2.5 100-HR-3

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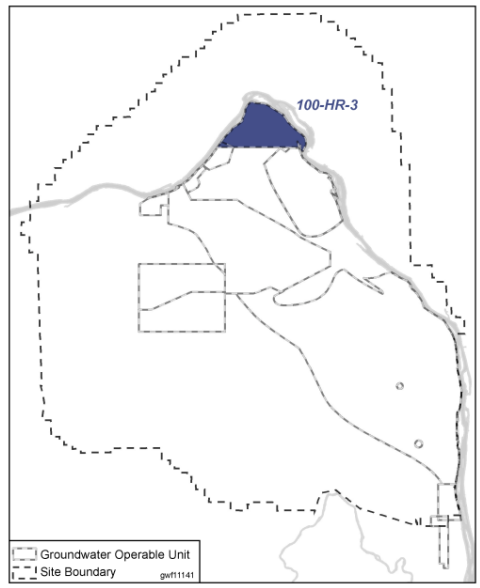


This section describes the hydrogeology and contaminant distribution within 100-HR-3, which includes groundwater underlying the 100-D and 100-H Areas, and the region between known as the Horn. Figures 2.5-1, 2.5-2, 2.5-3, and 2.5-4 show the facilities, wells, and shoreline monitoring sites in 100-HR-3.

Radioactive and chemical waste associated with past operation of the D, DR, and H Reactors and associated support facilities contaminated the groundwater in 100-HR-3. Characterization and remediation of waste sites in 100-HR-3 began in 1996 under the authority provided by RCRA closure plans and the interim action ROD (EPA/ROD/R10-96/134). Waste site remediation mainly consists of removing and disposing of soil, debris, and waste material and then backfilling the excavation site. At the end of 2011, approximately 45 percent of the waste sites had been remediated or were classified as not requiring remediation. In 2011, DOE began remediating the 100-D-100 waste site, which is one of the major sources of the high-concentration hexavalent chromium plume in the southern 100-D Area. Excavation revealed hexavalent chromium contamination in the deep vadose zone, and the site is being excavated to the water table. DOE/RL-2008-46-ADD1 provides additional details about 100-HR-3 history, waste sites, and hydrogeology.

The vadose (unsaturated) zone in 100-HR-3 consists predominantly of Hanford formation gravel and is 2 to 30 meters thick. The unconfined aquifer is predominantly Ringold Formation unit E gravels in the 100-D Area and Hanford formation in the 100-H Area (Figure 2.1-2 in Section 2.1; Appendix E). The geology across the Horn is a transitional zone, changing from dominantly Ringold unit E closer to the 100-D Area to Hanford formation farther east. Pockets of Ringold unit E are remnants in various locations. Aquifer thickness varies from about 6 to 9 meters beneath the 100-D Area, and from 2 to

100-HR-3 at a Glance

Reactor Operations: D 1944-1967; DR 1950-1964; H 1949-1965				
2011 Groundwater Monitoring				
Contaminant	**Drinking Water Standard**	**Maximum Concentration**	**Plume Area[a] (km^2)**	**Shoreline Impact (m)**
Hexavalent Chromium	10/48 µg/L[b]	28,100	7.73[c]	190[c]
Nitrate	45 mg/L	98.8	1.44	0
Strontium-90	8 pCi/L	45	0.12	190
Tritium	20,000 pCi/L	18,000	0	0
Remediation				
Waste Sites (interim action): >45 percent complete[d] Groundwater (interim action for hexavalent chromium): • HR-3 pump-and-treat: 1997-2011, removed 406 kg • DR-5 pump-and-treat: 2004-2011, removed 338 kg • DX pump-and-treat: 2010-2011, removed 461 kg • HX pump-and-treat: 2011, removed 11 kg • In Situ Redox Manipulation barrier: 1997-2011 Final ROD anticipated in 2013.				

a. Estimated area above listed water quality standard.

b. 10 µg/L aquatic standard; 48 µg/L groundwater cleanup standard.

c. At the 10 µg/L level.

d. Waste sites with status closed, interim closed, no action, not accepted, or rejected.

5 meters beneath the 100-H Area. The uneven surface of the Ringold Formation upper mud unit forms the base of the aquifer.

DOE monitors groundwater in 100-HR-3 to meet the requirements of CERCLA, AEA, and RCRA. Constituents of interest in the unconfined aquifer include hexavalent chromium, strontium-90, tritium, nitrate, technetium-99, and uranium. Figure 2.5-5 illustrates changes in contaminant plume areas since 2003. The sizes of most of the plumes have decreased as a result of remediation and natural processes, with less mobile contaminants decreasing at a slower rate. In addition, the current remediation systems are targeting specific contaminant plumes, such as hexavalent chromium.

Figure 2.5-6 presents a March 2011 water table map for 100-HR-3. In 2011, the volume of groundwater being extracted, treated, and reinjected at the 100-D Area increased from previous years. This change resulted from the operation of the DX pump-and-treat system (Figure 2.5-7), which started operating in December 2010. The DX system operation has created larger groundwater mounds and cones of depression than previously observed. The regional flow direction in 100-HR-3 is to the east-northeast, from 100-D toward 100-H. Extraction and injection wells in the 100-H Area influence flow, but the new high-capacity HX system was not in operation until October 1, 2011; therefore, the changes to the water table and plumes are not yet evident.

Daily and seasonal fluctuations in the river stage also affect groundwater flow in 100-HR-3. As would be expected, longer term changes in the river stage produce more extensive and longer lived changes in the water levels, hydraulic gradient, and flow directions in the unconfined aquifer. Seasonal changes in hexavalent chromium concentrations in wells do not clearly increase or decrease as the distance from the river increases.

2.5.1 Hexavalent Chromium

Figures 2.5-8 and 2.5-9 show the distribution of hexavalent chromium in 100-HR-3 groundwater during spring and fall 2011. The overall area of the plume, with a concentration above 20 µg/L, continues to be about 7 square kilometers, with similar plumes during both spring and fall periods. Operation of the DX pump-and-treat system, which started in December 2010, measurably reduced the concentrations in the 100-D Area plumes during 2011. Measurable reduction at HX is expected to occur in 2012. Since 2003, the area of the plume at 20 µg/L has decreased approximately 37 percent, and the portion above 100 µg/L has decreased by more than 50 percent (Figure 2.5-5).

The total area of the hexavalent chromium plume in 100-HR-3 (at levels greater than 20 µg/L) is about 6 square kilometers, and has decreased 37 percent since 2003.

Sections 2.5.1.1 through 2.5.1.4 describe hexavalent chromium distribution and trends in the southern and northern 100-D, the Horn, and 100-H.

Hexavalent chromium is present throughout the 6 to 9 meter thickness of the unconfined aquifer in 100-D. Vertical sampling during Remedial Investigation drilling efforts and in other sampling events over the past several years show that concentrations may vary with depth, but changes are not necessarily consistent between wells or over time (Section 4 of SGW-49739, *Cr(VI) Density Stratification Study, 100-D Area, Hanford Site, Washington*).

In Remedial Investigation well 199-D5-134, total chromium and hexavalent chromium were detected at the first water-bearing unit of the Ringold upper mud unit, with levels at 12.6 and 12.2 µg/L, respectively. An evaluation of the boring logs and daily reports indicates the sample was collected following equipment and well drilling problems, which resulted in a delay in sample collection of more than two days. Based on an evaluation of the sample results at this well and the vertical distribution, it is

likely that this sample was contaminated by contact with water from the unconfined aquifer or materials used during sample collection, and is not representative of the Ringold Formation upper mud unit. Well 199-D5-134 was screened in the Ringold upper mud unit, and a sample collected in January 2012 was below the detection level. This result confirms that the sample collected during drilling was not representative. Monitoring results from well 199-D5-134 will continue to be evaluated for contamination.

DOE collected information on the vertical distribution of hexavalent chromium and total chromium during installation of each new Remedial Investigation well, and grab samples were collected from boreholes. Data are summarized in the subsections that follow.

2.5.1.1 Hexavalent Chromium in Southern 100-D Area

Hexavalent chromium is in the unconfined aquifer in two distinct plumes at 100-D. Historical handling of 70 percent sodium dichromate solution at the 100-D Area (100-D-12 liquid waste site) and the railcar unloading area at waste site 100-D-100 are likely sources of the southern plume (DOE/RL-2009-92, *Report on Investigation of Hexavalent Chromium Source in the Southwest 100-D Area*). Remediation of the 100-D-100 waste site began in late 2011. Excavation of soil contaminated with chromium will eliminate an ongoing contributing source of contamination to groundwater. In addition, continued operation of the new DX facility will facilitate hexavalent chromium removal from the groundwater.

The southern 100-D Area plume has the highest hexavalent chromium concentrations on the Hanford Site. Concentrations of hexavalent chromium were as high as 69,700 µg/L in well 199-D5-122 in August 2010. As a result of the DX pump-and-treat system operations, the concentrations in well 199-D5-122 decreased from a maximum of 27,900 µg/L in February, to as low as 9,400 µg/L in September 2011, which is a 66 percent drop in concentrations (Group 3 in Figure 2.5-10). While the change in concentrations in neighboring wells has not been as dramatic, the effect of the DX pump-and-treat system is evident in several locations. Wells 199-D5-102, 199-D5-98, and 199-D5-99 have all shown a drop in hexavalent chromium concentrations, but the response is not as clearly linked to the new pump-and-treat operations. Other locations have not shown a response to date (199-D5-104), with concentrations remaining fairly stable in 2011 (Figure 2.5-10). Also related to the new pump-and-treat system, concentrations fluctuated in extraction wells (Group 4) as the system has continued to operate. While significant reductions have been observed in hexavalent chromium concentrations, the main aerial footprint of the plume did not change in 2011. The operation of two extraction wells (199-D-104 and 199-D5-39) in the center of the hot spot has reduced concentrations sufficiently to separate the hot spot into two areas (Figure 2.5-10).

Chromium concentrations fell in many southern 100-D Area wells in 2011. Further declines can be expected as the DX pump-and-treat system removes contamination.

To delineate the southern 100-D Area plume, new Remedial Investigation well 199-D3-5 was installed in 2010. The well was installed southeast of the In Situ Redox Manipulation barrier, and sampling during drilling detected hexavalent chromium. Groundwater samples collected at discrete depths indicated concentrations increasing with depth, with a maximum concentration of 73.1 µg/L detected at the bottom of the unconfined aquifer. The well was not sampled in 2011; however, the Remedial Investigation results indicate the plume extends farther south than previously thought. Well 199-D3-5 was screened through the entire unconfined aquifer, and contamination was noted at the bottom of the aquifer.

Chromium concentrations generally are declining in monitoring wells 199-D4-15 and 199-D5-38, upgradient from the In Situ Redox Manipulation barrier and downgradient from the extraction wells (Group 5 on Figure 2.5-10). Monitoring well 199-D4-22, also upgradient from the barrier, had more variable results with an increase in concentrations in December. Concentrations downgradient from the

barrier (Group 1) continued to be variable, but were generally lower in 2011 than in 2010. Wells downgradient from the barrier were converted to extraction wells for the DX pump-and-treat system in 2011.

Wells that monitor the unconfined aquifer in the central 100-D Area (199-D5-33 and 199-D5-36) continued to have hexavalent chromium concentrations near or below detection limits. These wells are between the southern and northern hexavalent chromium plumes. An evaluation of the groundwater geochemistry, conducted as a part of the RI/FS (Chapter 3 in DOE/RL-2010-95), indicates that groundwater in well 199-D5-33 has similar geochemistry to river water. Because river water is pumped directly into the 182-D Reservoir, this finding indicates that leakage from the 182-D Reservoir is contributing directly to groundwater and affecting the plume configuration and concentrations in that area. However, the amount of water being contributed by the reservoir is unclear because water levels in well 199-D5-33 also show a response to river level fluctuations.

In southern 100-D Area aquifer tubes, concentrations of hexavalent chromium in 2011 were at the lower end of the historical range (Figure 2.5-11). The highest hexavalent chromium concentration detected in a 100-D Area aquifer tube in 2011 was 96 µg/L in Redox-1-6.0. Hexavalent chromium concentrations in aquifer tubes downgradient from the In Situ Redox Manipulation barrier have decreased since the late 1990s, but remain variable in some aquifer tubes.

2.5.1.2 Hexavalent Chromium in Northern 100-D Area

The northern hexavalent chromium plume area of high concentrations is north of the D Reactor. A maximum value of 1,474 µg/L was reported in 2011. Source investigations were conducted to determine potential waste site sources for the hexavalent chromium in that area (DOE/RL-2010-40, *Report on Investigation of Hexavalent Chromium Source in the Northern 100-D Area*). Vadose zone sampling conducted during the source investigations revealed 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. Since waste site remediation is ongoing, sources that are contributing to the groundwater plume may remain in the vadose zone; key waste sites in this area that could be sources to groundwater are 100-D-30 and 100-D-104. An alternate theory about the origin of the northern plume is based on historical leakage from the 182-D Reservoir and its associated piping, and the location of the reservoir relative to the two plumes. It has been hypothesized that the northern plume has split off from the southern plume and is part of the same source area. Figure 2.5-12 shows hexavalent chromium concentrations within the northern plume and concentration plots for selected wells within the plume. The maximum extent of the northern plume did not change significantly compared to 2010. Well 199-D5-15 monitors groundwater near, but slightly upgradient from, potential sources for the northern hexavalent chromium plume. Concentrations reached a maximum of more than 2,000 µg/L in 2007 and subsequently declined, ranging from 100 to 700 µg/L in 2011. Concentrations in nearby wells 199-D5-14 and 199-D5-16 decreased between 2009 and 2011 (Group 7 on Figure 2.5-12).

Recent changes to groundwater extraction and injection at 100-HR-3 are modifying groundwater flow directions. This modification, in turn, causes variations in concentrations of chromium and other contaminants in many wells.

The highest concentrations in the northern plume were detected in wells 199-D5-125 and 199-D5-126, with concentrations ranging from above 1,000 to near 2,000 µg/L in 2011, but generally declining. The next downgradient well, 199-D5-13, showed a sharp increase in its hexavalent chromium concentration from 120 µg/L in April 2011, to 1,090 µg/L in December 2011 (Group 6 on Figure 2.5-12). Wells 199-D5-32 and 199-D8-88 (Group 5) also showed increasing concentrations. These wells are now

extracting water to the DX system; and concentrations are decreasing, with the decrease expected to continue under the influence of the pump-and-treat system.

Hexavalent chromium concentrations in aquifer tubes downgradient from the northern plume have declined since the late 1990s (Group 4 on Figure 2.5-12; Figure 2.5-11). Aquifer tubes 36-D, DD-16-4, AT-D-3-D, and DD-17-3 had concentrations at or slightly above the 20 µg/L remedial action goal in 2011.

2.5.1.3 Hexavalent Chromium in Horn Area

A portion of the chromium plume originated at the 116-DR-1&2 Trench and extends across the Horn to the 100-H Area (Figure 2.5-9). This area makes up for the majority of the footprint of the hexavalent chromium plume at 100-HR-3 but has concentrations consistently below 100 µg/L. This plume originated in the 100-D as a result of releases of cooling water to the trenches and retention basins after passing through the reactors. Large volumes of contaminated cooling water were released and created an extensive groundwater mound facilitating the migration of contamination across the Horn.

The Horn chromium plume is migrating slowly eastward. The new HX pump-and-treat system is intercepting the plume before it reaches the Columbia River.

The concentrations gradually declined between 2008 and 2011 (Group 2 on Figure 2.5-13), even before the HX pump-and-treat system began to operate in late 2011. Injection wells in the 100-H Area create a hydrologic barrier on the northeastern side of the plume that prevents the plume from extending father eastward into the northern portion of 100-H Area. This same line of injection wells (199-H3-3, 199-H3-4, and 199-H3-5) may be pushing the plume to the south, as shown on Figure 2.5-9, although the impact of these wells is small given the high transmissivity of the aquifer in the region. Encroachment of the plume in the southern portion of 100-H has been observed since injection in these wells stopped.

Three wells in the Horn Area monitor water-bearing zones in the Ringold upper mud unit: 699-97-43C, 699-97-45B, and 699-97-48C. Two of the wells (699-97-43C and 699-97-45B) were sampled during 2011 with no detection of hexavalent chromium in groundwater samples. Concentrations in well 699-97-48C have increased since it was installed and ranged from 27 µg/L to 52.9 µg/L in 2011 (Figure 2.5-13). Section 2.5.1.4 includes additional discussion of contamination in the Ringold upper mud unit.

Aquifer tubes north of the 100-H Area monitor groundwater approaching the Columbia River. Hexavalent chromium concentrations greater than 20 µg/L continued to be detected in some of these aquifer tubes in 2011. The highest concentration was 42 µg/L in aquifer tube C5641 (Group 1 on Figure 2.5-13), which is consistent with previous years.

2.5.1.4 Hexavalent Chromium in 100-H Area

The size of the hexavalent chromium plume in the unconfined aquifer underlying the 100-H Area has been reduced since pump-and-treat operations began in 1997. The 2011 plume shape did not change compared to 2010. A relatively smaller and lower concentration hexavalent chromium plume remains adjacent to the Columbia River (Figures 2.5-9 and 2.5-13). In addition, hexavalent chromium from the Horn Area is on the western side of 100-H. The maximum concentration in the unconfined aquifer in this area is at well 199-H4-76, which had a concentration of 90 µg/L in September 2011. The new HX pump-and-treat system will help the remediation effort by expanding the capture area and treating additional contaminated groundwater.

Hexavalent chromium concentrations in the 100-H Area have declined as a result of remediation efforts and natural processes.

Hexavalent chromium concentrations in 100-H Area extraction wells were below the 20 µg/L remedial action goal, except for a few isolated samples (Groups 5 and 6 on Figure 2.5-13). Concentrations in 100-H Area monitoring wells generally were low, except for a sharp increase in well 199-H4-65 in August 2011. This may be caused by the pump-and-treat system drawing in contaminant mass from the aquifer or from vadose zone source area contributions increasing as a result of high water table conditions in 2011.

In the southern portion of 100-H, concentrations declined in 2011 near the original injection wells for the 100-HR-3 pump-and-treat system. Injection of treated water into wells 199-H3-3, 199-H3-4, and 199-H3-5 ceased in 2004; and the Horn chromium plume began to encroach, causing concentrations to increase from 2006 to 2010. Concentrations have since declined in well 199-H3-3. Wells 199-H3-4 and 199-H3-5 had declining concentrations until late 2011 (Group 4 on Figure 2.5-13).

The unconfined aquifer beneath the 100-H Area is thin; thus, during Remedial Investigation well drilling, only two to four groundwater samples were collected from each well. In most wells, hexavalent chromium contaminations were relatively low, so characterization samples did not show marked differences with depth.

New Remedial Investigation wells 199-H2-1, 199-H3-9, and 199-H3-10 were completed in the first water-bearing unit of the Ringold upper mud unit. Hexavalent chromium concentrations during the drilling of wells 199-H2-1 and 199-H3-10 were near or below the detection limits. In well 199-H3-9, the hexavalent chromium concentration in the first water-bearing unit was 287 µg/L during drilling and 115 µg/L after well completion and development. Within the next two deeper water-bearing units of the Ringold upper mud unit, hexavalent chromium concentrations were below detection limits. Some older wells monitoring a water-bearing zone of the Ringold upper mud unit in the 100-H Area have higher hexavalent chromium concentrations than wells screened in the unconfined aquifer. Monitoring wells 199-H3-2C and 199-H4-12C, and piezometer 199-H4-15CS are screened within the first water-bearing layer in the mud unit. Hexavalent chromium concentrations in wells 199-H4-12C and 199-H4-15CS continued to be above 100 µg/L in 2011 (Figure 2.5-14).

In 2009, wells 199-H4-12C, 199-H3-2C, and 199-H4-15CS were used for a series of aquifer tests to gather data on the presence of deep chromium in the Ringold upper mud unit (SGW-47776, *Aquifer Testing and Rebound Study in Support of the 100-H Deep Chromium Investigation*). Hexavalent chromium concentrations in the Ringold upper mud unit rose slightly as a result of the pumping during the test. The aquifer tests indicated that the Ringold upper mud unit at well 199-H3-2C is connected to the upper aquifer. The erosional forces that removed the Ringold Formation unit E at the 100-H Area may have scoured off portions of the Ringold upper mud unit, which exhibits an undulating surface typical of erosion. A discontinuous Ringold upper mud unit in 100-H Area would have allowed groundwater mounding of reactor cooling water to drive relatively large volumes of contaminated water into the Ringold upper mud unit near the retention basins. This theory is supported by the presence of contamination in the Ringold upper mud unit.

Hexavalent chromium concentrations in aquifer tubes in the main 100-H Area were below 20 µg/L, with the exception of aquifer tube C7650, which had a concentration of 27 µg/L in December 2011 (Group 7 on Figure 2.5-13). This aquifer tube was installed downgradient from the 116-H-7 waste site as part of the RI/FS in 2010 to define the extent of the hexavalent chromium and strontium-90 contamination.

2.5.2 Nitrate

Nitrate concentrations continued to exceed the 45 mg/L drinking water standard in 100-D Area groundwater and in a few isolated wells in the 100-H Area. Nitrate is not found above the drinking water standard in the Horn, except at well 199-H1-27 along the river. The combined area of the nitrate plumes increased between 2010 and 2011 (Figure 2.5-15) as a result of data from new wells and increases in concentrations in some areas.

2.5.2.1 Nitrate in 100-D Area

Primary sources of nitrate in 100-HR-3 included gas condensate from the reactors, septic systems and sewer lines, former agricultural practices, and waste sites that received nitric acid.

Nitrate forms two distinct plumes in 100-D (Figure 2.5-15). Nitrate concentrations in the southern plume extraction wells (199-D5-39 and 199-D5-104) are currently stable at approximately 45 mg/L. However, as a result of the startup of the DX pump-and-treat system in December of 2010, previously identified trends in the remaining portion of the plume are no longer apparent. For example, monitoring well 199-D4-15, which is between two extraction wells, had stable values ranging from approximately 52 mg/L to 65 mg/L during 2009 and 2010. Concentrations dropped dramatically to 44.3 mg/L in April 2011, the first monitoring event following the DX system startup in December 2010, and levels continue to decrease. The changes in nitrate concentration are related to changes in groundwater flow caused by the operation of the DX pump-and-treat system in 2011. The plume interpretation changed between 2010 and 2011 in the following ways:

Nitrate concentrations generally are decreasing in the 100-D Area, causing the plume to shrink. However, levels increased sharply in a few wells, as groundwater flow directions shifted.

- Concentrations declined to levels below the drinking water standard in many wells (Figure 2.5-16). These changes were noted in the northwest (199-D8-5 and 199-D8-72), in central 100-D Area (199-D5-133), and in the south (199-D5-98 and 199-D4-15).
- Nitrate concentrations increased sharply in well 199-D5-36 at the northern end of the In Situ Redox Manipulation barrier. The concentration rose from 5 mg/L in 2010 to 46.5 mg/L in August 2011 (Figure 2.5-17). Nitrate concentrations in nearby well 199-D4-48 remained within their previously observed range.

The southern portion of the nitrate plume is intercepted by the In Situ Redox Manipulation barrier, which chemically reduces the nitrate to nitrite. Nitrite concentrations were below the 3.3 mg/L drinking water standard in 2011. Concentrations have increased in recent years in well 199-D4-13, where the maximum value in 2011 was 3.2 mg/L.

Characterization samples collected during drilling of new Remedial Investigation wells in the 100-D Area showed that in the northern plume, nitrate concentrations declined with depth or remained relatively constant through the unconfined aquifer. In the southern plume, nitrate concentrations increased modestly with depth in wells 199-D3-5 and 199-D5-144, and decreased with depth in well 199-D5-141. Nitrate concentrations in the Ringold upper mud unit are much lower than in the unconfined aquifer.

2.5.2.2 Nitrate in 100-H Area

Nitrate concentrations exceeded the drinking water standard in isolated 100-H Area wells, as follows:

- Well 199-H4-3 has a history of elevated nitrate concentrations, with maximum concentrations at more than 3,000 mg/L in 1986. Concentrations were below the drinking water standard from 2008 through 2010, but increased to 72 mg/L by October 2011. The nitrate source in that area was the 183-H solar evaporation basins.

- Well 199-H1-27, a new extraction well north of 100-H Area, had a concentration of 69.5 mg/L in December 2011. This level was much higher than the 10.5 mg/L detected in a characterization sample collected in 2010, and higher than in nearby wells. Additional monitoring is needed to determine if the analytical result was accurate.
- Remedial Investigation well 199-H3-7 was not sampled in 2011 but had a nitrate concentration of 47.8 mg/L on January 4, 2012. This concentration was an increase from 38 mg/L in 2010 characterization samples. This well is west of the 116-H-1 Trench. A characterization sample from nearby well 199-H4-73 (now an injection well) had a concentration of 43.4 mg/L in 2009, confirming the presence of elevated nitrate in this region.
- Well 199-H4-75, a new extraction well on the western (upgradient) boundary of the 100-H Area, had a concentration of 167 mg/L in 2011, the highest in the region. Wells to the north and south had much lower concentrations (less than 30 mg/L). The concentrations of other anions in 199-H4-75 also were high (for example, sulfate at 359 mg/L). Additional sampling for anions is recommended, to determine whether these high nitrate concentrations were representative and persistent.

Several new wells in the 100-H Area showed elevated levels of nitrate in widely scattered locations.

The sources of the elevated nitrate concentrations in 199-H1-27 and 199-H4-75 are undetermined. However, nitrate has several different possible sources. The possible sources include: septic systems, reactor operations, a remnant that came across the Horn with the hexavalent chromium plume, and pre-Hanford agriculture uses.

Characterization samples collected during drilling of the new Remedial Investigation well in the 100-H Area showed that nitrate concentrations did not vary with depth in the unconfined aquifer. Concentrations in the Ringold upper mud unit are much lower than in the unconfined aquifer.

Nitrate concentrations generally are low in 100-H Area aquifer tubes, except for several aquifer tubes downstream from the operational area, where concentrations have previously been slightly above the drinking water standard previously. Aquifer tubes 50-M and 51-M had concentrations of 37 and 35.9 mg/L, respectively, in February 2011. Analytical results from Remedial Investigation well 199-H6-3 during drilling were at 44.3 mg/L. This well is west of aquifer tube 51-M, indicating that the nitrate plume extends farther to the southwest than expected.

2.5.3 Strontium-90

Strontium-90 was present in waste disposed of in the 100-D and 100-H Areas. In 2011, concentrations in groundwater exceeded the 8 pCi/L drinking water standard in several 100-H Area wells and in one 100-D Area well.

2.5.3.1 Strontium-90 in 100-D Area

Strontium-90 was detected historically in well 199-D5-12, near the fuel storage basin at the D Reactor, at levels as high as 52.6 pCi/L (March 1990). This well was decommissioned in 2002 when water levels dropped below the pump intake level, but the well had not been sampled since late 1999. Analytical results from 1999 and 1998 were showing a decreasing trend, but the strontium-90 levels remained above 25 pCi/L. New Remedial Investigation well 199-D5-132 was installed in 2011 as a replacement to well 199-D5-12. Characterization samples collected at discrete depths during drilling had concentrations ranging from 65 to 13 pCi/L at depths of 29.4 and 31.1 meters, respectively. The well was screened across the unconfined aquifer, which may result in a diluted sample result from the completed

well. A sample collected after the well was completed had a concentration of 45 pCi/L. The contamination is apparently localized; nearby wells 199-D5-15, 199-D5-16, and 199-D5-133 had no detectable strontium-90 in 2010 or 2011.

The area near the former retention basins in the northern 100-D Area historically had strontium-90 detections in groundwater. Well 199-D8-68, near the former retention basins, had the highest concentrations. In 2011, concentrations in this well and nearby wells were 3 pCi/L or lower. Aquifer tube samples from this region of the 100-D Area were analyzed for strontium-90. Concentrations were near detection limits, with a maximum of 5.4 pCi/L in aquifer tube C6278.

Samples from a new well in the 100-D Area exceeded the drinking water standard for strontium-90. Concentrations in all other wells were below the standard.

2.5.3.2 Strontium-90 in 100-H Area

Strontium-90 concentrations in 100-H Area groundwater exceed the drinking water standard near the former 116-H-7 Retention Basin and 116-H-1 Trench (Figure 2.5-18). The plume was slightly larger in 2011 than in 2010, and concentrations increased in wells 199-H4-16 and 199-H4-45. The high river stage in June 2011 raised the water table near the river and appears to have mobilized strontium-90 in the lower part of the vadose zone, temporarily increasing concentrations in groundwater. The highest strontium-90 concentration detected in 2011 was 33 pCi/L in well 199-H4-13 in December, which was within the typical range seen in this well.

Several 100-H Area aquifer tubes, all near the former retention basins, had strontium-90 detections in 2011. Only aquifer tube 47-M had a concentration above the drinking water standard (18 pCi/L in April 2011), but concentrations declined to 6.4 pCi/L in December 2011. Concentrations in this aquifer tube have fluctated above and below the standard since 1998.

2.5.4 Tritium

Tritium concentrations are below the 20,000 pCi/L drinking water standard in groundwater in most parts of 100-HR-3. Well 199-D8-89 had a sample result of 24,000 pCi/L in February 2011; however, the duplicate sample result was undetected, which was more in line with previous and subsequent results. The high value is undergoing review as a suspected error. With the exception of the anomalous result from well 199-D8-89, the maximum value detected in 100-D in 2011 was 18,000 pCi/L in well 199-D4-95. In 100-H, the maximum concentration was 4,100 pCi/L in well 199-H3-3.

Several wells and aquifer tubes in the southern 100-D Area have elevated concentrations (greater than 10,000 pCi/L) and have exceeded the standard in the past, but levels are declining (Figure 2.5-19). These elevated concentrations reflect groundwater migration from the 100-N Area.

Characterization samples collected during the drilling of well 199-D6-3 in December 2010 had tritium concentrations ranging from 18,000 to 20,000 pCi/L. Concentrations did not vary with depth. A sample collected in 2011 after the well was completed (east of the D Reactor) had a concentration of 2,600 pCi/L. Nearby well 199-D6-1 was converted to an injection well in late 2010, which may explain the decrease in the tritium concentration in 199-D6-3.

2.5.5 Other Contaminants

Technetium-99 and uranium also are co-contaminants of concern for groundwater. Their concentrations typically are highest in well 199-H4-3, downgradient from the 116-H-6 (183-H) Basins, which was a source of these contaminants. Technetium-99 concentrations last exceeded the 900 pCi/L drinking water standard in 1999. In 2011, the concentration in 199-H4-3 was 157 pCi/L. Technetium-99 was detected in a few other samples; however, those results have been flagged as under further review or

as suspect results. Uranium concentrations in well 199-H4-3 exceeded the 30 µg/L drinking water standard as recently as 2006. In 2011, the concentration in well 199-H4-3 was 28.9 µg/L, the highest value since 2006. In the 100-D Area, uranium concentrations are at background levels, and technetium-99 is undetected.

In 2011, sulfate concentrations in groundwater underlying much of the southern 100-D Area remained greater than 100 mg/L. Excluding wells influenced by the In Situ Redox Manipulation barrier, concentrations were below the secondary drinking water standard of 250 mg/L. Previous injections of sodium dithionite solution at the barrier increased sulfate concentrations to levels above the standard in the barrier and in some downgradient wells and aquifer tubes. One well and one aquifer tube downgradient from the barrier had sulfate concentrations above the drinking water standard in 2011: well 199-D4-99 (358 mg/L) and aquifer tube DD-42-4 (466 mg/L in January 2011; lower in subsequent quarters).

Groundwater samples collected from some wells in the In Situ Redox Manipulation barrier contain concentrations of gross beta above the 50 pCi/L drinking water standard. This gross beta activity is primarily caused by naturally present potassium-40 in the pH buffer, which is used during injection of sodium dithionite (Section 2.5 of PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*). The highest gross beta concentration in 2011 was 186 pCi/L in 199-D4-1, with strontium-90 data not available for 2011. Concentrations in barrier wells have declined from the peak levels seen in 2001 or 2002.

Gross beta concentrations up to 130 pCi/L were detected in characterization samples from new well 199-D5-132. The results are consistent with strontium-90 detections (Section 2.5.3).

An unexpectedly high gross beta concentration was detected in a routine sample from a well near the 183-D water treatment plant.

An unexpectedly high gross beta concentration was detected in a routine sample from well 199-D5-93 (152 pCi/L). This was the first time a sample from this well was analyzed for gross beta. No strontium-90 data are available. The well is near the 183-D water treatment plant, which is not a known area of strontium-90 contamination. Future sampling for beta-emitting radionuclides is recommended.

In the 100-H Area, gross beta concentrations exceeded the drinking water standard in two wells. Well 199-H4-4 had concentrations of 19 pCi/L in February and 68 pCi/L in December. The well had not been sampled for gross beta since 2004. The beta activity appears to reflect the presence of technetium-99 (16 pCi/L in February and 75 pCi/L in December). The well also has detectable strontium-90 (3.5 pCi/L). Well 199-H4-13 had a gross beta concentration of 55 pCi/L, which is caused by the presence of strontium-90 (Section 2.5.3).

2.5.6 CERCLA Groundwater Activities

An interim remedial action ROD for the 100-HR-3 OU was issued in April 1996 (EPA/ROD/R10-96/134). The goal of the resulting interim remedial action is to prevent discharge of hexavalent chromium to the Columbia River.

The interim remedial action goal was changed from 22 µg/L to 20 µg/L in 2000 under the interim action ROD Amendment (EPA/AMD/R10-00/122, *Interim Remedial Action Record of Decision Amendment for the 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington*). The amendment sets a 20 µg/L threshold at onshore, near-river monitoring locations to achieve the ambient water quality criterion of 10 µg/L. According to the interim remedial action 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.

DOE/RL-2006-20, published in 2006, identified numerous actions pertaining to 100-HR-3 groundwater. Two of the actions resulted in expansions of the 100-HR-3 pump-and-treat systems (Section 2.5.6.2). The actions have all been completed.

Groundwater sampling under CERCLA includes monitoring interim remedial actions for effectiveness, and monitoring wells throughout 100-HR-3 to track plumes and concentration trends. Appendix A lists wells and constituents monitored and the status of monitoring in 2011.

2.5.6.1 Remedial Investigation/Feasibility Study

In 2010 and 2011, DOE conducted extensive field studies as described in an RI/FS work plan addendum for the 100-D and 100-H Areas (DOE/RL-2008-46-ADD1) and the sampling and analysis plan (DOE/RL-2009-40). Changes to the sampling and analysis plan were also made during the RI/FS field effort and are documented in Tri-Party Agreement Change Notices (TPA-CN-460, *Tri-Party Agreement Change Notice Form: 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, Rev. 0*; TPA-CN-368, *Tri-Party Agreement Change Notice Form: 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, Rev. 0*). The fieldwork included the following:

- Installing 12 wells completed in the unconfined aquifer, 5 wells completed in the Ringold upper mud unit, and 10 vadose zone boreholes (5 of which were completed as temporary wells)
- Sampling and characterizing the sediment and groundwater during drilling for all wells and boreholes
- Excavating and sampling five test pits
- Installing and sampling six aquifer tubes, with four at one location and two at a second location
- Sampling 52 wells three times for temporal and spatial analysis

Results of recent remedial investigation studies will support selection of final remedies for former waste sites and groundwater.

The results of the RI/FS (in progress) will support selection of final remedies under CERCLA, using an approach that integrates the data needs for waste sites and groundwater.

2.5.6.2 Groundwater Remediation

Five CERCLA interim action remedies operated in 100-HR-3 in 2011:

- The original 100-HR-3 pump-and-treat system treated groundwater from the 100-D and 100-H Areas. Its focus was on the northern 100-D Area plume and the main 100-H Area. It operated from 1997 through April 2011 and was replaced by the DX and HX systems.
- The DR-5 pump-and-treat system in the 100-D Area treated groundwater from the southern 100-D Area plume, upgradient from the In Situ Redox Manipulation barrier. It operated from 2004 until March 2011, when it was replaced by the DX system.
- The DX pump-and-treat system formally entered service December 17, 2010, and was operational in 2011. It treats groundwater from the northern and southern 100-D plumes.

- DOE conducted tests of the new HX pump-and-treat system in summer 2011 and began to operate it fully beginning in October 1, 2011. Its focus is hexavalent chromium contamination in 100-H Area and the Horn.
- The In Situ Redox Manipulation barrier is a treatment system that intercepts most of the southern chromium plume in place at 100-D, reducing chromium from the hexavalent to the trivalent form.

The remedial action objectives for the 100-HR-3 Operable Unit are as follows (EPA/ROD/R10-99/039; EPA/AMD/R10-00/122):

- ***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 contaminant of concern is hexavalent chromium. The ROD specifies 20 µg/L as the concentration at compliance wells that is protective of aquatic organisms in the river environment.

Pump-and-Treat Systems

Operation of remediation systems and groundwater monitoring results are described in DOE/RL-2012-02. A summary is presented in this section.

In 2011, the original HR-3 system and the DR-5 system were shut down and replaced by the DX and HX systems. As of December 2011, 68 extraction wells and 29 injection wells were in use (Appendix A). Combined, the two systems are capable of treating 7.6 million liters of groundwater per day.

Between 1997 and 2011, pump-and-treat systems have removed 1,215 kilograms of hexavalent chromium from 100-HR-3 groundwater. The new DX system removed 443 kilograms in 2011 alone.

The combined pump-and-treat systems in 100-HR-3 removed 471 kilograms of hexavalent chromium from groundwater in 2011 (Table 2.5-1 and Figure 2.5-20). During its first full year of operation, the new DX system removed more than 400 kilograms of chromium, which is as much as the HR-3 system removed in its entire period of operation. Since 1997, the 100-HR-3 pump-and-treat systems have removed 1,215 kilograms of chromium from the aquifer.

Under the new configuration, the 100-HR-3 pump-and-treat systems are meeting remedial action objectives. Containment of the plumes addresses the first two objectives: (1) protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River, and (2) protect human health by preventing exposure to contaminants in the groundwater. Operation and refinement of the systems are also meeting the third objective, which is to provide information that will lead to the final remedy.

Most of the mass removed from the DX and HX systems originated within the interior of the plumes; the areal extent of the plumes as defined by the 10 µg/L contour did not change significantly.

Concentrations of hexavalent chromium in some compliance wells and extraction wells remained above the 20 µg/L remedial action goal, and the DX and HX systems will continue to operate in 2012.

The HR-3 system includes a network of compliance wells or dual-purpose wells (extraction/compliance or extraction/performance monitoring). In 2011, hexavalent chromium concentrations remained above the 20 µg/L interim remedial action goal in wells 199-D8-54A, 199-D8-71, and 199-H4-63. Concentrations were below the remedial action goal in wells 199-H4-3, 199-H4-4, 199-H4-5, and 199-H4-64. These wells are screened across all, or nearly all, of the thin, unconfined aquifer. The DR-5, DX, and HX pump-and-treat systems currently have no designated compliance wells, but monitoring wells and extraction wells are sampled routinely.

Plume capture effectiveness in 100-HR-3 was evaluated for the combined capture zones of the DR-5, DX, HR-3, and HX pump-and-treat systems (DOE/RL-2012-02). Capture is inconclusive or unsatisfactory in the southeastern portion of the 100-H Area (such as, upgradient of wells 199-H4-64, 199-H4-12C, 199-H4-4, and 199-H4-63) and in portions of the Horn. The pump-and-treat report (Section 2.6 of DOE/RL-2012-02) recommends modifying the extraction well network in this region.

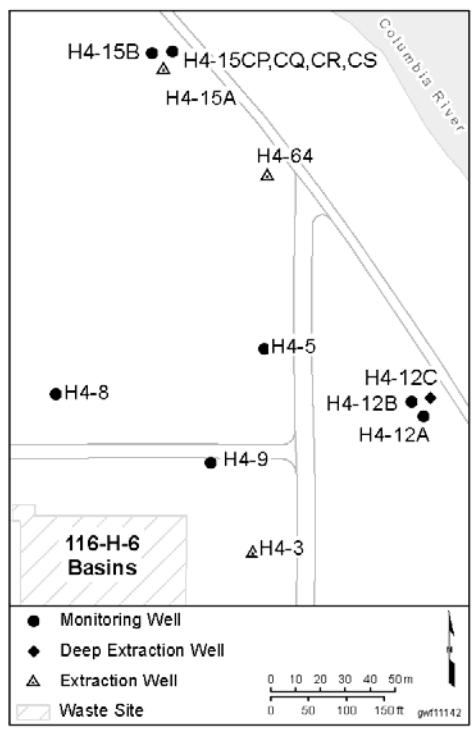
In Situ Redox Manipulation System

Beginning in 2000, DOE emplaced a permeable reactive barrier for in situ chemical treatment of hexavalent chromium in the southern 100-D Area plume as an interim remedial action in accordance with the interim action ROD amendment (EPA/AMD/R10-00/122). The treatment zone is approximately 680 meters long (aligned parallel to the Columbia River) and 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 concentrations in groundwater to no more than 20 µg/L at seven compliance wells between the treatment zone and the Columbia River.

The In Situ Redox Manipulation barrier 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. Concentrations were below 20 µg/L in three of the seven downgradient compliance wells in 2011, but concentrations remained far above that level in other wells (Figure 2.5-10). Seven wells downgradient from the barrier were converted into extraction wells for the DX pump-and-treat system.

2.5.7 RCRA Facility Monitoring at 183-H (116-H-6) 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 fall 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 modified-closure option, with specified measures for post-closure care.



The Hanford Facility RCRA Permit (WA7890008967) requires annual groundwater 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 as indicators and were incorporated by reference in the Hanford Facility RCRA Permit (WA7890008967).

In 2011, the RCRA wells were sampled as scheduled for the constituents of interest listed in the groundwater monitoring plan (PNNL-11573, *Groundwater Monitoring Plan for the 183-H Solar Evaporation Basins*) (Appendix B). The concentrations of fluoride, and technetium-99, and uranium remained below applicable concentration limits in all four 183-H Basins wells. Nitrate increased to 72 mg/L in October 2011 at well 199-H4-3, exceeding the 45 mg/L concentration limit. Total chromium continued to exceed the 122 µg/L concentration limit in 199-H4-12C (137 and 142 µg/L in unfiltered and filtered samples, respectively). Because none of the other 183-H solar evaporation basin co-contaminants were elevated in 199-H4-12C, it is likely that the total chromium in this well has an alternate source (Section 2.5.1.4). Uranium was detected at 28.9 µg/L in November, exceeding the permit limit.

2.5.8 Comparison of Surface Water and Groundwater Chemistry

Surface water sample data were evaluated for the distribution of the major ions in the Columbia River. The major ions evaluated include: calcium (Ca^{+2}), chloride (Cl^{-}), sulfate (SO_4^{-2}), carbonate (CO_3^{-2}), sodium (Na^{+}), potassium (K^{+}), and magnesium (Mg^{+2}). The distribution of these ions over time was compared to determine if the chemistry upriver from the Hanford Site has been impacted by contaminant plumes. To compare the concentrations of the ions, laboratory analytical results are collected. The concentrations are then converted from µg/L or mg/L into the milli-equivalent (meq) per liter of the ion, based on its atomic weight. This methodology allows for a true comparison of the ion concentrations.

The United States Geological Survey (USGS) collected water samples from the Columbia River for anions between 1961 and 1972. Samples were collected below Priest Rapids Dam at USGS Station 12472800. Raw data are available at the USGS National Water Information System water quality database. Analytical data was also available in HEIS. One sample was available for evaluation from 1994, and numerous other samples were available from 2009.

As shown on Figure 2.5-21, while there appears to be a seasonal variation, the chemistry has not changed over time.

Two wells and one piezometer are completed in the first water bearing unit of the Ringold upper mud at 100-H, and are located near the Columbia River. Well 199-H4-12C and piezometer 199-H4-15CS are nested with at least two other wells, completed in different geologic units. Both wells have a geochemistry that is similar to river water, and dissimilar to the chemistry found in the associated nested wells. The water levels in these wells also respond to changes in river stage (SGW-47776). The observation of similar geochemistry supports the theory that the Ringold upper mud is hydrologically connected to the river in that area.

Well 199-H4-12C is currently an extraction well. Groundwater is being pumped from the well at a sustained rate of 20 to 30 gallons per minute as part of the HX pump-and-treat system. This is an increase from 10 to 20 gallons per minute that was being extracted when the well was connected to the HR-3 pump-and-treat system. The increase in pumping roughly correlates with an increase in hexavalent chromium concentrations (Figure 2.5-22). Concentrations from well 199-H4-12C were consistent at about 135 µg/L in 2011. With sustained pumping and a connection to the Columbia River, it would be expected that hexavalent chromium concentrations would decrease over time. Since that is not the case, it is recommended that well 199-H4-12C and the other wells completed in the deeper formations be sampled for anions along with hexavalent chromium to evaluate if the well is drawing water from upgradient or from the river.

Table 2.5-1. 100-HR-3 Interim Action Pump-and-Treat Systems, 2011

Performance	HR3		DR-5		DX		HX
	2011	**1997–2011**	**2011**	**2004-2011**	**2011**	**2010–2011**	**2011**
Groundwater processed (million L)	134	4,170	9.1	384	919	974	303
Mass of hexavalent chromium removed (kg)	5.6	406	11.3	338	443	461	11
Wells	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**
Number of extraction wells	0	12	0	4	34	0*	34
Number of injection wells	0	3	0	2	14	0*	15
Total for All Systems, 1997 through 2011							
Groundwater processed (million L)	5,831						
Mass of hexavalent chromium removed (kg)	1,215						
Plume Area	**2011**				**Change from 2010**		
Plume area above 20 µg/L	5.68 km^2				18 percent decrease		

* DX system became operational in December 2010.

Figure 2.5-1. Facilities and Groundwater Monitoring Wells in 100-D

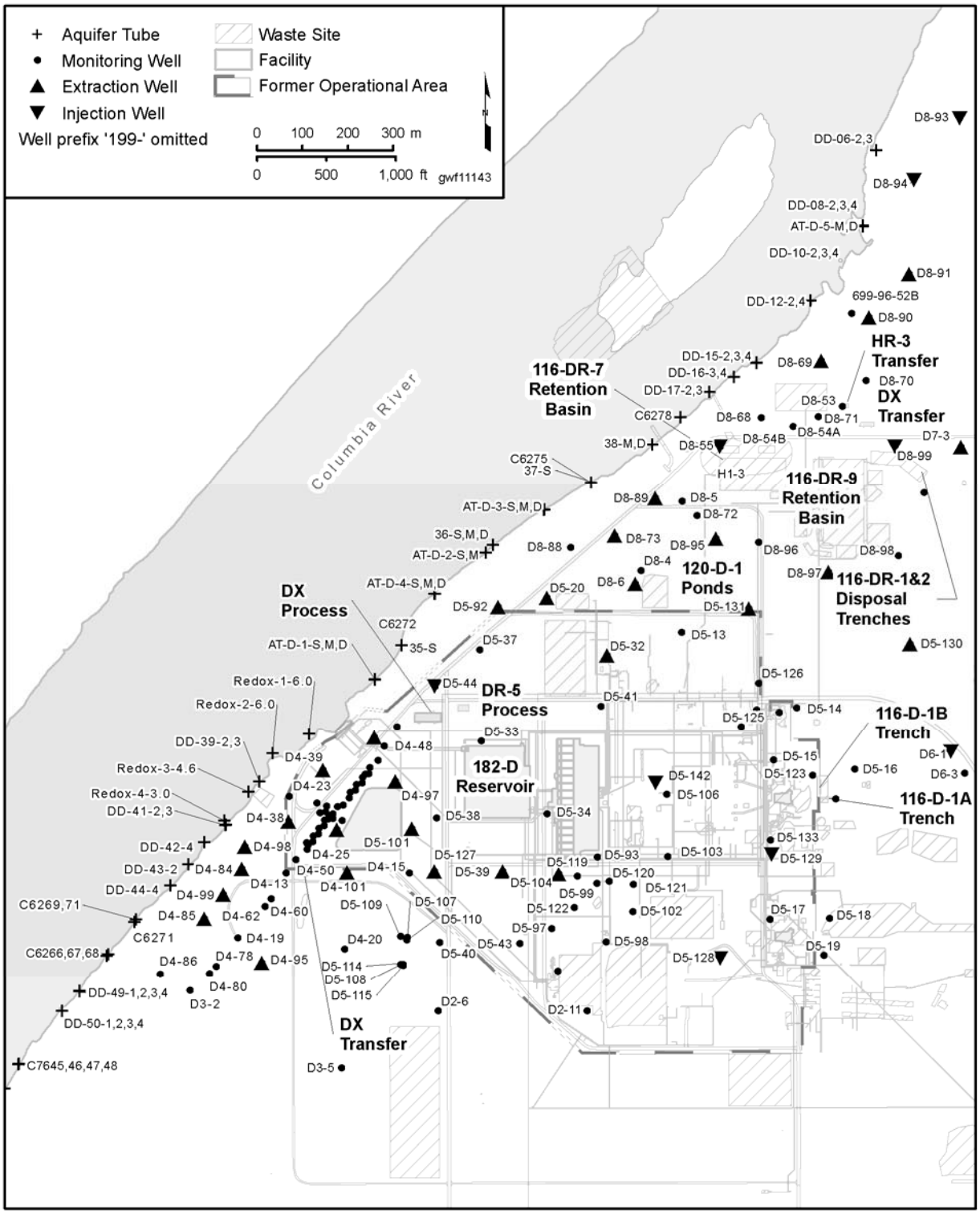


Figure 2.5-2. Well Locations in ISRM Region

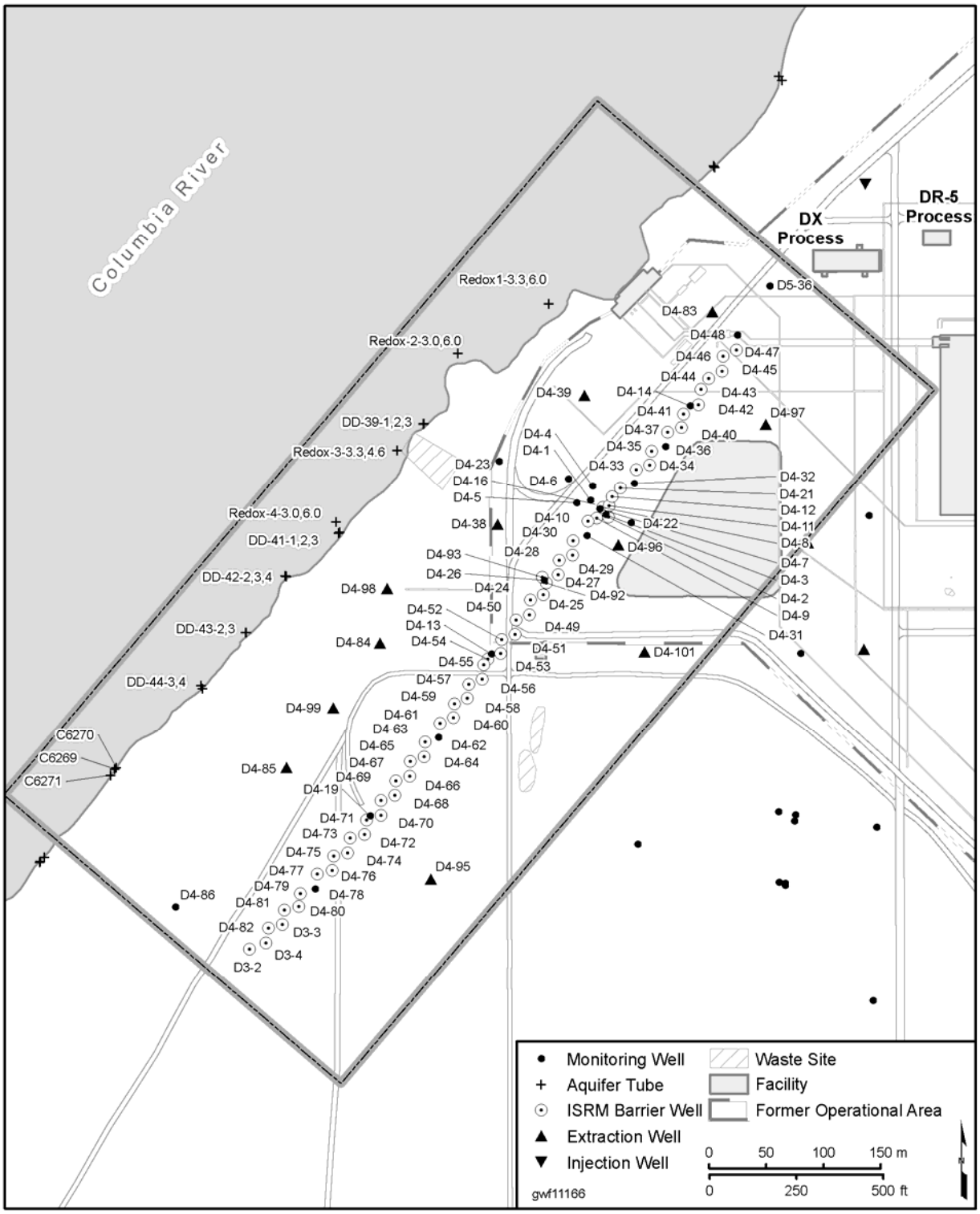


Figure 2.5-3. Facilities and Groundwater Monitoring Wells in 100-H

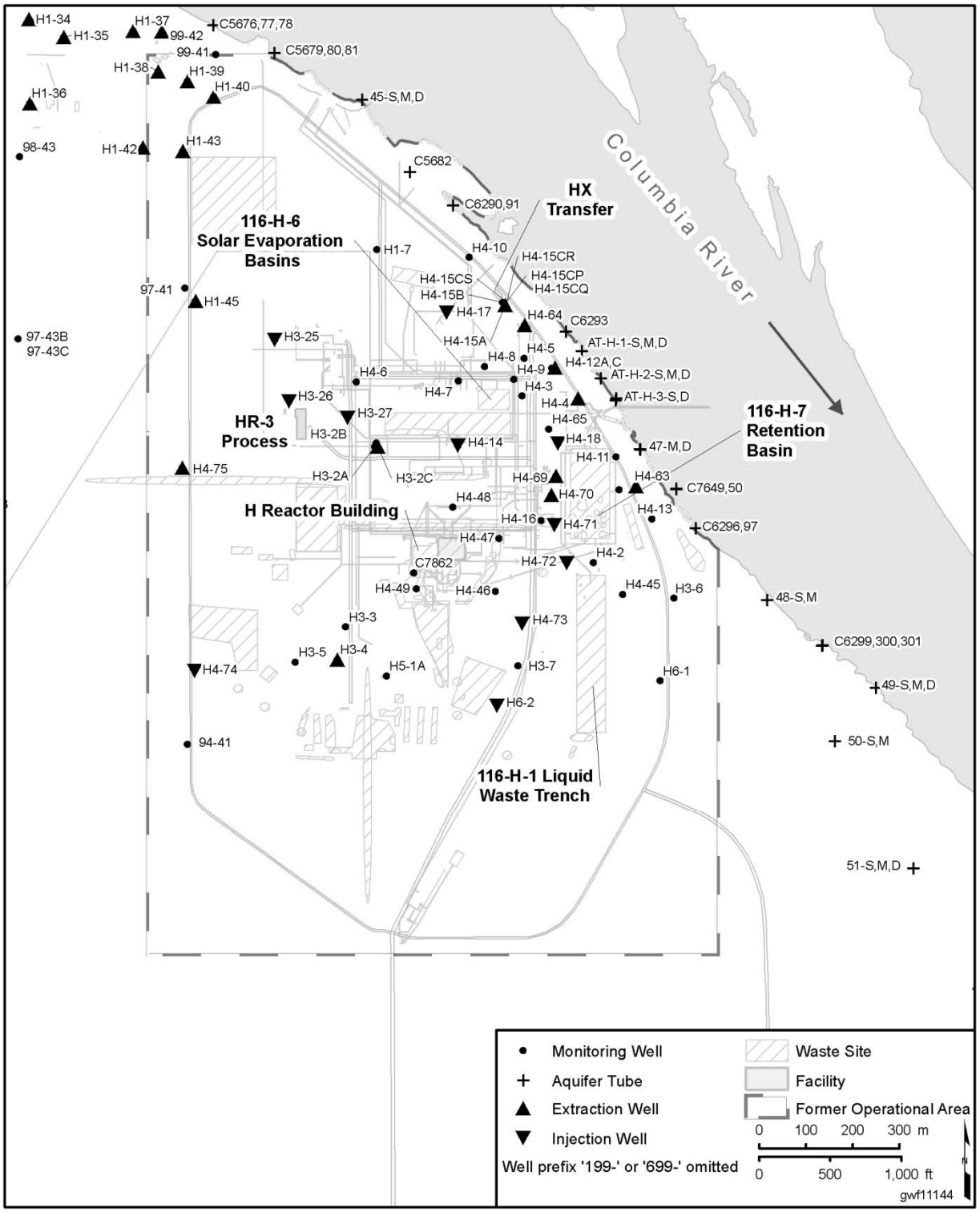


Figure 2.5-4. Facilities and Groundwater Monitoring Wells in the Horn

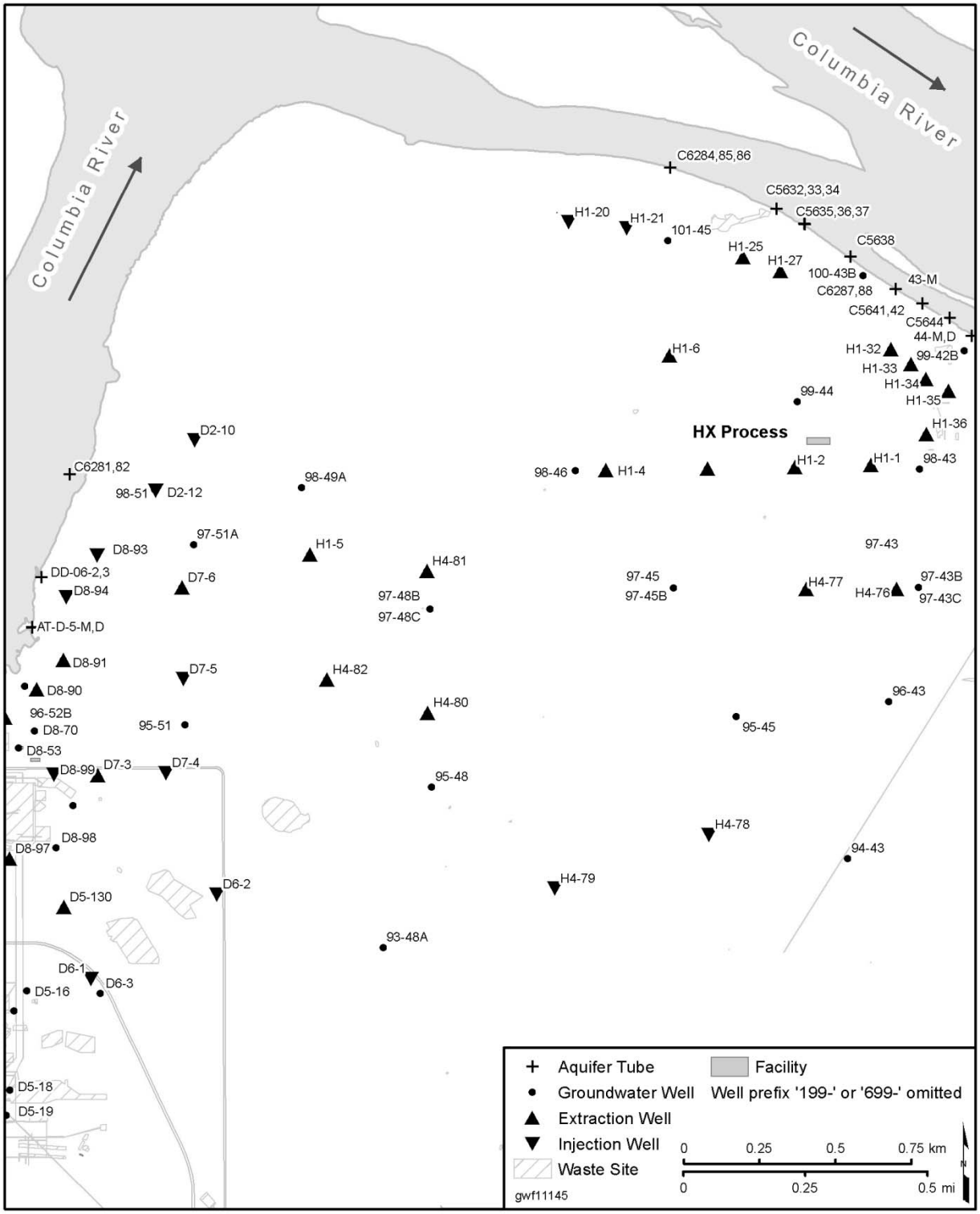


Figure 2.5-5. Changes in 100-HR-3 Plume Areas with Time

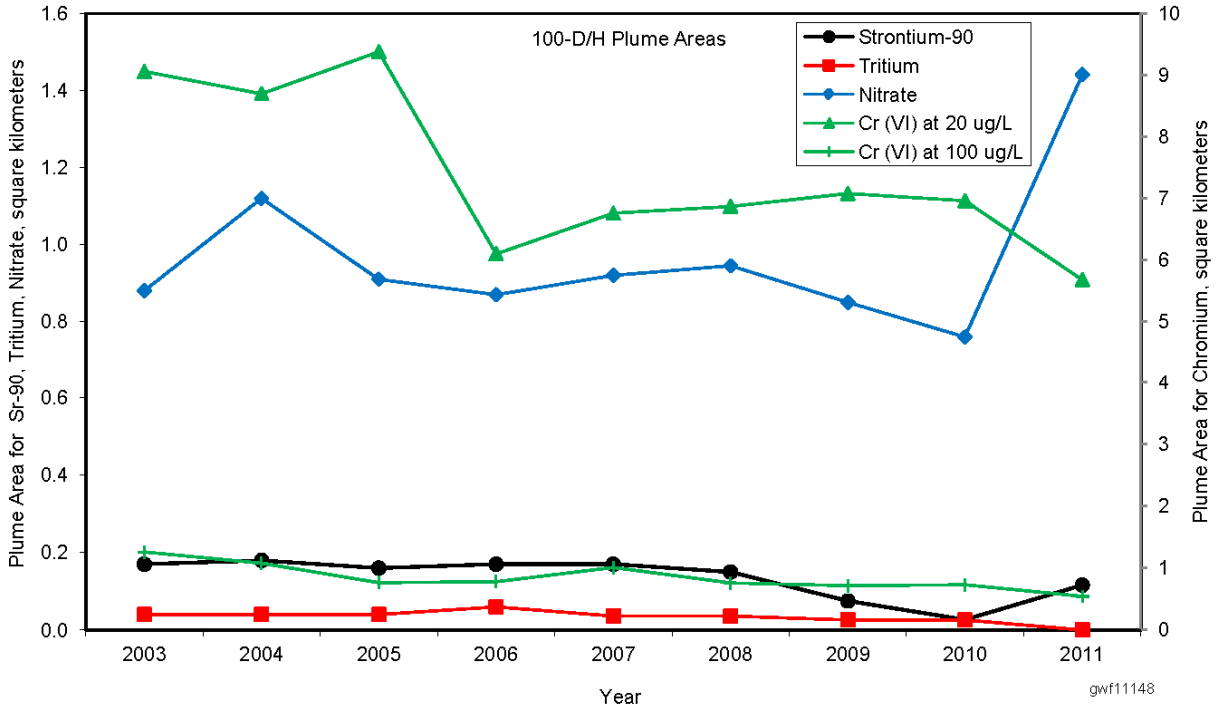


Figure 2.5-6. 100-HR-3 Water Table, March 2011

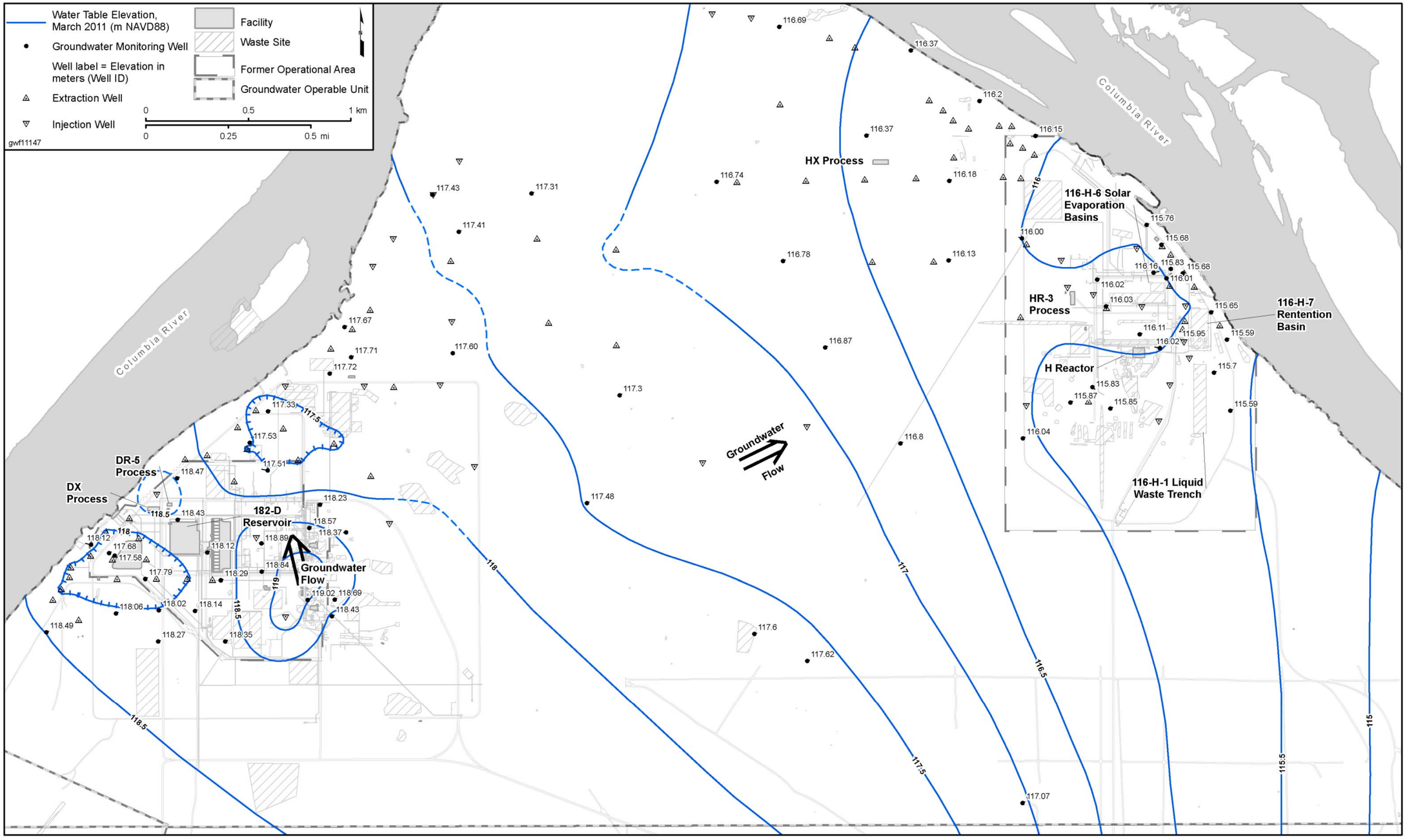


Figure 2.5-7. Aerial Photo of DX and HX Systems

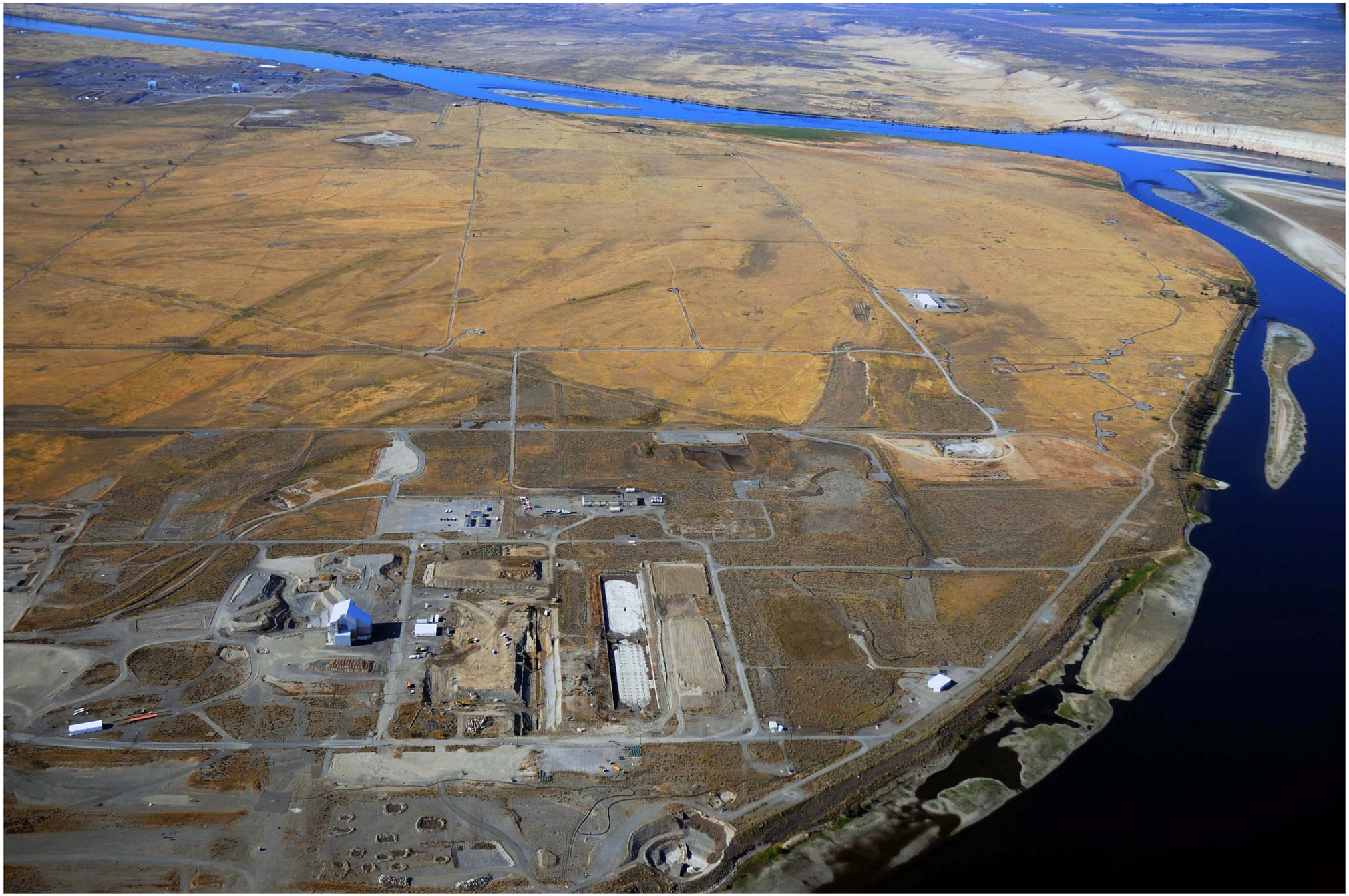


Figure 2.5-8. Hexavalent Chromium Concentrations in 100-HR-3, Low River Stage 2011

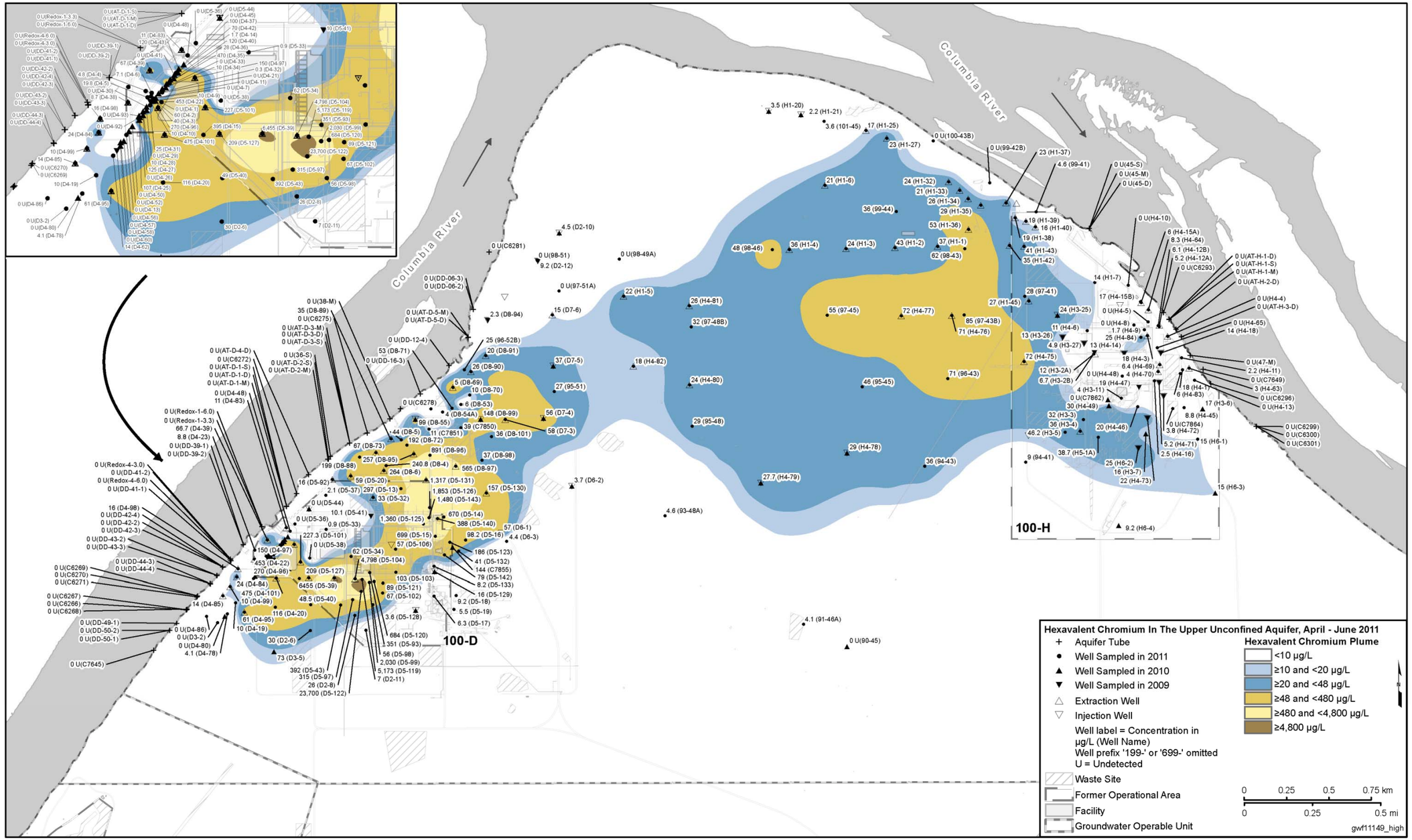


Figure 2.5-9. Hexavalent Chromium Concentrations in 100-HR-3, High River Stage 2011

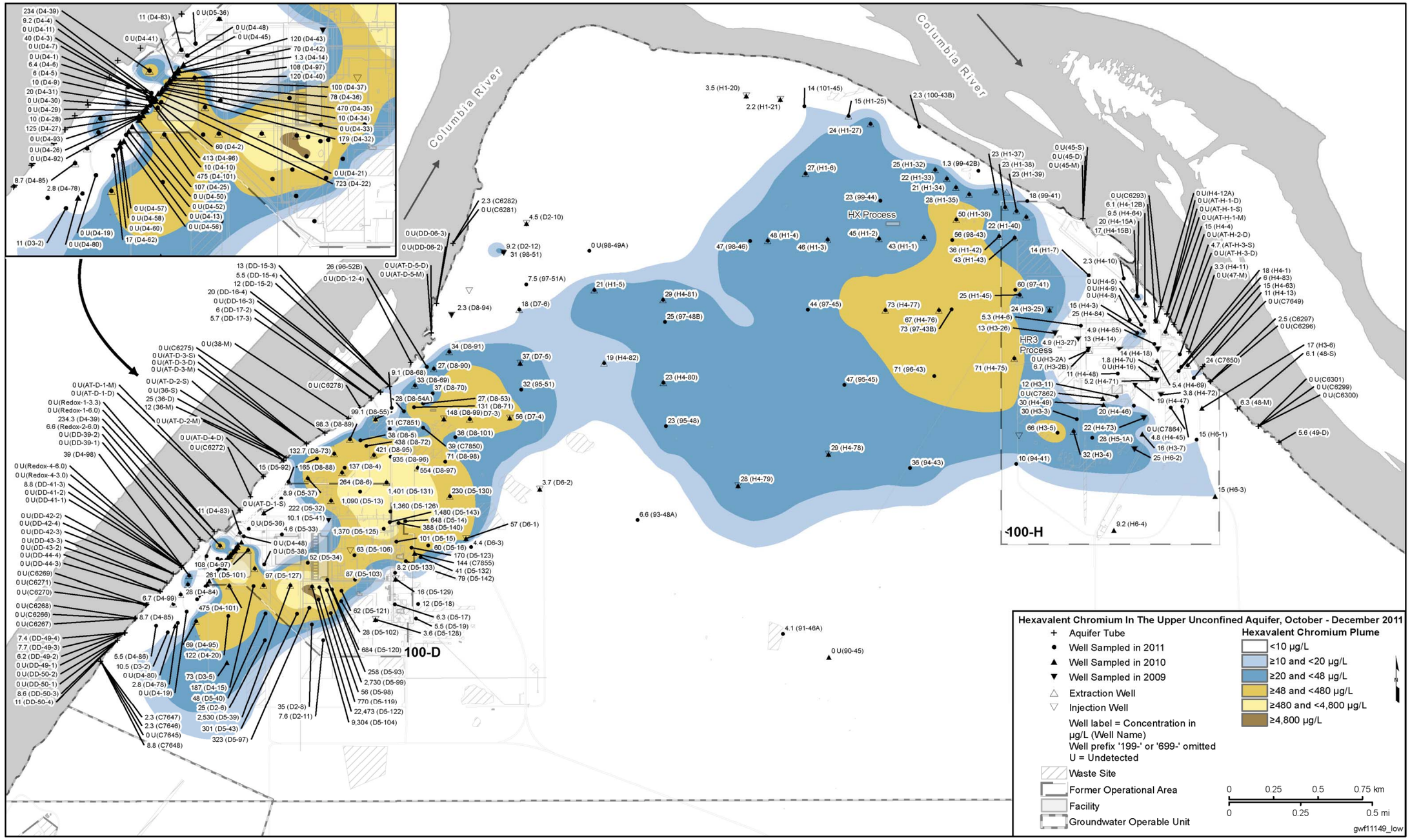
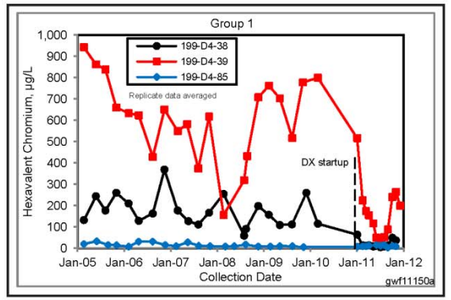
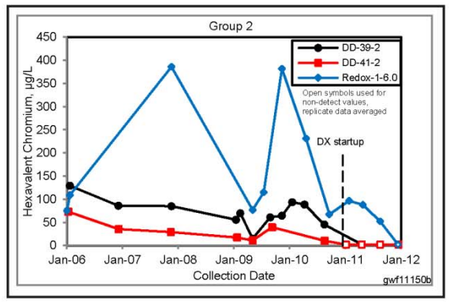
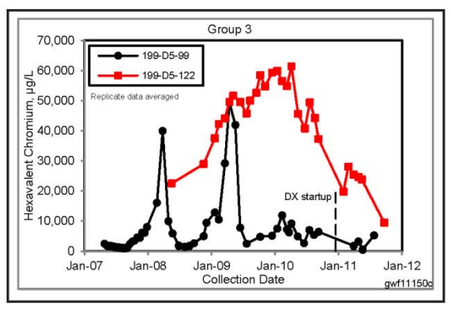
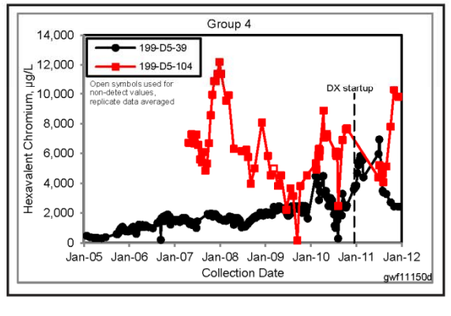


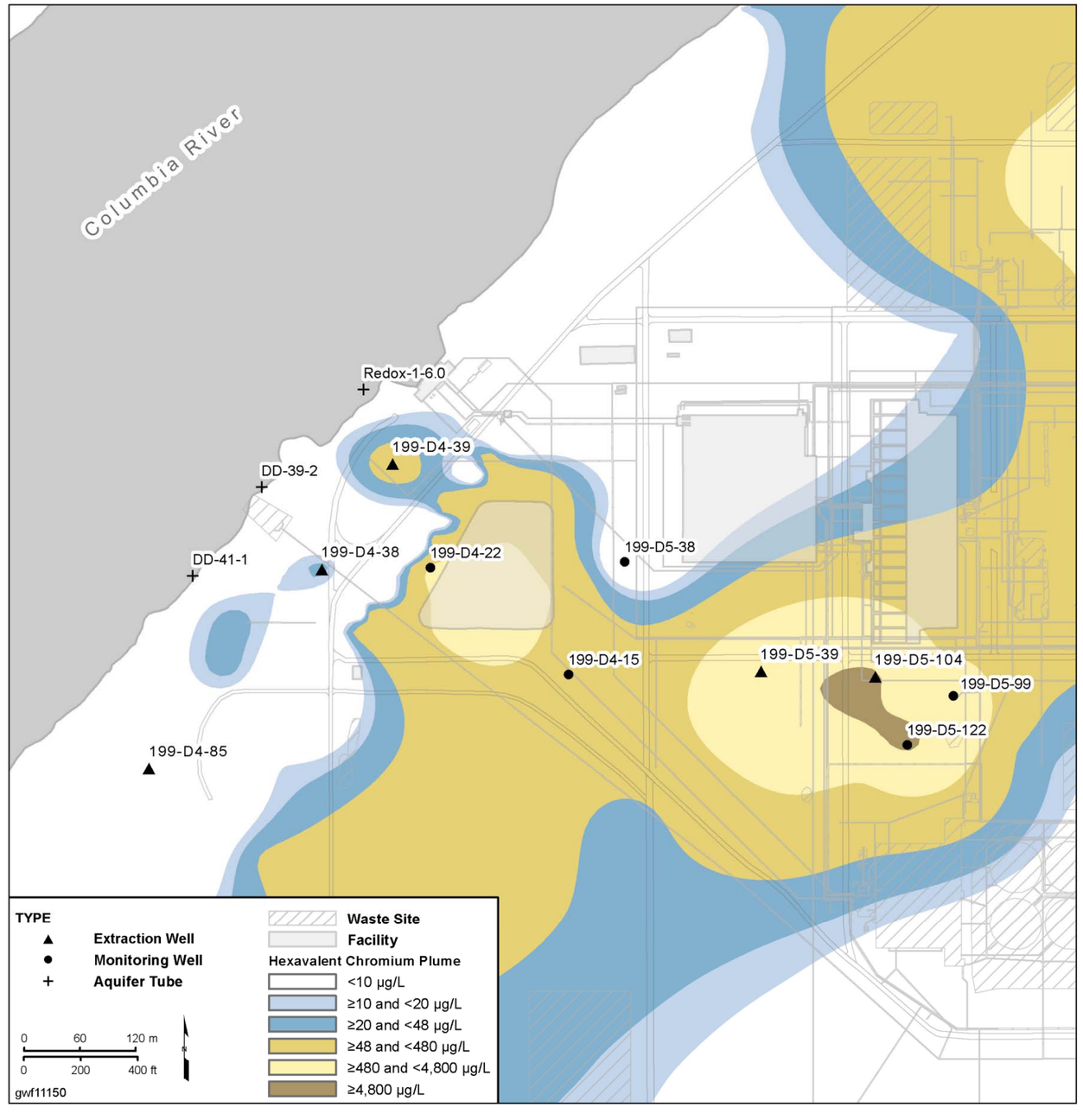
Figure 2.5-10. Hexavalent Chromium Concentrations and Trends in Southern 100-D Area Plume











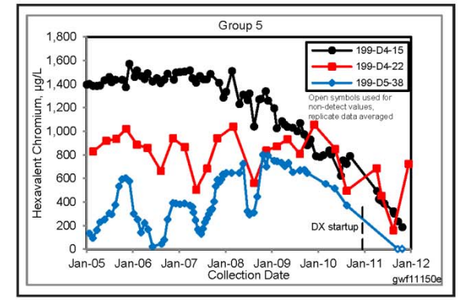


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Figure 2.5-11. 100-D Area Aquifer Tubes

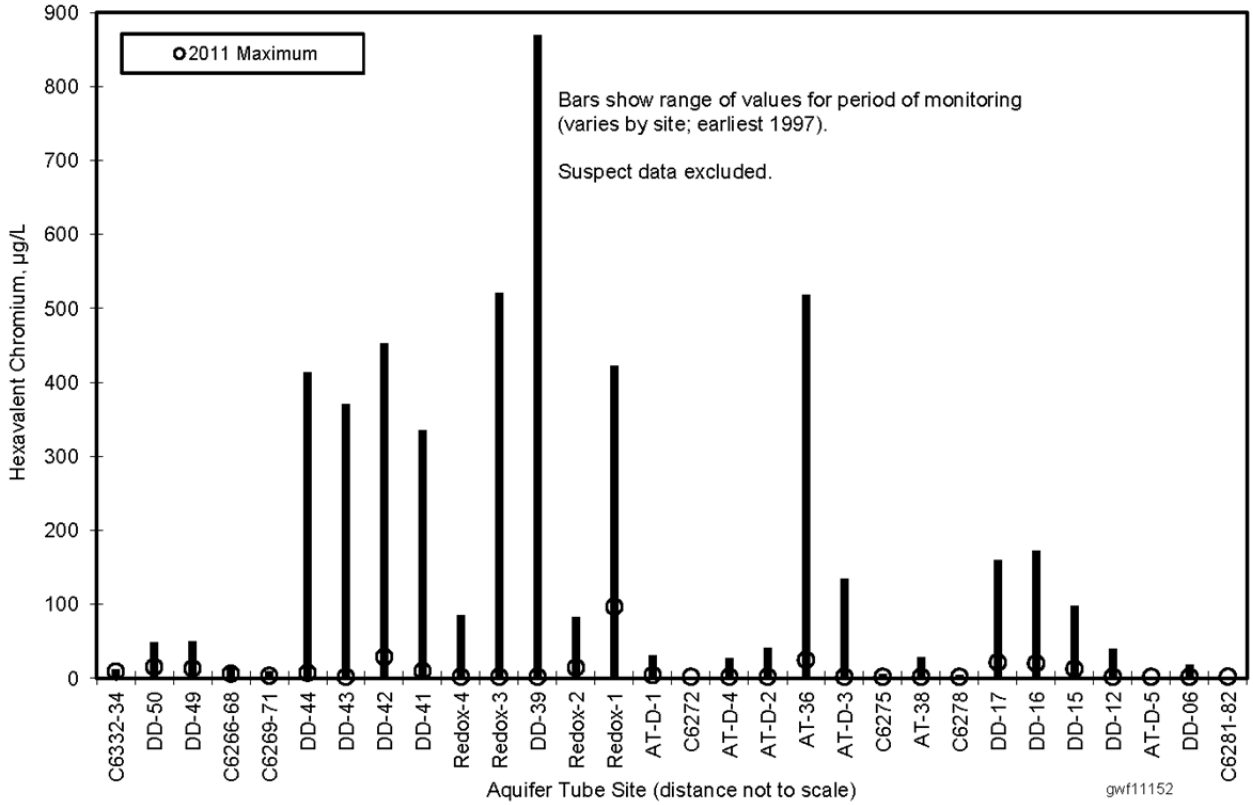

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Figure 2.5-12. North 100-D Area Hexavalent Chromium Plume

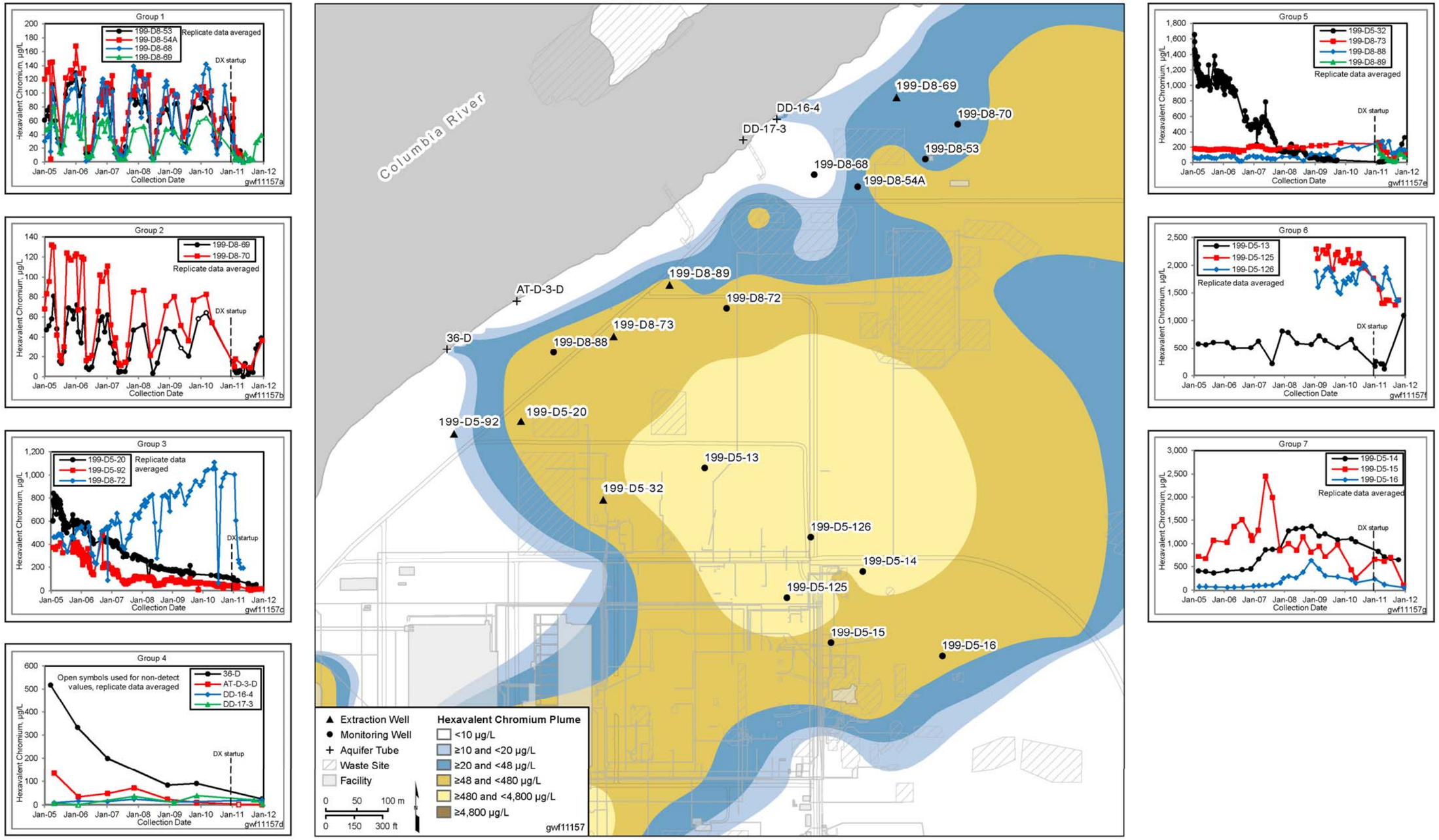

Figure 2.5-13. Composite Map and Trends for North 100-D Area Hexavalent Chromium Plumes (2005 to 2011)

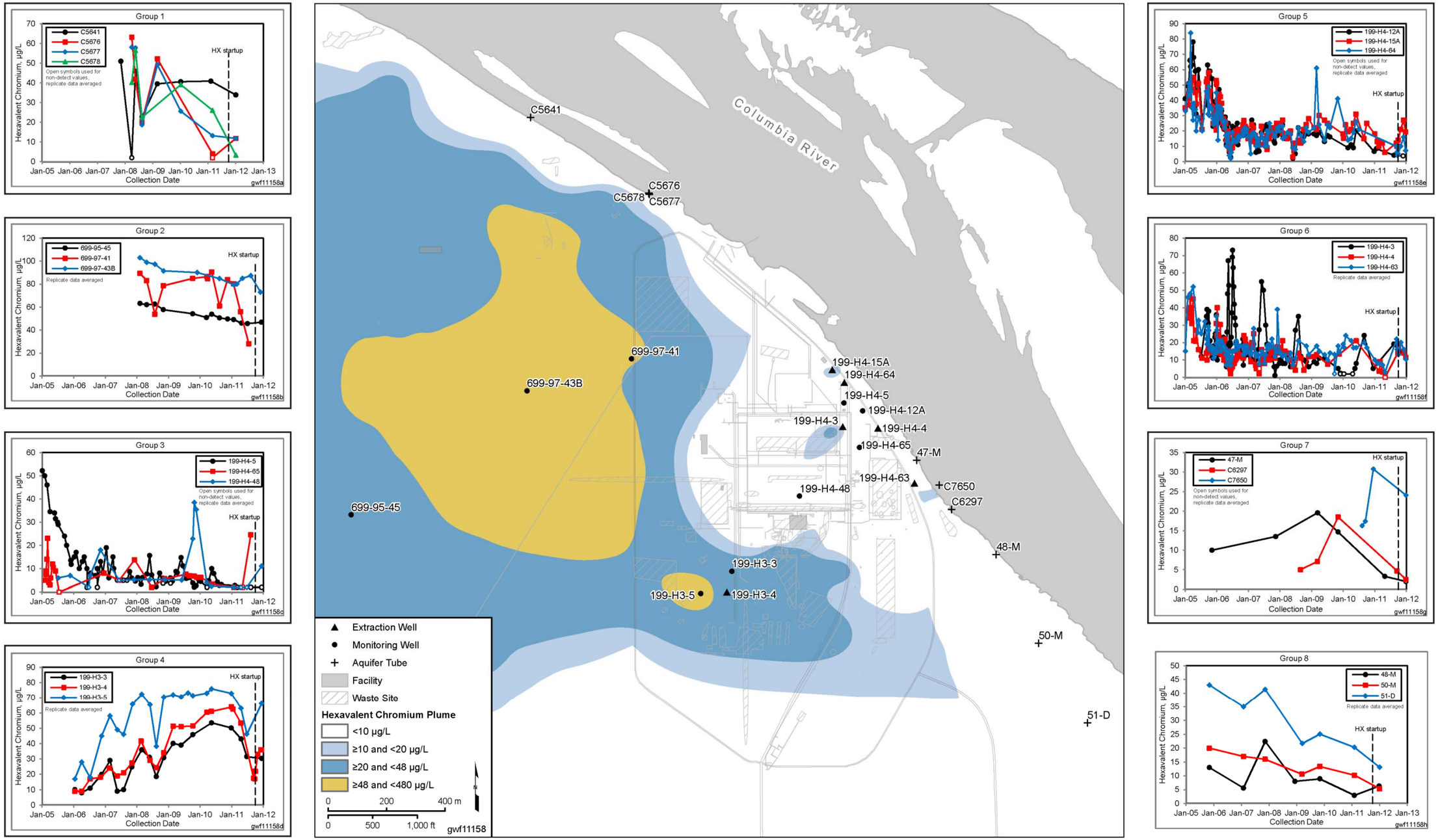

Figure 2.5-14. Hexavalent Chromium Trends in Wells Monitoring the Ringold Upper Mud Unit

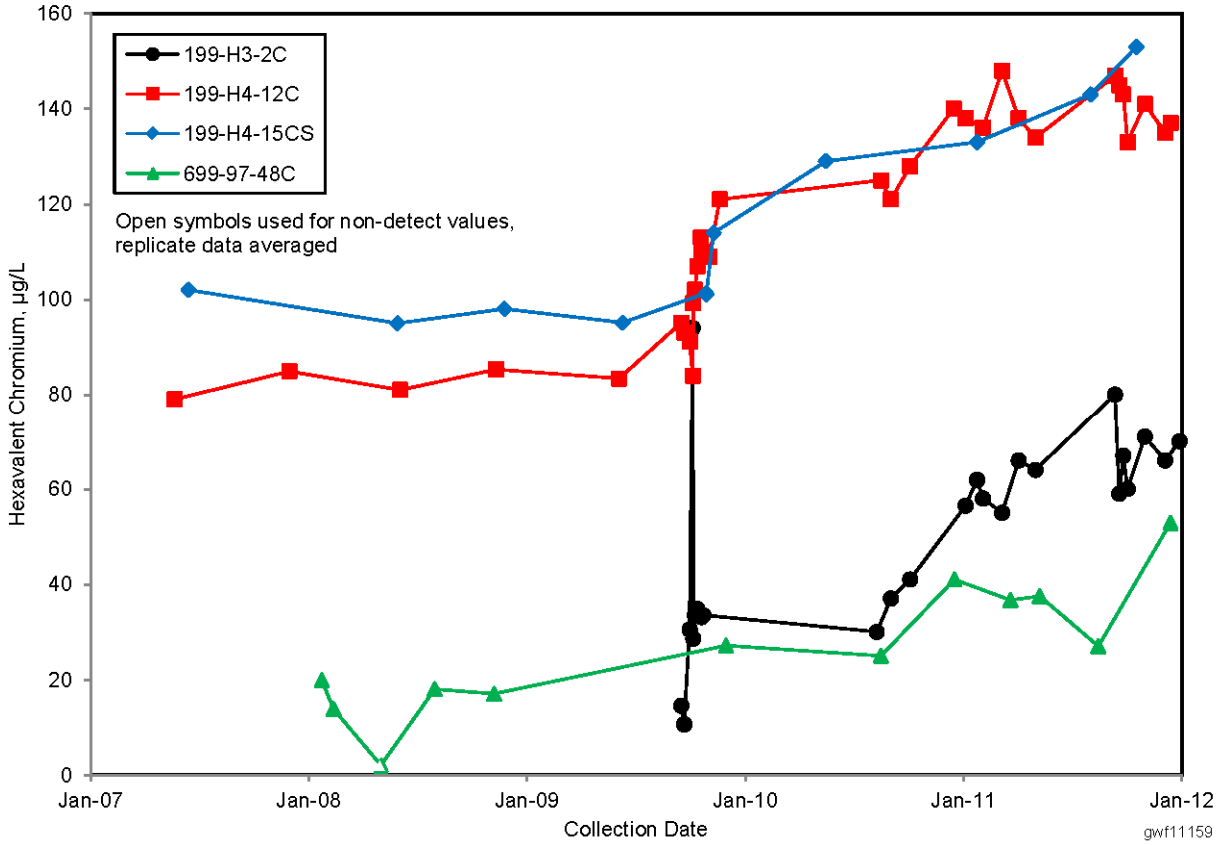

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Figure 2.5-15. Nitrate Plume Map

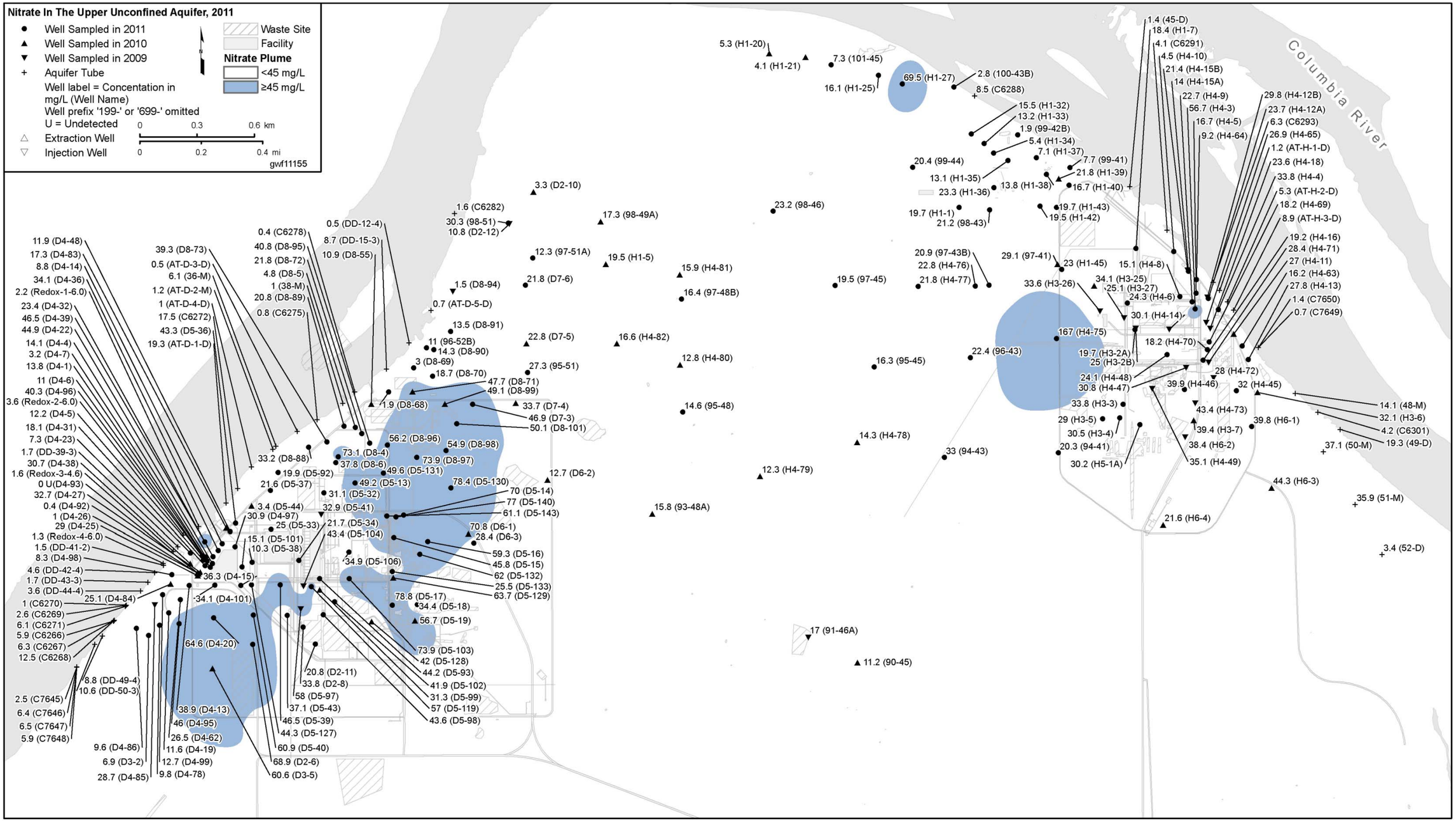

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Figure 2.5-16. Two-Panel Nitrate Trend Plot

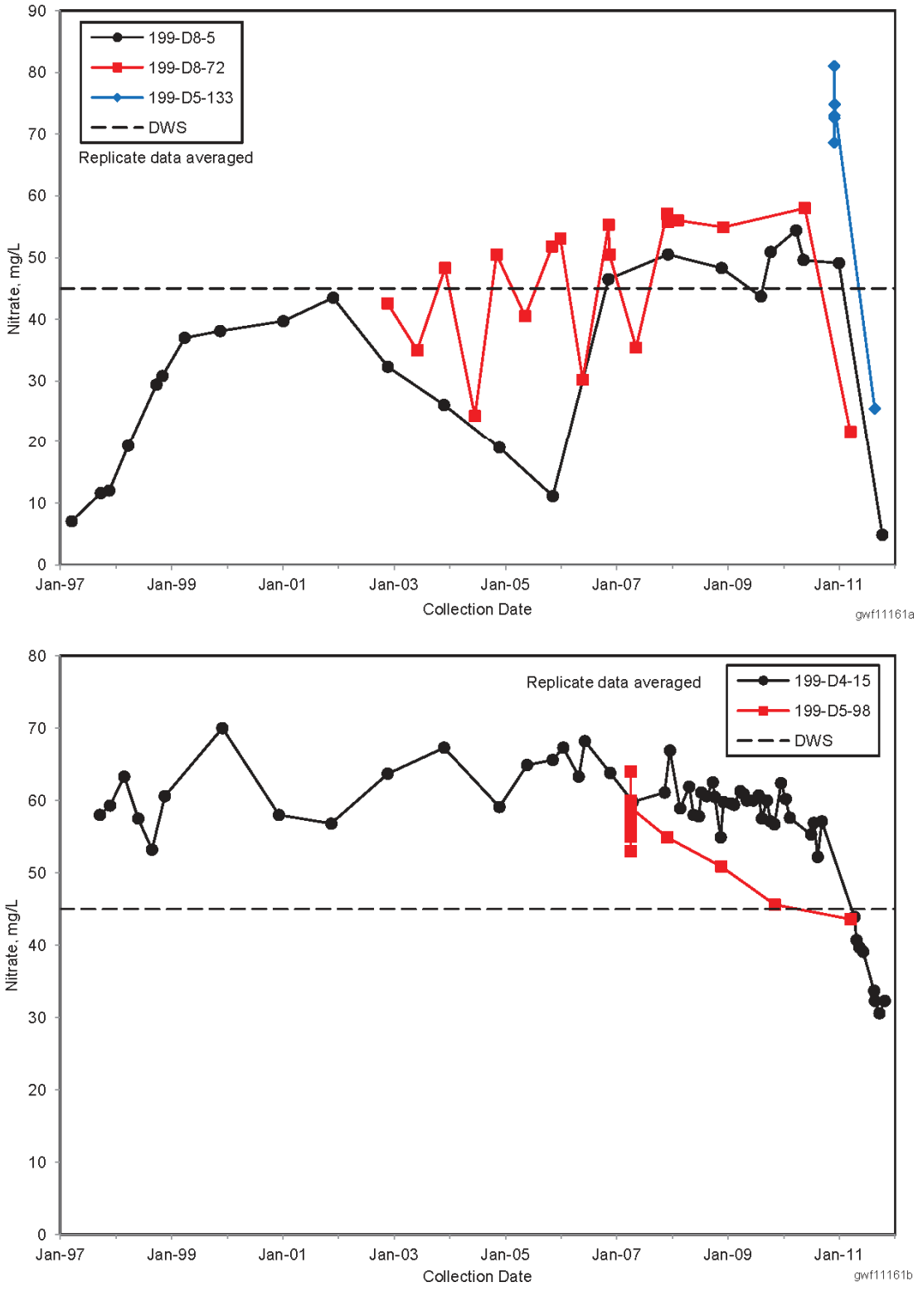

Figure 2.5-17. Trend Plot: Nitrate D5-36 and D5-38; Line for Drinking Water Standard

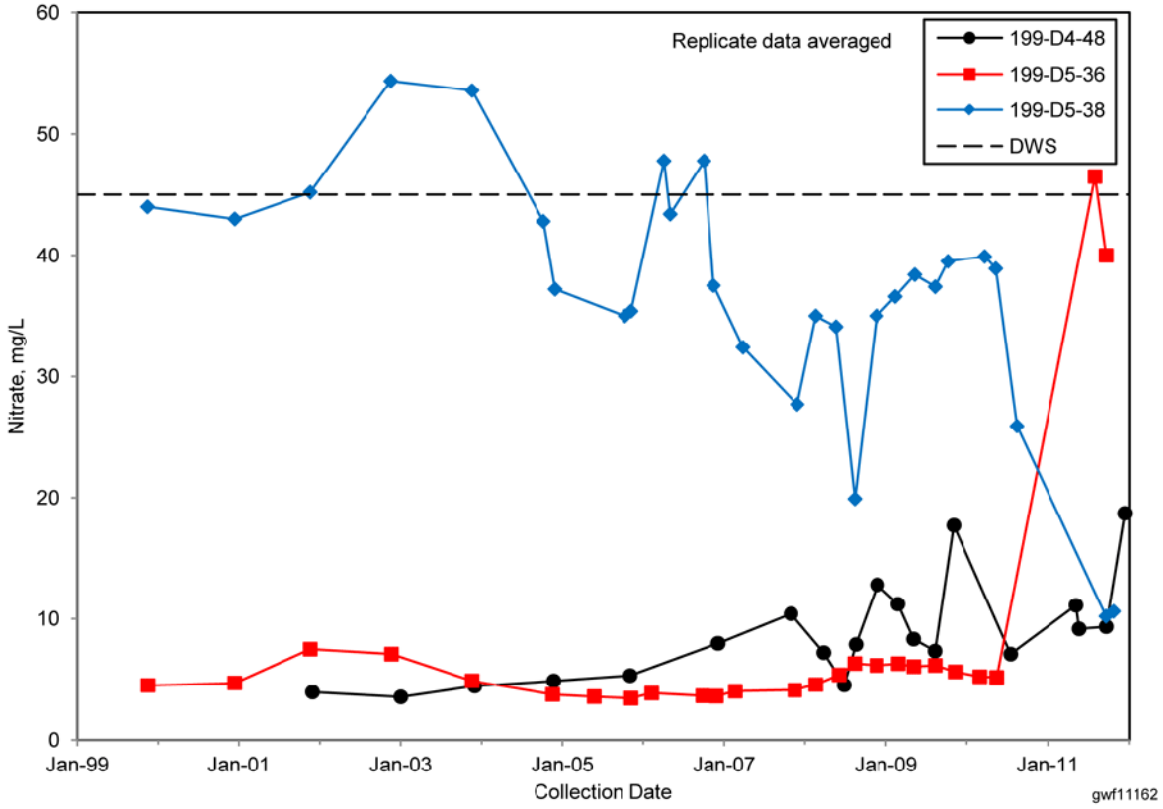

Figure 2.5-18. Strontium-90 Concentrations, Average 2011

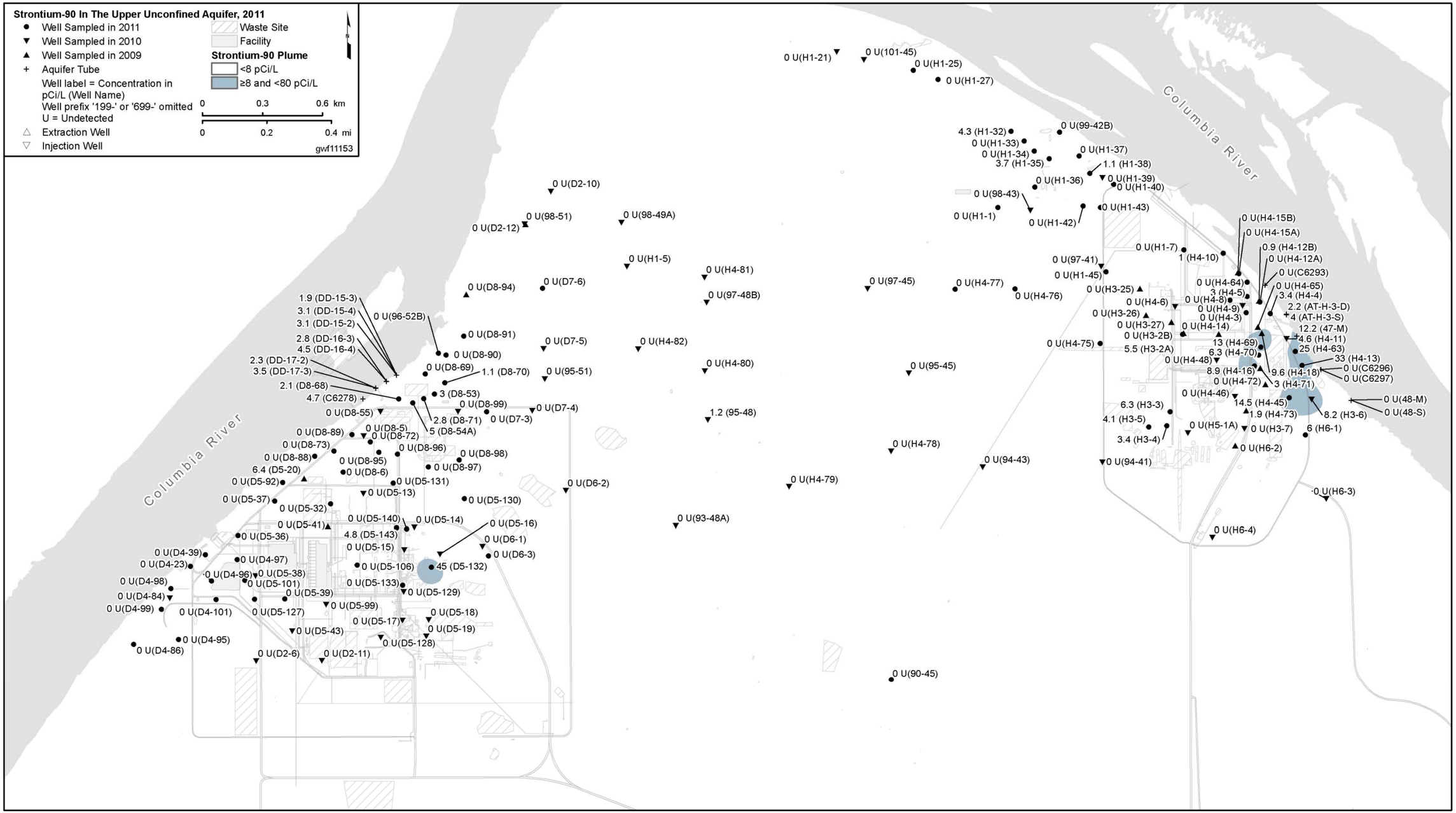

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Figure 2.5-19. Trend Plot for Tritium in 199-D3-2, 199-D4-19, and 199-D4-78 Compared to Drinking Water Standard

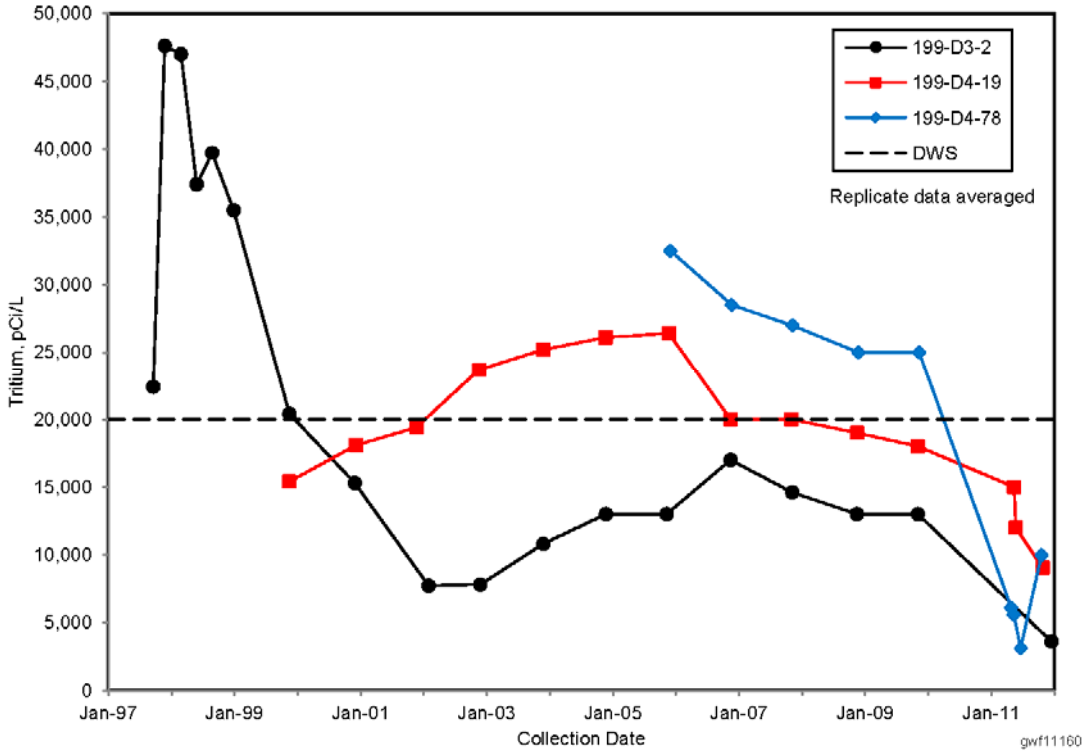

Figure 2.5-20. Stacked Bar Graph Showing Volume Water Treated and Mass Chromium Removed Over Time

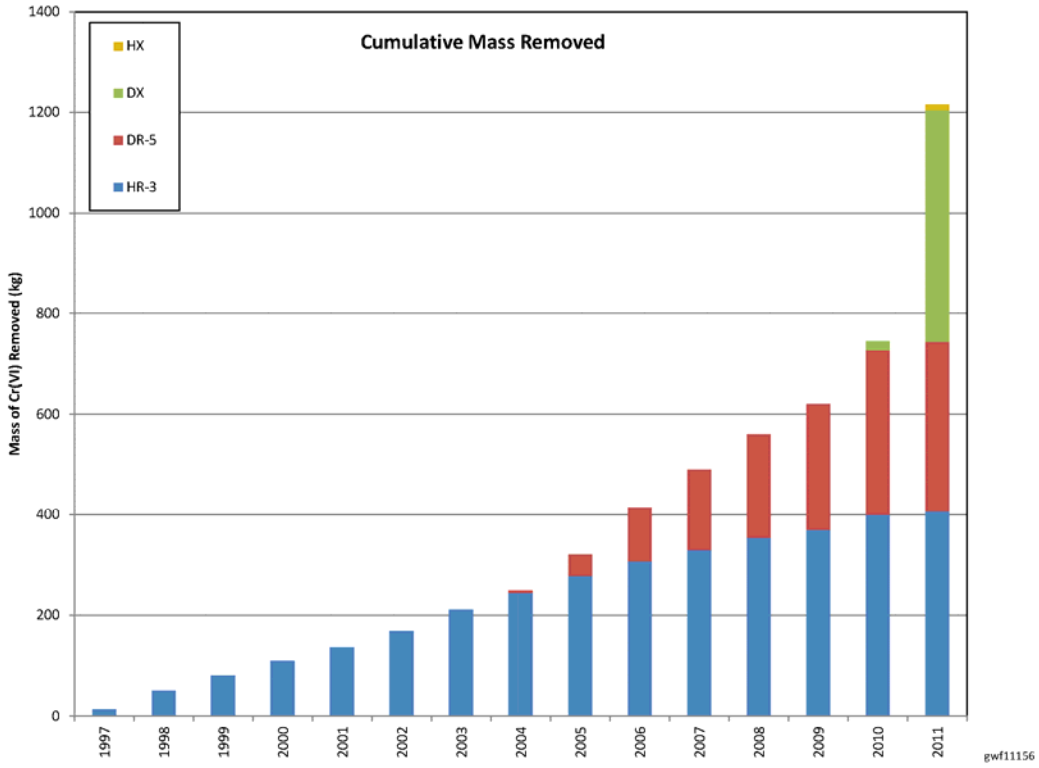

Figure 2.5-21. River Water Stiff Diagram

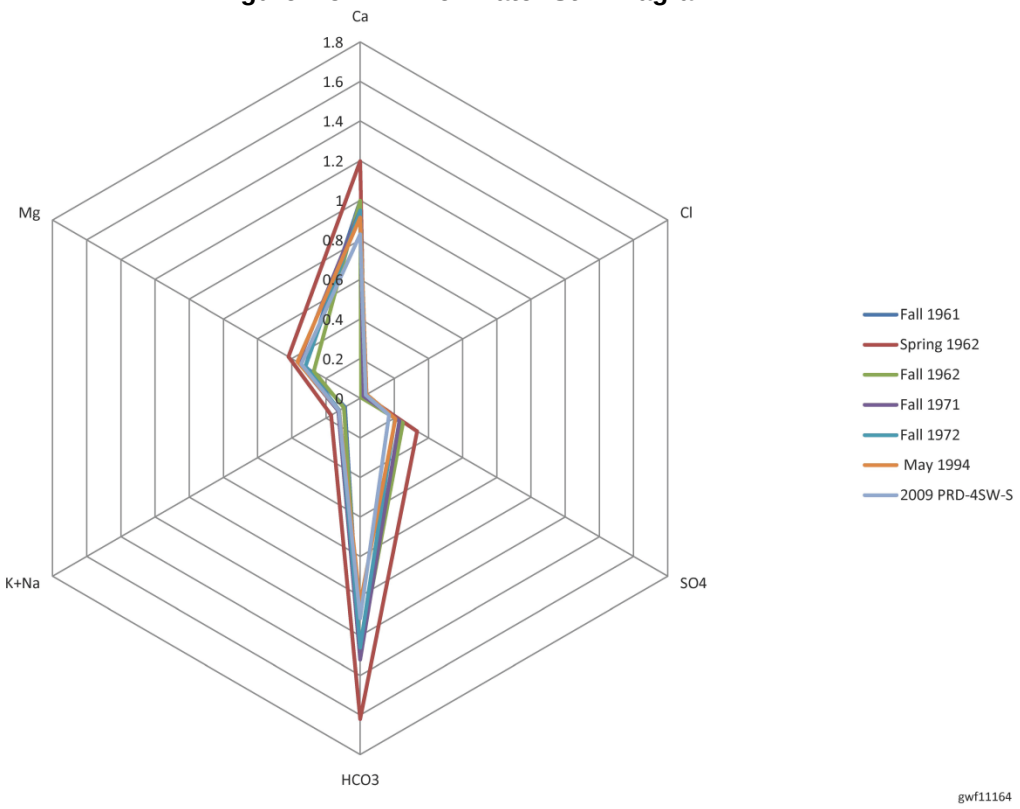
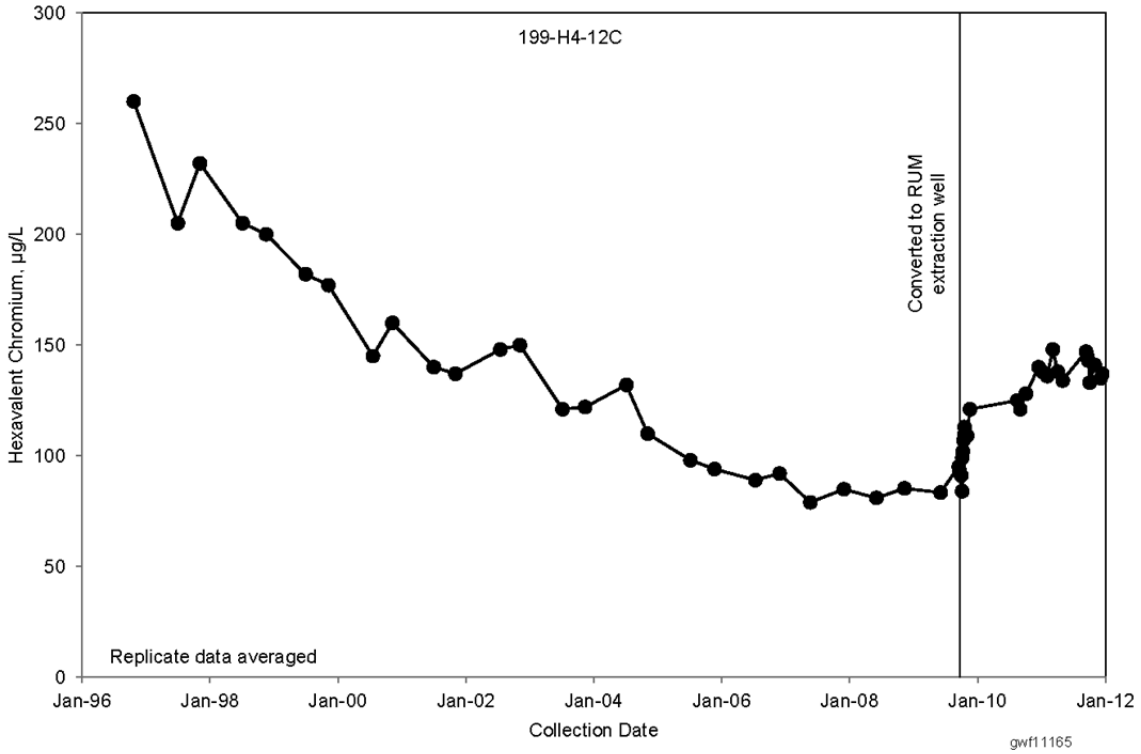
Figure 2.5-22. River Water Trend Chart (Hexavalent Chromium in Well 199-H4-12C)