DOE/RL-2017-67
Revision 0

Calendar Year 2017 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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Date Published
August 2018

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APPROVED
By Janis D. Aardal at 2:42 pm, Aug 30, 2018

Release Approval Date

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Executive Summary

This annual summary report describes the operations and results of groundwater treatment remedies during 2017, including details on the volume of water treated, contaminant mass removed, efficiency, effectiveness of the interim remedial actions, and the resulting effect on groundwater concentrations. 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 a Record of Decision (ROD) for interim remedial action.[1] Two P&T systems (DX and HX) are operating in the 100-HR-3 OU, and three P&T systems (KR4, KW, and KX) are operating in the 100-KR-4 OU. Operation of the P&T systems continues to provide progress toward meeting the objectives of the 100-HR-3 and 100-KR-4 interim action ROD, which are as follows:

- Protect aquatic receptors.
- Protect human health from exposure to groundwater.
- Provide information that will lead to a final remedy.

The P&T systems in the 100-HR-3 and 100-KR-4 OUs extract groundwater, remove the Cr(VI) using an ion-exchange resin in the treatment plants, and then reinject the treated water into the aquifer. A total of 5,224 million L (1,380 million gal) of groundwater were extracted and treated by the P&T systems in the 100-HR-3 and 100-KR-4 OUs during 2017. These actions removed 93 kg of Cr(VI) from the aquifer, described as follows:

- At the 100-HR-3 OU, the combined DX and HX P&T systems processed 2,915 million L (770 million gal) of groundwater and removed 56.3 kg of Cr(VI) in 2017. Since startup, the 100-HR-3 OU P&T systems have treated 21,047 million L (5,560 million gal) of groundwater and removed 2,490 kg of Cr(VI).

[1] EPA/ROD/R10-96/134, 1996, *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0078950H.

- Cr(VI) concentrations in 100-D Area groundwater have decreased since 2010 due to DX P&T system operations and source area removal of waste sites (e.g., the 100-D-100 waste site, and the combined 100-D-30/100-D-104 waste sites). Maximum Cr(VI) concentrations have dropped to less than 1,000 µg/L since 2015, compared to 69,700 µg/L in 2010. In 2017, the maximum Cr(VI) concentration detected in groundwater was 730 µg/L. The areal extent of the plume at the remedial action target concentration of 20 µg/L declined between 2016 and 2017. The extent of the high-concentration portions of the plume were also reduced.

- The combined 100-KR-4 OU P&T systems treated 2,309 million L (610 million gal) of groundwater, removing 36.7 kg (of Cr(VI)) from groundwater during calendar year 2017. Since startup, the 100-KR-4 OU P&T systems have treated 23,591 million L (6,232 million gal) of groundwater and removed 904 kg of Cr(VI). Increased extraction rates resulting from installation of new wells and realignment of existing wells during the last 3 years is providing enhanced plume control in near-river regions of the 100-KR-4 OU.

- At the beginning of 2016, Cr(VI) concentrations had reached levels less than 20 µg/L at all groundwater monitoring locations in the area affected by the KW P&T. Between May 2016 and April 2017, the KW P&T system was shut down to perform a rebound study to evaluate whether contaminant concentrations would remain below cleanup levels and to determine if continuing secondary source material exists in the deep vadose zone. Concentrations between the KW Reactor and the Columbia River remained below the groundwater remediation target of 20 µg/L during the rebound study and afterward, with no indication of any continuing sources or residual plumes in this area. A portion of the KW P&T area exhibited increasing Cr(VI) concentrations between the KW Reactor and the 183.1KW Head House area, and extraction and treatment of groundwater was restarted at selected locations in 2017. SGW-62061[2] documents the results of the rebound study.

Cr(VI) is also being addressed in the 100-HR-3 OU through continued monitoring of a permeable reactive barrier (PRB) that was implemented under a ROD amendment for

[2] SGW-62061, 2018, *KW Rebound Study Summary Report and Assessment*, Rev.0, CH2M HILL Plateau Remediation Company, Richland, Washington. (in publication)

the interim remedial action.[3] In situ redox manipulation (ISRM) is used to produce a PRB for treatment of Cr(VI). This passive system reduces Cr(VI) to the immobile 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, [4] 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 continues to chemically reduce Cr(VI), supplemented by the P&T system extraction wells. At the end of 2017, Cr(VI) concentrations at barrier wells ranged from below detection to 68 µg/L, with an overall decrease in concentrations compared to 2016. The observed changes in Cr(VI) concentration are attributed to a combination of residual chemical reduction by the ISRM PRB, as well as extraction and treatment of contaminated groundwater in areas where the PRB is no longer effective.

Protection of the Columbia River from the discharge of chromium-contaminated groundwater continues to improve. River protection is assessed against conditions that may cause the river interface area to exceed the 10 µg/L ambient water quality criterion. In 2017, the affected length of shoreline in the 100-D Area was extended to include an additional 500 m (1,640 ft) to the north delineated at concentrations above 10 µg/L at two new monitoring locations. An extraction well located in this area provides some hydraulic containment of this portion of the plume, and works with the hydraulic gradient that is toward the east to keep contaminants from reaching the river. During 2017, 200 m (655 ft) of the 2,800 m (9,185 ft) shoreline impacted by the Cr(VI) plume in the 100-D Area were identified as not adequately protected, which was the same observation made for 2016. Of the 4,400 m (14,430 ft) of shoreline impacted by the Cr(VI) plume in the 100-H Area, 400 m (1,310 ft) was identified as not adequately protected in 2017, which was also the same observation made for 2016. The remainder of the affected

[3] EPA/AMD/R10-00/122, 2000, *Interim Remedial Action Record of Decision Amendment for the 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Region 10, Washington State Department of Ecology, and U.S. Department of Energy, Seattle, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D199159580.

[4] 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.

100-H Area shoreline was identified as either "protected," or as "protected but additional action may be required."

In the 100-K Area, 100 m (330 ft) of shoreline was identified as not protected due to decreased hydraulic containment at shoreline locations, with Cr(VI) concentrations exceeding 10 µg/L in 2017. The remaining 3,900 m (12,790 ft) of affected shoreline was identified as either "protected" or as "protected but additional action may be required." In both the 100-HR-3 and 100-KR-4 OUs, improvements in river protection status are the direct result of ongoing improvements in the capture and treatment of contaminated groundwater by the P&T systems through realignments to increase extraction rates and placement of new extraction wells at locations selected to intercept targeted plume segments.

In the 100-NR-2 OU, interim remedial actions are implemented for strontium-90 and total petroleum hydrocarbons (TPH) as groundwater COCs in accordance with the interim action ROD.[5] The objectives of the interim action ROD are as follows:

- Protect the Columbia River from adverse impacts from 100-NR-2 groundwater.
- Protect the unconfined aquifer by reducing contaminants present in groundwater.
- Obtain information to evaluate strontium-90 removal technologies and evaluate ecological receptor impacts from contaminated groundwater.
- Prevent destruction of sensitive wildlife habitat.

A P&T system developed in the 1990s for removing and treating strontium-90-contaminated groundwater proved ineffective. Subsequently, a PRB was installed along the shoreline to intercept and treat the migrating groundwater contaminated with strontium-90 using a mineral apatite, as described in a ROD amendment.[6] An initial 91 m (300 ft) length of the barrier was installed from 2006 to 2008, which was then later expanded to 311 m (1,020 ft) in 2011, to target the

[5] EPA/ROD/R10-99/112, 1999, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Region 10, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Seattle, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0078951H.

[6] EPA, 2010, *U.S. Department of Energy 100-NR-1 and NR-2 Operable Units Hanford Site – 100 Area Benton County, Washington Amended Record of Decision, Decision Summary and Responsiveness Summary*, U.S. Environmental Protection Agency, Seattle, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084198.

shoreline downgradient of the highest strontium-90 concentration areas. As groundwater flows through the barrier, strontium-90 contamination adsorbs to the apatite and is immobilized within the barrier where it radiologically decays, thereby reducing the amount of contamination migrating to the Columbia River. Groundwater samples at the PRB monitoring points show that concentrations in the majority of the monitoring wells in 2017 continued to be lower than pre-barrier levels by nearly 90%. However, in 2015, strontium-90 concentrations increased in some of the monitoring wells and remained elevated during 2017.

Removal of TPH-free product (primarily in the diesel range) from well 199-N-18 continued in 2017. The diesel is removed using a polymer “smart sponge” that selectively absorbs petroleum products from the groundwater within the well. In 2017, smart sponge assemblies were also installed in well 199-N-183, which was drilled near well 199-N-18 as a replacement well. Diesel odor and an oil sheen have been observed in the new well periodically during sampling. The smart sponges were installed and changed out at the same frequency used at well 199-N-18. In 2017, 900 g of diesel were removed from well 199-N-18, and 600 g of diesel were removed from well 199-N-183.

Since interim remedies were implemented in the 1990s, additional characterization activities (i.e., remedial investigations), including information gained from continued operation of the remedial systems and expansion of well networks, have improved the understanding of the nature and extent of contaminants of interest in the groundwater. Data evaluation and presentation have been improved by implementing enhanced contaminant plume interpolation processes and developing a method to evaluate the degree of river protection afforded by the remedial systems in place.

Although the interim remedial actions are effective and have demonstrated improvement in both protecting the Columbia River and reducing groundwater contaminant concentrations, remedies are not yet complete. Interim remedial action operations will continue, as well as monitoring activities and remedial process optimization. Routine monitoring and optimization activities include the following:

- Evaluating results from analytical samples collected from wells, aquifer tubes, and treatment process locations.
- Evaluating individual extraction and injection well performance.

- Evaluating estimated hydraulic capture by remedial systems.
- Evaluating treatment process performance.
- Adjusting P&T system operations to optimize system performance in response to observed conditions. System adjustments have included modifying the treatment plants in the 100-K Area to expand treatment capacity by reducing the number of resin vessels in each treatment train to more effectively use the ion-exchange resin.
- Evaluating the 100-NR-2 apatite PRB performance for additional apatite chemical injections.

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Terms

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
D&D	deactivation and decommissioning
DCS	derived concentration standard
DOE	U.S. Department of Energy
DWS	drinking water standard
Ecology	Washington State Department of Ecology
ESD	explanation of significant differences
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FSB	fuel storage basin
FY	fiscal year
IC	institutional control
ICFM	interpolated capture frequency map
ISRM	in situ redox manipulation
IX	ion exchange
MCL	maximum contaminant level
MDA	minimum detectable activity
MTCA	Model Toxics Control Act
O&M	operations and maintenance
OU	operable unit
P&T	pump and treat
PRB	permeable reactive barrier

PRZ	periodically rewetted zone
QA	quality assurance
QC	quality control
RAO	remedial action objective
RD/RAWP	remedial design report/remedial action work plan
RI/FS	remedial investigation/feasibility study
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
TED	total effective dose
TPH	total petroleum hydrocarbons
TPH-D	total petroleum hydrocarbons-diesel
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
UPR	unplanned release

1 Introduction

Along the Columbia River Corridor of the Hanford Site, the U.S. Department of Energy (DOE) currently operates and maintains five pump-and-treat (P&T) systems: three within 100-KR-4 Operable Unit (OU), and two within 100-HR-3 OU. In addition, DOE maintains one permeable reactive barrier (PRB) (the 100-NR-2 apatite barrier) and continues to monitor a second PRB (the 100-HR-3 in situ redox manipulation [ISRM] barrier). Petroleum free-floating product is also being removed at the 100-NR-2 OU. These systems are part of ongoing efforts to remediate contaminated groundwater in the Hanford Site 100-KR-4, 100-HR-3, and 100-NR-2 Groundwater 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.

Two P&T systems (DX and HX) operated throughout 2017 to remediate Cr(VI) in the 100-HR-3 OU, which includes the combined 100-D and 100-H Areas and the Horn area. An ISRM PRB was installed in the southwestern portion of the 100-D Area in 2000. This barrier continues to reduce Cr(VI) in groundwater but is no longer maintained as an active remediation treatment. The remaining three P&T systems (KR4, KX, and KW) remediate Cr(VI) contamination associated with the 100-KR-4 OU. Table 1-1 provides a performance summary for the five P&T systems for 2017.

Interim actions 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* (hereinafter referred to as the 100-HR-3 and 100-KR-4 OU interim action Record of Decision [ROD]):

- **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 ion-exchange (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 Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Change Number M-16-06-01 (*Establish Interim Milestone M-016-14, Complete Construction of a Permeable Reactive Barrier at 100-N*), the 100-NR-2 P&T system was placed in cold-standby status on March 9, 2006. Demolition and decommissioning of the 100-NR-2 P&T system began in 2016 and was completed in 2017. DOE began installing 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 remedial technology implemented uses apatite as a reactive material to sequester strontium-90 from the groundwater.

This report presents the 2017 performance summary for the interim remedial actions in accordance with annual remedy reporting identified in the Remedial Design/Remedial Action Work Plans for the interim remedies (DOE/RL-2013-31, *100-HR-3 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan*, DOE/RL-2013-33, *Remedial Design/Remedial Action Work Plan for the 100-KR-4 Groundwater Operable Unit Interim Action*, and DOE/RL-2001-27, *Remedial Design/Remedial Action Work Plan for the 100-NR-2 Operable Unit*).

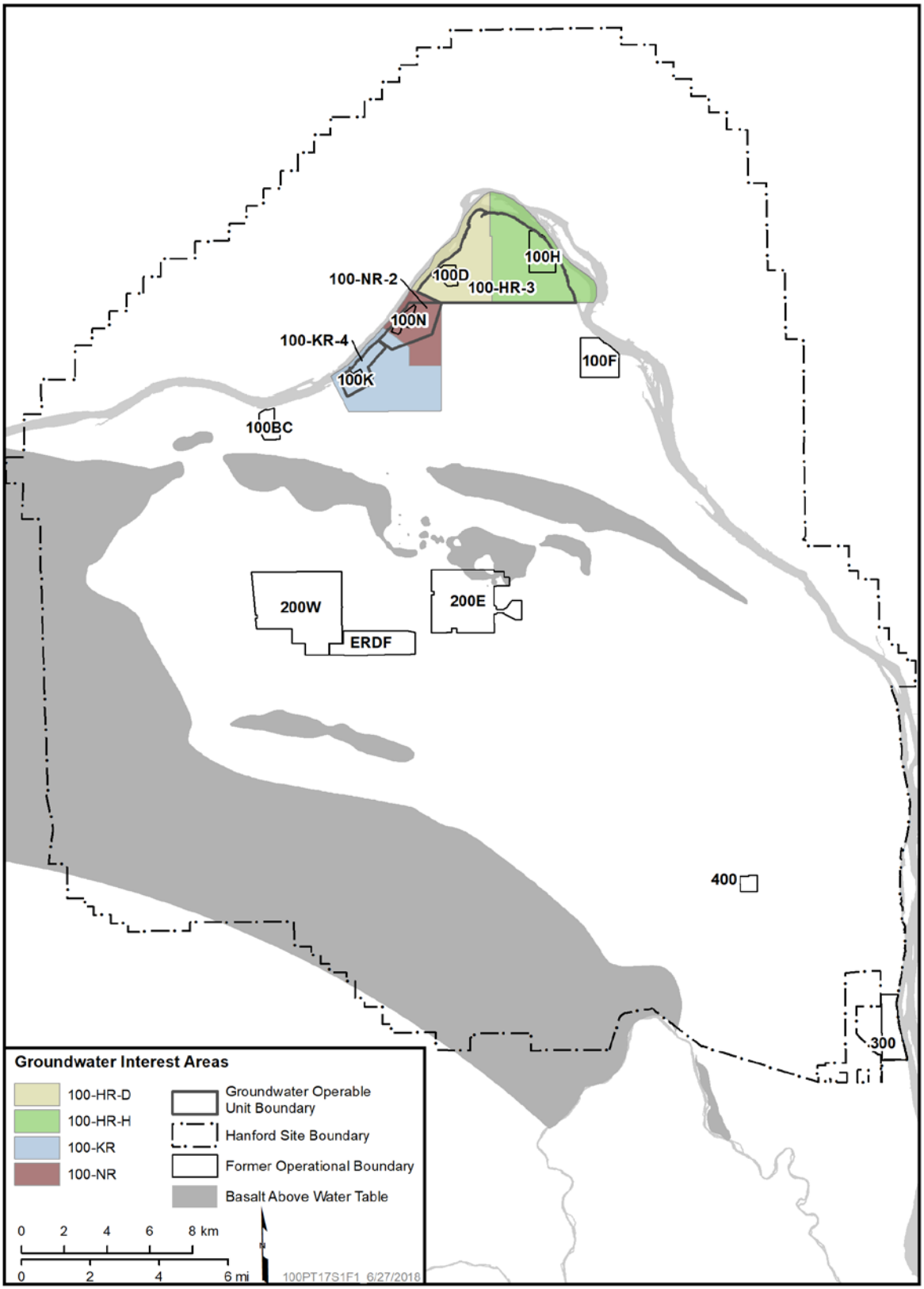

Figure 1-1. Locations of Groundwater OUs and Interest Areas Along the Columbia River

Table 1-1. P&T Performance Summary, 2017

Groundwater Operable Unit: P&T System	100-HR-3		100-KR-4		
	DX	HX	KW[a]	KR4	KX
Design capacity (L/min [gal/min])	2,936 (775)	3,407 (900)	1,249 (330)	1,249 (330)	3,407 (900)
Extraction wells[b]	48	37	5[c]	11	21
Injection wells[b]	11	17	4[c]	5	10
Average flow rate (L/min [gal/min])	2,829 (747)	2,805 (740)	1,162[d] (307)	994 (262)	2,729 (721)
Volume treated (million L [million gal])	1,469 (388)	1,450 (383)	433 (114)	516 (136)	1,360 (359)
Cr(VI) mass removed (kg)	30.4	25.9	14.4	1.4	21
Average Cr(VI) influent concentration (µg/L)	21.8	18.3	35.1	3.3	16.1
Average Cr(VI) effluent concentration (µg/L)	<2	<2	<2	<2	<2

a. The KW P&T was on standby between May 2016 and April 2017 for a rebound test.

b. The number of extraction and injection wells includes those that are not in service but are still connected to the system as of December 31, 2017.

c. The KW P&T extraction wells were reconnected to focus pumping efforts between the KW Reactor and the 183.1KW Head House.

d. Average flow rate while the KW P&T was operating after restart.

Cr(VI) = hexavalent chromium

P&T = pump and treat

The following four RAOs for the 100-NR-2 OU are described in the interim action ROD (EPA, 2010, *U.S. Department of Energy 100-NR-1 and NR-2 Operable Units Hanford Site – 100 Area Benton County, Washington Amended Record of Decision, Decision Summary and Responsiveness Summary*):

- **RAO #1**: Protect the Columbia River from adverse impacts from 100-NR-2 OU 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.

Tri-Party Agreement (Ecology et al., 1989) milestone target dates 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 Tri-Party Agreement milestones are directly applicable to the 100-HR-3, 100-KR-4, and 100-NR-2 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 National Priorities List (NPL) Operable Units such that ambient water quality standards for hexavalent chromium are achieved in the hyporheic zone and river column water.*

Remedial actions toward achieving Tri-Party Agreement 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'").

- ***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 operation and enhancement of Cr(VI) groundwater remedies in the 100-HR-3 and 100-KR-4 OUs continues to reduce overall groundwater chromium concentrations. Plume areas exceeding drinking water standards (DWSs) continue to decrease in the 100-HR-3 and 100-KR-4 OUs.

DOE continues to optimize P&T remedies in the 100-HR-3 and 100-KR-4 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 remedy completion timeframe. Remedial process optimization (RPO) activities for 2017 at the 100-HR-3 and 100-KR-4 OU remedial systems focused on the following:

- **Assessing extraction and injection well performance:** Includes evaluating individual well performance and identifying wells needing maintenance. This also includes evaluating individual pumping rates for extraction wells located within specific portions of contaminant plumes (e.g., at or near source areas, or along the leading edge of plumes).

- **Evaluating well network performance:** Includes evaluating the placement and pumping rates of wells with respect to contaminant plume distribution and monitoring. Modeling tools were used to evaluate anticipated well field performance under selected pumping scenarios. Based on these assessments, additional monitoring and extraction capability was added to the P&T systems by realigning selected existing wells as extraction wells and by drilling and constructing new wells, focusing on enhancing plume monitoring, contaminant capture and mass removal in source areas, and protecting the river by enhancing capture along the leading edges of plumes that approach or intersect the river.

- **Assessing treatment process effectiveness:** This evaluation led to the changeover in 2011 to using the current ResinTech® SIR-700 IX resin. In 2017, the resin continued to provide highly efficient Cr(VI) removal from extracted groundwater.

Groundwater P&T systems in the 100-HR-3 and 100-KR-4 OUs continue to show progress in river protection. In 2017, the affected length of shoreline in the 100-D Area was extended to include an additional 500 m (1,640 ft) to the north delineated at concentrations above 10 µg/L at two new monitoring locations. An extraction well located in this area provides hydraulic containment. During 2017, net change was not observed from 2016 in regard to the 200 m (655 ft) of shoreline length identified as not adequately protected. Of the 4,400 m (14,430 ft) of shoreline impacted by the Cr(VI) plume in the 100 H Area, 400 m (1,310 ft) were identified as not adequately protected in 2017, which was

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the same observation made for 2016. The remainder of the affected 100-H Area shoreline was identified as either "protected," or as "protected but additional action may be required."

In the 100-K Area, 100 m (330 ft) of shoreline were identified as not protected because of decreased hydraulic containment at shoreline locations with Cr(VI) concentrations above 10 μg/L in 2017. The remaining 3,900 m (12,790 ft) of affected shoreline were identified as either "protected" or as "protected but additional action may be required."

The P&T 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 Chapter 2 for the 100-HR-3 OU, and in Chapter 3 for the 100-KR-4 OU) indicate ongoing progress for river protection for the two OUs.

Groundwater samples at the PRB monitoring points for the 100-NR-2 OU show that concentrations in the majority of the monitoring wells during 2017 continued to be lower than pre-barrier levels by nearly 90%. However, in 2015, concentrations of strontium-90 increased in some of the monitoring wells and remained elevated throughout 2017.

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*, provides additional information on site history for the 100-HR-3, 100-KR-4, and 100-NR-2 OUs. The appendix presents a chronology of the investigations and decisions for the interim remedial actions, as well as a summary of the conceptual site models (CSMs) associated with groundwater contamination at the OUs.

This annual summary report discusses groundwater remedial actions conducted during 2017 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. Chapter 5 provides the references cited in this report.

1.1 100-HR-3 Operable Unit Activities

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

1.1.1 100-HR-3 Operable Unit Pump-and-Treat Systems

The DX and HX P&T systems operated throughout 2017, with several wells realigned to improve capture and remove contaminant mass from the aquifer. The methodology for evaluating river protection was initially presented in DOE/RL-2014-25, where areas along the Columbia River were classified as "protected," "not protected," or "action may be required." Those areas considered at risk for contamination impacts were evaluated, and actions were initiated to improve river protection in those areas.

Figure 1-2 shows the 2017 P&T system layout for 100-HR-3, and Figure 1-3 highlights the well changes to the P&T system configuration. The 2017 system modifications to the DX P&T system included converting injection wells 199-D2-10, 199-D2-12, 199-D8-93, and 199-D8-94 to monitoring wells. These wells were located on the northern portion of the 100-D Area and were not suitable for receiving large volumes of water due to their proximity to the river. The wells had only been used periodically and were converted to allow for plume monitoring in that area. At the HX P&T system, extraction well 199-H1-3 was disconnected from the P&T system because it had historically low run-times due to low water levels. In addition, the conveyance line size was increased at extraction well 199-H1-45, allowing the well to run at a higher flow rate and provide better capture in that area of the plume. The pumping rate had increased during 2016. Section 2.2 provides further details on the changes to the DX and HX P&T systems.

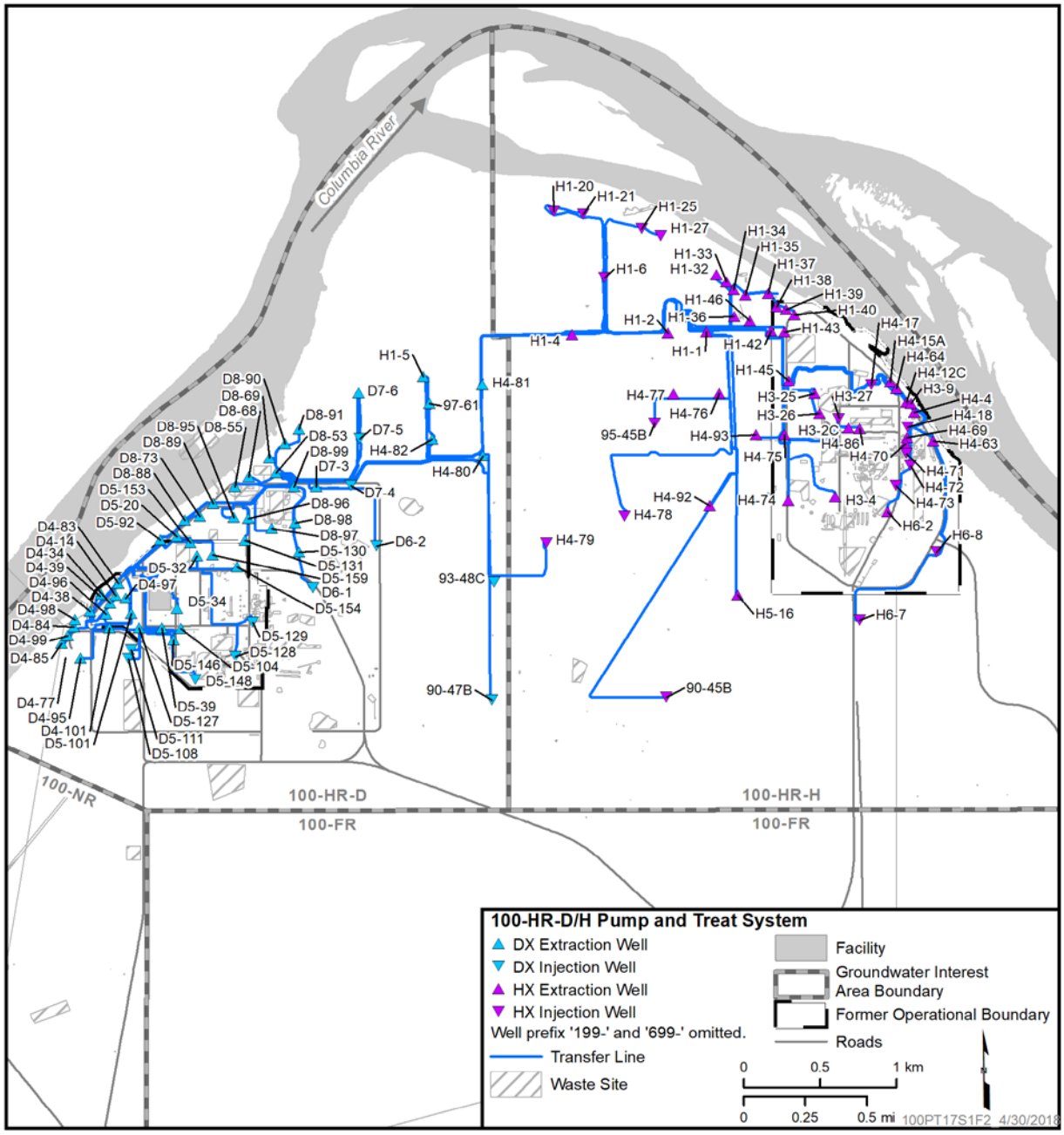

Figure 1-2. Layout of the 100-HR-3 OU P&T Systems (as of December 31, 2017)

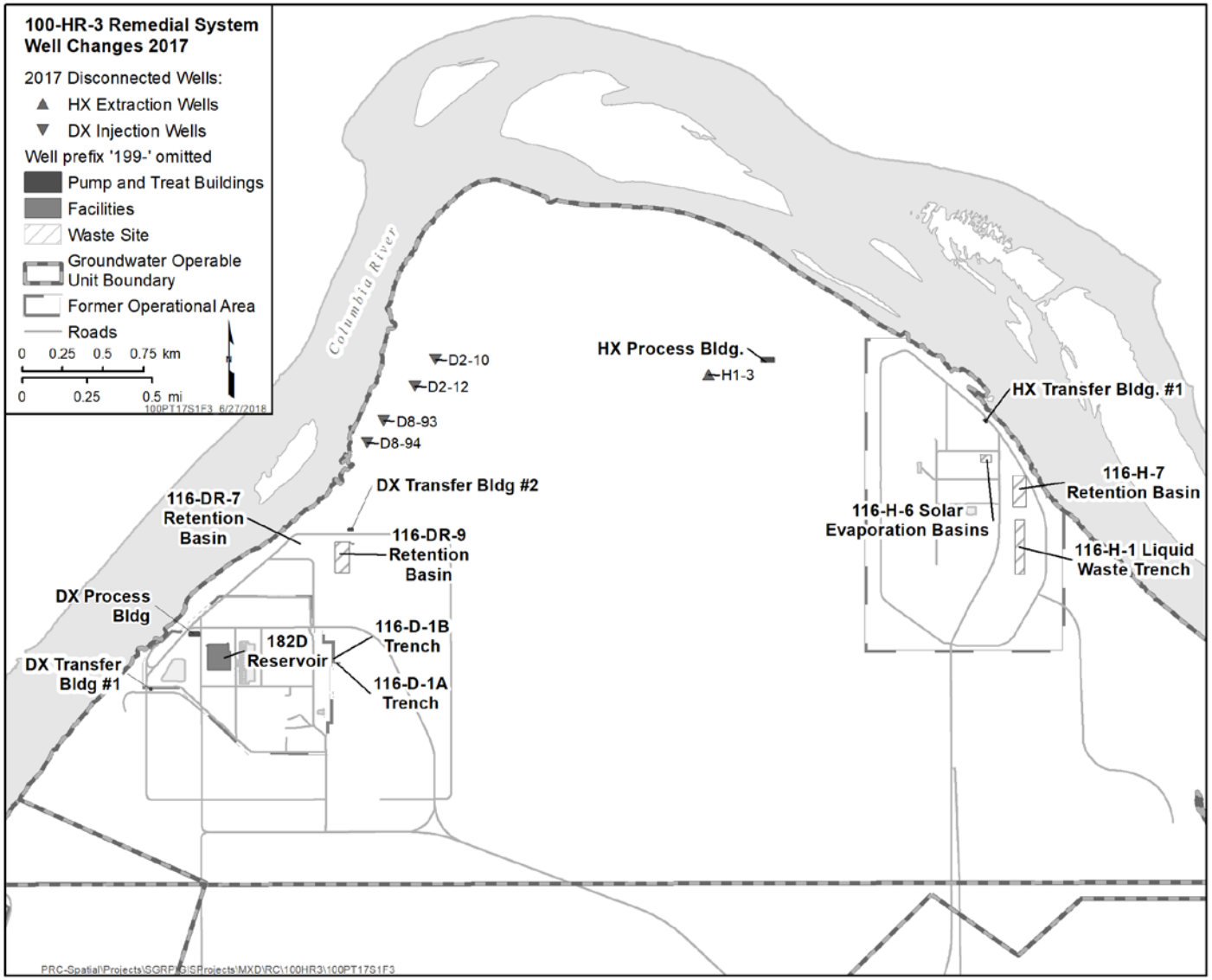

Figure 1-3. Well Changes Completed to the 100-HR-3 OU P&T Systems

Figures 1-4 and 1-5 show the annual and cumulative trends for groundwater volume treated and Cr(VI) mass removed by the 100-HR-3 P&T systems. Table 1-1 presents the amount of water treated and mass removed by each system during 2017. The amount of mass removed by the system began to decrease after the main source areas were remediated, and the areas of high concentrations have reduced in size. This trend continued in 2017, as shown in Figure 1-5.

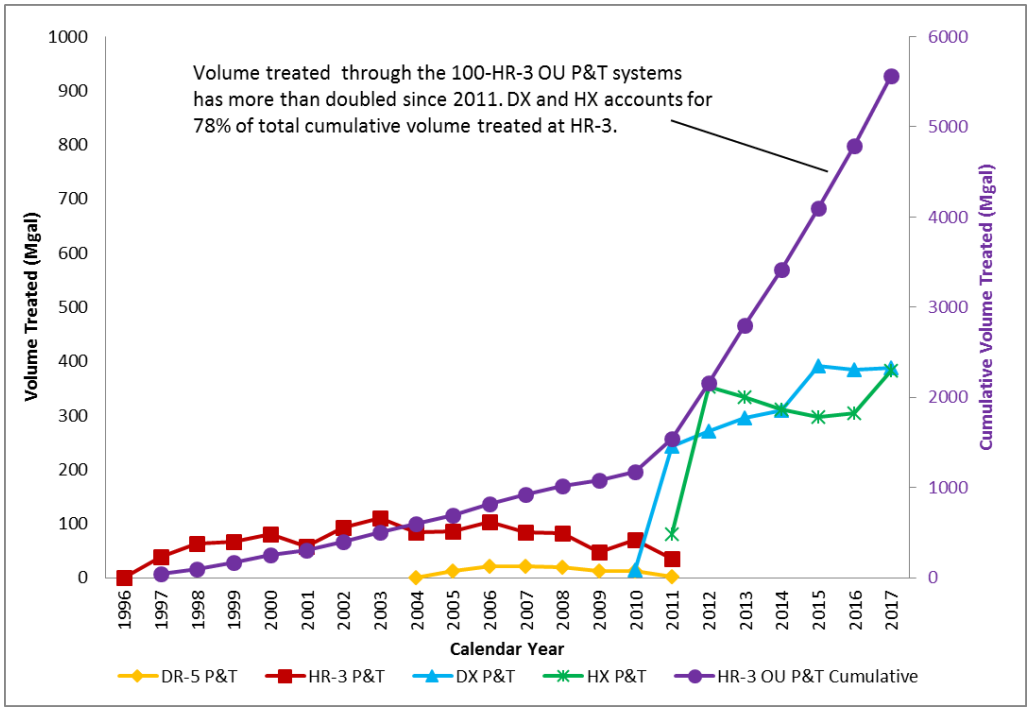

Figure 1-4. Volume Treated at the 100-HR-3 OU P&T Systems

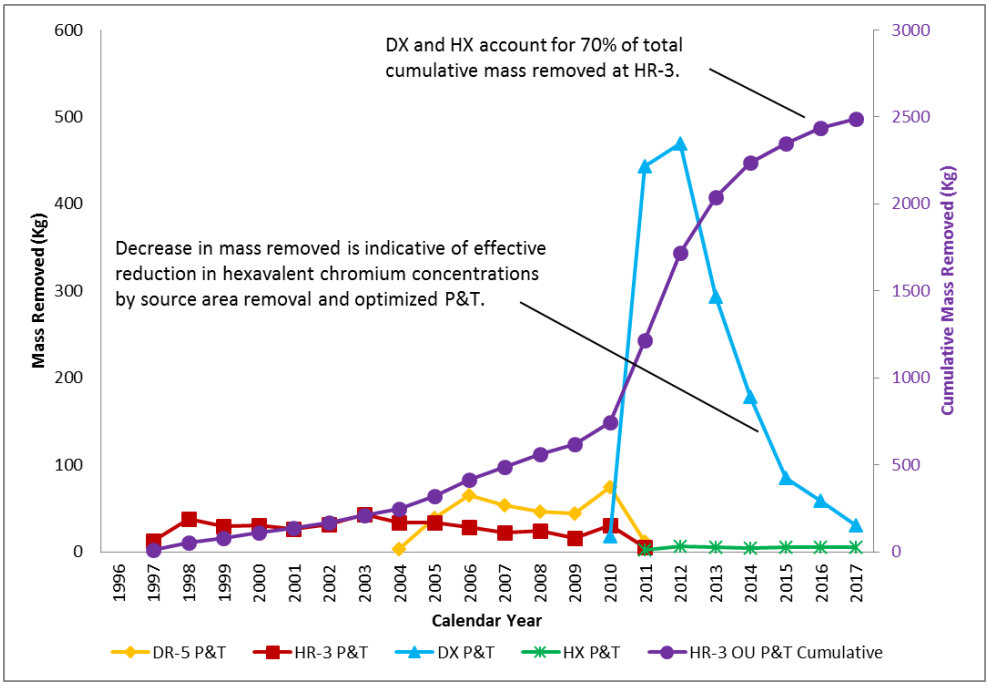

Figure 1-5. Cr(VI) Mass Removed by the 100-HR-3 OU P&T Systems

1.1.2 In Situ Redox Manipulation

In 2000, additional cleanup action was taken using an in situ chemical treatment technology, 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. Monitoring showed that Cr(VI) concentrations in groundwater passing through the ISRM barrier were above the required treatment level indicating Cr(VI) contamination breakthrough at several portions of the ISRM barrier. The ROD amendment stated "If barrier breakthrough is identified, Ecology and EPA will determine alternative action to be taken." Due to breakthrough of Cr(VI) 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 use of the P&T system.

Groundwater monitoring at the ISRM barrier showed that the barrier continued to convert Cr(VI) to trivalent chromium within a portion of the aquifer in 2017. Cr(VI) concentrations in some downgradient wells remained above the ambient water quality criterion and interim remedial action target of 10 μg/L and 20 μg/L, respectively, because the northeast segment of the barrier is no longer effective. Groundwater in this area is captured by extraction wells installed for the DX P&T system. Sections 2.1.2 and 2.2.8 further discuss the ISRM treatment technology and its effectiveness.

1.2 100-KR-4 Operable Unit Activities

Three active P&T systems continued operating in the 100-KR-4 OU during 2017. The KR4 P&T system treats groundwater downgradient from the 116-K-2 Trench, with a treatment capacity of 1,249 L/min (330 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 3,407 L/min (900 gal/min) design treatment capacity. The KW P&T system extracts groundwater around the KW Reactor facility and has a treatment capacity of 1,249 L/min (330 gal/min). Figure 1-6 shows the layout of the 100-KR-4 OU P&T systems.

Figure 1-7 highlights changes to the 100-KR-4 OU P&T system configuration implemented from 2013 through 2017. All planned modifications proposed in the SGW-59936, *FY17 Plume Contaminant and Remediation Utilization Plan*, were implemented for the 100-KR-4 OU and are discussed in Chapter 3 of this annual report.

Cr(VI) concentrations in monitoring wells in the area affected by the KW P&T system were below the interim remedial action target concentration of 20 μg/L in January 2016. Between May 2016 and April 2017, the KW P&T system was shut down to perform a rebound study to evaluate whether contaminant concentrations would remain below cleanup levels and to evaluate if secondary vadose zone sources affect groundwater. The results of the rebound study are documented in SGW-62061, *KW Rebound Study Summary Report and Assessment*. Chapter 5 of DOE/RL-2017-66, *Hanford Site Groundwater Monitoring Report for 2017*, discusses the measurements and observations collected between January and April 2017.

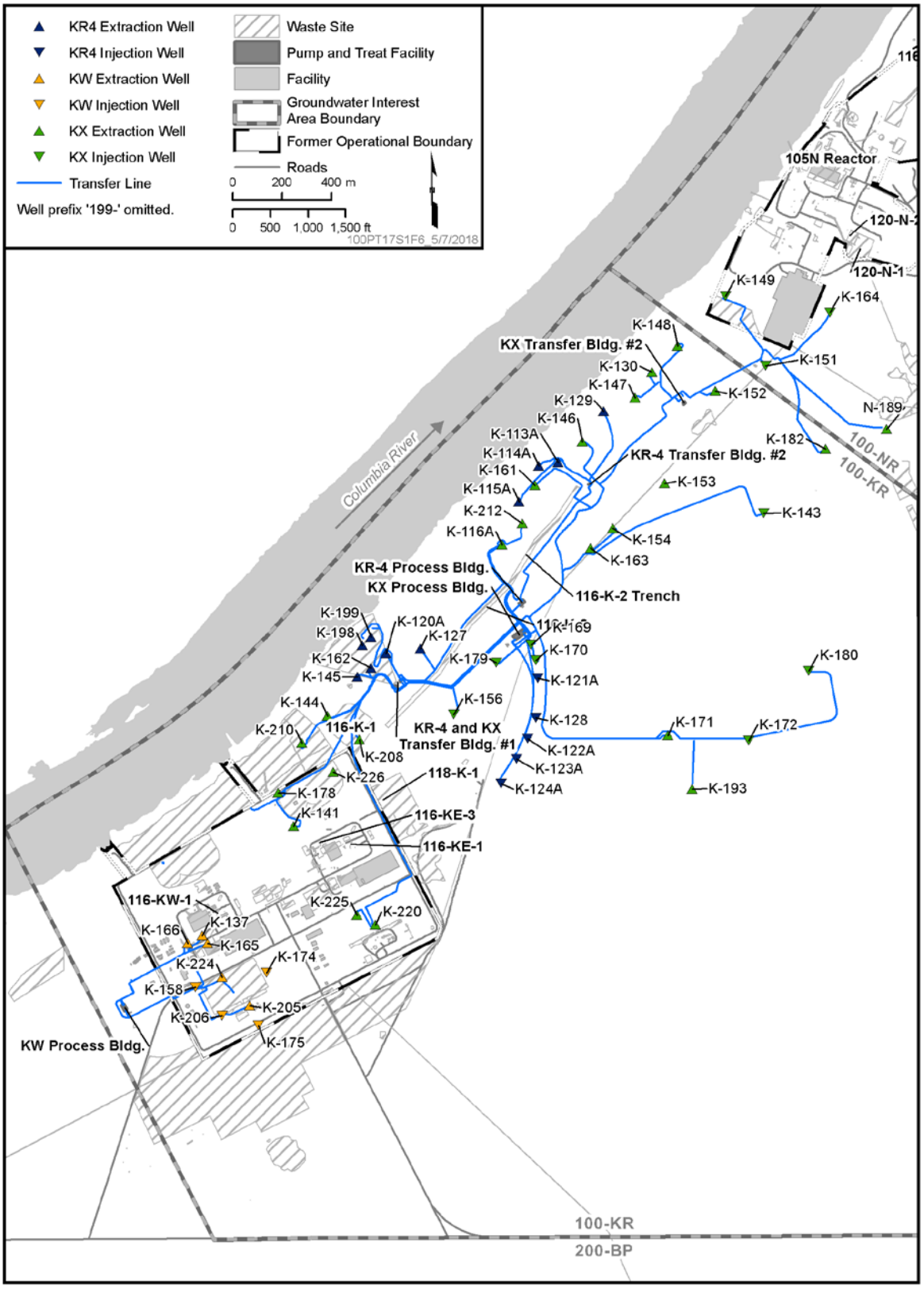

Figure 1-6. Layout of 100-KR-4 OU P&T Systems

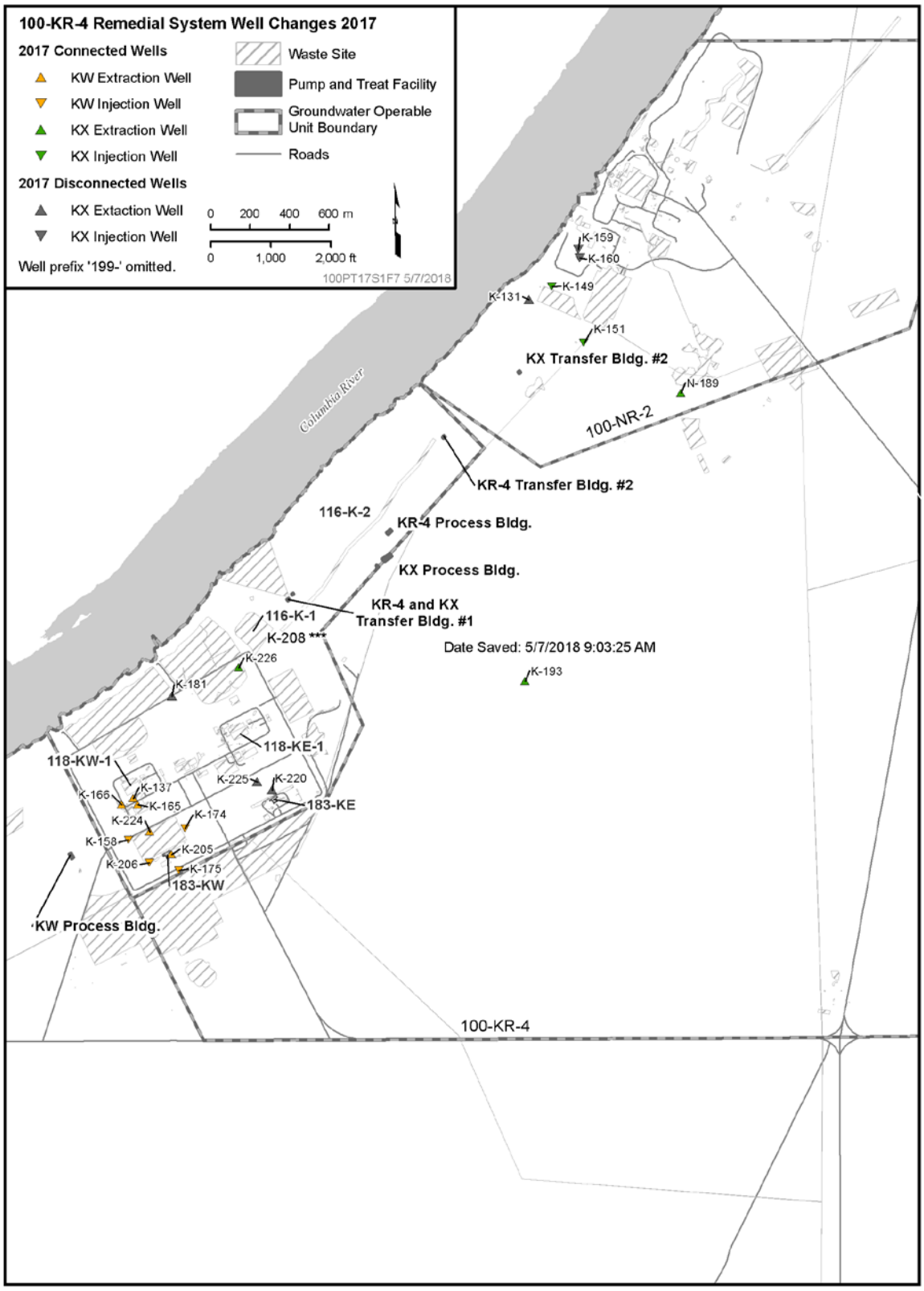

Figure 1-7. Extraction, Injection, and Monitoring Wells Added to 100-KR-4 OU Well Network, 2017

Figures 1-8 and 1-9 show the annual and cumulative volume treated and mass removed by the 100-KR-4 P&T systems. Table 1-1 presents the amount of water treated and mass removed by each system during 2017. With the use of high-efficiency, high-capacity SIR-700 IX resin, the systems 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 plant treatment capacity, thus increasing the treatment capacity of each system.

1.3 100-NR-2 Operable Unit Activities

The following sections summarize the activities at the 100-NR-2 OU for the reporting period.

1.3.1 100-NR-2 Operable Unit Pump-and-Treat System

The 100-NR-2 P&T system was placed in cold-standby status in March 2006. This system was demolished, excavated, and removed during the period of August through November 2016. Demolition and decommissioning was completed in 2017 to remove piping from the former injection wells and demolish the 1323N sample shack (located near the shore of the Columbia River). Surface and subsurface features associated with the system (including permanent and temporary structures, concrete slab, vaults and culverts beneath roads and three 100-NR-2 P&T signs) were removed from the site and disposed at the Environmental Restoration Disposal Facility (ERDF).

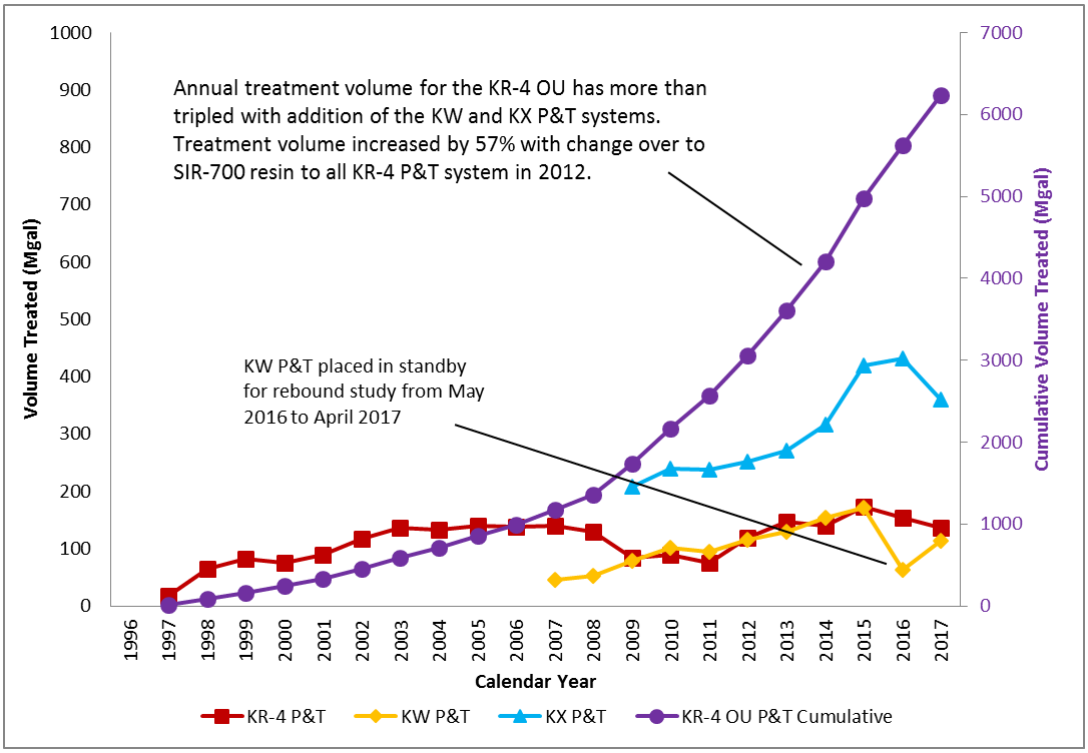

Figure 1-8. Volume Treated at the 100-KR-4 OU P&T Systems

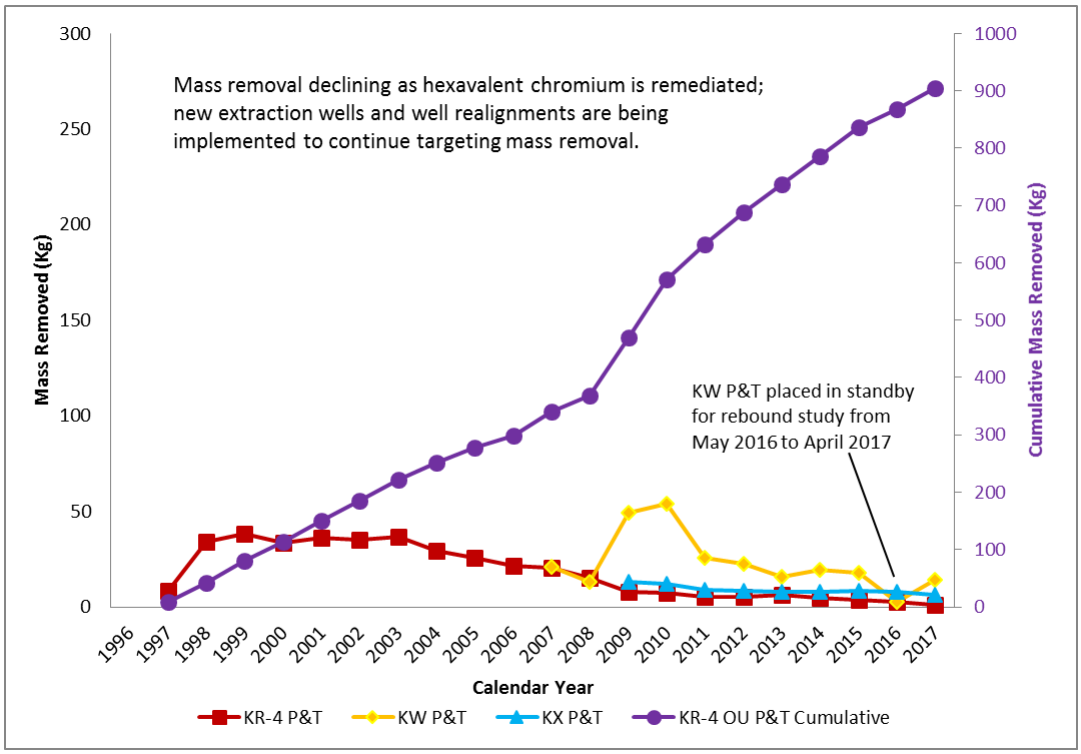

Figure 1-9. Cr(VI) Mass Removed by the 100-KR-4 OU P&T Systems

1.3.2 100-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 Change Control Form M-16-06-01 dated February 15, 2006 (*Federal Facility Agreement and Consent Order Change Control Form: Establish Interim Milestone M-016-14, Complete Construction of a Permeable Reactive Barrier at 100-N*), 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) remedial investigation/feasibility study (RI/FS) process. Change Number M-16-06-01 established two new milestones (M-016-14A and M-016-14B) for constructing and evaluating a 91.4 m (300 ft) PRB using apatite sequestration at the 100-N Area. Milestones M-016-14(a) and M-016-14(b) were completed in 2007 (as documented by 07-AMCP-0266, "Completion of Hanford Federal Facility Agreement and Consent Order [Tri-Party Agreement] Milestone M-16-14A, "Complete Construction of a Permeable Reactive Barrier at 100-N" and Completion of Calendar Year 2007 Construction Activities at the 100-N Sequestration Barrier") and 2009 (as documented by 10-AMCP-0032, "Proposed Plan for Amendment of 100-NR-1/NR-2 Interim Action Record of Decision, DOE/RL-2009-54, Draft B"), respectively.

Performance monitoring is ongoing along the entire treated portion of the barrier and is discussed further in Chapter 4. Figure 1-10 shows the location of the original PRB and the upstream and downstream extensions. Additional injections were not conducted in 2017. Wells and aquifer tubes downgradient of the treated segments of the PRB continued to be monitored. Groundwater monitoring of the upriver and downriver PRB extension indicates that concentrations in the majority of the monitoring wells during 2017 were lower than the pre-injection levels. However, strontium-90 concentrations at two of the downriver PRB monitoring wells increased to pre-injection concentrations in 2016 and 2017. Chapter 4 further discusses PRB performance.

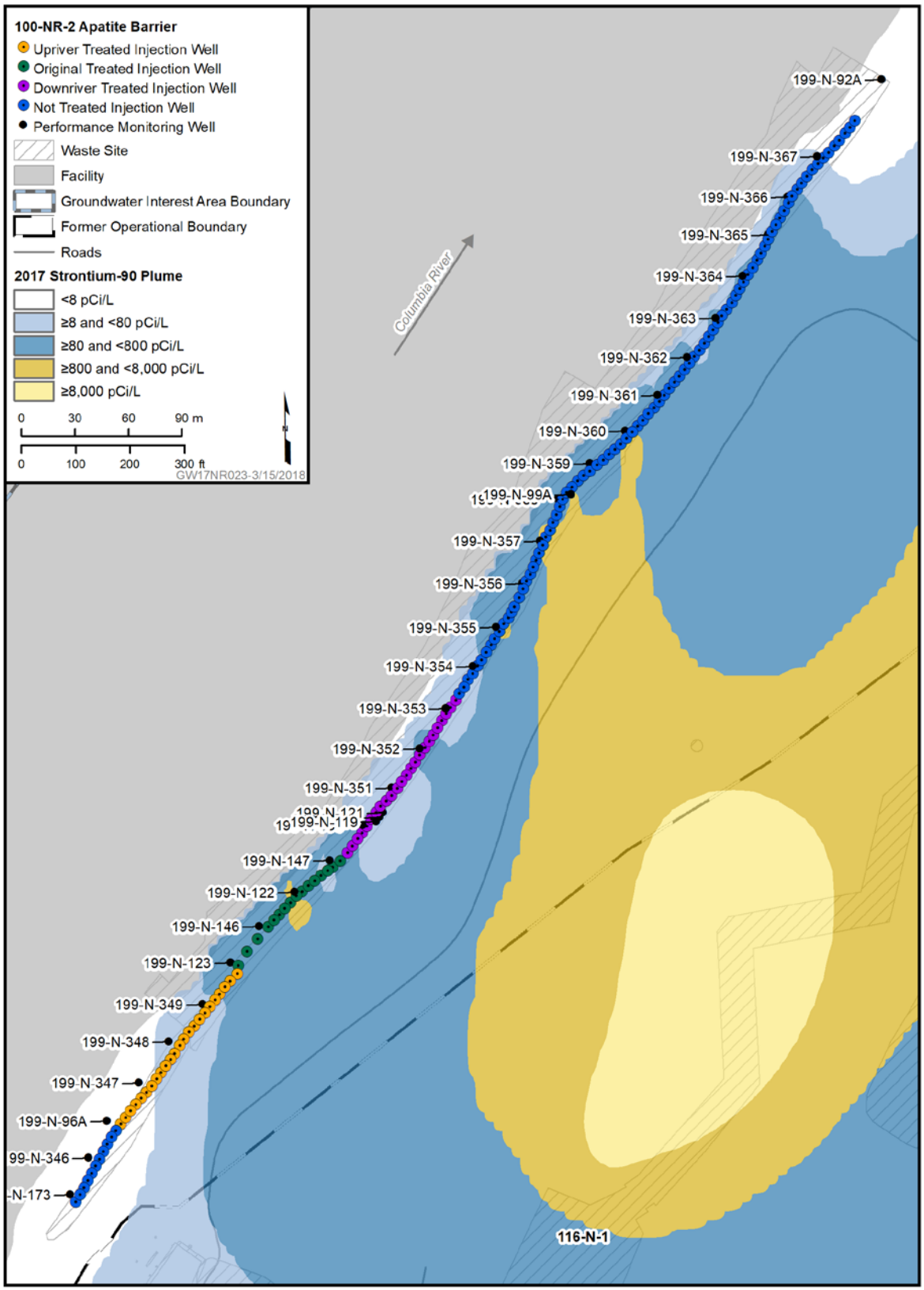

Figure 1-10. Treated Segments of the 100-NR-2 OU Apatite PRB

1.3.3 Total Petroleum Hydrocarbons Removal

Removal of total petroleum hydrocarbons (TPH) free-floating product from well 199-N-18 continued in 2017 using a polymer "smart sponge" that selectively absorbs petroleum products from the groundwater within the well. In 2017, smart sponge assemblies were also installed in well 199-N-183, which was drilled near well 199-N-18 as a replacement. Chapter 4 provides a further discussion on TPH remediation.

1.4 Remedial Investigation/Feasibility Study Activities

An RI/FS was completed for the 100-D and 100-H Areas and the Horn. 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*, was issued in October 2014. The RI/FS results support selection of final remedies under CERCLA using an approach that integrates source and groundwater remedial actions, which is documented in the DOE/RL-2011-111, *Proposed Plan for Remediation of the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*. Public comment was completed on the proposed plan in 2016. Public comments have been addressed, and a ROD has been prepared that identifies the final remedial alternatives. The ROD is anticipated to be signed in calendar year 2018.

DOE/RL-2010-97, Draft A, *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. The U.S. Environmental Protection Agency (EPA) and DOE identified a need for additional characterization beneath the former KE Reactor fuel storage basin (FSB) and the former 116-KE-3 FSB crib/reverse well to fill a data gap regarding the nature and extent of vadose zone contamination near the reactor structures before issuing Rev. 0 of the RI/FS report. This data gap has been filled and documented in SGW-60149, *Report for Soil Borings and Well Installations in the UPR 100-K-1 and 116-KE-3 Waste Sites*, and preparation of the RI/FS and Proposed Plan is ongoing.

In June 2013, DOE/RL-2012-15, *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units*, Draft A, was submitted to the Washington State Department of Ecology (Ecology) (the lead regulatory agency for the 100-NR-1 and 100-NR-2 OUs) for review. The comment resolution process continued through 2017 for the Draft A RI/FS, and it was determined that a Draft B RI/FS would be prepared. The Draft B RI/FS and the associated Proposed Plan are being prepared in 2018.

The RI/FS reports will be used to support future cleanup decisions specified in a proposed plan and ROD.

1.5 Atomic Energy Act Groundwater Monitoring Evaluation of Liquid Effluent

The *Atomic Energy Act of 1954* (AEA) groundwater monitoring plan was established for sitewide monitoring at the Hanford Site in 2015 (DOE/RL-2015-56, *Hanford Atomic Energy Act Sitewide Groundwater Monitoring Plan*). The AEA groundwater monitoring and evaluation of liquid effluents is required at P&T systems in accordance with DOE O 458.1, *Radiation Protection of the Public and the Environment*. This DOE order requires monitoring of effluents to prevent unacceptable exposure of public and ecological receptors to radiation and managing of discharges that could result in new or increased plumes that would require mitigation action or remediation.

Evaluating effluent water from the P&T systems in 100 Area includes calculating the total effective dose (TED) produced by radioisotopes present in the effluent water following treatment of extracted groundwater to remove identified contaminants. The resulting dose is compared to the target cumulative dose limit of 100 mrem/yr to the public, as established by DOE O 458.1. The cumulative TED is based on use of the derived concentration standard (DCS), as defined in DOE-STD-1196-2011, *Derived Concentration Technical Standard*. In addition to evaluating the effluent constituents, selected monitoring

wells in the 100-K Area have been identified for additional evaluation of potential dose contribution in areas downgradient of effluent injection wells.

Additional guidance for screening radiological dose related to discharge of liquid effluents at DOE facilities is provided in DOE-HDBK-1216-2015, *DOE Handbook – Environmental Radiological Effluent Monitoring and Environmental Surveillance*. The DOE handbook provides recommended criteria for radiological effluent monitoring based on the DCS to ensure effective effluent monitoring to identify problematic effluent conditions before conditions exceed target metrics.

This evaluation further compares the radioisotopes present in effluent water to the following radiological DWSs: (1) the 4 mrem/yr maximum contaminant level (MCL) dose for beta/photon emitters, and (2) the 30 µg/L uranium mass concentration MCL.

1.6 Quality Assurance/Quality Control

Appendix E of the annual Hanford Sitewide groundwater monitoring report for 2017 (DOE/RL-2017-66) provides discussions on quality assurance (QA) and quality control (QC) encompassing sampling and analysis of the wells. The annual report includes information on the QA/QC issues that may affect groundwater data interpretation.

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 interim remedy P&T system performance and ISRM barrier monitoring.

2.1 Overview of Operable Unit Activities

The 100-HR-3 OU consists of the groundwater contaminated by releases from facilities and waste sites associated with past operations at the D, DR, and H Reactors. Contamination from these reactors spread across the 100-HR-3 OU and underlies 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 and target of remedial action identified in the 100-HR-3 and 100-KR-4 interim action ROD (EPA/ROD/R10-96/134) for groundwater in the 100-HR-3 OU. Groundwater co-contaminants identified for the interim remedial action are nitrate, strontium-90, tritium, uranium, and technetium-99.

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 ambient water quality criterion at that time of 11 µg/L. Based in part on the assumption 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 for 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 remediation target 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, “Model Toxics Control Act—Cleanup” (MTCA).

To mitigate the risks associated with Cr(VI) contamination in groundwater discharging to the river, DOE installed a CERCLA interim action P&T system, HR3, in the 100-HR-3 OU in 1997. The P&T interim remedial actions were implemented in accordance with 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 100-HR-3 and 100-KR-4 interim action ROD (EPA/ROD/R10-96/134). A second P&T system, DR5, was installed in 2004. In 2010, the two original systems were replaced with the larger DX and HX P&T systems, which continue to operate. In addition, an ISRM barrier was installed in the southern portion of the 100-D Area in 2000. Due to early breakthrough of contaminants at the ISRM barrier, a notice of nonsignificant change to the ROD was issued in 2010 (11-AMCP-0002), which indicated that the barrier would no longer be actively maintained. The notice of nonsignificant change shifted the groundwater remedy in the ISRM barrier area to P&T but maintained monitoring of the ISRM barrier. The current interim action remedy in the 100-HR-3 OU is P&T, consisting of the DX and HX P&T systems.

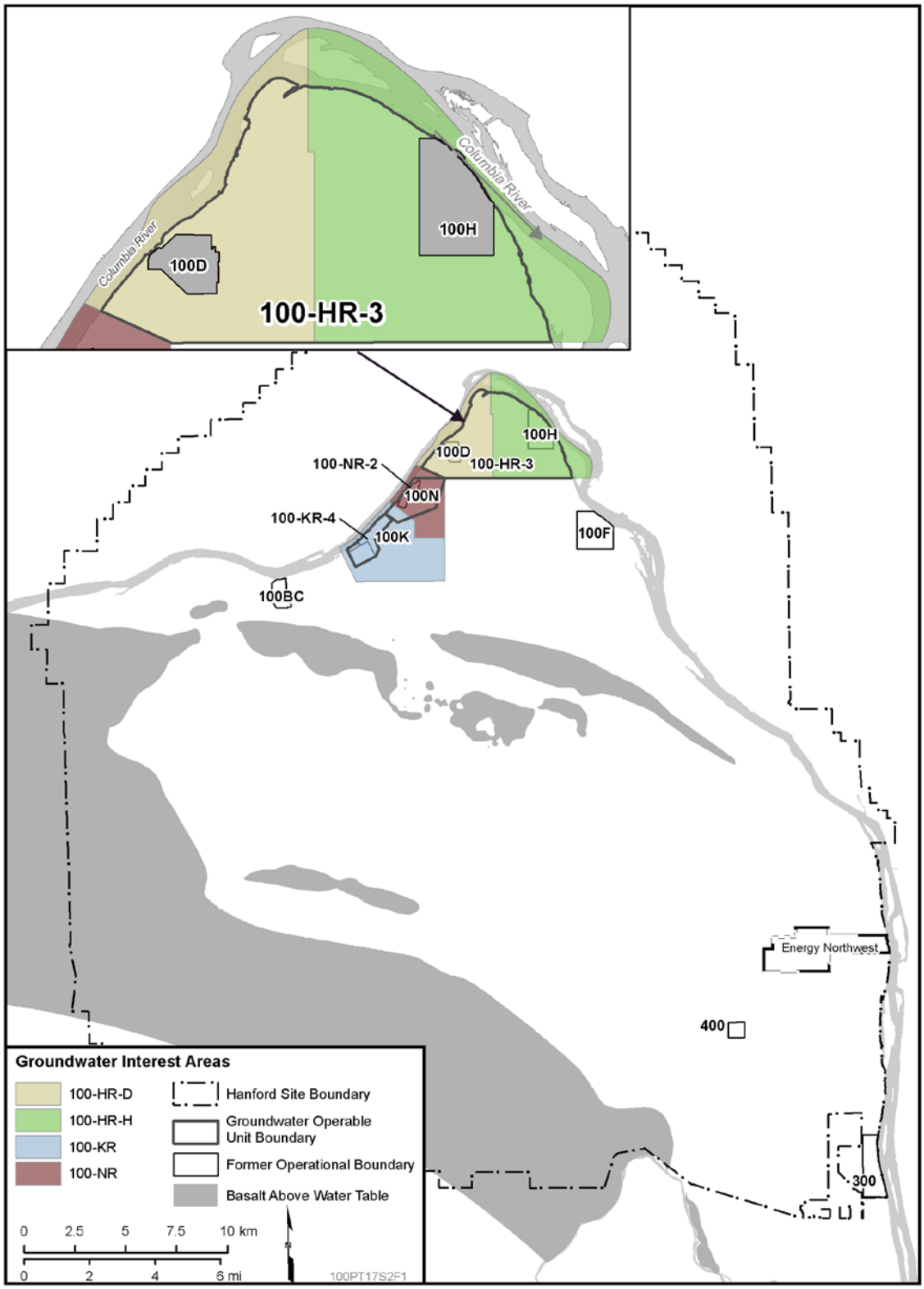

Figure 2-1. Location of the 100-HR-3 OU and Groundwater Interest Areas

A new remedial design/remedial action work plan (RD/RAWP) (DOE/RL-2013-31, *100-HR-3 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan*) was issued in May 2016 to supersede DOE/RL-96-84 and DOE/RL-99-51, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation*. DOE/RL-2013-31 includes the design and completion of the DX and HX P&T systems and the operation of these systems to meet the RAOs described in Chapter 1. A sampling and analysis plan (SAP) (DOE/RL-2013-30, *Sampling and Analysis Plan for 100-HR-3 Groundwater Operable Unit Monitoring*) was also issued in May 2016, establishing groundwater monitoring to track changing conditions, performance of the remedy, and effectiveness of interim remedial actions in meeting performance criteria required by the interim action ROD (EPA/ROD/R10-96/134).

Monitoring, data evaluation, and site characterization activities are conducted to evaluate 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 2017 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 the ISRM barrier.
- Section 2.3 discusses the radiological dose analysis of the system effluent.
- Section 2.4 provides the remedial action cost summary.
- Section 2.5 presents the conclusions regarding 2017 remedy performance.

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

Changes to the 100-HR-3 OU remedial systems during 2017 consisted of the following:

- Disconnecting selected extraction and injection wells to use as monitoring wells (DX and HX P&T systems)
- Increasing the conveyance piping and pump size in one extraction well (HX P&T system) to increase extraction output

These actions were intended to increase system efficiency, enhance hydraulic plume capture, and reduce Cr(VI) plume concentrations. Four injection wells and one extraction well were realigned during 2017. In addition, one extraction well was reconfigured to allow for higher flow rates. Table 2-1 summarizes the changes to the remedial systems, and Sections 2.2.1.1 and 2.2.2.1 provide further details for the DX and HX P&T systems, respectively.

Table 2-1. 100-HR-3 Groundwater OU Remedial System Well Changes Completed in 2017

System	Well	Action	Purpose	Status as of December 31, 2017
DX	199-D2-10	Disconnect injection well	Operational	Removed from DX P&T
	199-D2-12	Disconnect injection well	Operational	Removed from DX P&T
	199-D8-93	Disconnect injection well	Operational	Removed from DX P&T
	199-D8-94	Disconnect injection well	Operational	Removed from DX P&T
HX	199-H1-3	Disconnect extraction well	Operational	Removed from HX P&T
	199-H1-45	Increased conveyance line and pump size	Plume control	Conducted in 2017

Note: "Operational" purpose includes increasing system throughput capabilities and removing low-production wells from the system.

P&T = pump and treat

Figures 2-2, 2-3, and 2-4 present the 2017 extraction, injection, monitoring well, and aquifer tube locations for the 100-D Area, the ISRM portion of the 100-D Area, and the 100-H Area. Figure 2-5 shows the well and aquifer tube locations in the Horn. Figure 1-2 in Chapter 1 shows the layouts of the two P&T systems, and Figure 1-3 shows the locations of the new wells and realigned wells (i.e., wells with a change in use) in 2017.

In 2017, six new wells were installed as part of RPO efforts. Wells 199-H1-47, 199-H1-48, and 199-H1-49 were installed for use as extraction wells. These wells were completed in the unconfined aquifer along the shoreline north of the 100-H Area, where plume containment has been difficult. Three wells were also installed in the Ringold Formation upper mud unit (RUM) aquifer: 199-H3-28, 199-H3-29, and 199-H3-30. These wells are located in the 100-H Area, with well 199-H3-28 located inland near well 199-H3-2C; well 199-H3-29 located near the 183-H Solar Evaporation Basins; and well 199-H-3-30 located within the 107H retention basin. RUM wells 199-H3-28 and 199-H3-29 are currently planned for connection to the HX P&T system.

2.1.2 In Situ Redox Manipulation Barrier

Prior to installing 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 implemented 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 less toxic and less mobile form. Groundwater at the ISRM site is still monitored for Cr(VI) and dissolved oxygen as part of CERCLA interim action monitoring, with Cr(VI) as the target contaminant. The dissolved oxygen levels are monitored along the barrier because the treatment process reduces oxygen content in the aquifer. Section 2.2.8 provides details for ISRM barrier monitoring.

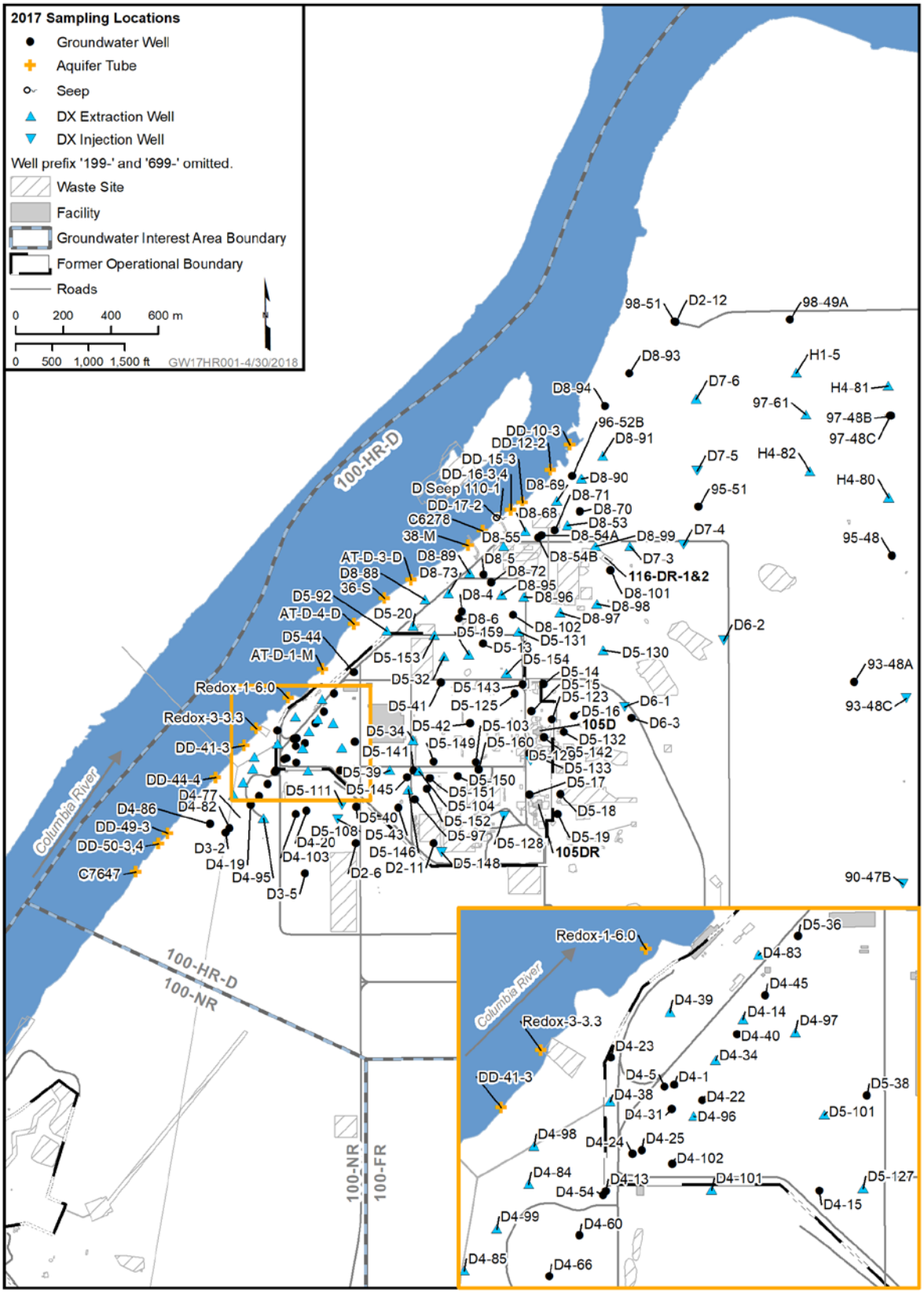

Figure 2-2. 100-D Area Wells and Aquifer Tubes

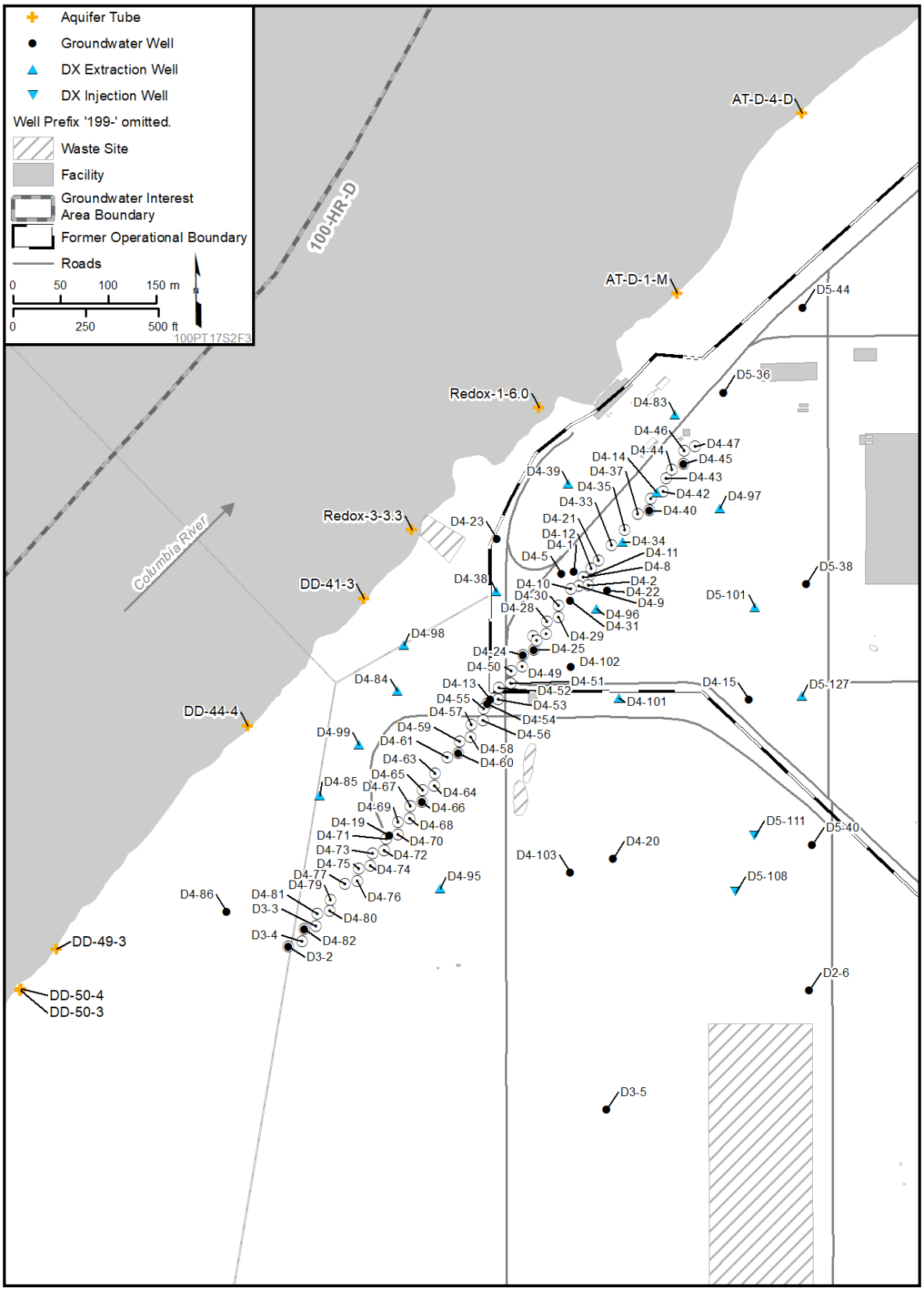

Figure 2-3. ISRM Barrier Detail Map

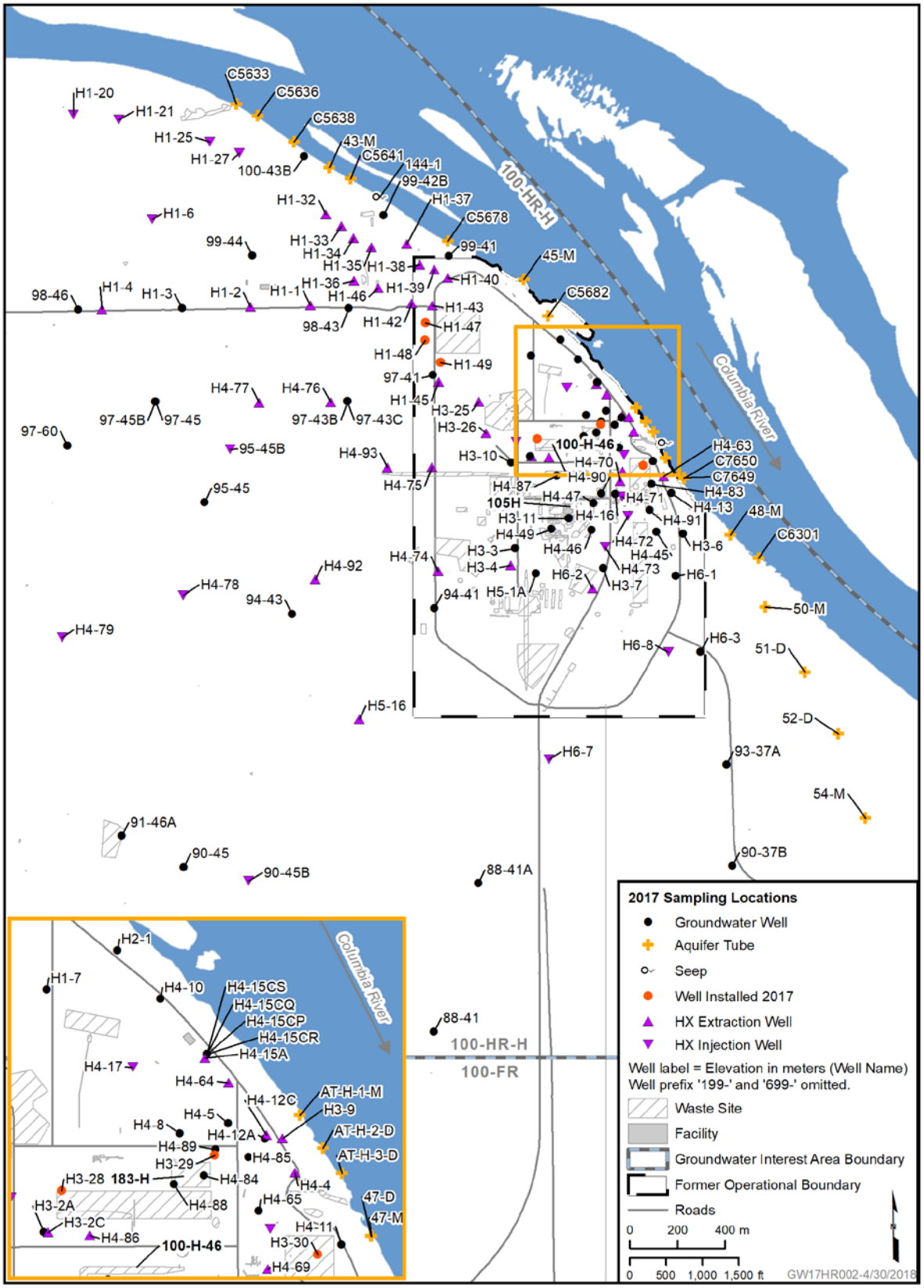

Figure 2-4. 100-H Area Wells and Aquifer Tubes

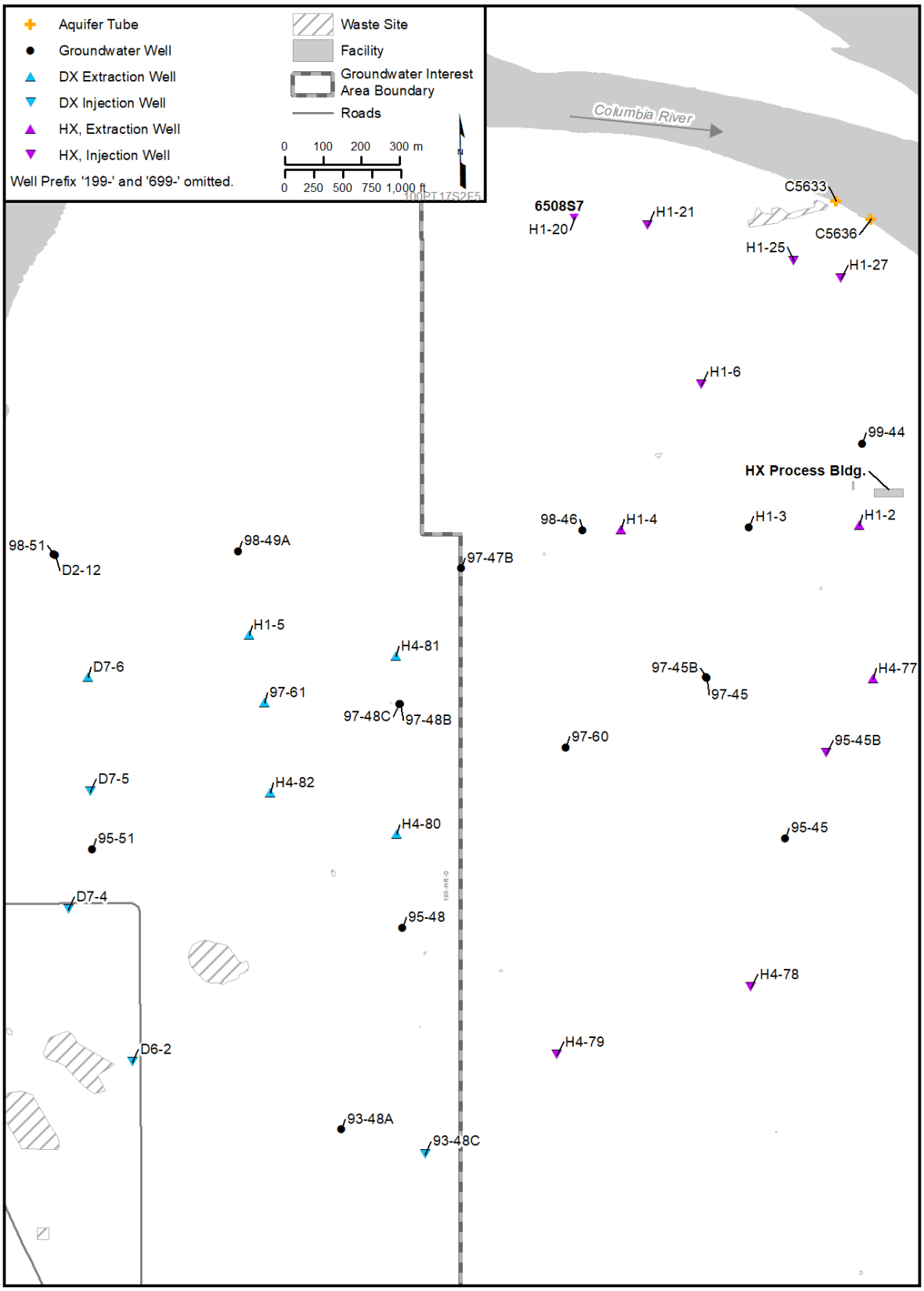

Figure 2-5. Horn Wells and Aquifer Tubes

2.2 100-HR-3 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 2017. 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 reinjected groundwater, and waste generation.

2.2.1 DX Pump-and-Treat System

The DX P&T system was designed to capture and treat the Cr(VI) plume located in the 100-D Area. The DX P&T system was originally designed to extract and process up to 2,273 L/min (600 gal/min). Optimization activities have increase the operational capacity of the system to 2,936 L/min (775 gal/min) and expanded the well network to include the western Horn area. Figure 2-6 provides a schematic of the DX P&T system, which was current at the end of 2017. Figures 1-4 and 1-5 (in Chapter 1) and Table 2-2 show the cumulative amount of water treated and Cr(VI) removed since startup of the DX P&T system. The number of extraction and injection wells listed for each system includes those that are "out of service" but are still physically connected to the system. Wells that are out of service includes those wells that are scheduled for disconnection from the system but still have piping and other equipment in place, in addition to wells that are in a standby mode and available for use if needed to manage system capacity.

The DX P&T system uses SIR-700 resin to bind Cr(VI) as influent groundwater flows through resin beds in the treatment facility. The SIR-700 resin is a high-capacity, single-use resin that does not require regeneration. The resin was not replaced at DX during 2017. The DX P&T system improved the groundwater treatment capacity along the Columbia River and is a key component in DOE's strategy for keeping Cr(VI) from entering the river. Section 2.2.3 discusses the changes in concentrations and the overall trends.

2.2.1.1 DX Pump-and-Treat System Configuration and Changes

The annual evaluation of the plume capture from 2016 (DOE/RL-2016-68, *Calendar Year 2016 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. In addition, the evaluation identified areas where Cr(VI) concentrations were declining slower than in other areas. The DX P&T system changes completed in 2017 (Figure 1-3 in Chapter 1) included disconnecting injection wells 199-D2-10, 199-D2-12, 199-D8-93, and 199-D8-94 from the DX P&T system and converted these wells to monitoring wells during 2017. These wells are located in the northern portion of the 100-D Area and were determined not to be suitable for receiving large volumes of water due to their proximity to the river. The wells had only operated periodically and were converted to monitor the plume in that area.

The November 2017 Cr(VI) concentrations in these former injection wells were 7.5 µg/L in well 199-D2-12, 17.0 µg/L in well 199-D8-93, and 18.0 µg/L in well 199-D8-94. A sample was not collected from well 199-D2-10 in November because the P&T system equipment had not yet been completely removed; however, the well is scheduled for quarterly monitoring in 2018.

The DX P&T system will 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.

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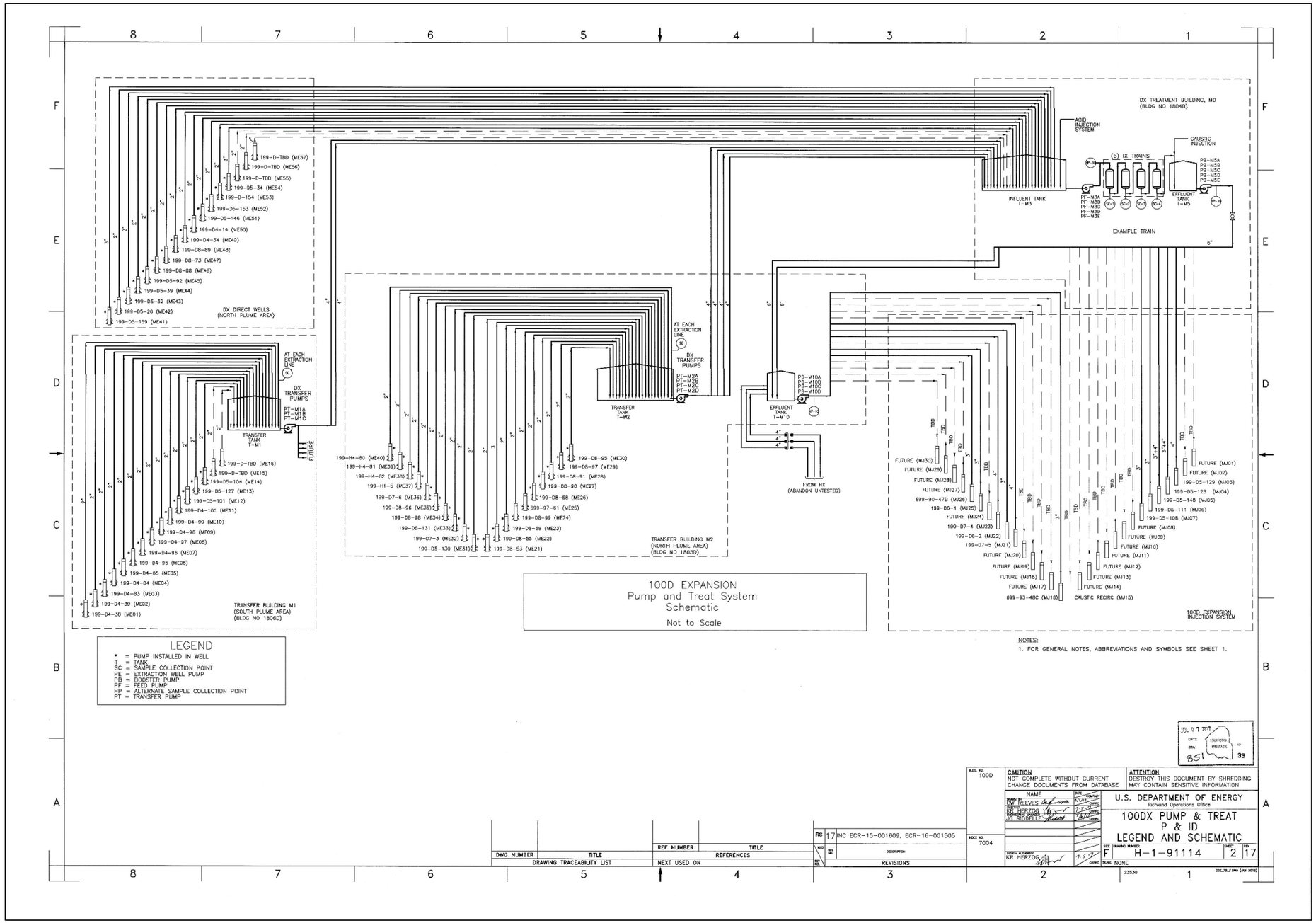

Figure 2-6. DX P&T System Schematic (as of December 2017)

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Table 2-2. Cumulative P&T Performance Summary

Groundwater Operable Unit: Pump-and-Treat System	100-HR-3	
	DX[a]	HX[b]
Extraction wells[c]	48	37
Injection wells[c]	11	17
Cumulative volume treated (million L [million gal]) since startup	1,469 (388)	1,450 (383)
Cumulative hexavalent chromium mass removed (kg) since startup	1,577	170

a. The DX P&T system was started in 2010.

b. The HX P&T system was started in 2011.

c. The number of extraction and injection wells includes those that are not in service but still connected to the system as of December 31, 2017.

2.2.1.2 Treatment System Performance

The DX P&T system operated 99% of the time throughout 2017 (except for short downtimes for planned corrective maintenance). Table 2-3 presents an overview of groundwater extracted, mass removed, and system performance. As shown in Table 2-3, a greater volume of water was treated at DX during 2017 than was treated in 2016, but less mass was removed. The mass of Cr(VI) removed each year continues to decrease primarily a result of rapidly declining Cr(VI) concentrations in the historical high-concentration areas; this reduction is the combined result of source removal actions and effective P&T system operations.

Figure 2-7 shows the influent and effluent concentrations for the DX P&T system. The average influent Cr(VI) concentration in 2017 was 21.8 µg/L, which was a decline from the previous year. The effluent concentration was usually below the laboratory detection limit for 2017, with a maximum reported value of 5 µg/L. The average reported effluent concentration was less than 2 µg/L, with more than 40% of the results being below the detection limit.

As in previous years, the influent Cr(VI) concentration predominantly reflects the concentrations from extraction wells 199-D5-34 and 199-D5-104, which are located in the southern 100-D plume source area. Well 199-D8-95 is located in a high-concentration area of the northern 100-D plume and also contributes the largest amount to the DX P&T system influent concentrations. The overall declining influent concentration trend in both the southern and northern 100-D plumes is a result of mass removal from source sites in those areas, with resulting reduction in continuing source contributions and ongoing remediation of the aquifer.

Figure 2-8 shows the system availability for the reporting period. The total flow rate through the DX P&T system (in terms of percentage of system capacity) was reduced slightly during periods of system and well maintenance, and also during piping reconfiguration.

Table 2-4 presents the pumping flow rates and total run-time for the extraction and injection wells active in the DX P&T system in 2017. The flow rate was calculated by dividing the total volume extracted for the period by the hours of pumping. Figure 2-9 provides hydrographs for the Columbia River at the 100-D and 100-H Areas. Variations in extraction and injection rates due to downtime (e.g., low water in wells during low river-stage, repair, and/or maintenance) are reflected in the yearly average flow rate calculations and the total run-time percentages for each extraction well.

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

Total DX P&T System Processed Groundwater	2016	2017
Cumulative volume of groundwater treated (since December 2010 startup) (million L)	7,234	8,703
Total volume of groundwater treated during CY (million L)	1,454	1,469
Mass of Cr(VI) Removed	**2016**	**2017**
Cumulative mass of Cr(VI) removed (since December 2010 startup) (kg)	1,547	1,577
Total mass of Cr(VI) removed in CY (kg)	59	30.4
Summary of Operational Parameters	**2016**	**2017**
Average system process rate (L/min)	2,760	2,829
Average Cr(VI) influent concentration (µg/L)	36.8	21.8
Average Cr(VI) effluent concentration (µg/L)	<2	<2
Removal efficiency (% by mass)	95.6	94.4
Waste generation (m^3)	7.5	3.6
Regenerated resin spent resin disposed (m^3)	0	0
New resin installed (m^3)	0	0
Number of resin vessel changeouts	0	0
Summary of Co-Contaminants Detected in Effluent	**2016**	**2017**
Average tritium concentration (pCi/L)	1,830	1,290
Average nitrate concentration (µg/L)	23,900	21,312
Average strontium-90 concentration (pCi/L)	1.0	1.4
Average total chromium concentration (µg/L)	6.2	6.9
Summary of Operational and System Availability	**2016**	**2017**
Total possible run-time (hours)	8,784	8,760
Total time online (hours)	8,678	8,671
Total availability (%)*	98.8	99.0

* Total availability [(total time online) ÷ (total possible run-time)] × 100.

Cr(VI) = hexavalent chromium

CY = calendar year

P&T = pump and treat

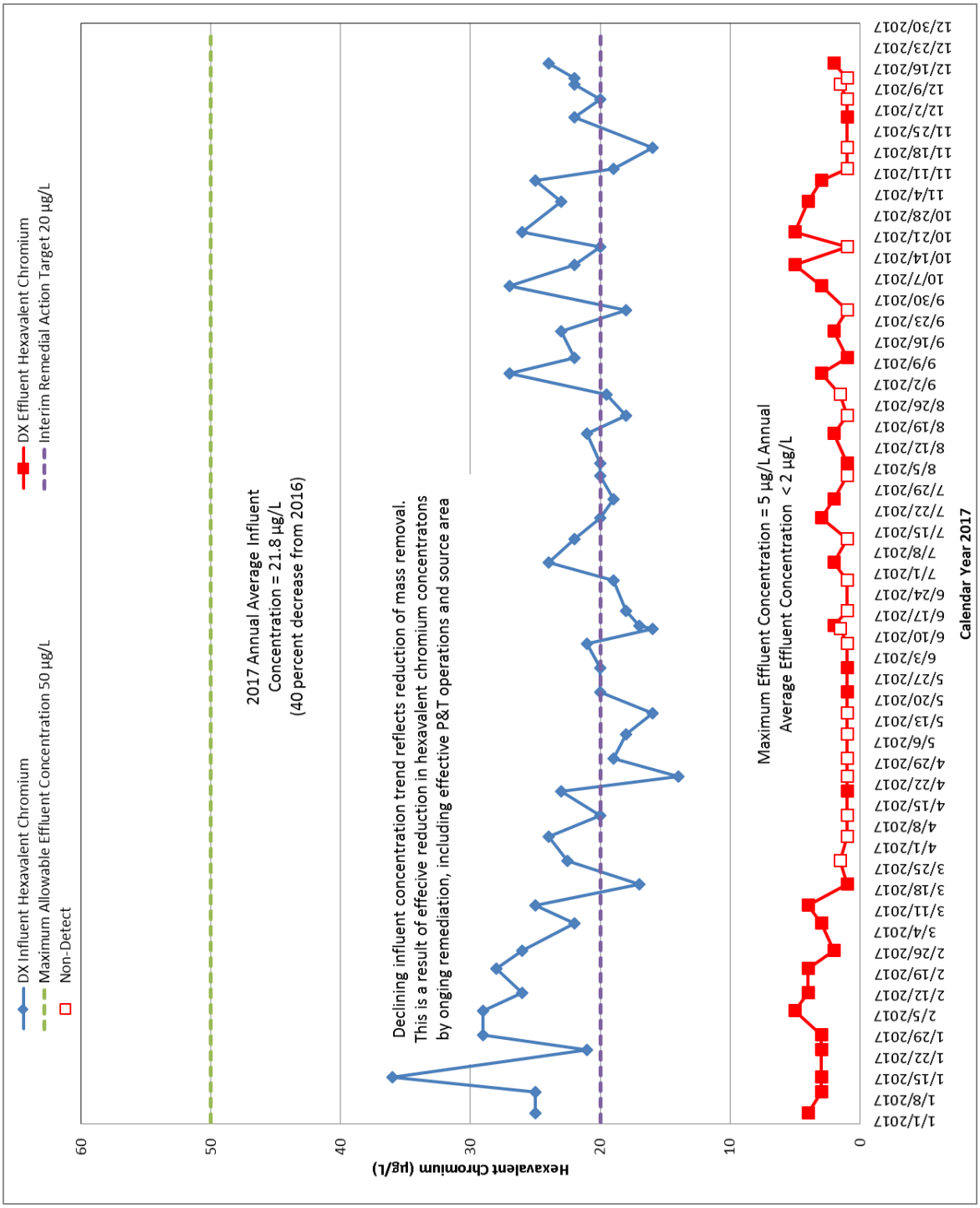

Figure 2-7. Influent/Effluent Concentrations for the DX P&T System

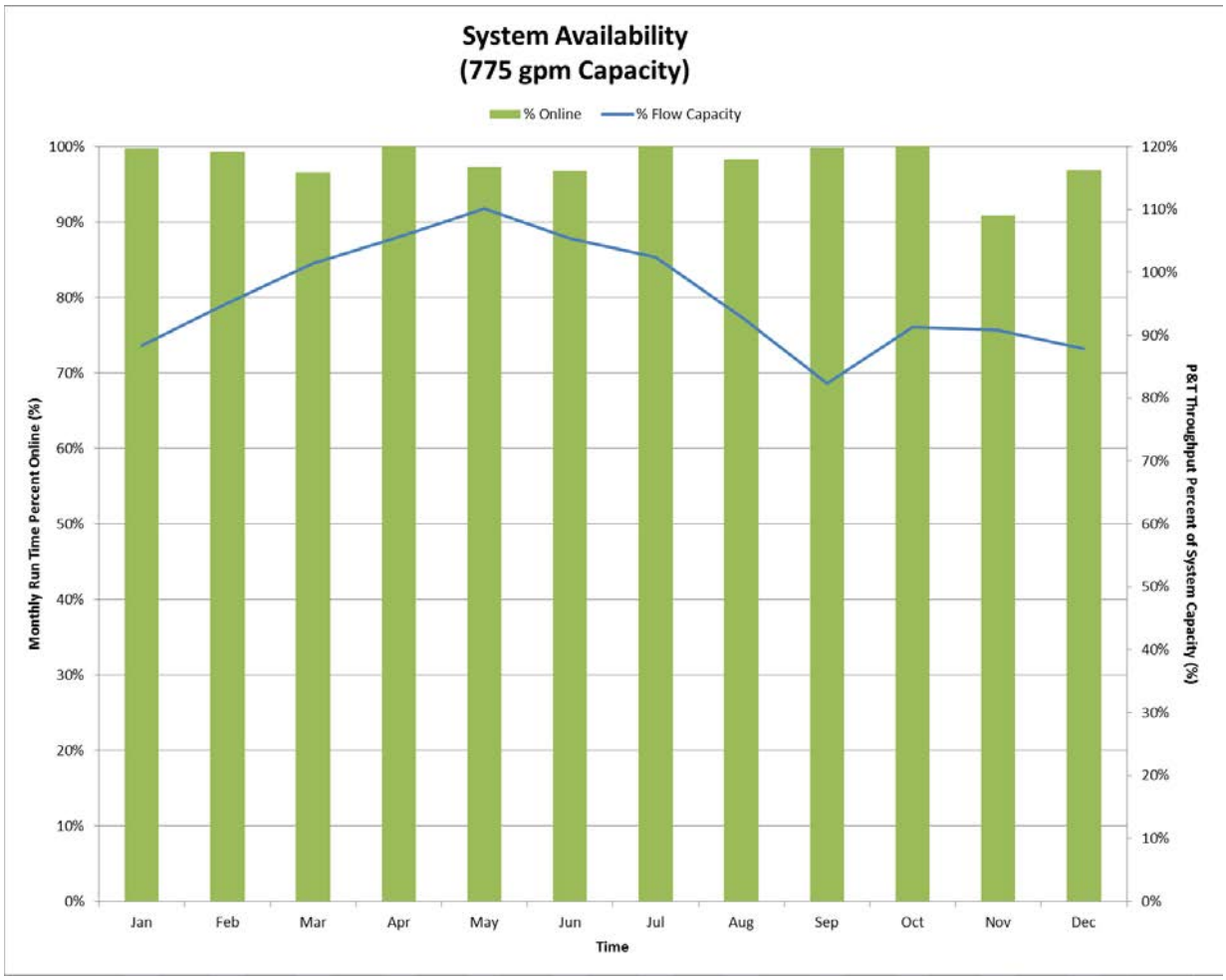

Figure 2-8. Monthly DX P&T System Availability, 2017

Table 2-4. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours in 2017	Total Run-Time[a] (%)	Purpose
			Low River-Stage Average	High River-Stage Average			
B8989	199-D4-38	ME01	25.1 (6.6)	30.3 (8)	7,248	83	Extraction
B8990	199-D4-39	ME02	29 (7.7)	75.2 (19.8)	4,224	48	Extraction
C3315	199-D4-83	ME03	33.8 (8.9)	64.5 (17)	7,248	83	Extraction
C3316	199-D4-84	ME04	19.2 (5.1)	37.8 (10)	8,760	100	Extraction
C3317	199-D4-85	ME05	77.2 (20.4)	70.2 (18.5)	8,736	100	Extraction
C7083	199-D4-95	ME06	84 (22.2)	88.3 (23.3)	8,760	100	Extraction
C7084	199-D4-96	ME07	41.6 (11)	53.3 (14.1)	5,544	63	Extraction
C7085	199-D4-97	ME08	49 (12.9)	46.2 (12.2)	8,736	100	Extraction
C7086	199-D4-98	ME09	51.1 (13.5)	47.6 (12.6)	8,760	100	Extraction
C7087	199-D4-99	ME10	76.3 (20.1)	64.5 (17)	8,760	100	Extraction
C7580	199-D4-101	ME11	27.8 (7.3)	38.3 (10.1)	4,584	52	Extraction
C7583	199-D5-101	ME12	57.9 (15.3)	90.8 (24)	8,760	100	Extraction
C7591	199-D5-127	ME13	67.7 (17.9)	64.3 (17)	8,616	98	Extraction
C5400	199-D5-104	ME14	88.8 (23.4)	91.6 (24.2)	8,520	97	Extraction
A4581	199-D8-53	ME21	82.5 (21.8)	75.6 (20)	8,760	100	Extraction
A4584	199-D8-55	ME22	11.1 (2.9)	28.7 (7.6)	5,064	58	Extraction
B2773	199-D8-69	ME23	79.3 (20.9)	75.5 (19.9)	8,760	100	Extraction
C7593	199-D8-99	ME24	85.1 (22.5)	100 (26.4)	8,760	100	Extraction

Table 2-4. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours in 2017	Total Run-Time[a] (%)	Purpose
			Low River-Stage Average	High River-Stage Average			
C8794	699-97-61	ME25	46.8 (12.3)	48.3 (12.8)	8,256	94	Extraction
B2772	199-D8-68	ME26	60.7 (16)	132.9 (35.1)	5,440	62	Extraction
C7092	199-D8-90	ME27	74.7 (19.7)	71.8 (18.9)	8,760	100	Extraction
C7093	199-D8-91	ME28	90.4 (23.9)	93.9 (24.8)	8,760	100	Extraction
C7582	199-D8-97	ME29	69.9 (18.4)	94.4 (24.9)	8,760	100	Extraction
C7589	199-D8-95	ME30	31.8 (8.4)	47.8 (12.6)	8,616	98	Extraction
C7590	199-D5-130	ME31	32.6 (8.6)	35.9 (9.5)	7,656	87	Extraction
C7599	199-D7-3	ME32	80.7 (21.3)	75.6 (20)	8,760	100	Extraction
C7601	199-D5-131	ME33	73.3 (19.3)	59.8 (15.8)	6,422	73	Extraction
C7602	199-D8-98	ME34	66.9 (17.7)	71.8 (19)	7,416	85	Extraction
C7603	199-D8-96	ME35	92.5 (24.4)	94.2 (24.9)	8,616	98	Extraction
C7611	199-D7-6	ME36	70.5 (18.6)	69.9 (18.5)	8,725	100	Extraction
C7610	199-H1-5	ME37	79.7 (21)	75.5 (19.9)	8,328	95	Extraction
C7609	199-H4-82	ME38	90.6 (23.9)	90.4 (23.9)	7,920	90	Extraction
C7596	199-H4-81	ME39	58.8 (15.5)	58.8 (15.5)	7,992	91	Extraction
C7595	199-H4-80	ME40	67.2 (17.7)	64.5 (17)	8,760	100	Extraction
C9377	199-D5-159	ME41	2.7 (0.7)	60 (15.8)	2,200	25	Extraction
A4577	199-D5-20	ME42	4.8 (1.3)	29.5 (7.8)	2,352	27	Extraction

Table 2-4. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours in 2017	Total Run-Time[a] (%)	Purpose
			Low River-Stage Average	High River-Stage Average			
C4185	199-D5-32	ME43	61.4 (16.2)	56.7 (15)	8,750	100	Extraction
B8748	199-D5-39	ME44	68 (17.9)	90.3 (23.8)	7,992	91	Extraction
C4583	199-D5-92	ME45	43.3 (11.4)	53.5 (14.1)	7,718	88	Extraction
C4536	199-D8-88	ME46	10.3 (2.7)	24.4 (6.5)	7,728	88	Extraction
C4474	199-D8-73	ME47	1.4 (0.4)	20.1 (5.3)	2,160	25	Extraction
C7091	199-D8-89	ME48	40.1 (10.6)	71.8 (18.9)	8,750	100	Extraction
B8985	199-D4-34	ME49	37.9 (10)	37 (9.8)	6,720	77	Extraction
B8072	199-D4-14	ME50	35.7 (9.4)	35.8 (9.5)	8,736	100	Extraction
C8726	199-D5-146	ME51	107.2 (28.3)	99.7 (26.3)	8,448	96	Extraction
C8789	199-D5-153	ME52	84.2 (22.2)	70.8 (18.7)	8,280	95	Extraction
C8790	199-D5-154	ME53	158.1 (41.8)	168.7 (44.5)	8,736	100	Extraction
C4187	199-D5-34	ME54	133.2 (35.2)	128.8 (34)	8,712	99	Extraction
C7600	199-D5-129	MJ03	462.2 (122)	531.2 (140.2)	8,736	100	Injection
C7612	199-D5-128	MJ04	246.8 (65.2)	298 (78.7)	8,760	100	Injection
C8728	199-D5-148	MJ05	433 (114.3)	567.7 (149.9)	8,760	100	Injection
C5581	199-D5-111	MJ06	39.4 (10.4)	74.7 (19.7)	8,424	96	Injection
C5578	199-D5-108	MJ07	46 (12.1)	46.5 (12.3)	8,568	98	Injection
C8929	699-93-48C	MJ16	205 (54.1)	253.7 (67)	8,112	93	Injection

Table 2-4. Flow Rates and Total Run-Times for DX P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Flow Rate, L/min (gal/min)		Total Flow Hours in 2017	Total Run-Time[a] (%)	Purpose
			Low River-Stage Average	High River-Stage Average			
C7090[b]	199-D2-12	MJ17	0 (0)	0 (0)	0	0	Injection
C7089[b]	199-D2-10	MJ18	0 (0)	0 (0)	0	0	Injection
C7096[b]	199-D8-94	MJ19	0 (0)	0 (0)	0	0	Injection
C7095[b]	199-D8-93	MJ20	0 (0)	0 (0)	0	0	Injection
C7608	199-D7-5	MJ21	165.8 (43.8)	236.5 (62.4)	8,760	100	Injection
C7607	199-D6-2	MJ22	234.6 (61.9)	246.2 (65)	8,760	100	Injection
C7594	199-D7-4	MJ23	568.5 (150.1)	585.4 (154.6)	8,760	100	Injection
C7592	199-D6-1	MJ25	102.9 (27.2)	100.4 (26.5)	6,744	77	Injection
C9584	699-90-47B	MJ26	170.5 (45)	220.1 (58.1)	8,760	100	Injection

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

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

b. Flows at well have been minimal and the well was disconnected in May 2017.

ID = identification

PLC = programmable logic controller

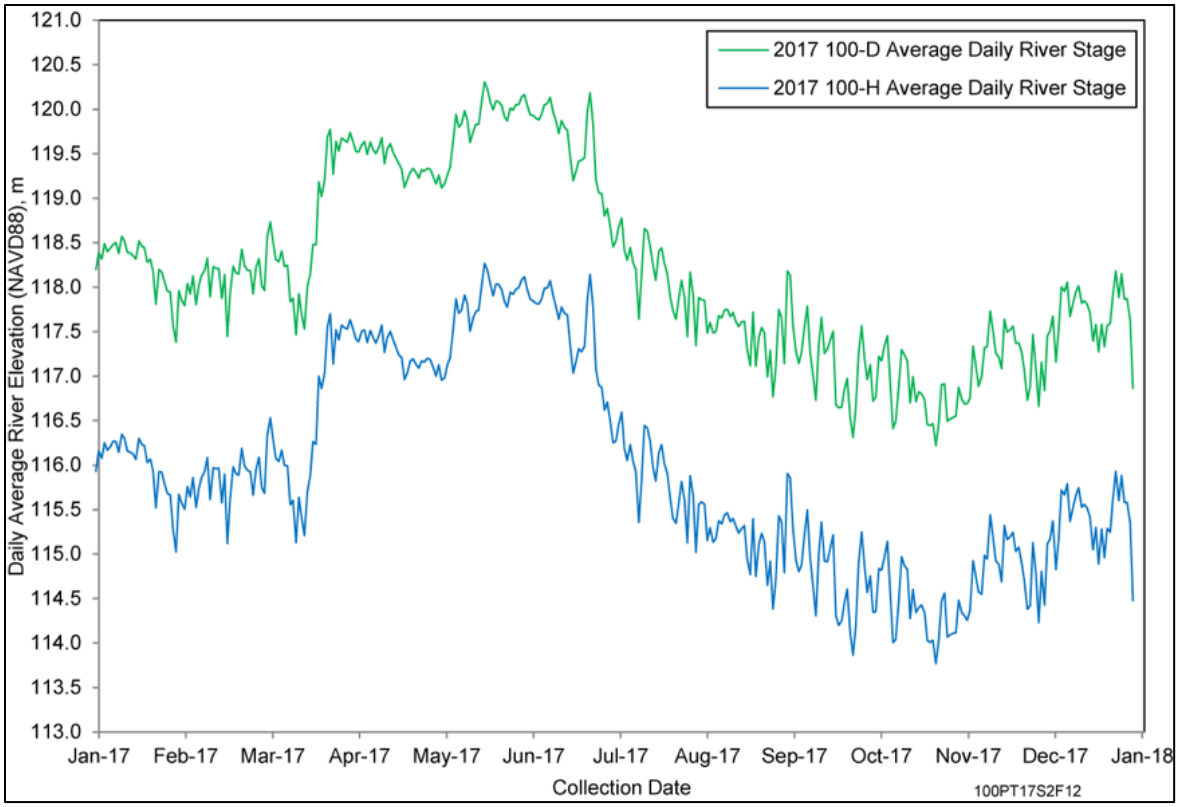

Figure 2-9. River Stage Hydrograph for 100-D and 100-H Areas
(Derived from Priest Rapids Dam Water Elevation)

Extraction wells with low operational run-time percentages in 2017 are primarily located near the shoreline and are affected by low river-stage. Those wells with less than 70% operational run-times were wells 199-D4-39, 199-D4-96, 199-D4-101, 199-D5-20, 199-D5-159, 199-D8-55, 199-D8-68, and 199-D8-73. Of these wells, only well 199-D5-159 is located away from the river. Well 199-D5-159 had a low run-time due to operational issues related to pump failure and well rehabilitation needs. In addition, four injection wells did not operate during 2017. Injection wells 199-D2-12, 199-D2-10, 199-D8-94, and 199-D-93, which have historically exhibited limited injection capacity due to shallow depth to groundwater, were converted to monitoring wells in May 2017. Injection wells 199-D5-108 and 199-D5-111 generally have low flow rates but have been maintained as injection wells for plume control purposes.

Range fires on May 25, 2017, also affected P&T system operations. The fires were apparently caused by electrical arching associated with powerline components suspected to have been damaged during a windstorm the previous day. Power was restored to the HX and DX P&T facilities on May 25, 2017, following repairs to the powerlines. The fire affecting the DX P&T facility caused damage to conveyance lines for wells 199-D5-39, 199-D5-146, and 199-D5-111. The interruption in operations is reflected in the run-time shown in Table 2-4. Well 199-D5-146 was returned to service on June 7, 2017, and wells 199-D5-39 and 199-D5-111 returned to service on June 9, 2017, after powerline repairs.

2.2.2 HX Pump-and-Treat System

The HX P&T system became fully operational in 2011. The design of the system is described in SGW-43616, *Functional Design Criteria for the HX Pump and Treat System*. During 2014 and 2015, the system capacity was upgraded from the original design of 3,000 L/min (800 gal/min) to 3,407 L/min (900 gal/min). Figure 2-10 provides a schematic of the HX P&T system, which was current at the end of 2017. Overall, the water available in the aquifer limits the throughput volume for the system. The design and operational philosophy optimizes containment along the river, and containment and removal of contaminant mass in areas with higher contamination. Figures 1-4 and 1-5 (in Chapter 1) and Table 2-2 provide the cumulative volume of water treated and Cr(VI) removed since startup of the HX P&T system. The number of extraction and injection wells listed for each system includes those wells that are out of service but are still physically connected to the system.

Similar to the 100-DX P&T, SIR-700 resin is used to treat the Cr(VI) as it flows through resin beds in the HX P&T system. The resin at the HX P&T has not been replaced; however, two vessels were filled in 2017 that were previously unused.

2.2.2.1 HX Pump-and-Treat System Configuration and Changes

The HX P&T system capture analysis of the previous year was used to identify areas along the Columbia River where additional plume capture was needed. In addition, the evaluation identified areas where Cr(VI) concentrations were declining more slowly than in other areas. These assessments were used to determine the kinds of system modifications needed. The HX P&T system changes completed in 2017 (shown in Figure 1-3 in Chapter 1) include the following:

- Extraction well 199-H1-3 was disconnected from the HX P&T system because the well had historically low run-times due to low water levels.
- The conveyance line at well 199-H1-45 was increased in 2017 from 5.1 cm (2 in.) to 7.6 cm (3 in.) diameter to accommodate extraction rate increases resulting from a pump upgrade in 2016.

2.2.2.2 Treatment System Performance

The HX P&T system operated 98% of the time throughout 2017 (except for short downtimes for planned corrective maintenance). Table 2-5 presents an overview of groundwater extracted, mass removed, and system performance. A similar volume of water was treated at the HX P&T during 2017 that was treated in 2016, and a similar amount of mass was also removed. The levels for mass removed have remained essentially unchanged over the years, which is primarily due to the high levels of mass present in the RUM where ongoing extraction that has resulted very little decline in Cr(VI) concentrations. In addition, the mass in the unconfined aquifer is spread out over a large area, and the Cr(VI) plume in the unconfined aquifer has low concentrations (less than 48 µg/L).

Figure 2-11 shows the influent and effluent concentrations for the HX P&T system. The average influent Cr(VI) concentration at the system in 2017 was 18.3 µg/L, which was a decline from the previous year. The average reported effluent concentration was less than 2 µg/L, with a maximum of 1.5 µg/L. The average removal efficiency for 2017 was 94.5%, and the system operated at an average rate of 2,806 L/min (741 gal/min) during 2017. Slightly higher influent concentrations were observed during the winter and fall, which is reflective of the seasonal fluctuation with decreased pumping rates at extraction wells closer to the river shoreline as water levels in the wells decline along with continued pumping from wells completed in the first water-bearing unit of the RUM. The RUM extraction wells 199-H3-2C and 199-H4-12C have relatively constant pumping rates throughout the year and exhibit high Cr(VI) concentrations.

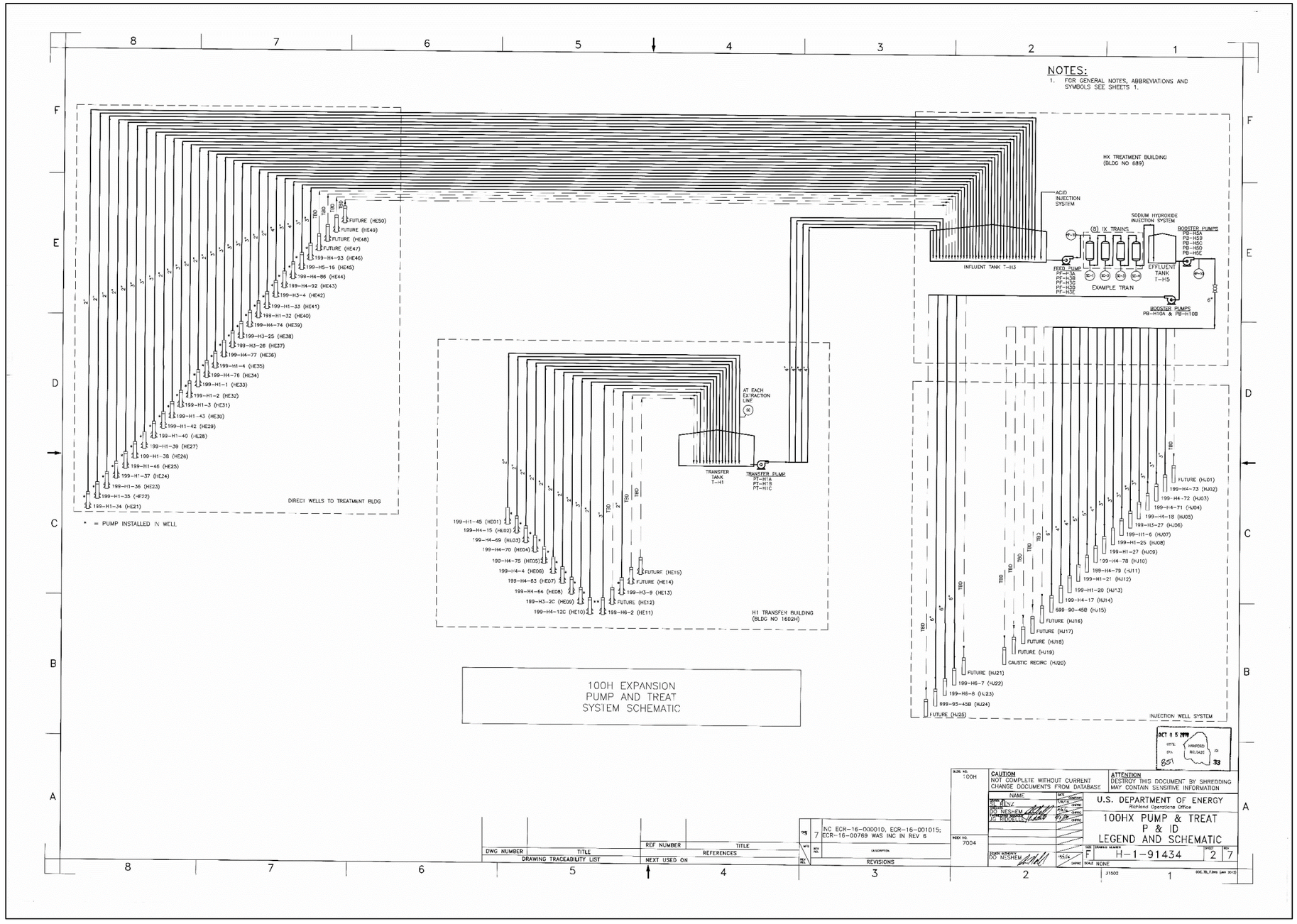

Figure 2-10. HX P&T System Schematic (as of December 2017)

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Table 2-5. HX P&T System Operational Parameters and System Performance, 2017

Total HX P&T System Processed Groundwater	2016	2017
Cumulative volume of groundwater treated (since September 2011 startup) (million L)	6,353	7,801
Total volume of groundwater treated in CY (million L)	1,149	1,451
Mass of Cr(VI) Removed	**2016**	**2017**
Cumulative mass of Cr(VI) removed (since September 2011 startup) (kg)	143.8	169.6
Total mass of Cr(VI) removed in CY (kg)	25.7	25.9
Summary of Operational Parameters	**2016**	**2017**
Average treatment process rate (L/min)	2,178	2,806
Average Cr(VI) influent concentration (µg/L)	22.7	18.3
Average Cr(VI) effluent concentration (µg/L)	<2	<2
Removal efficiency (% by mass)	95.1	94.5
Waste generation (m^3)	3.6	3.6
Spent resin disposed (m^3)	0	0
New resin installed (m^3)	0	4.4[a]
Number of resin vessel changeouts	0	0
Summary of Co-Contaminants Detected in Effluent	**2016**	**2017**
Average tritium concentration (pCi/L)	1,110	574
Average nitrate concentration (µg/L)	14,500	17,375
Average strontium-90 concentration (pCi/L)	1.2	1.9
Average total chromium concentration (µg/L)	3.7	6.3
Summary of Operational and System Availability	**2016**	**2017**
Total possible run-time (hours)	8,784	8,760
Total time online (hours)	8,739	8,588
Total availability (%)[b]	99.5%	98.0%

a. Two previously unused vessels in the HX P&T system ion-exchange treatment trains were filled with resin in 2017.

b. Total availability is calculated as [(total time online) ÷ (total possible run-time)].

Cr(VI) = hexavalent chromium
CY = calendar year
P&T = pump and treat

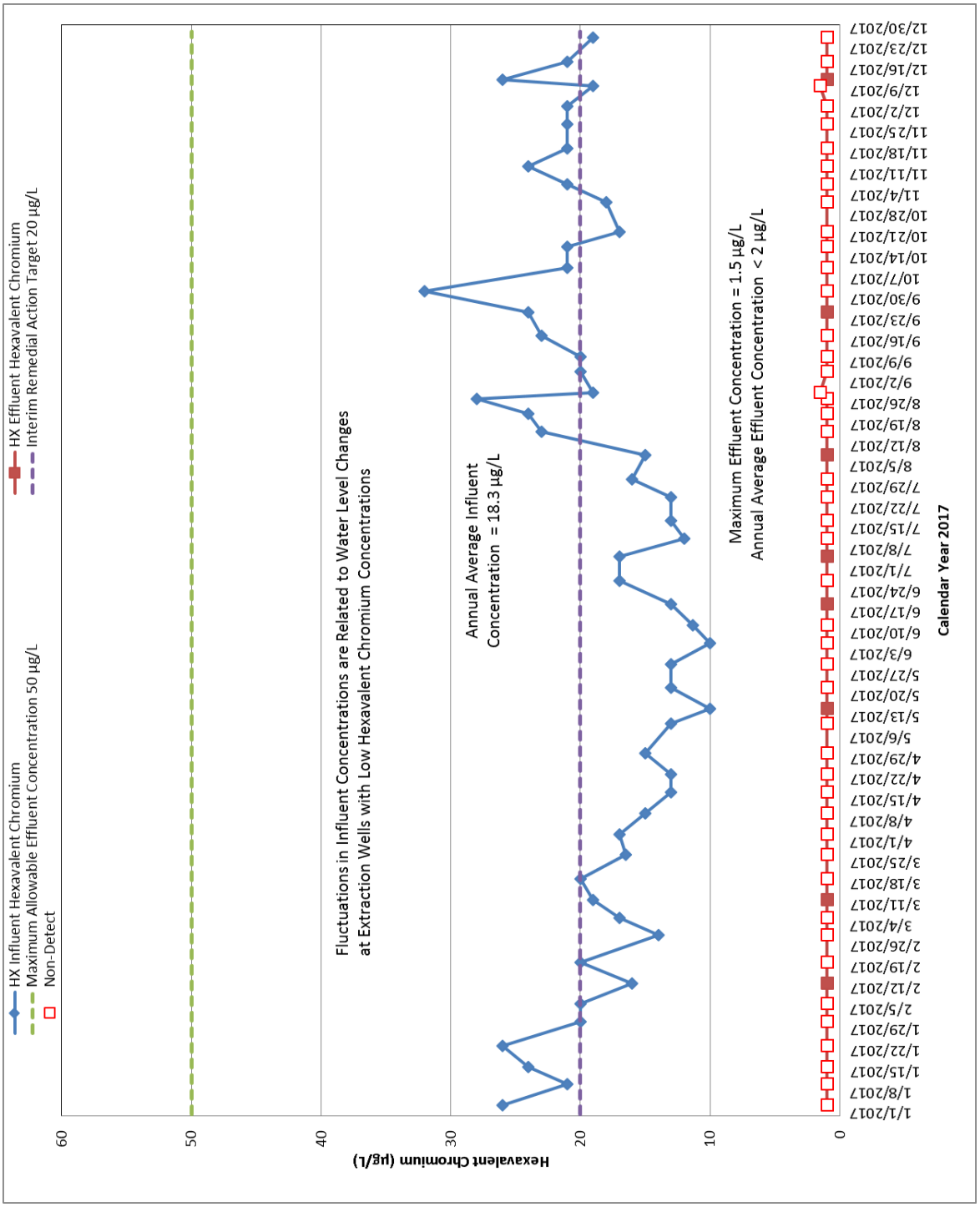

Figure 2-11. Influent/Effluent Concentrations for the HX P&T System

Figure 2-12 shows the system availability for the reporting period. The system operated 98% of the time in 2017, with short downtimes for planned corrective maintenance. The total flow rate through the HX P&T system (in terms of percentage of system capacity) was reduced during system outages. In addition, because extraction wells need sufficient water over the pump to maintain operations, the flow rate through the system declines during low river-stage periods. Extraction pumps require a minimum of 0.6 m (2 ft) of water above the pump intake to operate. Across the Horn and in the northern portion of the 100-H Area, the aquifer is less than 1 m (3.3 ft) thick in some locations during low river-stage, with the thinnest locations found along the northern portion of the Horn. During low river-stage periods, the amount of water available in the aquifer is minimal, and even when pumps are set low into well sumps, insufficient water may be available for the pumps to operate.

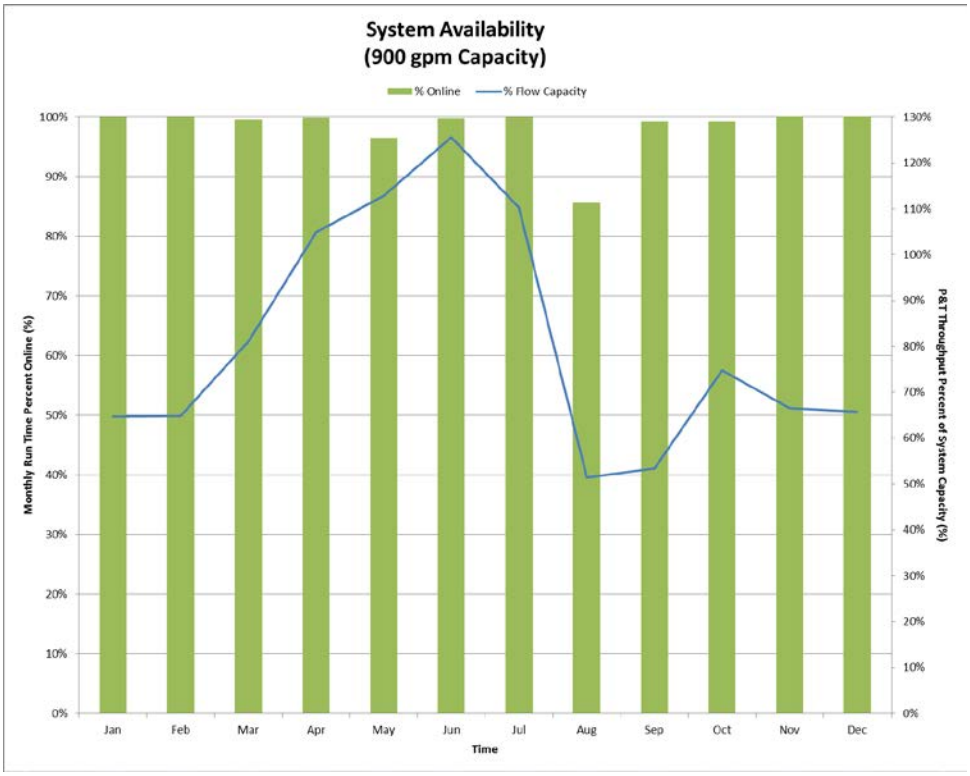

Figure 2-12. Monthly HX P&T System Availability, 2017

Table 2-6 presents the pumping flow rates and total run-times 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.

Extraction wells with low (less than 70%) operational run-time percentages in 2017 due to the effects of low river-stage included 199-H1-32, 199-H1-33, 199-H1-37, 199-H1-39, 199-H1-40, 199-H4-4, and 199-H6-2. 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 more than 75% of the time.

Operational run-time in extraction well 199-H1-45 was reduced to less than 70% as a result of downtime during conveyance piping replacement to increase the pipe size. The extraction well 199-H1-3 was offline during 2016 and was disconnected from the system in 2017.

Table 2-6. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Flow Rate (L/min [gal/min])		Total Flow Hours 2017	Total Run-Time[a] (%)	Purpose
			Low River-Stage Average	High River-Stage Average			
C7477	199-H1-45	HE01	235.3 (62.1)	228.4 (60.3)	6,072	69	Extraction
A4621	199-H4-15A	HE02	58.8 (15.5)	123.9 (32.7)	8,544	98	Extraction
C7485	199-H4-69	HE03	46.7 (12.3)	83.3 (22)	8,424	96	Extraction
C7483	199-H4-70	HE04	24.5 (6.5)	81.4 (21.5)	8,496	97	Extraction
C7597	199-H4-75	HE05	69.8 (18.4)	70.6 (18.6)	8,016	92	Extraction
A4630	199-H4-4	HE06	6.7 (1.8)	46.4 (12.2)	6,000	68	Extraction
B2776	199-H4-63	HE07	105.5 (27.9)	107.3 (28.3)	8,664	99	Extraction
B2777	199-H4-64	HE08	22.1 (5.8)	84.4 (22.3)	7,584	87	Extraction
A4613[b]	199-H3-2C	HE09	94 (24.8)	91.9 (24.3)	7,464	85	RUM extraction
A4618[b]	199-H4-12C	HE10	112.2 (29.6)	114.4 (30.2)	8,664	99	RUM extraction
C7489[c]	199-H6-2	HE11	10.8 (2.8)	27.5 (7.3)	4,032	46	Extraction
C7639[b]	199-H3-9	HE13	44.5 (11.8)	45.6 (12)	8,664	99	RUM extraction
C7108	199-H1-34	HE21	31.4 (8.3)	109.1 (28.8)	8,160	93	Extraction
C7106	199-H1-35	HE22	45.5 (12)	109.5 (28.9)	8,640	99	Extraction
C7102	199-H1-36	HE23	16.5 (4.4)	35.8 (9.5)	7,464	85	Extraction
C7099	199-H1-37	HE24	0.2 (0)	104.3 (27.5)	3,720	42	Extraction
C9486	199-H1-46	HE25	21.3 (5.6)	72 (19)	8,544	98	Extraction
C7098	199-H1-38	HE26	12.4 (3.3)	104.1 (27.5)	6,480	74	Extraction

Table 2-6. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Flow Rate (L/min [gal/min])		Total Flow Hours 2017	Total Run-Time[a] (%)	Purpose
			Low River-Stage Average	High River-Stage Average			
C7109	199-H1-39	HE27	7.4 (2)	133.7 (35.3)	4,584	52	Extraction
C7104	199-H1-40	HE28	10.3 (2.7)	109 (28.8)	4,872	56	Extraction
C7107	199-H1-42	HE29	31.8 (8.4)	111.2 (29.3)	7,248	83	Extraction
C7492	199-H1-43	HE30	71.8 (19)	114.1 (30.1)	8,664	99	Extraction
C7581[c]	199-H1-3	HE31	0 (0)	0 (0)	0	0	Extraction
C7584	199-H1-2	HE32	10.2 (2.7)	21.1 (5.6)	8,664	99	Extraction
C7585	199-H1-1	HE33	98.1 (25.9)	99 (26.1)	8,664	99	Extraction
C7587	199-H4-76	HE34	50.8 (13.4)	60.9 (16.1)	6,264	72	Extraction
C7604	199-H1-4	HE35	8.1 (2.1)	15.8 (4.2)	6,768	77	Extraction
C7605	199-H4-77	HE36	34 (9)	32.4 (8.6)	7,440	85	Extraction
C7115	199-H3-26	HE37	331.4 (87.5)	250.3 (66.1)	5,448	62	Extraction
C7110	199-H3-25	HE38	308.2 (81.4)	300.6 (79.4)	8,376	96	Extraction
C7598	199-H4-74	HE39	39.9 (10.5)	49.9 (13.2)	5,136	59	Extraction
C7100	199-H1-32	HE40	0 (0)	63.3 (16.7)	3,432	39	Extraction
C7105	199-H1-33	HE41	0 (0)	108 (28.5)	3,576	41	Extraction
B2779	199-H3-4	HE42	437.6 (115.5)	467.5 (123.4)	7,680	88	Extraction
C8792	199-H4-92	HE43	98.2 (25.9)	88.3 (23.3)	7,632	87	Extraction
C8724	199-H4-86	HE44	90.6 (23.9)	139.1 (36.7)	7,656	87	Extraction

Table 2-6. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Flow Rate (L/min [gal/min])		Total Flow Hours 2017	Total Run-Time[a] (%)	Purpose
			Low River-Stage Average	High River-Stage Average			
C8948	199-H5-16	HE45	211.3 (55.8)	202.5 (53.5)	7,656	87	Extraction
C8949	199-H4-93	HE46	83.6 (22.1)	70.7 (18.7)	5,856	67	Extraction
C7484[d]	199-H4-73	HJ02	0 (0)	0 (0)	0	0	Injection
C7488[d]	199-H4-72	HJ03	0 (0)	0 (0)	0	0	Injection
C7483[d]	199-H4-71	HJ04	0 (0)	0 (0)	0	0	Injection
A4628[d]	199-H4-18	HJ05	39.6 (10.4)	64 (16.9)	4,848	55	Injection
C7114	199-H3-27	HJ06	115.4 (30.5)	182.7 (48.2)	7,560	86	Injection
C7606	199-H1-6	HJ07	177 (46.7)	245.2 (64.7)	8,664	99	Injection
C7478	199-H1-25	HJ08	149.5 (39.5)	123 (32.5)	8,664	99	Injection
C7480	199-H1-27	HJ09	145.7 (38.5)	179.7 (47.4)	8,664	99	Injection
C7588	199-H4-78	HJ10	179 (47.3)	300.2 (79.3)	8,664	99	Injection
C7586	199-H4-79	HJ11	102.4 (27)	347.1 (91.6)	8,016	92	Injection
C7111	199-H1-21	HJ12	61.2 (16.1)	195.1 (51.5)	8,016	92	Injection
C7113	199-H1-20	HJ13	108.4 (28.6)	205.6 (54.3)	6,768	77	Injection
A4627	199-H4-17	HJ14	46.5 (12.3)	75.5 (19.9)	8,040	92	Injection
C9585	699-90-45B	HJ15	216 (57)	560.9 (148.1)	8,664	99	Injection
C8947	199-H6-7	HJ22	422.3 (111.5)	544.4 (143.7)	7,632	87	Injection
C8951	199-H6-8	HJ23	373.8 (98.7)	520.8 (137.5)	7,632	87	Injection

Table 2-6. Flow Rates and Total Run-Times for HX P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Flow Rate (L/min [gal/min])		Total Flow Hours 2017	Total Run-Time[a] (%)	Purpose
			Low River-Stage Average	High River-Stage Average			
C8950	699-95-45B	HJ24	504 (133)	668.2 (176.4)	5,568	64	Injection

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

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

b. Well is completed in the first water-bearing unit of the Ringold Formation upper mud unit and extracts water from that aquifer.

c. Well 199-H1-3 was disconnected as extraction well from system in 2017.

d. Flows to the injection well have been turned off or reduced to allow for rebound in the reactor area to determine if residual sources are present.

ID = identification

PLC = programmable logic controller

A range fire on August 12, 2017, resulted in shut down of the HX P&T facility from August 12 through August 15. Electrical equipment was also damaged, affecting seven extraction wells and one injection well. Other wells were also shut down periodically during repairs. As a result of the fire, extraction wells 199-H3-26 and 199-H3-25 were offline from August 12 through 28, 2017. Extraction wells 199-H3-2C, 199-H3-4, 199-H4-74, 199-H4-86, 199-H4-92, 199-H4-93, and 199-H5-16 were offline from August 12 through September 26, 2017. Injection well 199-H3-27 was offline from August 12 through October 1, 2017. The interruption in operations is reflected in the run-times shown in Table 2-6.

Injection well 699-95-45B, located in the Horn, had low operational run-times due to issues with the water-level transducer and the need for well rehabilitation. The operational run-times for injection wells 199-H4-18, 199-H4-71, 199-H4-72, and 199-H4-73 (located in the H Reactor area) were reduced or remained offline, as well as extraction wells in that area (e.g., 199-H4-18), to allow for evaluating potential Cr(VI) concentration rebound in the localized area and subsequently assessing the possible presence of secondary sources.

2.2.3 Performance Monitoring

Control of Cr(VI) in the groundwater remains the principal objective of the 100-HR-3 OU interim remedial action. Nitrate, strontium-90, tritium, uranium, and technetium-99 are listed in the interim action ROD (EPA/ROD/R10-96/134) as potential co-contaminants and are monitored as part of the remedial action. The ROD acknowledges that other (i.e., non-chromium) 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 ISRM barrier installation (the dithionite ion is oxidized to sulfate following placement in groundwater). Sulfate has also been detected at increasing levels in monitoring wells located near the DX P&T injection wells (discussed in Section 2.2.3.3). Increased sulfate concentrations have not occurred in the 100-H Area, primarily because the HX P&T system requires less sulfuric acid for pH adjustment due to lower Cr(VI) influent concentrations.

Contaminant concentration data are collected each year from 100-HR-3 OU compliance wells, monitoring and extraction wells, and aquifer tubes within the OU. The maximum contaminant concentrations and analysis of contaminant trends are presented in the annual groundwater monitoring report (e.g., Chapter 4 in DOE/RL-2017-66). 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 natural groundwater flow is directed toward the river.

Tables 2-7 through 2-9 present the high and low river-stage monitoring results for Cr(VI) during 2017. The P&T system performance assessment addresses longer term changes in Cr(VI) concentrations in the 100-HR-3 OU. Figures 2-13 and 2-14 illustrate the Cr(VI) plumes during periods of low river-stage and high river-stage in 2017 for the 100-D and 100-H Areas, respectively. The contaminant plume maps presented in this report are based on average results for samples collected either during the low river or high river-stage during 2017 for each well shown. During high river-stage periods, many of the aquifer tubes become submerged and cannot be sampled; therefore, aquifer tubes in the 100-HR-3 OU are usually only sampled during low river-stage.

Methods for generating contaminant plume representation are described in ECF-Hanford-18-0013, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2017 Hanford Site Groundwater Monitoring Report*. The following sections present the contaminant monitoring results. The annual groundwater monitoring report (Chapter 4 of DOE/RL-2016-66) provides further summary and analysis of co-contaminants.

2.2.3.1 River-Stage Effects

The Columbia River is the discharge boundary for groundwater in the unconfined aquifer beneath the Hanford Site. The semi-confined aquifer in the RUM has been shown to be in communication with the Columbia River; however, it is still uncertain if the river acts as a discharge boundary or to what extent. The rise and fall of the Columbia River creates a zone of interaction of surface water and groundwater. The river-stage varies over short (e.g., hourly) and long (e.g., seasonal) intervals in response to natural influences and the operation of dams on the Columbia River. High river-stage during 2017 was from April to mid-July. High river-stage at the Hanford Site remained for a longer period of time than usual during 2017 and was only 0.5 m (1.6 ft) below flood stage at Priest Rapids Dam. Low river-stage in 2017 occurred in mid-August through late December, which is typical.

Groundwater elevation in the unconfined aquifer adjacent to the river increases in response to increases in river-stage elevation. In locations near the river, some quantity of river water may actually enter the aquifer under conditions of rapid increases in river-stage, resulting in what is known as bank storage. In the 100-D Area where the aquifer adjacent to the river consists of the relatively finer grained Ringold unit E (as opposed to the Hanford formation), bank storage is limited to the aquifer volume very close to the river. In portions of the 100-H Area where the aquifer consists of the coarse-grained Hanford formation, river water intrusion and resulting bank storage may extend inland for many meters.

Groundwater contaminant concentrations vary as groundwater elevation changes seasonally. At locations near historical source release areas, contaminant concentrations are frequently observed to increase when groundwater elevation raises and comes into contact with residual contamination in the deep vadose zone/periodically rewetted zone (PRZ). Locations downgradient of source areas frequently exhibit decreased concentrations at high groundwater elevation.

Groundwater-specific conductance was mapped to evaluate the apparent mixing of river water with the aquifer as affected by seasonal elevation changes and due to capture by pumping (Figure 2-15). A specific conductance level of less than 200 µS/cm is indicative of river water (i.e., the Columbia River exhibits a relatively 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-HR-3 OU. Specific conductance of 200 to 300 µS/cm indicates likely mixing of groundwater with river water.

Well locations along the ISRM barrier exhibited specific conductance greater than 300 µS/cm in most locations (Figure 2-15). The shoreline along the middle portion of 100-D Area plume had specific conductance values that represented both river water and areas of mixing. Further north, where Cr(VI) extends to near the river, the specific conductance was higher, as is typical of groundwater. In the 100-H Area, the specific conductance was below 200 µS/cm along most of shoreline. South of 100-H, the specific conductance values were higher and more typical of groundwater, which is consistent with the current plume configuration for the area. The specific conductance values are consistent with the inferred water table maps and the areas of groundwater capture (as indicated by a definable groundwater depression), as discussed in Section 2.2.4.

Table 2-7. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
	199-D2-11	M	—	—	11/7/2017	1.5(U)	11/7/2017	1.5(U)
	199-D2-6	M	—	—	11/7/2017	2	11/7/2017	2
	199-D3-5	M	—	—	11/7/2017	7.9	11/7/2017	7.9
ISRM	199-D4-101	E	5/25/2017	26	9/27/2017	7	5/25/2017	26
	199-D4-102	M	5/18/2017	29	11/17/2017	3.3	5/18/2017	29
	199-D4-103	M	5/23/2017	14	11/20/2017	1.5(U)	5/23/2017	14
ISRM	199-D4-13	M	—	—	10/12/2017	33	10/12/2017	33
ISRM	199-D4-14	E/M	—	—	9/20/2017	17	9/20/2017	17
	199-D4-15	M	5/18/2017	3.7	11/15/2017	3	5/18/2017	3.7
	199-D4-20	M	—	—	11/6/2017	1.5(U)	3/20/2017	10
ISRM	199-D4-23	C	—	—	11/6/2017	1.5(U)	11/6/2017	1.5(U)
ISRM	199-D4-24	M	—	—	11/27/2017	6.9	11/27/2017	6.9
ISRM	199-D4-25	M	—	—	11/27/2017	14	11/27/2017	14
ISRM	199-D4-31	M	—	—	11/15/2017	20	11/15/2017	20
ISRM	199-D4-34	E	7/5/2017	18	9/20/2017	40	9/20/2017	40
ISRM	199-D4-38	C	6/6/2017	1.5(U)	10/18/2017	22	10/18/2017	22
ISRM	199-D4-39	E	5/1/2017	6	11/15/2017	30	11/15/2017	30
ISRM	199-D4-40	M	—	—	11/13/2017	23	11/13/2017	23

Table 2-7. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
ISRM	199-D4-45	M	—	—	11/27/2017	5.4	11/27/2017	5.4
ISRM	199-D4-54	M	—	—	11/13/2017	31	11/13/2017	31
ISRM	199-D4-60	M	—	—	11/6/2017	68	11/6/2017	68
ISRM	199-D4-66	M	—	—	11/6/2017	1.7	11/6/2017	1.7
ISRM	199-D4-77	M	—	—	11/15/2017	7.4	11/15/2017	7.4
ISRM	199-D4-82	M	—	—	11/6/2017	8.7	11/6/2017	8.7
ISRM	199-D4-83	E	7/13/2017	3	10/18/2017	2	1/17/2017	6
ISRM	199-D4-84	C	5/1/2017	6	10/18/2017	11	9/11/2017	12
ISRM	199-D4-85	C	5/1/2017	7	10/18/2017	9	9/11/2017	19
ISRM	199-D4-86	C	—	—	10/12/2017	8.9	10/12/2017	8.9
ISRM	199-D4-95	E	6/19/2017	16	11/15/2017	18	6/10/2017	18
ISRM	199-D4-96	E	4/26/2017	36	11/15/2017	29	3/28/2017	50
ISRM	199-D4-97	E	5/1/2017	17	11/1/2017	17	1/17/2017	22
ISRM	199-D4-98	M	5/1/2017	2	10/18/2017	14	10/18/2017	14
ISRM	199-D4-99	M	6/19/2017	9	10/18/2017	17	10/18/2017	17
DX	199-D5-101	E	4/26/2017	12	11/15/2017	17	11/15/2017	17
	199-D5-103	M	6/13/2017	340	11/16/2017	680	12/8/2017	730
DX	199-D5-104	E	3/28/2017	80	11/15/2017	86	11/15/2017	86

Table 2-7. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
	199-D5-123	M	—	—	—	—	12/8/2017	5.9
	199-D5-125	M	—	—	—	—	12/14/2017	22
DX	199-D5-127	E	6/19/2017	11	11/15/2017	8	6/19/2017	11
	199-D5-13	M	—	—	10/12/2017	30	10/12/2017	30
DX	199-D5-130	E	7/13/2017	28	10/23/2017	21	7/13/2017	28
DX	199-D5-131	E	7/13/2017	36	10/23/2017	37	10/23/2017	37
	199-D5-132	M	—	—	11/27/2017	5.8	11/27/2017	5.8
	199-D5-133	M	5/25/2017	2.7	11/27/2017	1.8	5/25/2017	2.7
	199-D5-14	M	—	—	11/16/2017	6	11/16/2017	6
	199-D5-142	M	—	—	11/16/2017	3.6	11/16/2017	3.6
	199-D5-143	M	—	—	11/28/2017	25	11/28/2017	25
	199-D5-145	M	5/25/2017	20	11/27/2017	34	11/27/2017	34
DX	199-D5-146	E	6/21/2017	19	11/13/2017	24	12/6/2017	27
	199-D5-149	M	5/25/2017	14	11/28/2017	19	11/28/2017	19
	199-D5-150	M	5/26/2017	11	11/28/2017	4.4	5/26/2017	11
	199-D5-151	M	6/9/2017	160	9/22/2017	120	6/9/2017	160
	199-D5-152	M	7/5/2017	16	9/22/2017	22	9/22/2017	22
DX	199-D5-153	E	7/5/2017	33	9/20/2017	53	9/20/2017	53

Table 2-7. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
DX	199-D5-154	E	6/8/2017	33	9/20/2017	37	9/20/2017	37
DX	199-D5-159	E	4/12/2017	34	—	—	4/12/2017	34
	199-D5-16	M	—	—	—	—	12/7/2017	10
	199-D5-160	M	4/4/2017	180	9/29/2017	81	4/4/2017	180
	199-D5-17	M	—	—	10/12/2017	4.3	10/12/2017	4.3
	199-D5-18	M	—	—	11/16/2017	4.6	11/16/2017	4.6
	199-D5-19	M	—	—	10/12/2017	4.3	10/12/2017	4.3
DX	199-D5-20	E	4/12/2017	9	—	—	4/12/2017	9
DX	199-D5-32	E	6/8/2017	52	10/12/2017	28	6/8/2017	52
DX	199-D5-34	E	5/20/2017	79	10/12/2017	78	2/2/2017	98
	199-D5-36	M	—	—	10/13/2017	4.2	10/13/2017	4.2
	199-D5-38	M	—	—	—	—	12/7/2017	7.9
DX	199-D5-39	E	7/5/2017	30	10/12/2017	17	1/16/2017	36
	199-D5-40	M	—	—	11/17/2017	5.2	11/17/2017	5.2
	199-D5-41	M	—	—	11/17/2017	1.7	11/17/2017	1.7
	199-D5-42	M	5/23/2017	1.5(U)	11/20/2017	1.5(U)	6/24/2017	1.5(U)
	199-D5-43	M	—	—	11/20/2017	9.4	11/20/2017	9.4
	199-D5-44	M	—	—	11/27/2017	8.8	11/27/2017	8.8

Table 2-7. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
DX	199-D5-92	E	4/12/2017	8	12/6/2017	59	12/6/2017	59
	199-D5-97	M	5/25/2017	3	11/27/2017	2.3	2/22/2017	4.2
	199-D6-3	M	—	—	11/28/2017	4.4	11/28/2017	4.4
DX	199-D7-3	E	7/13/2017	17	11/15/2017	10	7/13/2017	17
DX	199-D7-6	E	7/13/2017	6	11/2/2017	4.4	3/7/2017	7
	199-D8-101	M	—	—	10/13/2017	6.1	10/13/2017	6.1
	199-D8-102	M	7/28/2017	36	9/22/2017	46	9/16/2017	46
	199-D8-4	M	5/26/2017	6.2	11/20/2017	13	2/16/2017	17
	199-D8-5	M	—	—	12/18/2017	4.3	12/18/2017	4.3
DX	199-D8-53	E	6/27/2017	10	11/15/2017	7	6/27/2017	10
	199-D8-54A	M	—	—	12/18/2017	15	12/18/2017	15
DX	199-D8-55	E	7/13/2017	14	9/27/2017	9	7/13/2017	14
	199-D8-6	M	—	—	11/27/2017	23	3/1/2017	29
DX	199-D8-68	E	6/19/2017	13	11/29/2017	14	3/28/2017	15
DX	199-D8-69	E	7/13/2017	13	10/23/2017	12	10/23/2017	12
	199-D8-70	M	—	—	12/8/2017	2.5	12/8/2017	2.5
	199-D8-71	M	—	—	11/20/2017	23	11/20/2017	23
	199-D8-72	M	—	—	12/8/2017	83	12/8/2017	83

Table 2-7. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
DX	199-D8-73	E	6/8/2017	3	—	—	6/8/2017	3
DX	199-D8-88	E	6/8/2017	6	10/12/2017	9	10/12/2017	9
DX	199-D8-89	E	7/5/2017	9	10/12/2017	46	10/12/2017	46
DX	199-D8-90	E	6/19/2017	10	11/15/2017	15	11/15/2017	15
DX	199-D8-91	E	7/13/2017	19	10/23/2017	17	7/13/2017	19
	199-D8-93	M	—	—	11/27/2017	17	11/27/2017	17
	199-D8-94	M	—	—	11/27/2017	18	11/27/2017	18
DX	199-D8-95	E	7/13/2017	92	11/15/2017	96	1/4/2017	150
DX	199-D8-96	E	5/8/2017	52	10/23/2017	57	1/4/2017	68
DX	199-D8-97	E	7/13/2017	37	10/10/2017	38	1/18/2017	41
DX	199-D8-98	E	7/13/2017	14	10/23/2017	17	2/14/2017	24
DX	199-D8-99	E	4/25/2017	21	10/10/2017	11	4/25/2017	21
DX	199-H1-5	E	7/13/2017	16	11/15/2017	24	11/15/2017	24
DX	199-H4-80	E	7/13/2017	27	11/15/2017	25	7/13/2017	27
DX	199-H4-81	E	7/13/2017	24	10/23/2017	27	8/7/2017	28
DX	199-H4-82	E	5/28/2017	15	11/15/2017	15	5/28/2017	15

Table 2-7. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
Aquifer Sampling Tubes								
	38-M	AT	—	—	10/12/2017	1.5(U)	10/12/2017	1.5(U)
	699-93-48A	AT	—	—	10/27/2017	8	10/27/2017	8
	699-95-48	AT	—	—	10/26/2017	14	10/26/2017	14
	699-95-51	AT	—	—	10/26/2017	2.3	10/26/2017	2.3
	699-96-52B	AT	—	—	10/26/2017	5.3	10/26/2017	5.3
	699-97-48B	AT	—	—	10/25/2017	19	10/25/2017	19
	699-98-49A	AT	—	—	10/25/2017	1.5(U)	10/25/2017	1.5(U)
	699-98-51	AT	5/26/2017	1.5(U)	10/29/2017	5	10/29/2017	5
	AT-D-1-M	AT	—	—	10/12/2017	1.5(U)	10/12/2017	1.5(U)
	AT-D-3-D	AT	—	—	10/12/2017	1.8	10/12/2017	1.8
	AT-D-4-D	AT	—	—	10/12/2017	1.5(U)	10/12/2017	1.5(U)
	C6278	AT	—	—	10/12/2017	2.1	10/12/2017	2.1
	C7647	AT	—	—	10/12/2017	5.9	10/12/2017	5.9
	DD-10-3	AT	—	—	10/16/2017	1.5(U)	10/16/2017	1.5(U)
	DD-12-2	AT	—	—	10/16/2017	1.5(U)	10/16/2017	1.5(U)
	DD-15-3	AT	—	—	10/16/2017	4.7	10/16/2017	4.7
	DD-16-4	AT	—	—	10/16/2017	9	10/16/2017	9

Table 2-7. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (D) and DX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
	DD-17-2	AT	—	—	10/12/2017	11	10/12/2017	11
	DD-41-3	AT	—	—	10/12/2017	1.5(U)	10/12/2017	1.5(U)
	DD-44-4	AT	—	—	10/12/2017	4.6	10/12/2017	4.6
	DD-49-3	AT	—	—	10/12/2017	10	10/12/2017	10
	DD-50-3	AT	—	—	10/12/2017	11	10/12/2017	11
	DD-50-4	AT	—	—	10/12/2017	21	10/12/2017	21
	Redox-1-6.0	AT	—	—	10/12/2017	1.5(U)	10/12/2017	1.5(U)
	Redox-3-3.3	AT	—	—	10/12/2017	4.9	10/12/2017	4.9

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

Blank cells in the "System" column indicate that the well/aquifer tube is not tied directly to a pump-and-treat system.

*High river-stage represents the period from April through mid-July. Low river-stage represents the period from mid-August through December.

— = indicates that sample was not collected or analysis was not performed
AT = aquifer tube
C = compliance well
Cr(VI) = hexavalent chromium
E = extraction well
ISRM = in situ redox manipulation
M = monitoring well
U = undetected (detection limit is listed with qualifier in parentheses)

Table 2-8. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
HX	199-H1-1	E	4/4/2017	30	10/3/2017	42	10/3/2017	42
HX	199-H1-2	E	4/4/2017	41	10/3/2017	41	1/4/2017	49
HX	199-H1-3	E	—	—	—	—	11/29/2017	42
HX	199-H1-32	E	4/4/2017	18	—	—	4/4/2017	18
HX	199-H1-33	E	7/6/2017	14	—	—	3/1/2017	15
HX	199-H1-34	E	4/4/2017	17	12/4/2017	22	12/4/2017	22
HX	199-H1-35	E	7/6/2017	15	10/3/2017	17	10/3/2017	17
HX	199-H1-36	E	7/6/2017	35	10/3/2017	36	1/3/2017	47
HX	199-H1-37	E	5/1/2017	10	—	—	5/1/2017	10
HX	199-H1-38	E	5/3/2017	1.5(U)	10/3/2017	13	10/3/2017	13
HX	199-H1-39	E	5/1/2017	7	9/6/2017	10	9/6/2017	10
HX	199-H1-4	E	7/6/2017	42	—	—	7/6/2017	42
HX	199-H1-40	E	7/6/2017	4	9/6/2017	11	9/6/2017	11
HX	199-H1-42	E	5/1/2017	40	10/3/2017	24	5/1/2017	40
HX	199-H1-43	E	7/6/2017	5	10/3/2017	25	10/3/2017	25
HX	199-H1-45	E	3/26/2017	27	12/4/2017	19	1/4/2017	41
HX	199-H1-46	E	5/1/2017	14	10/3/2017	47	10/3/2017	47
	199-H1-7	M	5/23/2017	2.5	11/15/2017	2.3	2/13/2017	10

Table 2-8. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
	199-H3-11	M	—	—	11/9/2017	8.2	11/9/2017	8.2
HX	199-H3-25	E	7/6/2017	10	10/3/2017	17	5/20/2017	17
HX	199-H3-26	E	6/3/2017	8	9/6/2017	9	9/6/2017	9
	199-H3-2A	M	—	—	11/3/2017	2.1	11/3/2017	2.1
	199-H3-3	M	—	—	11/9/2017	8.5	11/9/2017	8.5
HX	199-H3-4	E	7/6/2017	14	10/3/2017	8	7/6/2017	14
	199-H3-6	M	—	—	11/3/2017	4.7	11/3/2017	4.7
	199-H3-7	M	—	—	11/9/2017	2.2	11/9/2017	2.2
	199-H4-10	M	—	—	12/14/2017	1.5(U)	12/14/2017	1.5(U)
	199-H4-11	M	—	—	11/3/2017	7.5	11/3/2017	7.5
	199-H4-12A	M	5/3/2017	1.5(U)	11/3/2017	1.6	11/3/2017	1.6
	199-H4-13	M	—	—	11/7/2017	24	11/7/2017	24
HX	199-H4-15A	E	4/4/2017	8	10/18/2017	4	1/4/2017	9
	199-H4-15CP	M	—	—	10/20/2017	1.5(U)	10/20/2017	1.5(U)
	199-H4-15CQ	M	—	—	11/3/2017	1.5(U)	11/3/2017	1.5(U)
	199-H4-15CR	M	—	—	10/20/2017	4.8	10/20/2017	4.8
HX	199-H4-4	E	—	—	—	—	4/4/2017	9
	199-H4-45	M	—	—	12/14/2017	4.1	12/14/2017	4.1

Table 2-8. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
	199-H4-46	M	—	—	11/9/2017	4.3	11/9/2017	4.3
	199-H4-49	M	—	—	11/13/2017	8.2	11/13/2017	8.2
	199-H4-5	M	—	—	12/14/2017	2.4	12/14/2017	2.4
HX	199-H4-63	E	6/2/2017	7	10/3/2017	23	10/3/2017	23
HX	199-H4-64	E	4/4/2017	5	12/4/2017	1	4/4/2017	5
	199-H4-65	M	—	—	11/7/2017	17	11/7/2017	17
HX	199-H4-69	E	4/4/2017	13	10/3/2017	15	10/3/2017	15
HX	199-H4-70	E	4/4/2017	14	10/3/2017	9	4/4/2017	14
HX	199-H4-74	E	7/6/2017	44	10/3/2017	29	7/6/2017	44
HX	199-H4-75	E	4/4/2017	48	10/3/2017	37	4/4/2017	48
HX	199-H4-76	E	7/6/2017	13	10/3/2017	22	10/3/2017	22
HX	199-H4-77	E	7/6/2017	14	10/3/2017	8	7/6/2017	14
	199-H4-8	M	5/3/2017	2	11/10/2017	1.5(U)	5/3/2017	2
	199-H4-83	M	6/7/2017	3.6	11/13/2017	1.5(U)	6/7/2017	3.6
	199-H4-84	M	4/4/2017	130	9/29/2017	12	4/4/2017	130
	199-H4-85	M	5/25/2017	2	—	—	2/14/2017	3.3
HX	199-H4-86	E	—	—	10/17/2017	20	8/1/2017	48
	199-H4-87	M	—	—	11/13/2017	4.9	5/23/2017	30

Table 2-8. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
	199-H4-88	M	5/3/2017	39	9/29/2017	16	5/3/2017	39
	199-H4-89	M	5/25/2017	2.9	11/10/2017	1.5(U)	5/25/2017	2.9
HX	199-H4-92	E	5/1/2017	16	12/4/2017	8	5/1/2017	16
HX	199-H4-93	E	—	—	10/3/2017	25	2/22/2017	62
HX	199-H5-16	E	7/6/2017	18	12/4/2017	12	1/4/2017	19
	199-H6-1	M	—	—	11/13/2017	3.7	11/13/2017	3.7
	199-H6-3	M	—	—	11/13/2017	1.5(U)	11/13/2017	1.5(U)
	699-100-43B	M	—	—	10/13/2017	4.8	10/13/2017	4.8
	699-88-41	M	—	—	10/23/2017	12	10/23/2017	12
	699-88-41A	M	4/14/2017	6.7	—	—	4/14/2017	6.7
	699-90-37B	M	—	—	10/23/2017	2.7	10/23/2017	2.7
	699-90-45	M	—	—	10/23/2017	6.7	10/23/2017	6.7
	699-91-46A	M	—	—	—	—	6/11/2017	6.1(U)
	699-93-37A	M	—	—	10/19/2017	14	6/22/2017	14
	699-94-41	M	—	—	10/25/2017	14	10/25/2017	14
	699-94-43	M	—	—	10/27/2017	4.8	10/27/2017	4.8
	699-95-45	M	—	—	10/26/2017	1.8	10/26/2017	1.8
	699-97-41	M	—	—	10/25/2017	16	10/25/2017	16

Table 2-8. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
	699-97-43B	M	—	—	10/27/2017	6	10/27/2017	6
	699-97-45	M	—	—	10/25/2017	33	10/25/2017	33
	699-97-47B	M	5/15/2017	22	10/27/2017	22(U)	2/24/2017	24(U)
	699-98-43	M	—	—	10/25/2017	27	10/25/2017	27
	699-98-46	M	—	—	10/29/2017	35	10/29/2017	35
	699-99-41	M	—	—	10/25/2017	12	10/25/2017	12
	699-99-42B	M	—	—	10/29/2017	2.6	10/29/2017	2.6
	699-99-44	M	—	—	10/26/2017	23	10/26/2017	23
Aquifer Tubes								
	45-M	AT	—	—	10/11/2016	1.5(U)	10/11/2016	1.5
	43-M	AT	—	—	10/23/2017	9.6	10/23/2017	9.6
	45-M	AT	—	—	10/19/2017	1.5(U)	10/19/2017	1.5(U)
	47-D	AT	—	—	10/23/2017	4.2	10/23/2017	4.2
	47-M	AT	—	—	11/1/2017	3.6	11/1/2017	3.6
	48-M	AT	—	—	10/23/2017	4.6	10/23/2017	4.6
	50-M	AT	—	—	11/7/2017	2.9	11/7/2017	2.9
	51-D	AT	—	—	9/22/2017	17	9/22/2017	17
	52-D	AT	—	—	11/7/2017	1.5	11/7/2017	1.5

Table 2-8. Maximum Cr(VI) Concentrations for Wells and Aquifer Tubes Monitoring the 100-HR-3 (H) and HX P&T Systems, 2017

System	Well or Aquifer Tube Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
	54-M	AT	—	—	—	—	11/7/2017	2.8
	AT-H-1-M	AT	—	—	10/19/2017	1.5(U)	10/19/2017	1.5(U)
	AT-H-2-D	AT	—	—	10/19/2017	1.9(U)	10/19/2017	1.9(U)
	AT-H-3-D	AT	—	—	10/19/2017	5.4	10/19/2017	5.4
	C5633	AT	—	—	10/16/2017	6.8	10/16/2017	6.8
	C5636	AT	—	—	10/16/2017	4.8	10/16/2017	4.8
	C5638	AT	—	—	10/23/2017	9.8	10/23/2017	9.8
	C5641	AT	—	—	10/23/2017	17	10/23/2017	17
	C5678	AT	—	—	10/19/2017	1.5(U)	10/19/2017	1.5(U)
	C5682	AT	—	—	10/19/2017	1.5(U)	10/19/2017	1.5(U)
	C6301	AT	—	—	10/23/2017	2.1	10/23/2017	2.1
	C7649	AT	—	—	10/23/2017	2.1	10/23/2017	2.1
	C7650	AT	—	—	10/23/2017	30	10/23/2017	30

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

Blank cells in the "System" column indicate that the well/aquifer tube is not tied directly to a pump-and-treat system.

* High river-stage represents the period from April through mid-July. Low river-stage represents the period from mid-August through December.

— = indicates that the sample was not collected or analysis was not performed
AT = aquifer tube
Cr(VI) = hexavalent chromium
E = extraction well
I = injection well
M = monitoring well
U = undetected (detection limit is listed with qualifier in parentheses)

Table 2-9. Maximum Cr(VI) Concentrations for 100-H Area and 100-D Area RUM Wells, 2017

System	Well Name	Well Use	High River-Stage* Maximum Cr(VI)		Low River-Stage* Maximum Cr(VI)		Annual Maximum Cr(VI)	
			Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
	199-D5-141	M	—	—	10/26/2017	1.5(U)	10/26/2017	1.5(U)
	199-D8-54B	M	—	—	12/8/2017	8.8	12/8/2017	8.8
	199-H2-1	M	5/23/2017	19	11/3/2017	20	11/3/2017	20
	199-H3-10	M	—	—	11/3/2017	3.2	11/3/2017	3.2
	199-H3-28	M	—	—	12/5/2017	32	12/5/2017	32
	199-H3-29	M	—	—	11/29/2017	140	11/29/2017	140
HX	199-H3-2C	E	7/6/2017	61	11/2/2017	64	11/2/2017	64
	199-H3-30	M	—	—	12/4/2017	88	12/4/2017	88
HX	199-H3-9	E	5/6/2017	57	10/3/2017	53	5/6/2017	57
HX	199-H4-12C	E	4/4/2017	107	11/2/2017	115	11/2/2017	115
	199-H4-15CS	M	—	—	10/20/2017	60	10/20/2017	60
	199-H4-90	M	5/25/2017	24	11/7/2017	13	5/25/2017	24
	199-H4-91	M	5/25/2017	32	11/7/2017	36	11/7/2017	36
	699-97-43C	M	6/11/2017	1.5(U)	10/27/2017	1.5(U)	6/11/2017	1.5(U)
	699-97-45B	M	5/25/2017	4	10/27/2017	3.1	5/25/2017	4
	699-97-48C	M	5/23/2017	110	10/31/2017	140	10/31/2017	140
	699-97-60	M	5/26/2017	1.5(U)	10/31/2017	38	10/31/2017	38
DX	699-97-61	M	6/19/2017	116	10/23/2017	105	3/28/2017	123

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

Blank cells in the "System" column indicate that the well/aquifer tube is not tied directly to a pump-and-treat system.

* High river-stage represents the period from mid-March through early September. Low river-stage represents the period from mid-September to early December.

— = indicates that the sample was not collected or analysis was not performed
Cr(VI) = hexavalent chromium
E = extraction well
M = monitoring well
U = undetected (detection limit is listed with qualifier in parentheses)

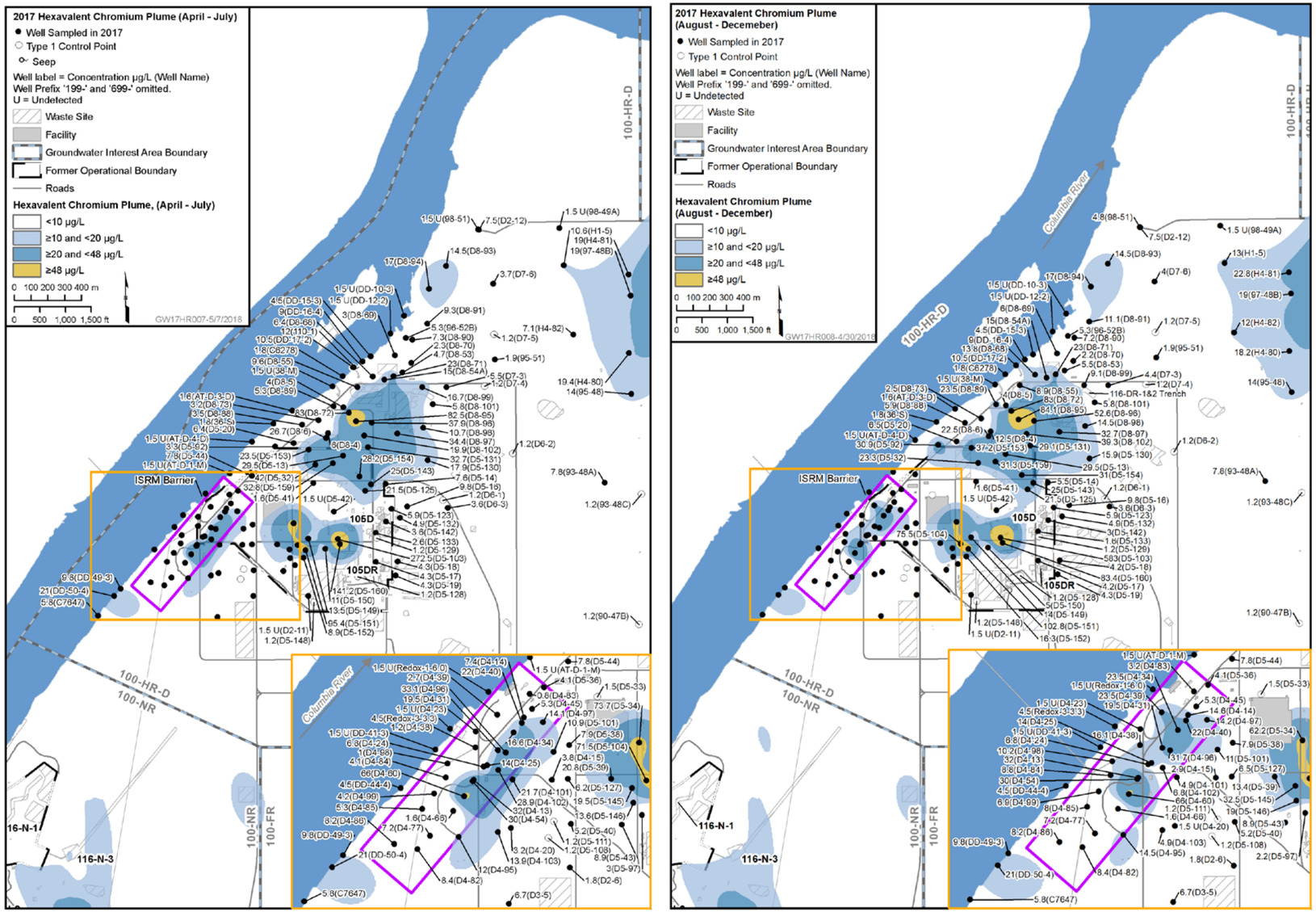

Figure 2-13. 100-HR-3 OU (100-D Area) Cr(VI) High River-Stage to Low River-Stage Comparison, 2017

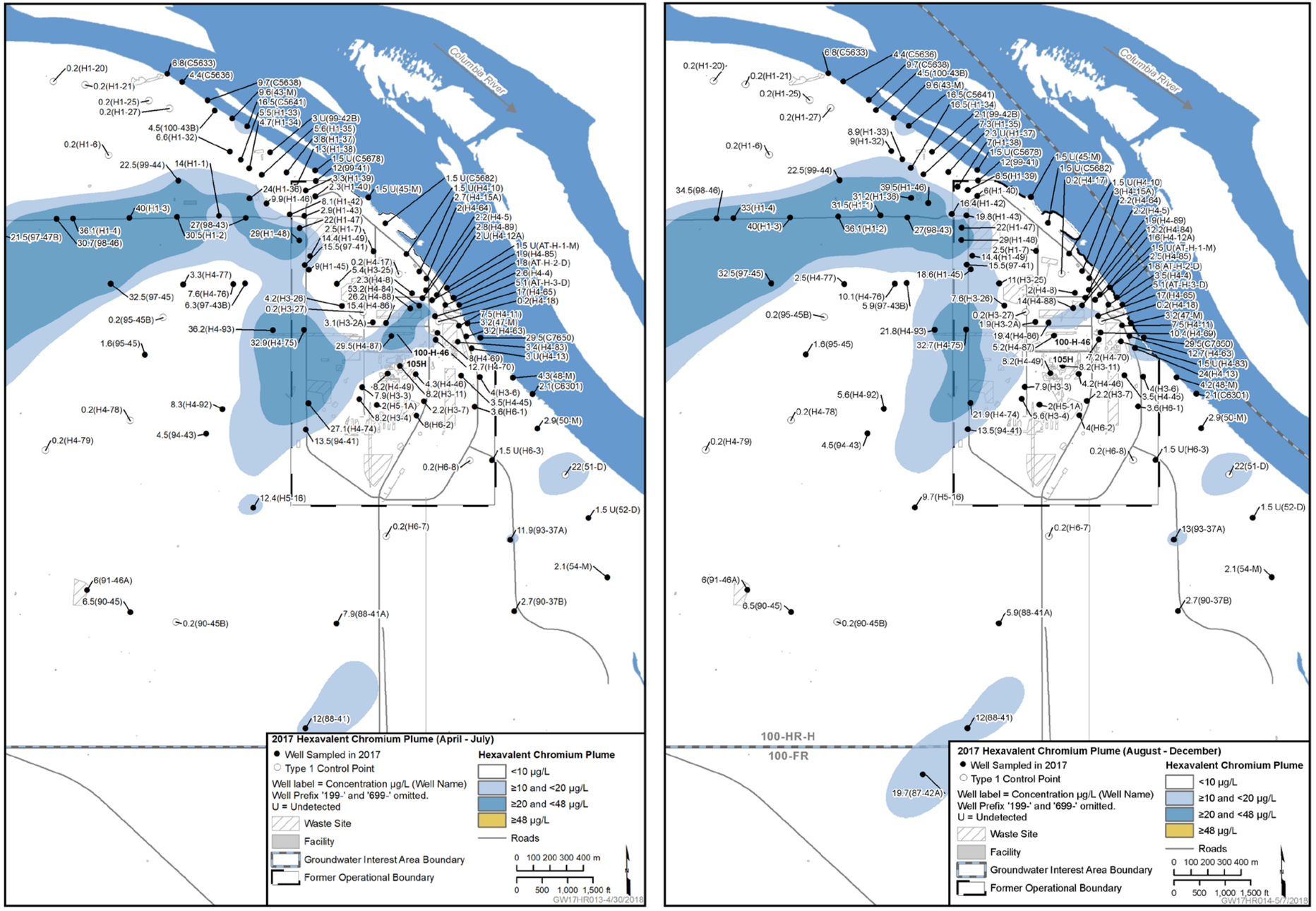

Figure 2-14. 100-HR-3 OU (100-H Area) Cr(VI) High River-Stage to Low River-Stage Comparison, 2017

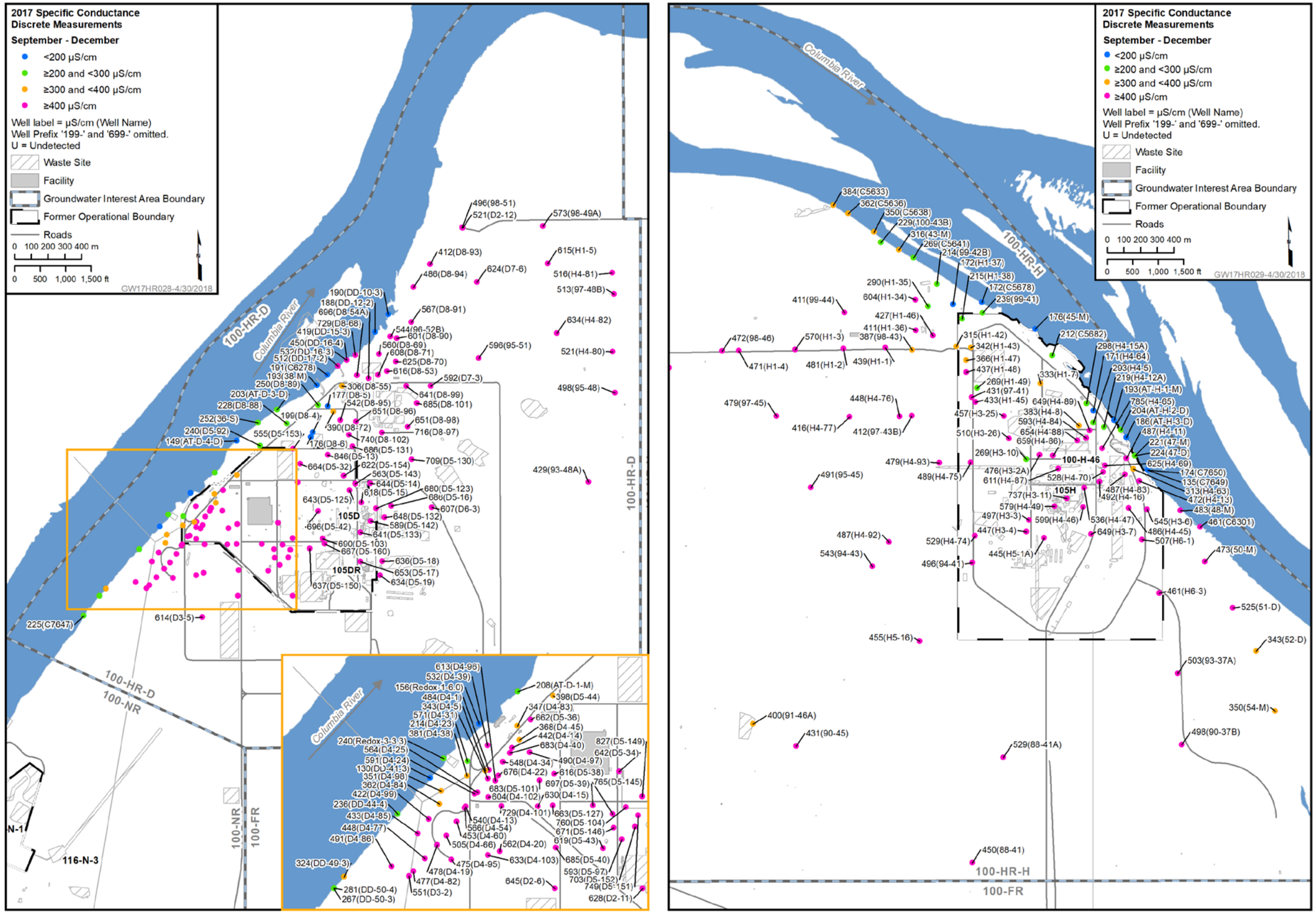

Figure 2-15. Specific Conductance at the 100-HR-3 OU, Fall 2017

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2.2.3.2 Hexavalent Chromium

The Cr(VI) concentrations are monitored in wells and aquifer tubes in the 100-HR-3 OU. Figures 2-13 and 2-14 show the 2017 spring and fall 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. As the P&T system has become more robust over time with the addition of wells in key locations; however, the effect of the river-stage on plume configuration has lessened. Plume changes are now primarily controlled by modifications in the P&T system during the year.

Cr(VI) in the 100-D Area. Areas with Cr(VI) concentrations greater than 48 µg/L decreased in size in 2017 (Figure 2-13), and the overall plume decreased as a result of ongoing remediation activities. In the southern portion of the 100-D Area, elevated concentrations remain near the former 100-D-100 waste site. Concentrations in wells 199-D5-104 and 199-D5-34, located downgradient, continue to show a decreasing trend, but concentrations in both wells began to approach an asymptote in excess of the cleanup target during 2016, with the rate of concentration decline slowing. This trend has continued throughout 2017, suggesting that some source material remains in the area (Figure 2-16). Further supporting the presence of a continuing source, Cr(VI) in well 199-D5-103 (located east of well 199-D5-104) showed an increasing trend in 2017.

The areas of concentrations greater tjam 48 µg/L in the 100-D northern plume are primarily located near the 120-D-1 (100-D Pond) waste site, southwest of the 116-DR-1&2 Trenches. Elevated Cr(VI) remains present in wells 199-D8-95 and 199-D8-96 (Figure 2-17) and has slowly declined over the last several years.

Cr(VI) in the Horn and 100-H Area. Discharges to the 116-DR-1&2 Trenches during 1967 resulted in an unconfined aquifer Cr(VI) plume that extends across the Horn from the 100-D Area to the 100-H Area (Figures 2-13 and 2-14). This plume encompasses the largest area of 100-HR, but concentrations in the unconfined aquifer remain consistently below 100 µg/L and are now less than the MTCA (WAC 173-340) standard of 48 µg/L.

The overall Cr(VI) concentrations in the Horn area unconfined aquifer are slowly declining and were less than 48 µg/L across the Horn for the first time in 2017. Areas of concentrations greater than 20 µg/L remain in the Horn near extraction wells 199-H4-93, 199-H4-75, 199-H1-4, and 199-H1-2, and near monitoring well 699-97-45. Wells 199-H4-93 and 199-H4-75 are located in the southwest Horn area and typically have low extraction rates. The extraction rate for well 199-H3-93 averaged 68 L/min (18 gal/min) when operational during 2017, but the well was offline until the end of February 2017. Similarly, well 199-H4-75 averaged 57 L/min (15 gal/min) during 2017. As a result of the low extraction rates, Cr(VI) concentrations are declining slowly. Concentrations in wells 199-H4-93 and 199-H4-75 were at 20 and 29 µg/L, respectively, by December 2017 compared to 47 µg/L observed for both wells at the end of 2016; this was the biggest decline over a one-year period since well installation. In previous years, wells 199-H4-93 and 199-H4-75 had concentrations averaging 52 µg/L from 2012 through 2016 and 57 µg/L from May 2015 through 2016 (Figure 2-18). Concentrations in wells 199-H1-4 and 199-H1-2 (located in the middle of the Horn) changed little during 2017, averaging 34 and 36 µg/L, respectively. The stable Cr(VI) concentrations in these two extraction wells were typical across the Horn during 2017.

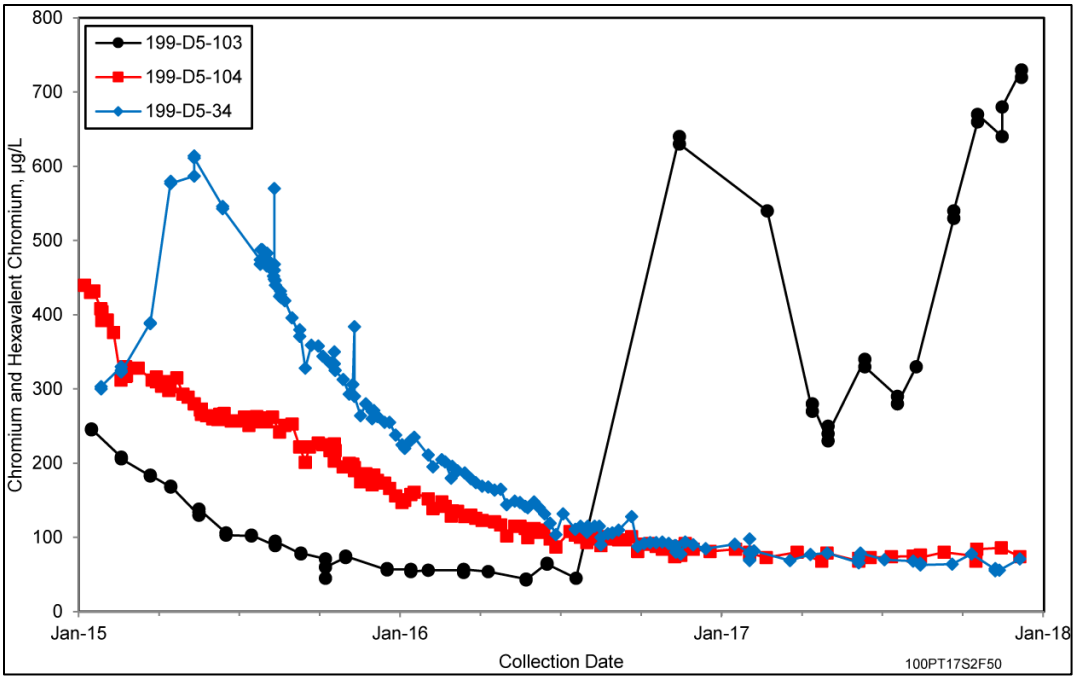

Figure 2-16. 100-HR Cr(VI) Data for Wells 199-D5-103, 199-D5-104, and 199-D5-34

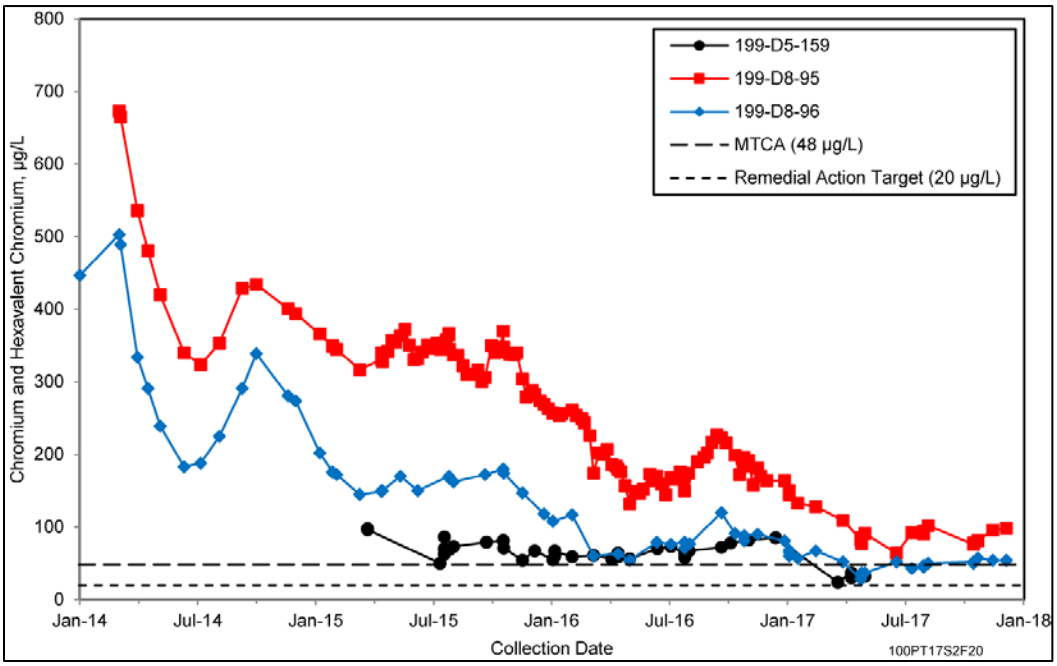

Figure 2-17. 100-HR Cr(VI) Data for Wells 199-D8-95 and 199-D8-96

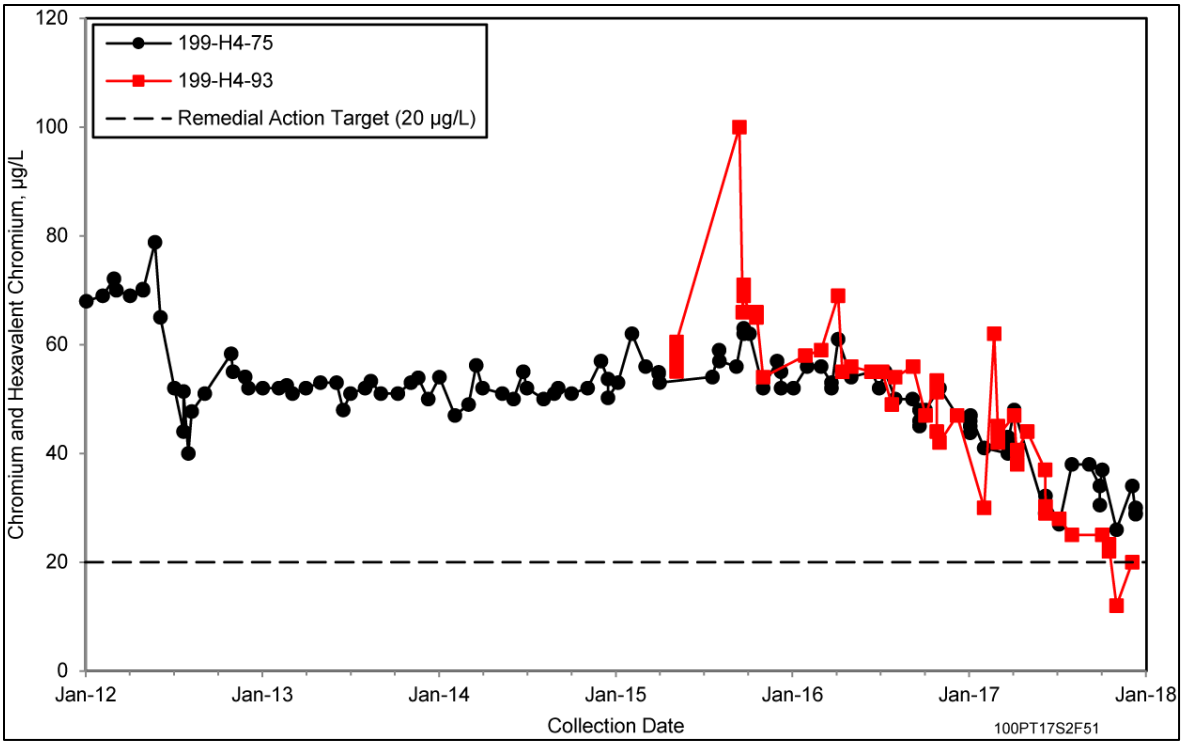

Figure 2-18. 100-HR Cr(VI) Trends for Wells 199-H4-75 and 199-H4-93

The Cr(VI) concentrations in the 100-H Area unconfined aquifer have typically been below 10 µg/L. In recent years, however, the amount of injection water within the 100-H operational area has been reduced. The reduction was conducted, in part, to determine if any continuing sources remained. Subsequently, a maximum Cr(VI) concentration of 130 µg/L was detected in well 199-H4-84 in April 2017, and concentrations above 30 µg/L were detected in several other monitoring wells in the 100-H Area during 2017 (Figure 2-14). The areas of elevated Cr(VI) are near the 183-H Solar Evaporation Basins (wells 199-H4-84 and 199-H4-88) and near upgradient waste sites 126-H-2 and 100-H-46 (wells 199-H4-86 and 199-H4-87). At each of the waste site locations, the associated wells exhibit elevated Cr(VI) concentrations during periods of high water levels, which is consistent with groundwater contacting residual contamination in the PRZ, and these are areas of suspected continuing sources in the lower vadose zone. Figure 2-19 shows an example of the correlation for well 199-H4-88.

Cr(VI) in the RUM. Three wells in the 100-D Area monitor the first water-bearing unit of the RUM. Cr(VI) has not been detected in well 199-D4-141, located south of the 182D reservoir. The other RUM wells are 199-D8-54B (located near the 116-DR-1&2 Trench) and 199-D5-134 (located north of D Reactor). Cr(VI) concentrations in these wells have fluctuated historically at concentrations below 10 µg/L. Concentrations in well 199-D8-54B have been trending slowly upward, with a maximum concentration in 2017 of 8.8 µg/L. These wells will continue to be monitored to track concentrations.

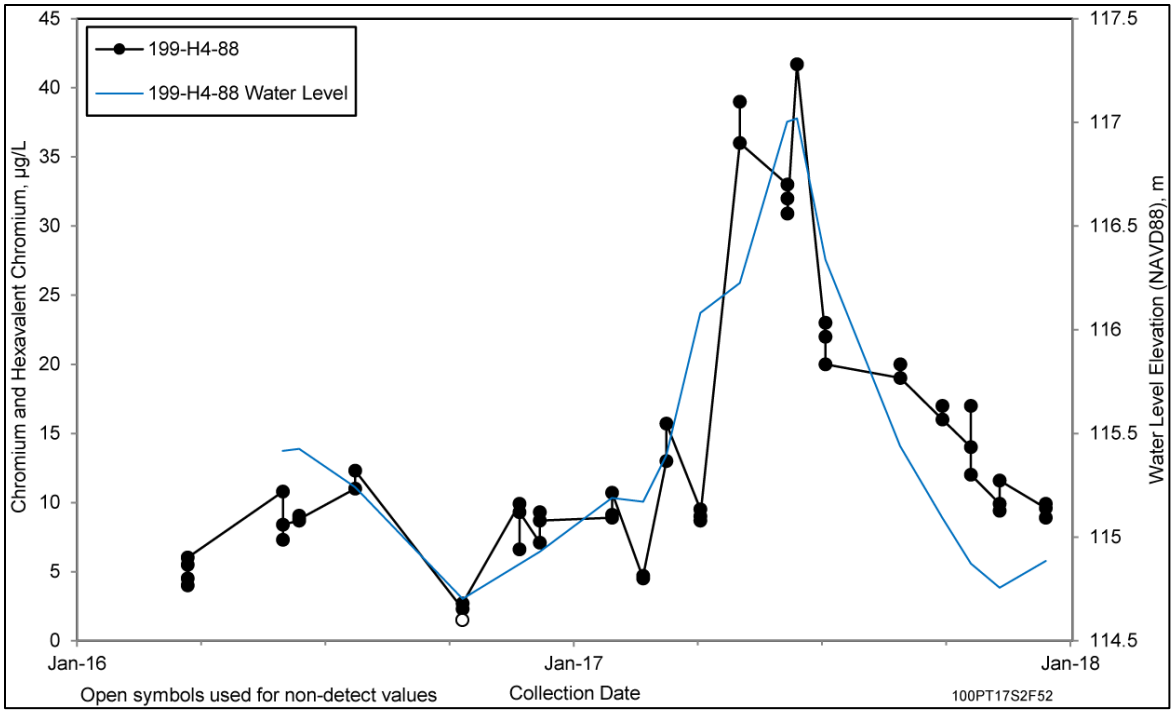

Figure 2-19. 100-HR Cr(VI) Data and Water Level for Well 199-H4-88

Elevated Cr(VI) concentrations are known to be present within the RUM in the Horn. Figure 2-20 presents the annual average concentrations for the RUM wells in 2017. The maximum concentration is presented for the wells that were drilled in 2017. A plume is not depicted due to the varied spatial distribution of Cr(VI) concentrations, a limited number of wells for such a large area, and uncertainty regarding the lateral continuity of the RUM aquifer. Based on current knowledge, elevated Cr(VI) concentrations are present in a small area centered near well 699-97-48C, which had a maximum concentration of 140 µg/L in 2017 and is exhibiting an increasing trend.

Concentrations are declining in the single RUM extraction well (699-97-61) in the Horn area. The reduction in concentrations may indicate effective remediation by the DX P&T system or the tailing edge of the plume. Well 699-97-61 had a maximum concentration of 196 µg/L in 2016 and 123 µg/L in 2017. There are no other wells in the area that are completed in the RUM, and it is uncertain if the plume extends farther to the north or south. To the east, RUM well 699-97-45B has levels of Cr(VI) just above the detection limit. It is presumed that this well represents the eastern boundary of the Cr(VI) plume; however, as in the west, there are limited wells in this location, and no wells are present to define the plume to the north or south. It should also be noted that wells 699-97-61 and 699-97-45B are 675 m (2,200 ft) apart. In the Horn, all of the RUM wells are nearly in a straight line, running west to east. Additional wells are planned for installation in the Horn as funding becomes available.

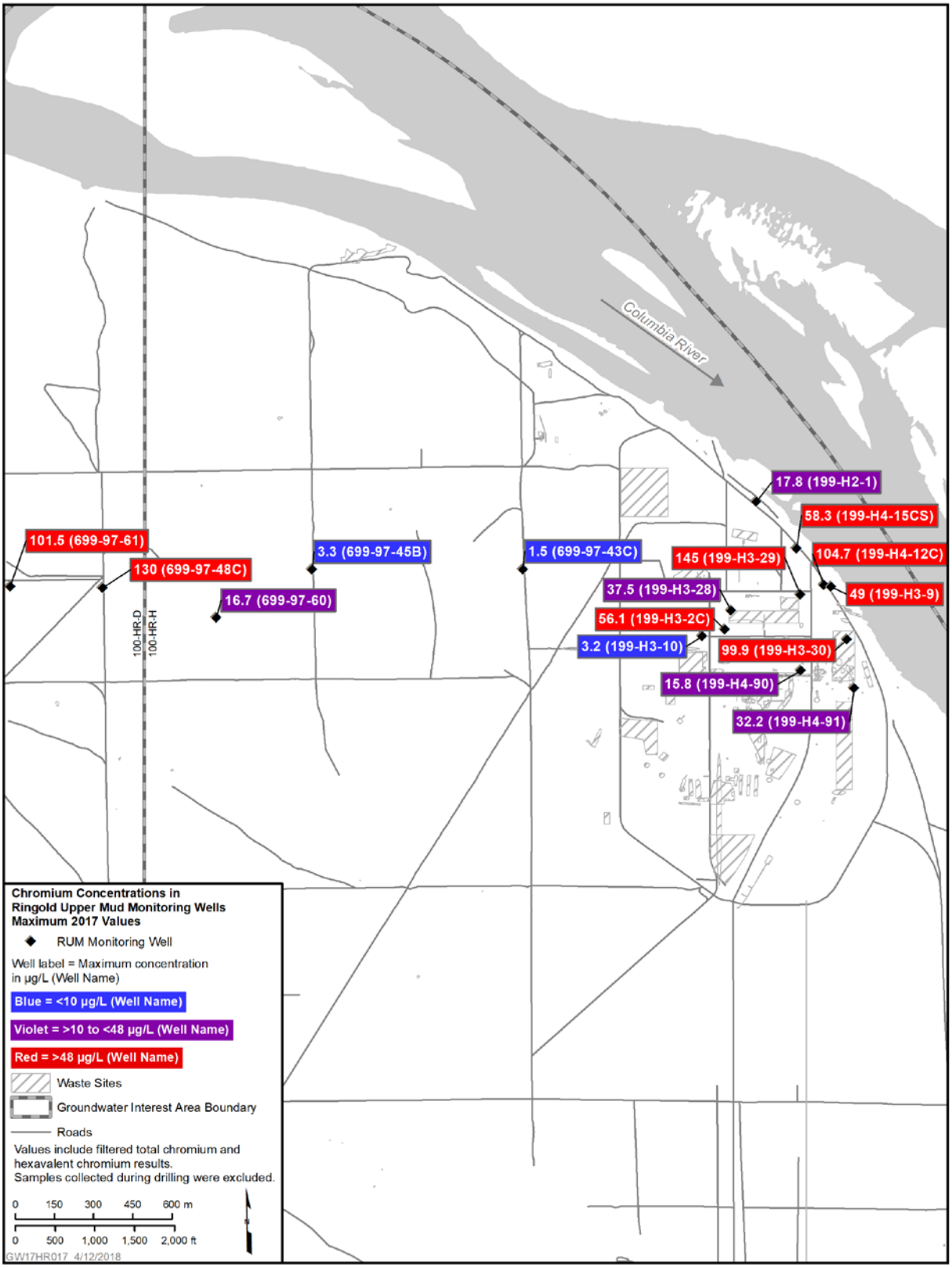

Figure 2-20. 100-H Area and Horn, Cr(VI) in the First Water-Bearing Unit of the RUM, 2017

The first water-bearing unit in the RUM is better defined in the 100-H Area than elsewhere across 100-HR. Three new RUM wells were installed in 2017: 199-H3-28, 199-H3-29, and 199-H3-30. Analytical results indicate that well 199-H3-29 has the highest Cr(VI) concentration (140 µg/L) in the 100-H Area (including in the unconfined aquifer). As a result, well 199-H3-29 is planned for connection to the HX P&T system as an extraction well. Assuming a hydraulic connection, well 199-H3-29 is located just upgradient of RUM extraction wells 199-H4-12C and 199-H3-9. A third RUM extraction well, 199-H3-2C, is located farther west and is potentially upgradient; however, a hydraulic connection for this well is less certain. Well 199-H3-2C has slowly declining Cr(VI) concentrations and was at 53 µg/L in December 2017. Downgradient RUM extraction wells 199-H4-12C and 199-H3-9 together average 158 L/min (42 gal/min). Cr(VI) concentrations in these wells have been slowly declining (Figure 2-21).

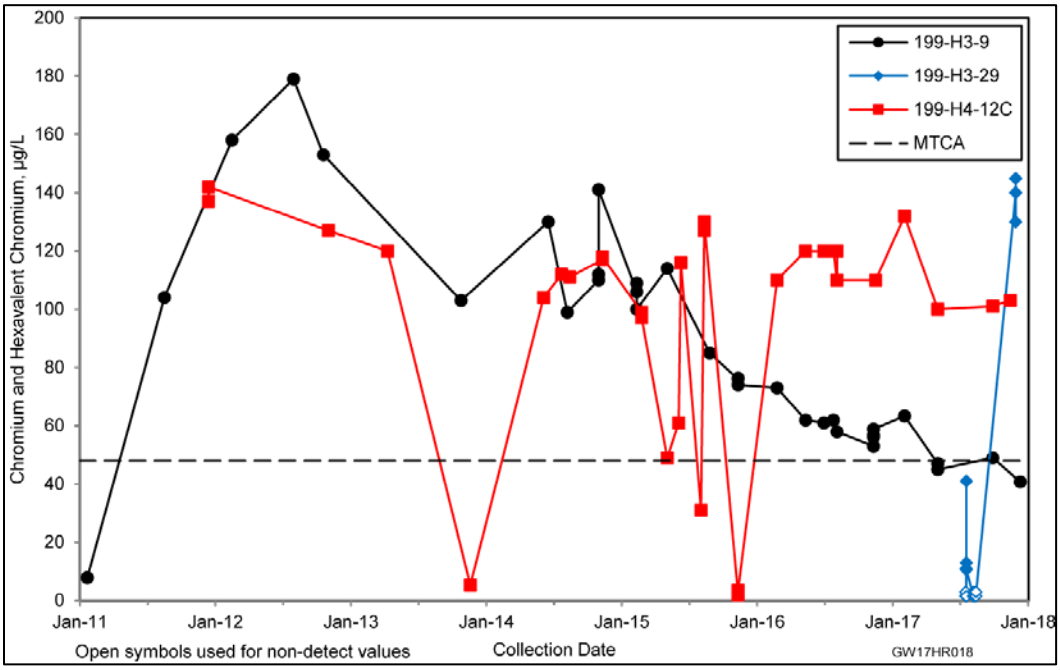

Figure 2-21. 100-HR Cr(VI) Data for RUM Wells 199-H3-9, 199-H3-29, and 199-H4-12C

New RUM well 199-H3-30 also exhibits high Cr(VI) levels, with a concentration of 8 µg/L in December 2017 (post-development). This well is located within the footprint of the former 107H retention basin (waste site 116-H-7). The presence of Cr(VI) at this location is consistent with the current CSM for the area. The well will not be connected to the HX P&T system due to low sustained flow rates (less than 11.4 L/min [3 gal/min]). New RUM well 199-H3-28 is planned for connection to the HX P&T system as an extraction well. Cr(VI) concentrations in this well were at 32 µg/L at post-well development.

To the north, well 199-H2-1 has been exhibiting an increasing trend, with concentrations at 20 µg/L in November 2017. It is unknown if this well is hydraulically connected to the high-concentration wells (199-H4-12C, 199-H3-9, and 199-H3-29) located near the 183-H Solar Evaporation Basins. South of the retention basin, concentrations at well 199-H4-91 have been stable, at about 30 to 40 µg/L. Slightly inland at well 199-H4-90, Cr(VI) levels are lower and typically range from 8 to 15 µg/L (Figure 2-22).

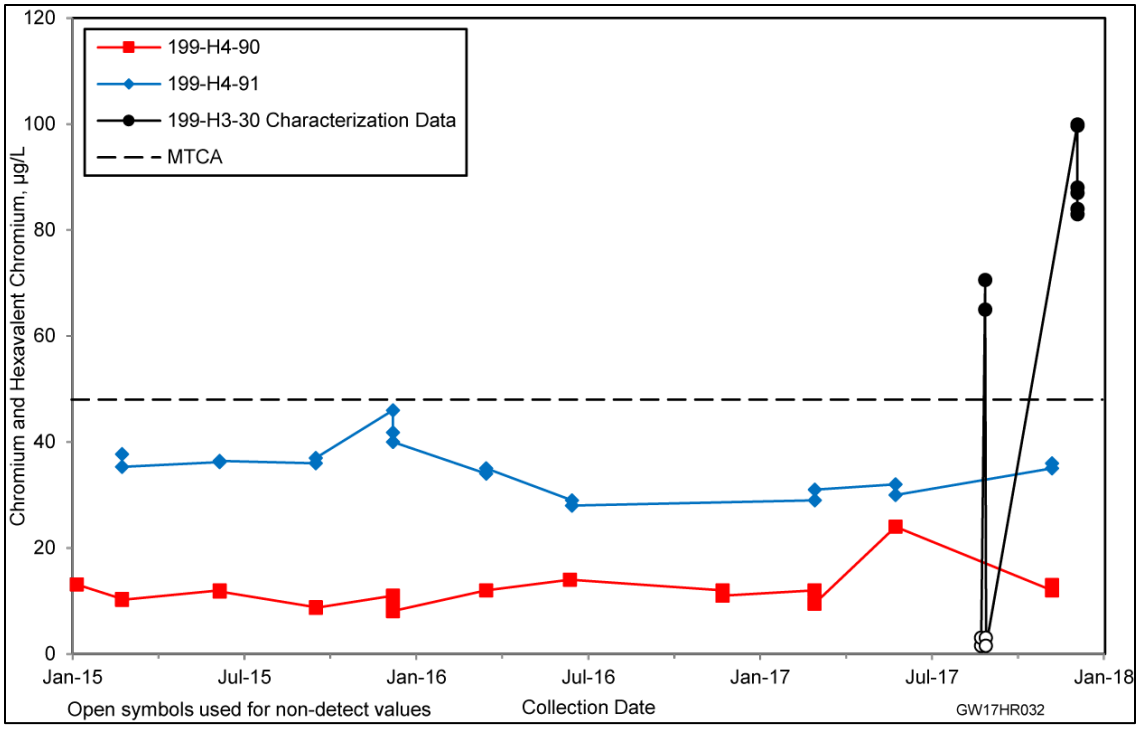

Figure 2-22. 100-HR Cr(VI) Data for RUM Wells 199-H3-30, 199-H4-90, and 199-H4-91

2.2.3.3 Sulfate

Sulfate concentrations tend to increase in wells located near P&T injection wells. Groundwater that has been treated at the DX P&T system is affected by the addition of sulfuric acid, which is used to lower the pH in the influent groundwater because the SIR-700 IX resin treatment technology 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 the pH to near neutral. Sulfate concentrations in the effluent during 2017 averaged 161 mg/L.

2.2.4 Hydraulic Monitoring

Hydraulic monitoring (i.e., water-level monitoring) is performed to evaluate the effect of 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 elevations are 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 (automated water-level network [AWLN]). The number and location of monitoring wells with AWLN data improve the certainty for the hydraulic monitoring system and, therefore, the ability to determine hydraulic capture. SGW-53543, *Automated Water Level Network Functional Requirements Document*, discusses system improvements and identifies AWLN configurations necessary to provide sufficient data to calculate gradients and to delineate capture zones in areas within the OU where a P&T system is implemented. A total of 69 AWLN stations are currently operating at in the 100-HR-3 OU, including both the 100-D and 100-H river gauges, which record water-level measurements on an hourly basis. The AWLN configuration is based on SGW-53543 to provide sufficient data to calculate gradients and to delineate capture zones from the DX and HX P&T systems. Additional localized, dynamic water-level

data are collected at each P&T extraction and injection well. Reported water-level data from AWLN wells and manual depth-to-water measurements are reviewed and reduced, and a final data set is compiled to assemble the groundwater elevation maps.

In the 100-HR-3 OU, natural groundwater gradient is toward the Columbia River, with seasonal hydraulic gradient reversal near the shoreline during high river-stage conditions. However, the hydraulic effects of the P&T systems (i.e., the formation of depressions at extraction wells and mounds at injection locations) are superimposed onto the seasonal fluctuations. In the 100-D Area, groundwater mounds are formed due to reinjecting treated groundwater from the P&T system at inland injection wells, causing outward flows from those locations, and increasing the magnitude of hydraulic gradients with direction toward downgradient extraction wells and the river. In the northern portion of the 100-D Area, the gradient changes to a northward direction, with groundwater flow inland being more eastward, moving across the Horn toward the 100-H Area. In the 100-H Area, the natural groundwater gradient is toward the east and the Columbia River. Extraction and injection well operations in that area cause similar hydraulic effects as in the 100-D Area, with groundwater flow from inland injection wells toward the downgradient extraction wells near the shoreline, where a broad depression zone of varying magnitude is developed over the course of the year (depending on the available saturated thickness in the aquifer). Figure 2-23 presents the March 2017 inferred groundwater elevation contour map, including inferred groundwater flow direction vectors.

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 on 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/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 move 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., at no time during the period was groundwater moving toward extraction wells). Intermediate frequencies indicate that the groundwater was contained under some conditions, but not all. However, CFMs are a measure of the relative strength of hydraulic containment over the year and do not directly translate to actual, transient capture that occurs over much longer timeframes. CFMs are meant to indicate areas where the effectiveness of the actual transient capture may require further attention over time.

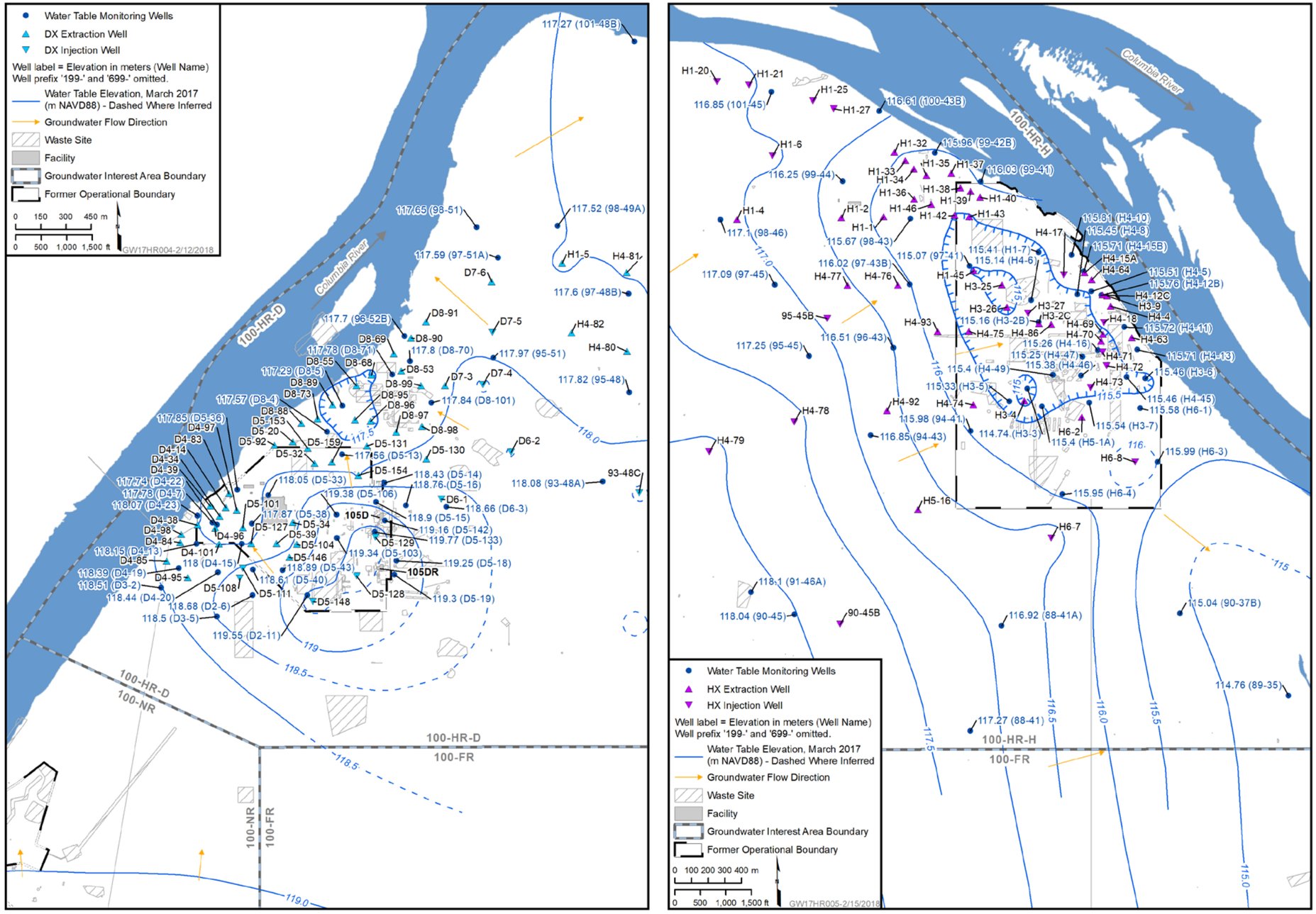

Figure 2-23. 100-HR-3 OU Water Table Elevation Map, March 2017

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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 average 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 collective 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 that it is either weak or it is not being achieved (where both maps suggest that containment is not achieved or, in most cases, where capture frequencies are very low). Where the ICFM and SCFM differ substantially, confidence is lower in the containment assessment because one method suggests that containment is being achieved whereas the other method suggests either that containment is not achieved or, as it should be interpreted, that it is weak.

The extent of chromium contamination in groundwater during high and low river-stage conditions is estimated using a systematic approach to develop contaminant plume maps using an integrated numerical interpolation methodology, as detailed in ECF-HANFORD-18-0013.

Figures 2-24 through 2-29 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 2-24 and Figure 2-25 depict chromium contamination under high river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-26 and Figure 2-27 depict chromium contamination under low river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-28 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 using flow rates for extraction and injection wells corresponding to the month with the maximum total flow per P&T system in 2017 and repeated annually. Figure 2-29 overlays the capture zone flow lines on the chromium plume contours under low river-stage conditions.

Figures 2-30 through 2-35 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 2-30 and Figure 2-31 depict chromium contamination under high river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-32 and Figure 2-33 depict chromium contamination under low river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 2-34 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 using flow rates for extraction and injection wells corresponding to the month with the maximum total flow per P&T system in 2017 and repeated annually. Figure 2-35 overlays the capture zone flow lines on the chromium plume contours under low river-stage conditions.

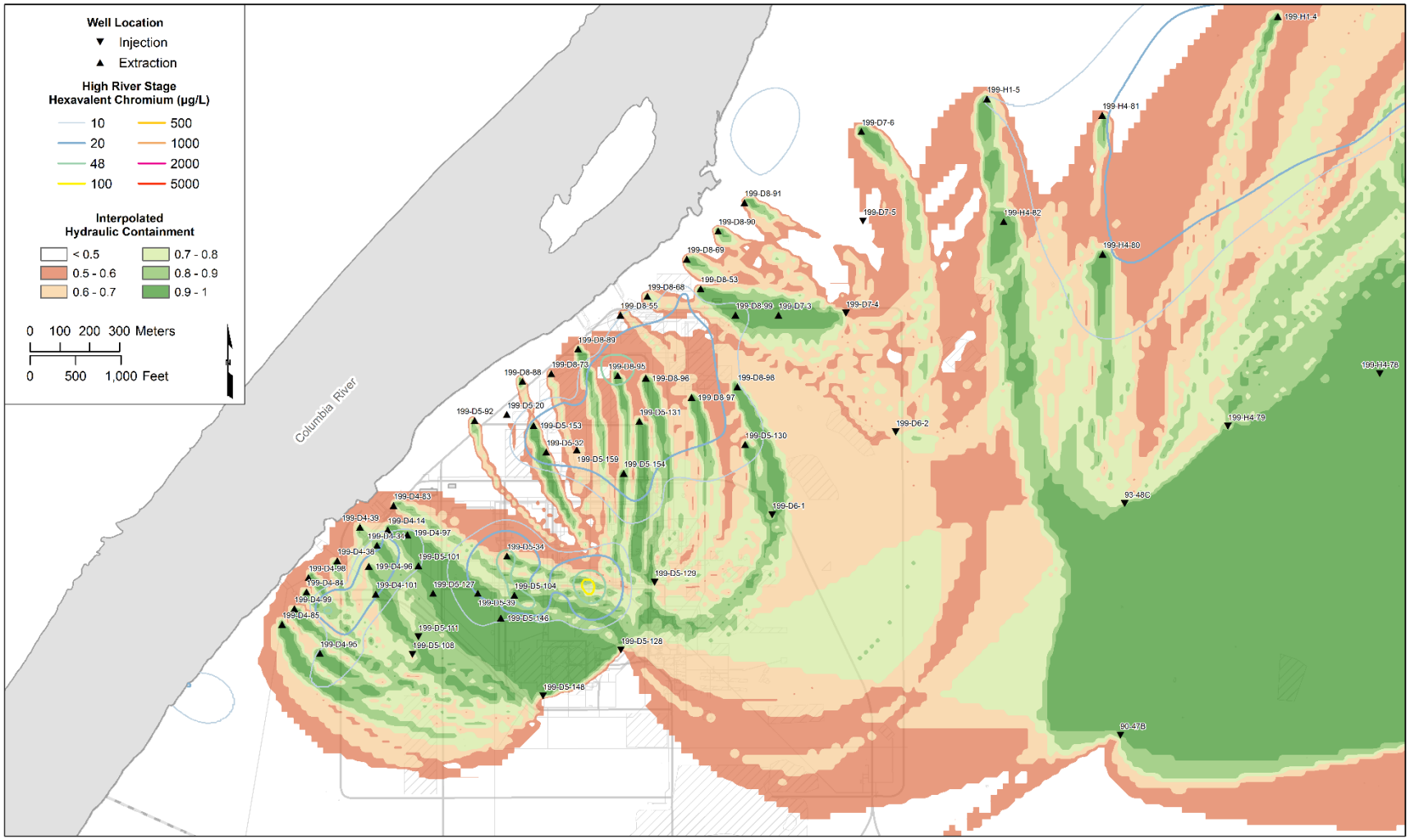

Figure 2-24. 100-D Area Interpolated CFM and High River-Stage Chromium Contamination

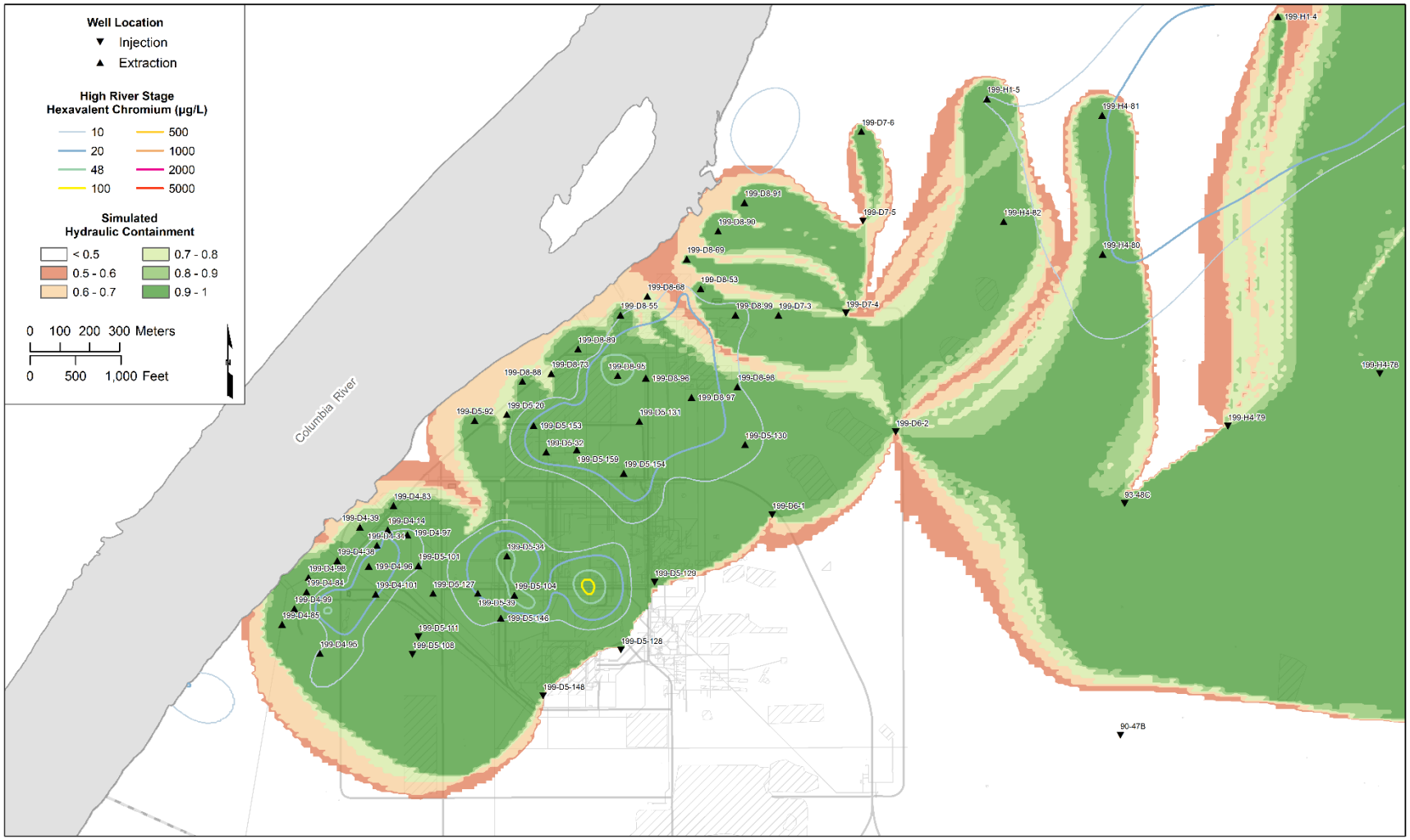

Figure 2-25. 100-D Area Simulated CFM and High River-Stage Chromium Contamination

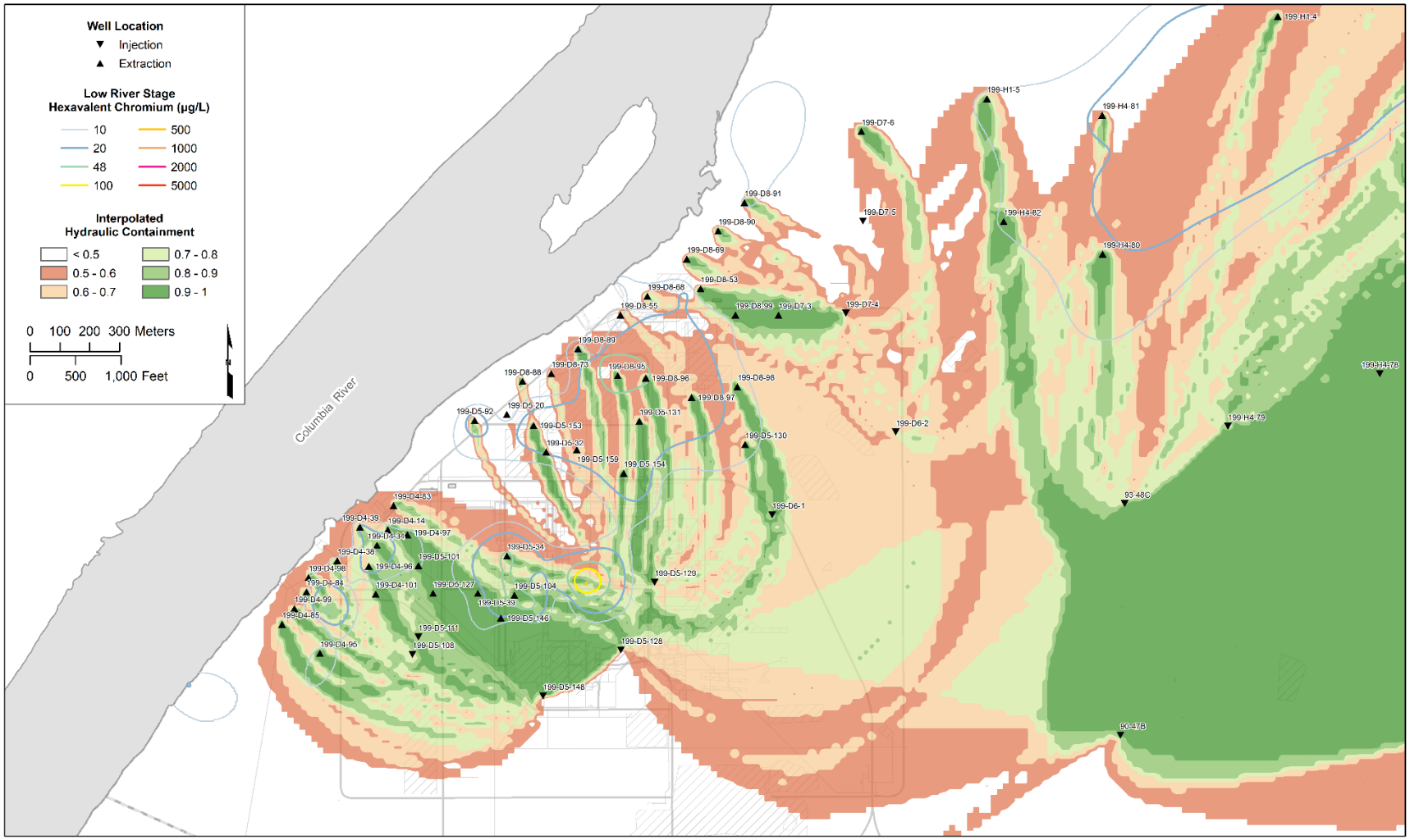

Figure 2-26. 100-D Area Interpolated CFM and Low River-Stage Chromium Contamination

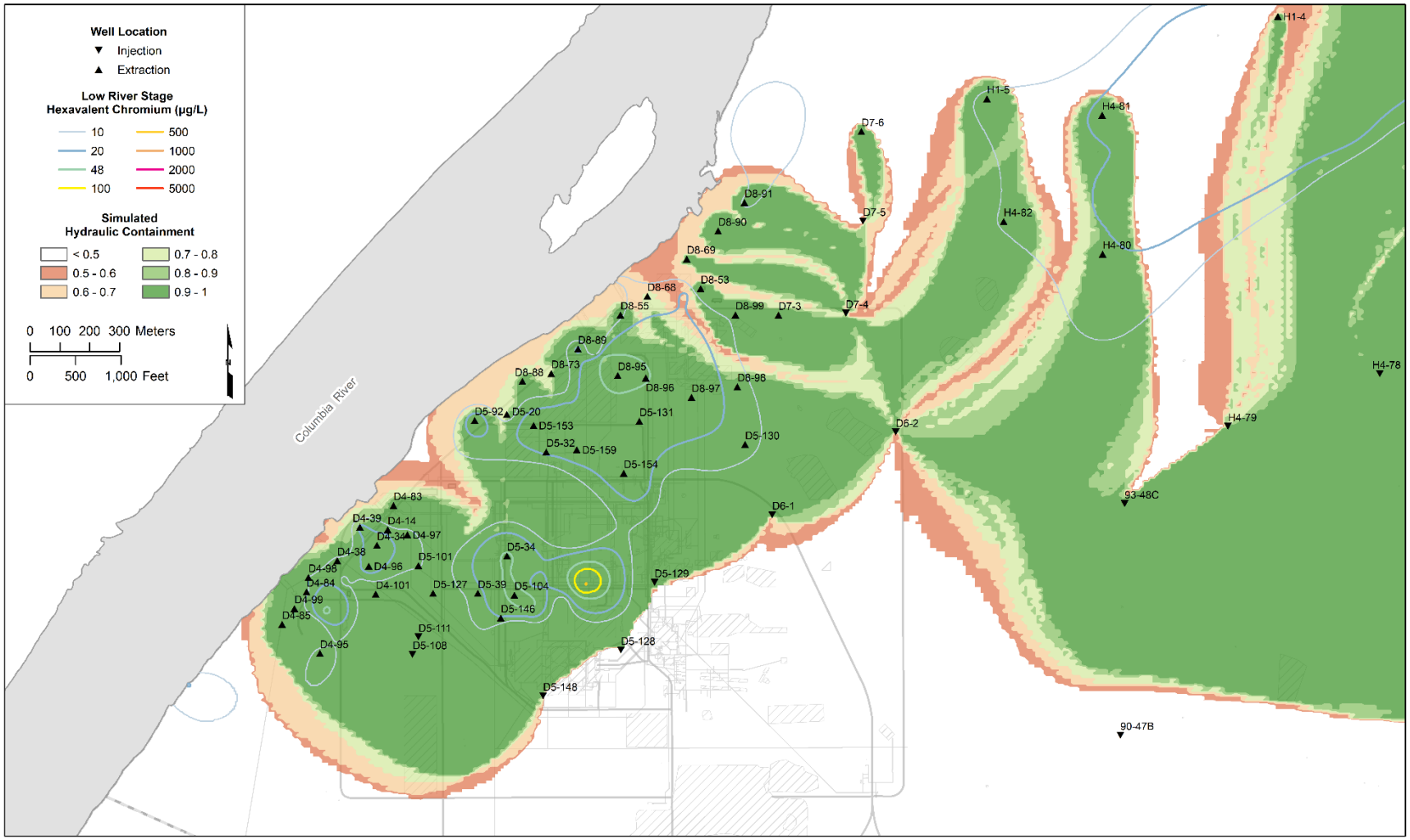

Figure 2-27. 100-D Area Simulated CFM and Low River-Stage Chromium Contamination

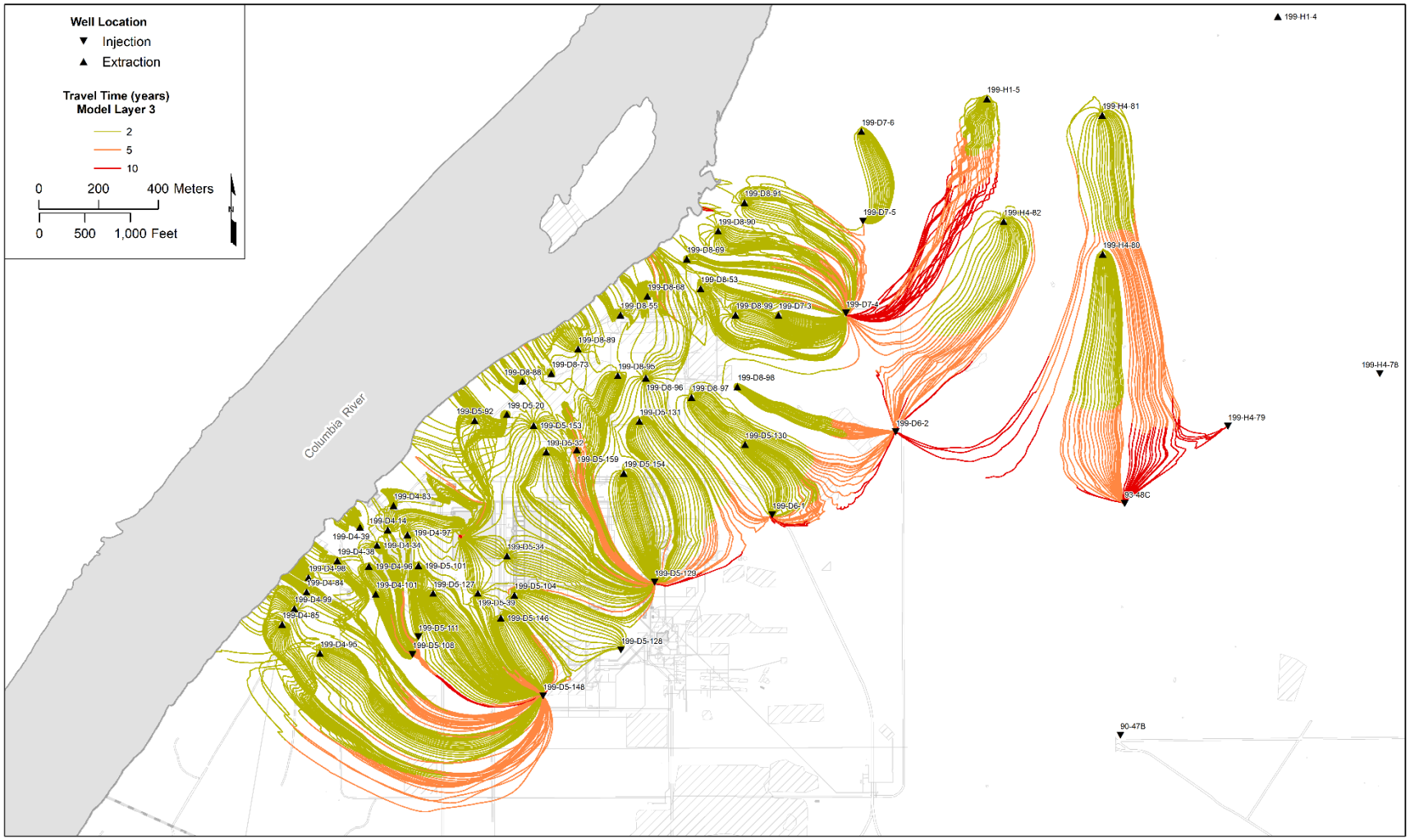

Figure 2-28. 100-D Area Groundwater Flow Lines of Capture Zone Flow Field, 2017

Figure 2-29. 100-D Area Groundwater Flow Lines of Capture Zone Overlay with Low River-Stage Chromium Plume Contours

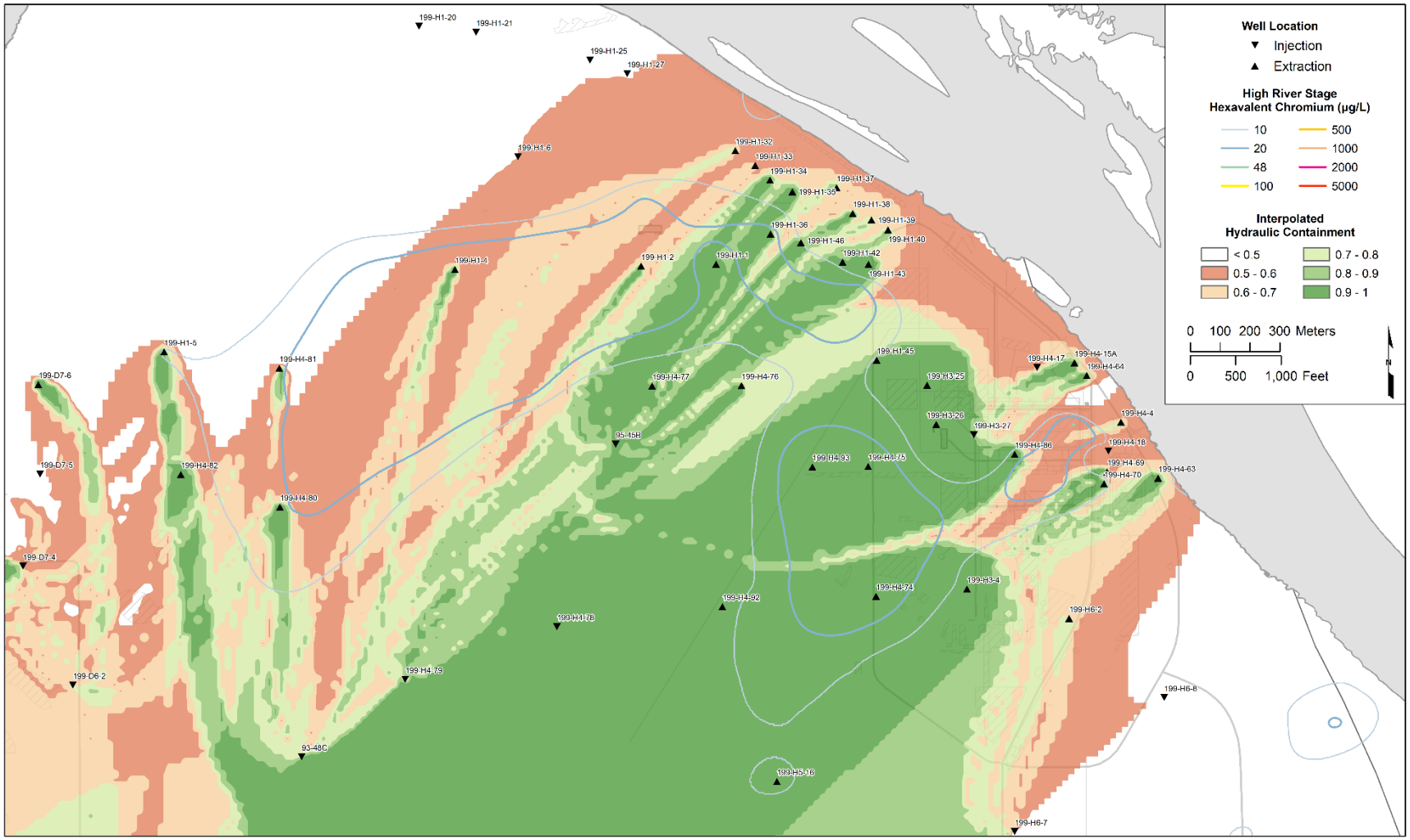

Figure 2-30. 100-H Area Interpolated CFM and High River-Stage Chromium Contamination

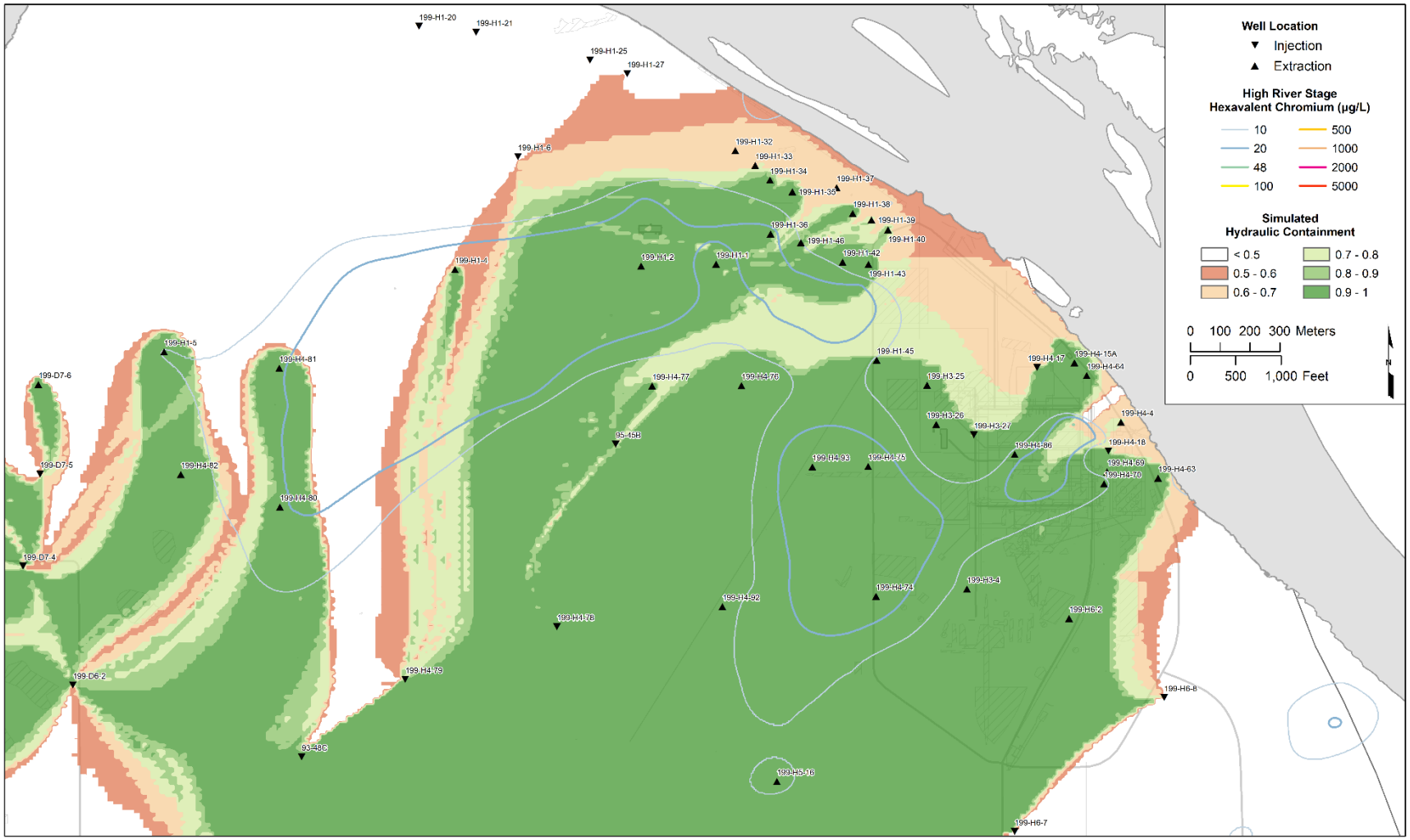

Figure 2-31. 100-H Area Simulated CFM and High River-Stage Chromium Contamination

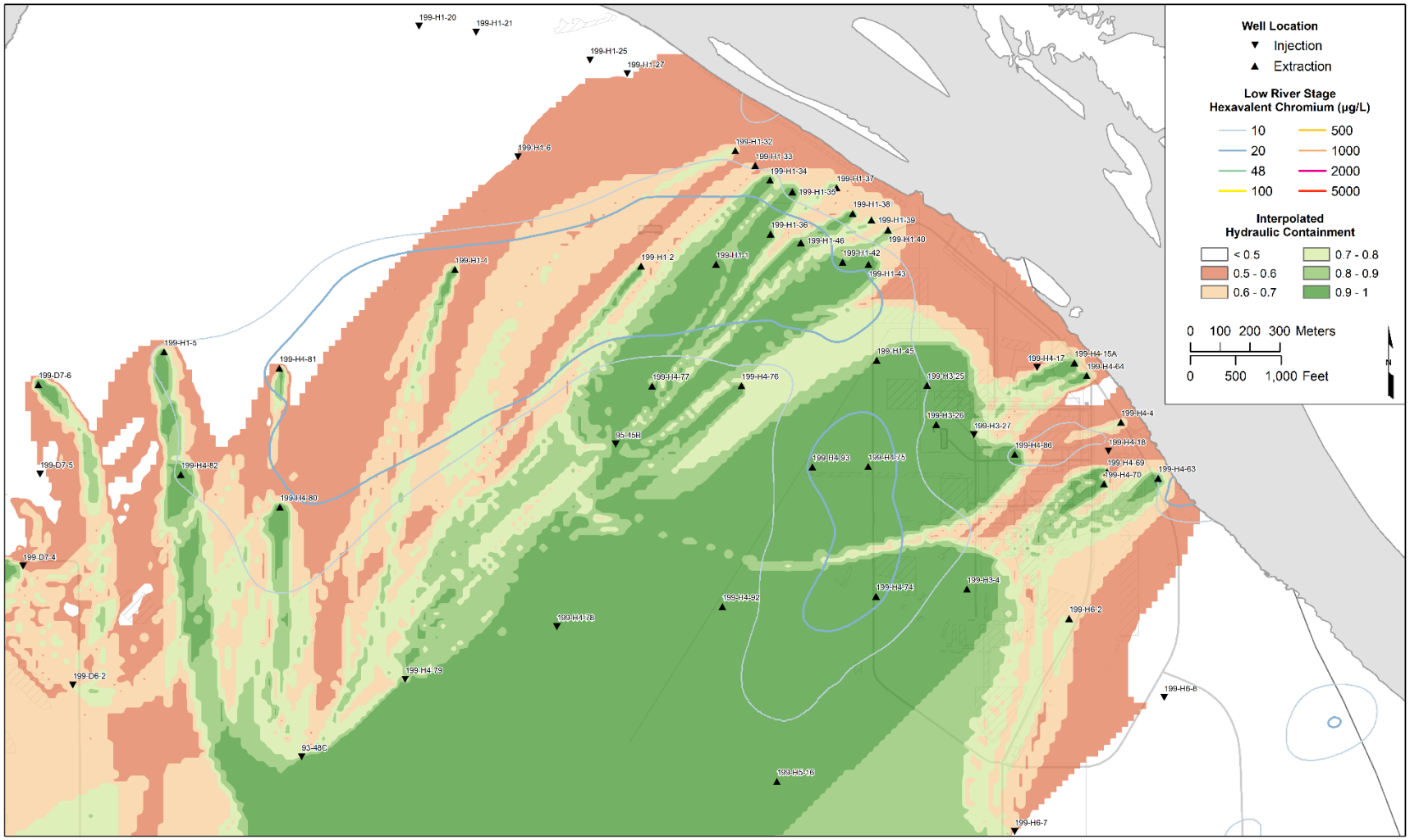

Figure 2-32. 100-H Area Interpolated CFM and Low River-Stage Chromium Contamination

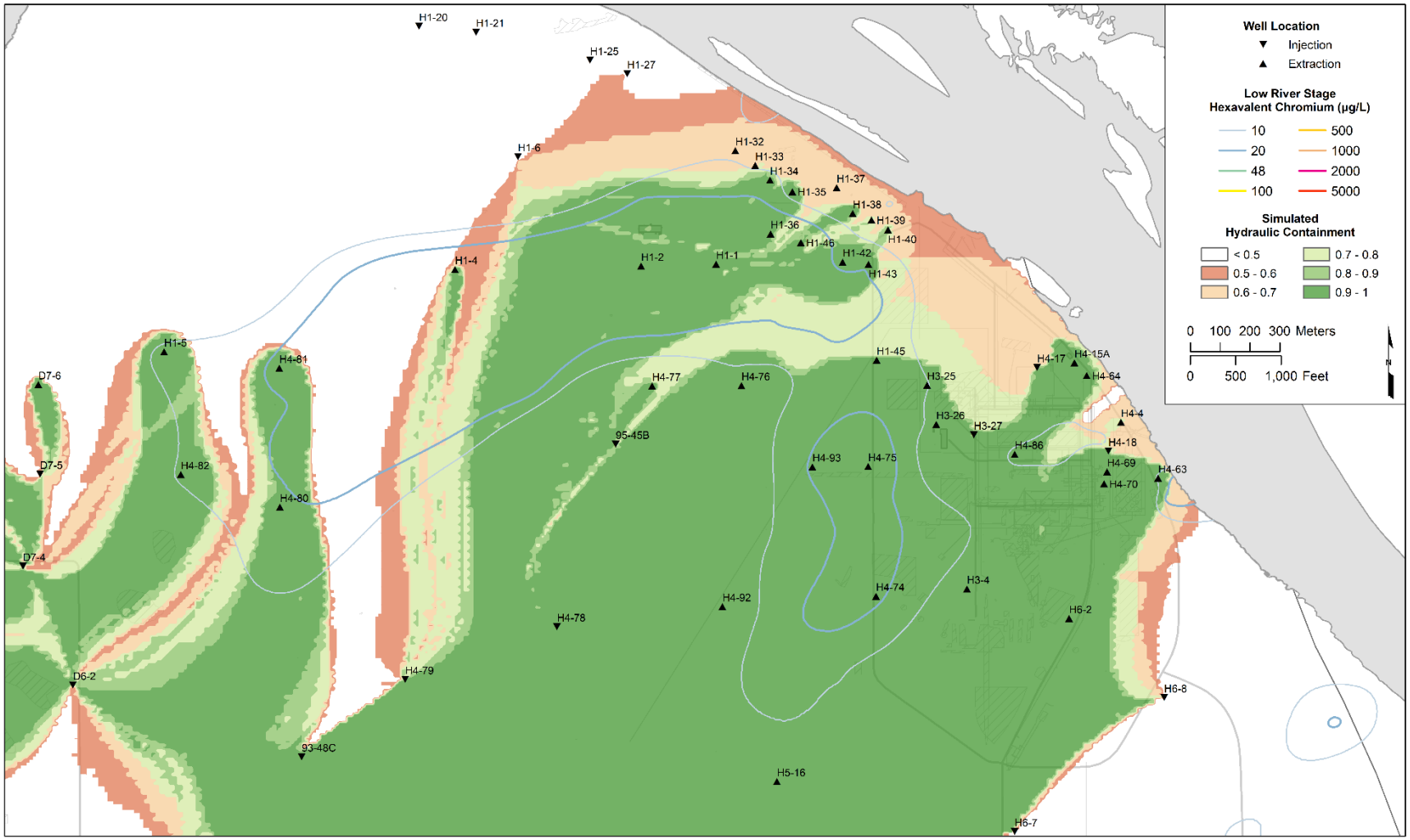

Figure 2-33. 100-H Area Simulated CFM and Low River-Stage Chromium Contamination

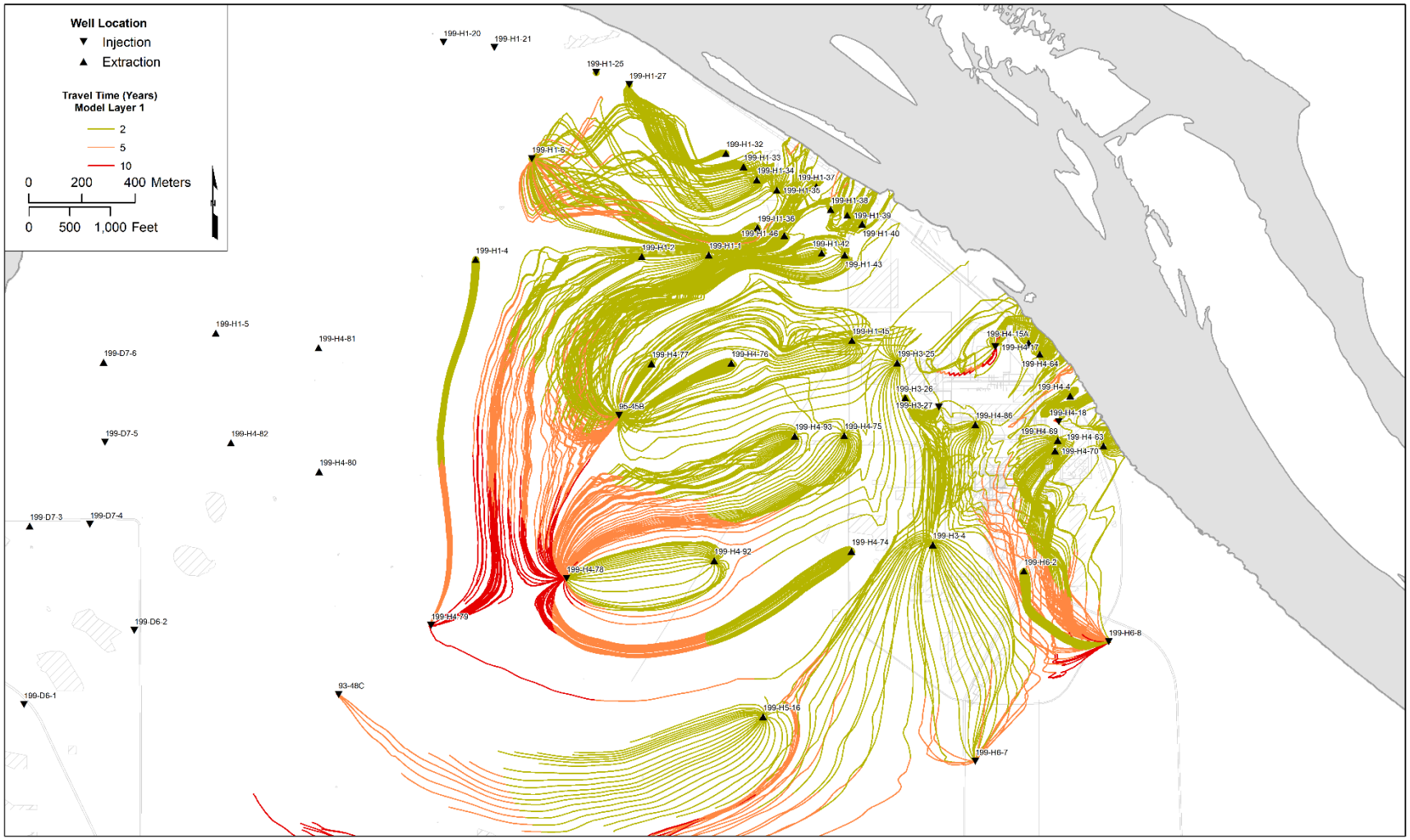

Figure 2-34. 100-H Area Groundwater Flow Lines of Capture Zone Flow Field, 2017

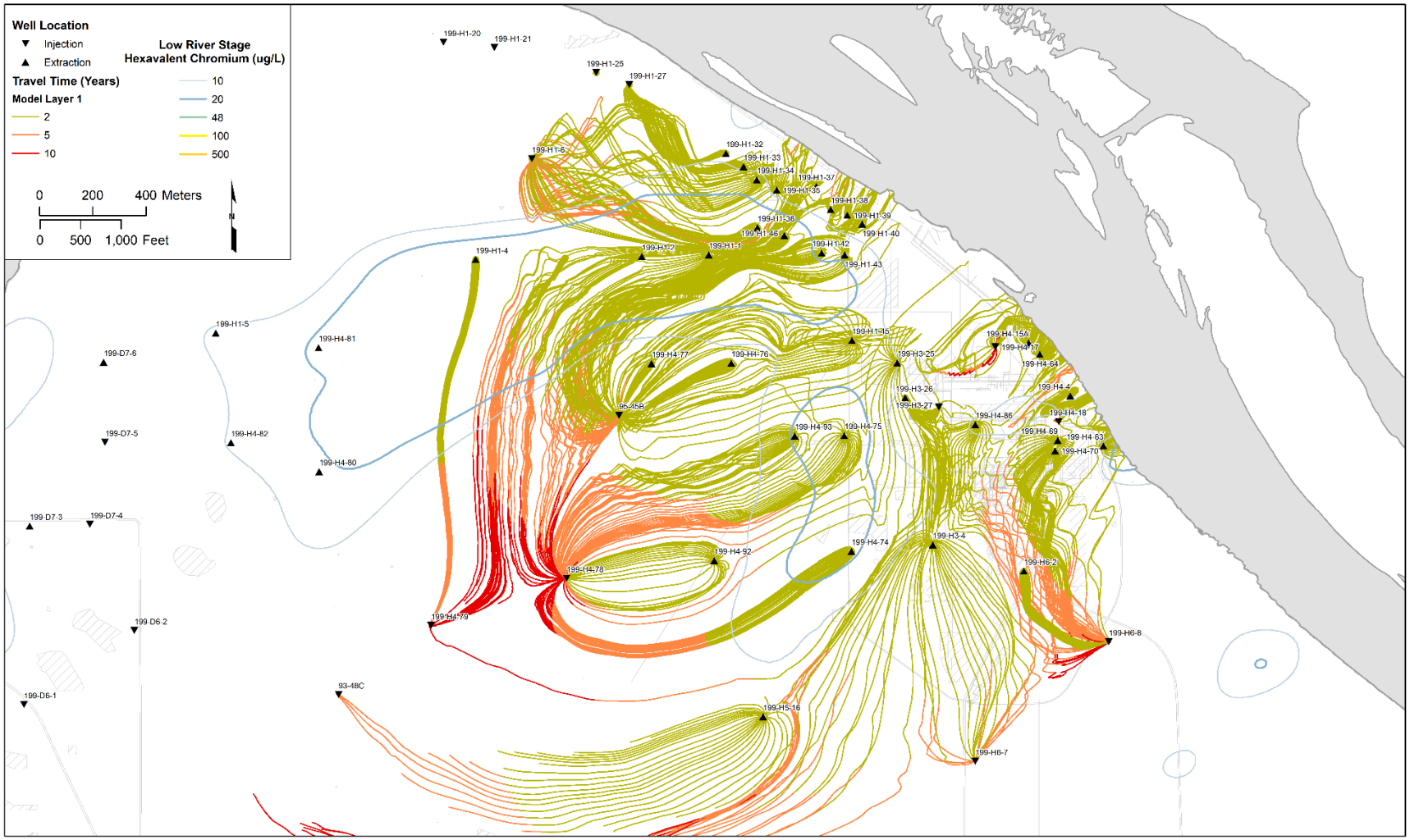

Figure 2-35. 100-H Area Groundwater Flow Lines of Capture Zone Overlay with Low River-Stage Chromium Plume Contours

The effect of river-stage fluctuations on groundwater flow, combined with the aquifer response to pumping, indicate that hydraulic containment was not as strong in 2017 as in previous years. Steep hydraulic gradients and resulting groundwater velocities caused by the sharp decline of the river-stage during the second half of the year resulted in weaker hydraulic containment in 2017, as reflected in the CFMs. The SCFM in 2017 indicates stronger hydraulic containment than reflected in the ICFM. This is because model-simulated aquifer response to high river-stage conditions underestimates water levels in the aquifer, resulting in stronger hydraulic containment.

The capture flow lines in some areas may undergo a more indirect path to an extraction well, as observed particularly in Figures 2-34 and 2-35, which reflects the effects of river-stage fluctuations and aquifer hydraulic conditions on a particle flow path. When comparing those tortuous flow paths to CFMs, it is shown that even in areas of relatively low capture frequency, flow lines calculated under transient conditions will, in most cases, result in migration pathways that ultimately lead to capture at an extraction well. In such cases, low capture frequency is not evidence of failure to protect the river from contaminant discharges; instead, it suggests that hydraulic containment is relatively weak, and that capture may take longer to occur.

ECF-HANFORD-18-0014, *Description of Groundwater Calculations and Assessments for the Calendar Year 2017 (CY2017) 100 Areas Pump-and-Treat Report*, presents details on the specific calculations used to produce these figures depicting capture, 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. Although advanced interpolation techniques are used to develop water-level maps, confidence in these maps is heavily dependent on the density of the monitoring well network and the quality of available data. During 2017, the extent and quality of available AWLN data continued improving in comparison to previous years due to station technology improvements and additional AWLN stations. 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 assessing the hydraulic effects of remedial action system operations, as well as evaluating 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 in 2017 was similar to the assessment for 2016.

This section describes the river protection evaluation process and presents the results of the 2017 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 greater than 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.

An assessment of the progress toward attaining the river protection objective for 2017 is presented in Figures 2-36 through 2-39. SGW-54209 details the technical methods and process that are used to complete the calculations necessary to prepare these figures. ECF-HANFORD-18-0014 presents details for the specific calculations used to produce these figures for 2017. Figures 2-36 through 2-39 present the results of contaminant standard and trend tests described in SGW-54209 to identify low-, moderate-, and high-concern wells, using the symbols identified in Table 2-10.

Shoreline lengths are calculated and reported in increments of 100 m (330 ft); the results of the assessment are presented in these figures as color-filled circles of diameter equal to 100 m (330 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. Table 2-11 presents the symbols depicting the results of the river protection evaluation.

Figures 2-36 and 2-37 depict the assessment of progress toward attaining the river protection objective for chromium in the 100-D Area. Figure 2-36 shows the results of the quantitative evaluation of the objective, which is determined based on overlay and quantitative comparison of the extent of chromium contamination with the extent of hydraulic containment. Figure 2-37 depicts the results of the qualitative evaluation of the objective, which is based on 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). Compared to the depictions presented for 2016, additional shoreline length evaluations are presented in 2017 for the 100-D Area because the presence of chromium was delineated at concentrations above 10 μg/L (defined by sampling data at wells 199-D8-91, 199-D8-93, and 199-D8-94). The additional shoreline length considered in the 2017 evaluations is 500 m (1,640 ft).

In 2017, the quantitative evaluation for the 100-D Area reflects the weaker hydraulic containment, as illustrated in the CFMs. As conservative, tight criteria for capture frequency are applied in determining river protection status, large stretches of the shoreline appear to be protected but possibly require additional action in the future. However, with the exception of the presence of chromium at the 116-DR-5 outfall at concentrations greater than 10 μg/L, hydraulic containment is not compromised in 2017. This is evident when considering the atypical river-stage fluctuation in 2017, the location and operation of the P&T wells, the decreasing concentration trends at the monitoring locations, and the receding interpolated plume extents. For the additional shoreline length considered north of the 100-D Area, the presence of the chromium plume at concentrations greater than 10 μg/L requires attention, as it is believed that some migration in that area is caused by the atypical hydraulic gradients due to the river-stage profile in 2017; however, these conditions are not expected to prevail in the future. Qualitative evaluation of the river protection status reflects these considerations. Conditions will continue to be monitored in 2018, and actions will be taken if there are indications the river protection objective may not be attained.

In the 100-H Area in 2017, the quantitative river protection evaluation is similar to 2016, reflecting similar tight criteria and a conservative approach to assessing hydraulic containment. Qualitative evaluation of the river protection status reflects the same considerations implemented in the 100-D Area, resulting in a qualitative assessment consistent with the conclusions presented in 2016 (DOE/RL-2016-68).

Table 2-10. Standard and Trend Test Symbology for Wells

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

Table 2-11. Symbology for Status of River Protection Objective

Symbol	Explanation
●	Protected
●	Protected (action may be required)
●	Not Protected

Based on these qualitative calculations, the river protection evaluation for the 100-D Area is as follows, considering the same shoreline length as 2016 (all lengths are rounded to the nearest 5 m [5 ft]):

- Total length of shoreline adjacent to the 100-D Area: 2,800 m (9,185 ft)
- Length identified as protected: 2,400 m (7,870 ft)
- Length identified as protected (action may be required): 200 m (655 ft)
- Length identified as not protected: 200 m (655 ft)

When considering the new shoreline evaluation length, the river protection evaluation for the 100-D Area based on qualitative evaluations is as follows (all lengths are rounded to the nearest 5 m [5 ft]):

- Total length of shoreline adjacent to the 100-D Area: 3,300 m (10,825 ft)
- Length identified as protected: 2,400 m (7,870 ft)
- Length identified as protected (action may be required): 700 m (2,300 ft)
- Length identified as not protected: 200 m (655 ft)

Figures 2-38 and 2-39 depict the assessment of progress toward attaining the river protection objective for chromium in the 100-HR-3 OU/100-H Area. Figure 2-38 depicts the results of the quantitative evaluation of the objective, which are determined based on an overlay and quantitative comparison of the extent of chromium contamination with the extent of hydraulic containment. Figure 2-39 shows the results of the qualitative evaluation of the objective. Based on these qualitative 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: 3,600 m (11,810 ft)
- Length identified as protected (action may be required): 400 m (1,310 ft)
- Length identified as not protected: 400 m (1,310 ft)

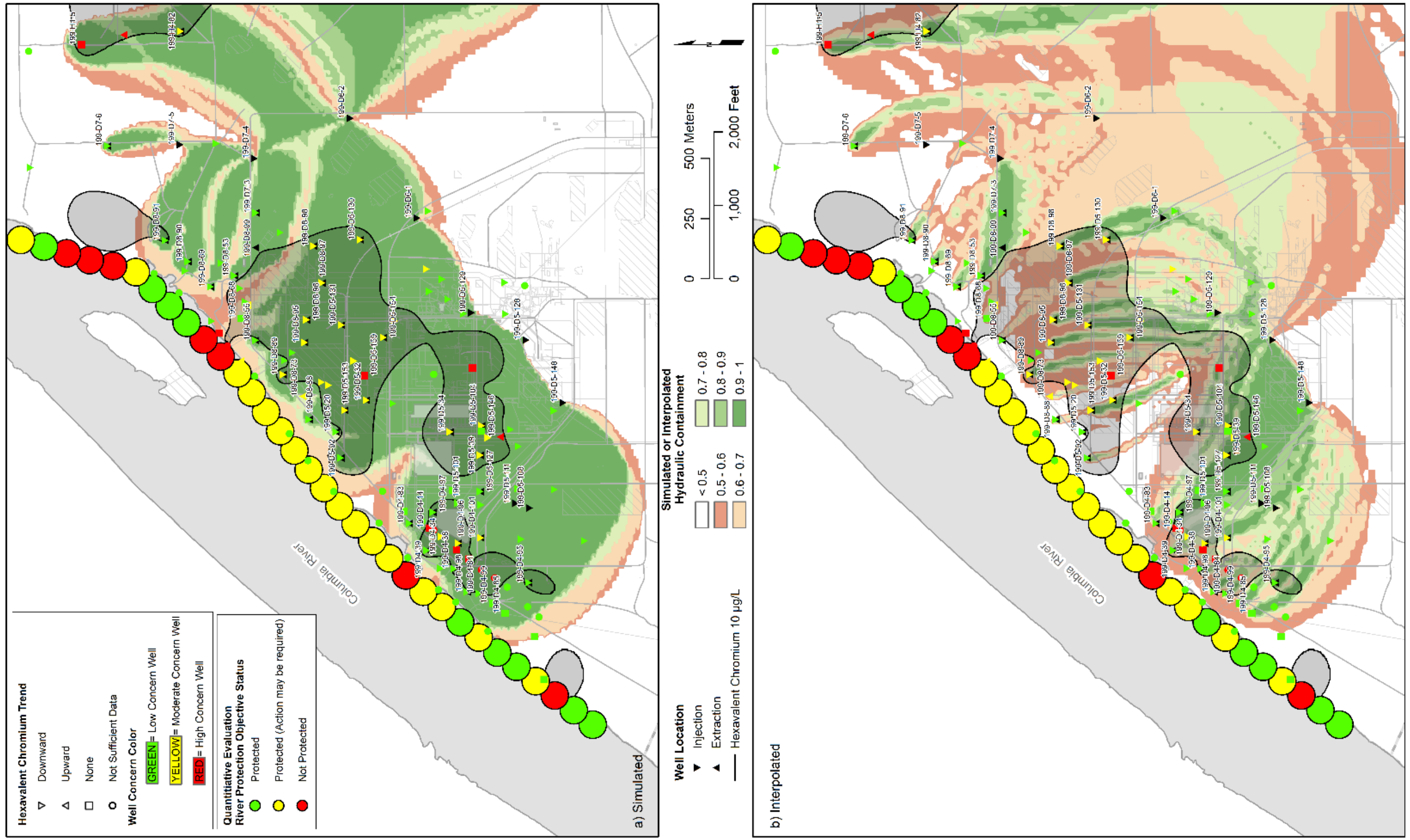

Figure 2-36. 100-D Area Quantitative Assessment of Shoreline Protection for 2017 with (a) Simulated and (b) Interpolated CFM, Together with Mapped Extent of Low River-Stage Chromium Contamination Above 10 µg/L and Results of Standard Test and Trend Test

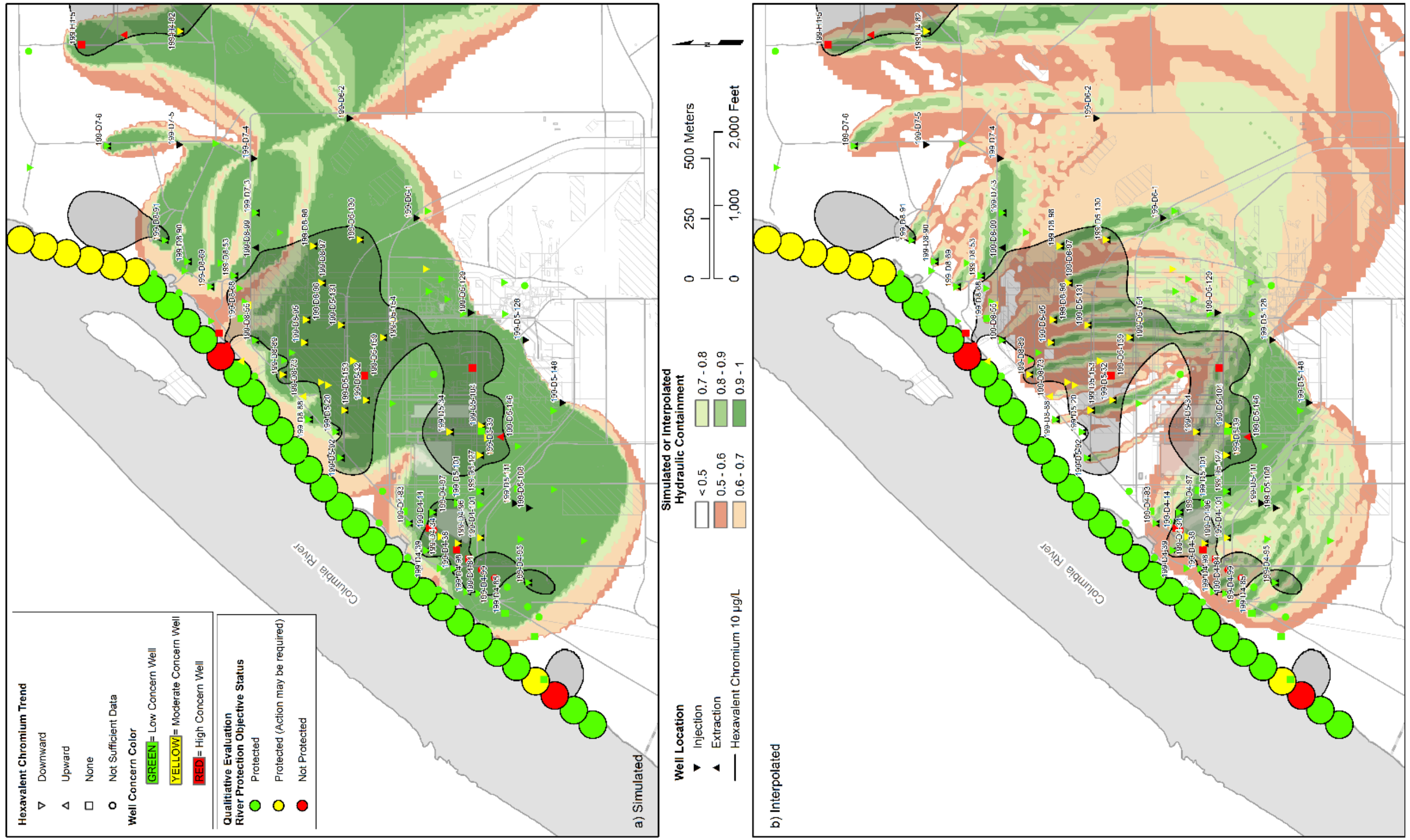

Figure 2-37. 100-D Area Qualitative Assessment of Shoreline Protection for 2017 with (a) Simulated and (b) Interpolated CFM, Together with Mapped Extent of Low River-Stage Chromium Contamination **Above 10 µg/L** and Results of Standard Test and Trend Test

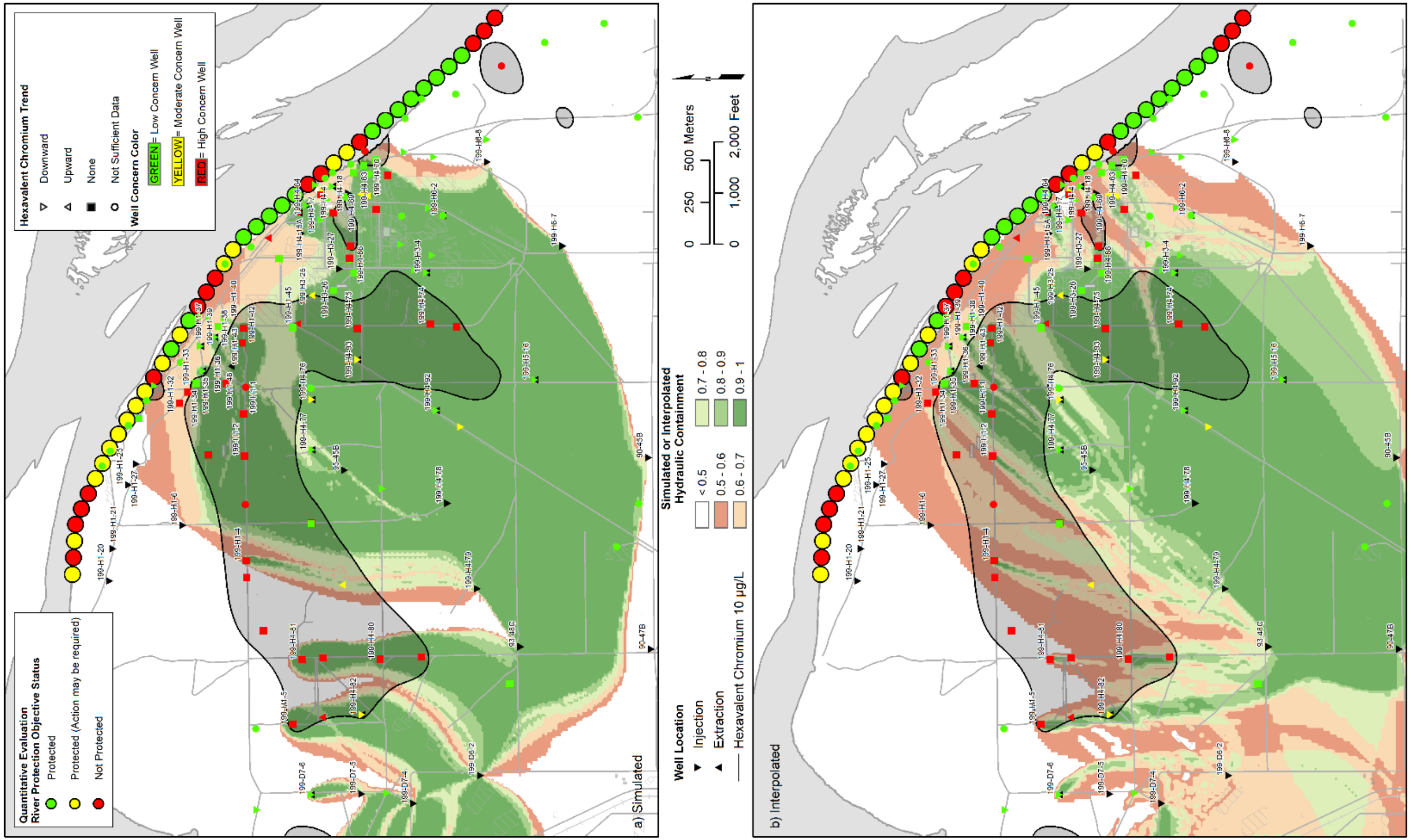

Figure 2-38. 100-H Area Quantitative Assessment of Shoreline Protection for 2017 (a) Simulated and (b) Interpolated CFM, Together with Mapped Extent of Low River-Stage Chromium Contamination A**bove 10 µg/L** and Results of Standard Test and Trend Test

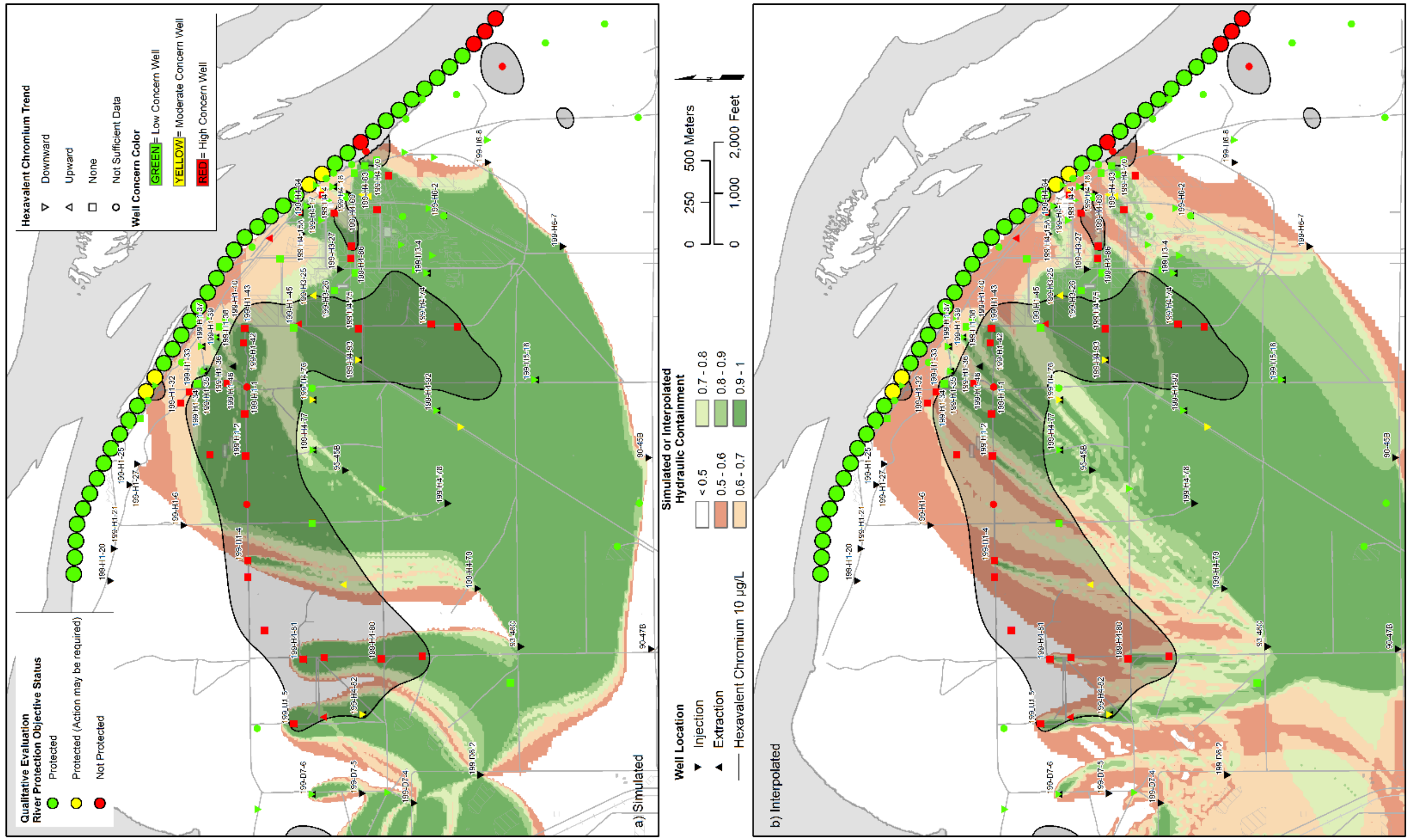

Figure 2-39. 100-H Area Qualitative Assessment of Shoreline Protection for 2017 with (a) Simulated and (b) Interpolated CFM, Together with Mapped Extent of Low River-Stage Chromium Contamination A**bove 10 µg/L** and Results of Standard Test and Trend Test

Table 2-12 compares the results of the qualitative evaluations for the 100-D Area and 100-H Area for 2017 and 2016 based on the comparable shoreline lengths for those 2 years, which also includes notations regarding the additional shoreline length considered in 2017.

Table 2-12. Comparison of River Protection Assessment Results

Assessed Shoreline Lengths 100-HR-3/100-D	**2016**	**2017**	**Change from 2016 to 2017***
Total length of shoreline adjacent to the 100-D Area	2,800 m (9,185 ft) *or 3,300 m (10,825 ft), including the additional shoreline length*		
Length identified as "protected" Percent of shoreline "protected"	2,200 m (7,215 ft) 79% of shoreline	2,400 m (7,870 ft) 86% of shoreline	100 m (330 ft) of shoreline identified as "protected" now identified as "not protected" 400 m (1,315 ft) of shoreline identified as "protected (action may be required)" now identified as "protected" 100 m (330 ft) of shoreline identified as "protected" now identified as "protected (action may be required)"
Length identified as "protected (action may be required)" Percent of shoreline "protected (action may be required)"	400 m (1,315 ft) 14% of shoreline	200 m (655 ft) 7% of shoreline *Additional 500 m (1,640 ft) in 2017* *15% of extended shoreline*	100 m (330 ft) of shoreline identified as "protected" now identified as "protected (action may be required)" 400 m (1,315 ft) of shoreline identified as "protected (action may be required)" now identified as "protected" 100 m (330 ft) of shoreline previously identified as "not protected" now identified as "protected (action may be required)" *500 m (1,640 ft) of shoreline identified as "protected (action may be required)"*
Length identified as "not protected" Percent of shoreline "not protected"	200 m (655 ft) 7% of shoreline	200 m (655 ft) 7% of shoreline	100 m (330 ft) of shoreline previously identified as "not protected" now identified as "protected (action may be required)" 100 m (330 ft) of shoreline previously identified as "protected" now identified as "not protected"
Total length of shoreline adjacent to the 100-H Area	4,400 m (14,430 ft)		
Length identified as "protected" Percent of shoreline "protected"	3,700 m (12,135 ft) 84% of shoreline	3,600 m (11,810 ft) 82% of shoreline	100 m (330 ft) of shoreline previously identified as "protected (action may be required)" now identified as "protected" 300 m (985 ft) of shoreline previously identified as "protected" now identified as "protected (action may be required)" 100 m (330 ft) of shoreline previously identified as "not protected" now identified as "protected"
Length identified as "protected (action may be required)" Percent of shoreline "protected (action may be required)"	300 m (985 ft) 7% of shoreline	400 m (1,310 ft) 9% of shoreline	100 m (330 ft) of shoreline previously identified as "protected (action may be required)" now identified as "protected" 300 m (985 ft) of shoreline previously identified as "protected" now identified as "protected (action may be required)" 100 m (330 ft) of shoreline previously identified as "protected (action may be required)" now identified as "not protected"

Table 2-12. Comparison of River Protection Assessment Results

Assessed Shoreline Lengths 100-HR-3/100-D	2016	2017	Change from 2016 to 2017*
Length identified as "not protected" Percent of shoreline "not protected"	400 m (1,310 ft) 9% of shoreline	400 m (1,310 ft) 9% of shoreline	100 m (330 ft) of shoreline previously identified as "not protected" now identified as "protected" 100 m (330 ft) of shoreline previously identified as "protected (action may be required)" now identified as "not protected"

*Details on year-to-year changes are provided in ECF-HANFORD-18-0014, *Description of Groundwater Calculations and Assessments for the Calendar Year 2017 (CY2017) 100 Areas Pump-and-Treat Report*.

Quantitative evaluations of the river protection objective provide a conservative assessment of shoreline protection. The qualitative evaluations 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 fluctuations. As a result, CFMs only indicate the relative strength of hydraulic containment and are 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.

2.2.7 Comparison of Simulated to Measured Contaminant Mass Recovery

Comparison of the ICFM and SCFM provides comparative depiction of the hydraulic simulation capabilities of the 100 Area groundwater model flow component. 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 2-40 presents a comparison of the monthly and cumulative mass of chromium recovered at the DX and HX P&T systems during 2017, as determined using actual influent concentrations and flow rates versus the mass recovery simulated using the 100 Area groundwater model. For the DX and HX P&T systems, mass recovery is presented showing the results with 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 2-40, about one-third of the 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 2016, reflecting data collected from August 15, 2016, through December 31, 2016, as presented in ECF-HANFORD-16-0138, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2016 (CY2016) Hanford Site Groundwater Monitoring Report*.

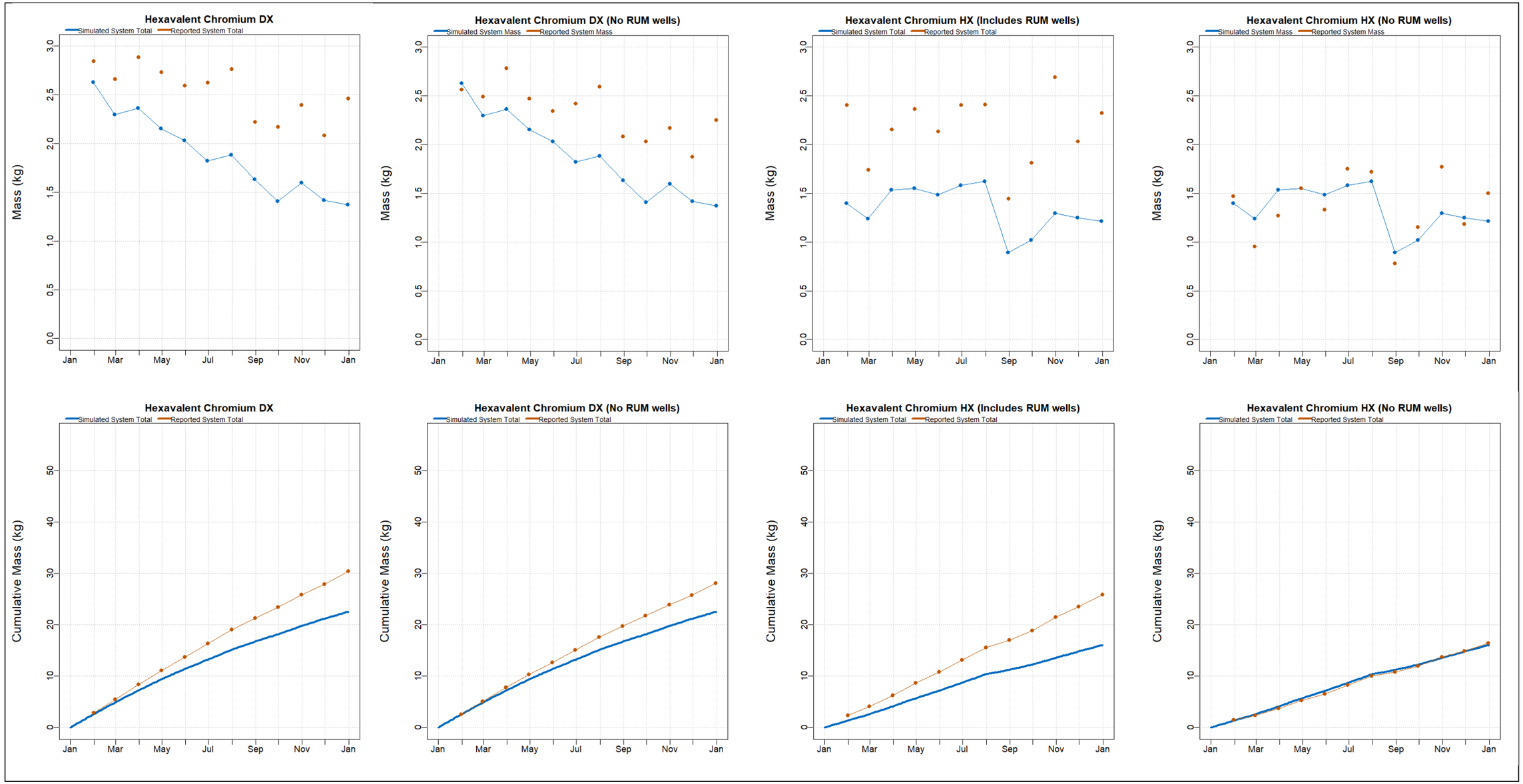

Figure 2-40. Comparison of Observed to Calculated Cr(VI) Mass Removal for 2017 (Top Row = Monthly Mass Removal; Bottom Row = Cumulative Mass Removal)

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ECF-HANFORD-18-0014 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 2-40. 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 continuing sources are not present.

At the DX P&T system, chromium mass immediately downgradient of the 100-D-100 waste site is again under-represented in the initial conditions of the numerical model. Mass recovery at wells 199-D5-104 and 199-D5-34 suggests that higher chromium concentrations are present in the aquifer near those wells compared to the initial plume for the simulation. The investigation at the 100-D-100 waste site (SGW-58416, *Persistent Source Investigation at 100-D Area*) indicated that chromate-substituted calcite remaining in the PRZ soil and aquifer sediment provides a source of ongoing release of Cr(VI) into groundwater. Similar to observations made in 2016, since the simulated mass recovery reflects only the dissolved chromium distribution (as delineated for low river-stage conditions in 2016) and does not include any contribution from continuing sources, the mass recovery does not correlate well in locations near/downgradient of a source.

Unlike conditions observed in 2016, the 2017 recovery data from extraction wells near the northwestern end of the ISRM barrier (e.g., 199-D4-96 and 199-D4-97) are in excellent agreement with simulated concentrations, indicating improved delineation of the chromium plume in that area.

Comparing the simulated and measured mass recovery for wells located near the high-concentration zone in the north 100-D Area indicates that higher concentrations are still present near the downgradient wells (e.g., 199-D8-95 and 199-D8-89) rather than near the inland wells (e.g., 199-D5-131). In 2017, the interpolated chromium distribution in that area was again developed based on data from extraction wells and some monitoring wells that essentially define the perimeter of that high-concentration zone, with some uncertainty associated with the distribution and magnitude of the highest concentrations within that zone. In addition, the potential presence of continuing sources in that area could also result in mass recovery differences between the simulated and measured values.

The HX P&T system removed 25.9 kg of Cr(VI) during 2017 (Figure 2-40). Approximately 9.4 kg of the mass recovered by the HX P&T system was extracted from wells completed within the RUM (i.e., 199-H3-2C, 199-H4-12C, 199-H3-9, 199-H3-10, and 199-H4-90), which are not included in the 100 Area groundwater model. The remaining mass of approximately 16.4 kg originated from the unconfined aquifer, which is simulated by the 100 Area groundwater model. In comparing the observed mass removed from the unconfined aquifer to the mass recovery simulated by the 100 Area groundwater model (16.1 kg), measured and simulated mass are in excellent agreement (Figure 2-40). ECF-HANFORD-18-0014 presents a detailed comparison between simulated and measured concentrations at the extraction wells for the HX P&T system. In general, the comparison between simulated and measured concentrations indicates patterns similar to those observed for 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, are below 48 μg/L. The excellent agreement between measured and simulated concentrations and mass recovery, as well as the low concentrations measured at the monitoring and extraction wells, suggests that the HX P&T chromium plume is contained and shrinking over time. The extent of the plume and the limited saturated thickness may impair the ability of the extraction wells to remove large masses of chromium during portions of the year, but system operation is considered effective and aquifer restoration has progressed as projected in recent years.

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. Simulated mass recovery estimates, however, present a useful tool for estimating system performance over time and developing estimates of time to complete remediation. However, these estimates 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 located approximately 100 to 200 m (330 to 660 ft) inland. 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 less than 20 µg/L at the compliance wells located between the treatment zone and the Columbia River. Figure 2-41 shows the Cr(VI) concentrations along the barrier for 2017.

As discussed in Section 2.1.2, a notice of nonsignificance shifted the groundwater remedy at the ISRM barrier to the P&T system (11-AMCP-0002). Groundwater at the ISRM site continues to be monitored for Cr(VI) as part of CERCLA interim action. ISRM monitoring is discussed in this report in order to provide a consolidated discussion of all interim remedies being used in the River Corridor. Dissolved oxygen is monitored since the treatment process reduces oxygen content in the aquifer, and groundwater with depleted oxygen levels could harm aquatic receptors. Other groundwater constituents and properties are monitored to provide a better understanding of the chemical characteristics of the plume.

2.2.8.1 Hexavalent Chromium

The ISRM barrier initially included seven compliance wells. Of these wells, monitoring wells 199-D4-86 and 199-D4-23 are the only remaining wells that have not been converted to extraction wells. Figure 2-42 shows the 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 in all but one of the seven ISRM compliance wells during 2017 (well 199-D4-39 had a Cr(VI) concentration of 30 µg/L one sample collected in November).

The highest concentrations in the ISRM barrier were at well 199-D4-60 (68 µg/L), well 199-D4-96 (50 µg/L in March), and the wells surrounding those two areas. Overall, the Cr(VI) concentration in groundwater flowing through the ISRM barrier continued to decrease in 2017. The declining or stabilizing of the overall concentrations in the barrier vicinity are attributed to the effects of the P&T system. DOE/RL-2013-31 provides further discussion on the remedial action monitoring.

Figures 2-43 through 2-46 show the Cr(VI) concentrations in the ISRM barrier for the four quarters of 2017. Consistent with previous years, the Cr(VI) concentrations were the lowest in the late spring and early 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 2-46). The northeastern portion of the barrier continues to have a large number of wells with concentrations greater than 20 µg/L.

The Cr(VI) concentrations in barrier wells in 2017 ranged from below detection limits to a maximum of 68 µg/L at well 199-D4-60. Only a few wells within the barrier itself were monitored; however, sampling results from wells around the ISRM barrier resulted in a smaller overall plume. Concentrations in individual wells where Cr(VI) remained in 2017 had similar concentrations to those observed in 2016, with a seasonal variation in concentrations as water levels fluctuated. The overall declining Cr(VI) concentrations are attributed to the ongoing P&T system operations and the upgradient removal of source material. The effect of the barrier is considered minimal when compared to the ongoing P&T system effectiveness.

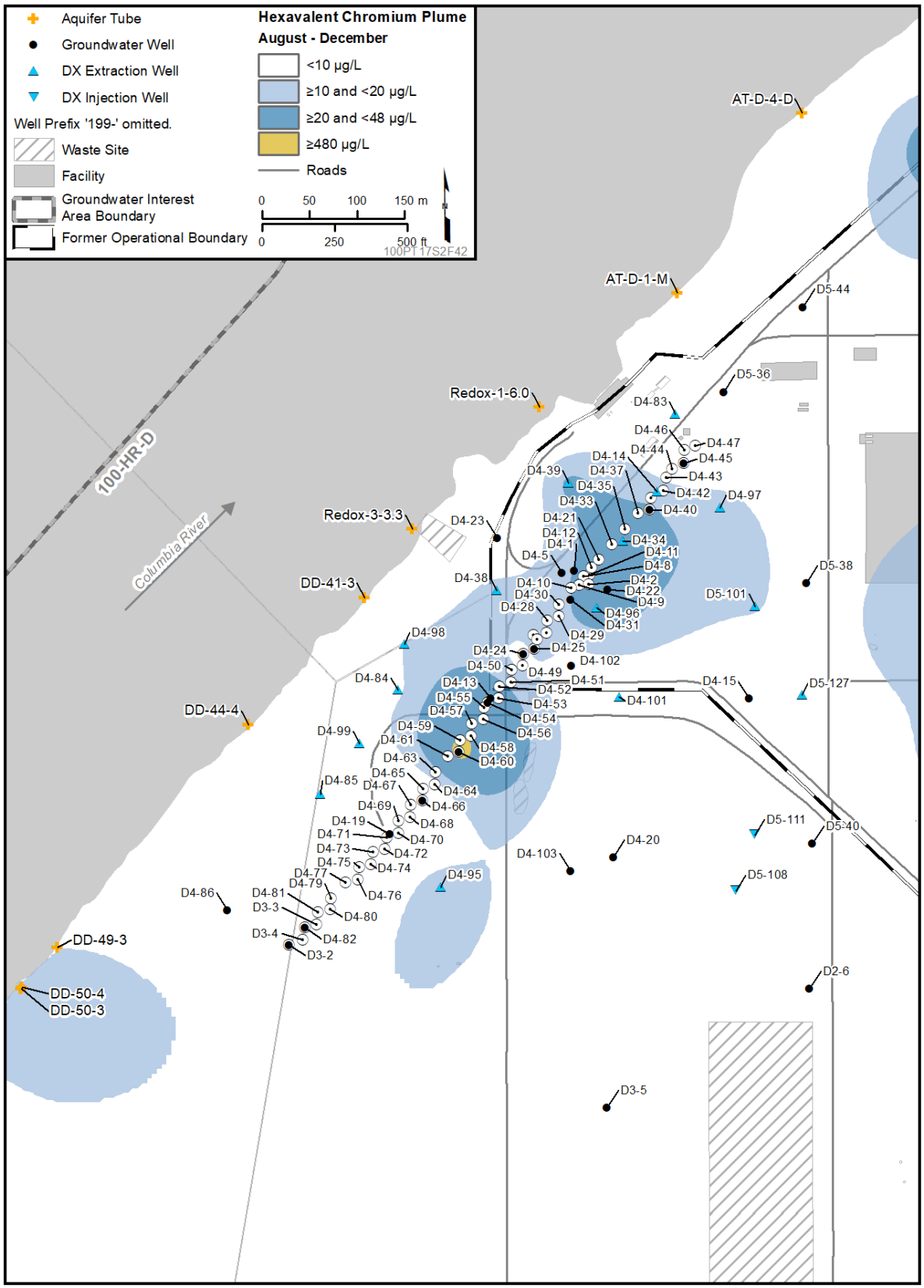


Figure 2-41. ISRM Cr(VI) Map, 2017

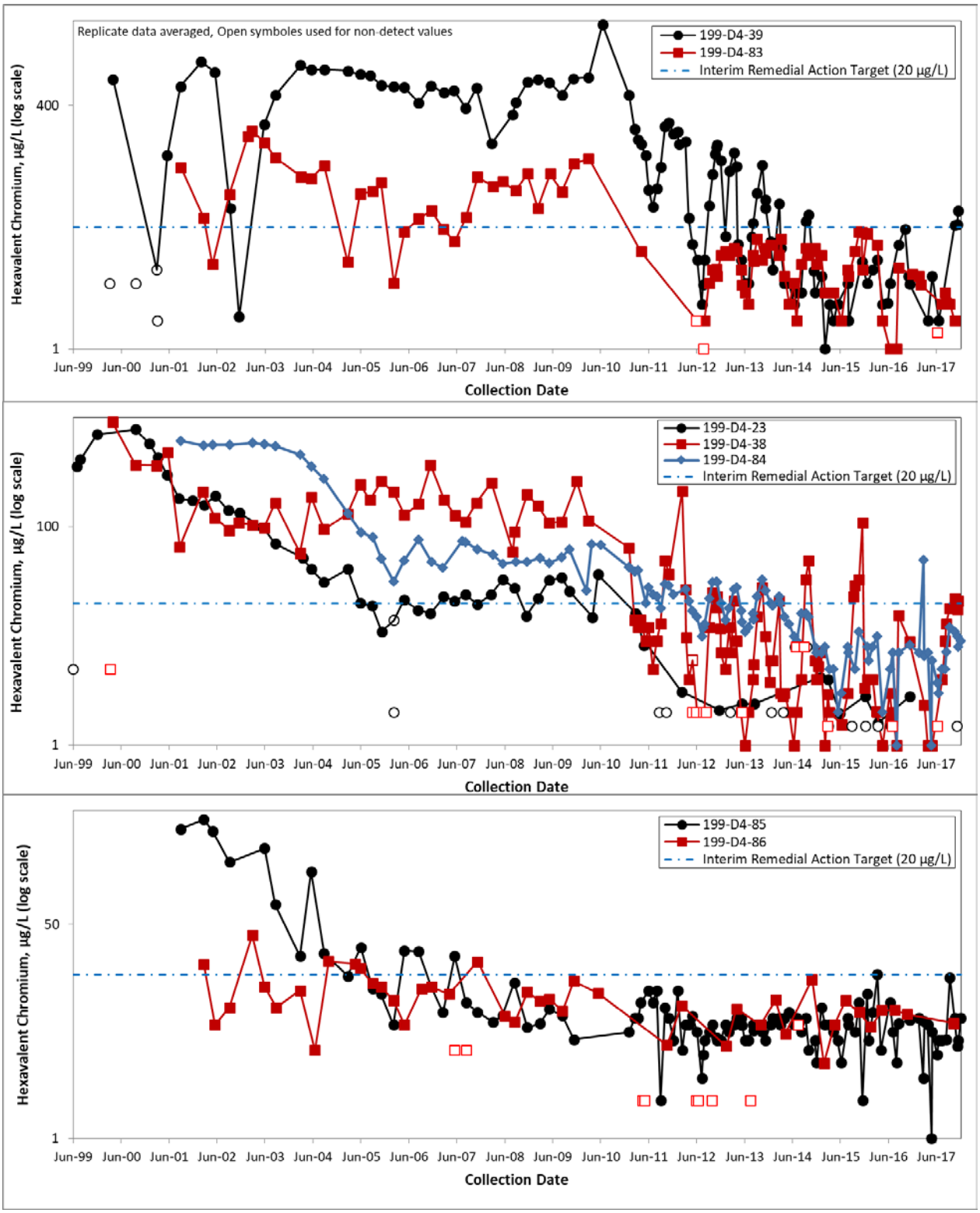


Figure 2-42. ISRM Cr(VI) Trend Plots for Compliance Wells

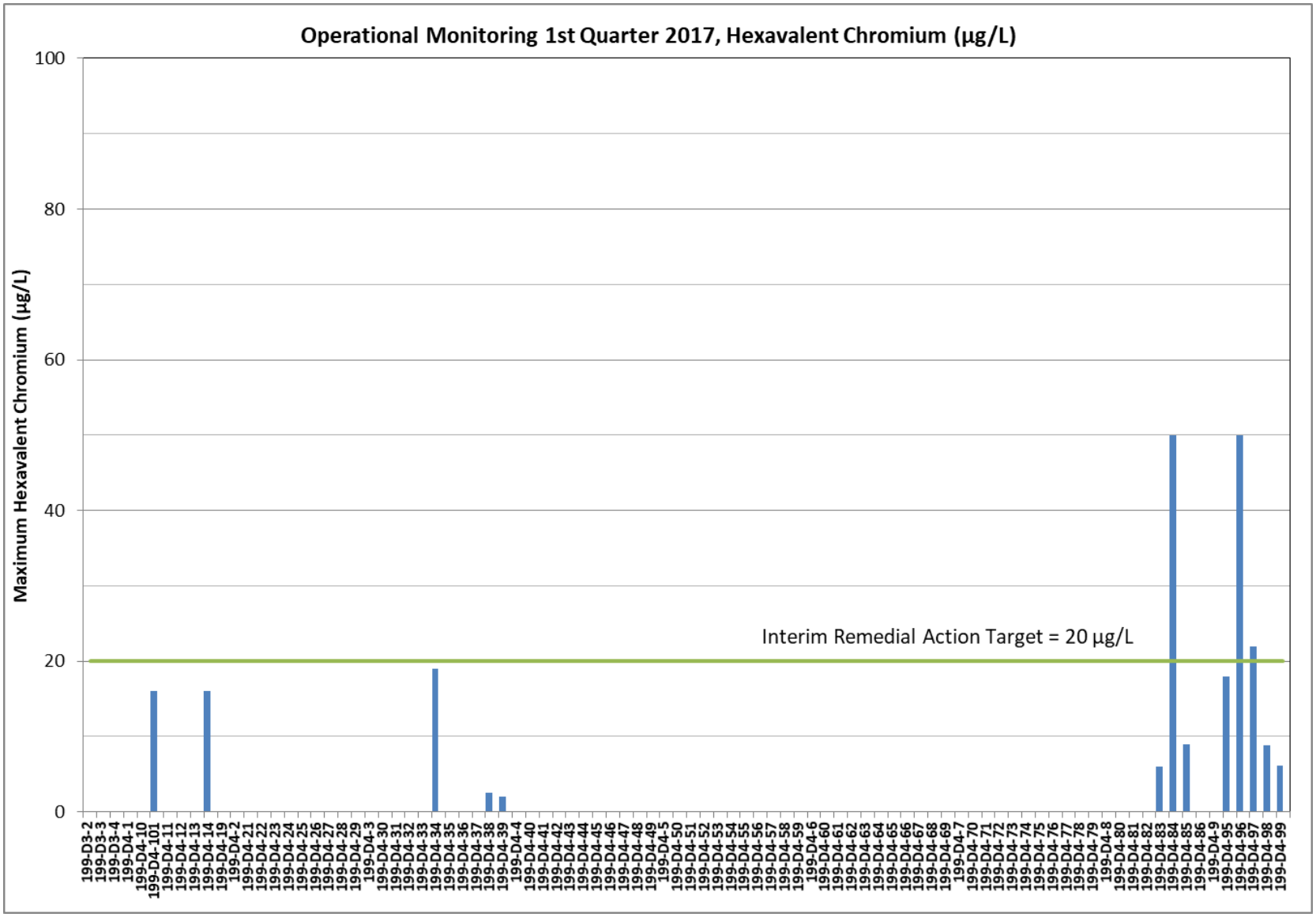
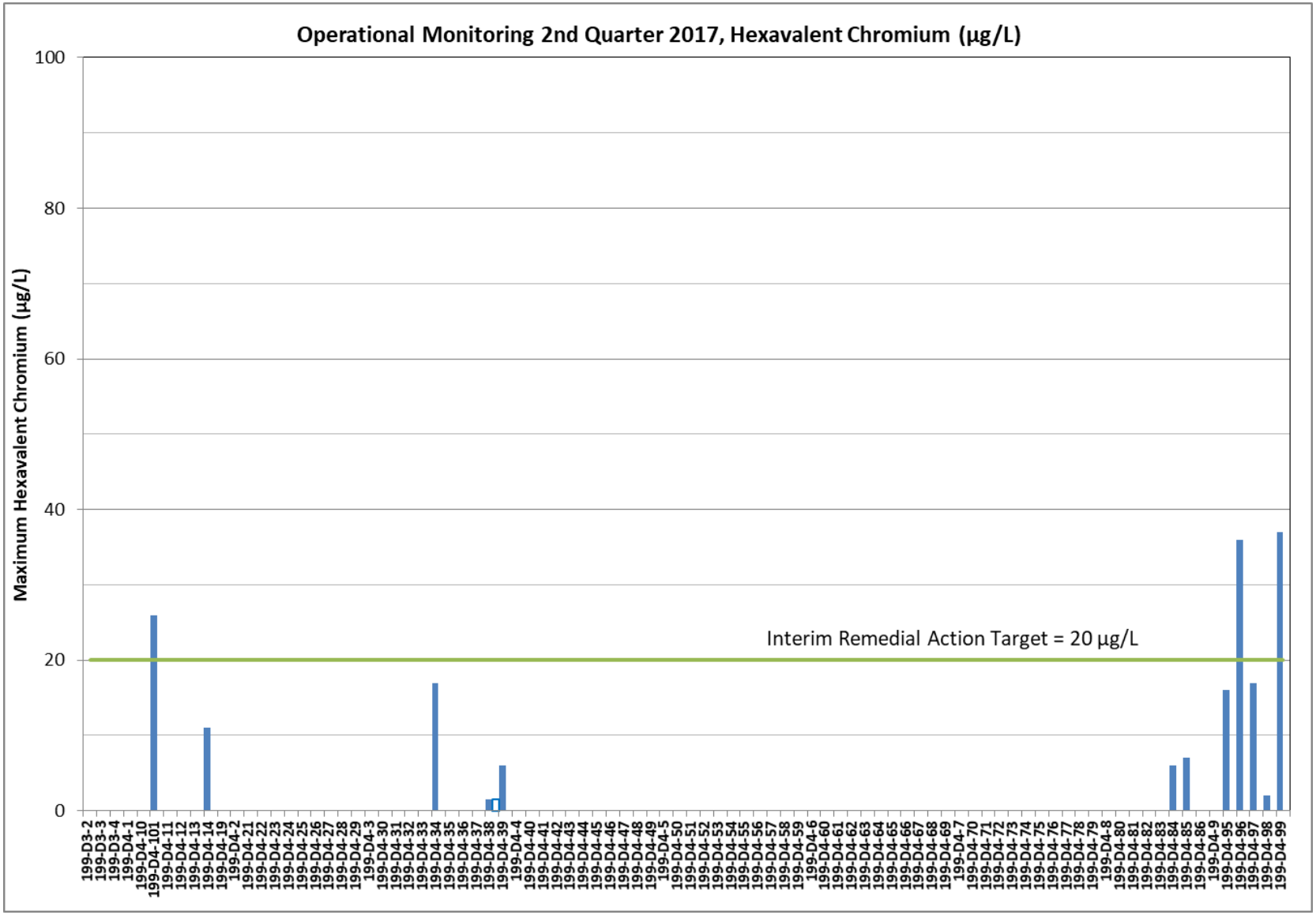


Figure 2-43. ISRM Operational Monitoring for Cr(VI), First Quarter



Note: Unshaded bars indicate values below detection limit.

Figure 2-44. ISRM Operational Monitoring for Cr(VI), Second Quarter

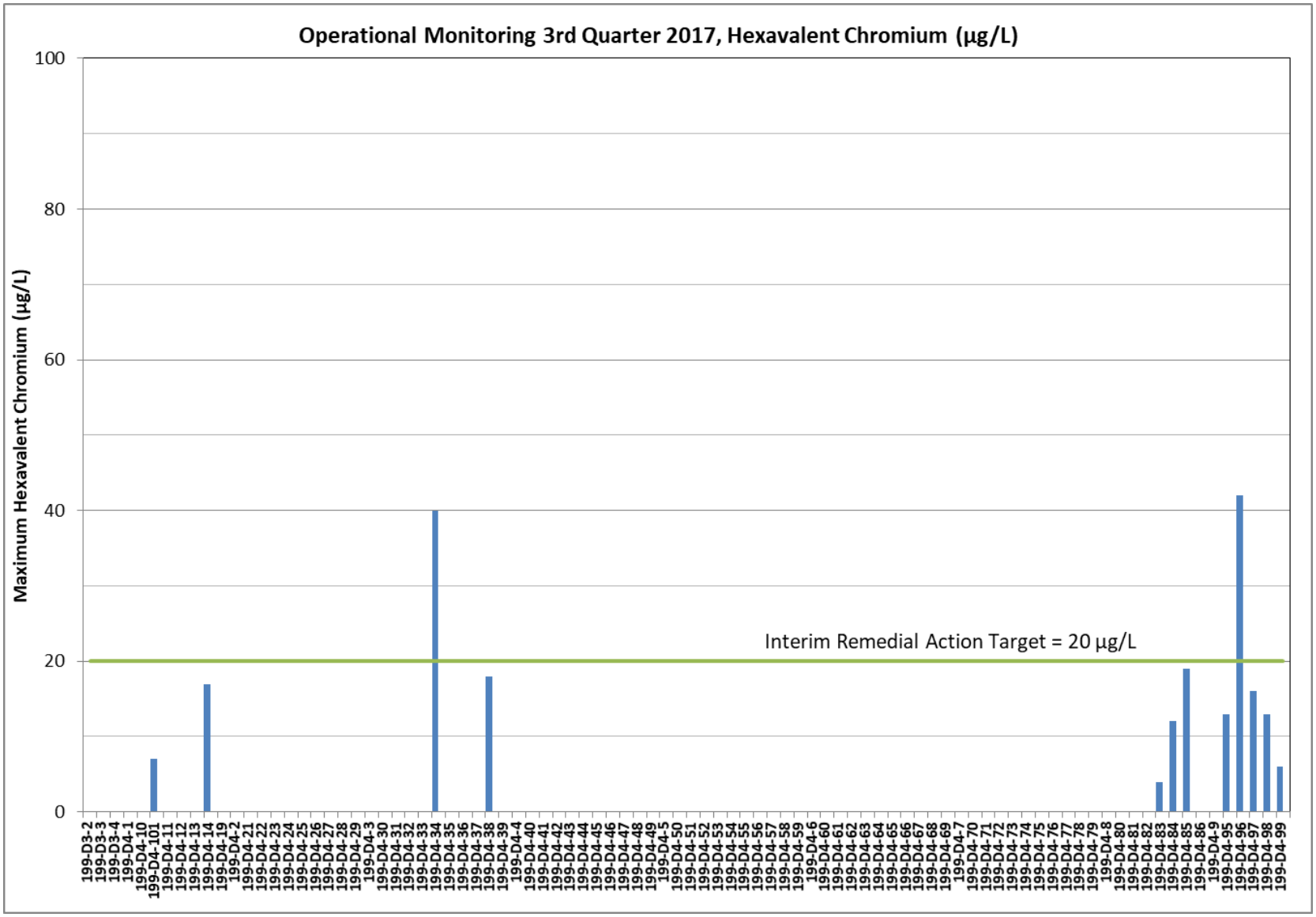
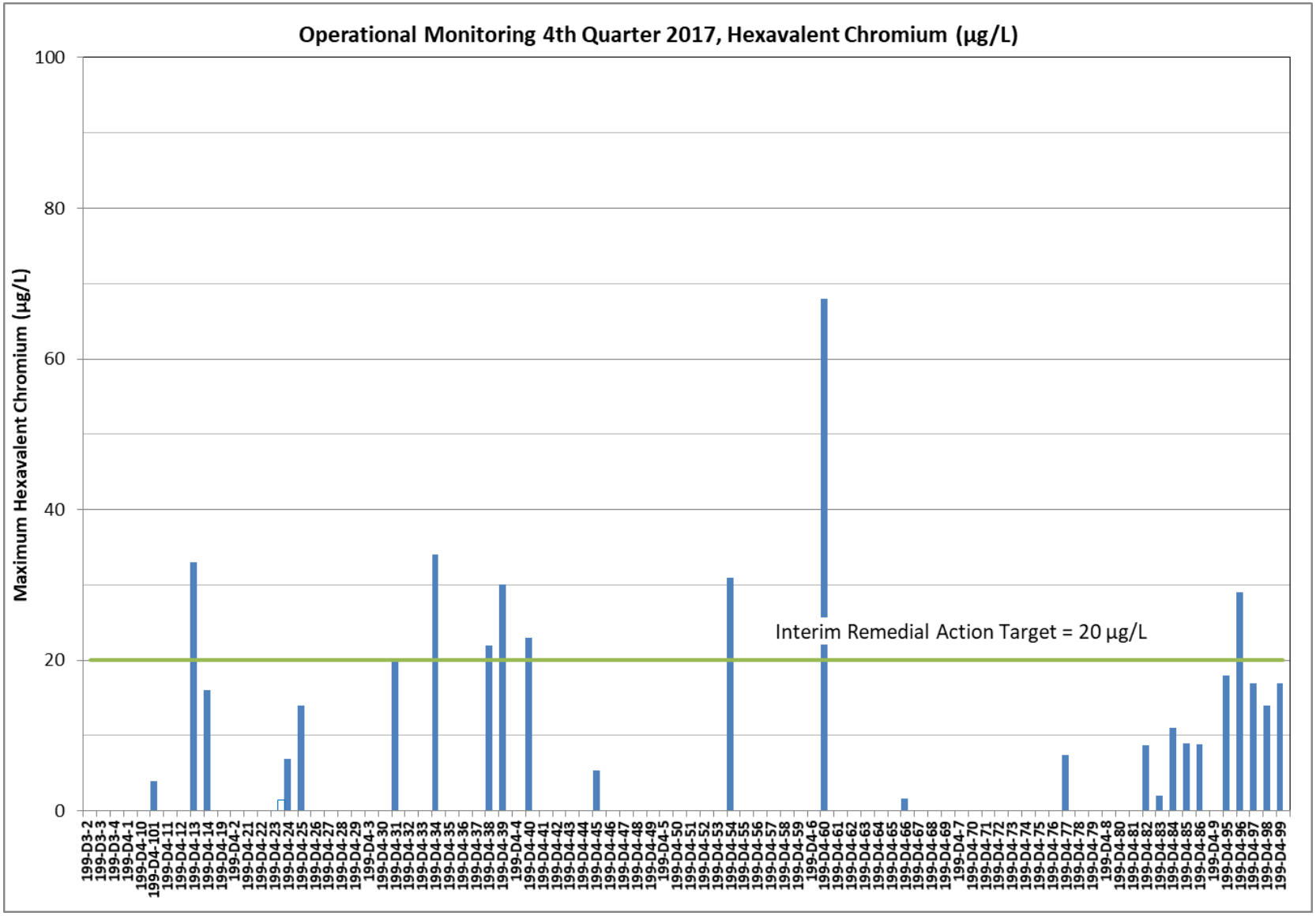


Figure 2-45. ISRM Operational Monitoring for Cr(VI), Third Quarter



Note: Unshaded bars indicate values below detection limit.

Figure 2-46. ISRM Operational Monitoring for Cr(VI), Fourth Quarter

2.2.8.2 Dissolved Oxygen

Dissolved oxygen concentrations are monitored as required by the ROD amendment (EPA/AMD/R10-00/122) and the 100-HR-3 OU RDR/RAWP (DOE/RL-2013-31). The sodium dithionite injection process reduced oxygen in the groundwater at the barrier to low levels. Dissolved oxygen is monitored to assess changes as groundwater approaches the Columbia River. Low oxygen levels in the river may pose a risk to aquatic organisms. Monitoring dissolved oxygen will assist in developing actions to increase the oxygen in groundwater via air sparging (or other means) if significant low values persist. Groundwater in the ISRM region is generally characterized by relatively high oxygen concentrations upgradient of the treatment zone (except in the area of former treatability test wells 199-D5-107 and 199-D5-108), decreasing significantly through the treatment zone, and recovering to higher concentrations as groundwater flow approaches the river. The areas with dissolved oxygen levels less than 3 mg/L are located near wells 199-D4-24 and 199-D4-62. Dissolved oxygen levels in the majority of the barrier are currently below 6 mg/L (Figure 2-47).

The distribution of lower dissolved oxygen levels is consistent with observations in previous years. The area within the barrier where levels remain low coincides with areas where groundwater velocity is slower and the aquifer is thinner due to a high RUM surface (the base of the unconfined aquifer). The oxygen levels on the downgradient side of the barrier are within normal ranges. A second area of lower dissolved oxygen is associated with former treatability tests wells 199-D5-107 and 199-D5-108 (PNNL-18784, *Hanford 100-D Area Biostimulation Treatability Test Results*). Overall, the area of low dissolved oxygen was slightly larger than in 2016, but the reason for the increase is not defined.

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. Sulfate previously exceeded the 250 mg/L secondary DWS in wells within and downgradient of the ISRM barrier as a result of oxidation of the sodium dithionite solution injections. No exceedances of the sulfate DWS were observed at the ISRM barrier during 2017.

2.2.9 Remedial Process Optimization Activities

Contractors have developed a pumping optimization model and interface (based on the 100 Area groundwater model) that is used by OU scientists to evaluate the relative performance of alternative well configurations. The OU scientists evaluate pumping configurations throughout the year and provide recommended adjustments to flow rates, as well as recommendations for well realignment and/or the installation of new wells. Specific remedial process activities performed at the 100-HR-3 OU during 2017 included the following:

- Identifying and installing new wells based on previous years’ evaluations of plume capture and river protection analyses for use as extraction or monitoring locations
- Realigning monitoring wells for use as extraction wells and enhance plume capture
- Maintaining 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
- Using the pumping optimization model to evaluate expected extraction/injection well effects on plume capture

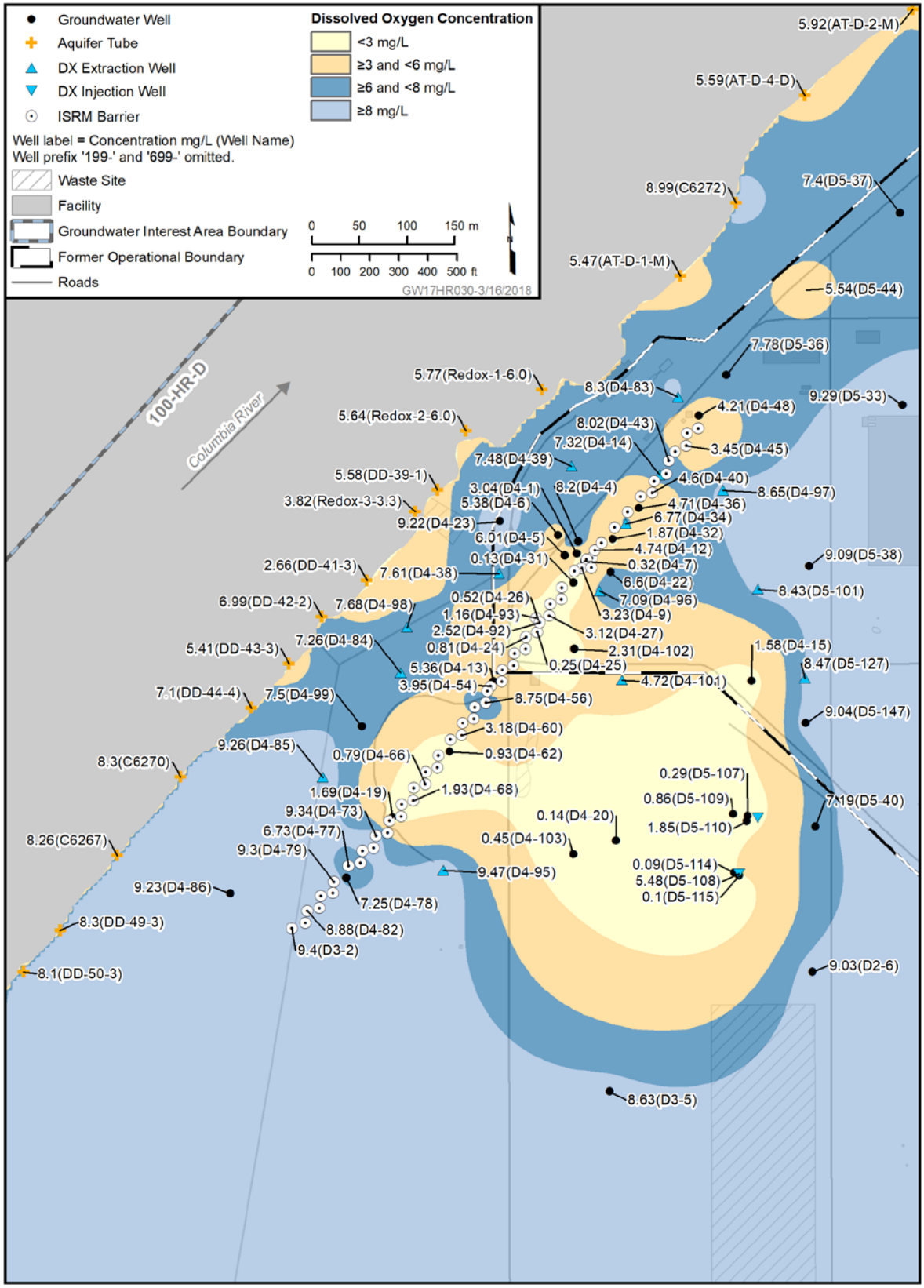


Figure 2-47. ISRM Area Dissolved Oxygen Concentrations, 2017

2.3 Radiological Dose and Drinking Water Standard Analysis of DX and HX Pump-and-Treat Effluent

This section discusses the results of radiological dose and DWS evaluation of the DX and HX P&T systems for 2017 against the requirements of DOE O 458.1 and DOE-STD-1196-2011. Additional guidance is provided in DOE-HDBK-1216-2015 and summarized in Table 2-13 for evaluating radiological effluent monitoring based on the DCS to ensure that mitigating steps are implemented before conditions exceed target metrics. These criteria are applied to the DX and HX P&T system and are evaluated each year for adequacy and are updated as necessary.

Table 2-13. Recommended Criteria for Liquid Radiological Effluent Monitoring

Criterion Number	DCS Sum of Fractions	And	Potential Annual Dose from Exposure to a Likely Receptor (mrem)	Minimum Criteria for Liquid Radiological Effluent Monitoring
1	>/= 1		—	Apply best available technology to reduce effluent releases (except H-3). Use continuous monitoring/sampling, but where effluent streams are low flow and potential public dose is very low (<<1mrem in a year), alternative sampling approaches may be appropriate.
2	>/= 0.01 to 1		>1	Continuously monitor or sample. Identify radionuclides contributing >/= 10% of the dose. Determine accuracy of results (± accuracy and percent confidence level).
3	>/= 0.001 to 0.01		<1	Monitor using a graded approach to select the appropriate method and duration. Identify radionuclides contributing >/= 10% or more of the dose. Assess annually the facility inventory and potential for radiological effluent release.
4	<0.001		—	No monitoring required. Evaluate annually the potential for liquid radiological effluent release.

Source: Table 3-1 of DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance.*

— = not applicable

DCS = derived concentration standard

2.3.1 Evaluation of Effluent Water Total Effective Dose for DX and HX Pump-and-Treat Systems for Calendar Year 2017

Effluent monitoring at the DX and HX P&T systems was performed by sampling and analyzing the stream exiting the plant prior to pumping effluent to the injection well fields. Sampling and analysis were performed periodically for target radionuclides identified as contaminants of interest for the groundwater remedial actions supported by the treatment system. The radionuclides of interest for the DX and HX P&T systems are tritium, technetium-99, strontium-90, and uranium. Table 2-14 summarizes the results of the periodic sampling and analysis of effluent from DX and HX P&T systems in 2017. Where multiple measurements were determined for an analyte during a single sampling and analysis event, the maximum value was selected for use in this evaluation.

Table 2-14. Summary of Effluent Radioisotope Sampling and Analysis Results for CY 2017 at the DX and HX P&T Systems

Sample Location	Sample Date	Tritium (pCi/L)	Technetium-99[a] (pCi/L)	Strontium-90 (pCi/L)[a]	Uranium (µg/L)[a]	Uranium-238[b] (pCi/L)	Uranium-235[b] (pCi/L)	Uranium-234[b] (pCi/L)
DX P&T								
Effluent tank –M5	3/28/2017	NM	NM	NM	(0.027)	(0.027)	(1.9E-04)	(1.6E-06)
Effluent tank –M5	6/13/2017	NM	NM	NM	(0.4)	(0.4)	(3E-03)	(2E-05)
Effluent tank –M5	8/30/2017	NM	(39.4)	(1.22)	(0.4)	(0.4)	(3E-03)	(2E-05)
Effluent tank –M5	12/11/2017	1290	(36.5)	(1.68)	(0.4)	(0.4)	(3E-03)	(2E-05)
HX P&T								
Effluent tank – H5	3/28/2017	NM	NM	NM	0.03	0.03	2E-04	2E-06
Effluent tank – H5	6/13/2017	NM	NM	NM	(0.4)	(0.4)	(3E-03)	(2E-05)
Effluent tank – H5	8/30/2017	NM	(37.1)	(1.1)	(0.4)	(0.4)	(3E-03)	(2E-05)
Effluent tank – H5	12/11/2017	618	(42.4)	3.37	(0.4)	(0.4)	(3E-03)	(2E-05)

a. Values in parentheses were reported as not detected. Value presented is the reported minimum detectable activity concentration for samples reported as analyzed but not detected.

b. Uranium isotope (i.e., uranium-234, uranium-235, and uranium-238) activity concentrations are derived from uranium mass concentration values assuming the mass distribution and specific activity of isotopes in natural uranium.

CY = calendar year

NM = analyte not measured in this sampling event

P&T = pump and treat

Individual radioisotope activity concentrations were subsequently converted to estimated effective dose using the DCS values in Table 2-15.

Table 2-15. Derived Concentration Standards for Radioisotopes Evaluated in DX and HX P&T Effluent

DCS	Tritium	Technetium-99	Strontium-90	Uranium[c]	Uranium-238	Uranium-235	Uraniuum-234
DCS (µCi/ml)[a]	1.90E-03	4.40E-05	1.10E-06	—	7.50E-07	7.20E-07	6.80E-07
DCS (pCi/L)[b]	1.90E+06	4.40E+04	1.10E+03	—	7.50E+02	7.20E+02	6.80E+02

a. DCS from Table 5 of DOE-STD-1196-2011, *Derived Concentration Technical Standard*.

b. DCS converted to pCi/L for direct comparison to measurement results.

c. Uranium in mass concentration is not assigned a DCS value

DCS = derived concentration standard

Table 2-16 shows the individual radioisotope dose contributions for each effluent sampling event at the DX and HX P&T systems and the cumulative TED estimates for calendar year (CY) 2017. The TED was calculated using two approaches: the first, a conservative approach, incorporated the minimum detectable activity (MDA) for nondetect measurements as a value; the second approach included no value for nondetect measurements. The resulting TED and DCS fractions were then compared to the criteria presented in Table 2-13.

The cumulative TED and DCS fraction values shown in Table 2-16 indicated that results of effluent sampling events during 2017 at the DX and HX P&T systems met monitoring criterion #3 for the sample analyzed on December 11, 2017. The samples collected on March 28, June 13, and August 30, 2017, were not analyzed for all detectable radionuclides. Only the sample analyzed on December 11, 2017, exhibited detectable concentrations for all radionuclides. This indicates that the calculated TED and DCS fraction for the samples analyzed on March 28, June 13, and August 30, 2017, may not be completely representative of the effluent.

2.3.2 Comparison of DX and HX Pump-and-Treat Effluent Water Radiological Constituents to Drinking Water Standards for Beta/Photon Emitters and Uranium for Calendar Year 2017

The radioisotopes measured in P&T effluent from DX and HX systems were also evaluated against the 4 mrem/yr drinking water MCL for beta and photon emitters. The cumulative beta/photon dose MCL is based on a sum-of-fractions calculation (similar to the AEA, DCS, and TED), using the derived concentration values published by EPA. The beta/photon MCL dose analysis was performed in two ways; first using the reported MDA as a value for measurements reported as nondetects, and secondly without including any value for nondetected isotopes. The first approach is a conservative screen used to assess potential dose contributions. Individual and average values for beta/photon emitters measured in the effluent at these two systems do not exceed the dose MCL. Total uranium mass concentration for both systems does not exceed the 30 µg/L MCL. Table 2-17 summarizes the results of the evaluation.

Table 2-16. Calculated Individual Radioisotope Dose Contributions and TED for DX and HX P&T Effluent, CY 2017

Sample Location	Sample Date	Individual Isotope Effective Dose Contribution						TED Cumulative (mrem/yr)	DCS Fraction Cumulative (Fraction)	TED Detects Only (mrem/yr)	DCS Fraction Detects Only (Fraction)
		Tritium (mrem/yr)	Technetium-99 (mrem/yr)[a]	Strontium-90 (mrem/yr)[a]	Uranium-238[a,b] (mrem/yr)	Uranium-235[a,b] (mrem/yr)	Uranium-234[a,b] (mrem/yr)				
DX P&T											
Effluent tank –M5	3/28/2017	NM	NM	NM	(3E-03)	(2E-05)	(2E-07)	0.004[c]	4E-05[c]	NC	NC
Effluent tank –M5	6/13/2017	NM	NM	NM	(5E-02)	(4E-04)	(3E-06)	0.05[c]	0.0005[c]	NC	NC
Effluent tank –M5	8/30/2017	NM	(8.9E-02)	(1.1E-01)	(5E-02)	(4E-04)	(3E-06)	0.2[c]	0.002[c]	NC	NC
Effluent tank –M5	12/11/2017	6.8E-02	(8.3E-02)	(1.5E-01)	(5E-02)	(4E-04)	(3E-06)	0.4	0.004	7E-02	7E-04
HX P&T											
Effluent tank – H5	3/28/2017	NM	NM	NM	4E-03	3E-05	3E-07	0.004[c]	4E-05[c]	4E-03[c]	4E-05[c]
Effluent tank – H5	6/13/2017	NM	NM	NM	(5E-02)	(4E-04)	(3E-06)	0.05[c]	0.0005[c]	NC	NC
Effluent tank – H5	8/30/2017	NM	(8.4E-02)	(1.0E-01)	(5E-02)	(4E-04)	(3E-06)	0.2[c]	0.002[c]	NC	NC
Effluent tank – H5	12/11/2017	3.2E-02	(9.6E-02)	3.1E-01	(5E-02)	(4E-04)	(3E-06)	0.5	0.005	0.3	0.003

Note: Shaded cells indicate cumulative TED and DCS fraction values meet criterion #3 in Table 2-13.

a. Values in parentheses were reported as nondetected. Value presented is dose contribution based on minimum detectable activity concentration for samples reported as analyzed but not detected.

b. Uranium isotope activity concentrations were derived from total uranium mass concentration for use in calculation of dose contribution.

c. The absence of a measured value for strontium-90, technetium-99, and tritium indicates nonrepresentative underestimation of the TED and DCS fraction.

DCS = derived concentration standard
NC = not calculated
NM = analyte not measured in this sampling event
P&T = pump and treat
TED = total effective dose

Table 2-17. Summary of Drinking Water Beta/Photon Emitter MCL Comparison for DX and HX P&T Effluent for CY 2017

Sample Location	Sample Date	Contributing Radioisotopes			Sum of Fractions[a]	Drinking Water β/ϒ Dose (mrem/yr)[a]	Sum of Fractions Detects Only[b]	Drinking Water β/ϒ Dose from Detects Only (mrem/yr)[b]
		Tritium	Tc-99	Sr-90				
		Derived Concentrations (pCi/L)						
		20,000	900	8				
		Beta/Photon MCL Fraction						
DX P&T								
Effluent tank – T-H5	3/28/2017	NM	NM	NM	NC	NC	NC	NC
Effluent tank – T-H5	6/13/2017	NM	NM	NM	NC	NC	NC	NC
Effluent tank – T-H5	8/30/2017	NM	(0.044)[c]	(0.15)[c]	0.20[d]	0.78[d]	NC	NC
Effluent tank – T-H5	12/11/2017	0.0645	(0.040)[c]	(0.21)[c]	0.31	1.3	0.064	0.26
HX P&T								
Effluent tank – T-H5	3/28/2017	NM	NM	NM	NC	NC	NC	NC
Effluent tank – T-H5	6/13/2017	NM	NM	NM	NC	NC	NC	NC
Effluent tank – T-H5	8/30/2017	NM	(0.0412)[c]	(0.14)[c]	0.18[d]	0.71[d]	NC	NC
Effluent tank – T-H5	12/11/2017	0.0309	(0.0471)[c]	0.42	0.50	2.0	0.45	1.8

a. Sum of MCL fractional derived concentration values and calculated MCL dose, including nondetect values using the MDA as a value.

b. Sum of MCL fractional derived concentration values and calculated MCL dose, excluding nondetect measurements.

c. Values in parentheses were reported as nondetects; the value is the reported value of the MDA.

d. The absence of a measured value for tritium indicates nonrepresentative underestimation of the sum-of-fractions and the resultant dose.

NC = parameter not calculated for this sampling event

NM = analyte not measured in this sampling event

MCL = maximum contaminant level

MDA = minimum detectable activity

P&T = pump and treat

2.3.3 Conclusions of Evaluation of Radiological Constituents in DX and HX Pump-and-Treat Effluent Water for Calendar Year 2017

The radiological dose evaluation for the DX and HX P&T effluent water during 2017 indicates that the effluent met the following standards and criteria:

- The calculated DCS-based TED of the effluent for both the DX and HX P&T systems was less than 1 mrem/yr, substantially below the 100 mrem/yr public dose limit.
- The calculated DCS-based sum of fractions and resulting TED of the effluent for both the DX and HX P&T systems on December 11, 2017, were consistent with recommended monitoring using a graded approach and annual review. All other sampling events met criterion #3 or #4 but are not considered representative of the system due to unmeasured radioactive contaminants.
- The calculated MCL-based beta/photon-emitter drinking water dose was below the 4 mrem/yr MCL dose for both the DX and HX P&T systems.
- Total uranium mass concentration in effluent for both systems was below the 30 µg/L MCL. Uranium was detected above the detection limit in only one sample of HX P&T effluent; uranium was not detected in any sample at the DX P&T system.

No changes in the standard effluent monitoring sampling and analysis frequency or analytical suite are indicated for CY 2018. Short-term additional sampling will be conducted when well 199-H3-29 becomes operational due to the elevated levels of Cr(VI), nitrate, and technetium-99 in the well.

2.4 100-HR-3 Operable Unit Pump-and-Treat System Cost

This section summarizes the actual costs for the 100-HR-3 OU P&T systems for 2017. 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 operations and periodic maintenance.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis, as required in accordance with the 100-HR-3 OU RD/RAWP (DOE/RL-2013-31) and the 100-HR-3 OU SAP (DOE/RL-2013-30).
- **Waste management:** Includes the cost for managing 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.

- **Field studies:** Includes costs for conducting field tests (e.g., step tests, pumping tests, and tracer studies) to support evaluation of hydraulic properties and remedy optimization.
- **Well realignments:** Includes costs for well conversions to add/remove wells as extraction or injection wells to the P&T facilities. Costs include fabrication and installation/modification of equipment and systems for well conversions and installation of piping runs and electrical cables from the P&T facilities to wells.

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 2017 are associated with four P&T systems: HR3, DR5, DX, and HX. The cost breakdowns for each of these P&T systems are shown in Tables 2-18 through 2-21, respectively. The HR3 and DR5 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 2-18 and 2-19). Costs for the HR3 and DR5 P&T systems after system shutdown in 2011 are associated with surveillance and maintenance, and decommissioning of the facilities, which was completed in 2016. Decommissioning and equipment removal of the DR5 P&T system was completed in 2015 so the facility could be used for maintenance. Decommissioning and demolition of the HR3 P&T facility was completed in 2016. Costs are burdened and are based on actual operating costs incurred during 2017. Summaries of the costs for the DX and HX P&T systems are presented in the following sections.

2.4.1 DX Pump-and-Treat System

The total cost for the DX P&T system during 2017 was approximately $4.29 million, which consists of the sum of the categories shown in Table 2-20. Well realignment and O&M costs made up 66% of the total cost for the year. The cost breakdown percentage for the DX P&T system (Figure 2-48) is as follows, in decreasing order:

- **O&M:** 34.5% ($1,480,700)
- **Well realignments:** 31.8% ($1,365,000)
- **Treatment system capital construction:** 17.2% ($736,800)
- **Performance monitoring:** 6.3% ($270,800)
- **Design:** 4.4% ($188,800)
- **Project support:** 3.8% ($165,100)
- **Waste management:** 1.7% ($72,200)
- **Field studies costs:** negligible in 2017

The cost increase compared to 2014 for the DX P&T system is associated with capital construction for well installation and realignments conducted in 2015 through 2017. Section 2.2.1 describes the DX P&T system changes and well realignment activities for 2017.

Based on the total 2017 cost of $4,290,000, the yearly production rate of 1,469 million L (388 million gal), and 30.4 kg of Cr(VI) removed, the annual treatment cost is $0.0029/L, or $141.12/g of Cr(VI) removed.

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Table 2-18. 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[e]**	**2013[f]**	**2014[e]**	**2015[g]**	**2016[g]**	**2017[g]**
Design	—	—	97.7	15.4	8.1	196.1	196.0	55.0	92.0	—	0.0	26.5	—	0.7	—	—	0.0	—	—
Treatment system capital construction	—	57.7	(36.1)	750.3	—	496.6	10.0	—	—	—	—	—	—	—	—	—	1,053.2	—	—
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	—	0.1	—	—
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	29.4	104.4	—
Performance monitoring	—	173.7	219.9	120.0	163.2	120.3	353.0	489.6	219.5	508.5	237.7	240.0	—	—	—	—	0.1	—	—
Waste management	—	895.3	424.9	720.1	877.2	501.7	202.2	217.6	434.7[h]	192.2	16.6	75.0	—	3.0	—	—	5.1	—	—
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**	**$1,088**	**$104**	**$0**

Note: Dowex® is a registered trademark of the Dow Chemical Company, Midland, Michigan.

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

f. Costs for 2013 were associated with disposal of Dowex 21K resin.

g. Costs for 2015 and 2016 are associated with surveillance and maintenance and decommissioning of the HR-3 P&T facility. Facility demolition completed in 2016, no costs in 2017.

h. Additional waste management costs in 2007 were associated with drilling wastes and resin cleared for shipment and handling.

— = not available

P&T = pump and treat

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Table 2-19. 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]**	**2015[d]**	**2016[d]**	**2017[d]**
Design	246.9	196.8	100.4	—	3.2	3.4	—	(0.1)	—	0.0	—	—
Treatment system capital construction	—	22.2	—	—	—	—	—	—	—	1,053.2	—	—
Project support	586.4	370.6	240.3	233.6	204.7	139.6	2.7	—	—	0.1	—	10.6
Operations and maintenance	459.6	605.7	541.3	884.7	1,091.7	919.9	185.4	21.6	9.5	25.6	7.5	3.7
Performance monitoring	106.2	1.6	11.3	127.1	237.7	240.0	—	—	10.7	0.0	—	—
Waste management	28.3	154.7	45.4	23.8	1.7	29.0	—	—	—	5.2	—	—
Totals	**$1,427**	**$1,352**	**$939**	**$1,269**	**$1,539**	**$1,332**	**$188**	**$21**	**$20**	**$1,084**	**$8**	**$14**

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. 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.

d. Costs for 2015 are associated with decommissioning and removal of P&T equipment from the DR-5 P&T facility. Costs after 2015 are for ongoing facility surveillance and maintenance.

— = not available

P&T = pump and treat

Table 2-20. Breakdown of DX P&T System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)								
	2009[a]	**2010**	**2011[b]**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Design	2,115.2	1,287.8	100.7	34.3	28.9	5.7	44.4	11.0	188.8
Treatment system capital construction	5,759.8	16,266.3	—	(3.1)	244.2	565.7	851.4	714.1	736.8
Project support	495.1	1,236.9	45.7	71.3	186.0	132.4	14.3	118.7	165.1
Operations and maintenance	—	—	2,979.3	1,566.3	2,186.4	1,857.9[c]	1,618.4[c]	1,931.5	1,480.7
Performance monitoring	—	—	1.8	294.9	125.4	226.6	167.4	271.4	270.8
Waste management	7.4	9.2	—	0.8	0.0	0.6	114.7	44.1	72.2
Field studies	—	—	—	—	—	0.4	—	—	10.7
Well realignments	—	—	—	—	—	171.9	2,750.4	2,224.8	1,365.0
Totals	**$8,377**	**$18,800**	**$3,128**	**$1,965**	**$2,771**	**$2,961**	**$5,561**	**$5,316**	**$4,290**

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

c. Cost for well realignments were previously included as part of the O&M costs, but are now reported as a separate cost category. The 2014 and 2015 O&M costs reported in previous reports have been adjusted in this report to separate out the well realignment costs.

— = not available

P&T = pump and treat

Table 2-21. Breakdown of HX P&T System Construction Costs

Description	Actual Costs (Dollars × 1,000)								
	2009[a]	**2010**	**2011[b]**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Design	896.4	1,047.5	1,079.8	35.9	3.6	6.0	37.8	9.4	161.0
Treatment system capital construction	214.1	9,354.2	11,316.2	(2.3)	220.0	566.9	725.8	608.7	628.1
Project support	—	400.2	1,981.4	53.2	179.4	128.7	10.9	101.2	123.2
Operations and maintenance	—	—	321.2	1,187.4	1,727.6	1,792.7[c]	1,586.4[c]	1,905.0	1,391.2
Performance monitoring	—	—	8.0	189.7	122.7	189.7	153.1	225.4	195.0
Waste management	—	0.1	—	1.0	—	—	103.3	31.3	66.9
Field studies	—	—	—	—	—	0.4	—	446.4	81.5
Well Realignments	—	—	—	—	—	171.9	2,344.6	1,896.5	691.3
Totals	**$1,111**	**$10,802**	**$14,707**	**$1,465**	**$2,253**	**$2,856**	**$4,962**	**$5,224**	**$3,338**

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 and entered acceptance test procedures. It became fully operational in October 2011.

c. Cost for well realignments were previously included as part of the O&M costs, but are now reported as a separate cost category. The 2014 and 2015 O&M costs reported in previous reports have been adjusted in this report to separate out the well realignment costs.

— = not available

P&T = pump and treat

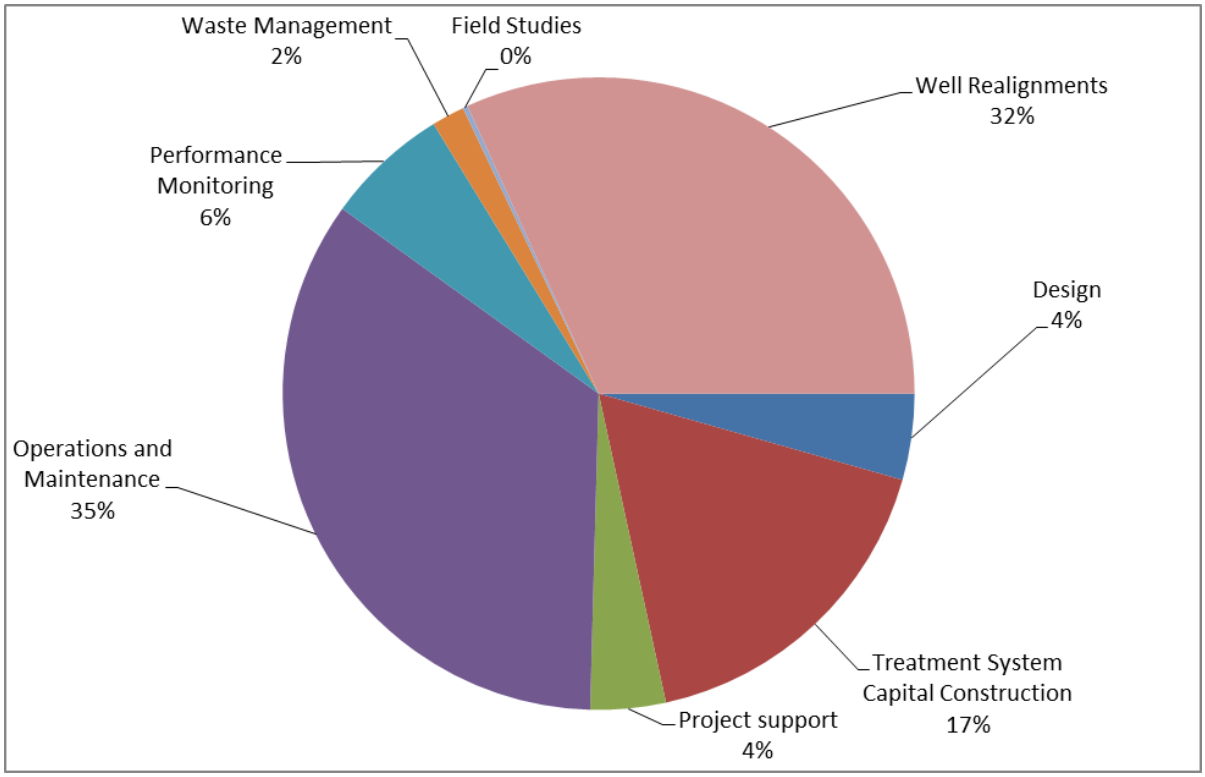

Figure 2-48. DX P&T System, 2017 Cost ($4.29 Million) Breakdown (by Percentage)

2.4.2 HX Pump-and-Treat System

The total cost for the HX P&T system during 2017 was approximately $3.34 million, which consists of the sum of the categories shown in Table 2-21. Well realignment and O&M costs made up 62% of the total cost during the year. The cost breakdown for the HX P&T system for 2017 (Figure 2-49) is as follows, in decreasing order:

- **O&M:** 41.7% ($1,391,200)
- **Well realignments:** 20.7% ($691,300)
- **Treatment system capital construction:** 18.8% ($628,100)
- **Performance monitoring:** 5.8% ($195,000)
- **Design:** 4.8% ($161,000)
- **Project support:** 3.7% ($123,200)
- **Field studies:** 2.4% ($81,500)
- **Waste management:** 2.0% ($66,900)

The cost increase compared to 2014 for the HX P&T system is associated with capital construction for well installation and realignments conducted from 2015 through 2017. Section 2.2.2 describes the HX P&T system changes and well realignment activities for 2017.

Based on the total 2017 cost of $3,338,000, the yearly production rate of 1,449 million L (383 million gal), and 25.9 kg of Cr(VI) removed, the annual treatment cost is $0.0023/L, or $128.99/g of Cr(VI) removed.

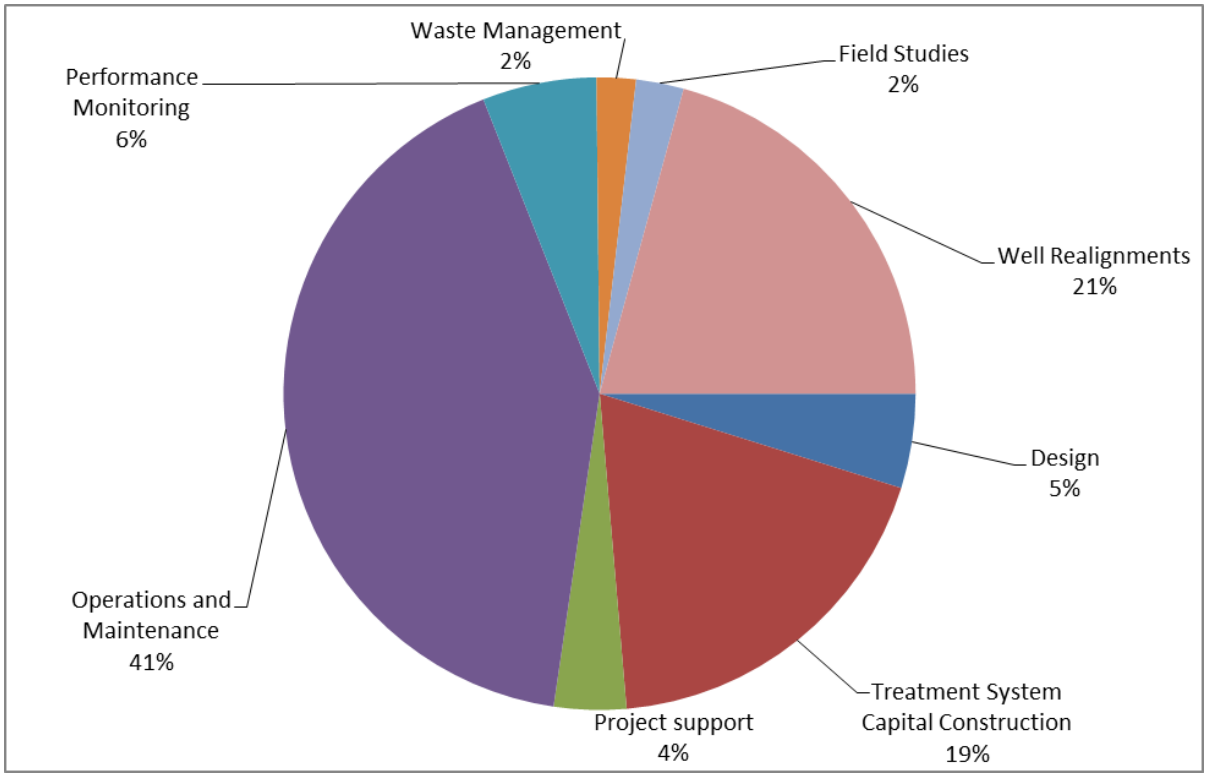

Figure 2-49. HX P&T System, 2017 Cost ($3.34 Million) Breakdown (by Percentage)

2.5 Conclusions

The status of the 100-HR-3 OU illustrates that remediation has progressed regarding the Cr(VI) groundwater contamination associated with each of the P&T systems operating in 2017 within the 100-HR-3 OU.

The DX and HX P&T systems removed a substantial mass of Cr(VI) from the aquifer in 2017. The amount of mass removed each year 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 and increase river protection.

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 2017 is consistent with the design of the systems and within expectations. Calculations indicate that the river protection objective is being achieved along the majority of the 100-HR-3 OU shoreline.

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: The effect of river-stage fluctuations on groundwater flow, combined with the aquifer response to pumping, indicates that hydraulic containment was not as strong in 2017 as in previous years. Steep hydraulic gradients and resulting groundwater velocities caused by river-stage decline during the fall resulted in weaker hydraulic containment in 2017, as reflected in the CFMs.

The capture flow lines in some areas may undergo a more indirect path to an extraction well, as observed especially in Figures 2-34 and 2-35, which reflects the effects of river-stage fluctuations and aquifer hydraulic conditions on a particle flow path. In such cases, low capture frequency is not evidence of failure to protect the river from contaminant discharges; instead, it suggests that hydraulic containment is relatively weak and capture may take longer to occur.

In 2017, the quantitative evaluation for the 100-D Area reflects the weaker hydraulic containment, as illustrated in the CFMs. As conservative, tight criteria for capture frequency are applied to determine river protection status, large stretches of the shoreline appear to be protected but may possibly require additional action in the future. However, with the exception of presence of chromium at the 116-DR-5 outfall at greater than 10 μg/L, hydraulic containment was not compromised in 2017. For the additional shoreline length considered toward the Horn, the presence of the chromium plume at concentrations greater than 10 μg/L requires some attention. The evaluation suggest some plume migration occurred in that area, caused by the atypical hydraulic gradients due to the river-stage profile in 2017; however, these conditions are not expected to prevail in the future. Qualitative evaluation of river protection status reflects these considerations. Conditions will continue to be monitored in 2018, and actions will be taken if there are indications that the river protection objective may not be attained.

In the 100-H Area, the quantitative river protection evaluation was similar to 2016, reflecting similar tight criteria and conservative approach to assessing hydraulic containment. Qualitative evaluation of river protection status reflects the same considerations implemented in the 100-D Area, resulting in a qualitative assessment consistent with the conclusions presented in 2016.

Calculations indicate that the river protection objective is being achieved along most of the 100-HR-3 OU shoreline. The performance of remedial action systems confirms that DOE has taken the necessary measures to control the discharge of Cr(VI) into the Columbia River (Tri-Party Agreement [Ecology et al., 1989] Milestone M-016-110-T01). The observed concentrations of Cr(VI) in groundwater at the DX and HX P&T systems are declining as remediation progresses.

The 100-HR-3 OU P&T systems have removed substantial amounts of Cr(VI) from the groundwater. Since startup of the DX and HX P&T systems, an estimated total of 1,737 kg of Cr(VI) has been removed from the shallow unconfined aquifer and RUM, with the DX P&T system alone removing 1,577 kg of that total.

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

  Results: The interim action 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 MSA-1105355.6, *FY2017 Sitewide Institutional Control Assessment*. 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), which will lead to issuance of a ROD for cleanup of contaminated soil and groundwater at the 100-D and 100-H Areas, was completed in July 2016 and issued for public comment. The final ROD is currently under review and is anticipated to be signed in calendar year 2018.

  Additional information on 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. Information collected during source remediation actions is assessed to provide 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.

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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 Groundwater OU. The following discussion includes the interim remedy P&T system performance for 2017 and a summary of progress made toward remediating the aquifer since the start of P&T operations.

3.1 Overview of Operable Unit Activities

The 100KR-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 100-HR-3 and 100-KR-4 interim action ROD (EPA/ROD/R10-96/134) as the primary groundwater COC in this OU. Groundwater co-contaminants identified in the interim action ROD are nitrate, tritium, strontium-90, carbon-14, and trichloroethene (TCE).

The interim action ROD (EPA/ROD/R10-96/134) for the 100-KR-4 OU defined the cleanup goal for Cr(VI) in groundwater discharging to the Columbia River as the ambient water quality criterion at the time of 11 µg/L. Based in part on the assumption 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 remediation target 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 P&T systems (KR4, KW, and KX) operated in 2017. The KR4 P&T system was the first system installed and began operating in 1997; it was designed to remediate groundwater around the 116-K-2 Trench (Figure 3-1). The KW P&T system was the second system installed and began remediating Cr(VI) in the KW Reactor area in February 2007. Between May 2016 and April 2017, the KW P&T system was shut down to perform a rebound study. The rebound study would evaluate the potential for contaminant concentrations to remain below cleanup levels and determine if continuing secondary source material exists in the deep vadose zone. The third and newest P&T system, KX, began operating in November 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 the 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 Cr(VI) in groundwater in the 100-KR-4 OU vicinity, as well as the inferred groundwater elevation contours for the high and low river-stage periods during 2017, are shown in Figures 3-3 and 3-4, respectively.

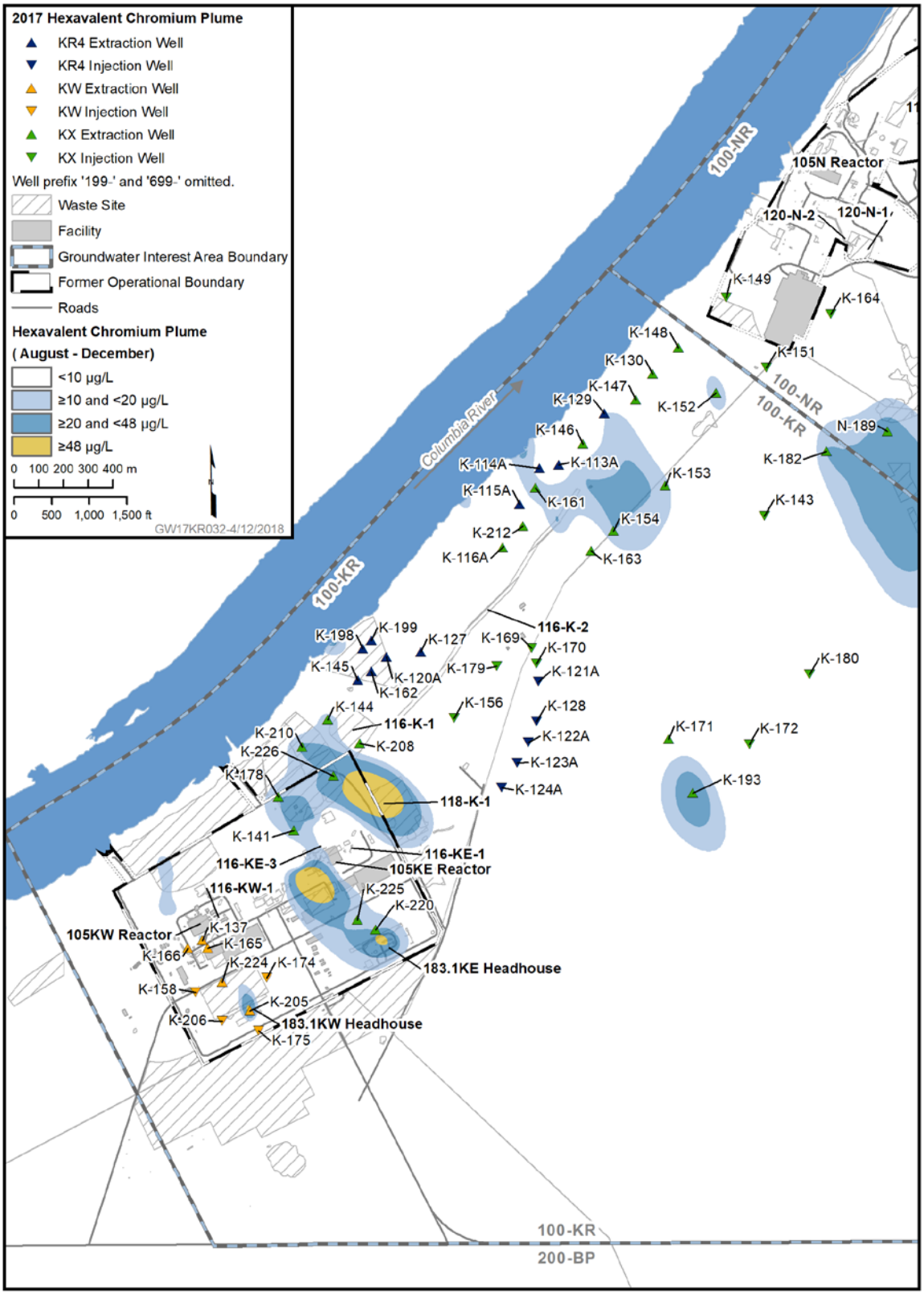


Figure 3-1. Layout of the 100-KR-4 OU P&T Systems (as of December 31, 2017) and Key Waste Sites and Facilities

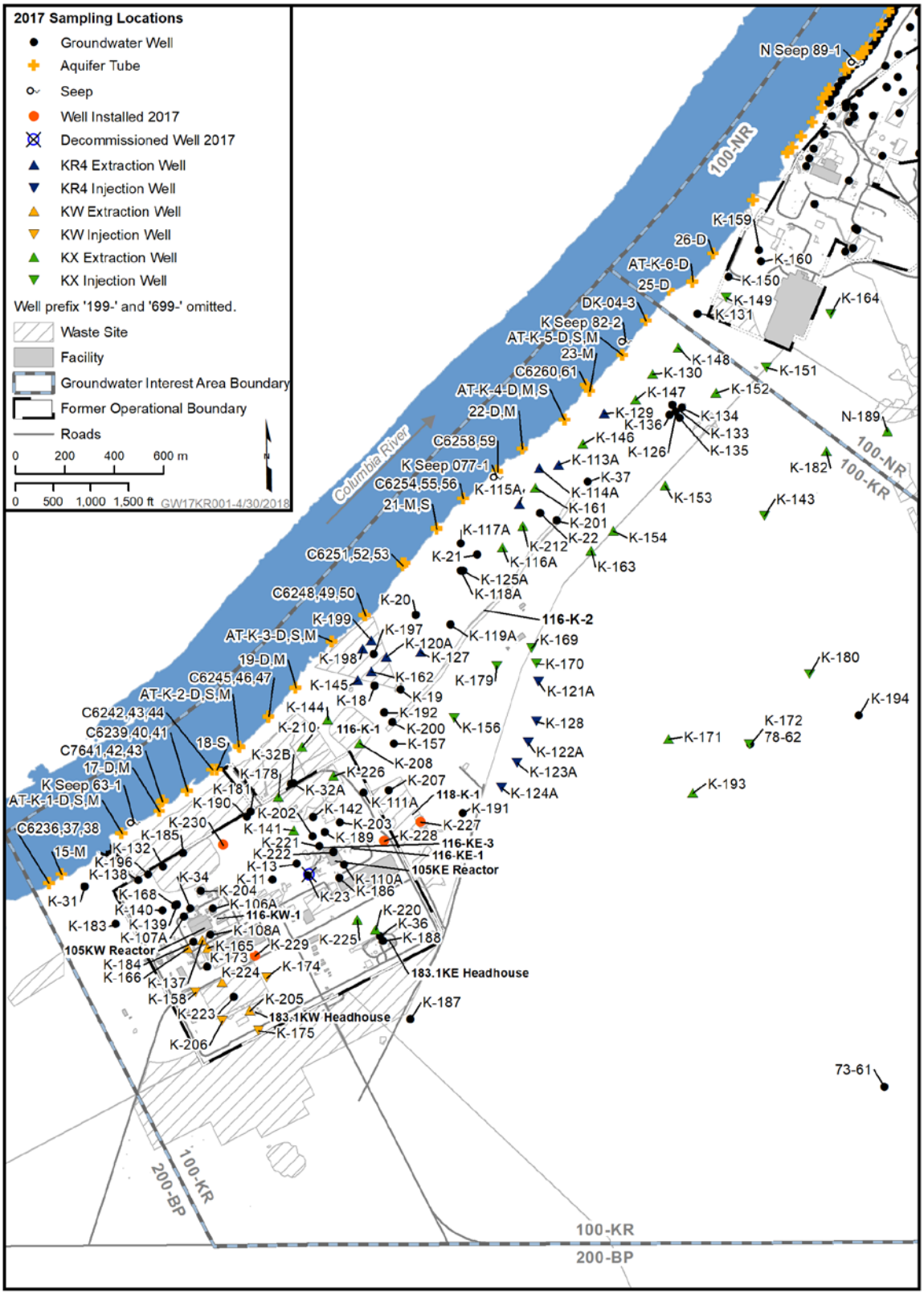


Figure 3-2. 100-KR-4 OU 2017 Remedial System Wells, Monitoring Wells, and Aquifer Sampling Tubes

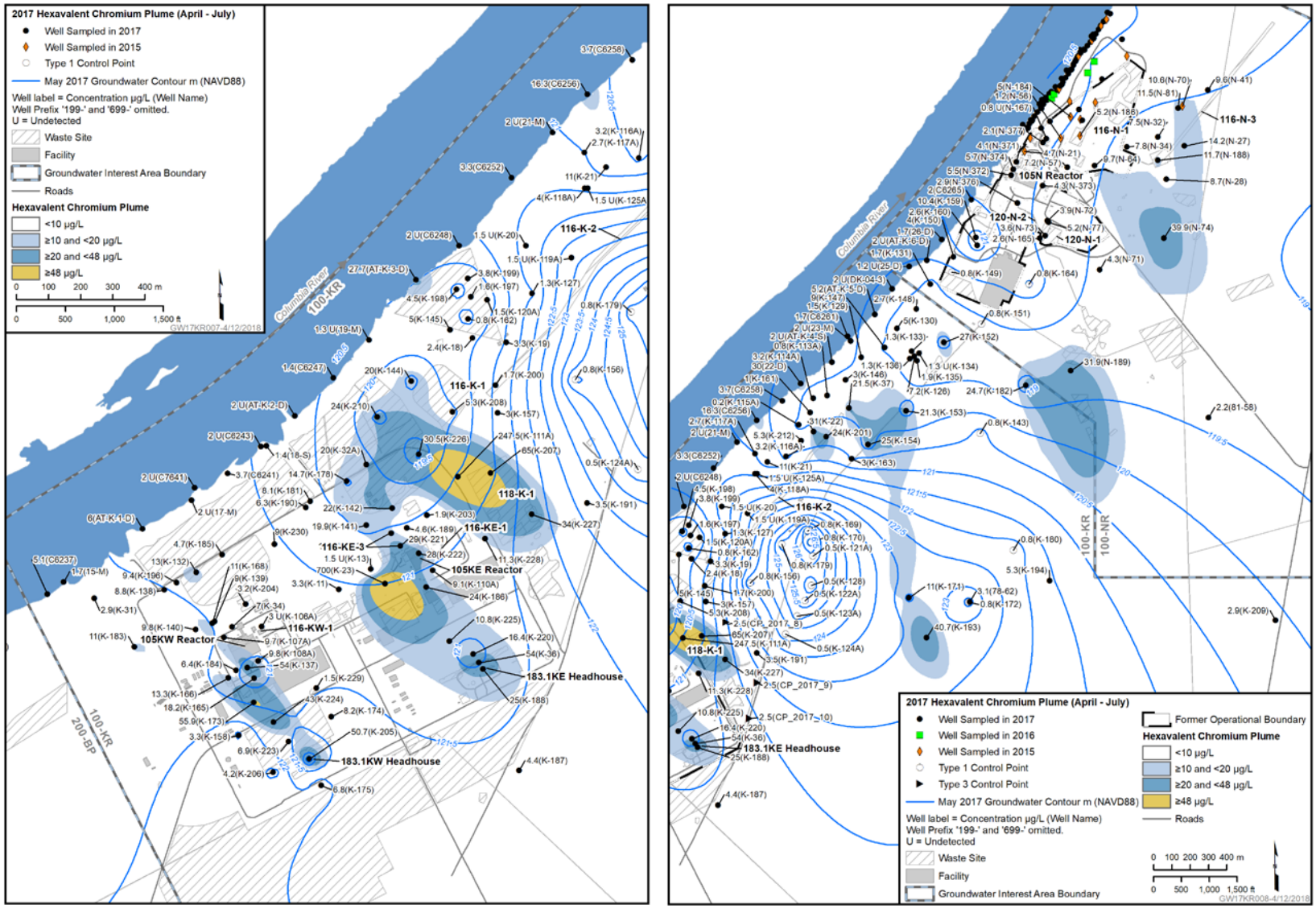


Figure 3-3. Cr(VI) Plume Distribution in Groundwater at the 100-KR-4 OU (High River-Stage, 2017)

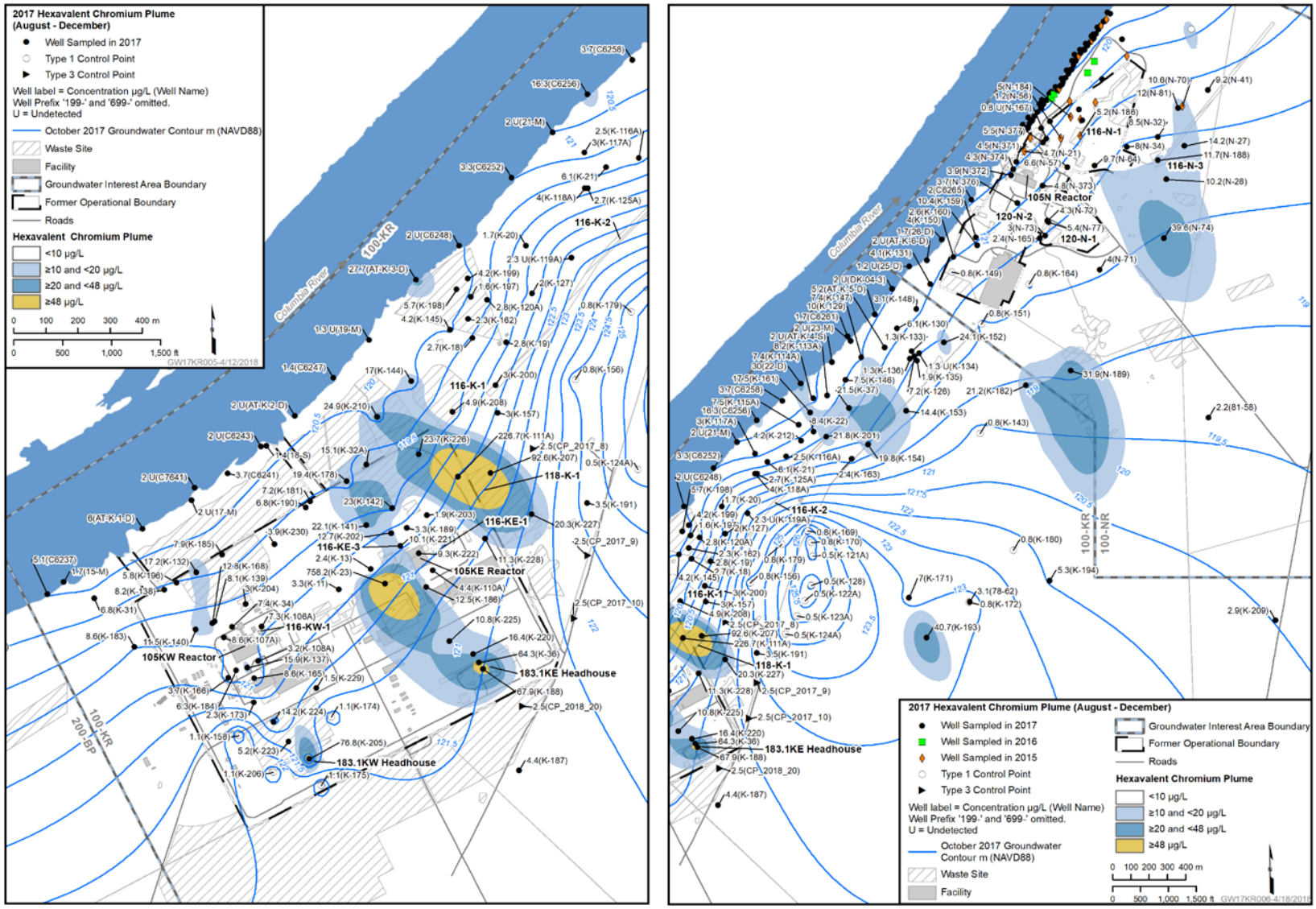


Figure 3-4. Cr(VI) Plume Distribution in Groundwater at the 100-KR-4 OU (Low River-Stage, 2017)

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 the 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 100-KR-4 OU P&T evaluation for 2017, including the following:

- Section 3.2 discusses the interim action groundwater remediation activities.
- Section 3.3 discusses the radiological dose analysis of the effluent from the 100-KR-4 OU P&T systems.
- Section 3.4 provides the remedial action cost summary.
- Section 3.5 presents conclusions on 2017 remedy performance for the 100-KR-4 OU.

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

Changes to the 100-KR-4 OU interim action P&T systems during 2017 (Table 3-1) included installing additional wells for monitoring, extraction, and injection; realigning selected existing wells for use as extraction or injection wells; and restarting the KW P&T after completion of the rebound study. Well installation and realignment were intended to enhance hydraulic plume capture, reduce Cr(VI) plume concentrations, and remove mass from source areas. Figure 1-7 in Chapter 1 shows the locations of the new and realigned wells for 2017.

Table 3-1. 100-KR-4 Groundwater OU Remedial System Well Changes Initiated in 2017

System	Well	Action	Purpose	Status as of December 31, 2017
100-KR4	None	No realignments in 2017		
100-KW	199-K-166 199-K-165 199-K-137 199-K-205	Reconnect extraction wells to KW P&T system	Restart extraction from identified wells following observed rebound in well area	Restarted KW P&T in April 2017 to extract from selected wells
	199-K-224	Aligned monitoring well as new extraction well to the KW P&T system	Improve capture downgradient of high concentration plume at former KW Head House	Completed in May 2017
	199-K-158 199-K-206 199-K-174 199-K-175	Reconnect injection wells to KW P&T system	Restart injection for plume control	Restarted KW P&T in April 2017
100-KX	199-K-181	Disconnect extraction well from the KX P&T system	Disconnect low concentration well to improve mass removal at other locations	Completed in March 2017
	199-K-226	Aligned monitoring well as new extraction well to KX P&T system	Target mass removal	Completed in May 2017

Table 3-1. 100-KR-4 Groundwater OU Remedial System Well Changes Initiated in 2017

System	Well	Action	Purpose	Status as of December 31, 2017
100-KX	199-K-131 199-N-189	Realignment to disconnect extraction well 199-K-131 and connect well 199-N-189 to the KX P&T system	Increase mass removal	Completed in August 2017
	199-K-193	Aligned monitoring well as new extraction well to the KX P&T system	Target mass removal	Completed in October 2017
	199-K-159 199-K-160 199-K-149 199-K-151	Realignment to convert injection wells 199-K-159 and 199-K-160 to monitoring wells, and monitoring wells 199-K-149 and 199-K-151 to injection wells for the KX P&T system	Improve plume containment	Completed in July 2017
	199-K-220 199-K-225	Disconnect extraction wells 199-K-220 and 199-K-225 from the KX P&T system	Enable backfill of 183.2KE sedimentation basin	Completed in October 2017

P&T = pump and treat

3.1.2 Remedial Investigation/Feasibility Study Activities

An RI/FS was conducted to support the ROD for final action for the 100-K Area in 2010 and 2011. Draft A of the RI/FS report (DOE/RL-2010-97) was submitted for regulatory review in September 2011. EPA and DOE identified a need for additional characterization beneath the KE Reactor FSB and the 116-KE-3 FSB crib/reverse well to fill a data gap regarding the nature and extent of vadose zone contamination around the reactor structures before issuing Rev. 0 of the RI/FS report. These characterization activities, including drilling two exploratory boreholes (199-K-221 and 199-K-222), collecting and analyzing subsurface soil and groundwater samples, and completing the two boreholes as monitoring wells, were performed during 2015. Contaminated soil and groundwater were observed beneath the two waste sites. SGW-60149, *Report for Soil Borings and Well Installations in the UPR-100-K-1 and 116-KE-3 Waste Sites*, documents the observations and analytical results from soil and groundwater samples. The results will be incorporated into the revision of the RI/FS report, which began in 2017.

3.1.3 Other CERCLA Document and Plans

Tri-Party Agreement Change Notice (TPA-CN-0797, *Tri-Party Agreement Change Notice Form: DOE/RL-2013-29, Sampling and Analysis Plan for the 100-KR-4 Groundwater Operable Unit Monitoring, Rev. 0*) was signed in 2017, modifying DOE/RL-2013-29, *Sampling and Analysis Plan for the 100-KR-4 Groundwater Operable Unit Monitoring*. The change notice updated the 100-KR-4 OU

SAP to include newly installed wells and updated sampling requirements for wells that may have been realigned or decommissioned.

In May 2016, DOE finalized and issued the KW rebound study SAP (DOE/RL-2016-42, *Sampling and Analysis Plan for KW Pump and Treat System Rebound Study*). The purpose of the SAP was to define the sampling requirements for wells affected by the KW P&T during system shutdown. The SAP was designed to assess the completion of the interim action. The original sampling performance period was May 30, 2016, through September 30, 2016. Based on initial sampling results, which indicated that increasing Cr(VI) concentrations were limited to an area near the 183KW Head House, a Tri-Party Agreement (Ecology et al., 1989) change notice was prepared to extend the duration of the rebound study and associated sampling. TPA-CN-0752, *TPA Change Notice for DOE/RL-2016-42 Sampling and Analysis Plan for KW Pump and Treat System Rebound Study Rev. 0*, was signed on September 29, 2016, modifying the sampling requirements for some locations and extending the period of performance until March 2017. The results of the rebound study are documented in SGW-62061. Sections 5.2 through 5.8 in DOE/RL-2017-66 discusses the analytical results from samples collected between January 1 and March 31, 2017.

3.2 100-KR-4 Operable Unit Interim Remedial Action Activities

This section summarizes the activities related to operation and performance monitoring of the KR4, KW, and KX P&T systems during 2017. 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, hydraulic monitoring, 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 1-6 in Chapter 1). 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 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 9,006 million L (2,378 million gal) of groundwater and has removed 379 kg of Cr(VI). The KR4 P&T system has remediated much of the original Cr(VI) plume along the central 116-K-2 Trench to concentrations less than 20 µg/L. Contamination greater than 20 µg/L remains in the groundwater at both ends of the trench and inland areas. The plume dissection was caused by extracting high-concentration groundwater along the trench and injecting treated water into wells near the middle of the trench. The contaminant mass reduction near the central 116-K-2 Trench is reflected in the overall decline in system influent concentrations (Figure 3-5).

During the 2017 high river-stage, all KR4 P&T extraction wells exhibited Cr(VI) concentration of less than 10 µg/L, with the exception of well 199-K-114A. Well 199-K-114A had a single exceedance in May 2017 of 12 µg/L During low river-stage, several KR4 P&T extraction wells exhibited Cr(VI) concentrations that were greater than 10 µg/L but less than 20 µg/L. Continued operation of the KR4 P&T system provides hydraulic containment of groundwater near the Columbia River at the proximal and distal regions of the trench (discussed in Section 3.2.6).

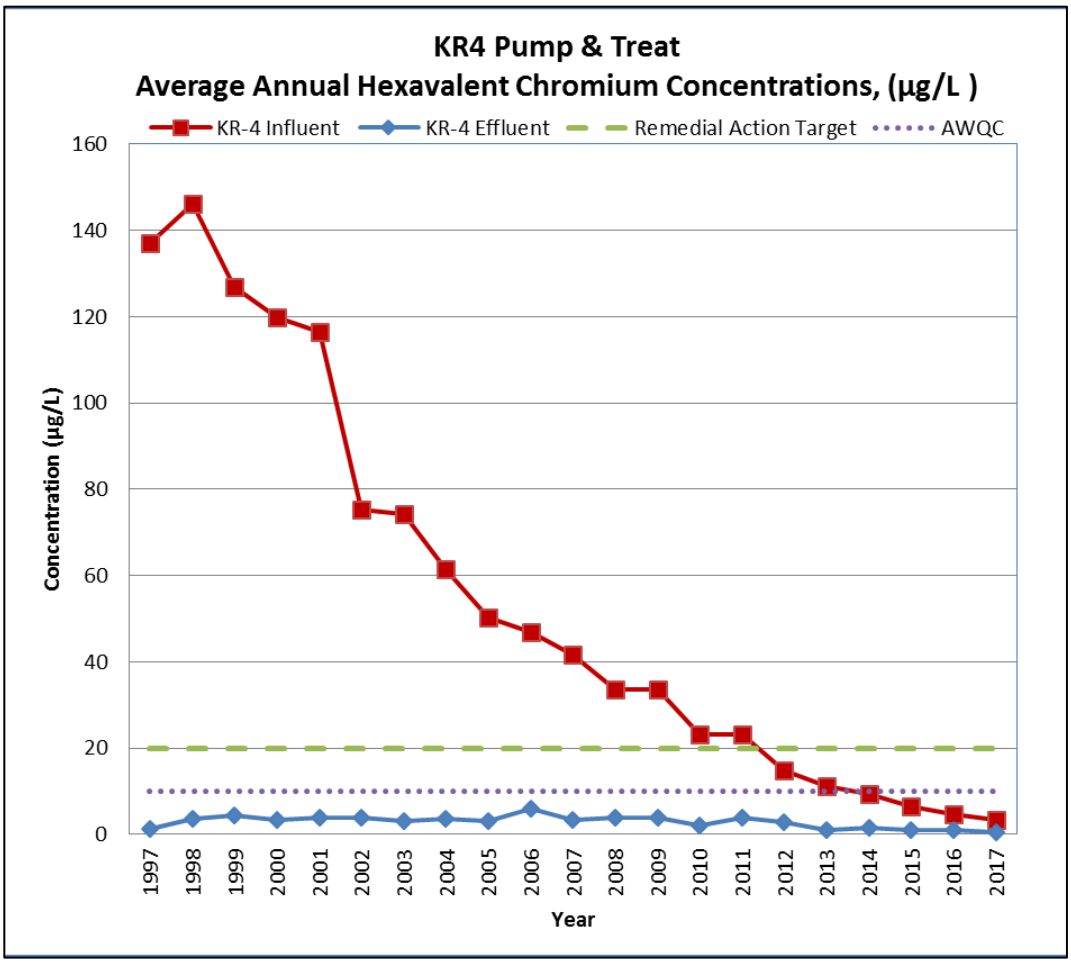


Figure 3-5. KR4 P&T System Annual Average Influent and Effluent Concentrations

3.2.1.1 KR4 Pump-and-Treat System Configuration and Changes

The KR4 P&T system was originally designed to receive and process up to 1,137 L/min (300 gal/min). Over the past several years, optimization activities have increased the operational capacity of the system to 1,249 L/min (330 gal/min). As of December 31, 2017, the system design included 11 extraction wells and 5 injection wells (Figure 3-6). No modifications were made to the KR4 P&T system operating parameters or well field during 2017.

Beginning in December 2017, facility maintenance activities were initiated to repair and replace IX vessel distributors. During this activity, a fine material was observed to have accumulated in the SIR-700 resin. Earlier in the year, a similar material was observed at the KX P&T system (Section 3.2.3.1). These two conditions were assumed to be analogous. As a result, the SIR-700 resin was replaced, and the total amount of resin added to each vessel was decreased at the KR4 P&T system to align with the approach used at the KX P&T system. The resin changeout event continued into early 2018 and is the first since the KR4 P&T system switched over to using the SIR-700 resin in 2012.

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 2017 was 6.73 units; the average effluent pH for this system was 6.99 units. No changes in treatment process chemistry were implemented during 2017.

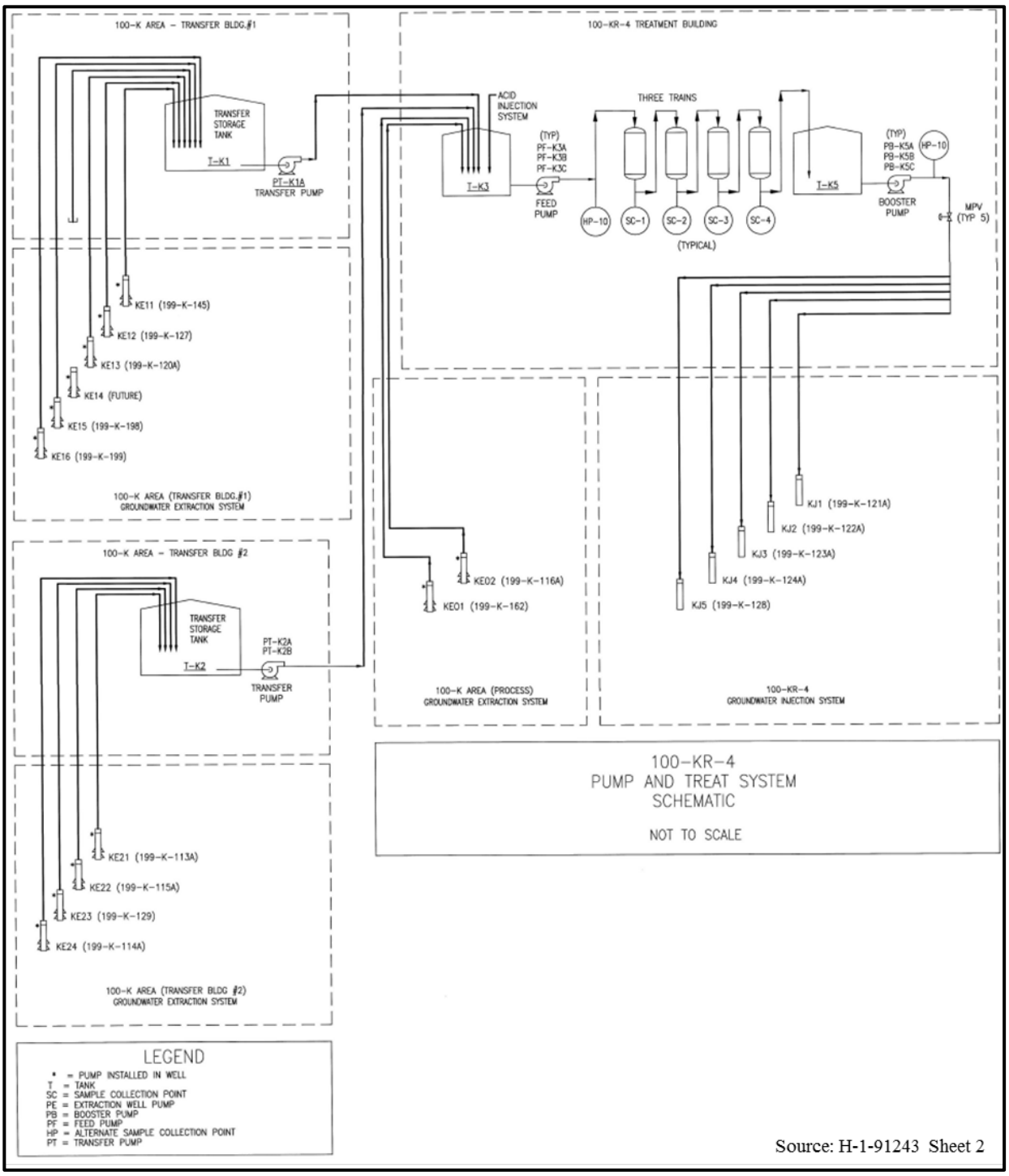


Figure 3-6. KR4 P&T System Schematic (December 31, 2017)

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 2017. Groundwater was processed at an annual average pumping rate of 994 L/min (262 gal/min) during 2017 and the overall run-time was 98.5%. The average Cr(VI) concentration in the P&T system influent for 2017 was 3.3 µg/L (Figure 3-5). The influent concentration ranged from a minimum of 1 µg/L to a maximum of 11 µg/L (Figure 3-7). The maximum Cr(VI) concentration observed in system effluent during 2017 was 8 µg/L, and the average concentration was less than 2 µg/L. Additional operational and system characteristics of the KR4 P&T system for 2017 are summarized as follows:

- A total of 516 million L (136 million gal) of groundwater was treated, and approximately 1.4 kg of Cr(VI) were removed.
- Mass removal efficiency was 61%, which is less than the 77% reported in 2016. The decrease in process removal of Cr(VI) is related to the decreasing concentration in extracted groundwater and not IX resin effectiveness. The effluent concentrations were at or below detection for all process samples, and the average annual influent concentrations have been decreasing over time (Figure 3-5).

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

Total Processed Groundwater	**2016**	**2017**
Total amount of groundwater treated (since September 1997 startup) (million L)	8,484	9,006
Total amount of groundwater treated during CY (million L)	580.0	516
Mass of Cr(VI) Removed		
Total amount of Cr(VI) removed since September 1997 startup (kg)	377.8	379.2
Total amount of Cr(VI) removed in CY (kg)	2.5	1.4
Summary of Operational Parameters		
Average pumping rate (L/min)	1,116	994.3
Average Cr(VI) influent concentration (µg/L)	4.8	3.3
Average Cr(VI) effluent concentration (µg/L)	<2	<2
Removal efficiency (% by mass)	77.1[a]	60.7[a]
Waste generation (m^3)	0	0[c]
Regenerated resin installed (m^3)	0	0
New resin installed (m^3)	0	2.4
Number of resin vessel changeouts	0	8.8[d]

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

Total Processed Groundwater	2016	2017
Summary of Co-Contaminants Detected in Effluent		
Average tritium concentration (pCi/L)	3,560	2,470
Average nitrate concentration (µg/L)	10,200	11,325
Average strontium-90 concentration (pCi/L)	2.3	2.7
Average carbon-14 concentration (pCi/L)	8.5	32.3
Average total chromium concentration (µg/L)	3.1	3.4
Summary of System Availability		
Total possible run-time (hours)	8,784	8,760
Total time online (hours)	8,659	8,630
Total availability (%)[b]	98.6	98.5

a. The low removal efficiency is because of the low influent concentration.

b. Calculated as [(total time online) ÷ (total possible run-time)].

c. Resin containers not shipped in 2017 due to requested reanalysis.

d. Resin offloaded from four ion-exchange vessels in December for diffuser repairs. Repairs and resin reloading not completed until 2018.

Cr(VI) = hexavalent chromium

CY = calendar year

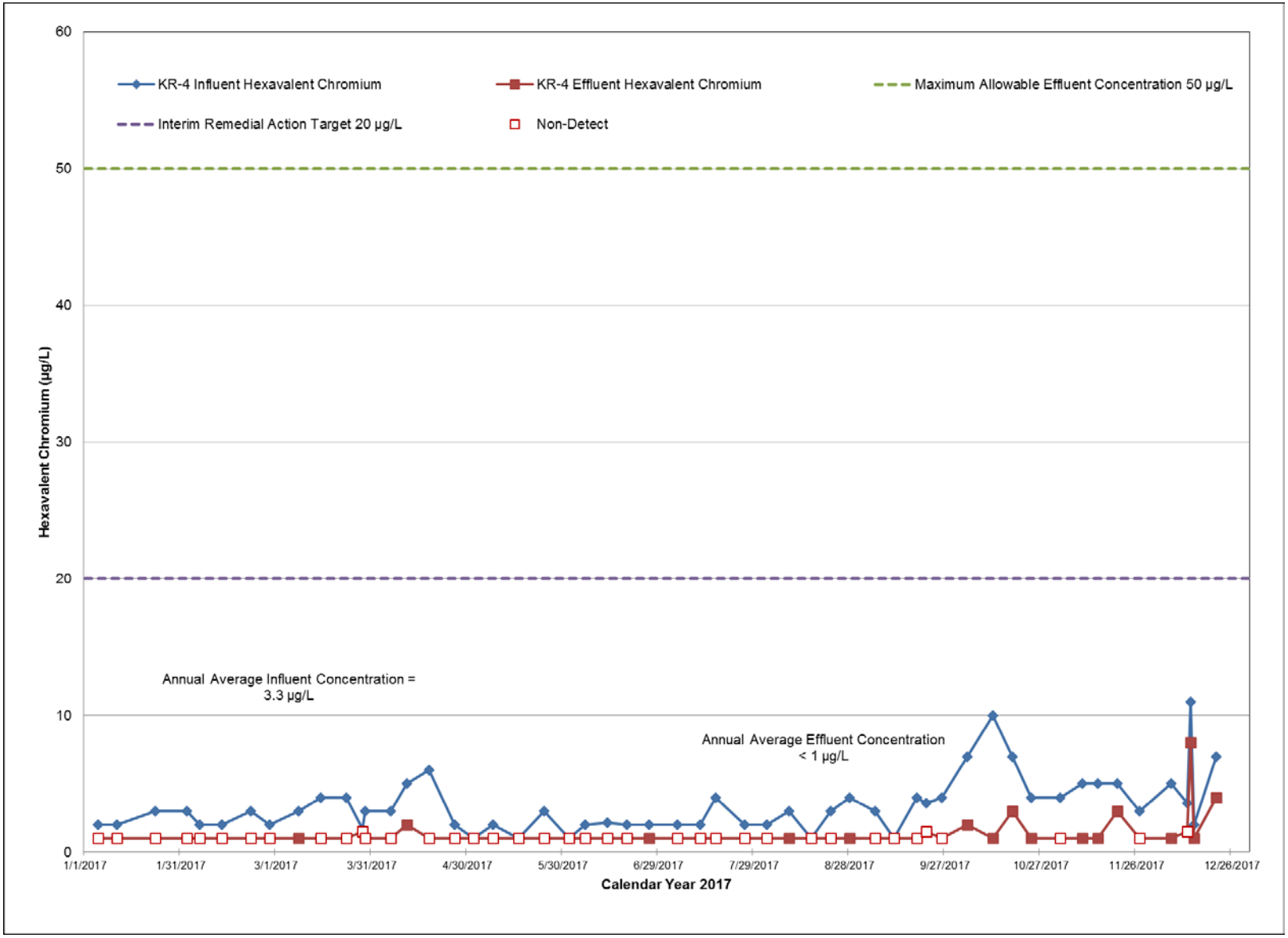


Figure 3-7. KR4 P&T System Trends of Influent and Effluent Cr(VI) Concentrations, 2017

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 connected to the KR4 P&T system during 2017. The average flow rate was calculated by dividing the total volume extracted by the hours of pumping. Some 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. Figure 3-8 shows the monthly online availability for the KR4 P&T system for 2017. Beginning in May 2017, the average flow rate through the KR4 P&T system was reduced to support planned facility repairs and maintenance activities.

Co-contaminants including carbon-14, nitrate, strontium-90, and tritium were detected in the effluent from the KR4 P&T system during 2017. These contaminants are unaffected by the SIR-700 resin treatment system and, therefore, pass through the system. The annual average concentration for each co-contaminant is listed in Table 3-2. All effluent concentrations were less than their respective DWSs. TCE was not analyzed at the KR4 P&T system.

Table 3-3. Flow Rates and Total Run-Times for KR4 P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Yearly Average Flow Rate, L/min (gal/min)	Total Flow Hours in 2017	Total Run-Time* (%)	Purpose
C5940	199-K-162	KE01	125.4 (33.1)	8,736	100	Extraction
B2803	199-K-116A	KE02	107 (28.2)	8,736	100	Extraction
C5361	199-K-145	KE11	108.8 (28.7)	6,672	76	Extraction
C3662	199-K-127	KE12	106.6 (28.1)	7,512	86	Extraction
B2807	199-K-120A	KE13	109.6 (28.9)	8,712	99	Extraction
C7698	199-K-198	KE15	114 (30.1)	8,712	99	Extraction
C7699	199-K-199	KE16	102.8 (27.1)	8,712	99	Extraction
B2800	199-K-113A	KE21	48.5 (12.8)	8,736	100	Extraction
B2802	199-K-115A	KE22	75.4 (19.9)	8,448	96	Extraction
C4117	199-K-129	KE23	40.8 (10.8)	8,736	100	Extraction
B2801	199-K-114A	KE24	99.5 (26.3)	8,736	100	Extraction
B2808	199-K-121A	KJ1	149.4 (39.4)	8,736	100	Injection
B2809	199-K-122A	KJ2	263.9 (69.7)	8,736	100	Injection
B2810	199-K-123A	KJ3	131.2 (34.6)	8,184	93	Injection
B2811	199-K-124A	KJ4	148.6 (39.2)	8,736	100	Injection
C3663	199-K-128	KJ5	288.5 (76.2)	8,712	99	Injection

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

CY = calendar year
ID = identification
P&T = pump and treat
PLC = programmable logic controller

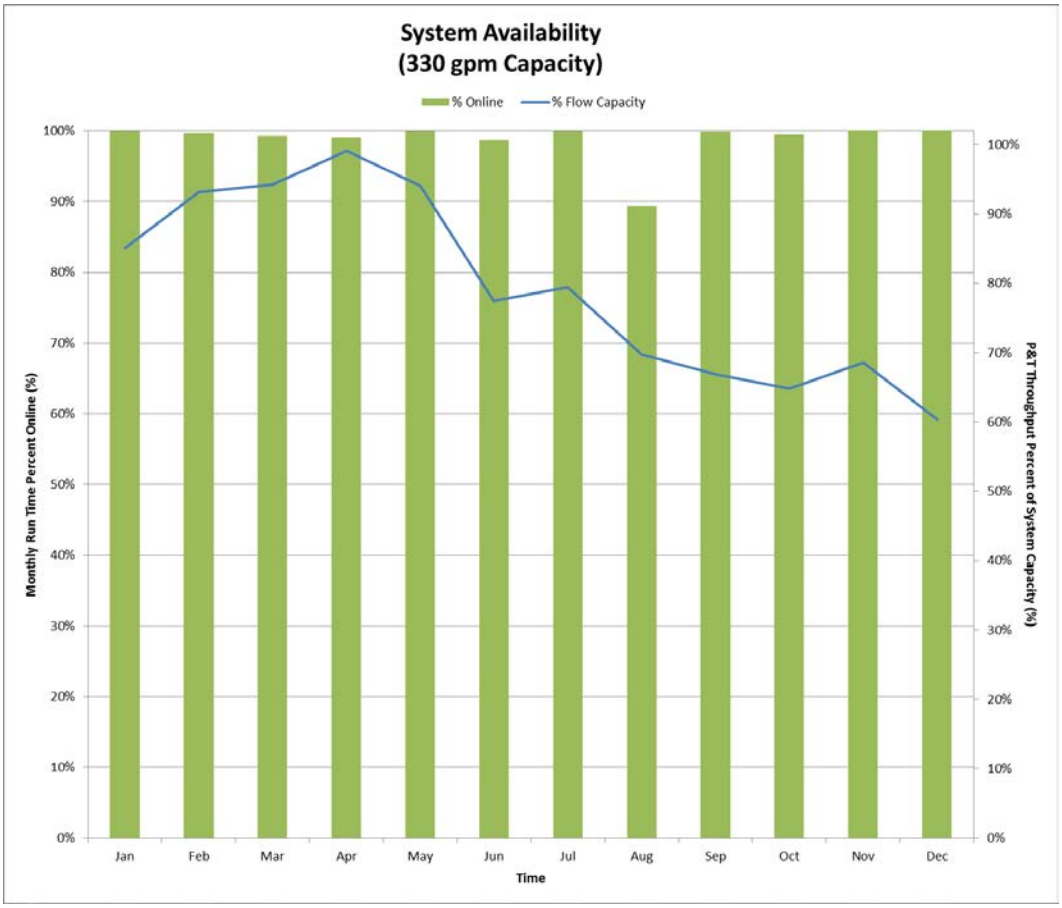


Figure 3-8. Monthly KR4 P&T System Availability, 2017

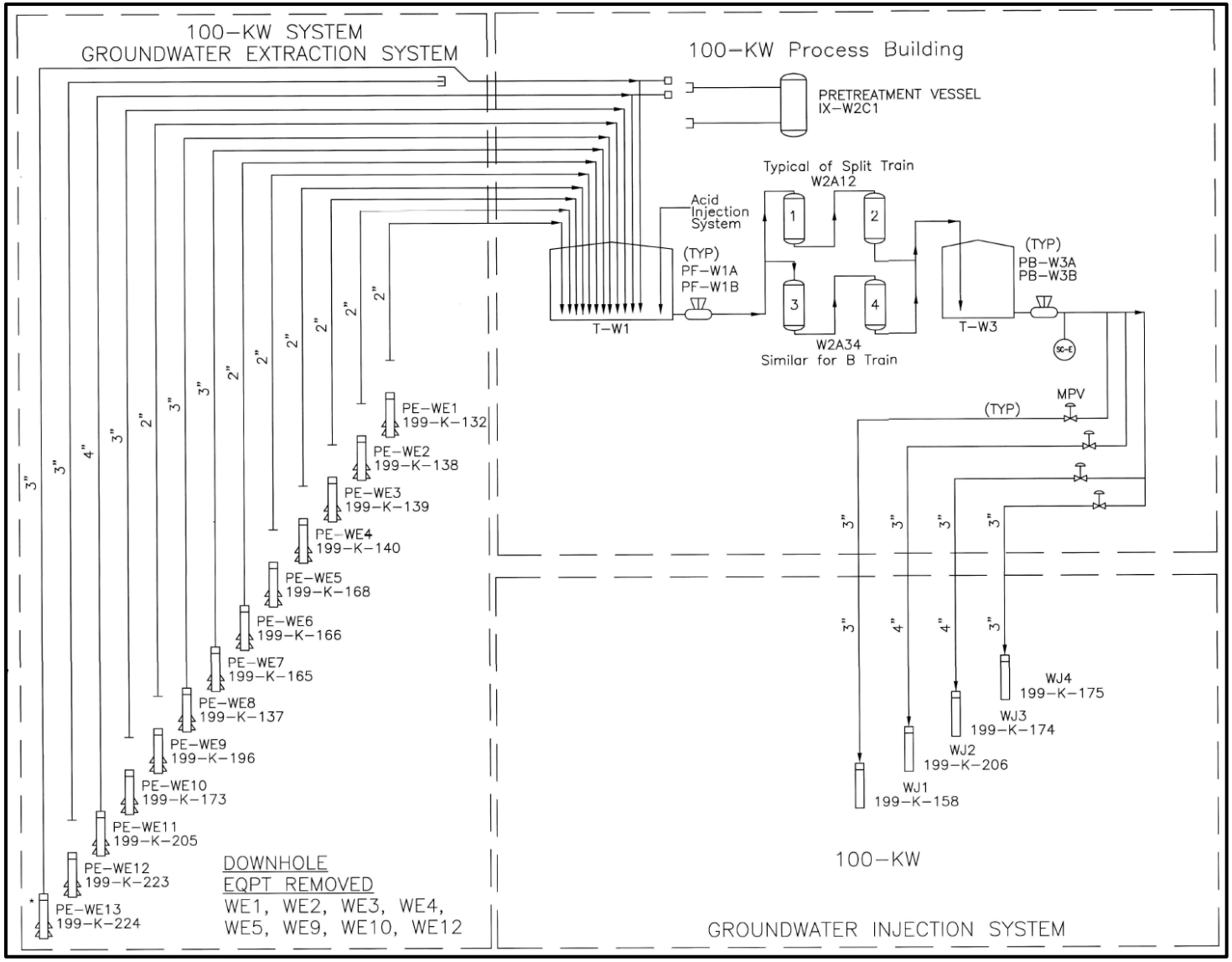
3.2.2 KW Pump-and-Treat System

The KW P&T system was installed to address Cr(VI) groundwater contamination in the KW Reactor vicinity (Figure 3-2). The system began operating on January 29, 2007, and has treated over 4,242 million L (1,120 million gal) of groundwater and removed 255.5 kg of Cr(VI) since startup. The sources of Cr(VI) in the groundwater were intentional and unplanned release (UPRs) of water treatment chemicals near the 183.1KW Head House. 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.

3.2.2.1 KW Pump-and-Treat System Configuration and Changes

The KW P&T system was originally designed to receive and process up to 757 L/min (200 gal/min). Optimization activities have increased the operational capacity of the system to 1,249 L/min (330 gal/min). As of December 31, 2017, the system design included five extraction wells and four injection wells (Figure 3-9).

From May 16, 2016, through April 12, 2017, the KW P&T system was shut down for a rebound study to evaluate the potential for continuing sources in the area affected by the system. When the system restarted in April, the well field was modified to focus extraction efforts between the KW Reactor and the 183.1KW Head House area, where Cr(VI) concentrations rebounded. Monitoring well 199-K-224, which was installed in 2016, was converted to an extraction well and began operating in May 2017. The KW P&T system continued to operate using the two-vessel train configuration and SIR-700 resin.



Source: Hanford Drawing H-1-89139, Sheet 1.

Figure 3-9. KW Reactor Area P&T System Schematic (as of December 31, 2017)

Process stream pH is measured near the inlet to the IX vessels and before the treated process effluent is discharged from the plant. After system restart, the average influent pH for the KW P&T system during 2017 was 6.78 units and ranged from 6.25 to 7.06; the average effluent pH for this system was 6.78 units and ranged from 6.59 to 7.33. No changes in treatment process chemistry were implemented during 2017.

3.2.2.2 KW Pump-and-Treat System Performance

Table 3-4 presents an overview of the operational parameters and total system performance for the KW P&T system during 2017. After system restart in April, the system processed groundwater at an annual average pumping rate of 1,162 L/min (307 gal/min) and operated at an overall run-time of 97%. The Cr(VI) concentration in the P&T system influent averaged 35.1 µg/L, which is about three times greater than the 2016 average influent concentration of 12.4 µg/L (Figure 3-10). The influent concentration ranged from 18 to 56 µg/L in 2017 (Figure 3-11). Influent concentration decreased from May through July but began to increase at the end of July through August. From September through the end of December, the Cr(VI) concentration decreased to about 20 µg/L.

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

Total Processed Groundwater	**2016[a]**	**2017[b]**
Total groundwater treated since January 2007 startup (million L)	3,807	4,242
Total groundwater treated in CY (million L)	241.5	432.7
Mass of Cr(VI) Removed		
Total Cr(VI) removed since January 2007 startup (kg)	241.1	255.5
Total Cr(VI) removed in CY (kg)	2.9	14.4
Summary of Operational Parameters		
Average pumping rate (L/min)	1,229	1,162.3
Average Cr(VI) influent concentration (µg/L)	12.4	35.1
Average Cr(VI) effluent concentration (µg/L)	<2	<2
Removal efficiency (% by mass)	90.8	96.4
Waste generation (m^3)	0	0.83
Regenerated resin installed (m^3)	0	0
New resin installed (m^3)	0	0
Number of resin vessel changeouts	0	0
Summary of Co-Contaminants Detected in Effluent[c]		
Average tritium concentration (pCi/L)	—	1,418
Average nitrate concentration (µg/L)	—	23,040
Average strontium-90 concentration (pCi/L)	—	1.4
Average carbon-14 concentration (pCi/L)	—	317
Average TCE concentration (µg/L)	—	3.3

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

Average total chromium concentration (µg/L)	—	3.0
Summary of System Availability[a,b]		
Total possible run-time (hours)	3,288	6,312
Total time online (hours)	3,272.5	6,131
Total availability (%)[d]	99.5	97.1

a. 2016 system parameter calculated based on the operational period between January 1 and May 16, 2016, prior to system shutdown for a rebound study.

b. 2017 system parameter calculated based on the operational period between April 12 and December 31, 2017.

c. Influent and effluent samples for co-contaminants where not collected in 2016 due the rebound study.

d. Total availability is calculated as [(total time online) ÷ (total possible run-time)].

— = KW P&T was shut down for rebound study

Cr(VI) = hexavalent chromium

CY = calendar year

TCE = trichloroethene

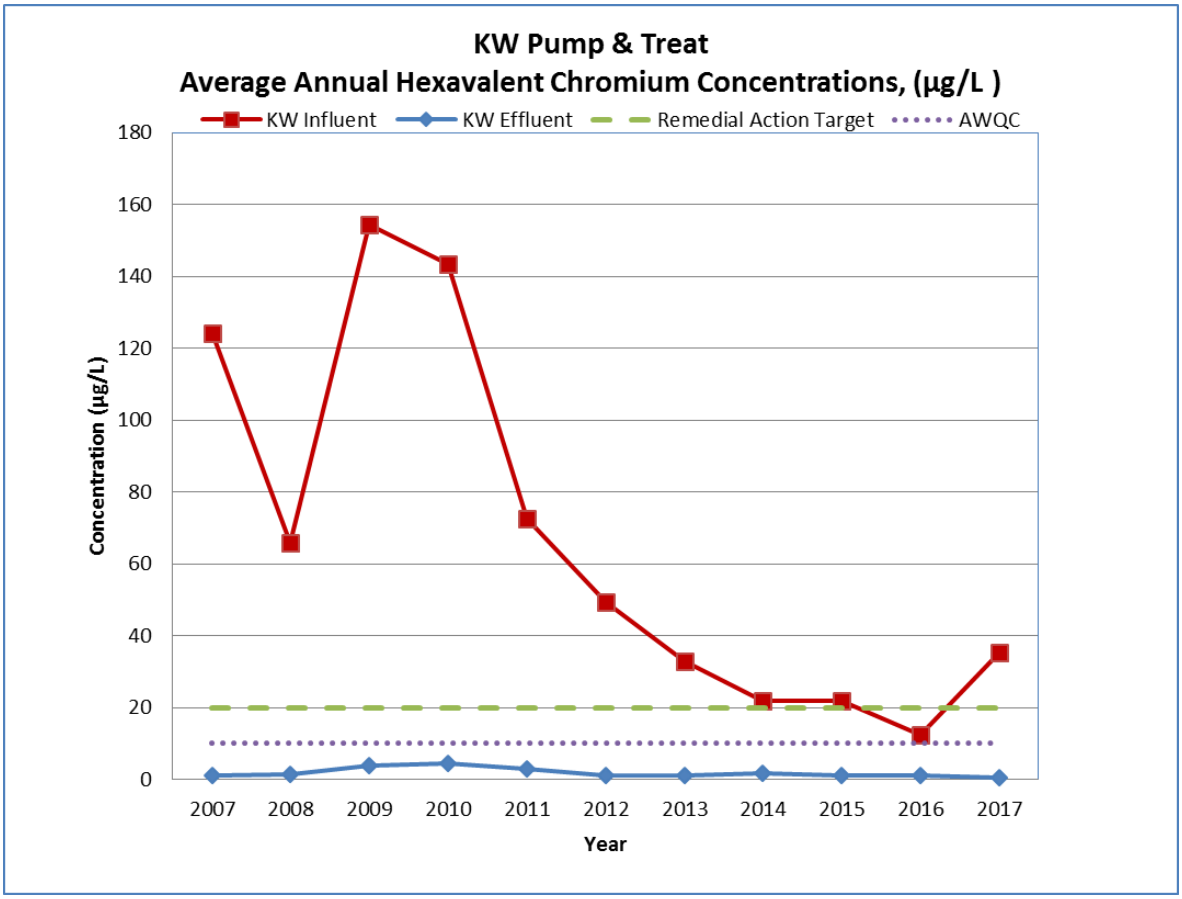


Figure 3-10. KW P&T System Annual Average Influent and Effluent Concentrations

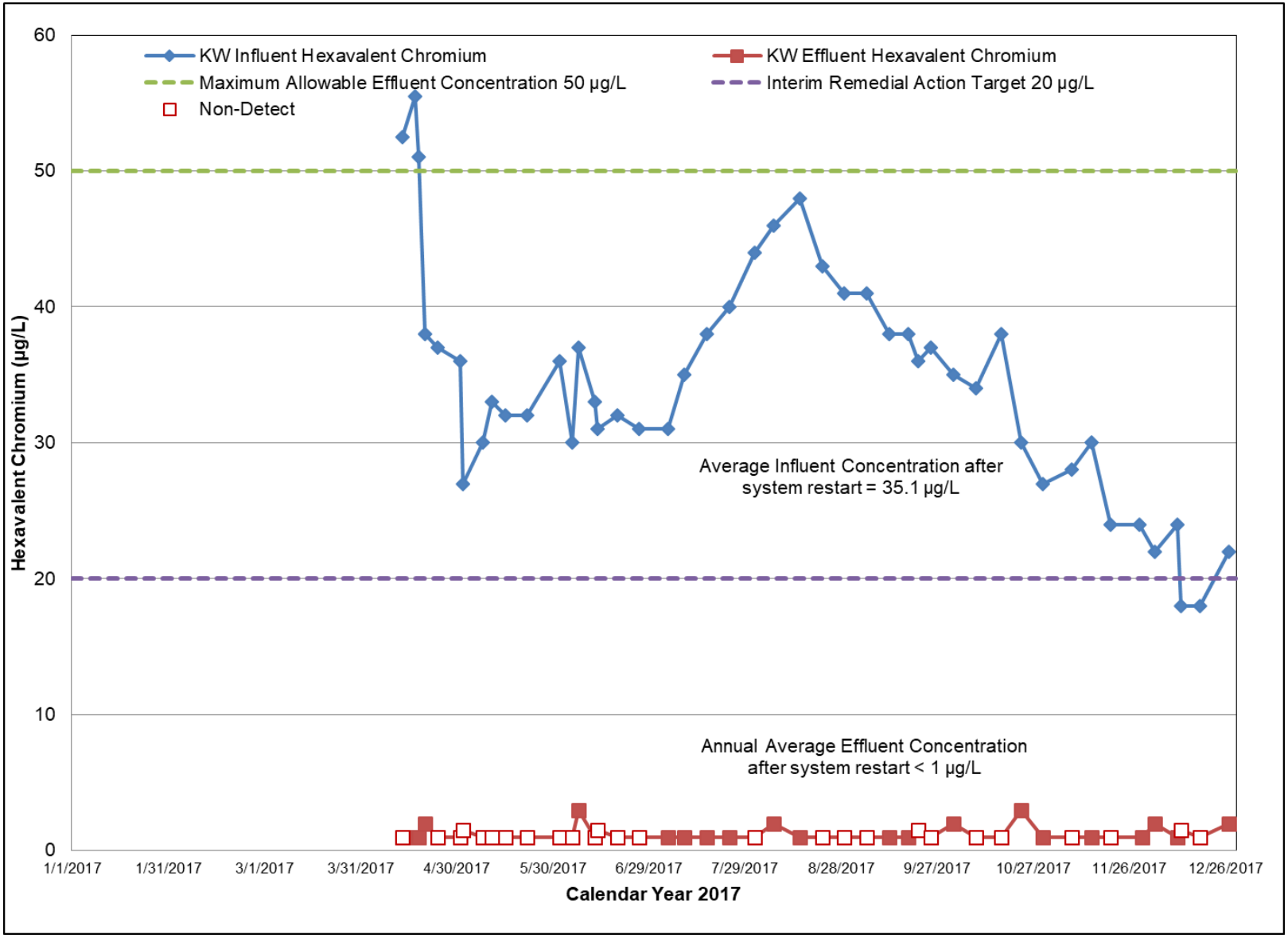


Figure 3-11. KW P&T Trends for Influent and Effluent Cr(VI) Concentrations, 2017

The Cr(VI) concentration observed in the system effluent during 2017 ranged below detection to a maximum of 3 µg/L. A concentration of 12 µg/L was reported on November 27, 2017. This sample is considered suspect since a confirmatory sample collected 2 days later was below detection. Additional operation and system characteristics of the KW P&T system for 2017 are summarized as follows:

- A total of 433 million L (114.3 million gal) of groundwater was treated in 2017, and approximately 14.4 kg of Cr(VI) were removed.
- The average mass removal efficiency was 96.4%, an increase from 2016 (Table 3-4), as extraction focused on areas of Cr(VI) concentration rebound.

Table 3-5 presents the pumping flow rates and total run-time percentage for each extraction and injection well connected to the KW P&T system during 2017 after system restart. The average flow rate was calculated by dividing the total volume extracted by the hours of pumping after the system was restarted on April 12, 2017. All wells were subject to downtime for repair and/or maintenance activities during the year. The downtime is reflected in the yearly average flow-rate calculations and the total run-time percentages for each extraction well. Figure 3-12 shows the monthly online availability for the KW P&T system for 2017. For 2017, the KW P&T system operated at less than 100% during startup in April and experienced minor outages in June and August.

Table 3-5. Flow Rates and Total Run-Times for KW P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Average Flow Rate (L/min [gal/min])	Total Flow Hours in 2017	Total Run-Time[a] (%)	Purpose
C4670	199-K-132[b]	WE1	0 (0)	0	0	Extraction
C5113	199-K-138[b]	WE2	0 (0)	0	0	Extraction
C5114	199-K-139[b]	WE3	0 (0)	0	0	Extraction
C5115	199-K-140[b]	WE4	0 (0)	0	0	Extraction
C6454	199-K-168[b]	WE5	0 (0)	0	0	Extraction
C6452	199-K-166	WE6	171.4 (45.2)	6,168	97	Extraction
C6451	199-K-165	WE7	243.6 (64.3)	6,168	97	Extraction
C5112	199-K-137	WE8	116.4 (30.7)	5,808	91	Extraction
C7696	199-K-196[b]	WE9	0 (0)	0	0	Extraction
C7016	199-K-173[b]	WE10	0 (0)	0	0	Extraction
C8292	199-K-205	WE11	389.4 (102.8)	6,264	98	Extraction
C9596	199-K-224[c]	WE13	317 (83.7)	5,064	98	Extraction
C5484	199-K-158	WJ1	394.3 (104.1)	6,216	98	Injection
C8293	199-K-206	WJ2	276.5 (73)	6,240	98	Injection
C7061	199-K-174	WJ3	231.7 (61.2)	6,216	98	Injection

Table 3-5. Flow Rates and Total Run-Times for KW P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Average Flow Rate (L/min [gal/min])	Total Flow Hours in 2017	Total Run-Time[a] (%)	Purpose
C7062	199-K-175	WJ4	260.6 (68.8)	6,192	97	Injection

a. Percentage total run-time is calculated by [(days well in operation) ÷ (number of days in the CY)]. The total number of available days in CY 2017 was 263 after system restart on April 12, 2017, following completion of the rebound study.

b. Well remains disconnected from the KW P&T system.

c. Well reconnected May 31, 2017. Percentage total run-time calculation adjusted appropriately.

CY = calendar year

ID = identification

PLC = programmable logic controller

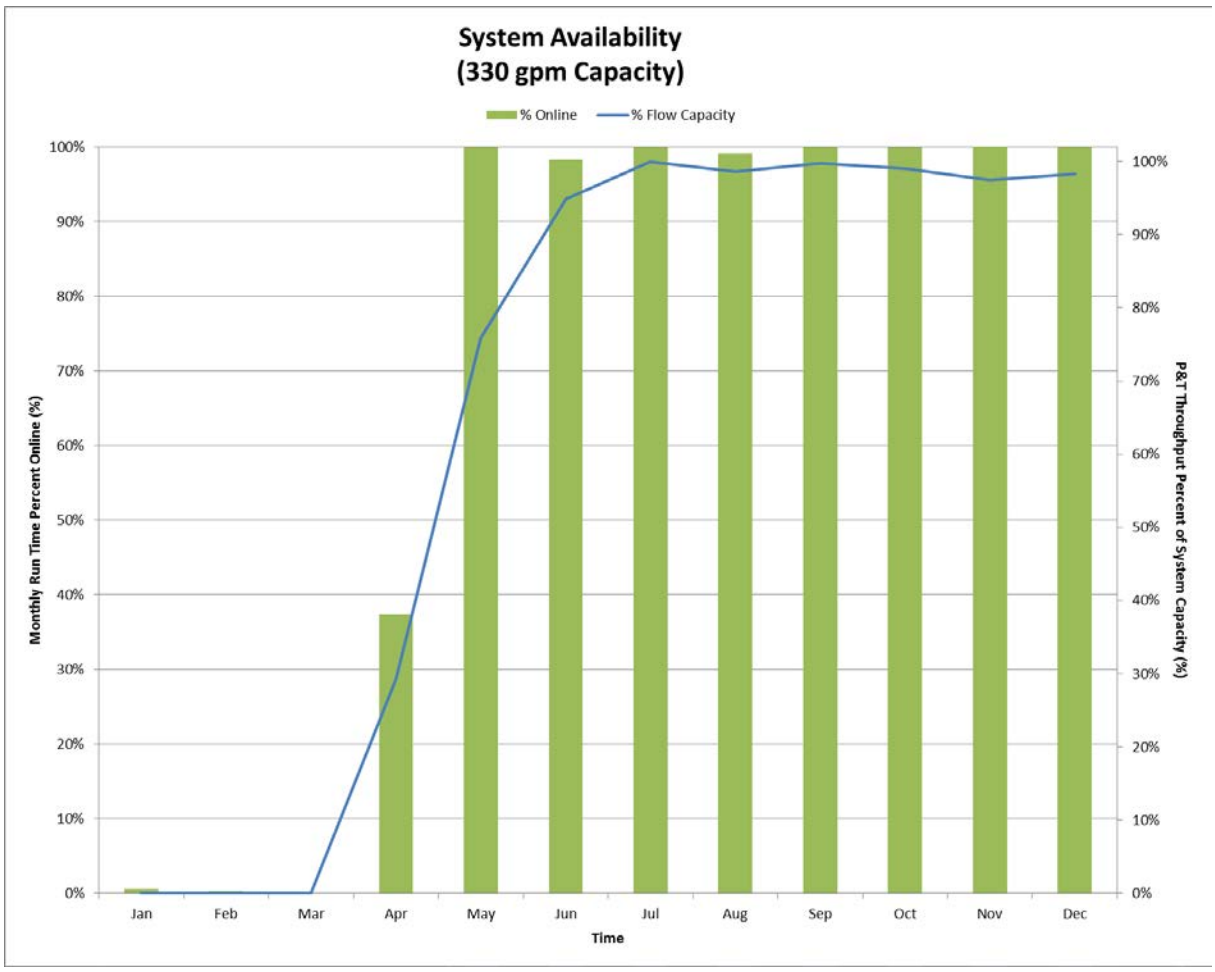


Figure 3-12. Monthly KW P&T System Availability, 2017

Co-contaminants including carbon-14, nitrate, strontium-90, tritium, and TCE were detected in the effluent from the KW P&T system during 2017. These contaminants are unaffected by the SIR-700 resin treatment system and, therefore, pass through the system. Table 3-4 lists the annual average concentration for each co-contaminant. All effluent concentrations were less than their respective DWSs.

3.2.3 KX Pump-and-Treat System

The KX P&T system was primarily designed to treat Cr(VI) found between the northern end of the 116-K-2 Trench and the N Reactor fence line (also known as the K North plume). However, in its current well configuration, the KX P&T system is used for remediating the inland portions of the remaining Cr(VI) outside the influence of the KW P&T system. This includes the commingled Cr(VI) contamination from the 116-K-1 Crib, 116-K-2 Trench, and the 183.1KE Head House; the central plume segment from the 116-K-2 Trench; and the northeastern portion of the 116-K-2 Trench, which extends into the 100-N Area. This system began partial operation in November 2008 and was fully operational in early February 2009. Since startup, the system has treated more than 10,358 million L (2,736 million gal) of water and removed 269.5 kg of Cr(VI).

3.2.3.1 KX Pump-and-Treat System Configuration and Changes

The KX P&T system was originally designed to receive and process groundwater at a rate of up to 2,300 L/min (600 gal/min). Over the past several years, optimization activities have increased the operational capacity of the system to 3,407 L/min (900 gal/min). At the end of 2017, the KX P&T system included 22 extraction wells and 10 injection wells (Figure 3-13). The following highlights modification to the KX P&T system during 2017:

- Disconnected extraction well 199-K-181 from the KE P&T system in March, primarily due to low Cr(VI) concentrations. A secondary benefit was opening a spot in the system for the connection of other wells for removal of mass. This disconnect allows for the realignment of well 199-K-226.
- Converted monitoring well 199-K-226 to a KX P&T extraction well to target mass removal of the KE P&T system Cr(VI) plume in May.
- Disconnected KX P&T extraction well 199-K-131 and connected monitoring well 199-N-189 in August. This realignment improves Cr(VI) mass removal between the 100-KR-4 and 100-NR-2 OUs.
- Converted monitoring well 199-K-193 to a KX P&T extraction well to improve mass removal in the inland Cr(VI) plume in October.
- Disconnected KX P&T system injection wells 199-K-159 and 199-K-160 and converted monitoring wells 199-K-149 and 199-K-151 to injection wells in July. This realignment moved the injection mound closer to the 100-K Area to improve containment.
- Disconnected KX P&T extraction wells 199-K-220 and 199-K-225 to allow for backfilling of the 183.2KE Sedimentation Basins. These wells will be reconnected to the P&T system after backfilling is complete.
- Made several modifications to the KX P&T system, including adding a feed pump, replacing selected PVC components with stainless-steel pipe, and replacing PVC IX vessel distributors with stainless steel. The modifications were designed to enhance system performance and reliability.

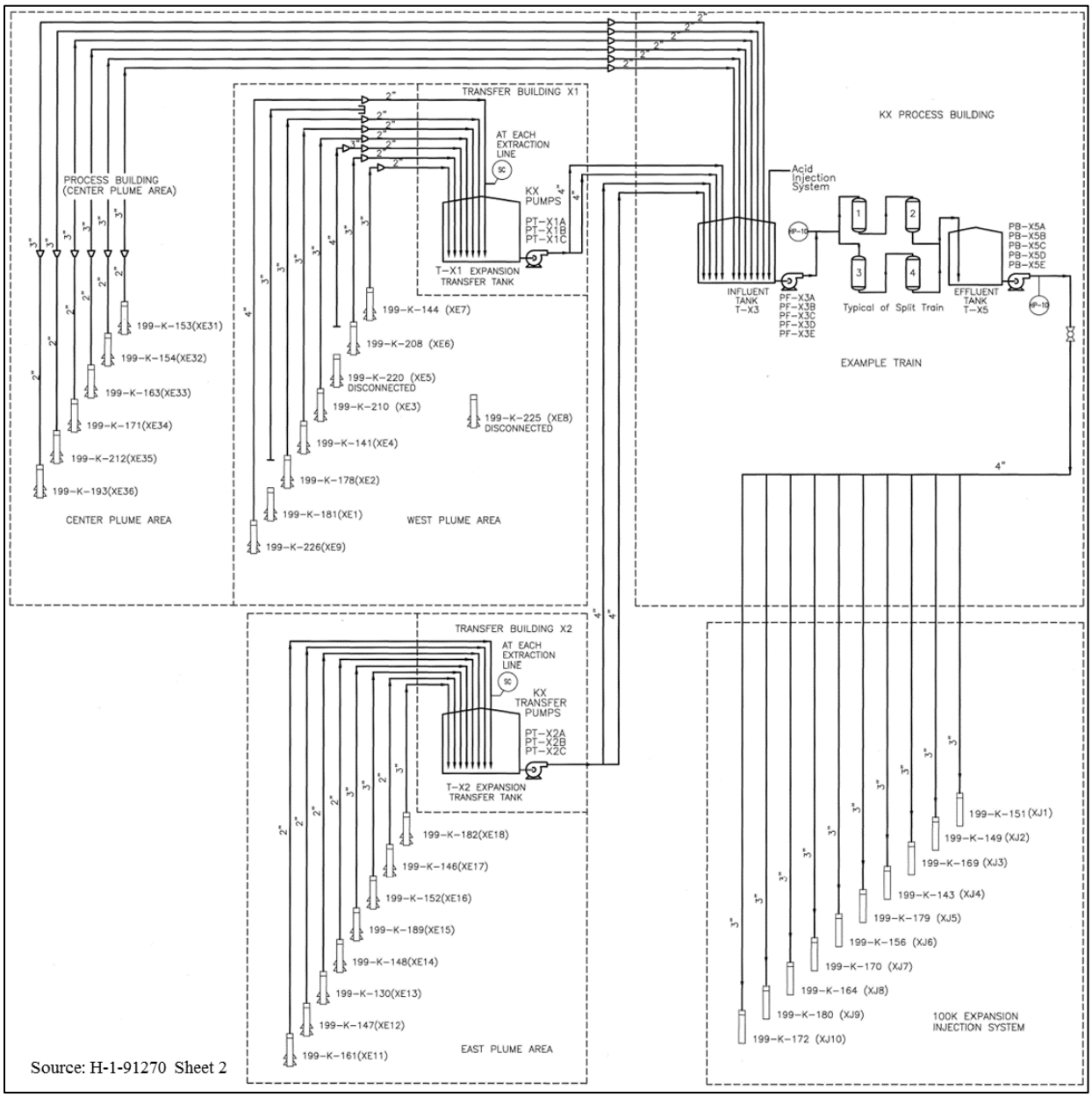


Figure 3-13. KX P&T System Schematic (as of December 31, 2017)

Beginning in May 2017, facility maintenance activities were initiated to repair and replace IX vessel distributors. During this activity, a fine material was observed to have accumulated in the SIR-700 resin. The material was sampled and analyzed, and found to be a combination of finely divided residue of the SIR-700 resin, likely generated by abrasion of the resin during operation and handling, and fine soil which built up in the IX vessels over an extended period of time. After several backwashing events to remove the fine material from the resin, it was determined that replacing the SIR-700 resin was the best approach. To improve efficiency through the vessels, the amount of resin loaded into each of the IX vessels was decreased, which allows for more frequent backwashing of the resin and lower differential pressure though the treatment system.

The average influent pH for KX P&T system in 2017 was 6.76 units; the average effluent pH (i.e., treated water returned to the aquifer) was 7.06 units. No changes in treatment process chemistry were implemented during 2017.

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 2017. Groundwater was processed at an annual average pumping rate of 2,729 L/min (723 gal/min) during 2017 and operated at overall run-time of 93.8%. The decrease in overall run-time was due to maintenance activities that occurred starting in May.

The average Cr(VI) concentration in the P&T system influent for 2017 was 16.1 µg/L and ranged from 10 to 23 µg/L (Figures 3-14 and 3-15). The maximum Cr(VI) concentration observed in the system effluent during 2017 was 6 µg/L, and the average was less than 2 µg/L. Additional operational and system parameters for the KX P&T system for 2017 are as follows:

- A total of 1,359.6 million L (359.2 million gal) of groundwater was treated, and 21.0 kg of Cr(VI) were removed
- The average mass removal efficiency was 90.9%, which is similar to 2016 (Table 3-6)

Table 3-7 presents the pumping flow rates and total run-time percentage for each extraction and injection well connected to the KX P&T system during 2017. The average flow rate was calculated by dividing the total volume extracted by the hours of pumping. For the KX P&T system, all wells were subject to downtime for facility repair and/or maintenance activities during the year. The downtime is reflected in the yearly average flow-rate calculations and the total run-time percentages for each extraction well.

Figure 3-16 shows the monthly online availability for the KX P&T system for 2017. Beginning in May 2017, to support facility maintenance and repair activities, flows to various injection and extraction wells were reduced or the system was shutdown. Maintenance and repair activities include both planned and unplanned events. Some of the major events that impacted the overall run-time of the KX P&T system included the following:

- Adding an additional feed pump
- Replacing selected PVC components with stainless steel
- Replacing PVC IX vessel distributors with stainless steel
- Replacing failed acid pump

By November, plant operation had resumed normal run-time and throughput started to increase to normal operating conditions.

Co-contaminants including carbon-14, nitrate, strontium-90, tritium, and TCE were detected in the effluent from the KX P&T system during 2017. These contaminants are unaffected by the SIR-700 resin treatment system and, therefore, pass through the system. Table 3-6 lists the annual average concentration for each co-contaminant. All effluent concentrations were less than their respective DWSs.

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

Total Processed Groundwater	2016	2017
Total groundwater treated since November 2008 startup (million L)	8,991.9	10,358.1
Total groundwater treated in CY (million L)	1,636.1	1,360
Mass of Cr(VI) Removed		
Total Cr(VI) removed since November 2008 startup (kg)	248.5	269.5
Total Cr(VI) removed in CY (kg)	25.6	21.0
Summary of Operational Parameters		
Average pumping rate (L/min)	3,121	2,729
Average Cr(VI) influent concentration (µg/L)	16.9	16.1
Average Cr(VI) effluent concentration (µg/L)	<2	<2
Removal efficiency (% by mass)	90.6	90.9
Waste generation (m^3)	7.46	25.4[a]
Regenerated resin installed (m^3)	0	0
New resin installed (m^3)	0	16.1
Number of resin vessel changeouts	0	13[c]
Summary of Co-Contaminants Detected in Effluent		
Average tritium concentration (pCi/L)	3,543	4,235
Average nitrate concentration (µg/L)	15,767	14,167
Average strontium-90 concentration (pCi/L)	1.9	2.8
Average carbon-14 concentration (pCi/L)	62.5	48.3
Average TCE concentrations (µg/L)	0.4	<0.25
Average total chromium concentration (µg/L)	5.6	4.9
Summary of System Availability		
Total possible run-time (hours)	8,784	8,760
Total time online (hours)	8,707.5	8,219.6
Total availability (%)[b]	99.1	93.8

a. Waste volume includes resin change out.

b. Total availability is calculated by [(total time online) ÷ (total possible run-time)].

c. Resin changed out for IX vessel diffuser repairs. This number includes nine vessels loaded with new resin and four vessels reloaded with used resin.

Cr(VI) = hexavalent chromium

CY = calendar year

TCE = trichloroethene

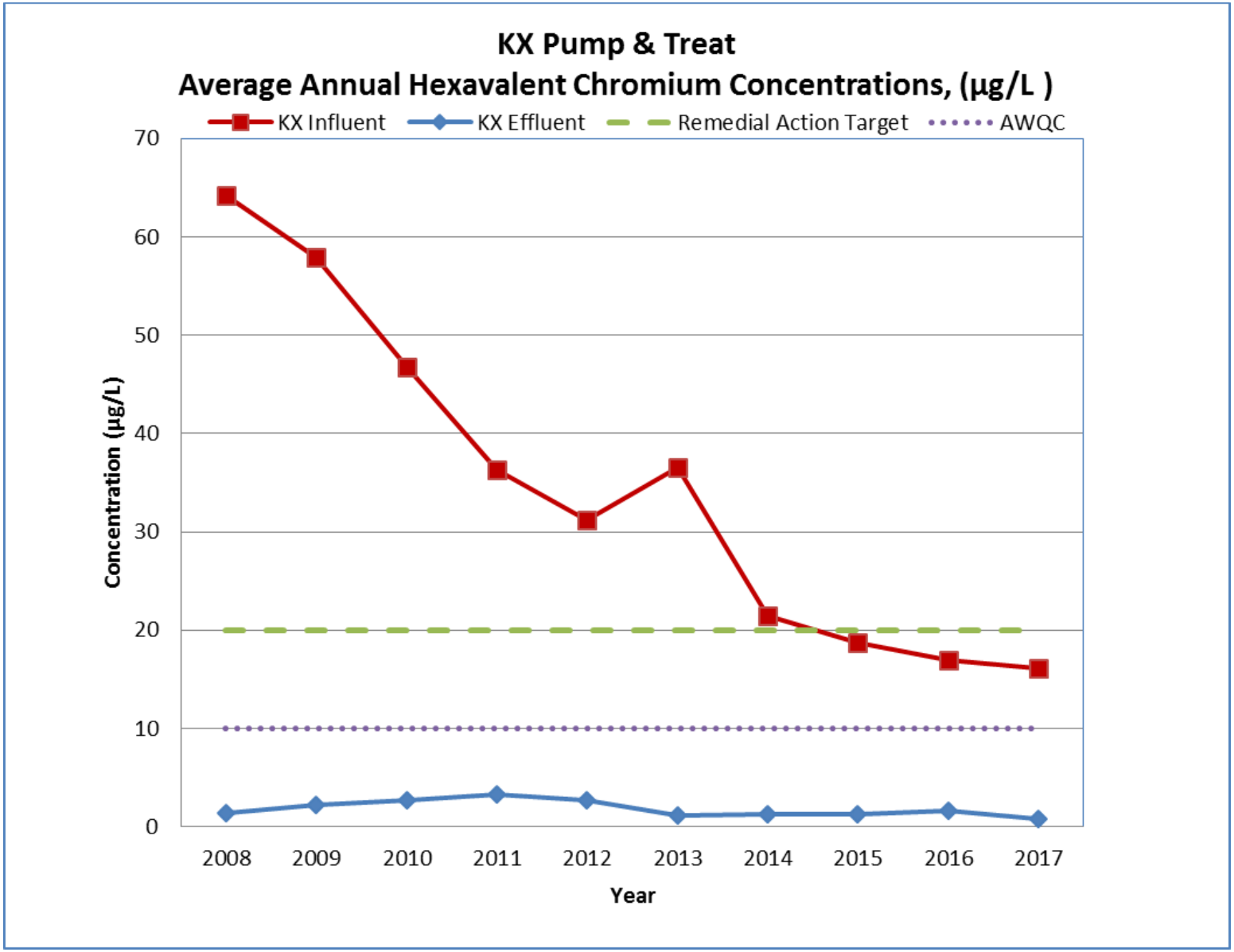
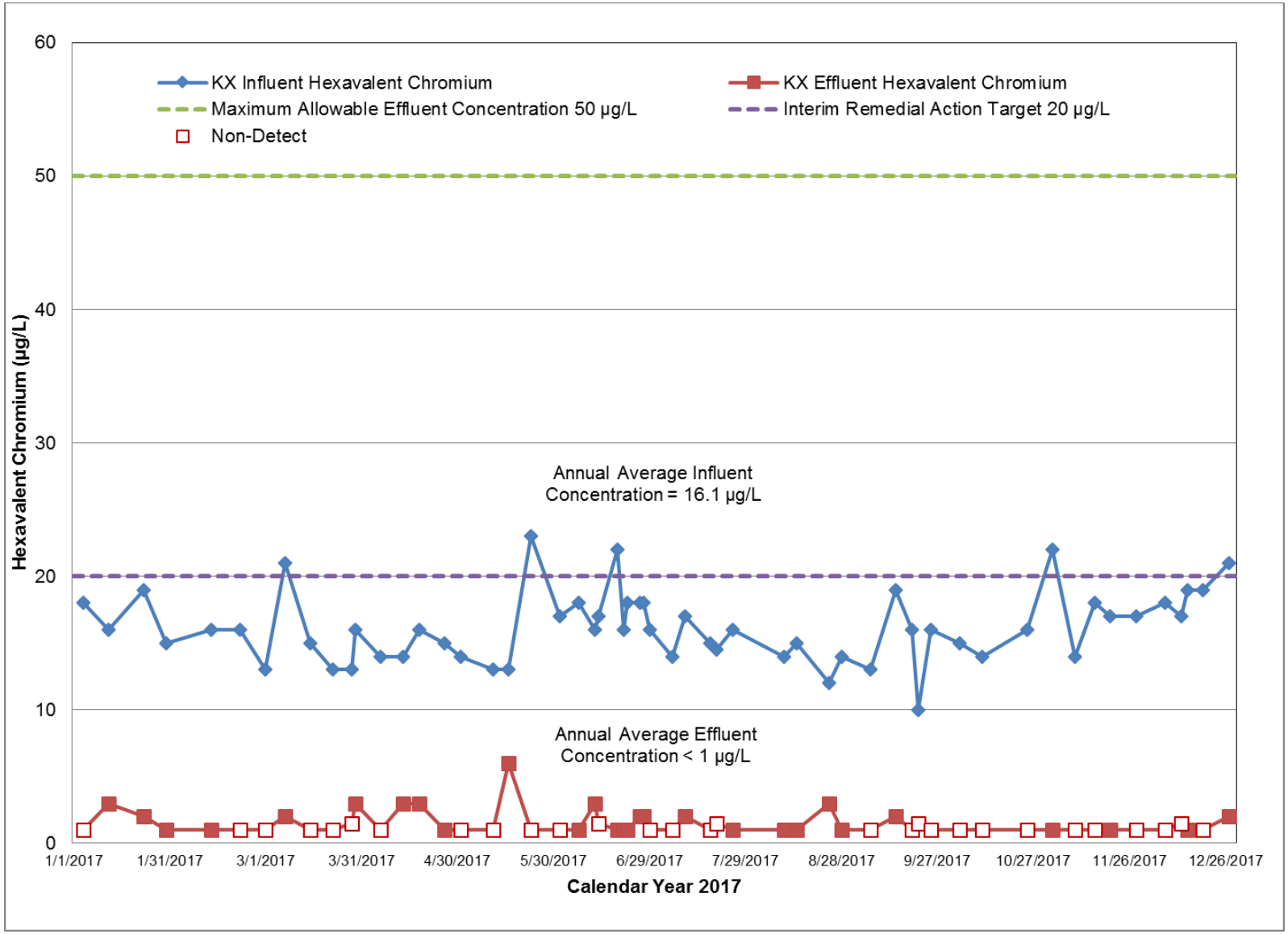


Figure 3-14. KX P&T System Annual Average Influent and Effluent Concentrations



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, 2017

Table 3-7. Flow Rates and Total Run-Times for KX P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Yearly Average Flow Rate (L/min [gal/min])	Total Flow Hours in 2017	Total Run-Time (%)[a]	Purpose
C7464	199-K-181[b]	XE1	189.7 (50.1)	1,920	22	Extraction
C7149	199-K-178	XE2	129.6 (34.2)	6,528	75	Extraction
C8297	199-K-210	XE3	217.8 (57.5)	7,752	88	Extraction
C5303	199-K-141	XE4	75 (19.8)	6,096	70	Extraction
C8795	199-K-220[c]	XE5	215.7 (56.9)	2,952	34	Extraction
C8295	199-K-208	XE6	158.3 (41.8)	7,752	88	Extraction
C5360	199-K-144	XE7	223.4 (59)	7,896	90	Extraction
C9597	199-K-225[c]	XE8	274 (72.3)	2,232	25	Extraction
C9598	199-K-226[d]	XE9	348.2 (91.9)	5,064	58	Extraction
C5939	199-K-161	XE11	60.9 (16.1)	7,296	83	Extraction
C5363	199-K-147	XE12	67.2 (17.7)	4,896	56	Extraction
C4120	199-K-130	XE13	96.1 (25.4)	7,416	85	Extraction
C5364	199-K-148	XE14	100 (26.4)	7,224	82	Extraction
C4561 C7689	199-K-131 199-N-189[e]	XE15	119.3 (31.5)	6,960	79	Extraction
C5368	199-K-152	XE16	157.3 (41.5)	7,392	84	Extraction
C5362	199-K-146	XE17	30.1 (7.9)	5,328	61	Extraction
C7476	199-K-182	XE18	267.1 (70.5)	7,128	81	Extraction
C5369	199-K-153	XE31	192.8 (50.9)	7,656	87	Extraction
C5370	199-K-154	XE32	225.3 (59.5)	8,376	96	Extraction
C6172	199-K-163	XE33	154.5 (40.8)	6,456	74	Extraction
C6746	199-K-171	XE34	190.3 (50.2)	8,376	96	Extraction
C8299	199-K-212	XE35	151.9 (40.1)	7,800	89	Extraction
C7693	199-K-193[f]	XE36	180.8 (47.7)	1,656	19	Extraction
C5937 C5367	199-K-159 199-K-151[g]	XJ1	220.2 (58.1)	6,840	78	Injection
C5938 C5365	199-K-160 199-K-149[h]	XJ2	217.2 (57.3)	6,792	78	Injection
C6744	199-K-169	XJ3	493.7 (130.3)	8,424	96	Injection

Table 3-7. Flow Rates and Total Run-Times for KX P&T System Extraction and Injection Wells, 2017

Well ID	Well Name	PLC ID	Yearly Average Flow Rate (L/min [gal/min])	Total Flow Hours in 2017	Total Run-Time (%)[a]	Purpose
C5305	199-K-143	XJ4	191.9 (50.7)	8,424	96	Injection
C7150	199-K-179	XJ5	258.9 (68.3)	8,424	96	Injection
C5372	199-K-156	XJ6	354.6 (93.6)	8,424	96	Injection
C6745	199-K-170	XJ7	474.8 (125.3)	8,424	96	Injection
C6386	199-K-164	XJ8	217.5 (57.4)	7,176	82	Injection
C7151	199-K-180	XJ9	199.4 (52.6)	7,800	89	Injection
C6747	199-K-172	XJ10	244.9 (64.7)	7,848	90	Injection

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

b. Well 199-K-181 was disconnected from the KX P&T on March 22, 2017.

c. Wells 199-K-220 and 199-K-225 were temporarily disconnected from the KX P&T on September 21, 2017, to enable backfill of the 183.2KE Sedimentation Basin.

d. Well 199-K-226 was connected to the KX P&T on May 1, 2017.

e. Well realignment to remove well 199-K-131 and connect well 199-N-189. Realignment performed August 1 through September 13, 2017.

f. Well 199-K-193 was connected to the KX P&T on October 25, 2017.

g. Well realignment to relocate injection from well 199-K-159 to 199-K-151. Realignment performed June 9 through August 20, 2017.

h. Well realignment to relocate injection from well 199-K-160 to 199-K-149. Realignment performed June 29 through August 20, 2017.

CY = calendar year

ID = identification

PLC = programmable logic controller

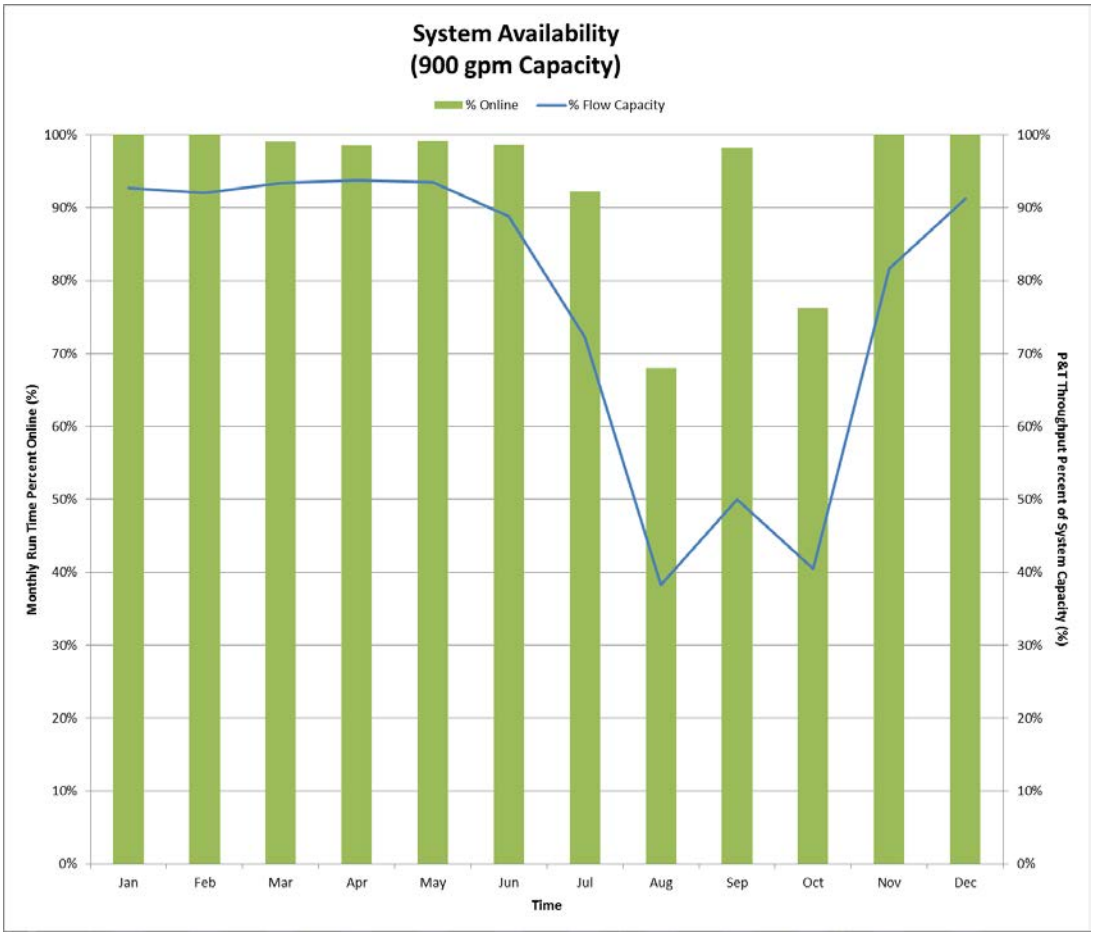


Figure 3-16. Monthly KX P&T System Availability, 2017

3.2.4 Performance Monitoring

Removal of Cr(VI) and protection of the river are the principal objectives of the active groundwater 100-KR-4 OU interim remedial action. 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 the interim action remedy does not treat co-contaminants. The groundwater COCs identified in the RI/FS report (DOE/RL-2010-97, Draft A) are chromium (total and Cr(VI)), 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. The data are used to update the nature and extent of groundwater contamination 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, leading to steeper groundwater gradients toward the river and higher contaminant flux toward the river. This report focuses on evaluating the analytical results for Cr(VI) being remediated through the interim action P&T systems. Chapter 5 of DOE/RL-2017-66 presents further summary and analysis information for the other contaminants of potential concern.

Tables 3-8 and 3-9 present the 2017 maximum concentration for Cr(VI) in the 100-KR-4 OU plume areas at high and low river-stages. CERCLA system performance assessment addresses longer term changes in Cr(VI) concentrations at selected monitoring and extraction wells in the 100-KR-4 OU.

Table 3-8. Cr(VI) 2017 Maximum Concentrations KW Reactor Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
199-K-106A	M	—	—	11/3/2017	7.4	11/3/2017	7.4
199-K-107A	M	5/26/2017	9.3	11/3/2017	8.4	4/11/2017	9.3
199-K-108A	M	—	—	11/3/2017	2.1	2/24/2017	7.9
199-K-132	M, C	5/8/2017	12	10/29/2017	17	8/14/2017	18
199-K-137	E-KW	4/20/2017	69	12/4/2017	18	4/20/2017	69
199-K-138	M, C	5/8/2017	8.8	10/29/2017	8.3	5/8/2017	8.8
199-K-139	M	5/17/2017	9	11/2/2017	9.1	11/2/2017	9.1
199-K-140	M	—	—	11/2/2017	9.2	8/22/2017	15
199-K-165	E-KW	4/20/2017	28	12/4/2017	10	4/20/2017	28
199-K-166	E-KW	4/20/2017	27	12/4/2017	5	4/20/2017	27
199-K-168	M	5/22/2017	11	11/2/2017	14	11/2/2017	14
199-K-173	M	5/26/2017	100	11/7/2017	1.6	4/8/2017	100
199-K-183	M	5/30/2017	11	11/2/2017	7.9	5/30/2017	11
199-K-184	M	—	—	11/3/2017	6.1	2/24/2017	6.3
199-K-185	M	5/22/2017	4.7	11/6/2017	5.1	8/17/2017	11
199-K-196	M	5/22/2017	9.4	11/8/2017	4.8	5/22/2017	9.4
199-K-204	M	—	—	11/17/2017	1.9	1/29/2017	4.3
199-K-205	E-KW	7/5/2017	65	10/5/2017	87	2/22/2017	150

Table 3-8. Cr(VI) 2017 Maximum Concentrations KW Reactor Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
199-K-223	M	5/22/2017	6.9	11/15/2017	4.8	3/15/2017	16
199-K-224	E-KW	6/7/2017	56	11/1/2017	18	2/15/2017	450
199-K-229	M	—	—	10/22/2017	1.5(U)	10/22/2017	1.5(U)
199-K-230	M	5/30/2017	1.6	11/15/2017	1.5(U)	5/30/2017	1.6
199-K-31	M	—	—	10/27/2017	6.6	10/27/2017	6.6
199-K-34	M	5/19/2017	6.6	11/3/2017	7.2	3/17/2017	7.8
15-M	M	—	—	11/15/2017	1.5(U)	11/15/2017	1.5(U)
17-D	M	—	—	9/18/2017	1.5(U)	6/5/2017	1.5(U)
17-M	M	—	—	9/18/2017	1.5(U)	6/5/2017	1.5(U)
AT-K-1-D	M	—	—	—	—	9/6/2017	6.3
AT-K-1-M	M	—	—	—	—	9/6/2017	1.6
AT-K-1-S	M	—	—	—	—	9/6/2017	1.5(U)
C6236	M	—	—	—	—	9/5/2017	3.7
C6237	M	—	—	—	—	9/6/2017	4.8
C6238	M	—	—	—	—	9/6/2017	4.6
C6239	M	—	—	9/19/2017	1.5(U)	9/19/2017	1.5(U)
C6240	M	—	—	9/19/2017	1.5(U)	9/19/2017	1.5(U)
C6241	M	—	—	9/19/2017	2.7	9/19/2017	2.7

Table 3-8. Cr(VI) 2017 Maximum Concentrations KW Reactor Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
C7641	M	—	—	9/18/2017	1.5(U)	9/18/2017	1.5(U)
C7642	M	—	—	9/18/2017	1.5(U)	9/18/2017	1.5(U)
C7643	M	—	—	9/18/2017	1.5(U)	9/18/2017	1.5(U)

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

Laboratory qualifiers: U = nondetect (shown with detection limit).

a. High river-stage represents the period from April 1 to July 15. Low river-stage represents the period from August 15 to December 31.

b. Well use: C = compliance, E = extraction, I = injection, M = monitoring, and AT = aquifer tube,

— = sample was not collected or analysis was not performed

Cr(VI) = hexavalent chromium

P&T = pump and treat

RI/FS = remedial investigation/feasibility study

Table 3-9. Cr(VI) 2017 Maximum Concentrations in the KE Reactor Area and 116-K-2 Trench Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
199-K-11	M	—	—	10/30/2017	2.5	10/30/2017	205
199-K-110A	M	5/3/2017	8.6	10/30/2017	1.5(U)	5/3/2017	8.6
199-K-111A	M	5/8/2017	240	10/31/2017	250	10/31/2017	250
199-K-113A	E-KR4, C	4/6/2017	3	10/30/2017	11	10/30/2017	11
199-K-114A	E-KR4, C	5/2/2017	12	10/30/2017	11	5/2/2017	12
199-K-115A	E-KR4, C	4/6/2017	1	10/30/2017	11	10/30/2017	11
199-K-116A	E-KR4, C	4/6/2017	6	10/24/2017	3	4/6/2017	6
199-K-117A	M, C	—	—	10/31/2017	3	10/31/2017	3
199-K-119A	M, C	5/17/2017	1.5(U)	10/29/2017	1.5(U)	8/27/2017	1.5(U)
199-K-120A	E-KR4, C	4/6/2017	4	10/4/2017	4	6/21/2017	4
199-K-125A	M, C	5/17/2017	1.5(U)	10/31/2017	2	8/17/2017	2.1
199-K-126	M	—	—	10/27/2017	5	10/27/2017	5
199-K-127	E-KR4, C	4/19/2017	3	10/4/2017	5	10/4/2017	5
199-K-129	E-KR4, C	4/6/2017	5	10/4/2017	13	10/4/2017	13
199-K-13	M	5/26/2017	1.5(U)	10/30/2017	1.9	10/30/2017	1.9
199-K-130	E-KX, C	4/18/2017	6	10/24/2017	8	2/7/2017	9
199-K-131	M, C	5/25/2017	2	11/17/2017	3.3	2/7/2017	4
199-K-133	M	—	—	10/27/2017	1.5(U)	10/27/2017	1.5(U)

Table 3-9. Cr(VI) 2017 Maximum Concentrations in the KE Reactor Area and 116-K-2 Trench Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
199-K-134	M	—	—	10/27/2017	1.5(U)	10/27/2017	1.5(U)
199-K-135	M	—	—	10/27/2017	2.1	10/27/2017	2.1
199-K-136	M	—	—	10/27/2017	1.5(U)	10/27/2017	1.5(U)
199-K-141	E-KX, C	4/18/2017	21	11/15/2017	21	12/18/2017	28
199-K-142	M	—	—	11/2/2017	23	11/2/2017	23
199-K-144	E-KX, C	6/22/2017	22	11/8/2017	17	6/22/2017	22
199-K-145	E–KR4, C	7/5/2017	5	10/4/2017	4	3/8/2017	8
199-K-146	E-KX, C	4/18/2017	6	11/14/2017	9	11/14/2017	9
199-K-147	E-KX, C	4/18/2017	10	—	—	2/15/2017	12
199-K-148	E-KX, C	4/18/2017	4	11/16/2017	3.3	3/15/2017	4
199-K-150	M	—	—	10/27/2017	1.5(U)	10/27/2017	1.5(U)
199-K-152	E-KX, C	4/18/2017	28	11/15/2017	24	3/14/2017	28
199-K-153	E-KX	6/22/2017	23	9/25/2017	17	6/22/2017	23
199-K-154	E-KX	4/18/2017	27	9/25/2017	22	4/18/2017	27
199-K-157	M	—	—	10/31/2017	2.8	10/31/2017	2.8
199-K-159	M	—	—	11/7/2017	8.6	11/7/2017	8.6
199-K-160	M	—	—	11/7/2017	1.5	11/7/2017	1.5
199-K-161	E-KX, C	6/22/2017	2	11/16/2017	19	12/18/2017	22

Table 3-9. Cr(VI) 2017 Maximum Concentrations in the KE Reactor Area and 116-K-2 Trench Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
199-K-162	E-KR4, C	4/6/2017	3	10/4/2017	3	6/21/2017	3
199-K-163	E-KX	6/24/2017	4	9/25/2017	3	6/24/2017	4
199-K-171	E-KX, C	4/18/2017	12	10/20/2017	8	2/26/2017	14
199-K-178	E-KX, C	5/2/2017	16	9/25/2017	21	11/6/2017	21
199-K-18	M, C	—	—	10/27/2017	2.1	10/27/2017	2.1
199-K-181	M, C	—	—	11/29/2017	6.3	2/7/2017	11
199-K-182	E-KX, C	6/22/2017	26	11/16/2017	21	6/22/2017	26
199-K-186	M	5/22/2017	24	10/30/2017	7.3	5/22/2017	24
199-K-187	M	—	—	11/6/2017	3.9	11/6/2017	3.9
199-K-188	M	6/27/2017	25	11/17/2017	70	11/17/2017	70
199-K-189	M	5/26/2017	4.6	11/7/2017	3.6	5/26/2017	4.6
199-K-19	M, C	5/3/2017	3.3	10/27/2017	2.1	5/3/2017	3.3
199-K-190	M	5/30/2017	6.3	11/7/2017	7.6	11/7/2017	7.6
199-K-191	M	—	—	11/6/2017	3.2	11/6/2017	3.2
199-K-192	M	—	—	11/6/2017	5.7	11/6/2017	5.7
199-K-193	E-KX	—	—	11/14/2017	42	12/18/2017	43
199-K-194	M	—	—	11/6/2017	4.9	11/6/2017	4.9
199-K-197	M	—	—	11/8/2017	1.5(U)	11/8/2017	1.5(U)

Table 3-9. Cr(VI) 2017 Maximum Concentrations in the KE Reactor Area and 116-K-2 Trench Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
199-K-198	E-KR4, C	7/5/2017	7	10/4/2017	6	7/22/2017	7
199-K-199	E-KR4, C	6/17/2017	5	10/4/2017	5	3/8/2017	6
199-K-20	M, C	5/3/2017	1.5(U)	10/27/2017	1.5	9/21/2017	1.6
199-K-200	M	5/30/2017	1.7	11/13/2017	3.7	11/13/2017	3.7
199-K-201	M	5/30/2017	24	11/8/2017	15	8/17/2017	31
199-K-202	M	—	—	11/8/2017	15	11/8/2017	15
199-K-203	M	—	—	11/17/2017	1.5(U)	11/17/2017	1.5(U)
199-K-207	M	6/1/2017	65	11/28/2017	74	8/17/2017	99
199-K-208	E-KX, C	5/1/2017	7	9/25/2017	4	12/18/2017	12
199-K-209	M	—	—	11/15/2017	3.2	11/15/2017	3.2
199-K-21	M	7/12/2017	11	10/27/2017	2.8	7/12/2017	11
199-K-210	E-KX, C	4/18/2017	25	9/25/2017	27	12/18/2017	30
199-K-212	E-KX, C	6/22/2017	6	11/13/2017	4.1	2/7/2017	7
199-K-22	M	5/3/2017	31	10/27/2017	6.6	5/3/2017	31
199-K-220	E-KX	4/18/2017	19	—	—	4/18/2017	19
199-K-221	M	6/1/2017	29	10/30/2017	10	6/1/2017	29
199-K-222	M	—	—	—	—	—	—
199-K-225	E-KX	—	—	—	—	—	—

Table 3-9. Cr(VI) 2017 Maximum Concentrations in the KE Reactor Area and 116-K-2 Trench Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
199-K-226	E-KX	5/23/2017	37	10/24/2017	25	5/23/2017	37
199-K-227	M	6/14/2017	34	11/17/2017	20	6/14/2017	34
199-K-228	M	4/20/2017	89	11/15/2017	11	4/20/2017	89
199-K-32A	M, C	—	—	10/30/2017	14	10/30/2017	14
199-K-32B	M	—	—	10/30/2017	7	10/30/2017	7
199-K-36	M	6/27/2017	54	11/17/2017	69	11/17/2017	69
199-K-37	M	—	—	10/31/2017	21	10/31/2017	21
199-N-189	E-KX	—	—	11/8/2017	32	11/8/2017	32
699-73-61	M	—	—	10/26/2017	1.7	10/26/2017	1.7
699-78-62	M	—	—	10/27/2017	2	10/27/2017	2
18-S	AT	—	—	9/26/2017	1.5(U)	9/26/2017	1.5(U)
19-D	AT	—	—	9/26/2017	1.5(U)	9/26/2017	1.5(U)
19-M	AT	—	—	9/26/2017	1.5(U)	9/26/2017	1.5(U)
21-M	AT	—	—	9/21/2017	1.5(U)	9/21/2017	1.5(U)
21-S	AT	—	—	9/21/2017	1.5(U)	9/21/2017	1.5(U)
22-D	AT	—	—	10/13/2017	35	10/13/2017	35
22-M	AT	—	—	10/13/2017	1.5(U)	10/13/2017	1.5(U)
23-M	AT	—	—	10/3/2017	1.5(U)	10/3/2017	1.5(U)

Table 3-9. Cr(VI) 2017 Maximum Concentrations in the KE Reactor Area and 116-K-2 Trench Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
AT-K-2-D	AT	—	—	9/20/2017	1.5(U)	9/20/2017	1.5(U)
AT-K-2-M	AT	—	—	9/20/2017	1.5(U)	9/20/2017	1.5(U)
AT-K-2-S	AT	—	—	9/20/2017	1.5(U)	9/20/2017	1.5(U)
AT-K-3-D	AT	—	—	9/20/2017	29	9/20/2017	29
AT-K-3-M	AT	—	—	9/20/2017	5.5	9/20/2017	5.5
AT-K-3-S	AT	—	—	9/20/2017	2.9	9/20/2017	2.9
AT-K-4-D	AT	—	—	9/26/2017	1.5(U)	9/26/2017	1.5(U)
AT-K-4-M	AT	—	—	9/26/2017	1.5(U)	9/26/2017	1.5(U)
AT-K-4-S	AT	—	—	9/26/2017	1.5(U)	9/26/2017	1.5(U)
AT-K-5-D	AT	—	—	10/3/2017	4.8	10/3/2017	4.8
AT-K-5-M	AT	—	—	10/3/2017	1.5(U)	10/3/2017	1.5(U)
AT-K-5-S	AT	—	—	10/3/2017	1.7	10/3/2017	1.7
AT-K-6-D	AT	—	—	10/3/2017	1.5(U)	10/3/2017	1.5(U)
AT-K-6-S	AT	—	—	10/3/2017	1.5(U)	10/3/2017	1.5(U)
C6242	AT	—	—	9/19/2017	1.5	9/19/2017	1.5
C6243	AT	—	—	9/19/2017	1.5(U)	9/19/2017	1.5(U)
C6244	AT	—	—	9/19/2017	1.5(U)	9/19/2017	1.5(U)
C6245	AT	—	—	9/20/2017	1.5(U)	9/20/2017	1.5(U)

Table 3-9. Cr(VI) 2017 Maximum Concentrations in the KE Reactor Area and 116-K-2 Trench Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
C6246	AT	—	—	9/20/2017	1.5(U)	9/20/2017	1.5(U)
C6247	AT	—	—	9/20/2017	1.5(U)	9/20/2017	1.5(U)
C6248	AT	—	—	9/21/2017	1.5(U)	9/21/2017	1.5(U)
C6249	AT	—	—	9/21/2017	1.7	9/21/2017	1.7
C6250	AT	—	—	9/21/2017	1.9	9/21/2017	1.9
C6251	AT	—	—	9/21/2017	1.7	9/21/2017	1.7
C6252	AT	—	—	9/21/2017	3.1	9/21/2017	3.1
C6253	AT	—	—	9/21/2017	1.5(U)	9/21/2017	1.5(U)
C6254	AT	—	—	9/25/2017	1.5(U)	9/25/2017	1.5(U)
C6255	AT	—	—	9/25/2017	9	9/25/2017	9
C6256	AT	—	—	9/25/2017	17	9/25/2017	17
C6258	AT	—	—	9/25/2017	11	9/25/2017	11
C6259	AT	—	—	9/25/2017	1.5(U)	9/25/2017	1.5(U)
C6260	AT	—	—	10/3/2017	1.5(U)	10/3/2017	1.5(U)
C6261	AT	—	—	10/3/2017	1.5(U)	10/3/2017	1.5(U)

Table 3-9. Cr(VI) 2017 Maximum Concentrations in the KE Reactor Area and 116-K-2 Trench Area Plume

Well or Aquifer Tube Name	Current Well Use and P&T System[b]	High River-Stage[a] Maximum Cr(VI)		Low River-Stage[a] Maximum Cr(VI)		Annual Maximum Cr(VI)	
		Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)	Date Collected	Concentration (µg/L)
DK-04-3	AT	—	—	10/11/2017	1.5(U)	10/11/2017	1.5(U)

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

Laboratory qualifiers: U = nondetect (shown with detection limit).

a. High river-stage represents the period from April 1 to July 15. Low river-stage represents the period from August 15 to December 31.

b. Well use: C = compliance, M = monitoring, AT = aquifer tube, E-KR4 = KR4 extraction, and E-KX = KX extraction.

— = sample was not collected or analysis was not performed

Cr(VI) = hexavalent chromium

P&T = pump and treat

Figures 3-3 and 3-4 present Cr(VI) plume maps for 2017 high river-stage and low 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 2017 for each well shown. The plume maps, data summary tables, and a summary of notable data observations are presented in the following sections. Methods for generating contaminant plume representation are described in ECF-Hanford-18-0013.

3.2.4.1 River-Stage Effects

The Columbia River is the discharge boundary for groundwater in the shallow unconfined aquifer underlying the Hanford Site. Groundwater flows toward the river at a rate defined by the hydraulic gradient, which varies in response to the seasonal and diurnal changes in river-stage. Columbia River stage in the Hanford Reach varies daily with controlled release of water from the upstream Priest Rapids Dam and seasonally in response to annual snowmelt in the mountains of the upstream drainage. High river-stage during 2017 was generally from April to early July. River-stage at the Hanford Site remained for a longer period of time than typical, as illustrated in the hydrograph of river-stage at 100-K Area (Figure 3-17). After the peak in June, the river-stage mostly declined due to the seasonal drought conditions experienced in the region. Low river-stage in 2017 occurred in September and October, which is typical. 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. Low river-stage at the 100-K Area was observed starting at the end of August, which is consistent with previous years. In 2017, the lowest river-stage observed was 116.6 m (382.5 ft), occurring in late October.

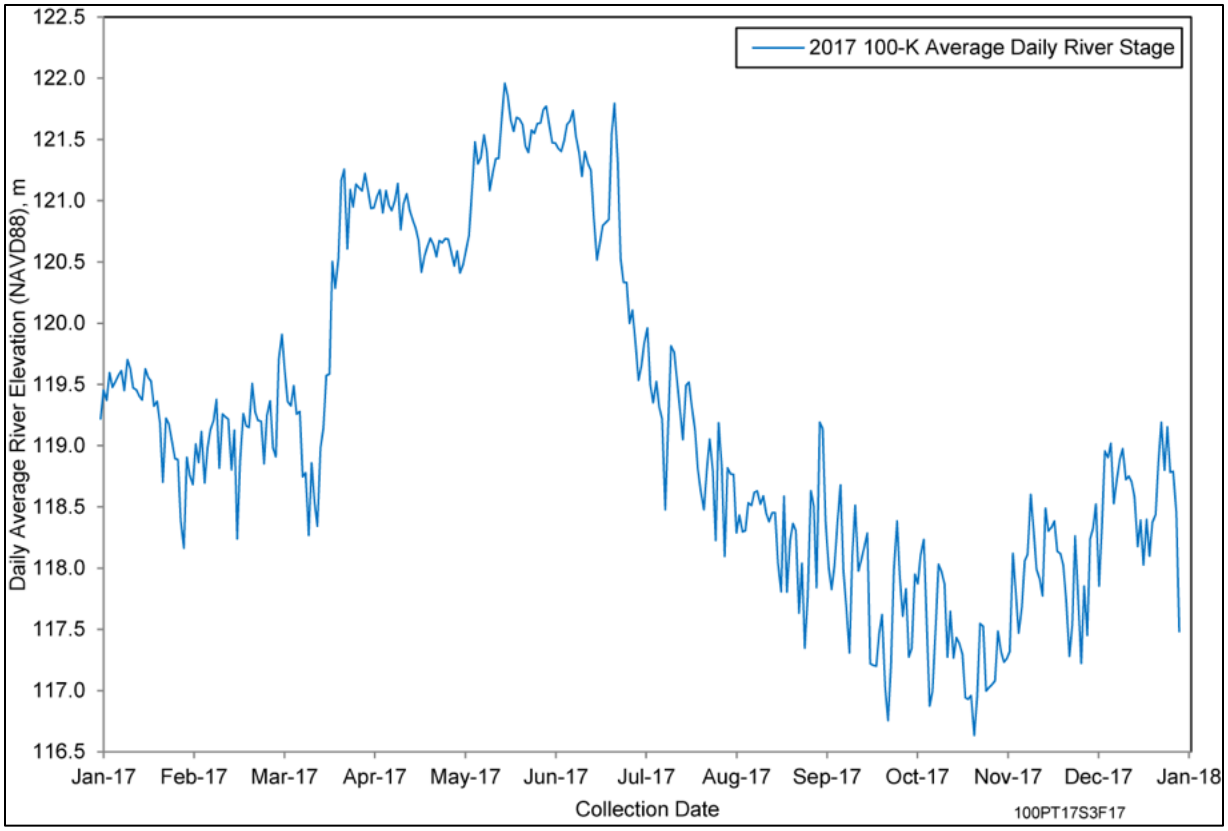


Figure 3-17. Columbia River-Stage Elevation at the 100-K Area, 2017
(Derived from Priest Rapids Dam Water Elevation Data)

During high river-stage, river water may intrude into the aquifer and cause displacement and/or dilution of the aquifer water in the near-shore environment. The March 2017 water table map (Figure 3-18) represents transitional and moderate river-stage conditions. Increased pumping at groundwater extraction wells, particularly those riverward of the distal portion of the 116-K-2 Trench, creates a cone of depression and gradient reversal near the river. Groundwater specific conductance was mapped to evaluate the potential for migration of river water into the aquifer due to capture by extraction wells (Figure 3-19). During 2017, several wells exhibited specific conductance measurements consistently less than 200 µS/cm, indicating the samples were primarily river water (the Columbia River exhibits 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. Thus, a specific conductance of 200 to 300 µS/cm likely indicates a mixing of groundwater with river water. In 2017, wells 199-K-113A, 199-K-114A, and 199-K-129 all had specific conductance above 200 µS/cm, suggesting that these extraction wells were extracting a high fraction of groundwater versus river water.

3.2.4.2 Hexavalent Chromium Plumes

Several separate Cr(VI) plumes are differentiated by geographic distribution and by the location and nature of probable source areas. The plumes are associated with three general areas: (1) a plume originating at or near the 183.1KW Head House and extending toward the river, (2) a plume originating at or near the 183.1KE Head House and extending toward the river, and (3) 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 183.1KE and 183.1KW 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 PRZ in those areas. The 116-K-2 Trench received primarily spent reactor cooling water containing a substantially lower concentration of sodium dichromate. The potential also remains for continuing contributions from secondary sources in the vadose zone and PRZ associated with the trench area.

The plumes have been reshaped and/or dissected by operation of the 100-KR-4 OU groundwater P&T systems. The P&T operations have also reduced the groundwater Cr(VI) concentrations at many locations. The plume near the KW Reactor is 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 being remediated by the KX and KR4 P&T systems. 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. Figures 3-3 and 3-4 show the inferred Cr(VI) plume distribution for 2017 at high and low river-stage, respectively.

KW Reactor Area. This plume is located near the KW Reactor, supporting water treatment facilities, and associated waste sites (Figures 3-3 and 3-4), and it originated from releases of concentrated sodium dichromate solutions near the 183.1KW Head House and chemical storage tanks. The KW Reactor area plume has been monitored since the early 1990s, when many of the monitoring wells were initially installed. The KW P&T system, initially consisting of four extraction wells and two injection wells, began operating in January 2007 after elevated Cr(VI) concentrations were detected in aquifer tube AT-K-1-D. The upgradient edge of the plume is controlled by injection wells 199-K-175, 199-K-174, 199-K-158, and 199-K-206. The plume does not extend inland past well 199-K-175, which exhibited concentrations less than 10 µg/L when the well was sampled before conversion to an injection well.

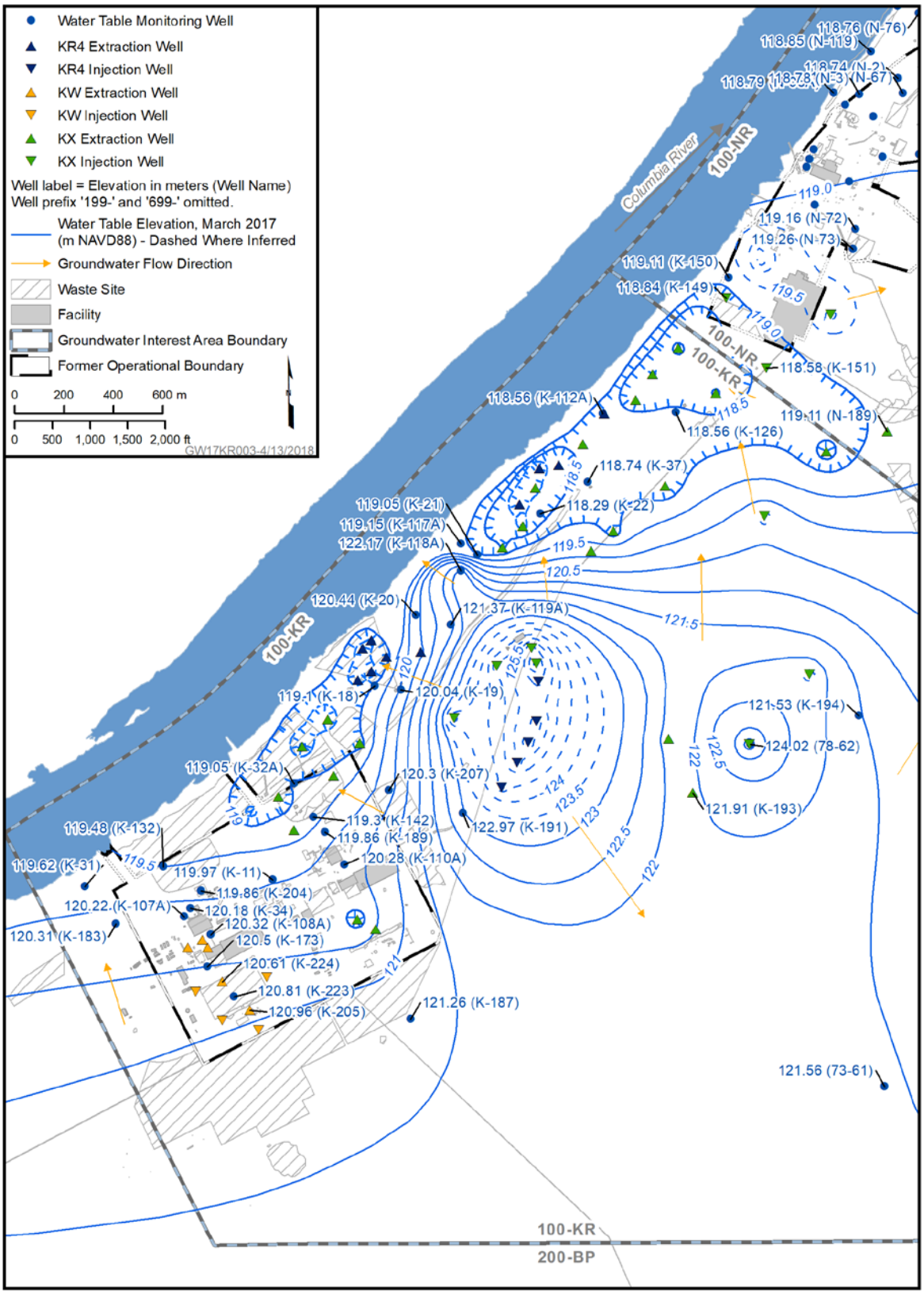


Figure 3-18. Groundwater Elevation Contour Map, March 2017

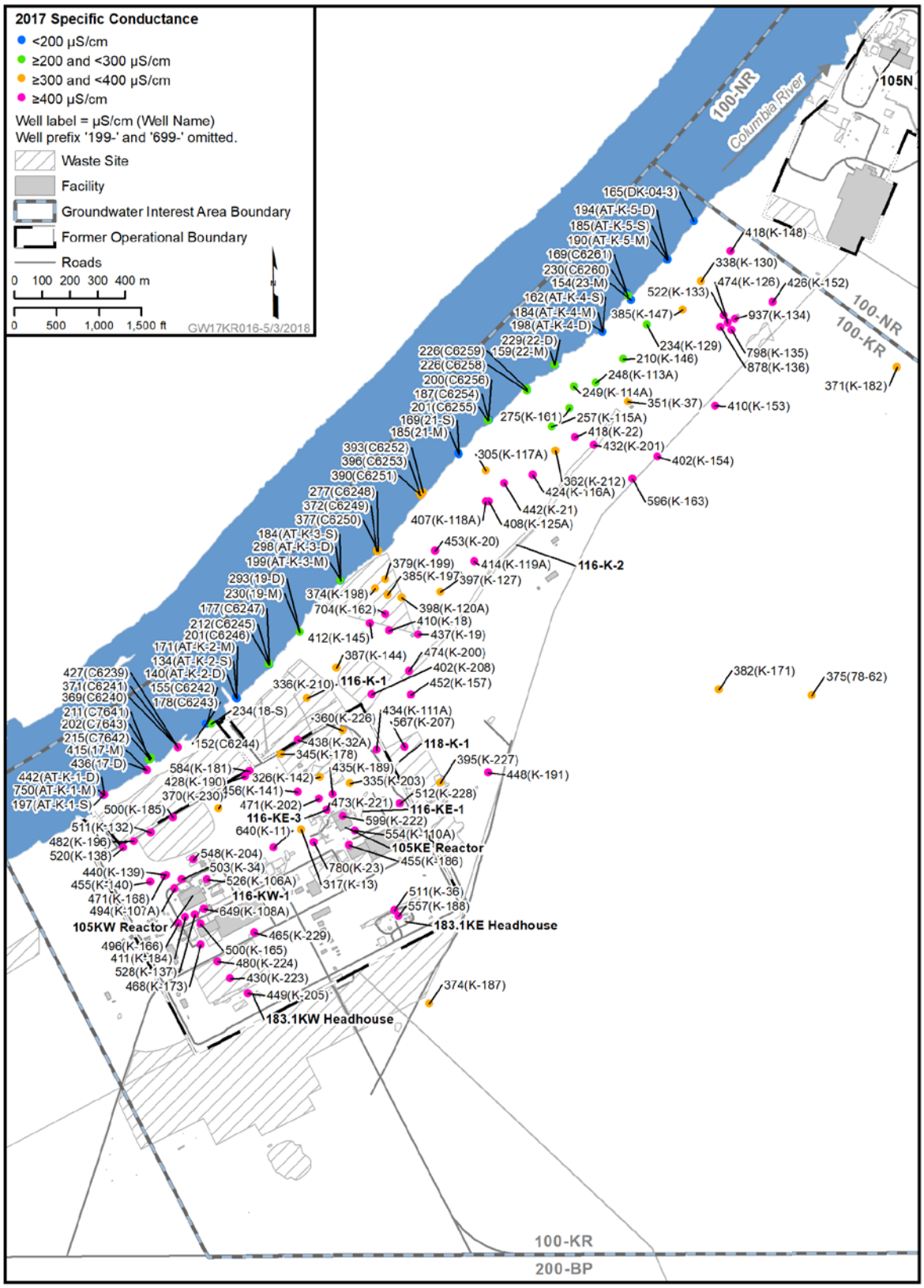


Figure 3-19. Plot of Groundwater Specific Conductance Relative to the Columbia River, 2017

Since 2013, river-stage effects have had less influence on plume geometry than in earlier years. Instead, changes between high and low river-stage appear to reflect P&T progress made over the CY. At the end of CY 2015, all groundwater wells (including extraction and monitoring wells) near the KW P&T system exhibited concentrations below the interim remedial action target of 20 µg/L. Beginning on May 16, 2016, the KW P&T system was shut off, and a rebound study was initiated to evaluate the completion of the interim action, as defined in the RD/RAWP (DOE/RL-2013-33, *Remedial Design/Remedial Action Work Plan for the 100-KR-4 Groundwater Operable Unit Interim Action*). As discussed in Section 3.1.3, the rebound study continued through the end of March 2017 and the results are documented in SGW-62061. Sections 5.2 through 5.8 of DOE/RL-2017-66 further discuss the analytical results and observations made between January and March 2017. On April 12, 2017, the KW P&T system was restarted to continue groundwater cleanup efforts for Cr(VI). Prior to restart, the well system was changed to optimize the remedial action.

Table 3-8 presents the maximum Cr(VI) concentrations for wells and aquifer tubes monitoring the KW Reactor area plume during 2017. The findings and observations are summarized as follows:

- From January through March 2017, Cr(VI) concentrations in wells downgradient from the KW Reactor remained below the groundwater remediation target of 20 µg/L. Well 199-K-132 had the highest concentration in this area at 17 µg/L. In contrast, Cr(VI) concentrations in wells between the KW Reactor and the 183.1KW Head House increased when the P&T system was off, indicating a potential continuing source in that area. Wells 199-K-205 and 199-K-224 had maximum concentrations of 150 and 450 µg/L, respectively, during the first quarter of 2017.

- Between April and July 2017 (Figure 3-3), which roughly correlates to the restart of the KW P&T system, the Cr(VI) plume extended from the 183.1KW Head House to the south side of the KW Reactor. The highest observed Cr(VI) concentration during this period was at well 199-K-173 (100 µg/L). Several smaller plume segments with concentrations greater than 10 µg/L were also identified between the KW Reactor and Columbia River.

- Between August and December 2017 (Figure 3-4), the Cr(VI) plume area declined as a result of continued operation of the KW P&T system. The highest average Cr(VI) concentration during this period was 76.8 µg/L at extraction well 199-K-205 at the 183.1KW Head House. Wells between the KW Reactor and the river continued the 2016 trend with concentrations less than the groundwater remediation target of 20 µg/L.

The remedial performance of the KW P&T system has been evaluated using Cr(VI) data from 2017 and the long-term concentration trends for selected KW P&T system monitoring locations (Figure 3-20). The results of the rebound study (SGW-62061) and the observed persistent elevated Cr(VI) concentration at well 199-K-205 after resuming P&T efforts indicate a secondary source at the 183.1KW Head House, and Cr(VI) in the deep vadose zone will continue to produce groundwater contamination. In general, Cr(VI) concentration downgradient from the KW Reactor are at or below the 10 µg/L ambient water quality criterion. During 2017, a soil flushing treatability test plan was prepared to provide an alternative method for dealing with the secondary source material in the deep vadose zone near the 183.1KW Head House (DOE/RL-2017-30, *KW Soil Flushing/Infiltration Treatability Test Plan*).

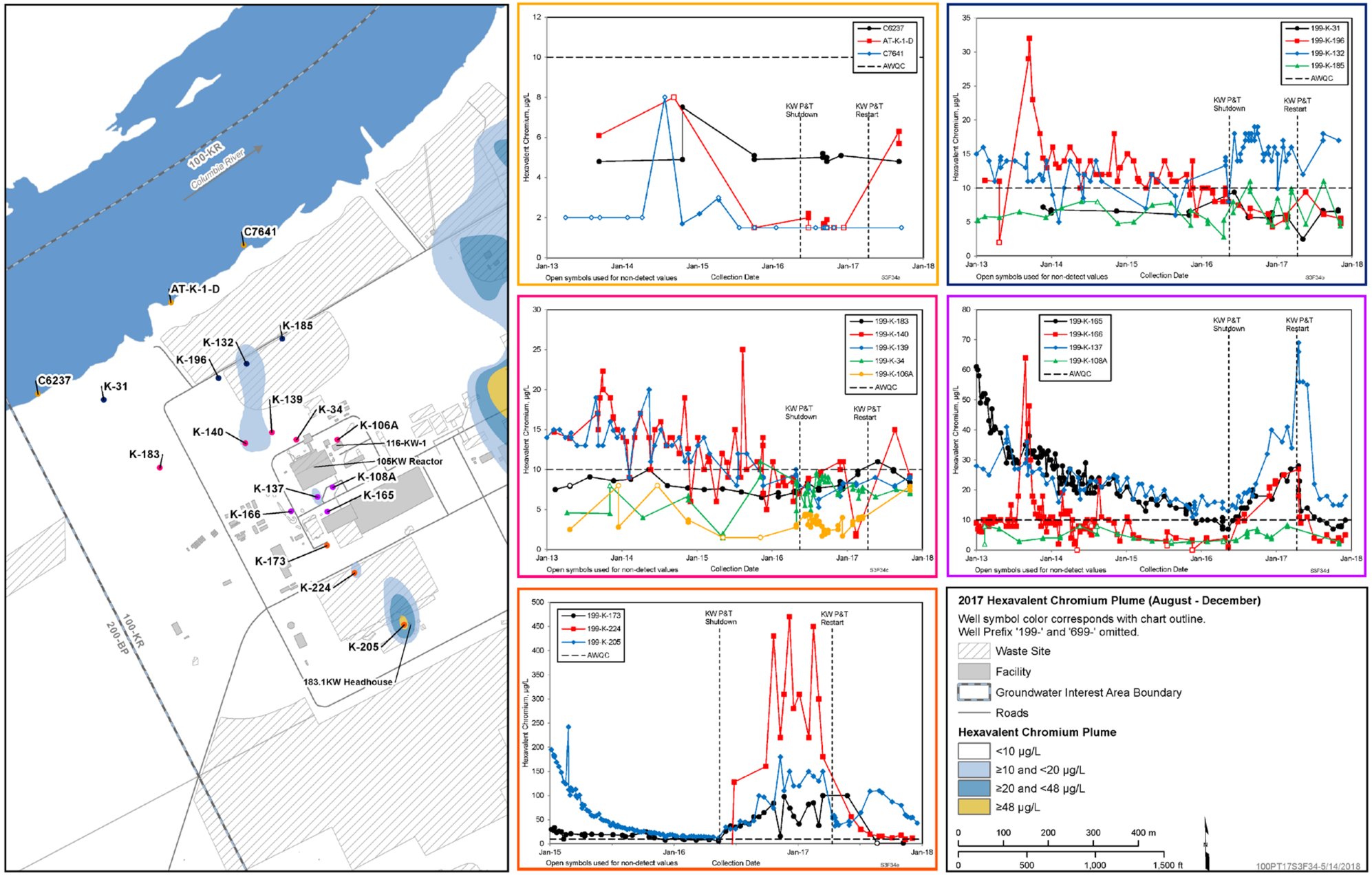


Figure 3-20. Cr(VI) Groundwater Concentration Time-Series Plots for Selected KW Reactor Wells, 2017

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KE Reactor Area. The KE Reactor Cr(VI) plume has been monitored since the early 1990s, when several monitoring wells were installed to characterize potential groundwater contamination in the area. The source of the Cr(VI) plume near the KE Reactor is attributed to the commingling of contamination from the 116-K-1 Crib, 116-K-2 Trench, and the 183.1KE Head House. The contamination originated from spills or leaks of highly concentrated sodium dichromate solution associated with the KE Reactor water treatment facilities (i.e., 183.1KE Head House area) 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 area and the geochemical characteristics of groundwater at selected wells, the current Cr(VI) plume near the KE Reactor appears to represent releases from these sites. In 2017, the KE Reactor Cr(VI) plume was being remediated by the KX P&T system.

In the 183.1KE Head House area, well 199-K-36 continues to exhibit the highest Cr(VI) concentration, with a maximum of 75.5 µg/L in 2017 (in a filtered total chromium aliquot). This was an increase from the 2016 maximum of 45 µg/L. Waste site remediation in this area began at the end of 2015 and continued until September 2017. Cr(VI) concentrations in well 199-K-188 also increased between 2016 and 2017, from 15 to 68.7 µg/L (in a filtered total chromium aliquot). Downgradient extraction wells 199-K-220 and 199-K-225 exhibited Cr(VI) concentrations between 10 and 20 µg/L in 2017.

West of the KE Reactor, elevated Cr(VI) concentrations were observed at well 199-K-23, at a maximum concentration of 840 µg/L in August 2017. This was an increase from less than 10 µg/L during 2015 and 2016 and may be related to contamination originating near the 183.1KE Head House (similar to the condition observed at 100-K West). Until mid-2014 when well 199-K-220 was installed, there was no monitoring between the 183.1KE Head House and well 199-K-23. It is likely that the elevated Cr(VI) concentrations now observed in well 199-K-23 originated near the sedimentation basin, downgradient of any previous monitoring locations.

Table 3-9 presents the Cr(VI) concentrations for wells and aquifer tubes associated with plume segments outside of the KW P&T system during 2017 and includes the annual maximum concentration, as well as the maximum for high and low river-stage. 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 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 2017.

Although aquifer tubes are not compliance points for treatment system performance, samples collected from the 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 extraction wells 199-K-145, 199-K-198, and 199-K-199. Cr(VI) concentrations in this aquifer tube group have been as high as 85 µg/L since it first sampled in 2004. During 2017, the maximum concentration was 29 µg/L in AT-K-3-D (Figure 3-21). It is not currently clear what is causing the persistence of Cr(VI) in these aquifer tubes when concentrations in upgradient extraction wells have decreased less than 10 µg/L. Other notable observations from the 2017 including the following:

- The maximum Cr(VI) concentration in the northern KE Reactor plume was 250 µg/L in well 199-K-111A, apparently related to migration of chromium from near the 116-K-2 Trench and/or the 118-K-1 Burial Ground. Concentrations at cross-gradient monitoring well 199-K-207 ranged from 65 to 110 µg/L in 2017.
- New KX P&T extraction well 199-K-226, which is located downgradient of well 199-K-111A, exhibited Cr(VI) concentrations ranging from 21 to 37 µg/L in 2017. In 2016, a maximum concentration of 330 µg/L was observed in the post-development sample. The decrease in

concentration is likely the result of dilution. The current pump set depth is about 7.6 m (25 ft) below the highest concentrations encountered during post-development.

- Based on observations and measurements from monitoring wells 199-K-227 and 199-K-228, which were installed in 2017 and located near the southern end of the 118-K-1 Burial Ground, the deep vadose zone near the 118-K-1 Burial Ground (or waste site 100-K-132) is likely a contributor to the Cr(VI) plume in this area.
- Cr(VI) concentrations ranged between 19 and 28 µg/L in well 199-K-141 (a KX P&T system extraction well located downgradient of the KE Reactor), and strontium-90 concentration were elevated during 2017. This well is located on the downgradient edge of the inferred high-concentration strontium-90 plume originating at the KE Reactor FSB and 116-KE-3 FSB crib and is apparently capturing part of that plume. Strontium-90 in well 199-K-141 was variable during 2017 (between 57.6 and 84.4 pCi/L).

116-K-2 Trench Area (K North). The current Cr(VI) groundwater plume associated with the 116-K-2 Trench occurs in multiple, isolated plume segments at the 10 µg/L contour (Figure 3-3 and 3-4). This plume, which was initially inferred in the mid-1990s (PNNL-12086, *Hanford Site Groundwater Monitoring for Fiscal Year 1998*) as being continuous over the length of the 116-K-2 Trench, has been dissected by operation of the P&T systems. The Cr(VI) plume associated with the head end (southwest end) of the 116-K-2 Trench (e.g., wells 199-K-111A and 199-K-226) may be continuous with chromium originating at the 183.1KE Head House area or the 118-K-1 Burial Ground.

The central plume segment of the 116-K-2 Trench continues to exhibit concentrations above 10 µg/L extending from the trench inland to well 199-K-193 during high river-stage (Figure 3-3). However, during low river-stage (Figure 3-4), the plume was split because the concentration in well 199-K-171 declined. This could be the result of aligning well 199-K-193 as a KX P&T system extraction well, which was completed in October and operated at an average rate of 180.8 L/min (47.7 gal/min). The Cr(VI) concentrations in well 199-K-193 increased from about 30 µg/L in 2016 to 43 µg/L at the end of 2017. However, due to the presence of only a few wells between well 199-K-193 and the trench, the isolation of Cr(VI) in that area is not conclusive.

At the north (distal) end of the former 116-K-2 Trench central plume, Cr(VI) concentrations greater than 20 µg/L continued to be observed in wells 199-K-201, 199-K-37, and 199-K-154 and occasionally wells 199-K-22 and 199-K-153. Between August and December 2017, Cr(VI) concentrations in KR4 P&T system extraction wells 199-K-113A, 199-K-114A, and 199-K-115A briefly increased to greater than 10 µg/L (Figure 3-21). However, KX P&T system extraction well 199-K-161 increased from 9 to 22 µg/L, and the Cr(VI) plume is interpolated to have reached the Columbia River (Figure 3-4). During this time, KX P&T extraction wells 199-K-161 and 199-K-146 were both offline or operated at reduced flow rates to support KX P&T facility maintenance and repairs. At the same time, KR4 P&T extraction wells 199-K-113A, 199-K-114A, and 199-K-115A all experienced a reduction in flow rates as a result of low river-stage.

At aquifer tube 22-D, Cr(VI) concentrations decreased slightly in 2017 to 35 and 27 µg/L in unfiltered and filtered samples. This aquifer tube is downgradient of KR4 P&T extraction well 199-K-114A. The specific conductance in the aquifer tube remained greater than 200 µS/cm, suggesting that groundwater is continuing to discharge to the Columbia River at this location (Figure 3-19).

Cr(VI) concentrations continued to decline at inland KX extraction wells 199-K-153, 199-K-154, and 199-K-163. Well 199-K-163 exhibited Cr(VI) concentrations of less than 10 µg/L in 2017. At wells 199-K-153 and 199-K-154, the maximum concentration between high and low river-stage declined (Table 3-9).

Extraction wells 199-K-147, 199-K-130, 199-K-148, and 199-K-131 are located progressively farther to the northeast. These well locations are 152 to 183 m (500 to 600 ft) upgradient from (and roughly parallel to) the Columbia River shoreline (Figure 3-22). The Cr(VI) concentrations in these wells have steadily decreased since system startup. During 2017, well 199-K-147 was the only well in this group that exhibited Cr(VI) concentrations above 10 µg/L. Per the fiscal year (FY) 2017 optimization scope (SGW-59936), well 199-K-131 was identified to be converted from a KX P&T extraction well to a monitoring well. The realignment is paired with the conversion of well 199-N-189 to an extraction well, which is located in the inland plume segment between the 100-KR-4 and 100-NR-2 OUs. Both of these alignment activities were completed by August 2017.

Inland extraction well 199-K-152 continued to exhibit a declining trend, with concentrations ranging from 24 to 28 µg/L (Figure 3-22). Realignment of monitoring wells 199-K-49 and 199-K-151, as injection wells for the KX P&T system, which was identified in the FY 2017 optimization scope (SGW-59936), was complete by July 2017. This change will shorten the injection lines to current KX P&T injection wells 199-K-159 and 199-K-160, which will reduce head loss and potentially increase injection capacity of the KX P&T system.

The most 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 P&T extraction well 199-K-182) detected Cr(VI) over the full thickness of the unconfined aquifer, with concentrations ranging from 29 to 39 µg/L in 2011. Well 199-N-189, which was realigned to the KX P&T system as an extraction well in August 2017, pumped at an average rate of 121.9 L/min (32.2 gal/min), with an average Cr(VI) concentrations of 31.9 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 an average Cr(VI) concentration of 39.6 µg/L in 2017. 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 groundwater mound beneath 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.

The overall pumping strategy used in this area is being evaluated to determine if the center of mass for each of these higher concentration zones should be more directly targeted for remediation. Part of the FY 2019 optimization scope is to install wells to help better define Cr(VI) plumes within the 100-KR-4 OU, with the potential to realign newly installed wells to increase total mass removal, as well as to increase river protection.

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 116-K-2 Trench (K North area).

3.2.4.3 Other Contaminants

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 were identified as COCs in the RI/FS (DOE/RL-2010-97, Draft A) include nitrate, TCE, strontium-90, carbon-14, tritium, and total chromium.

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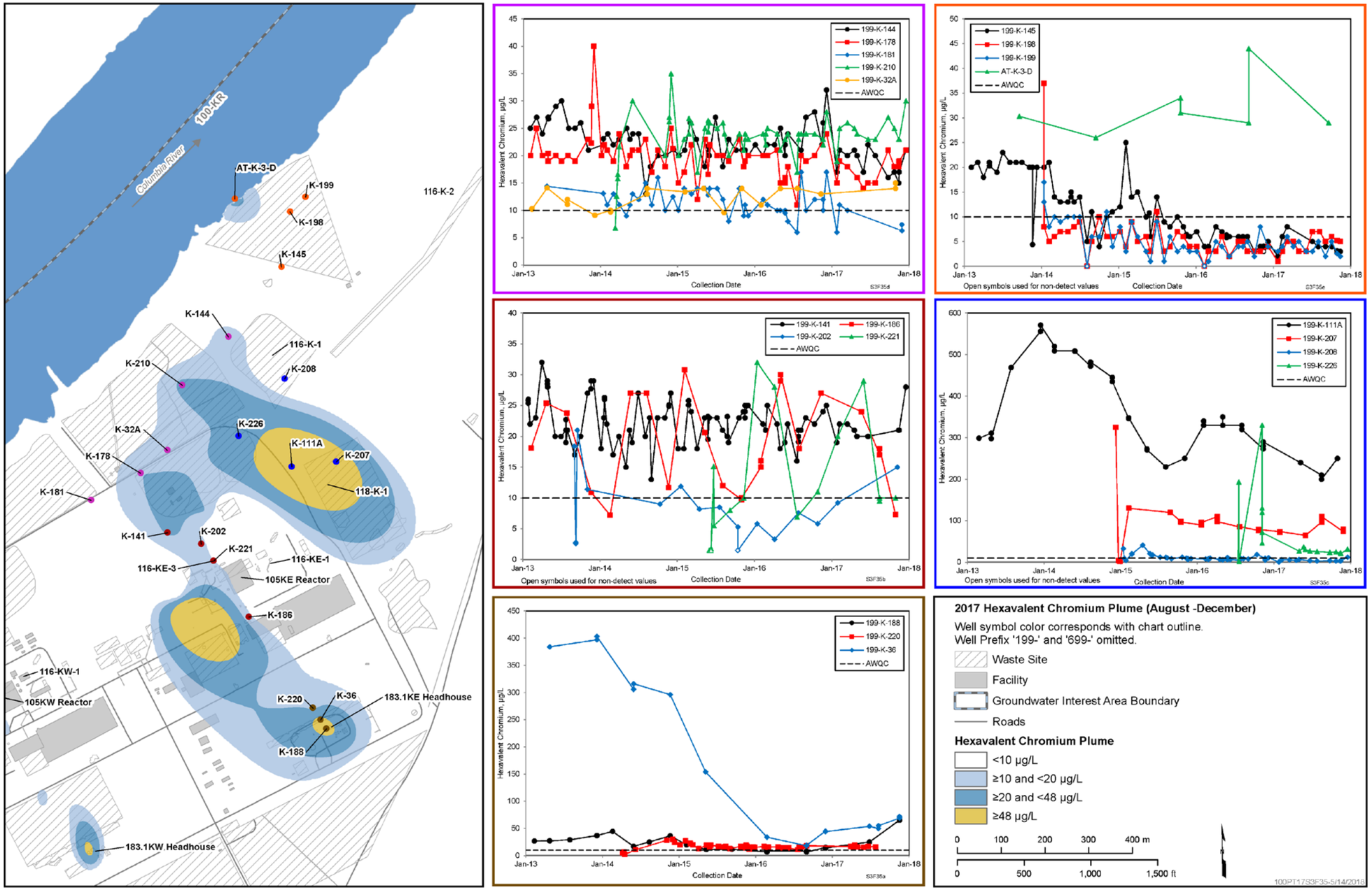

Figure 3-21. Cr(VI) Groundwater Concentration Time-Series Plots for Selected KE Reactor Wells, 2017

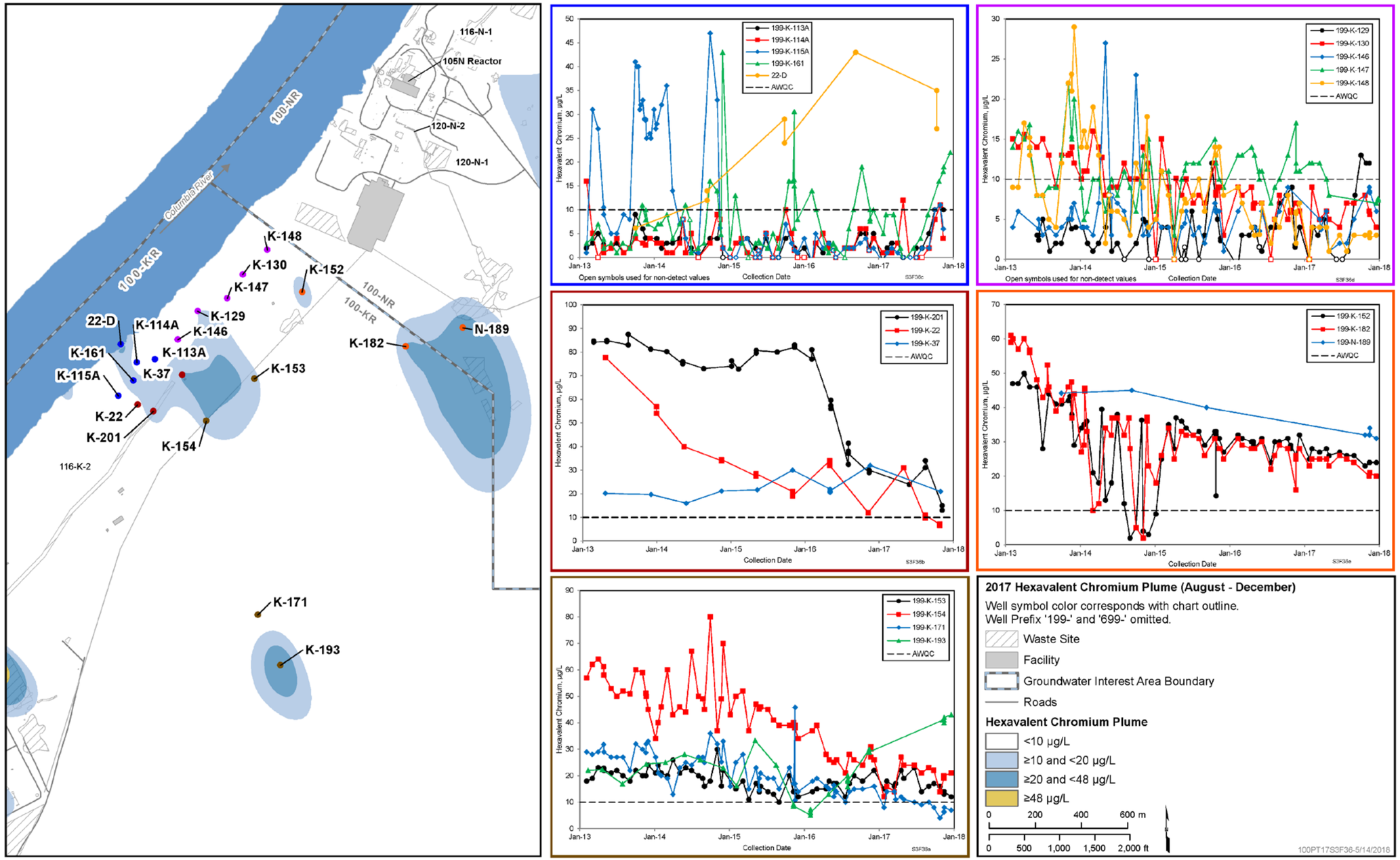

Figure 3-22. Cr(VI) Groundwater Concentration Time-Series Plots for Selected 116 K 2 Trench Area (K North) Wells, 2017

These constituents are present in the groundwater being treated for Cr(VI) at varying concentrations and are not subject to a remedial action decision at this time. The releases that caused the contamination by these constituents are generally not coincidental with the sources for the Cr(VI) (except for total chromium, which is present as Cr(VI)). The constituent concentrations of in groundwater range from slightly greater than DWSs (e.g., TCE at concentrations less than 9 µg/L versus the DWS of 5 µg/L) to substantially exceeding the standards (e.g., carbon-14 at over 40,100 pCi/L compared to the single-nuclide DWS equivalent of 2,000 pCi/L, and strontium-90 at greater than 12,000 pCi/L compared to the single-nuclide DWS equivalent of 8 pCi/L). Chapter 5 of DOE/RL-2017-66 discusses the occurrence and distribution of these constituents in groundwater at the 100-KR-4 OU.

The non-chromium contaminant plumes are variably captured by the Cr(VI) P&T systems, pass untreated through the P&T systems, and are then returned to the aquifer at the injection wells at concentrations below their DWSs, which is consistent with the interim action ROD requirements (EPA/ROD/R10-96/134). This results in the potential relocation of contaminants into portions of the aquifer where they did not originally exist.

Four of the constituents (TCE, strontium-90, carbon-14, and tritium) are currently found in groundwater and treatment system effluent at concentrations that may ultimately affect the interim action P&T operations, as described in the following discussion.

Trichloroethene. By the end of 2017, concentrations of TCE exceeded the 5 µg/L DWS in seven wells near the KW Reactor. Monitoring wells 199-K-11 and 199-K-185 exhibited the highest observed concentration of TCE at 8.1 µg/L in routine samples. New well 199-K-230 also had concentrations exceeding the DWS during most of the year, with a maximum of 9.7 µg/L collected during drilling. The historical maximum was 35 µg/L observed in well 199-K-106A; however, a specific source of TCE contamination has not been identified.

The ongoing injection of TCE at levels below the 5 µg/L DWS through KW P&T injection wells has resulted in a dispersed, low-concentration TCE plume near the KW Reactor. For the purpose of continued mapping, Figure 5-25 in DOE/RL-2017-66 shows the TCE plume using the maximum concentration observed throughout the KW Reactor area. Prior to 2017, the TCE plume was mapped using the annual average (see Figure 5-24 in DOE/RL-2017-66), which can cause the plume to artificially disappear due to averaging. For plume delineation, the maximum concentration will be used to map the TCE plume in 100-KR. This will ensure that the plume does not artificially disappear due to averaging.

Strontium-90. Strontium-90 is present in groundwater at concentrations exceeding the 8 pCi/L DWS at several locations within the 100-KR-4 OU. These locations are primarily downgradient of the 116-KW-2 FSB crib/reverse well, downgradient of the former KE Reactor FSB and 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 former KE Reactor FSB and 116-KE-3 FSB crib, near the KE Reactor. The 2017 maximum strontium-90 concentration in groundwater in this area was observed in well 199-K-222 at 15,600 pCi/L. KX P&T extraction well 199-K-141 continues to exhibit increasing strontium-90 concentrations, increasing from 61.7 pCi/L in mid-2016 to 84.4 pCi/L in early 2017. This well is inferred to be on the leading edge of the strontium-90 plume, which is migrating riverward from near the former KE Reactor FSB. Strontium-90 extracted by well 199-K-141 provides a measurable contribution of strontium-90 to the KX P&T system process stream, with an average effluent concentration of 2.8 pCi/L in 2017. As a result, well 199-K-141 was shut down for about 4 months during 2017 due to an observed increase in strontium-90 to 6.7 pCi/L in the KX P&T effluent. Subsequent results declined into normal ranges and well 199-K-141 was restarted.

Strontium-90 concentrations in this area will be monitored for potential effects on the P&T operation, which is currently focused on Cr(VI) removal.

Carbon-14. Carbon-14 present in groundwater at the100-KR-4 OU originated from historical discharges of reactor gas dryer regeneration condensate to the 116-KE-1 and 116-KW-1 gas condensate cribs. The 2017 carbon-14 plumes exhibited little change in extent from 2016. In the 100-K West Area, concentrations remained consistent with previous years in most of the area, including during the KW P&T system rebound study. Downgradient of the 116-KW-1 gas condensate crib, however, concentrations increased during rebound study. For example, carbon-14 concentrations in well 199-K-106A increased to 40,100 pCi/L in July 2016. In 2017, concentrations in well 199-K-106A ranged from 14,200 to 28,500 pCi/L. In well 199-K-204, concentrations declined from 26,600 pCi/L in January 2017 to 15,000 pCi/L in November. In 2016, the increase in carbon-14 in the KW Reactor area was accompanied by increases in nitrate (to 70.8 mg/L) and tritium (to 91,900 pCi/L), indicating the apparent migration of contamination originating at the 116-KW-1 gas condensate crib. Carbon-14 has historically been captured by the KW P&T system and distributed to the injection wells. Contamination in groundwater continued to be observed as widely distributed over the KW area at concentrations less than 1,000 pCi/L.

A lower concentration carbon-14 plume exists in the KE Reactor area. The plume was formerly defined by wells 199-K-29 and 199-K-30, which have been decommissioned. These wells monitored conditions downgradient of the 116-KE-1 Crib waste site. As with conditions near the KW Reactor, the carbon-14 plume at the KE Reactor area appears to be migrating downgradient, away from the source area. The carbon-14 plume at the KE Reactor area may not lie completely within the capture zone of the operating KX P&T extraction wells. In 2017, only two wells in the KE Reactor area exceeded the DWS. Well 199-K-202 had a maximum carbon-14 concentration of about 3,170 pCi/L in 2017. Well 199-K-222, located in the footprint of the former KE Reactor FSB, carbon-14 concentrations rose from less than 200 pCi/L in 2016 to 2,240 pCi/L in October 2017, after the pump intake depth was raised to the upper part of the well screen.

Tritium. Tritium concentrations exceed the DWS at multiple locations in the 100-K Area, with the primary source areas at the 116-KE-1 Crib, 116-KW-1 Crib, and 118-K-1 Burial Ground. The highest concentrations are in wells downgradient of these source areas. During 2017, tritium concentrations in wells 199-K-111A and 199-K-207 continued the decline observed in 2016, reaching a low of 71,200 and 157,000 pCi/L, respectively. Well 199-K-227, which was installed at the south end of the 118-K-1 Burial Ground to investigate the tritium concentrations in this area, exhibited a tritium concentration as high as 3,810,000 pCi/L during drilling. The KR4 and KX P&T system effluent exhibited 2017 average concentrations of tritium at 2,470 and 4,235 pCi/L, respectively. At the KW P&T system, effluent tritium concentration dropped below the DWS in 2017. 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 P&T systems on the water table and to evaluate the groundwater flow direction and gradient. The hydraulic effects of the P&T systems are superimposed on seasonal fluctuations in the river-level boundary conditions and inland groundwater elevation to evaluate the effectiveness of providing hydraulic containment and capture of Cr(VI) plumes.

Groundwater elevation is measured manually 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, as part of the AWLN. The 100-K Area AWLN system includes 31 stations that were operating in and around the 100-KR-4 OU as of the end of CY 2017. The AWLN configuration is based on the proposed AWLN

configuration in SGW-53543 to provide sufficient data to calculate gradients and to delineate capture zones from the 100-K P&T systems. Additional dynamic water-level measurements are collected from transducers at each of the P&T extraction and injection wells (separate from the AWLN). Reported water-level data from AWLN wells and manual depth-to-water measurements are reviewed and reduced, and a final data set is compiled to assemble the groundwater elevation maps for high and low river-stage conditions (Figures 3-3 and 3-4).

Under natural gradient conditions, regional groundwater generally flows to the north and northwest, generally perpendicular toward the Columbia River beneath the 100-KR-4 OU. Hydraulic effects of the P&T systems (i.e., the formation of depressions at extraction wells and mounds at injection locations) are superimposed onto these regional flow patterns. As shown in Figure 3-18, extensive water table depressions were present during 2017 from the near-river area of KE Reactor and extending to the distal end of the 116-K-2 Trench. This depression is interrupted near the mid-point of the 116-K-2 Trench by the inferred extension of the recharge mound associated with the KR4 and KX P&T system injection wells. The inferred water table is consistent with the observation that the P&T systems are providing groundwater containment, resulting in river protection along the 100-K Area river shore.

Section 3.2.6 discusses the effects of seasonal changes in river-stage (and corresponding water table elevation response) on contaminant concentrations in the aquifer and treatment system performance. River-stage behavior in 2017 was similar to historically high years (e.g., 2011 or 2012), and the absolute peak river-stage was observed in May. The river-stage remained high until June, steeply declining through the summer before reaching typical seasonal low levels in October (Figure 3-17).

Under natural high river-stage flow conditions, the local groundwater gradient has a reduced magnitude near the river and flattened. The very near river area may exhibit a flow direction reversal, with river water intruding into the aquifer as seasonal bank storage. This change at the river boundary causes the inland groundwater to also slow its riverward migration, resulting in a flatter water table gradient and creating the seasonal increase 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. In areas of substantial groundwater extraction (e.g., the area between 116-K-2 Trench and the river), inland flow from the river is maintained. 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 3-18 presents a groundwater contour map of the area, which was developed using concurrent measurements collected in early March 2017 when river level was moderate.

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, 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 on 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 universal kriging/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., groundwater was not moving toward extraction wells at any time during the period). 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 average 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 average 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. Therefore, each depiction reflects a steady-state flow field, which results from the operation of P&T wells and the average river-stage for a particular month. These depictions are not meant to reflect transient flow conditions over the year; therefore, hydraulic containment calculated for each month does not directly translate to actual, transient capture over time. Rather, the depictions are meant to illustrate the relative strength of hydraulic containment over the year, indicating areas where the effectiveness of the actual transient capture may require further attention over time.

The ICFM and SCFM are collective 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 that it is either weak or it is not being achieved (where both maps suggest that containment is not achieved or, in most cases, where capture frequencies are very low). 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 either that containment is not being achieved or, as it should be interpreted, that it is weak.

The extent of chromium contamination in groundwater during high and low river-stage (and corresponding high and low groundwater elevation) conditions is estimated using a systematic approach to develop contaminant plume maps using an integrated numerical interpolation methodology, as detailed in ECF-Hanford-18-0013. Figures 3-23 to 3-28 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-KR-4 OU as follows:

- Figure 3-23 and Figure 3-24 depict chromium contamination under high river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.
- Figure 3-25 and Figure 3-26 depict chromium contamination under low river-stage conditions, with an ICFM and SCFM illustrating hydraulic containment, respectively.

- Figure 3-27 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 3-28 overlays the capture flow lines with the chromium plume contours for low river-stage conditions.

ECF-HANFORD-18-0014 presents details on 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.

3.2.7 River Protection Evaluation

The river protection status of conditions at the 100-KR-4 OU is based on assessment of the hydraulic effects of the remedial action systems, as well as an 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, in general, the river protection status improved in 2017. However, the higher-than-normal river-stage conditions in 2017, and especially the steep river-stage decline after June, resulted in higher than usual hydraulic gradients and, therefore, groundwater velocities. Therefore, hydraulic containment was not as strong during several months of the year, although long-term transient capture is not expected to be significantly impacted unless such adverse river-stage conditions prevail consistently in the future. The 100-KW P&T system shutdown from May 2016 to April 2017 resulted in ambient flow conditions with an average gradient direction toward the northeast. In addition, hydraulic containment near the shoreline in 100-KW Reactor area was reduced due to cessation of operation of wells 199-K-132, 199-K-138, and 199-K-196.

This section describes the river protection evaluation process and presents the results of the 2017 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 greater than 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 attaining the river protection objective using data obtained during (or prior to) 2011.

Figures 3-29 and 3-30 present an assessment of progress during 2017 toward attaining the river protection objective. The technical methods and process that were used to complete the calculations necessary to prepare these figures are detailed in SGW-54209. ECF-HANFORD-17-0028, *Description of Groundwater Calculations and Assessments for the Calendar Year 2016 (CY2016) 100 Areas Pump-and-Treat Report*, presents details on the specific calculations used to produce the figures for 2017. The results of contaminant standard and trend tests described in SGW-54209 to identify low-, moderate-, and high-concern wells are presented in Figures 3-29 and 3-30 using the symbols in Table 3-10.

Shoreline lengths are calculated and reported in increments of 100 m (330 ft); the results of the assessment are presented in these figures as color-filled circles of diameter equal to 100 m (330 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). Table 3-11 presents the symbols depicting the results of the river protection evaluation.

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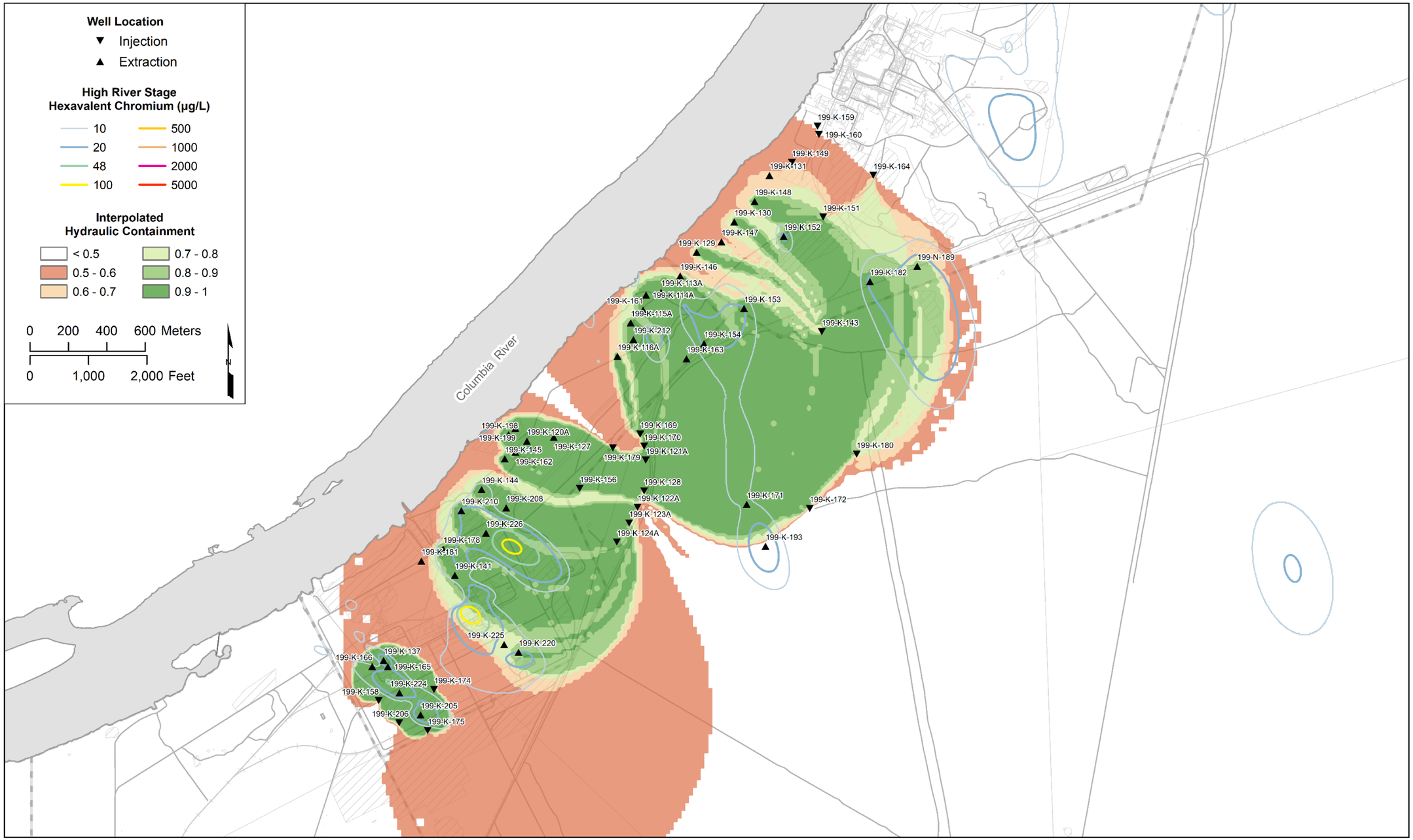

Figure 3-23. 100-K Area Interpolated CFM and High River-Stage Chromium Contamination, 2017

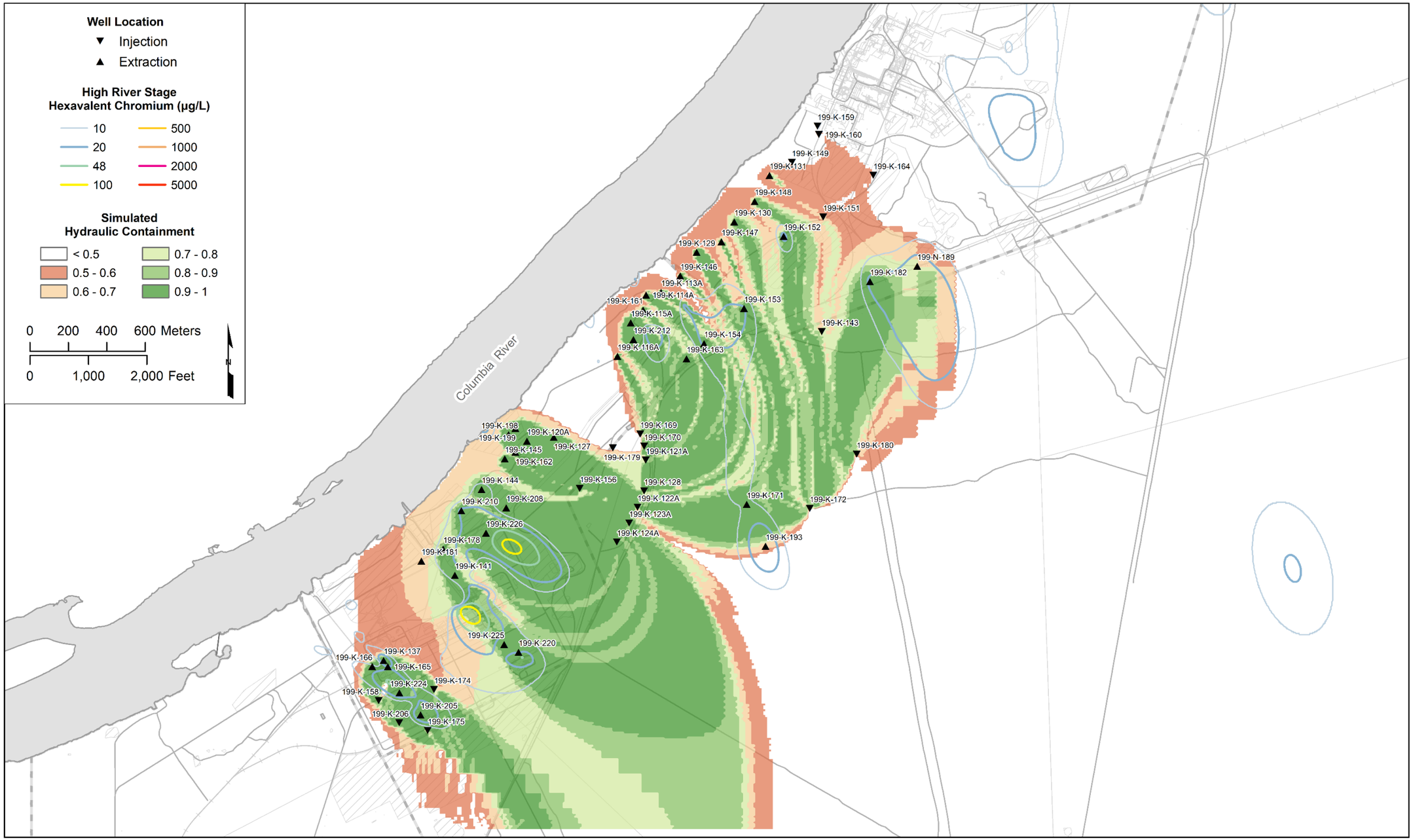

Figure 3-24. 100-K Area Simulated CFM and High River-Stage Chromium Contamination, 2017

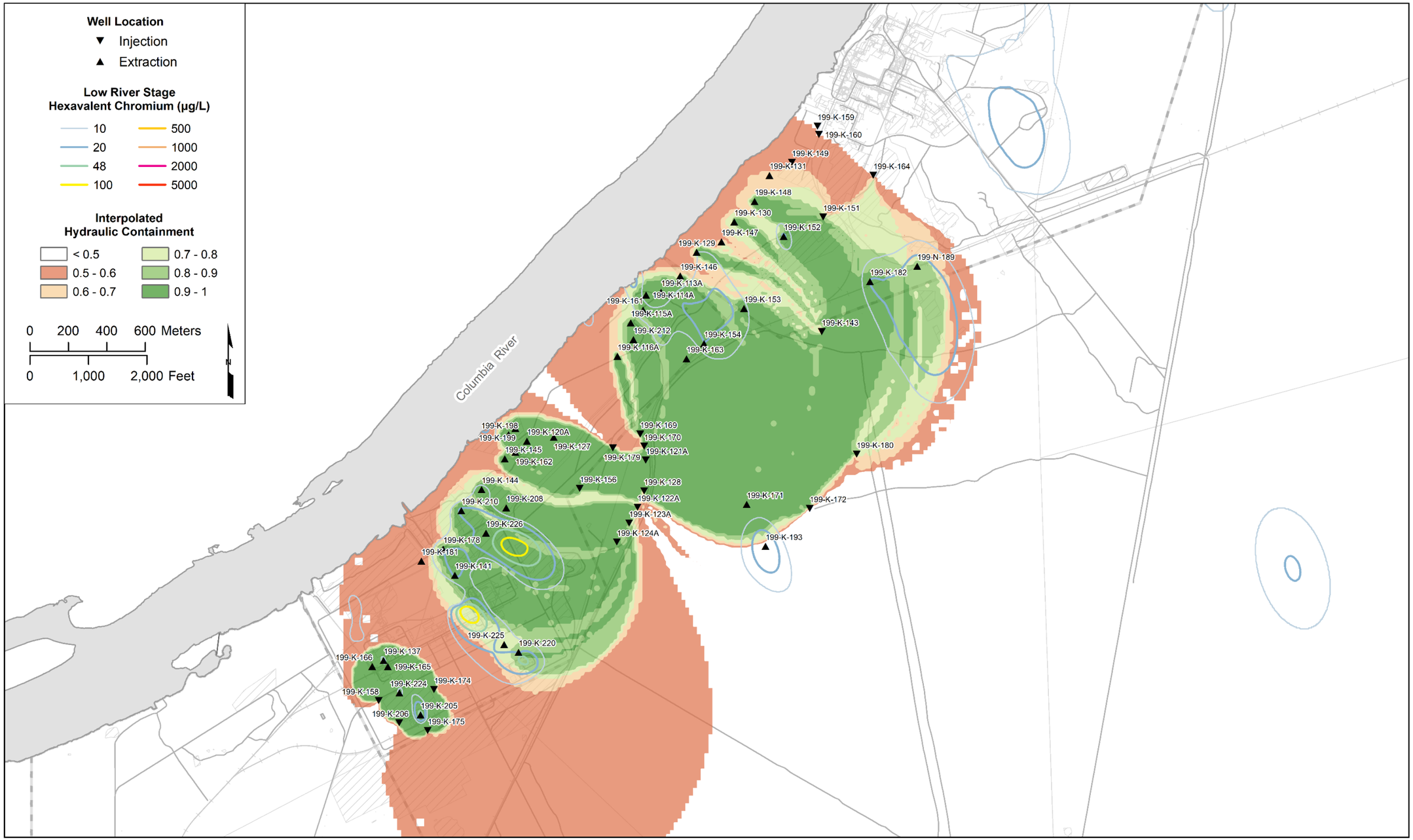

Figure 3-25. 100-K Area Interpolated CFM and Low River-Stage Chromium Contamination, 2017

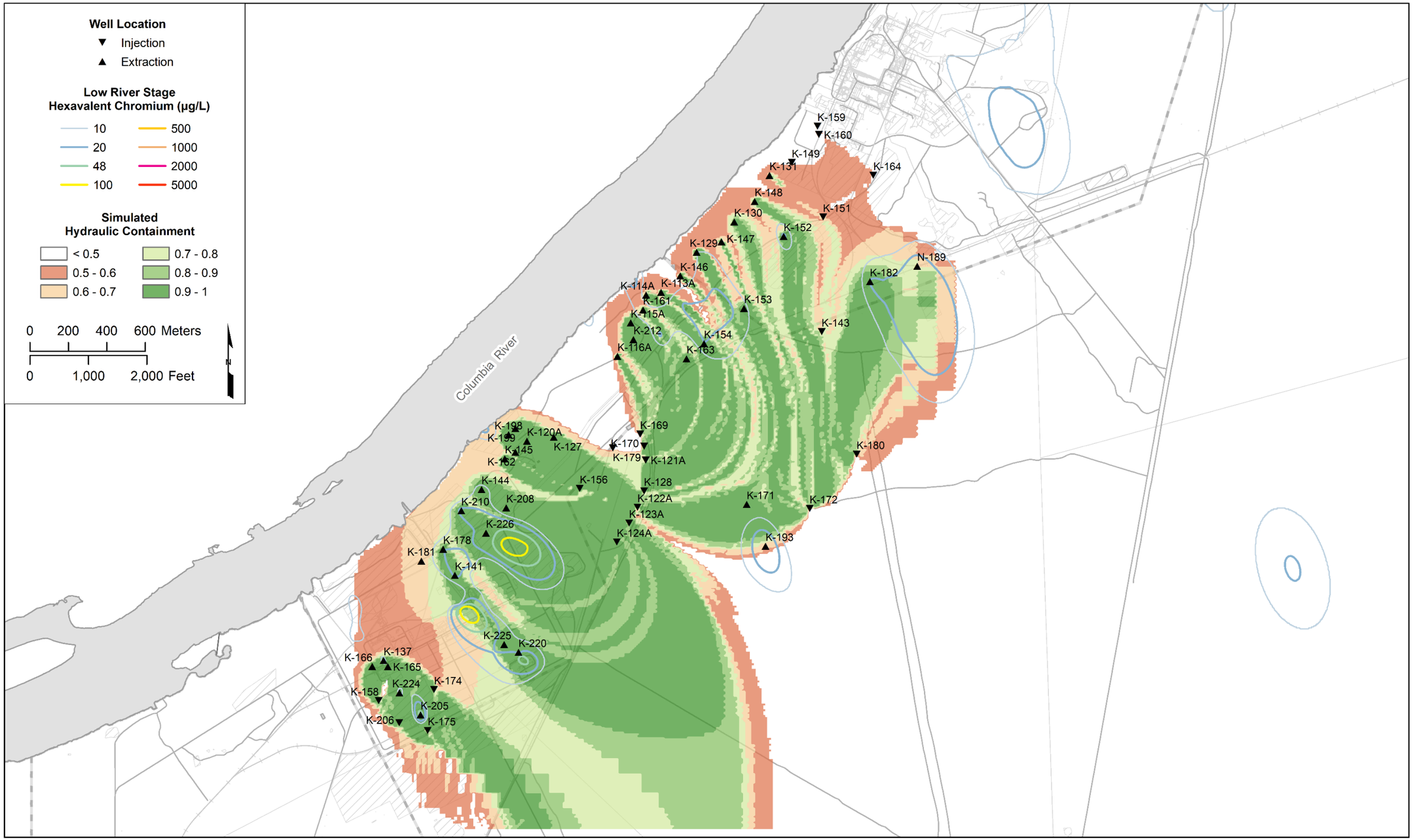

Figure 3-26. 100-K Area Simulated CFM and Low River-Stage Chromium Contamination, 2017

Figure 3-27. 100-K Area Groundwater Flow Lines of Capture Zone Flow Field, 2017

Figure 3-28. 100-K Area Groundwater Flow Lines of Capture Zone Overlay with Low River-Stage Chromium Plume Contours, 2017

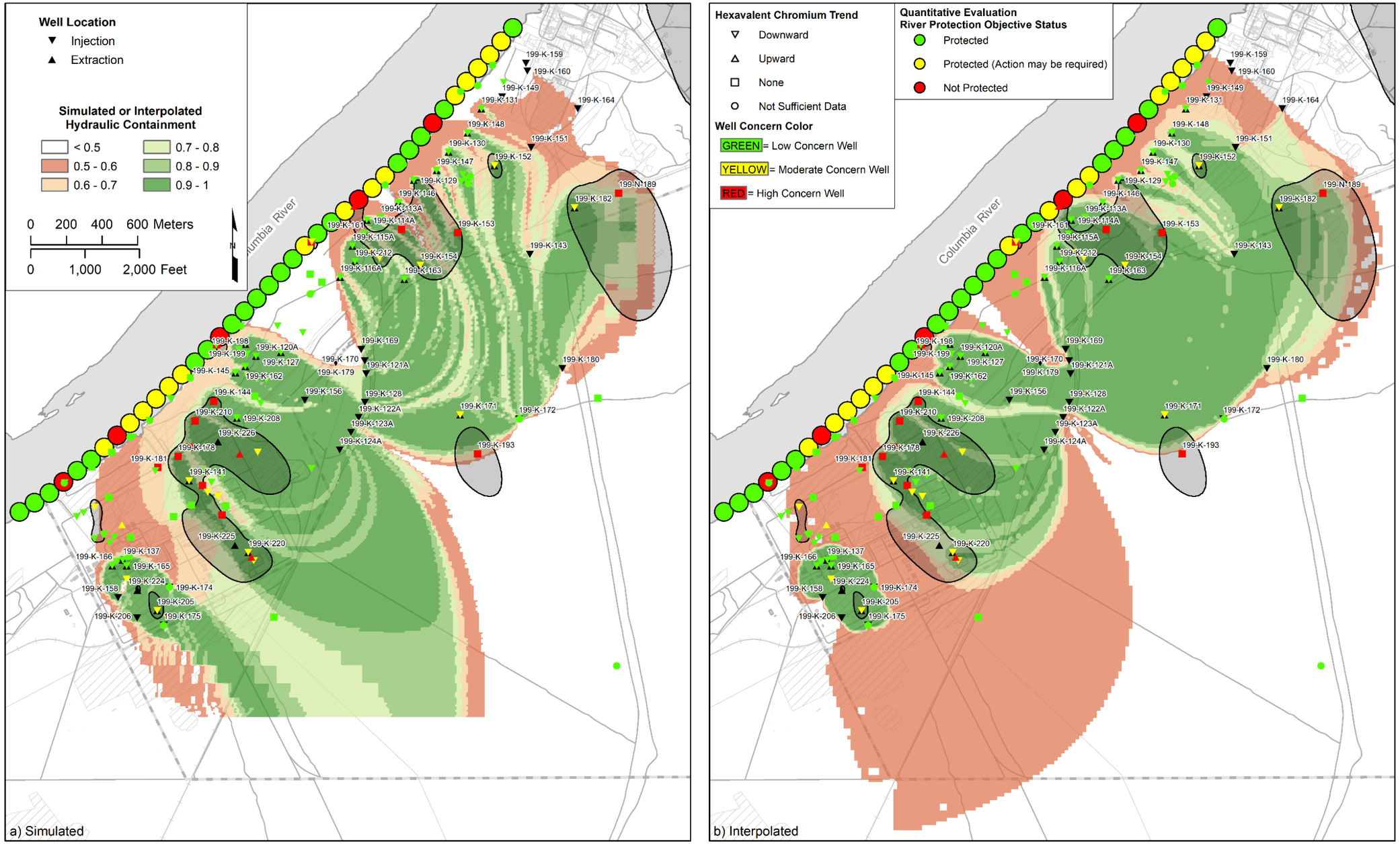

Figure 3-29. 100-K Area Quantitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, Together with Mapped Extent of Low River-Stage Chromium Contamination Above 10 **µg/L and Results of Standard Test and Trend** Test

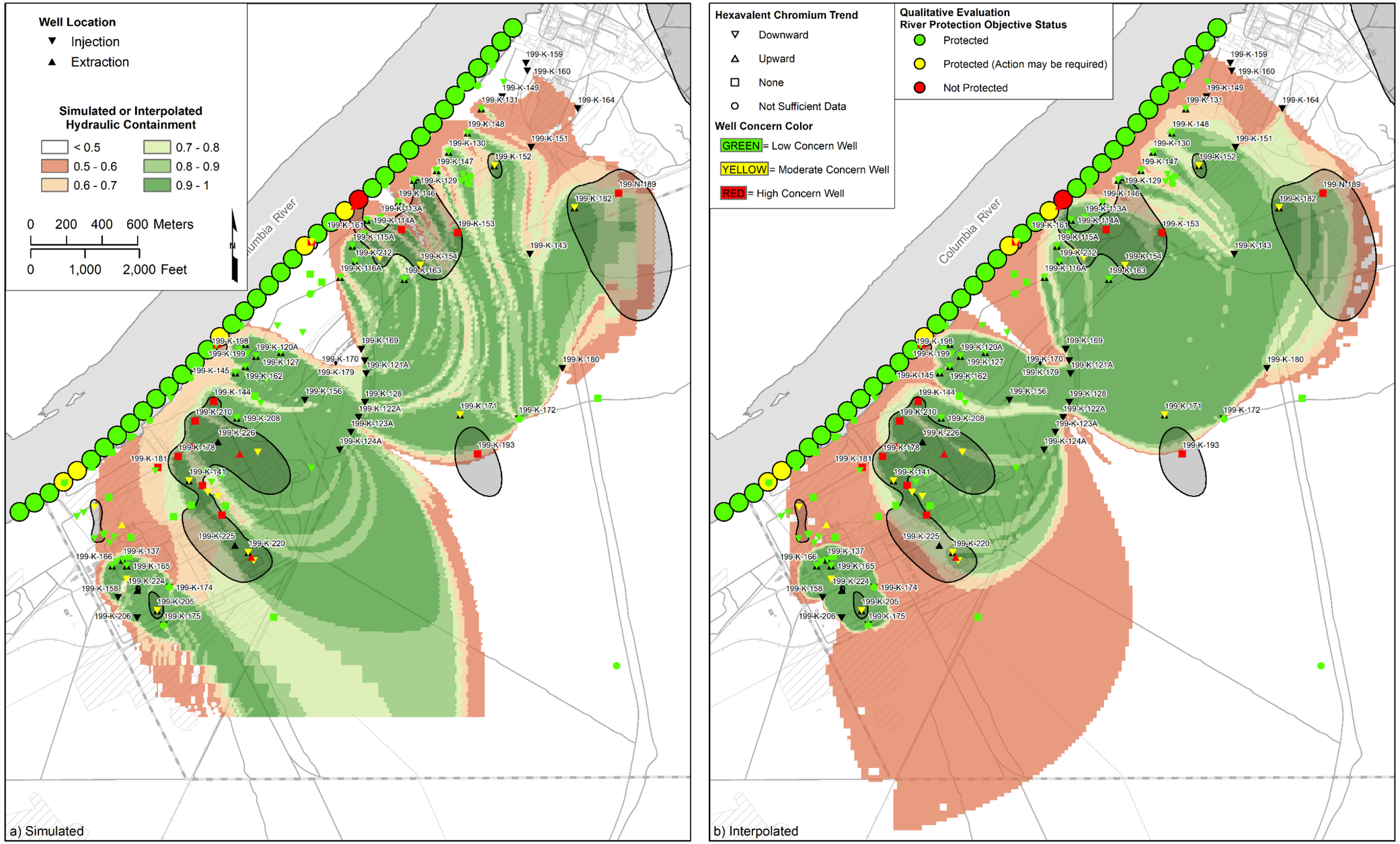

Figure 3-30. 100-K Area Qualitative Assessment of Shoreline Protection with (a) Simulated and (b) Interpolated CFM, with Mapped Extent of Low River-Stage Chromium Contamination A**bove 10 µg/L and Results of Standard Test and Trend Test**

Table 3-10. Standard and Trend Test Symbology for Wells

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

Table 3-11. Symbology for Status of River Protection Objective

Symbol	Explanation
●	Protected
●	Protected (action may be required)
●	Not protected

Figures 3-29 and 3-30 depict the results of assessing progress toward attaining the river protection objective for chromium in the 100-K Area. Figure 3-29 depicts the results of the quantitative evaluation, which is determined based on overlay and quantitative comparison of the extent of chromium contamination and the extent of hydraulic containment. Figure 3-30 depicts the results of the qualitative evaluation, which is based on the quantitative evaluation but also relies on qualitative considerations (e.g., the duration, magnitude and direction of hydraulic gradients along the shoreline, location of the P&T wells, and concentration trends). Based on these calculations, the river protection evaluation for the 100-K Area is as follows (that all lengths are rounded to the nearest 5 m [or 5 ft]):

- Total length of shoreline adjacent to the 100-K Area: 4,000 m (13,120 ft)
- Length identified as protected: 3,400 m (11,150 ft)
- Length identified as protected (action may be required): 500 m (1,640 ft)
- Length identified as not protected: 100 m (330 ft)

The results of the qualitative river protection evaluations for the 100-K Area for 2017 are compared to those presented for 2016 (DOE/RL-2016-19, *Calendar Year 2015 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation*). Table 3-12 provides a comparison of the river protection evaluation for 2016 and 2017.

Table 3-12. Comparison of River Protection Assessment Results

Assessed Shoreline Lengths, 100-K	2016	2017	Change from 2016 to 2017*
Total length of shoreline adjacent to 100-K Area	4,000 m (13,120 ft)		
Length identified as "protected" Percent of shoreline "protected"	3,500 m (11,480 ft) 88% of shoreline	3,400 m (11,150 ft) 85% of shoreline	100 m (330 ft) previously identified as "protected (action may be required)" now identified as "protected" 200 m (660 ft) previously identified as "protected" now identified as "protected (action may be required)"
Length identified as "protected (action may be required)" Percent of shoreline "protected (action may be required)"	500 m (1,640 ft) 12.5% of shoreline	500 m (1,640 ft) 12.5% of shoreline	100 m (330 ft) previously identified as "protected (action may be required)" now identified as "protected" 100 m (330 ft) previously identified as "protected (action may be required)" now identified as "not protected 200 m (660 ft) of shoreline previously identified as "protected" now identified as "protected (action may be required)"
Length identified as "not protected" Percent of shoreline "not protected"	0 m (0 ft) 0% of shoreline	100 m (330 ft) 2.5% of shoreline	100 m (330 ft) of shoreline previously identified as "protected (action may be required)" now identified as "not protected"

* Details on year-to-year changes are provided in ECF-HANFORD-18-0014, *Description of Groundwater Calculations and Assessments for the Calendar Year 2017 (CY2017) 100 Areas Pump-and-Treat Report*.

The KW P&T system shutdown from May 2016 to March 2017 resulted in reduced hydraulic containment near the shoreline. Although system restart in March 2017 re-established strong hydraulic containment inland in this area, hydraulic containment is compromised near the shoreline as wells 199-K-132, 199-K-138, and 199-K-196 remained inactive. However, water quality samples collected from these wells showed only a minor increase in Cr(VI) concentrations, confirming the slow transient nature of plume migration toward the shoreline in 2017, even under reduced hydraulic containment conditions. Well 199-K-196 is planned to be operational again in 2018, which will expand the hydraulic containment zone near the river shoreline.

The effect on river protection from the extraction wells operating near the shoreline will be further evaluated. Additional investigation is planned to better understand the source of elevated Cr(VI) near the shoreline, downgradient of the 116-K-2 Trench. A new monitoring well is planned to be installed between wells 199-K-144 and 199-K-145; and aquifer tubes AT-K-3-D, AT-K-3-M, AT-K-3-S, 22-D, and 22-M were extended to allow sampling during high river-stage conditions. Sampling data from these monitoring locations will help determine if Cr(VI) is migrating to the shoreline from inland or if it is present in low transmissivity zones and leaching slowly into the aquifer.

Given the significant river-stage decline during the second half of 2017, it should be noted that quantitative evaluations of the river protection objectives provide a conservative assessment of shoreline protection; qualitative evaluations for 2017 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 Cr(VI) plume depictions for 2016 and 2017 indicates a consistent number of shoreline segments where Cr(VI) 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 Comparison of Simulated to Measured Contaminant Mass Recovery

Comparison of the ICFM and SCFM provides a 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 3-31 presents a comparison of monthly and cumulative mass of Cr(VI) recovered throughout the 100-K Area at each of the KX, KW, and KR4 P&T systems for 2017, 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 Cr(VI) in groundwater was assumed to be the low river-stage depiction of Cr(VI) for 2016, as presented in ECF-HANFORD-16-0138.

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-18-0014. In each case, there are system-specific and systematic conditions that might lead to differences between the simulated and measured values. ECF-HANFORD-18-0014 presents graphs comparing the simulated and measured mass recovery at each individual extraction well for each P&T system.

For the KW P&T system, the model over-predicts mass recovery, mainly due to high simulated influent concentrations at wells 199-K-224 and 199-K-165. Comparison of measured to simulated concentrations at these wells suggests that the extent of the high-concentration zone near those wells, as well as the concentration distribution in the same area, were overestimated in the fall 2016 plume, which was used as the initial condition in the simulation. However, measured and simulated mass recovery trends appear more consistent in the fall. Finally, measured influent concentrations at wells 199-K-205 and 199-K-137 confirm the presence of continuing sources within the groundwater interface, as concentrations in the aquifer increase due to water table fluctuations in response to river-stage variations.

The model simulated mass recovery tracks well in the measured mass recovery in the KR4 P&T system. Only minor differences between measured and simulated concentrations are observed on a monthly basis at the extraction wells, but simulated concentrations do not significantly over- or under-predict the measured concentrations.

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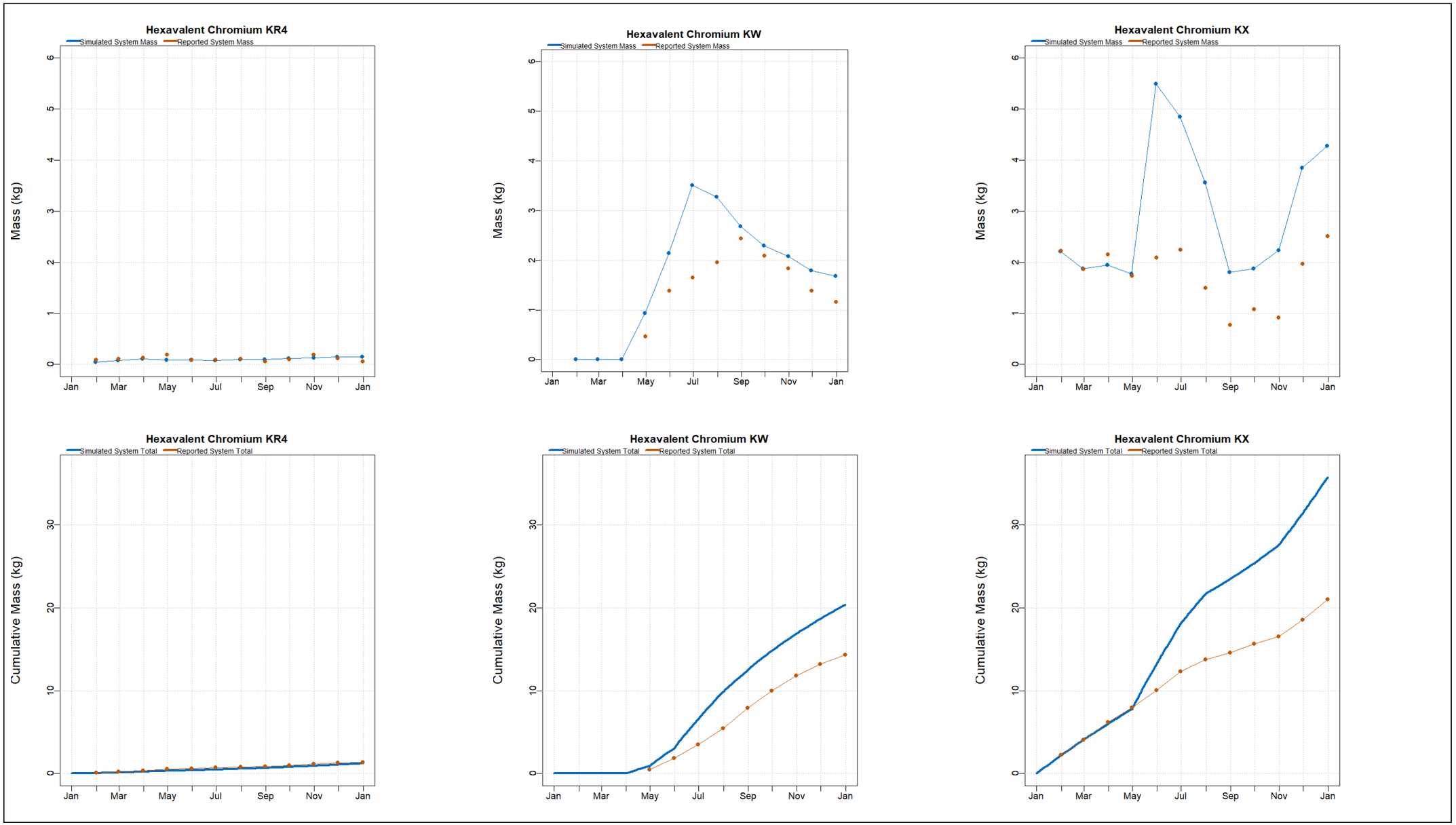

Figure 3-31. Comparison of Observed to Calculated Cr(VI) Mass Removal (Top Row = Monthly Mass Removal; Bottom Row = Cumulative Mass Removal)

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Discrepancies between measured and simulated concentrations in the KX P&T system are attributed almost exclusively to over-predicting mass recovery at well 199-K-226 due to high-concentration distribution near the well in the fall 2016 interpolated Cr(VI) plume. Measured and simulated concentration trends and mass recovery in the remaining KX P&T extraction wells are in excellent agreement.

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 and interface based on the 100 Area groundwater model that is used by OU scientists to evaluate the relative performance of alternative well configurations. The OU scientists evaluate pumping configurations throughout the year and provide recommended adjustments to flow rates and recommendations for well realignment and/or the installation of new wells. Specific RPO activities performed at the 100-KR-4 OU during 2017 included the following:

- Converted monitoring well 199-N-189 to an extraction well at the KX P&T system and converted KX P&T extraction well 199-K-131 to a monitoring well
- Converted monitoring wells 199-K-149 and 199-K-151 to injection wells at the KX P&T system and converted KX P&T injection wells 199-K-159 and 199-K-160 to monitoring wells
- Converted monitoring wells 199-K-193 and 199-K-226 to extraction wells at the KX P&T system
- Installed an additional feed pump at the KX P&T system to increase operating capacity
- Drilled and installed four new monitoring wells to enhance the CSM and delineate contaminant plumes

3.3 Radiological Dose and Drinking Water Standard Analysis of 100-K Area Pump-and-Treat Effluent

This section discusses the results of radiological dose and DWS evaluation of the 100-K Area P&T system for 2017 against the requirements of DOE O 458.1 and DOE-STD-1196-2011. Additional guidance to proactively evaluate radiological effluent monitoring based on the DCS to ensure that mitigating steps are implemented before conditions exceed target metrics is described in DOE-HDBK-1216-2015 and summarized in Table 3-13. These criteria are applied to the 100-K Area P&T systems and are evaluated each year for adequacy and are updated as necessary.

Table 3-13. Recommended Criteria for Liquid Radiological Effluent Monitoring

Criterion Number	DCS Sum of Fractions	And	Potential Annual Dose from Exposure to a Likely Receptor (mrem)	Minimum Criteria for Liquid Radiological Effluent Monitoring
1	>/= 1		—	Apply best available technology to reduce effluent releases (except H-3). Use continuous monitoring/sampling, but where effluent streams are low flow and potential public dose is very low, (<1 mrem/yr) alternative sampling approaches may be appropriate.
2	>/= 0.01 to 1		>1	Continuously monitor or sample. Identify radionuclides contributing >/= 10% of the dose. Determine accuracy of results (+/- accuracy and percent confidence level).
3	>/= 0.001 to 0.01		<1	Monitor using a graded approach to select the appropriate method and duration. Identify radionuclides contributing >/= 10% or more of the dose. Assess annually the facility inventory and potential for radiological effluent release.
4	<0.001		—	No monitoring required. Evaluate annually the potential for liquid radiological effluent release.

Source: Table 3-1 of DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

— = not applicable

DCS = derived concentration standard

3.3.1 Evaluation of Effluent Water Total Effective Dose for 100-K Area Pump-and-Treat Systems for Calendar Year 2017

Effluent monitoring at the three 100-K Area P&T systems was performed by sampling and analyzing the stream exiting the plant prior to pumping effluent to the injection well fields. Sampling and analysis were performed on a quarterly basis for target radionuclides identified as contaminants of interest for the groundwater remedial actions supported by the treatment system. The radionuclides of interest for the 100-K Area P&T systems are tritium, strontium-90, carbon-14, and technetium-99.

Table 3-14 summarizes the results of periodic sampling and analysis of effluent from the KR4, KW, and KX P&T systems. Where multiple measurements were determined for an analyte during a single sampling and analysis event, the maximum value was selected for use in this evaluation.

Table 3-14. Summary of Effluent Radioisotope Sampling and Analysis Results for CY 2017 for KR4, KW, and KX P&T Systems

Sample Location	Sample Date	Tritium (pCi/L)	Strontium90* (pCi/L)	Carbon-14* (pCi/L)	Technetium-99* (pCi/L)
KR4 P&T					
Effluent tank – T-K5	6/13/2017	2,750	4.6	(30.1)	(39.2)
Effluent tank – T-K5	9/21/2017	2,890	2.86	36.5	(26.8)
Effluent tank – T-K5	12/12/2017	1,960	(1.06)	(28.1)	(39.5)
KW P&T					
Effluent tank – T-W3	5/2/2017	1,390	(1.1)	246	21.6
Effluent tank – T-W3	6/13/2017	1,500	(1.55)	356	59.8
Effluent tank – T-W3	9/21/2017	1,360	(0.869)	312	75.9
Effluent tank – T-W3	12/12/2017	1,490	(1.6)	327	58.7
KX P&T					
Effluent tank – T-X5	3/28/2017	3,320	2.75	NM	NM
Effluent tank – T-X5	6/13/2017	3,470	6.67	45.9	(41)
Effluent tank – T-X5	7/20/2017	NM	(1.55)	NM	NM
Effluent tank – T-X5	9/21/2017	5,690	2.55	55.2	(26.1)
Effluent tank – T-X5	12/12/2017	4,460	(1.55)	43.7	(36.8)

* Values in parentheses were reported as not detected. Value presented is the reported minimum detectable activity concentration for samples reported as analyzed but not detected.

NM = not measure for this sampling event

P&T = pump and treat

Individual radioisotope activity concentrations were subsequently converted to estimated effective dose using the DCS values in Table 3-15.

Table 3-15. Derived Concentration Standards for Radioisotopes Evaluated in KR4, KW, and KX P&T System Effluent

DCS	Tritium	Strontium-90	Carbon-14	Technetium-99
DCS (µCi/mL)[a]	1.90E-03	1.10E-06	6.20E-05	4.40E-05
DCS (pCi/L)[b]	1.90E+06	1.10E+03	6.20E+04	4.40E+04

a. DCS from Table 5 of DOE-STD-1196-2011, *Derived Concentration Technical Standard*.

b. DCS converted to pCi/L for direct comparison to measurement results.

DCS = derived concentration standard

Table 3-16 shows the individual radioisotope dose contributions for each effluent sampling event for the 100-K Area P&T systems and the cumulative TED estimates for 2017. The TED was calculated using two approaches: the first approach was conservative, incorporating the MDA for nondetect measurements as a value, and the second approach includes no value for nondetect measurements. The resulting TED and DCS fractions were then compared to the criteria presented in Table 3-13.

The cumulative TED and DCS fraction values shown in Table 3-16 indicate that the results of effluent sampling events during 2017 at the KR4, KW, and KX P&T systems met monitoring criterion #3, with the exception of samples from the KX P&T system analyzed on March 28 and July 20, 2017. These samples were not analyzed for carbon-14, technetium-99, and tritium; the other samples from this system exhibited detectable carbon-14, technetium-99, and tritium concentrations. This indicates that the calculated TED and DCS fraction for these samples may not be completely representative of the effluent.

3.3.2 Comparison of KR4, KW, and KX Pump-and-Treat Effluent Water Radiological Constituents to Drinking Water Standards for Beta/Photon Emitters and Uranium for Calendar Year 2017

The radioisotopes measured in P&T effluent from the KR4, KW, and KX P&T systems were also evaluated against the 4 mrem/yr drinking water MCL for beta and photon emitters. The cumulative beta/photon dose MCL is based on a sum-of-fractions calculation (similar to the *Atomic Energy Act of 1954* DCS TED), using the derived concentration values published by EPA. The beta/photon MCL dose analysis was performed in two ways: first, using the reported MDA as a value for measurements reported as nondetects; and, secondly, without including values for nondetected isotopes. The first approach is a conservative screen used to assess potential dose contributions. With both methods, one of the sampling events (June 13, 2017) exceeded the beta/photon emitter dose MCL at the KX P&T system. Using the nonconservative approach, the sample analyzed for the June 13, 2017, sampling event exceeded the MCL with a sum of fractions of 1.0 and a resulting dose of 4.1 mrem/yr. This was driven primarily by strontium-90 detection in the effluent.

While the sampling events on March 28 and July 20, 2017, may not be representative of the effluent, it is not likely that these sampling events would exceed the drinking water dose based on MDA and detected strontium-90 values. Using this analysis, it is determined that the KX P&T effluent consistently (although not exclusively) met the MCL dose standard for beta/photon emitters. Furthermore, the monthly sampling and analysis frequency appears to be adequate to address potential variability in the effluent stream. Table 3-17 provides a summary of this evaluation.

3.3.3 Conclusions of Evaluation of Radiological Constituents in KR4, KW, and KX Pump-and-Treat Effluent Water for Calendar Year 2017

Evaluation of radiological dose of the KR4, KW, and KX P&T effluent water during 2017 indicates that the effluent met the following standards and criteria:

- The calculated DCS-based TED of the effluent for KR, KW, and KX P&T systems was less than 1 mrem/yr, substantially below the 100 mrem/yr public dose limit.
- The calculated DCS-based sum of fractions and resulting TED of the effluent for the KR4, KW, and KX P&T systems consistently met criterion #3 for a graded approach with annual sampling.
- The calculated MCL-based beta/photon-emitter drinking water dose was below the 4 mrem/yr MCL dose for the KR4 and KW P&T systems. One event exceeded the MCL dose for the KX P&T system due to low-level strontium-90 detection. With the exception of the June 13, 2017, sampling event at the KX P&T system, all other calculated MCL drinking water doses were below the 4 mrem/yr MCL.

Table 3-16. Calculated Individual Radioisotope Dose Contributions and TED for KR4, KW, and KX P&T Effluent, 2017

Sample Location	Sample Date	Individual Isotope Effective Dose Contribution				TED Cumulative (mrem/yr)	DCS Fraction Cumulative (Fraction)	TED – Detects Only (mrem/yr)	DCS Fraction – Detects Only (Fraction)
		Tritium (mrem/yr)	Strontium-90[a] (mrem/yr)	Carbon-14[a] (mrem/yr)	Technetium-99[a] (mrem/yr)				
KR4 P&T									
Effluent tank – T-K5	6/13/2017	1.3E-01	4.2E-01	(4.8E-02)	(8.9E-02)	0.69	0.0069	5.5E-01	0.0055
Effluent tank – T-K5	9/21/2017	1.5E-01	2.6E-01	5.9E-02	(6.1E-02)	0.53	0.0053	4.7E-01	0.0047
Effluent tank – T-K5	12/12/2017	1.0E-01	9.6E-02	4.5E-02	(9.0E-02)	0.33	0.0033	2.4E-01	0.0024
KW P&T									
Effluent tank – T-W3	5/2/2017	7.3E-02	(1.0E-01)	4.0E-01	4.9E-02	0.62	0.0062	0.52	0.0052
Effluent tank – T-W3	6/13/2017	7.9E-02	(1.4E-01)	5.7E-01	1.4E-01	0.93	0.0093	0.79	0.0079
Effluent tank – T-W3	9/21/2017	7.2-02	(7.9E-02)	5.0E-01	1.7E-01	0.83	0.0083	0.75	0.0075
Effluent tank – T-W3	12/12/2017	7.8E-02	(1.4E-01)	5.3E-01	1.3E-01	0.88	0.0088	0.74	0.0074
KX P&T									
Effluent tank – T-X5	3/28/2017	1.7E-01	2.5E-01	NM	NM	0.42[b]	0.0042[b]	4.2E-01[b]	0.0042[b]
Effluent tank – T-X5	6/13/2017	1.8E-01	6.1E-01	7.4E-02	(9.3E-02)	0.96	0.0096	8.6E-01	0.0086
Effluent tank – T-X5	7/20/2017	NM	(1.4E-01)	NM	NM	0.14[b]	0.0014[b]	NC	NC
Effluent tank – T-X5	9/21/2017	3.0E-01	2.3E-01	8.9E-02	(5.9E-02)	0.68	0.0068	6.2E-01	0.0062
Effluent tank – T-X5	12/12/2017	2.3E-01	(1.4E-01)	7.0E-02	(8.4E-02)	0.53	0.0053	4.5E-01	0.0045

Note: Shaded cells indicate cumulative TED and DCS fraction values meet criterion #3 in Table 3-13.

a. Values in parentheses were reported as not detected. Value presented is dose contribution based on minimum detectable activity concentration for samples reported as analyzed but not detected.

b. The absence of a measured value for carbon-14, technetium-99, and tritium indicates nonrepresentative underestimation of the TED and the DCS fraction.

DCS = derived concentration standard
NC = not calculated
NM = not measured for this sampling event
P&T = pump and treat
TED = total effective dose

Table 3-17. Summary of Drinking Water Beta/Photon Emitter MCL Comparison for KR4, KW, and KX P&T System Effluent for CY 2017

Sample Location	Sample Date	Contributing Radioisotopes				Sum of Fractions[a]	Drinking Water β/ϒ Dose (mrem/yr)[a]	Sum of Fractions Detects Only[b]	Drinking Water β/ϒ Dose from Detects Only (mrem/yr)[b]
		Tritium	Strontium-90[c]	Carbon-14[c]	Technetium-99[c]				
		Derived Concentrations (pCi/L)							
		20,000	8	2,000	900				
		Beta/Photon MCL Fraction							
KR4 P&T									
Effluent tank – T-K5	6/13/2017	0.1285	0.57	(0.0150)	(0.0435)	0.76	3.0	0.70	2.8
Effluent tank – T-K5	9/21/2017	0.1445	0.36	0.0182	(0.0297)	0.55	2.2	0.52	2.1
Effluent tank – T-K5	12/12/2017	0.0980	0.13	0.0140	(0.0439)	0.29	1.1	0.24	0.98
KW P&T									
Effluent tank – T-W3	5/2/2017	0.069	(0.14)	0.12	0.0240	0.35	1.4	0.22	0.86
Effluent tank – T-W3	6/13/2017	0.075	(0.19)	0.18	0.0664	0.51	2.0	0.32	1.3
Effluent tank – T-W3	9/21/2017	0.068	(0.11)	0.16	0.0843	0.42	1.7	0.31	1.2
Effluent tank – T-W3	12/12/2017	0.074	(0.20)	0.16	0.0652	0.50	2.0	0.30	1.2
KX P&T									
Effluent tank – T-X5	3/28/2017	0.166	0.344	NM	NM	0.51[e]	2.0[e]	0.51[e]	2.0[e]
Effluent tank – T-X5	6/13/2017	0.173	0.834	0.0229	(0.045)	1.1	4.3[d]	1.0	4.1[d]
Effluent tank – T-X5	7/20/2017	NM	(0.194)	NM	NM	0.19[e]	0.77[e]	NC	NC
Effluent tank – T-X5	9/21/2017	0.284	0.318	0.0276	(0.029)	0.66	2.6	0.63	2.5
Effluent tank – T-X5	12/12/2017	0.223	0.194	0.0218	(0.041	0.48	1.9	0.44	1.7

a. Sum of MCL fractional derived concentration values and calculated MCL dose, including nondetect values using the minimum detectable activity as a value.

b. Sum of MCL fractional derived concentration values and calculated MCL dose, excluding nondetect measurements.

c. Values in parentheses were reported as nondetects; the value is the reported value of the minimum detectable activity.

d. Shaded cells indicated sampling event exceeds the MCL of 4 mrem/yr.

e. The absence of a measured value for carbon-14, technetium-99, and tritium indicates nonrepresentative underestimation of the sum of fractions and the resultant dose.

CL = maximum contaminant level

NC = not calculated

NM = not measured for this sampling event

P&T = pump and treat

3.4 100-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 2017. 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 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 P&T operations and periodic maintenance.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis as required in accordance with the 100-KR-4 OU RD/RAWP (DOE/RL-2013-33).
- **Waste management:** Includes the cost for managing spent resin at the 100-KR-4 OU in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes. Costs 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 2017 are associated with three P&T systems (KR4, KX, and KW). The total cost breakdown includes nonrecurring costs related to installing new wells and the P&T system modifications described in Section 3.2. Tables 3-18 through 3-20 provide the yearly cost breakdowns for each of the KR4, KX, and KW P&T systems. The costs are burdened and are based on actual operating costs incurred during 2017.

Summaries of the costs for each P&T system are presented in the following sections.

3.4.1 KR4 Pump-and-Treat System

Table 3-18 shows the total cost for the KR4 P&T system during 2017 was $1.68 million, which consists of the sum of the categories. The percentage that each category comprises of the total cost for the KR4 P&T system (Figure 3-32) is as follows, in decreasing order:

- **O&M:** 51.3% ($862,000)
- **Treatment system capital construction:** 25.9% ($435,100)
- **Project support:** 5.7% ($96,300)
- **Performance monitoring:** 5.4% ($91,300)
- **Design:** 5.4% ($91,200)
- **Field studies:** 3.3% ($55,500)
- **Waste management:** 2.9% ($48,700)

Based on the total 2017 cost of $1,680,000, the yearly production rate of 516 million L (163 million gal), and 1.34 kg of Cr(VI) removed, the annual treatment costs is $0.0033/L, or $1,254/g of Cr(VI) removed.

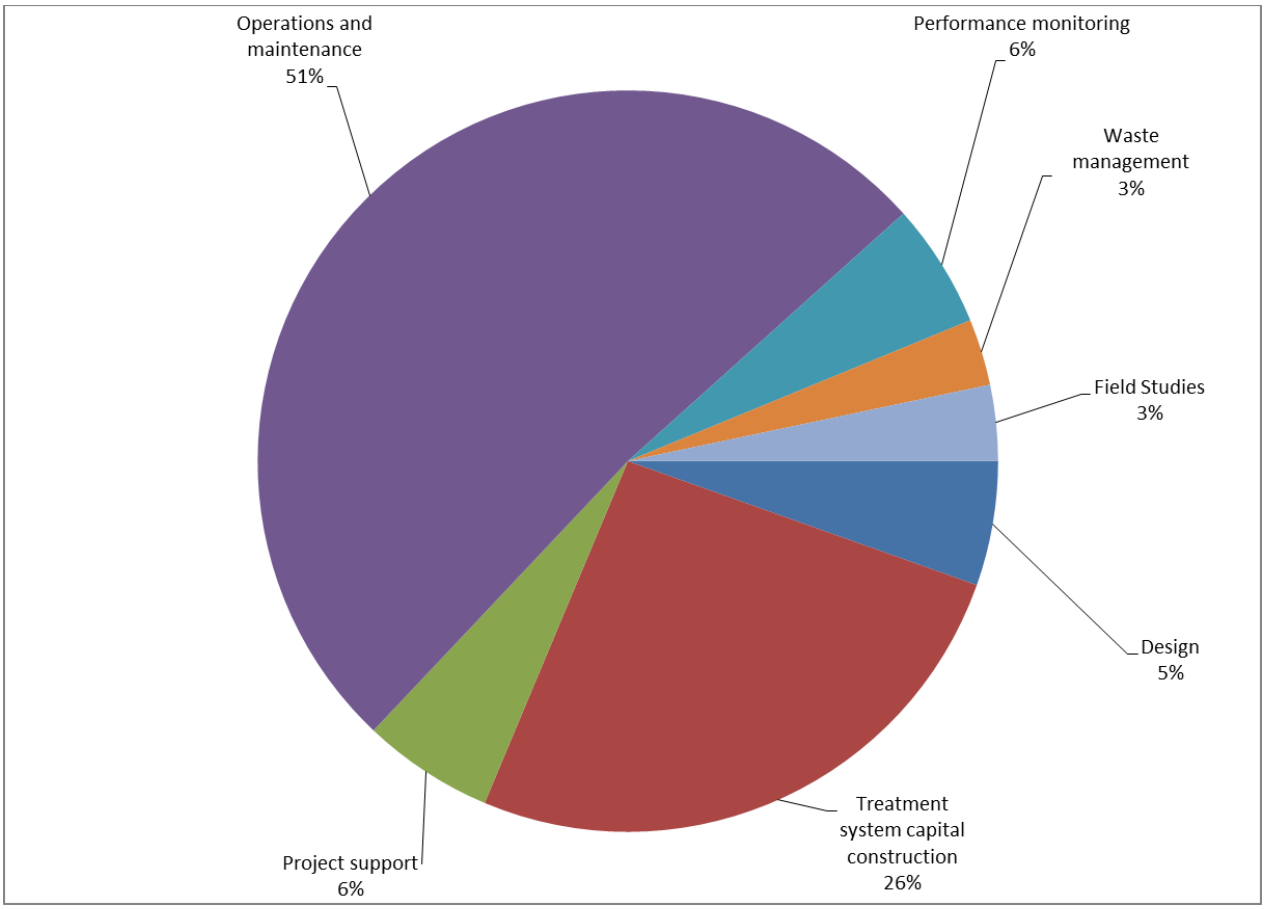

Figure 3-32. KR4 P&T System, 2017 ($1.68 Million) Cost Breakdown (by Percentage)

3.4.2 KW Pump-and-Treat System

The total cost for the KW P&T system during 2017 was $2.00 million, which consists of the sum of the categories shown in Table 3-19. The percentage that each category comprises of the total cost for the KW P&T system (Figure 3-33) is as follows, in decreasing order:

- **O&M:** 34.8% ($695,200)
- **Treatment system capital construction:** 21.8% ($435,100)
- **Well realignment:** 14.2% ($284,800)
- **Field studies:** 13.2% ($263,300)
- **Performance monitoring:** 4.7% ($94,000)
- **Project support:** 4.6% ($92,800)
- **Design:** 4.6% ($91,200)
- **Waste management:** 2.1% ($42,800)

Based on the total 2017 cost of $1,999,000, the yearly production rate of 433 million L (114 million gal), and 14.4 kg of Cr(VI) removed, the annual treatment costs are $0.0046/L, or $139/g of Cr(VI) removed.

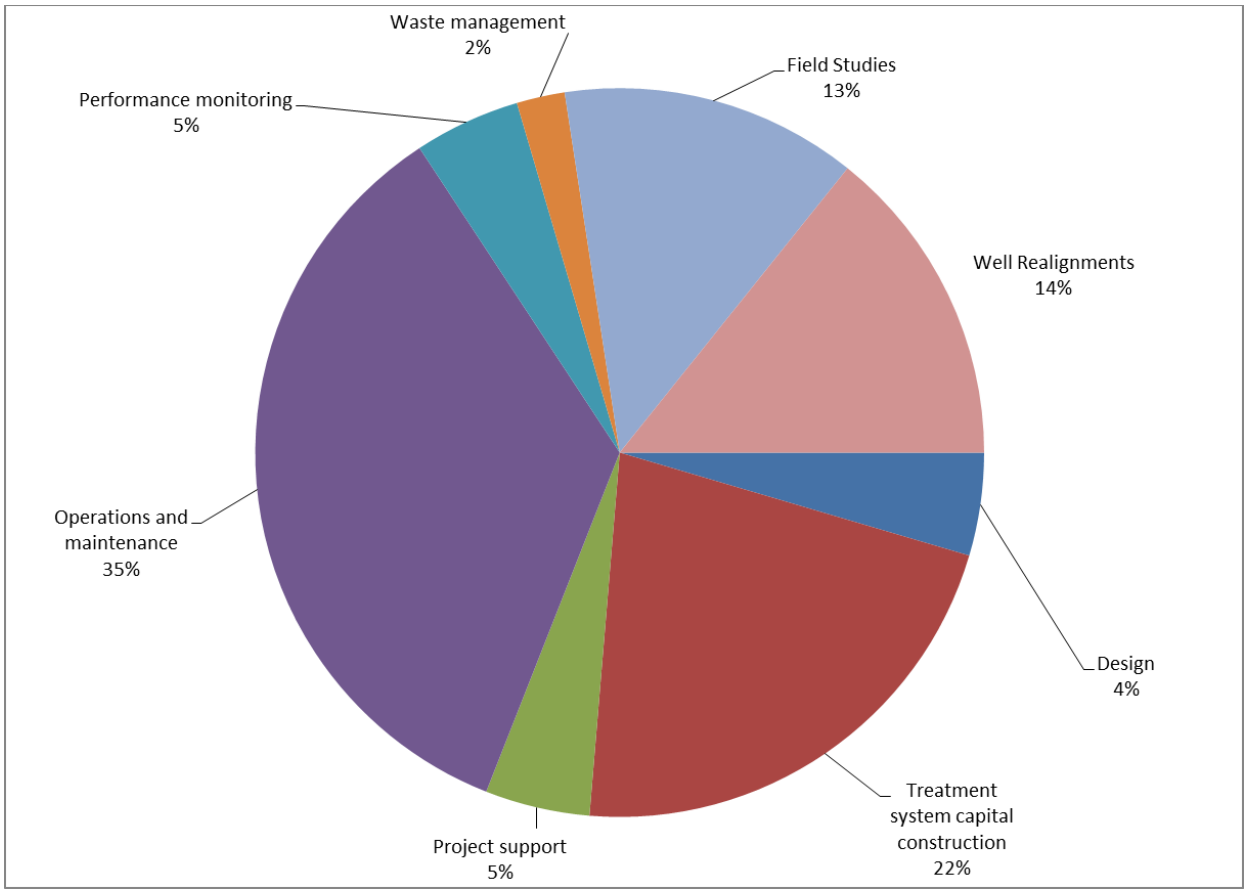

Figure 3-33. KW P&T System, 2017 ($2.00 Million) Cost Breakdown (by Percentage)

3.4.3 KX Pump-and-Treat System

The total cost for the KX P&T system for 2017 was $3.76 million (Table 3-20). The increase in annual cost in 2016 and 2017 compared to 2015 is associated with the KX P&T system configuration changes described in Section 3.2.3.1. The percentage that each category comprises of the total cost for the KX P&T system (Figure 3-34) is as follows, in decreasing order:

- **O&M:** 51.8% ($1,945,900)
- **Well realignment:** 16.9% ($634,500)
- **Treatment system capital construction:** 11.6% ($435,100)
- **Waste management:** 10.9% ($409,900)
- **Project support:** 3.4% ($125,800)
- **Performance monitoring:** 2.9% ($107,700)
- **Design:** 2.4% ($91,200)
- **Field studies:** negligible in 2017

Based on the total 2017 cost of $3,755,000, the yearly production rate of 1,360 million L (359 million gal), and 21.0 kg of Cr(VI) removed, the annual treatment costs are $0.0028/L, or $179/g of Cr(VI) removed.

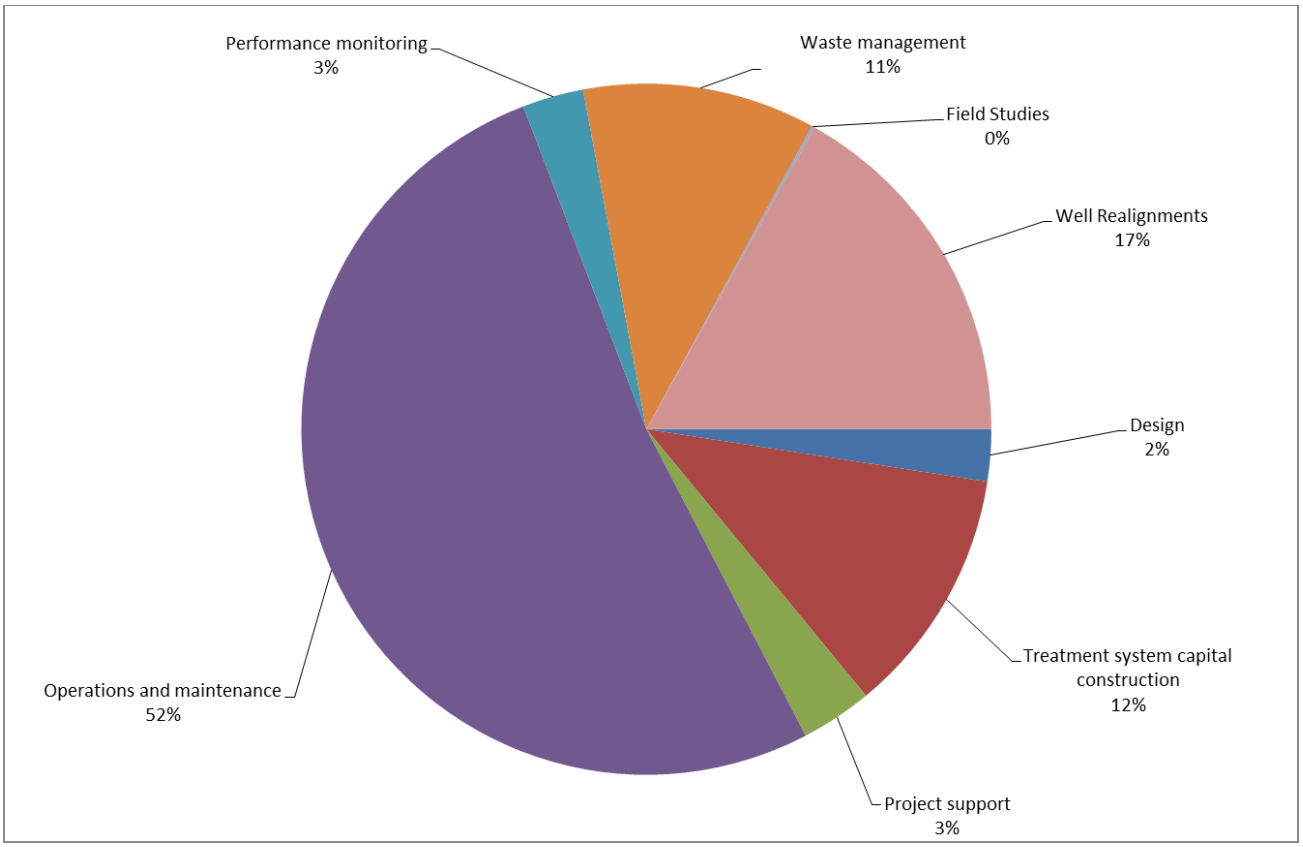

Figure 3-34. KX P&T System, 2017 ($3.76 Million) Cost Breakdown (by Percentage)

Table 3-18. 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[c,d]**	**2010[e]**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Design	—	96.5	55.2	70.8	163.9	190.8	97.8	187[f]	63.1	157.7	25.4	52.2	(1.7)	0.9	3.3	47.1	0.0	91.2
Treatment system capital construction	109.1	(0.1)	860.1	379.9	94.2	273.8	1,505.8	2,114.1[g]	8,368.5	6,651.0[g]	3,556.2	1,860.8	350.8[h]	30.7	78.8	123.0	252.3	435.1
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	75.4	60.7	96.3
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	866.8	616.1	862.0
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	78.2	137.5	91.3
Waste management	481.8	367.5	343.3	684.7	475.8	198.3	230.2	458.9[i]	438.2	599.8	266.7	110.6	17.3	0.0	0.0	3.4	28.4	48.7
Field studies	—	—	—	—	—	—	—	—	—	25.0	653.1	3.0	0.2	(0.0)	0.0	0.0	0.0	55.5
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**	**$1,194**	**$1,095**	**$1,680**

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

e. 2010 accrual costs were corrected. The KR4 and KX P&T expense calculations were incorrectly grouped together.

f. Additional design costs were associated with P&T expansion.

g. Additional treatment system capital construction costs were associated with new wells and buildings to support P&T system expansion.

h. Includes costs for facility modifications to change ion-exchange resin from Dowex® 21K (Dowex® is a registered trademark of the Dow Chemical Company, Midland, Michigan) to ResinTech® SIR-700 (ResinTech® is a registered trademark of Resintech, Inc., West Berlin, New Jersey).

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

— = not available

P&T = pump and treat

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Table 3-19. Breakdown of KW P&T System Costs

Description	Actual Costs (Dollars × 1,000)										
	2007	**2008**	**2009[a]**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Design	13.0	27.7	78.1	11.6	20.0	8.6	20.6	32.4	47.1	0.0	91.2
Treatment system capital construction	2,187.8	1,088.3	2,301.8	324.3	794.8[b]	(0.4)	30.9	421.7	123.0	252.3	435.1
Project support	118.9	155.3	174.1	77.6[c]	94.3	58.0	121.0	240.9	75.4	60.7	92.8
Operations and maintenance	402.4	599.6	758.6	1,149.6[c]	1,041.3	1,055.9[d]	1,217.4	1,251.0	778.7	518.1	695.2
Performance monitoring	9.7	126.6	215.9	528.9[c]	674.9	324.4	160.0	156.9	78.4	475.0	94.0
Waste management	405.4	164.3	95.4	207.5[c]	84.0	84.6	0.0	0.0	3.5	27.7	42.8
Field studies	—	—	—	—	—	—	—	0.0	0.0	0.0	263.3
Well realignment[e]	—	—	—	—	—	—	—	—	—	—	284.8
Totals	**$3,137**	**$2,162**	**$3,624**	**$2,300**	**$2,709**	**$1,531**	**$1,550**	**$2,103**	**$1,106**	**$1,334**	**$1,999**

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. Includes costs for facility modifications to change ion-exchange resin from Dowex® 21K (Dowex® is a registered trademark of the Dow Chemical Company, Midland, Michigan) to ResinTech® SIR-700 (ResinTech® is a registered trademark of Resintech, Inc., West Berlin, New Jersey).

c. Values were incorrectly calculated and later corrected.

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

e. Well realignment costs were provided separately in 2017

— = not available

Table 3-20. Breakdown of KX P&T System Costs

Description	Actual Costs (Dollars × 1,000)							
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Design	31.4	21.4	2.8	9.5	46.0	51.5	0.0	91.2
Treatment system capital construction	22.9	(1.7)	639.9[a]	62.5	462.6	122.9	252.3	435.1
Project support	77.6	94.3	58.0	161.3	221.8	75.4	60.7	125.8
Operations and maintenance	1,224.4	1,647.8	1,340.4[b]	1,875.0	1,530.6	1907.1	2745.1	1945.9
Performance monitoring	528.9	674.9	324.4	152.0	158.4	76.6	103.7	107.7
Waste management	579.6	219.1	2.1	0.0	0.0	3.3	31.7	409.9
Field studies	—	—	—	—	0.0	0.0	0.0	4.7
Well realignment[c]	—	—	—	—	—	—	—	634.5
Totals	**$2,465**	**$2,656**	**$2,368**	**$2,260**	**$2,419**	**$2,237**	**$3,193**	**$3,755**

a. Includes costs for facility modifications to change ion-exchange resin from Dowex® 21K (Dowex® is a registered trademark of the Dow Chemical Company, Midland, Michigan to ResinTech® SIR-700 (ResinTech® is a registered trademark of Resintech, Inc., West Berlin, New Jersey).

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

c. Well realignment costs were provided separately from operations and maintenance costs in 2017.

— = not available

3.5 Conclusions

Remedial progress has been achieved for 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: 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 2017 that is consistent with the last few years of effective river protection. However, hydraulic containment was not as strong in 2017 as in previous years due to the steep hydraulic gradients and resulting groundwater velocities caused by the sharp decline of the river-stage during the second half of the year.

  The effectiveness on river protection for the extraction wells operating near the shoreline will be further evaluated with additional investigation planned for understanding the source of Cr(VI) present near the shoreline (downgradient of the 116-K-2 Trench) at concentrations greater than 10 μg/L. A new monitoring well is planned for installation between wells 199-K-144 and 199-K-145, and aquifer tubes AT-K-3-D, AT-K-3-M, AT-K-3-S, 22-D, and 22-M have been extended to allow sampling during high river-stage conditions. Sampling data from these monitoring locations will help determine if Cr(VI) is migrating to the shoreline from inland or if it is present in low transmissivity zones leaching slowly into the aquifer.

  Given the substantial and rapid river-stage decline during the second half of 2017, it should be noted that quantitative evaluations of the river protection objective provide a conservative assessment of shoreline protection; qualitative evaluations for 2017 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 do not provide 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 Cr(VI) plume depictions for 2016 and 2017 indicates that a consistent number of shoreline segments where Cr(VI) 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.

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

  Results: The interim 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 MSA-1105355.6. ICs remain in operation in 100-KR-4 OU.

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

  Results: Additional information continues to be gathered on the 100-KR-4 OU groundwater contamination. Ongoing groundwater monitoring activities provide information regarding 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 Cr(VI), as well as other COCs in the OU.

  An evaluation of information from multiple activities indicates that while interim groundwater remedial actions at the 100-K Area have reduced Cr(VI) concentrations and 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. Starting in 2016 and ending in 2017, the KW P&T system was shut down to evaluate the potential for secondary source material in the PRZ. Based on the data collected through March 2017, secondary source material in the PRZ upgradient of the KW Reactor was validated. The rebound study results are documented in SGW-62061. A treatability test plan to perform a soil flushing activity at the 183.1KW Head House was issued in 2018 (DOE/RL-2017-30). The goal of the treatability test is to remove mobile Cr(VI) from the PRZ and treat the Cr(VI) using the KW P&T system. The result would reduce the time to achieve cleanup goals, thereby protecting human health and the environment. These conditions will also be evaluated and the information incorporated into the final 100-K Area RI/FS report.

  In addition to information regarding Cr(VI) distribution and behavior, the interim remedial action and its associated monitoring activities have provided additional information regarding the nature and extent of groundwater plumes for other COCs present in the100-KR-4 OU (strontium-90, tritium, nitrate, carbon-14, and TCE).

3.5.1 Conclusions of Evaluation of Radiological Constituents in KR4, KW, and KX Pump-and-Treat Effluent Water for Calendar Year 2017

The evaluation of radiological doses of KR4, KW, and KX P&T effluent during CY 2017 indicates that the effluent met the following standards and criteria:

- The calculated DCS-based TED of the KR4, KW, and KX P&T systems effluent was less than 1 mrem/yr, substantially below the 100 mrem/yr public dose limit.
- The calculated DCS-based sum of fractions and resulting TED of the KR4, KW, and KX P&T systems effluent meet criterion #3 for sampling events in 2017. A graded monitoring approach with annual review is recommended.
- The calculated MCL-based beta/photon-emitter drinking water dose was below the 4 mrem/yr MCL dose for KR4 and KW P&T system effluents. One effluent sampling event exceeded the MCL dose for the KX P&T system, due largely to the presence of strontium-90.

4 100-NR-2 Operable Unit Remediation

This chapter provides the annual performance report for 100-NR-2 OU groundwater remediation, as required by DOE/RL-2001-27, *Remedial Design/Remedial Action Work Plan for the 100-NR-2 Operable Unit*. The performance of the apatite PRB is discussed, and an update is provided on the remediation of petroleum hydrocarbon contamination. Groundwater monitoring data collected during 2017 that are pertinent to the interim remedial action are also provided. Discussion in this chapter includes the following:

- Section 4.1 provides a summary of the 100-NR-2 OU groundwater remedial activities.
- Section 4.2 describes water-level monitoring.
- Section 4.3 summarizes groundwater contaminant sources and monitoring activities.
- Section 4.4 discusses the remediation of strontium-90 contamination.
- Section 4.5 discusses the remediation of petroleum contamination.
- Section 4.6 discusses demolition of the 100-NR-2 P&T system.
- Section 4.7 presents the 2017 costs for the apatite PRB.
- Section 4.8 presents conclusions on remedy performance for 2017.

The 100-NR-2 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 the remediation of groundwater is identified in the interim action ROD (EPA/ROD/R10-99/112). When the 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. The P&T system was placed into cold-standby status in 2006 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.

The initial apatite PRB was constructed from 2006 through 2008 for the treatability test that placed a 91 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. 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*).

Based on the treatability test results, the apatite technology showed promise as a remediation option. Ecology, EPA, and DOE amended the interim action ROD in 2010 to allow for permanent decommissioning of the 100-NR-2 OU P&T system and expansion of the existing PRB from approximately 91 m (300 ft) long to 760 m (2,500 ft) long (EPA, 2010).

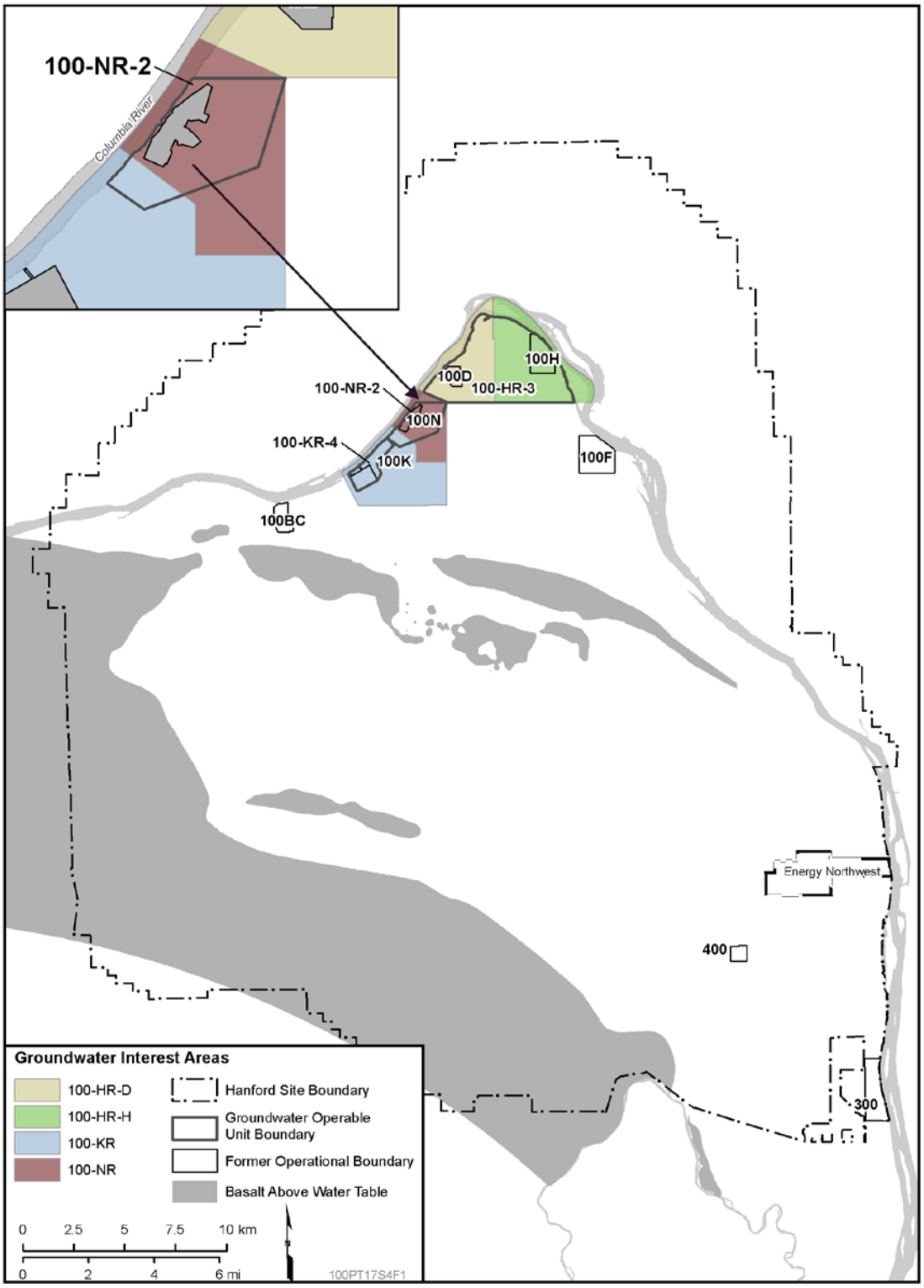


Figure 4-1. Location of the 100-NR-2 OU

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 91 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, which included the addition of 146 injection wells and 25 monitoring wells along the 100-N Area shoreline. The wells were installed both upriver and downriver, adjacent to the original 16 well 91 m (300 ft) long PRB.

  Future injection of apatite solutions will extend the apatite PRB throughout this network along the 100-N Area shoreline to intercept the strontium-90 groundwater plume before it reaches the Columbia River. Section 4.4 discusses the performance on treated portions of the PRB and future injections.

- Inject apatite-forming solutions into two 90 m (300 ft) long segments of the expanded barrier well network in accordance with two design optimization studies (DOE/RL-2010-29, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*; 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 and upriver of the original barrier, and into 24 wells located northeast and downriver of the original barrier in 2011 in accordance with DOE/RL-2010-29. These injections extended the apatite barrier by 110 m (360 ft) upriver and 110 m (360 ft) downriver. Performance monitoring was conducted for all three barrier segments (upriver, central [original], and downriver) during 2016 (SGW-56970, *Performance Report for the 2011 Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*).

  Figure 4-2 shows the locations of the 100-NR-2 OU groundwater monitoring wells for 2017 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.

  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: No additional rounds of injections were performed in 2017. Not all first-round apatite injections have been completed. Injection of the remainder of the apatite barrier network wells with apatite forming solutions is not anticipated to be completed until after 2018.

- Use monitored natural attenuation.

  Status: Strontium-90 moves very slowly through the aquifer and naturally attenuates through radioactive decay. Groundwater monitoring wells are periodically sampled in accordance with Appendix A of DOE/RL-2001-27 to assess the ongoing decline in contaminant concentrations within the OU.

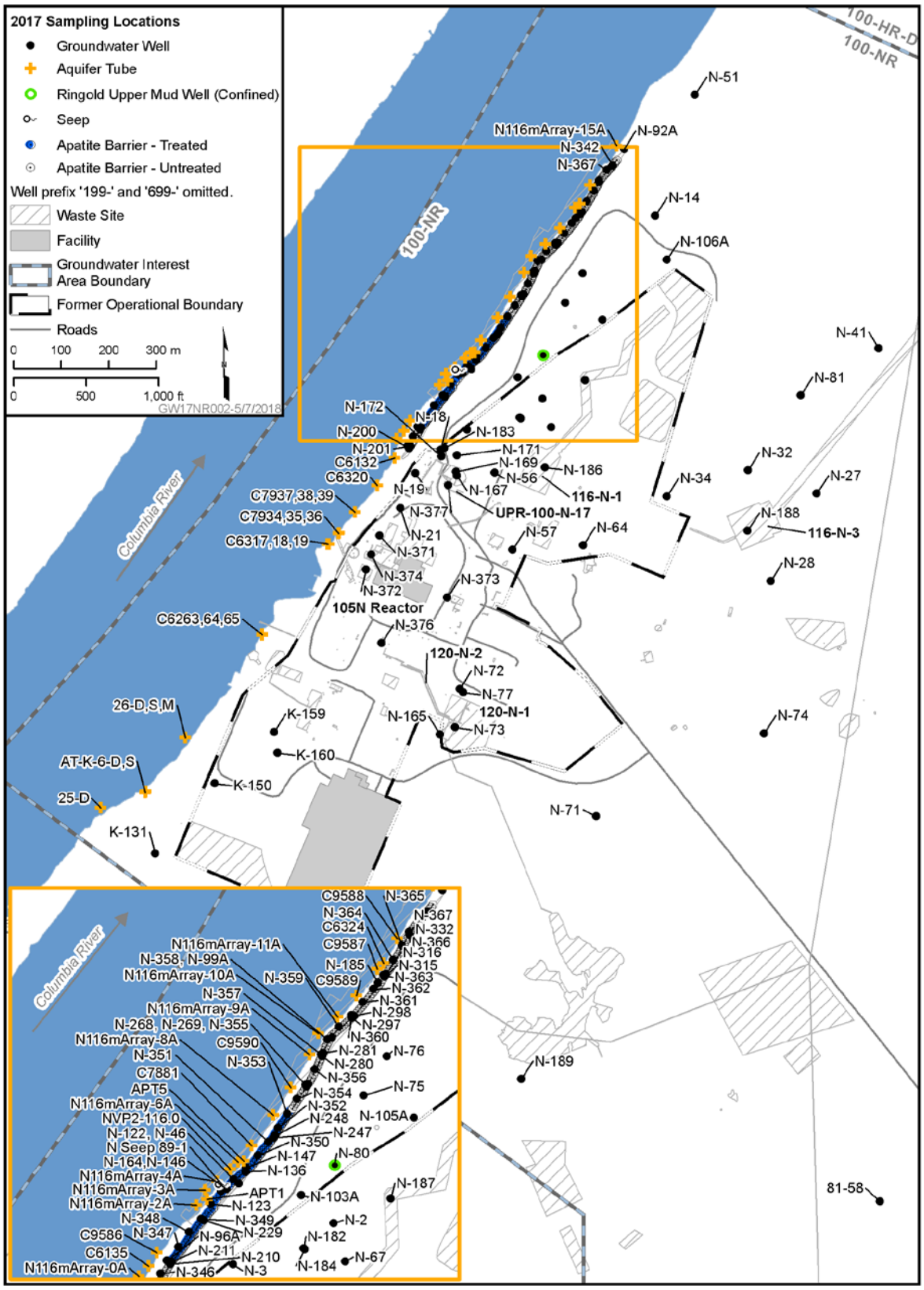


Figure 4-2. Locations of Wells in the 100-N Area

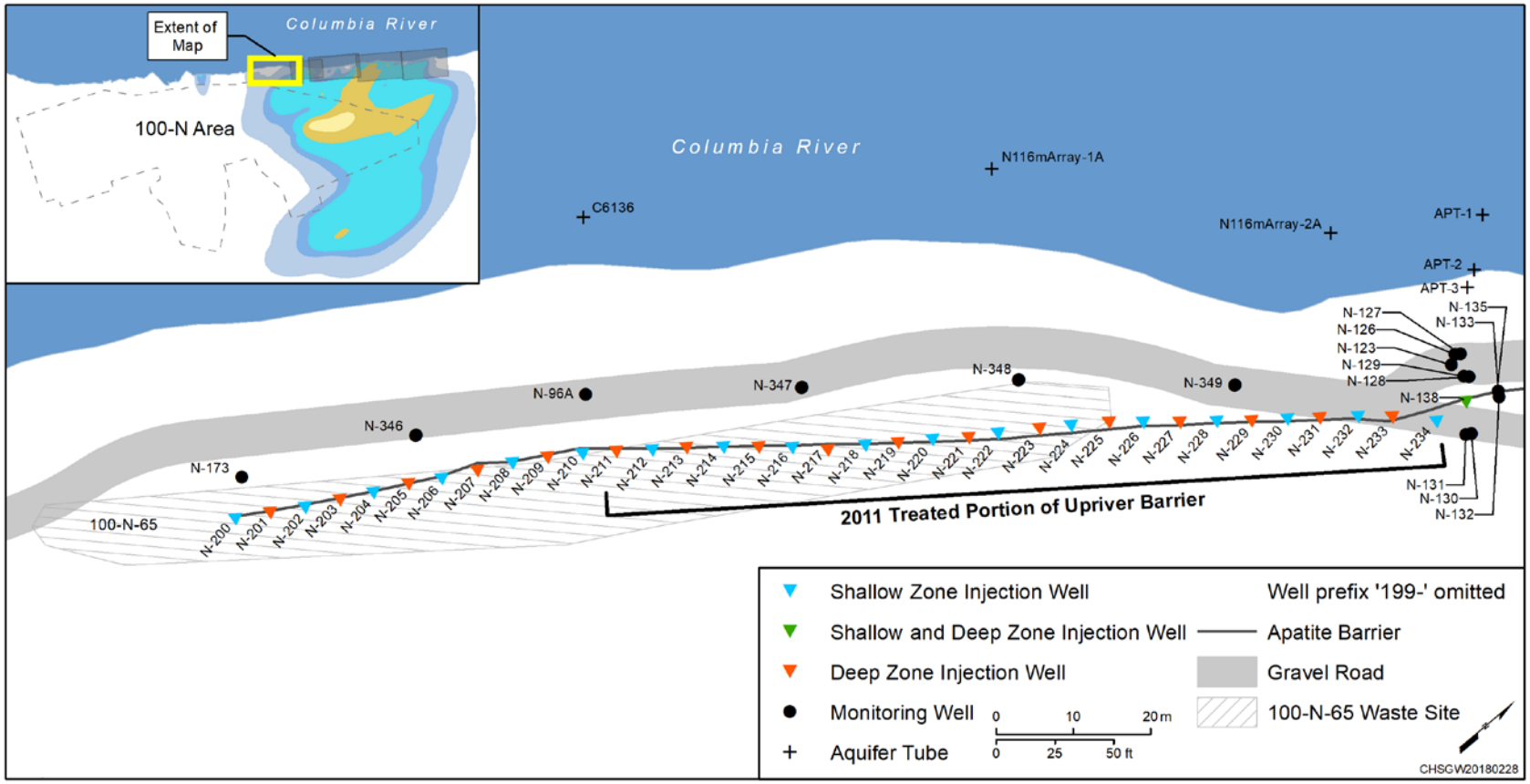


Figure 4-3. Upriver Extension Apatite Barrier Monitoring Wells and Aquifer Tubes Along the Columbia River Shoreline

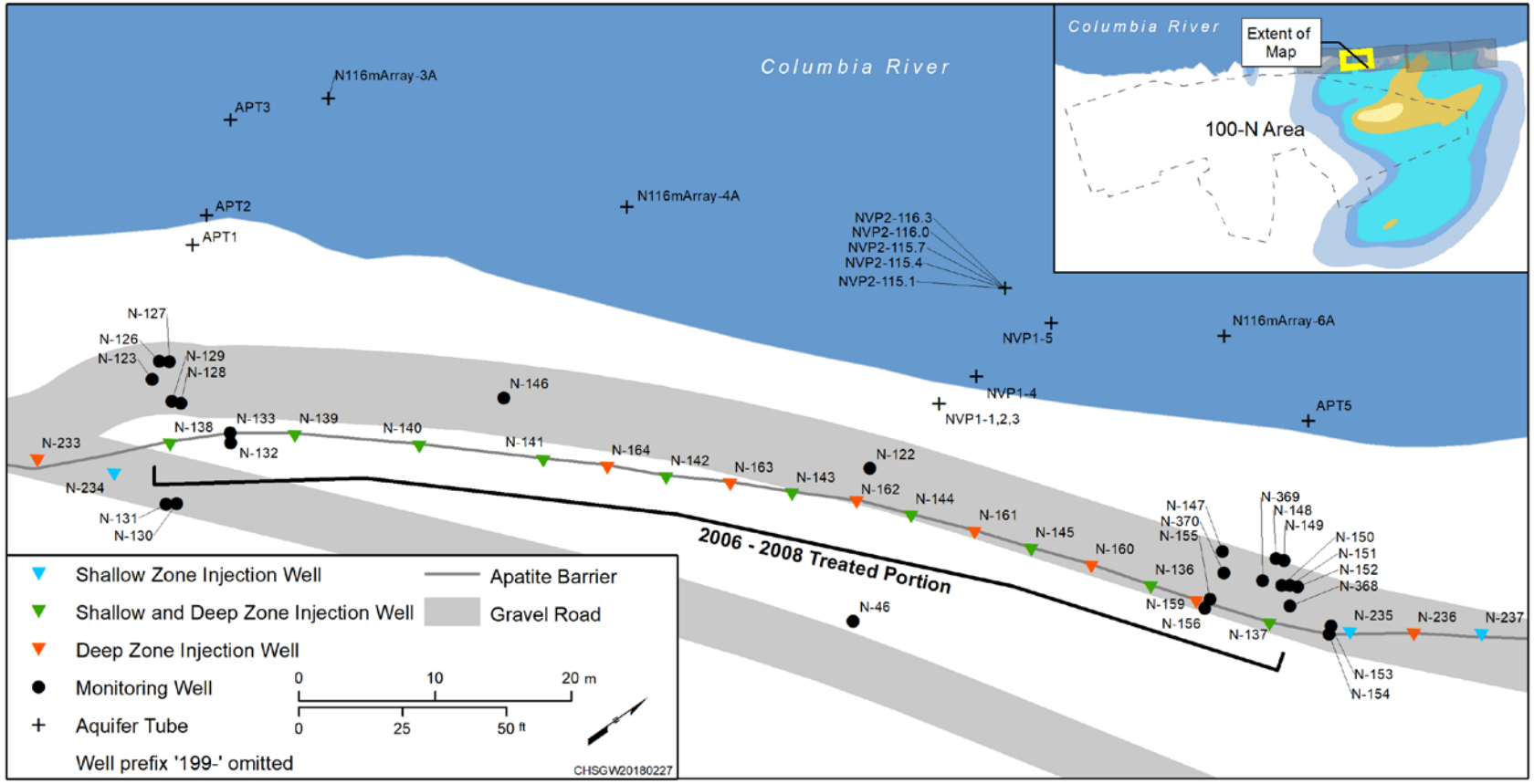


Figure 4-4. Central (Original) Apatite Barrier Monitoring Wells and Aquifer Tubes Along the Columbia River Shoreline

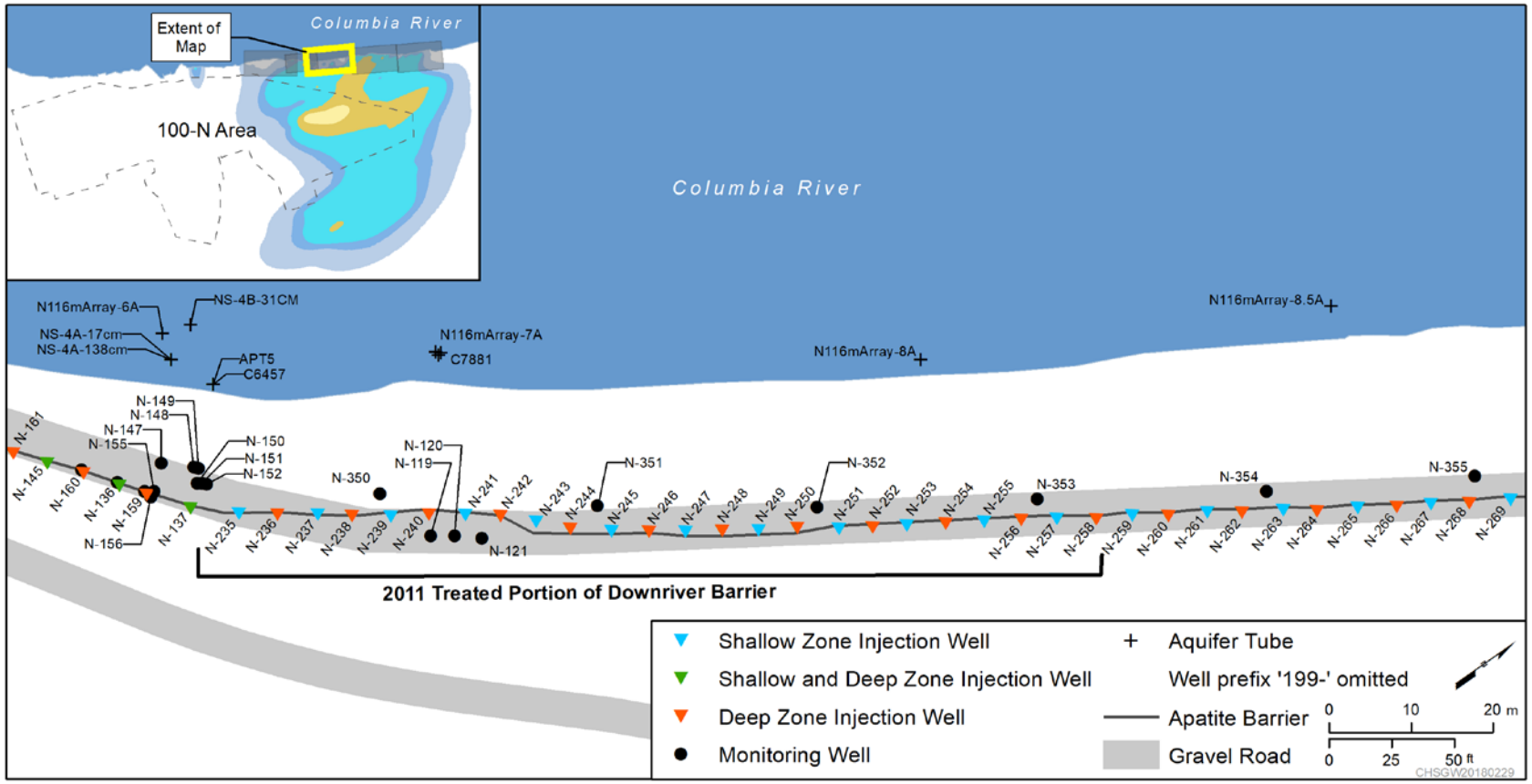


Figure 4-5. Downriver Extension Apatite Barrier Monitoring Wells and Aquifer Tubes Along the Columbia River Shoreline

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

  Status: The 100-NR-2 P&T system was demolished, excavated, and removed in 2016. Demolition debris was disposed at ERDF. The former P&T extraction wells were converted to support groundwater monitoring prior to the start of demolition. Demolition and decommissioning was completed in 2017 to remove piping from the former injection wells and to demolish the 1323N sample shack (located near the shore of the Columbia River).

- Maintain existing ICs.

  Status: Existing ICs include entry restrictions (security), escorts and badging of site visitors, excavation permits, surveillance, posted signs, and 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: Performance monitoring of the expanded 311 m (1,020 ft) long PRB continued through 2017. Periodic groundwater monitoring is performed in accordance with Appendix A of DOE/RL-2001-27 (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.

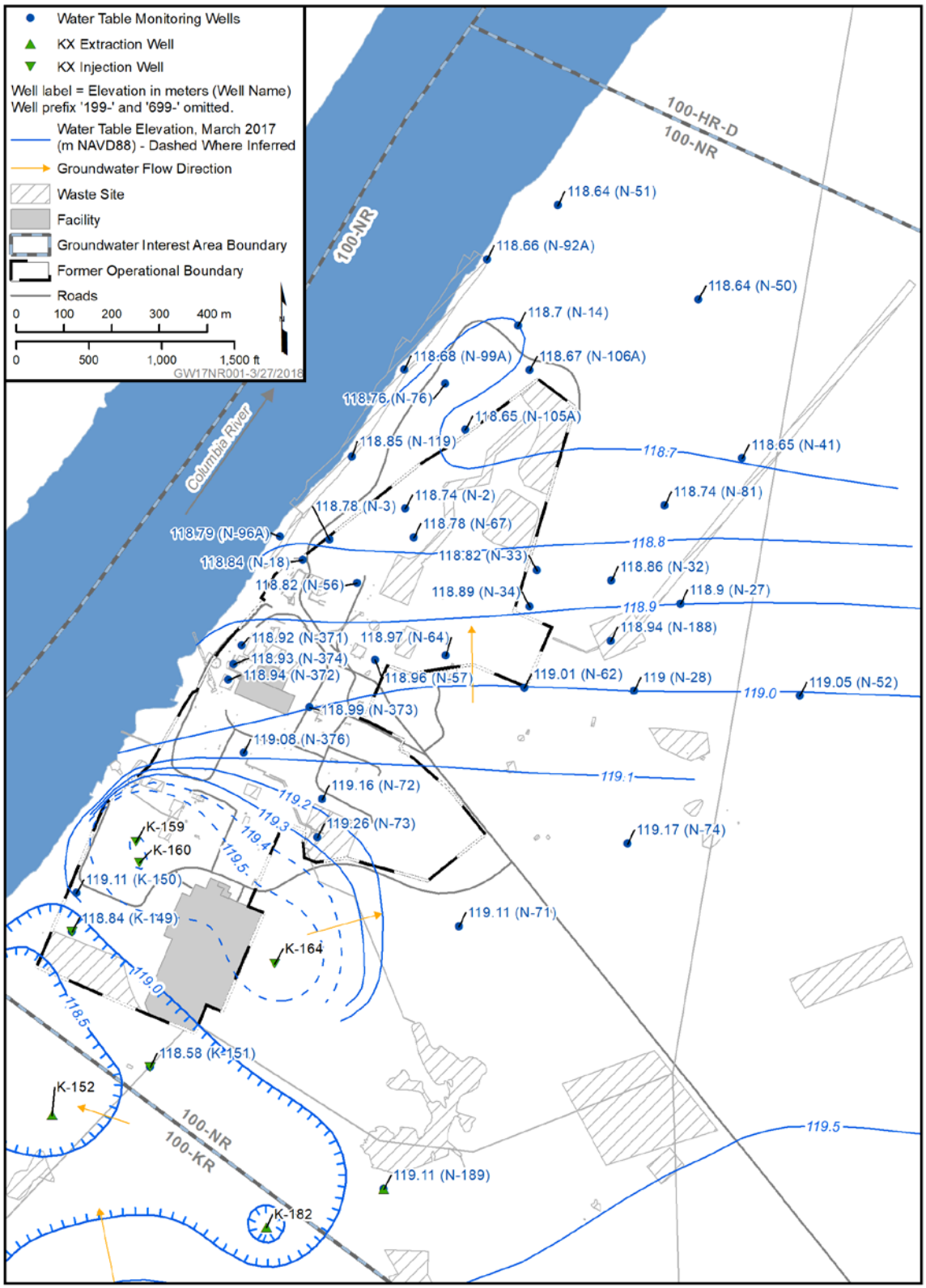
  Status: Petroleum hydrocarbon contamination as free product was occasionally observed at wells 199-N-17 and 199-N-18. Well 199-N-17 went dry and was taken out of service and decommissioned in 2002. Removal of petroleum hydrocarbon light nonaqueous-phase liquid from well 199-N-18 continued during 2017.

  During 2017, smart sponge assemblies were also installed in well 199-N-183, which was drilled near 199-N-18 as a replacement well. Diesel odor and an oil sheen have periodically been observed in the new well during sampling. The smart sponges were installed and changed out at the same frequency used for well 199-N-18.

4.2 Water-Level Monitoring

Water-level monitoring is conducted in the 100-N Area to assess groundwater flow direction.

Groundwater generally flows north and 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 2017 was about 0.8 m (2.6 ft) (Figure 4-6). Groundwater flow in 2017 continued 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 groundwater mound approximately 1 m (3.3 ft) high surrounding the KX P&T system injection wells creates local radial flow. A depression is also present around 100-KR-4 OU groundwater extraction wells along the 100-NR/100-KR boundary.



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

Figure 4-6. 100-N Area Water Table Map, March 2017

Groundwater flow in the 100-NR-2 OU is influenced by Columbia River stage. 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 thickness of the aquifer 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*). The river-stage is controlled by releases of water at Priest Rapids Dam upstream from the 100-N Area. The 100-N Area river-stage shown in Figure 4-7 is derived from water elevation data from Priest Rapids Dam using regression analysis described in ECF-Hanford-13-0028, *Columbia River Stage Correlation for the Hanford Area*. The high river-stage period in 2017 occurred in April through mid-July, with the highest elevation recorded in May at 121.2 m (397.6 ft). The low river-stage period was from mid-August through December, with a low of 116.2 m (381.2 ft) in October. There was a longer sustained high river-stage from releases from Priest Rapids Dam in 2017 compared to 2016 (Figure 4-7).

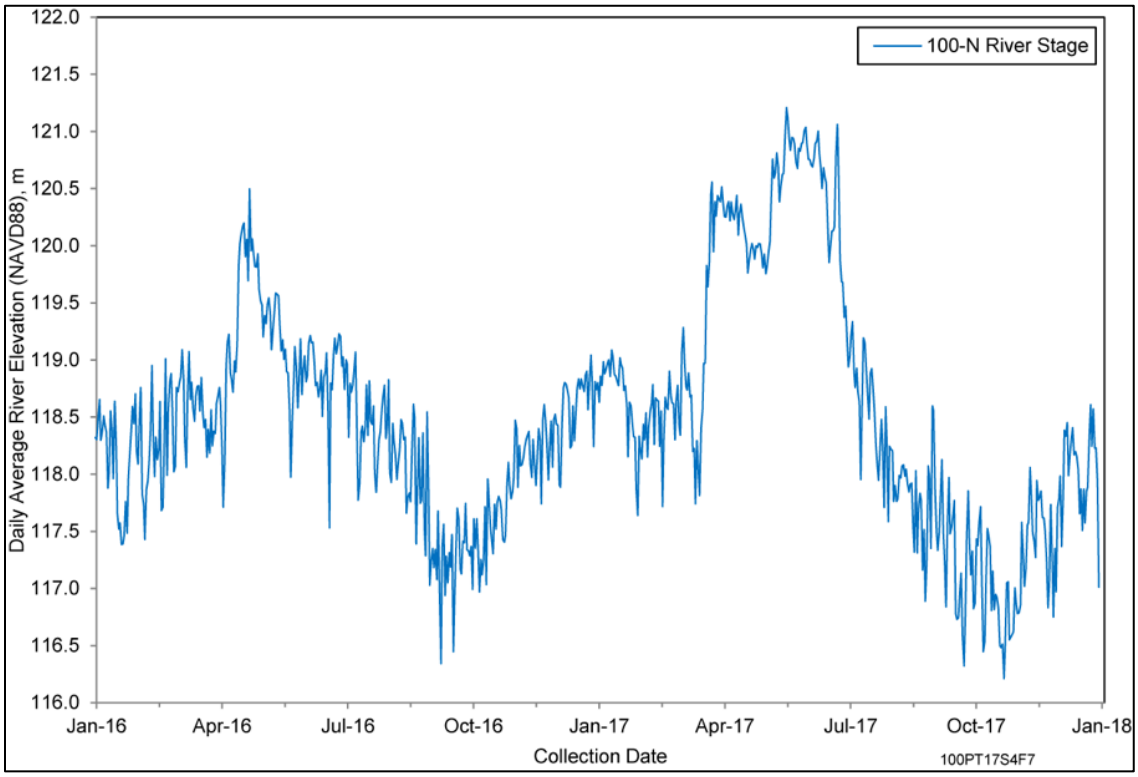


Figure 4-7. 100-N Area River-Stage Derived from Priest Rapids Dam Data, 2016 Through 2017

4.3 Groundwater Contaminant Sources and Monitoring

This section summarizes the sources of strontium-90 and petroleum hydrocarbon contaminants to groundwater and the contaminant monitoring performed in 2017.

4.3.1 Strontium-90

The primary source of the strontium-90 contamination in the subsurface of the 100-N Area was disposal of N Reactor primary coolant solution to the 116-N-1 and 116-N-3 waste sites (Figure 4-2). 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 4-8). 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 extends northwest to near the Columbia River shoreline. Concentrations also exceed 800 pCi/L in one well beneath the 116-N-3 Crib. The lateral distribution of the groundwater plume with concentrations between 8 and 800 pCi/L is consistent with historical radial flow away from the two waste sites (areas of highest original concentration) and elongated toward the river parallel to the 116-N-1 waste site (Figure 4-8).

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 lower vadose zone above the aquifer and upper portion of the unconfined aquifer. Approximately 99% of the strontium-90 in the subsurface within the 100-NR-2 OU is adsorbed, and 1% remains in solution in the groundwater (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*). Although primarily adsorbed, some strontium-90 is remobilized by seasonal water-level increases that release strontium-90 from sediments within the lower vadose zone that are not usually in contact with groundwater (PNNL-16891).

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 approximately 100 times slower than the groundwater flow rate (PNNL-19572, *100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization, Final Report*). Table 4-1 provides the strontium-90 concentrations in selected monitoring wells and aquifer tubes, as well as information on how concentrations have changed between 1994 and 2017.

The highest concentration of strontium-90 in 100-NR groundwater in 2017 was 14,200 pCi/L at well 199-N-187 in the main body of the plume beneath the 116-N-1 Trench. This was higher than the 2016 maximum of 12,600 pCi/L at well 199-N-67 within the same high concentration area of the plume. The strontium-90 concentration at well 199-N-67 decreased to 10,400 pCi/L in 2017.

As a result of the low mobility of strontium-90 in groundwater, high strontium-90 concentrations (greater than 150 pCi/L) are limited to the upper portion of the aquifer, binding to the soil in that area of the aquifer instead of migrating vertically through the aquifer thickness. The seasonal low water table elevation in this area ranges from 116.8 to 117.8 m (383.1 to 386.4 ft) (in *North American Vertical Datum of 1988*). Comparison of strontium-90 concentrations in shallow/deep well pairs shows that concentrations greater than 150 pCi/L are limited to the upper 3 m (9.8 ft) of the aquifer (DOE/RL-2016-68).

Strontium-90 concentration trends in monitoring wells near the 116-N-1 waste site increase during higher water-level periods and decrease as water levels decline. 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. As the water table decreases, strontium-90 resorbs to sediment, and concentrations in the groundwater decrease. Figure 4-9 shows strontium-90 concentrations and water levels in well 199-N-67 (located downgradient of the liquid waste disposal end of the 116-N-1 Trench). 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. Figure 4-10 shows strontium-90 concentrations and water levels in former extraction well 199-N-105A. From 1996 until 2007, groundwater extraction lowered the water table to a deeper part of the aquifer where strontium-90 concentrations are lower. After extraction ceased, water levels increased to normal levels, and strontium-90 concentration in well 199-N-105A increased as the PRZ with strontium-90 adsorbed on the sediments became resaturated.

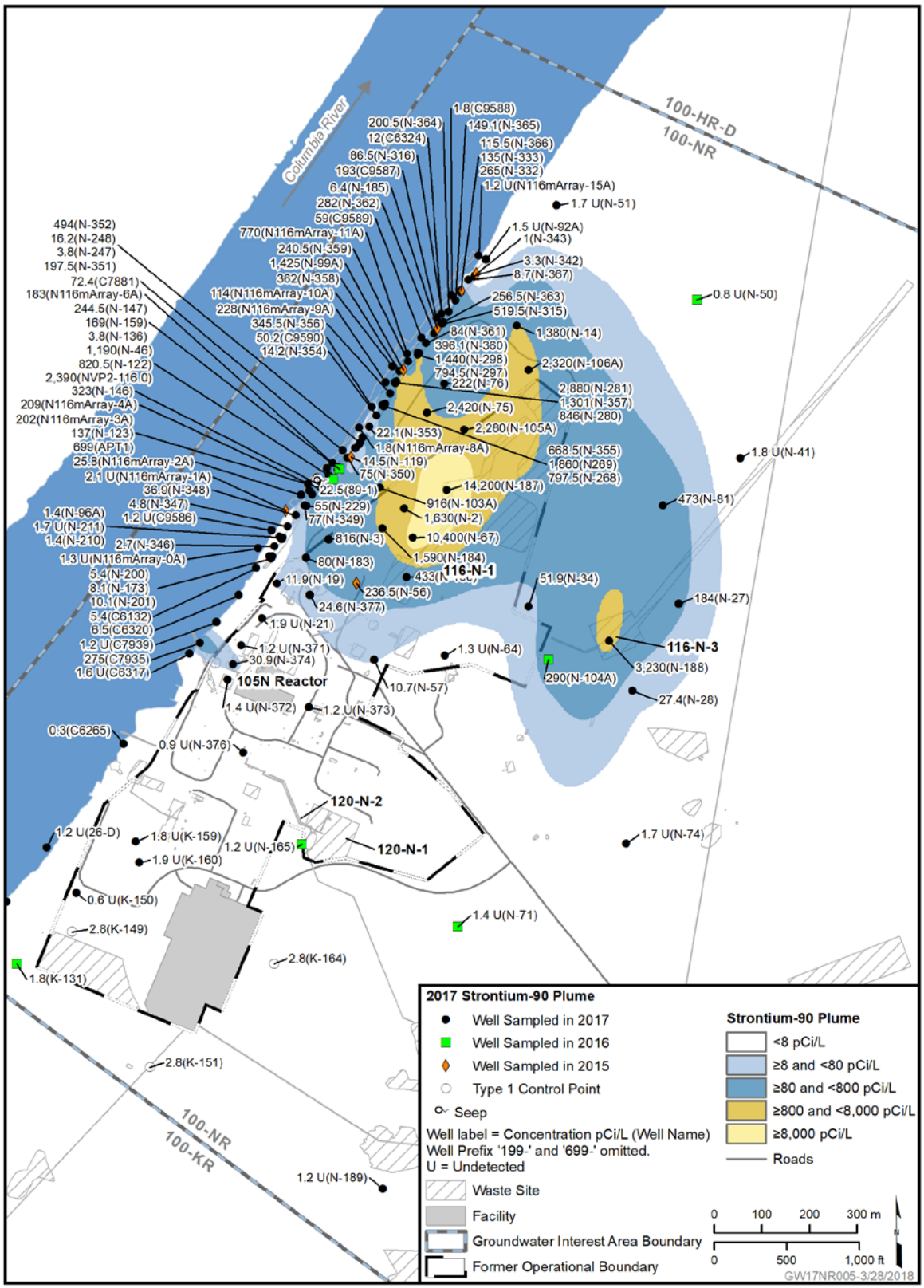


Figure 4-8. Strontium-90 Plume Map for the 100-N Area, 2017

Table 4-1. 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)	2015 (pCi/L)	2016 (pCi/L)	2017 (pCi/L)	Percent Change 1994 to 2017	Percent Change 2005 to 2017
Monitoring Wells														
199-N-2	121	80.7	1,100	160	NS	NS	3,300	1,040	777	164	261	1,630	1247	1920
199-N-3	927	1,330	1,200	1,060	870	1,200	1,300	960	938	859	768	863	-7	-35
199-N-14	1,210	1,070	1,300	1,360	1,400	1,730	960	1,200	1,120	1,380	1,360	1,380	14	29
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	Decommissioned 12/18/2012	Decommissioned 12/18/2012	Decommissioned 12/18/2012	NC	NC
199-N-18	392	NS	290	-12 (U)	260	203	In use for TPH-D remediation	In use for TPH-D remediation	In use for TPH-D remediation	In use for TPH-D remediation	In use for TPH-D remediation	In use for TPH-D remediation	NC	NC
199-N-19	43.6	28.2	NS	NS	23	26.4	23	22	23[a]	17.1	16.3	11.9	-73	-58
199-N-21	1.50	NS	NS	-2.60 (U)	-7.6 (U)	1.22	1.2	1.8	0.31 (U)	-0.193 (U)	0.944 (U)	0.278 (U)	-81	NC
199-N-27	171	167	160	130	125	194	200	130	129	126	127	184	8	10
199-N-28	120	25.1	21	25	20	34.9	35	24	33	32.5	30.1	27.4	-77	9
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)	0.06 (U)	-0.606 (U)	-0.494 (U)	-139	NC
199-N-34	69.3	53.5	67	44	37	57.4	45	42	42	35.9	39.3	51.9	-25	-3
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)	0.50 (U)	0.26 (U)	-0.519 (U)	NC	NC
199-N-46	5,850	2,690	630	580	530	1,220	1,035	1,400	1,570	1,730	1,190[i]	NS	NC	NC
199-N-50	-0.02 (U)	NS	NS	NS	-0.20 (U)	-0.13 (U)	0.23 (U)	0.8 (U)	0.17 (U)	0.73	0.348	NS	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)	-0.54 (U)	0.972 (U)	-0.869	NC	NC

Table 4-1. 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)	2015 (pCi/L)	2016 (pCi/L)	2017 (pCi/L)	Percent Change 1994 to 2017	Percent Change 2005 to 2017
199-N-56	164[b]	317	170	140	-7.5 (U)	490	560	380	338	246	NS	NS	NC	NC
199-N-57	26	9.71	8.51	2.90	5.80	15.2	15.5	12	10	6.86	5.18	10.7	-59	10
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)	0.35 (U)	0.857	0.016	NC	NC
199-N-67	3,680	9,710	10,000	9,000	9,800	13,500	11,550	14,000	15,500	13,600	12,600	10,400	183	7
199-N-69[c]	-0.09 (U)	0.21 (U)	NS	NS	-3.20 (U)	2.96	12	4.8	3	0.57 (U)	NS	NS	NC	NC
199-N-70[c]	0.321 (U)	0.156 (U)	-2.60 (U)	-2.40 (U)	-3.80 (U)	0.79	1.2	1.2	0.54 (U)	-0.27 (U)	NS	NS	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)	0.27 (U)	0.21 (U)	NS	NC	NC
199-N-72	2.59[d]	NS	-1.00 (U)	NS	-1.70 (U)	-2.60 (U)	NS	NS	NS	NS	1.475[d]	NS	NC	NC
199-N-73	0.53	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.83[d]	NS	NC	NC
199-N-74	0.415	-0.08 (U)	2.3[d]	405[d]	-2.0 (U)	-3.60 (U)	NS	NS	NS	NS	-0.54 (U)	0.611 (U)	47	NC
199-N-75[e]	2,110	307	2,500	3,000	2,400	NS	3,200	2,500	2,540	3,200	3,050	2,420	15	688
199-N-76	84.9	216	180	180	120	387	1,120	690	440	177	302	222	161	3
199-N-77	0.45	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.225[d]	1.55[d]	NC	NC
199-N-80[c]	0.734 (Q)	-0.154 (U)	0.82 (U)	-0.07 (U)	-5.9 (U)	0.22 (U)	0.77 (U)	1.5	2	0.06 (U)	0.502 (U)	0.63 (U)	NC	NC
199-N-81	746	734	970	400	320	395	450	490	475	513	493	473	-37	-36
199-N-92A	0.59 (U)	0.92	1.22	3.50	-9 (U)	0.60	0.47 (U)	0.69 (U)	1	-0.05 (U)	0.487 (U)	0.209	NC	-77

Table 4-1. 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)	2015 (pCi/L)	2016 (pCi/L)	2017 (pCi/L)	Percent Change 1994 to 2017	Percent Change 2005 to 2017
199-N-96A	4.90[f]	5.74	1.65	-1.30 (U)	3.94	9.90	2.04	5.9	2	4.36	7.15	1.62	-67	-72
199-N-99A	2,860[f]	1,270	1,200	1,400	1,500	1,020	666.5	1,230	1,600	1,540	NS	NS	NC	NC
199-N-103A[e,g]	4.08[f]	422	1,200	1,200	1,400	1,360	1,600	1,300	1,420	1,560	1,090	916	NC	117
199-N-104A	5.68[f]	NS	NS	NS	NS	NS	380	260	NS	NS	290	NS	NC	NC
199-N-105A[e,g]	112[f]	1,360	1,900	1,500	1,600	6,580	6,100	1,900	2,210	1,150	1,180	2,280	NC	68
199-N-106A[e,g]	2,890[f]	3,260	2,200	1,800	NS	2,370	3,035	2,200	2,240	1,580	2,010	2,320	-20	-29
199-N-119	—	280	250	210	220	274	56	41	29	14.5	NS	NS	NC	NC
199-N-120[c]	—	10.1	6.55	NS	1.40 (U)	6.93	58	5.7	4	1.93	NS	NS	NC	NC
199-N-121[c]	—	0.272 (U)	0.0169 (U)	NS	-2.00 (U)	-0.02 (U)	0.23 (U)	-0.21 (U)	0.33 (U)	0.52 (U)	NS	NS	NC	NC
199-N-122	—	730	1,160	260	800	740	656	560	907	1,100	1,580	1,120	NC	53
199-N-123	—	871	255	-1.60 (U)	280	1,770	204	140	120	55.8	133	162	NC	-81
199-N-146	—	318[h]	412	260	300	328	215	270	256	200	286	503	NC	58
199-N-147	—	522[h]	791	250	250	478	250	120	231	157	244	238	NC	-54
199-N-165	—	—	—	-1.90 (U)	-6.60 (U)	0.14 (U)	0.57 (U)	1.6	-0.39 (U)	0.24 (U)	-0.166 (U)	1.92[d]	NC	NC
199-N-173	—	—	—	16	23	19	14.5	22	25	21.5	23.6	20.8	NC	NC
199-N-182	—	—	—	—	—	—	110	140	144	83.9	NS	NS	NC	NC
199-N-183	—	—	—	—	—	—	120	100	82	81.2	89.3	80	NC	NC

Table 4-1. 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)	2015 (pCi/L)	2016 (pCi/L)	2017 (pCi/L)	Percent Change 1994 to 2017	Percent Change 2005 to 2017
199-N-184	—	—	—	—	—	—	5,000	1,100	1,150	320	212	1,590	NC	NC
199-N-185	—	—	—	—	—	—	3.9	7.6	8	6.43	NS	NS	NC	NC
199-N-186	—	—	—	—	—	—	810	390	420	207	193	433	NC	NC
199-N-187	—	—	—	—	—	—	8,600	11,400	12,800	9,860	10,100	14,200	NC	NC
199-N-188	—	—	—	—	—	—	1,500	2,500	2,280	1,520	1,780	3,230	NC	NC
199-N-189	—	—	—	—	—	—	0.02 (U)	0.39 (U)	0.85 (U)	0.27 (U)	NS	NS	NC	NC
Aquifer Tubes														
C7934	—	—	—	—	300	NS	93	310	321	344	361	260	NC	NC
C7935	—	—	—	—	300	NS	190	280	356	331	320	275	NC	NC
C7936	—	—	—	—	69	NS	55	96	83	80.4	85.6	59.7	NC	NC
APT-1	—	3,400[h]	NS	NS	500	530	840	270	211	331	480	699	NC	-79
APT-5	—	2,100[h]	NS	NS	450	420	270	120	184	238	216	181	NC	-91
N116mArray-3A	—	379	1,750[d]	500	110	248	240	170	190	120	144	202	NC	-47
N116mArray-4A	—	1,260	7,000[d]	340	270	226	250	280	342	186	200	209	NC	-83
NVP2-116.0	—	3,200	2,550[d]	1,100	1,200	1,100	733	700	845	1,680	2,070	2,390	NC	-25
N116mArray-6A	—	477	370[d]	95[d]	110	170	190	130	251	75.2	155	183	NC	-62

Notes: Data are maximum values reported from the fall of the year, unless otherwise noted.

Cells with "—" indicate the well or aquifer tube was constructed after this date.

Yellow-shaded cells indicate wells with concentrations above the drinking water standard (8 pCi/L).

a. Sampled on January 20,2015.

b. Not sampled in 1994; value from 1993 used for this table.

Table 4-1. 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)	2015 (pCi/L)	2016 (pCi/L)	2017 (pCi/L)	Percent Change 1994 to 2017	Percent Change 2005 to 2017

c. Screened at depth in the Ringold Formation.

d. Value calculated from gross-beta data (no strontium-90 data available); value listed is one-half of the gross-beta value measured.

e. Former P&T extraction well.

f. Not sampled in 1994; value from 1995 used for table.

g. A P&T system was operated from 1995 through 2006.

h. Not sampled in 2005; value from 2006 used for table.

i. Sampled on July 1, 2016.

NC	=	not calculated	Q	=	associated with out-of-limits quality control samples
NS	=	not sampled for strontium-90 or gross beta	TPH-D	=	total petroleum hydrocarbon-diesel
P&T	=	pump and treat	U	=	nondetect

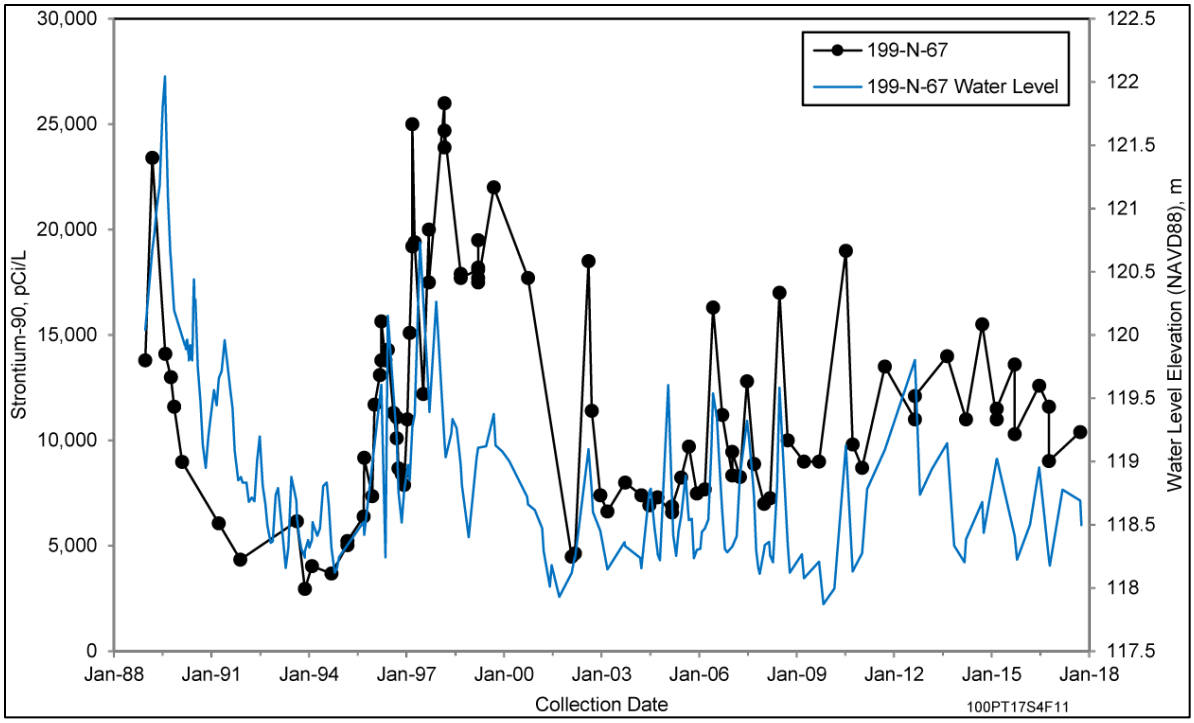
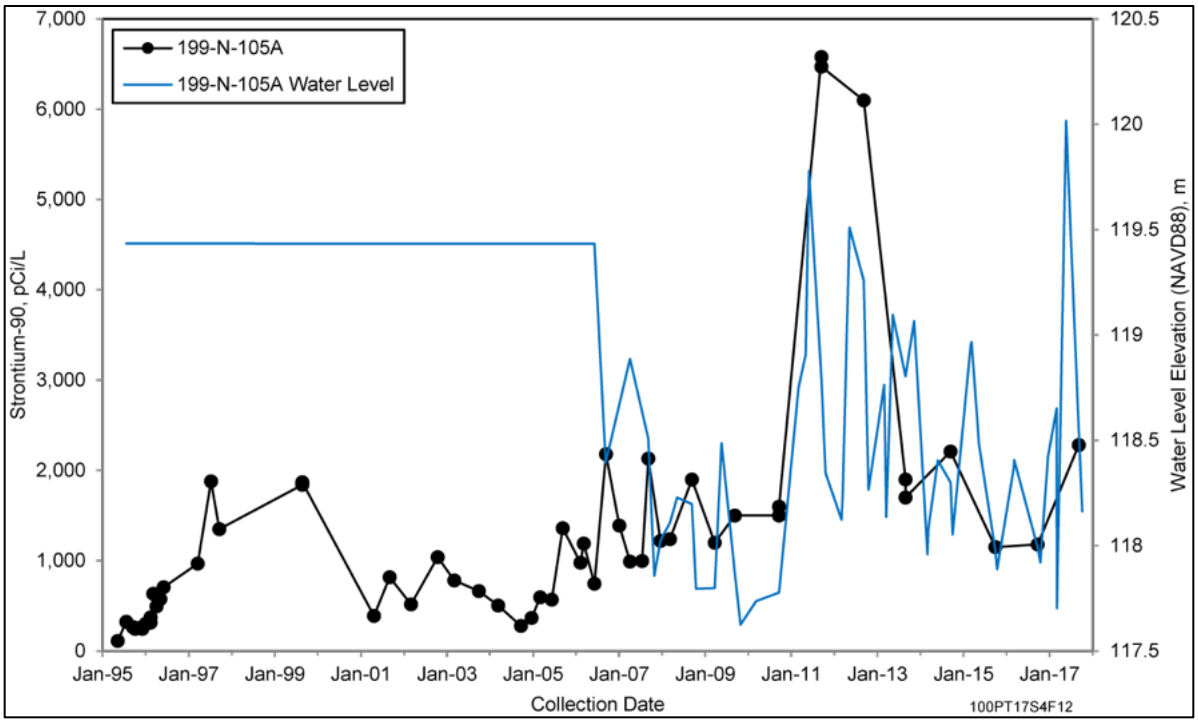


Figure 4-9. Strontium-90 Trend Plot and Water Levels for Well 199-N-67



Note: Well was former pump-and-treat extraction well from 1995 through 2006.

Figure 4-10. Strontium-90 Trend Plot and Water Levels for Well 199-N-105A

Strontium-90 concentrations, as well as the water table elevation in well 199-N-81 (downgradient of the 116-N-3 Trench), have declined since the late 1990s (Figure 4-11). High-water table elevations in 2011 and 2012 caused a slight increase in the strontium-90 concentration that continued into the fall 2015 sampling. The water table elevation returned to more normal elevations from the high-water table elevations observed in 2011 and 2012, and strontium-90 concentrations in well 199-N-81 stabilized in 2016. The high river-stage was higher in 2017 and over a longer period compared to that observed in 2016 (Figure 4-7), resulting in significant increase in strontium-90 concentrations measured in wells downgradient of the 116-N-1 Trench and 116-N-3 Crib as reflected in Table 4-1 wells 199-N-2, 199-N-105A, 199-N-184, and 199-N-188. The positive correlation of strontium-90 concentrations with water-level changes is more evident near the 116-N-1 and 116-N-3 waste sites, which presumably have more residual strontium-90 in the lower vadose zone than locations further from the waste sites.

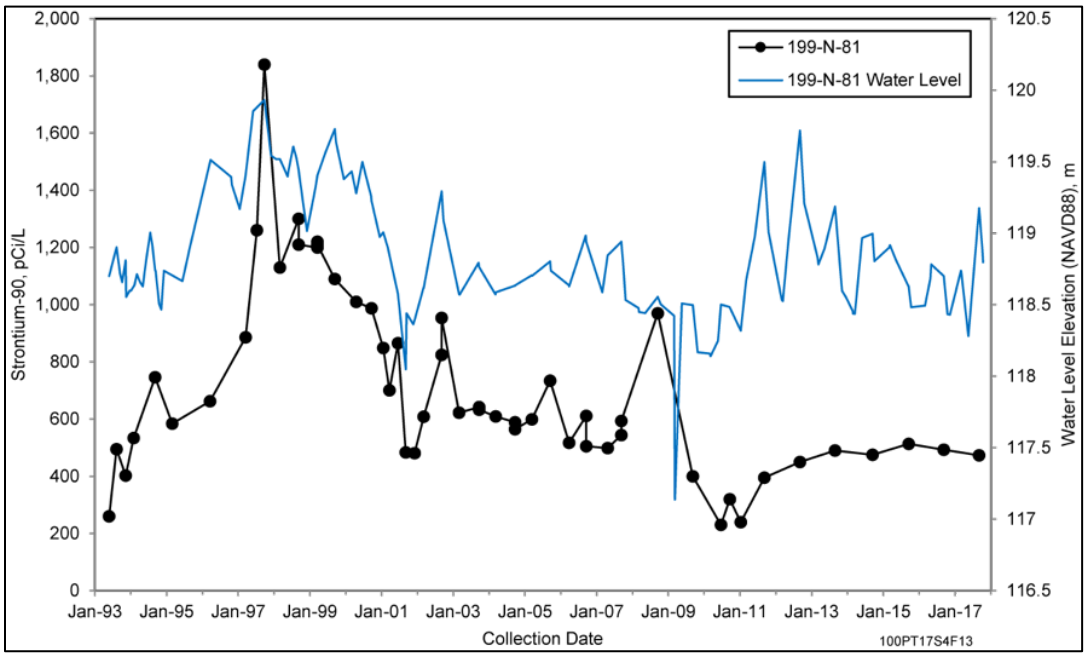


Figure 4-11. Strontium-90 Trend Plot and Water Levels for Well 199-N-81

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 4-8). This region of the 100-N Area river shoreline was impacted by highly contaminated effluent during 116-N-1 waste site operations. Effluent discharged to the 116-N-1 waste site emerged at the steeply sloping, near-shore surface as springs along the shoreline (also known as N Springs) because of the artificially elevated water table. This contaminated area has been the focus of increased monitoring and remediation.

Strontium-90 concentrations in aquifer tubes are consistent with concentrations in monitoring wells. Concentrations greater than the DWS are present only above approximately 115 m (377 ft) (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. Table 4-1 provides the maximum concentrations in the aquifer tubes during 2017. The maximum strontium-90 concentration during 2017 was 2,390 pCi/L in aquifer tube NVP2-116.0.

Outside of the main strontium-90 plume area, strontium-90 was identified only in upriver aquifer tube cluster C7934/C7935/C7936 (Figure 4-8). The highest detected strontium-90 concentration at this aquifer tube cluster in 2017 was 260 pCi/L at C7934. These aquifer tubes are located near the engineered fill

around the 1908-N outfall, on the back side of the N Reactor building. The outfall construction may have created a preferential pathway in the fill for contaminant migration. Leaks from the FSB and associated facilities and pipelines between N Reactor and the river are likely sources of the elevated strontium-90 concentrations at this location.

As presented in DOE/RL-2016-69, three documented UPRs (UPR-100-N-3, UPR-100-N-7 and UPR-100-N-12) are the likely sources of the strontium-90 contamination at aquifer tube cluster C7934/C7935/C7936. During 2016, wells 199-N-371, 199-N-372, and 199-N-374 were installed between N Reactor and the river (Figure 4-2) to evaluate the source of the strontium-90 contamination detected at the aquifer tube cluster C7934/C7935/C7936. The wells were placed parallel to the river to delineate the plume in that area and to provide a better understanding of the contamination source. Strontium-90 contamination was detected at 1.29 pCi/g in a soil sample at the water table collected from well 199-N-374, which supports the conceptual model that the source of contamination is from UPRs from the FSB and associated facilities and pipelines. Groundwater samples collected at the water table during drilling of well 199-N-374 had a strontium-90 concentration of 18.4 pCi/L at well 199-N-374. Concentrations have fluctuated slightly since installation, with concentrations less than 20 pCi/L. In June 2017, concentrations at this well increased to 73.7 pCi/L, associated with the increased water levels from the high river-stage and declining as water levels decreased. Soil and groundwater samples collected in boreholes 199-N-371 and 199-N-372 were nondetect and below the 8 pCi/L DWS for strontium-90, respectively. The low strontium-90 concentrations at 199-N-374 and nondetect at 199-N-371 and 199-N-372 indicate a narrow contamination plume from the UPR sites to the aquifer tube cluster C7934/7935/7936 (Figure 4-8).

River shore seep 100-N SPRINGS 089-1 was sampled in November 2017. 100-N SPRINGS 089-1 is located on the shoreline near aquifer tube N116mArray-4A (Figure 4-2), and strontium-90 concentration in the seep sample was 22.5 pCi/L. No seep was observed for sampling in 2017 at seep location 100 N SPRINGS 8-13. This sample location is north of the strontium-90 plume extent and 2016 concentrations were below the MDA for strontium-90.

4.3.2 Total Petroleum Hydrocarbons-Diesel

The primary source of the total petroleum hydrocarbons-diesel (TPH-D) groundwater contamination was a 1966 diesel fuel tank spill (UPR-100-N-17). A small, relatively narrow groundwater plume persists downgradient from the spill location to the river (Figure 4-12). The data used to prepare the TPH plume map for 2017 includes routine groundwater monitoring data and monitoring data for the in situ bioventing project (Section 4.5.1). Groundwater samples for in situ bioventing performance monitoring were collected twice in 2017 (July and November). The data were used to interpret the extent of the petroleum plumes for high- and low-water periods (Figures 4-13 and 4-14) and are similar in extent to the annual average TPH-D plume (Figure 4-12). Over the years, the plume extent has not significantly changed, although concentrations fluctuate with changes in water elevation.

The highest TPH-D concentration in 2017 was detected in well 199-N-18 at 16,600 µg/L. Well 199-N-172 was scheduled for sampling in November 2017 along with other petroleum hydrocarbon monitoring wells, but water levels were below the bottom of the well screen and a sample could not be collected. This well was sampled in January 2018 after water levels increased enough for sample collection. In January 2018, the TPH-D concentration was 28,600 µg/L; this high concentration is attributed sorption of petroleum hydrocarbon contamination from the rewetted sediments during the extended high river-stage period in 2017.The current highest detected TPH-D concentrations in the 100-N Area are lower than the 2011 and 2010 maximum concentrations (well 199-N-18) of 48,000 and 420,000 µg/L, respectively.

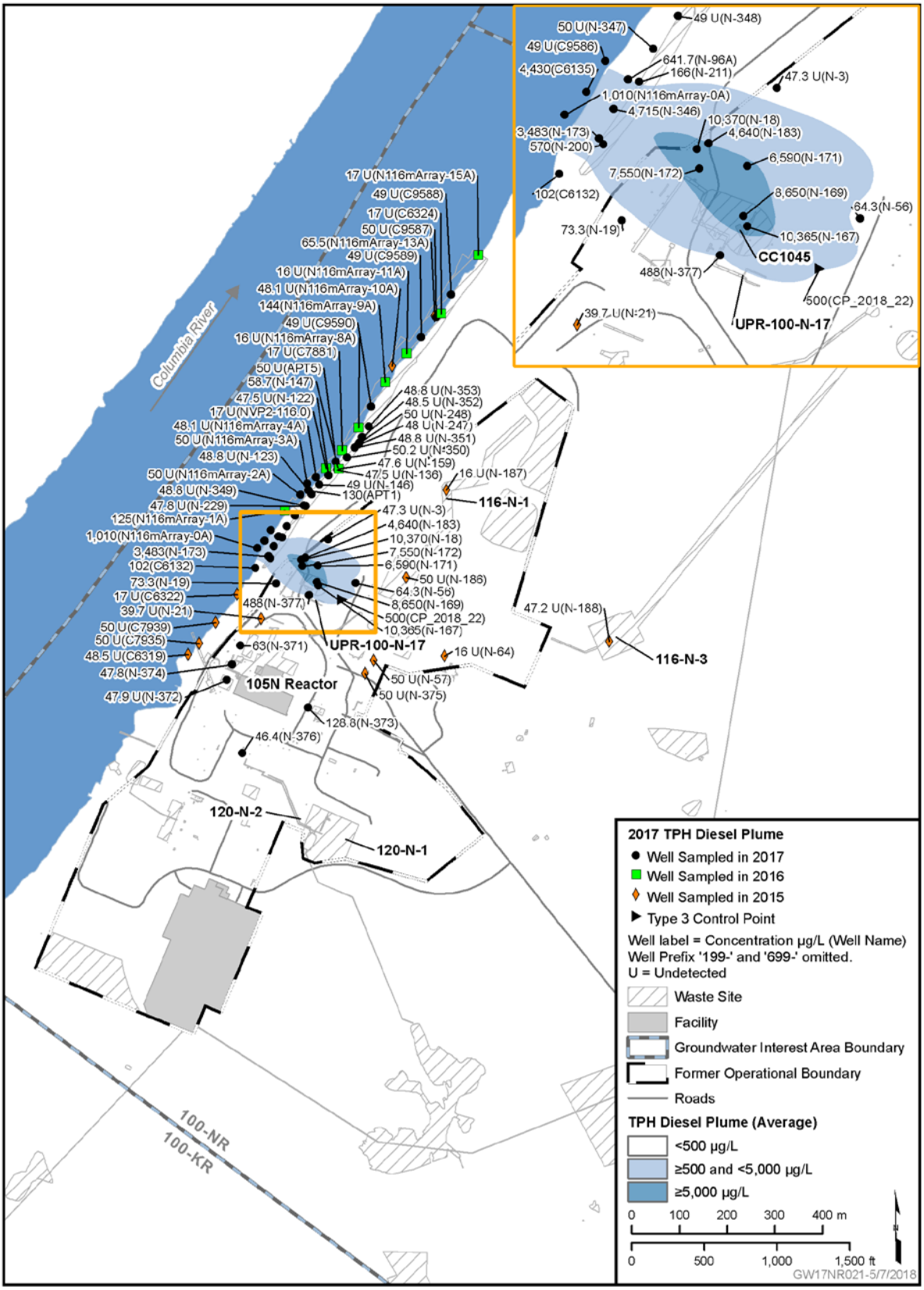


Figure 4-12. TPH-D Plume Map for the 100-N Area, 2017

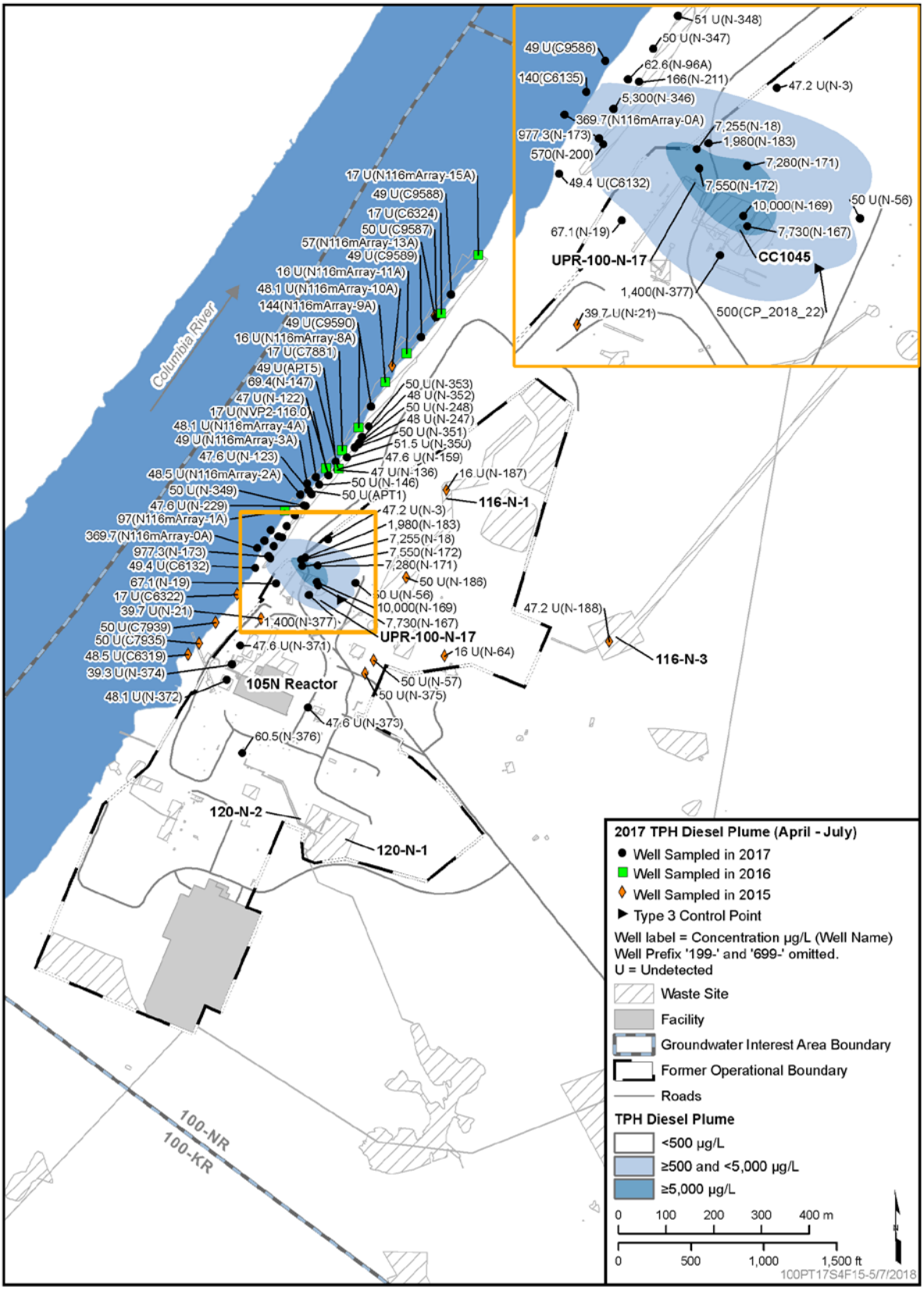


Figure 4-13. TPH-D and TPH Motor Oil Plume Map, Spring/Summer 2017

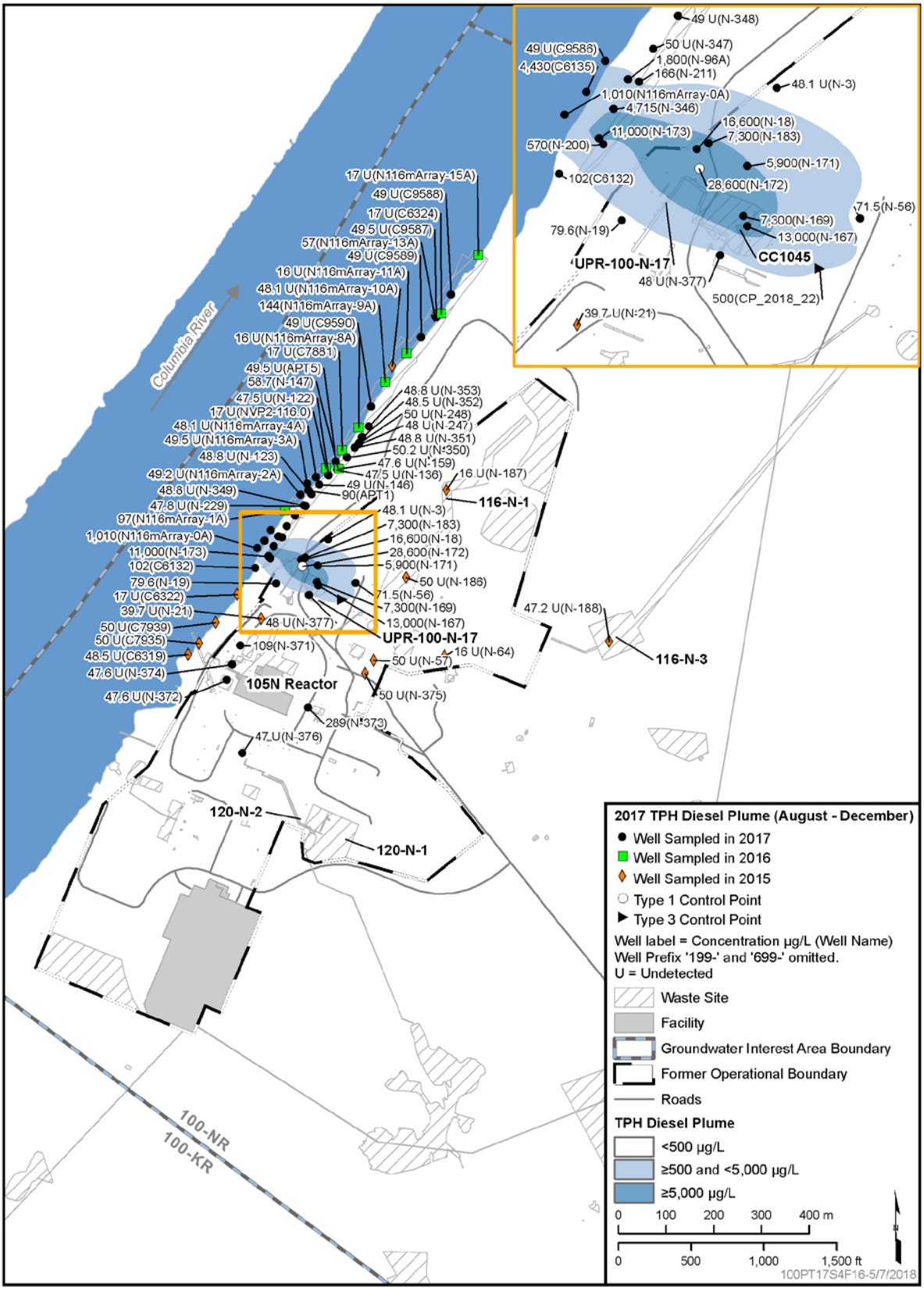


Figure 4-14. TPH-D and TPH Motor Oil Plume Map, Fall 2017

TPH concentrations in groundwater generally decreased from 2012 through 2016, presumably due to in situ bioventing in the vadose zone. However, in 2017 the TPH-D concentrations increased in most monitoring wells and aquifer tubes. The increases are related to the longer high water-elevation period in 2017, which likely remobilized TPH-D contamination in the vadose zone. This is reflected in the June 2017 sample at well 199-N-377, which had a TPH-D concentration of 1,500 µg/L. The TPH concentration at this well was less than detection 2016, and concentrations returned to less than detection in the samples from November and December 2017, when water elevations returned to typical levels.

TPH-D is detected in three aquifer tubes located on the river shore, immediately adjacent and downgradient of the TPH-D plume in groundwater. In 2017, a maximum concentration of 4,430 µg/L was detected in aquifer tube C6135. River shore seep 100-N SPRINGS 089-1 was sampled in November 2017 for TPH, and the concentration was less than detection in the seep sample.

4.4 Strontium-90 Remediation

During 2017, the 311 m (1,020 ft) long apatite PRB continued to reduce the flux of strontium-90 contamination in the 100-NR-2 OU groundwater along the majority of the apatite PRB in accordance with the amended interim action ROD (EPA, 2010). Performance monitoring indicated two locations in the apatite PRB with decreased performance that started in 2015 and continued through 2017 (Section 4.3.1).

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 isomorphic substitution and eventually become trapped as part of the mineral matrix during apatite crystallization (PNNL-16891). 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 Evaluation

Groundwater samples were collected from performance monitoring wells and aquifer tubes during high river-stage in June and low river-stage in September. Table 4-2 compares the spring and fall 2017 data to pre-treatment baseline conditions. Table 4-3 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 4-4 lists the injection wells for the 760 m (2,500 ft) long barrier and indicates which sections have been treated as of 2017.

The central (original) segment of the apatite PRB extends 91 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 4-4). Apatite-forming solutions were injected into the Hanford formation and Ringold Formation over a period of 3 years (from 2006 through 2008).

The 110 m (360 ft) long upriver and 110 m (360 ft) 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 4-4). The apatite barrier extensions increased the length of 100-N Area shoreline treated to sequester strontium-90 from 91 to 311 m (300 to 1,020 ft) (SGW-56970). The barrier was expanded in accordance with the design optimization study (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 the objectives in SGW-56970.

Table 4-2. 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 Maximum to 2017)[c]	
			Minimum Detected Baseline	Maximum Baseline	Spring 2017[a]	Fall 2017[b]		
Upriver Apatite Permeable Reactive Barrier								
			04/06/10		**June 2017**	**Oct 2017**	**Spring**	**Fall**
199-N-96A	56	8	1.54[d]	37.9[d]	1.08	1.62[h]	97	96
199-N-347	1	1	7[e]	7[e]	4.17	7.76	52	0
199-N-348	1	0	1,800	1,800	11.4	62.3	99	97
199-N-349	2	0	220	230	98.6	36	58	84
Central (Original) Apatite Permeable Reactive Barrier								
(See footnote f)			(See footnote g)		**June 2017**	**Sept 2017**	**Spring**	**Fall**
199-N-122	10	0	657	4,630	521	1,120	89	76
199-N-146	4	0	318	985	143	503	85	49
199-N-147	3	0	522	1,842	211	238	89	87
199-N-123	6	0	689	1,180	112	162	90	86
Downriver Apatite Permeable Reactive Barrier								
			07/28/10 and 07/29/10		**June 2017**	**Oct 2017**	**Spring**	**Fall**
199-N-350	1	0	240	240	81.1	69.0	66	71
199-N-351	1	0	350	350	80.9	436	78	0
199-N-352	1	0	580	580	123	865	79	0

Table 4-2. 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 Maximum to 2017)[c]	
			Minimum Detected Baseline	Maximum Baseline	Spring 2017[a]	Fall 2017[b]		
199-N-353	1	0	83	83	5.97	55.6	94	33

a. Spring 2017 samples were collected from June 13 through June 29.

b. Fall 2017 samples were collected from September 26 through October 2.

c. The percentage reduction in strontium-90 concentration is calculated as (([baseline value] – [2016 value])/[baseline value]) × 100. Maximum baseline value used for comparison.

d. 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.

e. Strontium-90 is a beta emitter. Gross beta concentrations are approximately two times the strontium-90 concentrations (PNNL-17429, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization*). The strontium-90 concentration was 1.1(U) pCi/L. The gross beta concentration, 14 pCi/L, was divided by two to approximate the strontium-90 concentration of 7 pCi/L.

f. From Table 8.1 in PNNL-17429.

g. 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*.

h. The fall 2017 sample for well 199-N-96A was taken on November 8, 2017.

Table 4-3. 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	199-N-359/C7452	MW
199-N-173/C7038	MW	N116mArray-6A/C5259	AT	N116mArray-11A/C5265	AT
N116mArray-0A/C5514	AT	199-N-147/C5116	MW	199-N-360/C7453	MW
199-N-346/C7442	MW	APT-5/C5386	AT	N116mArray-12A/C5266	AT
C6135	AT	199-N-350/C7443	MW	199-N-361/C7454	MW
199-N-96A/A9882	MW	C7881*	AT	199-N-362/C7455	MW
C6136	AT	199-N-351/C7444	MW	199-N-363/C7456	MW

Table 4-3. Apatite PRB Performance Monitoring Wells and Aquifer Tubes

Well Name/ID	Well Type	Well Name/ID	Well Type	Well Name/ID	Well Type
199-N-347/C7441	MW	199-N-352/C7445	MW	N116mArray-13A/C5267	AT
N116mArray-1A/C5255	AT	199-N-353/C7446	MW	199-N-364/C7457	MW
199-N-348/C7440	MW	N116mArray-8A/C5261	AT	199-N-365/C7458	MW
N116mArray-2A/C5256	AT	199-N-354/C7447	MW	N116mArray-14A/C5268	AT
199-N-349/C7439	MW	N116mArray-8.5A/C5262	AT	199-N-366/C7459	MW
199-N-123/C4955	MW	199-N-355/C7448	MW	199-N-367/C7463	MW
APT-1/C5269	AT	199-N-356/C7449	MW	199-N-92A/A8878	MW
N116mArray-3A/C5257	AT	199-N-357/C7450	MW	N116mArray-15A/C5512	AT
199-N-146/C5052	MW	N116mArray-9A/C5263	AT		
N116mArray-4A/C5258	AT	199-N-358/C7451	MW		
199-N-122/C4954	MW	N116mArray-10A/C5264	AT		

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 4-4. 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

Table 4-4. Apatite PRB Injection Wells

Well Name/ID	Depth	Well Name/ID	Depth	Well ID	Depth	Well Name/ID	Depth
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
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

Table 4-4. Apatite PRB Injection Wells

Well Name/ID	Depth	Well Name/ID	Depth	Well ID	Depth	Well Name/ID	Depth
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		
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 yet treated.

Wells identified with “shallow” depth are screened in the upper region (typically about 2 m [6 ft]) of the unconfined aquifer; wells identified with “deep” depth are screened below the shallow wells (typical screen length of 2.5 m [8 ft]) about 0.6 m (2 ft) below the depth of shallow screened wells; wells identified with “shallow, deep” depths are screened across both the shallow and deep depths.

ID = identification

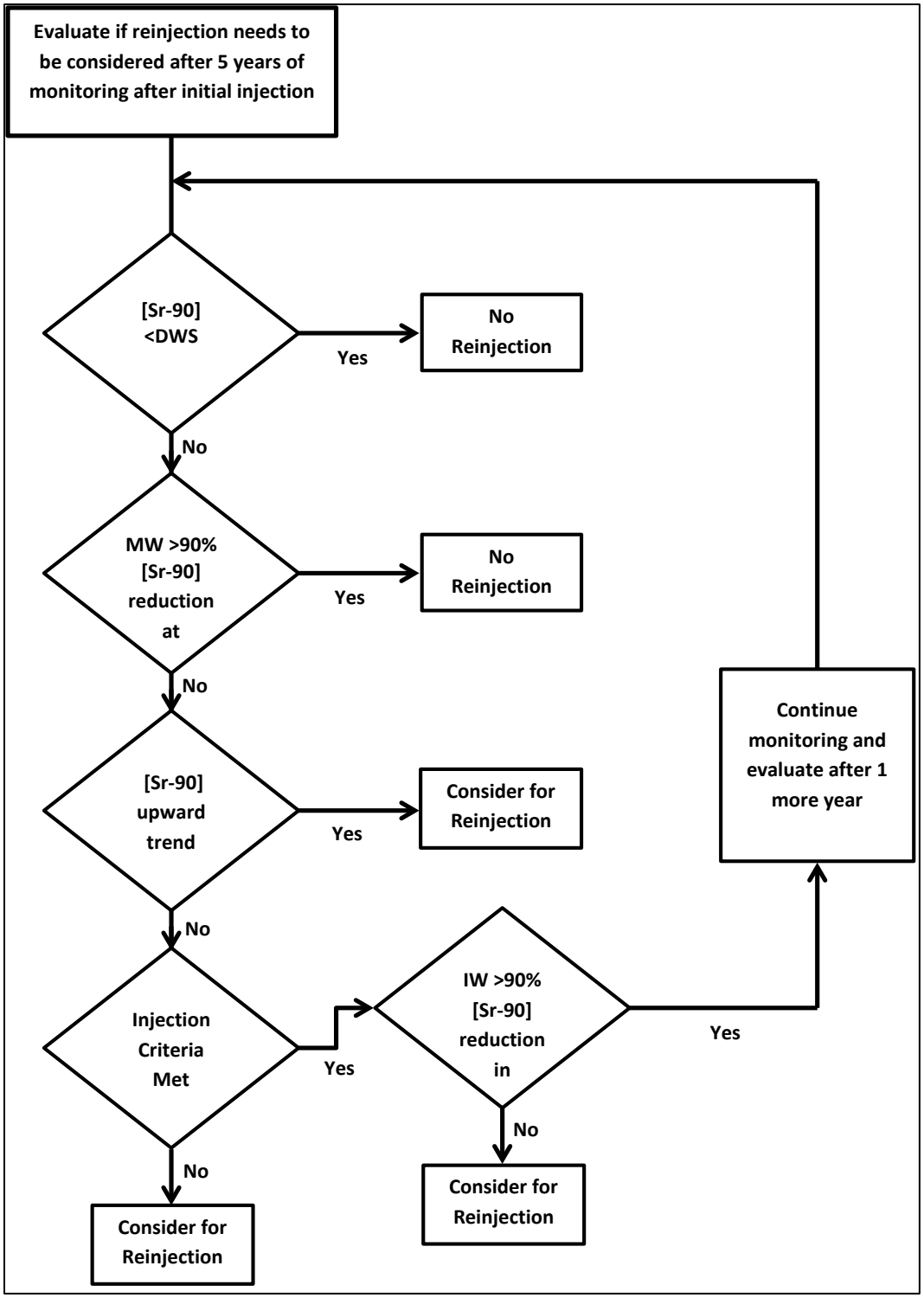
The original apatite PRB segment has been in place for 9 years, and the upriver and downriver extensions have been in place for 6 years. The objective of the treatability test plan was a 90% reduction in strontium-90 groundwater concentrations in the performance monitoring wells (Section 4.4.3 in DOE/RL-2005-96).

Figure 4-15 provides a decision flow diagram for evaluating whether reinjection of apatite-forming chemicals should be considered based on PRB performance. The performance evaluation is based on measurements collected from the PRB monitoring wells listed in Table 4-3. The aquifer tubes listed in Table 4-3 are used to support evaluating PRB performance trends but are not used in assessing PRB performance to achieve the remedial objective target since they are not constructed as resource protection wells (as specified in WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"). Based on the decision flow logic presented in Figure 4-15, a qualitative assessment for performance of the treated PRB segments are shown in figures in Sections 4.3.1.1 through 4.3.1.3 using colored circles at each injection well location to represent the 9 m (30 ft) design injection radius. Green color fill indicates that strontium-90 concentrations at the monitoring well meet the target strontium-90 reduction, are less that the DWS, or that continued strontium-90 reduction is observed with stable or decreasing trend. Yellow color fill indicates that the calculated strontium-90 reduction does not meet the target strontium-90 reduction, and there is an increasing strontium-90 concentration trend at the monitoring well. Red color fill indicates that the calculated strontium-90 reduction does not meet the target strontium-90 reduction, there is an increasing strontium-90 concentration trend at the monitoring well, and the injection criteria were not met. Injection criteria includes meeting target injection volumes and phosphate concentrations, and radial distribution of amendment (identified in DOE/RL-2010-29).

4.4.1.1 Original Permeable Reactive Barrier Segment Performance

Following apatite injections in wells in the central (original) segment of the barrier in 2008, strontium-90 concentrations declined in the performance monitoring wells (Figure 4-16). The wells showed temporary, higher strontium-90 concentrations immediately following injection of the apatite solution, which had a higher ionic strength than groundwater and displacing cations and anions from the sediments, causing their concentrations in groundwater to increase. Strontium-90 concentrations in performance monitoring well 199-N-123 (near the upriver end of the central barrier segment) temporarily increased following injections into the nearby upriver barrier extension wells in 2011 (Figure 4-16). The injection effects were temporary, as concentrations declined following the injections as the strontium-90 was incorporated through initial precipitation and adsorption/slow incorporation into the apatite and as the reagent plume dissipated.

Strontium-90 concentrations at well 199-N-122 have been trending upward (Figure 4-16). The fluctuation in strontium-90 concentration (Figure 4-16) is associated with high and low river sampling periods, where concentrations tend to be lower during high river-stage, indicating some dilution from river water. As of fall 2017, the strontium-90 concentrations were still considerably lower in the performance monitoring wells along the central segment of the barrier than before the injections began in 2006. The percent reduction from baseline strontium-90 concentrations ranged from 85% (well 199-N-146) to 90% (well 199-N-123) in spring 2017, and 49% (well 199-N-146) to 87% (well 199-N-147) in fall 2017 (Table 4-2; Figure 4-17).



Source: Figure 3-18 in DOE/RL-2001-27, *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit*.

Figure 4-15. Reinjection Decision Flow Diagram

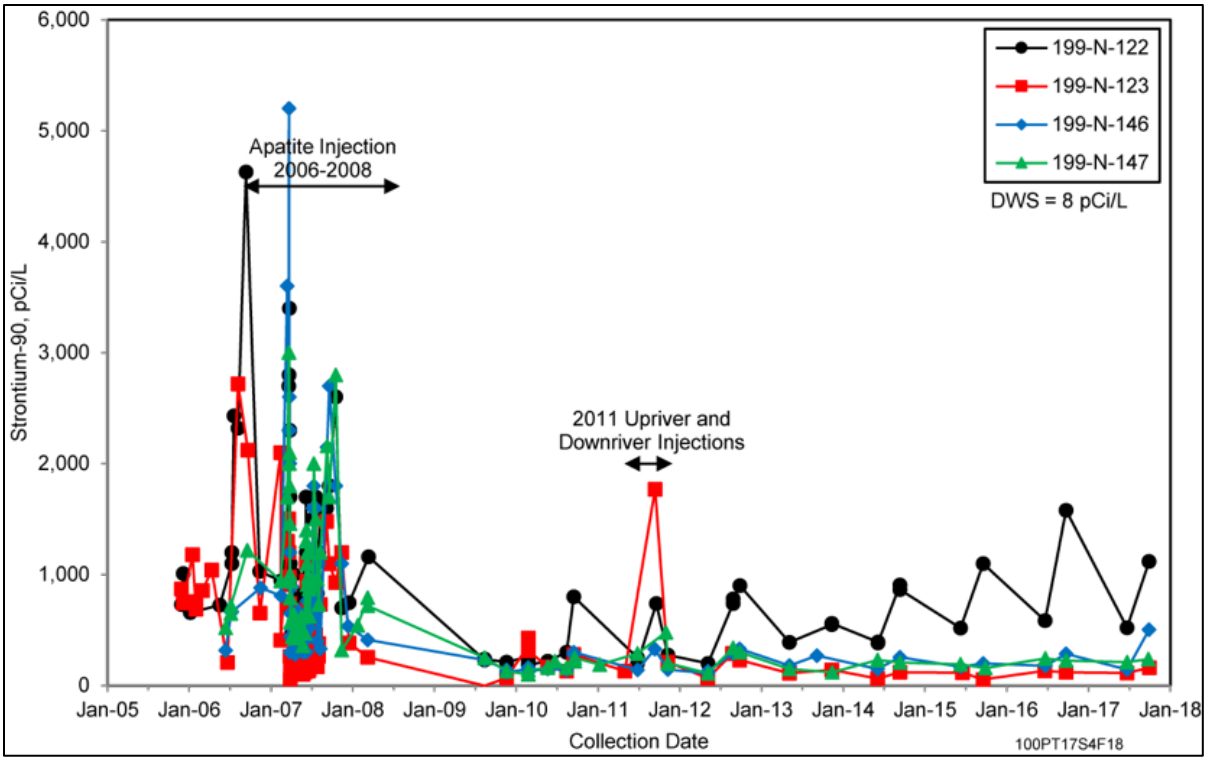


Figure 4-16. Strontium-90 Data for Performance Monitoring Wells Along the Central Segment of the Apatite PRB

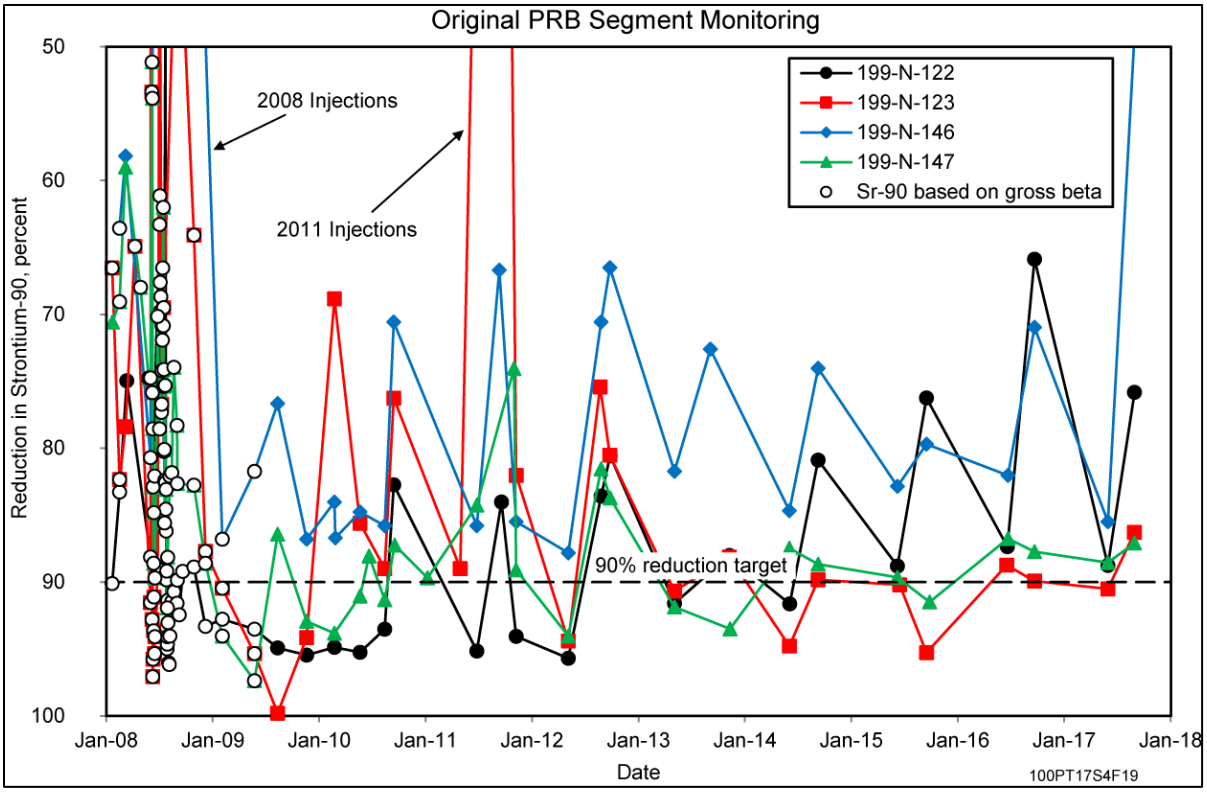


Figure 4-17. Original Apatite Performance Monitoring Wells Percent Strontium-90 Reductions

Aquifer tubes that are monitored downgradient of the original PRB segment also continue to show decreased concentrations from pre-injection strontium-90 concentrations (Figure 4-18).

Tables 4-5 and 4-6 provide the percent reduction in strontium-90 concentrations since 2011 for the original PRB segment monitoring wells and aquifer tubes, respectively. Concentrations in two of the original PRB segment monitoring wells continue to be near the 90% reduction target. The percent reduction in strontium-90 concentration at monitoring well 199-N-122 was 89% in the spring and 76% in the fall. This monitoring well had the highest baseline strontium-90 concentration of the PRB monitoring wells at 4,630 pCi/L. Three injection wells (199-N-161, 199-N-144, and 199-N-163) did not meet one or more of the injection criteria (PNNL-19572). The assessment indicates that the portion of the original PRB segment (near monitoring well 199-N-122) is colored yellow (i.e., below target reduction with an increasing trend) in Figure 4-19 and should continue to be monitored to determine if this area should be reinjected. Strontium-90 concentration is trending upward in well 199-N-146, and the percent reduction in the fall was at 49%. Overall concentration reduction for 2017 at well 199-N-146 was 67%. Injection wells in this area (199-N-140 and 199-N-141) are among the farthest apart of PRB injection wells. Injections in well 199-N-141 did not meet the target radial extent of amendment distribution, and results were inclusive for injections to well 199-N-140 (PNNL-19572). The assessment indicates that the portion of the original PRB segment near monitoring well 199-N-146 is below target reduction with an increasing trend (i.e., colored yellow in Figure 4-19) and should continue to be monitored to determine if the area should be reinjected. The remaining length of the upriver PRB segment continues to provide strontium-90 reduction.

The aquifer tubes downgradient from the original PRB segment continue to show strontium-90 reduction and stable trends, except for NVP2-116.0, which is trending upward. Aquifer tube NVP2-116.0 is located downgradient of monitoring well 199-N-122. The assessment indicates the original PRB segment continues to provide strontium-90 reduction, but trends at wells 199-N-122, 199-N-146, and aquifer tube NVP2-116.0 indicate that performance of the PRB in this area may declining (Figure 4-19).

4.4.1.2 Upriver Permeable Reactive Barrier Segment Performance

The upriver segment of the PRB forms the upriver portion of the barrier, near the outside edge of the strontium-90 groundwater plume. Strontium-90 concentrations are below the DWS at performance monitoring wells 199-N-96A and 199-N-347 and the target strontium-90 reduction is being met at well 199-N-348. However, these goals have not been achieved in the vicinity of well 199-N-349.

In the performance monitoring wells along this extension, the percentage reduction in strontium-90 concentrations in 2017 (the sixth year following the injections) ranged from no reduction (well 199-N-347) to 97% (199-N-348) in the fall, and 52% (199-N-347) to 99% (199-N-348) in the spring (Table 4-2; Figure 4-20). The relatively low percent reduction at well 199-N-347 reflects 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) and the low concentrations (4.2 and 7.8 pCi/L) detected in 2017. Both the baseline and the 2017 sample concentrations in well 199-N-347 are below the DWS (8 pCi/L), while concentrations in well 199-N-96A have been below the DWS since 2012. Because concentrations in well 199-N-347 are below the DWS, the percent reduction in strontium-90 concentration is not plotted in Figure 4-20. In groundwater monitoring well 199-N-349, 58% and 84% reductions in strontium-90 concentration were observed in the fall and spring of 2017, respectively (Table 4-2; Figure 4-20). The percent reduction in well 199-N-349 may be an indication of areas of limited radial amendment distribution due to high injection rates. Table 4-7 provides the injection volume of apatite chemicals into the injection wells near monitoring well 199-N-349. The injection flow rate was not controlled for even flow distribution in all injection wells (SGW-56970), so some wells received more than 150% the target injection volume of 227,000 L (60,000 gal) and other wells received only about 50% of the target injection volume.

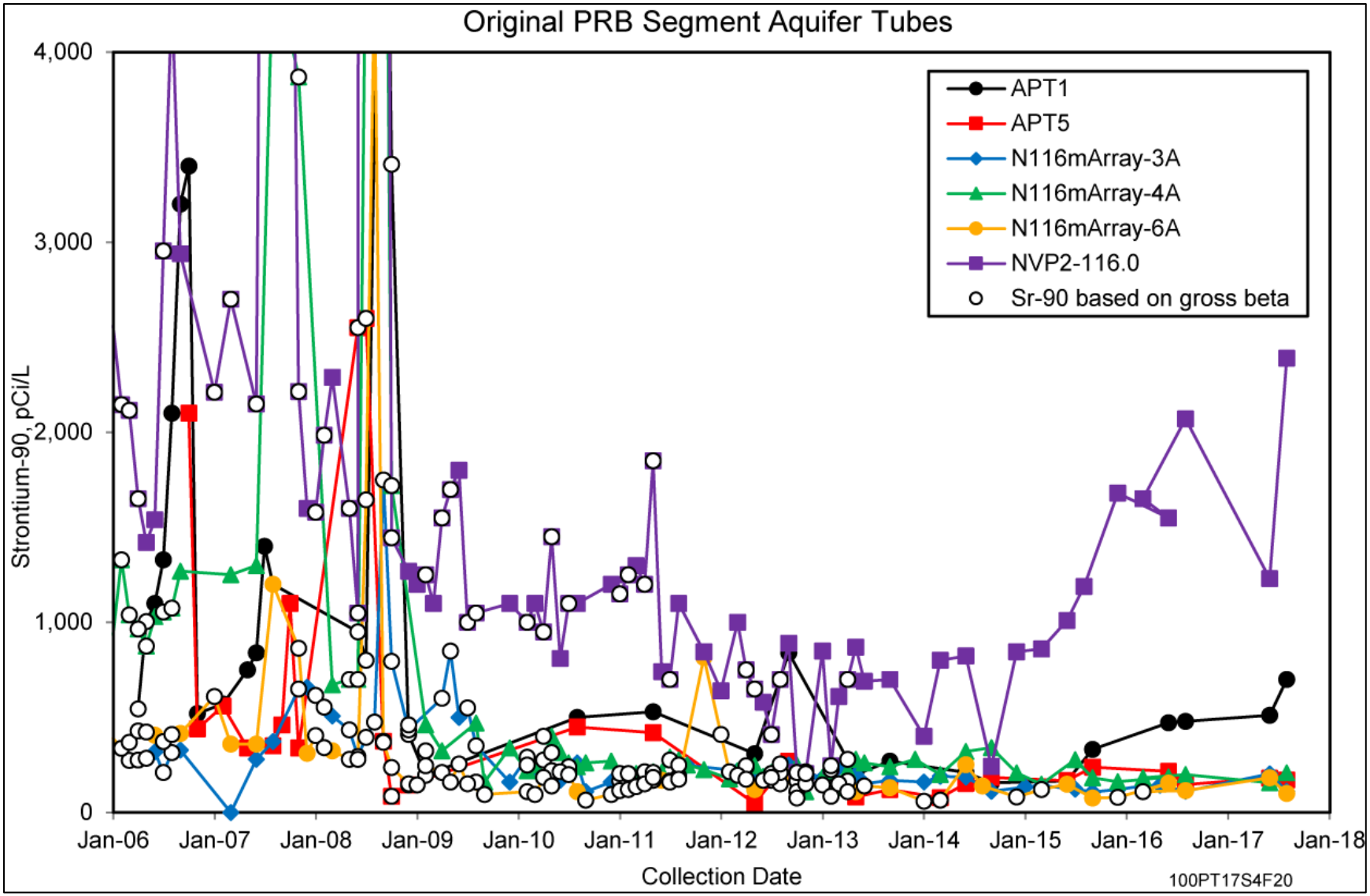


Figure 4-18. Strontium-90 Data for Aquifer Tubes Along the Central Segment of the Apatite PRB

Table 4-5. PRB Monitoring Well 2011, Performance Summary for 2017

Monitoring Well	Pre-Injection Baseline[a]	Month/Year Treated		Concentration (pCi/L) (Percent Reduction from Baseline[b])					
			2011	2012	2013	2014	2015	2016	2017
Upriver Apatite PRB (Treated in 2011)									
199-N-96A	37.9	Sept. 2011	—[c]	2.3 (94%)	4.1 (89%)	1.6 (96%)	3.8 (90%)	3.04 (92%)	1.6 (96%)
199-N-347	7[d]	Sept. 2011	—[c]	7.8 (-12%)	6.9 (1.4%)	5.1 (27%)	4.7 (33%)	4.8 (32%)	6.0 (31%)
199-N-348	1,800	Sept. 2011	—[c]	54 (97%)	34 (98%)	35 (98%)	71 (96%)	76 (96%)	37 (98%)
199-N-349	230	Sept. 2011	—[c]	37 (84%)	46 (80%)	87 (62%)	111 (52%)	90 (61%)	67 (66%)
Central (Original) Apatite PRB (Treated 2006 Through 2008)									
199-N-122	4,630	July 2008	366 (93%)	656 (86%)	472 (90%)	637 (86%)	809 (82%)	1,083 (77%)	821 (82%)
199-N-146	985	July 2008	204 (79%)	215 (78%)	225 (77%)	204 (79%)	184 (81%)	232 (77%)	323 (67%)
199-N-147	1,842	July 2008	272 (85%)	250 (86%)	135 (93%)	230 (88%)	174 (90%)	235 (87%)	225 (88%)
199-N-123	1,180	July 2008	704 (40%)[e]	204 (83%)	125 (89%)	91 (92%)	96 (92%)	126 (89%)	137 (88%)
Downriver Apatite PRB (Treated in 2011)									
199-N-350	240	Sept. 2011	—[c]	34 (86%)	21 (91%)	27 (89%)	76 (68%)	78 (68%)	75 (69%)
199-N-351	350	Sept. 2011	—[c]	26 (93%)	39 (89%)	95 (73%)	376 (-7%)	388 (-11%)	258 (44%)
199-N-352	580	Sept. 2011	—[c]	30 (95%)	29 (95%)	42 (93%)	368 (37%)	683 (-17%)	494 (15%)

Table 4-5. PRB Monitoring Well 2011, Performance Summary for 2017

Monitoring Well	Pre-Injection Baseline[a]	Month/Year Treated		Concentration (pCi/L) (Percent Reduction from Baseline[b])					
			2011	2012	2013	2014	2015	2016	2017
199-N-353	83	Sept. 2011	—[c]	5.0 (94%)	3.2 (96%)	4.0 (95%)	7.3 (91%)	39 (54%)	31 (73%)

a. Pre-injection baseline concentrations for the upriver and downriver PRB monitoring wells area based on samples collected in 2010. Pre-injection baseline concentrations for the central PRB monitoring wells are 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*.

b. The percentage reduction in strontium-90 concentration is calculated as ([pre-injection value] – [average value for the year] ÷ [pre-injection value]) × 100.

c. Injections were performed in September 2011, so performance was not calculated for this year.

d. Strontium-90 is a beta emitter. Gross-beta concentrations are approximately two times the strontium-90 concentrations. The strontium-90 concentration was 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.

e. Increase in strontium-90 concentrations observed at monitoring well 199-N-123 in 2011 is attributed to injection treatment of the upriver segment in September 2011.

PRB = permeable reactive barrier

Table 4-6. PRB Aquifer Tube 2011 - 2017 Performance Summary

Aquifer Tube	Pre-Injection Baseline[a]	Month/ Year Treated	Concentration (pCi/L) (Percent Reduction from Baseline[b])						
			2011	2012	2013	2014	2015	2016	2017
Upriver Apatite PRB (Treated in 2011)									
C6135[c]	2.3	Sept. 2011	1.5 (33%)	2.8 (0%)	—[d]	—[d]	—[d]	—[d]	—[d]
N116mArray-1A	34	Sept. 2011	94 (0)[e]	162 (0)[e]	50 (0%)[e]	2.1 (94%)	1.9 (94%)	4.4[g] (87%)	—[h]
N116mArray-2A	199	Sept. 2011	244 (0%)[e]	29 (85%)	16 (92%)	16 (92%)	17 (92%)	15 (93%)	22 (89%)
Central (Original) Apatite PRB (Treated from 2006 Through 2008)									
APT-1	1,454	July 2008	530 (64%)	575 (60%)	235 (84%)	184 (87%)	276 (81%)	476 (67%)	605 (58%)
APT-5	420	July 2008	420 (3%)	196 (55%)	97 (78%)	149 (66%)	202 (53%)	182 (57%)	176 (58%)
N116mArray-3A	379	July 2008	185 (52%)	202 (47%)	185 (52%)	162 (58%)	125 (67%)	132 (65%)	157 (59%)
N116mArray-4A	1,220	July 2008	230 (81%)	207 (83%)	215 (82%)	245 (80%)	202 (83%)	180 (85%)	209 (83%)
N116mArray-6A	445	July 2008	203 (54%)	205 (54%)	126 (72%)	119 (73%)	106 (76%)	135 (72%)	142 (68%)
NVP2-116.0	3,466	July 2008	1,078 (69%)	588 (83%)	633 (82%)	639 (82%)	1,146 (67%)	1,733 (50%)	1,810 (49%)

Table 4-6. PRB Aquifer Tube 2011 - 2017 Performance Summary

Aquifer Tube	Pre-Injection Baseline[a]	Month/ Year Treated	Concentration (pCi/L) (Percent Reduction from Baseline[b])						
			2011	2012	2013	2014	2015	2016	2017
Downriver Apatite PRB (Treated 2011)									
N116mArray-7A/C7881[f]	336	Sept. 2011	755 (0%)[e]	73 (78%)	32 (91%)	23 (93%)	27 (92%)	36 (89%)	65 (81%)
N116mArray-8A	7.8	Sept. 2011	8.9 (0%)[e]	2.4 (68%)	1.7 (78%)	1.3 (83%)	1.7 (78%)	1.6 (79%)	1.3 (84%)

a. Pre-injection baseline concentrations are based on a 95 upper confidence limit of pre-injection strontium-90 and gross beta measurements. Strontium-90 is a beta emitter. Gross-beta concentrations are approximately two times the strontium-90 concentrations. The gross beta concentrations were divided by two to approximate the strontium-90 concentration in determining pre-injection baseline concentrations.

b. The percentage reduction in strontium-90 concentration is calculated as ([pre-injection value] – [average value for the year] / [pre-injection value]) × 100.

c. Concentrations at C6135 are below the DWS (8 pCi/L).

d. Aquifer tube is missing and/or in need of repair and could not be sampled.

e. Increased concentrations at aquifer tube attribute to residual spike from injection treatment.

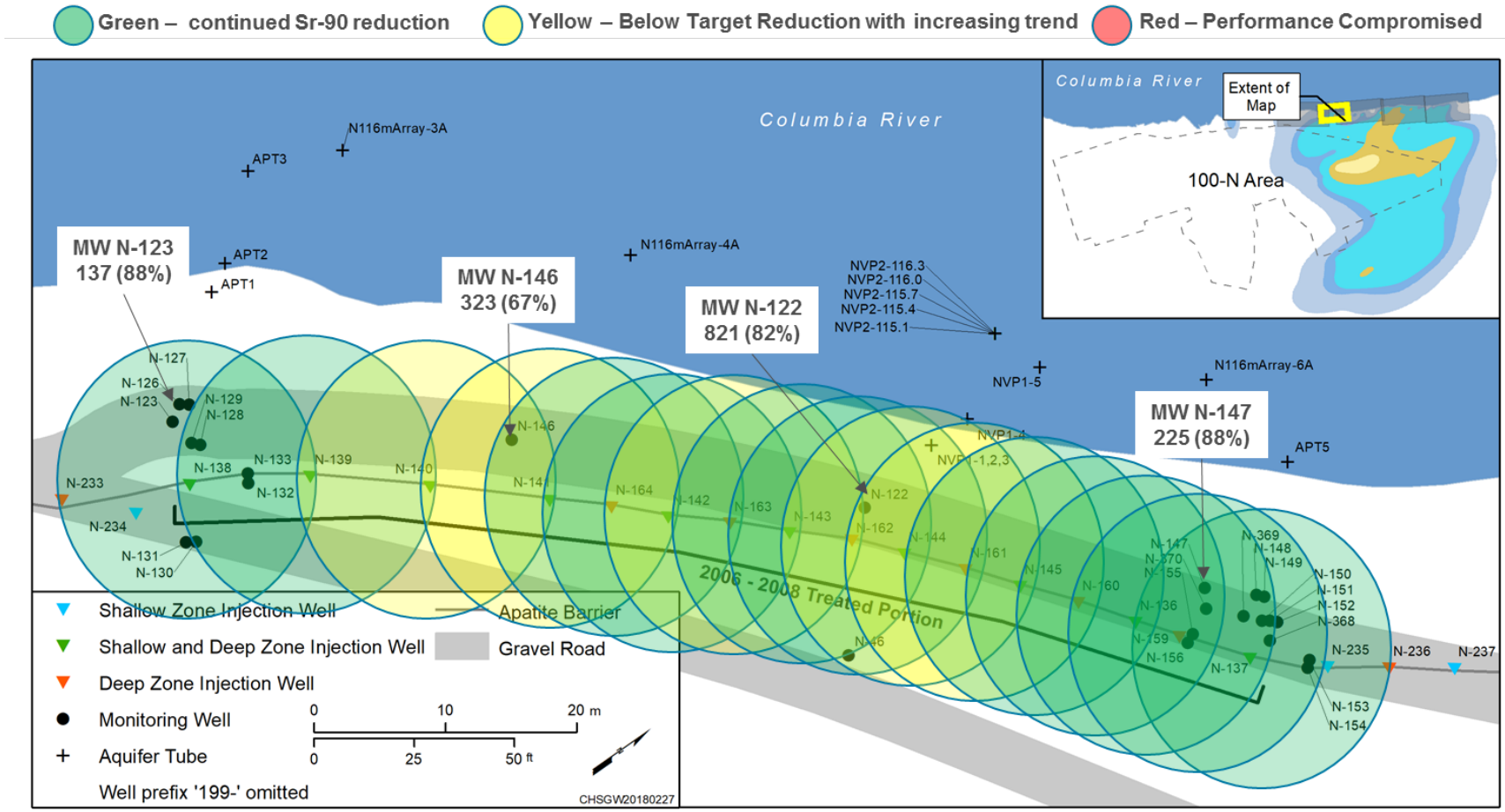
f. Aquifer tube C7881 is a replacement for N16mArray-7A installed in the same location.

g. Value calculated from gross-beta data (no strontium-90 data available); value listed is one-half of the gross-beta value measured.

h. Concentrations at N116mArrary-1A were below the DWS (8 pCi/L) before the aquifer tube became damaged and could no longer be sampled.

DWS = drinking water standard

PRB = permeable reactive barrier



Note: Text boxes in figure show the 2017 yearly average strontium-90 concentrations and percent reduction (in parenthesis) from baseline concentration for permeable reactive barrier monitoring wells.

Figure 4-19. Original PRB Segment Performance Assessment for 2017

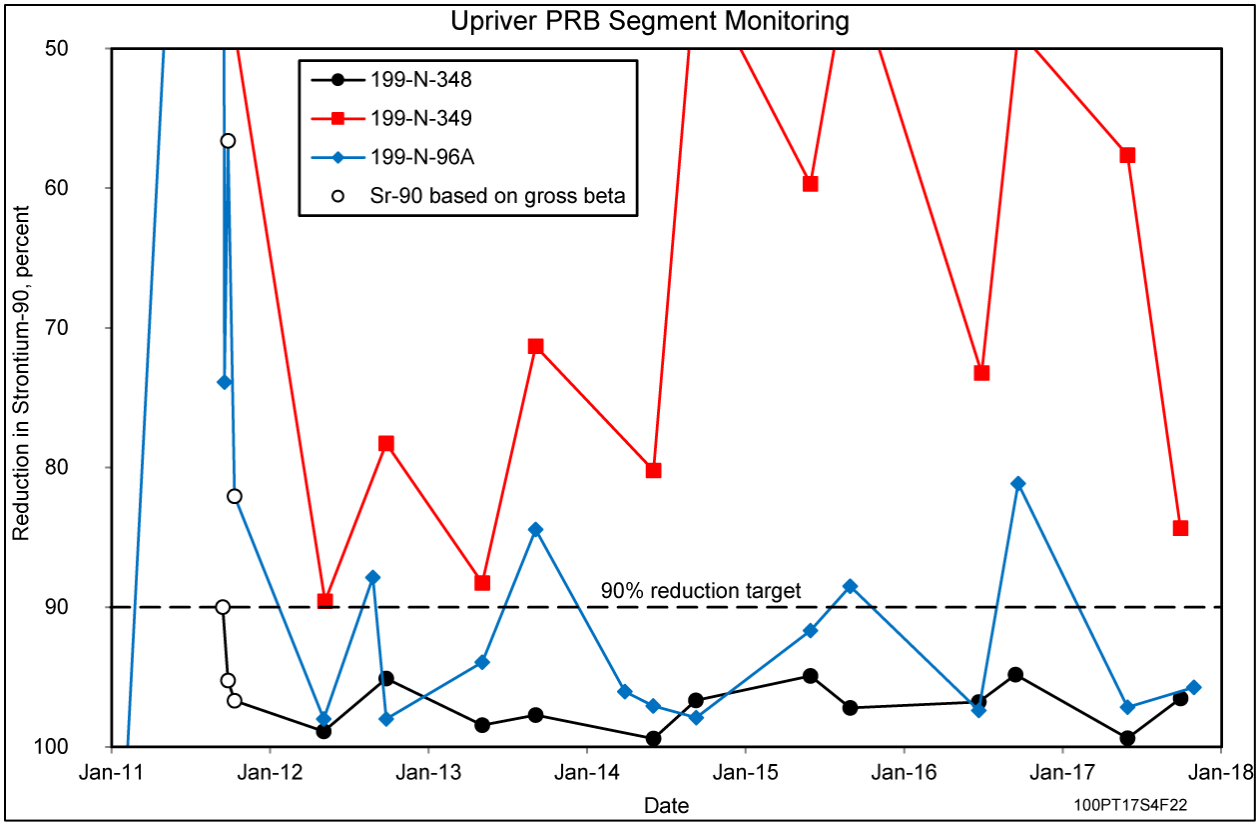


Figure 4-20. Upriver Apatite Barrier Extension Performance Monitoring Wells Percent Strontium-90 Reductions, 2017

Table 4-7. Injection Volume in Upriver Injection Wells near Well 199-N-349

Injection Well	Screen/Formation	Injected Volume (L [gal]) (Percent of Target Volume*)
199-N-225	Deep/backfill	327,693 (86,511) (144%)
199-N-226	Shallow/backfill	320,655 (84,653) (141%)
199-N-227	Deep/backfill	368,818 (97,368) (162%)
199-N-228	Shallow/Ringold	348,163 (91,915) (153%)
199-N-229	Deep/Hanford	567,508 (149,822) (250%)
199-N-230	Shallow/Ringold	90,496 (23,891) (40%)
199-N-231	Deep/Ringold	122,814 (32,423) (54%)

* Target injection volume is 227,000 L (60,000 gal).

Figure 4-21 shows the strontium-90 concentration trends for the upriver PRB wells. Table 4-5 shows the percentage reduction in strontium-90 concentrations each year since 2011. Downgradient aquifer tubes continue to show decreased strontium-90 concentrations (Figure 4-22; Table 4-6).

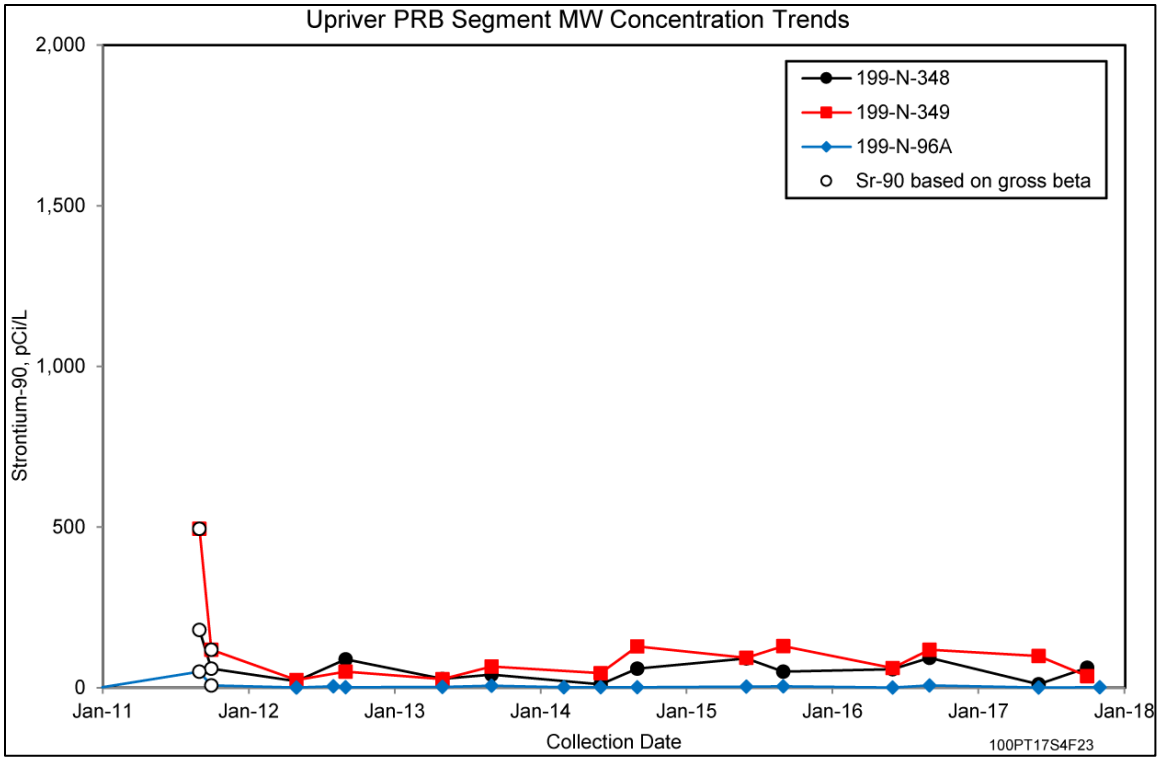


Figure 4-21. Strontium-90 Data for Performance Monitoring Wells Along the Upriver Segment of the Apatite PRB

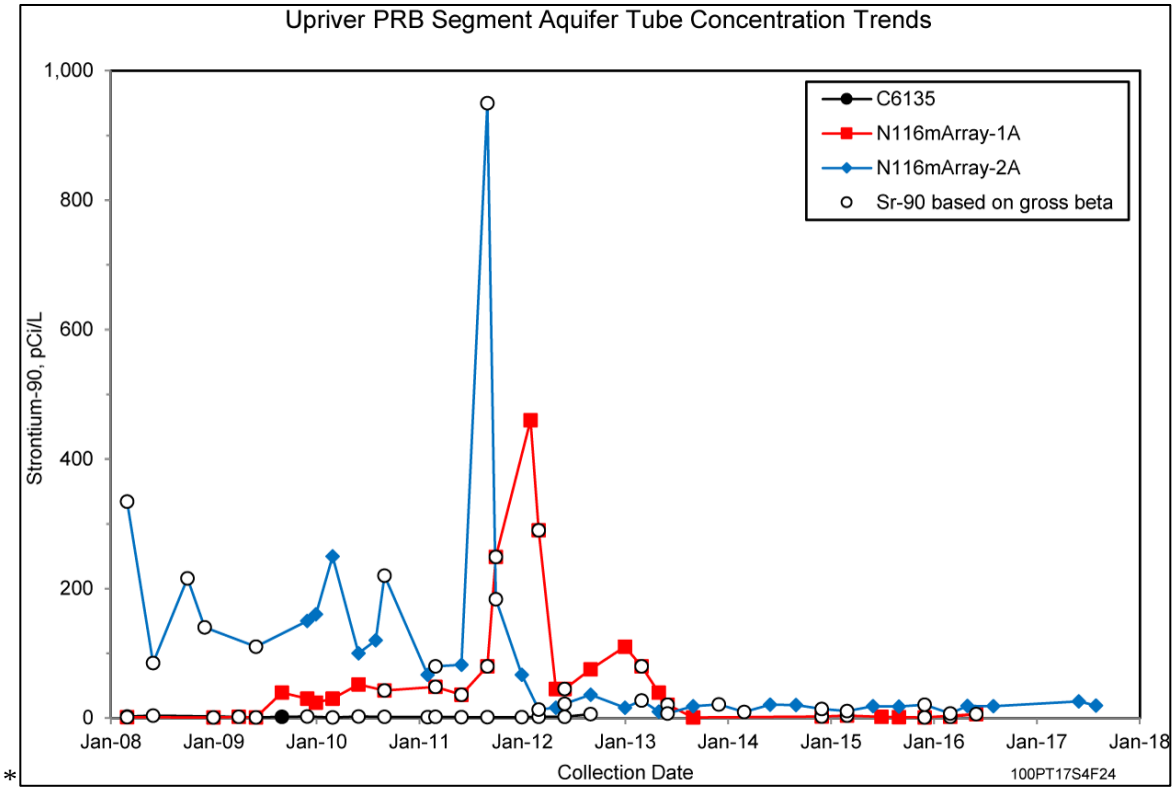


Figure 4-22. Strontium-90 Data for Aquifer Tubes Along the Upriver Segment of the Apatite PRB

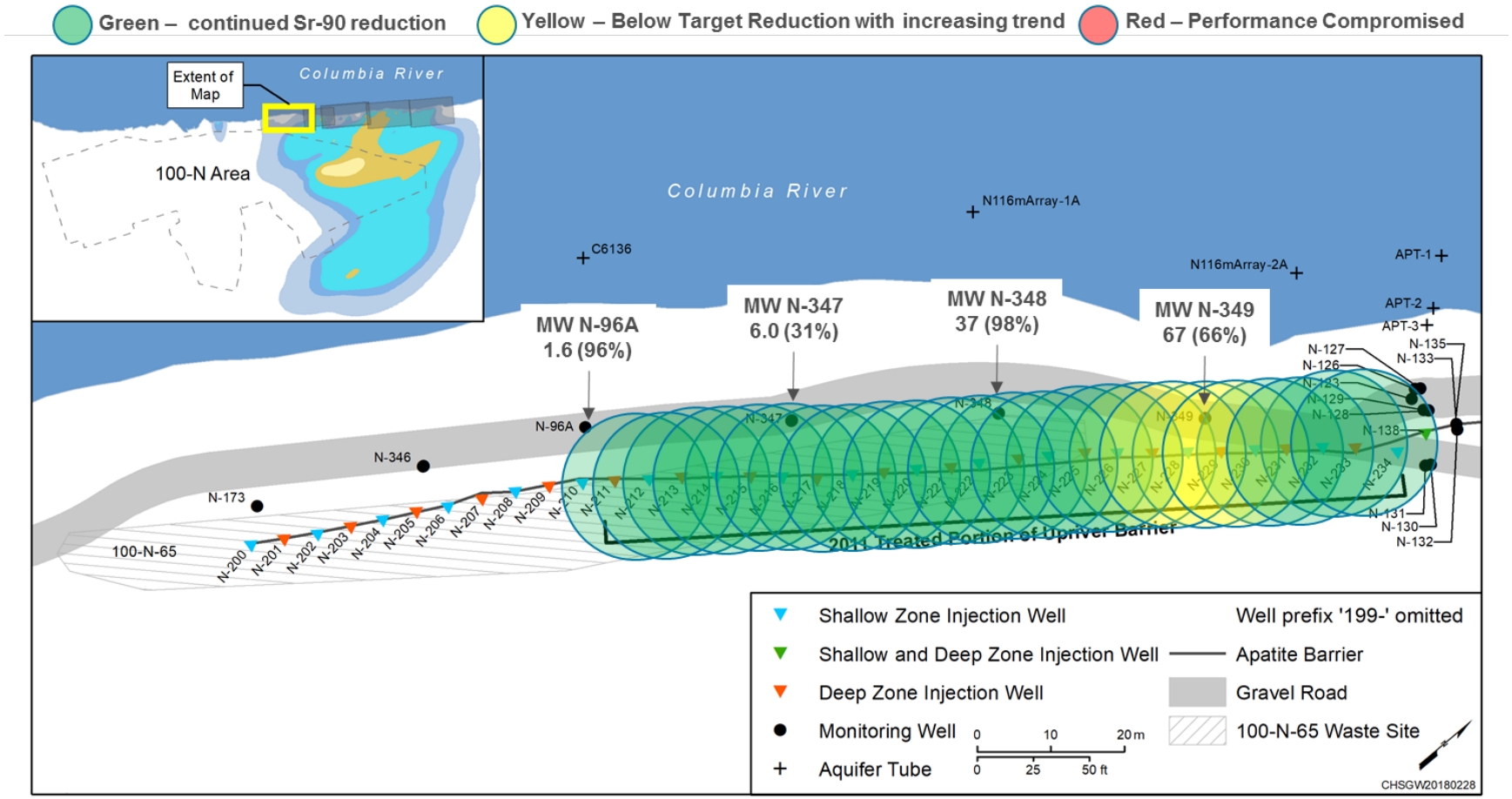
Strontium-90 concentrations are below the DWS at monitoring well 199-N-347, and the target strontium-90 reduction is being met at the remaining two monitoring wells. The assessment indicates that the portion of the upriver PRB segment near monitoring well 199-N-349 is below target reduction with an increasing trend (i.e., colored yellow in Figure 4-23) and should continue to be monitored to determine if this area should be reinjected. The remaining length of the upriver PRB segment continues to provide strontium-90 reduction.

4.4.1.3 Downriver Permeable Reactive Barrier Segment Performance

The downriver extension intercepts higher strontium-90 groundwater concentrations than the upriver extension and indicated initial successful barrier performance. The percentage reduction in strontium-90 concentrations in 2017 at performance monitoring wells along the downriver barrier extension ranged from no reduction (wells 199-N-351 and 199-N-352) to 71% (well 199-N-350) (Table 4-2; Figure 4-24) in the fall, and 66% (well 199-N-350) to 94% (well 199-N-353) in the spring. The data indicates that PRB performance in this segment of the PRB has declined since 2014, as shown generally by increasing concentration over time (Table 4-5; Figure 4-24.).

Strontium-90 concentration trends for the downriver PRB segment monitoring wells (Figure 4-25) show that strontium-90 concentrations at wells 199-N-351 and 199-N-352 increased to pre-injection concentrations in 2016 and 2017. Concentrations at well 199-N-350 were increasing but stabilized in 2017. Table 4-5 shows the percentage reduction in strontium-90 concentrations since 2012 for the downriver PRB segment monitoring wells. Decreased performance along the PRB and increasing strontium-90 concentration may be associated with injection volumes. Table 4-8 provides the injection volume of apatite chemicals into the injection wells near the monitoring wells. Several wells received less than 30% of the target injection volume. Other injection wells received target injection volumes of more than 50% above the target injection volumes. The injection flow rate was not controlled for even flow distribution in all injection wells (SGW-56970), which contributed to the large contrast in injection volumes. This likely resulted in limited radial amendment distribution in these areas of the downriver PRB segment. Downgradient aquifer tubes for the downriver PRB segment continue to show significant strontium-90 reduction (Table 4-6; Figure 4-26).

The assessment indicates that the injection wells treating the portion of the downriver PRB segment monitored by wells 199-N-351 and 199-N-352 and injection wells that received less than 30% of the target amendment volume should be considered for reinjection (colored red in Figure 4-27). Ongoing monitoring will determine PRB effectiveness at well 199-N-353. This well shows substantial fluctuation (94% and 33% reduction) between spring and fall measurements (Table 4-2). Portions of the downriver PRB near wells 199-N-350 and 199-N-353 should continue to be monitored to evaluate if these areas should be reinjected.



Note: Text boxes in figure show the 2017 yearly average strontium-90 concentrations and percent reduction (in parenthesis) from baseline concentration for permeable reactive barrier monitoring wells.

Figure 4-23. Upriver PRB Segment Performance Assessment, 2017

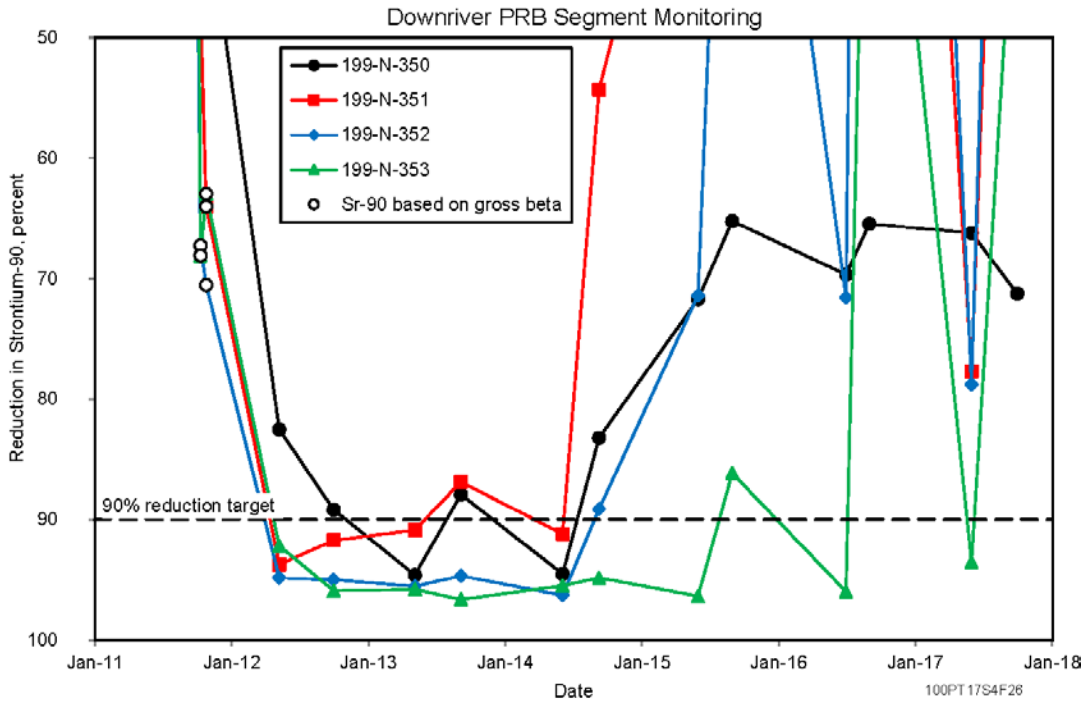


Figure 4-24. Downriver Apatite Barrier Extension Performance Monitoring Wells Percent Strontium-90 Reductions, 2017

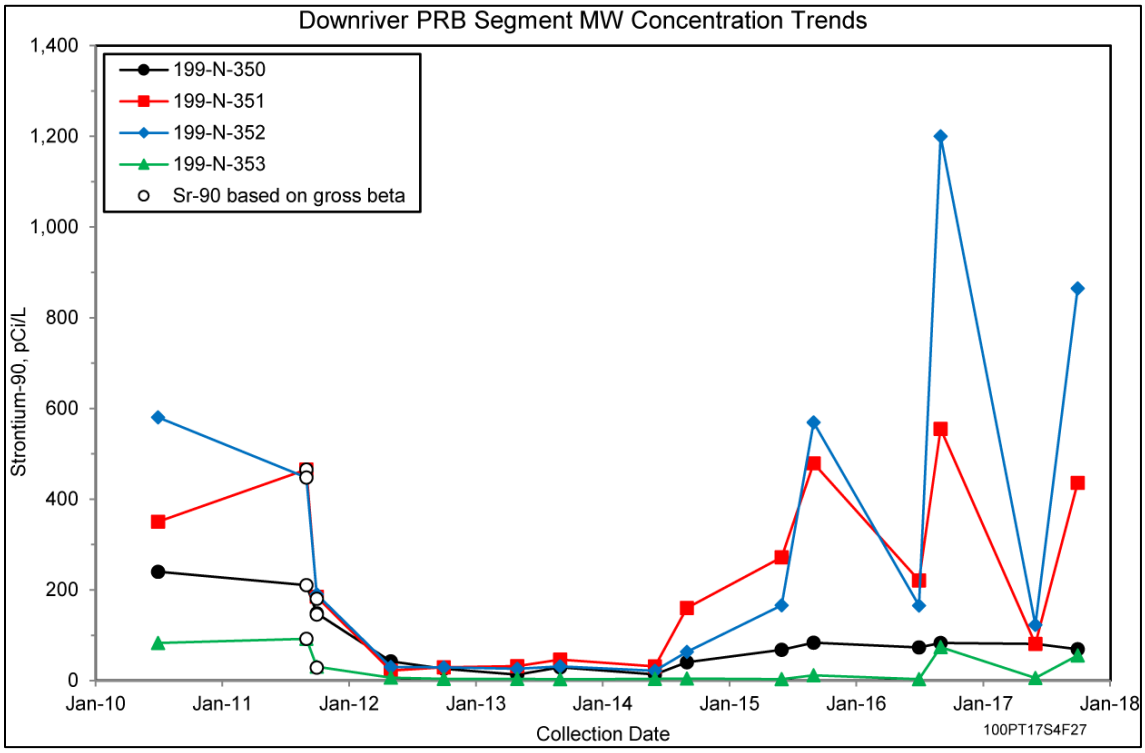


Figure 4-25. Strontium-90 Data for Performance Monitoring Wells Along the Downriver Segment of the Apatite PRB

Table 4-8. Injection Volume in Downriver Injection Wells near Wells 199-N-350, 199-N-351, and 199-N-352

Injection Well	Screen/Formation	Injected Volume (L [gal]) (Percent of Target Volume*)
199-N-237	Shallow/Ringold	79,739 (21,051) (35%)
199-N-238	Deep/Ringold	351,576 (92,816) (155%)
199-N-239	Shallow/Ringold	5,678 (1,499) (2%)
199-N-240	Deep/Ringold	85,648 (22,611) (38%)
199-N-241	Shallow/Ringold	112,553 (29,714) (50%)
199-N-242	Deep/Ringold	51,803 (13,676) (23%)
199-N-243	Shallow/Ringold	87,920 (23,211) (39%)
199-N-244	Deep/Ringold	58,610 (15,473) (26%)
199-N-245	Shallow/Ringold	247,591 (65,364) (109%)
199-N-246	Deep/Ringold	265,019 (69,965) (117%)
199-N-247	Shallow/Ringold	23,348 (6,164) (10%)
199-N-248	Deep/Ringold	236,216 (62,361) (104%)
199-N-249	Shallow/Ringold	231,879 (61,216) (102%)
199-N-250	Deep/Ringold	256,856 (67,810) (113%)
199-N-251	Shallow/Ringold	437,163 (115,411) (192%)
199-N-252	Deep/Ringold	219,333 (57,904) (97%)

* Target injection volume is 227,000 L (60,000 gal).

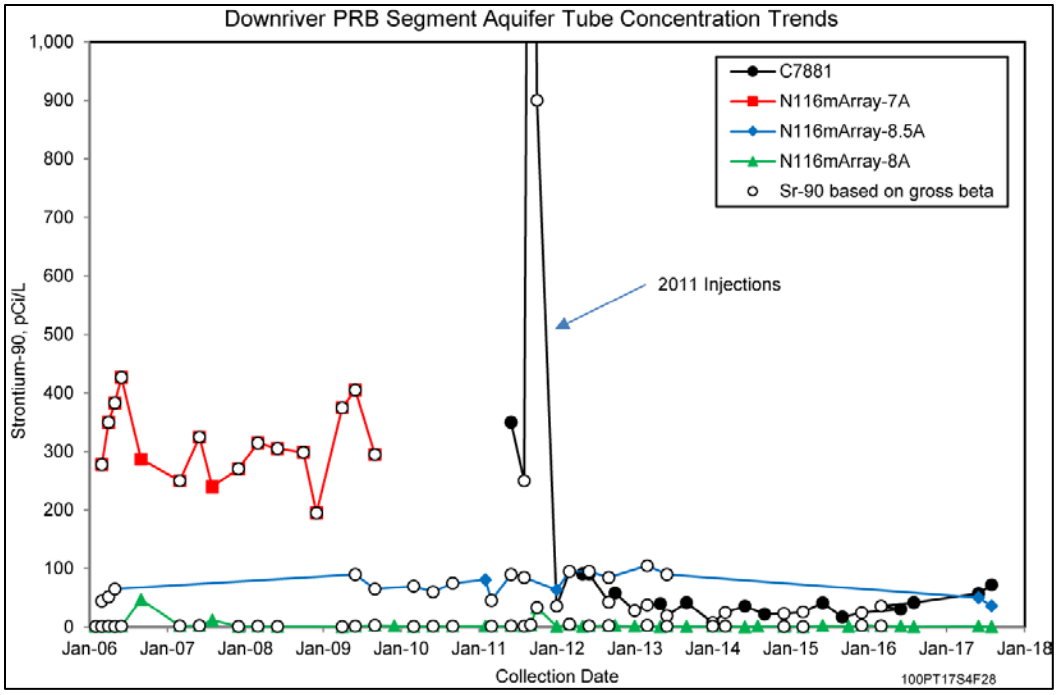
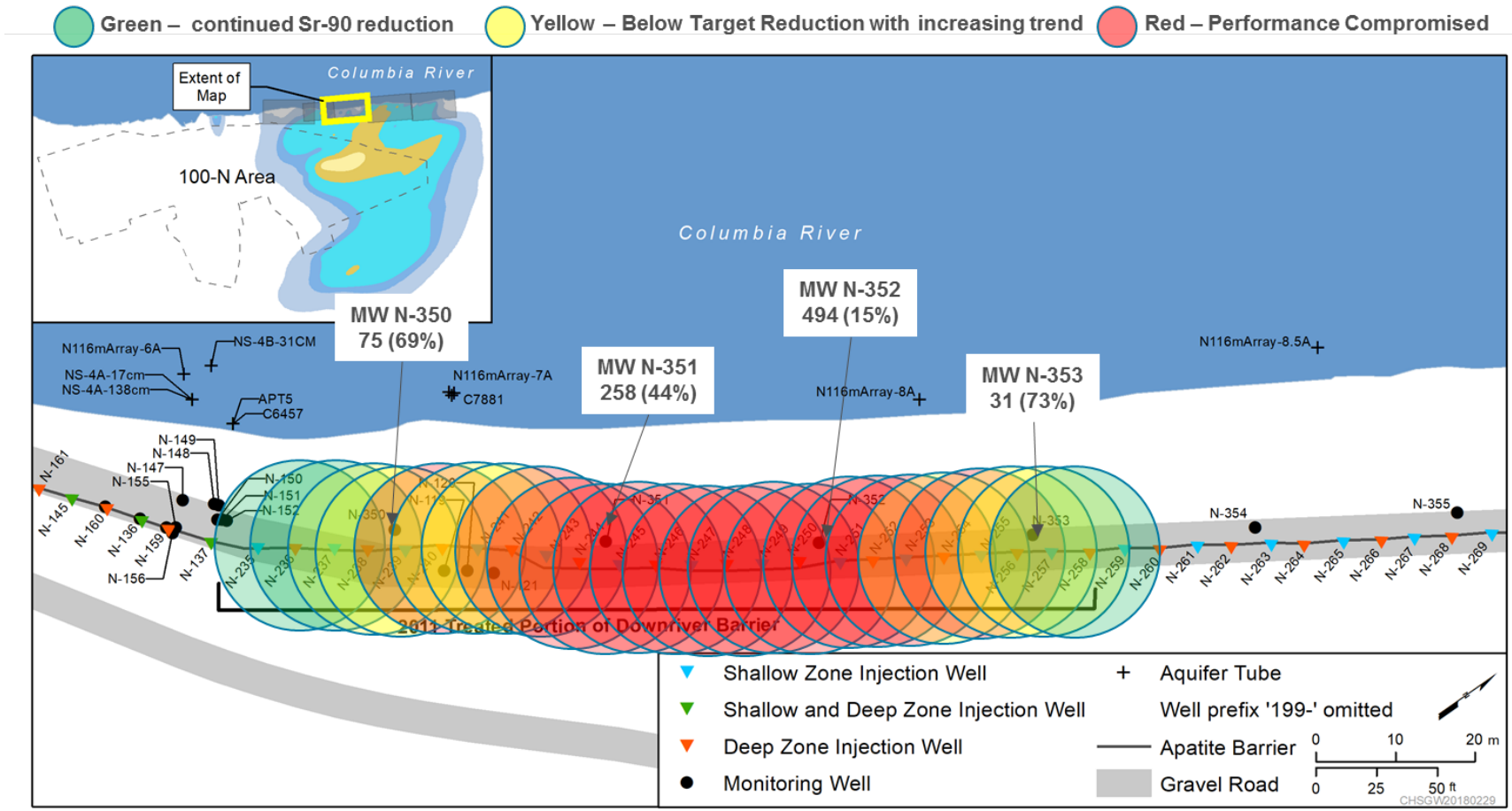


Figure 4-26. Strontium-90 Data for Aquifer Tubes Along the Downriver Segment of the Apatite PRB



Note: Text boxes in figure show the 2017 yearly average strontium-90 concentrations and percent reduction (in parenthesis) from baseline concentration for permeable reactive barrier monitoring wells.

Figure 4-27. Downriver PRB Segment Performance Assessment, 2017

4.4.1.4 Summary of Permeable Reactive Barrier Performance Evaluation

Table 4-9 summarizes the qualitative PRB performance evaluation for each treated PRB segment. The PRB performance evaluation for 2017 is summarized as follows:

- **Total length of treated PRB:** 311 m (1,020 ft)
- **Green:** Continued strontium-90 reduction; 156 m (510 ft)
- **Yellow:** Below target reduction with increasing trend; 105 m (345 ft)
- **Red:** Performance compromised; 50 m (165 ft)

4.4.2 Permeable Reactive Barrier Extensions

Additional treatment to expand the PRB did not occur in 2017. Work to complete the barrier is dependent upon completion of the *National Historic Preservation Act of 1966*, Section 106 reviews and is subject to schedule delays pending the establishment of a memorandum of agreement for the project activities that are deemed to have an adverse effect on the traditional cultural property encompassing PRB area. Efforts to establish a memorandum of agreement for expansion of the PRB were initiated in 2015 and will continue during 2018.

4.5 Total Petroleum Hydrocarbon–Diesel Remediation

The primary source of petroleum hydrocarbon contamination to groundwater was a 1966 diesel fuel spill releases (UPR-100-N-17) near the former 1715-N storage tanks and 166-N transfer areas (166-N Tank Farm). Residual petroleum hydrocarbons in the vadose zone remains a source to groundwater contamination. Remediation continued in 2017 for the residual petroleum hydrocarbon contamination in the vadose zone and groundwater in the 100-N Area.

4.5.1 Vadose Zone

DOE is using in situ bioventing to remediate TPH-D contamination identified in the deep vadose zone beneath UPR-100-N-17 in the 100-N Area. Oxygen is introduced into the deep vadose zone to promote microbial activity and enhance hydrocarbon degradation. The oxygen stimulates natural, in situ aerobic biodegradation of the TPH-D in the deep vadose zone to carbon dioxide and water.

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, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*). Groundwater monitoring samples from the eight performance monitoring wells and three aquifer tubes (N116mArray-0A, C6132, and C6135) were collected in July and November 2017.

Semiannual performance monitoring (high and low river-stages) was conducted for the bioventing system in 2017. Ongoing monitoring will determine the continued effectiveness of the bioventing remediation for the TPH-D plume. Table 4-10 provides the TPH-D groundwater concentrations for the eight performance monitoring wells (Figure 4-12). The performance of the full-scale bioventing system during 2016 is provided in DOE/RL-2016-34, *Annual Operations and Monitoring Report for UPR-100-N-17: March 2015 – February 2016*; and DOE/RL-2017-29, *Annual Operations and Monitoring Report for UPR-100-N-17 March 2016 – February 2017*.

Table 4-9. PRB Performance Evaluation Summary

Assessed Treated PRB Length		Treated PRB			Upriver Segment			Original Segment			Downriver Segment		
		2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
Total length of Treated PRB	m	311	311	311	110	110	110	91	91	91	110	110	110
	ft	1,020	1,020	1,020	360	360	360	300	300	300	360	360	360
Length identified as "Green – continued Sr-90 reduction"	m	169	169	156	87	87	87	91	68	55	28	14	14
	ft	555	555	510	285	285	285	300	225	180	90	45	45
	% green	54	54	50	79	79	79	100	75	60	25	13	13
Length identified as "Yellow – Below Target Reduction with increasing trend"	m	92	92	105	23	23	23	0	23	36	32	46	46
	ft	300	300	345	75	75	75	0	75	120	105	150	150
	% yellow	30	30	34	21	21	21	0	25	40	29	41	41
Length identified as "Red – Performance Compromised"	m	50	50	50	0	0	0	0	0	0	50	50	50
	ft	165	165	165	0	0	0	0	0	0	165	165	165
	% red	16	16	16	0	0	0	0	0	0	46	46	46

PRB = permeable reactive barrier

Table 4-10. TPH-D Concentrations (C10-C20) (in µg/L) for Bioventing Performance Monitoring Wells and Aquifer Tubes

Date	Bioventing Air Injection Wells		Bioventing Monitoring Wells								Upgradient Well	Aquifer Tubes		
	199-N-167	199-N-172	199-N-3	199-N-19	199-N-96A	199-N-169	199-N-171	199-N-173	199-N-183	199-N-377[a]	199-N-56	C6132	N116mArray-0A	C6135
July 2017	7,730 (DT)	7,550 (DT)	47.2 (U)	67.1 (JT)	77.2 (JT)	10,000 (DT)	7,280 (DT)	1,690 (T)	1,980 (T)	1,400 (B)	50.0 (TU)	50.0 (TU)	—[b]	140 (J)
November 2017	13,000 (B)	28,600[c] (D)	48.1 (TU)	97.6 (JT)	1,800[d] (B)	7,300[d] (B)	5,900 (D)	11,000[d] (B)	7,300[d] (B)	48.0 (U)	71.5 (JB)	102 (J)	1,010	4,430 (D)

a. New well installed in August 2016.

b. Unable to sample N116mArray-0A in July because aquifer tube needed repairs.

c. Unable to sample in November with other wells because of low water level in the well. Sampled on January 8, 2018, when water level increased.

d. Results were flagged as "B" to indicate that TPH-D was also detected in the associated quality control blank. Values are high and out of trend, but most of the bioremediation monitoring wells had higher values due to higher-than-normal water levels in the summer.

TPH-D = total petroleum hydrocarbons-diesel

Data flags:

B = analyte was detected in both the associated quality control blank and in the sample

D = analyte was identified in an analysis at a secondary dilution factor

J = estimated

T = spike and/or spike duplicate sample recovery is outside control limits

U = analyzed for but not detected above reporting limit

4.5.2 Groundwater

Groundwater containing the TPH-D plume (also associated with the UPR-100-N-17 release) is being remediated to remove remaining petroleum free product. The interim action ROD (EPA/ROD/R10-99/112) specifies that petroleum hydrocarbons (free-floating product) will be removed if observed in a monitoring well. The 100-N RI/FS currently being prepared for the 100-N Area includes an evaluation for remedial alternatives to remediate groundwater petroleum hydrocarbon contamination.

If present as light nonaqueous-phase liquid (or free product), TPH-D 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 2017 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 placed into well 199-N-18 and are left to absorb and remediate 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 2017, smart sponge assemblies were also used in well 199-N-183, which was drilled near 199-N-18 as a replacement monitoring well. Diesel odor and an oil sheen have periodically been observed in the new well during sampling. The smart sponges were used and changed out at the same frequency as used for well 199-N-18. In 2017, a total of 900 g of diesel was removed from well 199-N-18 and 600 g of diesel were removed from well 199-N-183 (Table 4-11). Diesel removal from wells 199-N-18 and 199-N-183 will continue in 2018.

Table 4-12 provides the TPH-D concentrations in the known area of the diesel plume for TPH-D monitoring wells identified in the 100-NR-2 SAP (Appendix A of DOE/RL-2001-27, Rev. 2) (Figure 4-12). Table 4-13 provides the TPH-D concentrations for the adjacent upriver apatite barrier extension injection and performance monitoring wells.

Table 4-11. Petroleum Hydrocarbon Removal from Wells 199-N-18 and 199-N-183

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.
2015	1,050	Changed in January (twice), April, June, July, September, and December (twice) 2015.
2016	950	Changed in June, July, October, and December 2016.
2017	1,500	Sponges were changed out in well 199-N-18 in February, April, July, September, and November, removing a total of 900 g of product in 2017. Installed sponges in well 199-N-183 beginning February 2017 and were changed out in April, July, September, and November, removing a total of 600 g of product in 2017.
Total		**16,544.5 g (approximately 17 kg) removed through the end of 2017**

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 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 4-12. TPH Monitoring Wells Maximum TPH-D Concentrations

Date	199-N-3	199-N-16/ 199-N-373	199-N-18	199-N-183	199-N-56	199-N-96A	199-N-173	199-N-169	199-N-171	199-N-346	199-N-377[e]
1992	NR	200 (U)	NR	N/A	1,000 (U)	NR	NR	N/A	N/A	N/A	N/A
1993	1,000 (U)	67 (J)	NR	N/A	NR	NR	NR	N/A	N/A	N/A	N/A
1994	1,000	4,000	NR	N/A	NR	NR	NR	N/A	N/A	N/A	N/A
1995 to 1998	NR	NR	NR	N/A	NR	NR	NR	N/A	N/A	N/A	N/A
1999	NR	NR	16,000 (D)	N/A	NR	NR	NR	N/A	N/A	N/A	N/A
2000	92 (U)	NR	23,000 (D,N)	N/A	NR	NR	NR	N/A	N/A	N/A	N/A
2001	92 (U)	NR	6,800,000 (D,N)	N/A	NR	50 (U)	NR	N/A	N/A	N/A	N/A
2002	50 (U)	NR	440,000 (D,N)	N/A	NR	1,500	NR	N/A	N/A	N/A	N/A
2003	50 (U)	6,500 (N)	630,000,000 (D)	N/A	NR	900	NR	N/A	N/A	N/A	N/A
2004	50 (U)	6,100 (N)	340,000 (D,N)	N/A	60 (U)	750 (N)	NR	N/A	N/A	N/A	N/A
2005	50 (U)	11,000 (N)	69,000 (D,N)	N/A	50 (U)	610	NR	N/A	N/A	N/A	N/A

Table 4-12. TPH Monitoring Wells Maximum TPH-D Concentrations

Date	199-N-3	199-N-16/ 199-N-373	199-N-18	199-N-183	199-N-56	199-N-96A	199-N-173	199-N-169	199-N-171	199-N-346	199-N-377[e]
2006	50 (U)	50 (U)	23,000 (D)	N/A	50 (U)	50 (U)	NR	N/A	N/A	N/A	N/A
2007	50 (U)	33 (U,D,N)	190,000	N/A	50 (U)	50 (U)	NR	N/A	N/A	N/A	N/A
2008	33 (U)	NR	809,000 (D)	N/A	NR	71 (U)	NR	N/A	N/A	N/A	N/A
2009	17 (U)	70 (U)	67,000 (D)	N/A	70 (U)	260	2,100	N/A	N/A	N/A	N/A
2010	70 (U)	79 (J)	420,000 (D)	N/A	70 (U)	200	2,100	1,100 (N)	2,800 (N)	3,700	N/A
2011	70 (U)	70 (U)	48,000 (H)	N/A	70 (U)	70 (U)	70 (U)	760	70 (U,N)	NR	N/A
2012	70 (U)	70 (U)	Not sampled[a]	2,100	70 (U)	140	1,900	1,150	4,620	NR	N/A
2013[b]	70 (U)	—[c]	Not sampled[a]	3,350	70 (U)	70 (U)	410	1,370	9,450 (D)	NR	N/A
2014	51 (U)	—[c]	Not sampled[a]	2,600 (T)	112 (J,T)	446 (T)	4,700 (T)	1,920	4,680 (D)	18,000 (D)	N/A
2015	48 (U)	—[c]	Not sampled[a]	2,180 (T)	233 (T)	161 (J,T)	1,280 (T)	576	4,360 (D,T)	6,400 (D)	N/A
2016	47.6 (U)	—[c]	17,200 (DT)	3300	48.1 (U)	420 (J)	3600	1,190 (T)	11,900 (D)	3,800 (N)	N/A

Table 4-12. TPH Monitoring Wells Maximum TPH-D Concentrations

Date	199-N-3	199-N-16/ 199-N-373	199-N-18	199-N-183	199-N-56	199-N-96A	199-N-173	199-N-169	199-N-171	199-N-346	199-N-377[e]
2017	48.1 (U)	289[d]	16,600 (D)	7,300 (B)	73 (JB)	1,800 (B)	11,000 (B)	10,000 (DT)	7,280 (DT)	5,300 (D)	1,500 (B)

Note: Highest detected result or lowest nondetectable result for a calendar year are reported in this table.

a. Well 199-N-18 was replaced by well 199-N-183 for groundwater sampling

b. 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.

c. Well 199-N-16 decommissioned on December 18, 2012.

d. Well 199-N-373 installed August 2016 as replacement for well 199-N-16.

e. Well 199-N-377 installed August 2016.

N/A = not applicable

NR = not reported

Data flags:

B = analyte was detected in both the associated quality control blank and in the sample

D = sample was diluted for analysis

H = laboratory holding time exceeded before sample was analyzed

J = concentration is estimated

N = spike sample outside limits

T = spike and/or spike duplicate sample recovery is outside control limits

U = undetected

Table 4-13. TPH-D Concentrations 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	—	3,200	—	3,000	—	2,700	—	1,400	—
6/4/2014	856	2,800	—	—	—	—	—	—	—	—
6/7/2015	—	17 (U)	—	—	—	—	—	—	—	—
9/15/2015	—	15 (U)	—	—	—	—	—	—	—	—
6/13/2017	570	—	—	—	—	—	—	—	—	—
9/26/2017	—	600	—	—	—	—	—	—	—	—
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)	—	—	—	—	—	—	—	—	—
7/29/2015	—	590)	—	—	—	—	—	—	—	—
9/15/2015	—	827	—	—	—	—	—	—	—	—
6/13/2017	50 (U)	—	—	—	—	—	—	—	—	—
9/26/2017	—	166 (J)	—	—	—	—	—	—	—	—
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)	—	—	—	—	—	—

Table 4-13. TPH-D Concentrations for Upriver Apatite Barrier Injection and Monitoring Wells

6/25/2010	90 (U)	—	100 (U)	—	70 (U)	—	70 (U)	—	70 (U)	—
7/29/2015	—	—	—	—	—	—	—	—	—	16 (U)
9/18/2015	—	—	—	—	—	—	—	—	—	17 (U)
6/22/2017	—	—	—	—	—	—	—	—	—	47.6 (U)
9/26/2017	—	—	—	—	—	—	—	—	—	48 (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)	—	—	—	
1/18/2011	—	—	—	—	—	70 (U)	—	—	—	
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)	

Table 4-13. TPH-D Concentrations for Upriver Apatite Barrier Injection and Monitoring Wells

1/20/2015	—	—	—	—	—	52.1 (U)	—	—	—	
6/7/2015	—	—	—	—	—	18 (U)	50 (T,U)	17 (U)	48.1 (T,U)	
7/29/2015	—	—	—	—	—	161 (J,T)	—	—	—	
Date	**N-230**	**N-231**	**N-232**	**N-233**	**N-234**	**N-96A**	**N-347**	**N-348**	**N-349**	
9/22-28/2015	—	—	—	—	—	17 (U)	89.1 (J)	16 (U)	47.6 (U)	
6/23-30/2016	—	—	—	—	—	—	48.1 (U)	16 (U)	50 (U)	
2/17/2017	—	—	—	—	—	260	—	—	—	
7/27/2016	—	—	—	—	—	17 (U)	—	—	—	
9/16-23/2016	—	—	—	—	—	62.6 (JT)	47.6 (U)	16 (UN)	47.6 (TU)	
12/27/2016	—	—	—	—	—	420 (J)	—	—	—	
6/13-28/2017	—	—	—	—	—	47.2 (U)	50 (TU)	51 (U)	50 (U)	
11-Jul-17	—	—	—	—	—	48 (U)	—	—	—	
01-Oct-17	—	—	—	—	—	77.2 (JT)	50 (TU)	47 (U)	47.6 (TU)	
08-Nov-17	—	—	—	—	—	1800 (B)	—	—	—	

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).

— = entry indicate well was not sampled for TPH-D on the identified date

TPH-D = total petroleum hydrocarbons-diesel

Data flags:

B = analyte was detected in both the associated quality control blank and in the sample

J = estimated value

N = spike sample outside limits

T = spike and/or spike duplicate sample recovery is outside control limits

U = undetected

4.6 Demolition of the 100-NR-2 Pump-and-Treat System

The interim action ROD (EPA, 2010) and DOE/RL-2001-27 required the decommissioning, demolition, and removal of the 100-NR-2 P&T system. These documents required removing the residual resin and disposing the material at ERDF, dismantling all noncontact treatment system hardware and salvaging reusable components, and cutting the high-density polyethylene conveyance piping into short lengths for transportation and disposal at ERDF. Continued use and reconfiguration of the existing wells for monitoring purposes was also a part of the decommissioning plan.

The 100-NR-2 P&T system was demolished, excavated, and removed from August through November 2016. Surface and subsurface features associated with the system, including permanent and temporary structures, concrete slab, vaults and culverts beneath roads and three 100-NR-2 P&T signs, were removed from the site and disposed at ERDF. Approximately 308 m^3 (10,875 ft^3) of concrete, soil, piping, conduit, and miscellaneous debris and equipment weighing a total of 430,913 kg (475 tons) were removed and disposed at ERDF. Excavated areas were backfilled and contoured to match the surrounding terrain. A revegetation and site contouring plan will be prepared to complete environmental restoration.

Demolition and decommissioning was completed in 2017 to remove piping from the former injection wells and demolish the 1323N sample shack (located near the shore of the Columbia River). Extraction wells were converted to support groundwater monitoring prior to the start of demolition and piping was removed from injection wells in January 2017.

4.7 100-NR-2 Apatite Permeable Reactive Barrier System Costs

This section summarizes the burdened costs for 100-NR-2 OU groundwater remediation for 2017. 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. Decontamination and decommissioning (D&D) of the 100-NR-2 P&T system are included in this category.
- **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 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 2017 cost breakdown for the 100 NR-2 groundwater remediation systems is presented in Table 4-14 and Figure 4-28. The total 2017 remedial action costs were $1,299,000. Costs for D&D of the 100-NR-2 P&T facility accounted for 15% of the total 2017 costs, and the remaining 2017 costs were for performance monitoring (74%), project support (9%), and barrier maintenance (2%).

Table 4-14. Breakdown of 100-NR-2 Remediation System Construction and Operation Costs

Description	Actual Costs (Dollars × 1,000)											
	1995 – 2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014[c]**	**2015**	**2016**	**2017**
Design	3,872	—	—	20.5	31.0	—	0.6	0.0	0.0	0.0	0.0	0.0
Treatment system capital construction	9,303	—	—	316.2	(0.1)	(32.1)	0.0	0.0	0.0	0.0	796.4[d]	189.0[d]
Project support	2,031	79.8	10.7	278.5	276.5	178.9	133.3	284.2	173.9	170.8	68.1	113.7
Operations and maintenance	9,104	199.9	107.4	50.2	23.6	30.4	0.4	0.0	0.0	0.0	0.0	0.0
Performance monitoring	960	62.7	36.2	466.2	956.3	1,069.0	1,801.1	769.3	1,077.1	967.7	624.1	966.1
Waste management	438	43.4	8.9	3.6	0.5	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Field studies	—	—	—	874.1	1,228.3	119.5	(2.2)	68.0	0.0	0.0	0.0	0.0
Barrier maintenance	—	—	—	634.3	1,468.0	1,844.4	15.9	46.4	1,079.8	0.0	0.0	30.1
Totals	**$25,708**	**$386**	**$163**	**$2,644**	**$3,984**	**$3,212**	**$1,949**	**$1,168**	**$2,331**	**$1,139**	**$1,489**	**$1,299**

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

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

c. Barrier maintenance costs for 2014 were associated with preparation and procurement of chemicals for injections to extend the barrier but an adverse impact determination to a traditional cultural property has put further injections on hold until a memorandum of agreement is established for expansion of the permeable reactive barrier.

d. Treatment system capital construction costs for 2016 and 2017 are associated with decontamination and decommissioning of the 100-NR-2 pump-and-treat facility.

— = not available

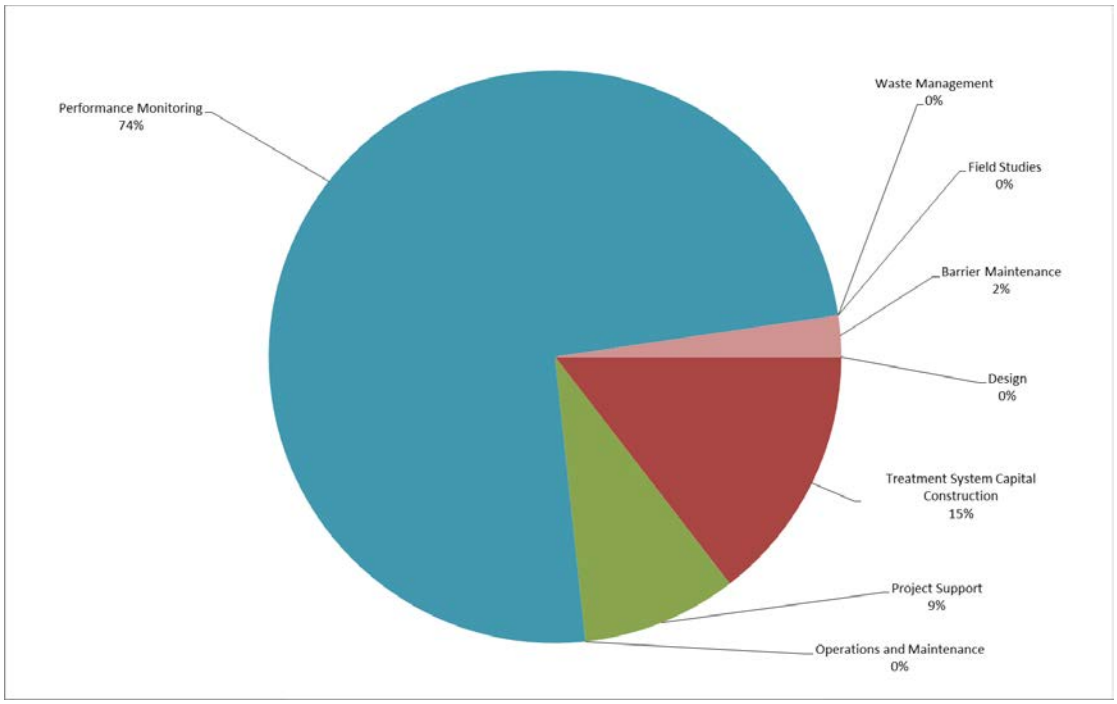


Figure 4-28. 100-NR-2 Remediation Cost Breakdown (by Percentage), 2017

4.8 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. Apatite solutions were injected in wells of the central (original) barrier segment from 2006 to 2008 and wells in 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. Concentrations in the majority of the monitoring wells during 2017 were lower than pre-injection levels. The concentrations in most of the monitoring wells in 2017 had declined from pre-injection levels by 66% to 98%. However, in 2015, concentrations of strontium-90 increased in some of the monitoring wells and remained elevated during 2017, with concentrations in two monitoring wells at pre-injection levels. DOE plans to reinject apatite into poor-performing sections of the PRB and expand the PRB in the future.

  The TPH-D 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 to 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 P&T facility was demolished and removed in 2016. The only components of the P&T system remaining are the former extraction wells and

injection wells. Piping was removed from injection wells in January 2017, and the 1323N sample shack near the shoreline was demolished and removed.

The apatite PRB was installed along the section of the 100-N Area shoreline with the highest historical groundwater contamination. The injection design provides emplacement of sufficient apatite in the PRB to sequester the strontium-90 flux to the river for the duration needed for the upland strontium-90 groundwater contamination to naturally decay.

Smart sponges deployed in wells 199-N-18 and 199-N-183 removed a total of 1,500 g of TPH-D free product in 2017.

A full-scale bioventing system for remediation of TPH-D in the deep vadose zone near waste site UPR-100-N-17 was implemented in December 2012 and continued to operate in 2017.

- **RAO #3:** Obtain information to evaluate technologies for strontium-90 removal and evaluate ecological receptor impacts from contaminated groundwater.

  Results: A 311 m (1,020 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 in the 100-K Area. No additional work on these technologies occurred in 2017.

  Technologies for remediation of strontium-90 are being evaluated in the RI/FS report for the 100-NR-1 and 100-NR-2 OUs. DOE submitted DOE/RL-2012-15, Draft A to Ecology (the lead regulatory agency for the 100-NR-1 and 100-NR-2 OUs) for review in June 2013. The comment resolution process continued through 2017 for the draft RI/FS. The comment resolution process for Draft A of the RI/FS report determined that a Draft B RI/FS would be prepared. The Draft B RI/FS report is planned for issuance in 2019 for regulatory agency review. The RI/FS report will be used to support future cleanup decisions specified in a proposed plan and ROD.

- **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) established ICs that must be implemented and maintained throughout the interim action period. These provisions include the following:

- Access control and visitor escorting requirements
- Maintain signs prohibiting public access (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

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