the following:

  - Access control and visitor escorting requirements
  - Signage providing visual identification and warning of hazardous or sensitive areas

- Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
- Regulatory agency notification of any trespassing incidents

The effectiveness of ICs was presented in DOE/RL-2004-56, *2004 Site Wide Institutional Controls Annual Assessment Report for Hanford CERCLA Response Actions*. The findings of this report indicate that ICs were maintained to prevent public access, as required.

- **RAO #3:** Provide information that will lead to a final remedy.

  Results: Rev. 0 of the RI/FS report (DOE/RL-2010-95) was completed in October 2014. The Proposed Plan (DOE/RL-2011-111) leading to a ROD for cleanup of contaminated soil and groundwater at the 100-D and 100-H Areas is under review.

  Additional information on the groundwater contamination at the 100-HR-3 OU continues to be gathered. Ongoing groundwater monitoring activities provide information on the changes in contaminant concentrations, as well as the spatial distribution of the groundwater plumes. Assessment of information collected during source remediation actions provides details regarding the sources of groundwater contamination, including the persistence of source material within the aquifer and the potential for continuing contributions from secondary sources within the vadose zone for Cr(VI).

  Evaluation of information from multiple activities indicates that while the interim groundwater remedial actions at the 100-HR-3 OU have been successful at reducing Cr(VI) concentrations and reducing plume sizes across the OU, residual secondary sources likely remain. A final remedy will need to address ongoing contributions from vadose zone sources, as well as high contaminant concentrations in groundwater at or near source release areas.

2.5 Recommendations

Recommendations for the 100-HR-3 OU are as follows:

- Continue RPO activities for the DX and HX P&T systems to:
  - Evaluate the well network for improved efficiencies to maximize use of treatment system capacity, particularly during periods of low river stage when treatment capacity usage has historically decreased.
  - Evaluate and identify adjustments to pumping rates, locations for new well installations and/or well realignments to meet the primary objectives: control hydraulic gradients, protect the Columbia River, remove contaminant mass, and restore the aquifer.
- Develop and prioritize well additions and/or realignments based on the RPO evaluations to include in future planning for the P&T systems.

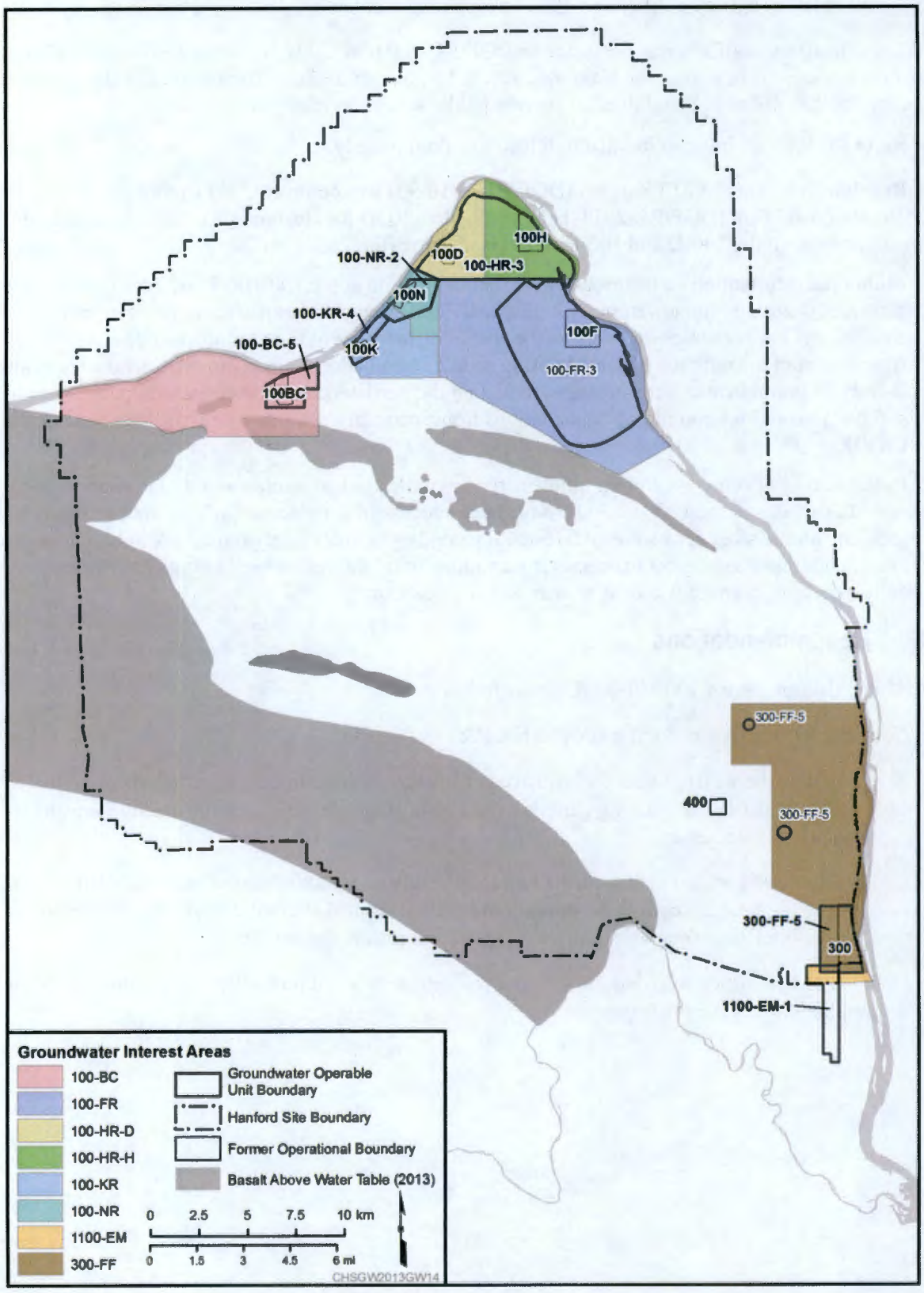

Figure 2-1. Location of the 100-HR-3 OU and Groundwater Interest Areas

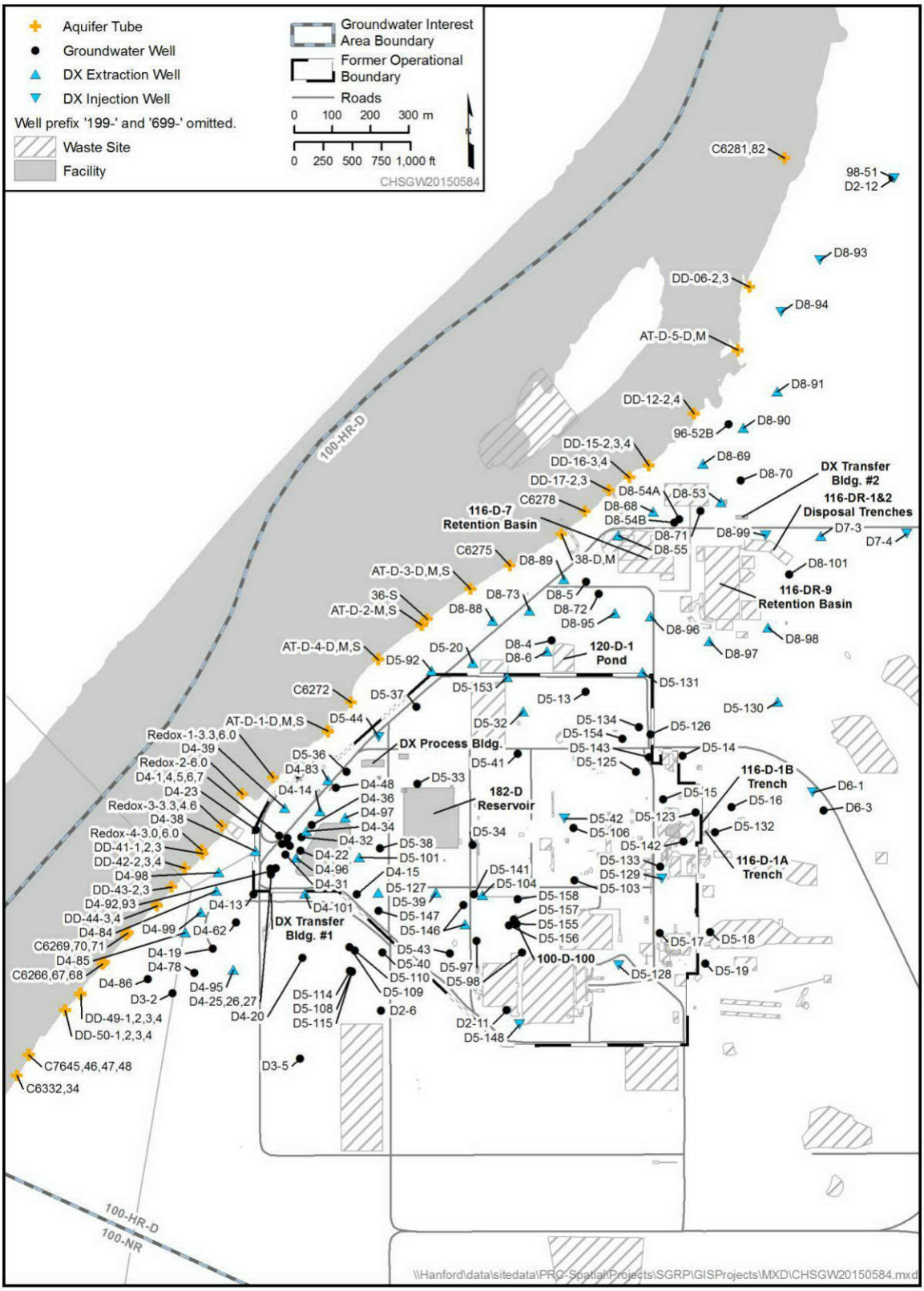

Figure 2-2. 100-D Area Wells and Aquifer Tubes

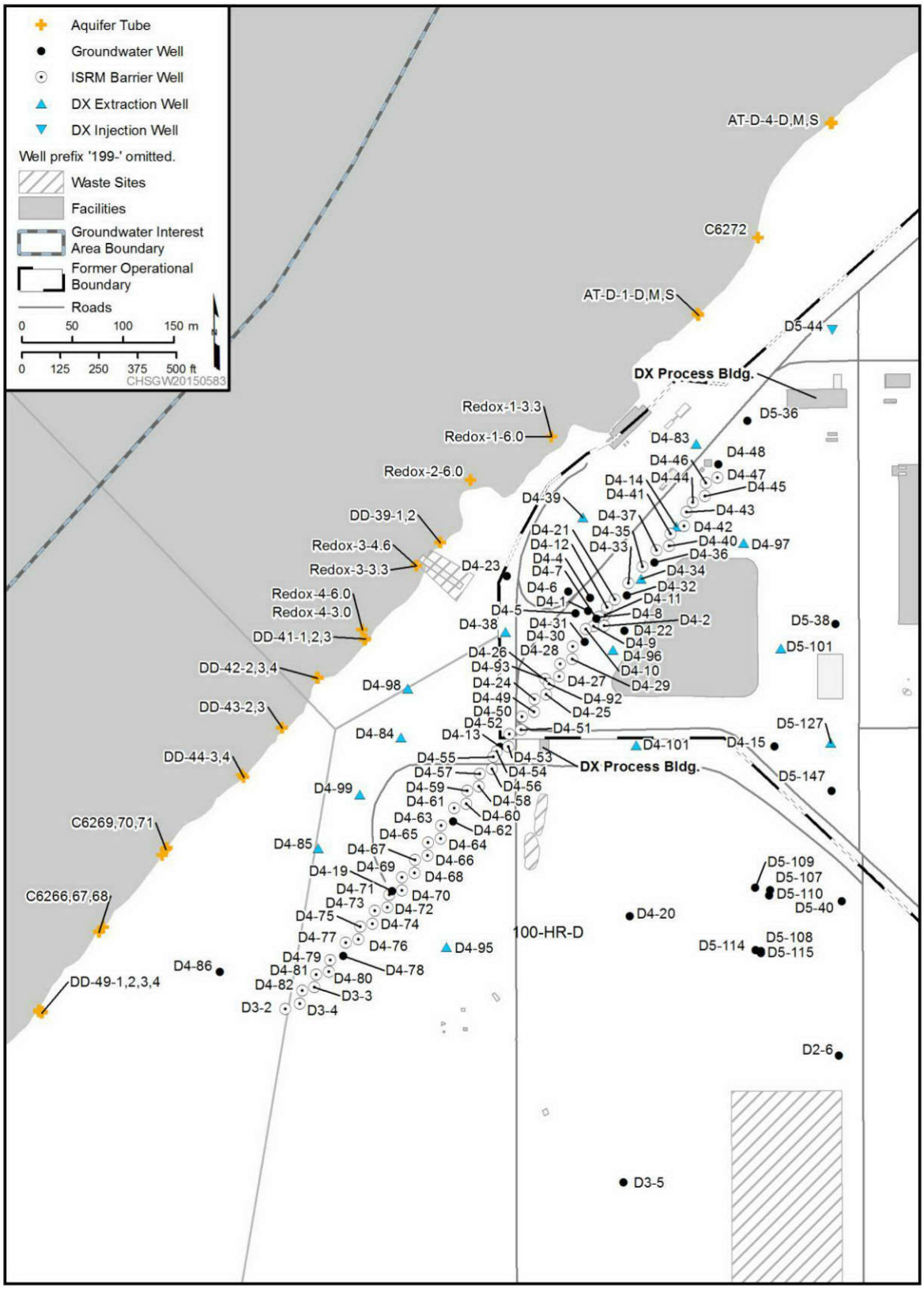

Figure 2-3. ISRM Detail Map

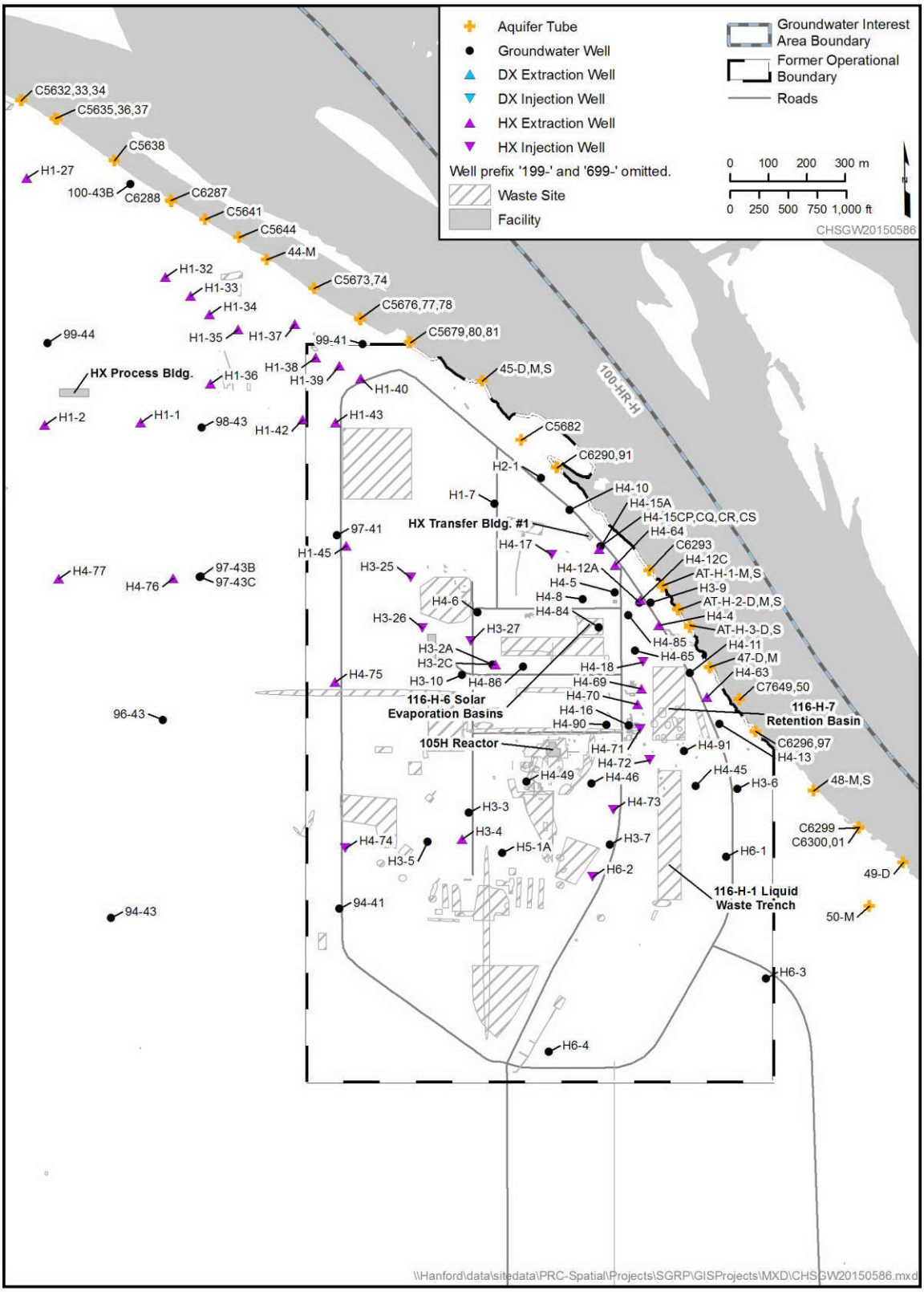

Figure 2-4. 100-H Area Wells and Aquifer Tubes

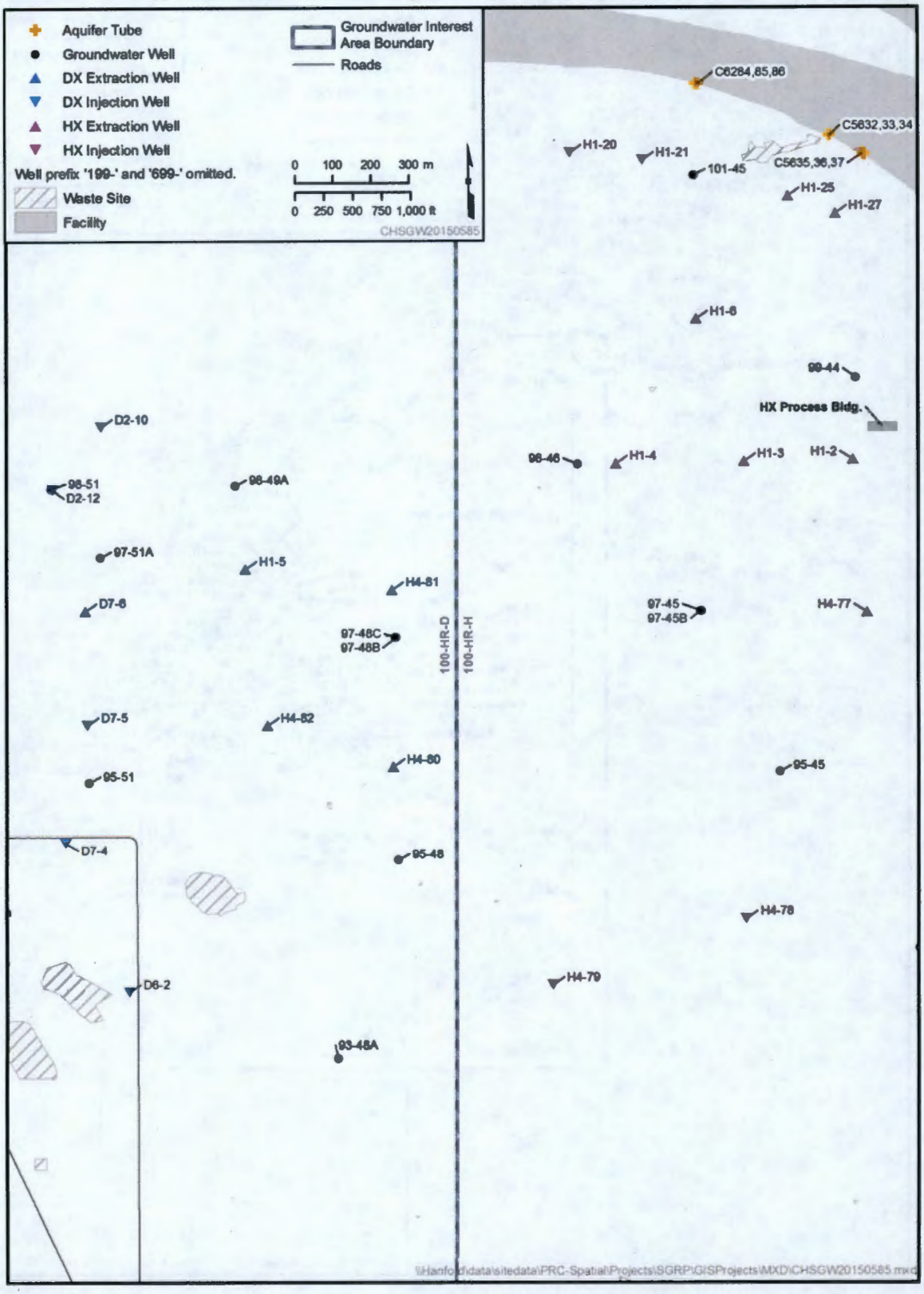

Figure 2-5. Horn Wells and Aquifer Tubes

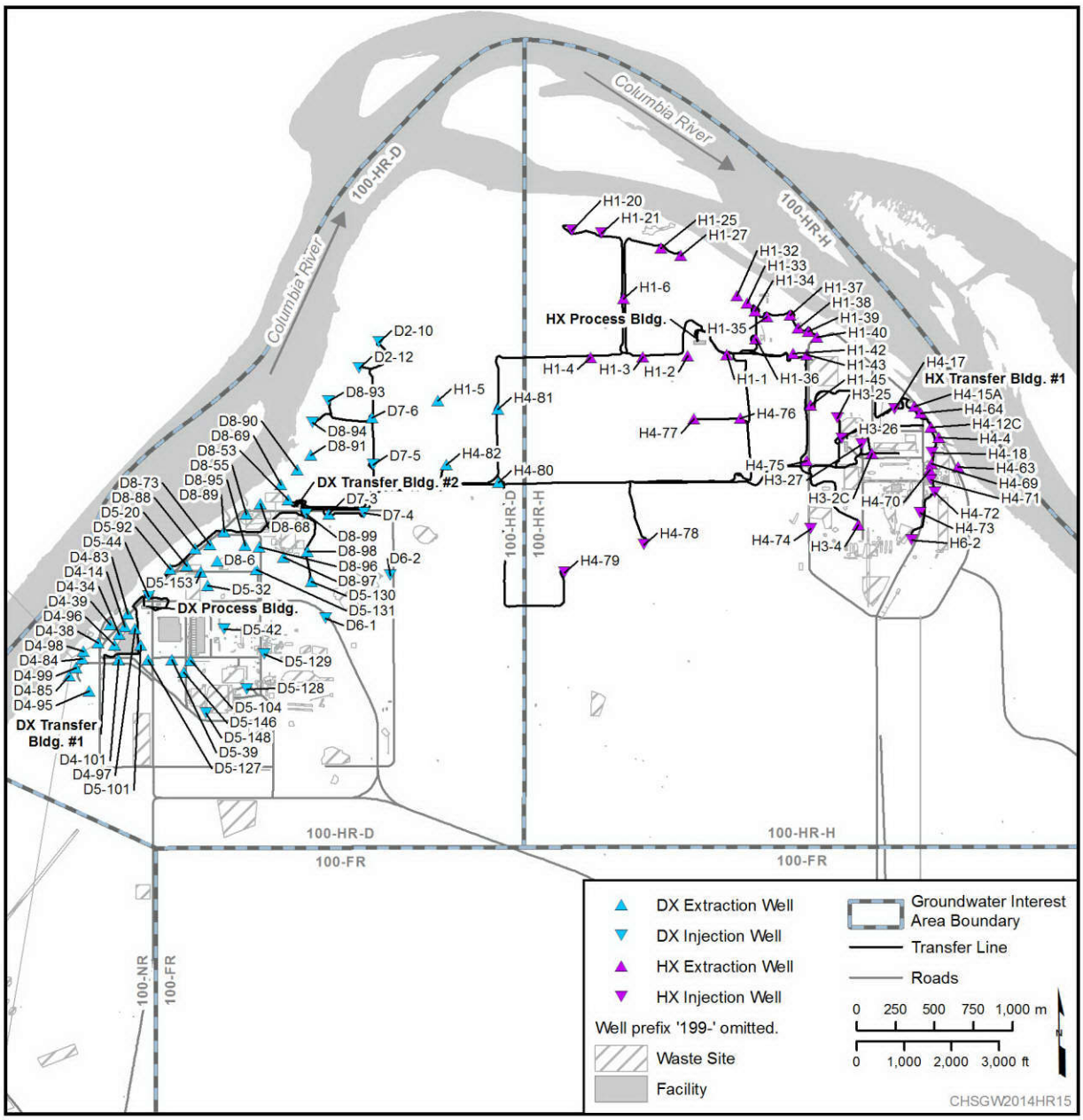

Figure 2-6. Layout of the 100-HR-3 OU P&T Systems (as of December 31, 2014)

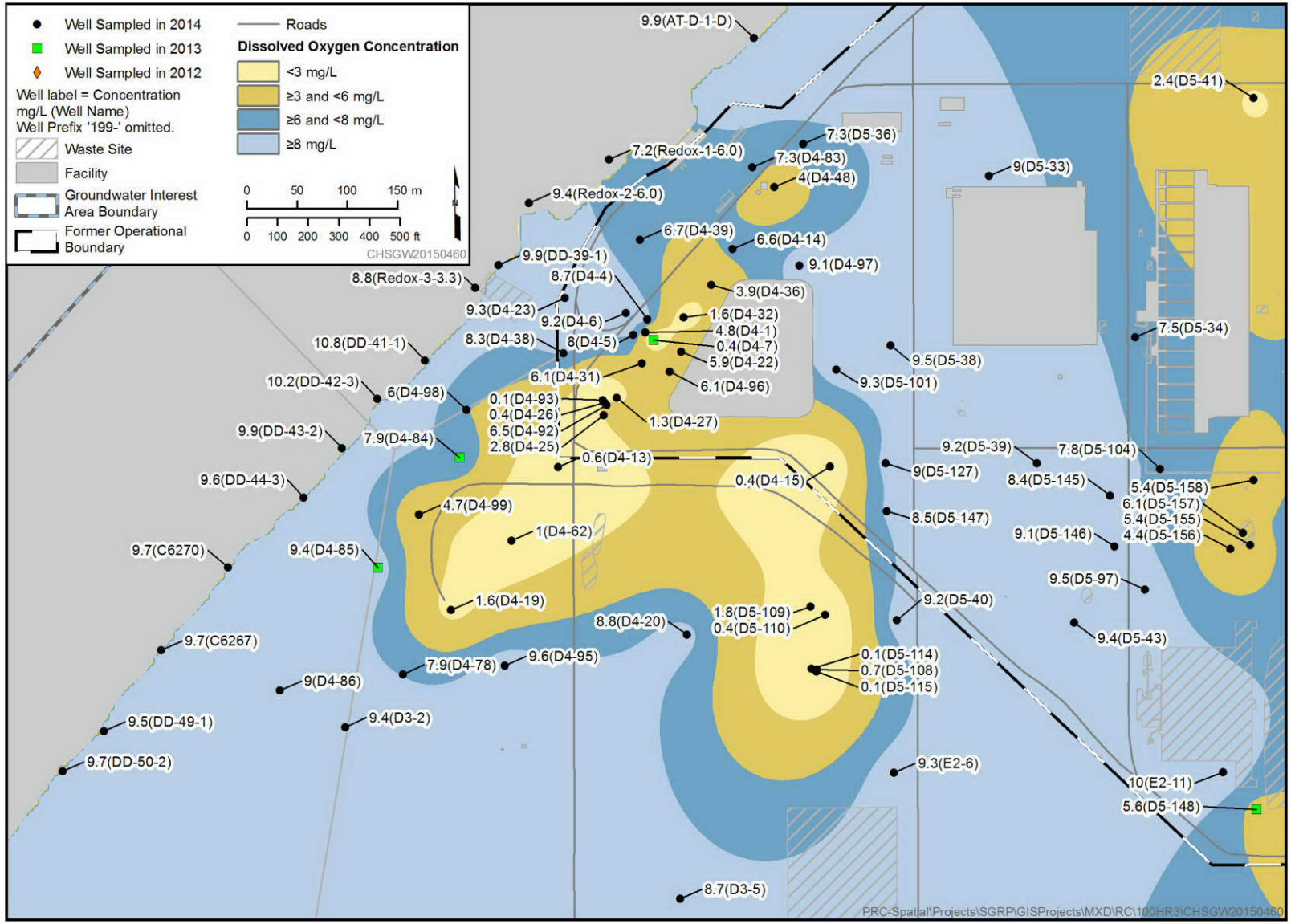

Figure 2-7. ISRM Area DO Concentrations, 2014

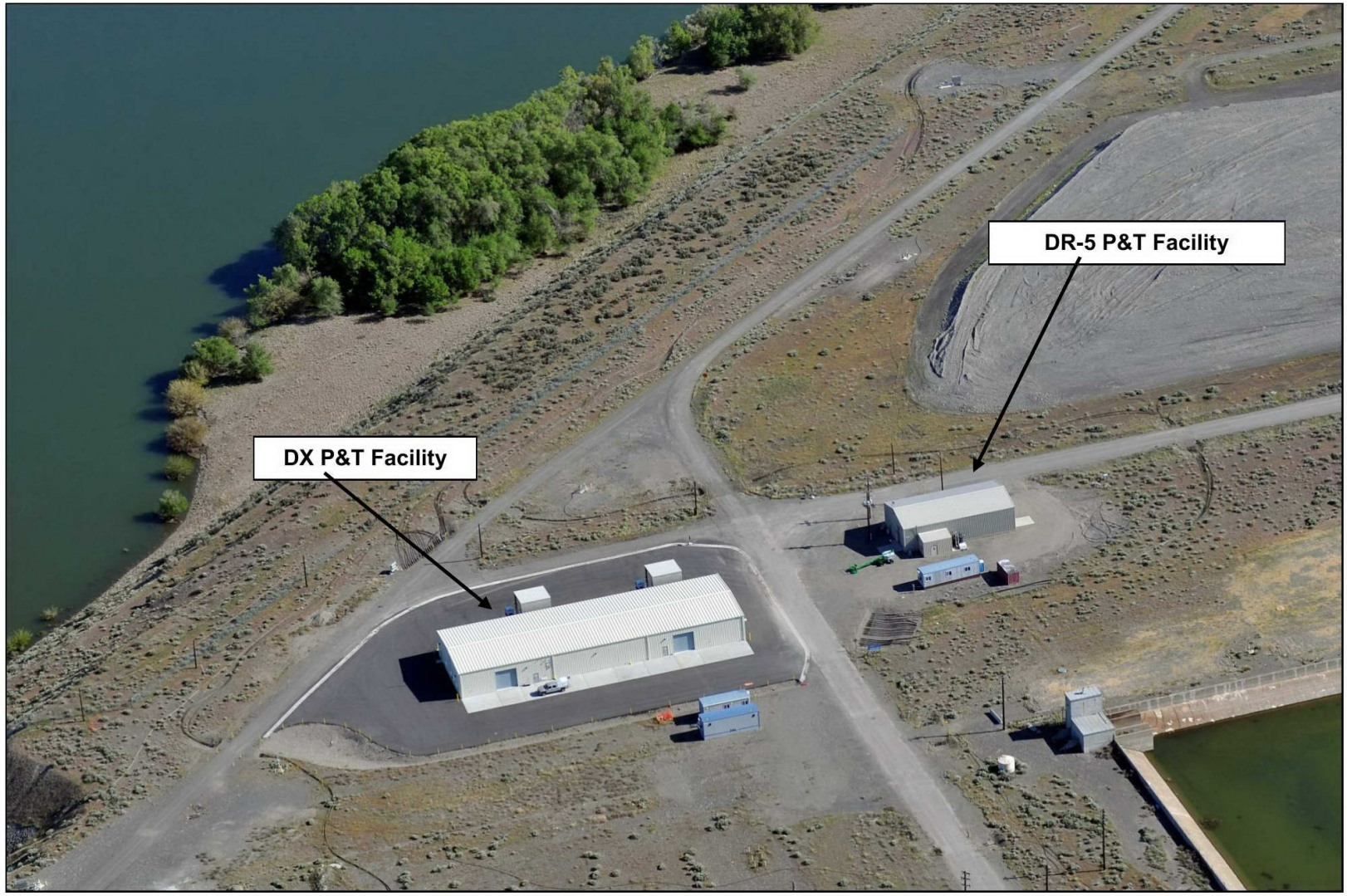

Figure 2-8. Aerial View of the DX P&T System

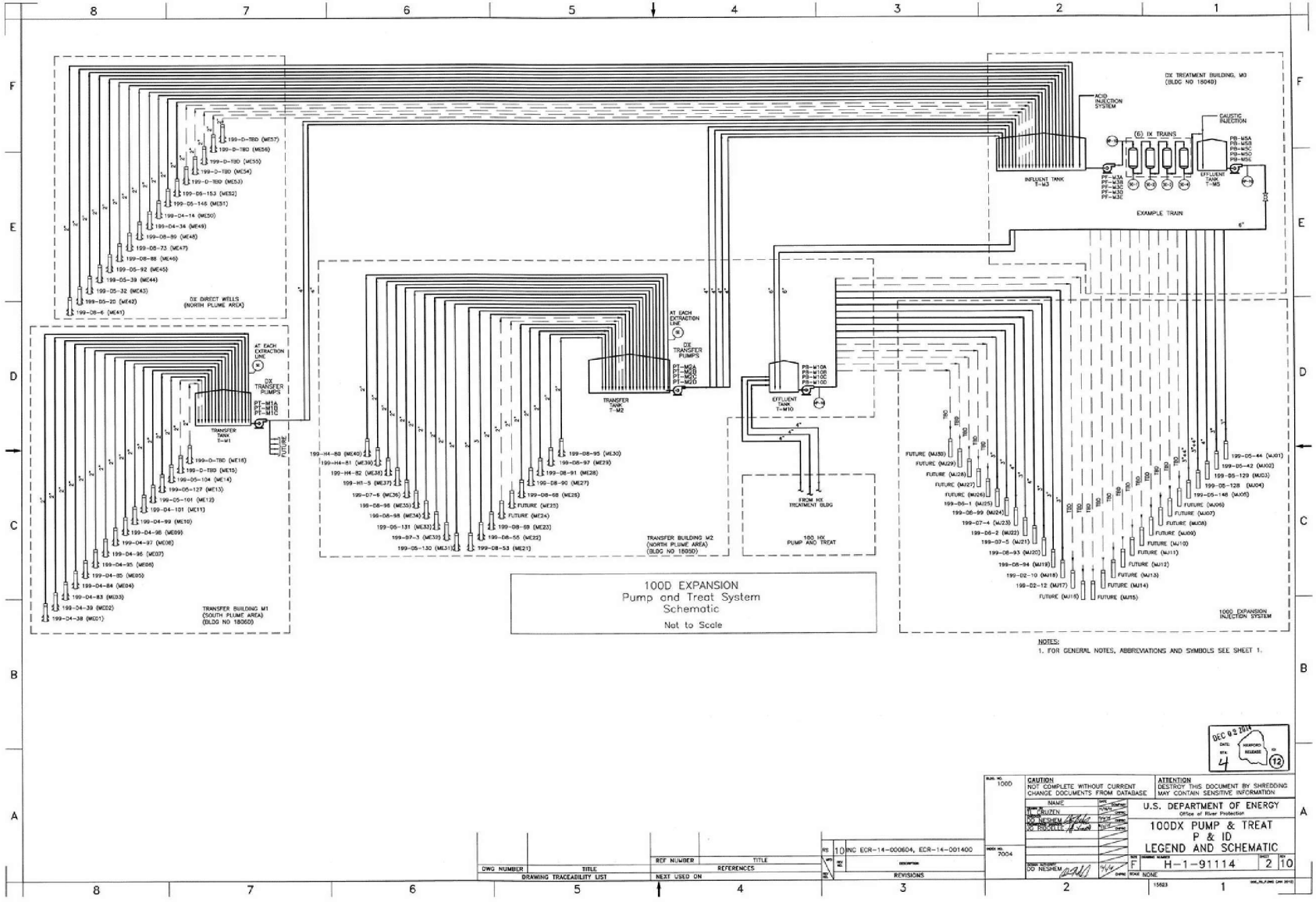

Figure 2-9. DX P&T System Schematic

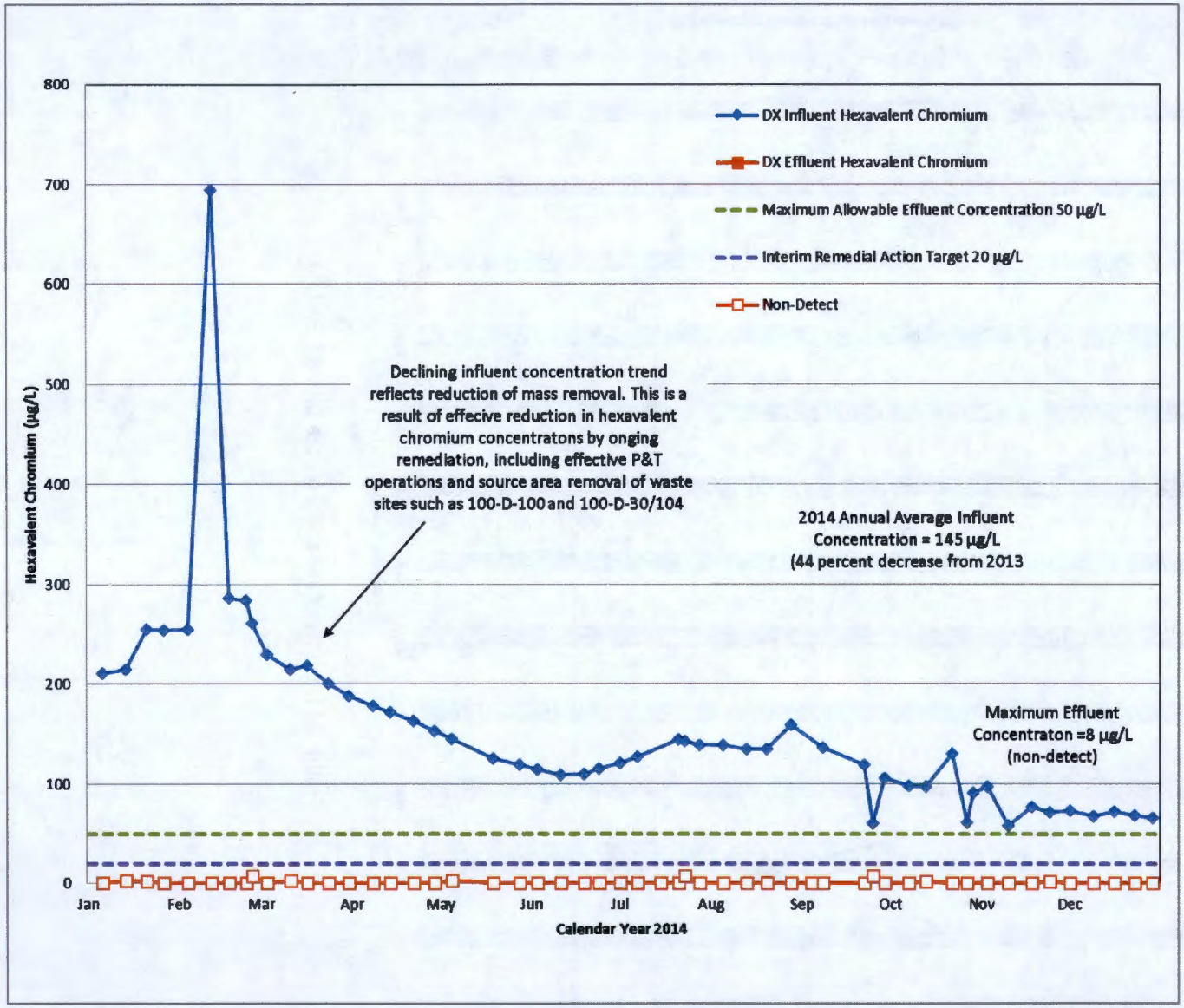

Figure 2-10. Influent/Effluent Concentrations for the DX P&T System

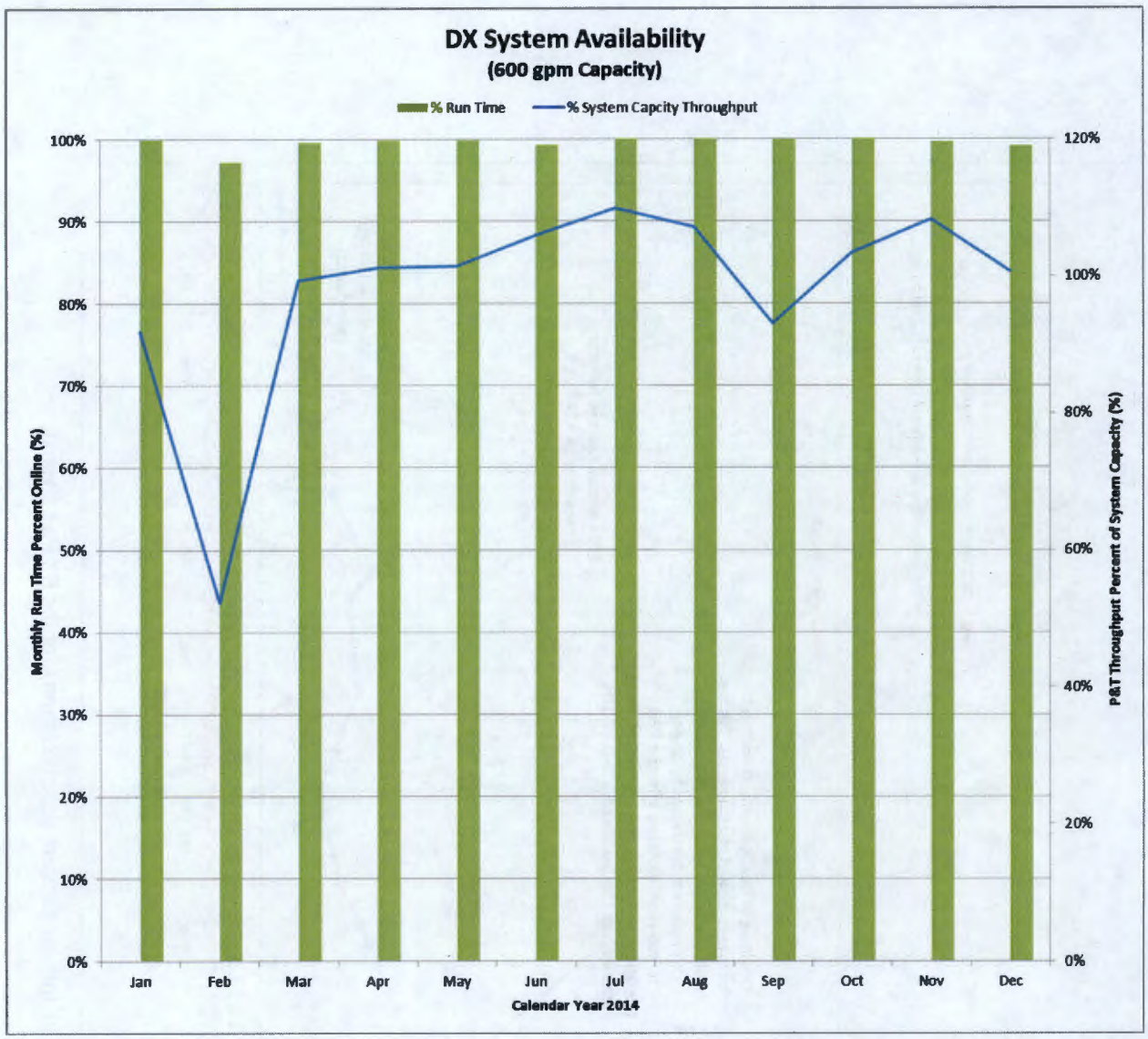

Figure 2-11. System Availability for the DX P&T System

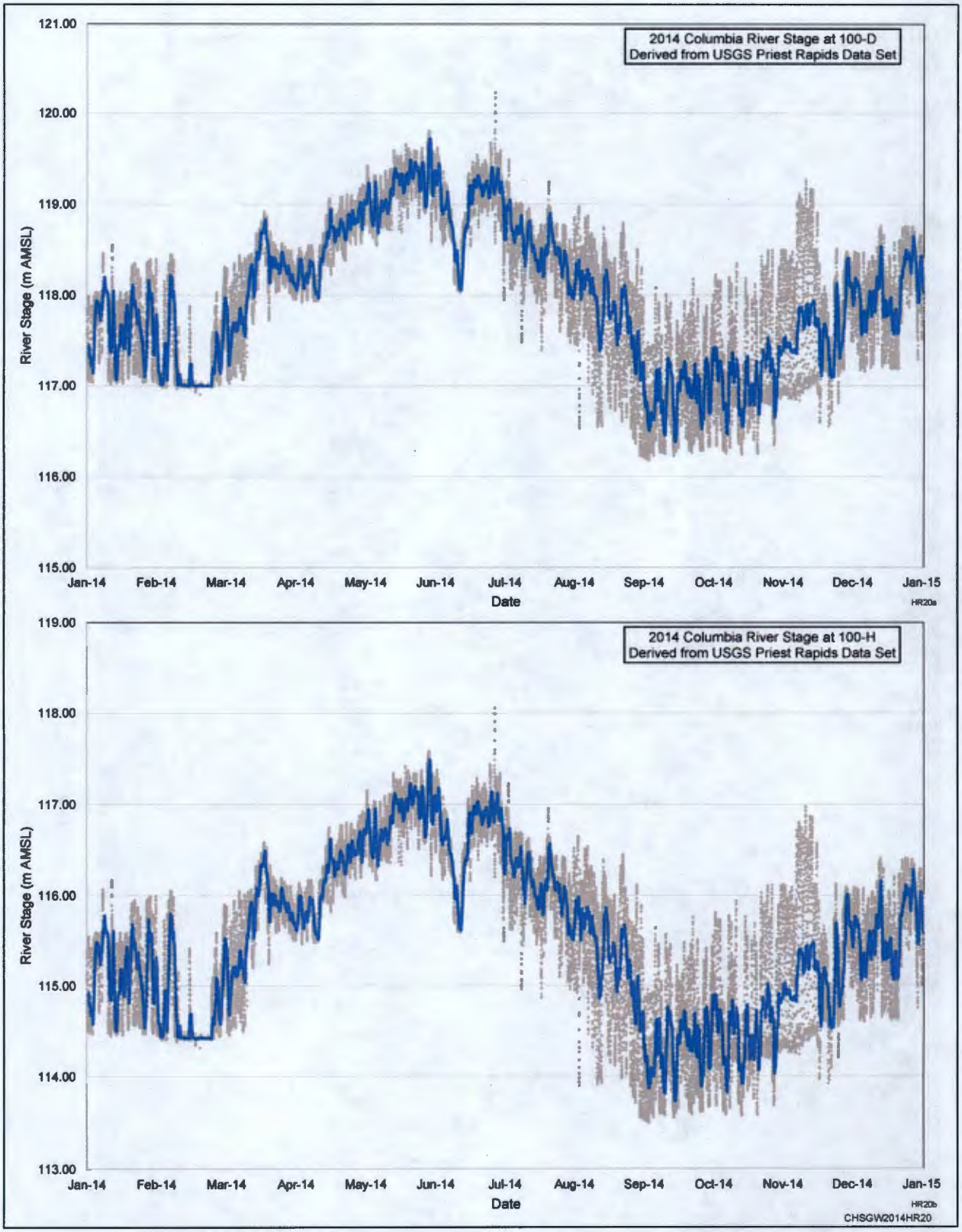

Figure 2-12. River Stage Hydrograph at 100-D and 100-H

Figure 2-13. Aerial View of the HX P&T System

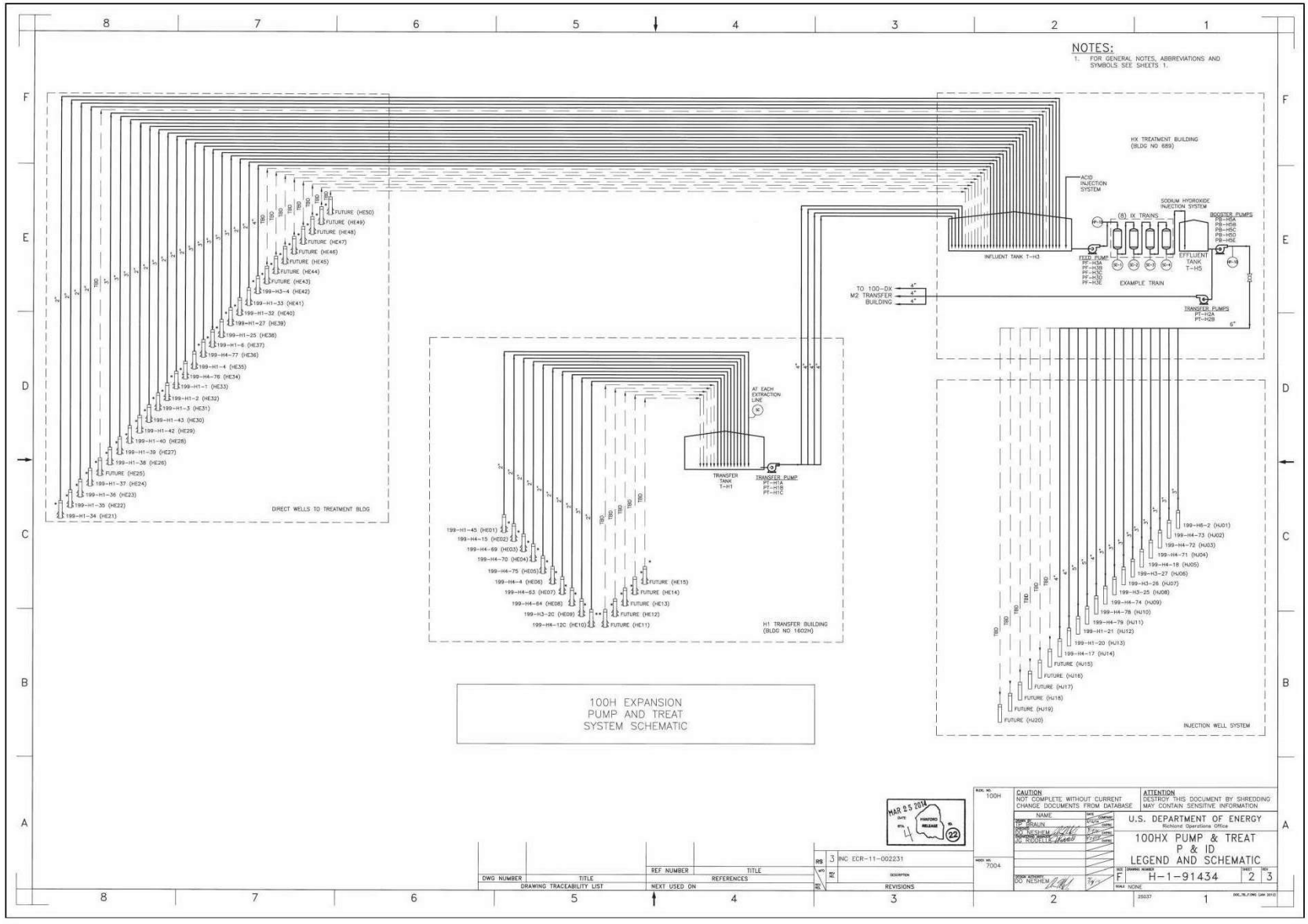

Figure 2-14. HX P&T System Schematic

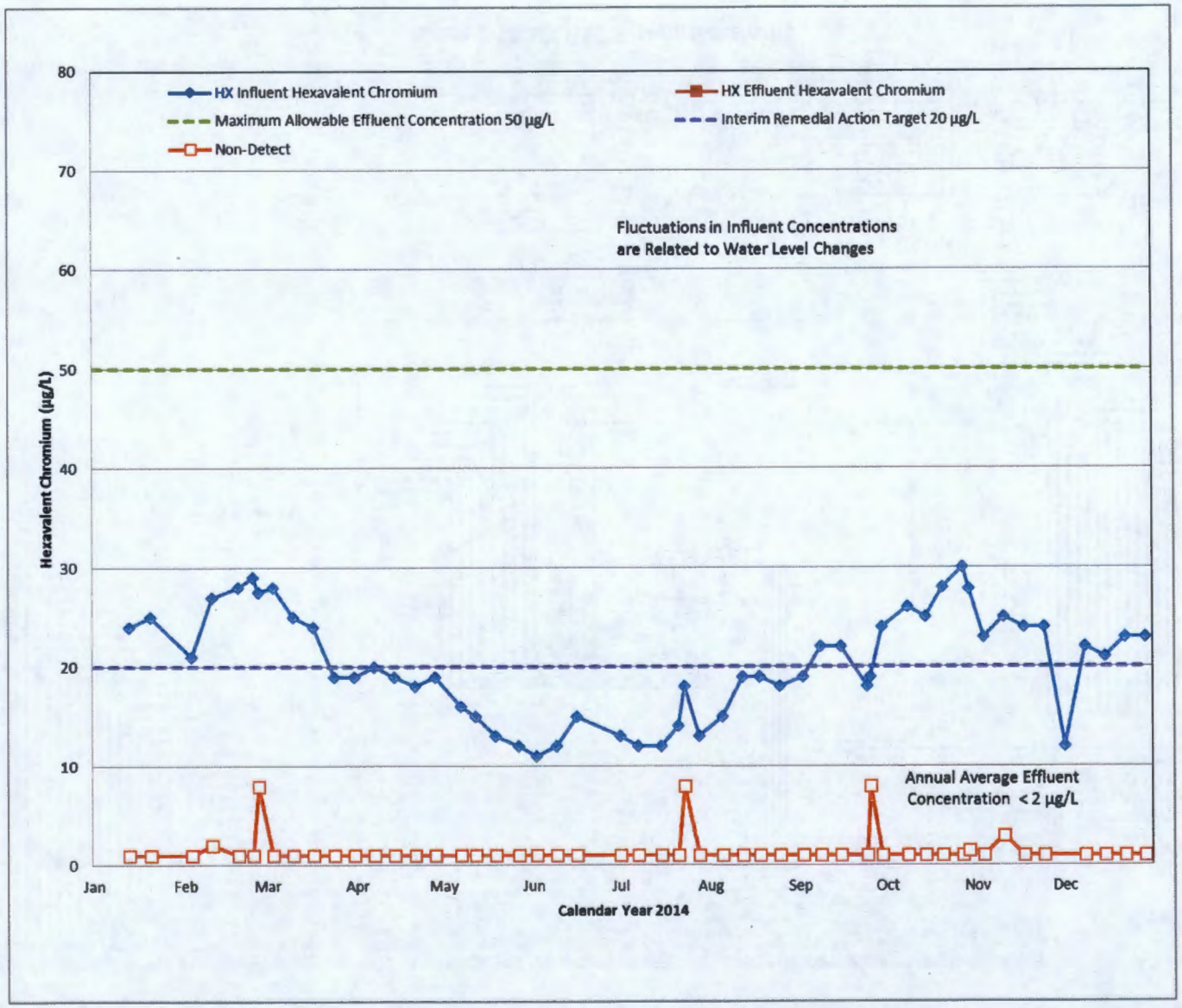

Figure 2-15. Influent/Effluent Concentrations for the HX P&T System

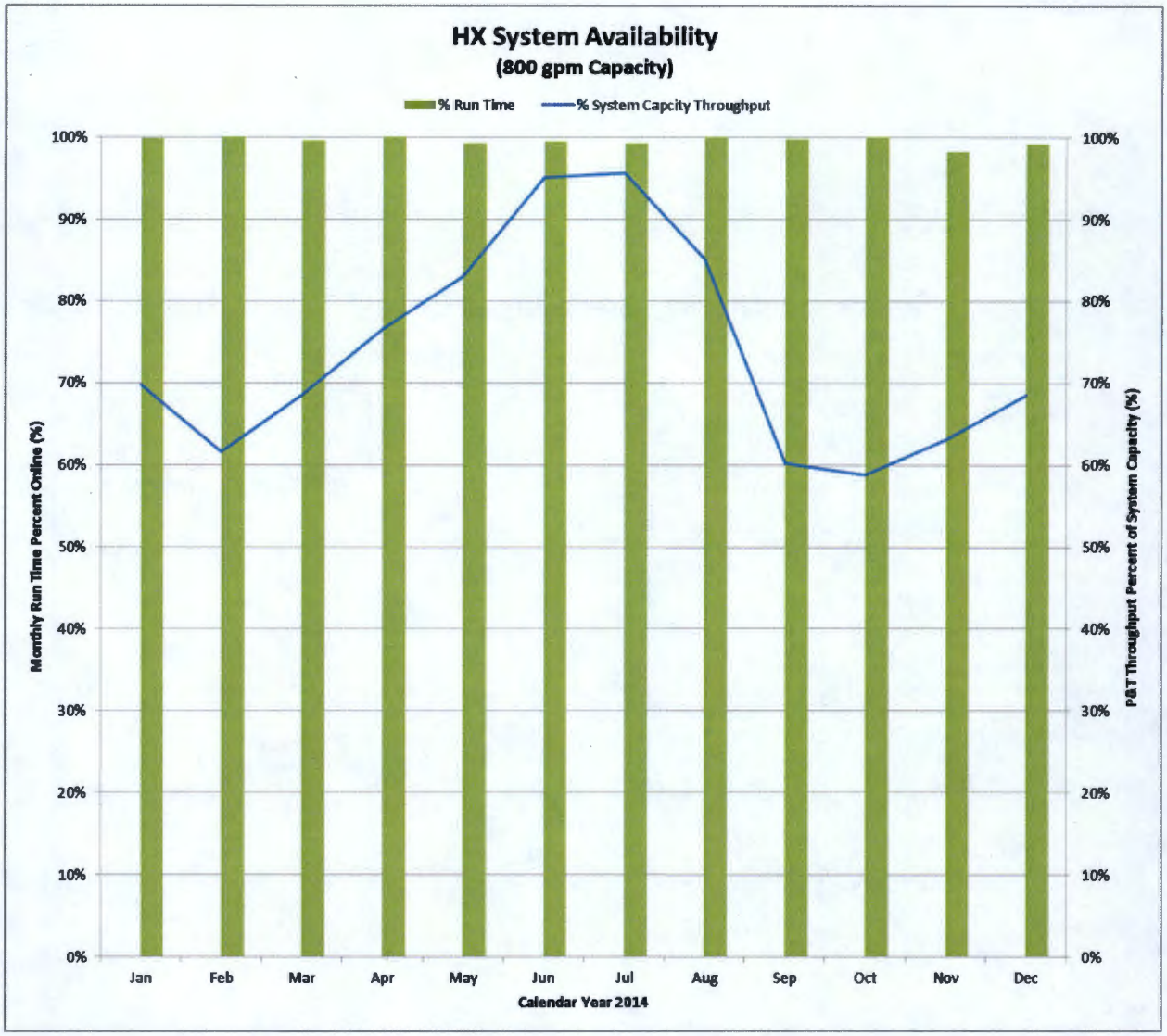

Figure 2-16. System Availability for the HX P&T System

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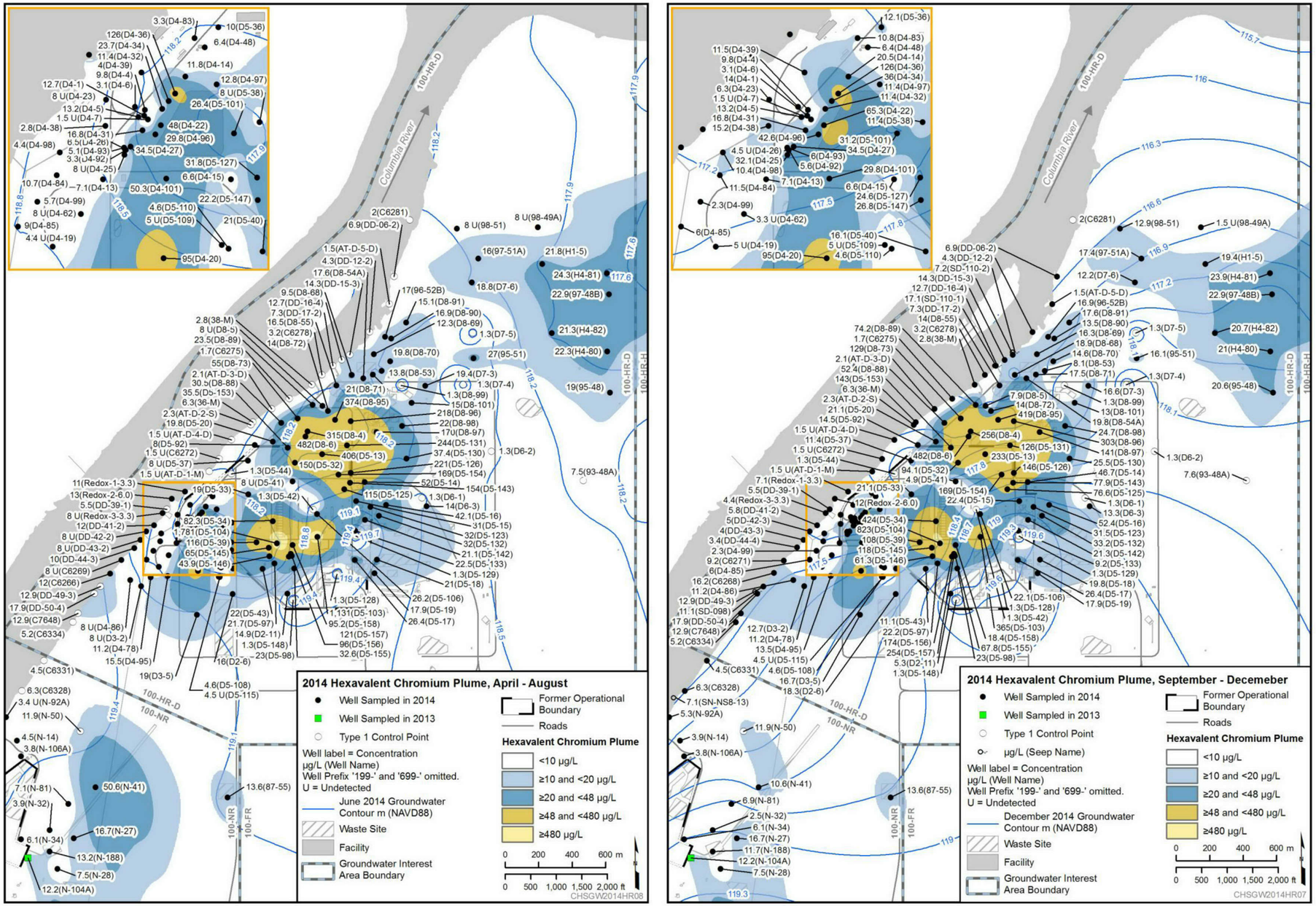

Figure 2-17. 100-HR-3 OU (100-D Area) Cr(VI) High River Stage to Low River Stage Comparison, 2014

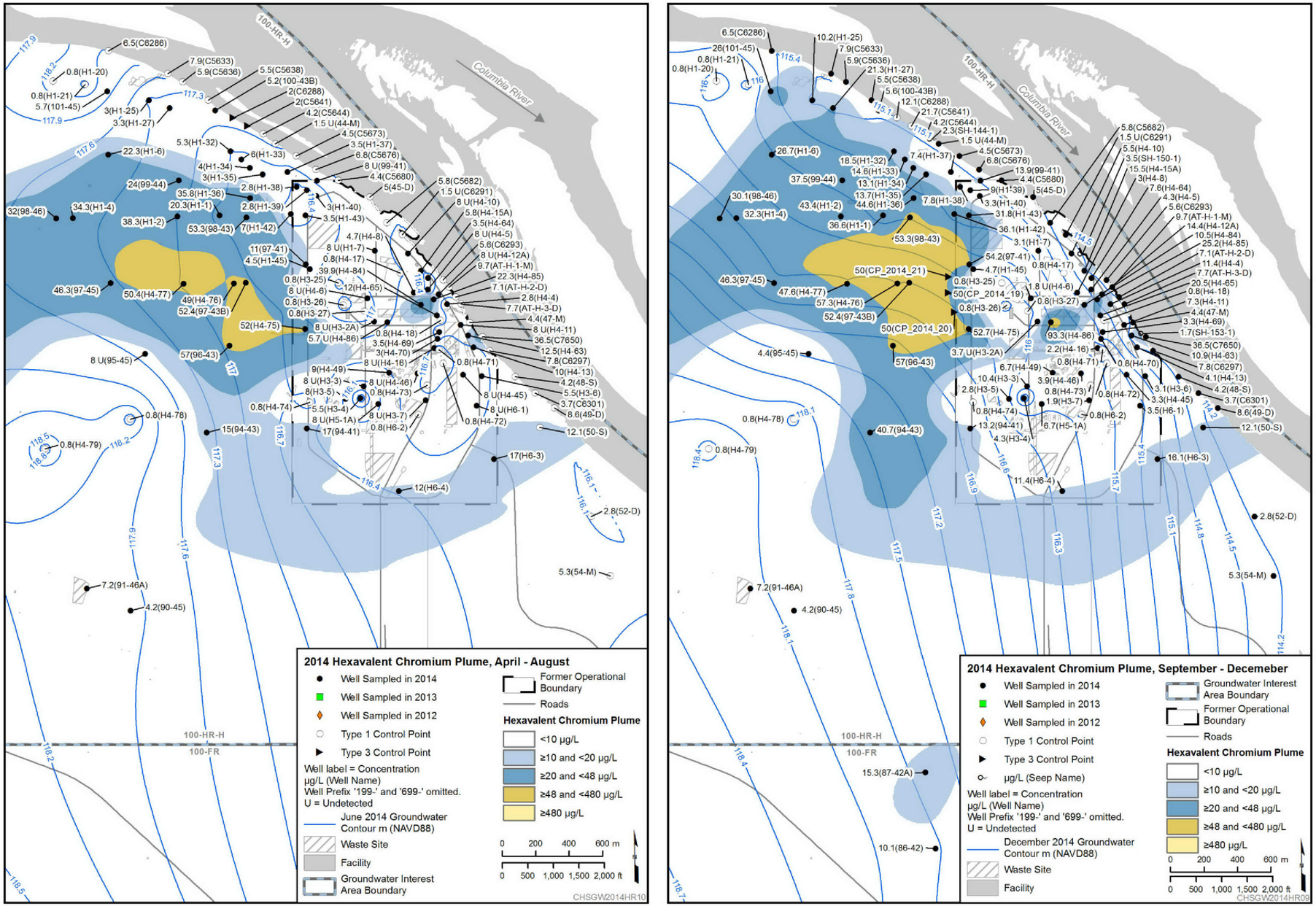

Figure 2-18. 100-HR-3 OU (100-H Area) Cr(VI) High River Stage to Low River Stage Comparison, 2014

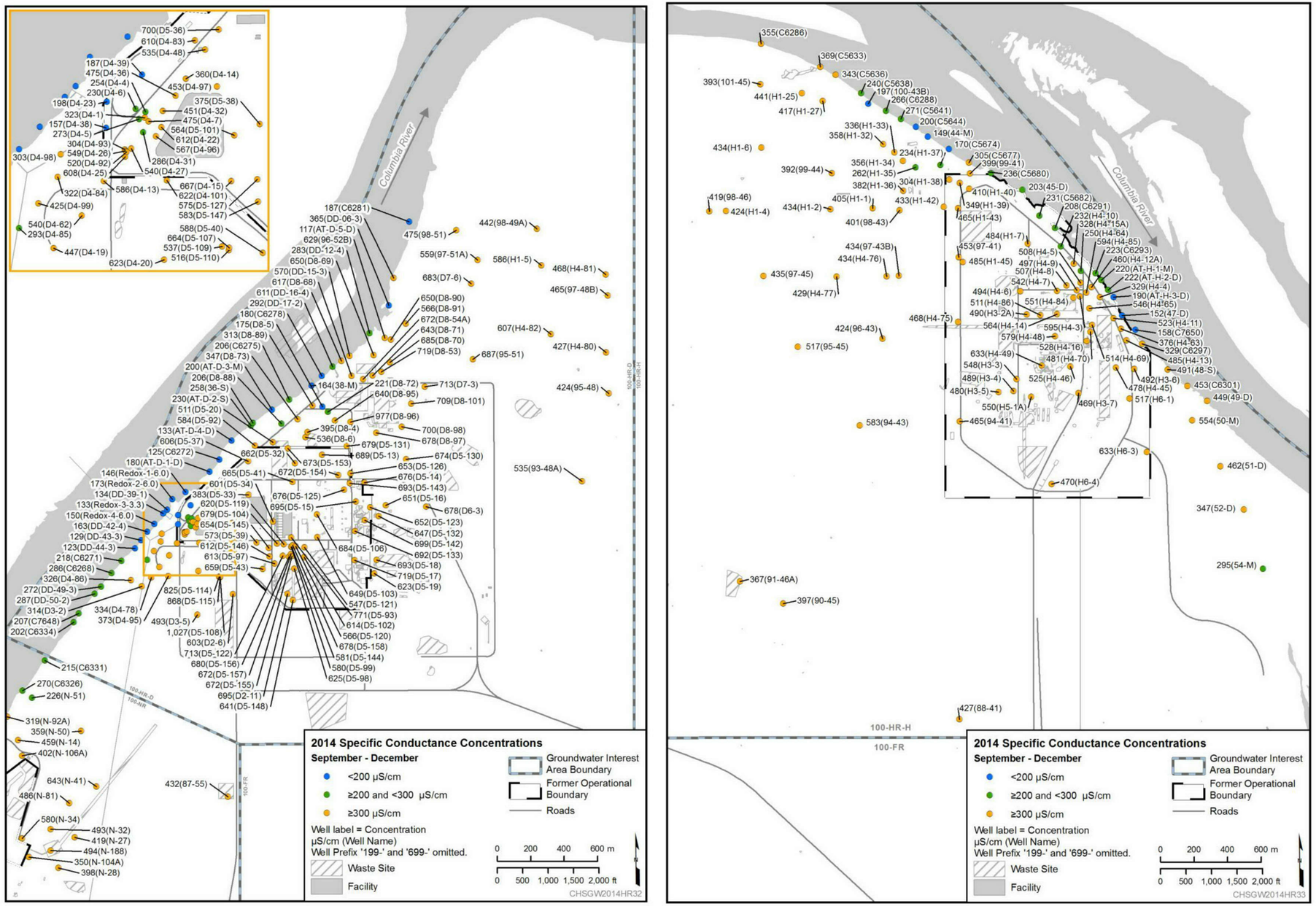

Figure 2-19. Specific Conductance at 100-HR-3 (Fall 2014)

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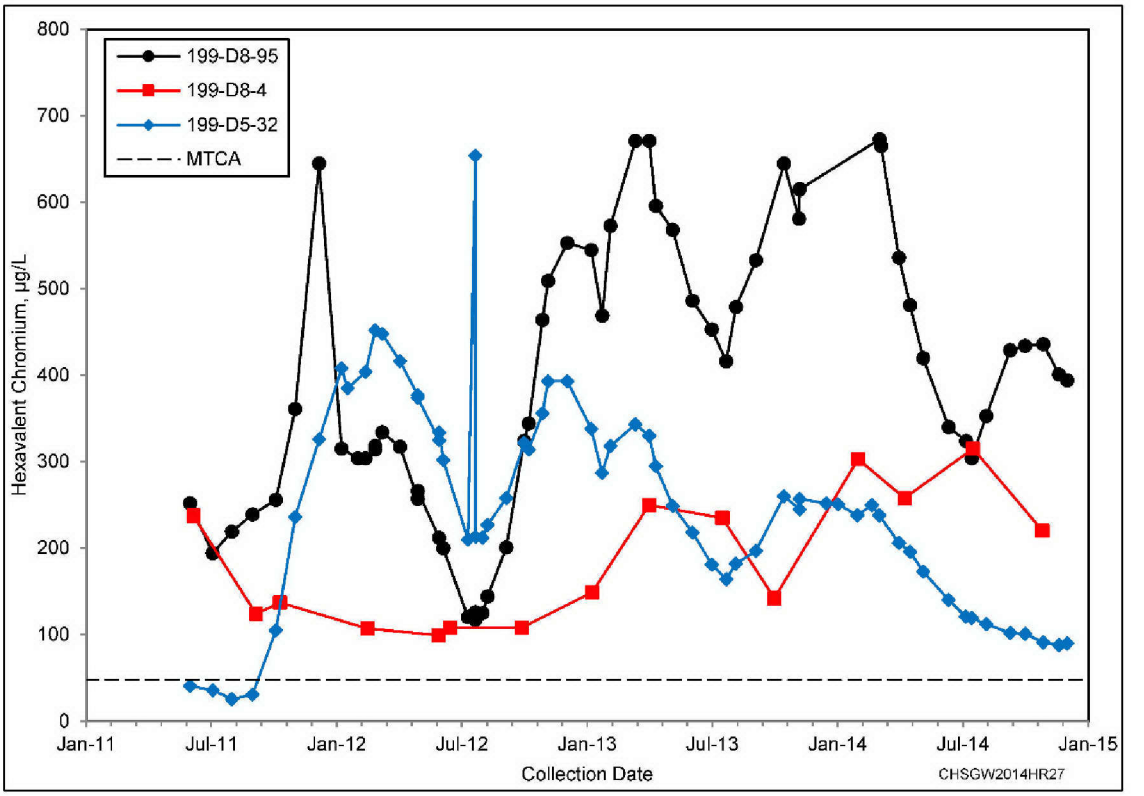

Figure 2-20. Trend Plot for Wells near the 120-D-1 and 126-D-1 Waste Sites

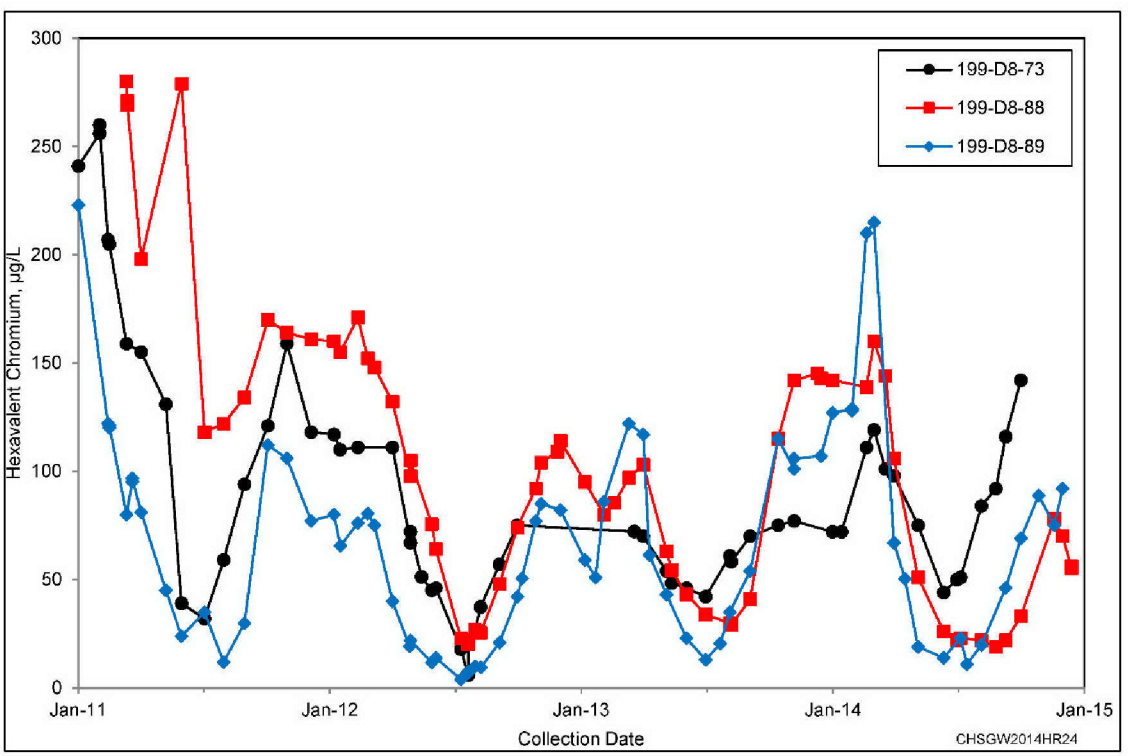

Figure 2-21. Trend Plot for Wells Downgradient of the 120-D-1 and 126-D-1 Waste Sites

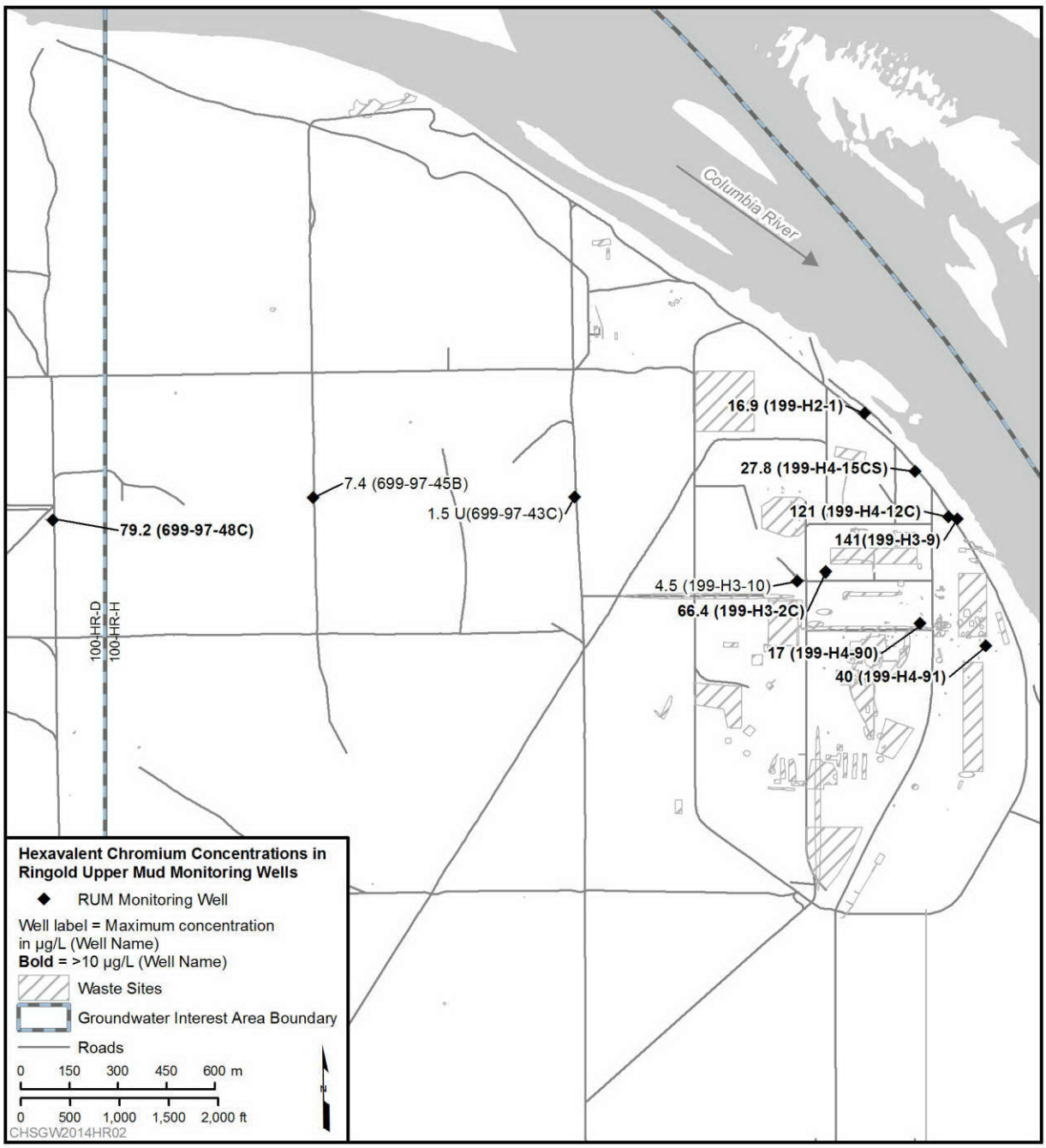

Figure 2-22. 100-H Area and Horn: Cr(VI) in the First Water-Bearing Unit of the RUM, 2014

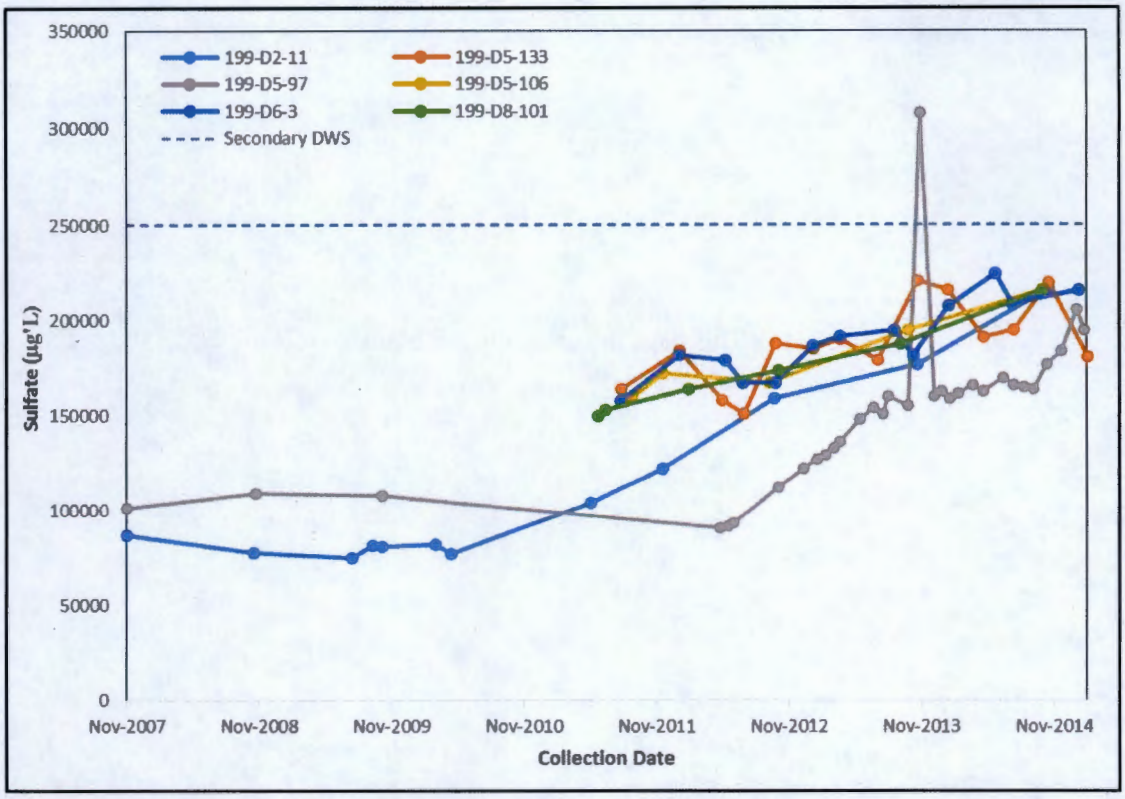

Figure 2-23. Sulfate Concentration in Select Wells

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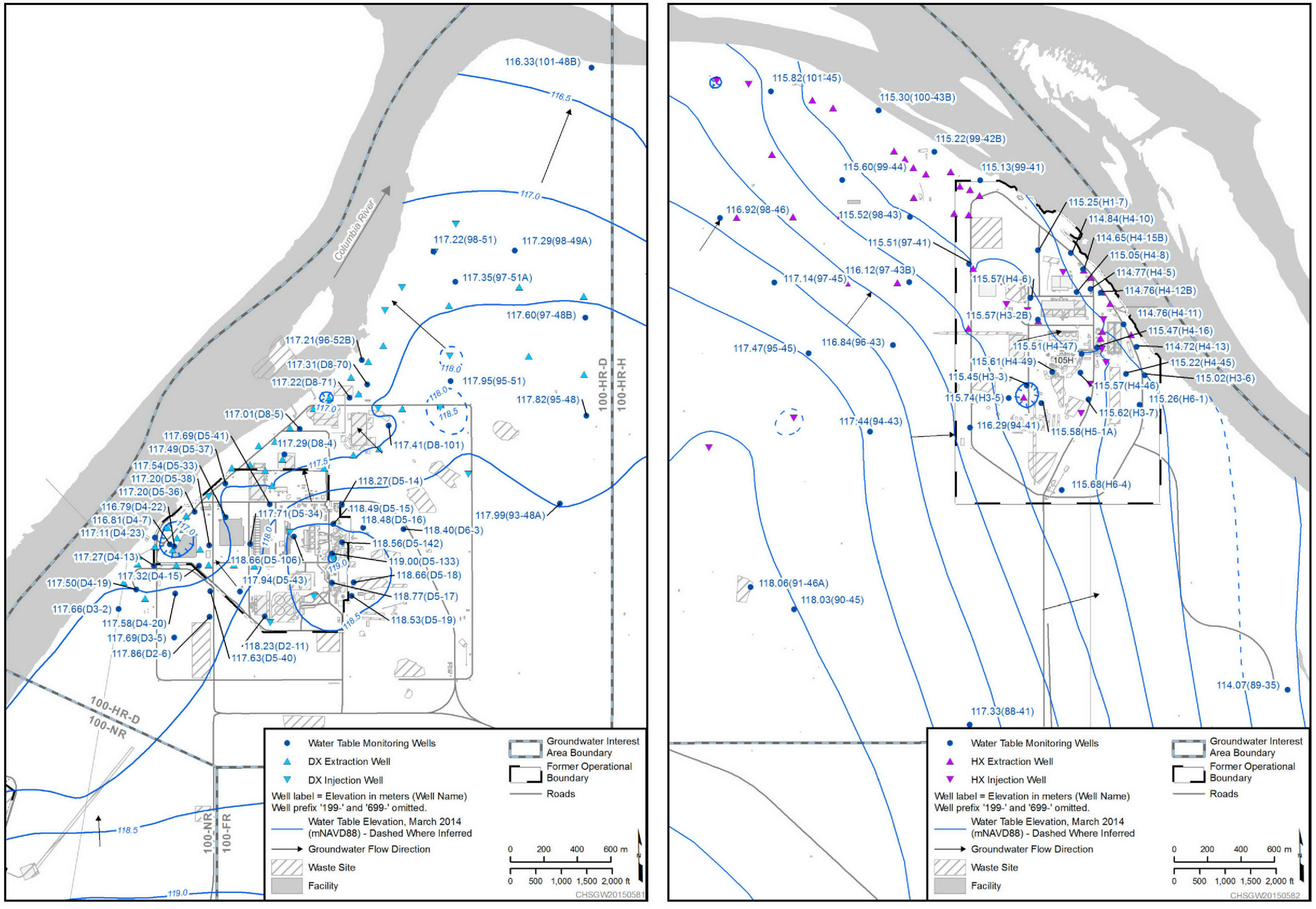

Figure 2-24. 100-HR-3 OU Water Table Elevation Map, March 2014

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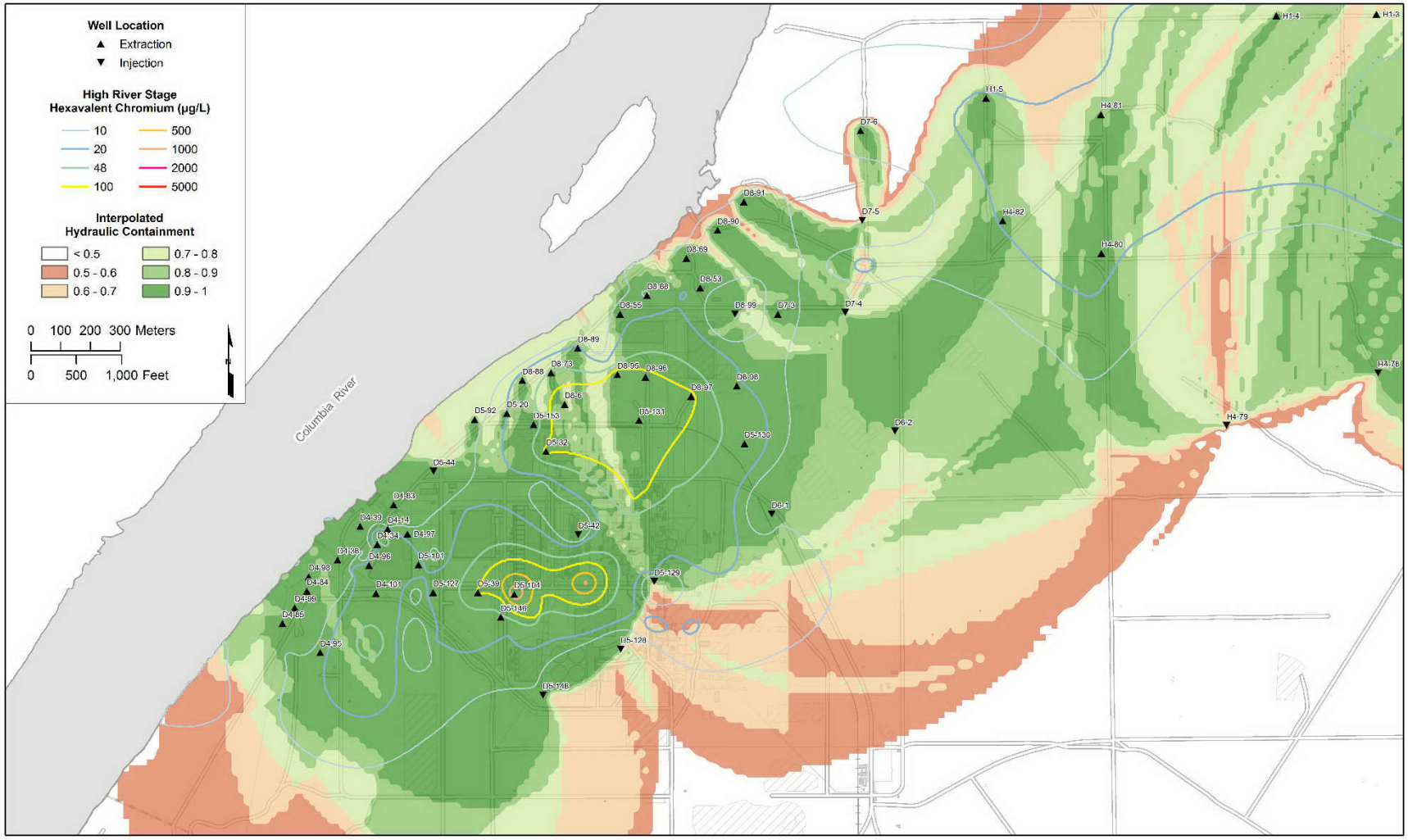


Figure 2-25(a). 100-D Area Interpolated CFM and High River Stage Chromium Contamination

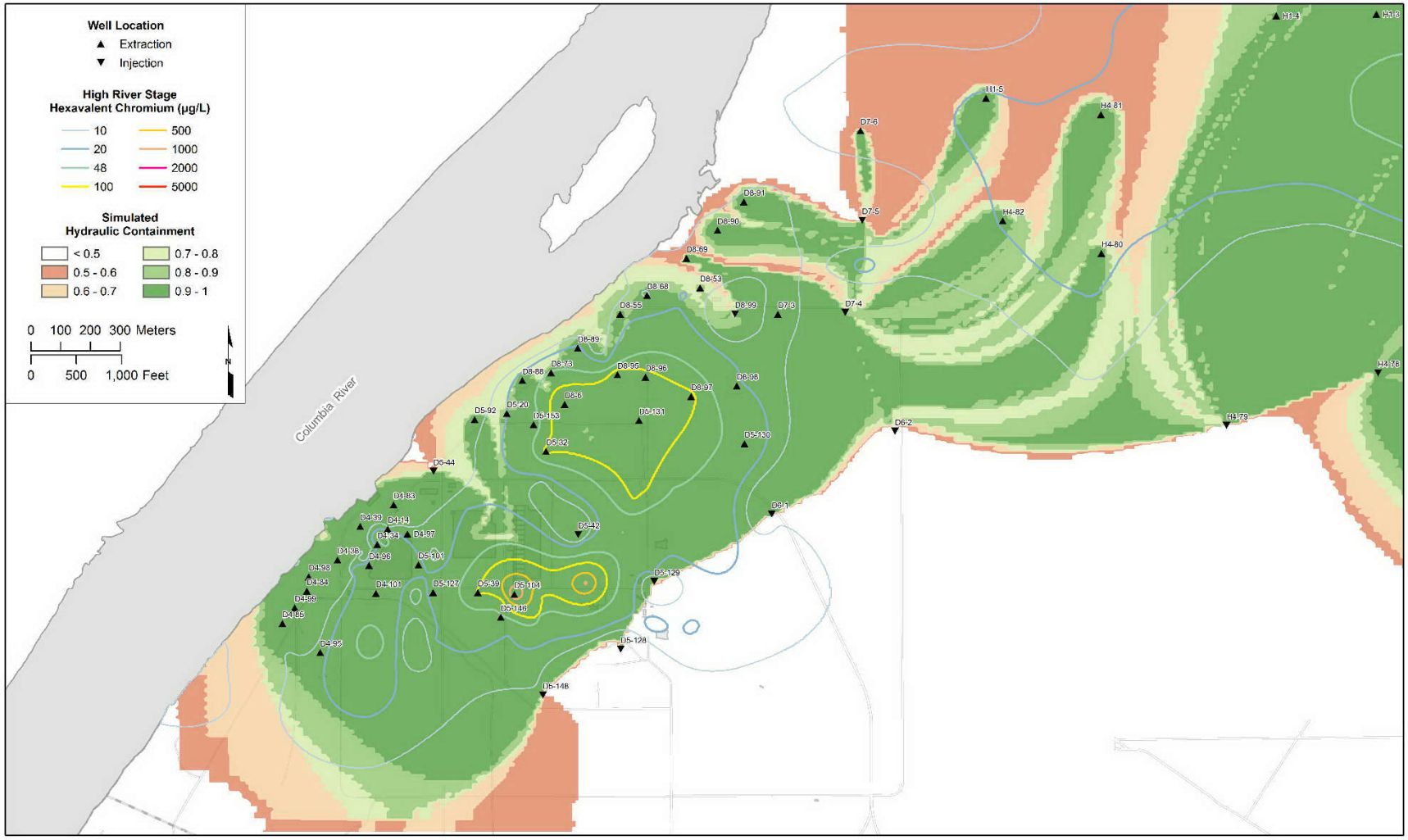


Figure 2-25(b). 100-D Area Simulated CFM and High River Stage Chromium Contamination

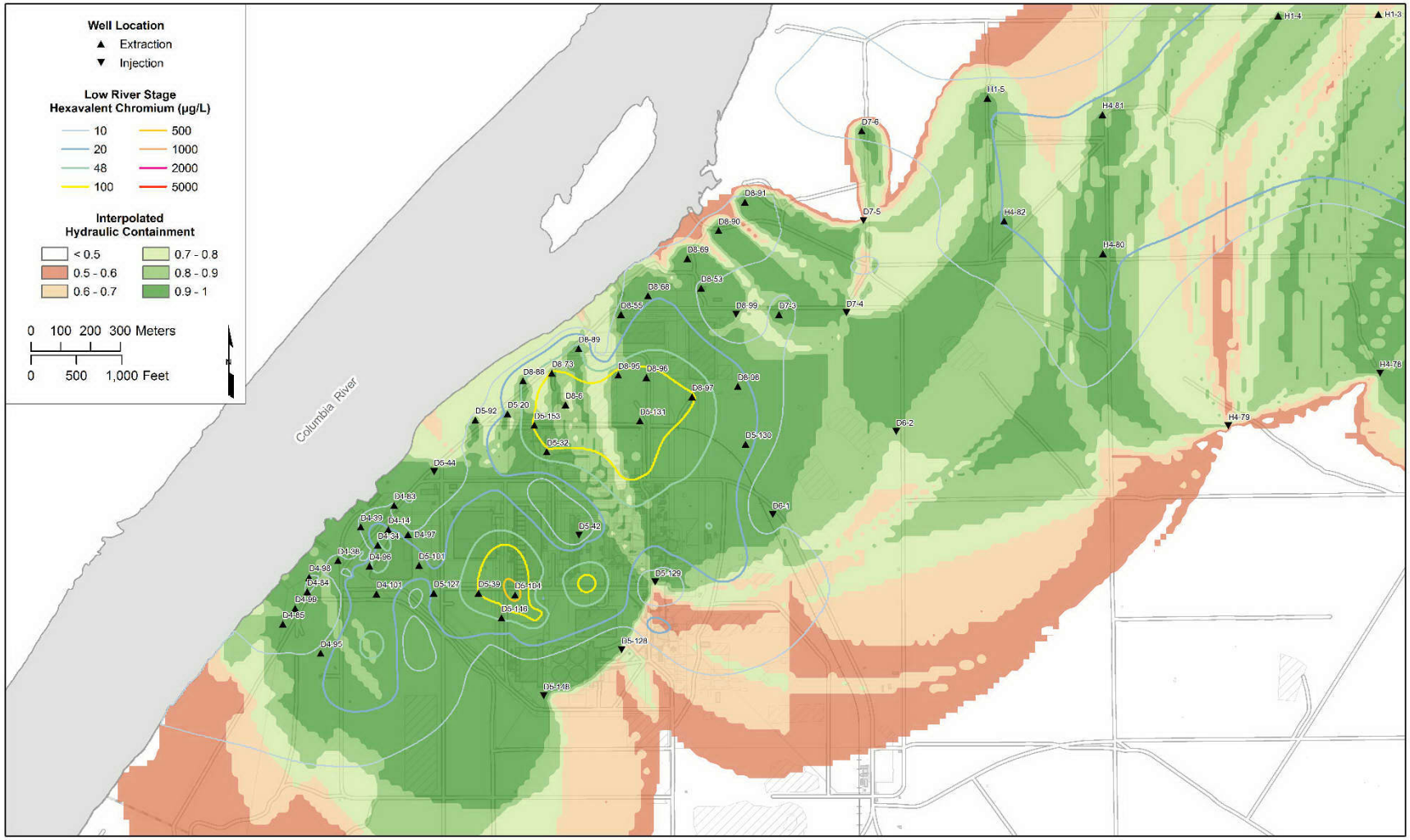


Figure 2-25(c). 100-D Area Interpolated CFM and Low River Stage Chromium Contamination

Figure 2-25(d). 100-D Area Simulated CFM and Low River Stage Chromium Contamination

Figure 2-25(e). 100-D Area Groundwater Flow Lines of Capture Zone for Low River Stage Chromium Contamination

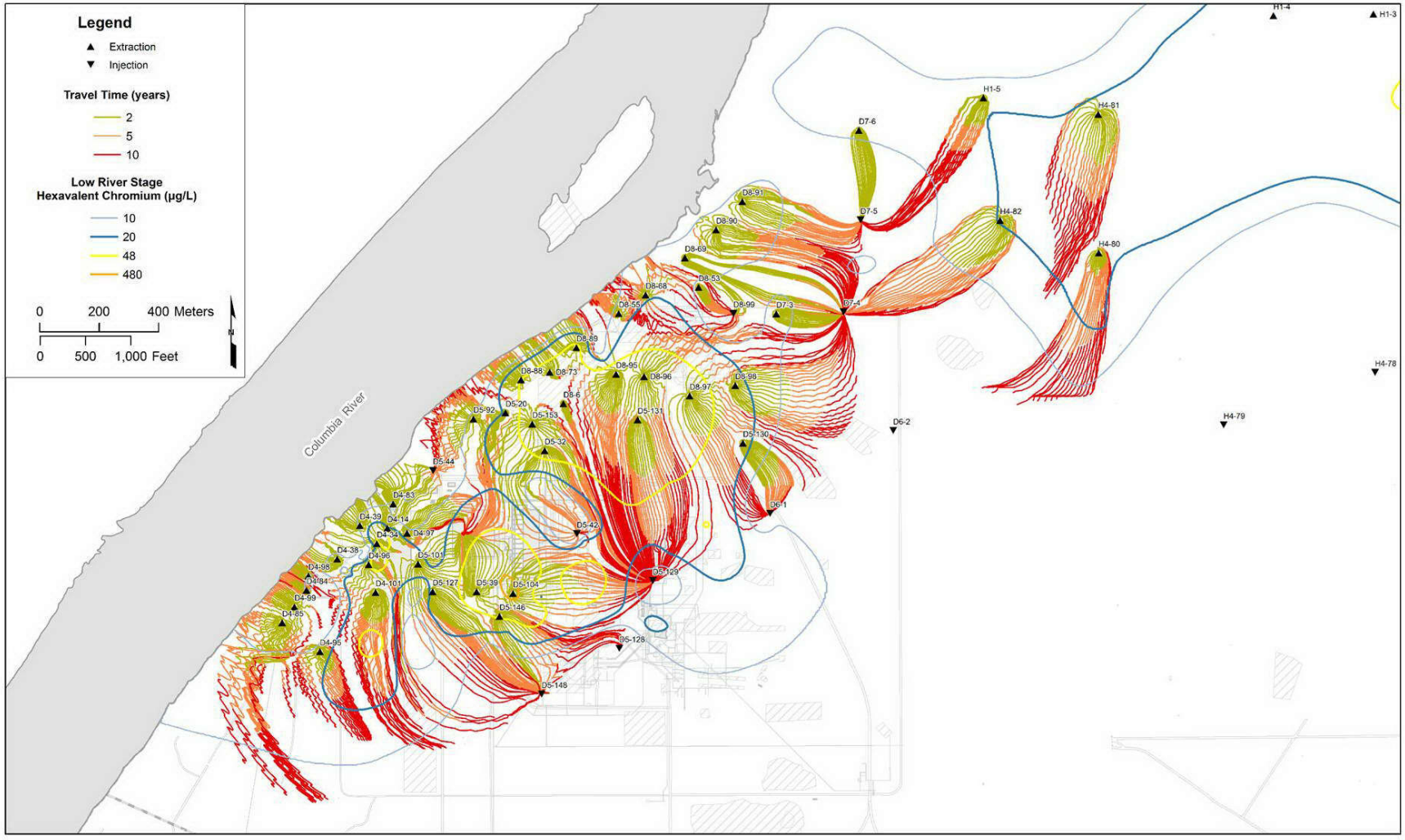


Figure 2-25(f). 100-D Area Groundwater Flow Lines of Capture Zone Overlay with Low River Stage Chromium Plume Contours

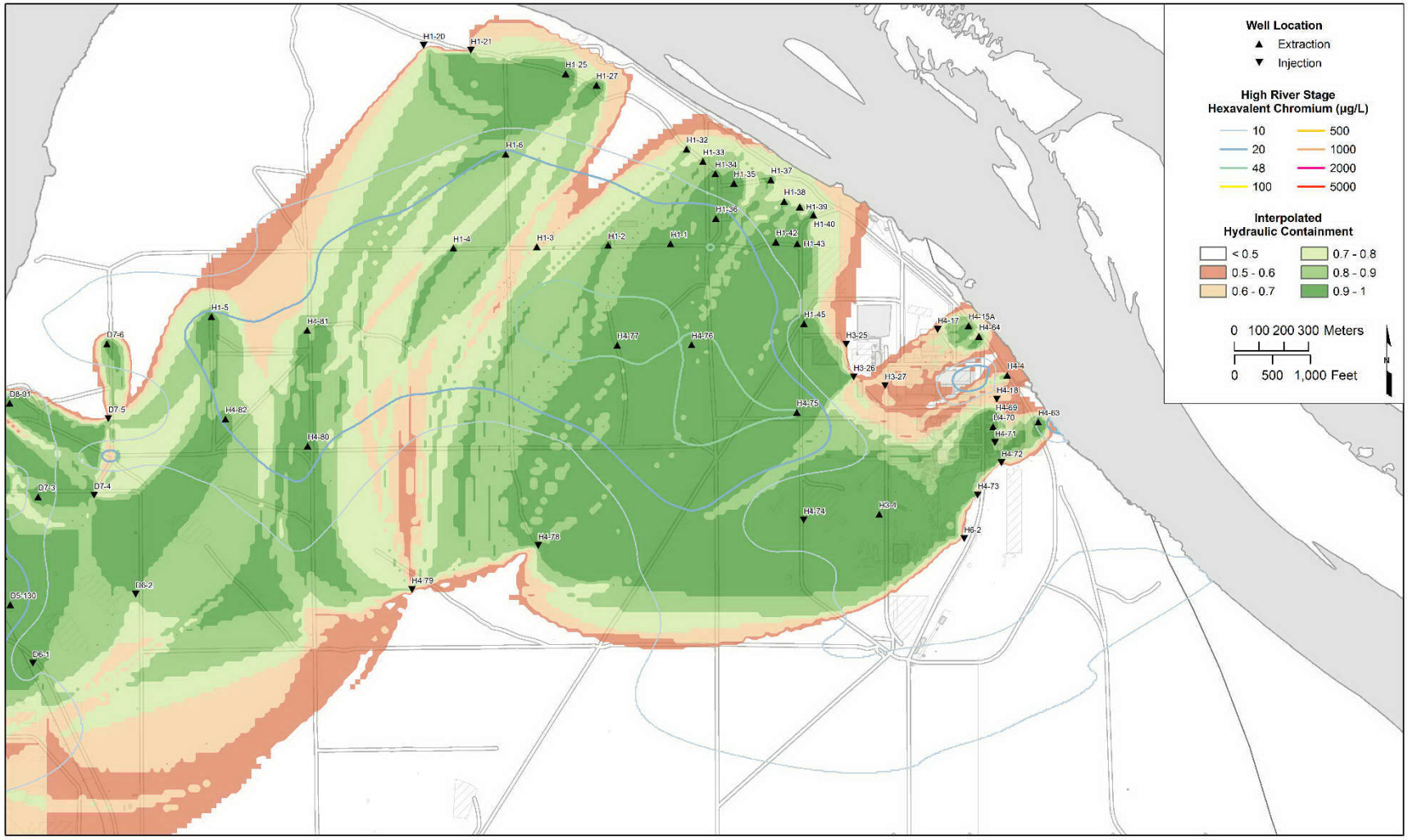


Figure 2-26(a). 100-H Area Interpolated CFM and High River Stage Chromium Contamination

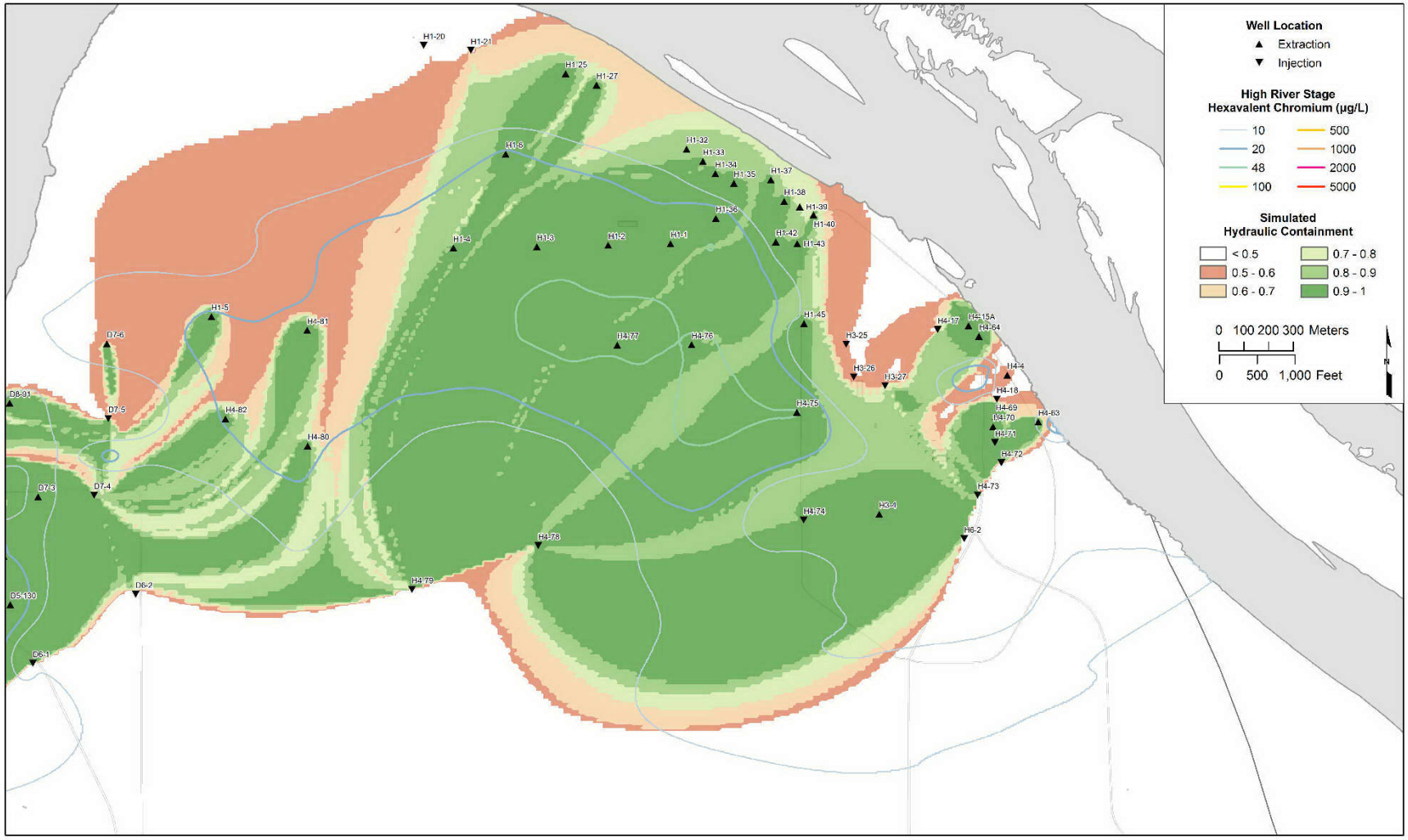


Figure 2-26(b). 100-H Area Simulated CFM and High River Stage Chromium Contamination

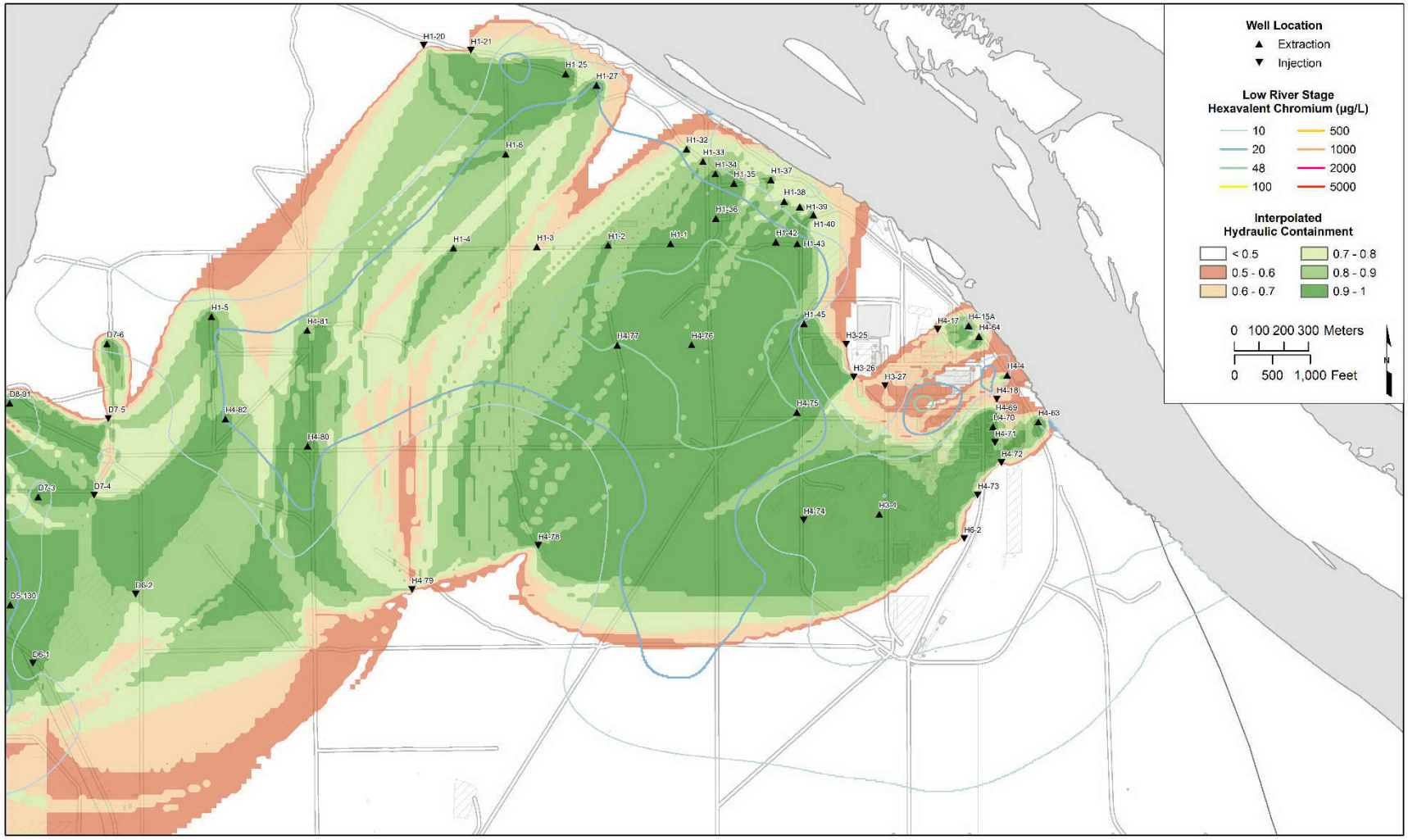


Figure 2-26(c). 100-H Area Interpolated CFM and Low River Stage Chromium Contamination

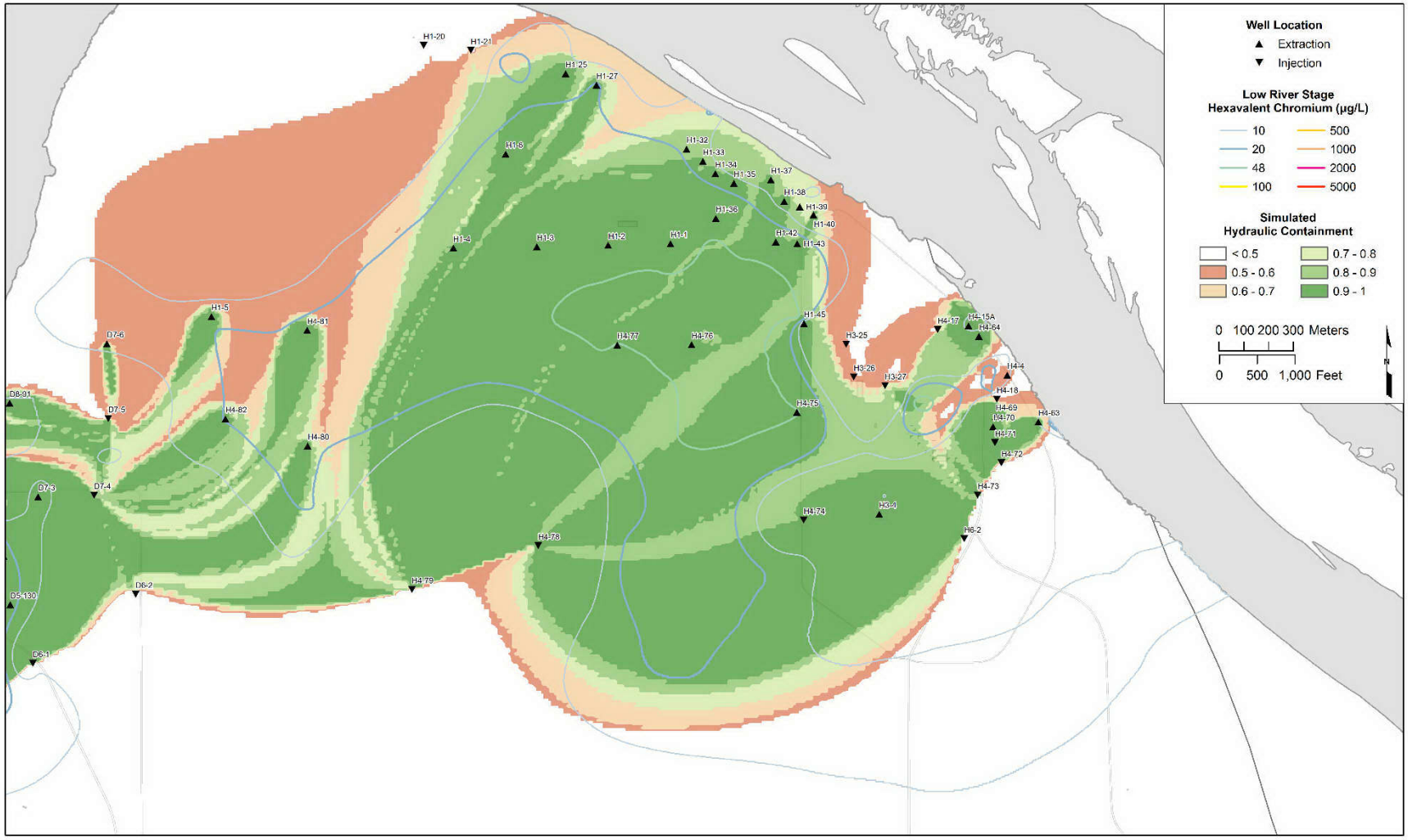


Figure 2-26(d). 100-H Area Simulated CFM and Low River Stage Chromium Contamination

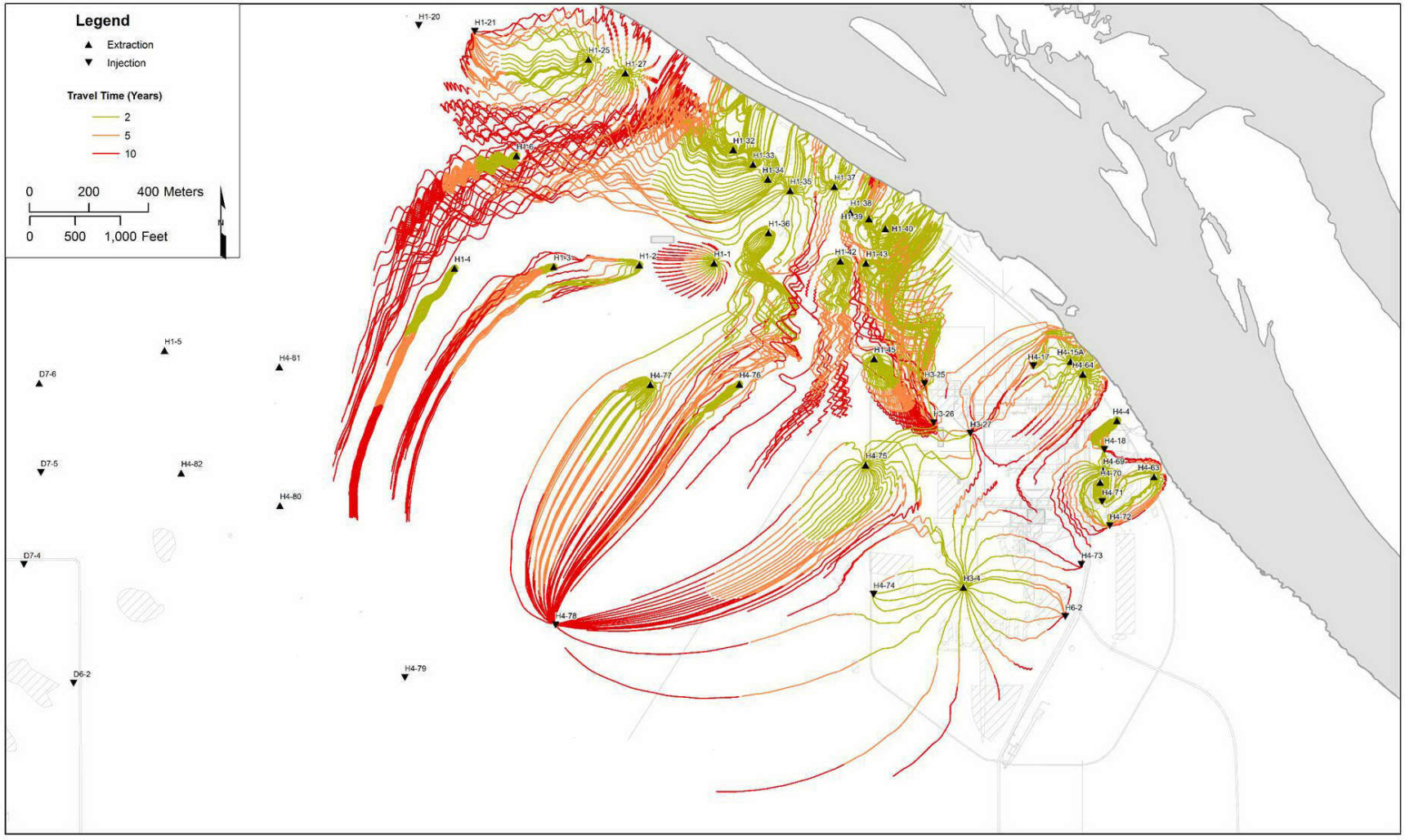


Figure 2-26(e). 100-H Area Groundwater Flow Lines of Capture Zone for Low River Stage Chromium Contamination

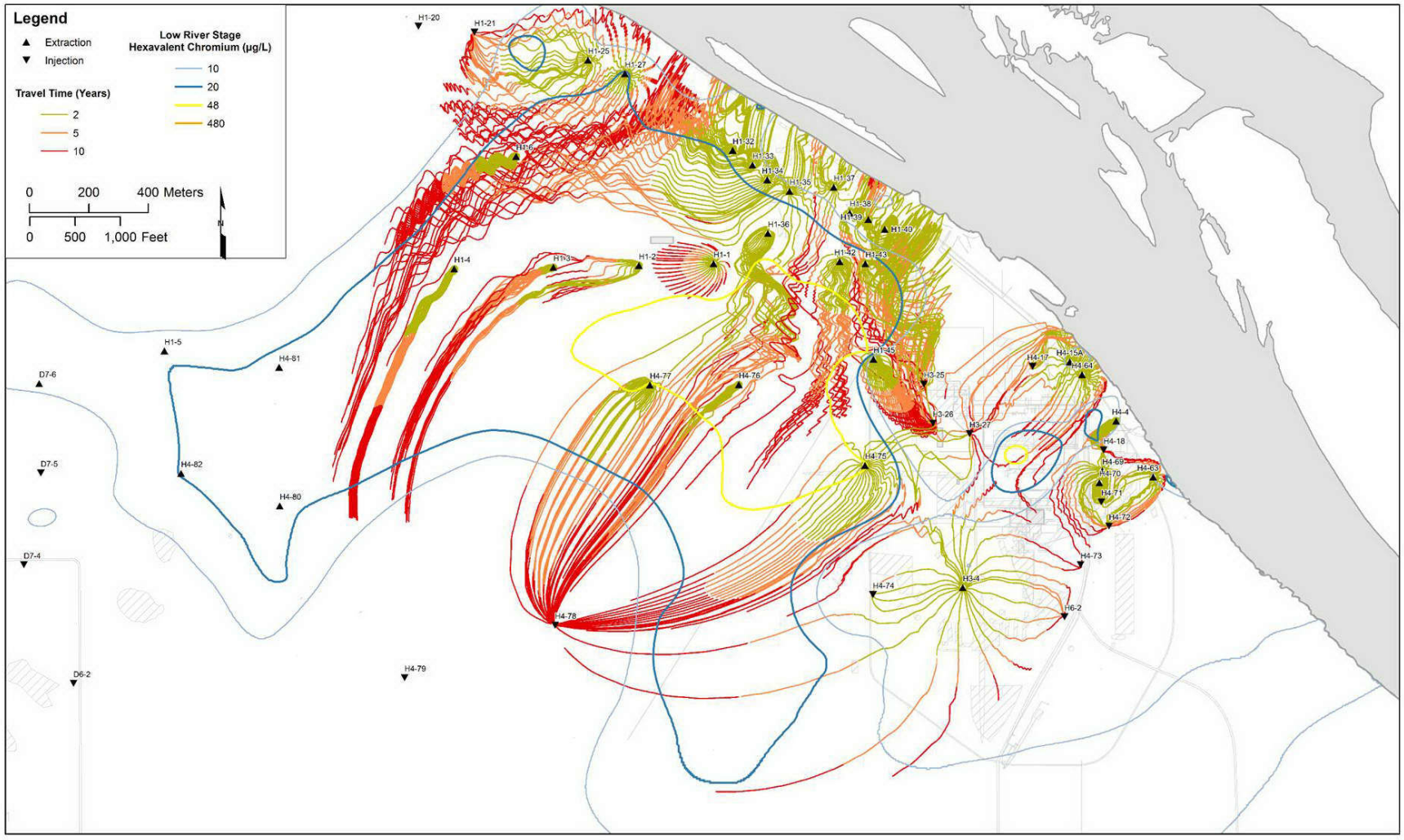


Figure 2-26(f). 100-H Area Groundwater Flow Lines of Capture Zone Overlay with Low River Stage Chromium Plume Contours

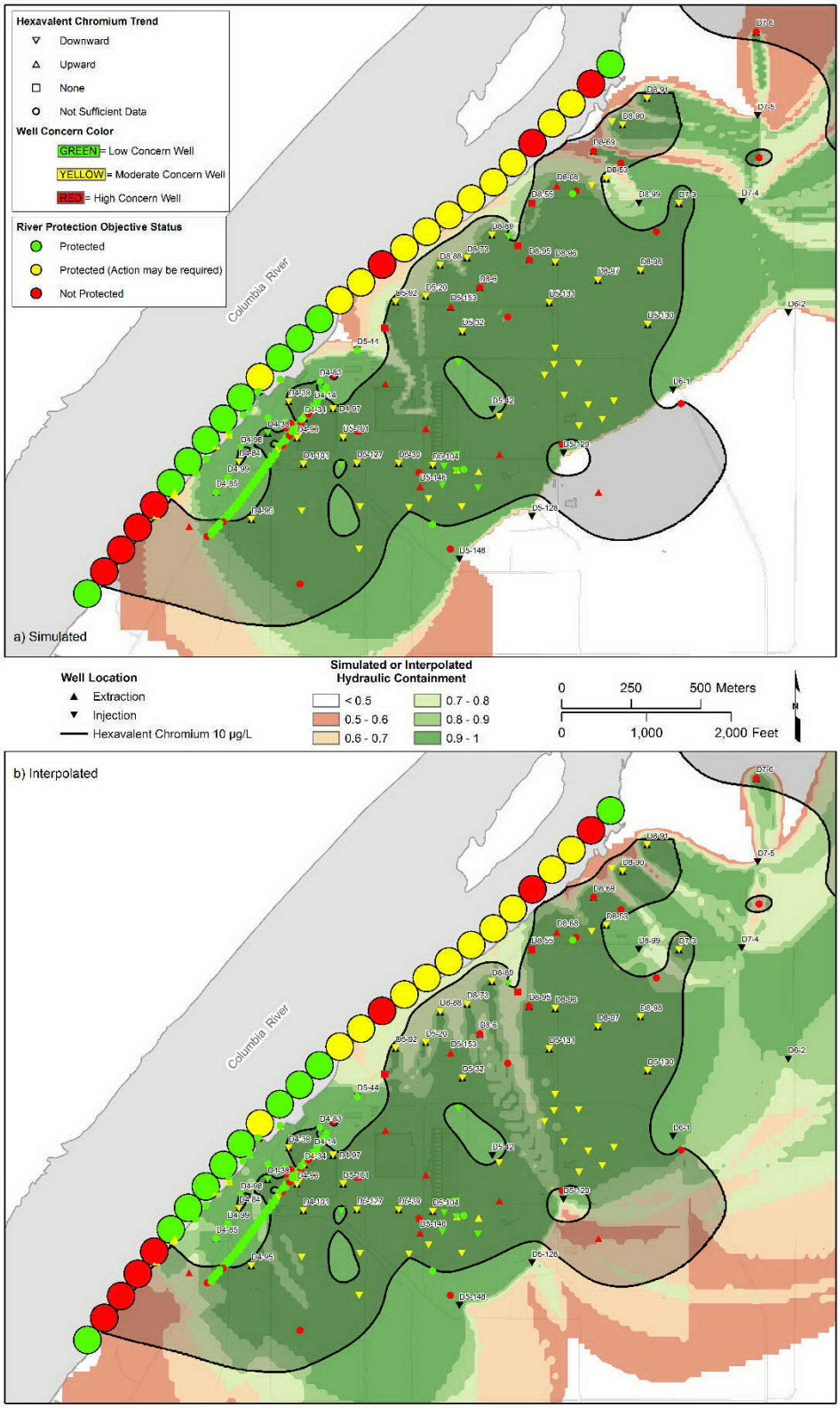


Figure 2-27(a). 100-D Area Quantitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

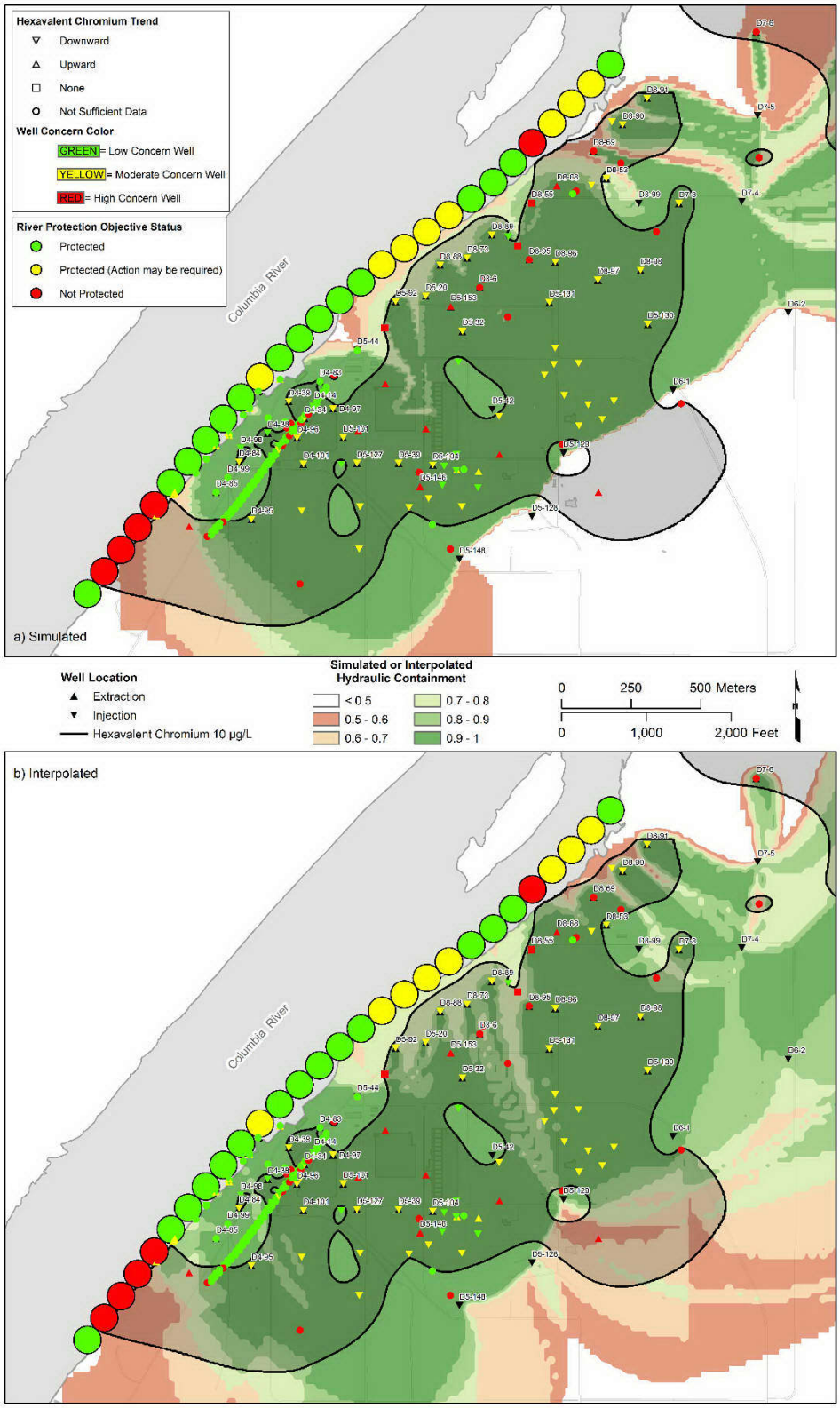


Figure 2-27(b). 100-D Area Qualitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

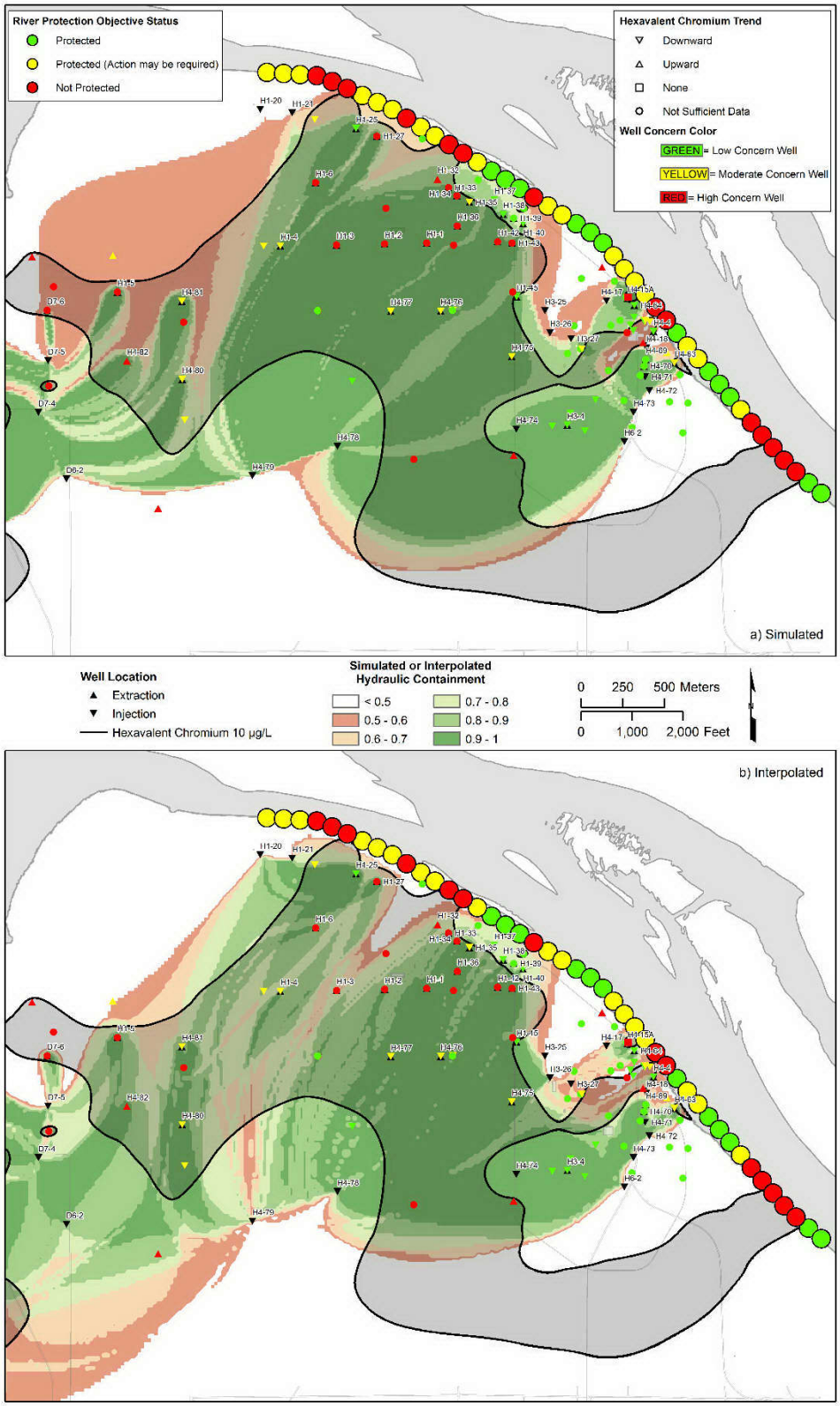


Figure 2-28(a). 100-H Area Quantitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

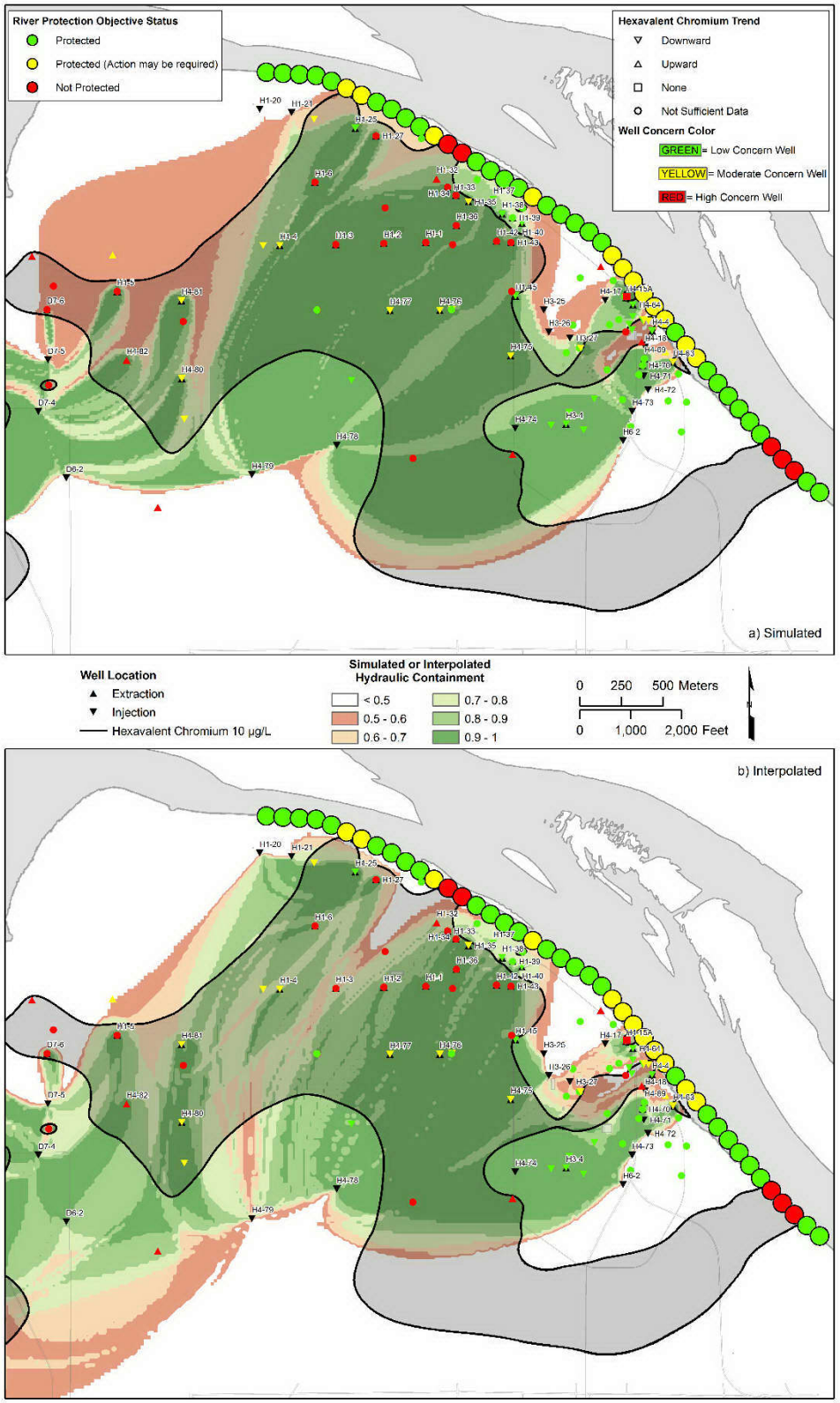


Figure 2-28(b). 100-H Area Qualitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

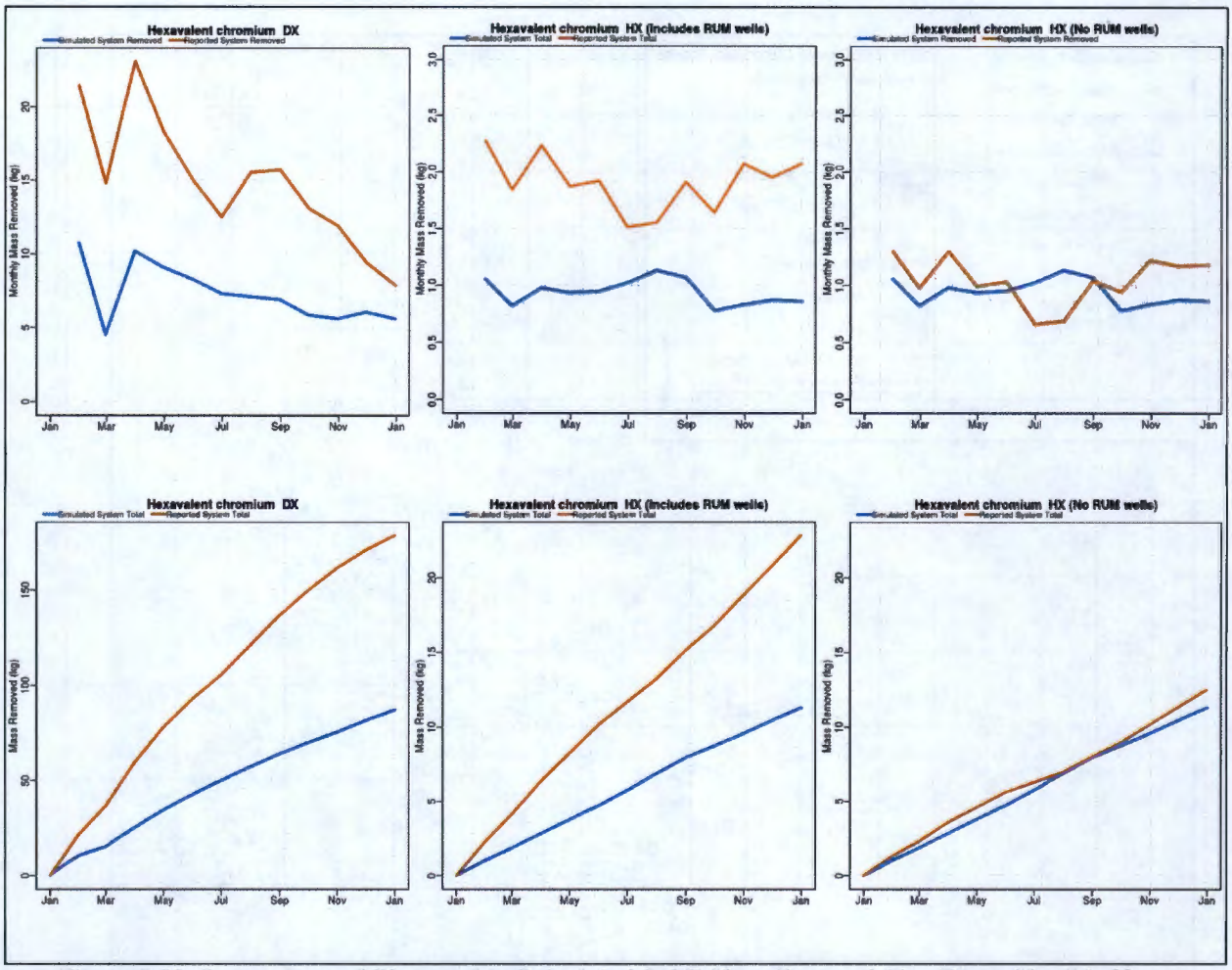


Figure 2-29. Comparison of Observed to Calculated Cr(VI) Mass Removal (Top Row = Monthly Mass Removal; Bottom Row = Cumulative Mass Removal)

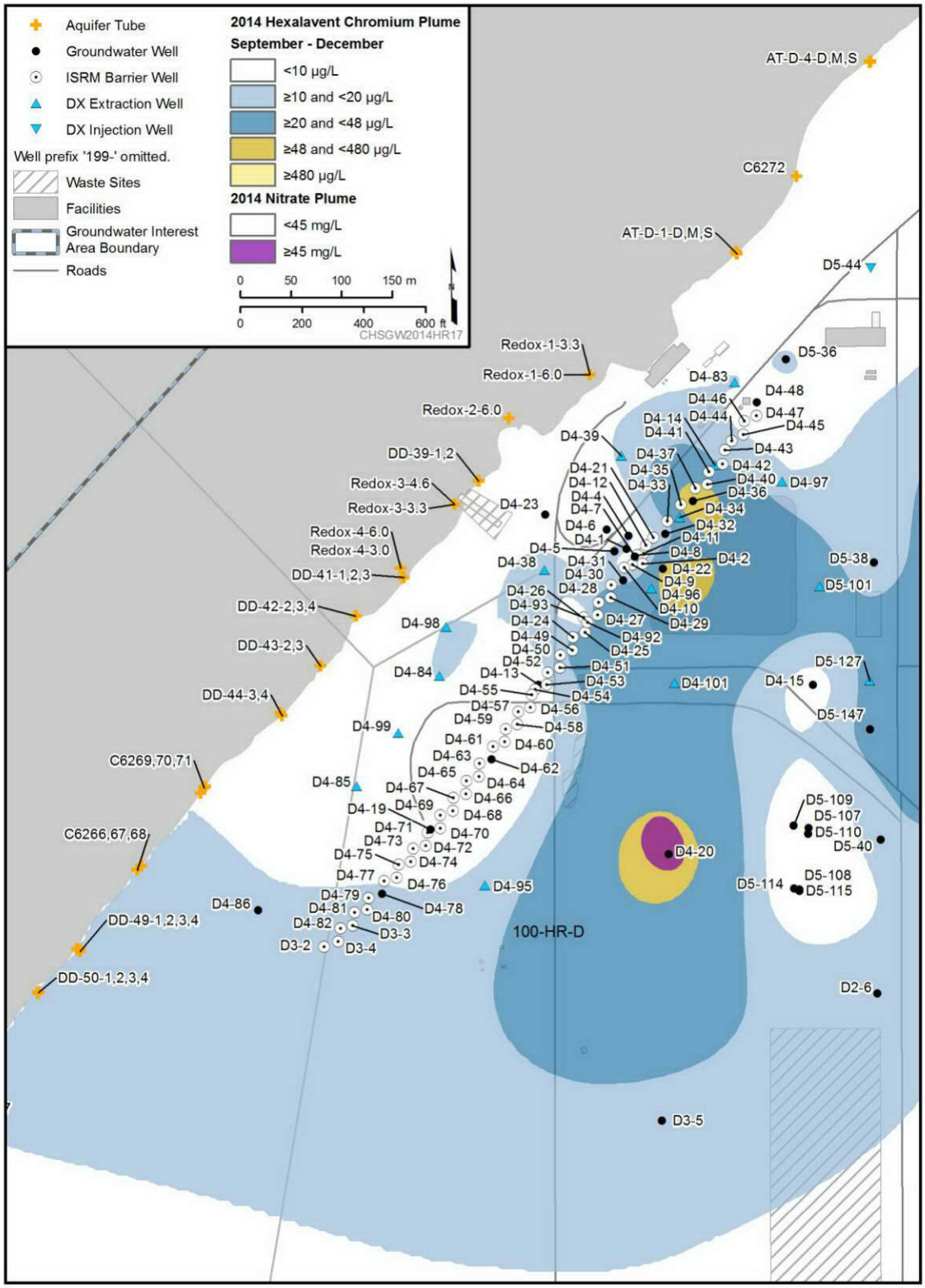


Figure 2-30. ISRM Cr(VI) Map, 2014

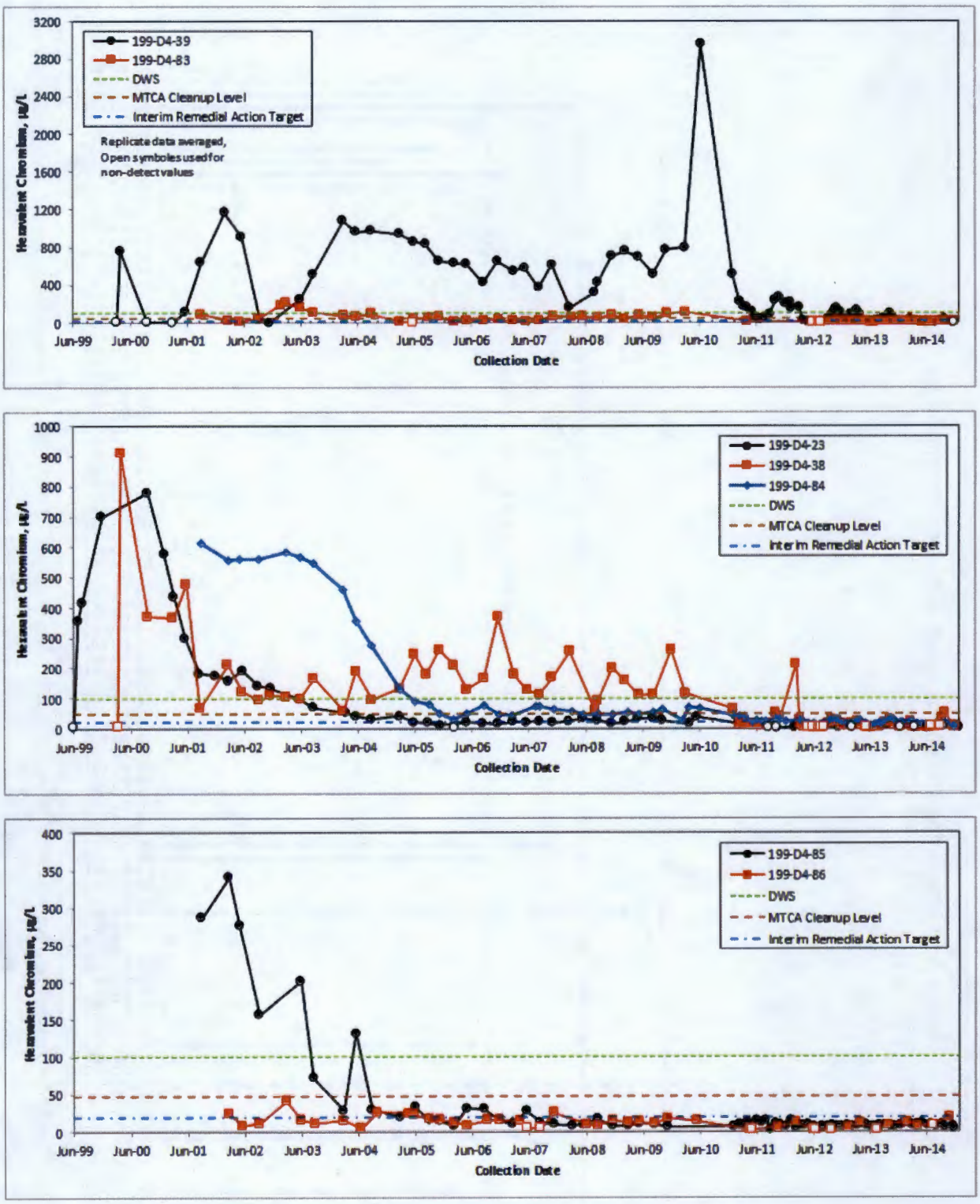
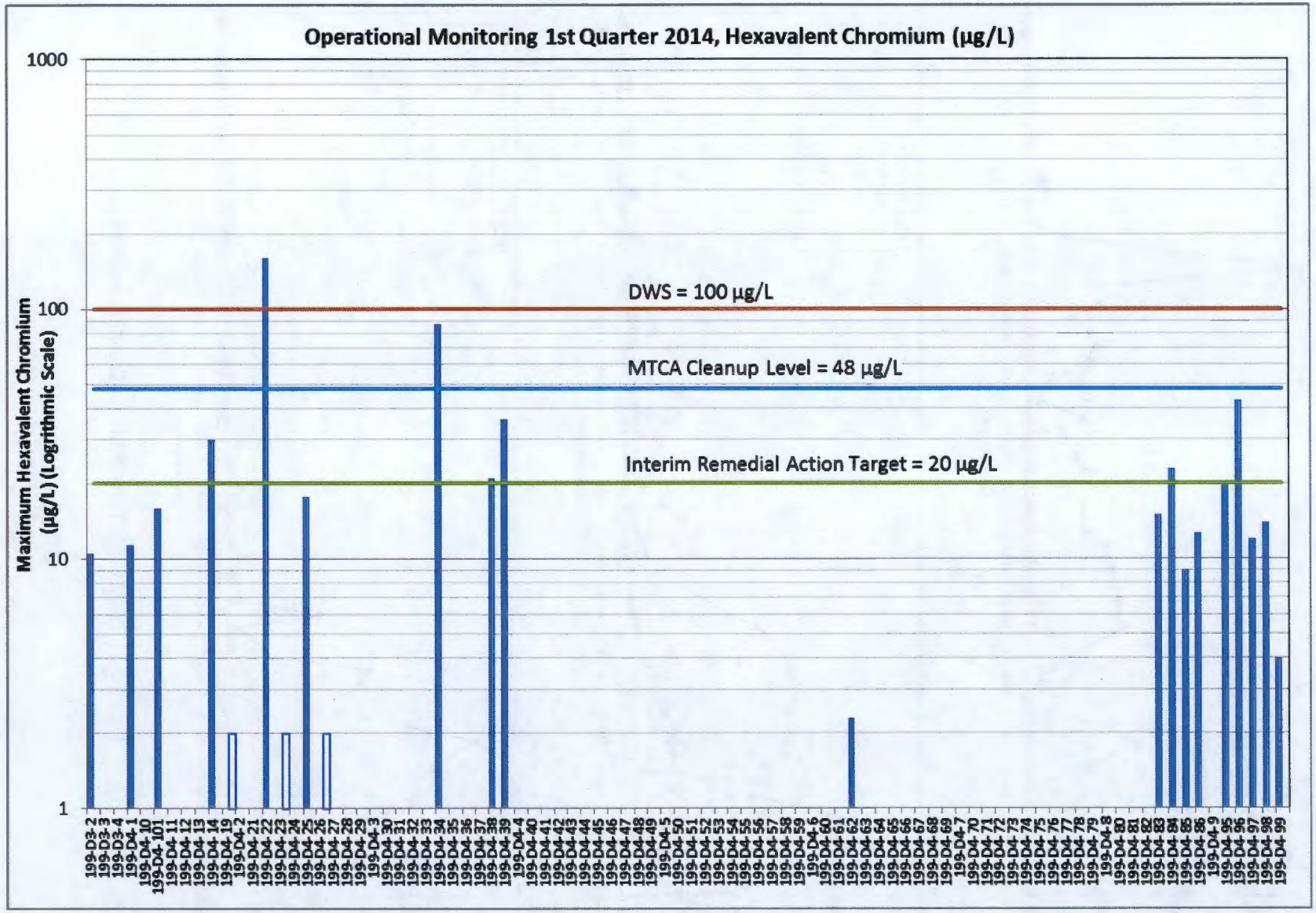
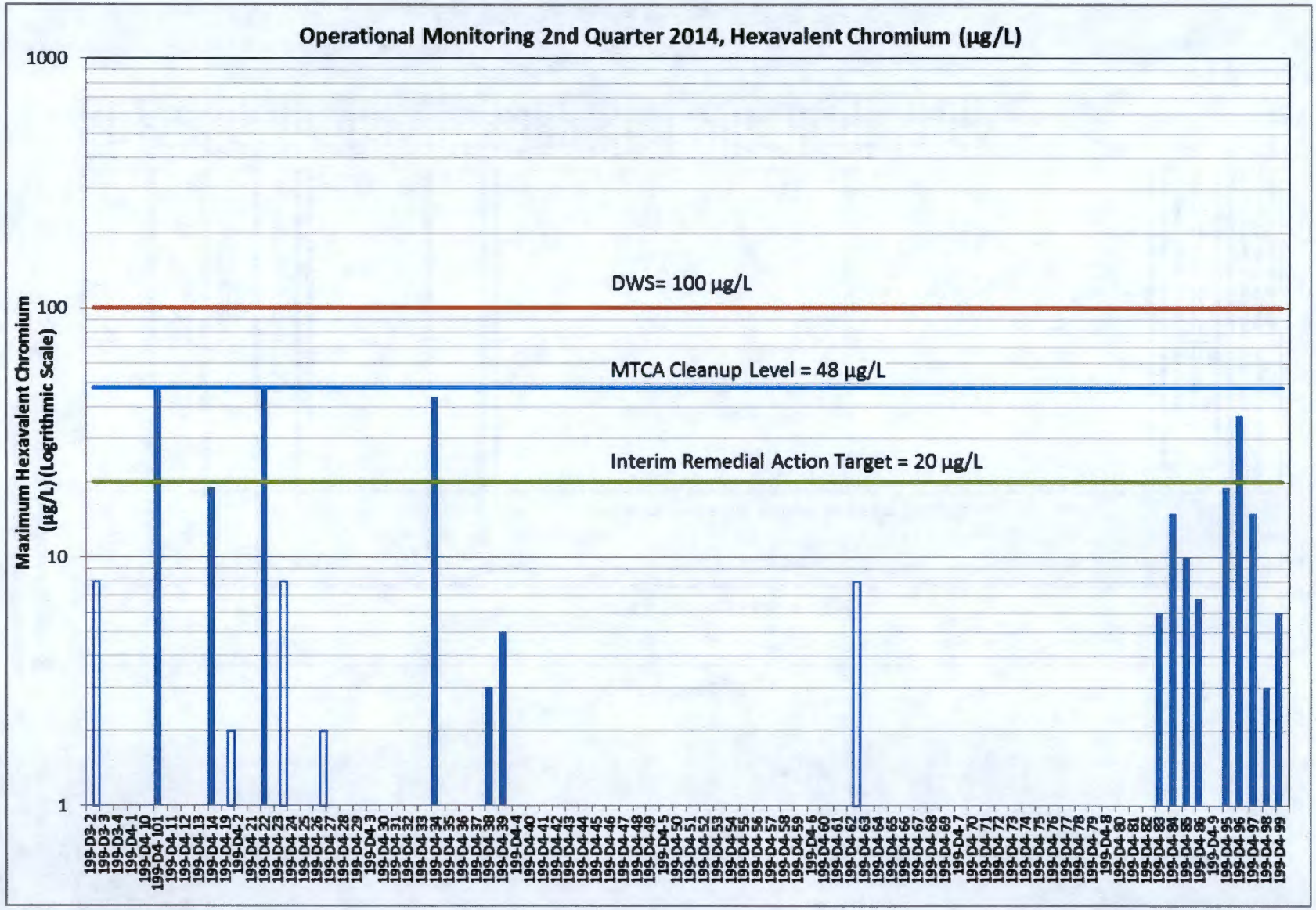


Figure 2-31. ISRM Cr(VI) Trend Plots for Compliance Wells



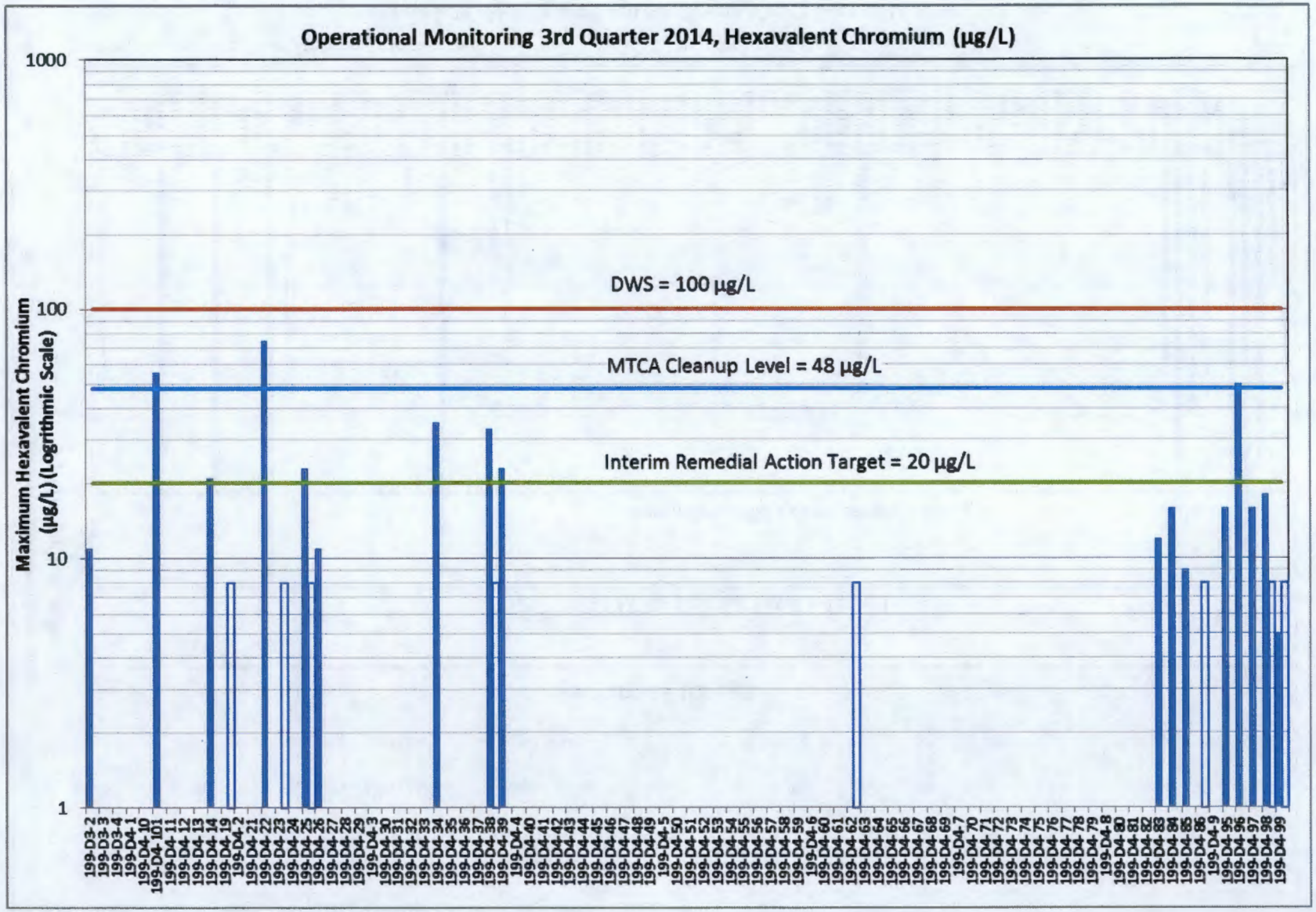
Note: Unshaded bars indicate values are below detection limit.

Figure 2-32. ISRM Operational Monitoring, Cr(VI), First Quarter



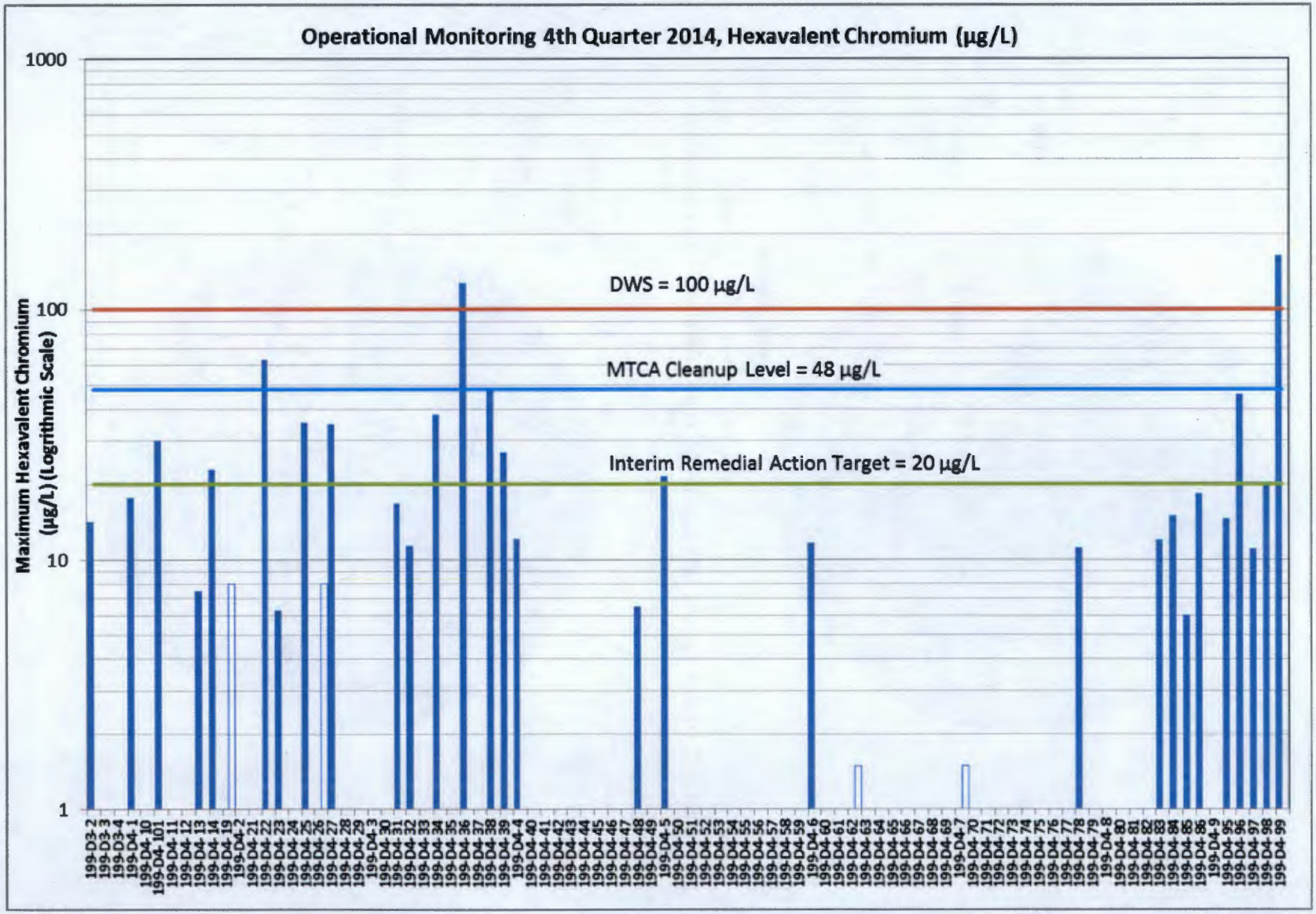
Note: Unshaded bars indicate values are below detection limit.

Figure 2-33. ISRM Operational Monitoring, Cr(VI), Second Quarter



Note: Unshaded bars indicate values are below detection limit.

Figure 2-34. ISRM Operational Monitoring, Cr(VI), Third Quarter



Note: Unshaded bars indicate values are below detection limit.

Figure 2-35. ISRM Operational Monitoring, Cr(VI), Fourth Quarter

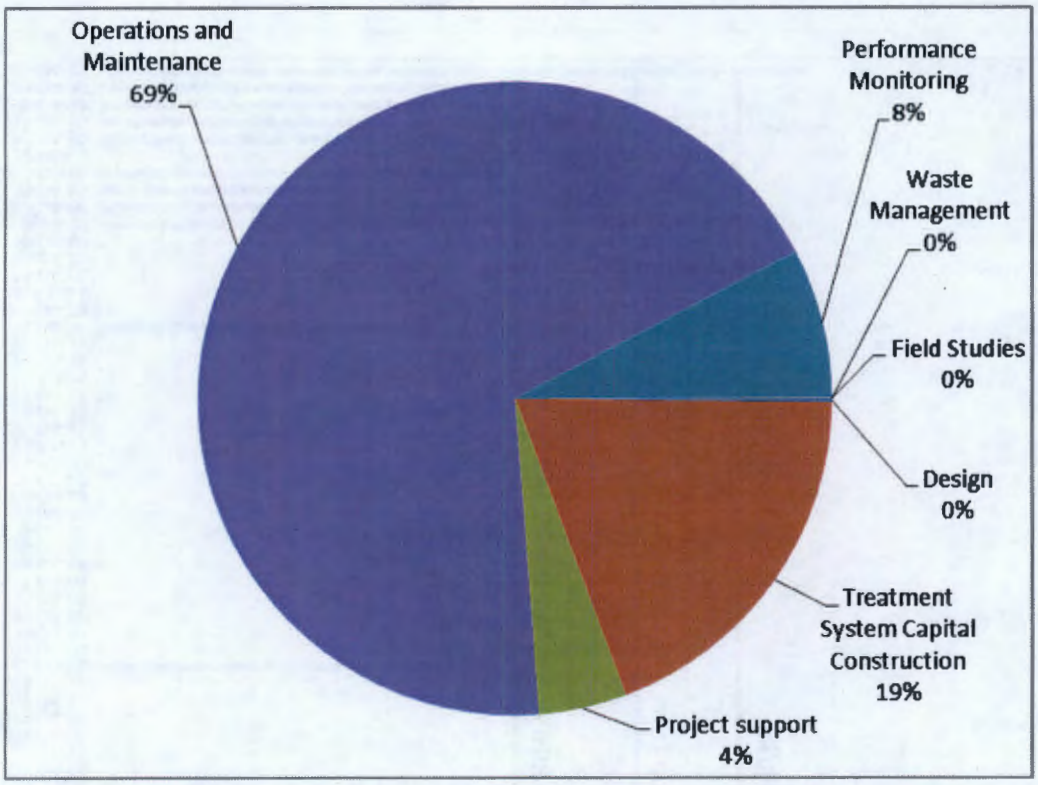


Figure 2-36. DX P&T System, 2014 Cost ($2.96 million) Breakdown (by Percentage)

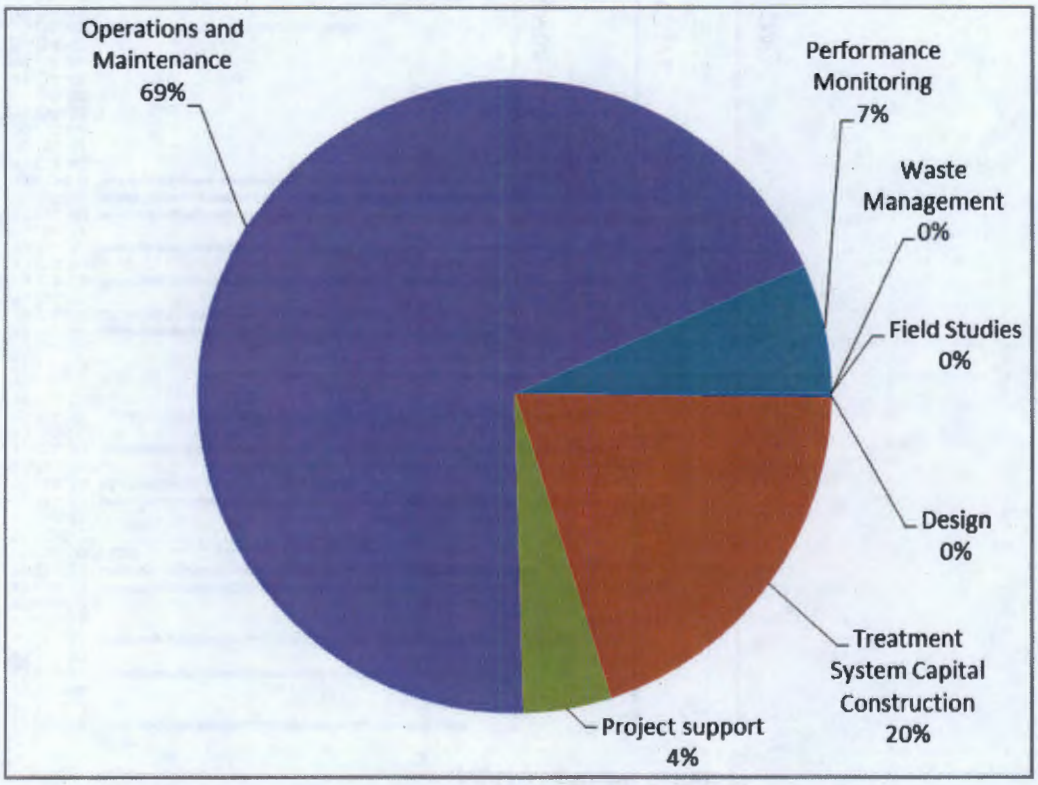


Figure 2-37. HX P&T System, 2014 Cost ($2.85 million) Breakdown (by Percentage)

Table 2-1. 100-HR-3 Groundwater OU Remedial System Well Changes Initiated in 2014

System	Well	Action	Purpose	Status as of December 31, 2014
DX	199-D8-55	Realign existing well from injection to extraction	River protection/ hydraulic control	In service, operating as extraction well
	199-D5-146	Construct new extraction well	River protection/ hydraulic control	In service as extraction well
	199-D5-148	Construct new injection well	Hydraulic control/system operations	In service as extraction well
	199-D5-153	Construct new extraction well	River protection/ hydraulic control	In service as extraction well
	199-D5-154	Construct new extraction well	River protection/ hydraulic control	Drilled, connection planned for 2015
	199-D2-10	Turn low flow injection well off	Discontinue operations	Off, remains connected
	199-D2-12	Turn low flow injection well off	Discontinue operations	Off, remains connected
	199-D8-93	Turn low flow injection well off	Discontinue operations	Off, remains connected
	199-D8-94	Turn low flow injection well off	Discontinue operations	Off, remains connected
	199-D8-6	Turn fouled extraction well off	Discontinue operations	Off, to be converted to monitoring
HX	199-H1-3	Turn low flow extraction well off	Discontinue operations	Off, remains connected

Table 2-2. DX P&T System Operating Parameters and System Performance for 2014

Total DX P&T System Processed Groundwater	**2013**	**2014**
Cumulative amount of groundwater treated (since December 2010 startup) (million L)	3,124	4,298
Total amount of groundwater treated during CY (million L)	1,120	1,174
Mass of Hexavalent Chromium Removed	**2013**	**2014**
Cumulative amount of hexavalent chromium removed (since December 2010 startup) (kg)	1,224	1,403
Total amount of hexavalent chromium removed in CY (kg)	294	179
Summary of Operational Parameters	**2013**	**2014**
Removal efficiency (% by mass)	99.3	99.1
Waste generation (m^3)	28.8	7.2
Regenerated resin Spent resin disposed (m^3)	0	0
New resin installed (m^3)	0	2.2
Number of resin vessel changeouts	0	1
Summary of Operational and System Availability	**2013**	**2014**
Total possible run-time (hours)	8,760	8,760
Total time online (hours)	8,660	8,699
Total availability (%)*	98.9%	99.3%

* Total availability [(total time online) ÷ (total possible run-time)].

CY = calendar year

P&T = pump and treat

Table 2-3. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2014

Well ID	Well Name	PLC ID	Flow Rate L/min (gal/min)		Total Flow Hours in 2014	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
B8989	199-D4-38	ME01	29.2 (7.7)	30.8 (8.1)	8,736	99.73%	Extraction
B8990	199-D4-39	ME02	36.6 (9.7)	39.8 (10.5)	8,232	93.97%	Extraction
C3315	199-D4-83	ME03	55.7 (14.7)	56.2 (14.8)	8,376	95.62%	Extraction
C3316	199-D4-84	ME04	17.2 (4.5)	21.2 (5.6)	8,568	97.81%	Extraction
C3317	199-D4-85	ME05	69.7 (18.4)	68 (17.9)	8,760	100.00%	Extraction
C7083	199-D4-95	ME06	50.3 (13.3)	48.7 (12.9)	7,008	80.00%	Extraction
C7084	199-D4-96	ME07	35.5 (9.4)	30.6 (8.1)	8,616	98.36%	Extraction
C7085	199-D4-97	ME08	42.2 (11.1)	35 (9.2)	8,616	98.36%	Extraction
C7086	199-D4-98	ME09	47.3 (12.5)	49.1 (13)	8,616	98.36%	Extraction
C7087	199-D4-99	ME10	67.9 (17.9)	64.6 (17)	7,464	85.21%	Extraction
C7580	199-D4-101	ME11	48.2 (12.7)	41.5 (11)	8,760	100.00%	Extraction
C7583	199-D5-101	ME12	95.6 (25.2)	94.8 (25)	8,760	100.00%	Extraction
C7591	199-D5-127	ME13	45.6 (12)	30.6 (8.1)	8,616	98.36%	Extraction
C5400	199-D5-104	ME14	92.1 (24.3)	93.6 (24.7)	8,544	97.53%	Extraction
A4581	199-D8-53	ME21	75.8 (20)	75.2 (19.9)	6,792	77.53%	Extraction
A4584	199-D8-55[b]	ME22	13 (3.4)	21.3 (5.6)	2,544	29.04%	Extraction
B2773	199-D8-69	ME23	76.5 (20.2)	74.8 (19.7)	8,760	100.00%	Extraction
B2772	199-D8-68	ME26	166 (43.8)	148.3 (39.1)	8,472	96.71%	Extraction

Table 2-3. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2014

Well ID	Well Name	PLC ID	Flow Rate L/min (gal/min)		Total Flow Hours in 2014	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C7092	199-D8-90	ME27	70.5 (18.6)	50.9 (13.4)	8,520	97.26%	Extraction
C7093	199-D8-91	ME28	79.2 (20.9)	50.9 (13.4)	8,568	97.81%	Extraction
C7582	199-D8-97	ME29	82 (21.7)	81.9 (21.6)	8,592	98.08%	Extraction
C7589	199-D8-95	ME30	44.6 (11.8)	87.6 (23.1)	7,392	84.38%	Extraction
C7590	199-D5-130	ME31	29.8 (7.9)	33.1 (8.7)	7,896	90.14%	Extraction
C7599	199-D7-3	ME32	74.5 (19.7)	67.6 (17.8)	7,896	90.14%	Extraction
C7601	199-D5-131	ME33	65.9 (17.4)	65.5 (17.3)	6,936	79.18%	Extraction
C7602	199-D8-98	ME34	70.5 (18.6)	66.3 (17.5)	7,752	88.49%	Extraction
C7603	199-D8-96	ME35	80.5 (21.3)	86.6 (22.9)	7,896	90.14%	Extraction
C7611	199-D7-6	ME36	62.6 (16.5)	61.6 (16.3)	7,464	85.21%	Extraction
C7610	199-H1-5	ME37	68.3 (18)	61.8 (16.3)	7,392	84.38%	Extraction
C7609	199-H4-82	ME38	76.5 (20.2)	61.9 (16.3)	7,464	85.21%	Extraction
C7596	199-H4-81	ME39	54.5 (14.4)	56.6 (15)	7,392	84.38%	Extraction
C7595	199-H4-80	ME40	58.2 (15.4)	56.7 (15)	7,464	85.21%	Extraction
A4585	199-D8-6[d]	ME41	0 (0)	5.2 (1.4)	1,536	17.53%	Extraction
A4577	199-D5-20	ME42	8.6 (2.3)	22.7 (6)	5,712	65.21%	Extraction
C4185	199-D5-32	ME43	67.2 (17.7)	68.3 (18)	8,616	98.36%	Extraction
B8748	199-D5-39	ME44	92.7 (24.5)	94.3 (24.9)	8,616	98.36%	Extraction

Table 2-3. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2014

Well ID	Well Name	PLC ID	Flow Rate L/min (gal/min)		Total Flow Hours in 2014	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C4583	199-D5-92	ME45	45.7 (12.1)	67.8 (17.9)	7,728	88.22%	Extraction
C4536	199-D8-88	ME46	14.6 (3.8)	24.4 (6.4)	8,616	98.36%	Extraction
C4474	199-D8-73	ME47	12.2 (3.2)	17.2 (4.5)	6,552	74.79%	Extraction
C7091	199-D8-89	ME48	34.3 (9.1)	34.4 (9.1)	8,616	98.36%	Extraction
B8985	199-D4-34	ME49	31 (8.2)	37.7 (10)	8,616	98.36%	Extraction
B8072	199-D4-14	ME50	45.4 (12)	45.2 (11.9)	8,616	98.36%	Extraction
C8726	199-D5-146[c]	ME51	105.9 (28)	103.4 (27.3)	5,088	58.08%	Extraction
C8789	199-D5-153[c]	ME52	99.8 (26.3)	79.7 (21)	4,992	56.99%	Extraction
B8754	199-D5-44	MJ01	62.7 (16.5)	73.1 (19.3)	8,760	100.00%	Injection
B8752	199-D5-42	MJ02	67.6 (17.8)	72.6 (19.2)	7,896	90.14%	Injection
C7600	199-D5-129	MJ03	373.4 (98.6)	429 (113.3)	7,896	90.14%	Injection
C7612	199-D5-128	MJ04	183.5 (48.4)	220.2 (58.1)	7,896	90.14%	Injection
C8728	199-D5-148[c]	MJ05	471 (124.3)	478.8 (126.4)	5,088	58.08%	Injection
C7608	199-D7-5	MJ21	407.9 (107.7)	483.2 (127.6)	8,616	98.36%	Injection
C7607	199-D6-2	MJ22	69.1 (18.2)	81.3 (21.5)	8,664	98.90%	Injection
C7594	199-D7-4	MJ23	436.7 (115.3)	541.8 (143)	8,664	98.90%	Injection
C7593	199-D8-99	MJ24	174.3 (46)	188 (49.6)	8,760	100.00%	Injection

Table 2-3. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2014

Well ID	Well Name	PLC ID	Flow Rate L/min (gal/min)		Total Flow Hours in 2014	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C7592	199-D6-1	MJ25	66.4 (17.5)	78.9 (20.8)	8,616	98.36%	Injection

Note: For purposes of deriving average flow rates for low river and high river stage, flow rates from mid-August through early-December were averaged for low river, and flow rates from mid-March through early-August were averaged for high river..

a. Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)].

b. 199-D8-55 converted from an injection to an extraction well in 2014.

c. New well connection in 2014.

d. Well 199-D8-6 had precipitate accumulation due to geochemistry at well location and was off for part of the year. Well is to be replaced.

CY = calendar year

ID = identification

PLC = programmable logic controller

Table 2-4. HX P&T System Operating Parameters and System Performance for 2014

Total HX P&T System Processed Groundwater	**2013**	**2014**
Cumulative amount of groundwater treated (since September 2011 startup) (million L)	2,903	4,081
Total amount of groundwater treated in CY (million L)	1,266	1,178
Mass of Hexavalent Chromium Removed	**2013**	**2014**
Cumulative amount of hexavalent chromium removed (since September 2011 startup) (kg)	70.3	93.1
Total amount of hexavalent chromium removed in CY (kg)	27.5	22.8
Summary of Operational Parameters	**2013**	**2014**
Removal efficiency (% by mass)	98.6	95.9
Waste generation (m^3)	7.2	3.6
Spent resin disposed (m^3)	0	0
New resin installed (m^3)	0	0
Number of resin vessel changeouts	0	0
Summary of Operational and System Availability	**2013**	**2014**
Total possible run-time (hours)	8,760	8,760
Total time online (hours)	8,649	8,698
Total availability (%)*	98.7%	99.3%

* Total availability [(total time online) ÷ (total possible run-time)].

CY = calendar year

P&T = pump and treat

Table 2-5. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells for 2014

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours in 2014	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C7477	199-H1-45	HE01	102 (26.9)	101.8 (26.9)	8,760	100.00%	Extraction
A4621	199-H4-15	HE02	103 (27.2)	120.5 (31.8)	8,760	100.00%	Extraction
C7485	199-H4-69	HE03	79.8 (21.1)	101.9 (26.9)	8,760	100.00%	Extraction
C7483	199-H4-70	HE04	86 (22.7)	90.1 (23.8)	8,760	100.00%	Extraction
C7597	199-H4-75	HE05	74 (19.5)	72.2 (19.1)	8,688	99.18%	Extraction
A4630	199-H4-4	HE06	20.6 (5.4)	40.4 (10.7)	5,880	67.12%	Extraction
B2776	199-H4-63	HE07	102.3 (27)	103.7 (27.4)	8,184	93.42%	Extraction
B2777	199-H4-64	HE08	31 (8.2)	75.6 (20)	8,712	99.45%	Extraction
A4613	199-H3-2C	HE09	99.4 (26.3)	126.1 (33.3)	8,760	100.00%	Extraction
A4618	199-H4-12C	HE10	110.2 (29.1)	112.8 (29.8)	8,640	98.63%	Extraction
C7108	199-H1-34	HE21	29.5 (7.8)	80.2 (21.2)	8,568	97.81%	Extraction
C7106	199-H1-35	HE22	74.1 (19.6)	102.4 (27)	8,760	100.00%	Extraction
C7102	199-H1-36	HE23	22.4 (5.9)	30.5 (8.1)	8,760	100.00%	Extraction
C7099	199-H1-37	HE24	43 (11.4)	95.3 (25.2)	7,488	85.48%	Extraction
C7098	199-H1-38	HE26	20.1 (5.3)	76.4 (20.2)	8,400	95.89%	Extraction
C7109	199-H1-39	HE27	27.1 (7.2)	84.5 (22.3)	6,408	73.15%	Extraction
C7104	199-H1-40	HE28	14.2 (3.8)	64.6 (17.1)	7,992	91.23%	Extraction
C7107	199-H1-42	HE29	59.6 (15.7)	96.6 (25.5)	8,688	99.18%	Extraction

Table 2-5. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells for 2014

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours in 2014	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C7492	199-H1-43	HE30	111.2 (29.4)	103.7 (27.4)	7,344	83.84%	Extraction
C7581	199-H1-3[b]	HE31	0 (0)	1.3 (0.3)	1,056	12.05%	Extraction
C7584	199-H1-2	HE32	9.4 (2.5)	13.2 (3.5)	8,400	95.89%	Extraction
C7585	199-H1-1	HE33	112.8 (29.8)	103.7 (27.4)	8,760	100.00%	Extraction
C7587	199-H4-76	HE34	33.4 (8.8)	38.4 (10.1)	3,816	43.56%	Extraction
C7604	199-H1-4	HE35	6 (1.6)	6.7 (1.8)	7,584	86.58%	Extraction
C7605	199-H4-77	HE36	37.3 (9.8)	31.4 (8.3)	7,488	85.48%	Extraction
C7606	199-H1-6	HE37	10.5 (2.8)	25.3 (6.7)	6,720	76.71%	Extraction
C7478	199-H1-25	HE38	80.1 (21.1)	105.1 (27.7)	8,688	99.18%	Extraction
C7480	199-H1-27	HE39	50.4 (13.3)	105.8 (27.9)	8,400	95.89%	Extraction
C7100	199-H1-32	HE40	8 (2.1)	38.8 (10.3)	5,112	58.36%	Extraction
C7105	199-H1-33	HE41	53.4 (14.1)	93.3 (24.6)	5,640	64.38%	Extraction
B2779	199-H3-4	HE42	489.2 (129.1)	421 (111.2)	8,760	100.00%	Extraction
C7489	199-H6-2	HJ01	70.2 (18.5)	137.6 (36.3)	8,544	97.53%	Injection
C7484	199-H4-73	HJ02	74.9 (19.8)	143.8 (38)	8,592	98.08%	Injection
C7488	199-H4-72	HJ03	126.1 (33.3)	175 (46.2)	8,616	98.36%	Injection
C7483	199-H4-71	HJ04	124.9 (33)	167.1 (44.1)	8,616	98.36%	Injection
A4628	199-H4-18	HJ05	42.4 (11.2)	58.9 (15.6)	8,424	96.16%	Injection

Table 2-5. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells for 2014

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours in 2014	Total Run-Time[a] (Percent)	Purpose
			Low River Stage Average	High River Stage Average			
C7114	199-H3-27	HJ06	140.9 (37.2)	194.1 (51.3)	8,760	100.00%	Injection
C7115	199-H3-26	HJ07	163.6 (43.2)	230.2 (60.8)	8,736	99.73%	Injection
C7110	199-H3-25	HJ08	158.9 (41.9)	231.6 (61.1)	8,256	94.25%	Injection
C7598	199-H4-74	HJ09	137.9 (36.4)	212.1 (56)	8,760	100.00%	Injection
C7588	199-H4-78	HJ10	237.4 (62.7)	334.7 (88.4)	8,760	100.00%	Injection
C7586	199-H4-79	HJ11	237.4 (62.7)	253.2 (66.8)	8,328	95.07%	Injection
C7111	199-H1-21	HJ12	242.9 (64.1)	270.3 (71.4)	8,760	100.00%	Injection
C7113	199-H1-20	HJ13	193.7 (51.1)	189.6 (50)	8,760	100.00%	Injection
A4627	199-H4-17	HJ14	22.9 (6.1)	34.1 (9)	8,016	91.51%	Injection

Note: For purposes of deriving average flow rates for low river and high river stage, flow rates from mid-August through early-December were averaged for low river, and flow rates from mid-March through early-August were averaged for high river.

a. Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)].

b. 199-H1-3 was removed from service in August 2014 due to low production rates

CY = calendar year

ID = identification

PLC = programmable logic controller

Table 2-6. Maximum Contaminant and Co-Contaminant Concentrations for 100-D Area, 2014 and 2013

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well/Aquifer Tube Name
2014				
Hexavalent chromium	1,650	F	11/20/2014	199-D5-156
Hexavalent chromium	3,616	UF	2/20/2014	199-D5-104
Total chromium	3,400	F	1/15/2014	199-D5-104
Total chromium	4,240	UF	2/26/2014	199-D5-104
Nitrate	53,100	UF	10/15/2014	199-D4-20
Strontium-90	36.4	UF	8/18/2014	199-D5-132
Tritium	20,400	UF	10/15/2014	199-D4-20
Technetium-99	Not detected	—	—	—
Sulfate	353,000	UF	6/26/2014	199-D5-155
Uranium	5	UF	11/4/2014	199-D5-37
Gross beta	82	UF	10/14/2014	199-D4-19
Gross alpha	4.53	UF	12/17/2014	199-D5-38
2013				
Hexavalent chromium	96.6	F	9/19/2013	199-D5-14
Hexavalent chromium	5,392	UF	4/8/2013	199-D5-104
Total chromium	4,990	F	11/21/2013	199-D5-104
Total chromium	4,980	UF	5/1/2013	199-D5-104
Nitrate	70,400	UF	10/1/2013	199-D4-20

Table 2-6. Maximum Contaminant and Co-Contaminant Concentrations for 100-D Area, 2014 and 2013

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well/Aquifer Tube Name
Strontium-90	31	UF	11/5/2013	199-D5-132
Tritium	20,000	UF	10/1/2013	199-D4-20
Technetium-99	Not detected	—	—	—
Sulfate	230,000	UF	11/15/2013	199-D4-62
Uranium	3.73	UF	10/1/2013	199-D8-101
Gross beta	190	UF	1/7/2013	199-D5-93
Gross alpha	11	UF	1/7/2013	199-D5-93

Notes: Results tabulated represent the maximum reported concentration for calendar years 2013 and 2014.

This table considers those wells included in the 100-D groundwater area of interest, with the exception of those wells screened in the Ringold Formation upper mud unit (199-D5-134, 199-D5-141, 199-D8-54B, and 699-97-48C).

Table 2-7. Maximum Contaminant and Co-Contaminant Concentrations for 100-H and Horn Area, 2014 and 2013

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well/Aquifer Tube Name
2014				
Hexavalent chromium	56.8	F	11/21/2014	699-96-43
Hexavalent chromium	85.5	UF	11/7/2014	199-H4-86
Total chromium	101	F	11/7/2014	199-H4-86
Total chromium	93.8	UF	11/7/2014	199-H4-86

Table 2-7. Maximum Contaminant and Co-Contaminant Concentrations for 100-H and Horn Area, 2014 and 2013

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well/Aquifer Tube Name
Nitrate	41,200	UF	5/12/2014	199-H6-3
Strontium-90	26	UF	3/19/2014	199-H4-13
Tritium	3,670	UF	12/16/2014	199-H4-77
Technetium-99	32	UF	2/21/2014	199-H4-12A
Sulfate	137,000	UF	5/5/2014	199-H4-85
Uranium	52.1	UF	7/18/2014	199-H4-84
Gross beta	58.8	UF	12/12/2014	199-H4-13
Gross alpha	18.3	UF	8/18/2014	199-H4-84
2013				
Hexavalent chromium	40.4	F	9/19/2013	699-97-45
Hexavalent chromium	90.8	UF	11/15/2013	199-H4-86
Total chromium	102	F	11/15/2013	199-H4-86
Total chromium	99.5	UF	11/15/2013	199-H4-86
Nitrate	42,800	UF	4/22/2013	199-H6-3
Strontium-90	30	UF	2/12/2013	199-H4-13
Tritium	3,900	UF	11/13/2013	699-96-43
Technetium-99	45	UF	10/25/2013	199-H4-12A
Sulfate	152,000	UF	8/14/2013	199-H4-13
Uranium	21.2	UF	6/12/2013	199-H4-84

Table 2-7. Maximum Contaminant and Co-Contaminant Concentrations for 100-H and Horn Area, 2014 and 2013

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well/Aquifer Tube Name
Gross beta	73	UF	2/12/2013	199-H4-13
Gross alpha	13	UF	3/20/2013	199-H4-9

Notes: Results tabulated represent the maximum reported concentration for calendar years 2013 and 2014.

This table considers wells included in the 100-H groundwater area of interest, with the exception of those wells screened in the Ringold Formation upper mud unit (199-H2-1, 199-H3-2C, 199-H3-9, 199-H3-10, 199-H4-12C, 199-H4-15CS, 699-97-43C, and 699-97-45B) or other deeper aquifer wells (199-H4-15CQ and 199-H4-15CR).

Table 2-8. Maximum Contaminant and Co-Contaminant Concentrations for 100-H Area and 100-D Area RUM Wells, 2014 and 2013

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
2014				
Hexavalent chromium	120	F	11/10/2014	199-H4-12C
Hexavalent chromium	130	UF	6/17/2014	199-H3-9
Total chromium	141	F	10/31/2014	199-H3-9
Total chromium	140	UF	10/31/2014	199-H3-9
Nitrate	23,500	UF	10/31/2014	199-H3-9
Strontium-90	Not detected	—	—	—
Tritium	1,500	UF	11/21/2014	199-D5-134
Technetium-99	50.6	UF	10/31/2014	199-H3-9
Sulfate	45,100	UF	11/21/2014	199-D5-134
Uranium	3.33	UF	12/19/2014	199-D8-54B
Gross beta	18.3	UF	10/31/2014	199-H3-9

Table 2-8. Maximum Contaminant and Co-Contaminant Concentrations for 100-H Area and 100-D Area RUM Wells, 2014 and 2013

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
Gross alpha	2.25	UF	12/16/2014	199-H3-2C
2013				
Hexavalent chromium	121	F	11/19/2013	199-H4-12C
Hexavalent chromium	133	UF	4/17/2013	199-H3-9
Total chromium	103	F	10/25/2013	199-H3-9
Total chromium	126	UF	10/25/2013	199-H3-9
Nitrate	16,800	UF	10/25/2013	199-H3-9
Strontium-90	2.6	UF	10/25/2013	199-H3-9
Tritium	1,700	UF	10/1/2013	199-D5-134
Technetium-99	26	UF	10/25/2013	199-H3-9
Sulfate	39,800	UF	10/1/2013	199-D5-134
Uranium	2.36	UF	10/25/2013	199-H3-10
Gross beta	21	UF	10/25/2013	199-H3-9
Gross alpha	Not detected	—	—	—

Notes: Results tabulated represent the maximum reported concentration for calendar years 2013 and 2014.

This table considers wells included in the 100-D and 100-H groundwater areas of interest that are screened in the Ringold Formation upper mud unit (100-D: 199-D5-134, 199-D5-141, 199-D8-54B, and 699-97-48C; and 100-H: 199-H2-1, 199-H3-2C, 199-H3-9, 199-H3-10, 199-H4-12C, 199-H4-15CS, 699-97-43C, and 699-97-45B).

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
ISRM	199-D2-6	M	10/17/2012	17.6	11/18/2013	15.9	11/14/2014	11.6	10	27
	199-D2-11	M	10/17/2012	12.9	11/15/2013	12.3	11/14/2014	5.5	5	55
ISRM	199-D3-2	M	11/20/2012	12	9/13/2013	9.9	12/9/2014	13.3	18	-34
	199-D3-5	M	10/17/2012	14.6	11/18/2013	7.4	11/7/2014	17.2	49	-132
ISRM	199-D4-1	M	11/20/2012	11.1	1/8/2014[b]	11.4	12/9/2014	17.7	-3	-55
ISRM	199-D4-4	M	12/11/2012	10.2	12/20/2013	12.8	12/9/2014	12.1	-25	5
ISRM	199-D4-5	M	10/5/2012	9.8	10/2/2013	24.9	11/21/2014	23.2	-154	7
ISRM	199-D4-6	M	10/5/2012	8.8	10/2/2013	10.4	12/19/2014	11.7	-18	-13
ISRM	199-D4-7	T	12/3/2012	2 (U)	12/20/2013	2 (U)	12/12/2014	1.5 (U)	NC	NC
ISRM	199-D4-13	M	9/25/2012	9	10/1/2013	3.3	11/21/2014	7.5	63	-127
ISRM	199-D4-14	T/M	11/20/2012	7.3	11/7/2013	36 (B)	10/2/2014	23	-393	36
ISRM	199-D4-15	M	9/27/2012	47.8	10/2/2013	13.3	11/21/2014	5.3	72	60
ISRM	199-D4-19	M	9/25/2012	2 (U)	10/1/2013	2 (U)	10/14/2014	8 (U)	NC	NC
ISRM	199-D4-20	M	9/26/2012	174	10/1/2013	120	10/15/2014	87	31	28
ISRM	199-D4-22	M	—	—	12/20/2013	148	9/26/2014	75	—	49
ISRM	199-D4-23	C	11/20/2012	2.1 (B)	12/20/2013	2 (U)	12/30/2014	6.3	5	-215
	199-D4-25	M	—	—	12/20/2013	24.6	12/19/2014	35.6	—	-45

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	199-D4-26	M	—	—	11/13/2013	2 (U)	10/14/2014	8 (U)	—	NC
	199-D4-27	M	—	—	12/20/2013	12.1	12/19/2014	34.1	—	-182
ISRM	199-D4-31	T	12/11/2012	20.2	12/20/2013	18.4	12/12/2014	16.5	9	10
ISRM	199-D4-32	T	12/11/2012	142	12/20/2013	8.4	12/19/2014	11.4	94	-36
	199-D4-34	M	—	—	10/15/2013	128	10/2/2014	38	—	70
ISRM	199-D4-36	T	12/3/2012	52.7	12/20/2013	158	12/17/2014	127	-200	20
DX	199-D4-38	E	10/1/2012	25	10/15/2013	28	10/2/2014	49	-12	-75
DX	199-D4-39	E	11/5/2012	151	10/15/2013	92	10/2/2014	27	39	71
ISRM	199-D4-48	T	12/11/2012	3.6 (B)	12/20/2013	5.1	12/19/2014	6.5	-42	-27
ISRM	199-D4-62	T	—	—	12/20/2013	5.4	12/19/2014	1.5 (U)	—	72
ISRM	199-D4-78	T	9/25/2012	2.2 (B)	10/1/2013	4.9 (B)	11/21/2014	11.2	-123	-129
DX	199-D4-83	E	12/3/2012	10	12/16/2013	13	9/10/2014	12	-30	8
DX	199-D4-84	E	10/28/2012	31.6	10/15/2013	33	9/10/2014	16	-4	52
DX	199-D4-85	E	10/1/2012	8	12/16/2013	8	9/10/2014	9	0	-13
ISRM	199-D4-86	C	9/25/2012	2 (U)	10/1/2013	8	10/27/2014	18.3	-300	-129
	199-D4-92		—	—	11/13/2013	2 (U)	10/14/2014	8 (U)	—	NC
	199-D4-93		—	—	11/13/2013	13.9	10/15/2014	8 (U)	—	42

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
DX	199-D4-95	E	10/1/2012	30	10/14/2013	22	12/11/2014	14.6	27	34
DX	199-D4-96	E	11/5/2012	168	10/15/2013	64	9/10/2014	50	62	22
DX	199-D4-97	E	10/1/2012	59	10/15/2013	14	9/10/2014	13	76	7
DX	199-D4-98	E	10/1/2012	24	10/15/2013	15	10/2/2014	20	38	-33
DX	199-D4-99	E	10/1/2012	7	12/16/2013	4	11/20/2014	2	43	50
DX	199-D4-101	E	9/5/2011	40	12/16/2013	17	9/10/2014	42	58	-147
	199-D5-13	M	10/5/2012	934	10/2/2013	589	11/4/2014	226	37	62
	199-D5-14	M	9/27/2012	162	10/2/2013	93.3	10/24/2014	47.2	42	49
	199-D5-15	M	12/3/2012	29.6	12/20/2013	25.3	9/5/2014	29	15	-15
	199-D5-16	M	11/20/2012	57.9	12/20/2013	67.4	12/12/2014	55.2	-16	18
	199-D5-17	M	9/26/2012	16	10/2/2013	21.8	10/24/2014	28.9	-36	-33
	199-D5-18	M	10/17/2012	23.7	11/5/2013	21.5	11/7/2014	19.8	9	8
	199-D5-19	M	9/26/2012	5.8	10/1/2013	9.9	10/24/2014	17.9	-71	-81
DR-5/DX	199-D5-20	E/E	10/1/2012	26	11/7/2013	25	8/6/2014	14	4	44
DR-5/DX	199-D5-32	E/E	11/5/2012 and 12/3/2012	393	10/15/2013	260	9/10/2014	102	34	61
	199-D5-33	M	10/30/2012	3.2 (B)	10/2/2013	9.9	10/27/2014	21.1	-209	-113
	199-D5-34		10/17/2012	85.8	10/16/2013	216	10/1/2014	459	-152	-113

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	199-D5-36	M	9/25/2012	2 (U)	10/2/2013	12.3	10/27/2014	12.1	-515	2
	199-D5-37	M	9/27/2012	8.5	10/1/2013	10.9	11/4/2014	14.3	-28	-31
ISRM	199-D5-38	M	12/20/2012	19.3	12/13/2013	16.7	12/17/2014	13.4	13	20
DR-5/DX	199-D5-39	E/E	12/3/2012	935	11/7/2013	198	12/2/2014	115	79	42
	199-D5-40		10/17/2012	27.4	11/15/2013	20.5	11/7/2014	16.8	25	18
	199-D5-41		—	—	11/25/2013	5.7	12/19/2014	6.2	—	-9
ISRM	199-D5-43	M	12/3/2012	124	9/13/2013	42.3	9/26/2014	18	66	57
DR-5/DX	199-D5-92	E/E	11/5/2012 and 12/3/2012	17	10/15/2013	38	11/10/2014	16.8	-124	56
	199-D5-93		9/26/2012	102	4/16/2013	37.7	Decommissioned in 2013	—	63	—
	199-D5-97	M	10/30/2012	46.1	10/21/2013	22.7	9/4/2014	28	51	-23
	199-D5-98		11/27/2012	18.3	Decommissioned in 2012	—	—	—	—	—
	199-D5-99		10/12/2012	1,990	Decommissioned in 2012	—	—	—	—	—
DX	199-D5-101	E	10/1/2012	144	10/15/2013	61	9/10/2014	36	58	41
	199-D5-102		10/5/2012 and 11/27/2012	16.5	Decommissioned in 2012	—	—	—	—	—

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	199-D5-103	M	12/11/2012	666	10/16/2013	1,380	9/4/2014	440	-107	68
DR-5/DX	199-D5-104	E/E	10/1/2012	4,544	11/7/2013	3552	9/4/2014	1810	22	49
	199-D5-106	M	10/5/2012	33.1	11/26/2013	32.4	9/5/2014	28	2	14
	199-D5-107	M	6/28/2012	2 (UN)	11/12/2013	10.8	—	—	-440	—
	199-D5-108	M	—	—	11/12/2013	32.5	10/14/2014	8 (U)	—	75
	199-D5-109	M	—	—	11/12/2013	2 (U)	10/15/2014	8 (U)	—	NC
	199-D5-110	M	—	—	11/12/2013	2 (U)	10/15/2014	8 (U)	—	NC
	199-D5-114	M	—	—	11/12/2013	27.3	10/15/2014	8 (U)	—	71
	199-D5-115	M	—	—	11/12/2013	36.8	10/15/2014	8 (U)	—	78
	199-D5-119		12/10/2012	1,410	Decommissioned in 2012	—	—	—	—	—
	199-D5-120		10/5/2012	930	Decommissioned in 2012	—	—	—	—	—
	199-D5-121		10/5/2012	93.4	Decommissioned in 2012	—	—	—	—	—
	199-D5-122		9/7/2012	3,970	Decommissioned in 2012	—	—	—	—	—
	199-D5-123	M	11/20/2012	50.5	9/13/2013	41.1	9/5/2014	34	19	17
	199-D5-125	M	12/11/2012	379	12/20/2013	258	9/19/2014	95	32	63

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	199-D5-126	M	12/11/2012	540	10/2/2013	367	9/19/2014	162	32	56
DX	199-D5-127	E	12/3/2012	63	12/16/2013	47	10/29/2014	26.8	25	43
DX	199-D5-130	E	10/1/2012	94	10/15/2013	46	9/10/2014	36	51	22
DX	199-D5-131	E	9/5/2012	749	10/15/2013	323	9/10/2014	195	57	40
	199-D5-132	M	10/22/2012	45.5	11/5/2013	34.5	11/7/2014	31.2	24	10
	199-D5-133	M	10/22/2012	14.4	11/15/2013	16.6	9/4/2014	18	-15	-8
	199-D5-142	M	10/17/2012	24.3	11/15/2013	20	11/7/2014	22.1	18	-11
	199-D5-143	M	10/22/2012	292	11/15/2013	235	11/13/2014	76.6	20	67
	199-D5-144		9/6/2012	6,060	Decommissioned in 2012	—	—	—	—	—
	199-D5-145	M	—	—	11/18/2013	79.6	12/17/2014	143	—	-80
DX	199-D5-146	E	—	—	10/16/2013	28	12/2/2014	67	—	-139
	199-D5-147	M	—	—	11/15/2013	49.6	11/13/2014	26.6	—	46
	199-D5-148	M	—	—	11/25/2013	10.8	4/4/2014	11.8	—	-9
DX	199-D5-153	E	—	—	9/24/2013	20.4	10/2/2014	159	—	-679
	199-D5-154	M	—	—	9/18/2013	306	4/3/2014	171	—	44
	199-D6-3	M	10/22/2012	12.6	9/13/2013	15.1	11/21/2014	14.5	-20	4
DX	199-D7-3	E	10/1/2012	60	10/15/2013	23	9/10/2014	18	62	22

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
DX	199-D7-6	E	10/1/2012	20	12/16/2013	19	9/10/2014	16	5	16
	199-D8-4	M	9/27/2012	108	10/1/2013	142	10/27/2014	220	-31	-55
	199-D8-5	M	11/27/2012	19.7	12/20/2013	7.5	12/17/2014	8.9	62	-19
DX	199-D8-6	M	10/28/2012	177	8/6/2013	237	3/3/2014	500	-34	-111
HR-3/DX	199-D8-53	E/E	—	—	12/16/2013	17	12/15/2014	9.3	—	45
HR-3/DX	199-D8-54A	E&C/M	—	—	Disconnected	—	12/17/2014	19.6	—	—
DX	199-D8-55	E	—	—	—	—	9/10/2014	14	—	—
HR-3/DX	199-D8-68	E/E	—	—	12/16/2013	27	12/15/2014	22.2	—	18
HR-3/DX	199-D8-69	C/E	10/28/2012	25.2	12/16/2013	22	9/10/2014	19	13	14
HR-3	199-D8-70	C	11/27/2012	24.7	8/13/2013	10.7	12/19/2014	16.1	57	-50
HR-3	199-D8-71	C	10/17/2012	86.1	11/5/2013	30.8	11/14/2014	17.5	64	43
HR-3/DX	199-D8-72	E/M	—	—	Disconnected	—	6/24/2014	14	—	—
DX	199-D8-73	E	10/1/2012	75	11/7/2013	77	10/2/2014	142	-3	-84
DX	199-D8-88	E	12/3/2012	114	12/11/2013	145	11/20/2014	78	-27	46
DX	199-D8-89	E	11/5/2012	85	10/15/2013	115	12/2/2014	92	-35	20
DX	199-D8-90	E	12/3/2012	24	10/15/2013	21	10/2/2014	17	13	19
DX	199-D8-91	E	10/1/2012	28	10/15/2013	28	9/10/2014	19	0	32

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
DX	199-D8-95	E	12/3/2012	553	10/15/2013	645	10/28/2014	436	-17	32
DX	199-D8-96	E	10/8/2012	728	10/15/2013	526	10/2/2014	339	28	36
DX	199-D8-97	E	10/1/2012	492	10/15/2013	282	10/2/2014	151	43	46
DX	199-D8-98	E	12/3/2012	58	12/16/2013	34	9/10/2014	28	41	18
DX	199-H1-5	E	10/1/2012	17	11/7/2013	25	10/2/2014	23	-47	8
DX	199-H4-80	E	10/1/2012	24	12/16/2013	26	10/2/2014	22	-8	15
DX	199-H4-81	E	10/1/2012 and 12/3/2012	24	12/16/2013	25	12/15/2014	31.2	-4	-25
DX	199-H4-82	E	12/3/2012	23	12/16/2013	26	10/2/2014	22	-13	15
	699-93-48A	M	11/8/2012	9.9	11/13/2013	7.6	11/3/2014	19.7	23	-159
	699-95-48	M	11/30/2012	19.8	11/18/2013	22.3	11/4/2014	20.5	-13	8
	699-95-51	M	11/15/2012	22.6	11/15/2013	18.4	11/4/2014	16	19	13
	699-96-52B	M	11/15/2012	20.5	11/15/2013	15.9	12/19/2014	17.2	22	-8
	699-97-48B	M	10/17/2012	22.3	11/1/2013	20.4	10/24/2014	23.2	9	-14
	699-97-51A	M	11/13/2012	4 (B)	11/13/2013	15	11/3/2014	16.7	-275	-11
	699-98-49A	M	11/13/2012	2 (U)	10/25/2013	2 (UN)	11/4/2014	1.5 (U)	NC	NC
	699-98-51	M	11/13/2012	12.3	11/12/2013	14.2	11/21/2014	13.8	-15	3

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
Aquifer Sampling Tubes										
	36-S	AT	11/27/2012	2 (U)	11/26/2013	3.2 (B)	12/12/2014	3.1	-60	3
	36-M	AT	11/27/2012	6.2	11/26/2013	3.5 (B)	—	—	44	—
	38-M	AT	11/27/2012	2 (U)	12/2/2013	105 (F)	12/12/2014	1.5 (U)	-5,150	99
	AT-D-1-S	AT	11/26/2012	2 (UN)	11/26/2013	2 (U)	12/11/2014	1.5 (U)	NC	NC
	AT-D-1-M	AT	11/26/2012	2 (UN)	11/26/2013	2 (U)	12/11/2014	1.5 (U)	NC	NC
	AT-D-1-D	AT	11/26/2012	2 (UN)	11/26/2013	2 (U)	12/11/2014	1.5 (U)	NC	NC
	AT-D-2-S	AT	11/26/2012	2 (UN)	11/26/2013	2 (U)	12/11/2014	1.5 (U)	NC	NC
	AT-D-2-M	AT	11/26/2012	2 (UN)	11/26/2013	2 (U)	12/11/2014	1.5 (U)	NC	NC
	AT-D-3-S	AT	11/27/2012	2 (U)	12/2/2013	146 (Y)	12/12/2014	1.5 (U)	-7,200	99
	AT-D-3-M	AT	11/27/2012	2 (U)	12/2/2013	117 (Y)	12/12/2014	2	-5,750	98
	AT-D-3-D	AT	11/27/2012	2 (U)	12/2/2013	150 (F)	12/12/2014	2.1	-7,400	99
	AT-D-4-D	AT	11/26/2012	2 (UN)	11/26/2013	2 (U)	12/11/2014	1.5 (U)	NC	NC
	AT-D-5-M	AT	11/28/2012	2 (U)	—	—	12/19/2014	1.5 (U)	—	—
	AT-D-5-D	AT	11/28/2012	2 (U)	—	—	12/19/2014	1.5	—	—
	C6266	AT	11/15/2012	2 (U)	5/1/2013	3.2 (B)	12/8/2014	7.5	-60	-134
	C6267	AT	11/15/2012	3.8 (B)	5/1/2013	9	12/8/2014	8.2	-137	9
	C6268	AT	11/15/2012	2 (U)	5/1/2013	2 (U)	12/8/2014	13.2	NC	-560

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	C6269	AT	11/15/2012	2 (U)	5/1/2013	2 (U)	12/8/2014	3.7	NC	-85
	C6270	AT	11/15/2012	2 (U)	5/1/2013	2 (U)	12/8/2014	4.3	NC	-115
	C6271	AT	11/15/2012	2 (U)	5/1/2013	2 (U)	12/8/2014	7.2	NC	-260
	C6272	AT	11/26/2012	2 (UN)	—	—	12/11/2014	1.5 (U)	—	—
	C6275	AT	11/27/2012	2 (U)	—	—	12/12/2014	1.5	—	—
	C6278	AT	11/27/2012	2 (U)	—	—	12/12/2014	3	—	—
	C6281	AT	11/28/2012	2 (U)	1/30/2014[b]	2 (U)	—	—	NC	—
	C6282	AT	11/28/2012	2 (U)	1/30/2014[b]	2 (U)	—	—	NC	—
	C7645	AT	11/15/2012	5	11/25/2013	4.9 (B)	12/8/2014	8	2	-63
	C7646	AT	11/15/2012	3.5 (B)	1/15/2014[b]	5.5 (N)	12/8/2014	11.2	-57	-104
	C7647	AT	11/15/2012	3.9 (B)	1/15/2014[b]	2.7 (BN)	12/8/2014	9.8	31	-263
	C7648	AT	11/15/2012	2 (U)	1/15/2014[b]	2 (UN)	12/8/2014	12.1	NC	-505
	DD-06-2	AT	11/28/2012	2 (U)	—	—	12/19/2014	7.3	—	—
	DD-06-3	AT	11/28/2012	2 (U)	—	—	12/19/2014	4.8	—	—
	DD-12-2	AT	11/28/2012	2 (U)	12/4/2013	2.6 (B)	12/19/2014	7	-30	-169
	DD-12-4	AT	11/28/2012	3.5 (B)	1/30/2014[b]	6.1	12/19/2014	3.7	-74	39
	DD-15-2	AT	11/28/2012	9.7	1/30/2014[b]	13.4	12/19/2014	7.5	-38	44
	DD-15-3	AT	11/28/2012	13.3	1/30/2014[b]	18.4	12/19/2014	14.5	-38	21

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	DD-15-4	AT	11/28/2012	9.8	1/30/2014[b]	14.3	12/19/2014	8.7	-46	39
	DD-16-3	AT	11/27/2012	5.1	1/20/2014[b]	13.6	12/12/2014	6.4	-167	53
	DD-16-4	AT	11/27/2012	15.5	12/2/2013	11.6 (B)	12/12/2014	13.7	25	-18
	DD-17-2	AT	11/27/2012	11.8	—	—	12/12/2014	7.5	—	—
	DD-17-3	AT	11/27/2012	7.9	—	—	12/12/2014	2.5	—	—
	DD-41-1	AT	11/20/2012	2 (U)	1/16/2014[b]	2 (U)	12/9/2014	1.5 (U)	NC	NC
	DD-41-2	AT	11/20/2012	2 (U)	1/30/2014[b]	2 (U)	12/9/2014	5.5	NC	
	DD-41-3	AT	11/20/2012	2 (U)	11/25/2013	2.1 (B)	12/9/2014	3.7	-5	-76
	DD-42-2	AT	11/20/2012	2 (U)	1/15/2014[b]	2 (UN)	12/9/2014	4.9	NC	-145
	DD-42-3	AT	11/20/2012	2 (U)	1/15/2014[b]	2 (UN)	12/9/2014	8.3	NC	-315
	DD-42-4	AT	11/20/2012	2 (U)	1/16/2014[b]	2 (U)	12/9/2014	2	NC	0
	DD-43-2	AT	11/26/2012	2 (UN)	1/15/2014[b]	2 (UN)	12/8/2014	5.3	NC	-165
	DD-43-3	AT	11/26/2012	2 (UN)	1/15/2014[b]	2 (UN)	12/8/2014	7.2	NC	-260
	DD-44-3	AT	11/15/2012	2 (U)	1/16/2014[b]	2 (U)	12/8/2014	3.7	NC	-85
	DD-44-4	AT	11/15/2012	2 (U)	12/2/2013	9.68 (U)	12/8/2014	3	NC	69
	DD-49-1	AT	11/15/2012	4.9 (B)	1/15/2014[b]	11.6 (N)	10/28/2014	35.3	-137	-204
	DD-49-2	AT	11/15/2012	2 (U)	1/15/2014[b]	11.1 (N)	10/28/2014	49.2	-455	-343
	DD-49-3	AT	11/15/2012	10	12/2/2013	44 (BY)	10/28/2014	22.3	-340	49

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	DD-49-4	AT	11/15/2012	2 (U)	1/15/2014[b]	7.5 (N)	10/28/2014	21.3	-275	-184
	DD-50-1	AT	11/15/2012	2 (U)	1/15/2014[b]	5 (N)	10/28/2014	70.9	-150	-1,318
	DD-50-2	AT	11/15/2012	2 (U)	1/15/2014[b]	5.3	10/28/2014	36.9	-165	-596
	DD-50-3	AT	11/15/2012	4.2 (B)	1/15/2014[b]	9	10/28/2014	29	-114	-222
	DD-50-4	AT	11/15/2012	11.5	1/15/2014[b]	6.3	10/28/2014	58.9	45	-835
	Redox-1-3.3	AT	11/26/2012	2 (UN)	1/20/2014[b]	2 (U)	12/9/2014	6.6	NC	-230
	Redox-1-6.0	AT	11/26/2012	2 (UN)	11/26/2013	2 (U)	12/9/2014	6.8	NC	-240
	Redox-2-6.0	AT	11/26/2012	9.9 (N)	1/20/2014[b]	7.4	12/9/2014	14.1	25	-91
	Redox-3-3.3	AT	11/20/2012	2 (U)	1/16/2014[b]	2 (U)	12/9/2014	5.8	NC	-190
	Redox-3-4.6	AT	11/20/2012	2 (U)	11/25/2013	2 (U)	12/9/2014	2.5	NC	-25
	Redox-4-3.0	AT	11/20/2012	2 (U)	1/16/2014[b]	2 (U)	12/9/2014	5.4	NC	-170
	Redox-4-3.0	AT	11/20/2012	2 (U)	1/16/2014[b]	2 (U)	12/9/2014	1.5 (U)	NC	NC

Notes: The percent change in concentration is calculated using the following formula: $([Cr(VI)]_{year\ 1}-[Cr(VI)]_{year\ 2})/[Cr(VI)]_{year\ 1}$.

If more than one sample was collected on the same date, the maximum result was used.

a. Fall represents the period from October 1 to December 31 for the specified calendar year. The maximum concentration reported during this period is listed. If a higher result was reported in September, the September result is listed.
If no Cr(VI) results were reported during this period, the result reported for the next closest date prior to October 1, but no earlier than September 1, is listed.

b. Fall 2013 sample was collected in January 2014.

Table 2-9. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D), DR-5, and DX P&T Systems, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014

— = indicates that the sample was not collected, analysis was not performed, or the change in concentration was not calculated
AT = aquifer tube
C = compliance well
Cr(VI) = hexavalent chromium
E = extraction well
I = injection well
ISRM = in situ redox manipulation
M = monitoring well
NC = not calculated (if both results included a nondetect "U" laboratory qualifier)
T = in situ redox manipulation aquifer treatment well
U = undetected (detection limit is listed with qualifier in parentheses)

Table 2-10. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H), HR-3, and HX P&T Systems, 2011 to 2013

P&T System	Well or Aquifer Tube Name	Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
HX	199-H1-1	E	12/3/2012	42	11/19/2013	37.8	10/2/2014	39	10	-3
HX	199-H1-2	E	11/26/2012	44.2	11/19/2013	49.8	12/11/2014	46.1	-13	7
HX	199-H1-25	E	10/1/2012	34	10/8/2013	28	10/2/2014	22	18	21
HX	199-H1-27	E	10/28/2012	32.9	10/8/2013	35	10/2/2014	41	-6	-17
HX	199-H1-3	E	9/4/2011	31	8/13/2013	2 (U)	8/5/2014	46	94	-2200
HX	199-H1-32	E	11/26/2012	23.8	9/3/2013	17	12/11/2014	20.8	29	-22
HX	199-H1-33	E	11/26/2012	16.4	9/3/2013	16	12/11/2014	17.1	2	-7
HX	199-H1-34	E	10/28/2012	13.2	10/8/2013	19	10/2/2014	18	-44	5
HX	199-H1-35	E	10/28/2012	18.6	11/4/2013	22	11/10/2014	19.4	-18	12
HX	199-H1-36	E	12/3/2012	48	11/19/2013	48.5	11/4/2014	49	-1	-1
HX	199-H1-37	E	10/16/2012	12.1	11/19/2013	10.2	11/10/2014	9.3	16	9
HX	199-H1-38	E	12/3/2012	12	11/19/2013	10.4	11/10/2014	11.1	13	-7
HX	199-H1-39	E	10/28/2012	7.7	8/13/2013	3.8 (B)	10/2/2014	12	51	-216
HX	199-H1-4	E	10/28/2012	45.7	11/4/2013	37	10/2/2014	35	19	5
HX	199-H1-40	E	10/1/2012	6	10/8/2013	4 (B)	11/10/2014	8.1	33	-103
HX	199-H1-42	E	11/26/2012	26.6	11/19/2013	36.2	11/4/2014	43	-36	-19
HX	199-H1-43	E	12/3/2012	26	11/19/2013	38.3	11/4/2014	35	-47	9
HX	199-H1-45	E	11/26/2012	7.9	11/4/2013	4	12/2/2014	8	49	-100

Table 2-10. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H), HR-3, and HX P&T Systems, 2011 to 2013

P&T System	Well or Aquifer Tube Name	Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
HX	199-H1-6	E	12/3/2012	24	11/19/2013	28.9	12/16/2014	31.3	-20	-8
	199-H1-7	M	10/19/2012	4.2 (B)	10/25/2013	2 (U)	10/31/2014	17.2	52	-760
	199-H3-2A	M	11/15/2012	2 (U)	12/13/2013	2 (U)	12/12/2014	1.5 (U)	NC	NC
	199-H3-2B	M	—	—	—	—	—	—	—	—
	199-H3-3	M	10/19/2012	14	10/25/2013	17.2	10/31/2014	10.4	-23	40
HX	199-H3-4	E	10/16/2012	16.3	11/19/2013	8.3	11/10/2014	6.3	49	24
	199-H3-5	M	10/19/2012	11.7	10/25/2013	2.1 (B)	10/31/2014	2.8	82	-33
	199-H3-6	M	10/19/2012	4.7 (B)	9/13/2013	3.8 (B)	10/31/2014	12.1	19	-218
	199-H3-7	M	10/19/2012	2 (U)	9/13/2013	2.1 (B)	10/31/2014	1.7	-5	19
HR-3	199-H4-3		9/7/2012	65.6	Decommissioned in 2013	—	—	—	—	—
HR-3/HX	199-H4-4	EC/E	11/1/2012	14.8	11/19/2013	14.1	12/16/2014	11.4	5	19
HR-3	199-H4-5	C	11/15/2012	12.5	12/13/2013	8	12/12/2014	2.8	36	65
	199-H4-6	M	10/12/2012	2 (U)	10/17/2013	2 (U)	10/24/2014	1.5 (U)	NC	NC
	199-H4-7		12/20/2012	37.3	Decommissioned in 2013	—	—	—	—	—
	199-H4-8	M	11/1/2012	13.4	—	—	11/5/2014	4.7	—	—

Table 2-10. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H), HR-3, and HX P&T Systems, 2011 to 2013

P&T System	Well or Aquifer Tube Name	Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	199-H4-9		10/12/2012	12.2	Decommissioned in 2013	—	—	—	—	—
	199-H4-10	M	11/15/2012	7.4	12/13/2013	2.1 (B)	12/12/2014	4.4	72	-110
	199-H4-11	M	10/19/2012	7	12/13/2013	7.5	10/31/2014	7.4	-7	1
HR-3	199-H4-12A	M	11/1/2012	32.4	10/25/2013	22.3	11/5/2014	14.7	31	34
	199-H4-12B	M	—	—	—	—	—	—	—	—
	199-H4-13	M	11/15/2012	5.2	12/13/2013	4 (B)	12/12/2014	3.1	23	23
	199-H4-14		—	—	5/9/2013	10.6	Decommissioned in 2013	—	—	100
HR-3/HX	199-H4-15A	E/E	12/3/2012	17	11/4/2013	22	12/2/2014	18	-29	18
	199-H4-15B	M	—	—	—	—	—	—	—	—
	199-H4-15CP (deep well)	M	10/12/2012	5.3	10/17/2013	4.5 (B)	11/23/2014	1.5 (U)	15	67
	199-H4-15CR (deep well)	M	10/12/2012	2 (U)	10/17/2013	7	11/23/2014	9.7	-250	-39
	199-H4-15CQ	M	10/17/2012	2 (U)	10/17/2013	2 (U)	11/23/2014	4.8	NC	-140
	199-H4-16	M	10/19/2012	2 (U)	10/25/2013	2 (U)	10/31/2014	2.2	NC	-10
	199-H4-45	M	11/26/2012	2.9 (B)	12/13/2013	4 (B)	12/12/2014	1.5 (U)	-38	63

Table 2-10. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H), HR-3, and HX P&T Systems, 2011 to 2013

P&T System	Well or Aquifer Tube Name	Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	199-H4-46	M	10/19/2012	2 (B)	10/25/2013	2 (U)	10/31/2014	5	0	-150
	199-H4-48		11/15/2012	14.8	Decommissioned in 2013	—	—	—	—	—
	199-H4-49	M	10/22/2012	11.2	10/25/2013	10.4	10/31/2014	6.7	7	36
HR-3/HX	199-H4-63	EC/E	9/4/2012	17	11/4/2013	13	9/4/2014	13	24	0
HR-3/HX	199-H4-64	EC/E	11/26/2012	13.7	10/8/2013	12	12/2/2014	9	12	25
	199-H4-65	M	10/19/2012	2.1 (B)	11/15/2013	16.4	10/31/2014	20.5	-681	-25
HX	199-H4-69	E	11/26/2012	6.2	11/4/2013	8	12/16/2014	10.1	-29	-26
HX	199-H4-70	E	10/28/2012 and 11/26/2012	2 (U)	11/19/2013	2 (U)	9/4/2014	2	NC	0
HX	199-H4-75	E	10/28/2012	58.3	11/19/2013	53.9	12/2/2014	57	8	-6
HX	199-H4-76	E	9/4/2012	65	11/19/2013	66.5	11/4/2014	60	-2	10
HX	199-H4-77	E	9/4/2012	73	11/19/2013	69.3	10/29/2014	51.2	5	26
	199-H4-84	M	12/10/2012	24.4	12/2/2013	9.68 (U)	9/9/2014	16	60	-65
	199-H4-85	M	—	—	10/25/2013	26.4	10/31/2014	27.1	—	-3
	199-H4-86	M	—	—	11/15/2013	90.8	11/7/2014	85.5	—	6
	199-H4-90	M	—	—	9/12/2013	10.4	9/12/2014	17	—	-63
	199-H4-91	M	—	—	9/9/2013	62.2	9/26/2014	40	—	36
	199-H5-1A	M	10/19/2012	20.3	10/25/2013	7.7	11/7/2014	6.7	62	13

Table 2-10. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H), HR-3, and HX P&T Systems, 2011 to 2013

P&T System	Well or Aquifer Tube Name	Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	199-H6-1	M	10/19/2012	10.3	10/25/2013	4.3 (B)	11/5/2014	3.2	58	26
	199-H6-3	M	10/19/2012	18.6	10/25/2013	17.2	11/5/2014	16.1	8	6
	199-H6-4	M	10/19/2012	24	10/25/2013	14.5	11/7/2014	11.4	40	21
	699-88-41	M	10/17/2012	10.5	11/1/2013	12.8	10/24/2014	9.5	-22	26
	699-90-45	M	10/12/2012	4.7 (B)	10/25/2013	6.7	10/24/2014	4.2	-43	37
	699-91-46A	M	10/12/2012	6.5	10/2/2013	8.8	10/24/2014	7.2	-35	18
	699-94-41	M	11/13/2012	12.7	11/18/2013	14.3	11/3/2014	13.1	-13	8
	699-94-43	M	11/14/2012	43.2	11/25/2013	48	11/3/2014	41.1	-11	14
	699-95-45	M	11/14/2012	36.9	11/18/2013	10.7	11/3/2014	5.4	71	50
	699-96-43	M	10/12/2012	65.2	11/13/2013	58.2	11/21/2014	53.6	11	8
	699-97-41	M	11/28/2012	15.6	11/25/2013	21.9	12/19/2014	55.6	-40	-154
	699-97-43B	M	10/12/2012	67.5	11/1/2013	59.1	10/24/2014	53.7	12	9
	699-97-45	M	10/17/2012	40.1	11/1/2013	44.5	10/24/2014	47	-11	-6
	699-98-43	M	10/12/2012	54.9	11/1/2013	56.7	10/24/2014	52.6	-3	7
	699-98-46	M	11/13/2012	37.8	11/26/2013	32.4	11/4/2014	31.8	14	2
	699-99-41	M	11/28/2012	5.6	11/25/2013	4.7 (B)	11/7/2014	14.4	16	-206
	699-99-44	M	11/13/2012	26.5	11/26/2013	39.7	11/14/2014	35.1	-50	12

Table 2-10. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H), HR-3, and HX P&T Systems, 2011 to 2013

P&T System	Well or Aquifer Tube Name	Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	699-100-43 B	M	10/12/2012	7.3	11/1/2013	3.3 (B)	10/24/2014	5.4	55	-64
	699-101-45	M	10/17/2012	19.7	11/1/2013	23	10/24/2014	26.1	-17	-13
Aquifer Tubes										
	44-M	AT	11/1/2012	2.4 (B)	11/25/2013	2 (U)	11/3/2014	1.5 (U)	17	NC
	45-S	AT	11/7/2012	2 (U)	1/13/2014[b]	2 (UN)	11/4/2014	1.6	NC	20
	45-M	AT	11/6/2012	2 (U)	1/13/2014[b]	2 (UN)	11/4/2014	1.5 (U)	NC	NC
	45-D	AT	11/6/2012	2 (U)	1/13/2014[b]	3.6 (B)	11/4/2014	7.1	-80	-97
	47-M	AT	11/13/2012	2.6 (B)	12/3/2013	8	11/12/2014	6.2	-208	23
	47-D	AT	11/13/2012	2 (U)	12/3/2013	9	11/12/2014	4	-350	56
	48-S	AT	11/8/2012	10.2	12/4/2013	4.5 (B)	11/13/2014	4.7	56	-4
	48-M	AT	11/8/2012	10.3	12/3/2013	8	11/13/2014	4.4	22	45
	49-D	AT	11/14/2012	6.4	11/25/2013	10.3	11/13/2014	8.2	-61	20
	50-S	AT	11/26/2012	7.4	—	—	1/13/2015[c]	12	—	—
	50-M	AT	11/14/2012	7.1	—	—	1/13/2015[c]	8.5	—	—
	52-S	AT	11/14/2012	2 (U)	—	—	12/18/2015	1.5 (U)	—	—
	52-M	AT	11/14/2012	2 (U)	—	—	12/18/2015	1.5 (U)	—	—
	52-D	AT	11/14/2012	2 (U)	—	—	12/18/2015	1.5 (U)	—	—
	54-S	AT	11/14/2012	2 (U)	—	—	12/18/2015	2	—	—

Table 2-10. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H), HR-3, and HX P&T Systems, 2011 to 2013

P&T System	Well or Aquifer Tube Name	Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	54-M	AT	11/14/2012	2 (U)	—	—	12/18/2015	4.7	—	—
	54-D	AT	11/14/2012	2 (U)	—	—	12/18/2015	3.4	—	—
	AT-H-1-D	AT	11/7/2012	4.5 (B)	—	—	—	—	—	—
	AT-H-1-M	AT	11/7/2012	2 (U)	12/3/2013	8	11/5/2014	19.2	-300	-140
	AT-H-1-S	AT	11/7/2012	4.6 (B)	12/3/2013	8	11/5/2014	14.7	-74	-84
	AT-H-2-D	AT	11/7/2012	4.5 (B)	1/9/2014[b]	2 (U)	11/6/2014	7.8	56	-290
	AT-H-3-D	AT	11/7/2012	4.2 (B)	12/3/2013	11	11/5/2014	48.6	-162	-342
	AT-H-3-S	AT	11/7/2012	2.9 (B)	12/3/2013	13	11/5/2014	22.3	-348	-72
	C5632	AT	10/31/2012	2.1 (B)	—	—	10/30/2014	1.5 (U)	—	—
	C5633	AT	10/31/2012	7	—	—	10/30/2014	8.2	—	—
	C5634	AT	10/31/2012	4.7 (B)	—	—	10/30/2014	1.5	—	—
	C5635	AT	10/31/2012	2 (U)	—	—	10/30/2014	2.6	—	—
	C5636	AT	10/31/2012	11.2	—	—	10/30/2014	10.2	—	—
	C5637	AT	10/31/2012	7	—	—	10/30/2014	5.7	—	—
	C5638	AT	10/31/2012	8.6	12/2/2013	17 (B)	10/30/2014	5.7		
	C5641	AT	10/31/2012	24.7	12/2/2013	29.7 (B)	10/30/2014	33.5		
	C5644	AT	11/1/2012	4.9 (B)	—	—	11/3/2014	3.8	—	—
	C5673	AT	11/1/2012	5.7	—	—	11/4/2014	6.8	—	—

Table 2-10. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H), HR-3, and HX P&T Systems, 2011 to 2013

P&T System	Well or Aquifer Tube Name	Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	C5674	AT	11/1/2012	4.8 (B)	—	—	11/4/2014	5.5	—	—
	C5676	AT	11/1/2012	4.3 (B)	—	—	11/4/2014	9.1	—	—
	C5677	AT	11/1/2012	5.2	—	—	11/4/2014	6.3	—	—
	C5678	AT	11/1/2012	6.6	12/2/2013	9.68 (U)	11/4/2014	4.7	-47	51
	C5679	AT	11/1/2012	2.6 (B)	1/14/2014[b]	2 (BN)	11/4/2014	1.5 (U)	23	25
	C5680	AT	11/1/2012	5.5	1/14/2014[b]	5.2 (N)	11/4/2014	5.2	5	0
	C5681	AT	11/1/2012	4.4 (B)	—	—	12/22/2014	2.4	—	—
	C5682	AT	11/6/2012	2 (U)	12/3/2013	9	11/5/2014	9.5	-350	-6
	C5684	AT	10/31/2012	3.9 (B)	—	—	10/30/2014	3.3	—	—
	C5685	AT	10/31/2012	4.3 (B)	—	—	10/30/2014	4.3	—	—
	C6286	AT	10/31/2012	6.5	—	—	10/30/2014	6.6	—	—
	C6287	AT	10/31/2012	5.9	—	—	*10/30/2014*	11.4	—	—
	C6288	AT	10/31/2012	12.5	1/14/2014[b]	10.4	10/30/2014	13.1	17	-26
	C6290	AT	11/6/2012	2 (U)	1/13/2014[b]	2 (UN)	—	—	NC	—
	C6291	AT	11/6/2012	2.1 (B)	1/13/2014[b]	2 (UN)	11/6/2014	17.7	5	-785
	C6293	AT	11/6/2012	2 (U)	1/9/2014[b]	2 (U)	11/5/2014	12	NC	-500
	C6296	AT	11/13/2012	2 (U)	1/9/2014[b]	3.2 (B)	11/12/2014	1.5 (U)	-60	53

Table 2-10. Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H), HR-3, and HX P&T Systems, 2011 to 2013

P&T System	Well or Aquifer Tube Name	Use	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	C6297	AT	11/13/2012	8.3	1/9/2014[b]	10.5	11/12/2014	8.3	-27	21
	C6299	AT	11/13/2012	2 (U)	1/9/2014[b]	2 (U)	11/13/2014	1.5 (U)	NC	NC
	C6300	AT	11/13/2012	4.4 (B)	1/9/2014[b]	2.3 (B)	11/13/2014	1.5 (U)	48	35
	C6301	AT	11/13/2012	9.2	1/9/2014[b]	2 (U)	11/13/2014	15.6	78	-680
	C7649	AT	11/13/2012	2.1 (B)	1/9/2014[b]	2.1 (B)	1/13/2015	28.2[c]	0	-1,243
	C7650	AT	11/13/2012	24.6	1/9/2014[b]	30.9	1/12/2015	4.5 (B)[c]	-26	85

Notes: The percent change in concentration is calculated using the following formula: $([Cr(VI)]_{year\ 1}-[Cr(VI)]_{year\ 2})/[Cr(VI)]_{year\ 1}$.

If more than one sample was collected on the same date, the maximum result was used.

a. Fall represents the period from October 1 to December 31 for the specified calendar year. The maximum concentration reported during this period is listed. If a higher result was reported in September, the September result is listed.
If no Cr(VI) results were reported during this period, the result reported for the next closest date prior to October 1 but no earlier than September 1 is listed.

b. Fall 2013 sample was collected in January 2014.

c. Fall 2014 sample was collected in January 2015

— = indicates that the sample was not collected, analysis was not performed, or the change in concentration was not calculated
AT = aquifer tube
C = compliance well
Cr(VI) = hexavalent chromium
E = extraction well
I = injection well
M = monitoring well
NC = not calculated (if both results included a nondetect "U" laboratory qualifier)
P = performance well
U = undetected (detection limit is listed with qualifier in parentheses)

Table 2-11. Cr(VI) Concentrations for 100-H Area and 100-D Area RUM Wells, 2012 to 2014

System	Well or Aquifer Tube Name	Well Use	Fall* 2012 Unfiltered Cr(VI)		Fall*2013 Unfiltered Cr(VI)		Fall* 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Increase)	
			Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
	199-D5-134	M	—	—	10/1/2013	5.9	11/21/2014	7	—	-19
	199-D5-141	M	9/26/2012	2 (U)	10/21/2013	2 (UN)	11/21/2014	10.7	NC	-435
	199-D8-54B	M	—	—	12/20/2013	4.9 (B)	6/24/2014	9	—	-84
	199-H2-1	M	10/22/2012	6.5	10/25/2013	9.1	10/31/2014	16.3	-40	-79
	199-H3-10	M	10/19/2012	2.2 (B)	10/25/2013	2.6 (B)	10/31/2014	4.5	-18	-73
HX	199-H3-2C	E	10/28/2012	66	11/19/2013	64	3/19/2014	66.4	3	-4
	199-H3-9	M	10/19/2012	146	10/25/2013	116	6/17/2014	130	21	-12
HX	199-H4-12C	E	12/3/2012	137	11/19/2013	121	12/2/2014	121	12	0
	199-H4-15CS	M	10/12/2012	85.7	10/17/2013	52.3	11/23/2014	27.8	39	47
	699-97-43C	M	11/13/2012	2 (U)	11/25/2013	2.3 (B)	10/24/2014	1.5 (U)	-15	35
	699-97-45B	M	11/15/2012	2 (U)	11/26/2013	2 (U)	10/24/2014	7.4	NC	-270
	699-97-48C	M	11/8/2012	62.6	12/2/2013	105	10/24/2014	78.1	-68	26

Notes: The percent change in concentration is calculated using the following formula: $([Cr(VI)]_{year\ 1}-[Cr(VI)]_{year\ 2})/[Cr(VI)]_{year\ 1}$.

If more than one sample was collected on the same date, the maximum result was used.

* Fall represents the period from October 1 to December 31 for the specified calendar year. The maximum concentration reported during this period is listed. If a higher result was reported in September, the September result is listed.

If no Cr(VI) results were reported during this period, the result reported for the next closest date prior to October 1 but no earlier than September 1 is listed.

— = indicates that the sample was not collected, analysis was not performed, or the change in concentration was not calculated

M = monitoring well

E = extraction well

Cr(VI) = hexavalent chromium

NC = not calculated (if both results included a nondetect "U" laboratory qualifier)

U = undetected (detection limit is listed with qualifier in parentheses)

Table 2-12. Comparison of River Protection Assessment Results

Assessed Shoreline Lengths 100-HR-3/100-D	2013	2014	Change from 2013 to 2014
Total length of shoreline adjacent to 100-D Area	2,800 m (9,180 ft)		
Length identified as "protected" Percent of shoreline "protected"	1,200 m (3,930 ft) 43% of shoreline	1,500 m (4,920 ft) 54% of shoreline	Additional 300 m (990 ft) of shoreline identified as "protected"
Length identified as "protected (action may be required)" Percent of shoreline "protected (action may be required)"	1,100 m (3,610 ft) 39% of shoreline	800 m (2,620 ft) 28% of shoreline	Net change of 300 m (990 ft) of shoreline previously identified as "protected (action may be required)" now identified as protected
Length identified as "not protected" Percent of shoreline "not protected"	500 m (1,640 ft) 18% of shoreline	500 m (1,640 ft) 18% of shoreline	No net change in length of shoreline identified as "not protected
Assessed Shoreline Lengths 100-HR-3/100-H	**2013**	**2014**	**Change from 2013 to 2014**
Total length of shoreline adjacent to 100-H Area	4,400 m (14,430 ft)		
Length identified as "protected" Percent of shoreline "protected"	2,300 m (7,540 ft) 52% of shoreline	2,700 m (8,855 ft) 61% of shoreline	Additional 400 m (1,315 ft) of shoreline identified as "protected"
Length identified as "protected (action may be required)" Percent of shoreline "protected (action may be required)"	1,000 m (3,280 ft) 23% of shoreline	1,200 m (3,935 ft) 27% of shoreline	Additional 200 m (655 ft) of shoreline identified as "protected (action may be required)"
Length identified as "not protected" Percent of shoreline "not protected"	1,100 m (3,610 ft) 25% of shoreline	500 m (1,640 ft) 11% of shoreline	600 m (1,970 ft) of shoreline previously identified as "not protected" now identified as "protected" or "protected (action may be required)"

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Table 2-13. Breakdown of HR-3 P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)															
	1999	2000	2001[a]	2002[b]	2003	2004	2005	2006	2007	2008	2009[c]	2010	2011[d]	2012[f]	2013[g]	2014[f]
Design	—	—	97.7	15.4	8.1	196.1	196.0	55.0	92.0	—	0.0	26.5	—	0.7	—	—
Treatment system capital construction	—	57.7	(36.1)	750.3	—	496.6	10.0	—	—	—	—	—	—	—	—	—
Project support	265.3	276.7	225.8	309.3	229.8	211.8	722.6	697.6	171.9	169.5	204.7	139.6	11.7	—	0.7	—
Operations and maintenance	1,650.8	799.1	739.2	816.6	733.7	1,049.5	618.5	891.2	679.6	1,084.8	1,091.8	1,411.5	788.9	42.5	201.6	2.2
Performance monitoring	—	173.7	219.9	120.0	163.2	120.3	353.0	489.6	219.5	508.5	237.7	240.0	—	—	—	—
Waste management	—	895.3	424.9	720.1	877.2	501.7	202.2	217.6	434.7[e]	192.2	16.6	75.0	—	3.0	—	—
Totals	**$1,916**	**$2,203**	**$1,671**	**$2,732**	**$2,012**	**$2,576**	**$2,102**	**$2,351**	**$1,598**	**$1,955**	**$1,551**	**$1,893**	**$801**	**$46**	**$202**	**$2**

a. 2001 costs were corrected for project support and waste management. Initial expense calculations for 2001 were not properly categorized.

b. 2002 accrual costs were corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

c. Annual report has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

d. The HR-3 P&T system went into cold-standby status in May 2011.

e. Additional costs were associated with drilling wastes and resin cleared for shipment and handling.

f. Costs after system shutdown in 2011 are associated with surveillance and maintenance pending decommissioning of the HR-3 P&T facility.

g. Costs for 2013 were associated with disposal of Dowex® (a registered trademark of the Dow Chemical Company, Midland, Michigan) 21K resin.

— = not available

P&T = pump and treat

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Table 2-14. Breakdown of DR-5 P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)								
	2005	2006	2007	2008	2009[a]	2010	2011[b]	2012[c]	2014[c]
Design	246.9	196.8	100.4	—	3.2	3.4	—	(0.1)	—
Treatment system capital construction	—	22.2	—	—	—	—	—	—	—
Project support	586.4	370.6	240.3	233.6	204.7	139.6	2.7	--	—
Operations and maintenance	459.6	605.7	541.3	884.7	1,091.7	919.9	185.4	21.6	9.5
Performance monitoring	106.2	1.6	11.3	127.1	237.7	240.0	—	—	10.7
Waste management	28.3	154.7	45.4	23.8	1.7	29.0	—	—	—
Totals	**$1,427**	**$1,352**	**$939**	**$1,269**	**$1,539**	**$1,332**	**$188**	**$21**	**$20**

a. Annual report has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

b. The DR-5 P&T system went into cold standby in March 2011.

c. Costs after system shutdown in 2011 are associated with ongoing surveillance and maintenance while the facility is in standby. In 2014, the facility was transitioned for use as a well maintenance facility.

— = not available

P&T = pump and treat

Table 2-15. Breakdown of DX P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)					
	2009[a]	2010	2011[b]	2012	2013	2014
Design	2,115.2	1,287.8	100.7	34.3	28.9	5.7
Treatment system capital construction	5,759.8	16,266.3	—	(3.1)	244.2	565.7
Project support	495.1	1,236.9	45.7	71.3	186.0	132.4
Operations and maintenance	—	—	2,979.3	1,566.3	2,186.4	2,029.8
Performance monitoring	—	—	1.8	294.9	125.4	226.6
Waste management	7.4	9.2	—	0.8	0.0	0.6
Field studies	—	—	—	—	—	0.4
Totals	**$8,377**	**$18,800**	**$3,128**	**$1,965**	**$2,771**	**$2,961**

Table 2-15. Breakdown of DX P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)					
	2009[a]	2010	2011[b]	2012	2013	2014

a. Annual report has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

b. DX P&T construction was completed in December 2010, entered acceptance test procedures, and became fully operational in January 2011.

— = not available

P&T = pump and treat

Table 2-16. Breakdown of HX P&T System Construction Costs

Description	Actual Costs (Dollars × 1,000)					
	2009[a]	2010	2011[b]	2012	2013	2014
Design	896.4	1,047.5	1,079.8	35.9	3.6	6.0
Treatment system capital construction	214.1	9,354.2	11,316.2	(2.3)	220.0	566.9
Project support	—	400.2	1,981.4	53.2	179.4	128.7
Operations and maintenance	—	—	321.2	1,187.4	1,727.6	1,964.6
Performance monitoring	—	—	8.0	189.7	122.7	189.7
Waste management	—	0.1	—	1.0	—	—
Field studies	—	—	—	—	—	0.4
Totals	**$1,111**	**$10,802**	**$14,707**	**$1,465**	**$2,253**	**$2,856**

a. Annual reporting has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

b. HX P&T construction was completed in September 2011, entered acceptance test procedures, and became fully operational in October 2011.

-- = not available

P&T = pump and treat

3 100-KR-4 Operable Unit Remediation

This chapter describes the status of interim groundwater remedies and other CERCLA activities for the 100-KR-4 OU. The following sections describe the system operation results for 2014 and summarize the progress in remediating the aquifer since P&T startup.

3.1 Summary of Operable Unit Activities

The 100-KR-4 OU incorporates groundwater contaminated by releases from facilities and waste sites associated with past operation of the KE and KW Reactors (Figure 3-1). The Cr(VI) released from these facilities and waste sites poses a risk to human health and/or the environment and was identified in the interim action ROD (EPA/ROD/R10-96/134) as the primary groundwater COC in the 100-KR-4 OU. Groundwater co-contaminants identified in this interim remedial action scope are nitrate, tritium, strontium-90, carbon-14, and trichloroethene (TCE).

The interim action ROD for the 100-KR-4 OU (EPA/ROD/R10-96/134) defined the Cr(VI) cleanup goal in groundwater discharging to the Columbia River as the current ambient water quality criterion of 11 µg/L. Based in part on the expectation that contaminated groundwater (prior to discharging to the river) is mixed on a 1:1 basis with relatively uncontaminated water within a near-shore mixing zone along the river, attaining less than 22 µg/L of Cr(VI) in the compliance monitoring well network is consistent with achieving this RAO. The ESD for the 100-HR-3 and 100-KR-4 OUs (EPA et al., 2009) reduced the groundwater remediation target to 20 µg/L to meet a revised surface water quality criterion of 10 µg/L. Consequently, a compliance level of 20 µg/L for Cr(VI) in groundwater is currently applied to near-shore and compliance wells along the river. The DWS for total chromium remains at 100 µg/L. Ecology has established a Method B groundwater cleanup level of 48 µg/L for Cr(VI) in accordance with WAC 173-340.

To mitigate risks associated with Cr(VI) contamination in groundwater discharging to the river, three CERCLA interim action IX P&T systems have been installed in the 100-KR-4 OU. All three systems (KR4, KW, and KX P&T systems) were operational throughout 2014. The KR4 P&T system was the first system installed and began operation in 1997; it was designed to remediate groundwater around the 116-K-2 Trench (Figure 3-2). The KW P&T system was the second system installed and began remediating Cr(VI) in the KW Reactor area in January 2007. The third and newest P&T system, KX, began operation in February 2009. The KX P&T system is used primarily to treat Cr(VI) in groundwater that migrated from the 116-K-2 Trench area toward N Reactor and near the proximal end of the trench near the KE Reactor area. Figure 3-2 shows the extraction and injection wells comprising the well fields for these systems, as well as associated monitoring wells and other monitoring locations. The inferred distribution of hexavalent chromium in groundwater in the 100-KR-4 OU vicinity, as well as the inferred groundwater elevation contours for the low and high river stage periods of 2014 are shown in Figures 3-3 and 3-4, respectively.

Monitoring, data evaluation, and site characterization activities are conducted each year in an ongoing effort to determine the 100-KR-4 OU P&T systems' performance compared to design criteria, whether system design modifications or operating parameters will further optimize performance, and the measurable progress toward achieving plume cleanup and river protection RAOs. This chapter discusses the results of the 2014 100-KR-4 OU P&T evaluation and includes the following:

- Section 3.2 discusses the interim action groundwater remediation activities.
- Section 3.3 provides the remedial action cost summary.

- Sections 3.4 and 3.5 present the conclusions and recommendations, respectively, for the 100-KR-4 OU.

3.1.1 100-KR-4 Operable Unit Pump and Treat Systems

This subsection describes the general operating status and notable modifications to the 100-KR-4 OU interim action P&T systems during 2014.

Changes to remedial systems during 2014 consisted primarily of constructing additional wells for monitoring, extraction, and injection, as well as realigning selected existing wells for use as extraction wells. These actions were intended to enhance hydraulic plume capture, reduce Cr(VI) plume concentrations, and remove mass from source areas. In addition, two other new well installations are planned for implementation in early 2015. Changes to the remedial systems are shown in Table 3-1. The locations of the new and realigned wells in 2014 are shown in Figure 1-7.

3.1.2 Remedial Investigation/Feasibility Study Activities

An RI/FS was conducted to support the final ROD for the 100-K Area in 2010 and 2011. Characterization activities began in 2009 (as described in DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*) and were implemented through the sampling and analysis plan (SAP) (DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*). DOE/RL-2010-97, *Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*, was submitted for regulatory review in September 2011. EPA and DOE identified a need for additional characterization beneath the 105-KE Reactor fuel storage basin (FSB) and the 116-KE-3 FSB/Reverse Well to fill a data gap regarding vadose zone contaminant nature and extent around the reactor structures before issuing Rev. 0 of the RI/FS report. Plans for this additional characterization are complete and work will commence during 2015.

3.2 CERCLA Operable Unit Interim Action Activities

This section summarizes the non-RI/FS CERCLA activities for the 100-KR-4 OU during the reporting period, including activities related to operation and performance monitoring of the KR4, KW, and KX P&T systems during 2014. Specific activities and operational performance details for these systems include system configuration changes and availability, contaminant mass removed during operation, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, and waste generation.

3.2.1 KR4 Pump and Treat System

The KR4 P&T system was designed to capture and treat the Cr(VI) plume associated with the 116-K-2 Trench (Figure 3-2). A large volume of reactor cooling water was discharged to the 116-K-1 Crib and subsequently to the 116-K-2 Trench during reactor operations. This water contained Cr(VI) at varying concentrations, up to 600 µg/L. The releases created a large, widespread Cr(VI) plume centered on the trench that extends to the Columbia River and several kilometers inland in all directions. Since startup in 1997, the KR4 P&T system has treated more than 7.25 billion L (1.91 billion gal) of groundwater and has removed 371.4 kg (818.8 lb) of Cr(VI). The KR4 P&T system has remediated much of the original plume along the central 116-K-2 Trench to less than 20 µg/L (DOE/RL-2014-25, Appendix A); however, substantial contamination remains in the groundwater at either end of the trench and inland areas (i.e., KR4 and K North plumes). Continued operation of the KR4 P&T system is indicated to remediate Cr(VI) plumes at the proximal and distal regions of the trench. This plume dissection has resulted primarily from extracting high-concentration groundwater along the trench and

from the effects of injecting treated effluent water into wells located near the middle of the trench with a subsequent low-concentration mound established at that location. The substantial contaminant mass reduction near the central 116-K-2 Trench reflects the overall influent concentration decline due to the treatment system (Figure 3-5). The average influent concentration at the KR4 P&T system was less than 10 µg/L in 2014. The KR4 P&T system continues to operate to sustain hydraulic containment of the inland plumes. Since the changeover to SIR-700 resin, no resin changeouts have been required at KR4 P&T system.

3.2.1.1 KR4 Pump and Treat System Configuration and Changes

The KR4 P&T system (Figure 3-6) was designed to receive and process up to 1,135.6 L/min (300 gal/min). The current system design includes 12 extraction wells and 5 injection wells (Figure 3-2). Project staff realigned Wells 199-K-198 and 199-K-199 in 2013 and placed them into service as extraction wells in 2014 to enhance groundwater capture near the river at that location. No changes to the KR4 P&T system well network were made in 2014 other than the realignment of these two wells.

The KR4 P&T system continued to operate in 2014 using SIR-700 chromate-specific IX resin. Process stream pH is measured near the inlet to the IX vessels and before the treated process effluent is discharged. The average influent pH for the KR4 P&T system during 2014 was 6.58 units; the average effluent pH for this system was 6.86 units. No changes in treatment process chemistry were implemented during 2014. Technical evaluation of optimal system pH for influent and effluent discharge is ongoing.

Selected instrumentation and control components of the KR4 P&T system were upgraded during 2014. These included replacing flowmeters with larger capacity units to allow measurement of increased extraction flow.

3.2.1.2 KR4 Pump and Treat System Performance

Table 3-2 presents an overview of the operational parameters and total system performance for the KR4 P&T system during 2014. Groundwater was processed at an average pumping rate of 848 L/min (240 gal/min). The average Cr(VI) concentration in the KR4 P&T system influent for 2014 was 9.5 µg/L (Figure 3-7) compared to 19 µg/L in 2013.

Only three KR4 P&T extraction wells exhibited Cr(VI) concentrations above the interim remedial action groundwater target concentration of 20 µg/L during at least one sampling event during 2014 (Wells 199-K-115A, 199-K-144, and 199-K-145). The maximum measured Cr(VI) concentration in an extraction well was 47 µg/L in Well 199-K-115A. The average influent Cr(VI) concentration during 2014 was 9.5 µg/L. The maximum Cr(VI) concentration observed in the KR4 P&T system effluent during 2014 was 8.7 µg/L, and the average concentration was below the 2 µg/L detection limit. Additional operational and system characteristics of the KR4 P&T system for 2014 are summarized as follows:

- A total of 526 million L (139 million gal) of groundwater was treated, and approximately 5 kg (11 lb) of Cr(VI) was removed.
- The 2014 mass removal efficiency was 93.7 percent, which is about the same as that reported in 2013 (94.7 percent). The slight decrease in total mass of chromium removed (Figure 3-5; Table 3-2) reflects the decreasing concentration in groundwater extracted.
- Total system availability for 2014 was 93.5 percent.

Table 3-3 presents the pumping flow rates and total run-time percentage (total flow hours divided by total possible run-time) for each extraction and injection well currently in use for the KR4 P&T system. The average flow rate was calculated by dividing the total volume extracted by the hours of pumping.

During 2014, all wells were subject to downtime due to equipment repair and/or maintenance. The downtime is reflected in the yearly average flow-rate calculations and the total run-time percentages for each extraction well. The monthly online availability for the KR4 P&T system for 2014 is illustrated in Figure 3-8.

Average annual influent concentrations are decreasing over time since 1997 (Figure 3-5). Within the plume area treated by the KR4 P&T system, only two (i.e., Wells 199-K-22 and 199-K-37) of the original six extraction wells exhibit Cr(VI) concentrations above the 20 µg/L remedial action target.

Other COCs were detected in effluent from the KR4 P&T system during 2014. These include tritium at 6,835 pCi/L (compared to the DWS equivalent of 20,000 pCi/L), nitrate at 10,295 µg/L (compared to the DWS equivalent of 45,000 µg/L), and strontium-90 at an average of 2.5 pCi/L (compared to the DWS equivalent of 8 pCi/L). Carbon-14 was detected in effluent at an average of 17.5 pCi/L (substantially less than the DWS equivalent of 2,000 pCi/L), and total chromium was detected at an average concentration of 13 µg/L (less than the DWS of 100 µg/L). TCE was not analyzed at the KR4 P&T system. These contaminants are unaffected by the SIR-700 resin treatment system and were reinjected into the aquifer.

3.2.2 KW Pump and Treat System

The KW P&T system became operational on January 29, 2007, and has treated over 2.9 billion L (776 million gal) of groundwater and removed 221 kg (487 lb) of Cr(VI). This P&T system was installed to address Cr(VI) groundwater contamination in the KW Reactor vicinity (Figure 3-2). The sources for Cr(VI) in groundwater are historically intentional and unplanned releases (UPRs) of water treatment chemicals near the 183-KW Head House chemical storage tank farm. Possible UPRs from the pipeline that transferred sodium dichromate solution from the tank farm to the injection point at the clear wells may have contributed to the condition. The KW P&T system includes groundwater extraction wells located downgradient of the head house area and three injection wells located around the former tank farm area.

3.2.2.1 KW Pump and Treat System Configuration and Changes

The KW P&T system continued to operate in 2014 at a process rate of 1,130 L/min (300 gal/min) using the two-vessel train configuration and SIR-700 resin (Figure 3-9). Measurements of Cr(VI) concentrations in the effluent averaged less than 2 µg/L during testing (Figure 3-10), and mass removal efficiency averaged 91.4 percent. Cr(VI) concentrations were analyzed using in-plant measurement systems. Four effluent samples were collected for laboratory analysis during the year. Analytical laboratory results were below detection limits for the effluent samples, consistent with the in-plant measurements. Resin replacement has not been required at the KW P&T system since SIR-700 resin was placed in service in September 2011. Operating the treatment system with SIR-700 resin has resulted in less system resin changeout downtime and significant cost reduction by eliminating the need for resin regeneration.

During 2014, the KW P&T system consisted of 11 extraction wells and 4 injection wells. Well realignment changes in 2014 at the KW P&T system included construction of one new extraction well (Well 199-K-205, located at the 183-KW Head House area) and one new injection well (Well 199-K-206, located between injection Wells 199-K-158 and 199-K-175). These wells provided a substantial increase in the treatment rate of extracted water at the KW P&T system, as well as providing high-capacity extraction in the head house vicinity, which is an apparent source area. Well 199-K-205 is capable of producing more than 378.5 L/min (100 gal/min) of extracted groundwater. System modifications at the KW P&T system were primarily related to changes required to bring Well 199-K-205 on line as an

extraction well. This included putting all the well controls and conveyance in service in addition to installing a pre-treatment resin vessel in the plant, described below.

The IX treatment system was modified in 2014 to operate with two vessels per treatment train. Modifications to operating systems at the KW P&T system, along with installation of the two new remediation wells, allowed the throughput capacity of the KW P&T system to exceed 1,135.6 L/min (300 gal/min). The initial concentration of Cr(VI) in groundwater from Well 199-K-205, installed in 2013, was greater than 1,000 µg/L. In order to accommodate this elevated influent concentration while maintaining a high chromium removal efficiency, a pre-treatment vessel containing a separate load of SIR-700 resin was installed to allow a primary treatment of water from Well 199-K-205. Water leaving the pretreatment vessel was subsequently commingled with the extracted groundwater from the other extraction wells and passed through the regular resin treatment vessels.

Process stream pH is measured near the inlet to the IX vessels and before the treated process effluent is discharged. The average influent pH for the KW P&T system during 2014 was 6.74 units; the average effluent pH for this system was 6.79 units. No changes in treatment process chemistry were implemented during 2014. Technical evaluation of optimal system pH for influent and effluent discharge is ongoing.

3.2.2.2 KW Pump and Treat System Performance

Table 3-4 presents the operational parameters and total system performance overview for 2014 for the KW P&T system. During 2014, the KW P&T system processed groundwater at an average annual pumping rate of approximately 926.5 L/min (244.6 gal/min) and operated at overall 89 percent availability (Figure 3-11). The average influent Cr(VI) concentration for 2014 was 22 µg/L, a decrease from about 32 µg/L in 2013.

A clear downward trend was evident in the influent concentrations in 2014 (Figures 3-10 and 3-12). Cr(VI) concentrations in the KW P&T influent system gradually decreased from less than 40 µg/L in January to about 20 µg/L by mid-year. Bringing Well 199-K-205 on line in mid-year produced an increase in the average influent concentration during the fall but declining concentrations resumed in October through December. The observed concentration of Cr(VI) in groundwater from Well 199-K-205 declined to about 100 µg/L by the end of 2014.

The Cr(VI) concentrations in the KW P&T system effluent remained consistently below 2 µg/L (average of 1.9 µg/L) for field samples analyzed during the year. The maximum detected Cr(VI) concentration in the KW P&T effluent samples in 2014 was 5 µg/L (Figure 3-10). Selected operational and system characteristics of the KW P&T system for 2014 are summarized as follows:

- Overall total system availability (calculated as the fraction of time the plant was in operation) for 2014 was 97 percent. The monthly online percentages are shown in Figure 3-11. The KW P&T system treatment throughput continued to exceed the original design treatment capacity during 2014 due to reconfiguration into multiple treatment trains using SIR-700 resin (Figure 3-11).
- A total of 580 million L (153 million gal) of groundwater was treated during 2014, and approximately 19 kg (42 lb) of Cr(VI) was removed.
- The average mass removal efficiency for 2014 was 91.4 percent, similar to that observed in 2013 (Table 3-4; Figure 3-10).

Table 3-5 presents the pumping flow rates and total run-time percentage (total flow hours divided by total possible run-time) for the extraction and injection wells currently active in the KW P&T system. The average flow rate was calculated by dividing the total volume extracted by the hours of pumping.

All wells were subject to downtime for repair and/or maintenance. This downtime is reflected in the yearly average flow-rate calculations and the total run-time percentages for the individual extraction wells.

Other COCs were detected in effluent from the KW P&T system, including tritium at an average of 1,480 pCi/L, nitrate at 23,400 µg/L, strontium-90 at an average of 0.4 pCi/L, and TCE at 3.8 µg/L. Total chromium was detected at an average concentration of 3.1 µg/L in effluent. All of these effluent contaminant concentrations were less than their respective DWSs. These contaminants are unaffected by the SIR-700 resin treatment system and pass through the system unaffected.

3.2.3 KX Pump and Treat System

The KX P&T system (Figure 3-13) was designed to receive and process groundwater at a rate of up to 2,300 L/min (600 gal/min). The system was primarily designed to treat the K North Cr(VI) plume, located between the northern end of the 116-K-2 Trench and the N Reactor fence line. A portion of the Cr(VI) plume downgradient of the KE Reactor, originating near the 183-KE Head House, is also being captured and treated by the KX P&T system. This system began partial operation in November 2008 and became fully operational in early February 2009. The 2014 average annual pumping rate for the KX P&T system was approximately 2,294 L/min (606 gal/min). Since startup, the system has treated more than 5.8 billion L (1.5 billion gal) of water and removed approximately 194 kg (428 lb) of Cr(VI).

3.2.3.1 KX Pump and Treat System Configuration and Changes

The KX P&T system currently includes 18 extraction wells and 9 injection wells (Figure 3-2). Wells 199-K-210 and 199-K-212 were installed to improve river protection by enhancing capture of the Cr(VI) plume in the near-river vicinity downgradient of the KE Reactor (199-K-210) and along the 116-K-2 Trench (199-K-212). Well 199-K-220 was installed near the 183-KE Head House to provide mass removal from that source area.

During 2014, the KX P&T system continued to operate using the SIR-700 IX resin in the treatment process. The average influent pH for KX P&T system in 2014 was 6.61 units; the average effluent pH (i.e., treated water returned to the aquifer) was 6.92 units. No changes in treatment process chemistry were implemented during 2014. Technical evaluation of optimal system pH for influent and effluent discharge is ongoing.

The third and fourth vessels in the treatment trains at KX treatment system were loaded with SIR-700 resin during 2014 to provide additional treatment capacity. This increased capacity was demonstrated during 2014 when the KX P&T system was operated at a maximum daily throughput rate of 2,926.1 L/min (773 gal/min).

3.2.3.2 KX Pump and Treat System Performance

Table 3-6 presents an overview of the operational parameters and total system performance for the KX P&T system during 2014. During the year, the KX P&T system processed groundwater at an average pumping rate of approximately 2,294 L/min (606 gal/min). The system operated 99 percent of the time during 2014 (Figure 3-14).

The average influent Cr(VI) concentration for 2014 was 21.5 µg/L, which is about 30 percent lower that observed in 2013. The KX influent Cr(VI) concentrations exhibited variability during 2014, ranging from about 15 to 25 µg/L during the year (Figure 3-15).

The maximum reported concentration of Cr(VI) in the KX P&T system effluent during 2014 was 1 µg/L. Effluent concentrations were nondetectable for most of the year and averaged below the estimated 2 µg/L

detection limit (i.e., most of the measurements indicated "0"). Additional operational and system parameters for the KX P&T system for 2014 are as follows:

- A total of 1.2 billion L (317 million gal) of groundwater was treated, and approximately 26 kg (57 lb) of Cr(VI) was removed.
- The annual average mass removal efficiency was 96.4 percent (Table 3-6; Figure 3-16).
- The total system uptime was 99 percent for 2014.

Table 3-7 presents the 2014 pumping flow rates and total run-time for the extraction and injection wells currently active in the KX P&T system. The average flow rate of 2,294 L/min (606 gal/min) was calculated by dividing the total volume extracted by the hours of pumping. During 2014, each of the wells was subject to downtime due to repair and/or maintenance. The downtime is reflected in the yearly average flow rate calculations and the total run-time percentages for each extraction well.

Other COCs were detected in the effluent from the KX P&T system, including tritium at 1,570 pCi/L, nitrate at 13,300 µg/L, strontium-90 at 2 pCi/L, and carbon-14 at 70 pCi/L. Total chromium averaged 2.2 µg/L in effluent. As with the other two systems, these effluent concentrations were all well below their corresponding DWSs. These contaminants are unaffected by the SIR-700 resin treatment system and pass through the system unaffected.

3.2.4 Performance Monitoring

Control of Cr(VI) in groundwater remains the principal objective of the active groundwater interim remedial action at the 100-KR-4 OU. Strontium-90 and tritium are listed in the interim action ROD for the OU (EPA/ROD/R10-96/134) as co-contaminants and are monitored as part of the remedial action. The ROD acknowledges that other nonchromium groundwater contaminants are not treated by the interim action remedy. The groundwater COCs identified in the RI/FS report (DOE/RL-2010-97) are chromium (total and hexavalent), nitrate, carbon-14, strontium-90, tritium, and TCE.

Contaminant concentration data are collected each year from 100-KR-4 OU compliance wells, other monitoring and extraction wells, and aquifer tubes within the OU. The data are used to update the status of the plumes and evaluate the effectiveness of ongoing remedial activities. Particular emphasis is given to data collected during the fall of each year, when river levels are low and contaminant flux toward the river is highest. Tables 3-8 through 3-10 depict the highest 2014 concentrations for Cr(VI), tritium, strontium-90, carbon-14, nitrate, and TCE for the 116-K-2 Trench (K North) area, KW Reactor area, and the KE Reactor area, respectively, which are described in the following subsections. This report focuses on evaluating the analytical results for Cr(VI) being remediated through the interim action P&T systems.

Further summary and analysis of the other COCs and contaminants of interest are presented in the annual groundwater monitoring report (DOE/RL-2015-07).

Tables 3-11 through 3-13 present fall 2014 monitoring results for Cr(VI) at the 100-KR-4 OU plume areas. Where data for fall 2012 and 2013 were previously collected at the locations monitored during fall 2014, the older data were included in these tables. In wells where sufficient data were available, the concentration trends between the fall of 2012 and 2014 were evaluated. Additionally, the data summary tables present the percent increases or percent decreases in concentrations between 2012 and 2013, and between 2013 and 2014. CERCLA system performance assessment addresses longer term changes in Cr(VI) concentrations at selected monitoring and extraction wells in the 100-KR-4 OU.

Figures 3-3 and 3-4 present Cr(VI) plume maps for 2014 low river stage and high river stage, respectively. Contaminant plume maps in this report are based on average results for samples collected

either during the low- or high-river period in 2012 for each well shown. The plume maps, data summary tables, and a summary of notable data observations are presented in the following subsections. Contaminant plume maps were constructed by computer programs using quantile kriging to produce a continuous spatial illustration of the contaminant distribution (described in Chapter 2).

3.2.4.1 River-Stage Effects

During the period of low river stage (generally during fall, winter, and early spring), groundwater beneath the 100-K Area flows readily toward the Columbia River. Aquifer tube samples collected during the low river-stage period detected Cr(VI) at some locations along the length of river shore associated with 100-KR-4 OU. High river stage in 2014 included the seasonal rising portion of the hydrograph (observed starting in late February) and extended through the falling portion of the freshet (through August 2014) (Figure 3-17). The 2014 high river-stage period exhibited the highest stage (about 121 m [397 ft] amsl) occurring at two periods during early and late June, with substantially lower point (i.e., about 119 m [390.4 ft]) occurring in mid-June. The observed high river stage in 2014 was similar in peak stage elevation to that observed in 2013. The seasonal river stage increase began about one month earlier in 2014 than in 2013. This is due to changes in river pool elevation in response to a crack in the Wanapum Dam, upstream from the Hanford Site. The crack was observed in late February, and the pool level behind the Wanapum Dam was immediately lowered, resulting in increased downstream river flow and the observed rapid increase in river stage along the Hanford Reach. This response appears to have affected only the timing of the early part of the freshet at the 100-K Area, not the peak river stage. With peak river stage occurring in a manner similar to that observed in 2013, conditions at the 100-K Area are expected to have exhibited only minimal (if any) bank storage during 2013 due to natural river water intrusion into the adjacent aquifer. As the river stage rises toward its peak level, the water table surface also rises in response to the change in boundary condition at the river shore. Although aquifer tube samples were not collected at the 100-K Area during high river stage in 2014 (the tube locations were generally inundated at that time), the Cr(VI) values measured in the aquifer tubes at low river stage were assigned to the aquifer tube locations for both high and low river-stage plume map constructions for 2014 (Figure 3-4).

Increased pumping rates at extraction well locations did influence river water intrusion into the aquifer at some locations with the 100-KR-4 OU. During the last quarter of 2014, pumping rates at extraction wells were increased substantially to evaluate treatment plant capacity and groundwater capture effects. Groundwater specific conductance was mapped to evaluate the potential for migration of river water into the aquifer due to capture by pumping (Figure 3-18).

Specific conductance of less than 140 μS/cm is indicative of river water (i.e., the Columbia River exhibits a relative low dissolved solids load, thus a low specific conductance). Specific conductance of 300 μS/cm (or greater) is typical of groundwater in the former industrial operating area of the 100-KR-4 OU. Specific conductance of 200 to 300 μS/cm indicates a likely mixing of groundwater with river water. Ten well locations near the distal end of the 116-K-2 Trench exhibited specific conductance less than 300 μS/cm (Figure 3-18). This is consistent with the inferred water table map (Figure 3-19), which illustrates a substantial area of groundwater capture (as indicated by a definable groundwater depression) in that area.

3.2.4.2 Hexavalent Chromium Plumes

Several separate hexavalent chromium plumes are differentiated by geographic distribution and by the location and nature of probable source areas. The plumes are associated with three general areas: a plume originating at or near the 183-KW Head House and extending toward the river, a plume originating at or near the 183-KE Head House and extending toward the river, and a plume originating at the 116-K-1 Crib and 116-K-2 Trench and extending radially away from those sites. Conditions observed in groundwater at

the KE and KW Head Houses, where historical releases included high-concentration sodium dichromate-dihydrate solution, are likely related to continuing contributions from secondary sources remaining in the vadose zone and/or the periodically rewetted zone in those areas. The 116-K-2 Trench received primarily spent reactor cooling water, containing a substantially lower concentration of sodium dichromate. There remains a potential for continuing contributions from secondary source(s) in the vadose zone and periodically rewetted zone in the trench area as well.

These plumes have been reshaped and/or dissected by operation of the 100-K Area groundwater P&T systems. The P&T operations have also substantially reduced the observed groundwater Cr(VI) concentrations at many locations. The plume near the KW Reactor is being remediated by the KW P&T system. The plume at the KE Reactor is being remediated primarily by the KX P&T system. The Cr(VI) plume associated with the 116-K-1 Crib and 116-K-2 Trench is under remediation by the KX P&T system and the KR4 P&T system. Injection wells for the KX and KR4 P&T systems are located inland and to the northeast of the 116-K-1 Crib and 116-K-2 Trench plume. The injection wells place treated groundwater back into the aquifer and, over time, create a body of groundwater within the aquifer that exhibits a very low concentration of Cr(VI). Figures 3-3 and 3-4 show the inferred hexavalent chromium plume distribution for 2014for low and high river stage, respectively.

116-K-2 Trench Area (K North)

The northeastern portion of the 116-K-2 Trench plume extends into the 100-NR-2 OU (Figures 3-3 and 3-4). Groundwater sampling during drilling of Well 199-N-189, located east of KX extraction Well 199-K-182, detected Cr(VI) over the full thickness of the shallow unconfined aquifer, at concentrations ranging from 29 to 39 µg/L in 2011. Sampling of the completed well in 2014 detected Cr(VI) at a concentration of 45 µg/L. Well 199-N-74, located 2 km (1.2 mi) from the end of the trench and farther north than Well 199-N-189, exhibited Cr(VI) an average concentration of 40.5 µg/L in 2014. The contamination in both locations likely resulted from migration of the plume at the 116-K-2 Trench during the historical discharge period, when the large discharge mound at the trench moved contaminated water radially to the surrounding area. The Cr(VI) concentrations in these 100-N Area wells are consistent with the historical measurement of total chromium in filtered samples (a confident indication of Cr[VI]) in wells in that area over the past 20 years. Management and ultimate disposal of sodium dichromate solutions to wastewater cribs and trenches at the 100-N Area likely contributed to some of the Cr(VI) observed near the 100-N Area; migration of hexavalent chromium away from the 116-K-2 Trench also likely accounts for some of the Cr(VI) observed in the vicinity of the 100-N Area. Operation of the current P&T systems at the 100-K Area does not appear to be affecting the portions of the Cr(VI) plume(s) that lie inland of the 100-N Area.

The upgradient extent of the plume south of the 116-K-2 Trench suggests that considerable mass may remain to be treated. In the northeastern lobe, the plume is bounded inland of Well 199-K-182 by historical measurements of less than 2 µg/L at Well 699-81-58. A new monitoring well (199-K-209), drilled in 2014 inland of the 116-K-2 Trench and east of the northeastern plume lobe, will provide bounding information in that area when sampled in 2015. The overall pumping strategy used in this area is being evaluated to determine if the center of mass for each of these higher concentration plume zones should be more directly targeted for remediation. The 116-K-2 Trench chromium plume is being actively remediated by the KR4 and KX P&T systems. Based on evaluation of groundwater elevation contours inland of the 100-K Area, groundwater in the inland area appears to flow north-northeast away from the 100-K Area under natural gradient.

Table 3-11 compares data collected from 2012 to 2014 from wells and aquifer tubes associated with the 116-K-2 Trench K North plume. Table 3-8 presents the highest Cr(VI) concentrations from these

locations in 2014. Figure 3-20 provides trend charts for Cr(VI) concentrations for monitoring and extraction wells for the KR4 and KX P&T systems in the 116-K-2 Trench K North area.

The remedial performance of the 100-KR-4 P&T system (i.e., extent and effectiveness of plume capture and reduction in Cr[VI] concentration in groundwater) has been evaluated using Cr(VI) data from selected monitoring locations identified in the supplement to the 100-HR-3 and 100-KR-4 OUs RDR/RAWP (DOE/RL-2006-75, *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump-and-Treat System*). The general effectiveness of the KR4 P&T system in the central section of the 116-K-2 Trench area is evident by the long-term decreasing concentration trends of Cr(VI) in compliance monitoring Wells 199-K-117A, 199-K-21, and 199-K-20, which have averaged below 20 µg/L since 2008 (Figure 3-20). In addition, the concentrations in Wells 199-K-125A and 199-K-119A have steadily decreased, from about 40 µg/L in 2004 to consistently less than 10 µg/L since 2010 (Figure 3-20; Table 3-11). This likely reflects both the removal of Cr(VI) from the plume segments in this area and the effects of being located on the downgradient side of the large injection mound formed by the effluent returned to the aquifer by the KX and KR4 P&T system injection wells.

The KR4 extraction/compliance Wells 199-K-113A, 199-K-114A, 199-K-115A, 199-K-116A, and 199-K-129 are located downgradient of the northeast section of the 116-K-2 Trench and near the river in the K North plume (Figure 3-20). These wells have historically exhibited a distinct "saw-tooth" pattern of seasonal fluctuation in Cr(VI) concentration, likely resulting from seasonal influence from capture of increasing and decreasing quantities of river water (Figure 3-20). These wells have all shown a general decreasing trend in Cr(VI) and since late 2010 have averaged below 20 µg/L.

The decreasing concentration trends observed throughout 2014 for KR4 P&T system monitoring and extraction wells indicate that the P&T system is achieving the interim action objective of protecting the Columbia River along this section of the K North plume (Figures 3-3 and 3-20). Portions of the identified plumes continue to exhibit Cr(VI) concentrations in excess of the interim remedial action target concentration of 20 µg/L, and remedial actions will continue.

The remedial performance of the KX P&T system has been evaluated using the 2012 through 2014 Cr(VI) data (Table 3-11) and long-term concentration trend plots (Figure 3-20) for the 15 extraction wells for the KX P&T and associated monitoring wells, including compliance monitoring/extraction Wells 199-K-130, 199-K-131, 199-K-146, 199-K-147, 199-K-148, and 199-K-161.

Most of the KX P&T extraction wells currently capture and remediate the plume area between the northern end of the 116-K-2 Trench and the N Reactor fence line (i.e., K North plume). Monitoring Wells 199-K-149 and 199-K-150 were formerly the most northeastern extraction wells in the KX P&T system well field (Figure 3-2). The Cr(VI) concentrations in these wells decreased from approximately 80 µg/L in late 2008 to less than 10 µg/L in fall 2010. The decreased concentrations observed in both wells likely reflects upgradient aquifer cleanup, as well as partial capture and recirculation of treated effluent from injection Wells 199-K-159 and 199-K-160 (located 150 to 200 m [492 to 656 ft] cross-gradient to the northeast) and possibly from injection Well 199-K-164 (located 430 m [1,411 ft] upgradient) (Figure 3-2).

The Cr(VI) concentrations in Wells 199-K-149 and 199-K-150 have remained below 10 µg/L since fall 2010 and bound the northern boundary of the northeastern lobe of the K North plume.

Extraction Wells 199-K-131, 199-K-148, 199-K-130, and 199-K-147 are located progressively farther to the southwest. These well locations extend across the northeastern plume lobe of the K North plume, approximately 152 to 183 m (500 to 600 ft) upgradient from, and roughly parallel to, the Columbia River

shoreline (Figure 3-20). The concentrations in these wells have steadily decreased since system startup. During 2014, only Well 199-K-148 exhibited Cr(VI) concentrations above 20 µg/L (29 µg/L in December).

Upgradient extraction Well 199-K-152 (converted to an extraction well in 2011) and monitoring Well 199-K-151 have demonstrated very different concentration trends since KX P&T system startup. Well 199-K-152 is located in the core of the northeastern plume lobe. The concentrations in this well continue to decline but exhibit variations between 3 and 35 µg/L (Table 3-11; Figure 3-20). Monitoring Well 199-K-151 is located 230 m (755 ft) northeast/cross-gradient of monitoring Well 199-K-152. In September 2008, prior to startup of the KX P&T system, the concentration of Cr(VI) in this well was 75.5 µg/L. After startup, the concentrations in monitoring Well 199-K-151 rapidly declined, reaching approximately 10 µg/L by early 2011. Concentrations continued to decline and continue to be less than 10 µg/L in 2014.

Chromium concentrations at Well 199-K-182, the farthest upgradient of wells in this plume segment, decreased from 73 µg/L in October to about 44 µg/L by the end of December 2013 and continued to decline during 2014. This well was modified in 2014 to increase the diameter of the extracted water conveyance line resulted in increased pumping rate at the well.

Well 199-N-189 was installed in 2011 northeast of Well 199-K-182 as part of 100-NR-2 OU RIs. Sampling during drilling detected Cr(VI) concentrations above 30 µg/L at sample intervals taken throughout the aquifer thickness. This well continued to exhibit a 45 µg/L Cr(VI) concentration in 2014.

The concentration trends described for extraction Wells 199-K-131, 199-K-148, 199-K-130, and 199-K-147 and the nearby monitoring wells suggest that injection of large volumes of treated effluent in injection Wells 199-K-159, 199-K-160, and 199-K-164 (Figures 3-3 and 3-4) continues to shift the northeastern lobe of the K North plume further to the southwest.

Other KX P&T system extraction wells are located in the southwestern plume lobe of the K North plume (Figure 3-20). Extraction Wells 199-K-146 and 199-K-161 are closer to the river than Wells 199-K-153, 199-K-154, and 199-K-163, and the Cr(VI) concentrations in these two extraction wells exhibited intermittent increases to more than 30 µg/L during 2014. This is attributed to increasing the pumping rates from these extraction wells later in 2014. Concentrations at Wells 199-K-153, 199-K-154, and 199-K-163 continued to decline, with 199-K-153 and 199-K-163 approaching 20 µg/L and 199-K-154 consistently higher, with an average concentration of 50 µg/L in 2014.

Monitoring Wells 199-K-22 and 199-K-37 are located between upgradient extraction Wells 199-K-154 and 199-K-163 and downgradient of extraction Wells 199-K-146 and 199-K-161. The Cr(VI) concentration in Well 199-K-22 declined, ending at 34 µg/L by November 2014. At monitoring Well 199-K-37, cross-gradient of the higher concentration area defined by monitoring Well 199-K-22, concentrations remained below 20 µg/L during 2014.

KW Reactor Area

The KW Reactor area Cr(VI) plume is located near the KW Reactor, supporting water treatment facilities, and associated waste sites (Figures 3-3 and 3-4). The plume apparently originated with releases of concentrated sodium dichromate solutions near the 183-KW Head House and chemical storage tank farm. The KW Reactor area plume has been monitored since the early 1990s, when many of the CERCLA monitoring wells were initially installed. The KW P&T system, initially consisting of four extraction wells and two injection wells, became operational in January 2007 to remediate this plume after elevated Cr(VI) concentrations were detected in Aquifer Tube AT-K-1. The upgradient edge of the plume is controlled by the presence of injection Wells 199-K-175, 199-K-174, and 199-K-158. The plume does not

extend inland past Well 199-K-175, which had concentrations below 10 µg/L when the well was sampled before conversion to an injection well.

Table 3-9 presents the Cr(VI) concentrations for wells and aquifer tubes for monitoring the KW Reactor area plume during 2014 and includes data from 2012 and 2013 for comparison. Table 3-9 presents the highest Cr(VI) concentrations from these locations in 2014. The findings and observations based on the results presented in Tables 3-9 and 3-12 are summarized as follows:

- New extraction Well 199-K-205, in the 183-KW Head House vicinity, exhibits the highest Cr(VI) concentration in the KW area. Measured Cr(VI) concentration declined from 1,000 to 200 µg/L in this well after pumping was initiated in late 2014.
- The highest concentrations in the plume are located in the upgradient section of the plume that generally extends from the reactor to the former 183.1-KW Head House (Figure 3-3). This plume includes Wells 199-K-137 and 199-K-165 (Figure 3-21), which historically had Cr(VI) concentrations of 1,390 and 2,530 µg/L, respectively. Concentrations in these wells by late 2014 remained at about 20 µg/L (Table 3-12). The concentration in nearby extraction Well 199-K-166 had declined to less than 10 µg/L by December 2014.
- Cr(VI) concentrations in Well 199-K-173 decreased from 66 µg/L in January 2014 to 27 µg/L in December 2014. This well is located upgradient of extraction Well 199-K-165 and northeast of injection Well 199-K-158. The high concentrations historically observed at this location (e.g., greater than 900 µg/L in 2010) likely resulted from downgradient migration of the high-concentration portion of the plume from the head house area near new Well 199-K-205. Well 199-K-173 continued operating as an extraction well during 2014.

The remedial performance of the KW P&T system has been evaluated using Cr(VI) data from 2012 through 2014 (Table 3-12) and the long-term concentration trends for selected KW P&T system monitoring locations (Figure 3-21).

Extraction Wells 199-K-132, 199-K-138, and 199-K-196 are located downgradient of the KW Reactor, near the leading edge of the KW Reactor area plume. Since startup of the KW P&T system, concentrations in these wells have steadily declined (Figure 3-21). Cr(VI) concentration in these wells remained between 5 and 18 µg/L during 2014. Aquifer Tube AT-K-1-D, which exhibited Cr(VI) as high as 44 µg/L in 2005, exhibited no detectable Cr(VI) during 2014.

Inland extraction Wells 199-K-168, 199-K-139, and 199-K-140 each exhibited Cr(VI) concentrations of less than 25 µg/L during all of 2014 (Figure 3-21; Table 3-12).

KE Reactor Area and 116-K-2 Trench (KR4 Plume)

The KE Reactor area plume is currently being remediated by KX P&T system Wells 199-K-141, 199-K-178, and 199-K-181, and new Well 199-K-210, which was brought on line in 2014. The plume segment inferred to be east of the reactor is addressed by downgradient Wells 199-K-144 and 199-K-145 of the KR4 P&T system. The plume has been monitored since the early 1990s, when several CERCLA monitoring wells were installed to characterize potential groundwater contamination in the area.
The source of plume segments in this area is attributed to a combination of localized spills or leaks of highly concentrated sodium dichromate solution associated with the KE Reactor water treatment facilities and the large plume created by mounding around the 116-K-2 Trench (caused by historical release of cooling water to the trench). Based on examination of inferred groundwater gradients in this vicinity and the geochemical characteristics of groundwater at selected wells, the current chromium plume near the KE Reactor appears to represent conditions related to at least two different source areas.

Well 199-K-36 (located near the former 183-KE Head House) continues to exhibit about 300 μg/L Cr(VI) and indicates the potential for continuing contribution from the vadose zone in that location. Well 199-K-188, located just upgradient of Well 199-K-36 continues to exhibit concentration less than 50 μg/L, suggesting that the plume does not extend much inland of that location. A new KX P&T system extraction well, 199-K-220, was installed and brought on line in 2014. This well, located near and downgradient of 199-K-36, has exhibited a slowly increasing Cr(VI) concentration since startup to 30 μg/L in late 2014.

Table 3-13 provides a comparison of data from 2012 to 2014 collected from wells and aquifer tubes associated with the KE Reactor area and 116-K-2 Trench KR4 plume. Table 3-10 presented the highest Cr(VI) concentrations in 2014 from these locations. Figure 3-21 provides trend charts for Cr(VI) concentrations for monitoring and extraction wells for the KR4 and KX P&T systems in the plume area. The remedial performance of the KX and KR4 P&T systems for the KE Reactor area and 116-K-2 Trench KR4 plume (i.e., extent and effectiveness of plume capture and reduction in Cr[VI] concentration in groundwater) have been evaluated using Cr(VI) data from 2012 to 2014 (Table 3-13). Compliance Well 199-K-18 is located in the KR4 plume, near the head end of the 116-K-2 Trench (Figures 3-3 and 3-21). Cr(VI) concentrations in this well continued at less than 10 μg/L in 2014.

Although aquifer tubes are not compliance points for treatment system performance, samples collected from these tubes are helpful to locate areas where Cr(VI) may be discharging to the Columbia River. Aquifer tube cluster AT-K-3-S/M/D is located downgradient of monitoring Well 199-K-18, extraction Wells 199-K-162 and 199-K-145, and extraction Wells 199-K-198 and 199-K-199. This aquifer tube group has had concentrations ranging as high as 85 μg/L since it was first sampled in 2004 (Figure 3-21). During 2014, these three aquifer tubes exhibited Cr(VI) concentrations between 21 and 29 μg/L, and concentrations are expected to continue to decrease in this area of the KR4 plume. Continued operation of extraction wells in this area of historically elevated Cr(VI) concentrations and apparent discharge to the river is important. Other notable observations from the data presented in Tables 3-10 and 3-13, and illustrated in Figure 3-21, include the following:

- The maximum 2014 Cr(VI) concentration in the plume was 520 μg/L in Well 199-K-111A. This increase in Cr(VI) at Well 199-K-111A appears to be related to migration of chromium from the vicinity of the 116-K-2 Trench and/or the 118-K-1 Burial Ground. A groundwater grab sample collected near the water table during drilling of new monitoring Well 199-K-207 exhibited a Cr(VI) concentration of 325 μg/L, consistent with that observed at 199-K-111A.

- Aquifer Tubes C6247 and C4246, located at the river downgradient of the KE Reactor, exhibited slight increases in Cr(VI) to 11 and 12 μg/L during low river stage in 2014, which was slightly higher than the 9 and 5 μg/L, respectively, observed in 2013. Operation of new extraction Well 199-K-210, located inland of these aquifer tubes, is expected to capture upgradient Cr(VI) in this area.

- Cr(VI) concentrations have decreased in the core of the plume downgradient of the KE Reactor. However, the upgradient plume around Well 199-K-23 is likely connected to the main KE Reactor plume originating near the former 183-KE Head House.

- Well 199-K-141, a KX extraction well located downgradient of the KE Reactor and FSB, exhibited decreasing Cr(VI) concentration, but continued to exhibit elevated, increasing strontium-90 concentration during 2014. This well is located on the downgradient edge of the inferred high-concentration strontium-90 plume originating at the 116-KE-3 FSB crib and is apparently capturing part of that plume. Strontium-90 in Well 199-K-141 was variable during 2014 (between 45 and 55 pCi/L).

3.2.4.3 Other Contaminants of Concern

The interim remedial action for groundwater contamination at the 100-KR-4 OU is directed toward control of Cr(VI). Other constituents present in groundwater within this OU that have been identified as COCs include the following:

- Nitrate
- TCE
- Strontium-90
- Carbon-14
- Tritium
- Chromium (as total chromium)

These COCs are present in the groundwater being treated for Cr(VI) at varying concentrations. The releases that caused the contamination by the other COCs are generally not coincidental with the sources for the Cr(VI) (except for total chromium, which is present as Cr[VI]). The concentrations of the COCs observed in groundwater range from only slightly greater than DWSs (e.g., TCE at concentrations less than 9 μg/L versus the maximum contaminant level [MCL] of 5 μg/L), to substantially exceeding the standards (e.g., carbon-14 at over 20,000 pCi/L compared to the single-nuclide MCL equivalent of 2,000 pCi/L, and strontium-90 at greater than 12,000 pCi/L compared to the single-nuclide MCL equivalent of 8 pCi/L). The occurrence and distribution of COCs in groundwater at the 100-KR-4 OU is described in detail in DOE/RL-2014-32.

The nonchromium COC plumes are variably captured by the Cr(VI) P&T systems. None of these other COCs is treated by the existing interim remedial action P&T systems, and the captured COCs pass unaffected through the systems to be returned to the aquifer at the injection wells. This results in the potential for relocation of COCs into portions of the aquifer where they did not originally exist, or at concentrations different from the pre-injection concentration.

Three of the additional COCs are currently found in conditions that may ultimately affect the interim action P&T operations, as described in the following discussion.

Trichloroethene

TCE is present in three wells (199-K-132, 199-K-185, and 199-K-168) at a groundwater concentration only slightly exceeding the 5 μg/L MCL in the vicinity downgradient of the KW Reactor. The historical maximum observed concentration of TCE was about 40 μg/L, although the actual monitoring history is short and a specific primary source for the material has not been identified. The plume exceeding 5 μg/L has been generally diminished in size during operation of the KW P&T system. The treatment system effluent at the KW P&T system during 2014 continued to contain TCE at about 3.8 μg/L. This has resulted in the evolution of a plume of TCE in the upgradient portion of the KW chromium plume area that currently exhibits TCE at between 3.5 and about 4.8 μg/L. This condition will continue to be monitored.

Strontium-90

Strontium-90 is present in groundwater at a concentration exceeding the 8 pCi/L DWS at several locations within the 100-KR-4 OU. The primary locations of concern for strontium-90 in groundwater are downgradient of the 116-KW-2 FSB Crib/Reverse Well downgradient of the 116-KE-3 FSB Crib/Reverse Well and at multiple locations beneath and downgradient of the 116-K-2 Trench. Of particular interest for the P&T systems is the high-concentration strontium-90 plume located downgradient of the 116-KE-3 FSB Crib, near the KE Reactor. Strontium-90 concentrations in groundwater in this area are

estimated at greater than 10,000 pCi/L. Extraction Well 199-K-141 (in the KX P&T system) has exhibited increasing strontium-90 concentration. Concentrations were below detection limits prior to start of extraction and increased steadily to its current high of 48 pCi/L in 2014. This well location is inferred to be on the leading edge of the strontium-90 plume migrating riverward from the 116-KE-3 Crib. This condition will be monitored for potential effects on P&T operation that is currently focused on Cr(VI) removal.

Tritium

Tritium is found in groundwater at multiple locations, with the primary source areas at the 100-K Area being the 116-KE-1 Crib, 116-KW-1 Crib, and 118-K-1 Burial Ground. The highest concentrations of tritium are currently observed in wells downgradient of these source areas. During 2014, tritium concentrations in Well 199-K-111A remained between 30,000 and 40,000 pCi/L. However, during drilling of Well 199-K-207, located upgradient of Well 199-K-111A and within the footprint of the former 118-K-1 Burial Ground, a groundwater grab sample collected near the water table exhibited tritium at 414,000 pCi/L. Tritium concentrations will continue to be monitored.

3.2.5 Hydraulic Monitoring

Hydraulic monitoring (i.e., water-level monitoring) is performed to evaluate the effect of the P&T systems on the water table and to evaluate groundwater flow direction and gradient. The hydraulic effects of the P&T systems are superimposed on seasonal fluctuations in the river levels and inland groundwater elevation to evaluate the effectiveness of providing hydraulic containment and capture of Cr(VI) plumes.

Groundwater elevation is measured during regularly scheduled groundwater sampling events, during focused events to collect elevation measurements from many wells over a short period of time, and in selected wells by automated data-logging pressure transducers placed in the wells (the AWLN). The 100-K Area AWLN system was refurbished and expanded during 2014 with addition of new measurement stations for a total of 37 stations operating at the end of 2014. Additional localized dynamic water level data are collected at each of the P&T extraction and injection wells operating within the 100-K Area. Manual depth-to-groundwater measurements are collected routinely during groundwater sampling missions. All of the available data are used, where applicable, to assemble the groundwater elevation maps.

Under natural gradient conditions, groundwater generally flows to the northwest toward the Columbia River beneath the 100-KR-4 OU (Figure 3-19). Hydraulic effects of the P&T systems at the 100-KR-4 OU (i.e., the formation of depressions at extraction wells and mounds at injection locations) are superimposed onto these broad seasonal fluctuations. The effects of seasonal changes in river stage (and water table elevation) on contaminant concentrations in the aquifer and treatment system performance are discussed in Section 3.2.6. Increasing river stage was observed starting in late February 2014, with peak stage elevation observed in June. The river stage declined from late June through the end of August, returning to low-stage levels by September 1, 2014 (Figure 3-17).

During high river-stage periods, the local groundwater gradient magnitude is reduced near the river; the vicinity very near the river may actually exhibit a flow direction reversal, with river water intruding slowly into the aquifer (i.e., seasonal bank storage). In addition, this change (i.e., increased elevation) of the boundary condition causes the groundwater inland of the river to backup during high river stage, thus creating the seasonal rise in groundwater elevation typically observed inland of the river. As the river stage declines following the seasonal freshet, the boundary condition again adjusts, the groundwater gradient steepens toward the river, and velocity increases. This condition continues until the groundwater head again equilibrates with the low river stage condition, Seasonal groundwater elevation transients are observed up to several kilometers from the river as the water table and river stage equilibrate, although

the magnitude of the increase progressively decreases with distance from the river. Figure 3-19 presents a groundwater contour map of the area, which was developed using concurrent measurements collected on February 28, 2014 (near the end of the low river-stage period). Long-term groundwater flow near the 100-K Area is toward the Columbia River.

3.2.6 Hydraulic Containment

Hydraulic containment of the contaminant plumes is an essential element of the performance of P&T remediation in the 100-KR-4 OU. In general, the hydraulic containment of the Cr(VI) plume segments in the 100-KR-4 OU is effective. This section presents a comparison of the estimated extent of hydraulic containment for the three 100-KR-4 OU P&T systems with the estimated extent of chromium contamination in groundwater. The assessment is based upon a joint evaluation of groundwater level, pumping rate (extraction and injection), and water quality data. The extent of hydraulic containment is estimated using two methods:

- Water-level mapping using an extension of the hybrid UK/analytic element method technique (detailed in SGW-42305)
- Groundwater modeling using the 100 Area groundwater model (documented in SGW-46279)

In each case, the estimated extent of hydraulic containment is depicted using a CFM. The CFM constructed using the water-level mapping technique is referred to as an ICFM, whereas the CFM constructed using the 100 Area groundwater model is referred to as an SCFM. In each case, the CFM depicts the frequency with which particles representing mobile groundwater and contaminants are moving toward extraction wells, calculated over a series of mapped or simulated groundwater levels that represent conditions throughout the year. A frequency of 1.0 indicates that groundwater in the area is hydraulically contained under all conditions encountered during the period (i.e., groundwater is always moving toward extraction wells). A frequency of zero indicates that groundwater in the area was not hydraulically contained under any conditions encountered during the period (i.e., was at no time during the period moving toward extraction wells). Intermediate frequencies indicate that the groundwater was contained under some, but not all, conditions.

Water-level mapping using the ICFM approach was completed using monthly averaged groundwater elevations, pumping rates, and stage of the Columbia River, which resulted in 12 water-level maps encompassing the River Corridor, and correspondingly, 12 individual depictions of the extent of hydraulic containment for use in constructing an ICFM. Groundwater modeling using the 100 Area groundwater model was completed using monthly averaged pumping rates, stage of the Columbia River, and other time-varying boundary conditions. This resulted in 12 simulated groundwater level and flow fields, and correspondingly 12 individual depictions of the extent of hydraulic containment for use in constructing an SCFM.

The ICFM and SCFM are ensemble estimates for the monitoring period; emphasis is placed on regions of high frequency and on comparing areas where the ICFM and SCFM are similar or where they differ. Where the ICFM and SCFM are similar, confidence is relatively high that containment is being achieved (where both maps suggest that containment is achieved) or is not being achieved (where both maps suggest that containment is not achieved). Where the ICFM and SCFM differ substantially, confidence is lower in the assessment of containment because one method suggests that containment is being achieved whereas the other method suggests it is not.

Figures 3-22(a) to (f) compare the estimated extent of hydraulic containment and the estimated extent of chromium contamination in groundwater for both high and low river-stage conditions for the 100-K Area as follows:

- Figure 3-22(a) and Figure 3-22(b) depict chromium contamination under high river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 3-22(c) and Figure 3-22(d) depict chromium contamination under low river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 3-22(e) depicts the groundwater flow lines from particle tracking to estimate the aquifer capture zone of the 100-KR-4 OU P&T systems over a 10-year period.
- Figure 3-22(f) overlays the capture flow lines with the chromium plume contours for low river-stage conditions.

ECF-HANFORD-15-0001 presents details for the specific calculations used to produce these figures, including updates to and implementation of the 100 Area groundwater model, the methodology for water-level mapping, and the development of the ICFM and SCFM. During 2014, data from AWLN monitoring locations were not always available or usable for the entire period; therefore, the data set was again not as extensive as in previous years. Although the interpolated water-level maps are consistent with observations and qualitative interpretations of aquifer conditions and resulting flow fields during the year, improvements to the monitoring network are required to increase confidence in these interpretations.

3.2.7 River Protection Evaluation

The river protection status of conditions at 100-KR-4 OU is based on assessment of the hydraulic effects of operation of the remedial action systems, along with evaluation of changes in the discharge boundary head conditions associated with the Columbia River and the inferred distribution of hexavalent chromium in groundwater. Both a quantitative and a qualitative approach are used for this assessment. In 2014, this assessment indicated that the river protection status improved in 2014 over the assessment for 2013.

This subsection describes the river protection evaluation process and presents the results of the 2014 analysis. SGW-54209 describes a method for evaluating progress toward attaining RAO #1, referred to as the "river protection objective." Since RAO #1 emphasizes protection of aquatic receptors, the river protection objective focuses on the performance of P&T (and other remedies) to protect the Columbia River from further discharges of dissolved chromium from inland at concentrations above 10 μg/L. Use of this standard is consistent with Tri-Party Agreement (Ecology et al., 1989) Milestone M-016-110-T01. ECF-HANFORD-12-0078 demonstrates the methods described in SGW-54209 for evaluating the progress toward attainment of the river protection objective using data obtained during (or prior to) 2011.

Assessment of progress toward attainment of the river protection objective for 2014 is presented in Figures 3-23(a) and (b). The technical methods and process that are used to complete the calculations necessary to prepare this figure are detailed in SGW-54209. ECF-HANFORD-15-0001 presents details on the specific calculations that produced the figures for 2014. The results of contaminant standard and trend tests described in SGW-54209 to identify low-, moderate-, and high-concern wells are presented in Figures 3-23(a) and (b) using the following symbols:

Low-Concern Wells			High-Concern Wells			Moderate-Concern Wells		
Symbol	Standard	Trend	Symbol	Standard	Trend	Symbol	Standard	Trend
▼	Less than	Down	▲	Exceed	Up	△	Less than	Up
■	Less than	None	■	Exceed	None	▽	Exceed	Down
●	Less than	NSD	●	Exceed	NSD			

NSD = not sufficient data to calculate

Shoreline lengths are calculated and reported in increments of 100 m (328 ft); the results of the assessment are presented in these figures as color-filled circles of radius equal to 100 m (328 ft). The color fill of each circle indicates the relative river protection objective status (i.e., green = protected; yellow = protected, but action may be required to ensure long-term protectiveness; and red = not protected). The following symbols depict the results of the river protection evaluation:

River Protection Objective - Status

● Protected ● Protected (Action May Be Required) ● Not Protected

Figures 3-23(a) and (b) depict the results of the assessment of progress toward attaining the river protection objective for chromium in the 100-K Area. Figure 3-23(a) depicts the results of the quantitative evaluation of the objective, which is determined based upon overlay and quantitative comparison of the extent of chromium contamination and the extent of hydraulic containment. Figure 3-23(b) depicts the results of the qualitative evaluation of the objective, which is based upon the quantitative evaluation but also considers more qualitative considerations (e.g., the duration and magnitude of hydraulic gradients along the shoreline). Based on these calculations, the river protection evaluation for the 100-K Area is as follows:

- Total length of shoreline adjacent to the 100-K Area: 4,000 m (13,120 ft)
- Length identified as protected: 3,000 m (9,840 ft)
- Length identified as protected (action may be required): 800 m (2,620 ft)
- Length identified as not protected: 200 m (655 ft)

Results of the qualitative evaluations for 100-K Area for 2014 are compared to those presented in DOE/RL-2014-25. Table 3-14 provides a comparison of the river protection evaluation for 2013 and 2014.

The effect of river-stage fluctuations on groundwater flow, combined with the aquifer response to pumping, resulted in qualitative evaluations of the river protection objective for 2014 that indicate improved system performance compared to 2013.

Quantitative evaluations of the river protection objective provide conservative assessment of shoreline protection; qualitative evaluations for 2014 incorporate the transient effects of hydraulic capture. The CFMs describe the aggregate fate of particles, under an ensemble of steady-state conditions, each reflecting a snapshot of hydraulic gradient magnitude and direction due to pumping and river stage. As a result, CFMs only indicate the relative strength of hydraulic containment and not a depiction of the actual transient hydraulic capture patterns. CFMs provide an effective metric to evaluate the relative strength of the capture zone, but they should not be considered an absolute indicator of hydraulic containment success or failure. Even during months of steeper hydraulic gradients, groundwater flow velocities result in actual plume migration expected to occur over very short distances. Relative dissipation of hydraulic gradient magnitude in subsequent months results in even slower plume migration and transient hydraulic containment. Capture can, and does, occur in areas where the CFMs indicate relatively low capture frequency. Comparison of the chromium plume depictions for 2013 and 2014 indicates an increased number of shoreline segments in 2014 where chromium concentrations are below the aquatic standard despite the prolonged periods of low river stage. Acknowledgement of these processes is reflected on the qualitative evaluation results.

3.2.8 Contaminant Mass Recovery

Comparison of the ICFM and SCFM provides comparative depiction of the hydraulic simulation capabilities of the flow component of the 100 Area groundwater model. A similar qualitative comparison can be made for the transport component of the 100 Area groundwater model by comparing simulated and measured rates of contaminant mass recovery.

Figure 3-24 presents a comparison of monthly and cumulative mass of chromium recovered throughout the 100-K Area at each of the KX, KW, and KR4 P&T systems for 2014, as determined using actual influent concentrations and flow rates, versus the mass recovery simulated using the 100 Area groundwater model. For this simulation, the initial distribution of chromium in groundwater was assumed to be the low river-stage depiction of chromium for 2013, as presented in ECF-HANFORD-14-0034.

The pattern of correspondence between the model and the measured data, which varies by system, is fairly well reflected in the model results presented in ECF-HANFORD-15-0001. In each case, there are system-specific and systematic conditions that might lead to differences between the simulated and measured values. ECF-HANFORD-15-0001 presents graphs comparing the simulated and measured mass recovery at each individual extraction well for the each P&T system.

The model predicts the measured mass recovery in the KR4 P&T system very closely. Mass recovery in the KX P&T system is slightly under-predicted during the first three quarters of the year, due to the cumulative effect of differences between simulated and measured concentrations at a few wells located near the delineated plume boundaries. However, mass recovery is over-predicted during the last quarter of 2014, mainly due to the simulated recovery at Well 199-K-220, which can be attributed to the possibly over-estimated extent of the high-concentration zone downgradient of that well, as defined by the elevated concentration at Well 199-K-36 in the low river-stage plume of 2013.

For the KW P&T system, the model also predicts mass recovery very well through the first three quarters of the year. The model under-predicts mass recovery during the last quarter of the year, which coincides with the commencement of operation of Well 199-K-205. Mass recovery from that well suggests that the extent of the high-concentration zone near that well was under-estimated in the 2013 low river-stage

plume. Similarly, the difference between simulated and measured concentrations at Well 199-K-173 suggest that the elevated concentrations are present within a larger zone in the area between that well and upgradient Well 199-K-205.

From a systematic perspective, the differences between the simulated and measured mass recovery could result from using estimated hydraulic and/or contaminant transport parameters in the transport model that do not accurately reflect actual conditions encountered at specific locations in the subsurface. The simulated mass recovery estimate, however, presents a useful tool for estimating the system performance over time and developing estimates of time to remediation.

3.2.9 Remedial Process Optimization Activities

Contractors have developed a pumping optimization model, based on the 100 Area Groundwater Model that will be used by OU scientists along with a detailed simulation display interface to evaluate the relative performance of alternative well configurations. The OU scientists will evaluate pumping configurations throughout the year and provide adjustments to flow rates and recommendations for well realignment and/or the installation of new wells. Specific remedial process activities performed at the 100-KR-4 OU during 2014 included the following:

- Installing new extraction wells at locations based on previous years' evaluation of plume capture and river protection analyses
- Designing and constructing new extraction and injection wells as high-performance wells (i.e., using high-capacity well screens, and matching filter pack to screen and formation).
- Placing new and realigned extraction and injection wells in service to enhance plume capture
- Repairing and expanding the AWLN system to enhance hydraulic monitoring capacity
- Identifying low-performing extraction wells for maintenance
- Identifying system infrastructure components to be changed to enhance groundwater extraction and injection performance
- Initially using the pumping optimization model to evaluate expected extraction/injection well effects on plume capture

3.3 100-KR-4 Operable Unit Pump and Treat Systems Costs

This section summarizes the actual costs for the 100-KR-4 OU P&T systems for 2014. The primary categories of expenditures are described as follows:

- **Capital design:** Includes design activities to construct the P&T systems, including wells, and designs for major system upgrades and modifications.
- **Capital construction:** Includes oversight labor, material, and subcontractor fees for capital equipment, initial construction, construction of new wells, redevelopment of existing wells, and modifications to the P&T system.
- **Project support:** Includes project coordination-related activities and technical consultation, as required, during the course of the facility design, construction, acceptance testing, and operation.

- **O&M:** Represents facility supplies, labor, and craft supervision costs associated with operating the facility. It also includes the costs associated with routine field screening and engineering support as required during the course of P&T operation and periodic maintenance.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis, as required in accordance with the 100-HR-3 and 100-KR-4 OU interim action work plan (DOE/RL-96-84).
- **Waste management:** Includes the cost for the management of spent resin at the 100-KR-4 OU in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes. Cost includes waste designation sampling and analysis, resin regeneration, and new resin purchase.

The costs include all activities associated with the interim remedial actions, including the construction of new wells and interim action performance monitoring. The 100-KR-4 OU costs for 2014 are associated with three P&T systems (KR4, KX, and KW). The total cost breakdown includes nonrecurring costs related to the installation of new wells and the P&T system modifications described in Section 3.2. The yearly cost breakdowns for each of the three 100-KR-4 OU P&T systems are shown in Tables 3-15 through 3-17, respectively. Costs are burdened and are based on actual operating costs incurred during 2014.

The overall P&T system costs have decreased since changeover from Dowex[5] 21K resin to SIR-700 resin. Resin changeout occurred in 2011 for the KW P&T, and costs have decreased from approximately $2.3 and $2.7 million in 2010 and 2011, respectively, to approximately $1.5 million in 2012 and 2013, respectively. The resin in the KR4 and KX P&T systems was changed over in 2012. The KR4 P&T system costs have decreased from $3.9 million in 2011, to $1.8 million in 2012, and $1.4 million in 2013. The KX P&T system costs have decreased from $2.6 million in 2011, to $2.4 million in 2012, and $2.3 million in 2013.

The cost increase in 2014 compared to 2013 is attributed to system modifications to each of the three P&T systems (described in Section 3.2) for well installation and realignments and increasing system throughput. Summaries of the costs for each P&T system are presented in the following subsections.

3.3.1 KR4 Pump and Treat System

The total cost for the KR4 P&T system during 2014 was $1.54 million, which consists of the sum of the categories shown in Table 3-15. The percentage that each category comprises of the total cost for the KR4 P&T system (Figure 3-25) is as follows, in decreasing order: O&M (78.7 percent), performance monitoring (10.5 percent), project support (5.5 percent), and treatment system capital construction (5.1 percent). Design, waste management, and field study costs during 2014 were negligible.

Based on the total 2014 cost of $1,537,000, the yearly production rate of 527 million L (139 million gal), and 5.0 kg (11 lb) of Cr(VI) removed, the annual treatment costs equate to $0.0029/L, or $310/g of Cr(VI) removed.

3.3.2 KX Pump and Treat System

The total cost for the KX P&T system for 2014 was $2.42 million (Table 3-16). The percentage that each category comprises of the total cost for the KX P&T system (Figure 3-26) is as follows, in decreasing order: O&M (63.3 percent), treatment system capital construction (19.1 percent), project support

[5] Dowex® is a registered trademark of the Dow Chemical Company, Midland, Michigan.

(9.2 percent), performance monitoring (6.5 percent), and design (1.9 percent). Costs for field studies and waste management during 2014 were negligible.

Based on the total 2014 cost of $2,419,000, the yearly production rate of 1,199 million L (316 million gal), and 25.8 kg (57 lb) of Cr(VI) removed, the annual treatment costs equate to $0.0020/L, or $94/g of Cr(VI) removed.

3.3.3 KW Pump and Treat System

The total cost for the KW P&T system during 2014 was $2.10 million, which consists of the sum of the categories shown in Table 3-17. The percentage that each category comprises of the total cost for the KW P&T system (Figure 3-27) is as follows, in decreasing order: O&M (59.5 percent), treatment system capital construction (20.1 percent), project support (11.5 percent), performance monitoring (7.5 percent), , and design (1.5 percent). Costs for waste management and field studies during 2014 were negligible.

Based on the total 2014 cost of $2,103,000, the yearly production rate of 580 million L (153 million gal), and 19.4 kg (42.8 lb) of Cr(VI) removed, the annual treatment costs equate to $0.0036/L, or $108/g of Cr(VI) removed.

3.4 Conclusions

The status of the 100-KR-4 OU illustrates that remedial progress has been achieved for the plume areas associated with each of the three P&T systems currently active within the 100-KR-4 OU. The following conclusions for the OU are based on each of the RAOs:

- **RAO #1:** Protect aquatic receptors in the river bottom substrate from contaminants in the groundwater entering the Columbia River.

  Results: Capture zone analysis suggests that operation of the KX, KW, and KR4 P&T systems is resulting in a capture efficiency of 74 to 94 percent over most of the 100-KR-4 OU Cr(VI) plumes above 10 µg/L.

  The combined hydraulic and water quality data evaluation indicates that the extent of hydraulic containment developed by the KX, KW, and KR4 P&T systems during 2014 improved over that identified in 2013. This improvement is consistent with expectations from well locations and planned extraction rates. Calculations indicate that the river protection objective is being achieved along the majority of the 100-KR-4 OU shoreline. The performance of remedial action systems currently in place in the 100-KR-4 OU confirms that DOE has taken necessary measures to control the discharge of Cr(VI) into the Columbia River. The two locations along the 100-KR-4 OU river shore that are identified as "not protected" during 2014 are associated with new extraction wells that did not operate for the full year during 2014. Operation of these wells throughout 2015 is expected to further enhance river protection in 2015.

  Based on the aquifer tube data for 2014, the general extent and concentration of Cr(VI) discharged to the Columbia River within the 100-KR-4 OU has decreased in response to P&T activities. Exceptions are localized areas at the downgradient edge of the KE Reactor area plume and the downgradient edge of the plume at the head end of the 116-K-2 Trench.

  The 100-KR-4 OU P&T systems have removed substantial amounts of Cr(VI) from the unconfined aquifer. In total, the systems have removed an estimated 585 kg (1,290 lb) of Cr(VI) from the shallow unconfined aquifer.

The KR4 P&T system has removed a substantial mass of Cr(VI) from the plume zones located along the 116-K-2 Trench. Between September 1997 and December 31, 2014, the KR4 P&T system extracted and treated approximately 7.3 billion L (1.93 billion gal) of groundwater, resulting in the removal of 371 kg (818 lb) of Cr(VI) from the aquifer. As a result of remediation activities, Cr(VI) concentrations have been reduced in most wells.

The KR4 P&T system has largely attained the RAO for river protection along the central portion of the 116-K-2 Trench area. Elevated Cr(VI) concentrations remain in plume areas located at either end of the 116-K-2 Trench (i.e., the KR4 plume and the southern portion of the K North plume). These areas are expected to be captured in 2015.

Cr(VI) concentrations at former compliance monitoring Well 199-K-18 (located in the KR4 plume) exhibited Cr(VI) concentrations below the remedial action target of 20 µg/L during all of 2014. This decrease likely resulted from changes in groundwater flow dynamics due to nearby downgradient KR4 P&T system extraction wells (e.g., 199-K-145 and 199-K-162). This well is also located downgradient of the KX and KR4 injection wells.

The KW P&T system started up in January 2007. One new extraction well and one new injection well were added to this system in 2014. As of December 31, 2014, the system had extracted approximately 2.9 billion L (766 million gal) of groundwater and removed an estimated 221 kg (487 lb) of Cr(VI). Long-term trends for Cr(VI) in the monitoring network for the KW Reactor area plume indicate that this system is rapidly reducing the remaining mass of this plume.

The KX P&T system was designed to treat the K North Cr(VI) plume, located between the northern end of the 116-K-2 Trench and the N Reactor fence line. Three KX P&T system extraction wells were added to enhance remediation in the western and central portions of the KE plume.
The KX P&T system began partial operation in November 2008 and became fully operational in early February 2009. Since system startup, more than 5.8 billion L (1.5 billion gal) of water have been treated, and approximately 194 kg (427.7 lb) of Cr(VI) have been removed. The data collected during 2014 and the capture zone analysis suggest that this system should intercept the majority of the K North plume before it can discharge to the Columbia River.

RPO extraction Wells 199-K-196, 199-K-198, and 199-K-199 were drilled in 2011. Wells 199-K-198 and 199-K-199 were added to the KR4 P&T system in early 2014 to capture Cr(VI) closer to the river in the river mixing zone. Well 199-K-196 was added as an extraction well for the KW P&T system; the well is necessary to provide improved capture deeper in the aquifer in this near-river location.

The observed concentrations of Cr(VI) in groundwater at all three of the 100-KR-4 OU P&T systems are declining as remediation progresses.

- **RAO #2:** Protect human health by preventing exposure to contaminants in groundwater.

Results: The interim remedial action ROD (EPA/ROD/R10-96/134) establishes a variety of ICs that must be implemented and maintained throughout the interim action period. These provisions include the following:

- Access control and visitor escorting requirements
- Signage providing visual identification and warning of hazardous or sensitive areas
- Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
- Regulatory agency notification of any trespassing incidents

The effectiveness of ICs is presented in DOE/RL-2004-56. The findings of this annual report indicate that ICs were maintained to prevent public access, as required.

- **RAO #3:** Provide information that will lead to a final remedy.

  Results: Additional information on the groundwater contamination at the 100-KR-4 OU continues to be gathered. Ongoing groundwater monitoring activities provide information on the changes in contaminant concentrations, as well as the spatial distribution of the groundwater plumes. Assessment of information collected during source remediation actions provides details regarding the sources of groundwater contamination and the potential for continuing contributions from secondary sources within the vadose zone for hexavalent chromium as well as other contaminants of concern in this OU.

  Evaluation of information from multiple activities indicates that while the interim groundwater remedial actions at the 100-K Area have been successful at reducing Cr(VI) concentrations and reducing plume sizes across the OU, residual secondary sources likely remain at multiple locations. A final remedy will need to address ongoing contributions from vadose zone sources, as well as high contaminant concentrations in groundwater at or near source release areas.

3.5 Recommendations

Recommendations for the 100-KR-4 OU are as follows:

- Continue RPO activities for the 100-KR-4 OU P&T systems to:
  - Evaluate the well network for improved efficiencies to maximize use of treatment system capacity, particularly during periods of low river stage when treatment capacity usage has historically decreased.
  - Evaluate and identify adjustments to pumping rates, locations for new well installatios and/or well realignments to meet the primary objectives: control hydraulic gradients, protect the Columbia River, remove contaminant mass, and restore the aquifer.
- Develop and prioritize well additions and/or realignments based on the RPO evaluations to include in future planning for the P&T systems.

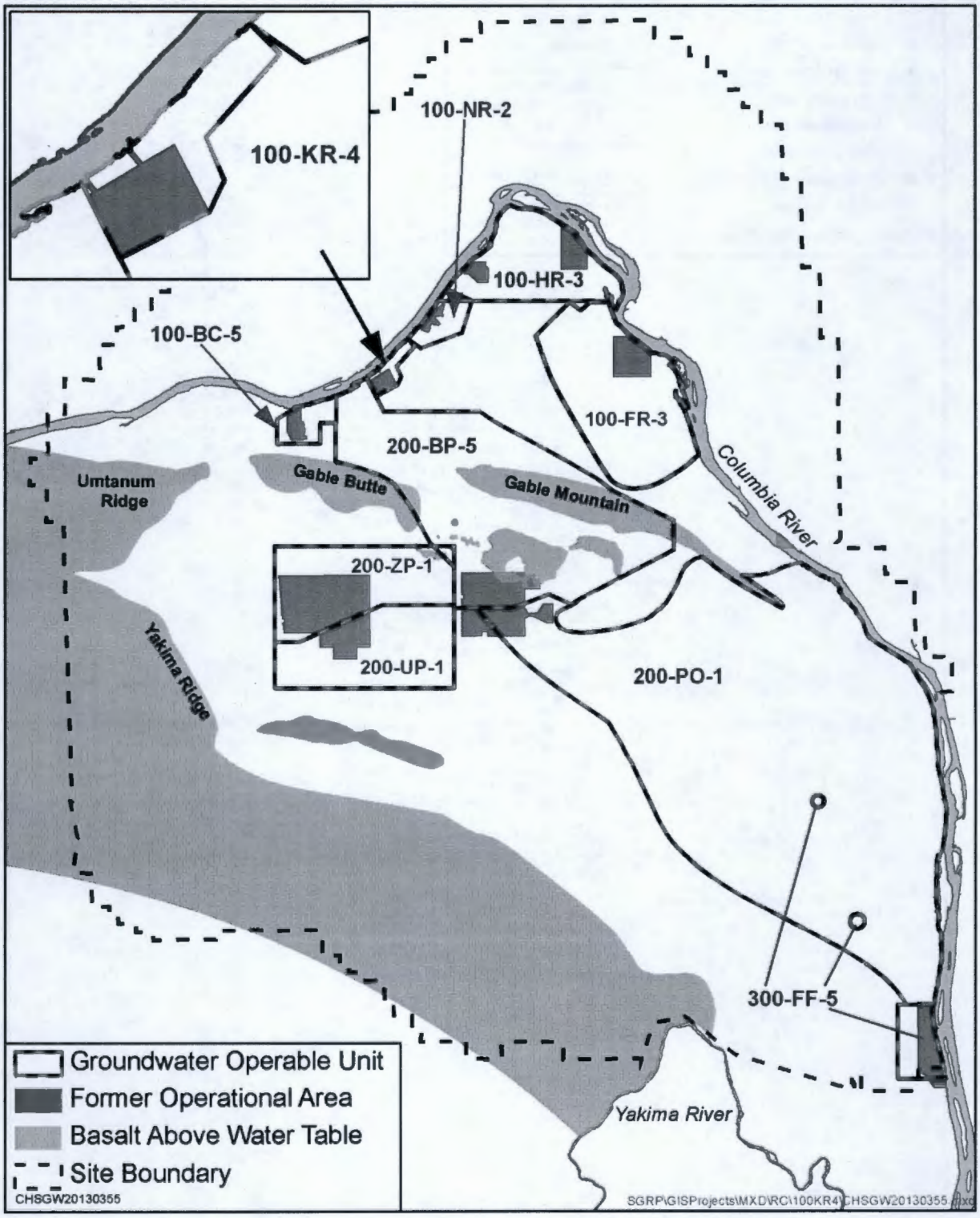


Figure 3-1. Location of the Hanford Site and the 100-KR-4 OU

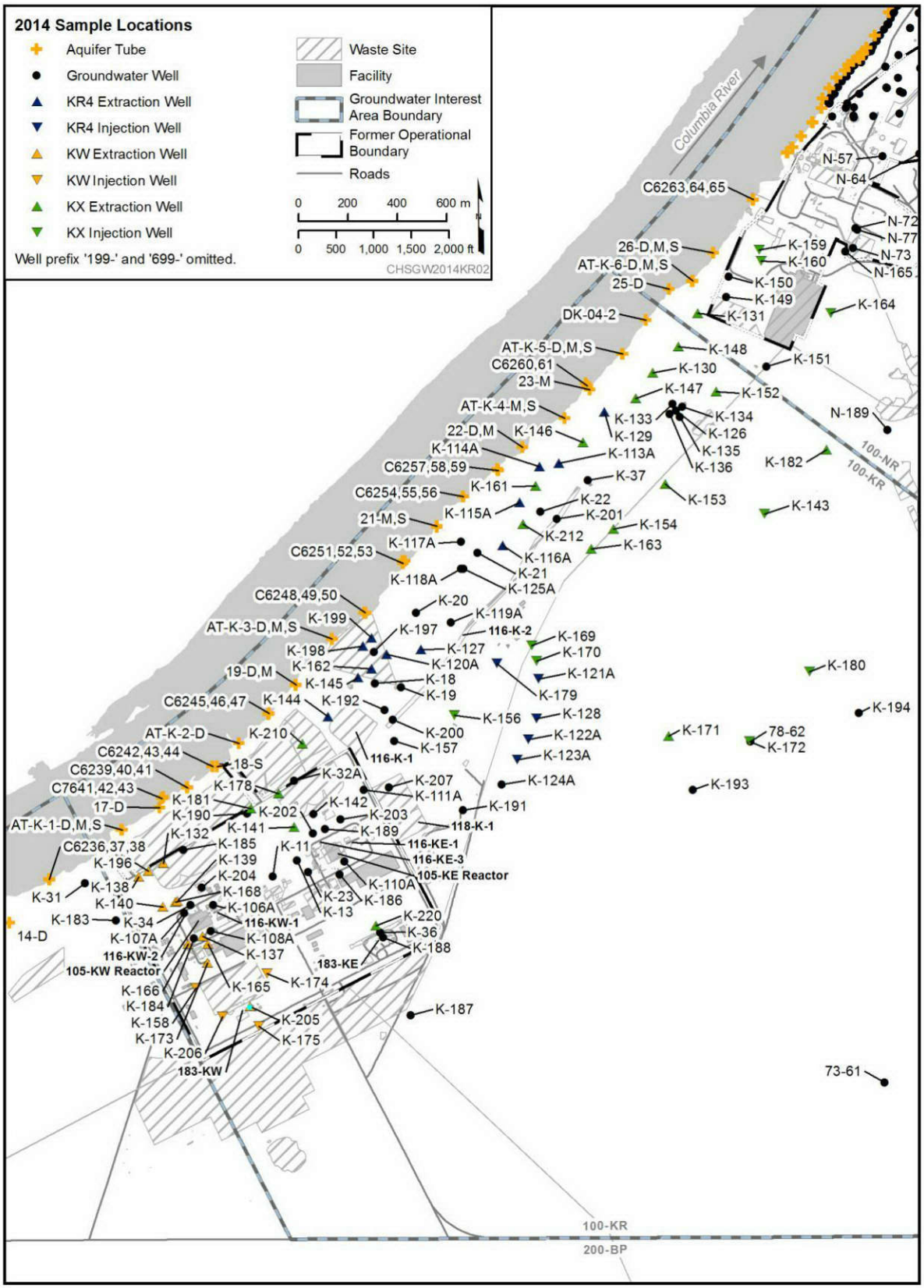


Figure 3-2. 100-KR-4 OU Remedial System Wells, Monitoring Wells, and Aquifer Sampling Tubes

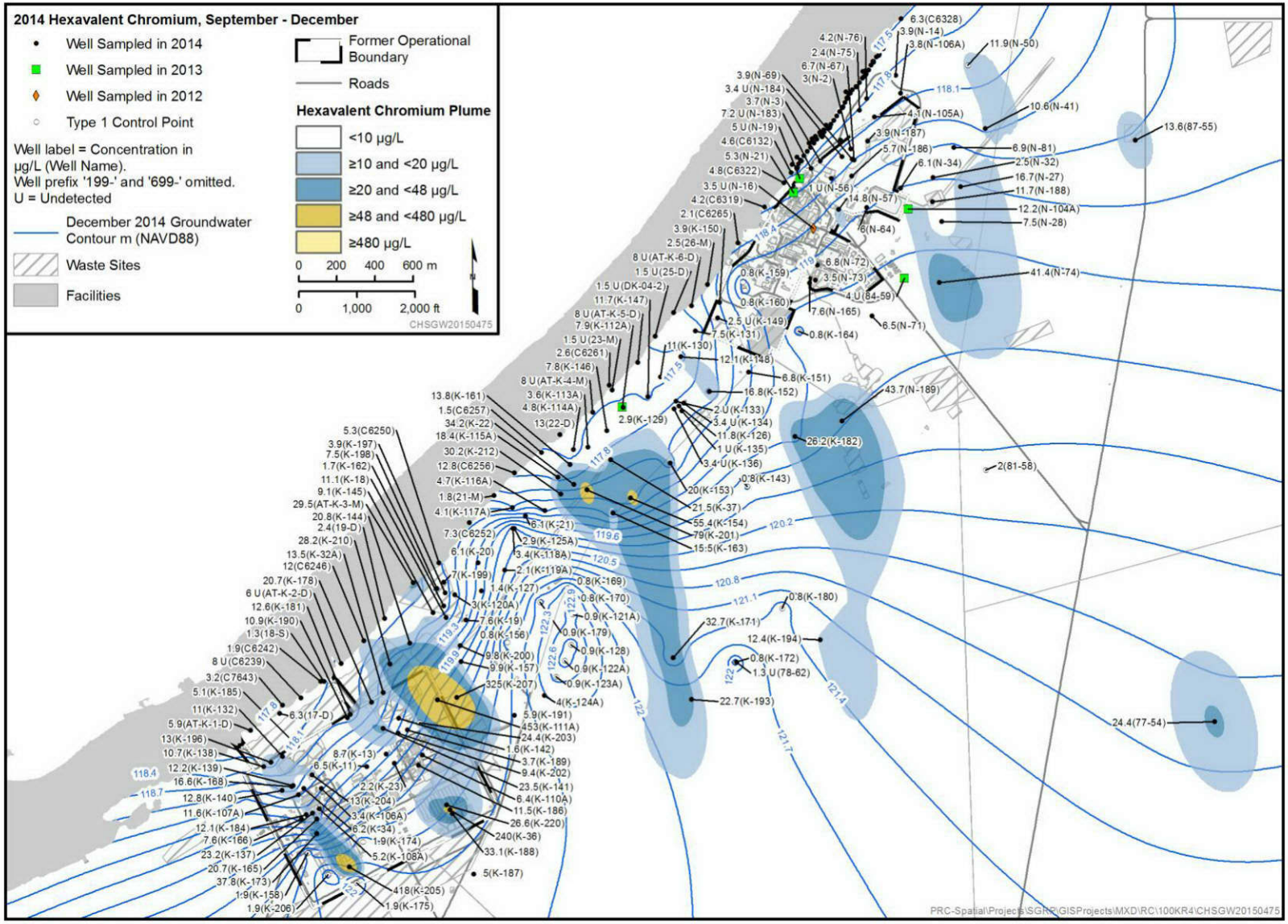


Figure 3-3. Cr(VI) Plume Distribution in Groundwater at the 100-KR-4 OU (Low River Stage, 2014)

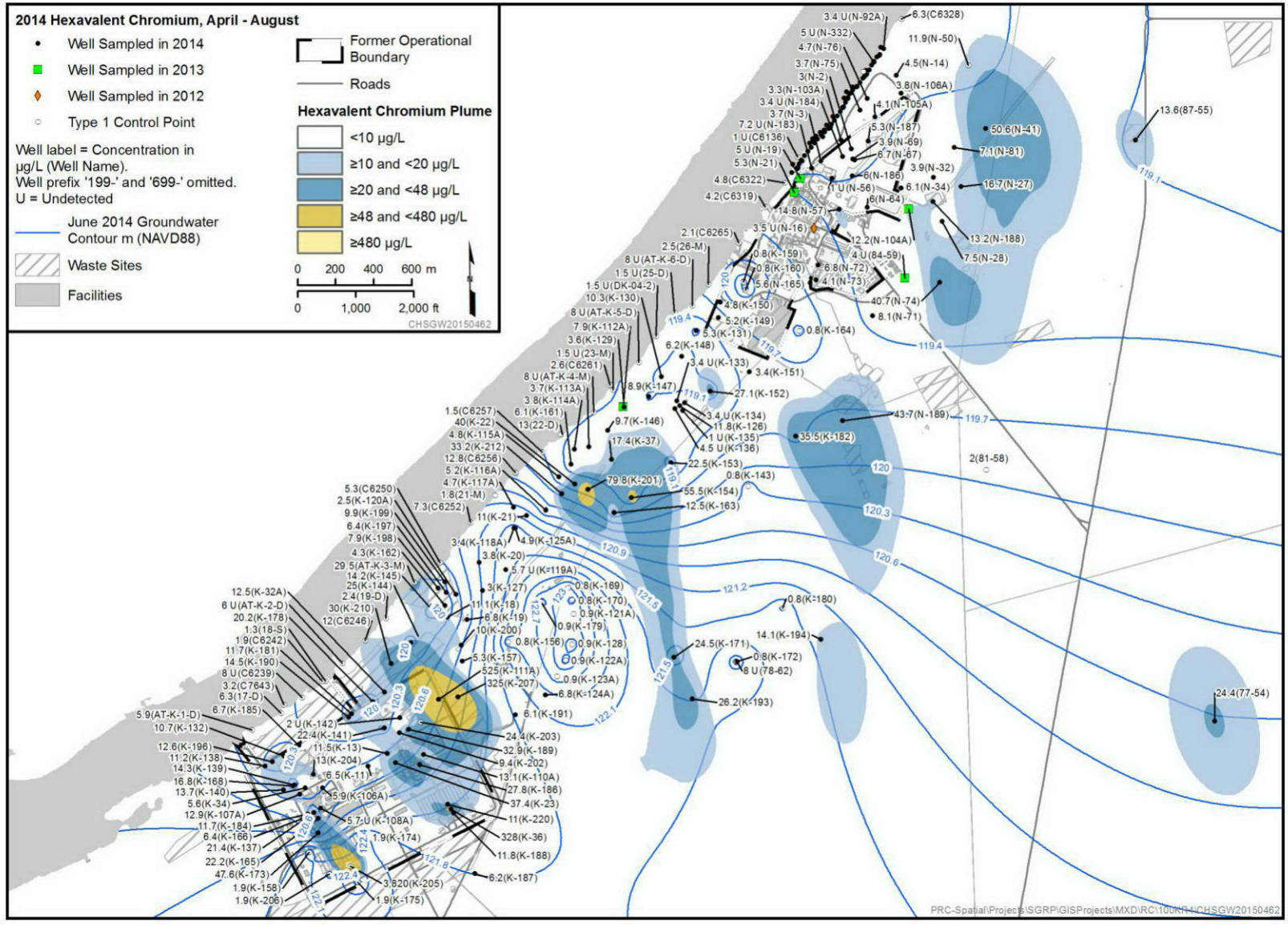


Figure 3-4. Cr(VI) Plume Distribution in Groundwater at the 100-KR-4 OU (High River Stage, 2014)

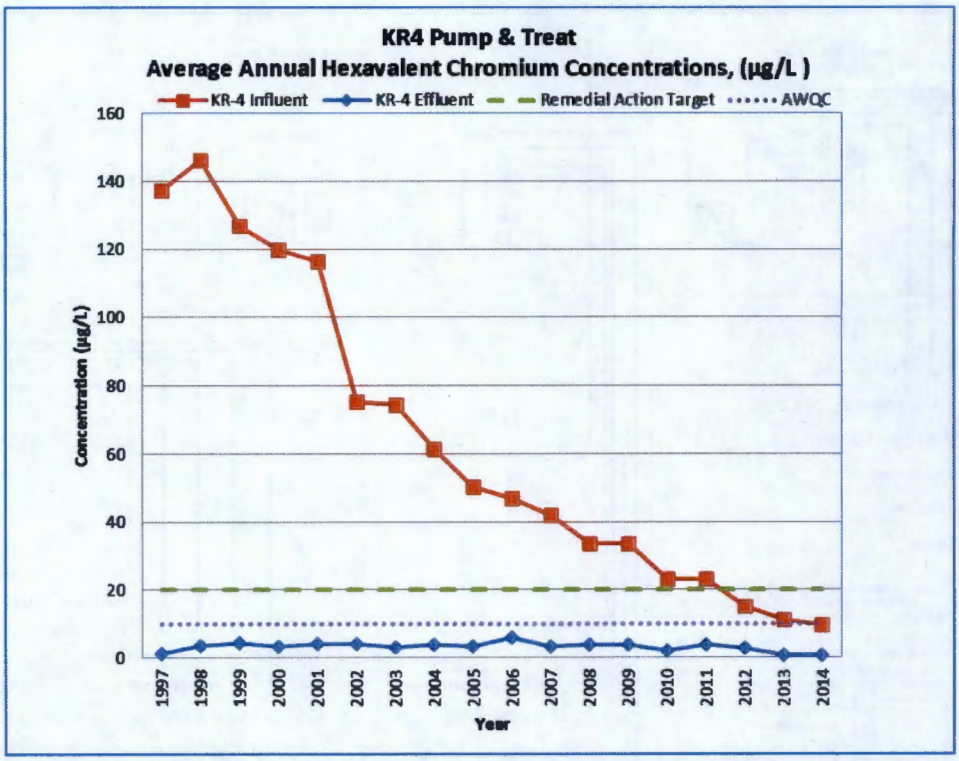


Figure 3-5. KR4 P&T System Annual Average Influent and Effluent Concentrations

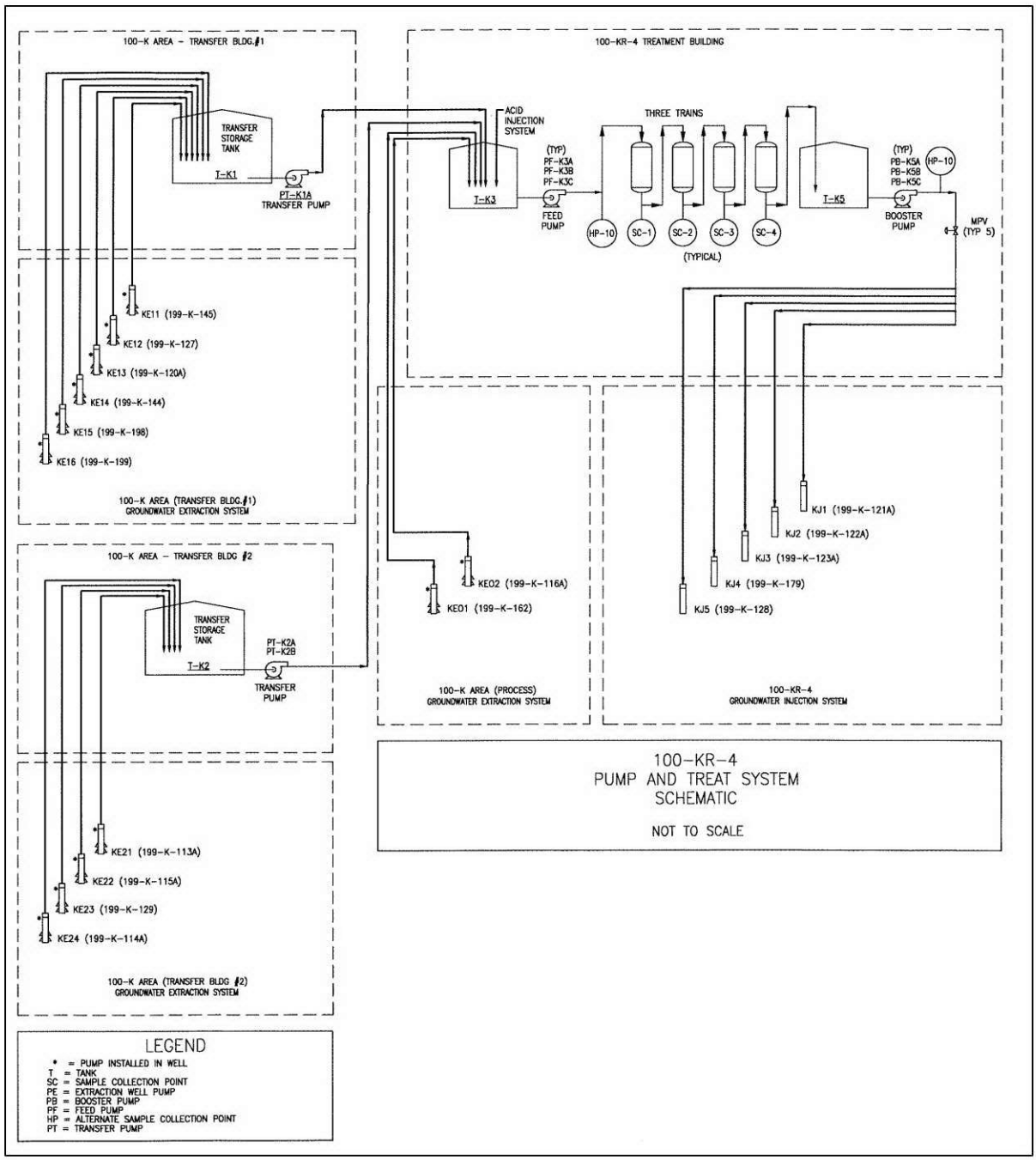


Figure 3-6. KR4 P&T System Schematic

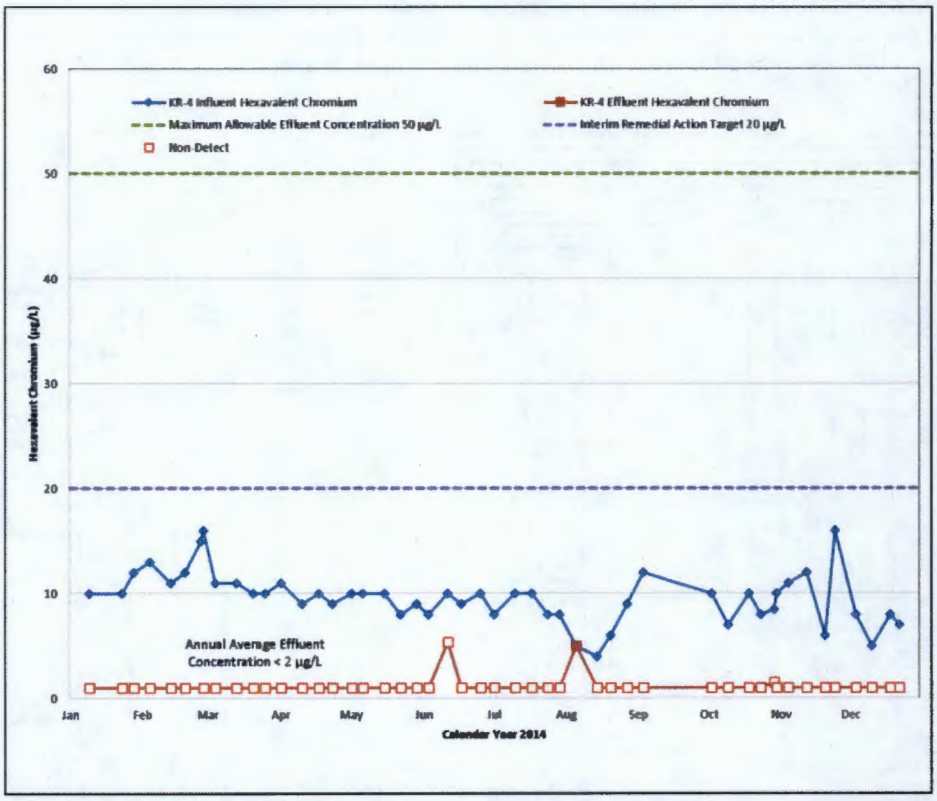


Figure 3-7. KR4 P&T System Trends of Influent and Effluent Cr(VI) Concentrations, 2014

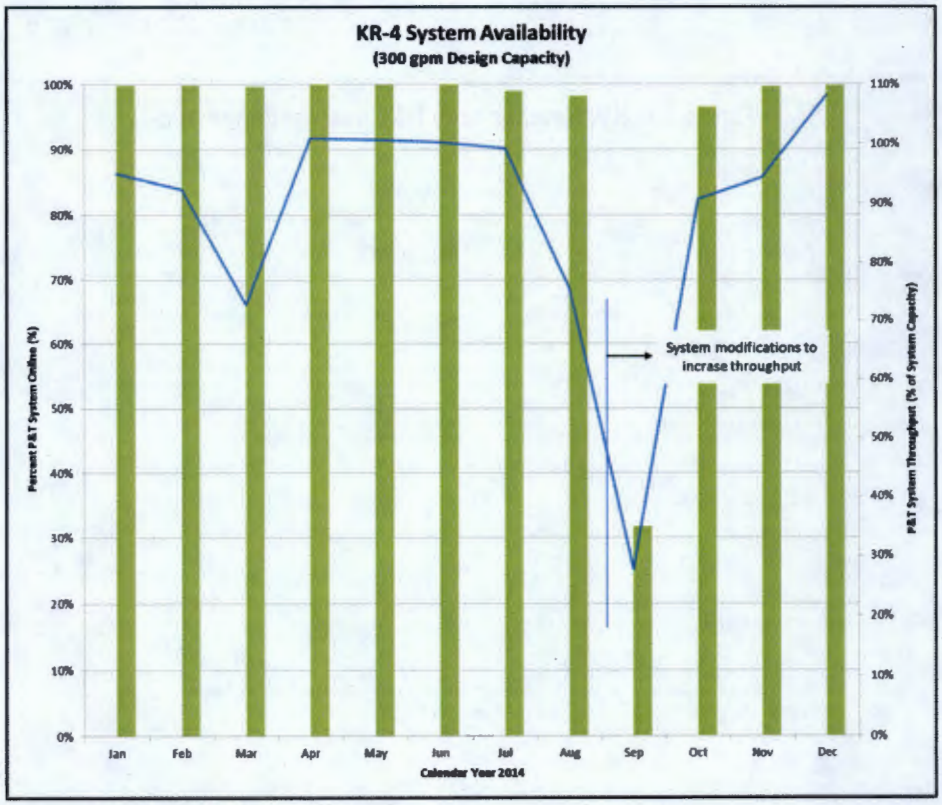


Figure 3-8. Monthly Online Availability for the KR4 P&T System, 2014

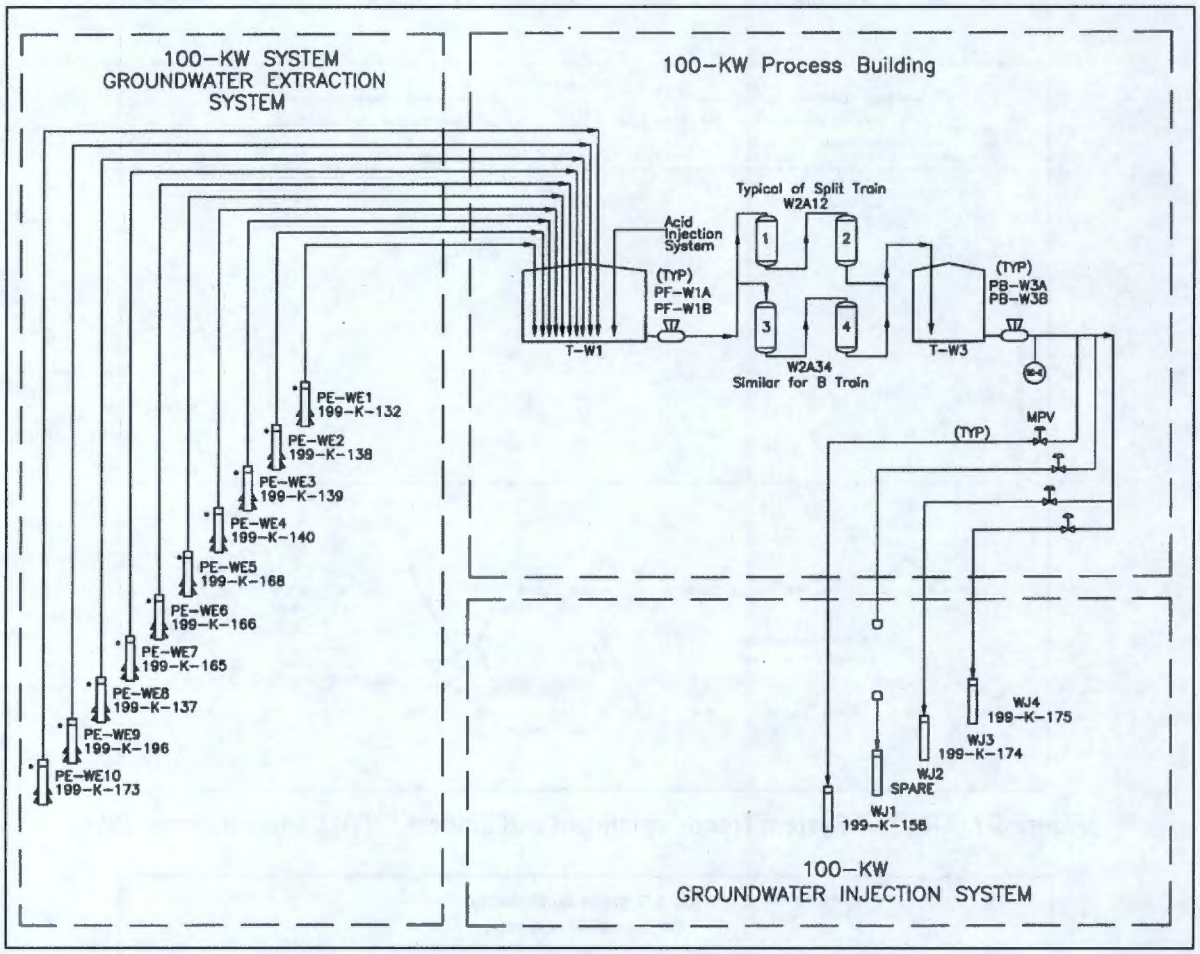


Figure 3-9. KW Reactor Area P&T System Schematic

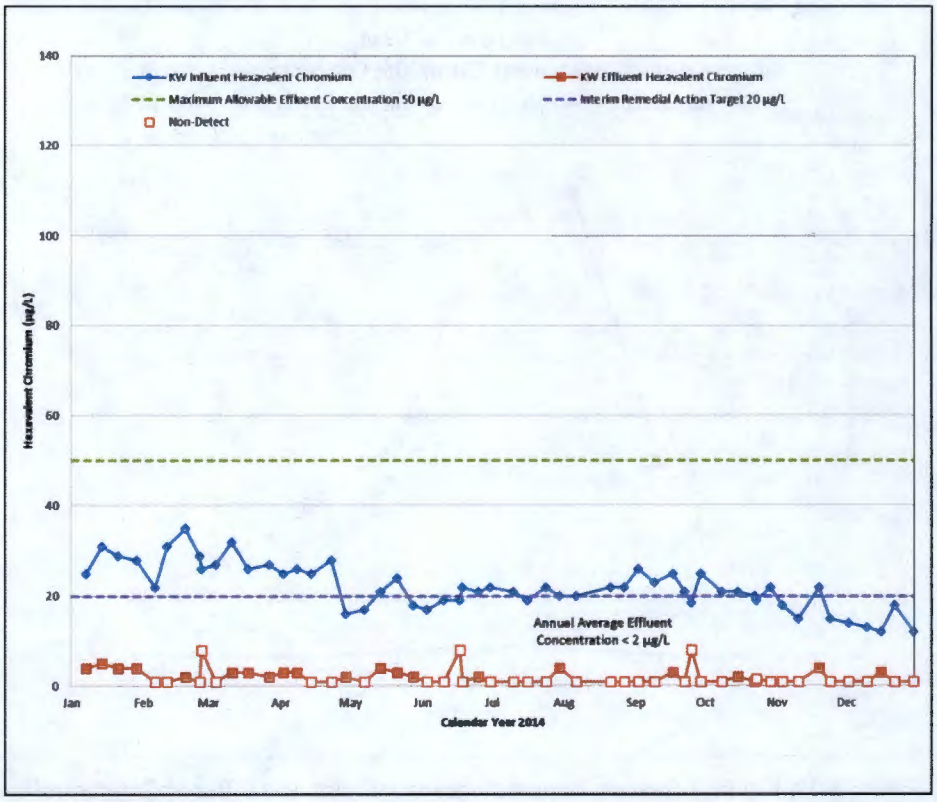


Figure 3-10. KW P&T Trends for Influent and Effluent Cr(VI) Concentrations, 2014

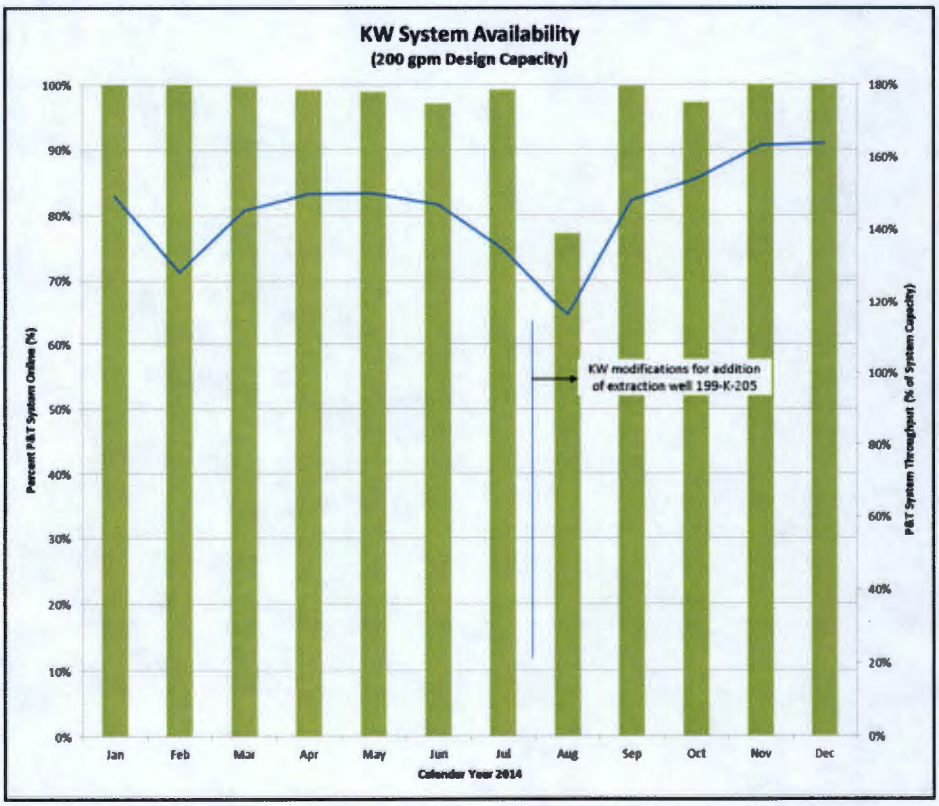


Figure 3-11. Monthly Online Availability for the KW P&T System, 2013

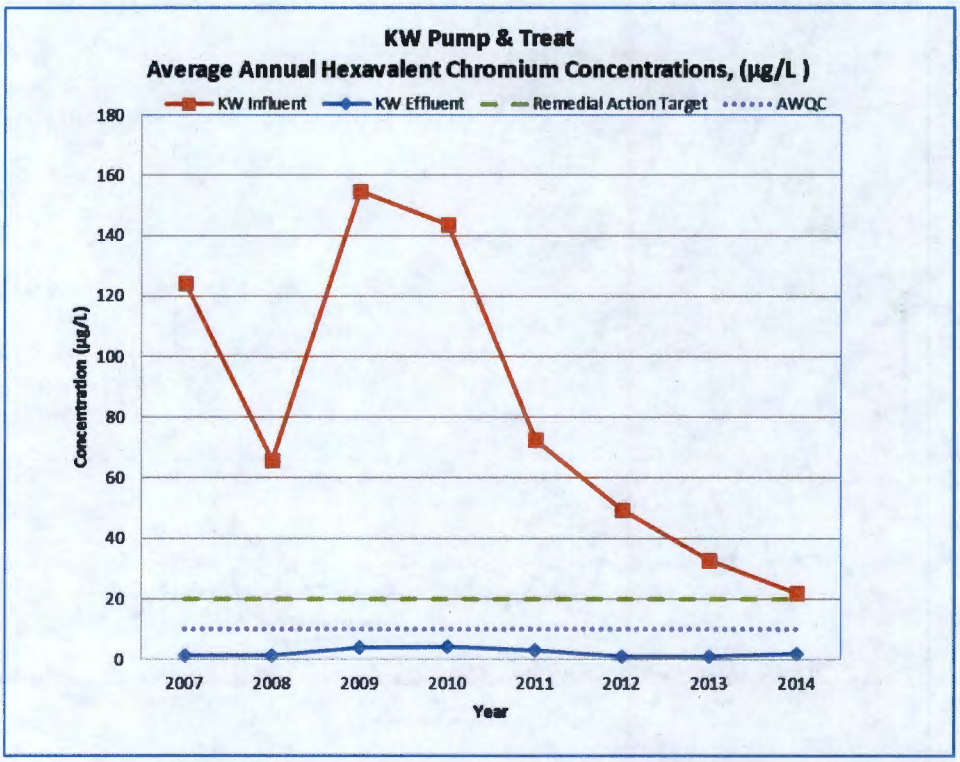


Figure 3-12. KW P&T System Annual Average Influent and Effluent Concentrations

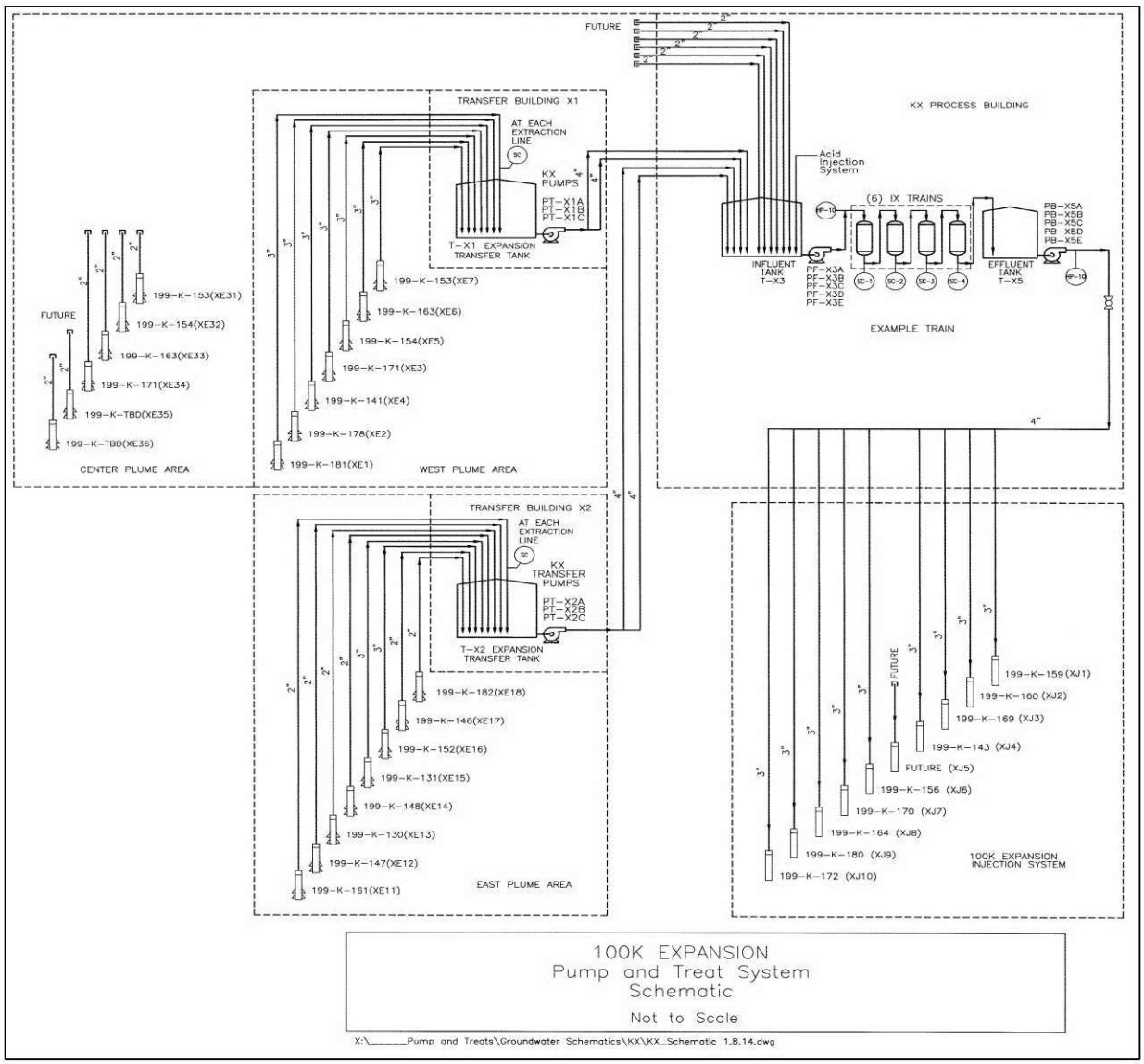


Figure 3-13. KX P&T System Schematic

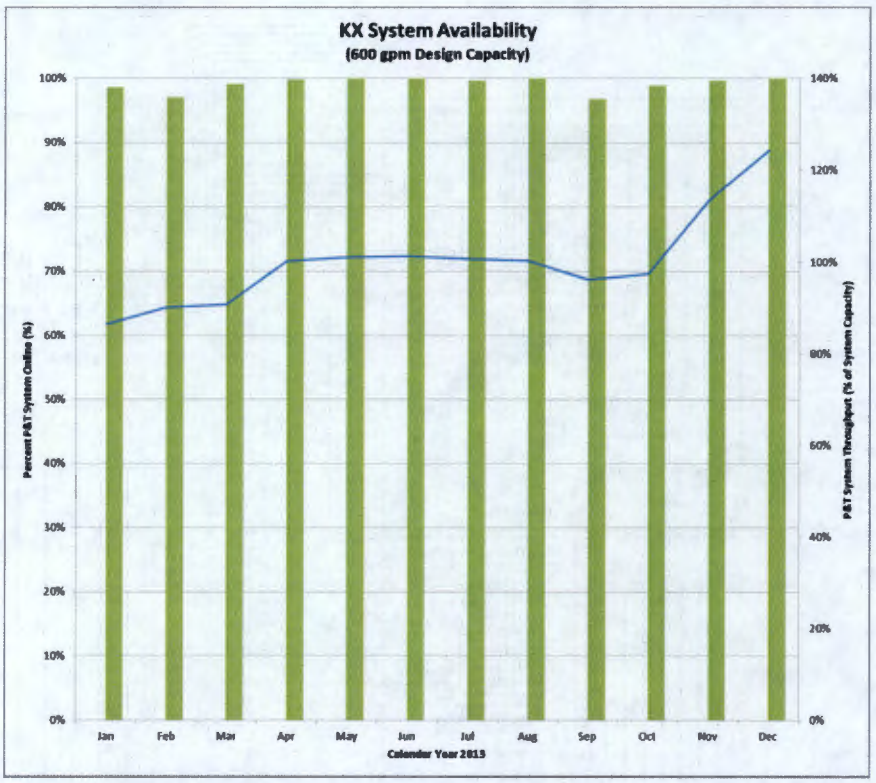
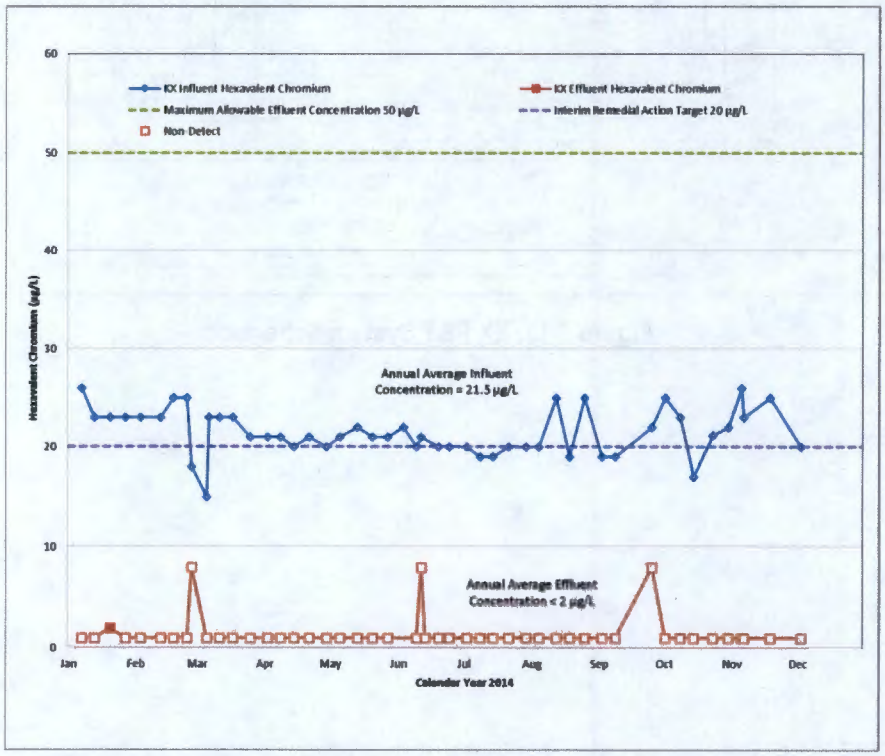


Figure 3-14. Monthly KX P&T System Availability, 2014



Note: These trends reflect a combination of laboratory and in-plant measurements.

Figure 3-15. KX P&T System Trends of Influent and Effluent Cr(VI) Concentrations, 2014

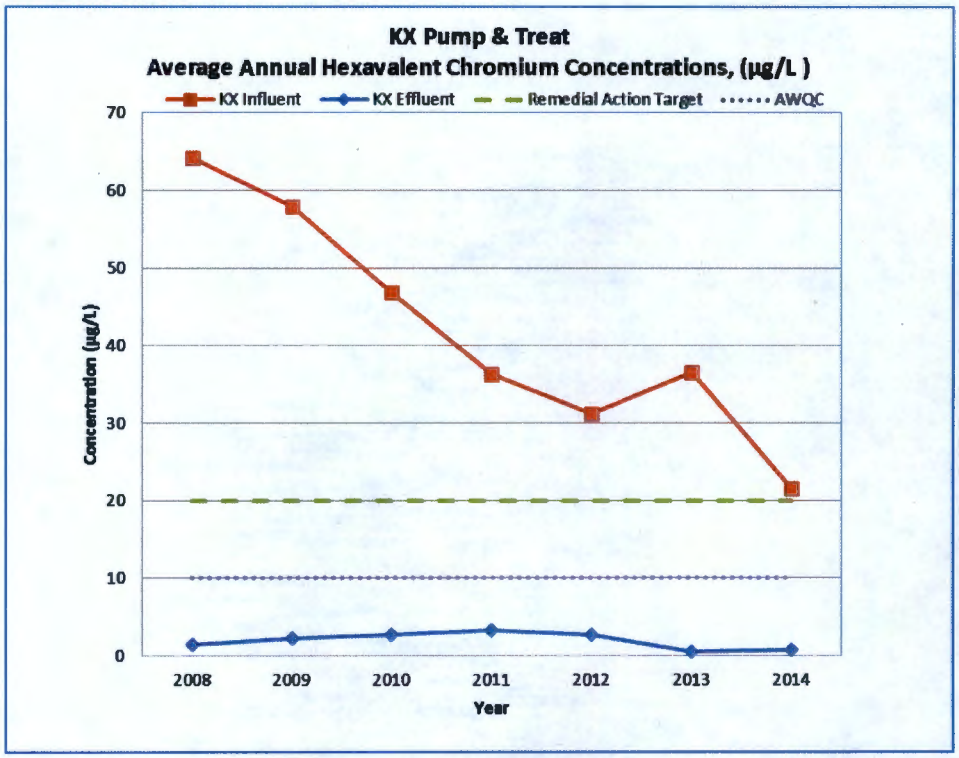


Figure 3-16. KX P&T System Annual Average Influent and Effluent Concentrations

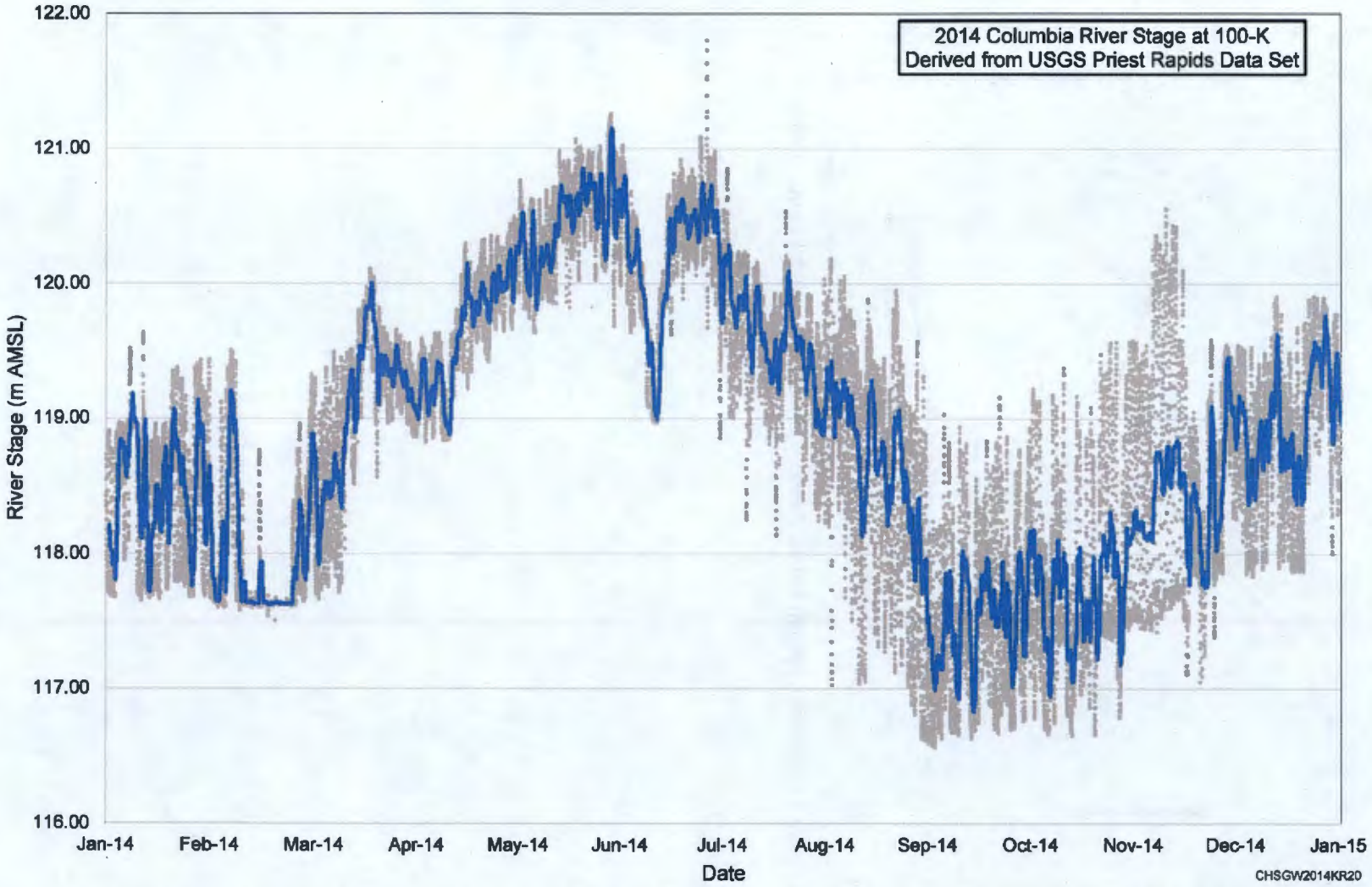


Figure 3-17. Columbia River-Stage Elevation at the 100-K Area, 2014 (96-point moving average represents daily average river stage)

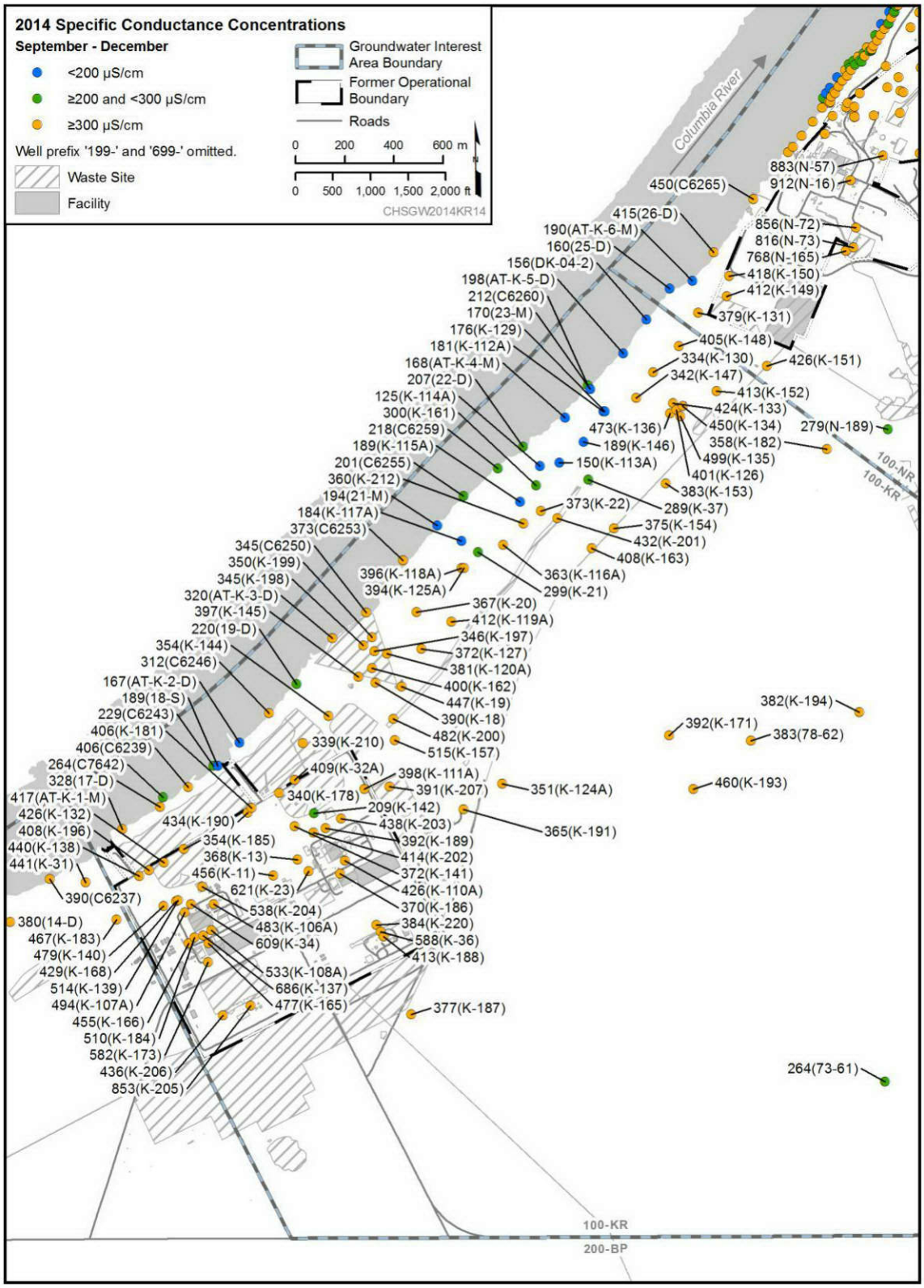


Figure 3-18. Plot of Groundwater Specific Conductance Relative to the Columbia River, 2014

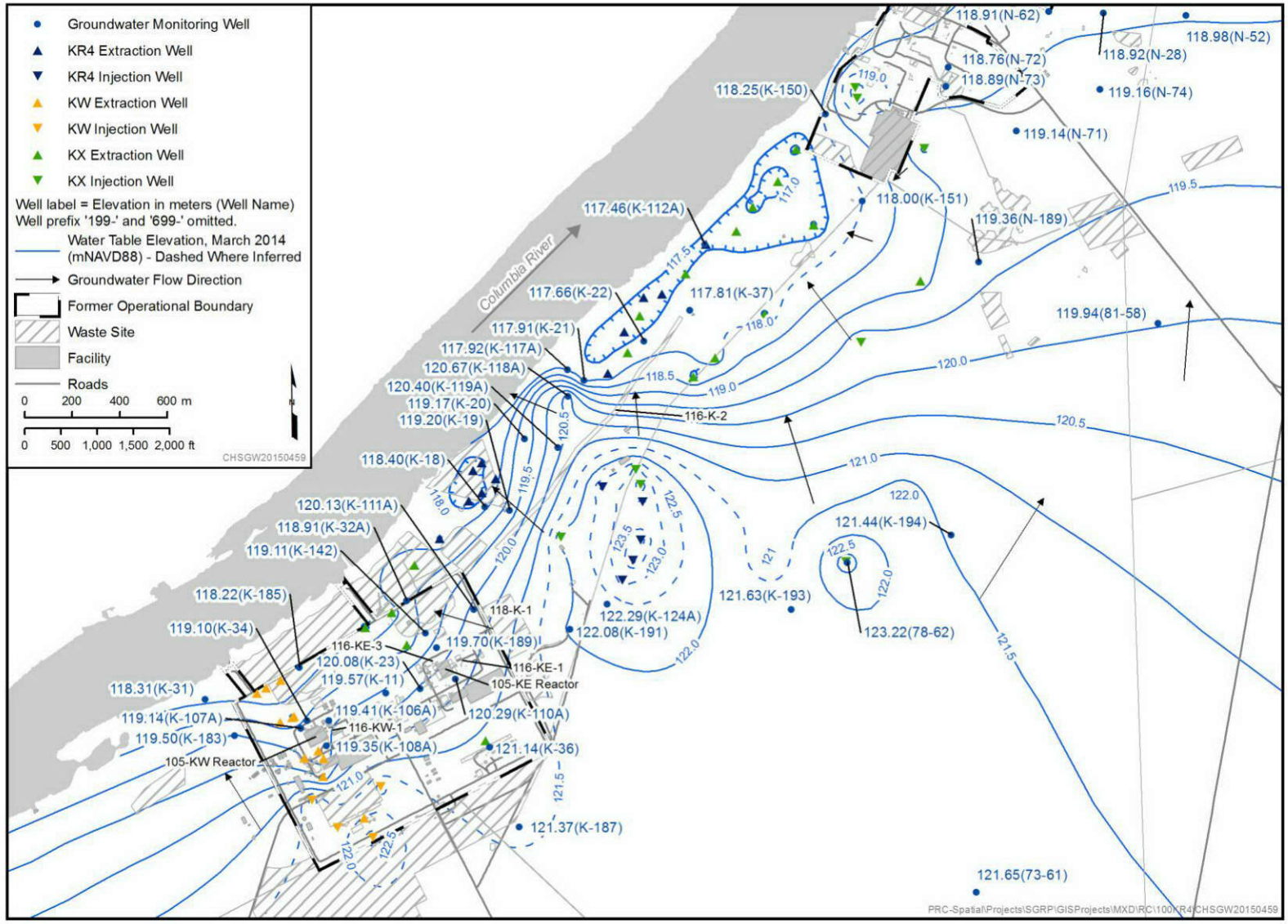


Figure 3-19. Groundwater Elevation Contour Map, March 2014

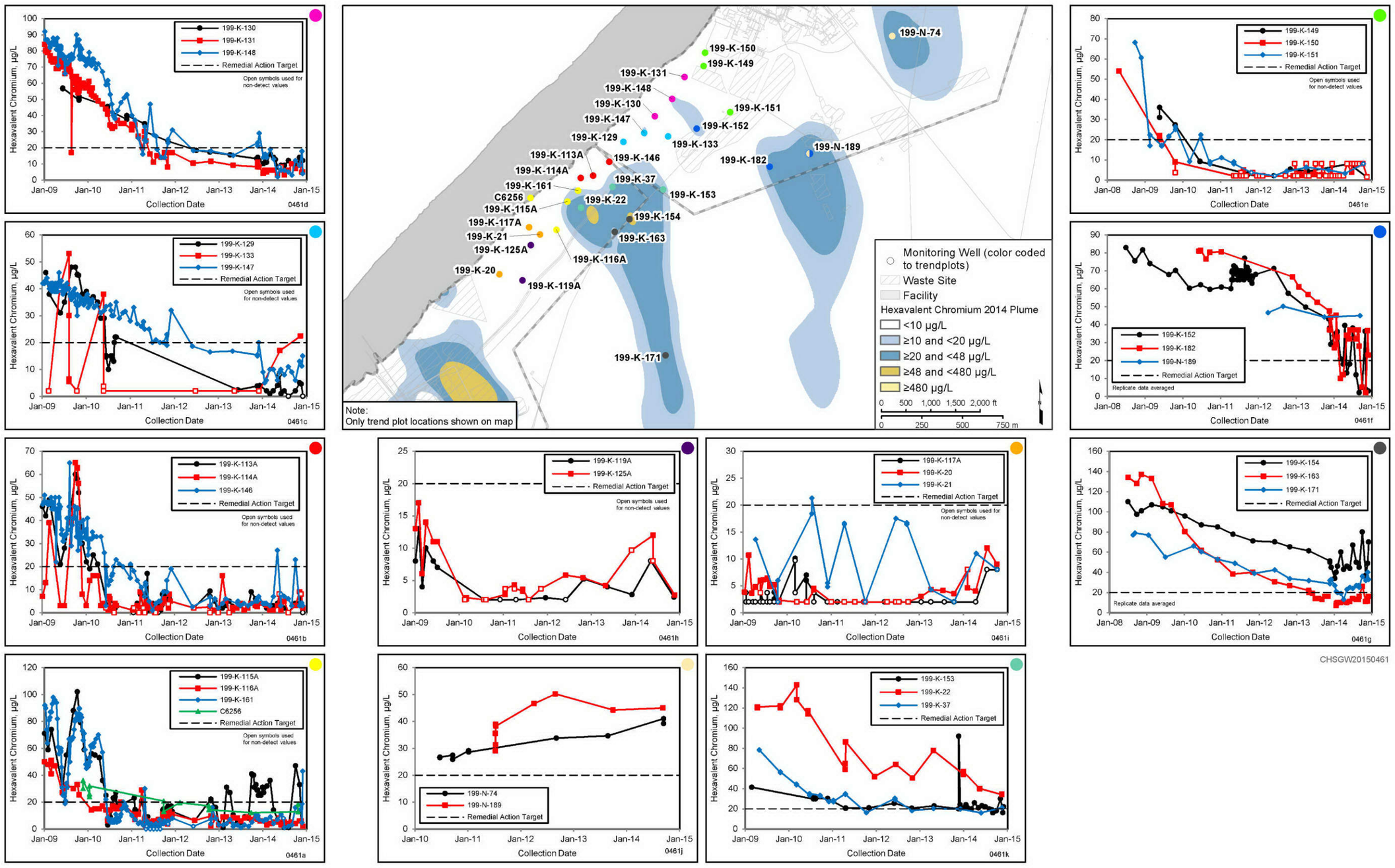


Figure 3-20. 2014 Cr(VI) Groundwater Concentration Time-Series Plots for Selected Wells near the 116-K-2 Trench Source Area

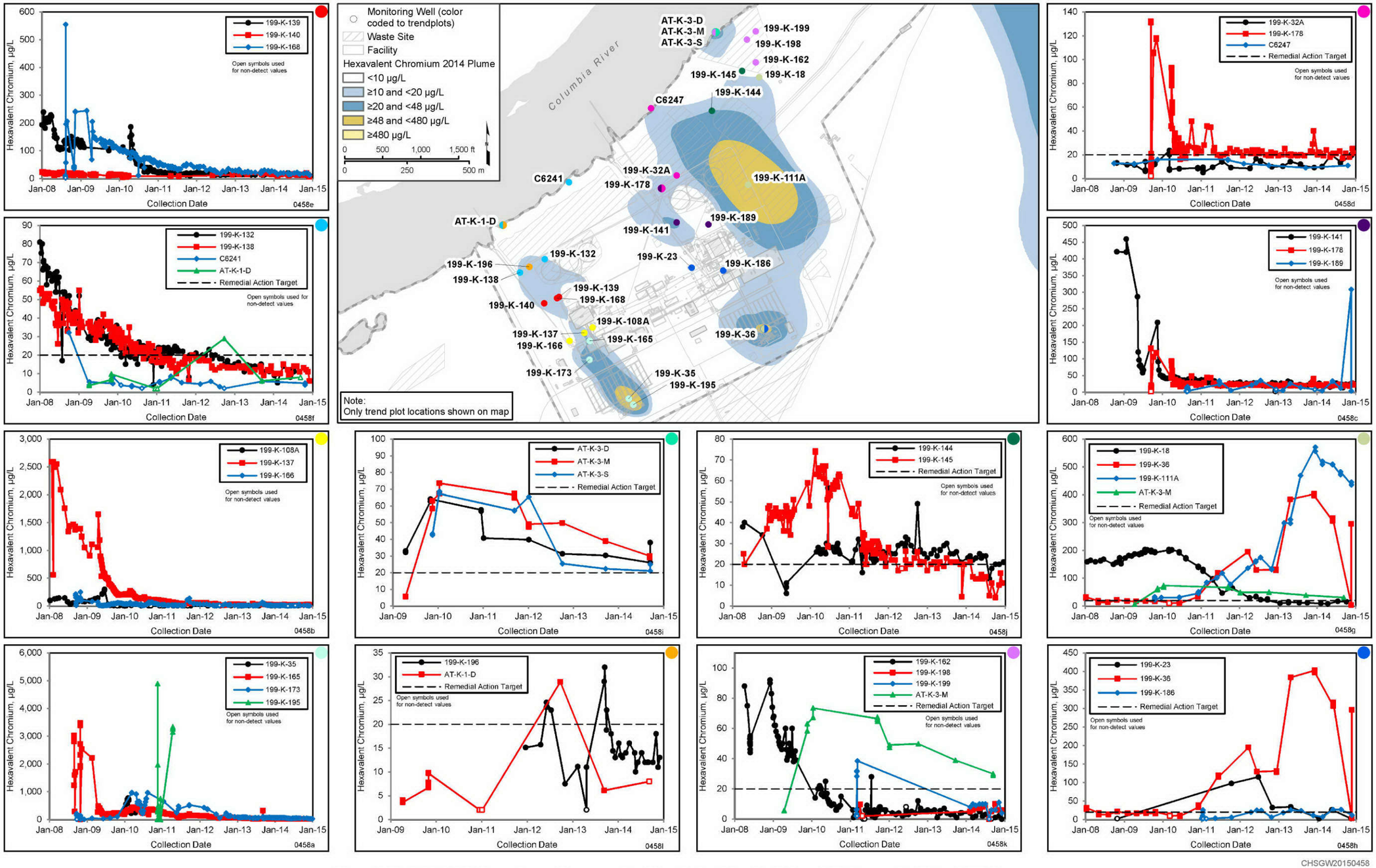


Figure 3-21. 2014 Cr(VI) Groundwater Concentration Time-Series Plots for Selected Wells near the KE and KW Reactors

Figure 3-22(a). 100-K Area Interpolated CFM and High River-Stage Chromium Contamination

Figure 3-22(b). 100-K Area Simulated CFM and High River-Stage Chromium Contamination

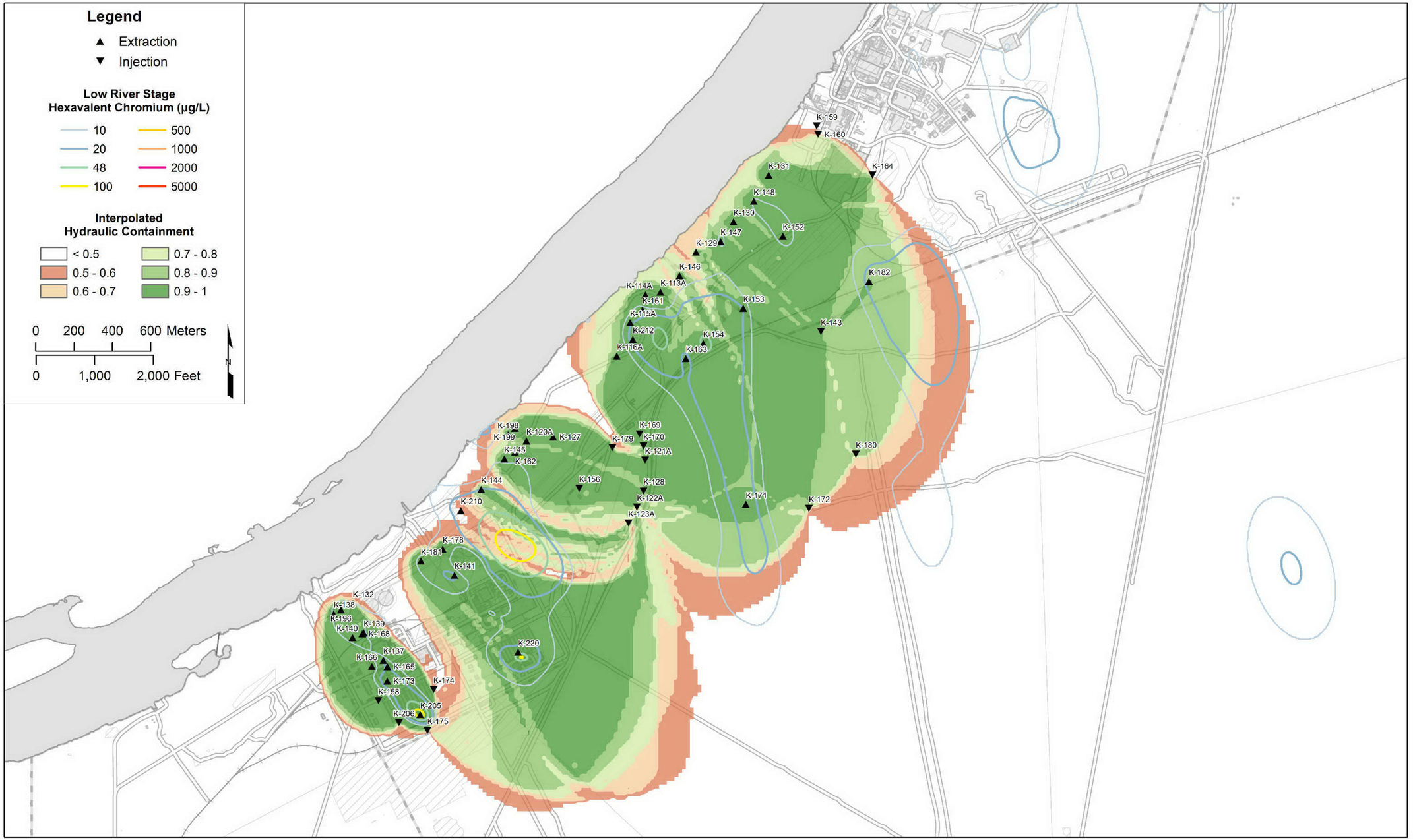


Figure 3-22(c). 100-K Area Interpolated CFM and Low River-Stage Chromium Contamination

Figure 3-22(d). 100-K Area Simulated CFM and Low River-Stage Chromium Contamination

Figure 3-22(e). 100-K Area Groundwater Flow Lines of Capture Zone for Low River Stage Chromium Contamination

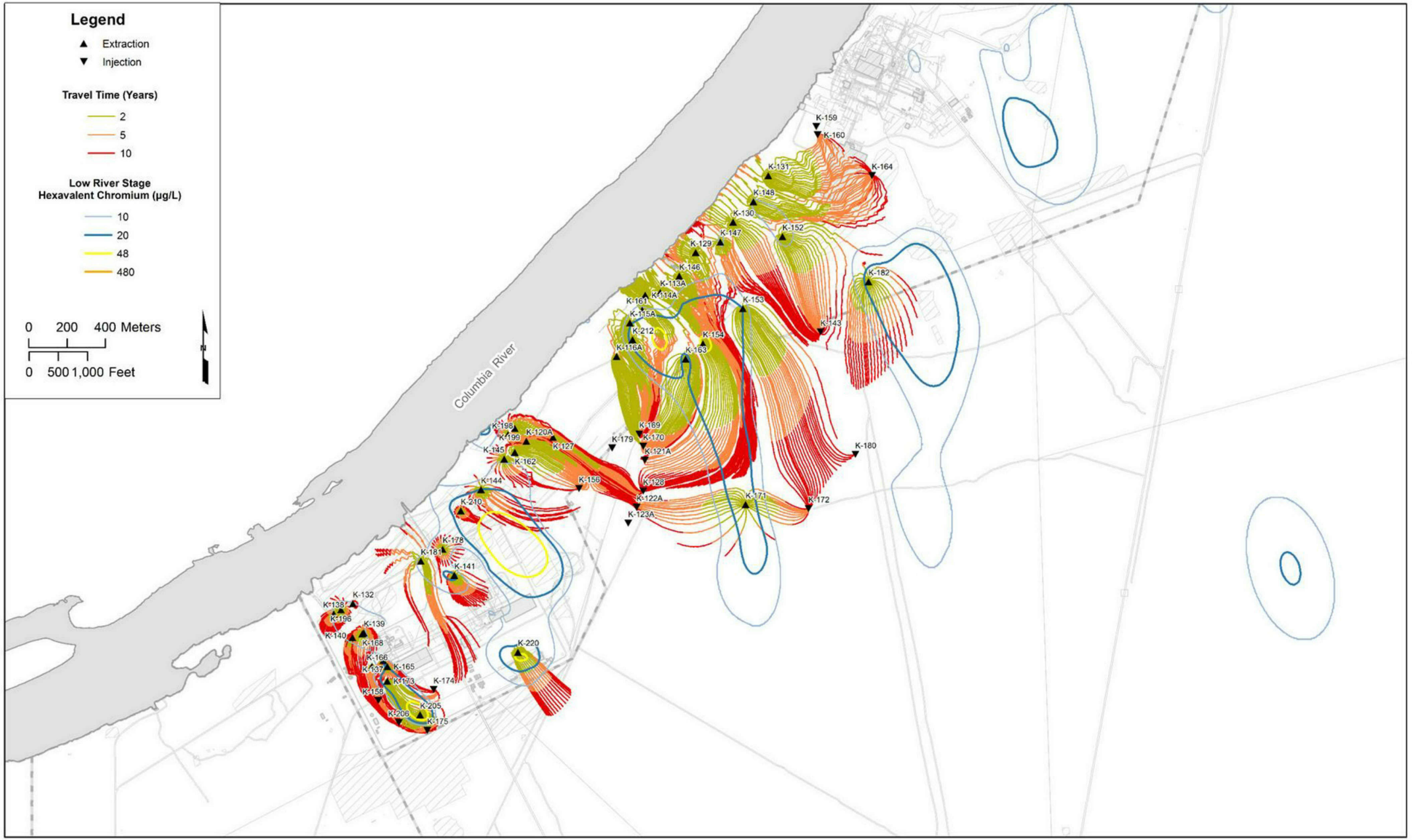


Figure 3-22(f). 100-K Area Groundwater Flow Lines of Capture Zone Overlay with Low River Stage Chromium Plume Contours

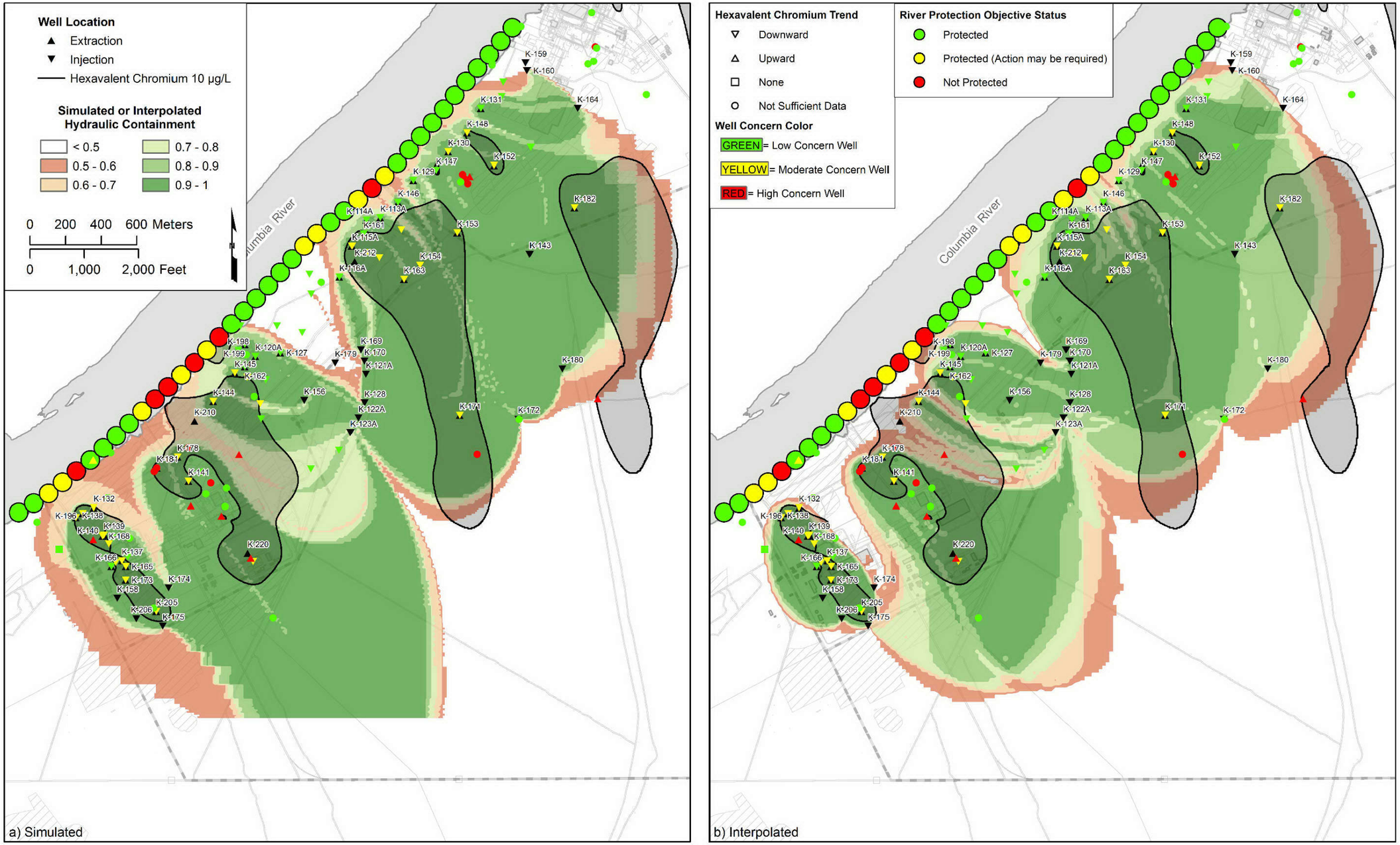


Figure 3-23(a). 100-K Area Quantitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River-Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

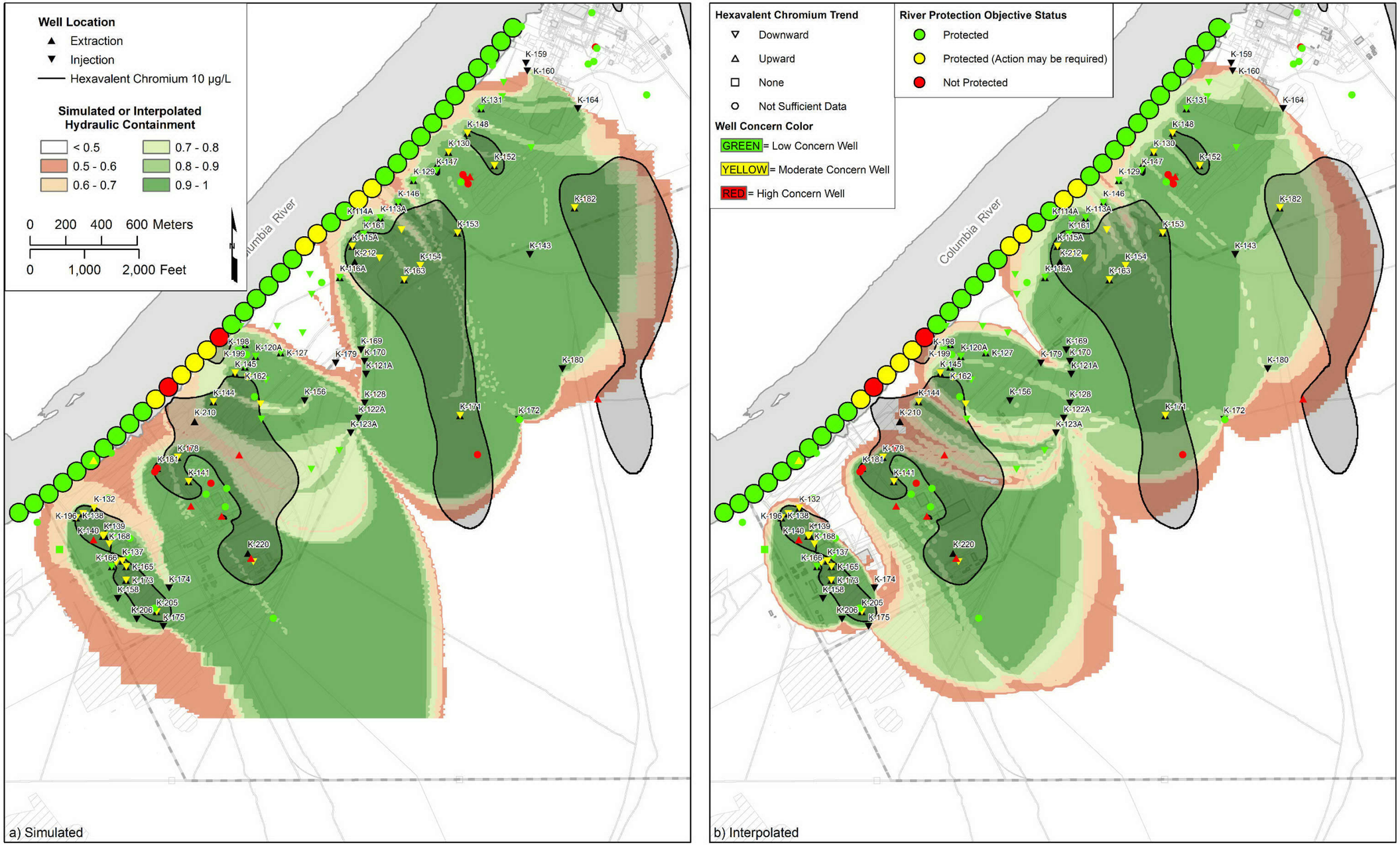


Figure 3-23(b). 100-K Area Qualitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, together with Mapped Extent of Low River-Stage Chromium Contamination above 10 µg/L and Results of Standard Test and Trend Test

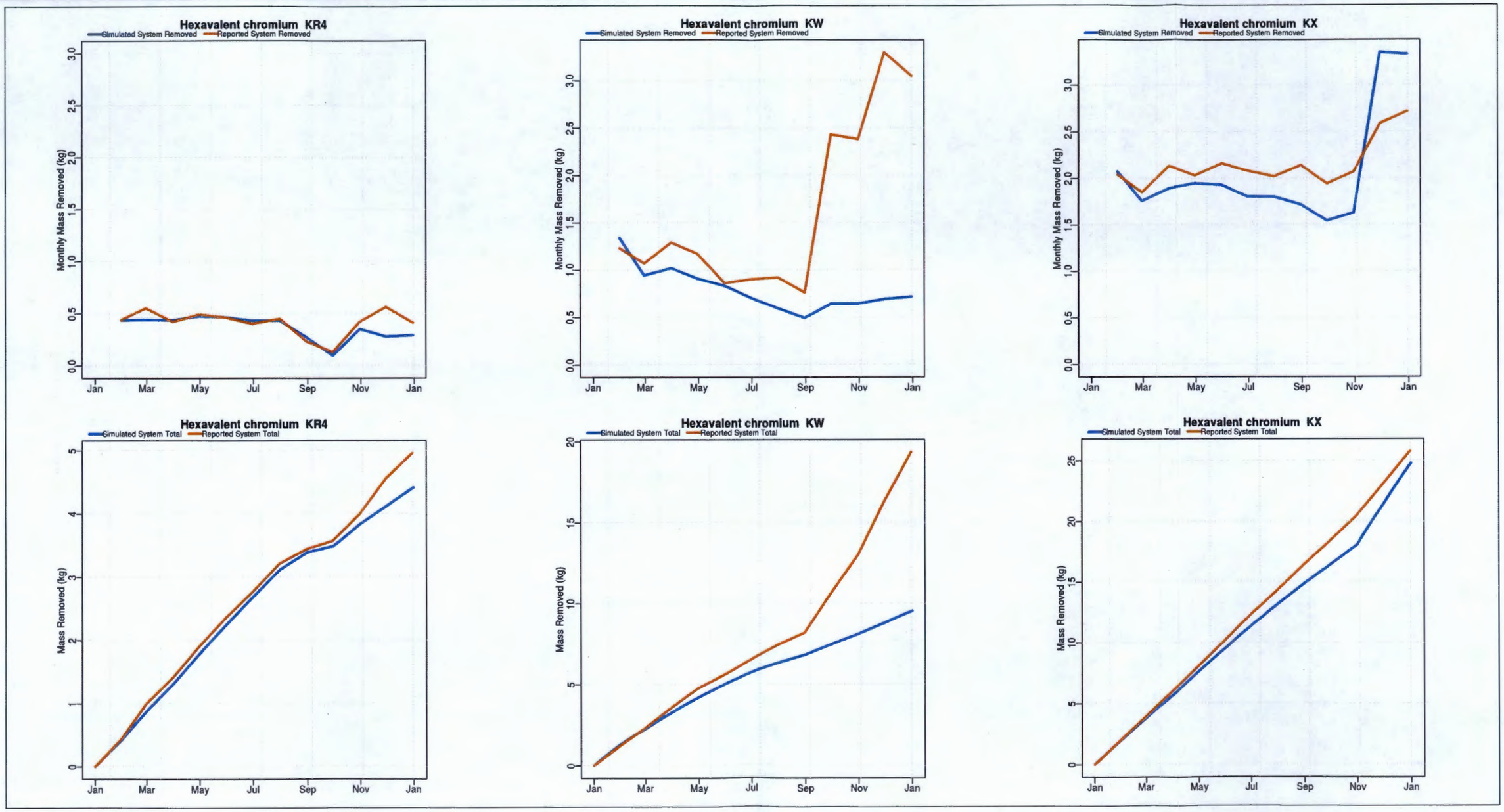


Figure 3-24. Comparison of Observed to Calculated Hexavalent Chromium Mass Removal (Top Row = Monthly Mass Removal, Bottom Row = Cumulative Mass Removal)

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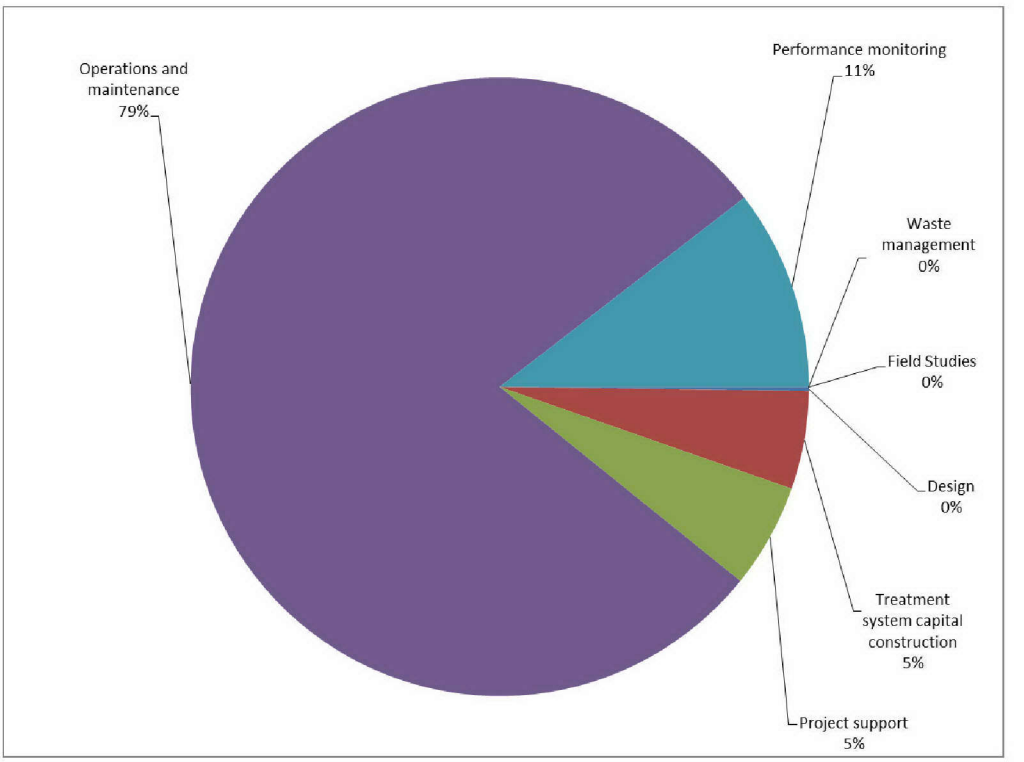


Figure 3-25. KR4 P&T System, 2014 ($1.54 million) Cost Breakdown (by Percentage)

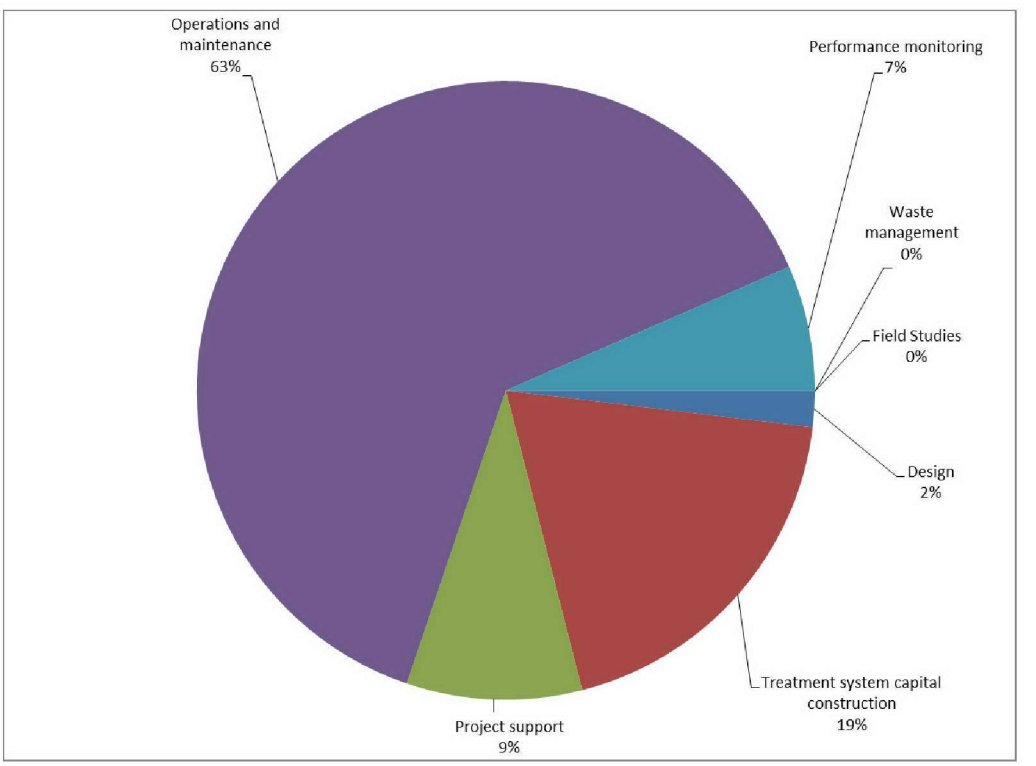


Figure 3-26. KX P&T System, 2014 ($2.42 million) Cost Breakdown (by Percentage)

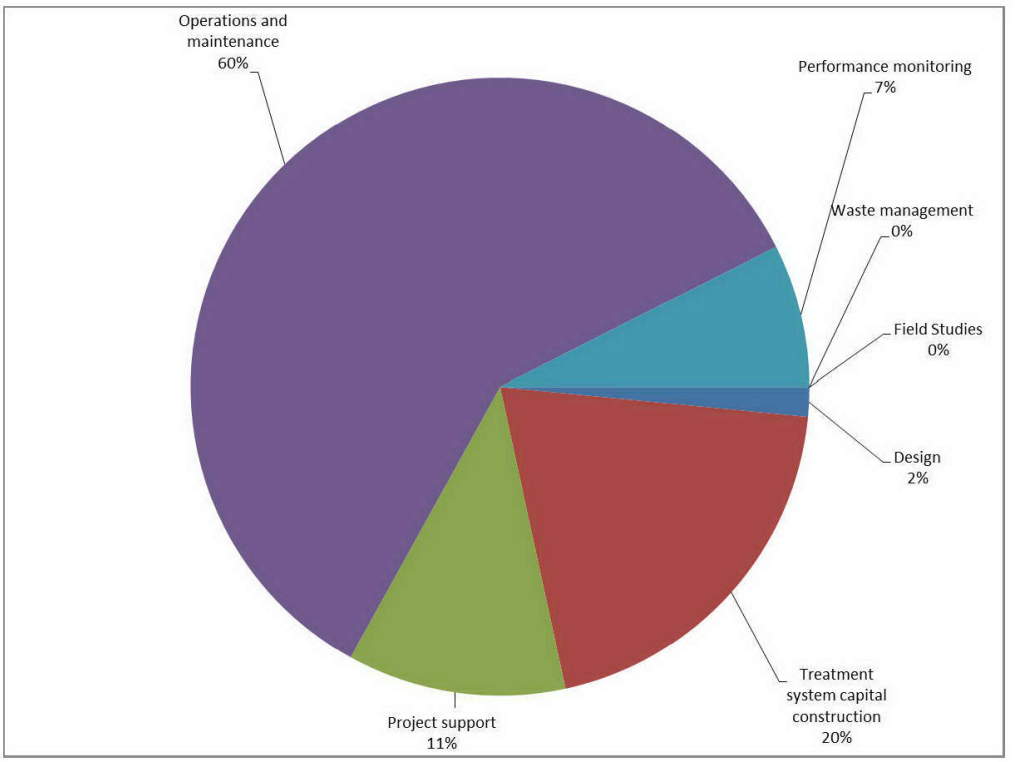


Figure 3-27. KW P&T System, 2014 ($2.10 million) Cost Breakdown (by Percentage)

Table 3-1. 100-KR-4 Groundwater OU Remedial System Well Changes Initiated in 2014

System	Well	Action	Purpose	Status as of December 31, 2014
100-KR-4	199-K-198	Realign existing well for extraction	River protection/hydraulic control	In service
	199-K-199	Realign existing well for extraction	River protection/hydraulic control	In service
100-KW	199-K-205	Construct new extraction well	Mass removal at source area – 183-KW	In service
	199-K-206	Construct new injection well	Hydraulic control	In service
100-KX	199-K-181	Realign existing well for extraction	River protection/hydraulic control	In service
	199-K-210	Construct new extraction well	River protection/hydraulic control	In service
	199-K-212	Construct new extraction well	River protection/hydraulic control	In service
	199-K-220	Construct new extraction well	Mass removal at source area – 183-KE	In service
	199-K-208	Construct new extraction well	River protection/hydraulic control	Under construction
Monitoring wells	199-K-202	Construct new monitoring well	Strontium-90 plume delineation – 105-KE	In service
	199-K-203	Construct new monitoring well	Carbon-14 plume delineation – 105-KE	In service
	199-K-204	Construct new monitoring well	Strontium-90 plume delineation – 105-KW	In service
	199-K-207	Construct new monitoring well	Tritium plume delineation – 118-K-1	Under construction
	199-K-209	Construct new monitoring well	Chromium plume delineation – 116-K-2	Under construction

Table 3-2. Operational Parameters and System Performance of KR4 P&T System

Total Processed Groundwater	**2013**	**2014**
Total amount of groundwater treated (since September 1997 startup) (billion L)	6.7	7.3
Total amount of groundwater treated during CY (million L)	553.3	527.0
Mass of Hexavalent Chromium Removed		
Total amount of hexavalent chromium removed since September 1997 startup (kg)	366.4	371.4
Total amount of hexavalent chromium removed in CY (kg)	6.1	5.0
Summary of Operational Parameters		
Removal efficiency (% by mass)	94.7	93.7
Waste generation (m^3)	78.6	0
Regenerated resin installed (m^3)	0	0
New resin installed (m^3)	0	0
Number of resin vessel changeouts	0	0
Summary of System Availability		
Total possible run-time (hours)	8,760	8,760
Total time online (hours)	8,676.6	8,215
Total availability (%)*	99.0	93.8

* Total availability [(total time online) ÷ (total possible run-time)].

CY = calendar year

Table 3-3. Flow Rates and Total Run-Times for KR4 P&T System Extraction and Injection Wells, 2014

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2012	Total Run-Time[a] (Percent)	Purpose
C5940	199-K-162	KE01	154.8 (40.9)	8,016	91.5%	Extraction
B2803	199-K-116	KE02	151.4 (40)	8,280	94.5%	Extraction
C5361	199-K-145	KE11	166.8 (44)	8,064	92.1%	Extraction
C3662	199-K-127	KE12	66.2 (17.5)	3,168	36.2%	Extraction
B2807	199-K-120A	KE13	77.6 (20.5)	3,168	36.2%	Extraction
C5360	199-K-144	KE14	168.1 (44.4)	7,440	84.9%	Extraction
C7698	199-K-198[b]	KE15	78.1 (20.6)	7,728	88.2%	Extraction
C7699	199-K-199[b]	KE16	79.5 (21)	7,752	88.5%	Extraction
B2800	199-K-113A	KE21	38.6 (10.2)	8,088	92.3%	Extraction
B2802	199-K-115A	KE22	77 (20.3)	8,088	92.3%	Extraction
C4117	199-K-129	KE23	37.1 (9.8)	8,040	91.8%	Extraction
B2801	199-K-114A	KE24	96.5 (25.5)	8,088	92.3%	Extraction
B2808	199-K-121A	KJ1	138.8 (36.6)	8,280	94.5%	Injection
B2809	199-K-122A	KJ2	260.7 (68.8)	8,280	94.5%	Injection
B2810	199-K-123A	KJ3	108.7 (28.7)	8,160	93.2%	Injection
C7150	199-K-179	KJ4	242.1 (63.9)	8,280	94.5%	Injection
C3663	199-K-128	KJ5	286.8 (75.7)	8,280	94.5%	Injection

a. Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)].

b. New extraction wells connected to the KR4 pump and treat system and operational in 2014.

CY = calendar year

ID = identification

N/A = not applicable

PLC = programmable logic controller

Table 3-4. Operational Parameters and System Performance for KW P&T System

Total Processed Groundwater	2013	2014
Total groundwater treated since January 2007 startup (million L)	2,337.0	2,916.6
Total groundwater treated in CY (million L)	487.1	579.6
Mass of Hexavalent Chromium Removed		
Total hexavalent chromium removed since January 2007 startup (kg)	201.3	220.6
Total hexavalent chromium removed in CY (kg)	15.6	19.4
Summary of Operational Parameters		
Removal efficiency (% by mass)	96.7	91.4
Waste generation (m^3)	30.6	0
Regenerated resin installed (m^3)	0	0
New resin installed (m^3)	0	0
Number of resin vessel changeouts	0	0
Summary of System Availability		
Total possible run-time (hours)	8,760	8,760
Total time online (hours)	7,760.9	8,504.8
Total availability (%)*	88.6	97.1

* Total availability [(total time online) ÷ (total possible run-time)].

CY = calendar year

Table 3-5. Flow Rates and Total Run-Times for KW P&T System Extraction and Injection Wells, 2014

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2012	Total Run-Time[a] (Percent)	Purpose
C4670	199-K-132	WE1	45.4 (12)	6,432	73.4%	Extraction
C5113	199-K-138	WE2	61.9 (16.3)	8,640	98.6%	Extraction
C5114	199-K-139	WE3	55.7 (14.7)	8,616	98.4%	Extraction
C5115	199-K-140	WE4	63.8 (16.8)	8,616	98.4%	Extraction
C6454	199-K-168	WE5	147 (38.8)	8,616	98.4%	Extraction
C6452	199-K-166	WE6	105.6 (27.9)	8,616	98.4%	Extraction
C6451	199-K-165	WE7	197.5 (52.1)	8,640	98.6%	Extraction
C5112	199-K-137	WE8	82.8 (21.9)	8,640	98.6%	Extraction
C7696	199-K-196	WE9	137 (36.2)	8,640	98.6%	Extraction
C7016	199-K-173	WE10	203.1 (53.6)	8,520	97.3%	Extraction
C8292	199-K-205[b]	WE11	163.9 (43.3)	1,920	21.9%	Extraction
C5484	199-K-158	WJ1	375.4 (99.1)	8,616	98.4%	Injection
C8293	199-K-206[c]	WJ2	359.9 (95)	4,608	52.6%	Injection
C7061	199-K-174	WJ3	267.4 (70.6)	8,616	98.4%	Injection
C7062	199-K-175	WJ4	283.9 (75)	8,616	98.4%	Injection

a. Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)].

b. Extraction well connected to KW pump and treat system and operational in September 2014.

c. Injection well connected to KW pump and treat system and operational in June 2014.

CY = calendar year

ID = identification

N/A = not applicable

PLC = programmable logic controller

Table 3-6. Operational Parameters and System Performance for KX P&T System

Total Processed Groundwater	2013	2014
Total groundwater treated since November 2008 startup (million L)	4.575.1	5,773.9
Total groundwater treated in CY (million L)	1.024.5	1,198.8
Mass of Hexavalent Chromium Removed		
Total hexavalent chromium removed since November 2008 startup (kg)	168.5	194.3
Total hexavalent chromium removed in CY (kg)	27.0	25.8
Summary of Operational Parameters		
Removal efficiency (% by mass)	98.5	96.4
Waste generation (m^3)	7.2	7.2
Regenerated resin installed (m^3)	0	0
New resin installed (m^3)*	0	26.2
Number of resin vessel changeouts	0	0
Summary of System Availability		
Total possible run-time (hours)	8,760	8,760
Total time online (hours)	8,705.9	8,661.9
Total availability (%)**	99.4	98.9

* The third and fourth vessels in each train of the KX P&T system were loaded with SIR-700 resin in 2014.

** Total availability [(total time online) ÷ (total possible run-time)].

CY = calendar year

Table 3-7. Flow Rates and Total Run-Times for KX P&T System Extraction and Injection Wells, 2014

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2012	Total Run-Time (Percent)[a]	Purpose
C7464	199-K-181[b]	XE1	193.3 (51)	8,424	96.2%	Extraction
C7149	199-K-178	XE2	149.7 (39.5)	8,760	100.0%	Extraction
C8297	199-K-210[c]	XE3	210.9 (55.7)	2,760	31.5%	Extraction
C5303	199-K-141	XE4	85.6 (22.6)	8,760	100.0%	Extraction
C8795	199-K-220[c]	XE5	222.6 (58.8)	2,736	31.2%	Extraction
C6172	199-K-163[c]	XE6	206.5 (54.5)	1,008	11.5%	Extraction
C5369	199-K-153[c]	XE7	232.4 (61.3)	1,368	15.6%	Extraction
C5939	199-K-161	XE11	72.4 (19.1)	8,760	100.0%	Extraction
C5363	199-K-147	XE12	73.9 (19.5)	8,760	100.0%	Extraction
C4120	199-K-130	XE13	101 (26.7)	8,760	100.0%	Extraction
C5364	199-K-148	XE14	133.3 (35.2)	8,760	100.0%	Extraction
C4561	199-K-131	XE15	168.4 (44.5)	8,760	100.0%	Extraction
C5368	199-K-152	XE16	178.6 (47.2)	8,760	100.0%	Extraction
C5362	199-K-146	XE17	31.1 (8.2)	8,760	100.0%	Extraction
C7476	199-K-182	XE18	98.4 (26)	8,760	100.0%	Extraction
C5369	199-K-153[c]	XE31	243.3 (64.2)	7,248	82.7%	Extraction
C5370	199-K-154[c]	XE32	229.9 (60.7)	7,248	82.7%	Extraction
C6172	199-K-163[c]	XE33	228 (60.2)	7,248	82.7%	Extraction
C6746	199-K-171[c]	XE34	229.8 (60.7)	7,272	83.0%	Extraction
C8299	199-K-212[d]	XE35	203.3 (53.7)	1,392	15.9%	Extraction
C5937	199-K-159	XJ1	257.4 (68)	8,760	100.0%	Injection
C5938	199-K-160	XJ2	255.9 (67.6)	8,760	100.0%	Injection
C6744	199-K-169	XJ3	272.8 (72)	8,760	100.0%	Injection
C5305	199-K-143	XJ4	156.3 (41.3)	8,760	100.0%	Injection
C5372	199-K-156	XJ6	305.2 (80.6)	8,496	97.0%	Injection
C6745	199-K-170	XJ7	320.3 (84.6)	8,760	100.0%	Injection
C6386	199-K-164	XJ8	212.8 (56.2)	8,664	98.9%	Injection

Table 3-7. Flow Rates and Total Run-Times for KX P&T System Extraction and Injection Wells, 2014

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2012	Total Run-Time (Percent)[a]	Purpose
C7151	199-K-180	XJ9	208.8 (55.1)	8,760	100.0%	Injection
C6747	199-K-172	XJ10	295.1 (77.9)	8,760	100.0%	Injection

a. Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)].

b. Extraction well connected to KW pump and treat system and operational in January 2014.

c. Extraction wells realigned in March 2014 to accommodate system modifications.

d. Extraction well connected to KW pump and treat system and operational in November 2014.

CY = calendar year

ID = identification

PLC = programmable logic controller

Table 3-8. Maximum Contaminant and Co-Contaminant Concentrations for 116-K-2 Trench Area (K North Plume), 2013 and 2014

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
2013				
Hexavalent chromium	98.7	F	8/14/2013	199-K-201
Hexavalent chromium	87.5	UF	8/14/2013	199-K-201
Strontium-90	203	UF	12/16/2013	199-K-200
Tritium	33,000	UF	10/1/2013	199-K-18
Carbon-14	26.1	UF	5/15/2013	199-K-119A
Nitrate	32,300	UF	4/25/2013	199-K-200
Trichloroethene	1 (U)	UF	Multiple	Multiple
2014				
Hexavalent chromium	40.0	F	11/24/2014	199-K-212
Hexavalent chromium	80.2	UF	2/20/2014	199-K-201
Strontium-90	231	UF	8/21/2014	199-K-200
Tritium	414,000	F	12/9/2014	199-K-207*
Carbon-14	37.2	UF	11/23/2014	199-K-119A
Nitrate	30,800	UF	2/19/2014	199-K-200
Trichloroethene	0.5 (U)	UF	3/31/2014	199-K-212

* Well 199-K-207 was installed in 2014; samples collected during drilling

Table 3-9. Maximum Contaminant and Co-Contaminant Concentrations for KW Reactor Area, 2013 and 2014

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
2013				
Hexavalent chromium	97.2	F	4/4/2013	199-K-173
Hexavalent chromium	101	UF	9/5/2013	199-K-173
Strontium-90	56.3	UF	11/4/2013	199-K-34
Tritium	3,600	UF	11/21/2013	199-K-139
Carbon-14	9,520	UF	12/16/2013	199-K-106A
Nitrate	63,700	UF	11/4/2013	199-K-34
Trichloroethene	8.3	UF	1/1/2013	199-K-185
2014				
Hexavalent chromium	241	F	12/11/2014	199-K-205*
Hexavalent chromium	3,280	UF	1/9/2014	199-K-205*
Strontium-90	56.1	UF	11/21/2014	199-K-34
Tritium	3,050	UF	11/19/2014	199-K-139
Carbon-14	14,300	UF	11/21/2014	199-K-106A
Nitrate	62,900	UF	7/30/2014	199-K-34
Trichloroethene	6.8	UF	11/21/14	199-K-185

* Well 199-K-205 was installed in late 2013.

Table 3-10. Maximum Contaminant and Co-Contaminant Concentrations for KE Reactor Area, 2013 and 2014

Constituent	Maximum Value Detected (µg/L or pCi/L)	Filtered (F) or Unfiltered (UF)	Date Sampled	Well Name
2013				
Hexavalent chromium	Not reported	F	—	—
Hexavalent chromium	571	UF	12/16/2013	199-K-111A
Strontium-90	42	UF	11/20/2013	199-K-141
Tritium	76,000	UF	11/4/2013	199-K-202
Carbon-14	2,120	UF	12/12/2013	199-K-189
Nitrate	62,000	UF	4/23/2013	199-K-23
Trichloroethene	3.7	UF	12/6/2013	199-K-190
2014				
Hexavalent chromium	24.6	F	12/11/2014	199-K-220
Hexavalent chromium	520	UF	2/20/2014	199-K-111A
Strontium-90	54.1	UF	8/25/2014	199-K-141
Tritium	39,000	UF	10/13/2014	199-K-202
Carbon-14	6,230	UF	11/5/2014	199-K-203*
Nitrate	66,800	UF	5/16/2014	199-K-23
Trichloroethene	4.72 J	UF	11/23/2014	199-K-190

* Well 199-K-203 was installed in 2014.

Table 3-11. Cr(VI) Concentrations in the 116-K-2 Trench Area (K North Plume), 2012 to 2014

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Decrease)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
199-K-19	P	10/26/2012	6	11/22/2013	5.4	11/17/2014	8.2	-10	52
199-K-20	C	10/2/2012	2 (U)	10/17/2013	5.93	10/7/2014	9	197	52
199-K-21	P	9/20/2012	16.7	10/17/2013	19.2	10/9/2014	8 (U)	15	-58
199-K-22	P	10/31/2012	50.5	12/31/2013	56.8	11/17/2014	34.5	13	-39
199-K-37	P	10/26/2012	18.2	12/5/2013	22.5	11/17/2014	21.2	23	-3
199-K-113A	E/C-KR4	10/25/2012	9.3	10/1/2013	9	11/6/2014	4	NC	-56
199-K-114A	E/C-KR4	10/1/2012	4	10/1/2013	4	11/6/2014	9	NC	125
199-K-115A	E/C-KR4	10/25/2012	22.1	10/1/2013	41	10/2/2014	47	86	15
199-K-116A	E/C-KR4	10/1/2012	17	9/4/2013	9	11/6/2014	6	-47	-33
199-K-117A	C	10/2/2012	2 (U)	10/17/2013	2 (U)	10/9/2014	8 (U)	NC	NC
199-K-119A	P-KR4	11/1/2012	5.2	12/4/2013	2.8	11/17/2014	2.4	-46	-14
199-K-125A	C	10/26/2012	5.4	12/2/2013	9.7 (U)	11/23/2014	2.7	80	-72
199-K-129/K-112A	E/C-KR4	10/26/2012	3.7 (B)	11/6/2013	5	11/6/2014	5	35	NC
199-K-130	E/C-KX	10/16/2012	17.3	11/21/2013	14	11/5/2014	14	-19	NC
199-K-131	E/C-KX	10/25/2012	11.5	11/21/2013	11	9/2/2014	10	NC	-9
699-78-62	M	—	—	11/12/2013	2 (U)	11/4/2014	1.5 (U)	—	NC
199-K-121A	I-KR4	2012 avg.	2.55	2013 avg.	1	2014 avg.	0.9	-60	-10
199-K-122A	I-KR4	2012 avg.	2.55	2013 avg.	1	2014 avg.	0.9	-60	-10

Table 3-11. Cr(VI) Concentrations in the 116-K-2 Trench Area (K North Plume), 2012 to 2014

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Decrease)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
199-K-123A	I-KR4	2012 avg.	2.55	2013 avg.	1	2014 avg.	0.9	-60	-10
199-K-128	I-KR4	2012 avg.	2.55	2013 avg.	1	2014 avg.	0.9	-60	-10
199-K-143	I-KX	2012 avg.	2.38	2013 avg.	0.6	2014 avg.	0.8	-75	33
199-K-146	E/C-KX	10/25/2012	6.7	12/2/2013	7	10/1/2014	23	4	229
199-K-147	E/C-KX	10/25/2012	16.5	11/4/2013	22	12/1/2014	15	33	-32
199-K-148	E/C-KX	10/25/2012	17.9	12/2/2013	29	11/24/2014	17.8	62	-39
199-K-149	C-KX	11/6/2012	5.3	—	—	11/14/2014	1.5 (U)	—	—
199-K-150	C-KX	12/19/2012	2 (U)	10/17/2013	2 (U)	10/9/2014	8 (U)	NC	NC
199-K-151	P	10/2/2012	4.4 (B)	11/12/2013	4.9	10/13/2014	8 (U)	11	63
199-K-152	E/C-KX	10/16/2012	57.4	11/12/2013	43.2	10/29/2014	36.3	-25	-26
199-K-153	E-KX	10/25/2012	20.6	11/21/2013	92	11/4/2014	30	345	-67
199-K-154	E-KX	10/25/2012	65.3	10/2/20123	60	10/1/2014	80	-8	33
199-K-159	I-KX	2012 avg.	2.38	2013 avg.	0.6	2014 avg.	0.8	-75	33
199-K-160	I-KX	2012 avg.	2.38	2013 avg.	0.6	2014 avg.	0.8	-75	33
199-K-161	E/C-KX	10/25/2012	7.3	11/4/2013	11	12/1/2014	43	51	291
199-K-163	E/C-KX	10/25/2012	26.8	10/2/2013	16	10/1/2014	26	-40	63
199-K-164	I-KX	2012 avg.	2.38	2013 avg.	0.6	2014 avg.	0.8	-75	33
199-K-169	I-KX	2012 avg.	2.38	2013 avg.	0.6	2014 avg.	0.8	-75	33

Table 3-11. Cr(VI) Concentrations in the 116-K-2 Trench Area (K North Plume), 2012 to 2014

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Decrease)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
199-K-170	I-KX	2012 avg.	2.38	2013 avg.	0.6	2014 avg.	0.8	-75	33
199-K-171	E/C-KX	10/25/2012	33.7	12/2/2013	33	11/24/2014	54.7 -	NC	66
199-K-172	I-KX	2012 avg.	2.38	2013 avg.	0.6	2014 avg.	0.8	-75	33
199-K-179	I-KR4	2012 avg.	2.38	2013 avg.	0.6	2014 avg.	0.9	-75	33
199-K-180	I-KX	2012 avg.	2.38	2013 avg.	0.6	2014 avg.	0.8	-75	33
199-K-182	E/C-KX	11/29/2012	66.6	11/20/2013	47.5	11/24/2014	37.2	-29	-22
199-K-193	RI/FS	11/6/2012	19.4	11/22/2013	24.4	12/2/2014	22.9	26	-6
199-K-201	RI/FS	9/20/2012	102	12/3/2013	81.2	1/6/2015	76.3	-20	-6
199-N-16	P	11/6/2012	2 (U)	—	—	—	—	—	—
199-N-71	P	11/7/2012	4 (B)	12/18/2013	4.2	11/12/2014	3.8	5	-10
Effluent annual avg. (KR4)	—	2013 avg.	2.55	2013 avg.	1	2014 avg.	0.9	-61	-10
Effluent annual avg. (KX)	—	2013 avg.	2.38	2013 avg.	0.6	2014 avg.	0.8	-75	33
21-M	AT	10/8/2012	2 (U)	9/25/2013	2 (U)	10/22/2014	2.1	NC	5
22-M/D	AT	10/9/2012	5	10/1/2013	6.2	9/17/2014	12	24	94
26-D	AT	10/11/2012	4.4 (B)	10/2/2013	2.2	10/23/2014	1.5 (U)	-50	-32
C6251	AT	10/4/2012	2 (B)	9/19/2013	3.9	10/22/2014[c]	3.9	95	NC

Table 3-11. Cr(VI) Concentrations in the 116-K-2 Trench Area (K North Plume), 2012 to 2014

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Decrease)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
C6252	AT	10/4/2012	12.5	9/19/2013	8.3	10/22/2014	8	-34	-4
C6253	AT	10/4/2012	12.2	9/19/2013	7.6	10/22/2014[c]	7.1	-38	-7
C6254	AT	10/8/2012	2 (U)	9/25/2013	2 (U)	10/22/2014	4.6	NC	130
C6255	AT	10/8/2012	9.4	9/25/2013	7.9	10/22/2014	7.6	-16	-4
C6256	AT	10/8/2012	17.2	9/25/2013	12.1	10/22/2014[c]	12.8	-30	6
C6257	AT	10/8/2012	2 (U)	9/25/2013	2 (U)	10/23/2014	1.5	NC	-25
C6258	AT	10/8/2012	2 (U)	9/25/2013	2 (U)	10/23/2014	1.5 (U)	NC	NC
C6259	AT	10/8/2012	2 (U)	9/25/2013	2 (U)	10/23/2014	1.5 (U)	NC	NC
C6260	AT	10/9/2012	2 (U)	10/1/2013	2 (U)	10/23/2014	1.7	NC	-15
C6263	AT	10/11/2012	3.8 (B)	10/2/2013	3.9	10/28/2014	2	3	-49
C6264	AT	10/11/2012	3 (B)	10/2/2013	3.5	10/28/2014	1.5 (U)	17	-57
C6265	AT	10/11/2012	4.9 (B)	10/2/2013	4.6	10/23/2014	2.7	-6	-41
DK-04-2	AT	10/30/2012	2 (U)	10/2/2013	2 (U)	10/23/2014	1.5 (U)	NC	NC
AT-K-4-M	AT	10/9/2012	2 (U)	10/1/2013	2 (U)	9/16/2014	8 (U)	NC	NC
AT-K-5-D	AT	10/9/2012	8.8	10/3/2013	7.8	9/15/2014	8 (U)	11	NC
AT-K-6-M	AT	10/11/2012	2 (U)	10/2/2013	2 (U)	9/15/2014	8 (U)	NC	NC

Table 3-11. Cr(VI) Concentrations in the 116-K-2 Trench Area (K North Plume), 2012 to 2014

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Decrease)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014

Notes: The percent change in concentration is calculated using the following formula: ([Cr(VI)] year 2 – [Cr(VI)]year 1) / [Cr(VI)] year 1). Decreases in concentration are reported as negative values. Increases in concentration are reported as positive values. Where values are reported as nondetects (i.e., "U"-qualified data), the indicated detection limit was used as the value.

Aquifer tube nomenclature regarding relative depth: D = deepest and M = middle.

The average (avg.) results for injection wells are Cr(VI) concentrations from treated effluent.

Laboratory qualifiers: U = nondetect (shown with detection limit), B = detected above instrument or method detection limit but below contract-required detection limit, and N = spiked sample recovery not within control limits.

a. Fall represents the period from September 1 to December 31 for the specified calendar year. The maximum concentration reported during this period is listed.

b. Well use: C = compliance, E = extraction, I = injection, M = monitoring, P = performance, AT = aquifer tube, E/C-KR4 = KR4 extraction/compliance, E/C-KX = KX extraction/compliance.

c. Unfiltered result was rejected. Value presented is the filtered result.

– = sample was not collected or analysis was not performed

Cr(VI) = hexavalent chromium

NC = no change in concentration; not calculated because results are both nondetect

P&T = pump and treat

RI/FS = remedial investigation/feasibility study

Table 3-12. Cr(VI) Concentrations KW Reactor Area Plume, 2012 to 2014

Well Name	Current Well Use and P&T System[b]	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Decrease)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
199-K-34	M	9/20/2012	2.6 (B)	11/4/2013	8	10/21/2014	6.7	208	-16
199-K-106A	M	11/5/2012	2 (U)	12/16/2013	8	11/21/2014	3.7	300	-54
199-K-107A	M	11/5/2012	15.3	11/22/2013	14.8	11/21/2014	11.4	-3	-23
199-K-108A	M	10/29/2012	5.1	11/22/2013	4.1	11/21/2014	5.4	-20	32
199-K-31	M	11/13/2012	7.4	11/22/2013	7.2	11/14/2014	6.6	-3	-8
199-K-132	E/C	9/4/2012	18	11/6/2013	12	9/2/2014	11	-33	-8
199-K-137	M/E	10/25/2012	33	9/16/2013	28	11/3/2014	25	-15	-11
199-K-138	E/C	9/4/2012	14	2/4/2013	14	10/8/2014	13	NC	-7
199-K-139	E	12/3/2012	16	9/5/2013	17	10/8/2014	14	6	-18
199-K-140	E	12/5/2012	13.3	9/30/2013	22.3	11/3/2014	19	68	-15
199-K-158	I (KW)	2012 avg.	2 (U)	2013 avg.	0.73	2014 avg.	1.9	-64	160
199-K-165	E	10/22/2012	80	9/5/2013	320	11/3/2014	24	300	-93
199-K-166	E	9/4/2012	35	9/16/2013	48	9/2/2014	11	37	-77
199-K-168	E	10/25/2012	35.1	10/1/2013	30	11/3/2014	20	-14	-33
199-K-173	M	9/13/2012	231	9/5/2013	101	11/3/2014	51	-56	-50
199-K-174	I (KW)	2012 avg.	2 (U)	2013 avg.	0.73	2014 avg.	1.9	-64	160
199-K-175	I (KW)	2012 avg.	2 (U)	2013 avg.	0.73	2014 avg.	1.9	-64	160
199-K-183	RI/FS	10/26/2012	6.6	11/22/2013	8.6	11/18/2014	7.7	30	-10
199-K-184	RI/FS	12/20/2012	13.8	11/22/2013	15.1	11/21/2014	11.9	9	-21

Table 3-12. Cr(VI) Concentrations KW Reactor Area Plume, 2012 to 2014

Well Name	Current Well Use and P&T System[b]	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Decrease)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
199-K-185	RI/FS	—	—	12/6/2013	5.7	11/21/2014	4.8	—	-16
199-K-196	M	11/1/2012	7.5	9/16/2013	32	11/3/2014	18	327	-44
199-K-205	E-KW	—	—	—	—	9/22/2014	1,020	—	—
199-K-206	I-KW	—	—	—	—	2014 avg.	1.9	—	—
Effluent annual avg. (KW)	—	2012 avg.	2 (U)	2013 avg.	0.73	2014 avg.	1.9	-64	160
AT-K-1-D	AT	9/24/2012	28.9	9/12/2013	6.1	9/10/2014	8 (U)	-79	31
C7641	AT	10/10/2012	2 (U)	9/16/2013	2 (U)	10/20/2014	1.7	NC	-15
C7642	AT	10/10/2012	8 (U)	9/16/2013	8 (U)	10/20/2014	3 (U)	NC	NC
C7643	AT	10/10/2012	2 (U)	9/16/2013	2 (U)	10/20/2014	4.3	NC	115

Notes: The percent change in concentration is calculated using the following formula: ([Cr(VI)] year 2 – [Cr(VI)] year 1) / [Cr(VI)] year 1). Decreases in concentration are reported as negative values. Increases in concentration are reported as positive values. Where values are reported as nondetects (i.e., "U"-qualified data), the indicated detection limit was used as the value.

The average (avg.) results for injection wells are Cr(VI) concentrations from treated effluent.

Laboratory qualifiers: U = nondetect (shown with detection limit), B = detected above instrument or method detection limit but below contract-required detection limit.

a. Fall represents the period from September 1 to December 31 for the specified calendar year. The maximum concentration reported during this period is listed.

b. Well use: C = compliance, E = extraction, I = injection, M = monitoring, P = performance, AT = aquifer tube, E/C-KR4 = KR4 extraction/compliance. E/C-KX = KX extraction/compliance.

-- = sample was not collected or the analysis was not performed

Cr(VI) = hexavalent chromium

NC = no change in concentration; not calculated because results are both nondetect

P&T = pump and treat

RI/FS = remedial investigation/feasibility study

Table 3-13. Cr(VI) Concentrations, KE Reactor Area Plume, 2012 to 2014

Well Name	Current Well Use and P&T System[b]	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Decrease)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
199-K-18	C	9/20/2012	25	10/1/2013	11.7	10/7/2014	Rejected	-53	—
199-K-32A	P	11/1/2012	9.7	12/6/2013	9.1	11/23/2014	Rejected	-6	—
199-K-32B	M	11/7/2012	6	12/6/2013	5.7	—	—	-5	—
199-K-23	M	10/31/2012	32.1	—	—	11/14/2014	2.2	—	—
199-K-11	M	11/5/2012	3.2 (B)	11/22/2013	6.2	11/23/2014	6.1	94	-2
199-K-110A	M	11/5/2012	4.5 (B)	11/22/2013	7	11/23/2014	6.7	56	-4
199-K-111A	P	10/29/2012	134	12/16/2013	556	11/23/2014	445	315	-20
199-K-120A	E/C-KR4	10/1/2012	8	11/21/2013	5.1	11/19/2014	6.2	-36	22
199-K-124A	M	10/29/2012	8	11/22/2013	4.6	12/2/2014	4.1	-43	-11
199-K-127	E/C-KR4	10/1/2012	5	11/20/2013	21	11/19/2014	3.3	320	-84
199-K-36	M	12/11/2012	131	12/6/2013	403	11/21/2014	296	208	-27
199-K-141	E-KX	9/4/2012	28	11/21/2013	29	12/2/2014	27	4	-7
199-K-142	M	11/5/2012	2 (U)	11/22/2013	2 (U)	11/23/2014	1.5 (U)	NC	NC
199-K-144	E/C-KR4	10/1/2012	49	10/2/2013	26	12/16/2014	21.1	-47	-19
199-K-145	E/C-KR4	10/1/2012	26	9/4/2013	21	12/3/2014	11	-19	-48
199-K-156	I-KX	2012 avg.	2.38	2013 avg.	0.6	2014 avg.	0.8	-75	33
199-K-157	P	10/23/2012	13	12/4/2013	9.8	11/23/2014	Rejected	-25	—

Table 3-13. Cr(VI) Concentrations, KE Reactor Area Plume, 2012 to 2014

Well Name	Current Well Use and P&T System[b]	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Decrease)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
199-K-162	E/C-KR4	10/1/2012	12	11/6/2013	4	11/19/2014	2.8	-67	-30
199-K-178	E/C-KX	10/25/2012	22.1	12/2/2013	40	12/2/2014	25	81	-38
199-K-181	C	11/5/2012	10.3	—	—	10/1/2014	16	—	—
199-K-186	RI/FS	10/23/2012	6.1	11/22/2013	10.9	11/23/2014	11.7	79	7
199-K-187	RI/FS	10/23/2012	4.7 (B)	11/22/2013	4.9	11/18/2014	3.5	4	-29
199-K-190	RI/FS	10/26/2012	14	12/6/2013	13.3	11/23/2014	10.4	-5	-22
199-K-191	RI/FS	10/26/2012	6.9	11/22/2013	10.4	11/18/2014	6.4	51	-38
199-K-192	RI/FS	10/26/2012	5.6	12/4/2013	5.9	11/23/2014	5.7	5	-3
199-K-197	M	—	—	—	—	—	—	—	—
199-K-198	M	—	—	—	—	10/2/2014	10	—	—
199-K-199	M	—	—	—	—	11/6/2014	11	—	—
199-K-200	RI/FS	12/4/2012	14.1	12/16/2013	13	12/2/2014	10.5	-8	-19
199-K-202	M	—	—	9/17/2013	21	10/13/2014	9	—	-57
C6242	AT	9/24/2012	2 (U)	9/17/2013	2.7	10/21/2014	2.2	35	-19
C6243	AT	9/24/2012	2 (U)	9/17/2013	2.4	10/21/2014	1.5 (U)	20	-38
C6244	AT	9/24/2012	2 (U)	9/17/2013	2.7	10/21/2014	1.5 (U)	35	-44
C6245	AT	10/3/2012	3.7 (B)	9/17/2013	7.5	10/20/2014	10	103	33
C6246	AT	10/3/2012	5.6	9/17/2013	5	10/20/2014	12	-11	140

Table 3-13. Cr(VI) Concentrations, KE Reactor Area Plume, 2012 to 2014

Well Name	Current Well Use and P&T System[b]	Fall[a] 2012 Unfiltered Cr(VI)		Fall[a] 2013 Unfiltered Cr(VI)		Fall[a] 2014 Unfiltered Cr(VI)		Percent Change in Concentration (Negative = Decrease)	
		Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	Date Collected	Unfiltered Concentration (µg/L)	2012 to 2013	2013 to 2014
C6247	AT	10/3/2012	11.1	9/17/2013	9	10/20/2014	11	-19	22
C6248	AT	10/4/2012	3 (B)	9/19/2013	2.5	10/22/2014	2.6	-17	4
C6249	AT	10/4/2012	6.4	9/19/2013	5.3	10/22/2014	5.6	-17	6
C6250	AT	10/4/2012	5.6	9/19/2013	5	10/22/2014	5.6	-11	12
19-D	AT	10/3/2012	2 (U)	9/17/2013	2 (U)	10/21/2014	3.6	NC	80
AT-K-2-D	AT	10/10/2012	2 (U)	9/17/2013	2.2	9/10/2014	8 (U)	10	264
AT-K-3-M	AT	10/4/2012	49.8	9/19/2013	38.9	9/11/2014	30	-22	-23

Notes: The percent change in concentration is calculated using the following formula: ([Cr(VI)] year 2 – [Cr(VI)] year 1) / [Cr(VI)] year 1). Decreases in concentration are reported as negative values. Increases in concentration are reported as positive values. Where values are reported as nondetects (i.e., "U"-qualified data), the indicated detection limit was used as the value.

The average (avg.) results for injection wells are Cr(VI) concentrations from treated effluent.

Aquifer tube nomenclature regarding relative depth: D = deep.

Laboratory qualifiers: U = nondetect (shown with detection limit), B = detected above instrument or method detection limit but below contract-required detection limit, and N = spiked sample recovery not within control limits.

a. Fall represents the period from October 1 to December 31 for the specified calendar year. The maximum concentration reported during this period is listed. If a higher result was reported in September, however, the September result is listed. If no Cr(VI) results were reported during this period, the result reported for the next closest date prior to October 1, but no earlier than September 1, is listed.

b. Well use: C = compliance, E = extraction, M = monitoring, P = performance, AT = aquifer tube, KX = expansion well.

-- = sample was not collected or the analysis was not performed

Cr(VI) = hexavalent chromium

NC = no change in concentration; not calculated because results are both nondetect

P&T = pump and treat

RI/FS = remedial investigation/feasibility study

Table 3-14. Comparison of River Protection Assessment Results

Assessed Shoreline Lengths, 100-K	2013	2014	Change from 2013 to 2014
Total length of shoreline adjacent to 100-K Area	4,000 m (13,120 ft)		
Length identified as "protected" Percent of shoreline "protected"	2,600 m (8,530 ft) 65% of shoreline	3,000 m (9,840 ft) 75% of shoreline	Additional 400 m (1,310 ft) of shoreline identified as "protected"
Length identified as "protected (action may be required)" Percent of shoreline "protected (action may be required)"	1,000 m (3,280 ft) 25% of shoreline	800 m (2,625 ft) 20% of shoreline	Net change of 200 m (655 ft) where 300 m (980 ft) of shoreline previously identified as "protected (action may be required)" now identified as protected and 100 m (325 ft) of shoreline previously identified as "not protected" now identified as "protected (action may be required)"
Length identified as "not protected" Percent of shoreline "not protected"	400 m (1,310 ft) 10% of shoreline	200 m (655 ft) 5% of shoreline	200 m (655 ft) of shoreline previously identified as "not protected" now identified as "protected" or "protected (action may be required)"

Table 3-15. Breakdown of KR4 P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)														
	2000	2001[a]	2002[b]	2003	2004	2005	2006	2007	2008	2009[f,g]	2010[h]	2011	2012	2013	2014
Design	—	96.5	55.2	70.8	163.9	190.8	97.8	187[c]	63.1	157.7	25.4	52.2	(1.7)	0.9	3.3
Treatment system capital construction	109.1	(0.1)	860.1	379.9	94.2	273.8	1,505.8	2,114.1[d]	8,368.5	6,651.0[d]	3,556.2	1,860.8	350.8[i]	30.7	78.8
Project support	143.0	188.2	257.8	171.0	211.8	851.9	530.5	489.8	963.0	174.1	77.6	94.3	58.0	109.8	83.9
Operations and maintenance	538.0	578.6	771.9	789.7	1,118.2	878.6	1,350.8	804.3	916.0	1,619.3	1,418.1	911.8	1,032.9	1,096.0	1,210.0
Performance monitoring	111.2	122.6	124.6	119.7	83.3	446.3	548.8	395.7	634.9	569.1	928.1	897.9	324.4	156.9	161.0
Waste management	481.8	367.5	343.3	684.7	475.8	198.3	230.2	458.9[e]	438.2	599.8	266.7	110.6	17.3	0.0	0.0
Field studies	—	—	—	—	—	—	—	—	—	25.0	653.1	3.0	0.2	(0.0)	0.0
Totals	**$1,383**	**$1,353**	**$2,413**	**$2,216**	**$2,147**	**$2,840**	**$4,264**	**$4,450**	**$11,384**	**$9,796**	**$6,925**	**$3,931**	**$1,782**	**$1,394**	**$1,537**

a. 2001 costs were corrected for project support and waste management. Initial expense calculations for 2001 were not properly categorized.

b. 2002 accrual costs were corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

c. Additional design costs were associated with pump and treat expansion.

d. Additional treatment system capital construction costs were associated with new wells and buildings to support pump and treat system expansion.

e. Additional costs were associated with drilling wastes and resin cleared for shipment and handling.

f. Annual report has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

g. KX P&T system costs prior to startup are included in with 2009.

h. 2010 accrual costs were corrected. The KR4 and KX expense calculations were incorrectly grouped together.

i. Includes costs for facility modifications to change ion exchange resin from Dowex 21K to ResinTech SIR-700.

— = not available

Table 3-16. Breakdown of KX P&T System Costs

Description	Actual Costs (Dollars × 1,000)				
	2010	2011	2012	2013	2014
Design	31.4	21.4	2.8	9.5	46.0
Treatment system capital construction	22.9	(1.7)	639.9[a]	62.5	462.6
Project support	77.6	94.3	58.0	161.3	221.8
Operations and maintenance	1,224.4	1,647.8	1,340.4[b]	1,875.0	1,530.6
Performance monitoring	528.9	674.9	324.4	152.0	158.4
Waste management	579.6	219.1	2.1	0.0	0.0
Field studies	—	—	—	—	0.0
Totals	**$2,465**	**$2,656**	**$2,368**	**$2,260**	**$2,419**

a. Includes costs for facility modifications to change ion exchange resin from Dowex 21K to ResinTech SIR-700.

b. Includes costs for connecting extraction Well 199-K-182 to the KX pump and treat system.

— = not available

Table 3-17. Breakdown of KW P&T System Costs

Description	Actual Costs (Dollars × 1,000)							
	2007	2008	2009[a]	2010	2011	2012	2013	2014
Design	13.0	27.7	78.1	11.6	20.0	8.6	20.6	32.4
Treatment system capital construction	2,187.8	1,088.3	2,301.8	324.3	794.8[c]	(0.4)	30.9	421.7
Project support	118.9	155.3	174.1	77.6[b]	94.3	58.0	121.0	240.9
Operations and maintenance	402.4	599.6	758.6	1,149.6[b]	1,041.3	1,055.9[d]	1,217.4	1,251.0
Performance monitoring	9.7	126.6	215.9	528.9[b]	674.9	324.4	160.0	156.9
Waste management	405.4	164.3	95.4	207.5[b]	84.0	84.6	0.0	0.0
Field studies	—	—	—	—	—	—	—	0.0
Totals	**$3,137**	**$2,162**	**$3,624**	**$2,300**	**$2,709**	**$1,531**	**$1,550**	**$2,103**

a. Annual report has been transitioned from a fiscal year reporting period to a calendar year reporting period. The cost breakdown for 2009 is for the 15-month period from October 2008 through December 2009.

b. Values were incorrectly calculated and later corrected.

c. Includes costs for facility modifications to change ion exchange resin from Dowex 21K to ResinTech SIR-700.

d. Includes costs for converting to split train operation and connecting extraction Well 199-K-173 to the KW pump and treat system.

— = not available

4 100-NR-2 Operable Unit Remediation

This chapter provides the annual performance report for 100-NR-2 OU groundwater remediation, as required by the interim action RDR/RAWP (DOE/RL-2001-27, *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit*). The purpose of this chapter is to describe the performance of the apatite PRB. An update also is provided on the remediation of total petroleum hydrocarbon (TPH)-diesel range contamination. Groundwater monitoring data collected in 2014 pertinent to the interim remedial action are also included. Discussion in this chapter includes the following:

- Section 4.1 provides a summary of the 100-NR-2 OU groundwater remedial activities that occurred during 2014.
- Section 4.2 describes water-level monitoring and hydrogeologic conditions as they relate to remedial activities.
- Section 4.3 discusses the nature and extent of strontium-90 and TPH-diesel range in the 100-NR-2 OU groundwater.
- Section 4.4 discusses the remediation of strontium-90 contamination.
- Section 4.5 discusses the remediation of TPH-diesel range contamination.
- Section 4.6 presents the 2014 costs for the apatite PRB.
- Section 4.7 and Section 4.8 present the conclusions and recommendations, respectively.

The 100-NR-2 Groundwater OU is located along the Columbia River, between the 100-KR-4 and the 100-HR-3 OUs (Figure 4-1). The 100-NR-2 OU consists of the groundwater affected by contaminant releases from waste sites and facilities in the 100-N Area. The CERCLA interim action for remediation of groundwater is identified in the interim action ROD (EPA/ROD/R10-99/112). When the interim ROD was issued in 1995, the interim action for remediation of strontium-90 in groundwater was P&T. The 100-NR-2 P&T system operated from 1995 to 2006, when it was placed in cold-standby status to facilitate a treatability test for construction of an apatite PRB along the 100-N Area shoreline. The authorization for the P&T status change in the 100-NR-2 interim action is documented in Tri-Party Agreement (Ecology et al., 1989) Change Number M-16-06-01, dated February 15, 2006.

A summary of the activities associated with installation of the 100-NR-2 OU PRB includes the following:

- 2006 – 2008: DOE emplaced a 90 m (300 ft) long apatite PRB along the 100-N Area shoreline in accordance with the strontium-90 treatability test plan for the 100-NR-2 OU (DOE/RL-2005-96). The barrier was created by injecting apatite-forming solutions into 16 wells located adjacent to the shoreline downgradient of the highest strontium-90 groundwater plume contamination between 2006 and 2008. The treatability test results were documented in PNNL-17429, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization* and PNNL-SA-70033, *100-NR-2 Apatite Treatability Test FY09 Status: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization*).
- 2009 – 2010: Based on the treatability test results, the apatite technology showed promise as a remediation option. The Tri-Parties amended the interim action ROD in 2010 to allow for permanent decommissioning of the 100-NR-2 P&T system and expansion of the existing PRB from approximately 90 m (300 ft) long to 760 m (2,500 ft) long (EPA, 2010).

Between late 2009 and early 2010, DOE completed the PRB well network installation/expansion with the addition of 146 injection wells and 25 monitoring wells; when treated these new wells would form the 760 m (2,500 ft)-long PRB along the 100-N Area shoreline where strontium-90 concentrations exceed the DWS (8 pCi/L). The wells were installed both upriver and downriver adjacent to the original 16 well 90 m (300 ft)-long PRB installed between 2006 and 2008.

- 2011: The treated portion of the PRB was expanded 90 m (300 ft) both upriver and downriver of the original treated PRB. The expansion was completed by injecting apatite-forming solutions into 24 injection wells both upriver and downriver of the original PRB. These injections extended the treated portion of the PRB to a total length of 270 m (900 ft) (SGW-56970, *Performance Report for the 2011 Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*). The barrier was expanded in accordance with the design optimization study (DOS) (DOE/RL-2010-29).
- Performance monitoring of the expanded 270 m (900 ft) long PRB continued during 2014.

Figure 4-2 shows the locations of the 100-NR-2 OU groundwater monitoring wells for 2014 and the location of the apatite PRB in relation to these wells (shown in the inset of the figure). Figures 4-3, 4-4, and 4-5 show the details for the three segments of the apatite PRB that have received apatite treatment to date.

4.1 Summary of Operable Unit Activities

The selected interim action remedy to address strontium-90 contamination in 100-NR-2 OU groundwater (EPA, 2010) consists of the following:

- Extend the length of the apatite PRB from 90 m (300 ft) to approximately 760 m (2,500 ft).

  Status: The well network for future apatite-forming solution injections to expand the PRB to 760 m (2,500 ft) was installed and completed in 2010. Future injection of apatite solutions will extend the apatite PRB throughout this network along the 100-N shoreline to intercept the strontium-90 groundwater plume before it reaches the river.

- Inject apatite-forming solutions into two 90 m (300 ft) long segments of the expanded barrier well network in accordance with two DOSs (DOE/RL-2010-29 and DOE/RL-2010-68, *Jet Injection Design Optimization Study for 100-NR-2 Groundwater Operable Unit*).

  Status: Apatite solutions were injected into 24 wells, located southwest, upriver of the original barrier and into 24 wells, located northeast, downriver of the original barrier in 2011 in accordance with DOE/RL-2010-29 (SGW-56970). These injections extended the apatite barrier by 90 m (300 ft) upriver and 90 m (300 ft) downriver. Performance monitoring was conducted for all three barrier segments (upriver, central [original], and downriver) during 2014.

  Jet injection of apatite into the vadose zone along the PRB well network to enhance the existing PRB treated interval has not been conducted.

- Apply one additional round of apatite injections within 5 years of completion of all first-round apatite injections.

  Status: All first-round apatite injections have not yet been completed. Injection of the remainder of the apatite barrier network wells with apatite forming solutions is anticipated during 2016–2018.

- Use monitored natural attenuation.

  Status: Strontium-90 in the aquifer is naturally attenuating through radioactive decay. Groundwater monitoring wells are periodically sampled to assess the ongoing decline in contaminant concentrations within the groundwater OU.

- Decommission the existing 100-NR-2 groundwater P&T system building and components. The P&T system has not been operated since March 2006.

  Status: The in-well P&T equipment (e.g., pumps) has been removed, and the extraction and injections wells have been returned to routine groundwater sampling schedules. The P&T system buildings and components have not yet been decommissioned.

- Maintain existing ICs.

  Status: Existing ICs include entry restrictions (security), escorts and badging of site visitors, excavation permits, surveillance, posted signs, deed notifications to restrict land and groundwater use (DOE/RL-2001-27). Existing ICs are being maintained.

- Maintain the riprap cover along the shoreline.

  Status: The riprap cover was placed over the groundwater seeps and springs along the shoreline. The existing riprap cover is being maintained.

- Perform periodic groundwater monitoring.

  Status: Periodic groundwater monitoring is performed in accordance with approved SAPs and complies with RCRA and CERCLA requirements (Section 4.3)

The selected interim action remedy to address TPH contamination in 100-NR-2 OU groundwater (EPA/ROD/R10-99/112) consists of the following:

- Remove petroleum hydrocarbon (free-floating product) from any groundwater monitoring well.

  Status: Removal of petroleum hydrocarbon light nonaqueous-phase liquid (NAPL) from Well 199-N-18 continued in 2014.

4.2 Water-Level Monitoring

Under natural conditions, groundwater generally flows northwest toward the Columbia River beneath the 100-N Area. The magnitude of the difference in groundwater hydraulic head across the 100-N Area in March 2014 was about 2 m (6.6 ft) (Figure 4-6). Groundwater flow in 2014 continues to be influenced by groundwater extraction and injection through wells installed in the southwestern portion of the 100-N Area as part of the KX P&T remediation system for the 100-KR-4 OU (Chapter 3). A small groundwater mound approximately 1 m (3 ft) high surrounding the KX P&T system injection wells creates local radial flow. The river stage can change daily (±1.5 m [5 ft]) and seasonally (±2.4 m [7.8 ft]) for sustained periods, which affects the saturated zone thickness and may create temporal flow reversals (Section 1.1 of PNNL-16891, *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO4 Solution Injection and Sr-90 Immobilization in 100-N Sediments*).

Groundwater flow in the 100-NR-2 OU is influenced by the Columbia River stage. Columbia River water stage is controlled by releases of water at Priest Rapids Dam upstream from the 100-N Area. Figure 4-7 compares the estimated river stage at the 100-N Area derived from water elevation data from Priest Rapids Dam and water levels recorded from the automated water-level monitoring station in Well 199-N-146 for 2014. As shown in Figure 4-7, the groundwater elevation in Well 199-N-146 (located near the 100-NR-2 OU river shoreline) is similar to the river elevation at the 100-N Area. Since Well 199-N-146 is on the AWLN, the water-level elevation in this well is used to represent river elevation along the 100-N Area shoreline.

The estimated average river stage at the 100-N Area for 2014 was 118.50 m (388.7 ft) (Table 4-1) derived from water-elevation data from Priest Rapids Dam. Table 4-1 compares the yearly average river stages over

the last 10 years. The values in the table indicate that minor changes have occurred from year to year and that the difference is usually less than 1 percent. During 2014, high river stage is the period from March 15 through August 7 and low river stage is the period from August 16 through December 2 (Figure 4-7).

Water levels in wells respond to changes in river stage. Wells on the river shoreline respond very quickly to changes in river levels, and the response is delayed in wells further inland from the river. It can take several days before a change in river level has an effect on wells further inland; however, unless the river level stays high or low for several days or more in a row, the effect may not have propagated inland to a great distance that would be noticeable at inland locations. This effect is due to the relatively low permeability of the saturated Ringold Formation sediment that comprises the unconfined aquifer beneath most of the 100-N Area.

The 2014 hydrographs for three 100-N Area monitoring wells are shown in Figure 4-8; the locations of the wells are shown in Figure 4-2. Well 199-N-146, on the 100-N Area shoreline approximately 2 m (6.5 ft) inland from the river, has the most variable (and responsive) water-level elevation graph because it is highly influenced by nearby river-level changes (see comparison to river stage in Figure 4-7). Wells 199-N-3 and 199-N-72 (approximately 107 and 762 m [351 and 2,500 ft], respectively, from the river) have much smoother hydrographs. River-level changes influence these wells more gradually, and they have delayed responses compared to Well 199-N-146. However, the effects of high and low river-stage influences are also visible at these inland wells (Figure 4-8). Table 4-2 provides the average water levels in these three wells for days representing low and high river stage.

In 2014, the water level in Well 199-N-146 (and inferred river stage) increased by approximately 1.57 m (5.2 ft) in May. Water levels in Well 199-N-2, 170 m (557.7 ft) from the river, rose approximately 0.94 m (3.1 ft) with a lag time of approximately 21 days (Figure 4-9). Water levels in Well 199-N-50, 425 m (1,394.4 ft) from the river, rose more than 1.04 m (3.4 ft) with a shorter lag time than Well 199-N-2. The water table at Well 199-N-50 appears to respond more quickly than at Well 199-N-2, which is located closer to the river. This suggests that the saturated formation near Well 199-N-50 is more permeable than near Well 199-N-2.

Vertical hydraulic gradients are difficult to measure in the unconfined aquifer at the 100-NR-2 OU. The differences in water levels in well pairs 199-N-81/199-N-70, 199-N-119/199-N-121, and 199-N-182/199-N-184 were negligible. The largest difference was only 0.05 m (1.97 in.), recorded in the 199-N-81/199-N-70 Well pair during 2014. The screen depths differ by approximately 5 to 6 m (16.4 to 19.7 ft).

4.3 100-NR-2 Operable Unit Groundwater Contaminants

The following discussion summarizes the results of 2014 groundwater monitoring in the 100-NR-2 OU. Wells and constituents were monitored in 2014 in accordance with the following documents:

- DOE/RL-2001-27, Rev. 1 (October through December 2014)
- DOE/RL-2001-27, Rev. 0 (January through September 2014), as modified by the following:
  - TPA-CN-256, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: DOE/RL-2001-27, Rev 0, Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit and the Interim Action Waste Management Plan for the 100-NR-2 Operable Unit, DOE/RL-2000-41, Rev. 1*
  - TPA-CN-569, *Tri-Party Agreement Change Notice Form: DOE/RL-2001-27, Rev 0, Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit*
- DOE/RL-2008-46-ADD5, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 5: 100-NR-1 and 100-NR-2 Operable Units*, and the associated SAP (DOE/RL-2009-42, *Sampling and Analysis Plan for the 100-NR-1 and 100-NR-2 Operable Units Remedial Investigation Feasibility Study*), as modified by the following:
  - TPA-CN-478, *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study, DOE/RL-2009-42, Rev. 0*
- DOE/RL-2000-59, *Sampling and Analysis Plan for Aquifer Sampling Tubes*, as modified by the following:
  - TPA-CN-353, *Change Notice for Sampling and Analysis Plan for Aquifer Sampling Test Tubes, DOE/RL-2009-59, Rev. 1*

The following subsection describe the analytical monitoring results for strontium-90 and TPH-diesel range in groundwater which are the contaminants being remediated through the 100-NR-2 OU interim actions. Results for these and other contaminants of interest also are summarized in the annual groundwater monitoring report (DOE/RL-2015-07).

4.3.1 Strontium-90

The primary source of the strontium-90 contamination in the subsurface of the 100-N Area was liquid waste disposal to the 116-N-1 and 116-N-3 waste sites. The size and shape of the strontium-90 plume changes very little from year to year, except near the apatite PRB. The plume extends from beneath the 116-N-1 and 116-N-3 waste sites to the Columbia River at concentrations above the DWS (8 pCi/L) (Figure 4-10). The highest concentration portion of the strontium-90 groundwater plume (i.e., the area with concentrations exceeding 800 pCi/L) primarily underlies the 116-N-1 Trench and the 116-N-3 Crib. The lateral distribution of the groundwater plume with concentrations between 8 and 800 pCi/L is found peripheral to the highest concentration, in a distribution consistent with historical radial flow away from the two waste sites and elongated toward the river parallel to the 116-N-1 waste site.

Because strontium-90 adsorbs strongly to sediment grains, the majority of the strontium-90 remaining in the subsurface in the 100-N Area is in the vadose zone above the aquifer. The high sorption (i.e., a high distribution coefficient) of strontium-90 also causes its rate of transport in groundwater toward the Columbia River to be considerably slower than the groundwater flow rate. The relative velocity of strontium-90 compared to that of groundwater is approximately 1 to 100 (PNNL-19572). Strontium-90 is found in the upper portion of the unconfined aquifer, and concentrations decrease with depth; deeper wells are essentially free of strontium-90 contamination. The lateral extent of the strontium-90 groundwater plume is similar to the lateral extent of residual strontium-90 in the vadose zone.

Residual strontium-90 contamination in the 100-N Area is primarily adsorbed to sediments by IX in the lower vadose zone and upper portion of the unconfined aquifer. Approximately 99 percent of the strontium-90 is adsorbed, and 1 percent remains in solution in the groundwater. Although primarily adsorbed, some strontium-90 is remobilized by seasonal water-level increases that release strontium-90 from sediments not usually in contact with groundwater (PNNL-16891).

Strontium-90 concentration trends in monitoring wells near the 116-N-1 waste site show no obvious long-term decline but do show significant variability related to water levels. Figure 4-11 shows strontium-90 concentrations and water levels in Well 199-N-67 (located just downgradient of the liquid waste disposal end of the 116-N-1 Trench). Figure 4-12 shows strontium-90 concentrations and water levels in Well 199-N-105A, which is located further downgradient and further along the disposal trench. When the water table rises, some of the residual strontium-90 adsorbed to sediment in the deep vadose zone is released to groundwater, and concentrations in the groundwater increase. When the water table decreases, strontium-90 resorbs to sediment, and concentrations in the groundwater decrease. Annual concentration peaks are correlated with periods when the water table was higher and saturated the lower vadose zone (Ringold Formation) containing residual strontium-90 contamination.

Strontium-90 concentrations along with the water table elevation in Well 199-N-81 (downgradient of the 116-N-3 Trench) have declined since the late 1990s (Figure 4-13). However, high water table elevations in 2011 and 2012 have caused a slight increase in the strontium-90 concentration that continued into the fall 2014 sampling. Based on the correlation observed between water table elevation and strontium-90 concentrations in Well 199-N-81, concentrations are expected to stabilize or decline slightly as the water table returns to lower elevations. The positive variation of strontium-90 concentration with water-level changes may be more pronounced at wells nearer to the 116-N-1 waste site, which received a much larger mass of strontium-90 than the 116-N-3 waste site and presumably has more residual strontium-90 in the lower vadose zone downgradient of the 116-N-1 waste site than near 116-N-3. Table 4-3 provides the strontium-90 concentrations in selected monitoring wells and aquifer tubes. While strontium-90 concentrations in groundwater fluctuate with groundwater elevation, the high sorption rate for strontium-90 results in very little mass flow of contaminant in groundwater toward the river over time.

The highest strontium-90 concentrations in groundwater in the near-shore area along the Columbia River were found near the original segment of the apatite PRB and downriver to the northeast (Figure 4-10). This region of the 100-N Area river shore was impacted by highly contaminated effluent during operations of the 116-N-1 waste site. Effluent discharged to the 116-N-1 waste site emerged at the steeply sloping near-shore surface as springs along the shoreline because of the artificially elevated water table (also known as N Springs). This contaminated area has been the focus of increased monitoring and remediation.

Strontium-90 concentrations in aquifer tubes are consistent with those seen in monitoring wells. Concentrations greater than the DWS are present only above approximately 115 m (377 ft) amsl (i.e., the top 2 to 3 m [6.5 to 9.8 ft] of the aquifer); thus, most of the aquifer tubes are screened at this elevation interval. The majority of the aquifer tubes completed above this elevation are in the area where strontium-90 concentrations along the river are known to be the highest. The maximum concentrations in the aquifer tubes in 2014 are shown in Figure 4-10. The maximum strontium-90 concentration in 2014 was 845 pCi/L in Aquifer Tube NVP2-116.0, which is a slight decrease from the peak value in 2013.

The only strontium-90 detections in aquifer tubes outside of the area where the main strontium-90 plume intersects the Columbia River (Figure 4-10) are found upriver at aquifer tube cluster C7934/C7935/C7936. These aquifer tubes are located near the engineered fill around the 1908-N Outfall, on the back side of the N Reactor building, which indicates that outfall construction created a preferential pathway in the fill for contaminant migration. Potential sources of strontium-90 contamination at this location include the N Reactor building/FSB, the 1909-N Waste Disposal Valve Pit, the 107-N Basin Recirculating Cooling Facility, the 1304-N Emergency Dump Tank, the 1300-N Emergency Dump Basin, and other associated structures (Section 4.2 of SGW-49370, *Columbia River Pore Water Sampling in 100-N Area, December 2010*). Three new groundwater wells are proposed for installation in this area in 2015. Analytical results for vadose zone and groundwater samples collected during drilling are expected to reduce the uncertainty about the source of the strontium-90.

4.3.2 Total Petroleum Hydrocarbon-Diesel

The primary source of the TPH-diesel groundwater contamination was a 1966 diesel fuel tank spill (UPR-100-N-17) (Figure 4-14). A small, relatively narrow groundwater plume persists downgradient from the spill location to the river. The highest TPH-diesel concentration in groundwater in 2014 was 18,000 µg/L (Well 199-N-346), which is a substantial decrease from the 2011 and 2010 maximum concentrations (Well 199-N-18) of 48,000 and 420,000 µg/L, respectively, but an increase from the 2013 maximum concentration of 9,450 µg/L (Well 199-N-171). Well 199-N-18 is being used for removal of TPH-diesel free product (Section 4.5) and was last sampled in 2011. Prior to 2014, Well 199-N-346 was last analyzed for TPH-diesel in 2010 with a maximum concentration of 3,700 µg/L.

The overall reduction in TPH-diesel concentrations in 2012 through 2014 is attributed primarily to the bioventing remediation being conducted for remediation of diesel in the deep vadose zone at UPR-100-N-17. The bioventing pilot test was conducted in 2010 and 2011 (WCH-490, *UPR-100-N-17; Bioventing Pilot Plant Performance Report*), and the full-scale bioventing remediation was initiated in 2012 (Appendix H of DOE/RL-2005-93, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*) (Section 4.5.1). Introduction of large amounts of air into the vadose zone injection wells contributes to an increased rate of diesel biodegradation and possible reduction in the residual flux to the aquifer. Continued monitoring will indicate whether a long-term groundwater concentration decrease has occurred.

TPH-diesel is also detected in two aquifer tubes located on the river shore immediately adjacent and downgradient of the TPH-diesel plume in groundwater. During 2014, the maximum TPH-diesel concentration in Aquifer Tubes N116mArray-0A was 2,200 µg/L. Samples were collected in September when the river level was low. Diesel contamination is more likely to be detected in aquifer tubes under these conditions when groundwater flows into the river.

The data used to prepare the 2014 plume maps include routine groundwater monitoring data and monitoring data for the in situ bioventing project. In 2014, the in situ bioventing project collected groundwater performance monitoring data in June 2014 and January 2015, at high and low water table, respectively. The performance monitoring results quantified petroleum contamination in the diesel to motor oil range (C10 through C36). The routine monitoring program analyzes diesel/Bunker C range only (C10 through

C28). The extent of the petroleum plumes using the July and December performance monitoring results are shown in Figures 4-15 and 4-16 and are similar in extent to the annual average TPH-diesel plume (Figure 4-14).

4.4 Strontium-90 Remediation

During 2014, the 274 m (900 ft) long apatite PRB continued to perform to reduce the flux of strontium-90 contamination in the 100-NR-2 OU groundwater in accordance with the amended interim action ROD (EPA, 2010). The apatite PRB was formed by injecting a high-concentration calcium-citrate-phosphate solution into the aquifer through a network of vertical wells (i.e., the barrier well network). After the solution is injected, biodegradation of the citrate results in formation of apatite, a calcium phosphate mineral ($Ca_5[PO_4]_3[F, Cl, OH]$). Strontium ions (including strontium-90) in groundwater substitute for calcium ions in apatite via cation exchange and eventually become trapped as part of the mineral matrix during apatite crystallization (PNNL-16891, Section 1.3). The strontium-90 is sequestered within the apatite PRB as contaminant-laden groundwater flows through the barrier. The sequestered strontium-90 continues to decay in place within the barrier.

4.4.1 Permeable Reactive Barrier Performance Monitoring

Performance monitoring of the 274 m (900 ft) apatite barrier was conducted twice in 2014. Groundwater samples were collected from performance monitoring wells and aquifer tubes during high river stage in June and during low river stage in September. A comparison of fall 2014 data to pre-treatment baseline conditions is shown in Table 4-4. Table 4-5 lists the monitoring points for the 760 m (2,500 ft) long apatite barrier and indicates which points are being used to monitor the three treated segments of the barrier. Table 4-6 lists the injection wells for the 760 m (2,500 ft) long barrier and indicates which sections have been treated as of 2014.

The central (original) segment of the apatite PRB extends approximately 90 m (300 ft) along the Columbia River shoreline (Figure 4-4). Sixteen injection wells comprise the PRB well network in the central segment, and four performance monitoring wells are located between the river and the barrier wells (Table 4-6). Apatite-forming solutions were injected into the Hanford formation and Ringold Formation over a period of 3 years (from 2006 through 2008).

The 90 m (300 ft) long upriver and the 90 m (300 ft) long downriver segments of the apatite barrier were injected with apatite solutions in fall 2011 (Figures 4-3 and 4-5). The barrier well networks in each of these segments consist of 24 injection wells (Table 4-6). The apatite barrier extensions increased the length of 100-N Area shoreline treated to sequester strontium-90 from 90 m to approximately 274 m (300 ft to approximately 900 ft) (SGW-56970). The barrier was expanded in accordance with the DOS (DOE/RL-2010-29), which had seven objectives for evaluating barrier implementation and effectiveness. Data from the injections and subsequent performance monitoring are used to evaluate these objectives in SGW-56970.

Following the apatite injections in 2008 in wells in the central (original) segment of the barrier, strontium-90 concentrations declined in the performance monitoring wells (Figure 4-17). The wells showed temporary, higher strontium-90 concentrations immediately following injection of the apatite solution, which had a higher ionic strength than groundwater and temporarily mobilized cations and anions, causing their concentrations in groundwater to increase. Strontium-90 concentrations in performance monitoring Wells 199-N-122 and 199-N-123, which are near the upriver and downriver ends of the central barrier segment, temporarily increased again following injections into the nearby upriver and downriver barrier extension wells in 2011. These temporary elevated concentrations have since declined (Figure 4-17).

As of fall 2014, the strontium-90 concentrations were still considerably lower in the performance monitoring wells along the central segment of the barrier than before the injections started in 2006. The treatability test-plan objective was a 90 percent reduction in strontium-90 groundwater concentrations in the performance monitoring wells (DOE/RL-2005-96, Section 4.4.3). The post-injection data indicate that the strontium-90 concentrations in groundwater have been reduced by approximately 90 percent in three of the four performance monitoring wells (Figure 4-18). The percent reduction in strontium-90 concentrations ranged from 74 percent (Well 199-N-146) to 90 percent (Well 199-N-123) in the fall (Table 4-4), and 85 percent (Well 199-N-146) to 95 percent (Well 199-N-123) in the spring.

In the performance monitoring wells along the upriver barrier extension, the percent reduction in strontium-90 concentrations in 2014 (the third year following the injections) ranged from 10 percent (Well 199-N-347) to 98 percent (Well 199-N-96A) (Table 4-4 and Figure 4-19) in the fall, and 44 percent (Well 199-N-347) to 99 percent (Well 199-N-348) in the spring. This segment of the barrier forms the furthest upriver portion of the barrier near the outside edge of the strontium-90 groundwater plume. The relatively low percent reduction in Well 199-N-347 reflects comparison of the low baseline strontium-90 concentration in this well (the strontium-90 concentration was nondetect, and the strontium-90 concentration estimated from gross beta was 7.0 pCi/L) to the low strontium-90 concentration measured during September 2014 performance monitoring (6.3 pCi/L). Both the baseline and the September 2013 sample concentrations are below the DWS (8 pCi/L). Because concentrations in Well 199-N-347 are below the DWS, the percent reduction in strontium-90 concentrations in this well is not plotted in Figure 4-19. The percent strontium-90 concentration reduction from 2014 low river stage monitoring for Well 199-N-349 was 44 percent. Ongoing monitoring will determine PRB effectiveness at this location.

The downriver extension intercepts higher strontium-90 groundwater concentrations than the upriver extension and indicates an initial successful barrier performance. The percent reduction in strontium-90 concentrations in 2014 at the performance monitoring wells along the downriver barrier extension ranged from 54 percent (Well 199-N-351) to 95 percent (Well 199-N-353) (Table 4-4) in the fall, and 91 percent (Well 199-N-351) to 96 percent (Well 199-N-352) in the spring. The percent strontium-90 concentration reduction from 2014 low river stage monitoring at Well 199-N-351 of 54 percent is a significant decrease from the 87 percent reduction observed in 2013 (Figure 4-20). Ongoing monitoring will determine PRB effectiveness at this location.

Semiannual performance monitoring (high and low river stages) will continue for the apatite PRB during 2015. Ongoing monitoring will determine the continued effectiveness of the apatite treatment along the expanded barrier.

4.4.2 Permeable Reactive Barrier Extensions

No additional treatment to expand the PRB occurred in 2014. Activities to expand the treated portion of the PRB by 305 m (1,000 ft) were initiated in 2014 and included refurbishing the injection skids, procuring piping and injection amendment monitoring instrumentation, procuring chemicals and storage tanks, and preparing internal contractor injection plans and work documents. Activities were also conducted in 2014 to procure services to emplace apatite within the vadose zone overlapping the treated saturated portion of the PRB.

To carry out the barrier expansion, both in the saturated zone by chemical injection and in the vadose zone by jet injection, Rev. 0 of DOE/RL-2001-27, *Remedial Design/Remedial Action Work Plan for the 100-NR-2 Operable Unit*, was revised to include a SAP for the barrier expansion. DOE/RL-2001-27, Rev. 1 was issued in September 2014.

The schedule to perform the PRB extension in 2014 was based on working within previously disturbed locations outside of any traditional cultural property. However, a boundary revision to an existing traditional cultural property boundary became effective in January 2014. The new boundary encompasses the project area. A cultural review of the project activities addressing the requirements of the *National Historic Preservation Act of 1966* Section 106 process (specifically, 36 CFR 800.3 through 800.5, "Protection of Historic Properties") have deemed the project to have an "adverse effect" on the traditional cultural property, as defined in 36 CFR 800.5(b). As such, the work involved in completion of the barrier is dependent upon completion of the *National Historic Preservation Act of 1966* Section 106 reviews and is subject to schedule delays pending establishment of a memorandum of understanding to conduct the project activities that are deemed to have an adverse effect on the traditional cultural property. Efforts to establish a memorandum of understanding for expansion of the PRB will continue in 2015.

4.5 Total Petroleum Hydrocarbon–Diesel Remediation

Throughout its operational history, the N Reactor and support facilities had UPRs of petroleum products. The types of releases included corrosion failure of diesel and fuel oil piping systems, overfilling of storage facilities, and spills during fuel transfers. Two of the releases were substantial, resulting in petroleum hydrocarbon contamination through the vadose zone and into the groundwater. Estimates made in reports at the time of operation indicate that up to 39,000 m^3 (1,377,272 ft^3) of soil was contaminated with petroleum hydrocarbons (Section 1.1 of WCH-323, *Sampling and Analysis Instruction for Installation of UPR-100-N-17 Bioremediation Wells and Performance of Bioventing Pilot Tests*). The releases occurred in two general areas and in other isolated areas, and the releases were divided in three groups based on their occurrences. Table 4-7 shows these three groups and the associated releases:

- **Group 1:** Includes releases (UPR-100-N-17) near the 1715-N Storage Tanks and 166-N transfer areas (166-N Tank Farm). Figures 4-14 and 4-21 show this location and nearby monitoring Well 199-N-183 (replacement for Well 199-N-18).
- **Group 2:** Includes releases (UPR-100-N-42) around the 184-N Day Tank Storage Facility. Groundwater Well 199-N-16 was used to monitor this location; this well is now decommissioned, but a new groundwater monitoring well is planned near this location.
- **Group 3:** Includes miscellaneous other sites.

Only the release from Group 1 has resulted in persistent groundwater contamination. Remediation continued in 2014 for the residual petroleum hydrocarbon contamination in the vadose zone and in groundwater at the 100-N Area.

4.5.1 Vadose Zone

DOE is using in situ bioventing to remediate TPH-diesel contamination identified in the deep vadose zone beneath the UPR-100-N-17 release at the 100-N Area. Oxygen is introduced into the deep vadose zone to promote microbial activity, enhancing hydrocarbon degradation. The oxygen stimulates natural, in situ aerobic biodegradation of the TPH-diesel in the deep vadose zone to carbon dioxide and water. Some natural biodegradation of diesel is also occurring in groundwater, as shown by the anomalously low nitrate groundwater concentrations that are coincident with the TPH groundwater plume but within the larger regional nitrate plume in this area (Figure 4-22).

A pilot test for bioventing was conducted from February 2010 through May 2011 to evaluate contaminant removal rates and the distribution of airflow within the vadose contaminated zone. All results of the pilot test are provided in WCH-490.

Data from the bioventing pilot test were used to support the design of a full-scale bioventing system. Full-scale bioventing system operations began at UPR-100-N-17 in December 2012 using two injection wells (199-N-167 and 199-N-172), two vadose zone vapor monitoring wells (199-N-169 and 199-N-171), and eight groundwater monitoring wells (199-N-3, 199-N-19, 199-N-56, 199-N-96A, 199-N-169, 199-N-171, 199-N-173, and 199-N-183) (Appendix H of DOE/RL-2005-93). Groundwater monitoring samples from the eight performance monitoring wells and two aquifer tubes (N116mArray-0A and C6132) were collected for high and low water conditions in 2014. High water samples were collected in June 2014, and low water samples were collected in January 2015. A third aquifer tube (C6135) sampled in previous years was broken and could not be sampled in 2014.

Table 4-8 provides the TPH-diesel groundwater concentrations for the eight performance monitoring wells (Figure 4-14). The performance of the full-scale bioventing system during 2014 is provided in WCH-600, *Annual Operations and Monitoring Report for UPR-100-N-17: November 2012 - February 2014*, and DOE/RL-2015-20, *Annual Operations and Monitoring Report for UPR-100-N-17: March 2014 – February 2015*.

Semiannual performance monitoring (high and low river stages) will continue for the bioventing system in 2015. Ongoing monitoring will determine the continued effectiveness of the bioventing remediation for the TPH-diesel plume.

4.5.2 Groundwater

The groundwater containing the TPH-diesel plume, also associated with the UPR-100-N-17 release, is being remediated to remove remaining free product. The CERCLA interim action for remediation of TPH-diesel in groundwater is identified in the interim action ROD (EPA/ROD/R10-99/112). The interim action ROD specifies that petroleum hydrocarbons (free-floating product) will be removed if observed in a monitoring well.

If present as NAPL (or free product), the TPH-diesel in groundwater is found in the shallowest portion of the aquifer or floating on top of the water table (Section 4.4 of DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and 100-NR-2 Groundwater Remediation*). Removal of free product from Well 199-N-18 continued in 2014 in accordance with the interim action ROD (EPA/ROD/R10-99/112). The diesel is removed using a polymer "smart sponge" that selectively absorbs petroleum products from the groundwater within the well. Approximately every 2 months, two sponges are lowered to the surface of the aquifer in Well 199-N-18 and left to soak up the diesel. The sponges are weighed prior to placement in the well and again after removal. The weight difference between the two measurements is the amount of diesel fuel removed from the well. In 2014, 550 g of diesel were removed from Well 199-N-18 (Table 4-9). Removal of petroleum product from this well will continue in 2015.

Table 4-10 provides the TPH-diesel concentrations in the known area of the diesel plume for selected sampled wells and aquifer tubes (Figure 4-14). Table 4-11 provides the TPH-diesel concentrations for the adjacent upriver apatite barrier extension injection and performance monitoring wells.

The TPH-diesel range concentrations in wells in the groundwater plume were reduced between 2010 and 2011. This reduction may be attributed to biodegradation of TPH in the vadose zone and periodically rewetted sediments by the bioremediation pilot study and reducing potential source from water elevation changes in the periodically rewetted zone. In 2012, following the pilot test and prior to implementation of the full-scale system, concentrations of TPH-diesel range organics were elevated above levels measured during the previous 2 years in all the monitored wells that had previous detections, and concentrations have been reduced following startup of full-scale bioventing operations. This increase may indicate rebound of the TPH-diesel concentrations in the absence of large volumes of introduced air.

Comparison of TPH-diesel range data to water levels at the time of well sampling shows that wells sampled during higher water levels had lower concentrations than when sampled during low water levels. As a result, concentration decreases that occurred in 2011 may have been due, in part, to this effect because most of the wells were sampled during high water levels. The wells sampled in 2014 during lower water levels had higher diesel concentrations compared with concentrations reported during higher water levels.

4.6 100-NR-2 Apatite Permeable Reactive Barrier System Costs

This section summarizes the costs for the 100-NR-2 apatite PRB for 2014. The primary categories of expenditures are described as follows:

- **Capital design:** Includes design activities to construct the PRB and designs for system expansion.
- **Capital construction:** Includes oversight labor, material, and subcontractor fees for capital equipment, initial construction, construction of new wells, well injections, and modifications to the PRB.
- **Project support:** Includes project coordination-related activities and technical consultation, as required, during the course of the system design, construction, acceptance testing, and operation.
- **O&M:** Represents facility supplies, labor, and craft supervision costs associated with operating and maintaining the former P&T system.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis.
- **Waste management:** Includes the cost for the management at the 100-NR-2 OU in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes.
- **Barrier maintenance:** Includes costs for maintenance of the PRB, including well injections and modifications to the PRB.

The cost breakdown for 2014 for the apatite PRB is presented in Table 4-12 and Figure 4-23. The total 2014 remedial action costs was $2,331,000. The increase compared to 2013 costs is attributed to costs incurred from activities and procurements to expand the PRB (described in Section 4.4.2). The cost breakdown indicates that the majority of the 2014 costs were for performance monitoring (46 percent), barrier maintenance (46 percent), and project support (8 percent). Costs for field studies, waste management, design, and treatment system capital construction were negligible.

4.7 Conclusions

Conclusions for the 100-NR-2 OU are as follows:

- **RAO #1:** Protect the Columbia River from adverse impacts from the 100-NR-2 OU groundwater so designated beneficial uses of the Columbia River are maintained.

  Results: The PRB captures strontium-90 contamination moving in groundwater along the section of the 100-N Area shoreline with the highest historical groundwater contamination. DOE plans to expand the PRB in the future.

  The TPH-diesel plume bioremediation and free-product removal continues to reduce the contaminant mass in groundwater and the lower vadose zone that could eventually affect the river.

- **RAO #2:** Protect the unconfined aquifer by implementing remedial actions that reduce concentrations of radioactive and nonradioactive contaminants in the unconfined aquifer.

Results: The P&T system was not effective at removing strontium-90 from the groundwater because strontium-90 strongly adsorbs to sediment grains; therefore, the P&T system was placed in cold-standby status on March 9, 2006.

The apatite PRB was installed along the river shore to sequester the strontium-90 while it naturally decays. Apatite solutions were injected in wells of the central (original) barrier segment from 2006 to 2008 and in wells of the upriver and downriver segments in 2011. Strontium-90 concentrations in some monitoring wells near the apatite PRB temporarily increased in response to the apatite injections. The concentrations in most of these wells in 2014 were lower than pre-injection levels by at least 90 percent. However, concentrations of strontium-90 have begun to increase slightly in some monitoring wells.

Smart sponges deployed in Well 199-N-18 removed 550 g of TPH-diesel free product in 2014.

A full-scale bioventing system for remediation of TPH-diesel in the deep vadose zone near waste site UPR-100-N-17 was implemented in December 2012 and continued to operate in 2014. The performance evaluation for 2014 is documented in separate reports (WCH-600; DOE/RL-2015-20).

- **RAO #3:** Obtain information to evaluate technologies for strontium-90 removal and evaluate ecological receptor impacts from contaminated groundwater.

  Results: A 270 m (900 ft) long apatite PRB is installed near the Columbia River shoreline. The remainder of the planned PRB extension to approximately 760 m (2,500 ft) will be performed in the future.

  Three other types of strontium-90 remediation technologies were tested for potential use in the 100-NR-2 OU in addition to the apatite PRB. Passive infiltration did not prove to be a viable method for emplacement of apatite-forming chemicals along the 100-N Area shoreline. Jet injection tests showed that the technology could effectively place apatite or apatite-forming chemicals into the upper vadose zone with good coverage. Phytoextraction has the potential to remove strontium-90 from the shoreline area, as demonstrated by greenhouse and laboratory (growth chamber) studies of strontium-90 uptake, and field studies in a contaminant-free location at the 100-K Area. No additional work on these technologies occurred in 2014.

  Technologies for remediation of strontium-90 were evaluated in the RI/FS report for the 100-NR-1 and 100-NR-2 OUs (DOE/RL-2012-15, *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units*).

- **RAO #4:** Prevent destruction of sensitive wildlife habitat. Minimize disruption of cultural resources and wildlife habitat, in general, and prevent adverse impacts to cultural resources and threatened or endangered species.

  Results: The interim remedial action ROD (EPA/ROD/R10-99/112) establishes a variety of ICs that must be implemented and maintained throughout the interim action period. These provisions include the following:

  - Access control and visitor escorting requirements
  - Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)
  - Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
  - Regulatory agency notification of any trespassing incidents

4.8 Recommendations

Recommendations for the 100-NR-2 OU are as follows:

- Continue to monitor strontium-90 concentrations in the performance monitoring wells for the expanded apatite PRB.
- Continue apatite barrier expansion along the currently untreated portions of the shoreline.
- Collect groundwater samples to evaluate the vertical distribution of TPH-diesel in the aquifer and the locations and thicknesses of free product at the top of the water table. Continue to remove TPH-diesel free product from Well 199-N-18 using the smart sponge technology. Evaluate the optimal interval for change out of the sponge technology.

Continue to evaluate the extent of possible shoreline water quality impacts related to the diesel spill that occurred in about 1966 (UPR-100-N-17). Aquifer tubes at the upstream end of the array and groundwater monitoring wells within the TPH-diesel plume will continue to be sampled for TPH-diesel and related contaminants.

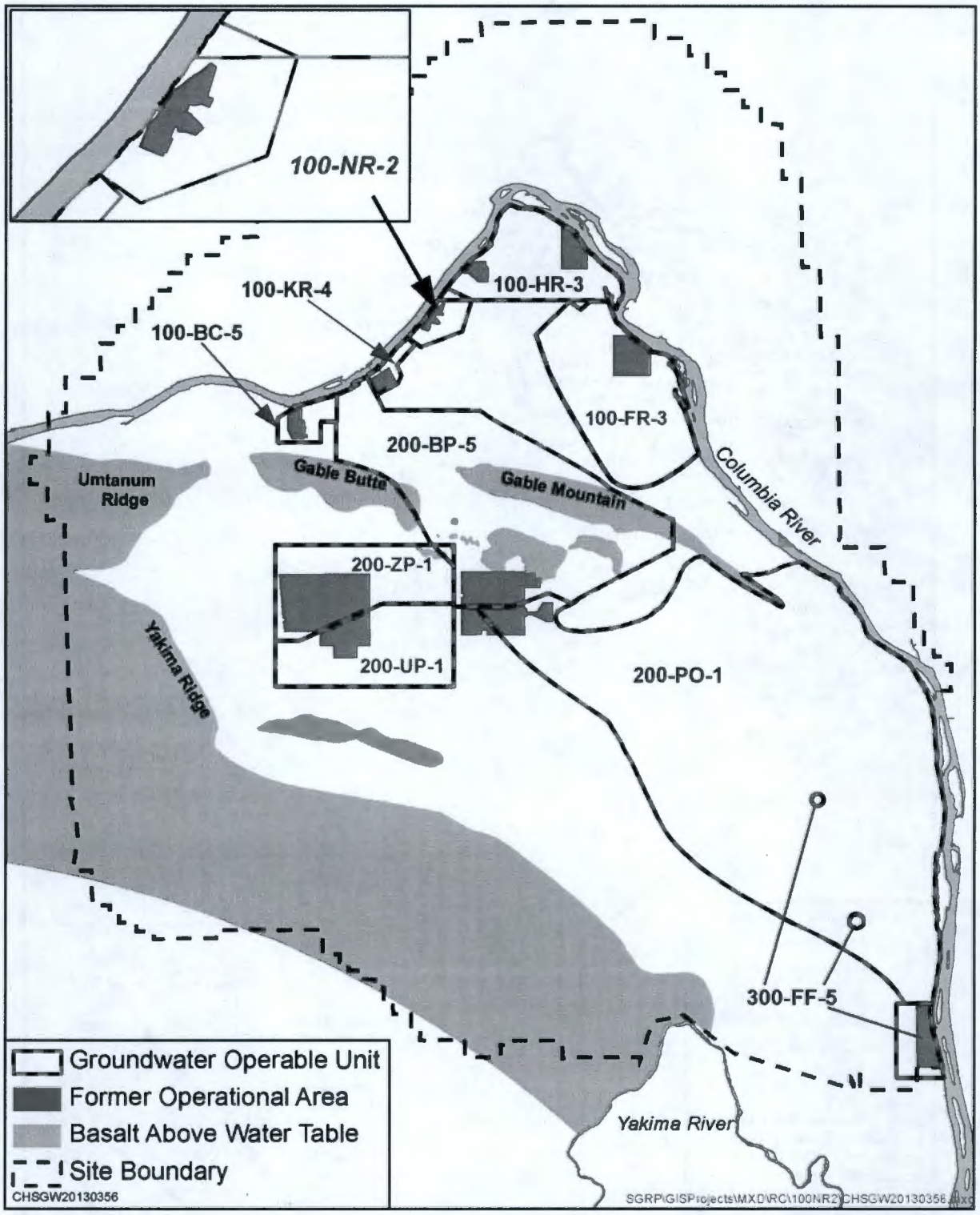


Figure 4-1. Location of the 100-NR-2 OU

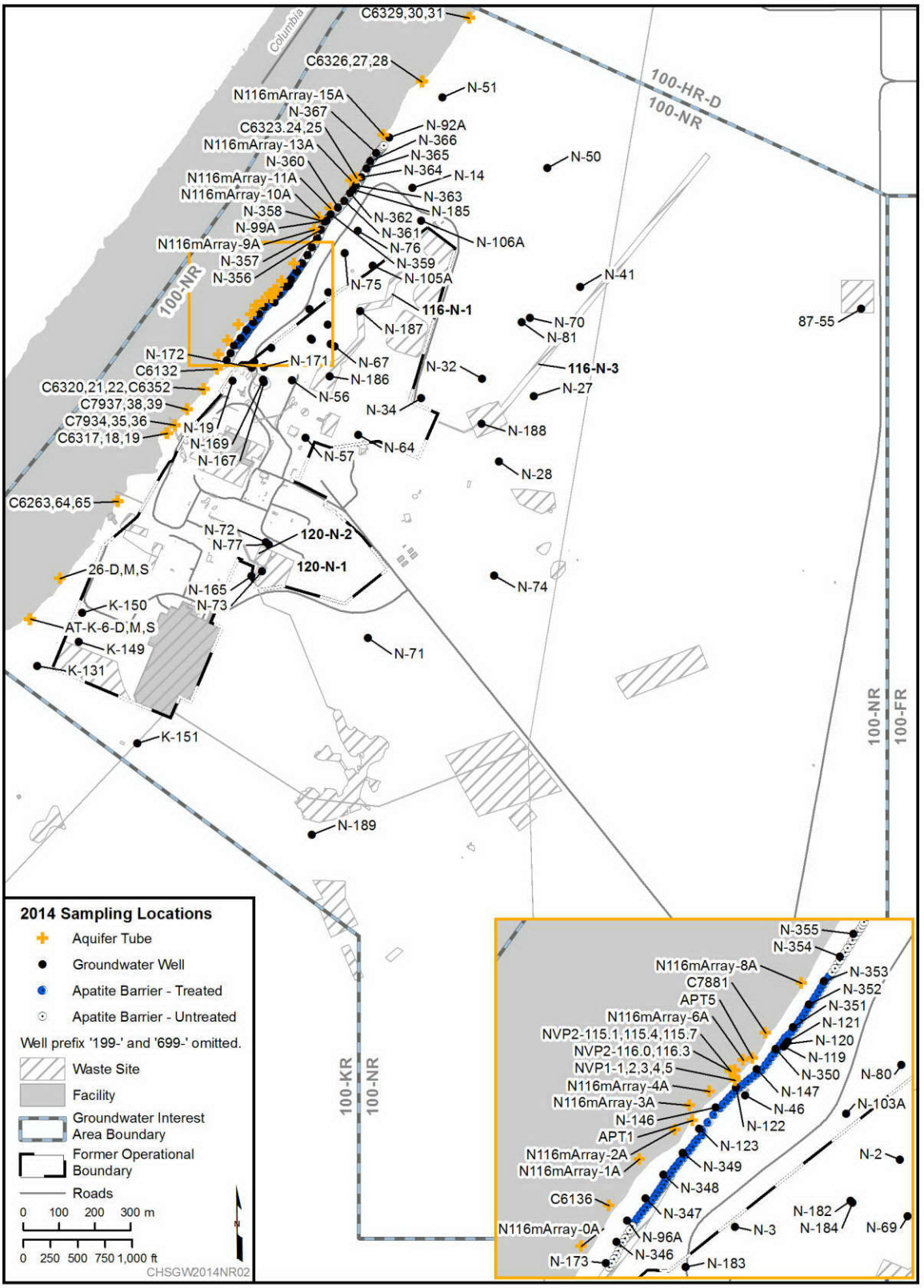


Figure 4-2. Locations of Wells in the 100-N Area

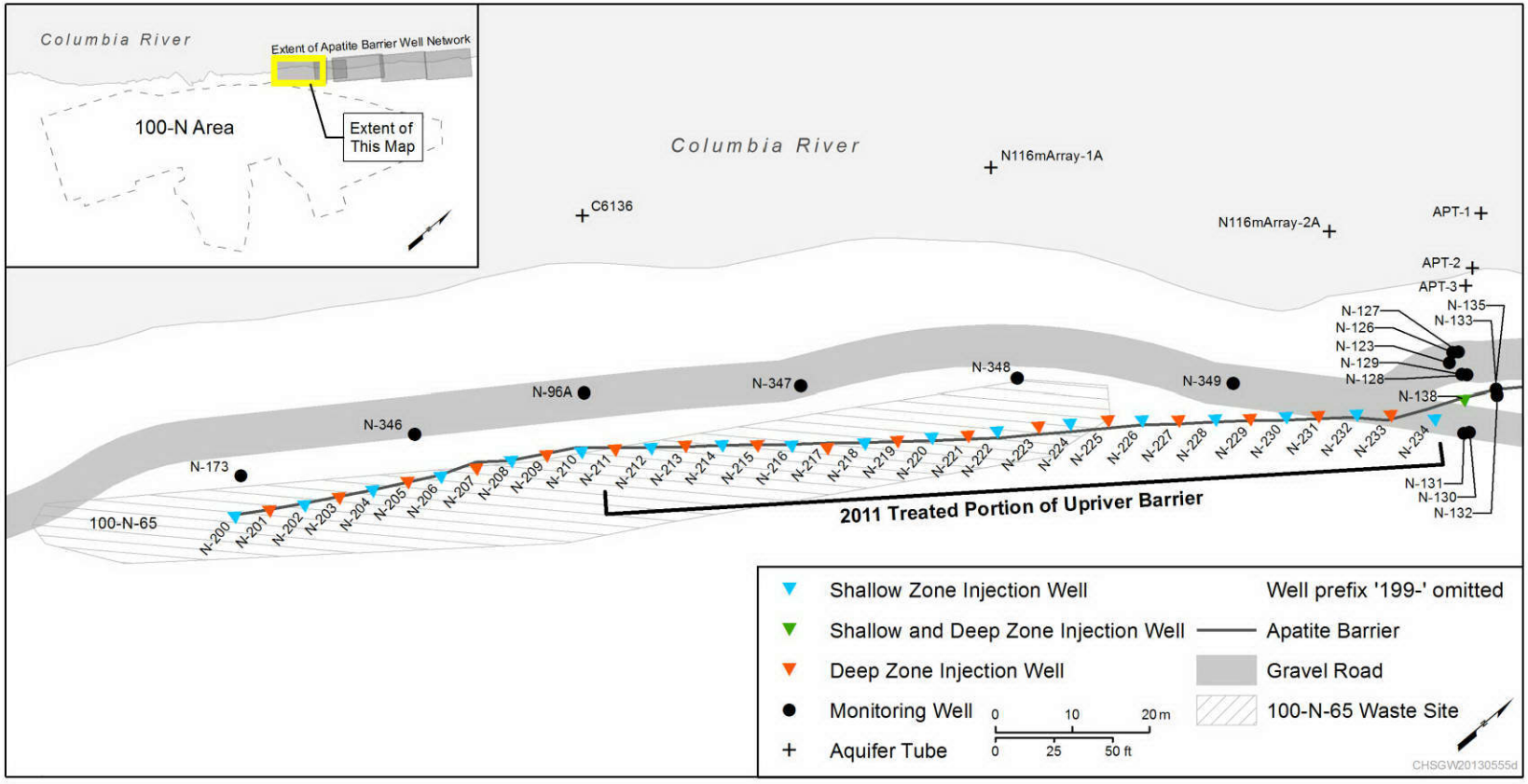


Figure 4-3. Upriver Extension Apatite Barrier Monitoring Wells and Aquifer Tubes along the Columbia River Shoreline

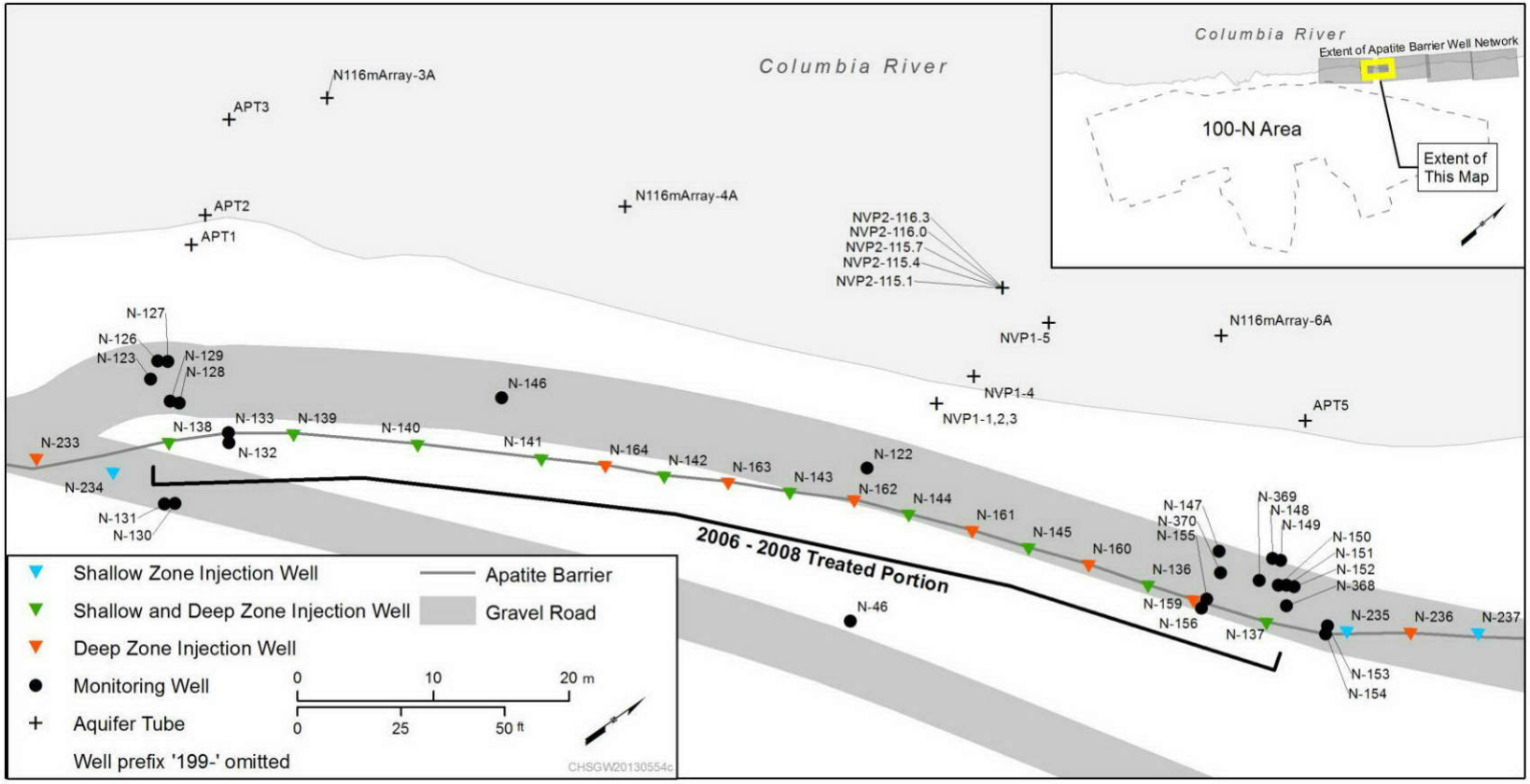


Figure 4-4. Central (Original) Apatite Barrier Monitoring Wells and Aquifer Tubes along the Columbia River Shoreline

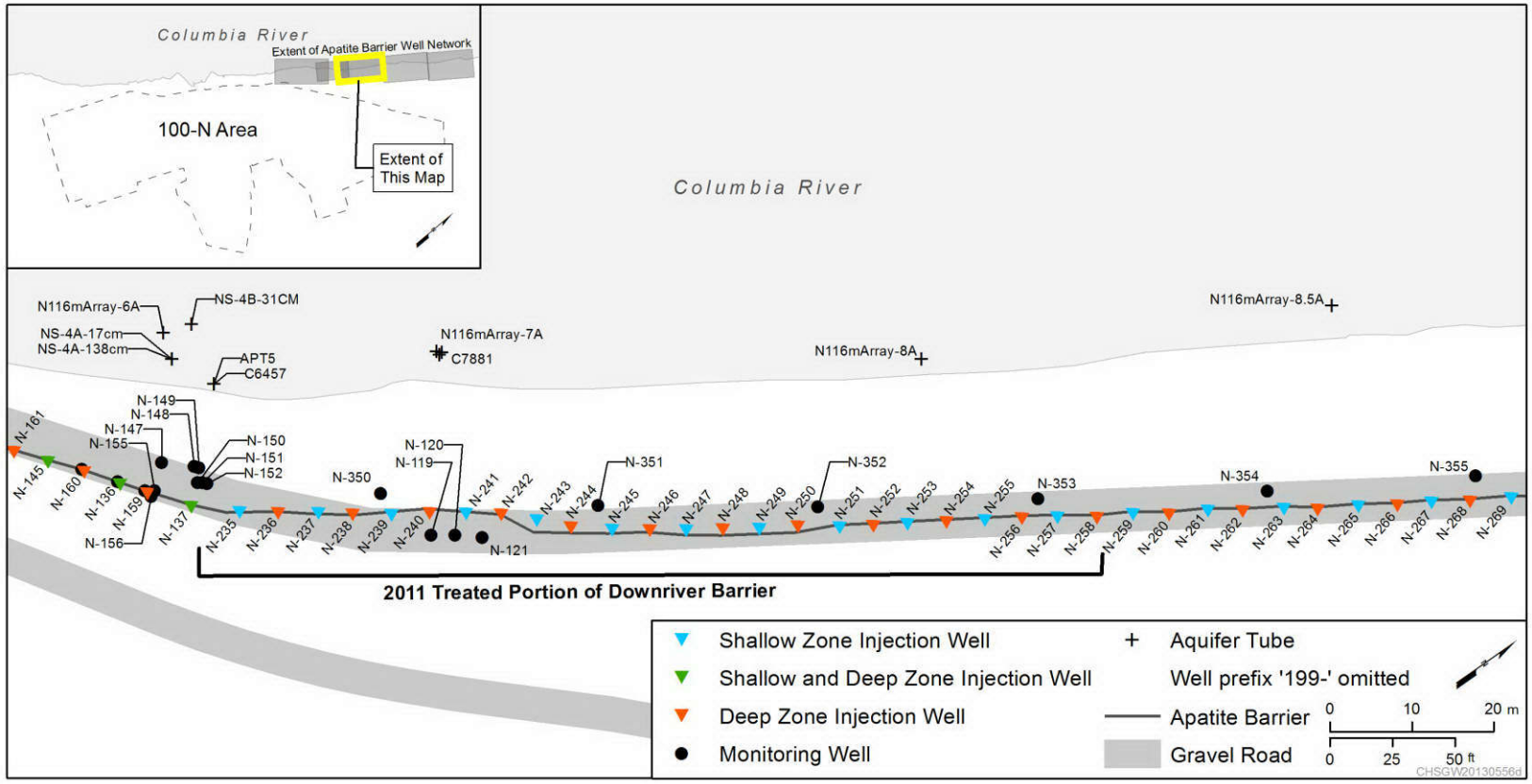
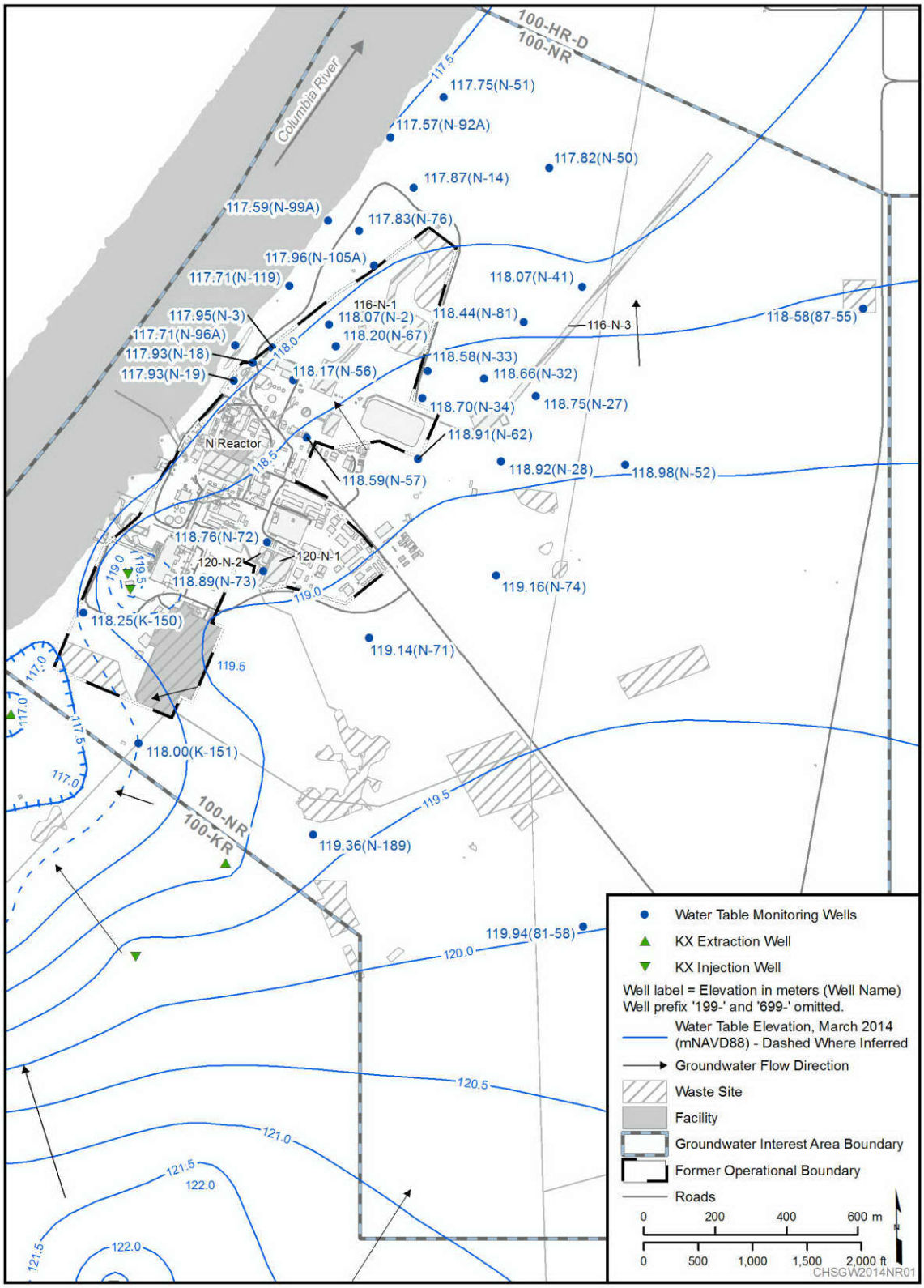
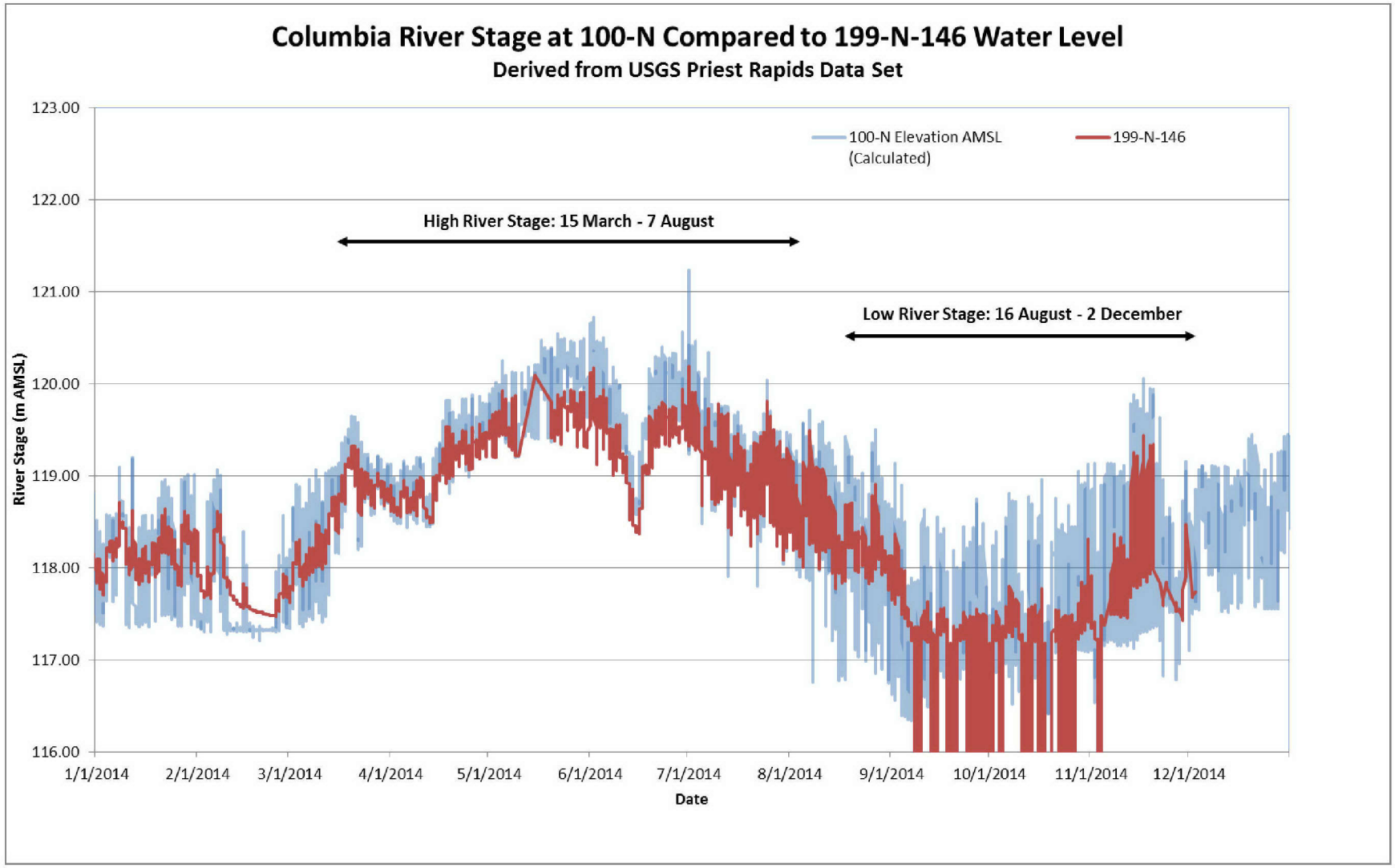


Figure 4-5. Downriver Extension Apatite Barrier Monitoring Wells and Aquifer Tubes along the Columbia River Shoreline



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

Figure 4-6. 100-N Area Water Table Map, March 2014



High and low river-stage periods determined by upper and lower 1/3 percentile of 2014 derived river water elevation measurements, respectively.

Figure 4-7. Well 199-N-146 Water Level Compared to Elevation of the Columbia River at the 100-N Area, 2014

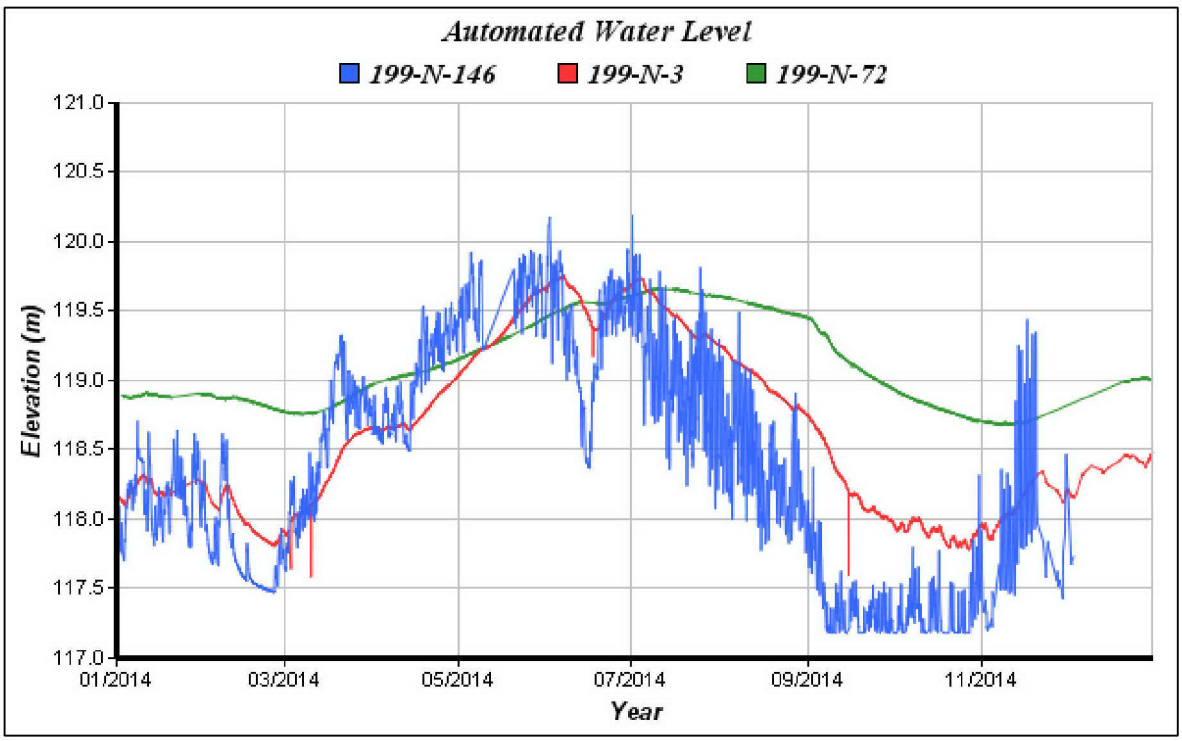


Figure 4-8. Daily Average Water Level in Wells 199-N-146, 199-N-3, and 199-N-72, 2014

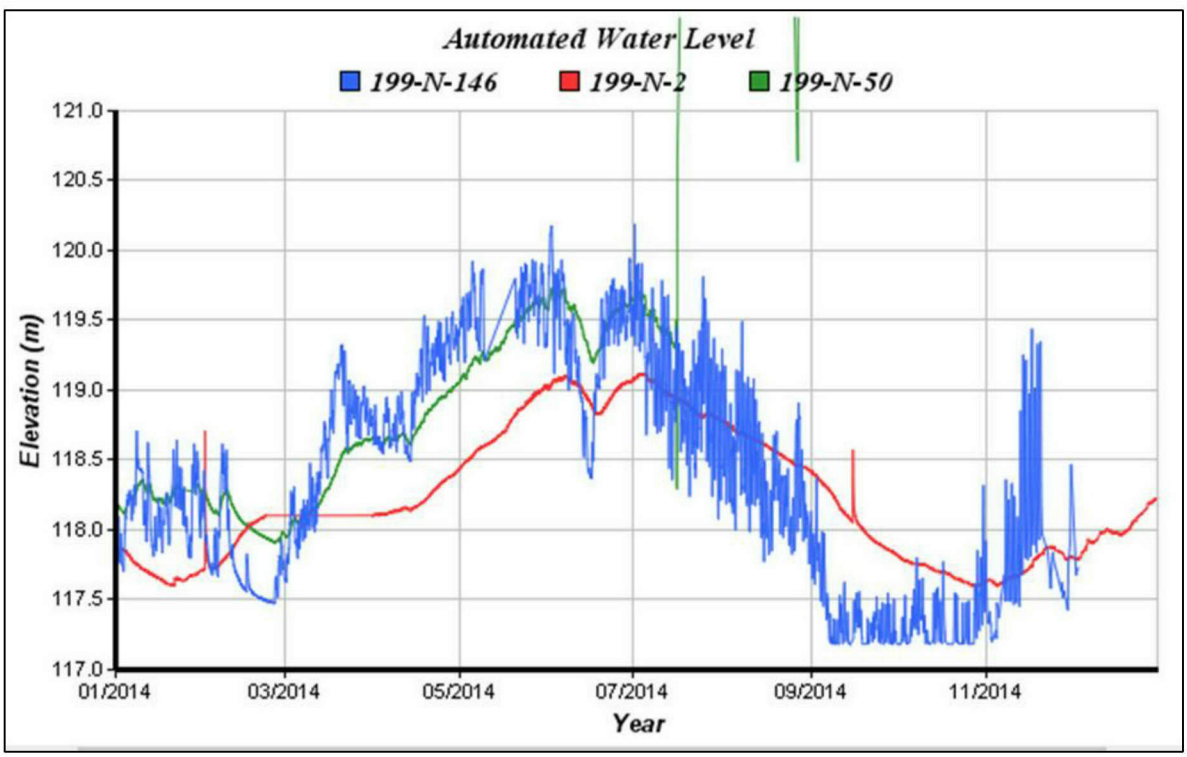


Figure 4-9. Daily Average Water Level in Wells 199-N-146, 199-N-2, and 199-N-50, 2014

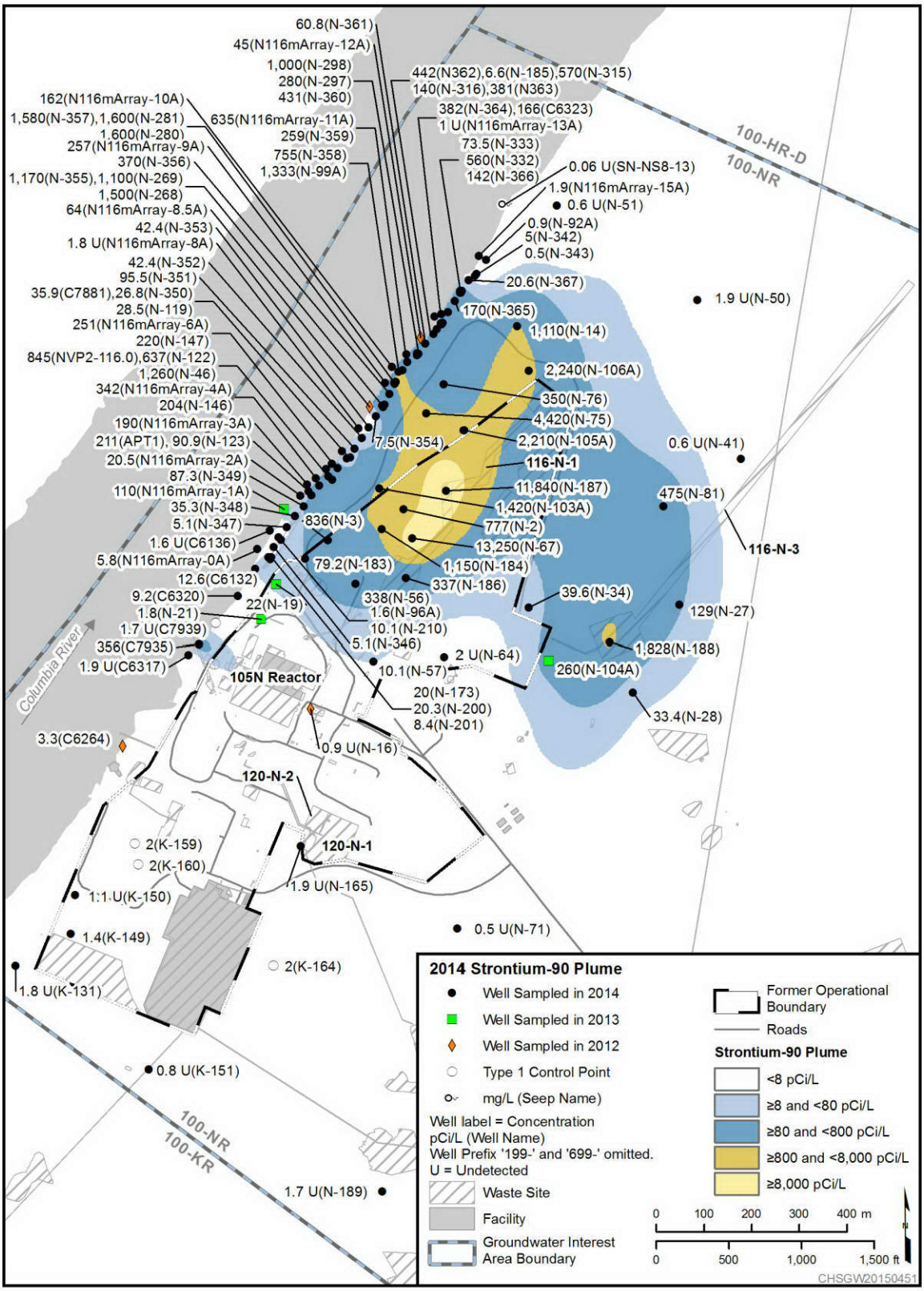


Figure 4-10. Strontium-90 Plume Map for the 100-N Area, 2014

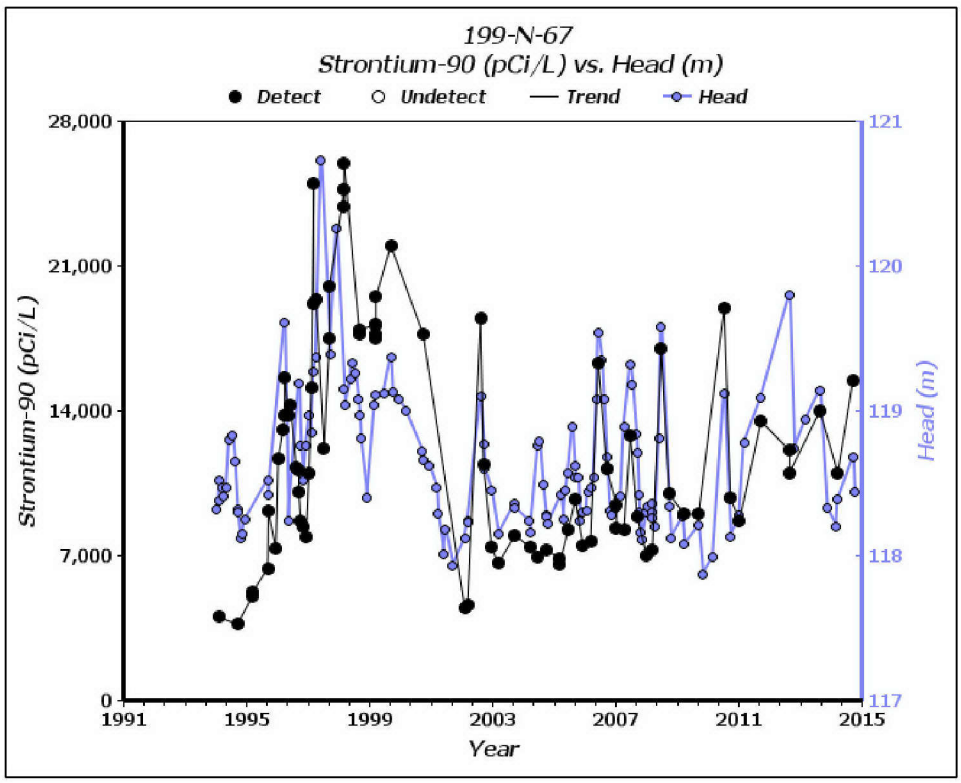
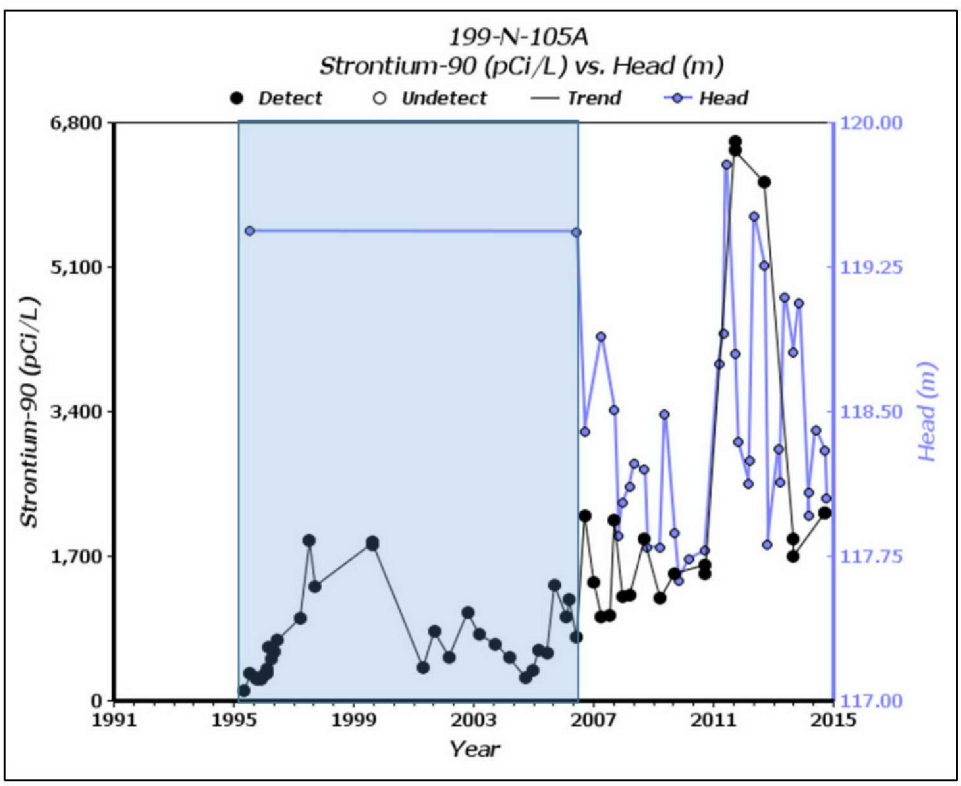


Figure 4-11. Strontium-90 Trend Plot and Water Levels for Well 199-N-67



Note: Well was former pump and treat extraction well from 1995-2006 (shaded band area).

Figure 4-12. Strontium-90 Trend Plot and Water Levels for Well 199-N-105A

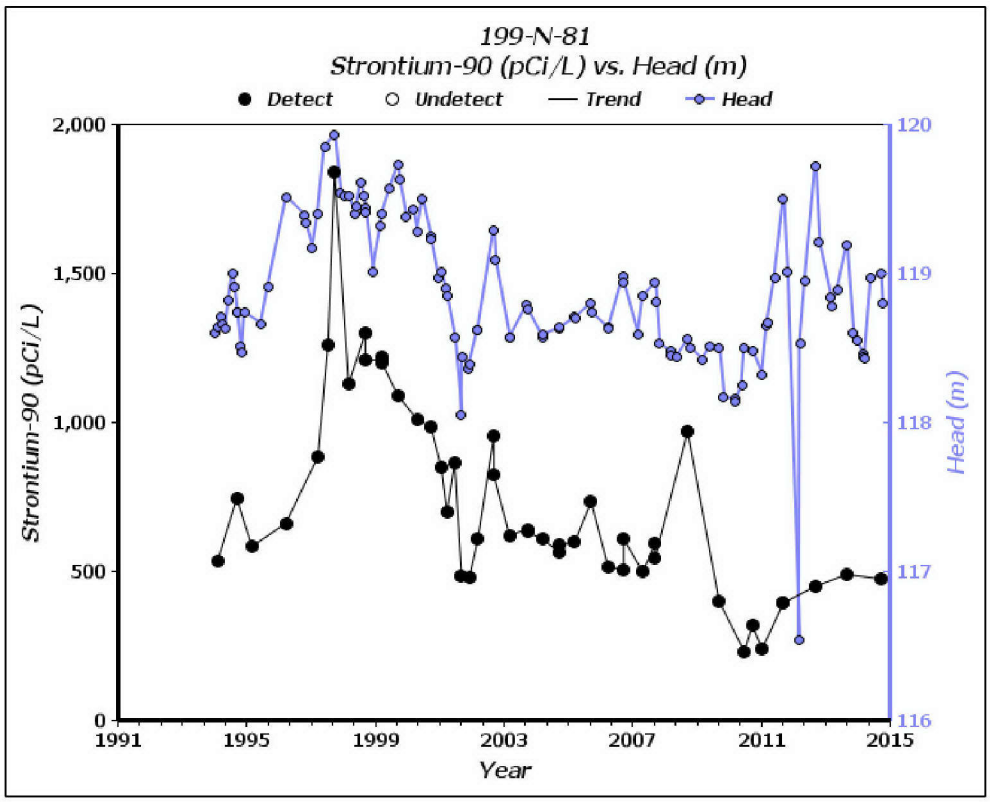


Figure 4-13. Strontium-90 Trend Plot and Water Levels for Well 199-N-81

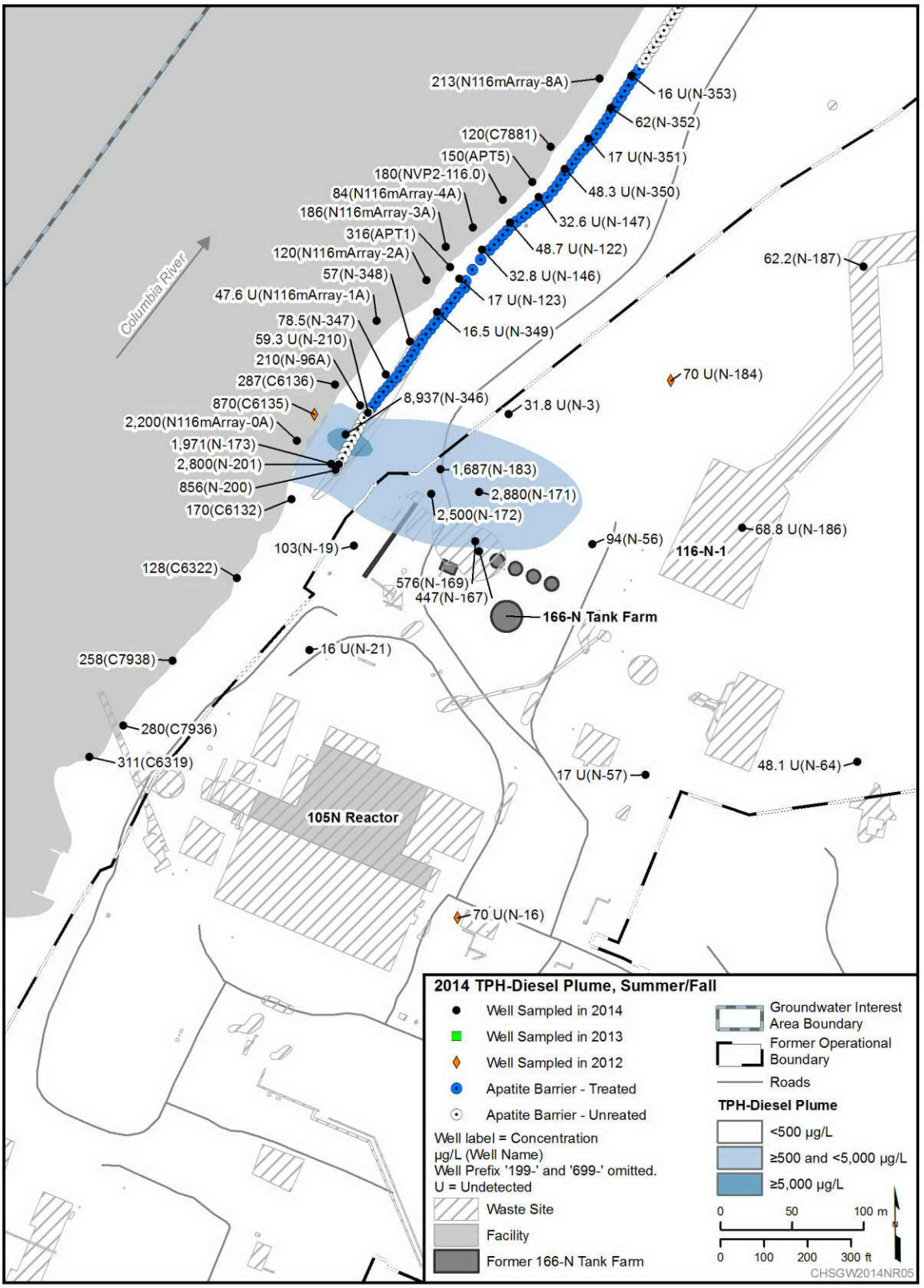


Figure 4-14. TPH-Diesel Plume Map for the 100-N Area, 2014

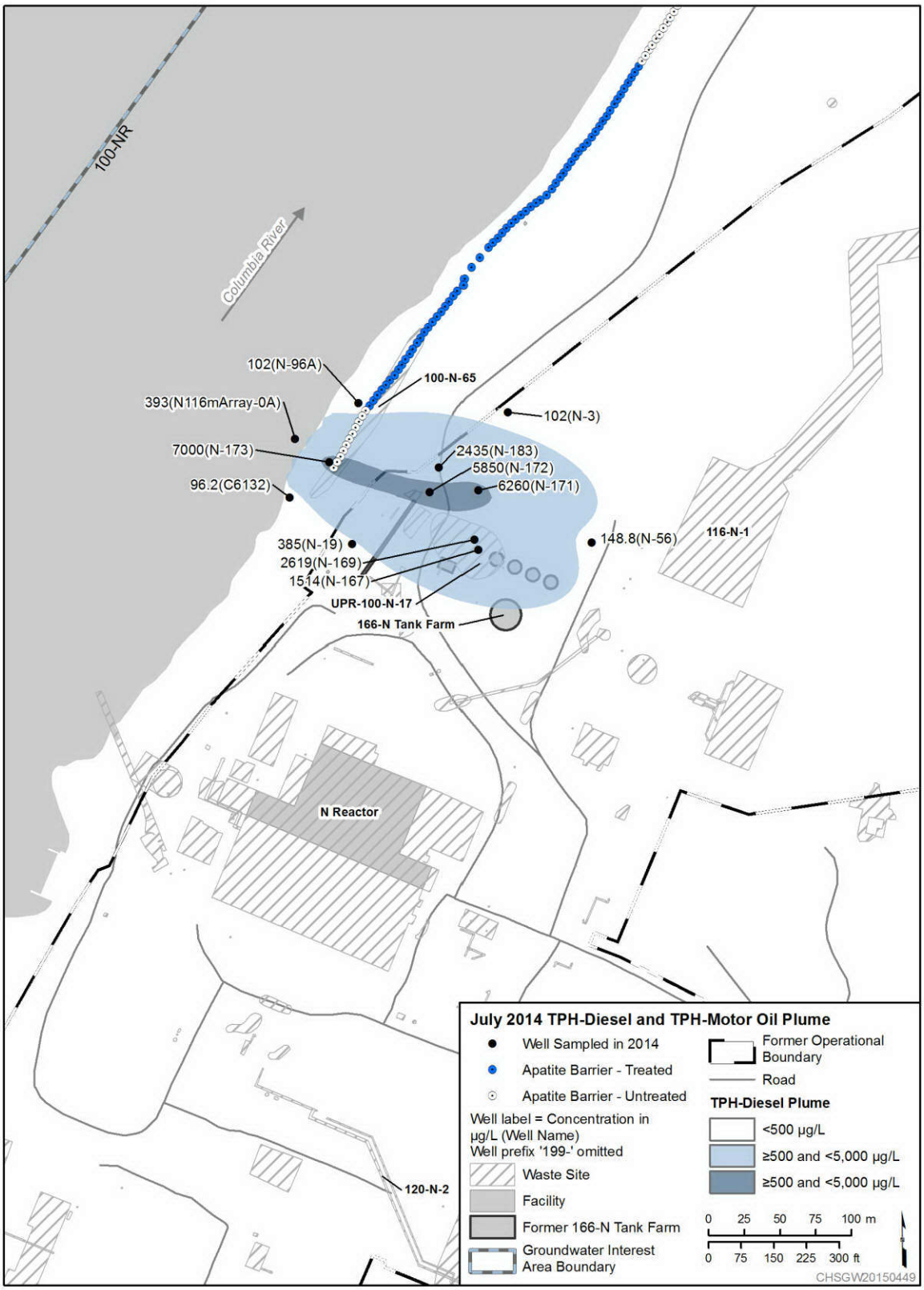


Figure 4-15. TPH-Diesel and TPH Motor Oil Plume Map, July 2014

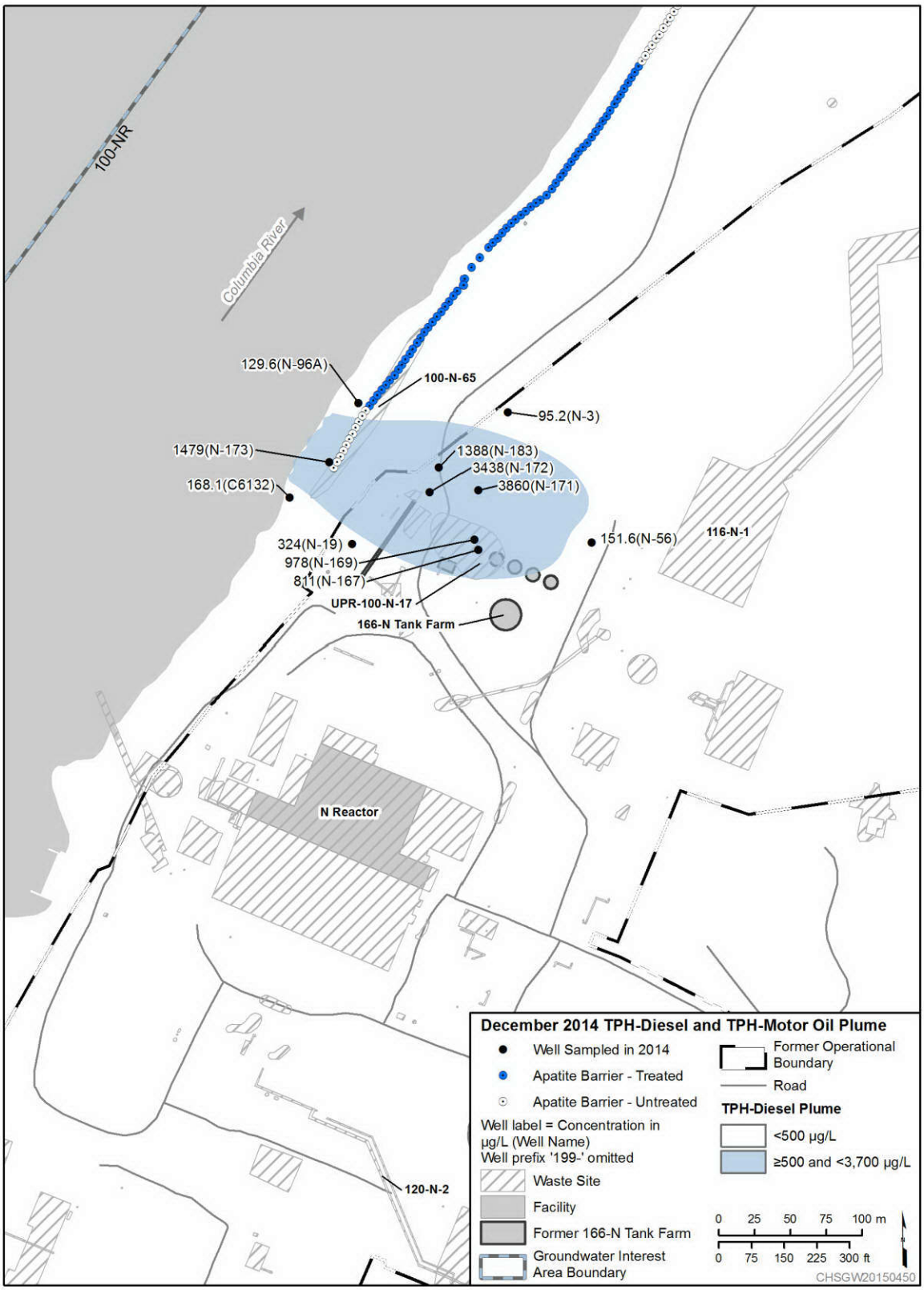


Figure 4-16. TPH-Diesel and TPH Motor Oil Plume Map, December 2014

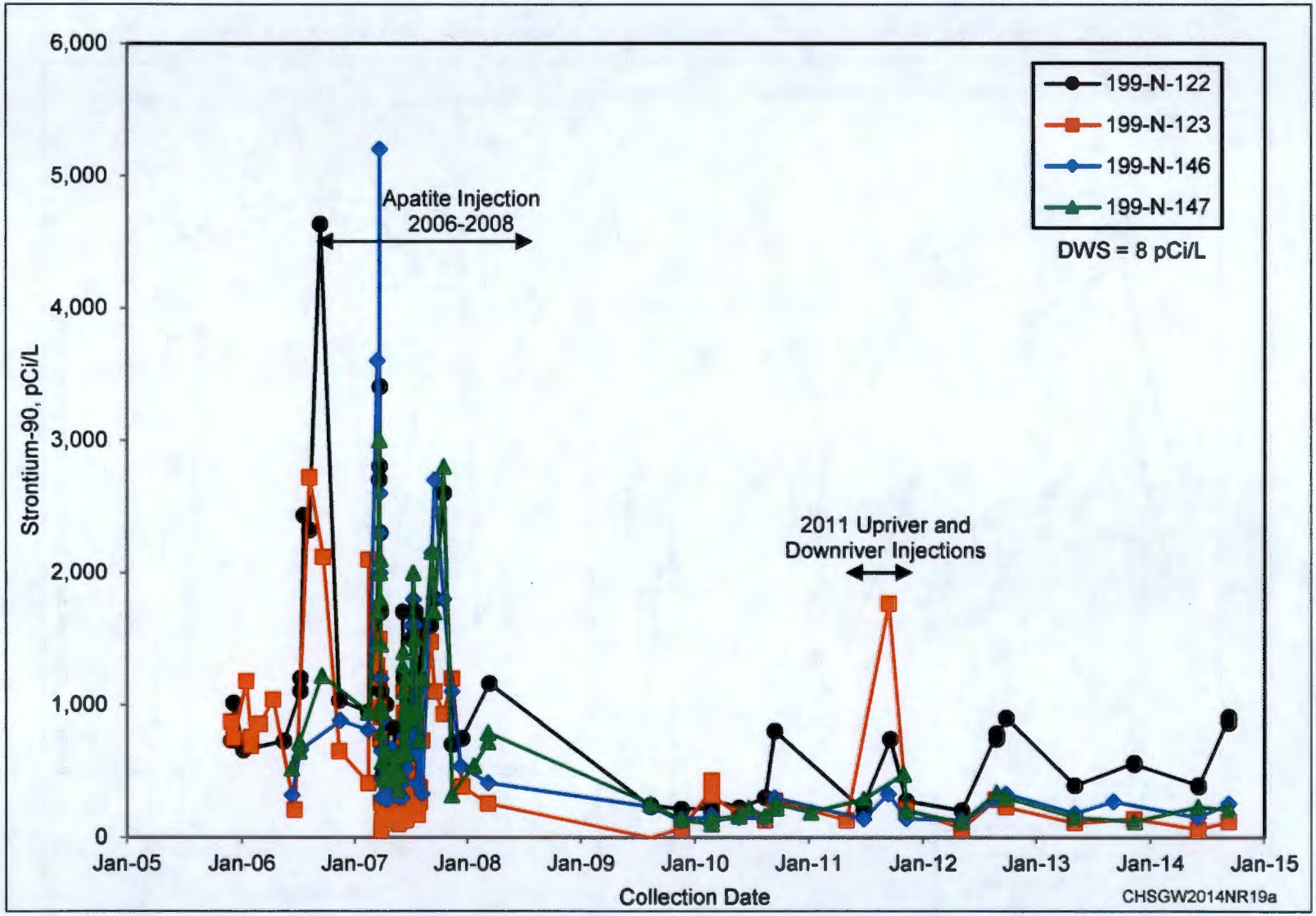


Figure 4-17. Strontium-90 Data for Performance Monitoring Wells along the Central Segment of the Apatite PRB

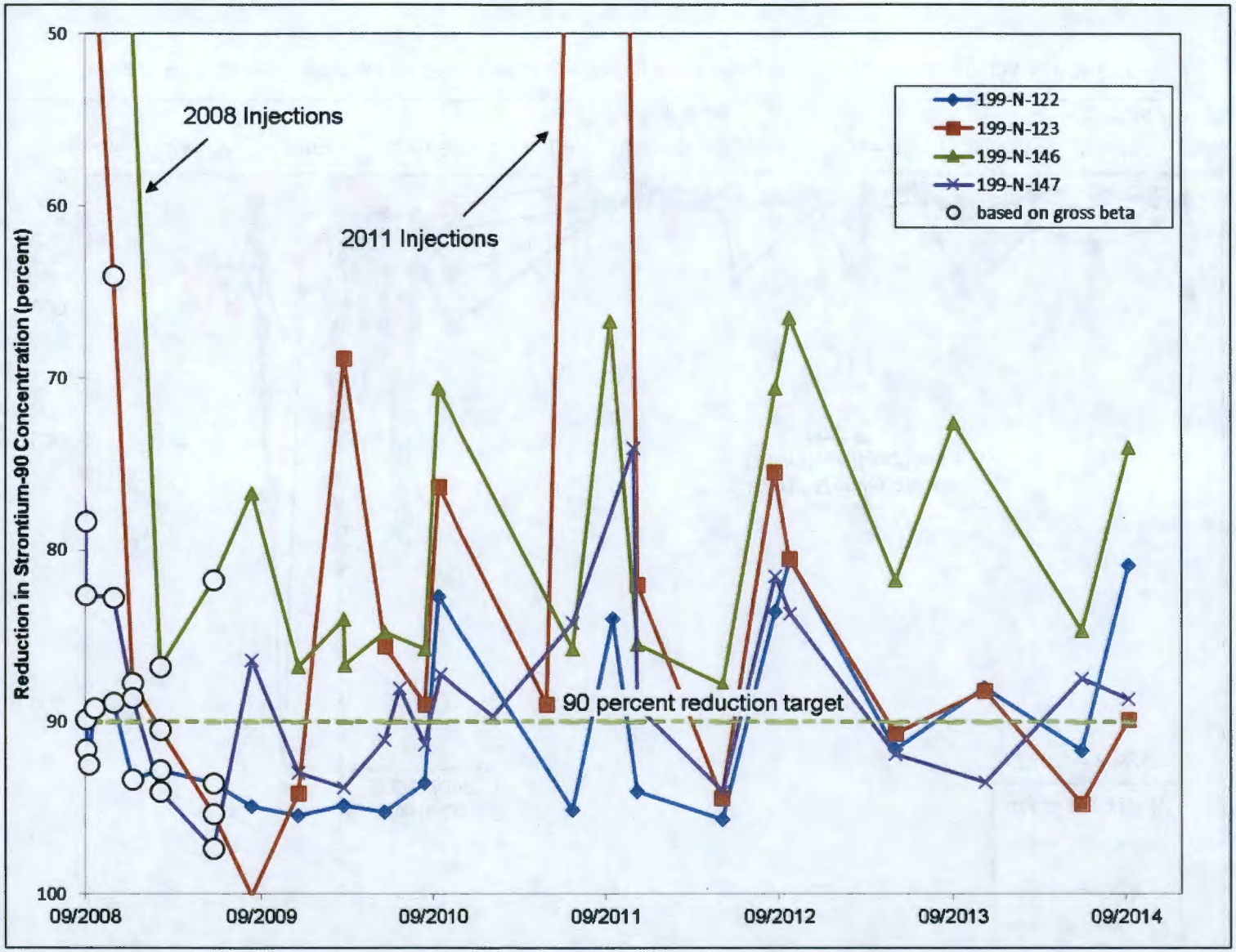


Figure 4-18. Original Apatite Performance Monitoring Wells Percent Strontium-90 Reductions, 2014

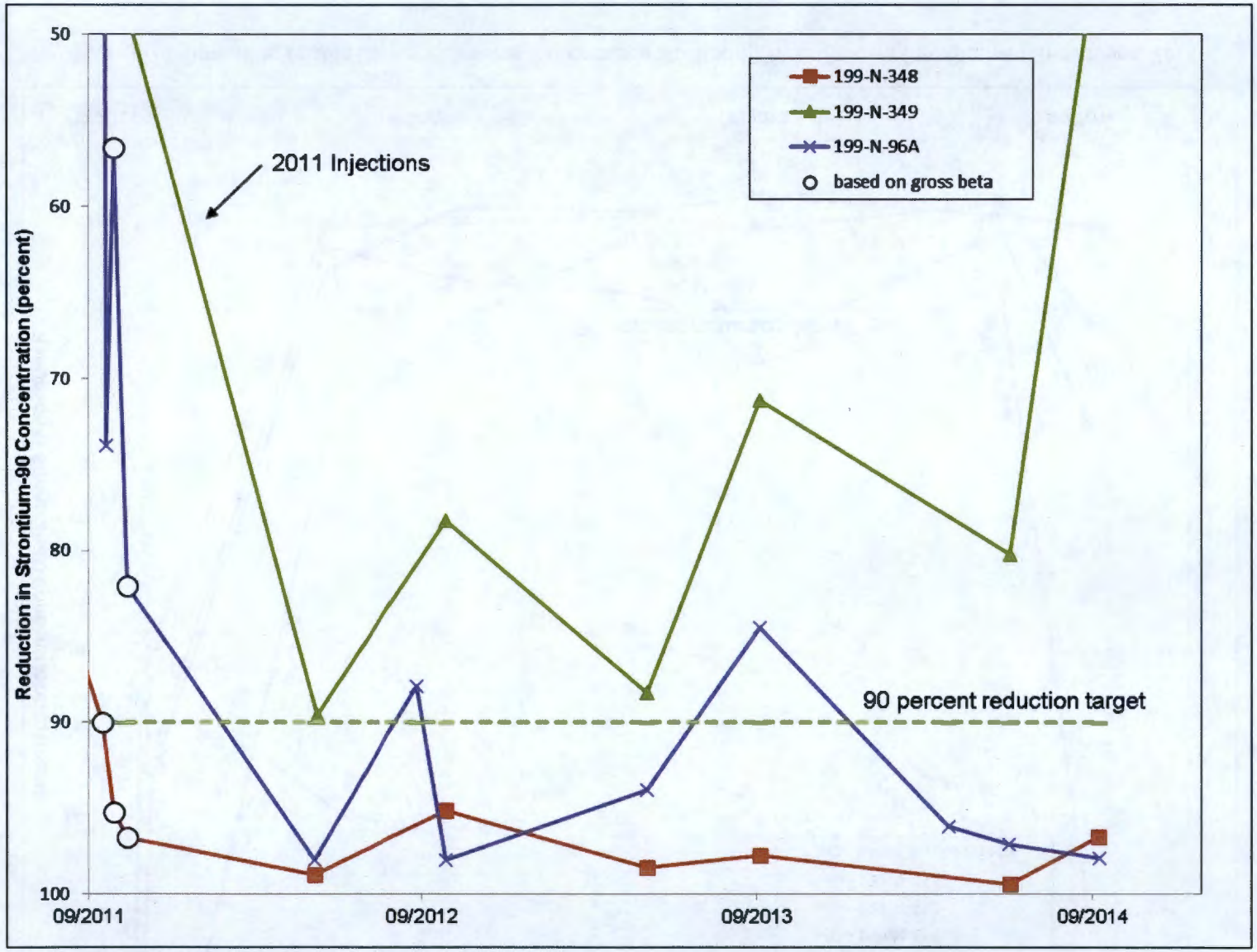


Figure 4-19. Upriver Apatite Barrier Extension Performance Monitoring Wells Percent Strontium-90 Reductions, 2014

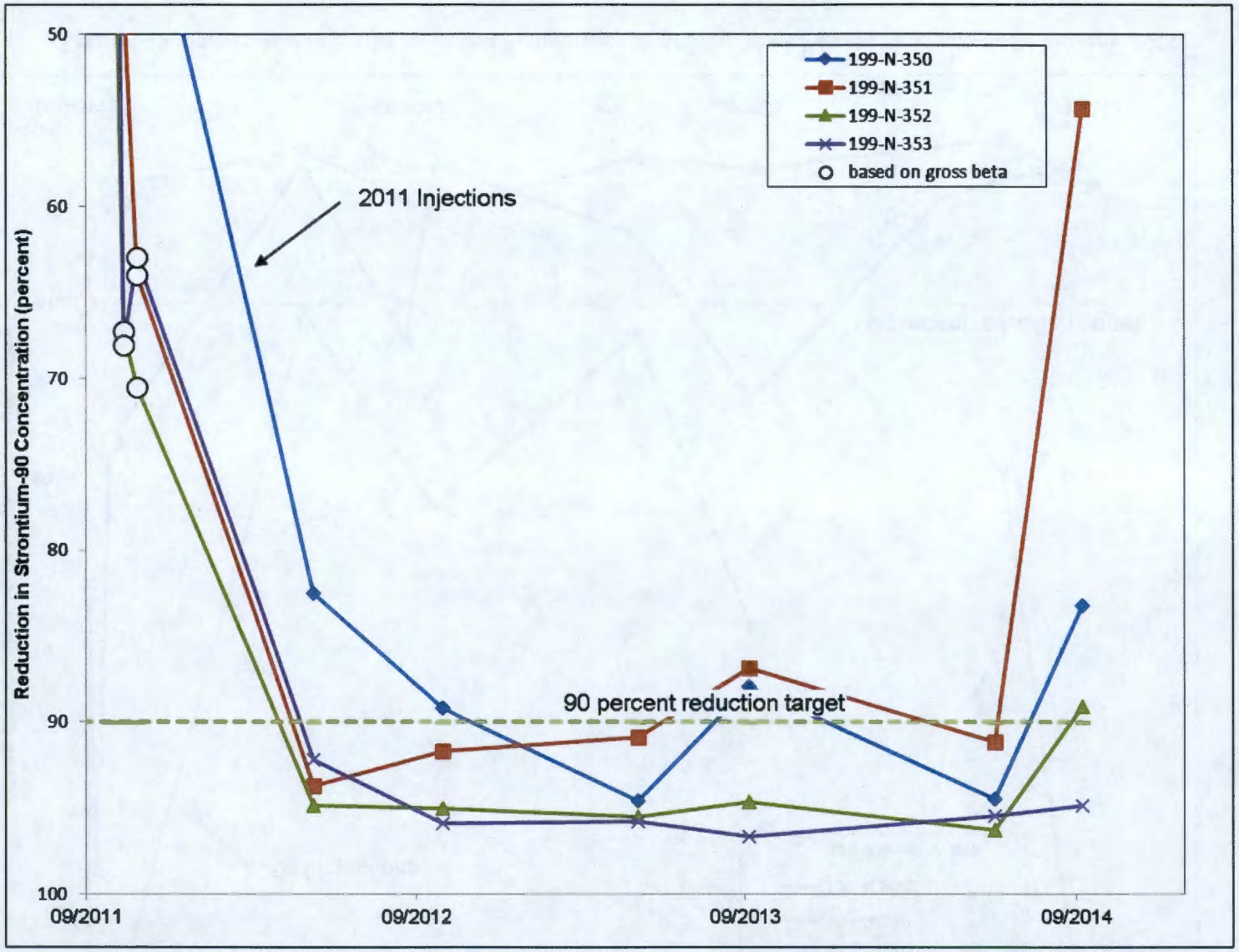


Figure 4-20. Downriver Apatite Barrier Extension Performance Monitoring Wells Percent Strontium-90 Reductions, 2014

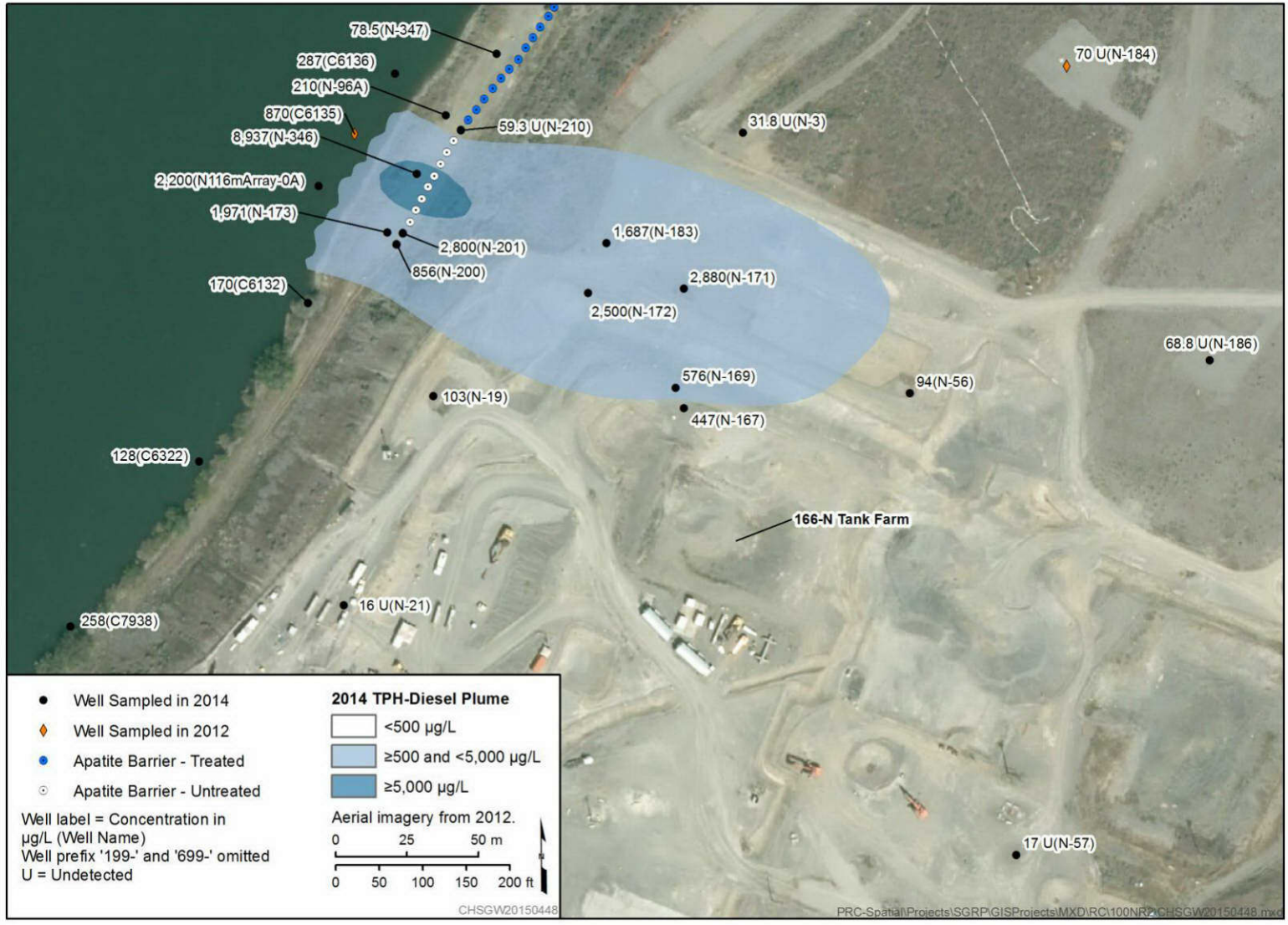


Figure 4-21. 166-N Tank Farm Facility, Location of Well 199-N-183 and 2014 TPH Groundwater Plume

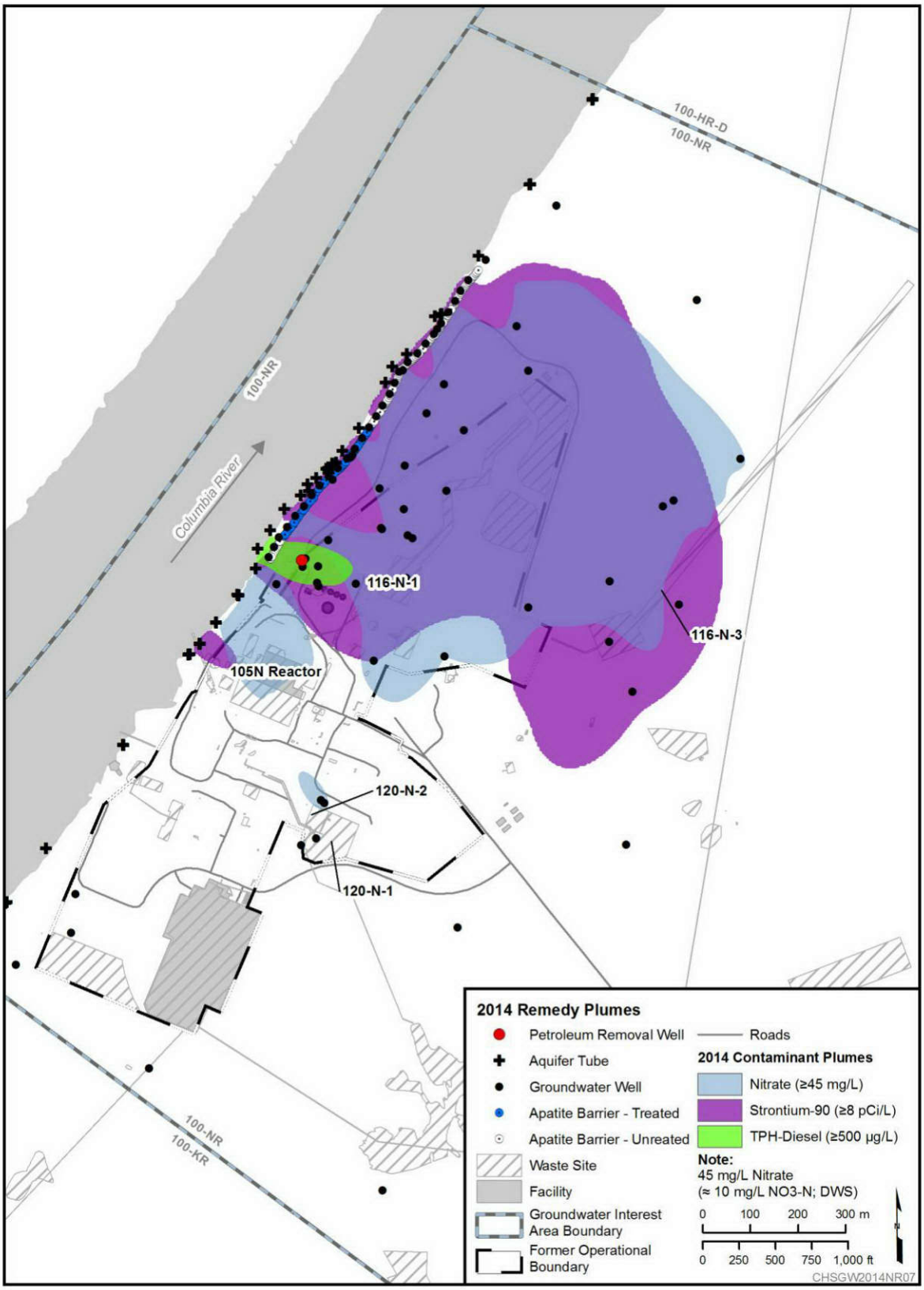


Figure 4-22. 100-NR Contaminant Plumes, 2014

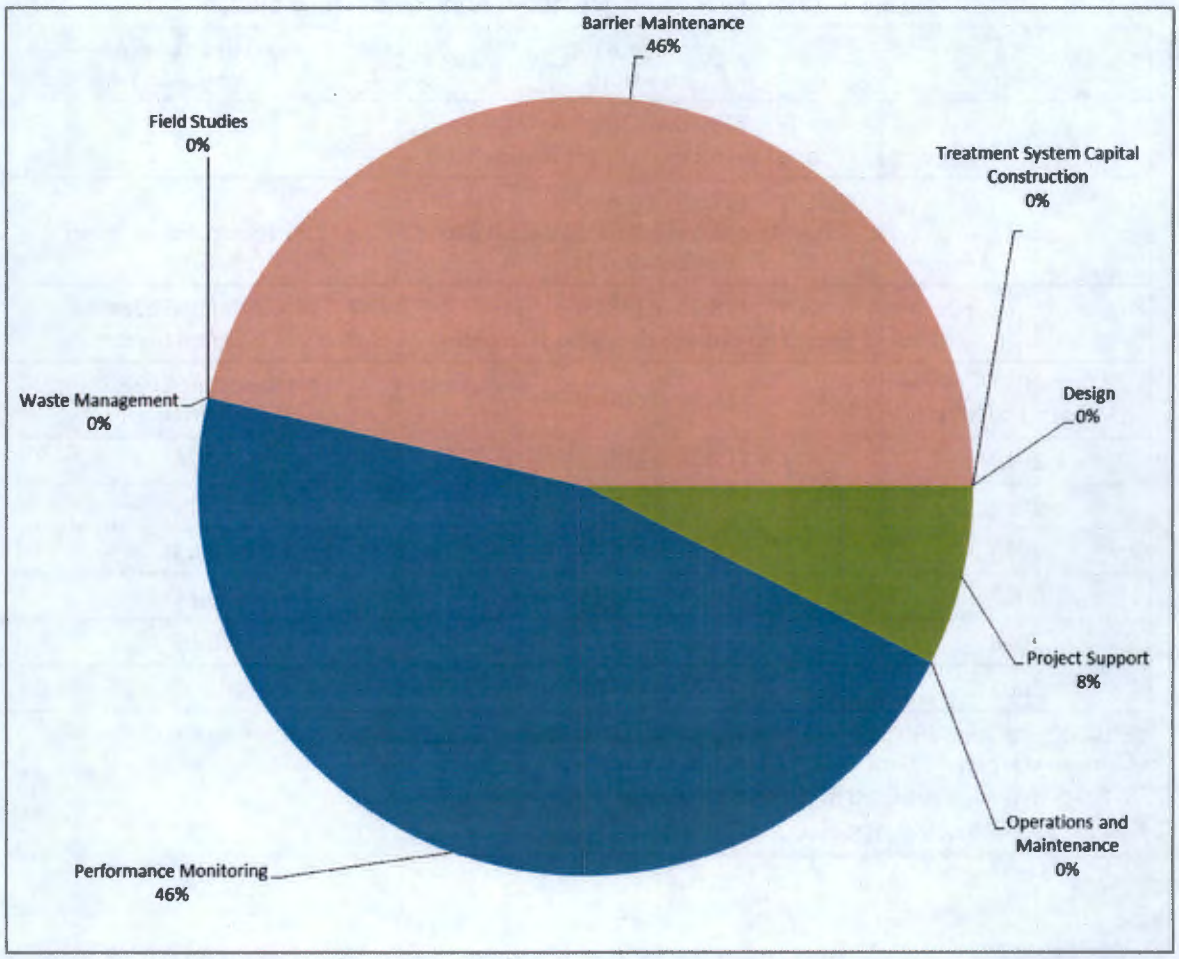


Figure 4-23. 100-NR-2 Apatite Barrier 2014 Cost Breakdown (by Percentage)

Table 4-1. Yearly Peak Averages, 100-N Area River Gauge Station

Year	Average River Elevation	Percent Difference from Previous Year
2014	118.50 m (388.7 ft)[a] (derived from USGS Priest Rapids data)	0.95
2013	117.39 m (385.2 ft)[b] (based on average data 12/04/2012 to 12/04/2013)	0.31 (compared to 2010)
2012	118.28 m (388.1 ft)[b] (based on average over first 10 months)	Not calculated because it is a partial year
2011 (January 1 to May 1)	118.59 m (389.07 ft)	Not calculated because it is a partial year
2010	117.76 m (386.35 ft)	0.28
2009	118.09 m (387.43 ft)	0.09
2008	118.20 m (387.47 ft)	0.03
2007	118.24 m (387.93 ft)	0.14
2006	118.41 m (387.47 ft)	0.17
2005	118.21 m (387.83 ft)	—

a. 100-N river stage derived from USGS Priest Rapid Dam data per ECF-Hanford-13-0028, *Columbia River Stage Correlation for the Hanford Area.*

b. 100-N river stage estimated from 100-B river stage.

USGS = U.S. Geological Survey

Table 4-2. Well Water-Level Response to Changes in River Stage

199-N-146		199-N-3		199-N-72	
Date	Average Elevation* (m)	Date	Average Elevation* (m)	Date	Average Elevation* (m)
Late Winter Low					
2/24/2014	117.483	2/28/2015	118.101	3/7/2014	118.760
Early Summer High					
6/2/2014	119.978	6/8/2014	119.075	7/10/2014	119.659
Late Fall/Early Winter Low					
NA	NA	10/27/2014	117.791	11/10/2014	118.688

* Based on hourly water-level elevation data.

NA = not available

Table 4-3. Strontium-90 Concentrations in Monitoring Wells and Aquifer Tubes

Well/Tube Name	1994 (pCi/L)	2005 (pCi/L)	2008 (pCi/L)	2009 (pCi/L)	2010 (pCi/L)	2011 (pCi/L)	2012 (pCi/L)	2013 (pCi/L)	2014 (pCi/L)	Percent Change, 1994 to 2014	Percent Change 2005 to 2014
199-N-2	121	80.7	1,100	160	NS	NS	3,300	1,040	777	542	863
199-N-3	927	1,330	1,200	1,060	870	1,200	1,300	960	938	1	-29
199-N-14	1,210	1,070	1,300	1,360	1,400	1,730	960	1,200	1,120	-7	5
199-N-16	0.34	-0.08 (U)	0.06 (U)	-0.04 (U)	-2.70 (U)	-0.12 (U)	0.11 (U)	Decommissioned 12/18/2012	Decommissioned 12/18/2012	NC	NC
199-N-18	392	NS	290	-12 (U)	260	203	In use for TPH-diesel remediation	In use for TPH-diesel remediation	In use for TPH-diesel remediation	NC	NC
199-N-19	43.6	28.2	NS	NS	23	26.4	23	22	23[h]	-48	-20
199-N-21	1.50	NS	NS	-2.60 (U)	-7.6 (U)	1.22	1.2	1.8	0.31 (U)	NC	NC
199-N-27	171	167	160	130	125	194	200	130	129	-25	-23
199-N-28	120	25.1	21	25	20	34.9	35	24	33	-72	33
199-N-32	1.27	0.358 (U)	-1.40 (U)	-1.60 (U)	-4.8 (U)	0.15 (U)	0.36 (U)	0.77 (U)	0.37 (U)	NC	NC
199-N-34	69.3	53.5	67	44	37	57.4	45	42	42	-40	-22
199-N-41	0.004 (U)	-0.10 (U)	-0.41 (U)	-1.20 (U)	-1.80 (U)	0.50 (U)	1	NS	0.48 (U)	NC	NC
199-N-46	5,850	2,690	630	580	530	1,220	1,035	1,400	1,570	-73	-42
199-N-50	-0.02 (U)	NS	NS	NS	-0.20 (U)	-0.13 (U)	0.23 (U)	0.8 (U)	0.17 (U)	NC	NC
199-N-51	0.254 (U)	0.11 (U)	NS	N	-5.30 (U)	0.52 (U)	0.26 (U)	0.78 (U)	0.16 (U)	NC	NC
199-N-56	164[a]	317	170	140	-7.5 (U)	490	560	380	338	NC	7
199-N-57	26	9.71	8.51	2.90	5.80	15.2	15.5	12	10	-60	6
199-N-64	0.185 (U)	0.785 (U)	0.256 (U)	-5.30 (U)	-4.60 (U)	0.48 (U)	3	0.49 (U)	1.2 (U)	NC	NC

Table 4-3. Strontium-90 Concentrations in Monitoring Wells and Aquifer Tubes

Well/Tube Name	1994 (pCi/L)	2005 (pCi/L)	2008 (pCi/L)	2009 (pCi/L)	2010 (pCi/L)	2011 (pCi/L)	2012 (pCi/L)	2013 (pCi/L)	2014 (pCi/L)	Percent Change, 1994 to 2014	Percent Change 2005 to 2014
199-N-67	3,680	9,710	10,000	9,000	9,800	13,500	11,550	14,000	15,500	321	60
199-N-69[b]	-0.09 (U)	0.21 (U)	NS	NS	-3.20 (U)	2.96	12	4.8	3	NC	NC
199-N-70[b]	0.321 (U)	0.156 (U)	-2.60 (U)	-2.40 (U)	-3.80 (U)	0.79	1.2	1.2	0.54 (U)	NC	NC
199-N-71	0.55	NS	0.38 (U)	-0.05 (U)	-2.80 (U)	-3.90 (U)	0.29 (U); 1.1	0.65 (U)	0.60 (U)	NC	NC
199-N-72	2.59[c]	NS	-1.00 (U)	NS	-1.70 (U)	-2.60 (U)	NS	NS	NS	NC	NC
199-N-73	0.53	NS	NS	NS	NS	NS	NS	NS	NS	NC	NC
199-N-74	0.415	-0.08 (U)	2.3[c]	405[c]	-2.0 (U)	-3.60 (U)	NS	NS	NS	NC	NC
199-N-75[d]	2,110	307	2,500	3,000	2,400	NS	3,200	2,500	2,540	20	727
199-N-76	84.9	216	180	180	120	387	1,120	690	440	418	104
199-N-77	0.45	NS	NS	NS	NS	NS	NS	NS	NS	NC	NC
199-N-80[b]	0.734 (Q)	-0.154 (U)	0.82 (U)	-0.07 (U)	-5.9 (U)	0.22 (U)	0.77 (U)	1.5	2	NC	NC
199-N-81	746	734	970	400	320	395	450	490	475	-36	-35
199-N-92A	0.59 (U)	0.92	1.22	3.50	-9 (U)	0.60	0.47 (U)	0.69 (U)	1	NC	41
199-N-96A	4.90[e]	5.74	1.65	-1.30 (U)	3.94	9.90	2.04	5.9	2	NC	-74
199-N-99A	2,860[e]	1,270	1,200	1,400	1,500	1,020	666.5	1,230	1,600	NC	26
199-N-103A[d,g]	4.08[e]	422	1,200	1,200	1,400	1,360	1,600	1,300	1,420	NC	236
199-N-104A	5.68[e]	NS	NS	NS	NS	NS	380	260	NS	NC	NC
199-N-105A[d,g]	112[e]	1,360	1,900	1,500	1,600	6,580	6,100	1,900	2,210	NC	63
199-N-106A[d,g]	2,890[e]	3,260	2,200	1,800	NS	2,370	3,035	2,200	2,240	NC	-31

Table 4-3. Strontium-90 Concentrations in Monitoring Wells and Aquifer Tubes

Well/Tube Name	1994 (pCi/L)	2005 (pCi/L)	2008 (pCi/L)	2009 (pCi/L)	2010 (pCi/L)	2011 (pCi/L)	2012 (pCi/L)	2013 (pCi/L)	2014 (pCi/L)	Percent Change, 1994 to 2014	Percent Change 2005 to 2014
199-N-119	—	280	250	210	220	274	56	41	29	NC	-90
199-N-120[b]	—	10.1	6.55	NS	1.40 (U)	6.93	58	5.7	4	NC	-58
199-N-121[b]	—	0.272 (U)	0.0169 (U)	NS	-2.00 (U)	-0.02 (U)	0.23 (U)	-0.21 (U)	0.33 (U)	NC	NC
199-N-122	—	730	1,160	260	800	740	656	560	907	NC	24
199-N-123	—	871	255	-1.60 (U)	280	1,770	204	140	120	NC	-86
199-N-146	—	318[f]	412	260	300	328	215	270	256	NC	NC
199-N-147	—	522[f]	791	250	250	478	250	120	231	NC	NC
199-N-165	—	—	—	-1.90 (U)	-6.60 (U)	0.14 (U)	0.57 (U)	1.6	-0.39 (U)	NC	NC
199-N-173	—	—	—	16	23	19	14.5	22	25	NC	NC
199-N-182	—	—	—	—	—	—	110	140	144	NC	NC
199-N-183	--	--	--	—	—	—	120	100	82	NC	NC
199-N-184	—	—	—	—	—	—	5,000	1,100	1,150	NC	NC
199-N-185	—	—	—	—	—	—	3.9	7.6	8	NC	NC
199-N-186	—	—	—	—	—	—	810	390	420	NC	NC
199-N-187	—	—	—	—	—	—	8,600	11,400	12,800	NC	NC
199-N-188	—	—	—	—	—	—	1,500	2,500	2,280	NC	NC
199-N-189	—	—	—	—	—	—	0.02 (U)	0.39 (U)	0.85 (U)	NC	NC
C7934	—	—	—	—	300	—	93	310	321	NC	NC
C7935	—	—	—	—	300	—	190	280	356	NC	NC
C7936	--	—	—	—	69	—	55	96	83	NC	NC

Table 4-3. Strontium-90 Concentrations in Monitoring Wells and Aquifer Tubes

Well/Tube Name	1994 (pCi/L)	2005 (pCi/L)	2008 (pCi/L)	2009 (pCi/L)	2010 (pCi/L)	2011 (pCi/L)	2012 (pCi/L)	2013 (pCi/L)	2014 (pCi/L)	Percent Change, 1994 to 2014	Percent Change 2005 to 2014
APT-1	--	3,400[f]	—	—	500	530	840	270	211	NC	NC
APT-5	—	2,100[f]	—	—	450	420	270	120	184	NC	NC
N116mArray-3A	—	379	1,750[c]	500	110	248	240	170	190	NC	-50
N116mArray-4A	—	1,260	7,000[c]	340	270	226	250	280	342	NC	-73
NVP2-116.0	—	3,200	2,550[c]	1,100	1,200	1,100	733	700	845	NC	-74
N116mArray-6A	—	477	370[c]	95[c]	110	170	190	130	251	NC	-47

Notes: Data are reported from the fall of the year, unless otherwise noted.

Yellow-shaded cells indicate wells with concentrations above the drinking water standard (8 pCi/L).

a. Not sampled in 1994; value from 1993 used for table.

b. Screened at depth in Ringold Formation.

c. Value calculated from gross-beta data (no strontium-90 data available); value listed is one-half of the gross-beta value measured.

d. Former P&T extraction well.

e. Not sampled in 1994; value from 1995 used for table.

f. Not sampled in 2005; value from 2006 used for table.

g. A P&T system was operated from 1995 through 2006.

h. Sampled on 1/20/2015.

NC = not calculated
NS = not sampled
P&T = pump and treat
Q = associated with out-of-limits quality control samples
TPH = total petroleum hydrocarbon-diesel
U = nondetect

Table 4-4. Performance Monitoring at the Apatite PRB, 100-NR-2 OU

Well Name	Number of Baseline Samples	Number of Baseline Nondetects	Strontium-90 Concentration (pCi/L)				Percent Reduction in Strontium-90 (Baseline to Fall 2014)[e]	
			Minimum Detected Baseline	Maximum Baseline	Spring 2014	Fall 2014	Minimum Baseline	Maximum Baseline
Upriver Apatite Permeable Reactive Barrier								
			04/06/10		06/04-05/2014	09/09-10/2014		
199-N-96A	56	8	1.54[a]	37.9[a]	1.1 (U)	0.8 (U)	48	98
199-N-347	1	1	7[b]	7[b]	3.9	6.3	10	10
199-N-348	1	0	1,800	1,800	10	60	97	97
199-N-349	2	0	220	230	45.5	129	42	44
Central (Original) Apatite Permeable Reactive Barrier								
(See footnote c)			(See footnote d)		06/04-05/2014	09/11/2014		
199-N-122	10	0	657	4,630	388	886	-35	81
199-N-146	4	0	318	985	151	256	20	74
199-N-147	3	0	522	1,842	231	209	60	89
199-N-123	6	0	689	1,180	61.7	120	83	90
Downriver Apatite Permeable Reactive Barrier								
			07/28/10 and 07/29/10		06/05/2014	09/10/2014		
199-N-350	1	0	240	240	13.2	40.3	83	83
199-N-351	1	0	350	350	30.9	160	54	54
199-N-352	1	0	580	580	21.6	63.2	89	89
199-N-353	1	0	83	83	3.8	4.3	95	95

Table 4-4. Performance Monitoring at the Apatite PRB, 100-NR-2 OU

Well Name	Number of Baseline Samples	Number of Baseline Nondetects	Strontium-90 Concentration (pCi/L)				Percent Reduction in Strontium-90 (Baseline to Fall 2014)[e]	
			Minimum Detected Baseline	Maximum Baseline	Spring 2014	Fall 2014	Minimum Baseline	Maximum Baseline

Note: Between 1995 and 2011, the maximum baseline was measured on December 6, 1995; the minimum detected baseline was measured on June 13, 2006, and June 22, 2007.

a. Based on samples data from April 1995 through January 2011.

b. Strontium-90 is a beta emitter. Gross-beta concentrations are approximately two times the strontium-90 concentrations. The strontium-90 concentration was a. 1.1 pCi/L (U). The gross-beta concentration, 14 pCi/L, was divided by two to approximate the strontium-90 concentration of 7 pCi/L.

c. From Table 8.1 in PNNL-17429, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization.*

d. From Table 4.1 in PNNL-19572, *100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization.*

e. The percent reduction in strontium-90 concentration is calculated as ([baseline value] – [fall 2014 value] / [baseline value]) × 100. For Well 199-N-96A, the minimum baseline value used in the calculation was the lowest detected value.

U = analyzed for but not detected

Table 4-5. Apatite PRB Performance Monitoring Wells and Aquifer Tubes

Well Name/ID	Well Type	Well Name/ID	Well Type	Well Name/ID	Well Type
C6132	AT	NVP2-116.0m/C5251	AT	N116mArray-10A/C5264	AT
199-N-173/C7038	MW	N116mArray-6A/C5259	AT	199-N-359/C7452	MW
N116mArray-0A/C5514	AT	199-N-147/C5116	MW	N116mArray-11A/C5265	AT
199-N-346/C7442	MW	APT-5/C5386	AT	199-N-360/C7453	MW
C6135	AT	199-N-350/C7443	MW	N116mArray-12A/C5266	AT
199-N-96A/A9882	MW			199-N-361/C7454	MW
C6136	AT	C7881*	AT	199-N-362/C7455	MW
199-N-347/C7441	MW	199-N-351/C7444	MW	199-N-363/C7456	MW
N116mArray-1A/C5255	AT	199-N-352/C7445	MW	N116mArray-13A/C5267	AT
199-N-348/C7440	MW	199-N-353/C7446	MW	199-N-364/C7457	MW
N116mArray-2A/C5256	AT	N116mArray-8A/C5261	AT	199-N-365/C7458	MW
199-N-349/C7439	MW	199-N-354/C7447	MW	N116mArray-14A/C5268	AT
199-N-123/C4955	MW	N116mArray-8.5A/C5262	AT	199-N-366/C7459	MW
APT-1/C5269	AT	199-N-355/C7448	MW	199-N-367/C7463	MW
N116mArray-3A/C5257	AT	199-N-356/C7449	MW	199-N-92A/A8878	MW
199-N-146/C5052	MW	199-N-357/C7450	MW	N116mArray-15A/C5512	AT
N116mArray-4A/C5258	AT	N116mArray-9A/C5263	AT		
199-N-122/C4954	MW	199-N-358/C7451	MW		

Note: Yellow shading indicates locations currently being monitored for treated portion of barrier.

* Aquifer tube N116mArray-7A was monitored from June 2006 through September 2009. The aquifer tube became unusable in 2009 and was replaced with C7881at the same location.

AT = aquifer tube
ID = identification
MW = monitoring well (6 in.)

Table 4-6. Apatite PRB Injection Wells

Well Name/ID	Depth	Well Name/ID	Depth	Well ID	Depth	Well Name/ID	Depth
199-N-200/C7327	Shallow	199-N-222/C7305	Shallow; core	199-N-144/C5050	Shallow, deep	199-N-250/C7343	Deep
199-N-201/C7326	Deep	199-N-223/C7304	Deep	199-N-161/C6179	Deep	199-N-251/C7344	Shallow
199-N-202/C7325	Shallow	199-N-224/C7303	Shallow	199-N-145/C5051	Shallow, deep	199-N-252/C7345	Deep
199-N-203/C7324	Deep	199-N-225/C7302	Deep	199-N-160/C6178	Deep	199-N-253/C7346	Shallow
199-N-204/C7323	Shallow	199-N-226/C7301	Shallow	199-N-136/C5042	Shallow, deep	199-N-254/C7347	Deep
199-N-205/C7322	Deep	199-N-227/C7300	Deep	199-N-159/C6177	Deep	199-N-255/C7348	Shallow
199-N-206/C7321	Shallow	199-N-228/C7299	Shallow	199-N-137/C5043	Shallow, deep	199-N-256/C7349	Deep
199-N-207/C7320	Deep	199-N-229/C7298	Deep	199-N-235/C7328	Shallow	199-N-257/C7350	Shallow
199-N-208/C7319	Shallow	199-N-230/C7297	Shallow	199-N-236/C7329	Deep	199-N-258/C7351	Deep
199-N-209/C7318	Deep	199-N-231/C7296	Deep	199-N-237/C7330	Shallow	199-N-259/C7352	Shallow
199-N-210/C7317	Shallow	199-N-232/C7295	Shallow	199-N-238/C7331	Deep	199-N-260/C7353	Deep
199-N-211/C7316	Deep	199-N-233/C7294	Deep	199-N-239/C7332	Shallow	199-N-261/C7354	Shallow
199-N-212/C7315	Shallow	199-N-234/C7293	Shallow	199-N-240/C7333	Deep	199-N-262/C7355	Deep
199-N-213/C7314	Deep	199-N-138/C5044	Shallow, deep	199-N-241/C7334	Shallow	199-N-263/C7356	Shallow
199-N-214/C7313	Shallow	199-N-139/C5045	Shallow, deep	199-N-242/C7335	Deep	199-N-264/C7357	Deep
199-N-215/C7312	Deep	199-N-140/C5046	Shallow, deep	199-N-243/C7336	Shallow	199-N-265/C7358	Shallow
199-N-216/C7311	Shallow	199-N-141/C5047	Shallow, deep	199-N-244/C7337	Deep	199-N-266/C7359	Deep
199-N-217/C7310	Deep; core	199-N-164/C182	Deep	199-N-245/C7338	Shallow	199-N-267/C7360	Shallow
199-N-218/C7309	Shallow	199-N-142/C5048	Shallow, deep	199-N-246/C7339	Deep	199-N-268/C7361	Deep
199-N-219/C7308	Deep; core	199-N-163/C6181	Deep	199-N-247/C7340	Shallow	199-N-269/C7362	Shallow
199-N-220/C7307	Shallow; core	199-N-143/C5049	Shallow, deep	199-N-248/C7341	Deep	199-N-270/C7363	Deep

Table 4-6. Apatite PRB Injection Wells

Well Name/ID	Depth	Well Name/ID	Depth	Well ID	Depth	Well Name/ID	Depth
199-N-221/C7306	Deep	199-N-162/C6180	Deep	199-N-249/C7342	Shallow	199-N-271/C7364	Shallow
199-N-272/C7365	Deep	199-N-291/C7384	Shallow	199-N-310/C7403	Deep	199-N-329/C7422	Shallow
199-N-273/C7366	Shallow	199-N-292/C7385	Deep	199-N-311/C7404	Shallow	199-N-330/C7423	Deep
199-N-274/C7367	Deep	199-N-293/C7386	Shallow	199-N-312/C7405	Deep	199-N-331/C7424	Shallow
199-N-275/C7368	Shallow	199-N-294/C7387	Deep	199-N-313/C7406	Shallow	199-N-332/C7425	Deep
199-N-276/C7369	Deep	199-N-295/C7388	Shallow	199-N-314/C7407	Deep	199-N-333/C7426	Shallow
199-N-277/C7370	Shallow	199-N-296/C7389	Deep	199-N-315/C7408	Shallow	199-N-334/C7427	Deep
199-N-278/C7371	Deep	199-N-297/C7390	Shallow	199-N-316/C7409	Deep	199-N-335/C7428	Shallow
199-N-279/C7372	Shallow	199-N-298/C7391	Deep	199-N-317/C7410	Shallow	199-N-336/C7429	Deep
199-N-280/C7373	Deep	199-N-299/C7392	Shallow	199-N-318/C7411	Deep	199-N-337/C7430	Shallow
199-N-281/C7374	Shallow	199-N-300/C7393	Deep	199-N-319/C7412	Shallow	199-N-338/C7431	Deep
199-N-282/C7375	Deep	199-N-301/C7394	Shallow	199-N-320/C7413	Deep	199-N-339/C7432	Shallow
199-N-283/C7376	Shallow	199-N-302/C7395	Deep	199-N-321/C7414	Shallow	199-N-340/C7433	Deep
199-N-284/C7377	Deep	199-N-303/C7396	Shallow	199-N-322/C7415	Deep	199-N-341/C7434	Shallow
199-N-285/C7378	Shallow	199-N-304/C7397	Deep	199-N-323/C7416	Shallow	199-N-342/C7435	Deep
199-N-286/C7379	Deep	199-N-305/C7398	Shallow	199-N-324/C7417	Deep	199-N-343/C7436	Shallow
199-N-287/C7380	Shallow	199-N-306/C7399	Deep	199-N-325/C7418	Shallow	199-N-344/C7437	Deep
199-N-288/C7381	Deep	199-N-307/C7400	Shallow	199-N-326/C7419	Deep	199-N-345/C7438	Shallow
199-N-289/C7382	Shallow	199-N-308/C7401	Deep	199-N-327/C7420	Shallow		

Table 4-6. Apatite PRB Injection Wells

Well Name/ID	Depth	Well Name/ID	Depth	Well ID	Depth	Well Name/ID	Depth
199-N-290/C7383	Deep	199-N-309/C7402	Shallow	199-N-328/C7421	Deep		

Notes: "Core" indicates that a core was taken at this well for jet injection study (2010).

Blue shading indicates downriver barrier extension wells treated in September 2011.

Green shading indicates original barrier wells treated in 2006 through 2008.

Pink shading indicates upriver barrier extension wells treated in September 2011.

No shading indicates that wells are not treated yet.

ID = identification

Table 4-7. Petroleum Hydrocarbon Releases in the 100-N Area

Group	WIDS Number	Location	Description
Group 1 – 166-N & 1715-N	UPR-100-N-17	166-N diesel oil supply line leak	In August 1966, an estimated 302,832 L (80,000 gal) of diesel leaked from a failed transfer system near the 166-N facility. In August 1967, J.M. Shelby documented the possible impacts on the Columbia River. Diesel was slipping from the bluff below the 166-N Tank Farm and into the river. A trench was excavated below the bluff to collect the diesel to be burned off; WIDS site 100-N-65 diesel burn trench (BNWL-CC-1296; UNI-228).
	UPR-100-N-18	166-N diesel oil supply line leak	In August 1973, an estimated 757 L (200 gal) of diesel oil leaked from a transfer line between 166-N and 184-N facilities (PNL-6456; UNI-228).
	UPR-100-N-20	166-N diesel oil supply line leak	In June 1985, an estimated 757 L (200 gal) of diesel oil leaked from a transfer line near Tank 1 in the 166-N facility (UNI-228).
	UPR-100-N-24	166-N diesel oil supply line leak	On February 1, 1987, a line leak was reported. Petroleum product type and quantity were not reported. No further information is available (WHC-SD-EN-TI-251).
Group 2 – 184-N	UPR-100-N-42	184-N Day Tank area liquid unplanned release	On October 9, 1987, an unspecified quantity of petroleum material with an unspecified description was documented around the 184-N facility day tanks (WIDS).
	UPR-100-N-19	184-N Day Tank fuel oil line leak	In April 1984, an estimated 28,391 L (7,500 gal) of No. 6 fuel oil leaked at the 184-N Day Tank facility. It was reported that all the fuel oil stayed within the tank confinement basin and did not penetrate the hard-packed sand bottom. Waste oil was removed and disposed (UNI-228).
	UPR-100-N-21	184-N Diesel Oil Day Tank overflow	On April 25, 1986, an estimated 3,028 L (800 gal) of diesel oil spilled into the area surrounding a day tank at 184-N. Approximately 2,461 L (650 gal) were reported as pumped/cleaned up. Nearby monitoring Well 199-N-16 reported no detections (WIDS).
	UPR-100-N-22	Diesel oil supply line leak No. 1	On June 23, 1986, an estimated 3,785 L (1,000 gal) of diesel oil leaked from a transfer line. This release was detected in nearby Well 199-N-16 (WIDS). An unspecified quantity of petroleum material was pumped from the well (WHC-SD-EN-TI-251).
	UPR-100-N-23	Diesel oil supply line leak No. 2	On January 10, 1987, an estimated 757 L (200 gal) of diesel oil leaked from a transfer line. This release was detected in nearby Well 199-N-16. An unspecified quantity of petroleum material was pumped from the well (WHC-SD-EN-TI-251).
	100-N-12	184-N Pipeline spill	A spill inside the 184-N Pipeline that leaked to the outside occurred on October 14, 1987. An unknown amount of fuel oil leaked from a loose pipe fitting at the 184-N Annex. Spill was contained in a drain trench and cleaned up (WIDS).

Table 4-7. Petroleum Hydrocarbon Releases in the 100-N Area

Group	WIDS Number	Location	Description
Group 2 – Other Miscellaneous Sites	UPR-100-N-43	166-N to 184-N Transfer Line multiple leak	Diesel oil leaks occurred at three locations along a pipeline from 166-N to 184-N at three different flange points. The exact locations of the flange points were not provided. The release was reported on April 26, 1989. In total, 46 drums and 8 dump trucks of contaminated soil were removed. Sampling was conducted in nearby Wells 199-N-16 and 199-N-17 and oil was detected. Reported as cleaned up by April 26, 1989 (DOE/RL-90-22; WHC-C-89-047-100N-20).
	UPR-100-N-36	184-N Annex diesel generator area release	During excavation between 184-N and 153-N (area of approximately 40 m by 18 m (130 ft by 60 ft), a strong smell of petroleum was noted. Neither date nor quantity of material is reported (WIDS).
	100-N-36	Oil-stained pad (near 107-N Building)	This site was once used to support an air compressor. Neither date nor amount of petroleum material leaked is available; however, available documentation suggests that the quantity was minimal and limited to the soil immediately beneath the pad. The small amount of petroleum released may have leaked to the ground through a crack between the concrete pads and asphalt (WIDS).
	100-N-35	Hanford Generating Plant/Bonneville Power Administration Switchyard	This portion of the 100-N Area is still in use by the Bonneville Power Administration and is reported to contain spills of oil materials that could contain polychlorinated biphenyls.
	100-N-65	Diesel burn pit adjacent to river	This site was a trench/pit excavated adjacent to the river to intercept and burn diesel oil before it could significantly affect the Columbia River (refer to UPR-100-N-17). In 1994, the trench was backfilled with material to the top of the adjacent berm (WIDS).
	124-N-2	182-N Septic System	This site was a septic system east of 182-N that was reported to have had petroleum introduced into it. This site includes a septic tank and seepage pit and was reported pumped and isolated after the 124-N-10 Septic Treatment Facility was placed in service in February 1987 (WIDS).

Sources: BNWL-CC-1296, *Environmental Significance of Diesel Fuel Entering Columbia River at 100-N.*

DOE/RL-90-22, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit, Hanford Site, Richland, Washington.*

PNL-6456, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford: Volume 1 – Evaluation Methods and Results.*

UNI-228, *Oil Spill Prevention, Control, and Countermeasures Plan.*

WHC-C-89-047-100N-20, *Critique Report, 184-N Powerhouse Diesel Oil Leak (April 26, 1989).*

WHC-SD-EN-TI-251, *100-N Area Technical Baseline Report.*

WIDS = Waste Information Data System

Table 4-8. TPH-Diesel Concentrations (C10-C20) (µg/L) for Bioventing Performance Monitoring Wells and Aquifer Tubes

Date	199-N-3	199-N-19	199-N-56	199-N-96A	199-N-169	199-N-171	199-N-173	199-N-183	C6132	N116mArray-0A
June 2014	51 (U)	108 (J)	77.3 (J)	51 (U)	1,920	4,680 (D)	3,320 (D)	1,740	48.1 (U)	59 (U)
January 2015[a]	47.6 (U)	103 (J)	75.9 (J)	52.1 (U)	576	2,880	2,500	1,060	48.1 (U)	650[b]

Source: Tables 4-2 and 4-3 in WCH-600, *Annual Operations and Monitoring Report for UPR-100-N-17: November 2012 – February 2014.*

a. Groundwater samples for low river stage bioventing performance monitoring were collected in January 2015 to coincide with respirometry testing conducted during December 2014 to January 2015.

b. Sample collected from N116mArray-0A in December 29 as part of annual 100-NR-2 Operable Unit groundwater monitoring.

D = analyte was identified in an analysis at a secondary dilution factor

J = estimated

U = analyzed for but not detected above reporting limit

Table 4-9. Petroleum Hydrocarbon Removal from Well 199-N-18

Year	Product Removed (g)	Notes
2003[a]	~1,200[b]	Estimate provided per information given in table note; data records lost when original work package was lost in the field.
2004	3,475	Changed out twice per month.
2005	780	Changed approximately every 2 months.
2006	1,370	Changed every 2 months.
2007	1,294	Changed every 2 months.
2008	920	Changed every 2 months.
2009	1,380	Changed approximately every 2 months.
2010	225.5	Changed only twice prior to June 2010; smart sponge broke apart in well. No removal for second half of 2010.
2011	500	Changed every 2 months.
2012	600	Changed in January, April, June, and August 2012.
2013	750	Changed in January, March, May, July, September, and November 2013.
2014	550	Changed in February, April, June, August, and October 2014.
	Total	**13,044.5 g (approximately 13 kg) removed through end of 2014**

a. DOE/RL-2004-21, *Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump & Treat Operations*, reports that product removal began in October 2003.

b. DOE/RL-2005-18, *Calendar Year 2004 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, states that the average mass removal for fiscal year 2004 (October 2003 through October 2004) was approximately 0.4 kg/month; therefore, an estimate is provided for the 3 months missing in 2003.

Table 4-10. Maximum TPH-Diesel Concentrations (µg/L) for Selected Wells and Aquifer Tubes

Date	199-N-3	199-N-16	199-N-18	199-N-183	199-N-19	199-N-21	199-N-56	199-N-57	199-N-96A	199-N-173	116m Array-0A	C6135	116m Array-1A
1992	NR	200 (U)	NR	N/A	200 (U)	200 (U)	1,000 (U)	NR	NR	NR	NR	NR	NR
1993	1,000 (U)	67 (J)	NR	N/A	100 (U)	100 (U)	NR	100 (U)	NR	NR	NR	NR	NR
1994	1,000	4,000	NR	N/A	500 (U)	1,000	NR	NR	NR	NR	NR	NR	NR
1995 to 1998	NR	NR	NR	N/A	NR	NR	NR	NR	NR	NR	NR	NR	NR
1999	NR	NR	16,000 (D)	N/A	NR	NR	NR	NR	NR	NR	NR	NR	NR
2000	92 (U)	NR	23,000 (D,N)	N/A	NR	NR	NR	NR	NR	NR	NR	NR	NR
2001	92 (U)	NR	6,800,000 (D,N)	N/A	NR	NR	NR	NR	50 (U)	NR	NR	NR	NR
2002	50 (U)	NR	440,000 (D,N)	N/A	50 (U)	NR	NR	NR	1,500	NR	NR	NR	NR
2003	50 (U)	6,500 (N)	630,000,000 (D,Z)	N/A	50 (U)	NR	NR	NR	900	NR	NR	NR	NR
2004	50 (U)	6,100 (N)	340,000 (D,N)	N/A	50 (U)	60 (U,H)	60 (U)	NR	750 (N)	NR	NR	NR	NR
2005	50 (U)	11,000 (N)	69,000 (D,N)	N/A	580 (N,Q)	50 (U)	50 (U)	NR	610	NR	NR	NR	NR
2006	50 (U)	50 (U)	23,000 (D)	N/A	50 (U)	50 (U)	50 (U)	NR	50 (U)	NR	NR	NR	50 (U,D)
2007	50 (U)	33 (U,D,N)	190,000	N/A	50 (U)	71 (U)	50 (U)	NR	50 (U)	NR	970	290	15 (U)
2008	33 (U)	NR	809,000 (D)	N/A	72 (U)	NR	NR	NR	71 (U)	NR	94 (U)	320	72 (U)
2009	17 (U)	70 (U)	67,000 (D)	N/A	17 (U)	70 (U)	70 (U)	70 (U)	260	2,100	840	770	70 (U)
2010	70 (U)	79 (J)	420,000 (D)	N/A	70 (U)	70 (U)	70 (U)	70 (U)	200 (X)	2,100	570	910	200
2011	70 (U)	70 (U)	48,000 (H)	N/A	670	70 (U)	70 (U)	70 (U)	70 (U)	70 (U)	360	670	80 (U)

Table 4-10. Maximum TPH-Diesel Concentrations (μg/L) for Selected Wells and Aquifer Tubes

Date	199-N-3	199-N-16	199-N-18	199-N-183	199-N-19	199-N-21	199-N-56	199-N-57	199-N-96A	199-N-173	116m Array-0A	C6135	116m Array-1A
2012	70 (U)	70 (U)	Not sampled[d]	2,100 (X)	70 (U)	70 (U)	70 (U)	70 (U)	140	1,900	440	870 (X)	70 (U)
2013[a]	70 (U)	—[b]	Not sampled[d]	3,350 (X)	70 (U)	70 (U)	70 (U)	70 (U)	70 (U)	410	880	—[c]	70 (U)
2014	51 (U)	—[b]	Not sampled[d]	2,600 (T)	108 (J)	Not sampled	112 (J,T)	17 (U)	446 (T)	4,700 (T)	2,200 (T)	—[c]	47.6 (U)

Note: Highest detected result or lowest nondetectable result for a calendar year are reported in this table.

a. Does not include results in WCH-600, *Annual Operations and Monitoring Report for UPR-100-N-17: November 2012 – February 2014*, for performance monitoring of bioventing.

b. Decommissioned on December 18, 2012.

c. Aquifer tube was broken and could not be sampled.

d. Well 199-N-18 was replaced by Well 199-N-183 for groundwater sampling

Data flags:

D = sample was diluted for analysis
H = laboratory holding time exceeded before sample was analyzed
J = concentration is estimated
N = spike sample outside limits
N/A = not applicable
NR = not reported
Q = associated with out-of-limit quality control data
T = spike and/or spike duplicate sample recovery is outside control limits
U = undetected
X = see hardcopy data report for further explanation
Z = miscellaneous circumstances exist; see project file

Table 4-11. TPH-Diesel Concentrations (in µg/L) for Upriver Apatite Barrier Injection and Monitoring Wells

Date	N-200	N-201	N-202	N-203	N-204	N-205	N-206	N-207	N-208	N-209
4/1/2010	—	—	—	—	—	—	—	17 (U)	—	—
4/6/2010	—	3,500	—	3,600	—	3,200	—	—	—	2,200
6/24/2010	2,100 (X)	—	3,200 (X)	—	3,000 (X)	—	2,700 (X)	—	1,400 (X)	—
6/4/2014	856	2,800	—	—	—	—	—	—	—	—
Date	**N-210**	**N-211**	**N-212**	**N-213**	**N-214**	**N-215**	**N-216**	**N-217**	**N-218**	**N-219**
4/1/2010	—	17 (U)	—	17 (U)	—	17 (U)	—	17 (U)	—	17 (U)
4/6/2010	—	—	—	—	—	—	—	—	—	—
6/24/2010	70 (U)	—	70 (U)	—	—	—	—	—	—	—
6/25/2010	—	—	—	—	70 (U)	—	70 (U)	—	70 (U)	—
3/31/2014	70 (U)	—	—	—	—	—	—	—	—	—
6/4/2014	49.5 (U)	—	—	—	—	—	—	—	—	—
Date	**N-220**	**N-221**	**N-222**	**N-223**	**N-224**	**N-225**	**N-226**	**N-227**	**N-228**	**N-229**
3/31/2010	—	—	—	—	—	70 (U)	—	70 (U)	—	70 (U)
4/1/2010	—	17 (U)	—	17 (U)	—	—	—	—	—	—
6/25/2010	90 (U)	—	100 (U)	—	70 (U)	—	70 (U)	—	70 (U)	—
Date	**N-230**	**N-231**	**N-232**	**N-233**	**N-234**	**N-96A**	**N-347**	**N-348**	**N-349**	
3/31/2010	—	70 (U)	—	70 (U)	—	—	—	—	—	
4/6/2010	—	—	—	—	—	—	17 (U)	3,800	17 (U)	
6/25/2010	70 (U)	—	70 (U)	—	70 (U)	—	—	—	—	
11/14/2010	—	—	—	—	—	200 (X)	—	—	—	
1/18/2011	—	—	—	—	—	70 (U)	—	—	—	

Table 4-11. TPH-Diesel Concentrations (in μg/L) for Upriver Apatite Barrier Injection and Monitoring Wells

9/16/2011	—	—	—	—	—	70 (U)	80 (U)	80 (U)	70 (U)
9/20/2011	—	—	—	—	—	70 (U)	—	—	—
9/28/2011	—	—	—	—	—	—	80 (U)	80 (U)	80 (U)
10/13/2011	—	—	—	—	—	—	85 (U)	85 (U)	85 (U)
5/6/2012	—	—	—	—	—	—	70 (U)	70 (U)	—
8/27/2012	—	—	—	—	—	140	—	—	—
5/9/2012	—	—	—	—	—	—	—	—	91 J
5/6/2013	—	—	—	—	—	70 (U)	70 (U)		70 (U)
9/6/2013	—	—	—	—	—	70 (U)	70 (U)	70 (U)	70 (U)
6/5/2014	—	—	—	—	—	—	17 (U)	48.5 (U)	17 (U)
9/10/2014	—	—	—	—	—	—	140 (J)	65/5 (J.T)	—
9/11/2014	—	—	—	—	—	446 (T)	—	—	16 (U)

Notes: Highest detected result or lowest nondetectable result for a calendar year is reported in this table.

Orange shading indicates barrier injection well (deep).

Pink shading indicates barrier monitoring well (deep).

Yellow shading indicates barrier injection well (shallow).

J = estimated value

T = spike and/or spike duplicate sample recovery is outside control limits

U = undetected

X = see hardcopy data report for further explanation

Table 4-12. Breakdown of 100-NR-2 Remediation System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)														
	2000	2001[a]	2002[b]	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Design	—	—	—	—	—	447.9	—	—	—	20.5	31.0	--	0.6	0.0	0.0
Treatment system capital construction	—	—	—	—	—	161.9	922.6	—	—	316.2	(0.1)	(32.1)	0.0	0.0	0.0
Project support	96.3	183.5	219.4	133.0	329.7	416.5	284.4	79.8	10.7	278.5	276.5	178.9	133.3	284.2	173.9
Operations and maintenance	462.2	631.5	631.8	604.3	553.0	650.6	592.6	199.9	107.4	50.2	23.6	30.4	0.4	0.0	0.0
Performance monitoring	82.6	83.1	72.4	51.6	79.6	408.7	182.2	62.7	36.2	466.2	956.3	1,069.0	1,801.1	769.3	1,077.1
Waste management	131.6	112.5	100.0	45.4	27.4	7.6	13.0	43.4	8.9	3.6	0.5	2.3	0.0	0.0	0.0
Field studies	—	—	—	—	—	—	—	—	—	874.1	1,228.3	119.5	(2.2)	68.0	0.0
Barrier maintenance	—	—	—	—	—	—	—	—	—	634.3	1,468.0	1,844.4	15.9	46.4	1,079.8
Totals	**$773**	**$1,011**	**$1,024**	**$834**	**$990**	**$2.093**	**$1,995**	**$386**	**$163**	**$2,644**	**$3,984**	**$3,212**	**$1,949**	**$1,168**	**$2,331**

a. 2001 costs corrected for project support and waste management. Initial expense calculations for 2001 were not properly categorized.

b. 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

— = not available

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