7.0 100-HR-3 Operable Unit

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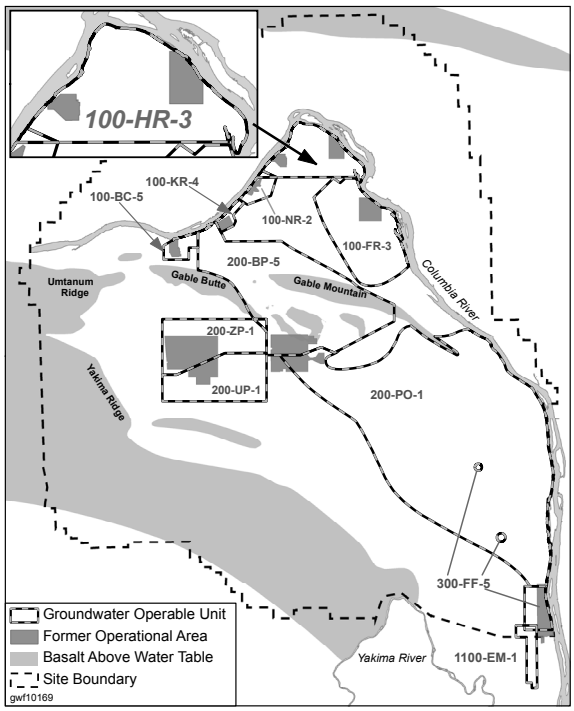
This chapter describes the hydrogeology and contaminant distribution within the 100-HR-3 Operable Unit (OU), which includes groundwater underlying the 100-D Area, 100-H Area, and the region between known as the horn area. Figures 7-1, 7-2, and 7-3 show the facilities, wells, and shoreline monitoring sites in the 100-D Area, 100-H Area, and horn area, respectively.



Groundwater underlying the 100-D and 100-H Area is monitored to meet the requirements of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA); the *Atomic Energy Act of 1954*; and the *Resource Conservation and Recovery Act of 1976* (RCRA) at the 116-H-6 (183-H) solar evaporation basins (a RCRA unit). No RCRA sites are located in the 100-D Area, and no active waste disposal facilities are located in either the 100-D or the 100-H Areas.

In calendar year (CY) 2010, three CERCLA interim action remedies operated in the 100-HR-3 OU. These included the original HR-3 pump-and-treat system in the 100-H Area, which treats groundwater from both the 100-D and 100-H Areas; the DR-5 pump-and-treat system in the 100-D Area; and the In Situ Redox Manipulation (ISRM) barrier, also in the 100-D Area. The new DX pump-and-treat system entered acceptance testing in the fourth quarter of the CY and became operational in 2011.

A summary of 100-HR-3 OU operations for CY 2010 is provided below:

- Hexavalent chromium is the principal contaminant of concern (COC) in groundwater. New wells have helped to define the core of the hexavalent chromium plume, with concentrations over 69,000 µg/L in some groundwater samples collected in the south 100-D Area plume.
- The DR-5 and HR-3 pump-and-treat systems continued to operate at normal capacity of ~132 liters per minute and ~757 liters per minute, respectively. The two pump-and-treat systems removed a combined 106 kilograms of hexavalent chromium from the 100-HR-3 OU in CY 2010; however, concentrations in groundwater remained above the remedial action goal of 20 µg/L.
- Expanded pump-and-treat systems are being implemented in both the 100-D (DX system) and 100-H (HX system) Areas to meet remedial action objectives. During CY 2010, the DX pump-and-treat facility was completed and operations began at the end of the reporting period. In December 2010, the DX system treated an additional 55.3 million liters of groundwater, with 18.4 kilograms of hexavalent chromium removed. The DR-5 system is being shutdown in CY 2011 for realignment of its wells to the DX pump-and-treat system. The HR-3 system also will be shut down in CY 2011 for realignment of its wells to the HX pump-and-treat system.
- The size of the 100-H Area hexavalent chromium plume has been significantly reduced since the start of pump-and-treat operations in 1997. However, because the HR-3 system has been realigned to treat water further north, contaminated groundwater has flowed into the southern portion of the area that is being targeted

by planned HX system extraction in that area. A relatively smaller and lower concentration hexavalent chromium plume remains adjacent to the Columbia River, particularly to the north of the remediated zone, as well as in the vicinity of well 199-H4-11. In contrast, the size of the 100-D Area hexavalent chromium plume has not been affected significantly by pump-and-treat operations. The new DX and HX pump-and-treat systems will help facilitate remediation efforts by expanding the capture zone in the 100-D and 100-H Areas, and, for the first time, in the horn area.

- The ISRM barrier continued to convert hexavalent chromium to a non-toxic, immobile form (trivalent chromium) within a portion of the aquifer. Concentrations in some downgradient wells remained above the remedial action goal of 20 μg/L due to breakthrough along the northeast segment where the barrier is not working effectively. Therefore, new DX extraction wells were installed downgradient of the barrier to treat this area.
- In CY 2010, the remedial investigation (RI)/feasibility study (FS) field work was initiated, with a planned completion date of April 2011. At the end of CY 2010, progress was underway and more than 50% of the work was completed. The results will be provided in Draft A of the RI report in fiscal year (FY) 2012.

In the 100-HR-3 OU, the groundwater system comprises several hydrostratigraphic units. Figure 7-4 shows a hydrogeologic cross section of the 100-D and 100-H Areas. From shallowest to deepest, these units include the following:

- Surface deposits, which consist of recent localized surficial deposits and backfill overlying the Hanford formation beneath the 100-D and 100-H Areas
- Vadose (unsaturated) zone, which are predominantly Hanford formation gravels; the vadose zone is 2 to 30 meters thick beneath the 100-D and 100-H Areas
- Unconfined aquifer, which is predominantly Ringold Formation unit E gravels in the 100-D Area and predominantly Hanford formation underlying the horn area and 100-H Area
- Uppermost aquitard, which includes the Ringold Formation upper mud unit (RUM) (clay and silt)
- Confined and semiconfined, discontinuous, water-bearing lenses and/or aquifers in the Ringold Formation, separated by fine-grained deposits (overbank and paleosol)
- Confined aquitards and aquifers in basalt beneath the Ringold Formation.

Groundwater generally enters the 100-HR-3 OU from the south, with most of the flow moving toward lower elevations of the 100-H Area. A much smaller portion of regional flow moves directly toward the 100-D Area. Underlying the 100-D Area, groundwater generally flows toward the Columbia River. Inland from the Columbia River and beneath the eastern portions of the 100-D Area, groundwater generally flows northeast. Northeast of the 100-D Area, groundwater flows east-northeast across the horn area and toward the 100-H Area. Groundwater below the 100-H Area discharges northeast and east to the Columbia River. Figure 7-5 presents a spring groundwater contour map of the area that was developed using data from CY 2010. This map represents average CY 2010 groundwater flow conditions beneath the 100-HR-3 OU. Groundwater levels are measured across the Hanford Site in March during a time when flows in the Columbia River are close to the annual average rate. While the river stage is very dynamic, this is assumed to represent a nominal average groundwater flow condition.

Groundwater flow in the 100-D and 100-H Areas is significantly influenced by Columbia River stage. The river stage fluctuates regularly in seasonal and shorter cycles (e.g., daily river stage changes) due to a combination of natural and anthropogenic influences. During the latter part of the year when the river stage is relatively low (e.g., September 2010; see Figure 7-6), natural groundwater flow is toward the river; when the river stage is high (e.g., June 2010; see Figure 7-7), groundwater can flow away from or parallel to the river. The high river stage can rise more than 3 meters above the low river stage and can fluctuate several feet over short periods (i.e., hours to days) based on operations at the upstream Priest Rapids Dam. Changing river stage can influence groundwater elevations over one kilometer inland from the river in the 100-HR-3 OU. In addition, because the hydraulic head is lower at the 100-H Area, regional flow from the south tends to move across the horn area toward the 100-H Area.

Other significant influences on groundwater flow are historical leakage from the 182-D reservoir and drawdown or mounding from the groundwater extraction and injection well network. Administrative controls are in place to minimize future leakage from the 182-D reservoir. The zone of uncontaminated groundwater near the 182-D facility suggests long-term contaminant mixing and diversion of contaminated groundwater from the mounding caused by the leaks. In response to the reservoir leakage information, a specific issue was included in *The Second CERCLA Five-Year Review Report for the Hanford Site* (DOE/RL-2006-20) for the U.S. Department of Energy (DOE) to provide direction to its operating contractor to conduct changes to reservoir operation to minimize leakage. Those actions were completed and documented during closeout of the 5-year review issue. These leaks and their impact to groundwater flow have significantly diminished since the reduction of storage volume in the reservoir in 2004.

Groundwater flow is influenced by the stage of the Columbia River.

The primary sources of contamination in the 100-HR-3 OU were the support systems for the three water-cooled nuclear reactors (D, DR, and H Reactors) and the structures and processes associated with the reactors. These operations generated large quantities of liquid and solid waste contaminated with radionuclides, hazardous chemicals, or both. Most contaminant sources can be characterized as high-volume, low-concentration wastes emplaced under high hydraulic head or low-volume, high-concentration wastes emplaced under low hydraulic head. Wastes released to the environment created secondary sources of contamination beneath ponds, ditches, cribs, burial grounds, and unplanned release sites where contaminants may be retained in the subsurface (vadose zone) and released to the aquifer over long periods.

Ongoing characterization and remediation of waste sites in the 100-D and 100-H Areas began in 1996 under the authority provided by the interim action Records of Decision (RODs) and RCRA closure and monitoring plans. Remediation consists mainly of removal and disposal of soil, debris, and waste material and then backfilling the remediated waste site. A portion of the 100-D and 100-H Area waste sites (i.e., trenches, pits, and burial grounds) have already been remediated and dispositioned. The remediation status of each waste site and the data gaps are described in detail in the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 1: 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* (DOE/RL-2008-46-ADD1). The RI/FS characterization workscope identified in this document was initiated in 2010. The data collected for the RI/FS characterization will be published in Draft A of the RI report in FY 2012.

7.1 Groundwater Contaminants

Plume Areas (7.0 square kilometers) in the 100-HR-3 Operable Unit:
Chromium, 100 µg/L — 0.728
Chromium, 20 µg/L — 6.96
Nitrate, 45 mg/L — 0.76
Tritium, 20,000 pCi/L — 0.026

Hexavalent chromium is the principal COC in groundwater in the 100-D and 100-H Areas. The co-contaminants are strontium-90, technetium-99, tritium, uranium, and nitrate. This section describes the distribution and trends of these groundwater contaminants beneath the 100-D and 100-H Areas. The *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE/RL-96-90) and associated Tri-Party Agreement change notice define the sampling protocols implemented for CY 2010. The contaminant monitoring results are presented in the following subsections.

7.1.1 Hexavalent Chromium

The remedial action goal for hexavalent chromium for 100-HR-3 OU groundwater interim actions is 20 µg/L in a near-shore compliance well for both the pump-and-treat systems, and the ISRM barrier system; these systems are given an allowance for a 1:1 attenuation factor to meet the 10 µg/L ambient water quality criteria in the hyporheic zone, as determined by the following:

- EPA/ROD/R10-96/134, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Benton County, Richland, Washington*
- EPA/AMD/R10-00/122, *Interim Remedial Action Record of Decision Amendment for the 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington*
- *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* (EPA et al., 2009b).

Hexavalent chromium is the principal COC in the 100-D Area.

Figures 7-8 and 7-9 show the distribution of hexavalent chromium in 100-HR-3 OU groundwater during spring and fall 2010, respectively. Note that the fall 2010 map includes only a partial data set due to the stop work that occurred at that time, which affected sample collection. The isoconcentration contours were drawn based on 2010 data, where available; however, in areas where data are sparse, historical isoconcentration contours were used to aid in completing the map.

7.1.1.1 Horn Area Hexavalent Chromium Plume

The hexavalent chromium plume underlying the horn area is believed to have originated in the 100-D Area and has subsequently migrated toward the 100-H Area. A significant portion of the horn area mass may have resulted from the routing of cooling water to the 116-DR-1&2 Trench during the last months of operation (i.e., 1967) at 105-D.

In CY 2010, groundwater sampling results show that hexavalent chromium is present in groundwater beneath the horn area; however, the plume did not change significantly compared to CY 2009. Higher concentrations of hexavalent chromium are restricted to the area immediately adjacent to the 100-D Area. Injection wells in the 100-H Area create a hydrologic barrier on the northeastern side of the plume that prevents the plume from extending eastward into the northern portion of 100-H Area, as illustrated in Figures 7-8 and 7-9.

The central core of the horn area plume had concentrations between 50 and 90 µg/L in wells 699-98-43, 699-98-46, 699-97-41, 699-97-45, 699-97-43B, 699-96-52B, and 699-95-45. Well 699-97-41 is located northeast of the 100-H Area on the edge of the horn area. Thus, hexavalent chromium concentrations in these wells were largely unchanged between CY 2009 and CY 2010.

Three wells in the horn area monitor the RUM: 699-97-43C, 699-97-45B, and 699-97-48C. Wells 699-97-43C and 699-97-45B were sampled during CY 2010 with no detection of hexavalent chromium in groundwater samples. Well 699-97-48C reported a high hexavalent chromium concentration of 42.3 µg/L in December 2010; which is slightly higher than the CY 2009 concentration of 38.7 µg/L.

7.1.1.2 Southern 100-D Area Hexavalent Chromium Plume

Underlying the 100-D Area, hexavalent chromium in the unconfined aquifer occurs in two distinct plumes often referred to as the southern and northern plumes. Historical handling activities of 70% sodium dichromate solution at the 100-D Area (100-D-12 and former railcar unloading station) are the likely sources of the southern plume. The southern plume lies south and west of the 183-DR filter plant. In CY 2010, the plume configuration did not change compared to CY 2009. In addition, despite removing more than 326 kilograms of hexavalent chromium through pump-and-treat operations, the groundwater plume size and average concentrations beneath the 100-D Area have not markedly decreased over the past decade. The new DX facility, with a treatment capacity of 2,300 L/min (600 gpm), will help facilitate hexavalent chromium removal from the 100-D Area groundwater.

The 100-D Area hexavalent chromium plume for spring 2010 is shown in Figure 7-10. The figure also shows hexavalent chromium concentration plots for selected wells within the plume. Maximum hexavalent chromium levels generally coincide with low river-stage conditions that occur in the late fall to early spring. Among the wells in the southern hexavalent chromium plume, the highest concentrations in groundwater samples were found in wells 199-D5-99 and 199-D5-122, with concentrations as high as 11,900 µg/L (February 2010) and 69,700 µg/L (August 2010), respectively. For well 199-D5-99, hexavalent chromium concentrations are considerably lower than measured in CY 2009 (49,300 µg/L); however, hexavalent chromium concentrations in groundwater samples from well 199-D5-122 have increased from the CY 2009 value of 59,600 µg/L.

Hexavalent chromium concentrations in 100-D Area groundwater are the highest on the Hanford Site. For CY 2010, three remediation systems operated to reduce the amount of hexavalent chromium reaching the Columbia River.

Wells that monitor the aquifer in the central 100-D Area (199-D5-33, 199-D5-36, and 199-D5-44) continue to have low hexavalent chromium concentrations. These wells are located between the southern and northern hexavalent chromium plumes. In CY 2010, hexavalent chromium was not detected in groundwater samples from these wells, which may be the result of infiltration of clean water from the 182-D reservoir, leaking raw water pipes, or injection of treated water into wells 199-D5-41 and 199-D5-42. Repairs and operational changes have reduced the amount of infiltration from the 182-D reservoir, but hexavalent chromium concentrations have not fully rebounded in the aquifer beneath this area.

In 100-D Area aquifer tubes, concentrations of hexavalent chromium in 2010 were at the lower end of the historical range (Figure 7-11). The highest hexavalent chromium concentration detected in an aquifer tube was 294 µg/L in Redox-1-3.3, which is located downgradient of the ISRM barrier. Hexavalent chromium concentrations downgradient of the ISRM barrier have decreased since the late 1990s but continued to remain above the cleanup standard in CY 2010.

A cluster of four new aquifer tubes (C7645, C7646, C7647, and C7648) were installed as part of the RI/FS upstream of the ISRM barrier in April 2010 to define the extent of hexavalent chromium and strontium-90 southwest of the 100-D Area. Groundwater samples collected from these new tubes during the last half of CY 2010 showed hexavalent chromium concentrations ranging from nondetect to 8.9 µg/L.

7.1.1.3 Northern 100-D Area Hexavalent Chromium Plume

The northern hexavalent chromium plume extends north from the D Reactor to the Columbia River. Operationally, the northern plume is located downgradient of the former sodium dichromate distribution system, which contained less concentrated solutions than the initial 70% solution brought in by railcar at 100-D-12. Figure 7-12 shows hexavalent chromium concentrations within the northern plume. The figure also shows hexavalent chromium concentration plots for selected wells within the plume. In CY 2010, the northern hexavalent chromium plume had not changed significantly compared to CY 2009. Among the wells in the northern hexavalent chromium plume, the highest concentrations in groundwater were found in wells 199-D5-125 and 199-D5-126, with concentrations as high as 2,310 and 2,150 µg/L, respectively. This is largely unchanged from the CY 2009 concentrations of 2,350 µg/L (199-D5-125) and 1,970 µg/L (199-D5-126). These wells were added in the first quarter of FY 2009 and are located in the center of the plume. Some increase in concentration was observed in the vicinity of well 199-D8-88; this well is now extracting water to the DX system and concentrations are expected to decrease under the influence of the pump-and-treat system.

Well 199-D5-15 monitors groundwater near a potential source of the northern hexavalent chromium contamination. Hexavalent chromium concentrations were low from 1999 to 2003 because of mixing with nearby leaking water lines, which were repaired in 2004 (PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*). Concentrations began to increase in 2004 and reached a maximum of 2,450 µg/L in May 2007. Hexavalent chromium in this well subsequently declined to ~1,000 µg/L in 2008 and remained below 700 µg/L during CY 2010, with a maximum concentration of 659 µg/L. Hexavalent chromium concentrations in wells 199-D5-14 and 199-D5-16 (downgradient of well 199-D5-15) also increased in 2008 but steadily decreased during the reporting period. Vadose zone soil sampling conducted during the 100-D Area chromium source investigations (DOE/RL-2009-92, *Report on Investigation of Hexavalent Chromium Source in the Southwest 100-D Area*; DOE/RL-2010-40, *Report on Investigation of Hexavalent Chromium Source in the Northern 100-D Area*) discovered small amounts of hexavalent chromium in the vadose zone in a few locations but did not identify a large source capable of producing the high concentrations seen in some groundwater monitoring wells. Another theory for the northern plume is that it was split off from the south plume hydraulically via leakage from the 182-D reservoir and associated piping.

Hexavalent chromium concentrations in aquifer tubes downgradient of the northern plume have declined since the late 1990s. Only two of the five aquifer tube clusters used to monitor the northern plume were sampled in CY 2010. The only aquifer tube with a groundwater sample above the remedial action goal was tube 36-M with a concentration of 22.1 µg/L.

7.1.1.4 100-H Area Hexavalent Chromium Plume

The size of the hexavalent chromium plume in the unconfined aquifer underlying the 100-H Area has been significantly reduced since pump-and-treat operations began in 1997. However, in CY 2010, this plume did not change significantly compared to CY 2009. A relatively smaller and lower concentration hexavalent chromium plume remains adjacent to the Columbia River. The new HX pump-and-treat system will help facilitate the remediation effort by expanding the capture area and treating additional contaminated groundwater.

In CY 2010, groundwater in the 100-H Area predominantly contained less than 20 µg/L hexavalent chromium; however, several wells upgradient of the 100-H Area continued to have hexavalent chromium concentrations above the remedial action goal. Figure 7-13 shows hexavalent chromium concentrations in groundwater underlying the 100-H Area. The highest hexavalent chromium concentration for CY 2010 was 91.8 µg/L in well 199-H1-43. This well is downgradient of well 699-97-43B, which has had the highest concentration since 2007. In CY 2010, well 699-97-43B had a maximum hexavalent chromium concentration of 85.2 µg/L, which is a decrease from the previous reporting period (sampled in November 2008) of 91.5 µg/L. An increase in hexavalent chromium was noted in the southern portion of the area near well 199-H3-5, which is one of the original injection wells for the HR-3 pump-and-treat system. Since shutdown of these wells, some encroachment of the horn plume has occurred in this area. Well 199-H3-5 will be added to the HX pump-and-treat system.

Hexavalent chromium concentrations in 100-H Area have declined due to remediation efforts and natural processes.

Monitoring wells 199-H3-2C and 199-H4-12C, and piezometer 199-H4-15CS are screened within the first water-bearing layer within the RUM. In CY 2010, groundwater samples collected from these wells/piezometer continued to show elevated hexavalent chromium concentrations. In CY 2009, these wells/piezometer were used for a series of aquifer tests to gather data on the presence of deep chromium in the RUM (SGW-47776, *Aquifer Testing and Rebound Study in Support of the 100-H Deep Chromium Investigation*). Preliminary observations from the tests are summarized in Section 7.2.5. For CY 2010, the following observations were noted:

- Well 199-H3-2C (fully screened across the first water-bearing layer in the RUM) is located on the western side of the 100-H Area, upgradient of the 100-H Area waste sites. Hexavalent chromium concentrations in groundwater samples from this well have increased over the last several years to ~50 µg/L in FY 2007 and 2008. During the 2009 aquifer test, the highest value observed was 112 µg/L. The highest hexavalent chromium concentration detected in CY 2010 was 41 µg/L. Adjacent well 199-H3-2A, completed in the unconfined aquifer, had much lower hexavalent chromium concentrations of less than 16 µg/L.
- Well 199-H4-12C (fully screened across the first water-bearing layer in the RUM) is located near the Columbia River, downgradient of the 183-H solar evaporation basins and adjacent to extraction well 199-H4-12A (screened in the unconfined aquifer). Well 199-H4-12C showed declining hexavalent chromium concentrations during FY 2008, decreasing to ~80 µg/L. During CY 2009, the concentrations ranged between 80 and 100 µg/L until early November 2009, when concentrations increased to a maximum of 121 µg/L as a result of aquifer testing. The highest hexavalent chromium concentration in CY 2010 was 140 µg/L.
- Piezometer 199-H4-15CS is adjacent to an extraction well. Hexavalent chromium concentrations in this piezometer were steady at levels near 100 µg/L until November 2009, when the concentration increased to 115 µg/L as a result of aquifer testing (Section 7.3.6). The highest hexavalent chromium concentration in CY 2010 was 129 µg/L. Hexavalent chromium in shallower piezometers 199-H4-15A and 199-H4-15B were much lower at 31 and 28 µg/L, respectively.
- Concentrations in the RUM rose slightly as a result of the pumping during the test but have remained at relatively constant levels. It appears that the erosional forces that removed the Ringold Formation unit E east of the 100-D Area have also scoured off portions of the RUM to the extent that groundwater mounding

of reactor cooling water (less than or equal to 700 µg/L) provided sufficient hydraulic head to drive relatively large volumes of cooling water into the RUM in the vicinity of the retention basins. Concentrations decrease inland and no hexavalent chromium is found in this layer to the west into the horn area.

- Hexavalent chromium concentrations in aquifer tubes in the main 100-H Area were below 20 µg/L, with the exception of tube C7650. Aquifer tube C7650 was installed as part of the RI/FS downgradient of the 116-H-7 waste site in April 2010 to define the extent of the hexavalent chromium and strontium-90 contamination. Groundwater samples collected from this new tube during the last half CY 2010 had concentrations of hexavalent chromium ranging from 6.6 to 30.8 µg/L.
- Concentrations greater than 20 µg/L were also observed along the horn area, reflecting the plume as it intercepts the Columbia River. The highest concentration upstream of the 100-H Area was 42.2 µg/L in aquifer tube C5641. Appendix C provides additional information on 100-H Area aquifer tube sampling.

7.1.2 Strontium-90

7.1.2.1 100-D Area

In the 100-D Area, only one groundwater sample collected in CY 2010 had a strontium-90 concentration exceeding the drinking water standard (DWS) of 8 pCi/L (RI/FS borehole characterization sample from well 199-D3-5 at 8.5 pCi/L); however, groundwater samples collected from the well the previous day had a maximum detection of only 4.5 pCi/L and neither sample reported any gross beta. The areas near the former retention basins in the north and near the D Reactor in the central 100-D Area have historically had strontium-90 detections in groundwater. Well 199-D8-68, near the former retention basins, has had concentrations ranging from 2 to 14 pCi/L since 1998; however, in 2010, concentrations were 3 pCi/L.

Only one groundwater sample exceeded the DWS for strontium-90 in groundwater at the 100−D Area.

During CY 2010, none of the 100-D Area aquifer tubes were sampled for strontium-90.

7.1.2.2 100-H Area

The distribution of strontium-90 in groundwater underlying the 100-H Area has not significantly changed in recent years. Strontium-90 concentrations in groundwater continued to exceed the 8 pCi/L DWS in several wells located to the southeast. The highest strontium-90 concentration detected in groundwater was 28 pCi/L in well 199-H4-13, downgradient of the 116-H-7 retention basin. A value of 160 pCi/L was sampled at well 199-H1-20 in the northern portion of the horn area. However, this value is suspect because the corresponding value of gross beta was zero and the well location is far outside the expected extent of strontium-90. The data will continue to be evaluated.

During CY 2010, none of the 100-H Area aquifer tubes were sampled for strontium-90.

7.1.3 Technetium-99 and Uranium

7.1.3.1 100-D Area

In CY 2010, technetium-99 and uranium concentrations in groundwater underlying the 100-D Area were less than their respective DWSs of 900 pCi/L and 30 µg/L, respectively. The highest detected technetium-99 concentration was 190 pCi/L in an RI/FS borehole characterization sample from well 199-D3-5, which is far below the DWS. However, a duplicate of this sample was analyzed as undetected. Further

technetium-99 analyses will be conducted during FY 2011. The highest concentration of uranium in groundwater was 5.82 µg/L in well 199-D6-3 (also an RI/FS borehole characterization sample). This value is much lower than both the Hanford Site background for uranium (9.85 µg/L) and the DWS of 30 µg/L.

During CY 2010, none of the 100-D Area aquifer tubes were sampled for technetium-99 or uranium.

Technetium-99 and uranium concentrations in groundwater were below their respective DWS in both the 100-D and 100-H Areas.

7.1.3.2 100-H Area

In CY 2010, technetium-99 and uranium concentrations in groundwater underlying the 100-H Area were less than their respective DWSs. Although a groundwater sample from well 199-H6-4 had a technetium-99 concentration of 68 pCi/L, this radionuclide has not historically been detected in this area. This well represents the southernmost point of the 100-H Area. Technetium-99 in this area may be the result of groundwater mounding during reactor operations. Additional analyses will be conducted in 2011 in this area. Samples from surrounding wells were below the laboratory detection limit, and this well will be sampled in the future to determine the validity of this result. In addition, values of 68 and 29 pCi/L were reported from duplicate samples at well 199-H4-12A, and the discrepancy is being addressed by the laboratory.

In CY 2010, uranium was positively detected in all groundwater samples analyzed from the 100-H Area. The maximum concentration was identified in the groundwater sample collected from well 199-H4-3 at 12.2 µg/L. This is a decrease from CY 2009; however, the value is below both the Hanford Site background for uranium and the DWS.

During CY 2010, none of the 100-H Area aquifer tubes were sampled for technetium-99 or uranium. However, in CY 2009, three 100-H Area aquifer tubes (AT-H-1-D, AT-H-2-D, and AT-H-3-D) were sampled for technetium-99 and uranium. Technetium-99 was not positively detected in any sample. Uranium was detected at low levels in all three aquifer tubes, with the maximum concentration of 1.67 µg/L in aquifer tube AT-H-3-D.

7.1.4. Tritium

7.1.4.1 100-D Area

In CY 2010, tritium concentrations in groundwater underlying the 100-D Area were less than the DWS of 20,000 pCi/L. The groundwater sample collected from well 199-D6-3 (RI/FS borehole characterization sample) had a tritium concentration of 20,000 pCi/L, which is at the DWS. This well is located on the east side of the 100-D Area, east of the reactor area, along the flow direction extending into the horn area. The reactor area is likely the tritium source.

In addition, tritium was detected in several aquifer tubes in the southern portion of the 100-D Area shoreline at concentrations approaching the DWS. This may represent migration of tritium from the 100-N Area. In general, tritium concentrations in groundwater underlying the 100-D Area are declining; however, further monitoring in this area is warranted to confirm the 100-N Area as a source for tritium in the southwest portion of the 100-D Area.

Tritium concentrations in groundwater were at or below the DWS in the 100-D Area, but a zone at the DWS was noted east of the reactor area at well 199-D6-3.

7.1.4.2 100-H Area

In CY 2010, tritium concentrations in groundwater underlying the 100-H Area were generally less than 5,000 pCi/L, with the exception of a concentration of 9,000 pCi/L at well 199-H3-3. These concentrations are below the DWS. In addition,

Tritium concentrations in groundwater were below the DWS in the 100-H Area.

groundwater samples collected from wells in the horn area had tritium concentrations ranging between 2,000 and 4,500 pCi/L. Therefore, since the horn area is upgradient of the 100-H Area, it is not anticipated that tritium concentrations will increase above the DWS in future sampling events. In general, tritium concentrations in groundwater underlying the 100-H Area and horn area are declining.

7.1.5 Nitrate and Nitrite

7.1.5.1 100-D Area

In CY 2010, nitrate concentrations in groundwater underlying the northern 100-D Area increased compared to CY 2009. The plume has two lobes, and nitrate concentrations continue to exceed the DWS (45 mg/L) in both lobes. A groundwater sample collected from well 199-D5-15 had the maximum detected concentration (99.2 mg/L). The RI/FS wells 199-D5-133 and 199-D6-3 were drilled during CY 2010 and also showed elevated nitrate, with maximum concentrations of 81 and 77.9 mg/L, respectively (RI/FS borehole characterization samples). Figure 7-14 shows the distribution of nitrate in groundwater underlying the 100-D Area. Potential sources of nitrate include nitric acid used during operations, as well as nitrate derived from septic systems.

The southern portion of the nitrate plume is intercepted by the ISRM barrier, which chemically reduces the nitrate. During CY 2009, a maximum nitrate concentration of 95 mg/L was detected in groundwater from well 199-D2-6 (southern 100-D Area); however, in CY 2010, the concentration in groundwater from this well decreased to 69.5 mg/L. Nitrate concentrations in 100-D Area aquifer tubes were less than 45 mg/L.

In CY 2010, nitrite was detected in groundwater samples collected from several wells near the ISRM barrier. However, the measured concentrations were less than the DWS of 3.3 mg/L.

7.1.5.2 100-H Area

In CY 2010, nitrate concentrations in groundwater underlying the 100-H Area were below the DWS of 45 mg/L. The highest concentration (44.3 mg/L) was observed in an RI/FS borehole characterization sample collected from well 199-H6-3 in the southern 100-H Area. This well is located upgradient of aquifer tube 51, which has historically had elevated nitrate concentrations. Aquifer tube 51 was not sampled for nitrate in CY 2010, and the highest value in CY 2009 was 46 mg/L. Aquifer tubes in the southern 100-H Area and further downstream have had concentrations near or above the 45 mg/L DWS in recent years; however, these sites were not sampled in CY 2010.

7.1.6 Sulfate

7.1.6.1 100-D Area

In CY 2010, sulfate concentrations in groundwater underlying much of the southern 100-D Area remained greater than 100 mg/L. Excluding wells influenced by the ISRM barrier, concentrations were below the secondary DWS (250 mg/L), with a maximum concentration of 202 mg/L in well 199-D6-3 (RI/FS borehole characterization sample). Sulfate concentrations in water samples from 100-D Area aquifer tubes are generally low, except downgradient of the ISRM barrier. Previous injections of sodium dithionite solution at the barrier increased sulfate concentrations to levels above the secondary DWS in the ISRM barrier and in some downgradient wells and aquifer tubes. The highest concentration in CY 2010 was 776 mg/L in aquifer tube DD-43-3, which is the highest sulfate concentration ever detected in an

aquifer tube. Aquifer tube DD-42-4 also had results above the 250 mg/L secondary DWS in CY 2009, with a maximum concentration of 616 mg/L in 2010. This could represent migration of sulfate from the vicinity of the ISRM barrier due to low river stage.

7.1.6.2 100-H Area

In CY 2010, sulfate concentrations in groundwater underlying the 100-H Area were below the secondary DWS (250 mg/L). The maximum concentration detected was 83.6 mg/L in a sample collected from well 199-H4-46.

7.1.7 Gross Beta

7.1.7.1 100-D Area

Historical groundwater samples collected from wells in the ISRM barrier have contained detectable amounts of gross beta, which was primarily caused by naturally present potassium-40 in the pH buffer used during injection (PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*). In CY 2010, three wells in the IRSM barrier were sampled for gross beta analysis. The three groundwater sample results were all below the DWS of 50 pCi/L, with a maximum concentration of 19 pCi/L in well 199-D4-84. Well 199-D4-19 was not sampled in CY 2010, but a maximum gross beta value of 140 pCi/L was detected in November 2009. A value of 27 pCi/L was reported at well 199-D5-40; however, the value in this well has consistently been less than 10 pCi/L for many years. Further review of the data is being conducted.

7.1.7.2 100-H Area

Strontium-90 is present in groundwater underlying the 100-H Area, which causes gross beta concentrations in groundwater to exceed the 50 pCi/L DWS. In CY 2010, the groundwater sample collected from well 199-H4-13 had the highest gross beta concentration (69 pCi/L) detected.

7.2 CERCLA Groundwater Activities

This section summarizes the CERCLA activities in the 100-D and 100-H Area, including groundwater remedial actions.

An interim remedial action ROD for the 100-HR-3 OU was issued in April 1996 (EPA/ROD/R10-96/134, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Benton County, Richland, Washington*) pursuant to listing of the Hanford Site on the National Priorities List in 1989 for CERCLA. The goal of the resulting interim remedial action is to prevent discharge of hexavalent chromium to the Columbia River.

The interim action goal was changed from 22 µg/L to 20 µg/L in August 2009 by the explanation of significant difference for the 100-HR-3 and 100-KR-4 OUs (EPA et al., 2009b). The explanation of significant difference sets a 20 µg/L threshold at onshore, near-river monitoring locations to achieve the ambient water quality criterion of 10 µg/L. As indicated in the ROD, an attenuation factor of 1:1 is expected before the groundwater would reach the aquatic receptor point of concern within the river substrate, ensuring that the ambient water quality criterion of 10 µg/L in the river substrate will be met.

The remedial action objectives for the 100-HR-3 OU are as follows (EPA/ROD/R10-99/039; EPA/AMD/R10-00/22):

- ***Protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River.***
- ***Protect human health by preventing exposure to contaminants in the groundwater.***
- ***Provide information that will lead to the final remedy. The COC is hexavalent chromium.***

The second CERCLA 5-year review (DOE/RL-2006-20) was published in November 2006. The review identified six actions for the 100-D Area and one action for the 100-H Area:

- **Action 8-1.** *Complete a field study to investigate additional sources of chromium groundwater contamination within the 100-D Area. Complete additional geologic and geochemical investigations of the vadose zone in the 100-D Area (March 2009).*

  Investigations were conducted for both the southern and northern plume (SGW-38757, *Investigation of Hexavalent Chromium Source in the Southwest 100-D Area*; DOE/RL-2010-40). In addition, several boreholes and wells will be installed as part of the RI/FS (DOE/RL-2008-46-ADD1).

- **Action 9-1.** *Perform additional characterization of the aquifer in the horn area and evaluate the need to perform remedial action to meet the remedial action objectives of the 100-D Area ROD for interim action (September 2009).*

  This action was previously completed and is summarized in the *Hydrogeological Summary Report for 600 Area Between 100-D and 100-H for the 100-HR-3 Groundwater Operable Unit* (DOE/RL-2008-42).

- **Action 9-2.** *Incorporate the horn area into the 100-HR-3 OU interim ROD (EPA/ROD/R10-99/039) if Action 9-1 indicates that the horn area contains a plume requiring immediate remediation (September 2009).*

  The DOE has completed the remedial process optimization (RPO) evaluation of the pump-and-treat system and is currently implementing the results (SGW-40044, *100-HR-3 Remedial Process Optimization Modeling Technical Memorandum*). The DOE installed additional extraction and injection wells throughout the horn area in FY 2009 and FY 2010 as part of RPO (Section 7.2.2).

- **Action 10-1.** *Direct the operating contractor to further minimize leaks from the 182-D reservoir.*

  Other local influences on groundwater flow are leakage from the 182-D reservoir and the groundwater extraction and injection from the pump-and-treat systems. The zone of uncontaminated groundwater near the 182-D facility suggests long-term contaminant mixing and diversion of contaminated groundwater from the mounding caused by the reservoir leaks. In response to the reservoir leakage information, a specific issue (Action 10-1) was included in the second CERCLA 5-year review (DOE/RL-2006-20) (see discussion in Section 7.3.1) for DOE to provide direction to its operating contractor to conduct changes

to the operation of the reservoir to minimize leakage. Those actions were completed and documented in the closeout of the 5-year review issue. The leaks and their impact on groundwater flow have significantly diminished since the reduction of storage volume in the reservoir in 2004, to the point that influences on groundwater flow from reservoir leakage are indistinguishable from those created by nearby pump-and-treat activities (PNNL-SA-50369, *Project Work Plan Hanford 100-D Area Treatability Demonstration: Accelerated Bioremediation Through Polylactate Injection*).

These actions were previously completed.

- **Action 11-1.** *Initiate limited iron amendments to evaluate whether this enhances ISRM barrier performance (September 2007).*

  Section 7.2.4 provides a summary of the results for this action. Results of the iron amendment tests are documented in *Treatability Test Report on Mending the In Situ Redox Manipulation Barrier Using Nano-Size Zero Valent Iron* (DOE/RL-2009-35).

- **Action 11-2.** *Expand groundwater pump-and-treat extraction within the 100-D Area by 378.5 liters per minute to enhance remediation of the chromium plume (no due date).*

  The DOE installed additional extraction and injection wells in FY 2009 as part of the RPO (SGW-38338, *Remedial Process Optimization for the 100-D Area Technical Memorandum Document*; SGW-40044; Section 7.2.2). The DX system became operational on December 16, 2010.

- **Action 12-1.** *Perform additional characterization of the 100-H Area aquifer below the initial aquitard (September 2009).*

  The DOE installed three wells in the horn area, screened in the RUM (DOE/RL-2008-42) (Section 7.1.1.1), and continued to monitor three wells in the 100-H Area (Section 7.1.1.4).

  Section 7.2.5 presents the summary of the aquifer tests performed in CY 2009 to gather data and provide additional information on the deep hexavalent chromium contamination in the 100-H Area (SGW-47776).

  Five wells (three in the 100-H Area and two in the 100-D Area) were installed as part of the RI/FS work plan. The wells will be drilled through the RUM and screened within the first water-bearing layer encountered (DOE/RL-2008-46-ADD1).

  A non-significant change to the ROD was issued in 2010 (Holten, 2010), which identifies that DOE no longer will maintain the ISRM barrier but will instead meet remedial action objectives with the pump-and-treat expansion.

7.2.1 Remedial Investigation Activities

In CY 2010, the RI/FS work plan addendum for the 100-D and 100-H Area (DOE/RL-2008-46-ADD1) and the sampling and analysis plan (DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*) were issued. The documents identify the data to be collected to support selection of final remedies under CERCLA, using an approach that integrates the data needs for waste sites and groundwater. A total of ten boreholes, fifteen groundwater wells, five test pits, and six aquifer tubes were proposed for installation in CY 2010/2011 under the work plan. In addition, 53 existing groundwater wells were scheduled for three sampling rounds for temporal spatial analysis. The results of the sampling and analysis for these

53 wells are not discussed in this report. Field work is scheduled to be completed by April 2011. At the end of CY 2010, progress was underway and the following work was completed:

- Seven of fifteen wells were drilled and sampled.
- Two of ten boreholes were drilled and sampled.
- Two of five test pits were installed.
- All aquifer tubes were installed and sampled.
- Three sampling rounds for temporal spatial analysis of 53 wells was completed (the first sample round occurred in 2009). Note that the analytical results for these wells are included in discussions, tables, and figures within this report.

The scheduled RI/FS activities were not completed before preparation of this annual report. The complete data set from these investigations will be fully evaluated and reported in the RI/FS report, which will lead to the selection of alternatives for final cleanup action. The RI/FS report is scheduled for completion in CY 2011. These highlights include observations based on data collected during CY 2011. Preliminary highlights of RI/FS findings are briefly summarized below.

- ***Soil — 100-D and 100-H Areas:***
  - Preliminary soil sampling results indicate that total chromium concentrations are much higher than hexavalent chromium concentrations. Concentrations of other contaminants of potential concern do not show significant concentration variation from previous investigations.
- ***Groundwater — 100-D Area:***
  - Hexavalent chromium concentrations in borehole characterization groundwater samples from RI/FS wells are generally within expected values, exceeding the ambient water quality criterion value of 10 µg/L and *Model Toxics Control Act* (MTCA) (WAC 173-340, "Model Toxics Control Act – Cleanup") value of 48 µg/L. The only unexpected concentrations are associated with well 199-D3-5, which is near the former 116-D-1A Burial Ground. This well was installed to define the southwestern extent of hexavalent chromium in the unconfined aquifer but actually shows higher-than-expected hexavalent chromium concentrations on top of the RUM.
  - Generally, hexavalent chromium concentrations are homogeneous throughout the unconfined aquifer. However, in groundwater samples from wells 199-D5-133 and 199-D3-5, hexavalent chromium concentrations are higher at the water table and on top of the RUM, respectively. This could be an artifact of sampling with depth during drilling, but stratification is occasionally observed in some wells. These observations could be explained by density-driven flow during initial contamination by concentrated solutions that have slowly dissipated, leaving a remnant at the base of the aquifer followed by more recent leaching of hexavalent chromium during recent vadose zone remediation. Alternatively, the concentration profile could represent a higher hydraulic conductivity zone in the center of the aquifer, allowing clean water from upgradient to flow through the middle of the aquifer more quickly than the top or bottom portions.
  - Nitrates in borehole water samples from the unconfined aquifer exceeded the DWS (45 mg/L) in wells 199-D5-141, 199-D5-134, 199-D5-140, 199-D6-3,

199-D5-132, 199-D5-133, and 199-D3-5. This is consistent with previous extent of the nitrate plume.

- Strontium-90 concentrations in groundwater samples collected from boreholes were all below the DWS of 8 pCi/L, excluding well 199-D3-5. Well 199-D3-5 is located downgradient of former waste burial site 118-D-2. Further strontium-90 analysis is warranted.
- Technetium-99 concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS for all samples collected from the 100-D Area.
- Tritium concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS (20,000 pCi/L) for all samples collected from the 100-D Area, except in well 199-D3-5 in the southwest portion of the 100-D Area, suggesting a possible source in the 100-N Area.
- Uranium concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS (30 µg/L) for all samples collected from the 100-D Area.
- Zinc concentrations in borehole groundwater samples collected from wells 199-D5-134 (unconfined aquifer and RUM), 199-D5-133, 199-D5-140, and 199-D6-3 exceeded the action level of 91 µg/L. Concentrations in the remaining "D" wells were below the action level.
- Two RUM wells were installed within the north and south hexavalent chromium plumes. The borehole samples collected from each of these wells within the RUM showed impact within the first water-bearing layer at concentrations exceeding the ambient water quality criterion but below the MTCA standard; however, hexavalent chromium concentrations in lower, water-bearing layers were below the laboratory method detection limits. Nitrate, strontium-90, technetium-99, and tritium are all below their respective DWSs. Uranium concentrations were low, and the zinc concentration appeared to be elevated in the sample from the first water-bearing layer at 331 µg/L.

- ***Groundwater — 100-H Area:***
  - Hexavalent chromium concentrations in borehole groundwater samples from RI/FS wells in the unconfined aquifer are generally rather low. Samples collected from wells 199-H6-4, 199-H6-3, 199-H3-7, 199-H3-6, 199-H3-9, and 199-H2-1 are either below or slightly elevated above the ambient water quality criterion.
  - Total chromium concentrations in groundwater from borehole samples are generally higher than the hexavalent chromium concentrations in the same sample. However, none of the groundwater samples collected from the unconfined aquifer exceeded the MTCA value. The total chromium should include both trivalent and hexavalent chromium, so the difference should represent the portion of total chromium that is trivalent chromium. Because hexavalent chromium should be a subset of total chromium, situations where hexavalent chromium is greater than total chromium suggest problems with the laboratory analysis.
  - Strontium-90 was detected above the DWS in only the borehole groundwater sample from well 199-H3-6. The remaining wells were below the minimum detection limit.

- Nitrate concentrations in borehole groundwater samples were below the DWS for all samples collected from the 100-H Area.
- Technetium-99 concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS for all samples collected from the 100-H Area.
- Tritium concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS for all samples collected from the 100-H Area.
- Uranium concentrations in borehole groundwater samples were below the minimum detection limit and/or DWS (30 µg/L) for all samples collected from the 100-H Area.
- Zinc concentrations in borehole groundwater samples collected from wells 199-H2-1 (unconfined aquifer and RUM) and 199-H6-3 exceeded the action level of 91 µg/L. The remaining "H" wells were below the action level.
- The northern extent of hexavalent chromium in the first water-bearing layer in the RUM is defined by well 199-H2-1 because the sample was below the ambient water quality criterion. However, the groundwater sample from 199-H3-9 collected within the first water-bearing layer in the RUM had the highest concentration of hexavalent chromium identified in groundwater underlying the 100-H Area.

7.2.2 Pump-and-Treat Systems

The DOE will expand and optimize the pump-and-treat systems in the 100-HR-3 OU to enhance treatment of the hexavalent chromium plumes in the 100-D Area, 100-H Area, and horn area.

During CY 2010, two pump-and-treat systems operated to remediate hexavalent chromium in groundwater. The HR-3 pump-and-treat system was the initial system and extracts water from both the 100-D and 100-H Areas. The DR-5 system supplements the HR-3 pump-and-treat system to improve hexavalent chromium control in the 100-D Area. The new DX pump-and-treat system entered acceptance testing in the fourth quarter of CY 2010 and became operational in 2011. The DX system will eventually incorporate some of the HR-3 and DR-5 wells into the system.

Expansion of pump-and-treat operations continues in the 100-HR-3 OU along the Columbia River, including, for the first time, the horn area. The current HR-3 and DR-5 pump-and-treat systems are being phased out by expanded systems (DX/HX) to improve overall system run-time, reduce individual well downtime, and capture and treat additional contaminated groundwater as a result of the U.S. Environmental Protection Agency (EPA) and Washington State Department of Ecology (Ecology) requirements specified in CERCLA 5-year reviews (Section 7.2).

An RPO evaluation began in 2008 to determine the how to optimize remediation of hexavalent chromium in the 100-HR-3 OU groundwater by 2012 (SGW-38338). RPO is a systematic approach for evaluating existing remediation systems with the goal of improving their effectiveness and reducing overall site cleanup costs without increasing risks. In the long run, efficient use of RPO reduces the operations and management burden. The RPO review recommended implementing additional pump-and-treat system capacity to address the hexavalent chromium groundwater concentrations that exceed cleanup levels established in the interim ROD and interim ROD amendment (EPA/AMD/R10-00/122). The new DX and HX pump-and-treat system will substantially increase the rate of groundwater cleanup in the 100-HR-3 OU.

Seventy new RPO extraction/injection wells were installed within the 100-HR-3 OU to further aid in groundwater remediation activities (Figures 7-15 and

7-16). To accommodate the additional extraction well production needed to capture the full extent of the plume in the 100-D Area and western portion of the horn area, the DX system was completed at the end of CY 2010. The DX system will be capable of treating up to 2,300 liters per minute of groundwater. Pilot testing of the facility began in December 2010 and, after one month of operation, treated approximately 55.3 million liters of groundwater and removed an additional 18.4 kilograms of hexavalent chromium. Construction of the HX system (3,000 liters per minute) is progressing ahead of schedule, with the system startup anticipated in December 2011.

Groundwater from the 100-D Area portion of the HR-3 pump-and-treat system continued to be piped to the 100-H Area for treatment. As an outcome of the RPO, the DOE has begun consolidating extraction, treatment, and injection within the two areas to reduce water movement across the horn area (DOE/RL-2009-09, *Sampling and Analysis Plan for Installation of 100-HR-3 Groundwater Operable Unit Remedial Process Optimization Wells*). The results of operational monitoring and additional details about the pump-and-treat systems for CY 2010 are presented in the pump-and-treat system annual performance report (DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*).

The total dissolved mass of hexavalent chromium remaining in the unconfined aquifer underlying the 100-HR-3 OU was estimated using the fall 2009 isoconcentration map. The areal extent of the average hexavalent chromium concentrations within each contour interval was multiplied by an assumed average porosity value of 15% by an average aquifer thickness of approximately 7.5 meters. The results indicate that approximately 1,125 kilograms of hexavalent chromium remained in the aquifer. These results will be used to provide better perspective on pump-and-treat system performance in the 100-HR-3 OU.

7.2.2.1 HR-3 Pump-and-Treat System

M. Tonkin

The HR-3 pump-and-treat system extracts groundwater through wells in the northern plume (100-D Area) and in the 100-H Area plume. The extracted groundwater is transferred through an above-ground pipeline to a treatment building in the 100-H Area. Hexavalent chromium is removed from extracted groundwater using ion-exchange resins, and the treated water is then discharged to three injection wells, which are screened in the unconfined aquifer underlying the 100-H Area. Figure 7-17 presents a capture efficiency/frequency map of the HR-3 system for CY 2010 and the spring 2010 hexavalent chromium concentration contours. The capture maps describe the zone of influence of the pump-and-treat system with respect to the extraction/injection well locations. By overlaying these maps with the map showing the extent of the plume, the ability of the system to capture the plume can be assessed. The capture is discussed in detail in the annual pump-and-treat report (DOE/RL-2011-25).

The HR-3 system has used up to twelve extraction wells (ten wells in the unconfined aquifer and two wells in the RUM). In CY 2010, well 199-H3-2C and 199-H4-12C (RUM wells) were added to the HR-3 pump-and-treat system. These wells previously monitored a water-bearing layer within the RUM, which showed elevated concentrations of hexavalent chromium. The configuration of the extraction network has varied at times, depending on need (i.e., not all extraction wells are operated simultaneously). The HR-3 pump-and-treat system also includes three

injection wells in the 100-H Area. The existing treatment capacity for the HR-3 pump-and-treat system is 1,100 liters per minute.

The HR-3 pump-and-treat system treated 268 million liters of water during CY 2010, removing 31 kilograms of hexavalent chromium.

In CY 2010, the HR-3 pump-and-treat system extracted 267.9 million liters of groundwater from the 100-HR-3 OU. This is a 51% increase in volume when compared to 177.3 million liters processed in CY 2009. The system removed 31 kilograms of hexavalent chromium during CY 2010, bringing the total removal to 392.9 kilograms since 1997, in addition to the 30 kilograms removed by a pilot-scale system in the early 1990s. The hexavalent chromium removed in CY 2010 was an increase of 95% in mass removed when compared to the 15.9 kilograms processed in CY 2009. The average removal efficiency for CY 2009 was 96.0%, which is slightly higher than the 95% reported in CY 2010.

Wells 199-D8-54A and 199-D8-71 are the two specified compliance points for the HR-3 pump-and-treat system in the 100-D Area. Well 199-D8-54A was sampled eleven times during the reporting period because it was an extraction well, with concentrations ranging from 25 to 109 µg/L. Well 199-D8-71 was sampled twice during the reporting period, in March and May of CY 2010. The highest hexavalent chromium concentration detected in groundwater from this well was 130 µg/L, which is slightly lower than CY 2009, with a maximum detected concentration of 136 µg/L. Hexavalent chromium concentrations in these compliance wells exceeded the 20 µg/L remedial action goal during CY 2010, which is unchanged from the previous reporting period.

In CY 2010, a small area of hexavalent chromium exceeded 50 µg/L across the eastern boundary of the 100-D Area. The zone appeared to have a north-south axis, with wells 199-D8-69 and 199-D8-70 (compliance wells) located in the portion of the zone with hexavalent chromium concentrations between 50 and 100 µg/L in CY 2010. The compliance wells continued to show variable hexavalent chromium concentrations, with the lowest concentrations in the early summer when the river stage was high (Figure 7-12). Most concentrations in these compliance wells exceeded the 20 µg/L remedial action goal during CY 2010, which is unchanged from the previous reporting period. The highest concentrations detected were 64.5 and 82.7 µg/L in wells 199-D8-69 and 199-D8-70, respectively.

In the 100-H Area, one compliance well (199-H4-5) was scheduled for monthly sampling to evaluate the performance of the HR-3 pump-and-treat system; however, this well could only be sampled for 8 of the 12 months, due to the safety issues discussed earlier. None of the samples exceeded the 20 µg/L remedial action goal, and the maximum hexavalent chromium concentration detected was 10 µg/L.

Four additional wells in the 100-H Area are designated as dual-purpose wells. Well 199-H4-3 is designated as an extraction/performance well, and wells 199-H4-4, 199-H4-63, and 199-H4-64 are designated as extraction/compliance wells. All four wells had at least one sample above the remedial action goal of 20 µg/L for hexavalent chromium during CY 2010. Well 199-H4-64 had the maximum detected concentration of 26 µg/L; the concentration in this well has decreased from CY 2009 (61 µg/L).

The size of the hexavalent chromium plume in the unconfined aquifer underlying the 100-H Area has been significantly reduced since the start of pump-and-treat operations in 1997; however, in CY 2010, this plume did not change significantly compared to CY 2009. A relatively smaller and lower concentration hexavalent chromium plume remains adjacent to the Columbia River. The new HX

pump-and-treat system will help facilitate the remediation effort by expanding the capture area and treating additional contaminated groundwater.

7.2.2.2 DR-5 Pump-and-Treat System

A second pump-and-treat system, DR-5, began operating at the end of July 2004 to treat increasing hexavalent chromium concentrations in 100-D Area wells southwest of the original pump-and-treat system. The DR-5 pump-and-treat system extracts, treats, and injects groundwater in the 100-D Area and has a treatment capacity of 190 liters per minute. Groundwater is extracted from four wells and treated in the 100-D Area at the DR-5 treatment facility using a metal anion-exchange system with onsite regeneration. Treated groundwater is then injected into wells 199-D5-41 and 199-D5-42. The system has been modified (e.g., pumping rate changes, extraction wells added or subtracted) several times throughout the years to increase the rate of remediation and widen the capture zone. In CY 2010, four extraction wells and two injection wells were operating on different schedules. Figure 7-18 presents a capture efficiency/frequency map for the DR-5 system for CY 2010 and shows the spring 2010 hexavalent chromium concentration contours.

During CY 2010, the DR-5 pump-and-treat system operated with various configurations. In February 2010, extraction well 199-D5-104 and injection well 199-D5-41 were added to the DR-5 system to aid in addressing the 100-D Area south plume. Injection well 199-D5-42 was taken offline in February for rehabilitation and then added back online in September 2010.

The DR-5 pump-and-treat system currently consists of four extraction wells: two of the wells (199-D5-20 and 199-D5-92) are located in the northern hexavalent chromium plume (100-D Area), and two wells (199-D5-39 and 199-D5-104) are located in the southern hexavalent chromium plume (100-D Area). The DR-5 system also includes two injection wells (199-D5-41 and 199-D5-42) in the 100-D Area.

During CY 2010, the DR-5 pump-and-treat system extracted 44.6 million liters of groundwater from the 100-D Area, which is an 8% decrease in volume when compared to 48.6 million liters processed in CY 2009. The system removed 74.9 kilograms of hexavalent chromium during the reporting period, bringing the total removal to 326.2 kilograms since 2004. The amount of hexavalent chromium removed in CY 2010 was an increase of 70% in mass removed when compared to 44.2 kilograms processed in CY 2009. The average removal efficiency for CY 2010 was 99.8%, which is essentially the same as the 99.9% reported in CY 2009.

During CY 2010, the DR-5 pump-and-treat system removed 75 kg of hexavalent chromium from the aquifer.

Currently there are no compliance wells for the DR-5 pump-and-treat system; however, the system is monitored on a regular basis. The sampling frequencies and constituents are listed in Appendix A. Appendix A, Table A-8 lists the deviations from required sampling for both pump-and-treat systems. New compliance wells are planned to monitor the expanded pump-and-treat systems in 100-D and 100-H Areas.

For CY 2010, the areal extent of the southern hexavalent chromium plume in the 100-D Area did not change significantly relative to CY 2009. In addition, despite removing over 326 kilograms of hexavalent chromium through pump-and-treat operations, average concentrations beneath the 100-D Area have increased dramatically since the hot spot was identified 3 years ago. The new DX facility, with a treatment capacity of 2,300 liters per minute, will help facilitate the remediation effort by expanding the capture area and treating additional contaminated groundwater. In addition, drilling and installation of new characterization and monitoring wells has aided in defining the extent of contamination.

7.2.3 In Situ Redox Manipulation System

A permeable reactive barrier for in situ chemical treatment of the hexavalent chromium in the southern plume (100-D Area) was emplaced as an interim remedial action in accordance with the interim ROD amendment (EPA/AMD/R10-00/122) beginning in 2000 (Figure 7-19). The reduction-oxidation treatment zone is ~680 meters long (aligned parallel to the Columbia River) and ~100 to 200 meters inland, and it consists of 65 wells spaced across almost the entire width of the southern hexavalent chromium plume. The treatment zone was designed to reduce the hexavalent chromium concentration in groundwater to no more than 20 µg/L at seven compliance wells located between the treatment zone and the Columbia River.

The ISRM barrier has reduced hexavalent chromium concentrations in the aquifer near the Columbia River.

The permeable reactive barrier uses ISRM technology to create a treatment zone in which ferric iron (iron III) is reduced to ferrous iron (iron II) within the aquifer matrix. This is accomplished by injecting sodium dithionite into the aquifer through wells, then withdrawing the unreacted reagent and reaction products (predominately sulfate) through the same wells and pumping this to the ISRM evaporation pond. The sodium dithionite serves as a reducing agent for iron, producing a reducing-type environment in the aquifer. As the groundwater migrates through the treatment zone, the mobile hexavalent chromium is reduced to the less toxic, immobile trivalent chromium, which precipitates from solution. Dissolved oxygen and some nitrate are also removed from the groundwater as it passes through the permeable reactive barrier.

The ISRM barrier (Figure 7-20) intersects the southern hexavalent chromium plume and has largely cut off the highest concentration portion of the plume and prevented it from extending to the Columbia River. Figure 7-21 shows hexavalent chromium concentration plots for the ISRM compliance wells. The 2010 hexavalent chromium concentrations were all below the 20 µg/L remedial action goal in the southernmost compliance well 199-D4-86, with a maximum measurement of 14.3 µg/L. The compliance monitoring wells in the northwest portion of the ISRM barrier generally contained higher concentrations of hexavalent chromium during the reporting period. The northernmost well, 199-D4-83, had levels of hexavalent chromium up to 109 µg/L during CY 2010, which is an increase from the CY 2009 maximum concentration of 95.8 µg/L. Groundwater in well 199-D4-39, also near the northeast end of the barrier, had a hexavalent chromium concentration of 798 µg/L in CY 2010; this level was slightly elevated from the range of 515 to 783 µg/L observed in CY 2009. Concentrations remained above the remedial action goal in well 199-D4-38 and 199-D4-84, downgradient from the central portion of the ISRM barrier, with maximum concentrations of 116 and 69µg/L, respectively.

The sample frequencies and constituents are listed in Appendix A. Table A-7 in Appendix A lists the deviations from planned sampling for the ISRM barrier. The results of operational monitoring and additional details about the ISRM barrier for CY 2010 will be published in the annual pump-and-treat performance report (DOE/RL-2011-25).

The dissolved oxygen concentrations are monitored as required by the ROD amendment (EPA/AMD/R10-00/122) and the remedial design report/remedial action work plan (DOE/RL-99-51, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation*). The sodium-dithionite injection process reduced dissolved oxygen in the groundwater at the barrier to low levels. Low levels of dissolved oxygen are monitored to assess changes as groundwater approaches the Columbia River, as well as to ensure that the dissolved oxygen levels have recovered sufficiently before water discharges into

the river. Low dissolved oxygen is a hazard to aquatic organisms. The dissolved oxygen profile in the vicinity of the ISRM treatment zone is generally characterized by relatively high dissolved oxygen concentrations upgradient of the treatment zone, dropping significantly through the treatment zone, and recovering to higher dissolved oxygen concentrations as groundwater flow approaches the river. A comparison was made between several wells in a line located upgradient of the ISRM (199-D4-15 and 199-D4-20), wells within the ISRM (199-D4-3 and 199-D4-19), and wells downgradient of the ISRM (199-D4-23 and 199-D4-84).

Since minimal data were collected in the fall of 2010, the dissolved oxygen sampling results from April through July were compared. The east line of wells moving from upgradient to downgradient (199-D4-15 at 8,920 µg/L; 199-D4-3 at 3,860 µg/L; and 199-D4-23 at 4,640 µg/L) show a reduction in oxygen of approximately 50%, with a slight increase occurring as moving downgradient. The west line of wells moving from upgradient to downgradient (199-D4-20 at 4,140 µg/L; 199-D4-19 at 1,220 µg/L; and 199-D4-84 at 1,620 µg/L) show a reduction in oxygen of approximately 70%, with a slight increase occurring as moving downgradient. Based on these results, it is evident that the ISRM barrier continues to create conditions that are favorable to hexavalent chromium reduction. This system, together with the downgradient DX pump-and-treat system extraction wells, will aid in meeting remedial action goals.

7.2.4 Zero-Valent Iron Injection

The ISRM barrier was completed in 2002 to intercept hexavalent chromium contamination in the unconfined aquifer. A 20-year service life was anticipated for the barrier, but some minor loss of barrier integrity was noted within 18 months of completion. In 2004, an independent technical panel recommended injection of micron-sized zero-valent iron to renew reducing conditions in the aquifer and mend portions of the barrier.

In 2007 and 2008, several zero-valent iron materials were evaluated in the laboratory to test their ability to move into the aquifer and chemically reduce groundwater. The compound RNIP-M2™ (trademark of Toda Kogyo Corporation, Hiroshima, Japan) was judged superior, and approximately 370,000 liters of iron slurry containing 2,400 kilograms of RNIP-M2 were injected into well 199-D4-26 within the ISRM barrier over a 5-day period in August 2008. Information from a network of monitoring wells and a post-injection verification well show that the iron was communicated greater than 7 meters into the aquifer. This is a sufficient radius of influence to form a continuous permeable reactive barrier if adjacent ISRM wells are injected.

Groundwater samples collected from the area influenced by the injection have hexavalent and total chromium values at or near detection limits and low dissolved oxygen and nitrate. Samples from a monitoring well 60 meters downgradient from the injection well showed decreasing concentrations of hexavalent chromium and dissolved oxygen in CY 2010, indicating that the reducing zone created in the ISRM barrier by the iron injection test is influencing the groundwater in a fairly large area.

Additional information on the iron injection test is provided in DOE/RL-2009-35.

7.2.5 Characterization of Hexavalent Chromium Within the Ringold Upper Mud Unit

In response to the 5-year review (Action 12-1), an investigation was conducted on the deep hexavalent chromium contamination in the sediments of the RUM (SGW-47776). The second 5-year review noted that groundwater samples from one

deep well extending below the aquitard (i.e., RUM) exceeded both the groundwater standard of 48 µg/L (Ecology Publication 94-06, *Model Toxics Control Act Cleanup Regulation 173-340 WAC*) and the federal DWS of 100 µg/L for hexavalent chromium. The extent of hexavalent chromium contamination in this zone is not well understood. Action 12-1 from the review was to "perform additional characterization of the aquifer below the initial aquitard"; therefore, field characterization and aquifer testing were performed in the 100-H Area to address this milestone. The purpose of aquifer testing was to (1) gather data to help refine the conceptual model for the source of contamination in the RUM, (2) examine the potential hydraulic connection between the RUM and the unconfined aquifer, (3) evaluate the hydraulic properties of the first water-bearing layer within the RUM, and (4) evaluate the extent of hexavalent chromium contamination in the upper mud unit.

The aquifer tests were conducted in late CY 2009. The three wells used for the aquifer pumping tests (199-H3-2C, 199-H4-12C, and 199-H4-l5CS) exhibit hexavalent chromium contamination in confined groundwater. The results indicated persistent hexavalent chromium concentrations over the duration of testing, suggesting a large-scale emplacement of hexavalent chromium consistent with a high-volume, low-concentration source such as reactor cooling water that mounded up in this area with sufficient hydraulic head to drive water into this sandy layer in the RUM. The concentration decreases upgradient toward the horn area, suggesting a limit on the eastward extent of contamination. This is consistent with the results of the horn area investigation (DOE/RL-2008-42), which found locations in the same horizon in the horn area with no hexavalent chromium contamination.

The results suggest that the most likely explanation for the origin of the hexavalent chromium in the RUM underlying the 100-H Area is from contaminated cooling water that passed through the H Reactor. The cooling water contained up to 1,000 µg/L of hexavalent chromium, which was subsequently discharged to the ground in large quantities. This water formed a mound that provided sufficient hydraulic driving force to push into the upper RUM and mix with existing groundwater in the unit, resulting in concentrations of one-tenth to one-thirtieth of the original cooling water. Concentrations decline inland, consistent with a reactor mound. The areal extent and relatively high continuous concentrations rule out localized contamination during well drilling.

Concurrent with the testing in the RUM layer, pumping was stopped in the overlying unconfined aquifer. Evaluation of the hexavalent chromium concentration versus time in the unconfined aquifer showed no clear concentration trends for hexavalent chromium in unconfined aquifer monitoring wells subsequent to temporary shutdown of the 100-HR-3 pump-and-treat system. Therefore, there is no support for any significant rebound of hexavalent chromium concentrations. This type of information will be needed in the future to assess whether the remedy is sufficient.

7.2.6 Horizontal Direction Drilling — Technology Demonstration

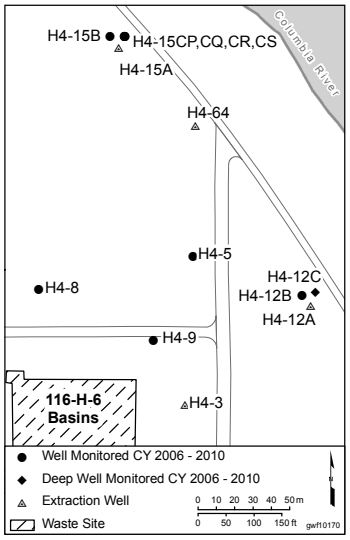
A technology demonstration of horizontal directional drilling was conducted in the 100-D Area to evaluate the capability of this technology in difficult geological conditions and to determine the feasibility of emplacing a horizontal well to intercept a groundwater hexavalent chromium plume. The primary goals of this demonstration were to drill through the 25-meter-thick vadose zone and emplace a 90-meter-long screen in the unconfined aquifer. Secondary objectives were to minimize the loss of drilling fluid to the vadose zone and aquifer and to place the screen within

1.5 meters of the middle of the aquifer. The field demonstration was performed from November 2009 through January 2010.

The drilling and construction of a blind entry horizontal well involved using a down-hole hammer to advance approximately 53.3 meters of casing at a 16-degree angle from horizontal (true vertical depth of 15.2 meters) to penetrate and case-off the full thickness of the Hanford formation. At this point, the drilling method would switch to mud rotary drilling to advance a directional borehole for a total distance of ~207 meters, sufficient to emplace a 90-meter string of slotted well screen at a total vertical depth of 27.4 meters below ground surface.

This test did not result in successful installation of a horizontal groundwater well. Despite best efforts, only 24.7 meters of surface casing was installed at a 16-degree angle from horizontal. The bottom of the casing was 8.17 meters below ground surface. The principal impediments to casing installation were difficulty in removing cuttings from the nearly horizontal casing and inability of the down-hole hammer to advance through the unconsolidated Hanford formation. Attempts to drill beyond the casing with the directional drilling equipment were unsuccessful due to nearly 100% loss of drilling fluids to the Hanford formation. Therefore, the drilling methods used were not capable of advancing casing to a depth sufficient to begin horizontal drilling. The down-hole hammer system could not advance casing or a boring any further than 7.1 meters below ground surface (true vertical depth) due to difficulties removing cuttings with insufficient air return flow. The results and analysis of this technology demonstration may be useful to project planners, scientists, and contractors who are considering similar types of projects at the Hanford Site.

7.3 RCRA Groundwater Monitoring of 183-H Solar Evaporation Basins



The 183-H solar evaporation basins (waste site 116-H-6) included four sedimentation and flocculation basins remaining from operation of the 183-H water treatment facility. The four basins received combined radioactive and dangerous (mixed) waste for storage and treatment from the 300 Area fuel fabrication facilities from July 1973 until November 1985. By the fall of 1996, the waste remaining in the basins was removed, the basins were demolished, and the underlying contaminated soil was removed and replaced with clean fill.

Clean closure of the site was not achieved because fluoride and nitrate levels in soil below the 4.6-meter-deep excavation exceed the Method B cleanup levels of WAC 173-340. Therefore, the unit was closed under the partial-closure option, with specified measures for post-closure care.

The Hanford Facility RCRA Permit requires annual monitoring of the facility, which includes sampling four wells (199-H4-3, 199-H4-8, 199-H4-12A, and 199-H4-12C) for total chromium, fluoride, nitrate, technetium-99, and uranium. Although not regulated under RCRA, technetium-99 and uranium were included in the monitoring plan for completeness and were incorporated by reference in the RCRA Permit. The sample frequencies and constituents are listed in Appendix B. Table B-7 in Appendix B documents the deviations from planned sampling for the RCRA site.

All four quarters of CY 2010 are included in this report. The four-quarter period includes one RCRA sampling event (December 2010). The RCRA wells were sampled as scheduled per the RCRA recovery schedule for the constituents of interest listed

in the groundwater monitoring plan (PNNL-11573, *Groundwater Monitoring Plan for the 183-H Solar Evaporation Basins*). The wells were originally scheduled for sampling in November 2010; however, due to safety concerns pertaining to all groundwater sampling, the wells were sampled in December 2010.

In CY 2010, the concentrations of most contaminants (e.g., nitrate, fluoride, technetium-99, and uranium) at the 183-H solar evaporation basins remained below applicable concentration limits. Total chromium concentrations were below the 122 µg/L RCRA Permit concentration limit in three wells, but concentrations in well 199-H4-12C in December 2010 were above this level (128 and 133 µg/L in filtered and unfiltered samples, respectively). The levels in this well have declined from ~300 µg/L in the early 1990s, and concentrations had been stable for the past several years before increasing since November 2009. Because none of the other 183-H solar evaporation basin co-contaminants were elevated in well 199-H4-12C, it is likely that the total chromium in this well has an alternate source (i.e., H Reactor coolant water that entered the RUM). Well 199-H4-12C began operating as an extraction well in August 2010. Table 7-1 shows the maximum concentration of each permit constituent and the corresponding well detected among the monitoring network.

7.4 Conclusions and Recommendations

The conclusions and recommendations for the 100-HR-3 OU are presented in this section.

7.4.1 Conclusions

The DR-5, HR-3, and ISRM remedies have contributed to meeting the remedial action objectives; however, the old pump-and-treat systems were undersized, and the ISRM barrier experienced some breakthrough in a high-concentration zone. The DX pump-and-treat system is now operational, with the HX pump-and-treat system scheduled to be online later in 2011. These additional remedies are much more robust and will reduce hexavalent chromium concentrations in groundwater before reaching the Columbia River.

The conclusions with respect to each remedial action objective are discussed below.

- **Remedial action objective #1.** *Protect aquatic receptors in the river bottom substrate from contaminants in the groundwater entering the Columbia River.*

  100-D Area:

  – During CY 2010, the DR-5 pump-and-treat system extracted 44.6 million liters of groundwater from the 100-D Area, which is an 8 percent decrease when compared to 48.6 million liters processed in CY 2009. The system removed 74.9 kilograms of hexavalent chromium during the reporting period, for a total of 326.2 kilograms removed since 2004.

  – The CY 2010 hexavalent chromium concentrations were above the 20 µg/L remedial action goal in both compliance wells 199-D8-69 and 199-D8-70. Well 199-D8-69 has since been converted into an extraction well for the DX pump-and-treat system, which should reduce the hexavalent chromium concentrations within this portion of the unconfined aquifer.

  – Overall, the ISRM barrier continues to help reduce hexavalent chromium in the aquifer. However, during periods of low flow, hexavalent chromium values above the remedial action goal were observed in some downgradient wells.

However, downgradient DX pump-and-treat system extraction wells now compensate for ISRM breakthrough, which will reduce hexavalent chromium concentrations in groundwater before reaching the river.

100-H Area:

– In CY 2010, the HR-3 pump-and-treat system extracted 267.9 million liters of groundwater from the 100-HR-3 OU, which is a 33% increase in volume compared to 177.3 million liters processed in CY 2009. The system removed 31 kilograms of hexavalent chromium in CY 2010, bringing the total amount removed since 1997 to 392.9 kilograms.

– The CY 2010 hexavalent chromium concentrations were less than the 20 µg/L remedial action goal in two of four original compliance wells, 199-H4-5 and 199-H4-13. A May 2010 groundwater sample from well 199-H4-11 had a hexavalent chromium concentration of 21.6 µg/L, but the March and December concentrations were less than 20 µg/L. The groundwater sample from well 199-H4-10 fluctuated between slightly exceeding and being beneath the remedial action goal. Groundwater samples from all four compliance wells continue to show decreasing hexavalent concentration trends.

– The CY 2010 hexavalent chromium concentrations were greater than the 20 µg/L remedial action goal in HR-3 pump-and-treat system extractions wells 199-H4-64 (26 µg/L) and 199-H4-15A (31 µg/L). Wells 199-H4-15A and 199-H4-64 will be incorporated as extraction wells in the new HX pump-and-treat system to continue remediation.

– Aquifer testing of the first water-bearing layer within the RUM indicates that hexavalent chromium concentrations were higher in RUM wells 199-H4-12C and 199-H4-15CS (~100 µg/L) than in unconfined wells 199-H4-12A and 199-H4-15A. Well 199-H3-2C had hexavalent chromium levels of ~30 to 40 µg/L. The source of the hexavalent chromium in the RUM at the 100-H Area is believed to be from contaminated H Reactor cooling water discharged to the ground in sufficient quantities to form a mound.

Horn area:

– Characterization wells and aquifer tubes completed during the past several years indicate that a low-concentration hexavalent chromium plume originating from the 100-D Area underlies the horn area. The last of the RPO wells were installed in 2010 to remediate groundwater underlying this area.

- **Remedial action objective #2.** *Protect human health by preventing exposure to contaminants in the groundwater.*

The interim remedial action ROD (EPA/ROD/R10-96/134) establishes a variety of institutional controls 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 institutional controls was presented in the *2004 Site Wide Institutional Controls Annual Assessment Report for Hanford CERCLA Response Actions* (DOE/RL-2004-56). The findings of this report indicate that institutional controls were maintained to prevent public access, as required.

- **Remedial action objective #3.** *Provide information that will lead to a final remedy.*
  - Since 1997, a significant mass of hexavalent chromium has been removed from groundwater underlying the 100-HR-3 OU (719 kilograms). However, the overall areal extent of the 100-D Area hexavalent chromium plume has not been affected significantly by pump-and-treat operations. The new DX pump-and-treat system will help facilitate the remediation effort by expanding the capture zone, thereby drawing a larger volume of contaminated groundwater for treatment. In addition, drilling and installation of new characterization and monitoring wells has aided in defining the extent of contamination.
  - Preliminary RI results indicate that the conceptual site model for the 100-HR-3 OU remains unchanged. Most of the hexavalent chromium is already contained in the groundwater; therefore, the proposed DX/HX system will capture and treat residual contaminants.
  - Contaminant concentrations in aquifer tubes have been reduced.
  - The ISRM technology is not fully functional for the purpose it was emplaced. Hexavalent chromium concentrations still exceed remedial action objectives in compliance wells downgradient after multiple years of operation. However, downgradient extraction wells for the DX pump-and-treat system were added to reduce hexavalent chromium concentrations before reaching the river and reduce concentrations to a level that are manageable by the ISRM barrier.

7.4.2 Recommendations

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

- Understand the operation of the newly designed and constructed DX and HX pump-and-treat systems. Extract and inject at the design rates and then vary the rates to understand the possible range of operation. Identify opportunities to optimize the performance and operation of existing components of the DX system that began operations at the end of CY 2010 and at the HX system that will begin operations in the fourth quarter of CY 2011.
- Update the groundwater model with actual well flow rates and pump-and-treat system data from the DX system startup late in CY 2010 for future analysis.
- Revise the remedial design/remedial action work plan to reflect upgrades to the DX and HX pump-and-treat systems, and obtain concurrence from Ecology on the associated monitoring well network and analyte list.
- Initiate installation of a compliance well network for the DX and HX pump-and-treat systems consisting of approximately eleven additional monitoring wells located primarily along the 100-D and 100-H Area shorelines for river protection monitoring, plus several wells interior to the plume for groundwater cleanup monitoring. Include these wells in future sampling events.
- Initiate pumping at the DX system in CY 2011 from the 100-D Area hot spot using wells 199-D5-99 and 199-D5-122.

Additional recommendations include the following:

- Evaluate the response of the 100-D Area hot spot to pumping of the larger volumes in the DX system.
- Evaluate the response of the 100-D Area hot spot to the 100-D-100 excavation of the overlying vadose zone sediments in the adjacent monitoring wells.
- Continue to pump the contaminated zone in the RUM in the 100-H Area after the HX system begins operations. Consider adding wells to the network based on the refined nature and extent developed in the 100-D and 100-H Areas RI/FS. Until system startup, monitor for potential rebound in concentrations in groundwater within the zone of influence of the HR-3 system.
- The timing of pump-and-treat system shutdowns will be planned to minimize contaminant flux to the Columbia River by scheduling outages during high river stage times of the year (i.e., spring and summer).
- Evaluate changes in concentrations in the 100-H Area during transition from HR-3 system to the HX system in CY 2011 while the pumps are shut down to determine whether any concentration rebound is occurring.
- Evaluate the effectiveness of the new DX and HX pump-and-treat systems with respect to 2012 Tri-Party Agreement Milestone M-016-110-TO1 target using groundwater concentration data, hydraulic head data, capture zone analyses, and further modeling to integrate the model with the data.
- Continue to review and modify the groundwater cleanup strategy for the interim actions and evaluate alternatives.

Table 7-1. Concentration Limits for 183-H Solar Evaporation Basins

Constituent	Concentration Limit	Maximum Concentration Detected in CY 2010
Dangerous Waste Constituents		
Chromium (total, filtered samples)[a]	122 µg/L; local background when compliance monitoring plan was written (1996); upgradient sources	133 µg/L (199-H4-12C)
Nitrate	45 mg/L; DWS (as NO_3)	37.7 mg/L (199-H4-3)
Fluoride	4,000 µg/L[b]	128 µg/L (199-H4-3)
Other 183-H Waste Indicators		
Technetium-99	900 pCi/L	94 pCi/L (199-H4-12A)
Uranium (total; chemical analysis)	20 µg/L; proposed DWS when monitoring plan was written (1996)	12.2 µg/L (199-H4-3)

a. Chromium results discussed here represent hexavalent chromium, which can be measured either by analyses specifically for the hexavalent species or from total chromium measured in filtered samples. Dissolved chromium in Hanford Site groundwater is nearly all hexavalent.

b. The *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste* (WA7890008967) erroneously gives the value 1,400 µg/L as the U.S. Environmental Protection Agency's maximum contaminant level (DWS) for fluoride. The actual limit is 4,000 µg/L.

Figure 7-1. Facilities, Wells, and Shoreline Monitoring Sites in the 100-D Area

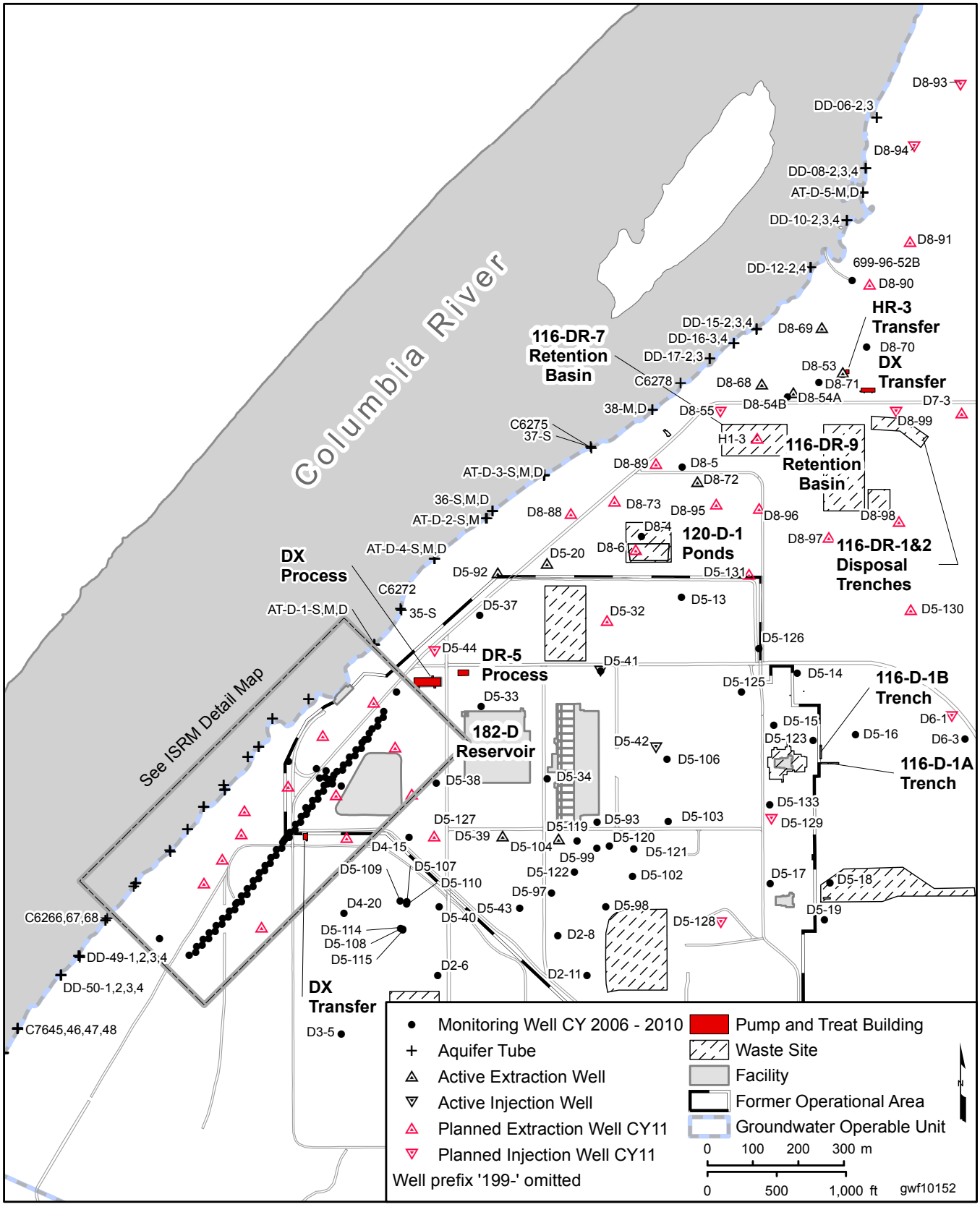


Figure 7-2. Facilities, Wells, and Shoreline Monitoring Sites in the 100-H Area

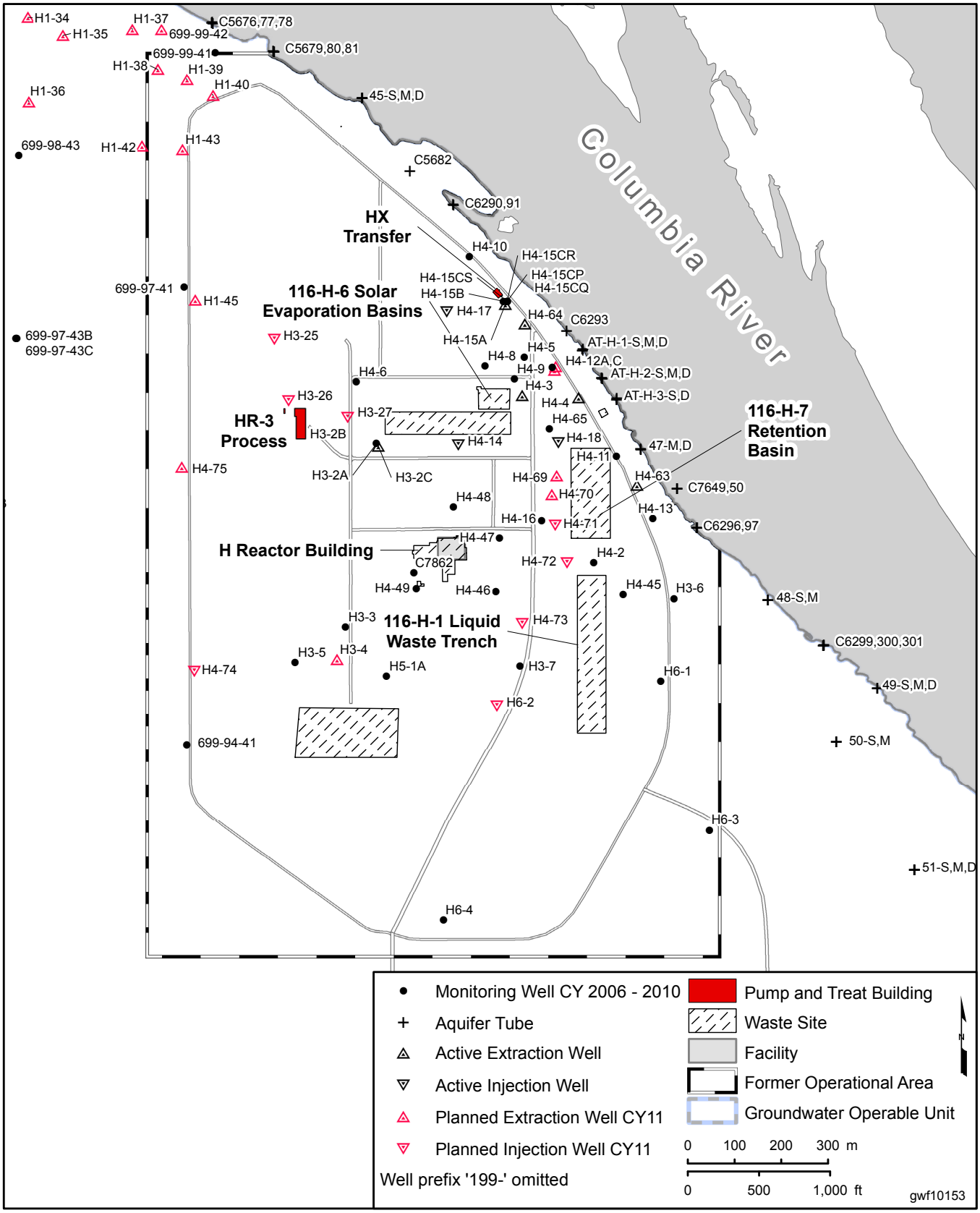


Figure 7-3. Facilities, Wells, and Shoreline Monitoring Sites within the Horn Area of the 100-HR-3 Operable Unit

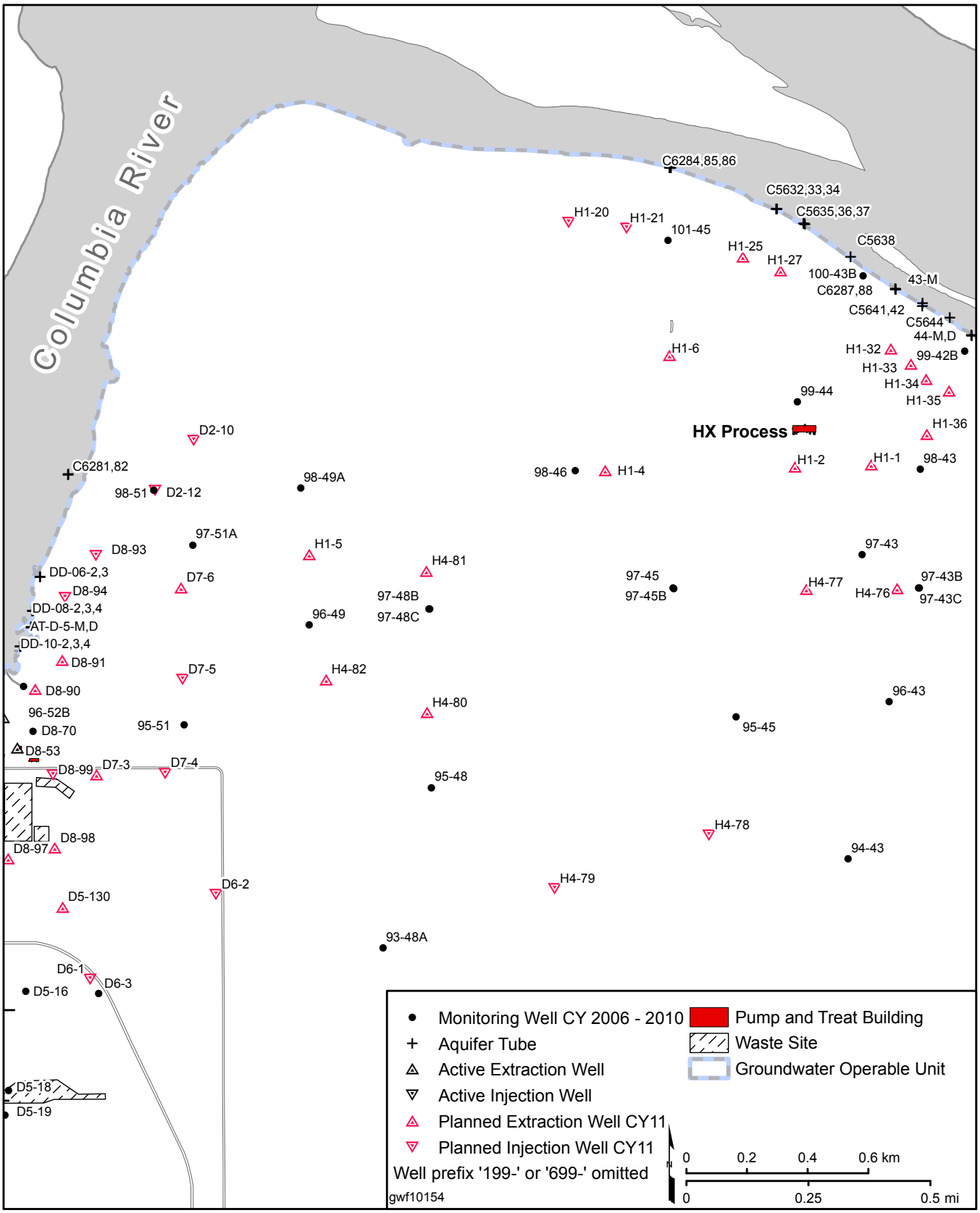


Figure 7-4. Conceptual Cross Section of the 100-D and 100-H Areas

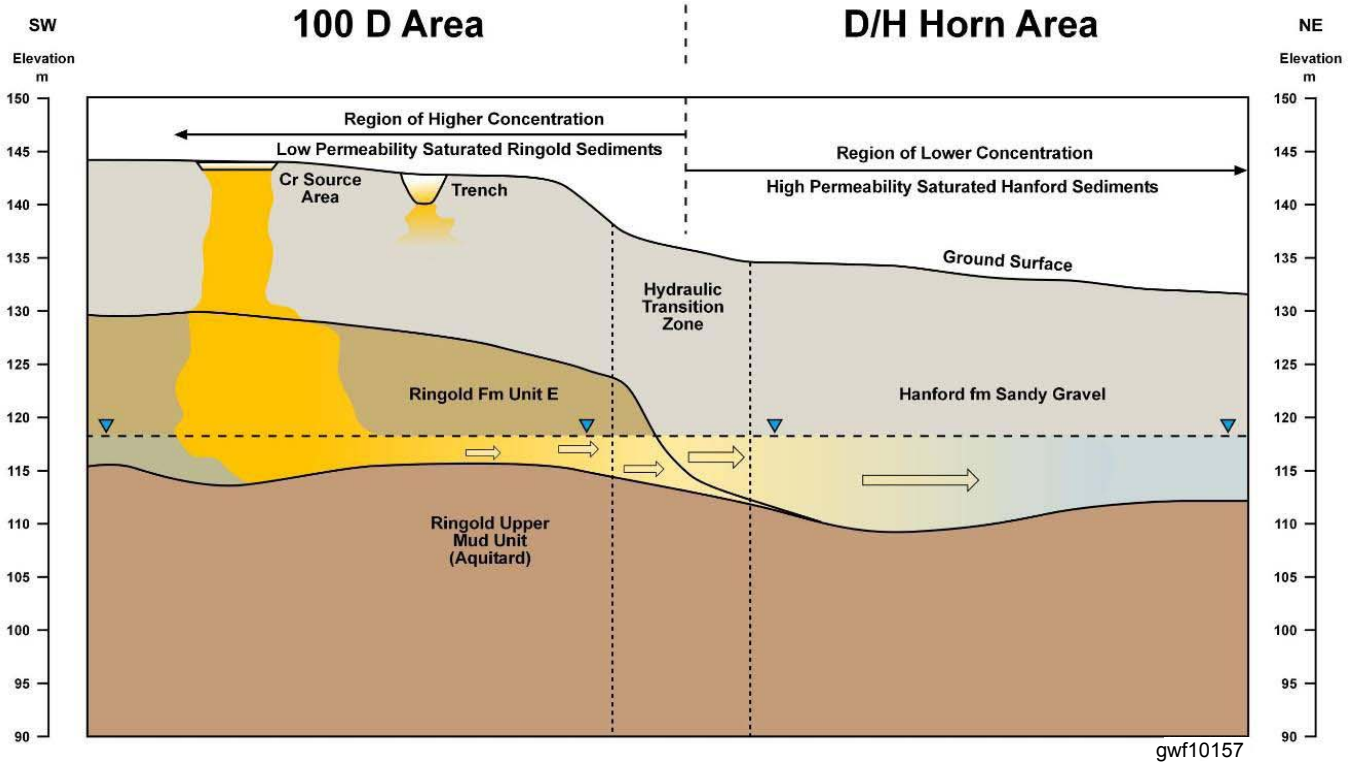


Figure 7-5. 100-HR-3 Operable Unit Water Table Elevation Map, March 2010

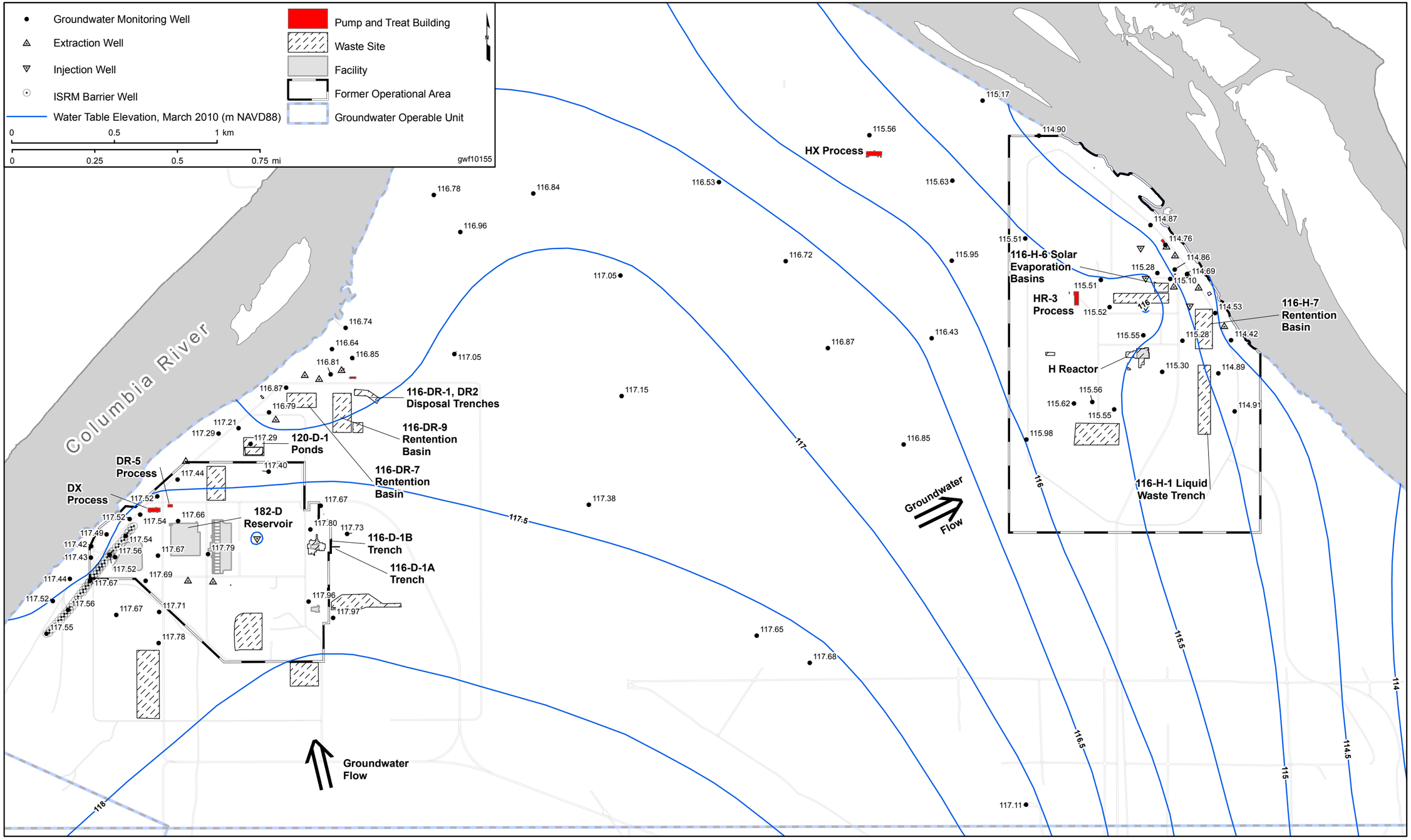


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Figure 7-6. 100-HR-3 Operable Unit Water Table Elevation Map, September 2010

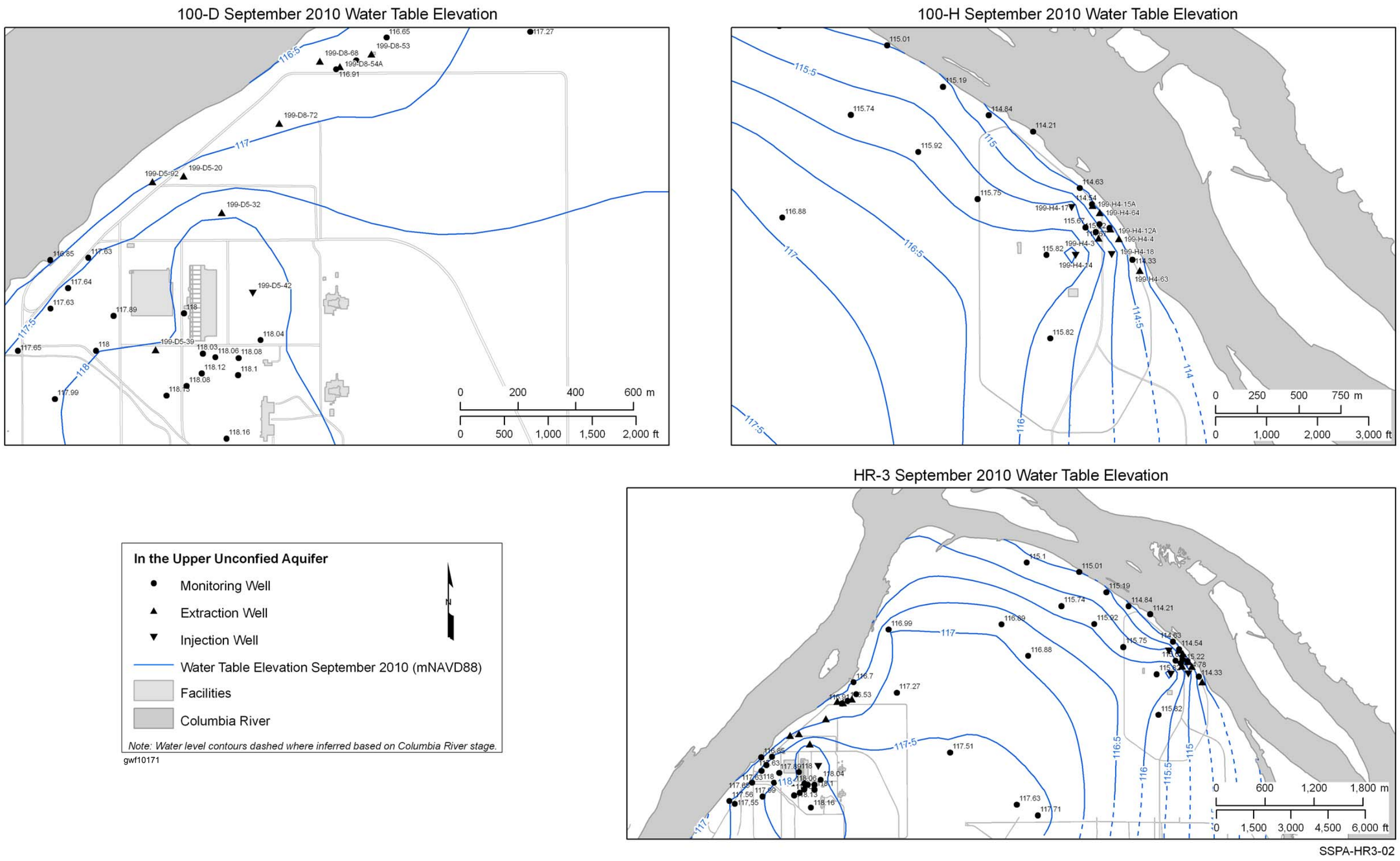

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Figure 7-7. 100-HR-3 Operable Unit Water Table Elevation Map, June 2010

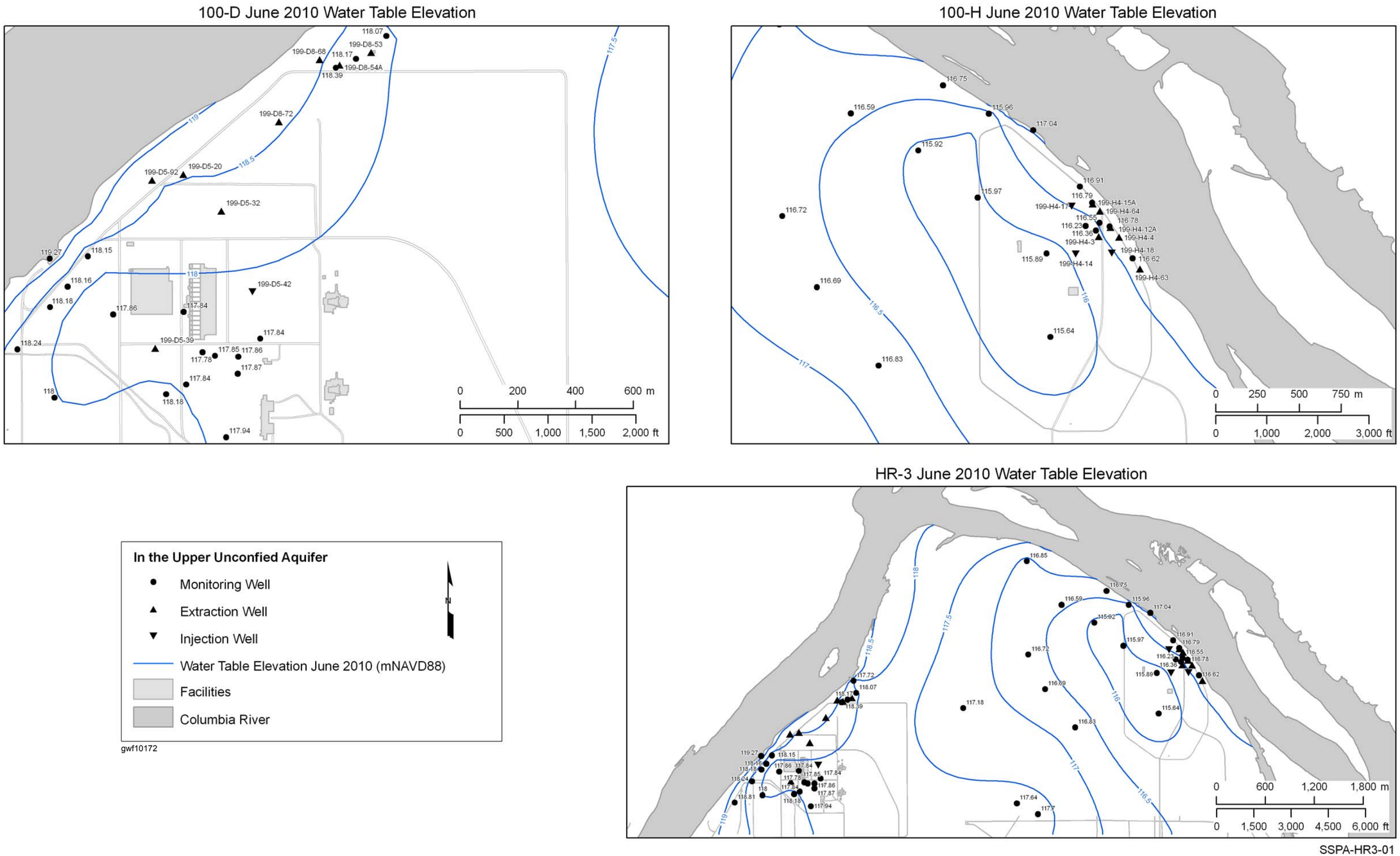

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Figure 7-8. 100-HR-3 Operable Unit Hexavalent Chromium Map, Spring 2010

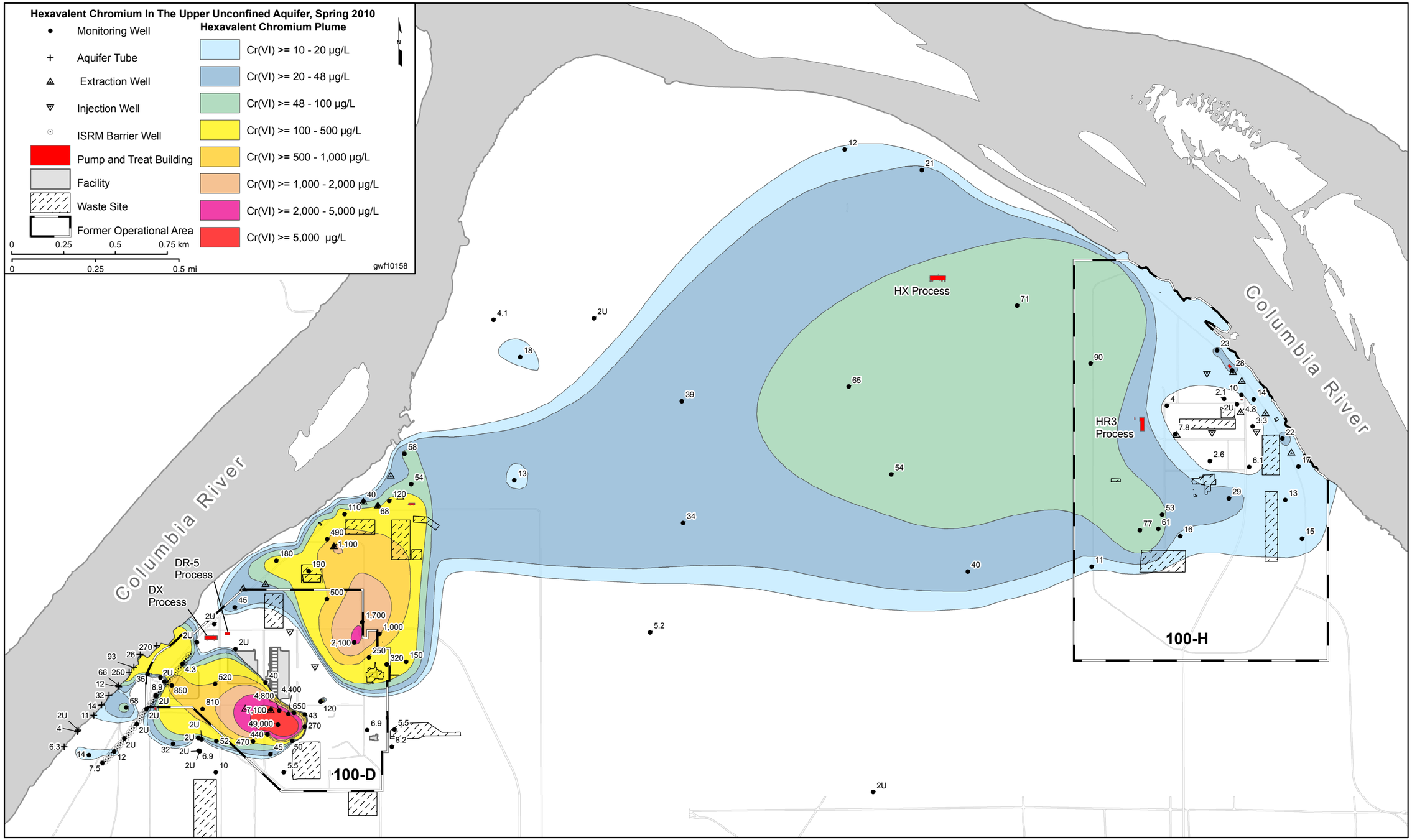

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Figure 7-9. 100-HR-3 Operable Unit Hexavalent Chromium Map, Fall 2010

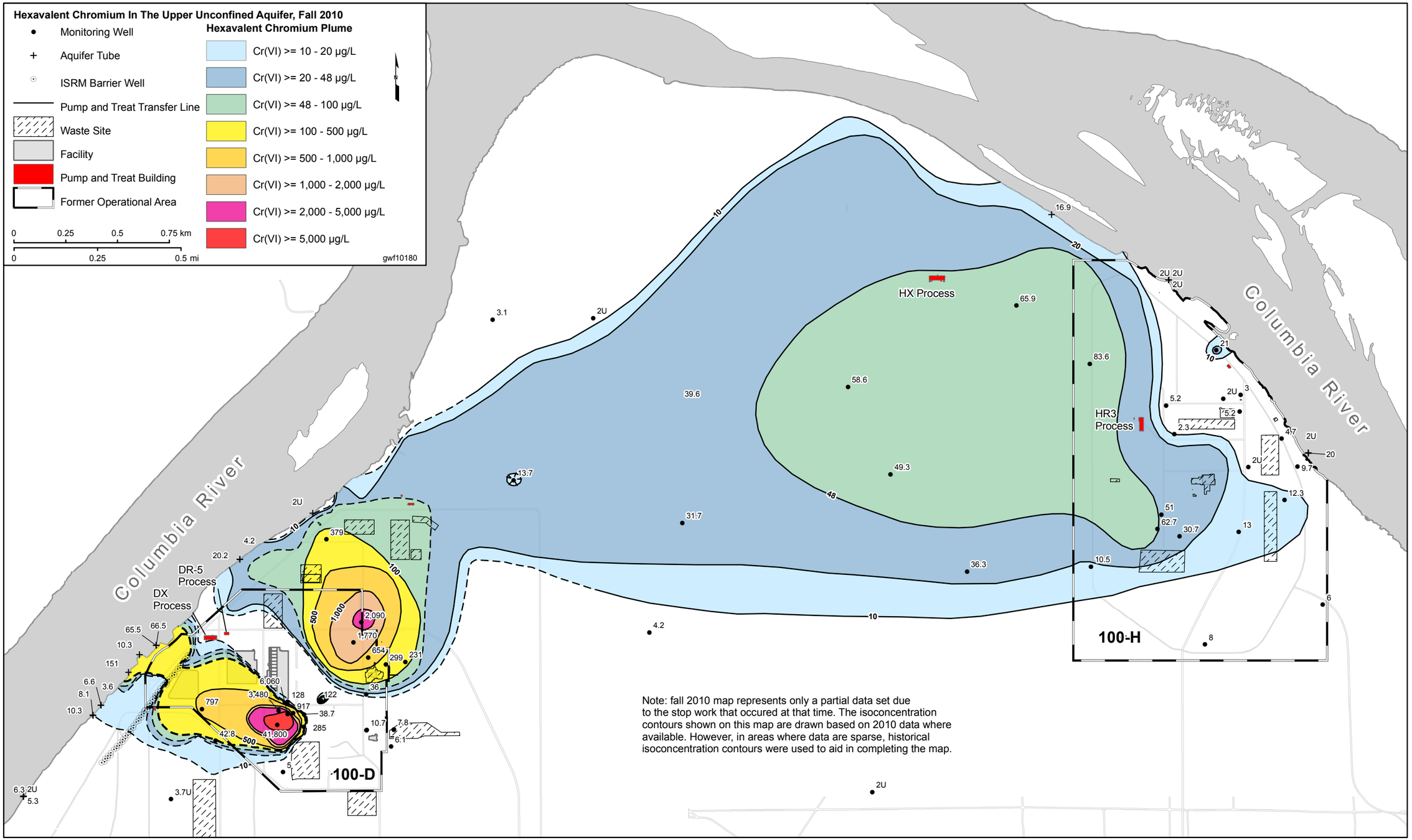

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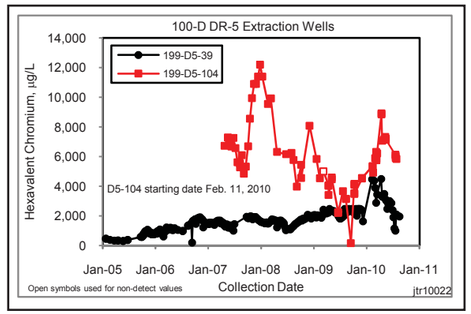
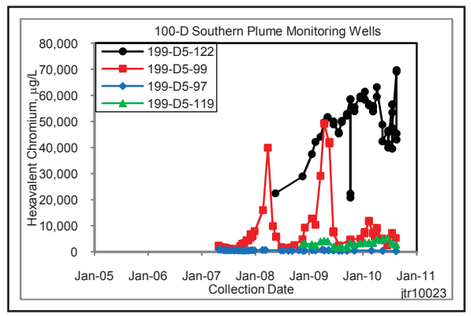
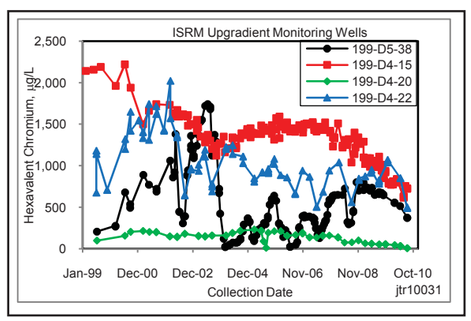
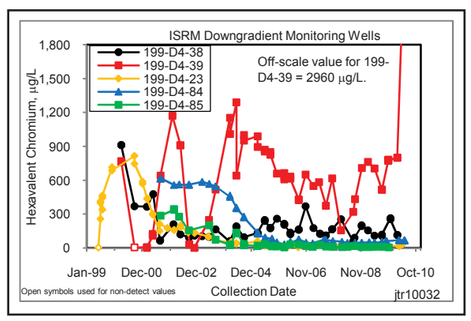
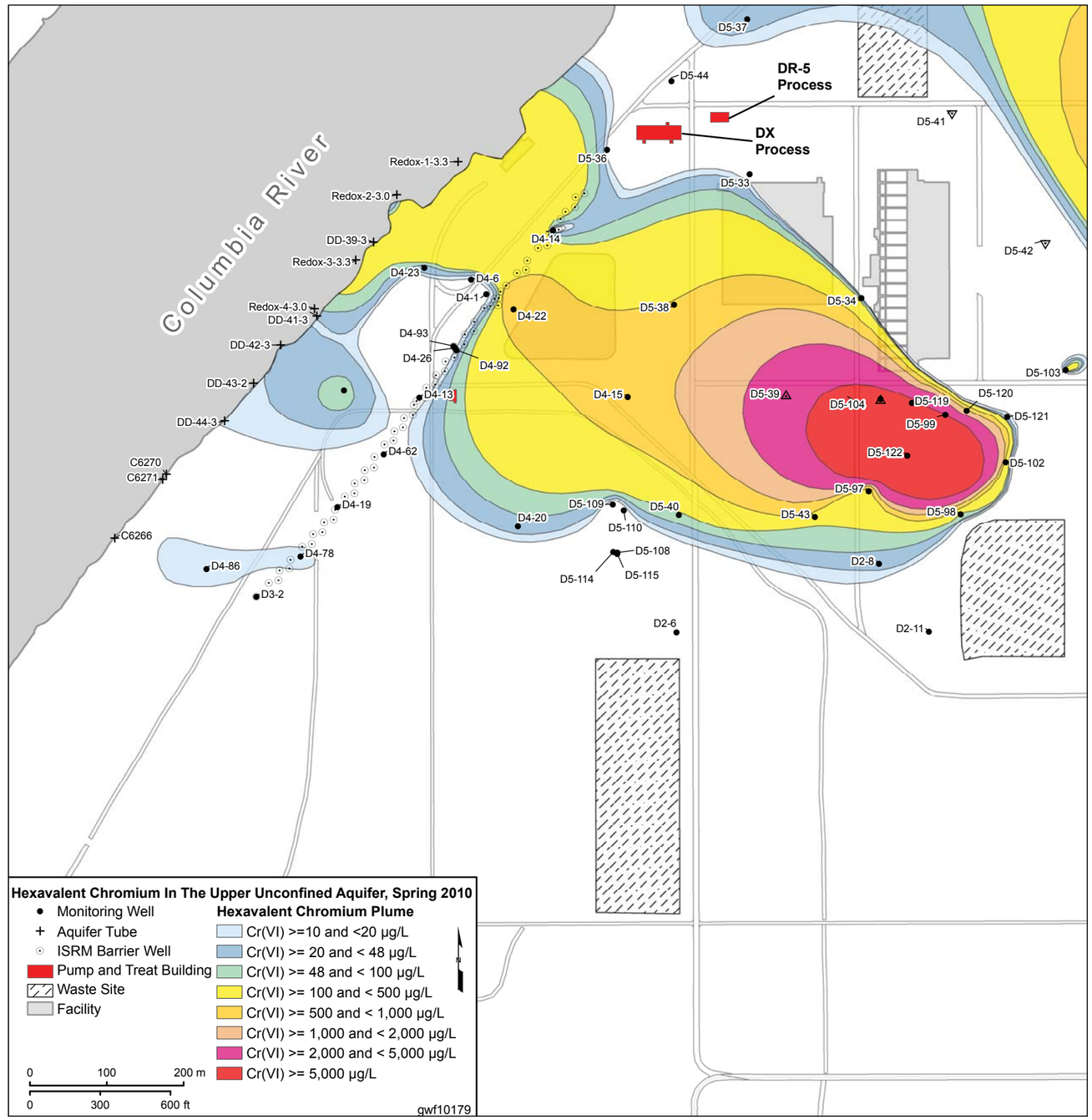
Figure 7-10. 100-D Area Hexavalent Chromium Trend Plots (South Plume)











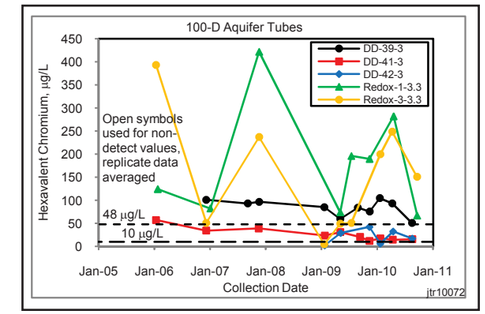


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Figure 7-11. 100-D Area Aquifer Tubes

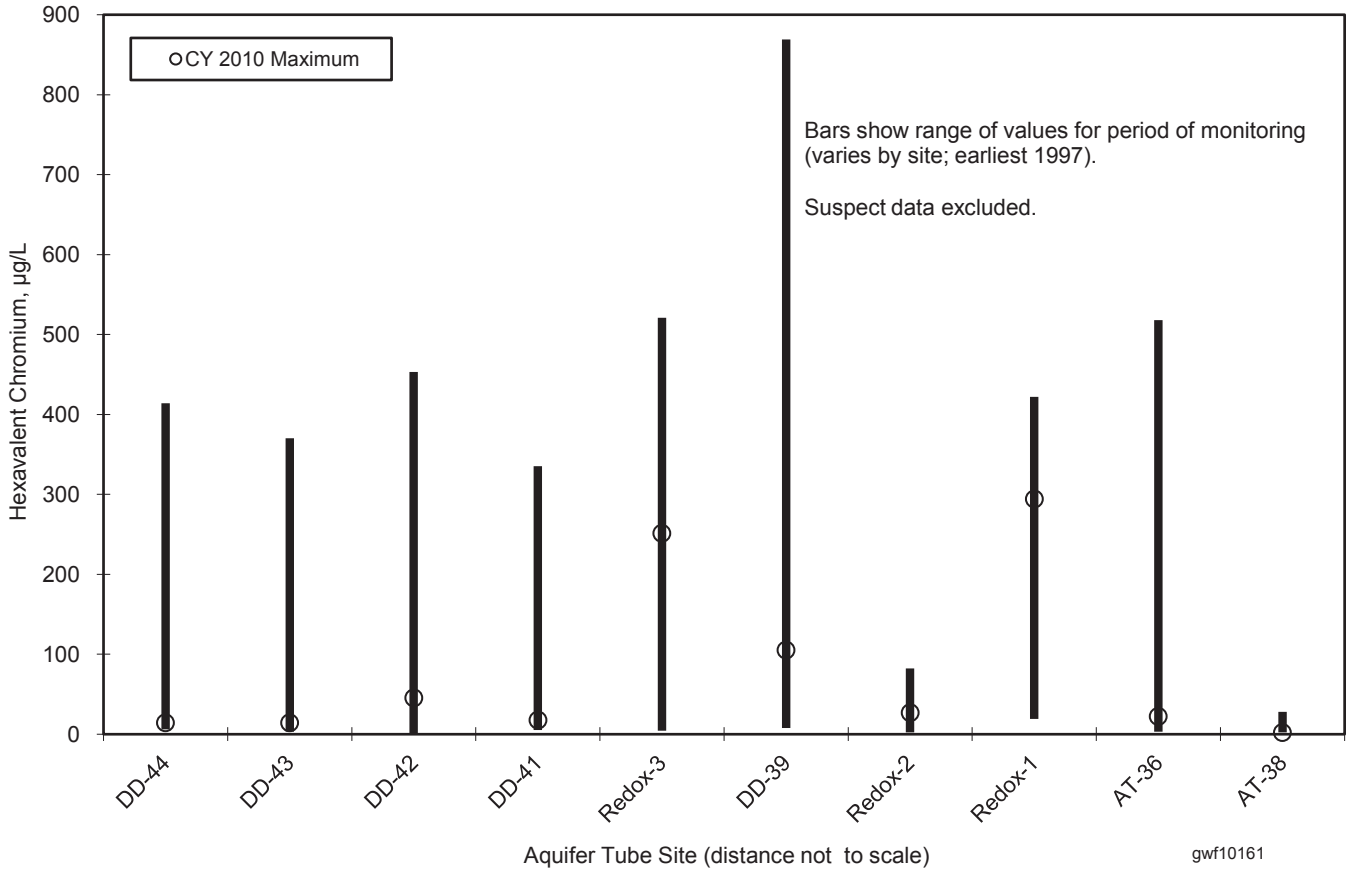

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Figure 7-12. 100-D Area Hexavalent Chromium Trend Plots (North Plume)

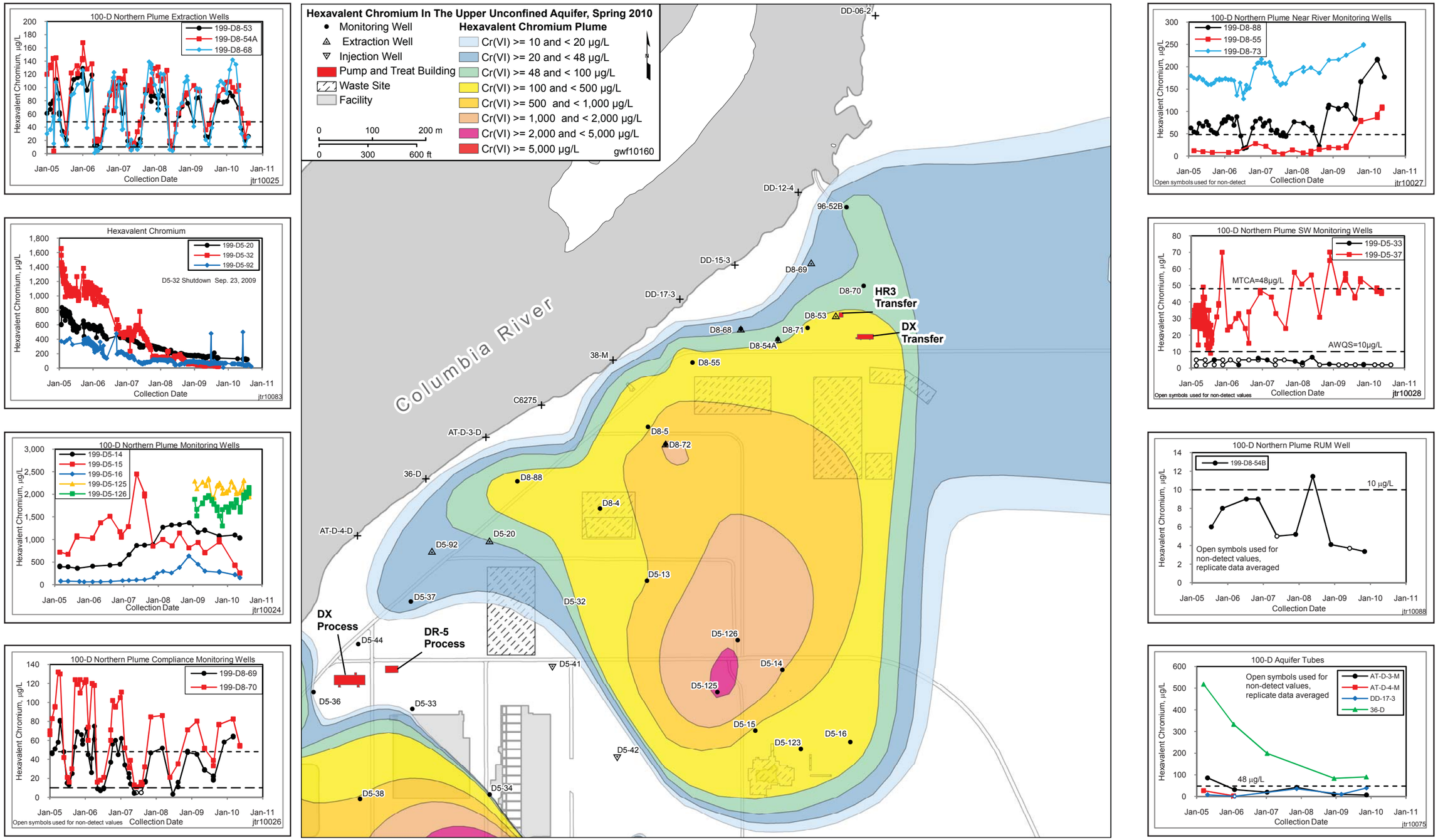

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Figure 7-13. 100-H Area Hexavalent Chromium Trend Plots

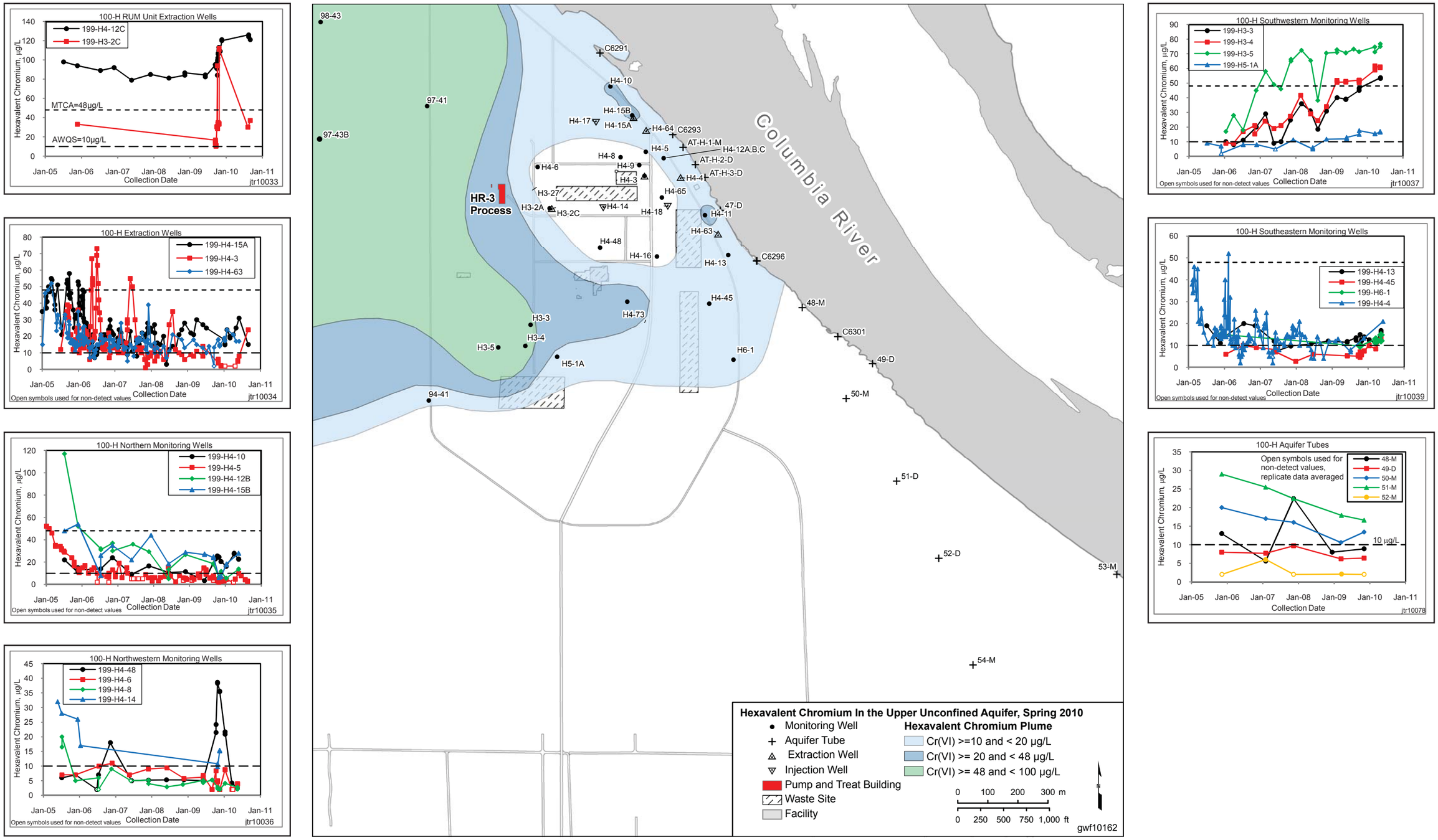

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Figure 7-14. 100-D Area Nitrate Map, Spring 2010

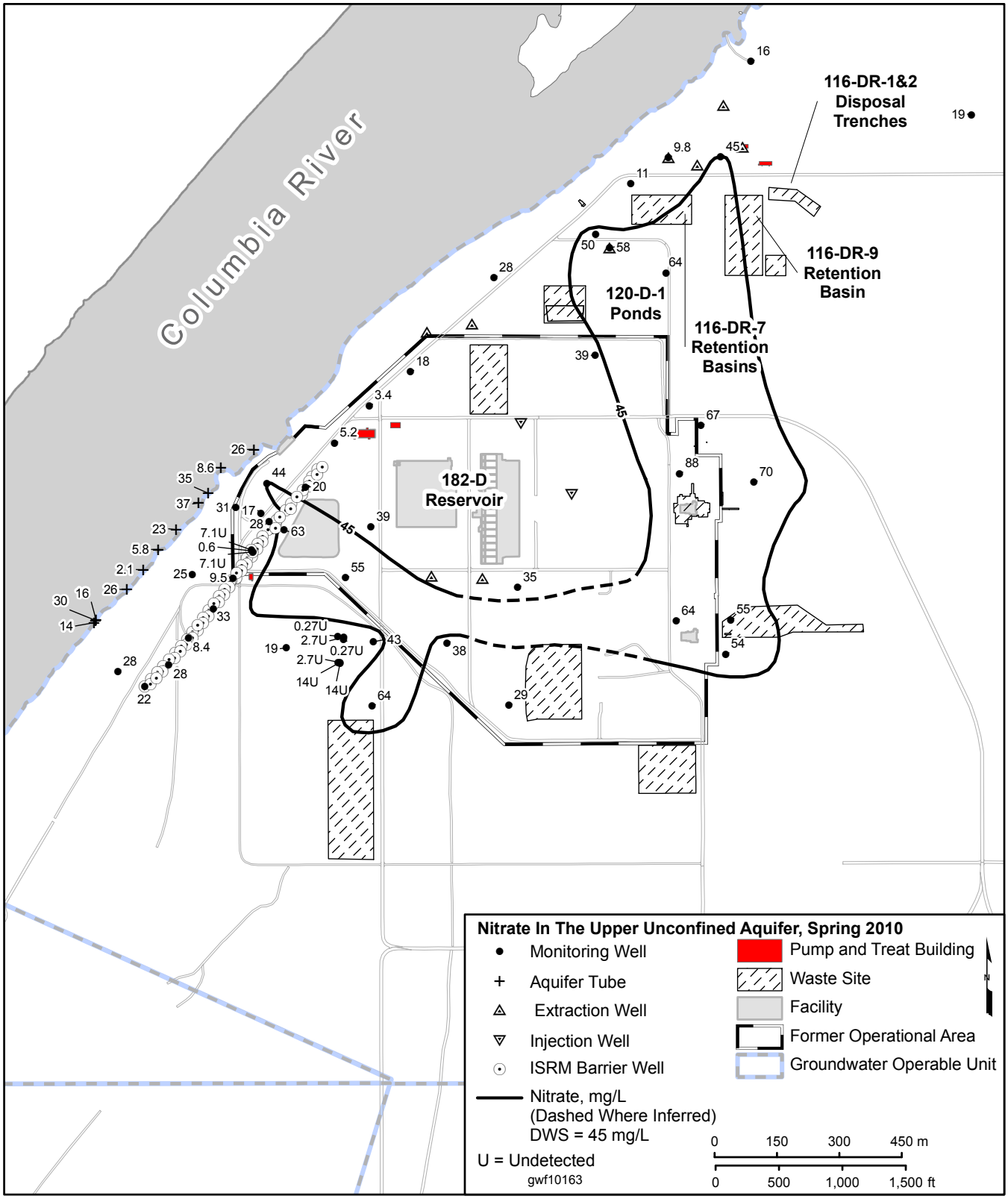

Figure 7-15. Injection/Extraction Well Locations in the 100-D Area

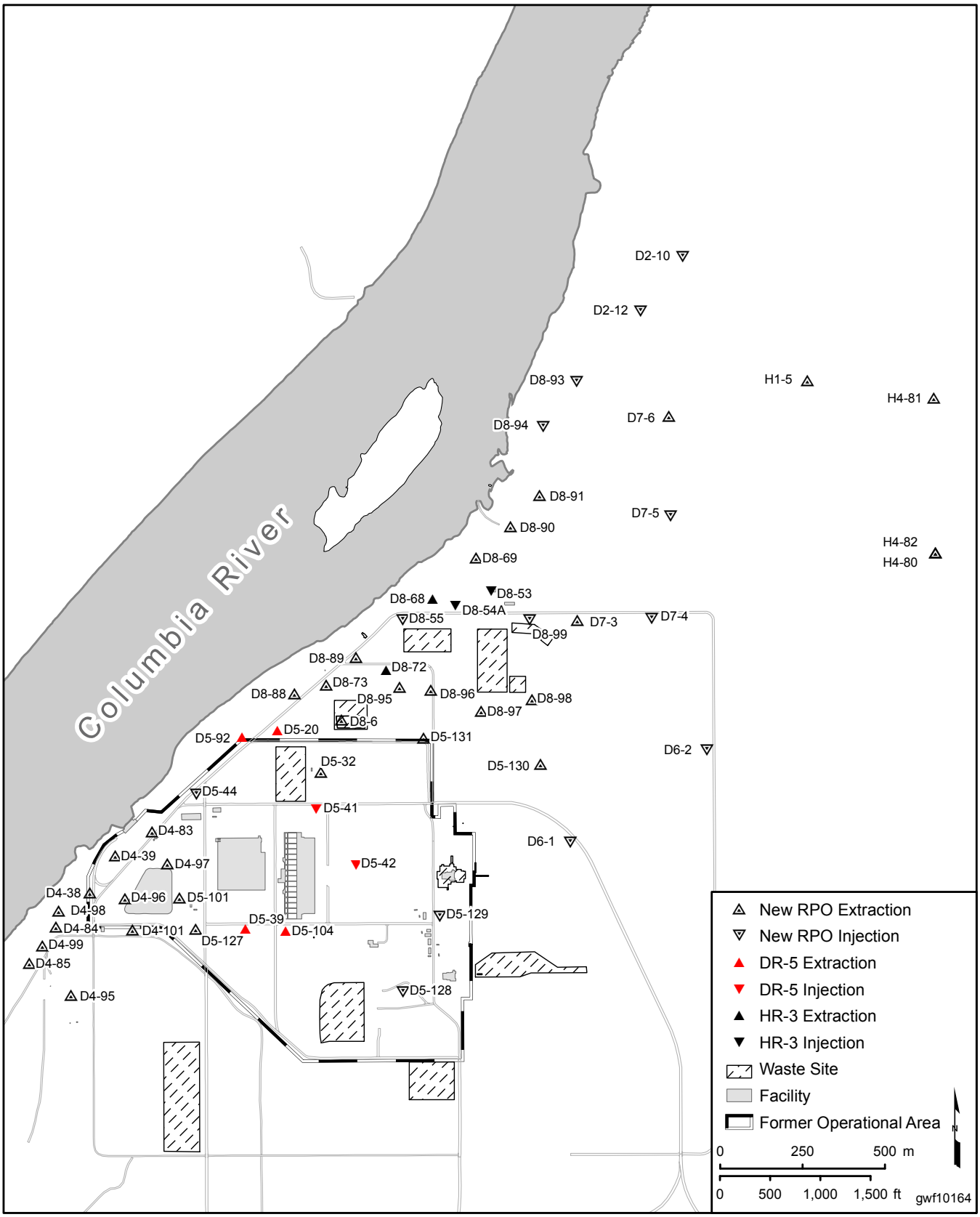

Figure 7-16. Injection/Extraction Well Locations in the 100-H Area

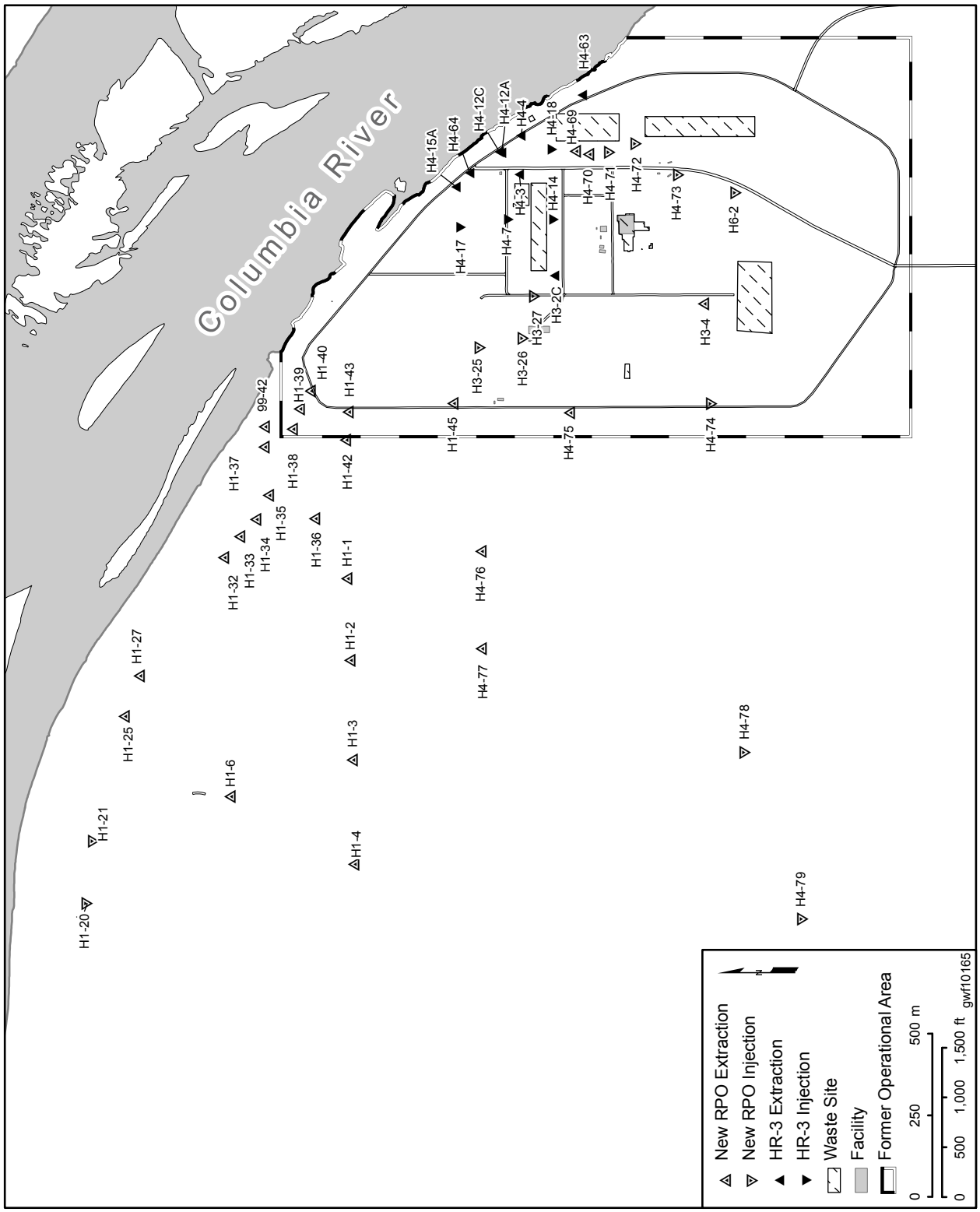

Figure 7-17. HR-3 Pump-and-Treat System Capture Efficiency/Frequency Map, CY 2010

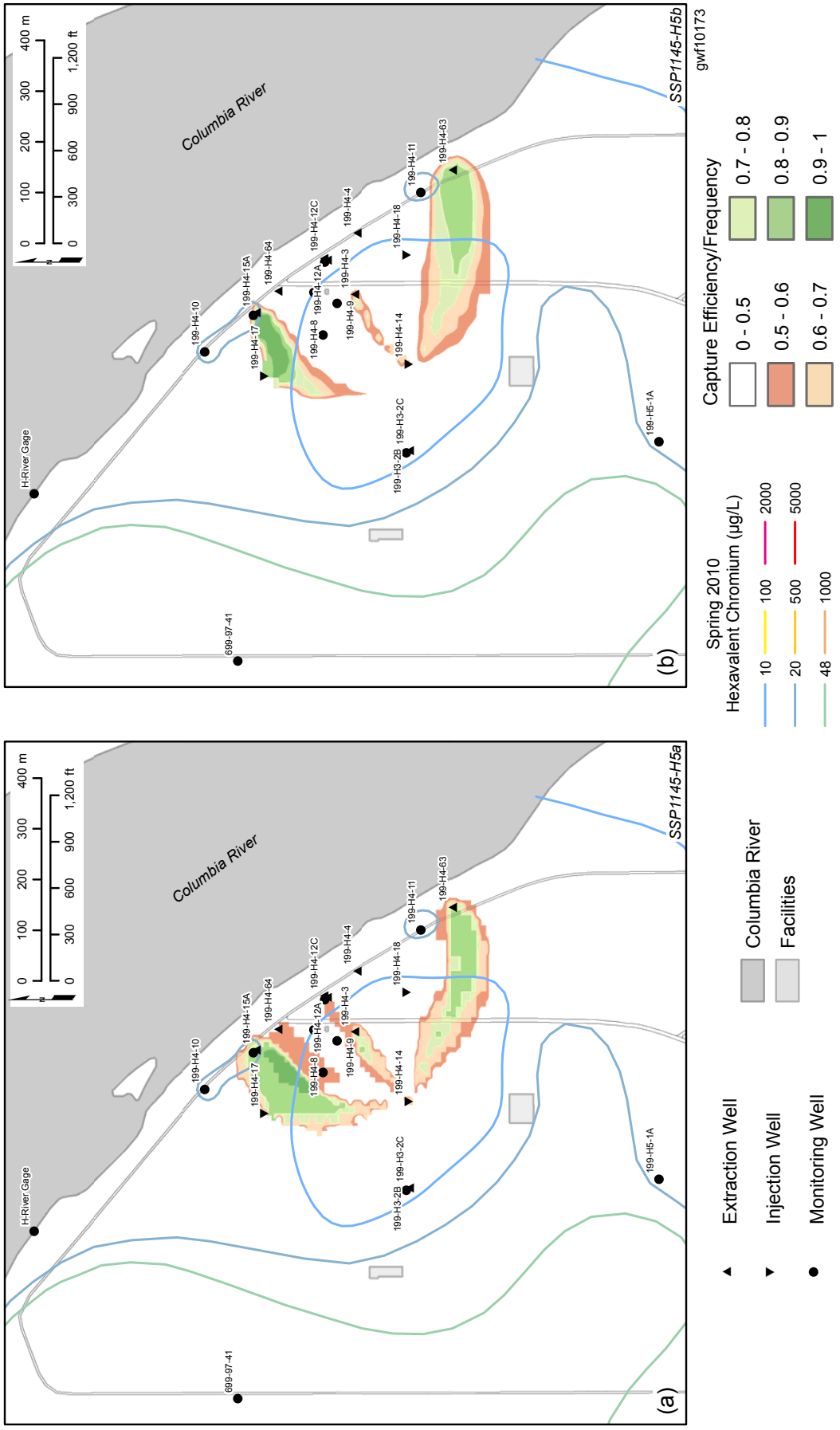

Figure 7-18. DR-5 Pump-and-Treat System Capture Efficiency/Frequency Map, CY 2010

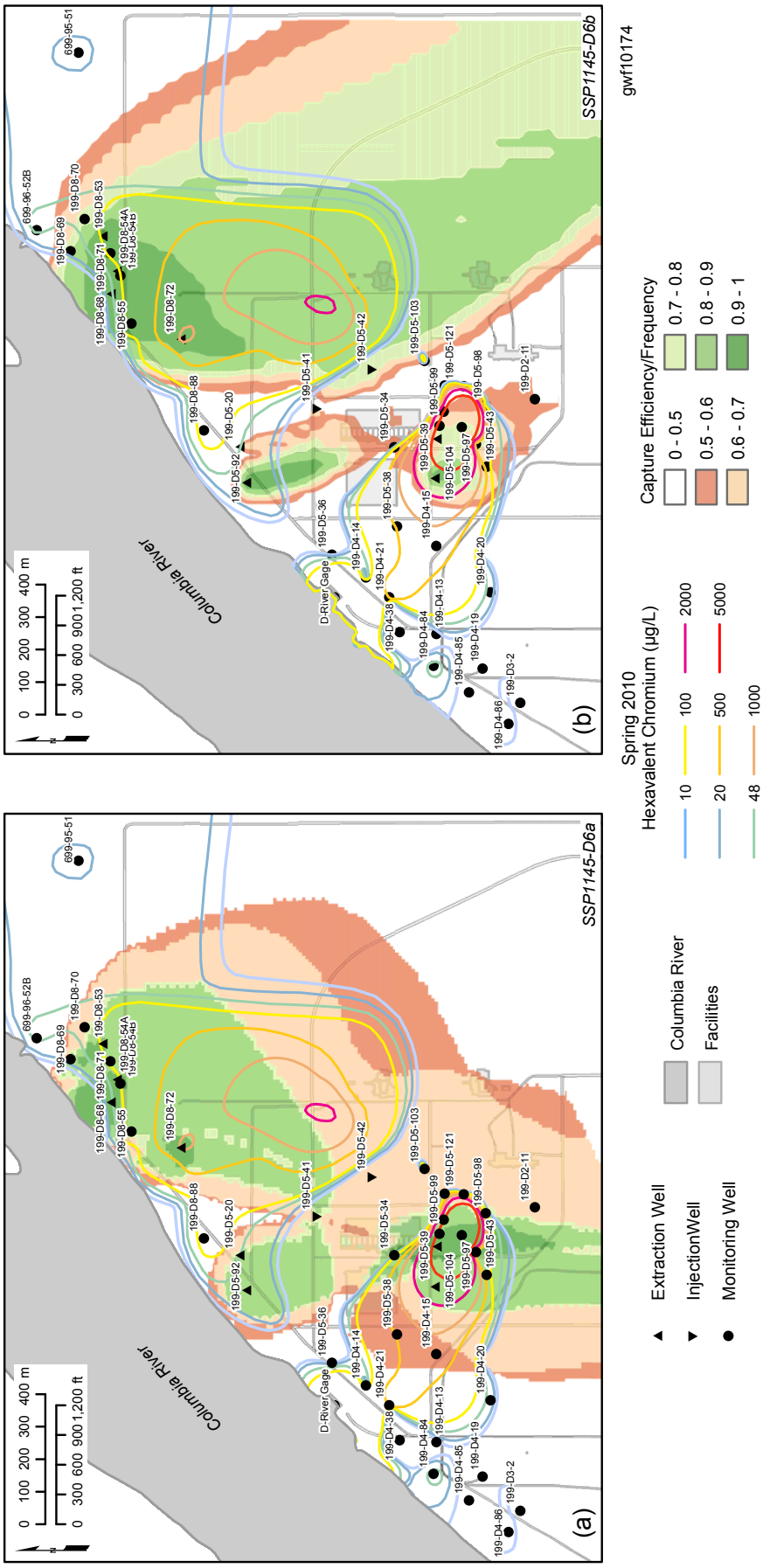

Figure 7-19. In Situ Redox Manipulation Detail Map

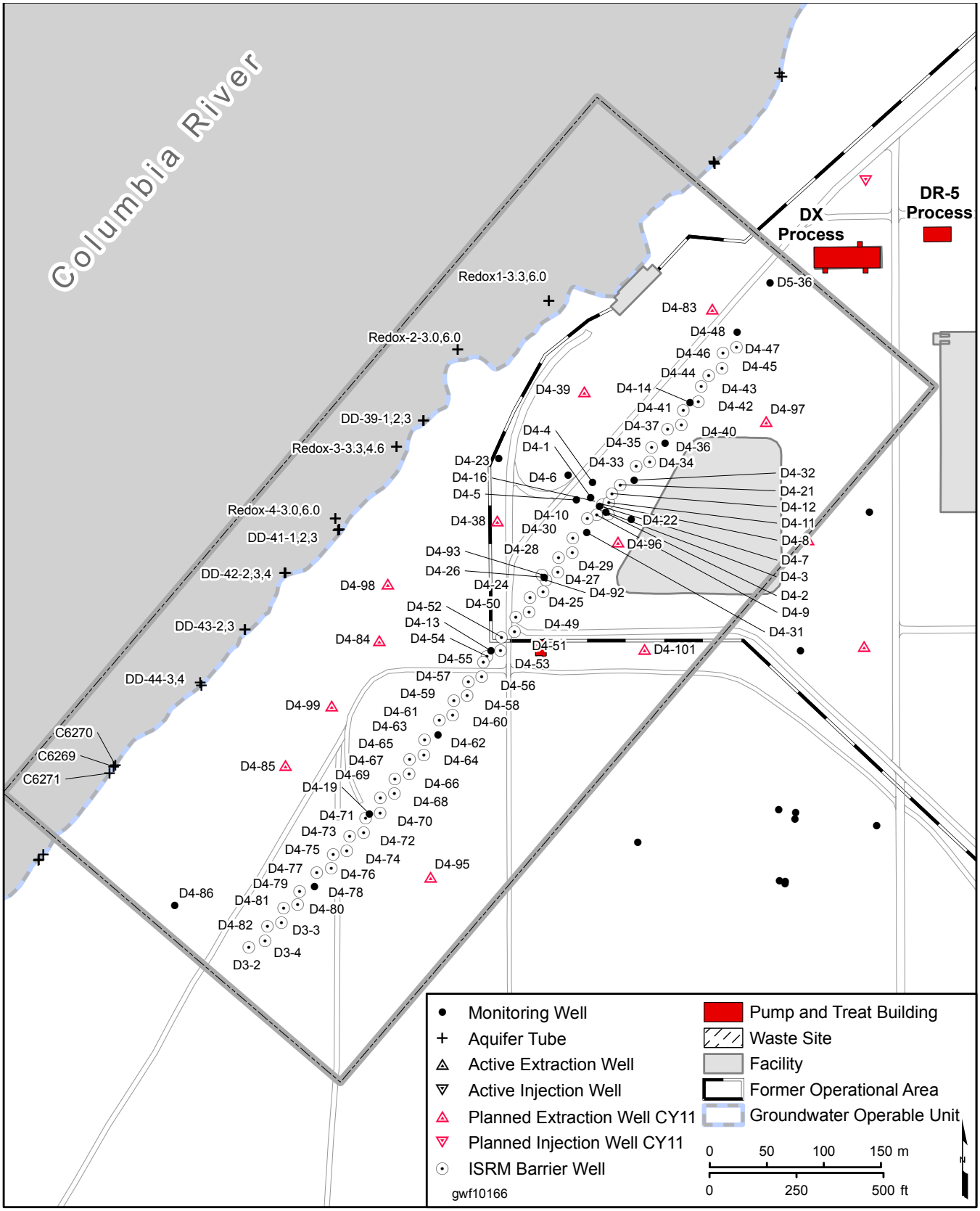

Figure 7-20. In Situ Redox Manipulation Map

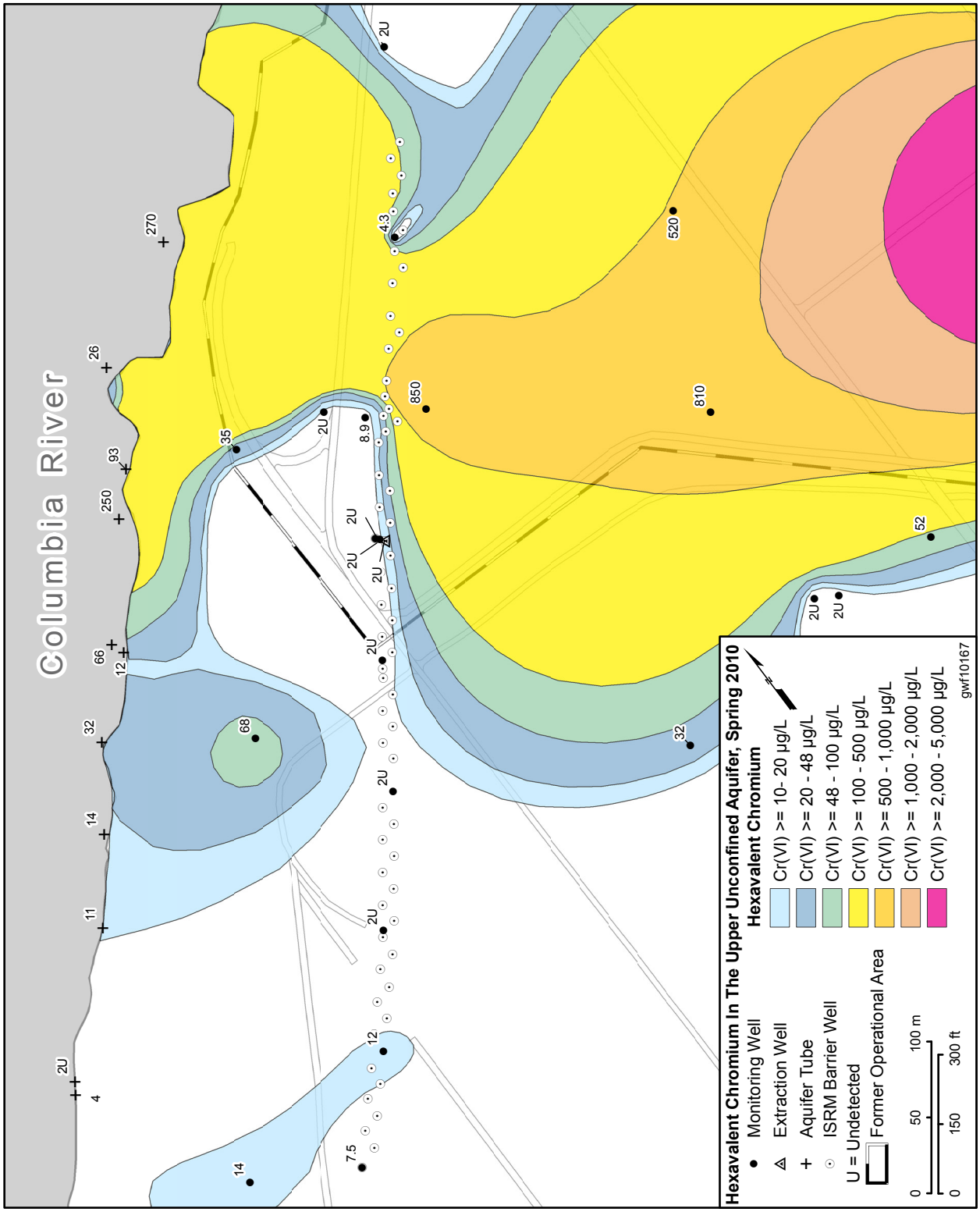
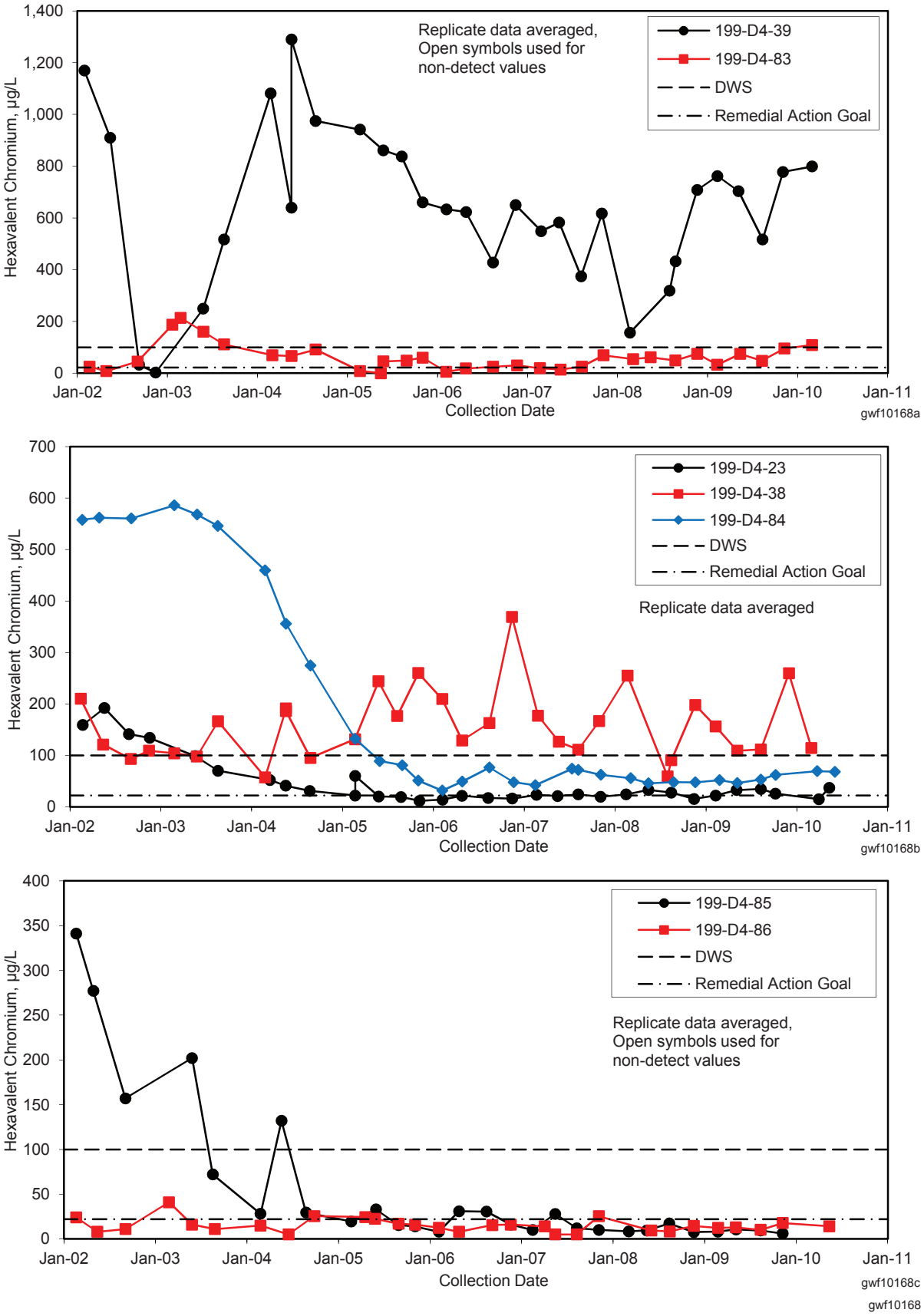
Figure 7-21. Chromium Trend Plots for Compliance Wells