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Revision 0

In Situ Redox Manipulation (ISRM) Annual Report Fiscal Year 2007

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

United States Department of Energy
P.O. Box 550
Richland, Washington 99352

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In Situ Redox Manipulation (ISRM) Annual Report Fiscal Year 2007

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EXECUTIVE SUMMARY

This report presents the annual summary and evaluation of the performance of the in situ redox manipulation (ISRM) interim remedial action located in the 100-D Area, within the 100-HR-3 Operable Unit (OU) at the Hanford Site. The ISRM is a groundwater-permeable reactive barrier established to remedy a hexavalent chromium plume. This report covers the period from October 1, 2006, through September 30, 2007.

The remedial action objectives (RAOs) of the ISRM treatment zone are presented in the original Record of Decision (ROD) for the 100-HR-3 OU (EPA/ROD/R10-96/134, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units at the Hanford Site*). The specific RAOs are identified as follows.

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

An ISRM treatability test was conducted in the 100-D Area in 1997 and 1998 in the center of the most contaminated portion of the groundwater plume. The purpose of the test was to evaluate the technology in Hanford Site groundwater for large-scale implementation.

The 1999 amended ROD decision for the 100-HR-3 OU (EPA, et al., 1999, *U.S. Department of Energy Hanford Site – 100 Area Benton County, Washington – Amended Record of Decision Summary and Responsiveness Summary (100-HR-3 Operable Unit)*) identified ISRM as the selected remediation alternative to address a newly defined groundwater plume located west of the D/DR Reactors. The amended ROD authorized large-scale deployment of the ISRM technology to remediate the plume and deferred the details of the design to the DOE/RL-99-51, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation*. A 3-year, three-phase emplacement schedule was developed. The 680 m (2,231-ft)-long permeable reactive barrier was completed in the fall of 2004.

Seven compliance monitoring wells located between the barrier and the Columbia River shoreline are sampled quarterly to assess the performance of the ISRM treatment zone in the protection of aquatic receptors. During fiscal year (FY) 2007, the annual average hexavalent chromium concentrations in two of the seven compliance wells have met the RAO #1 of 20 μg/L and two other wells are near the RAO. In the other three compliance wells, concentrations decreased in one well, increased in another well, and were steady in the third well. The highest annual average chromium concentration seen in the compliance wells was 539 μg/L in Well 199-D4-39. This well is downgradient from that part of the plume with the highest concentrations.

Performance of the barrier is not uniform, and an understanding of this variability will be important to the final remedy. The southwestern portion of the barrier generally appears to be mitigating hexavalent chromium contamination. Some areas in the northeastern portion of the barrier show some loss in reductive capacity and are showing increasing hexavalent chromium concentrations. On the average, approximately 74 percent of the barrier achieved the RAO of 20 μg/L. The best performance occurred from April to June, with 90 percent of the wells meeting the RAO. The lowest performance occurred from October to December, with 61 percent of the wells achieving 20 μg/L.

RAO #2 requires protection of human health by preventing exposure to contaminants in the groundwater. This RAO has been met as stated in the ROD through the use of institutional controls.

To enhance barrier performance, other approaches or technologies are being evaluated that could be used to mend the barrier, test alternative technology, and better define the source of the hexavalent chromium. These include an in situ biostimulation study, an electrocoagulation test (treatment technology), and a barrier amendment test with micron-size zero-valent iron. Twelve wells were drilled as part of the in situ biostimulation study in FY 2007, and one well was injected with an organic substrate in September 2007.

Although not specifically targeted for directly remediating the hexavalent chromium plume, an electrocoagulation test was initiated in FY 2007 east of the barrier. This test operated for five months, ending in October 2007. Data from the test are currently being analyzed.

Laboratory tests using micron-size zero-valent iron were carried out in FY 2007, with barrier injections expected to take place in the 4th quarter of FY 2008. In addition to these mitigation efforts, a chromium source investigation study was initiated this year and will continue into FY 2008. During the second quarter of FY 2007, seven wells were drilled in the upgradient portion of the plume that impacts the ISRM barrier. These wells were sampled in the vadose zone and are now being sampled bi-weekly as groundwater wells. A hexavalent chromium concentration range of 960 to 12,560 µg/L was measured in Well 199-D5-99 during the third quarter of FY 2007. It is presumed that this well, which is located near the former Sodium Dichromate Transfer Facility, is near or within the vadose zone source of chromium contamination.

In summary, the barrier is having an overall positive impact on groundwater quality. Some segments of the barrier perform better than others. Access controls in the 100-D Area continue to protect human health by restricting access to contaminants in the groundwater. Monitoring groundwater contamination upgradient from and within the barrier is providing information that will play a key role in leading to the final remedy.

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TERMS

CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
DO	dissolved oxygen
EC	electrocoagulation
Eh	reduction-oxidation potential
EPA	U.S. Environmental Protection Agency
FY	fiscal year
HEIS	*Hanford Environmental Information System* database
IAM	interim action monitoring
ISRM	in situ redox manipulation
MCL	maximum contaminant level
OU	operable unit
QC	quality control
RAO	remedial action objective
RCRA	*Resource Conservation and Recovery Act of 1976*
ROD	record of decision
ROD Amendment	*U.S. Department of Energy Hanford Site – 100 Area Benton County, Washington – Amended Record of Decision Summary and Responsiveness Summary (100-HR-3 Operable Unit)* (EPA, et al., 1999)
RPD	relative percent difference
SDWS	40 CFR 143, "National Secondary Drinking Water Regulations"
WAC	*Washington Administrative Code*

METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	Hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerels	millibecquerels	0.027	picocuries

1.0 INTRODUCTION

This annual progress and performance report discusses the in situ redox manipulation (ISRM) interim remedial action at the 100-HR-3 Operable Unit (OU) from October 1, 2006, through September 30, 2007 (fiscal year [FY] 2007). This report specifically addresses remedial actions performed at the hexavalent chromium plume in the southwestern portion of the 100-D Area (Figure 1-1). Interim pump-and-treat remedial actions performed at the northeastern portion of the 100-D Area and in the 100-H Area are discussed in a separate annual summary report. This is the seventh annual summary report that specifically addresses the ISRM remediation technology, as presented in the 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 ISRM technology creates a permeable subsurface treatment zone through the injection of sodium dithionite into the aquifer, thus forming a chemically reduced environment. As groundwater containing hexavalent chromium passes through the treatment zone, it is reduced to less toxic and less mobile trivalent chromium.

The regulatory decision document for deployment of the ISRM is *U.S. Department of Energy Hanford Site – 100 Area Benton County, Washington – Amended Record of Decision Summary and Responsiveness Summary (100-HR-3 Operable Unit)* (EPA, et al., 1999) (ROD Amendment). The following remedial action objectives (RAO) are identified in EPA/ROD/R10-96/134, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units at the Hanford Site* and the ROD Amendment.

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

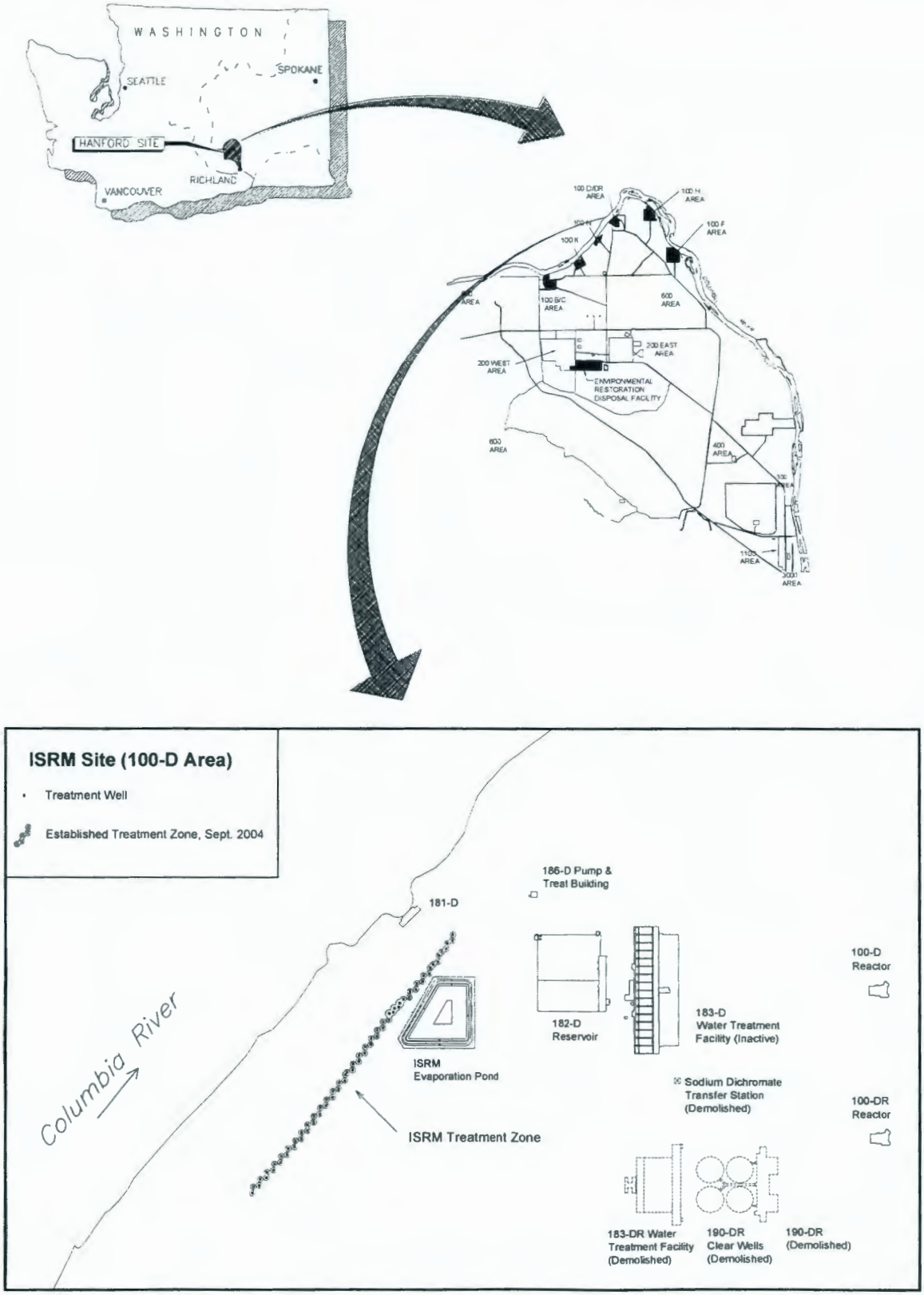
In addition to these RAOs, the ISRM system has been constructed in accordance with key design elements described in the DOE/RL-99-51.

1.1 PURPOSE

The purpose of this annual report is to provide the following:

- Document the progress toward achieving key design elements specified in the DOE/RL-99-51
- Document groundwater remediation system performance and status
- Document general aquifer conditions and aquifer response to remedial actions
- Provide discussion on remediation efforts.

Figure 1-1. In Situ Redox Manipulation Site Location Map.



ISRM = in situ redox manipulation.

1.2 HISTORY OF OPERATIONS

The 100-HR-3 OU is located in the northern portion of the Hanford Site along the Columbia River. This OU includes the groundwater underlying the source OUs associated with the D/DR and H Reactor areas and the property lying between the two areas. During operation of the D/DR Reactors between 1944 and 1967, large volumes of water were pumped from the Columbia River and used as reactor coolant. Sodium dichromate was added to the cooling water to inhibit corrosion of the reactor piping and subsequently leaked into the soil and contaminated the groundwater.

Following discovery of hexavalent chromium contamination in groundwater in 1995, an ISRM treatability test was conducted in the 100-D Area. The first ISRM treatment took place in Well 199-D4-7 in September 1997, and four additional wells were treated between May and July 1998. The five treated wells created a reducing zone in the unconfined aquifer that was approximately 46 m (151 ft) long by 15 m (49 ft) wide (Figure 1-2).

During the fall of 1999, the treatment zone in the treatability test area was extended by the treatment of Well 199-D4-21, resulting in hexavalent chromium concentrations being reduced from 1,050 μg/L to less than detection in that well. The success of these six treatment wells provided sufficient additional data to support advancing from treatability testing to emplacement of a large-scale treatment zone.

The ISRM technology was identified in the ROD Amendment as the selected alternative for hexavalent chromium treatment within the newly defined groundwater plume located to the west of the D/DR Reactor Area. This alternative differed from the selected remedial action of pump-and-treat reinjection activities specified in the record of decision (ROD) for the 100-HR-3 OU (EPA/ROD/R10-96/134). The ROD Amendment deferred the details of the full-scale design of the treatment zone to DOE/RL-99-51. A three-year emplacement schedule was developed in the DOE/RL-99-51 to meet the ROD Amendment requirements. The three phases (Phases I, II, and III) coincide with FY 2000, FY 2001, and FY 2002, respectively. The ISRM treatment zone was constructed outward from the center of the most contaminated portion of the groundwater plume near the Columbia River shoreline. The treatment zone was to be expanded until the edge of the 20 μg/L hexavalent chromium groundwater plume was reached, as identified in DOE/RL-99-51.

In FY 2000, Phase I of the large-scale deployment of the ISRM technology was initiated. Sixteen wells were installed (2 compliance wells and 14 treatment zone wells), and chemical treatment was performed in 10 wells. During this phase, the ISRM treatment zone was extended 60 m (197 ft) toward the northeast and 60 m (197 ft) toward the southwest.

In FY 2001, Phase II well construction and treatment zone emplacement activities began. Thirty-two wells were installed (4 compliance wells and 28 treatment zone wells), and chemical treatment was performed in 28 wells. These 28 treatment wells extended the ISRM treatment zone to a length of over 195 m (640 ft).

The ISRM barrier was extended to the west during Phase III drilling in FY 2002. Seventeen ISRM treatment wells and three characterization boreholes were drilled, and chemical treatment was performed in 12 of 17 treatment wells. Chemical treatment was subsequently completed in the last five wells during FY 2003, which extended the ISRM treatment zone to a length of 680 m (2,231 ft). The barrier consists of 72 wells for the purposes of treatment, monitoring, and compliance.

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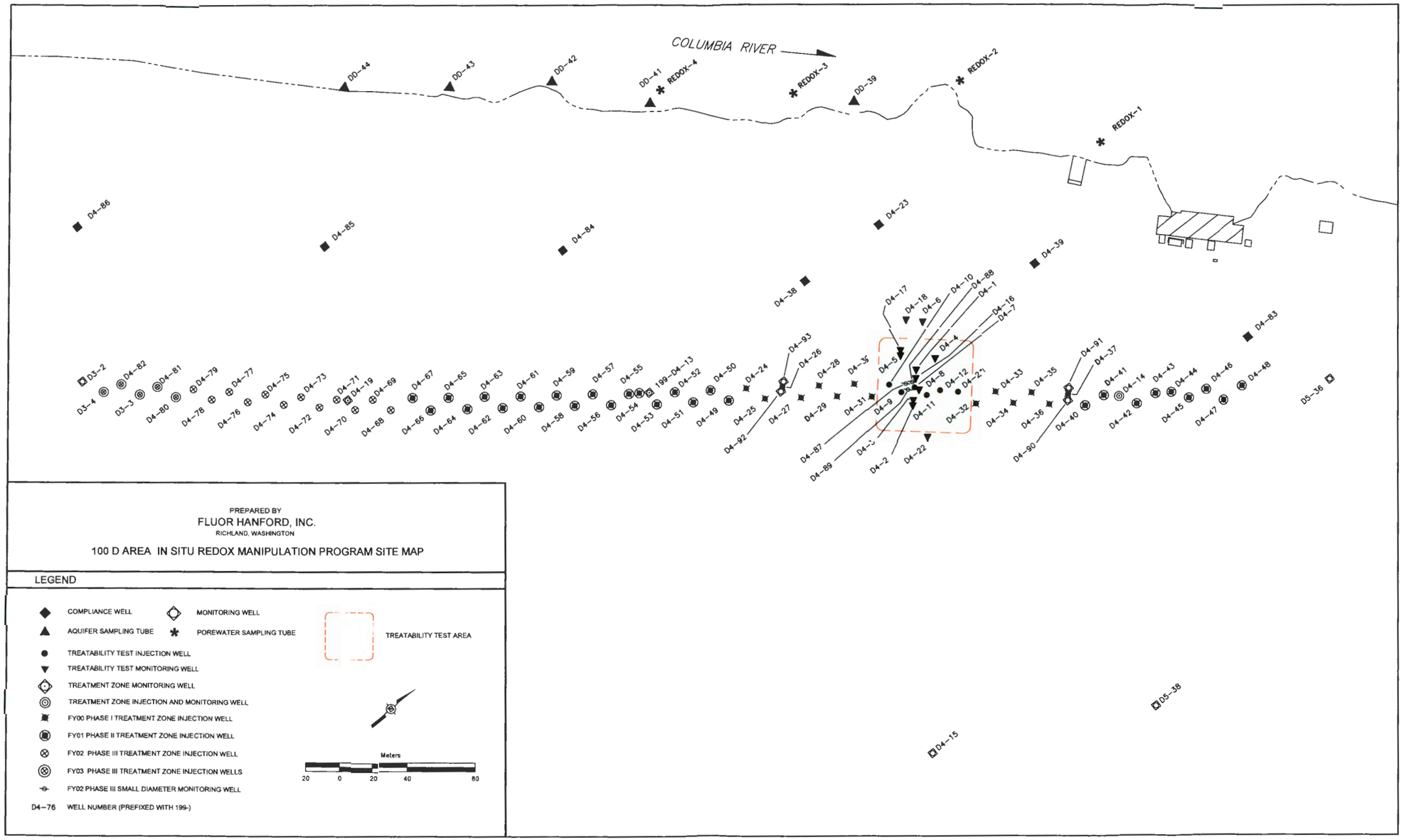
Figure 1-2. In Situ Redox Manipulation Treatment Zone Well Locations.



1.3 REPORT ORGANIZATION

This document consists of nine sections. Chapter 1.0 contains the introduction. Chapter 2.0 provides an overview and discussion of the ISRM technology and its development and demonstration at the Hanford Site. Chapter 3.0 discusses barrier performance in terms of both hydraulic monitoring and contaminant monitoring. Chapter 4.0 provides a brief discussion of pending treatability tests and drilling. Chapter 5.0 discusses the quality assurance/quality control (QC) for the samples analyzed in FY 2007, and Chapter 6.0 presents ISRM cost data. Chapter 7.0 provides conclusions, and Chapter 8.0 presents recommendations. A list of the references cited for preparation of this document is found in Chapter 9.0. Appendix A describes water table conditions, Appendix B contains plots of flow direction and gradient solutions for groundwater, Appendix C consists of hexavalent chromium concentration trend plots, and Appendix D contains supporting contaminant data and analysis information.

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2.0 IN SITU REDOX MANIPULATION TECHNOLOGY OVERVIEW

A plume of dissolved hexavalent chromium in the groundwater was discovered in 1995 during groundwater characterization activities along the Columbia River shoreline to the west of the D/DR Reactors in the 100-D Area. The source of the observed hexavalent chromium contamination is believed to be sodium dichromate. Sodium dichromate-dihydrate was previously used for corrosion control in reactor cooling water. Chemical stock material or concentrated sodium dichromate solution may have been released near the reactor inlet cooling water treatment facilities. The geometry of the current groundwater plume indicates that the release(s) occurred near the facility where water was treated before it was used as cooling water in the reactors. The actual source has not been confirmed, and specific release point(s) of the chromium into the groundwater system have not yet been identified. However, an ongoing chromium source investigation in FY 2007 and continuing into FY 2008 found hexavalent chromium concentrations that may be indicative of at least one source area.

The ISRM technology creates a chemically reduced permeable treatment zone that reduces hexavalent chromium in groundwater to trivalent chromium, which is less mobile and less toxic than the hexavalent form. A diagram showing the chemical speciation of chromium at varying reduction-oxidation potential (Eh) and pH conditions is provided in Figure 2-1. For reference, Eh in the 100-D Area typically ranges from 0.2 to 0.4 volts, generally decreasing across the barrier; pH typically ranges from 7.5 to 8.5, although values above 9 are measured.

The aquifer treatment zone is created by injecting a solution of sodium dithionite into the aquifer through a series of groundwater wells (Figure 1-2). Sodium dithionite is a strong reducing agent that scavenges unbound dissolved oxygen (DO) from the aquifer and reduces numerous metallic elements and oxy-ions present in the aquifer in an oxidized state. Numerous reduction reactions occur in the groundwater system during the ISRM treatment process. In addition, numerous oxidation reactions occur on a continuous basis following establishment of the treatment zone. The principal reaction that provides the residual reduction capacity to treat chromate ions flowing through the treatment zone is the reduction of ferric iron to ferrous iron. After the reduction treatment, ferrous iron is present in two forms: (1) dissolved ferrous iron in solution in the groundwater, and (2) structural ferrous iron associated with the geologic material forming the aquifer matrix. Some dissolved ferrous iron may migrate slowly downgradient with the groundwater flow, while structural ferrous iron provides residual reduction capacity that can react with the hexavalent chromium in incoming groundwater.

Hexavalent chromium in aqueous solution flows into and through the treatment zone at the natural groundwater velocity. When dissolved hexavalent chromium (in the form of the water-soluble chromate ion) in the aquifer enters the reducing environment, it reacts with ferrous iron in the treatment zone and is reduced to trivalent, or chromic, chromium. The resulting trivalent chromium ultimately precipitates from the groundwater as chromic hydroxide or a chromic-ferric hydroxide complex. Both of these compounds have very low solubility in water and are less toxic and mobile than dissolved hexavalent chromium at typical groundwater pH and Eh conditions.

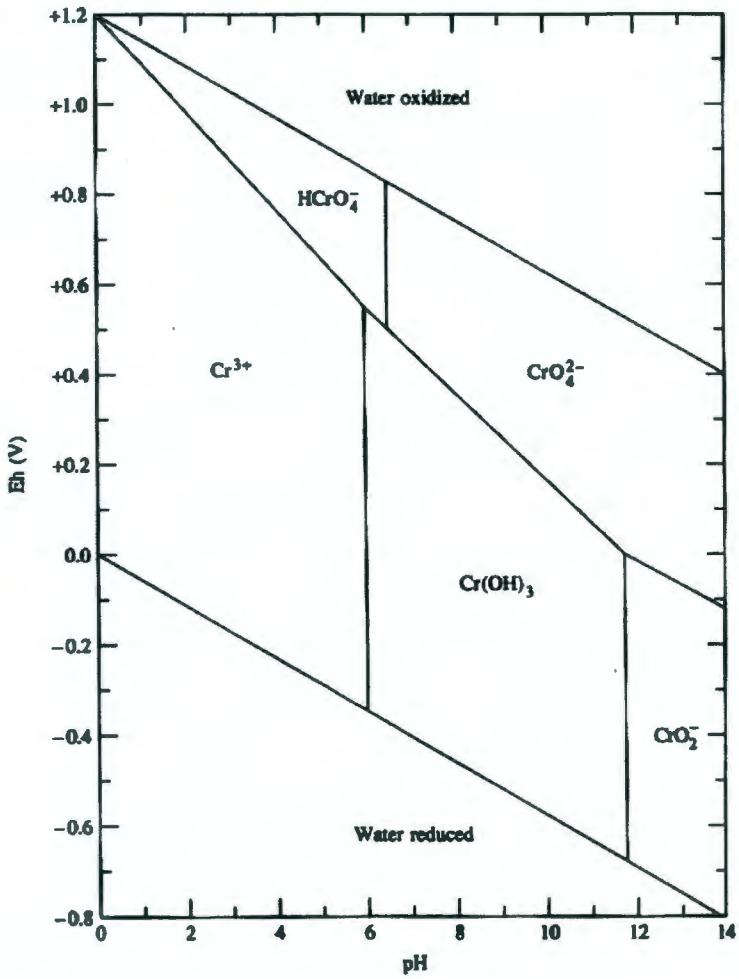
The results of the ISRM technology evaluation are presented in the PNNL-13349, *100-D Area In Situ Redox Treatability Test for Chromate-Contaminated Groundwater, September 2000*. The

year-end report provides additional information regarding the feasibility and apparent effectiveness of the ISRM technology.

The longevity of the treatment zone's capacity to reduce hexavalent chromium within the aquifer (estimated to be 23 years [PNNL-13349]) is a function of the combined effects of chemical and physical characteristics of the aquifer, including the following aspects:

- Quantity and distribution of residual ferrous iron within the aquifer matrix following the treatment process
- Flow rate of untreated groundwater into and through the treatment zone
- Concentration of oxidizing constituents in the incoming groundwater (e.g., DO, nitrate, and hexavalent chromium).

Figure 2-1. Chromium Speciation Under Standard Conditions.



Source: Fetter, C. W., 1993, *Contaminant Hydrogeology*, p. 278.

CrO_4^{-2} = water-soluble chromate ion.
$Cr(OH)_3$ = chromic hydroxide.

3.0 IN SITU REDOX MANIPULATION BARRIER PERFORMANCE

Overall ISRM barrier performance in FY 2007 was similar to barrier performance in FY 2006. Some changes occurred in the plume configuration and the hydraulic system. The following sections discuss hydraulic conditions in the aquifer, plume movement and configuration, and changes in contaminant concentrations. Section 3.1 provides an update on hydraulic monitoring, and Section 3.2 discusses contaminant monitoring results.

3.1 HYDRAULIC MONITORING

Groundwater elevations in the unconfined aquifer were measured in monitoring wells at the ISRM site in FY 2007. The water levels were measured using an automated recording system, and quarterly manual measurements were made using an electric tape. The automated water-level monitoring system recorded data from pressure transducers on an hourly basis throughout the year at 15 groundwater monitoring wells at the site (Figure 3-1). The river-stage cycles and corresponding groundwater responses (i.e., hydrographs) for wells monitored by automated processes during part or all of FY 2007 (October 2006 through September 2007) are contained in Appendix A.

Both automated and manual depth-to-water measurements were used to calculate groundwater elevations through comparison with known survey elevations. The resulting groundwater elevation data were used to prepare contour maps of water levels at the site and to develop a detailed assessment of variations in groundwater flow direction and gradient across the ISRM site. A number of conclusions can be drawn from these assessments, which are presented by quarter.

- During the first quarter of FY 2007 (October through December 2006), the Columbia River was at a low stage with the groundwater flow direction generally toward the river. Figure 3-2 shows the water table map for the first quarter based on November 2006 water levels.
  - The 182-D Reservoir influenced groundwater flow north of the ISRM barrier because of a continued leak during the period, although at a reduced rate. The leakage rate was calculated at 98 L/min (26 gal/min) during the first quarter of FY 2007 with no leakage during the remainder of the year. In the first quarter of FY 2006, the highest leakage rate was 401 L/min (106 gal/min). Consequently, the rate has decreased approximately by a factor of four since FY 2006. These observations are consistent with 182-D operations logs which indicate that the reservoir level was lowered from 7 ft to 3 ft in late 2005, 3 to 6 ft in the first half of 2006, and then maintained at 3 ft since June 2006. In the future, the 182-D Reservoir will be used only if needed to support 182-B activities; otherwise, 182-D will be maintained on standby with levels from 1 to 3 ft.
  - A small groundwater mound, because of injection of treated groundwater from the 116-DR-5 pump-and-treat operation at Well 199-D5-42, was also present. The injection rate (which is equivalent to the summed extraction rate from all of the extraction wells used for the pump-and-treat operation) ranged from approximately 144 to 174 L/min (38 to 46 gal/min). A number of small groundwater

depressions/impressions related to the 116-DR-5 Outfall and 100-D Area pump-and-treat extraction wells were evident.

  - The injection rate at the 116-DR-5 Outfall Injection Well was approximately 170 L/min (45 gal/min) during the quarter. Groundwater mounding at this well does not appear to have an effect in the area of the ISRM barrier.

- During the third quarter of FY 2007 (April through June 2007), increased flow in the Columbia River generally created flow from the river inland (Figure 3-3). No leakage was observed at the 182-D Reservoir during this period.
- During the fourth quarter of FY 2007 (July through September 2007), a secondary hydraulic effect was observed from the electrocoagulation (EC) treatability test. Well 199-D5-33 was used as an injection well and is located near the northwest corner of the 182-D Reservoir. The injection rate was 189 L/min (50 gal/min) from August 21 to September 7, 2007. This short-term operation did not produce any observable effects in the area of the barrier. No leakage was observed at the 182-D Reservoir during this period.

For optimal treatment, the ISRM treatment zone was oriented to be perpendicular to the groundwater flow direction and plume axis. The net-flow direction is calculated each year in order to evaluate the position of the treatment zone relative to plume movement. The optimal groundwater flow direction toward the treatment barrier is modeled to be perpendicular to the barrier at an azimuth of 307° (±30°).

Data collected from seven groupings of three wells (i.e., seven triangles) were evaluated in FY 2007. Figure 3-4 shows the well locations and the seven sets of three-point triangles, and the figure also includes a summary table of the triangle solutions for FY 2007. Appendix B contains a description of how the triangles are created, the calculated flow directions, and gradient graphs for the seven sets of triangles.

As previously stated, the optimal groundwater flow direction towards the treatment barrier is an azimuth of 307° (±30°). Flow directions for triangles 2, 3, 4, 6, and 9 fall within these coordinate limits 36 to 68 percent of the year. Variations in flow direction are closely related to the river stage, although leakage at the 182-D Reservoir and pump-and-treat extraction at Well 199-D5-39 may also have some influence. The period of optimum interception was during low river stage (from fall through winter). The time when flow was away from the barrier was from late March through June, coinciding with higher river stage.

In the area away from the barrier, net-flow direction for triangles 5 and 8 fall outside the optimal direction. The net-flow direction for triangle 5 (upgradient from the barrier) is more to the north-northwest (345.4°). It is likely that flow direction in this area has been modified by extraction pumping at Well 199-D5-39.

Triangle 8 (centered on the 182-D Reservoir) has a westerly flow direction of 261.2°, which probably reflects leakage from the 182-D Reservoir. Based on these perturbations to the hydraulic system, a more detailed evaluation is warranted that would evaluate the current effects of the 182-D Reservoir and future potential of a large-scale pump-and-treat system at the 100-D Area on the flow dynamics. It is important that the optimum flow direction be maintained so the chromium plume moves through the treatment barrier.

Figure 3-1. Automated Water-Level Monitoring Network.

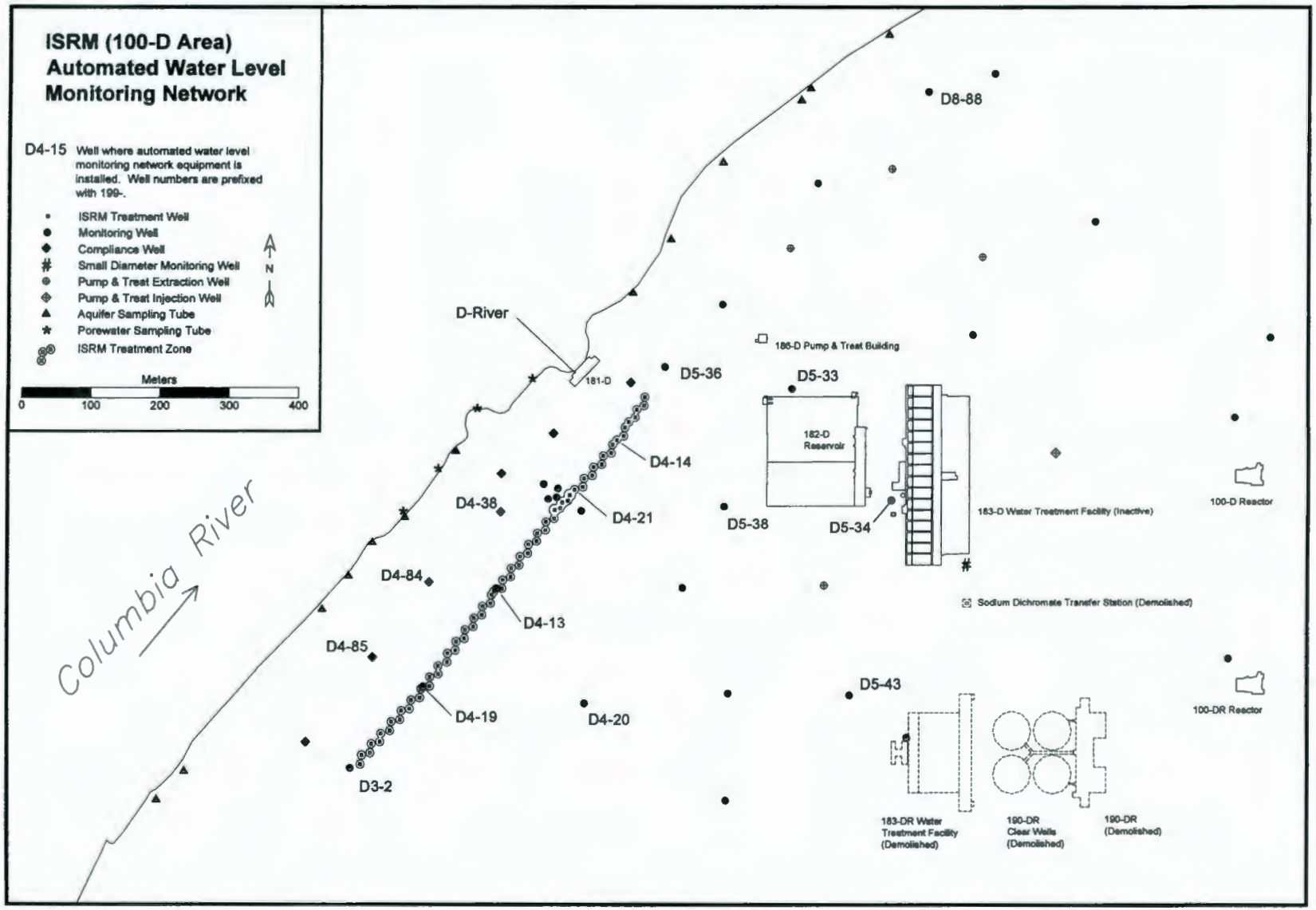


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Figure 3-2. 100-D Area Water Table Map, First Quarter Fiscal Year 2007 (November 2006).

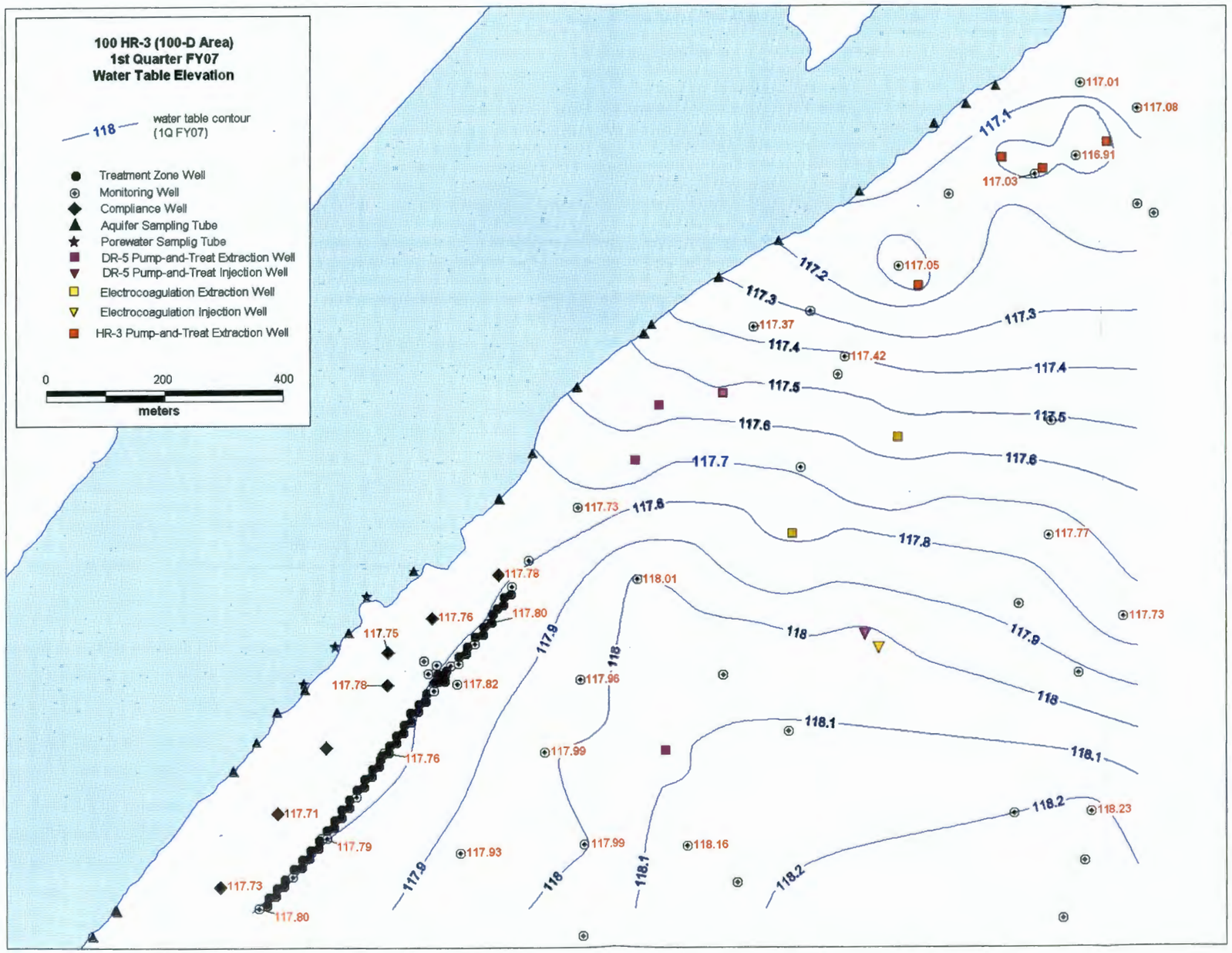


Figure 3-3. 100-D Area Water Table Map, Third Quarter Fiscal Year 2007 (June 2007).

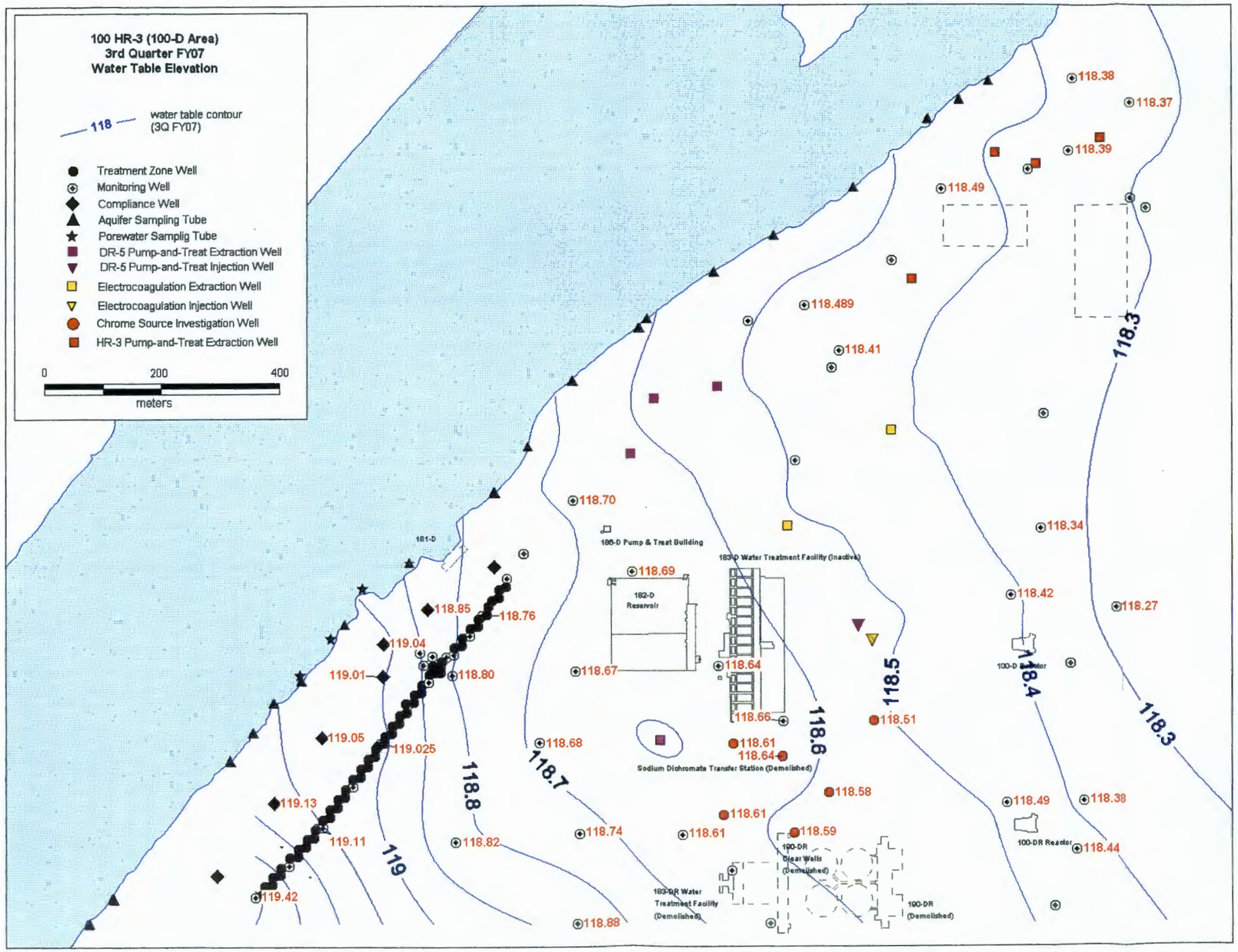
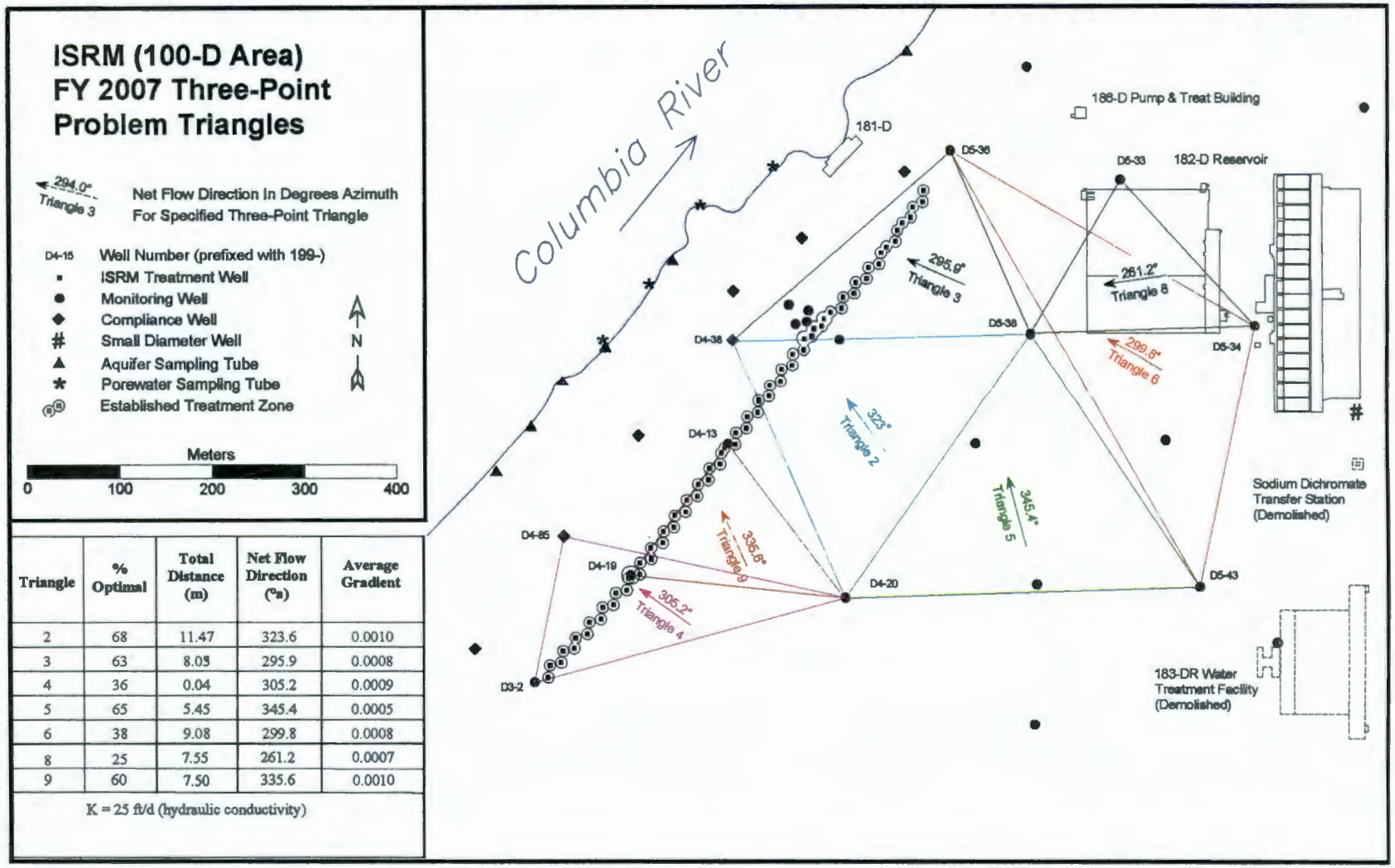


Figure 3-4. Three-Point Problem Triangles and Net-Flow Directions.



Triangle	% Optimal	Total Distance (m)	Net Flow Direction (°a)	Average Gradient
2	68	11.47	323.6	0.0010
3	63	8.03	295.9	0.0008
4	36	0.04	305.2	0.0009
5	65	5.45	345.4	0.0005
6	38	9.08	299.8	0.0008
8	25	7.55	261.2	0.0007
9	60	7.50	335.6	0.0010

K = 25 ft/d (hydraulic conductivity)

3.2 CONTAMINANT MONITORING

Groundwater at the ISRM site is sampled as part of *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) interim action monitoring (IAM). The contaminant of concern is hexavalent chromium. As required by the sampling documents, DO is also monitored. The barrier treatment process reduced oxygen content in the aquifer. Groundwater with depleted DO levels could potentially harm aquatic receptors. Other groundwater constituents and properties are also monitored in order to understand plume chemical characteristics.

The IAM is controlled by DOE/RL-2003-63, *Sampling and Analysis Plan for In Situ Redox Manipulation Project* and includes wells that have been completed since 1999. The sampling and analysis plan contains the long-term monitoring approach for the ISRM treatment zone and also addresses sampling of near-shore aquifer sampling tubes and porewater sampling tubes.

The IAM sampling occurs predominantly on a quarterly schedule to assess compliance with RAOs and performance of the ISRM barrier. The wells that are sampled include the following.

- **Compliance wells:** These seven wells, located between the barrier and the river, are sampled to determine if hexavalent chromium concentrations are ≤ 20 μg/L in order to achieve the goal of 10 μg/L at the Columbia River.
- **Treatment zone wells:** These include both aquifer treatment wells (wells previously used to treat the aquifer [i.e., barrier wells]) and treatment zone monitoring wells within the barrier. These wells are sampled to measure changes in hexavalent chromium concentrations within the ISRM barrier and to assess the barrier performance against the RAO.
- **Plume monitoring wells:** These wells are located throughout the OU and are sampled to monitor changes in plume configuration and movement and to obtain other chemical and physical properties.

Table D-1 in Appendix D lists the compliance, treatment zone, and monitoring wells. Information is provided on the type of well, sampling frequency, and the sampling purpose. Data from IAM samples are controlled by and maintained in the *Hanford Environmental Information System* (HEIS) database.

In addition to IAM, supplemental operational monitoring of the treatment zone was performed to provide more detailed information regarding barrier performance and, in particular, changes in hexavalent chromium concentrations within the ISRM treatment zone. Groundwater samples were collected from 65 treatment wells and 5 monitoring wells. Most of these wells were sampled on a quarterly basis, although some wells were sampled monthly. The monthly samples were collected at wells that show an increase in hexavalent chromium concentrations above 30 μg/L. Field-screening data from this sampling are used as an indicator of performance and are a cost-effective means of determining whether more expensive laboratory analytical data are required. Data from the supplemental operational monitoring are controlled and maintained by Fluor Hanford, Inc. project personnel and are not included in the HEIS database. Table D-6 in Appendix D shows these data for FY 2007.

Aquifer tubes are also sampled yearly to provide an indication of hexavalent chromium concentrations prior to entering the river. Generally, three tubes are installed at each site that monitor a deep zone (approximately 6.1 to 9.1 m [20 to 30 ft]), a medium zone (approximately 3 to 9.1 m [10 to 20 ft]), and a more shallow zone (approximately 1.5 to 3 m [5 to 10 ft]). Some porewater installations measure hexavalent chromium concentrations in the substrate of the Columbia River itself.

The results from IAM and supplemental operational monitoring are summarized in the following subsections.

3.2.1 Interim Action Monitoring

During FY 2007, 38 to 45 compliance, treatment zone, and monitoring wells were sampled during each quarter. In addition to hexavalent chromium, groundwater samples were also analyzed for total chromium, other metals, anions (e.g., nitrate), and tritium, as well as field parameters including DO, pH, specific conductance, temperature, and turbidity. Sampling and analysis for nitrate, total chromium, and other metals (including arsenic) were conducted during the first quarter of FY 2007. Sampling and analysis for sulfate took place during all four quarters. Table D-1 (Appendix D) specifies the wells, sampling frequencies, and sampling types.

The results of monitoring for chromium, DO, sulfate, nitrate, and tritium are addressed in the subsections below. Appendix D provides detailed summaries and additional discussion for the analytical results and individual trends in wells, and Appendix C provides chromium trend plots for individual wells. None of the wells sampled during the first quarter of FY 2007 exceeded the maximum contaminant level (MCL) of 10 μg/L for arsenic.

3.2.1.1 Hexavalent Chromium

This section discusses the results and trends for hexavalent chromium concentrations in the monitoring wells (plume configuration), treatment zone wells, and the compliance wells. It also discusses the data collected in aquifer tubes along the river. The following discussion and data are summarized from more detailed information presented in Appendix D. Table D-2 (Appendix D) provides a detailed summary for the chromium and hexavalent chromium results and significant trends for each of the compliance, treatment zone, and monitoring wells sampled for IAM. The table includes annual averages for FY 2004, FY 2005, FY 2006, and FY 2007, as well as percentage change values and trends based on comparisons of FY 2006 and FY 2007 annual data.

3.2.1.2 Treatment Zone (Barrier) and Proximal Monitoring Wells

Operational monitoring of the ISRM was conducted on a quarterly basis in FY 2007. This operational monitoring is focused on the RAO of 20 μg/L for the current barrier configuration completed in FY 2002 under Phase III drilling, as described in Section 1.2. The operational monitoring results for the first quarter of FY 2007 are shown in the first panel of Figure 3-5. These results indicate that 61 percent of the wells are below the RAO of 20 μg/L. The remaining quarters are shown in subsequent panels. Compliance during the second quarter increased to 67 percent in the second quarter, reaching a maximum of 90 percent in the third quarter before declining to 79 percent in the fourth quarter. The following general conclusions are drawn from

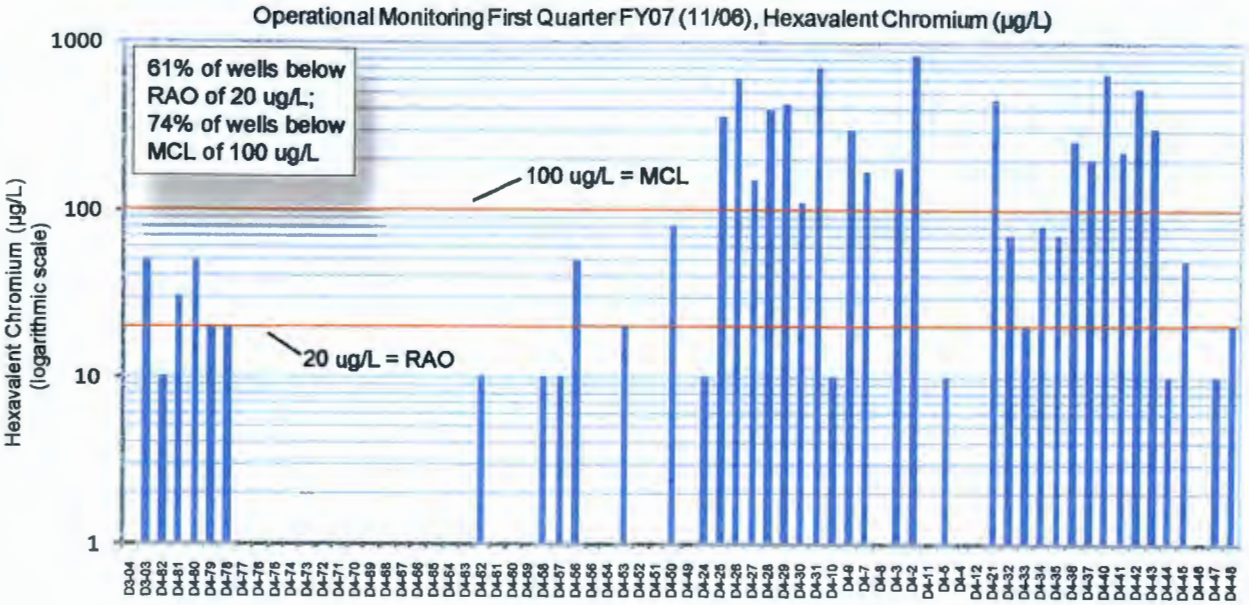
the histograms in Figure 3-5, the data contained in Appendix D, and the fall and spring plume maps for FY 2007 which are described in detail in the following sections.

- Barrier performance in FY 2007 was similar to that observed in FY 2006. The percentage of barrier wells below the RAO averaged 74 percent during all of FY 2007. Evaluated by quarter, the percentage of barrier wells meeting the RAO of 20 μg/L and the MCL of 100 μg/L are as follows.

Quarter	RAO (20 μg/L)	MCL (100 μg/L)
October to December:	61%	74%
January to March:	67%	84%
April to June:	90%	96%
July to September:	79%.	93%

- Hexavalent chromium concentrations in the barrier were lowest (<20 μg/L) during the third quarter (from April to June). This is also the period when spring run-off occurs in the Columbia River. In the fall, fewer barrier wells were below the RAO. Groundwater flow at this time is predominately toward the river and the hydraulic gradient is the highest. This latter factor would decrease residence time in the barrier.
- The portion of the barrier with the greatest number of wells above the RAO is located in the northeastern half of the barrier. This area receives the highest upgradient concentrations of hexavalent chromium. To reduce chromium loading on the barrier in this area and increase barrier effectiveness, it may be prudent to evaluate technologies that would lower plume concentrations prior to entering the barrier.
- The highest annual increase in chromium concentration was in Well199-D4-19, located in the southwestern portion of the barrier. Concentrations in this well have increased from less than detection (5 μg/L) in 2002 to 199 μg/L in the fourth quarter of FY 2007. Wells with increasing annual trends are located in the northeast (Well 199-D4-14) and southwest portions (Well 199-D4-19) of the treatment zone, as well as proximally downgradient of the original treatability test area (Well 199-D4-7). Additional discussion on the performance of individual barrier wells is presented in Appendix C (trend plots) and Appendix D (data).

Figure 3-5. In Situ Redox Manipulation Operational Monitoring – Quarterly Hexavalent Chromium Concentrations, Fiscal Year 2007. (2 Pages)



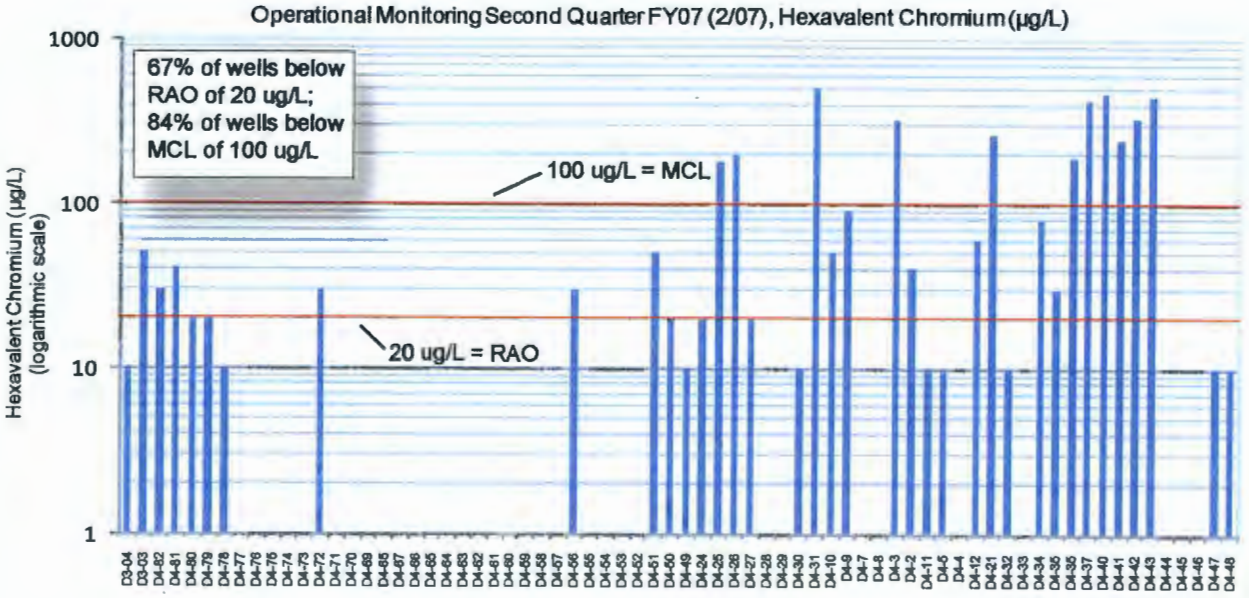
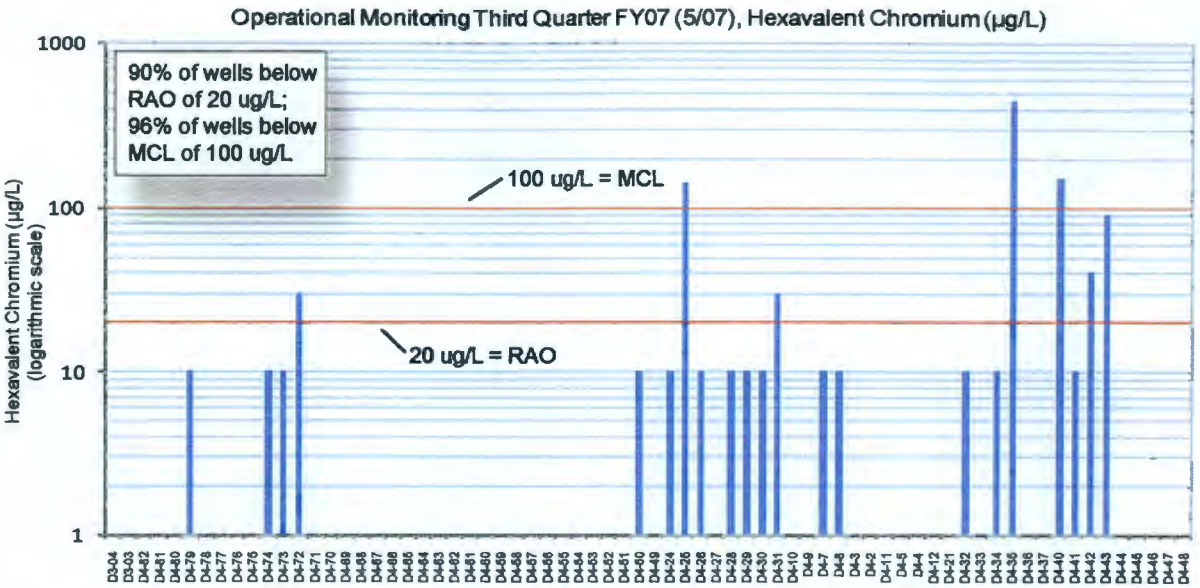
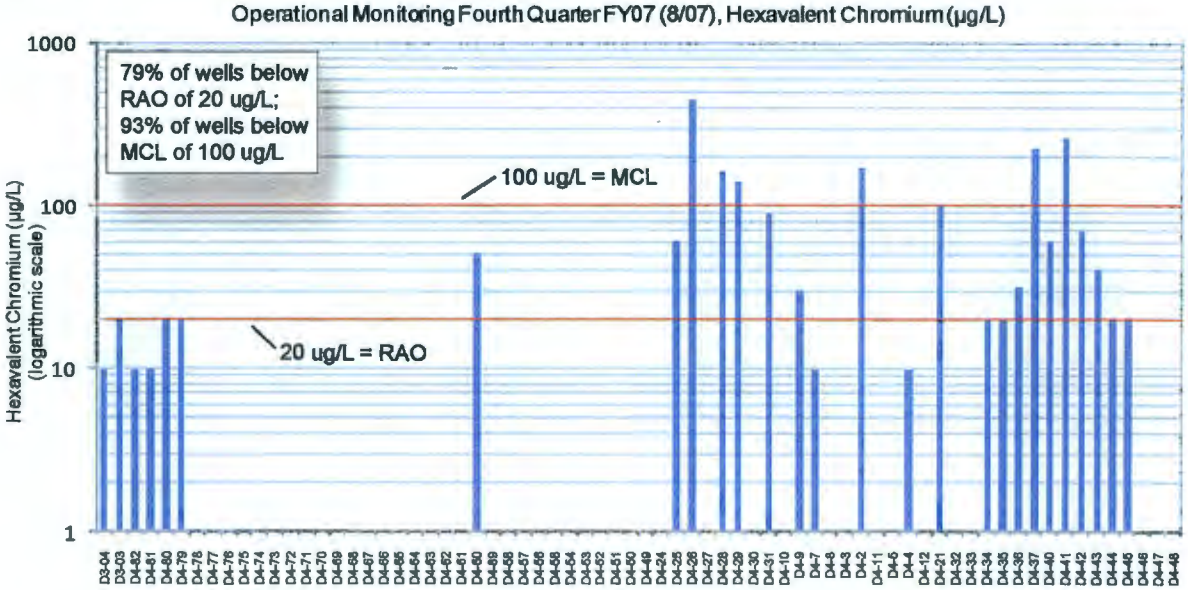


Figure 3-5. In Situ Redox Manipulation Operational Monitoring – Quarterly Hexavalent Chromium Concentrations, Fiscal Year 2007. (2 Pages)





3.2.1.2.1 Compliance Monitoring Wells

Seven compliance monitoring wells were installed and sampled since 2002 to meet the following criteria.

- Establish whether the 20 µg/L hexavalent chromium RAO #1 has been achieved in groundwater that has passed through the ISRM treatment barrier.
- Define the boundaries of the plume so compliance with the RAO #1 can be verified for groundwater beyond the limits of the ISRM treatment barrier.
- Detect and allow assessment of hexavalent chromium breakthrough in the ISRM treatment barrier.

Historical trends in the seven compliance wells are plotted in Figure 3-6. Four of the seven compliance wells were near or below the RAO of 20 µg/L in FY 2007. Generally, these wells are located near the ends of the ISRM barrier (southwest and northeast corners) (Figure 3-5). Table D-2 in Appendix D contains chromium data for these wells.

Compliance wells downgradient from the central part of the barrier have the highest concentrations, particularly where upgradient plume concentrations are the highest. Even so, Well 199-D4-39 has declined since 2004 from a high of 1,290 µg/L to approximately 375 µg/L and appears to be on a continuing downward trend (Figure 3-6). In contrast, concentrations in compliance Well 199-D4-38 have been increasing, as hexavalent chromium was below 100 µg/L at one time but was high as 369 µg/L in FY 2007 (Figure 3-6). Little change was observed at Well 199-D4-38, which fluctuates roughly between about 100 and 380 µg/L. This level was reached near the end of calendar year 2005 and has been sustained.

The barrier was installed from 6 to 8 years ago. Since chromium is still significantly above the RAO in three compliance wells, other technologies or approaches for bringing them into compliance should be evaluated.

Figure 3-6. Trend Plots for In Situ Redox Manipulation Compliance Wells. (3 Pages)

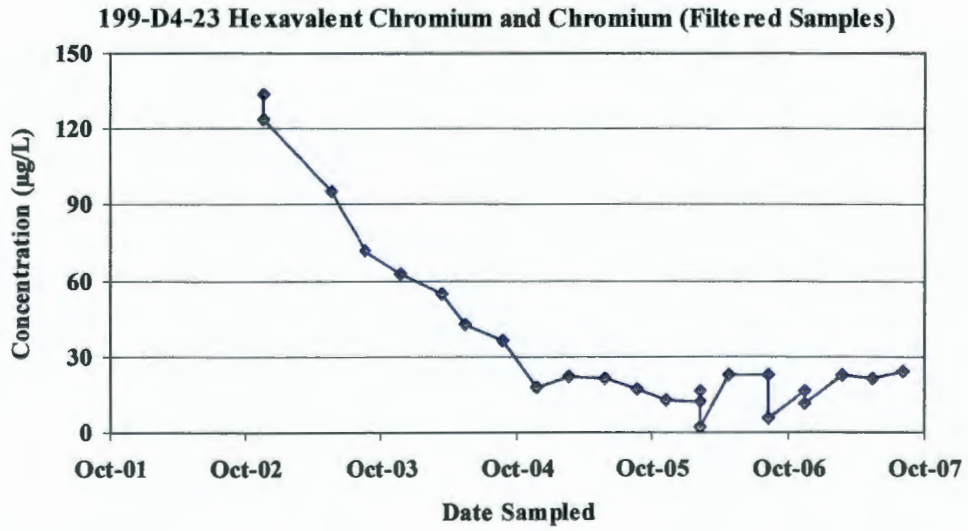
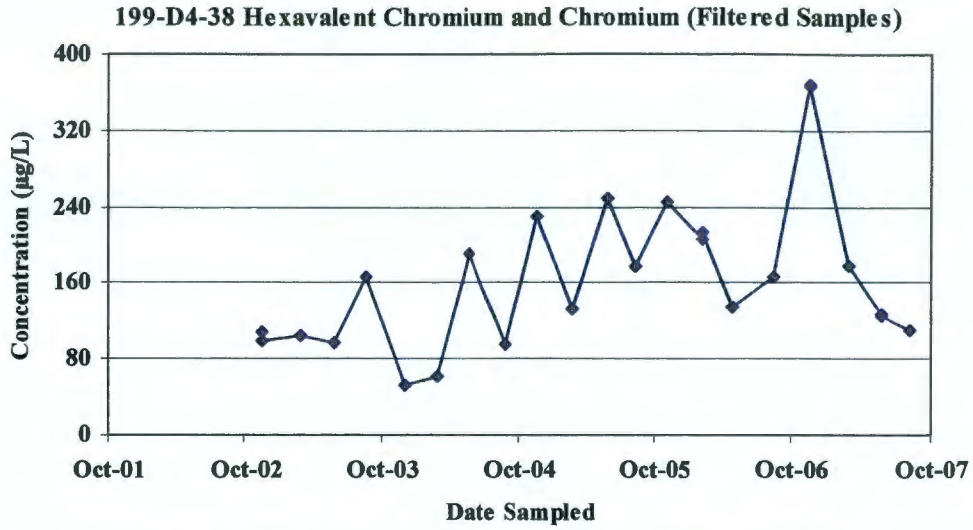
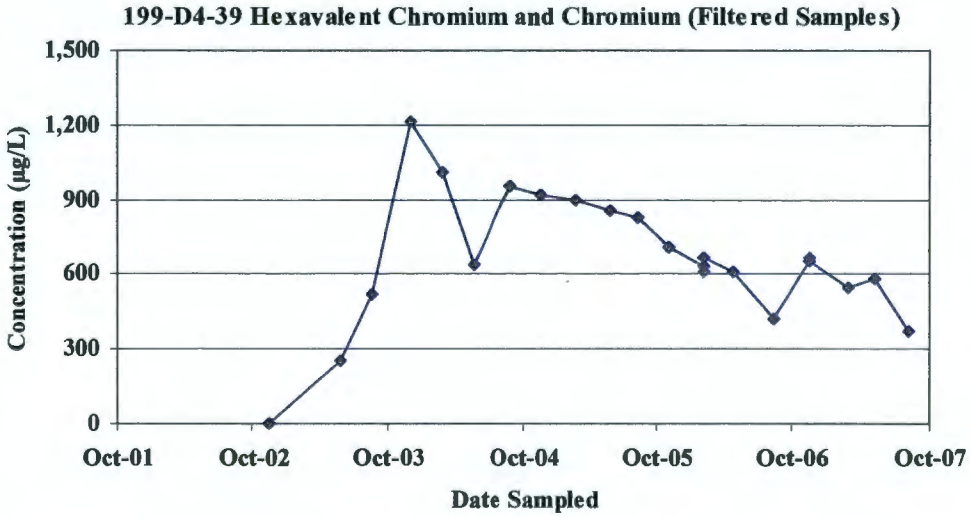


Figure 3-6. Trend Plots for In Situ Redox Manipulation Compliance Wells. (3 Pages)





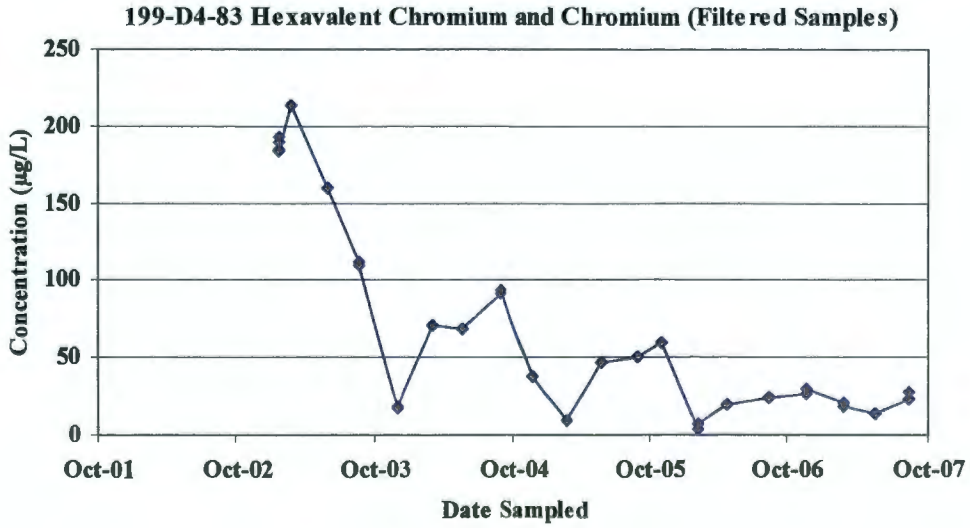
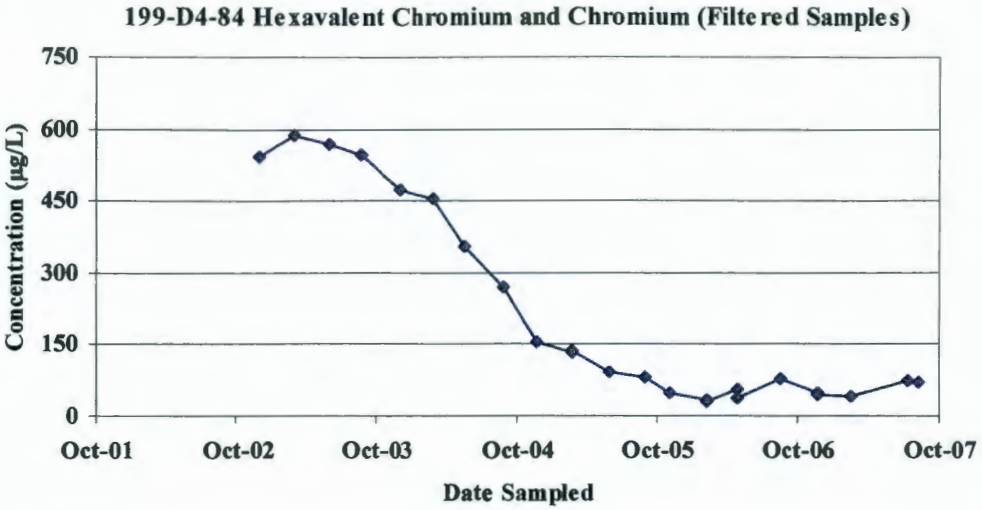
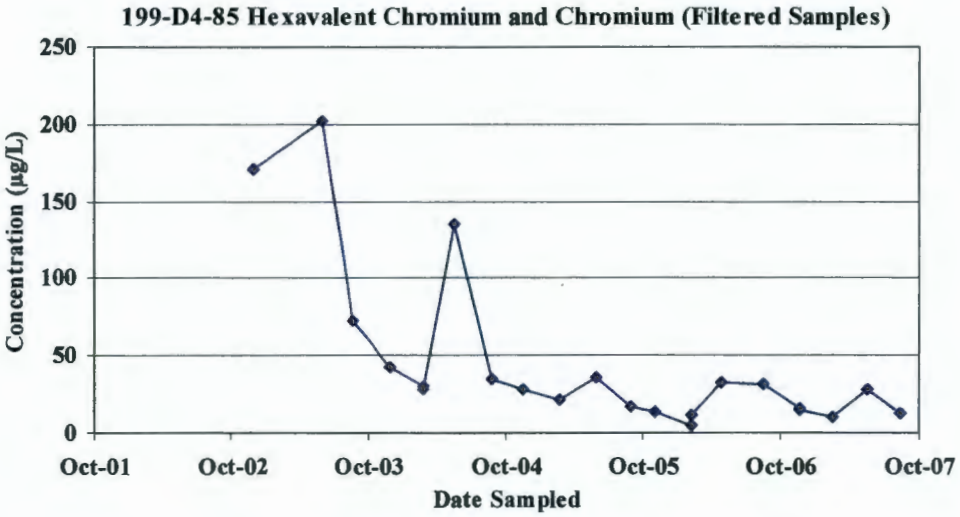
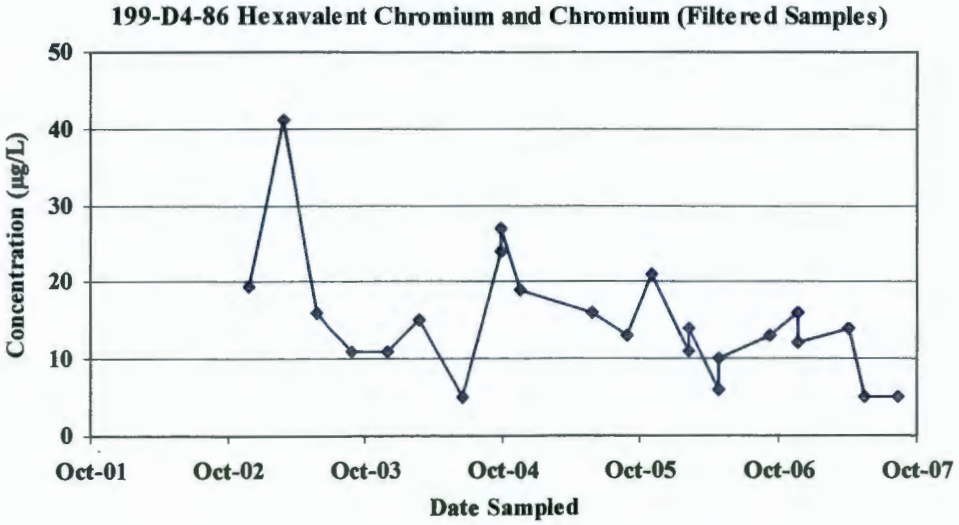


Figure 3-6. Trend Plots for In Situ Redox Manipulation Compliance Wells. (3 Pages)







3.2.1.2.2 Plume Monitoring Wells

Overall, plume configuration in FY 2007 did not change significantly from FY 2006 to FY 2007. One change was observed in the highest concentration area upgradient from the barrier. Figures 3-7 and 3-8 show the fall plume maps for FY 2006 and FY 2007, and Figure 3-9 shows the spring plume map for FY 2007. The following observations are made in regard to plume configuration, as interpreted from the plume monitoring well data.

- The northeastern third of the barrier continues to intercept the highest concentration of hexavalent chromium in the groundwater plume. General plume movement is toward the barrier, as discussed in Section 3.1.
- Concentrations increased in the area of the 182-D Reservoir at Well 199-D5-34. The increase may be related to a lower leakage rate from the reservoir. As discussed in Section 3.1, leakage was estimated at 98 L/min (26 gal/min) during the first quarter of FY 2007. This compares with a high of 401 L/min (106 gal/min) in FY 2006. Continued monitoring for the remainder of FY 2007 indicated no further leakage. The reduced leakage may be allowing chromium concentrations to re-equilibrate to conditions in the aquifer (i.e., there is less mixing between infiltrating reservoir water and groundwater).
- Chromium concentrations at Well 199-D5-39 increased. This well is located upgradient from the barrier and in the center of the high-concentration area of the plume (Figure 3-8). Well 199-D5-39 is an extraction well for the 116-DR-5 Outfall pump-and-treat system. The increase in hexavalent chromium may be the result of pumping at this well, drawing in higher levels of contamination situated close to the well. A chromium source investigation has discovered much higher chromium concentrations at a new monitoring well (Well 199-D5-99), located east of this well. The third quarter plume map for June 2007 (Figure 3-9) shows this newly discovered high-concentration area. Chromium exceeded 12,000 μg/L at Well 199-D5-99. These high concentrations imply that this well is near a potential vadose zone source area. Section 4.2 provides additional details regarding this ongoing investigation.

The largest hexavalent chromium increase in a monitoring well this year was at Well 199-D2-8 (+61 percent), located to the south of the plume (Figure 3-9). Concentrations increased from 24 to 39 μg/L. The largest hexavalent chromium decrease was measured at Well 199-D5-40 (-69 percent), located to the south of Well 199-D5-39. Concentrations declined from 279 to 85 μg/L. This change also affected the shape of the central portion of the plume. For more detailed information on chromium changes in the monitoring wells, refer to Appendix D.

3.2.1.2.3 Aquifer Sampling Tubes

Aquifer tubes monitor the quality of the water entering the Columbia River. The FY 2007 data from aquifer sampling tubes and porewater sampling tubes were collected in December 2006 and January 2007. The FY 2007 sample data indicate that groundwater in excess of 20 μg/L hexavalent chromium is entering the Columbia River at several sites. Figure 3-10 shows the location of the tubes as solid triangles along the river together with hexavalent chromium trend plots. The trend plots generally show decreasing hexavalent chromium over times.

Aquifer tube data cannot be collected because of high river stage in the spring; consequently, no contemporaneous data are available for the June map. It is assumed, that because of high river levels, the concentrations were below detection. This assumption was consistent with the lower

contaminant levels observed in the barrier wells during high water (90 percent less than the RAO). Other means for sampling these tubes during high river levels should be explored to provide the hard data to confirm this assumption.

Key elements of aquifer tube and porewater sampling can be summarized as follows.

- Hexavalent chromium concentrations in excess of 20 μg/L were found at 9 of 12 aquifer tube sites sampled during the year, with concentrations ranging from 7 to 199 μg/L. However, of these aquifer tubes, only shallow aquifer tube DD-43, downgradient from the ISRM barrier, exceeded the RAO. This is significant because the shallow tubes are closer to the point of discharge to the river where aquatic species could be affected.
- Several aquifer tubes downgradient of the treatment zone have shown substantial decreases in hexavalent chromium concentration over the past decade. In particular, aquifer tubes DD-44, DD-41, and DD-39 show decreases approaching an order of magnitude.
- Hexavalent chromium concentrations in excess of 20 μg/L were found at seven of eight porewater tubes (samples from river bottom substrate), with a maximum concentration of 82 μg/L.

Analytical data from aquifer and porewater tube sites downgradient of the ISRM treatment barrier define a length of Columbia River shoreline approximately 820 m (2,690 ft) in length. At least one depth-discrete interval in each of seven aquifer tubes and four porewater tube sites had hexavalent chromium concentrations that exceeded 20 μg/L.

Hexavalent chromium concentrations in excess of 100 μg/L were found at the following aquifer tube sampling sites located downgradient of the ISRM treatment barrier:

- DD-39 (DD-39-3): 102 μg/L
- DD-42 (DD-42-4): 164 μg/L
- DD-42 (DD-43-3): 171 μg/L.

Elevated hexavalent chromium analyses suggest that the barrier and the pump-and-treat operation are not fully effective in reducing or removing the contaminant, although it is clear that some aquifer tubes have seen significant reductions in hexavalent chromium concentration over the past several years. For example, site DD-39-3 had an FY 2000 concentration of 641 μg/L and an FY 2007 concentration of 102 μg/L. Since the barrier has been in place for several years, other technologies should be evaluated that would support a more rapid reduction in chromium concentrations near the river.

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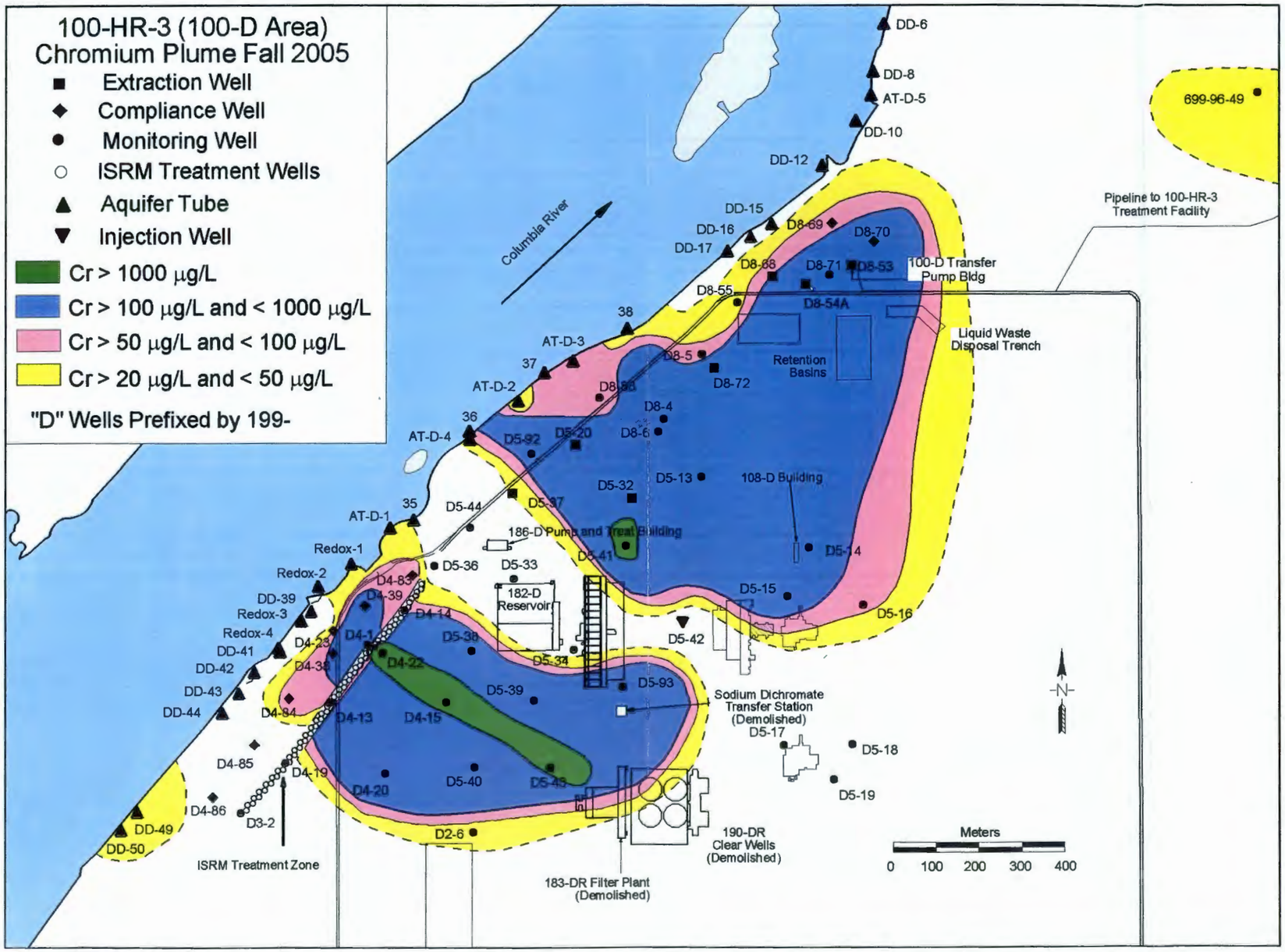
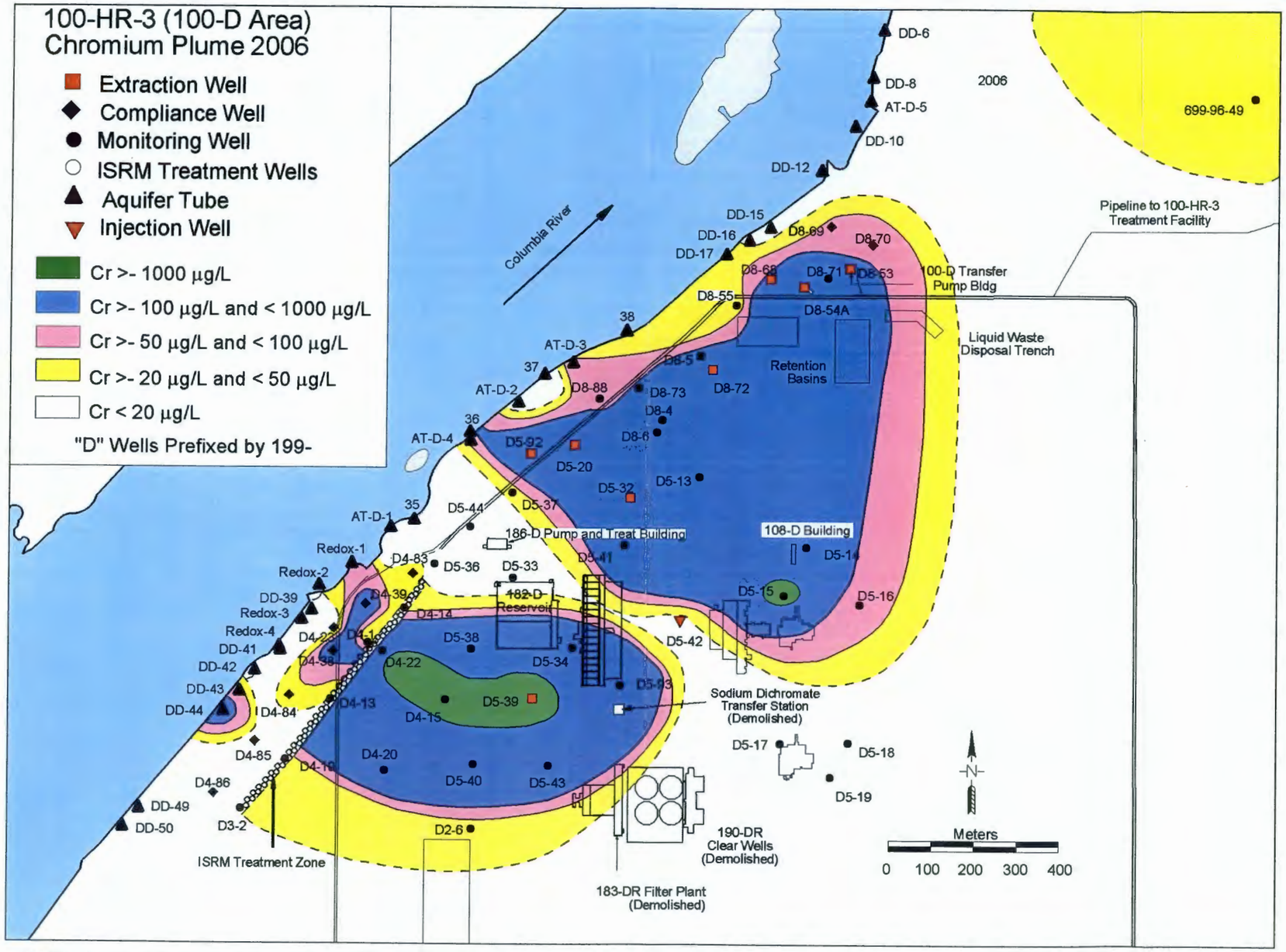
Figure 3-7. In Situ Redox Manipulation Hexavalent Chromium Plume Map, First Quarter Fiscal Year 2006.



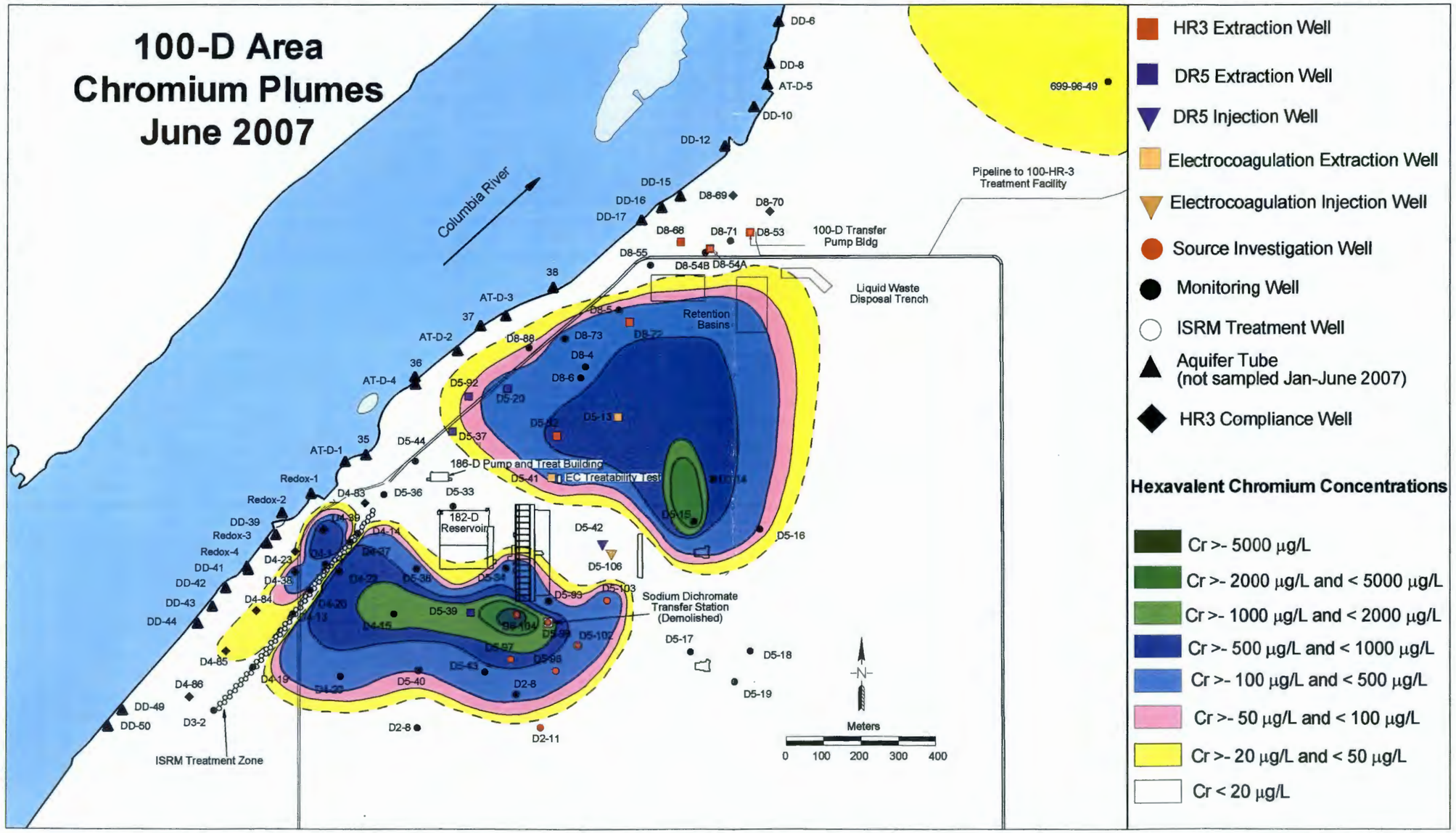
NOTE: This figure has been modified from DOE/RL-2006-08, *Calendar Year 2005 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unite Pump-and-Treat Operations*, Rev. 0.

Figure 3-8. In Situ Redox Manipulation Hexavalent Chromium Plume Map, First Quarter Fiscal Year 2007.



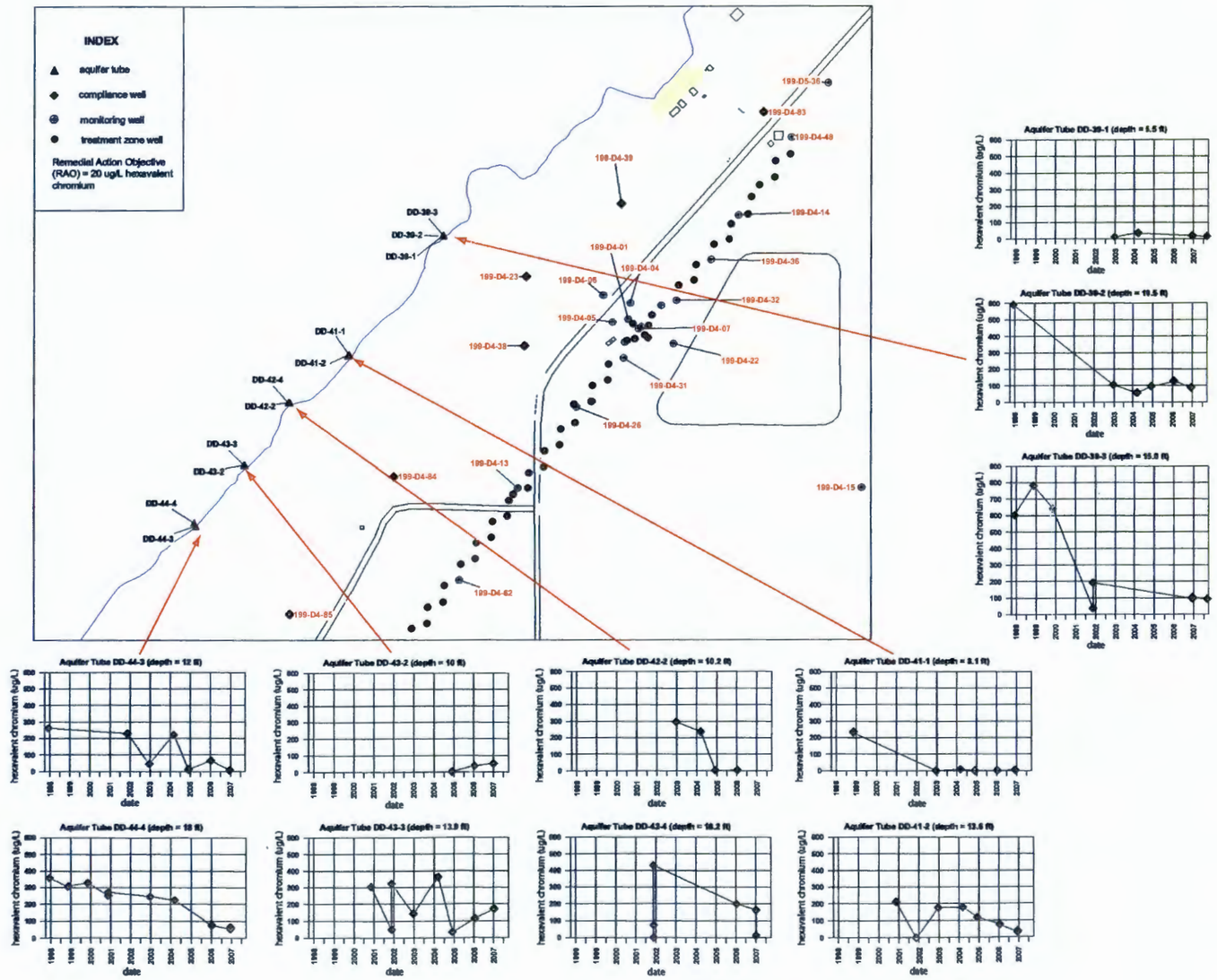
NOTE: This figure has been modified from DOE/RL-2006-08, *Calendar Year 2005 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unite Pump-and-Treat Operations*, Rev. 0.

Figure 3-9. In Situ Redox Manipulation Hexavalent Chromium Plume Map, Third Quarter Fiscal Year 2007.



NOTE: This figure was obtained from SGW-34971, *Calendar Year 2007 Semi-Annual Technical Memorandum for the 100-HR-3, 100-KR-4, and 100-NR-2 Pump-and-Treat Operations.*

Figure 3-10. Hexavalent Chromium Trend Plots for Aquifer Tubes Downgradient of In Situ Redox Manipulation Treatment Barrier.



3.2.1.3 Dissolved Oxygen

The DO concentrations are monitored as required by the ROD Amendment (EPA et al. 1999), DOE/RL-99-51, and the sampling and analysis plan (DOE/RL-2003-63). The sodium dithionite injection process effectively reduced DO in the groundwater at and near the barrier to near zero. The RAO for DO specifies that measurements at the compliance wells be at least 75 percent of saturation (DOE/RL-99-51). Appendix D contains tables with DO data for wells and for aquifer and porewater tubes for FY 2006 and FY 2007 and evaluates the change between years (Tables D-3 and D-4).

The DO profile in the vicinity of the ISRM treatment zone is characterized by relatively high DO concentrations upgradient of the treatment zone, dropping significantly through the treatment zone, and recovering to higher DO concentrations as groundwater flow approaches the river (Figure 3-11).

The DO saturation was calculated assuming a temperature of 18 °C (64.4 °F), which results in a saturated DO of 9.6 mg/L, consistent with measured values for a wide variety of Hanford Site groundwater across the 100 and 200 Areas. Groundwater upgradient of the ISRM treatment zone is moderately saturated on the order of 80 to 90 percent, dropping as it approaches the barrier. The values shown in Figure 3-11 are presented for monitoring wells downgradient of the barrier and aquifer tubes further downgradient prior to discharging into the Columbia River. Measurements were taken in February for the compliance wells. The DO saturation at aquifer tubes was collected over a 2-month period, in December 2006 and January 2007.

Saturations in the compliance monitoring wells ranged from 16 to 88 percent. This is generally less than the 75 percent DO saturation level specified in the performance objectives. However, the measured DO concentrations at shallow aquifer tubes just before the water discharges into the Columbia River were near 100 percent. This may indicate that ISRM performance is in compliance with DO performance objectives by the time treated groundwater reaches the river and is protective of aquatic life.

3.2.1.4 Sulfate

Sulfate is a byproduct of the sodium dithionite reaction used to establish the ISRM treatment zone. It is also listed as a groundwater contaminant with a "National Secondary Drinking Water Standards" (SDWS) (40 CFR 143, "National Secondary Drinking Water Regulations") MCL of 250 mg/L. Table D-5 in Appendix D provides a summary of annual average sulfate concentrations, a comparison of FY 2006 averages versus FY 2007 averages, and quarterly FY 2007 sulfate concentrations for all sampled wells.

Sulfate concentrations only exceeded the SDWS in a couple of areas at the ISRM barrier and downgradient from the barrier (Figure 3-12). Upgradient background sulfate concentrations may be a result of aluminum sulfate discharged to the soils. The sulfate was used to reduce raw water turbidity (flocculent). A summary of sulfate results during FY 2007 is as follows.

- Overall, sulfate concentrations in FY 2007 were comparable to those seen in FY 2006, with most wells showing stable or slightly decreasing sulfate concentrations.
- Average annual sulfate concentrations in 36 wells ranged from 13 to 340 mg/L.

- Seven wells had average annual sulfate concentrations exceeding the secondary MCL of 250 mg/L:
  - Downgradient compliance well 199-D4-84
  - Three proximal downgradient monitoring wells (199-D4-6, 199-D4-4, and 199-D4-1)
  - Three treatment zone injection/monitoring wells.

  All of these wells showed stable or decreasing trends. The general area of these wells is shown in Figure 3-12.
- Sulfate concentrations may have exceeded the MCL along the Columbia River shoreline in an area downgradient of compliance Well 199-D4-84, based solely on the plume map.

3.2.1.5 Nitrate

During the FY 2007, nitrate levels in monitoring wells 199-D2-8, 199-D4-15, 199-D5-38, and 199-D5-43 exceeded the U.S. Environmental Protection Agency's (EPA) drinking water MCL of 45 mg/L, ranging from 45 to 65 mg/L. Three of these wells were sampled for nitrate during the first quarter of FY 2007 and Well 199-D5-38 was sampled during the third quarter of FY 2007. Three of these wells are located within the upgradient portion of the contaminant plume that impacts the ISRM treatment barrier.

3.2.1.6 Tritium

Samples from three wells exceeded the MCL of 20,000 pCi/L for tritium (40 CFR 141, "National Primary Drinking Water Regulations," and 40 CFR 142, "National Primary Drinking Water Regulations Implementation") during sampling in the first quarter of FY 2007. Wells 199-D4-19 (20,000 pCi/L) and 199-D4-78 (28,500 pCi/L) are treatment zone monitoring wells located within the southwestern portion of the ISRM treatment barrier, and Well 199-D4-85 (25,500 pCi/L) is a compliance well located downgradient of these two treatment zone monitoring wells.

3.2.1.7 pH

All of the 100-D Area wells are sampled quarterly for pH, with pH generally ranging from 7.5 to 8.5, although some values greater than 9 are reported. As apparent in Figure 2-1, pH is an important component of the ISRM barrier performance; trivalent and hexavalent chromium speciation in the aquifer is dependent on both pH and Eh. While the scoping studies for the barrier stressed the importance of maintaining basic pH levels above 7 for optimum barrier performance, it is possible that excessively high pH may be counterproductive, given that hexavalent chromium is the predominant species for pH greater than approximately 8.5 and for Eh greater than 0.3 volts (Figure 2-1). Consequently, the factors impacting pH in the vicinity of the barrier should be better quantified.

Figure 3-11. In Situ Redox Manipulation Dissolved Oxygen Concentrations, Fourth Quarter Fiscal Year 2007.

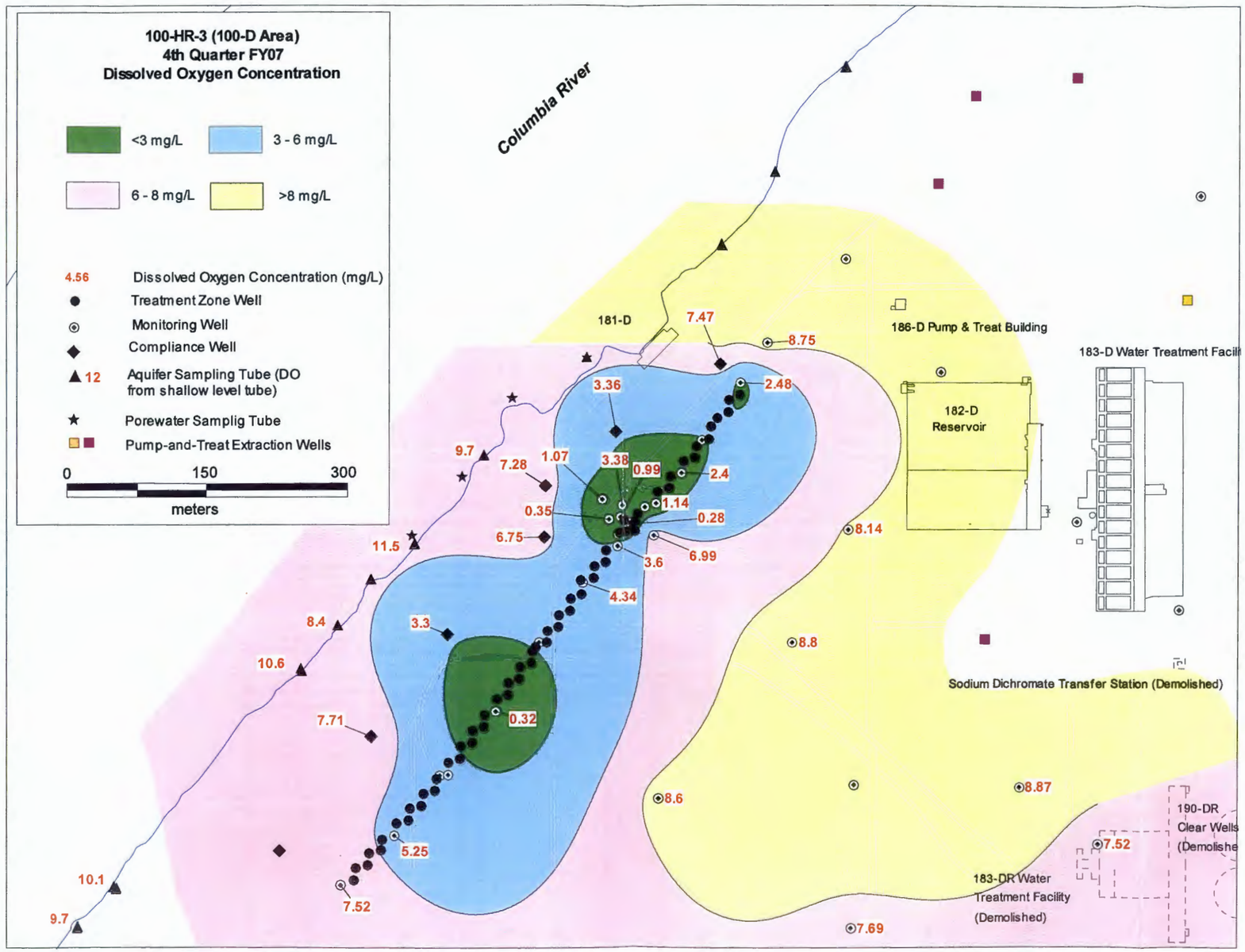
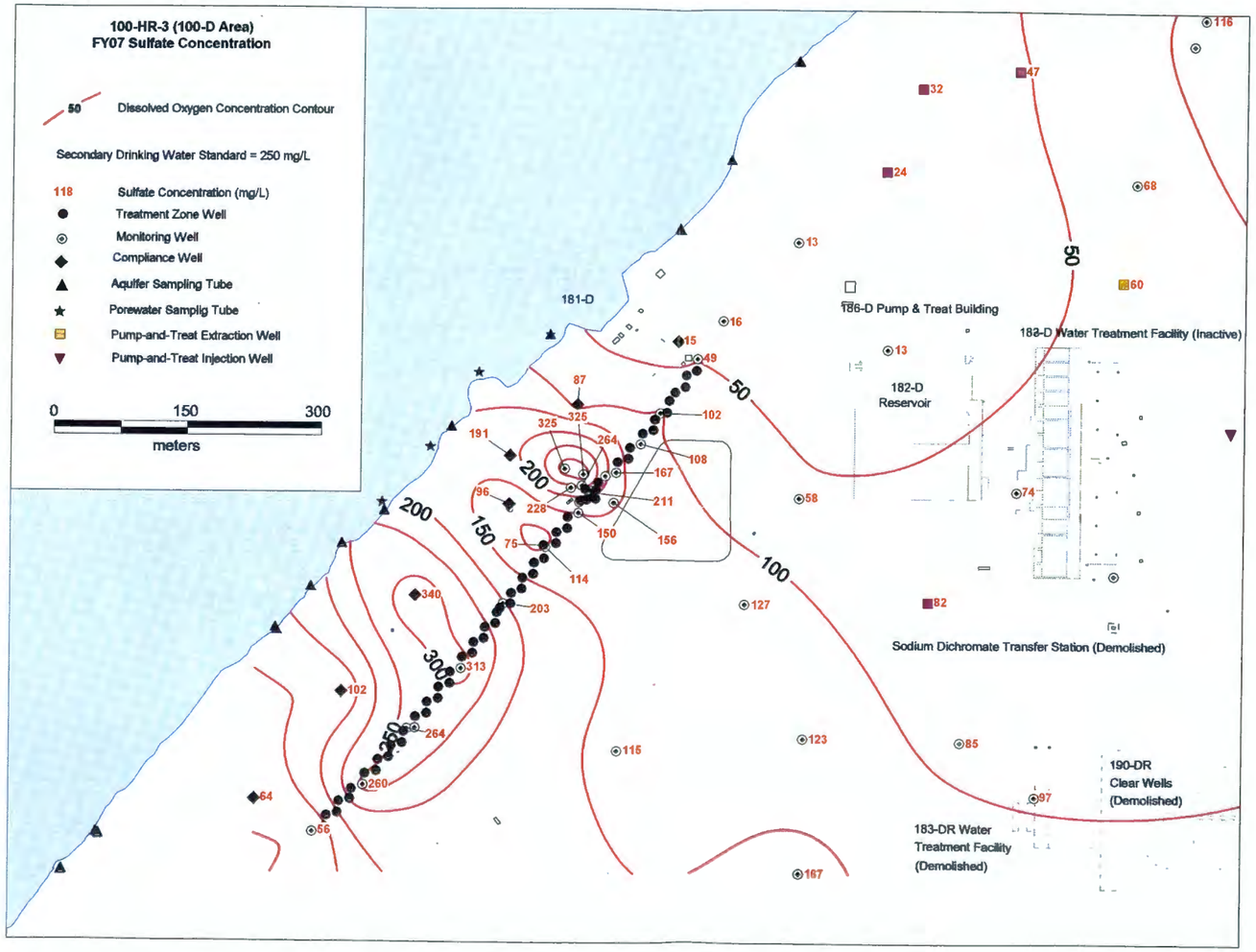


Figure 3-12. In Situ Redox Manipulation Sulfate Plume Map, Fiscal Year 2007.



4.0 REMEDIATION AND CHROMIUM SOURCE STUDIES

Several remediation technology studies and one chromium source study were carried out in FY 2007 and are summarized in this section.

4.1 BARRIER AMENDMENT WITH MICRON-SIZE ZERO-VALENT IRON

A project was begun in FY 2007 to test the feasibility of injecting iron particles into selected ISRM wells (DOE/RL-2007-19, *Fiscal Year 2007 Annual Summary Report for the In Situ Redox Manipulation Operations;* PNNL-15573, *Experimental Study of Micron-Size Zero-Valent Iron Emplacement in Permeable Porous Media Using Polymer-Enhanced Fluids*). If reduced iron can be emplaced in sections of the aquifer that have exhibited some loss of reductive capacity, the effectiveness of the barrier could be restored in these areas.

During FY 2007, a contractor tested various iron compounds in the laboratory for their ability to be injected into Ringold Formation sediments and reduce chromium in synthesized 100-D Area groundwater. Laboratory tests are scheduled to be completed by the third quarter of 2008, with the goal of injecting one or two of the most suitable compounds during the fourth quarter of 2008. The U.S. Department of Energy's Office of Engineering and Technology (EM-20) provided funding for the laboratory work.

4.2 CHROMIUM SOURCE IDENTIFICATION STUDY

The concentration of hexavalent chromium in the 100-D Area groundwater has not been declining significantly, which strongly suggests that chromate is still present in the vadose zone, providing a source for groundwater contamination. Chromium concentrations are above 2,000 μg/L and, in some areas, are above 12,000 μg/L, which confirms that the source is not historic reactor cooling water but a considerably more concentrated solution.

Two EM-20 projects have been funded to refine the area of the source for each plume. The objectives are to obtain soil samples from the suspected source areas and to refine the source location by collecting groundwater samples for several months. The groundwater samples will be used to refine the location of the proximal portion of each of the plumes in the 100-D Area. Seven wells were drilled in the southeastern plume (i.e., the plume that directly impacts the treatment barrier) in February and March 2007 and have been sampled bi-weekly since that time. Data from these wells, which have also been instrumented to automatically measure groundwater levels, have identified a source area near the former Sodium Dichromate Transfer Facility. Plans for the northern plume include approximately 15 vadose zone direct-push drill holes to collect soil samples using a hydraulic hammer drill rig developed specifically for the Hanford Site and installation of three groundwater monitoring wells. This work will be performed in calendar year 2008.

4.3 IN SITU BIOSTIMULATION STUDY

The ISRM barrier was installed to reduce the amount of hexavalent chromium entering the Columbia River. Additional actions are required to address the high-concentration portion of the

chromium plume upgradient of the ISRM barrier and to increase the longevity of the barrier. The longevity of the barrier is significantly impacted by relatively high concentrations of nitrate and oxygen flowing into the barrier that are in addition to the chromate contamination, the primary treatment target of the barrier. A proposed method to accomplish these goals is to use in situ biostimulation to reduce hexavalent chromium, nitrate, and DO and to establish a permeable reactive barrier upgradient of the ISRM barrier. Biostimulation is expected to decrease the concentrations of chromate, nitrate, and DO flowing into the ISRM barrier, thereby increasing the longevity of the ISRM barrier and protecting the Columbia River. Biostimulation can be designed to sustain reduction of groundwater species over relatively long time periods via slow-release substrates, buildup of biomass, and/or relatively inexpensive reinjection of substrates. The injected substrates enable bacteria that exist in the aquifer to grow, and these bacteria catalyze reduction of hexavalent chromium, nitrate, and DO as part of their metabolic processes.

During FY 2007, 12 wells were drilled as part of this test (two injection wells and ten monitoring wells). The first phase of field testing for a biostimulation barrier was initiated in September 2007 with the injection of a substrate into the aquifer via a single injection well at a selected testing location in the 100-D Area. The substrate was successfully injected to form a treatment zone approximately 30 m (100 ft) in diameter. This testing zone is now being monitored to evaluate the effectiveness and longevity of the biostimulation process for reducing hexavalent chromium, nitrate, and DO. The initial results show that the expected microbial activity in the aquifer was stimulated within the targeted treatment zone and that the desired reducing conditions are being maintained.

4.4 ELECTROCOAGULATION TEST

An EC treatability test system has been designed, built, and operated to determine if the EC process should be pursued to remove hexavalent chromium from the 100-D Area's northeast plume. A report on the treatment system will be prepared during FY 2008. The treatment system is located northeast of the 182-D Reservoir (at the intersection of Palouse Street and Puget Avenue) and will be designed for unattended outdoor operation. To meet the 189 L/min (50 gal/min) target process rate, two existing wells (199-D5-13 and 199-D5-41) were used as extraction wells to supply contaminated groundwater to the treatment system. Injection Well 199-D5-106 was drilled to accept the treated effluent. The EC treatability test lasted approximately five months, from mid-May 2007 to mid-October 2007.

The EC treatment system consisted of influent and effluent tanks, an EC cell designed for up to 189 L/min (50 gal/min) continuous flow, solids separation equipment (e.g., clarifier, media filters), a filter press for solids dewatering, and process control instrumentation.

Initial startup of the treatment system was performed in batch operation mode to verify that the treatment system could meet injection standards. Concentrations of hexavalent chromium and iron in the treated effluent were closely monitored using field colorimetric sampling methods. The target reduction level for hexavalent chromium was <10 μg/L in the treated effluent. Semi-continuous operation of the system commenced once the treatment system was shown to be effective in batch operation mode. The EC system was then operated in continuous mode for 52 days to demonstrate continuous operation.

Injection of treated water was switched from Well 199-D5-106 to Well 199-D5-33 after plugging problems were experienced with Well 199-D5-106. Treated water from the EC system was injected into Well 199-D5-33 from August 21, 2007 until September 8, 2007. At that time, water injection was switched back to Well 199-D5-106.

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5.0 QUALITY ASSURANCE/QUALITY CONTROL

Field replicates, offsite laboratory replicates, and field/offsite laboratory splits are QC samples used to assess the precision of chemical analyses. Establishing the precision of analyses by field screening consisted of comparing analyses for field replicates and field/offsite laboratory splits and calculating the relative percent difference (RPD), as follows:

$$\text{RPD} = \frac{(c1 - c2)}{(c1 + c2)/2} \text{ x } 100\%$$

where $c1$ and $c2$ are replicate or split concentrations.

The EPA's functional guideline is ±20 percent for replicates (EPA/540/R-94/083, *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses*). The RPD values that are <±20 percent are acceptable. Split samples do not have a specific criteria; however, this same criteria of ±20 percent is applied as a general quality indicator. The QC samples analyzed in FY 2007 indicate that there was acceptable data quality for most hexavalent chromium analyses, as discussed below. However, there is a variance between sulfate samples analyzed in the field and corresponding sample splits analyzed in an offsite laboratory. A total of 41 percent of sulfate samples split and analyzed in the field and in an offsite laboratory did not meet chosen acceptance criteria. Field analyses are being phased out. Appendix D contains the data used for the RPD evaluation of hexavalent chromium and sulfate.

5.1 HEXAVALENT CHROMIUM

The results of the QC analyses performed for hexavalent chromium during FY 2007 are included in Table D-7 in Appendix D and are listed by well number, sample date, sample number, result, and RPD.

Five field replicates were analyzed for hexavalent chromium using the using field Method COLOR_TK_CR6_FLD.[1] Filtered samples were used for all but one sample pair. The RPD calculation for two sample pairs was not conducted because the analytical data included results that were less than the detection limit. The RPD values for the remaining three sample pairs ranged from 0 to 0.8 percent. None of the sample pairs exceeded the EPA guideline.

Thirty-one samples were split and analyzed in the field for total chromium using Method COLOR_TK_CR6_FLD and then in an offsite laboratory using Method 7196_CR6. Filtered samples were used for all but two sample pairs. The RPD calculation for three sample pairs was not conducted because the analytical data included results that were less than the detection limit. The RPD values for 26 of the remaining 28 sample pairs (93 percent) were within the EPA function guideline of ±20 percent.

Twenty replicate sample pairs were collected and analyzed for hexavalent chromium in offsite laboratories using Method 6010_METALS_ICP. Filtered samples were used for all of the sample pairs. The RPD calculation for one sample pair was not conducted because the analytical

[1] Methods are taken from the HEIS database.

data included results that were less than the detection limit. The RPD values for 18 of the remaining 19 sample pairs (95 percent) were within the EPA guideline.

Finally, 12 sample pairs were split and analyzed for total chromium in offsite laboratories using Method 6010_METALS_ICP. Filtered samples were used for all sample pairs. The RPD values for sample pairs ranged from 0 to 2.1 percent, with 100 percent of samples within the EPA guideline.

5.2 SULFATE

The results of the QC analyses for sulfate performed during FY 2007 are included in Table D-8 in Appendix D and are listed by well number, sample date, sample number, result, and RPD.

Three field replicates were analyzed for sulfate using field Method COLOR_TK_FIELD. The RPD values of these three unfiltered field replicates ranged from 5.7 to 21.3 percent. Ninety-four percent of the samples were within the EPA functional guideline of ±20 percent for these types of analyses (EPA 540/R-94-083).

Thirty-nine samples were split and analyzed in the field using field Method COLOR_TK_FIELD and then in an offsite laboratory using method 300_ANIONS_IC. The RPD values for 23 of these unfiltered replicate samples were within the chosen range of ±20 percent. Field analyses are being phased out. Analyses from Severn Trent Laboratories, Inc., St. Louis were higher in 12 cases (75 percent of the time), while the field laboratory was higher in two cases, and the Waste Sampling and Characterization was higher in two cases.

Finally, 20 replicate sample pairs were collected and analyzed for sulfate in an offsite laboratory using method 300.0_ANIONS_IC. The RPD values for 18 of these unfiltered samples were within the EPA functional guideline.

6.0 IN SITU REDOX MANIPULATION COST DATA

All projected costs are burdened and are based on costs through September 30, 2007. These costs are inclusive of design, construction, operation, and performance monitoring of the ISRM, as discussed in Price, 2003, "Explanation of Significant Difference for the Record of Decision, U.S. Department of Energy Hanford 100-HR-3 Operable Unit Interim Remedial Action, Involving In Situ Redox Manipulation (ISRM)." Actual costs for the 100-D Area ISRM interim remedial action were recorded in the Fluor Hanford, Inc. code of accounts databases. Cost accruals are recorded, sorted by activity, and summed bi-monthly in the database. These data can then be used to determine the actual capital and labor costs associated with a specific activity over a given time period. These data have been used to estimate actual project costs (burdened) and projected future costs (based on actual costs to date). Brief descriptions of specific activities are as follows.

- **Remedial design:** This includes all initial design activities to support ISRM construction, permitting, peer reviews, quality assurance, and all other design documentation. No remedial design costs were incurred in FY 2007.
- **Capital construction:** This includes all fees paid to the construction subcontractor for capital equipment, initial construction (i.e., construction of new wells and an evaporation pond), and modifications to the system. This includes all Fluor Hanford, Inc. labor required for oversight and support, as well as all fees paid to the construction subcontractor for capital equipment, installation of new wells, pond construction, and operation and maintenance. This cost represents the labor and material costs associated with establishment of the treatment zone. No capital construction costs were incurred in FY 2007.
- **Performance monitoring:** This includes the costs associated with monitoring water levels and the associated systems used to support these activities. It also includes groundwater sampling, analysis, and the technical evaluation and reporting of results and certain technical studies (e.g., geochemical studies, geophysical studies, groundwater flow meter studies, and laboratory groundwater chemistry studies). Performance monitoring costs have declined over the past 2 years because of improved efficiencies during data collection.
- **Waste management:** This includes the costs incurred from the processing of wastes associated with the placement of the barrier, monitoring of water levels, and groundwater sampling.

The cost breakdown for the ISRM project is presented in Figure 6-1 and Table 6-1. Total costs by percent of the total in the pie chart (Figure 6-1) show that the majority of cost for FY 2007, in decreasing order of magnitude, is charged to performance monitoring (98.8 percent) and waste management (0.2 percent). No capital construction or remedial design was carried out in FY 2007.

Figure 6-1. Cost Breakdown for 100-D Area
In Situ Redox Manipulation Operations, Fiscal Year 2007.

Table 6-1. In Situ Redox Manipulation Operating Cost Breakdown.

Description	Costs for 100-D Area ISRM				
	Actual Cost x 1,000				
	2003	2004	2005	2006	2007
Remedial design	--	--	--	$47.31	--
Capital construction	$330.67	--	$692.70	--	--
Performance monitoring	$536.10	$430.30	$778.30*	$229.72	$157.5
Waste management	$19.60	$7.40	$4.60	$2.94	$0.3
Totals	**$886.37**	**$437.70**	**$1,475.60**	**$279.97**	**$157.8**

*Fiscal year 2005 performance monitoring costs include technical studies (i.e., electromagnetic borehole flow-meter study, sediment/geophysical studies, and laboratory nitrate investigation).

ISRM = in situ redox manipulation.

7.0 CONCLUSIONS

Monitoring results collected in FY 2007 allow for a preliminary performance evaluation of ISRM barrier performance in relation to the RAOs (EPA/ROD/R10-96/134). Specific progress for FY 2007 toward meeting each RAO is as follows.

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

  Result: Operational monitoring of treatment zone (barrier) wells indicates that reducing conditions persist throughout most of the ISRM barrier, particularly in the southwestern portion. Operational monitoring data from the northeastern portion of the barrier showed hexavalent chromium concentrations greater than 20 μg/L in two areas, indicating either a periodic higher concentration from upgradient or a decrease in reductive capacity in these areas.

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

  Result: Institutional controls were maintained to prevent public access to groundwater.

- **RAO 2:** Provide information that will lead to the final remedy.

  Result: The project continues to collect operational and monitoring data to support development and implementation of a final remedy. Although no capital construction work was carried out during FY 2007, several field programs were carried out in FY 2007 (Chapter 4.0). This work includes an upgradient biostimulation test, a drilling program aimed at identifying the upgradient source of the hexavalent chromium found in the groundwater plume, and an EC test. Another test involving injection of micron-size zero-valent iron into two treatment barrier wells is planned for FY 2008.

The ROD Amendment (EPA et al., 1999) and DOE/RL-99-51 identified the overall key design elements of the ISRM remedial action. The following is a summary of the key design elements and current assessment of ISRM performance through FY 2007.

- The barrier will be approximately parallel to the Columbia River but may contain other orientations, depending on the distribution of the chromium contaminant plume.

  Result: The treatment zone is currently 680 m (2,230.96 ft) in length and roughly parallels the Columbia River. The axis of ISRM treatment zone has an orientation of approximately 220°. The optimum flow direction of groundwater for treatment is 307°, which is roughly perpendicular to the axis of the barrier.

  The net groundwater-flow directions in FY 2007 along the barrier itself were within the optimum range (307° [±30°]) and achieve this key design element. Groundwater flow further upgradient from the barrier may be more north-northwest.

- The treatment barrier will be designed in accordance with the DOE/RL-99-51 to attain RAOs.

  Result: The ISRM barrier construction and implementation is consistent with the key design elements outlined in the DOE/RL-99-51.

- The treatment zone shall treat the chromium plume to 20 μg/L or less at each compliance well to achieve 10 μg/L at the river.

  Result: Hexavalent chromium concentrations were below the RAO of 20 μg/L in four of the seven compliance wells. On an annual basis, hexavalent chromium concentrations met the RAO in two of these four wells. Annual average concentrations in the other compliance wells that exceed the RAO are either decreasing, slightly increasing, or steady.

- Compliance monitoring wells will monitor chromium and DO concentrations between the injection wells and the Columbia River to determine the effectiveness of the treatment zone.

  Result: Compliance monitoring wells are sampled quarterly for chromium, DO, and other constituents. Hexavalent chromium concentrations were near or below the RAO of 20 μg/L in four of the seven compliance wells. Two of seven compliance wells had DO concentrations exceeding 75 percent of the DO saturation.

- Performance monitoring wells will measure other field parameters including sulfate, DO, pH, temperature, and specific conductance.

  Result: Monitoring wells are sampled on a quarterly basis for these field parameters.

- The siting, design, and sampling of the compliance monitoring wells shall be adequate to define the boundaries of the plume and the effectiveness of the treatment zone and shall be capable of assessing if barrier "breakthrough" occurs. This requires wells to be located between the treatment barrier and the Columbia River and also to be located beyond the end of the treatment barrier to ensure compliance with the RAOs.

  Result: There are seven compliance wells for the ISRM treatment zone. The wells are distributed parallel to the treatment zone. Five of the wells are located approximately midway between the treatment zone and the Columbia River, and two wells are located slightly beyond the limits of the treatment zone (one at the southwest and one at the northeast [wells 199-D4-86 and 199-D4-83, respectively]).

  Hexavalent chromium concentrations in compliance wells generally have been decreasing over the past 3 to 4 years, with the exception of compliance Well 199-D4-38, which generally shows a slight upward trend, and Well 199-D4-84, which has changed very little over the past two years. In August 2007, Well 199-D4-38 had a concentration of 111 μg/L while Well 199-D4-84 had a concentration of 72 μg/L.

- Installation of the treatment barrier shall be initiated within 15 months after signing the ROD Amendment and shall be fully implemented by the end of FY 2002, based on current knowledge of the plume and implementability of the treatment technology.

  Result: Phase I of the large-scale deployment of the ISRM was initiated in FY 2000; Phases II was initiated in FY 2001, and Phase III was initiated in FY 2002. All three phases have been completed.

- If barrier breakthrough is identified, the Washington State Department of Ecology and EPA will determine alternative action to be taken.

  Result: Treatment zone wells are monitored and reported quarterly. Areas of the barrier that have some loss of reductive capacity are being closely monitored. These areas are being evaluated to determine the best option(s) for enhancing reductive capacity, including zero-valent iron injections planned in FY 2008; reducing chromium concentrations upgradient of the barrier to decrease barrier loading; or other technologies such as biostimulation, if found to be effective. Additional sodium dithionite injections are also possible.

- Post-treatment extraction purgewater shall be collected and disposed to an evaporation pond constructed at the ISRM site. High-concentration purgewater generated during post-treatment extraction shall be disposed to the evaporation pond, with the option of sending a portion of the concentrated purgewater to the Purgewater Storage and Treatment Facility (*Resource Conservation and Recovery Act of 1976* [RCRA] interim status unit) and/or to the Effluent Treatment Facility (RCRA final status unit), both of which are located in the 200 Areas. Subsequent low-concentration purgewater volumes will continue to be disposed to the evaporation pond or to the ground surface through a localized drip field constructed at the ISRM site. The withdrawn water that is to be discharged to the ground will be analyzed to confirm that the sulfate SDWS of 250 mg/L will not be exceeded in the underlying groundwater.

  Result: Extraction of post-treatment water from the treatment zone was completed during FY 2003. There has been no subsequent disposal of post-treatment extraction purgewater. The ISRM evaporation pond will be maintained to support additional sodium dithionite injections if they become necessary.

- Institutional control for protection of human health required by EPA is unchanged (EPA/ROD/R10-96/134).

  Result: Institutional controls were maintained to prevent public access to the groundwater.

- Applicable or relevant and appropriate requirements set forth in the 100-HR-3 and 100-KR-4 ROD (EPA/ROD/R10-96/134) are unchanged, with the exception of WAC 173-218, "Underground Injection Control Program," and 40 CFR 144, Subpart B, "Underground Injection Control Program," "General Program Requirements," which are not applicable or relevant and appropriate requirements of the ROD Amendment.

  The underground injection control regulations in WAC 173-218 and 40 CFR 144, Subpart B, prohibit the use of an injection well that may result in a violation of any 40 CFR 141 or that may otherwise adversely affect beneficial use of groundwater. The solution being injected does not contain any constituents that have a DWS, and beneficial use of groundwater will not be affected. However, the groundwater will exceed the sulfate SDWS for a brief period following injection. WAC 173-218 prohibits certain discharges to groundwater; however, this regulation specifically excludes cleanup actions undertaken pursuant to CERCLA.

  Result: Sulfate concentrations above the SDWS of 250 mg/L were noted in seven wells during FY 2007. Concentrations of sulfate continue to decline.

Additional conclusions are supported by assessment of the data collected during the course of the year.

- Leakage was detected in the 182-D Reservoir during the first quarter of FY 2007, with no measurable leakage during the remainder of the fiscal year. Water-level monitoring data in the 182-D Reservoir detected the loss of approximately 5.5 million L (1.5 million gal) of water to the ground between November 1, 2006, and December 8, 2006, corresponding to a leakage rate of approximately 98 L/min (26 gal/min). This leakage rate was much lower than the rate estimated in FY 2006 (401 L/min [106 gal/min]). The lower leakage rates during the remainder of the year probably are a result of maintaining relatively low water levels in the reservoir, based on 182-D operational records.
- Arsenic was analyzed in the first quarter of FY 2007 because of concerns that the injection of sodium dithionite might mobilize naturally occurring arsenic. Thirty wells were sampled and analyzed for arsenic, including 15 monitoring wells (which included 6 proximal monitoring wells), 7 compliance wells, and 8 aquifer treatment zone (barrier) wells. Arsenic was detected in one compliance well, four monitoring wells (including two proximal monitoring wells), and four treatment zone wells. Analytical values ranged from 2.6 to 5.5 μg/L, with all results below the MCL of 10 μg/L. Arsenic was not detected in other sampled wells. Consequently, arsenic is a potential candidate constituent for less frequent analysis.
- Aquifer and porewater sampling tubes along the Columbia River shoreline were sampled during the first and second quarters of FY 2007. Samples were collected from four aquifer tube sites and two porewater sites during the first quarter and from six aquifer tube sites and two porewater tube sites during the second quarter. Groundwater containing hexavalent chromium exceeding 20 μg/L was found at nine aquifer tube sites and four porewater tube sites, with concentrations ranging from 7 to 199 μg/L. Many of the aquifer tube sites and porewater tube sites in an area immediately downgradient of the northeastern portion of the treatment barrier (i.e., from aquifer tube site DD-50 to porewater tube site 166-D-1), over a distance of approximately 820 m (2,690 ft), had hexavalent chromium concentrations from at least one depth in excess of 20 μg/L.

8.0 RECOMMENDATIONS

Based on observations made during FY 2007, the following recommendations are made.

- Continue quarterly operational monitoring of all treatment zone wells in the barrier for hexavalent chromium and continue monthly operational monitoring of treatment zone wells that exceed 30 μg/L, including wells near the southwestern end of the barrier where hexavalent chromium concentrations appear to be slowly rising.
- Continue to maintain low water levels in the 182-D Reservoir in order to minimize leakage to the groundwater. Administrative controls that limit the water level in the reservoir have reduced leakage, most notable the last three quarters in FY 2007 compared to FY 2006.
- Modify the sampling and analysis plan to reduce the frequency of monitoring at wells where long-term trends are well established. This would include arsenic, which has not been detected above the drinking water standard.
- Continue to maintain the ISRM pond for future use. Additional campaigns where sodium dithionite injections are used to enhance barrier performance may require use of the evaporation pond for injection treatment recovery. Other technologies may be used for mending the barrier and may require the use of an evaporative pond.
- Continue to evaluate the residual influence of 182-D Reservoir leakage on the hydraulic flow field near the ISRM barrier. Significant past leakage created a small hydraulic mound that appears to direct the plume toward the barrier. Continued evaluation will support optimization and implementation of future remedial systems planned in the 100-D Area.
- Evaluate more frequent sample collection from aquifer tube and porewater tube sites in order to better monitor changes in hexavalent chromium levels downgradient of the ISRM treatment barrier. Currently, samples are collected annually because of river water level and equipment limitations.
- Evaluate other technologies to reduce chromium and nitrate loading where the high-concentration portion of the plume intersects the barrier. This would help to enhance barrier effectiveness, prevent breakthrough, and promote barrier longevity.
- Evaluate other technologies to accelerate reduction of hexavalent chromium in the area of the compliance wells, downgradient from the barrier. The barrier has been operational for 6 to 8 years, and while hexavalent chromium trends remain downward, concentrations in three compliance wells are above the more stringent aquatic standard contained in RAO #1.

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APPENDIX A

FISCAL YEAR 2007 WATER TABLE CONDITIONS

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APPENDIX A

FISCAL YEAR 2007 WATER TABLE CONDITIONS

A1.0 WATER TABLE CONDITIONS

Water table conditions at the In Situ Redox Manipulation (ISRM) site are influenced by both natural and artificial conditions. The primary natural influence is the Columbia River, while artificial influences include groundwater extraction and injection activities at the 116-DR-5 Outfall and 100-D Area pump-and-treat operations, as well as ongoing leakage at the 182-D Reservoir. Seasonal variations in groundwater elevations in monitoring wells (Figure A-1) reflect changes in the stage and flow rate of the Columbia River and are generally lowest in the fall (September through November) and highest from mid-spring to mid-summer (mid-May through mid-August).

Data from the automated monitoring network indicate substantial seasonal and diurnal variations in water levels across the site (Figure A-2). Well-defined seasonal variations are seen in all monitored wells and primarily reflect variations in river stage (Figure A-2A). Wells located close to the Columbia River show diurnal fluctuations that are closely coupled to short-term changes in the river stage. The magnitudes of diurnal fluctuations decrease in wells further from the river, and wells further from the river exhibit greater lag time in response to river fluctuations. The magnitudes of diurnal fluctuations can be seen in Figures A-2B and A-2C, each of which presents a week of data for two distinct flow regimes: reverse discharge and summer high flow. During the period of reverse discharge, flow volumes are intentionally kept low during daylight hours by the Grant County Public Utility District in order to encourage salmon to spawn in deeper water. Flows are greatest between sunset and sunrise, which is the opposite of normal flow patterns for generation of hydroelectric power. In fiscal year (FY) 2007, reverse discharge occurred between November 18 and November 28, 2007 (Figure A-2B).

Beginning with FY 2005, manual water-level measurements have been collected quarterly throughout the year. During FY 2007, water-level measurements were collected manually in November and December 2006 (first quarter of FY 2007), February and March 2007 (second quarter of FY 2007), May and June 2007 (third quarter of FY 2007), and August and September 2007 (fourth quarter of FY 2007) from most of the monitoring wells associated with the ISRM site.

During FY 2007, there was continued uncertainty about the water elevation in the aquifer immediately surrounding 116-DR-5 Outfall Injection Well 199-D5-42 in relation to the measured water elevation because the well screen in this well is not capable of instantaneously transmitting all of the injected water to groundwater. For the third quarter contour map (Figure 3-3 in the main text of this report), quarterly water-elevation data from Well 199-D5-106, located 34 m (112 ft) to the southeast, are used in conjunction with water-elevation data from Well 199-D5-93 to provide an estimate of water elevation near Well 199-D5-42. Water-level data were not available for proximal wells 199-D5-93 and 199-D5-106 during the first quarter of FY 2007, so the water elevation near Well 199-D5-42 was interpolated from the elevations of more distal wells by comparing those elevations to those measured during the third quarter of FY 2007.

The water table map for the first quarter of FY 2007 shows a groundwater flow regime where the Columbia River was at a low stage and groundwater was discharging into the river. A relatively

steep gradient towards the river was present within about 200 m (656 ft) of the shoreline. Further inland, the gradient flattened somewhat and was generally directed northward toward the Columbia River. A generally similar groundwater flow regime was present in the first quarter of FY 2006 (DOE/RL-2007-19, *Annual Summary Report for the In Situ Redox Manipulation Operations*). The primary difference in water levels between the first quarter of FY 2006 and the first quarter of FY 2007 is the groundwater mound related to the 116-DR-5 Outfall Injection Well 199-D5-42. The mound is much less evident in FY 2007 because proximal Well 99-D5-106 (installed in the second quarter of FY 2007) can be used to estimate a more reasonable water level in the area of the injection well. Some flattening of contours near the 182-D Reservoir is evident due to relatively elevated first quarter water level in Well 199-D5-33. The water level in this well was likely somewhat elevated due to leakage from the 182-D Reservoir, estimated to be about 98 L/min (26 gal/min) during the first quarter of FY 2007. Small groundwater depressions located to the north-northeast of D Reactor, near the Columbia River, are related to pumping withdrawals by the 100-D Area pump-and-treat operation. Pumping withdrawals for the 116-DR-5 Outfall pump-and-treat operation appeared to have little impact on the water table. The influence in the high concentration plume area will be minimal.

The water table elevations for the third quarter of FY 2007 represent a groundwater flow regime where the Columbia River generally flows inland. The regional northeastward-directed groundwater gradient dominates the contour pattern seen at this time. A small groundwater mound is seen near the 199-D5-42 Injection Well, and a general flattening of the water table is evident near the 182-D Reservoir. The injection rate at the 199-D5-42 Injection Well ranged from approximately 148 to 178 L/min (39 to 47 gal/min) during the period. The 182-D Reservoir showed little evidence of leakage during the third quarter and little effect was seen in proximal monitoring wells. Relatively low water levels were maintained in the reservoir from early December 2006 through September 30, 2007 (Figure A-1).

Table A-1 compares FY 2006 and FY 2007 semi-annual water-level measurements for spring (June) and fall (November). These measurements were made manually, and a comparison shows that average FY 2007 elevations were 0.113 m (0.37 ft) higher in the spring and 0.467 m (1.553 ft) lower in the fall than the corresponding elevations reported in FY 2006, indicating that water table maps from FY 2006 and FY 2007 are generally comparable. Table A-2 summarizes water-level measurements in FY 2006 and FY 2007 from remotely monitored stations at the Columba River and at 16 wells located from 92 m to 665 m (300 to 2,180 ft) from the river. These data were recorded hourly and represent continuous water-level profiles for wells and the river station. Average water elevations recorded from wells during FY 2007 were generally lower than those recorded in FY 2006, although the average Columbia River stages were slightly higher in FY 2006. The maximum river stage was 0.392 m (1.286 ft) lower in FY 2007 than in FY 2006, while the minimum level was nearly identical in both years. Overall, the average Columbia River stage was 0.041 m (0.135 ft) higher in FY 2007 than it was in FY 2006.

A2.0 GROUNDWATER FLOW DIRECTION

For optimal treatment, the ISRM treatment zone was oriented to be perpendicular to the groundwater flow direction and plume axis. The net flow direction is calculated each year to evaluate the position of the treatment zone relative to plume movement. The optimal

groundwater flow direction towards the treatment barrier is modeled to be perpendicular to the barrier at an azimuth of 307° (±30°).

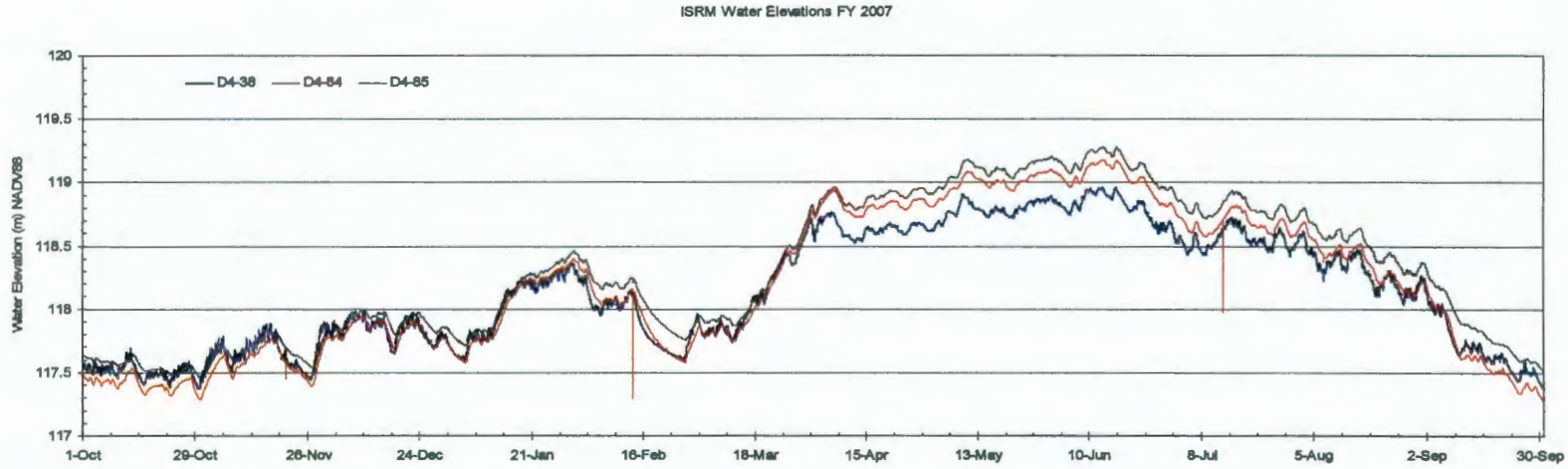
At the ISRM site, automated water-level data were collected hourly from eleven wells and were used to solve a series of three-point problems to determine flow direction and estimates of flow velocity. Wells 199-D4-38 and 199-D4-85 are located between the Columbia River and the ISRM barrier. Wells 199-D3-2, 199-D4-19, 199-D4-13, and 199-D5-36 are collinear with the treatment zone, from the southwest to the northeast, respectively. Wells 199-D4-20, 199-D5-33, 199-D5-34, 199-D5-38, and 199-D5-43 are located further inland from the barrier, with Well 199-D5-43 being the farthest from the Columbia River.

The principle behind the three-point calculation is that if the hydraulic head at three unique locations for the same time is known, it is possible to calculate the azimuth and magnitude of the flow direction for that time. The hourly water-level data allow for a large number of calculations throughout the entire year (e.g., 8,305 sets of data were used for the calculations for Triangle 2). A net-flow vector (magnitude and azimuth) can then be calculated from these data. A more detailed discussion of the three-point problem method is presented in DOE/RL-2003-05, *Fiscal Year 2002 Annual Summary Report for the In Situ Redox Manipulation Operations*.

Data collected from seven groupings of three wells (i.e., seven triangles) were evaluated in FY 2007 and are discussed in the main body of this report. Table A-3 presents a summary of the solutions of the seven triangles, including the flow direction and gradient graphs for the seven sets of triangles.

Figure A-1. Comparison of Seasonal Water-Level Fluctuations at the In Situ Redox Manipulation Site. (2 Pages)

Hydrographs for Wells 199-D4-38, 199-D4-84, 199-D4-85, 199-D5-36, 199-D5-33, and 199-D8-88



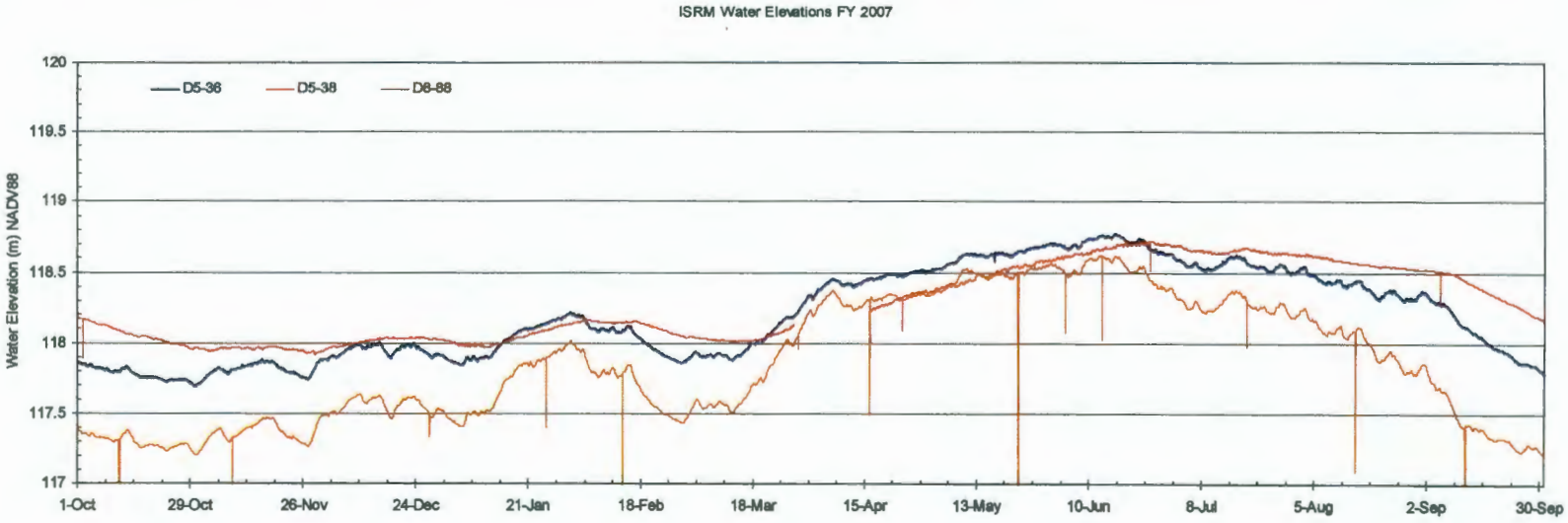
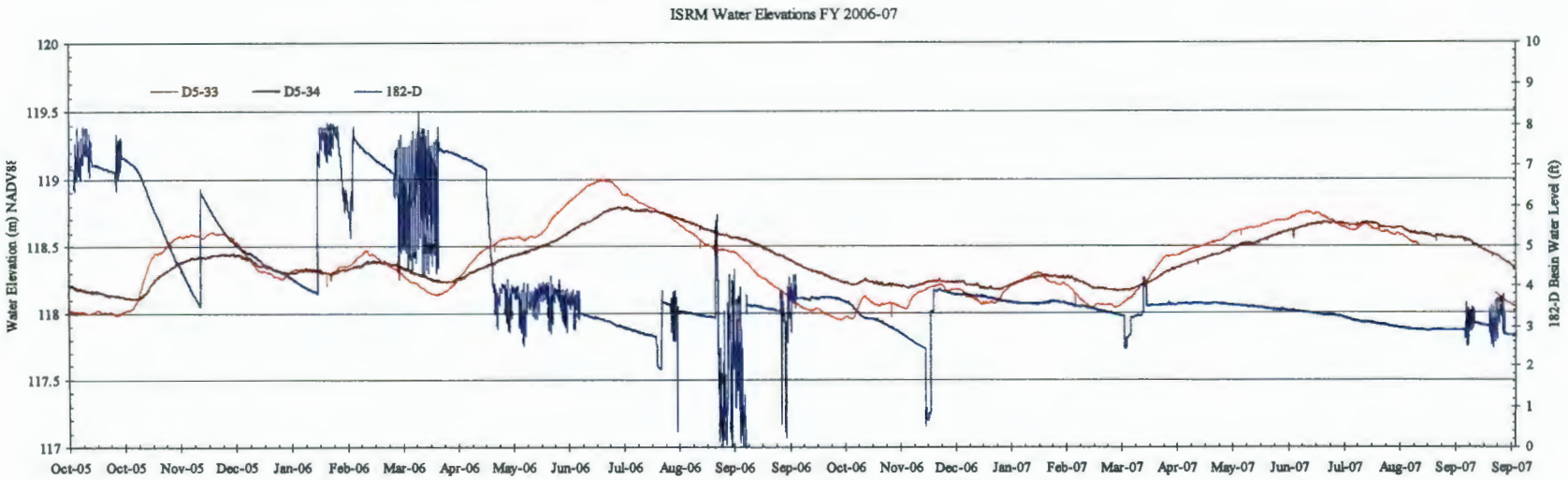


Figure A-1. Comparison of Seasonal Water-Level Fluctuations at the In Situ Redox Manipulation Site. (2 Pages)



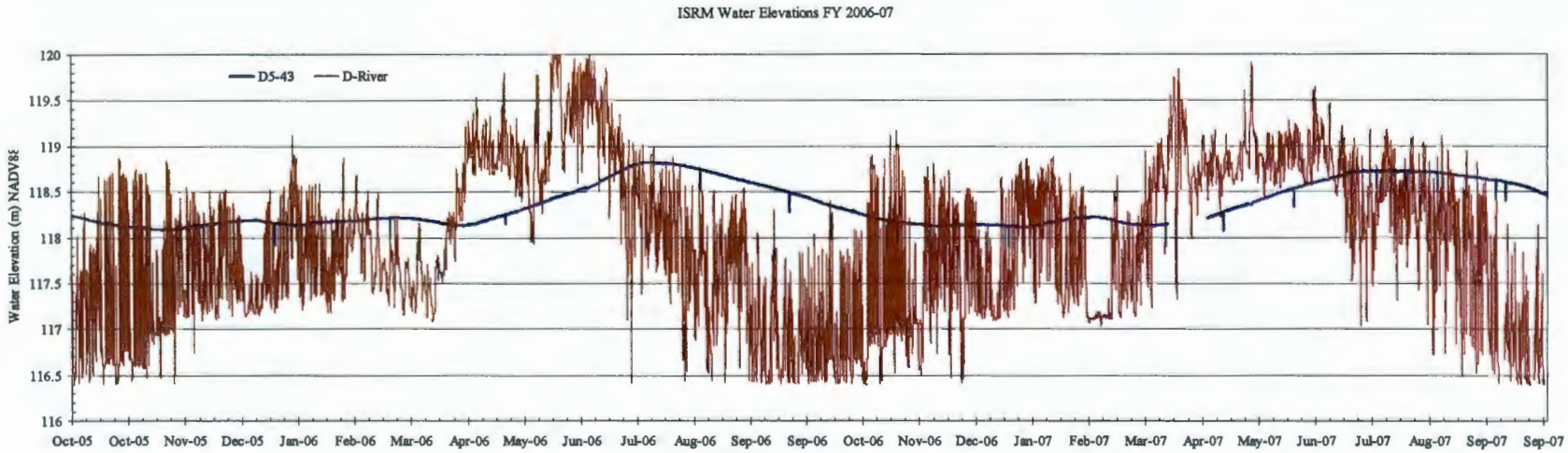
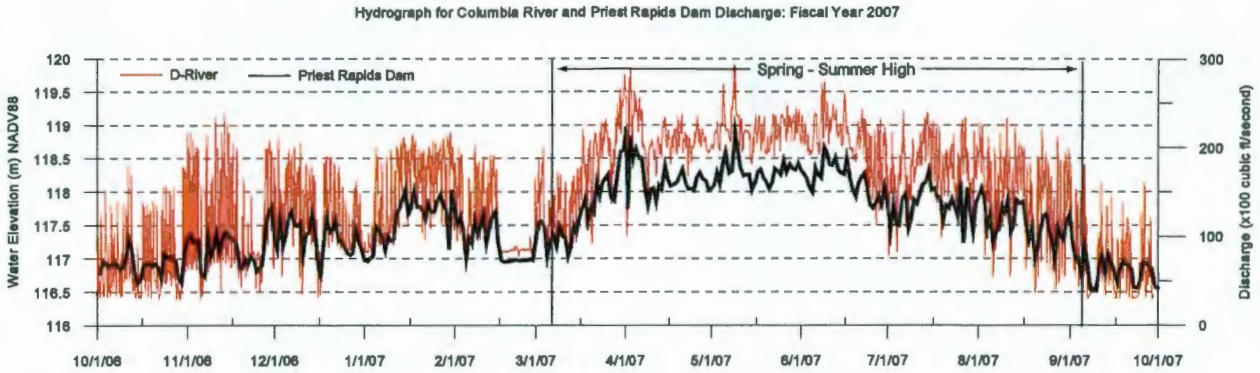
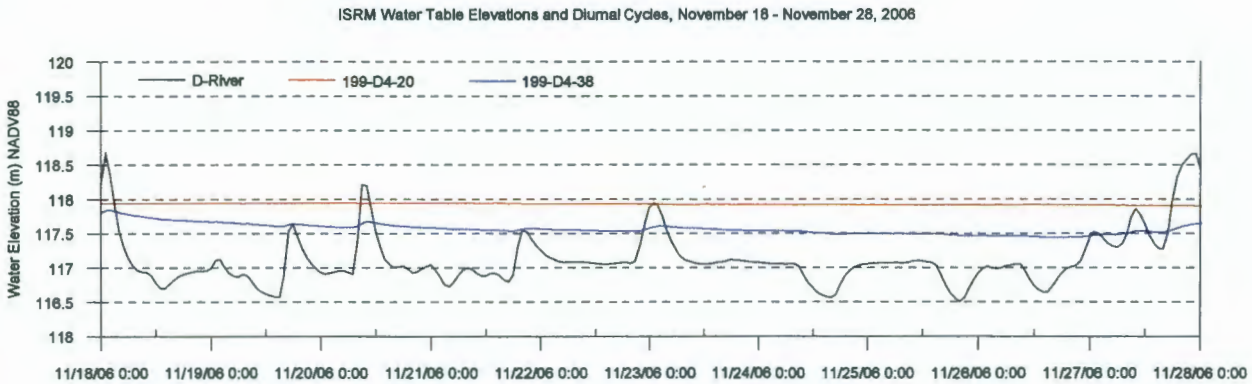


Figure A-2. Seasonal and Diurnal Cycles at the In Situ Redox Manipulation Site.

(A) Seasonal Cycles



(B) Diurnal Cycles - Reverse Discharge Flow Regime



(C) Diurnal Cycles - Summer High-Flow Regime

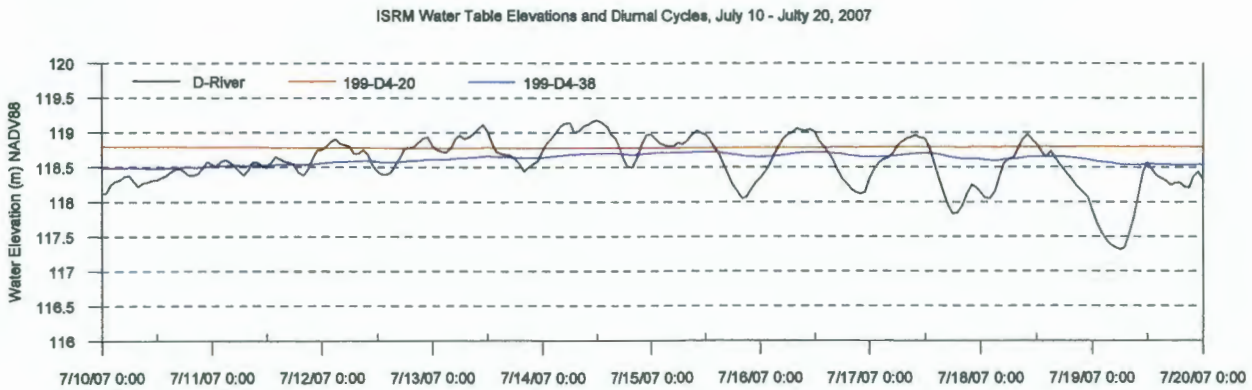


Table A-1. Comparison of 2006 and 2007 Semi-Annual Water Level Measurements at 100-D Area. (2 Pages)

Well Name	June 2006 Water Level Elevation NAVD88 (m)	June 2007 Water Level Elevation NAVD88 (m)	Change (m)	November 2006 Water Level Elevation NAVD88 (m)	November 2007 Water Level Elevation NAVD88 (m)	Change (m)
199-D2-6	117.985	117.991	0.006	118.969	118.884	-0.085
199-D3-2	117.814	117.774	-0.04	119.551	119.420	-0.131
199-D4-13	117.819	117.762	-0.057	119.176	119.025	-0.151
199-D4-14	117.833	117.79	-0.043	119.049	118.763	-0.286
199-D4-15	117.993	117.983	-0.01	118.758	118.673	-0.085
199-D4-19	117.83	117.763	-0.067	119.512	119.112	-0.400
199-D4-20	117.953	117.935	-0.018	118.959	118.821	-0.138
199-D4-21	117.812	117.766	-0.046	119.095	ND	N/A
199-D4-22	117.863	117.802	-0.061	119.042	118.797	-0.245
199-D4-23	117.807	ND	N/A	119.428	119.035	-0.393
199-D4-38	117.657	117.706	0.049	119.361	119.006	-0.355
199-D4-39	117.758	117.737	-0.021	119.167	118.849	-0.318
199-D4-83	117.86	117.808	-0.052	119.009	118.543	-0.466
199-D4-84	117.698	117.658	-0.04	119.478	119.047	-0.431
199-D4-85	117.781	117.714	-0.067	119.552	119.134	-0.418
199-D4-86	117.801	117.782	-0.019	119.553	ND	N/A
199-D5-13	117.628	117.695	0.067	118.451	118.260	-0.191
199-D5-14	117.841	117.994	0.153	118.247	118.339	0.092
199-D5-15	117.938	118.103	0.165	118.283	118.417	0.134
199-D5-16	116.912	118.062	1.15	118.199	118.269	0.070
199-D5-17	118.12	118.297	0.177	118.333	118.490	0.157
199-D5-18	118.064	118.229	0.165	118.271	118.378	0.107
199-D5-19	118.182	118.346	0.164	120.181	118.438	-1.743
199-D5-33	118.348	118.062	-0.286	118.927	118.685	-0.242
199-D5-34	118.193	118.217	0.024	118.681	118.641	-0.040
199-D5-36	ND	117.822	N/A	119.005	118.758	-0.247
199-D5-37	117.993	117.944	-0.049	119.245	118.631	-0.614

Table A-1. Comparison of 2006 and 2007 Semi-Annual Water Level Measurements at 100-D Area. (2 Pages)

Well Name	June 2006 Water Level Elevation NAVD88 (m)	June 2007 Water Level Elevation NAVD88 (m)	Change (m)	November 2006 Water Level Elevation NAVD88 (m)	November 2007 Water Level Elevation NAVD88 (m)	Change (m)
199-D5-38	118.006	117.972	-0.034	118.768	118.657	-0.111
199-D5-39	117.743	117.798	0.055	118.374	ND	N/A
199-D5-40	117.993	117.996	0.003	118.828	118.738	-0.090
199-D5-41	117.876	117.943	0.067	118.721	118.564	-0.157
199-D5-42	122.456	124.776	2.32	124.44	118.611	-5.829
199-D5-43	118.118	118.185	0.067	118.624	118.644	0.020
199-D5-44	117.862	117.761	-0.101	118.987	118.696	-0.291
		Average Change	**0.113**		**Average Change**	**-0.467**

N/A = not applicable.
NAVD88 = *North American Vertical Datum of 1988.*
ND = not measured.

Table A-2. Comparison of Fiscal Year 2006 and Fiscal Year 2007 Water-Level Monitoring Data.

Well	Distance from River (m)	Average Water Level Elevation (m)			Maximum Water Level Elevation (m)			Minimum Water Level Elevation (m)		
		FY 2006	FY 2007	Change*	FY 2006	FY 2007	Change*	FY 2006	FY 2007	Change*
Columbia River	0	117.97	118.011	0.041	120.299	119.907	-0.392	116.402	116.401	-0.001
199-D4-84	92	118.225	118.198	-0.027	119.725	119.176	-0.549	117.388	117.270	-0.118
199-D4-85	92	118.313	118.309	-0.004	119.813	119.277	-0.536	117.559	117.448	-0.111
199-D4-38	95	118.163	118.153	-0.010	119.396	118.961	-0.435	117.446	117.369	-0.077
199-D4-14	112	118.187	118.203	0.016	119.116	118.849	-0.267	117.757	117.684	-0.074
199-D5-36	114	118.242	118.199	-0.043	119.06	118.773	-0.287	117.746	117.689	-0.057
199-D4-21	145	118.216	118.184	-0.032	119.137	118.828	-0.309	117.748	117.656	-0.092
199-D4-13	165	118.293	118.262	-0.031	119.362	118.994	-0.368	117.756	117.400	-0.356
199-D4-19	191	118.31	118.303	-0.007	119.693	119.206	-0.487	117.64	117.532	-0.108
199-D3-2	195	118.291	118.352	0.061	119.651	119.167	-0.484	117.662	117.548	-0.114
199-D5-33	269	118.447	118.313	-0.134	118.996	118.755	-0.241	117.987	117.946	-0.041
199-D5-38	320	118.332	118.273	-0.059	118.975	118.719	-0.256	117.936	117.893	-0.043
199-D4-20	370	118.345	118.346	0.001	119.179	118.921	-0.258	117.725	117.707	-0.018
199-D5-34	483	118.426	118.382	-0.044	118.791	118.677	-0.114	118.103	118.160	0.057
199-D5-43	665	118.343	118.381	0.038	118.822	118.731	-0.091	117.867	117.896	0.029
199-D8-88	110	ND	117.862	N/A	ND	118.620	N/A	ND	114.401	N/A

* Difference between FY 2006 and FY 2007 values.
FY = fiscal year
NA = not applicable
ND = no remote water-level monitoring data available

Table A-3. Groundwater Flow Summary.

Triangle	% Optimal	Well "A"	Well "B"	Well "C"	Total Distance (m)	Net Flow Direction (°a)	Average Gradient
2	68	199-D4-20	199-D4-38	199-D5-38	11.47	323.6	0.0010
3	63	199-D4-38	199-D5-38	199-D5-36	8.05	295.9	0.0008
4	36	199-D4-20	199-D3-2	199-D5-85	0.04	305.2	0.0009
5	65	199-D5-43	199-D4-20	199-D5-38	5.45	345.4	0.0005
6	38	199-D5-34	199-D5-43	199-D5-36	9.08	299.8	0.0008
8	25	199-D5-34	199-D5-38	199-D5-33	7.55	261.2	0.0007
9	60	199-D4-20	199-D4-13	199-D4-19	7.50	3335.6	0.0010

°a = degrees azimuth

A3.0 REFERENCES

DOE/RL-2003-05, 2003, *Fiscal Year 2002 Annual Summary Report for the In Situ Redox Manipulation Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2007-19, 2007, *Fiscal Year 2007 Annual Summary Report for the In Situ Redox Manipulation Operations*, Rev. 0 REISSUE, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

NAVD88, 1988, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland.

APPENDIX B

FISCAL YEAR 2007 GROUNDWATER FLOW DIRECTION AND GRADIENT SOLUTIONS

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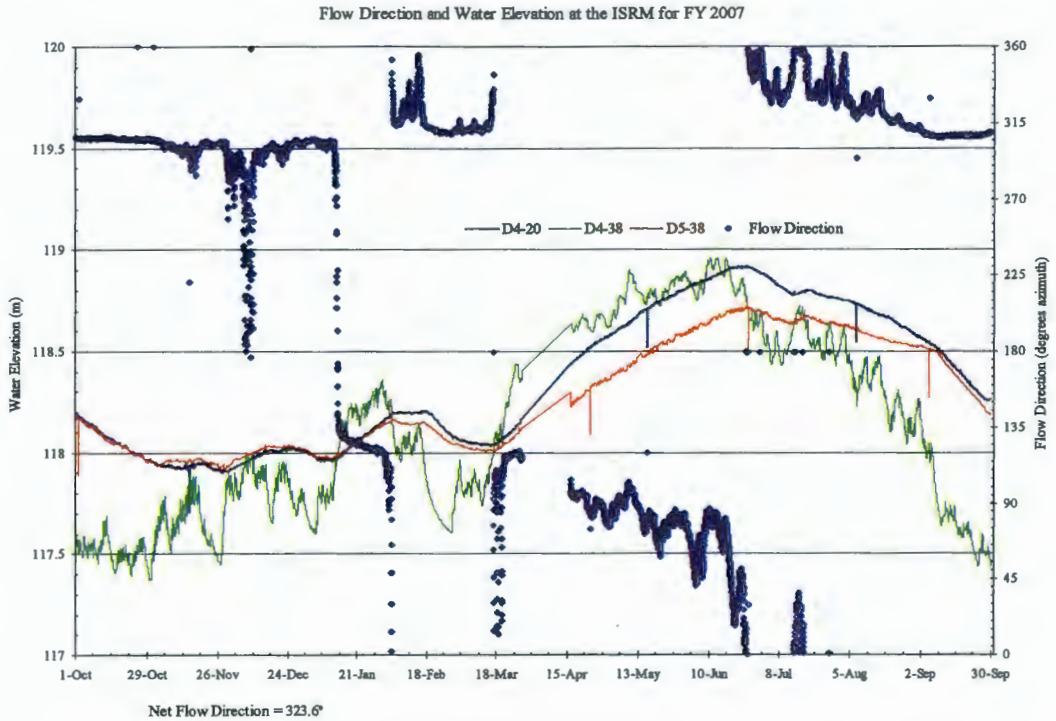
APPENDIX B

FISCAL YEAR 2007 GROUNDWATER FLOW DIRECTION AND GRADIENT SOLUTIONS

Figure B-1. Flow Direction and Gradient Triangle #2, Wells 199-D4-20, 199-D4-38, and 199-D5-38, Fiscal Year 2007.

Total distance 11.47 m, net flow direction 323.6°, average gradient 0.0010, 68% optimal flow direction.



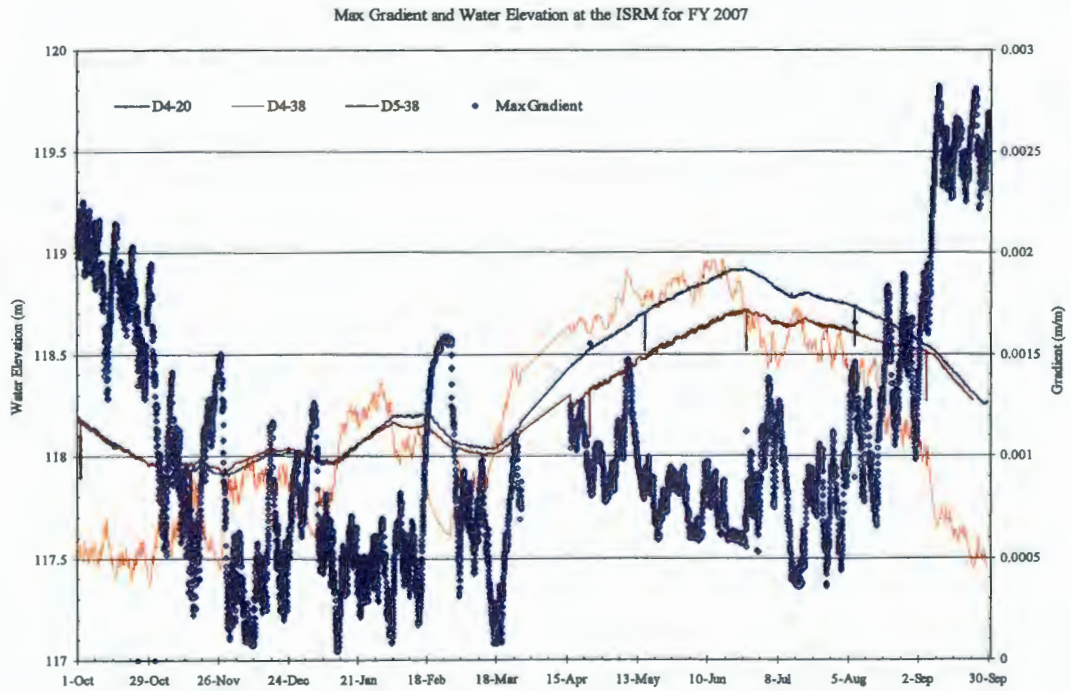
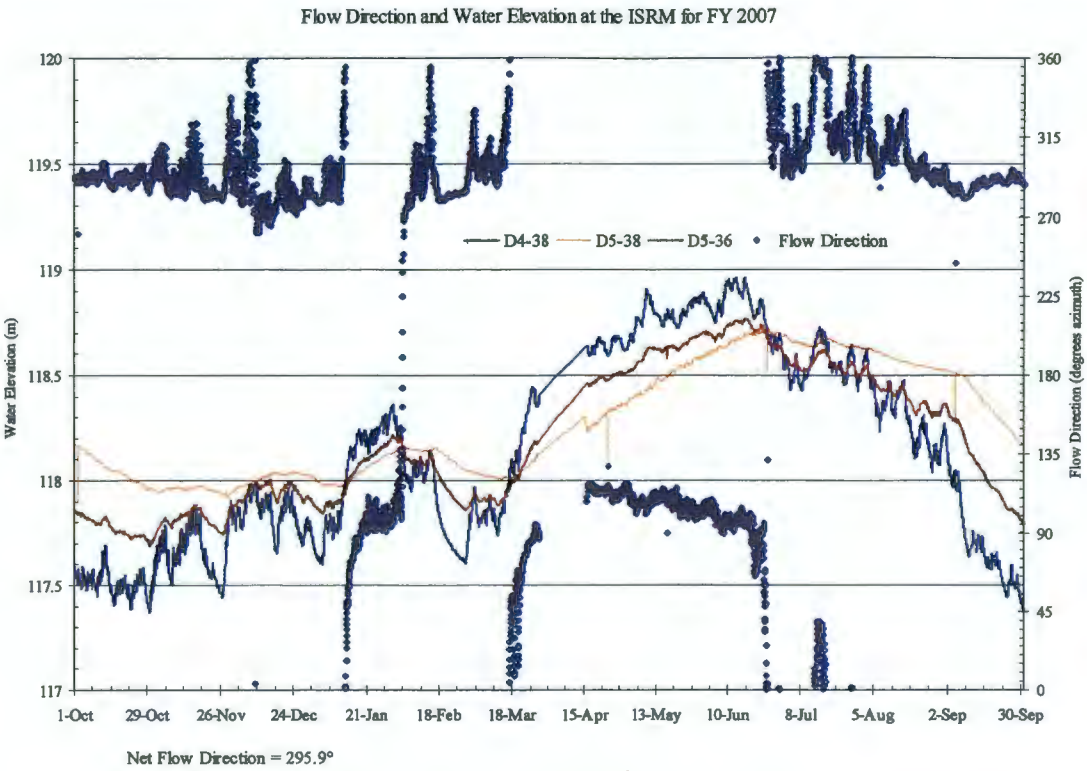


Figure B-2. Flow Direction and Gradient Triangle #3, Wells 199-D4-38, 199-D5-38, and 199-D5-36, Fiscal Year 2007.

Total distance 8.05 m, net flow direction 295.9°, average gradient 0.0008, 63% optimal flow direction.



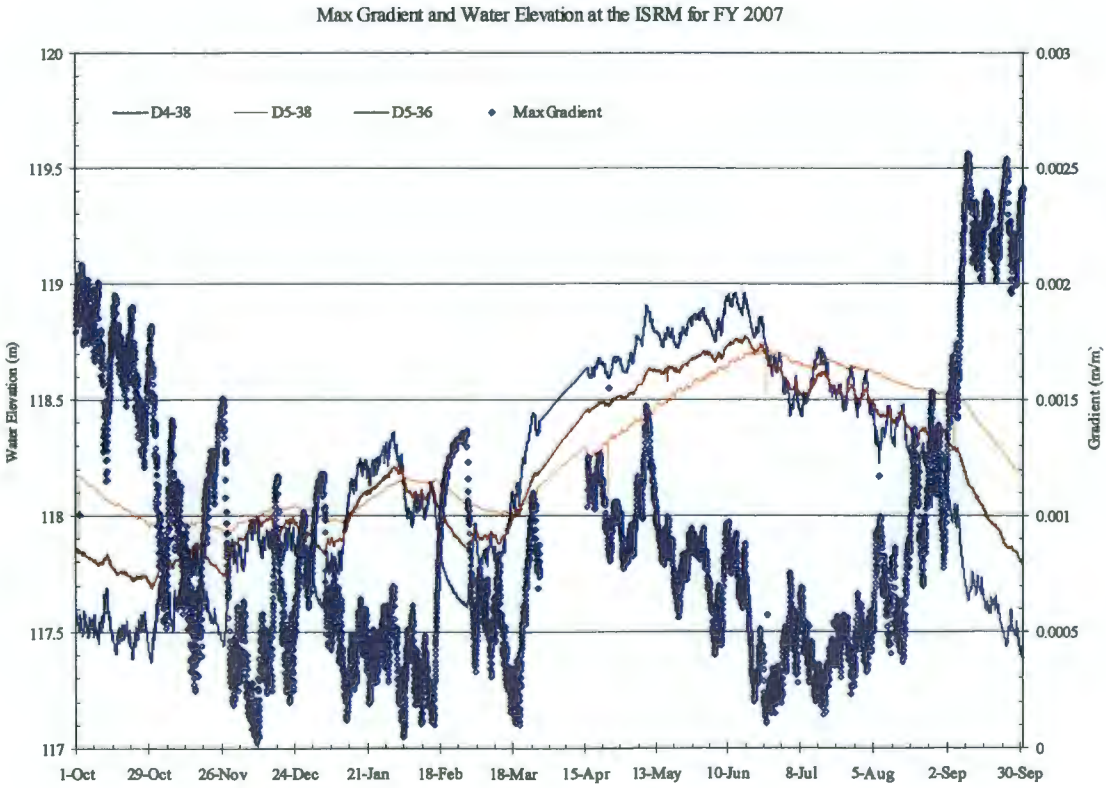
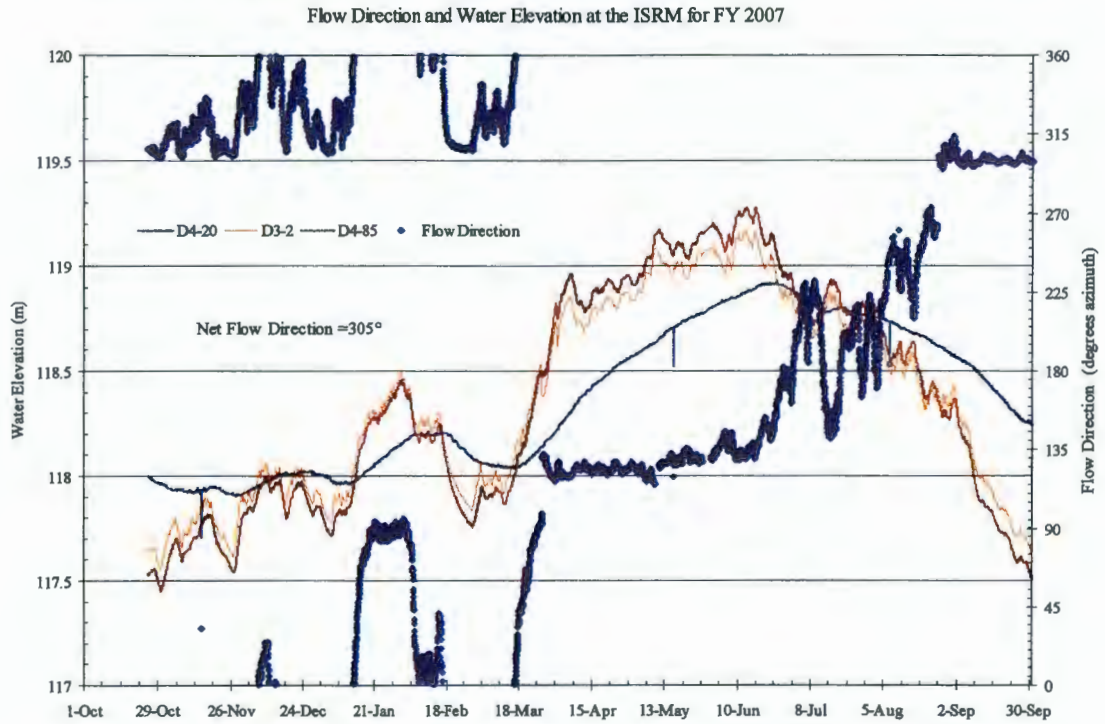


Figure B-3. Flow Direction and Gradient Triangle #4, Wells 199-D4-20, 199-D3-2, and 199-D4-85, Fiscal Year 2007.

Total distance 0.04 m, net flow direction 305°, average gradient 0.0009, 36% optimal flow direction.



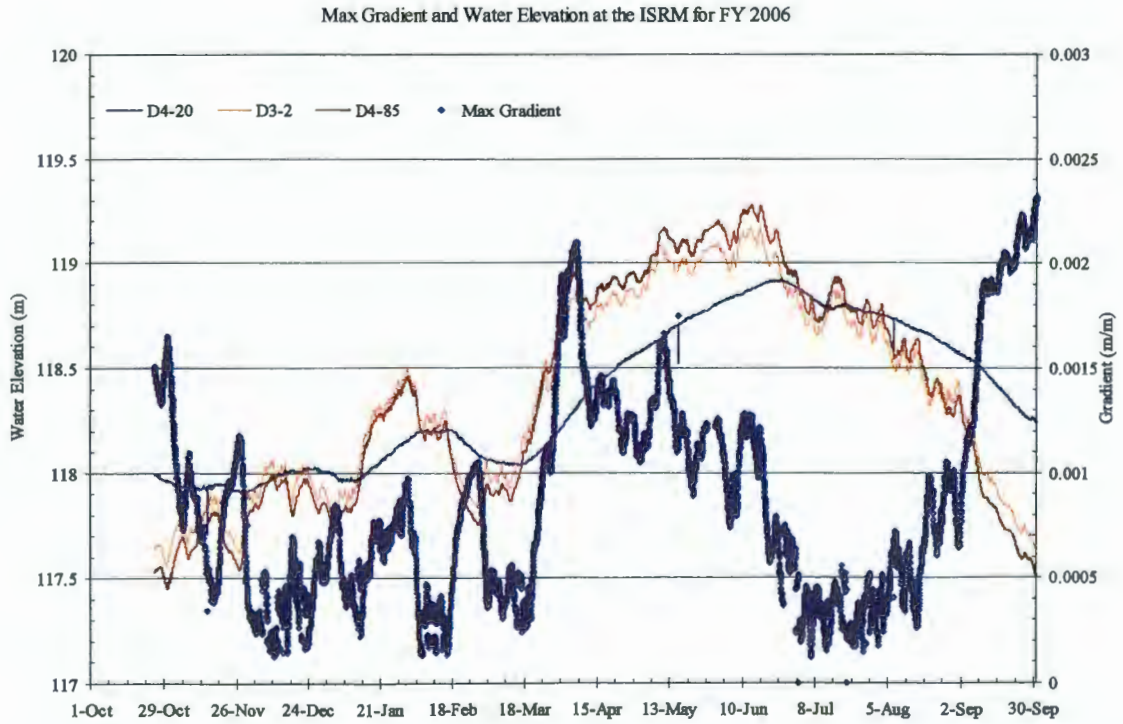


Figure B-4. Flow Direction and Gradient Triangle #5, Wells 199-D5-43, 199-D4-20, and 199-D5-38, Fiscal Year 2007.

Total distance 5.45 m, net flow direction 345.4°, average gradient 0.0005, 65% optimal flow direction.

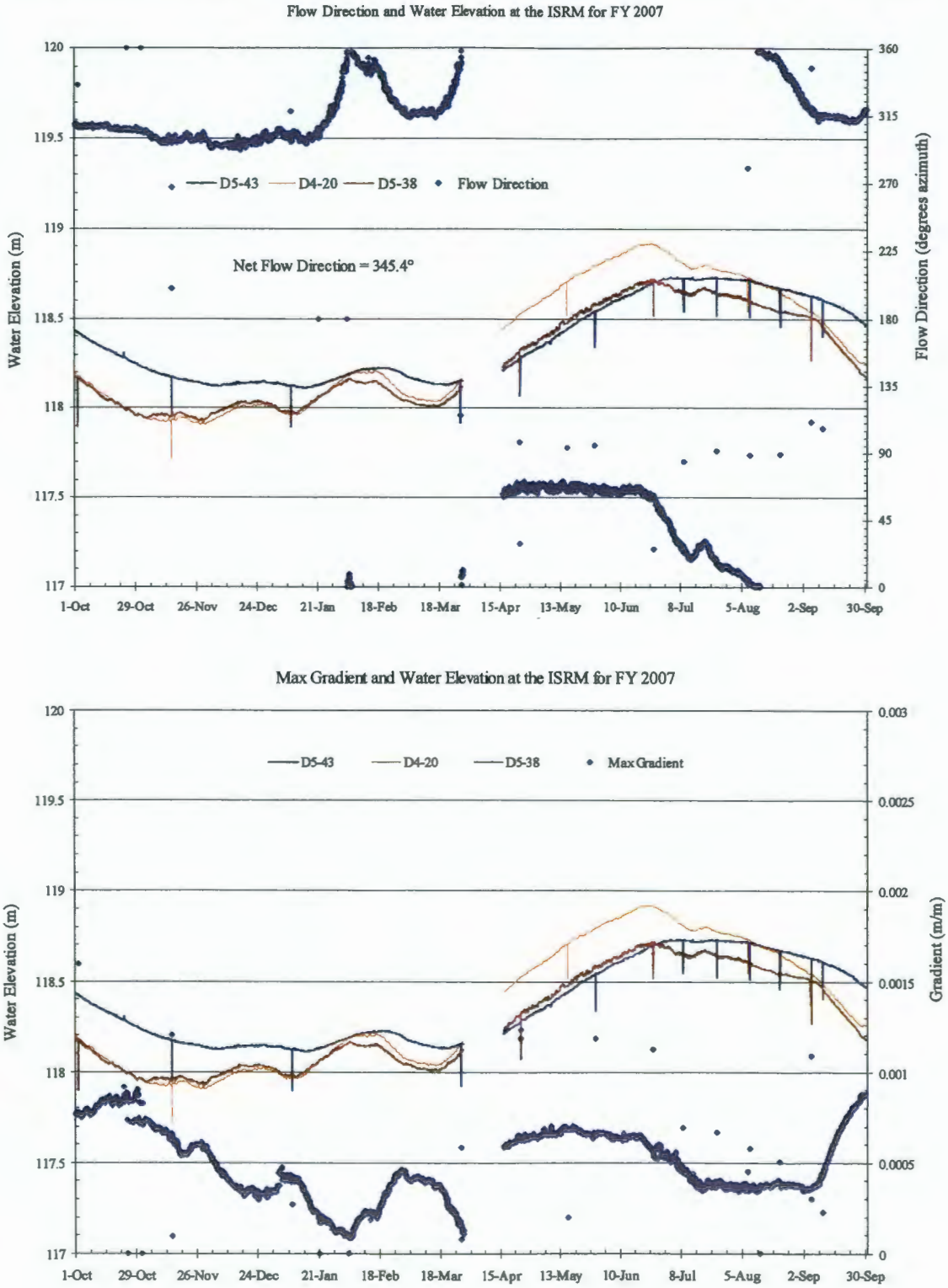
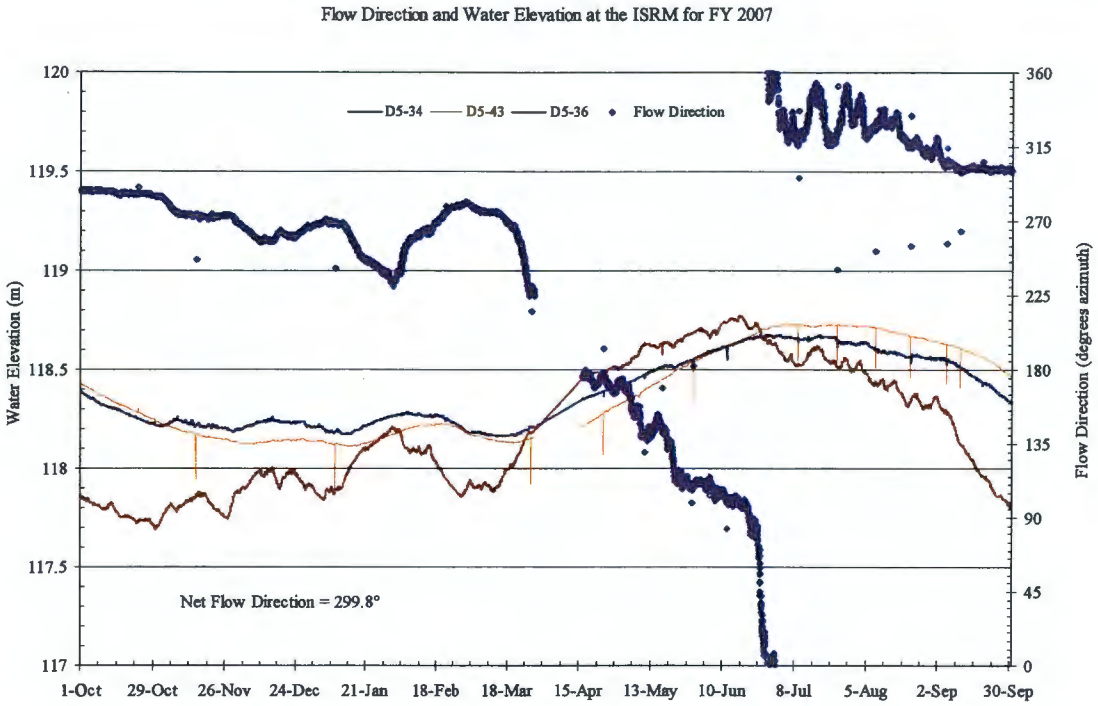


Figure B-5. Flow Direction and Gradient Triangle #6, Wells 199-D5-34, 199-D5-43, and 199-D5-36, Fiscal Year 2007.

Total distance 9.08 m, net flow direction 299.8°, average gradient 0.0008, 38% optimal flow direction.



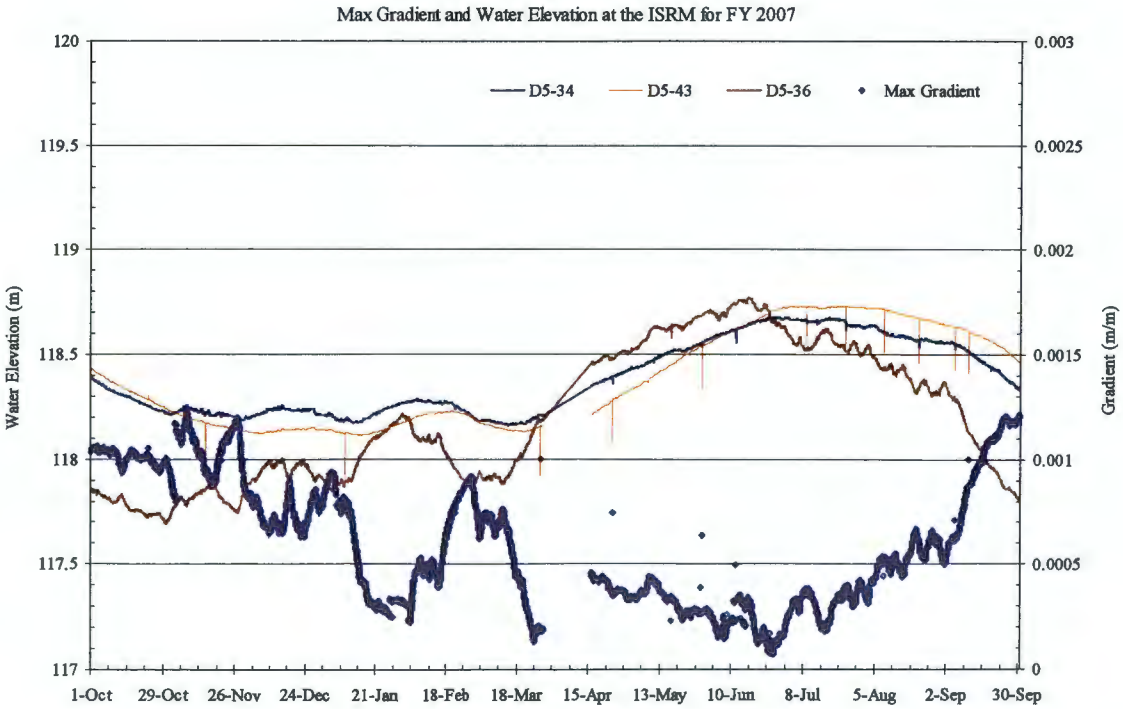
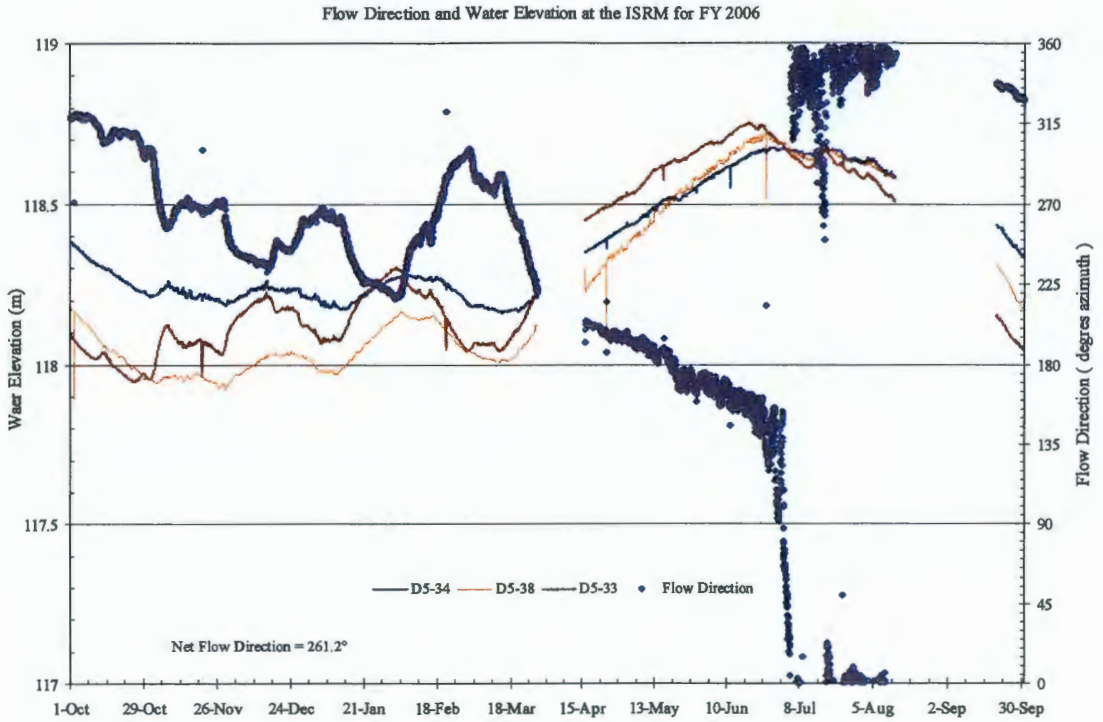


Figure B-6. Flow Direction and Gradient Triangle #8, Wells 199-D5-34, 199-D5-38, and 199-D5-33, Fiscal Year 2007.

Total distance 7.55 m, net flow direction 261.2°, average gradient 0.0007, 25% optimal flow direction.



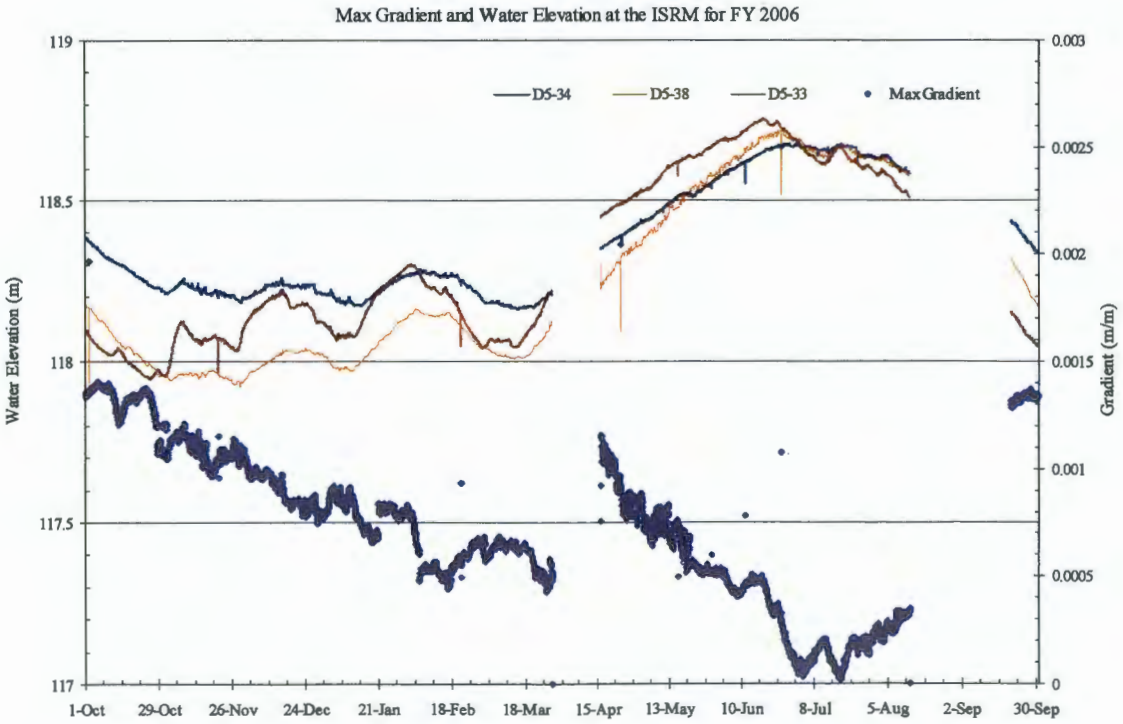
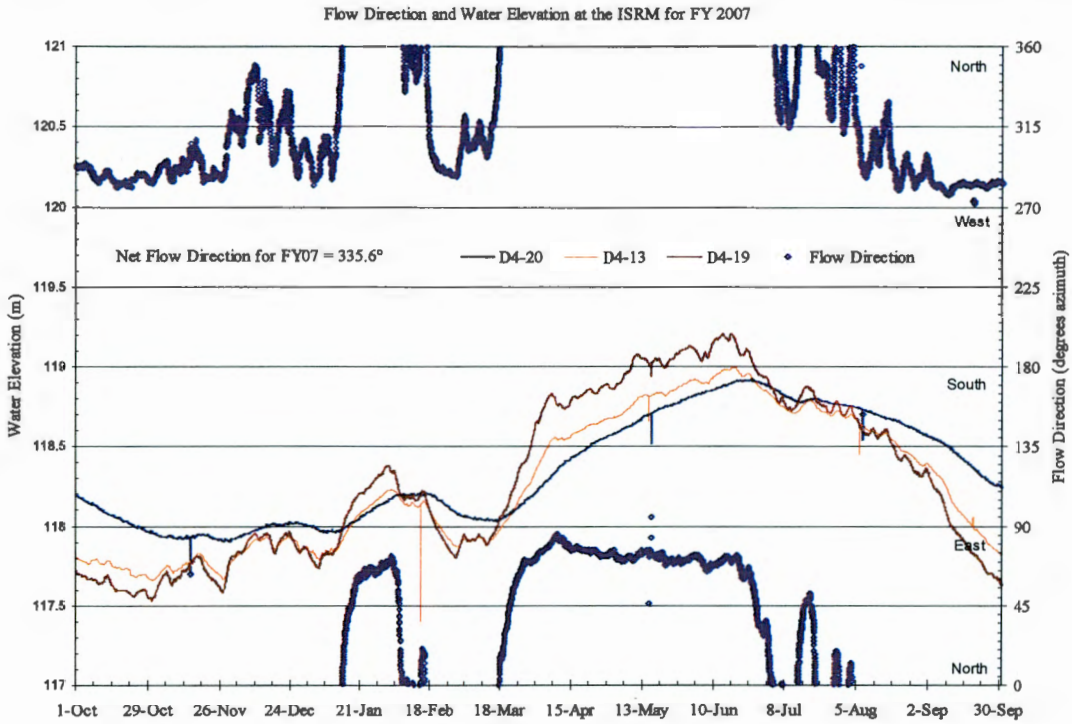
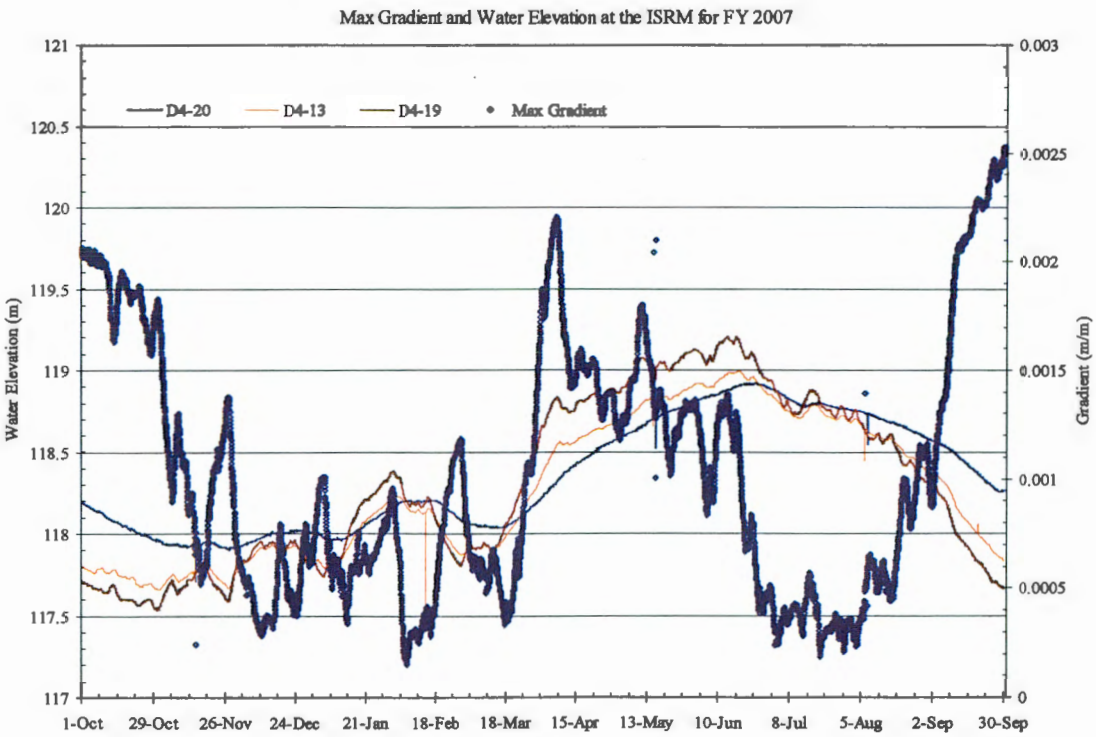


Figure B-7. Flow Direction and Gradient Triangle #9, Wells 199-D4-20, 199-D4-13, and 199-D4-19, Fiscal Year 2007.

Total distance 7.55 m, net flow direction 335.6°, average gradient 0.0010, 60% optimal flow direction.





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APPENDIX C

FISCAL YEAR 2007 HEXAVALENT CHROMIUM AND CHROMIUM TREND PLOTS FOR MONITORING AND COMPLIANCE WELLS IN THE IN SITU REDOX MANIPULATION AREA

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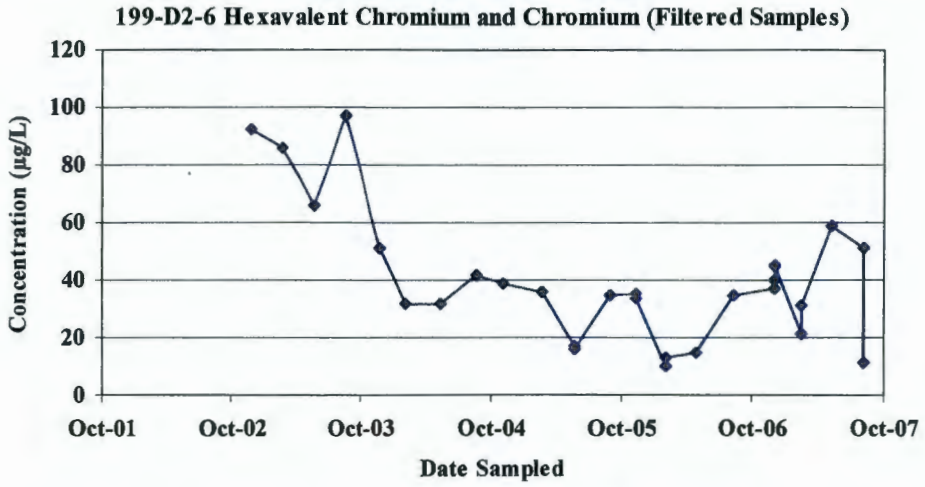
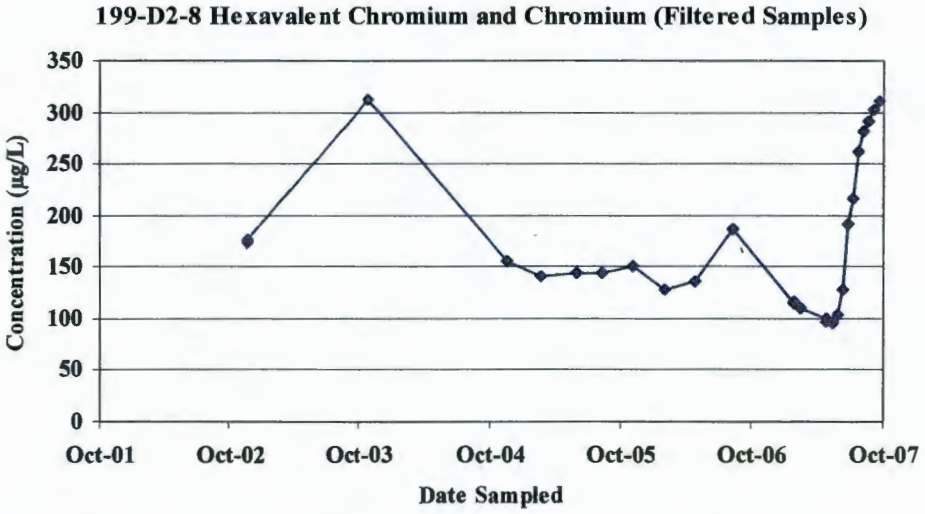
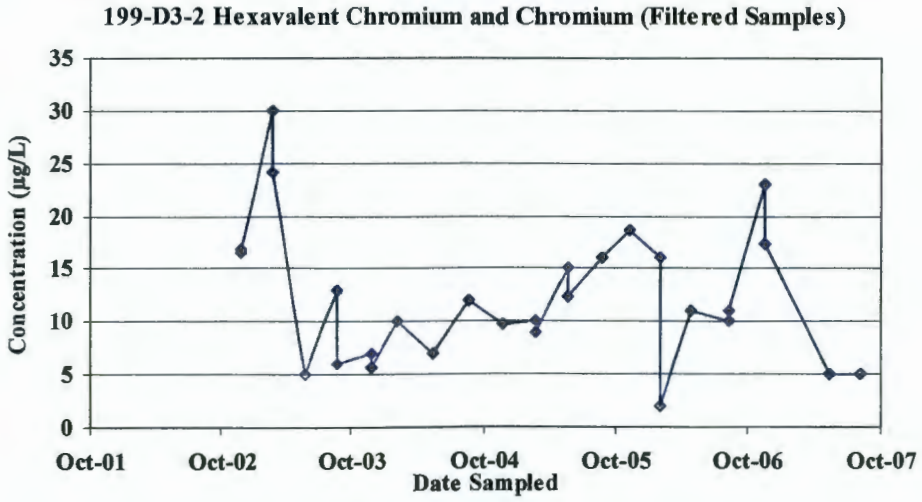
APPENDIX C

FISCAL YEAR 2007 HEXAVALENT CHROMIUM AND CHROMIUM TREND PLOTS FOR MONITORING AND COMPLIANCE WELLS IN THE IN SITU REDOX MANIPULATION AREA







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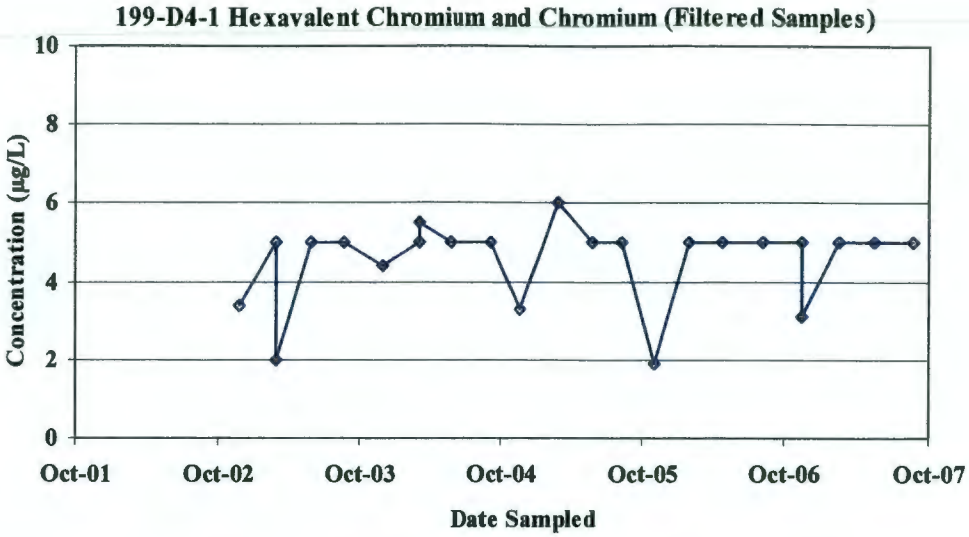

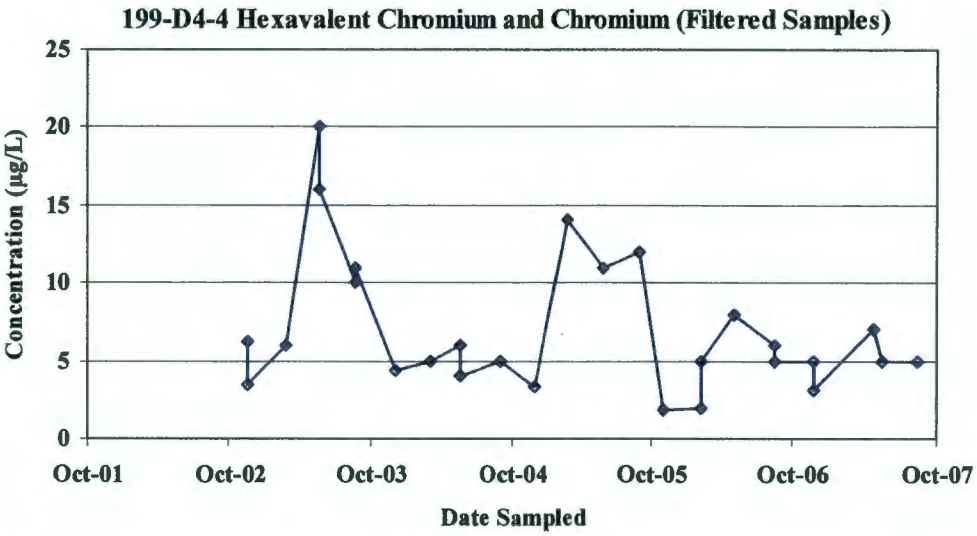

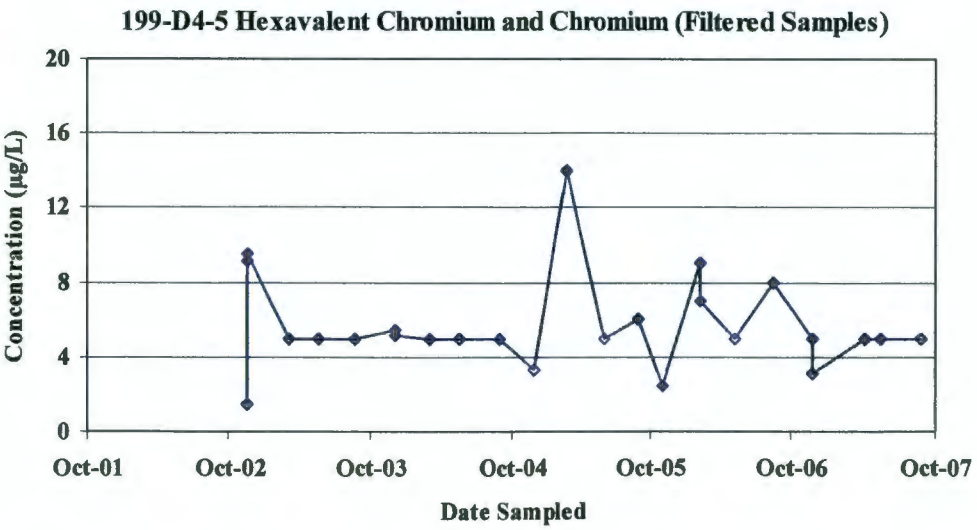

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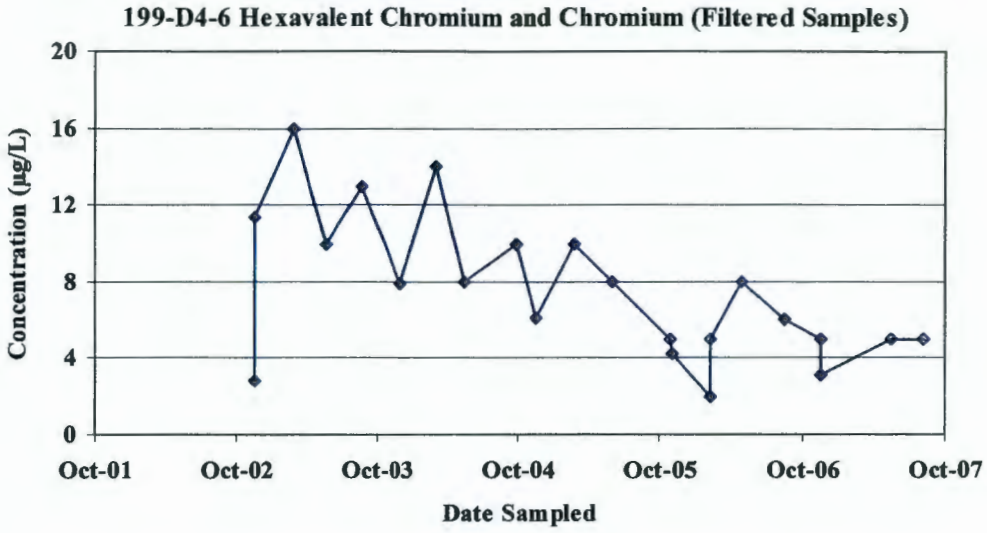
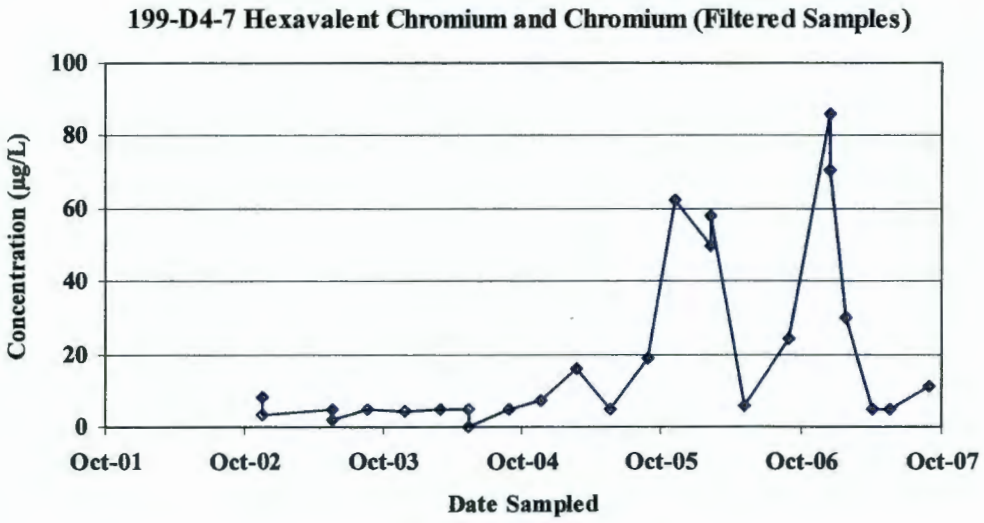
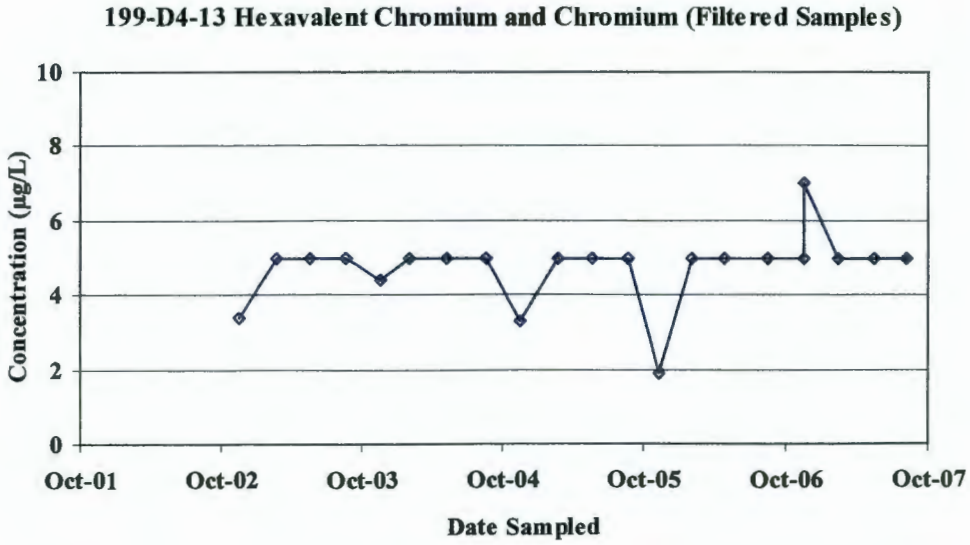
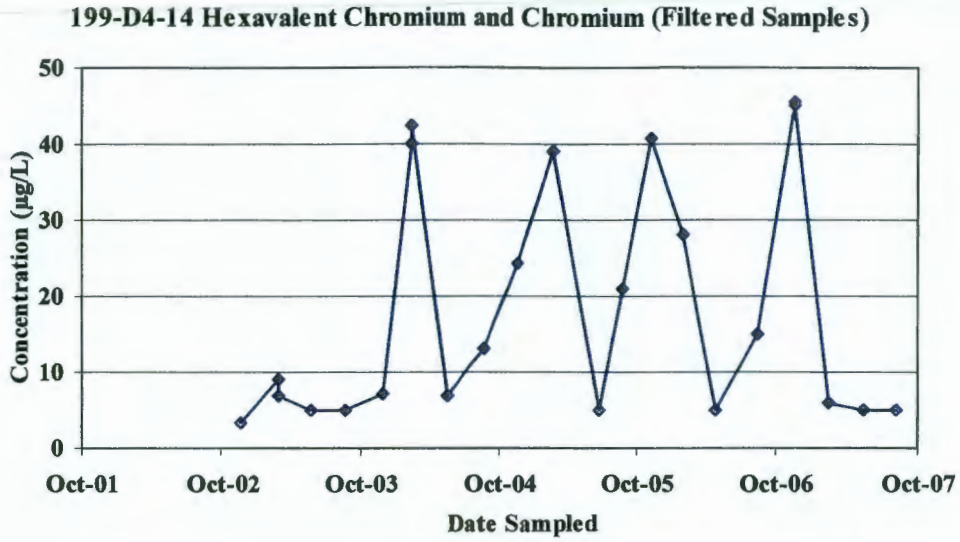
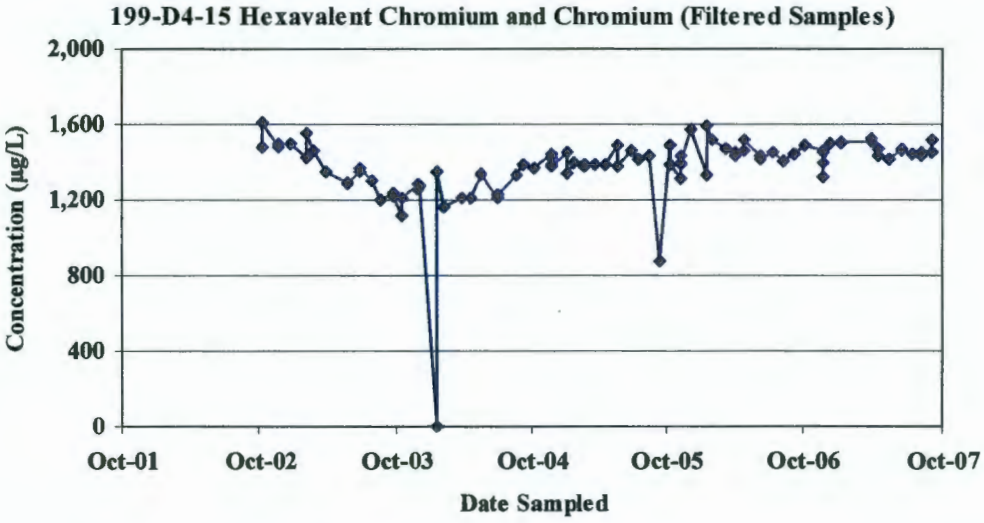


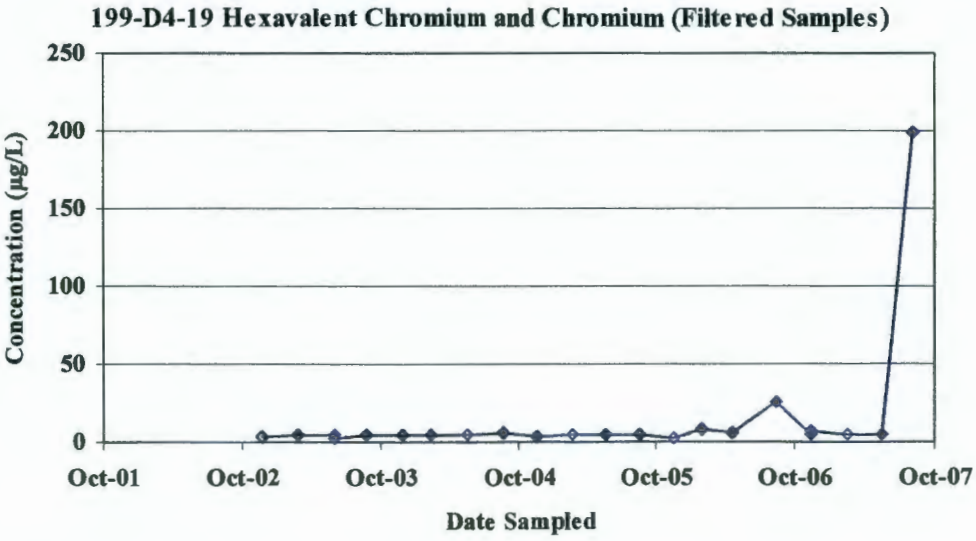




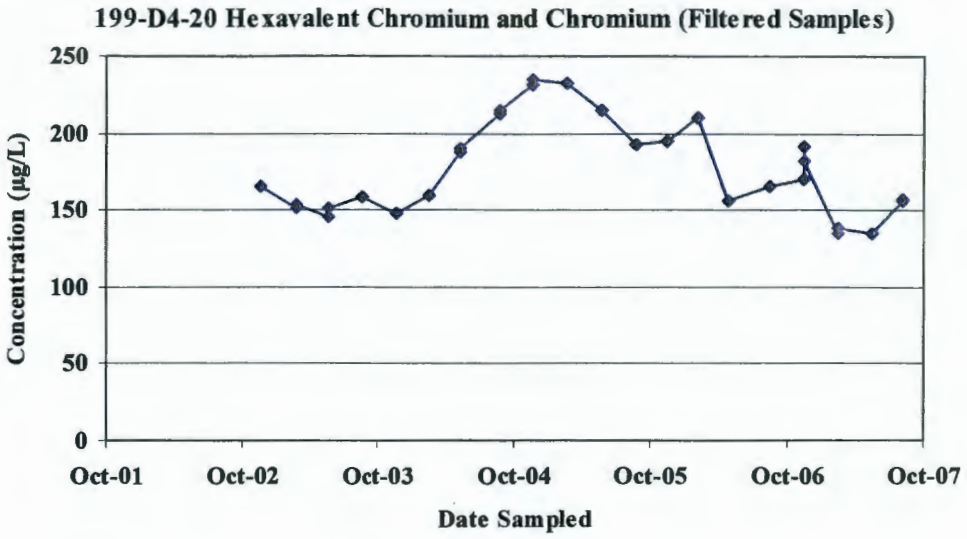
◊ = Analyte not detected, plotted value is laboratory reporting limit for the analysis.

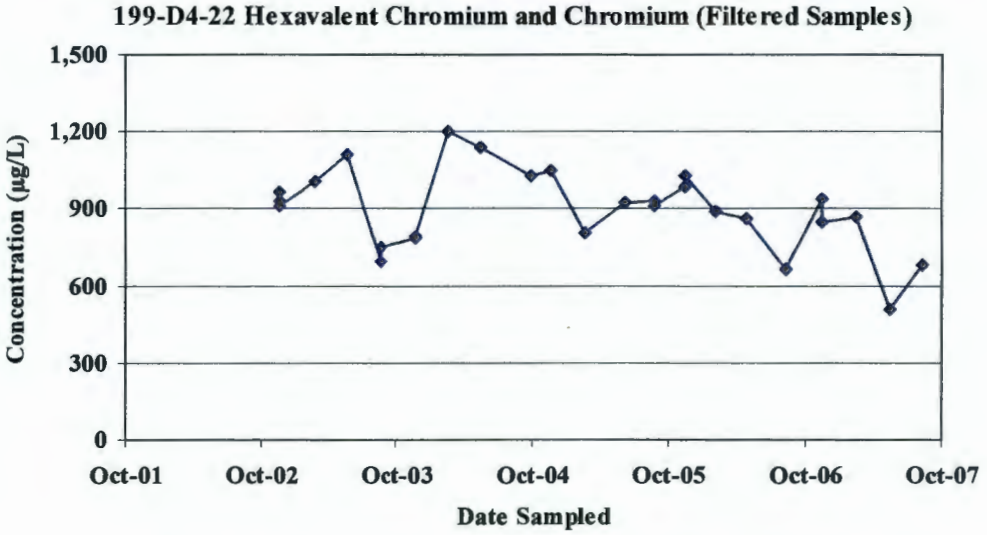


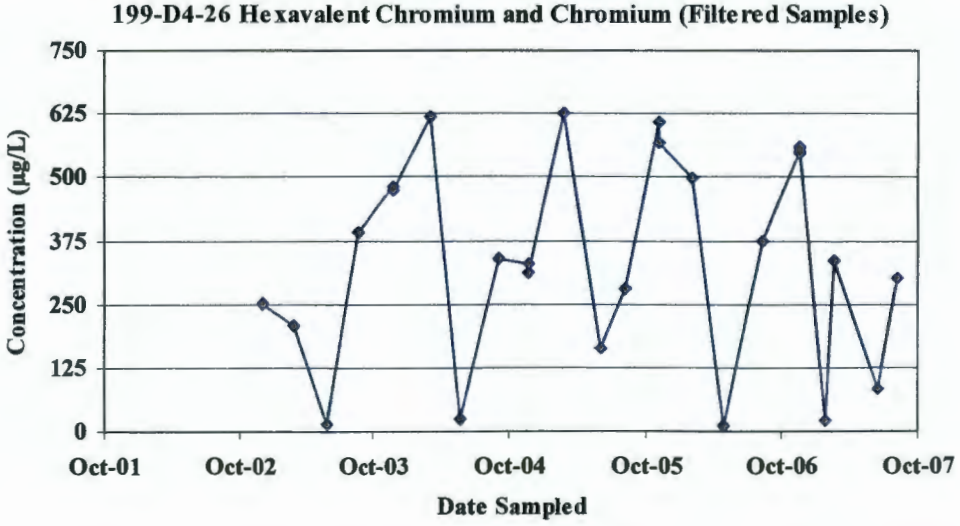


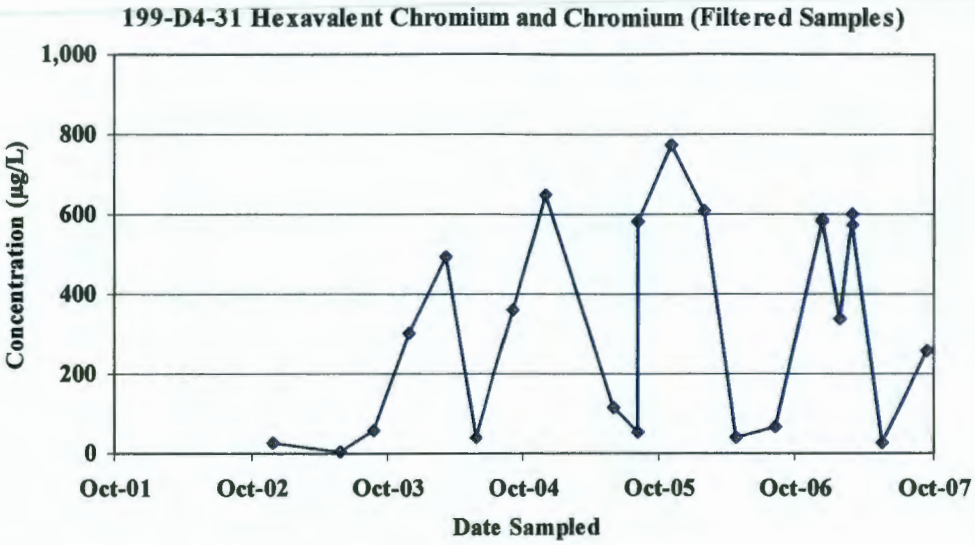


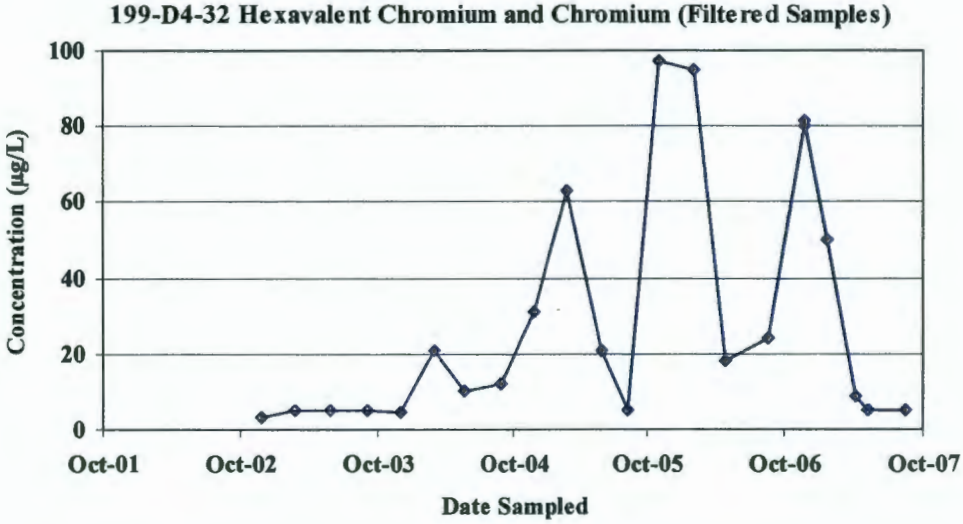
◊ = Analyte not detected, plotted value is laboratory reporting limit for the analysis.

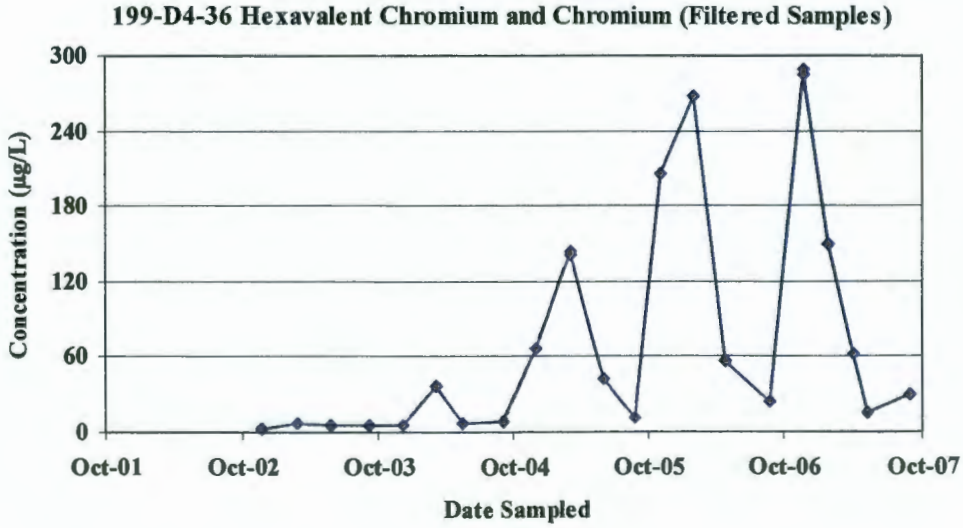

199-D4-20 Hexavalent Chromium and Chromium (Filtered Samples)
Concentration (µg/L)
250
200
150
100
50
0
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07
Date Sampled


199-D4-22 Hexavalent Chromium and Chromium (Filtered Samples)
Concentration (µg/L)
1,500
1,200
900
600
300
0
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07
Date Sampled

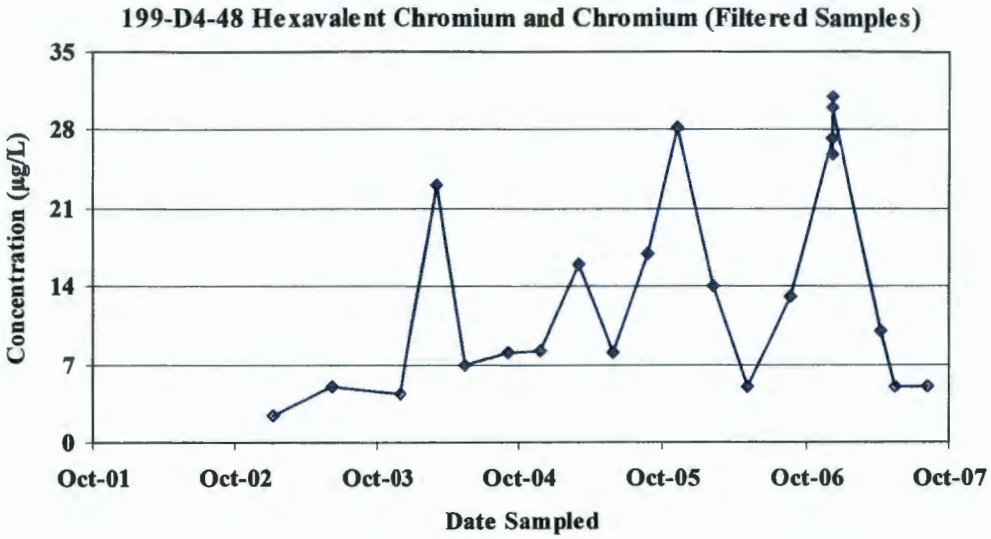

199-D4-26 Hexavalent Chromium and Chromium (Filtered Samples)
Concentration (µg/L)
750
625
500
375
250
125
0
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07
Date Sampled

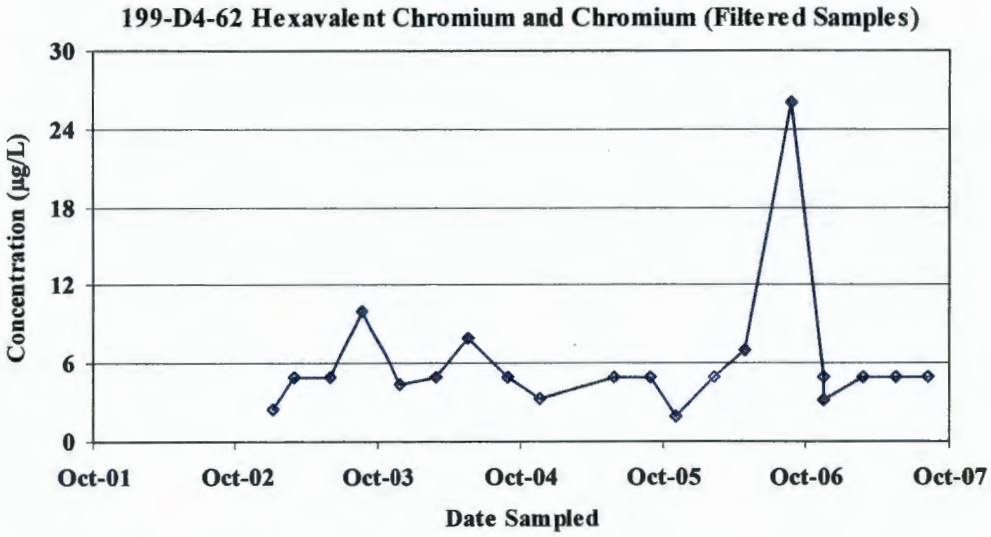


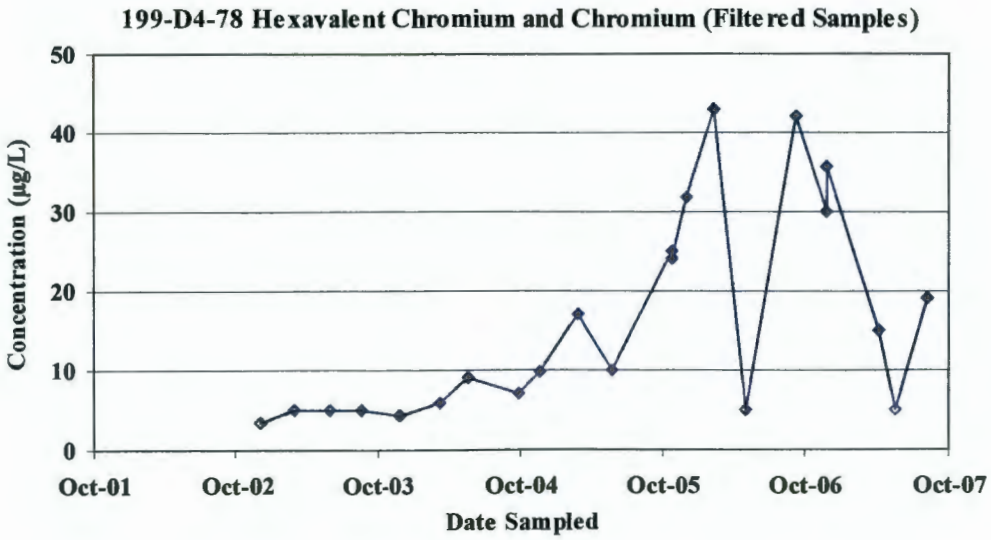




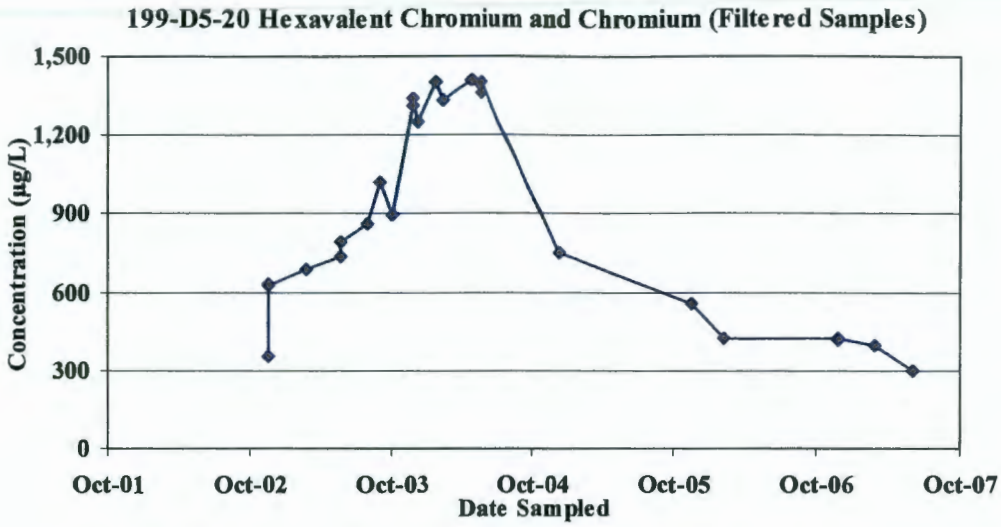
◊ = Analyte not detected, plotted value is laboratory reporting limit for the analysis.

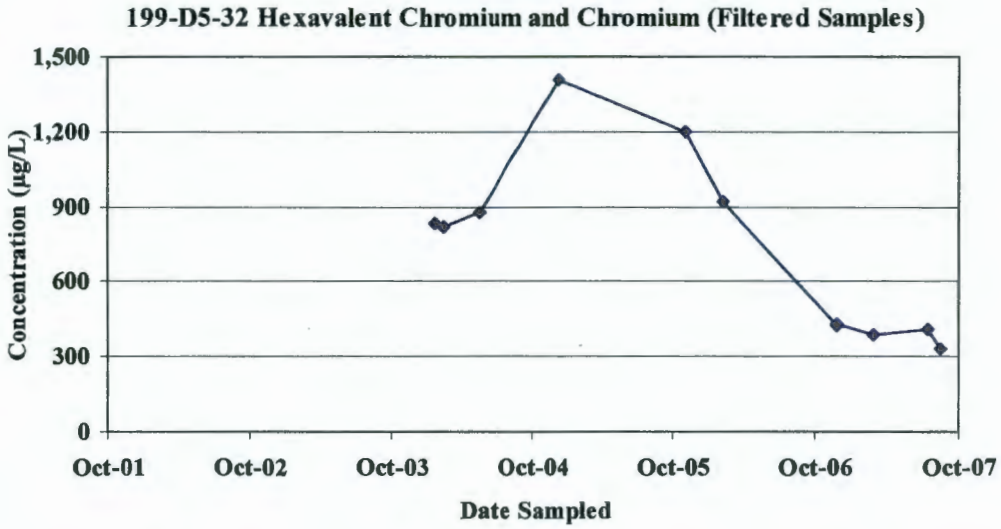


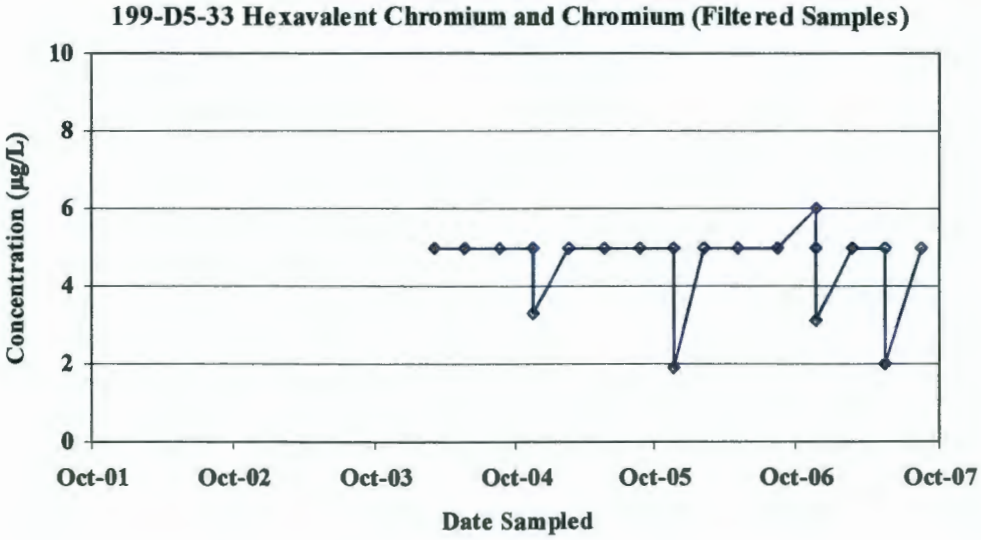




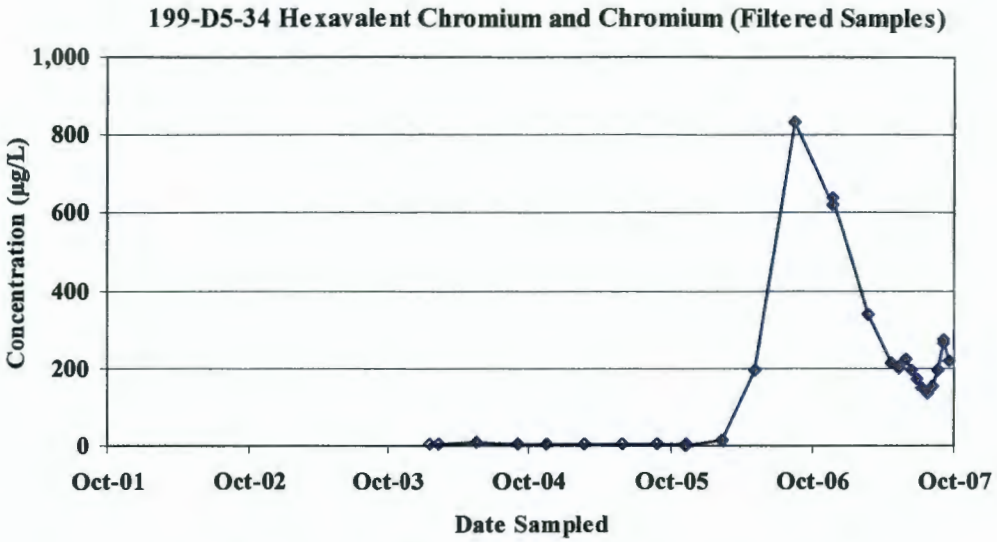
◊ = Analyte not detected, plotted value is laboratory reporting limit for the analysis.

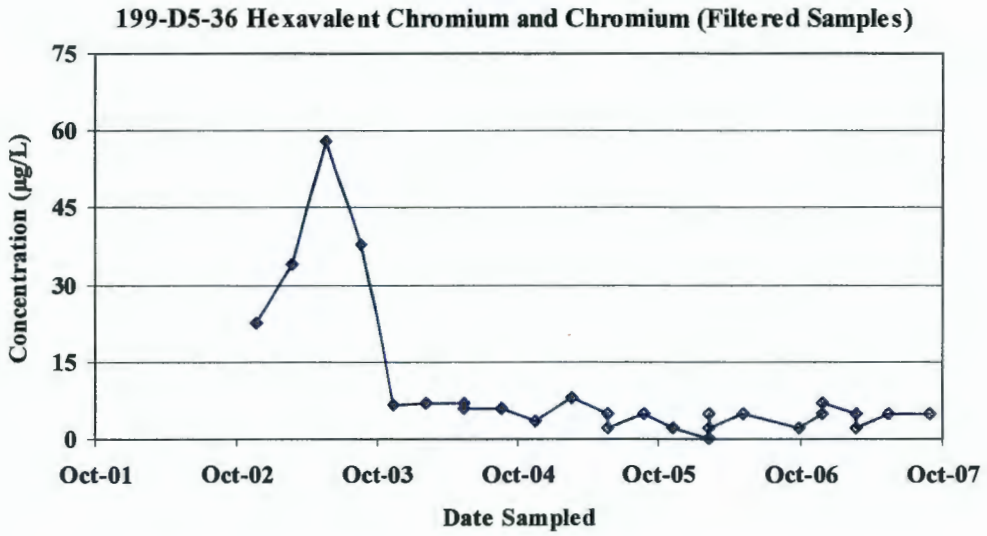


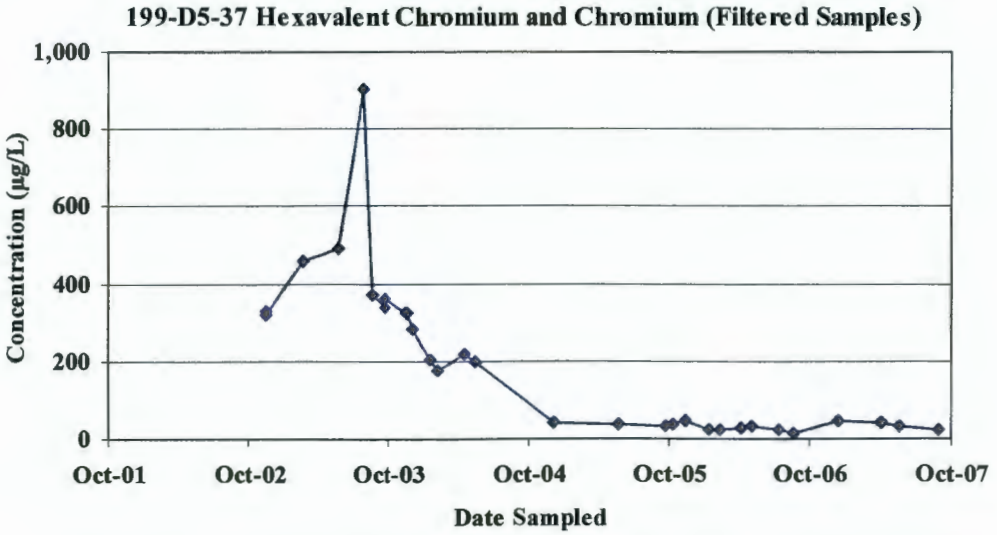




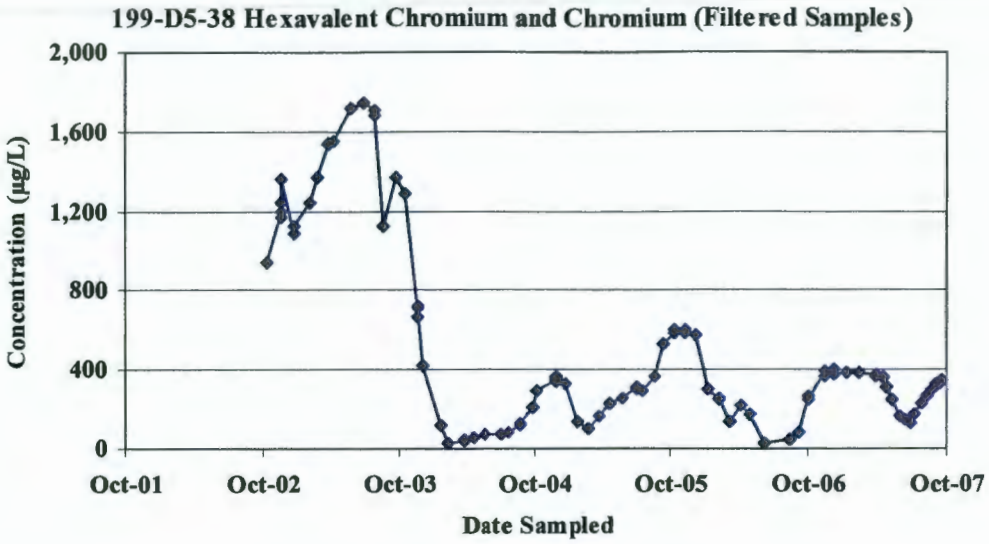
◊ = Analyte not detected, plotted value is laboratory reporting limit for the analysis.

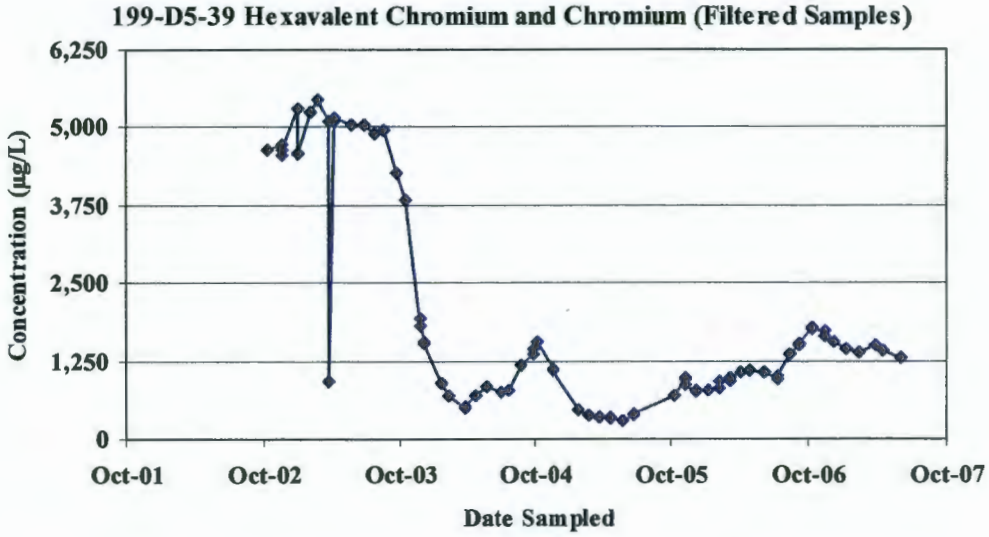


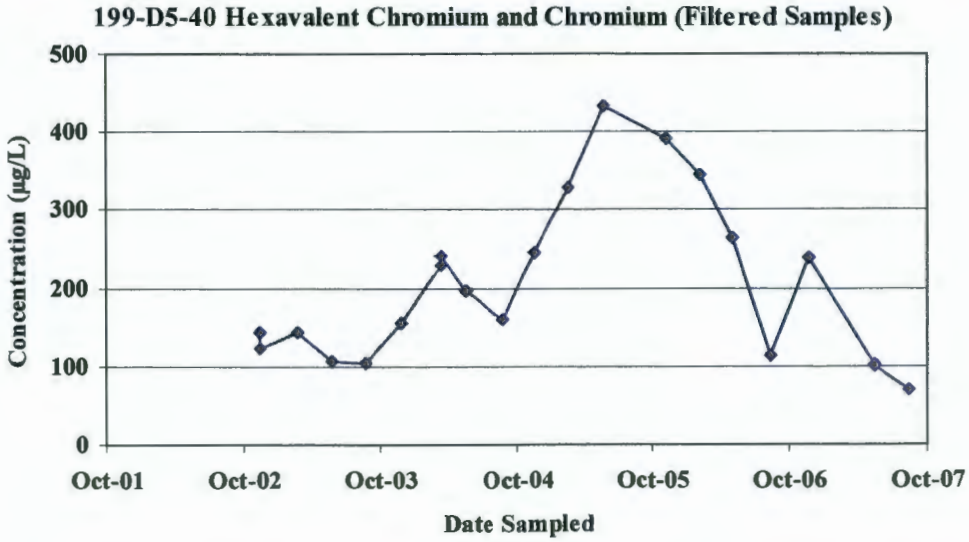


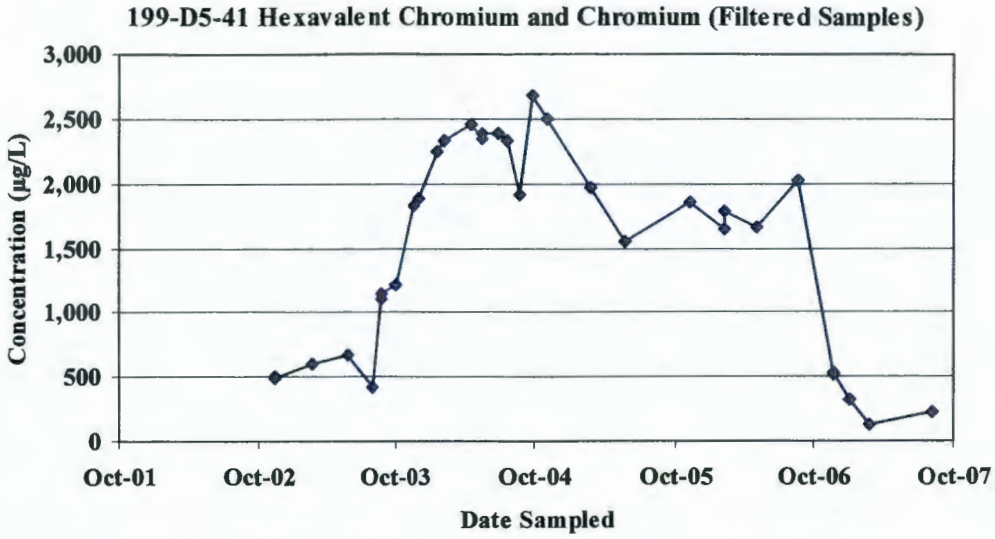


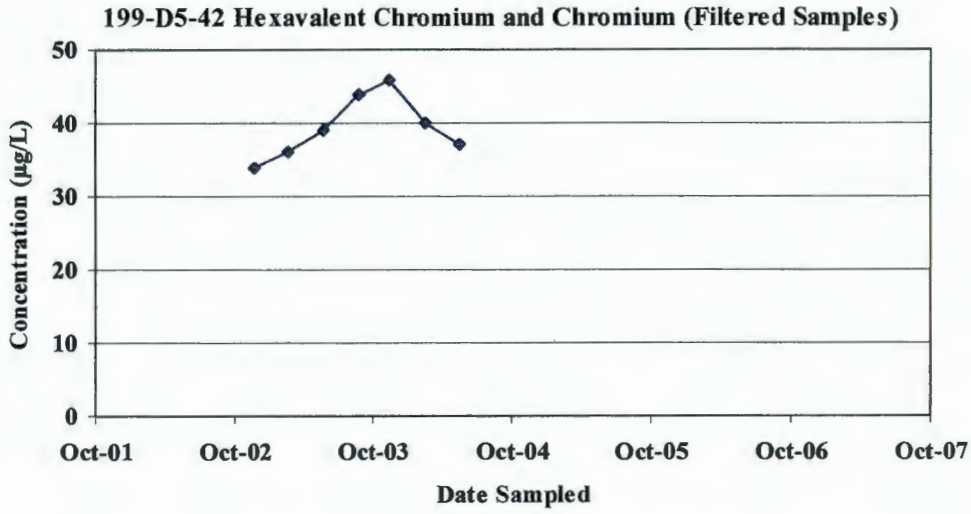
◊ = Analyte not detected, plotted value is laboratory reporting limit for the analysis.

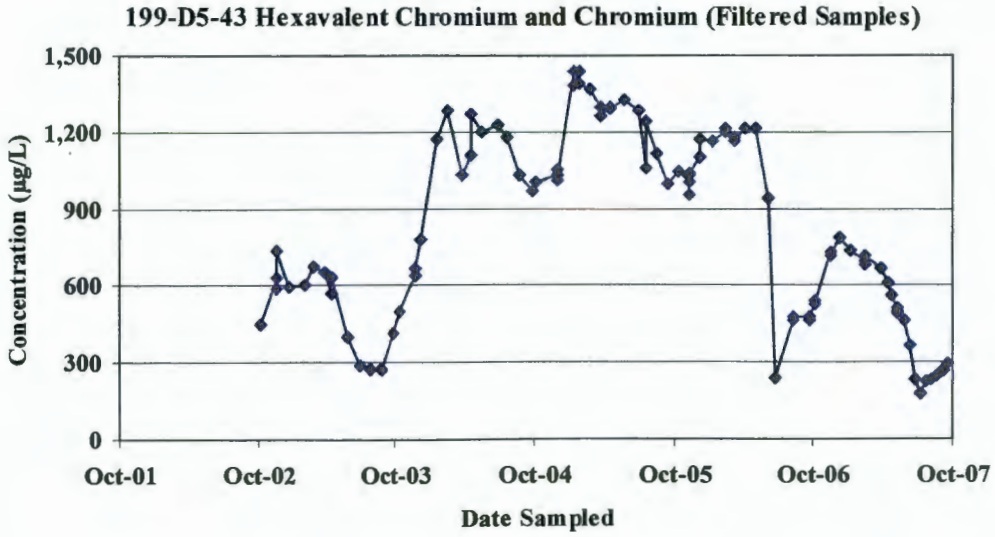

199-D5-38 Hexavalent Chromium and Chromium (Filtered Samples)
Concentration (µg/L)
2,000
1,600
1,200
800
400
0
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07
Date Sampled

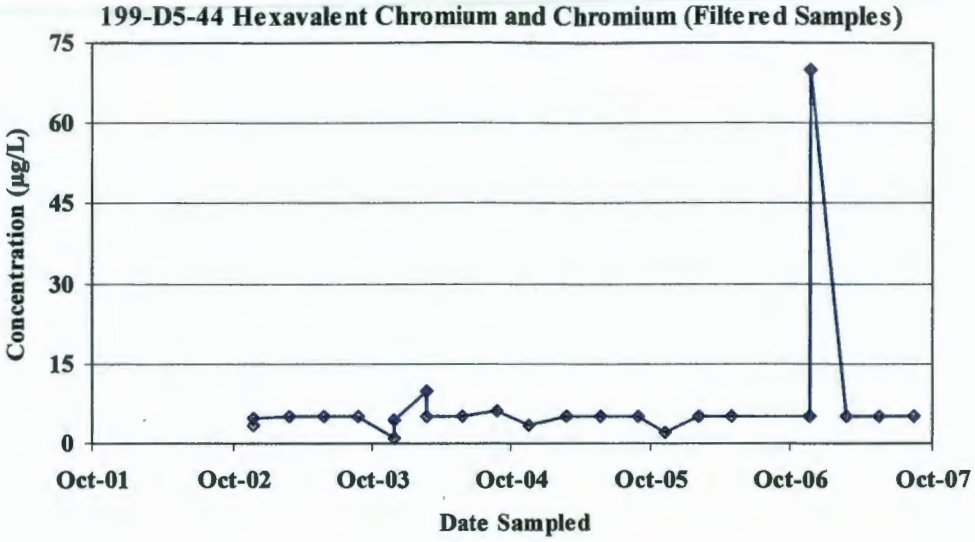

199-D5-39 Hexavalent Chromium and Chromium (Filtered Samples)
Concentration (µg/L)
6,250
5,000
3,750
2,500
1,250
0
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07
Date Sampled

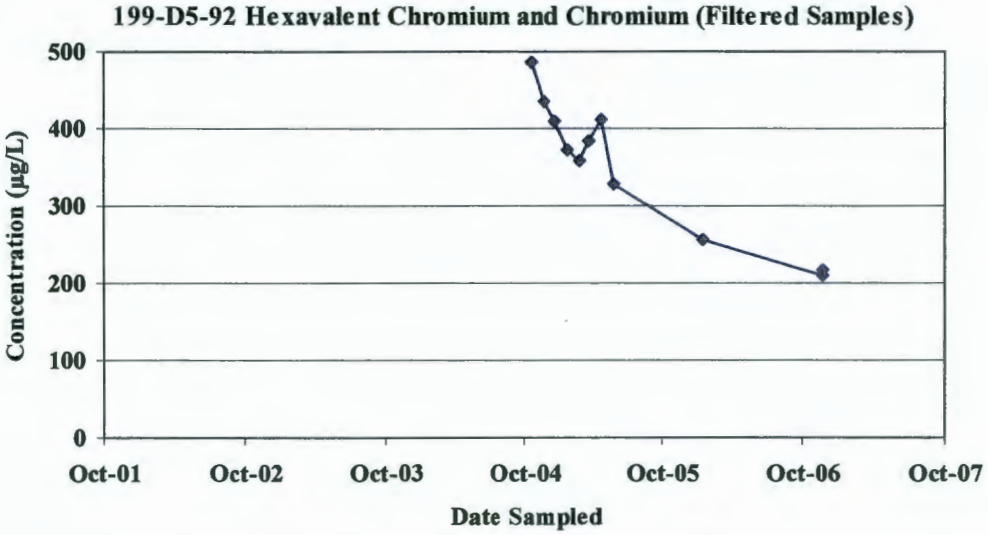

199-D5-40 Hexavalent Chromium and Chromium (Filtered Samples)
Concentration (µg/L)
500
400
300
200
100
0
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07
Date Sampled

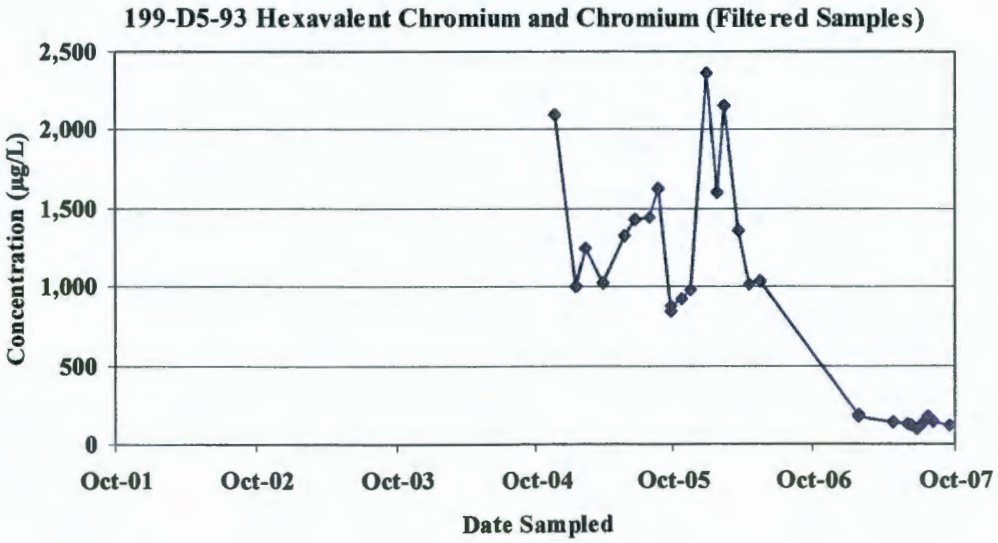

199-D5-41 Hexavalent Chromium and Chromium (Filtered Samples)
Concentration (µg/L)
3,000
2,500
2,000
1,500
1,000
500
0
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07
Date Sampled


199-D5-42 Hexavalent Chromium and Chromium (Filtered Samples)
Concentration (µg/L)
50
40
30
20
10
0
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07
Date Sampled


199-D5-43 Hexavalent Chromium and Chromium (Filtered Samples)
Concentration (µg/L)
1,500
1,200
900
600
300
0
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07
Date Sampled







◊ = Analyte not detected, plotted value is laboratory reporting limit for the analysis.

APPENDIX D

FISCAL YEAR 2007 SUPPORTING CONTAMINANT DATA AND ANALYSES

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APPENDIX D

FISCAL YEAR 2007 SUPPORTING CONTAMINANT DATA AND ANALYSES

Table D-1. In Situ Redox Manipulation Aquifer Treatment, Compliance, and Monitoring Wells. (3 Pages)

Well			Sampling	
Name	**Type**	**Location**	**Frequency**	**Type**
199-D4-23	Compliance	Downgradient	A/Q	IAM
199-D4-38	Compliance	Downgradient	A/M	IAM
199-D4-39	Compliance	Downgradient	A/M	IAM
199-D4-83	Compliance	Downgradient	A/Q	IAM
199-D4-84	Compliance	Downgradient	A/Q	IAM
199-D4-85	Compliance	Downgradient	A/Q	IAM
199-D4-86	Compliance	Downgradient	A/Q	IAM
199-D3-2	Proximal monitoring	Cross-gradient	A/Q	IAM
199-D4-1	Proximal monitoring	Downgradient	A/Q	IAM
199-D4-4	Proximal monitoring	Downgradient	A/Q	IAM/operational monitoring
199-D4-5	Proximal monitoring	Downgradient	A/Q	IAM/operational monitoring
199-D4-6	Proximal monitoring	Downgradient	A/Q	IAM
199-D4-22	Proximal monitoring	Upgradient	A/Q	IAM
199-D4-7	Aquifer treatment	Treatment zone	A/Q	IAM/operational monitoring
199-D4-13	Monitoring	Treatment zone	A/Q	IAM
199-D4-14	Aquifer treatment/ monitoring	Treatment zone	A/Q	IAM
199-D4-19	Monitoring	Treatment zone	A/Q	IAM
199-D4-26	Aquifer treatment	Treatment zone	A/Q/m	IAM/operational monitoring
199-D4-31	Aquifer treatment	Treatment zone	A/Q/m	IAM/operational monitoring
199-D4-32	Aquifer treatment	Treatment zone	A/Q	IAM/operational monitoring
199-D4-36	Aquifer treatment	Treatment zone	A/Q	IAM/operational monitoring
199-D4-48	Aquifer treatment	Treatment zone	A/Q	IAM/operational monitoring
199-D4-62	Aquifer treatment	Treatment zone	A/Q	IAM/operational monitoring
199-D4-78	Aquifer treatment	Treatment zone	A/Q	IAM/operational monitoring
199-D2-6	Monitoring	Upgradient	A/Q	IAM
199-D2-8	Monitoring	Upgradient	A/Q	IAM
199-D4-15	Monitoring	Upgradient	A/Q	IAM
199-D4-20	Monitoring	Upgradient	A/Q	IAM
199-D5-13	Monitoring	Upgradient	A/Q	IAM
199-D5-14	Monitoring	Upgradient	A/Q	IAM
199-D5-15	Monitoring	Upgradient	A/Q	IAM
199-D5-20	Monitoring/P&T EW	Cross-gradient	A/Q	IAM
199-D5-32	Monitoring/P&T EW	Cross-gradient	A/Q	IAM
199-D5-33	Monitoring	Upgradient	A/Q	IAM
199-D5-34	Monitoring	Upgradient	A/Q	IAM
199-D5-36	Monitoring	Cross-gradient	A/Q	IAM
199-D5-37	Monitoring/P&T EW	Cross-gradient	A/Q	IAM
199-D5-38	Monitoring	Upgradient	A/Q	IAM
199-D5-39	Monitoring/P&T EW	Upgradient	A/Q	IAM
199-D5-40	Monitoring	Upgradient	A/Q	IAM

Table D-1. In Situ Redox Manipulation Aquifer Treatment, Compliance, and Monitoring Wells. (3 Pages)

Well			Sampling	
Name	**Type**	**Location**	**Frequency**	**Type**
199-D5-41	Monitoring	Upgradient	A/Q	IAM
199-D5-42	Monitoring/P&T IW	Upgradient	A/Q	IAM
199-D5-43	Monitoring	Upgradient	A/M	IAM
199-D5-44	Monitoring	Cross-gradient	A/Q	IAM
199-D5-92	Monitoring/P&T EW	Cross-gradient	A/Q	IAM
199-D8-73	Monitoring	Cross-gradient	A/Q	IAM
199-D8-88	Monitoring	Cross-gradient	A/Q	IAM
199-D4-47	Aquifer treatment	Treatment zone	A/Q	Operational monitoring
199-D4-46	Aquifer treatment	Treatment zone	A/Q	Operational monitoring
199-D4-45	Aquifer treatment	Treatment zone	A/Q	Operational monitoring
199-D4-44	Aquifer treatment	Treatment zone	A/Q	Operational monitoring
199-D4-43	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-42	Aquifer treatment	Treatment zone	Q/m	Operational monitoring
199-D4-41	Aquifer treatment	Treatment zone	Q/m	Operational monitoring
199-D4-37	Aquifer treatment	Treatment zone	Q/m	Operational monitoring
199-D4-35	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-34	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-33	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-21	Aquifer treatment	Treatment zone	Q/m	Operational monitoring
199-D4-12	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-11	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-2	Monitoring	Upgradient	Q	Operational monitoring
199-D4-3	Monitoring	Upgradient	Q	Operational monitoring
199-D4-8	Monitoring	Treatment zone	Q	Operational monitoring
199-D4-9	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-10	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-30	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-29	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-28	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-27	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-25	Aquifer treatment	Treatment zone	Q/m	Operational monitoring
199-D4-24	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-49	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-50	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-51	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-52	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-53	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-54	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-55	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-56	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-57	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-58	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-59	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-60	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-61	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-63	Aquifer treatment	Treatment zone	Q	Operational monitoring

Table D-1. In Situ Redox Manipulation Aquifer Treatment, Compliance, and Monitoring Wells. (3 Pages)

Well			Sampling	
Name	**Type**	**Location**	**Frequency**	**Type**
199-D4-64	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-65	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-66	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-67	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-68	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-69	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-70	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-71	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-72	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-73	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-74	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-75	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-76	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-77	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-79	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-80	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-81	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D3-3	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-82	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D3-4	Aquifer treatment	Treatment zone	Q	Operational monitoring
199-D4-40	Aquifer treatment	Treatment zone	Q/m	Operational monitoring

NOTE: Locations are relative to the long axis of the ISRM treatment zone. "Upgradient," "downgradient," and "cross-gradient" locations assume a typical groundwater gradient for the fall when there are low-flow conditions in the Columbia River.

A = annual sampling schedule.
IAM = interim action monitoring.
ISRM = in situ redox manipulation.
m = monthly sampling schedule for supplemental operational monitoring.
M = monthly sampling schedule for IAM sampling.
Q = quarterly sampling schedule.
P&T EW = pump-and-treat extraction well (DR-5 pump-and-treat operation).
P&T IW = pump-and-treat injection well (DR-5 pump-and-treat operation).

Table D-2. Total Chromium and Hexavalent Chromium Concentrations, In Situ Redox Manipulation Monitoring and Compliance Wells. (4 Pages)

Well		Total Chromium/Hexavalent Chromium Concentration (µg/L) – Filtered Samples [a]									
		Annual FY Averages						Quarterly Samples			
						FY06 vs. FY07		FY07			
Name	Type	2004	2005	2006	2007	% Change	Trend [b]	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
199-D4-23	C	49	20	16	21	31	Increasing	16	23	21	24
199-D4-38	C	100	197	189	196	4	Stable	369	177	128/125	111
199-D4-39	C	953	873	595	539	-9	Stable	(651/649(D))	549	582	374
199-D4-83	C	62	36	22	22	0	Stable	30	20/18	14	(23/27.6)
199-D4-84	C	388	116	51	54	7	Stable	48	42	--	74, 72
199-D4-85	C	60	25	21	17	-21	Decreasing	16	10	28	12
199-D4-86	C	14	17	14	9	-33	Decreasing	16	--	14, 5(U)	5(U)/5(U)
199-D4-7	Ti	2	11	22	33	52	Increasing	86	30	5, 5/5	11
199-D4-13	Tm	2	3	2	3	18	Stable	5(U)	5(U)	5(U)	5(U)
199-D4-14	Ti	17	22	11	14	23	Increasing	45	6	5(U)	5(U)
199-D4-19	Tm	3	8	10	52	411	Increasing	5(U)	5(U)	5/5	199
199-D4-26	Ti	366	345	486	279	-43	Decreasing	550/556	20, 336	82	301
199-D4-31	Ti	299	272	372	332	-11	Stable	583	340, (598/572(D))	26	256
199-D4-32	Ti	11	29	59	35	-40	Decreasing	80	50	9, 5(U)	5
199-D4-36	Ti	15	65	138	127	-8	Stable	289	150	62, 15	30
199-D4-48	Ti	10	12	15	13	-13	Stable	30/31	--	10, 5(U)	5(U)
199-D4-62	Ti	4	2	3	3	-23	Decreasing	5(U)	5(U)	5(U)	5(U)
199-D4-78	Ti	6	16	29	19	-33	Decreasing	30	--	15, 5(U)	19
199-D3-2	PM	9	12	12	9	-23	Decreasing	23	--	5 (U)	5(U)
199-D4-1	PM	3	3	2	3	18	Stable	5(U)	5(U)	5(U)	5(U)
199-D4-4	PM	3	10	4	3	-24	Decreasing	5(U)	--	7, 5(U)	5(U)

Table D-2. Total Chromium and Hexavalent Chromium Concentrations, In Situ Redox Manipulation Monitoring and Compliance Wells. (4 Pages)

Well		Total Chromium/Hexavalent Chromium Concentration (µg/L) – Filtered Samples [a]									
		Annual FY Averages						Quarterly Samples			
						FY06 vs. FY07		FY07			
Name	Type	2004	2005	2006	2007	% Change	Trend [b]	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
199-D4-5	PM	3	6	5	4	-20	Decreasing	5	--	5, 5	5(U)
199-D4-6	PM	9	7	5	3	-27	Decreasing	5	--	5(U)	5(U)
199-D4-22	PM	1043	929	854	749	-12	Stable	940	866	(505/504(D))	684
199-D2-6	M	39	32	24	39	61	Increasing	40/37	31/21	59	(51/11.4)
199-D2-8	M	313	146	150	171	14	Stable	--	(114/114), 109	(100/97), 96/95/96, 103, 127, 192	216, 262, 281, 291, 302, 310
199-D4-15	M	1259	1354	1443	1470	2	Stable	1488, (1462/1450(D)/ 1400), 1498	(1494/1510(D)), 1524/1508	(1470/1430(D)), 1412, 1465/1470	1440, (1450/1430(D)), (1450/1520(D))
199-D4-20	M	178	218	182	154	-15	Stable	(191/182)	(135/138(D))	135	157/156
199-D5-13	M	705	583	495	450	-9	Stable	506	627		217
199-D5-14	M	297	389	405	713	76	Increasing	450	663	865	875
199-D5-15	M	503	673	1064	1710	61	Increasing	1172, (1050(D)/1090)	1284	2450	(1960/2010(D))
199-D5-16	M	--	--	64	99	55	Increasing	88	94	102	110
199-D5-20	M/E	1369	--	--	374	--	--	424/425	398	299	
199-D5-32	M/E	843	--	--	396		--	429	389		409, 332
199-D5-33	M	4	3	2	3	47	Stable	5(U)/6	5	(5(U)/2(U))	5(U)
199-D5-34	M	5	3	261	336	29	Increasing	622	339	211, 201/202, 220, 193, 169	150, 134, 153, 193, (265/271(D)), 219

Table D-2. Total Chromium and Hexavalent Chromium Concentrations, In Situ Redox Manipulation Monitoring and Compliance Wells. (4 Pages)

Well		Total Chromium/Hexavalent Chromium Concentration (µg/L) – Filtered Samples [a]									
		Annual FY Averages						Quarterly Samples			
						FY06 vs. FY07		FY07			
Name	Type	2004	2005	2006	2007	% Change	Trend [b]	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
199-D5-36	M	7	4	2	3	44	Increasing	5(U)	(2(U)/5)	5(U)	5(U)/5(U)
199-D5-37	M/E	224	30	29	36	23	Increasing	(47/45.5)		43, 33	24
199-D5-38	M	254	332	329	305	-7	Stable	(261/248(D)/ 246), 392, (376(D)/400)	382/381, 388, (375/365(D))	361/359, 312, 251/243, 167, 147, 130/131, 130	174, 227, 262, 298, 332, 328, 345
199-D5-39b	M/E	1493	--	1280	1494	17	Stable	1786/1768, 1734, 1544	1442, 1396/1390, 1488	1405, 1310	--
199-D5-40	M	187	--	279	85	-69	Decreasing	--	--	99/101	70
199-D5-41	M	2055	--	1819	322	-82	Decreasing	512	324, 131	--	225
199-D5-42	M/I	31	--	--	--	--	--	no FY07 data	--	--	--
199-D5-43	M	1244	1186	958	522	-46	Decreasing	540/529, 726, 782	735, (697/714(D)/695), 668	612, 558, 499/491, 512(D), 463, 365, 232	199-D5-43
199-D5-44	M	4	2	3	3	13	Stable	5(U)	5	5(U)	5(U)
199-D5-92	M/E	--	--	--	210	--	--	210	--	--	--
199-D5-93	M	--	1013	--	230	--	--	--	190, 175	135, 121, 115, 91	130, 169, 140, 112
199-D8-73	M	--	173	161	190	17	Stable	197, 208, 209	(217/208(D)), 208/208, 210	202/203, 176, 167/168	159/160, 163, 162
199-D8-88	M	--	50	61	63	4	Stable	63, 78, 84	67, 74, 79	58, 53/52, 58	46, (45/52.1), (44/45.9)

Table D-2. Total Chromium and Hexavalent Chromium Concentrations, In Situ Redox Manipulation Monitoring and Compliance Wells. (4 Pages)

Well		Total Chromium/Hexavalent Chromium Concentration (µg/L) – Filtered Samples [a]									
		Annual FY Averages						Quarterly Samples			
						FY06 vs. FY07		FY07			
Name	Type	2004	2005	2006	2007	% Change	Trend [b]	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter

[a] Concentrations are total chromium from filtered inductively coupled plasma metals analysis and can be assumed to be entirely hexavalent chromium.
[b] Well converted to pump-and-treat extraction well in third quarter of FY05.
% change = (Average annual FY07 – average annual FY06) / (average annual FY06) X 100%. Wells are considered stable if there is less than a 20% change in concentration from FY06 to FY07. Where a (U) qualifier is involved in the % change or average calculation, one-half of the listed detection limit is used in the calculation.

Well Type:
- C = compliance well.
- E = pump-and-treat extraction well.
- I = pump-and-treat injection well.
- M = monitoring well.
- PM = proximal monitoring well located near the treatment zone.
- Ti = treatment zone injection well; well has been used to treat the aquifer.
- Tm = treatment zone monitoring well; well has not been used to treat the aquifer.

Quarterly Results: (651|649) = Indicates sample results from splits. 128|125 = Indicates sample results from replicates.
- (D) = analyte was identified in an analysis at a secondary dilution factor (i.e., dilution factor different than 1.0).
- (U) = analyzed but not detected; value shown is analysis detection limit; one-half of the detection limit is used to calculate average or % change values.

-- = no data available.
FY = fiscal year.
N/A = not applicable.

Table D-3. Aquifer Sampling Tubes and Porewater Sampling Tubes, Hexavalent Chromium, Specific Conductance, Dissolved Oxygen, and Temperature. (3 Pages)

Tube Site*	Tube Name	Sample Depth (ft)	Cr^{+6} Concentration (µg/L) and Specific Conductance (µS/cm)				FY07 DO and Temperature -- DO (mg/L,% Saturation) @ Temperature (°C) – Unfiltered Samples
			FY04	FY05	FY06	FY07	
DD-50	DD-50-1	15.0	NS	23:241.1	18:223.9	11:187.8	9.7 (100) @ 9.4
	DD-50-2	20.0	18:278	23: 280.9	25:256.2	18:220.5	9.5 (99) @ 8.5
	DD-50-3	24.7	24:299	23:247.3	38:271.5	**31**:289.3	9.3 (97) @ 11
	DD-50-4	31.0	23: –	32:250.4	30:246.1	**40**:255.8	8 (83) @ 8.3
DD-49	DD-49-1	12.0	12: –	29:292	6:190.4	9:181.4	10.1 (100) @ 8.9
	DD-49-2	21.8	18:319	NS	NS	7:168,6	10 (100) @ 9.7
	DD-49-3	25.0	20:237	16:231.3	18:263.2	**23**:306.9	9.1 (95) @ 10
	DD-49-4	31.0	21:258	23:267.3	19:264.1	16:237,3	8.3 (86) @ 7.8
DD-44	DD-44-3	12.0	216:534	13:183.4	65:527.6	7:163	10.6 (100) @ 7.6
	DD-44-4	18.0	217: –	NS	75:707.3	**66**:704,2	5.6 (58) @ 7.4
DD-43	DD-43-2	10.0	293: –	3:133.3	38:310	**51**:182.7	8.4 (88) @ 91.
	DD-43-3	13.9	347:581	35:214.6	114:688.4	**171**:575.6	10.8 (100) @ 10.7
DD-42	DD-42-2	10.2	270:304	2:131.2	4:140.8	NS	NS
	DD-42-3	15.2	383:–	NS	NS	NS	NS
	DD-42-4	18.2	357: –	NS	200:597.6	**164**:972	NS
DD-41	DD-41-1	8.1	14:141	<1.5:128.8	2:123.6	5:116	11.5 (100) @ 9.2
	DD-41-2	13.6	186:936	119:739.9	73:727.7	**39**:457	8.02 (84) @ 9.1
	DD-41-3	18.6	153:401	53:452.8	57:497	**34**:409	Incomplete data

Table D-3. Aquifer Sampling Tubes and Porewater Sampling Tubes, Hexavalent Chromium, Specific Conductance, Dissolved Oxygen, and Temperature. (3 Pages)

Tube Site*	Tube Name	Sample Depth (ft)	Cr^{+6} Concentration (µg/L) and Specific Conductance (µS/cm)				FY07 DO and Temperature – DO (mg/L,% Saturation) @ Temperature (°C) – Unfiltered Samples
			FY04	FY05	FY06	FY07	
166-D-4	Redox-4-3.0	3.0	157: 991	79:541.2	81:687.5	**46**:485	7.19 (75) @ 3.1
	Redox-4-6.0	6.0	181:952	85:593.7	76:686.4	**51**:656	7.95 (83) @ 5.4
166-D-3	Redox-3-3.3	3.3	163:828	223: –	394:622.6	**51**:247	8.25 (86) @ 3.5
	Redox-3-4.6	4.6	160:824	233|233: –	375:619.2	**68**:276	8.11 (84) @ 3.7
DD-39	DD-39-1	5.5	42:330	{17.4:-}	NS	19:185.4	9.7 (100) @ 3.7
	DD-39-2	10.5	55:499	95:800	129:564.8	**86**:511	5.77 (60) @ 10
	DD-39-3	15.0	62:102	NS	NS	**102**:556	5.75 (60) @ 10
166-D-2	Redox-2-3.0	3.0	39:728	42:322.7	6:265.5	7:281.9	9.1 (95) @ 5.9
	Redox-2-6.0	6.0	13:478	38:490.2	41:496.8	**27**:434	3.6 (38) @ 4.4
166-D-1	Redox-1-3.3	3.3	780:656	19:137.7	124:196.7	**82**:136.4	11.1 (100) @ 10.1
	Redox-1-6.0	6.0	581:642	123:185	109:193.7	**75**:171.8	10.2 (100) @ 9.1
AT-D-1	AT-D-1-S	7.0	8:224	4:279.2	10:131.2	NS	NS
	AT-D-1-M	10.8	4:53	20:240	31:253.9	6:164.5	10 (100) @ 8.8
	AT-D-1-D	13.3	10:268	25:241.8	20:266.8	8:226.6	9.4 (98) @ 8.9
AT-D-4	AT-D-4-S	12.4	20:153	27:160.8	2:150	NS	NS
	AT-D-4-M	13.8	23:153	27:161.3	3:150.5	NS	NS
	AT-4-D-D	15.7	33:169	23:158.4	2:152.1	NS	NS
AT-D-2	AT-D-2-S	14.3	91:282	26:189.9	11:234.1	14:224	5.2 (54) @ 9.6
	AT-D-2-M	16.3	78:287	25:181.9	14:192.9	18:197.8	4.5 (47) @ 10.2
36	36-S	8.0	NA	NS	37:275.2	**31**:303.7	3.8 (40) @ 9.8
	36-M	14.0	NA	NS	120:251.9	**106**:248.5	7 (73) @ 11.4
	36-D	21.0	NA	NS	333:286	**199**:259.5	9.1 (95) @ 11

Table D-3. Aquifer Sampling Tubes and Porewater Sampling Tubes, Hexavalent Chromium, Specific Conductance, Dissolved Oxygen, and Temperature. (3 Pages)

Tube Site*	Tube Name	Sample Depth (ft)	Cr^{+6} Concentration (µg/L) and Specific Conductance (µS/cm)				FY07 DO and Temperature – DO (mg/L,% Saturation) @ Temperature (°C) – Unfiltered Samples
			FY04	FY05	FY06	FY07	
AT-D-3	AT-D-3-S	7.3	290:339	NS	30:223	NS	NS
	AT-D-3-M	8.8	316:37	NS	32:223.2	NS	NS
	AT-D-3-D	11.8	233:321.5	134:235.4	34:221.4	**50**:229.8	6.5 (68) @ 12.2

NOTES: The "166-" prefix sites are porewater sampling tubes installed in river substrate.
6.4 mg/L @ 10.1°C = bold text indicates DO concentration is less than the 60% saturation value.
* Tube sites are listed from southwest to northeast.

28:278 = hexavalent chromium concentration in µg/L : specific conductance in µS/cm.
17:263|25:256 = replicate sample, "|" separates values.
– = specific conductance value not listed in the Hanford Environmental Information System.
DO = dissolved oxygen.
FY = fiscal year.
NA = not available.
NS = not sampled.
{123}= hexavalent chromium from automated system installed on July 20, 2004 (averaged value).
Water samples were collected from four aquifer sampling tube sites and two porewater sampling tube sites during the first quarter of fiscal year 2007, and from six aquifer tube sampling tube sites and two porewater sampling tube sites during the second quarter of fiscal year 2007. No samples were collected during other quarters of the year. One to four aquifer or porewater sampling tubes were sampled at each location. The results are shown in Table D-3 (dissolved oxygen in mg/L, and temperature in degrees Celsius for unfiltered samples).

Table D-4. Dissolved Oxygen Concentrations and Temperature,
In Situ Redox Manipulation Monitoring, Compliance and Treatment Wells. (3 Pages)

Well		DO (mg/L, % saturation) and Temperature (°C) – Unfiltered Samples					
		Quarterly Samples		4th Quarter Average DO			
Name	Type	FY06 4th Quarter	FY07 4th Quarter	FY06 (mg/L)	FY07 (mg/L)	% Change	Trend
199-D2-6	M	7.64 (80) @ 24.8	7.69 (80) @ 17.9	7.64	7.69	1	Stable
199-D2-8	M	4.93 (51) @ 19.1	7.52 (78) @ 16.3	4.93	7.52	53	Increasing
199-D3-2	PM	6.54 (68) @ 17.7	7.52 (78) @ 17	6.54	7.52	15	Stable
199-D4-1	PM	1.95 (20) @ 19.3	0.99 (10) @ 19.4	1.95	0.99	-49	Decreasing
199-D4-4	PM	2.33 (24)@ 18.7; 1.83 (19)@ 27.3	3.38 (35) @ 21.4	2.08	3.38	63	Increasing
199-D4-5	PM	0.67 (7)@ 18.6	0.35 (4) @ 18.2	-0.67	0.35	-152	Decreasing
199-D4-6	PM	--	1.07 (11) @ 17.1	--	1.07	--	--
199-D4-7	Ti	1.65 (17) @ 24.3; 0.27 (3) @ 19.2	0.28 (3) @ 19.9	0.96	0.28	-71	Decreasing
199-D4-14	Ti	1.29 (13) @ 17.2	--	1.29	--	NA	NA
199-D4-15	M	8.30 (86) @ 17.5; 8.55 (89) @ 17.7, 8.48 (88) @ 17.7	8.15 (85) @ 17.6; 9.45 (98) @ 17.8	8.44	8.80	4	Stable
199-D4-20	M	7.41 (77) @ 17.5	8.16 (85) @ 16.5	6.72	8.16	21	Increasing
199-D4-22	PM	6.13 (64) @ 18.0	6.99 (73) @ 17.9	6.13	6.99	14	Stable
199-D4-23	C	4.03 (42) @ 17.2	7.28 (76) @ 18.6	4.03	7.28	81	Increasing
199-D4-26	Ti	4.31 (45) @ 18.6; 5.94 (62) @ 17.9; 3.96 (41) @ 16.4	3.2 (33) @ 24.5; 4.98 (52) @ 18.1; 4.83 (50) @ 19.0	4.74	4.34	-9	Stable
199-D4-31	Ti	1.34 (14) @ 22.5; 1.63 (17) @ 20.0; 3.98 (41) @ 28.1; 4.08 (43) @ 16.0	1.55 (16) @ 27.5; 3.3 (34) @ 21.1; 5.95 (62) @ 16.8	2.76	3.60	30	Increasing
199-D4-32	Ti	3.17 (33) @ 24.6; 1.00 (10) @ 19.5	1.14 (12) 19.4	2.09	1.14	-45	Decreasing

Table D-4. Dissolved Oxygen Concentrations and Temperature,
In Situ Redox Manipulation Monitoring, Compliance and Treatment Wells. (3 Pages)

Well		DO (mg/L, % saturation) and Temperature (°C) – Unfiltered Samples					
		Quarterly Samples		4th Quarter Average DO			
Name	Type	FY06 4th Quarter	FY07 4th Quarter	FY06 (mg/L)	FY07 (mg/L)	% Change	Trend
199-D4-36	Ti	0.92 (10) @ 22.7; 0.92 (10) @ 24.3; 1.07 (11) @ 17.7; 3.36 (35) @ 19.0	1.25 (13) @ 26.2; 0.98 (10) @ 17.5; 4.96 (52) @ 19.3	2.09	2.40	15	Stable
199-D4-38	C	5.19 (54) @ 17.8	6.75 (70) @ 17.3	5.19	6.75	30	Increasing
199-D4-39	C	3.13 (33) @ 17.2	3.36 (35) @ 17.1	3.13	3.36	7	Stable
199-D4-48	Ti	2.42 (25) @ 20.9; 1.51 (16) @ 21.1	2.48 (26) @ 17.7	1.97	2.48	26	Increasing
199-D4-62	Ti	0.79 (8) @ 25.2; 0.25 (3) @ 18.7	0.32 (3) @ 17.9	0.52	0.32	-38	Decreasing
199-D4-78	Ti	2.78 (29) @ 27.6; 2.72 (28) @ 18.1	5.25 (55) @ 17.9	2.75	5.25	91	Increasing
199-D4-83	C	7.19 (75) @ 16.3	7.47 (78) @ 15.7	7.19	7.47	4	Stable
199-D4-84	C	2.40 (25) @ 17.6	2.42 (25) @ 17.4; 2.42 (25) @ 17.4	2.40	3.30	37	Increasing
199-D4-85	C	6.83 (71) @ 17.9	7.71 (80) @ 17.4	6.83	7.71	13	Stable
199-D4-86	C	6.47 (67) @ 17.6	--	6.47	--	NA	NA
199-D5-20	M	--	--	--	--	NA	NA
199-D5-33	M	--	--	--	--	NA	NA
199-D5-34	M	--	--	--	--	NA	NA
199-D5-36	M	7.53 (78) @ 16.0	8.75 (91) @ 15.8	7.53	8.75	16	Stable
199-D5-37	M	7.33 (76) @ 18.5		7.33	--	NA	NA
199-D5-38	M	7.43 (77) @ 16.3; 7.96 (83) @ 16.3; 7.49 (78) @ 16.4	8.14 (85) @ 16.1	7.63	8.14	7	Stable

Table D-4. Dissolved Oxygen Concentrations and Temperature, In Situ Redox Manipulation Monitoring, Compliance and Treatment Wells. (3 Pages)

Well		DO (mg/L, % saturation) and Temperature (°C) – Unfiltered Samples					
		Quarterly Samples		4th Quarter Average DO			
Name	Type	FY06 4th Quarter	FY07 4th Quarter	FY06 (mg/L)	FY07 (mg/L)	% Change	Trend
199-D5-39	M	8.59 (89) @ 16.2; 9.25 (96) @ 16.0; 8.03 (84) @ 16.4	--	8.62	--	NA	NA
199-D5-40	M	--	--	--	--	NA	NA
199-D5-41	M	--	--	--	--	NA	NA
199-D5-43	M	8.61 (90) @ 18.1; 8.28 (86) @ 17.2	8.34 (87) @ 17.2; 9.39 (98) @ 17.8	8.45	8.87	5	Stable
199-D8-88	M	--	--	--	--	NA	NA

% change = (Average 4th quarter FY07 – average 4th quarter FY06) / (average 4th quarter FY06) X 100%. Wells are considered stable if there is less than a 20% change in concentration from FY06 to FY07.

Well Type: C = compliance well.
M = monitoring well.
PM = proximal monitoring well located near the treatment zone.
Ti = treatment zone injection well; well has been used to treat the aquifer.

-- = no data available.
DO = dissolved oxygen.
FY = fiscal year.
NA = not available.

Table D-5. Sulfate Concentrations, In Situ Redox Manipulation Monitoring and Compliance Wells. (3 Pages)

Well		Sulfate Concentration (mg/L) – Unfiltered Samples									
		Annual FY Averages						Quarterly Samples			
								FY07			
Name	Type	2004	2005	2006	2007	% Change	Trend	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
199-D2-6	M	131	122	136	167	23	Increasing	168|156; 136|138	168|160	188	(164|165)
199-D2-8	M	--	187	102.8	97	-6	Stable	--	(81.8|90);88	104|96	104
199-D3-2	PM	119	101	67.2	56	-17	Stable	(86|78.7)	--	42	45
199-D4-1	PM	561	421	278.3	264	-5	Stable	(190|298)	260	290	260
199-D4-4	PM	513	414	381.5	325	-15	Stable	(180|339)	--	370;340	360
199-D4-5	PM	769	376	304	228	-25	Decreasing	(283|185)	--	250;230	210
199-D4-6	PM	527	409	416	325	-22	Decreasing	(265|366)	--	360	300
199-D4-7	Ti	381	290	257.8	211	-18	Stable	(179|205)	--	200;220|260	215
199-D4-13	Tm	186	174	187.5	203	8	Stable	(153|164)	170	270	215
199-D4-14	Ti	117	123	112.8	102	-10	Stable	(92.7|92)	90	120	105
199-D4-15	M	139	142	139.8	127	-9	Stable	140;(135|139); (126|104);144	80;115|115	(136|140);180; 135|130	125;130;135
199-D4-19	Tm	796	800	533.8	264	-51	Decreasing	(360|327)	390	220|205	110
199-D4-20	M	141	130	126.5	115	-9	Stable	(82|112)	(115|116)	130	130|105
199-D4-22	PM	225	145	145.9	156	7	Stable	(132|144)	150	155	180
199-D4-23	C	404	398	293.3	191	-35	Decreasing	(226|300)	200	170	130
199-D4-26	Ti	152	147	148.5	114	-23	Decreasing	80|64;125|126	136	90	130
199-D4-31	Ti	195	166	175.5	150	-15	Stable	(148|140)	132	170	155
199-D4-32	Ti	157	172	162.5	167	3	Stable	(141|148)	--	140	215
199-D4-36	Ti	98	117	124.5	108	-13	Stable	(106|94)	--	116;108	112
199-D4-38	C	239	143	123.3	96	-22	Decreasing	(94|140)	124	76|72	68
199-D4-39	C	123	101	91.3	87	-5	Stable	(56|84.7)	78	100	100
199-D4-48	Ti	81	57	44.7	49	10	Stable	41.3;40.2;50|49	--	55;49	49
199-D4-62	Ti	376	252	286.8	313	9	Stable	(145|190)	215	420	450

Table D-5. Sulfate Concentrations, In Situ Redox Manipulation Monitoring and Compliance Wells. (3 Pages)

Well		Sulfate Concentration (mg/L) – Unfiltered Samples									
		Annual FY Averages						Quarterly Samples			
								FY07			
Name	Type	2004	2005	2006	2007	% Change	Trend	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
199-D4-78	Ti	823	418	443.3	260	-41	Decreasing	(581|350)	--	100;270	130
199-D4-83	C	26	23	23.6	15	-36	Decreasing	20.4;8	17|18	10	20
199-D4-84	C	182	348	427	340	-20	Decreasing	(195|367)	310	--	440;420
199-D4-85	C	256	149	173.8	102	-41	Decreasing	(120|150)	115	36	120
199-D4-86	C	88	77	68.7	64	-7	Stable	(50|80.5)	--	44;140	34|36
199-D5-13	M	--	99	--	125	--	--	125.0	--	--	--
199-D5-14	M	--	123	--	119	--	--	119.0	--	--	--
199-D5-15	M	--	110	--	109	--	--	105;(117|104)	--	--	--
199-D5-16	M	--	--	--	140	--	--	--	140	--	--
199-D5-17	M	--	110	--	101	--	--	101.0	--	--	--
199-D5-20	M/E	63	41	--	47	--	--	46.4|46.8	--	--	--
199-D5-32	M/E	--	59	--	68	--	--	68.1	--	--	--
199-D5-33	M	--	13	--	13	--	--	13.1	--	--	--
199-D5-34	M	--	58	--	74	--	--	74.1	--	--	--
199-D5-36	M	16	15	16.9	16	-5	Stable	(17|16.6)	(15.7|12)	17	18|18
199-D5-37	M/E	27	20	22.1	24	9	Stable	(19.8|23)	--	25;23	28
199-D5-38	M	85	116	100.4	58	-42	Decreasing	(45|75.2)(76|63.5);63	38|36;58;(71|59.8)	66|70;50;39	54;65
199-D5-39	M/E	90	56	79.6	82	3	Stable	92|94;(90|81.8);76	46;80|88;98	84;76	--
199-D5-40	M	76	112	117.8	123	4	Stable	108.0	110	145|130	135
199-D5-41	M	69	59	69.2	60	-13	Stable	(66|55)	60	--	58
199-D5-42	M/I	147	--	--	--	--	--	--	--	--	--

Table D-5. Sulfate Concentrations, In Situ Redox Manipulation Monitoring and Compliance Wells. (3 Pages)

Well		Sulfate Concentration (mg/L) – Unfiltered Samples									
		Annual FY Averages						Quarterly Samples			
								FY07			
Name	Type	2004	2005	2006	2007	% Change	Trend	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
199-D5-43	M	110	116	144.8	85	-41	Decreasing	54|106;(109|72);48	59;(106|92.9|95.6);96	92;92	90;70|80
199-D5-44	M	14	14	15.5	13	-16	Stable	(15|13.9)	11	14	13

% change = (Average 4th quarter FY07 – average 4th quarter FY06) / (average 4th quarter FY06) X 100%.

Well Type: C = compliance well.
E = pump-and-treat extraction well.
M = monitoring well.
PM = proximal monitoring well located near the treatment zone.
Ti = treatment zone injection well; well has been used to treat the aquifer.
Tm = treatment zone monitoring well; well has not been used to treat the aquifer.

(132|131) = Indicates sample results from splits.
172|152= Indicates sample results from replicates.
-- = no data available.
FY = fiscal year.

Table D-6. In Situ Manipulation Treatment Zone Operational Sampling – Hexavalent Chromium. (3 Pages)

Well Name[a]	Injection Date(s)	Hexavalent Chromium Concentrations in Treatment Zone Wells (µg/L)														
		July 2006	Aug. 2006	Sept. 2006	Oct. 2006	Nov. 2006	Dec. 2006	Jan. 2007	Feb. 2007	Mar. 2007	Apr. 2007	May 2007	June 2007	July 2007	Aug. 2007	Sept. 2007
199-D3-4	2003	--	10	--	--	0	--	--	10	--	--	0	--	--	10	--
199-D3-3	2003	--	30	--	--	50	--	--	50	0	--	0	--	--	20	--
199-D4-82	2003	--	30	--	--	10	--	--	30	--	--	0	--	--	10	--
199-D4-81	2003	--	30	--	--	30	--	--	40	--	--	0	--	--	10	--
199-D4-80	2003	--	20	--	--	50	--	--	20	--	--	0	--	--	20	--
199-D4-79	2002	--	30	--	--	20	--	--	20	--	--	10	--	--	20	--
199-D4-78	2002	--	30	--	--	20	--	--	10	--	--	0	--	--	0	--
199-D4-77	2002	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-76	2002	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-75	2002	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-74	2002	--	0	--	--	0	--	--	0	--	--	10	--	--	0	--
199-D4-73	2002	--	10	--	--	0	--	--	0	--	--	10	--	--	0	--
199-D4-72	2002	--	0	--	--	0	--	--	30	--	--	30	--	--	0	--
199-D4-71	2002	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-70	2002	--	10	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-69	2002	--	10	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-68	2002	--	10	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-67	2002	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-66	2002	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-65	2002	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-64	2002	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-63	2002	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-62	2001	--	0	--	--	10	--	--	0	--	--	0	--	--	0	--
199-D4-61	2001	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-60	2001	--	0	--	--	0	--	--	0	--	--	0	--	--	50	--
199-D4-59	2001	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-58	2001	--	0	--	--	10	--	--	0	--	--	0	--	--	0	--
199-D4-57	2001	--	0	--	--	10	--	--	0	--	--	0	--	--	0	--

Table D-6. In Situ Manipulation Treatment Zone Operational Sampling – Hexavalent Chromium. (3 Pages)

Well Name[a]	Injection Date(s)	Hexavalent Chromium Concentrations in Treatment Zone Wells (µg/L)														
		July 2006	Aug. 2006	Sept. 2006	Oct. 2006	Nov. 2006	Dec. 2006	Jan. 2007	Feb. 2007	Mar. 2007	Apr. 2007	May 2007	June 2007	July 2007	Aug. 2007	Sept. 2007
199-D4-56	2001	--	0	--	--	50	--	--	30	--	--	0	--	--	0	--
199-D4-55	2001	--	10	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-54	2001	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-53	2001	--	20	--	--	20	--	--	0	--	--	0	--	--	0	--
199-D4-52	2001	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-51	2001	--	10	--	--	0	--	--	50	40	0	0	--	--	0	--
199-D4-50	2001	--	0	--	--	80	150	80	20	90	10	10	--	--	0	--
199-D4-49	2001	--	0	--	--	0	--	--	10	--	--	0	--	--	0	--
199-D4-24	2001	-	0	-	--	10	---	--	20	--	--	10	--	--	0	--
199-D4-25	2001	50	180	640	560	360	220	190	180	240	150	140	100	130	60	590
199-D4-26	2000	--	380	530	520	610	720	20	200	280	10	10	60	190	440	440
199-D4-27	2000	--	10		--	150	170	50	20	220	0	0	0	--	0	--
199-D4-28	2000	--	50	60	170	400	420	50	0	180	10	10	10	--	160	110
199-D4-29	2000	--	60	150	170	430	470	30	0	440	10	10	20	--	140	80
199-D4-30	2000	--	0		--	110	50	30	10	10	0	10	--	--	0	--
199-D4-31	2000	60	70	470	690	700	650	340	510	690	30	30	30	30	90	530
199-D4-10	1998, 2002	--	10	--	--	10	--	--	50	0	--	0	--	--	0	--
199-D4-9	1998, 2002	--	60	250	720	300	180	120	90	350	0	0	0	--	30	260
199-D4-7	1997, 2002	--	30	--	--	170	90	30	0	230	0	10	0	--	10	--
199-D4-8[b]	Not treated	--	30	--	--	0	--	--	0	--	--	10	--	--	0	--
199-D4-3[b]	Not treated	--	0	--	---	180	260	30	320	360	0	0	0	--	0	--
199-D4-2[b]	Not treated	--	140	530	840	840	840	20	40	530	0	0	--	--	170	700
199-D4-11	1998, 2002	--	10		--	0	--	--	10	--	--	0	--	--	0	--

Table D-6. In Situ Manipulation Treatment Zone Operational Sampling – Hexavalent Chromium. (3 Pages)

Well Name[a]	Injection Date(s)	Hexavalent Chromium Concentrations in Treatment Zone Wells (µg/L)														
		July 2006	Aug. 2006	Sept. 2006	Oct. 2006	Nov. 2006	Dec. 2006	Jan. 2007	Feb. 2007	Mar. 2007	Apr. 2007	May 2007	June 2007	July 2007	Aug. 2007	Sept. 2007
199-D4-5[b]	Not treated	--	20	--	--	10	--	--	10	--	--	0	--	--	0	--
199-D4-4[b]	Not treated	--	0	--	--	0	--	--	0	--	--	0	--	--	10	--
199-D4-12	1998, 2002	--	10	--	--	0	--	--	60	10	0	0	--	--	0	--
199-D4-21	1999	--	90	480	530	460	440	180	260	340	0	0	0	--	100	550
199-D4-32	2000	--	10	--	--	70	70	50	10	10	0	10	--	--	0	--
199-D4-33	2000	--	0	--	--	20	--	--	0	--	--	0	--	--	0	--
199-D4-34	2000	--	50	150	150	80	100	40	80	100	0	10	10	20	20	210
199-D4-35	2000, 2002	50	30	40	10	70	30	190	30	490	540	450	320	250	20	30
199-D4-36	2000	20	30	170	340	260	350	150	190	310	10	0	0	10	32	270
199-D4-37	2001	150	210	520	210	200	570	40	420	420	60	0	10	100	220	500
199-D4-40	2001	140	20	330	670	660	550	570	470	560	210	150	70	60	60	460
199-D4-41	2001	--	260	280	220	220	230	10	240	230	0	10	0	160	260	340
199-D4-42	2001	130	50	320	590	540	490	370	330	480	60	40	40	0	70	420
199-D4-43	2001	--	20	--	--	310	360	130	450	380	50	90	80	10	40	380
199-D4-44	2001	--	20	--	--	10	--	--	0	--	--	0	--	--	20	--
199-D4-45	2001	--	30	--	--	50	--	--	0	--	--	0	--	--	20	--
199-D4-46	2001	--	10	--	--	0	--	--	0	--	--	0	--	--	0	--
199-D4-47	2001	--	10	--	--	10	--	--	10	--	--	0	--	--	0	--
199-D4-48	2001	--	10	--	--	20	--	--	10	--	--	0	--	--	0	--

[a] Wells are listed from southwest to northeast.
[b] Monitoring wells in the original treatability test zone.
-- = well not sampled during this time interval.

Table D-7. Hexavalent Chromium and Chromium Quarterly Quality Control Results. (3 Pages)

Well Name	Sample Date	Constituent	Reported Value #1 (µg/L)	Sample Number	Reported Value #2 (µg/L)	Sample Number	RPD (%)	Filtered
Field Replicates (COLOR_TK_FLD)								
199-D4-20	8/7/2007	Hexavalent chromium	157	B1P6L5	156	B1P6L3	0.6	Yes
199-D4-86	8/10/2007	Hexavalent chromium	5 (U)	B1P6V3	5 (U)	B1P6V5	N/A	Yes
199-D5-36	8/28/2007	Hexavalent chromium	5 (U)	B1P4D4	5 (U)	B1P4D2	N/A	Yes
199-D5-43	10/16/2006	Hexavalent chromium	496	B1KX59	500	B1KX65	0.8	No
199-D8-70	8/10/2007	Hexavalent chromium	14	B1P4J0	14	B1P4H9	0.0	Yes
Field/Laboratory Splits (COLOR_TK_CR6_FLD or 7196_CR6)								
199-D2-6	8/6/2007	Hexavalent chromium	11.4	B1P487	51	B1P485	126.9	Yes
199-D2-8	1/25/2007	Hexavalent chromium	114	B1L2K4	114	B1L2K0	0.0	Yes
199-D2-8	4/26/2007	Hexavalent chromium	100	B1N761	97	B1N762	3.0	Yes
199-D4-15	1/8/2007	Hexavalent chromium	1,494	B1LNH1	1,510	B1LNH3	1.1	Yes
199-D4-15	4/16/2007	Hexavalent chromium	1,430	B1MMV0	1,470	B1MMT8	2.8	Yes
199-D4-15	8/6/2007	Hexavalent chromium	1,450	B1P6K9	1,430	B1P6L1	1.4	Yes
199-D4-15	9/5/2007	Hexavalent chromium	1,520	B1PFB5	1,450	B1PFB3	4.7	Yes
199-D4-20	11/14/2006	Hexavalent chromium	182	B1L2M5	191	B1L2M1	4.8	Yes
199-D4-20	2/14/2007	Hexavalent chromium	135	B1M634	138	B1M636	2.2	Yes
199-D4-22	5/16/2007	Hexavalent chromium	505	B1N386	504	B1N388	0.2	Yes
199-D4-31	2/27/2007	Hexavalent chromium	598	B1M758	572	B1M760	4.4	Yes
199-D4-39	11/14/2006	Hexavalent chromium	649	B1L2V5	651	B1L2V1	0.3	Yes
199-D4-83	8/10/2007	Hexavalent chromium	23	B1P6T3	27.6	B1P6T5	18.2	Yes
199-D5-15	12/7/2006	Hexavalent chromium	1,090	B1L023	1,050	B1L027	3.7	Yes
199-D5-15	8/10/2007	Hexavalent chromium	1,960	B1P4C3	2,010	B1P4C4	2.5	Yes
199-D5-33	5/16/2007	Hexavalent chromium	2 (U)	B1N276	5 (U)	B1N275	N/A	Yes
199-D5-34	9/5/2007	Hexavalent chromium	271	B1P7R3	265	B1P7R2	2.2	Yes
199-D5-36	2/21/2007	Hexavalent chromium	5	B1M678	2 (U)	B1M680	N/A	Yes
199-D5-37	12/12/2006	Hexavalent chromium	45.5	B1L062	47	B1L060	3.2	Yes
199-D5-38	12/7/2006	Hexavalent chromium	376	B1LKB1	400	B1LK99	6.2	Yes

Table D-7. Hexavalent Chromium and Chromium Quarterly Quality Control Results. (3 Pages)

Well Name	Sample Date	Constituent	Reported Value #1 (µg/L)	Sample Number	Reported Value #2 (µg/L)	Sample Number	RPD (%)	Filtered
199-D5-38	3/27/2007	Hexavalent chromium	365	B1MDM5	375	B1MDM3	2.7	Yes
199-D5-43	9/19/2007	Hexavalent chromium	294	B1PFF4	292	B1PFF3	0.7	Yes
199-D8-68	11/14/2006	Hexavalent chromium	116	B1LB50	123	B1LB64	5.9	No
199-D8-68	5/8/2007	Hexavalent chromium	5 (U)	B1N861	5	B1N876	N/A	No
199-D8-69	3/27/2007	Hexavalent chromium	25	B1MD75	20.9	B1MD76	17.9	Yes
199-D8-70	7/30/2007	Hexavalent chromium	13	B1NWM8	15.8	B1NWM9	19.4	Yes
199-D8-72	11/14/2006	Hexavalent chromium	88	B1LB65	529	B1LB51	142.9	No
199-D8-72	5/8/2007	Hexavalent chromium	385	B1N862	379	B1N877	1.6	No
199-D8-73	1/8/2007	Hexavalent chromium	208	B1LN70	217	B1LN69	4.2	Yes
199-D8-88	8/15/2007	Hexavalent chromium	45	B1P4J4	52.1	B1P4J5	14.6	Yes
199-D8-88	9/11/2007	Hexavalent chromium	44	B1PDN2	45.9	B1PDN3	4.2	Yes
Laboratory Replicates (6010_METALS_ICP)5.2								
199-D2-6	11/27/2006	Hexavalent chromium	40	B1KYV2	37	B1KYT8	7.8	Yes
199-D2-6	2/14/2007	Hexavalent chromium	31	B1M790	21	B1M788	38.5	Yes
199-D2-8	5/11/2007	Hexavalent chromium	96	B1N369	95	B1N371	1.0	Yes
199-D4-15	3/27/2007	Hexavalent chromium	1,524	B1MDM0	1,508	B1MDL8	1.1	Yes
199-D4-15	6/14/2007	Hexavalent chromium	1,470	B1NK20	1,465	B1NK22	0.3	Yes
199-D4-26	11/14/2006	Hexavalent chromium	550	B1L2N6	556	B1L2P0	1.1	Yes
199-D4-38	5/21/2007	Hexavalent chromium	125	B1N3B4	128	B1N3B2	2.4	Yes
199-D4-48	12/7/2006	Hexavalent chromium	31	B1L2W5	30	B1L2W9	3.3	Yes
199-D4-7	5/21/2007	Hexavalent chromium	5	B1N3D4	5	B1N3D6	0.0	Yes
199-D4-83	2/21/2007	Hexavalent chromium	20	B1M780	18	B1M782	10.5	Yes
199-D5-20	11/27/2006	Hexavalent chromium	424	B1KYH5	425	B1KYH6	0.2	Yes
199-D5-33	11/20/2006	Hexavalent chromium	5 (U)	B1L051	6	B1L050	N/A	Yes
199-D5-34	5/10/2007	Hexavalent chromium	202	B1N798	201	B1N278	0.5	Yes
199-D5-38	1/8/2007	Hexavalent chromium	382	B1LNH7	381	B1LNH5	0.3	Yes
199-D5-38	4/16/2007	Hexavalent chromium	359	B1MN52	361	B1MN50	0.6	Yes

Table D-7. Hexavalent Chromium and Chromium Quarterly Quality Control Results. (3 Pages)

Well Name	Sample Date	Constituent	Reported Value #1 (µg/L)	Sample Number	Reported Value #2 (µg/L)	Sample Number	RPD (%)	Filtered
199-D5-38	5/10/2007	Hexavalent chromium	251	B1N286	243	B1N7B0	3.2	Yes
199-D5-38	6/25/2007	Hexavalent chromium	131	B1NP29	130	B1NK25	0.8	Yes
199-D5-39	10/11/2006	Hexavalent chromium	1,786	B1KMR9	1,768	B1KMT1	1.0	Yes
199-D5-39	2/13/2007	Hexavalent chromium	1,396	B1M667	1,390	B1M669	0.4	Yes
199-D5-40	5/17/2007	Hexavalent chromium	99	B1N296	101	B1N294	2.0	Yes
Laboratory Splits (6010_METALS_ICP [chromium] or CR6_HACH_M [hexavalent chromium])5.2								
199-D5-43	10/2/2006	Hexavalent chromium	529	B1KLC7	540	B1KLC5	2.1	Yes
199-D5-43	5/10/2007	Hexavalent chromium	499	B1N3H8	491	B1N7B2	1.6	Yes
199-D5-43	9/10/2007	Hexavalent chromium	263	B1PFC5	266	B1PFC3	1.1	Yes
199-D8-69	1/8/2007	Hexavalent chromium	62	B1LN65	62	B1LN64	0.0	Yes
199-D8-69	9/11/2007	Hexavalent chromium	17	B1PDM5	16	B1PDM6	6.1	Yes
199-D8-70	11/8/2006	Hexavalent chromium	95	B1KYK6	96	B1KYK5	1.0	Yes
199-D8-70	3/29/2007	Hexavalent chromium	31	B1MD78	31	B1MD79	0.0	Yes
199-D8-73	2/13/2007	Hexavalent chromium	208	B1M606	208	B1M605	0.0	Yes
199-D8-73	4/12/2007	Hexavalent chromium	202	B1MMR8	203	B1MMR9	0.5	Yes
199-D8-73	6/13/2007	Hexavalent chromium	168	B1NJ92	167	B1NJ91	0.6	Yes
199-D8-73	7/19/2007	Hexavalent chromium	159	B1NWN1	160	B1NWN2	0.6	Yes
199-D8-88	6/4/2007	Hexavalent chromium	52	B1N252	53	B1N251	1.9	Yes

N/A = RPD percentage not calculated because analytical results are below the detection limit.
RPD = relative percent difference.
U = constituent not detected; value shown is the analysis detection limit.

Table D-8. Sulfate Quarterly Quality Control Results. (3 Pages)

Well Name	Sample Date	Constituent	Reported Value #1 (mg/L)	Sample Number	Reported Value #2 (mg/L)	Sample Number	RPD (%)	Filtered
Field Replicates (COLOR_TK_FLD)								
199-D4-20	07-Aug-07	Sulfate	105	B1P6L4	130	B1P6L6	21.3	No
199-D4-86	10-Aug-07	Sulfate	36	B1P6V6	34	B1P6V4	5.7	No
199-D5-39	13-Feb-07	Sulfate	80	B1M668	88	B1M670	9.5	No
Field/Laboratory Splits (COLOR_TK_FLD/300.0_ANIONS_IC)								
199-D2-6	8/6/2007	Sulfate	165	B1P488	164	B1P486	0.6	No
199-D2-8	1/25/2007	Sulfate	81.8	B1L2K3	90	B1L2K1	9.5	No
199-D3-2	11/14/2006	Sulfate	78.7	B1KYW0	86	B1KYV8	8.9	No
199-D4-1	11/14/2006	Sulfate	298	B1L2L4	190	B1L2L2	44.3	No
199-D4-4	11/20/2006	Sulfate	339	B1L2W2	180	B1L2W0	61.3	No
199-D4-5	11/21/2006	Sulfate	185	B1L2X7	283	B1L2X9	41.9	No
199-D4-6	11/14/2006	Sulfate	265	B1L2Y3	366	B1L2Y5	32.0	No
199-D4-7	12/12/2006	Sulfate	205	B1L305	179	B1L307	13.5	No
199-D4-13	11/14/2006	Sulfate	153	B1KYW5	164	B1KYW3	6.9	No
199-D4-14	11/14/2006	Sulfate	92.7	B1KYX0	92	B1KYW8	0.8	No
199-D4-15	11/20/2006	Sulfate	135	B1KYX9	139	B1KYX5	2.9	No
199-D4-15	11/20/2006	Sulfate	126	B1KYX7	104	B1KYX3	19.1	No
199-D4-15	4/16/2007	Sulfate	140	B1MMT9	136	B1MMV1	2.9	No
199-D4-19	11/14/2006	Sulfate	360	B1KYY2	327	B1KYY4	9.6	No
199-D4-20	11/14/2006	Sulfate	82	B1L2M2	112	B1KYY7	30.9	No
199-D4-20	2/14/2007	Sulfate	115	B1M635	116	B1M637	0.9	No
199-D4-22	11/14/2006	Sulfate	144	B1L000	132	B1L002	8.7	No
199-D4-23	11/14/2006	Sulfate	300	B1L009	226	B1L011	28.1	No
199-D4-31	12/7/2006	Sulfate	140	B1L2R0	148	B1L2P8	5.6	No
199-D4-32	11/20/2006	Sulfate	148	B1L2R4	141	B1L2R6	4.8	No
199-D4-36	11/20/2006	Sulfate	106	B1L2T0	94	B1L2T2	12.0	No
199-D4-38	11/14/2006	Sulfate	94	B1L2T6	140	B1L2T8	39.3	No
199-D4-39	11/14/2006	Sulfate	56	B1L2V2	84.7	B1L2V4	40.8	No

Table D-8. Sulfate Quarterly Quality Control Results. (3 Pages)

Well Name	Sample Date	Constituent	Reported Value #1 (mg/L)	Sample Number	Reported Value #2 (mg/L)	Sample Number	RPD (%)	Filtered
199-D4-62	11/14/2006	Sulfate	145	B1L2Y9	190	B1L301	26.9	No
199-D4-78	11/21/2006	Sulfate	350	B1L311	581	B1L313	49.6	No
199-D4-84	11/20/2006	Sulfate	195	B1L323	367	B1L325	61.2	No
199-D4-85	11/20/2006	Sulfate	120	B1L329	150	B1L331	22.2	No
199-D4-86	11/20/2006	Sulfate	80.5	B1L337	50	B1L335	46.7	No
199-D5-15	12/7/2006	Sulfate	104	B1L028	117	B1L026	11.8	No
199-D5-36	11/27/2006	Sulfate	17	B1L056	16.6	B1L058	2.4	No
199-D5-36	2/21/2007	Sulfate	12	B1M679	15.7	B1M681	26.7	No
199-D5-37	12/12/2006	Sulfate	19.8	B1L415	23	B1L061	15.0	No
199-D5-38	10/2/2006	Sulfate	75.2	B1KMR7	45	B1KMR3	50.2	No
199-D5-38	11/14/2006	Sulfate	76	B1L066	63.5	B1L068	17.9	No
199-D5-38	3/27/2007	Sulfate	59.8	B1MDM6	71	B1MDM4	17.1	No
199-D5-39	11/14/2006	Sulfate	81.8	B1L073	90	B1L071	9.5	No
199-D5-41	11/22/2006	Sulfate	66	B1L081	55	B1L083	18.2	No
199-D5-43	11/14/2006	Sulfate	72	B1L353	109	B1L355	40.9	No
199-D5-44	11/22/2006	Sulfate	15	B1L086	13.9	B1L088	7.6	No
Laboratory Replicates (300.0_ANIONS_IC)								
199-D2-6	11/27/2006	Sulfate	168	B1KYV3	156	B1KYT9	7.4	No
199-D2-6	11/27/2006	Sulfate	136	B1KYV1	138	B1KYV5	1.5	No
199-D2-6	2/14/2007	Sulfate	168	B1M791	160	B1M789	4.9	No
199-D2-8	5/11/2007	Sulfate	104	B1N372	96	B1N370	8.0	No
199-D4-7	5/21/2007	Sulfate	220	B1N3D7	260	B1N3D5	16.7	No
199-D4-15	3/27/2007	Sulfate	115	B1MDL9	115	B1MDM1	0.0	No
199-D4-15	6/14/2007	Sulfate	130	B1NK23	135	B1NK21	3.8	No
199-D4-19	5/16/2007	Sulfate	205	B1N263	220	B1N261	7.1	No
199-D4-26	11/14/2006	Sulfate	80	B1L2N7	64	B1L2P1	22.2	No
199-D4-26	11/14/2006	Sulfate	125	B1L2N9	126	B1L2P5	0.8	No
199-D4-38	5/21/2007	Sulfate	76	B1N3B3	72	B1N3B5	5.4	No
199-D4-48	12/7/2006	Sulfate	49	B1L2X0	50	B1L2W6	2.0	No
199-D4-83	2/21/2007	Sulfate	18	B1M781	17	B1M783	5.7	No

Table D-8. Sulfate Quarterly Quality Control Results. (3 Pages)

Well Name	Sample Date	Constituent	Reported Value #1 (mg/L)	Sample Number	Reported Value #2 (mg/L)	Sample Number	RPD (%)	Filtered
199-D5-20	11/27/2006	Sulfate	46.4	B1L046	46.8	B1L048	0.9	No
199-D5-36	8/28/2007	Sulfate	18	B1P4D3	18	B1P4D5	0.0	No
199-D5-38	1/8/2007	Sulfate	36	B1LNH6	38	B1LNH8	5.4	No
199-D5-38	4/16/2007	Sulfate	70	B1MN51	66	B1MN53	5.9	No
199-D5-39	10/11/2006	Sulfate	92	B1KMT0	94	B1KMT2	2.2	No
199-D5-40	5/17/2007	Sulfate	145	B1N297	130	B1N295	10.9	No
199-D5-43	10/2/2006	Sulfate	54	B1KLC8	106	B1KLC6	65.0	No

RPD = relative percent difference.

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