DOE/RL-2011-118
Revision 0

HANFORD SITE GROUNDWATER MONITORING FOR 2011

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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office
P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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FOREWORD

Fred Biebesheimer, Groundwater Science Manager

Groundwater monitoring was reported in a variety of ways over the history of Hanford Site operations. While publically available descriptions of groundwater monitoring predated the 1980s, the "modern" annual groundwater monitoring report originated in 1996. Since then, the annual report evolved to reflect changes in regulations, the understanding of contaminants in Hanford groundwater, and refinements in the tools and methods used to evaluate data. Between 1996 and 2010, many of these changes were incremental, slowly shaping the content of the annual report without drastically changing its appearance. This report, Hanford Site Groundwater Monitoring for 2011, is a major advancement in the annual report's evolution. The changes in this year's report are needed to accomplish the following three objectives:

1. As DOE continues the cleanup process, the Hanford Site is transitioning from learning about the nature of groundwater contamination to making decision about the groundwater cleanup. To support this, changes must be made so the annual report can better report the effectiveness of cleanup activities.
2. Techniques and tools for studying very large environmental datasets are maturing. Many of these methods are now being implemented as process improvements with the goal of improving the timeliness, transparency, and technical integrity of scientific decisions.
3. In past years, the document has grown to more than 1,000 pages and several hundred figures. In many ways, this growth hampered the clarity of the report by introducing redundancy, or in some cases, inconsistency between sections. To correct this, scientists are improving clarity, consistency, and reducing redundancy in data presentation.

To meet these objectives, a number of changes were implemented in the annual report's presentation, as well as the underlying analyses and data evaluation. These changes are discussed throughout the report, but an overview of these improvements is presented below:

- **Focus on change** – To reduce redundancy and improve readability, report sections were focused on observing and explaining changes in the monitoring data. Effort is placed on communicating how contamination distribution has changed over the prior year, and what mechanisms are influencing its fate and transport.
- **Analysis and conclusions** – Additional emphasis was placed on drawing conclusions from data, rather than reporting it. Where data was found inconclusive, efforts are made to explain the uncertainty and provide recommendations to reduce uncertainty.
- **Reduce redundancy** – Rather than repeating information presented in other reports, information from those reports is presented in a summary fashion. For instance, only key data, findings, and conclusions from the pump-and-treat performance reports are presented in the annual report.
- **Report organization** – The annual report was reorganized to reflect regions (River Corridor and the Central Plateau) rather than each groundwater interest area to focus discussion and reduce repetitive text (for instance, reactor operations). Other changes to the report organization include efforts to eliminate broad background information. Background information essential to understanding groundwater contamination is still presented, but in some cases, it has been moved. For instance, a detailed discussion of Hanford geology and hydrogeology is now presented outside of the main report body (refer to Appendix E). The chapter on vadose zone activities was eliminated from this year's groundwater monitoring report. Discussion relevant

to groundwater monitoring was addressed as appropriate in each relevant section. The performance of the vapor extraction system in 200 West was discussed in SGW-51807, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Calendar Year 2011.*

- **Plume delineation and depiction** – In previous years, project scientists contoured the contaminant plumes in each groundwater interest area by hand. Given the refinement in computer interpolation algorithms and new data from remedial investigations currently underway, the 2011 contaminant plume maps were constructed by computers using quantile kriging. This method was used to increase the transparency and reproducibility in the findings of Hanford Site groundwater scientists. Computer interpolation also makes the data more widely available for evaluating the progress towards cleanup and provides another means of analysis. A discussion of this industry-standard approach is presented in Section 1.7. All electronic input data files and resulting spatial data are available for electronic download. Substantial effort was placed on depicting plumes and improving the cartography in this annual report.

Some improvements made in the 2011annual report are incremental. Additional efforts are underway to develop techniques necessary to meet the objectives described above. These changes include the following:

- **Measuring cleanup performance** – As the Hanford Site moves from describing the extent of contamination to active cleanup, meaningful benchmarks for measuring cleanup progress must be developed. Cleanup metrics are still being evaluated and proposed; the table at the beginning of each section in this year's report begins the process by presenting basic measurements of the nature and extent of contamination and progress towards cleanup. Development of these metrics will continue as new data evaluation and reduction processes are implemented.
- **Aquifer Tubes** – Aquifer tubes are installed and monitored at many locations along the Columbia River shoreline. These tubes are monitored to collect data regarding groundwater contaminants in proximity to the river. Aquifer tube data is used to describe the nature and extent of contamination near the river, but uncertainty remains regarding the representativeness of these data. Recommendations are being made to address this question and describe the utility of monitoring data from aquifer tubes.

In the coming year, additional changes are anticipated to increase the timeliness and usefulness of the Hanford groundwater monitoring report. These changes will make it easier to explore and understand the analyses conducted as part of Hanford Site groundwater monitoring. Project scientists are working with communications specialists and experts in data visualization to implement these changes.

Abstract

The U.S. Department of Energy's Hanford Site in southeastern Washington State was a weapons production facility from 1943 until the 1980s. During operations, process chemicals and radioactively contaminated water were released to the soil and migrated through the vadose zone to the groundwater. Groundwater flows to the Columbia River and is the primary exposure route for contaminants to reach human, environmental, and ecological receptors.

This report presents the results of groundwater monitoring at the Hanford Site during the 12-month period from January 1 through December 31, 2011. It describes monitoring results for *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and disposal units, for *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) groundwater operable units where no active remediation is currently taking place, and for the *Atomic Energy Act of 1954* (AEA), as required by DOE orders. The results of ongoing groundwater and vadose zone remediation activities are summarized; and the status of well drilling, maintenance, and decommissioning is provided.

The Hanford Site is broadly divided into the "River Corridor" and "Central Plateau" regions. As the names imply, the River Corridor is the portion of the Site located along the Columbia River, and the Central Plateau is in the middle of the Site, at a higher elevation. The River Corridor includes the 100 Areas, where nine nuclear reactors operated, and the 300 Area, which was home to the fuel manufacturing operations at the Site as well as the experimental and laboratory facilities. The primary groundwater contaminants in the River Corridor are hexavalent chromium, strontium-90, nitrate, and tritium in the 100 Area, and uranium in the 300 Area. Other contaminants of concern in the 100 Area include carbon-14 and trichloroethene. More than 60 percent of the former liquid waste sites near the river have been remediated or are classified as not requiring remediation under interim records of decision. This cleanup has reduced the potential for future groundwater contamination. Cleanup of the remaining sites is underway. Groundwater remediation systems in the 100 Area are limiting the amount of contamination reaching the Columbia River and reducing the mass of contaminants in the groundwater.

When the Hanford Site was operating, irradiated fuel reprocessing, isotope recovery, and associated waste management activities occurred on the Central Plateau. Contaminant sources included unlined cribs, trenches, and ponds, and leakage from underground storage tanks. Groundwater contaminant plumes of tritium, iodine-129, and nitrate formed when the waste discharged to ponds and cribs reached the aquifer. These contaminants form regional plumes originating on the Central Plateau. The tritium and nitrate plumes have shrunk over the years because of dispersion and radioactive decay. A large carbon tetrachloride plume originated in 200 West Area. This plume is expanding at the edges, but the high-concentration core is contained by a pump-and-treat system. The remediation system is being enlarged in 2012 to capture more of the contamination. Other groundwater contaminants in the Central Plateau include technetium-99, uranium, strontium-90, trichloroethene, and cyanide.

Highlights for 2011 include the following:

- DOE continued to conduct intensive field studies in the River Corridor. Results will be used to select methods for final remediation of soil and groundwater.
- Pump-and-treat systems in the 100 Areas were expanded. Combined, these systems have removed 1,847 kilograms of hexavalent chromium since 1997.
- DOE expanded an in-situ remediation method in the 100-N Area, which decreases the amount of strontium-90 reaching the Columbia River.

- In the Central Plateau, groundwater and vadose zone remediation systems have removed more than 93,000 kilograms of carbon tetrachloride from groundwater since 1992. In 2011, DOE completed construction of a new treatment facility that will greatly expand the groundwater remediation system.

During 2011, drillers completed 89 new wells for monitoring, remediation, or characterization. One hundred eight wells that are no longer needed were decommissioned (filled with grout) in accordance with State regulations.

This report is available on the Internet through the Hanford Site Soil and Groundwater Remediation Project, available at: http://www.hanford.gov/page.cfm/SoilandGroundwater.

Acknowledgements

This report represents the efforts of dozens of individuals who contribute to the Soil and Groundwater Remediation Project: planners, schedulers, samplers, laboratory technicians, data management staff, scientists, editors, GIS professionals, and production staff. Fred Biebesheimer, manager of the Groundwater Science group, provided leadership of the team. Mary Hartman and Kris Ivarson coordinated the document.

Patricia McNary headed up the editing and production team, which included Alexandra Amonette, Sarah Logue, Julie Moore, Kristina Nygaard, Gina Richey, Beverly Sanders, Janna Shaw, Wally Wallace, Melody Brock, and Toni Lucero.

Craig Arola led the efforts for plume mapping and graphics production. Rachel Shannon and Matt Tonkin, S.S. Papadopulos and Associates, Inc., created the plume maps. Other graphics team members included JoAnne Rieger and Catherine Clark.

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Report Contributors

The production of the *Hanford Site Groundwater Monitoring for 2011* required the knowledge, skill, expertise, and cooperation of many people and several organizations. The contributions and cooperation of the following authors are gratefully acknowledged.

The authors' names are listed in their respective sections of the report.

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Useful Information

Table 1. Radionuclides and Their Half-Lives

Symbol	Radionuclide	Half-Lives
^{3}H	tritium	12.31 yr
^{14}C	carbon-14	5,715 yr
^{60}Co	cobalt-60	5.271 yr
^{137}Cs	cesium-137	30.2 yr
^{129}I	iodine-129	1.7×10^{7} yr (17,000,000 yr)
^{239}Pu	plutonium-239	2.410×10^{4} yr (24,100 yr)
^{240}Pu	plutonium-240	6.56×10^{3} yr (6,500 yr)
^{90}Sr	strontium-90	28.9 yr
^{99}Tc	technetium-99	2.13×10^{5} yr (213,000 yr)
^{234}U	uranium-234	2.45×10^{5} yr (240,000 yr)
^{235}U	uranium-235	7.03×10^{8} yr (710,000,000 yr)
^{238}U	uranium-238	4.47×10^{9} yr (4.47 billion years)
^{239}U	uranium-239	23.5 min.

Source: *CRC Handbook of Chemistry and Physics, 2011-2012, 92nd Edition*, W.M. Haynes, Ed., CRC Press, Boca Raton, FL.

Various sources give slightly different half-lives, e.g., J.K. Tuli, *Nuclear Wallet Cards*, Brookhaven National Laboratory (April 2005), available at: http://www.nndc.bnl.gov/wallet/wcdoe.html.

Table 2. Units of Measure

Symbol	Definition
Ci	curie(s)
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter
m/m	meters per meter
mg/L	milligrams per liter
mm/yr	millimeters per year
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/mg	picocuries per milligram
ppb	parts per billion
ppm	parts per million
ppmv	parts per million volume

Table 3. Conversion Table

Multiply	By	To Obtain
centimeters	0.394	inches
meters	3.28	feet
kilometers	0.621	miles
kilograms	2.205	pounds
liters	0.2642	gallons
square meters	10.76	square feet
hectares	2.47	acres
square kilometers	0.386	square miles
cubic meters	1.308	cubic yards
picocuries	1,000	nanocuries
curie	3.7 × 1,010	becquerel
picocurie	0.03704	becquerel
rem	0.01	sievert
°Celsius	(°C × 9/5) + 32	°Fahrenheit

The primary units of measurement in this report are metric. To convert metric units to English units, use the "By" factors.

Table 4. Public Reading Rooms

University of Washington Government Publications Division - Suzzallo & Allen Libraries, Box 352900 Seattle, WA 98195-2900 (206) 543-4164 www.catalog.kub.wa.edu	Portland State University Government Information Branford Price Millar Library 1875 SW Park Avenue Portland, OR 97207-1151 (503) 725-4542 http://library.pdx.edu/governmentinformationservice.html and http://library.pdx.edu/public_comment.html#hanf
US DOE Public Reading Room, Washington State University, Tri-Cities Consolidated Information Center, Room 101-L 2770 University Drive Richland, WA 99352 (509) 372-7443 http://reading-room.labworks.org	Gonzaga University, Foley Center East 502 Boone Spokane, WA 99258-0001 (509) 313-3847 http://www.gonzaga.edu/Academics/Libraries/Foley-Library/Departments/Special-Collections/default.asp Hanford Health Info Archive: http://www.gonzaga.edu/Academics/Libraries/Foley-Library/Departments/Special-Collections/Collections/Hanford-Health-and-Information-Archives/default.asp
CHPRC's Documents and Reports Web Site: http://prc.rl.gov/rapidweb/Environmental/index.cfm?PageNum=36	

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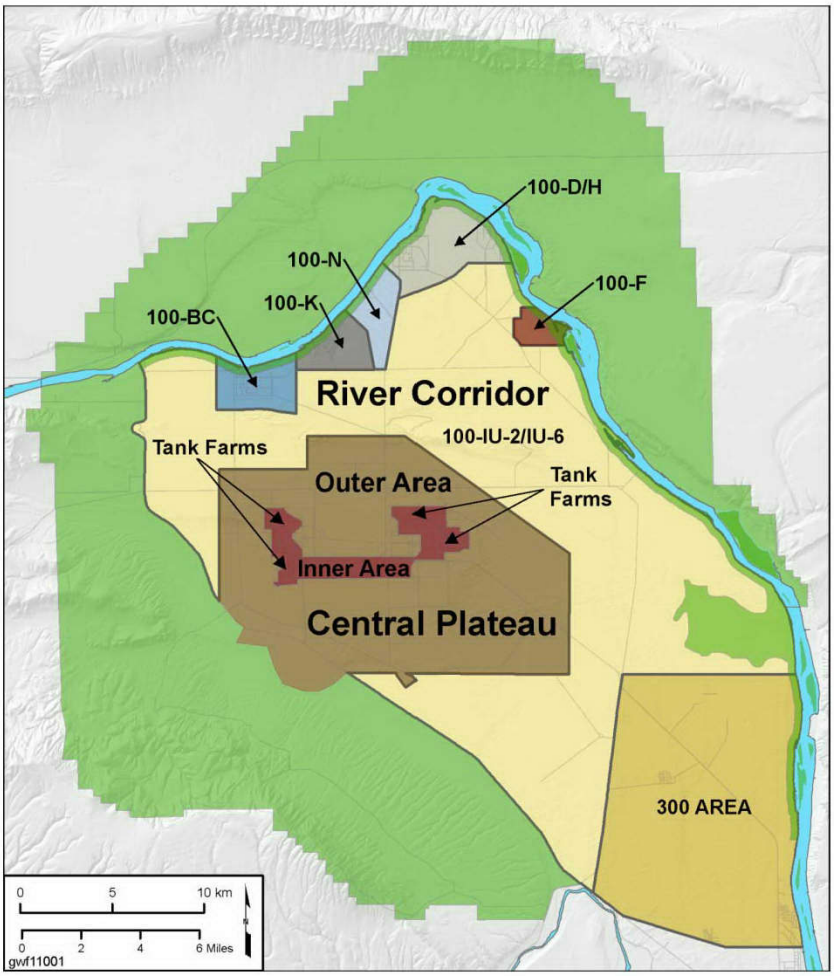
Executive Summary

M.J. Hartman and K.A. Ivarson

Introduction

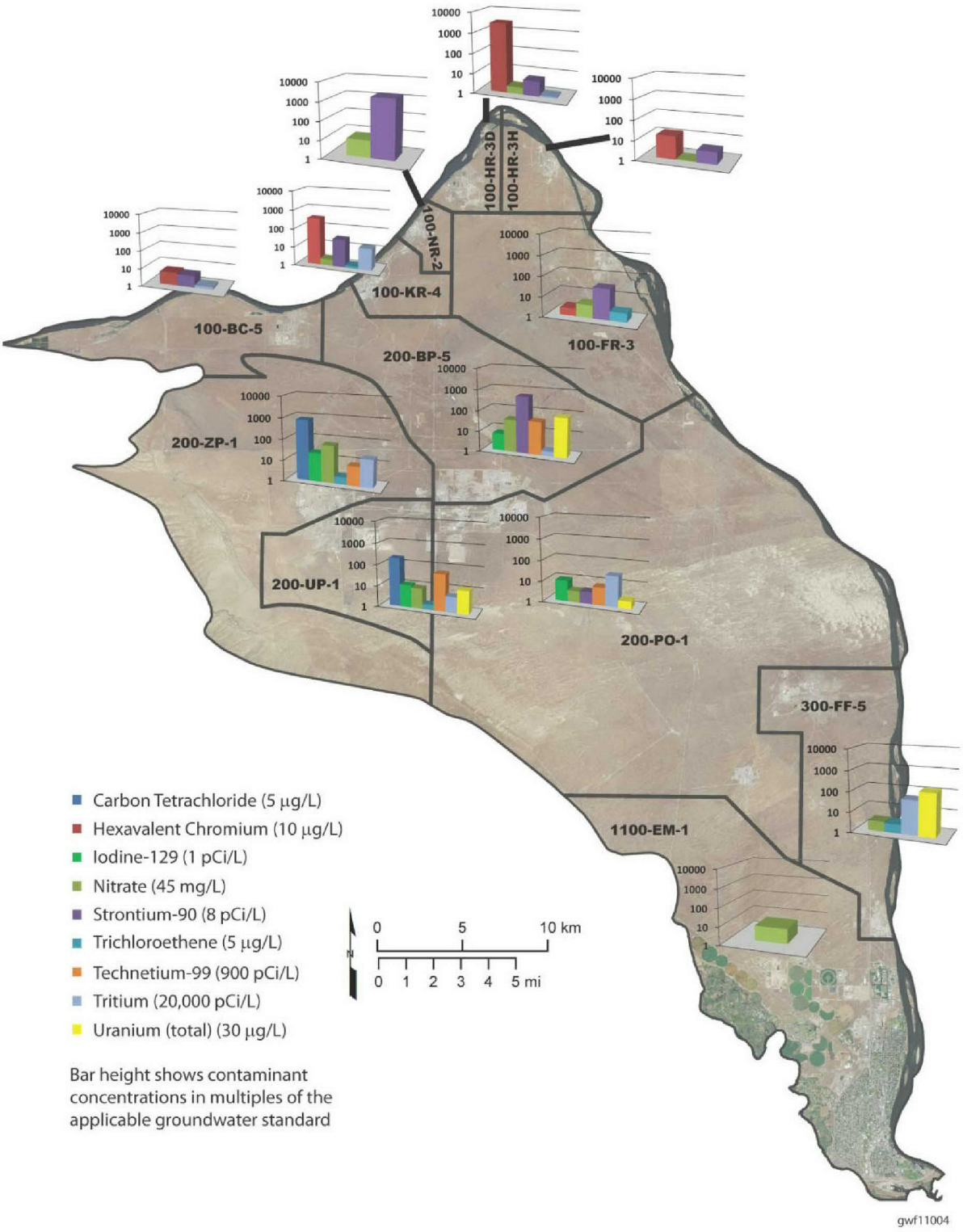
The Hanford Site, part of the U.S. Department of Energy's (DOE's) nuclear weapons complex, encompasses ~1,500 square kilometers northwest of the city of Richland along the Columbia River in southeastern Washington State. In 1943, as part of the top secret Manhattan Project, the federal government took possession of the Site to build the world's first large-scale plutonium production reactor, the B Reactor. This reactor was used to make the plutonium for the Trinity Test and the bomb that was dropped on Nagasaki, Japan in 1945. During the Cold War period (1945 to 1991), the government built a total of nine reactors along the Columbia River for the production of weapons-grade plutonium.



The Hanford Site is located in southeastern Washington State on the shore of the Columbia River. The River Corridor includes the 100 Area, where nine nuclear reactors formerly operated, and the 300 Area, where nuclear fuel assemblies were made. The Central Plateau includes the 200 Area, where chemical processing of nuclear fuel occurred.

During reactor operations, chemical and radioactive waste was released into the environment and contaminated the soil and groundwater beneath portions of the Hanford Site. Groundwater flows to the Columbia River and is the primary exposure route for contaminants to reach human, environmental, and ecological receptors.

Since the 1990s, DOE has worked to characterize, remove, treat, and dispose of contamination from past operations. DOE developed a plan to address groundwater and vadose (unsaturated) zone contamination in consultation with the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology). Key elements associated with managing the Hanford Site's groundwater and vadose zone contamination are to (1) protect the Columbia River and groundwater, (2) develop a cleanup decision process, and (3) achieve final cleanup.



This map shows the maximum concentrations of groundwater contaminants in each groundwater interest area in 2011. The heights of the bars represent multiples of the applicable water quality standards. For example, if the maximum strontium-90 concentration was 80 pCi/L, the bar is 10 units high because the drinking water standard is 8 pCi/L.

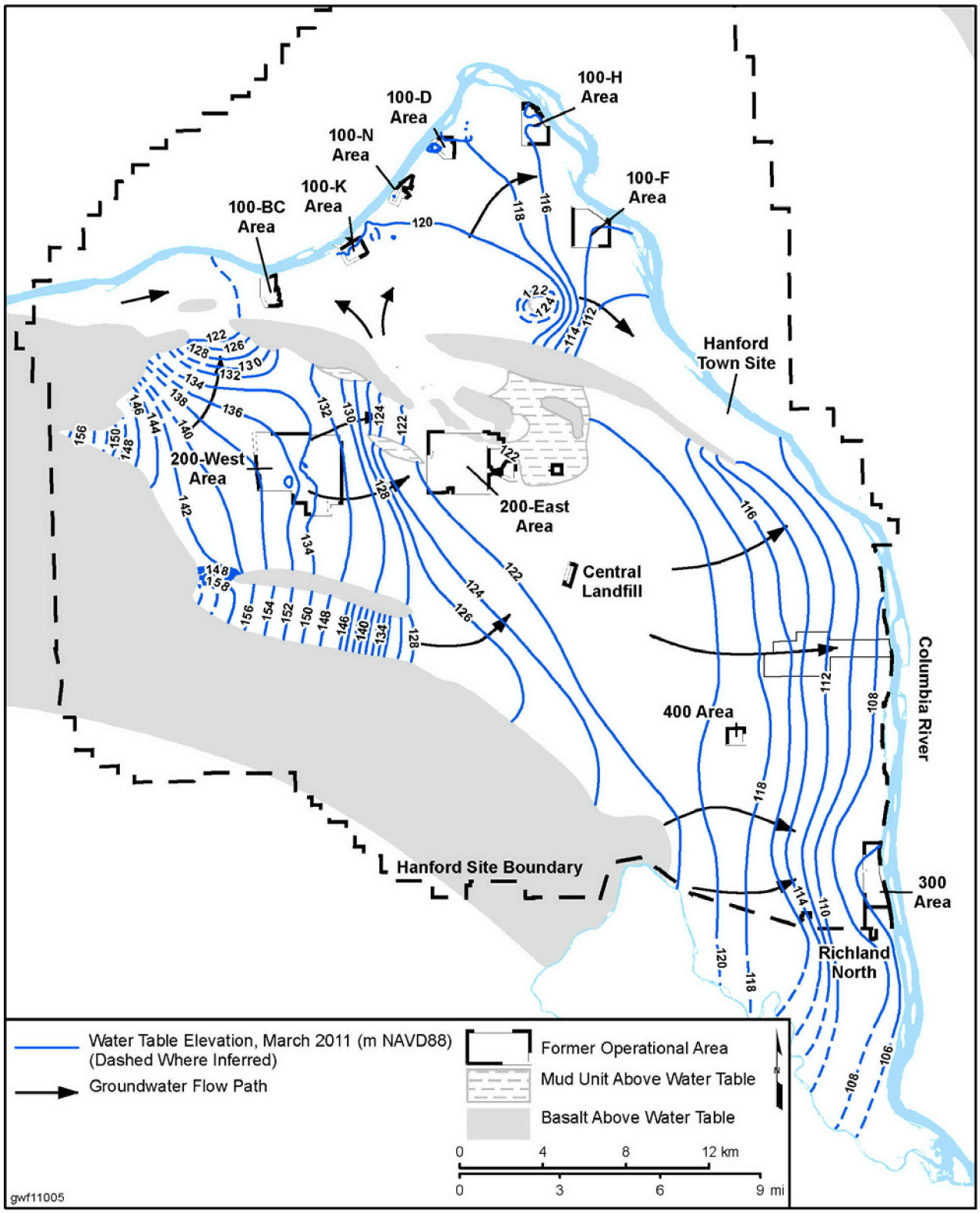
This document presents the results of Hanford Site groundwater monitoring for 2011. It describes monitoring results for Resource Conservation and Recovery Act of 1976 (RCRA) treatment, storage, and disposal units, for Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) groundwater operable units, where no active remediation is currently taking place, and for the Atomic Energy Act of 1954 (AEA), as required by DOE orders. This report provides a summary of vadose zone monitoring, investigations, and results, as well as well installation, remediation, and decommissioning activities. DOE publishes details on CERCLA remediation activities (for example, pump-and-treat operations) in separate reports that are summarized and referenced in this report. The data presented in this report—and information on well locations, construction, and screened intervals—can be found through the DOE's Environmental Dashboard Application at *http://environet.hanford.gov/EDA/.*

RCRA regulates the management of solid waste, hazardous waste, and certain underground storage tanks. It applies to active or recently-active treatment, storage, and disposal units. Monitoring is required at some units to determine if they are affecting groundwater quality in the uppermost aquifer. The uppermost aquifer is the unconfined aquifer beneath most of the Hanford Site. Groundwater monitoring requirements for the Site's RCRA units fall into one of two broad categories: interim status or final status. A permitted RCRA unit requires final status monitoring, as specified in WAC 173-303-645, "Dangerous Waste Regulations," "Releases from Regulated Units." The RCRA units not currently incorporated into a permit require interim status monitoring, as specified in WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards" (based on 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities"). Although the single-shell tank farms and inactive units are listed in Part A of the Hanford Facility Dangerous Waste Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*), they are operated under interim status requirements until an approved operating permit for each unit is issued.

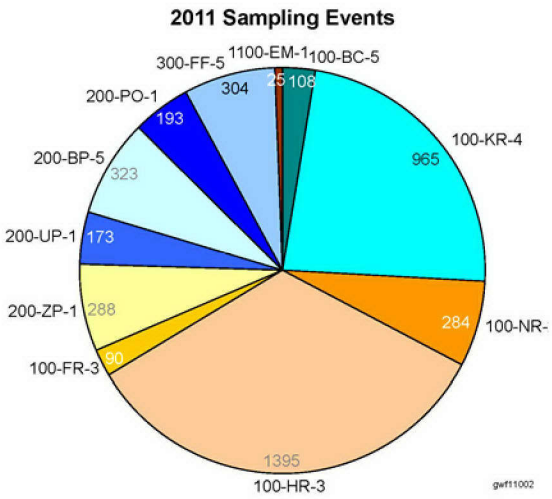
RCRA groundwater monitoring is conducted under one of three possible phases: (1) contaminant indicator evaluation (or detection) monitoring, (2) groundwater quality assessment (or compliance) monitoring, or (3) corrective action monitoring. In the interim-status contaminant indicator evaluation monitoring, four indicator parameters (pH, specific conductivity, total organic carbon, and total organic halides) are monitored and evaluated against statistically derived threshold values calculated from upgradient wells. In final status detection monitoring, site-specific indicators are evaluated using statistical methods identified in the respective permit. Groundwater quality assessment (interim status) or compliance (final status) monitoring occurs when a facility appears to have impacted groundwater quality. The objective of the monitoring program shifts from detection to assessing the nature and extent of the problem. Under corrective action monitoring, Ecology has stipulated some form of groundwater remediation. The goal of a corrective action groundwater monitoring program is to determine if the corrective action is effective.

CERCLA is the federal government's program to clean up the nation's uncontrolled hazardous and radioactive waste sites. Cleanup decisions are based on the results of environmental investigations that include the vadose zone and groundwater. CERCLA groundwater monitoring on the Hanford Site includes monitoring of contaminants and water levels, and monitoring the effectiveness of groundwater remedial actions, such as pump-and-treat systems.

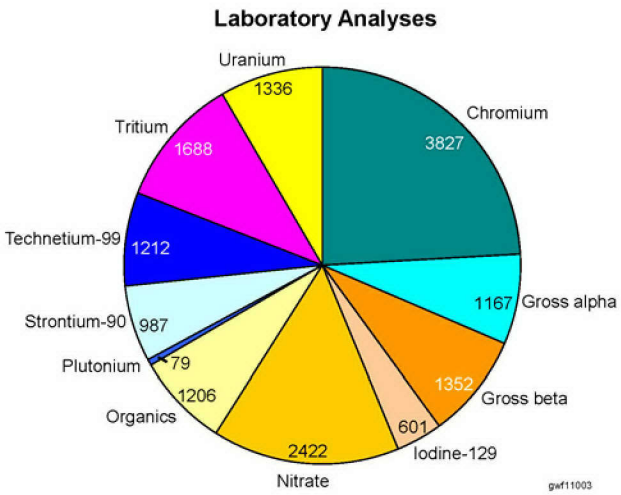
DOE Orders implement requirements of the AEA at DOE sites. These requirements include groundwater monitoring to detect, characterize, and respond to releases of radionuclides. This AEA monitoring is integrated with CERCLA and RCRA monitoring on the Hanford Site.



Groundwater flows from areas where the water table is high to where it is lower, and eventually discharges to the Columbia River.



DOE sampled 931 wells and 285 shoreline aquifer tubes in 2011. Many of the wells were sampled multiple times, for a total of 4,147 sampling events.



This chart shows the number of laboratory analyses run on Hanford Site groundwater samples for the most common constituents in 2011.

River Corridor

The Columbia River flows through the northern portion of the Hanford Site before turning south toward the City of Richland. The region of the Site along the shoreline is known as the River Corridor. Hanford Site groundwater flows toward the Columbia River, so groundwater is the primary exposure route for site contaminants to reach human and environmental receptors. Daily, monthly, and seasonal changes in river stage, controlled by operation of Priest Rapids Dam, affect the flow of nearby groundwater. During periods of high river stage, the river temporarily recharges the adjacent aquifer, whereas during periods of low or moderate river stage, groundwater discharges from the aquifer to the river. River stage changes cause a mixing zone to occur in the aquifer near the shore.

The table on the following page summarizes information about the River Corridor. In the 100 Area, groundwater contamination is related to past disposal of waste associated with water-cooled nuclear reactors. The primary groundwater contaminants are hexavalent chromium, strontium-90, nitrate, and tritium in the 100 Area, and uranium and tritium in 300-FF-5. Other contaminants of concern in the 100 Area include carbon-14 and trichloroethene. The primary sources of hexavalent chromium contamination were the routine disposal of reactor cooling water, which contained the corrosion inhibitor sodium dichromate, and unplanned spills and leaks of the high-concentration sodium dichromate stock solution.

DOE conducted intensive field studies in the River Corridor in 2010 and 2011. Results will be used to select methods for final remediation of soil and groundwater.

More than 60 percent of the waste sites near the river have been remediated or are classified as not requiring remediation under interim records of decision. Cleanup of the remaining sites is underway. Removal of contaminated soil reduces the potential for future groundwater contamination. Groundwater remediation systems in the 100 Area are limiting the amount of contamination reaching the Columbia River and reducing the mass of contaminants in the groundwater.

Interim cleanup of the River Corridor has achieved a great deal, but final decisions are yet to be made. CERCLA provides a process for making cleanup decisions. This process is known as a remedial

investigation/feasibility study (RI/FS), and the decision will be published in a record of decision (ROD). In 2010 and 2011, DOE conducted CERCLA investigations and drafted RI/FS reports for each of the river corridor units. DOE began submitting these reports to regulatory agencies for review in 2012.

River Corridor Overview

Area	Primary Operations	Status of Waste Site Remediation under interim ROD[a]	Groundwater Contamination: Maximum Concentration and Plume Area						
			Carbon-14	Hexavalent Chromium	Nitrate	Strontium-90	Trichloroethene	Tritium	Uranium
100-BC	Reactor operations – B Reactor 1944-69; C Reactor 1952-69	>90% complete	N		<DWS		<DWS		N
100-K	Reactor operations – KE Reactor 1955-71; KW Reactor 1955-70	>30% complete							<DWS
100-N	Reactor operations – N Reactor 1963-87	>30% complete	<DWS				N	<DWS	<DWS
100-D & 100-H	Reactor operations – D Reactor 1944-67; DR Reactor 1950-64; H Reactor 1949-65	>45% complete	N				N	<DWS	<DWS
100-F	Reactor operations – F Reactor 1945-65; Biological experiments until 1976	>85% complete	N					<DWS	
300	Nuclear fuel fabrication and research – 1940s-1960s	>75% complete	N	N	(b)	<DWS			
1100	Vehicle maintenance, 1954-85; solid waste landfill –1950s-1970	100% (final ROD)	N	N	(b)	N	N	<DWS	<DWS
Standards			2000 pCi/L	10 ug/L	45 mg/L	8 pCi/L	5 ug/L	20,000 pCi/L	30 ug/L
Mobility in subsurface			High	High to Moderate	High	Slight	Moderate	High	Moderate

Legend

Colors indicate maximum concentration in 2011

- ≥1000 x standard
- ≥100 x standard and <1000 x standard
- ≥10 x standard and <100 x standard
- ≥Standard and <10 x standard
- N — Not detected or not analyzed

Height of bar indicates plume area above standard (km^2)

- >10
- >1 and ≤ 10
- >0.1 and ≤ 1
- >0, ≤0.1

NOTES

(a) Approximate percentage by number of waste sites classified as closed, interim closed, no action, rejected, or not accepted (end of 2011).

(b) Nitrate in 300-FF-5 and 1100-EM-1 groundwater interest area originates from offsite sources, so plume are and maximum concentration are not shown

ABBREVIATIONS

COC Contaminant of concern
DWS Drinking water standard
ISRM
MNA
P&T Pump and treat system
ROD Record of decision

gwf11020

100-BC-5

Groundwater contamination in 100-BC-5 is related to disposal of solid and liquid waste associated with the operation of two water-cooled reactors. Contaminants include hexavalent chromium, which forms a large plume at relatively low concentrations (less than 50 µg/L). Concentrations appear to be declining very slowly in most wells. However, concentrations increased sharply in early 2012 downgradient of a large excavation at a contaminated waste site. Tritium and strontium-90 concentrations exceed the drinking water standards in several wells, and are declining overall.

Nearly all of the former waste sites have been excavated and backfilled under an interim record of decision. No groundwater interim action was required. Remedial investigation field studies were completed in 2011, and DOE is developing alternatives for remaining waste site and groundwater cleanup.

100-KR-4

The principal groundwater issues for 100-KR-4 are cleaning up hexavalent chromium in the groundwater, tracking contaminant plumes, and monitoring groundwater near the former KE and KW Fuel Storage Basins. Remediation of waste sites is underway. Groundwater contaminant plumes are decreasing in size due to remediation and natural processes including dispersion, discharge to the Columbia River, degradation and radioactive decay.

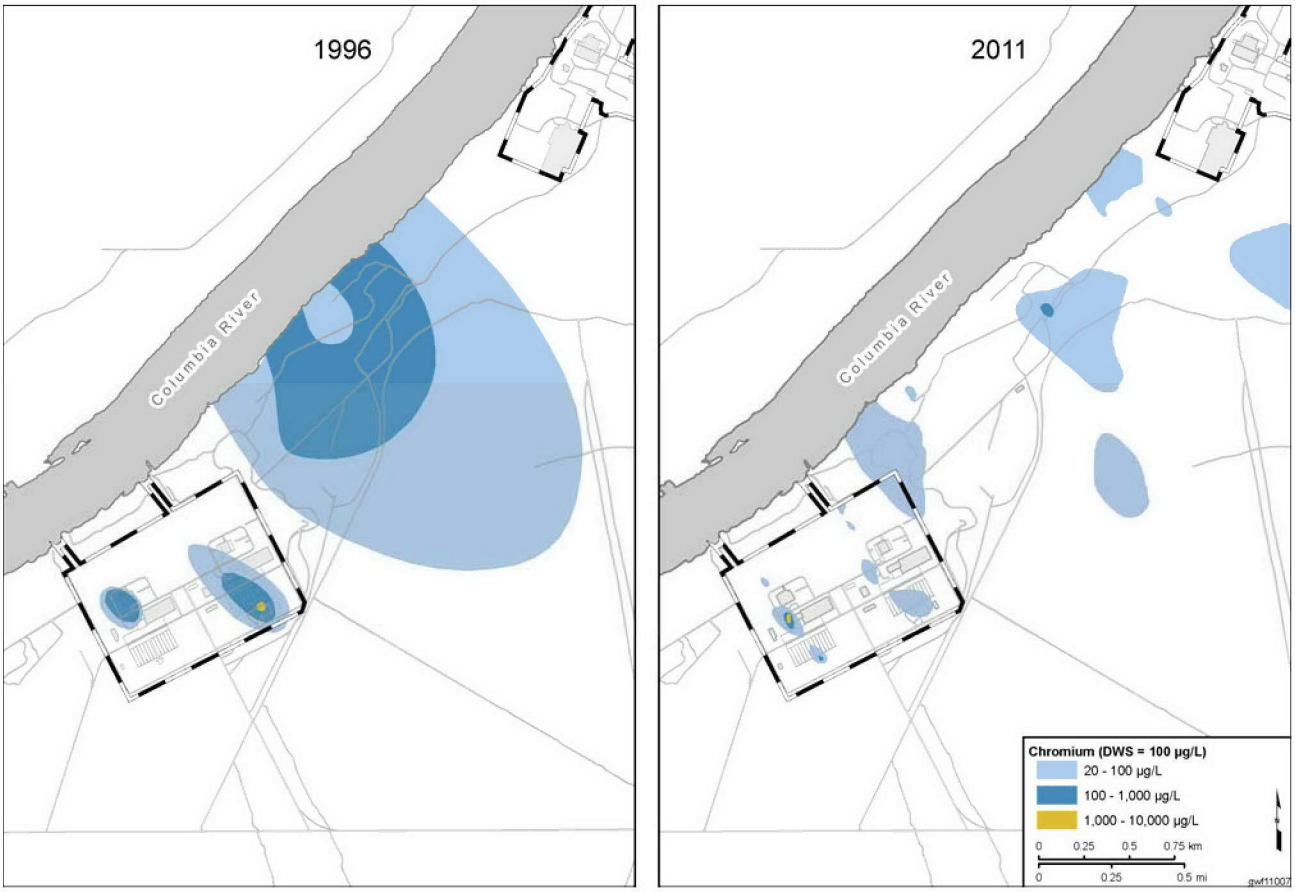
Pump-and-Treat systems in 100-KR-4 can process up to 4.6 million liters of contaminated groundwater every day. The systems have removed 632 kilograms of hexavalent chromium since 1997.

Hexavalent chromium is the primary contaminant of concern for groundwater. Three pump-and-treat systems operate as interim actions to remove hexavalent chromium from the groundwater. Between 1997 and 2011, 632 kilograms of hexavalent chromium have been removed, and the size of the plume (at the 20 µg/L contour) has shrunk by 32 percent.

Other groundwater contaminants in 100-KR-4 include tritium, carbon-14, strontium-90, nitrate, and trichloroethene. Tritium contamination is migrating downgradient from the 118-K-1 Burial Ground. The plume is intercepted by extraction wells near the river. Smaller tritium plumes are present near the KW and KE Reactors. Two wells in the K West region continued to have concentrations above the drinking water standard. The plume did not change significantly between 2010 and 2011. Few wells in 100-KR-4 had strontium-90 concentrations above the 8 pCi/L drinking water standard in 2011, and results were similar to 2010. A new, temporary well drilled through the 116-K-2 Trench had higher strontium-90 concentrations than other wells. The high concentrations have not migrated far from the source because strontium-90 has not been detected in downgradient wells. Nitrate continued to exceed the drinking water standard in a few wells in 100-K Area. Trichloroethene exceeded the drinking water standard in a single well in 2011.

The CERCLA process is underway to make final cleanup decisions for 100-KR-4. Remedial investigations in 2010 and 2011 included installing 15 wells and boreholes.

The concrete KE and KW Basins were integral parts of each reactor building. Until 2004, the water-filled basins were used to store irradiated fuel from the last run of N Reactor, as well as miscellaneous fuel fragments recovered during remedial actions at other reactor areas. Leaks at and around the basins have contaminated groundwater in the past. KE Basin was demolished, and soil remediation has begun. Demolition of the KW Basin is scheduled to begin after 2015. Groundwater monitoring in 2011 did not show new groundwater impacts from the basins.



Three pump-and-treat systems reduce the amount of hexavalent chromium entering the Columbia River from 100-KR-4. The concentrations and size of the main plume have declined as a result of remediation.

100-NR-2

Principal groundwater issues for 100-NR-2 include remediation of strontium-90 and RCRA monitoring. The major liquid waste sites have been remediated, and excavation is continuing at remaining waste sites.

The primary groundwater contaminant is strontium-90, which originated at the 116-N-1 and 116-N-3 waste sites. Strontium-90 tends to bind to sediment grains, and the shape and size of the plume does not change significantly from year to year. Pump-and-treat technology was found to be ineffective in cleaning up strontium-90; so DOE is applying an in situ technology, apatite sequestration. The goal is to create a reactive zone in the aquifer that captures strontium-90 as groundwater flows through it to the Columbia River. Apatite-forming chemicals were injected into a line of wells along the river shoreline several times since 2006. As the injected chemicals reacted with the aquifer and sediments, strontium-90 levels temporarily increased in downgradient wells and aquifer tubes. Subsequently, strontium-90 and gross beta concentrations declined. DOE expanded the barrier by 183 meters with additional injections in fall 2011.

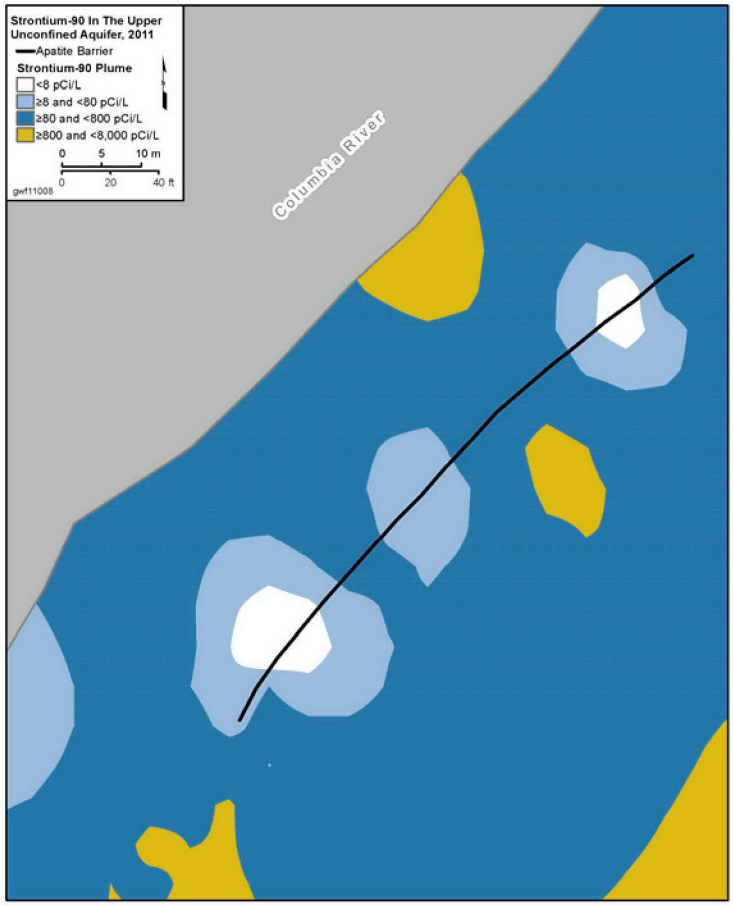
Other groundwater contaminants include nitrate and total petroleum hydrocarbons. Tritium concentrations have declined below the drinking water standard in recent years.

In 2011, RCRA monitoring continued under detection programs at the 1301-N, 1324-N/NA, and 1325-N facilities (waste sites 116-N-1, 120-N-1, 120-N-2, and 116-N-3). Results indicated no releases of dangerous waste constituents from the RCRA units.

In 2011, DOE released an RI/FS work plan addendum and drilled 8 boreholes that were completed as wells. Soil and water samples were collected from each of the boreholes during drilling.

100-HR-3

The 100-D and 100-H Areas, and the 600 Area between them, are combined into 100-HR-3. Remediation of waste sites continued in 2011. Hexavalent chromium is the primary contaminant of concern for groundwater, and a large plume extends from 100-D to 100-H Area. Hexavalent chromium also was detected at relatively high levels within the Ringold upper mud unit beneath 100-H, unlike elsewhere in the 100 Areas. Additional groundwater contaminants include strontium-90 and nitrate.



DOE injected chemicals into a line of wells along the river shore in 100-NR-2, creating a treatment zone in the aquifer. As contaminated groundwater flows through this zone, strontium-90 binds to the sediment grains before it can reach the river.

Pump-and-treat systems remove hexavalent chromium contamination from the groundwater as part of an interim action. Between 1997 and 2011, these systems removed 1,215 kilograms of hexavalent chromium. The new DX pump-and-treat system began to operate in December 2010 and the new HX system in October 2011. In 2011, the DX system alone removed nearly as much chromium as the older, lower-capacity 100-HR-3 system removed in its entire period of operation. Maximum concentrations have declined more than 75 percent in some areas.

DOE is remediating part of the southern 100-D Area hexavalent chromium plume using a permeable reactive barrier that immobilizes chromium in the aquifer. However, data from recent years indicate that contamination is breaking through in some areas of the barrier. New extraction wells downgradient of the barrier will remediate this contamination as part of the DX pump-and-treat system.

DOE expanded pump-and-treat systems in 100-HR-3 in 2010 and 2011. Treatment capacity is now 7.6 million liters per day. Since 1997, the systems have removed 1,215 kilograms of hexavalent chromium from the groundwater.

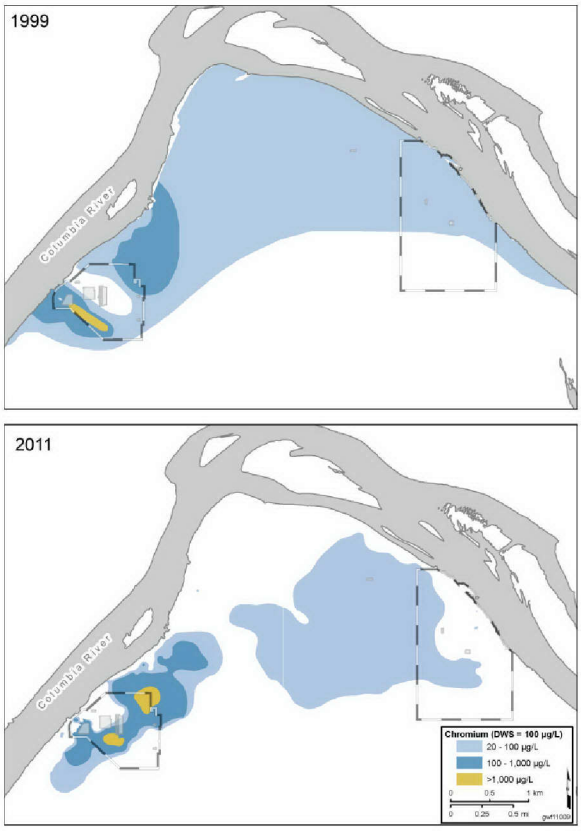
The CERCLA process is underway to make final cleanup decisions for 100-HR-3. Remedial investigations in 2010 and 2011 included installing 15 wells and 10 boreholes and characterizing the vadose zone and groundwater. During the remedial investigation, hexavalent chromium was identified farther south in 100-D Area than previously indicated. This new information will be evaluated in the FS.

The former 183-H solar evaporation basins (waste site 116-H-6) constitute the only RCRA site in 100-HR-3. The site is monitored in accordance with RCRA corrective action requirements during the post-closure period to track contaminant trends during operation of the CERCLA interim action for chromium. Concentrations of waste indicators increased in 2011.

100-FR-3

Groundwater contamination in 100-FR-3 originated from disposal of solid and liquid waste associated with operation of the water-cooled F Reactor and biological experiments. Nitrate concentrations in groundwater exceed the drinking water standard beneath much of the 100-F Area and a large region downgradient. Smaller plumes of hexavalent chromium, strontium-90, and trichloroethene are present. Strontium-90, hexavalent chromium, and trichloroethene concentrations are declining; and nitrate concentrations are stable. Uranium was detected at a level above the drinking water standard in a new well that was drilled through a former waste site.

Nearly all of the former waste sites have been excavated and backfilled under a ROD for interim action. No groundwater interim action was required. Remedial investigation field studies were completed in 2011, and DOE is developing alternatives for final waste site and groundwater cleanup.



A large hexavalent chromium plume is present in 100-HR-3. The size of the plume has decreased since 1999 due to groundwater remediation, discharge to the Columbia River, and dispersion. However, high concentrations remain in 100-D Area groundwater. DOE expanded the pump-and-treat systems in 2010 and 2011 to remediate the plumes.

300-FF-5

Three geographic regions comprise 300-FF-5: the 300 Area Industrial Complex, the 618-11 Burial Ground region, and a region including the 618-10 Burial Ground and 316-4 Cribs. Most of the liquid waste sites have been remediated.

Contaminants of concern in 300 Area groundwater are uranium, trichloroethene, and *cis*-1,2-dichloroethene. Uranium has persisted longer than expected, and concentrations remain above the drinking water standard (30 µg/L) in 300 Area groundwater. Another area of uranium contamination developed downgradient of a burial ground as a result of waste site remediation in 2007 and 2008. This plume has migrated downgradient and is merging with the larger uranium plume. Trichloroethene concentrations increased to levels above the drinking water standard in a few wells screened in the upper part of the unconfined aquifer in 2011. Higher concentrations were detected in groundwater samples collected from a deeper, finer-grained sediment during the RI, but only in a limited area. This sediment produces little water, so none of the monitoring wells are screened in it. However, at aquifer tube sites along the Columbia River, at least one aquifer tube is screened in this finer-grained sediment, and sampling reveals trichloroethene contamination.

Concentrations of uranium, trichloroethene, and cis-1,2-dichloroethene are relatively constant or gradually decreasing in 300-FF-5.

Groundwater downgradient of the 618-11 Burial Ground contains a high-concentration tritium plume, likely originating from irradiated material in the burial ground. Concentrations at a well adjacent to the burial ground have decreased from the peak values, and the plume has maintained its basic shape since its discovery in 1999. Concentrations are stable in the central portion of the plume, while increasing slightly at the downgradient edge of the plume, reflecting migration to the east.

Remedial investigation activities continued in 2011. Eleven wells and five boreholes were installed in 2010 and 2011. DOE issued a draft RI report and proposed plan in 2011 that will support remedy selection.

RCRA groundwater monitoring continued at the 300 Area Process Trenches (waste site 316-5). The unit is monitored in accordance with post-closure corrective action requirements. In June 2011, uranium concentrations increased sharply near the southern end of the trenches. The temporary increase likely was caused by mobilization of deep vadose zone contamination by the seasonal high water table.

The uranium plume in 300-FF-5 is attenuating slowly. DOE is investigating alternatives for more rapid remediation.

1100-EM-1

The only portion of the River Corridor for which final cleanup decisions have been made is 1100-EM-1. This operable unit was removed from the National Priorities List in 1996. The selected remedy for groundwater was monitored natural attenuation of volatile organic compounds, with institutional controls on drilling of new water supply wells. Trichloroethene was the primary contaminant of concern, but concentrations have remained below the cleanup level since 2001.

Wells in the North Richland Well Field are monitored frequently to detect any changes in potential Hanford Site contaminants near these wells. Tritium associated with the plume originating from sources in the 200 East Area has not been detected in these wells.

Uranium concentrations in wells downgradient of DOE's inactive Horn Rapids Landfill have slowly been increasing since 1996 but remained below the drinking water standard in 2011. The presence of uranium at these locations is likely associated with the plume moving northeast from an offsite facility.

Columbia River

Groundwater discharges to the Columbia River via riverbank springs and areas of upwelling in the river bed. DOE has taken actions to protect Columbia River and groundwater, including the following:

- Ceasing discharge of all unpermitted liquids in the central Hanford Site
- Remediating the former liquid waste sites in the 100 and 300 Areas to reduce the potential for future groundwater contamination
- Containing groundwater plumes and reducing the mass of primary contaminants through remedial actions such as pump-and-treat.

DOE samples Columbia River water, river sediment, and riverbank seeps to determine the extent of Hanford Site or other contaminants. The data provide a historical record of radionuclides and chemicals in the environment. Concentrations of tritium and uranium in river water downstream of the Site are slightly higher than upstream of the Site, but meet water quality standards. Concentrations of other contaminants are no higher in downstream samples.

The 100 Area and 300 Area component of DOE's River Corridor baseline risk assessment addresses post-remediation, residual contaminant concentrations in these areas, as well as the Hanford and White Bluffs town sites. The assessment is also investigating the risks related to the potential transport of Hanford Site contaminants into Columbia River riparian and near-shore environments adjacent to the operational areas.

DOE completed an investigation of Hanford Site contaminant releases in the Columbia River in 2010. Samples were collected of pore water (i.e., groundwater upwelling beneath the river bottom into the space between rocks and sediment of the river bed), river sediment, river water, fish, and island soil. Pore water in some of the 100 Area samples had concentrations of hexavalent chromium above the aquatic standard, and strontium-90 exceeded the drinking water standard in some 100-N Area samples. Tritium concentrations exceeded the drinking water standard in some pore water samples near the former Hanford town site, and uranium near the 300 Area. The information obtained from this investigation will ultimately be used to help make final cleanup decisions for Hanford Site contaminants that exist in and along the Columbia River.

Central Plateau

When the Hanford Site was operating, irradiated fuel reprocessing, isotope recovery, and associated waste management activities occurred in the 200 East and 200 West Areas in the central portion of the Site. For the purpose of Site cleanup, this region is defined as the Central Plateau and is divided into Inner and Outer Areas. The Inner Area is the final footprint area of the Hanford Site that will be dedicated to waste management and containment of residual contamination, while the Outer Area is the remainder of the Central Plateau. Contaminant sources included unlined cribs, trenches, and ponds, and leakage from underground storage tanks, and other unplanned releases. The table on the following page summarizes information about the Central Plateau.

Groundwater in the unconfined aquifer beneath the Central Plateau generally flows from upland areas in the west toward the regional discharge areas along the Columbia River. The flow of water divides

beneath the 200 East Area, with some water flowing toward the north through Gable Gap and some flowing southeast. Previous effluent discharges caused groundwater mounds to form beneath the 200 Area that significantly affected regional flow patterns in the past. These discharges largely ceased in the mid-1990s, and water levels declined; but remnants of groundwater mounds remain.

Central Plateau Overview

Area	Primary Operations	Status of Groundwater ROD	Groundwater Remedial Action	Groundwater Contamination: Maximum Concentration and Plume Area									
				Carbon Tetrachloride	Chromium	Cyanide	Iodine-129	Nitrate	Strontium-90	Trichloroethene	Technetium-99	Tritium	Uranium
200-ZP-1	T Plant (Pu separation) 1944-1956; Pu Finishing Plant: 1949-1969	Signed 2008	Interim action carbon tet. P&T: 1995-present; Soil vapor extraction 1991-present. Final remedy P&T to begin in 2012			<DWS			<DWS				<DWS
200-UP-1	REDOX Plant (Pu separation) 1952-1967; U Plant (U recovery) 1952-1957	Expected 2012	Interim action U plant Tc-99 & U: 1994-2011; Interim action S-SX P&T to begin 2012	See 200-ZP-1		N			<DWS				
200-BP-5	B Plant Pu separation: 1945-1952; B Plant Sr and Cs recovery: 1967-1985	Expected 2016	Perched aquifer P&T test: 2011	N						<DWS			
200-PO-1	PUREX Plant Pu separation: 1956-1972 and 1983-1989	Expected 2016	Vadose zone desiccation test: 2011	<DWS	<DWS	<DWS				<DWS			
Standards				5 ug/L	48 ug/L	200 ug/L	1 pCi/L	45 mg/L	8 pCi/L	5 ug/L	900 pCi/L	20,000 pCi/L	30 ug/L
Mobility in subsurface				Multi-phase	High to Moderate	Moderate	High	High	Slight	Moderate	High	High	Moderate

Legend

Colors indicate maximum concentration in 2011
- ≥1000 x standard
- ≥100 x standard and <1000 x standard
- ≥10 x standard and <100 x standard
- ≥Standard and <10 x standard

N Not detected or not analyzed

Height of bar indicates plume area above standard (km²)
- >10
- >1 and ≤10
- >0.1 and ≤ 1
- >0, ≤0.1

ABBREVIATIONS
DWS Drinking water standard P&T Pump and treat system ROD Record of decision

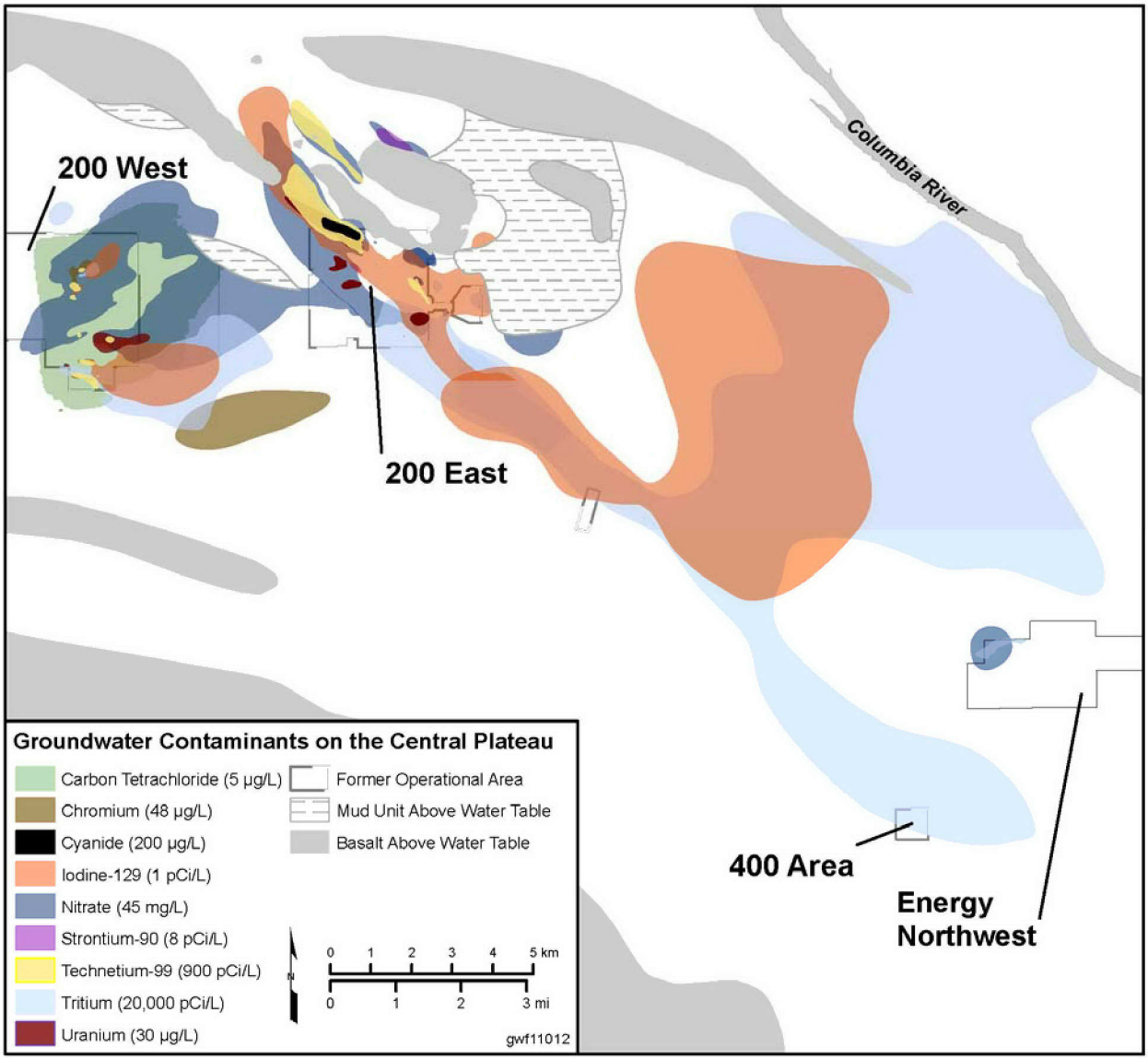
There are seven single-shell tank waste management areas in the 200 Area. Some of these tanks have leaked, contaminating the vadose zone and groundwater beneath the tanks. To minimize additional leaks, DOE has removed the drainable liquid in all of the single-shell tanks.

The vadose zone is up to 50 meters thick beneath the Central Plateau. Portions of it are contaminated with hazardous and radioactive waste. DOE is studying ways to clean up the deep vadose zone to prevent additional contaminants from reaching groundwater.

Waste sites in the Central Plateau currently are a lower priority for cleanup than waste sites in the River Corridor because they are farther from the Columbia River and pose less risk to human and ecological receptors. Remediation of the Central Plateau waste sites is expected to accelerate after River Corridor remediation is complete. Until then, cleanup activities on the Central Plateau focus on completing decision documents, remediating groundwater plumes, decontaminating and decommissioning facilities, and beginning to clean up waste sites in the Outer Area.

Groundwater contaminant plumes of tritium, iodine-129, and nitrate formed when the waste discharged to ponds and cribs reached the aquifer. These contaminants form regional plumes originating on the Central Plateau. The tritium and nitrate plumes have shrunk over the years as a result of dispersion

and radioactive decay. A large carbon tetrachloride plume originated in 200 West Area. This plume is expanding at the edges, but the high-concentration core is contained by a pump-and-treat system. Other groundwater contaminants in the Central Plateau include technetium-99, uranium, strontium-90, trichloroethene, and cyanide.



Large plumes of tritium and iodine-129 originated on the Central Plateau and moved to the east and southeast. Carbon tetrachloride and nitrate also form large plumes. Other contaminants are present in smaller areas.

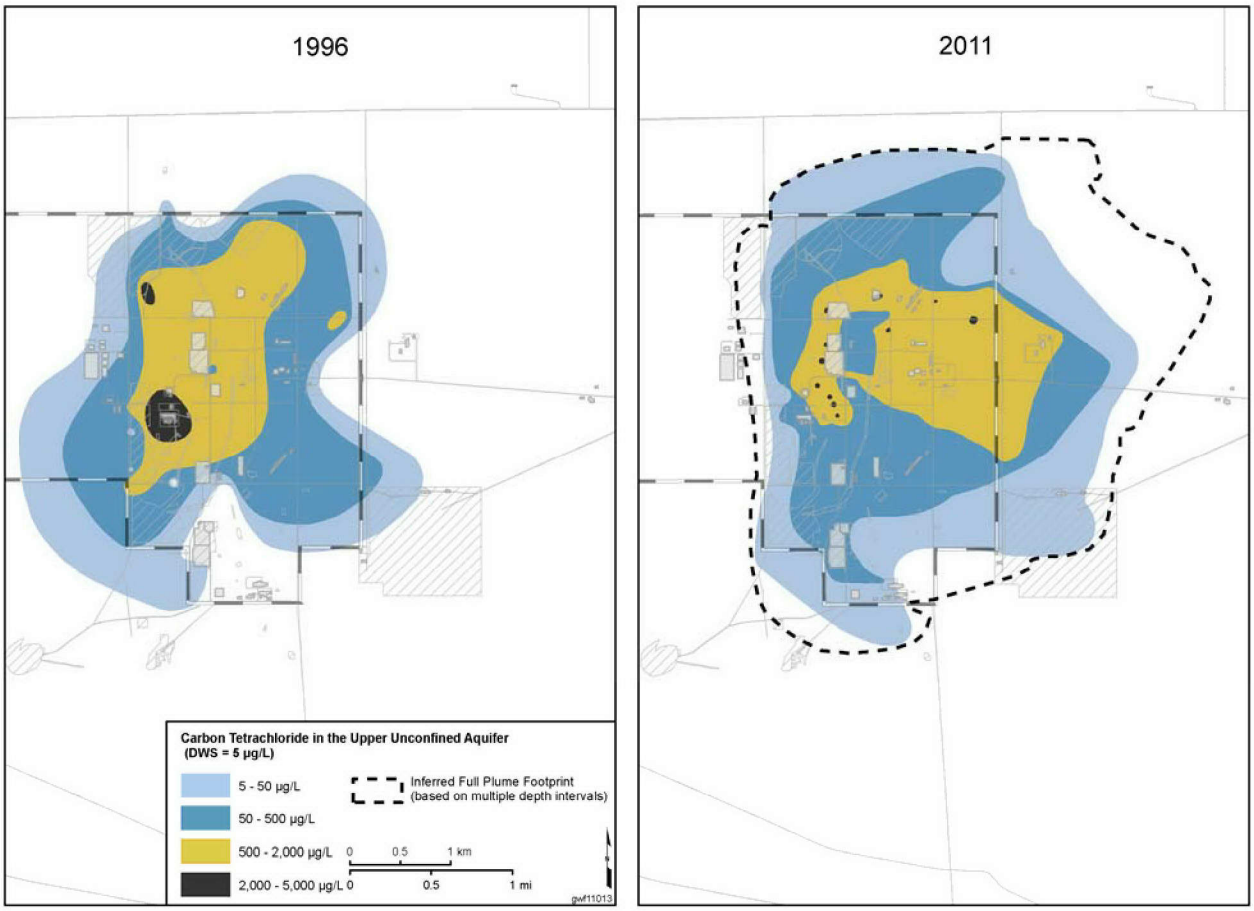
200-ZP-1

Contaminant sources in 200-ZP-1, located in 200 West Area, included cribs, ponds, and single-shell storage tanks. A final ROD for 200-ZP-1 groundwater identified carbon tetrachloride as the primary contaminant of concern. Other contaminants of concern are trichloroethene, iodine-129, technetium-99, nitrate, hexavalent chromium, total chromium, and tritium. Groundwater studies in recent years have improved DOE's knowledge of the complex, vertical distribution of carbon tetrachloride. Contamination occurs at increasing depth to the east (downgradient) of the source areas in 200-ZP-1.

Groundwater and vadose zone remediation systems have removed more than 93,000 kilograms of carbon tetrachloride from groundwater. That's equivalent to the weight of 30 full-size pickup trucks.

Drillers installed six injection wells in 2011 in support of the final ROD. When completed, the network will include 36 injection and extraction wells. These wells will support the new pump-and-treat system, which will remediate groundwater from the entire aquifer thickness. Construction activities for the new treatment facility were completed in 2011, and the system will be operational in 2012.

Since 1994, DOE has operated an interim action pump-and-treat system to prevent carbon tetrachloride in the upper portion of the aquifer from spreading. The system is limiting movement of the shallow, high-concentration portion of the plume but does not address contamination deeper in the aquifer and at the periphery of the plume. The system has removed 13,500 kilograms of carbon tetrachloride from groundwater. Soil vapor extraction systems have removed an additional 79,945 kilograms since 1992. Other pump-and-treat systems (200-UP-1 and Waste Management Area [WMA] T) have removed more than 220 kilograms.



The color shading on these maps of 200 West Area illustrates the carbon tetrachloride plume in the upper portion of the unconfined aquifer in 1996 (before interim remediation began) and in 2011. The dashed line on the 2011 map shows the full extent of the plume at all depths, based on data collected in recent years.

A second interim remediation, pump-and-treat test system has operated since 2007 to remove technetium-99 contamination downgradient of WMA T. During 2011, the system has extracted 13.3 grams (0.23 curies) of technetium-99, 57.9 kilograms of carbon tetrachloride, 6.9 kilograms of chromium, 405 grams of trichloroethene, and 23,024 kilograms of nitrate from the aquifer.

DOE conducted a treatability test in 2011 using one of the soil vapor extraction systems and associated vadose zone wells. The purpose of the test was to evaluate the flux of carbon tetrachloride from the vadose zone to the groundwater to assess the soil vapor concentrations to ensure that they are protective of groundwater. Results are currently being evaluated.

Two Low-Level Waste Management Areas (LLWMA) in 200-ZP-1 are monitored under RCRA interim-status, contaminant indicator parameter programs. At LLWMA-3, upgradient/downgradient comparisons have not been conducted in recent years because the upgradient wells were dry. A new upgradient well was installed in 2011, which will allow statistical evaluations to resume. No significant changes occurred at LLWMA-4 in 2011.

RCRA assessment monitoring continued at WMA T and WMA TX-TY. The concentrations and extent of dangerous waste constituents from these facilities are declining.

The State-Approved Land Disposal Site (SALDS) receives treated water from the Hanford Site's Effluent Treatment Facility. It is regulated under a state waste discharge permit. The declining water table in 200 West Area has caused several of the SALDS monitoring wells to go dry over the years, including two additional wells during 2011. This issue is being addressed during the permit renewal process.

200-UP-1

The southern portion of the 200 West Area and adjacent areas to the east and south comprise 200-UP-1. Contaminant sources included cribs, ponds, and single-shell tanks. Carbon tetrachloride, technetium-99, uranium, tritium, iodine-129, nitrate, and chromium plumes are present in groundwater. Strontium-90 and trichloroethene also exceed drinking water standards in some areas. Carbon tetrachloride originated from sources in 200-ZP-1. The technetium-99 plume area has decreased substantially at the U Plant pump-and-treat system, but the plume near WMA S-SX has grown. The tritium plume is attenuating due to dispersion and radioactive decay. The areal extents of other plumes have remained unchanged or have decreased slightly since 2003.

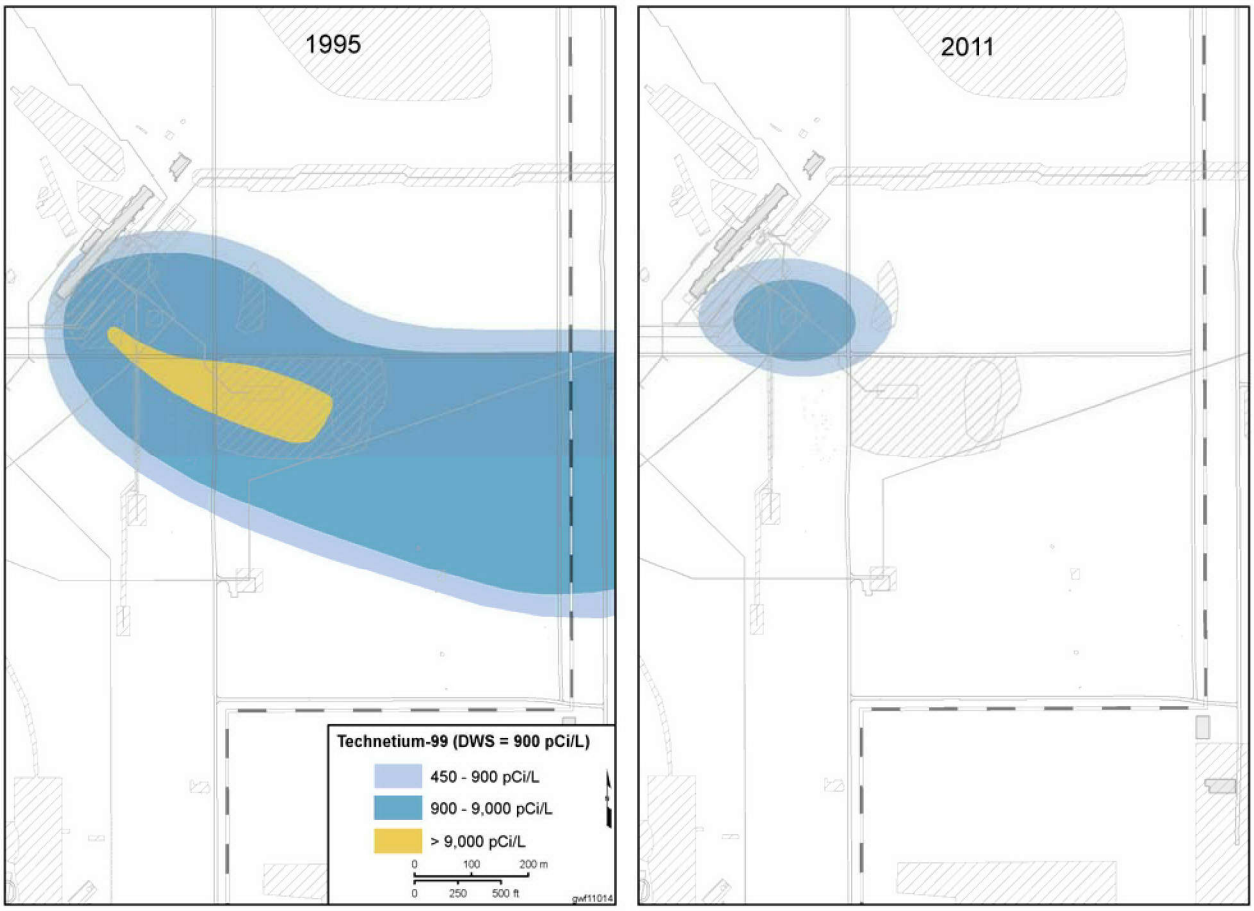
In 2011, DOE and EPA resolved comments concerning the technical approach and administrative strategy for remedial actions. Rather than including 200-UP-1 remedial actions in the existing 200-ZP-1 ROD (by amendment), DOE and EPA agreed that a separate ROD would be prepared for 200-UP-1. This ROD is expected to contain interim actions for all 200-UP-1 contaminants of concern.

Technetium-99 concentrations in 200-UP-1 groundwater are the highest on the Hanford Site. Pump-and-treat remediation has addressed one plume, but another plume near WMA S-SX has grown. A new pump-and-treat system will address that plume.

A CERCLA pump-and-treat system is being installed to remediate the technetium-99 plumes from WMA S-SX. Drillers installed three extraction wells in 2011. This system will replace extended purging of a monitoring well, which has removed ~0.011 curie (~0.63 gram) of technetium-99 since 2003.

During 2011, the U Plant interim action pump-and-treat system operated until March, when it was shut down in accordance with an agreement between DOE and EPA. Flow rates from extraction wells had decreased due to regional decline of the water table and reduced well efficiency. Since startup in 1994, the pump-and-treat system removed 220.5 kilograms of uranium and 127.4 grams of technetium-99. Overall, the U Plant pump-and-treat system achieved its objectives. The interim remedial action goal of

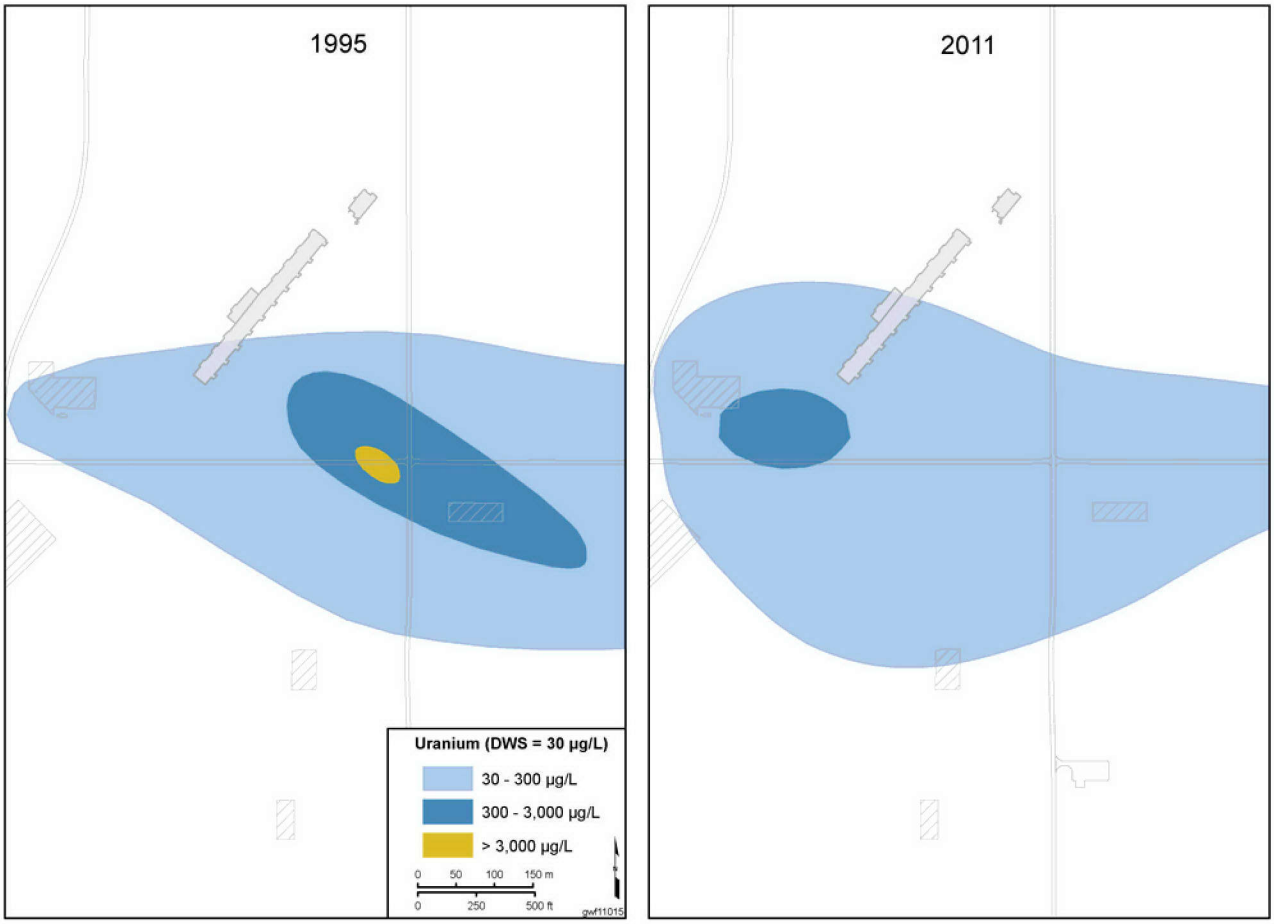
9,000 pCi/L for technetium-99 was achieved in 2005, and the goal of 300 µg/L for uranium was achieved in 2009. The final remedy for 200-UP-1 will address further remediation of the groundwater contaminant plumes.



A pump-and-treat system operated in 200-UP-1 as an interim action from 1994 until 2011. Remediation reduced the size of the technetium-99 plume.

RCRA monitoring in 200-UP-1 included interim status groundwater quality assessment monitoring at WMA S-SX and WMA U, and interim status indicator parameter evaluation monitoring at the 216-S-10 Pond and Ditch. Revised monitoring plans were implemented at WMA S-SX and WMA U in 2011. Monitoring results did not show major changes in the extent of contamination. Indicator parameters did not exceed statistical comparison values at the 216-S-10 Pond and Ditch during 2011.

The Environmental Restoration Disposal Facility is a low-level radioactive mixed waste landfill used for disposal of waste from surface remedial actions on the Hanford Site. The results of groundwater monitoring in 2011 continued to indicate that the facility has not adversely affected groundwater quality.



Uranium contaminant in 200-UP-1 did not respond to the pump-and-treat system as rapidly as technetium-99. Uranium interacts with aquifer sediment, slowing its movement and response to remediation. Interim remedial actions goals have been achieved for both contaminants.

200-BP-5

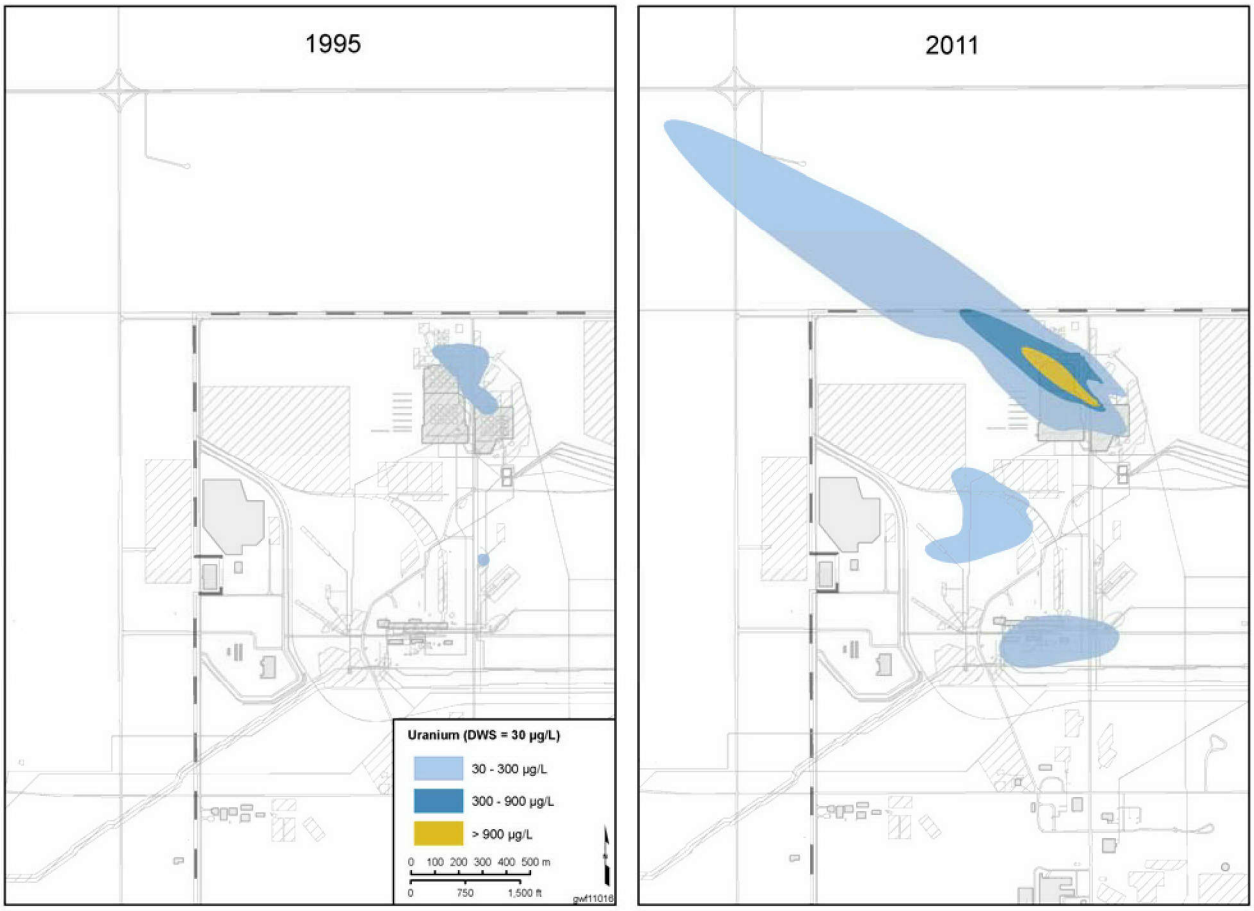
The 200-BP-5 operable unit includes groundwater beneath the northern 200 East Area and the region to the northwest where mobile contaminants have migrated between Gable Mountain and Gable Butte. Most of the groundwater contamination is concentrated beneath WMA B-BX-BY and adjacent waste sites in the northwestern portion of the 200 East Area. Cleanup decisions for 200-BP-5 are yet to be made, and preparation of a draft remedial investigation report began in 2011.

Wells in 200-BP-5 have the highest uranium concentrations in groundwater on the Hanford Site. DOE is testing methods to remove this contamination from the vadose zone and groundwater.

Nitrate, iodine-129, technetium-99, and tritium form the largest contaminant plumes in 200-BP-5. These mobile contaminants have migrated to the northwest as a result of past groundwater flow. The tritium plume has shrunk significantly, but the other large plumes have either grown or remained stable over the past decade. Cyanide and uranium are present in smaller plumes that have increased in size since 2002. A strontium-90 plume has decreased in size, and low-mobility contaminants cobalt-60, cesium-137, and plutonium-239/240 are present only near their former sources.

Scientists and engineers have designed a treatability test to evaluate pumping and treating groundwater to remediate uranium and technetium-99 contaminant plumes near WMA B-BX-BY. In 2011, drillers began to install an extraction well to support the test.

A fine-grained geologic unit beneath the B Plant region has created an area of saturated sediments (a "perched" aquifer) in the deep vadose zone above the regional water table. This perched water is contaminated with uranium and other contaminants at concentrations higher than in the underlying aquifer. In 2011, DOE began pumping to remove this perched water before it reaches groundwater. The pumping successfully removed ~95,000 liters of contaminated, perched water. Plans for a treatability test to use enhanced methods for continued pumping of perched water and pore water were completed in 2011.



A uranium plume with sources in WMA B-BX-BY began to develop in the late 1990s.

RCRA interim-status, indicator evaluation monitoring continued at LLWMA-1, LLWMA-2, and the 216-B-63 Trench with no significant changes in 2011. Assessment monitoring continued at WMA B-BX-BY, and WMA C; and results were consistent with previous years. The WMA B-BX-BY assessment plan will be revised in 2012 to incorporate the results of the recent CERCLA RI and the addition of new monitoring wells.

DOE monitors the Liquid Effluent Retention Facility under a RCRA final-status detection program. Monitoring results in 2011 indicated that all required constituents were undetected or below drinking water standards except for nitrate, which is from a regional plume. Drillers installed a new characterization well near this facility in 2011.

200-PO-1

The southern portion of the 200 East Area and a large region of the Hanford Site to the east and southeast comprise 200-PO-1. Disposal of large volumes of liquid waste created regional groundwater plumes of tritium, iodine-129, and nitrate. Concentrations of tritium are declining as the groundwater plume attenuates naturally as a result of radioactive decay and dispersion. The size of the tritium plume has decreased by one-third since 1980. The area of the iodine-129 plume above the 1 pCi/L contour has decreased slightly over the past decade, and maximum concentrations have declined significantly as a result of dispersion. Radioactive decay has not decreased the level of iodine-129 contamination noticeably because this isotope has a half-life of 15.7 million years. The nitrate plume covers a large area, with concentrations above background but mostly below the drinking water standard. Other contaminants in 200-PO-1 include strontium-90, technetium-99, and uranium in smaller areas near their sources.

DOE conducted a CERCLA remedial investigation in 200-PO-1 in 2008 and 2009. DOE submitted a draft RI report to Ecology in 2010 (DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*).

The tritium and iodine-129 plumes from sources in 200-PO-1 are the largest on the Hanford Site, having migrated more than 15 kilometers.

In 2011, a soil desiccation treatability test was conducted in an interval containing high moisture and associated technetium-99 contamination near the BC Cribs and Trenches. This technology is being considered as a remedy for contamination in the deep vadose zone. For approximately six months, nitrogen was injected into a well; and soil gas was extracted from another well. A combination of in situ sensors and geophysical measurements provided data to monitor performance. As anticipated, desiccation occurred more rapidly from higher-permeability sediment. The active portion of the test was completed, and DOE continues to monitor rewetting of the desiccated region. A comprehensive report will be issued in 2012.

RCRA assessment monitoring continued in 2011 at WMA A-AX, and data were consistent with previous results. RCRA indicator parameter monitoring continued at the 216-B-3 Pond. Monitoring results provided no indication of releases from this facility to groundwater.

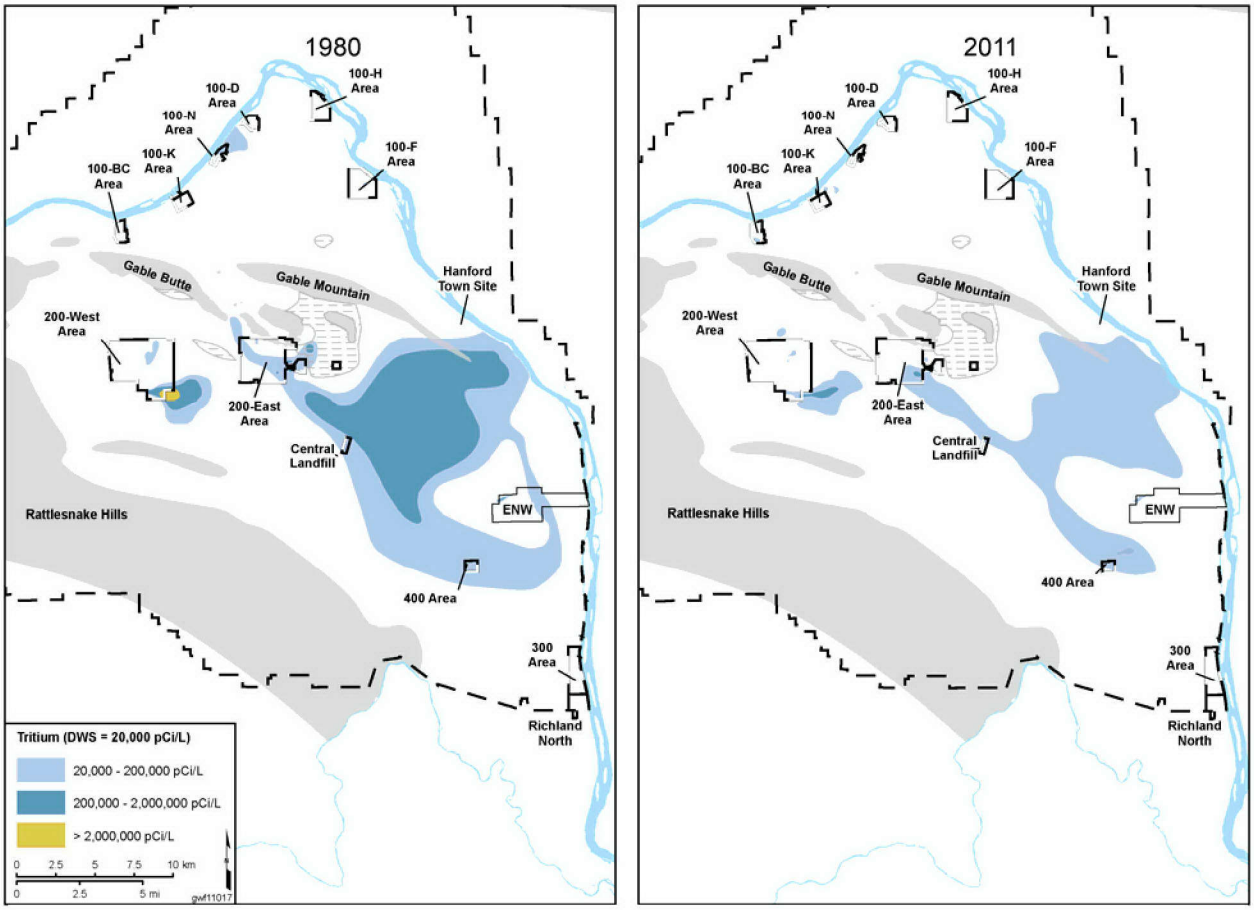
The Integrated Disposal Facility is an expandable, double-lined landfill that is regulated under RCRA and the AEA. It is not yet in use, and current groundwater monitoring is directed at obtaining baseline data.

New RCRA groundwater monitoring plans were implemented in 2011 at the 216-A-36B Crib and the 216-A-37-1 Crib. Background samples were collected so that critical mean values of contamination indicator parameters can be established.

The Treated Effluent Disposal Facility is a state-permitted liquid waste site. The uppermost aquifer beneath this facility is confined beneath the Ringold Formation lower mud unit. Groundwater monitoring is performed to demonstrate that the mud unit continues to protect the confined aquifer from potential impacts of discharges from the facility. The Permit is currently undergoing renewal; in the draft revised permit, it is proposed that groundwater monitoring be discontinued and the effluent monitored prior to discharge to the facility to comply with the Permit.

During 2010, DOE submitted a combination groundwater monitoring plan for the Nonradioactive Dangerous Waste Landfill and the adjacent Solid Waste Landfill to Ecology for review. Until that plan is approved and implemented, the Nonradioactive Dangerous Waste Landfill continues to be monitored under a RCRA detection program. Specific conductance in downgradient wells continued to exceed the

critical mean during 2011 but was previously determined to be caused by nonhazardous groundwater constituents from the nearby Solid Waste Landfill.



Hanford Site tritium plumes are gradually shrinking as concentrations decline as a result of radioactive decay, dispersion, and discharge to the Columbia River. Since 1980, the area of the plume has decreased by ~35%, and the maximum concentration has declined 90 percent.

The Solid Waste Landfill is regulated under Washington State solid waste handling regulations. As in previous years, some of the downgradient wells showed higher concentrations of regulated constituents than the statistically calculated background threshold values. Background threshold values exceeded during 2011 included coliform bacteria, pH, specific conductance, nitrite, sulfate, and total organic carbon.

Three water supply wells provide drinking water and serve as an emergency water supply for the 400 Area, which is in the footprint of 200-PO-1. Because the 400 Area is in the path of the Hanford Site-wide tritium plume, DOE routinely monitors the wells for tritium. These wells are screened deep in the unconfined aquifer, just above the Ringold lower mud unit. The 2011 sampling event was delayed until January 2012; concentrations were below the drinking water standard.

Confined Aquifers

Although most Hanford Site groundwater contamination is found in the unconfined aquifer, DOE monitors wells in deeper aquifers because of potential downward movement of contamination and potential migration of that contamination off site through the confined aquifers. There is no evidence of offsite migration via the confined aquifers.

One confined aquifer occurs within sand and gravel at the base of the Ringold Formation. Carbon tetrachloride, nitrate, and technetium-99 have contaminated this unit in a portion of 200 West Area where the upper confining unit is absent. New wells have been installed in recent years to monitor and remediate this contamination. The Ringold confined aquifer is the uppermost aquifer in a region east of 200 East (within portions of 200-BP-5 and 200-PO-1). Iodine-129 and tritium are detected in wells at this location, but the contamination has not migrated to wells farther downgradient.

In the northern Hanford Site, fine-grained sedimentary units informally called the Ringold upper mud confine deeper sediments in the Ringold Formation. This unit is contaminated with hexavalent chromium in some parts of 100-HR-3.

Groundwater within basalt fractures and joints, interflow contacts, and sedimentary interbeds make up the upper basalt-confined aquifer system. No significant contamination is detected in the basalt-confined aquifer, except in the northwestern 200 East Area, where poor well construction and temporary drilling effects allowed local migration of groundwater from the overlying unconfined aquifer.

Wells

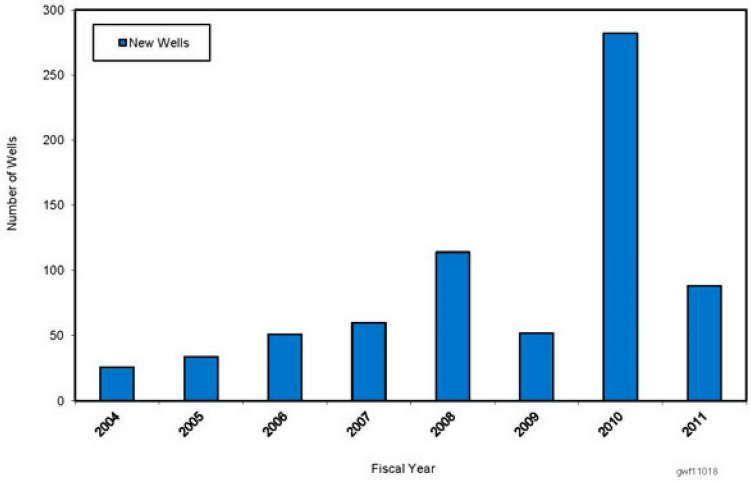
Over the lifetime of the Hanford Site, DOE has installed thousands of wells to monitor and remediate groundwater and provide geologic data. During 2011, DOE installed 89 new wells, primarily in support of RI studies or groundwater remediation.

During 2011, 49 direct-push and characterization boreholes were installed. The boreholes supported subsurface characterization of radiological constituents, volatile organics (e.g., carbon tetrachloride), or vadose zone properties (e.g., moisture content or grain-size distribution). The boreholes were decommissioned after data collection was complete.

DOE identifies wells, boreholes, or other subsurface installations for decommissioning when they are no longer needed. In 2011, 108 wells were physically decommissioned. This involved sealing the wells in compliance with Washington State groundwater protection laws. In additional to the physical decommissioning, 13 wells were administratively decommissioned. These wells could not be located and investigation showed they no longer exist.

Wells Installed in 2011

Location	Number of New Wells
100-BC-5	6
100-KR-4	15
100-NR-2	8
100-HR-3	25
100-FR-3	2
200-ZP-1	6
200-UP-1	4
200-BP-5	1
200-PO-1	2
300-FF-5	20
Total	**89**



New wells are installed to characterize, monitor, and remediate groundwater.

Conclusions

The items below highlight the primary conclusions based on Hanford Site groundwater monitoring in 2011.

- Decades of waste disposal have contaminated a large area of the Hanford Site's groundwater. The largest contaminant plume—tritium, from waste sites on the Central Plateau—is decreasing in size due to radioactive decay and dispersion. Hexavalent chromium is the primary concern in the River Corridor.
- Groundwater flows toward the Columbia River and is the primary exposure route for contaminants to reach human, environmental, and ecological receptors.
- More than half of the former waste sites in the River Corridor have been remediated or are classified as not needing remediation under interim records of decision. The rest of the waste sites will be remediated in the next few years. Thus, potential sources of additional groundwater contamination are being removed from the region that poses the greatest threat to the Columbia River. Remedial investigations have collected data to determine appropriate remedies for remaining vadose zone and groundwater contamination. The Tri Parties (Ecology, EPA, and DOE) will develop final RODs for the River Corridor units in coming years.
- Interim remediation of hexavalent chromium contamination in 100-KR-4 and 100-HR-3 continued in 2011. DOE has expanded pump-and-treat systems in these regions to control larger portions of the plumes. Chromium concentrations in compliance wells remained above cleanup goals, so remediation will continue.
- An in situ remediation method being applied in 100-NR-2 is reducing the amount of strontium-90 discharging to the Columbia River.
- On the Central Plateau, contamination is still present in many parts of the thick vadose zone, and may continue to drain into the groundwater. Remediation of the Central Plateau waste sites and vadose zone will accelerate after River Corridor remediation is complete. Meanwhile, DOE has been remediating groundwater and testing methods to remediate the deep vadose zone.
- Interim remediation of carbon tetrachloride contamination in 200-ZP-1, and the overlying vadose zone (200-PW-1), continued in 2011. Pump-and-treat is being used to clean up groundwater, and soil vapor extraction is being used to clean up the vadose zone. A second pump-and-treat system is being used in 200-ZP-1 to remove technetium-99.
- DOE continued to implement elements of the final remedy to clean up groundwater in 200-ZP-1. A total of 26 wells were installed between 2009 and 2011, and construction of the new groundwater treatment facility was completed in 2011. The new pump-and-treat system will begin to operate in 2012.
- Final cleanup decisions for 200-UP-1, 200-BP-5, and 200-PO-1 are yet to be made. Remedial investigation studies have gathered information to support cleanup decisions in coming years.
- Groundwater discharges to the Columbia River via springs and areas of upwelling. Contaminant concentrations in some springs are above applicable water quality standards. Concentrations are below these standards in river water samples.

Groundwater Contaminants on the Hanford Site

Contaminant	Primary Locations	Plume Area Above Standard (km^2)	Drinking Water Standard	Remediation in Place?	Mobility[a] and Half-Life
Carbon Tetrachloride	200-ZP-1	13.3	5 µg/L	Yes	Mobile and denser than water
Chromium (hexavalent)	100-KR-4, 100-HR-3	5.76	48 µg/L[b]	Yes	Mobile to moderate
Cyanide	200-BP-5	0.24	200 µg/L	No	Mobile
Iodine-129	200 Areas	60.1	1 pCi/L	No	Mobile; 17 million years
Nitrate (as NO_3^-)	200 Areas, 100-FR-3, 100-HR-3, 199-NR-2	37.7	45 mg/L	No[c]	Mobile
Strontium-90	100 Areas, 200-BP-5	1.51	8 pCi/L	Yes in 100-NR-2	Slightly mobile; 28.9 years
Technetium-99	200 Areas	3.1	900 pCi/L	Yes in 200 West[d]	Mobile; 213,000 years
Trichloroethene	100-FR-3, 200-ZP-1	0.90	5 µg/L	Yes in 200-ZP-1	Mobile to moderate
Tritium	200 Area, 300-FF-5, 100-BC-5, 100-KR-4	103	20,000 pCi/L	No	Mobile; 12.3 years
Uranium	200-UP-1, 200-BP-5, 300-FF-5	1.7	30 µg/L	No	Moderate; 240,000 years (U-234), 4.5 billion years (U-238)
Area of combined plumes[e]		**191**			

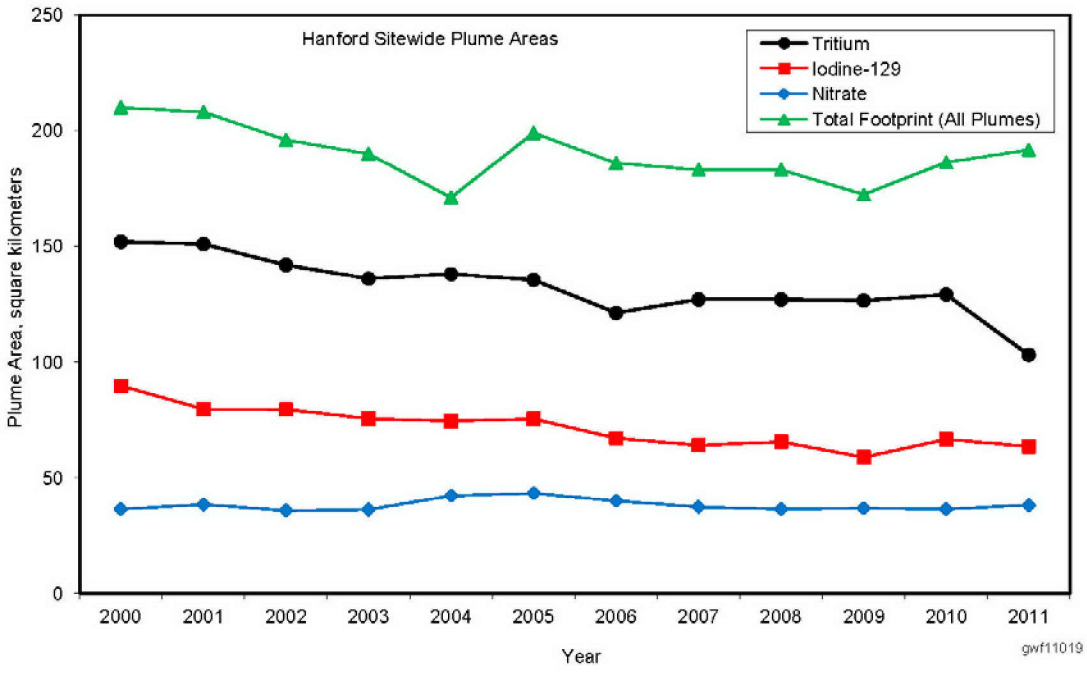
a. "Mobile" means a contaminant moves readily in groundwater. "Moderate" means a contaminant undergoes geochemical reactions in the aquifer and moves slower than the groundwater. "Slight" means a contaminant binds to sediment grains and moves much slower than the groundwater.

b. Washington State "Model Toxics Control Act—Cleanup" (WAC 173-340) groundwater cleanup level

c. Removed from treated water for the 200-ZP-1 pump-and-treat

d. 200-UP-1, WMA S-SX, and WMA T

e. Many plumes overlap so the area of combined plumes is less than the sum of the individual plume areas



The Hanford Site's largest contaminant plumes are tritium, iodine-129, and nitrate. The sizes of the Sitewide tritium and iodine-129 plumes have declined since 2000. Tritium has a half-life of approximately 12 years, so radioactive decay causes concentrations to decline. Iodine-129 has a half-life of 17 million years, so the decline in plume size was mainly caused by advection and dispersion. Nitrate plumes are present in all of the groundwater operable units. The total size of the nitrate plumes has changed very little since 2000.

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List of Terms

AEA	*Atomic Energy Act of 1954*
AWQS	Ambient Water Quality Standard
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	Code of Federal Regulations
DCS	DOE Derived Concentration Standard
DOE; DOE/RL	U.S. Department of Energy; Richland Operations Office
DWS	Drinking Water Standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
FS	feasibility study
HEIS	Hanford Environmental Information System
IDF	Integrated Disposal Facility
ISRM	In Situ Redox Manipulation
LERF	Liquid Effluent Retention Facility
LLWMA	low-level waste management area
LLBG	low-level burial ground
LWDF	liquid waste disposal facility
MTCA	*Model Toxics Control Act*
NAVD88	North American Vertical Datum of 1988
NRDWL	Nonradioactive Dangerous Waste Landfill
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
P&T	pump-and-treat
PUREX	Plutonium-Uranium Extraction (Plant)
PRB	permeable reactive barrier
RCBRA	River Corridor Baseline Risk Assessment
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	Revised Code of Washington
REDOX	Reduction-Oxidation (Plant)
RI	remedial investigation

ROD	Record of Decision
SALDS	State-Approved Land Disposal Site
SST	single-shell tank
SWL	Solid Waste Landfill
TEDF	Treated Effluent Disposal Facility
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
USGS	United States Geological Survey
VOC	volatile organic compound
WAC	Washington Administrative Code
WCH	Washington Closure Hanford
WIDL	Well Information and Document Lookup
WMA	waste management area

1.0 Introduction

M.J. Hartman

The Hanford Site, part of the U.S. Department of Energy's (DOE's) nuclear weapons complex, encompasses ~1,500 square kilometers northwest of the city of Richland along the Columbia River in southeastern Washington State (Figure 1-1). In 1943, as part of the top secret Manhattan Project, the federal government took possession of the Site to build the world's first large-scale plutonium production reactor. It made the plutonium for the Trinity Test and the bomb that was dropped on Nagasaki, Japan, in 1945. Between 1944 and 1963, nine nuclear reactors were built and operated, mainly to produce weapons-grade plutonium.

The Hanford Story: Chapter 1—Overview is a documentary that provides a history of the Hanford Site. Available at: http://www.hanford.gov/page.cfm/HanfordStory.

Large amounts of chemical and radioactive wastes were released into the environment that have contaminated the soil and groundwater beneath portions of the Hanford Site. Groundwater flows towards the Columbia River and is the primary exposure route for contaminants to reach human, environmental, and ecological receptors.

The Hanford Story: Chapter 2—Groundwater provides estimates of the amounts of liquids that were discharged directly into soil, the Columbia River, stored in underground tanks, and quantities of contaminated groundwater. Available at: http://www.hanford.gov/page.cfm/HanfordStory.

Since the 1990s, DOE has worked to characterize, remove, treat, and dispose of contamination from past operations. Key elements associated with managing the Hanford Site's groundwater and vadose zone contamination are to (1) protect the Columbia River and groundwater, (2) develop a cleanup decision process, and (3) achieve final cleanup.

Protect the Columbia River and groundwater. DOE has already taken many actions to protect the Columbia River and groundwater, including the following:

- Cease discharge of all unpermitted liquid effluents
- Remediate former liquid waste sites near the Columbia River to reduce the potential for future groundwater contamination
- Contain groundwater plumes and reduce the mass of primary contaminants through remedial actions such as pump-and-treat.

Develop a process for cleanup decisions. Final decisions will be based on the processes outlined in the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) and/or the *Resource Conservation and Recovery Act of 1976* (RCRA). Other sections of this report describe CERCLA cleanup in more detail.

Attain final cleanup. Substantial progress has been made toward cleanup of waste sites near the Columbia River. Strategies used for making final decisions in these areas will provide a basis for attaining similar final decisions for the central portion of the Site.

Because of the size and complexity of the Hanford Site, DOE has divided it into smaller units or areas of interest.

This report is designed to meet the following objectives:

- ***Describe the 2011 groundwater conditions on the Hanford Site***
- ***Fulfill regulatory reporting requirements***
- ***Summarize the characterization and remediation of the deep vadose zone***
- ***Summarize the installation, maintenance, and decommissioning of Site monitoring wells during 2011.***

- The Site is broadly divided into the **"River Corridor"** and **"Central Plateau"** regions (Figure 1-1). As the names imply, the River Corridor is the portion of the Site located along the Columbia River, and the Central Plateau is in the middle of the Site, at a higher elevation. Groundwater monitoring results for these regions are described in Chapters 2 and 3, respectively.
- The Hanford Site's former **operational areas** were given numerical names (Figure 1-1). These include the 100-BC, 100-K, 100-N, 100-D, 100-H, and 100-F Areas, which housed the nuclear reactors, and the 200 West and 200 East Areas, where chemical separation occurred. This also included the 300 Area, which was home to the fuel manufacturing operations at the Site as well as the experimental and laboratory facilities, and the 400 Area, which housed a research nuclear reactor.
- Waste sites have been sorted into **source operable units**, which include sites that received waste from the same or similar sources. The source operable units include contamination in the vadose zone.
- **Groundwater operable units** include groundwater beneath one or more source operable units, and may include larger regions where contaminated groundwater has migrated.
- The formal groundwater operable units do not cover the entire Hanford Site. Groundwater scientists have defined informal **groundwater interest areas**, which include the groundwater operable units and the intervening regions, to provide scheduling, data review, and data interpretation for the entire Site. Chapters 2 and 3 define the boundaries of the groundwater interest areas.
- **River corridor units** have been defined for making final cleanup decisions. These units combine source and groundwater operable units (Chapter 2).
- The **Central Plateau "Inner Area"** (Figure 1-1) is ~ 26 square kilometers in the middle of the Hanford Site, encompassing the region where chemical processing and waste management activities occurred.
- The **Central Plateau "Outer Area"** (Figure 1-1) has an area of more than 168 square kilometers and includes much of the open area where limited processing activity occurred.

1.1 Purpose and Scope

Hanford Site Groundwater Monitoring for 2011 presents the results of groundwater monitoring, providing the primary means to report monitoring results for RCRA treatment, storage, and disposal units; for CERCLA groundwater operable units where no active remediation is currently taking place; and the *Atomic Energy Act of 1954* (AEA) as required by DOE orders (Table 1-1). This report also provides a summary of deep vadose zone remediation and well installation, remediation, and decommissioning

activities. Appendices A, B, and C provide supporting information on CERCLA, RCRA, and aquifer tube monitoring, respectively. Appendix D reports results of the quality control program.

This report focuses on 2011 monitoring results and changes from the previous year. Details of previous studies (e.g. remedial investigations) are published in separate reports that are cited in applicable chapters of this report. Results are summarized if the information is new for 2011. Readers are referred to other documents for details of hydrogeology, characterization results, detailed conceptual site models, and descriptions of waste sites and the shallow vadose zone. Appendix E (provided electronically) contains a summary of Hanford hydrogeology and geochemistry and is taken from Chapter 2 of *Hanford Site Groundwater Monitoring Report for 2010* (DOE/RL-2011-01).

Results of groundwater remediation in CERCLA groundwater operable units are published in separate annual reports. Information for 2011 is summarized here, and the reports are cited and provided electronically.

Groundwater monitoring objectives of RCRA, CERCLA, and AEA often differ slightly, and the contaminants monitored are not always the same. For RCRA-regulated units, monitoring focuses on nonradioactive dangerous waste constituents. While radionuclides (source, special nuclear, and byproduct materials) may be monitored in some RCRA unit wells to support objectives of monitoring under AEA and/or CERCLA, they are not subject to RCRA regulation. Pursuant to RCRA, the source, special nuclear, and byproduct material components of radioactive mixed waste are not regulated under RCRA but are instead regulated by DOE, acting pursuant to its AEA authority. Therefore, while this report is used to satisfy RCRA reporting requirements, the inclusion of information on radionuclides in such a context is for information only and may not be used to create conditions or other restrictions set forth in any RCRA Permit.

1.2 Groundwater Monitoring

Specific groundwater monitoring plans and sampling and analysis plans define which wells to sample, how often to sample, and how to analyze the samples. These choices are based on the data needs for various monitoring purposes, such as complying with regulations, evaluating the performance of remediation activities, defining plumes and concentration trends, or identifying emerging problems. Chapters 2 and 3 provide references to applicable monitoring documents.

In 2011, staff sampled 924 wells and 280 aquifer tubes for radiological and chemical constituents.

In 2011, staff sampled 924 wells and 280 aquifer tubes. Many of the wells and some of the aquifer tubes were sampled more than once, for a total of 4,173 successful sampling events. These numbers include routine sampling and special sampling (i.e., sampling during drilling of new boreholes, performance monitoring of groundwater remediation systems, etc.).

Chromium (total or hexavalent) was the most frequently analyzed constituent. Nitrate, tritium, iodine-129, metals, technetium-99, strontium-90, and volatile organic compounds (carbon tetrachloride and trichloroethene) were other commonly analyzed constituents (Table 1-2).

Sampling was delayed at many wells because, in January 2011, a sampler received a mild electrical shock from a groundwater pump and all sampling was stopped as a safety precaution. It was determined that electrically controlled sample pumps were not electrically bonded. To reduce the likelihood of repeating this incident, pumps in ~400 wells were electrically bonded and inspected. The remainder of the electric pumps are operated using an approved, temporary bonding device until permanent modifications can be performed. Sampling work resumed on March 23, 2011.

Groundwater contaminant plumes are often illustrated as maps, that is, they are shown as two-dimensional features. The third dimension, distribution of contaminants with depth, also must be considered. Most of the monitoring wells on the Hanford Site are screened near the top of the unconfined aquifer. In many locations, characterization data show that contaminant concentrations are highest in the upper portion of the aquifer. In some cases, for example, the 200 West Area carbon tetrachloride plume, concentrations vary significantly with depth. Cross sections of contaminant distribution have been created for some regions of the Site, often in support of remedial investigations. These cross sections rely on groundwater samples collected from discrete depths during drilling through the entire aquifer thickness. The completed wells usually have a shorter screen, so routine monitoring results represent a single depth from each well. As such, these cross sections cannot be updated based on new monitoring data. Cross sections are supplied here only if new information is available for 2011. In most areas, some 2011 data are available from monitoring wells screened at different depths. More detailed descriptions of vertical distribution of contaminants can be found in remedial investigation reports or other documents cited in the chapters of this report.

In March 2011, staff measured water levels in an extensive network of wells monitoring the unconfined aquifer system and the underlying confined aquifers. In March, the Columbia River typically is at a moderate stage; and the March measurements represent average conditions near the river. In many areas of the Hanford Site, water levels are measured more frequently to evaluate seasonal changes. The water-level data were used for the following purposes:

- Prepare contour maps that indicate the general direction of groundwater movement within each aquifer
- Determine hydraulic gradients, which in conjunction with the hydraulic properties of the aquifer are used to estimate groundwater flow velocities
- Interpret sampling results.

Results of water-level monitoring are discussed in Chapters 2 through 4. The collection and analysis of manual water-level measurements at the Hanford Site are described in *Water-Level Monitoring Plan for the Hanford Site Soil and Groundwater Remediation Project* (SGW-38815).

1.3 Shoreline Monitoring

Groundwater is a potential pathway for contaminants to enter the Columbia River. Groundwater flows into the river from springs located above the water line and through areas of upwelling in the river bed. Hydrologists estimate that groundwater currently flows from the Hanford unconfined aquifer to the Columbia River at a rate of ~ 0.000012 cubic meter per second (Section 4.1 of PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River, Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project*). For comparison, the average flow of the Columbia River is ~3,400 cubic meters per second.

The rise and fall of the Columbia River creates a zone of interaction that influences contaminant concentrations and groundwater flow patterns. Water in the ground near the river nearly always represents a mixture of river water and approaching groundwater. In general, the degree of dilution by river water decreases with depth in the aquifer. The degree of dilution also varies by location and with seasonal river cycles (Chapter 3 of PNNL-13674).

Groundwater is a potential pathway for contaminants to enter the Columbia River. DOE monitors water quality near the shoreline.

DOE samples water near the Columbia River shoreline via natural seeps (riverbank springs) and aquifer tubes. Seeps represent water actually discharging to the river, and include a mix of groundwater and river water that previously flowed into the bank. Aquifer tubes are small-diameter, flexible tubes that have a screen on one end. The tubes are installed in the aquifer along the river shoreline, and groundwater is withdrawn with a portable peristaltic pump. Most aquifer tube sites include two or three individual tubes monitoring different depths, from ~1 to 8 meters. Section 2.1 and Appendix C provide additional information for the aquifer tubes. Section 2.9 includes a summary of monitoring results from seeps and river water.

1.4 CERCLA Five-Year Review

Whenever contaminants remain in the environment following a remedial action decision, CERCLA regulations require the regulatory agency to conduct a review of the decision at least every five years. DOE issued Revision 1 of *The Hanford Site Third CERCLA Five-Year Review Report* (DOE/RL-2011-56) in March 2012. DOE issued an errata sheet in June 2012 (12-EMD-0070, "Hanford Site Third Comprehensive Environmental Response, Compensation, and Liability Act Five-Year Review Report, April 2012"). The review covers the period ending September 30, 2010. The review provided the following protectiveness determinations for those groundwater operable units with existing records of decision:

- 100-HR-3: The interim remedy is not functioning within the specified remedial action objectives. Contamination has continued to migrate into the horn area between 100-H and 100-D. The new DX and HX pump-and-treat systems are designed to treat this plume.
- 100-KR-4: The interim remedy is functioning within the specified remedial action objectives.
- 100-NR-2: A protectiveness determination of the remedy cannot be made until further information is obtained. Institutional controls prevent human exposure to contaminants.
- 200-UP-1: The final remedy is expected to be protective of human health and the environment. The current interim actions ensure that exposure pathways are being controlled.
- 200-ZP-1: A protectiveness determination of the final remedy cannot be made until further information is obtained.
- 300-FF-5: The interim remedy is not protective because it is not expected to meet the groundwater cleanup standards. As a result, the remedial actions and remedial action objectives for the final remedy are being evaluated. Institutional controls are in place preventing the use of the groundwater.
- 1100-EM-1: The final remedy remains protective of human health and the environment.

The five-year review identified three issues and associated actions (Table 1-3).

1.5 Quality Control Summary

JG Douglas and SL Fitzgerald

Groundwater data quality is assessed and enhanced by a multifaceted quality assurance/quality control program. Major components of the program include performance evaluation studies, field quality control samples, blind standards, laboratory quality control samples, and laboratory audits. Overall,

evaluation of these components indicates that the majority of the data from the reporting period is reliable and defensible. Specific data values that are associated with out-of-limit quality control results (e.g., field blanks, field duplicates, and laboratory blanks) are flagged in the Hanford Environmental Information System (HEIS) database so users can properly assess the utility of the data for their purposes. Appendix D presents a detailed description of the quality control program and the quality control results for 2011; highlights include the following:

- Ninety-seven percent of the groundwater monitoring data was considered complete (i.e., not rejected, suspect, associated with a missed holding time, or out-of-limit quality control criteria). The majority of the incomplete results were associated with field quality control failures.
- The six primary laboratories supporting groundwater monitoring participated in several national performance evaluation studies. Overall, the performance was acceptable.
- Field quality control samples include three types of field blanks (full trip, field transfer, and equipment blanks), field duplicates, and split samples. Approximately 98 percent of the field blanks, 94 percent of the field duplicates, and 84 percent of the split sample results were acceptable, indicating reasonable sampling and analytical performance.
- Recommended holding times were met for 99 percent of nonradiological sample analysis requests.
- Overall, laboratory performance for Soil and Groundwater Remediation Project blind standards was fair; 84 percent of the results were acceptable. Failures for carbon-14, gross alpha, metals, total organic carbon, total uranium, and volatile organic compounds suggest that some groundwater results could also be biased. These problem areas will be investigated further during 2012.
- Approximately 99 percent of the laboratory quality control results for 2011 were within the acceptance limits. This percentage indicates that the analyses were in control and reliable data were generated. Laboratory quality control samples included method blanks, sample duplicates, laboratory control samples/duplicates, matrix spikes/duplicates, and surrogates.
- DOE Consolidated Audit Program audits were performed on four commercial laboratories. A total of 28 new findings, 10 open findings from previous audits, and 26 observations resulted from the four DOE audits. The four laboratories accepted all corrective actions; verification of the corrective actions will be performed in future audits. All of the laboratories have been recommended by the DOE Consolidated Audit Program to continue providing analytical services for samples generated at DOE sites.

1.6 Sources of Additional Information

All of the groundwater data presented in this report are provided as electronic files. Users also may retrieve historical and current data via the internet through DOE's Environmental Dashboard Application available at: http://environet.hanford.gov/EDA/.

The documents referenced in this report generally are available at the public reading rooms around Washington State (see Front Matter). Many documents also are available online as part of the Administrative Record available at http://www5.hanford.gov/arpir/ or other online libraries. Requests for documents can also be made through inter-library loan directly to DOE.

Hanford Site groundwater data are available online via the Environmental Dashboard Application available at: http://environet.hanford.gov/EDA/.

Other reports and databases relating to Hanford groundwater are listed in the following text and cited or summarized in this report as needed.

HEIS database. The HEIS database is the main environmental database for the Hanford Site. The database is used to store groundwater chemistry data and other environmental data (e.g., soil and surface water chemistry; soil physical properties; survey data).

Hanford Site Environmental Reports. The annual environmental report presents results of monitoring, including groundwater, riverbank seeps, river water, sediment, air, and biota. It also describes environmental management performance and reports the status of compliance with environmental regulations.

Quarterly RCRA summary. DOE provides informal quarterly presentations to the Washington State Department of Ecology (Ecology) after groundwater data associated with RCRA have been verified and evaluated. These presentations describe the status of RCRA sampling and analysis, statistical analysis results, and changes or highlights from the quarter.

Groundwater remediation reports. Independent annual reports describe the progress of groundwater remediation systems on the Hanford Site. The annual reports discuss the removal and treatment efficiencies for the year, as well as any operational issues for the groundwater remediation systems.

Remedial Investigation/Feasibility Study (RI/FS) documents. DOE recently released RI/FS reports for all of the River Corridor units (Section 2.1). These documents provide the results of RI studies and make recommendations for remediating the vadose zone and groundwater beneath the river corridor.

River Corridor Baseline Risk Assessment (RCBRA). A critical step in developing final remedial action decisions is the completion of a quantitative baseline risk assessment (Section 2.9).

1.7 Conventions Used in this Report

This section describes conventions for creating maps and trend plots, and for expressing contaminant concentrations.

The well location maps presented in this report include any wells used for sampling or water-level measurements over the past 5 years. Wells that have gone dry or that have been decommissioned during this period are shown with symbols that are different from regularly sampled wells. For clarity, the well name prefixes (e.g., “199-” in the 100 Area and “299-” in the 200 Area) are omitted from most of the maps.

For the first time in this report, contaminant plume maps were constructed by computer programs using a method called quantile kriging to produce a continuous spatial illustration of the contaminant distribution. The measured concentrations in wells are interpolated to a grid using a quantile kriging technique based on that described by *Geostatistical Software Library and User’s Guide* (Deutsch and Journel, 1992), “Rank Order Geostatistics: A Proposal for a Unique Coding and Common Processing of Diverse Data” (Journel and Deutsch, 1997), and “Spatial Interpolation Methods for Nonstationary Plume Data” (Reed et. al., 2004), among others. The quantile kriging approach is based upon two-dimensional ordinary kriging of a non-parametric (uniform-score) transform of the concentration, and a subsequent back-transform of the interpolated scores into the original units of measured concentration. Quantile kriging was accomplished using an open-source program based upon the United States Geological Survey kriging routines from *Semi-Variogram Estimation and Universal Kriging Program* (Skrivan and Karlinger, 1980) that incorporates routines to conduct the uniform-score transform/back-transform.

The computer factored in variables such as groundwater flow direction to create more realistic plumes. Limitations of the technique arise because the computer does not account for factors such as the locations of the known sources of contaminants, historical trends in concentrations, or relative mobility of contaminants. To minimize the adverse effects of these limitations, control data points were inserted where necessary, based on historical information and expert knowledge.

The following conventions were applied to create data sets for plume maps.

- For all maps except carbon tetrachloride in 200-ZP-1, wells screened in the upper portion of the unconfined aquifer were used. In most areas, there are insufficient numbers of deeper wells to create contour maps. Vertical distribution of contamination is discussed in the text.
- Data were selected and averaged from the period of interest (all of 2011 for most maps; high or low water-level conditions for some plumes near the Columbia River).
- Aquifer tubes are typically installed in clusters with screens at different depths in the unconfined aquifer. The mapped data sets include only the highest concentration in each cluster.
- If no data were available from a well during the desired time period, data were included from outside the time period.
- Data that appear to be nonrepresentative were excluded. Quality control staff and the project scientist in charge of the operable unit or monitored unit determine data representativeness. The evaluation employs a documented procedure and uses various methods and best professional judgment (Appendix D).
- For all constituents except iodine-129, "U" flagged data (less than detection limits) were counted as zero in averaging. Although this skews the averages low, the effect is insignificant at the current contouring levels with one exception. Reported values were averaged for iodine-129 even if they were flagged because detection limits are so close to the contour interval.

Contour levels for the maps in this report were chosen as follows:

- Drinking water standards and multiples of 10 (e.g., 8, 80, and 800 pCi/L for strontium-90)
- Cleanup levels or interim remedial action goals, where applicable (for example, 20 µg/L for hexavalent chromium)
- Intermediate levels to help define plume shape (for example, 90 µg/L for uranium; 500 µg/L for hexavalent chromium).

Plume maps are interpretations of contaminant distribution, based on data from individual monitoring wells. Computer programs were used to derive the 2011 contours.

Nitrate concentrations in this document are expressed as the NO_3^- ion. The federal and state drinking water standard for nitrate is 10 mg/L expressed as NO_3-N; this relates to the actual nitrogen in nitrate. Converting NO_3-N values to nitrate as the NO_3^- ion requires the NO_3-N value to be multiplied by 4.43. Nitrate data provided in this report reflect the converted values and, as such, the drinking water standard appears as 45 mg/L in figures and tables. Similarly, nitrite is expressed as the NO_2^- ion.

Dissolved chromium in Hanford Site groundwater is virtually all hexavalent. Thus, total chromium in filtered samples represents hexavalent chromium.

Unless specified otherwise, maps showing chromium include total chromium in filtered samples and hexavalent chromium in filtered or unfiltered samples. Dissolved chromium in Hanford groundwater is virtually all hexavalent (Chapter 7 of WHC-SD-EN-TI-302, *Speciation and Transport Characteristics of Chromium in the 100D/H Areas of the Hanford Site*; Appendix C of DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*), so filtered, total chromium data effectively represent hexavalent chromium. Maps for 100-KR-4 and 100-HR-3 illustrate hexavalent chromium and only include total chromium if a well had no hexavalent data.

Trend plots may omit results that appear to be erroneous if they distort or obscure the scale and data trends; the figure legends note the omission. All of the data, with appropriate data quality flags, are included in the data files accompanying this report and are available in the HEIS database. The trend plots presented in this report use open symbols to show values below the laboratory detection limit. These results are typically plotted as values that represent the detection limit for chemical parameters and reported values for radiological parameters (negative values are converted to zero). Discussion of increasing or decreasing trends is generally based on qualitative observation and not on statistical evaluation.

Contaminant concentrations are compared with state or federally enforceable drinking water standards (Table 1-4). Although Hanford groundwater is generally not used for the purpose of drinking water, these levels provide perspective on contaminant concentrations. Radionuclide concentrations also are compared with DOE-derived concentration standards and risk-based concentrations (Table 1-5). Note that the derived concentration standards were revised in 2011 based on a new DOE standard (DOE-STD-1196-2011, *Derived Concentration Technical Standard*). Where groundwater cleanup standards have been set, contaminant concentrations are compared to those standards.

The water-table mapping methodology is described in Chapter 4.0 of SGW-38815 (the water-level monitoring plan). In general, water-level measurements are displayed on a map using a geographic information system and contours are hand-drawn by a hydrogeologist. Generation of the March 2011 water-table map differed from the methodology described in SGW-38815 in that computer-generated contours were used as a guide to manual contouring near the groundwater pump-and-treat systems. The software employed, KT3D_H2O, uses the statistical, kriging numerical-grid generation method and includes additional drift terms in the kriging equation to represent extraction and injection wells ("KT3D_H2O: A Program for Kriging Water Level Data Using Hydrologic Drift Terms" [Karanovic et al., 2009]; SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*). This resulted in a better representation of water table drawdown and buildup around extraction and injection wells, respectively, especially in areas where observation wells are lacking.

Table 1-1. Reporting Requirements for Groundwater Monitoring

Operable Unit or Facility	Formal Report	Supplemental Report or Summaries
CERCLA		
Operable Units without interim groundwater RODs (100-BC-5, 100-FR-3, 200-BP-5, and 200-PO-1)	This report	Unit managers' meeting presentations
Operable Units with interim action RODs (100-KR-4, 100-NR-2, 100-HR-3, 200-UP-1, 200-ZP-1,* and 300-FF-5)	Interim Action annual reports, summarized in this report	Unit managers' meeting presentations; this report
Operable Unit with final action ROD (1100-EM-1)	This report	None
ERDF	Separate annual report summarized in this report	This report
RCRA		
Operating RCRA units (IDF, LERF, and LLBG)	This report	Informal quarterly presentations
Closure RCRA units (116-N-1 and 116-N-3; 120-N-1 and 120-N-2)	This report	Informal quarterly presentations
Post-closure RCRA units (116-H-6 and 316-5)	Semiannual reports to Ecology; this report	Informal quarterly presentations
Interim status groundwater quality assessment RCRA sites (WMAs A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U)	This report	Informal quarterly presentations
Interim status indicator evaluation RCRA sites (216-A-29, 216-A-36B, 216-A-37-1, 216-B-63, 216-S-10 Pond, and NRDWL)	This report	Informal quarterly presentations
Other Facilities		
AEA sites (K Basins; Richland North, 400 Area water supply wells, and confined aquifers)	This report	Unit managers' meeting presentations
SALDS (WAC 173-216)	Quarterly discharge monitoring reports; annual report (latest is SGW-51085)	This report
TEDF (WAC 173-216)	Quarterly discharge monitoring reports; this report	None
SWL (WAC 173-350)	This report	None

Note: WAC 173-216, "State Waste Discharge Permit Program;" WAC 173-350, "Solid Waste Handling Standards."

* 200-ZP-1 has both an interim and final groundwater ROD.

Table 1-2. Number of Groundwater Analyses for Selected Constituents, 2011

Constituent	Site Total
Carbon tetrachloride	1,189
Chromium (total)	3,726
Chromium (hexavalent)	3,804
Iodine-129	593
Nitrate	2,324
Plutonium-239/240	78
Strontium-90	930
Technetium-99	1,210
Trichloroethene	1,194
Tritium	1,671
Uranium	1,334

Table 1-3. CERCLA Five-Year Review Issues and Actions

Issues and Actions	Action Due Date
100 Area	
Issue 1: Recent data indicate a low spot in the surface of the Ringold Upper Mud in the 100-HR-3 OU that may trap hexavalent chromium in the aquifer, which in combination with a likely continuing vadose source of hexavalent chromium at the adjacent 100-D-100 waste site results in persistent hexavalent chromium concentrations in groundwater southeast of the 182-D Reservoir	
Action 1.1: Remove, treat, and dispose of the chromium source discovered in the deep vadose zone at 100-D-100.	4/30/2014
Issue 2: Leakage and spills from the 182-D Reservoir and export water system may contribute to movement of contaminants into the vadose zone.	
Action 2.1: Complete the engineering export water scoping study to evaluate whether the 182-D Reservoir and export water system is necessary to support the Hanford Cleanup Mission.	3/31/2012
300 Area	
Issue 3. Remediation approach in interim action ROD (EPA/ESD/R10-00/524) for natural attenuation is not effective in meeting groundwater remediation goals in the 300 Area.	
Action 3.1. Submit proposed plan for a ROD to support meeting groundwater remediation goals.	12/31/2011

Table 1-4. Drinking Water Standards and Groundwater Cleanup Levels for Hanford Site Groundwater Contaminants

Constituent	Unit	DWS	DWS Responsible Agency	MTCA[a]	Groundwater Quality Criteria[b]	Ambient Water Quality Criteria[c]
Chemical Constituents						
Aluminum	µg/L	50 to 200[d]	EPA	16,000	--	--
Antimony	µg/L	6	EPA, DOH	6.4	--	--
Arsenic	µg/L	10	EPA, DOH	0.058	50	190
Barium	µg/L	2,000	EPA, DOH	3,200	1,000	--
Cadmium	µg/L	5	EPA, DOH	8.0	10	Hardness dependent
Carbon tetrachloride	µg/L	5	EPA, DOH	0.337	300	--
Chloride	mg/L	250[d]	EPA, DOH	--	250	230
Chloroform (TTHM)[d]	µg/L	80	EPA, DOH	1.41	7.0	--
Chromium	µg/L	100[f]	EPA, DOH	24,000/48[f,g]	50[f]	10[g]
cis-1,2-Dichloroethene	µg/L	70	EPA, DOH	80	--	--
Copper	µg/L	1,300[h] 1,000[d]	EPA, DOH	640	--	Hardness dependent
Cyanide	mg/L	200	EPA, DOH	320	--	5.2
Fluoride	mg/L	4	EPA, DOH	960	4	--
		2[d]	EPA, DOH	--	--	--
Iron	µg/L	300[d]	EPA, DOH	11,200	--	--
Lead	µg/L	15[h]	EPA, DOH	--	50	Hardness dependent
Manganese	µg/L	50[d]	EPA, DOH	2,240	--	--
Mercury(inorganic)	µg/L	2	EPA, DOH	4.8	2	0.012
Methylene chloride (dichloromethane)	µg/L	5	EPA	5.83	--	--
Nitrate, as NO3-	mg/L	45[i]	EPA, DOH	114	45[i]	--
Nitrite, as NO2-	mg/L	3.31[j]	EPA, DOH	4.8	--	--
pH	--	6.5 to 8.5[d]	EPA, DOH	--	--	6.5 to 8.5
Selenium	µg/L	50	EPA, DOH	80	10	5.0
Silver	µg/L	100[d]	EPA, DOH	80	50	--
Sulfate	mg/L	250[d]	EPA, DOH	--	250	--
Tetrachloroethene	µg/L	5	EPA, DOH	0.081	0.8	--
Thallium	µg/L	2	EPA, DOH	--	--	--
Total dissolved solids	mg/L	500[d]	EPA, DOH	--	--	--
1,1,1-Trichloroethane	µg/L	200	EPA, DOH	16,000	200	--
Trichloroethene	µg/L	5	EPA, DOH	0.492	3	--
Uranium (total)	µg/L	30	EPA, DOH	48	--	--
Zinc	µg/L	5,000[d]	EPA, DOH	4,800	--	Hardness dependent

Table 1-4. Drinking Water Standards and Groundwater Cleanup Levels for Hanford Site Groundwater Contaminants

Constituent	Unit	DWS	DWS Responsible Agency	MTCA[a]	Groundwater Quality Criteria[b]	Ambient Water Quality Criteria[c]
Radionuclides						
Antimony-125	pCi/L	300[j]	EPA	--	--	--
Beta particle and photon activity	pCi/L	4 mrem/yr[k]	EPA, DOH	--	--	--
Carbon-14	pCi/L	2,000	EPA	--	--	--
Cesium-137	pCi/L	200	EPA	--	--	--
Cobalt-60	pCi/L	100	EPA	--	--	--
Iodine-129	pCi/L	1	EPA	--	--	--
Ruthenium-106	pCi/L	30	EPA	--	--	--
Strontium-90	pCi/L	8	EPA, DOH	--	--	--
Technetium-99	pCi/L	900	EPA	--	--	--
Total alpha (excluding uranium)	pCi/L	15	EPA, DOH	--	--	--
Tritium	pCi/L	20,000	EPA, DOH	--	--	--
Uranium	µg/L	30	EPA, DOH	--	--	--

a. Model Toxics Control Act (MTCA), Method B cleanup levels for groundwater (WAC 173-340, "Model Toxics Control Act—Cleanup"). Calculations documents in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

b. Groundwater quality criteria are regulated by Ecology under WAC 173-200, "Water Quality Standards for Groundwaters of the State of Washington."

c. Criteria for chronic exposure in fresh water, WAC 173-201A-240, "Water Quality Standards for Surface Waters of the State of Washington," "Toxic Substances," Table 240(3).

d. Secondary standards are not associated with health effects, but associated with taste, odor, staining, or other aesthetic qualities.

e. Standard is for total trihalomethanes.

f. Total chromium.

g. Hexavalent chromium.

h. Action level.

i. 45 mg/L as NO3- is equivalent to 10 mg/L of nitrate as nitrogen.

j. 3.3 mg/L as NO2- is equivalent to 1 mg/L of nitrite as nitrogen.

k. Beta and gamma radioactivity from anthropogenic radionuclides. Annual average concentration shall not produce an annual dose from anthropogenic radionuclides equivalent to the total body or any internal organ dose >4 mrem/year. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/year. Compliance may be assumed if annual average concentrations of total beta, tritium, and strontium-90 are <50, 20,000, and 8 pCi/L, respectively.

DOH = Washington State Department of Health (WAC 246-290, "Group A Public Water Supplies")

DWS = drinking water standard (maximum contaminant level for drinking water supplies)

EPA = U.S. Environmental Protection Agency (40 CFR 141, "National Primary Drinking Water Regulations;" 40 CFR 143, "National Secondary Drinking Water Regulations;" and EPA 822-R-96-001, *Drinking Water Regulations and Health Advisories*)

Table 1-5. Derived Concentration Standards, 4 mrem Effective Dose Equivalent Concentrations, and Risk-Based Concentrations for Hanford Site Radionuclides

Radionuclide	Derived Concentration Standard[a] (pCi/L)	4 mrem Effective Dose Equivalent[b] (pCi/L)	Risk-Based Concentration[c] (pCi/L)	
			10^{-6} Risk	10^{-4} Risk
Antimony-125	27,000	1,100	12.1	1,210
Carbon-14	62,000	2,500	1.43	143
Cesium-137	3,000	120	1.74	174
Cobalt-60	7,200	290	3.37	337
Iodine-129	330	13	0.358	35.8
Plutonium-239/240	140	6	0.392	39.2
Ruthenium-106	4,100	160	1.25	125
Selenium-79	8,500	340	7.26	726
Strontium-90	1,100	44	0.947	94.7
Technetium-99	44,000	1,800	19.2	1,920
Tritium	1,900,000	76,000	160	16,000
Uranium-234[d]	680	30	0.748	74.8
Uranium-235[d]	720	30	0.760	76.0
Uranium-238[d]	750	30	0.827	82.7

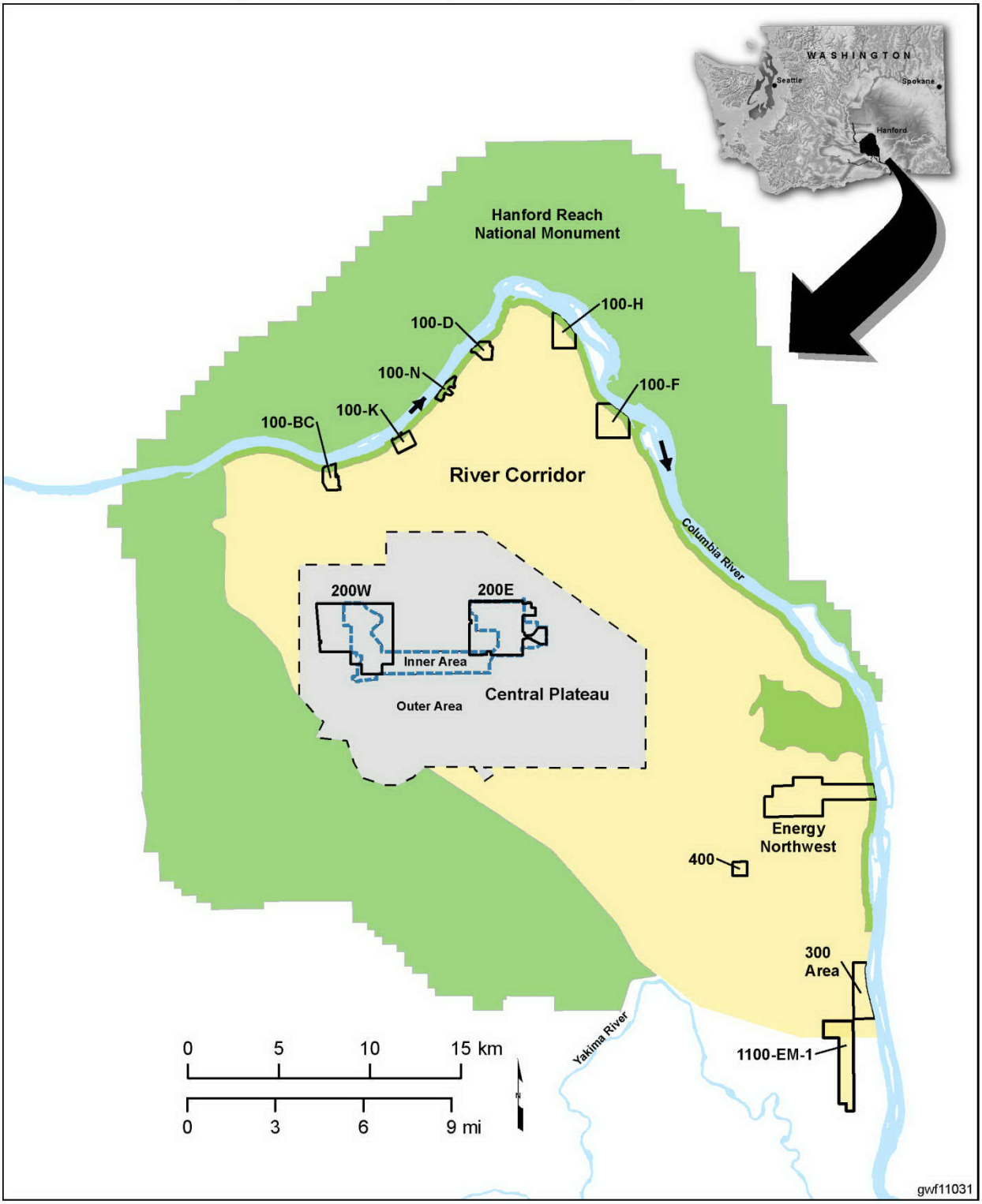
a. Concentration of a specific radionuclide in water that could be continuously consumed at average annual rates and not exceed an effective dose equivalent of 100 mrem/year. From Table 5 of DOE-STD-1196-2011, *Derived Concentration Technical Standard*.

b. Concentration of a specific radionuclide in water that would produce an effective dose equivalent of 4 mrem/year if consumed at average annual rates. The EPA DWSs for radionuclides listed in Table 1-3 were derived based on a 4 mrem/year dose standard using maximum permissible concentrations in water specified in *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure* (NBS Handbook 69). The 4 mrem/year dose standard listed in this table was calculated using a more recent dosimetry system adopted by DOE and other regulatory agencies (see footnote a).

c. From EPA's risk website: http://epa-prgs.ornl.gov/radionuclides/tapwaterimage.html "Preliminary Remediation Goals for Radionuclides" (EPA, 2012). These values represent the risk of getting cancer if a person ingested water contaminated with each radionuclide over a lifetime. The tritium and carbon-14 calculation also considers inhalation of tritium in air; for the other radionuclides, this path is insignificant.

d. See Table 1-3 for total uranium.

Figure 1-1. The U.S. Department of Energy Hanford Site



2.0 River Corridor

M.J. Hartman

The Columbia River flows through the northern Hanford Site before turning south toward the City of Richland. The region of the Site along the shoreline is known as the "River Corridor." Section 2.1 presents an overview of the River Corridor, describing common elements of its hydrogeology, groundwater flow, waste disposal, remediation, and monitoring. Sections 2.2 through 2.8 discuss the results of groundwater monitoring in each of the groundwater interest areas within the River Corridor. Section 2.9 summarizes results for the River Corridor as a whole, including the Columbia River itself.

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2.1 Introduction to the River Corridor

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The Columbia River flows through the northern Hanford Site before turning south toward the city of Richland. The region of the Site along the shoreline is known as the "River Corridor" (Figure 2.1-1). For purposes of cleanup, the River Corridor includes large inland areas of the Site known as the 100-IU-2 and 100-IU-6 Operable Units. However, most of the 100-IU-2/IU-6 source operable units overlie groundwater operable units associated with the Central Plateau. Therefore, in this document, the term River Corridor refers to the seven groundwater operable units and groundwater interest areas listed in the "at a glance" box.

River Corridor at a Glance

A total of 82 kilometers of Columbia River shoreline
River stage controlled by Priest Rapids Dam
Hanford Reach National Monument established in 2000

100 Area	300 Area and Outlying Regions	Former 1100 Area
Five groundwater operable units: 100-BC-5, 100-KR-4, 100-NR-2, 100-HR-3[a], 100-FR-3	One groundwater operable unit: 300-FF-5 (includes 300 Area Industrial Complex, 618-10/316-4 and 618-11 facilities)	One former groundwater operable unit: 1100-EM-1
Nine nuclear reactors and associated facilities	Historically used for nuclear fuel fabrication	Historically used for vehicle maintenance and solid waste disposal
Inactive liquid waste cribs, ditches, trenches, retention basins, pipelines, and spills; four RCRA sites	Inactive liquid waste cribs, trenches, ponds, pipelines, and spills; one RCRA site	Former waste sites remediated
Interim waste site remediation >50% complete overall[b]	Interim waste site remediation >75% complete overall[b]	Final waste site remediation 100% complete
Interim groundwater remediation active for hexavalent chromium in 100-KR-4 and 100-HR-3, and strontium-90 and petroleum hydrocarbons in 100-NR-2	Monitored natural attenuation of uranium, organics, and tritium	Final groundwater remediation complete
RI/FS underway	RI/FS underway	Final ROD in place

a. The 100-HR-3 Operable Unit includes the 100-D and 100-H Areas.
b. Percent of waste sites that have been remediated or classified as not requiring remediation.

The following groundwater contaminants are present in the River Corridor:

- Hexavalent chromium concentrations exceed the 10 µg/L ambient water quality standard in the unconfined aquifer in each of the 100 Areas, in a confined aquifer in 100-HR-3, and in one confined well in 100-NR-2.
- Nitrate concentrations exceed the 45 mg/L drinking water standard in each of the 100 Areas except 100-BC-5. A nitrate plume from agricultural sources south of the Hanford Site affects groundwater in 1100-EM-1.
- Strontium-90 concentrations exceed the 8 pCi/L drinking water standard in each of the 100 Areas.
- Tritium concentrations exceed the 20,000 pCi/L drinking water standard in 100-BC-5, 100-KR-4, and an outlying region of 300-FF-5.
- Trichloroethene concentrations exceed the 5 µg/L drinking water standard in 100-FR-3 and 100-KR-4 and within a deeper, finer-grained sedimentary unit at 300-FF-5.
- Other contaminants include uranium in 300-FF-5, carbon-14 in 100-KR-4, and petroleum hydrocarbons in 100-NR-2.

2.1.1 Hydrogeology

The geologic units beneath the River Corridor are a subset of those that underlie the Hanford Site as a whole (Appendix E). The stratigraphy of the 100 Area is distinct from that of the 300 and 1100 Areas.

2.1.1.1 100 Area

Figure 2.1-2 illustrates the general stratigraphy and hydrogeologic units of the 100 Area.

The vadose zone comprises the sand and gravel of the Hanford formation and, in some locations, a portion of Ringold Formation unit E. The vadose zone can be less than a meter thick near the Columbia River to as much as 30 meters beneath inland portions of the River Corridor.

The unconfined aquifer consists of the sand and gravel of Ringold unit E in the western 100 Areas and the Hanford formation in the 100-H and 100-F Areas. This aquifer is thickest in the western portion of the region (up to 48 meters in 100-BC-5) and thinnest near the 100-H and 100-F Areas, where in some places it is less than 2 meters thick.

The base of the unconfined aquifer is one of a number of fine-grained units of the Ringold Formation informally known as the Ringold upper mud unit. It is important to note that the "Ringold upper mud" is not a distinct stratigraphic unit, and the uppermost mud in one region may not be continuous with the uppermost mud elsewhere. However, mud units are ubiquitous across the 100 Areas and effectively form the base of the regional, unconfined aquifer. The Ringold upper mud is dominated by layers of silt and clay; this fine-textured material functions as an aquitard that forms the bottom boundary of the unconfined aquifer. Below the contact with the unconfined aquifer, the unit contains numerous distinct layers of sand and gravel. These layers typically contain water and act as local confined aquifers. The Ringold upper mud unit appears to be absent to the west of 100-BC-5, where sandy gravel overlies basalt.

The unconfined aquifer beneath the River Corridor resides in sand and gravel sediments. Layers of silt and clay form the bottom of the unconfined aquifer.

A series of confined aquifers within and beneath the upper mud are present through most of the 100 Areas. Basalt aquitards and basalt-confined aquifers are present beneath the Ringold Formation. Few wells are screened in the deeper units.

2.1.1.2 300 and 1100 Areas

Beneath 300-FF-5 and 1100-EM-1, the vadose zone is entirely within the gravel and sand of the Hanford formation. The unconfined aquifer includes the lower portion of the Hanford formation. Beneath 300-FF-5, the undulating contact between the bottom of the saturated Hanford formation and the underlying Ringold unit E sediment reveals paleochannels that act as preferential pathways for groundwater flow. Saturated Hanford formation sediment is much more permeable than the underlying Ringold sediment.

The Ringold lower mud unit underlies unit E. Coarse-grained sediments of Ringold unit A underlie the lower mud in some areas; elsewhere the mud overlies basalt.

2.1.2 Groundwater Flow

Figure 2.1-3 presents the Hanford Site water table map for March 2011 with River Corridor data displayed. Figure 2.1-4 shows locations of monitoring wells. Detailed maps for each groundwater interest area are provided in subsequent sections of this report. Groundwater in the unconfined aquifer generally flows from upland areas in the west toward the regional discharge area north and east along the Columbia River, which forms a groundwater discharge boundary. Steep hydraulic gradients occur in the western, eastern, and northern regions of the Site. Shallow gradients occur southeast of 100-FR-3 and in a broad arc extending from west of 100-BC-5 toward the southeast between Gable Butte and Gable Mountain (Gable Gap), through the 200 East Area and into the central portion of the Site. The steep gradients in the west and east are associated with low-permeability sediment of the Ringold Formation at the water table,

while the low gradients are generally associated with highly permeable sand and gravel of the Hanford formation (Chapter 7.0 of PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*).

North of Gable Butte and Gable Mountain, groundwater flow directions vary from northwest to east depending on location. Groundwater enters this region through the gaps between Gable Mountain, Gable Butte, and Umtanum Ridge, as well as from natural recharge. The Columbia River also recharges the unconfined aquifer west of 100-BC-5, even when the river stage is low. Water flowing north through Gable Gap fans out and flows toward the Columbia River. In each of the 100 Areas, the local groundwater flow is generally toward the Columbia River, although groundwater pump-and-treat systems in 100-KR-4 and 100-HR-3 alter this flow pattern locally.

An apparent groundwater mound exists ~2 kilometers north of Gable Mountain and is associated with low-permeability Ringold upper mud at the water table. This mound is contoured as part of the unconfined aquifer (Figure 2.1-3), but it could represent water perched on fine-grained sediment above the regional water table. Additional data would be needed to distinguish between these alternatives. Water-level elevations indicate that groundwater moving toward the east along the northern side of Gable Mountain flows around this apparent mound.

In the eastern portion of the Hanford Site, south of Gable Mountain and north of the 300 Area, groundwater flows due east toward the Columbia River. Groundwater flow converges on the 300 Area from the northwest, west, and southwest, then generally moves toward the southeast and discharges to the Columbia River (Section 3.1.2 of PNNL-15127, *Contaminants of Potential Concern in the 300-FF-5 Operable Unit: Expanded Annual Groundwater Report for Fiscal Year 2004*). The hydraulic gradient in the 300 Area is low because the aquifer is very permeable.

Groundwater flows from the unconfined aquifer into the Columbia River. When the river stage is high, flow temporarily reverses.

Daily, monthly, and seasonal changes in the Columbia River stage affect the flow of groundwater in the near-river environment. During periods of high river stage, the Columbia River temporarily recharges the adjacent aquifer all along the river (bank storage effects), whereas during periods of low or moderate river stage, groundwater discharges from the aquifer to the river. Concentrations of mobile and moderately-mobile contaminants like hexavalent chromium vary inversely with the river stage, as river water mixes with groundwater (top panel of Figure 2.1-5). For less mobile contaminants that sorb to sediment grains in the vadose zone, like strontium-90, the higher water table can mobilize contamination. This mobilization causes concentrations to vary directly with water levels (bottom panel of Figure 2.1-5[1]).

River stage changes create a mixing zone in the aquifer along the river. The extent of this zone varies, depending on the steepness of the hydraulic gradient and local geology. At any given time, water discharging from the aquifer to the river can comprise nearly all river water in bank storage, nearly all aquifer water, or some mixture depending on the recent history of river stage changes (PNNL-13674). The degree of mixing can be assessed by the specific conductance of the water, which reflects the concentrations of dissolved solids. The specific conductance of river water is typically 130 to 160 µS/cm, and of groundwater is 300 to 1,000 µS/cm, depending on location. Thus, specific conductance in the mixing zone varies inversely with river stage.

[1] The figure shows strontium-90 concentrations in well 199-N-67, where concentrations and sampling frequency create a clear seasonal trend. Water-level data are plotted for nearby well 199-N-2, because it contains an automated water-level system, and 199-N-67 does not.

Areas of groundwater upwelling have been identified adjacent to the shore and in the center of the river channel (WCH-380, Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling).

2.1.3 Waste Disposal and Distribution of Contaminants

The operational histories of the six reactor areas have many common elements. Common features of the types of waste generated and their behaviors in the environment are summarized here. Summaries also are provided for the 300 and 1100 Areas. Table 2.1-1 provides references to RI/FS reports for the River Corridor units, which provide additional detail about waste sites.

2.1.3.1 100 Areas

Liquid and solid waste discharged during the reactor operational periods were the primary contaminant sources in the reactor areas. Contaminant sources in the 100 Areas included cooling water conditioning and handling facilities, underground piping, liquid and solid waste disposal sites, and unplanned releases (surface spills).

Low mobility contaminants, including many metals and radionuclides, sorbed to sediment grains in the vadose zone. These contaminants were found at the greatest concentrations within and near the areas of discharge. When little or no liquid effluent was discharged to a waste site, soil contamination remained in the shallow sediment. High volumes of liquid modestly expanded the depth of low-mobility contamination, dispersing these contaminants deeper in the vadose zone than where lower volumes of water were used.

Strontium-90 is a slightly mobile contaminant in the subsurface and tends to sorb to soil. It was present in numerous 100 Area waste sites, including burial grounds and liquid waste sites, principally from decontamination solutions and contaminated reactor coolant or fuel storage basin water. Strontium-90 migrated through the vadose zone beneath some liquid waste disposal sites and moved a limited distance vertically and horizontally in groundwater.

Mobile and moderately-mobile contaminants common to the 100 Area include tritium, nitrate, and hexavalent chromium. Large volumes of water containing these contaminants were discharged to the soil via trenches, cribs, and leaks from pipelines and retention basins. Wastewater was also released through outfall piping to the Columbia River. Large groundwater mounds developed beneath surface discharge sites and helped spread mobile contaminants in groundwater in a radial pattern during operations.

In the 100 Area, low mobility contaminants, including many metals and radionuclides, sorbed to sediment grains in the vadose zone. Mobile and moderately-mobile contaminants, like hexavalent chromium, migrated to groundwater.

Sodium dichromate was added to reactor cooling water as an anti-corrosion agent. Typical sodium dichromate concentrations in the cooling water during the early years of reactor operations were 2,000 µg/L (~700 µg/L as hexavalent chromium). They decreased to 1,000 µg/L in the mid-1960s, and then 500 µg/L (~170 µg/L as hexavalent chromium) in the last stages of operations.

Historical process information suggests that small volumes of high-concentration solutions (up to 70 percent by weight) of sodium dichromate leaked or spilled in the 100 Areas, for example, during the transfer of sodium dichromate from rail cars to storage tanks. In some locations in 100-D and 100-K Areas, the current and historical concentrations of hexavalent chromium in groundwater exceed the concentrations found in reactor cooling water, indicating a high-concentration source. Residuals from the

high-concentration sodium dichromate solutions may remain in the vadose zone at some locations and may be a secondary source of groundwater contamination until the vadose zone is remediated.

After reactor operations and associated wastewater disposal ceased, the driving force for infiltration decreased. For an undetermined period, water in the vadose zone continued to drain beneath the waste sites, but at a much lower volume than during operations. Infiltration of rain and melted snow through the contaminated vadose zone carried some additional contamination to groundwater. During this period, short-lived radionuclides continued to decay. The groundwater mounds dissipated, and groundwater resumed natural flow directions.

DOE began interim remediation of 100 Area waste sites in the 1990s. Remediation generally included excavation to a depth of about 4.6 meters, which removed the most heavily contaminated sediment. Water was sprayed over the excavations to protect workers and the public from airborne, contaminated dust. Use of large volumes of dust suppression water has the potential to mobilize contaminants in the vadose zone, but the use of dust suppression water has not been quantified. Once the remediated waste sites are backfilled and revegetated, the plants consume the natural precipitation, limiting infiltration deep into the vadose zone. Most of the waste sites in 100-BC and 100-F have already been remediated and planted with native vegetation. Interim remediation of waste sites in 100-K, 100-N, 100-D, and 100-H is partially completed and scheduled to be finished by 2014.

Only one effluent discharge remains active in the 100 Area. Sanitary wastewater from 100-N Area and from septic tanks throughout the Hanford Site is discharged to the 100-N (124-N-10) sanitary sewage lagoon, approximately 1 kilometer southeast of the main 100-N Area.

2.1.3.2 300 and 1100 Areas

Sources of groundwater contamination in the 300 Area included routine disposal of liquid effluent associated with (1) fabrication of nuclear fuel assemblies, and (2) research involving the processing of irradiated fuel. The liquid waste was discharged to ponds and trenches designed for infiltration to the underlying soil. Periodic spills and accidental releases from various facilities also occurred. Nearly all of the principal liquid waste disposal facilities have been remediated. Groundwater contaminants in the 300 Area include uranium and volatile organic compounds.

Remaining sources of groundwater contamination beneath the 300 Area include the process sewer system and the 307 Process Trenches. Some release or remobilization of contamination may have occurred in more recent years because of continuing operations, excavation activities, removal of buildings, and processes potentially still active at some of the unremediated burial grounds (for example, formation of a tritium plume in groundwater at the outlying 618-11 subregion).

The 1100-EM-1 groundwater interest area encompasses a variety of onsite and neighboring offsite land uses. Numerous municipal, industrial, and agricultural activities may affect groundwater quality in this area. The areas comprising the Hanford Site's former 1100 Area have been converted to a variety of uses, including commercial activities, manufacturing, and equipment storage. Offsite facilities of particular interest with respect to groundwater include the following:

- The North Richland Well Field and recharge basins (a localized aquifer storage and recovery system)
- The Richland Sanitary Landfill
- AREVA's nuclear reactor fuel manufacturing facility
- Conagra Foods Lamb Weston processing plant

- The Horn Rapids off-road vehicle park
- Irrigated agricultural fields

2.1.4 Cleanup

The only groundwater operable unit in the River Corridor for which final cleanup decisions have been made is 1100-EM-1. The 1100-EM-1 Operable Unit was removed from the National Priorities List (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List") in 1996. The selected remedy for groundwater was monitored natural attenuation of volatile organic compounds with continuation of institutional controls for groundwater and land use at the Horn Rapids Landfill (EPA/ROD/R10-93/063, *Declaration of the Record of Decision for the USDOE Hanford 1100 Area*).

In the early 1990s, DOE, EPA, and Ecology decided that enough was known about contaminated soil and groundwater in the Hanford Site's River Corridor to begin interim remediation with a focus on protecting the Columbia River. This decision led to an early start for cleanup of contaminated soil and groundwater in the River Corridor. Key components of the early cleanup included the following:

- Removing contaminated facilities and soil (waste sites) near the river, and sending the contaminated material to a large, lined landfill in the central Hanford Site
- Conducting active groundwater remediation in 100-KR-4, 100-NR-2, and 100-HR-3

The interim cleanup actions provided information about where contamination exists and how it moves through soil and groundwater. This approach helps to plan future cleanup activities.

So far, DOE has cleaned up more than 60 percent of the waste sites in the River Corridor, removing contaminated soils to an engineered landfill on the Central Plateau.

During 2011, remediation of waste sites under interim RODs continued. Interim remediation is nearly finished in 100-BC and 100-F and is under way at the other River Corridor units. Table 2.1-2 lists the status of waste site remediation.

Groundwater cleanup under interim RODs also continued in 2011. Figure 2.1-6 shows the locations of remediation systems for hexavalent chromium and strontium-90, and the mass of chromium removed by pump-and-treat systems in 100-KR-4 and 100-HR-3. Interim remediation of strontium-90 in 100-NR-2 focuses on immobilizing the contamination so it can decay in place. The goal of the interim groundwater remediation is to prevent or reduce the movement of contaminated groundwater into the Columbia River. As defined in the current interim action RODs, the remedial action goal for hexavalent chromium is 20 µg/L in compliance wells. The ambient water quality standard is 10 µg/L. The remedial action goal is based on the estimated 1:1 mixing of groundwater (and the associated hexavalent chromium) with infiltrated river water before the water is accessible to aquatic life in the river.

Interim cleanup of the River Corridor has achieved a great deal, but final decisions are yet to be made. CERCLA provides a process for making final decisions about the actions needed to complete cleanup:

- Gather information about the site
- Conduct risk characterization
- Identify cleanup goals

- Evaluate alternatives for cleanup and the associated cost to meet cleanup goals
- Select the cleanup option that fits best

In 2010 and 2011, DOE continued to gather information to support decisions about cleaning up the remainder of the contamination in soil and groundwater of the River Corridor.

This process is known as a remedial investigation/feasibility study (RI/FS). The preferred alternatives for cleanup will be described in a proposed plan and the decision will be documented in a ROD. The Tri-Parties developed a strategy to make final decisions for the River Corridor under CERCLA. Part of the strategy was to split the region into smaller pieces of work that were more manageable. Final cleanup decisions are being developed for (1) 100-BC, (2) 100-K, (3) 100-N, (4) 100-D and 100-H, (5) 100-F and 100-IU-2/IU-6, and (6) 300 Area. Final decisions for each of these areas will address contaminated soil, solid waste burial grounds, and groundwater. The objective for all of these decisions is to protect human health and the environment.

The *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* (DOE/RL-2008-46) summarized how cleanup of the River Corridor is managed. From 2009 through 2011, DOE issued a series of addenda and sampling and analysis plans for each of the River Corridor units (Table 2.1-1) and conducted CERCLA investigations. These investigations included, for example, characterizing the vadose zone beneath some of the interim remediated waste sites to confirm whether cleanup was adequate. Interim cleanup was done to meet interim cleanup levels and the RI/FS process is identifying technically sound cleanup levels. Accordingly, some sites may require additional remediation before they are finally closed. Remedial investigation activities also included installing additional groundwater monitoring wells, refining the knowledge of contaminant distribution in three dimensions, and providing more information on groundwater flow and hydraulic properties to support computer models. The models are used to predict future behavior of contaminants in soil and groundwater. RI/FS reports are being prepared for release in 2012 and 2013 (Table 2.1-1).

Target TPA milestones have been established to ensure that the impact of hexavalent chromium and other contaminants to the Columbia River and groundwater are remediated in a timely manner. The following milestones are directly applicable to the 100 Area OUs:

- **Milestone M-016-110-TO1 (December 31, 2012):** DOE shall take actions necessary to contain or remediate hexavalent chromium groundwater plumes in each of the 100 Area NPL [National Priority List] Operable Units such that ambient water quality standards for hexavalent chromium are achieved in the hyporheic zone[2] and river column water.
- **Milestone M-016-110-TO2 (December 31, 2020):** DOE shall take actions necessary to remediate hexavalent chromium groundwater plumes such that hexavalent chromium will meet drinking water standards in each of the 100 Area NPL Operable Units.
- **Milestone M-016-110-TO3 (December 31, 2016):** DOE shall take actions to contain the strontium-90 plume at 100-NR-2 Operable Unit such that the default ambient water quality standard (8 pCi/L) is achieved in the hyporheic zone and river water column.

[2] The hyporheic zone is a shallow region adjacent to a stream bed where there is mixing of groundwater and surface water.

- **Milestone M-016-110-TO4 (December 31, 2016):** DOE shall implement remedial actions selected in all 100 Area Records of Decision for Groundwater Operable Units so that no contamination above drinking water standards enters the Columbia River unless otherwise specified in a CERCLA decision.
- **Milestone M-016-110-TO5 (December 31, 2015):** DOE will have a remedy in place designed to meet Federal Drinking Water Standards for uranium throughout the groundwater plume in the 300-FF-5 Operable Unit unless otherwise specified in a CERCLA decision document.

Hexavalent Chromium

- ***Hexavalent chromium is a common contaminant in 100 Area groundwater and is of concern because of its potential effects on salmon, other aquatic life, and human health.***
- ***DOE's goal is to remediate hexavalent chromium to the ambient water quality standard of 10 µg/L.***
- ***The state groundwater cleanup level is 48 µg/L. The drinking water standard for total chromium is 100 µg/L.***
- ***For the 100-KR-4 and 100-HR-3 Operable Units, an interim remedial action goal is set at 20 µg/L in near-river compliance wells. This gives an allowance for a 1 to 1 attenuation factor to meet the ambient water quality standard in the river environment.***
- ***Water samples may be analyzed specifically for hexavalent chromium or for total chromium, the latter of which includes the weakly soluble trivalent form. It should be noted that dissolved chromium in Hanford Site groundwater is virtually all in the hexavalent form.***

2.1.5 Aquifer Tubes

Aquifer tubes are small-diameter, flexible tubes with a screen on one end. The tubes are installed in the aquifer along the Columbia River shoreline at selected depths to provide a network of sampling points that allow characterization of water quality within the zone of groundwater and river water interaction. Appendix C provides additional information about aquifer tubes.

Groundwater is monitored in aquifer tubes to provide supporting data for the following purposes:

- Data indicate the minimum concentrations of contaminants in groundwater approaching the Columbia River. Because of mixing, undiluted groundwater concentrations may be higher.
- Long-term declines in contaminant concentrations could indicate movement of the plume, discharge of the plume to the river, dispersion, or the influence of an upgradient remediation system.
- Increasing concentrations may indicate plume movement or mobilization of contaminants.
- Data from aquifer tubes help determine locations for additional monitoring and remediation.

When interpreting these data, the following limitations are considered:

- Concentrations in aquifer tubes and seeps may vary with the Columbia River stage. Dilution of contaminants by mixing with river water can result in lower concentrations, though the amount (mass) of that contaminant is not decreased. The same is true for near-river wells.
- Because aquifer tubes have much shorter screens than monitoring wells (15 centimeters), the data may not be directly comparable to data from near-river wells.
- Aquifer tube and seep data are currently not used as groundwater monitoring compliance points.

Table 2.1-1. River Corridor Remedial Investigation/Feasibility Study Documents

Groundwater Interest Area	Source OUs Included in Document	Document Title	Published
100-BC-5	100-BC-1 and 100-BC-2	*Remedial Investigation/Feasibility Study for 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*, DOE/RL-2010-96, Draft A (in progress)	2012*
		Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study, DOE/RL-2009-44, Rev. 0	2010
		Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units, DOE/RL-2008-46-ADD3, Rev. 0	2010
100-KR-4	100-KR-1 and 100-KR-2	*Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*, DOE/RL-2010-97, Draft A	2011
		Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0	2009
		Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units, DOE/RL-2008-46-ADD2, Rev. 0	2010
100-NR-2	100-NR-1	*Sampling and Analysis Plan for the 100-NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, DOE/RL-2009-42, Rev. 0	2010
		Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 5:100-NR-1 and 100-NR-2 Operable Units, DOE/RL-2008-46-ADD5, Rev. 0	2011
100-HR-3	100-DR-1, 100-DR-2, 100-HR-1, and 100-HR-2	*Remedial Investigation/Feasibility Study for 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*, DOE/RL-2010-95, Draft A	2012*
		Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study, DOE/RL-2009-40, Rev. 0	2010
		Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 1: 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units, DOE/RL-2008-46-ADD1, Rev. 0	2010

Table 2.1-1. River Corridor Remedial Investigation/Feasibility Study Documents

Groundwater Interest Area	Source OUs Included in Document	Document Title	Published
100-FR-3	100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6	*Remedial Investigation/Feasibility Study for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*, DOE/RL-2010-98, Draft A (in progress)	2012*
		Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study, DOE/RL-2009-43, Rev. 0	2010
		Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units, DOE/RL-2008-46-ADD4, Rev. 0 REISSUE	2010
300-FF-5	300-FF-1 and 300-FF-2	*Remedial Investigation/Feasibility Study for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units*, DOE/RL 2010-99, Draft A	2011
		300 Area Remedial Investigation/Feasibility Study Work Plan for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units, DOE/RL-2009-30, Rev. 0	2010
1100-EM-1	None	*Draft Remedial Investigation/Feasibility Study for the 1100-EM-1 Operable Unit*, Hanford, DOE/RL-92-67, Draft C	1993

*Anticipated publication date

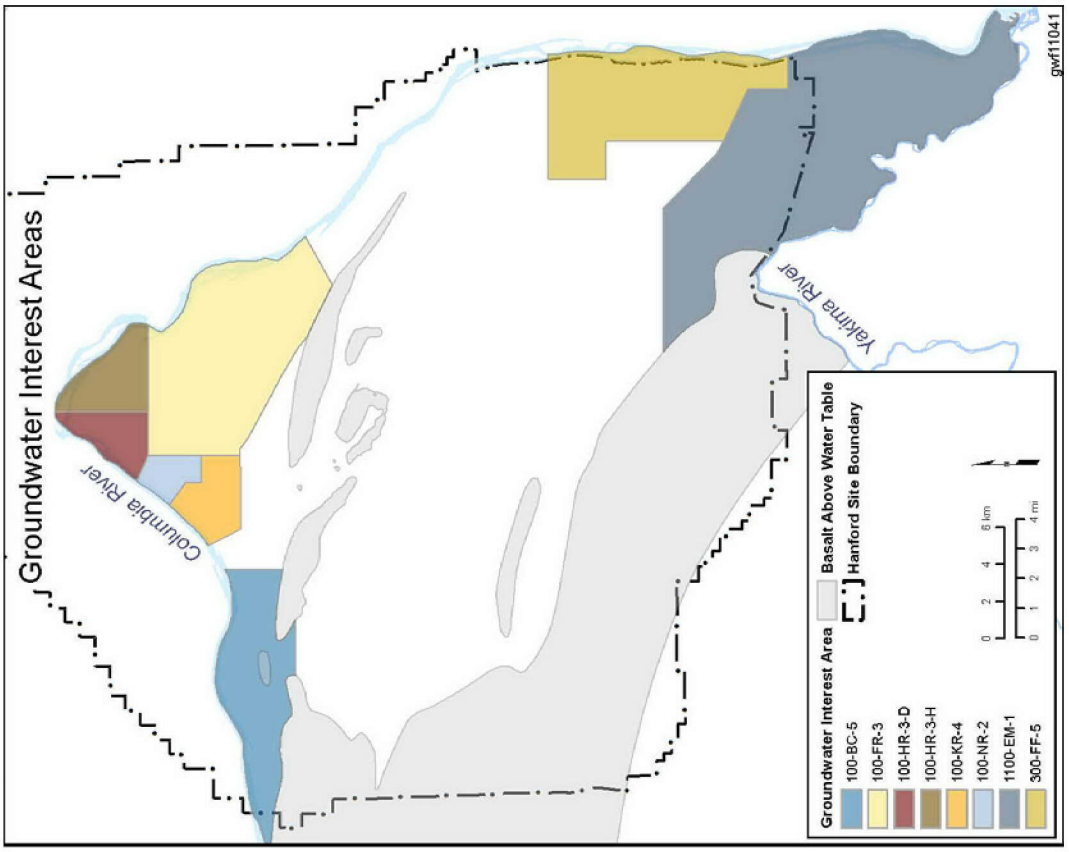
Table 2.1-2. Waste Site Remediation in the River Corridor[a]

Operable Unit Area	Number of Waste Sites Identified	Number of Waste Sites Completed[b]	Percent Completed
100-BC	150	136	91
100-K	168	52	31
100-N	190	57	30
100-D/H	342	154	45
100-F	157	134	85
300 Area	567	429	76
1100-EM-1	30	30	100
100-IU-2/IU-6[c]	250	136	54
River Corridor Total	1,854	1,128	61

a. Approximate numbers as of 2011; subject to change.

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

c. The 100-IU-2 and 100-IU-6 source operable units encompass a large portion of the Hanford Site's 600 Area.



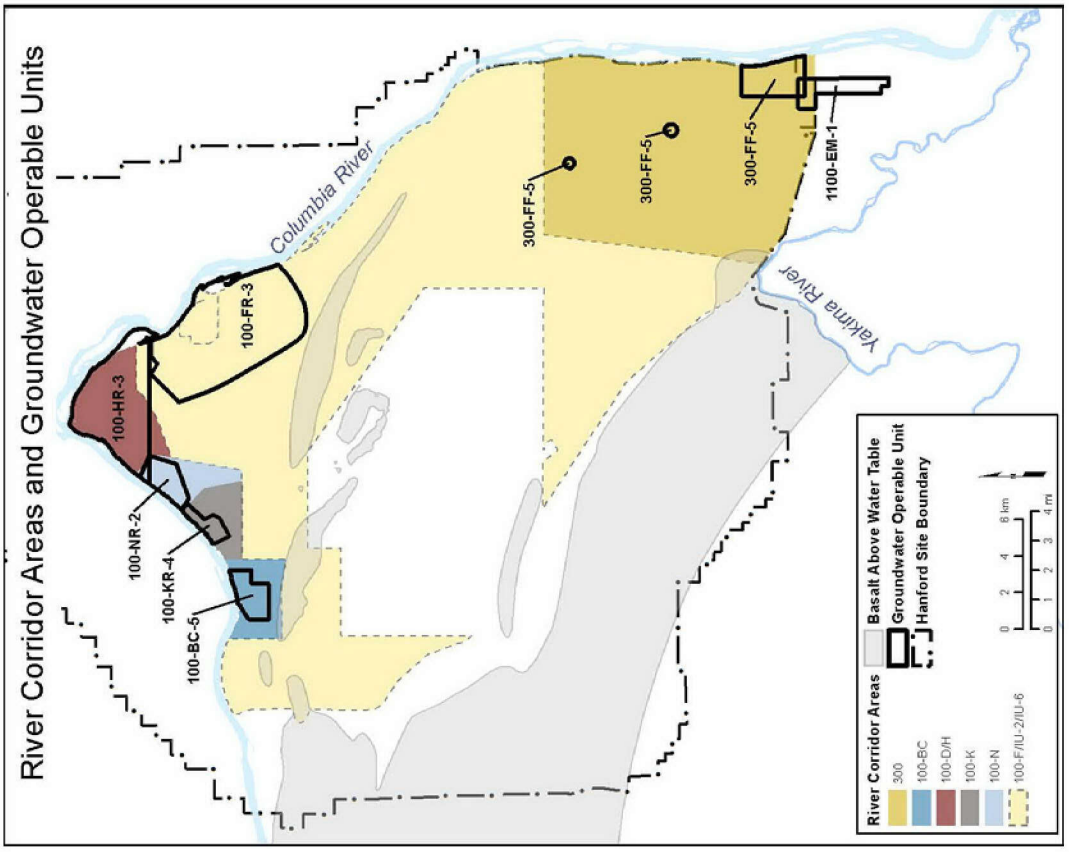


Figure 2.1-1. Hanford Site River Corridor Regions

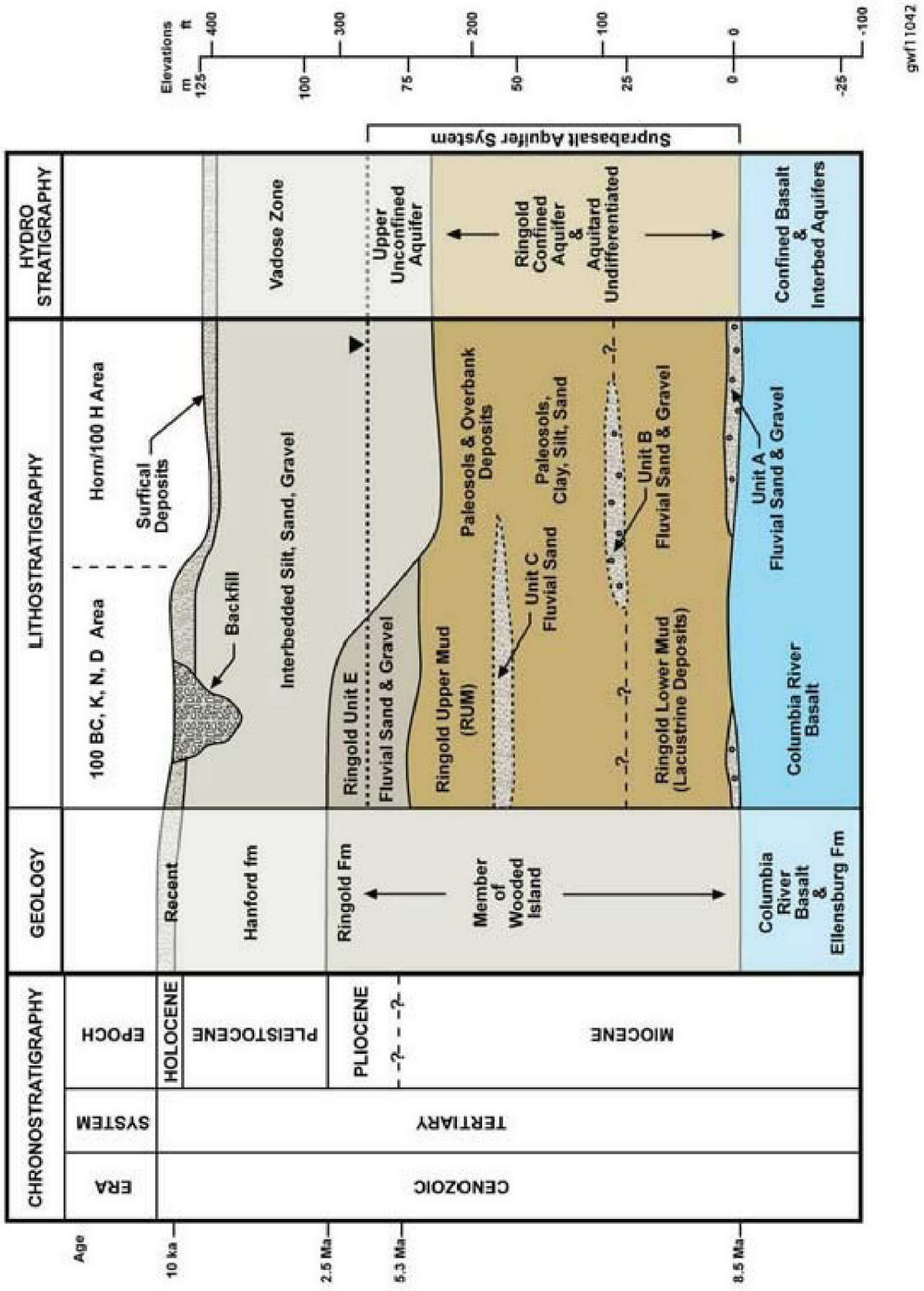


Figure 2.1-2. Generalized Hydrogeology of the 100 Area

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Figure 2.1-3. Hanford Site Water Table, March 2011

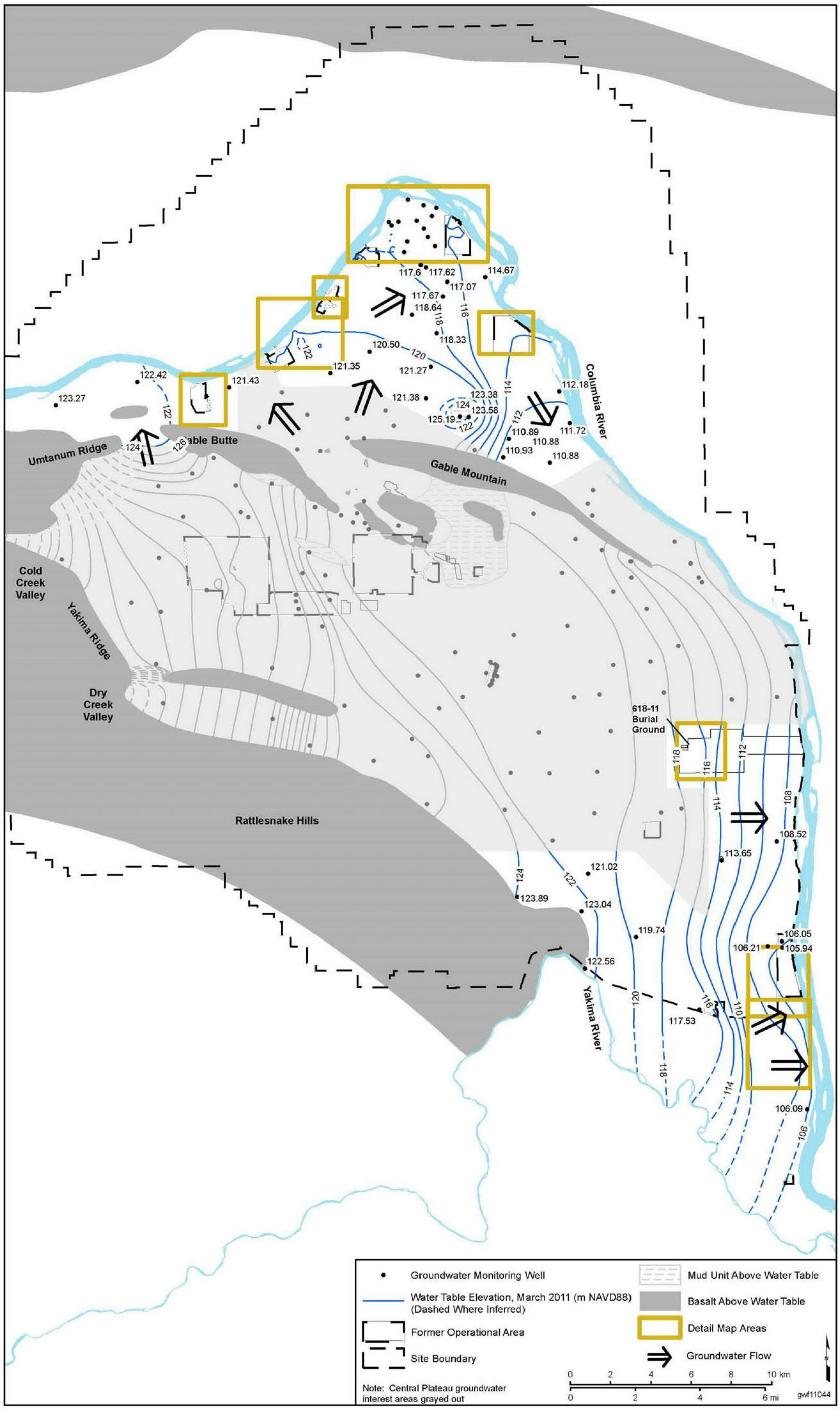


Figure 2.1-4. Groundwater Monitoring Wells on the Hanford Site

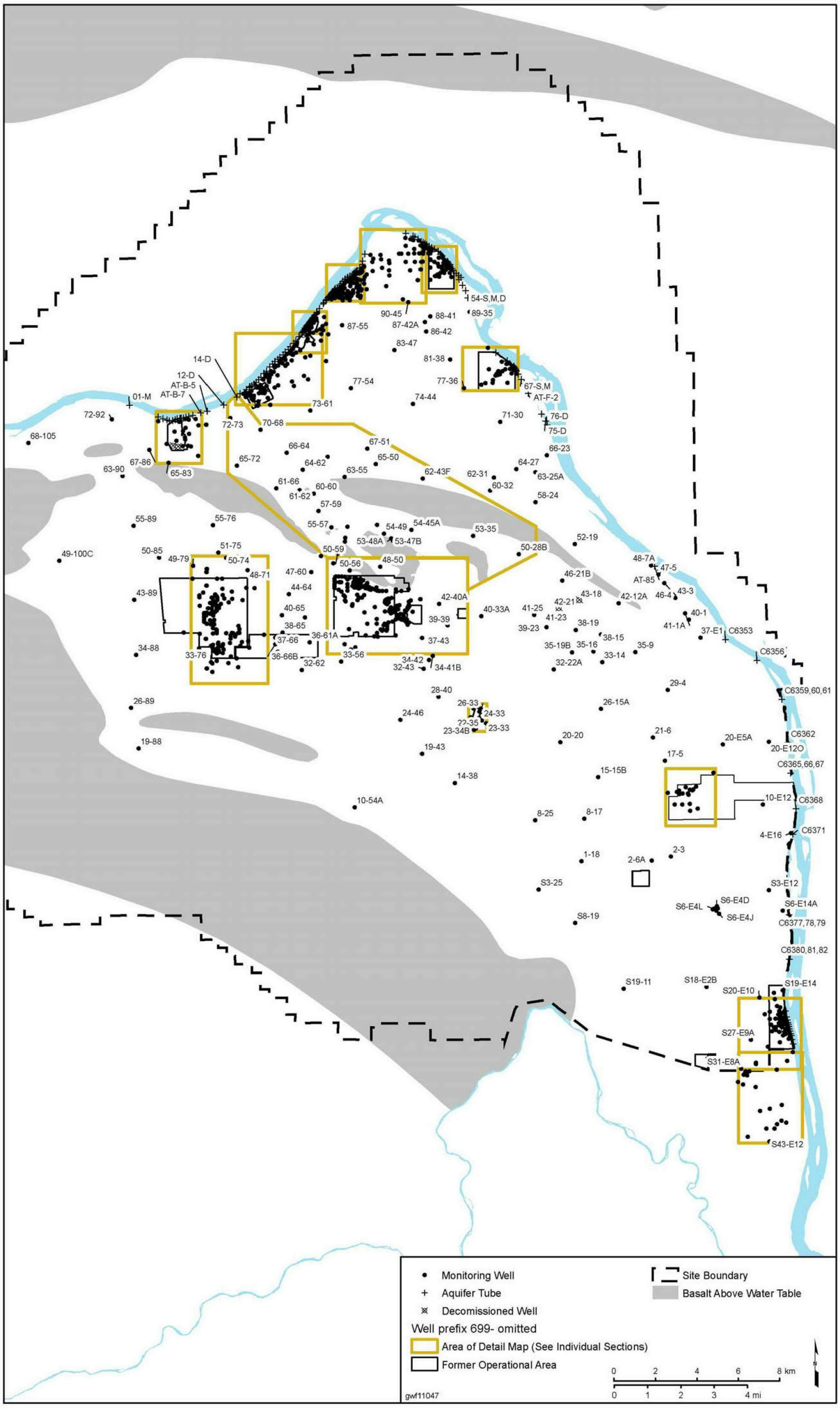
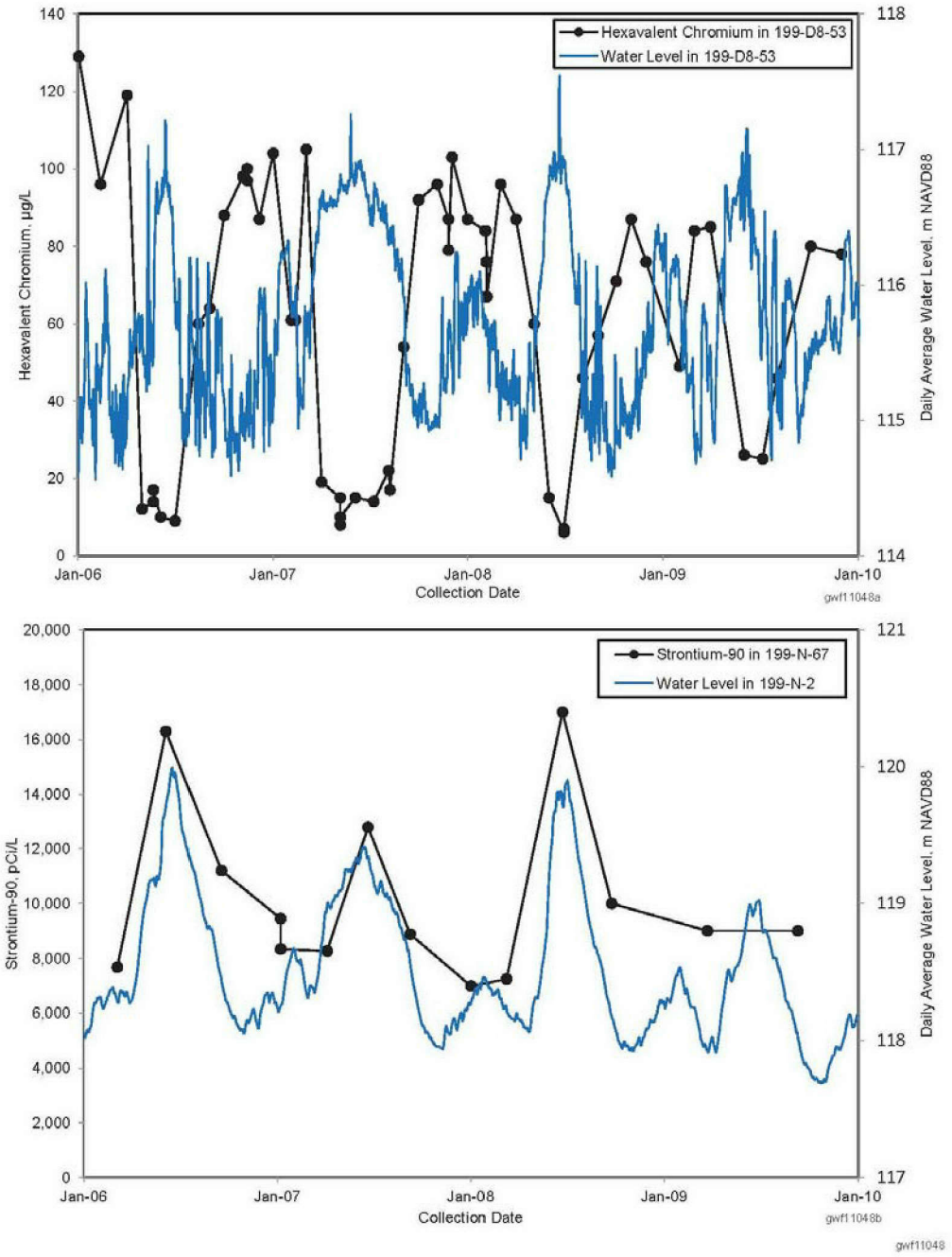


Figure 2.1-5. Examples of Effects of Water Table Variation on Contaminant Concentrations in Near-River Wells



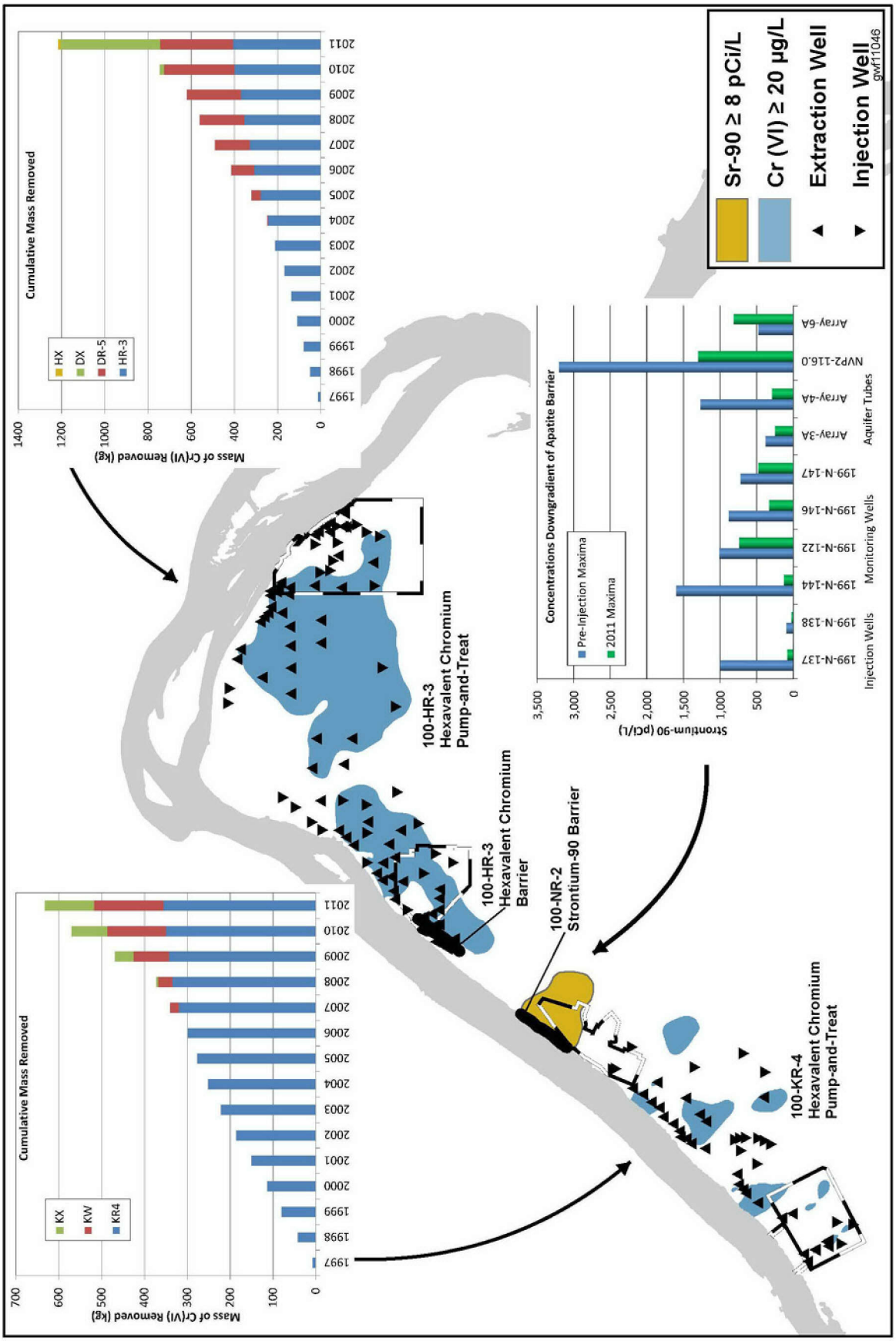
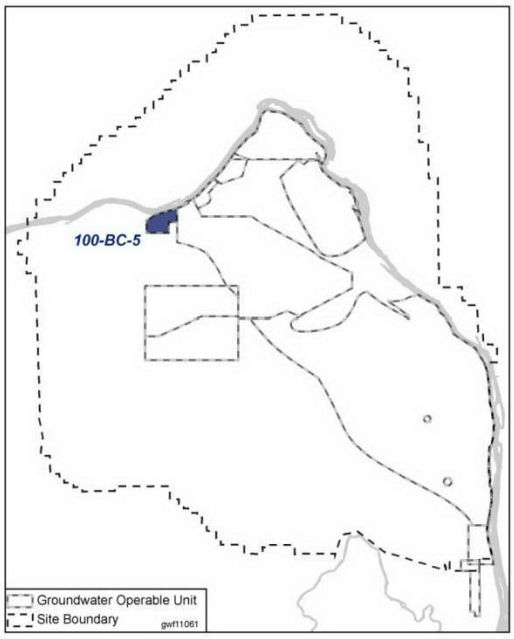


Figure 2.1-6. Interim Groundwater Remediation in the 100 Area

2.2 100-BC-5

M.J. Hartman

This section describes groundwater flow and contaminant distribution in the vicinity of the 100-BC Area, which is known as 100-BC-5. Figure 2.2-1 shows facilities, wells, and aquifer tubes. Groundwater monitoring for the AEA is integrated fully with CERCLA monitoring. No active waste disposal facilities or RCRA sites are in 100-BC-5. Previous assessments have not resulted in any interim remedial measures for groundwater. The area is currently undergoing a CERCLA RI/FS process, which will provide data to support final cleanup decisions. Additional details about 100-BC-5 history and waste sites are provided in Chapters 2 and 3 of DOE/RL-2008-46-ADD3, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*.



Most of the waste sites in the 100-BC Area have been remediated or are classified as not requiring remediation. In 2011, workers continued to excavate the 100-C-7 and 100-C-7:1 waste sites, removing sediment contaminated with hexavalent chromium. These excavations are very large and extend to depths of approximately 24 meters, nearly to the water table (Figure 2.2-2). During excavation, water was sprayed on the excavation to control dust for the protection of workers. Much of this water was subsequently removed from the site during excavation. However, when the holes reached total depth in late 2011, the application of dust-control water had the potential to move remaining contamination into the underlying aquifer.

The vadose zone in 100-BC-5 comprises Hanford formation sand and gravel. The water table is in the lower part of the Hanford formation or in the Ringold Formation unit E. The unconfined aquifer is 32 to 48 meters thick, and the base of the aquifer is the Ringold upper mud unit (Chapter 3 of DOE/RL-2010-96, *Remedial Investigation/Feasibility Study for 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units*, in progress).

100-BC-5 at a Glance

Reactor Operations: B 1944–1968; C 1952–1969				
2011 Groundwater Monitoring				
Contaminant	**Drinking Water Standard**	**Maximum Concentration**	**Plume Area[a] (km^2)**	**Shoreline Impact (m)**
Hexavalent Chromium	10/48[b] µg/L	53.5 µg/L	2.4[c]	1,400[c]
Strontium-90	8 pCi/L	36 pCi/L	0.41	280
Tritium	20,000 pCi/L	28,000 pCi/L	0.16	0
Remediation				
Waste Sites (interim action): >90% complete[d].				
Groundwater (interim action): None.				
Final Record of Decision anticipated in 2013.				

a. Estimated area above listed water quality standard.

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

c. At the 10 µg/L level.

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

Groundwater enters 100-BC-5 from upgradient areas along the Columbia River and the gaps between Umtanum Ridge, Gable Butte, and

Gable Mountain. Groundwater flows primarily to the north-northeast and discharges to the Columbia River (Figure 2.2-3). The water table is very flat in southern 100-BC-5. Effects of recharge from the 182-B Reservoir (used to store river water for the Site-wide water supply), or dust-control water at the 100-C-7 waste site, are not evident in the existing monitoring network. The changing river stage affects groundwater flow seasonally. The river stage was high in June 2011, causing water to flow from the river into the aquifer and the water table to slope toward the south-southwest.

Water levels in monitoring wells vary by as much as 4 meters near the river, and less than 1 meter in the southern part of 100-BC-5, approximately 1 kilometer inland. The changing river stage affects concentrations in near-river wells, but the effects are local and short-lived. Spring and fall 2010 plume maps showed little difference (Chapter 4 of DOE/RL-2011-01).

Routine groundwater monitoring requirements are described in *100-BC-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2003-38). Wells are sampled for the contaminants of concern selected using the data quality objectives process (PNNL-14287, *Data Quality Objectives Summary Report – Designing a Groundwater Monitoring and Assessment Network for the 100-BC-5 and 100-FR-3 Operable Units*). The contaminants of concern for routine monitoring are strontium-90, tritium, and hexavalent chromium. Most of the wells are sampled once per year or once every other year (Appendix A). Plume maps in this section are based on 2011 average concentrations. Ten wells installed from 2009 through 2011 for the RI/FS are not yet formally incorporated into the groundwater sampling and analysis plan. The wells were sampled annually to quarterly during 2011 (Appendix A).

A subset of 100-BC-5 aquifer tubes is scheduled for annual sampling in the fall of each year. Fall 2011 sampling was partially completed in December 2011. Some tubes could not be sampled because they were submerged or frozen, and sampling was delayed into 2012. Some 100-BC-5 tubes were also sampled in early 2011, delayed from the event scheduled in fall 2010. Appendix D lists sampling dates for the aquifer tubes.

Figure 2.2-4 shows how the sizes of the hexavalent chromium, strontium-90, and tritium plumes have changed since 2003. Some of the apparent changes in plume area were the result of new sampling locations and not an actual change in size. These changes are discussed in the following sections.

2.2.1 Hexavalent Chromium

Sources of hexavalent chromium included cribs near the reactor buildings, trenches, and retention basins near the Columbia River (e.g., 116-B-1, 116-B-11, 116-C-1, and 116-C-5), and pipelines from the reactor buildings to these near-river facilities. During remediation activities in recent years, additional chromium sources were identified in the 100-BC Area: the 100-C-7 and 100-C-7:1 sites and associated pipelines in the south, and the 100-B-27 sodium dichromate spill site in the northwest.

Figure 2.2-5 illustrates the portion of the plume with concentrations greater than 10 μg/L, based on 2011 average concentrations in wells screened in the upper portion of the unconfined aquifer. Hexavalent chromium concentrations are much lower than in the 100-K or 100-D Areas; concentrations typically exceed the 48 μg/L groundwater cleanup standard only in well 199-B3-47 (although the 2011 average concentration in that well was 44 μg/L, below the standard). The area of the plume above 10 μg/L is slightly smaller than in 2010, based on trends of declining concentrations in wells in western and southern 100-BC-5. Figure 2.2-4 shows the change in the size of the chromium plume over time. The apparent increase between 2006 and 2010 was primarily a result of the installation of new wells, which revealed that the plume in western 100-BC-5 was more extensive than previously thought. The increase between 2010 and 2011 was an artifact of the way the plume map was constructed (computer contouring in 2011 and manual contouring in 2010).

The western extent of the 100-BC-5 chromium plume is not well defined. Concentrations in well 199-B5-5 (screened in the lower part of the aquifer and not shown on the plume map) averaged 38 μg/L in 2011, about the same as in 2010. Concentrations at the top of the aquifer at this location, based

on characterization samples collected in 2009, are >20 µg/L. The only well farther west is 199-B2-13, where concentrations were less than 10 µg/L in 2010 (the well was not scheduled for sampling in 2011). Hexavalent chromium concentrations in aquifer tubes along the western shoreline of 100-BC-5 continued to be below 10 µg/L in 2011.

Two wells in southern 100-BC-5 showed sharp increases in hexavalent chromium concentrations in 2011 and early 2012. These changes may be caused by remediation activities at the 100-C-7 and 100-C-7:1 waste sites. The plume contours of Figure 2.2-5 have been adjusted to account for the apparent contamination beneath these waste sites. Concentrations in downgradient well 199-B4-14, a water-table well, rose to 40 µg/L in October 2011 and 144 µg/L in February 2012 (Figure 2.2-6). East of the waste sites, concentrations temporarily rose to approximately 50 µg/L in well 199-B8-9 in June 2011 (Figure 2.2-7). If these changes were caused by mobilization of hexavalent chromium from the vadose zone during remediation, then it took 1 year or less for the contamination to travel through the vadose zone and aquifer to well 199-B8-9, and no more than 20 months to reach well 199-B4-14. These travel times are shorter than expected, indicating the hydraulic conductivity of the shallow aquifer (Hanford formation) is higher than previously thought. The hydraulic gradient also may have increased because of artificial recharge by dust-control water. However, this effect is not evident in water level data from surrounding wells.

After remediation of the 100-C-7 and 100-C-7:1 sites is completed in 2012, no additional contamination will migrate into groundwater. DOE has increased the frequency of monitoring at well 199-B4-14 and adjacent deep well 199-B5-6 to determine the persistence and magnitude of the effects of remediation.

Two wells in southern 100-BC-5 showed sharp increases in hexavalent chromium concentrations in 2011 and early 2012. These changes may have been caused by remediation activities at the 100-C-7 or 100-C-7:1 waste sites.

The unconfined aquifer in 100-BC-5 is 32 to 48 meters thick, and contaminants are not evenly distributed with depth. Characterization data collected during drilling of the RI wells show that hexavalent chromium concentrations decrease with depth in eastern 100-BC-5 (for example, well 199-B3-51). Monitoring data confirm the characterization results. Shallow well 199-B3-47 typically has the highest chromium concentrations in 100-BC-5 (Figure 2.2-8), while adjacent well 199-B3-51, screened at the bottom of the aquifer, has concentrations near or below detection limits. The sharp dip in chromium concentrations in 199-B3-47 in mid-2011 was caused by inflowing river water when the river stage was high in late June. In western 100-BC-5 (at the locations of 199-B5-5 and 199-B5-6), hexavalent chromium concentrations are highest at the top and bottom of the aquifer and lower in between (Chapter 3 of DOE/RL-2010-96, in progress). The distribution is likely a result of different periods of contaminant release.

Hexavalent chromium contamination appears to be limited to the unconfined aquifer. Deep monitoring wells 199-B2-12 and 199-B2-15 are screened in a water-bearing unit within or beneath the Ringold Formation upper mud unit. Hexavalent chromium concentrations are near or below detection limits in that unit.

Hexavalent chromium concentrations in 100-BC-5 aquifer tubes range from less than detection limits to 35 µg/L and are generally declining. Sampling of Columbia River pore water[1] in 2009 showed

[1] Pore water samples were collected from the riverbed at depths of 30 to 40 centimeters. Aquifer tube depths range from 6 to 25 meters in 100-BC-5.

hexavalent chromium concentrations ranging from less than 2 to 112 µg/L. Two subsequent rounds of pore water sampling did not find such high concentrations, indicating no ongoing, highly-concentrated plume in pore water. Results are described in *Columbia River Pore Water Sampling in 100-BC Area, November 2010* (SGW-49368).

2.2.2 Strontium-90

Liquid effluent containing strontium-90 was disposed to cribs near the reactor buildings, and to cribs, trenches, and retention basins in northeastern 100-BC-5. Figure 2.2-9 shows an interpretation of the plume based on 2011 data. The plume split into two parts in 2011 as strontium-90 concentrations in central 100-BC-5 declined (Figure 2.2-10). Most of the 2011 data from wells near the former B Reactor were below the drinking water standard in 2011, but characterization borehole data from 2010 had higher concentrations. Strontium-90 concentrations in some aquifer tubes adjacent to the plume are near or above the drinking water standard.

Figure 2.2-4 shows how the plume has changed in size. The apparent decrease in size in 2006 reflects a change in interpretation, benefitting from new data. The declines in size in 2010 and 2011 were the result of falling concentrations in central 100-BC-5.

Strontium-90 concentrations in 100-BC-5 groundwater declined between 2009 and 2011, and the plume has decreased in size.

Figure 2.2-11 shows the strontium-90 trends in northern 100-BC-5 near some of the former contaminant sources: 199-B3-47 near the 116-B-11 Retention Basin and 116-B-14 Trench; 199-B3-1 near the 116-B-1 Trench; and 199-B3-46 near the 116-C-1 Trench. These sites have been remediated, although a borehole near the 116-B-14 Trench detected low levels of strontium-90 in the vadose zone (Section 4.2 of DOE/RL-2010-96, in progress). The highest concentrations in groundwater are approximately four times the drinking water standard, and concentrations have declined.

Groundwater samples collected during drilling indicate that strontium-90 contamination in 100-BC-5 groundwater is limited to the upper portion of the unconfined aquifer. Strontium-90 concentrations in well 199-B3-51, screened at the bottom of the aquifer, are below detection limits, while adjacent well 199-B3-47 has concentrations above the drinking water standard.

2.2.3 Tritium

Tritium was present in effluent discharged to former cribs near the B Reactor (for example, 116-B-5 Crib) and near the Columbia River. The former 118-B-1 Burial Ground in the southwestern 100-BC-5 was another source of contamination. All of these waste sites have been remediated. The unconfined aquifer beneath 100-BC-5 is contaminated with tritium at concentrations exceeding the drinking water standard in three areas (Figure 2.2-12). The plume decreased in size between 2010 and 2011 (Figure 2.2-4).

In northern 100-BC-5, tritium distribution formerly was interpreted as one narrow, continuous plume extending from central 100-BC Area to the Columbia River. The 2011 plume map (Figure 2.2-12) depicts tritium in two separate, small plumes because of lower concentrations in intermediate wells.

Tritium concentrations in northern 100-BC-5 have varied widely over the past two decades, but the peaks are declining (Figure 2.2-13). Some of the changes in the 1990s may have been caused by nearby waste site remediation that mobilized contamination, but that does not explain recent spikes. The tritium concentration declined sharply between 2010 and 2011 in 199-B5-2. The sharp decline in the tritium concentration in 199-B3-47 in late June 2011 was caused by an unusually high river stage. The well had not been sampled during the high river stage in previous years. Inflow of river water into the aquifer diluted the groundwater, as evidenced by the low specific conductance of the sample. Tritium

concentrations in aquifer tube 06-M have exceeded the drinking water standard several times in the past, but were below the standard when sampled in March 2011.

In northern 100-BC-5, tritium concentrations have varied widely over the past two decades, but the peak concentrations have declined.

Tritium concentrations in a portion of southern 100-BC-5 are interpreted as exceeding the drinking water standard (Figure 2.2-12), although no 2011 averages from this region exceeded the standard. Wells 199-B8-7 and 199-B8-8 had tritium concentrations above the drinking water standard before the wells were decommissioned in 2010. The tritium concentration in 199-B8-6, located near the 118-B-1 Burial Ground, was above the drinking water standard in the past, but below the standard in 2010 and 2011 (Figure 2.2-14). Tritium concentrations were elevated but below the drinking water standard in deep well 199-B5-6 and its shallow partner 199-B4-14. In well 199-B8-9, farther east, tritium concentrations rose to a level above the drinking water standard in October 2011 (Figure 2.2-14). The pattern of concentration changes in southern 100-BC-5 indicates the plume is gradually migrating toward the east.

Vertical characterization data from recently drilled wells indicate that tritium concentrations decrease with depth in the aquifer in most locations (Section 4.3 of DOE/RL-2010-96, in progress).

2.2.4 Other Contaminants

The 100-BC RI/FS work plan (DOE/RL-2008-46-ADD3) identified an extensive list of groundwater contaminants of potential concern. Evaluation of the RI data concluded that only hexavalent chromium, strontium-90, and tritium remain contaminants of concern (Chapter 6 of DOE/RL-2010-96, in progress).

Nitrate concentrations in most 100-BC-5 wells are below approximately 20 mg/L. Concentrations are higher in well 199-B3-47 in northeastern 100-BC-5, ranging from 29 to 44 mg/L in 2010, which was the last time this well was sampled for nitrate.

In 2010, low concentrations (below 5 µg/L) of trichloroethene and chloroform were detected in 100-BC-5 wells (Section 4.1.5 of DOE/RL-2011-01). Few wells were sampled for organic contaminants in 2011. Chloroform concentrations were all below the 1 µg/L detection limit. Trichloroethene was detected in upgradient well 199-B5-8 at 2.2 µg/L and in 199-B8-9 at 1.1 µg/L. The results are flagged as estimates because they are near the detection limit. The risk evaluation determined that trichloroethene and chloroform were not contaminants of concern (Chapter 6 of DOE/RL-2010-96, in progress).

2.2.5 CERCLA Groundwater Activities

In 2011, CERCLA activities associated with groundwater included continued RI studies and routine groundwater monitoring.

Routine groundwater sampling requirements are defined in DOE/RL-2003-38, as modified by Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records, 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38 Rev 1 (as modified by TPA-CN-240, 12/08/08) (TPA-CN-293). With one exception, well sampling occurred as planned in 2011 (Appendix A). One quarterly sample from new well 199-B2-16 was missed because of restrictions related to electrical work, coupled with dry weeds causing fire danger. The well was successfully sampled the next quarter.

The new wells installed for the RI/FS have been sampled quarterly for one year and will be sampled annually to quarterly, depending on monitoring objectives, in 2012. The routine sampling and analysis plan does not yet include new wells installed for the RI/FS and should be updated.

An RI was performed in 2010 and early 2011 (DOE/RL-2008-46-ADD3). The last two RI monitoring wells (199-B3-51 and 199-B5-8) were drilled and installed in 2011. A draft RI/FS report (DOE/RL-2010-96, in progress) is being prepared, which will lead to the selection of alternatives for site cleanup. The draft report will undergo review by regulatory agencies and the public.

Figure 2.2-1. Facilities and Groundwater Monitoring Wells in 100-BC-5

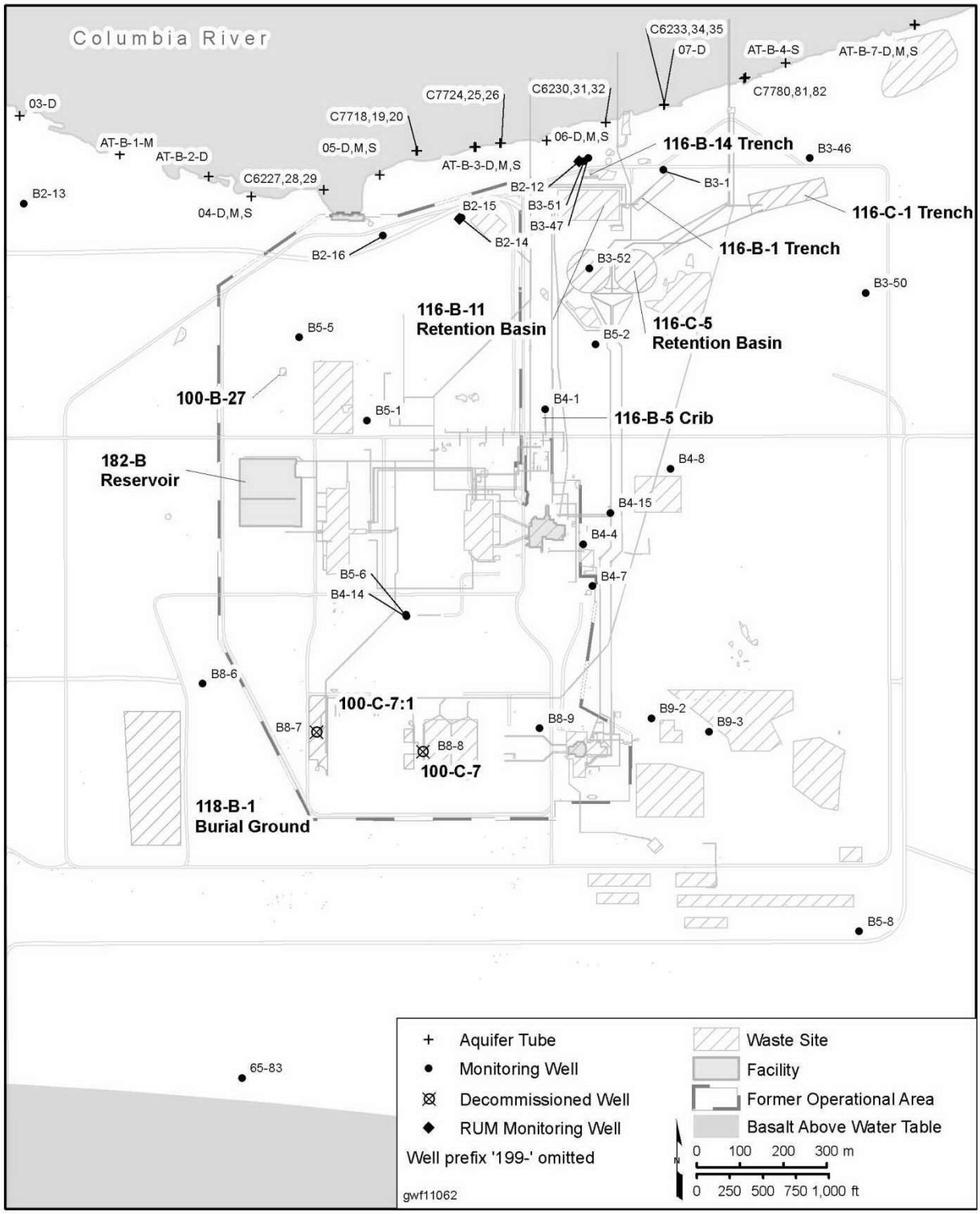


Figure 2.2-2. Aerial Photograph of Excavations at 100-C-7:1 (left) and 100-C-7 (right) Waste Sites, Early 2012

Figure 2.2-3. 100-BC-5 Water Table, March 2011

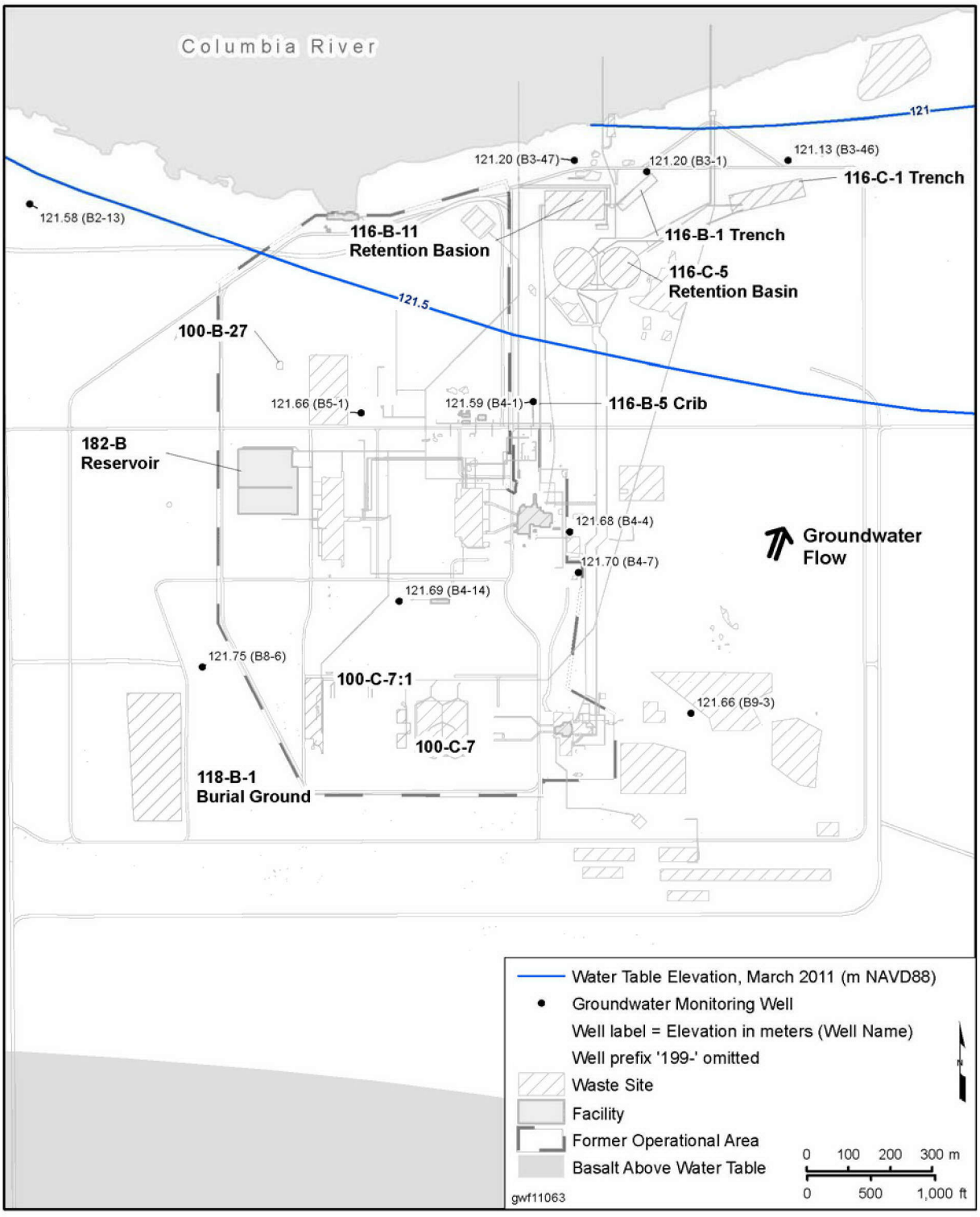


Figure 2.2.4. Changes in 100-BC-5 Plume Areas with Time

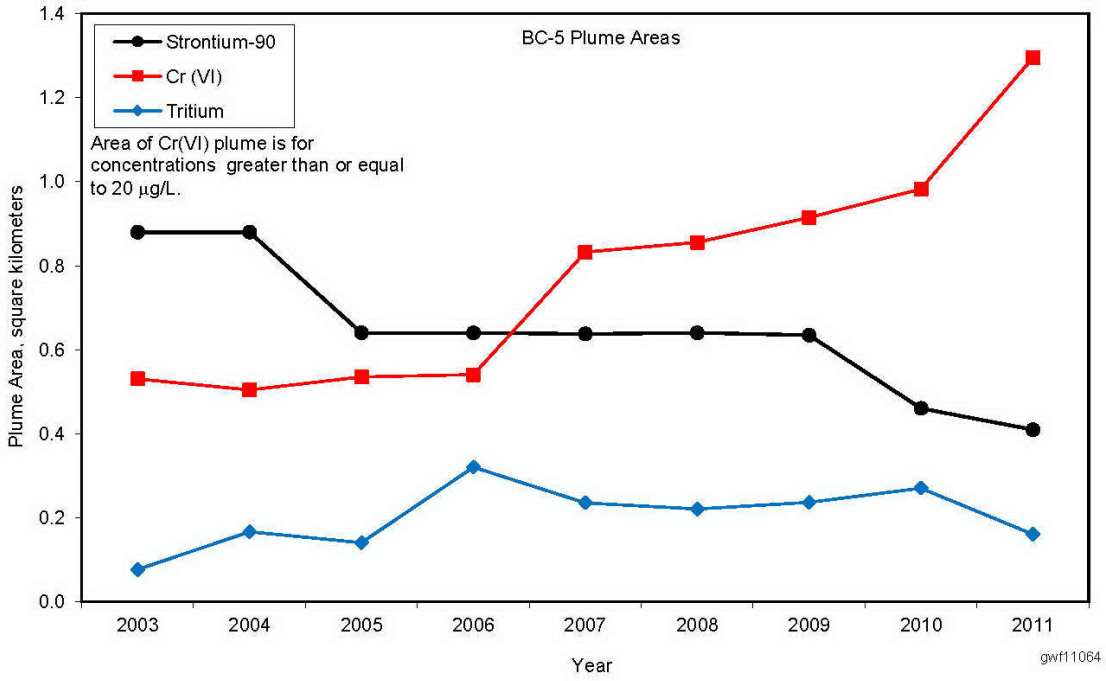


Figure 2.2-5. Average Chromium Concentrations in 100-BC-5 Upper Part of Unconfined Aquifer, 2011

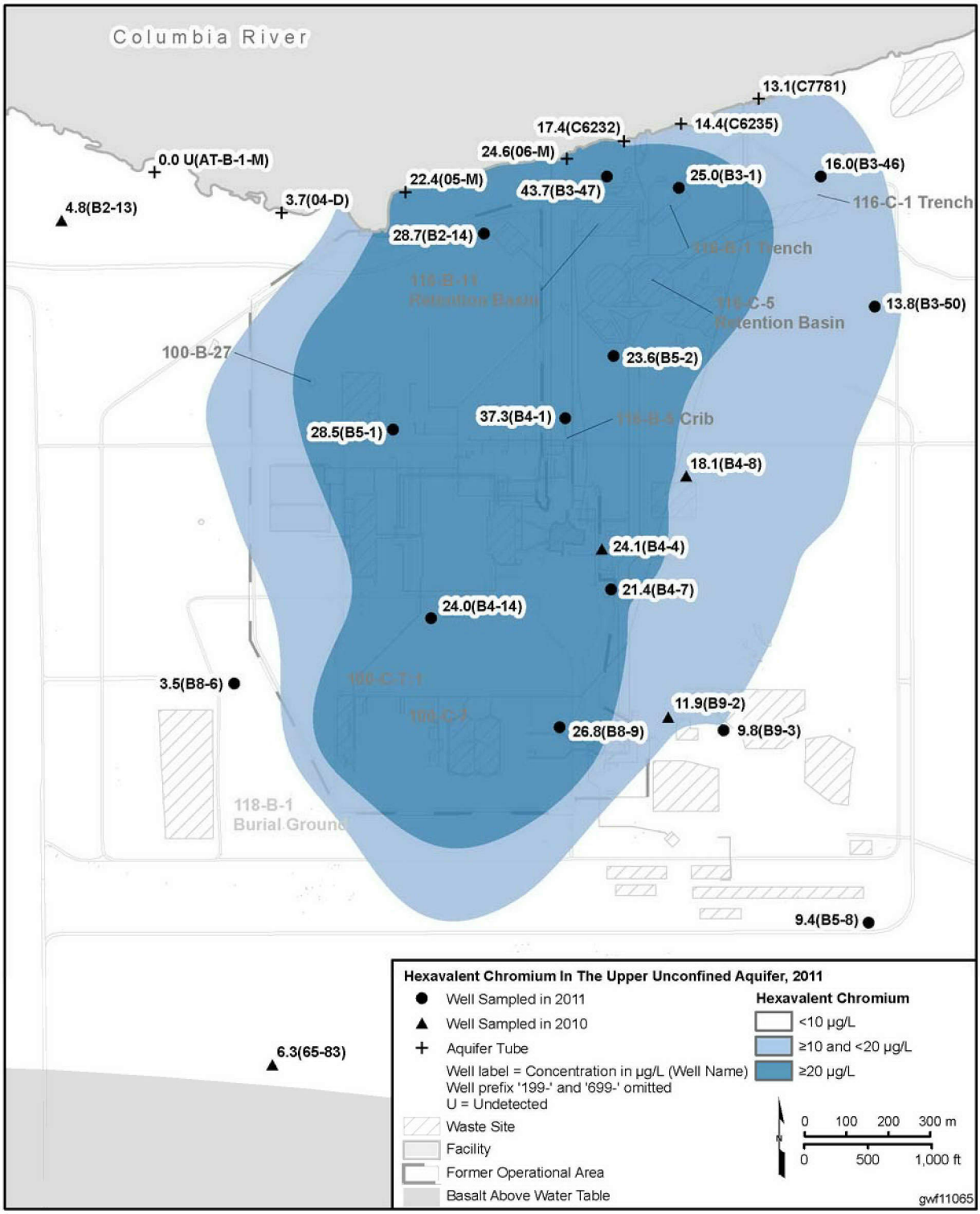


Figure 2.2-6. Hexavalent Chromium Trends in Shallow/Deep Well Pair, Central 100-BC-5

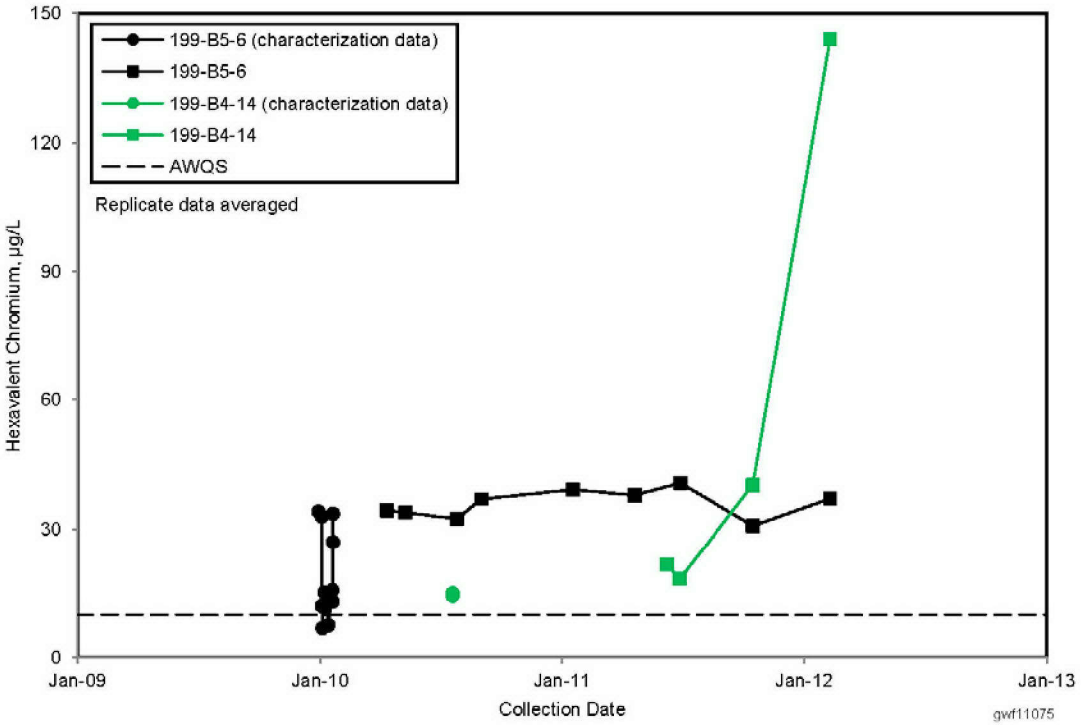


Figure 2.2-7. Hexavalent Chromium Trend in Well 199-B8-9, Southern 100-BC-5

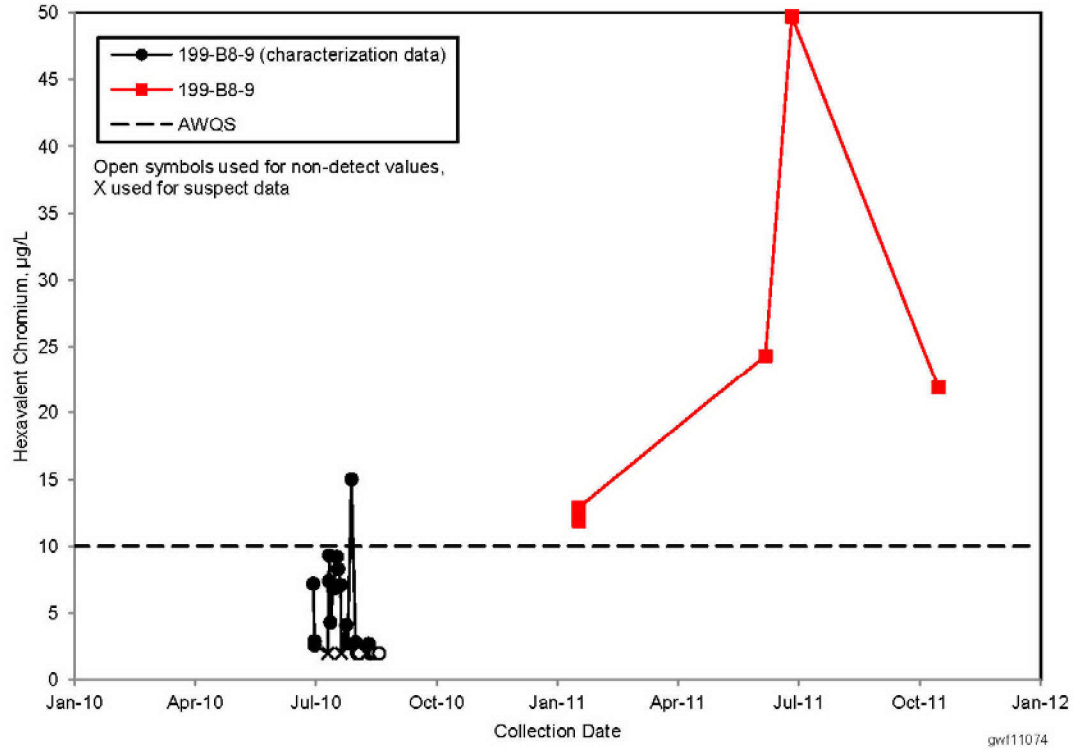


Figure 2.2-8. Dissolved Chromium Trends in Shallow/Deep Well Pair, Northern 100-BC-5

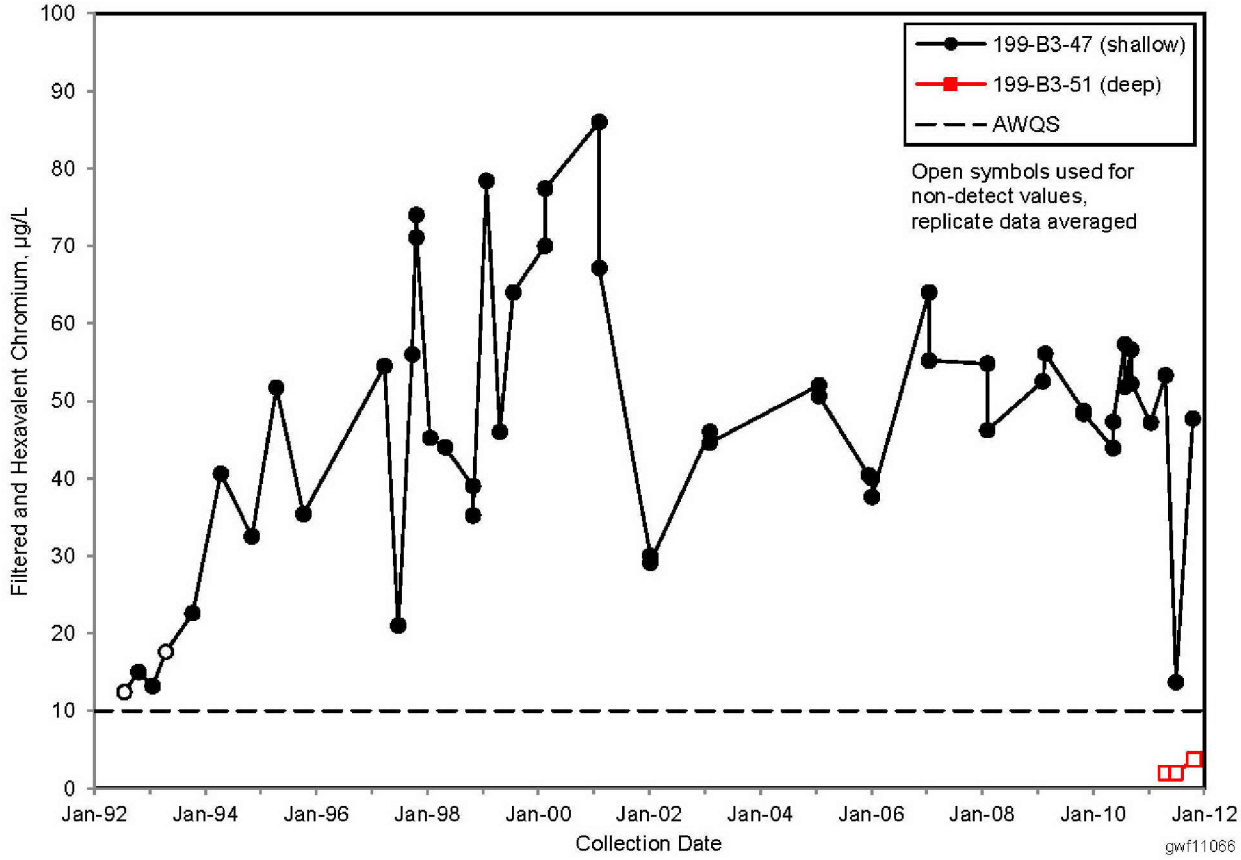


Figure 2.2-9. Average Strontium-90 Concentrations in 100-BC-5, Upper Part of Unconfined Aquifer, 2011

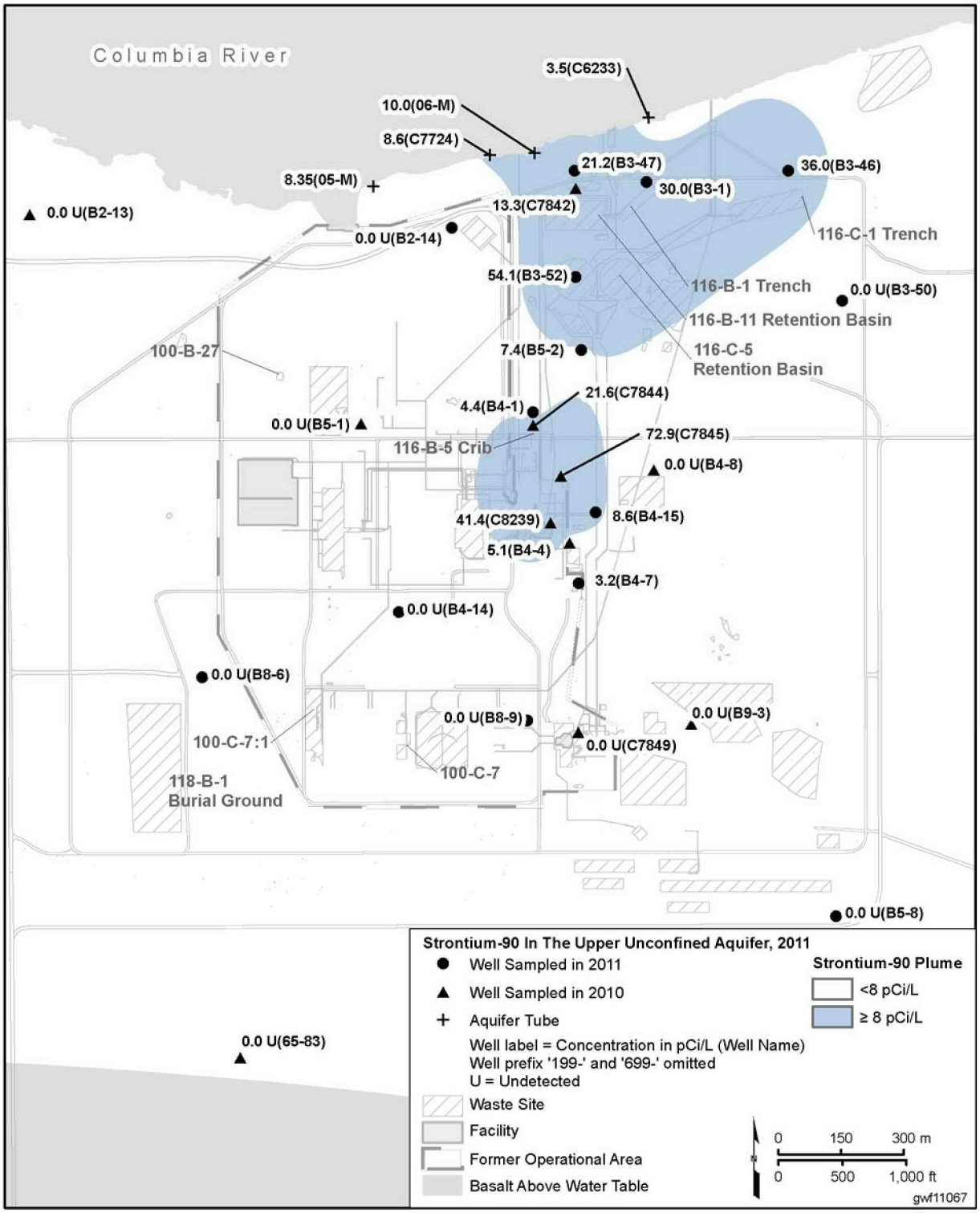


Figure 2.2-10. Strontium-90 Trends in Wells in Central 100-BC-5

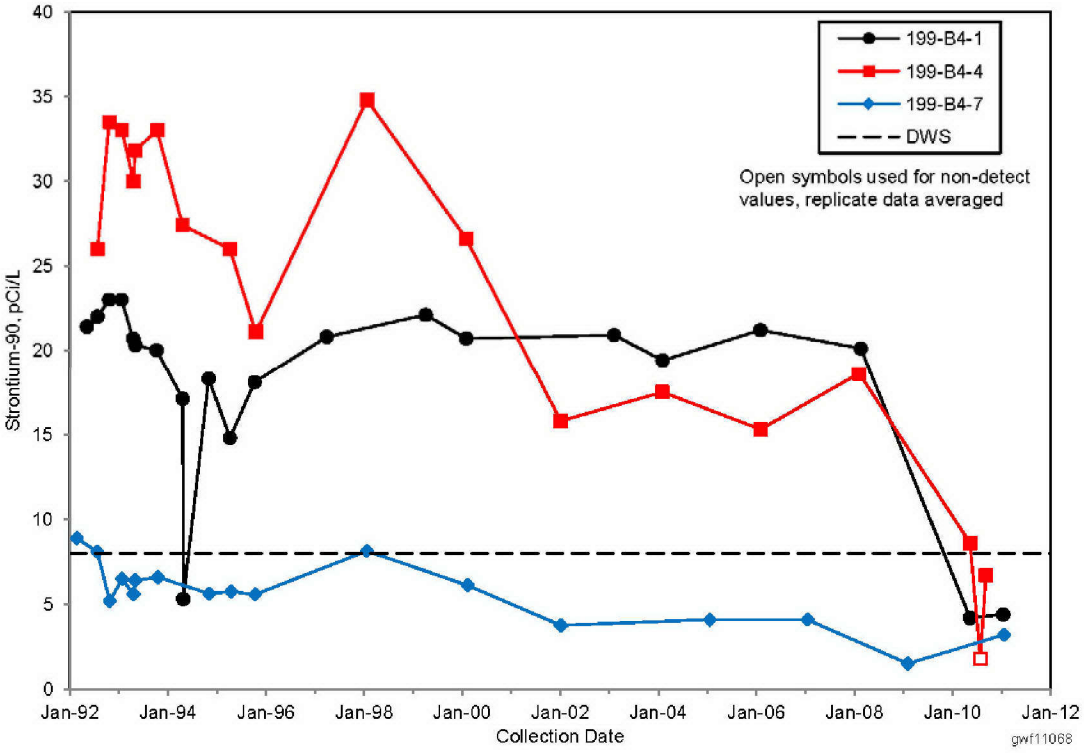


Figure 2.2-11. Strontium-90 Trends in Wells in Northern 100-BC-5

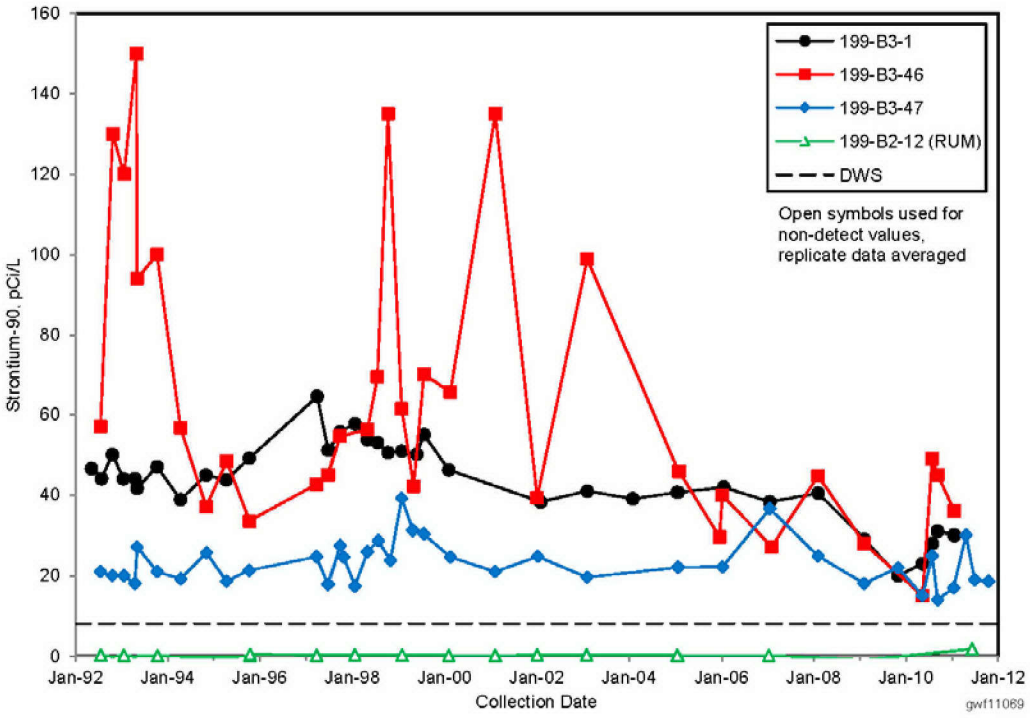


Figure 2.2-12. Average Tritium Concentrations in 100-BC-5, Upper Part of Unconfined Aquifer, 2011

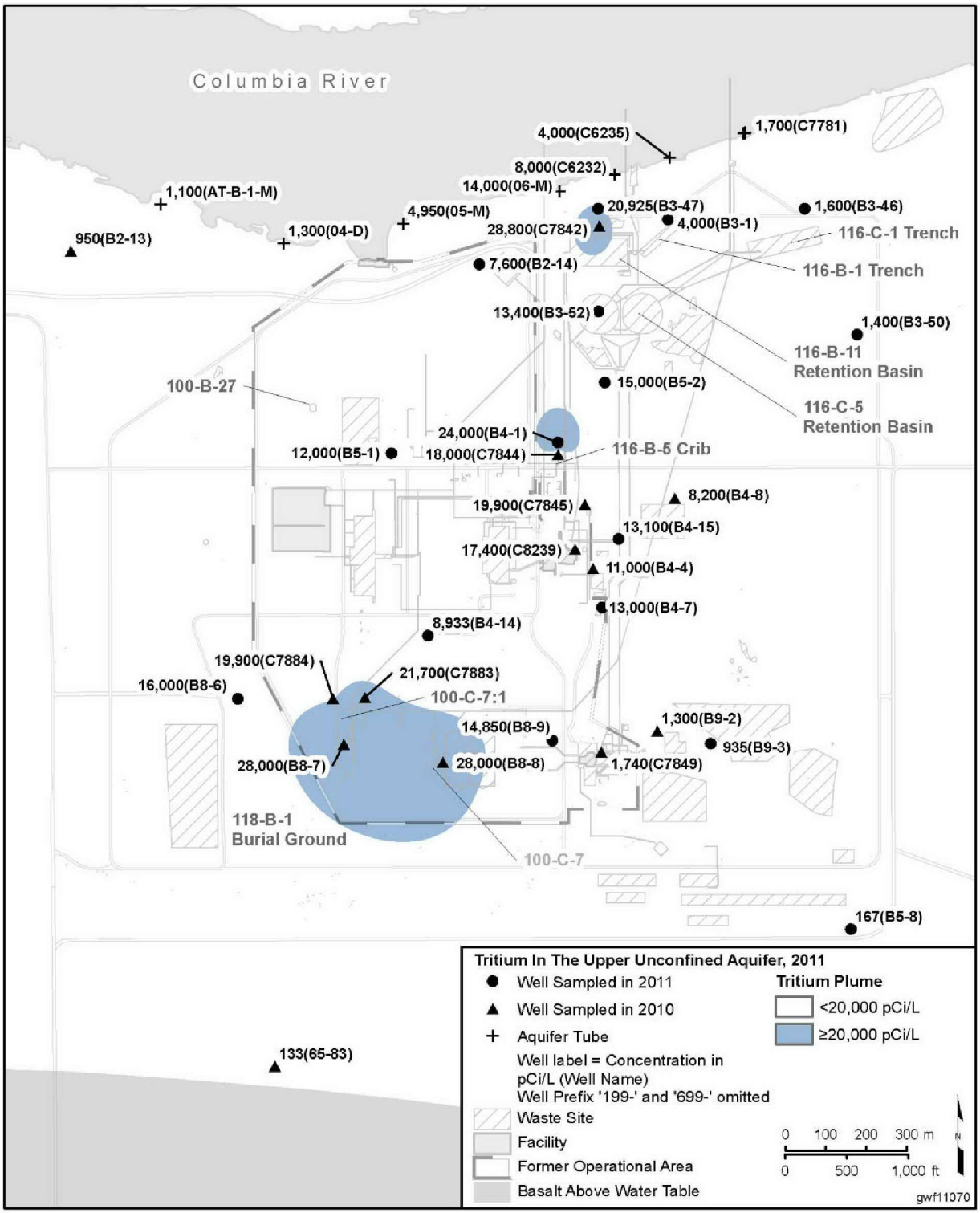


Figure 2.2-13. Tritium Trends in Wells in Northern 100-BC-5

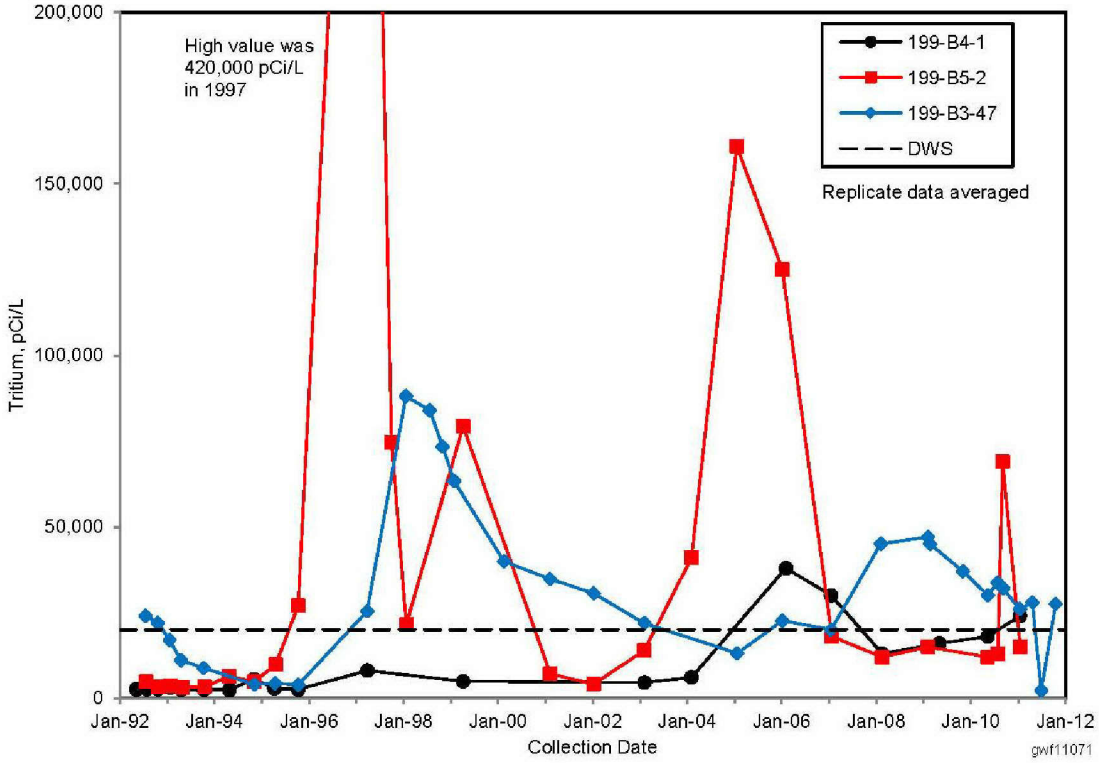
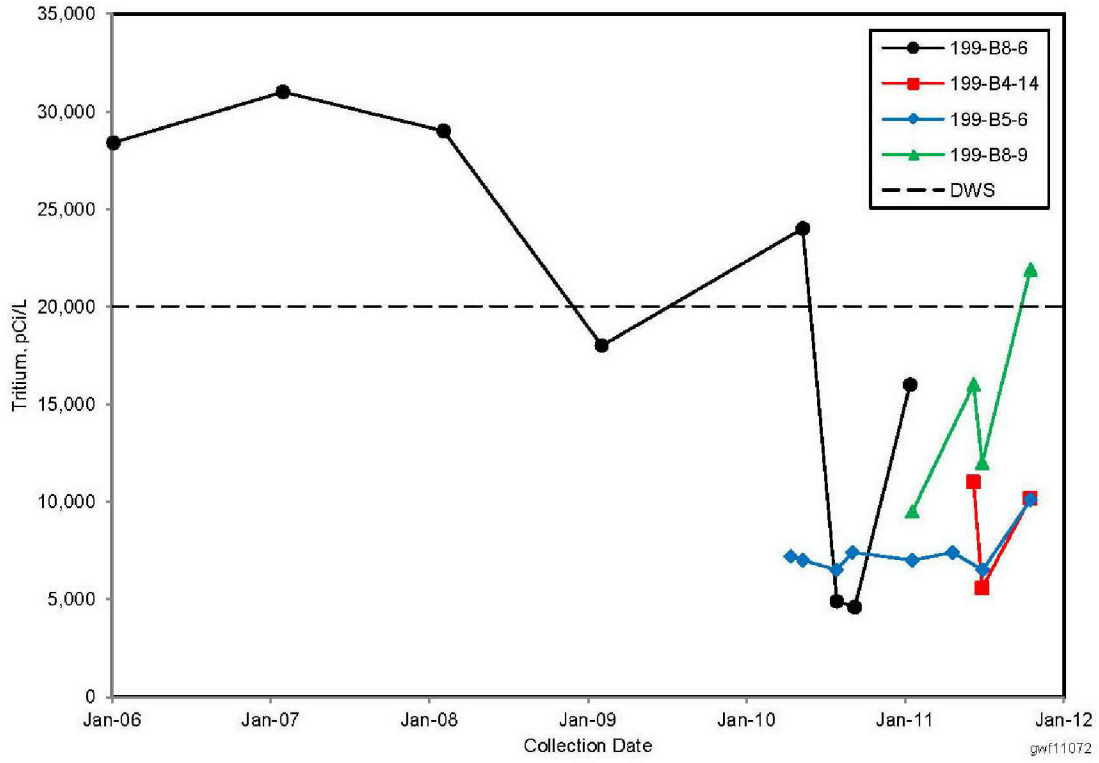


Figure 2.2-14. Tritium Trends in Wells in Southern 100-BC-5



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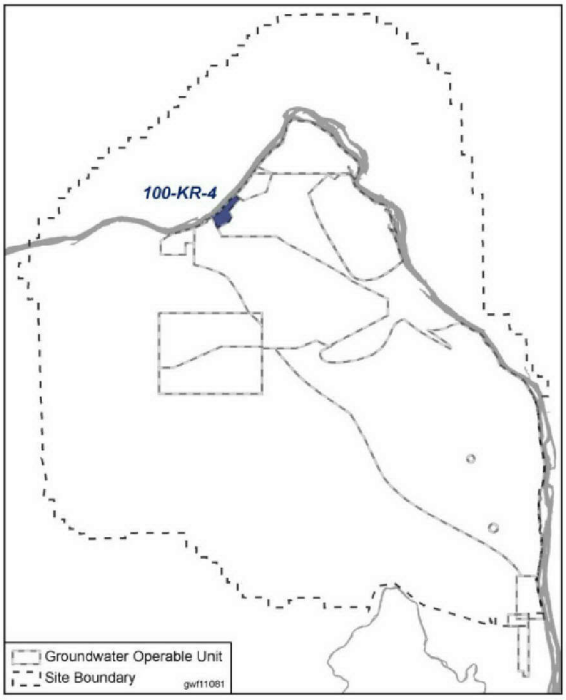
2.3 100-KR-4

K.A.. Ivarson, C.W. Miller, and M.J. Hartman



The 100-KR-4 Operable Unit is along the Columbia River in the northern-central portion of the Hanford Site. Groundwater in 100-KR-4 was contaminated by waste releases associated with past operation of the deactivated KE and KW Reactors and from associated support facilities. At the end of 2011, ~ 30 percent of the waste sites were classified as closed, interim closed, no action, not accepted or rejected, with ~ 10 percent having undergone active remediation. Removing contaminants from the vadose zone eliminates secondary sources of contamination that could migrate to groundwater. Additional details about 100-KR-4 history, waste sites, and hydrogeology are provided in Chapters 1 and 3 of DOE/RL-2010-97, *Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*. Figure 2.3-1 shows locations of former waste sites, groundwater monitoring wells, and groundwater extraction and injection wells.

The unconfined aquifer in 100-KR-4 ranges from 5.2 to more than 32 meters thick. This aquifer is primarily present in the Ringold Formation unit E sand and gravel. This unit is overlain by the gravels and interbedded sand and silt of the Hanford formation, which comprise the bulk of the vadose zone. Near the northeastern end of the 116-K-2 Trench, a portion of the Hanford formation becomes saturated at high river stage. The vadose zone ranges from less than 1 meter thick near the Columbia River to 32 meters thick inland. The uneven surface of the silt- and clay-rich Ringold Formation upper mud unit forms the bottom of the unconfined aquifer.

Groundwater in 100-KR-4 flows generally to the northwest toward the Columbia River (Figure 2.3-2). With the installation of the new pump-and-treat system, groundwater flow is being altered. The increased extraction and injection of groundwater in the expanded pump-and-treat system has created depressions and mounds in the water table, affecting the local flow direction. The most prominent groundwater mound is inland of the 116-K-2 Trench, creating radial flow and affecting the hexavalent chromium contaminant distribution. Another mound, resulting from several injection wells, is in the southern part of 100-NR-2. A region in which the water table is low, resulting from extraction wells, is at the northern end of the 116-K-2 Trench. The extraction wells are along the river and capture contaminated groundwater before it discharges to the Columbia River.

Daily and seasonal fluctuations in the river stage also affect groundwater flow in 100-KR-4. As would be expected, longer term changes in the river stage produce more extensive and longer lived changes in the water levels, hydraulic gradient, and flow directions in the unconfined aquifer. The effect of river water migrating into the aquifer can cause lower contaminant concentrations in near-river and aquifer tubes (Section 2.1.2). Seasonal changes in hexavalent chromium concentrations are most evident in wells within 200 meters of the shoreline. The high river stage in the Columbia River observed in 2011 was the highest river stage in the past five years.

Contaminants of potential concern in the unconfined aquifer include hexavalent chromium, tritium, nitrate, strontium-90, carbon-14, and trichloroethene. Figure 2.3-3 illustrates changes in contaminant plume areas since 2003 for strontium-90, nitrate, hexavalent chromium, and tritium. In the unconfined

aquifer, the sizes of the individual contaminant plumes within 100-K have generally decreased since 2010, with the exception of strontium-90, because of remediation and natural processes. Wells completed in the first water-bearing unit within the Ringold Formation upper mud unit have exhibited low levels (less than 10 µg/L) of hexavalent chromium. As noted in Section 2.1, the 10 µg/L represents the ambient water quality standard for hexavalent chromium and is applicable in the hyporheic zone (i.e., the point at which groundwater discharges into the river). As defined in the current interim action ROD, the remedial action goal for hexavalent chromium is 20 µg/L in compliance wells.

100-KR-4 at a Glance

Reactor Operations: KE 1955–1971; KW 1955–1970				
2011 Groundwater Monitoring				
Contaminant	**Drinking Water Standard**	**Maximum Concentration**	**Plume Area[a] (km^2)**	**Shoreline Impact (m)**
Hexavalent Chromium	10/48[b] µg/L	3,340 µg/L	2.5[c]	1,300[c]
Tritium	20,000 pCi/L	290,000 pCi/L	0.24	0
Nitrate	45 mg/L	97.4 mg/L	0.041	0
Strontium-90	8 pCi/L	251 pCi/L	0.063	0
Carbon-14	2,000 pCi/L	19,200 pCi/L	0.051	0
Trichloroethene	5 µg/L	6.6 µg/L	0.007	0
Remediation				
Waste Sites (interim action): ~ 10 percent remediated				
Groundwater Remediation (interim ROD for hexavalent chromium): • KR4 pump-and-treat: 1997–2011, removed 355 kg • KW pump-and-treat: 2007–2011, removed 163 kg • KX pump-and-treat: 2009–2011, removed 114 kg Final record of decision anticipated in 2012.				

a. Estimated area above listed water quality standard

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

c. At the 10 µg/L level

2.3.1 Hexavalent Chromium

Hexavalent chromium is a mobile contaminant at 100-KR-4, and its presence resulted from historical releases of two different types of wastewater contaminated with chromium. The first type of release included spills, leaks, and limited intentional discharge of concentrated sodium dichromate dihydrate solutions used as feed chemicals for conditioning reactor cooling water. These releases apparently occurred near the chemical storage tank farms at the cooling water treatment head houses at the KE and KW Reactor complexes. The second type of release included spent reactor cooling water from retention basin leaks and intentional discharges to the 116-K-1 Crib and 116-K-2 Trench. The first release type consisted of relatively small volumes of high-concentration solutions; the second release type consisted of very large volumes of low-concentration cooling water effluent.

Figure 2.3-4 illustrates the distribution of hexavalent chromium in 100-KR-4 at high and low river stages in 2011. Several separate plumes are differentiated by geographic distribution, and by the location and nature of probable source areas. Plumes are present on both the southwestern and northeastern ends of the 116-K-2 Trench, the original source area. These plumes are the remnants of a single large plume that formerly extended the length of the 116-K-2 Trench, and now connect to the KE plume. Operation of the KR4 and KX pump-and-treat systems has resulted in several residual plume areas, which the KR4 and KX pump-and-treat systems are remediating.

Farther north, a few monitoring wells associated with the 100-NR-2 interest area are contaminated with low levels of hexavalent chromium. Modest amounts of sodium dichromate were used during the years immediately following startup of N Reactor (estimated at ~ 6,300 to 8,200 kilograms). Management and ultimate disposal of sodium dichromate solutions at 100-N may have contributed to some of the hexavalent chromium observed at 100-N. The hexavalent chromium plume observed northeast of 100-K and inland of 100-N most likely resulted from migration of reactor cooling water away from 116-K-2

Trench during the period of operation of 105-KE and 105-KW Reactors. Subsurface geology also indicates a geologic contact trending to the north in that area which may be influencing contaminant migration. Although the monitoring well network within the hexavalent chromium-affected portion of the aquifer inland of 100-N is not extensive, the observed concentrations suggest that the hexavalent chromium plume exceeding 10 µg/L likely extends from well 199-K-182 all the way northeast to 100-D.

Inspection of groundwater monitoring data from inland wells between 100-K and 100-D indicates the long-term presence of hexavalent chromium in that area. Although sample analysis for hexavalent chromium as a specific analyte began relatively recently at numerous locations, historical analysis of total chromium in filtered and unfiltered aliquots started as early as the 1990s. Total chromium measurement in a filtered sample aliquot provides a good comparable value for hexavalent chromium.

Groundwater data indicate that at least four wells (i.e., 199-N-43, 699-87-55, 699-83-47, and 699-81-58) exhibited elevated hexavalent chromium in the 1990s. In recent samples, additional inland wells (i.e., 199-K-182, 199-N-71, 699-77-54, and 699-87-42A) still exhibit elevated hexavalent chromium in groundwater. Total chromium analyses performed on filtered and unfiltered groundwater samples in 2011 are consistent with the hexavalent chromium measurements.

The presence of hexavalent chromium in groundwater inland of 100-N Area, and between 100-K and 100-D Areas has been documented for ~ 20 years in groundwater samples collected from that area. The presentation of inferred hexavalent chromium plume maps that include coverage of both 100-K and 100-N Areas is intended to support the understanding that this condition most likely resulted from historical migration of chromium-contaminated groundwater in radial flow away from the large recharge mounds beneath 116-K-2 Trench with possible contribution from 116-DR-1 & 2 Cribs.

The K East plume extends from near the 183-KE Head House downgradient to the KX extraction wells 199-K-141 and 199-K-178. This plume originated from spills and leaks of high-concentration chromium solutions near the 183.1-KE Head House. The K West plume is near the KW Reactor and its associated water treatment facilities. The apparent sources were leaks and spills of high-concentration sodium dichromate solutions during unloading or storage at the 183.1-KW Head House. In 2012, the KW pump-and-treat system is remediating the K West plume.

2.3.1.1 116-K-2 Trench Hexavalent Chromium Plumes

Reactor coolant discharges to the 116-K-2 Trench between 1955 and 1971 raised the water table beneath 100-KR-4. The recharge mound that formed beneath the trench during operations extended for several kilometers in all directions. This extensive mound of contaminated water created a large hexavalent chromium plume with maximum concentrations similar to those of the reactor cooling water (i.e., up to 700 µg/L).

Overall distribution of hexavalent chromium in groundwater associated with the 116-K-2 Trench is consistent with the broad distribution of cooling water effluent being discharged to the trench. Pump-and-treat operations that began in 1997 have partially remediated the original plume, with the plume distribution showing the effect of the various remedial actions. Remedial activities divided the original plume into a southwestern segment, a central segment, and a northeastern segment along the length of the 116-K-2 Trench (Figure 2.3-4). Current evaluation of the northern segment indicates that it has been bifurcated by injection wells of the calcium polysulfide treatability test. In the south, the plume at the 183.1-KE Head house now combines with the southwestern portion of the 116-K-2 Trench plume.

The northeastern portion of the 116-K-2 Trench plume extends northeast into 100-NR-2. Well 199-N-189 was installed in 2011. Sampling during drilling detected hexavalent chromium concentrations of 35.5 µg/L at the water table, with concentrations of 38.9 µg/L deeper in the aquifer. This data point is not directly comparable to the other sample points, however, because the sample was collected during drilling and prior to well development. Additional monitoring of this well will be needed to substantiate the value. Well 199-N-74, which is located ~ 2.0 kilometers from the end of the trench and

farther north than 199-N-189, exhibits hexavalent chromium concentrations near 30 µg/L. Other wells inland from 100-N have also exhibited historical elevated hexavalent chromium in groundwater. These include well 699-87-55 (which historically exhibited total chromium up to 60 µg/L in a filtered sample in 1994), well 699-81-58 (which historically exhibited total chromium up to 25 µg/L in a filtered sample in 1991), and well 199-N-52 (which exhibited total chromium up to 10 µg/L in a filtered sample in 1990). These wells indicate that hexavalent chromium is relatively widespread inland of 100-N and downgradient of 100-K. Current hexavalent chromium concentrations at these wells are lower than historically measured.

The contamination in both locations likely resulted from migration of the plume at 116-K-2 Trench during the historical discharge period when radial flow away from the large discharge mound at the trench would have moved contaminated water toward 100-N in addition to the rest of the surrounding area. The historical use of sodium dichromate at 100-N was relatively small and of shorter duration than the historical treatment of cooling water at 100-K. Although there may be some contribution of hexavalent chromium to groundwater from historical 100-N activities, historical discharges of sodium dichromate-treated cooling water to116-K-2 Trench is the most likely source of the elevated concentrations observed near 100-N. Even though the overall hexavalent chromium plume at concentrations over 20 µg/L near extraction wells is shrinking based on the current plume depictions, the detection of hexavalent chromium in wells 199-N-189 and 199-N-74 indicates that the plume associated with the 116-K-2 Trench extends farther to the northeast than previously thought (Figure 2.3-4). Recent measurements of hexavalent chromium in the vicinity inland of 100-N are not spatially or temporally continuous. The observed distribution of chromium in that area, however, is consistent with historical migration of contaminated groundwater radially away from the 116-K-2 Trench during the period of 100-K Reactor operations (i.e., 1955 to 1971). Recent observations of groundwater flow direction near 100-K indicate groundwater flows toward the Columbia River. The plume segments inland of 100-N are likely now isolated from the plume associated with 116-K-2 Trench and will likely migrate toward the river as well. To the south, the plume extends at least 1.5 kilometers from the river at well 199-K-193. Detections of hexavalent chromium at concentrations greater than 20 µg/L also are observed as far inland as well 699-77-54 (3.4 kilometers from the river). As with the hexavalent chromium near 100-N, the condition at 699-77-54 also is most likely a result of the historical migration of chromium-contaminated groundwater from 116-K-2 Trench. Data are not sufficient to determine whether the plume is continuous inland to well 699-77-54.

The hexavalent chromium plume at 100-KR-4 extends inland at least 3.4 kilometers and northeast at least 2 kilometers into 100-NR-2. Evaluation of recent data indicates that the plume is present farther north than previously presented.

Hexavalent chromium concentrations in the northeastern 116-K-2 Trench plume have declined since 2009 (Figure 2.3-5). Concentrations in the northernmost extraction wells (Groups 5 and 6 on Figure 2.3-5) continued to decline in 2011, and many wells had concentrations below 20 µg/L. Concentrations were relatively low but variable in extraction wells near the central and southern part of the trench plume (Groups 1 through 4), and concentrations remained above 20 µg/L in some of these wells. Concentrations in extraction wells inland of the northeastern portion of the trench plume (Group 7) remained stable in 2011. Concentrations in monitoring wells (for example, Group 8) are similar to concentrations in extraction wells.

Hexavalent chromium concentrations in aquifer tubes downgradient from the 116-K-2 Trench plume have declined since groundwater remediation began in 1997. Concentrations are below the 10 µg/L ambient water quality standard in most of the aquifer tubes, but concentrations remain elevated in a few locations. The highest concentration in 2010 or 2011 was 57 µg/L in AT-K-3-D, near the southern end of the 116-K-2 Trench. This aquifer tube is located near existing extraction wells 199-K-198 and 199-K-199.

As of 2012, these wells are configured for extraction and it is recommended that they be connected to the KX pump-and-treat system.

Well 199-K-192 was sampled for characterization during drilling. Hexavalent chromium was detected at several intervals within the shallow unconfined aquifer unit, with a high concentration of 71 µg/L. The well was completed, however, within a water-bearing unit of the underlying Ringold Formation upper mud unit. No hexavalent chromium has been detected in this well since it was completed. Near the Columbia River, wells 199-K-197 and 199-K-199 showed the highest concentrations (31 and 38.5 µg/L) in the bottom half of the unconfined aquifer.

2.3.1.2 K East Hexavalent Chromium Plume

Hexavalent chromium distribution in the K East region is consistent with this plume's having originated with the release of high-concentration chromium solutions that reached groundwater and subsequently migrated toward the river near the 183.1-KE Head House and associated facilities. The existing monitoring well network does not clearly define the dimensions of the K East hexavalent chromium plume, but the plume definitions has improved from previous years.

Upgradient of the 183.1-KE Head House, new RI/FS well 199-K-187 was installed to further delineate the K East plume. The plume (Figure 2.3-4) extends from the 183.1-KE Head House (i.e., near wells 199-K-36 and 199-K-188) toward the river (i.e., near extraction wells 199-K-141 and 199-K-178). Previous interpretations of the plume showed a smaller, less continuous area, and did not indicate a connection to the southern plume from the 116-K-2 Trench. In addition, the plume had a small area of contamination associated with the 183.2 KE Sedimentation Basin that was not connected to the main portion of the plume closer to the river. With the installation of additional wells and more data, the extent of the plume has been reevaluated.

During the low river stage, the plume is less continuous and much smaller. The shape of the plume during this period is consistent with previous interpretations of the plume shape. However, during periods of high river state, the plume extended south of the head house to new well 199-K-187 and connected to the southernmost portion of the 116-K-2 Trench plume. The extent of the plume to the south has been connected to well 199-K-23, which had a hexavalent chromium concentration of 97.4 µg/L in October 2011; this well had not been sampled for three years. Well 199-K-187 had a maximum concentration of 19 µg/L in July 2011. However, the duplicate sample had a lower concentration (10.8 µg/L), and an October sample had no detectable hexavalent chromium. The primary difference in the inferred distribution of hexavalent chromium near 105-KE between high and low river stages is driven by the observed concentration in well 199-K-187, which was non-detect in the data assembled for the low river stage and was 12.6 µg/L in the high river stage data set. Interpolation of the plume contours around this single point produces the observed inland extension of the plume in the high river stage map. Recent measurements in that well have exhibited low concentrations. The high river stage is not expected to have caused the observed condition at distance from the river. Continued monitoring of wells 199-K-187, 199-K-188, and 199-K-36 is recommended to investigate the variable hexavalent chromium concentrations in that area and better define the plume.

Two wells within the former water treatment chemical tank farm at the 183.1-KE Head House have elevated hexavalent chromium levels. Concentrations in new well 199-K-188 increased from 10.7 µg/L in January to 41.6 µg/L in June 2011. In nearby well 199-K-36, concentrations increased from 37.5 µg/L in December 2010 to more than 119 µg/L in June 2011. These levels indicate an increase from recent concentrations in both wells (Group 7, Figure 2.3-6). The recent increase may be related to demolition and vadose zone remediation activities near these wells, which increases the amount of water applied to the ground surface to provide dust suppression. Operation of the expanded pump-and-treat system may also be affecting flow directions and, therefore, contaminant concentrations at specific locations.

Groundwater remediation has reduced hexavalent chromium concentrations between the reactor building and the Columbia River. Concentrations declined sharply in well 199-K-141 after it was

converted to an extraction well and incorporated into the KX pump-and-treat system in 2009 (Group 5 on Figure 2.3-6). The concentrations remained above 20 µg/L in two of the extraction wells (199-K-141 and 199-K-178) associated with this plume in 2011.

Grab samples of groundwater were collected and analyzed during drilling of five monitoring wells as part of the 100-K RI/FS. Those samples, collected from wells 199-K-187, 199-K-188, 199-K-186, 199-K-189, and 199-K-190 (in order from most upgradient to most downgradient), indicated a slight increasing concentration trend with depth. All of the observed hexavalent chromium concentrations were less than 35 µg/L. Well 199-K-32B, completed in a confined water-bearing unit within the Ringold Formation upper mud unit, has exhibited low levels (less than 10 µg/L) of hexavalent chromium. No hexavalent chromium was detected in the confined water-bearing unit at well 199-K-192, also completed in the Ringold Formation upper mud unit. However, well 199-K-192 did exhibit hexavalent chromium in groundwater throughout the thickness of the overlying unconfined aquifer unit.

2.3.1.3 K West Hexavalent Chromium Plume

The distribution of the K West plume is consistent with the migration of hexavalent chromium historically released as high-concentration solutions near the chemical storage tank farm at the 183.1-KW Head House and related facilities. Releases of these solutions migrated downward through the vadose zone and affected groundwater.

The K West hexavalent chromium plume extends in a narrow band starting near the head house (Figure 2.3-4) and extending toward the river. The dimensions of this plume did not change between 2010 and 2011. The highest hexavalent chromium concentrations in 100-KR-4 in 2011 were in wells upgradient from the KW Reactor building.

Following the start of the KW pump-and-treat system in 2007, hexavalent chromium concentrations declined sharply in extraction wells and monitoring wells just upgradient from the KW Reactor (Group 3 on Figure 2.3-6). Levels continued to decline in these wells and in those farther downgradient (Groups 1 and 2) in 2011. Concentrations in one extraction well (199-K-165) remained stable, near 150 µg/L during most of the year.

Maximum hexavalent chromium concentrations in K West extraction wells have decreased by more than 90 percent since the pump-and-treat system started in 2007. A new maximum concentration point was identified in 2011 (well 199-K-195).

New RI/FS well 199-K-195 exhibited a hexavalent chromium concentration of 3,340 µg/L in April 2011, which is consistent with the concentrations found in depth-discrete samples collected during drilling. The highest concentration collected during drilling was 4,890 µg/L at a depth of 30.4 meters. This maximum value is much higher than the previously observed maximum of 771 µg/L detected in well 199-K-35 in 2010. Well 199-K-195 and adjacent well 199-K-35 were decommissioned to permit continued waste site remediation efforts around the former 183.1-KW Head House. A replacement well is recommended to monitor groundwater conditions near the Head House during continued remediation activities. The well could be configured as an extraction well to provide capability to extract groundwater for treatment from this source area.

The next downgradient monitoring well, 199-K-173, exhibited concentrations as high as 659 µg/L in 2011 (Figure 2.3-7). The presence of injection wells 199-K-175, 199-K-174, and 199-K-158 controls the upgradient edge of the plume. The plume does not extend inland past well 199-K-175, which had concentrations below 10 µg/L when the well was sampled before conversion to an injection well.

Grab samples of groundwater were collected and analyzed during the drilling of five monitoring wells. These results illustrate the variation in vertical distribution of chromium in this area. Sample results from wells 199-K-195, 199-K-173, 199-K-165, and 199-K-184 (in order from upgradient to downgradient) indicated varying distribution of hexavalent chromium with depth. The well nearest the apparent release point (i.e., 199-K-195) exhibited the highest concentration near the water table; the other wells exhibited elevated concentrations at varying depths. Well 199-K-165, an extraction well as of 2012, exhibited elevated hexavalent chromium over the entire aquifer thickness during drilling.

2.3.2 Tritium

Tritium is a highly mobile contaminant in 100-KR-4 groundwater at levels up to 290,000 pCi/L (well 199-K-18) in completed wells, a concentration above the 20,000 pCi/L drinking water standard. The major sources of tritium contamination included the following:

- Releases of reactor gas dryer condensate to the 116-KE-1 and 116-KW-1 Cribs
- Release of fuel storage basin water to the 116-KE-3 and 116-KW-2 Cribs
- Contaminated solid waste disposed of at the 118-K-1 Burial Ground

Another source of tritium was the release of contaminated reactor cooling water to the retention basins, the 116-K-1 Crib, and the 116-K-2 Trench.

At the 20,000 pCi/L drinking water standard, the plume has previously been interpreted to have two parts: a larger portion near the southwestern end of the 116-K-2 Trench and the 118-K-1 Burial Ground and a smaller portion near the KE Reactor. Based on current data, these plumes are now considered a single plume. Figure 2.3-8 shows the tritium distribution in groundwater in 2011.

Because of the active remediation of hexavalent chromium, extraction wells are also capturing tritium. Because tritium is present primarily as tritiated water, it is not affected by the treatment system. The current treatment for tritium is recirculation of the contaminated water within the aquifer until tritium has decayed. Tritium has a relatively short half-life of 12.32 years (RS, 2012), so recirculation has been considered an acceptable method of addressing the analyte. Because of recirculation, tritium is now in groundwater near the active injection wells at 100-K. Based on the design of the pump-and-treat system, this water will be captured by the downgradient extraction wells and will continue to decay. The plume is not reaching the river at levels above the drinking water standard, based on data from aquifer tubes. Tritium was detected in effluent water from the KX and KR-4 pump-and-treat systems. These effluent values were assigned to the injection wells associated with each system and included in the plume map. Note that there is now presented an area of tritium concentration greater than the 20,000 pCi/L MCL near the KR-4 system injection wells. Wells 199-K-29 and 199-K-30 formerly defined the highest concentration portion of the plume near the KE Reactor building and the 116-KE-1 Crib. Concentrations in those wells had declined from peak levels in the 1990s before the wells were decommissioned in January 2011 to permit access for demolition of the 117-KE filter facility. New well 199-K-189, downgradient from the reactor building and decommissioned wells 199-K-29 and 199-K-30, exhibited a maximum tritium concentration of 140,000 pCi/L in vertical profile sampling during drilling. A concentration of 42,600 pCi/L was detected in a sample collected after well completion in October 2011 (Figure 2.3-9).

Tritium contamination continues to migrate downgradient from the historical release points at 116-KE-1 and 116-KW-1 Cribs, with some possible historical contribution from 118-K-1 Burial Ground. Maximum tritium concentrations continue to slowly decline.

A portion of the tritium plume at K East appears to have originated at 116-KE-1 Crib, with potential contribution from waste at the 118-K-1 Burial Ground. Concentrations have generally declined in the wells closest to the burial ground (199-K-111A and 199-K-157) but have increased in wells 199-K-18 and 199-K-145, located farther downgradient (Figure 2.3-9). This pattern is consistent with migration of contaminated groundwater downgradient from historical release points to locations where it is intercepted by extraction wells. Characterization sampling at 199-K-192 revealed elevated tritium concentration in the shallow unconfined aquifer, with a maximum observed concentration in a grab sample of 1,400,000 pCi/L. The concentrations observed in 199-K-18 and 199-K-145 are consistent with the elevated tritium concentration observed in the shallow unconfined aquifer at 199-K-192 during drilling.

Tritium concentrations in the K West region in 2011 were below the drinking water standard. However, concentrations as high as 430,000 pCi/L were measured in well 199-K-106A as recently as 2009 (with a historical maximum observed concentration of 2,240,000 pCi/L in 2005). It is unlikely that the plume has disappeared because the half-life of tritium is 12.32 years, but it is likely that the plume has migrated downgradient to a location without monitoring wells. The area downgradient from the 105-KW Reactor building is also under the capture influence of the active extraction wells of the 100-KW pump-and-treat system, which is affecting the migration of the tritium plume in this area.

Characterization samples collected during the drilling of RI wells showed that the tritium concentration declined with depth at some locations and increased with depth in others. Maximum concentrations were detected near the top of the aquifer in the two new wells with the highest tritium levels (199-K-189 [K East] and 199-K-192 [near the 116-K-2 Trench]). In addition, concentrations in 199-K-189 increased during October 2011, exceeding the drinking water standard with a concentration of 42,600 pCi/L.

Tritium plume behavior at 100-KR-4 is consistent with the downgradient migration of the plumes away from original source areas, modified by the effects of capture by groundwater extraction wells. The existing monitoring well network may not intercept the apparent maximum tritium concentrations in groundwater at K West.

2.3.3 Nitrate

Nitrate concentrations continued to exceed the drinking water standard (45 mg/L) in several 100-KR-4 wells in 2011. The nitrate observed in groundwater at 100-KR-4 originated from high concentrations of ammonia in reactor gas dryer condensate that was discharged to the 116-KE-1 and 116-KW-1 Cribs. Additional nitrate contributions to groundwater may have come from sanitary waste drain fields at various places within the 100-K Area. Figure 2.3-10 shows nitrate distribution in 2011. The size of the plume area exceeding the drinking water standard decreased between 2010 and 2011 (Figure 2.3-3), primarily because of migration and dispersion of the plume.

Well 199-K-198, downgradient from the southwestern end of the 116-K-2 Trench, had one sample with a nitrate concentration of 54.9 mg/L in the shallowest sample collected during drilling, but concentrations dropped quickly to lower levels (12 mg/L) in deeper strata. The average value for well 199-K-198 in 2011 was 19 mg/L. In October, new RI temporary wells 199-K-200 and 199-K-201 had maximum concentrations of 37 mg/L and 41 mg/L, respectively, both showing an increasing trend. At the same time, the concentration in well 199-K-18, located between well 199-K-200 and 199-K-198, declined to just below the standard for the first time in 2011.

Nitrate concentrations continued to exceed the drinking water standard in some 100-KR-4 wells in 2011.

In the K East region, only well 199-K-23 had a nitrate concentration above the drinking water standard in 2011 (46.5 mg/L). Concentrations are variable in this well, with no obvious increasing or decreasing trend since 1992. Recently decommissioned well 199-K-29 had a sharp increase in concentrations in 2010, with a value of 46.5 mg/L, and is included on Figure 2.3-10.

Three K West wells had nitrate levels above the drinking water standard in 2011: wells 199-K-34, 199-K-106A, and 199-K-108A. Two aquifer tubes downgradient from K West have had nitrate concentrations above the standard in recent years. Aquifer tube C6241 consistently has concentrations of 48 to 54 mg/L. The nitrate concentration in aquifer tube 17-D has been below the drinking water standard since 2009, when a maximum of 66.4 mg/L was observed. However, this aquifer tube exhibits substantial seasonal variations; and results may be directly linked to when the wells were sampled.

Characterization data from RI/FS wells indicate that nitrate concentrations decrease with depth in the aquifer at most locations in 100-KR-4. New RI well 199-K-185, which was installed in 2010, had nitrate levels at more than twice the drinking water standard at the top of the unconfined aquifer. Carbon-14 concentrations were also high in this well near the top of the aquifer. Because of the highly variable concentrations with depth, the average nitrate value for the well during drilling, shown on Figure 2.3-10, was below the drinking water standard. In addition, monitoring results in 2011 from this well, after completion and development, had a maximum value of 26.1 mg/L. However, this well was screened across the entire aquifer thickness, and while the sample was collected from the upper portion of the aquifer, results may not indicate the highest concentrations detected during drilling. Sealing off the lower section of this well would provide more representative values from the contaminated zone.

2.3.4 Strontium-90

Cooling water contaminated by fuel rod failures was held in the 107-KE or 107-KW retention basins and subsequently discharged to the 116-K-2 Trench. Fission products, including strontium-90, contaminated the discharged water. The fuel storage basins also had cooling water contaminated with strontium-90. Releases from the fuel storage basins and the discharges to the 116-K-2 Trench are the sources of the strontium-90 contamination in 100-KR-4 groundwater. Discharges to the 116-K-2 Trench resulted in strontium-90 distributed in groundwater at several locations along the length of the trench. Strontium-90 has also been released to groundwater via discharges to the 116-KW-2 and 116-KE-3 fuel storage basin cribs and reverse wells, or by direct leakage from the basins themselves.

Strontium-90 contamination in 100-KR-4 groundwater is found in numerous localized plumes (Figure 2.3-11). The areas with concentrations above the 8 pCi/L drinking water standard are limited in extent and do not extend to the Columbia River. Strontium-90 concentrations are near or below detection limits in most aquifer tubes. However, the maximum concentration for 2011 was 7.48 pCi/L in the September sample from aquifer tube 19-M, downgradient from the southern end of the trench.

The calculated historical area of the strontium-90 plume above the drinking water standard is subject to substantial uncertainty from the following aspects:

- The plume has not historically been delimited on the downgradient or cross-gradient directions from either of the fuel storage basin cribs.
- Historically, the plumes were allowed to diminish in size as concentrations at wells located near the release points declined. This is inconsistent with the apparent migration of strontium-90 away from those release areas.

- The inferred plumes presented in this annual report reflect the best effort to extrapolate strontium-90 concentrations in groundwater and are consistent with the general approach to plume presentation in this report.

The strontium-90 plume areas for 2011 are larger than in previous years (Figure 2.3-3), and the apparent maximum concentrations are higher than in 2010.

Many of the wells monitoring the 116-K-2 Trench have detectable strontium-90, but most concentrations are below or near the drinking water standard of 8 pCi/L (Figure 2.3-11). The highest concentrations near the trench in 2011 were from new RI well 199-K-200, which was drilled through the former trench near the head end (southwest). Concentrations increased in this well after well construction to a maximum of 251 pCi/L in 2011 (Figure 2.3-12). A grab sample was collected in 2010 during the drilling of well 199-K-192, immediately downgradient from 199-K-200. The sample collected near the water table had the only detection of strontium-90 in the well, at 19 pCi/L. This observation further

The K East strontium-90 plume has migrated downgradient to extraction well 199-K-141. Wells and aquifer tubes closer to the river have detectable concentrations below the drinking water standard.

indicates that strontium-90 is in localized areas. This well was later completed and screened in the Ringold Formation upper mud unit, and has no detectable strontium-90 contamination. Concentrations in other wells in the 116-K-2 Trench region were consistently less than 30 pCi/L.

Well decommissioning related to structure demolition in the 100-K Area has removed monitoring wells near historical high concentrations (e.g., near 116-KE-3 Crib). In addition, existing downgradient monitoring wells do not exhibit the extremely high strontium-90 concentrations that were previously exhibited (e.g., ~ 18,000 pCi/L at well 199-K-109A). This condition results in considerable uncertainty in the expected extent of the strontium-90 plume in the area downgradient of both of the 100-K Reactors and the expected maximum concentration as concentrations declined in near-source upgradient wells. In previous analyses, historical concentrations in decommissioned wells were generally removed from the plume depiction. To account for this, a revised plume extrapolation process was applied to estimate the distribution of strontium-90 (and carbon-14, discussed in Section 2.3.5) in groundwater downgradient of the 105-KE and 105-KW Reactors.

The plume extrapolation process started with identifying groundwater flow paths away from the historical release points at 116-KE-3 and 116-KW-2 Cribs. The flow paths, including apparent gradient and flow direction based on groundwater elevation measurements, were aligned, by inspection, with downgradient wells that exhibit detections of strontium-90. An arithmetic, analytical solution was applied to the historical peak concentrations at wells near the release points, providing an estimation of downgradient concentrations, as affected by plume movement, contaminant interaction with aquifer solids (defined by a selected distribution coefficient), and radioactive decay. The product of this estimation was points of varying concentration along the axis of the flow path. These points were then combined with the existing measured strontium-90 concentrations at local wells to provide an estimate of the expected plume distribution and apparent maximum concentration in groundwater. The results of the plume extrapolation are integrated into the 2011 strontium-90 plume map for 100-K shown in Figure 2.3-11.

A high concentration strontium-90 plume is in the K East region. The heart of the plume formerly was represented by well 199-K-109A, which had a strontium-90 concentration of 1,120 pCi/L the last time the well was sampled in 2008 and historical maximum concentration of 18,600 pCi/L. This well historically exhibited strontium-90 concentration greater than 5,000 pCi/L from 1996 to 2000. This well was decommissioned to facilitate demolition activities. A nearby well, 199-K-189, has low to undetectable levels of strontium-90. However, the well is not directly downgradient from former well

199-K-109A. About 120 meters directly downgradient from 199-K-109A, concentrations rose above the drinking water standard in extraction well 199-K-141 (Figure 2.3-13), with the increase beginning soon after starting groundwater extraction at that well. The increased concentration in extraction well 199-K-141 indicates part of the leading edge of the K East strontium-90 plume migrated downgradient in 2011. As of 2011, the leading edge of the plume is not well defined, and additional replacement wells would allow for monitoring the plume location as it migrates. Extrapolation of the estimated plume distribution downgradient of well 199-K-109A produced an estimated maximum groundwater concentration near 13,100 pCi/L, accounting for migration and radioactive decay.

Father downgradient, measured strontium-90 concentrations remained below the drinking water standard in 2011 at well 199-K-32A (maximum 7.4 pCi/L) and in aquifer tube 19-M (7.48 pCi/L). The observed decrease in strontium-90 concentration at 199-K-109A, as well as the arrival at downgradient wells 199-K-141 and 199-K-32A suggests that strontium-90 is migrating and may actually exhibit a substantially lower distribution coefficient in this vicinity. The inferred strontium-90 plume size and maximum concentration in groundwater are both indicated to be greater than was presented previously.

Two wells in the K West region consistently show strontium-90 concentrations above the drinking water standard (199-K-107A and 199-K-34). The maximum concentration of 50 pCi/L reported in early 2011 (well 199-K-34) was a slight increase from recent years. The concentrations are generally declining in well 199-K-107A (18.3 pCi/L in 2011). The concentrations in individual wells fluctuate, and the inferred plume size is indicated to be larger than indicated by previous analysis. This is due to the reinterpretation of potential downgradient migration away from the fuel storage basin cribs. Concentrations are near detection limits in wells farther downgradient.

Because of its limited mobility, strontium-90 contamination tends to be found in the upper part of the unconfined aquifer. This distribution is firmly established in 100-NR-2 (Section 2.4), and characterization data collected during installation of wells 199-K-189 and 199-K-192 in 100-KR-4 support this interpretation. Strontium-90 has not been detected in the water-bearing unit of the Ringold Formation upper mud unit.

The observed distribution of strontium-90 in groundwater at 100-KR-4 is consistent with the known releases at the fuel storage basin cribs and releases of contaminated cooling water to the 116-K-2 Trench.

2.3.5 Carbon-14

Carbon-14 in groundwater in 100-KR-4 (Figure 2.3-14) originated from historical discharges of reactor gas dryer regeneration condensate to the 116-KE-1 and 116-KW-1 gas condensate cribs. Shielding water in the KE and KW fuel storage basins also contained carbon-14. As with strontium-90 plumes described in the preceding subsection, the carbon-14 groundwater conditions were evaluated using a plume migration extrapolation to estimate the current plume configuration and apparent maximum concentration. The carbon-14 plumes associated with the reactor gas dryer condensate cribs (i.e., 116-KE-1 and 116-KW-1) were extrapolated using the historical maximum concentrations at wells 199-K-30 and 199-K-106A at KE and KW, respectively. As described previously for strontium-90, the historical carbon-14 maximum concentrations were migrated along selected downgradient flow paths, and the results were distributed using a distribution coefficient of 1.8 mL/g. Resultant migrated concentrations along the flow paths were selected for inclusion in the plume contouring analysis. This resulted in an enhanced estimate of the expected carbon-14 plume distribution and maximum concentrations in groundwater at 100-K. The highest residual carbon-14 concentrations in groundwater are associated with KW Reactor, where the estimated maximum concentration derived from the extrapolation is ~39,500 pCi/L. The extrapolated concentrations associated with KE Reactor are slightly lower, with the estimated maximum concentration of ~22,900 pCi/L. At both reactor areas, the resultant plume distribution exhibits an areal extent of concentrations exceeding the 2,000 pCi/L DWS that is larger than inferred in previous years.

Two wells in the K West region continued to exhibit concentrations above the 2,000 pCi/L drinking water standard: 199-K-34 and 199-K-106A. Both of these wells have exhibited an increasing trend in carbon-14 concentration since 2009, with concentrations in 199-K-106A reaching more than 10,000 pCi/L. The long-term trend in 199-K-34 shows more stable concentrations since 1996, with many yearly fluctuations. The highest concentration portions of this plume lie within the capture zone of groundwater extraction wells of the KW pump-and-treat system.

A new, temporary well drilled through the 116-K-2 Trench had higher strontium-90 concentrations than other wells in that area. The high concentrations have not migrated far from the source.

In new RI well 199-K-185, carbon-14 was detected in depth-discrete samples collected during drilling at levels as high as 2,390 pCi/L at the top of the unconfined aquifer. Monitoring results in 2011 from this well had a maximum value of 486 pCi/L. However, this well was screened across the entire aquifer thickness; and while the sample was collected from the upper portion of the aquifer, results may not indicate the highest concentrations detected during drilling. Sealing off the lower portion of the well would provide more representative sample results.

Detectable carbon-14 in groundwater extends downgradient to the river, where it has been detected in aquifer tubes at concentrations mostly below 100 pCi/L. Carbon-14 was detected at 162 pCi/L in aquifer tube C6241. This aquifer tube was not sampled in 2010, but the result is consistent with the result of 158 pCi/L in 2009.

A smaller carbon-14 plume exists in the K East region. The plume was formerly defined by wells 199-K-29 and 199-K-30, which have been decommissioned. In 2010, wells 199-K-29 and 199-K-30 had maximum concentrations of 3,120 and 6,900 pCi/L, respectively, which are above the drinking water standard. These wells had monitored conditions at the 116-KE-1 waste site. Monitoring well 199-K-109A, near the 116-KE-3 Crib, had concentrations at 118 pCi/L in 2008 prior to decommissioning, with an increasing concentration trend. The carbon-14 plume at K East may not lie completely within the expected capture zone of the operating extraction wells of the KX pump-and-treat system as of 2011. Additional monitoring wells are recommended to monitor the 116-KE-1 and 116-KE-3 areas, define the carbon-14 plume, and to track tritium, nitrate, and strontium-90 during remediation activities. None of the actively monitored wells had concentrations above the drinking water standard in 2011.

Carbon-14 has also been detected in aquifer tubes downgradient from K East. Aquifer tube C6247 had a carbon-14 result of 314 pCi/L in fall 2011. The other aquifer tubes in this cluster have not been sampled since 2008 but had similar results at that time.

The behavior of the carbon-14 plumes in groundwater at 100-K is consistent with historical releases of carbon-14 to the condensate cribs. Carbon-14 has moderate mobility in groundwater and is migrating downgradient toward the river; the highest concentrations have been consistently observed near the historical release points.

2.3.6 Other Contaminants

Trichloroethene continues to be detected in some 100-KR-4 wells, primarily in the K West region. Most concentrations were below the 5 µg/L drinking water standard (Figure 2.3-15) in 2011. The highest concentrations in routine samples in 2011 were 6.6 and 6.4 µg/L in wells 199-K-185 and 199-K-132, respectively. The sources of trichloroethene at 100-KR-4 are not apparent but are likely related to the use of solvents during equipment maintenance activities. As with other contaminants at 100-K, trichloroethene is detected in effluent water at the KW pump-and-treat system. The effluent concentrations were assigned to the injection wells, resulting in the presence of a more widespread low-concentration plume of trichloroethene in that area.

Technetium-99 is detected in groundwater at numerous locations within 100-KR-4 with concentrations consistently less than 100 pCi/L. Technetium-99 is a fission product, and it would be expected to have been present in cooling water contaminated by fuel ruptures and in the contaminated fuel storage basin water.

Total petroleum hydrocarbons have been encountered in the soil during the drilling of wells 199-K-167 (decommissioned), 199-K-173, and RI well 199-K-186. Total petroleum hydrocarbons were detected in groundwater during 2011 at a low concentration at only one location. A result of 8.61 µg/L gasoline range hydrocarbons was detected in well 199-K-137, and the result was qualified with a "J" flag, indicating the result was estimated. The overall results are consistent with previous sampling events.

Total organic carbon concentrations were elevated in wells at the location of a 2005 treatability test. Wells 199-K-133, 199-K-134, 199-K-135, and 199-K-136 showed total organic carbon at concentrations above 200,000 µg/L in 2008 and 2009. Levels subsequently declined, and samples were not analyzed for this constituent in 2011. The total organic carbon was a residual effect from the calcium polysulfide treatability test, when vegetable oil was injected to stimulate bacterial growth, to evaluate the effects of aquifer reduction on hexavalent chromium.

2.3.7 CERCLA Groundwater Activities

A ROD for the 100-KR-4 Operable Unit interim remedial action was issued in April 1996 (EPA/ROD/R10-96/134, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Benton County, Richland, Washington*). The goal of the resulting interim remedial action is to prevent discharge of hexavalent chromium to the Columbia River.

The interim action goal was changed from 22 µg/L to 20 µg/L in August 2009 by an explanation of significant differences for the 100-HR-3 and 100-KR-4 Operable Units that sets a 20 µg/L threshold at onshore, near-river monitoring locations to achieve the ambient water quality standard of 10 µg/L (EPA et al., 2009b, *Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision: Hanford Site Benton County, Washington*). As indicated in the interim action ROD (EPA/ROD/R10-96/134), an attenuation factor of 1:1 is expected before the groundwater would reach the aquatic receptor point of concern within the river substrate, ensuring that the ambient water quality criterion of 10 µg/L in the river substrate will be met.

The second CERCLA five-year review (DOE/RL-2006-20, *The Second CERCLA Five-Year Review Report for the Hanford Site*), published in 2006, identified four actions pertaining to 100-KR-4 groundwater. The actions involved installing new wells and expanding pump-and-treat systems. All of the actions have been completed. DOE finalized the third five-year review report (DOE/RL-2011-56) and submitted it to EPA in November 2011. These enhancements included installing the 100-KW and 100-KX pump-and-treat systems with their attendant extraction and injection wells and water conveyance systems.

Groundwater sampling under CERCLA includes monitoring interim remedial actions for effectiveness and monitoring wells throughout 100-KR-4 to track contamination. Appendix A lists wells and constituents monitored and the status of monitoring in 2011.

A subset of 100-KR-4 aquifer tubes is scheduled for annual sampling in the fall, and some tubes are sampled quarterly. The fall 2010 sampling event was delayed, and many tubes were sampled in 2011 instead. The fall 2011 sampling event was delayed into January and February 2012. Appendix D lists 2011 sampling dates for the aquifer tubes.

2.3.7.1 Remedial Investigation/Feasibility Study

In 2011, the sampling team completed drilling and sampling activities required by *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units* (DOE/RL-2008-46-ADD2) and implemented through the sampling and

analysis plan (DOE/RL-2009-41, as modified by TPA-CN-357, *Change Notice for Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0*). DOE/RL-2010-97 presents and discusses the results in detail. The field effort included the following:

- Installed nine monitoring wells in the unconfined aquifer, four monitoring wells into the Ringold Formation upper mud unit, and two vadose zone boreholes (all of which were completed as temporary wells)
- Conducted vadose zone and groundwater characterization sampling during drilling for all boreholes and wells
- Installed and sampled three aquifer tubes
- Sampled a selected set of 18 wells three times for temporal and spatial variation analysis

Data collected during the RI will support the selection of alternatives for final action site cleanup. The draft RI/FS report is undergoing public review in 2012.

2.3.7.2 Groundwater Remediation

DOE implemented three pump-and-treat systems to remediate hexavalent chromium contamination in 100-KR-4 groundwater and to protect the Columbia River. All three systems operated in 2011 and are continuing to operate in 2012, as follows:

- The original 100-KR-4 pump-and-treat system (KR-4) focuses on contamination beneath the 116-K-2 Trench. It began operating in 1997.
- The KX pump-and-treat system has two focus areas: one at the northeastern end of the 116-K-2 Trench, where the hexavalent chromium plume migrated toward 100-NR-2, and the K East hexavalent chromium plume. The KX system began operating in 2009.
- The KW pump-and-treat system, which began operating in 2007, focuses on the hexavalent chromium plume at K West.

As of December 2011, 30 extraction wells and 17 injection wells were in use (Table 2.3-1, Appendix A). Combined, the three systems are capable of treating more than 4.6 million liters of groundwater per day. The combined pump-and-treat systems in 100-KR-4 removed 61.4 kilograms of hexavalent chromium from groundwater in 2011 (Table 2.3-1 and Figure 2.3-16). Since 1997, the 100-KR-4 pump-and-treat systems have removed 632 kilograms of hexavalent chromium from the aquifer. *Calendar Year 2011 Annual Summary Report for the 100-HR-2 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation* (DOE/RL-2012-02) provides additional detail.

Under the current configuration, the 100-KR-4 pump-and-treat systems are meeting remedial action objectives. Containment of the plumes addresses the first two objectives: (a) protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River, and (b) protect human health by preventing exposure to contaminants in the groundwater. Operation and refinement of the systems are also meeting the third objective, which is to provide information that will lead to the final remedy. Concentrations of hexavalent chromium in some compliance wells and extraction wells remained above the 20 µg/L remedial action goal, and the 100-KR-4 systems will continue to operate in 2012.

Thirty-one wells have been identified as compliance wells for the three operating pump-and-treat systems (i.e., KR, KW, and KX systems) at 100-K (TPA-CN-359, *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: DOE-RL-2006-75, Rev. 1, Reissue Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System (As amended by TPA-CN-273, May 20, 2009) and DOE-RL-2006-52, Rev. 2, The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to the I 00-KR-4 Groundwater Operable Unit Interim Action, October 2009*). Most of these wells are operating

extraction wells located on the riverward side of the inland hexavalent chromium plumes and have exhibited a strong downward concentration trends since 2010. During 2011, eighteen of these wells exhibited annual average measured hexavalent chromium concentrations below the 20 µg/L remedial action objective. Eight wells exhibited annual average hexavalent chromium concentrations between 20 and 30 µg/L, and five wells exhibited annual average concentrations of greater than 30 µg/L. Of the wells exhibiting hexavalent chromium concentrations greater than 30 µg/L, the maximum was well 199-K-18 with an annual average of 102 µg/L. The downward concentration trends in these wells are an indication of effective plume capture and chromium mass removal from the aquifer. Extraction well capture analysis indicates that the well network is effectively capturing the targeted plume areas. Continued operation of the pump-and-treat systems until they are augmented, or replaced, by the final remedial action system is expected to produce continued reduction in groundwater hexavalent chromium concentration at these wells.

The remedial action objectives for the 100-KR-4 Operable Unit (EPA/ROD/R10-96/134) are as follows:

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

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

2.3.8 K Basins Groundwater Monitoring

The fuel storage basins in the KW and KE Reactor buildings were used from 1955 to 1971 to store irradiated fuel generated at the K Reactors and from the late 1970s to 2004 to store irradiated fuel from the 100-N Reactor, along with other miscellaneous fuel recovered during remedial actions at other reactor areas. Each basin held ~ 4.9 million liters of shielding water that became highly contaminated with fuel residues and fission products (for example, strontium-90, cesium-137, and tritium). In addition, each basin was connected to a combined crib and reverse well (waste sites 116-KE-3 and 116-KW-2) designed to receive basin overflow water. These waste sites, as well as leaks around the KE Basin, contaminated the adjacent vadose zone and groundwater. KW Basin had no documented leaks.

Fuel rods and debris were removed from the K Basins by 2008; and the KE Basin, substructure, and crib were demolished in 2009. The reverse well associated with the 116-KE-3 Crib remains in place. Contaminated soil around the basin and crib was removed. Prior to demolition and remediation, downgradient groundwater monitoring wells around the KE Basin were decommissioned. The KW Basin has been emptied of fuel rods but remains a depository for contaminated sludge from the KE and KW Basins. The KW Basin and the 116-KW-2 Crib are scheduled for removal after 2015.

Based on reported contamination in the basin shielding water, the contaminants of concern for groundwater include tritium, carbon-14, technetium-99, and other less-mobile radionuclides such as strontium-90 and cesium-137. Tritium is considered to be the primary indicator of water loss from the fuel rod basin and crib system.

Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins (PNNL-14033) specifies groundwater monitoring requirements. Although the basins are no longer filled with shielding water, a continuing sampling program is being maintained. Previous leakage at the KE Basin and the use of dust-suppression water during basin and vadose zone remediation warrant continued monitoring at downgradient wells for the near future. The well list has been modified to account for wells that have been decommissioned (Appendix B).

Tritium concentrations in wells downgradient from the KE Basins maintained previous trends (see Section 2.3.2), indicating no new releases. Strontium-90 concentrations increased in downgradient well 199-K-141 (an extraction well for the chromium pump-and-treat system; Section 2.3.4). This contamination could have originated in the KE Basins or the adjacent 116-KE-3 Crib. In the past, higher levels of strontium-90 were detected in 199-K-109A, adjacent to the crib, and it is likely that the decrease in concentration at 199-K-109A as well as the observed increase in 199-K-141 reflect movement of the plume.

Tritium and strontium-90 concentrations in wells downgradient from the KW Basins in 2011 were consistent with previous results (see Sections 2.3.2 and 2.3.4), indicating no new releases.

Table 2.3-1. 100-KR-4 Interim Action Pump-and-Treat Systems, 2011

	KR4		KX		KW	
Performance	**2011**	**1997–2011**	**2011**	**2009–2011**	**2011**	**2007–2011**
Groundwater processed (million liters)	285	5,721	900	2,593	357	1,409
Mass of hexavalent chromium removed (kilogram)	5.4	355	30	114	26	163
Wells	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**
Number of extraction wells	10	10	13	14	7	7
Number of injection wells	5	5	9	9	3	3
Total for All Systems, 1997 through 2011						
Groundwater processed (million liters)	1,542					
Mass of hexavalent chromium removed (kilogram)	632					
Plume Area	**2011**		**Change from 2010**			
Plume area at 20 µg/L	1.30 km^2		46%			

Figure 2.3-1. Facilities and Groundwater Monitoring Wells in 100-KR-4

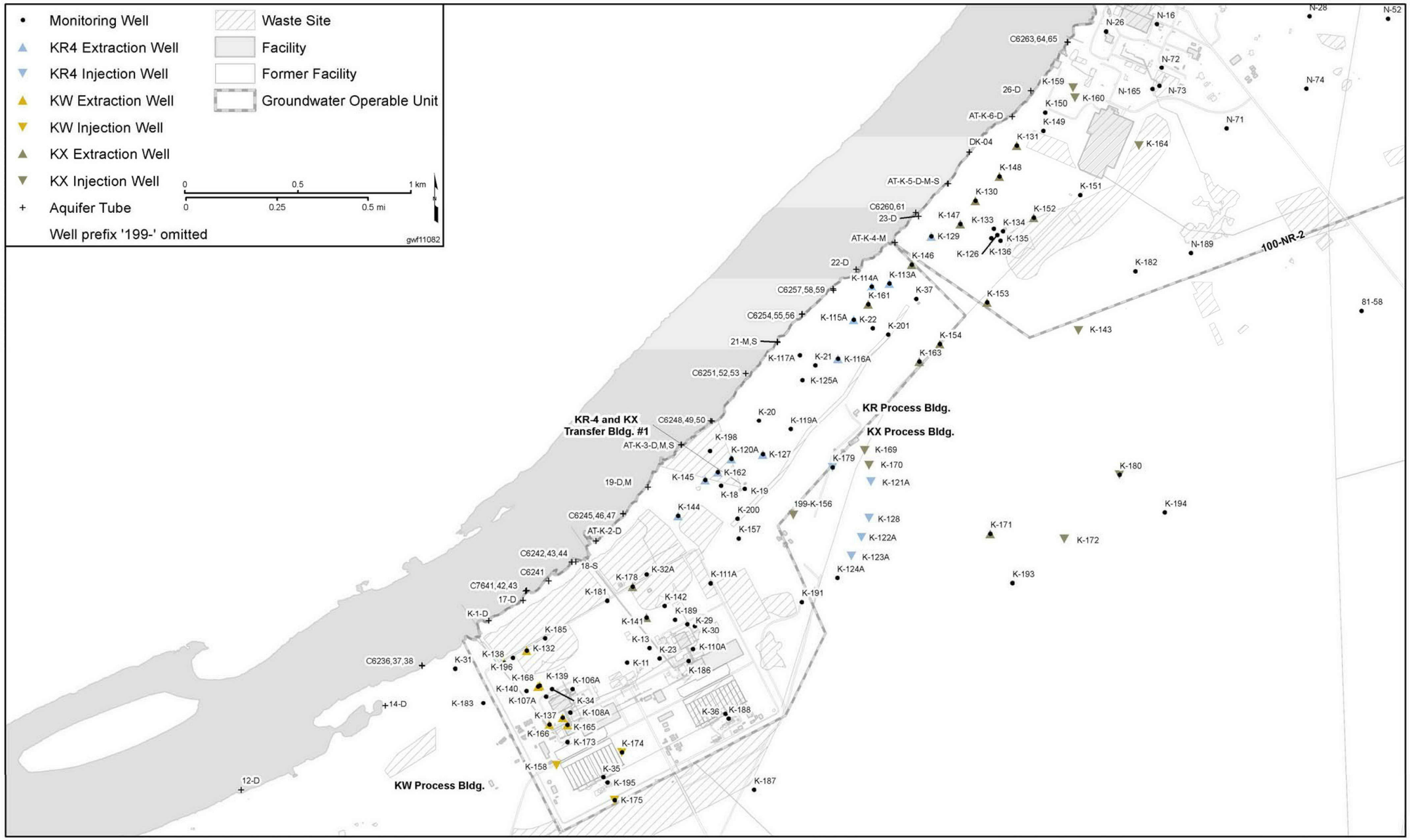


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Figure 2.3-2. 100-KR-4 Water Table, March 2011

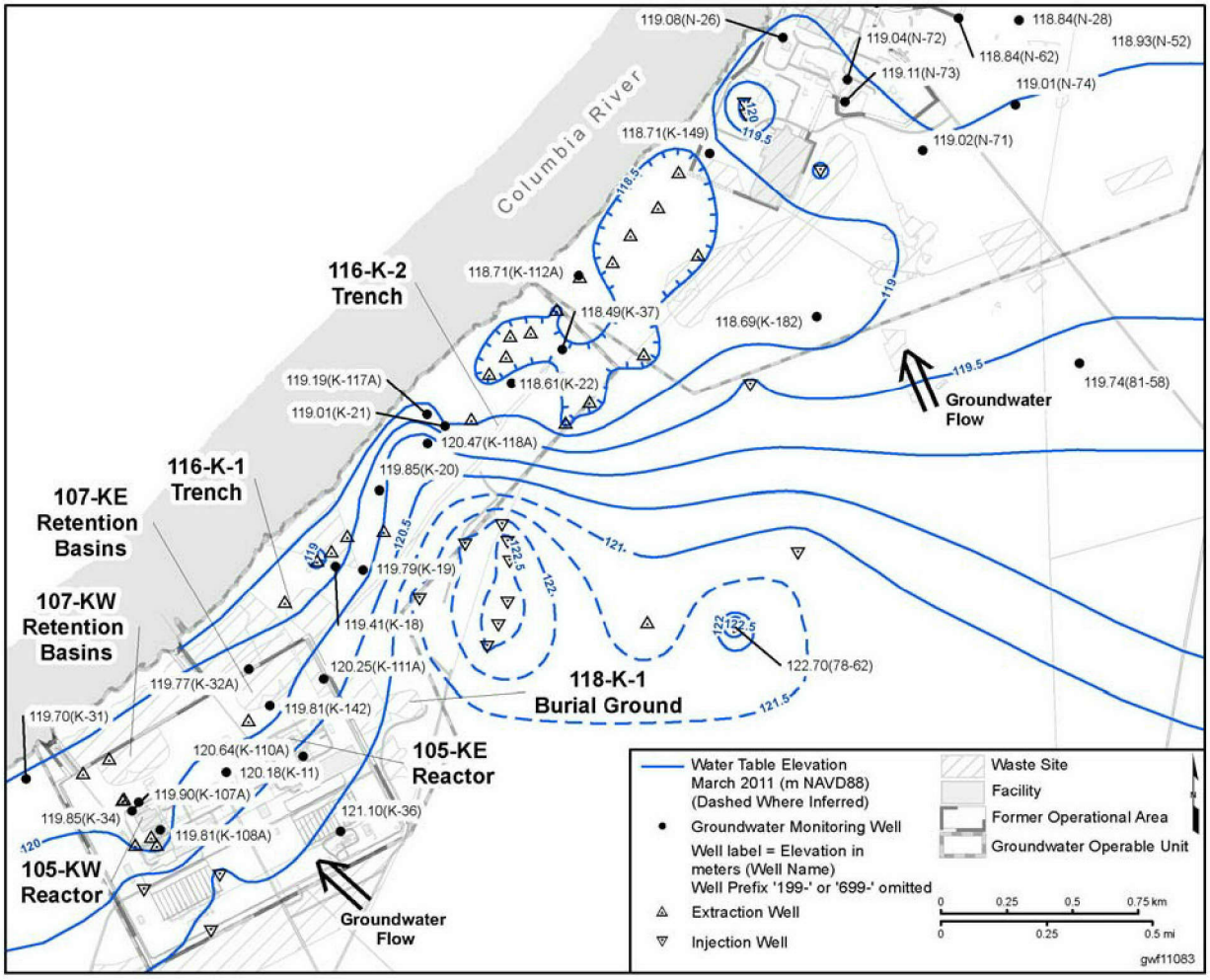


Figure 2.3-3. Changes to 100-KR-4 Plume Areas

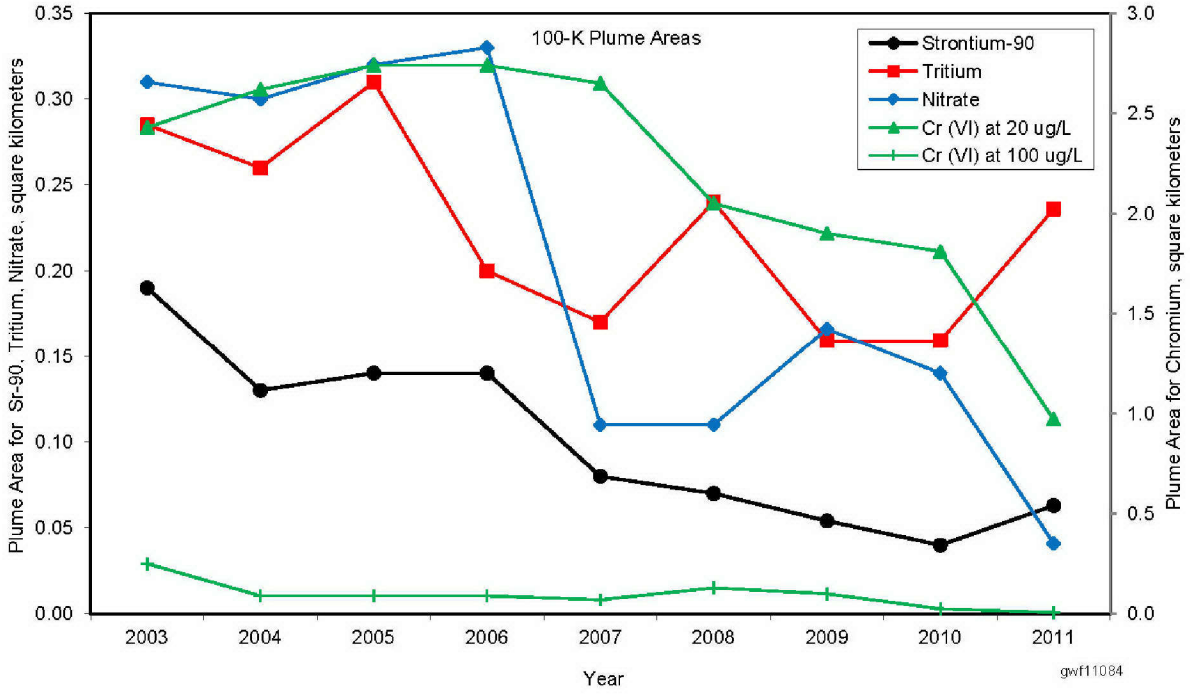


Figure 2.3-4. Hexavalent Chromium Concentrations and Trends in 100-KR-4, Upper Part of Unconfined Aquifer, Spring and Fall 2011

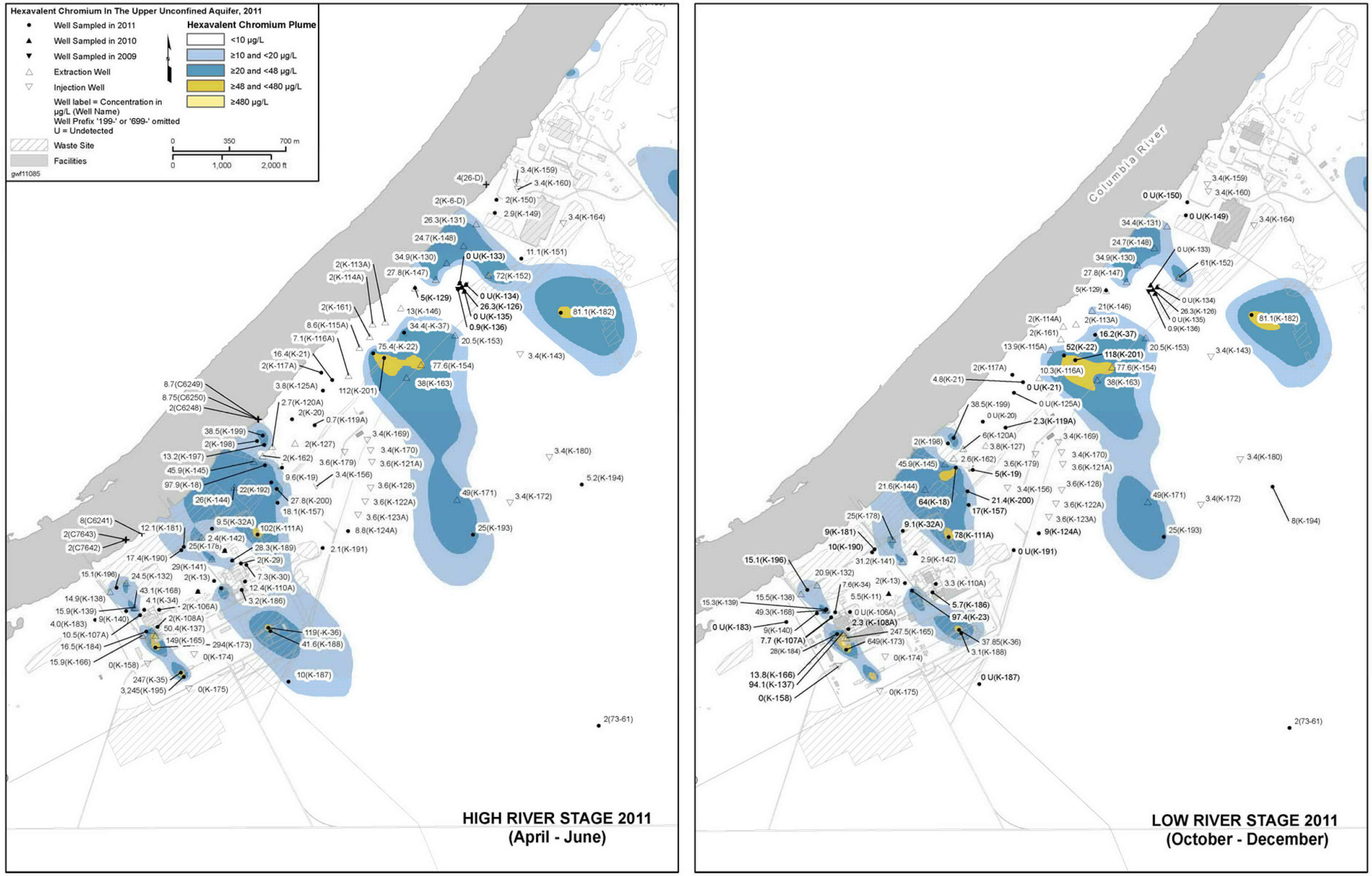
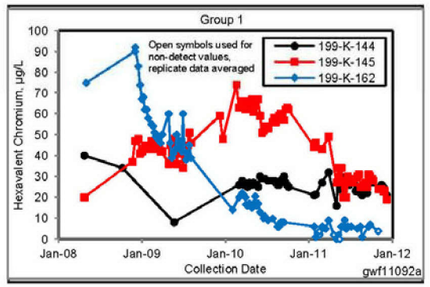
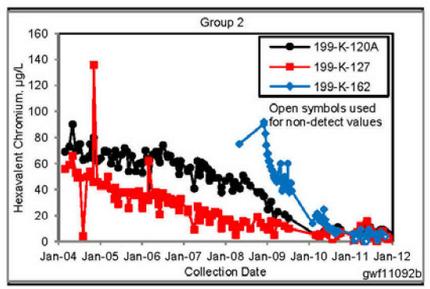
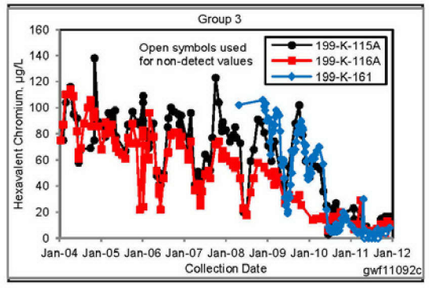
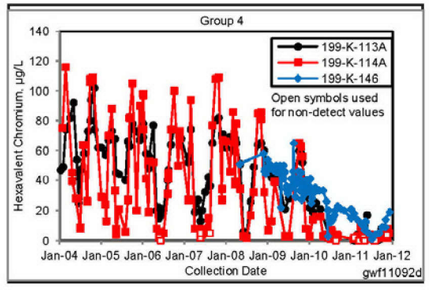


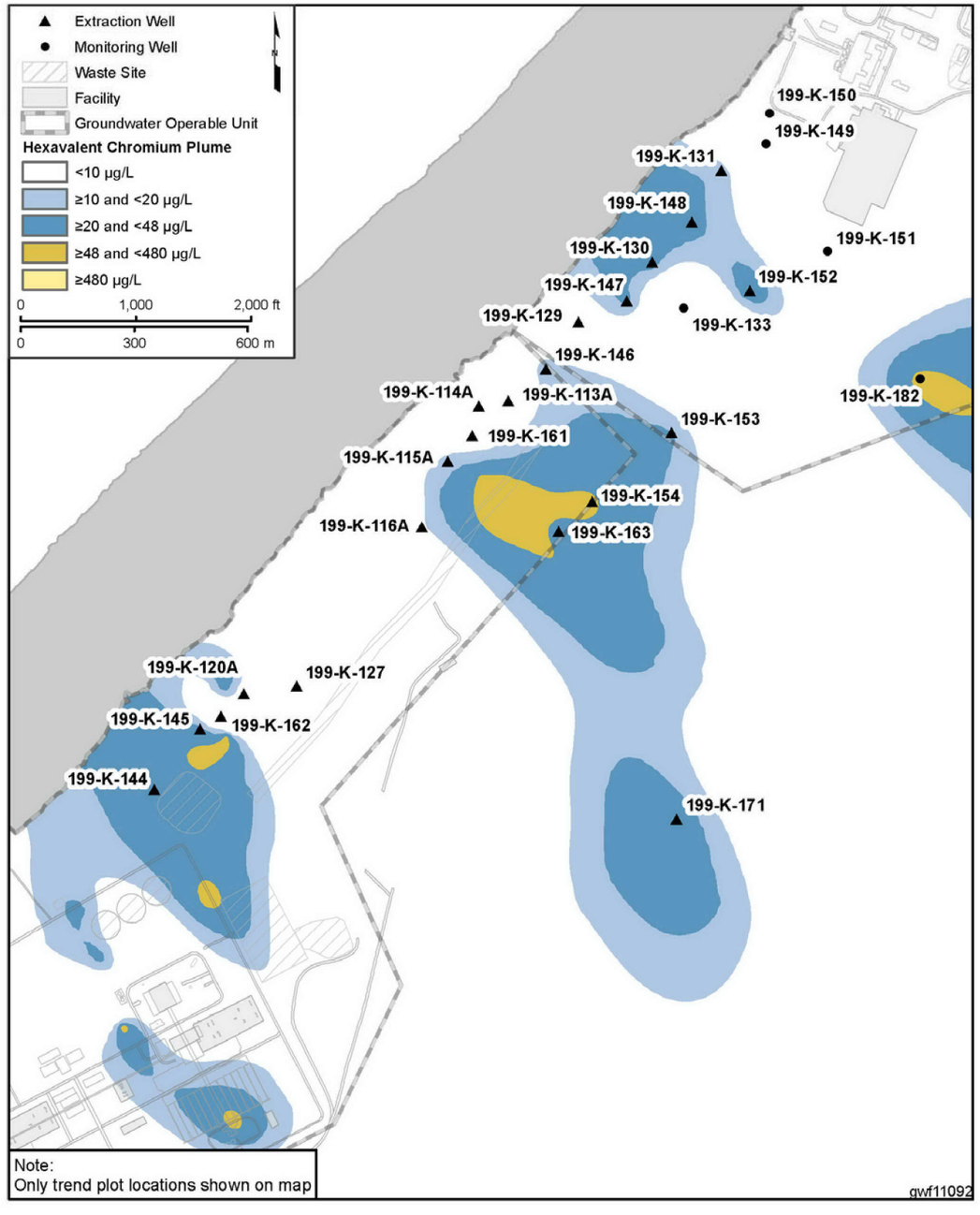
Figure 2.3-5. Hexavalent Chromium Trends in 116-K-2 Trench Plume

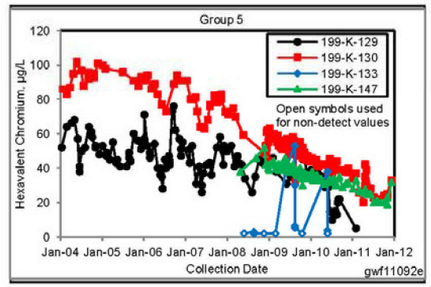


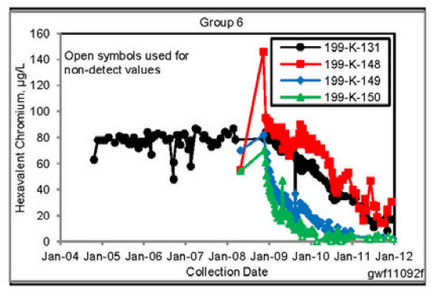


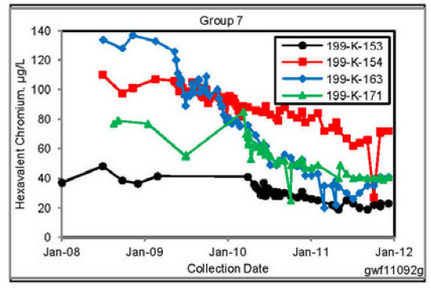












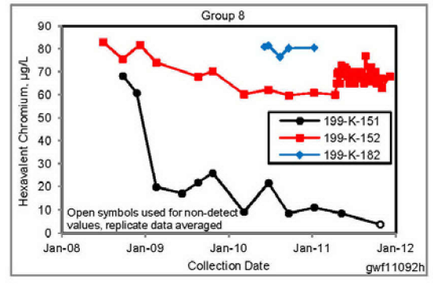
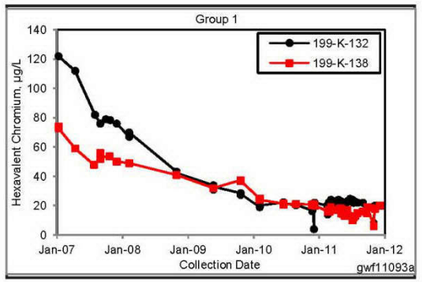
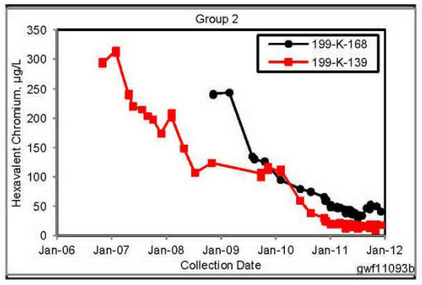
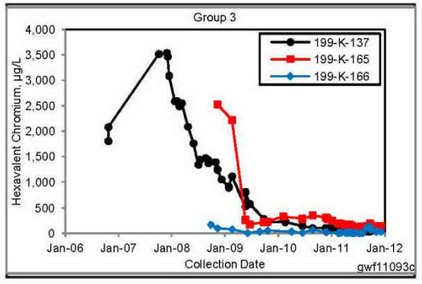
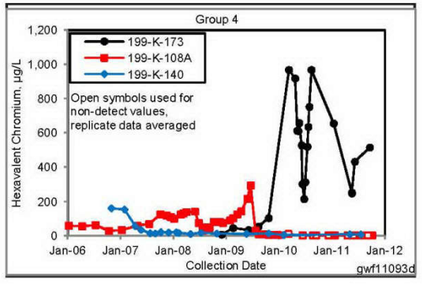


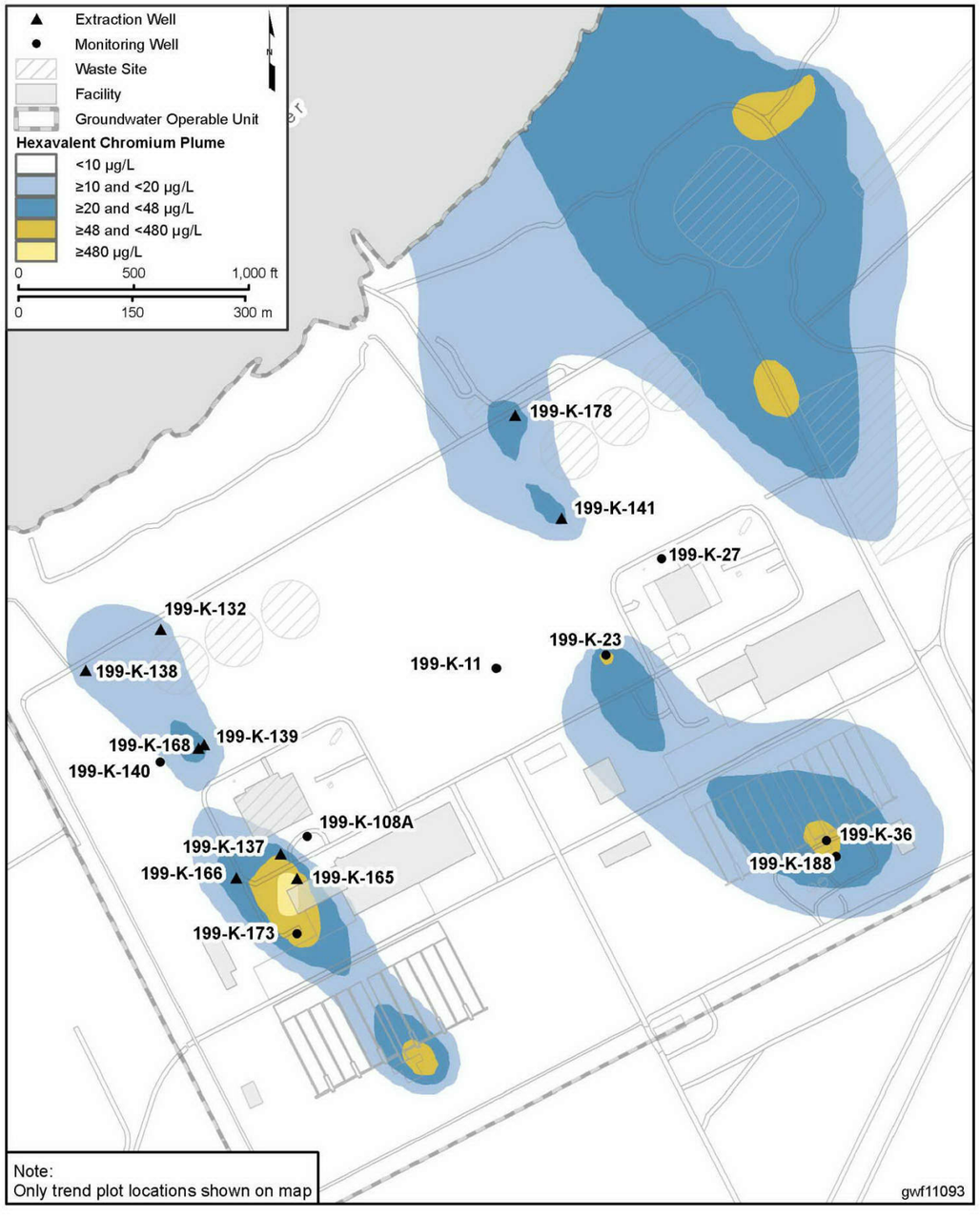
Figure 2.3-6. Hexavalent Chromium Trends in KE and KW Plumes

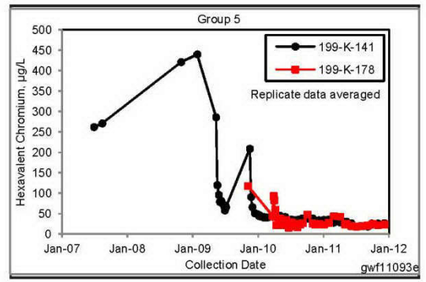


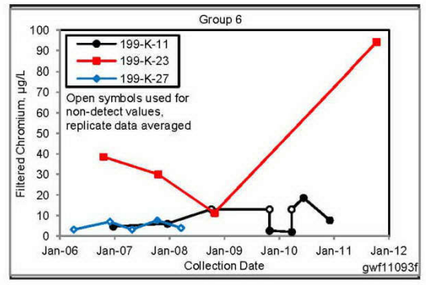












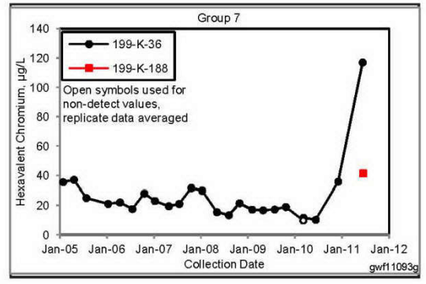


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Figure 2.3-7. Hexavalent Chromium Trends in K West Monitoring Wells

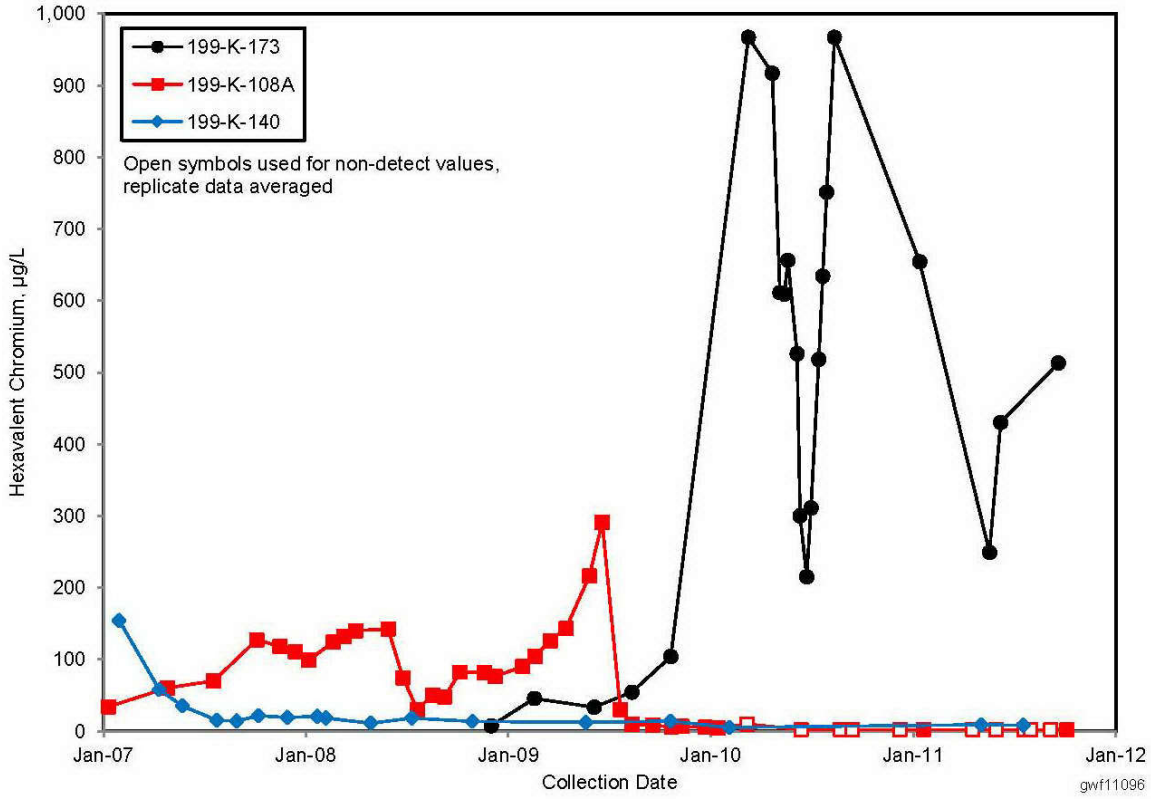


Figure 2.3-8. Average Tritium Concentrations in 100-KR-4, Upper Part of Unconfined Aquifer, 2011

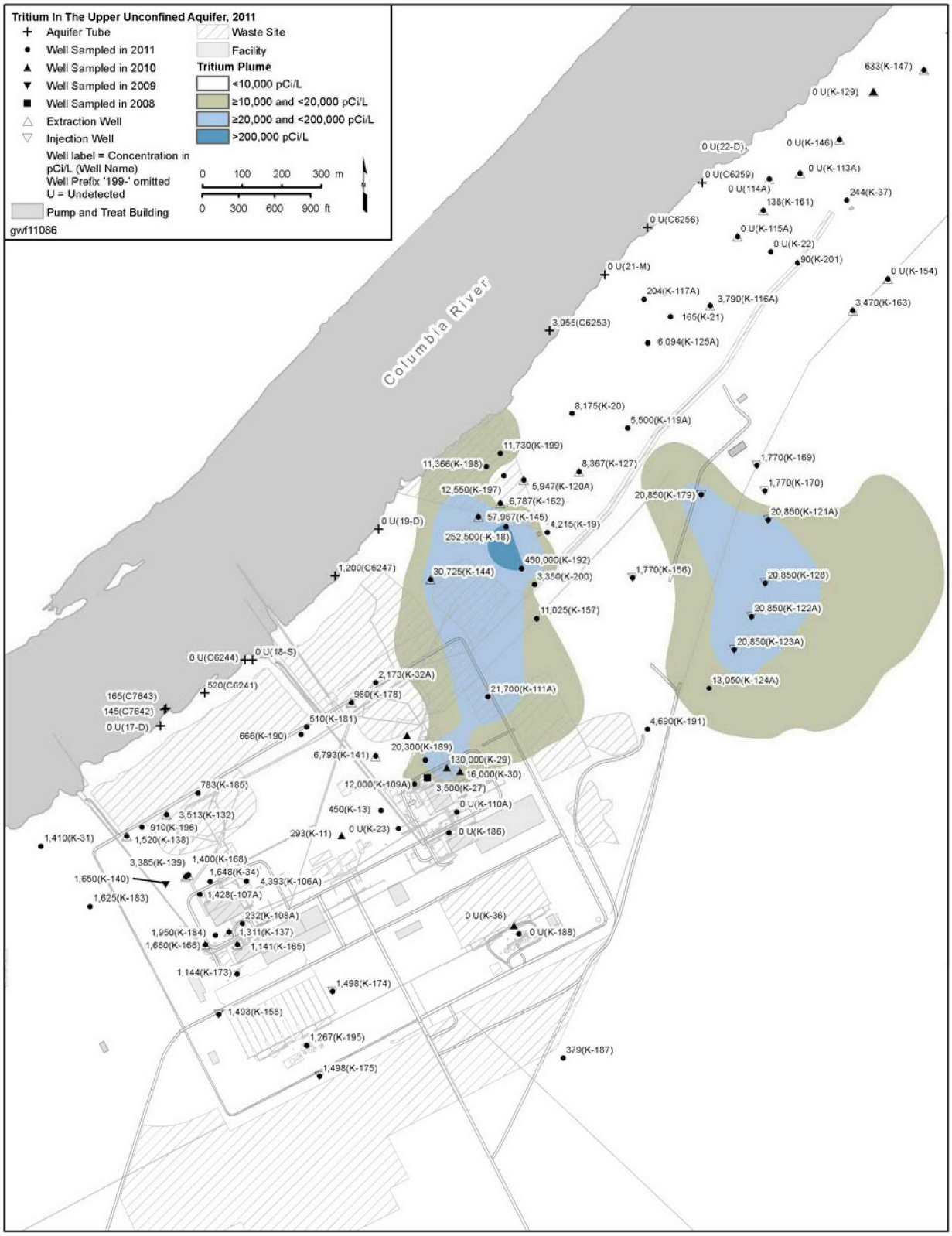


Figure 2.3-9. Tritium Trends in Wells Monitoring K East (Top) and 118-K-1 Burial Ground (Bottom)

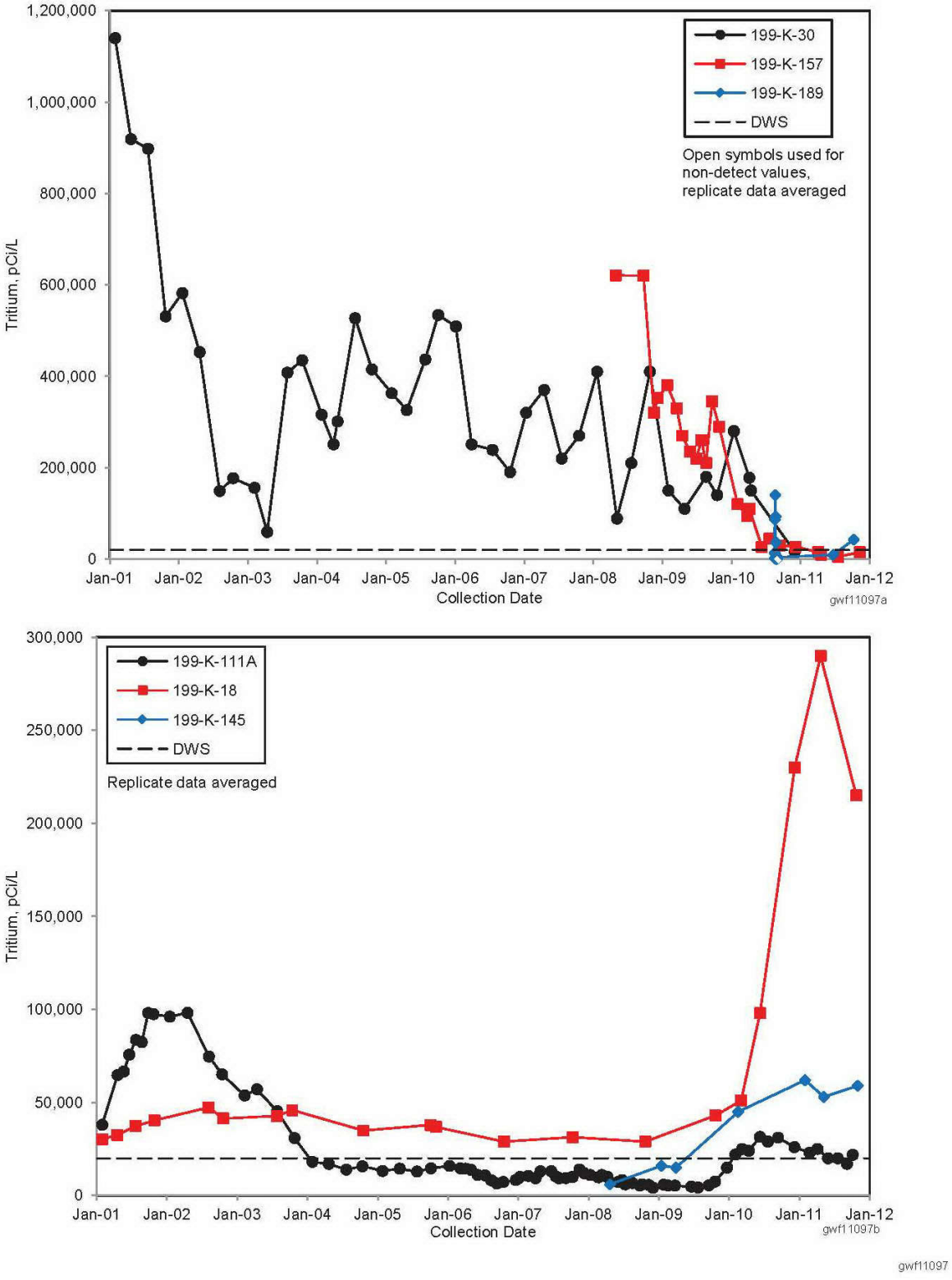


Figure 2.3-10. Average Nitrate Concentrations in 100-KR-4, Upper Part of Confined Aquifer 2011

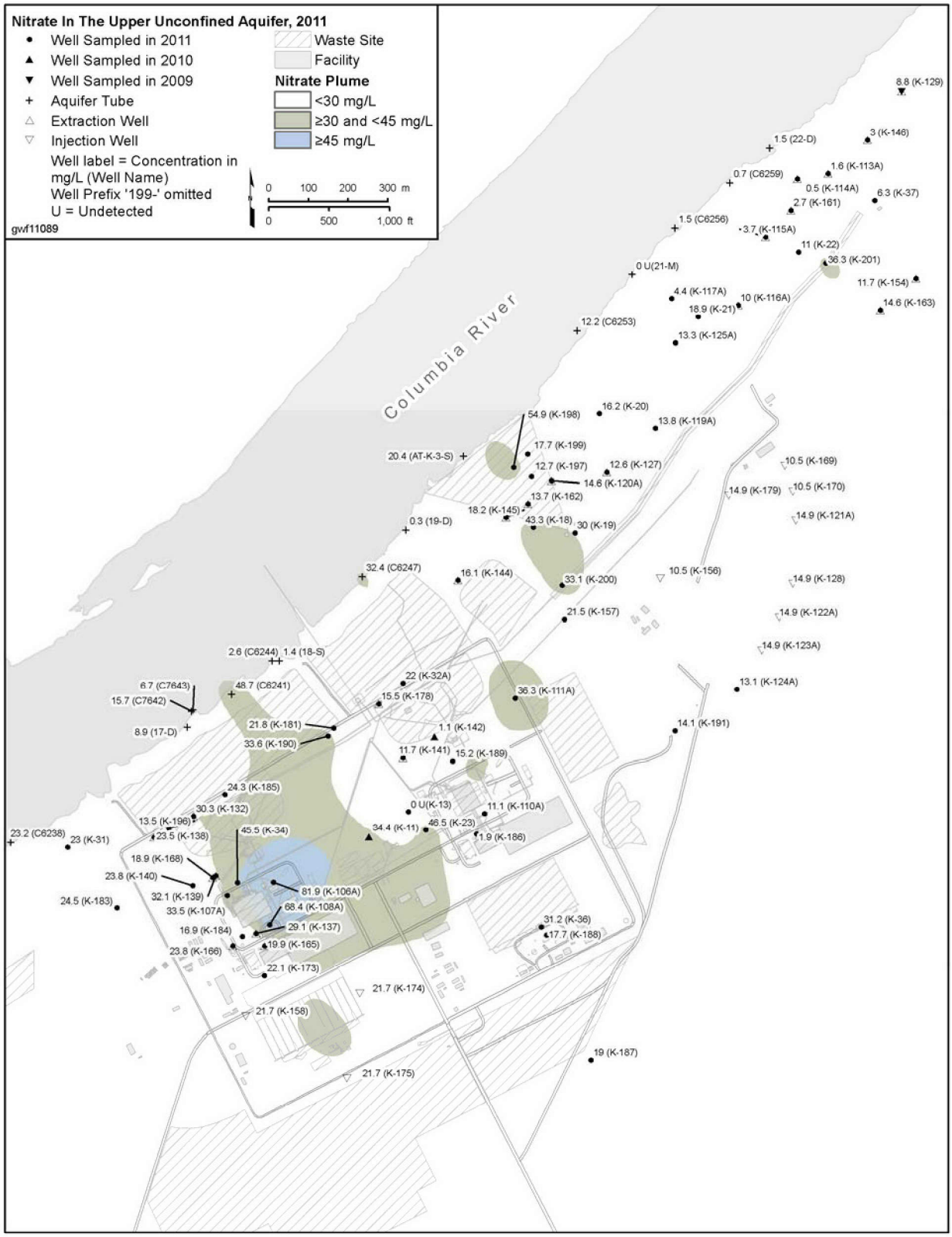


Figure 2.3-11. Average Strontium-90 Concentrations in 100-KR-4, Upper Part of Confined Aquifer 2011

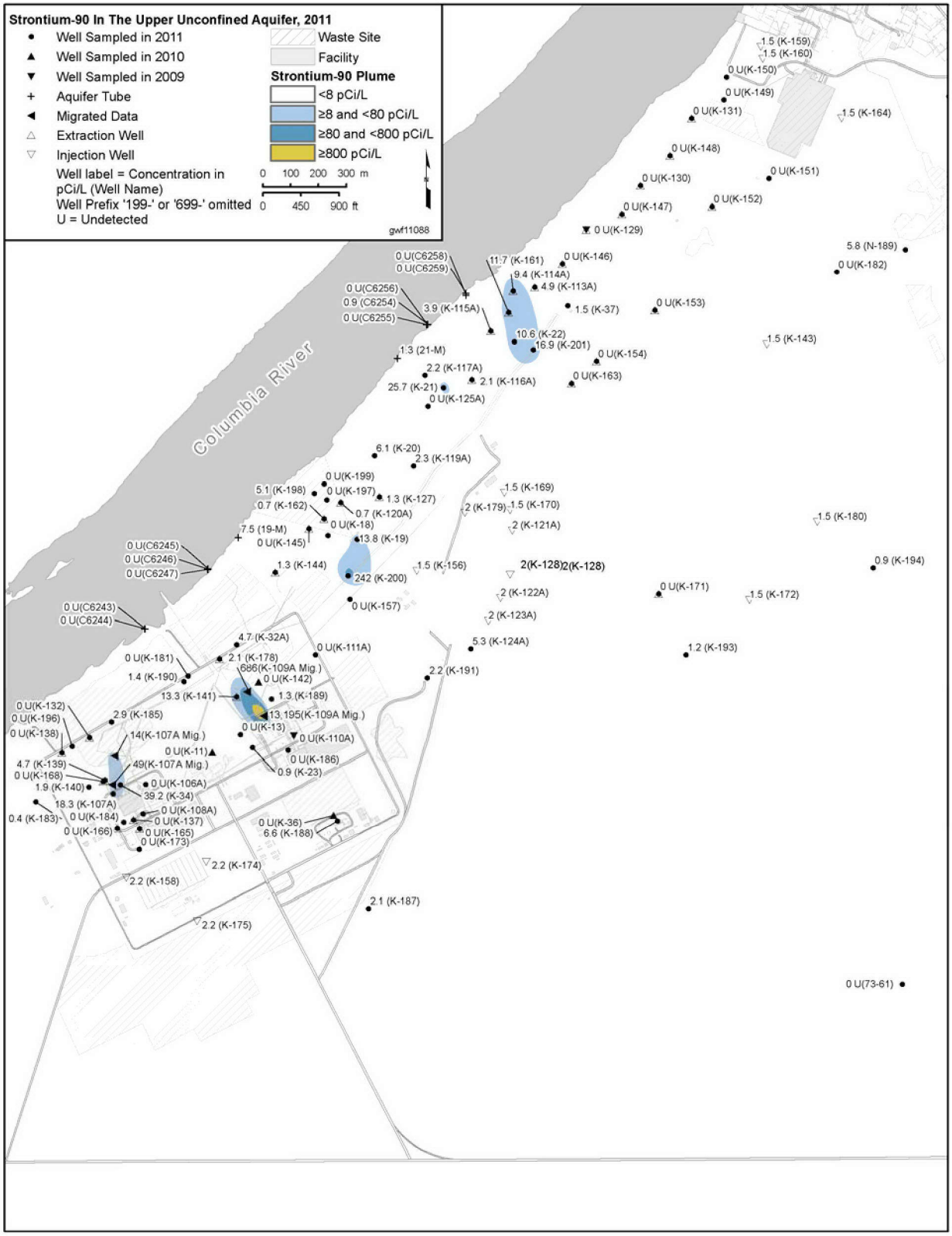


Figure 2.3-12. Strontium-90 Trend in Well 199-K-200 in the 116-K-2 Trench

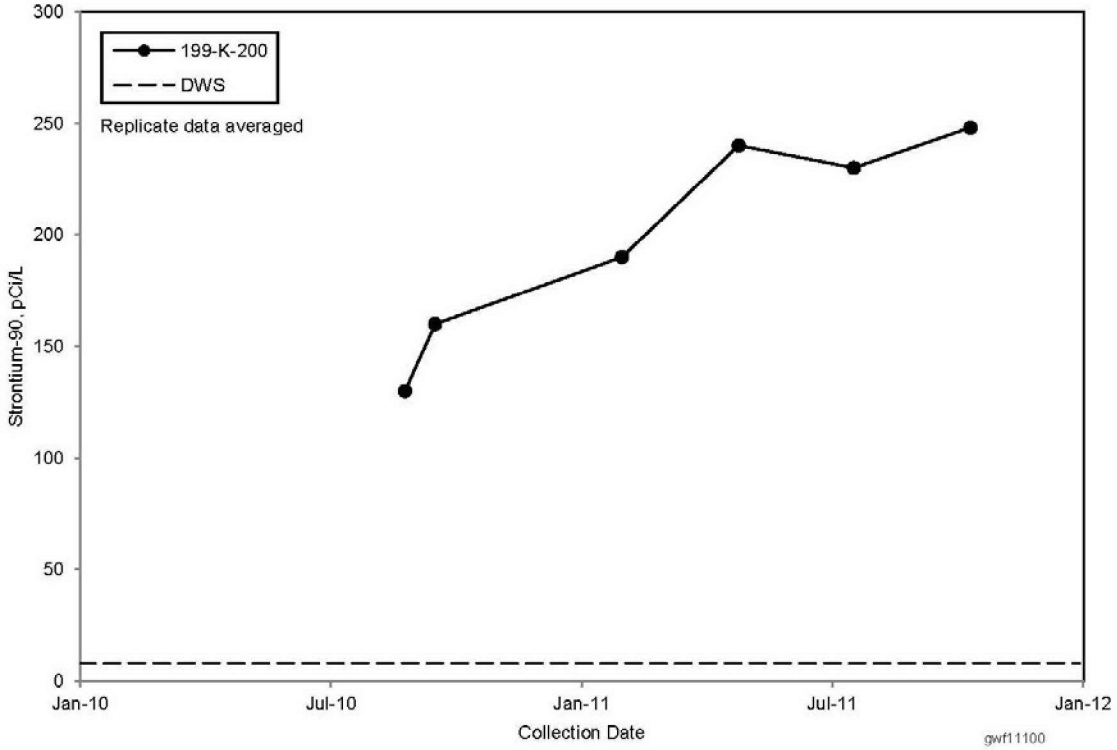


Figure 2.3-13. Strontium-90 Trend in Wells Downgradient of K East

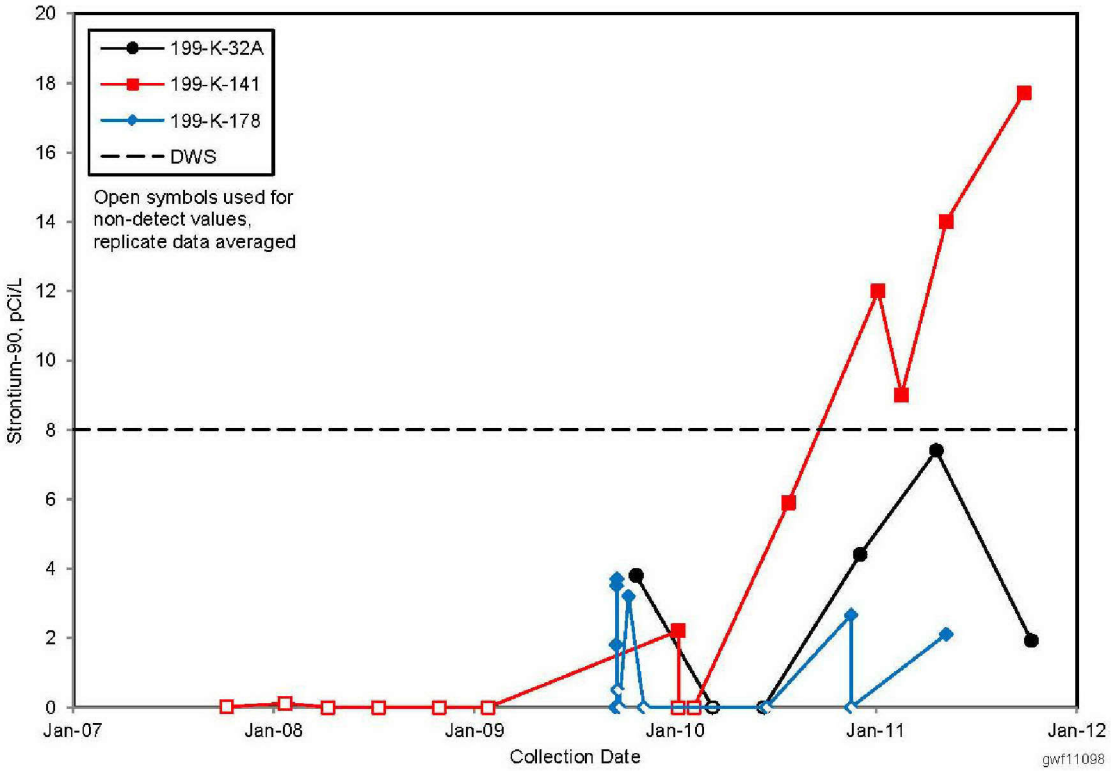


Figure 2.3-14. Average Carbon-14 Concentrations in 100-KR-4, Upper Part of Unconfined Aquifer, 2011

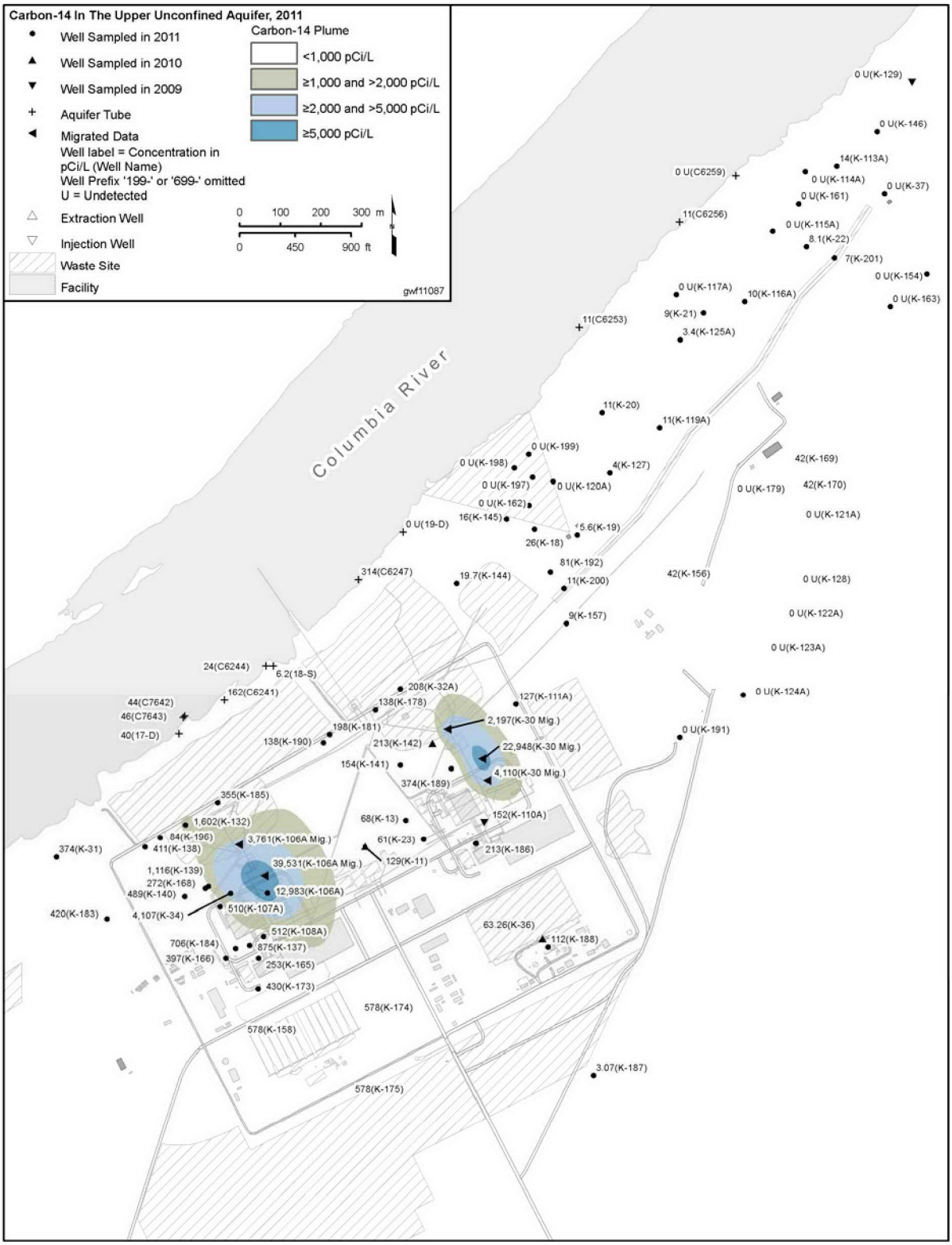


Figure 2.3-15. Average Trichloroethene Concentrations in 100-KR-4, Upper Part of Unconfined Aquifer 2011

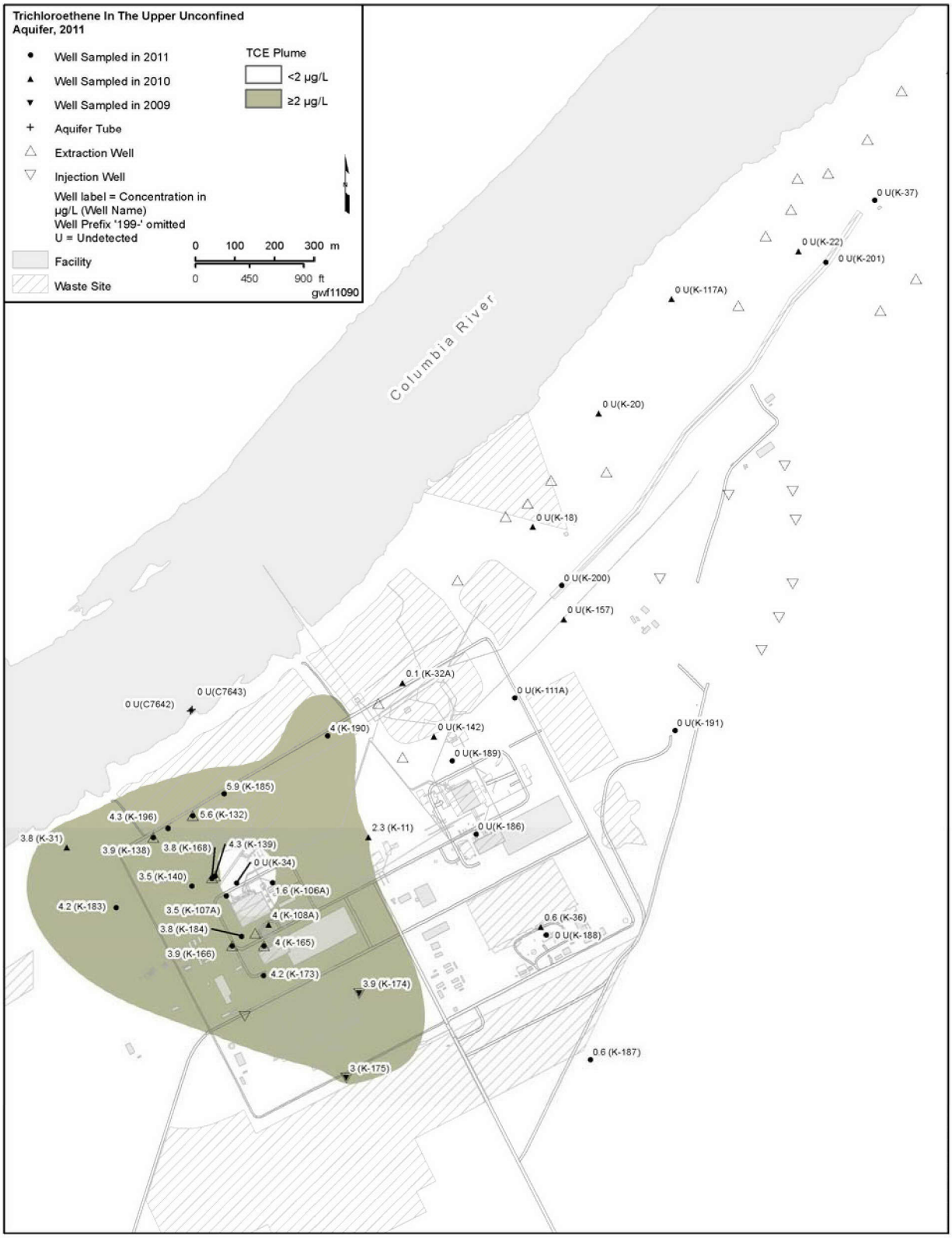
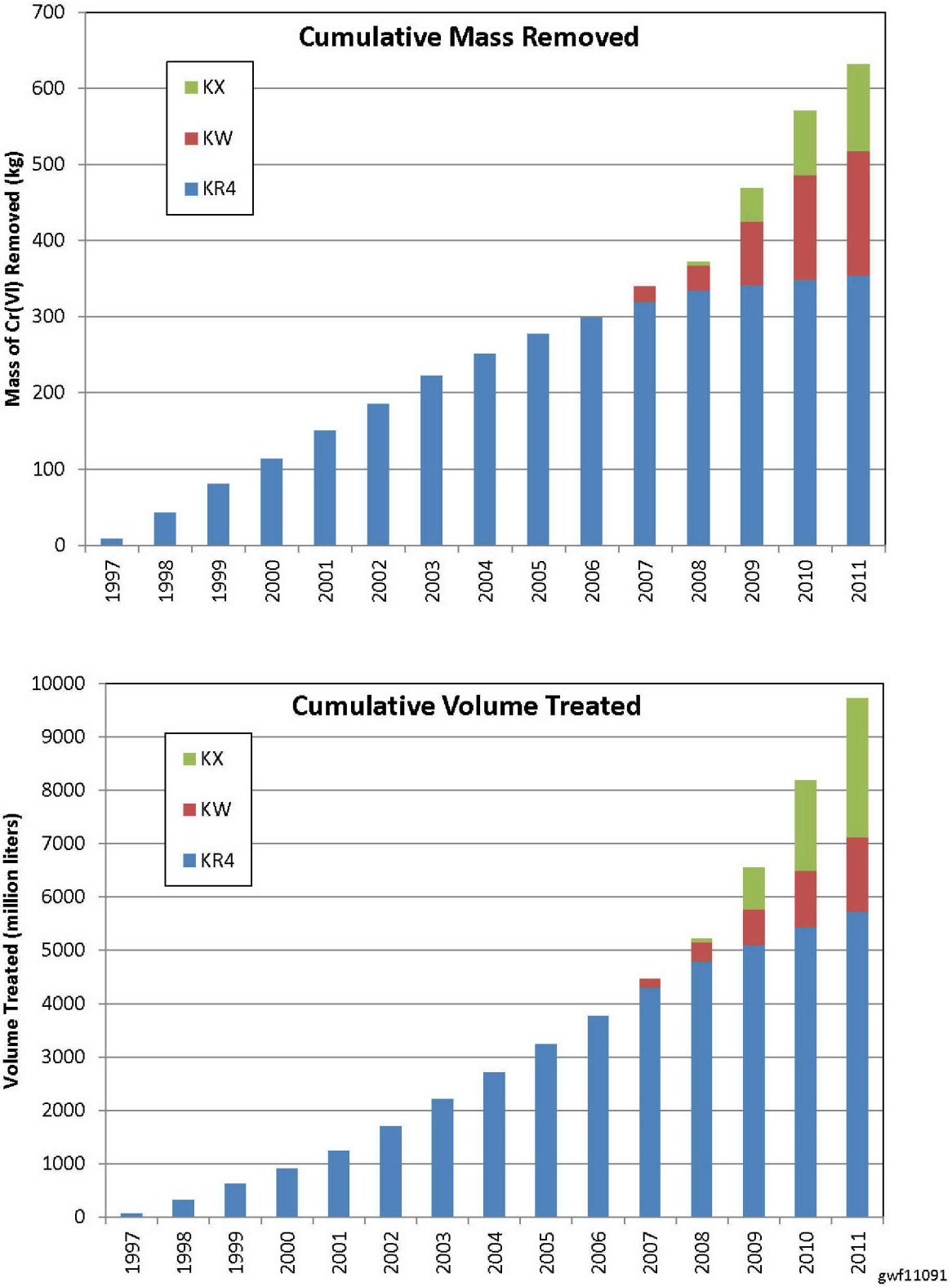


Figure 2.3-16. Volume of Groundwater Treated and Mass of Hexavalent Chromium Removed by 100-KR-4 Pump-and-Treat Systems, 1997 through 2011



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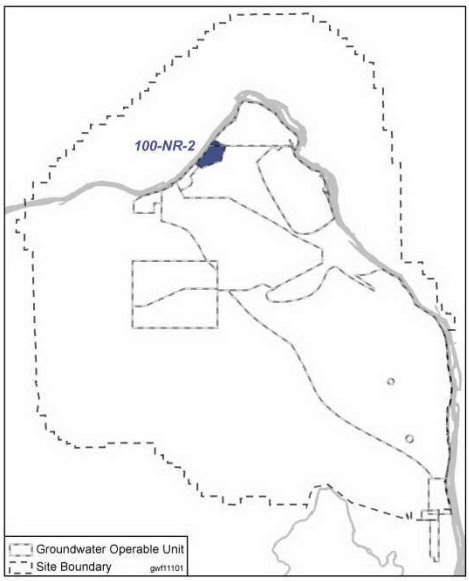
2.4 100-NR-2

D.J. Alexander and M.J. Hartman

This section describes the groundwater conditions and contaminant distributions in the 100-NR-2 Operable Unit, which includes groundwater affected by contaminant releases from facilities and waste sites in the 100-N Area. Figure 2.4-1 shows the facilities and wells in 100-NR-2. Figures 2.4-2, 2.4-3, and 2.4-4 show details for the shoreline monitoring locations and sites related to the original 300-foot apatite permeable reactive barrier installed from 2006 through 2008, and the upriver and downriver extension barriers installed in fall 2011.



Sections 2.4.1 through 2.4.7 discuss the contaminant plumes and concentration trends in the vicinity of 100-NR-2. Strontium-90 and petroleum hydrocarbons are the contaminants of concern for a CERCLA interim action (EPA/541/R-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*). Several ongoing remedial investigation activities will contribute to the development of a final ROD. The CERCLA activities completed during 2011 are discussed in Section 2.4.8. Section 2.4.9 identifies the groundwater monitoring activities at the four RCRA facilities for 2011.

DOE has identified 191 waste sites in the 100-N Area. Approximately 30 percent of the sites have been remediated or are classified as not needing to be remediated under an interim record of decision. The high-volume waste sites include the 116-N-1 and 116-N-3 Liquid Waste Disposal Facilities (LWDFs) and the 120-N-1 Percolation Pond.

Strontium-90 is the principal contaminant of concern in 100-NR-2. The areal extent of the strontium-90 plume has remained relatively unchanged from 1996 to 2012. Strontium-90 contamination is found in portions of the vadose zone that were saturated during discharge operations and also in the underlying aquifer extending to the Columbia River. Other groundwater contaminants include tritium, nitrate, petroleum hydrocarbons, sulfate, and chromium.

100-NR-2 at a Glance

N Reactor Operations: 1963–1987				
2011 Groundwater Monitoring				
Contaminant	**Drinking Water Standard**	**Maximum Concentration**	**Plume Area[a]**	**Shoreline Impact (m)**
Strontium-90	8 pCi/L	13,500 pCi/L	0.57 km^2	620
Nitrate	45 mg/L	394 mg/L	0.57 km^2	150
TPH	N/A	48 mg/L	0.003[b]	0
Tritium	20,000 pCi/L	16,500 pCi/L	0	0
Remediation				
Waste Sites (interim action): >30% complete[c] Groundwater (interim action): • Pump-and-treat: 1995-2006, 1.8 Ci strontium-90 removed • Apatite sequestration barrier: 2006-2011 Final record of decision anticipated in 2013				

a. Estimated area above drinking water standard.

b. Area at 200 µg/L.

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

TPH = Total petroleum hydrocarbons

N/A = Not applicable

The 100-N Area is underlain by the Hanford formation, the Ringold Formation unit E, and the Ringold Formation upper mud unit. The uppermost unit, the Hanford formation, is 6 to 23 meters thick and underlies most of the area. In a few places along the shoreline lower roadway, the Hanford formation is absent because of excavation and fill that was placed to build the road. Unit E of the Ringold Formation underlies the entire area and is 5 to 20 meters thick. The Ringold Formation upper mud unit forms the base of the unconfined aquifer and is 17 to 29 meters thick. Most of the monitoring wells in 100-NR-2 were completed in the upper portion of the unconfined aquifer, which is predominantly in the Ringold Formation unit E. At high Columbia River levels, the aquifer can rise into the Hanford formation in wells along the shoreline and nearby inland wells. Three wells monitor the base of the unconfined aquifer (199-N-69, 199-N-70, and 199-N-121). Another well, 199-N-80, was completed in a fine-grained sandy unit in the Ringold Formation upper mud unit, approximately 12 meters below the water table. Chapters 2.0 and 4.0 of the RI study/work plan provide further information about the geology and hydrology of 100-NR-2 (DOE/RL-2008-46-ADD5).

Groundwater flow in 2011 was influenced by groundwater extraction and injection for the KX remediation system in 100-KR-4 (Section 2.3). Figure 2.4-5 provides the March 2011 water table map for 100-NR-2. A groundwater mound at least 1 meter high creates the potential for radial flow in the southernmost part of 100-NR-2. The water table beneath the rest of the area was nearly flat in March 2011 when the river stage was higher than normal for that time of year. The river stage can change daily (plus or minus 1.5 meters) and seasonally (plus or minus 2.4 meters) for sustained periods, which changes the saturated zone thickness and causes flow reversals (Section 1.1 of PNNL-16891, *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO4 Solution Injection and Sr-90 Immobilization in 100-N Sediments*). In 2011, the river stage peaked in late May and early June, and remained high into early July. Water levels in well 199-N-2, 170 meters from the river, rose more than 1.5 meters with a lag time of a few days. Water levels in 199-N-34, 500 meters from the river, rose more than 0.5 meter with a lag time of approximately two months. The changes affected groundwater flow directions. Section 2.4.9 provides more information about groundwater flow.

The 100-KR-4 pump-and-treat system began injecting treated water into wells between the 100-K and 100-N Areas. The injections changed the direction of groundwater flow in the southern part of 100-NR-2 in 2011.

Vertical hydraulic gradients are difficult to measure in the unconfined aquifer at 100-NR-2. The difference in water levels in well pairs 199-N-81/199-N-70 and 199-N-119/199-N-121 was only a few hundredths of a meter during 2011—within measurement error. The screen depths differ by approximately 5 to 6 meters.

2.4.1 Strontium-90

The majority of the strontium-90 remaining in the subsurface of 100-NR-2 is in the vadose zone above the aquifer. Strontium-90 tends to sorb to sediment grains, so its rate of transport in groundwater is slower than the groundwater flow rate. The relative rate of the velocity of strontium-90 to groundwater is approximately 1 to 100.

Soil data have been collected from wells and borings at the 116-N-1 (1301-N) and 116-N-3 (1325-N) LWDFs, and along the Columbia River shoreline. Strontium-90 is generally distributed in a layer around the current water table, mostly in the upper portion of the Ringold Formation unit E. This contaminated layer is thickest beneath the LWDFs (up to 12.2 meters) and thins toward the Columbia River (1.5 to 6.1 meters). Strontium-90 concentrations in soil near the LWDFs decrease with distance and depth. The majority of strontium-90 contamination within the LWDFs was retained within the facilities (nearer the head end and immediately below the base). The LWDFs were interim-remediated between 2000 and

2005, and contaminated concrete and soil were removed to a depth of 4.5 to 6.5 meters depending on location. The sites were backfilled in 2006 (Section 4.1 of CVP-2002-00002, *Cleanup Verification Package/Clean Closure Report for the Soil Column of the 116-N-3 Trench and 100-N-63:1 Pipeline*; Section 3.1 of CVP-2006-00004, *Cleanup Verification Package/Clean Closure Report for the Soil Column of the 116-N-1 Crib and Trench*).

Strontium-90 concentrations in soil samples collected from the wells and borings farther from the LWDFs along the 100-NR-2 shoreline indicate that the majority of strontium-90 is in the top of the Ringold Formation unit E and the bottom of the Hanford formation. The water table near the Columbia River is in the top of the Ringold Formation unit E during low river-level conditions (late July through March), but the water table can rise up into the Hanford formation when river levels are elevated (April to June). This causes the strontium-90 contamination to smear vertically within the areal extent of the plume (Section 1.1 of PNNL-16891). The majority of the contamination in soil along the Columbia River is in the immediate vicinity of the original apatite permeable reactive barrier, between wells 199-N-123 and 199-N-121 (Section 5.2 of PNNL-16894, *Investigation of the Strontium-90 Contaminant Plume along the Shoreline of the Columbia River at the 100-N Area of the Hanford Site*).

Strontium-90 is the principal contaminant of concern in 100-NR-2. The plume's footprint has changed very little since 1996.

The size and shape of the strontium-90 plume in the groundwater have varied little over the years because of the way strontium and strontium-90 behave in the environment (Figures 2.4-6 and 2.4-7). The plume currently has nearly the same areal extent and shape as it had in 1996, before the startup of the 100-NR-2 pump-and-treat operations. The plume extends from beneath the 116-N-1 and 116-N-3 LWDFs to the Columbia River at levels exceeding the drinking water standard of 8 pCi/L. Concentrations in several wells and aquifer tubes exceeded the DOE's derived concentration standard of 1,100 pCi/L. Concentrations exceeding 100 pCi/L are limited to the upper approximately 3 meters of the aquifer (Section 2.4.1 of PNNL-16436, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*). Wells monitoring the base of the unconfined aquifer or in the Ringold upper mud unit are essentially free of strontium-90 contamination (that is, it is either not detected or is at levels barely above detection limits).

DOE estimates that the amount of strontium-90 discharged to the ground in 100-N, corrected for radioactive decay through 2010, is approximately 1,325 Ci (DOE/RL-2008-46-ADD5). In planning documents for remediation of the 116-N-1 and 116-N-3 crib and trench sediments (BHI-00368, *Data Quality Objectives Workshop Results for 1301-N and 1325-N Characterization*), it was estimated in 1995 that approximately 560 Ci of the strontium-90 inventory would be removed by the remedial action. Based on these estimates, approximately 850 Ci (corrected for radioactive decay through 2010) of the strontium-90 inventory remains. Of the inventory remaining, approximately 99 percent is absorbed on the soil in the vadose zone and upper aquifer, and 1 percent is in the groundwater (Section 1.1 of PNNL-16891).

The 116-N-3 LWDF was in use from 1983 through 1991. The highest concentration at this site in 2011 was 3,320 pCi/L in a characterization sample from the top of the aquifer at new characterization well 199-N-188, which was drilled through the former crib. Concentrations declined sharply with depth in this well (to 338 pCi/L at 3 meters below the shallowest sample).

Strontium-90 levels in well 199-N-81 near the 116-N-3 LWDF have declined since the late 1990s (Figure 2.4-8). A high water table in 2011 did not create a large increase in strontium-90 concentrations in 199-N-81 in the fall 2011 sample. Delayed effects may become evident in 2012.

The 116-N-1 LWDF was in use from 1963 to 1985. Strontium-90 concentrations in 199-N-67 show no obvious long-term decline, but concentrations vary in relation to water levels (Figure 2.4-9). Water levels were higher beneath the LWDFs in the 1980s and early 1990s when discharges were still occurring. As the water level decreased, strontium-90 remained in the vadose zone. Therefore, when the water table rises beneath the former LWDFs, strontium-90 from the vadose zone is remobilized, and the concentrations in groundwater increase.

Well 199-N-187 was drilled through the 116-N-1 LWDF in 2011. Characterization samples show that strontium-90 concentrations decline sharply with depth. At the water table, concentrations were 17,300 and 13,700 pCi/L in duplicate samples. At 1.8 meters below the water table, the concentration was 8,100 pCi/L; at 3.5 meters below the water table, the concentration was 1,600 pCi/L.

Seven wells downgradient from the 116-N-LWDF show increasing strontium-90 concentrations since the pump-and-treat system was shut down in 2006. These wells are as follows:

- Former extraction wells 199-N-75, 199-N-103A, 199-N-105A, and 199-N-106A (Figure 2.4-10)
- Wells 199-N-14, 199-N-67, and 119-N-76 downgradient from the 116-N-1 LWDF
- Well 199-N-119, located near one of the most contaminated portions of the shoreline

The strontium-90 concentration in former extraction well 199-N-105A increased four-fold in 2011. This increase may have been caused by a high water table and changes in groundwater flow directions.

The increases are partially attributable to a rebound effect after pump-and-treat operations ceased. However, some of the wells exhibited higher concentrations in 2011 than in 1996, before the pump-and-treat system was started, and concentrations increased four-fold in well 199-N-105A in 2011. The increase in well 199-N-105A may have been caused by the high water table in June 2011, which mobilized strontium-90 from contaminated sediments in the lower vadose zone. Another explanation is that the increases reflect a change in groundwater flow directions because of the groundwater mound in the southern part of 100-NR-2, caused by 100-KR-4 injection wells. Future groundwater monitoring will determine whether the changes persist and whether they are linked to changes in the river stage.

The highest strontium-90 concentrations in soil and groundwater along the Columbia River are found near the original apatite permeable reactive barrier and immediately downriver to the northeast. This area is the focus of increased monitoring and remediation activities. Figure 2.4-11 depicts the strontium-90 concentrations at the 100-NR-2 shoreline in the area affected by the original apatite barrier.

Figure 2.4-12 shows the effects of the original apatite barrier on strontium-90 concentrations (as represented by gross beta activity). Following initial injections in 2006, the barrier helped to reduce strontium-90 concentration in its immediate vicinity, including the wells within the barrier itself, on both sides of the injection wells on each end of the barrier, and the monitoring wells downgradient from the barrier.

Figure 2.4-12 also includes one well upgradient of the barrier; 199-N-46 has shown a decrease in strontium-90 concentrations. While most locations remain at 90 percent reduction in strontium-90 since injections began in 2006, some areas appear to be candidates for additional apatite treatment (Section 2.4.8.2). Concentrations in all but two monitoring points are below 1,000 pCi/L. Well 199-N-123 exhibited a strontium-90 increase to 1,770 pCi/L in September, and aquifer tube NVP2-116.0 showed an increase to 1,100 pCi/L in August. Concentrations subsequently decreased at both sites. The increase at well 199-N-123 was caused by the upstream barrier extension injections in September 2011. Variability in concentration is affected by the depth of well completion and local geology; but, overall, the values are

well below pre-treatment levels. Effects of the apatite barrier are discussed in greater detail in DOE/RL-2012-02.

Strontium-90 concentrations in aquifer tubes are consistent with those seen in monitoring wells. Levels greater than the drinking water standard are present only above approximately 115 meters in elevation (that is, the top 2 to 3 meters of the aquifer), so this is where most of the aquifer tubes are screened. The majority of the aquifer tubes completed below this elevation are in the area where strontium-90 concentrations along the river are known to be highest. Therefore, if the lower elevation tubes in this area are free of strontium-90 contamination, it is likely that the adjacent areas along the river shore will also be free of strontium-90.

The only strontium-90 detections in aquifer tubes outside the area where the strontium-90 plume intersects the Columbia River (Figure 2.4-6) are at aquifer tube cluster C7934/35/36. These tubes are in the engineered fill around the 1908-N Outfall, which indicates that outfall construction created a preferential pathway in the fill. The potential sources of strontium-90 contamination at this location are from the 105-N Reactor Building/Fuel Storage Basin, the 1909-N Waste Disposal Valve Pit, the 107-N Basin Recirculating Cooling Facility, the 1304-N Emergency Dump Tank, the 1300-N Emergency Dump Basin, and/or other associated structures (Section 4.2 of SGW-49370, *Columbia River Pore Water Sampling in 100-N Area, December 2010*).

2.4.2 Nitrate

A nitrate plume (Figure 2.4-13) lies under the former 116-N-1 and 116-N-3 LWDFs, under portions of the southwestern 100-N Area (the reactor and associated buildings), and extends to the Columbia River below well 199-N-21. The 2011 plume has a more limited extent to the southwest than in previous years because of the impact of treated water entering the aquifer through 100-KR-4 injection wells in this region. The highest concentrations (>100 mg/L) are observed beneath the 116-N-1 LWDF. The highest concentration in 2011 was 394 mg/L in well 199-N-67 in January. The concentration dropped sharply to 55.8 mg/L in September 2011. Nitrate was not documented as a waste source disposed to the LWDFs, but the sites are implicated as the primary nitrate source based on the persistent plume beneath them.

Figures 2.4-14 and 2.4-15 provide nitrate trend plots for wells near the former 116-N-1 and 116-N-3 LWDFs, respectively. At both sites, nitrate concentrations were high in the mid to late 1980s, declined sharply in the early 1990s, and increased between 2002 and 2010. Concentrations decreased in 2011. Continued monitoring will show whether the decrease will persist.

Figure 2.4-16 shows the nitrate concentrations for three wells near the 120-N-1 Percolation Pond. (Note that well 199-N-59 went dry and was replaced by well 199-N-165 in 2008.) Nitrate concentrations at this location were very low when the facility was in used, but began to increase in the mid-1990s. Concentrations in groundwater increased between 2010 and 2011. During the 120-N-1 Percolation Pond's period of use from 1977 to 1990, only low levels of nitrate (approximately 1 mg/L) were detected in the pond's effluent stream (Section 2.4.4 of DOE/RL-96-39, *100-NR-1 Treatment, Storage, and Disposal Units Corrective Measures Study/Closure Plan*). These factors suggest the pond was not the source of the nitrate plume in this region. However, the distribution of the contaminant implicates the pond as its source.

Well 199-N-18 has anomalously low nitrate concentrations related to chemical reduction and biodegradation of hydrocarbons (Section 15.2.3 of DOE/RL-2010-11). The lower concentrations are caused by the chemical reduction of nitrate from the biodegradation of petroleum hydrocarbons near the wells (Section 2.4.3). Other chemical constituents and parameters that support the interpretation of

chemical reduction in and around 199-N-18 include low dissolved oxygen, lower pH, detectable nitrite,[1] and elevated concentrations of iron and manganese.

Nitrate concentrations are highest in the upper part of the unconfined aquifer. Wells 199-N-69 and 199-N-70, screened near the bottom of the aquifer, consistently have lower concentrations than the adjacent, shallow wells. Well 199-N-80, screened in the Ringold upper mud unit, also has concentrations below the drinking water standard.

Nitrate concentrations in aquifer tubes in southwestern 100-NR-2 exceeded the drinking water standard of 45 mg/L in 2010 and in January 2012 (sampling delayed from fall 2011).

2.4.3 Petroleum Hydrocarbons

Petroleum hydrocarbon from a 1960s diesel fuel tank spill (site code UPR-100-N-17) continues to be detected in 100-NR-2 groundwater. The full nature and extent of subsurface hydrocarbon impacts in the UPR-100-N-17 waste site have not been determined (WCH-490, *UPR-100-N-17: Bioventing Pilot Plant Performance Report*). During the drilling of well 199-N-173, vertical profile samples were collected from the vadose zone and groundwater. If present in large enough quantities, the diesel in groundwater is found in the very top of the aquifer or floating on top of the water table (Section 4.4 of DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*). The petroleum hydrocarbon plume in groundwater (Figure 2.4-17) is confined to a relatively small region and is centered on well 199-N-18, with a concentration of 7,700 µg/L in 2011. This is a substantial decrease from the 2010 value of 420,000 µg/L. Fewer wells detected petroleum hydrocarbons in 2011 than in 2010. This reduction may be partly attributable to the high-volume bioventing test on the vadose zone that Washington Closure Hanford performed in 2010 and 2011, summarized in Section 2.4.8.3. Introduction of large amounts of air may have temporarily displaced the diesel in the vicinity of the well screens. Additional testing and monitoring are planned for 2012.

The diesel plume in 100-NR-2 has a limited extent. It stems directly from spills in and around the former 166-N Tank Farm facility.

In 2011, DOE continued passive remedial actions to remove free product from well 199-N-18 in accordance with the interim action ROD (EPA/541/R-99/112). Passive remediation involves the use of a polymer “smart sponge” that selectively absorbs petroleum products from the surface of the water within the well. Every two months, two of the sponges are lowered into the surface of the aquifer in well 199-N-18 and left in place to soak up the diesel fuel. The sponges are weighed prior to placement in the well and again after removal. The weight difference between the two measurements is the amount of product, or diesel fuel contamination, removed from the well. Table 2.4-1 shows the results of this remediation activity since it began in 2003. Removal of product from well 199-N-18 continued in 2011.

As part of the RI/FS process, well 199-N-183 was drilled to replace 199-N-18 as a monitoring well (Section 4.7 of DOE/RL-2008-46-ADD5). This decision was made for two reasons: (1) the low water level in well 199-N-18 makes sampling difficult and requires the use of a bailer, and (2) the inability to completely remove the smart-sponge material from the well will cause long-term potential for interference with sampling and the quality of samples that can be collected (Section 6.1.4 of DOE/RL-2011-01). Well 199-N-18 was kept for continued product removal because that particular process is not affected by the residual smart-sponge material on the well casing.

[1] The presence of nitrite (NO_2^-) is indicative of a reducing environment because this compound is rapidly converted to nitrate (NO_3^-) in the presence of oxygen.

Aquifer tubes near wells 199-N-173 and 199-N-96A along the 100-NR-2 shoreline are sampled for petroleum hydrocarbons. In 2011, two of four aquifer tubes sampled near the intersect of the plume and the Columbia River showed detections of total petroleum hydrocarbon-diesel (Figure 2.4-17). These samples were collected in mid-September 2011 when the river level was low. Diesel contamination is more likely to be upwelling into the river under these conditions because groundwater flows into the river.

2.4.4 Tritium

The source of the tritium in groundwater at 100-NR-2 is from past-practice disposal operations associated with the N Reactor. Liquid effluent disposed to the 116-N-1 and 116-N-3 LWDFs contained tritium. When effluent was discharged to the 100-N Area LWDFs, tritium was highly mobile and migrated through the vadose zone with the wastewater. Because it is part of the water molecule, tritium does not sorb to sediment grains.

In 2011, all tritium concentrations in 100-NR-2 groundwater were below the 20,000 pCi/L drinking water standard. At concentrations below the drinking water standard, the plume currently covers the area beneath the 116-N-1 and 116-N-3 LWDFs and extends to the Columbia River shoreline (Figure 2.4-18). The highest tritium concentration in 2011 was 16,500 pCi/L in well 199-N-32. Figure 2.4-19 shows tritium concentrations declining in wells 199-N-14 and 199-N-32 near the 116-N-1 and 116-N-3 LWDFs. The tritium plume has diminished since 1991, when effluent discharge to the 116-N-3 LWDF ceased, because of radioactive decay, advection, and dispersion (Figure 2.4-7).

Unlike strontium-90, tritium occurs throughout the entire thickness of the unconfined aquifer. Concentrations in wells 199-N-69 and 199-N-70, which are completed at the base of the unconfined aquifer, are similar to nearby wells completed in the upper unconfined aquifer. The tritium concentration in well 199-N-80, completed in a confined aquifer in the Ringold Formation, was 13,000 pCi/L in 2011 (unchanged from 2010).

2.4.5 Chromium

Chromium was present in the effluent discharged to the 116-N-1 LWDF, but was never detected in samples of the effluent waste stream (Section 3.1.1.4 of DOE/RL-90-22, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit, Hanford Site, Richland, Washington*). The dangerous waste discharged to the LWDFs collectively made up only 0.002 percent of the total volume of waste, according to the RCRA Part A Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*). Chromium levels in wells monitoring the unconfined aquifer were low when the facility was in use. Sodium dichromate was only used in 100-NR-2 from 1964 to 1973 and in lesser amounts than at the other 100 Area reactors because of the design of the N Reactor cooling system and the use of corrosion-resistant metals (such as zircaloy) in the fuel and facility (Section 4.3.4 of DOE/RL-2008-46-ADD5). The chromium fraction of the sodium dichromate used in the 100-N Area was approximately 24,704 kilograms. Given the mobility and nonsorbing nature of chromium in solution, the high continuous discharge rates and high temperatures while chromium was delivered to the 116-N-1 LWDF, and the fact that discharges continued for another 10 years after sodium dichromate use ceased, the mobile portion of discharged chromium was thoroughly flushed from the subsurface and into the Columbia River by the end of the reactor's operational period (Section 4.3.4 of DOE/RL-2008-46-ADD5).

Continued monitoring of wells in 100-NR-2 shows sporadic, low-level detections of chromium throughout the area. Even in wells where chromium is detectable, nearby wells often do not show any detection. The 100-N RI/FS borehole samples were taken from the vadose zone, Hanford formation, Ringold Formation, and from the Ringold Formation upper mud unit at several locations. Sampling results will be addressed in the 100-N RI report.

One well in the 100-NR-2 had dissolved (filtered) chromium concentrations above the drinking water standard of 100 µg/L. Well 199-N-80, which was completed in a thin, water-bearing zone in the Ringold upper mud unit, had a filtered chromium concentration of 200 µg/L in 2011, consistent with previous results. Attempts to drill other wells into this water-bearing zone were unsuccessful, indicating it is not laterally continuous.

Chromium concentrations above the 100 µg/L drinking water standard occur in only one well in 100-NR-2. Most wells show chromium levels near the detection limit.

A down-hole camera survey performed in 2001 showed visible corrosion along the length of the well screen (33.7 to 42.7 meters deep) in well 199-N-80. Corrosion of the stainless-steel well screen is likely the contributor of chromium to the groundwater sampled from this well. Stainless-steel corrosion is caused by sulfur impurities in the metal. These small sulfur inclusions cause depletion of the chromium from the surrounding metal, and a pit is created in the metal where this process is occurring ("Why Stainless Steel Corrodes" [Ryan et al., 2002]). In a stainless-steel well where this corrosion is occurring, chromium and sulfate are released into solution; when a groundwater sample is taken, similar trends are noted in chromium and sulfate concentrations. Soil and groundwater samples were taken from wells drilled near 199-N-80 as part of the RI/FS process.

In 2011, chromium continued to be detected in well 199-N-74, increasing to a maximum of 34 µg/L. Samples collected during drilling of new well 199-N-189 (see Figure 2.3-1 in Section 2.3 for location) had hexavalent chromium concentrations ranging from 29 to 39 µg/L. Hexavalent chromium contamination from 100-KR-4 migrated inland while the 100-K-2 Trench was in use and a groundwater mound was present. A portion of the plume has migrated northward into 100-NR-2. Figure 2.3-4 in Section 2.3 illustrates the chromium plume in 100-KR-4. DOE will continue to monitor well 199-N-89 and other wells in this region for chromium in 2012.

Total and hexavalent chromium concentrations were near or below detection limits in 100-NR-2 aquifer tube samples in 2011. All were below the 10 µg/L ambient water quality standard.

2.4.6 Sulfate

Wastewater from the former 120-N-1 Percolation Pond introduced sulfate and sodium into 100-NR-2 groundwater (Figure 2.4-20). The highest sulfate concentrations in 2011 were in wells 199-N-72 and 199-N-73, where results exceeded the 250 mg/L secondary drinking water standard at least once in 2011. Wells downgradient (north and northwest) from the Percolation Pond also had elevated sulfate levels, but concentrations were below the standard. Several wells near the 116-N-3 LWDF also have elevated sulfate concentrations. The contamination beneath this facility is residual from previous flow conditions that carried sulfate from the 120-N-1 Percolation Pond inland. Current groundwater flow conditions are carrying this plume to the north and northwest toward the Columbia River (Section 15.2.5 of DOE/RL-2010-11).

Well 199-N-172, in the northern part of the sulfate plume, also had concentrations above the secondary drinking water standard in 2011 (261 mg/L). This was an order of magnitude higher than in 2010, and the change may relate to the enhanced bioventing test conducted upgradient of the well (Section 2.4.8.3).

2.4.7 Manganese and Iron

Manganese and iron concentrations are elevated in some 100-NR-2 wells, but originated from well screens or aquifer sediments, not from waste sites. The high concentrations are observed primarily in areas affected by petroleum hydrocarbon contamination. Biodegradation of the organic contaminant

creates chemically reducing conditions in the aquifer, increasing the solubility of manganese, iron, and some other metals found in aquifer sediments or well screens and casings.

Eight wells in the region of the current diesel plume had manganese concentrations exceeding the secondary drinking water standard of 50 µg/L in 2011. The highest concentration in 2011 in a filtered sample was 7,870 µg/L in 199-N-18, which was lower than the peak value in 2010. This well also had the highest filtered iron concentration, 33,600 µg/L. The secondary drinking water standard for iron is 300 µg/L.

Manganese and iron continue to be detected in areas where diesel biodegradation is believed to be occurring.

Well 199-N-16 also has elevated levels of manganese and iron. This well shows the effects of diesel degradation from three separate diesel spills that occurred in the area of the well in 1987. In 2007 and 2010, this well had detectable levels of total petroleum hydrocarbon-diesel; it did not have detectable levels in 2008, 2009, or 2011.

Well 199-N-32, which is not near diesel contamination sites, also continued to show elevated manganese (485 µg/L) and iron (316 µg/L) in 2011. These metals are probably a result of screen corrosion, which was noted during a 2001 borehole camera survey.

Manganese and iron concentrations were elevated in numerous aquifer tubes in 2011. Tubes in southwestern 100-NR-2 are affected by petroleum hydrocarbon contamination and related chemical reduction effects. Tubes located northeast are affected by injection of chemicals for the apatite barrier (Section 2.4.8.2).

2.4.8 CERCLA Groundwater Activities

CERCLA groundwater activities in 100-NR-2 in 2011 included progress on an RI/FS and interim groundwater remediation of the strontium-90 in groundwater.

Wells and constituents monitored for 100-NR-2 are defined in the following documents:

(1) DOE/RL-2001-27, *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit*, as modified by TPA-CN-256, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: DOE/RL-2001-27, Rev 0, Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit and the Interim Action Waste Management Plan for the 100-NR-2 Operable Unit, DOE/RL-2000-41, Rev. 1*.

(2) DOE/RL-2005-96, *Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit*, as modified by TPA-CN-271, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: Treatability Test Plan Addendum for the 100-NR-2 Groundwater Operable Unit, DOE/RL-2005-96 Addendum*, and DOE/RL-2010-29, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*).

The CERCLA sampling is conducted mainly in September, with selected wells monitored in March. During 2011, three wells were not sampled as scheduled (Appendix A).

2.4.8.1 Remedial Investigation/Feasibility Study

DOE issued an RI/FS work plan (DOE/RL-2008-46-ADD5) and sampling and analysis plan (DOE/RL-2009-42, *Sampling and Analysis Plan for the 100-N Decision Unit Remedial Investigation Feasibility Study*) for 100-N in March 2011 and December 2010, respectively.

In 2011, eight boreholes were drilled and completed as wells as part of the RI. Soil and water samples were collected from each of the boreholes during drilling. Data collected as part of this effort will better define the extent of contamination in the vadose zone, groundwater, and groundwater plumes. The upcoming RI/FS report will provide detailed results. This information will be used to make decisions for remediation of waste sites and groundwater.

2.4.8.2 Groundwater Remediation

A groundwater pump-and-treat system operated from 1995 until March 2006 in 100-NR-2 as part of the CERCLA interim action (EPA/541/R-99/112). The system removed approximately 1.8 Ci of strontium-90 from the aquifer, which was less than the amount removed by radioactive decay during the same period. Because strontium-90 binds strongly to the sediment, the pump-and-treat system was not effective in cleanup of the aquifer. One of the requirements of the interim action ROD was to evaluate alternative technologies for groundwater cleanup. Therefore, Ecology, EPA, and DOE approved M-16-06-01, *Federal Facility Agreement and Consent Order Change Control Form: Establish Interim Milestone M-016-14, Complete Construction of a Permeable Reactive Barrier at 100-N*, in 2006, which required placing the pump-and-treat system in cold-standby status and constructing a permeable reactive barrier. Based on the treatability test results, the apatite technology showed promise as a remediation option. As a result, DOE proposed in June 2009 to amend the existing interim remedial action ROD for the 100-NR-1 and 100-NR-2 Operable Units (EPA/541/R-99/112) to include expansion of the existing apatite barrier to approximately 762 meters in the aquifer and the vadose zone. DOE issued DOE/RL-2009-54, *Proposed Plan for Amendment of 100-NR-1/NR-2 Interim Action Record of Decision*, in June 2010. Ecology approved the amendment to the interim action ROD in September 2010 to allow for expansion of the apatite barrier and permanent decommissioning of the 100-NR-2 pump-and-treat facility.

The amended, interim action remedy for strontium-90 (EPA, 2010, Amended Record of Decision, Decision Summary and Responsiveness Summary, 100-NR-1 and NR-2 Operable Units, Hanford Site – 100 Area, Benton County, Washington) includes the following actions:

- ***Extend the existing apatite permeable reactive barrier from 90 to approximately 760 meters.***
- ***Apply one round of additional apatite injections within 5 years of all first-round apatite injections.***
- ***Decommission the existing 100-NR-2 pump-and-treat building and components.***
- ***Use monitored natural attenuation.***
- ***Maintain existing institutional controls.***
- ***Perform periodic groundwater monitoring.***

The primary objective is protection of the Columbia River with a remedial action goal of 8 pCi/L for surface and groundwater. Successful implementation will support the goal of achieving a strontium-90 concentration of 8 pCi/L in the hyporheic and Columbia River water column by 2016. The interim remedial action is not intended to address aquifer restoration.

Implementation of the interim remedy apatite barrier expansion will be conducted under a revision to the 100-NR-2 Operable Unit interim action remedial action/remedial design work plan (DOE/RL-2001-27) that was submitted as Rev. 1, Draft A, to Ecology in March 2011.

Plans to optimize this apatite barrier technology before full-scale expansion will initially move forward under two approved design optimization studies: the barrier expansion design optimization study (DOE/RL-2010-29), and the jet injection design optimization study (DOE/RL-2010-68, *Jet Injection Design Optimization Study for 100-NR-2 Groundwater Operable Unit*). DOE/RL-2012-02 provides detailed results of 2011 remediation activities.

Original Apatite Permeable Reactive Barrier

DOE agreed to construct and evaluate the effectiveness of a permeable reactive barrier for strontium-90 using apatite sequestration technology as part of the of the CERCLA RI/FS process, which is consistent with the interim remedial action ROD for the 100-NR-1 and 100-NR-2 Operable Units (EPA/541/R-99/112) and the Tri-Party Agreement (Ecology et al., 1989) Change Control Form M-16-06-01. Strontium-90 sequestration using this technology occurs by injecting a calcium-citrate-phosphate solution into the aquifer. After the solution is injected, biodegradation of the citrate results in apatite (a calcium phosphate mineral [$Ca_5(PO_4)^3(F, Cl, OH)$]) precipitation. Strontium-90 (and strontium) ions in groundwater substitute for calcium ions via cation exchange and eventually become trapped as part of the mineral matrix during apatite crystallization (Section 1.3 of PNNL-16891).

The original apatite treatability test site covers approximately 90 meters along the Columbia River shoreline (Figure 2.4-2). A total of 45 monitoring points are associated with this site, including injection/barrier wells, monitoring wells, and aquifer tubes. A total of 16 wells comprise the actual permeable reactive barrier. Four monitoring wells are parallel to the barrier between the river and the injection/barrier wells. Two pilot test sites (PT#1 and PT#2) are at each end of the barrier (around the two end injection/barrier wells) and contain smaller diameter monitoring wells surrounding the individual end injection/barrier wells.

Gross beta concentrations have declined 90 percent three years after injections of apatite-forming chemicals ceased.

Strontium-90 contamination in the 100-N Area is primarily absorbed to sediments by ion exchange (99 percent absorbed and 1 percent in solution in the groundwater) in the lower vadose zone and upper portion of the unconfined aquifer. Although primarily absorbed, some strontium-90 is mobilized by seasonal water level increases that remove strontium-90 from sediments not previously in contact with groundwater (PNNL-16891). DOE injected apatite-forming solutions into the Hanford and Ringold formations over a period of 3 years (from 2006 through 2008). Performance monitoring at the existing apatite barrier was performed twice in 2011, with high river stage sampling in May and June, and low river stage sampling in November. Since injections ceased in July 2008, strontium-90 and gross beta concentrations have declined steadily in the sampled wells, with very few exceptions. As of November 2011, the strontium-90 and gross beta values were considerably less in all wells and aquifer tubes monitored along the barrier than before the injections started. All of the wells have shown an approximately 90 percent decline in gross beta from the measured pre-injection values, meeting established test criteria. However, concentrations remain above the 8 pCi/L drinking water standard (remedial action goal).

Figure 2.4-11 provides the strontium-90 contours for the apatite permeable reactive barrier. Figure 2.4-12 shows the gross beta[2] concentrations in the most contaminated portion of the 100-N shoreline. The scale on Figure 2.4-12 is logarithmic to make it easier to see the 90 percent decrease that has occurred in the treated wells and monitoring well 199-N-122. This set of four wells consists of a monitoring well (199-N-122) and two injection wells (well 199-N-162 screened only in the Ringold Formation, well 199-N-144 screened across the Hanford formation and Ringold Formation), and one monitoring well located behind the barrier (199-N-46, screened in the top of the unconfined aquifer). All four wells showed high strontium-90 concentrations following the injections in 2008. The high-concentration apatite injection solution had a higher ionic strength than groundwater. When the fluid was initially injected, it temporarily mobilized cations and anions, causing their concentrations in groundwater to increase. Over time, the concentration of gross beta began to decline, which is most evident in injection well 199-N-162. The injection wells show more fluctuation in gross beta values, but all four wells show much lower concentrations of gross beta than concentrations before injections in 2008. Well 199-N-46, which has historically had high levels of gross beta, is starting to slowly trend downward since treatments began.

Concentrations of strontium-90 and gross beta began to increase slightly in 2010 (Figure 2.4-12). This trend was occurring in more locations in 2011. Additional injections are needed in the existing permeable reactive barrier, based on data presented in the two reports on the initial low-concentration and high-concentration injections (PNNL-17429, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injections for In Situ Strontium-90 Immobilization*; PNNL-19572, *100-NR-2 Apatite Treatability Test: High-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immobilization, Final Report*) and the follow-up report on barrier performance progress (PNNL-20252, *100-NR-2 Apatite Treatability Test: An Update on Barrier Performance*). These additional injections are discussed in further detail in DOE/RL-2012-02.

Injections for the existing barrier will occur as budget and schedule allow within the next few years. The planned jet injections in the vadose zone should satisfy the retreatment needs in the near term. Semiannual performance monitoring (high and low river stages) will continue for the existing barrier until those injections occur, at which time a revised performance monitoring schedule will be initiated.

Apatite barrier extensions have increased the length of 100-N Area shoreline treated to sequester strontium-90, from 90 to approximately 290 meters.

Extension of Apatite Permeable Reactive Barrier

Apatite barrier extensions were installed in fall 2011 and included injecting wells along an additional 100 meters on each end of the original barrier. DOE performed the work under a design optimization study (DOE/RL-2010-29) and an upcoming remedial design/remedial action work plan.

The injections were performed using a two-step process, where the deeper Ringold Formation wells are injected first and then the overlying Hanford formation wells are injected second. These staggered injections overlay each other and maximize the coverage in the upper unconfined aquifer and lower vadose zones. The formulation for these injections was the high-concentration calcium-citrate-phosphate solution amendment that was tested in 2008.

[2] Strontium-90 is a beta-emitter. Gross beta concentrations are approximately two times the strontium-90 concentrations.

The goals of the study were as follows (DOE/RL-2010-29):

1. Refine the application of high-concentration calcium-citrate-phosphate solution over a large scale.
2. Test the effectiveness of high-concentration calcium-citrate-phosphate injection in previously untested sediment to compare with areas that received sequential injections of low- and then high-concentration injections.
3. Test the new well design installed under DOE/RL-2009-32 to evaluate the adequacy of injection solution delivery to the target zone.
4. Test and optimize operation of the new injection system to verify that the system can deliver the designed injection solution flow volume at multiple well locations.
5. Determine whether the new well design and injection system can complete chemical injections at various river stages, thereby eliminating the need for injections during specific river levels.
6. Further evaluate the high-concentration calcium-citrate-phosphate solution impact on the release of strontium-90 and other metals from previously untreated sediments to groundwater.
7. Evaluate whether the permeable reactive barrier can achieve up to a 90 percent reduction in strontium-90 flux to the Columbia River.

The first five objectives were adequately tested; to date, they have been met (DOE/RL-2012-02). The sixth objective is being tested in 2012 as samples are collected to determine how long the release of strontium-90 and other metals occurs after injections. Initial samples were collected for one month after injections, with the first set collected immediately after injections ceased, the second set collected after two weeks, and the third set collected after one month. At the end of a month, the strontium-90 and metal levels were almost back to pre-injection levels. The spring 2012 sampling event will happen more than six months after the end of 2011 injections. The last objective will require the collection of data over the next few years to determine whether the 90 percent reduction of strontium-90 has occurred in the permeable reactive barrier monitoring wells.

Other Strontium-90 Treatment Technologies

Several different types of strontium-90 treatment technologies are being evaluated at 100-NR-2 in addition to the current permeable reactive barrier. Several types of treatment are needed to treat the entire zone of contamination effectively. The existing barrier has treated groundwater and the lower vadose zone, but it has not treated the upper vadose zone and near-shore riparian zone. No additional work on these technologies occurred in 2011. The following reports provide additional information on other technologies that have been investigated previously:

Jet Injection – SGW-47062, *Treatability Test Report for Field-Scale Apatite Jet Injection Demonstration for the 100-NR-2 Operable Unit*

Infiltration Gallery – PNNL-20322, *100-NR-2 Apatite Treatability Test: Fall 2010 Tracer Infiltration Test*

Phytoextraction – PNNL-19120, *100-N Area Strontium-90 Treatability Demonstration Project: Phytoextraction Along the 100-N Columbia River Riparian Zone – Field Treatability Study*

2.4.8.3 Deep Vadose Zone Remediation

In situ bioremediation was chosen as the remedial technology for addressing petroleum contamination in selected subsurface areas at 100-N Area. Bioremediation uses naturally-occurring bacteria in the soil to remove contaminants from the vadose zone or aquifer. To enhance the population of bacteria, oxygen is added by forcing air through the vadose zone soils, a process known as bioventing.

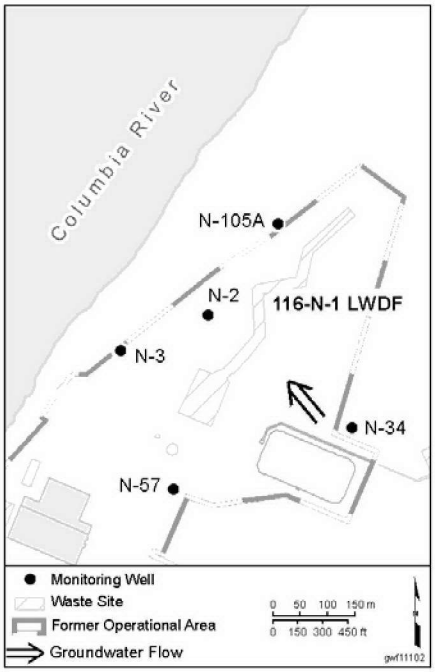
Washington Closure Hanford conducted a bioventing pilot test at the UPR-100-N-17 waste site between February 2010 and May 2011 (WCH-490). The pilot test included collection of baseline measurements in the vadose zone at seven bioremediation wells, a respirometry test to determine bacterial oxygen use, an air injection test to determine radius of influence, and a 6-month operational test. Results from the pilot testing indicate that the technology is a promising method of remediating hydrocarbon contamination in the deep vadose zone. The data from the pilot test will support the design of full-scale bioventing systems for UPR-100-N-17 and similar waste sites.

2.4.9 RCRA Facility Monitoring

This section describes the monitoring results for the 116-N-1 and 116-N-3 LWDFs, the 120-N-1 Percolation Pond, and the 120-N-2 Surface Impoundment. Groundwater is monitored at these facilities to meet the requirements of RCRA and WAC 173-303 ("Dangerous Waste Regulations") for dangerous waste constituents. Sections 2.4.1 and 2.4.4 discuss monitoring results for radionuclides. Groundwater data for these facilities are available in the Hanford Environmental Information System database and in the data files accompanying this report. Appendix B includes well and constituent lists, maps, flow rates, and statistical tables for the 100-NR-2 RCRA units.

2.4.9.1 116-N-1 (1301-N) Liquid Waste Disposal Facility

The 1301-N LWDF (Waste Site 116-N-1) was an unlined crib and trench used for disposal of liquid effluent from the 1960s through 1985. The effluent contained small quantities of dangerous waste in addition to the large volume of radioactive waste. The waste site has been excavated to remove shallow vadose zone sediment (where most of the radionuclide contamination resided) and was backfilled with clean fill.



The direction of groundwater flow beneath the 116-N-1 LWDF changed in 2011 under the influence of groundwater injection in 100-KR-4 to the south and the high river stage. In March 2011, the river stage was higher than normal for early spring. The water table beneath the 116-N-1 LWDF sloped to the northeast at 3.5×10^{-5}, and estimates of the groundwater flow rate ranged from 0.01 to 0.13 meter per day. In September 2011, when the river stage was lower, the water table sloped to the northwest at 2.3×10^{-3}, and flow rate estimates ranged from 0.05 to 0.84 meter per day (Appendix B).

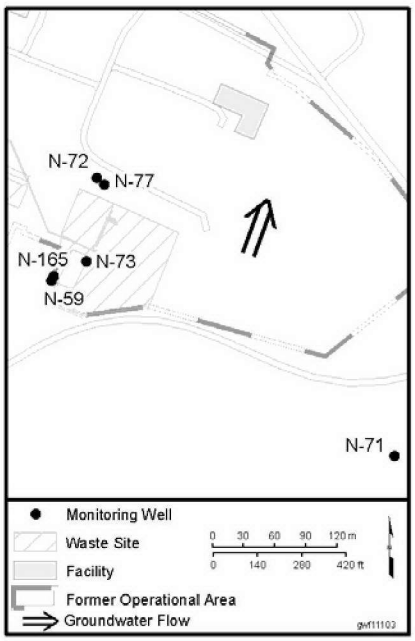
Two upgradient wells (199-N-34 and 199-N-57) and three downgradient wells (199-N-2, 199-N-3, and 199-N-105A) monitor the 116-N-1 LWDF (Appendix B). No changes to the monitoring network are planned until implementation of an integrated groundwater monitoring program (CERCLA, RCRA, and AEA) for 100-NR-2 is completed.

This facility is included in the Hanford Facility RCRA Permit (WA7890008967), which states that RCRA monitoring during closure activities will follow the requirements of BHI-00725, *100-N Pilot Project: Proposed Consolidated Groundwater Monitoring Program*. That plan, and a supplemental plan (PNNL-13914, *Groundwater Monitoring Plan for the 1301-N, 1324-N/NA, and 1325-N RCRA Facilities*), are similar to an interim status indicator evaluation program (40 CFR 265.93[b], "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Preparation, Evaluation, and Response"), as referenced by WAC 173-303-400 ("Dangerous Waste Regulations," "Interim Status Facility Standards").

Upgradient and downgradient wells are scheduled for sampling twice each year for RCRA contamination indicator parameters (that is, pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters. The wells were sampled as scheduled during 2011, and there were no critical mean exceedances.

2.4.9.2 120-N-1 (1324-NA) Percolation Pond and 120-N-2 (1324-N) Surface Impoundment

The 1324-NA Percolation Pond and the 1324-N Surface Impoundment (Waste Sites 120-N-1 and 120-N-2) were used to treat and dispose of corrosive, nonradioactive waste from 1977 to 1990. Both facilities have been remediated and backfilled.



Both of these units are included in the Hanford Facility RCRA Permit (WA7890008967), which states that RCRA monitoring during closure activities will follow the requirements of BHI-00725. BHI-00725 and a supplemental plan (PNNL-13914) are similar to an interim status indicator evaluation program (40 CFR 265.93[b], as referenced by WAC 173-303-400). The two units are monitored as a single site (waste management area) because of their proximity and similar waste types.

Upgradient well 199-N-71 and downgradient wells 199-N-72, 199-N-73, 199-N-77, and 199-N-165 monitor the 120-N-1 Percolation Pond and 120-N-2 Surface Impoundment. Well 199-N-77 is screened at the base of the unconfined aquifer, and statistical comparisons are not performed on data from this well. During 2011, all of the monitoring wells for this site were sampled as scheduled, twice for RCRA contamination indicator parameters and groundwater quality, and once for site-specific parameters (Appendix B).

New 100-KR-4 injection wells south and west of 1324-N/NA affected groundwater flow in 2011 (Figure 2.4-5). In March 2011, the hydraulic gradient sloped toward the northeast at 5.9×10^{-4}, and estimated flow rates ranged from 0.01 to 0.22 meter per day. In September 2011, the gradient sloped to the east-northeast at 9.1×10^{-4}, and flow estimates ranged from 0.02 to 0.34 meter per day. The groundwater monitoring network was designed for a northwestern flow direction. The network should be evaluated for revision in conjunction with development of an integrated groundwater monitoring program for 100-NR-2 and changes in the water table observed in 2011. Average specific conductance values in downgradient wells 199-N-72, 199-N-73, and 199-N-165 continued to exceed the critical mean value of 785 µS/cm at least once in 2011. A previous groundwater quality assessment indicated that the high specific conductance is caused by the nonregulated constituents sulfate and sodium (WHC-SD-EN-EV-003, *Results of Groundwater Quality Assessment Monitoring at the 1301-N and 1324-N/NA Facilities*). Recent data indicate that this conclusion remains valid (DOE/RL-2008-01, Appendix B).

Total organic carbon concentrations exceeded the critical mean value at the 120-N-1 site in 2011. The contamination is not from the RCRA facility, and DOE is investigating its source.

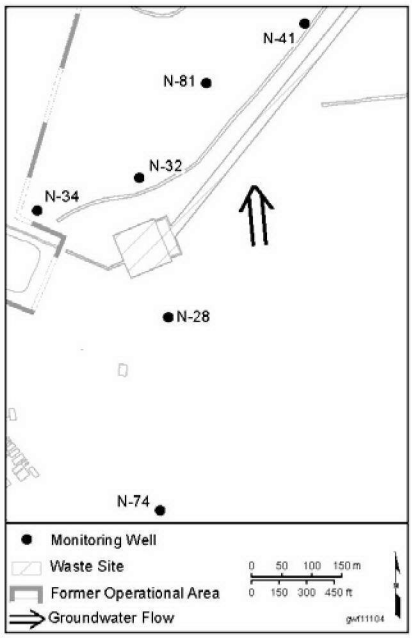
The average total organic carbon concentration exceeded the critical mean value of 860 µg/L in well 199-N-165 in September 2011, and was above the limit of quantitation of 1,000 µg/L. Confirmation samples were collected in November 2011, and the results were higher than the September samples.

Because there is no record of organic waste discharged to these facilities, it is believed the exceedance was not caused by releases from 1324-N/NA. DOE informed Ecology of the exceedance and recommended that additional sampling be performed to determine the source of the elevated total organic carbon. Plans are underway to perform this sampling in 2012 and will include all five RCRA wells for this location and two additional nearby 100-KR-4 wells. Several additional analytes have been added to the sampling event for all wells. No other critical mean exceedances occurred during 2011.

Specific conductance increased sharply in wells 199-N-72, 199-N-77, and 199-N-165 in September 2011. A similar increase was seen in 2010 in well 199-N-72. The changes were caused by increases in calcium, sodium, nitrate, sulfate, and other ions. The cause of the change is unknown. This will also be investigated by the additional 2012 sampling.

2.4.9.3 116-N-3 (1325-N) Liquid Waste Disposal Facility

The 1325-N LWDF (Waste Site 116-N-3) was an unlined crib and trench used to dispose of liquid effluent from 1983 through 1991. The effluent contained small quantities of dangerous waste in addition to the large volume of radioactive waste. The waste site was excavated to remove shallow vadose zone material (which contained the highest concentrations of radionuclides) and was backfilled.



Groundwater flows to the north beneath the 116-N-3 LWDF, turns to the northwest, and discharges to the Columbia River. The hydraulic gradient in March 2011 sloped to the north-northwest at 5.1×10^{-4}, with the groundwater flow rate estimated between 0.01 and 0.19 meter per day (Appendix B). Water levels in September 2011 were unusually high beneath the 116-N-3 LWDF as the effects of high river stage in May and June reached the inland monitoring wells. The gradient sloped toward the east-northeast at 8.0×10^{-4}, and flow estimates ranged from 0.02 to 0.30 meter per day.

The 116-N-3 LWDF is included in the Hanford Facility RCRA Permit (WA7890008967), which states that RCRA monitoring during closure activities will follow the requirements of BHI-00725. BHI-00725 and a supplemental plan (PNNL-13914) are similar to an interim status indicator evaluation program (40 CFR 265.93[b], as referenced by WAC 173-303-400).

Upgradient well 199-N-74 and downgradient wells 199-N-32, 199-N-41, and 199-N-81 monitor the 116-N-3 LWDF. Well 199-N-28 is monitored for supporting information, but its data are not evaluated statistically. No changes to the monitoring network are planned until implementation of an integrated groundwater monitoring program for the 100-NR-2 is completed.

All five wells in the RCRA network were sampled as planned during 2011, twice for RCRA contamination indicator parameters (that is, pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters.

Average specific conductance values in downgradient well 199-N-41 continued to exceed the critical mean value of 520 µS/cm in 2011, which is a continuation of previous exceedances noted from 1999 through 2010. DOE notified Ecology of the original exceedance and submitted an assessment report (00-GWVZ-054, *Results of Assessment at the 1325-N Facility*), which concluded that the exceedance was caused by past discharges of nonregulated contaminants to the 120-N-1 Percolation Pond. Recent data indicate that this conclusion remains valid (DOE/RL-2008-01, Appendix B). No other critical mean exceedances occurred during the reporting period.

Table 2.4-1. Hydrocarbon Product Removal from Well N-18 (2003 to 2011)

Year	Product Removed (gram)	Notes
2003[a]	~1,200[b]	Estimate provided per information given in table note; data records lost when original work package was lost in the field.
2004	3,475	Changed out twice per month.
2005	780	Changed approximately every two months.
2006	1,370	Changed every two months.
2007	1,294	Changed every two months.
2008	920	Changed every two months.
2009	1,380	Changed approximately every two months.
2010	225.5	Changed only twice prior to June 2010; smart sponge broke apart in well. No removal for second half of 2010.
2011	500	Changed every two months.
Total	**11,414.5 g (approximately 11.41 kg) removed through end of 2011**	

a. DOE/RL-2004-21, *Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump & Treat Operations*, reports that product removal started in October 2003.

b. DOE/RL-2005-18, *Calendar Year 2004 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, states that the average mass removal for fiscal year 2004 (October 2003 through October 2004) was approximately 0.4 kilogram per month; therefore, an estimate is provided for the 3 months missing in 2003.

Figure 2.4-1. Facilities and Groundwater Monitoring Wells in 100-NR-2

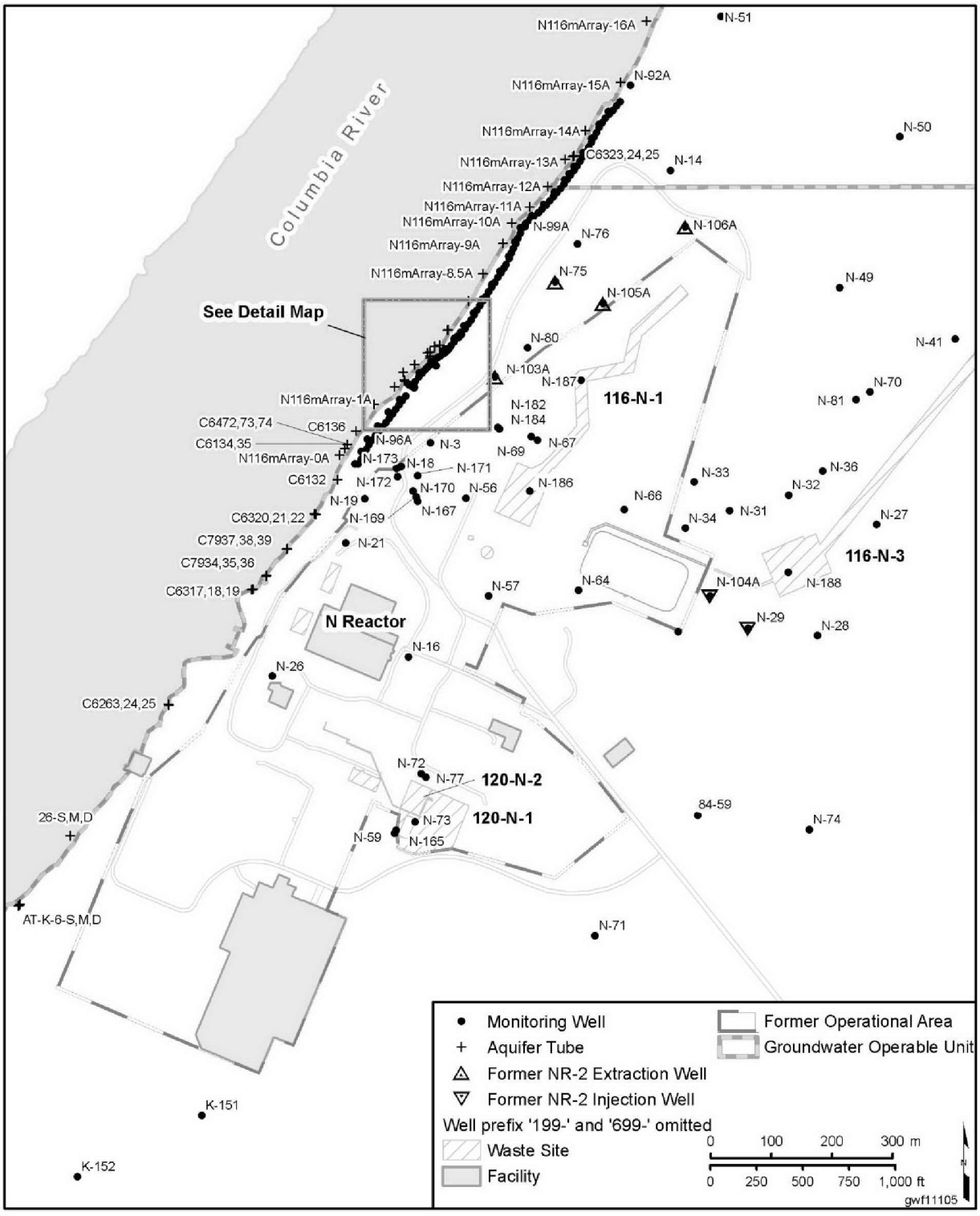


Figure 2.4-2. Groundwater Monitoring Wells in the Original Apatite Permeable Reactive Barrier

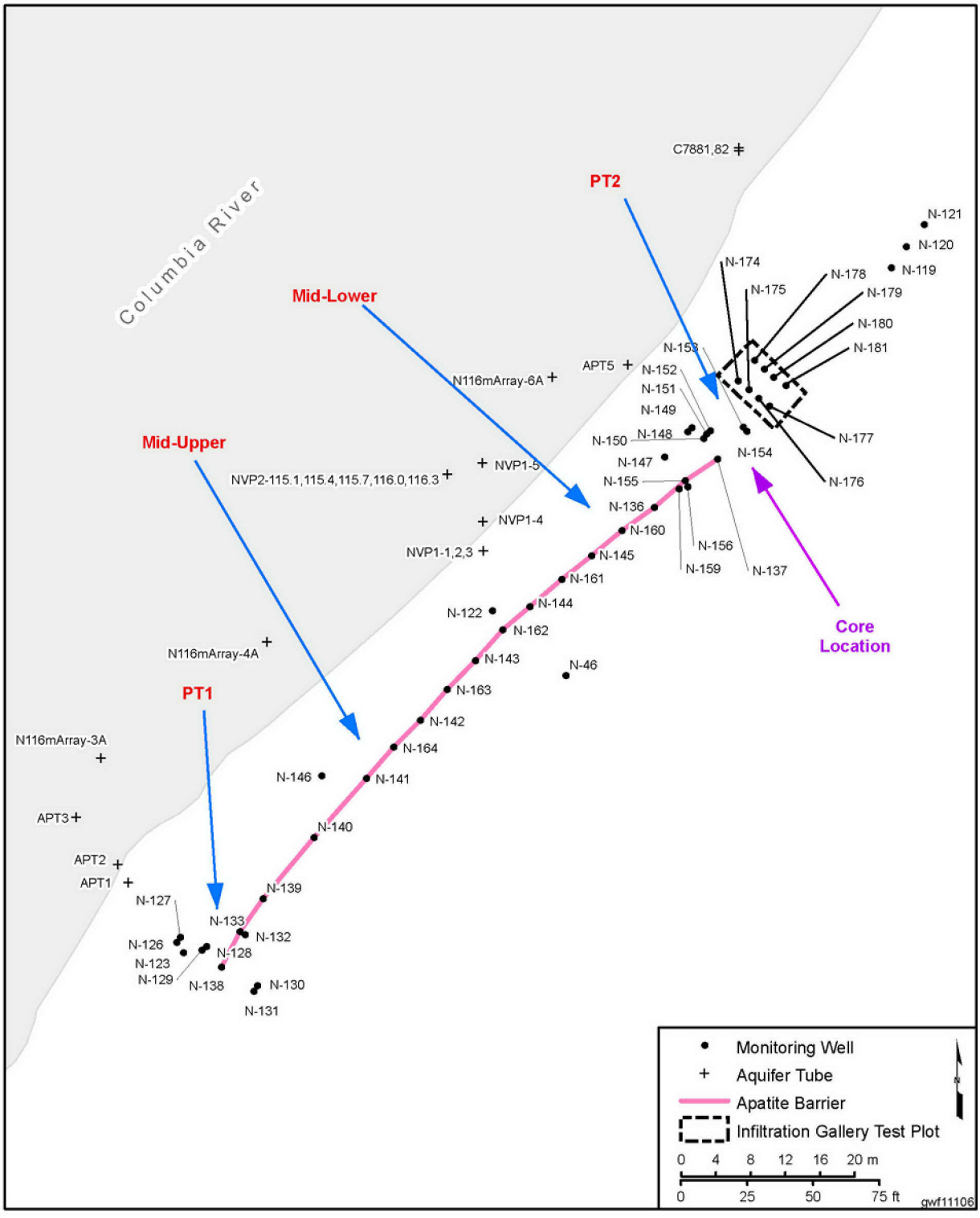


Figure 2.4-3. Groundwater Monitoring Wells in the Upriver Extension—Apatite Permeable Reactive Barrier

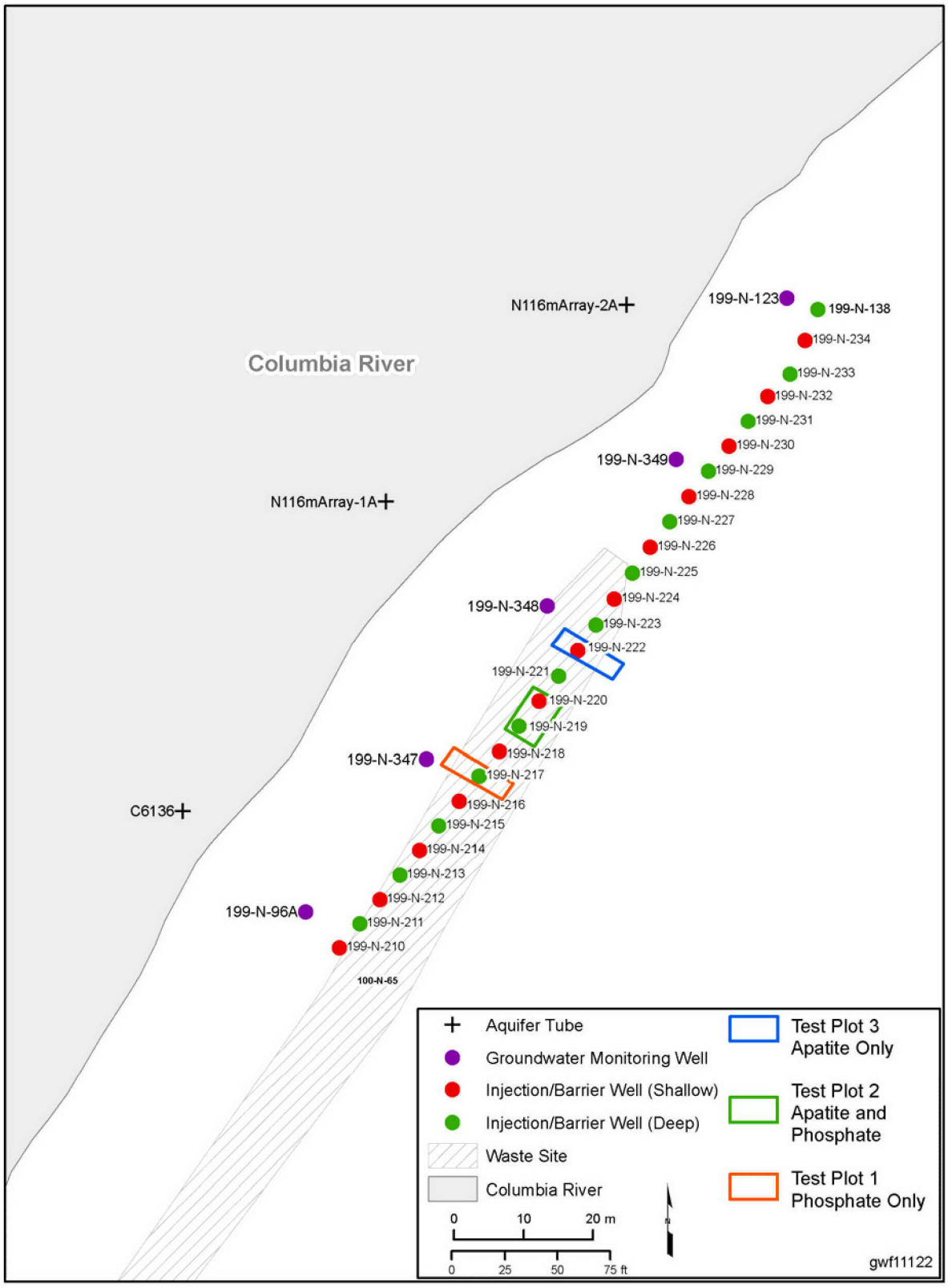


Figure 2.4-4. Groundwater Monitoring Wells in the Downriver Extension—Apatite Permeable Reactive Barrier

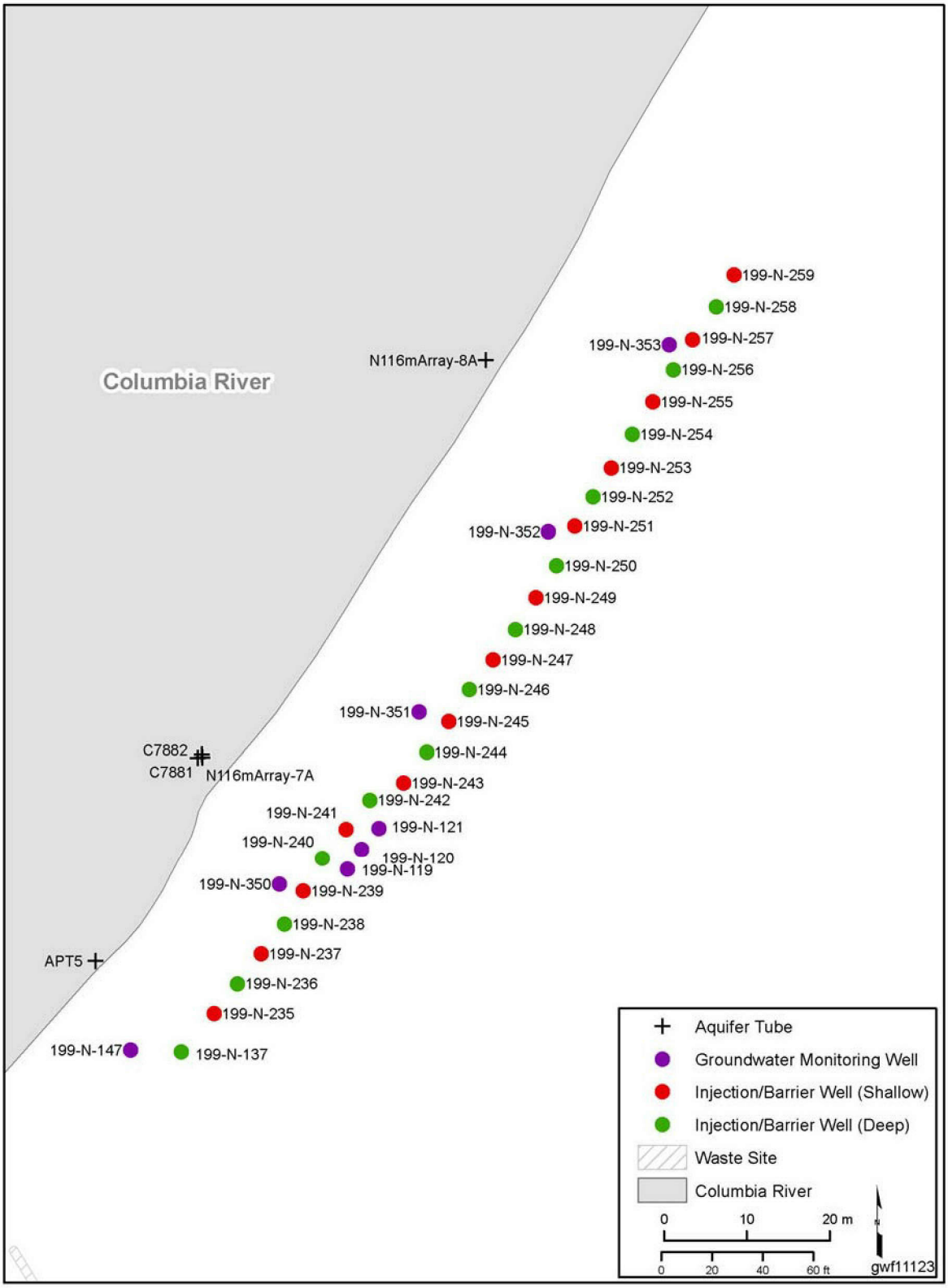


Figure 2.4-5. 100-NR-2 Water Table, March 2011

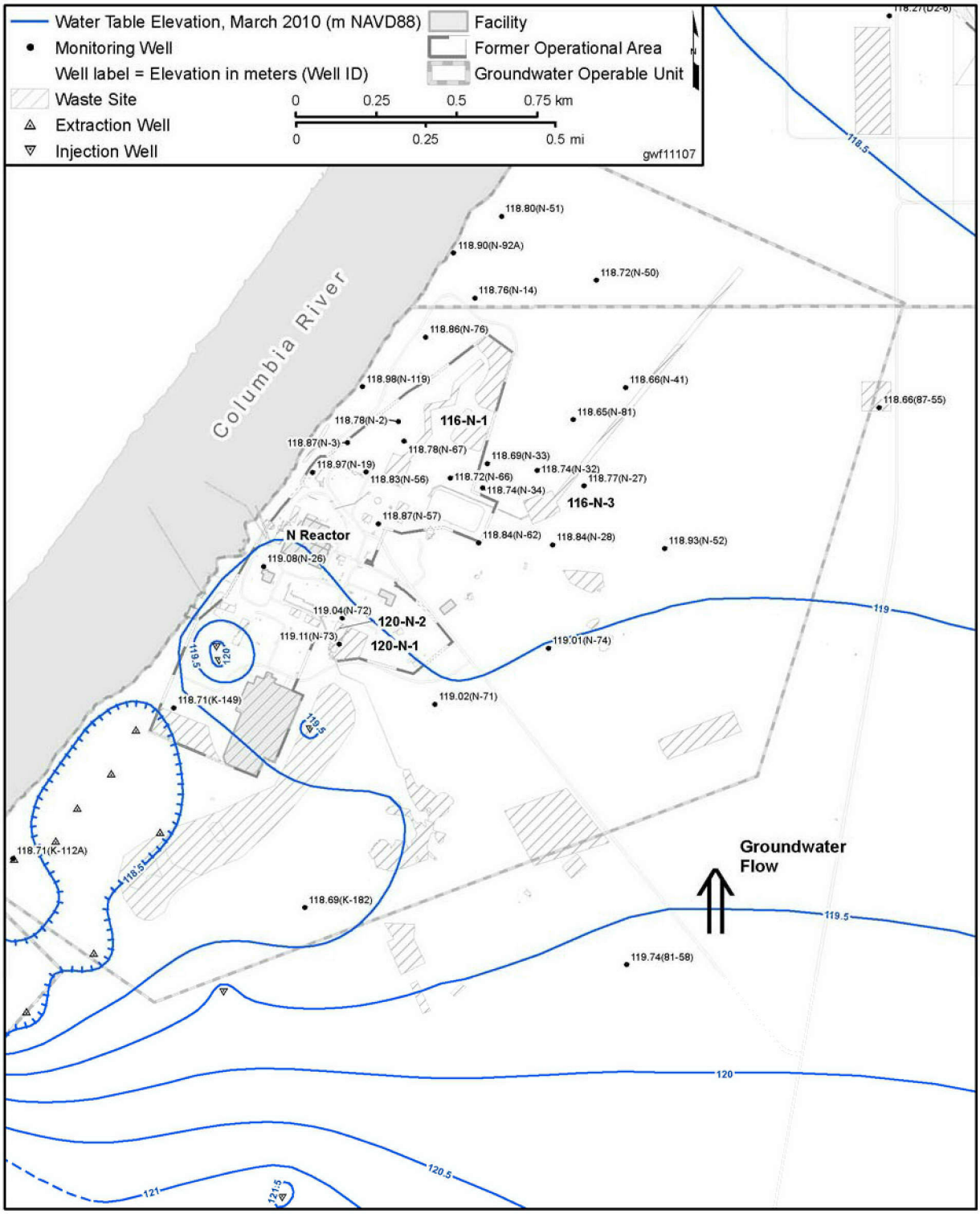


Figure 2.4-6. Average Strontium-90 Concentrations in 100-NR-2, Upper Part of Unconfined Aquifer, 2011

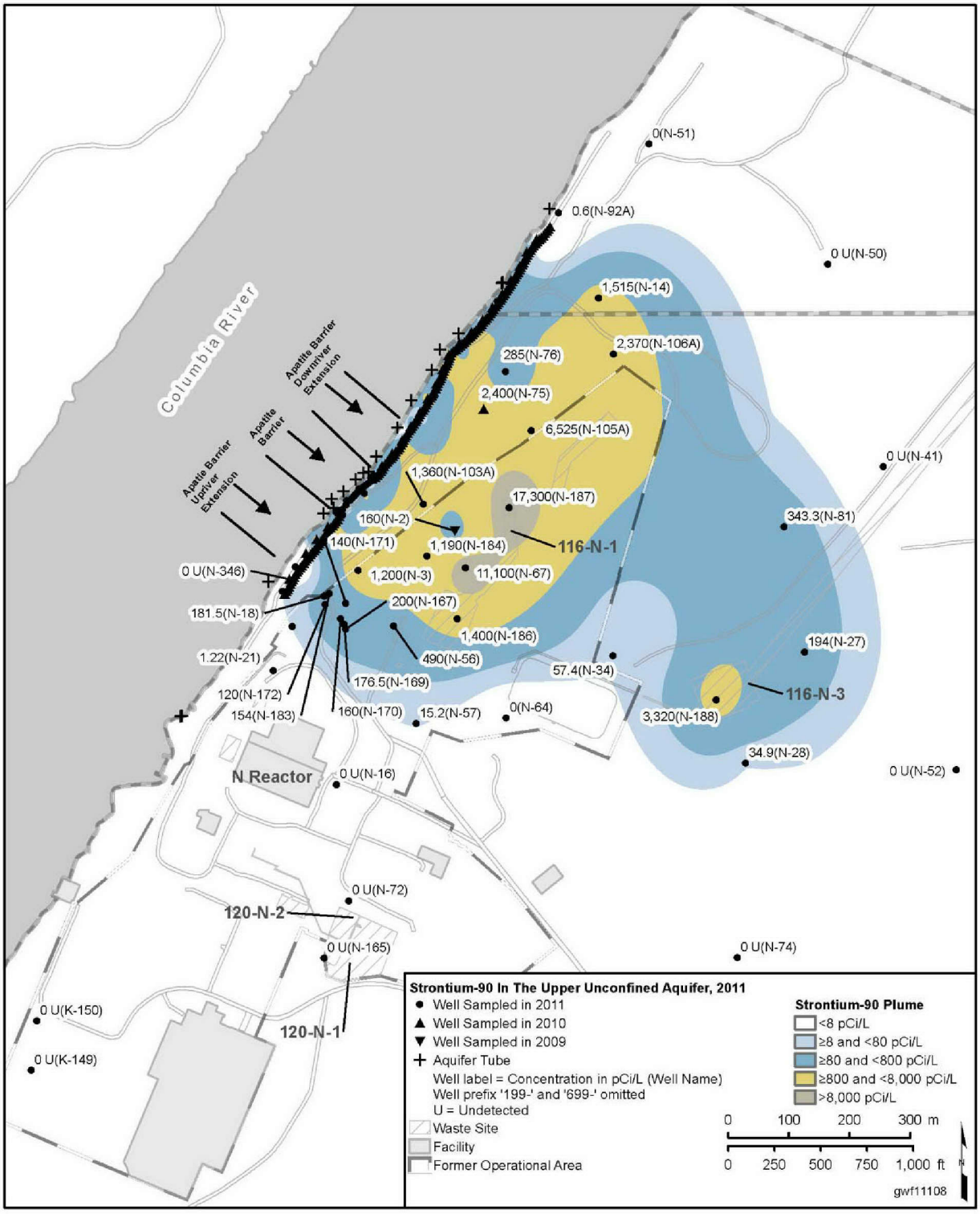


Figure 2.4-7. Changes in 100-NR-2 Plume Areas

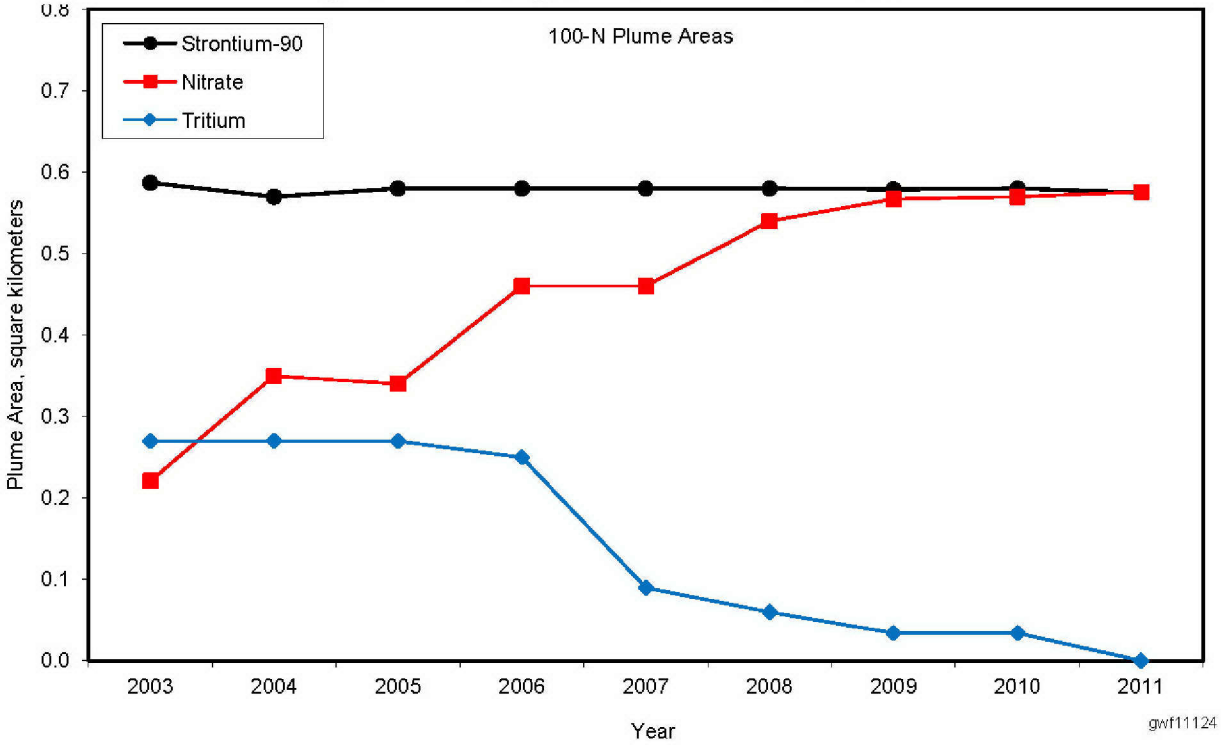


Figure 2.4-8. Strontium-90 and Water Level Trend in Well 199-N-81

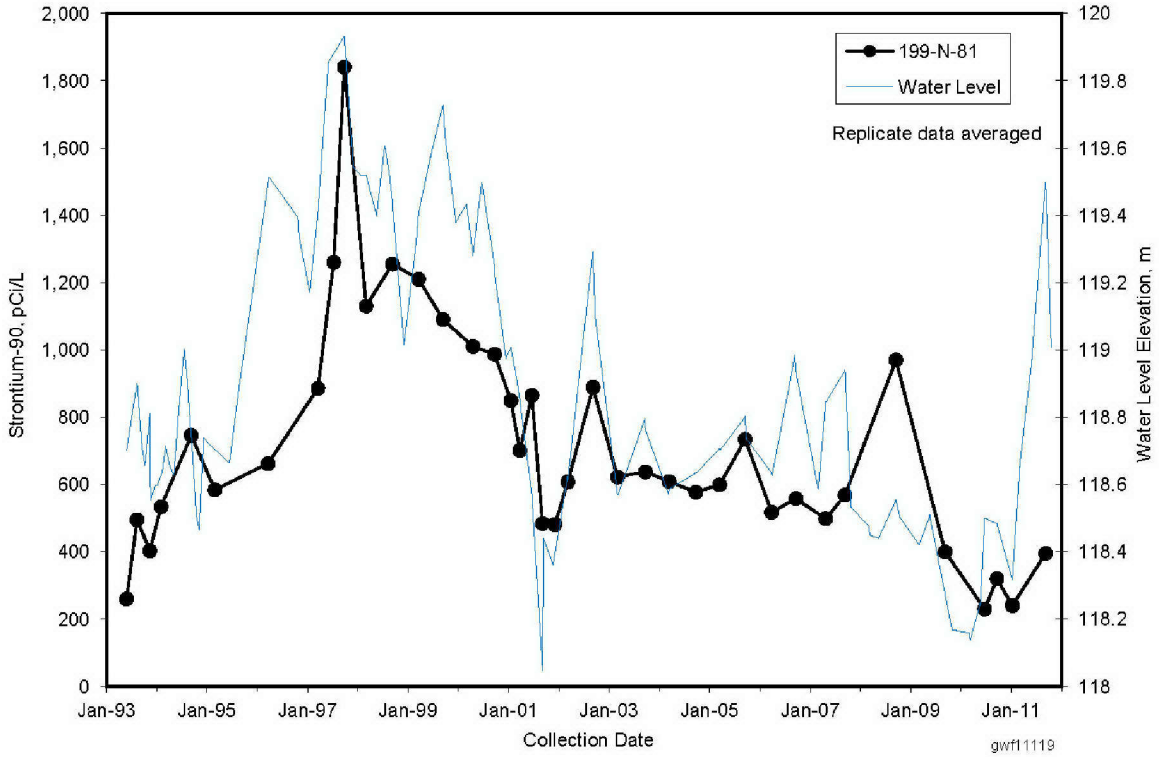


Figure 2.4-9. Strontium-90 and Water Level Trends in Well 199-N-67

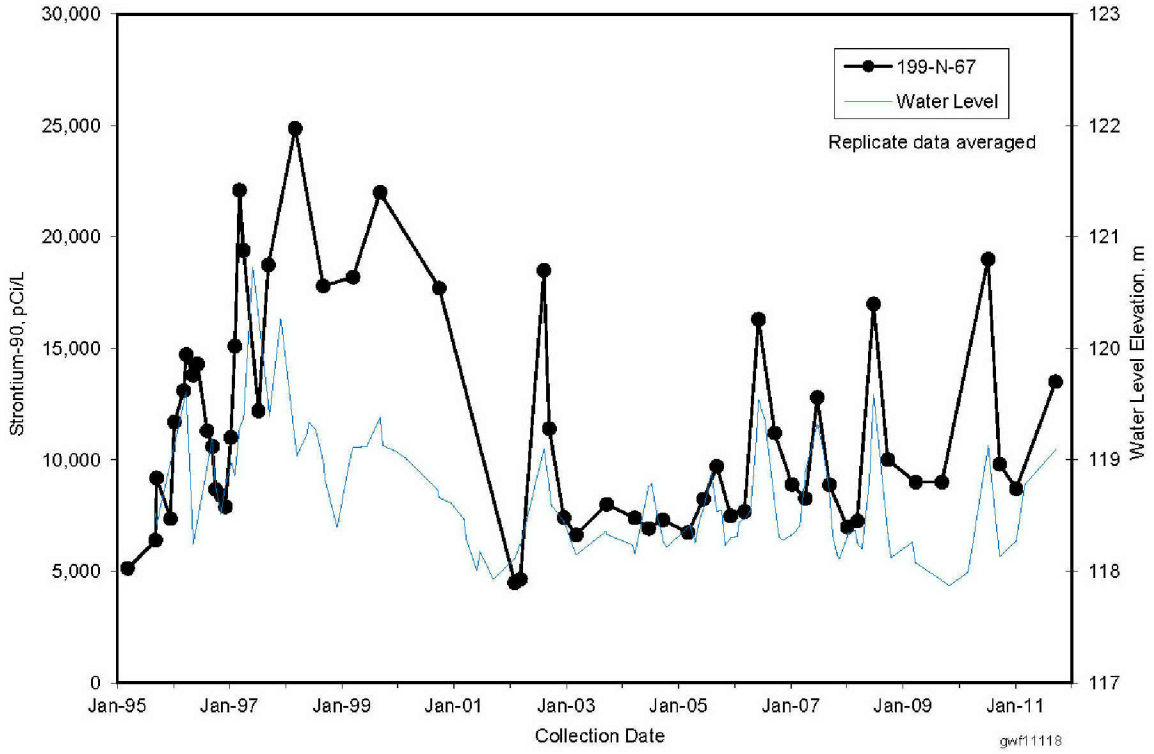


Figure 2.4-10. Strontium-90 Trends in 100-NR-2 Former Extraction Wells

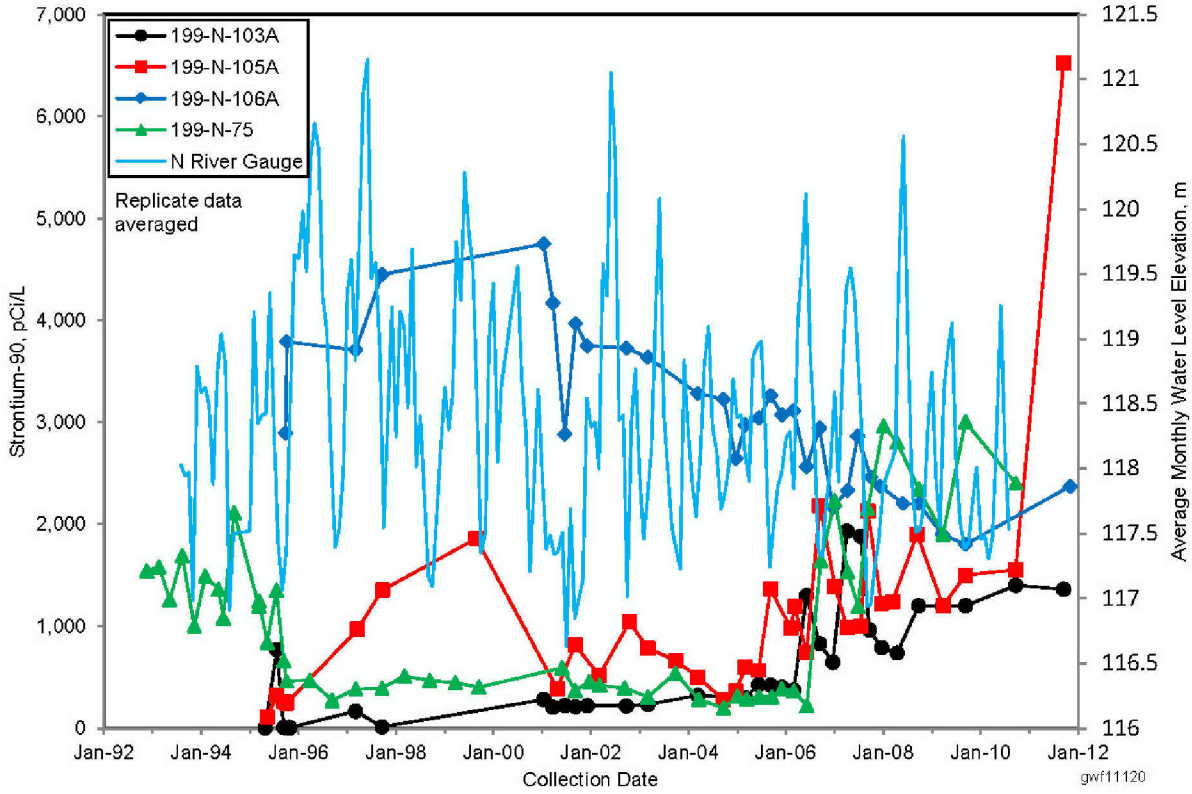


Figure 2.4-11. Average Strontium Concentrations in the 100-N Area, Apatite Permeable Reactive Barrier Study Area, Upper Part of Unconfined Aquifer, 2011

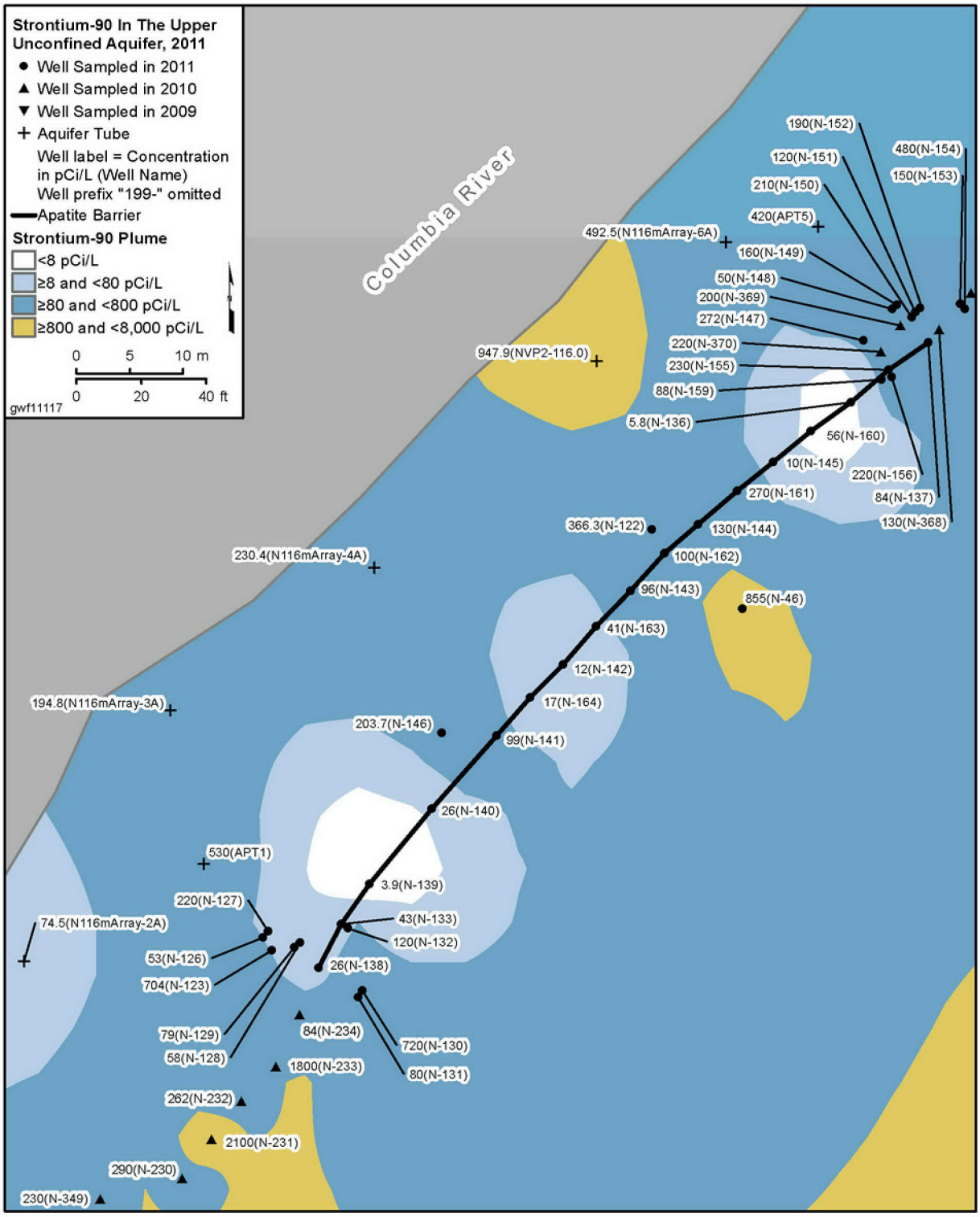


Figure 2.4-12. Gross Beta Trends in Wells near Apatite Barrier

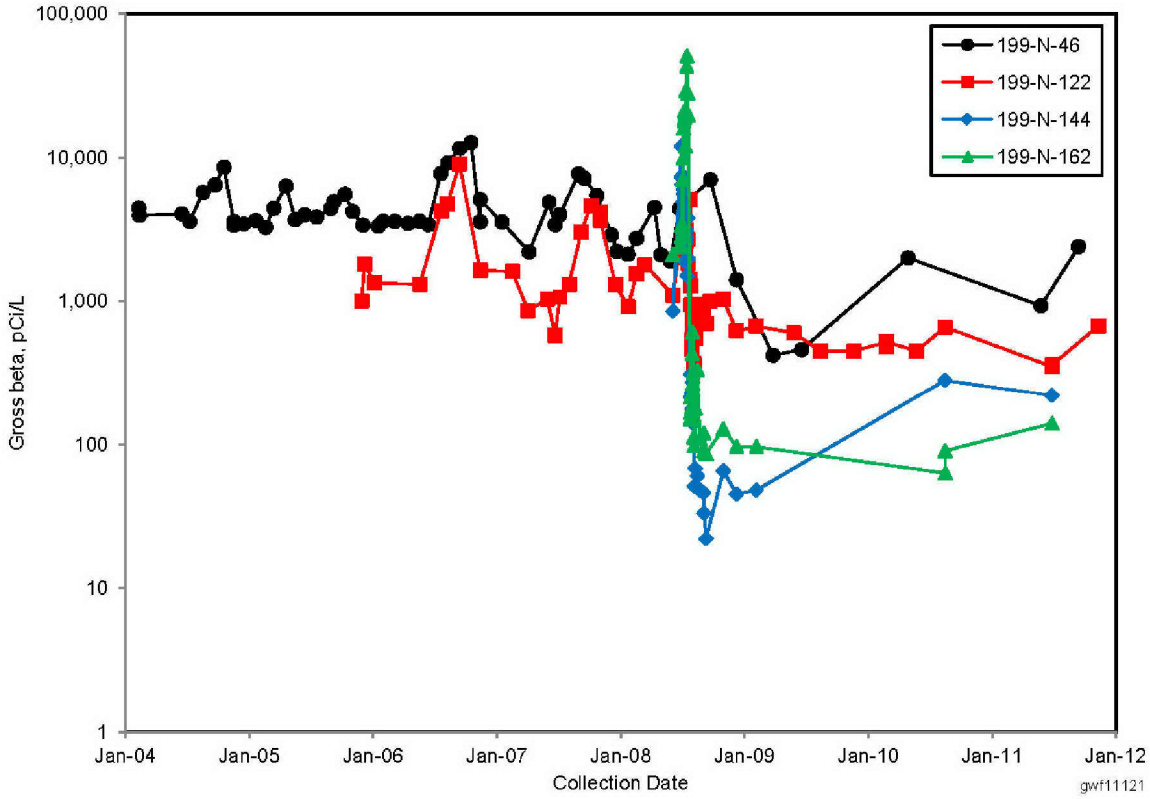


Figure 2.4-13. Average Nitrate Concentrations in 100-NR-2, Upper Part of Unconfined Aquifer, 2011

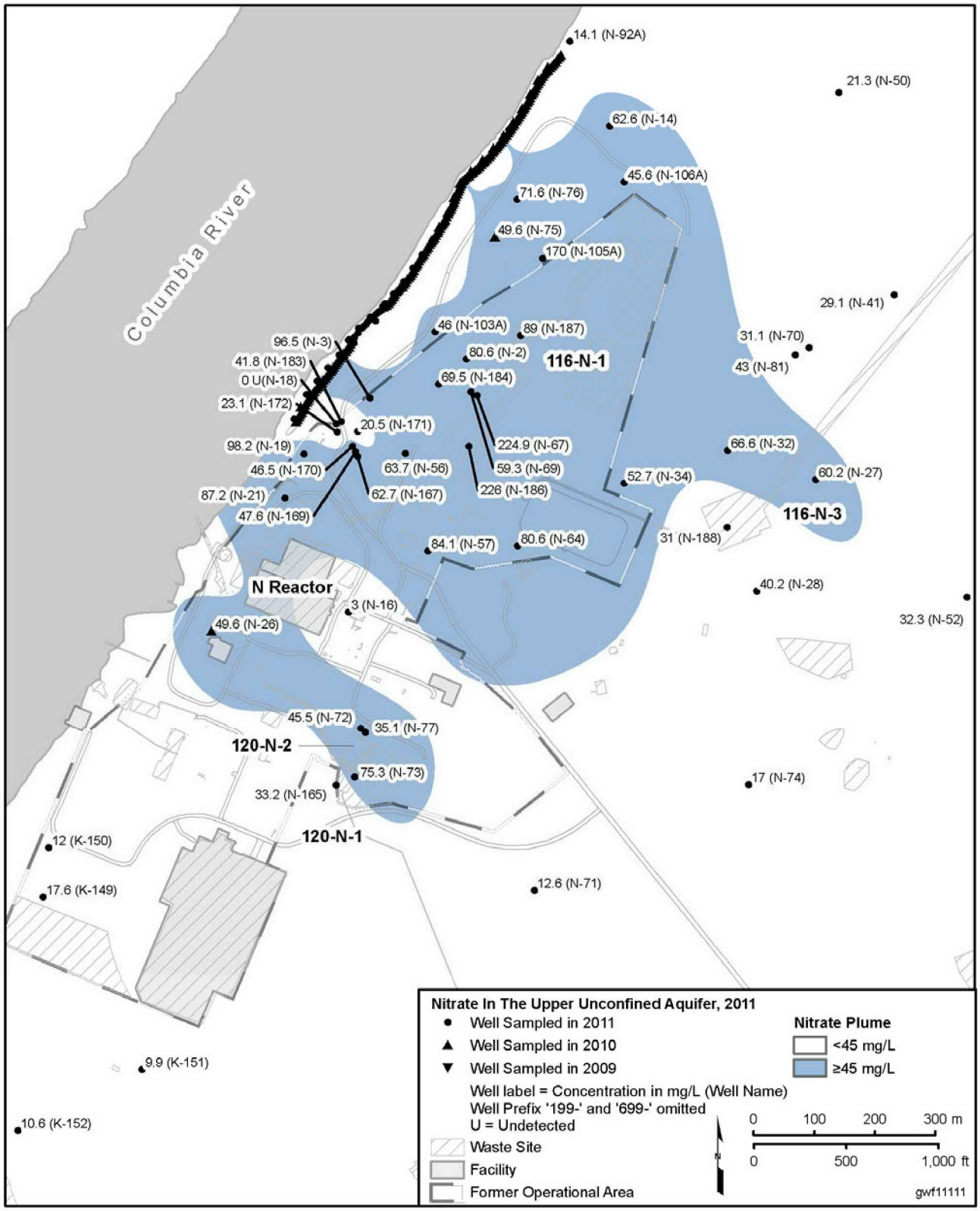


Figure 2.4-14. Nitrate Trends in wells 199-N-2 and 199-N-67 near the 116-N-1 LWDF

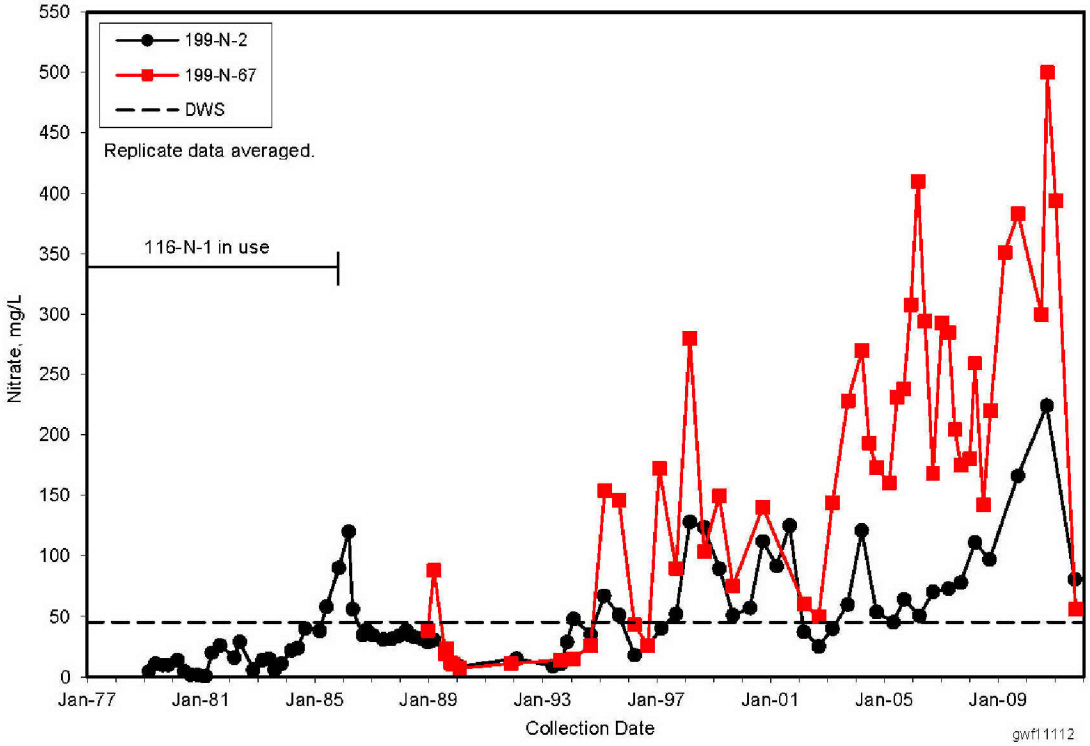


Figure 2.4-15. Nitrate Trend in Well 199-N-32 near the 116-N-3 LWDF

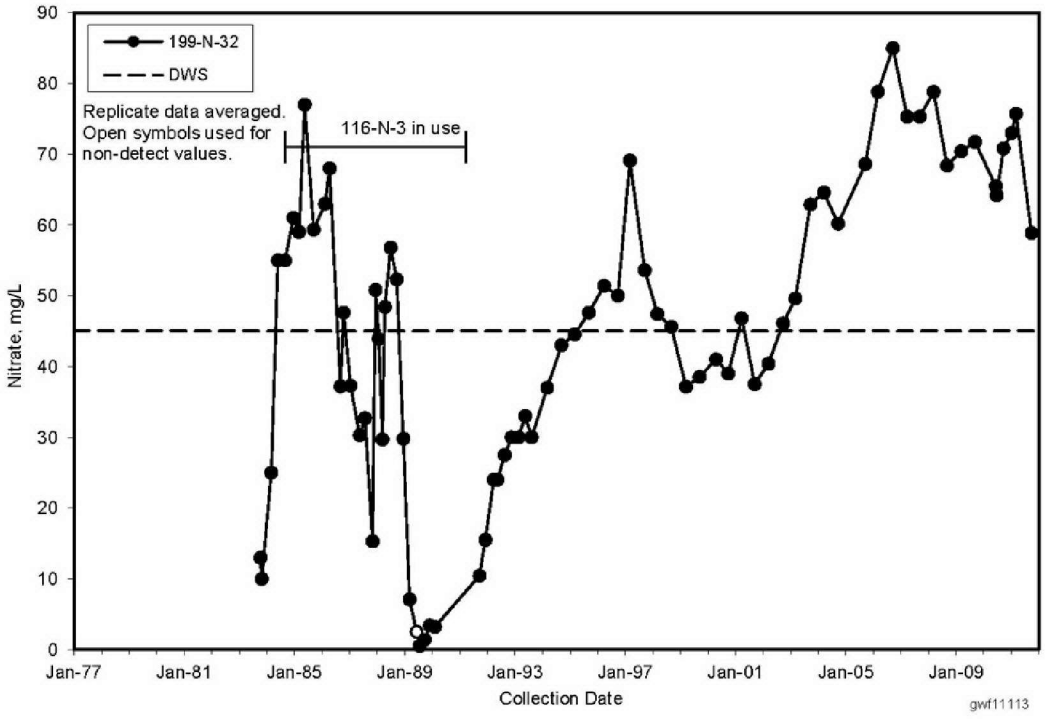


Figure 2.4-16. Nitrate Trends in Wells near the 120-N-1 Percolation Pond

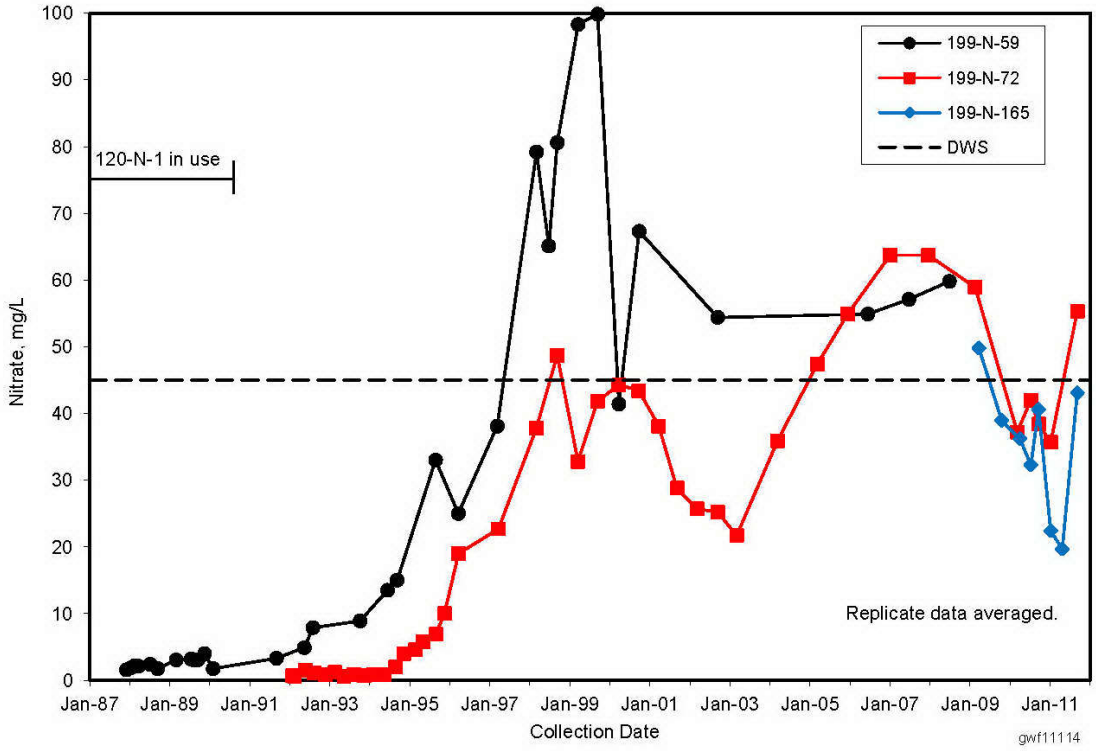


Figure 2.4-17. Total Petroleum Hydrocarbon-Diesel Concentrations in 100-NR-2, Upper Part of Unconfined Aquifer, Summer/Fall 2011

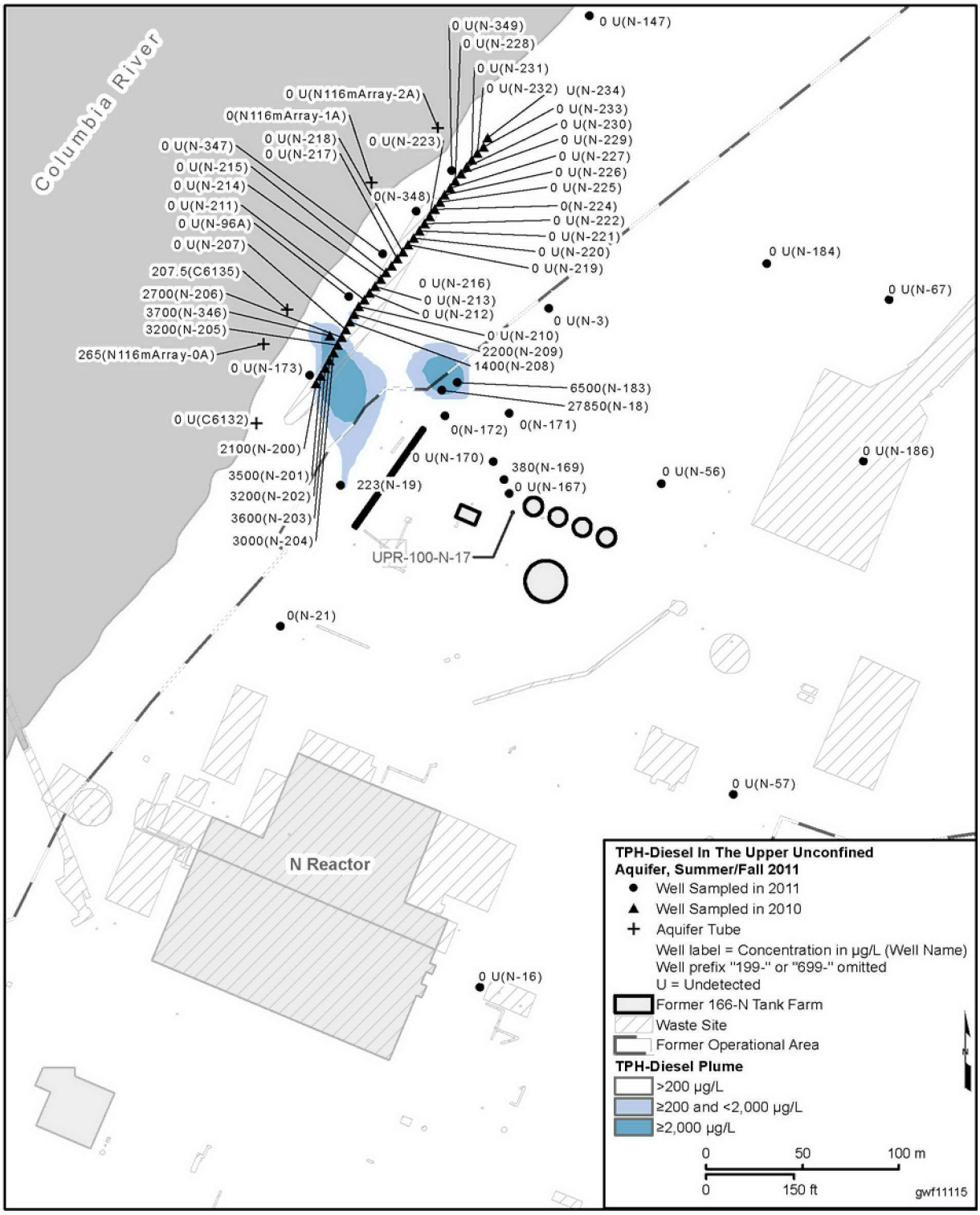


Figure 2.4-18. Average Tritium Concentrations in 100-NR-2, Upper Part of Unconfined Aquifer, 2011

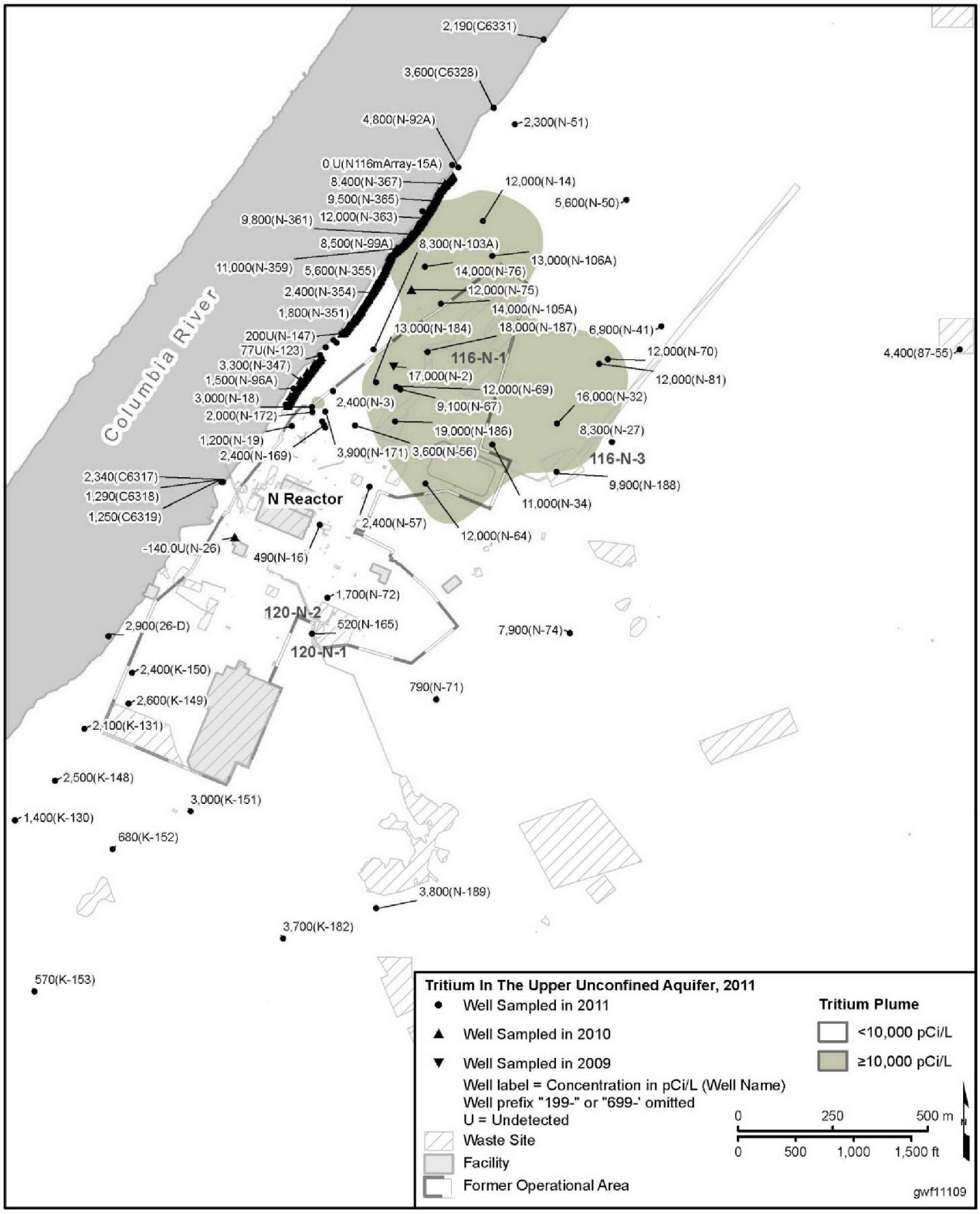


Figure 2.4-19. Tritium Trends in Wells 199-N-14 and 199-N-32

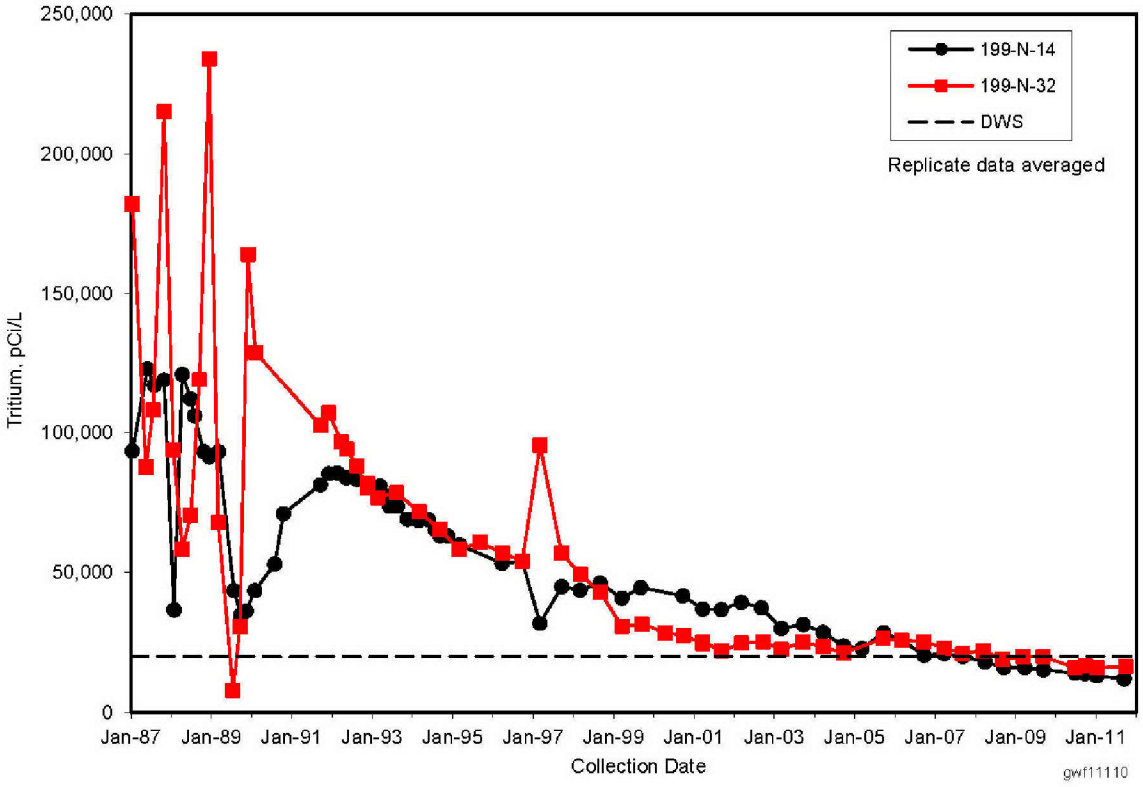
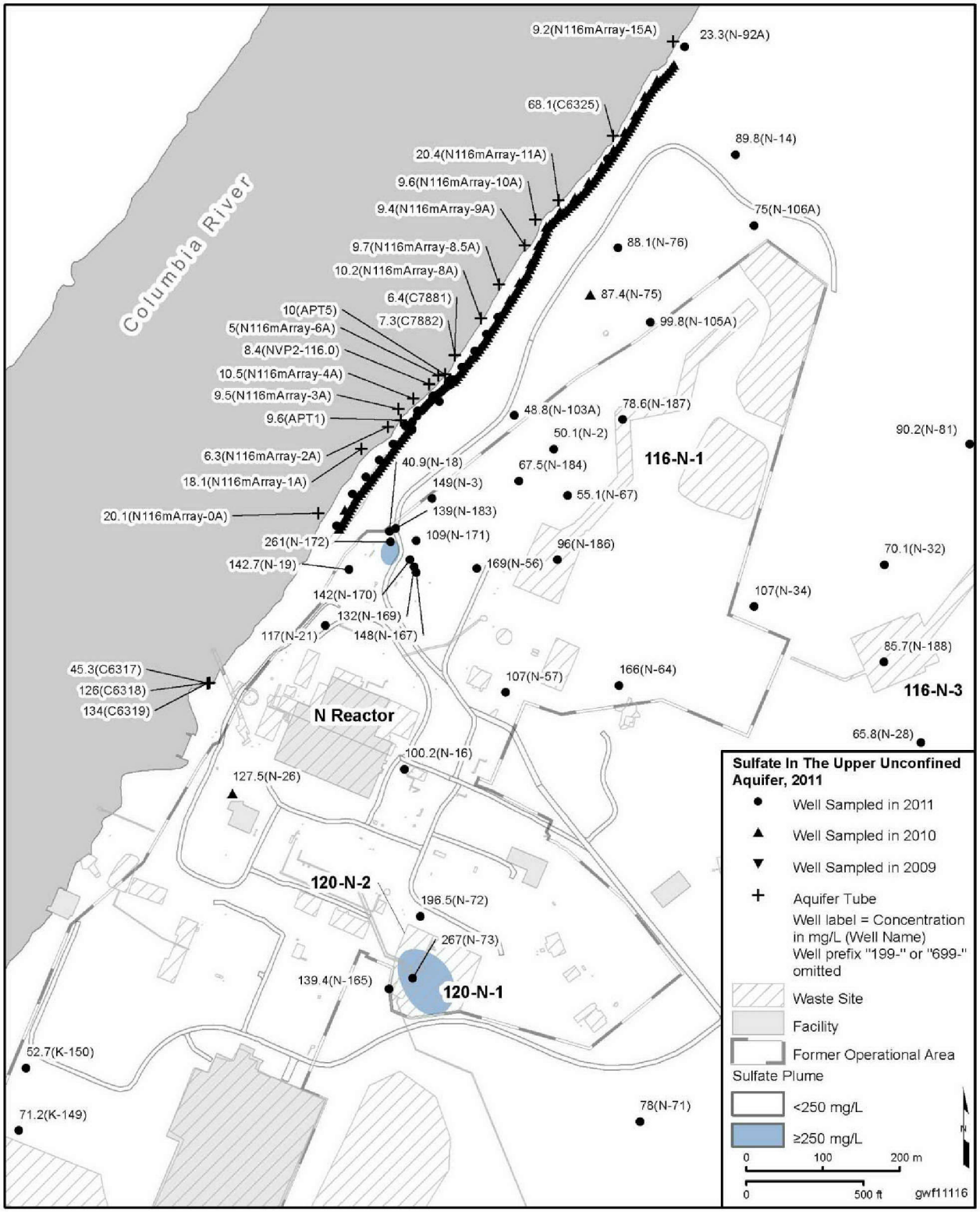


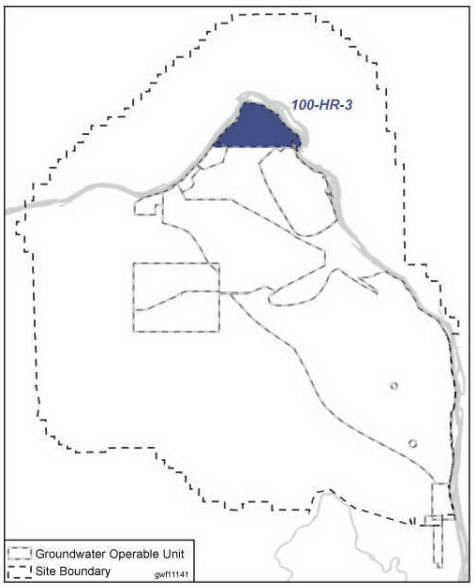
Figure 2.4-20. Average Sulfate Concentrations in 100-NR-2, Upper Part of Unconfined Aquifer, 2011



2.5 100-HR-3

K.A. Ivarson, M.J. Hartman, and J.L. Smoot

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



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

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

100-HR-3 at a Glance

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

a. Estimated area above listed water quality standard.

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

c. At the 10 µg/L level.

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

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

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

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

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

2.5.1 Hexavalent Chromium

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

The total area of the hexavalent chromium plume in 100-HR-3

(at levels greater than 20 µg/L) is about 6 square kilometers, and has decreased 37 percent since 2003.

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

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

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

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

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

2.5.1.1 Hexavalent Chromium in Southern 100-D Area

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

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

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

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

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

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

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

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

2.5.1.2 Hexavalent Chromium in Northern 100-D Area

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

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

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

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

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

2.5.1.3 Hexavalent Chromium in Horn Area

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

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

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

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

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

2.5.1.4 Hexavalent Chromium in 100-H Area

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

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

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

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

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

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

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

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

2.5.2 Nitrate

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

2.5.2.1 Nitrate in 100-D Area

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

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

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

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

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

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

2.5.2.2 Nitrate in 100-H Area

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

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

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

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

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

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

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

2.5.3 Strontium-90

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

2.5.3.1 Strontium-90 in 100-D Area

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

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

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

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

2.5.3.2 Strontium-90 in 100-H Area

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

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

2.5.4 Tritium

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

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

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

2.5.5 Other Contaminants

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

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

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

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

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

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

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

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

2.5.6 CERCLA Groundwater Activities

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

The interim remedial action goal was changed from 22 µg/L to 20 µg/L in 2000 under the interim action ROD Amendment (EPA/AMD/R10-00/122, *Interim Remedial Action Record of Decision Amendment for the 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington*). The amendment sets a 20 µg/L threshold at onshore, near-river monitoring locations to achieve the ambient water quality criterion of 10 µg/L. According to the interim remedial action ROD, an attenuation factor of 1:1 is expected before the groundwater would reach the aquatic receptor point of concern within

the river substrate, ensuring that the ambient water quality criterion of 10 µg/L in the river substrate will be met.

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

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

2.5.6.1 Remedial Investigation/Feasibility Study

In 2010 and 2011, DOE conducted extensive field studies as described in an RI/FS work plan addendum for the 100-D and 100-H Areas (DOE/RL-2008-46-ADD1) and the sampling and analysis plan (DOE/RL-2009-40). Changes to the sampling and analysis plan were also made during the RI/FS field effort and are documented in Tri-Party Agreement Change Notices (TPA-CN-460, *Tri-Party Agreement Change Notice Form: DOE/RL-2009-40 Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation /Feasibility Study, Rev. 0*; TPA-CN-368, *Tri-Party Agreement Change Notice Form: DOE/RL-2009-40, Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study, Rev. 0*). The fieldwork included the following:

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

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

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

2.5.6.2 Groundwater Remediation

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

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

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

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

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

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

Pump-and-Treat Systems

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

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

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

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

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

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

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

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

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

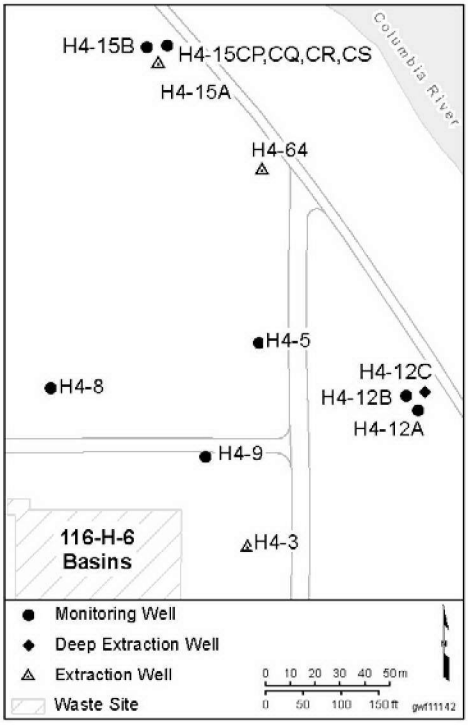
In Situ Redox Manipulation System

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

The In Situ Redox Manipulation barrier intersects the southern hexavalent chromium plume and has largely cut off the highest concentration portion of the plume and prevented it from extending to the Columbia River. Concentrations were below 20 µg/L in three of the seven downgradient compliance wells in 2011, but concentrations remained far above that level in other wells (Figure 2.5-10). Seven wells downgradient from the barrier were converted into extraction wells for the DX pump-and-treat system.

2.5.7 RCRA Facility Monitoring at 183-H (116-H-6) Solar Evaporation Basins

The 183-H solar evaporation basins (waste site 116-H-6) included four sedimentation and flocculation basins remaining from operation of the 183-H water treatment facility. The four basins received combined radioactive and dangerous (mixed) waste for storage and treatment from the 300 Area fuel fabrication facilities from July 1973 until November 1985. By fall 1996, the waste remaining in the basins was removed, the basins were demolished, and the underlying contaminated soil was removed and replaced with clean fill. Clean closure of the site was not achieved because fluoride and nitrate levels in soil below the 4.6 meter deep excavation exceed the Method B cleanup levels of WAC 173-340. Therefore, the unit was closed under the modified-closure option, with specified measures for post-closure care.



The Hanford Facility RCRA Permit (WA7890008967) requires annual groundwater monitoring of the facility,

which includes sampling four wells (199-H4-3, 199-H4-8, 199-H4-12A, and 199-H4-12C) for total chromium, fluoride, nitrate, technetium-99, and uranium. Although not regulated under RCRA, technetium-99 and uranium were included in the monitoring plan as indicators and were incorporated by reference in the Hanford Facility RCRA Permit (WA7890008967).

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

2.5.8 Comparison of Surface Water and Groundwater Chemistry

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

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

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

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

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

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

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

* DX system became operational in December 2010.

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

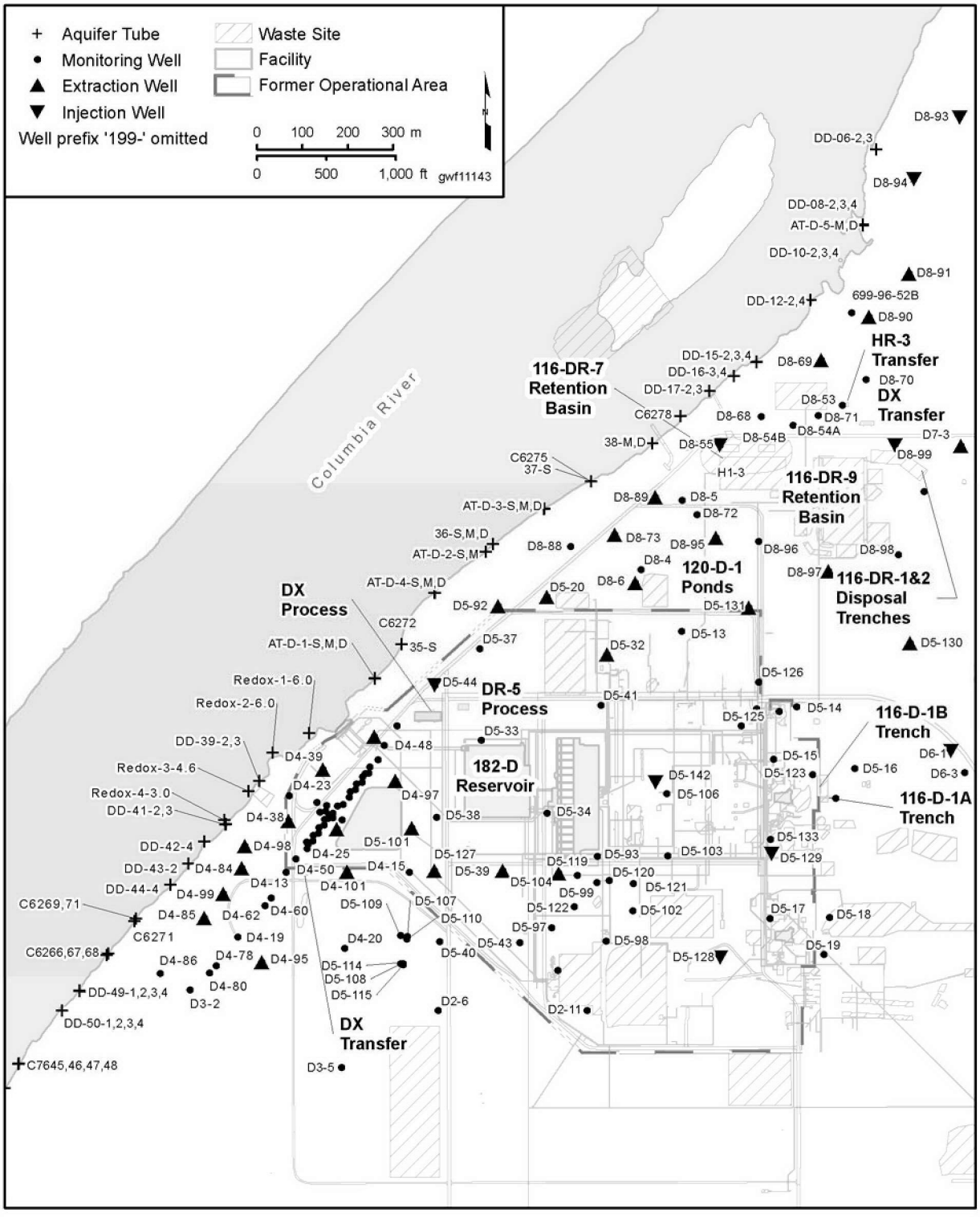


Figure 2.5-2. Well Locations in ISRM Region

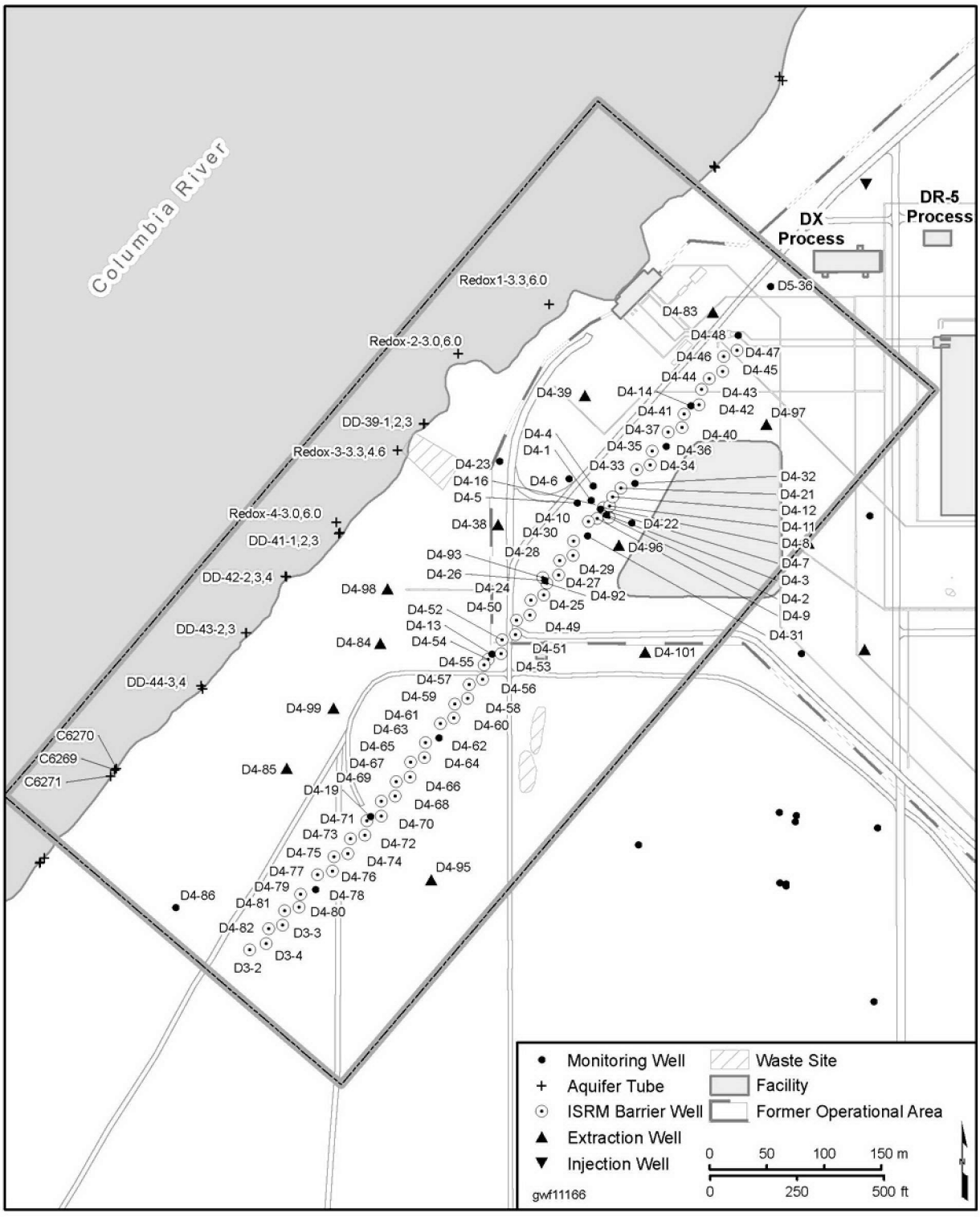


Figure 2.5-3. Facilities and Groundwater Monitoring Wells in 100-H

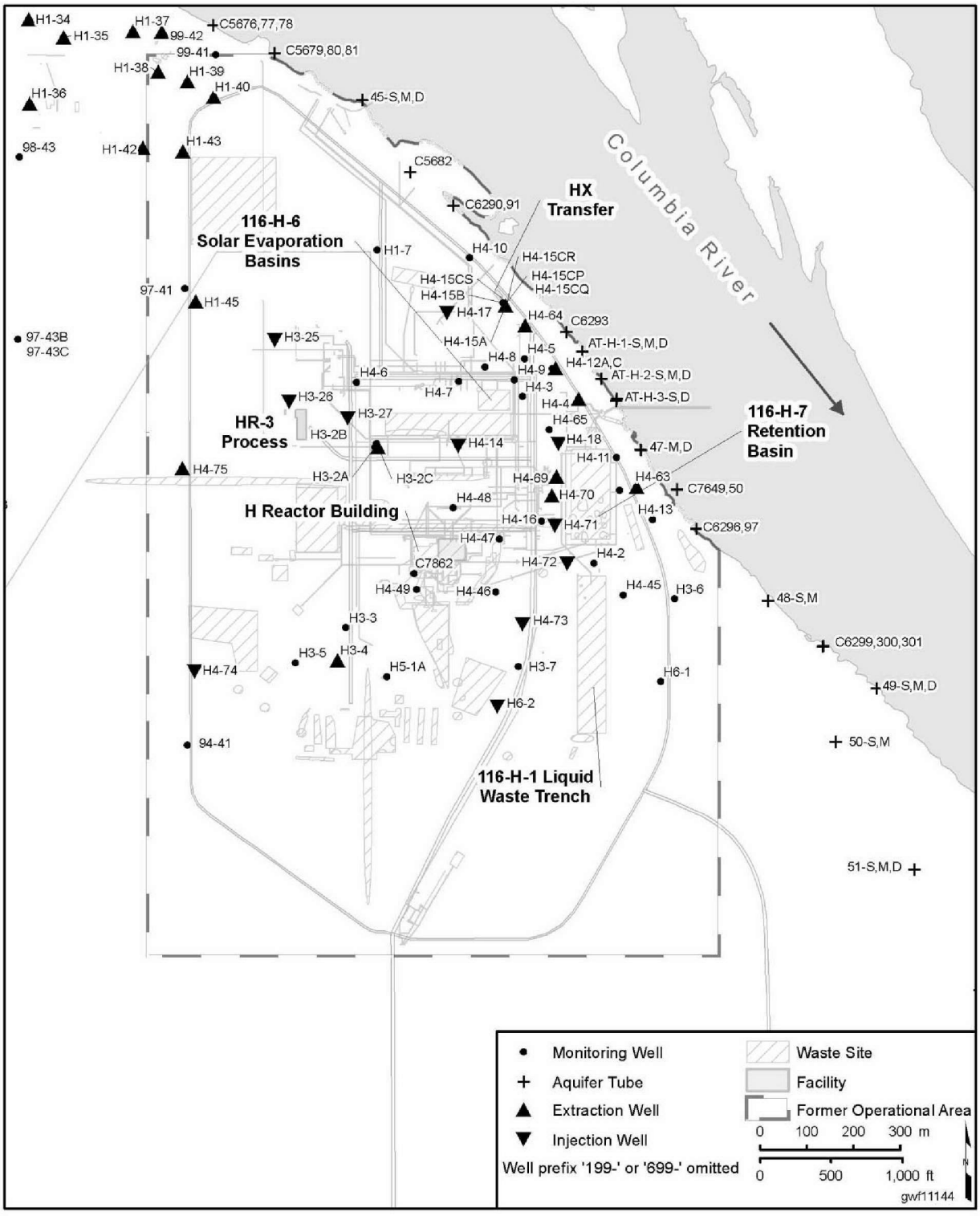


Figure 2.5-4. Facilities and Groundwater Monitoring Wells in the Horn

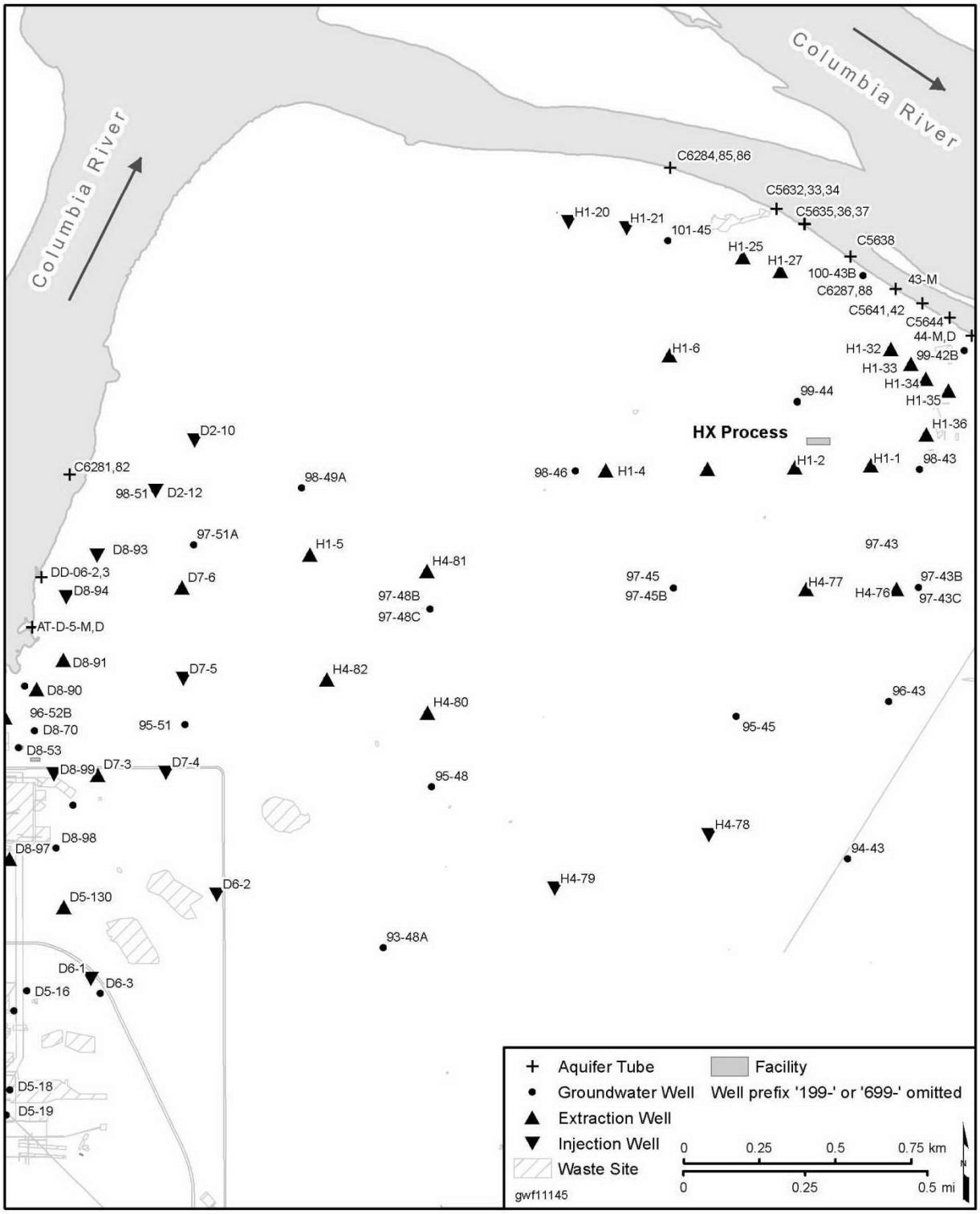


Figure 2.5-5. Changes in 100-HR-3 Plume Areas with Time

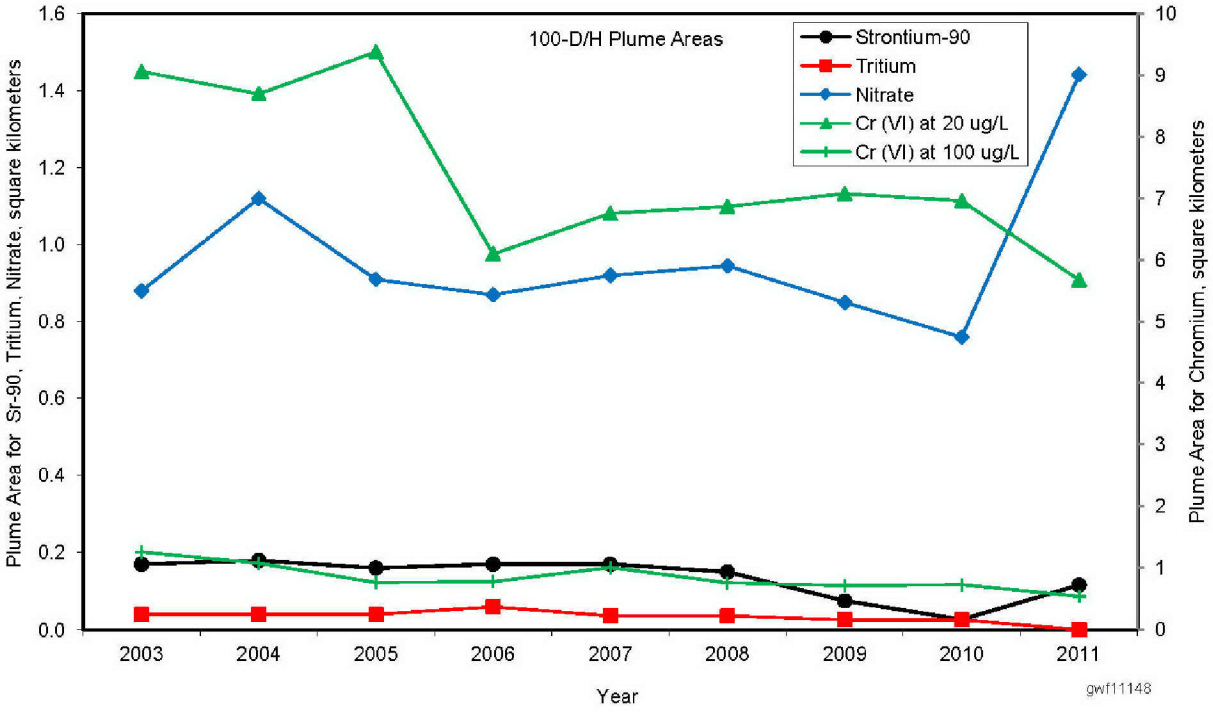


Figure 2.5-6. 100-HR-3 Water Table, March 2011

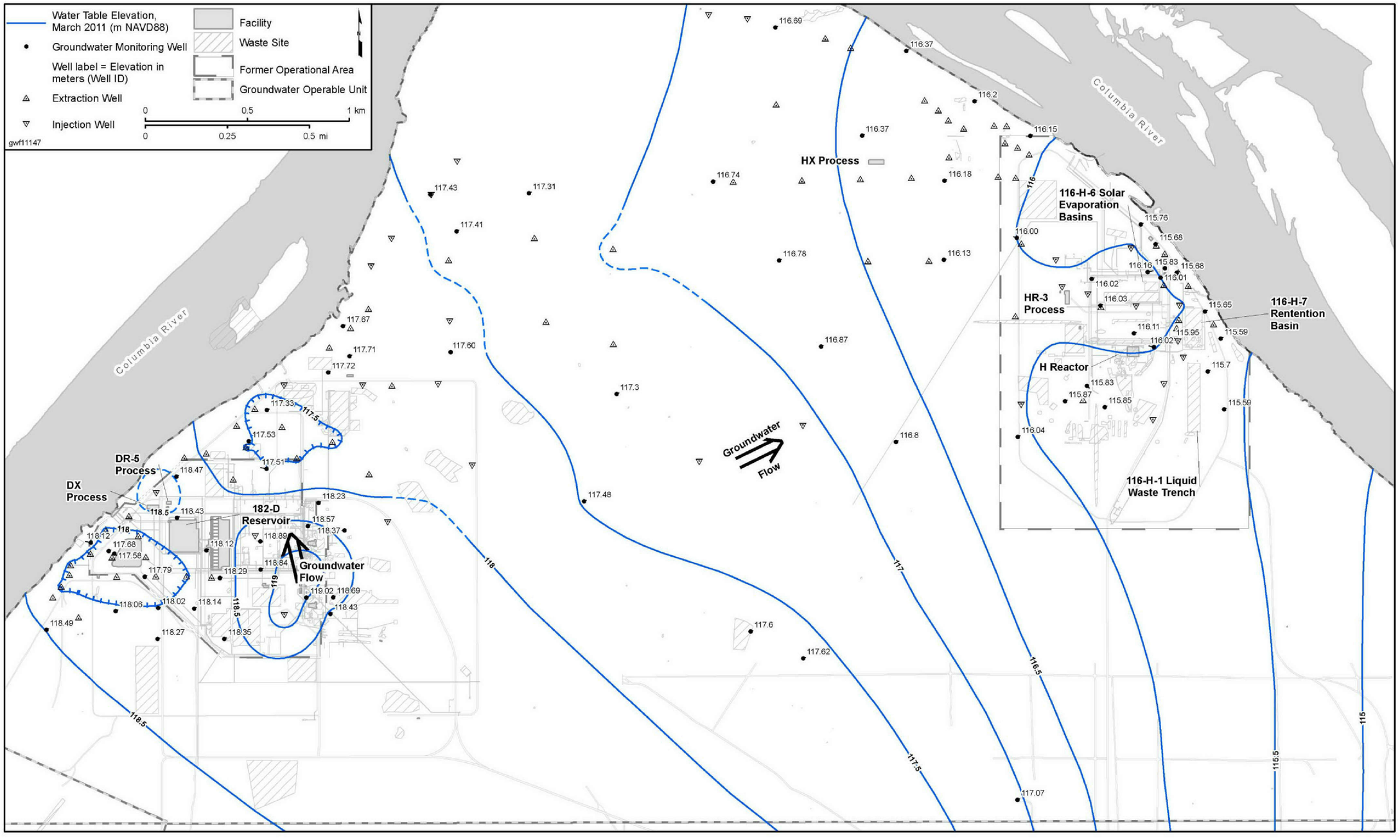


Figure 2.5-7. Aerial Photo of DX and HX Systems

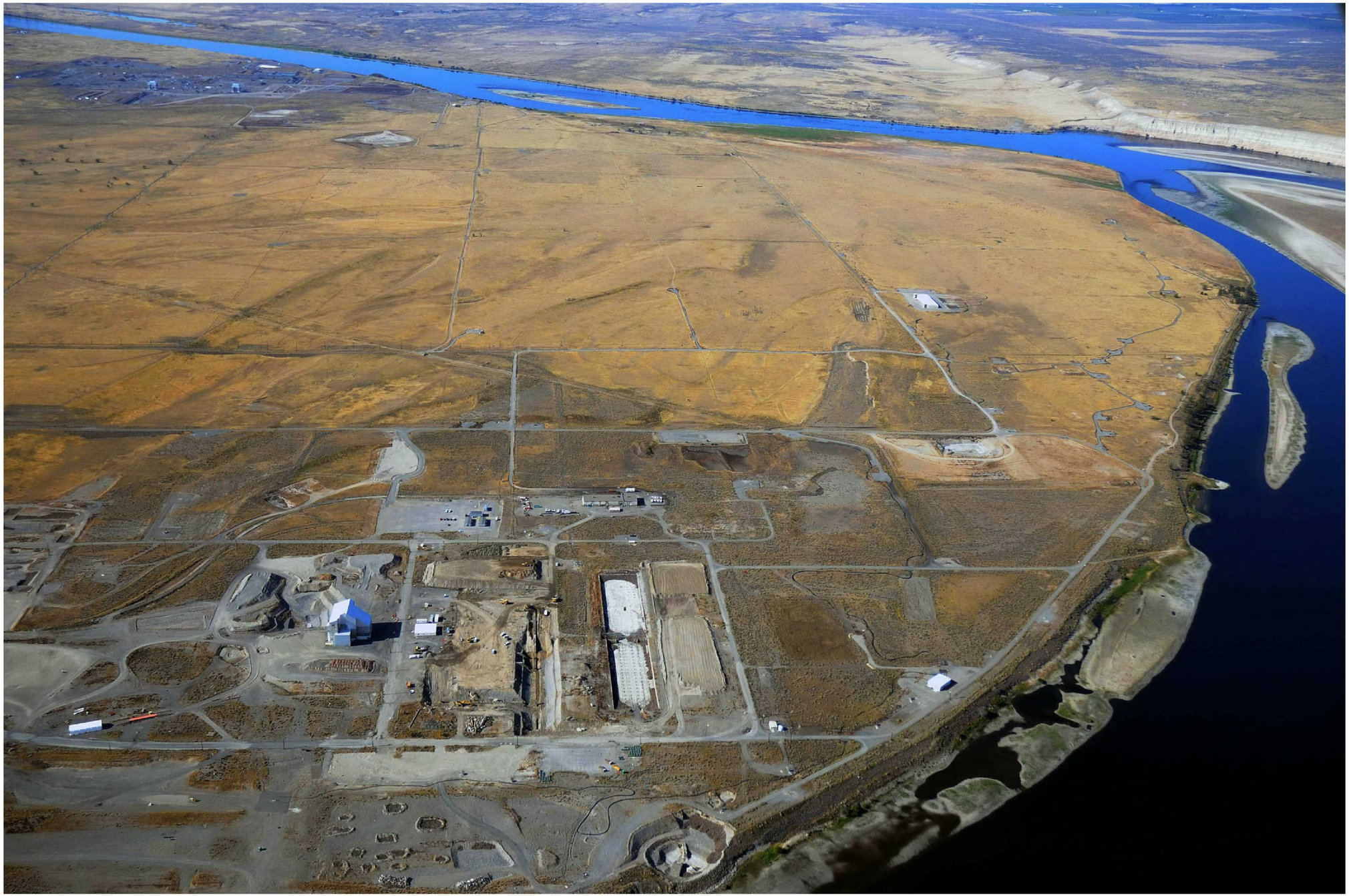


Figure 2.5-8. Hexavalent Chromium Concentrations in 100-HR-3, Low River Stage 2011

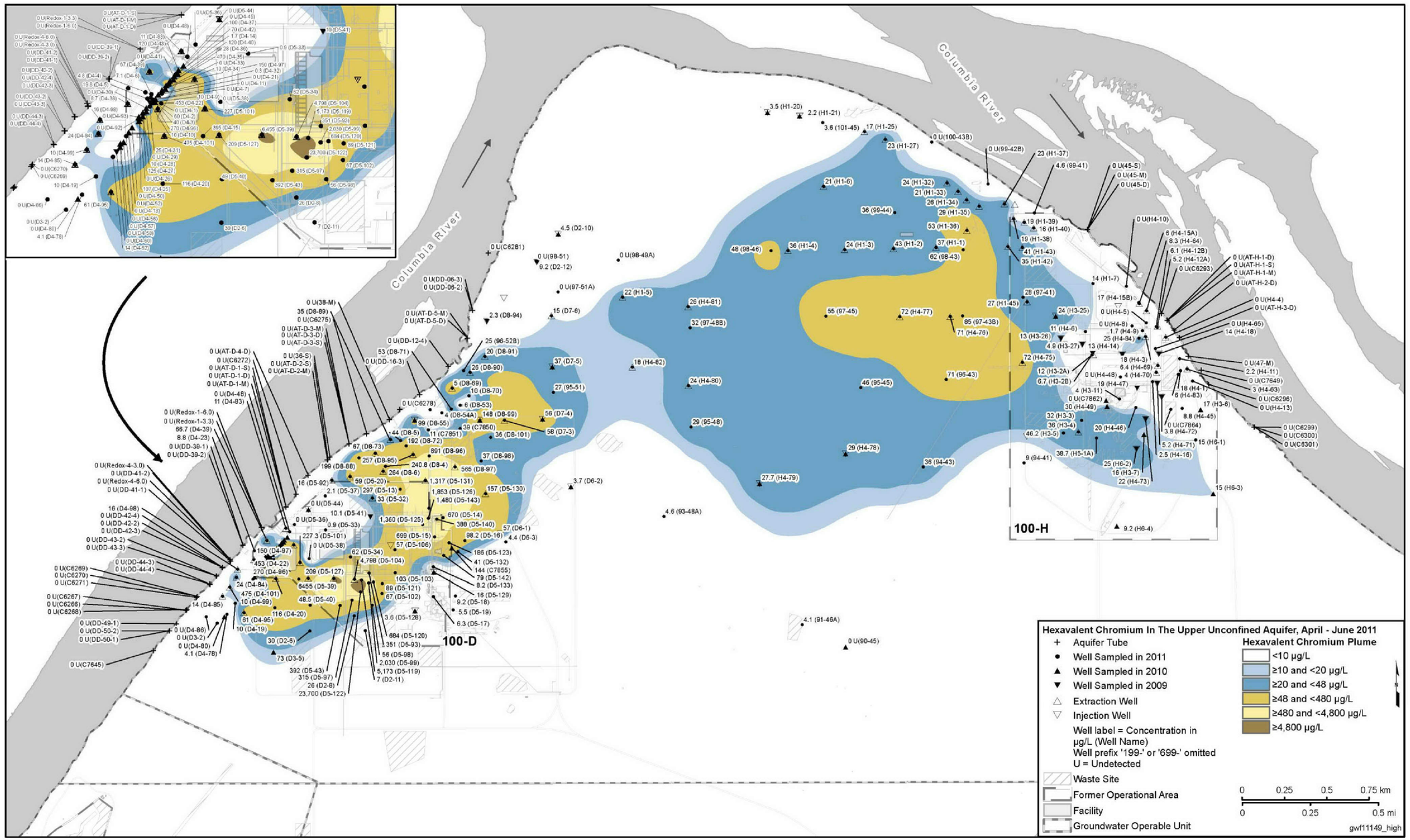


Figure 2.5-9. Hexavalent Chromium Concentrations in 100-HR-3, High River Stage 2011

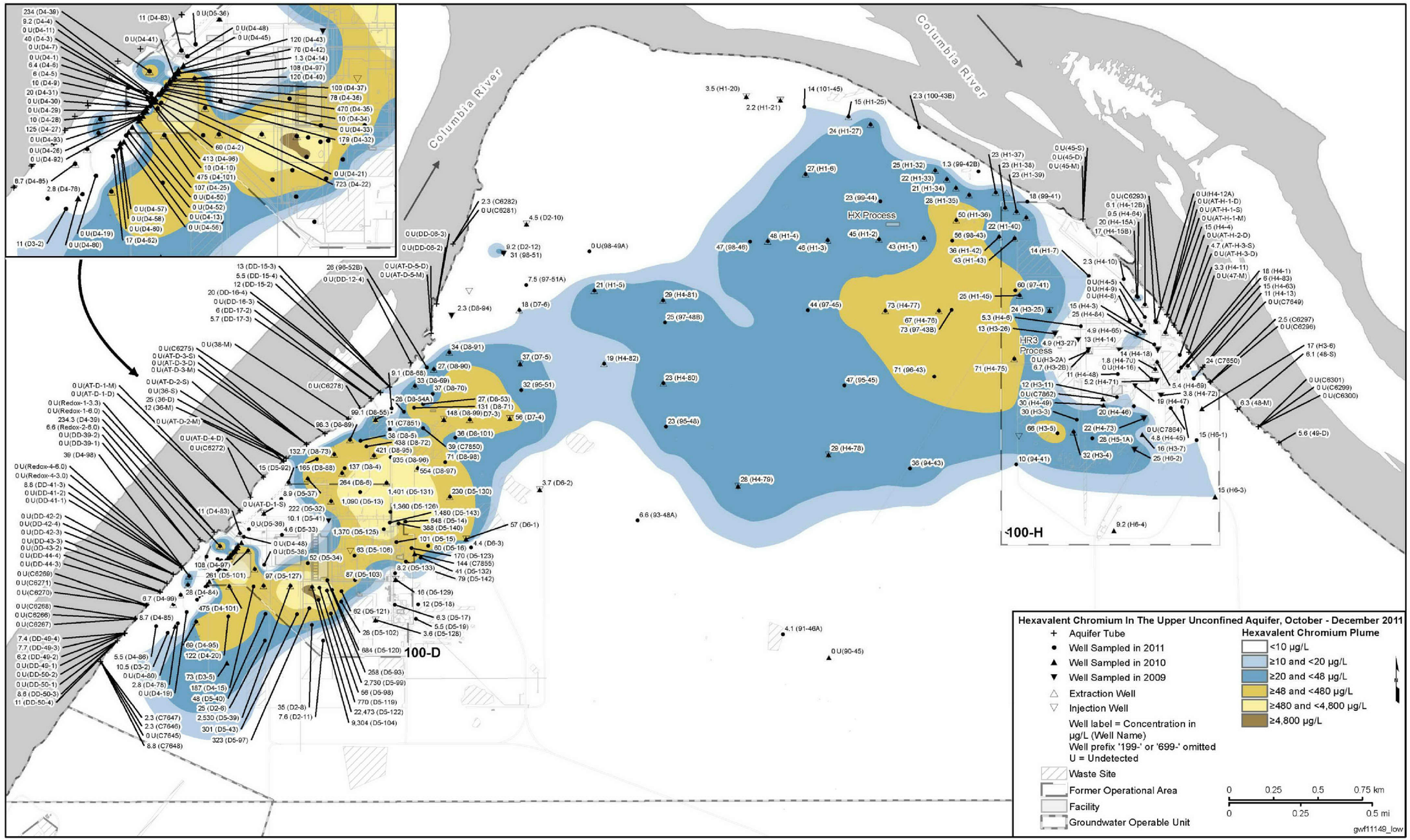
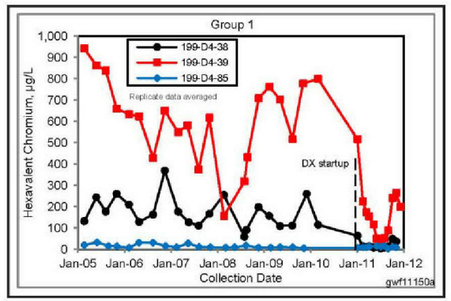
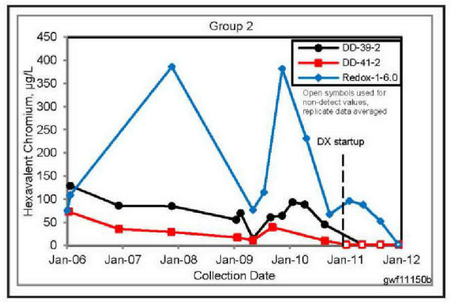
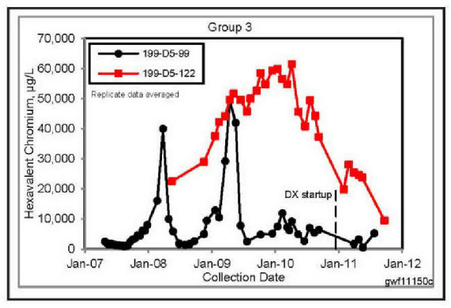
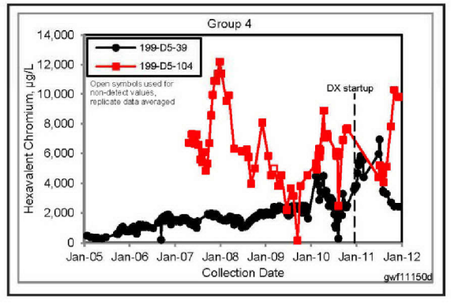


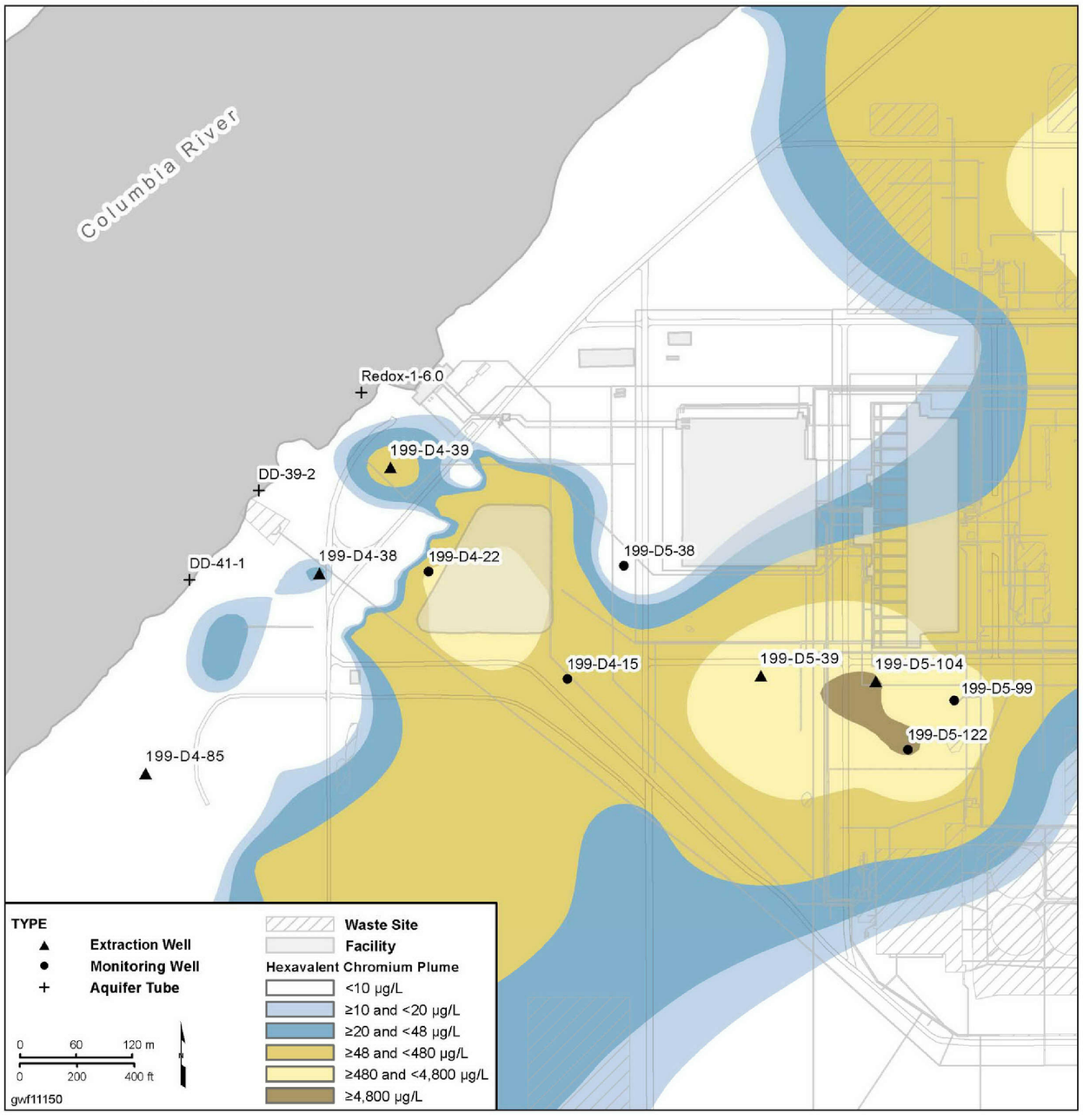
Figure 2.5-10. Hexavalent Chromium Concentrations and Trends in Southern 100-D Area Plume











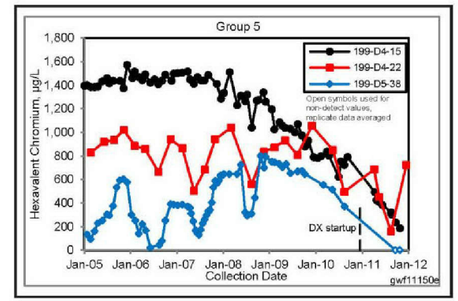


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Figure 2.5-11. 100-D Area Aquifer Tubes

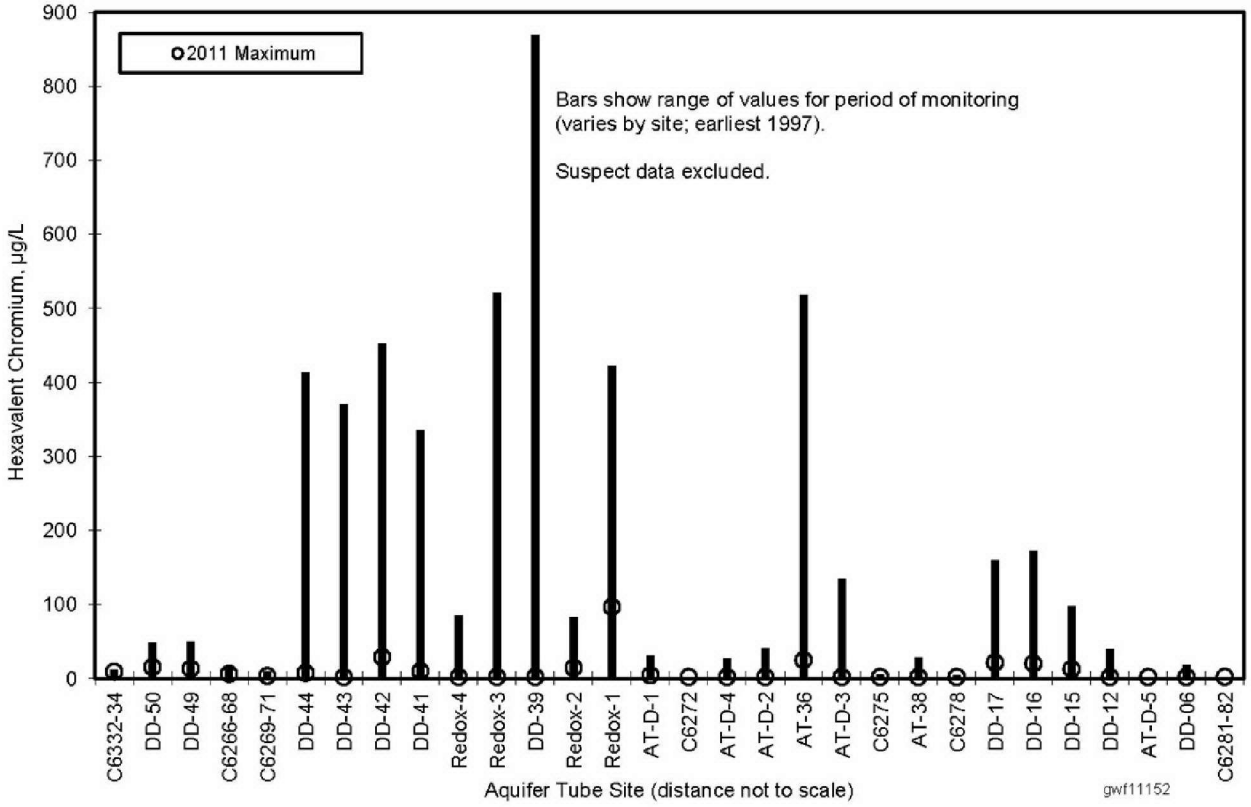

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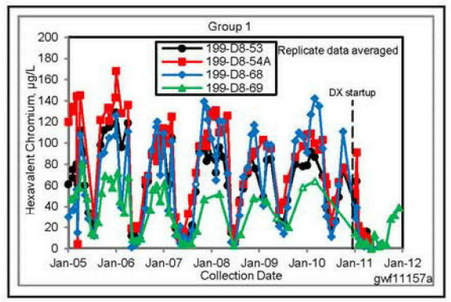
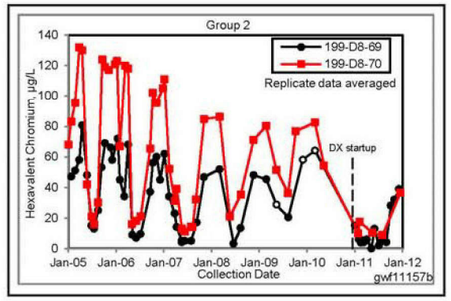
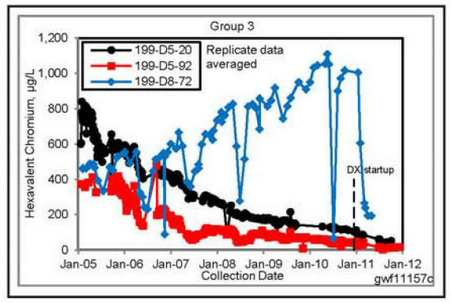
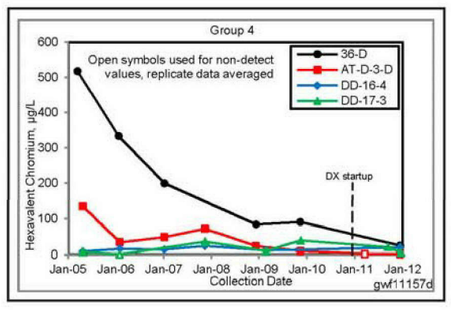
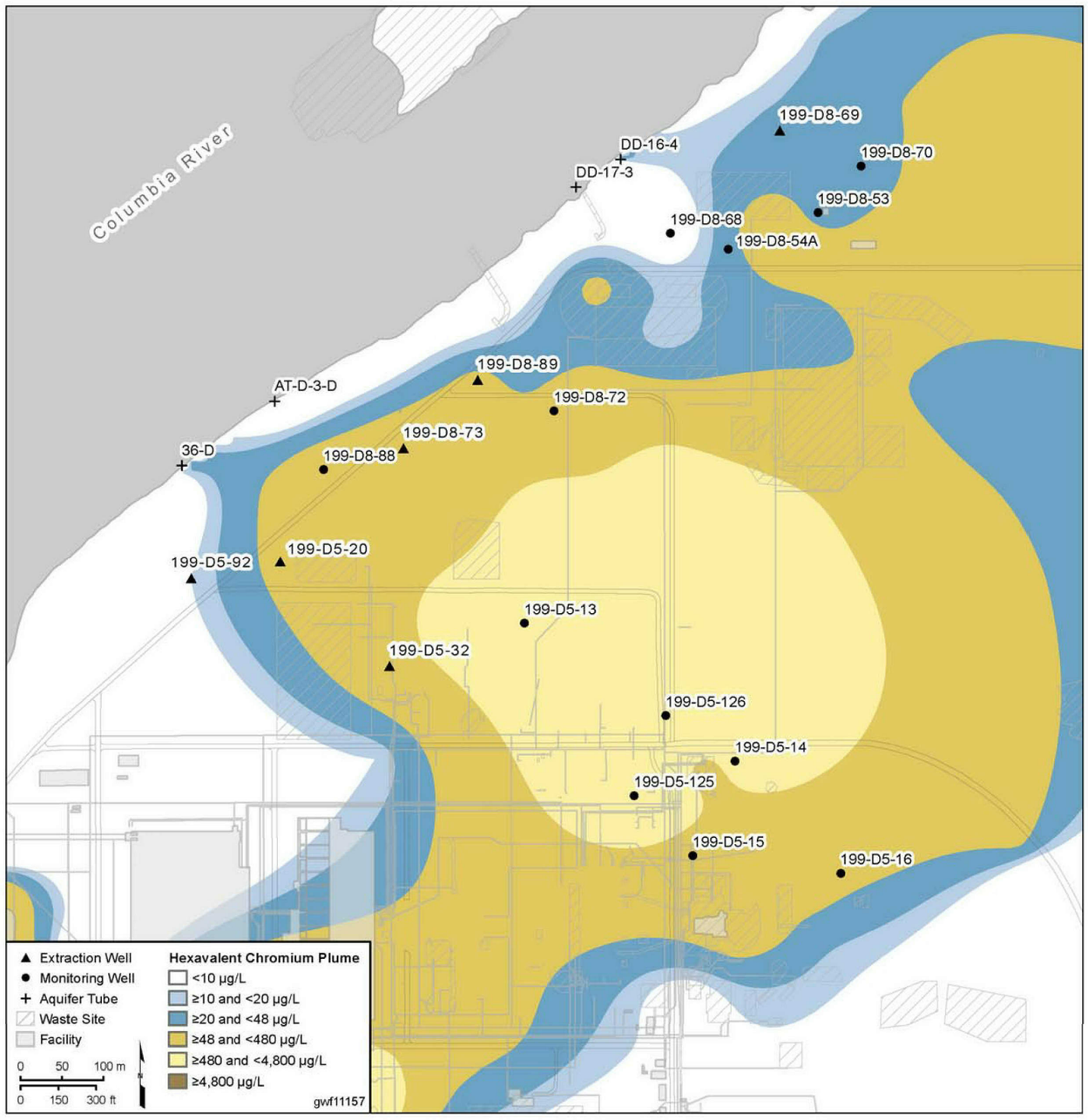
Figure 2.5-12. North 100-D Area Hexavalent Chromium Plume

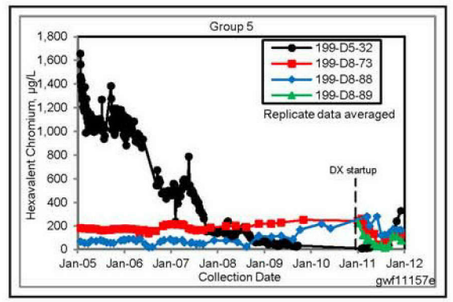


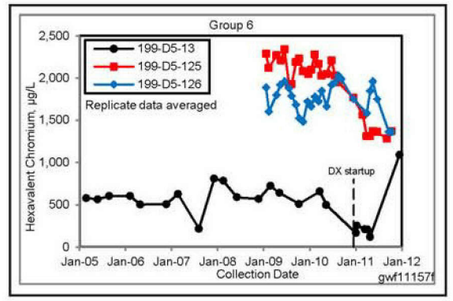












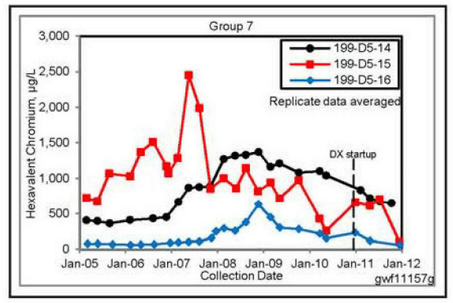
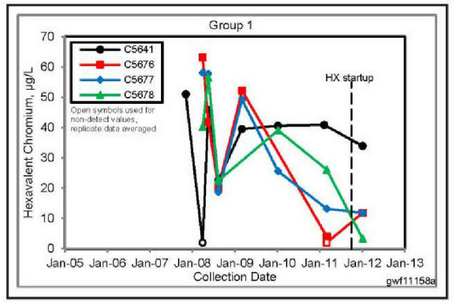
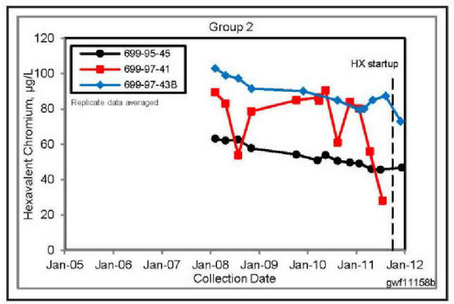
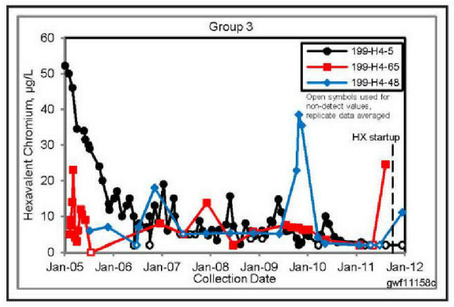
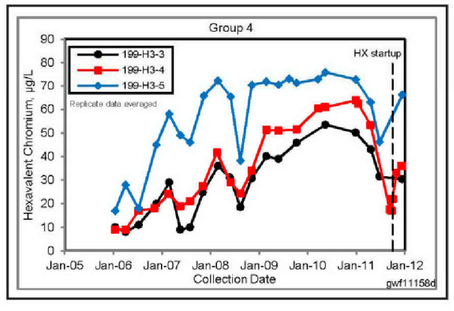


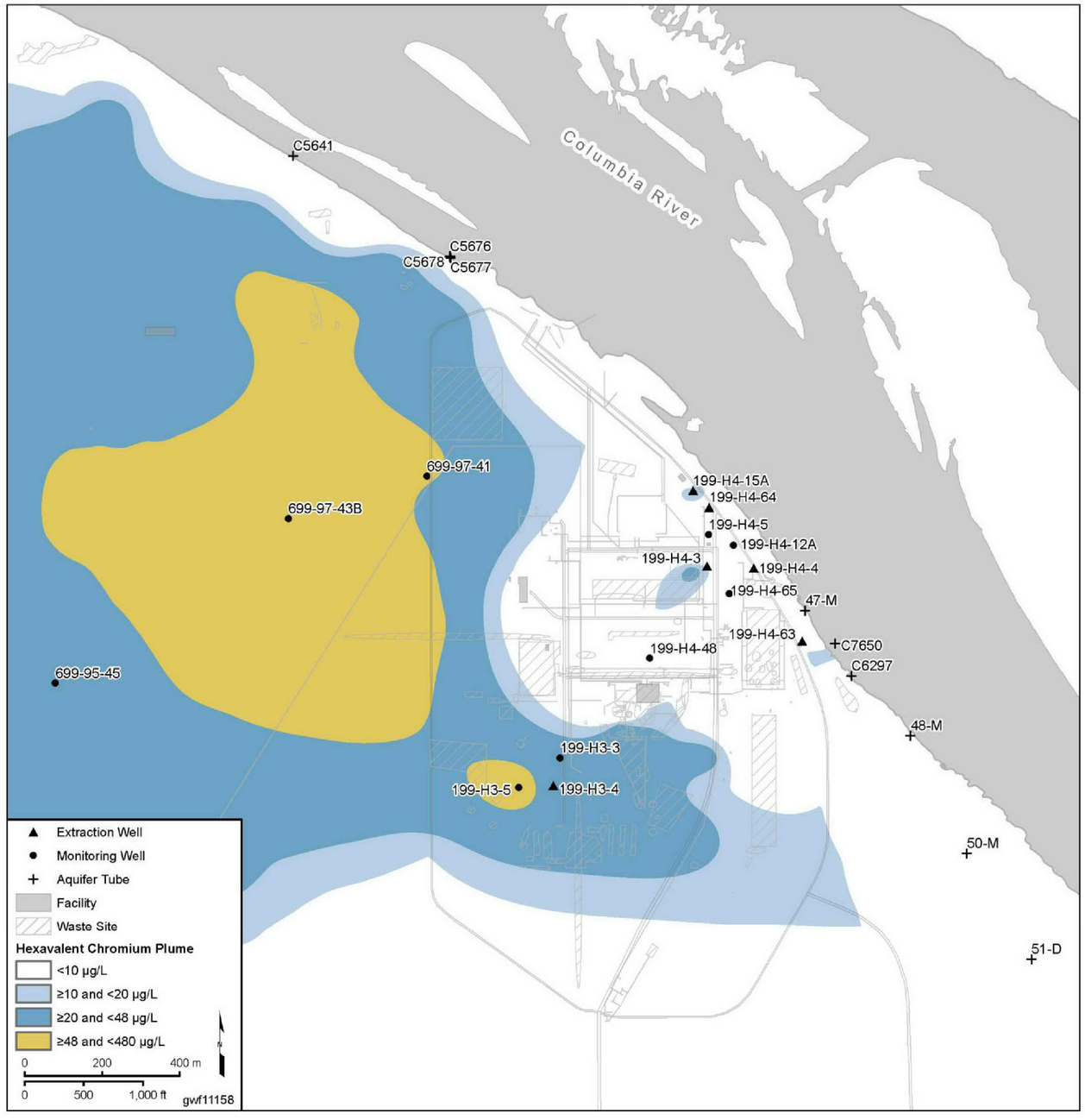
Figure 2.5-13. Composite Map and Trends for North 100-D Area Hexavalent Chromium Plumes (2005 to 2011)

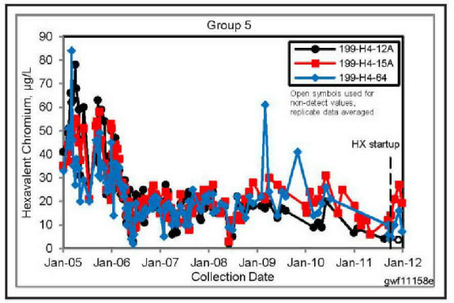


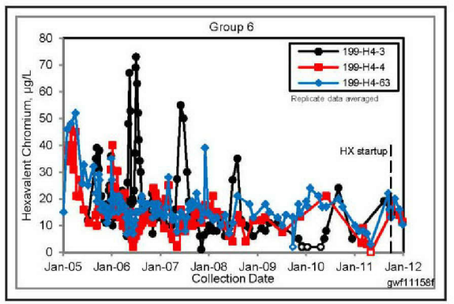


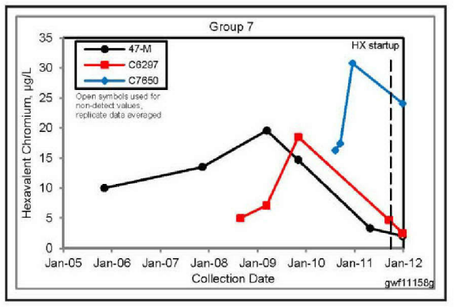












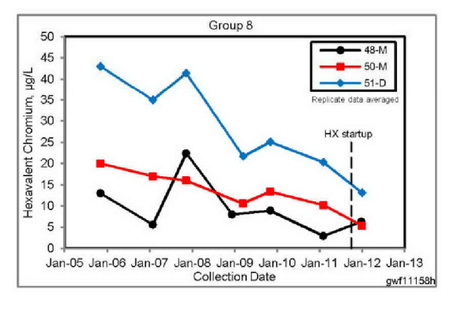


Figure 2.5-14. Hexavalent Chromium Trends in Wells Monitoring the Ringold Upper Mud Unit

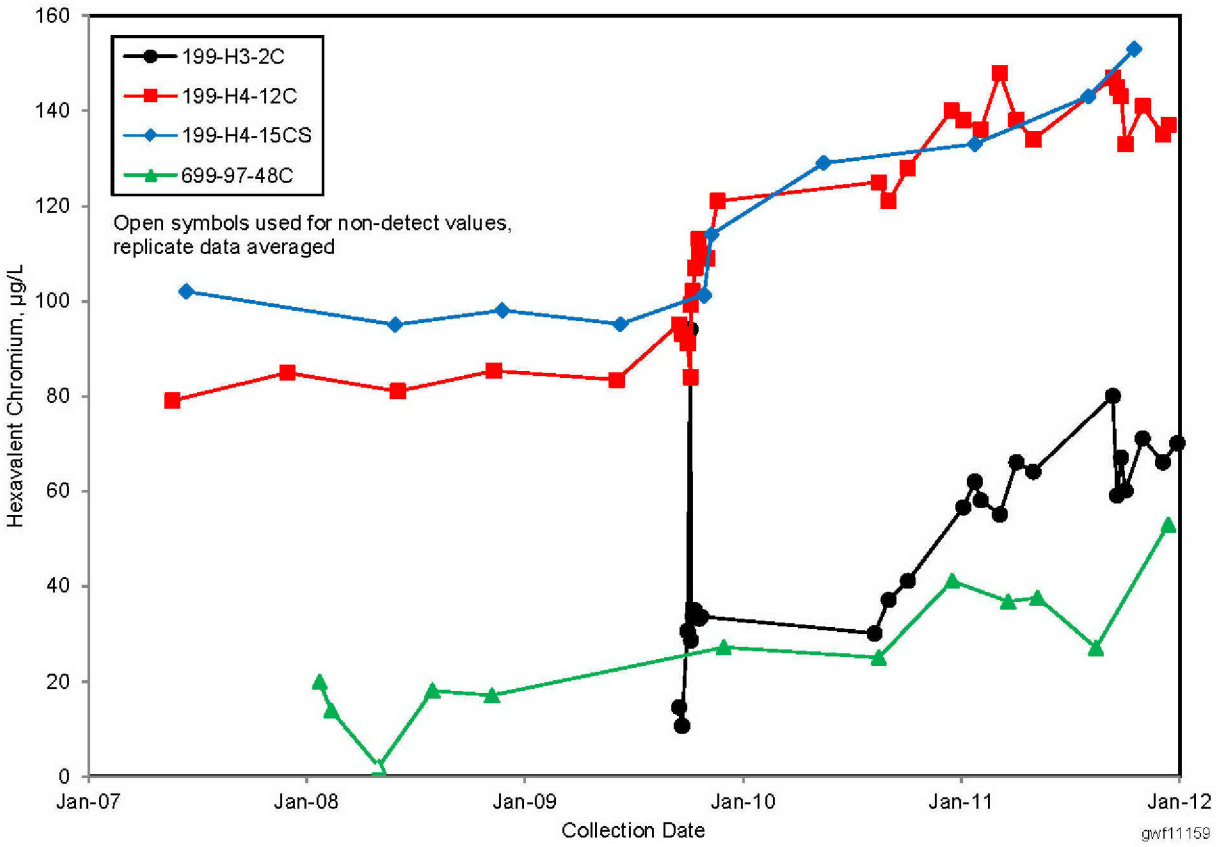


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Figure 2.5-15. Nitrate Plume Map

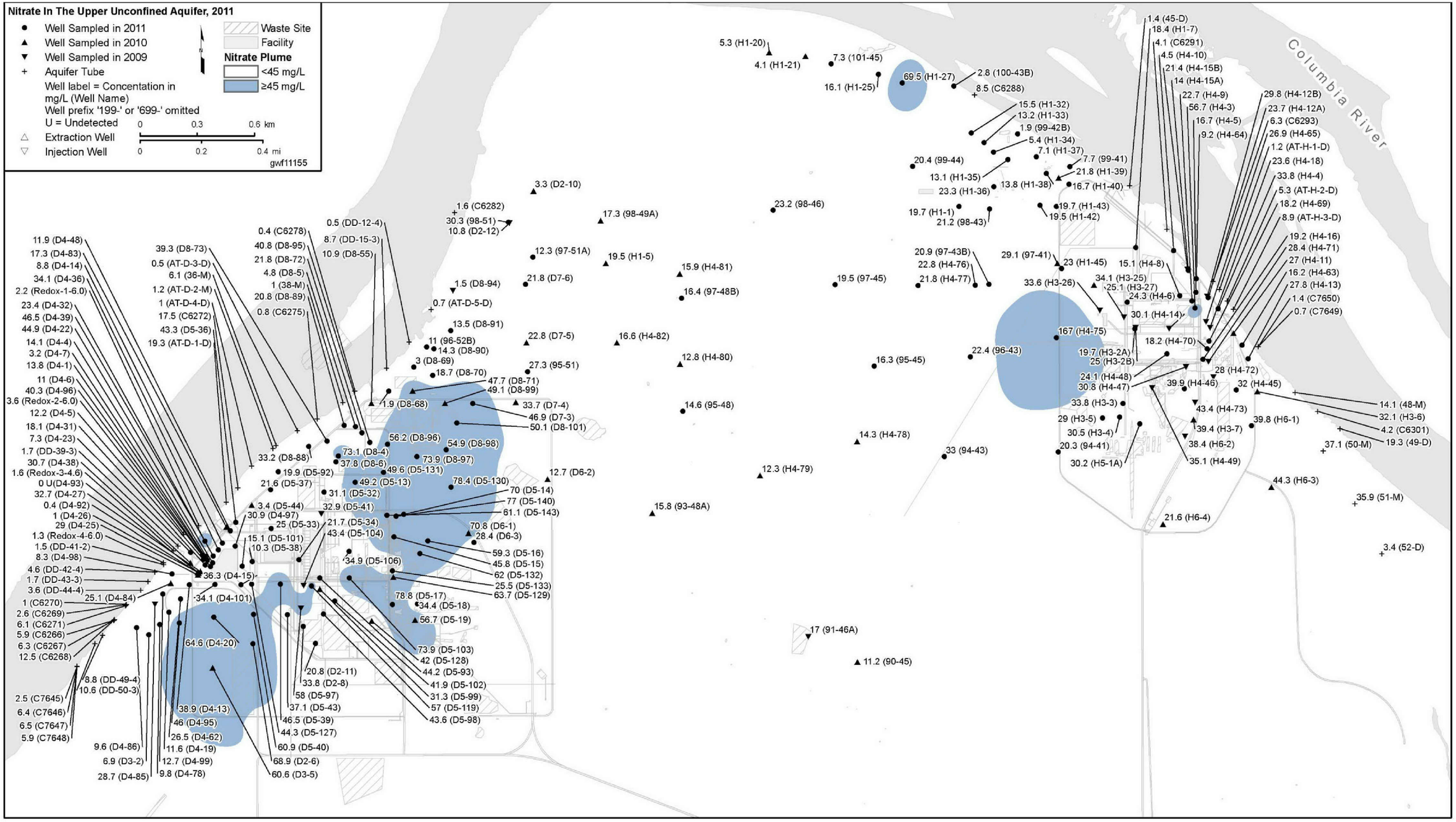

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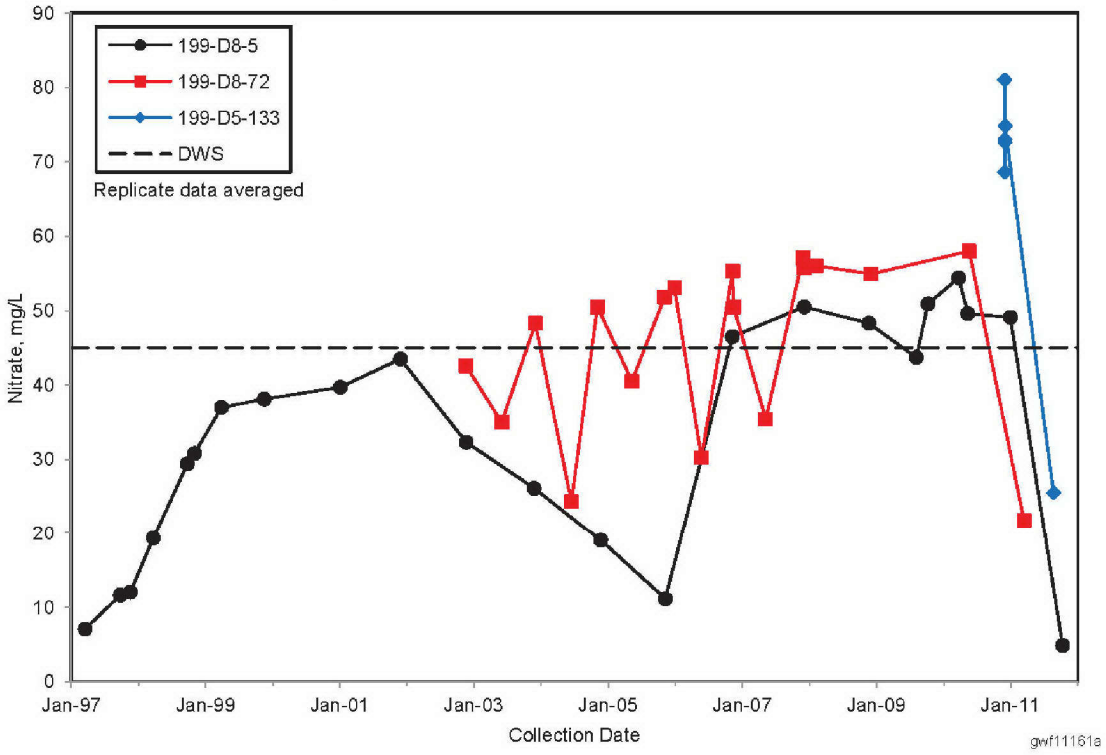
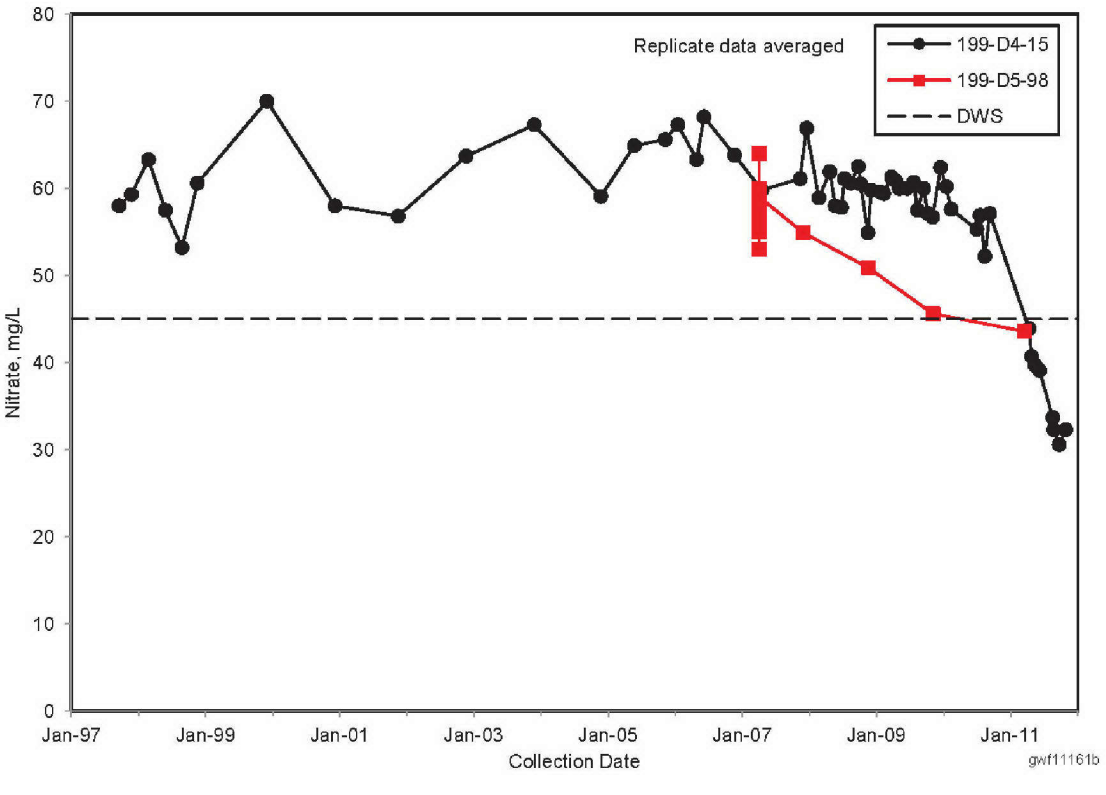
Figure 2.5-16. Two-Panel Nitrate Trend Plot





gwf11161

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

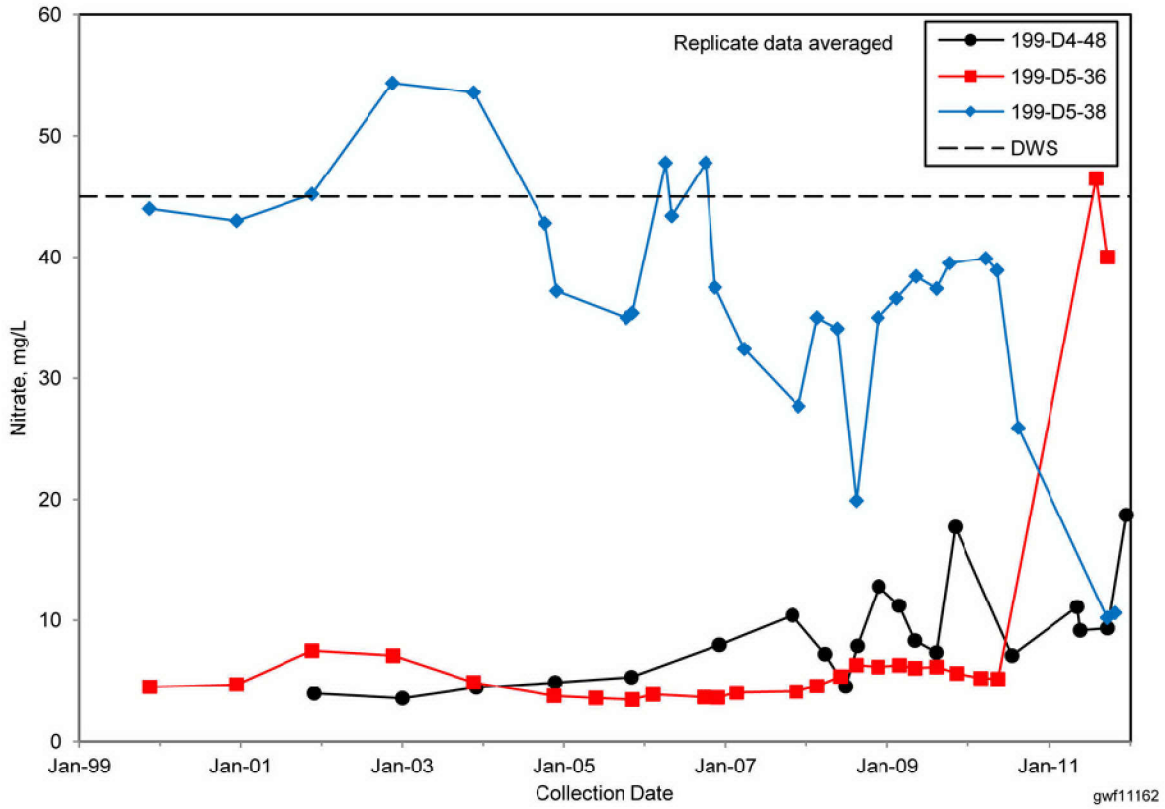


Figure 2.5-18. Strontium-90 Concentrations, Average 2011

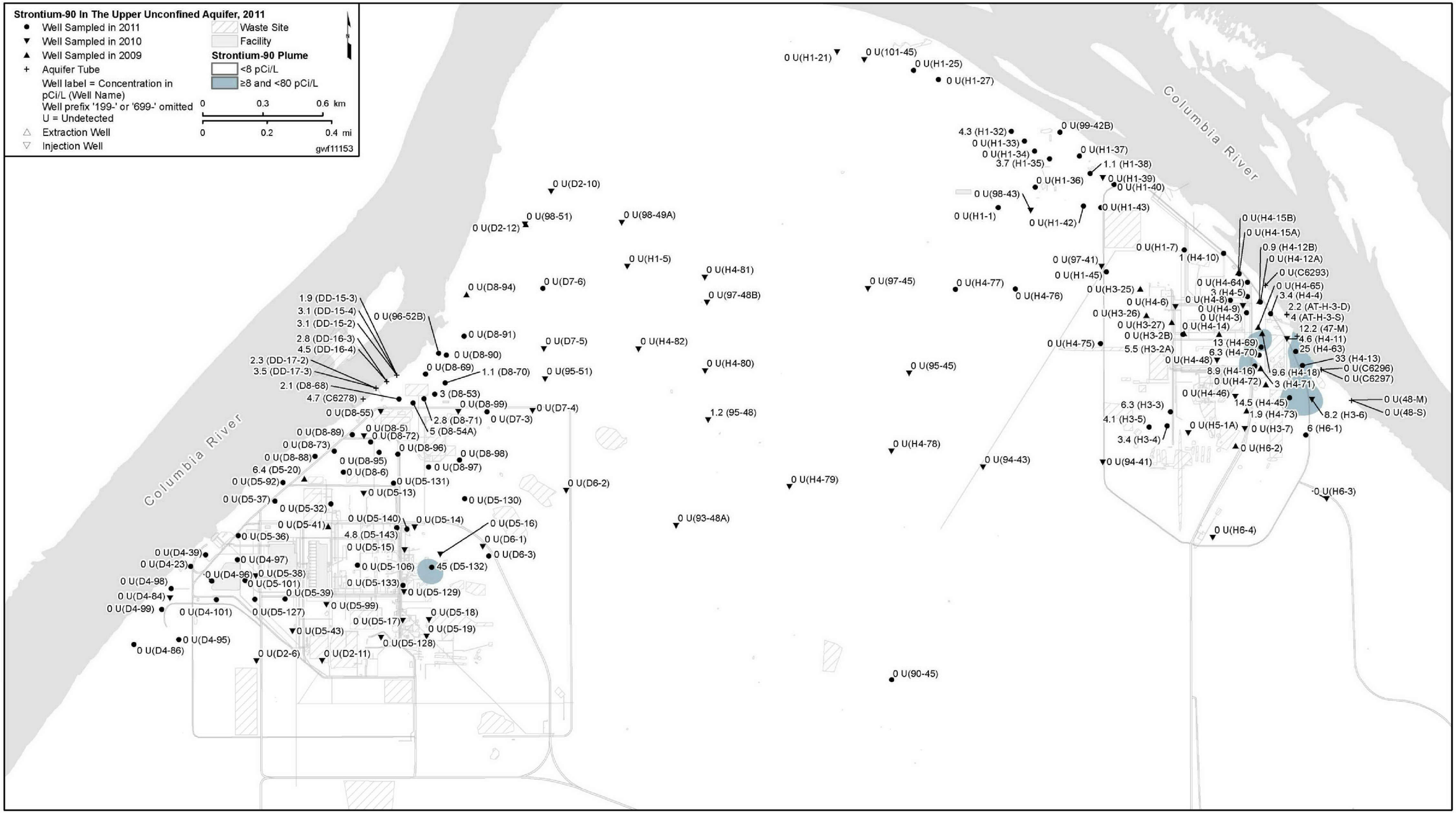


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Figure 2.5-19. Trend Plot for Tritium in 199-D3-2, 199-D4-19, and 199-D4-78 Compared to Drinking Water Standard

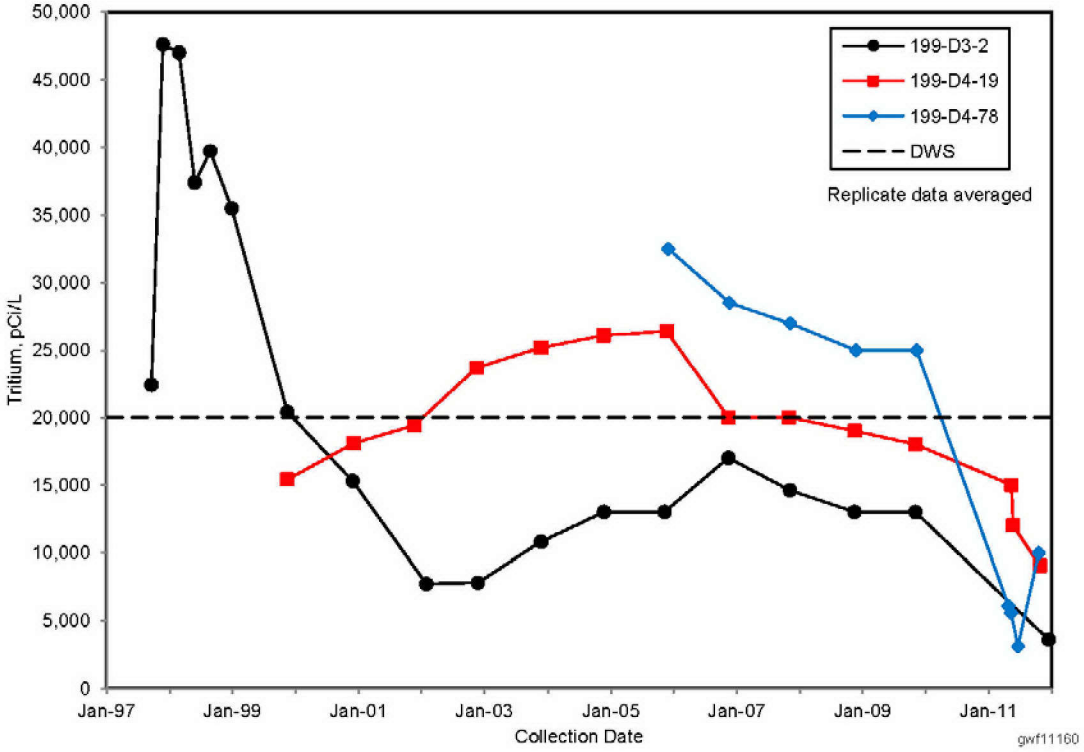


Figure 2.5-20. Stacked Bar Graph Showing Volume Water Treated and Mass Chromium Removed Over Time

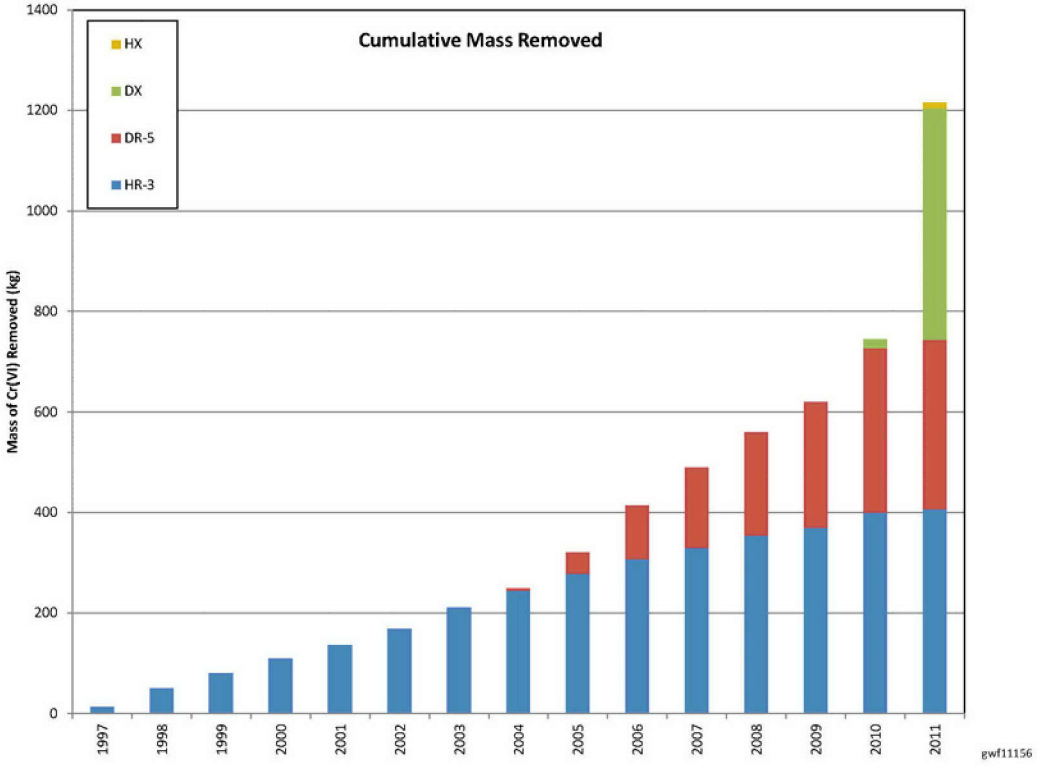


Figure 2.5-21. River Water Stiff Diagram

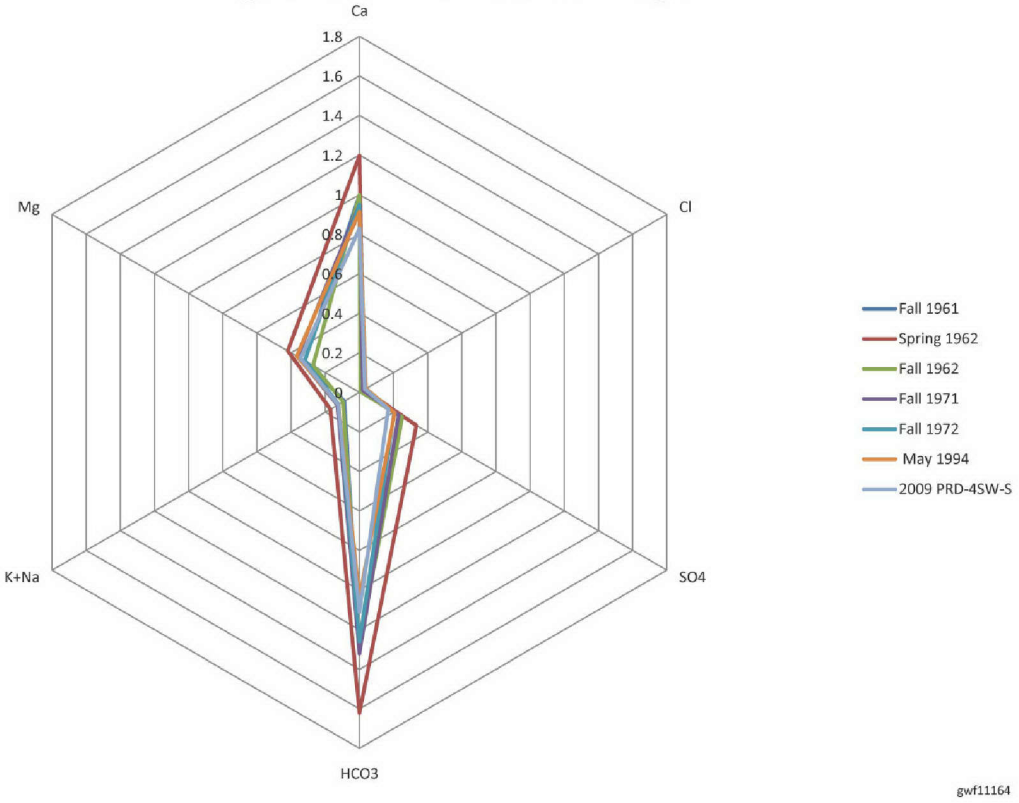
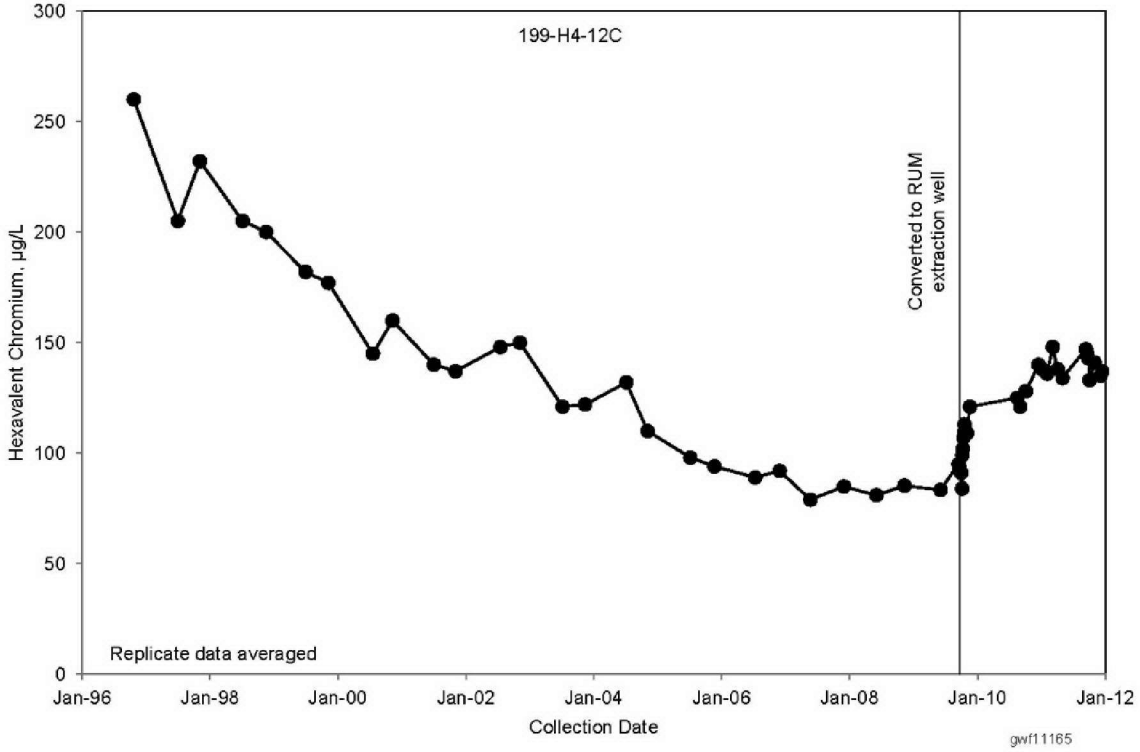


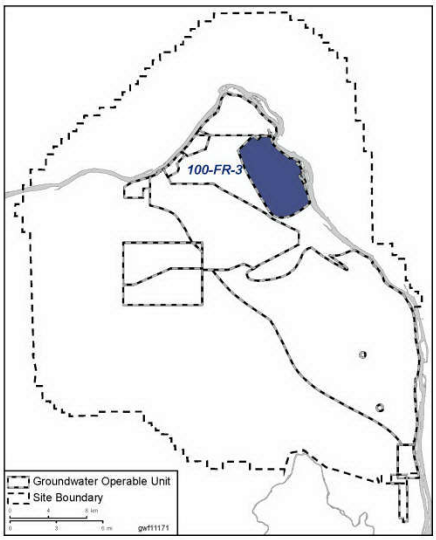
Figure 2.5-22. River Water Trend Chart (Hexavalent Chromium in Well 199-H4-12C)



2.6 100-FR-3

M.J. Hartman

This chapter describes groundwater flow and contaminant distribution in the vicinity of the 100-F Area, which is known as the 100-FR-3 Operable Unit. Figure 2.6-1 shows facilities, wells, and shoreline monitoring sites in 100-FR-3. Chapters 2 and 3 of DOE/RL-2008-46-ADD4 provide additional information on 100-F history, waste sites, and hydrogeology.



Groundwater monitoring for the AEA is integrated fully with CERCLA monitoring. No active waste disposal facilities or RCRA sites are in 100-FR-3. Previous assessments have not resulted in any interim remedial measures for groundwater. Most of the waste sites in the 100-F have been remediated or are classified as not requiring remediation. The area is currently undergoing a CERCLA RI, which will provide data to support final cleanup decisions.

The vadose zone and the unconfined aquifer in 100-FR-3 comprise Hanford formation sand and gravel. Ringold Formation unit E is largely absent in this region, limited to isolated remnants. The bottom of the aquifer is the Ringold upper mud unit. The aquifer ranges from 1 to 8 meters thick. Most of the monitoring wells are screened across all, or nearly all, of the aquifer.

Near the Columbia River, the direction of groundwater flow beneath 100-FR-3 varies with the Columbia River stage. Figure 2.6-2 shows the water table in March 2011, when the river was at a moderate level. The map indicates a flow direction toward the east-northeast (toward the river) in the western portion of 100-FR-3 and toward the southeast (approximately parallel to the river) in the eastern portion. Figure 2.1-3 in Section 2.1 illustrates the regional water table in this area. Southeast of 100-F, the water table slopes very gently at elevations ranging from 111 to 112 meters. This is approximately the same elevation as the Columbia River at this location. Consequently, the average direction of groundwater flow in this region is approximately parallel to the river.
The shoreline topography in this area is low and flat, and the shore is submerged during the high river stage (spring and early summer).

100-FR-3 at a Glance

F Reactor Operations: 1945–1965
Biological Experiments: 1945–1976

2011 Groundwater Monitoring				
Contaminant	**Drinking Water Standard**	**Maximum Concentration**	**Plume Area[a] (km^2)**	**Shoreline Impact (m)**
Nitrate	45 mg/L	201	10.6	0
Hexavalent Chromium	10/48[b] µg/L	23.5	0.17[c]	100[c]
Strontium-90	8 pCi/L	270	0.07	0
Trichloroethene	5 µg/L	14	0.70	0

Remediation

Waste Sites (interim action): >85% complete[d].
Groundwater (interim action): None.
Final ROD anticipated in 2013.

a. Estimated area above drinking water standard.

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

c. At the 10 µg/L level.

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

Normal seasonal variability in the water table in 100-FR-3 is more than 3 meters in wells near the river and decreases farther inland. During times of high river stage, water levels rise in the aquifer near the river, and a "valley" forms in the water table. Groundwater from east and west converges and moves toward the southeast, approximately parallel to the river. Flow may be influenced by a buried paleochannel of highly transmissive sediments. The changing river stage can affect concentrations in near-river wells temporarily, but the effects are local and short-lived. Spring and fall 2010 plume maps showed little difference (Chapter 8 of DOE/RL-2011-01). Most wells in 100-FR-3 were sampled once in 2011.

100-FR-3 Operable Unit Sampling and Analysis Plan (DOE/RL-2003-49) describes the routine groundwater monitoring requirements. Wells are sampled for the contaminants of concern selected using the data quality objectives process (PNNL-14287) (Appendix A). Most of the wells are sampled once per year or once every other year. Three wells installed in 2010 for the RI/FS have not yet been incorporated formally into the groundwater sampling and analysis plan. They were sampled quarterly during 2011 (Appendix A).

A subset of 100-FR-3 aquifer tubes is scheduled for annual sampling in the fall. All but one of the tubes were sampled in late 2011. Some 100-FR-3 tubes were also sampled in early 2011, delayed from the event scheduled in fall 2010. Appendix D lists sampling dates for the aquifer tubes.

Groundwater contaminants in 100-FR-3 include hexavalent chromium, nitrate, strontium-90, trichloroethene, and tritium. Figure 2.6-3 shows changes in plume sizes since 2003. Some of the apparent changes in plume sizes were the result of new data and not an actual change in size. These changes are discussed in the following sections.

2.6.1 Nitrate

A large nitrate plume from past sources in 100-FR-3 extends southward approximately 5 kilometers, although data are limited south of the 100-F Area (Figure 2.6-4). The size of the plume is stable, within the limits of what can be determined by the monitoring network. Because there are so few monitoring wells defining the large plume, the data are open to various interpretations. Changes in interpretation account for changes in the plume estimates illustrated on Figure 2.6-3.

Figure 2.6-5 shows nitrate trends in the three wells with the highest concentrations. Concentrations have declined since 2002 in well 199-F7-3 in southwestern 100-FR-3. New well 199-F5-54, in eastern 100-FR-3, had variable concentrations since it was installed in 2010, with a 2011 maximum of 145 mg/L. Temporary well 199-F5-56, near the F Reactor building, was sampled for nitrate for the first time in December 2011 and had the highest concentration in 100-FR-3 at 201 mg/L.

Aquifer tubes 62-M (northern 100-FR-3) and 75-D (approximately 2 kilometers downstream) historically have had the highest nitrate concentrations. Concentrations declined in these tubes in 2011 (Figure 2.6-6). The 2011 plume was interpreted to be narrower based on these changes.

2.6.2 Trichloroethene

Trichloroethene concentrations in the unconfined aquifer underlying southwestern 100-FR-3 (Figure 2.6-7) exceed the drinking water standard (5 μg/L), but are declining. A soil vapor investigation (DOE/RL-95-99, *100-FR-3 Groundwater/Soil Gas Supplemental Limited Field Investigation Report*) helped to define the area of contamination but did not identify the contamination source west of 100-F Area. Trichloroethene concentrations declined in wells in this region between 2010 and 2011 (Figure 2.6-8). The monitoring wells are screened across the entire aquifer thickness, which is less than 3 meters in this location.

Wells in other portions of the 100-F Area also detect trichloroethene at concentrations that fluctuate around the drinking water standard. Wells sampled in 2011 had concentrations below the standard.

One well in the 600 Area, approximately 6 kilometers west of 100-FR-3, consistently has trichloroethene concentrations above the drinking water standard. Concentrations have ranged from 7 to 11 µg/L in well 699-77-54 between 2005 and 2011. Figure 2.1-4 in Section 2.1 shows the location of this well. This contamination is not connected to the more prominent plume near 100-F Area, and its source has not been determined. It was not investigated during the RI.

2.6.3 Hexavalent Chromium

Sources of hexavalent chromium in 100-FR-3 included cribs near the reactor buildings, trenches, retention basins near the Columbia River, and pipelines from the reactor buildings to these near-river facilities. In 2011, soil contaminated with chromium was found in Waste Site 100-F-57, near the F Reactor building. The site was excavated to remove contaminated soil down to the water table (13 to 14 meters below ground surface) and is being backfilled in 2012. Other hexavalent chromium sources were previously remediated.

Figure 2.6-9 illustrates the portion of the chromium plume with concentrations greater than 10 µg/L in 2011. Wells 199-F5-6 and 199-F5-46 exhibited the highest concentrations in 2011 (~25 µg/L), and concentrations are declining with time (Figure 2.6-10).

Two 100-FR-3 wells are screened in a water-bearing zone of the Ringold upper mud unit, and concentrations of hexavalent chromium are near or below detection limits. Both are located within the footprint of the plume in the unconfined aquifer.

Hexavalent chromium concentrations in groundwater exceed the aquatic water quality standard in a few wells, but concentrations entering the river are below the standard.

Data from aquifer tubes and Columbia River pore water samples indicate that concentrations of hexavalent chromium entering the river are below the ambient water quality standard (10 µg/L). Two aquifer tubes formerly had concentrations slightly above the standard, but levels have declined (Figure 2.6-11). Columbia River pore water samples were collected near the 100-F Area in 2010 and early 2011. Hexavalent chromium concentrations were below detection limits at most locations. A single sample in 2010 exceeded the ambient water quality standard, but the result was questionable because the total chromium concentration was lower than that of the hexavalent; subsequent sampling showed no detectable chromium. All 2011 results were below the ambient water quality standard. Results are described in *Columbia River Pore Water Sampling in 100-F Area, February 2011* (SGW-49575).

2.6.4 Strontium-90

Primary sources of strontium-90 included the 116-F-14 Retention Basins and 116-F-2 Trench in the eastern 100-F Area. Additional sources were present near the reactor building and burial grounds. In eastern 100-FR-3, two wells had concentrations above the 8 pCi/L drinking water standard in 2011 (Figure 2.6-12). Data from aquifer tubes and pore water samples indicate that the plume does not reach the Columbia River at concentrations above the standard.

Two new temporary wells were sampled in December 2011 and had the highest strontium-90 concentrations in 100-FR-3 groundwater. These boreholes were installed in former waste sites to characterize the vadose zone and were completed as monitoring wells to obtain representative groundwater samples. Well 199-F5-55, in the center of the strontium-90 plume at the 116-F-14 retention basins, had a concentration of 270 pCi/L. Although there currently are no other wells adjacent to the retention basins, decommissioned well 199-F5-3 formerly had concentrations comparable to those detected in 199-F5-55 (Figure 2.6-13; see Figure 2.6-1 for well location). The next nearest downgradient well, 199-F5-1, has much lower concentrations.

Two new wells in former waste sites had higher concentrations of strontium-90 than have been seen in other wells in recent years.

Temporary well 199-F5-56, near the F Reactor building, had a concentration of 80 pCi/L in December 2011. This is the only well in this part of 100-FR-3 with strontium-90 concentrations above the drinking water standard. Nearby wells historically had strontium-90 concentrations ranging from less than the detection limit up to approximately 7 pCi/L, and strontium-90 is no longer analyzed at some of these wells. The contamination detected in 199-F5-56 is evidently part of a small, local plume. It is recommended that strontium-90 be added to the constituent lists for wells downgradient of this location, to watch for movement of the plume in the future.

Duplicate groundwater samples from characterization borehole C7971 in the 118-F-1 Burial Ground had strontium-90 concentrations of 7.99 and 8.5 pCi/L in February 2011. Wells 199-F8-3 and 199-F8-7 had lower concentrations (undetected and 5.5 pCi/L, respectively).

Strontium-90 shows vertical stratification in the only shallow/deep well pair in 100-FR-3. Deep well 199-F5-43B, which monitors a water-producing zone in the Ringold Formation upper mud unit, consistently has no detectable strontium-90. Its shallow counterpart screened in the unconfined aquifer, 199-F5-43A, typically has strontium-90 detections of 2 to 4 pCi/L.

2.6.5 Other Contaminants

Tritium concentrations in groundwater beneath 100-FR-3 have not exceeded the drinking water standard (20,000 pCi/L) since 2001. At lower concentrations, a plume extends to the southeast. Historically, tritium concentrations in groundwater samples from 199-F8-3 in southern 100-FR-3 have exceeded the drinking water standard. In the mid-1990s, concentrations at this well were approximately 180,000 pCi/L, and concentrations began to decline in the late 1990s. Because the decline began before most of the waste sites were remediated, the decline was likely caused by plume movement, dispersion, and radioactive decay. In 2011, the tritium concentration in 199-F8-3 was 12,000 pCi/L, an increase from 2010.

Uranium exceeded the drinking water standard in one new, temporary well.

The RI/FS work plan for 100-F (DOE/RL-2008-46-ADD4) did not identify uranium as a contaminant of potential concern for groundwater because uranium concentrations have historically been below the drinking water standard (30 µg/L). However, uranium is monitored in selected wells under the routine groundwater sampling and analysis plan (DOE/RL-2003-49). In 2011, new temporary well 199-F5-56, near the F Reactor building, was sampled for uranium with a result of 35 µg/L. The contamination is of limited extent. Nearby wells had uranium concentrations ranging from 11 to 15 µg/L in 2010 and 2011, which are consistent with Hanford Site background levels (Table ES-1 of DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*). DOE will continue to monitor this and other 100-FR-3 wells for uranium to track trends.

The 100-F RI work plan identified an extensive list of groundwater contaminants of potential concern (Table 4-3 of DOE/RL-2008-46-ADD4). Evaluation of the RI data concluded that only hexavalent chromium, nitrate, strontium-90, and trichloroethene remain contaminants of concern for groundwater (Section 6.3 of DOE/RL-2010-98, in progress).

2.6.6 CERCLA Groundwater Activities

In 2011, CERCLA activities associated with groundwater continued RI studies and routine groundwater monitoring.

Routine groundwater sampling requirements are defined in the groundwater sampling and analysis plan (DOE/RL-2003-49), as modified by TPA-CN-241, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records, 100-FR-3 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-49, Rev. 1 and TPA-CN-228 (July 14, 2008)*.

Fieldwork related to an RI/FS (DOE/RL-2008-46-ADD4) was performed in 2010 and early 2011. A draft RI/FS report (DOE/RL-2010-98) is being prepared, which will lead to the selection of alternatives for final action site cleanup. The draft report will undergo review by regulatory agencies and the public.

Well sampling occurred as planned in 2011 (Appendix A). The sampling and analysis plan does not yet include new wells installed for the RI/FS and should be updated. The new wells have been sampled quarterly for 1 year and will be sampled once in 2012. Two temporary monitoring wells, originally drilled as vadose zone boreholes under the RI, will also be sampled in 2012.

Figure 2.6-1. Facilities and Groundwater Monitoring Wells in 100-FR-3

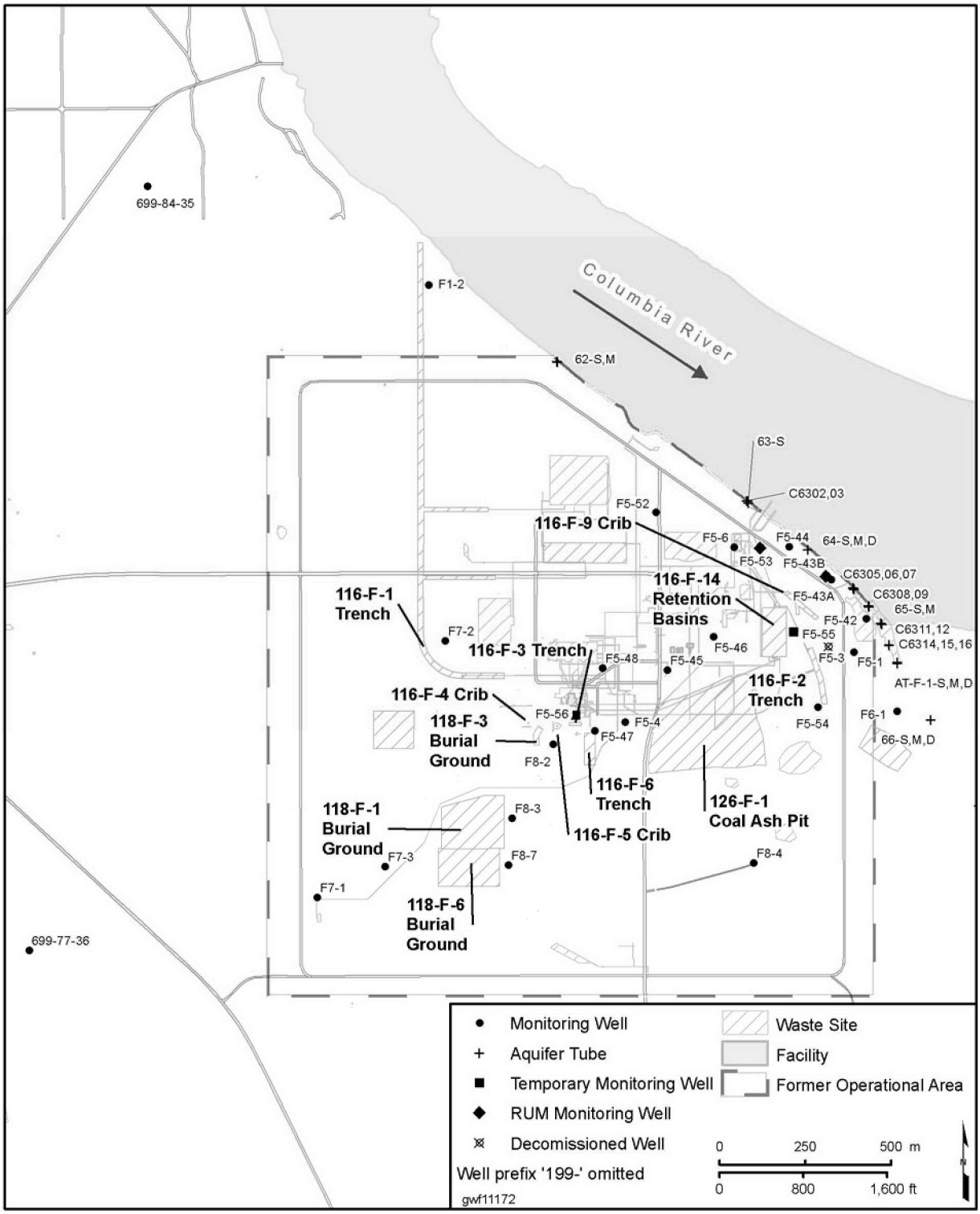


Figure 2.6-2. 100-FR-3 Water Table, March 2011

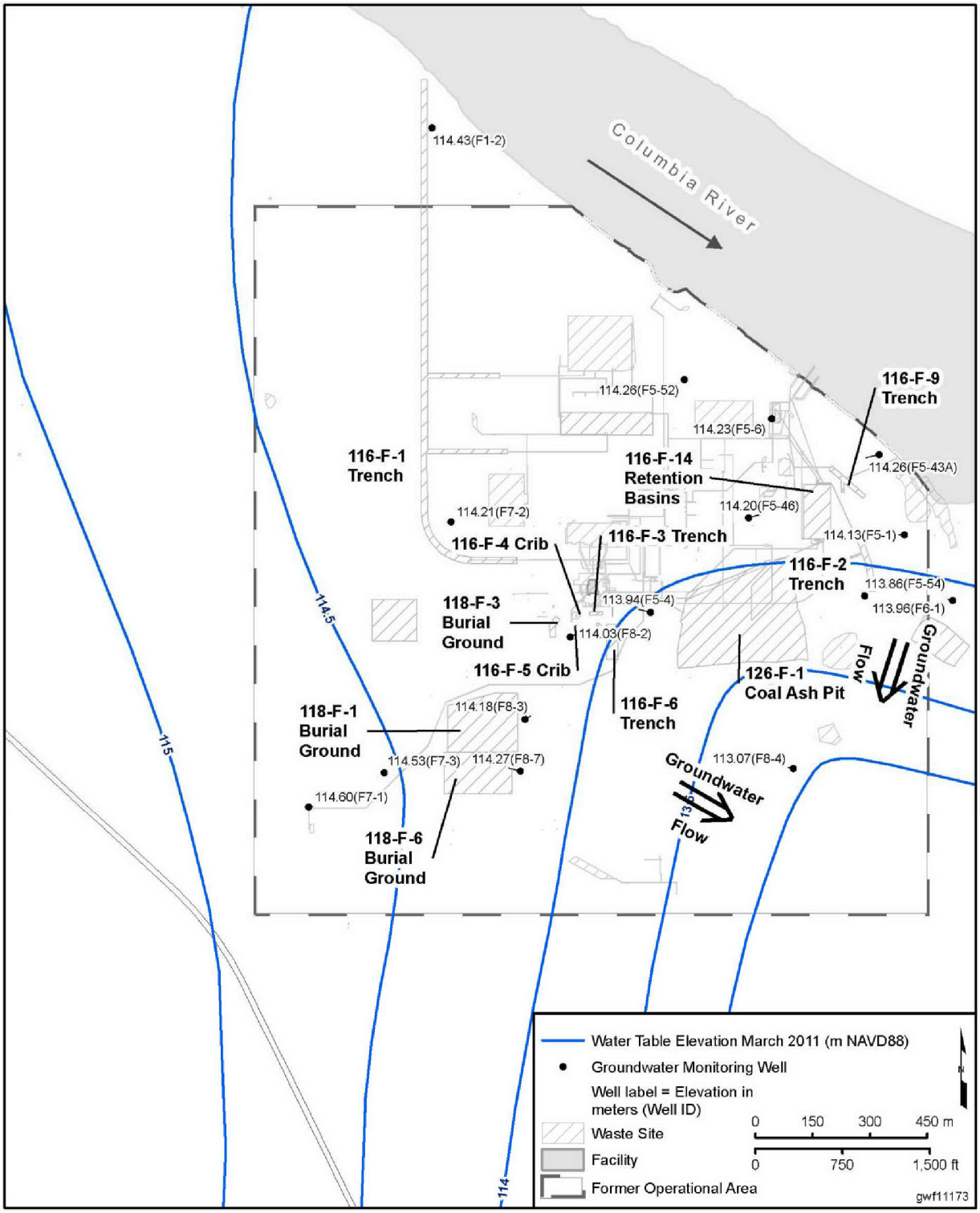


Figure 2.6-3. Changes in 100-FR-3 Plume Areas

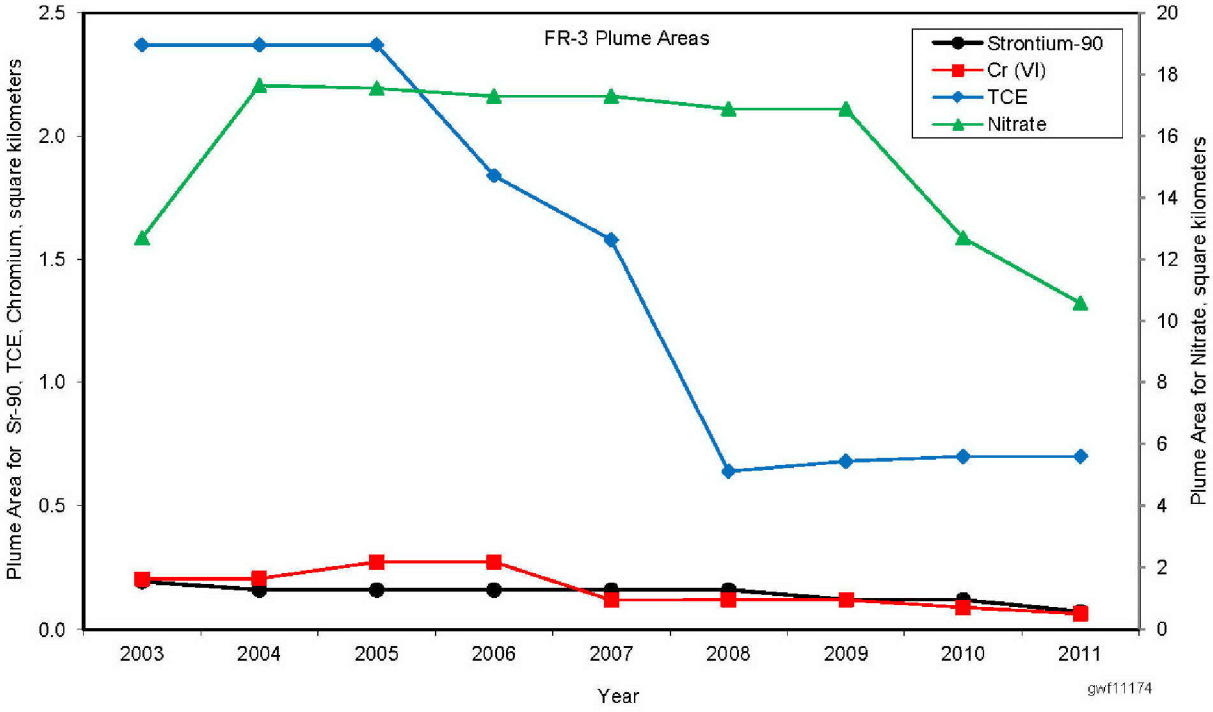


Figure 2.6-4. Average Nitrate Concentrations in 100-FR-3 and Vicinity, Upper Part of Unconfined Aquifer, 2011

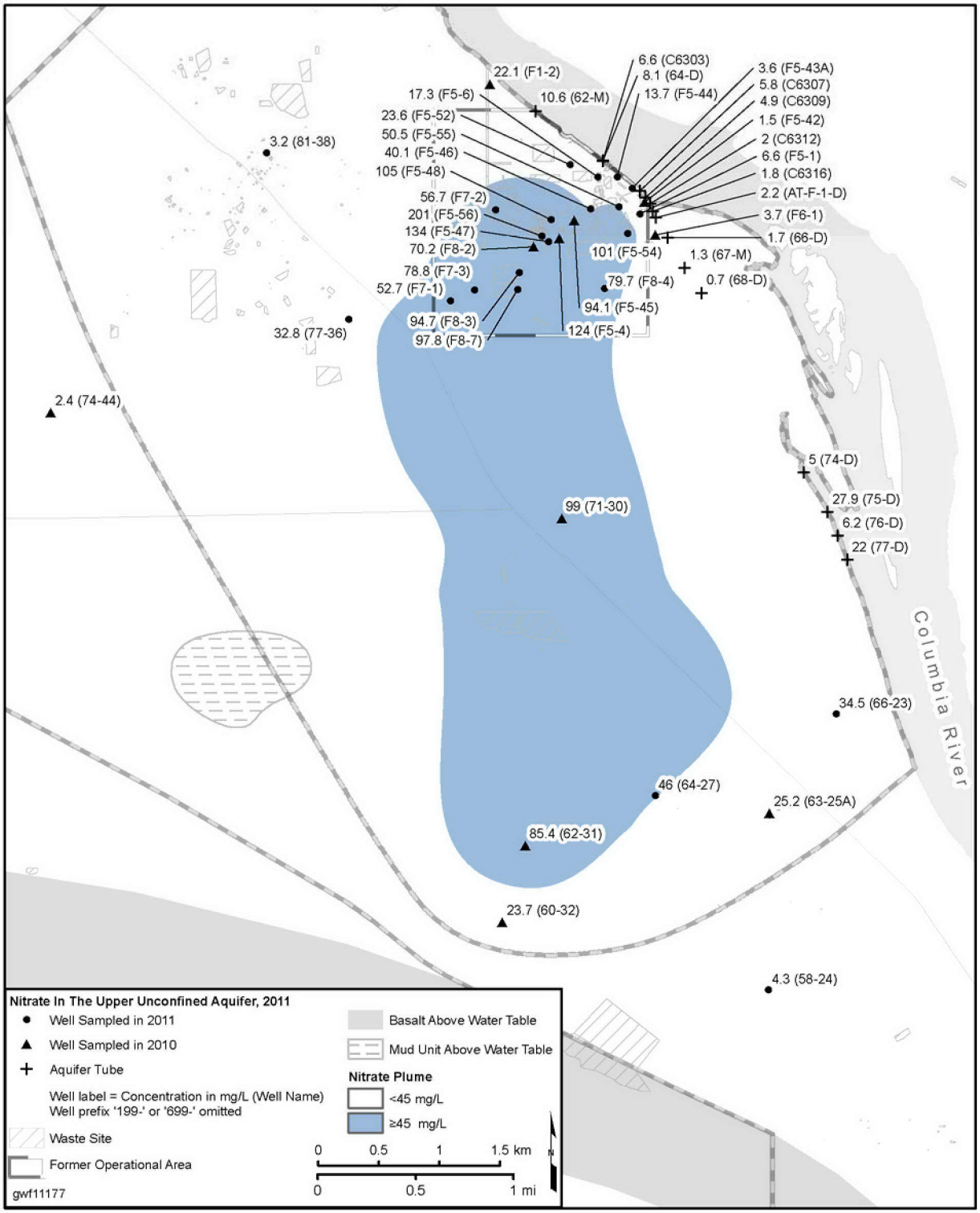


Figure 2.6-5. Nitrate Trends in Wells in 100-FR-3

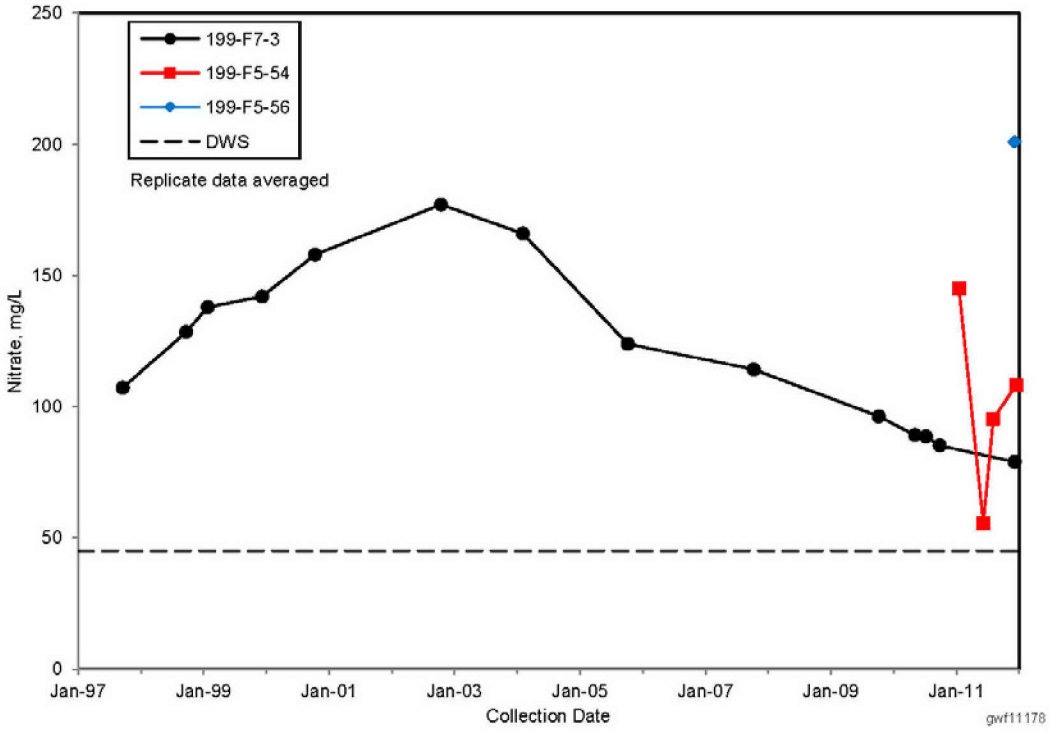


Figure 2.6-6. Nitrate Trends in 100-FR-3 Aquifer Tubes

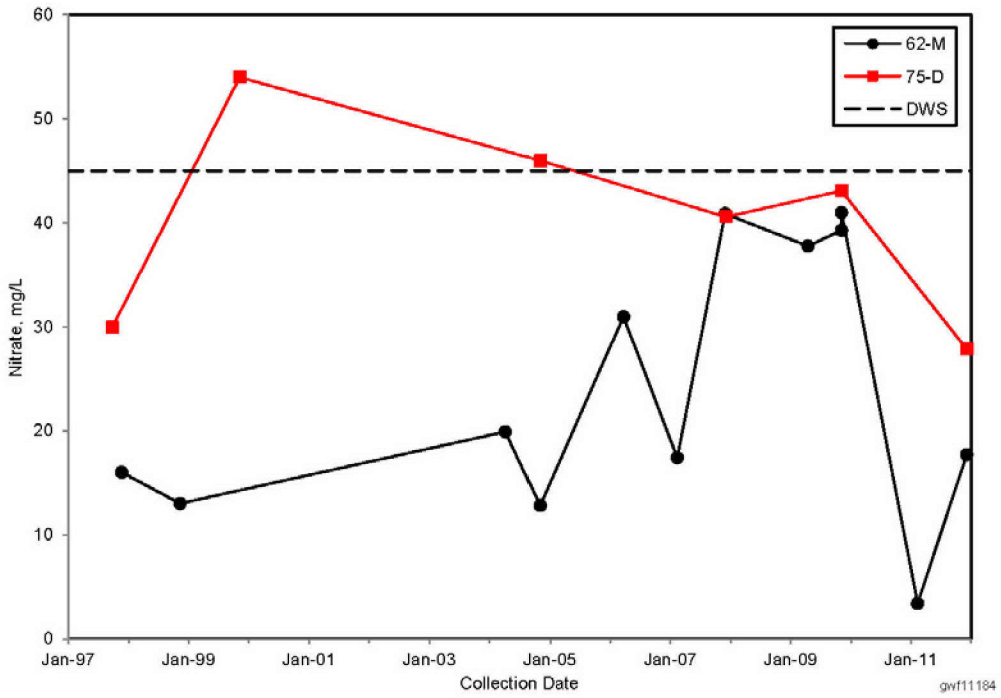


Figure 2.6-7. Average Trichloroethene Concentrations in 100-FR-3, Upper Part of Unconfined Aquifer, 2011

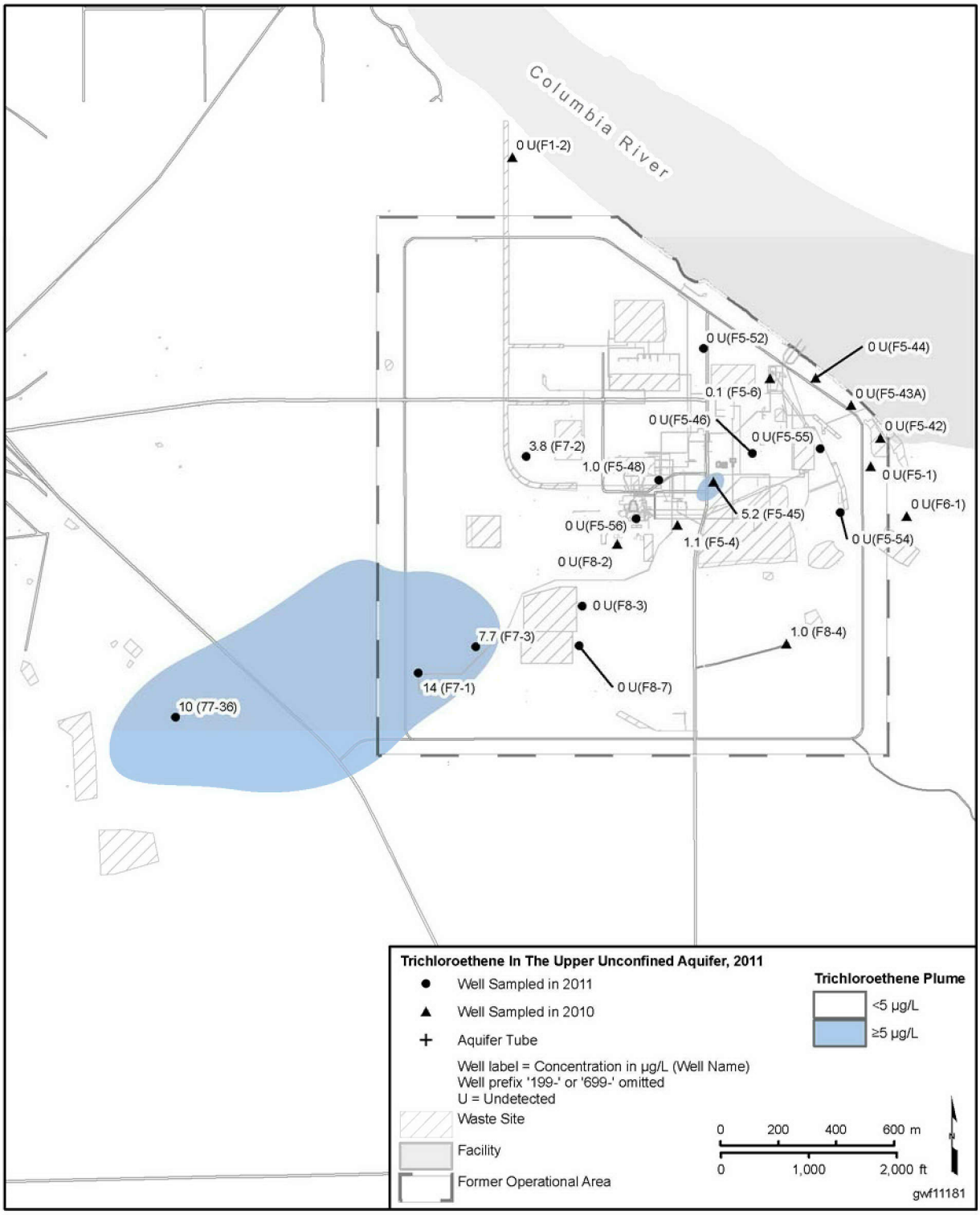


Figure 2.6-8. Trichloroethene Trends in Wells in Western 100-FR-3

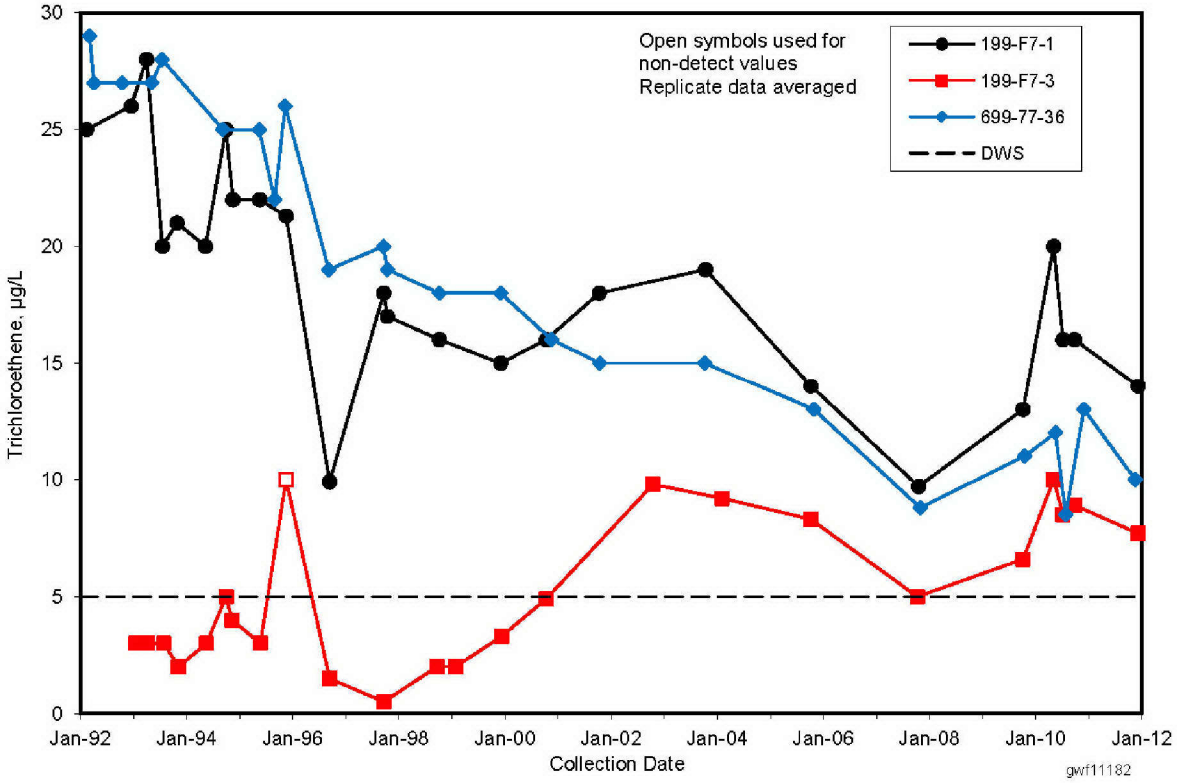


Figure 2.6-9. Average Chromium Concentrations in 100-FR-3, Upper Part of the Unconfined Aquifer, 2011

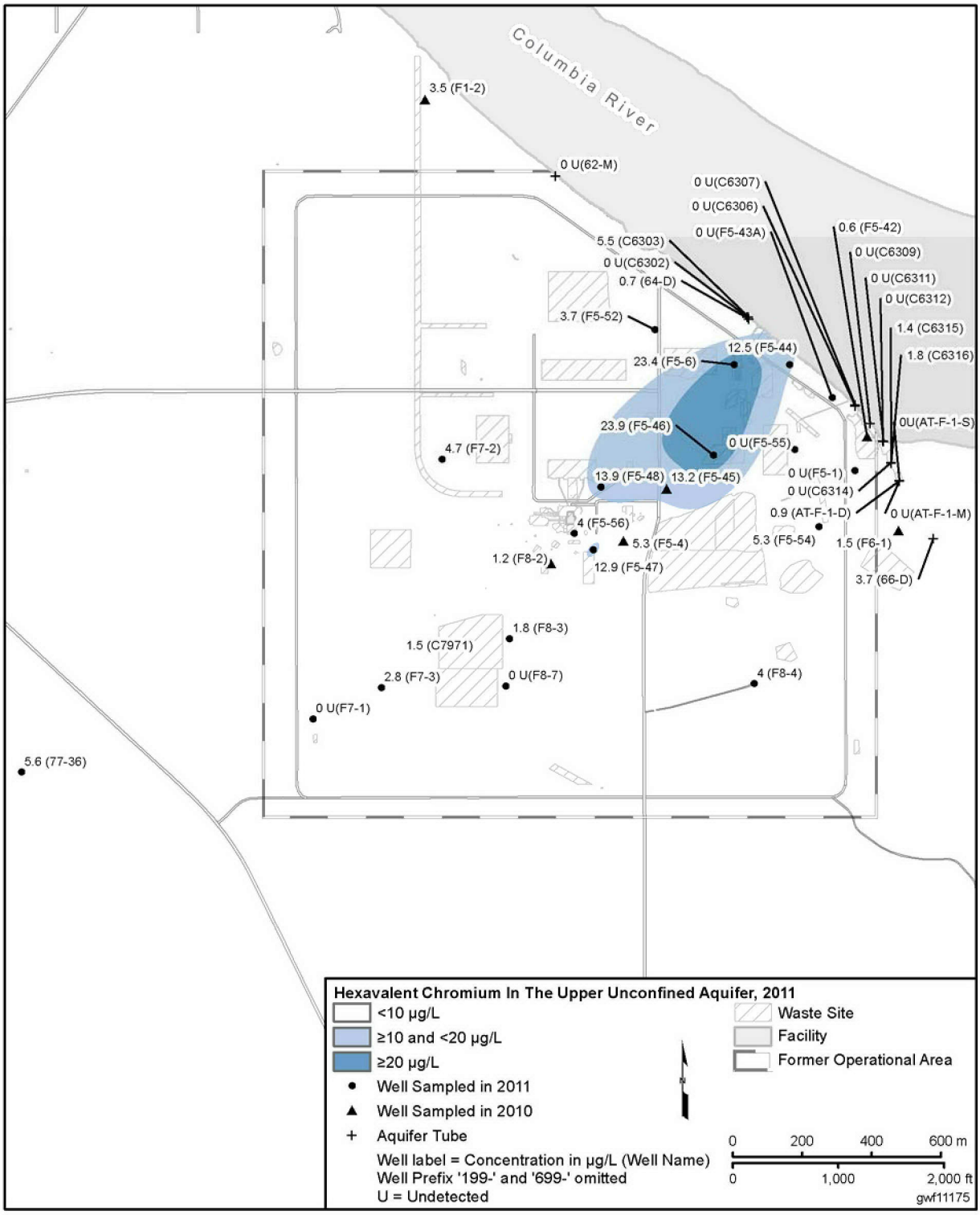


Figure 2.6-10. Dissolved Chromium Trends in Wells in Eastern 100-FR-3

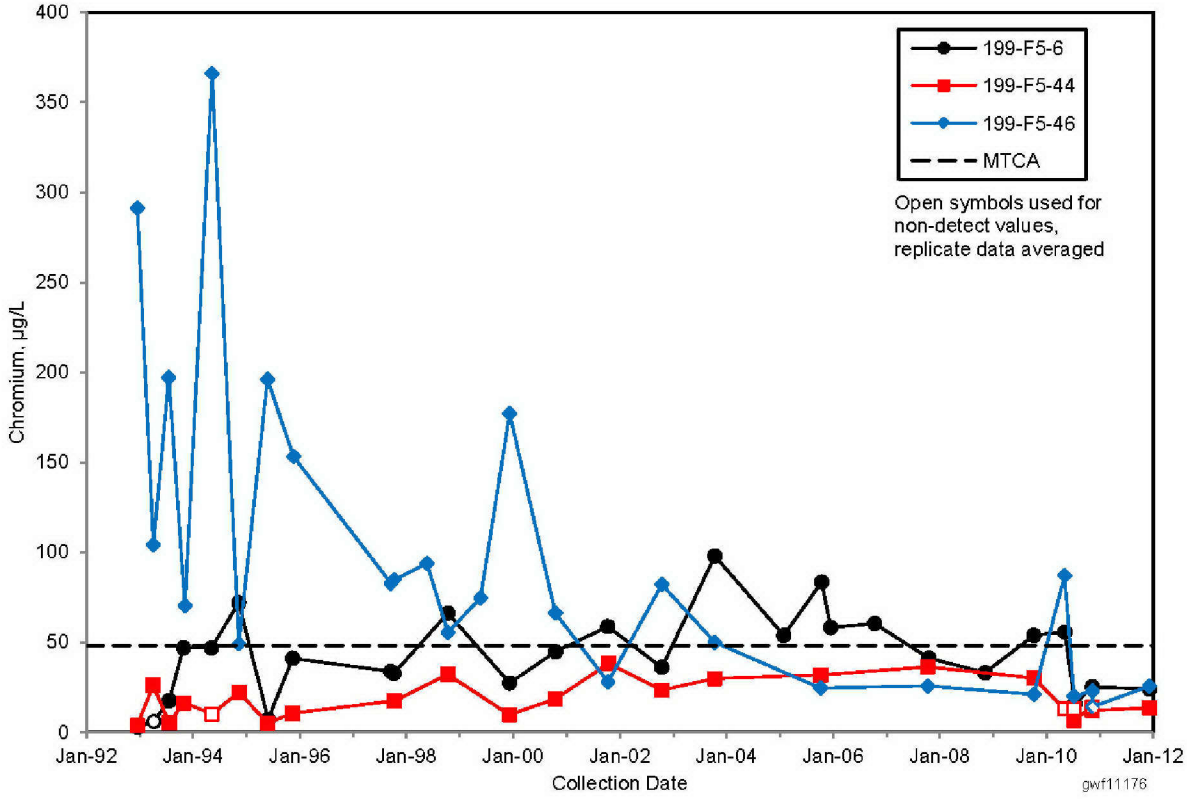


Figure 2.6-11. Hexavalent Chromium Trends in 100-FR-3 Aquifer Tubes

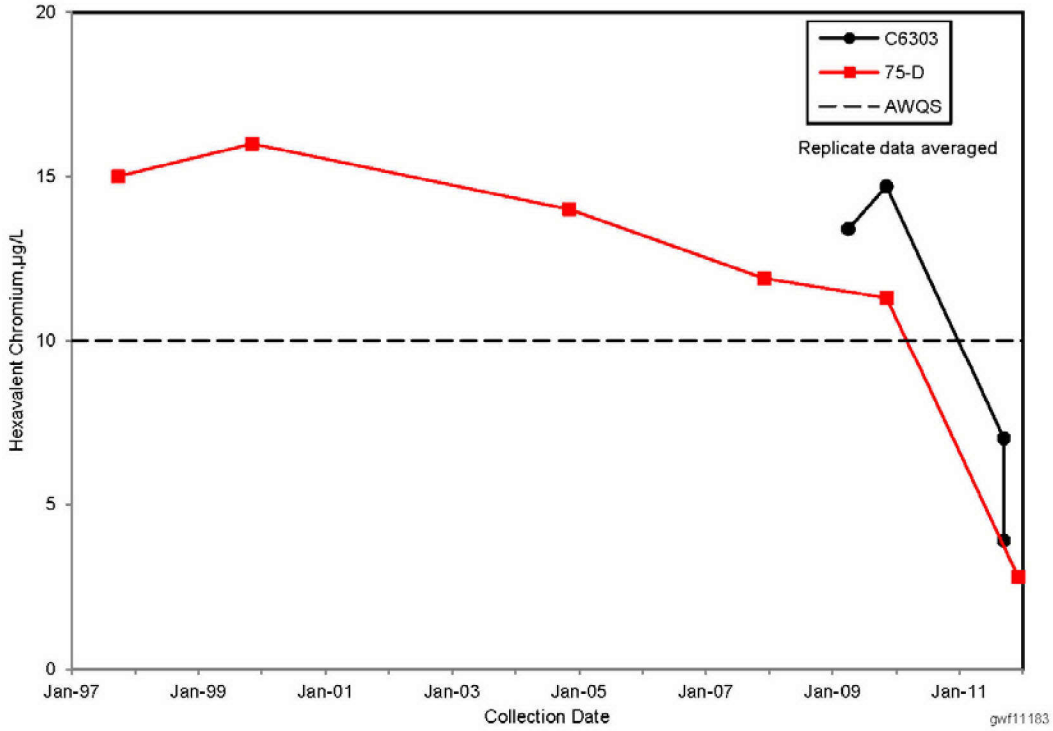


Figure 2.6-12. Average Strontium-90 Concentrations in 100-FR-3, Upper Part of Unconfined Aquifer, 2011

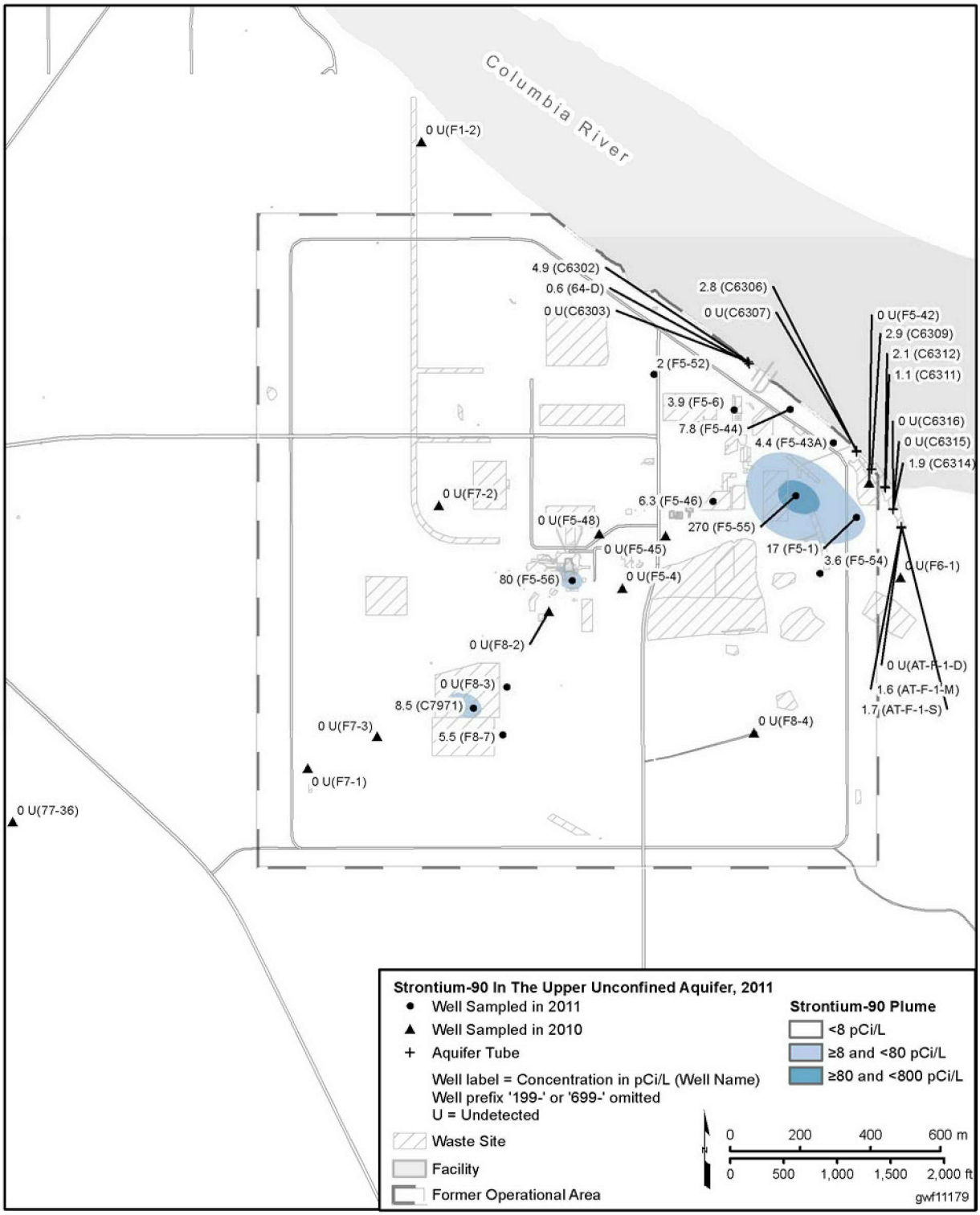
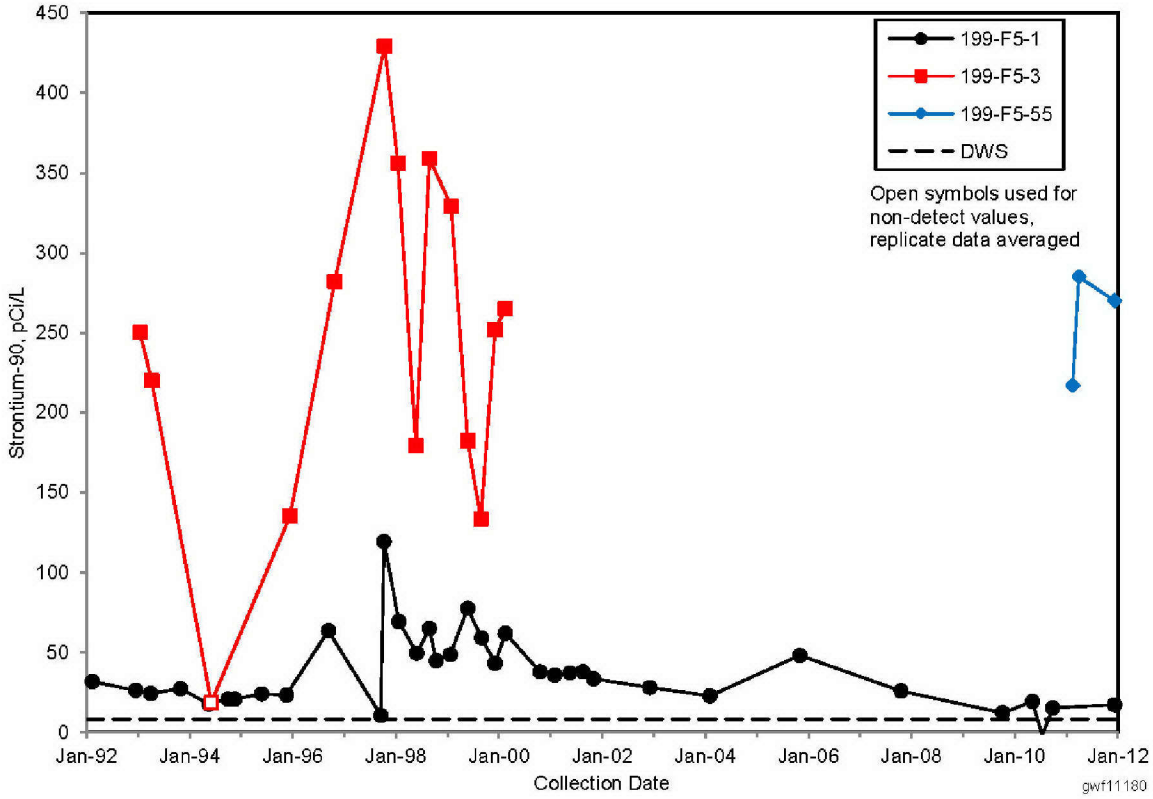
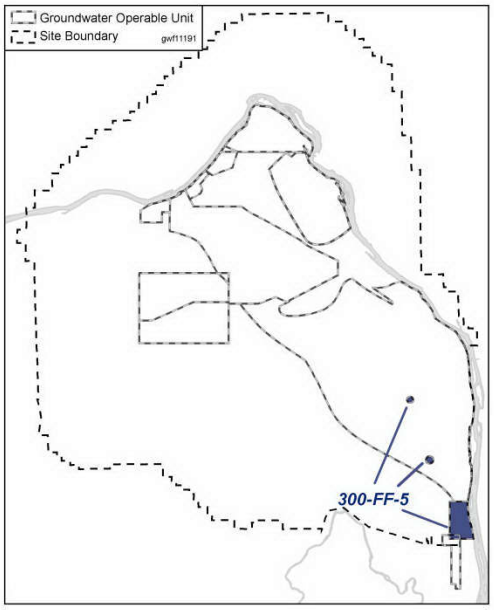


Figure 2.6-13. Strontium-90 Trends in Wells in Eastern 100-FR-3



2.7 300-FF-5

V.J. Rohay



The 300-FF-5 Groundwater Operable Unit is defined as groundwater that has been affected by waste disposal or unplanned releases associated with waste sites in the 300-FF-1 and 300-FF-2 Source Operable Units. The operable unit includes groundwater contaminated by releases at the 300 Area Industrial Complex, the 618-11 Burial Ground, and the 618-10 Burial Ground/316-4 Crib (Figure 2.7-1). Although 300-FF-2 includes waste sites in the 400 Area, the underlying groundwater has not been affected by releases associated with these waste sites and, therefore, is not included in 300-FF-5. Water supply wells in the 400 Area are monitored as part of 200-PO-1 to evaluate the potential impact of sitewide contamination (Section 3.5.9.10). Contaminated groundwater migrates to areas underlying 300-FF-1 and 300-FF-2 from waste sites associated with the 200 East Area (described as part of 200-PO-1 in Section 3.5) and from Hanford Site and non-Hanford Site sources to the southwest of the 300 Area (described as part of 1100-EM-1 in Section 2.8).

The contamination currently observed in 300-FF-5 groundwater originated primarily from historical routine disposal of liquid effluent associated with (1) fabrication of nuclear fuel assemblies and (2) research involving the processing of irradiated fuel. Periodic spills and accidental releases from various facilities also occurred. Because principal liquid waste disposal facilities have been out of service for decades and most have been remediated by removing contaminated soil (Section 4.0 of DOE/RL-2004-74, *300-FF-1 Operable Unit Remedial Action Report*), the contamination remaining in the underlying vadose zone and aquifer is residual. Limited release or remobilization of contamination from the lower vadose zone occurred after this remediation as a result of excavation of waste sites, removal of buildings, and migration processes still active at some of the unremediated sites.

The groundwater in 300-FF-5 is monitored under CERCLA and the AEA (DOE/RL-95-73, *Operation and Maintenance Plan for the 300-FF-5 Operable Unit*). Figures 2.7-2, 2.7-3, and 2.7-4 show the monitoring wells and waste sites for the 300 Area Industrial Complex, the 618-11 Burial Ground, and the 618-10 Burial Ground/316-4 Crib, respectively. The primary contaminants in the groundwater are uranium, volatile organic compounds (trichloroethene and cis-1,2-dichloroethene), tritium, and nitrate. In addition, the former 300 Area Process Trenches (316-5), an inactive treatment, storage, and disposal unit, are regulated under RCRA and undergoing post-closure monitoring.

Groundwater in the unconfined aquifer beneath the southeastern portion of the Hanford Site flows east or southeast toward the Columbia River, as indicated by the water table elevation contours shown on Figure 2.7-5. This flow direction is induced by regional groundwater flow that converges from the northwest, west, and southwest. Flow patterns throughout the region are complicated by the variable permeability of sediment in the upper portion of the unconfined aquifer. Near the Columbia River, groundwater flow is also influenced by river-stage fluctuations, which are related to upstream and downstream dam operations.

Contamination is generally found in the upper portion of the unconfined aquifer, i.e., the interval of Hanford formation gravelly sediment that lies below the water table (discussed in Section 2.1 and Appendix E). The thickness of the contaminated portion of the unconfined aquifer is variable because of

the undulating contact between the Hanford formation and the underlying Ringold Formation unit E. In addition, significant seasonal fluctuations in water table elevation (Section 3.0 of PNNL-17034, *Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington*) affect the thickness of the contaminated zone.

Beneath the 300 Area Industrial Complex, the undulating contact reflects paleochannels that act as preferential pathways for groundwater flow (Section 2.1.1; Figure 4-89 in DOE/RL-2010-99). Saturated Hanford formation sediment is much more permeable than the underlying sediment intervals. Tracer tests and tracking of unplanned releases indicate groundwater velocities as high as 18 meters per day in the Hanford formation (Section 3.2.2 of PNNL-18529, *300 Area Uranium Stabilization Through Polyphosphate Injection: Final Report*; Section 3.1 of PNNL-17666, *Volatile Organic Compound Investigation Results, 300 Area, Hanford Site, Washington*). Contamination introduced to the high velocity groundwater would be transported to the river environment as quickly as several weeks to months, depending on the input location and the mobility characteristics of the contaminant.

300-FF-5 at a Glance

Fabrication of nuclear fuel assemblies: 1943–1987

Research in irradiated fuel processing: 1950s–1960s

300-FF-5 includes 300 Area Industrial Complex, 618-10 Burial Ground/316-4 Crib, and 618-11 Burial Ground

2011 Groundwater Monitoring

Contaminant	Drinking Water Standard	Maximum Concentration	Plume Area[a] (km^2)	Shoreline Impact (m)
Uranium (300 Area)	30 µg/L	4,030 µg/L	0.49	1,160
cis-1,2-dichloroethene (300 Area)	70 µg/L	200 µg/L	Undefined[b]	Undefined[b]
Trichloroethene (300 Area)	5 µg/L	14 µg/L	Undefined[b]	Undefined[b]
Tritium (618-11)	20,000 pCi/L	1,000,000 pCi/L	0.33[c]	None
Nitrate (300 Area; 618-11)	45 mg/L	141 mg/L	0.24[c]	Not Calculated[c]

Remediation

Waste Sites (interim action): In progress 2011; >75 percent complete[d].

Groundwater (interim action): Monitored natural attenuation and institutional controls on the use of groundwater.

Record of Decision for final remedial action anticipated in 2013.

a. Estimated area above drinking water standard.

b. Organics are locally present in deeper sediments. Plumes cannot be defined by current data.

c. Excludes tritium and nitrate in plume associated with 200-PO-1 and nitrate from off-site.

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

Contaminant discharge to the river occurs via riverbank springs that flow across the beach region (riparian zone) during periods of low river stage and by upward movement through the riverbed. The rate of contaminant discharge to the river is influenced by daily and seasonal river-stage fluctuations (Section 3.2 of PNNL-17708, *Three-Dimensional Groundwater Models of the 300 Area at the Hanford Site, Washington State*). The highest seasonal river elevations typically occur from May through June, and the lowest seasonal river elevations typically occur from September through mid-November (Section 4.4.2 of DOE/RL-2010-99). Effects of high river elevations include temporary reversal of flow direction, dilution of contamination in groundwater near the river by the intrusion of clean river water, and possible influences on contaminant mobility caused by changes in the geochemical environment. Changes in the geochemical environment are most pronounced where river water intrudes into the aquifer. River water is lower in alkalinity (lower in bicarbonate content) and lower in specific conductance than groundwater (Section 2.1; Section 3.1.1.1 in DOE/RL-2010-99).

The rise and fall of the Columbia River results in a dynamic zone of interaction between groundwater and river water, causing distinct changes in contaminant plume characteristics.

The chemical and physical parameters associated with the groundwater vary among the hydrologic units within the aquifer beneath the 300 Area Industrial Complex (Section 3.1.1.1 and Table 3-7 in DOE/RL-2010-99). Groundwater in the upper portion of the unconfined aquifer (saturated Hanford sediment) has lower alkalinity (122 to 130 mg/L), higher specific conductance (422 to 484 µS/cm), and higher levels of dissolved oxygen (9.0 to 9.8 mg/L) than groundwater in the lower portion of the unconfined aquifer (Ringold sediment) (alkalinity 126 to 183 mg/L, specific conductance 295 to 373 µS/cm, dissolved oxygen 0.0 to 1.6 mg/L). The average pH of the groundwater is 7.6 (Table 4-22 in DOE/RL-2010-99).

The conceptual models describing the features, processes, and events associated with 300-FF-5 groundwater contamination were refined in 2011 as part of the RI/FS (Section 4.8 of DOE/RL-2010-99).

2.7.1 Uranium

Uranium is found in groundwater beneath the 300 Area Industrial Complex and, to a much lesser degree, beneath the 618-10 Burial Ground/316-4 Crib. Uranium contamination in groundwater is typically monitored by measuring total uranium in an unfiltered water sample. The drinking water standard for uranium is 30 µg/L. This standard is based on uranium's chemical toxicity to humans, which is associated with damage to internal organs. As of 2011, protection standards for freshwater aquatic organisms had not been established by EPA or Washington State. For the Hanford Site, natural background concentrations for uranium in groundwater in the unconfined aquifer are estimated to range between 0.5 and 12.8 µg/L (Table ES-1 of DOE/RL-96-61).

2.7.1.1 Uranium in the 300 Area Industrial Complex

Large volumes of liquid waste containing uranium were discharged to the former South Process Pond (316-1), North Process Pond (316-2), and 300 Area Process Trenches (316-5) (Figure 2.7-2). Disposal of uranium-bearing effluent to the last operational infiltration site, the 300 Area Process Trenches, ended in 1986. However, discharge of uncontaminated effluent continued at that site until December 1994 (Section 2.1 of PNNL-13645, *300 Area Process Trenches Groundwater Monitoring Plan*). Contaminated soil was removed from the site in 1991, with additional excavation of contaminated soil at this site and other major LWDFs in the 300 Area Industrial Complex occurring from 1997 through 2000. These excavations remained open until backfilling was completed at all excavated sites during early 2004 (Section 3.0 of DOE/RL-2004-74*).*

The areal extent of uranium-contaminated groundwater that exceeds the drinking water standard is estimated to be 0.5 square kilometers beneath the 300 Area Industrial Complex, based on the annual average concentrations (Figure 2.7-6). The mass of uranium dissolved in the plume is estimated to be 90 kilograms (Section 4.4.4.3 of DOE/RL-2010-99). Approximately 4,000 kilograms of uranium may remain in sediment and moisture associated with the vadose zone, and approximately 180 kilograms of uranium may be associated with aquifer sediments and groundwater (Section 6.3 of PNNL-17034). The flux of uranium to the Columbia River via groundwater discharge may be several tens of kilograms per year, with an additional 10 kilograms removed from the aquifer through well 399-4-12, providing water for the aquariums in the 331 Life Sciences Building at Pacific Northwest National Laboratory (Section 3.7.1.1 of DOE/RL-2010-99). The water withdrawn for the aquariums was not treated to remove the uranium prior to discharge to the river.

Figure 2.7-7A shows uranium concentrations for the seasonal high water table conditions in June 2011. Groundwater elevations during May and June 2011 were atypically high because of unusually high runoff in the Columbia River drainage basin. The water table was elevated sufficiently to rewet a portion of the vadose zone where residual amounts of mobile uranium remain at some locations. The rewetting of the vadose zone mobilized uranium into the groundwater, causing dramatically higher concentrations in several wells adjacent to the former 300 Area Process Trenches (316-5) and the North Process Pond (316-2) (Figure 2.7-8, Figure 2.7-9 inland wells). These wells are also near the process sewer system spur that transported effluent to the former North Process Pond (1948 to 1975) and subsequently to the former 300 Area Process Trenches (1975 to 1985). Of particular note, the uranium concentration observed at well 399-1-17A near the southern end of the 300 Area Process Trenches was 4,030 µg/L, which is an order of magnitude greater than the highest concentrations previously measured (Figure 2.7-8). The positive correlation between water table elevation and uranium concentration suggests that at or near these locations, uranium remains in the lower portion of the vadose zone and is available to be remobilized during periods of high water table conditions. Since June 2011, these anomalously high concentrations have declined to their more typical seasonal values.

Typical characteristics of the plume during seasonal high water table conditions include (1) lowered concentrations along portions of the Columbia River shoreline, and (2) increased concentrations farther inland near source areas. The reduction in concentrations near the shoreline is caused by dilution from intrusion of river water into the aquifer. The increase in concentrations near source areas is caused by mobilization of residual contamination resulting from temporary elevation of the water table. During seasonal low water table conditions, the highest concentrations in the plume are often observed near the river, where uranium introduced inland during the preceding period of high water table conditions has migrated downgradient to the shoreline, and intrusion of river water into the zone beneath the shoreline is lessened because of the lower river stage (Section 3.3 of PNNL-17034). Figure 2.7-7B shows the uranium concentrations for the seasonal low water table conditions in December 2011. Figure 2.7-9 shows the uranium concentration trends at locations representative of inland and near-river conditions.

Higher-than-normal uranium concentrations were observed in June 2011 as a result of the higher-than-normal river stage.

Figure 2.7-6 shows the trend in the areal extent of the uranium plume since 2004. The areal extent increased in 2006. The area has remained relatively constant from 2006 through 2011. Causes for the persistence of the plume include continued (1) resupply from secondary sources in the vadose zone and (2) interaction between dissolved uranium and solids in the unconfined aquifer and a widespread zone through which the water table fluctuates (‘periodically rewetted zone’) that contains mobile uranium (Section 4.4.4.3 of DOE/RL-2010-99).

A new area of uranium contamination in groundwater developed in 2008 immediately downgradient from the former 618-7 Burial Ground (Figure 2.7-7A). The contaminant plume resulted from the infiltration of dust-control water and soil fixatives used during remediation activities conducted during 2007 and 2008 at the former 618-7 Burial Ground. In addition to uranium, increases in the concentrations of chromium and constituents associated with soil fixatives (for example, calcium and chloride) also occurred at well 399-8-5A, which is adjacent to the waste site (Section 2.7.5). By the end of 2010, concentrations at nearby downgradient wells continued to decrease, indicating passage of the contaminant plume (Figure 2.7-10). However, uranium concentrations increased again in samples collected just after the seasonal high water table conditions (August 2011), suggesting that mobile uranium remains in the lower portion of former 618-7 Burial Ground near well 399-8-5A. Concentrations subsequently declined later in the year. The plume has not been clearly recognizable along its projected migration path at distances greater than approximately 340 meters (that is, at well 399-8-1), although some variability in

uranium concentrations at downgradient wells, such as well 399-3-6, may be associated with migration of this plume. Monitoring wells 399-1-58, 399-1-59, 399-6-3, and 399-6-5, which were installed as part of the remedial investigation during late 2010, provide additional locations to monitor the downgradient migration of this plume. In 2011, the uranium concentrations in these four wells were below the drinking water standard.

Remediation activities at the former 618-7 Burial Ground mobilized uranium, affecting the groundwater.

The uranium plume maps on Figures 2.7-7A and 2.7-7B show June and December 2011 conditions, respectively, in the upper portion of the unconfined aquifer where uranium contamination is contained within saturated Hanford formation gravel sediment. Wells that monitor the lower portion of the unconfined aquifer in the 300 Area Industrial Complex are screened in the Ringold Formation unit E gravelly sediment (wells with a "B" suffix and wells 399-1-8, 399-3-21, and 399-3-22). Uranium concentrations in samples from these wells are typical of natural background levels, indicating little or no downward migration of contaminant uranium below the saturated Hanford formation sediment. Hydrographs for wells screened in saturated Hanford formation sediment or Ringold Formation unit E sediment are virtually identical, indicating no significant vertical gradients. Contamination has not been detected in the few wells that monitor the uppermost confined aquifer, which is a low-to-moderately permeable interval within the Ringold Formation lower mud unit (wells with a "C" suffix and well 399-1-9). Hydrographs for these wells show a distinct upward hydraulic gradient, with a head difference of approximately 9 meters.

Uranium contamination in groundwater near the Columbia River is monitored by sampling near-river wells, aquifer tubes at twelve sites along the shoreline, and several prominent riverbank springs, if they are flowing (Section 3.1 of PNNL-17034). Figure 2.7-11 shows the uranium concentrations observed in samples collected from November and December 2011 from aquifer tubes and near-river monitoring wells. The lateral distribution of uranium, as indicated by the aquifer tube sample results, is consistent with the groundwater plume map for seasonal lower river stage conditions (Figure 2.7-7B). Maximum uranium concentrations measured at the twelve aquifer tube sites sampled in 2011 are lower than those seen previously (Figure 2.7-12).

Several thousand kilograms of contaminant uranium may remain in the vadose zone and aquifer beneath the 300 Area Industrial Complex.

The mass of uranium in the groundwater plume is approximately the same amount as the mass that leaves the plume each year via groundwater discharge to the Columbia River and withdrawal at a water supply well, suggesting continued resupply of the plume from the vadose zone and the periodically rewetted zone.

Concentrations in tube samples represent more discrete intervals in the aquifer than the concentrations determined for samples from traditional monitoring wells because of different lengths for screened openings (15-centimeter screen length for tubes and typically 5–meter screen length for monitoring wells). Contamination may become more evenly distributed vertically in the aquifer near the river because of mixing during transport from source areas to the river. The values at multiple depths in

tubes AT-3-4, C6347/48, C6350/51, AT-3-7, and AT-3-8 support this idea. Figure 2.7-11 indicates that most uranium contamination is contained within the saturated Hanford formation gravelly sediment. Based on projections of stratigraphic contacts from near-shore well drilling sites, aquifer tube AT-3-3-D is believed to be installed in the underlying Ringold Formation unit E, and concentrations at that tube are consistent with natural background uranium levels.

The contaminant concentrations measured in samples from aquifer tubes are lower than those in the approaching groundwater because river water intrudes into the unconfined aquifer beneath the shoreline, diluting the concentrations. Based on the specific conductance of river water and of groundwater, the aquifer water monitored by 300-FF-5 tubes during the high river stage is estimated to be 60 percent groundwater and 40 percent river water (Section 3.3.2 of PNNL-17034). A lowering of concentrations may also occur because of changes in geochemical conditions caused by the intrusion of river water, which could promote adsorption of dissolved uranium onto sediment near the river. The lower bicarbonate content of river water compared to groundwater enhances the tendency for adsorption, although the significance of this process with regard to influencing concentrations as observed in monitoring results is not known (Section 5.4 of PNNL-17031; Section 5.2 of Yabusaki et al., 2008, "Building Conceptual Models of Field-Scale Uranium Reactive Transport in a Dynamic Vadose Zone-Aquifer-River System").

2.7.1.2 Uranium at 618-10 Burial Ground/316-4 Crib

From 1948 to 1956, uranium-contaminated organic solvents were disposed to the former 316-4 Crib, which is adjacent to the easternmost corner of the 618-10 Burial Ground (Section 3.6.33 of BHI-00012, *300-FF-2 Operable Unit Technical Baseline Report*). The liquid effluent included methyl isobutyl ketone (hexone) and tributyl phosphate. The crib and some of the contaminated adjacent soil were removed in 2004, and the site was partially backfilled. However, some uranium and tributyl phosphate contamination was known to remain in the soil beneath the excavated site (Sections 3.4.1.4 and 3.4.2.1 of DOE/RL-2006-20; EPA/ESD/R10-00/524, *EPA Superfund Explanation of Significant Differences: Hanford 300-Area (USDOE)*).

Uranium was included in the waste disposed to the 316-4 Crib, but the impact to groundwater has been minimal.

Uranium concentrations in groundwater had been elevated above the drinking water standard at two wells near the southeastern fence line of the 618-10 Burial Ground and the former 316-4 Crib. Concentrations in that area have remained below the drinking water standard since 2007 (Figure 2.7-13). The cause for the 2004 increase in uranium concentrations at wells 699-S6-E4A and 699-S6-E4L was infiltration of dust-control water during the 316-4 Crib excavation and backfilling. Because the water table elevation in this area remains fairly constant, the increase in uranium is not attributed to rewetting of the vadose zone. In August 2010, the first intrusive work at 618-10 Burial Ground began in preparation for the more extensive removal actions, which started in March 2011. The increase in the uranium concentration in downgradient well 699-S6-E4L to 26 µg/L in January 2012 (Figure 2.7-13) is attributed to infiltration of dust-control water during this recent remediation.

2.7.2 Volatile Organic Compounds

Two volatile organic compounds, trichloroethene and *cis*-1,2-dichloroethene, are found in localized areas in groundwater beneath the 300 Area Industrial Complex at concentrations exceeding their respective drinking water standards of 5 µg/L and 70 µg/L. *Cis*-1,2-dichloroethene is a degradation product of trichloroethene and tetrachloroethene. The original compounds degrade by dechlorination under conditions that include very low oxygen and the presence of certain types of microbes (Section 1.2

of PNNL-17666 provides a summary of degradation processes). Vinyl chloride, a further degradation product, has not been detected in 300 Area Industrial Complex groundwater. If more oxygen were available in the subsurface environments where *cis*-1,2-dichloroethene persists in the 300 Area, the compound would degrade to non-hazardous constituents. Carbon tetrachloride, which was used in small quantities for testing fuel element integrity, is occasionally detected in groundwater beneath the 300 Area Industrial Complex but at levels below the drinking water standard of 5 µg/L. Tributyl phosphate, a semivolatile organic compound, is occasionally detected at low levels in the groundwater at the 618-10 Burial Ground/316-4 Crib. A drinking water standard for tributyl phosphate has not been established.

2.7.2.1 Volatile Organic Compounds in the 300 Area Industrial Complex

Trichloroethene and tetrachloroethene were widely used in the 300 Area Industrial Complex in degreasing operations associated with the fuels fabrication process (Section 3.3.4 of BHI-00012; Section 2.0 of EMO-1026, *Addendum to Data Compilation Task Report for the Source Investigation of the 300-FF-1 Operable Unit Phase I Remedial Investigations*; Section 1.0 of WHC-MR-0388, *Past Practices Technical Characterization Study – 300 Area – Hanford Site*). Trichloroethene was the primary degreaser used until the 1970s, followed by tetrachloroethene in the 1970s and 1980s.

Trichloroethene and tetrachloroethene were discharged in used degreaser fluids to the former South Process Pond (316-1) and North Process Pond (316-2) via the process sewer system. No major spills or leaks of trichloroethene or tetrachloroethene to the ground have been recorded. In the past, trichloroethene migrated into the 300 Area Industrial Complex from sources to the southwest (Sections 4.4.4.5 and 4.8.4.2 of DOE/RL-2010-99). In 2011, trichloroethene was not detected to the southwest in 1100-EM-1 (Section 2.8). Trichloroethene concentrations exceeded the drinking water standard in 2011 at least once in four wells (399-3-20, 399-4-7, 399-4-9, and 399-4-14) that are screened in the upper portion of the unconfined aquifer and in one well (399-1-57) screened within the mid-portion of the unconfined aquifer. The maximum concentration was 14 µg/L. In each well, the concentration in the subsequent sample was below the drinking water standard.

During drilling in 2006, trichloroethene (maximum concentration of 630 µg/L) was encountered in groundwater associated with an interval of relatively finer-grained sediment within Ringold Formation unit E (Section 2.1 of PNNL-17666). Because this finer-grained interval has a very low permeability and does not readily yield groundwater, monitoring wells have not been screened in this interval. This interval is incised by the river channel. Contamination slowly migrates within these sediments and into overlying or adjacent permeable Hanford formation sediment, as evidenced by periodic detections of trichloroethene in aquifer tube samples that are collected from screens positioned near this contact (Section 4.8.4.4 of DOE/RL-2010-99).

Elevated concentrations of trichloroethene are present in a layer of finer-grained sediment below the water table, but only in a limited area.

Trichloroethene was detected in 2011 at concentrations exceeding the drinking water standard at some aquifer tubes that are screened proximal to, or within, the finer-grained interval of Ringold Formation sediment that is contaminated by trichloroethene (Figure 2.7-14). Consistent with results from previous years, in 2011, the highest concentration (210 µg/L) was observed at aquifer tube AT-3-3-D, which is the aquifer tube believed to be placed in the finer-grained interval of Ringold Formation unit E sediment. Elevated concentrations are also consistently observed at tube site AT-3-7-D, where the highest trichloroethene concentration in 2011 was 98 µg/L. The origin for the trichloroethene in groundwater at this tube is not known, but is most likely associated with past disposal of trichloroethene used in the manufacture of nuclear fuel.

In the lower portion of the unconfined aquifer, *cis*-1,2-dichloroethene concentrations continue to exceed the drinking water standard at one well (399-1-16B). The maximum concentration in 2011 was 200 µg/L (Figure 2.7-15). Well 399-1-16B is along the downgradient flow path from the former 300 Area Process Trenches (316-5) and North Process Pond (316-2). It is screened in Ringold Formation gravelly sediment in the lower portion of the unconfined aquifer. The elevation of the well's screen is approximately 7 meters deeper than the elevation of the Columbia River's maximum channel depth (Section 4.4.4.5 of DOE/RL-2010-99). The origin for cis-1,2-DCE is likely degradation of trichloroethene and/or PCE disposed to the former North Process Pond (316-2) and/or 300 Area Process Trenches (316-5) (Sections 3.1 and 3.3 of PNNL-17666; Section 4.4.4.5 of DOE/RL-2010-99). The cis-1,2-dichloroethene concentration (110 µg/L) also exceeded the drinking water standard in 2011 in a sample from well 399-1-57, a remedial investigation well installed in 2010. Well 399-1-57 is located 80 meters to the southeast of well 399-1-16B, but in the mid-portion of the unconfined aquifer and in finer-grained, less permeable sediment (Section 4.4.4.5 of DOE/RL-2010-99).

Cis-1,2-dichloroethene, a degradation product of tetrachloroethene and trichloroethene, is detected at two wells, one that monitors the lower portion of the unconfined aquifer and one that monitors the middle portion.

2.7.2.2 Volatile Organic Compounds at the 618-10 Burial Ground/316-4 Crib

The former 316-4 Crib received liquid waste associated with research conducted at the 321 Separations Laboratory in the 300 Area Industrial Complex from 1948 to 1956 (Section 3.6.33 of BHI-00012). The liquid waste typically consisted of organic compounds (for example, methyl isobutyl ketone [hexone] and tributyl phosphate) containing uranium. Tributyl phosphate and uranium concentrations were elevated in early 2004 at well 699-S6-E4A (located within the footprint of the remedial action excavation) during crib removal activities. In 2011, the highest tributyl phosphate concentration detected at this well was estimated at 1.8 µg/L. Tributyl phosphate tends to bind to soil in the vadose zone where it slowly degrades over time. It is not soluble in water and, therefore, does not widely disperse via water transport mechanisms. Methyl isobutyl ketone breaks down quickly in the environment; it has been detected in groundwater near the 618-10 Burial Ground/316-4 Crib only once (in 1998) since analyses for it began in the mid-1990s.

2.7.3 Tritium

Tritium is found in groundwater associated with the 618-11 Burial Ground at concentrations exceeding the drinking water standard of 20,000 pCi/L. The source of the plume is tritium gas released from buried radiological solid wastes.

Tritium released from materials in the 618-11 Burial Ground has resulted in a groundwater plume with concentrations above the drinking water standard.

The narrow tritium plume extends for approximately 1.2 kilometers to the east of (downgradient from) the 618-11 Burial Ground. The plume passes just to the north of the Energy Northwest Columbia Generating Station (Figure 2.7-16). The plume appears to be contained within the saturated Hanford formation gravels portion of the unconfined aquifer. The size of the plume remained relatively unchanged from 2003 through 2010, but increased in 2011 (Figure 2.7-6). The tritium concentrations attributed to the

618-11 Burial Ground lie within the larger, lower concentration tritium plume that is part of 200-PO-1 (Section 3.5) (Section 4.4.5 of DOE/RL-2010-99).

Tritium concentrations near the 618-11 Burial Ground have declined from the maximum values observed in 1999 and 2000 (Figure 2.7-17). The trend in groundwater at well 699-13-3A, adjacent to the eastern fence line of the burial ground, suggests that an episodic event of unknown nature caused a tritium release from buried materials to contaminate groundwater. The relatively constant tritium concentrations at well 699-13-3A since 2006 suggest that buried materials are providing an ongoing source of tritium to groundwater. At wells farther downgradient from the 618-11 Burial Ground, such as wells 699-13-2D and 699-12-2C, concentration trends reflect the plume's migration. The conceptual model for the plume, including a simulation of plume evolution over time, indicates that tritium concentrations will be below the drinking water standard when the plume reaches the Columbia River (Section 5.1 of PNNL-15293, *Evaluation of the Fate and Transport of Tritium Contaminated Groundwater from the 618-11 Burial Ground*). Groundwater wells monitored by Energy Northwest do not show evidence of this plume, nor is tritium detected in Energy Northwest water supply wells (Mee, 2011, *Columbia Generating Station Radiological Environmental Monitoring Program, 2010 Annual Radiological Environmental Operating Report For Calendar Year 2010*).

2.7.4 Nitrate

Nitrate concentrations exceeding the 45 mg/L drinking water standard (i.e., 10 mg/L measured as nitrogen in nitrate) are found in the southern portion of the 300 Area Industrial Complex and near the 618-11 Burial Ground. The principal sources of nitrate currently observed in 300 Area Industrial Complex groundwater are agricultural and industrial activities not associated with the Hanford Site. At the 618-11 Burial Ground, nitrate contamination in the underlying groundwater has sources in the 200 East Area (Section 3.3), with localized releases from the 618-11 Burial Ground.

Nitrate exceeds the drinking water standard in groundwater, with sources including past disposal to 300 Area Industrial Complex waste sites, 200 East Area waste sites, and non-Hanford Site activities.

2.7.4.1 Nitrate in the 300 Area Industrial Complex

The nitrate concentrations exceeding the drinking water standard in the southern portion of the 300 Area Industrial Complex reflect the migration of nitrate-contaminated groundwater into the 300 Area Industrial Complex from sources to the southwest (Section 2.8) (Figure 2.8-5 in Section 2.8). Gradually increasing concentrations are observed in wells and at shoreline sites as the nitrate-laden groundwater migrates into the 300 Area Industrial Complex. For example, the maximum nitrate concentration at well 699-S28-E12 (near the southwestern corner of the 300 Area Industrial Complex) was 189 mg/L in March 2011, and the concentration was 84 mg/L approximately 616 meters to the northeast at well 699-S27-E14 in May 2010. Nitrate also migrates into the 300 Area Industrial Complex from the northwest as part of the sitewide plume that originates in the 200 East Area, with concentrations typically ranging from 25 to 30 mg/L (Section 3.5).

2.7.4.2 Nitrate in the 618-11 Burial Ground

Nitrate concentrations near the 618-11 Burial Ground continue to exceed the drinking water standard (Figure 3.5-10 in Section 3.5). Concentrations at well 699-13-3A have been increasing since 1995 when the well was installed; the maximum concentration during 2011 was 105 mg/L. Historical records for materials sent to the 618-11 Burial Ground do not indicate significant quantities of nitrate-bearing wastes. Given that the elevated nitrate contamination in the groundwater corresponds to the elevated tritium contamination, which is attributed to the 618-11 Burial Ground, the nitrate contamination is also attributed to the 618-11 Burial Ground (Section 4.4.5 of DOE/RL-2010-99). The plume size decreased in

2011 as a result of re-interpreting the locally elevated plume as originating from the 618-11 Burial Ground (Figure 2.7-6).

2.7.5 Other Constituents

Gross alpha activity, gross beta activity, strontium-90, technetium-99, and total chromium are constituents of interest being monitored at various locations in 300-FF-5 groundwater because the constituents either exceed the associated drinking water standard (15 pCi/L, 50 pCi/L, 8 pCi/L, 900 pCi/L, and 100 µg/L, respectively) or are helpful in characterizing contamination in the aquifer.

Other waste indicators monitored in groundwater include gross alpha, gross beta, strontium-90, technetium-99, and chromium.

2.7.5.1 Other Constituents in the 300 Area Industrial Complex

Gross alpha activity in the 300 Area Industrial Complex groundwater is attributed to uranium and exceeded the drinking water standard at numerous wells in areas where uranium concentrations were also elevated during the unusually high water table conditions in June 2011. Gross beta activity also temporarily exceeded the drinking water standard at several of the same wells. Sources for the gross beta activity include daughter isotopes from radioactive decay of uranium and background radiation from natural sources such as potassium-40 and uranium. Other contributors to gross beta activity include low levels of technetium-99 and strontium-90 released in the past at isolated locations, including the area near the former 340/307 complex retention basins, trenches, and associated underground piping.

On July 17, 2011, approximately 378,500 liters of clean water were released from a pipeline break near the southeastern corner of the 326 Building. Additional groundwater samples were collected from nearby wells 399-3-2 and 399-6-2 and analyzed for gross alpha and gross beta activity during August. Results did not indicate an impact to groundwater from the release.

Highly radioactive solutions have been released to the soil beneath the 324 Building, as discovered during deactivation, decommissioning, decontamination, and demolition activities at the building in 2009. The releases (site code UPR 300-296) included solutions containing cesium-137 and strontium-90, both of which are beta emitters. Figure 2.7-18 illustrates recent gross beta trends at several wells that monitor conditions downgradient from the 324 Building. Gross beta activity remained below the drinking water standard in downgradient wells 399-4-9, 399-4-10, and 399-4-14 in 2011.The multiple potential sources for the strontium-90 include a leak that occurred in about 1969 from a former underground pipeline at the 340 Complex (site code UPR-300-1), the 307 Retention Basins, 340 Complex, and/or 307 Process Trenches, as well as a release that may have occurred from the 324 Building. There is no evidence that past releases from the 324 Building have affected groundwater.

In 2008, chromium concentrations increased at well 399-8-5A, adjacent to the eastern (downgradient) fence line of the former 618-7 Burial Ground. The maximum concentration was 105 µg/L (measured as total chromium in filtered and unfiltered samples) in July 2009. Since then, concentrations at this well have declined, with the exception of an increase (66 µg/L) in August 2011 during the unusually high water table condition (Figure 2.7-10). By December 2011, chromium concentrations had declined almost to pre-2008 levels. Other constituents showing a concurrent increase at well 399-8-5A include calcium, chloride, gross alpha, gross beta, nitrate, sodium, and uranium (Section 2.7.1.1). The increases in many of these constituents indicate that dust control water and soil fixatives applied at the former 618-7 Burial Ground have infiltrated downward to groundwater.

Total chromium concentrations in unfiltered and filtered groundwater samples from beneath the 300 Area Industrial Complex were below the drinking water standard in 2011. Near the Columbia River,

total chromium concentrations in near-river wells were not detected or were lower than the Washington State value of 10 µg/L for hexavalent chromium for protection of aquatic life, with the exception of one sample from one well (11 µg/L in well 399-4-9) (WAC 173-201A-240, "Water Quality Standards for Surface Waters of the State of Washington," "Toxic Substances"). Concentrations in samples from aquifer tubes did not exceed 10 µg/L in 2011.

2.7.5.2 Other Constituents in the 618-10 Burial Ground/316-4 Crib and the 618-11 Burial Ground

Technetium-99 concentrations were below the drinking water standard in wells at the 618-11 and 618-10 Burial Ground/316-4 Crib in 2011. The maximum technetium-99 concentration near 618-11 Burial Ground was 190 pCi/L at downgradient well 699-12-2C, where concentrations have been decreasing since monitoring began in 2003. Historical concentration trends for technetium-99 and tritium at downgradient well 699-13-3A (adjacent to the 618-11 Burial Ground) are similar, indicating that small amounts of the technetium-99 in this area are associated with the local tritium plume (Section 2.7.3). In 2011, however, technetium-99 concentrations at this well increased to 150 pCi/L (Figure 2.7-17). Technetium-99 concentrations at downgradient well 699-13-2D increased to 120 pCi/L in 2011.

At the 618-10 Burial Ground, the maximum concentrations of gross alpha and gross beta in 2011 were 9.4 pCi/L and 34 pCi/L, respectively. The concentrations are below the drinking water standards. Increased disturbance of the ground surface and application of water for dust control during site remediation activities may be the source of the minor variability in concentrations of these parameters.

2.7.6 CERCLA Groundwater Activities

The RI/FS process under CERCLA for 300-FF-5 began in the late 1980s with work planning (DOE/RL-89-14, *Remedial Investigation/Feasibility Study Work Plan for 300-FF-5 Operable Unit, Hanford Site, Richland, Washington*). In 1996, interim remedial action under CERCLA targeted groundwater beneath waste sites in the 300 Area Industrial Complex (EPA/ROD/R10-96/143, *Declaration of the Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington*). The geographic extent of 300-FF-5 was expanded in 2000 to include groundwater affected by the 618-10 Burial Ground/316-4 Crib and the 618-11 Burial Ground (EPA/ESD/R10-00/524).

The interim remedy selected for 300-FF-5 in the ROD (EPA/ROD/R10-96/143) was monitored natural attenuation and institutional controls. The interim remedy, as stated in the record of decision, is as follows:

- Continued monitoring of groundwater contaminated above health-based levels to ensure that concentrations continue to decrease
- Institutional controls to ensure that groundwater use is restricted to prevent unacceptable exposures to groundwater contamination

Three 5-year reviews of the 1996 ROD have been conducted. The first review, in 2000, concluded that the remedy selected for 300-FF-5 in the 300 Area Industrial Complex was still appropriate (*USDOE Hanford Site First Five-Year Review Report* [EPA, 2001]). However, additional monitoring along the river shoreline was added, along with a request to assess the effectiveness of the monitored natural attenuation remedy. The second review, in 2005, concluded that remediation of the uranium plume in the 300 Area Industrial Complex groundwater through monitored natural attenuation had not achieved the remedial action objectives in the 10-year time frame envisioned when the interim action ROD for groundwater was established (DOE/RL-2006-20). To address this issue, the review identified an action to complete a focused feasibility study for uranium and concurrent field testing of polyphosphate injections to immobilize uranium. Results of the third review, in 2010, have been issued (DOE/RL-2011-56) and are being discussed by the Tri-Parties (Section 1.4).

The remedial action objectives for interim action involving 300-FF-5 groundwater are as follows (EPA/ROD/R10-96/143):

- ***Protect receptors from exposure to contaminants in the groundwater and control the sources of contamination to minimize future impacts to groundwater.***
- ***Protect the Columbia River such that contaminants in the groundwater or soil after remediation do not result in an impact to the river that would exceed the Washington State surface water quality standards.***

During 2009, new milestones and target completion dates were developed under the Tri-Party Agreement (Ecology et al., 1989). Those that applied to 300-FF-5 are as follows:

- **Milestone M-015-00D:** DOE will complete the RI/FS process through the submittal of a proposed plan for all 100 and 300 Area operable units (December 31, 2012).
- **Milestone M-015-71:** Submit CERCLA RI/FS work plan for the 300-FF-2 and 300-FF-5 Operable Units for groundwater and soil (October 31, 2009; completed).
- **Milestone M-015-72-T01:** Submit CERCLA RI/FS report and proposed plan for the 300-FF-2 and 300-FF-5 Operable Units for groundwater and soil (December 31, 2011; completed).
- **Milestone M-016-110-T05:** DOE will have a remedy in place designed to meet federal drinking water standards for uranium throughout the groundwater plume in the 300-FF-5 Operable Unit unless otherwise specified in a CERCLA decision document (target date December 31, 2015).

DOE submitted a proposed plan for final remedial action at waste sites and groundwater in the 300 Area Industrial Complex and outlying subregions in December 2011.

In September 2008, DOE initiated planning for RI/FS activities that would lead to final remedial actions for 300-FF-1, 300-FF-2, and 300-FF-5. The remedial investigation of 300-FF-5 included drilling during 2010 and 2011 at eleven locations in the 300 Area Industrial Complex to characterize contaminants in the vadose zone and unconfined aquifer. Each location was subsequently completed as a monitoring well. In addition to the permanent wells, five soil borings were completed as temporary groundwater monitoring wells. Computer simulation of uranium transport through the vadose zone and unconfined aquifer was conducted to develop new insight on preliminary remediation goals and future behavior of the uranium plume. The details of the remedial investigation are provided in the RI/FS report (DOE/RL-2010-99). Draft A of the RI/FS report and Draft A of the Proposed Plan (DOE/RL-2011-47, *Proposed Plan for the Remediation of 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units*) were issued in December 2011, in accordance with the Tri-Party Agreement (Ecology et al., 1989) Milestone M-015-72-T01.

DOE's Office of Science, Biological and Environmental Research, is supporting field research to address the mobility of uranium in the environment under a program referred to as the Integrated Field-Scale Research Challenge. The focus of the research is multi-scale, mass-transfer processes that control the sequestration and mobility of uranium contamination in the subsurface, including the vadose

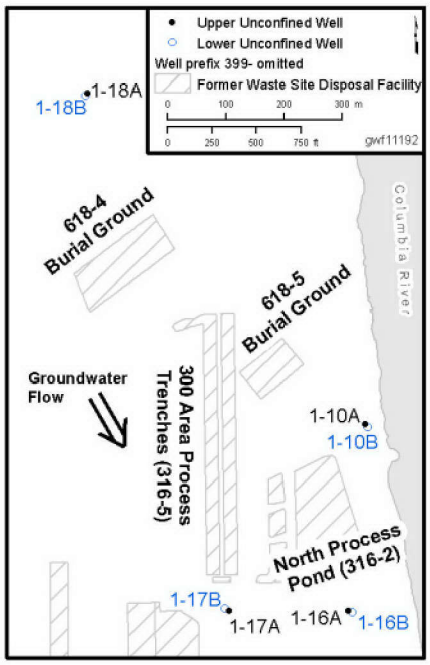
zone and groundwater. During 2011, field experiments as part of the Integrated Field-Scale Research Challenge were initiated to investigate uranium desorption from vadose zone sediment, and the following new report was issued: PNNL-21169, *Multi-Scale Mass Transfer Processes Controlling Natural Attenuation and Engineered Remediation: An IFRC Focused on Hanford's 300 Area Uranium Plume January 2011 to January 2012*.

Groundwater monitoring required under the 1996 ROD is implemented through a sampling and analysis plan (DOE/RL-2002-11, *300-FF-5 Operable Unit Sampling and Analysis Plan*). Samples are collected from wells and from aquifer tubes beneath the shoreline in the 300 Area Industrial Complex. Comprehensive sampling events occur semiannually, with more frequent sampling occurring when conditions change rapidly or major excavation activities are underway. Most monitoring wells have screens positioned to include the zone occupied by the water table. Several wells are screened in the lower portion of the unconfined aquifer, and a few wells are screened in the uppermost confined aquifer.

Wells and aquifer tubes were sampled as planned during 2011. Minor exceptions to planned monitoring occurred because of maintenance issues and scheduling constraints. Appendix A lists the sampling frequencies, types of laboratory analyses, and sample status for 2011 for the 300-FF-5 Operable Unit monitoring wells. Appendix C lists the aquifer tubes.

2.7.7 RCRA Facility Monitoring at 300 Area Process Trenches

The former 300 Area Process Trenches (316-5) received effluent discharges of mixed waste from fuel fabrication and nuclear research laboratories in the 300 Area Industrial Complex from 1975 through 1985, followed by continued discharge of clean effluent until December 1994. During this period of operation, the trenches were used as a treatment, storage, and disposal unit; therefore, the trenches are regulated under RCRA. A comprehensive description of the facility and its history of operations is provided in Section 2.1 of PNNL-13645. The trenches were remediated in 1991 under a CERCLA expedited response action by scraping contaminated soil to the north end of the facility (DOE/RL-92-32, *Expedited Response Action Assessment for 316-5 Process Trenches*). Additional removal actions were performed in 1997 and 1998, followed by backfilling and surface restoration in 2004 (Section 3.0 of DOE/RL-2004-74).



Groundwater monitoring required by RCRA is conducted in accordance with WAC 173-303-645(11) ("Dangerous Waste Regulations," "Releases from Regulated Units") and the Hanford Facility RCRA Permit (WA7890008967). The modified closure plan (DOE/RL-93-73, *300 Area Process Trenches Modified Closure/Postclosure Plan*), which is incorporated into the Hanford Facility RCRA Permit (WA7890008967), states that groundwater remediation is deferred to 300-FF-5 under CERCLA.

Groundwater potentially affected by past disposal to the former 300 Area Process Trenches continues to be monitored under RCRA requirements.

Post-closure groundwater monitoring under the corrective action program of WAC 173-303-645(11) under RCRA uses wells at four locations: one upgradient (northwest) and three downgradient (east,

southeast, and south) of the former 300 Area Process Trenches. The most distant downgradient location is approximately 200 meters to the southeast, along the dominant groundwater flow path from the trenches. Groundwater flows generally toward the south-southeast beneath the former trenches. The estimate for flow rate in March 2011 was 20 meters per day (Appendix B, Table B-1).

Two wells are at each of the four locations. The well with the well number ending in "A" is screened near the water table, and the well with the well number ending in "B" is screened in the lower portion of the unconfined aquifer. The sampling schedule for the eight wells is designed to accommodate two semiannual sampling events, with four time-independent samples collected during each period to provide data amenable to statistical analysis. As a result, the wells are sampled during eight months of the year: the first sampling event covers December, January, February, and March; and the second sampling event covers June, July, August, and September. During 2011, sampling was performed as planned at five wells; 1 or 2 months of sampling was missed at three wells (Appendix B, Table B-20). Reports on the effectiveness of the corrective action monitoring program were prepared semiannually in accordance with WAC 173-303-645(11)(g). The results for 2011 are provided in *First Semiannual Report for 2011 Post-Closure Corrective Action Groundwater Monitoring at the 183-H Solar Evaporation Basins and 300 Area Process Trenches, January – June 2011* (SGW-52135), and *Second Semiannual Report for 2011 Post-Closure Corrective Action Groundwater Monitoring at the 183-H Solar Evaporation Basins and 300 Area Process Trenches, July – December 2011* (SGW-52136).

Groundwater monitoring to meet RCRA requirements is conducted in accordance with the *Groundwater Monitoring Plan for the 300 Area Process Trenches* (WHC-SD-EN-AP-185). The constituents monitored under this plan include chemical uranium, trichloroethene, and *cis*-1,2-dichloroethene. The drinking water standards for these three contaminants are 30 µg/L, 5 µg/L, and 70 µg/L, respectively.

Analytical results for trichloroethene were all below the detection limit of 1 µg/L during 2011, with the exception of five samples from well 399-1-16B, where the maximum concentration was estimated to be 1.9 µg/L (Section 2.7.2.1). Analytical results for *cis*-1,2-dichloroethene were all below the detection limit of 1.0 µg/L during 2011, with the exception of all samples from well 399-1-16B, where concentrations ranged from 130 to 200 µg/L, and three samples from well 399-1-17B, where the maximum concentration was estimated to be 4.8 µg/L (Section 2.7.2.1).

Cis-1,2-dichloroethene and uranium continue to exceed their respective drinking water standards at RCRA network wells.

Uranium was detected at five of the monitoring wells in 2011. In the three downgradient wells screened in the upper portion of the unconfined aquifer, maximum concentrations ranged from 45 to 4,030 µg/L (Section 2.7.1.1). Concentrations at wells 399-1-10A and 399-1-16A, which are near the Columbia River, declined in summer when the river stage was high and increased in autumn with the arrival of uranium that had been remobilized upgradient. Concentrations at upgradient well 399-1-18A are consistent with background levels for saturated Hanford formation sediment and were in the range of 5.5 to 7 µg/L during 2011. Concentrations in the lower portion of the unconfined aquifer were typically below detection levels, with the exception of well 399-1-16B, where the maximum concentration was 11.9 µg/L. Uranium is reported as total uranium in an unfiltered sample.

Figure 2.7-1. Index Map Showing 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units

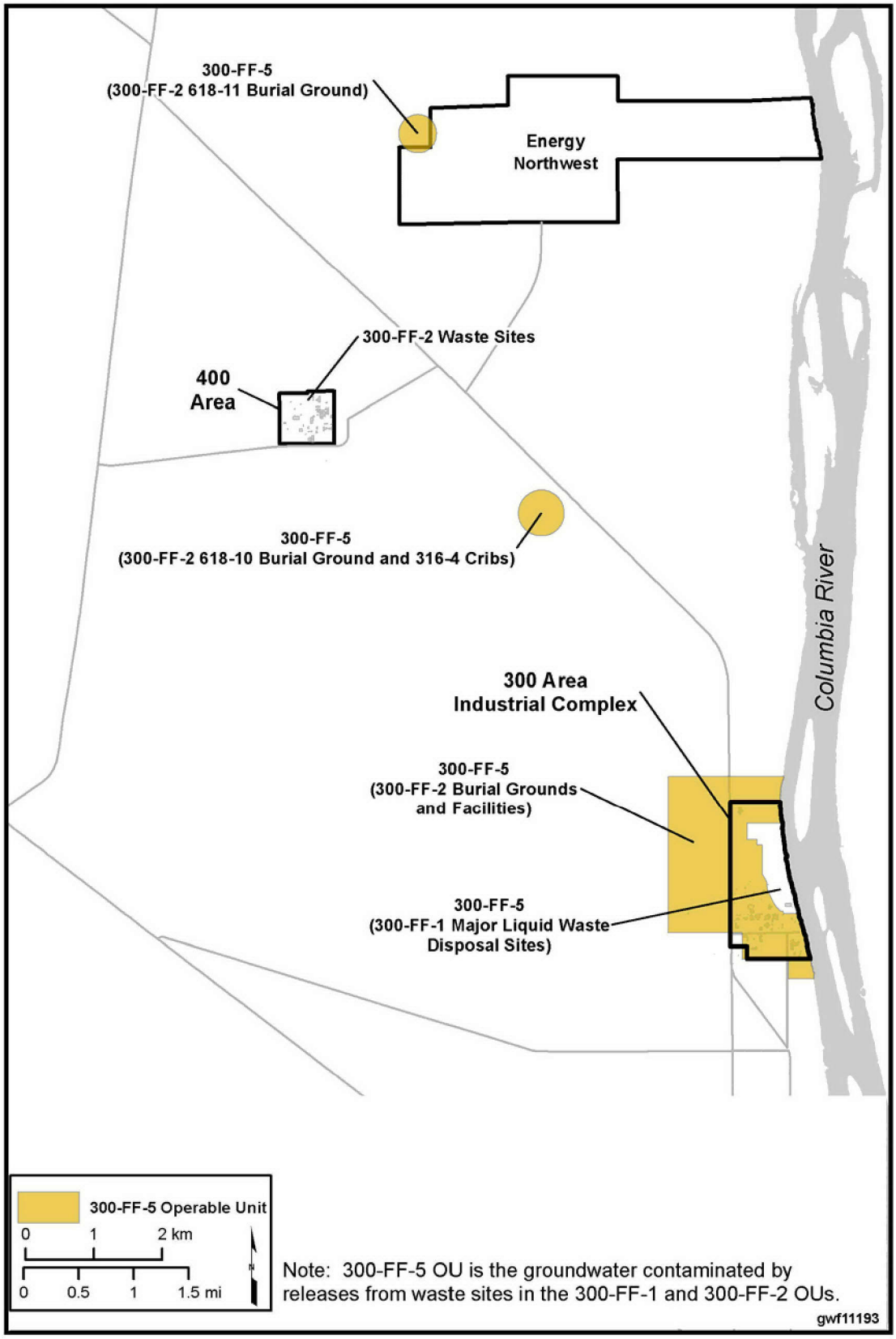


Figure 2.7-2. Monitoring Wells in and near 300 Area Industrial Complex

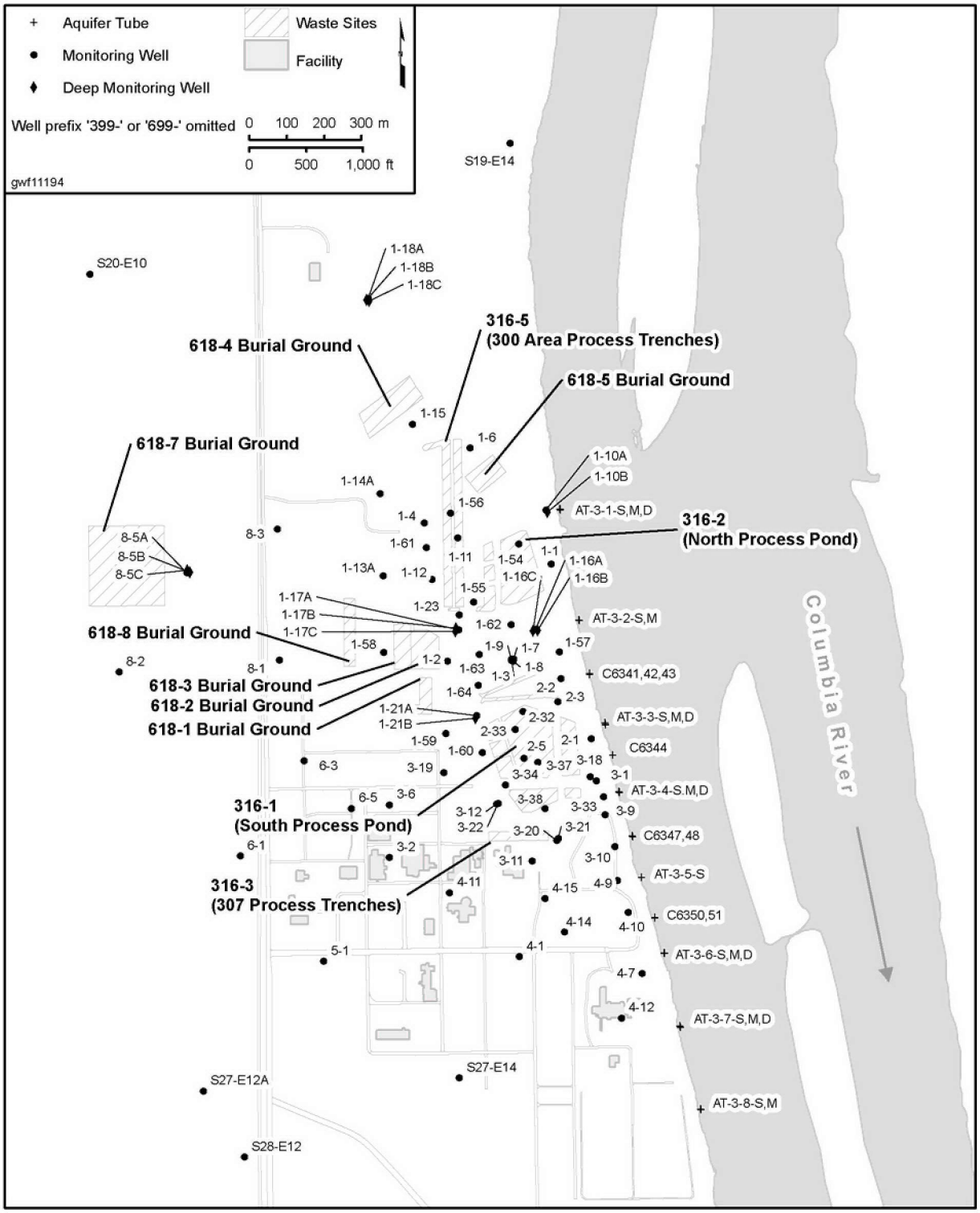


Figure 2.7-3. Monitoring Wells near 618-11 Burial Ground

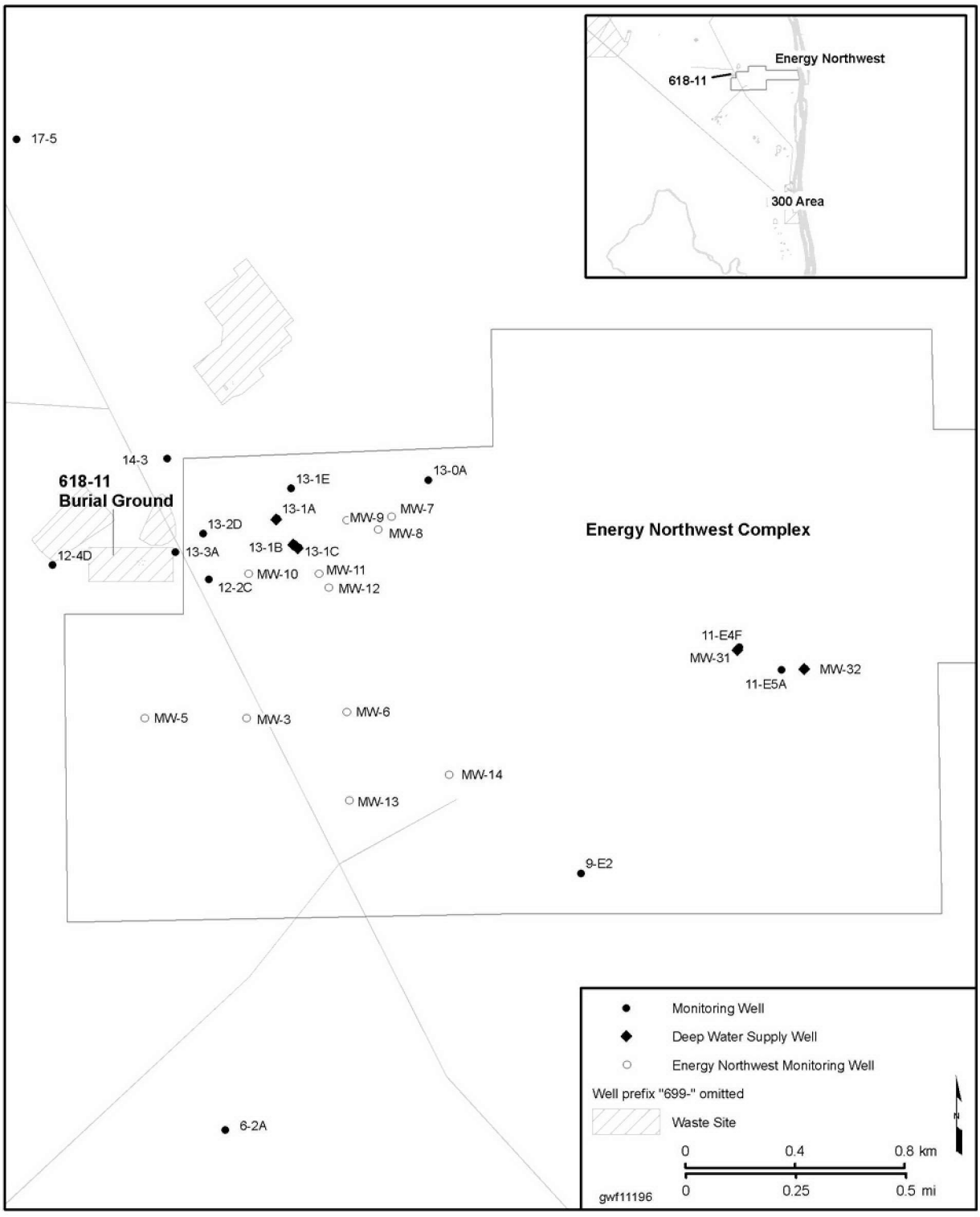


Figure 2.7-4. Monitoring Wells near 618-10 Burial Ground

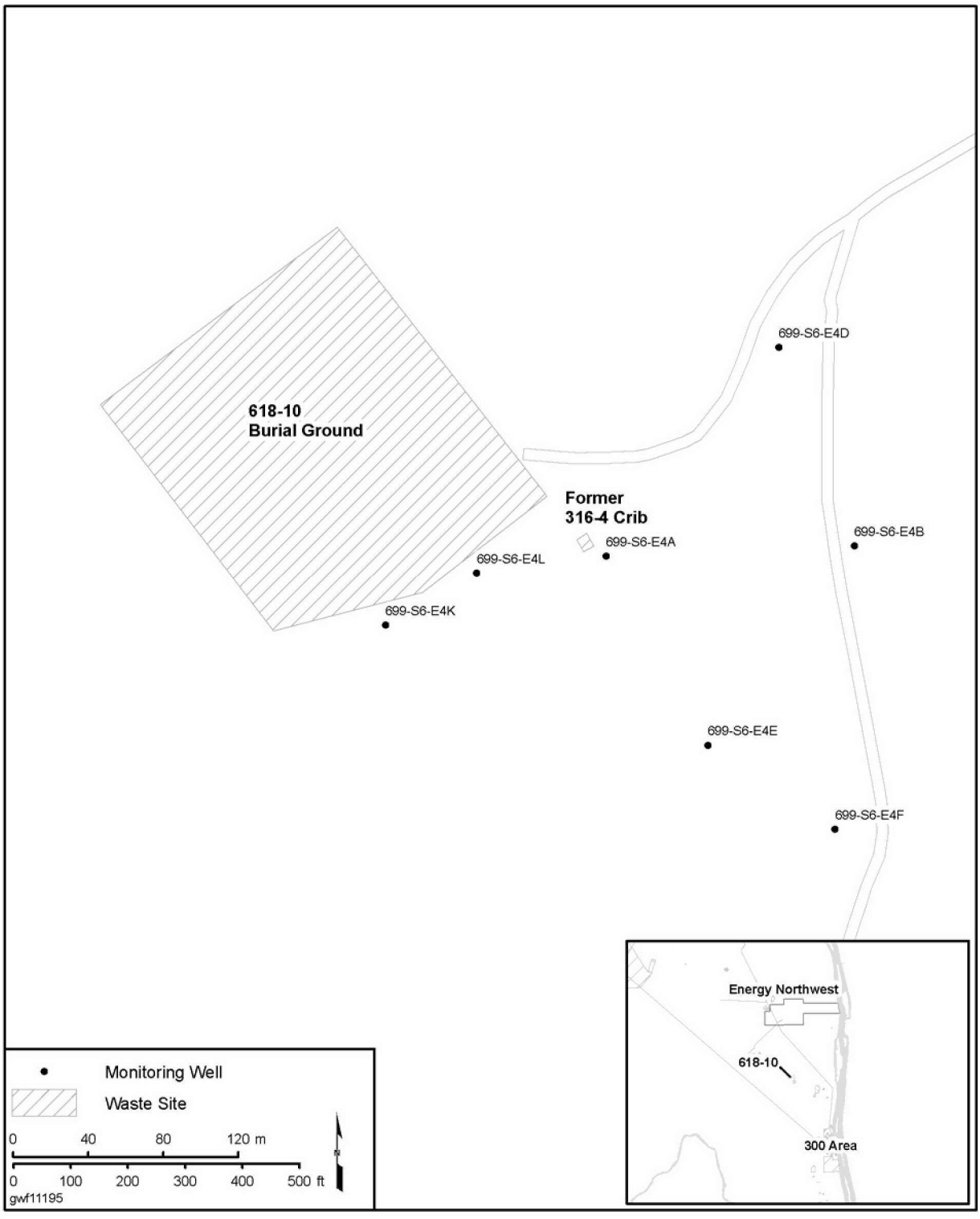


Figure 2.7-5. 300-FF-5 Water Table, March 2011

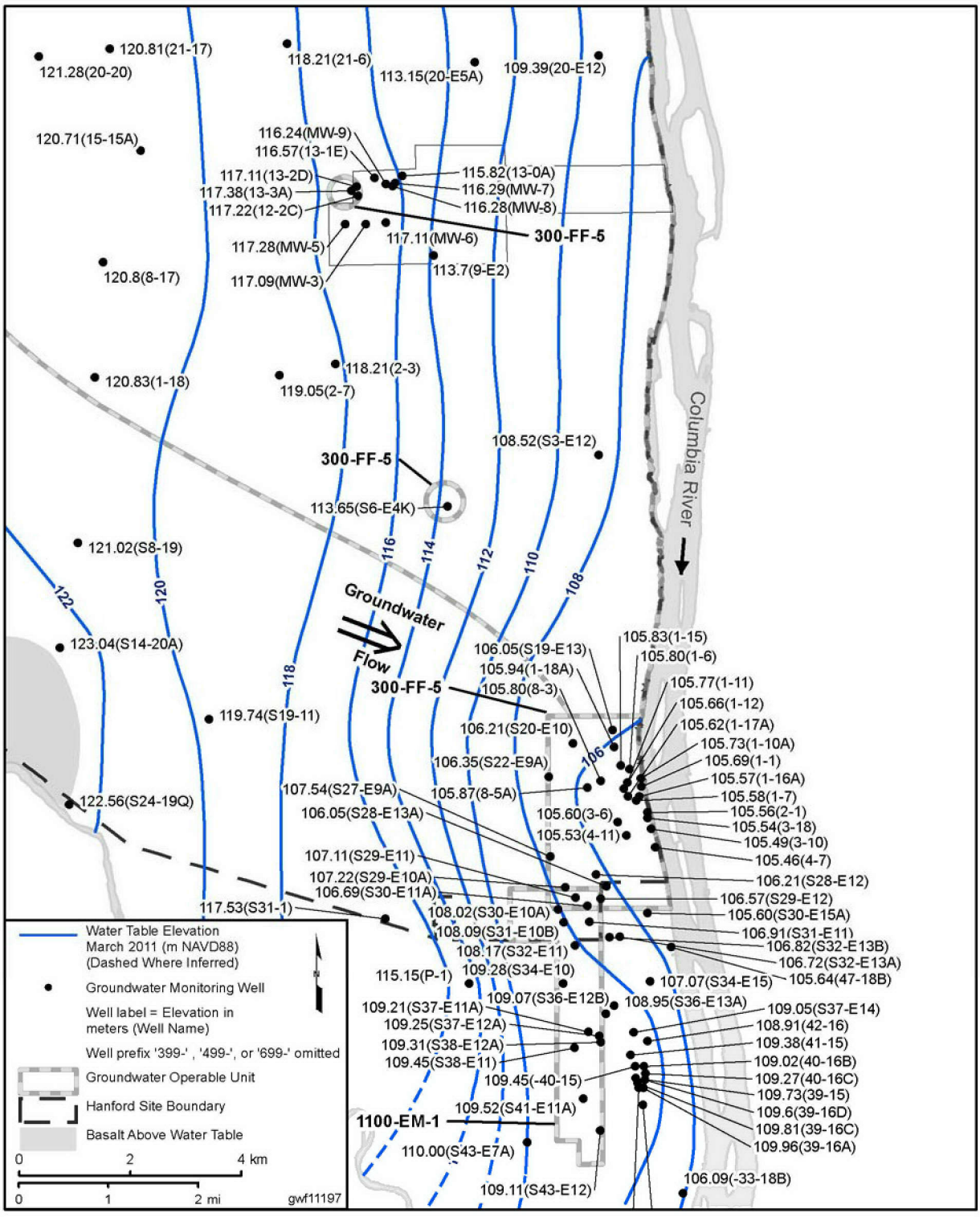


Figure 2.7-6. Changes in 300-FF-5 Plume Areas (Based on Annual Average Concentrations)

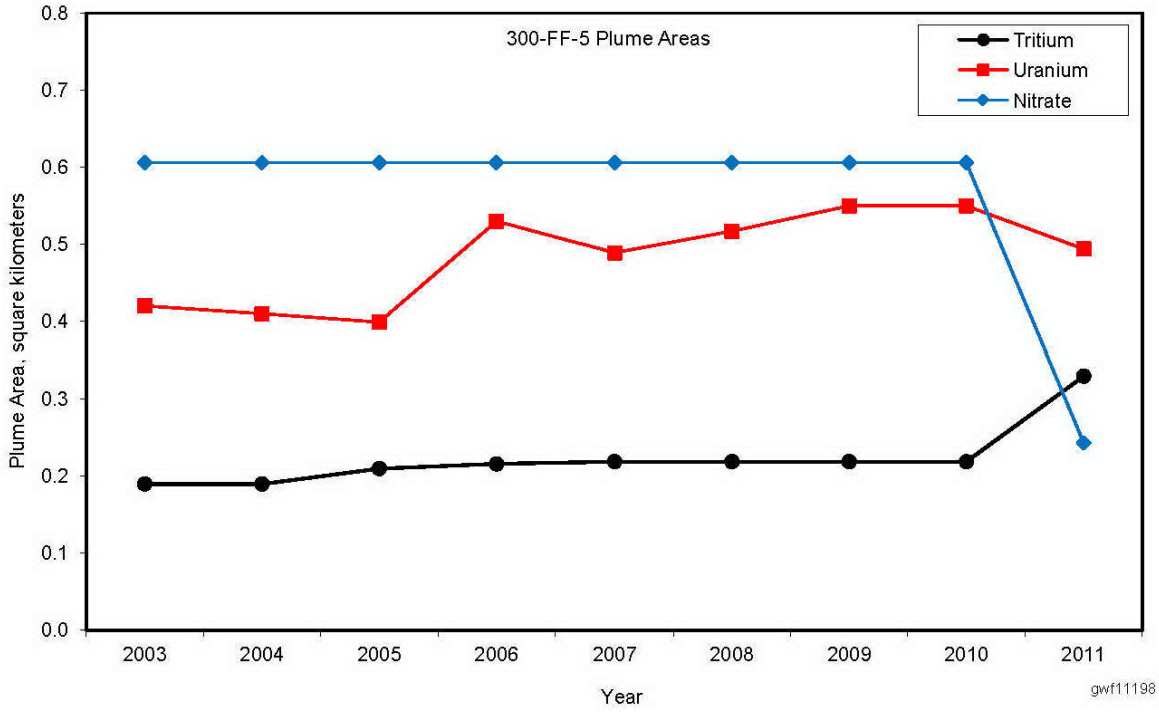


Figure 2.7-7A. Uranium Concentrations in the 300 Area Industrial Complex, Upper Part of Unconfined Aquifer, June 2011

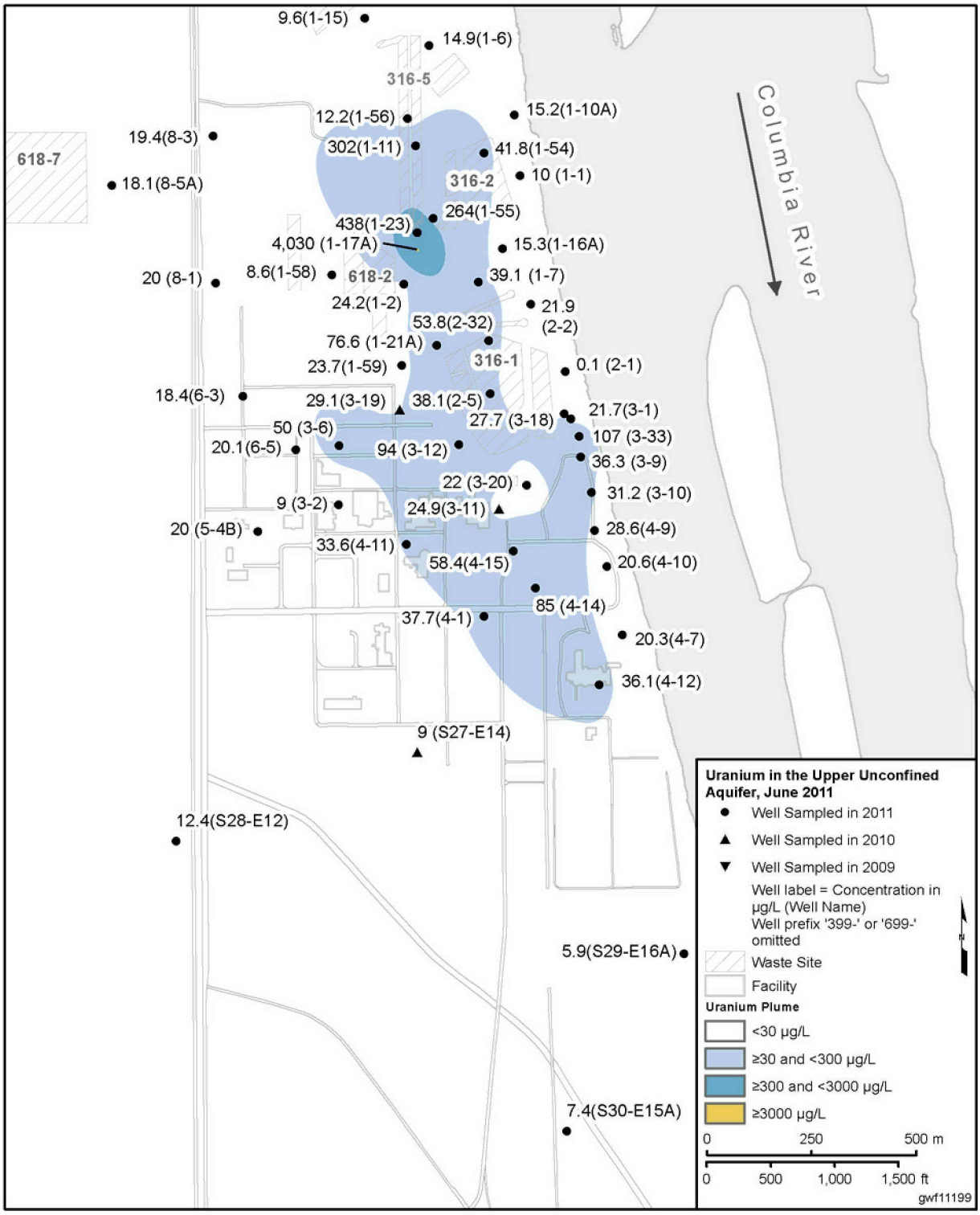
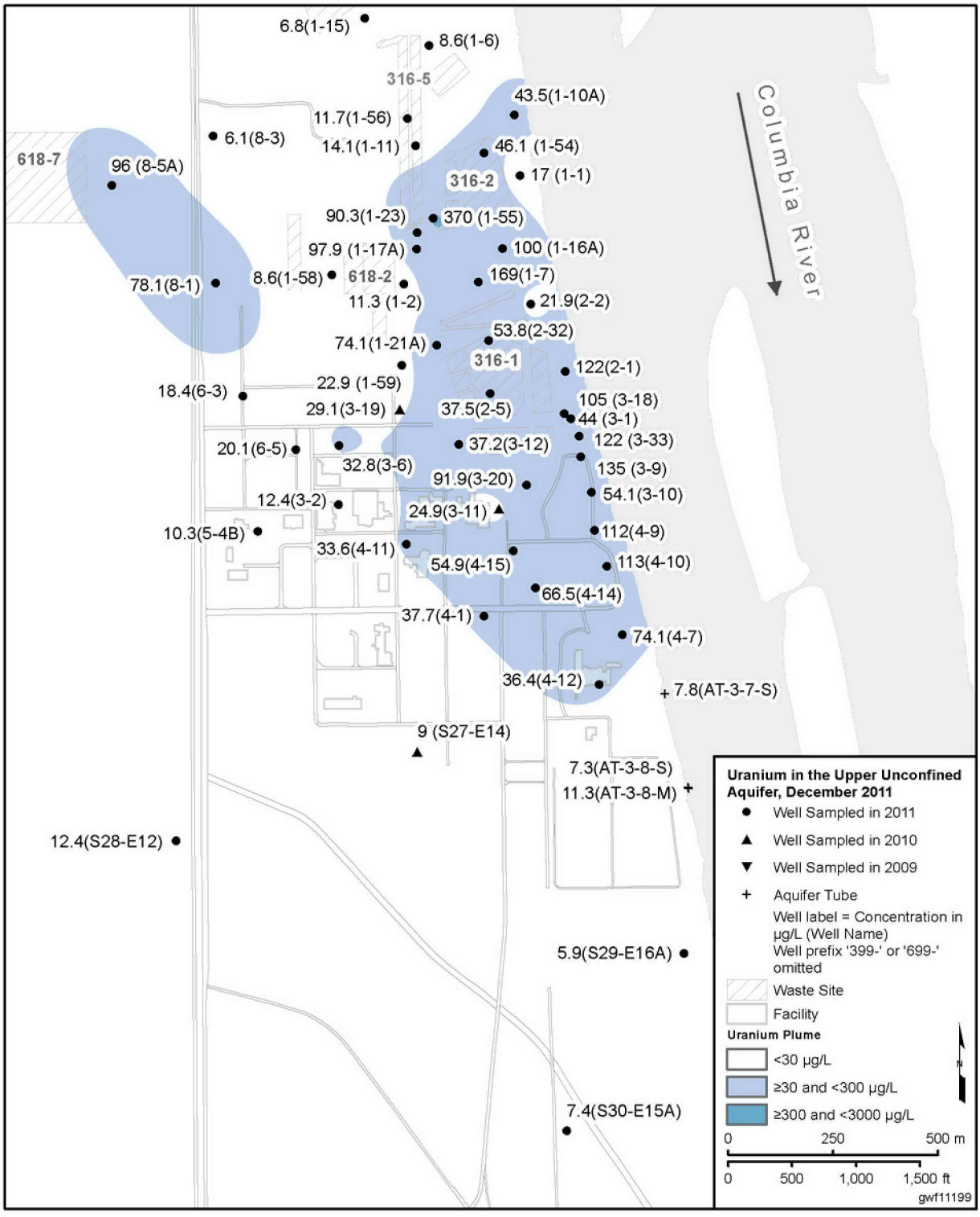


Figure 2.7-7B. Uranium Concentrations in the 300 Area Industrial Complex, Upper Part of Unconfined Aquifer, December 2011



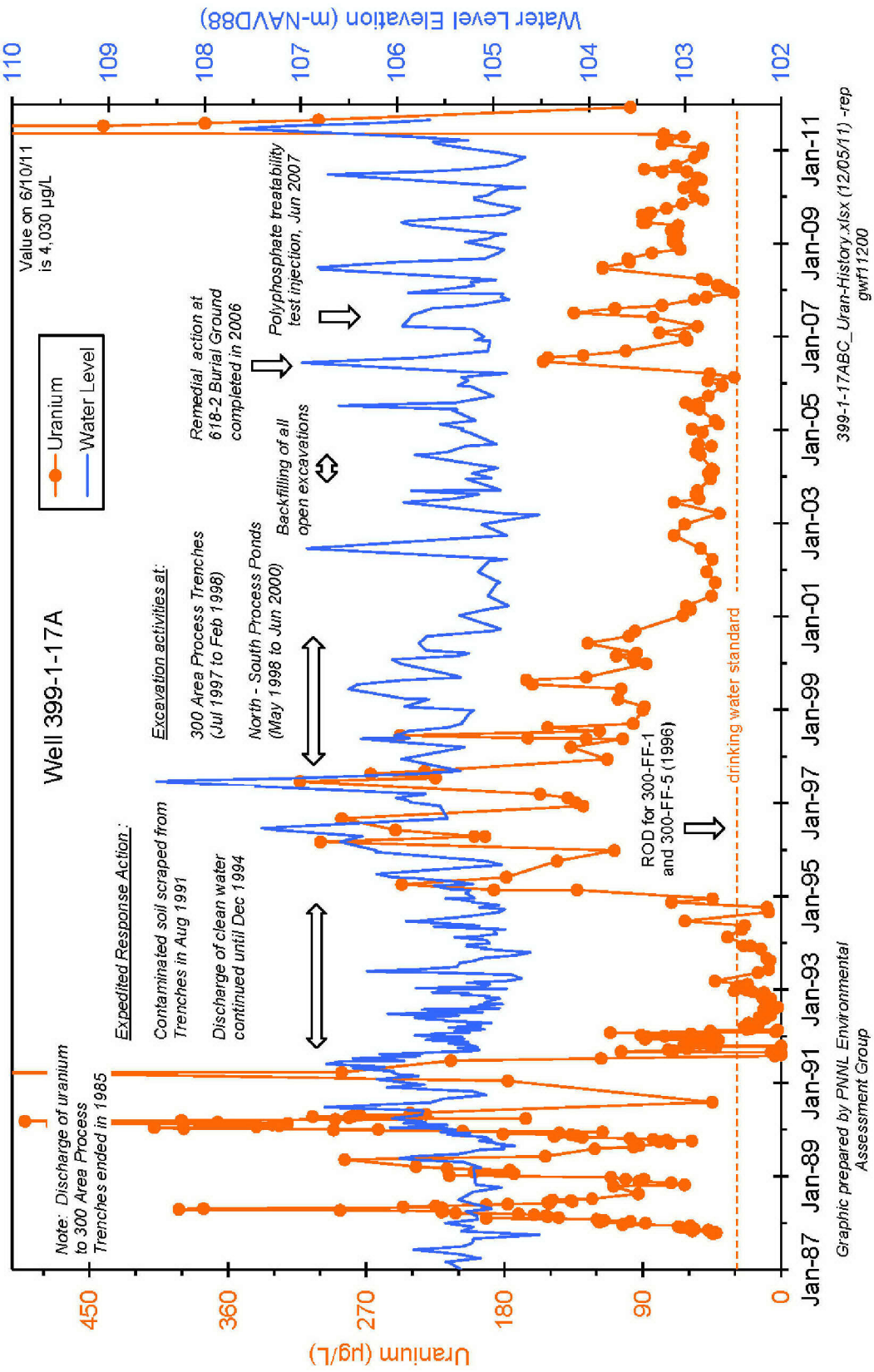


Figure 2.7-8. Uranium and Water Level Trends in Well 399-1-17A near Former 300 Area Process Trenches

Figure 2.7-9. Uranium and Water Level Trends at (A) Inland Wells and (B) Near-River Wells, 300 Area

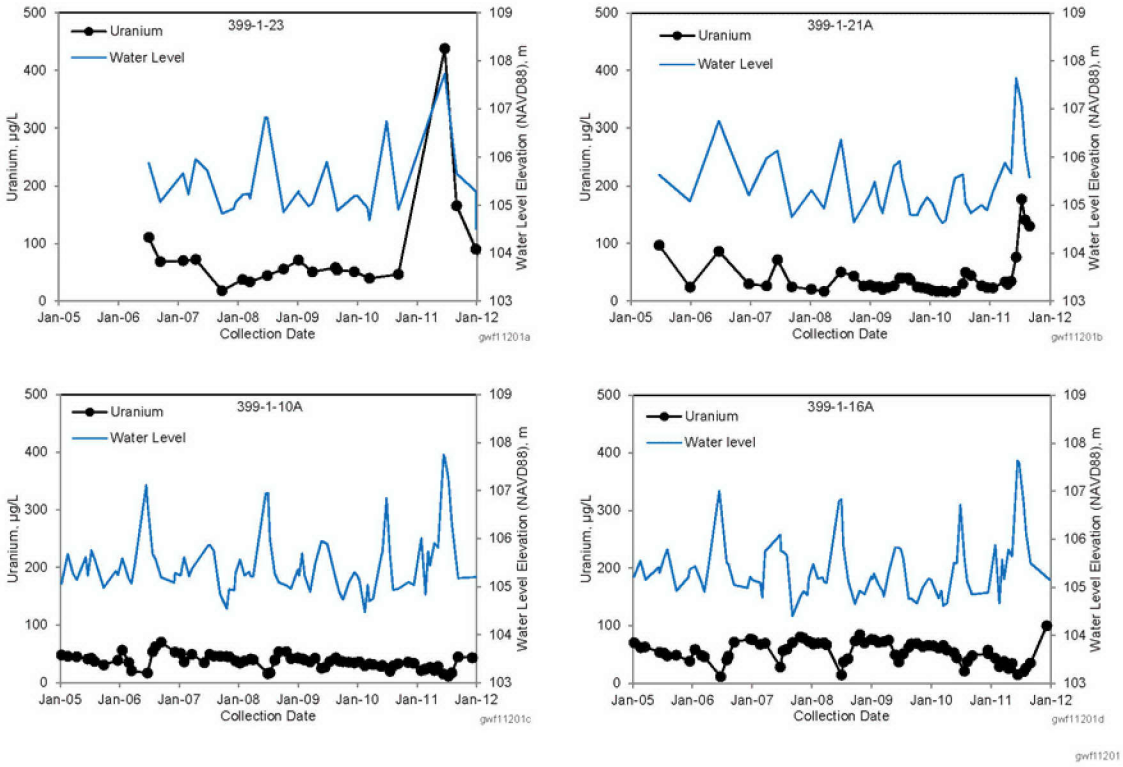


Figure 2.7-10. Uranium and Chromium Trends Downgradient from Former 618-7 Burial Ground

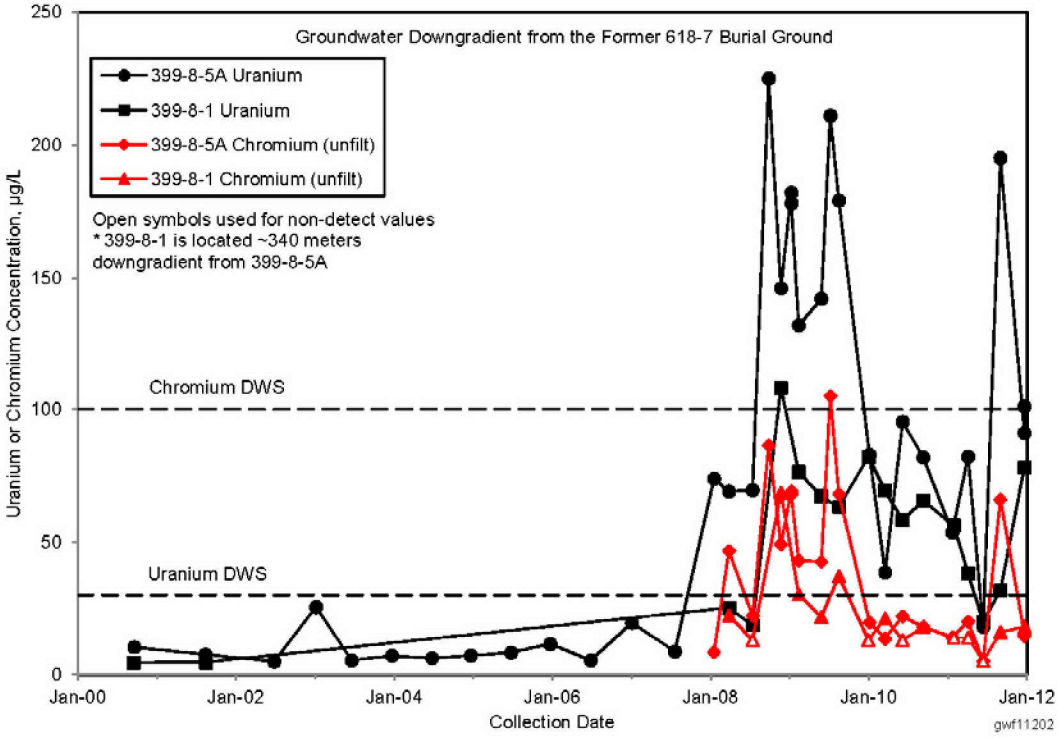


Figure 2.7-11. Uranium Concentrations in 300 Area Aquifer Tubes and Near-Shore Wells, Fall 2011

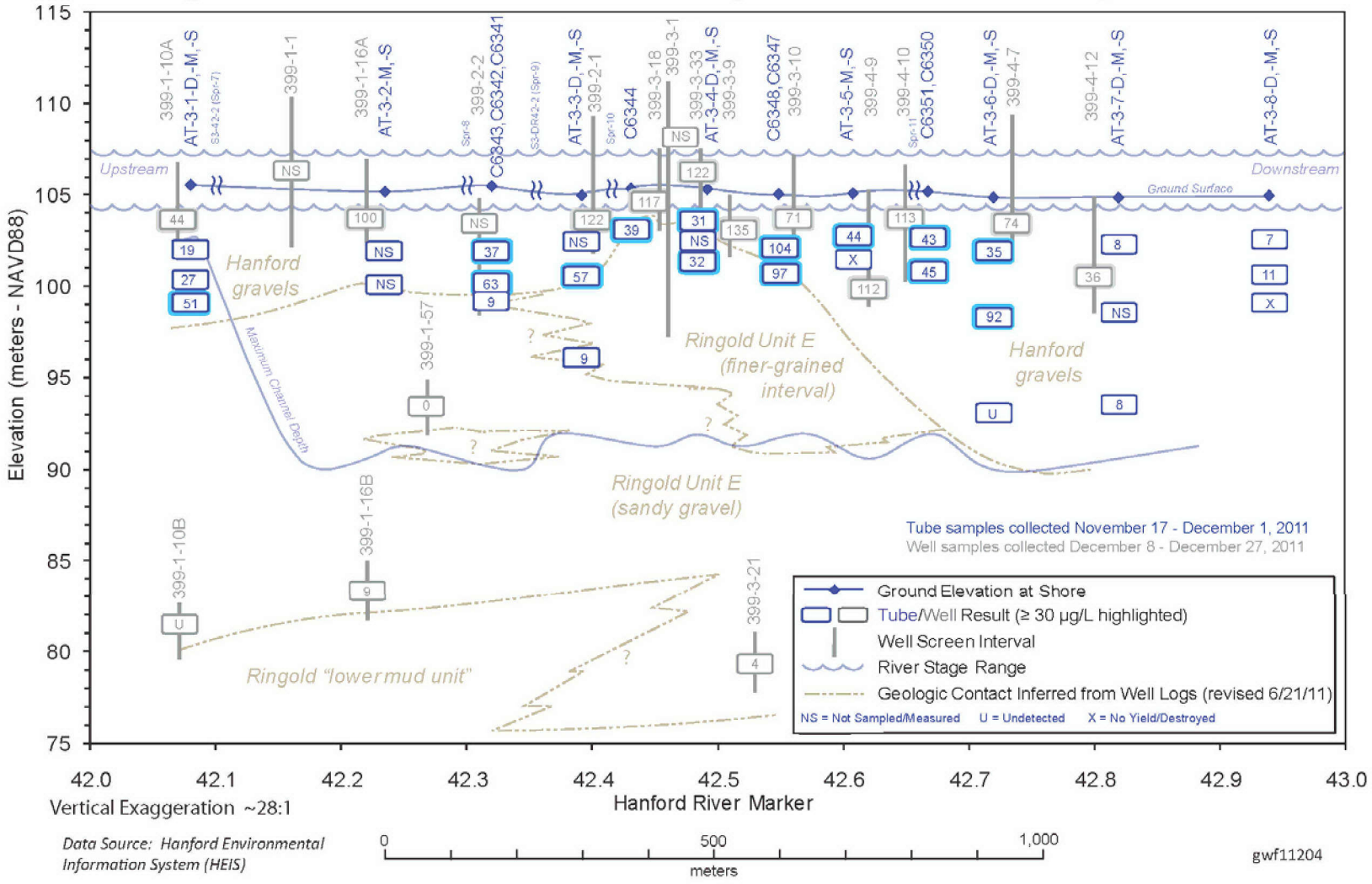


Figure 2.7-12. Minimum, Maximum, and 2011 Uranium Concentrations at 300-FF-5 Aquifer Tube

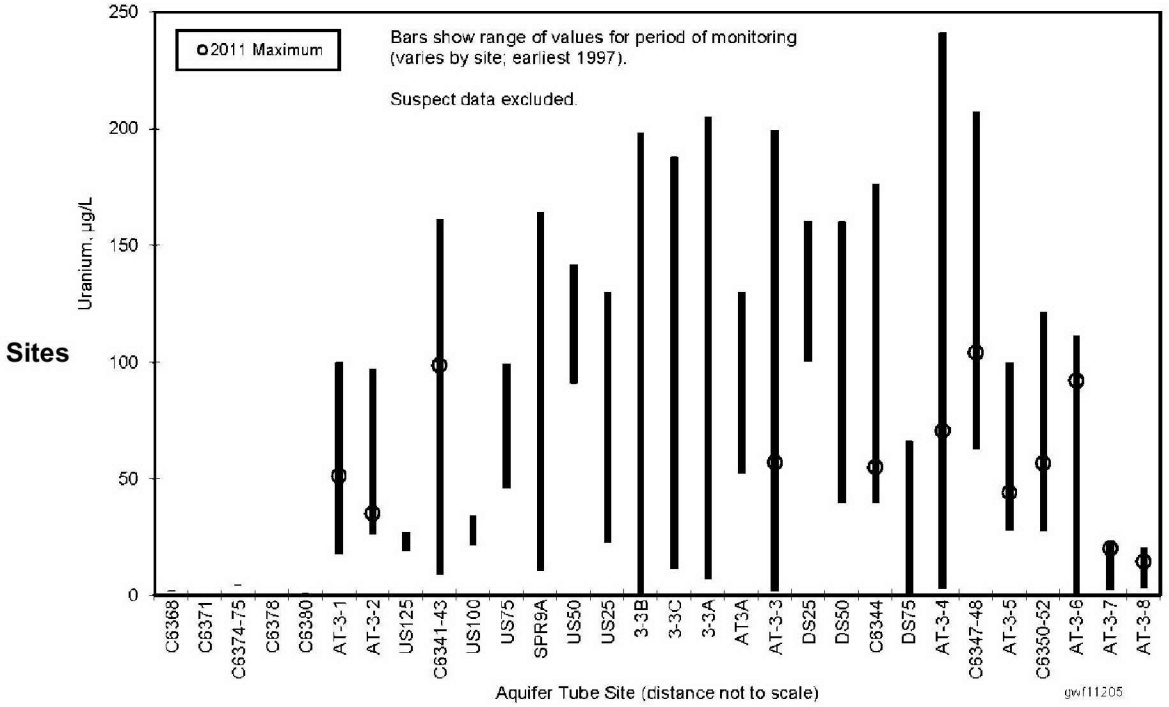


Figure 2.7-13. Uranium Trends in Wells Adjacent to 618-10 Burial Ground

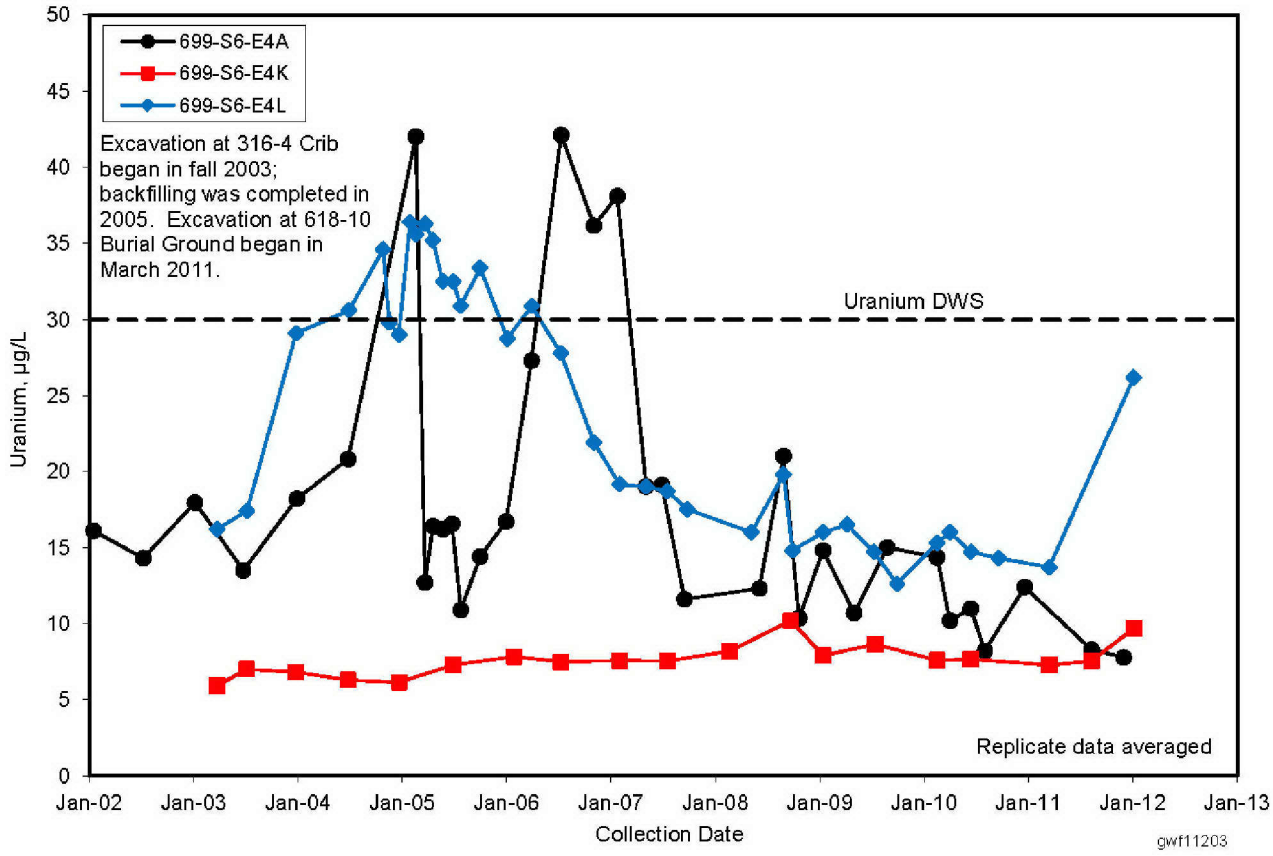


Figure 2.7-14. Trichloroethene Concentrations in 300-FF-5 Aquifer Tubes and Near-Shore Wells, Fall 2011

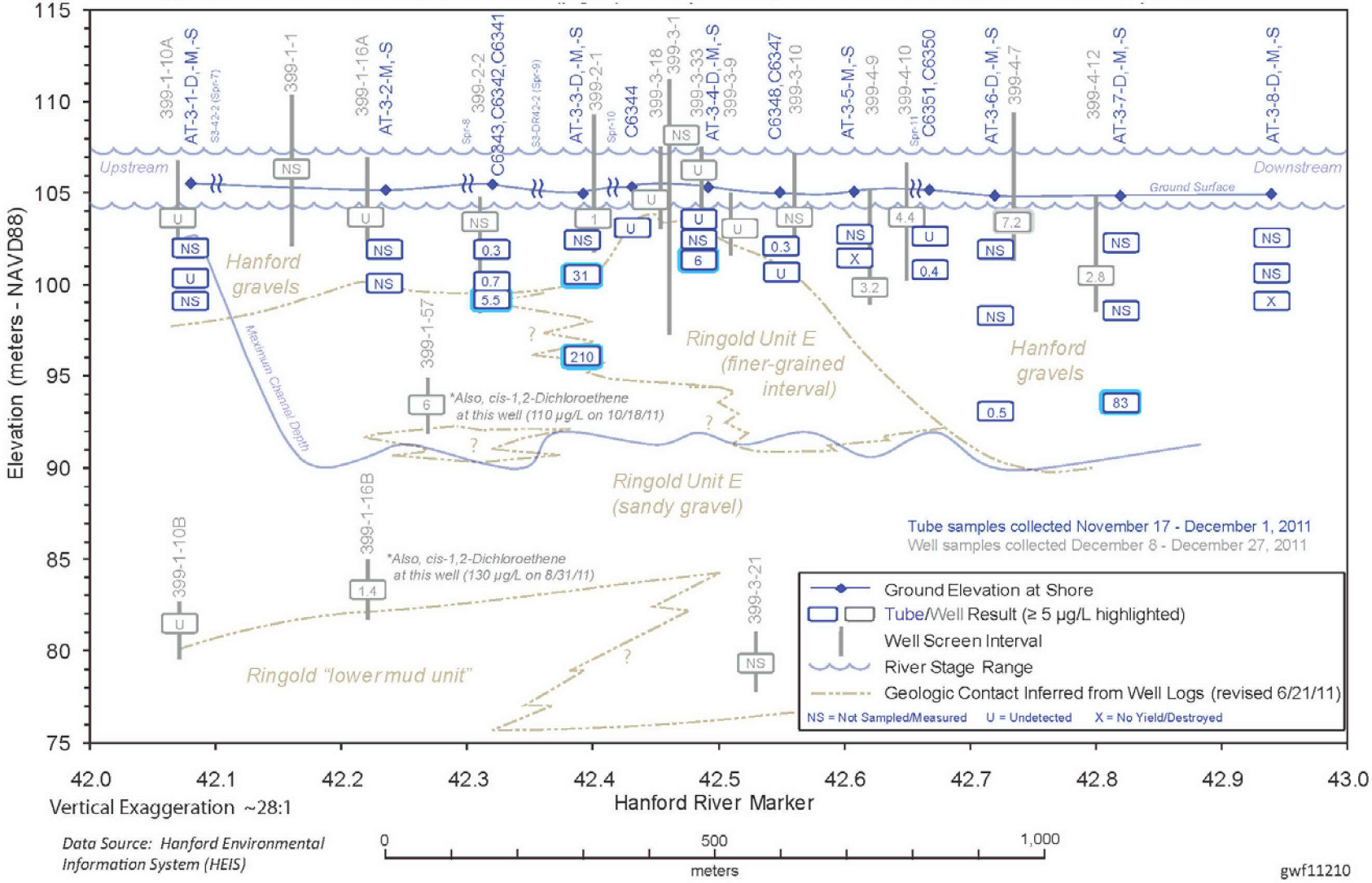


Figure 2.7-15. Volatile Organic Compound Trends in Lower Portion of Unconfined Aquifer at Well 399-1-16B

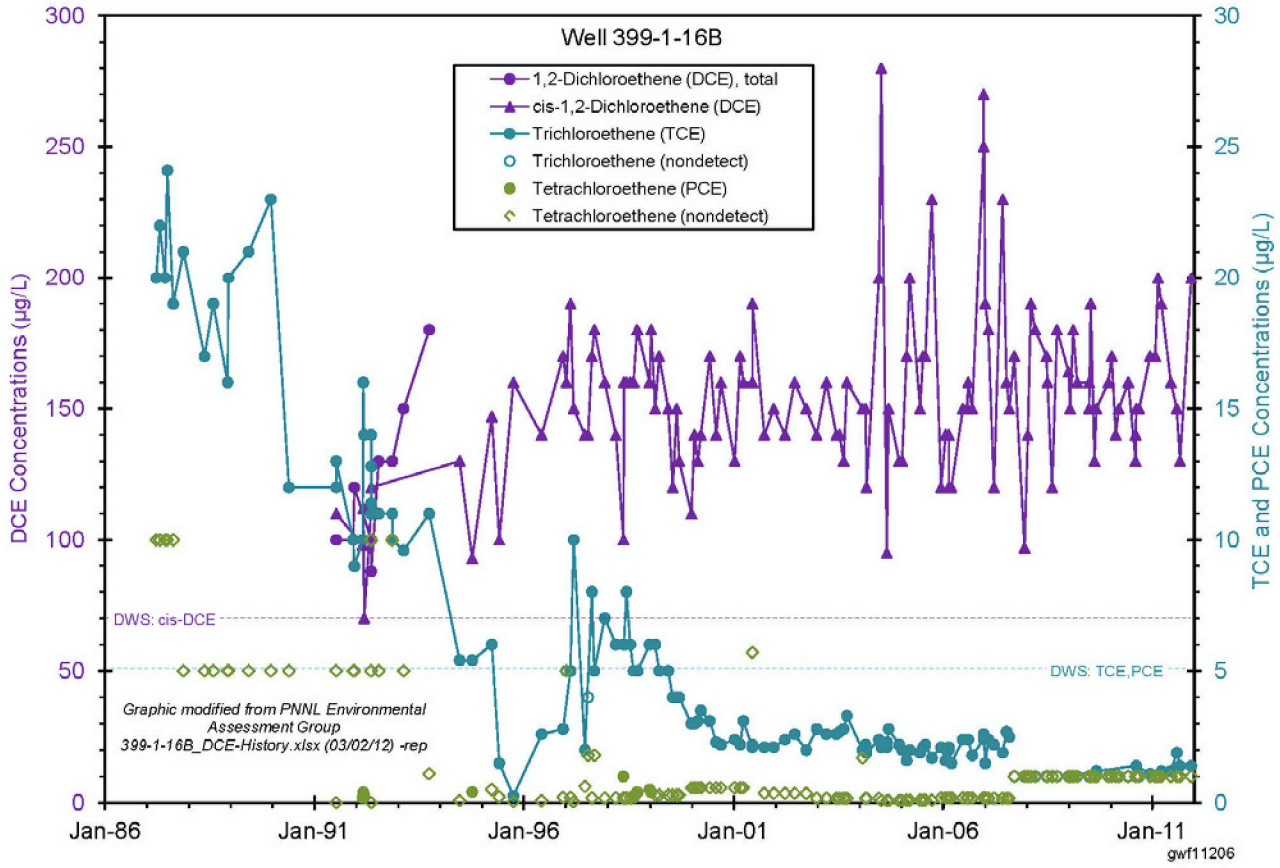


Figure 2.7-16. Average Tritium Concentrations near 618-11 Burial Ground, Upper Part of Unconfined Aquifer, 2011

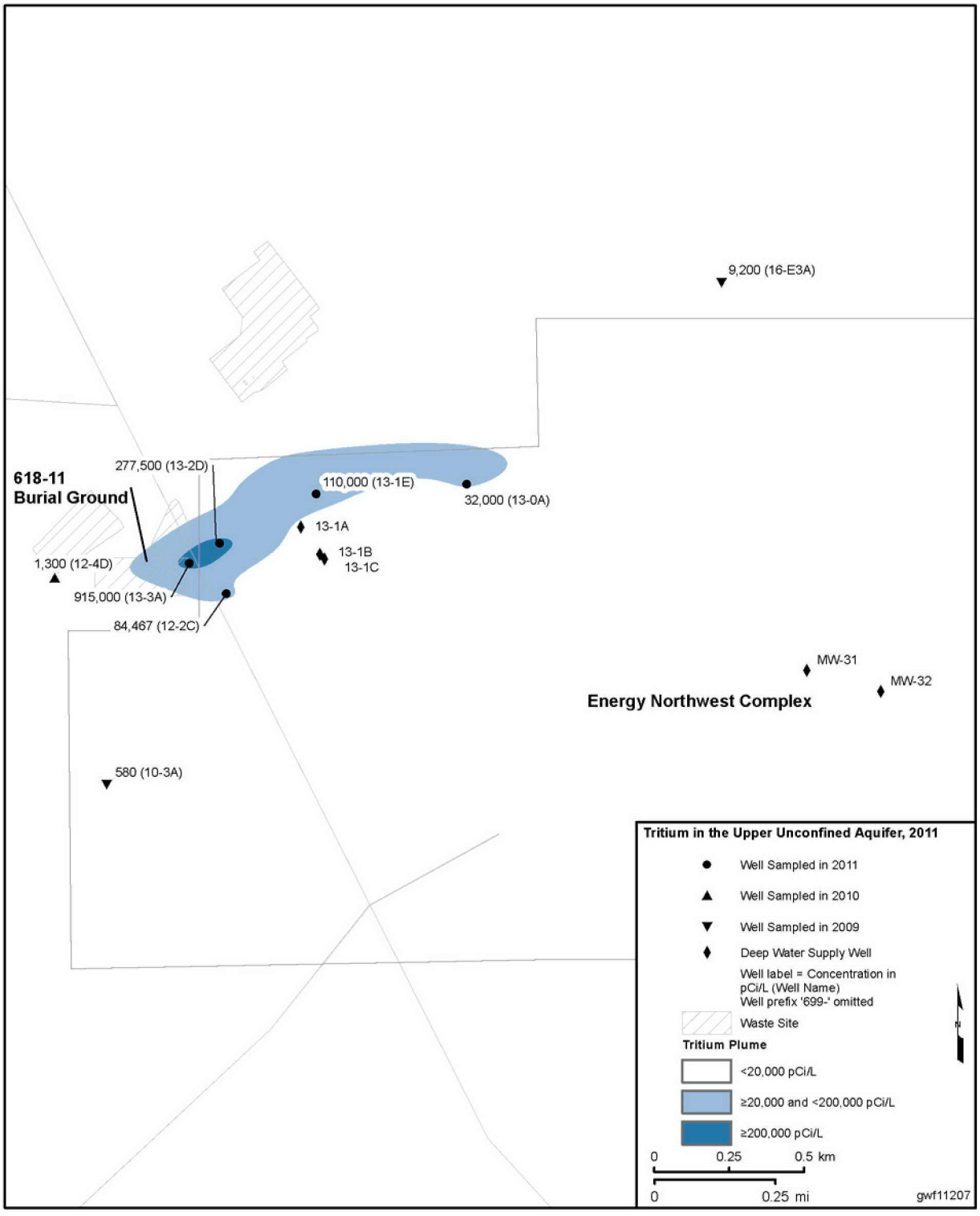


Figure 2.7-17. Tritium Trends in Wells near 618-11 Burial Ground

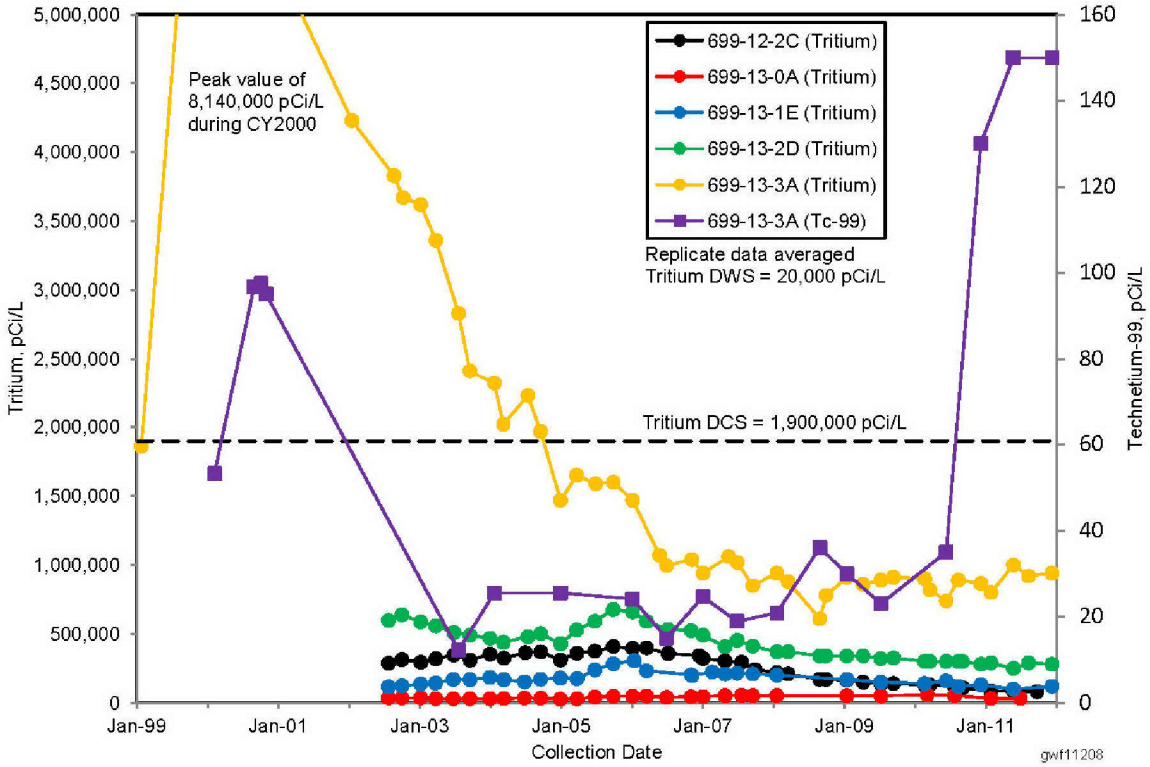
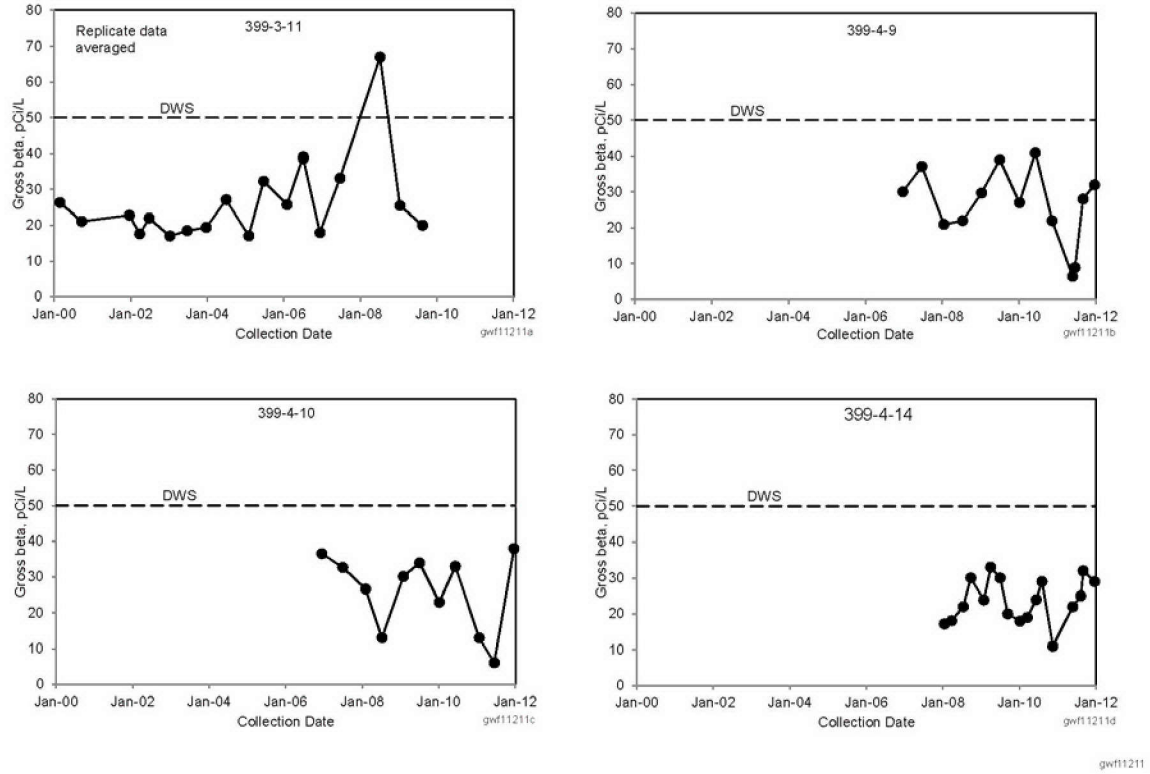


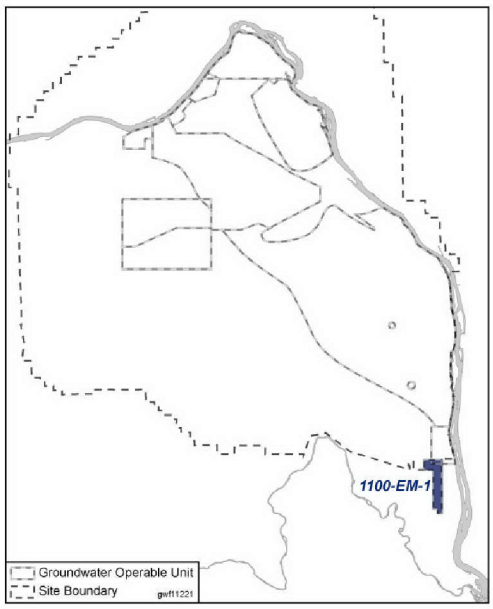
Figure 2.7-18. Gross Beta Trends in Wells Downgradient from the 324 Building



2.8 1100-EM-1

M.J. Hartman

The 1100-EM-1 groundwater interest area includes the former 1100-EM-1 Operable Unit in the southern portion of the Hanford Site and the Richland North Area, south of the Hanford Site. Figure 2.8-1 shows the groundwater monitoring wells in the portion of the interest area near the former operable unit. Figure 2.1-4 in Section 2.1 shows the locations of wells in the western part of the interest area.



The former 1100-EM-1 Operable Unit includes the inactive Horn Rapids Landfill.[1] Originally a borrow pit for sand and gravel, the landfill was used from the late 1940s to the 1970s for disposal of office and construction waste, asbestos, sewage sludge, fly ash, and reportedly numerous drums of unidentified organic liquids (DOE/RL-90-18, *Phase I Remedial Investigation Report for the Hanford Site 1100-EM-1 Operable Unit*; DOE/RL-92-67, Draft B, *Final Remedial Investigation/Feasibility Study-Environmental Assessment Report for the 1100-EM-1 Operable Unit, Hanford*). The landfill extends over 0.2 square kilometer of generally flat terrain. Following cleanup of 1100-EM-1 and related source operable units, DOE transferred ownership of a portion of the property in 1100-EM-1 to the Port of Benton.

The Richland North Area includes the City of Richland North Well Field and Recharge Ponds. The City of Richland pumps water from the Columbia River into the recharge ponds. The river water percolates to the groundwater, and the groundwater is then pumped through surrounding wells for municipal use during peak demand periods (WHC-MR-0033, *Recharge to the North Richland Well Field*). The Richland North Area also includes the AREVA NP, Inc. nuclear fuel production facility, which is southwest (upgradient) of the inactive Horn Rapids Landfill (Figure 2.8-1).

Groundwater beneath the northern part of 1100-EM-1 is monitored under CERCLA to assess the performance of natural attenuation in breaking down volatile organic compounds (TPA-CN-163, *Change Notice for Modifying Approved Documents Work Plans in Accordance with TPA Action Plan, Section 9.0 Documentation and Records, PNNL-12220, "Sampling and Analysis Plan Update*

1100-EM-1 at a Glance

Operations included industrial and automotive activities (1954–1985), and a landfill (1950s–1970)			
2011 Groundwater Monitoring			
Contaminant	**Drinking Water Standard**	**Maximum Concentration**	**Plume Area[a] (km^2)**
Trichloroethene	5 µg/L	< 1 µg/L	0
Nitrate	45 mg/L	302[b]	Not calculated[b]
Uranium	30 µg/L	26.4[b]	Not calculated[b]
Remediation			
Waste Sites (final action): 100% complete[c]. Groundwater (final action): Monitored natural attenuation. Final record of decision: 1993.			

a. Estimated area above drinking water standard.

b. From offsite sources.

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

[1] DOE's former Horn Rapids Landfill was located on the Hanford Site. The similarly named Horn Rapids Sanitary Landfill (formerly the Richland Landfill) is a separate facility that remains active and is used to dispose the City of Richland's residential waste.

for Groundwater Monitoring – 100-EM-1 Operable Unit"). Groundwater samples from three wells are analyzed for trichloroethene and its degradation products, which include 1,1-dichloroethene and vinyl chloride. Additional wells and constituents are monitored in the larger interest area to detect Hanford Site contaminants and contaminants originating from offsite sources. This monitoring currently is not governed by a specific sampling and analysis plan.

Groundwater beneath 1100-EM-1 flows primarily west to east and discharges to the Columbia River (Figure 2.8-2). In the northeastern portion of the region, groundwater flows to the northeast. In the Richland North Area, groundwater flow from the west is diverted to the northeast and southeast around a recharge mound beneath Richland's recharge ponds. The unconfined aquifer is recharged by water from the Yakima River, by infiltration of agricultural irrigation in the area between the Yakima and Columbia Rivers, and by natural precipitation. Water for agricultural irrigation is mainly extracted from the Columbia River.

None of the wells in 1100-EM-1 penetrate the full thickness of the Hanford and Ringold formations; however, wells in the nearby 300 Area suggest that the sediments above the basalt are up to 53 meters thick. The thickness of the unconfined aquifer in this area is approximately 5.6 to 9 meters, with all but the upper few meters residing in the Ringold Formation unit E (Section 2.1 and Appendix E). A silt- and clay-dominated facies form a local, laterally extensive upper aquitard that is up to 10 meters thick. Most of the wells used to monitor trichloroethene have screen intervals that penetrate the upper 4.5 to 7.5 meters of the unconfined aquifer and cross the water table.

2.8.1 Trichloroethene

Historically, trichloroethene-contaminated groundwater was found upgradient and downgradient of the inactive Horn Rapids Landfill. A review of available information indicated that trichloroethene contamination moved into the Hanford Site's 1100 Area via groundwater. AREVA, a facility adjacent to the landfill, has investigated soil and groundwater contamination as an independent action in accordance with WAC 173-340, which is discussed in the *2006 Annual RCRA Report – Groundwater Quality Assessment Program* (E06-02-2006). The past use of organic solvents at the AREVA lagoon area was the only documented record of trichloroethene occurrence or use near the contaminant plume identified during 1100-EM-1 RI/FS (DOE/RL-92-67). Trichloroethene was used during the installation, repair, and cleaning of lagoon liners at various times from 1978 through 1988 (for bonding overlapping liner sections together). While the Horn Rapids Landfill was alleged to have received drummed waste solvents (DOE/RL-90-18), soil vapor surveys, geophysical investigations, and trenching activities during the RI/FS did not reveal evidence of a trichloroethene source at the landfill (DOE/RL-92-67).

Trichloroethene concentrations continued to be below detection limits in 2011.

During 2011, trichloroethene concentrations in 1100-EM-1 continued to be less than the detection limit of 1.0 µg/L. Potential breakdown products of trichloroethene also remained undetected at a detection limit of 1.0 µg/L during 2011.

The City of Richland monitors groundwater quarterly in the upper portion of the unconfined aquifer for chemical constituents at their Horn Rapids Sanitary Landfill (formerly the Richland Landfill), approximately 1 kilometer south of the Hanford Site boundary on Highway 240. Various chlorinated hydrocarbons (e.g., tetrachloroethene, trichloroethene, and vinyl chloride), while exceeding drinking water standards in several of the city's monitoring wells, show signs of natural attenuation (*Horn Rapids Landfill Environmental Monitoring Report Calendar Year 2011* [City of Richland, 2012]). During 2011, chlorinated hydrocarbons were below their respective minimum detection limits at Hanford Site well 699-S31-1, which is northeast of the city's sanitary landfill.

2.8.2 Tritium

Tritium concentrations are above background in 1100-EM-1 groundwater, but the maximum concentration in 2011 was only 2 percent of the drinking water standard.

The Hanford Site tritium plume that originates in the 200 Area extends southeast through the 600 Area and into the 300 Area at levels below the 20,000 pCi/L drinking water standard (Figure 2.8-3). The leading edge of the sitewide tritium plume is closely monitored because of its proximity to the City of Richland's North Well Field. A representative background level of tritium in Hanford Site groundwater is 142 pCi/L (95th percentile; DOE/RL-96-61). Although tritium levels were above background in several 1100-EM-1 wells in 2011, these levels are far below the drinking water standard. Well 699-S34-E10 had the maximum tritium concentration in 2011 (380 pCi/L) and has shown an increasing trend in recent years (Figure 2.8-4). This well is southeast of AREVA and northwest of the Richland North Well Field, and no known sources of tritium contamination lie upgradient of the well. Tritium concentrations are lower between this well and the 200 East Area plume edge in the 300 Area. Consequently, the tritium is not believed to be caused by Hanford Site sources. The following factors limit migration of the tritium plume into the eastern portion of 1100-EM-1:

- Groundwater generally flows from west to east between the Yakima River, a recharge source, and the Columbia River.
- Artificial recharge from agricultural irrigation in the western and central portions of 1100-EM-1 south of the Hanford Site further contributes to the eastward and northeastward flow.
- Groundwater flow is directed radially outward from the elevated groundwater levels beneath Richland's recharge ponds.

These factors produce converging groundwater flow lines in the 300 Area where groundwater discharges to the Columbia River (Figure 2.8-2). Section 2.7 discusses tritium in groundwater in the 300 Area.

2.8.3 Nitrate

Nitrate concentrations are above the drinking water standard of 45 mg/L throughout much of 1100-EM-1 (Figure 2.8-5). The leading edge of the plume at the 45 mg/L contour in the 300 Area did not advance significantly in 2011. Nitrate contamination in this area has likely resulted from industrial and agricultural uses off the Hanford Site and migrated to the northeast. Agricultural uses include fertilizer applications to the irrigated fields west of 1100-EM-1. Some of the highest nitrate levels occur near the offsite AREVA facility and the inactive Horn Rapids Landfill. Nitrate data for the AREVA wells are reported in E06-09-004, *2011 Annual Groundwater Report*. The highest concentration in an AREVA well in 2011 was 234 mg/L, a decrease from 307 mg/L in 2010. The highest concentrations in Hanford Site wells in 2011 were approximately 300 mg/L in wells 699-S31-E10A and -E10C, slightly lower than in 2010 (Figure 2.8-6).

Elevated nitrate concentrations continue to be measured but are related to offsite industrial and agricultural activities.

Nitrate concentrations in aquifer tube AT-3-8-S in the southern 300 Area exceeded the drinking water standard in 2011 (79.2 mg/L in March; 45.2 mg/L in December).

2.8.4 Gross Alpha and Uranium

Elevated levels of gross alpha and uranium occur downgradient of the AREVA facility, near the former Horn Rapids Landfill. Gross alpha data for the AREVA wells are reported in Table 3 of E06-09-004. During 2011, several wells downgradient of the AREVA facility showed gross alpha levels higher than the 15 pCi/L drinking water standard, with the maximum observed concentrations of 98.1 and 82 pCi/L in duplicate samples from well SPC-GM-8 collected in June 2011. Gross alpha is largely attributed to uranium from fuels manufacturing activities at the facility. The uranium concentrations in well SPC-GM-8 in June were 40.5 and 61.4 µg/L, lower than peak levels seen in 2009 (Figure 2.8-7).

A small uranium plume in 1100-EM-1 originated at an offsite facility.

Uranium contamination from AREVA has been detected in 1100-EM-1 wells. Uranium concentrations in wells 699-S31-E10A and –E10C, adjacent to the former Horn Rapids Landfill, and 699-S28-E12, farther downgradient, have increased since the early 1990s (Figure 2.8-7). There was no increase between 2010 and 2011 in the two wells closest to the landfill, but there was an increase in the downgradient well showing continued movement of the contaminant at levels below the drinking water standard (30 µg/L).

2.8.5 CERCLA Groundwater Activities

The 1100-EM-1 Groundwater Operable Unit, including the inactive Horn Rapids Landfill, was placed on the National Priorities List (40 CFR 300, Appendix B) in 1989 and was delisted from the National Priorities List (40 CFR 300, Appendix B) in 1996. The results of the CERCLA investigation are presented in the final RI study (DOE/RL-92-67). EPA/ROD/R10-93/063 established natural attenuation as the remedial action alternative for the trichloroethene plume. Site characterization was conducted to evaluate natural attenuation as a remedial action alternative at the Horn Rapids Landfill during the RI/FS in the late 1980s and early 1990s (DOE/RL-90-18; DOE/RL-92-67). The degradation of trichloroethene by microbial action may result in the formation of organic compounds such as 1,1-dichloroethene and vinyl chloride. These degradation products also pose a risk to human health and the environment and are, therefore, monitored in groundwater at the operable unit. Since implementation of the selected remedy, concentrations of trichloroethene have declined dramatically and have been below the detection limit from 2008 to 2011. To date, degradation products have not been detected.

DOE/RL-2006-20, published in November 2006, stated that the plume mass and concentration have been adequately reduced to be protective of human health and the environment. The review also stated that groundwater monitoring is no longer necessary, but continues, indicating that trichloroethene levels are below the drinking water standard.

In June 2007, TPA-CN-163 was approved which reduced the groundwater monitoring requirements to annual monitoring and analysis of trichloroethene at three of the original network wells (699-S28-E12, 699-S31-E10A, and 699-S31-E10C). All three of the wells were sampled as scheduled in 2011 (Appendix A).

Figure 2.8-1. Facilities and Groundwater Monitoring Wells in 1100-EM-1

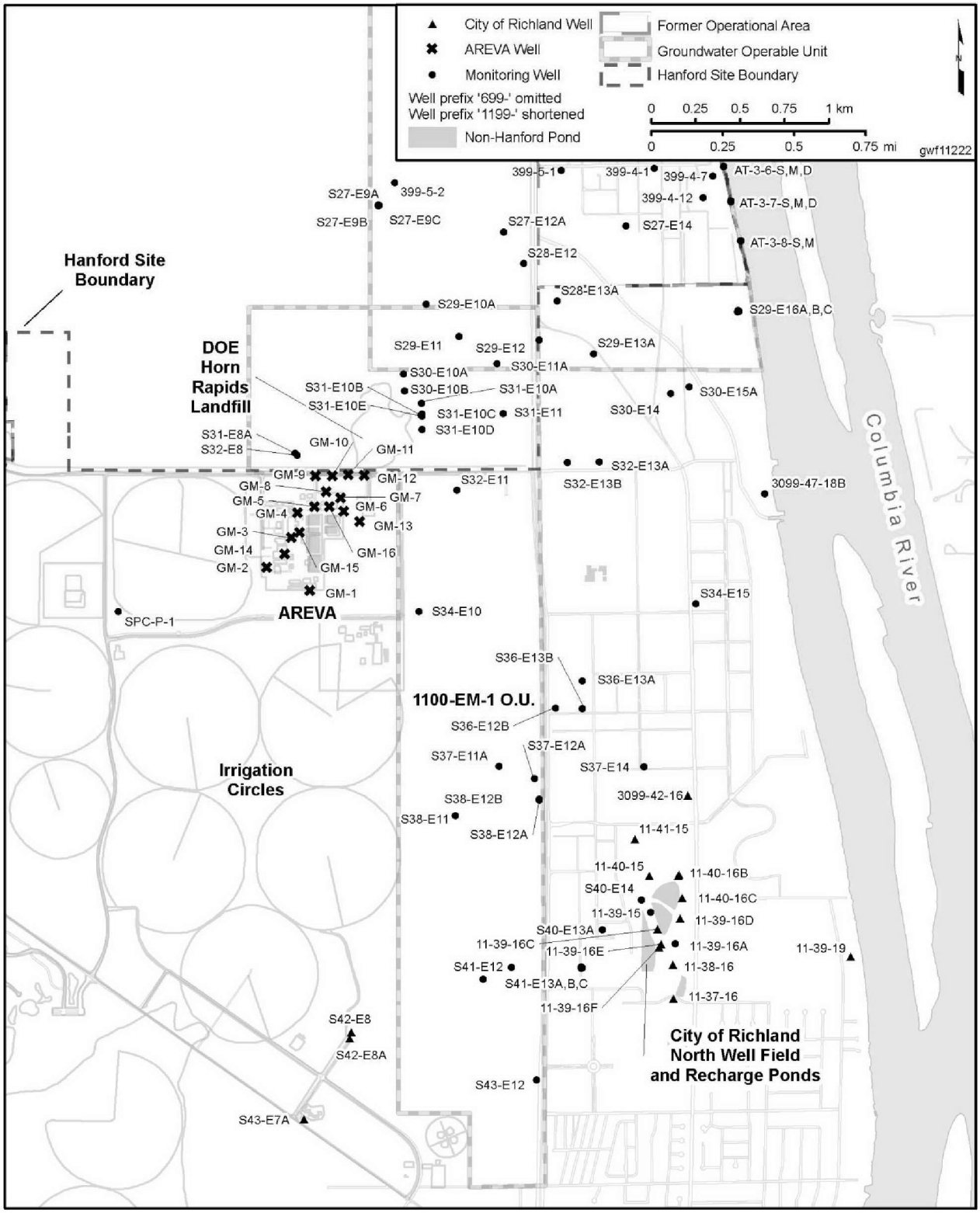


Figure 2.8-2. 1100-EM-1 Water Table, March 2011

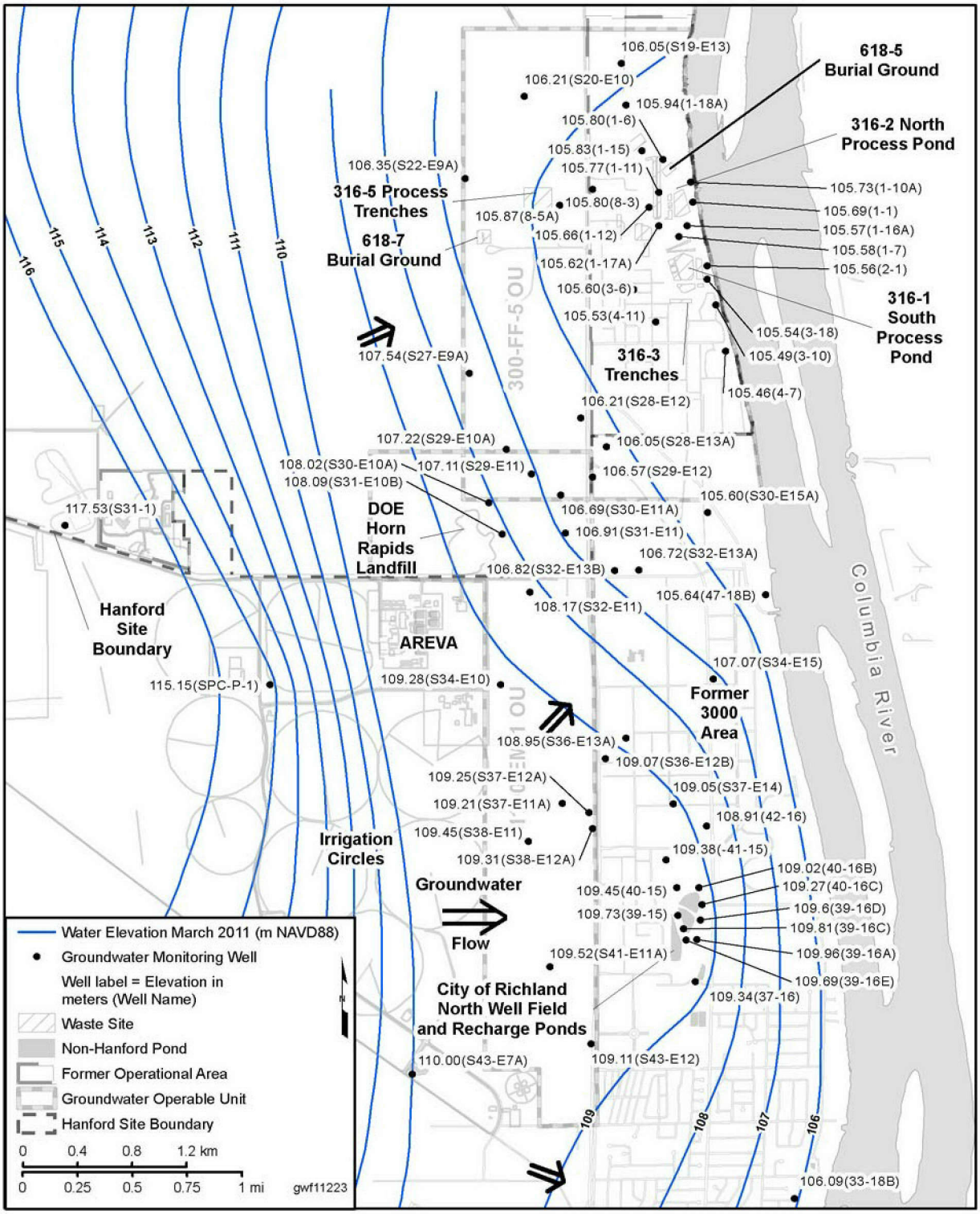


Figure 2.8-3. Average Tritium Concentrations in 1100-EM-1, Upper Part of Unconfined Aquifer, 2011

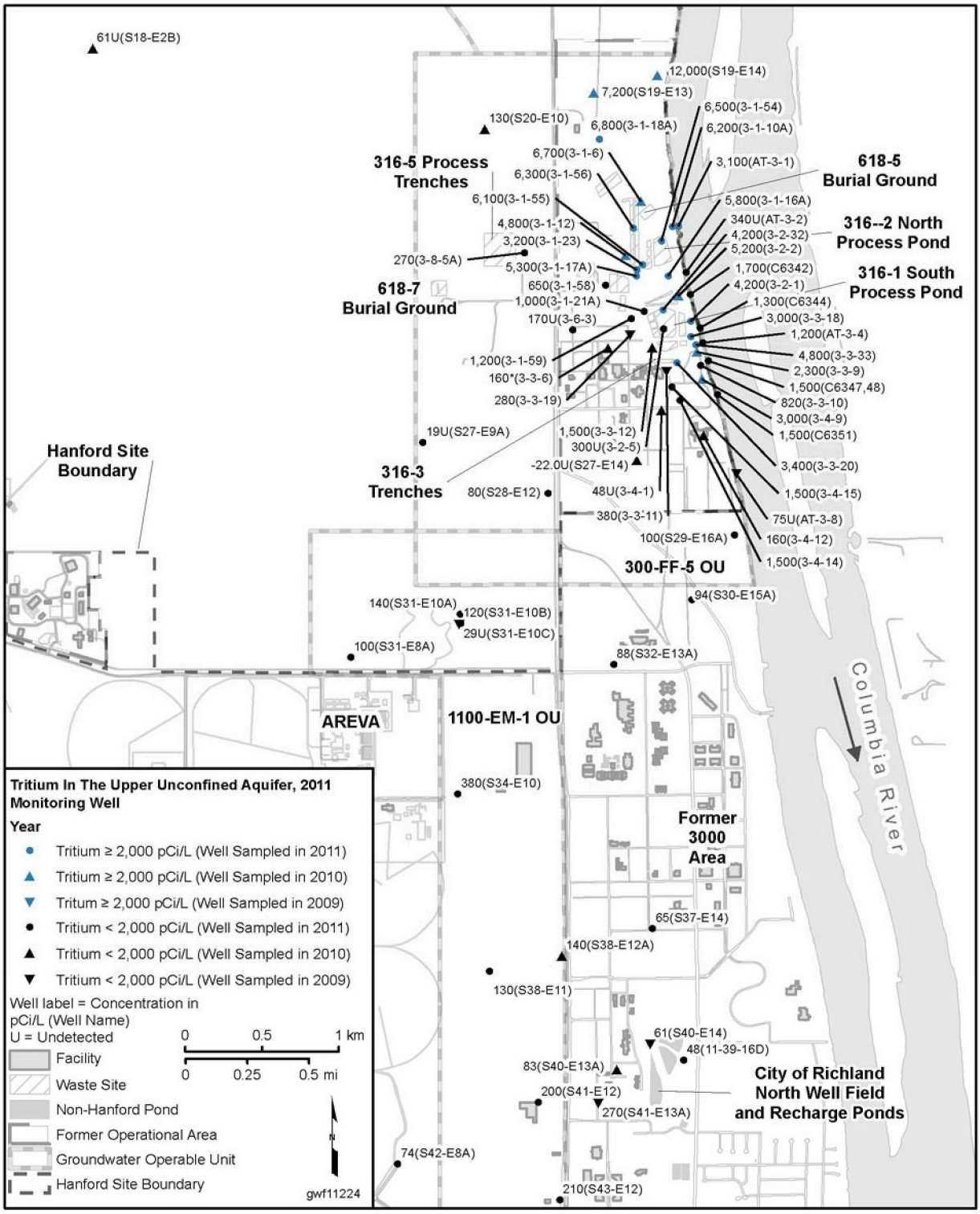


Figure 2.8-4. Tritium Trends in Well 699-S34-E10

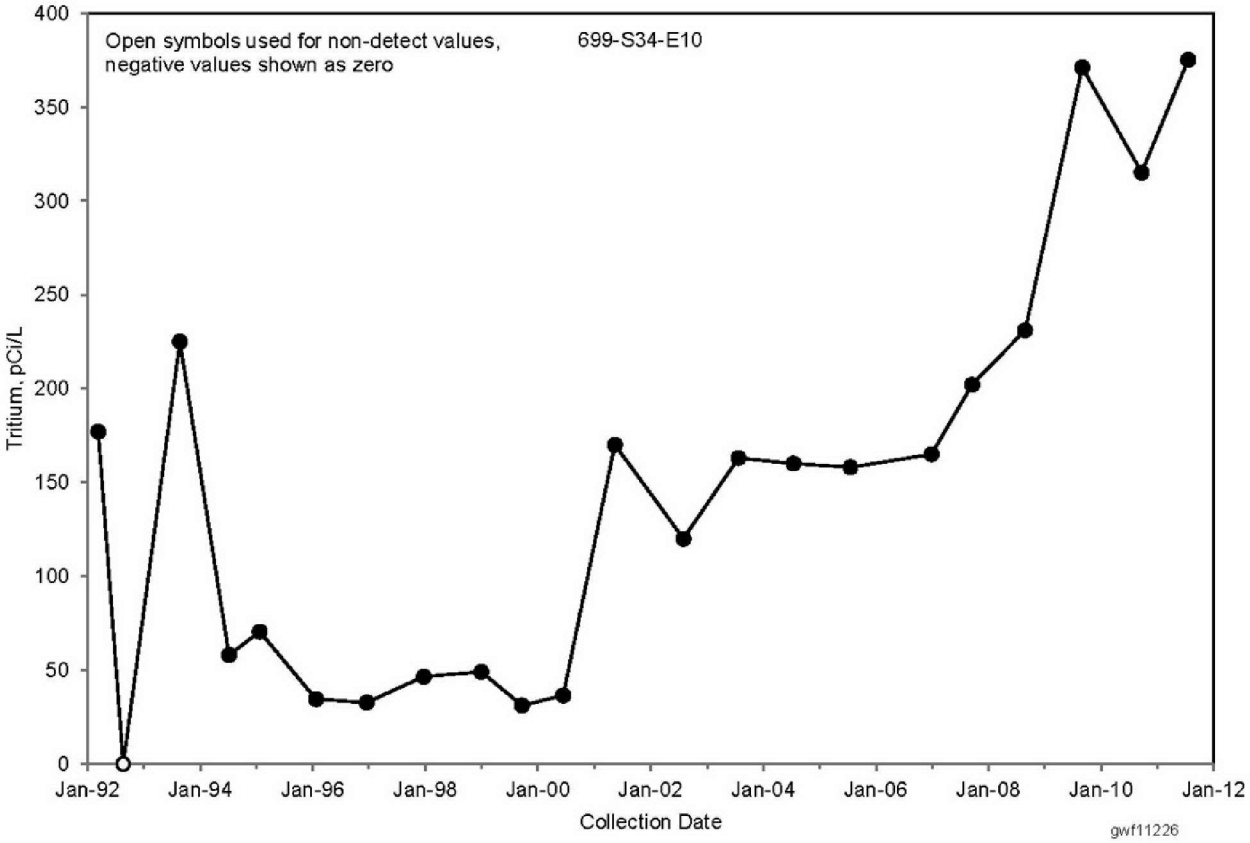


Figure 2.8-5. Average Nitrate Concentrations in 1100-EM-1, Upper Part of Unconfined Aquifer, 2011

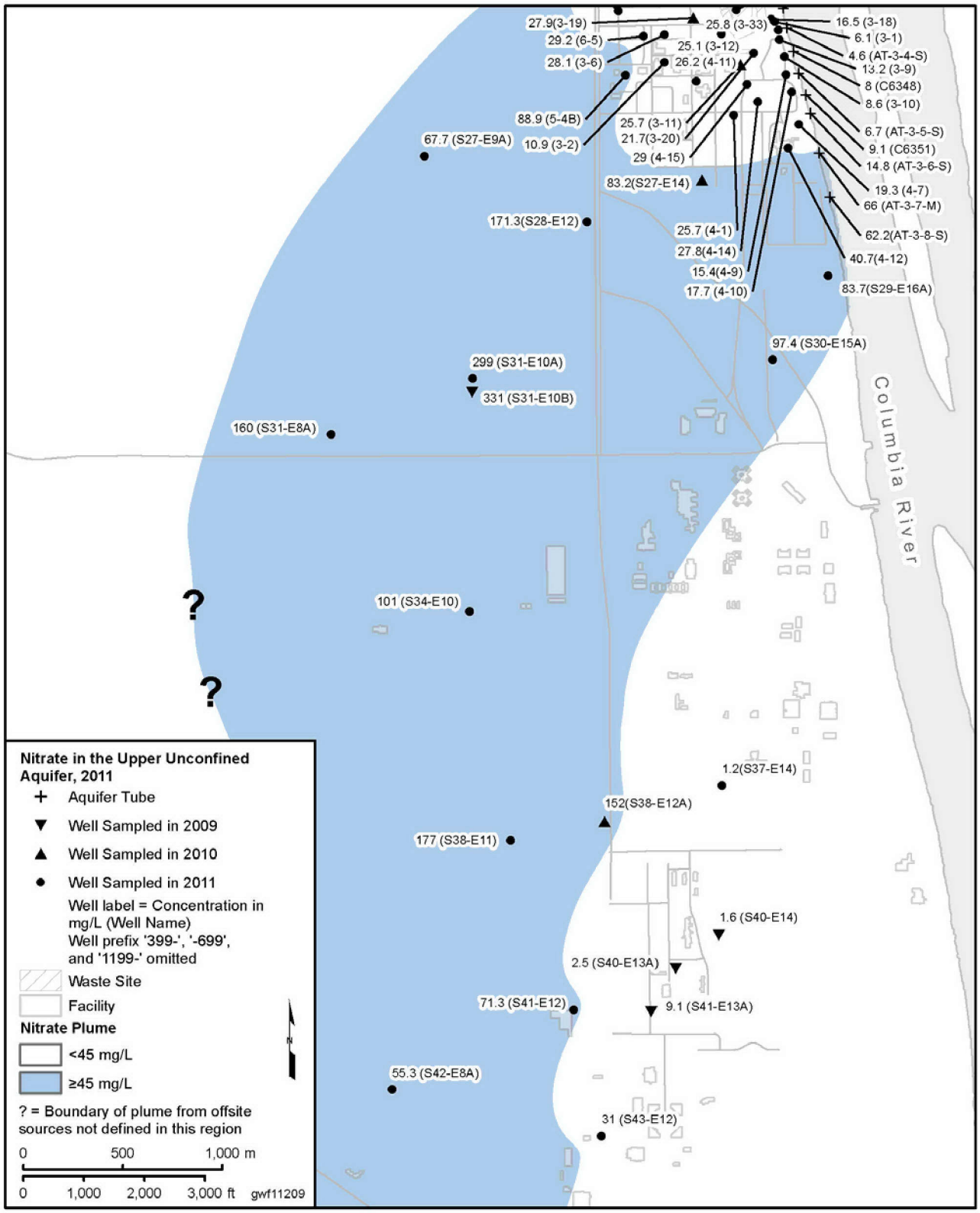


Figure 2.8-6. Nitrate Trends in 1100-EM-1 Monitoring Wells

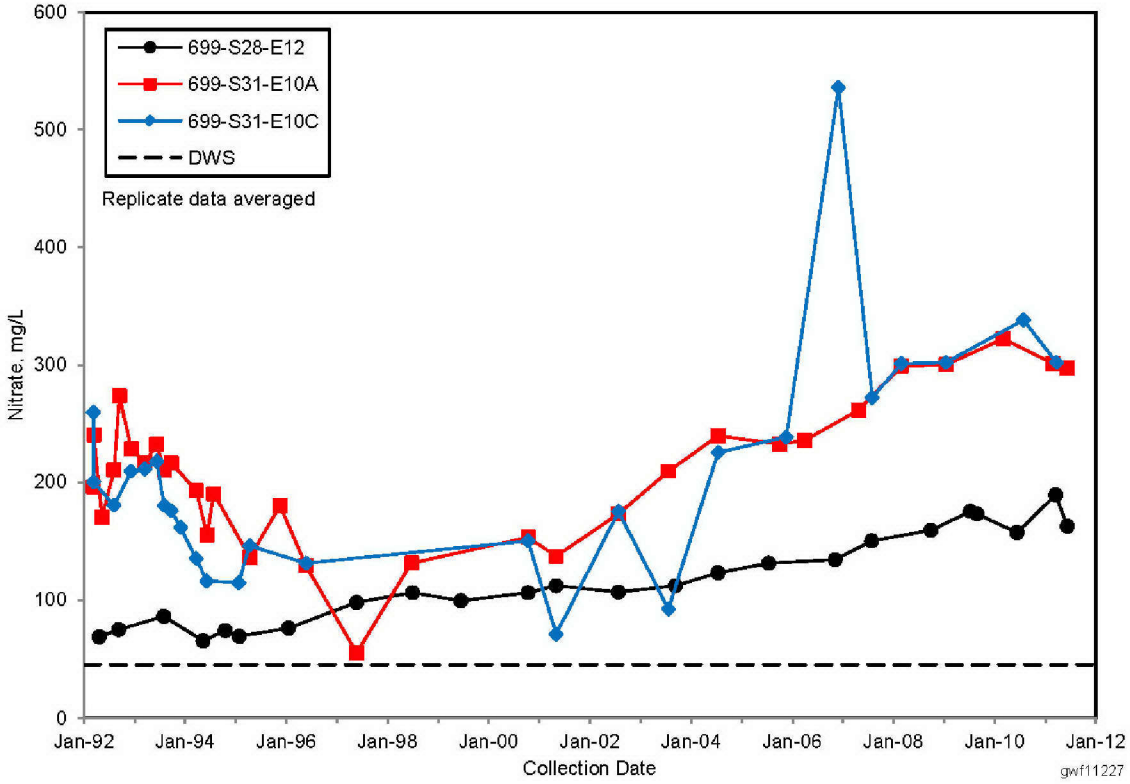
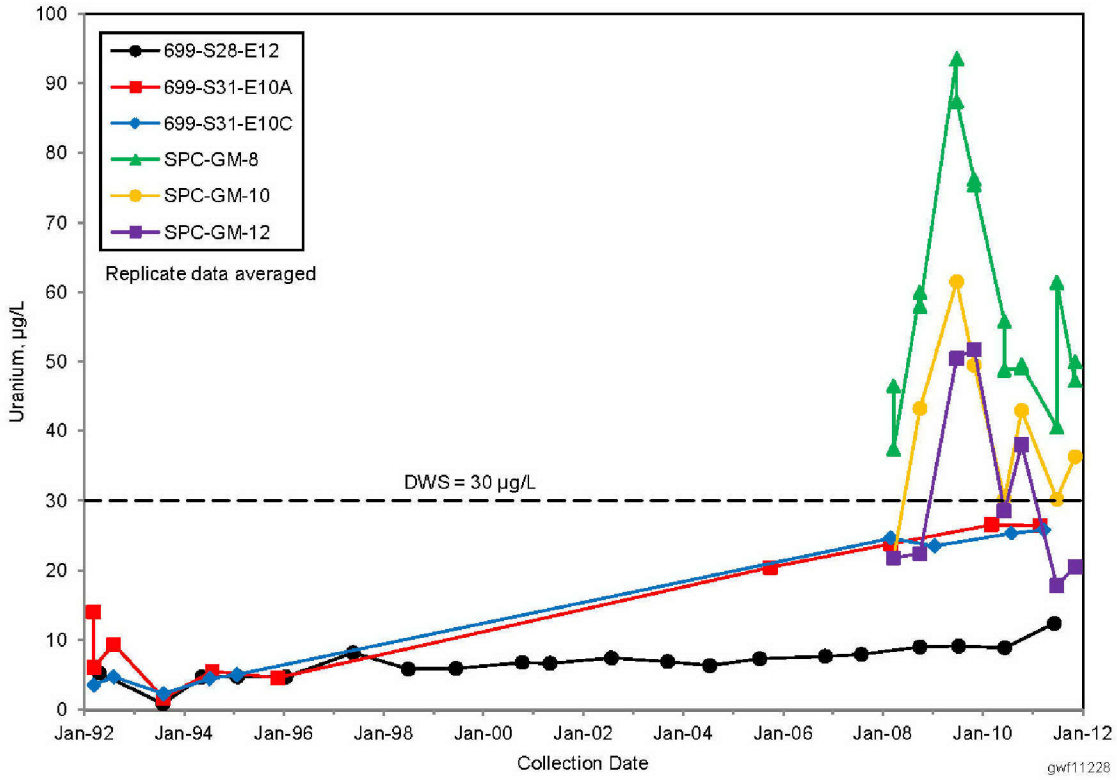


Figure 2.8-7. Uranium Trends in 1100-EM-1 Monitoring Wells



2.9 River Corridor Summary and Recommendations

M.J. Hartman

The Hanford Reach of the Columbia River begins upstream of the Hanford Site at Priest Rapids Dam and extends 82 kilometers downstream to the upper end of Lake Wallula, impounded by McNary Dam. Although flow volume and water levels are controlled by upstream dams, the Hanford Reach is essentially the only free-flowing stretch of the Columbia River in the United States.

This section summarizes the results of remediation and groundwater monitoring in the River Corridor for 2011. Results of monitoring the Columbia River and shoreline springs (seeps) are also summarized. References are provided for other DOE activities focused on the Columbia River at the Hanford Site. Finally, recommendations are made for future groundwater-related activities in the River Corridor.

2.9.1 Soil and Groundwater Remediation

Cleaning up the River Corridor of the Hanford Site is a high priority for DOE because discharge of contaminated groundwater to the Columbia River is a pathway for contaminants to reach human or ecological receptors. More than 60 percent of the waste sites in the River Corridor have been remediated or are classified as not requiring remediation under an interim record of decision. Most of the remaining sites are scheduled to be cleaned up in the next few years.

Since the mid-1990s, interim remediation of groundwater has been underway in the 100 Area to reduce the amount of contamination entering the river. Interim remedial action objectives for the 100-KR-4 and 100-HR-3 Operable Units are to (1) protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River; (2) protect human health by preventing exposure to contaminants in the groundwater; and (3) provide information that will lead to final remedies. Interim remedial action objectives for 100-NR-2 include the following: (1) protect the Columbia River from the adverse impact of groundwater contamination; (2) protect the unconfined aquifer by reducing contaminant concentrations; (3) obtain information to evaluate technologies; and (4) prevent destruction of sensitive wildlife habitat and minimize disruption of cultural resources. DOE continued to meet these objectives in 2011. However, compliance goals (for example, reducing concentrations to below applicable thresholds) have not been reached.

Final decisions regarding methods to clean up the remaining contamination in the River Corridor will be based on data collected during remedial investigation studies conducted in recent years. Draft reports that present the results of these studies and make recommendations for solutions are in progress (Table 2.1-1, Section 2.1).

2.9.2 Groundwater Monitoring Results

During 2011, groundwater staff sampled 525 wells in the River Corridor groundwater interest areas as part of routine groundwater monitoring programs (Table 2.9-1). Many of the wells were sampled numerous times, for a total of 2,690 successful well sampling trips. During the year, 280 aquifer tubes were sampled, with samples collected from a total of 528 sampling trips.

Table 2.9-2 lists maximum concentrations of groundwater contaminants detected in River Corridor wells and aquifer tubes during 2011. The 2011 data did not result in any major reinterpretations of the nature and extent of groundwater contamination. The following paragraphs summarize River Corridor groundwater contamination and results of monitoring. For additional summary information, see the Executive Summary of this report.

Hexavalent chromium contaminant plumes with concentrations above the 10 μg/L ambient water quality standard are present in the unconfined aquifer in all of the 100 Areas and in the Ringold upper mud unit in the 100-H Area. Concentrations exceeded the 48 μg/L groundwater cleanup standard in 100-KR-4 and 100-HR-3 in 2011, and a new exceedance was observed in 100-BC-5 in early 2012.

Some of these plumes are shrinking as a result of remediation and natural attenuation. However, the plumes are persistent even many years after waste discharge has ceased.

Tritium concentrations exceed the 20,000 pCi/L drinking water standard in 100-BC-5, 100-KR-4, and 300-FF-5 (at the 618-11 Burial Ground). Tritium was more widespread in the River Corridor in the past, and the plumes are gradually dissipating because of radioactive decay and other natural processes.

Strontium-90 contamination persists beneath each of the 100 Areas at concentrations above the 8 pCi/L drinking water standard. The most extensive, concentrated plume is in 100-NR-2, where levels exceed the 1,100 pCi/L derived concentration standard. Groundwater samples from new wells installed in or near former waste sites in the 100-D and 100-F Areas detected higher levels of strontium-90 in 2011 than in other wells in those regions. The strontium-90 contamination tends to be stable because this constituent sorbs to sediment grains. Concentrations are gradually declining in most areas as a result of radioactive decay.

Nitrate is a common groundwater contaminant in the River Corridor. Concentrations exceeded the 45 mg/L drinking water standard in 2011 in 100-KR-4, 100-NR-2, 100-HR-3, 100-FR-3, and 1100-EM-1, although the latter plume originated offsite. The largest onsite plume is in 100-FR-3. Concentrations are generally steady or declining.

Carbon-14 exceeds the 2,000 pCi/L drinking water standard in portions of 100-KR-4. The K West plume did not change significantly in 2011. The wells at K East that formerly had concentrations above the standard were decommissioned before a nearby facility was demolished and have not yet been replaced. Wells farther downgradient from K East have lower concentrations of carbon-14.

Uranium forms a persistent plume with levels above the 30 µg/L drinking water standard beneath portions of 300-FF-5. Concentrations vary with seasonal changes in the water table, and it appears that residual uranium remains in the vadose zone. The river was unusually high in June 2011, and uranium concentration temporarily increased by an order of magnitude in one well near the former process trenches.

Trichloroethene exceeds the 5 µg/L drinking water standard in the unconfined aquifer at 100-FR-3 and 100-KR-4. The plumes are attenuating naturally. In 300-FF-5, the contamination is generally limited to a local, finer-grained unit that is not monitored routinely. In 2011, one shallow well also had a concentration above the drinking water standard.

Remedial investigations have provided additional information about the vertical distribution of groundwater contamination in the River Corridor. In most locations and for most constituents, concentrations are highest near the top of the unconfined aquifer and decrease with depth. An exception includes hexavalent chromium concentrations in western 100-BC-5, which are highest at the top and bottom of the unconfined aquifer, and lower in between. This exception may indicate different periods of contaminant release. In some locations in 100-KR-4, hexavalent chromium concentrations were higher in the lower half of the aquifer.

Interim action performance monitoring continued to indicate that the groundwater remediation systems are functioning as designed and are meeting remedial action objectives. Contaminant concentrations in compliance wells remained above threshold values in 2011, and the remediation systems will continue to operate in 2012.

RCRA groundwater monitoring continued in 2011 at facilities in the 100-NR-2, 100-HR-3, and 300-FF-5 (Table 2.9-3). Results did not reveal any new impacts to groundwater, and the sites will continue to be monitored under existing requirements.

2.9.3 Seep and River Monitoring

DOE conducts water quality monitoring in the Columbia River environment as part of its Public Safety and Resource Protection Program, with the purpose of monitoring offsite migration of

contaminants of Hanford Site origin via multiple pathways (Section III.A of DOE/RL-91-50, *Environmental Monitoring Plan United States Department of Energy Richland Operations Office*). The Surface Environmental Surveillance Project conducts monitoring related to contaminants carried by groundwater to the Columbia River. Hanford Site shoreline monitoring is further discussed in Section 1.2 of *Water Quality Sampling Locations Along the Shoreline of the Columbia River, Hanford Site, Washington* (PNNL-19052), which also provides detailed location maps for near-river monitoring.

The DOE collects samples from seepage areas (springs) on the banks of the Columbia River in the fall when the river stage is low. Samples are analyzed for a variety of chemicals and radionuclides, and the results are published annually in the Hanford Site environmental report (Section 8.5 of PNNL-20548, *Hanford Site Environmental Report for Calendar Year 2010*). The 2010 results are summarized below. Results for 2011 were not available at the time this report was prepared.

Table 2.9-4 lists concentrations of contaminants of interest in seeps along each shoreline segment in 2010. Maximum concentrations in seep samples do not always correlate to maxima in groundwater monitoring wells because seeps are natural features that may not be near contaminant plumes. Concentrations of dissolved chromium exceeded the ambient water quality standard in seeps in 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3. Tritium was detected in most of the shoreline segments and exceeded the drinking water standard in a seep at the former Hanford town site. Strontium-90 was detected in the 100-BC-5, 100-KR-4, 100-HR-3, and 300-FF-5 seeps, but all concentrations were below the drinking water standard. The only seep in the 100-NR-2 is downstream from the strontium-90 groundwater plume. Uranium exceeded the drinking water standard in a 300-FF-5 seep. Nitrate concentrations were below the drinking water standard in all regions but were elevated in 100-FR-3, the Hanford town site, and 300-FF-5.

DOE monitors Columbia River water by collecting samples along several cross-river transects and at near-shore river locations adjacent to groundwater plumes, where humans and aquatic biota are potentially exposed to contaminants. The surveillance data provide a historical record of radionuclides and chemicals in the environment. The results of water quality monitoring along the shoreline and in the free-flowing river are presented annually in the Hanford Site environmental report (Section 8.4 of PNNL-20548) and are summarized below.

The Hanford Site environmental report for 2010 is available at: http://msa.hanford.gov/msa/index.cfm/Env._Reports_2001_-_Latest#352.

Radionuclide concentrations in river water samples collected at the city of Richland were far below applicable water quality standards in 2010. The average tritium (29 ± 17 pCi/L) and uranium (0.51 ± 0.12 pCi/L) concentrations at the City of Richland were slightly higher than at Priest Rapids Dam (19 ± 4.6 pCi/L and 0.41 ± 0.094 pCi/L, respectively). Plutonium and strontium-90 were detected in a few samples at the City of Richland, but all detections were near the minimum detectable concentrations. Concentrations of all other radionuclides were typically less than the minimum detectable concentrations. Tritium, strontium-90, and plutonium exist in worldwide fallout from historical nuclear weapons testing, as well as in effluent from Hanford Site facilities. Tritium and uranium occur naturally in the environment in addition to being present in Hanford Site effluent. Uranium from non-Hanford Site sources, such as fertilizer use, is also known to enter the Columbia River across from the Site.

All metal and anion concentrations in river water, including dissolved chromium, were less than the ambient water quality standard in 2010.

In 2010, the U.S. Geological Survey sampled Columbia River water at the Vernita Bridge (upstream from the Hanford Site) and the City of Richland. These measurements indicated no deterioration of water quality along the Hanford Reach of the Columbia River. Median concentrations of dissolved chromium

were similar for water samples collected near the Vernita Bridge and the City of Richland, and the concentrations were well below the ambient water quality criterion.

2.9.4 River Corridor Baseline Risk Assessment

A critical step in developing final remedial action decisions for portions of the Hanford Site along the Columbia River is the completion of a quantitative baseline risk assessment. The River Corridor Baseline Risk Assessment addresses potential risk to human health and the environment from post-remediation, residual contaminant concentrations in the 100 and 300 Areas, as well as the Hanford and White Bluffs town sites. This assessment also investigates risks related to the potential transport of Site contaminants to Columbia River riparian and near-shore environments adjacent to the former operational areas. Some recent documents associated with this effort include the following:

- DOE/RL-2007-21, Volume I, Part 1, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* (August 2011)
- DOE/RL-2007-21, Volume II, Part 2, *River Corridor Baseline Risk Assessment Volume II: Human Health Risk Assessment* (August 2011)

Additional information about the River Corridor Baseline Risk Assessment and links to supporting documents and reports are available at the following website: http://www.washingtonclosure.com/projects/environmental_protection/mission_completion/project_library/#rcbra.

2.9.5 Hanford Site Releases to the Columbia River

DOE is investigating Hanford Site contaminant releases to the Columbia River (DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River*). The contaminants, their concentrations, and their locations may have undesirable health effects for humans, animals, and plants that use or live in the Columbia River. The information obtained from this investigation will ultimately be used to help make final cleanup decisions for Hanford Site contaminants that are present in and along the Columbia River. Results of the study are presented in WCH-398, *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington.*

During the study, which concluded in 2010, samples were collected of pore water (i.e., groundwater upwelling beneath the river bottom into the space between rocks and sediment of the river bed), river sediment, river water, fish, and island soil. Pore water in some of the 100 Area samples had concentrations of hexavalent chromium above the aquatic standard, and strontium-90 exceeded the drinking water standard in some 100-N Area samples. Tritium concentrations exceeded the drinking water standard in some pore water samples near the former Hanford town site, and uranium near the 300 Area.

Additional information about the remedial investigation for Hanford Site releases to the Columbia River is available at the following website: http://www.washingtonclosure.com/projects/environmental_protection/mission_completion/project_library/#investigation.

Data collected as part of this investigation will contribute to the development of an ecological risk assessment and a baseline human health risk assessment for the Columbia River component of the River Corridor Baseline Risk Assessment. These risk assessments are anticipated to be completed by 2012.

2.9.6 Recommendations for River Corridor Groundwater

The 100 and 300 Area River Corridor units are undergoing the CERCLA process for completing remediation of waste sites and groundwater. RI/FS reports (Table 2.1-1) evaluate alternatives for remediation. In addition, the following recommendations are made regarding future groundwater monitoring and remedial action evaluations. Where possible, these recommendations provide sufficient detail to describe and plan the activity. As with any such recommendation, these warrant further review and their implementation depends on technical priorities and available funding. In some cases, these recommendations are either planned for implementation in 2012 or have already been implemented as process improvements.

- Multiple interest areas
    - Conduct an analysis of wells near the Columbia River to evaluate the sensitivity of the wells to changes in river stage. This information will be used to support the refinement of near-river sampling schedules and is a component to ongoing sample optimization activities (underway in 2012).
    - Conduct a workshop and develop a strategy to assess the suitability of aquifer tube data in near-shore performance monitoring. The strategy will define methods of evaluating the representativeness of aquifer tube data and a decision framework for incorporating aquifer tube data in remediation performance monitoring (2014).
    - Update groundwater sampling and analysis plans for 100-BC-5, 100-KR-4, 100-HR-3, 100-FR-3, and 300-FF-5 to include new monitoring wells and to revise constituents and sampling frequency based on recent remediation activities and groundwater data (2013).
    - Implement actions from the third CERCLA five-year review (DOE/RL-2011-56).
    - As the Hanford Site moves from describing the extent of contamination to active cleanup, meaningful benchmarks for measuring cleanup progress are under development. As new data evaluation and reduction tools are implemented, establish final long-term benchmarks for measuring the progress of cleanup and remedy performance.
- 100-BC-5
    - Increase monitoring frequency for hexavalent chromium concentrations downgradient of 100-C-7 and 100-C-7:1 waste sites (implemented in 2012).
- 100-KR-4
    - Implement the SIR-700 resin full time at the 100-K pump-and-treat systems (implementing in 2012).
    - Connect wells 199-K-198 and 199-K-199 to the KX pump-and-treat system as extraction wells (schedule dependent on funding priorities).
    - Continue to sample wells 199-K-36 and 199-K-187, upgradient of the 183.1-KE headhouse, to investigate variable hexavalent chromium concentrations (implemented in 2012).
    - Track strontium-90 concentrations in wells downgradient of K East as the plume front migrates downgradient (implemented in 2012).
    - Install replacement wells in the vicinity of the 183.1-KW headhouse to monitor hexavalent chromium groundwater at that apparent source area during remediation (schedule dependent on funding priorities).

  - Install replacement wells in the vicinity of the 116-KE-1 and 116-KE-3 cribs to monitor carbon-14, tritium, nitrate, and strontium-90 conditions during remediation (schedule dependent on funding priorities).
  - Install a packer at 6 meters below the water table in well 199-K-185. Very high nitrate and high carbon-14 levels were identified during drilling at the top of the aquifer. Results were significantly lower during subsequent monitoring because the well has a long screen. A packer would eliminate water from the lower portion of the aquifer from entering the pump during sampling and provide more representative results of upper aquifer conditions (recommend this is done as part of the selected remedy, under the remedial design report and remedial action work plan).

- 100-NR-2
  - Prepare an integrated sampling and analysis plan to include CERCLA and RCRA groundwater monitoring (schedule dependent on implementation of the Hanford Facility RCRA Permit (WA7890008967).
  - Evaluate the 1324-N/NA monitoring network with respect to flow direction changes, and incorporate the site into the integrated groundwater monitoring plan.
  - Conduct additional sampling in 100-NR-2 to investigate the total organic carbon increases in groundwater at the 1324-N/NA facilities (implemented in 2012).
  - Evaluate additional apatite injections in the permeable reactive barrier in response to increasing strontium-90 concentrations.

- 100-HR-3
  - Evaluate the effectiveness of the new DX and HX pump-and-treat systems in 2013, using groundwater concentration data, hydraulic head data, capture zone analyses, and further modeling to optimize the operation of the systems. Include a comparison of DX and HX to the HR-3 and DR-5 systems, and prepare a written report.
  - Conduct a data quality objectives analysis to determine data needs for performance monitoring of the new DX and HX systems in 2013. Document the evaluation, and develop a new monitoring plan for 100-HR-3.
  - Evaluate the realignment and/or addition of specific wells to the DX and HX pump-and-treat system well network in 2013, and prepare a written report.
  - Conduct additional sampling of 100-HR-3 wells 199-H1-27 and 199-H4-75 and nearby wells in 2013 to investigate the persistence and extent of nitrate contamination discovered in 2011.
  - Sample 100-HR-3 well 199-D5-93 and nearby wells for beta-emitting radionuclides in 2013 to investigate the cause and extent of elevated gross beta levels observed in 2011.

- 100-FR-3
  - Monitor temporary wells 199-F5-55 and 199-F5-56 (implemented in 2012).
  - Monitor strontium-90 in wells near the F Reactor to determine the extent of contamination in temporary well 199-F5-56 (implemented in 2012).

- 300-FF-5
    - Increase monitoring frequency for metals at the 618-10 Burial Ground during remediation activities to assess the impact of dust suppression water on contaminant mobility (implemented in 2012).
- 1100-EM-1
    - Prepare a groundwater sampling and analysis plan for 1100-EM-1 to include monitoring objectives for tracking Hanford Site and offsite plumes and trends.

Hanford Reach National Monument

The Hanford Reach of the Columbia River, the last free-flowing stretch of this river in the United States, is part of the Hanford Reach National Monument. The monument also includes the Saddle Mountains Wildlife Refuge north of the river, and the Fitzner-Eberhardt Arid Lands Ecology Reserve in the southwestern Hanford Site. The 195,000-acre monument contains a wealth of wildlife and remnants of human history spanning more than 10,000 years.

The monument was established by Presidential decree (Clinton, 2000, Hanford Reach National Monument) in 2000 and is administered by the U.S. Fish and Wildlife Service (USFWS, 2008, Hanford Reach National Monument: Final Comprehensive Conservation Plan and Environmental Impact Statement Adams, Benton, Grant and Franklin Counties, Washington).

For more information, see http://www.fws.gov/hanfordreach/.

Table 2.9-1. Number of Wells and Well Sampling Trips in the River Corridor, 2011

Interest Area	Number of Wells Sampled	Number of Successful Well Trips	Number of Aquifer Tubes Sampled	Number of Successful Aquifer Tube Trips
100-BC-5	25	82	19	26
100-KR-4	74	928	30	37
100-NR-2	102	152	43	132
100-HR-3-D	116	789	74	156
100-HR-3-H	84	380	55	67
100-FR-3	28	44	32	44
300-FF-5	82	256	25	47
1100-EM-1	18	20	2	5
Total	529	2,651	280	514

Note: A successful sampling trip is determined by the presence of data in HEIS. A trip may consist of routine sampling, characterization sampling, or sampling conducted to support groundwater remediation systems.

Table 2.9-2. Maximum Concentrations of Selected Groundwater Contaminants in River Corridor Interest Areas in 2011

Contaminant, Units	DWS (DCS)[a]	100-BC-5		100-KR-4		100-NR-2		100-HR-3-D		100-HR-3-H		100-FR-3		300-FF-5		1100-EM-1	
		Wells	Tubes	Wells	Tubes	Wells	Tubes	Wells	Tubes	Wells	Tubes	Wells	Tubes	Wells	Tubes	Wells	Tubes
Radionuclides																	
Carbon-14, pCi/L	2,000 (62,000)			19,200	314	40.4											
Cesium-137, pCi/L	200 (3,000)			1.9		7.16											
Cobalt-60, pCi/L	100 (7,200)					9.64											
Gross alpha, pCi/L	15	4.3	3.2	5.7	2.2	21		4.28		6.3	2.8	11.9		200	41.8	15	7.3
Gross beta, pCi/L	50	23	25	130	4.3	22,000	3,700	186		68	11	49		130	19.4	44	9.31
Plutonium-239/240, pCi/L	N/A (140)					0.099											
Strontium-90, pCi/L	8 (1,100)	36	10	251	7.48	13,500	1,300	45	5.4	33	18	270	4.85	2.1			
Technetium-99, pCi/L	900 (44,000)			49.6		57				157				190		54	
Tritium, pCi/L	20,000 (1,900,000)	28,000	14,000	290,000	4,060	16,500	12,000	18,000	11,000	4,330		12,000		1,000,000	3,080	375	
Uranium, µg/L	30			6.25		7.14		6.1		28.9	2.3	34.7		4,030	104	26.4[c]	14.4
Metals[b]																	
Arsenic (filtered), µg/L	10			7.4	2.18	16.5	4.4	11.2	2.63	2.8	2.2	4.72		5.2			
Arsenic, µg/L	10			7.5	2.23	16.8	5	12.5	2.55		2.41	4.86		3.8			
Barium (filtered), µg/L	2,000	97	50	67	45	241	54.3	114	74.3	102	45.8	107	113	245	64.6	165	79
Barium, µg/L	2,000	96	54	69	46	275	53	288	106	102	46.4	105	116	235	73.3	171	77
Beryllium (filtered), µg/L	4			1		0.55			0.91								
Beryllium, µg/L	4			1.5		1.5											
Chromium (filtered), µg/L	100	53	27	3,360	1.78	200	5.2	5,460	77	142	29.8	25.5	5.4	64			
Chromium, µg/L	100	52	27	3,250	2.09	204	5.4	5,420	78	143	30.3	41.6	5.7	67	4	11	
Hexavalent Chromium (filt.), µg/L	48	53.5	24.1	3,340	66.5	34.4	8.2	28,100	96.7	133	40.8	23	7	2			
Hexavalent Chromium, µg/L	48	53.1	23.3	3,310	67.4	198	7.7	27,900	95.8	153	40.9	24.1	3.9				
Mercury (filtered), µg/L	2			0.12			0.13										
Mercury, µg/L	2			0.18			0.097										
Selenium (filtered), µg/L	50			3.39		3.21						1.63		2.5			
Selenium, µg/L	50			2.4		5.54						1.98					
Anions																	
Cyanide, µg/L	200									4.4							
Fluoride, mg/L	4.0	0.301	0.130	0.430	0.162	0.650	0.485	0.534	0.231	0.886	0.195	0.682	0.213	3,500	0.359	1.35	0.174
Nitrate as NO_3, mg/L	45	12.4	26.7	97.4	48.7	394	44.7	98.3	32.2	49.1	37.1	201	27.9	141[c]	66[c]	302[c]	79.2[c]

Table 2.9-2. Maximum Concentrations of Selected Groundwater Contaminants in River Corridor Interest Areas in 2011

Contaminant, Units	DWS (DCS)[a]	100-BC-5		100-KR-4		100-NR-2		100-HR-3-D		100-HR-3-H		100-FR-3		300-FF-5		1100-EM-1	
		Wells	Tubes	Wells	Tubes	Wells	Tubes	Wells	Tubes	Wells	Tubes	Wells	Tubes	Wells	Tubes	Wells	Tubes
Nitrite as NO_2, mg/L	3.3	0.229	0.182	0.486	0.306	4.2	0.203	3.19	0.233	1.56	0.374	1.11	0.168	0.450	0.233	0.486	
Organics																	
1,1-Dichloroethene, µg/L	7					0.22									0.19		
Benzene, µg/L	5					0.14											
Benzo(a)pyrene, µg/L	0.2					0.72											
Carbon tetrachloride, µg/L	5					3.2						2.2		2.7	0.48	1.4	
Chloroform, µg/L	80	1.9		1.8		8.4		0.56	0.16	3.7	1.3	3.9		0.29	2.4		
cis-1,2-Dichloroethylene, µg/L	70													200	5.7		
Ethylbenzene, µg/L	700			2.5		1.1											
Methylene chloride, µg/L	5			0.31		0.29						0.28		0.3	1.7		
Tetrachloroethene, µg/L	5					2.6			0.26					0.22	1.8		
Toluene, µg/L	1,000					0.092						6.6			0.31		
Trichloroethene, µg/L	5	2.2		6.6								14		14	210		
Xylenes (total), µg/L	10,000			6.1		1.5									0.42		

Table lists highest value for 2011 for each groundwater interest area, excluding those flagged F, R or Y, or non-routine samples (e.g. characterization) Blank cells indicate a constituent was not detected or not analyzed. Blue cells exceed drinking water standard. Yellow cells exceed derived concentration standard.

a. References for drinking water standards and derived concentrations standards listed in Table 1-1.

b. Antimony, cadmium, and thallium excluded because detection limits are typically higher than DWS, creating false exceedances near the detection limits. Nickel excluded because it typically indicates corrosion of stainless steel well screens and casing.

c. From offsite sources.

Table 2.9-3. RCRA Monitoring Status for the River Corridor, 2011

RCRA Unit	Report Section	Status for Reporting Period
1301-N (116-N-1) LWDF	Section 2.4.9.1	Continued indicator evaluation.*
1324-NA (120-N-1) and 1324-N (120-N-2) Ponds	Section 2.4.9.2	Continued indicator evaluation.*
1325-N (116-N-3) LWDF	Section 2.4.9.3	Continued indicator evaluation.*
116-H-6 (183-H) Evaporation Basins	Section 2.5.7	Corrective action alternative program during interim remedial action; chromium and nitrate.
316-5 (300 Area) Process Trenches	Section 2.7.8	Compliance/corrective action; organics.

* Analysis of RCRA contamination indicator parameters provided no evidence of groundwater contamination with dangerous waste or dangerous waste constituents from the unit.

Table 2.9-4. Hanford Site Contaminants in Columbia River Seeps

Groundwater Interest Area	Spring Names Sampled Fall 2010	Maximum Concentration, Fall 2010					
		Chromium[a] (µg/L)	Nitrate (mg/L)	Strontium-90[b] (pCi/L)	Tritium[b] (pCi/L)	TCE (µg/L)	Uranium[c] (µg/L)
100-BC-5	100-B SPRING 38-3 100-B SPRING 39-2	12.4	6.0	1.65 ±0.294	2,140 ±469	0.48 J	no data
100-KR-4	100-K SPRING 63-1 100-K SPRING 77-1	63.4	16.5	1.38 ±0.228	1,390 ±340	3.04	no data
100-NR-2	100-N SPRING 8-13	8.3	13.9	<0.0331	3,640 ±749	no data	no data
100-HR-3	100-D SPRING 110-1	6.2	1.3	0.154 ±0.053	<134	no data	no data
100-HR-3	100-H SPRING 145-1 100-H SPRING 153-1	15.5	16.5[d]	6.27 ±0.982	1,570 ±373	no data	1.8
100-FR-3	100-F SPRING 207-1	11.1	38.5[d]	<0.032	749 ±237	<0.25	6.6
200-PO-1 (old Hanford town site)	HANFORD SPR DR 4-2; HANFORD SPR UR 28-2; HANFORD SPR 28-2	2.4	21.7 [d]	no data	36,700 ±7,170	no data	3.8
300-FF-5	300 AREA SPR DR 42-2; 300 AREA SPRING 41-9; 300 AREA SPRING 42-2	3.0	25.1	0.298 ±0.074	5,210 ±1,050	1.42 J	103
Offsite	RICHLAND SPR (SRL 437-1)	0.49	12.3	<0.031	306 ±161	no data	1.9

Source: Hanford Environmental Information System (HEIS) database.

a. Total chromium in filtered samples (equivalent to hexavalent chromium)

b. Reported result plus or minus total analytical error

c. Estimated based on isotopic uranium results

d. Analyzed past recommended holding time

J = estimated concentration; near detection limit

3.0 Central Plateau

J.P. McDonald

This chapter presents the results of groundwater monitoring in the central portion of the Hanford Site. This region contains the 200 East and 200 West Areas where plutonium separation activities occurred and is referred to as the Central Plateau. Section 3.1 presents an overview of the Central Plateau, including discussions on the hydrogeology, groundwater flow, waste disposal operations, and cleanup activities. Sections 3.2 through 3.5 discuss the 2011 results of groundwater monitoring in each of the groundwater interest areas associated with the Central Plateau. Section 3.6 summarizes the chapter and provides groundwater monitoring recommendations.

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3.1 Introduction to the Central Plateau

J.P. McDonald

When the Hanford Site was operating, spent fuel reprocessing, isotope recovery operations, and associated waste management activities occurred within the 200 East and 200 West Areas located in the central portion of the Site. This region is defined as the Central Plateau and is divided into Inner and Outer Areas (Figure 3.1-1). As stated in *Central Plateau Cleanup Completion Strategy* (DOE/RL-2009-81), the Inner Area is the "final footprint area of the Hanford Site that will be dedicated to waste management and containment of residual contamination," while the Outer Area is the remainder of the Central Plateau.

Spent fuel reprocessing, isotope recovery operations, and associated waste management activities occurred within the Central Plateau.

Four groundwater operable units are associated with the Central Plateau. These operable units encompass groundwater contamination from the 200 East and 200 West Areas, and regions in which this contamination migrated beyond the Central Plateau. As explained in Chapter 1.0, groundwater operable units are associated with informally defined groundwater interest areas that cover the entire Hanford Site. This chapter addresses monitoring results for the groundwater interest areas associated with the Central Plateau groundwater operable units: 200-BP-5, 200-PO-1, 200-UP-1, and 200-ZP-1 (Figure 3.1-1). This section provides background information regarding the Central Plateau.

Central Plateau at a Glance

Consists of the 200 West Area, 200 East Area, and nearby surrounding regions. Divided into Inner and Outer Areas for the purpose of cleanup activities.	
200 West Area	**200 East Area**
Two groundwater operable units: 200-UP-1 and 200-ZP-1	Two groundwater operable units: 200-BP-5 and 200-PO-1
Contains four deactivated plants formerly used for plutonium separation (T Plant and REDOX), plutonium finishing (Plutonium Finishing Plant), and uranium recovery operations (U Plant)	Contains two deactivated plants (B Plant and PUREX) formerly used for plutonium separation and recovery of specific isotopes
Contains many inactive waste sites, four active disposal sites (SY Tank Farm, State-Approved Land Disposal Site, Environmental Restoration Disposal Facility, and Mixed Waste Trenches), and seven RCRA sites	Contains many inactive waste sites, several active disposal sites (Treated Effluent Disposal Facility and AN, AP, AW, AY, and AZ Tank Farms), and 12 RCRA sites
Interim groundwater remediation active in 200-ZP-1 and formerly active in 200-UP-1; final pump-and-treat remedy for 200-ZP-1 planned to begin in 2012; pump-and-treat system at S-SX Tank Farms planned for 2012; soil vapor extraction being performed at Plutonium Finishing Plant	A treatability test is being performed on a uranium-containing perched water zone beneath the B Complex
Final ROD in place for 200-ZP-1; draft RI/FS released for 200-UP-1	RI/FS initiated for 200-BP-5; draft RI released for 200-PO-1

The following groundwater contaminants occur in substantial plumes within the Central Plateau groundwater operable units:

- Carbon tetrachloride is widespread in the 200 West Area at concentrations up to 780 times the 5 μg/L drinking water standard.
- Nitrate concentrations exceed the 45 mg/L drinking water standard in numerous wells within all four operable units, but the 200 West Area plumes are the largest in areal extent.
- Tritium concentrations exceed the 20,000 pCi/L drinking water standard in all four operable units. The plumes largest in areal extent occur within 200-UP-1 and 200-PO-1.
- Iodine-129 concentrations exceed the 1 pCi/L drinking water standard in all four operable units. The plume largest in areal extent occurs within 200-PO-1.
- Technetium-99 occurs above the 900 pCi/L drinking water standard in all four operable units, although it is mostly associated with tank farm and uranium recovery waste sites.
- Concentrations of total chromium occur above the 100 μg/L drinking water standard in the 200 West Area operable units. The plume in 200-UP-1 is the largest in areal extent.
- Uranium concentrations exceed the 30 μg/L drinking water standard in all but 200-ZP-1. The highest concentrations occur in 200-BP-5.

3.1.1 Hydrogeology

Important elements of the Central Plateau hydrogeology are the distribution and properties of the geologic units, structural features, and the presence of mud units and basalt bedrock above the water table. A stratigraphic column for the Hanford Site is shown in Figure 3.1-2. The stratigraphic units present beneath the Central Plateau consist of (in ascending sequence) (1) bedrock of the Saddle Mountains Basalt, (2) semiconsolidated sand and gravel of the Ringold Formation unit A, (3) silt and clay of the Ringold lower mud unit, (4) semiconsolidated sand and gravel of the Ringold Formation unit E, (5) the fine- to coarse-grained Cold Creek unit, and (6) unconsolidated sand and gravel of the Hanford formation. Appendix E describes these units in detail.

A hydrostratigraphic cross-section of the Hanford Site, including the 200 West and 200 East Areas, is shown on Figure 3.1-3. The unconfined aquifer occurs mostly within the Hanford formation and Ringold unit E, and the low-permeability Ringold lower mud unit forms the base of the aquifer in most areas. The thickness of the unconfined aquifer varies substantially within the Central Plateau from over 200 meters southeast of the 200 East Area to zero where the aquifer pinches out against mud units and basalt above the water table. Depths from land surface to the water table range from zero adjacent to the Columbia River to 106 meters between the 200 East and 200 West Areas. Confined aquifers occur within unit A between the lower mud unit and basalt and within sedimentary interbeds and interflow zones within the basalt. Deviations from this sequence are described in the following sections. Section 3.1.2 describes groundwater flow within the Central Plateau.

3.1.1.1 200 East Area and Vicinity

Within the 200 East Area, substantial portions of the Cold Creek unit and Ringold Formation unit E, lower mud unit, and unit A were removed by erosion such that the Hanford formation overlies basalt bedrock in some places. Thus, the Hanford formation fills a paleochannel trending from northwest to southeast across the 200 East Area (the high hydraulic conductivity region in Figure 3.1-4) (Section 6.2 of PNNL-19702; Chapter 4.0 of PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*). The upper part of the unconfined aquifer largely occurs within the Hanford formation, which consists of open-framework gravels in some places and is highly transmissive.

Sand and gravel of the Hanford formation fills a paleochannel trending from northwest to the southeast across the 200 East Area.

East of the 200 East Area near the 216-B-3 Pond and the Treated Effluent Disposal Facility (TEDF), low-permeability Ringold Formation muds occur above the water table (shown on Figure 3.1-3) and form a barrier to groundwater flow in the unconfined aquifer. The uppermost aquifer in this area is the confined aquifer between the Ringold muds and basalt. East of the TEDF is the north-south trending May Junction Fault. Hydraulic head and water chemistry differences across this fault (Sections 4.2.3 and 4.3.2 in PNNL-12261) indicate it is a barrier to groundwater flow in the confined aquifers. While impermeable units have been juxtaposed against more permeable units along part of the fault, the mud units may also have smeared along the fault zone and sealed it (Figure 3.1-3; Plates 8 and 9 in PNNL-12261).

Anticlinal ridges north of the 200 East Area have resulted in substantial areas of basalt above the water table which form barriers to groundwater flow. The most prominent anticline is Gable Butte/Gable Mountain, which is bisected by a sediment-filled water gap known as Gable Gap. Erosion in this gap extended into the uppermost basalt flows resulting in an area of intercommunication between the unconfined aquifer and the underlying confined aquifer in the uppermost sedimentary interbed, the Rattlesnake Ridge interbed (as well as the next underlying interbed, the Selah interbed) (see Figure E-10 in Appendix E). The paleochannel in the 200 East Area extends north through Gable Gap and then trends toward the west along the north side of Gable Butte to west of the 100-BC Area (Figure 3.1-4).

3.1.1.2 200 West Area and Vicinity

The stratigraphy within the 200 West Area is consistent with the sequence of units described in Section 3.1.1, except that the fluvial and lacustrine silts and clays of the upper Ringold are locally present between unit E and the Cold Creek unit. Both the Cold Creek unit and the upper Ringold are entirely above the water table within the 200 West Area (Figure 3.1-3) and have no effect on flow in the unconfined aquifer, but these units affect the vertical migration of constituents in the vadose zone. Along a portion of the east side of the 200 West Area, the Ringold lower mud unit is absent, and the unconfined aquifer is in direct communication with the underlying aquifer in unit A (Figure 3.2-3 in Section 3.2; Section 4.4.1 of DOE/RL-2006-24, *Remedial Investigation Report for the 200-ZP-1 Groundwater Operable Unit*).

The Ringold Formation lower mud unit is absent, and the unconfined aquifer is in direct communication with the underlying confined aquifer along part of the east side of the 200 West Area.

The sediments beneath the 200 West Area dip toward the southwest away from the Gable Butte/Gable Mountain anticline toward the Cold Creek syncline (the syncline is shown on Figure E-3 in Appendix E). As a result, the elevation of the Ringold lower mud unit (the base of the unconfined aquifer) increases toward the northeast. This unit is extrapolated to occur above the water table in a small region between the 200 West and 200 East Areas and is a barrier to flow in the unconfined aquifer (Section 4.2 of PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*).

An east-west trending paleochannel occurs north of the 200 West Area. Here, the Cold Creek unit, Ringold Formation unit E, and the lower mud unit were removed by erosion, and the Hanford formation directly overlies Ringold unit A (Sections 4.1.2.1 and 4.1.2.2 of PNNL-13858). The aquifer in this

paleochannel is not as transmissive as the paleochannel in the 200 East Area. Along the southern boundary of this paleochannel, the confined aquifer in Ringold unit A is in direct communication with the unconfined aquifer.

3.1.1.3 Central Hanford Site

While most of the 200-BP-5, 200-ZP-1, and 200-UP-1 Operable Units occur on the Central Plateau, much of the 200-PO-1 Operable Unit occurs within the 600 Area between the 200 East Area and the Columbia River. The stratigraphy in this region is very similar to that described in Section 3.1.1, except that the fluvial and lacustrine silts and clays of the upper Ringold are widespread within the vadose zone between unit E and the Cold Creek unit. The water table within the western and central portions of this region mostly occurs within the Hanford formation. In the eastern portion of the 200-PO-1 Operable Unit, the water table occurs within the sediment of Ringold unit E. The Cold Creek syncline reaches its maximum depth in the central portion of the 200-PO-1 Operable Unit, and the thickness of the unconfined aquifer is over 200 meters in this region.

3.1.2 Groundwater Flow

Figure 3.1-5 shows the March 2011 water table map for the Hanford Site, including the Central Plateau. Groundwater in the unconfined aquifer flows from upland areas in the west and southwest toward the Columbia River to the north and east, which is the regional discharge area. Within the Central Plateau, natural recharge to the unconfined aquifer comes from the Cold Creek Valley, Dry Creek Valley, Rattlesnake Hills, and infiltrating precipitation. Groundwater generally flows from west to east, although some of the flow from the 200 West Area and/or north of the 200 West Area turns north and flows through Gable Gap. Previous effluent discharges at U Pond and other facilities caused a groundwater mound to form beneath the 200 West Area that significantly affected regional flow patterns in the past (for example, see Figures 4 through 10 in PNNL-16069, *Development of Historical Water Table Maps of the 200 West Area of the Hanford Site [1950-1970]*). These discharges largely ceased in the mid-1990s, but a remnant mound remains, which is apparent from the shape of the water table contours passing through the 200 West Area (Figure 3.1-5). Currently, the water table elevation in the 200 West Area is up to 10 meters above the estimated water table elevation prior to the start of Hanford Site operations.[1] Equilibrium conditions will be reestablished in the aquifer after dissipation of the mound caused by artificial recharge. When this occurs, the water table still may be 5 to 7 meters higher than before Site operations as a result of increased irrigation activities west of the Hanford Site. The water table beneath the 200 West Area is perturbed locally by discharges occurring at the State-Approved Land Disposal Site (75 million liters were discharged during 2011), as well as by operation of a groundwater pump-and-treat remediation system at the 200-ZP-1 Operable Unit. The water table is expected to be further altered by the 20 extraction and 16 injection wells of the 200 West Area pump-and-treat system when this system begins operating during 2012.

[1] Based on the March 2011 water-level elevation in well 299-W18-15 (135.5 meters, *North American Vertical Datum of 1988* [NAVD88]) and the pre-Hanford water table elevation at the location of this well estimated from *Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation, 1944-1973* (BNWL-B-360) (~125.1 meters NAVD88). The peak historical water-level elevation in the 200 West Area occurred at well 299-W18-15 in 1984 (149.1 meters [NAVD88]).

Groundwater in the unconfined aquifer beneath the Central Plateau flows from upland areas in the west toward the regional discharge area north and east along the Columbia River.

Within the 200 East Area, the northwest to southeast trending paleochannel substantially affects groundwater flow. The water table in this area is very flat (i.e., the magnitude of the hydraulic gradient is estimated to be ~10^{-5} meters per meter or less) because of the high permeability of the Hanford formation sediments filling the paleochannel (Figure 3.1-4). Groundwater flow in this region is affected by the presence of low-permeability sediment (i.e., muds) of the Ringold Formation at the water table east and northeast of the 200 East Area, as well as basalt above the water table. These features generally constitute barriers to groundwater flow, although the unconfined aquifer can occur in the fractured and rubbly basalt flow top where it has not been removed by erosion. The extent of the basalt present above the water table continues to increase slowly because of the declining water table, resulting in an even greater effect on groundwater flow in this area. The water table beneath the 200 East Area is 1.8 meters higher than estimated pre-Hanford Site conditions.[2] This is lower than the 5 to 7 meters estimated for the 200 West Area because the aquifer beneath the 200 East Area is more transmissive, which allowed for more lateral flow and less mound formation. When equilibrium conditions are re-established, the water table in the 200 East Area is expected to return to very near the pre-Hanford Site elevation.

The direction of groundwater flow diverges beneath the 200 East Area; some water flows toward the north through Gable Gap, and some flows toward the southeast. This flow pattern can be temporarily altered by large increases in Columbia River stage.

Water enters the 200 East Area and vicinity from the west and southwest, as well as from beneath the mud units to the east and from the underlying aquifers where the confining units have been removed or thinned by erosion. The direction of groundwater flow diverges beneath the 200 East Area, with some water flowing toward the north through Gable Gap and some flowing southeast through the 200-PO-1 Operable Unit. Water-level measurements indicate that groundwater flow is generally north through Gable Gap, but flow conditions can vary due to seasonal changes in river stage that propagate along the paleochannel (Section 2.1.4 of DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*). During March 2011, the hydraulic gradient in Gable Gap was toward the north at 7.1×10^{-5} meters per meter. Later during 2011, high river stage conditions caused a flow reversal in Gable Gap. During September, flow through the gap was toward the south with a gradient magnitude of 9.0×10^{-5} meters per meter. Groundwater flow is toward the southeast within the region between the 200 East Area and the Central Landfill. During 2011, the average water-level elevation at the landfill (121.70 meters, *North American Vertical Datum of 1988* [NAVD88] for March 2011) was 0.14 meter lower than the average elevation in the 200 East Area (121.84 meters [NAVD88] for March 2011), yielding a regional hydraulic gradient magnitude of 1.8×10^{-5} meters per meter (see Figure 3.1-5 for the locations of the 200 East Area and the Central Landfill).

[2] Based on the average water-level elevation measured in 53 wells within the 200 East Area during March 2011, all of which have been corrected for deviations of the boreholes from true vertical (121.84 meters [NAVD88]) and the pre-Hanford water table elevation for the 200 East Area estimated from BNWL-B-360 (~120 meters [NAVD88]).

Although the water table is very flat in the 200 East Area, the accuracy of water-level measurements has been improved, leading to a better understanding of groundwater flow.

The accuracy of water-level measurements within the 200 East Area has been improved in recent years by conducting gyroscope surveys to determine well bore deviations from vertical and by performing highly accurate casing elevation surveys (Section 3.2 in DOE/RL-2011-01). Also, current and historical water-level elevation data in the 200 East Area were adjusted for barometric pressure fluctuations during 2011. The results of this work indicate that the groundwater flow direction in the northwest corner of the 200 East Area (at LLWMA-1) is toward the northwest, but flow can temporarily reverse toward the south during years with higher than normal Columbia River stage (Section 3.2.1 of DOE/RL-2011-01). This condition existed during 2011 when flow was toward the south during late summer and fall (Section 3.4). In the southeast part of the 200 East Area at the Integrated Disposal Facility (IDF) and PUREX Cribs, water-level measurements indicate flow is toward the east-northeast. These results have enabled a better understanding of the location of the groundwater flow divide, which occurs somewhere between LLWMA-1 and the IDF and PUREX Cribs (see Figure 3.4-3 in Section 3.4). Uncertainties in groundwater flow at specific monitored facilities within the 200 East Area are discussed in the subsections of Sections 3.4.13 for 200-BP-5 and 3.5.9 for 200-PO-1.

3.1.3 Contaminant Mobility

The rate and direction of groundwater flow is one factor that affects the size and distribution of contaminant plumes, but relative mobility of constituents in groundwater is also a major factor. An understanding of relative mobility is important for interpreting the groundwater sampling results presented in this chapter. Some constituents are fully dissolved in the groundwater and migrate with the groundwater flow, while others interact with the aquifer sediment to some degree (i.e., “sorb” by either adsorption or precipitation) and migrate at a slower rate than the groundwater flow. The degree of sorption for a particular constituent can be described by the value of its distribution coefficient, which is the ratio of the sorbed phase concentration to the dissolved phase concentration. Constituents that do not sorb at all have distribution coefficient values equal to zero, whereas sorbing constituents have distribution coefficient values greater than zero.

Contaminants in the Central Plateau groundwater exhibit variable mobility. Tritium is highly mobile under all conditions (i.e., has a distribution coefficient equal to 0 mL/g) because it is a hydrogen isotope that occurs as part of the water molecule. The mobility of other constituents depends, in part, on geochemical conditions in the aquifer. The groundwater in the Hanford Site unconfined aquifer is generally oxidizing and has a pH of neutral to slightly basic. Under these conditions, constituents such as technetium-99, chromium, and nitrate do not sorb onto aquifer sediments to any appreciable degree, are highly mobile, and migrate at the same rate as the groundwater flow (i.e., the distribution coefficients are equal to 0 mL/g). Other constituents, such as uranium and iodine-129, are considered moderately mobile (i.e., generally have distribution coefficient values between 0 and 1.0 mL/g). The mobility of uranium is complex and can be quite variable depending on geochemical conditions. Within the Central Plateau groundwater, uranium forms complexes with carbonate and hydroxide ions, which limits its sorption ability and increases its mobility. For a comprehensive discussion of uranium geochemistry, including the factors that affect speciation and mobility, see *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site* (PNNL-17031).

Organic constituents can also exhibit variable mobility because they interact with organic material in the aquifer. These constituents are considered moderately mobile in the Hanford unconfined aquifer because the amount of organic matter in the aquifer is relatively low (Hanford Site groundwater

background values for total organic carbon have a geometric mean of 1.3 mg/L and a 95th percentile of 3.3 mg/L [Table ES-1 in DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*]). Strontium-90 strongly sorbs to aquifer sediments and is considered only slightly mobile (i.e., has a distribution coefficient value greater than 1.0 mL/g). Other constituents, such as plutonium and cesium, sorb so strongly that they are nearly immobile in the subsurface and have not migrated far enough through the vadose zone to reach groundwater. There is some plutonium and cesium in groundwater within the 200-BP-5 Operable Unit, but they were directly injected into the aquifer through the 216-B-5 Injection Well and have not migrated very far from the source area in over 60 years (see Sections 3.4.8 and 3.4.9).

3.1.4 Waste Disposal and Distribution of Contaminants

Waste disposal within the 200 Areas began with startup of plutonium-separation operations in late 1944 (Chapter 4.0 of WHC-MR-0521, *The Plutonium Production Story at the Hanford Site: Processes and Facility History*). Three separations processes were used at the Hanford Site. The earliest was the bismuth-phosphate process, which was used between 1944 and 1956 at T Plant in the 200 West Area (200-ZP-1), and between 1945 and 1952 at B Plant in the 200 East Area (200-BP-5). The REDOX process was used between 1952 and 1967 at REDOX Plant in the 200 West Area (200-UP-1). Finally, the PUREX process was used from 1956 to 1972, and again from 1983 to 1989 at PUREX Plant in the 200 East Area (200-PO-1). Beginning in 1949, the product from the separations plants was further processed at the Plutonium Finishing Plant (PFP) (200-ZP-1), which operated until 1989. Other chemical processes performed in the 200 Areas included uranium recovery at U Plant (200-UP-1) between 1952 and 1957, using the tributyl phosphate process, and radionuclide recovery by various methods at B Plant (200-BP-5) between 1963 and 1983 (PNL-SA-23121 S, *Hanford Technical Exchange Program: Process Chemistry at Hanford (Genesis of Hanford Wastes)*; DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program*).

Plumes of carbon tetrachloride, iodine-129, nitrate, and tritium formed in groundwater beneath the Central Plateau when pond and crib waste reached the aquifer. Some plumes are dispersing naturally, but others require active remediation.

Each of the chemical processing facilities generated multiple waste streams and used multiple waste sites for waste management and disposal. This has resulted in a complex mixture of soil and groundwater contamination that complicates the process of interpreting specific contaminant sources for specific plumes, but the overall pattern of contaminant distribution can be related to chemical processing plant source areas. In general, radioactive waste of higher activity was stored in underground storage tanks, while other liquid waste streams lower in activity were disposed to ponds and cribs. Groundwater plumes of nitrate, tritium, and iodine-129 in all four operable units, as well as carbon tetrachloride in 200-ZP-1, formed when the pond and crib waste reached the aquifer. These plumes expanded as effluent disposal operations continued. Figures 3.1-6 and 3.1-7 show the tritium and iodine-129 plumes in Hanford Site groundwater during 2011. Both constituents occur in extensive plumes east and southeast of the 200 East Area and east of the southern 200 West Area. These plumes originated primarily from cribs associated with the PUREX Plant in the 200 East Area and the REDOX Plant in the 200 West Area. The plumes in the northern 200 West Area are associated with T Plant waste sites, and the iodine-129 plume migrating north from the 200 East Area has been associated primarily with sources in 200-PO-1. Effluent disposal to the ponds and cribs ceased during the 1990s. The groundwater plumes from these sources are dispersing naturally, although some will require active remediation (for example, the carbon tetrachloride plume). Residual contamination continues to enter the aquifer beneath some source areas. Also, constituents of lower mobility in the vadose zone beneath the ponds and cribs may reach the water table in the future, affecting groundwater quality.

There are seven single-shell tank farm waste management areas within the 200 Areas: A-AX, B-BX-BY, and C within the 200 East Area, and S-SX, T, TX-TY, and U within the 200 West Area. Some of the tanks in these farms have leaked and contaminated the vadose zone, and some of this contamination has migrated downward to the groundwater (PNNL-11810, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site*). Migration through the vadose zone may have been facilitated in the past by additions of water from various sources, most notably nearby wastewater ditches and cribs, water supply pipeline leaks, and rainfall/snowmelt runoff events (Sections 3.3.1, 5.1.1, and 5.1.3 of RPP-35485, *Field Investigation Report for Waste Management Area U*). Plumes of nitrate, technetium-99, and chromium from many of the tank farms, as well as uranium from the B-BX-BY Tank Farm, are currently found in the groundwater. These plumes are generally growing in areal extent and exhibit increasing constituent concentrations. This issue is being addressed by pump-and-treat systems where needed (for example, T Tank Farm and S-SX Tank Farms). To minimize the probability of future leaks, all of the single-shell tanks at the Hanford Site have been interim-stabilized, and the drainable liquid in each tank has been removed and transferred to double-shell tanks.

Plumes of chromium, nitrate, and technetium-99 in groundwater from Central Plateau tank farms represent a growing contamination issue which is being addressed by pump-and-treat systems.

3.1.5 Cleanup

Cleanup activities on the Central Plateau are being performed to protect human health, the environment, and the Columbia River. Waste sites within the Central Plateau are a lower priority for cleanup than waste sites within the River Corridor because of the proximity of the latter to the Columbia River (DOE/RL-2009-10, *Hanford Site Cleanup Completion Framework*). Thus, more progress has been made remediating waste sites in the River Corridor than on the Central Plateau. Remediation of the Central Plateau waste sites is expected to accelerate once many of the River Corridor waste sites transition into long-term stewardship. Until then, cleanup activities on the Central Plateau are focused on completion of decision documents, remediation of groundwater plumes, removal of the PFP, other facility decontamination and decommissioning, and initiation of waste-site cleanup in the Outer Area.

Two interim-action pump-and-treat systems have been remediating groundwater in the 200 West Area since 1995, and a third system started operating in 2007. The systems in 200-ZP-1 focus on the carbon tetrachloride plume near its source at the PFP and the technetium-99 plume from the T Tank Farm, while the U-Plant system within 200-UP-1 was designed for the uranium and technetium-99 plumes from the 216-U-1/2 Cribs (Figure 3.1-8). The final ROD for the 200-ZP-1 Operable Unit was issued in 2008 (EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*), and a final remedy pump-and-treat system for the carbon tetrachloride and other 200-ZP-1 plumes is being constructed. This system will consist of 20 extraction wells, 16 injection wells, and a treatment plant with a capacity of 9,500 liters per minute (see Figure 3.2-6 in Section 3.2 for the extraction and injection well locations). This new pump-and-treat system is planned to begin operating during 2012, at which time the 200-ZP-1 interim-action systems will be shut down. The 200-UP-1 system was shut down during 2011 because it had achieved its interim remedial action objectives and the flow rates from the extraction wells were too low to justify continued pumping. DOE released a draft RI/FS (DOE/RL-2009-122, *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit*) and proposed plan (DOE/RL-2010-05, *Proposed Plan to Amend the 200-ZP-1 Groundwater Operable Unit Record of Decision to Include the Remedial Actions for the 200-UP-1 Groundwater Operable Unit*) for 200-UP-1 in 2010, and is preparing final documents that address further remediation of the 200-UP-1 plumes. Figure 3.1-8 shows 200 West Area contaminant

plumes, locations of the pump-and-treat systems, and the amount of contaminant removed from the subsurface over time.

Soil vapor extraction is being used to remove carbon tetrachloride from the vadose zone beneath waste sites at the Plutonium Finishing Plant. Various systems have operated since 1992 with capacities ranging from 14.2 to 42.5 cubic meters per minute. Two systems are currently operating with a total combined capacity of 28.3 cubic meters per minute. Figure 3.1-8 shows where soil vapor extraction is being performed.

No active remediation is occurring within the 200 East Area groundwater operable units, but a treatability test to remediate a uranium-contaminated perched water zone beneath the B Complex began during 2011 as part of the deep vadose zone operable unit, 200-DV-1[3]. The draft RI for 200-PO-1 was released during 2010 (DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*) and the process to prepare the RI/FS for 200-BP-5 (DOE/RL-2009-127, *Remedial Investigation Report 200-BP-5 Groundwater Operable Unit*) has been initiated.

[3] The 200-DV-1 Operable Unit was created to address waste sites with deep vadose zone contamination posing a threat to groundwater quality and for which standard surface-based remedies cannot be used. It currently consists of waste sites in the vicinity of WMA B-BX-BY in the 200 East Area, and WMA T, WMA TX-TY, and WMA S-SX in the 200 West Area, although additional waste sites may be added in the future.

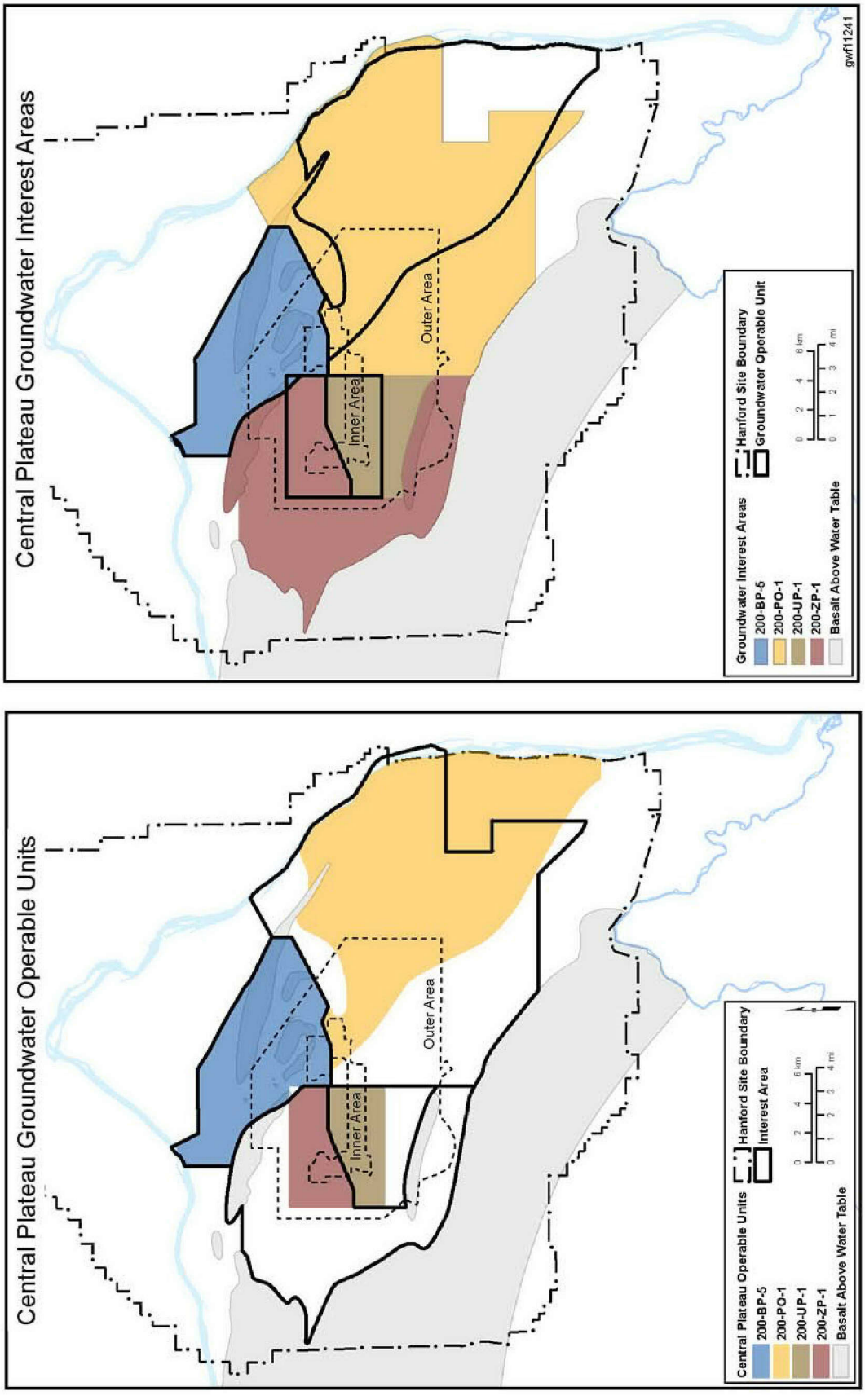
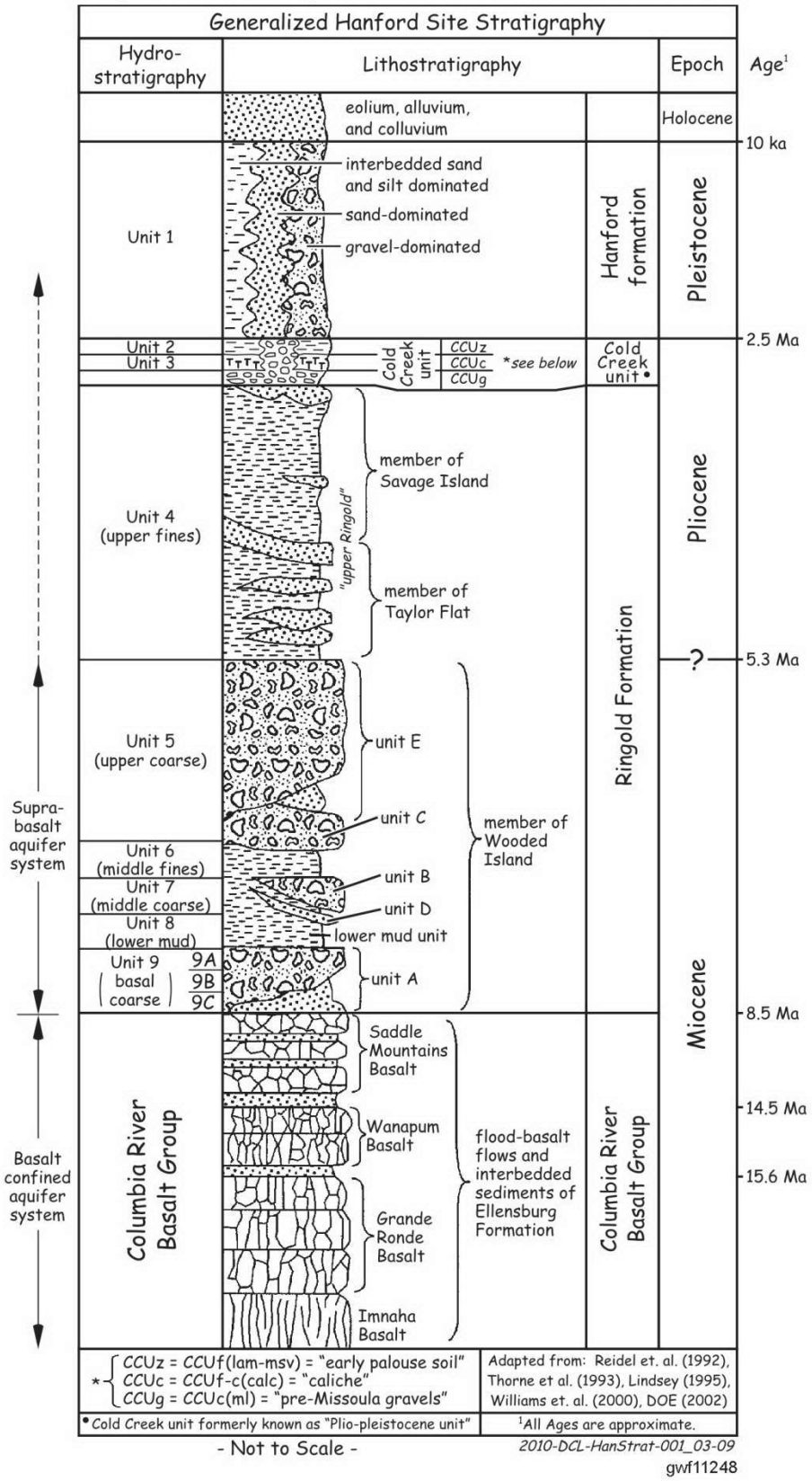


Figure 3.1-1. Hanford Site Central Plateau Regions

Figure 3.1-2. Stratigraphic Column for the Hanford Site



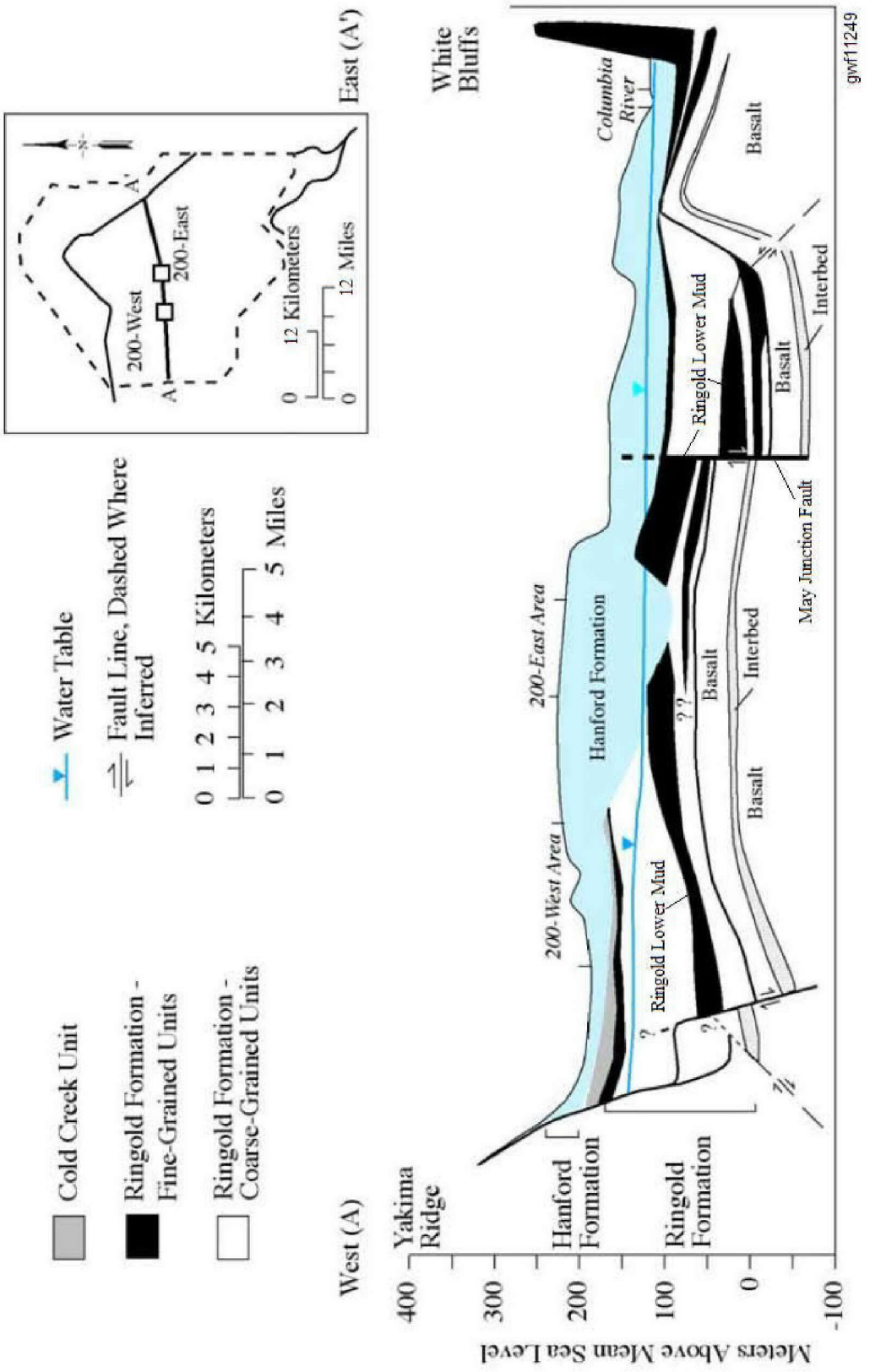


Figure 3.1-3. Hydrostratigraphic Cross-Section through the Hanford Site

Figure 3.1-4. Hydraulic Conductivity Distribution at the Maximum Table Elevation

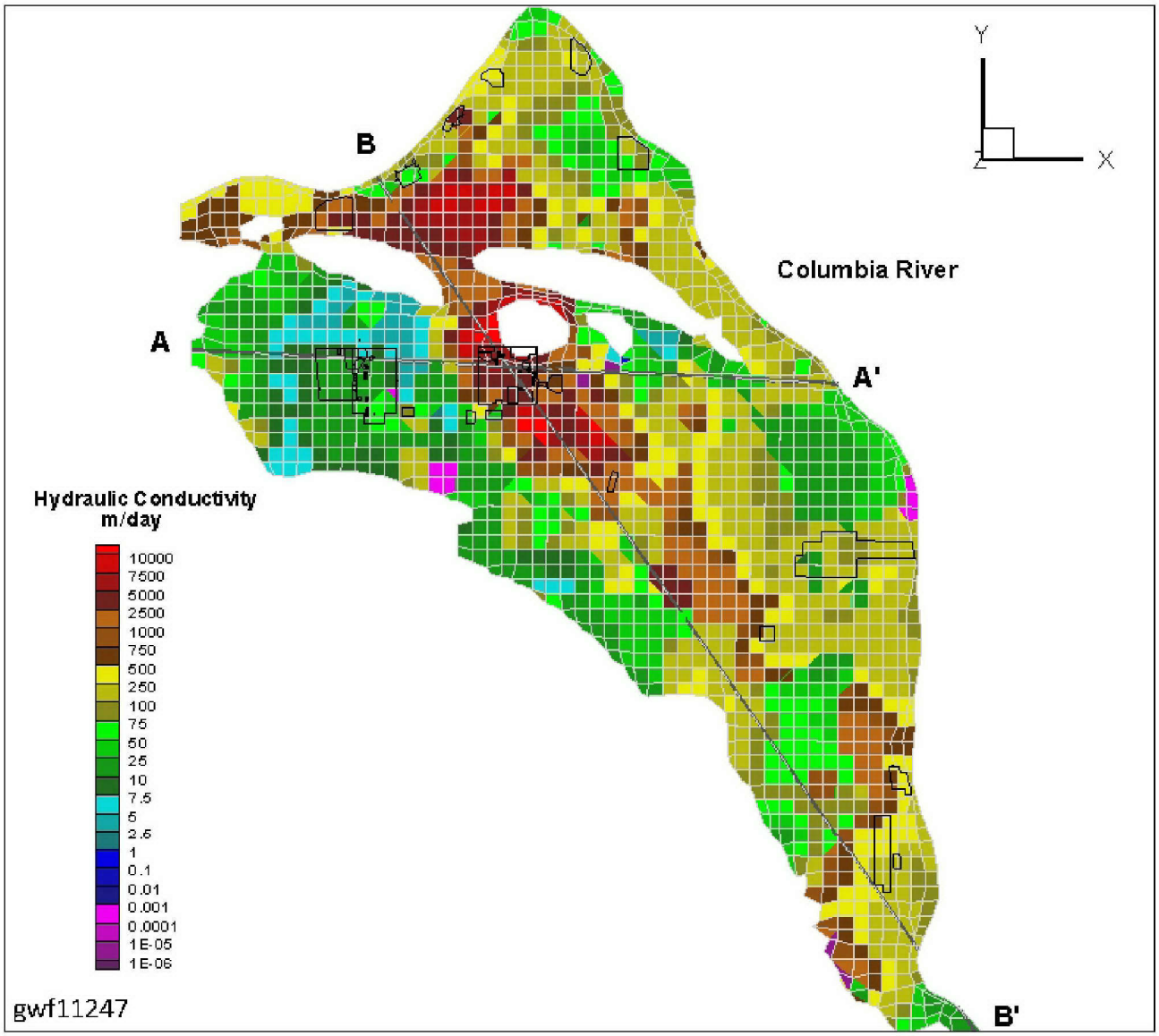


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Figure 3.1-5. Hanford Site Water Table, March 2011

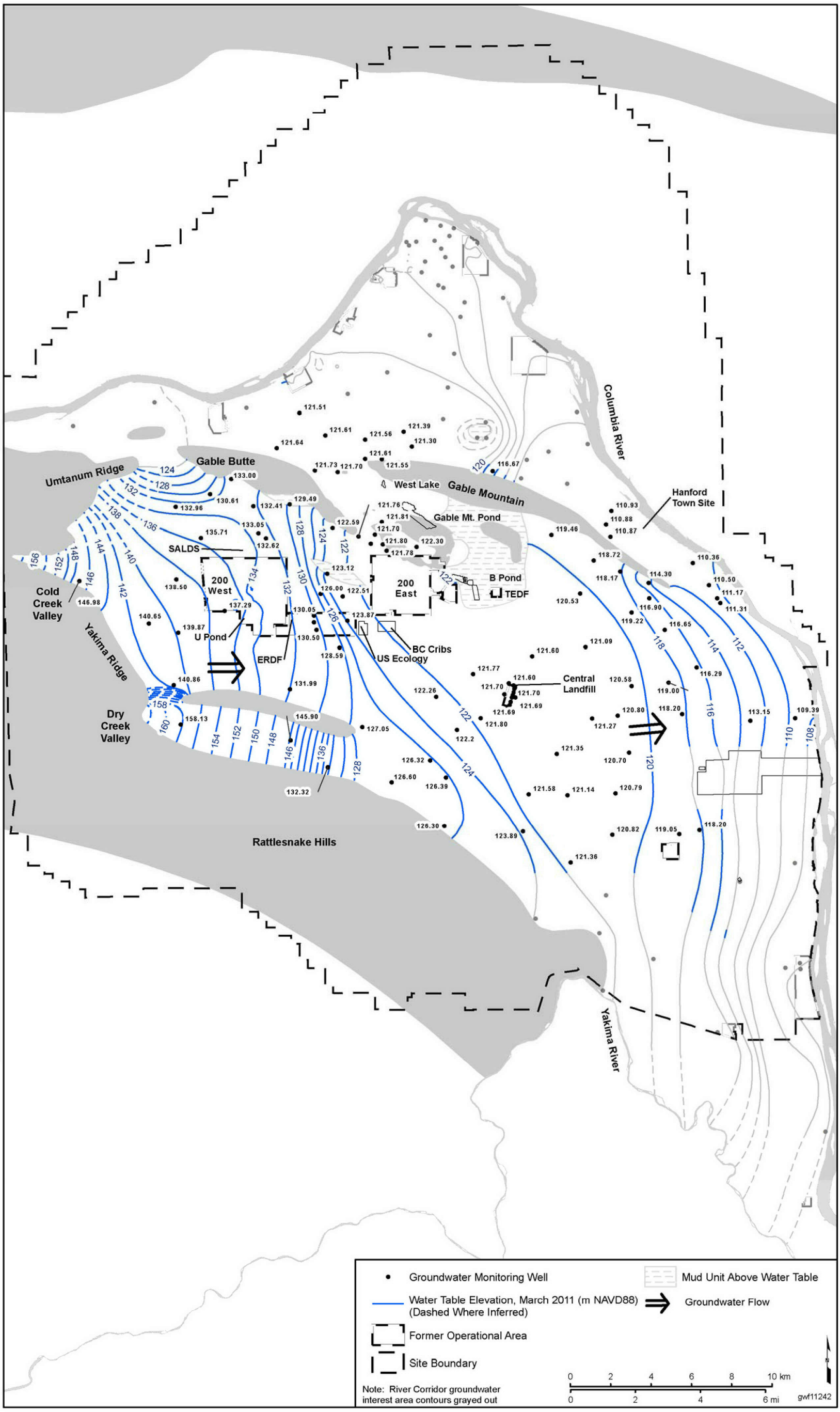

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Figure 3.1-6. Average Tritium Concentrations on the Hanford Site, Upper Part of Unconfined Aquifer, 2011

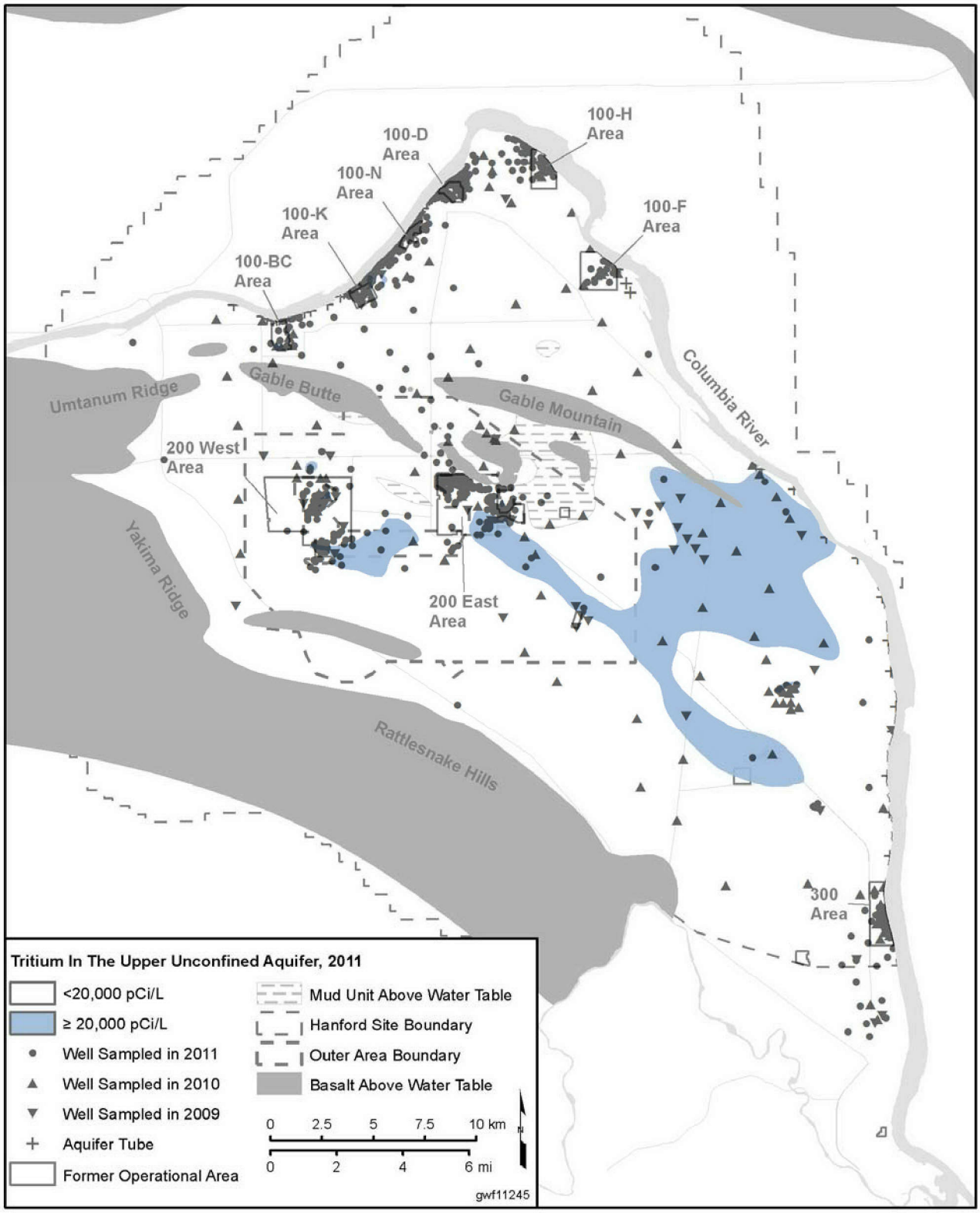


Figure 3.1-7. Average Iodine-129 Concentrations on the Hanford Site, Upper Part of Unconfined Aquifer, 2011

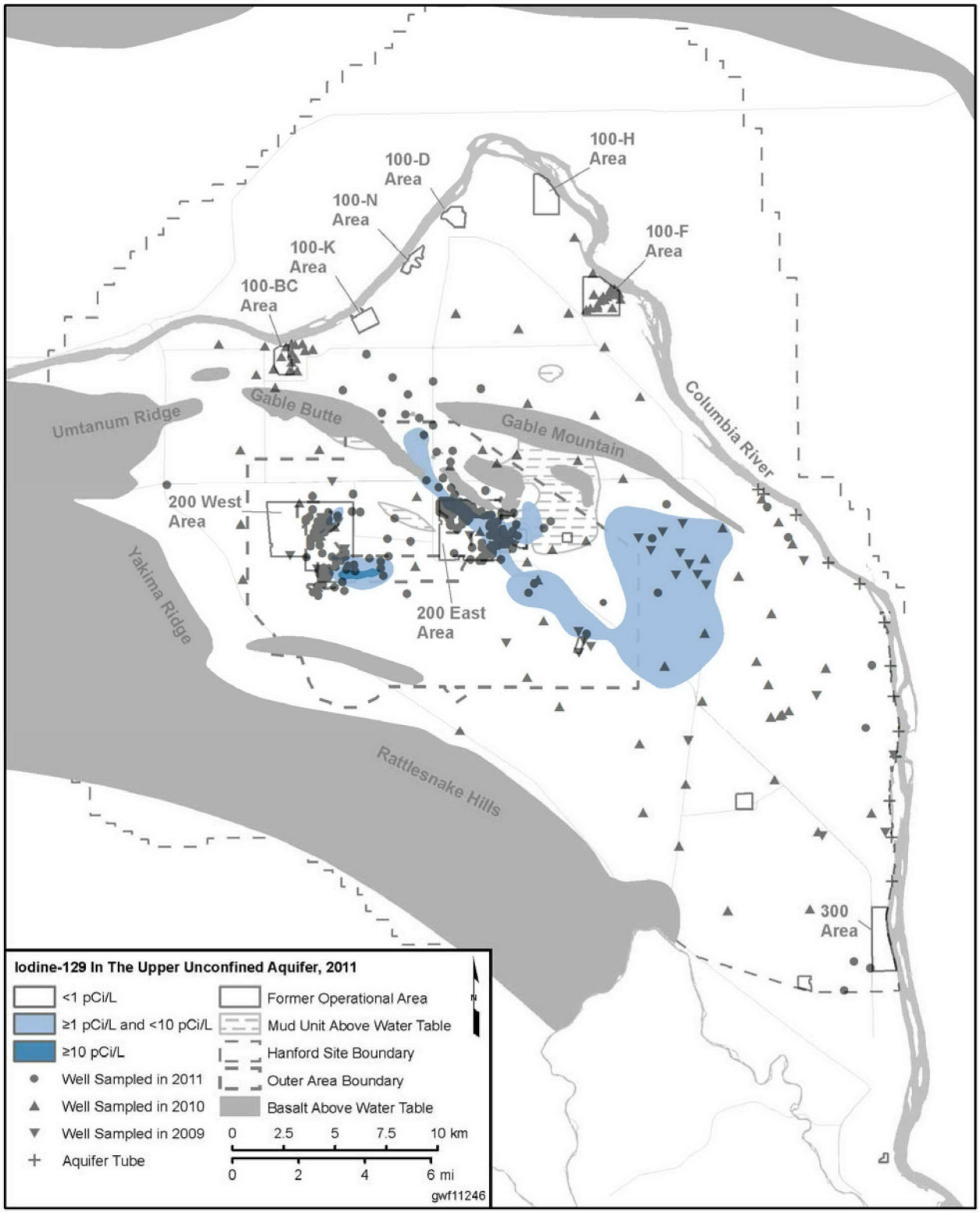
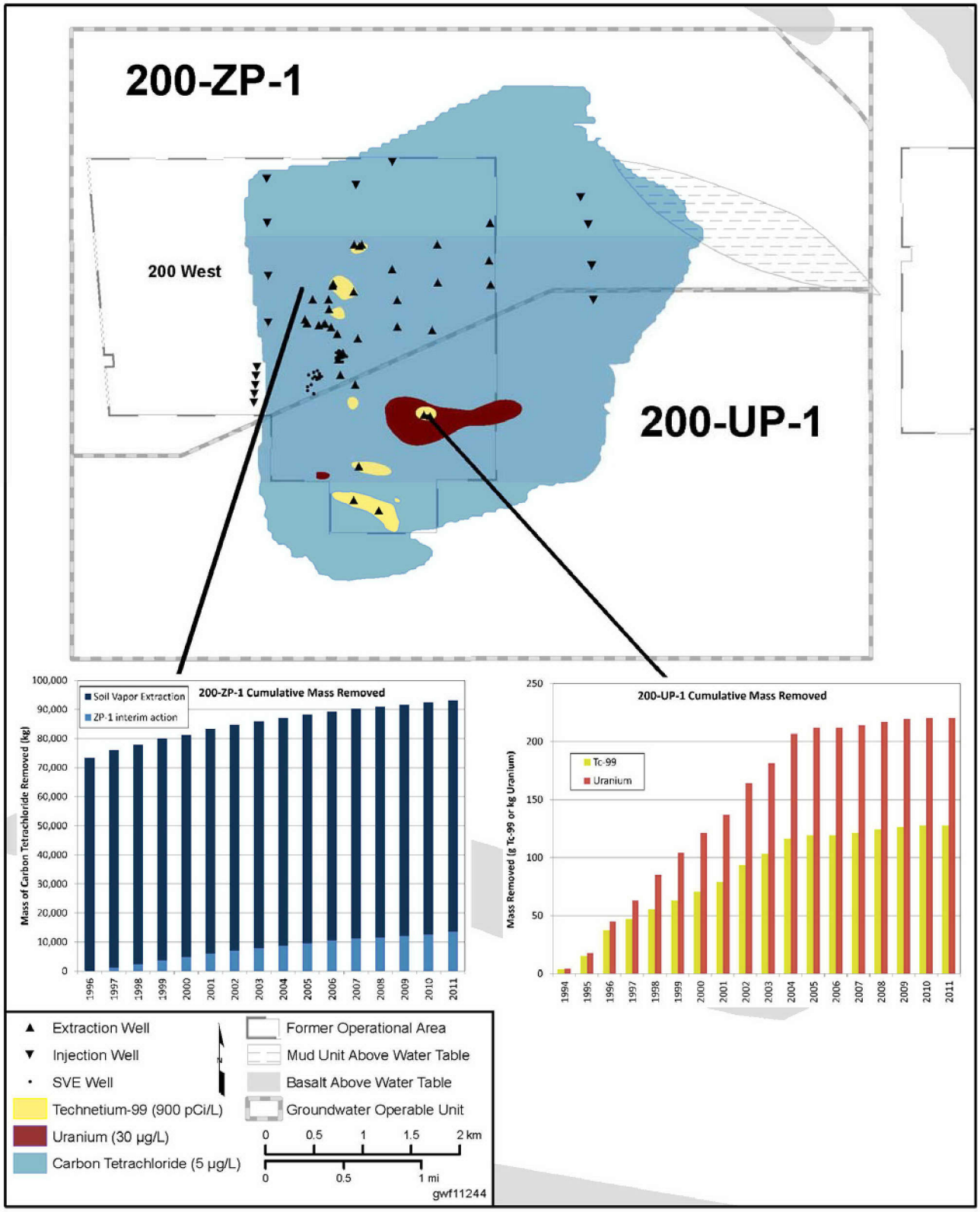


Figure 3.1-8. Remediation Systems in the 200 West Area



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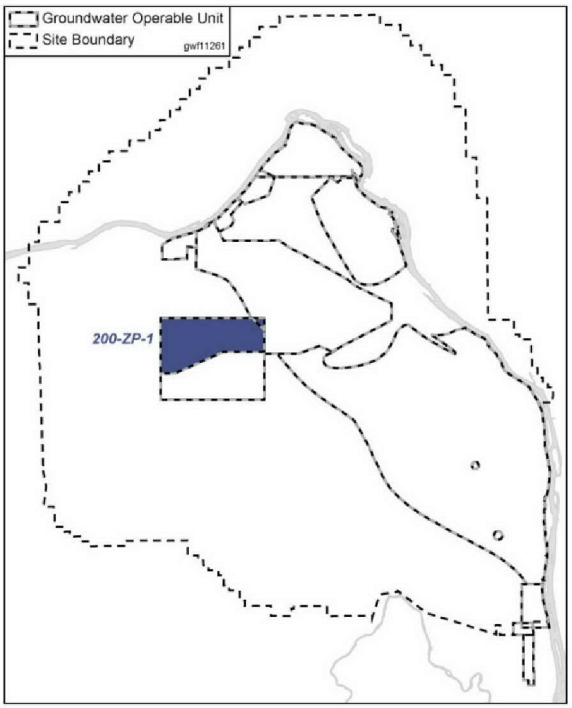
3.2 200-ZP-1

S.A. Simmons



Activities within the 200-ZP-1 Operable Unit focus on monitoring and remediation of groundwater contaminant plumes beneath the northern and central portions of the 200 West Area and nearby portions of the 600 Area. The operable unit lies within the larger 200-ZP-1 groundwater interest area, which was established for ease of management and work planning (Figure 3.1-1 in Section 3.1). Figure 3.2-1 shows the boundaries of the operable unit, some of the more prominent facilities that are present, and groundwater monitoring, extraction, and injection wells.

Groundwater is monitored to assess the performance of two interim action pump-and-treat systems. One of these pump-and-treat systems uses air stripping to remove carbon tetrachloride from groundwater. A second system that targets a technetium-99 plume near WMA T and transports the contaminated groundwater to the Effluent Treatment Facility where contaminants are removed by ion exchange, reverse osmosis, and ultraviolet light/oxidation. Groundwater monitoring is performed to track the movement of nitrate, iodine-129, chromium, trichloroethene,[1] and tritium plumes, as well as to support groundwater monitoring at four RCRA units and the State-Approved Land Disposal Site (SALDS). Data from facility-specific monitoring are used to support performance evaluations for CERCLA groundwater remediation activities. Radionuclide monitoring is performed in accordance with the AEA.

The primary sections that comprise this chapter are organized as follows:

- Sections 3.2.1 through 3.2.8 describe groundwater contaminants and monitoring results in 2011.
- Section 3.2.9 summarizes the CERCLA remediation activities and soil vapor extraction activities.
- Section 3.2.10 addresses groundwater monitoring of RCRA facilities and the SALDS.

The main contaminant of concern within 200-ZP-1 is carbon tetrachloride associated with discharges to the 216-Z-1A, 216-Z-9, and 216-Z-18 Trenches.

Carbon tetrachloride is the main contaminant of concern within 200-ZP-1, forming a plume >13 square kilometers in an area extending north and east from the source areas. The primary source is associated with discharges of liquid waste from the Plutonium Finishing Plant's processes to the 216-Z-1A, 216-Z-9, and 216-Z-18 Cribs and Trenches. The other contaminant plumes within 200-ZP-1

[1] Trichloroethene is also known as trichloroethylene, the contaminant of concern identified in the final ROD.

are much smaller and are contained within the boundaries of the carbon tetrachloride plume (Figure 3.2-2).

Monitoring activities in the past focused on the upper 15 meters of the aquifer, primarily to track water quality changes associated with vadose zone discharges and possible unplanned releases. More recent groundwater investigations revealed that, in some cases, higher concentrations are found much deeper within the aquifer. These findings are being incorporated into remedial action designs and compliance monitoring strategies.

The Columbia River Basalt Group forms the bedrock beneath 200-ZP-1. The uppermost basalt flow is the Elephant Mountain Member of the Saddle Mountains Basalt. Geologic units above the basalt (in ascending sequence) are the semiconsolidated sand and gravel of the Ringold Formation unit A, the silt and clay of the Ringold lower mud unit, the semiconsolidated sand and gravel of Ringold unit E, the fine- to coarse-grained Cold Creek unit, and unconsolidated sand and gravel of the Hanford formation (Section 3.1 and Appendix E). Groundwater occurs as an unconfined aquifer, as well as under locally confining conditions beneath the Ringold lower mud unit (Ringold confined aquifer), and within and between the basalt flows (upper basalt-confined aquifer and the lower basalt aquifers). The groundwater in the suprabasalt sediments is the only aquifer directly impacted by waste disposal operations in the central and northern 200 West Area. In those areas where the Ringold lower mud unit is missing in the stratigraphic sequence (Figure 3.2-3), carbon tetrachloride migrated below the mud unit and into the confined aquifer.

200-ZP-1 at a Glance

T Plant Operations: 1944 to 1956 (Plutonium Separation)
Plutonium Finishing Plant Operations: 1949 to 1989

2011 Groundwater Monitoring

Contaminant	Drinking Water Standard	Maximum Concentration	Plume Area[a] (km^2)
Carbon Tetrachloride	5 µg/L	3,900 µg/L	10.8/13.3[b]
Nitrate	45 mg/L	2,740 mg/L	8.3
Iodine-129	1 pCi/L	22.5 pCi/L	0.50
Tritium	20,000 pCi/L	420,000 pCi/L	0.39
Chromium	100/48 µg/L[c, d]	522 µg/L[e]	0.20/0.07
Trichloroethene	5 µg/L	11 µg/L	0.20
Technetium-99	900 pCi/L	7,600 pCi/L	0.08

Remediation

Groundwater pump-and-treat (interim action):
- 1996–2011, removed 13,503 kg carbon tetrachloride

Soil vapor extraction (expedited response action):
- 1991–2011, removed 79,945 kg carbon tetrachloride

Final action record of decision issued in 2008.

Groundwater pump-and-treat (final action):
- Scheduled to begin operating in 2012

a. Estimated area above listed drinking water standard.
b. Area in upper part of unconfined aquifer/Area of full plume footprint, all depths in unconfined aquifer.
c. 100 µg/L federal drinking water standard for total chromium.
d. 48 µg/L groundwater cleanup standard for hexavalent chromium.
e. Value is for unfiltered total chromium.

Depths from land surface to the water table range from 64 to 106 meters, with the greater depths occurring in the eastern portion of the interest area. The thickness of the unconfined aquifer within the interest area ranges from 8 to 68 meters on the east side and north side respectively (Section 3.1 of PNNL-13858). Moving east of the 200 West Area, the aquifer transitions into the more transmissive Hanford formation. The lower mud unit rises to the northeast and eventually is above the water table.

The water table within 200-ZP-1 has continued to decline since discharge of wastewater was terminated in the 1990s. The current rate of decline ranges from ~0.21 to 0.4 meter per year.

Groundwater in the northern 200 West Area flowed east-northeast over the past decade, but is locally influenced by the 200-ZP-1 interim pump-and-treat system and effluent discharges to the SALDS (Figure 3.2-4). Groundwater flow rates in 200-ZP-1 range from 0.0001 meter per day in fine-texture, low-permeability Ringold sediments to 0.5 meter per day in coarse-texture, higher-permeability Hanford sediments (SGW-38815).

Flow in the southern portion of 200-ZP-1 is strongly influenced by the operation of the interim pump-and-treat system's 14 extraction wells (Figure 3.2-1). The treatment system removes carbon tetrachloride and other volatile organic compounds. Treated effluent is injected into the aquifer through five wells upgradient of the plume. A small groundwater mound is present at the injection wells, while a cone of depression occurs near the extraction wells, setting up a recirculation zone between the two areas. The injection wells are positioned due west of LLWMA-4, affecting groundwater flow direction and contaminant concentrations beneath the surrounding sites.

3.2.1 Carbon Tetrachloride

Carbon tetrachloride is found at levels greater than the drinking water standard of 5 µg/L under most of the 200 West Area (Figure 3.2-5). Initially, carbon tetrachloride concentrations exceeding 2,000 µg/L were located beneath the PFP. After 15 years of pump-and-treat operations, the areal extent of the >2,000 µg/L contour in the upper portion of the aquifer has been reduced from 530,000 square meters in 1996 to 293,000 square meters consisting of several small, isolated areas in 2011. Areal extent of the plume was determined by sample analyses results across the operable unit. Sample results from wells in the upper 15 meters of the unconfined aquifer are indicated on Figure 3.2-5. Specific requirements for the interim action are outlined in *Record of Decision for the USDOE Hanford 200-ZP-1 Operable Unit, 200 Area NPL Site Interim Remedial Measure* (EPA/ROD/R10-95/114).

200-ZP-1 interim pump-and-treat remedial actions successfully reduced maximum concentrations and the number of wells with carbon tetrachloride concentrations exceeding 2,000 µg/L.

Continued investigations during drilling of new groundwater monitoring, extraction, and injection wells revealed carbon tetrachloride concentrations greater than 1,000 µg/L throughout the entire thickness of the aquifer, rather than just in the upper 15 meters. Figure 3.2-6 shows the carbon tetrachloride distribution throughout the unconfined aquifer and includes depth-discrete sample results obtained during installation of recent wells. Figure 3.2-7 provides a visual "slice" through a three-dimensional conceptual model of the carbon tetrachloride plume. The data supporting this figure were derived from groundwater samples collected for all wells screened above the basalt within the unconfined aquifer along the A to A′ transect shown on Figure 3.2-8. Both of these figures show carbon tetrachloride extending to the east and vertically downward from the source areas. Except for monitoring well 699-48-71, concentrations at a distance from the source are declining because of dispersion and degradation. During 2011, carbon tetrachloride concentrations increased in well 699-48-71 (located northeast and outside of the 200 West Area) to ~110 µg/L (Figure 3.2-9). Since 2002, carbon tetrachloride concentrations exceeded the DWS in this well. The steady increase in carbon tetrachloride in well 699-48-71 is the result of contaminated groundwater from central 200-ZP-1 migrating toward this well. The 200 West pump-and-treat well network is designed to capture and contain contamination within 200-ZP-1. The new extraction wells are large diameter (20 cm) with long screens (>30 meters) placed to within 3 meters of the bottom of each well. Spacing of extraction wells was determined through aquifer testing to be sufficient to capture contamination throughout the aquifer underlying 200-ZP-1. Contamination in the

vicinity of well 699-48-71 will be captured in the new 200 West pump-and-treat extraction well located south of well 699-48-71. Prior to 200-ZP-1 interim actions in 1996, 17 extraction wells and 23 monitoring wells exceeded 2,000 μg/L of carbon tetrachloride. In 2011, only five extraction wells and four monitoring wells showed carbon tetrachloride concentrations at or above 2,000 μg/L (Figure 3.2-10). Groundwater wells 299-W15-50, 299-W15-40, and 299-W15-765, located south and west of WMA TX-TY, had the highest 2011 carbon tetrachloride concentrations at 3,900 μg/L, 3,700 μg/L, and 2,800 μg/L, respectively. The remaining six wells are located south of WMA TX-TY and west and east of WMA T. Maximum concentrations in 200-ZP-1 extraction wells in 2011 averaged 63 percent less than the maximum concentrations recorded prior to the interim action. For the two extraction wells located east of WMA T (299-W11-45 and 299-W11-46), maximum concentrations in 2011 (1,200 μg/L in both wells) averaged 56 percent less than their maximum prior to startup operations in 2007 (3,900 μg/L and 2,100 μg/L, respectively). The significant decline in both maximum carbon tetrachloride concentration (from 8,700 μg/L in 1990 to 3,900 μg/L in 2011) and in the number of wells exceeding the RAO of 2,000 μg/L (from 40 wells to 9) demonstrates the effectiveness of the interim actions in reducing contamination in the area of highest concentration of carbon tetrachloride in groundwater.

3.2.2 Trichloroethene

Trichloroethene in 200-ZP-1 is detected at levels above the drinking water standard (5 μg/L) in two discrete plumes: (1) beneath WMA TX-TY, co-located with the high-concentration portion of the carbon tetrachloride plume; and (2) beneath WMA T and directly east of WMA T. Each of these plumes is along the centerline of the carbon tetrachloride plume (Figure 3.2-11).

The maximum trichloroethene concentration reported during 2011 was 11 μg/L in 299-W15-44, an increase from a maximum concentration of 7 μg/L in this well in 2010. The increase in trichloroethene concentration in monitoring well 299-W15-44 is due to the influence of groundwater flow by nearby extraction well 299-W15-225, which has been operating at 946 liters per minute (250 gpm) since July 2010. The high flow rate in this well diverts the groundwater flow direction, effectively capturing contamination in the southern portion of WMA TX-TY.

The trichloroethene plume beneath and east of WMA T is also located within the capture zone of the two pump-and-treat extraction wells downgradient of WMA T. Figure 3.2-12 depicts the 2011 maximum trichloroethene concentration in wells adjacent to both WMAs compared to maximum trichloroethene concentrations recorded prior to 2011. With three exceptions (wells 299-W11-40, 299-W11-41, and 299-W10-28), trichloroethene concentrations in wells adjacent to WMA T declined an average of 39 percent and, with two exceptions (299-W10-26 and 299-W14-13), trichloroethene concentrations in wells adjacent to WMA TX-TY declined an average of 51 percent because of remediation activities.

The increase in trichloroethene concentration in the three WMA T wells is due to the influence of the two extraction wells effectively drawing in trichloroethene contamination from the surrounding area. The increase in trichloroethene concentration in the two WMA TX-TY wells is due to the east-northeast flow of contaminant/groundwater beneath the WMA.

3.2.3 Nitrate

Nitrate concentrations are above the drinking water standard (45 mg/L, as nitrate) beneath much of 200-ZP-1 (Figure 3.2-13). Sources of nitrate include liquid waste disposal from PFP processes to the cribs near WMA T and the 216-Z Cribs and Trenches. Two discrete, high concentration plumes are discernible: (1) a plume located beneath WMA T and WMA TX-TY, and (2) a diminishing plume observed at well 299-W18-16 (near the 216-Z Cribs and Trenches). These plumes merge above the 45 mg/L contour extending from the 216-Z Cribs and Trenches to beyond the 200 West Area boundary to the northeast. The size and concentration of contours in 2011 are similar to those reported in 2010.

The high-concentration plume beneath WMA T is located within the capture zone of WMA T pump-and-treat wells 299-W11-45 and 299-W11-46. The highest concentration at the WMA T wells for 2011 was 2,740 mg/L at well 299-W10-4, a 74 percent decrease in nitrate concentration from the

maximum concentration reported for this well of 7,610 mg/L in 2004, confirming remediation of this plume. The nitrate concentration in well 299-W18-16 in the southern high-concentration plume is also declining. The maximum nitrate concentration for this well in 2011 was 314 mg/L, a 70 percent decrease from the maximum concentration of 1,060 mg/L reported in 2006. Figure 3.2-14 illustrates the decrease in maximum nitrate concentrations in WMA T and WMA TX-TY wells.

3.2.4 Chromium

Chromium contamination is found at levels above the drinking water standard (100 µg/L for total chromium and 48 µg/L for hexavalent chromium) beneath the single-shell tanks at WMA T and at WMA TX-TY (Figure 3.2-15). Sources of chromium contamination include past leaks from single-shell tanks containing metal and liquid waste from chemical processing of uranium-bearing, irradiated reactor fuel rods, the bismuth phosphate process, uranium-recovery process, and from REDOX and PUREX plant operations (DOE/RL-2009-66, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area T*; DOE/RL-2009-67, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area TX-TY*). For groundwater plume analysis, total chromium is used to characterize concentrations and plume extent; total chromium in filtered samples represents hexavalent chromium (Section 1.7) because the hexavalent form of chromium is soluble and mobile in water. In 2011, the 200-ZP-1 maximum chromium concentration of 522 µg/L was found at well 299-W10-4, a 28 percent decrease from the maximum chromium concentration of 722 µg/L measured in this well in 2004 (prior to remediation activities).

The highest concentration reported in WMA T extraction wells 299-W11-45 and 299-W11-46 during 2011 was 149 µg/L and 121 µg/L, respectively. Chromium contamination in the northeastern corner of WMA T is within the capture zone of the extraction wells. Maximum chromium concentrations decreased an average of 41 percent in WMA T wells and decreased an average of 42 percent in WMA TX-TY wells. Figure 3.2-16 illustrates the decrease in maximum chromium concentrations in WMA T and WMA TX-TY wells. In 2011, chromium concentrations in WMA T extraction wells are significantly less compared to values reported before remediation operations (from a maximum chromium concentration of 708 µg/L in 2007 to a maximum of 149 µg/L in 2011).

3.2.5 Tritium

Tritium concentrations exceeded the drinking water standard of 20,000 pCi/L within 200-ZP-1 at two locations: (1) adjacent to WMA T and WMA TX-TY and (2) adjacent to the SALDS. Active permitted discharges at the SALDS are an ongoing source of tritium to groundwater in 200-ZP-1. Other sources of contamination are the liquid wastes from plutonium processing to disposal facilities, including 216-T-25 Trench, and past leaks from tanks and pipelines adjacent to WMA TX-TY.

Tritium concentrations exceed the 20,000 pCi/L drinking water standard at wells adjacent to WMA T, WMA TX-TY, and near the SALDS. The plumes near WMA T and TX-TY are shrinking.

Figure 3.2-17 shows the geometry and extent of the tritium plumes, with contaminant levels greater than 20,000 pCi/L in wells south of WMA TX-TY to contaminant levels greater than 400,000 pCi/L east of WMA TX-TY. In 2011, the highest tritium concentration found in 200-ZP-1 measured 420,000 pCi/L at well 299-W14-13 located east of WMA TX-TY. Tritium concentrations at wells near the WMAs are declining (from a maximum tritium concentration of 2,940,000 pCi/L in 2000 to 420,000 pCi/L in 2011-an 86 percent decrease), suggesting that less contamination is moving from the vadose zone to groundwater. In addition, the area of the plume northeast of WMA T has gotten smaller, based on declining concentrations in wells downgradient of WMA T.

The tritium plume near the SALDS varies with discharge volumes and based on the concentration loading received from the Effluent Treatment Facility (ETF). In 2011, the highest tritium concentration in wells 699-48-77A, 699-48-77C, and 699-48-77D were 110,000 pCi/L, 155,000 pCi/L, and 160,000 pCi/L, respectively. The 2011 maximum concentrations are significantly less than past years' maximum concentrations in these three wells: 2,000,000 pCi/L in 1997 compared to 110,000 pCi/L in 2011 in well 699-48-77A (a 94.5 percent decrease); 980,000 pCi/L in 2001 in 699-48-77C compared to 155,000 pCi/L in 2011 (an 84 percent decrease); and 2,100,000 pCi/L in 1998 in 699-48-77D compared to 160,000 pCi/L in 2011 (a 92 percent decrease). Tritium concentrations are also declining in downgradient monitoring well 699-48-71: from a maximum concentration of 70,000 pCi/L in 1962 to 1,300 pCi/L in 2011—a 98 percent decrease.

3.2.6 Iodine-129

Iodine-129 concentrations exceed the 1 pCi/L drinking water standard in wells east of WMA T and WMA TX-TY. Sources of iodine-129 include past leaks from single-shell tanks containing metal and liquid waste from chemical processing and plant operations to liquid waste disposal facilities (for example, cribs and trenches) adjacent to the tank farms. Figure 3.2-18 shows the extent and geometry of the iodine-129 plume at the 1 pCi/L drinking water standard. In 2011, the maximum reported concentration of 22.5 pCi/L was at well 299-W14-13, adjacent to and east of WMA TX-TY. Concentrations also exceeded the drinking water standard at 299-W14-11, 299-W14-15, 299-W11-34P, and 299-W11-37.

Figure 3.2-19 depicts the decline in iodine-129 concentration in 200-ZP-1 wells prior to 2011 and during 2011, suggesting less contamination is moving from the vadose zone to groundwater. The flow path of the iodine-129 plume can be traced to downgradient wells along a northeast trend. The highest iodine-129 concentrations found in WMA T extraction wells 299-W11-45 and 299-W11-46 measured 0.803 pCi/L and 0.802 pCi/L, respectively. The detection limit for iodine-129 is ~0.5 pCi/L. Iodine-129 concentrations declined compared to 2010 data.

3.2.7 Technetium-99

Technetium-99 exceeded the 900 pCi/L drinking water standard at fourteen 200-ZP-1 groundwater wells in 2011. Sources of technetium-99 contamination in 200-ZP-1 were releases from past leaks in single-shell tanks and pipelines in WMA T and TX-TY, and liquid waste disposal from plutonium processing operations to cribs and trenches adjacent to the WMAs. Figure 3.2-20 shows three distinct technetium-99 plumes above the 900 pCi/L drinking water standard, centered at (1) the south end of WMA TX-TY, (2) the north end of WMA TX-TY, and (3) beneath WMA T. The highest concentration was 7,600 pCi/L in monitoring well 299-W11-41, located east (downgradient) of WMA T. High technetium-99 concentrations also occurred in wells 299-W15-765 (6,300 pCi/L), 299-W11-46 (5,120 pCi/L), and 299-W11-45 (2,500 pCi/L). The plume beneath WMA T assumes the same eastward trend as other contaminant plumes in the operable unit. Technetium-99 concentrations are declining compared to sample results prior to 2011 (Figure 3.2-21). Prior to remediation activities (Section 3.2.9.2) in 2007, nineteen wells exceeded the drinking water standard with the maximum technetium-99 concentration of 113,000 pCi/L found in WMA T extraction well 299-W11-46. In 2011, the maximum technetium-99 concentration in that same well measured 5,120 pCi/L—a 95.5 percent reduction in concentration. The same trend occurs in WMA T extraction well 299-W11-45—an 89.4 percent reduction from a maximum concentration of 23,500 pCi/L recorded in 2005 to 2,500 pCi/L in 2011 (Figure 3.2-22). Remediation activities resulted in an average 45 percent decrease in technetium-99 concentration in 200-ZP-1 wells since operations began in 2007.

The maximum technetium-99 concentration is steadily declining in extraction well 299-W11-46, from a high of 113,000 pCi/L in 2007 to 5,120 pCi/L in 2011.

3.2.8 Other Contaminants

In the past, detections of antimony were close to the reported detection limit and sporadic. Most detections before 2011 are believed to be false-positive results. In 2011, more stringent analytical methods with lower detection limits (ICP-MS Metals 6020 and ICP-MS Metals 200.8) were used to analyze for antimony and other metals enabling detection limits below the drinking water standard. Antimony concentrations were below the drinking water standard of 6 μg/L in 2011.

Other constituents detected in groundwater at concentrations above the drinking water standard include arsenic, fluoride, iron, and manganese. Chloroform and methylene chloride are monitored for the groundwater interest area as degradation products of carbon tetrachloride.

In 2011, the annual average chloroform concentrations in 200-ZP-1 groundwater remained below the 80 μg/L drinking water standard (defined for total trihalomethanes). The 2011 maximum chloroform concentration measured 50 μg/L at extraction well 299-W15-225. Concentrations are declining throughout the area. Chloroform sources include biotic and abiotic degradation of carbon tetrachloride and sanitary sewer discharges to the 2607-Z Tile Field.

In 2011, methylene chloride was detected above the drinking water standard (5 μg/L) in one well, new injection well 299-W6-14 (located near the northwestern boundary of 200-ZP-1). The maximum methylene chloride concentration of 24 μg/L was found during drilling. Methylene chloride (dichloromethane) is a degradation product of carbon tetrachloride (tetrachloromethane) and a common laboratory contaminant.

In 2011, arsenic was detected at levels above the 10 μg/L drinking water standard in well 299-W10-4, located southwest of WMA T, and in well 699-48-77A, located east of the SALDS. Maximum arsenic concentrations at these wells were reported at 12.2 and 12.8 μg/L, respectively. These maximum concentrations are slightly higher than the maximum recorded values of 12.0 μg/L at well 299-W10-4 and 10.8 μg/L at well 699-48-77A in 2010 (filtered arsenic). However, the 2011 average arsenic concentration in well 299-W10-4 is 11.1 μg/L and in well 699-48-77A the average is 10.6 μg/L. Average arsenic concentration in both wells are below the Hanford Site filtered groundwater background for arsenic, which is 11.8 μg/L (95th percentile) (DOE/RL-96-61).

Fluoride contamination at levels greater than the primary drinking water standard of 4 mg/L historically occurred in a local area around T Tank Farm. Fluoride concentrations are declining in the T Tank Farm area, from a maximum concentration of 10.5 mg/L at well 299-W10-8 in 2005 to the 2011 maximum fluoride concentration of 4.75 mg/L at well 299-W10-23 (located north of the tank farm). The 2011 maximum fluoride concentration of 4.75 mg/L at well 299-W10-23 is similar to the maximum concentration of 4.5 mg/L at well 299-W10-8 in 2010. The source of the fluoride is the historical surficial releases of lanthanum fluoride used in the bismuth phosphate process, which infiltrated to the unconfined aquifer.

Iron was present at levels above the 300 μg/L secondary drinking water standard (an EPA non-mandatory water quality guideline) in nineteen groundwater monitoring wells. The secondary drinking water standard for iron applies to taste, color, and odor of groundwater, but the iron content is not considered to present a risk to human health or the environment. The maximum reported concentration of 20,200 μg/L (unfiltered) was at well 699-48-77D (the filtered sample to remove sediments measured 118 μg/L). A review of samples collected for multiple years at individual wells indicates that iron concentration fluctuates over a wide range because iron is a naturally occurring component of aquifer sediment and is found in well construction materials. Iron concentration changes with changes in groundwater chemistry, level of turbidity during sampling, and with degradation of well materials. For example, iron concentration in well 699-48-77D fluctuated greatly in 2011 between 19 μg/L and 20,200 μg/L, but the maximum reported before 2011 was 1,390 μg/L (unfiltered) in 2007. The filtered sample in 2007 measured 59 μg/L. The background iron concentration for Hanford Site filtered groundwater is 55.3 μg/L (DOE/RL-96-61).

Manganese (unfiltered) was present at levels above the 50 µg/L secondary drinking water standard (an EPA non-mandatory water quality guideline) in nine groundwater monitoring wells. The secondary drinking water standard for manganese applies to taste, color, and odor of groundwater, but the manganese content is not considered to present a risk to human health or the environment. The maximum reported concentration of 590 µg/L (unfiltered) was at well 299-W7-4 (the filtered sample to remove sediments was undetectable for manganese at the detection limit of 5 µg/L).

3.2.9 CERCLA Groundwater Activities

This section summarizes the CERCLA groundwater performance monitoring and interim remedial measures at the 200-ZP-1 Operable Unit. It also summarizes remediation of the vadose zone by removal of carbon tetrachloride via soil vapor extraction.

Appendix A lists wells, constituents, and sampling frequencies for 200-ZP-1 CERCLA groundwater monitoring in 2011.

3.2.9.1 Final Groundwater Remediation

The plan and schedule for implementing all of the tasks applicable to the 200 West pump-and-treat system, as set forth in the final 200-ZP-1 ROD, were issued in the 200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan (DOE/RL-2008-78) in March 2009.

Based on groundwater characterization activities and interim pump-and-treat operations, the final remedy for the 200-ZP-1 Operable Unit was developed and formalized in the final ROD (EPA et al., 2008). The list of contaminants of concern from the interim action was expanded to include major contaminant plumes exceeding drinking water standards. The contaminants of concern include carbon tetrachloride, trichloroethene, iodine-129, technetium-99, nitrate, hexavalent chromium, total chromium, and tritium.

The remedial action objectives for 200-ZP-1 are as follows (EPA et al., 2008):

- ***Return the 200-ZP-1 Operable Unit groundwater to beneficial use.***
- ***Apply institutional controls to prevent use of groundwater until the cleanup levels have been attained.***
- ***Protect the Columbia River from degradation and unacceptable impacts caused by contamination from the 200-ZP-1 Operable Unit.***
- ***The final ROD addresses carbon tetrachloride and seven other groundwater contaminants through the full thickness of the unconfined aquifer.***

The remedial action objectives will be achieved through four remedy components: (1) monitored natural attenuation, (2) institutional controls, (3) flow-path controls, and (4) pump and treat of the contamination. The 200 West pump-and- treat system will begin operations in 2012.

The CERCLA cleanup process for the 200-ZP-1 Operable Unit is described in a series of regulatory documents, including the following:

- Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit (DOE/RL-2003-55), prepared in fiscal 2004 and implemented in fiscal year 2005.
- Remedial Investigation Report for 200-ZP-1 Groundwater Operable Unit (DOE/RL-2006-24), published in October 2006.
- Feasibility Study Report for 200-ZP-1 Groundwater Operable Unit (DOE/RL-2007-28) and Proposed Plan for Remediation of 200-ZP-1 Groundwater Operable Unit (DOE/RL-2007-33), completed in July 2008.
- *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan* (DOE/RL-2008-78), for implementing all of the tasks for design, installation, and operation of the 200 West Area Pump-and-Treat system (as set forth in the final 200-ZP-1 ROD), completed in July 2009.
- *200 West Area Groundwater Pump-and-Treat Remedial Design Report* (DOE/RL-2010-13) presents the site-specific data and considerations needed to successfully complete the remedial actions identified in the ROD.
- Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action (DOE/RL-2009-115).

In 2011, tasks performed to execute the final ROD remedial action objectives included the completion of six injection wells to supplement the twenty wells completed in 2009 and 2010. This moves the project closer to a final network of 36 injection and extraction wells. These wells will support the new 200 West pump-and-treat system, which will become operational in 2012. Construction activities for the new groundwater treatment facility were completed in 2011.

3.2.9.2 Interim Groundwater Remediation

The primary contaminants of concern identified for interim remediation are carbon tetrachloride, trichloroethene, and chloroform. The interim RAOs were identified in EPA/ROD/R10-95/114, and the interim remedial action is described in *200-ZP-1 Interim Remedial Measure Remedial Design Report* (DOE/RL-96-07) and DOE/RL-2003-55.

DOE began interim actions in 1996 to remediate carbon tetrachloride, chloroform, and trichloroethene near the 216-Z liquid waste disposal cribs and trenches. Fourteen extraction wells captured the high-concentration (greater than 2,000 µg/L) region of the carbon tetrachloride plume. Carbon tetrachloride, chloroform, and trichloroethene are removed from the waste stream at an interim treatment facility. The treated effluent is pumped back into the upgradient aquifer through five injection

The interim remedial action objectives for the 200-ZP-1 pump-and-treat system are as follows (EPA/ROD/R10-95/114):

- ***Reduce contamination in the area of highest concentration of carbon tetrachloride.***
- ***Prevent further movement of these contaminants from the highest concentration area.***
- ***Provide information that will lead to development of a final remedy that will protect human health and the environment.***
- ***The interim ROD addresses contamination in the upper portion of the unconfined aquifer.***

wells. This action creates a groundwater mound that increases the groundwater gradient of the plume toward the extraction wells.

During 2011, four extraction wells were taken offline because of low water levels that prevented sustainable operation: 299-W15-6, 299-W15-36, 299-W15-40, and 299-W15-765. Extraction well 299-W15-47 was taken offline because of a failed pump. In 2011, injection well 299-W18-37 was taken offline because condensation built up between the inner and outer pipeline, which triggered the leak detector alarm and shut the well down. Maintenance (scheduled for spring of 2012) to seal the outer pipeline needs to be completed prior to bringing the injection well back online.

The performance monitoring network for the interim system is intended to ensure that appropriate data are collected to evaluate remedy performance in the aquifer. Appendix A provides a list of the performance monitoring network wells and sampling frequency. Table 3.2-1 summarizes the performance of the interim action pump-and-treat system. A detailed status of the interim remediation is provided in *Calendar Year 2011 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations* (DOE/RL-2012-03).

Pumping and treating 758 million liters of 200-ZP-1 groundwater from 14 extraction wells removed 791.8 kilograms of carbon tetrachloride in 2011.

Analysis of the interim system's capture zone indicates that it continued to contain the high-concentration portion of the carbon tetrachloride plume (>2,000 µg/L) present in the upper 15 meters of the aquifer. The areal extent of the high-concentration plume at the water table has declined by approximately 55 percent over the life of the interim action pump-and-treat system.

In 2011, modifications were made at the 200-ZP-1 interim pump-and-treat system to improve performance. Major highlights of the 200-ZP-1 interim and final remedies for 2011 are as follows:

- Water level transducer cables in extraction wells were replaced with carbon tetrachloride resistant cabling resulting in fewer well shutdowns due to faulty signals from transducers.
- Adjustments were made to the new heater/chiller unit to optimize performance.
- Phase 1 operation of the new 200 West pump-and-treat system per DOE/RL-2008-78 was completed to meet Tri-Party Agreement (Ecology et al., 1989) Milestone M-016-122.
- Construction activities at the 200 West pump and treat system were completed in 2011.
- Six injection wells were drilled with three of them completed in 2011 compared to 11 wells completed in 2010, for a total of 26 wells (18 extraction wells and 8 injection wells).
- Several documents supporting 200-ZP-1 remedy implementation were completed, including the following:
  - *ZP-1 Pump and Treat Facility Layup Plan* (SGW-49761) describes the strategy and basis for the shutdown of the interim ZP-1 Pump-and-Treat facility.
  - *200 West Area Pump and Treat System Startup Plan* (SGW-49168) provides a general description of the 200 West pump-and-treat startup process.
  - Transition Plan from the Interim 200-ZP-1 Pump-and-Treat System to the Commissioning of the 200 West Groundwater Treatment Facility (DOE/RL-2011-75) documents the general approach for terminating operations

at the interim pump-and-treat system and startup and operations of the 200 West pump-and-treat facility.

- *Mitigation Action Plan for the 200 West Area Groundwater Remediation Project* (SGW-48726) describes the mitigation process and documents ecological and cultural surveys conducted to assess potential impacts to the environment by the project.
- *Predicted Impact of Future Water-Level Declines on Groundwater Well Longevity within the 200 West Area, Hanford Site* (SGW-50907) provides information about 200 West Area monitoring wells currently in use, but expected to become dry within the next 10 years.

Monitoring and interim remediation of technetium-99 and other contaminants from sources within WMA T and WMA TX-TY for both the CERCLA and AEA programs continued in 2011. The interim remediation activity was implemented as part of the remedial guidance for 200-ZP-1, based on EPA/ROD/R10-95/114 and the data quality objectives process (WMP-28389, *T-Area Technetium-99 Data Quality Objectives Summary Report*). Groundwater extracted from wells at WMA T is routed through resins that remove the technetium-99 before treatment for volatile organic compounds (carbon tetrachloride), nitrate, and metals (chromium). Remediation activities at WMA T include pumping of technetium-99-laden groundwater from extraction wells 299-W11-45 and 299-W11-46. Effluent from these wells is transferred to the ETF via a cross-transfer pipeline, where constituents are removed by ion exchange, reverse osmosis, and ultraviolet light/oxidation before the remediated water is discharged at the SALDS. Table 3.2-2 summarizes the 2011 performance for the two WMA T extraction wells.

During 2011, five wells were chosen to sample for plutonium, americium, and their isotopes. The five wells were identified for sampling based on proximity (and downgradient location) to potential sources (Figure 3.2-1): 299-W11-45 (east of WMA T Tank Farm), 299-W14-13 (east of WMA TX/TY Tank Farm), 299-W15-32 (on the north border of 216-Z-9 trench), 299-W15-46 (on the south border of 216-Z-9 trench), and 299-W18-16 (on the east side of 216-Z-1A trench). One well, 299-W15-46, was successfully sampled in 2011. No plutonium or americium was detected in the samples. The remaining four wells are scheduled for sampling in 2012.

3.2.9.3 Soil Vapor Extraction

Soil vapor extraction (SVE) is being used to remove carbon tetrachloride from the vadose zone at the carbon tetrachloride site in the 200-PW-1 Operable Unit overlying the 200-ZP-1 groundwater. The carbon tetrachloride site includes the three waste sites (216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib) used from 1955 through 1973 for disposal of waste liquids containing carbon tetrachloride. The purpose of the remediation using soil vapor extraction is to mitigate the threat to the environment caused by the migration of carbon tetrachloride vapors through the soil column and into the groundwater.

Soil vapor extraction (SVE) was implemented as an interim action in 1992 (Smith and Stanley, 1992, "Action Memorandum: Expedited Response Action Proposal for 200 West Area Carbon Tetrachloride Plume"). The CERCLA Record of Decision for the 200-PW-1 Operable Unit was finalized in September 2011 (EPA, 2011, *Record of Decision—Hanford 200 Area Superfund Site: 200-CW-5 and 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units, September 30, 2011*). The ROD selected SVE as the final remedial action for vadose zone carbon tetrachloride contamination at these waste sites that received the carbon tetrachloride waste liquids.

During SVE operations, vapor-phase carbon tetrachloride is extracted through vadose zone wells and adsorbed onto granular activated carbon before the treated, clean vapor is released to the atmosphere. Since 1992, soil vapor extraction has been implemented using soil vapor extraction systems with design capacities ranging from 14.2 to 42.5 cubic meters per minute. In 2011, two SVE systems, each with a design capacity of 14.2 cubic meters per minute, were used from March through October to remove carbon tetrachloride from the vadose zone. The systems were maintained in standby mode during the

winter (November through February) to allow time for carbon tetrachloride vapor concentrations to rebound.

In 2011, the two systems removed 195 kilograms of carbon tetrachloride from the vadose zone and treated 3.7 million cubic meters of vapor (Table 3.2-3). Since startup of soil vapor extraction operations in 1992, 79,945 kilograms of carbon tetrachloride have been removed from the vadose zone in 115 million cubic meters of soil vapor (Figure 3.2-23). Each SVE system extracts simultaneously from multiple wells; in 2011, vapor was extracted through 32 well intervals using 24 wells (eight of the wells have two isolated open intervals).

SVE Operations have removed 79,945 kilograms of carbon tetrachloride from 115 million cubic meters of soil vapor since startup in 1992.

Passive SVE systems were installed in 2001 at eight wells near the 216-Z-1A Tile Field and 216-Z-18 Crib. Passive soil vapor extraction is a naturally occurring process driven by barometric pressure fluctuations and is often referred to as "barometric pumping." These eight passive SVE systems operated throughout 2011 and removed approximately 4 kilograms of carbon tetrachloride. Since 2001, the passive systems have removed approximately 104 kilograms of carbon tetrachloride from the vadose zone.

Additional details for soil vapor extraction system operations and vadose zone monitoring for 2011 are available in SGW-51807, Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Calendar Year 2011. The performance evaluation report also provides a general overview of the entire operating period from February 25, 1992, through December 31, 2011 and a list of reports that contain detailed information on previous SVE operating periods.

Pacific Northwest National Laboratory conducted a treatability test in 2011 using one of the SVE systems and associated vadose zone wells (DOE/RL-2010-79, *Treatability Test Plan for Characterization of Vadose Zone Carbon Tetrachloride Source Strength Using Tomographic Methods at the 216-Z-9 Site*). The purpose of the test was to evaluate the flux of carbon tetrachloride from the vadose zone to the groundwater under site-specific conditions and to refine the conceptual site model of the location of the remaining carbon tetrachloride in the vadose zone. The testing involved testing one interval within an extraction well at a time. Many of the extraction wells have two screened (or perforated) intervals within one steel-cased well (one casing string). The intervals are isolated from each other by a packer placed in the well between the screens. The screened intervals are referred to as U (upper, above the Cold Creek unit) and L (lower, below the Cold Creek unit). So, for example, the upper screened extraction interval (299-W15-9U) in well 299-W15-9 was tested on one day and the lower screened extraction interval (299-W15-9L) was tested on a different day. During the test, which was conducted in August and September, 22 extraction well intervals were added online sequentially for single-well testing. The data and the evaluation of the results will be provided in a separate report in 2012.

3.2.10 RCRA and Other Facility Monitoring

This section describes the results of monitoring at individual RCRA treatment, storage, and disposal units or tank farms, as well as the SALDS. Some of these units are monitored under RCRA requirements for dangerous waste constituents, and under AEA for source, special nuclear, and byproduct materials.

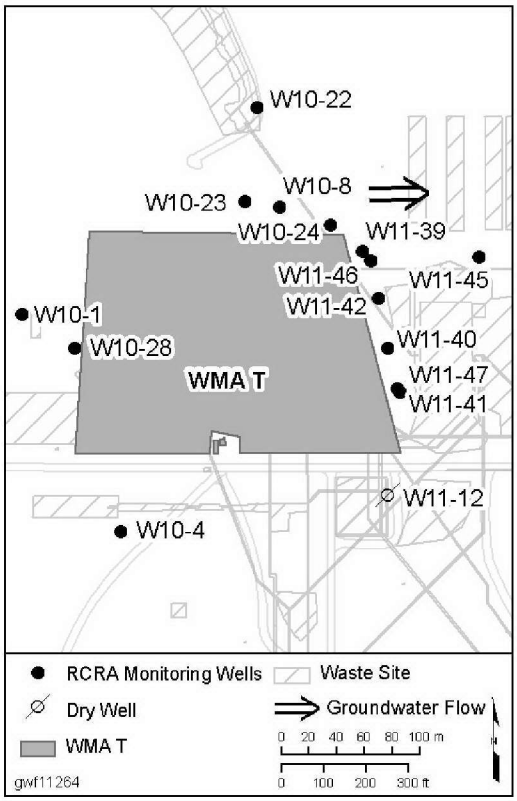
The 200-ZP-1 Operable Unit contains four RCRA sites with groundwater monitoring requirements: WMA T, WMA TX-TY, LLWMA-3, and LLWMA-4. Interim status groundwater quality assessment monitoring was conducted at WMA T and WMA TX-TY (40 CFR 265.93[d], as referenced by WAC 173-303-400). Interim status indicator parameter evaluation monitoring was conducted at the LLWMA-3 and LLWMA-4 (40 CFR 265.92, "Interim Status Standards for Owners and Operators of Hazardous

Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis;" and 40 CFR 265.93[b], as referenced by WAC 173-303-400). The following discussion summarizes the results of statistical comparisons, assessment studies, and other developments for the reporting period. LLWMA-3 and LLWMA-4 also have AEA monitoring conducted under a performance assessment monitoring plan (DOE/RL-2000-72, *Performance Assessment Monitoring Plan for the Hanford Site Low-Level Burial Grounds*).

Groundwater data are available in the HEIS database and in the appendices accompanying this report. The database is available at: http://environet.hanford.gov/eda/. Appendix B includes additional information (including well and constituent lists, maps, flow rates, and statistical tables).

3.2.10.1 Waste Management Area T

The WMA T, which includes the T Tank Farm, is located in the northern portion of the 200 West Area and was used for interim storage of radioactive waste from chemical processing of reactor fuel for plutonium production. In 2008, an interim corrective measure, consisting of surface barrier emplacement over a portion of the farm, was designed and constructed to reduce infiltration and the subsequent migration of contaminants through the vadose zone to groundwater. Sections 3.2.6 and 3.2.7 discuss the distribution of the non-RCRA constituents iodine-129 and technetium-99 near WMA T.



WMA T is in assessment monitoring due to concentrations of the dangerous constituent chromium exceeding the drinking water standard of 100 µg/L in downgradient wells. The well network was sampled quarterly in some wells, semiannually and annually in others for waste constituents and indicator parameters in the groundwater (DOE/RL-2009-66). Appendix B includes a list of wells and constituents monitored.

The water table declined beneath WMA T ~0.3 meter in 2011. This was in response to the cessation of wastewater discharges to surface facilities around the 200 West Area. Figure 3.2-4 provides a current groundwater map including WMA T. Estimates of groundwater/contaminant flow beneath WMA T (using the Darcy relationship) range from 0.12 to 0.19 meter per day. Appendix B contains calculations of groundwater flow rates and gradients.

The primary dangerous waste constituents found beneath WMA T in 2011 are chromium, carbon tetrachloride, and trichloroethene. Of these, only chromium originated at WMA T.

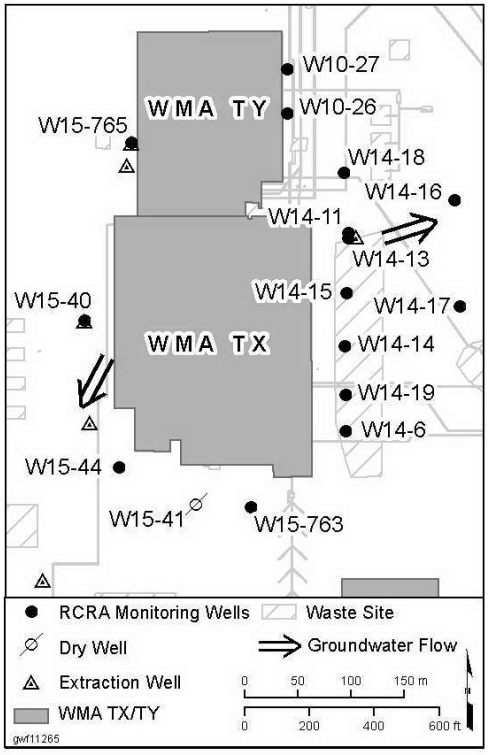
The WMA T monitoring well network consists of two upgradient, two assessment, one far-field, and seven downgradient monitoring wells (299-W11-12 went dry in 2010 and extraction well 299-W11-46 is no longer online). The two assessment wells are not directly upgradient or downgradient, and are used to help distinguish other contaminant plumes impinging on WMA T. The well network complies with RCRA groundwater monitoring requirements. The direction of groundwater flow is not expected to change until the new 200 West pump-and-treat system becomes operational. However, the magnitude and direction of these changes will not be known until after performance monitoring and assessment of the

system is completed, as defined in DOE/RL-2009-115. The groundwater flow direction in this portion of the 200 West Area is eastward, but is locally variable because of the pump-and-treat effects. Appendix B, Figure B-17, shows the location of wells in the WMA monitoring network.

The primary dangerous waste constituents found beneath WMA T during the reporting period were chromium, carbon tetrachloride, and trichloroethene. Carbon tetrachloride and trichloroethene contamination are not related to WMA T, but are associated with liquid disposal processes at the PFP (Section 3.2.1). These constituents are monitored as part of the 200-ZP-1 Operable Unit. Chromium is a dangerous constituent monitored under the RCRA assessment program. From 1944 to 1980, the WMA received metal and first-cycle waste from chemical processing including the bismuth phosphate process, tributyl phosphate process, and REDOX process. Past leaks from single-shell tanks and waste pipelines within the WMA are the sources of the chromium contamination.

In 2011, the highest chromium concentration in the upper portion of the aquifer was in assessment well 299-W10-4 (522 µg/L), located at the southwest corner of the WMA. The highest chromium concentration found in wells screened deeper within the upper portion of the aquifer (above the Ringold lower mud unit) in WMA T was 106 µg/L in downgradient well 299-W11-47 (screened between 7.5 and 17 meters below the water table). The highest chromium concentrations in downgradient extraction wells 299-W11-46 (screened between 6 and 12 meters below the water table) and 299-W11-45 (screened between 8.5 and 13 meters below the water table) were 120 µg/L and 137 µg/L, respectively. The highest chromium concentration in adjacent downgradient well 299-W11-39 (screened at the water table) was 62 µg/L. The higher concentrations in the deeper-screened wells show that the chromium plume at WMA T extends relatively deep in the aquifer downgradient of WMA T and is present laterally at least 80 meters downgradient (eastward) at concentrations above the drinking water standard of 100 µg/L (Figure 3.2-15). However, as a result of remediation activities at WMA T, chromium concentrations are declining, and the plume extent is shrinking.

Nitrate is also found in the groundwater beneath the WMA from the same source as chromium. A nitrate plume beneath WMA T is located within the regional nitrate plume and is consistent with the configuration in 2010 (Figure 3.2-13). During the reporting period, the highest nitrate concentrations were in upgradient wells 299-W10-4 (2,740 mg/L) and 299-W10-28 (1,760 mg/L). The nitrate concentrations above the drinking water standard in the remaining WMA T wells were between 115 and 695 mg/L. While WMA T is a source of nitrate, other upgradient sources are larger contributors.



3.2.10.2 Waste Management Area TX-TY

WMA TX-TY, which includes the TX and TY Tank Farms, is located in the northern portion of the 200 West Area and was used for interim storage of radioactive waste from chemical processing of reactor fuel for plutonium production. The WMA is regulated under RCRA and its implementing requirements in WAC 173-303-400. Sections 3.2.6 and 3.2.7 discuss the distribution of the non-RCRA constituents iodine-129 and technetium-99 near WMA TX-TY.

In 2011, the water table declined beneath WMA TX-TY ~0.4 meter due to cessation of artificial recharge from liquid waste disposal operations. The 200-ZP-1 pump-and-treat extraction wells on the west and south sides of the WMA altered the flow direction and hydraulic gradients, shifting the flow south-southwest in the southern portion of the WMA. This change in groundwater flow direction also shifts contaminant distribution in the uppermost aquifer beneath

WMA TX-TY to the south.

The WMA TX-TY well network currently consists of two upgradient, two mid-field, and eleven downgradient monitoring wells. The well network complies with RCRA groundwater monitoring requirements. Once operational, the new 200 West pump-and-treat system will influence and change groundwater flow direction and velocity at WMA TX-TY. The magnitude and direction of the changes will not be known until after the new system becomes operational and performance monitoring and assessment of the system is completed as defined in DOE/RL-2009-115.

Technetium-99, iodine-129, nitrate, and chromium showed the same declining trend during the reporting period. This may indicate that all four contaminants shared a common source.

The WMA TX-TY well network was sampled quarterly and semiannually for contamination indicator parameters and supporting constituents (DOE/RL-2009-67). Appendix B includes a map of wells in the WMA monitoring network and a list of wells and constituents monitored in 2011. Some wells were not sampled as scheduled during the reporting period as follows:

- Well 299-W14-13 was not sampled during the first and second quarters of 2011 because the pump required lowering by well maintenance staff. The pump was lowered and successfully sampled in the third and fourth quarterly events.
- Well 299-W15-765 has not been sampled since the March 2011 event because of a failed pump. This extraction well has subsequently been taken offline because of low water.
- Well 299-W15-41 was not sampled in 2011 because the well is dry.

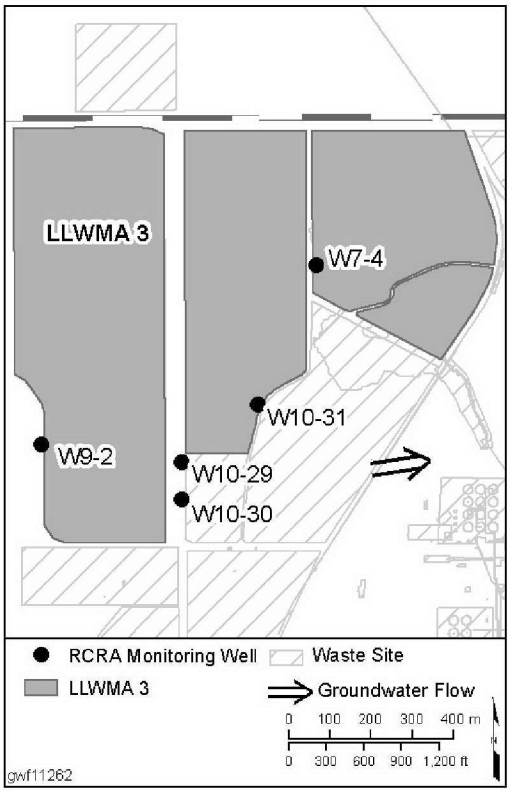
Well 299-W15-765 is being converted to a monitoring well to restore its status as a WMA TX-TY upgradient monitoring well. Downgradient wells 299-W15-44 and 299-W15-763 (in the vicinity of 299-W15-41) continue to be monitored for contaminant movement. While there are replacement monitoring wells (for dry wells) planned for in future years, the locations for these wells will not be defined until the effects of the 200 West pump-and-treat system are known.

The dangerous waste constituent chromium was monitored under the RCRA assessment program in WMA TX-TY during the reporting period. Other dangerous waste constituents found at the WMA during the reporting period included carbon tetrachloride and trichloroethene, which come from other sources associated with PFP operations. Nitrate and fluoride are also found in the groundwater beneath the WMA.

In 2011, chromium was detected above the 100 µg/L drinking water standard in three wells monitoring WMA TX-TY (Figure 3.2-16). The highest chromium concentration was 374 µg/L in downgradient well 299-W14-13, which was a decrease from 732 µg/L in 2010. The highest chromium concentration in 299-W14-11 was 112 µg/L, which was lower than the 2010 high concentration of 178 µg/L. The highest chromium concentration in 299-W10-27 was 119 µg/L, which was higher than the 83 µg/L recorded in 2010. The source for the chromium was past leaks from tanks and pipelines at WMA TX-TY. During 2011, nitrate concentrations exceeded the drinking water standard (45 mg/L) in all wells in the monitoring network (Figure 3.2-13). Nitrate concentrations decreased from the highest concentration found at 299-W14-11 (3,600 mg/L) during drilling in 2005 to the highest concentration found in 2011 at 299-W10-27 (832 mg/L). Nitrate concentrations in other WMA TX-TY wells ranged between 48.3 mg/L (299-W14-14) and 562 mg/L (299-W15-763). Most of the nitrate contamination is attributed to PFP operations, as well as past-practice disposal to cribs and trenches in the area.

Nitrate (Figure 3.2-14) and chromium (Figure 3.2-16), and the non-RCRA constituents iodine-129 (Section 3.2.6; Figure 3.2-19) and technetium-99 (Section 3.2.7; Figure 3.2-21) showed a declining trend during 2011 indicating that all four contaminants may share a common source.

3.2.10.3 Low-Level Waste Management Area 3



The LLWMA-3, located in the northwest corner of the 200 West Area, consists of the 218-W-3A Burial Ground, 218-W-3AE Burial Ground, and 218-W-5 Burial Ground. The 218-W-3A Burial Ground (20.4 hectares) contains 57 unlined trenches operated between 1970 and 1998. The 218-W-3AE Burial Ground (20 hectares) contains eight unlined trenches operated between 1981 and July 2004. The 218-W-5 Burial Ground (37.2 hectares) contains ten unlined trenches and two lined trenches. This burial ground began operating in 1986, and the two double-lined mixed waste trenches are the only trenches continuing to receive waste.

The LLWMA-3 well network was sampled semiannually for RCRA indicator and site-specific parameters (DOE/RL-2009-68, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*). All of the wells were sampled in 2011. Well 299-W7-4 was sampled only once because it went dry. Appendix B includes a list of wells and constituents monitored.

The water table declined ~0.3 meter beneath LLWMA-3 during 2011. This is consistent with regional water table declines resulting from the cessation of Hanford Site discharges. The groundwater flow direction across LLWMA-3 is east-northeast at a calculated rate (using the Darcy relationship) of 0.04 to 0.15 meter per day.

DOE installed a new upgradient well for LLWMA-3 in 2011, which will allow statistical evaluations to resume.

The LLWMA-3 wells are sampled semiannually and annually from a network of four wells. Samples are analyzed for indicator parameters and supporting constituents semiannually. Anions, metals, and phenols are sampled annually. Water-level measurements are taken each time a groundwater sample is collected, and site-wide water-level measurements are collected annually, usually during the month of March.

As RCRA monitoring wells, the network is screened at the water table. Because of water-level decline, the only previously upgradient well on the western side of the WMA (299-W9-1) went dry in 2000. Without sample data from an upgradient well to provide background groundwater quality data, statistical evaluations between background and downgradient groundwater quality could not be performed. DOE drilled and installed a new upgradient well, 299-W9-2, in 2011. Data from this well (sampled quarterly to establish background levels more quickly) will be used to calculate new critical mean values, so statistical evaluations can resume. The well network complies with RCRA groundwater monitoring requirements. No other wells are expected to be installed at LLWMA-3 until the effects on groundwater flow direction from the new 200 West pump-and-treat system are known.

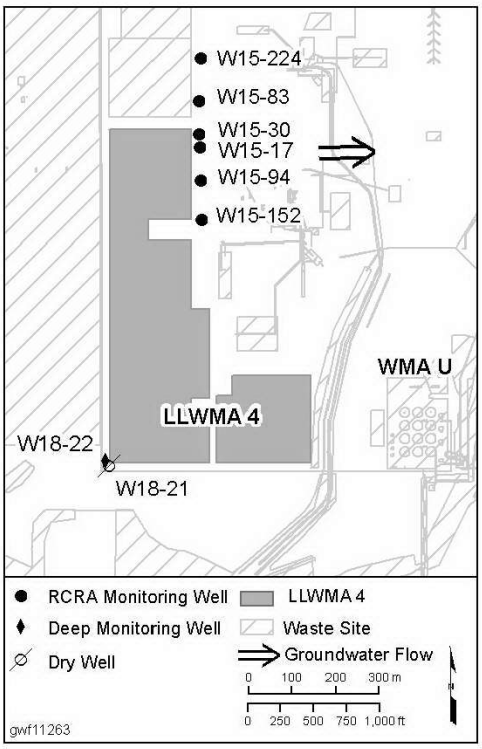
Appendix B includes a map showing the location of wells in the LLWMA-3 monitoring network. During the reporting period, all wells except 299-W7-4 were sampled as scheduled for indicator parameters: pH, specific conductance, total organic carbon, and total organic halides. Well 299-W7-4 went dry in 2011. Appendix B includes a table with indicator parameter averages for LLWMA-3 downgradient wells in 2011 and 2010. Indicator parameter averages are similar to 2010 except for total

organic carbon, which decreased significantly in 299-W10-29 (from 1,766 µg/L in 2010 to 436 µg/L in 2011) and 299-W10-30 (from 2,059 µg/L to 1,696 µg/L) but increased slightly in 299-W10-31 (from 463 µg/L to 615 µg/L).

DOE monitors the LLWMAs for AEA radionuclides, as described in DOE/RL-2000-72. Constituents iodine-129, technetium-99, and uranium are monitored semiannually. Both iodine-129 and technetium-99 were undetected in all three wells. Uranium was detected in all three wells with a maximum concentration of 1.21 µg/L (background level) in 299-W10-31.

3.2.10.4 Low-Level Waste Management Area 4

LLWMA-4 consists of the 218-W-4B and 218-W-4C Burial Grounds, and contains 28 unlined trenches used for disposal of low-level radioactive wastes and low-level mixed wastes since 1967. The 218-W-4B Burial Ground also contains twelve below-grade caissons at the southern end of the facility. The caissons in the 218-W-4B Burial Ground contain remote-handled, low-level waste, and retrievable transuranic waste. Burial Ground 218-W-4B was closed in 1990, and 218-W-4C was closed in 2004. The dangerous chemicals in the low-level mixed waste portions of LLWMA-4 are regulated under RCRA and its implementing requirements (WAC 173-303-400).



The LLWMA-4 well network was sampled semiannually for contamination indicator parameters and supporting constituents (DOE/RL-2009-69, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4*). Appendix B includes lists of wells and the indicator parameter comparison values to be used in 2012.

The water table declined ~0.3 meter beneath the LLWMA-4 in 2011. This decline is in response to the cessation of discharges of wastewater to surface facilities around the 200 West Area. Water levels in upgradient wells declined more slowly than levels in downgradient wells as a result of the effects of the upgradient 200-ZP-1 pump-and-treat system injection wells. The groundwater flow direction in this portion of the 200 West Area is generally east-northeast, but can be locally variable because of the effects of the 200-ZP-1 pump-and-treat system. Groundwater flows (using the Darcy relationship) at a rate of 0.08 to 0.32 meter per day beneath this WMA.

The monitoring network at LLWMA-4 includes six downgradient wells and one upgradient well, 299-W18-21. Upgradient wells 299-W15-15 and 299-W18-23 went sample dry in 2008. Upgradient well 299-W18-22 (screened at the bottom of the unconfined aquifer) is located at the southwestern corner of LLWMA-4 and currently is not truly upgradient; the well was upgradient until the 200-ZP-1 pump-and-treat system began injecting water into five injection wells located just west (upgradient) of the LLWMA. This injection caused groundwater to flow toward the southeast at the location of this well. The well network complies with RCRA groundwater monitoring requirements. No new wells are expected at LLWMA-4 until the effects of the new 200 West pump-and-treat system are known.

Except for downgradient, deep-screened well 299-W15-17, all other wells in the network are screened across the water table. These water table wells have adequate water columns in the screened interval (from 4 to 8 meters) available for sampling.

The groundwater flow to the east at LLWMA-4 is largely affected by injection wells to the west and extraction wells to the east.

The well network was sampled semiannually for indicator and site-specific parameters including: pH, specific conductance, total organic carbon, and total organic halides. All wells, except 299-W15-224, were successfully sampled. Well 299-W15-224 was sampled only once because of electrical problems with the well pump. Appendix B includes a table with indicator parameter averages for LLWMA-4 wells in 2011 and 2010. Total organic halides and total organic carbon results declined in 2011 compared to 2010 results. Indicator parameter averages for pH and specific conductance are similar to 2010. Specific conductance, pH, and total organic carbons in downgradient wells remained below their critical mean values (Appendix B).

As in previous years, downgradient wells continued to exceed the statistical comparison value (critical mean) for total organic halides (24.3 µg/L for 2011) in samples during the reporting period. The critical mean value for 2011 was based on sampling events from January 2007 through July 2007 for upgradient well 299-W15-15, from January 2007 through February 2010 of upgradient well 299-W18-21, and from February 2007 through May 2008 for upgradient well 299-W18-23. DOE previously reported the exceedance of the critical mean in 299-W15-16 (now dry) to the EPA and Ecology in August 1999. These exceedances have been reported in annual groundwater reports since 2001. Well 299-W15-30 replaced 299-W15-16, and exceedance of the critical mean for total organic halides continued. In 2011, 299-W15-30 (with 46 µg/L) and 299-W15-224 (with 26 µg/L) exceeded the critical mean. All LLWMA-4 wells declined in total organic halide concentration in 2011. The elevated total organic halide concentrations do not indicate contamination from LLWMA-4 and are consistent with observed levels of carbon tetrachloride in the aquifer (Section 3.2.1).

Total organic carbon did not exceed the critical mean in any of the network monitoring wells during the reporting period. Well 299-W15-224, which exceeded the critical mean in 2009, had total organic carbon concentrations decrease drastically from the 2009 high of 2,210 µg/L to a low of 540 µg/L in 2010. The decline continued in this well to an average of 269 µg/L total organic carbon in 2011.

DOE monitors the LLWMAs for AEA radionuclides, as described in DOE/RL-2000-72. Constituents iodine-129, technetium-99, and uranium are monitored semiannually. Iodine-129 was undetected in all wells, technetium-99 was undetected in wells 299-W15-17 and 299-W18-22 and detected at very low levels in the remaining five wells (maximum detected was 260 pCi/L in 299-W15-224), and uranium was detected in all wells with a maximum of 1.87 µg/L (background level) in 299-W15-152. Detection of technetium-99 is consistent with observed levels in the aquifer and does not indicate contamination from LLWMA-4.

3.2.10.5 State-Approved Land Disposal Site

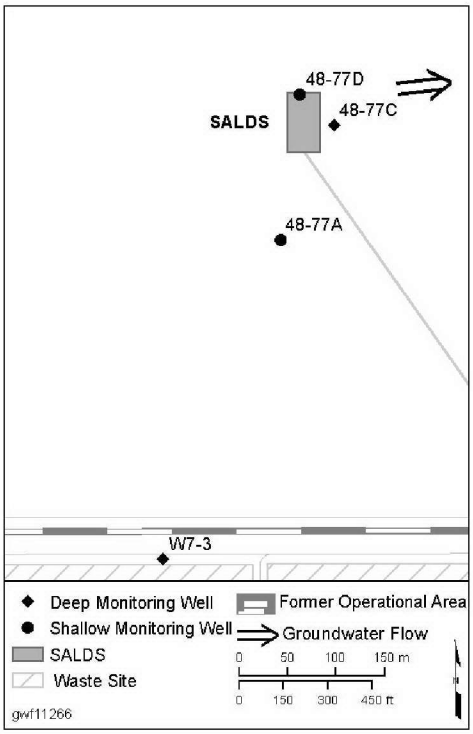
J.P. McDonald

The ETF processes aqueous wastes from various Hanford Site facilities. Treated water from the ETF is discharged to SALDS, which is authorized to receive the effluent by *State Waste Discharge Permit Number ST 4500* (Ecology, 2000a; hereinafter referred to as the "permit"). The permit (Ecology, 2000a) was issued in June 1995, and the site began operating in December 1995. The SALDS is located 400 meters outside the northern boundary of the 200 West Area (Figure 3.2-1) and consists of a 35 meter by 61 meter drain field. During 2011, 75.2 million liters of water were discharged to the SALDS, which is a slight increase to the 71.4 million liters discharged during 2010.

A total of 75.2 million liters of effluent containing 1.35 curies of tritium was discharged to the SALDS during 2011.

Much of the effluent disposed to the SALDS contains tritium because there is no cost-effective treatment technology to remove tritium from wastewater. The 2011 releases contained a total of 1.35 curies of tritium, and monthly average concentrations in the effluent ranged from 7,400 to 131,000 pCi/L. No releases occurred during August and September. These releases resulted in a tritium plume in groundwater beneath the facility.

DOE monitors groundwater in the SALDS vicinity to track the migration of the tritium plume and to compare concentrations of other constituents to permit limits. Groundwater monitoring requirements are described in *Groundwater Monitoring and Tritium-Tracking Plan for the 200 Area State-Approved Land Disposal Site* (PNNL-13121). Quarterly sampling is required for three wells proximal to the SALDS facility and both annual and semiannual sampling is required for a set of tritium-tracking wells located farther afield. Appendix B includes a well location map and a list of wells and constituents sampled for the SALDS. Except for proximal well 699-48-77A and tritium-tracking well 299-W8-1, both of which became dry during 2011, all wells were sampled as planned. Monitoring results for the SALDS are reported in annual reports (on a fiscal-year basis), most recently in *Results of Tritium Tracking and Groundwater Monitoring at the Hanford Site 200 Area State Approved Land Disposal Site, Fiscal Year 2011* (SGW-51085). The permit (Ecology, 2000a) also specifies that periodic numerical modeling of the tritium plume be performed to predict future plume migration. The model was updated during 2011 and the results are described in SGW-51085.



Water-Level and Well Network Evaluation. Discharges from the SALDS form a small groundwater mound, causing a localized area of radial flow beneath the facility. The center of the mound is offset from the facility to the south because the southward dip of the Cold Creek unit diverts the effluent while it infiltrates through the vadose zone. Water table mapping indicates that the regional groundwater flow direction in the SALDS vicinity is currently towards the east-northeast (Figure 3.2-4).

Between March 2010 and March 2011, the water table in the SALDS vicinity declined by 0.33 meter (SGW-51085). The ongoing decline of the water table has caused 11 of the 19 tritium-tracking wells listed in the monitoring plan (PNNL-13121) to become dry, including 299-W8-1, which became dry during 2011. Two attempts were made to sample proximal well 699-48-77A during the fourth quarter of 2011, but both were unsuccessful because of a lack of water. The same issue is also affecting proximal well 699-48-77D. The first attempt to sample this well during the fourth quarter was not successful because of a lack of water, but a second attempt was successful because the water level had increased in response to effluent discharges to the SALDS during November and December. The third proximal well, 699-48-77C, is completed deeper in the unconfined aquifer and is not in danger of becoming dry. The permit (Ecology, 2000a) is due to be renewed, and the issue of the proximal wells becoming dry will be addressed during the renewal process.

The declining water table has caused several of the groundwater wells used for monitoring the SALDS to become dry over the years, including two additional wells during 2011.

Sampling Results. The proximal wells are sampled for 17 constituents/parameters, as listed in the permit (Ecology, 2000a), which sets concentration limits for acetone, benzene, cadmium (total), chloroform, copper (total), lead (total), mercury (total), field pH, sulfate, tetrahydrofuran, and total dissolved solids. Sampling of gross alpha, gross beta, strontium-90, and tritium is also required by the permit (Ecology, 2000a), but these constituents are not assigned permit limits. All groundwater sampling results from the SALDS proximal wells were within permit compliance limits during 2011.

All groundwater sample results from the SALDS wells during 2011 were within permit concentration limits.

Tritium concentrations in the proximal wells are affected by releases from the SALDS. Concentrations exhibit a correlation with the activity of tritium released, although the concentration response in the deeper well, 699-48-77C, exhibits a time lag of several years. During 2011, concentrations increased, and then declined in 699-48-77A, fluctuated in 699-48-77D, and generally increased in the deeper well 699-48-77C (Figure 3.2-24). Concentration changes in the shallow wells are attributed to increases in the activity of tritium discharged between August and December 2010. Changes in the deeper well 699-48-77C are probably due to tritium releases during 2006 and 2007. Peak tritium concentrations in 2011 were 110,000 pCi/L, 155,000 pCi/L, and 160,000 pCi/L in wells 699-48-77A, 699-48-77C, and 699-48-77D, respectively.

Figure 3.2-17 shows the tritium plume beneath the SALDS. To date, tritium from the SALDS has not been detected in any of the tritium tracking wells, and this observation is consistent with numerical model predictions (SGW-51085). The low levels of tritium observed in wells 299-W6-11, 299-W6-12, and 699-48-71 is interpreted to have originated from past wastewater releases from other 200 West Area sources to the south (Figure 3.2-17).

Table 3.2-1. 200-ZP-1 Operable Unit Interim Action Pump-and-Treat, Performance in 2011 and Since Startup

Performance	2011	Since Startup (March 1994)
Total groundwater processed (L)	758.0 million	5.8 billion
Total mass of carbon tetrachloride removed (kg)	791.8	13,503.4
Average mass removal efficiency mass [(influent – effluent) ÷ (influent)] × 100	99%	99%
System availability	97%	95%
Plume area at 2,000 µg/L (km^2)	0.29	0.53
Wells	**End of 2011**	**Change from 2010**
Extraction Wells	9	-5
Injection Wells	4	-1

Table 3.2-2. WMA T Extraction Well Performance in 2011

Performance [a]	299-W11-45	299-W11-46
Total groundwater processed (L)	18.8 million	39.4 million
Total mass of carbon tetrachloride removed (kg)	22.4	35.5
Total mass removed chromium (kg)	2.5	4.4
Total mass removed nitrate (kg)	6,815	16,209
Total mass removed technetium-99 (g) [Ci] [b]	2.5 [0.044]	10.8 [0.187]
Total mass removed trichloroethene (g)	175.3	229.9
System availability	89.9%	80.7%
Average mass removal efficiency mass [(influent – effluent) ÷ (influent)] × 100	99%	99%

a. Mass removed is calculated from volume extracted, not volume treated.

b. Technetium-99 in Curies converted to grams from activity 58.7 g/Ci.

Table 3.2-3. Soil Vapor Extraction Performance in 2011 and Since Startup

Performance	2011	Since Startup (February 1992[a])
Total soil vapor processed (cubic meters)	3,718,000	115,246,000
Total mass of carbon tetrachloride removed (kg)[b]	195	79,945
System availability	74%[c]	(d)

a. Includes the pilot test operations in April 1991.

b. Does not include the mass removed by the passive soil vapor extraction systems.

c. Average of the availability of two soil vapor extraction systems operating from March through October.

d. Not calculated.

Figure 3.2-1. Facilities and Groundwater Monitoring Wells in 200-ZP-1

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Figure 3.2-2. Changes in 200-ZP-1 Plume Areas

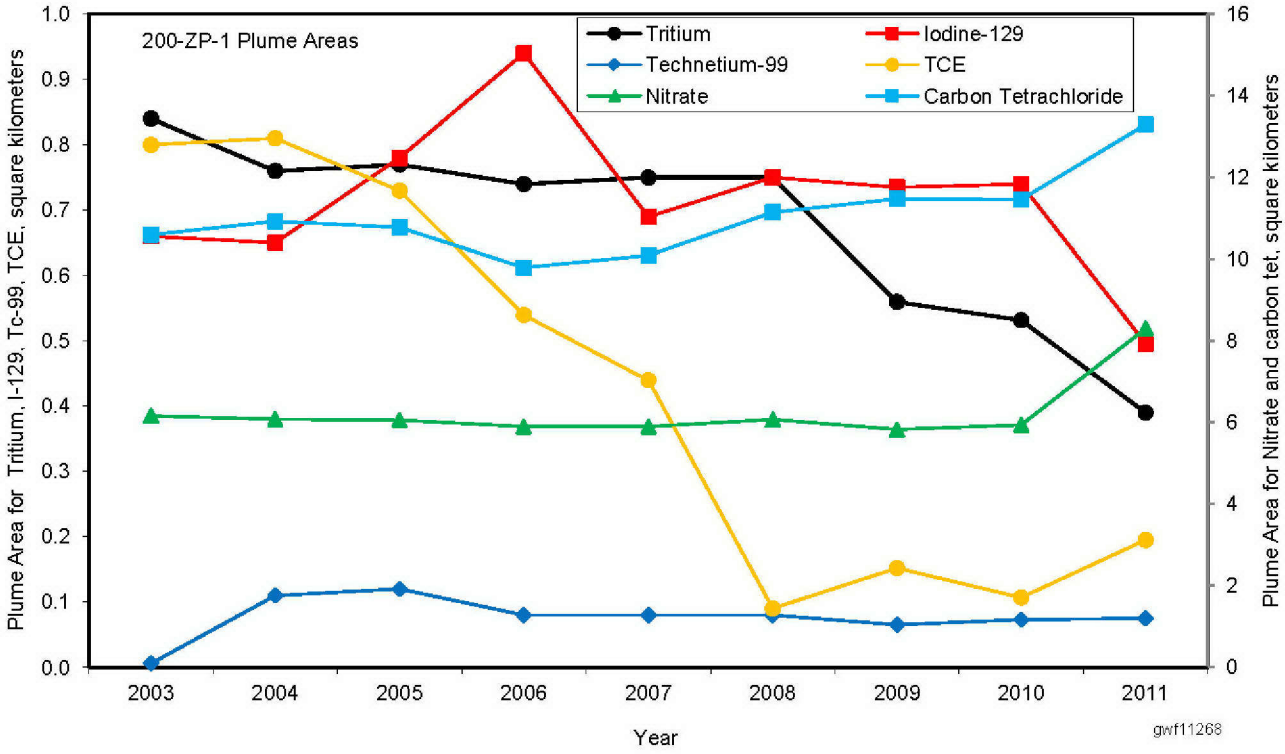


Figure 3.2-3. Ringold Formation Lower Mud Unit Extent Areas across the Central Plateau

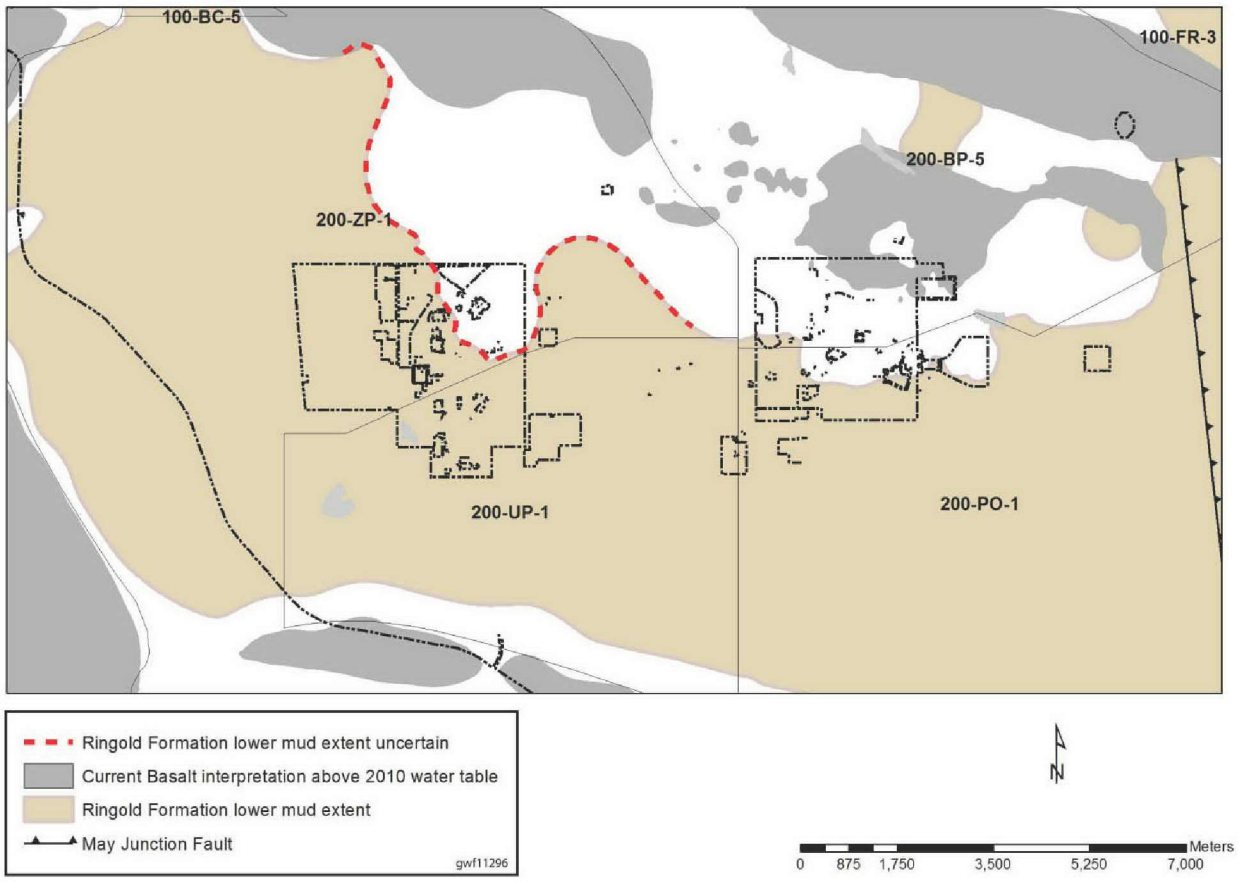


Figure 3.2-4. 200-ZP-1 Water Table, March 2011

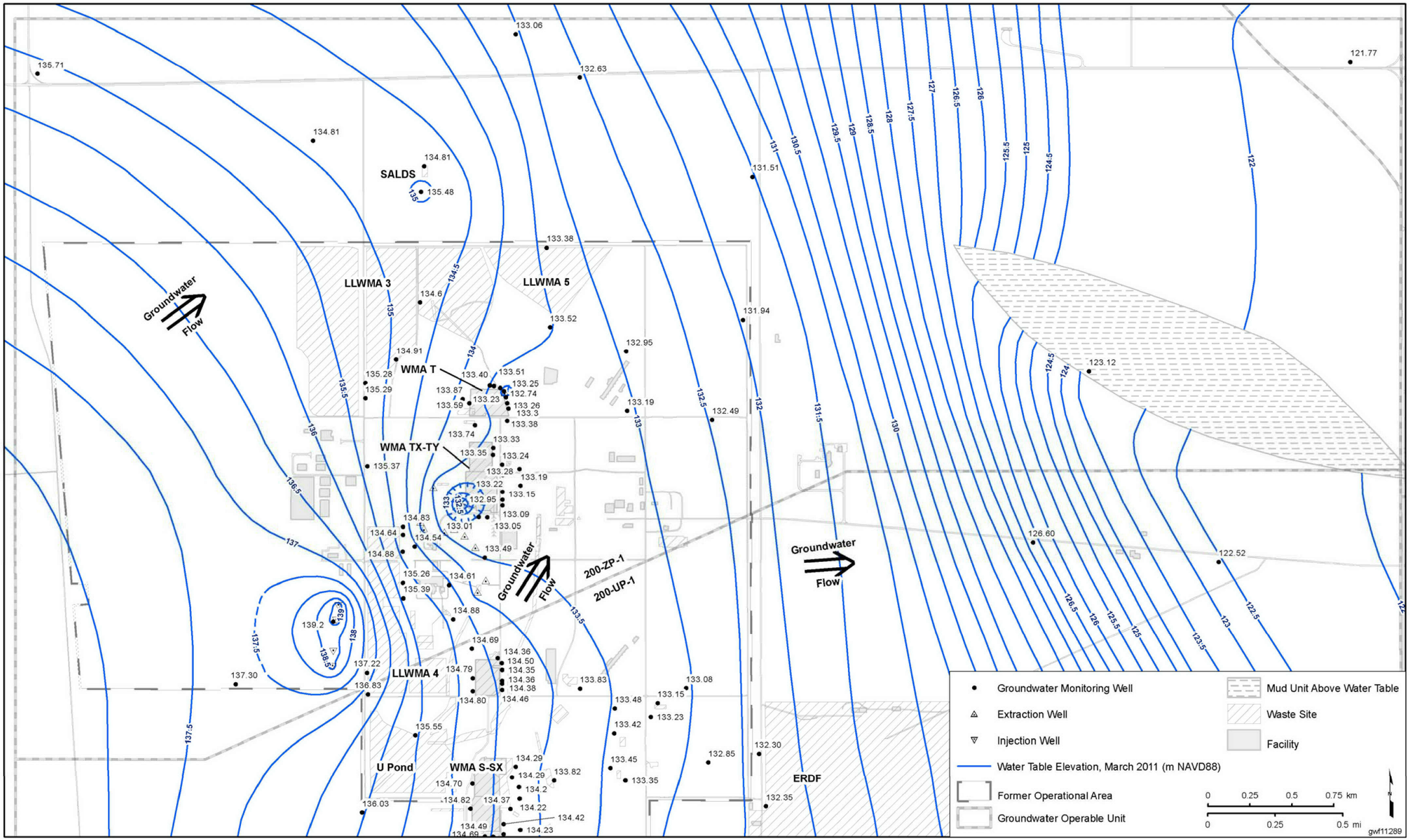


Figure 3.2-5. Average Carbon Tetrachloride Concentrations in the 200 West Area and Vicinity, Upper Part of Unconfined Aquifer, 2011

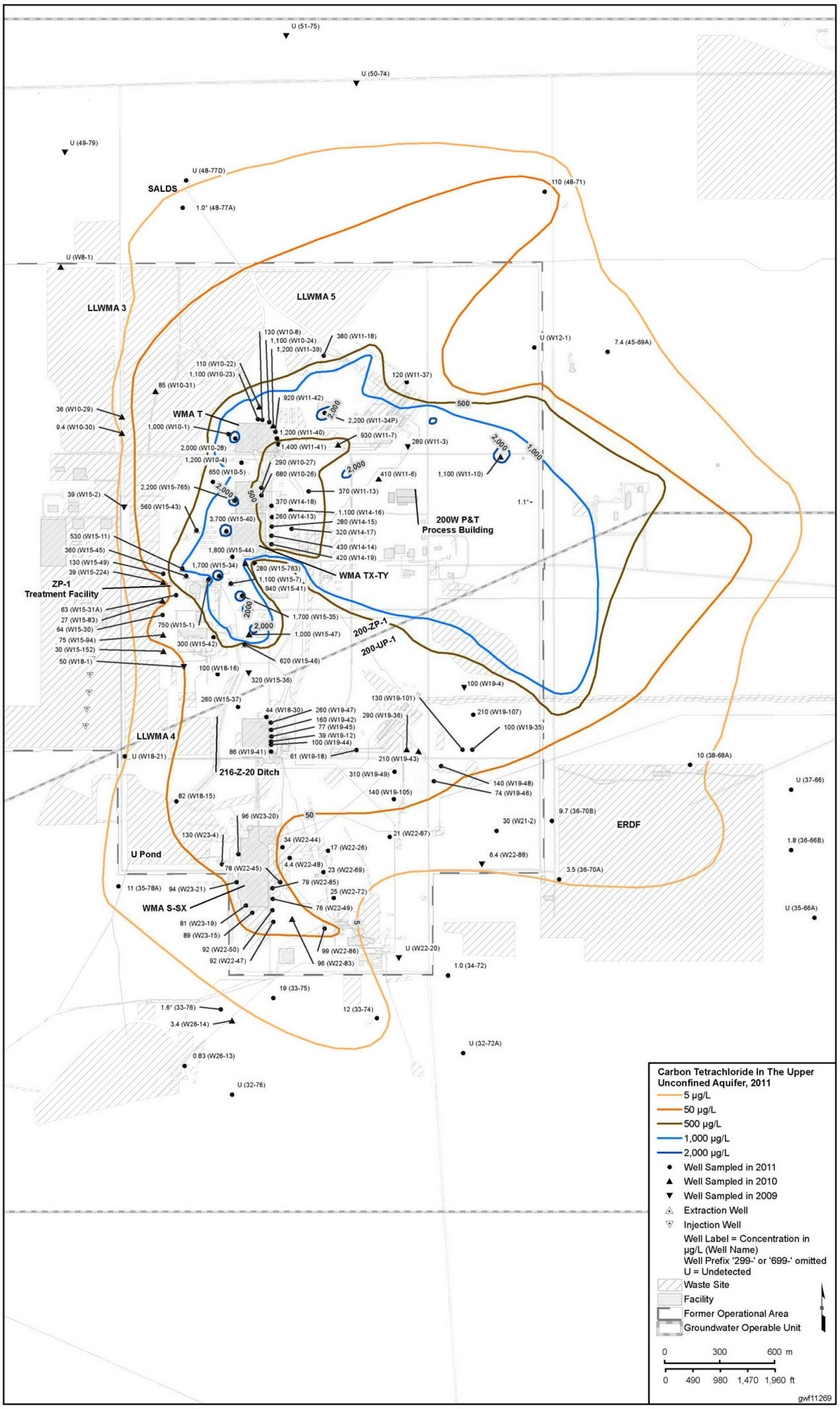
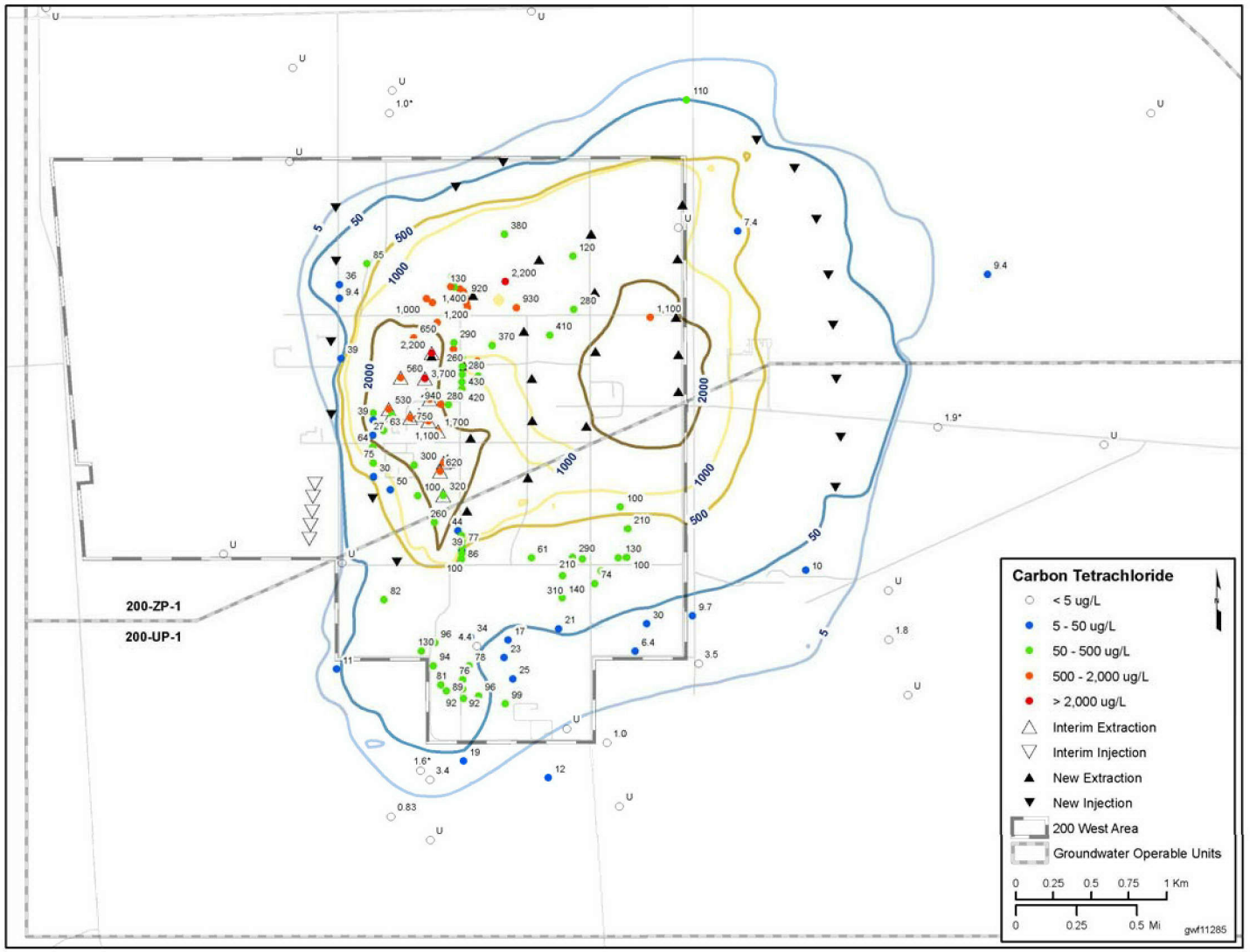


Figure 3.2-6. Average Carbon Tetrachloride Concentrations in 200 West Area throughout the Unconfined Aquifer and Locations of the Final Remedy Extraction and Injection Wells



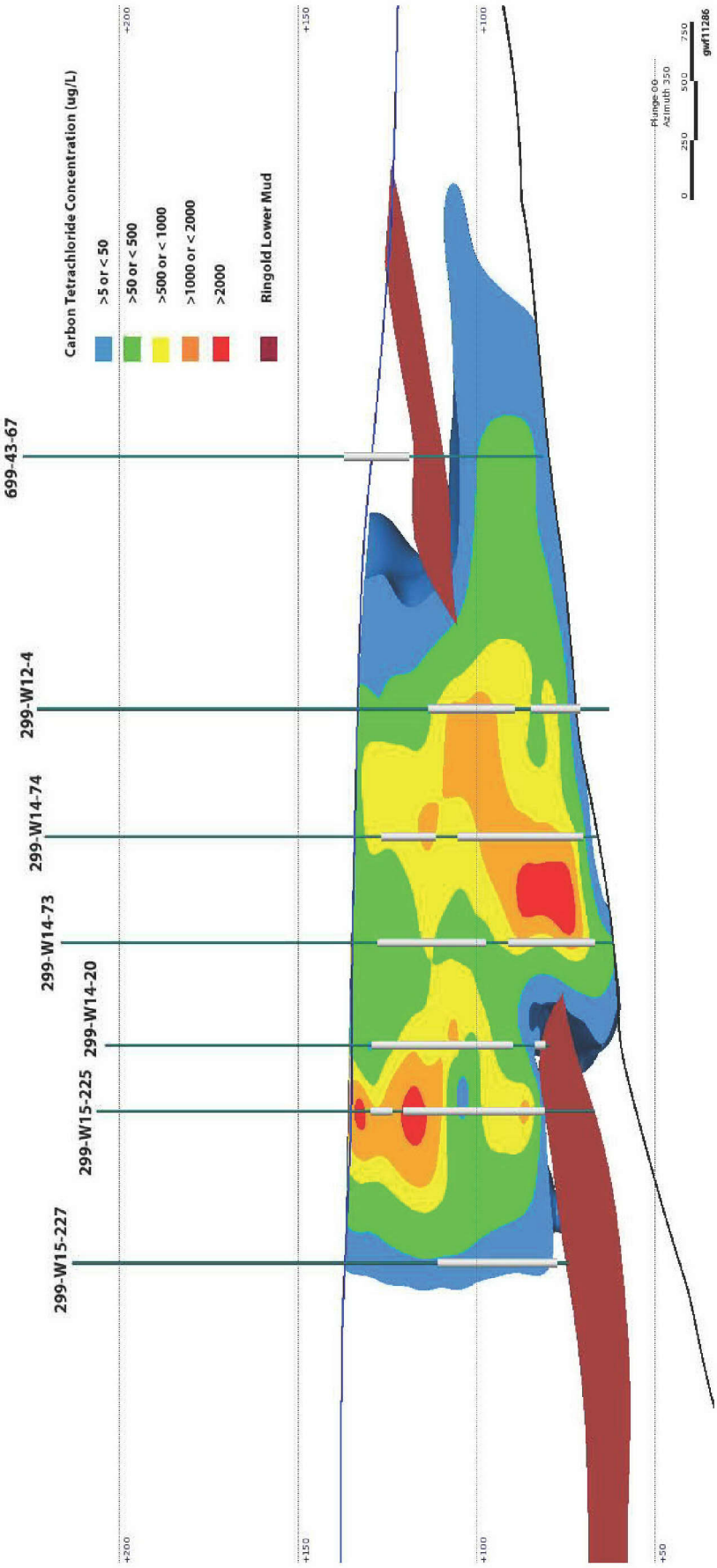


Figure 3.2-7. 200-ZP-1 Carbon Tetrachloride Plume Cross Section A-A'

Figure 3.2-8. 200-ZP-1 Groundwater Operable Unit Carbon Tetrachloride Concentration Plan View and Transect through Cross Section A-A'

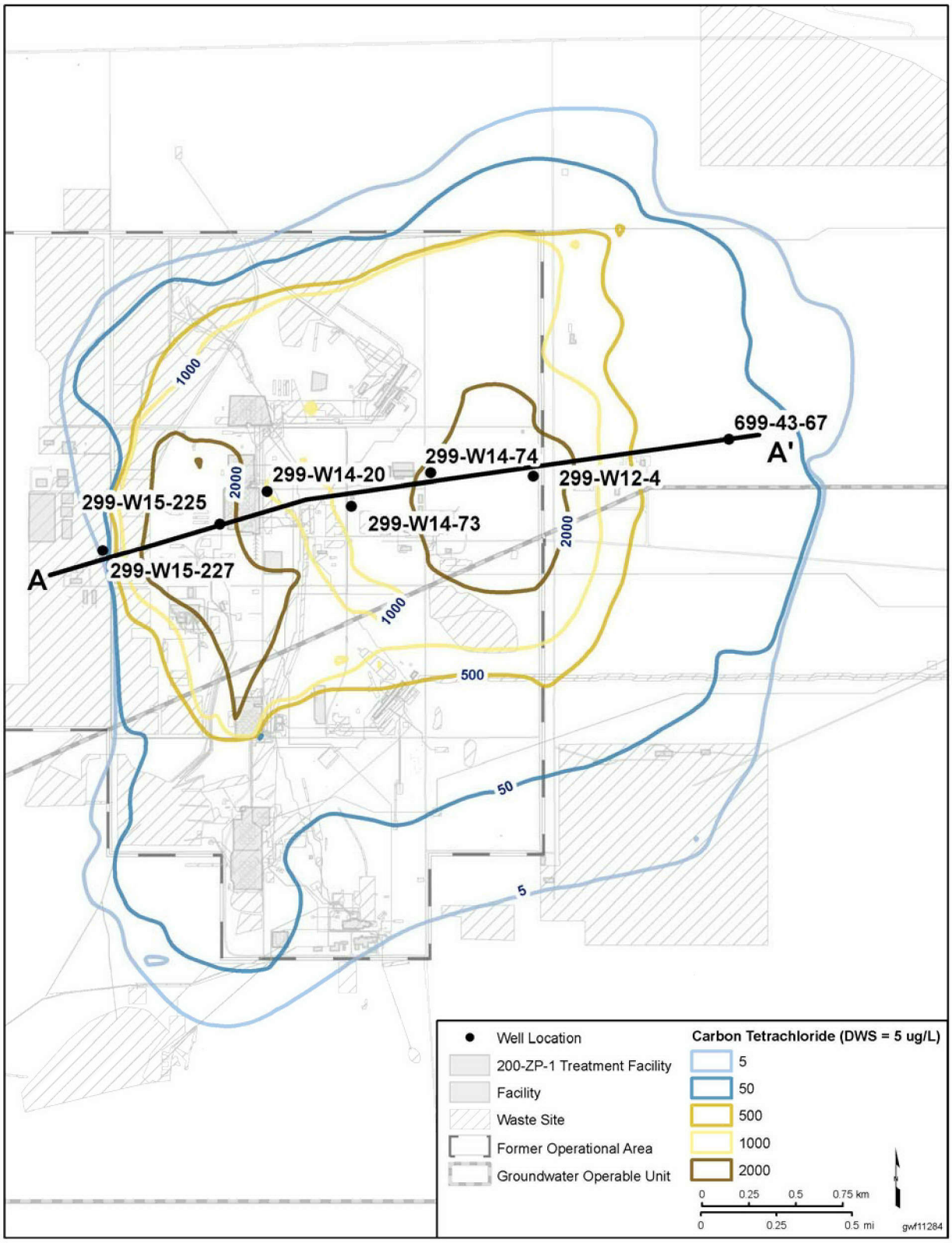


Figure 3.2-9. Carbon Tetrachloride Concentrations in Well 699-48-71, Northeast of 200 West Area

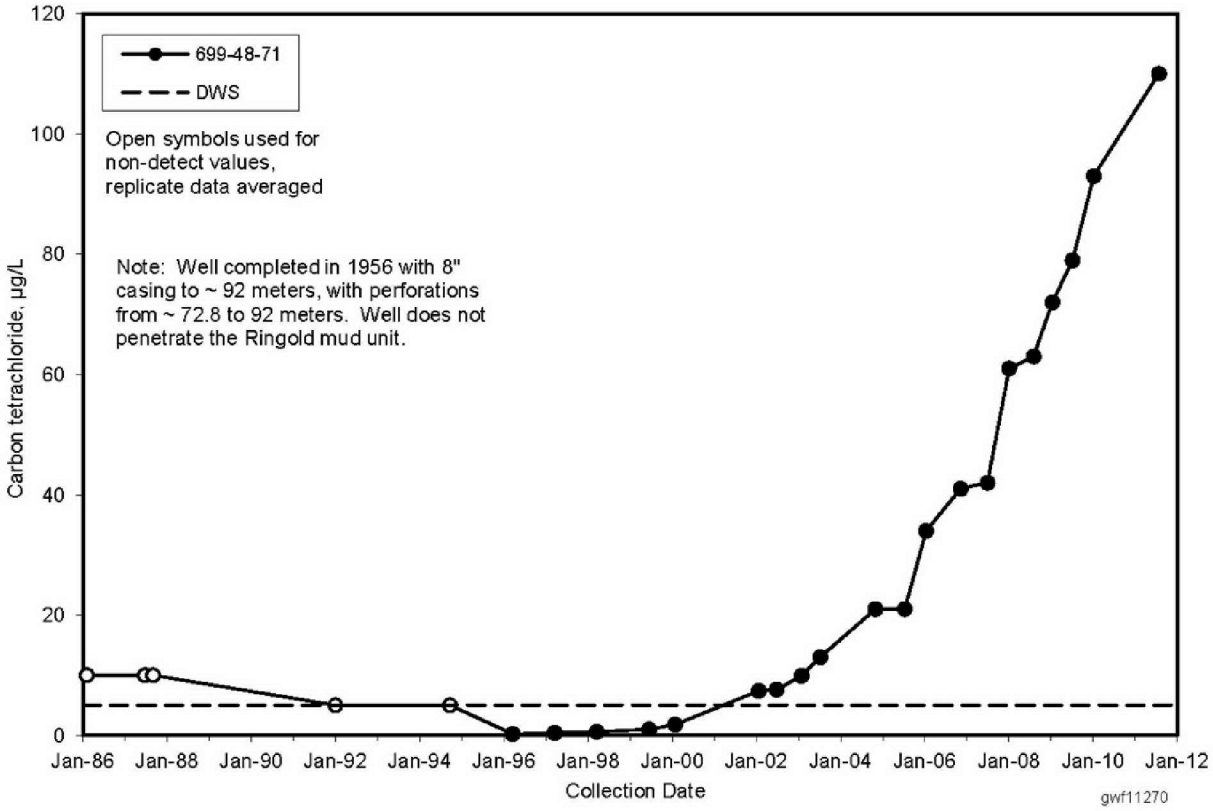


Figure 3.2-10. 200-ZP-1 Wells Exceeding 2,000 µg/L Carbon Tetrachloride prior to 2011 and during 2011

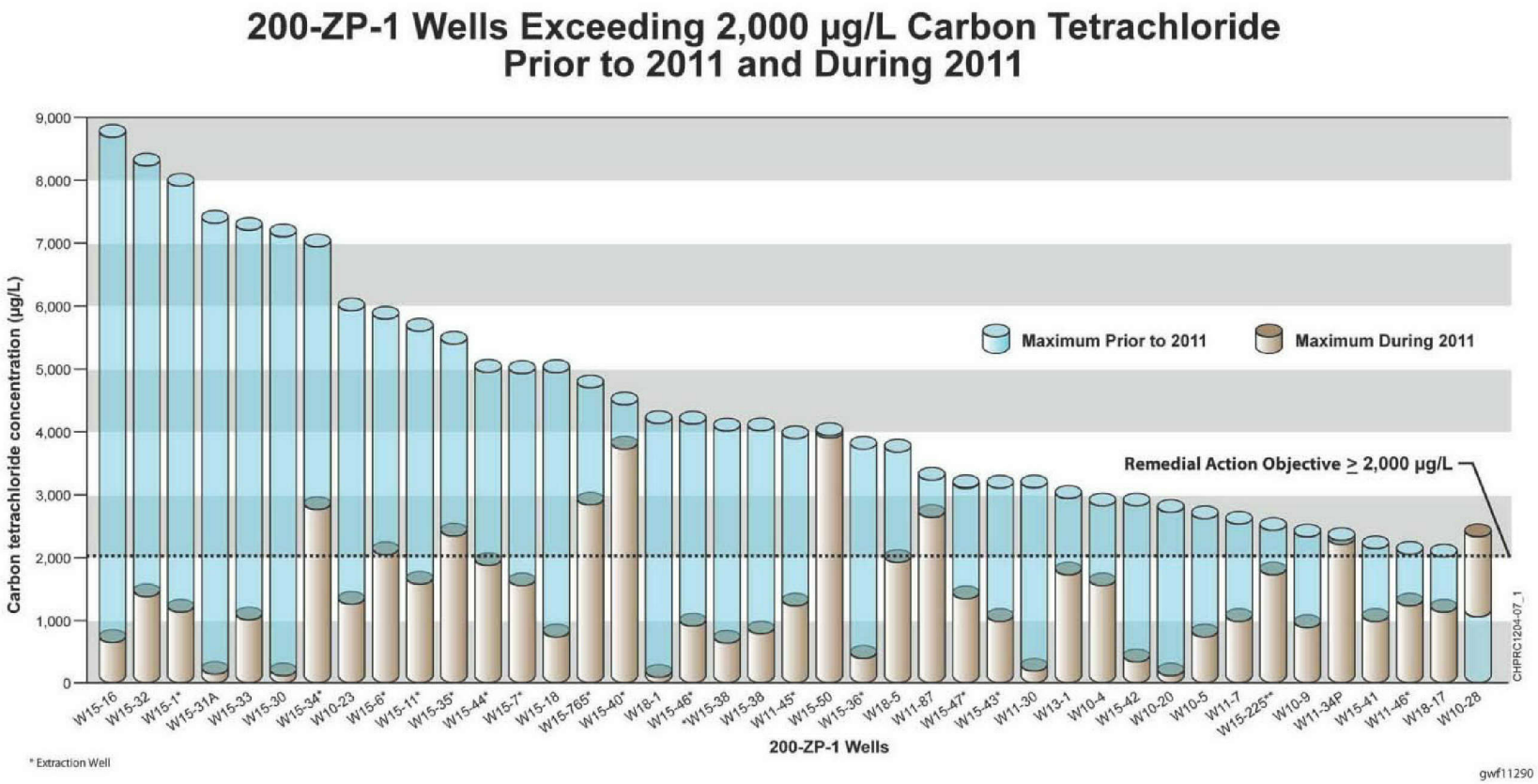


Figure 3.2-11. Average Trichloroethene Concentrations in 200-UP-1, Upper Part of Unconfirmed Aquifer, 2011

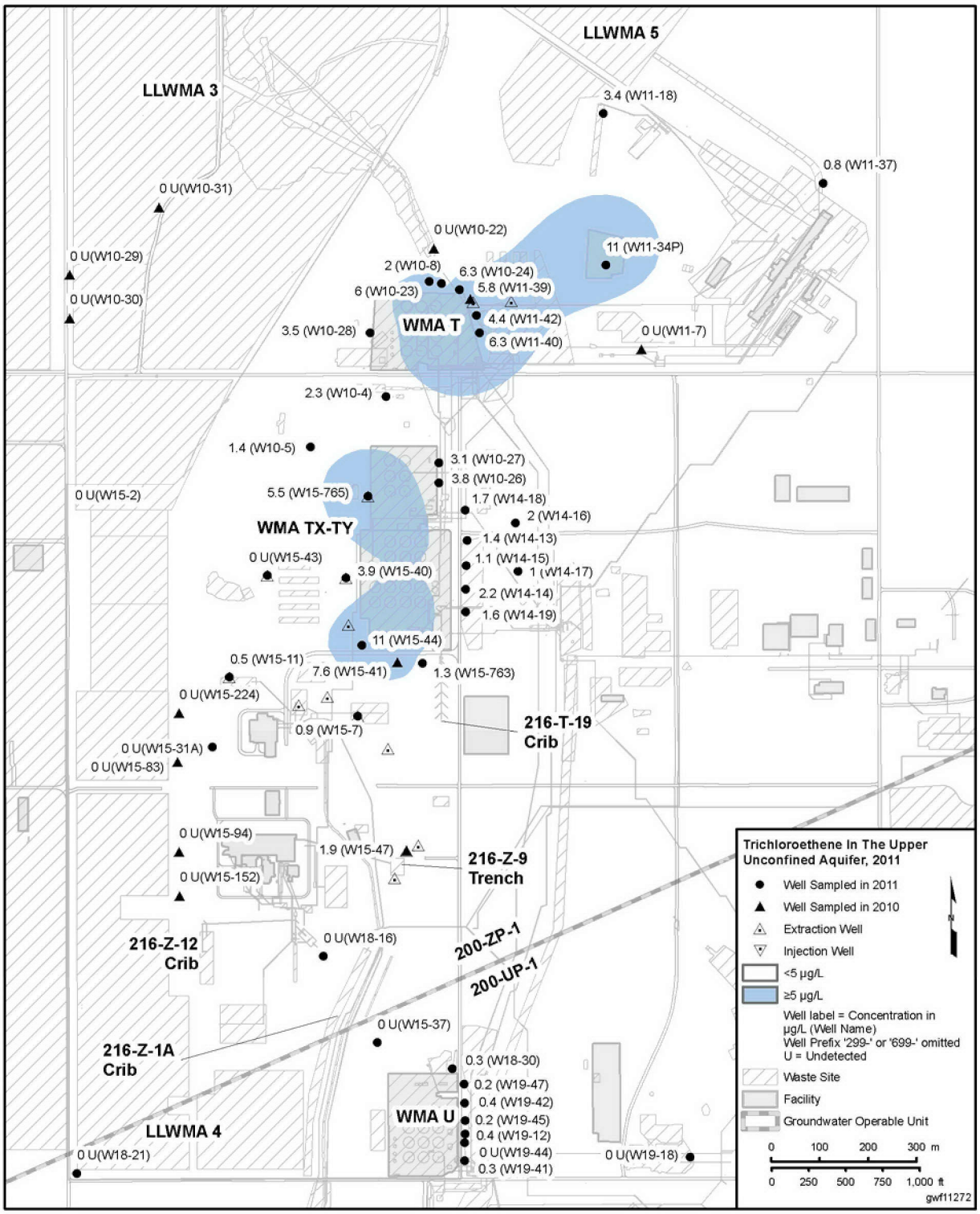


Figure 3.2-12. Maximum Trichloroethene Concentrations in WMA T and TX-TY Wells in 2011 and prior to 2011

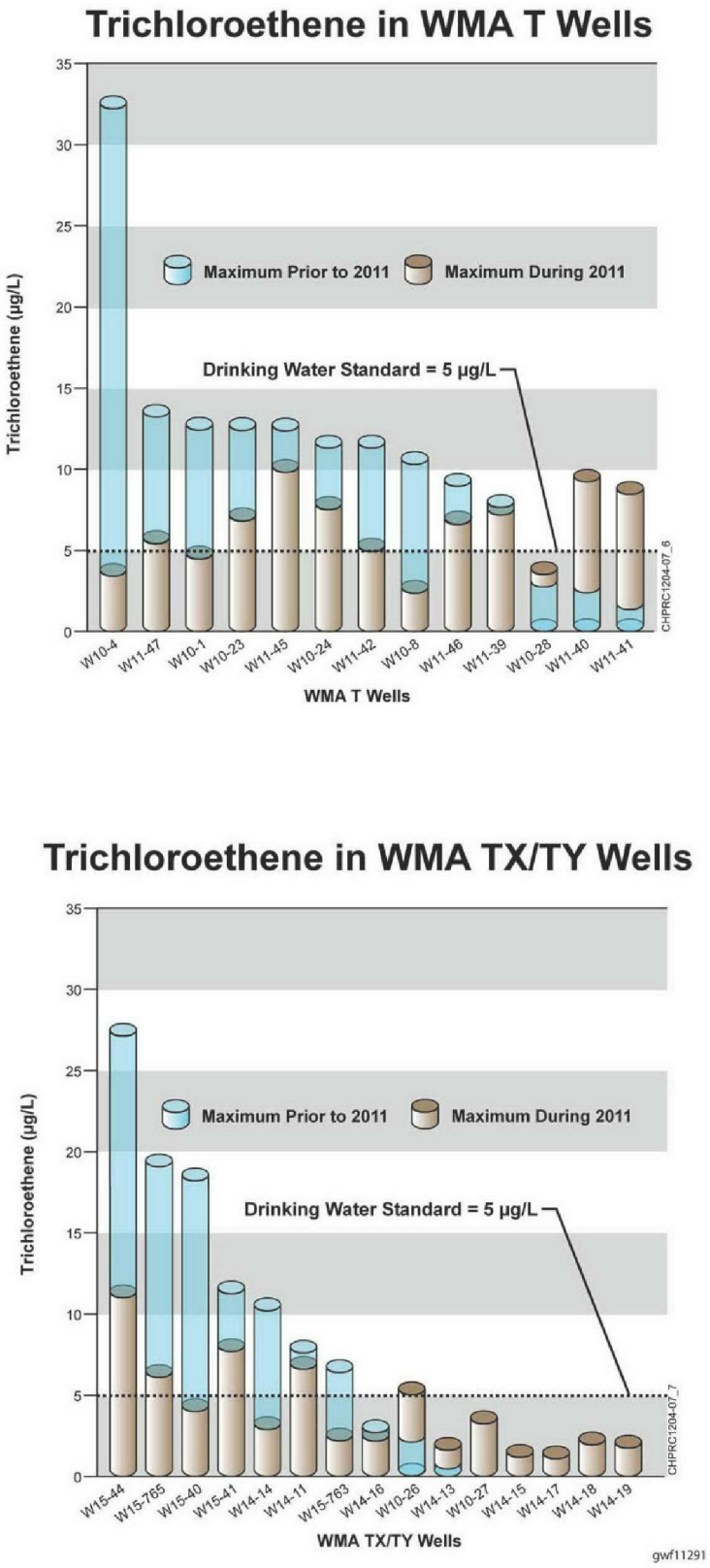


Figure 3.2-13. Average Nitrate Concentrations in 200-ZP-1, Upper Part of Unconfined Aquifer, 2011

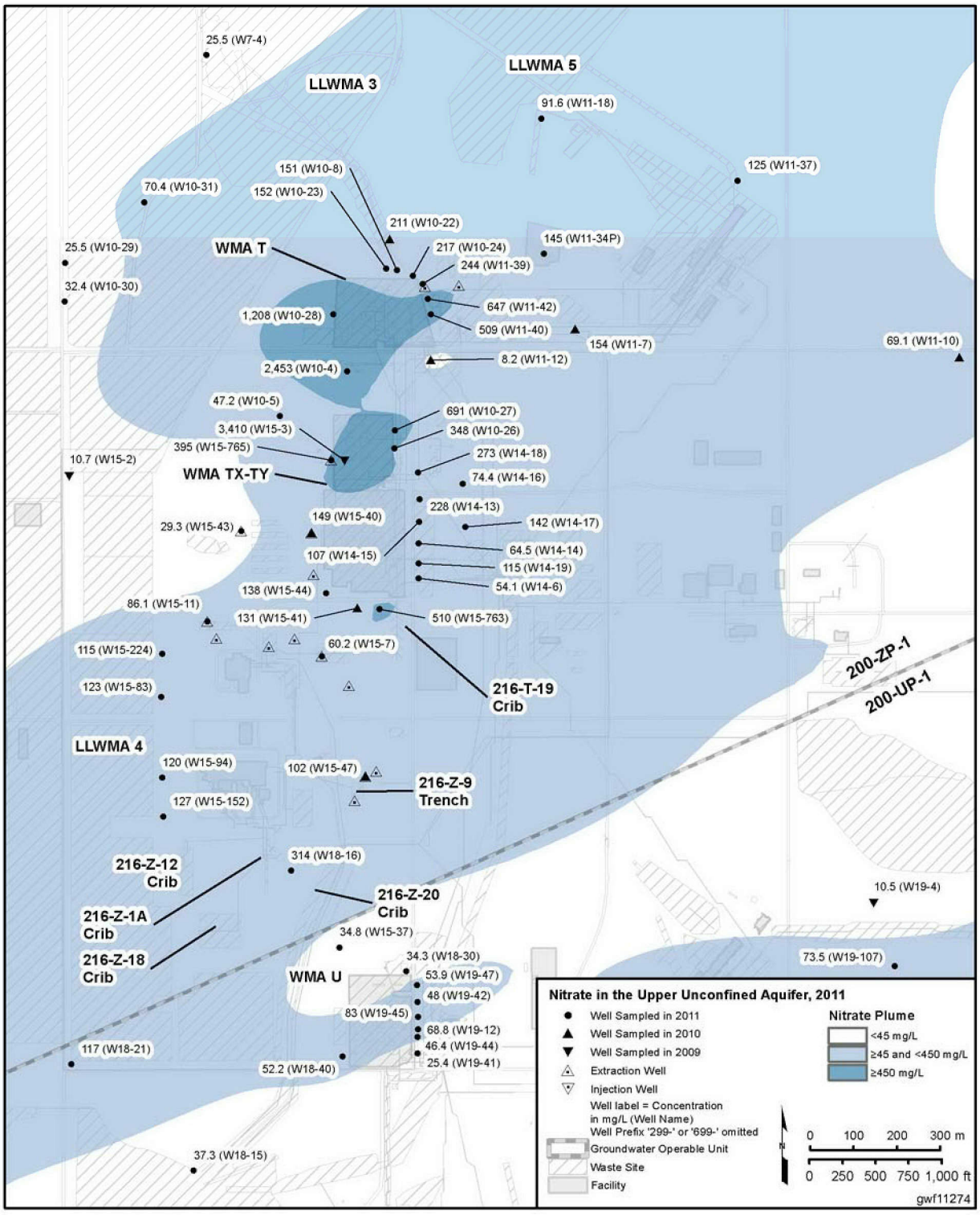


Figure 3.2-14. Maximum Nitrate Concentrations in WMA T and TX-TY Wells in 2011 and prior to 2011

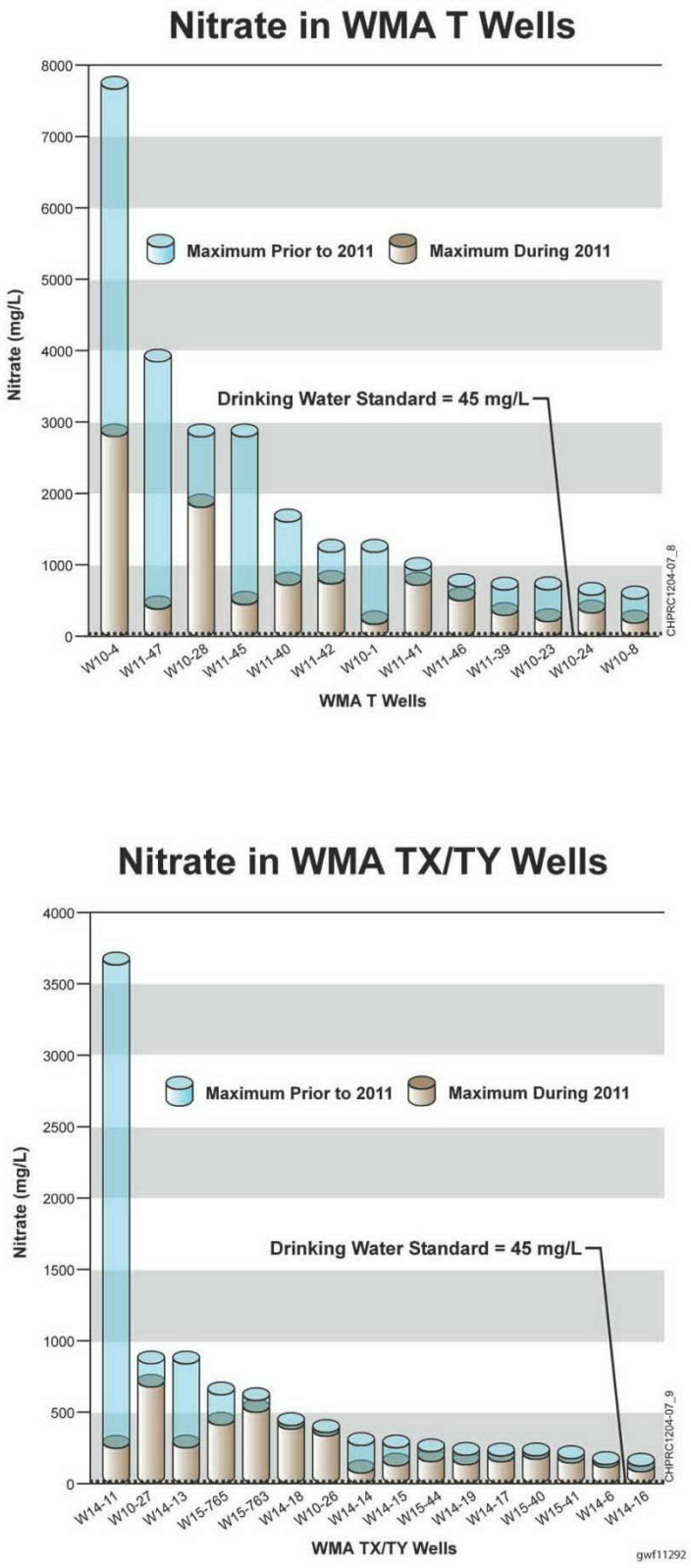


Figure 3.2-15. Average Chromium Concentrations in 200-ZP-1, Upper Part of Unconfined Aquifer, 2011

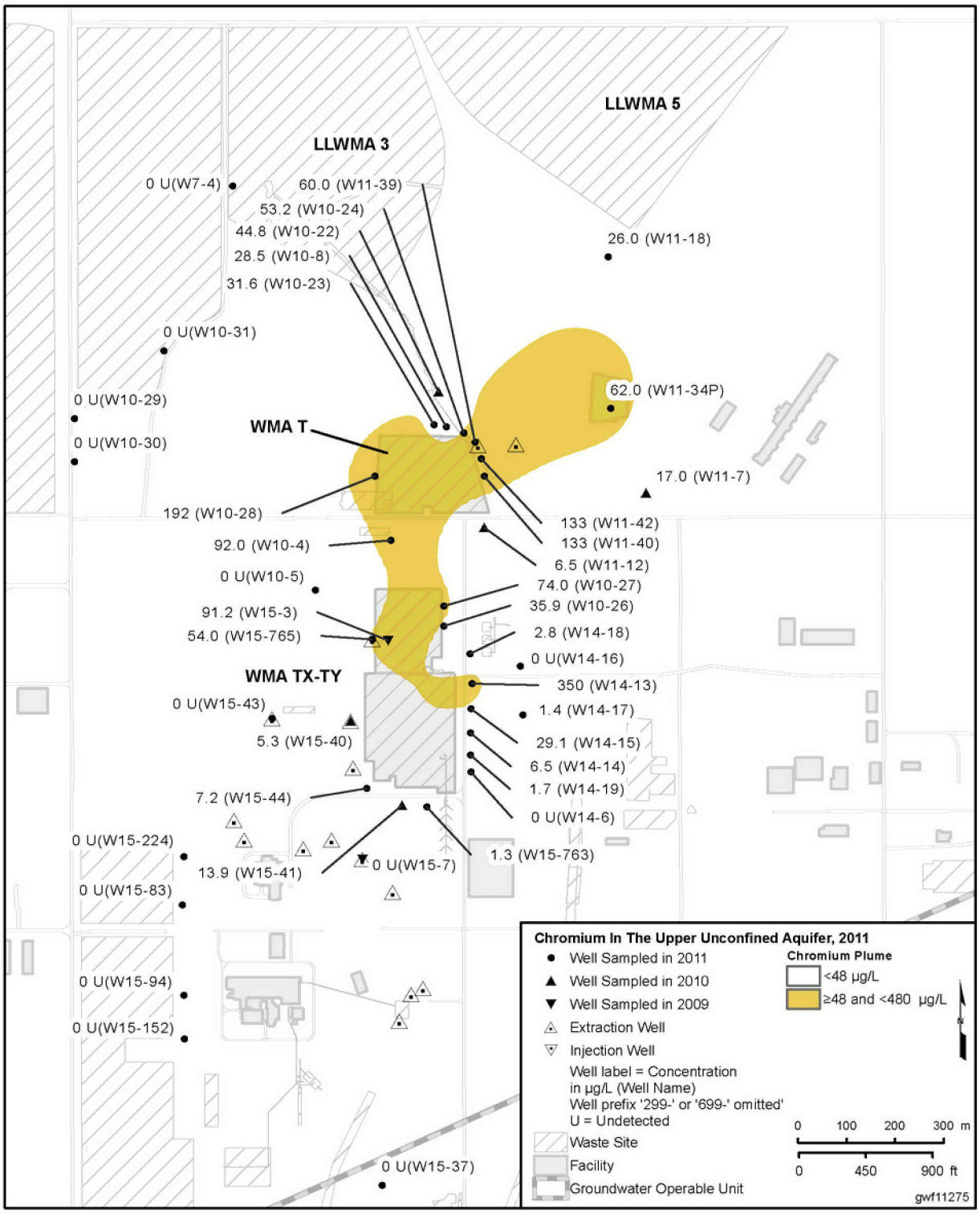


Figure 3.2-16. Maximum Chromium Concentrations in WMA T and TX-TY Wells in 2011 and prior to 2011

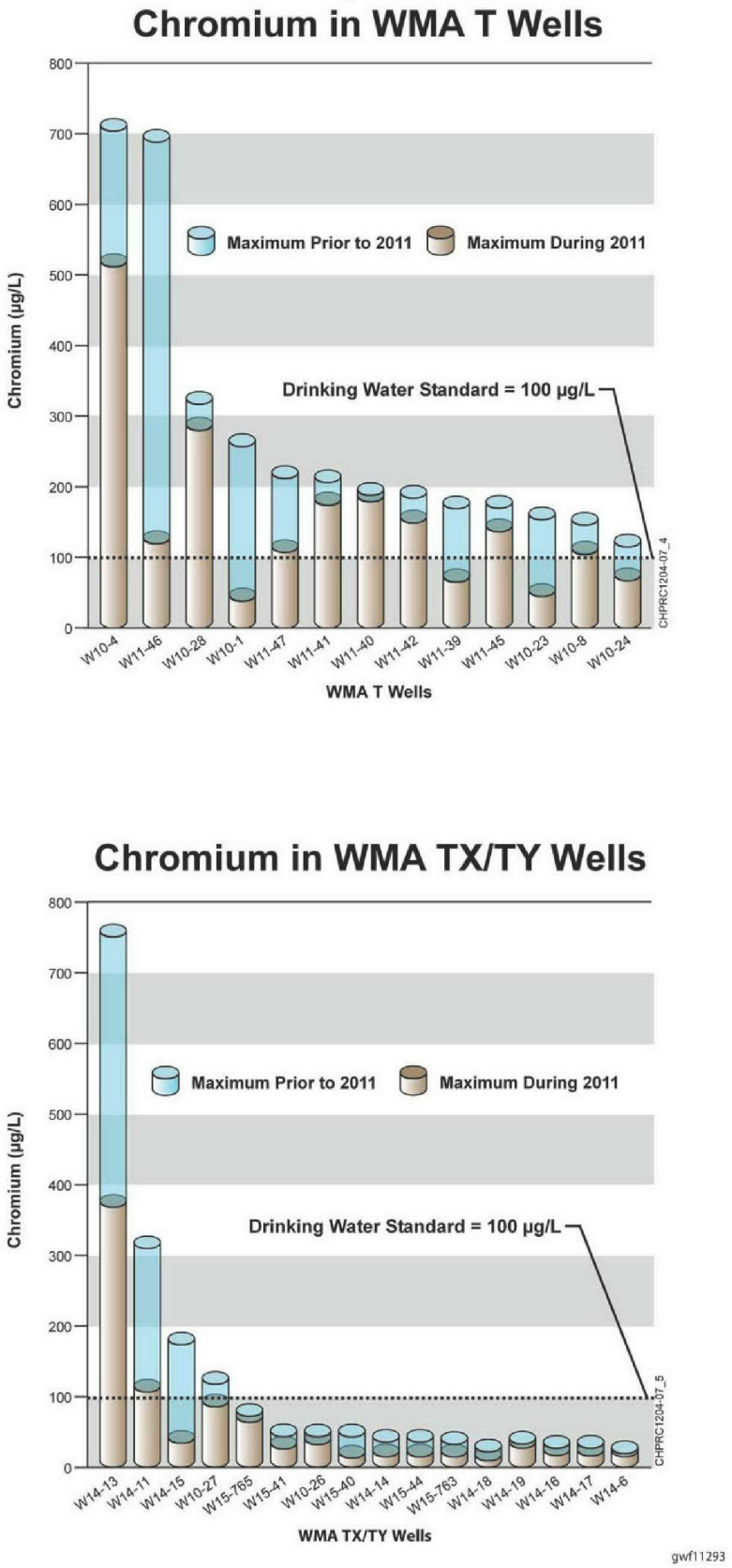


Figure 3.2-17. Average Tritium Concentrations in 200-ZP-1, Upper Part of Unconfined Aquifer, 2011

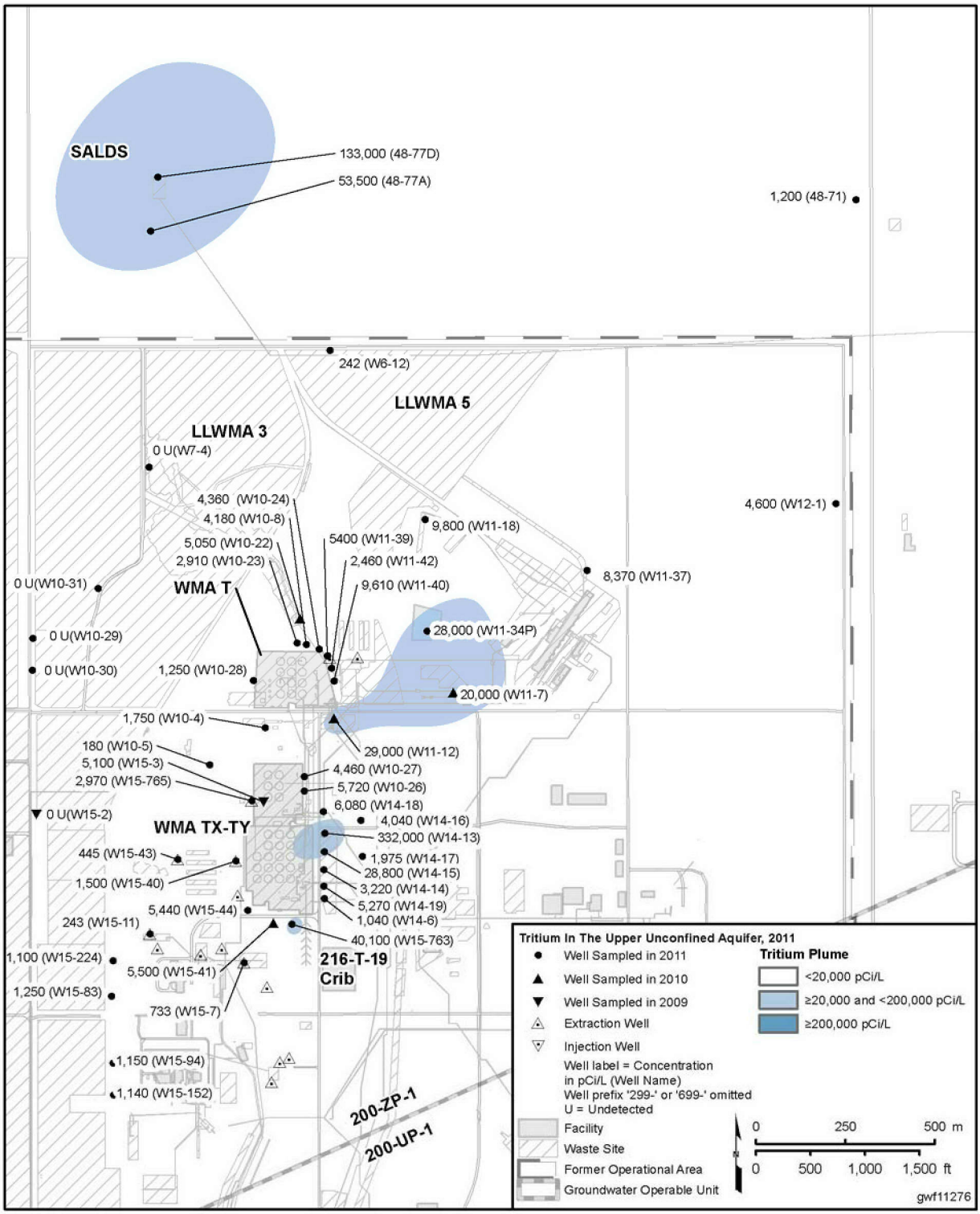


Figure 3.2-18. Average Iodine-129 Concentrations in 200-ZP-1, Upper Part of Unconfined Aquifer, 2011

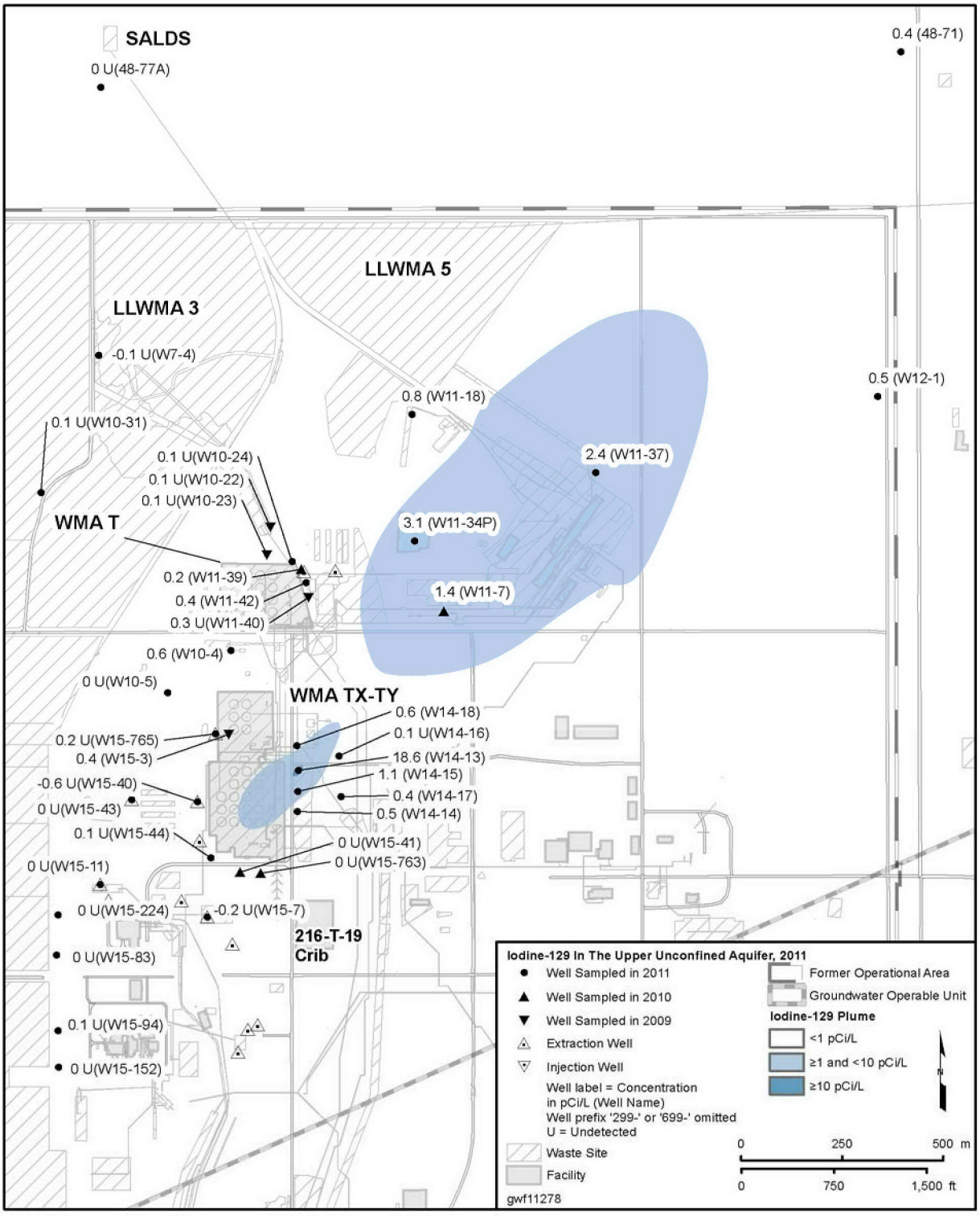


Figure 3.2-19. Maximum Iodine-129 Concentrations in 200-UP-1 Wells in 2011 and prior to 2011

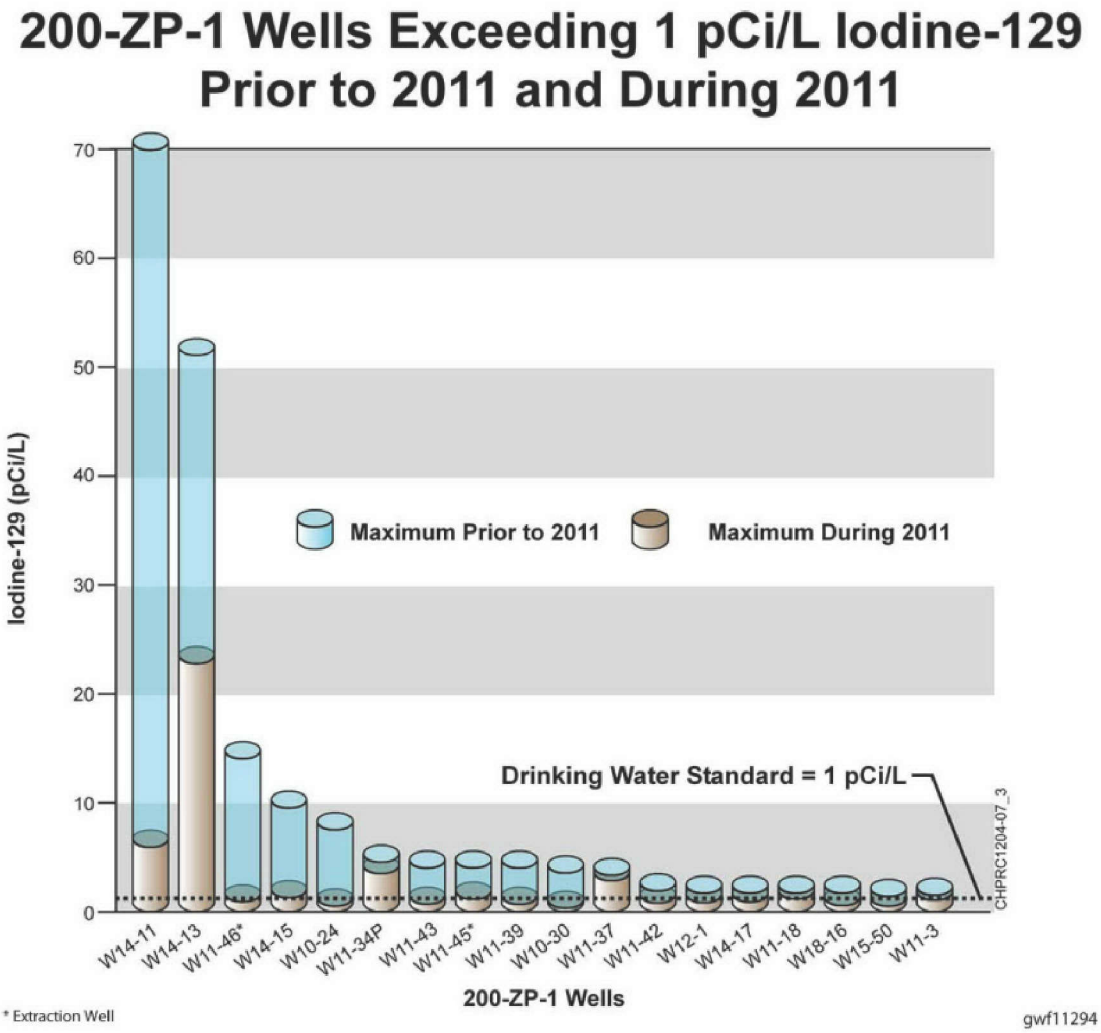


Figure 3.2-20. Average Technetium-99 Concentrations in 200-ZP-1, Upper Part of Unconfined Aquifer, 2011

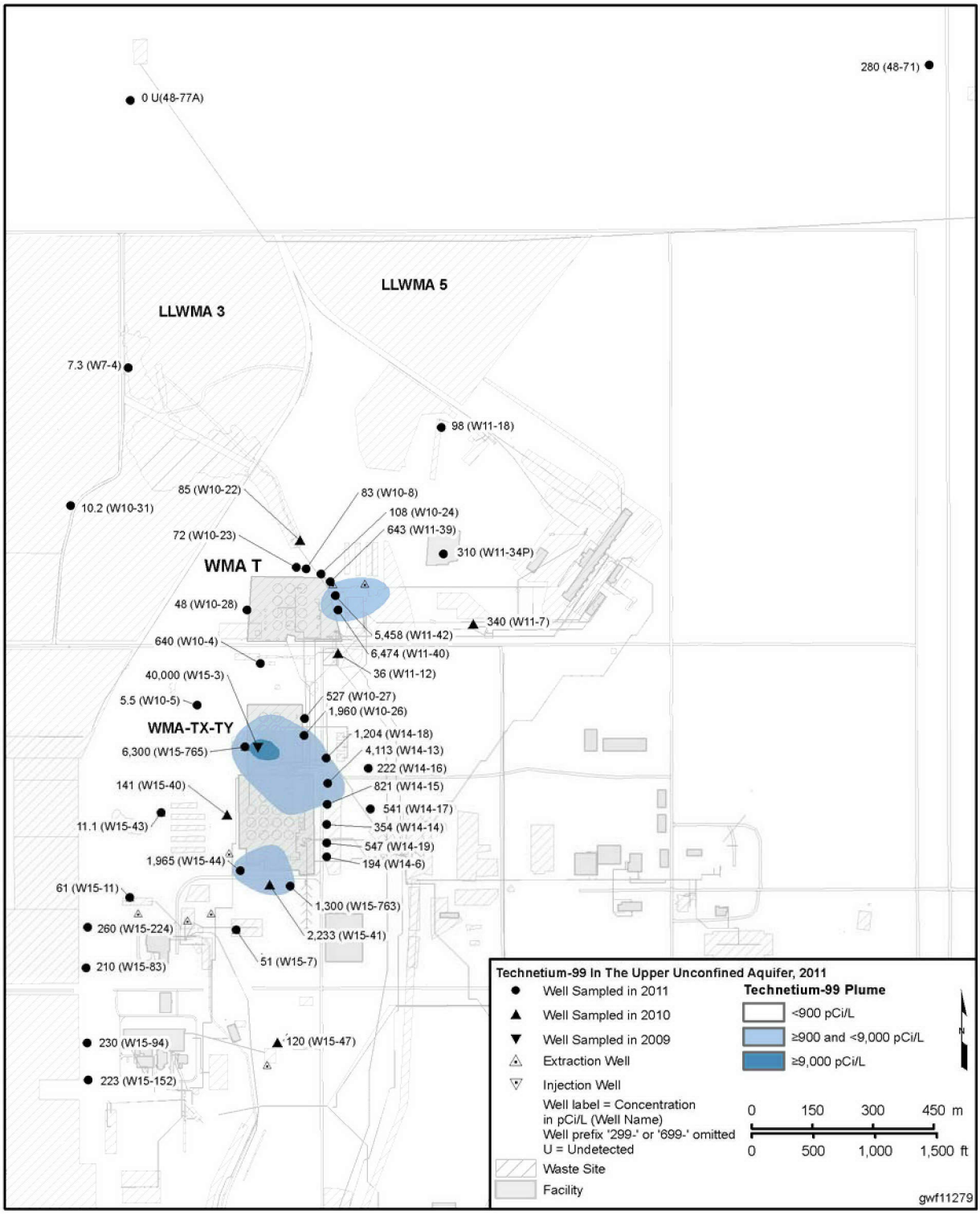


Figure 3.2-21. Maximum Technetium-99 Concentrations in 200-ZP-1 Wells in 2011 and prior to 2011

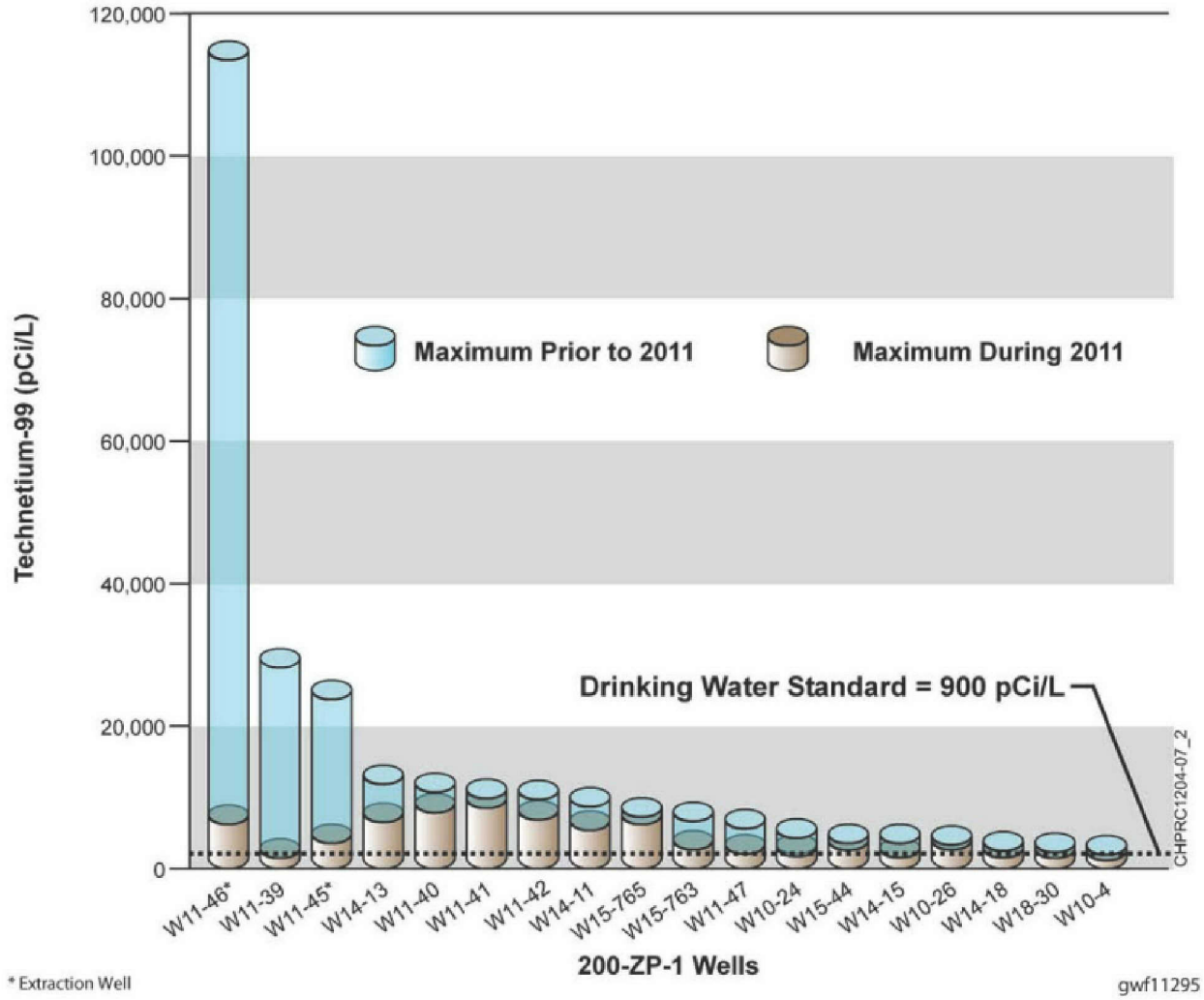


Figure 3.2-22. Technetium-99 Trends in WMA T Extraction Wells

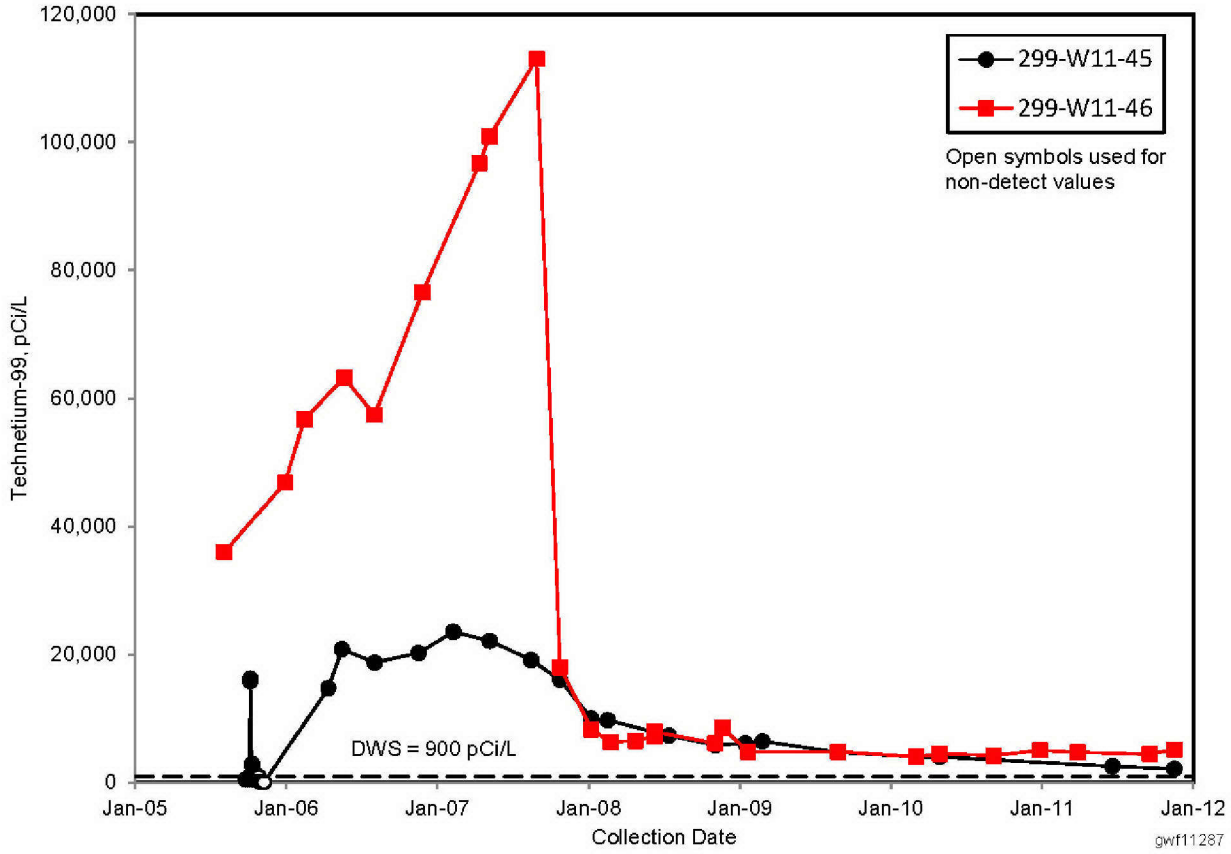


Figure 3.2-23. Mass of Carbon Tetrachloride Removed from 200-ZP-1 Vadose Zone

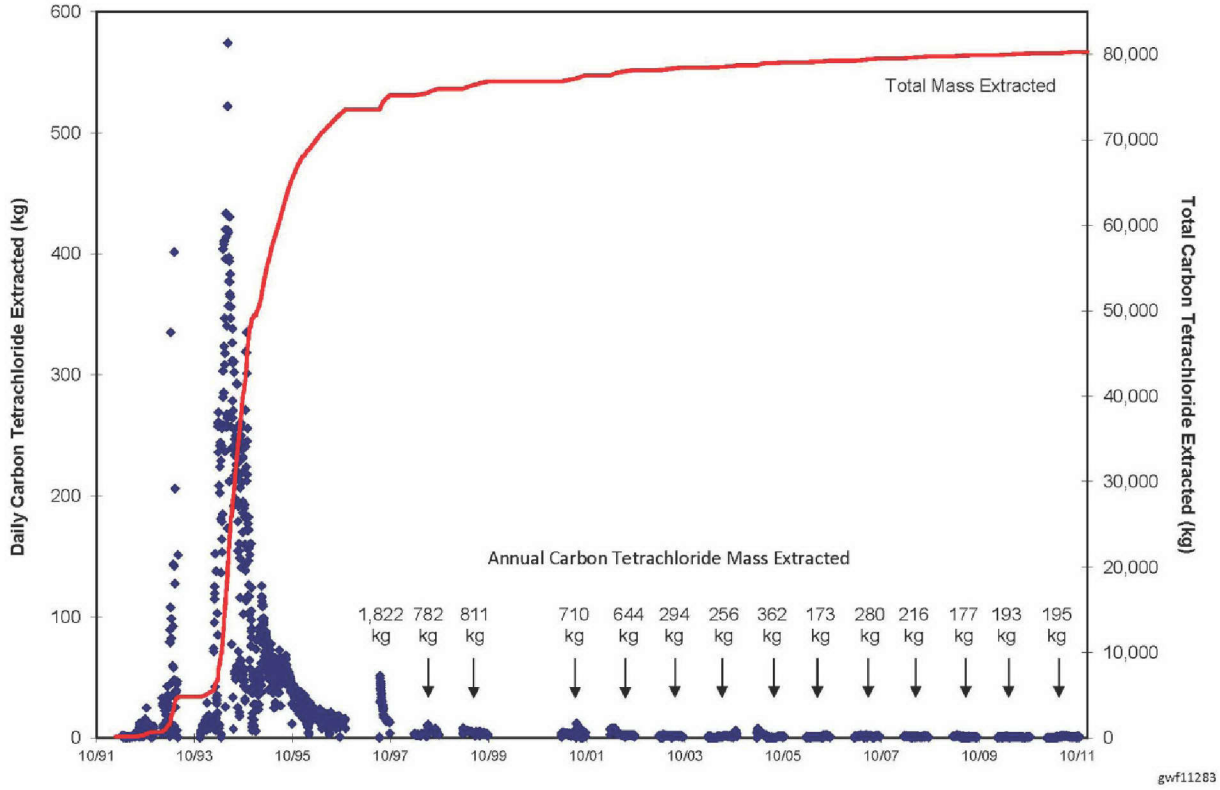
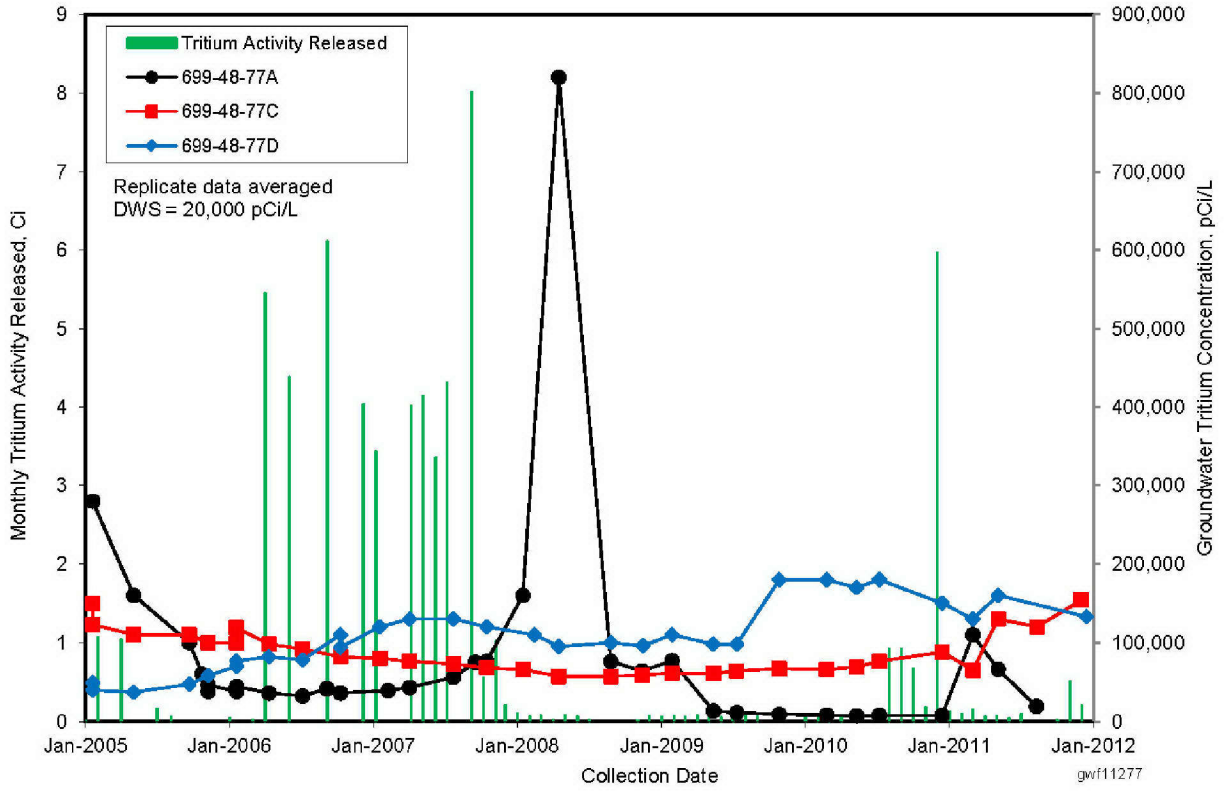


Figure 3.2-24. Tritium Trends in Wells Monitoring the State-Approved Land Disposal Site



3.3 200-UP-1

J.P. McDonald

The 200-UP-1 Operable Unit lies within the larger 200-UP-1 groundwater interest area, informally defined to facilitate sample scheduling, data review, and interpretation. The 200-UP-1 Operable Unit addresses groundwater contaminant plumes beneath the southern third of the 200 West Area and adjacent portions of the surrounding 600 Area. With the exception of the Environmental Restoration Disposal Facility (ERDF), most of the facilities and waste sites within the operable unit are associated with former operation of the Reduction-Oxidation (REDOX) Plant (plutonium separation) and U Plant (uranium recovery). Figure 3.3-1 shows facilities and wells in a large portion of 200-UP-1. Figure 3.1-1 in Section 3.1 shows the interest area and operable unit boundaries.

DOE conducts groundwater monitoring in 200-UP-1 under three regulatory drivers:

- CERCLA governs the 200-UP-1 Operable Unit and the ERDF. The CERCLA requirements for the operable unit are further subdivided into monitoring conducted to (1) characterize and track contaminants in groundwater; and (2) evaluate the performance of an interim-action pump-and-treat system that removed technetium-99, uranium, carbon tetrachloride, and nitrate from groundwater near U Plant.
- RCRA (and RCW 70.105, "Hazardous Waste Management") interim status assessment monitoring for dangerous constituents is performed at single-shell tank WMAs S-SX and U. Detection monitoring for interim-status indicator parameters under RCRA is performed at the 216-S-10 Pond and Ditch.
- Monitoring of radionuclides is performed to meet the requirements of the AEA.

Groundwater monitoring within the 200-UP-1 Operable Unit is performed under a sampling and analysis plan incorporated into the RI/FS work plan (Appendix A of DOE/RL-92-76, *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit*). The high-priority contaminants of concern for groundwater monitoring (as listed in Appendix A, Table A1-1 of DOE/RL-92-76) are iodine-129, strontium-90, technetium-99, tritium, uranium, carbon tetrachloride, chloroform, trichloroethene, total chromium, arsenic, cadmium, and nitrate. Technetium-99, uranium, tritium, iodine-129, nitrate, chromium, and carbon tetrachloride form extensive groundwater plumes within the region. These contaminants have sources within the operable unit, except for carbon tetrachloride, which has migrated into 200-UP-1 from 200-ZP-1. In addition to these constituents, 43 other contaminants of potential concern for CERCLA monitoring were identified in the work plan (Table A1-4 of DOE/RL-92-76) for 1 year of sampling in selected wells (Table A3-2 of DOE/RL-92-76). Based on the results of this sampling, the contaminants carbon-14, 1,4-dioxane, and selenium-79 were found in groundwater to a limited extent, and are routinely sampled in selected wells. The "at a glance" box briefly summarizes 200-UP-1 Operable Unit.

Technetium-99, uranium, tritium, iodine-129, nitrate, chromium, and carbon tetrachloride form extensive groundwater plumes within 200-UP-1.

Within 200-UP-1, groundwater occurs as an unconfined aquifer, as well as confined aquifers beneath the Ringold lower mud unit and between the basalt flows (see Section 3.1 for a generalized stratigraphic column for the Hanford Site [Figure 3.1-2] and a hydrostratigraphic cross-section through the Hanford Site [Figure 3.1-3]). The unconfined aquifer is the aquifer directly impacted by waste disposal operations. The unconfined aquifer occurs within Ringold unit E; its base is the fine-grained Ringold lower mud unit.

200-UP-1 at a Glance

Depths from land surface to the water table range from 64 to 106 meters, with the largest depths occurring in the northeastern portion of the operable unit. The thickness of the unconfined aquifer within the operable unit is variable. The aquifer is 70 meters thick in the western portion of the operable unit. The top of the lower mud unit rises to the northeast, and a portion of this unit has been extrapolated to occur above the water table north of the operable unit's boundary (shown on Figure 3.1-5 in Section 3.1). Thus, the aquifer thickness approaches zero in the northeastern corner of the operable unit.

Groundwater flow in the unconfined aquifer is toward the east within the southern 200 West Area and toward the east-northeast in the eastern portion of the interest area (Figure 3.3-2). Water levels have been declining in this area since the 1980s as a result of the curtailment of effluent discharges to the soil column. Between March 2010 and March 2011, the water table elevation declined by an average of 0.19 meter in the southern portion of the 200 West Area. The water table is expected to decline another 3 to 5 meters before reaching equilibrium (see Section 3.1.2).

REDOX Plant Operations:
1952 to 1967 (plutonium separation)
U Plant Operations: 1952 to 1957 (uranium recovery)

2011 Groundwater Monitoring

Groundwater Contaminant	Drinking Water Standard	Maximum Concentration	Plume Area[a] (km^2)
Chromium	48[b]/100[c] µg/L	1,300 µg/L	0.78[d]
Nitrate	45 mg/L	409 mg/L	8.0
Iodine-129	1 pCi/L	11.2 pCi/L	3.8
Technetium-99	900 pCi/L	51,000 pCi/L	0.19
Tritium	20,000 pCi/L	110,000 pCi/L	6.9
Uranium	30 µg/L	374 µg/L	0.42

Remediation

U Plant pump-and-treat (interim action):

- 1994–2011, removed 220.5 kg uranium
- 1994–2011, removed 2.17 Ci technetium-99

WMA S-SX Groundwater Extraction System (interim action):

- Scheduled to begin operating in 2012

Interim-action record of decision scheduled for 2012.

a. Estimated area above listed drinking water standard.

b. *Model Toxics Control Act—Cleanup* (WAC 173-340) Method B groundwater cleanup standard for hexavalent chromium.

c. Federal drinking water standard for total chromium.

d. Plume area above the 100 µg/L federal drinking water standard.

Sections 3.3.1 through 3.3.8 provide an overview of the contaminant plumes and contaminants of concern for 200-UP-1. The discussion provides a summary of the combined results of CERCLA, RCRA, and AEA monitoring performed in this area. Information on the vertical distribution of contaminants in the aquifer is included, if available.

3.3.1 Technetium-99

Technetium-99 concentrations occur above the drinking water standard of 900 pCi/L in three regions of the operable unit: (1) downgradient (east) from the 216-U-1/2 Cribs near U Plant, (2) at WMA S-SX Tank Farms, and (3) at WMA U Tank Farm (Figure 3.3-3).

216-U-1/2 Cribs. A technetium-99 plume originates from the 216-U-1/2 Cribs, which were active in the 1950s and 1960s. When wastewater was disposed at the nearby 216-U-16 Crib in the mid-1980s, it migrated north along a caliche layer and mobilized the technetium-99 and uranium in the vadose zone soil column beneath the 216-U-1/2 Cribs, which added contaminant mass to the groundwater plume (Section 2.1.1 of WHC-EP-0133, *U1/U2 Uranium Plume Characterization, Remedial Action Review and Recommendation for Future Action*; Section 2.2.11 of PNL-8073, *Hanford Site Ground-Water Monitoring for 1990*). This plume is separated into two parts: one downgradient from the 216-U-1/2 Cribs near U Plant, and one east of the 200 West Area boundary. This separation was caused by capture of the high-concentration portion of this plume by the U Plant pump-and-treat system, while the lower concentration portion that was downgradient of the capture zone continued to migrate to the east. The portion east of the 200 West Area is no longer mapped because of a lack of well coverage in this

area. The maximum concentration east of the 200 West Area during 2011 was 710 pCi/L in well 699-38-70C, which is screened deep within the unconfined aquifer near the top of the Ringold lower mud unit.

Within the U Plant pump-and-treat area (near wells 299-W19-36 and 299-W19-43), the plume occurs in the upper portion of the aquifer (see the cross section in Figure 11-7 of DOE/RL-2011-01). Depth-discrete sampling during drilling of well 699-38-70C in 2004 indicated the plume occurs throughout the aquifer thickness east of the 200 West Area. This is attributed to dispersion.

The U Plant pump-and-treat system operated in the central portion of the 216-U-1/2 Cribs plume from 1994 until the system was shut down during March 2011. The pump-and-treat system reduced technetium-99 concentrations in the aquifer. The extraction wells were not sampled during 2011 because the system was shut down prior to sampling, but the concentrations during 2010 were 6,300 pCi/L and 3,600 pCi/L in wells 299-W19-36 and 299-W19-43, respectively, which are the highest concentrations in this plume. These results are well below the historical plume maximum concentration of 41,000 pCi/L (299-W19-24 in 1989) and below the 9,000 pCi/L remedial action objective, but above the 900 pCi/L drinking water standard. The highest concentration in a monitoring well within the area targeted for remediation was 330 pCi/L (299-W19-35) during 2011. Section 3.3.9.2 as well as DOE/RL-2012-03, provide additional discussion of the pump-and-treat system.

WMA S-SX Tank Farms. At WMA S-SX, technetium-99 plumes occur downgradient of the SX Tank Farm (the south plume) and downgradient of the S Tank Farm (the north plume). The highest technetium-99 concentrations within the operable unit occur in the southern plume at well 299-W23-19 (located inside the SX Tank Farm). During 2011, concentrations in this well decreased from 51,000 pCi/L in April to 40,000 pCi/L in December (Figure 3.3-4). This indicates that the mass flux of technetium-99 entering the aquifer has been decreasing in recent years. The southern plume from WMA S-SX represents a growing contamination issue because the plume is increasing in areal extent and concentrations are increasing in many of the downgradient wells. An interim-action groundwater extraction system to remediate the plumes from the S-SX Tank Farms is currently under construction and is planned to begin operating during July 2012 (discussed in Section 3.3.9.2).

A groundwater extraction system to remediate technetium-99 at the S and SX Tank Farms is under construction. The system is planned to begin operating in July 2012.

The technetium-99 plume from the SX Tank Farm occurs largely within the upper 20 meters of the 70-meter-thick aquifer (see the cross section in Figure 11-9 of DOE/RL-2011-01). This earlier conclusion was further supported by samples collected in 2011 during installation of two new extraction wells (299-W22-91 and 299-W22-92) within the SX Tank Farm plume. The sample results for these wells are listed in Table 3.3-1, and Figures 3.3-5 and 3.3-6 depict the profiles of the depth-discrete samples for technetium-99, as well as nitrate and tritium.

Within the technetium-99 plume from the SX Tank Farm, low concentrations occur in wells 299-W22-80 and 299-W23-15. An in-well tracer test at 299-W22-80 (to evaluate flow within the well under non-pumping conditions, Section 8.3 of PNNL-14113, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2001*), and time-series sampling during extensive purging indicated that relatively clean water may be migrating into the bottom of the well, moving up the wellbore, and diluting concentrations in the upper portion of the plume (Section 2.9.3.2 of PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*). A similar process is assumed to be occurring at 299-W23-15. Although shown on the plume map (Figure 3.3-3), sample results from these wells were not used in generating the plume contours.

The northern plume at WMA S-SX originates from an overfill event at tank S-104 in the S Tank Farm. Concentrations began increasing substantially in this plume during late 2006, but increasing

trends in the monitoring wells have now reversed. In 299-W22-44, the nearest downgradient well to the S Tank Farm, the technetium-99 concentration began increasing in 2006, peaked in 2009 at 20,000 pCi/L, and declined to 12,000 pCi/L in December 2011 (Figure 3.3-7). A similar trend occurred at far downgradient well 299-W22-26, where concentrations began increasing in 2006, peaked at 6,000 pCi/L in December 2010, and declined to 4,700 pCi/L in December 2011 (Figure 3.3-8). Although technetium-99 in these wells is mapped as a single plume (at the 900 pCi/L concentration level on Figure 3.3-3), the peak concentrations in these wells is attributed to separate episodes of contaminant migration from the tank farm. Both wells exhibited a similar technetium-99 trend with peak concentrations occurring within a year of each other (Figures 3.3-7 and 3.3-8), but the travel time between the wells is estimated to be 7 years, based on the calculated groundwater flow velocity of 36 meters per year (Section 3.3.10.1). Thus, the recent near simultaneous concentration declines in these wells could not have been caused by the migration of a single pulse of contamination between the wells.

Evidence for an earlier release from the tank farm is found in the concentration trend for well 299-W22-48 (south of well 299-W22-44), where the technetium-99 concentration peaked during 2002 (Figure 3.3-9). Well 299-W22-26 is 210 meters downgradient from 299-W22-48, and this equates to an estimated 6-year travel time in reasonable agreement with the 8-year lag between concentration peaks in these wells (i.e., 2002 in well 299-W22-48 to 2010 in well 299-W22-26). Wells 299-W22-44 and 299-W22-26 are nearly dry, which means the sample results from these wells progressively represent the upper portion of the aquifer as the water table continues to decline. This may also cause an apparent decline in constituent concentrations if the highest plume concentrations are not right at the water table, which is sometimes the case (see the nitrate and technetium-99 sample results for 299-W22-91 and 299-W22-92 in Table 3.3-1 and Figures 3.3-5 and 3.3-6). However, because of the large magnitude of the concentration changes during 2011, an earlier release from the tank farm is the best explanation for the technetium-99 peak concentration at 299-W22-26.

An extraction well for the WMA S-SX groundwater extraction system, 299-W22-90, was installed during 2011 adjacent to 299-W22-44. Table 3.3-1 lists depth-discrete groundwater sample results during drilling of this well, and the data are plotted on Figure 3.3-10. The results indicate that the plume is limited to the upper part of the aquifer. The maximum technetium-99 concentration was 5,520 pCi/L at 4.1 meters below the water table, which was the uppermost sample collected.

WMA U Tank Farm. Technetium-99 concentrations in the downgradient wells at the U Tank Farm are elevated compared to concentrations in the upgradient well, indicating the U Tank Farm is a source of technetium-99 contamination (PNNL-13282, *Groundwater Quality Assessment for Waste Management Area U: First Determination*). However, concentrations are lower than in the WMA S-SX plumes. In previous years, technetium-99 concentrations in many of the downgradient wells have been stable or slowly increasing, but concentrations in well 299-W19-45 began to increase more rapidly during 2011 (Figure 3.3-11). Between July 2010 and July 2011, technetium-99 increased in this well from 2,000 to 3,000 pCi/L. Future sample results will indicate if this is a temporary increase or the beginning of a more substantial technetium-99 contamination issue at this tank farm. Technetium-99 concentrations were also greater than the drinking water standard in three other wells during 2011, as shown on Figure 3.3-11.

Technetium-99 concentrations in 299-W19-45 at the U Tank Farm began to increase more rapidly during 2011; the maximum concentration was 3,000 pCi/L.

The total areal extent of technetium-99 above the DWS within 200-UP-1 since 2003 is shown on Figure 3.3-12. In general, the areal extent is increasing. The decline between 2010 and 2011 was due to no longer mapping the portion of the 216-U-1/2 Cribs plume east the 200 West Area.

3.3.2 Uranium

Uranium occurs within two regions of 200-UP-1, downgradient of the 216-U-1/2 Cribs and near the 216-U-10 Pond (U Pond).

216-U-1/2 Cribs Plume. The 216-U-1/2 Cribs were the source of a uranium plume that is interpreted to extend 1.5 kilometers to the east at levels above the 30 µg/L drinking water standard (Figure 3.3-13). Uranium sorbs to soil particles and is moderately mobile in the 200-UP-1 groundwater. The 216-U-1/2 Cribs were active in the 1950s and 1960s; however, much of the uranium entered the aquifer in the mid-1980s when effluent disposed of at the nearby 216-U-16 Crib migrated north along a caliche layer in the vadose zone and mobilized uranium in the soil column beneath the 216-U-1/2 Cribs (Section 2.1.1 of WHC-EP-0133).

The U Plant pump-and-treat system operated in the central portion of the 216-U-1/2 Cribs plume from 1994 until the system was shut down during March 2011. Throughout 2011, uranium sample results were below the 300 µg/L remedial action objective at all wells within the area targeted for remediation. The maximum concentration measured within this area during 2011 was 219 µg/L in 299-W19-48. Concentrations at most wells continue to exceed the drinking water standard of 30 µg/L. Section 3.3.9.2 and DOE/RL-2012-03 provide additional information regarding the U Plant pump-and-treat system.

All uranium sample results in the U Plant pump-and-treat area were below the 300 µg/L remedial action objective during the year, although the concentration at well 299-W19-18, upgradient from the remedial action target area, continued to exceed 300 µg/L.

Near the 216-U-1/2 Cribs, uranium continues to be elevated in 299-W19-18. The March 2011 sample result in this well was 374 µg/L, a decline from over 400 µg/L in 2009 and 2010. The persistence of elevated concentrations in this well may be due to an ongoing source of uranium to the aquifer. Possible sources include continued leaching from the vadose zone beneath the 216-U-1/2 Cribs and/or desorption of uranium from aquifer sediment. However, the uranium concentration may also result from the slow migration of this constituent compared to technetium-99. The plume is limited to the upper 20 meters of the aquifer (see the cross-section in Figure 11-13 of DOE/RL-2011-01). There have been no exceedances of the drinking water standard in any of the 23 samples collected deeper than 20 meters below the water table within this plume.

The total areal extent of uranium above the DWS in 200-UP-1 is due mostly to the 216-U-1/2 Cribs plume. Although the plume is shown as declining in areal extent in Figure 3.3-12, this is due mostly to reinterpretations of the plume, especially the portion to the east of the 200 West Area boundary where well coverage is less dense compared to the U Plant pump-and-treat area. The areal extent of this plume is thought to be stable, especially within the pump-and-treat area.

U Pond. Uranium concentrations are elevated in wells near U Pond. Uranium concentrations exceed the drinking water standard in one well in this area, 299-W23-4 (near the 216-S-21 Crib), which had a concentration of 37.8 µg/L during 2011. Concentrations are stable in this well. Two other wells in this area have historically had concentrations above the drinking water standard: 299-W18-21 (2001 to 2004) and 299-W18-15 (2006 and prior to 2002). Uranium is interpreted to be leaching from the vadose zone beneath U Pond. The pond received an estimated 2,100 kilograms of uranium (Section 4.2.2 of DOE/RL-2009-122; Appendix C of RPP-26744, *Hanford Soil Inventory Model, Rev. 1*).

3.3.3 Tritium

Disposal facilities associated with REDOX Plant, which operated from 1952 until 1967, were the primary sources of tritium in the 200-UP-1 Operable Unit. The most substantial sources were the 216-S-1/2, 216-S-7, 216-S-21, and 216-S-25 Cribs (Section 4.2.2 in DOE/RL-2009-122; Appendix C in

RPP-26744). A substantial amount of tritium was also released at the 216-U-8, 216-U-12, and 216-U-16 Cribs associated with U Plant (Appendix C in RPP-26744). A large tritium plume from the REDOX Plant cribs extends 5 kilometers toward the east and northeast at concentrations above the 20,000 pCi/L drinking water standard (Figure 3.3-14). The large extent of this plume is due to the number of sources, the elapsed time since releases began, and the high mobility of tritium in the aquifer.
Two high-concentration areas occur within the region of tritium contamination: one extending to the east and northeast from the 200 West Area, and a smaller one extending 550 meters to the east-southeast from the 216-S-25 Crib (Figure 3.3-14).

The tritium plume originating from the southern 200 West Area is attenuating naturally through dispersion and radiological decay.

Eastern High Concentration Area. Over the past 3 years, sample results in the eastern tritium plume have been as high as 270,000 pCi/L (299-W22-20 in 2009, now dry). Within the 20,000 pCi/L contour, concentration trends are declining in some wells and stable in others. Because of the large number of sources, the plume has localized high-concentration areas. This would account for the trend changes as these areas move by the wells. The extent of the plume has changed little in recent years (Figure 3.3-12), indicating natural attenuation by dispersion and radiological decay.

Past annual reports have documented that tritium occurs in the upper 10 to 20 meters of the aquifer (see Section 11.1.3 in DOE/RL-2011-01). This was also the case at new well 299-W22-96, which was installed north of REDOX Plant during 2011. Depth-discrete sampling during the drilling of this well yielded a tritium result of 130,000 pCi/L at 3.4 meters below the water table, but the concentration at 8.7 meters depth was only 1,400 pCi/L (Table 3.3-1). However, since depth-discrete sample results are not available within the high-concentration regions of this plume east of the 200 West Area, additional data would be needed to confirm a shallow tritium interpretation in this area.

216-S-25 Crib. Tritium occurs above the drinking water standard in wells downgradient of the 216-S-25 Crib. The maximum tritium concentration in this area during 2011 was 49,000 pCi/L in well 299-W23-21 located between the SX Tank Farm and the 216-S-25 Crib. This portion of the tritium plume is also limited to the upper part of the aquifer. In 2011, depth-discrete sampling during drilling of 299-W22-91—a new WMA S-SX groundwater extraction system pumping well—indicated concentrations above the drinking water standard to a depth of 10.5 meters below the water table (Table 3.3-1 and Figure 3.3-5).

Radioactive liquid effluent was disposed to the 216-S-25 Crib from 1973 through 1980, and effluent from a pump-and-treat system at the 216-U-1/2 Cribs was disposed to this crib for 6 months during 1985. The continued presence of a tritium plume downgradient from this crib indicates that tritium in the vadose zone beneath the crib continues to migrate to the water table. The plume has migrated under the SX Tank Farm, but the tanks in this farm are not a substantial direct source of tritium to the groundwater. Much of the tritiated water in the tanks was removed by the 242-S Evaporator and disposed to the 216-S-25 Crib.

Tritium concentrations increased to above the 20,000 pCi/L drinking water standard in S Tank Farm downgradient well 299-W19-44, but the probable source is the 216-S-3 Crib.

S Tank Farm/216-S-3 Crib. During 2011, the tritium concentration in the S Tank Farm downgradient well 299-W22-44 increased to above the drinking water standard for the first time since this well was installed in 1991. The June 2011 sample result was 22,000 pCi/L, but the concentration declined to 19,000 pCi/L in December 2011. While tritium concentrations in this well appear to trend with the tank waste constituents, chromium, nitrate, and technetium-99, the increase in tritium concentrations occurred

later than the other constituents (Figure 3.3-7). Tritium has not been detected in samples from the S Tank Farm upgradient well, 299-W23-20. Possible sources for this tritium are the tank farm (an estimated 51 Ci were released from tank S-104 [Appendix C in RPP-26744]) and the 216-S-3 Crib (estimated to have received 245 Ci of tritium [Appendix C in RPP-26744]) located between the tank farm and 299-W22-44. The tritium is interpreted to have originated from the 216-S-3 Crib, because it received the larger tritium inventory and the trend in 299-W22-44 lags behind the chromium, nitrate, and technetium-99 trends resulting from the from tank S-104 overfill event.

216-S-21 Crib. The tritium concentration in groundwater near the 216-S-21 Crib (west of WMA S-SX) continued to increase during 2011. The concentration reached 66,000 pCi/L in 299-W23-4 during August 2011, an increase from 50,000 pCi/L in 2010. These results indicate that tritium is entering the groundwater from the vadose zone beneath the crib, which was a major source of tritium. The peak tritium concentration in 299-W23-4 occurred in 1963 and 1964 at 110 million pCi/L.

3.3.4 Iodine-129

Iodine-129 plumes in the 200-UP-1 Operable Unit originate from U Plant and REDOX Plant waste sites (Figure 3.3-15). The primary sources were the REDOX facilities, particularly the 216-S-1/2, 216-S-7, and 216-S-9 Cribs (Appendix C of RPP-26744). Iodine-129 occurs as two plumes, one from the 216-U-1/2 Cribs near U Plant and a second from the REDOX Plant waste sites in the southern portion of the 200 West Area. These plumes merge downgradient and become indistinguishable. This combined plume (as defined by the 1 pCi/L contour) extends to the east a distance of 3 kilometers. Iodine-129 sorbs slightly to the aquifer sediments and is considered moderately mobile (Section 5.1.2 of DOE/RL-2009-122). This is likely one factor that explains the more limited extent of this plume in the 600 Area compared to that of the tritium and nitrate plumes, which were released concurrently from the same sources.

The highest concentrations of iodine-129 within 200-UP-1, greater than ten times the drinking water standard, occur in a 2-kilometer region extending eastward from the southeastern 200 West Area.

REDOX Waste Sites Plume. The highest concentrations of iodine-129 within the operable unit, greater than 10 times the drinking water standard, originate from the REDOX Plant waste sites and occur in a region extending 2 kilometers east into the 600 Area from the southeastern 200 West Area (Figure 3.3-15). The maximum sample result in this area was at 699-35-70 in March 2008, where the iodine-129 concentration was determined to be 37 pCi/L. This well is now dry and can no longer be sampled. The maximum sample result in this plume during 2011 was 11.2 pCi/L in well 699-36-70A. During 2011, well 299-W22-72, near the 216-S-7 Crib, had a maximum concentration of 2.2 pCi/L, and the maximum concentration in 299-W22-26 at the 216-S-9 Crib was 2.9 pCi/L. These results indicate that iodine-129 is still entering the aquifer from the vadose zone beneath these cribs. East of the 200 West Area, concentrations are declining in some wells and are stable in others. The plume extent has been stable since 2003 (Figure 3.3-12).

At new well 299-W22-96, north of REDOX Plant and downgradient from the 216-S-7 Crib, the iodine-129 concentration was 2.4 pCi/L at 8.7 meters below the water table, the deepest groundwater sample collected during drilling of this well. Thus, the full depth of the plume at this location is not known but concentrations above the drinking water standard occur deeper in the aquifer at this location than the tritium plume (Section 3.3.3 and Table 3.3-1). In addition, information is not available on the vertical extent of the high-concentration portion of this plume west of the 200 West Area.

216-U-1/2 Cribs Plume. The maximum iodine-129 sample result downgradient from the 216-U-1/2 Cribs during 2011 was 2.5 pCi/L in well 299-W19-49. This plume occurs at a shallow depth near the source, but deepens as the plume extends eastward. The plume is fully mixed vertically

throughout the aquifer at well 699-38-70C, located 1.8 kilometers east of the cribs (see the plume cross section in DOE/RL-2011-01, Figure 11-16). Full mixing of the plume is attributed to vertical dispersion.

3.3.5 Nitrate

Nitrate plumes in the 200-UP-1 Operable Unit originated from U Plant and REDOX Plant disposal facilities, although U Plant sources were more substantial (Appendix C of RPP-26744). The nitrate plumes from these sources merge downgradient into a single, large plume that extends to the east and northeast from the 200 West Area (Figure 3.3-16). Like tritium, nitrate is widespread within the operable unit because of the large number of sources, the time since releases began, and the high mobility of nitrate.

U Plant Crib Sources. Sources of nitrate from U Plant include the 216-U-1/2, 216-U-8, and 216-U-12 Cribs. The high-concentration portion of the nitrate plume outside the 200 West Area occurs to the north of the tritium and iodine-129 plumes. This is due to tritium and iodine-129 coming primarily from different source cribs (i.e., REDOX Plant waste sites). With a few exceptions, concentrations throughout the large plume east of the 200 West Area are stable in some wells and declining in others. On the eastern edge of the plume, concentrations are stable in wells 699-36-61A, 699-40-62, and 699-44-64.

Nitrate plumes are widespread within the 200-UP-1 interest area and originated from multiple sources.

Within the U Plant pump-and-treat area, nitrate concentrations have been highest in the two extraction wells, 299-W19-36 and 299-W19-43. The pump-and-treat system was shut down during March 2011 before sampling of the extraction wells (see Section 3.3.9.2). The maximum concentrations in these wells during 2010 were 234 mg/L and 1,080 mg/L in wells 299-W19-36 and 299-W19-43, respectively. The maximum historical nitrate concentration at 299-W19-43 (1,930 mg/L in 2003) is higher than concentrations measured historically at the 216-U-1/2 Cribs in the 1970s and 1980s (~100 to ~300 mg/L). This indicates that nitrate has a local source near the pump-and-treat area. Similar to the technetium-99 and iodine-129 plumes in this area, nitrate occurs at shallow depths near the source and becomes fully mixed vertically throughout the aquifer 1.5 to 2 kilometers downgradient from the source (see the plume cross section in Figure 11-18 in DOE/RL-2011-01). The deeper occurrence of nitrate with distance from the source is attributed to dispersion.

WMA U Tank Farm. During 2011, nitrate concentrations were greater than the 45 mg/L drinking water standard in six of the eight monitoring wells at the U Tank Farm. This included the upgradient well (299-W18-40) indicating an upgradient source, which is interpreted to be the 200-ZP-1 interim-action pump-and-treat system injection wells. This conclusion is supported by several lines of evidence. First, the 200-ZP-1 interim-action extraction wells are located within a nitrate plume (shown on Figure 3.3-16 as well as Figure 3.2-13 in Section 3.2). Thus, nitrate is certainly being drawn into the extraction wells. Second, the 200-ZP-1 interim-action treatment process uses an air stripper system that removes volatile organic compounds (e.g., carbon tetrachloride) from the water, but this system is not capable of removing non-volatile contaminants, such as nitrate. Although the water from the treatment system is not sampled for nitrate, it must be the case that water containing nitrate is being injected back into the aquifer. This is further supported by the nitrate sample results from wells near and downgradient of the injection wells (Figures 3.3-16 and Figure 3.2-13 in Section 3.2). In addition, the distribution of this plume is consistent with the mapped groundwater flow system, assuming the injection wells as the source. Thus, the nitrate forms a plume between the injection and extraction wells, and the U Tank Farm is on the southeast edge of this plume (Figure 3.3-16).

The maximum nitrate concentration measured at the U Tank Farm during 2011 was 87 mg/L (October) in 299-W19-45. Concentrations are higher in the downgradient wells compared to the

upgradient well, confirming that the U Tank Farm is also a source of nitrate to the groundwater (Section 3.3.10.2).

WMA S-SX Tank Farms/216-S-25 Crib. A nitrate plume originates from the 216-S-25 Crib and merges with a nitrate plume from the SX Tank Farm. Nitrate from the tank farm correlates with technetium-99 and chromium concentrations. At 299-W23-19 in the southwestern corner of SX Tank Farm, the nitrate concentration exhibited a decreasing trend during 2011, declining from 409 mg/L in April to 324 mg/L in December (Figure 3.3-4). This well has had a declining nitrate trend since 2009, indicating that the mass flux of nitrate into the aquifer from the vadose zone beneath the tank farm has been decreasing in recent years.

A nitrate plume also originates from the S Tank Farm. The maximum concentration in this plume during 2011 was 249 mg/L at 299-W22-44 (March 2011). Nitrate in this well began increasing in 2006, peaked during 2010, and has been decreasing since (Figure 3.3-7). This indicates that a pulse of contamination entered the aquifer from beneath the tank farm and is migrating past the well. Tank S-104 is the only tank within the S Tank Farm known to have had a leak/release (from an overfill event). A surface electrical-resistivity survey conducted during fiscal year 2006 indicated that a portion of the vadose zone plume beneath Tank S-104 at the 2- to 5-ohmmeter level had apparently reached groundwater (Figure 10 in RPP-RPT-30976, *Surface Geophysical Exploration of S Tank Farm at the Hanford Site*).

A declining nitrate trend is also noted at well 299-W22-26 (Figure 3.3-8), further downgradient from well 299-W22-44. Although nitrate in these wells is mapped as a single plume (at the 45 mg/L concentration level), the near simultaneous concentration declines are not related because of the 7-year travel time between the wells. The best explanation is that the nitrate at 299-W22-26 represents an earlier release from the tank farm (see the discussion for technetium-99 at WMA S-SX Tank Farms in Section 3.3.1).

Depth-discrete sampling during drilling of 299-W22-47 in 2005 indicated concentrations above the drinking water standard in the southern plume are limited to the upper 23 meters of the aquifer (Section 2.9.3.2 in PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*). Depth-discrete sampling during drilling of the new WMA S-SX groundwater extraction system pumping wells have confirmed that the plumes from both the S and SX Tank Farms are in the upper part of the aquifer, although the maximum concentrations are not always in the uppermost sample (Table 3.3-1 and Figures 3.3-5, 3.3-6, and 3.3-10).

3.3.6 Chromium

Chromium in the groundwater at the Hanford Site occurs as the soluble oxidized form, hexavalent chromium. The reduced form, trivalent chromium, is not soluble in Hanford Site groundwater (see Section E.5.2 in Appendix E for a discussion of chromium geochemistry). Hexavalent chromium concentrations are determined by either hexavalent chromium analyses or total chromium analyses on filtered samples. High concentrations of chromium are found in two regions of 200-UP-1: in two plumes at WMA S-SX and another plume in the 600 Area east and southeast of the 200 West Area (Figure 3.3-17).

WMA S-SX Tank Farms. Chromium concentrations in seven wells at WMA S-SX exceed the 100 µg/L drinking water standard. The highest concentrations occur at 299-W23-19, where sample results declined during 2011 from 1,300 µg/L in April to 880 µg/L during December (Figure 3.3-4). Concentrations have been fluctuating in this well between 800 and 1,300 µg/L since 2009. This well is near the source of a chromium, technetium-99, and nitrate plume originating from the SX Tank Farm, and the fluctuating trend indicates that the mass flux of contamination from the vadose zone to the groundwater fluctuates.

High concentrations of chromium are found in two regions of 200-UP-1: at WMA S-SX and in the 600 Area (east and southeast of the 200 West Area).

A second chromium plume occurs in the northern portion of WMA S-SX, downgradient from the S Tank Farm and originated from tank S-104. At near-field downgradient well 299-W22-44, chromium concentrations ranged from 619 to 450 µg/L during 2011, and exhibited a declining trend (Figure 3.3-7). Chromium concentrations at well 299-W22-26, 250 meters east of well 299-W22-44, ranged between 109 and 71 µg/L during 2011 and exhibited a declining trend (Figure 3.3-8). Chromium in both of these wells is mapped as a single plume (at the 48 µg/L concentration level), but the concentration declines are not related because of the 7-year travel time between these wells. The best explanation is that chromium at 299-W22-26 represents an earlier release from the tank farm (see the discussion for technetium-99 at WMA S-SX Tank Farms in Section 3.3.1).

Depth-discrete sample results were collected for chromium during installation of the WMA S-SX groundwater extraction system pumping wells (Table 3.3-1), but the results are deemed not representative of aquifer conditions. At well 299-W22-90, chromium was not detected in the uppermost sample collected during drilling, whereas well 299-W22-44, located only 6 meters away, had a peak chromium concentration of 619 µg/L during 2011. Nonrepresentative chromium sample results during drilling have also been documented in other wells, further supporting the interpretation that the results from the WMA S-SX extraction wells are not representative of aquifer conditions. At 299-W22-47, some of the chromium sample results during drilling were deemed not representative of aquifer conditions because of prolonged contact with fresh sediment surfaces in the sample containers (Section 2.9.3.2 of PNNL-15670). At 699-30-66, southeast of the 200 West Area, chromium results during drilling ranged from not detected to 53 µg/L, whereas sample results from the completed well are greater than 100 µg/L. Further, it took a full year before the chromium concentrations in well 699-30-66 recovered from the drilling process and stabilized (Figure 3.3-18). The inverse change in manganese concentrations during this time was indicative of a change from reducing conditions induced by the drilling process back to the oxidizing conditions representative of the unconfined aquifer.

Chromium in the plume southeast of the 200 West Area is distributed throughout the unconfined aquifer thickness.

Southeast Plume. Within the chromium plume east-southeast of the 200 West Area, concentrations in 699-32-62 have declined since this constituent was first measured in 1992 (from 254 µg/L in 1992 to 137 µg/L in 2011). Chromium is also elevated at well 699-30-66 (results between 104 and 122 µg/L during 2011), which is completed deep in the aquifer just above the Ringold lower mud unit (Figure 3.3-18). These data indicate chromium is present throughout the aquifer thickness in this region because of dispersion (see the cross section on Figure 11-20 in DOE/RL-2011-01). This plume originated primarily from effluent disposal to the 216-S-20 Crib during the 1950s, although the REDOX Plant ponds and ditches to the south of the 200 West Area were also sources (Section 4.2.4 of DOE/RL-2009-122). An estimated 5,900 kilograms of chromium were disposed to the 216-S-20 Crib, and an estimated 3,000 kilograms were disposed to the 216-S-10 Pond and Ditch (Appendix C of RPP-26744). Chromium concentrations remain elevated in groundwater near both of these source locations. In well 699-34-72, downgradient from the 216-S-20 Crib, a total chromium concentration of 30 µg/L was detected in a filtered sample collected during July 2008. In well 299-W26-13 at the 216-S-10 Pond and Ditch, chromium averaged 86 µg/L during 2011 (hexavalent chromium and filtered total chromium results combined) and the trend has been increasing (Figure 3.3-19). Chromium is also elevated in well 699-32-76, located 300 meters further downgradient (Figure 3.3-19).

3.3.7 Chlorinated Hydrocarbons

Carbon tetrachloride at concentrations above the 5 µg/L drinking water standard is widespread within 200-UP-1. This constituent originates from disposal sites in the 200-ZP-1 Operable Unit.

Carbon Tetrachloride. Carbon tetrachloride at concentrations above the drinking water standard (5 µg/L) is widespread within 200-UP-1. Concentrations were greater than ten times the drinking water standard in 29 wells during 2011. In the southern portion of the 200 West Area, the plume extends as much as 1.2 kilometers east into the 600 Area (Figures 3.2-5 and 3.2-6 in Section 3.2). The plume originated from waste disposal sites associated with the Plutonium Finishing Plant in the 200-ZP-1 Operable Unit.

In the eastern portion of the plume, concentrations increase with depth (see the plume cross section in Figure 11-21 in DOE/RL-2011-01). The highest carbon tetrachloride concentration measured within 200-UP-1 during 2011 was 980 µg/L at 699-38-70B, which is screened from 36.1 to 40.8 meters below the water table (8 meters above the Ringold lower mud unit). Section 3.2.1 provides additional information regarding carbon tetrachloride in the 200 West Area.

Chloroform. Chloroform, a degradation product of carbon tetrachloride, tends to occur in the same wells with carbon tetrachloride. Thus, natural degradation of carbon tetrachloride is occurring, although chloroform was also introduced to the aquifer from the 2607-Z Tile Field (Section 3.2). During 2011, 117 chloroform analyses were performed on samples from 59 wells within the 200-UP-1 groundwater interest area, and there were no exceedances of the drinking water standard (80 µg/L for total trihalomethanes). The maximum concentration measured during 2011 was 24 µg/L at well 299-W14-71, located north of U Plant and screened deep within the unconfined aquifer just above the Ringold lower mud unit (this well had the second highest carbon tetrachloride sample result of 720 µg/L). Depth-discrete sampling during new well installation indicates that concentrations tend to increase with depth, similar to carbon tetrachloride.

Trichloroethene. During 2011, trichloroethene was found above the drinking water standard (5 µg/L) north and east of the U Plant pump-and-treat area. Depth-discrete samples during well drilling show that trichloroethene concentrations also increase with depth. During 2011, 118 trichloroethene analyses were performed on samples from 59 wells within the interest area. The drinking water standard was exceeded only at 299-W14-71 (8.8 µg/L) and 699-38-70B (5.6 µg/L). Both of these wells are screened deep within the unconfined aquifer, just above the Ringold lower mud unit. Three of the four trichloroethene degradation products, 1,1-dichloroethene, 1,2-dichloroethene (cis- and trans-), and chloroethene (i.e., vinyl chloride), were also analyzed for, but there were no detections during 2011.

3.3.8 Other Contaminants

Arsenic and Cadmium. Arsenic and cadmium are contaminants of concern for groundwater monitoring within the 200-UP-1 Operable Unit (DOE/RL-92-76), but the groundwater is not contaminated with either of these constituents. During 2011, 80 analyses were performed for arsenic in 34 wells, and 231 analyses were performed for cadmium in 49 wells. No detections above a drinking water standard (10 µg/L for arsenic and 5 µg/L for cadmium) were observed in either the filtered or unfiltered samples.

1,4-Dioxane. 1,4-Dioxane has been detected historically at 299-W22-20 near the 216-S-20 Crib, which is the presumed source. The maximum sample result was 160 µg/L during January 2003. The last sampling of this well was in August 2009, when 1,4-dioxane was detected at 39 µg/L. This well has since gone dry; therefore, no further samples can be collected. Well 699-34-72 was installed ~230 meters east-southeast of well 299-W22-20 in 2008. A low-level detection of 1,4-dioxane occurred during 2010 at 5.8 µg/L, but this constituent was not detected in a sample collected during August 2011. 1,4-Dioxane is a local contamination issue near the 216-S-20 Crib and is not detected elsewhere within 200-UP-1.

Selenium-79. Selenium-79 is present in groundwater downgradient from WMA S-SX. Eight wells are sampled annually for selenium-79 in this area. Detections were found in all but the two upgradient wells during 2011, confirming the tank farms are the source. The maximum concentration during 2011 was 226 pCi/L in well 299-W23-19. The trend in this well is stable, but concentrations are increasing in many of the other downgradient wells, indicating a growing contamination issue. An estimated 0.18 Ci of selenium-79 was released to the soil column beneath the S and SX Tank Farms (Appendix C of RPP-26744). This small release inventory indicates that selenium-79 concentrations, although increasing, should remain low compared to other tank farm constituents with larger release inventories, such as the 64 Ci of technetium-99 estimated to have been released (Appendix C of RPP-26744). A drinking water standard has not been established for selenium-79, but DOE has established a derived concentration standard of 8,500 pCi/L (100 mrem/year dose).

Strontium-90. During 2011, nine analyses for strontium-90 were performed on samples collected from six wells within 200-UP-1. Only one detection was noted (2.3 pCi/L at 299-W22-48). This result is likely a false positive, as strontium-90 was not detected in a sample collected from this well later in the year (see Section D.6.5.2 in Appendix D for a discussion of strontium-90 false positive results).

Nickel. Nickel concentrations are substantially elevated at well 299-W14-71 (1,670 µg/L) and 299-W27-2 (89 µg/L) during 2011. These wells also have elevated iron, chromium, and manganese (see Figure 3.3-20 for well 299-W27-2), and all four of these constituents are the primary components of stainless steel. Both wells 299-W14-71 and 299-W27-2 are constructed of stainless steel; therefore, corrosion of the well screens and/or casings was suspected. A camera survey was performed in well 299-W27-2, and substantial corrosion was found below the water level at the casing joints and along the screen. Corrosion is also inferred to exist in well 299-W14-71.

3.3.9 CERCLA Groundwater Activities

This section describes activities for the 200-UP-1 Operable Unit involving the RI/FS study, the status of the U Plant interim action pump-and-treat system, extended well purging for technetium-99 in the SX Tank Farm plume, and closeout of actions related to the 2006 CERCLA 5-year review (DOE/RL-2006-20). Monitoring within the operable unit is performed in accordance with a sampling and analysis plan incorporated into the RI/FS work plan for the 200-UP-1 Operable Unit (Appendix A of DOE/RL-92-76). Appendix A, Table A-12 presents monitoring information for the 200-UP-1 Operable Unit, including a well list, sampling frequency, and a list of analytes.

The second CERCLA 5-year review was published in November 2006 (DOE/RL-2006-20). Only one issue and associated action were identified for the 200-UP-1 Operable Unit pertaining to the interim remedial action objective for uranium and the growing technetium-99 plume from the S and SX Tank Farms. This issue was addressed in *Explanation of Significant Differences for the Interim Action Record of Decision for the 200-UP-1 Groundwater Operable Unit Hanford Site Benton County, Washington* (EPA et al., 2009) and the revised *200-UP-1 Groundwater Remedial Design/Remedial Action Work Plan* (DOE/RL-97-36). The work plan included the preliminary design for a groundwater extraction system targeting both the north and south technetium-99 plumes at the S and SX Tank Farms. This system is discussed further in Section 3.3.9.2.

3.3.9.1 Remedial Investigation/Feasibility Study

The draft RI/FS (DOE/RL-2009-122) and proposed plan (DOE/RL-2010-05) were released during September 2010, meeting Tri-Party Agreement (Ecology et al., 1989) Milestone M-015-17A. Progress made during 2011 consisted of resolution of EPA comments concerning the determination of a technical approach and administrative strategy for remedial actions. Rather than including the 200-UP-1 remedial actions in the existing 200-ZP-1 ROD (by amendment), as was stated in Section 3.3.2 of DOE/RL-2009-81, it was decided that a separate, interim ROD would be prepared for the 200-UP-1 Operable Unit. A final ROD for 200-UP-1 will not be issued until a determination of future impacts to groundwater from vadose zone sources is understood. The interim ROD is expected to contain cleanup actions for all 200-UP-1 contaminants of concern, except for iodine-129. No treatment

technology to remove iodine-129 from water currently exists that will meet the 1 pCi/L drinking water standard; therefore, hydraulic control will be specified in the ROD while a treatment technology is developed. A second draft of the RI/FS is expected in 2012 and the interim ROD is planned to be issued by September 30, 2012.

The interim remedial action objectives for the U Plant pump-and-treat system are as follows (EPA/ROD/R10-97/048, as modified by EPA et al., 2009):

- ***Reduce contamination in the area of highest concentrations of uranium and technetium-99 to below 300 µg/L for uranium and 9,000 pCi/L for technetium-99.***
- ***Reduce potential adverse human health risks through reduction of contaminant mass.***
- ***Prevent further movement of these contaminants from the highest concentration area.***
- ***Provide information that will lead to development and implementation of a final remedy that will be protective of human health and the environment.***

3.3.9.2 Groundwater Remediation

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During 2011, two groundwater remediation measures were active within the 200-UP-1 Operable Unit: the U Plant pump-and-treat system and extended purging of monitoring well 299-W23-19 at the SX Tank Farm. In addition, progress was made in constructing a groundwater extraction system targeting the technetium-99 plumes from the S and SX Tank Farms.

U Plant Pump-and Treat System. The U Plant pump-and-treat system, which targeted the uranium and technetium-99 plume downgradient from the 216-U-1/2 Cribs (Figures 3.3-3 and 3.3-13), was shut down during 2011 because of low flow rates from the extraction wells. The remedial action objectives that addressed plume concentrations and target locations for remediation were specified in an interim ROD (EPA/ROD/R10-97/048, *Declaration of the Record of Decision for the 200-UP-1 Operable Unit*), as modified by the explanation of significant differences (EPA et al., 2009). The primary contaminants of concern for the pump-and-treat system were uranium and technetium-99, with carbon tetrachloride and nitrate as secondary contaminants of concern. As designed, groundwater pumped from the two 200-UP-1 extraction wells (299-W19-36 and 299-W19-43) was transported by pipeline to the LERF in the 200 East Area and then processed at the ETF. This section discusses system operation and monitoring results for 2011 and summarizes the overall effectiveness of this system. For additional details, see DOE/RL-2012-03.

Because of low yield from the extraction wells, the U Plant interim pump-and-treat system was shut down during March 2011 and will no longer be operated.

During 2011, the U Plant pump-and-treat system was operated until March 28, 2011, when the system was shut down. Flow rates from the extraction wells had declined for several years because of the regional decline of the water table and reduced well efficiency. Attempts to rehabilitate the wells in 2010 were not successful (Section 11.2.2.2 of DOE/RL-2011-01). Also, the pump in well 299-W19-36 ceased operating on November 13, 2010, and did not operate during 2011. The flow rate during 2011 from extraction well 299-W19-43 averaged 9.4 liters per minute, which was much lower than the 51 liters per

minute achieved when this well went online in 2003 (Section 2.2 of DOE/RL-2003-58, *Fiscal Year 2003 Annual Summary Report for 200-UP-1 and 200-ZP-1 Pump-and-Treat Operations*). A capture zone analysis was not performed for 2011, but previous analyses indicated the system was no longer effective in capturing the remaining uranium and technetium-99 contamination (Section 11.2.2.3 of DOE/RL-2011-01). Because of the cost of repair/replacement of the pump in well 299-W19-36, and the low production from the remaining extraction well and the resulting ineffective capture zone, EPA and DOE agreed to no longer operate the pump-and-treat system. However, groundwater monitoring in this area will continue, although at a reduced sample frequency in some wells.

No groundwater samples were collected in 2011 from extraction well 299-W19-43 because of the short operating period. All uranium and technetium-99 samples from the monitoring wells in the area targeted for remediation had concentrations below the remedial action objectives for uranium and technetium-99. Maximum sample results during 2011 were 219 µg/L for uranium in 299-W19-48 and 330 pCi/L for technetium-99 in 299-W19-35. Well 299-W19-18, near the 216-U-1/2 Cribs and upgradient of the area targeted for remediation, had maximum concentrations of 374 µg/L for uranium and 280 pCi/L for technetium-99. Table 3.3-2 lists the volume of water pumped and mass/activity of contaminants removed by the system during 2011 and since startup in 1994 (Figure 3.3-21).

The U Plant pump-and-treat system was successful in achieving its interim remedial action objectives. Between 1994 and 2011, maximum uranium and technetium-99 concentrations in groundwater were reduced by 92 percent and 65 percent, respectively.

Overall, the U Plant pump-and-treat system was successful in achieving its objectives. The areal extent of the uranium and technetium-99 plumes downgradient from the 216-U-1/2 Cribs at concentrations above the remedial action objectives have declined since 1997 (Figure 3.3-22). In the area targeted for remediation, the interim remedial action objective of 9,000 pCi/L for technetium-99 was achieved during 2005, and the remedial action objective of 300 µg/L for uranium was achieved during 2009. Prior to system startup in 1994, the maximum concentrations within the targeted remediation area were 3,320 µg/L for uranium and 20,500 pCi/L for technetium-99. The extraction wells were last sampled during 2010, and the maximum concentrations were 257 µg/L for uranium at well 299-W19-43 and 7,100 pCi/L for technetium-99 at well 299-W19-36. This constitutes a reduction in maximum concentrations since startup of 92 percent for uranium and 65 percent for technetium-99.

In addition to achieving the remedial action objectives, the U Plant pump-and-treat system also reduced the technetium-99 concentration to below the 900 pCi/L drinking water standard at all wells within the area targeted for remediation, except the extraction wells. This was not the case for uranium, however, as concentrations at all the wells remained above the 30 µg/L drinking water standard. As described in Section 3.3.2, additional uranium may have been added to the aquifer water by continued leaching from the vadose zone beneath the source cribs. Also, the sorption of uranium to sediment grains and the resulting slower migration rate in the aquifer may explain why uranium concentrations persist above the drinking water standard within the pump-and-treat area.

Extended Purging at 299-W23-19. In 2001, DOE investigated the feasibility of using 299-W23-19 as a pump-and-treat extraction well to remediate the southern plume from the SX Tank Farm. The results of an aquifer test indicated that the production capacity was too small for a pump-and-treat system (Section 6.0 of RPP-10757, *Technetium-99 in Groundwater at Hanford Well 299-W23-19: Options Analysis and Recommended Action Report*). To perform some remediation of the technetium-99, the practice of extended purging during sampling at well 299-W23-19 was agreed to by DOE and Ecology, and began in 2003. This agreement was formalized in the explanation of significant differences for the 200-UP-1 Operable Unit (EPA et al., 2009). After samples are collected from this well each quarter, purging is continued at a higher flow rate until a minimum of 3,785 liters of water are removed from the

aquifer. This water is transferred to the ETF for treatment and disposal. The objective of this activity is to reduce the technetium-99 concentration in the aquifer.

Table 3.3-3 presents the date, amount of water collected, and a calculation of the mass and activity of technetium-99 removed from the aquifer. A total of 0.0009 curies (0.05 grams) of technetium-99 were recovered during 2011. Since the start of this treatment in 2003, 0.011 curies (0.63 grams) of technetium-99 have been recovered. This practice is not an effective remedy for the technetium-99 plume, as evidenced by the small amount of technetium-99 recovered to date. This practice will be discontinued when the S-SX Tank Farms pump-and-treat system begins operating, which is scheduled for July 2012.

Three extraction wells for the WMA S-SX Groundwater Extraction System were installed during 2011. The system is planned to come online during July 2012.

WMA S-SX Groundwater Extraction System. The implementation of a groundwater extraction system for the technetium-99 plumes at the S-SX Tank Farms is underway as required by the revised remedial design/remedial action work plan (DOE/RL-97-36). The remedial design was completed and consists of a three-well extraction system, above-ground pipelines, and a transfer building to pump extracted groundwater to the 200 West Treatment Facility. The system is designed for a capacity of 450 liters per minute, but is planned to operate at an average pumping rate of 300 liters per minute. During 2011, the three extraction wells, 299-W22-90, 299-W22-91, and 299-W22-92, were drilled near existing monitoring wells 299-W22-44, 299-W22-50, and 299-W22-86, respectively. In addition, one monitoring well, 299-W22-96, was drilled north of REDOX Plant. A second monitoring well, 299-W22-95, is planned to be installed within the S Tank Farm plume. An automated water-level monitoring system was installed in existing wells to provide data needed to evaluate plume capture by the extraction system. By December 2011, the necessary piping was laid and the transfer station was constructed. Acceptance testing of the constructed system will be complete in early 2012. Operations are planned to begin during July 2012.

3.3.9.3 Special Studies

During drilling of the S-SX Tank Farms pump-and-treat system extraction wells, split-spoon soil samples of the vadose zone were collected from well 299-W22-91 for the Deep Vadose Zone Project (200-DV-1 Operable Unit), as well as by Washington River Protection Solutions for its Closure and Corrective Measures Project in support of tank farm vadose zone investigations (Section 1.4.2 of DOE/RL-2010-90, *Sampling and Analysis Plan for the 200-UP-1 Remedial Wells*). Most of the samples were collected in the lower Hanford formation and within the Cold Creek unit, and were analyzed for a variety of constituents as well as physical and geochemical parameters (listed in Tables 1-5 and 1-6 in DOE/RL-2010-90).

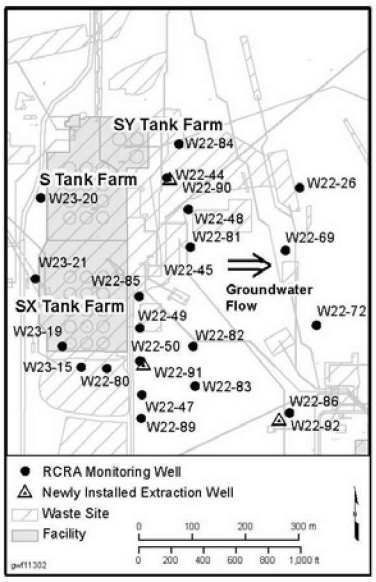
Contamination of the deep vadose zone at the location of well 299-W22-91 was not expected, and this was confirmed by the soil sample results. No contamination was found in any of the samples. The tank waste constituent technetium-99 was not detected, and while nitrate and chromium were detected, the results were consistent with Hanford Site background levels (DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*).

3.3.10 RCRA and Other Facility Monitoring

The following sections describe the results of monitoring at four individual waste management/ disposal facilities within the 200-UP-1 Operable Unit. Three of the sites were monitored in accordance with RCRA regulations. Interim status groundwater quality assessment monitoring was conducted at WMA S-SX and WMA U (40 CFR 265.93[d], as referenced by WAC 173-303-400). Interim status detection monitoring for indicator parameter evaluation was conducted at the 216-S-10 Pond and Ditch (40 CFR 265.92, “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment,

Storage, and Disposal Facilities," "Sampling and Analysis;" and 40 CFR 265.93[b], as referenced by WAC 173-303-400). Groundwater monitoring at the ERDF was conducted in accordance with a CERCLA ROD (EPA/ROD/R10-95/100, *EPA Superfund Record of Decision: Hanford 200-Area (USDOE) Hanford Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*). Groundwater data for these facilities are available from the data files accompanying this report and from the Hanford Environmental Information System (HEIS) database, which can be accessed via the internet through DOE's 2012 Environmental Dashboard Application.

3.3.10.1 Waste Management Area S-SX



WMA S-SX consists of two tank farms: the S Tank Farm and the SX Tank Farm. The S Tank Farm consists of twelve tanks, each with a capacity of 2.9 million liters. The SX Tank Farm consists of fifteen tanks, each with a capacity of 3.8 million liters (Section 1.2 of RPP-7884, *Field Investigation Report for Waste Management Area S-SX*). The WMA also includes ancillary equipment consisting of three catch tanks, one receiver tank, six diversion boxes, associated piping, valve pits, and pumps (Section 1.2 of RPP-7884). Both tank farms received waste generated from REDOX Plant in the 1950s and 1960s. To minimize the probability of future leaks, all drainable liquid in each tank has been removed and transferred to double shell tanks.

WMA S-SX was placed into assessment status in 1996 at the direction of Ecology because of elevated specific conductance in downgradient monitoring wells. The first determination assessment found that multiple sources within the WMA had affected groundwater quality with elevated concentrations of nitrate and chromium (Section 5.0 of PNNL-11810). The current objective of RCRA monitoring at WMA S-SX is to assess the extent and concentrations of dangerous waste constituents in the groundwater and determine their rate of movement (for a discussion of technetium-99 and selenium-79 in groundwater, see Sections 3.3.1 and 3.3.8, respectively).

A new groundwater assessment plan for WMA S-SX was implemented during 2011. The frequency of sample collection was reduced at many wells.

A new monitoring plan, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area S-SX* (DOE/RL-2009-73), was implemented in 2011. The major change from the previous plan, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area S-SX at the Hanford Site, Interim Change Notice 4* (PNNL-12114-ICN-4), was the reduction of the sampling frequency for all but four of the network monitoring wells from quarterly to semiannual or annual. It was concluded from a sample frequency analysis that quarterly monitoring was not required at many of the wells to adequately define constituent trends (Section 3.1 in DOE/RL-2009-73).

Appendix B includes a well location map (Figure B-16) and a list of the wells and constituents monitored for WMA S-SX (Table B-38). With the exception of well 299-W22-83, all required sampling was performed successfully during 2011, although a few wells were sampled later than scheduled because of maintenance or other issues. Well 299-W22-83, scheduled for annual sampling, was missed because of a safety issue associated with electrical sample pumps (discussed in Section 1.2).

Water-Level and Well Network Evaluation. The water table elevation declined an average of 0.22 meter in the monitoring wells between March 2010 and March 2011, which is consistent with the long-term rate of decline since 2007 of 0.25 meter per year. A trend-surface analysis of water-level data collected during March 2011 indicated that the hydraulic gradient is 2.0×10^{-3} meter per meter due east

(90 degrees azimuth), and the groundwater flow rate (i.e., average linear velocity) ranges from 0.013 to 0.31 meter per day (5 to 114 meters per year), depending on the hydraulic conductivity and effective porosity selected. Using values of 6.1 meters per day for the hydraulic conductivity and 0.12 for the effective porosity (average values from multiple constant-rate pumping tests in wells at the WMA [PNNL-13514, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2000*; PNNL-14113; PNNL-14186, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2002*]), the groundwater flow rate most representative for this site is 0.10 meter per day (36 meters per year). This is consistent with a previous estimate of 0.096 meter per day (35 meters per year) made in 1999, based on the movement of chromium, nitrate, and technetium-99 between wells (Section 5.1.1 of PNNL-12114, *RCRA Assessment Plan for Single-Shell Task Waste Management Area S-SX at the Hanford Site*).

Based on the distribution of the monitoring wells compared to the extent of contamination, DOE believes the current well network is capable of monitoring the distribution of contamination at this WMA. The WMA S-SX will remain in interim status groundwater quality assessment monitoring for 2012.

Assessment Results. Groundwater beneath WMA S-SX is contaminated with the dangerous waste constituent chromium and supporting constituent, nitrate. This contamination is attributed to two general source areas within the WMA: (1) a source area in the S Tank Farm, and (2) a source area located to the south in the SX Tank Farm. Chromium and nitrate are mobile in the aquifer, and thus, their rate of migration (toward the east) is equal to the calculated groundwater flow rate of 0.10 meter per day (36 meters per year). For a discussion of the sample results for nitrate and chromium, see Sections 3.3.5 and 3.3.6, respectively.

Groundwater beneath WMA S-SX is contaminated with the dangerous waste constituent chromium and supporting constituent, nitrate.

The new monitoring plan for WMA S-SX (DOE/RL-2009-73) required once sampling of those constituents potentially present in the tanks that are also on the RCRA groundwater monitoring list (Appendix 5 in Ecology Publication 97-407, *Chemical Test Methods for Designating Dangerous Waste: WAC 173-303-090 & -100*). Seventy-two constituents were selected for sampling, consisting of various volatile organic compounds, semivolatile organic compounds, and trace metals and anions (the specific constituents are listed in Table 3.1 of DOE/RL-2009-73). Confirmation sampling would be performed for those constituents detected above Hanford Site background levels (DOE/RL-96-61), unless the constituent can be attributed to another facility (for example, carbon tetrachloride from the 200-ZP-1 Operable Unit).

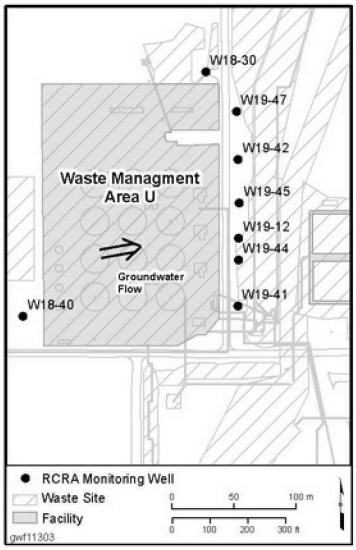
Selenium was detected in all the wells sampled, but all concentrations were below the 50 µg/L drinking water standard. Only one result, 21.1 µg/L for a filtered sample from 299-W22-85, was higher than the Hanford Site 95th percentile background value of 20.7 µg/L for filtered samples (Table ES-1 in DOE/RL-96-61). Laboratory split samples were collected later in the year for confirmation, but the maximum result of the filtered analyses was 18.1 µg/L, which was below the background value. All of the unfiltered selenium sample results from this well were below the 24.0 µg/L background value for unfiltered samples (Table 5-2 in DOE/RL-96-61).

Lead was detected in an unfiltered sample from well 299-W22-26 at 9.1 µg/L but was not detected in the filtered sample. The Hanford Site 95th percentile background value for lead in unfiltered samples is 3.4 µg/L (Table 5-2 in DOE/RL-96-61). Laboratory split samples (unfiltered only) collected later in the year had concentrations ranging from 4.7 to 16.2 µg/L. However, 299-W22-26 is a perforated, carbon-steel cased well, and samples from it have elevated turbidity (14.5 nephelometric turbidity units for the first sample event, and 22.2 nephelometric turbidity units for the second sample event). Because of the difference in results between the filtered and unfiltered samples, and the fact that lead is naturally present in Hanford Site soils (DOE/RL-92-24), it is concluded that the unfiltered lead results are caused

by elevated turbidity from the sampling process and are deemed not representative of aquifer conditions. There were no other detections of a constituent requiring confirmation sampling.

3.3.10.2 Waste Management Area U

The WMA U contains 16 underground single-shell tanks constructed between 1943 and 1944. Twelve of the single-shell tanks have capacities of 2 million liters and four have capacities of 210,000 liters (Section 1.2 of RPP-35485, *Field Investigation Report for Waste Management Area U*). The WMA also contains a variety of ancillary equipment used to manage tank waste during operations, including six diversion boxes, the 271-UR control house, the 244-UR process vault, the 244-U double-contained receiver tank, waste transfer lines, pits, and junction boxes.



The tank farm received waste from the bismuth-phosphate process between 1946 and 1948, and from the REDOX process between 1954 and 1957 (WHC-MR-0132, *A History of the 200 Area Tank Farms*). In 1952, some waste was retrieved and pumped to the 242-T Evaporator, and between 1952 and 1957, the metal wastes (stored in nine of the 2-million-liter-capacity tanks) were transferred to U Plant for uranium recovery. To minimize the probability of future leaks, all drainable liquid in each tank has been removed and transferred to double shell tanks.

WMA U was placed into assessment status in 2000 when specific conductance in groundwater monitoring wells downgradient of the WMA exceeded upgradient levels (Section 1.1 of PNNL-13185, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U at the Hanford Site*). An assessment of that finding determined that the WMA had affected groundwater quality, based on elevated concentrations of nitrate and possibly chromium in wells downgradient of the WMA (Section 6.0 of PNNL-13282). Contaminant concentrations did not exceed their respective drinking water standards, and the affected area was limited to the southeastern corner of the WMA at that time. The current objective of RCRA monitoring at WMA U is to assess the extent and concentrations of dangerous waste constituents in the groundwater and determine their rate of movement. See Section 3.3.1 for a discussion of technetium-99 in groundwater, and see RPP-35485 for a discussion of vadose zone conditions beneath the waste management area.

A new groundwater assessment plan for WMA U was implemented during 2011. There were no changes to the well network or frequency of sample collection.

A new monitoring plan, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U* (DOE/RL-2009-74) was implemented in 2011. There were no changes to the routine monitoring well network or sample frequencies.

Appendix B includes a well location map (Figure B-16) and a list of wells and constituents monitored for WMA U (Table B-41). The second and third quarter sample events of the upgradient well, 299-W18-40, were missed because of a safety issue associated with electrical sampling pumps (discussed in Section 1.2). All other wells were sampled as planned.

Water-Level and Well Network Evaluation. Groundwater flow conditions at WMA U have varied over the past several decades due to changing wastewater disposal in areas surrounding the WMA, but flow has been generally to the east-northeast since 1996 (~80 degrees azimuth). The decline in monitoring well water levels has averaged 0.25 meter per year since 2007. Analysis of water-level data collected during 2011 indicated an average hydraulic gradient of 2.1×10^{-3} meter per meter in a direction of

80 degrees azimuth (east-northeast). The groundwater flow rate (i.e., average linear velocity) ranged from 0.018 to 0.20 meter per day (7 to 74 meters per year), depending on the hydraulic conductivity and effective porosity selected. Using values believed to be most representative, 6.12 meters per day for the hydraulic conductivity and 0.17 for the effective porosity from a constant-rate pumping test conducted in 299-W19-42 (Section 7.4 of PNNL-13378, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 1999*), the groundwater flow rate most representative for this site is 0.077 meter per day (28 meters per year).

Based on the distribution of wells at the WMA and the groundwater flow direction, DOE believes the well network is currently capable of monitoring the distribution of contamination from the WMA; however, downgradient well 299-W18-30 is nearly dry. Two new replacement wells have been proposed for WMA U: one for 299-W18-30 and one for 299-W19-12, whose construction does not comply with the well construction standards found in WAC 173-160. All new RCRA wells proposed for installation at the Hanford Site are negotiated annually by Ecology, DOE, and EPA under Tri-Party Agreement (Ecology et al., 1989) Milestone M-24-00. The WMA U will remain in interim status groundwater quality assessment monitoring for 2012.

Assessment Results. WMA U has been identified as the source of groundwater contamination limited to the downgradient (east) side of the site (Section 6.0 of PNNL-13282). The dangerous waste constituent chromium and supporting constituent nitrate were originally found in the groundwater, but monitored chromium concentrations had decreased in the past to below the analytical detection limit. During 2011, the analytical detection limit was less than in previous years, and chromium was detected in several downgradient wells at concentrations ranging from 4 to 14 µg/L. This is below the peak chromium concentration of 30 µg/L observed at 299-W19-41 during 2000, when the site was placed into assessment monitoring. While chromium is highly mobile in the aquifer, it can migrate more slowly than nitrate in the vadose zone beneath the tank farms, at least initially. This has been attributed to a reduction process where iron(II) minerals in the sediment are dissolved by tank fluids, and the iron then reacts with the soluble chromium(VI) reducing it to chromium(III), which precipitates as an insoluble iron-chromium hydroxide (Zachara et al., 2004, "Chromium Speciation and Mobility in a High Level Nuclear Waste Vadose Zone Plume," and Qafoku et al., 2003, "Effect of Coupled Dissolution and Redox Reactions on Cr(VI)aq Attenuation during Transport in the Sediments Under Hyperalkaline Conditions," as referenced by PNNL-17154, *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site*). This vadose zone reaction and the relatively low tank leak volumes that occurred at WMA U may explain the present low concentrations of chromium in the groundwater. For a discussion of the nitrate sample results at WMA U, see Section 3.3.5. Chromium and nitrate are mobile in the aquifer, and thus, their rate of migration (toward the east-northeast) is equal to the calculated groundwater flow rate of 0.077 meter per day (28 meters per year).

Chromium occurs in the downgradient wells at WMA U, but concentrations are well below the drinking water standard and below the 48 µg/L cleanup level for 200-UP-1.

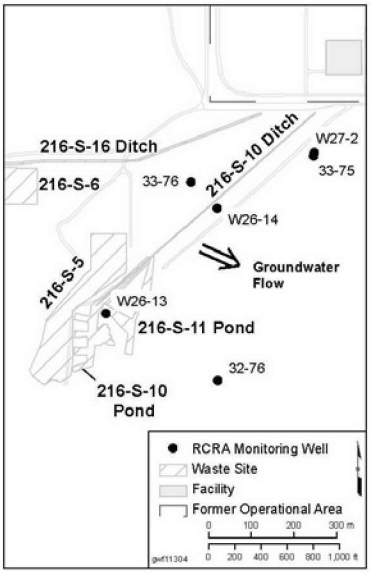
In the January 2011 sample from 299-W19-41, pH was measured at 8.54, which is above the secondary drinking water standard of 8.50. For the other three sample events during 2011, pH in this well was either below or equal to 8.50. This parameter has been slowly increasing since 2004, when the values averaged 7.78. The pH trend does not correlate with contaminant concentrations, or major anions or cations. The cause of the increase remains unknown.

The new monitoring plan for WMA U (DOE/RL-2009-74) specified a one-time sampling of those constituents potentially present in the tanks that are also on the RCRA groundwater monitoring list (Appendix 5 in Ecology Publication 97-407). Seventy-two constituents were selected for sampling, consisting of various volatile organic compounds, semivolatile organic compounds, trace metals, and anions (the specific constituents are listed in Table 3.1 of DOE/RL-2009-74). Confirmation sampling

would be performed for those constituents detected above Hanford Site background levels (DOE/RL-96-61), unless the constituent can be attributed to another facility (for example, carbon tetrachloride from the 200-ZP-1 Operable Unit).

Mercury was detected in well 299-W19-44 at concentrations of 0.12 and 0.13 µg/L (filtered and unfiltered, respectively), which are above the Hanford Site 95th percentile background value of 0.06 µg/L (for filtered samples) but below the 2 µg/L drinking water standard. Confirmation sampling is scheduled for 2012. There were no other detections of a constituent requiring confirmation sampling.

3.3.10.3 216-S-10 Pond and Ditch



The 216-S-10 Pond and Ditch (referred to as the S-10 unit) is located outside the southwestern corner of the 200 West Area (Figure 3.3-1). It consisted of an unlined ditch, 1.2 meters wide at its base and 686 meters long, connected to a pond covering 2 hectares. The pond was shaped like a backwards "E" with an extra leg, where each leg was a separate leaching trench. The ditch was also connected to the 216-S-11 Pond, which was an overflow pond to accommodate excess discharges. The site was active from 1951 through 1991 and received a total of 6.6×10^9 liters of effluent, primarily from the REDOX Plant chemical sewer.

The groundwater beneath the S-10 unit is monitored under interim status regulations to determine if dangerous waste constituents have impacted groundwater (DOE/RL-2008-61, *Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch*). The monitoring well network consists of one upgradient well (699-33-76), four downgradient wells screened in the upper part of the aquifer at the water table (299-W26-13, 299-W26-14, 699-32-76, and 699-33-75), and one downgradient well screened ~50 meters below the water table (299-W27-2). Appendix B includes a well location map (Figure B-6), a list of wells and constituents sampled for the S-10 unit (Table B-18), the critical means[1] used for 2011 (Table B-2), and the critical means for calculated for 2012 (Table B-19).

During 2011, all groundwater sampling required by the monitoring plan (DOE/RL-2008-61) was completed, although the months in which the samples were collected differed from previous years to facilitate co-sampling with CERCLA projects.

Water-Level and Well Network Evaluation. The hydraulic gradient beneath the S-10 unit was determined by trend-surface analysis using water-level measurements collected during March 2011 from six wells: 299-W26-13, 299-W26-14, 699-32-76, 699-32-77, 699-33-75, and 699-33-76. The direction of groundwater flow was calculated to be east-southeast (108 degrees azimuth) with a hydraulic gradient magnitude of 2.5×10^{-3} meter per meter. Using a hydraulic conductivity range of 2 to 42.7 meters per day (range of 14 hydraulic test results in the upper part of the aquifer at the S-10 unit, excluding the high and low values) and an assumed effective porosity range of 0.1 to 0.2, the average linear velocity was estimated to range from 0.025 to 1.1 meters per day (9.0 to 390 meters per year). Using a best hydraulic conductivity value of 10.4 meters per day (constant-rate discharge test at 299-W27-2 performed within a temporary open interval near the water table [WHC-SD-EN-DP-052, *Borehole Completion Data Package for the 216-S-10 Facility, CY 1992*]) and an assumed effective porosity of 0.15, the best-estimate average linear velocity is 0.17 meters per day (64 meters per year). The water table elevation declined an average of 0.19 meter in the monitoring wells between March 2010 and March 2011. Based on the calculated flow

[1] The critical mean is the value above which a sample result in a downgradient well would be statistically higher than background sample results from the upgradient well. Calculation of the critical mean is based on the Student's *t*-test at the 0.01 level of significance as required by 40 CFR 265.93(b), referenced by WAC 173-303-400.

direction, DOE believes the monitoring well network remains capable of detecting constituents migrating from the S-10 unit into the uppermost aquifer.

Sampling Results. Two sample results exceeded critical mean values during 2011. The December 2011 sampling of downgradient well 699-32-76 yielded a specific conductance result of 352 µS/cm (average of four replicate measurements), which exceeded the critical mean of 350 µS/cm (Figure 3.3-23). However, this exceedance was not confirmed when verification sampling was performed during January 2012 (result of 341 µS/cm). Specific conductance has been elevated in well 699-32-76 since routine sampling began in 2008. This well has slightly elevated alkalinity (bicarbonate), sulfate, nitrate (Figure 3.3-19), and the cations calcium and magnesium. Sulfate concentrations in this well have averaged 24.1 mg/L since 2009, compared to a range of ~12 to ~18 mg/L for the other network monitoring wells. All of the elevated ions are less than the 95th percentile Hanford Site groundwater background values (Table ES-1 in DOE/RL-96-61).

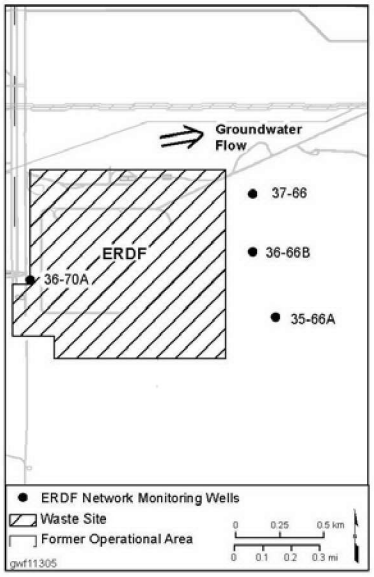
There were no confirmed exceedances of a groundwater contamination indicator parameter at the 216-S-10 Pond and Ditch during 2011. The site will remain in detection monitoring for 2012.

The May 2011 sampling of downgradient well 699-33-75 yielded a total organic halides result of 23.8 µg/L (average of four replicate sample results), which exceeded the critical mean of 17.6 µg/L. However, this result also was not confirmed. Verification sampling conducted during June 2011 yielded replicate values of 11.4 and 15.2 µg/L for laboratory split samples, both which were below the critical mean. Elevated total organic halides in this well has been attributed to carbon tetrachloride, which has been detected in several wells within the S-10 unit monitoring network. Well 699-33-75 has the highest concentrations in the network with an average of 20 µg/L during 2011, which is above the 5 µg/L drinking water standard. Carbon tetrachloride is also detected in the upgradient well, 699-33-76, at 3 to 4 µg/L. This constituent does not originate from the S-10 unit. It is widespread in the groundwater beneath and near the 200 West Area and originates from waste disposal sites at the Plutonium Finishing Plant. There were no other exceedances of an indicator parameter in the network wells. The site remains in detection monitoring for indicator parameters. Chromium at well 299-W26-13 is discussed in Section 3.3.6 and corrosion of well 299-W27-2 is discussed in Section 3.3.8.

3.3.10.4 Environmental Restoration Disposal Facility

R.L. Weiss

The ERDF is a low-level radioactive mixed waste facility used for disposal of waste from surface remedial actions on the Hanford Site. It began operations in 1996. The location of the ERDF is shown on Figure 3.3-1. The facility is currently composed of ten disposal cells, six of which were active during 2011. Each disposal cell was constructed with a double-liner system to collect leachate from natural precipitation and water added as a dust suppressant. Leachate collects in sumps beneath the cells and is then pumped to two holding tanks before being sent to the ETF for treatment. During 2011, 1,806,000 metric tons of remediation waste were disposed of at the facility.



Groundwater monitoring at the ERDF is regulated under a CERCLA ROD (EPA/ROD/R10-95/100), which states that groundwater monitoring will be conducted in accordance with RCRA regulations. The site was designed to meet RCRA standards, although it is not actually permitted as a RCRA facility.

Results of the ERDF leachate and groundwater monitoring programs are provided in annual reports. The most recent report is *Groundwater, Leachate, and Lysimeter Monitoring and Sampling at the ERDF, CY 2011* (WCH-536). A summary of the leachate monitoring and any potential impact the vadose zone might have on groundwater, as well as the groundwater monitoring results for 2011, are discussed in the following paragraphs.

Leachate Monitoring. Periodic sampling and analyses of the ERDF leachate is performed to ensure the leachate meets the ETF waste acceptance criteria and to assess whether additional analytes should be added to the routine groundwater monitoring program. The ERDF leachate was delisted as a hazardous waste in 1999, allowing the leachate to be managed as a non-hazardous waste for transfer to the ETF for treatment. To maintain the delisting status, concentrations of certain constituents in the leachate must remain below the delisting levels. These constituents (all nonradionuclides), their delisting levels, and criteria to maintain delisting status are specified in *Environmental Restoration Disposal Facility Leachate Sampling and Analysis Plan* (WCH-173).

Leachate samples are collected every year, but the analyte list alternates between an expanded list containing at a minimum all the constituents having a specified delisting level (the “long list”) and a reduced list of constituents (the “short list”). The long list is analyzed once every 2 years. Prior to performing the long-list analyses, ERDF disposal records and delisting criteria are reviewed to determine if additional analytes (from new compounds disposed to the ERDF) are required and to determine if any delisting values have changed, or if any values have been established for potential contaminants. The results of the long-list analyses are evaluated to determine if any constituent not on the short list is present at levels greater than 10 percent of an established delisting level. These constituents would then be added to both the groundwater monitoring list and routine ERDF leachate short list. The most recent long-list sampling was performed during 2010.

Analyses of leachate samples at the ERDF indicated that the leachate continues to meet the hazardous waste delisting criteria and can be treated at the ETF. The results also indicated that no additional analytes need to be added to the groundwater monitoring program.

Samples are collected from the holding tanks and represent composite samples of all the leachate collected. Leachate samples were collected in March and October 2011, and analyzed for the short list of constituents, which consists of selected metals, anions, organic compounds, and radionuclides, as well as total dissolved solids, gross alpha, and gross beta. Many of the metals showed concentration spikes in the March sampling event, but none of the results approached delisting levels. Except for lead, all of the results had returned to at or below 2010 values during the October 2011 sampling. While the lead results remained elevated in the October 2011 sample results, concentrations remained below 10 percent of the delisting level. The nitrate results for March 2011 showed a similar spike to the metals but remained below previous maximum values. The October nitrate values were the lowest in over 10 years. The other anions showed no significant fluctuations during 2011. One total dissolved solids result for March was also elevated. The spikes in the March sample results have been attributed to a low liquid level in the holding tank from which the samples were collected, and thus, some sludge may have been incorporated into the samples. There were no exceedances of a delisting level during the year, and the results of leachate sampling indicated that no additional analytes need to be added to the groundwater monitoring program.

All detected radionuclides (including uranium) declined in 2011 compared to the 2010 results, and all showed downward trends during the year. No analytical issues were noted with the 2011 analyses.

Groundwater Sampling. Groundwater monitoring at the ERDF is performed under the *Groundwater Protection Plan for the Environmental Restoration Disposal Facility* (WCH-198). The groundwater flow direction beneath the ERDF is toward the east-northeast. One upgradient well (699-36-70A) and three downgradient wells (699-37-66, 699-36-66B, and 699-35-66A) are sampled semiannually, typically in March and September. To detect impacts to groundwater quality, sample results are compared to baseline conditions established when monitoring began in 1996 using a tolerance interval approach (WCH-198). All monitoring wells were sampled successfully during 2011. Appendix B includes a well location map (Figure B-21) and lists of the wells and constituents monitored for the ERDF (Table B-43).

The results of groundwater monitoring at the ERDF continued to indicate that the facility has not affected groundwater quality.

The results of groundwater monitoring at the ERDF continued to indicate that the facility has not affected groundwater quality. Several constituents (tritium, iodine-129, nitrate, and carbon tetrachloride) are present in the groundwater near or above drinking water standards, but these constituents are elevated in both the upgradient and downgradient wells. Figures 3.2-5 and 3.2-6 in Section 3.2, and Figures 3.3-14, 3.3-15, and 3.3-16 in this section indicate that these plumes originated in the 200 West Area and have migrated toward the ERDF.

The uranium concentrations at 699-36-70A and 699-35-66A are consistent with Hanford Site background levels. Both technetium-99 and gross beta are trending downward in upgradient well 699-36-70A. The technetium-99 concentration is an order of magnitude below the drinking water standard (900 pCi/L), and gross beta is approximately one-half the drinking water standard (50 pCi/L). The only analyses indicating upward trends are technetium-99 and gross beta (impacted by the technetium-99) in downgradient well 699-35-66A. The 2011 sample results showed maximums for this well but remained below historical maximums for other nearby wells. The maximum technetium-99 result

remains ~10 percent of the drinking water standard value. Nitrate levels are decreasing in upgradient well 699-36-70A and downgradient well 699-36-66B, but the levels remain stable in downgradient wells 699-37-66 and 699-35-66A. These trends will continue to be monitored.

Barium results for downgradient well 699-37-66 remain greater than in the other monitoring wells, but are below the maximum concentrations encountered early in the monitoring program. Nitrate concentrations in this well remained more than twice the concentrations observed in the other monitoring wells and near the highest concentrations encountered in the monitoring program. However, these values are below the 226 mg/L tolerance limit and are trending downward.

All vanadium results reported in 2010 were elevated relative to previous sampling (~30 percent higher). Review of the analytical data showed no indications of issues with the analyses. A similar spike in vanadium was seen previously during August 1998. The vanadium results for 2011 trended downward from the 2010 maximum values. This constituent will continue to be monitored during 2012.
No analytical performance issues were identified during the 2011 sampling.

Table 3.3-1. Depth-Discrete Groundwater Sample Results Within the 200-UP-1 Operable Unit During 2011

Well Name and Sample Date Range	Depth Below Water Table (m)	Sample Results								
		Carbon Tetrachloride (µg/L)[a]	Trichloroethene (µg/L)[a]	Total Chromium (µg/L)[a,b]	Hexavalent Chromium (µg/L)[a,b]	Nitrate (mg/L)	Technetium-99 (pCi/L)[a]	Iodine-129 (pCi/L)[a]	Tritium (pCi/L)[a]	Uranium (µg/L)
299-W22-90	4.1	<0.12	<0.25	<3.3(?)	<3.7(?)	254	5,520	0.404	24,300	3.3
10/24/2011 – 11/3/2011	10.6	12	<0.25	38.5(?)	27(?)	14.6	727	-0.019(U)	352	1.3
	16.7	0.28	<0.25	<3.3(?)	<3.7(?)	4.43	13.7	0.067(U)	778	0.36
	22.6	16	<0.25	<3.3(?)	<3.7(?)	2.17	1.75(U)	-0.0264(U)	-86(U)	0.83
299-W22-91	4.4	39	<1.0	<3.3(?)	<2.0(?)	77.0	4,280	0.331	25,000	2.5
9/7/2011 – 9/21/2011	10.5	81	<1.0	235(?)	228(?)	226	29,100	1.16	22,000	1.6
	16.4	53	<1.0	24.3(?)	25.9(?)	24.3	1,690	0.291(U)	5,040	0.55
	22.4	5.3	<1.0	<3.3(?)	<2.0(?)	0.850	17.1(U)	0.0942(U)	596	0.34
299-W22-92	2.9	48	<1.0	<1.0(?)	<2.0(?)	54.0	5,300	0.279	6,200	1.73
6/15/2011 – 7/18/2011	9.1	55	<1.0	77.4(?)	75.6(?)	69.1	10,300	0.197(U)	10,000	0.977
	14.9	10	<1.0	<1.0(?)	<2.0(?)	18.2	2,220	-0.0349(U)	5,600	1.16
	21.3	3.7	<1.0	<1.0(?)	<2.0(?)	41.3	257	0.168(U)	8,000	0.204
299-W22-96	3.4	5.4	<1.0	1.59(?)	<2.0(?)	24.7	1,390	3.96	130,000	1.97
5/23/2011 – 5/26/2011	8.7	<1.0	<1.0	<1.0(?)	<2.0(?)	6.06	17.1(U)	2.37	1,400	0.605

a. Non-detect results are shown with the "U" qualifier for radionuclides and as less than the detection limit for nonradionuclides.

b. Total and hexavalent chromium results may not be representative of aquifer conditions; chromium concentrations can be affected by reducing conditions induced by the drilling process.

Table 3.3-2. U Plant Pump-and-Treat System Summary

Parameter	2011	Since Startup (March 1994)
Total groundwater processed, L	1,113,994	886,583,062
Mass of uranium removed, kg	0.236	220.5
Mass (activity) of technetium-99[a] removed, g (Ci)	0.24 (0.0041)	127.4 (2.17)
Mass of carbon tetrachloride removed, kg	0.234	41.4
Mass of nitrate removed, kg	734	49,201
Uranium plume area at 300 µg/L (km^2)	0.018	0.040[b]
Technetium-99 plume area at 9,000 pCi/L (km^2)	0.000	0.006[c]
System availability between 1/1/11 and 3/30/11	<50%	n/a

a. For technetium-99, grams convert to curies at a ratio of 58.7 g/Ci.

b. Area of uranium plume above 500 µg/L in 1997 (the former remedial action objective was 480 µg/L).

c. Area of technetium-99 plume above 9,000 pCi/L in 1997.

Table 3.3-3. Summary of Extended Purging of Well 299-W23-19

Sample Date	Volume of Water Treated L (gal)	Technetium-99 Concentration (pCi/L)	Activity of Technetium-99 Removed (Ci)	Mass of Technetium-99 Removed (g)
4/7/11	4,679 (1,236)	51,000	2.4×10^{-4}	0.014
6/20/11	5,035 (1,330)	43,000	2.2×10^{-4}	0.013
8/31/11	4,164 (1,100)	46,000	1.9×10^{-4}	0.011
12/13/11	6,435 (1,700)	40,000	2.6×10^{-4}	0.015
Totals	**20,313 (5,366)**	**N/A**	**9.0×10^{-4}**	**0.053**
Totals since startup*	**177,972 (47,016)**	**N/A**	**1.1×10^{-2}**	**0.626**

* Totals for all quarterly events since startup of extended purging in March 2003.

N/A = not applicable

Figure 3.3-1. Facilities and Groundwater Monitoring Wells in the 200-UP-1 Operable Unit

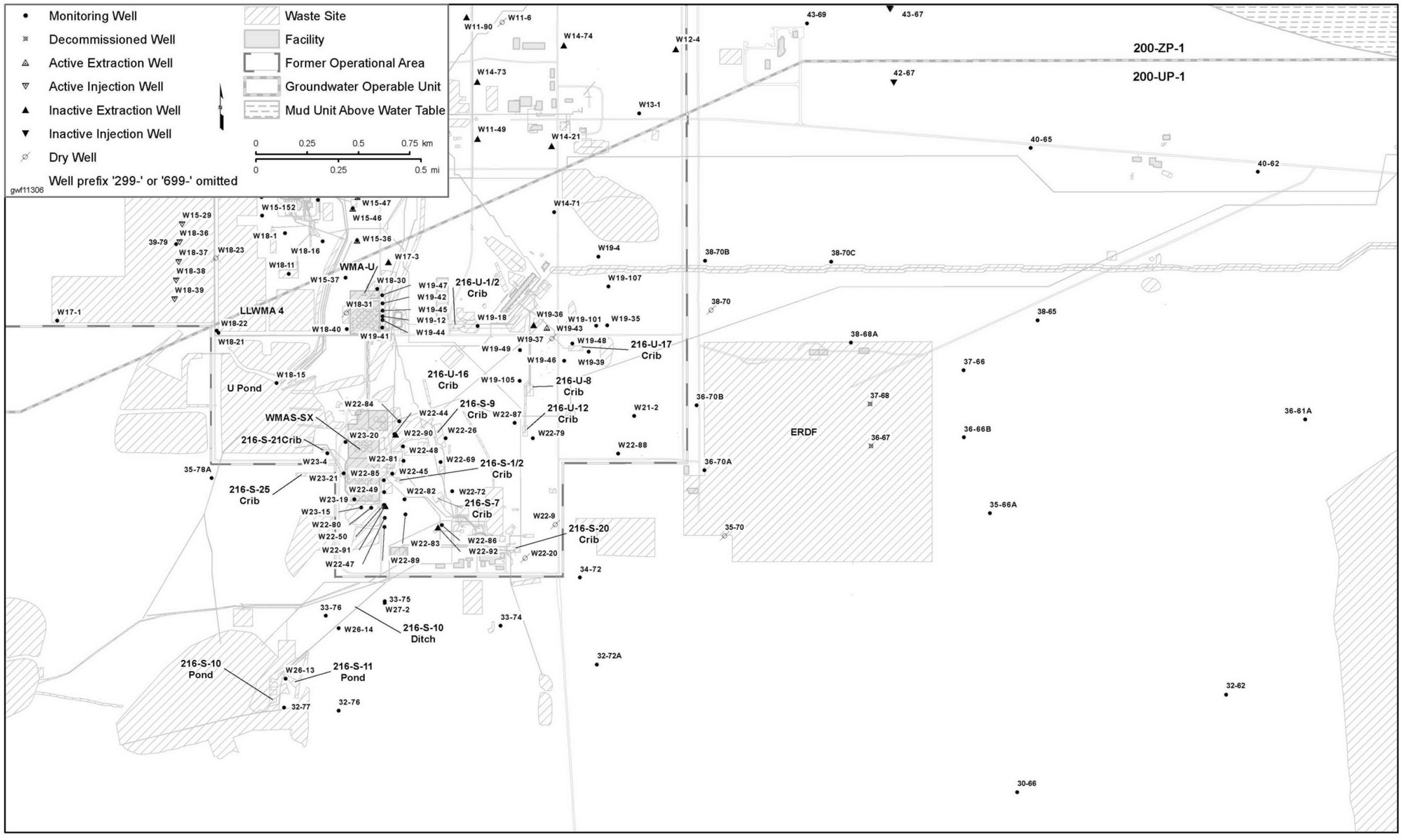


Figure 3.3-2. Water Table Map for the 200-UP-1 Groundwater Interest Area, March 2011

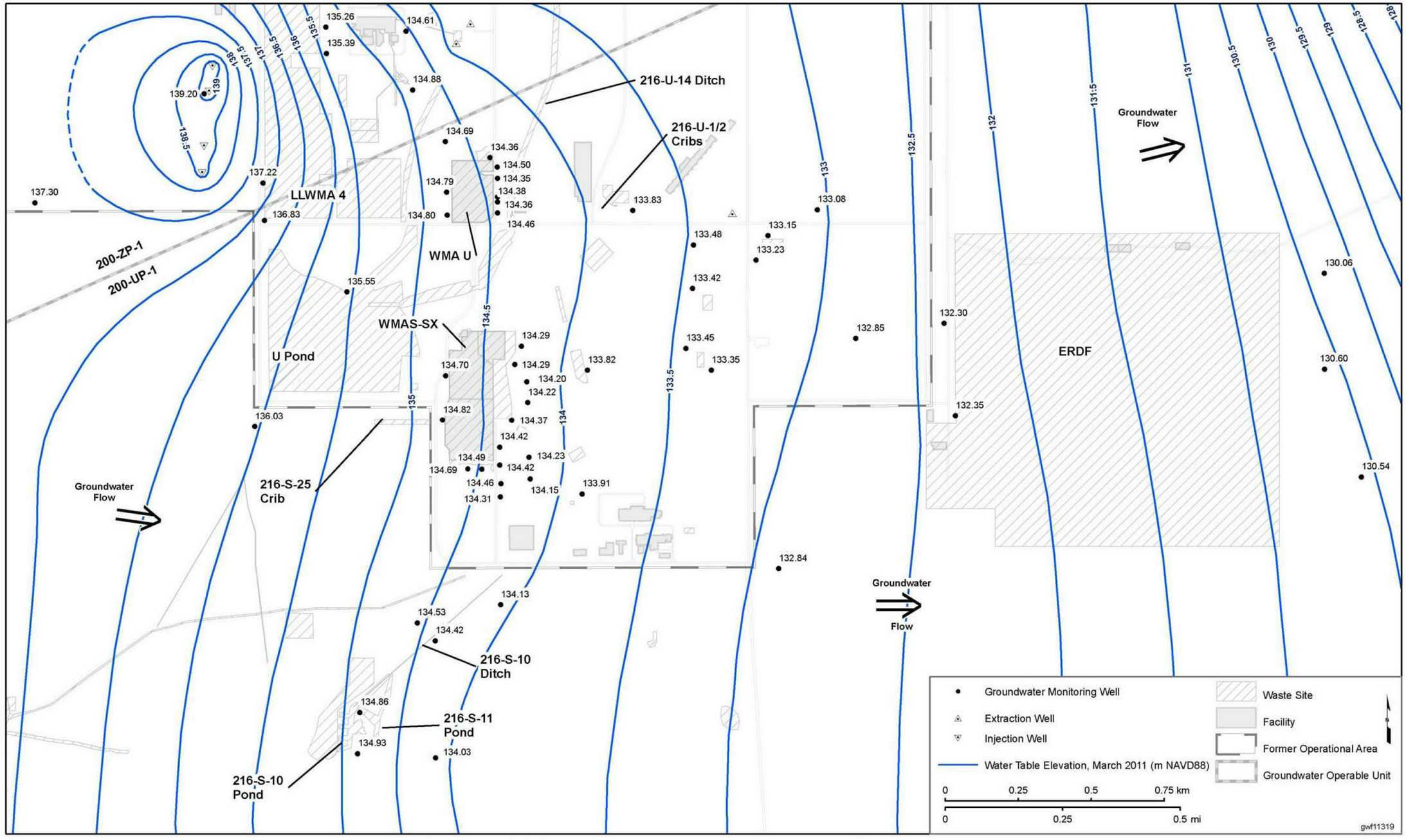


Figure 3.3-3. Average Technetium-99 Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer

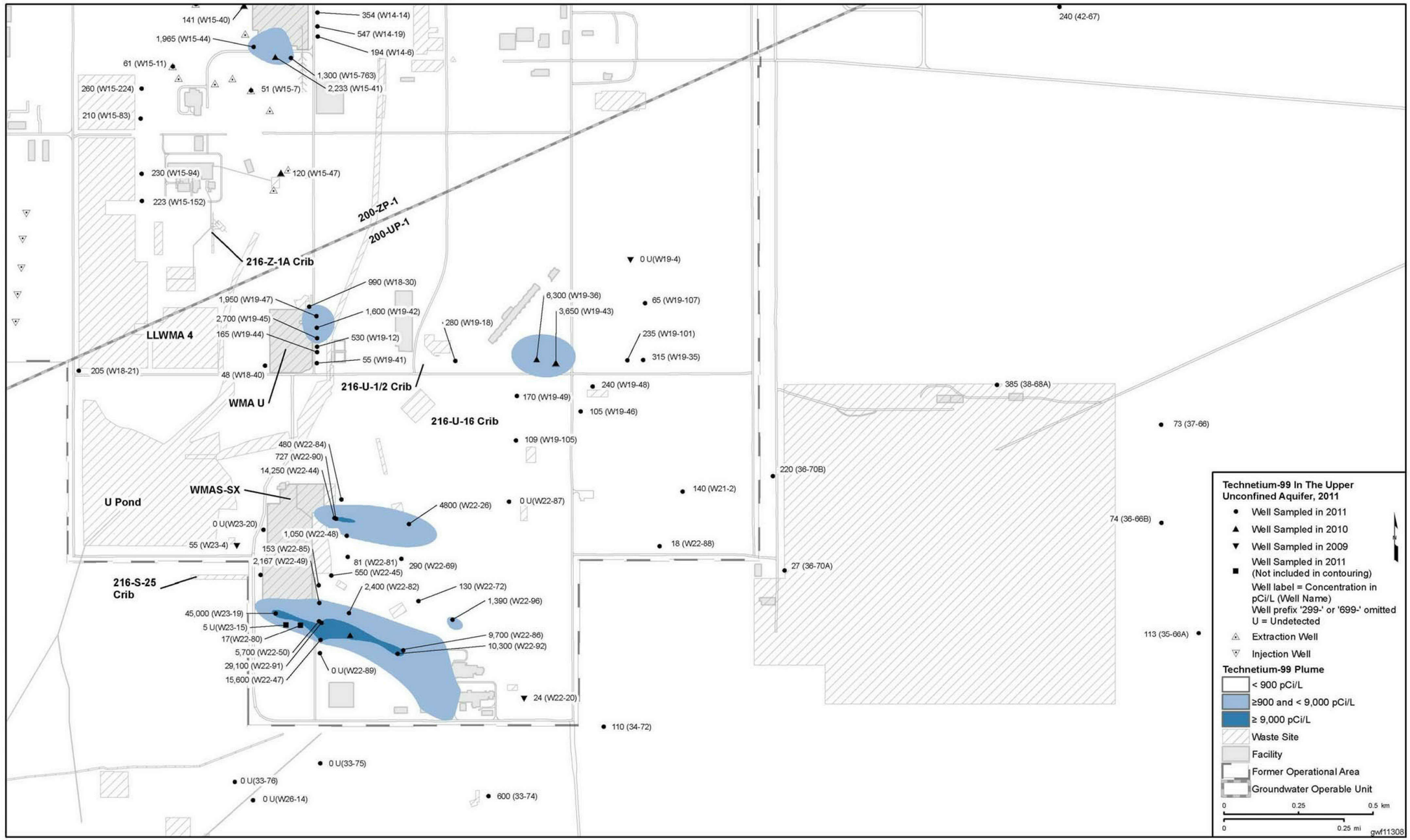


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Figure 3.3-4. Contaminant Concentrations in Well 299-W23-19, Southern Portion of Waste Management Area S-SX

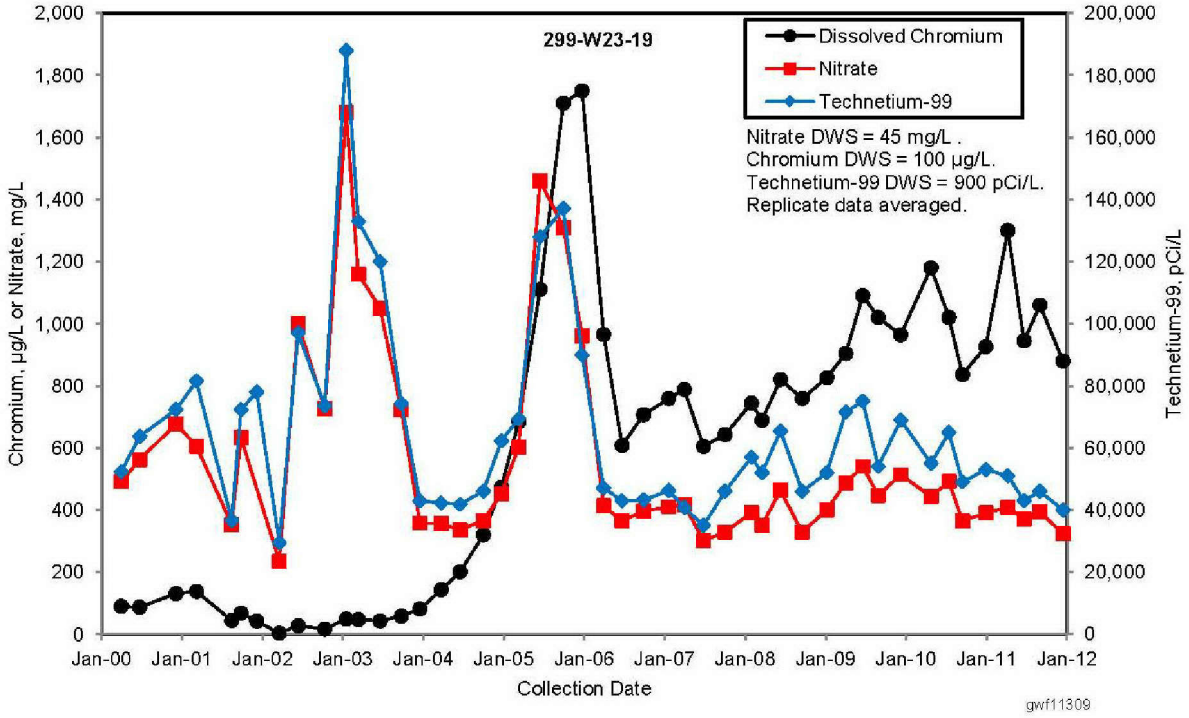

Figure 3.3-5. Vertical Profile Sampling Results at 299-W22-91, Downgradient from the SX Tank Farm

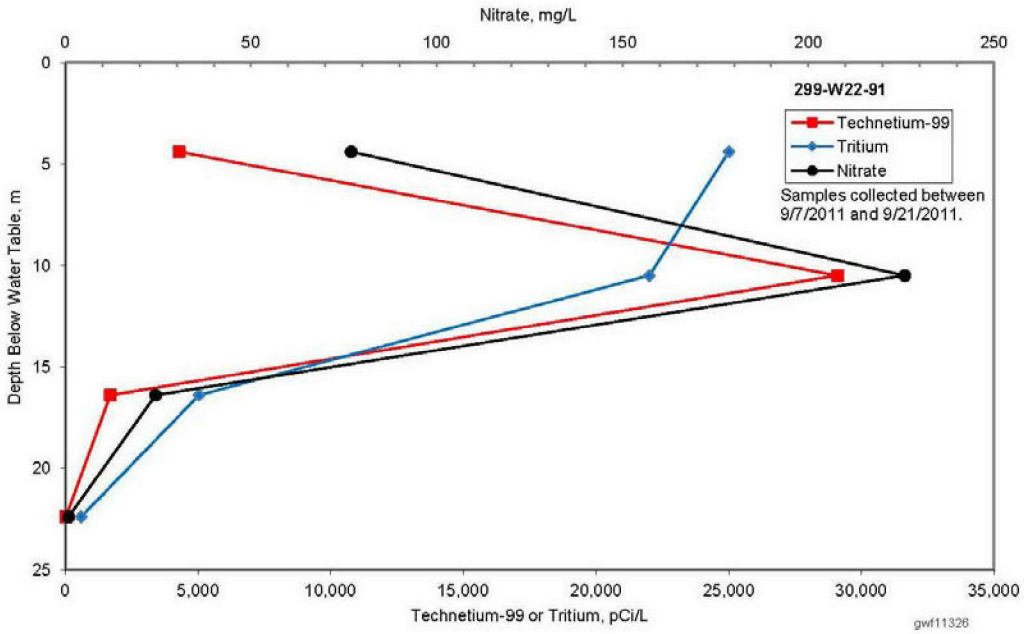

Figure 3.3-6. Vertical Profile Sampling Results at 299-W22-92, Downgradient from the SX Tank Farm

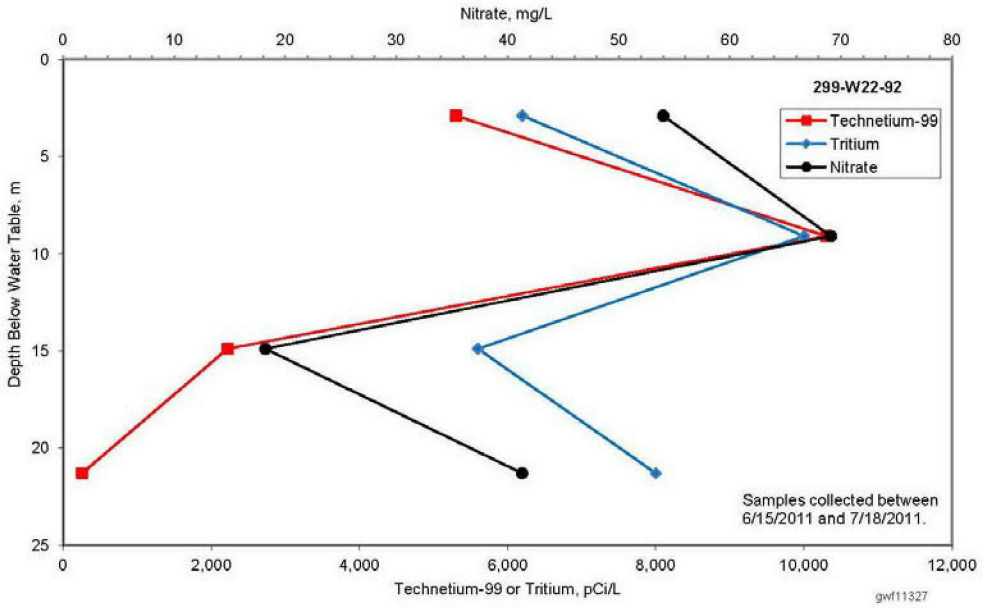

Figure 3.3-7. Contaminant Concentration Trends in Well 299-W22-44, Downdgradient from S Tank Farm

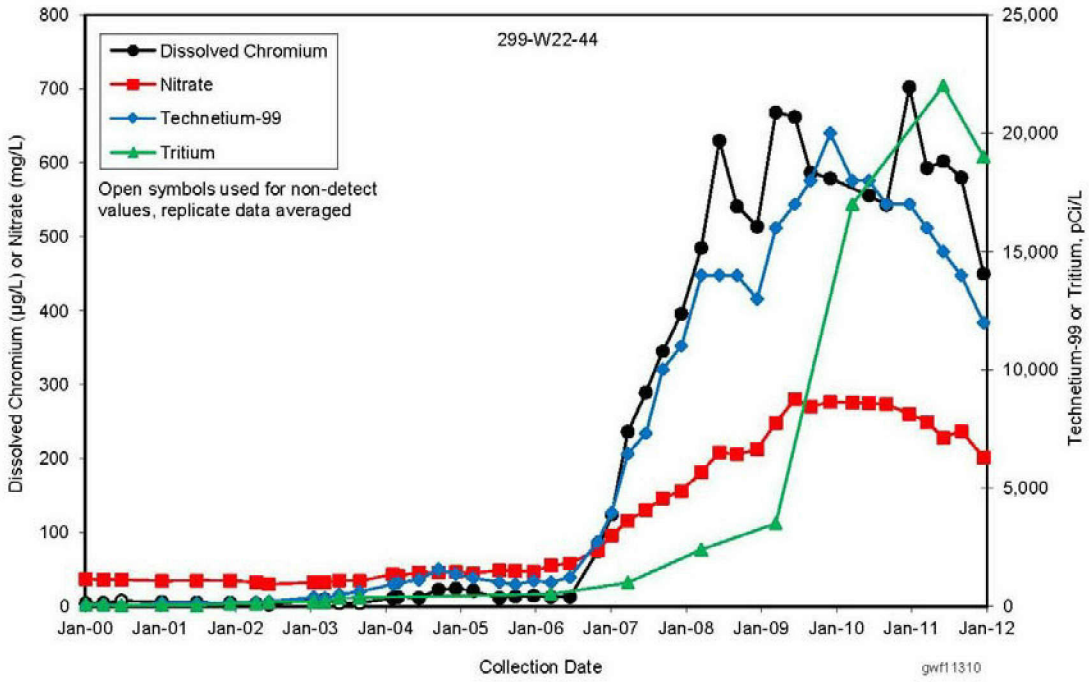

Figure 3.3-8. Contaminant Concentrations in Well 299-W22-44, Downgradient from the S Tank Farm

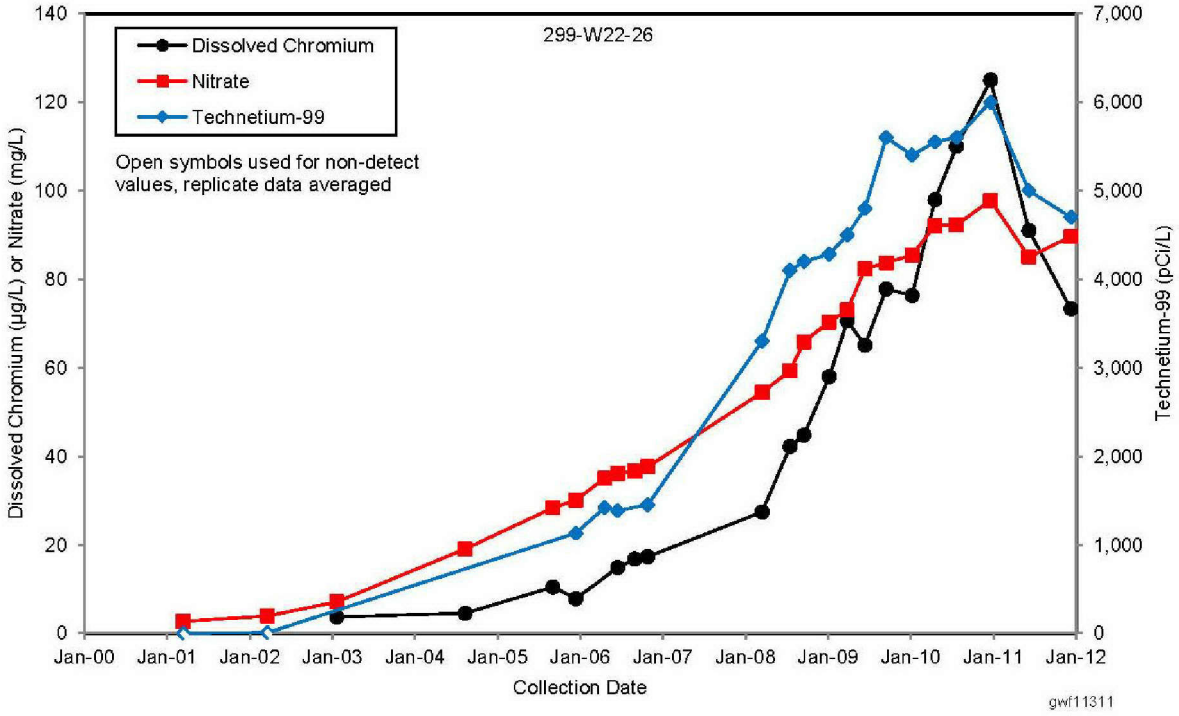

Figure 3.3-9. Technetium-99 Trend at Well 299-W22-48, Downgradient from S Tank Farm

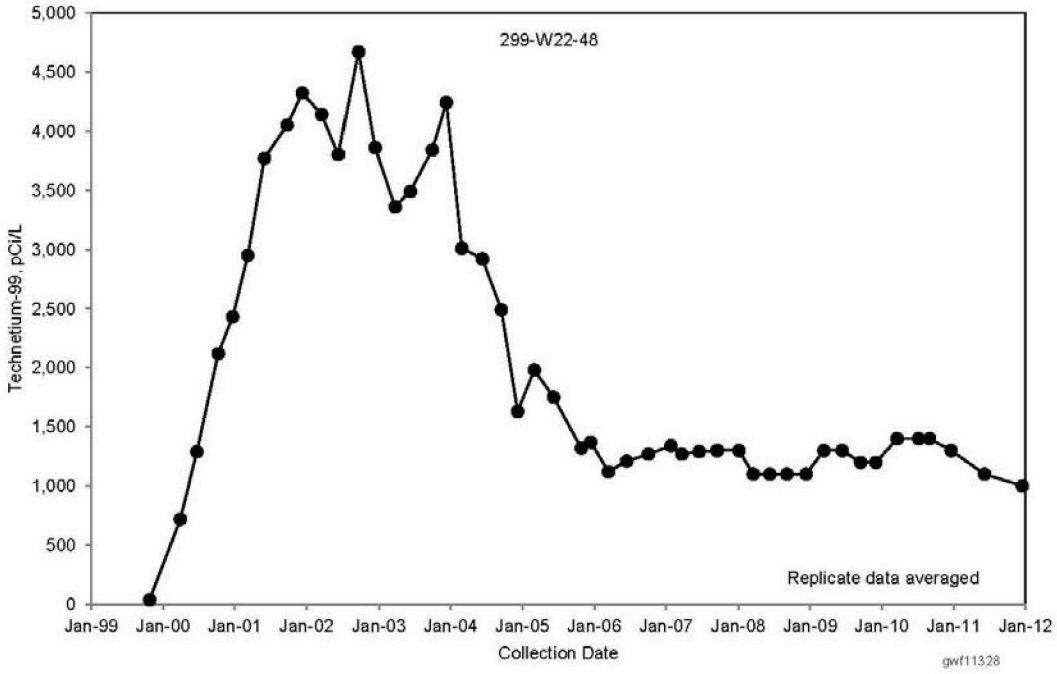

Figure 3.3-10. Vertical Profile Sampling Results at 299-W22-90, Downdgradient from S Tank Farm

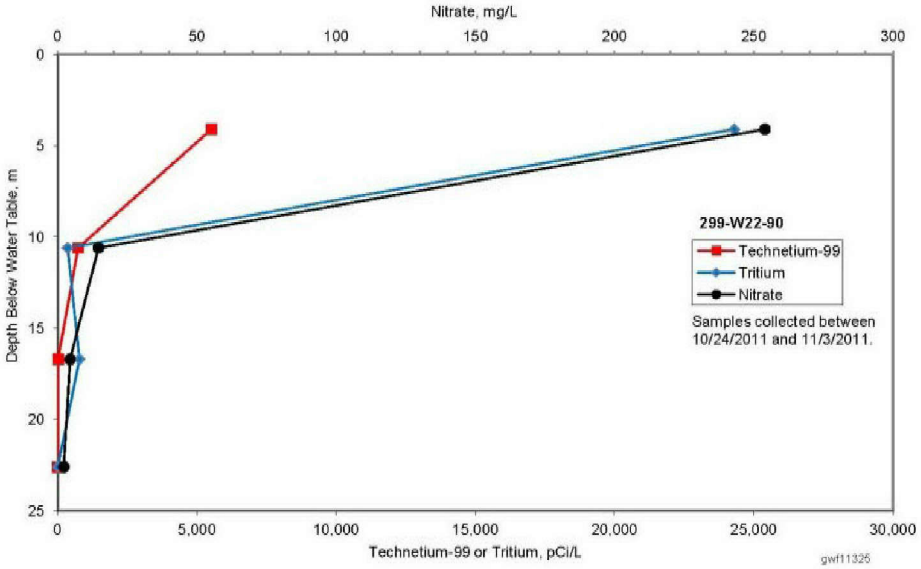

Figure 3.3-11. Technetium-99 Concentrations in Selected Downgradient Wells at the U Tank Farm

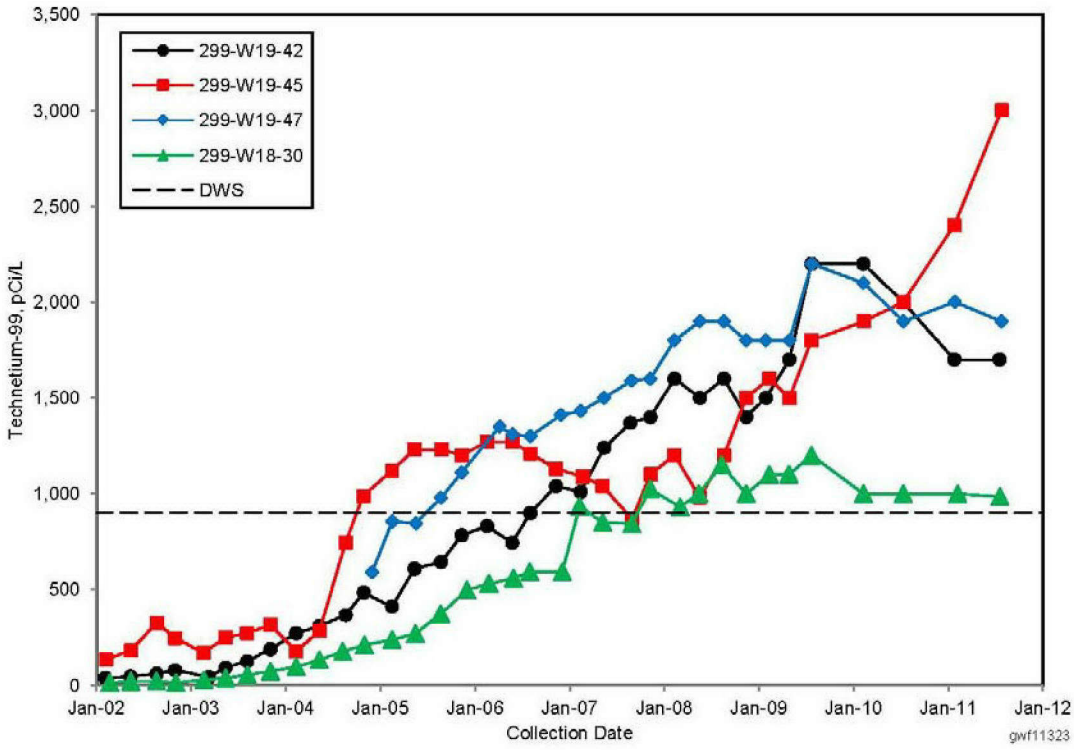

Figure 3.3-12. Trends in the Areal Extent of the Major 200-UP-1 Contaminant Plumes

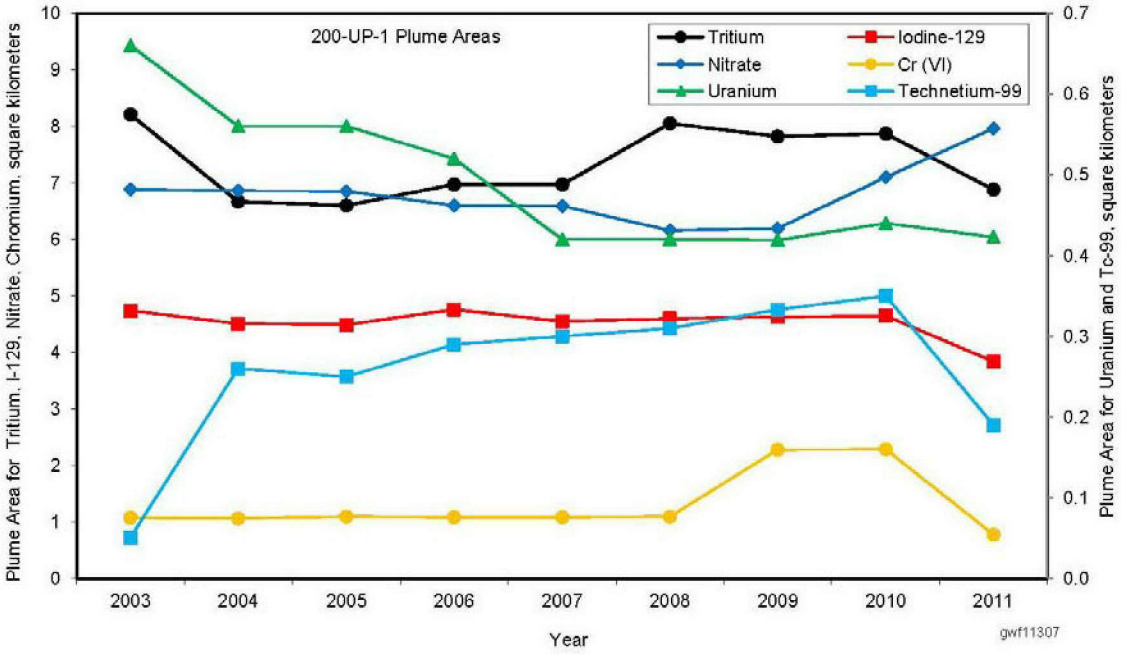

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Figure 3.3-13. Average Uranium Concentrations in the 200-UP-1, Upper Part of Unconfined Aquifer, 2011

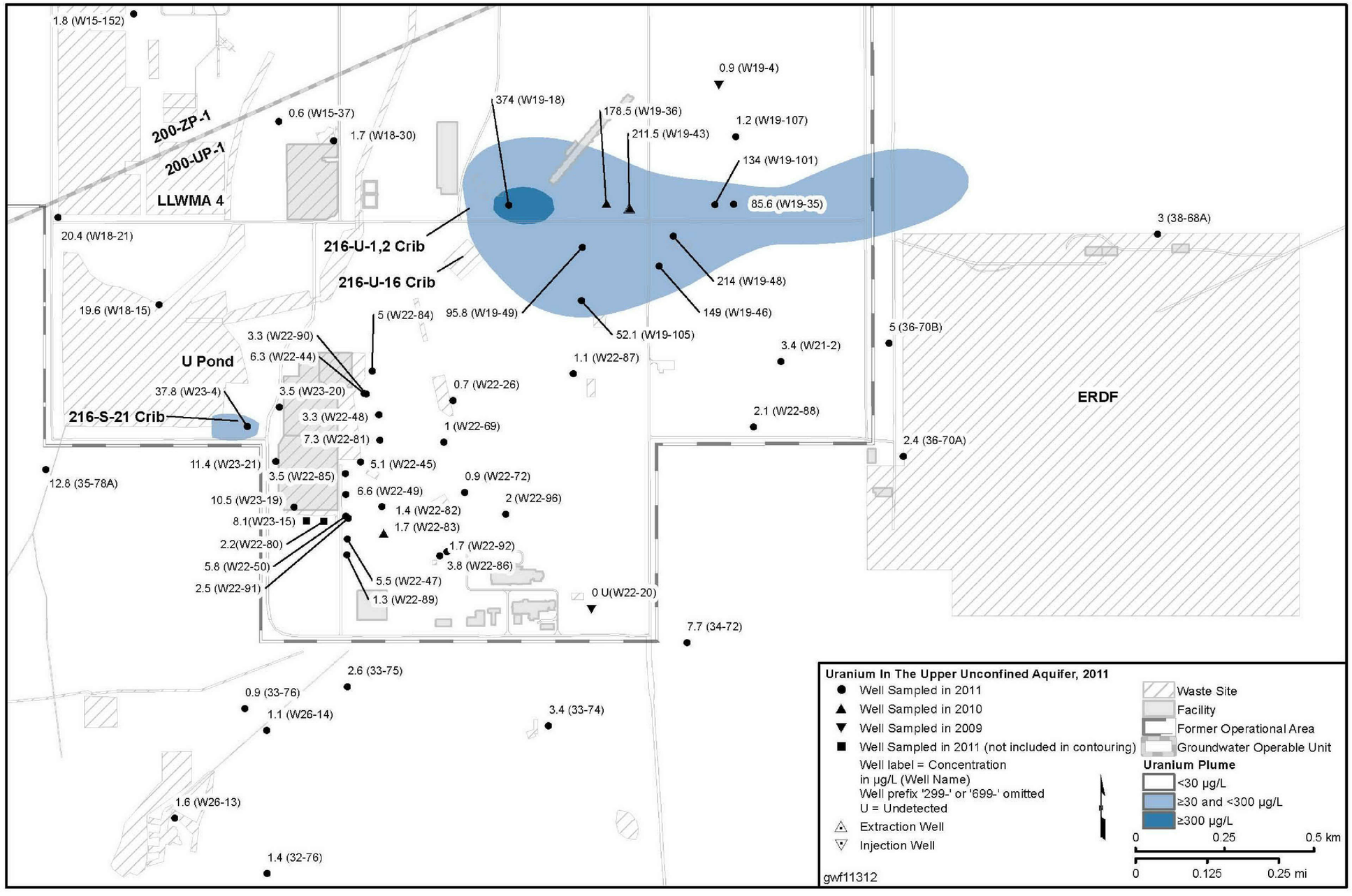

Figure 3.3-14. Average Tritium Concentrations in 200-UP-1, Upper Part of Unconfined Aquifer, 2011

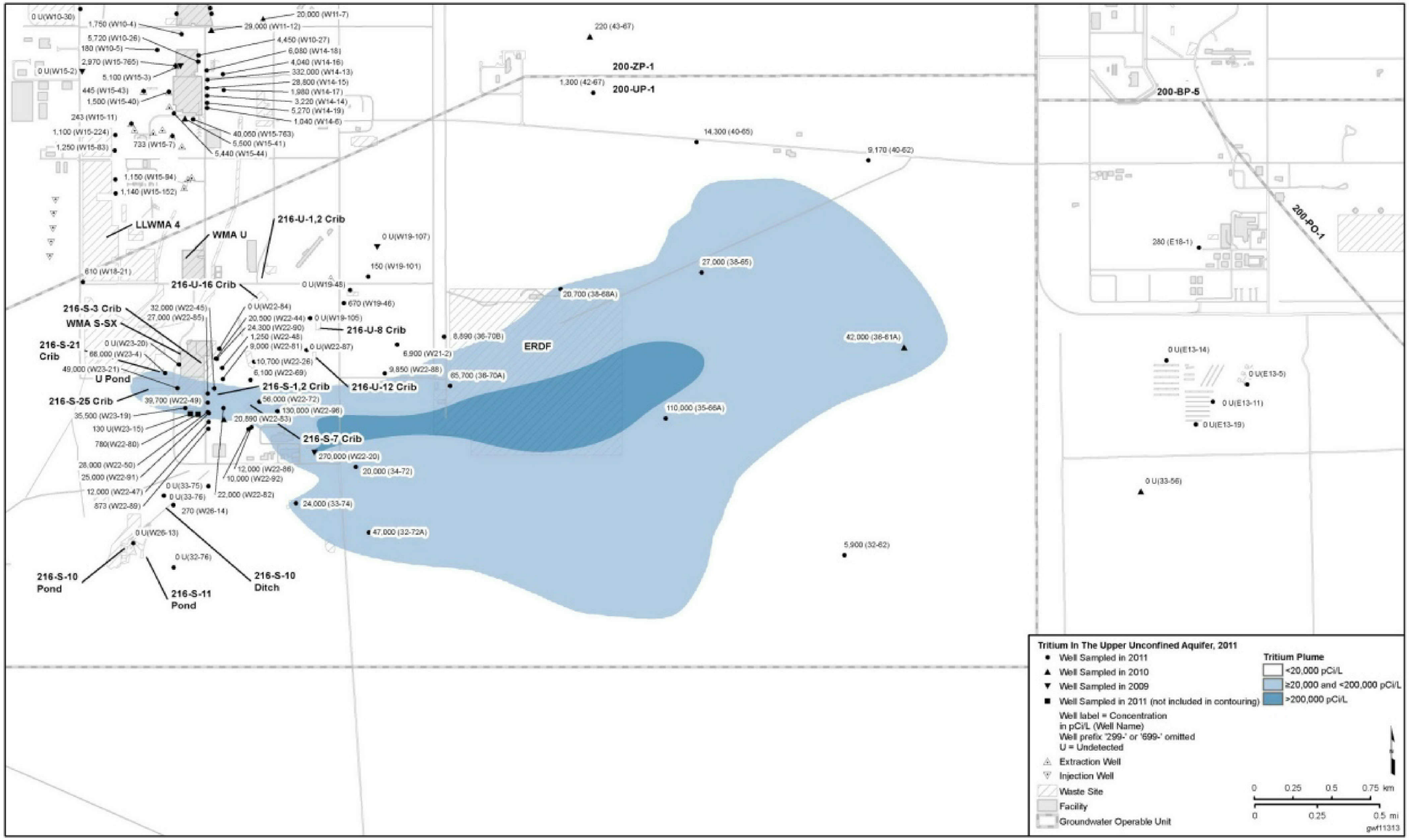

Figure 3.3-15. Average Iodine-129 Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer

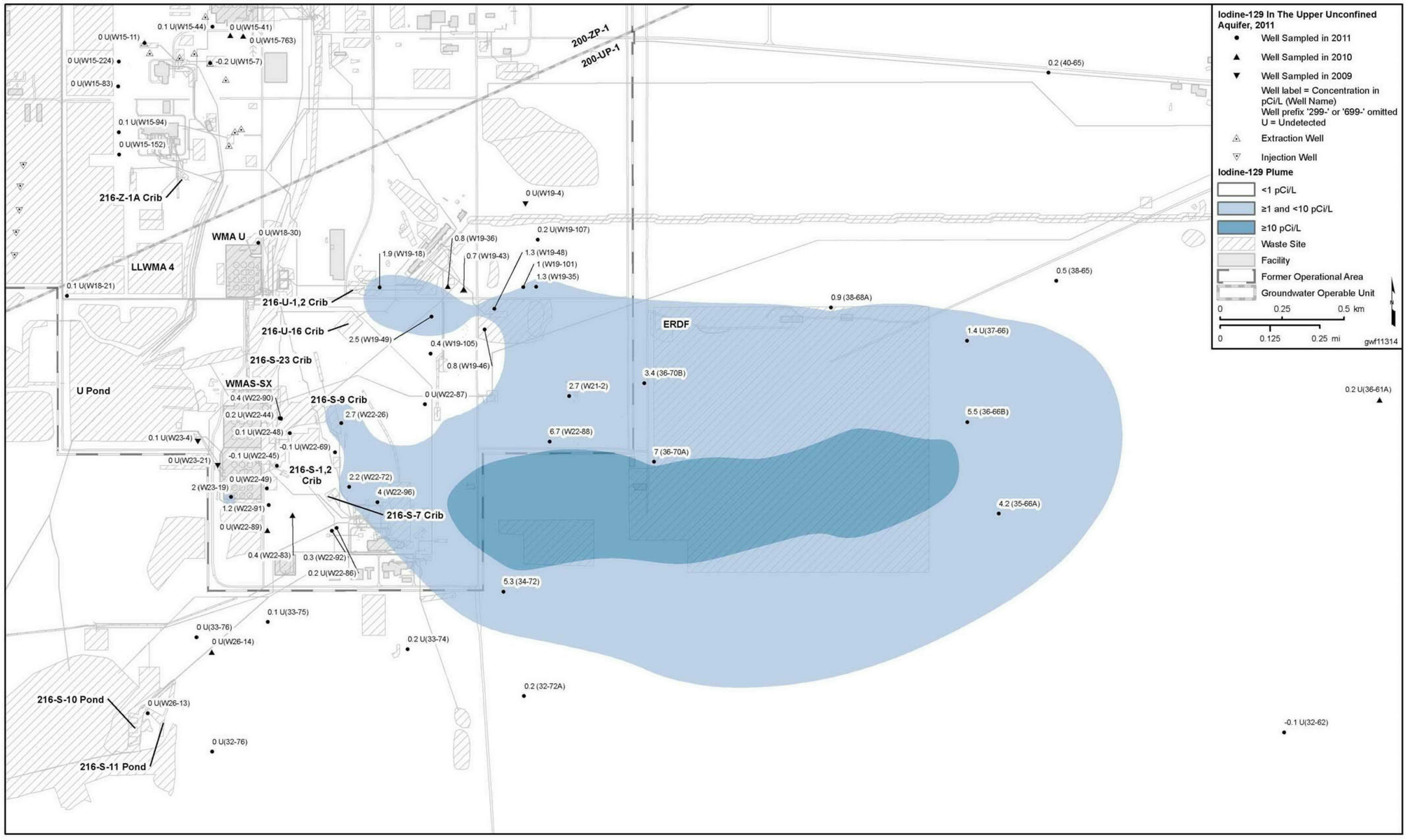

Figure 3.3-16. Average Nitrate Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer

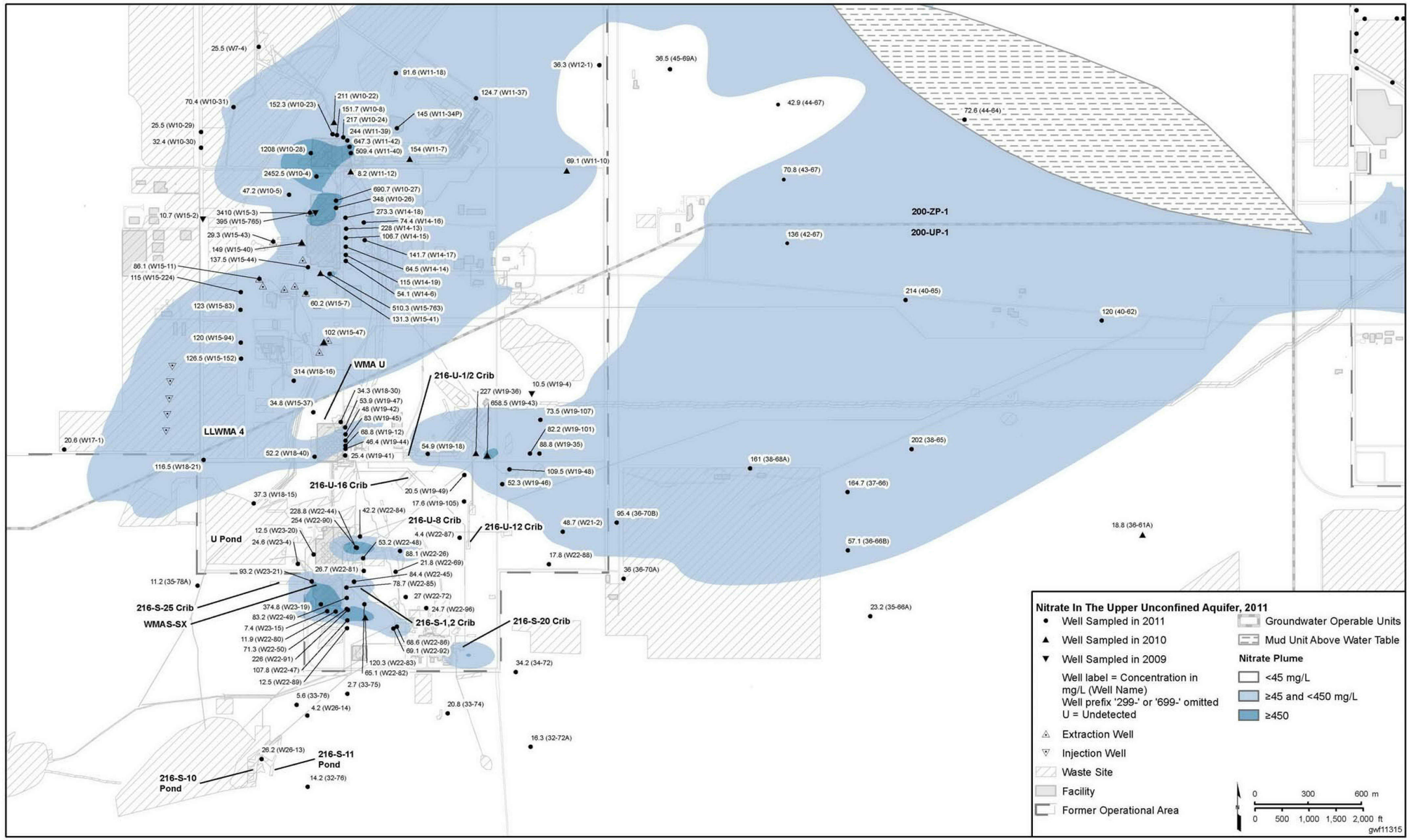

Figure 3.3-17. Average Chromium Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer

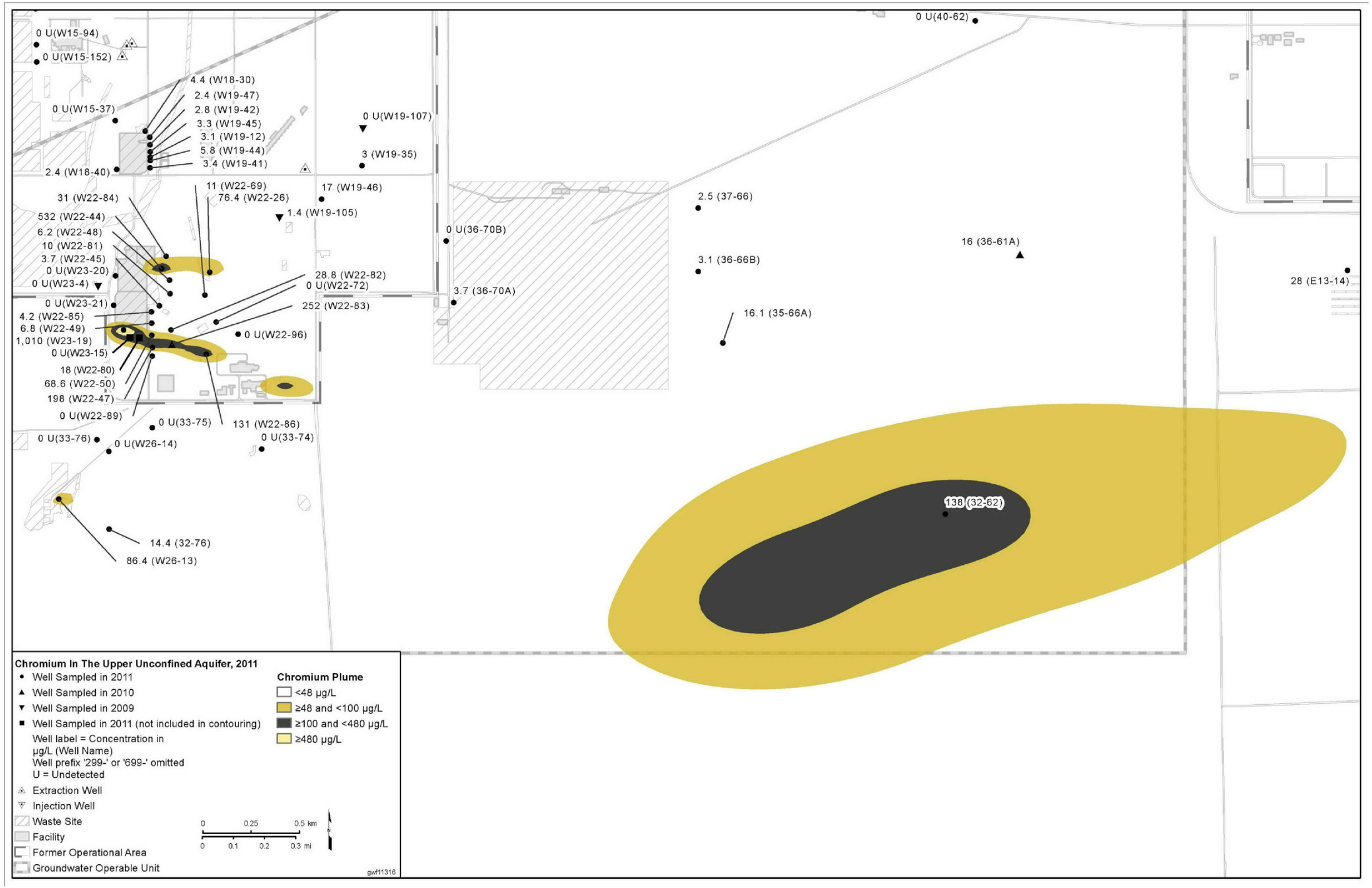

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Figure 3.3-18. Chromium and Manganese Concentrations at 699-30-66, Southeast of the 200 West Area

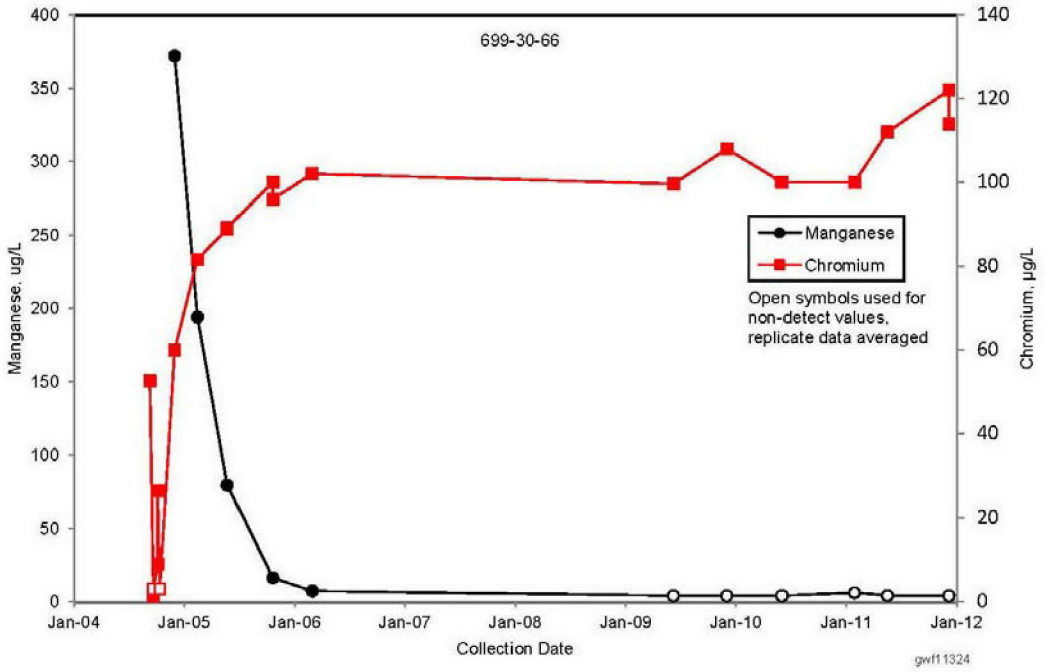


Figure 3.3-19. Chromium and Nitrate Concentrations in Wells 299-W26-13 and 699-32-76 at the 216-S-10 Pond and Ditch

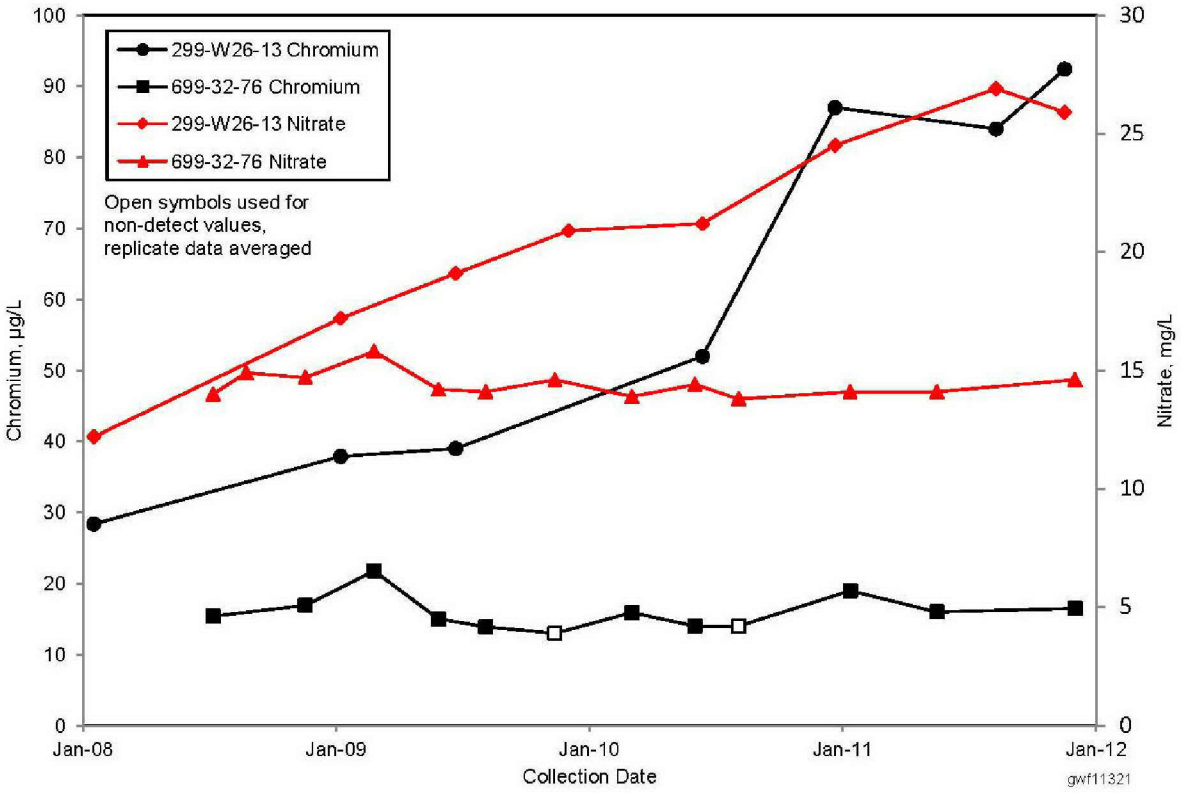


Figure 3.3-20. Chromium, Iron, and Nickel Concentrations in Well 299-W27-2 at the 216-S-10 Pond and Ditch

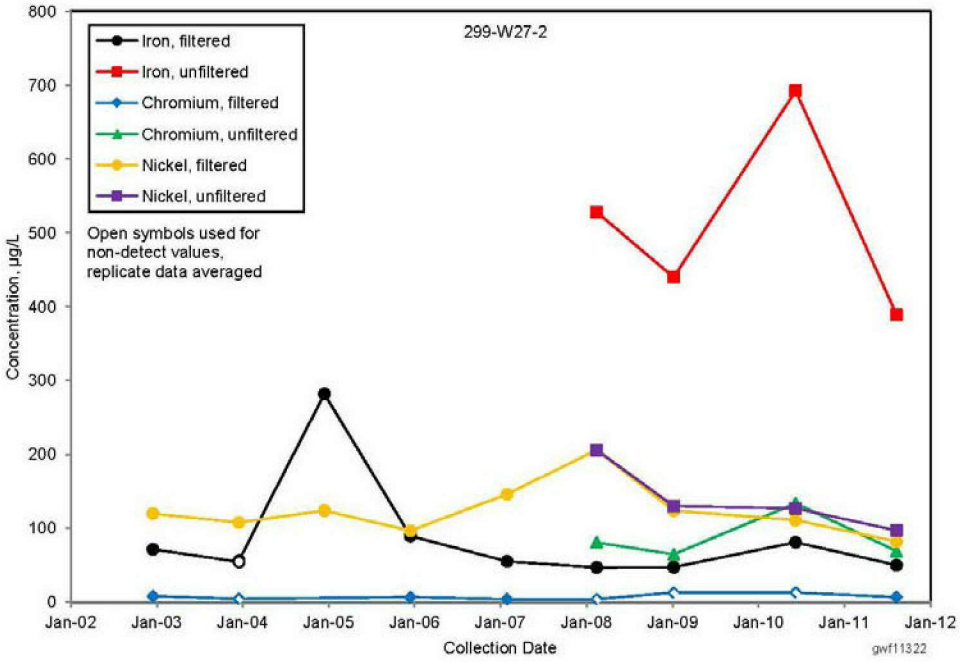


Figure 3.3-21. Cumulative Volume of Water Treated and Mass/Activity of Contaminants Removed from the Aquifer by the U Plant Pump-and-Treat System

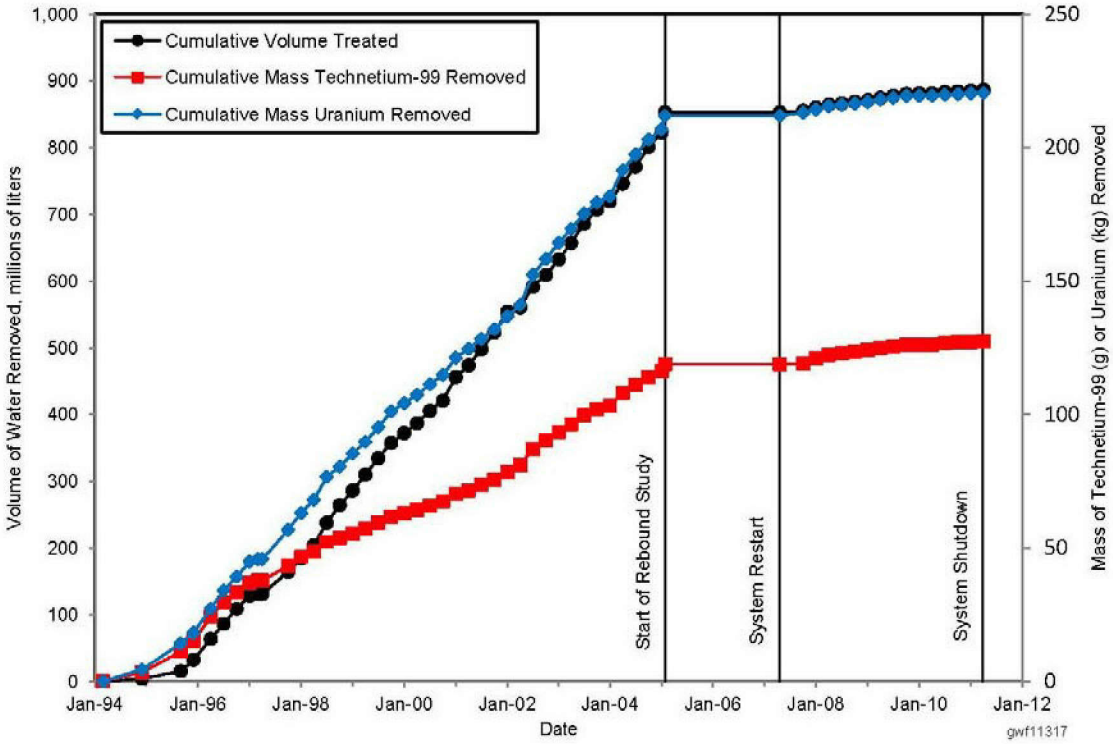


Figure 3.3-22. Areal Extent of the Uranium and Technetium-99 Plumes at Concentrations above Interim Remedial Action Objectives at the U Plant Pump-and-Treat System

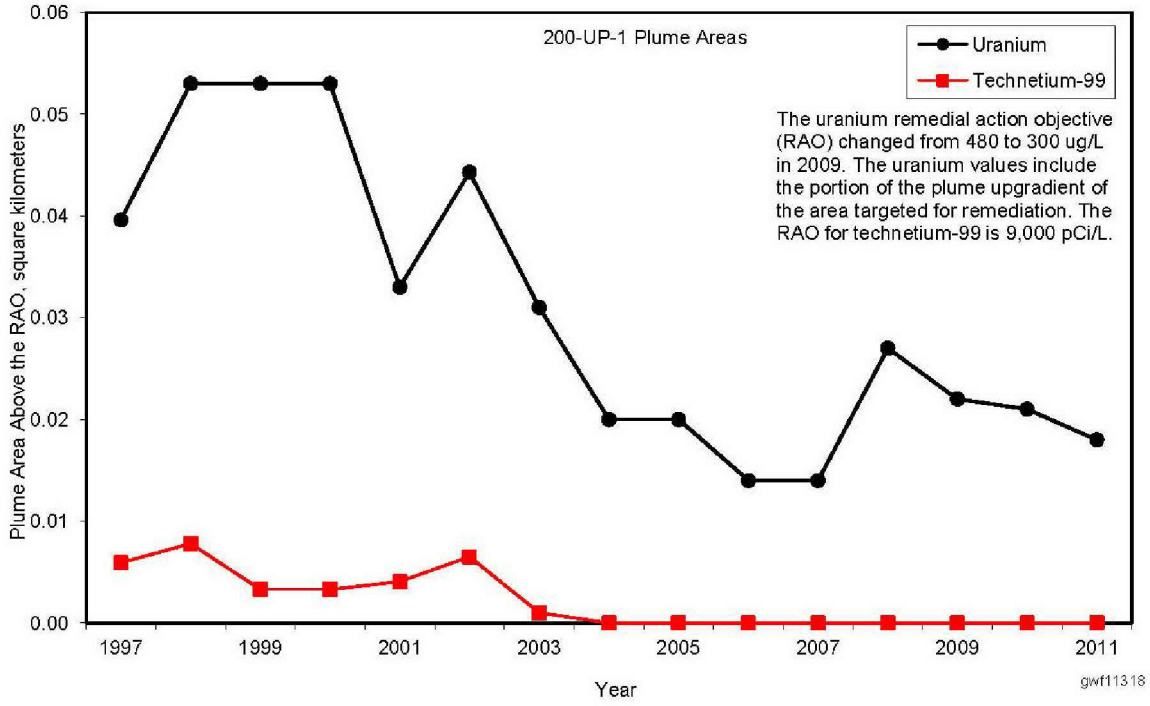
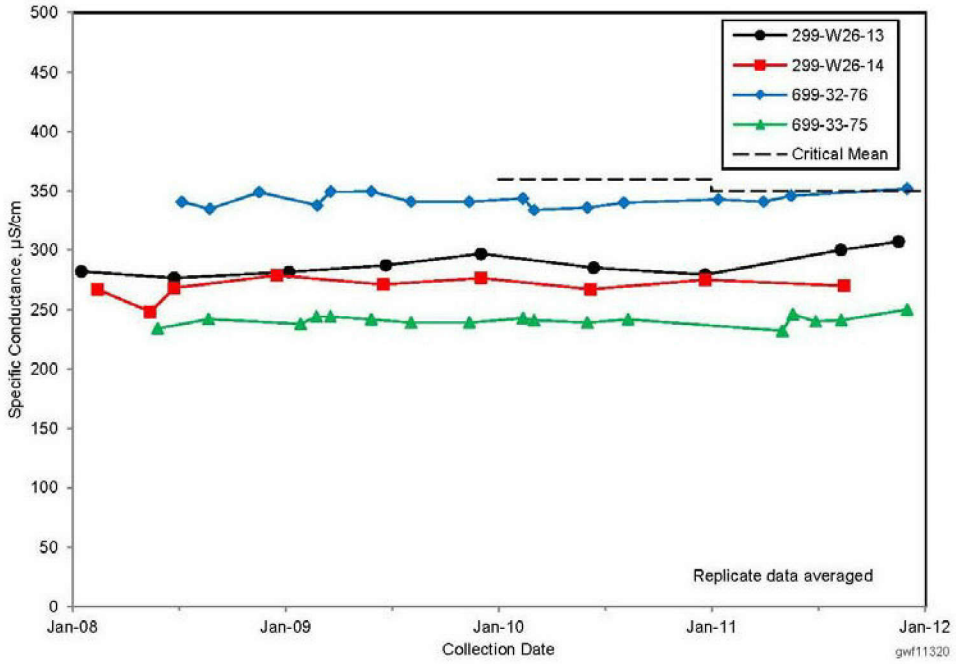


Figure 3.3-23. Specific Conductance in Selected 216-S-10 Pond and Ditch Groundwater Monitoring Wells



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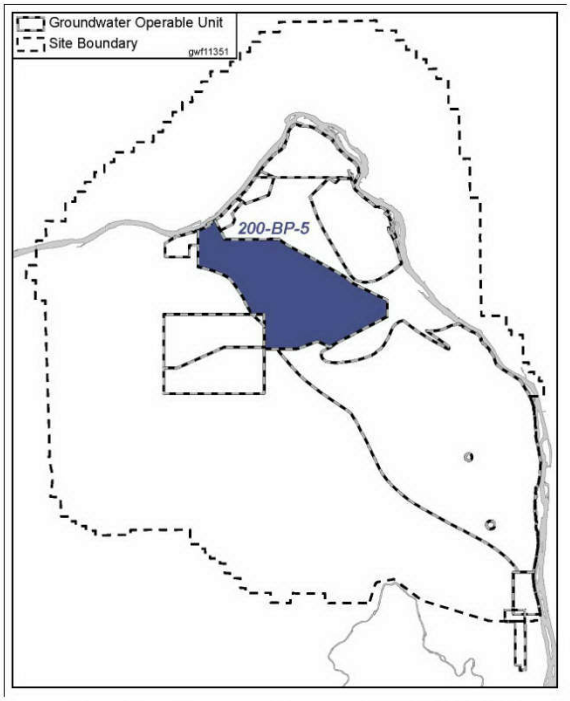
3.4 200-BP-5

G.S. Thomas



This section describes the groundwater flow and contaminant distribution in 200-BP-5, which includes the north portion of the 200 East Area and adjacent 600 Area. The 200-BP-5 area within the adjacent 600 Area extends eastward to the east end of Gable Mountain, then northwest to the Columbia River between interest areas of 100-BC and 100-K. Finally, the 200-BP-5 area is closed by a line extending back to the 200 East Area through the Gable Butte/Gable Mountain Gap (Gable Gap). Figures 3.4-1 and 3.4-2 identify the waste sites, waste management units, and wells in the 200 East Area and 600 Area portions of the interest area. Currently, there are84 routinely sampled wells located south of the Gable Gap (near major sources of groundwater contamination) considered near-field 200-BP-5 wells. Eight additional routinely sampled wells located north of Gable Gap are considered far-field wells.

DOE monitors groundwater in 200-BP-5 to track local and regional contaminant plumes associated with past-practice sites in accordance with CERCLA and the AEA. The current monitoring is in association with the RI/FS process until final cleanup decisions are made. A ROD has not yet been prepared. Ninety-two wells are routinely monitored for CERCLA in accordance with *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit* (DOE/RL-2001-49). An additional 15 wells were added in accordance with the *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2007-18). The main CERCLA sites that have contributed or are currently contributing to groundwater contamination in 200-BP-5 include:

- 216-A-25 Pond (Gable Mountain Pond)
- 216-B-2-2 Ditch
- 216-B-5 Injection Well
- 216-B-12 Crib
- BY Cribs and other proximal waste sites (216-B-7A&B and 216-B-8 Cribs)

In addition, the monitoring network is supplemented by 76 wells associated with sites that are monitored in accordance with RCRA Plans. Forty-six of the 76 RCRA wells are sampled for both CERCLA and RCRA requirements. The RCRA sites in 200-BP-5 include:

- Single-shell tank farms at WMA B-BX-BY and WMA C
- 216-B-63 Trench
- LERF
- LLWMAs-1 and 2

Two of these sites, WMA B-BX-BY and WMA C, have impacted groundwater quality and are in assessment monitoring. Twenty-six wells are also monitored for AEA requirements at LLWMA-1 and

2 in accordance with DOE/RL-2000-72. All 26 of the AEA wells are also sampled for RCRA requirements and 20 are also sampled for CERCLA requirements.

A detailed discussion of the geology and hydrogeology within the 200-BP-5 Operable Unit is provided in DOE/RL-2007-18. The following summarizes key characteristics of the aquifer and flow characteristics.

The geology within 200-BP-5 consists of sediments of the Hanford formation and Ringold Formation overlying the Saddle Mountains Basalt. The uppermost basalt member of the Saddle Mountains Basalt is generally the Elephant Mountain Member. This member defines the base of the unconfined aquifer, with the exception of the Gable Gap and area further north. In the Gable Gap area, portions of the Elephant Mountain, Pomona, Esquatzel, and Asotin members of the Saddle Mountains Basalt were removed by erosion, exposing and interconnecting the lower permeability Rattlesnake Ridge and Selah interbed hydraulic units to the unconfined aquifer. An excellent cross section of this area is provided in Figure E-5 and E-10 in Appendix E. Groundwater elevations in the interbeds are higher than the overlying unconfined aquifer water table, indicating an upward hydraulic gradient and flow regime. Therefore, groundwater contamination migrating north of the 200 East Area is constrained to the unconfined aquifer within the highly permeable Hanford formation. North of Gable Gap, a high-angle reverse fault shifted basalt upward across the Ringold Formation lower mud, which defines the base of the unconfined aquifer north of the fault.

200-BP-5 at a Glance

B Plant Operations:	**1945–1952 (Plutonium separation)** **1967–1985 (Strontium and Cesium recovery)**		
2011 Groundwater Monitoring			
Contaminant	**Drinking Water Standard**	**Maximum Concentration[a]**	**Plume Area[b] (km^2)**
Nitrate	45 mg/L	1,700 mg/L	7.2
Iodine-129	1 pCi/L	6.8 pCi/L	6.4
Technetium-99	900 pCi/L	36,500 pCi/L	2.4
Uranium	30 µg/L	2,420 µg/L	0.85
Strontium-90	8 pCi/L	4,400 pCi/L	0.27
Cyanide	200 µg/L	1,500 µg/L	0.24
Tritium	20,000 pCi/L	39,000 pCi/L	0.21
Remediation			
B Complex perched aquifer pump-and-treat (treatability test): • Being performed by the 200-DV-1 Operable Unit • Test successful; ~90,000 liters pumped in 2011 Final action 200-BP-5 record of decision scheduled for 2016			

a. Maximum concentration within the regional unconfined aquifer (i.e., excludes the perched aquifer beneath the B Complex).

b. Estimated area above listed drinking water standard.

The unconfined aquifer is mainly contained within moderate to low-permeability Ringold Unit A (hydraulically subdivided into units 9A, 9B, and 9C as explained in Appendix E) sediments along the southwestern boundary of the Operable Unit. The Ringold sediments extend from the southerly portion of the LLWMA-1, east of B Plant near well 299-E28-6, and into the 200-PO-1 OU as defined in PNNL-12261 (plate maps 3, 4, and 5). Two 200-BP-5 RI wells were drilled through the Ringold Formation to basalt near B Plant in CY 2010. Based on these wells, the aquifer thickness in this area is ~18.3 meters and it lies entirely within the Ringold Formation.

North and east of this area, cataclysmic flooding eroded some to all of the Ringold Formation sediments and deposited sediments of the Hanford formation. As a result of past folding of the underlying basalts, the aquifer thins to the north-northeast. Along the northern boundary of the 200 East Area, the aquifer becomes very thin or is absent. East of the 200 East Area, the Ringold sediments are again present throughout the aquifer. Most of the sediments east of the 200 East Area are comprised of the Ringold lower mud unit. This unit creates a semiconfined aquifer where it overlies the silty, sandy, gravelly Ringold Unit A and the Elephant Mountain Basalt. The Ringold lower mud unit is mainly the only saturated unit that extends north to Gable Mountain, and groundwater contaminants are generally west of

this unit. An exception is beneath both the Gable Mountain Pond and B Pond, where a few contaminants still reside.

The saturated glaciofluvial Hanford formation and/or Cold Creek units are deposited in an eroded channel between the Ringold Formation sediments discussed above (i.e., to the east and west). Some remnant Ringold Formation sediments are present within paleochannels north of the 200 East Area, as discussed in PNNL-19702. The saturated Hanford sediments are thickest within the southerly portion of the operable unit and thin as the sediments extend to the northwest toward Gable Gap. Previous folding of the underlying basalts causes the aquifer to thin to apparently a couple meters or less between the 200 East Area and Gable Gap. The saturated Hanford sediment extending northwest of the 200 East Area is the primary groundwater flow path from the northwest portion of the 200 East Area to Gable Gap. It is worth noting that the more permeable Hanford sediments are juxtaposed with the remnant Ringold Formation paleochannel sediments. Groundwater contaminants migrate primarily within the more permeable Hanford sediments as opposed to the Ringold sediments. The thinnest part of the saturated Hanford sediments is thought to be northwest of well 699-49-57A (Figure 3.4-2). A cross section of this area is provided on Figure A.5 of PNNL-19702; the primary flow path is shown between wells 699-50-59 and 699-50-56 on Figure A.5. Geophysical methods have been used in this area, but the aquifer thickness remains uncertain.

In the 200 East Area, groundwater flows into 200-BP-5 from the southwest (Figure 3.4-3). A groundwater divide is assumed to be located near the boundary between 200-BP-5 and 200-PO-1. Flow entering north of the divide flows north and northwest towards the Gable Gap, while south of the divide groundwater flows northeast-east. Flow in the northeast part of the 200 East Area also appears divided, with groundwater near the west part of the LLWMA-2 flowing west and northwest towards WMA B-BX-BY. Near the east part of LLWMA-2, flow appears to be south. Occasionally, this flow regime is disrupted by high Columbia River spring stages. The first disruption occurred in 2008-2009 when a flow reversal was observed in the northwest corner of the 200 East Area (DOE/RL-2008-66). Another disruption in the northwest corner of the 200 East Area occurred in 2011. Flow began to change from northwest to south-southeast in June 2011. By August 2011, a statistically significant gradient to the south-southeast was measured (Figure 3.4-4). The south-southeast flow direction was maintained through the remainder of the year. This reversal was also visible by the change in groundwater contaminant concentrations beneath the WMA B-BX-BY and BY Cribs, discussed further in Sections 3.4.1.1, 3.4.3.1, 3.4.4.1, and 3.4.6. Gradient declines were observed in December, initiating a probable return to prior flow conditions.

In 2011, the groundwater gradient measurements in the north part of 200 East Area were corrected for barometric responses to normalize the data to a constant pressure. This action was included with the highly accurate casing elevation surveys and borehole deviation surveys previously completed at fourteen wells across this area. The drivers for this action are the RCRA regulations requiring understanding of the groundwater flow direction for upgradient/downgradient well comparisons during detection monitoring and rate of hazardous waste constituent movement for sites in assessment. Locally, this information is derived for LLWMA-1 and WMA B-BX-BY. In addition, 11 wells near LLWMA-2 with previous corrections as stated above were also corrected for barometric response. Because of the flat nature of the water table and a possible divide near the 216-B-63 Trench and LLWMA-2, the gradient was not measurable. It is recommended that a regional approach be investigated to determine the gradient in this area. The regional approach would entail evaluating existing wells across the east portion of the 200 East Area for spatial continuity, correcting for deviation and barometric response, and resurveying to a common datum.

Other important concepts associated with 200-BP-5 include the following:

- Principal sources of groundwater contamination include cribs, ponds, ditches, injection wells, and single-shell tanks that formerly leaked. These facilities are currently inactive. In addition,

the pumpable liquids within the single-shell tanks have been removed. However, residual liquid waste within the vadose zone has not yet been remediated and remains a source of present and future contamination to the groundwater.

- Nitrate, iodine-129, technetium-99, and uranium are the principal groundwater contaminants of concern because of either their widespread distribution or concentrated levels associated with ongoing drainage from the vadose zone.
- Smaller plumes of cesium-137, cyanide, plutonium-239/240, strontium-90, sulfate, and tritium also exceed their respective drinking water standards. These plumes are generally limited to wells beneath the contributing waste site. Cesium-137, plutonium-239/240, strontium-90, and tritium are either stable or decreasing in concentrations because of decay. Cyanide is also decreasing in concentration at the two locations where elevated concentrations occur. Sulfate, while increasing slowly, is at levels just exceeding the secondary drinking water standard.
- All of the near field monitoring wells screened in the unconfined aquifer are screened across the upper part of the aquifer except wells 299-E27-24 and 299-E27-155 near the 241-C Tank Farm and wells 699-53-55A&B west of Gable Mountain Pond.

The ten contaminants of concern identified in DOE/RL-2001-49 are the main constituents discussed in Sections 3.4.1 through 3.4.11. The sections are discussed in descending order of the size of the plume. Additional contaminants exceeding the secondary drinking water standard are also discussed. The additional contaminants and associated sections are as follows: sulfate (Section 3.4.10), iron (Section 3.4.6), arsenic (Section 3.4.11), and fluoride (Section 3.4.11). Manganese also exceeded the secondary drinking water standard in five wells this year, but appears to be associated with well degradation based on visual findings in two representative wells, 299-E33-337 and 299-E33-339. Thus, manganese is not discussed further. In addition, iron is only discussed for wells associated with the ferrocyanide waste disposed at the BY Cribs. Other elevated iron concentrations are generally unfiltered results and are considered to be associated with well degradation, and therefore not discussed further.

Section 3.4.12 summarizes the CERLCA activities completed in 2011, including monitoring, document preparation, treatability test preparation for the unconfined aquifer near WMA B-BX-BY, and treatability test in the perched water horizon near the 241-B Tank Farm.

Section 3.4.13 discusses monitoring results associated with the six RCRA sites. Three of the sites (LLWMA-1, LLWMA-2, and 216-B-63 Trench) are in interim status detection monitoring programs, two (WMA B-BX-BY and WMA C) are in interim status assessment monitoring programs, and one (LERF) has been issued a permit. Summaries in this section discuss indicator parameters, groundwater quality parameters, assessment results, and determinations.

Groundwater data are available in the HEIS database and in the data files accompanying this report. Appendix B provides additional information (including well and constituent lists, maps, and statistical tables) for RCRA monitoring.

One new well was partially drilled in 2011, and no wells were decommissioned. Four wells with high chrome, iron, manganese, and nickel concentrations were internally surveyed using a television camera; and evidence of stainless steel degradation was observed. The degradation appears widespread based on two other television surveys in other areas of 200 East. The degradation appears to be associated with the corrosive nature of the aquifer, local presence of iron rich clay materials, and bacteria. Further discussion on the iron-rich clay materials can be found in *Geochemical Processes Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site* (PNNL-16663). Based on visual observation, the casing conditions were not significant; therefore, no maintenance has been requested at this time.

3.4.1 Nitrate

Nitrate contamination in 200-BP-5 groundwater is primarily due to waste sites that received liquid effluent with high nitrate concentrations. For example, the 216-B-46 and 216-B-49 Cribs received liquid waste with nitrate concentrations near 198,600 mg/L (Appendix C of RPP-26744). The other six cribs associated with the BY Cribs received similar concentrated waste. Dilution of these wastes with groundwater has resulted in concentrations ranging from 841 to 1,700 mg/L in wells beneath the BY Cribs. Other sites that contribute to nitrate contamination at the B Complex include the 216-B-7A&B Cribs, 216-B-8 Crib, and the 241-BX-102 unplanned release (Section 9.1 of PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*). Other waste sites, such as Gable Mountain Pond and B Pond, received effluent with lower concentrations of nitrate according to RPP-26744. In some cases, the nitrate concentration data in RPP-26744 is not consistent with the monitoring results. One example is Gable Mountain Pond where groundwater concentrations should not exceed one mg/L; however, concentrations exceed the drinking water standard of 45 mg/L. In addition, unplanned releases may not have been included for some sites where nitrate plumes exist, such as the 216-B-2 Ditch. Additional inventory information is provided in each subsection.

The 200-BP-5 nitrate plume has expanded in several areas since 2007. Total area of the plume has grown by ~30 percent.

Figure 3.4-5 illustrates the 2011 nitrate plume in 200-BP-5. The plume area has increased in recent years (Figure 3.4-6). Comparing the 2011 plume to that of 2007 (Figures 2.10-10 and 2.10-11 of DOE/RL-2008-01) provides seven significant changes:

1. Nitrate concentrations in wells 299-E32-8, 299-E33-28, 299-E33-29, and 299-E33-30, located beneath the central part of LLWMA-1, now exceed the drinking water standard. The concentration increases in these wells indicate nitrate migration from the B Complex located to the east and from the 216-B-12 Crib to the south.
2. Residual waste drainage from the deep vadose zone beneath the BY Cribs and the predominant historical northwest groundwater flow has caused increased nitrate concentrations to the northwest and expansion of the 450 mg/L nitrate contour toward Gable Gap.
3. Interpretation of basalt above the water table has changed because of recent well installations.
4. The nitrate plume from well 699-53-55C was expanded upgradient towards well 699-50-53A, located to the southeast, because of the new top of basalt interpretation and the past nitrate plume at well 699-50-53A.
5. The Gable Mountain Pond plume has expanded to the west.
6. The plume located east of the 216-B-2 Ditches has expanded to the south.
7. A new plume has formed beneath WMA C.

The distribution of nitrate above the drinking water standard (45 mg/L) in 200-BP-5 is widespread and split into the following eight regions for presentation of the 2011 results:

- B Complex (BY Cribs, 216-B-7A&B Cribs, 216-B-8 Crib, and 241-BX-102 unplanned release)
- Grouped wells 699-53-55A, B, and C near Gable Gap
- Gable Mountain Pond

- 216-B-12 Crib and north to LLWMA-1
- B Plant
- 216-B-5 Injection Well
- 216-B-2 Ditches
- WMA C

The following sections provide additional details on these nitrate plumes and their related sources.

3.4.1.1 Nitrate Near B Complex

The highest nitrate concentrations in 200-BP-5 continued to be reported in wells monitoring the BY Cribs.

Significant nitrate inventories, received at the BY Cribs in the past, have drained through approximately 70 meters of vadose zone to the groundwater. The highest nitrate concentrations in 200-BP-5 in 2011 continued to be reported in wells monitoring the BY Cribs. The highest result (1,700 mg/L) was at well 299-E33-7 in August 2011 (Figure 3.4-7). The value is equal to the highest value reported, November 2009. The nitrate concentration declined significantly in November because of the groundwater flow change to the south-southwest. The decrease at well 299-E33-38 was less than in the other wells beneath the BY Cribs in November because of its south location to the cribs.

The next highest average nitrate concentrations were beneath the 216-B-8 Crib. In 2011, well 299-E33-16 recorded concentrations of 753 mg/L in both January and August (Figure 3.4-8). These concentrations are consistent with the discharge associated with the 216-B-8 Crib. Concentrations increased significantly in December, to 961 mg/L, as a result of the flow change and nitrate migration from the BY Cribs.

Nitrate concentrations to the southeast of the 216-B-8 Crib were between 558 and 584 mg/L in well 299-E33-20 in March and August, respectively (Figure 3.4-8). The concentrations beneath the perched water horizon in wells 299-E33-18, 299-E33-343, and 299-E33-345 were lower by comparison (Figure 3.4-8). In December, concentrations at 299-E33-345 increased from 302 to 382 mg/L. However, this increase may not be representative of groundwater conditions because of problems during well construction (Section 3.4.4.1). In nearby well 299-E33-18, concentrations increased significantly during the same time frame, rising from 392 to 620 mg/L. The increase is primarily due to migration from the 216-B-8 Cribs, but may also be associated with increases within the perched water horizon.

Nitrate concentrations at 299-E33-344, within the perched water horizon, increased from 401 to 810 mg/L between September and December 2011.

Nitrate concentrations at 299-E33-344, within the perched water horizon, increased from 401 to 810 mg/L between September and December. The increase at this well was due to the perched water pumping test in accordance with *Field Test Plan for the Perched Water Pumping/Pore Water Extraction Treatability Test* (DOE/RL-2011-40). The source of the increase is consistent with early discharge concentrations of nitrate to the 216-B-7A&B Crib versus the 241-BX-102 unplanned release. The early 216-B-7A&B Crib discharges were eight times more concentrated with nitrate than the 241-BX-102 unplanned release. This observation is supported by the lower nitrate groundwater concentrations identified close to the 241-BX-102 unplanned release (for example, wells 299-E33-41 and 299-E33-343)

versus wells located near the 216-B-7A&B Cribs (for example, wells 299-E33-18, 299-E33-20, and 299-E33-345) (Figure 3.4-8). Note the comparison is prior to the flow reversal when infiltration from the perched water horizon was the main source of the elevated nitrate.

The contaminated perched water horizon was considered to be contributing to nitrate increases at well 299-E33-18 in December through the short circuit between the perched horizon and perforations across the perched water zone. However, a recent television survey within well 299-E33-18 showed no moisture within the inner casing. In addition, nitrate increase comparisons for wells 299-E33-343 and 299-E33-18 between August and late November/early December are nearly identical (Figure 3.4-8). Figure 3.4-8 provides the trend in upgradient wells 299-E33-16 and 299-E33-44 for comparison with increases at wells 299-E33-18 and 299-E33-343 associated with migration after the reversal. This indicates the nitrate increases at well 299-E33-18 are primarily associated with migration of higher contaminated plumes to the north.

Nitrate concentrations continue to increase at wells 299-E33-47 and are most likely associated with releases associated with the 216-B-7A&B Crib.

Continuing to the south along the east boundary of the 241-B Tank Farm, nitrate concentrations increased from 300 and 452 mg/L from March to August at well 299-E33-47. Elevated concentrations in March and June indicate residual contaminant drainage near this well. The groundwater flow during that time was towards the northwest, and no significant source is located to the south to southeast (Figure 3.4-9). Because of the limited volume or concentration associated with other waste sites and unplanned releases in the area, the source is believed to be associated with the 216-B-7A&B Cribs.

Nitrate concentrations increased in well 299-E33-337 through July, prior to the flow reversal (Figure 3.4-10). The increase was consistent with technetium-99 increases. The increase was local as no significant increases were seen in adjacent wells 299-E33-48 or 299-E33-338 prior to the flow reversal. The source of the increase is indeterminate.

The nitrate plume from B Complex extends northwest beyond the 200 East Area boundary (Figure 3.4-5). The pathway of migration in this area was discussed in Section 9.1.1.1 of DOE/RL-2011-01. Nitrate concentrations at well 699-49-57A increased from 269 mg/L in 2010 to 322 mg/L in April of 2011, prior to the flow reversal. Farther northwest at wells 699-60-60 and 699-61-62 nitrate concentrations only increased approximately 1.5 mg/L. Concentrations at these wells range between 27 and 35 mg/L. As a result of past tritium and iodine-129 migration between well 699-49-57A and these wells, the 45 mg/L nitrate plume contour is drawn between these wells (Figure 3.4-5). The plume was expanded to the northwest because of the significant increase at well 699-49-57A. The sample was collected in April, before the flow reversal.

3.4.1.2 Nitrate Near Gable Gap

Nitrate infiltration from the BY Cribs into the unconfined aquifer prior to the 1990s migrated north. The center of mass is now 2.2 kilometers to the north near well 699-53-55C. Based on 2011 results compared to 2010, nitrate is continuing to migrate to the northwest into the Gable Gap, as modeled in DOE/RL-95-59, *200-BP-5 Operable Unit Treatability Test Report*. Six wells (699-52-55, 699-53-55A, 699-53-55B, 699-53-55C, 699-55-57, and 699-57-59) to the north of the BY Cribs are the primary wells used to define past nitrate migration and the current extent near well 699-53-55C (Figure 3.4-5). In 2011, the plume's orientation extends to the northwest from well 699-53-55C and includes well 699-55-57, where concentrations increased slightly from 2010 (83.2 to 85.9 mg/L). This indicates continued migration to the northwest. Bounding the plume to the northwest is well 699-57-59, where concentrations did not change significantly.

3.4.1.3 Nitrate in Gable Mountain Pond Area

The former Gable Mountain Pond received low nitrate containing discharges (less than 0.6 mg/L) (RPP-26744). However, there are nitrate concentrations exceeding the drinking water standard within the aquifer beneath this site.

Nitrate concentrations in the upgradient well (east) of the former pond (e.g., 699-54-45A) averaged less than 2 mg/L. This is significantly lower than wells 699-53-48A and 699-54-49 adjacent to the inactive pond, which returned 141 mg/L and 48.3 mg/L, respectively. Note the result for well 699-53-48A is from 2010. Concentrations at well 699-54-49 increased slightly compared to 2010 (48.3 mg/L versus 46.9 mg/L). Over the previous 5 years, concentrations at this well have increased approximately 6 mg/L. The nearest downgradient well (699-55-55), located about 1 kilometer west of the waste site, has nitrate concentrations significantly lower than the drinking water standard. Based on current analytical results, the plume size is increasing slowly to the west.

3.4.1.4 Nitrate near 216-B-12 Crib and Low-Level Waste Management Area 1

The 216-B-12 releases from the 1950s ranged in concentration from 7,650 to 8,300 mg/L, enough to source the 800 mg/L found at depth during the drilling of well 299-E28-30.

Nitrate levels at well 299-E28-18 declined from 190 to 100 mg/L between 2009 and 2011. The source of nitrate contamination at 299-E28-18 is the 216-B-12 Crib. This is based on waste discharge information provided in Appendix C of RPP-26744 and depth-discrete groundwater data collected near the crib. The 216-B-12 liquid waste releases from the 1950s ranged in concentration from 7,650 to 8,300 mg/L, enough to source the 800 mg/L found at depth during drilling of well 299-E28-30. Continued groundwater flow to the north causes elevated nitrate levels at well 299-E28-18. The estimated extent of the 450 mg/L nitrate plume was provided in Section 9.1.1.2 of DOE/RL-2011-01. The methodology used to create the plume configuration is provided in an environmental calculation brief (ECF-200BP5-11-0160, *450 mg/L Nitrate Contour Map at Depth for 2010 Annual Report*). The primary data for the interpretation was based on depth-discrete data during drilling from wells 299-E28-30 and 299-E29-54. Both these wells show lower results in 2011 because they were completed with screens across the upper part of the aquifer, not extending to the depth of the high nitrate levels. Wells will be proposed in the revised 200-BP-5 Operable Unit Sampling and Analysis Plan to better define the extent and movement of this deep plume. The draft Sampling and Analysis Plan will be completed in 2012.

The prevailing groundwater flow direction near LLWMA-1 has been to the north-northwest over the past two decades. A change in the flow direction in 2011 may have contributed to concentration declines in 2011 results. Most of the wells had concentrations that declined 10 to 20 mg/L. Results at two wells (299-E28-28 and 299-E32-4) were unchanged. The larger declines occurred in the wells closer to the 216-B-12 Crib.

3.4.1.5 Nitrate in the B Plant Area

B Plant is located near the southern boundary of 200-BP-5. The contaminants in this region appear to have originated at the 216-B-12 Crib, with a nitrate inventory of 2.9 million kilograms. Eight other waste sites in the area have a combined total of 2,934 kilograms of nitrate (Appendix C in RPP-26744). The only other waste site in the area with significant inventory was the 216-B-6 Injection Well, located just south of B Plant, with an inventory of 58,373 kilograms of nitrate. In addition, vadose zone sample results near the 216-B-6 Injection Well indicated little to no nitrate in the deep vadose zone, greater than 61 meters below ground surface. Depth to groundwater in the area is approximately 93 meters.

Nitrate concentrations decrease to the east as seen in the following well comparisons. Nitrate concentration in well 299-E28-17 was 67.7 mg/L compared with 58.9 mg/L at well 299-E28-6, which is located approximately 325 meters to the east of well 299-E28-17. The well construction in both of these wells is similar with 6.1 and 9.1 meters of perforations across the upper unconfined aquifer, respectively. Dilution appears to be the reason for the decrease to the east. Note that a flow divide may exist between these wells.

3.4.1.6 Nitrate near 216-B-5 Injection Well

The two highest nitrate concentrations near the 216-B-5 Injection Well came from wells located to the southwest and west (well 299-E28-3 [67.7 mg/L] and well 299-E29-54 [65.1 mg/L], respectively). According to the conceptual model for flow and the evidence of a deep nitrate plume beneath the B Plant area, nitrate at the 216-B-5 Injection Well (ranging between 56.2 and 59.3 mg/L) appears to migrate from this area. The deep plume beneath sites to the west are discussed in Section 3.4.1.4. Nitrate concentrations drop significantly east of the 216-B-5 Injection Well at well 299-E28-1 (28.2 mg/L). Based on regional iodine-129 results discussed in Section 3.4.2, groundwater at well 299-E28-1 appears to be influenced by sources to the east. Thus, the convergence of flow from the southwest and east appears to occur near the 216-B-5 Injection Well. The groundwater divide is considered to be south-southeast of this location.

Nitrate at the 216-B-5 Injection Well appears to migrate from B Plant.

3.4.1.7 Nitrate near 216-B-2 Ditches

Nitrate concentrations have been increasing since 1994 beneath the 216-B-2 Ditches, primarily due to the unplanned release UPR-200-E-138. This unplanned release was associated with the strontium-90 Product Storage Tank (8-1) located inside the 221-B Building. At the time of the release, strontium-90 was part of a waste fractionization campaign (Section 3.2.2 of DOE/RL-98-28). The process used significant amounts of nitrate in order to dissolve the original precipitates, and additional nitrate was added with calcium for strontium-90 separation. In addition, nitrate contributions may be associated with drainage from fractured basalts to the north. Further discussion on the conceptual transport is discussed in Section 9.1.10.3 of DOE/RL-2011-01.

Nitrate concentrations have been increasing since 1994 beneath the 216-B-2 Ditches, primarily due to the unplanned release UPR-200-E-138.

The nitrate concentrations near the eastern portion of the 216-B-2 Ditches in well 299-E27-10 have continued to record the highest nitrate concentrations in this area since well 299-E34-7 went dry in 2005. There was one exception in fall 2011, when concentrations declined and higher concentrations were at well 299-E27-9, which is located to the west (Figure 3.4-11). Figure 3.4-11 shows nitrate progressively increasing in wells to the southwest to west over the past decade. These increases either infer slow southwest to westward migration at a maximum of 0.1 meter per day or increased extent of residual liquid waste drainage from the vadose zone.

Nitrate increases were also observed in wells 299-E27-22 and 299-E27-25 located to the south and southeast of well 299-E27-10 (Figure 3.4-11), respectively. Because the average nitrate concentrations in well 299-E27-25 increased relative to well 299-E27-22, the plume extent in Figure 3.4-5 was expanded towards well 299-E27-25 compared to 2010.

3.4.1.8 Nitrate at Waste Management Area C

Only two of the ten WMA C wells adjacent the 241-C Tank Farm exceeded the drinking water standard in 2011. The two wells are 299-E27-14 and 299-E27-24. The elevated nitrate concentration in

well 299-E27-14 (southeast side of WMA C) is clearly associated with 241-C Tank Farm releases. However, no known nitrate releases are capable of causing nitrate concentrations of this magnitude (Appendix C of RPP-26744). Nitrate concentrations in well 299-E27-14 are nearly twice as high as upgradient wells along the north part of WMA C. The highest released nitrate inventory is 5,806 kilograms from UPR-200-E-81. These inventories are not significant compared to other sites where groundwater nitrate concentrations have been linked to a vadose zone source such as the 241-BX-102 unplanned release. In addition, past vadose zone investigations at the 241-C Tank Farm have not encountered significant nitrate at depth. Thus, the source of nitrate for the 241-C Tank Farm remains uncertain.

Nitrate concentrations at well 299-E27-14 averaged 91 mg/L, which was only 2 mg/L higher than 2010. The next highest average nitrate concentration, 70 mg/L, was collected at well 299-E27-24, located ~61 meters south of well 299-E27-14. Note that well 299-E27-14 is screened across the upper 2.6 meters of the aquifer, while well 299-E27-24 is screened across the lower 6.1 meters of the aquifer, with the top of the screen ~9 meters below the water table. Approximately 215 meters south, well 299-E24-33 has elevated nitrate concentrations, although below the drinking water standard. Therefore, the orientation of the plume was expanded to the southeast toward this well (Figure 3.4-5).

3.4.2 Iodine-129

Figure 3.4-12 shows iodine-129 distribution in 200-BP-5. Three sources in the southeastern 200 East Area (216-A-10 Crib vicinity, 216-A-29 Ditch, and 216-B-3 Pond) were contributors to the widespread distribution of iodine-129 within the 200 East Area and Gable Gap. Historical review of the contaminant data indicates groundwater migration from the southern portion of the 200 East Area to WMA B-BX-BY and into the Gable Gap. Contaminant contributions of iodine-129 from these waste sites ceased to contribute to the 200-BP-5 plume because the flow divide moved north of these sites as the water table continued to decline. Other likely contributors of iodine-129 to groundwater include the BY Cribs, 241-BX-102 unplanned release, 216-B-8 Cribs, and the 216-B-2 Ditches. All these sites received significant inventories of iodine-129. For example, the average iodine-129 concentrations in waste discharges to the 216-B-49 Crib were ~4,870 pCi/L (Appendix C of RPP-26744). The other BY Cribs and the 216-B-8 Crib received similar concentrations. The 241-BX-102 unplanned release was ~2,900 pCi/L of iodine-129. Water samples from a perched water horizon, approximately 3 meters above the aquifer, have shown average iodine-129 levels exceeding 2.5 pCi/L. Iodine-129 levels at wells 299-E33-343 and 299-E33-345, within the unconfined aquifer beneath this perched zone, are consistently higher than surrounding wells, reflecting drainage from this perched zone.

Three sources in the southeastern 200 East Area (216-A-10 Crib vicinity, 216-A-29 Ditch, and 216-B-3 Pond), now inactive, were contributors to the widespread distribution of iodine-129 within the 200 East Area and Gable Gap.

Other waste sites received effluent with lower concentrations of iodine-129 and/or did not have significant liquid volumes according to RPP-26744. For example, iodine-129 concentrations associated with the 241-B-107 release were 155,358 pCi/L; however, the liquid volume was approximately 53,000 liters, indicating little impact, if any, on the unconfined aquifer. Alternatively, although the iodine-129 concentration for the former 216-B-3 Pond was inconsequential, less than 0.03 pCi/L, according to Appendix C of RPP-26744, there are levels in the groundwater below exceeding the drinking water standard (1 pCi/L). Thus, the information in Appendix C of RPP-26744 for this waste site is not complete.

The 200-BP-5 iodine-129 plume has expanded in several areas since 2007. Total area of the plume has grown by ~10 percent.

Figure 3.4-12 illustrates the 2011 iodine-129 plume in 200-BP-5. The plume area has increased in recent years (Figure 3.4-6). Comparing the 2011 plume to that of 2006 (Figures 2.10-10 and 2.10-11 of PNNL-16346) and 2007 (Figure 2.10-12 of DOE/RL-2008-01) provides five significant changes/observations:

1. The 1 pCi/L iodine-129 contour beneath B Pond has shifted southward and expanded including the former 216-B-3B and C Lobes.
2. Concentrations more than doubled in well 699-43-45 downgradient of 216-B-3 Pond.
3. Concentrations along the south and east side of the 241-B Tank Farm more than doubled.
4. The 200 East Area and Gable Gap plume were connected.
5. The Gable Gap plume expanded to the northwest.

The distribution of iodine-129 above the 1 pCi/L drinking water standard is widespread and split into six regions for 2011 result discussions:

1. B Pond
2. WMA C
3. LLWMA-2
4. 216-B-5 Injection Well
5. 216-B-2 Ditches
6. B Complex and extending northwest beyond well 699-49-57A.

3.4.2.1 Iodine-129 near B Pond

Levels as high as 9 pCi/L were detected in well 699-43-45 downgradient of B Pond. Elevated iodine-129 was also located at well 699-45-42, 2.74 pCi/L, located northeast of 216-B-3. One other well, 699-43-41G (1.81 pCi/L), exceeded the drinking water standard. This well is located north of the 216-B-3B Lobe and east of the 216-B-3A Lobe. These results indicate the iodine-129 inventory for the 216-B-3 Pond, published in Appendix C of RPP-26744, is not representative.

Iodine-129 levels as high as 9 pCi/L were detected in well 699-43-45 downgradient of B Pond.

3.4.2.2 Iodine-129 near Waste Management Area C

All of the wells at WMA C had iodine-129 levels exceeding the drinking water standard (Figure 3.4-12). The levels have fluctuated, but not much decrease has been noted over the past two decades. The source of the iodine-129 was from the southeast, where higher concentrations were present when the flow direction was west-northwest.

3.4.2.3 Iodine-129 near Low-Level Waste Management Area 2

Elevated iodine-129 has been detected in the wells along the south side of LLWMA-2 since monitoring began in the early 1990s. The highest level was in well 299-E27-10 when sampling began, but

have since declined below 2 pCi/L. Iodine-129 concentrations in wells west of well 299-E27-11 have primarily been lower than 1 pCi/L since the mid-1990s when monitoring for iodine-129 began. This indicates the northern and western extent of iodine-129 in this area.

3.4.2.4 Iodine-129 near the 216-B-5 Injection Well

The spatial distribution of iodine-129 at wells near the 216-B-5 Injection Well continue to demonstrate elevated levels of iodine-129 is from the east and the 1 pCi/L drinking water standard contour extends south of this former waste site and to the northwest (Figure 3.4-12). The groundwater flow for transport of iodine-129 from east to west is different from the flow direction of nitrate in this area which indicated southwest to northeast. Thus, the 216-B-5 Injection Well may be near a convergence of flow from the east and southwest.

3.4.2.5 Iodine-129 near 216-B-2 Ditches

Elevated iodine-129 levels were detected in wells beneath the 216-B-2 Ditches as early as the 1990s (Figure 3.4-13). Levels were highest in well 299-E33-36 located just north of the head end of the ditches. The correlation of elevated iodine-129 levels at the 216-B-3 Pond, wells beneath the 216-B-2 Ditches, and wells to the northwest along the south side of WMA B-BX-BY may indicate past contributions from the 216-B-2 Ditches. Because of the recent increases along the south side of WMA B-BX-BY, well 299-E33-36 will be included in the revised 200-BP-5 Sampling and Analysis Plan to better define iodine-129 changes. Alternatively, the iodine-129 increases may be associated with continued migration from sources to the east-southeast, as described in Section 3.4.2.

3.4.2.6 Iodine-129 near B Complex

Elevated iodine-129 in wells along the south side of the 241-B Tank Farm indicates a preferential west-northwest pathway from past sources. Well 299-E33-338 had one of the highest levels of iodine-129, 4.14 pCi/L, in May 2011, before the groundwater flow direction changed. Well 299-E28-8, located approximately 270 meters southwest of well 299-E33-338, also showed elevated levels of iodine-129 (3.45 pCi/L). Contributions from other sources in the vicinity (216-B-63 Trench and 241-B-107 tank release) were ruled out for one or more of the following reasons: limited liquid discharges, location, stratigraphic dip of vadose zone sediments, and low concentrations in groundwater. Note that wells 299-E34-8, 299-E34-10, and 299-E34-12, all located beneath the 216-B-63 Trench, have much lower iodine-129 levels, indicating no contributions from this waste site.

Elevated iodine-129 in wells along the south side of the 241-B Tank Farm indicates a preferential west-northwest pathway from past sources within 200-PO-1 and possibly the 216-B-2 Ditches.

The highest iodine-129 activity in WMA B-BX-BY was at well 299-E33-343 (5.38 pCi/L in May 2011), located adjacent the northwest corner of 241-B Tank Farm and northeast of the 241-BX-102 tank release. Based on inventory levels associated with RPP-26744, the stratigraphic dip of vadose zone sediment, and the iodine-129 levels in the perched water horizon, contributions of iodine-129 from the 241-BX-102 unplanned release at well 299-E33-343 are evident.

Because of the wide swath of elevated iodine-129 from well 299-E28-8 to the BY Cribs, past sources to the southeast appear to have contributed in this area. Iodine-129 from these sources has extended to the northwest beyond the 200 East Area. The 1 pCi/L (drinking water standard) leading contour is shown between wells 699-57-59, 699-59-58, and 699-61-62 (Figure 3.4-12). Because of the increase in iodine-129 levels in these wells, the plume configuration in this area was expanded from 2010.

3.4.3 Technetium-99

Technetium-99 in 200-BP-5 groundwater is primarily because of large disposal inventories to the BY Cribs. Six of the seven cribs received between approximately 14 to 25.5 Ci of technetium-99 (Appendix C of RPP-26744). Other waste sites either received less than 1 Ci of technetium-99 or had relatively small release volumes. Two other sources that impacted the groundwater are associated with the 241-BX and 241-C Tank Farms.

The 241-BX-102 unplanned release was slightly more than 2.27 Ci and is currently the only documented source impacting groundwater from the 241-BX Tank Farm. The 241-C Tank Farm source has not been identified, but inventories exceeding 1 Ci are only associated with the UPR-200-E-82 and UPR-200-E-86 sites (Appendix C of RPP-26744). Recent vadose zone investigations associated with these sites found limited technetium-99 at depth, resulting in conclusions of low potential for groundwater impact. In 2011, an updated leak assessment (RPP-ENV-33418, *Hanford C-Farm Leak Assessments Report*) was released, increasing the technetium-99 inventory for the 241-C-105 and 241-C-110 Tanks to 0.8 and 1.6 Ci, respectively.

The interpretation of the technetium-99 plume (Figure 3.4-14) has changed since 2006 because of new wells installed during the 200-BP-5 remedial investigation and reinterpretation of the top of basalt surface. The most prominent change was redirecting the plume from north to northwest of well 699-49-57A. For comparison, see Figure 2.10-9 of PNNL-16346. The change was based on the 2007 Remedial Investigation results at wells 699-50-56 and 699-52-55. The other change occurred in 2010 when top of basalt reinterpretations found evidence for a paleochannel extending into the basalt southeast of well 699-53-55C. Based on this interpretation, the elevated technetium-99 at well 699-53-55C was extended towards well 699-50-53A, where a significant technetium-99 plume existed in the 1990s. Overall, the size of the technetium-99 plume has not changed significantly since at least 2003 (Figure 3.4-6).

The distribution of technetium-99 above the 900 pCi/L drinking water standard was limited to three isolated regions in 200-BP-5 during 2011 (Figure 3.4-14):

- B Complex and extending northwest beyond well 699-49-57A
- Grouped wells 699-53-55A, B, and C near Gable Gap
- WMA C

3.4.3.1 Technetium-99 near B Complex

Technetium-99 at the BY Cribs was present in liquid effluent in the form of pertechnetate, a negatively charged oxyanion. This form is highly mobile, which contributed to migration of a significant inventory through approximately 70 meters of Hanford vadose zone sediments to the groundwater. The calculated technetium-99 mass in the aquifer continued to increase from 2000 to 2009 (Section 5.3 of PNNL-19277), while the technetium-99 levels rose to historical highs (Figure 3.4-15). By 2009, approximately 6.06 Ci were calculated as being in the groundwater (Table 5-2 of PNNL-19277). The 241-BX-102 unplanned release is also responsible for elevated technetium-99 in the groundwater near wells 299-E33-18, 299-E33-343, and 299-E33-345. These two sources are the primary technetium-99 sources in the B Complex.

The highest technetium-99 activity in 200-BP-5 continued to be reported in wells monitoring the BY Cribs.

The highest technetium-99 sample results in 200-BP-5 continued to be reported in wells monitoring the BY Cribs. The highest result in the unconfined aquifer (36,500 pCi/L) was at well 299-E33-38 in

August 2011 (Figure 3.4-15). This value was 1,500 pCi/L lower than the maximum value in 2010; however, it is one of the highest ever reported at this well. The increase was coincident with a groundwater flow direction change to the south-southwest. The flow change is the reason for the increase at 299-E33-38 because larger inventories of technetium-99 were disposed to Cribs 216-B-44, 216-B-45, 216-B-46, 216-B-48, and 216-B-49, located north of this well.

Adjacent to the north side of the 241-B Tank Farm, technetium-99 concentrations increased in the groundwater during 2011. The highest result was at well 299-E33-18 with a maximum of 30,800 pCi/L in December 2011 (Figure 3.4-15). This result is the highest result reported at this well. The 2011 increase indicates continued infiltration from the perched water horizon. Concentrations in the perched water horizon rose from 5,640 pCi/L in September 2011 to 45,100 pCi/L by December 2011. The increase at the perched water well, 299-E33-344, was because of the perched water pumping test performed in accordance with DOE/RL-2011-40. The source of the increase appears to be consistent with discharge concentrations of technetium-99 to the 241-BX-102 unplanned release versus the 216-B-7A&B Crib. The 241-BX-102 unplanned release was at least three orders of magnitude more concentrated than the 216-B-7A&B Crib discharges.

Technetium-99 also increased significantly in well 299-E33-337 along the south boundary of the 241-B Tank Farm. The increase, ~3,000 pCi/L, occurred over a 7-month period (128 pCi/L in December 2010 to 3,210 pCi/L in July 2011). The increase appears local as no significant increases were seen in adjacent wells 299-E33-48 or 299-E33-338. Near the end of 2011, a significant increase was seen in well 299-E33-338, where concentrations increased from 89.1 pCi/L to 1,100 pCi/L. The increase is a result of contaminant migration associated with the groundwater flow direction change. A smaller increase was seen in well 299-E33-48, indicating a preferential east to southeast flow direction in this area. The source of the increase is indeterminate but may be associated with the 241-BX-102 unplanned release.

Contaminant migration into the upper basalt-confined aquifer, the Rattlesnake Ridge interbed, at well 299-E33-12 is linked to past migration of waste received by the BY Cribs and poor well construction during early Hanford Site operations. Technetium-99 is currently the only contaminant that still exceeds the drinking water standard. The 2011 result was 200 pCi/L lower than the 1,200 pCi/L from 2010. Two new 200-BP-5 RI wells, 299-E33-50 and 299-E33-340, installed to the north and south of well 299-E33-12 were also found to have low levels of technetium-99. Both wells are screen across the upper 4.6 meters of the confined aquifer. Technetium-99 activity in well 299-E33-340 ranged between non-detect and 10 pCi/L in 2011. Technetium-99 in well 299-E33-50 was 47.3 pCi/L.

The technetium-99 plume from B Complex extends northwest beyond the 200 East Area boundary and the trend correlations are the same as those discussed in Section 3.4.1.1 for nitrate. Because of the technetium-99 concentration increases, the 900 pCi/L technetium-99 plume contour is drawn just beyond well 699-49-57A (Figure 3.4-14).

3.4.3.2 Technetium-99 Near Gable Gap

By the early 1990s, the center of mass of the technetium-99 plume, associated with the BY Cribs, had migrated approximately one kilometer to the north, creating an elevated region of technetium-99 around well 699-50-53A, as shown on Figure 4-12 of *Hydrogeologic Model for the 200 East Groundwater Aggregate Area* (WHC-SD-EN-TI-019). Continued migration northward over the last two decades has created the current plume conditions near well 699-53-55C. The plumes current orientation extends to the northwest and includes well 699-55-57. Low levels of technetium-99 contamination extend all the way to wells near the Columbia River between 100-BC-5 and 100-KR-4.

The continued decline in technetium-99 concentrations at well 699-53-55C indicates the center of mass from the south may have migrated past this well. In addition, the continued decrease in other wells to the northwest may indicate this plume is attenuating.

Technetium-99 results were 200 pCi/L lower at well 699-53-55C in 2011 than in 2010 (2,600 pCi/L versus 2,800 pCi/L). The technetium-99 decline at well 699-53-55C has continued since 2008 and indicates the center of mass from the south has migrated past this well as modeled in DOE/RL-95-59. In addition, the continued decrease in wells to the northwest (e.g., 699-55-57 and 699-57-59) indicates the plume is being diluted because of the increased thickness of the aquifer in this area versus well 699-50-53A.

3.4.3.3 Technetium-99 Near Waste Management Area C

The source of elevated technetium-99 found beneath WMA C is more elusive than at the B Complex. Based on current inventory calculations, the unplanned release, UPR-200-E-86, has by far the most technetium-99 inventory (4.92 Ci) (Appendix C of RPP-26744). However, recent investigation using thirteen direct-push holes surrounding the release site found little technetium-99 in the vadose zone. Pushes varied from 30 to 61 meters below ground surface. Based on the direct push investigation, an updated leak assessment concluded the initial leak loss estimate was high (Section 5.4.1 of RPP-ENV-33418). Another unplanned release, UPR-200-E-82, with approximately 1.4 Ci of technetium-99 inventory (RPP-26744), also found limited technetium-99 in the vadose zone. Based on the investigation at UPR-200-E-82, the prominent conclusion was "*the leak was of low volume and not a source of groundwater contamination for the waste management area.*" Another possibility provided was "*actions taken to control exposure to the spill resulted in it being diluted and/or flushed into the underlying groundwater*" (Section 5.4.1 of RPP-ENV-33418). Another release of 1.6 Ci of technetium-99 was associated with the 241-C-110 tank (Section 4.0 of RPP-ENV-33418). Although this site has not been investigated, a recent assessment update concluded the tank is sound with a maximum port overflow of only 7,570 liters (Section 4.3 of RPP-ENV-33418). The last known source with sizeable technetium-99 inventory is the 241-C-105 release (0.8 Ci) (Section 4.0 of RPP-ENV-33418). After site characterization of this area, technetium-99 was limited to a depth of 48.8 meters below ground surface. Depth to groundwater is approximately 70 meters.

Wells located along the west to southwest and south-southeast sides of the 241-C Tank Farm have technetium-99 concentrations above the drinking water standard (Figure 3.4-14). All these wells are considered downgradient of the 241-C Tank Farm.

Small decreases in Technetium-99 were seen in well 299-E27-23 until December 2011, when levels rose to a new high of 25,000 pCi/L.

Steeply increasing trends over the past 4 to 6 years are unique to wells 299-E27-13 and 299-E27-23 (Figure 3.4-16). However, technetium-99 began to decline at well 299-E27-13 in 2011. Small decreases were also seen in well 299-E27-23 until December 2011, when activity rose to a new high of 25,000 pCi/L. Currently, no other wells at WMA C return a quarter of the technetium-99 activity as well 299-E27-23. This indicates that the residual liquid drainage from the vadose zone is near this well. Further information regarding depth discrete sampling at WMA C can be found in the 2010 report (DOE/RL-2011-01). Well information is provided in DOE/RL-2009-77, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C.*

3.4.4 Uranium

Uranium found in 200-BP-5 groundwater is primarily because of large disposal inventories to the 216-B-12 Crib and the 241-BX-102 unplanned release. The uranium inventory disposed to these sites exceeded 10,000 kilograms, which is at least an order of magnitude greater than other waste sites overlying 200-BP-5. The 216-B-3 Pond and Gable Mountain Pond both received inventories of this magnitude; however, the liquid discharge volumes were so significant that historical concentrations beneath these sites did not exceed the drinking water standard. One final site to impact the groundwater was the 216-B-5 Injection Well. This site only received 10.5 kilograms (Appendix C of RPP-26744); however, the injection well extended into the aquifer allowing the entire inventory to reach the aquifer.

Additional wells will be proposed in the revised 200-BP-5 Sampling and Analysis Plan to better define the deep uranium plume and associated movement.

The plume configurations within 200-BP-5 have not changed significantly over the past five years (Figure 3.4-17). A minor change associated with the uranium plume in the B Complex area was the expansion of contamination within the south part of the 241-BX Tank Farm. Another area of change, although not shown on Figure 3.4-17, was the identification of a deep uranium plume (greater than 6.2 meters below the water table) beneath the 216-B-12 Crib. Evidence of this plume was discovered in the 2010 drilling of the 200-BP-5 RI well 299-E28-30. A discussion of the data was provided in the 2010 Annual Groundwater Monitoring report (Section 9.1.4.2 of DOE/RL-2011-01). Data are not yet available to define the extent and movement of this plume. Wells will be proposed in the revised 200-BP-5 Operable Unit Sampling and Analysis Plan (DOE/RL-2001-49) to better define the plume and movement.

The distribution of uranium above the 30 µg/L drinking water standard was limited to four regions during 2011 (Figure 3.4-17):

- B Complex and northwest beyond the 200 East Area
- 216-B-12 Crib and north to LLWMA-1
- 216-B-5 Injection Well
- B Plant

The following sections provide additional details about the uranium distribution and related sources.

3.4.4.1 Uranium near B Complex and Northwest Beyond the 200 East Area

The uranium isotopic signatures from samples within the vadose zone, including boreholes 299-E33-45 and 299-E33-343, and within the groundwater, demonstrate the 241-BX-102 tank release as the primary source of uranium in groundwater at WMA B-BX-BY (Section 5.7 of PNNL-19277). The uranium inventory associated with this release was established at 10,100 kilograms (Appendix C of RPP-26744). Rough order of magnitude calculations indicated that 1,050 kilograms of water-extractable uranium may reside in the Cold Creek unit silt zone approximately 3 meters above the aquifer. This estimate was based on three wells in an east-west orientation within the perched water zone. Continued liquid waste drainage of uranium laden pore water from 2000 to 2009 caused the mass within the aquifer to increase from 3.4 to 22.3 kilograms (Table 5.4 of PNNL-19277).

Because of the groundwater impact associated with infiltration from the perching horizon, a perched water pumping test was initiated in 2011. The perched water contained the highest uranium concentrations detected at the Hanford Site in 2011.

To address the groundwater impact associated with infiltration from the perching horizon, DOE initiated a perched water pumping test in 2011 (DOE/RL-2011-40). Well 299-E33-344 was used for perched water extraction during the test. Pumping began in August and continued until early December when extracted perched water results received from the lab rose significantly and required a different waste disposal path before continued testing. Pumping resumed in April 2012. The uranium results showed an increase from 4,500 µg/L in September to 63,600 µg/L in October. The increase in concentration was confirmed in December with a result of 71,500 µg/L. These were the highest uranium concentrations detected at the Hanford Site in 2011. Approximately 90,000 liters of contaminated water were removed through the 4-month test. The actual drawdown may be several centimeters; however, because of uncertain baseline conditions, it is not possible to quantify the perched water level decline.

Well 299-E33-343 (adjacent to the northwest corner of B Tank Farm) continued to record the highest average groundwater uranium results in 200-BP-5 in 2011. This well is approximately 39 meters west of well 299-E33-344, but is screened in the unconfined aquifer. The maximum uranium result in 2011 was 2,420 µg/L in February; however, concentrations continued to steeply decline from the 5,550 µg/L result in June 2009 until December 2011, when concentrations rose to 1,750 µg/L. The trend indicates liquid waste drainage of uranium from the vadose zone is declining near this well.

Elsewhere in the unconfined aquifer, near well 299-E33-18, which is located approximately 4 meters west of well 299-E33-344, uranium concentrations increased this year. Uranium concentrations increased from 605 µg/L in December 2010 to 1,830 µg/L in December 2011. The concentration increases before the flow reversal imply increased liquid waste drainage of uranium from the vadose zone, while increases after the flow reversal (August through December 2011) are mostly because of southeast migration of a highly contaminated local plume due to the flow reversal. It is believed that the later elevated uranium concentrations are associated with the same plume that was present near well 299-E33-343 in 2009. Conceptually, this plume migrated slowly northward from 2009 to June, 2011 and then to the southeast from July, 2011 (e.g., towards 299-E33-18). It is believed concentrations will continue to increase, possibly meeting or exceeding the 5,500 µg/L seen earlier at well 299-E33-343. Well 299-E33-345, located about 3 meters north of well 299-E33-18, does not appear to be representative of the uranium plume because of construction issues during well completion. The permanent casing was smashed near the ground surface during well construction, causing the well and completion materials, including the bentonite seal across the perching horizon, to be drilled out. It appears that during drilling out this material, bentonite may have been smeared across the aquifer sediments. This is supported by the observation that the well water production is low, as compared to other wells in the B Complex. Therefore, this well will not be included in sampling plans for uranium in the future.

The high uranium concentrations in wells 299-E33-38 and 299-E33-342 beneath the south side of the BY Cribs suggest a historical north-northwest flow path from well 299-E33-343. The northwest flow path extends further to the northwest through wells 299-E33-26 and 299-E33-34, and is bounded to the south by well 299-E33-35. Westward flow during the past 2 to 4 years is seen along the north boundary of LLWMA-1, from well 299-E33-34 to well 299-E32-9. The westward flow between these two wells may be due to declining groundwater levels and possibly remnant Ringold sediments reaching farther south than as defined in PNNL-19702. Alternatively, folds in the underlying basalt may also divert groundwater westward in this area. Groundwater, then, appears to migrate northwest from well 299-E32-9 towards well 699-49-57A because the uranium concentrations at 699-49-57A are higher than at well 299-E32-8. Because of the flow direction change in mid-2011, uranium concentrations decreased at many of the wells

along this flow path and increased at wells to the south. For example, well 299-E33-38, located along the northerly flow path, decreased from 997 µg/L in May 2011, before the flow change, to 331 µg/L by December 2011. Also, well 299-E33-41, located south of the flow path, increased from 82.7 µg/L in May 2011 to 567 µg/L by December 2011.

Uranium increases in May along the south boundary of the 241-BX Tank Farm (299-E33-334) indicate another possible point of infiltration from the vadose zone.

Uranium increases in May along the southwest boundary of the 241-BX Tank Farm (299-E33-334) indicate another possible point of residual liquid waste drainage from the vadose zone. The increase was before the south groundwater flow direction change. Of the sources in this area, only the 241-BX-102 unplanned release appears to be a viable option. Another possible source may be the 216-B-12 Crib; however, the extent of this plume is poorly understood, and elevated uranium would have been expected in well 299-E33-335 before well 299-E33-334, which did not occur.

3.4.4.2 Uranium near 216-B-12 Crib and Low-Level Waste Management Area 1

Over the past 10 years, uranium has been detected at levels near the 30 µg/L drinking water standard in well 299-E28-18, which monitors the 216-B-62 Crib located northwest of B Plant (Figure 3.4-17). Uranium concentrations exceeded 200 µg/L in the mid-1980s, but decreased by the late 1980s to levels similar to those reported during 2011 (33.9 µg/L).

Well 299-E28-21 also monitors the 216-B-62 Crib and is located northwest of well 299-E28-18. Uranium concentrations have been decreasing at this well since maximum values were observed in the mid-1980s. The 2011 uranium concentration in well 299-E28-21 was 10.4 µg/L.

Evidence for the 216-B-12 Crib as the source of elevated uranium in the aquifer is provided by the elevated analytical results from depth-discrete samples collected during drilling near this crib in 2010.

The source of uranium for these wells (299-E28-18 and 299-E28-21) was initially linked to the 216-B-62 Crib; however, the only waste site with significant uranium inventory is the 216-B-12 Crib located southeast of the 216-B-62 Crib (Appendix C in RPP-26744). Supporting evidence for the 216-B-12 Crib as the source of elevated uranium in the aquifer is provided by the elevated analytical results from depth-discrete samples collected during drilling near this crib in 2010. Approximately 35 µg/L of uranium was reported for a sample collected 7.6 meters below the water table. Elevated uranium is interpreted to extend to the northwest, north, and northeast from the 216-B-12 Crib at depth within the unconfined aquifer. Additional wells are needed to better define the extent and movement of this deep plume.

The prevailing groundwater flow direction near LLWMA-1 has been to the north-northwest for more than two decades. Previous uranium groundwater concentrations were observed to migrate from near wells 299-E28-18 and 299-E28-21 to the north-northwest. The elevated uranium concentrations along the western side of LLWMA-1 show the northwest extent of the migration. In 2011, uranium concentrations in wells along the western boundary of LLWMA-1 ranged from less than 3 µg/L to 18.6 µg/L, and the highest concentration was in well 299-E32-7. Higher concentrations are also found in well 299-E28-27 (southeast corner of LLWMA-1), where the June 2011 value was 35.9 µg/L. Based on the historical flow direction in this area and at WMA B-BX-BY, it appears that deep uranium from beneath the 216-B-12 Crib is responsible for the increased concentrations beneath the 216-B-62 Crib, the south to southeast corner of LLWMA-1, and along the west side of LLWMA-1.

3.4.4.3 Uranium near 216-B-5 Injection Well

The 216-B-5 Injection Well was located northeast of B Plant (Figure 3.4-17). A small uranium plume has been reported since 1981 when groundwater monitoring began at the injection well. Since 2007, concentrations in all the 216-B-5 Injection Well monitoring network wells have been below the drinking water standard so no contours are provided in this area (Figure 3.4-18). Previously, the highest uranium concentrations were associated with well 299-E28-23 located approximately one meter from the 216-B-5 Injection Well. Since 2001, uranium concentrations at well 299-E28-23 have continued to decrease while concentrations have increased in well 299-E28-25, located about 7 meters northwest of the 216-B-5 Injection Well. The highest 2011 uranium concentration from the three wells was 28 μg/L at well 299-E28-25. Based on the history of uranium concentrations, flow is continuing to the northwest from the 216-B-5 Injection Well.

3.4.4.4 Uranium near B Plant

Elevated uranium concentrations were present in three wells south and southeast of B Plant during 2011. The uranium concentration at well 299-E29-54, located just south of B Plant, was 30.9 μg/L. Farther south in well 299-E28-17, the uranium concentration was 33.9 μg/L. Finally, in well 299-E28-6, the concentration was 40.2 μg/L. Historically, concentrations have been higher in well 299-E28-6 since sampling began in the early 1990s. Other than the 216-B-12 Crib, there does not appear to be a significant inventory in this area to source this plume. Additional wells are needed to better define the apparent deep plume in this area as discussed further in Section 3.4.4.2.

3.4.5 Strontium-90

Strontium-90 found in 200-BP-5 groundwater is primarily due to high concentrations in waste disposed into areas with a limited vadose zone thickness (<12 meters) at the Gable Mountain Pond and at the 216-B-5 Injection Well. The strontium-90 inventory disposed to these sites was approximately 183 and 7.5 Ci, respectively. The injection of strontium-90 at the 216-B-5 Injection Well occurred during the years 1945 through 1947. The majority of the Gable Mountain Pond discharge was associated with the 1964 unplanned release (UPR-200-E-34). This release was estimated at approximately 178.9 Ci of strontium-90.

Strontium-90 has relatively low mobility in the subsurface and does not migrate significant distances, as observed by concentrations at wells adjacent to these sites. Based on historical activity comparisons for these plumes, decay with little attenuation appears to be the dominant reason for the strontium-90 decline, as modeled and concluded in Sections 5.4.2 and 5.4.3 of DOE/RL-95-59. The area of the plume has decreased since 2006 (Figure 3.4-6). Comparison of the 8 and 80 pCi/L contours for 2010 and 2011 show no change.

Four of the five strontium-90 results above the drinking water standard were from wells near the 216-B-5 Injection Well (Figure 3.4-19). The high concentrations seen at this location are because of the strontium-90 inventory received by the injection well and the depth of the injection well, perforated within the upper part of the unconfined aquifer. The highest strontium-90 concentration (4,400 pCi/L) was from well 299-E28-23, ~1 meter from the 216-B-5 Injection Well. The concentrations within this well have fluctuated between 3,290 to 4,900 pCi/L since 2005. Higher concentrations of strontium-90 are present in well 299-E28-25 (~7 meters to the northwest) than well 299-E28-24 (~5 meters to the southeast) because of the dominant northwest flow direction over the past 25 years since discharges to Gable Mountain Pond were terminated. Concentrations in well 299-E28-25 have ranged between 1,500 and 2,420 pCi/L since 1997, and are currently at 2,200 pCi/L. Farther north in well 299-E28-2 (~170 meters to the north), strontium-90 has fluctuated between 180 and 190 pCi/L and are currently 180 pCi/L, which is no change from 2010. Strontium-90 concentrations farther north have been suspected to be false positives. Concentrations in well 299-E28-24 remained the same as 2010 at 350 pCi/L.

Strontium-90 activity has been steadily decreasing at Gable Mountain Pond, and the highest activity reported was 310 pCi/L in wells monitoring this area.

The highest historical strontium-90 activity reported at Gable Mountain Pond has been at well 699-53-47 (beneath the southeastern portion of the once active pond). In 2010, strontium-90 at this well was 310 pCi/L. The activity at this well has steadily decreased from 1,320 pCi/L over the last 13 years. This well was not sampled in 2011 because of schedule constraints, but is planned to be sampled in 2012.

Another well not sampled in 2011 was 699-54-48, located approximately 330 meters north of well 699-53-47A. Strontium-90 concentrations at this well have been approximately 30 pCi/L. This well is also scheduled for sampling in 2012. Farther west beneath the central portion of Gable Mountain Pond at well 699-54-49, the strontium-90 activity increased from 160 pCi/L in 2010 to 200 pCi/L in 2011. Regionally, concentrations decrease to the west indicating the majority of strontium-90 drainage into the aquifer occurred near the outlet pipe to the former Gable Mountain Pond.

Well 699-55-55, located approximately 1.2 kilometers west of the pond, was also sampled in 2011. The result from this well was 4.4 pCi/L; however, based on several false positive results for strontium-90 in 2011 (Appendix D), it is uncertain whether this result is another false positive or not. The result has been flagged and the well is scheduled to be sampled again in 2012. Based on the results in 2012, a determination will be made on the 2011 result.

3.4.6 Cyanide and Iron

Cyanide and elevated iron found in 200-BP-5 groundwater probably originated from disposal of wastes associated with scavenging cesium-137 and strontium-90. After scavenging was completed, the ferrocyanide complex was discharged to the BY Cribs. Migration of a significant inventory of cyanide and iron was able to drain through approximately 70 meters of Hanford vadose zone soils to the groundwater because of the initial discharge volume and the negatively charged ferrocyanide complex. In the late 1990s, cyanide concentrations began to increase beneath the BY Cribs. Cyanide and iron trend plots are nearly identical in most of the wells beneath the BY Cribs, confirming the complex nature (Figure 3.4-20).

The distribution of cyanide above the 200 µg/L drinking water standard originates beneath the BY Cribs and extends predominantly to the northwest beyond the 200 East Area boundary (Figure 3.4-21). The plume configuration has expanded over the past 5 years because of the continued residual liquid drainage from the BY Cribs and groundwater flow to the northwest (Figure 3.4-3). In the summer of 2011, concentrations beneath the BY Cribs began to decrease significantly coincident with the flow reversal, causing the plume to contract from the west and north.

The maximum cyanide concentration in 200-BP-5 in 2011 was located beneath the BY Cribs in well 299-E33-7 (1,500 µg/L), but this was 90 µg/L less than the value reported in 2010.

The maximum cyanide concentration in 200-BP-5 during 2011 was beneath the BY Cribs in well 299-E33-7 (1,500 µg/L), but was 90 µg/L less than the value reported in 2010. Because of the groundwater flow direction change, cyanide concentrations exceeded the drinking water standard in November 2011 at wells 299-E33-16, 299-E33-39, and 299-E33-44 located to the south-southeast. However, the yearly average concentrations in these wells were still below the drinking water standard. The cyanide 200 µg/L (drinking water standard) contour continues to extend predominantly to the

west-northwest beyond the 200 East Area boundary between wells 299-E33-34 and 699-49-57A (Figure 3.4-21).

The maximum filtered iron concentration in 200-BP-5 groundwater was also located beneath the BY Cribs at well 299-E33-7 (748 µg/L). Besides wells located beneath the BY Cribs, only one other well, 299-E33-34 (317 µg/L), exceeded the secondary drinking water standard. Well 299-E33-15 exceeded the standard in November 2011 because of the flow reversal, but the average concentration was lower than the drinking water standard.

Elevated cyanide concentrations are also associated with well 699-53-55C, where concentrations have continued to decrease since the peak value in April 2009 (195 µg/L). The June 2011 concentration was 135 µg/L compared with 158 µg/L in July 2010 and 170 µg/L in January 2010. As stated for technetium-99, it appears the center of mass has passed by this well. Thus, there are no plume contours associated with well 699-53-55C in 2011.

3.4.7 Tritium

The tritium distribution within the unconfined aquifer from the 216-B-12 Crib is poorly understood; however, the levels found at depth during the RI are within the realm of decay associated with the 1950 releases.

Tritium found in 200-BP-5 groundwater primarily originated from large inventories disposed to the 216-B-50 and 216-B-57 Cribs in the mid- to late 1960s to the early to mid-1970s. Also contributing were cribs in the north part of 200-PO-1, which received large tritium waste inventories that migrated to groundwater and to the northwest within the aquifer in the late 1980s, after liquid disposal was discontinued to the Gable Mountain Pond. The discontinuation of discharges to Gable Mountain Pond resulted in a significant flow change in the 200 East Area towards the northwest and the Gable Gap. In addition, a large inventory of tritium was disposed to the 216-B-12 Crib in the 1950s. The tritium distribution within the unconfined aquifer from the 216-B-12 releases is poorly understood; however, the levels found at depth during the RI are within the realm of decay associated with the 1950 releases. Finally, significant inventories of tritium were discharged to the 216-B-3 Pond in the mid-1960s to mid-1970s and mid-1980s to mid-1990s, causing elevated levels of tritium in the past and currently at wells beneath and downgradient this site.

The distribution of tritium above the 20,000 pCi/L drinking water standard was limited to two isolated regions during 2011 (Figure 3.4-22):

- Wells at the B Complex and northwest beyond the 200 East Area
- Wells near the 216-B-3 Pond

Both of these plumes are detected in the upper portion of the unconfined aquifer. Although not shown on Figure 3.4-22, a plume deeper in the aquifer appears to exist beneath the 216-B-12 Crib and B Plant. This plume appears to be associated with the elevated tritium levels to the north along the southern and western portion of LLWMA-1. Section 3.4.7.2 provides additional information about this site.

The size of the plume exceeding the drinking water standard in the upper part of the unconfined aquifer within 200-BP-5 has decreased significantly over the past 8 years (Figure 3.4-6). The plume formerly extended through Gable Gap to wells and aquifer tubes near the Columbia River between 100-BC-5 and 100-KR-4. Concentrations declined because of radioactive decay and other natural processes.

3.4.7.1 Tritium Near B Complex and Northwest Beyond the 200 East Area

A small tritium plume with concentrations above the drinking water standard is located in the thin unconfined aquifer at the B Complex.

A small tritium plume is located in the thin unconfined aquifer at the B Complex. Wells 299-E33-7, 299-E33-13, 299-E33-26, and 299-E33-38 are located in the north part of the B Complex beneath or adjacent to the 216-B-50 and 216-B-57 Cribs. Elevated tritium at this location is not surprising as these two cribs received over 100 Ci of tritium (Appendix C of RPP-26744). The 216-B-50 Crib received approximately 126.3 Ci and 216-B-57 Crib received approximately 194.6 Ci. Except for the 216-B-49 Crib, this is 100 Ci more than any of the other BY Crib inventories. Overall, the groundwater tritium levels in this area are declining. Although some samples from wells 299-E33-7, 299-E33-13, and 299-E33-38 exceeded the drinking water standard, the yearly average results were below it. The increases in these wells from August to December of 2011 were associated with a flow reversal and the southeast position of the wells to the source sites. In addition, wells located to the northwest (299-E33-26, 299-E33-34, and 299-E32-10) continued to show declining levels even before the flow reversal. For example, well 299-E33-34 declined from an average of 18,000 pCi/L in 2010 to an average of 14,000 pCi/L in 2011. The continued declines indicate subsiding tritium-laden pore water drainage from the vadose zone beneath these source sites. As a result, the plume size in Figure 3.4-22 was reduced compared to 2010.

Farther north and within the Gable Gap, elevated tritium levels continue to decrease. The initial source of elevated tritium in this area can be traced back to 200 Area plumes from the 1970s and 1990s. Over the past 10 years, maximum levels have declined from 32,000 to 16,000 pCi/L at well 699-60-60. The decline is slightly faster than the decay rate, indicating some dilution. The decrease in this well is consistent with the decrease in other wells in the area.

As a result of residual tritium laden liquid waste drainage from the perched horizon, three unconfined aquifer wells had activities exceeding 10,000 pCi/L.

One additional well at the B Complex that exceeded the drinking water standard in 2011 was well 299-E33-344, located in a perched water horizon above the unconfined aquifer. Specifically, this well is located in the perched water horizon approximately 3 meters above the aquifer. Tritium levels increased significantly from September 2011 to October 2011 (1,400 to 41,300 pCi/L). A verification sample, collected December 5, 2011, confirmed the increase with 43,500 pCi/L. The tritium increase was observed after initiating a pumping test at this well. The source of the increase appears to be consistent with the 241-BX-102 unplanned release versus the 216-B-7A&B Crib. The 241-BX-102 unplanned release was at least three orders of magnitude more concentrated than the 216-B-7A&B Crib discharges (Appendix C of PNNL-19277). As a result of drainage from the perched horizon, three unconfined aquifer wells (299-E33-16, 299-E33-18, and 299-E33-44) had activities exceeding 10,000 pCi/L. Tritium levels in the unconfined aquifer decrease away from these wells, indicating attenuation of the contaminant levels.

It is worth noting that elevated tritium concentrations near 10,000 pCi/L were also located along the south boundary of the 241-B and 241-BX Tank Farms. The elevated tritium levels may be associated with the 241-BX-102 unplanned release. This is based on the elevated uranium also observed in this area. Alternatively, the increases may be associated with an apparent deep plume observed beneath the 216-B-12 Crib and B Plant (Section 3.4.7.2).

3.4.7.2 Tritium Near 216-B-62 Crib and Low-Level Waste Management Area 1

The highest tritium concentrations in 200-BP-5 in 2010 were in new RI Wells located near the 216-B-12 Crib and B Plant in the deeper part of the aquifer.

The two groundwater wells with the highest tritium concentrations in 2010 were the two new Remedial Investigation wells, 299-E28-30 and 299-E29-54, located near the 216-B-12 Crib and B Plant, respectively. The highest tritium activity, 150,000 pCi/L, was reported during sample collection while drilling at well 299-E29-54. The elevated result was encountered at ~18.3 meters below the water table, the deepest sample collected. There was no duplicate sample to confirm the result; however, the sample was run twice with different dilution factors and provided consistent results. Shallower samples had tritium concentrations ranging from 4,300 to 18,000 pCi/L. During drilling of well 299-E28-30, a tritium concentration of 93,500 pCi/L was encountered at ~7.62 meters below the water table, near the middle of the aquifer. This result was an average of two samples, 93,000 pCi/L and a duplicate of 94,000 pCi/L. The results are consistent with the significant tritium inventory associated with the 216-B-12 Crib (2,340 curies) versus the less than one curie for the other combined waste sites in this area (Appendix C of RPP-26744). Samples from other depths had tritium results ranging from 4,000 to 11,000 pCi/L.

Additional wells will be proposed in the revised 200-BP-5 Operable Unit Sampling and Analysis Plan to better define the tritium plume and movement.

The high tritium level in well 299-E28-30 coincides with the Ringold Formation unit 9A (Plate 5 of PNNL-12261). The top of the Ringold unit 9A is interpreted to extend from just above the water table through most of the saturated thickness, overlying a thin layer of unit 9B and ~6.1 meters of unit 9C. North of this well, Ringold unit 9A is truncated by the glaciofluvial Hanford sediments, which overlie the Ringold unit 9C. The change in hydraulic conductivity between these two formations ranges from an order of magnitude to several orders of magnitude (Table 3.1 of PNNL-12261). It is believed that tritium migrates north within these Ringold units, causing elevated activities to the north, beneath the 216-B-62 Crib. The elevated tritium at depth, beneath the 216-B-12 Crib, is also interpreted as the source of elevated tritium to the north along the southeast and west side of LLWMA-1. A tritium contour is not provided around well 299-E28-30 because the results are based on vertical data obtained during drilling; therefore, the tritium contour is not shown on Figure 3.4-22. Additional wells will be proposed in the revised 200-BP-5 Operable Unit Sampling and Analysis Plan (DOE/RL-2001-49) to better define the plume and movement.

3.4.7.3 Tritium in 216-B-3 Pond Area

In 2010, the tritium distribution was overestimated at the 216-B-3 Pond because of the elevated concentrations at well 699-45-42. Based on the result at well 699-43-41G and evaluation of the historical levels between wells 699-45-42, 699-44-43B, and 699-44-42, the north part of the 20,000 pCi/L contour has been contracted to the confines of the southern part of the 216-B-3 Pond and the A, B, and C lobes.

One well, 699-42-40A (near B Pond), had tritium concentrations exceeding the drinking water standard in 200-BP-5 in 2011. Well 699-42-40A is screened over 9.45 meters of Ringold lower mud and unit A (Ringold confined aquifer). The lower mud adjacent to the upper two meters of the screen is described as silt and clay with cobbles. The upper 3 meters of unit A is described as cemented gravels. The pump intake is located just below the cemented gravels within silty sandy gravels. The tritium levels in this well increased to a peak of 46,000 pCi/L in 2009. Levels appear to be in flux as considerable variation was seen in samples collected on June 8th and 22nd of 2011. The analytical results were

39,000 pCi/L and 28,000 pCi/L, respectively. It appears the recent increase in tritium at this well may correlate to the elevated tritium-to-liquid ratio from 1986 to 1997.

The southern extent of the 20,000 pCi/L contour is defined by wells 299-E25-25 and 299-E25-39 which had concentrations of 22,000 and 23,000 pCi/L in 2008. The wells have not been sampled since. The concentration in these wells increased significantly between the late 1990s and 2008 because of the elevated concentrations beneath B Pond. The concentrations in these wells are considered to be increasing.

3.4.8 Plutonium

Plutonium-239 is found in the groundwater at the 216-B-5 Injection Well because the waste was injected into the aquifer. Approximately 39.68 Ci of the plutonium isotopes 239 and 240 were released to the 216-B-5 Injection Well in the mid to late-1940s (Appendix C of RPP-26744).

In 2011, only three wells, 299-E28-23, 299-E28-24, and 299-E28-25 (all at the 216-B-5 Injection Well), had detectable plutonium-239/240. Detectable activities in these wells have been continuous since monitoring began in 1986. The concentrations reported for 2011 ranged between 0.56 pCi/L and 52 pCi/L; comparable with the 2010 range of 0.21 and 42.6 pCi/L. Well 299-E28-23, located ~1 meter from the 216-B-5 Injection Well, had the highest activity at 52 pCi/L. Plutonium-239/240 has limited mobility, as reflected by the low stable results in wells 299-E28-24 (0.56 pCi/L) and 299-E28-25 (1.2 pCi/L), which are located ~5 to 7 meters from the 216-B-5 Injection Well, respectively. Concentrations in well 299-E28-25, located to the northwest, are slightly higher because it is in the predominant direction of historical groundwater flow.

Historically, plutonium has been detected at locations other than at the 216-B-5 Injection Well; however, the results were below 1 pCi/L. All but four of the historical results from the late 1980s and early 1990s were less than 0.1 pCi/L. The majority of the plutonium detections were located northwest of the 216-B-5 Injection Well; the prominent flow direction at that time. Some of the results are suspect because of the location, such as within the Rattlesnake Ridge interbed (basalt confined aquifer).

Between 2007 and 2011, a total of 123 samples have been collected with 9 detectable results, omitting the 3 wells near the 216-B-5 Injection Well. The positive results were associated with the new Remedial Investigation wells and were generally single occurrences measured shortly after drilling. All the results were less than 0.1 pCi/L. Because of the number of samples collected at each of these Remedial Investigation wells since drilling, the results have become statistically inconsistent or are approaching this level.

Migration of colloidal particles of plutonium have been of interest to some (Kaplan et al., 2006, "Eleven-year Field Study of Pu Migration from Pu III, IV, and VI Sources"), but based on data collected at the Hanford Site, the levels are so low that it is impractical to track potential particles. Thus, future sampling will be focused at wells near the 216-B-5 Injection Well.

3.4.9 Cesium-137

Cesium-137 is found in the groundwater at the 216-B-5 Injection Well because the well was completed in the unconfined aquifer. Approximately 8.67 Ci of cesium-137 was released to the 216-B-5 Injection Well in the mid to late-1940s (Appendix C of RPP-26744).

Only three wells (all near the 216-B-5 injection well) had detectable cesium-137 within 200-BP-5.

Consistent with past results, only three wells (all near the 216-B-5 Injection Well) had detectable cesium-137 within 200-BP-5. The values ranged from 34.5 to 2,140 pCi/L. The levels were slightly lower

than 2010 when the results ranged from 35.4 to 2,180 pCi/L. Well 299-E28-23, located ~1 meter from the 216-B-5 Injection Well, had the highest activity at 2,140 pCi/L. The reported activity is above the 200 pCi/L drinking water standard and is less than the DOE-derived concentration standard of 3,000 pCi/L.

Cesium-137 has relatively low mobility in the subsurface and does not migrate significant distances, as observed by the much lower concentration (62 pCi/L) at well 299-E28-24, located ~5 meters to the southeast of the 216-B-5 Injection Well. An even lower concentration (34.5 pCi/L) is found ~7 meters to the northwest in well 299-E28-25. Based on historical activity comparisons, this plume is decaying with little migration, as modeled and concluded in Section 5.4.2 of DOE/RL-95-59.

3.4.10 Sulfate

Sulfate within 200-BP-5 groundwater is primarily because of large inventories to liquid disposal sites with sufficient fluid to migrate through more than 70 meters of vadose zone. For example, the 216-B-46 and 216-B-49 Cribs received past liquid waste inventories of sulfate near 11,750 mg/L (Appendix C of RPP-26744). Another waste site in the same area, 216-B-8 Crib, received much lower sulfate concentrations; however, levels in the groundwater are higher beneath this site than under the BY Cribs. Other sites, such as Gable Mountain Pond and B Pond, which had sufficiently large inventories of sulfate, had even more liquid discharges, thus reducing the concentrations to little consequence. Note that although Gable Mountain Pond had low concentrations in the effluent according to RPP-26744, there are sulfate concentrations that exceed the secondary drinking water standard within the aquifer beneath this site. When the inventory of sulfate for the Gable Mountain Pond site was reviewed in RPP-26744 on a year-by-year basis, the average concentration were less than 18 mg/L. Thus, RPP-26744 does not represent accurate sulfate records for the former Gable Mountain Pond and 216-B-8 Crib waste sites.

Some unplanned releases may not have been included for certain sites such as the UPR-200-E-138, which was not included in RPP-26744 for the 216-B-3 Pond. The unplanned release was associated with the strontium-90 Product Storage Tank (8-1) inside the 221-B Building. At the time of the release, strontium-90 was part of a waste fractionization campaign (Section 3.2.2 in DOE/RL-98-28). It is believed the fractionization process was similar to the process described in "*In-Farm Scavenging" Operating Procedure and Control Data* (HW-38955). This process used nickel sulfate for the separation of strontium. Large quantities of sulfate are believed to have been associated with this process because of the elevated sulfate beneath the 216-B-2 Ditch. Further information regarding the conceptual model transport mechanism associated with the 216-B-2 Ditch was presented in the 2010 Annual Groundwater Monitoring Report, (Section 9.1.10.3 of DOE/RL-2011-01). The fractionation process was also used at WMA C, however, large sulfate release inventories are not provided for WMA C releases in RPP-26744.

The distribution of sulfate above the secondary drinking water standard (250 mg/L) was limited to four locations within 200-BP-5 (Figure 3.4-23):

- B Complex
- WMA C
- 216-B-2 Ditches
- Gable Mountain Pond

In comparing the sulfate plume from 2007 (Figure 2.10-19 of DOE/RL-2008-01) with 2011 contours, three changes are noticed, as follows:

1. The extent of the 250 mg/L contour has increased at the B Complex. In 2007, only two wells had concentrations at or exceeding the secondary drinking water standard at the B Complex. These wells were located beneath the 216-B-8 Crib and the BY Cribs. In 2011, the plume stretches to the northeast corner of LLWMA-1 from the BY Cribs and from the 216-B-8 Crib to the BY Cribs.

2. The extent of the 250 mg/L contour has increased beneath the 216-B-2 Ditch. Only a small region east of LLWMA-2 and south of Trench 94 had sulfate concentrations exceeding 250 mg/L in 2007. In 2011 the 250 mg/L contour extends south to southeast beyond well 299-E27-25 located east of WMA C. The change in distance of the contour is 375 meters. Because there are no wells located between wells 299-E27-10 and 299-E27-25, correlating the flow rate and direction from the expansion of the interpreted contour line is not advised. This is because the infiltration of sulfate-laden pore water from the vadose zone may also extend towards well 299-E27-25.
3. The plume along the southeast side of WMA C has been extended to the south-southeast. The concentration along the southeast side of WMA C in well 299-E27-14 has increased from about 250 to 300 mg/L. Likewise, the sulfate concentration in well 299-E24-33, located to the south-southeast of well 299-E27-14, has increased from approximately 108 mg/L to 150 mg/L.

3.4.10.1 Sulfate near B Complex

Sulfate concentration increases were seen beneath the BY Cribs and the 216-B-8 Crib in August 2011, coincidental with a midyear flow direction change. The concentration decreased in November, indicating increased flow rates to the south. Concurrently, wells south of these waste sites saw increased concentrations in November.

3.4.10.2 Sulfate near Waste Management Area C

The elevated sulfate concentration reported in well 299-E27-14 (on the southeast side of WMA C) is clearly associated with WMA C.

The elevated sulfate concentration reported in well 299-E27-14 (southeast side of WMA C) is clearly associated with WMA C. This is based on the lower sulfate concentrations upgradient along the north part of the tank farm. No known sulfate releases are capable of the concentrations in the groundwater based on RPP-26744 (discussed further in Sections 3.4.1.8 and 3.4.3.3). The orientation of the plume has been expanded to the south towards well 299-E24-33 because of the increasing sulfate trend at this well. Lower sulfate concentrations to the west bound the 250 mg/L contour. Lack of a bounding well to the east requires an estimation of the elevated sulfate extent in this direction.

3.4.10.3 Sulfate near the 216-B-2 Ditches

The sulfate concentration beneath the east end of the 216-B-2 Ditches in well 299-E27-10 has continued to be the highest sulfate concentrations in this area since well 299-E34-7 went dry in 2005. Like the discussion for nitrate (Section 3.4.1.7), sulfate concentrations have shown increases to the west and south over the past decade. The increases infer radial spreading or increased lateral extent from the vadose zone drainage in the area.

3.4.10.4 Sulfate near Gable Mountain Pond

Historically, sulfate concentrations beneath the former Gable Mountain Pond exceeded the secondary drinking water standard in only one well, 699-53-48A. This well was not sampled in 2011, but is scheduled to be sampled in 2012. Concentrations to the east near the former outlet are historically less although the aquifer is thinner. Farther west, concentrations decrease as the aquifer thickness increases.

3.4.11 Other Constituents

Elevated arsenic was found at one well, 299-E33-16, located beneath the 216-B-8 Crib. Review of historical chemicals used at the site during the active discharges to this crib revealed no arsenic or arsenic compounds. The 216-B-8 Crib did receive acetic and/or hydrochloric acid. However, it is unclear how or why arsenic in the dissolved state has migrated into the groundwater at concentrations near ten times

background levels (at a maximum of 104 µg/L). Based on lower than background levels at the eight surrounding monitoring wells, arsenic preferentially adsorbs to the sediments near the point of drainage.

Cobalt-60 concentrations were elevated in 200-BP-5 groundwater in the past, but contaminant levels continued to decline in 2011. Levels have not exceeded the drinking water standard since 2008. The elevated levels were only at one well, 299-E33-4, which went sample dry in 2008.

Fluoride concentrations exceeded the drinking water standard in well 299-E33-344. This well is screened within a perched water horizon ~3 meters above the unconfined aquifer near the 216-B-7A&B Cribs. The elevated fluoride concentrations are associated with the elevated concentrations of fluoride laden liquid waste received by the 216-B-7A&B Cribs. The fluoride concentration declined in this well during 2011 because of mixing with the 241-BX-102 unplanned release. Concentrations declined from a maximum of 97 mg/L in December 2010 to 9.4 mg/L in December 2011. Fluoride-laden pore water drainage from the perched water zone into the underlying unconfined aquifer is not significant as concentrations are ten times less than the drinking water standard of 4 mg/L.

3.4.12 CERCLA Groundwater Activities

The following paragraphs provide information about the CERCLA groundwater activities for 2011, which included routine groundwater monitoring, report writing, and preparation of a treatability test (DOE/RL-2011-40) to address technetium-99 and uranium contamination, and preparation and startup.

Routine CERCLA groundwater monitoring requirements are described in DOE/RL-2001-49. Appendix A of this report provides information about the monitoring network, constituent lists, and sampling frequency. The CERCLA monitoring data are used to define the extent of groundwater contamination. Each year, contours are revised for each contaminant of concern identified in DOE/RL-2001-49. The certainty of the plume interpretation is also assessed to determine the effectiveness of the CERCLA and AEA monitoring program. The assessment determines if the selected analytical methods, sampling frequencies, and well locations are appropriate. In addition, the new contours are compared each year with previous contours to interpret groundwater flow and track concentration trends near contaminant sources. DOE/RL-2001-49 also provides the direction for the integrated use of RCRA analytical data.

DOE/RL-2001-49 is in the process of being revised and should be completed in 2012. Data from the new Remedial Investigation wells and the existing monitoring network are being used to determine data gaps. Also, new AEA requirements at various RCRA facilities that were included since completion of revision 1.0 in 2004 are being added for an all-inclusive document.

The 2011 contaminant concentrations near source sites were lower than 2010 for most areas. Reduced residual liquid waste drainage may be one reason, for example, technetium-99 levels beneath the BY Cribs continued to see declines (Section 3.4.3.1). Concentrations of cyanide, sulfate, and tritium decreased beneath the BY Cribs (Sections 3.4.6, 3.4.10.1, and 3.4.7.1, respectively). Most of these same constituents also decreased at well 699-53-55C (Sections 3.4.6, 3.4.1.2, and 3.4.3.2 for notable contaminants). Contaminant levels beneath the 216-B-2 Ditches also began to decrease towards the end of the year (Sections 3.4.1.7 and 3.4.10.3). Contaminant levels at Gable Mountain Pond also saw decreases in 2011.

The 2011 contaminant concentrations near source sites were lower than 2010 for most areas.

In 2011, eight of the 200-BP-5 required wells were not sampled in accordance with DOE/RL-2001-49. The main reason for the wells not sampled was schedule constraints; however, some wells were mistakenly not scheduled or maintenance was required. Besides the wells not sampled, several

required contaminants were not sampled. The majority of contaminants not sampled were associated with cesium-137, plutonium-239/240, and strontium-90. Appendix A provides a list of the required 200-BP-5 wells to be sampled. This appendix also provides the contaminants and supporting constituents to be sampled and those not sampled. Note, because of significant knowledge obtained over the past decade (e.g., geologic environment, source sites, flow regime, and contaminant nature and extent) and the changes to well network (for example, dry, decommissioned, and new wells) the 200-BP-5 Groundwater SAP (DOE/RL-2001-49) needs updated. Thus, the Sampling and Analysis Plan is being revised and will be used to derive the FY 2013 groundwater sampling requirements. In addition, new well installations will be proposed to define deep plume extent and movement. Finally, additional wells will be proposed to track migrating plumes for the probable near term flow direction change.

Two major reports saw activity in 2011. The draft *Remedial Investigation Report 200-BP-5 Groundwater Operable Unit* (DOE/RL-2009-127) was completed and submitted to DOE in 2011. The draft Feasibility Study/Proposed Plan are due June 30, 2015 in accordance with the Tri-Party Agreement (Ecology et al., 1989) Milestone M-15-21A. The other major report, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2010-74), is associated with the pumping tests near the 241-B and BY Tank Farms. Minor reports completed in 2011 associated with the treatability test included a small project functional design report and work packages for drilling two wells near the 241-BY Tank Farm.

The treatability test for 200-BP-5 is designed to evaluate the practicality of performing a groundwater pump-and-treat system for the extraction of uranium and technetium-99 contaminant plumes near WMA B-BX-BY. The well site selection was discussed in the 2010 report (Section 9.2.3 of DOE/RL-2011-01). Field activities beginning in 2011included the following:

- Preparation of the drill site west of the 241-BY Tank Farm
- Initial drilling of the extraction well 299-E33-268, located west of the 241-BY Tank Farm (i.e, started in 2011 and completed in 2012)
- Initial construction of an aboveground pipeline from both extraction wells, 299-E33-268 (to be located west of the 241-BY Tank Farm and 299-E33-343 (located along the northwest corner of the 241-B Tank Farm), to the tie with the cross-site line to the Effluent Treatment Facility, including road crossings
- Construction of a utility distribution rack
- Barometric response measurements in existing monitoring wells associated with the pump test at wells 299-E33-268 and 299-E33-343

The barometric response activity was tied with the completion of the Treatability Test for the completion of Milestone M-15-82B.

The barometric response activity was tied with the completion of the treatability test for the completion of Milestone M-15-82B.

In addition to the 200-BP-5 CERCLA activities, two deep vadose zone CERCLA activities were completed associated with the perched water horizon near the 241-BX-102 unplanned release and the 216-B-7A&B Cribs. The first was issuance of DOE/RL-2011-40, which focuses on a perched water zone. The test plan includes the parameters for evaluating perched water pumping/pore water extraction as a potential remedy for uranium extraction. In addition, information needed to conduct fate and transport modeling will be collected so numerical models can be used to estimate the effectiveness of the treatment for protection of groundwater. The second activity was startup of perched water pumping from

well 299-E33-344. Pumping began in August 2011 and continued until early December 2011, when contaminant concentrations increased significantly and required a different waste disposal path before continued testing. Approximately 90,000 liters of contaminated water were removed before pumping was halted. The uranium results associated with the test showed an increase from 4,500 µg/L on September 7, 2011, to 63,600 µg/L on October 4, 2011. Another sample, collected December 5, 2011, confirmed the uranium increase at well 299-E33-344 with a result of 71,500 µg/L. The increase in uranium indicates a lateral radius influence to the west where more concentrated levels of uranium were found in depth-discrete samples collected across the perched horizon during drilling at well 299-E33-343. Thus, the retrievable liquid volumes and the radius of influence associated with the 299-E33-344 are evidence of the effectiveness of perched water pumping.

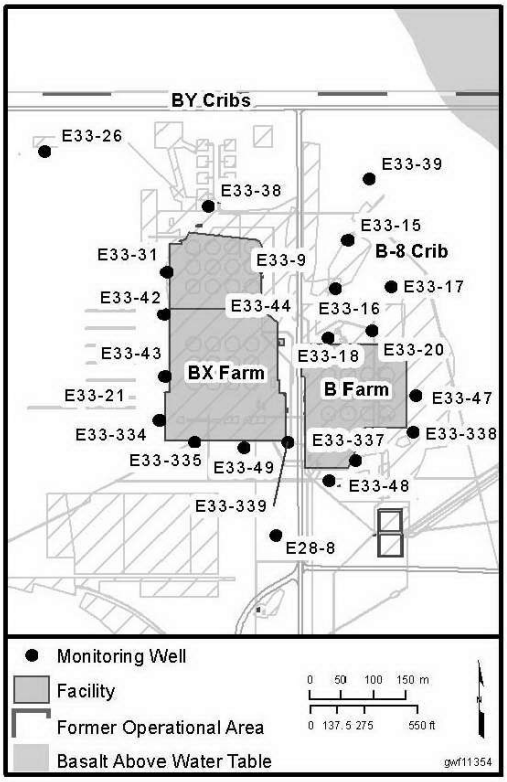
3.4.13 RCRA and Other Facility Monitoring

This section describes the results of monitoring at individual units such as treatment, storage, and disposal units. These units are monitored under RCRA requirements for dangerous waste/dangerous waste constituents and under AEA for source, special nuclear, and byproduct materials. Data from unit-specific monitoring are also integrated into CERCLA groundwater investigations. Dangerous constituents and radionuclides are occasionally discussed jointly in this section to provide comprehensive interpretations of groundwater contamination. As previously discussed and pursuant to RCRA, the source, special nuclear, and byproduct material components of radioactive mixed waste are not regulated under RCRA but are instead regulated by DOE, acting pursuant to its AEA authority. Therefore, while this report may be used to satisfy RCRA reporting requirements, the inclusion of information on radionuclides in such a context is for information only and may not be used to create conditions or other restrictions set forth in any RCRA permit.

The 200-BP-5 Operable Unit contains six RCRA sites with groundwater monitoring requirements: WMA B-BX-BY, WMA C, 216-B-63 Trench LERF, LLWMA-1, and LLWMA-2. The following discussion summarizes the results of statistical comparisons, assessment studies, and other developments for this reporting period. Groundwater data are available in the HEIS database and in the data files accompanying this report. Appendix B provides additional information (including well and constituent lists, maps, and statistical tables).

3.4.13.1 Waste Management Area B-BX-BY

The WMA B-BX-BY is located in the north-northwest part of the 200 East Area. It includes the 241-B-BX-BY Tank Farms, which consists of 36 underground storage tanks ranging from 1,892,500-liter to 2,869,000-liter capacity. There are four additional 208,000-liter underground storage tanks in the 241-B-Tank Farm. Twenty-one of the forty underground tanks are confirmed or assumed to have leaked. Additional sources of unplanned releases include waste loss from spare inlet nozzles or cascade lines, pipeline leaks, and surface releases. Currently, only one of these releases, the 241-BX-102 unplanned release, has been confirmed as impacting the groundwater. No dangerous waste/dangerous waste constituents have been identified with this release.



In June 1996, the specific conductance indicator parameter exceeded the critical mean at well 299-E33-32 initiating an assessment of the 241-B-BX-BY Tank Farms. During the course of the initial assessment contaminants exceeding the drinking water standard were identified at

well 299-E33-41. A subsequent assessment to identify the source was planned (PNNL-13022, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area B-BX-BY at the Hanford Site*). Field investigations (RPP-10098, *Field Investigation Report For Waste Management Area B-BX-BY*; DOE/RL-2007-18) provided significant vadose zone samples to fingerprint the source of contamination. Based on these investigations, a determination was made identifying the source as the 241-BX-102 unplanned release (Section 5.7 of PNNL-19277). The various contaminants associated with this release are discussed in Sections 3.4.1.1, 3.4.2.6, 3.4.3.1, 3.4.4.1, and 3.4.9.1. Another objective of monitoring identified in PNNL-13022 was to determine the contaminant levels and the extent/rate of migration on a quarterly basis, discussed below.

During the 200-BP-5 remedial investigation, the unplanned release from tank 241-BX-102 was identified as the source of groundwater contamination beneath WMA B-BX-BY.

In accordance with 40 CFR 265.93(d)(7) (as referenced by WAC 173-303-400), the WMA B-BX-BY well network was sampled quarterly in order to make continued determinations of the concentration and extent of dangerous waste/dangerous waste constituents in the groundwater. All of the WMA B-BX-BY monitoring wells defined in PNNL-13022—except 299-E33-7, 299-E33-9, 299-E33-16, and 299-E33-26—were sampled as required during the reporting period. Appendix B Table B-35 includes a list of WMA B-BX-BY wells, constituents monitored, and whether the wells were sampled as scheduled.

The flow direction and rate have been reported as indeterminate to nearly stagnant over the past 5 years. This was because of variability in the regional groundwater monitoring measurements from a network of fourteen wells located near B Plant, 216-B-5 Injection Well, WMA B-BX-BY, LLWMA-1, and north of the 200 East Area. The use of this regionally corrected groundwater measurement network (survey to single bench mark, deviation and barometrically corrected) has helped to define the variability of uncorrected measurements and determined flow direction and rate occasionally over the past five years. Based on the water level measurements from this monitoring network, the groundwater flow direction was north-northwest over the first five months of 2011. However, high Columbia River spring stages caused a flow direction to change to the south-southwest in August 2011. Because of the flow change, the overall groundwater flow direction and rate are defined as indeterminate this year (Table B-1, Appendix B).

The network well screens range from 0.90 to 11.67 meters into the aquifer. All the wells have adequate water columns in the screened interval for sampling except possibly well 299-E33-26. This well is being investigated because water was not able to be retrieved during the November 2011 sampling event. The next shortest water column is 1.63 meters in well 299-E33-39, which should be sufficient for the next decade or more.

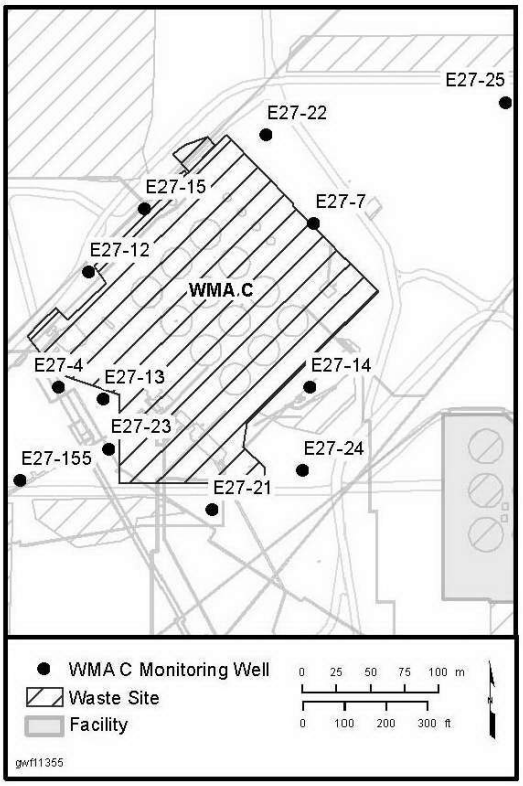
During 2011, no dangerous wastes/dangerous waste constituents were determined to impact groundwater from WMA B-BX-BY. However, as explained in the other sections of this report, groundwater continues to be impacted by non-RCRA constituents from the 241-BX-102 unplanned release. Because no dangerous waste/dangerous waste constituent has been determined to impact groundwater, the extent of WMA B-BX-BY monitoring network is confined to the boundary of WMA. Other non-RCRA contaminants are monitored by the 200-BP-5 Operable Unit.

During 2011, no dangerous waste constituents were determined to impact groundwater from WMA B-BX-BY.

Although no dangerous waste constituents were determined to impact groundwater from WMA B-BX-BY, the presence of non-RCRA contaminants associated with the 241-BX-102 unplanned release in the groundwater indicates the WMA is affecting the groundwater quality. Thus, the site will remain in assessment monitoring as allowed in 40 CFR 265.93(d)(6). Because of the findings in recent investigations in this area and the addition of new monitoring wells, the assessment plan will be revised in 2012 and submitted to Ecology for review.

3.4.13.2 Waste Management Area C

The WMA C is located in the east central part of the 200 East Area. It includes the 241-C Tank Farm, which consists of twelve underground storage tanks with an approximate capacity of 1.9 million liters. There are four additional underground storage tanks with an approximate capacity of 208,000 liters. Seven of the sixteen underground tanks are confirmed or assumed to have leaked. Additional sources of unplanned releases include waste loss from spare inlet nozzles or cascade lines, pipeline leaks, and surface releases. Significant uncertainty is associated with the extent of contaminant migration from both the underground storage tanks and unplanned releases.



In July 2009, the specific conductance indicator parameter exceeded the critical mean at well 299-E27-14 initiating an assessment of the 241-C Tank Farm. Furthermore, the dangerous waste constituent cyanide was detected in the groundwater. Based on these findings, with no upgradient source the 241-C Tank Farm entered into assessment monitoring in accordance with 40 CFR 265.93(d)(7) (as referenced by WAC 173-303-400).

In accordance with 40 CFR 265.93(d)(7) (as referenced by WAC 173-303-400), the well network was sampled quarterly in order to make continued determinations of the concentration and extent of cyanide in the groundwater (DOE/RL-2009-77, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*). All of the wells were sampled quarterly, as required, during 2011. Appendix B Tables B-36 and B-37 includes a list of WMA-C wells, constituents monitored, and indicates if the wells were sampled as scheduled. Flow direction and rate were indeterminate based on lack of corrected groundwater level measurements as discussed in the following text and in Table B-1 of Appendix B.

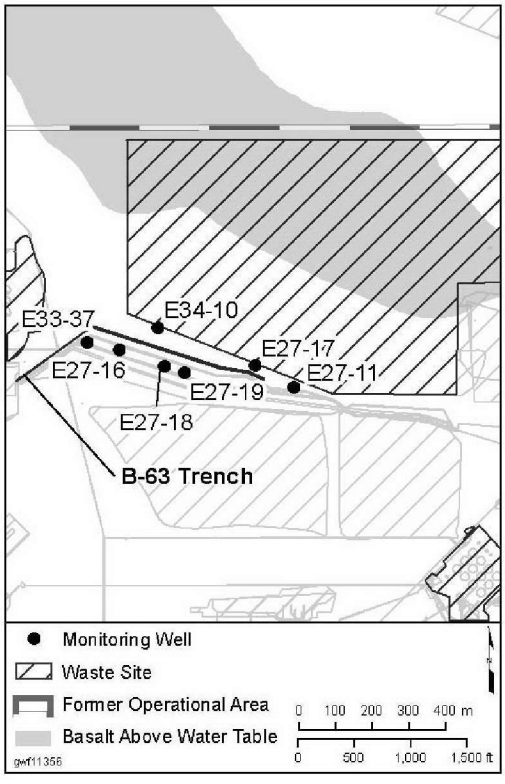
The monitoring network as defined in DOE/RL-2009-77 consists of three upgradient, seven downgradient, and three cross-gradient wells. The definition of upgradient and downgradient is based on a southwest flow direction. Currently, the flow direction and flow rate is indeterminate by water table measurements because the measurement error exceeds the gradient. Use of regionally corrected measurements (survey to single bench mark, deviation and barometrically corrected) in the northwest corner of the 200 East Area have helped to define the variability of uncorrected measurements and occasionally determine flow direction and rate. Regional corrections near WMA C may also help define the flow direction and rate. Until corrections are made, the flow direction continues to be generally defined as southward (from southwest to southeast). Regional nitrate and sulfate contaminants have recently shown a possible southeast flow direction north of WMA C (Sections 3.4.1.7 and 3.4.10.3). However, distribution of certain contaminants indicates a southwest flow direction (Section 3.4.3.3). Based the lack of a definitive gradient measurement in this area, flow direction and rate are indeterminate.

The network well screens range from 1.61 to 13.47 meters into the aquifer. These wells all have adequate water columns in the screened interval for sampling through the next decade or more.

During 2011, the only dangerous waste/dangerous waste constituent impacting groundwater at WMA C was cyanide.

During 2011, the only dangerous waste/dangerous waste constituent impacting groundwater was cyanide. The concentrations were significantly below the 200 µg/L drinking water standard with a yearly high of 21.7 µg/L at well 299-E27-14. Note that cyanide was reported as high as 37.4 µg/L at well 299-E27-7, but the value was flagged because cyanide was also found in the associated quality control blank. Four other possible dangerous wastes/dangerous waste constituents that continued to be evaluated from 2010 are discussed as follows:

- Carbon tetrachloride was not detected in any WMA C monitoring well in 2011 and therefore the one detection in 2010 was determined to be false positive. This constituent is excluded from further review.
- Chloroform was continuously detected in well 299-E27-12, but excluded because this well is an upgradient well (see SGW-51057, *WMA C April through June 2011 Quarterly Groundwater Monitoring Summary Report*, for further explanation).
- Nickel, like manganese (discussed in Section 3.4), was determined to be associated with well screen degradation based on the investigation associated with similar findings at wells 299-E33-337 and 299-E33-339.
- Elevated vanadium was determined to be associated with an upgradient source because of the levels in wells north of WMA C.



The presence of the dangerous waste constituent cyanide implies the 241-C Tank Farm is continuing to impact the groundwater. The current monitoring network is sufficient to determine the extent of contamination, as shown on Figure 3.4-24. Because of the lack of a measurable groundwater gradient, as described above, the rate of migration is indeterminate. Existing wells in the region will be assessed in 2012 to determine whether a sufficient network capable of defining the groundwater gradient is possible. If not, locations will be proposed where additional wells are needed to thoroughly evaluate the groundwater gradient.

3.4.13.3 216-B-63 Trench

The 216-B-63 Trench is located in the north central portion of the 200 East Area. The trench was constructed by 1970 as an emergency percolation trench for radioactively contaminated cooling water from B Plant. Through 1985, acidic and caustic treatments were completed to neutralize the waste. The actual corrosive portion from the demineralizers was less than 1,890 liters per day, while the remainder of the 378,000 to 1,408,000 liters per day was a combination of chemical sewer and cooling water. The corrosive waste

discharges were regulated under RCRA and its implementing requirements WAC 173-303-400. Discharges to this trench ceased in 1992.

In accordance with 40 CFR 265.93(b) (as referenced by WAC 173-303-400), the well network was sampled semiannually for contaminant indicator parameters and supporting constituents (DOE/RL-2008-60, *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*). All of the wells were sampled semiannually, as required, during 2011. Appendix B Table B-16 includes a list of 216-B-63 Trench wells, the constituents monitored, and indicates if the wells were sampled as scheduled. Because of the midyear flow direction change as noted in the introduction of Section 3.4, the flow direction and rate were indeterminate. Appendix B Tables B-2 and B-17 provides the indicator parameter comparison values for 2011 and 2012, respectively.

The monitoring network for the 216-B-63 Trench consists of two upgradient and five downgradient wells.

The monitoring network, as defined in DOE/RL-2008-60, consists of two upgradient and five downgradient wells. The definition of upgradient and downgradient is based on a west-southwest flow direction. Currently, the flow direction is undefined because of the flat nature of the water table. Barometric response corrections were included for the 216-B-63 Trench network in 2011; however, the variability in the measurements compared to the water table change was too great to return a statistically significant flow direction determination. Because of the local variability, taking a more regional approach may provide sufficient data to determine a gradient in this area. A regional approach for evaluating existing wells will be assessed in 2012 to determine whether a sufficient network capable of defining the groundwater gradient is possible. If not, locations will be proposed where additional wells are needed to thoroughly evaluate the groundwater gradient.

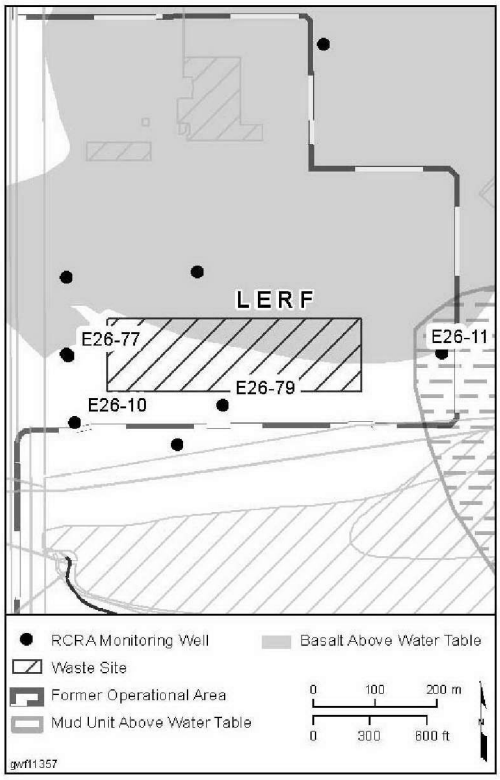
Regional contaminant evaluations provide additional information on groundwater flow directions. These evaluations indicate flow to the west-northwest from the west end of the 216-B-63 Trench (wells 299-E27-16, 299-E33-33, 299-E33-36, 299-E33-37, 299-E33-337, 299-E33-338, and 299-E34-8). Some of the wells are not associated with the RCRA monitoring network. Sections 3.4.2.5 and 3.4.2.6 discuss historical contaminant migration observations in this area. Based on these observations, the dominant flow direction appears to be west-northwest along the west end of the trench. However, a midyear groundwater flow change deters stating a prominent flow direction in 2011. The regional contamination discussed above is assumed to be associated with the 216-B-2 Ditches and other past sources to the east-southeast.

The network well screens range from 2.09 to 4.69 meters into the aquifer. These water table wells all have adequate water columns in the screened interval for sampling through the next decade and beyond.

During 2011, the indicator parameter measurements for pH, specific conductance, total organic carbon, and total organic halides did not exceed the statistically derived background comparison values (e.g., critical mean). The pH levels for all of the 216-B-63 Trench wells ranged from 7.91 to 8.28, which is within the lower and upper bound of the critical mean (7.42 to 8.67, respectively). The highest specific conductance level was 470 µS/cm, which is below the critical mean (1,030 µS/cm). The highest average total organic carbon level was 517 µg/L, which is below the critical mean (1,000 µg/L). The highest average total organic halide concentration was 10.18 µg/L, which is below the critical mean (10.9 µg/L). In addition, the annual groundwater phenol results were all reported as non-detects for the April 2011 sampling event. Thus, this site remained in interim status indicator evaluation monitoring.

3.4.13.4 Liquid Effluent Retention Facility

Located on the eastern boundary of the 200 East Area, the LERF consists of three lined surface impoundment basins. Construction of the complex was completed in 1991. The basins are arranged side by side, with an 18.2 meter separation between each basin. The dimensions of each basin (cell) are 100.5 meters by 82.2 meters, with a maximum fluid depth of 6.7 meters.



Groundwater at LERF continued to be monitored under RCRA final status permit conditions. The LERF is a RCRA-regulated unit under RCW 70.105 ("Hazardous Waste Management") and is subject to groundwater monitoring requirements pursuant to WAC 173-303-645. All of the wells were sampled semiannually, as required, for RCRA indicator and site-specific parameters (PNNL-11620, *Liquid Effluent Retention Facility Final-Status Groundwater Monitoring Plan*) during 2011.

The uppermost aquifer directly beneath the LERF consists of thin aquifer(s) in the Hanford formation and Elephant Mountain Member flow top. The aquifer in the Hanford formation is unconfined; however, recent analysis of water-level data for barometric pressure responses indicates that the aquifer near well 299-E26-11 is semiconfined.

A new well (299-E26-14) was installed on the north side of the LERF in 2011 to acquire more hydrologic data because of the complexity of the basalt-Hanford formation contact and the flow top lithology on the top of the basalt. The well will be sampled in 2012 along with the other LERF wells and a characterization report will be issued with a recommendation as to whether the well should be added to the existing network.

The current groundwater monitoring network consists of one upgradient well and three downgradient wells, which are sampled semiannually (Appendix B Table B-22). All monitoring wells are compliant with WAC 173-160.

Work began in fiscal year 2008 to better understand the groundwater flow direction beneath the LERF. Vertical elevation surveys and gyroscopic surveys were performed at three wells (299-E26-10, 299-E26-77, and 299-E26-79) in 2009as a result of the flatness of the water table. Trend-surface analyses were applied in 2011 to the measurements to determine gradient magnitudes and flow directions on two data sets: one data set without barometric corrections, and the second data set with barometric corrections. The two sets are very similar, so only the corrected set will be discussed. Since well 299-E26-11 is considered to be in the semiconfined aquifer and possibly not in direct hydraulic communication with the other three wells, it shows ~0.8 meter higher head than the remainder of the wells and was excluded from the analyses. The semiconfined aquifer is in communication with the unconfined aquifer; however, it is a different hydrostratigraphic unit with different properties. Trend-surface analysis was performed for the three remaining wells in the network (exclusive of well 299-E26-11), and the data set corrected for barometric effects showed average groundwater flow direction to be south-southwest at 199 (±28) degrees) and the average gradient magnitude was 2.6×10^{-4} ($\pm 5.8 \times 10^{-4}$) meter per meter, with a calculated groundwater flow of ~0.02 meter per day (Table B-1, Appendix B). This analysis is similar to the 2009 groundwater flow direction of 199 degrees. The gradient magnitude increased from the 2009 value of 1.3×10^{-4} meter per meter.

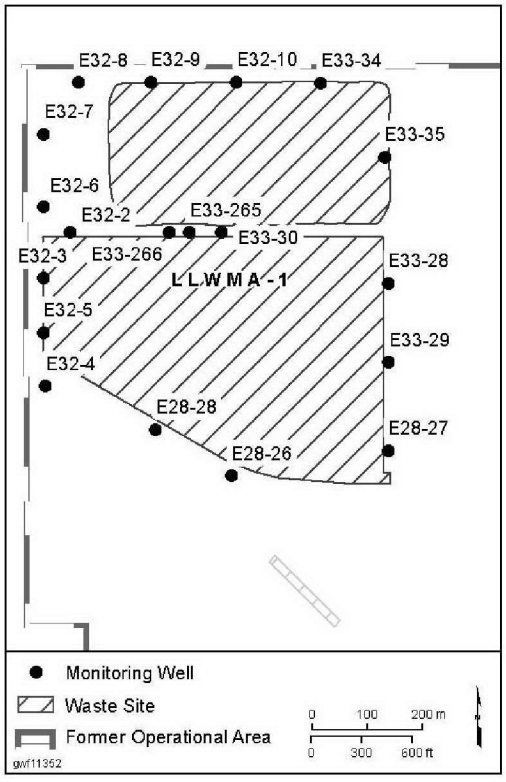
The uppermost aquifer beneath the LERF is being evaluated as part of a groundwater evaluation plan. This plan will be part of a revision of the LERF operating permit that will form the basis for future groundwater monitoring at the unit. The results from drilling new wells suggest that the fractured basalt flow top makes up the basal portion of the unconfined aquifer. New well 299-E26-14 on the north side of the LERF is screened in the Hanford formation and contains sufficient water to further delineate groundwater flow direction.

The dangerous waste constituents and groundwater quality parameters currently monitored according to the permit are alkalinity, ammonium, anions, metals, phenols, and volatile organics. The contaminants of concern are nitrate, total organic halogen, and total organic carbon.

Analyses of samples collected during the reporting period indicate that all constituents in the permit were either undetected or below drinking water standards, except for nitrate. Sulfate concentrations slightly increased in well 299-E26-10. Nitrate continued to exceed the drinking water standard in wells 299-E26-10 and 299-E26-77, with maximum concentrations of 51.4 and 50 mg/L, respectively. Nitrate stabilized in well 299-E26-10, but has increased since 2003 and in wells south and east of the LERF. The regional increase of anions and cations is evident in wells located in the central and eastern portions of the 200 East Area. Wells installed prior to LERF operations showed increasing nitrate from a regional plume.

3.4.13.5 Low-Level Waste Management Area 1

The LLWMA-1 is located in the northwest corner of the 200 East Area. It includes the 218-E-10 Burial Ground, which consists of 14 unlined trenches. The LLWMA-1 received low-level radiological waste and low-level mixed wastes beginning in 1955. The dangerous chemicals in the low-level mixed waste portions of LLWMA-1 are regulated under RCRA and its implementing requirements WAC 173-303-400, as defined in DOE/RL-2009-75, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-1*. DOE monitors the LLWMAs for radionuclides under the requirements of the AEA, as described in DOE/RL-2000-72.



In accordance with 40 CFR 265.93(b) (as referenced by WAC 173-303-400), the well network was sampled semiannually for RCRA contaminant indicator parameters and supporting constituents. All of the wells were sampled semiannually, as required, during the reporting period. Appendix B Table B-23 includes a list of LLWMA-1 wells, constituents monitored, and indicates if the wells were sampled as scheduled. Because of the midyear flow direction change as noted in the introduction of Section 3.4, the flow direction and rate were indeterminate (Table B-1, Appendix B). Appendix B Tables B-2 and B-24 provide the indicator parameter comparison values for 2011 and 2012, respectively.

The monitoring network for LLWMA-1 consists of six upgradient and eleven downgradient wells.

The monitoring network as defined in DOE/RL-2009-75 consists of six upgradient and eleven downgradient wells. The definition of upgradient and downgradient is based on a northwest flow

direction. Occasionally the flow direction changes as a result of high Columbia River spring stages. This occurred in 2011 and previously in June 2008. The previous reversal back to the north was not statistically realized until the summer of 2009. Fortunately, wells are located on all sides of the burial ground and indicator parameters are collected at all wells semiannually.

The network well screens range from 1.72 to 3.36 meters into the aquifer. These groundwater wells all have adequate water columns in the screened interval available for sampling, possibly for several decades.

In 2011, the indicator parameter measurements for pH, total organic carbon, and total organic halides did not exceed the statistically derived background comparison values (e.g., critical mean). The pH levels for all of the LLWMA-1 wells ranged from 7.53 to 8.20, which is within the lower and upper bound of the critical mean (7.43 to 8.57, respectively). The highest total organic carbon level was 1,009 µg/L, which is below the critical mean (1,330 µg/L). Note that the average total organic carbon level was even lower. The highest total organic halide concentration was 10.32 µg/L, which is below the critical mean (11.1 µg/L). Also, note that the average total organic halide concentration was even lower. In addition, the annual groundwater phenol results were all reported as non-detects for the January 2011 sampling event.

The indicator parameter specific conductance was reported below the critical mean of 1,100 µS/cm for all wells except 299-E32-10 and 299-E33-34. DOE initially reported the exceedance of specific conductance in well 299-E33-34 to Ecology in 1999. The elevated specific conductance levels are influenced by the migration of BY Cribs plumes. Thus, the elevated specific conductance in wells 299-E32-10 and 299-E33-34 is not a cause for a change to the interim status indicator evaluation monitoring.

Performance assessment monitoring of radionuclides at LLWMA-1 (in accordance with AEA authority) is designed to complement RCRA detection monitoring and specifically at monitoring radionuclides not regulated under RCRA. The current monitoring plan (DOE/RL-2000-72) includes technetium-99, iodine-129, tritium, and uranium specifically for performance assessment. Based on observations at the LLWMA-1 wells and other 200-BP-5 monitoring wells, the LLWMA-1 did not impact the groundwater. The paragraphs that follow provide summaries of the performance assessment monitoring results and source interpretations for each of the contaminants of concern.

Technetium-99 concentrations exceed the drinking water standards in wells monitoring the northeast portion of the WMA. The technetium-99 groundwater concentrations in the northeast wells (299-E32-10 and 299-E33-34) is primarily associated with the technetium-99 plume migrating from the BY Cribs. Technetium-99 detected in wells 299-E32-8, 299-E32-9, 299-E33-28, 299-E33-29, 299-E33-30, and 299-E33-35 is associated with either the 241-BX-102 unplanned release or a combination of the 241-BX-102 unplanned release and the BY Cribs. Technetium-99 from the B Complex is discussed further in Section 3.4.3.1.

Elevated iodine-129 activities found predominantly in the northeast portion of the WMA is from sources to the east-southeast, as discussed in Section 3.4.2. The highest level was in well 299-E33-35 (4.93 pCi/L). Levels decrease across the WMA to the southwest.

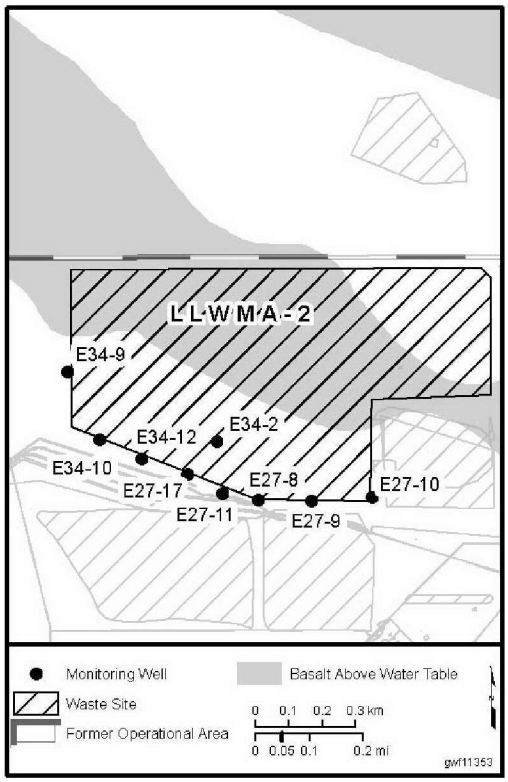
Uranium concentrations exceed the drinking water standards in wells monitoring the northwest corner of the WMA. The elevated concentrations are associated with the 241-BX-102 unplanned release. The highest concentrations was in well 299-E33-34 at 159 µg/L. Uranium concentrations also exceed the drinking water standard at well 299-E28-27 (southeast corner of WMA). The source is the 216-B-12 Crib, as discussed in Section 3.4.4.2.

Tritium was not reported above the drinking water standard in any LLWMA-1 monitoring well in 2011. The highest activity continued to be in well 299-E33-34, which is the result of migration from the 216-B-57 and 216-B-50 Cribs (Section 3.4.7.1).

3.4.13.6 Low-Level Waste Management Area 2

The LLWMA-2 is located in the northeast corner of the 200 East Area. It includes the 218-E-12 Burial Ground, which consists of 40 unlined trenches. The LLWMA-2 received low-level radiological waste and low-level mixed wastes beginning in 1967. The dangerous chemicals in the low-level mixed waste portions of LLWMA-2 are regulated under RCRA and its implementing requirements WAC 173-303-400. DOE monitors the LLWMAs for radionuclides under the requirements of the AEA, as described in DOE/RL-2000-72.

In accordance with 40 CFR 265.93(b), as referenced by WAC 173-303-400, the well network was sampled semiannually for contaminant indicator parameters and supporting constituents (DOE/RL-2009-76, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-2*). All of the wells were sampled semiannually, as required, during the reporting period. Appendix B Table B-25 includes a list of LLWMA-2 wells, constituents monitored, and indicates if the wells were sampled as scheduled. Flow direction and rate were indeterminate as a result of the flat nature of the water table, as discussed in the following paragraphs and shown in Table B-1, Appendix B. Appendix B Tables B-2 and B-26 provide the indicator parameter comparison values for 2011 and 2012, respectively.



The monitoring network, as defined in DOE/RL-2009-76, consists of one cross-gradient and eight downgradient wells. Previously, when the water table was higher, there were seven additional LLWMA-2 monitoring wells. The upgradient well, 299-E35-1, went sample dry in 1999. An additional well is proposed to replace this well, and installation is scheduled for 2013. The location is provided on Figure 2-5 of DOE/RL-2009-76. More specifically, the well will be positioned adjacent to well 299-E35-1.

The flow direction beneath LLWMA-2 is undefined because of the variability associated with the water table measurements, possibly related to minor measurement errors.

The initial definition of upgradient and downgradient was based on a west-southwest flow direction shown in Figure 3.2 of *Revised Ground-Water Monitoring Plan for the 200 Areas Low-Level Burial Grounds* (WHC-SD-EN-AP-015). Currently, the flow direction is undefined because of the flat nature of the water table. Barometric response corrections were included for the LLWMA-2 network in 2011; however, the variability in the measurements compared to the water table change was too great to return a statistically significant flow direction determination. Because of the local variability, taking a more regional approach may provide sufficient data to determine a gradient in this area. A regional approach for evaluating existing wells will be assessed in 2012 to determine whether a sufficient network capable of defining the groundwater gradient is possible. If not, locations will be proposed where additional wells are needed to thoroughly evaluate the groundwater gradient.

Groundwater quality parameter evaluations have helped to define the direction of groundwater flow near LLWMA-2 in the past. The 2011 data evaluations indicate groundwater movement to the west-southwest at LLWMA-2 wells (299-E27-8, 299-E27-9, 299-E27-10, and 299-E27-11). There is also evidence of south-southeast movement based on nitrate and sulfate increases at wells 299-E27-22 and 299-E27-25 (as discussed in Sections 3.4.1.7 and 3.4.10.3). These observations indicate a varying flow direction based on location along the south boundary of the WMA.

The network well screens range from 1.24 to 2.78 meters into the aquifer. These water table wells all have adequate water columns in the screened interval available for sampling, possibly for the next decade or more.

During 2011, the indicator parameter measurements for pH, specific conductance, total organic carbon, and total organic halides did not exceed the statistically derived background comparison values (e.g., critical mean). The pH levels for all of the LLWMA-2 wells ranged from 7.64 to 8.21, which is within the lower and upper bound of the critical mean (6.72 to 8.89, respectively). The highest specific conductance level was 1,112 µS/cm which is below the critical mean (1,460 µS/cm). The highest average total organic carbon level was 988 µg/L, which is below the critical mean (2,220 µg/L). The highest average total organic halide concentration was 13 µg/L, which is below the critical mean (37.1 µg/L). In addition, the annual groundwater phenol results were all reported as non-detects for the April 2011 sampling event. Thus, this site remained in interim status indicator evaluation monitoring.

Performance assessment monitoring of radionuclides at LLWMA-2 (in accordance with AEA authority) is designed to complement RCRA detection monitoring and specifically at monitoring radionuclides that are not regulated under RCRA. The current monitoring plan (DOE/RL-2000-72) includes technetium-99, iodine-129, tritium, and uranium. Based on observations at the LLWMA-2 wells and other 200-BP-5 monitoring wells, the LLWMA-2 did not impact the groundwater. The following paragraphs provide summaries of the performance assessment monitoring results and source interpretations for contaminants of concern if applicable.

The highest average technetium-99 concentrations were at well 299-E27-10 (76 pCi/L) during 2011. The concentration was 5 pCi/L lower than in 2010. The low technetium-99 is assumed to be associated with the elevated nitrate and sulfate from the 216-B-2 Ditches. Alternatively, contributions may be associated with drainage from fractured basalts to the north.

Iodine-129 concentration was most prominent in well 299-E27-8 at 2.43 pCi/L in April 2011. Levels of iodine-129 exceeding the drinking water standards are limited to wells east of well 299-E27-17. The iodine-129 is associated with past migration from sources to the south-southeast, as discussed in Section 3.4.2.

Tritium concentrations have also decreased over the past two decades, with maximum concentrations currently below 500 pCi/L (396 pCi/L at well 299-E27-9 in November 2011). The tritium is associated with past migration from sources to the south-southeast, as discussed in Section 3.4.7.

Uranium concentrations at LLWMA-2 were less than 5 µg/L, which is below background levels (DOE/RL-96-61).

Figure 3.4-1. Facilities and Groundwater Monitoring Wells in the 200 East Area Portion of the 200-BP-5 Operable Unit

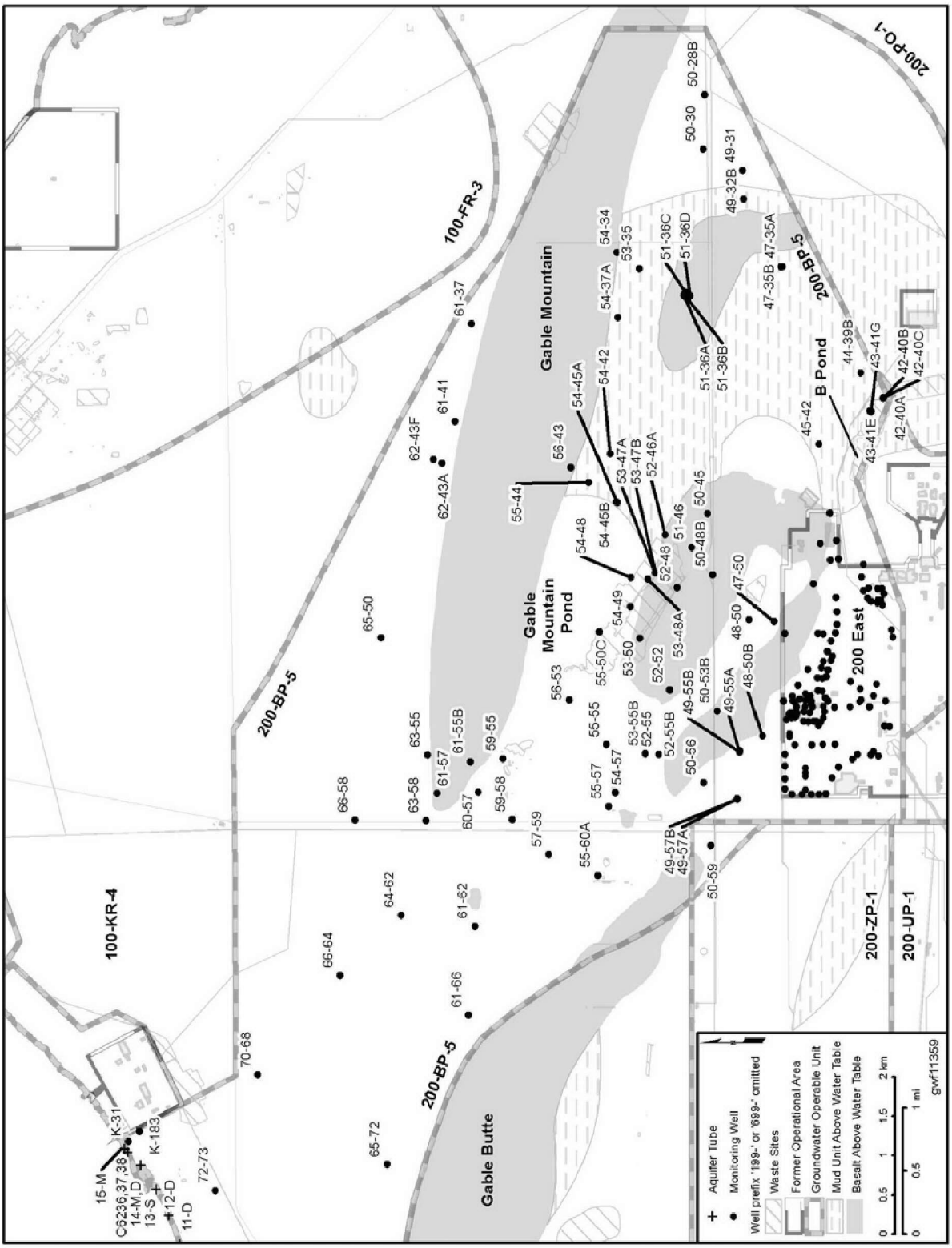


Figure 3.4-2. Facilities and Groundwater Monitoring Wells in the 600 Area Portion of the 200-BP-5 Operable Unit

Figure 3.4-3. 200 East Groundwater Table Map, March 2011

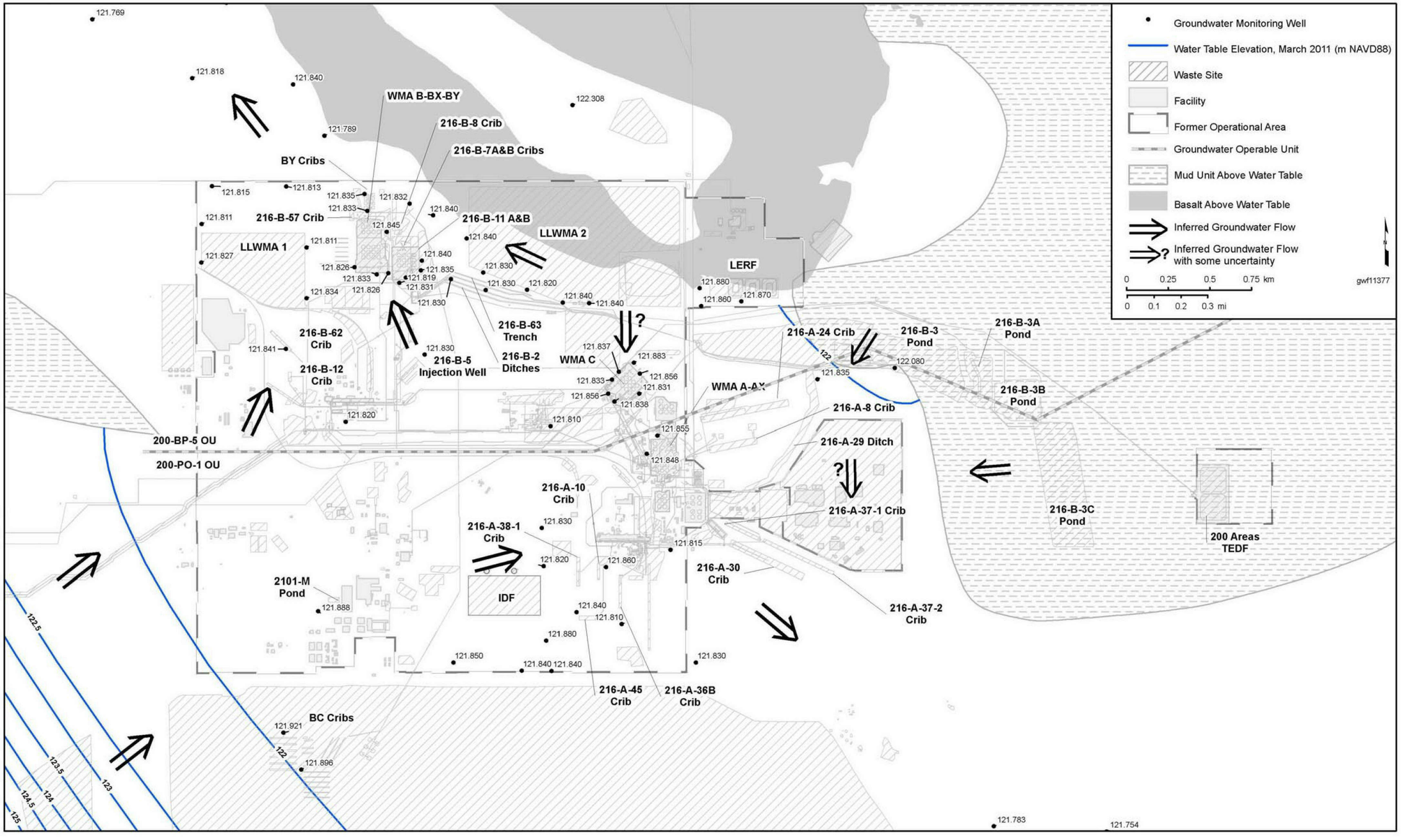


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Figure 3.4-4. Northwest Corner of 200 East Groundwater Table Map, August 2011

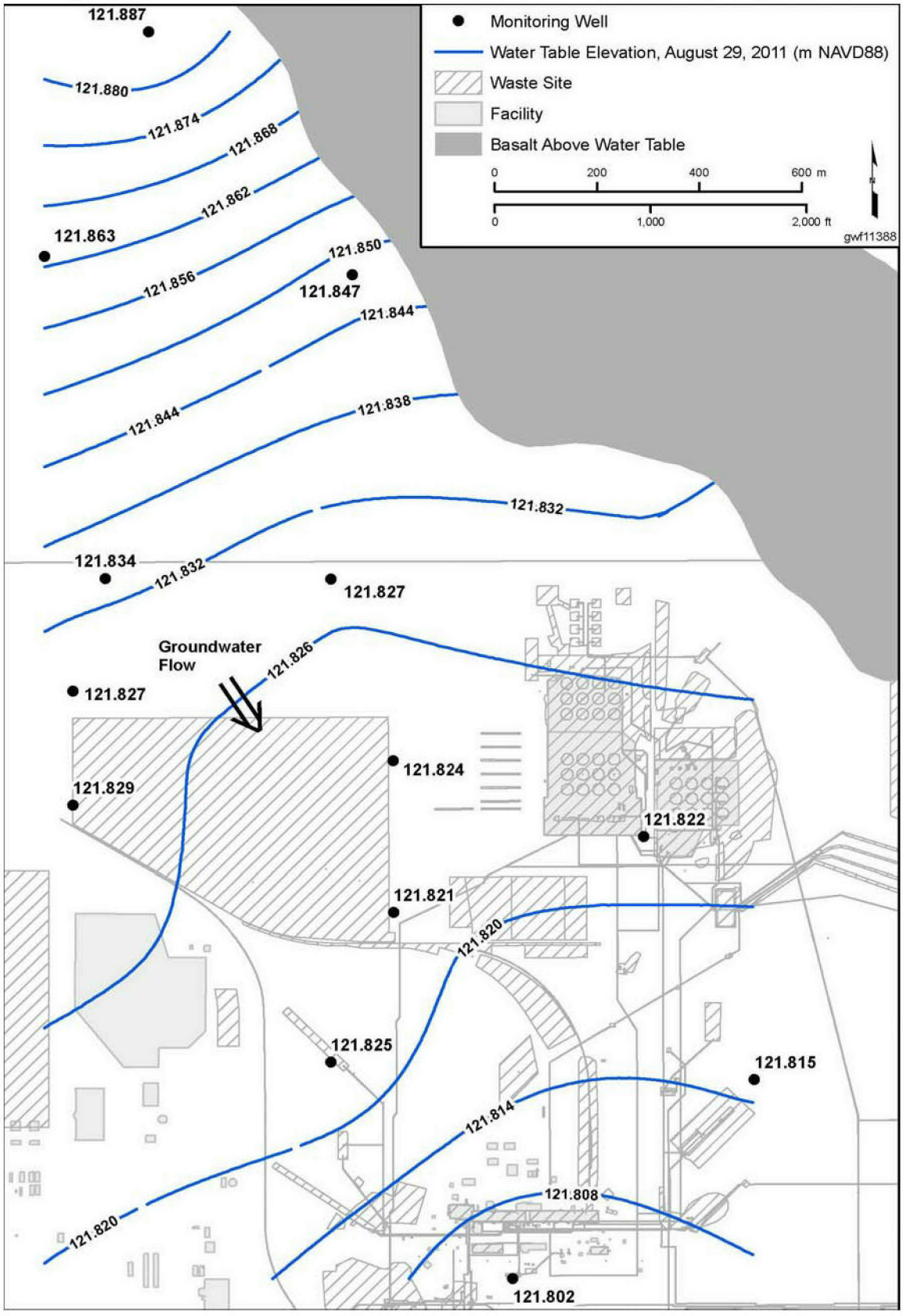

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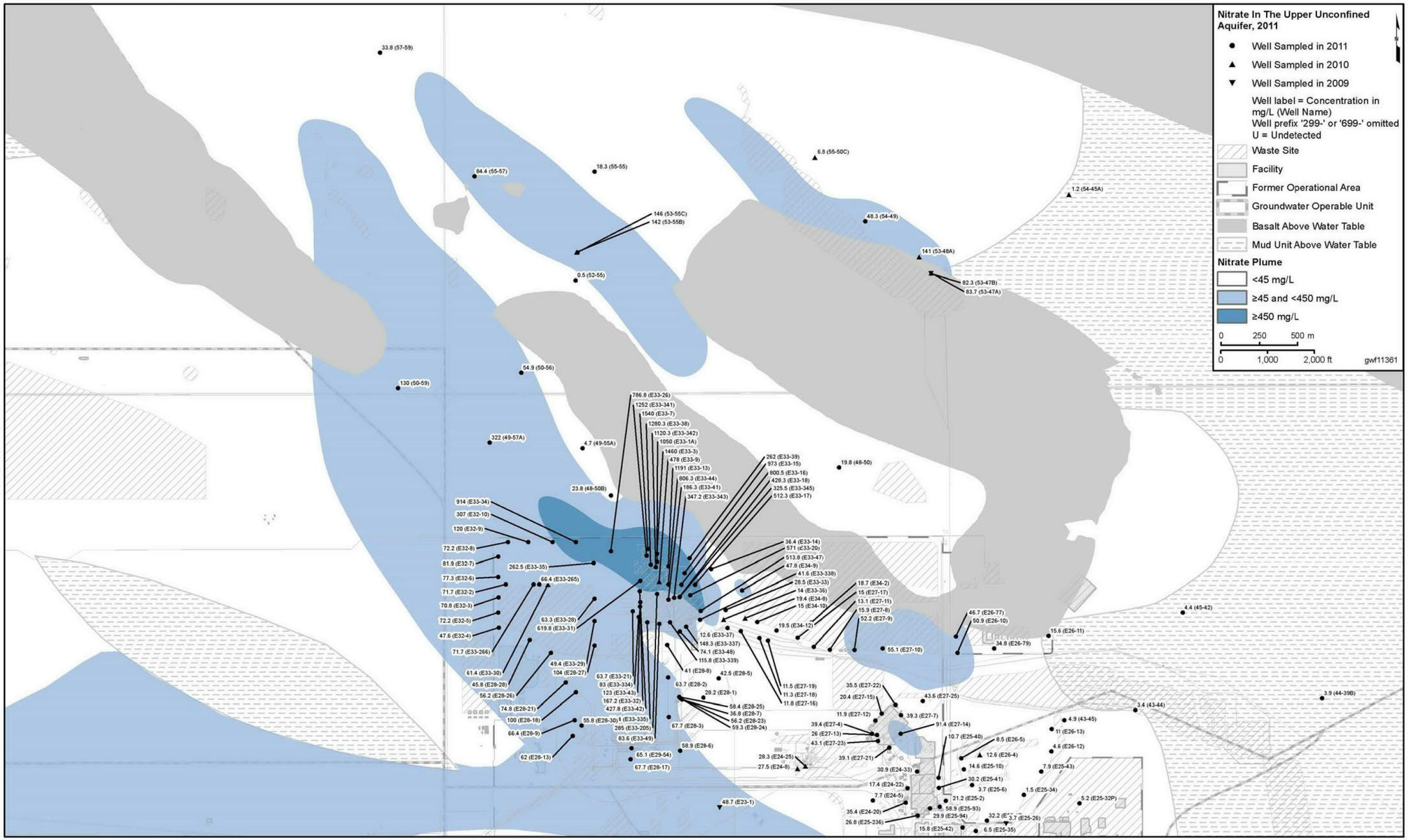
Figure 3.4-5. Average Groundwater Nitrate Concentrations in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit



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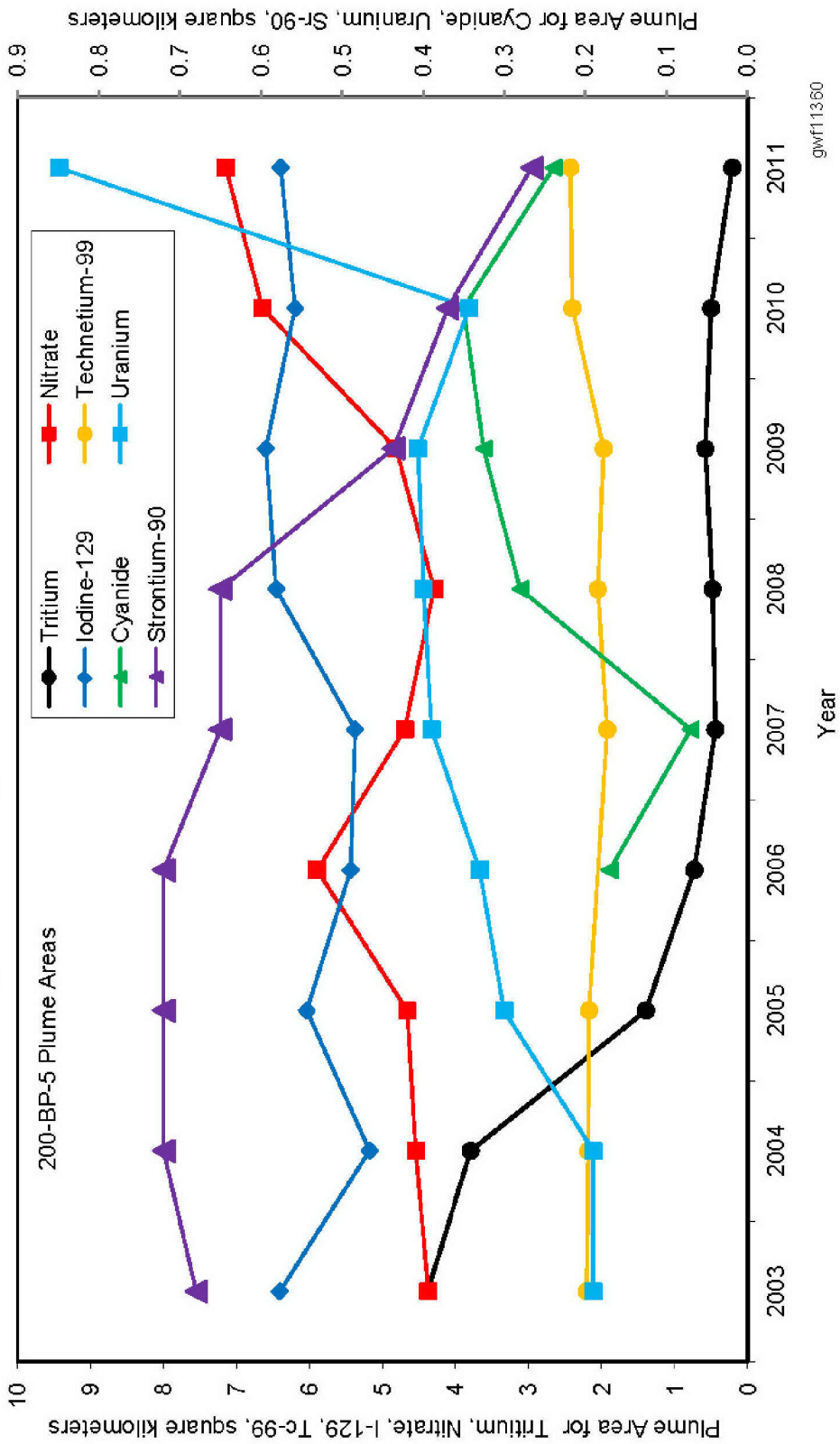

Figure 3.4-6. Changes in 200-BP-5 Plume Areas

Figure 3.4-7. Nitrate Trend Plot of Wells Located beneath the BY Cribs

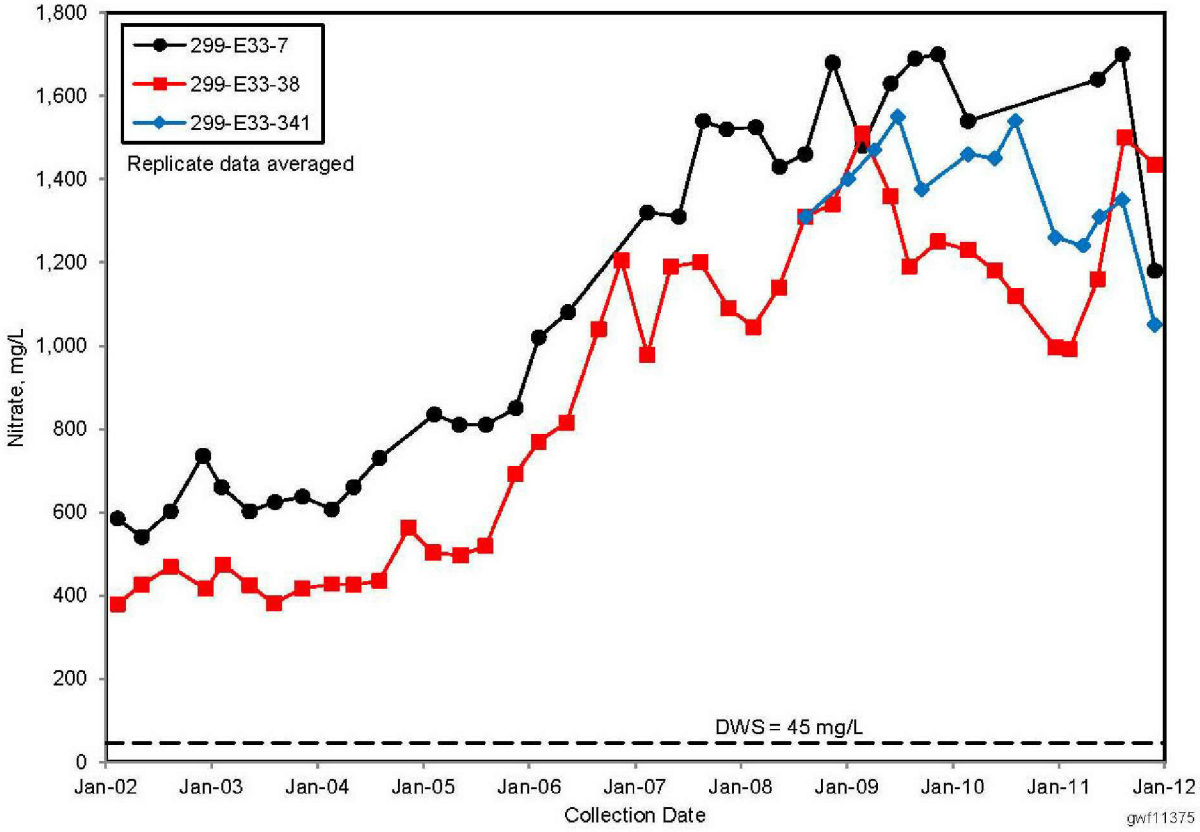

Figure 3.4-8. Nitrate Trend Plot in the Central Portion of the B Complex

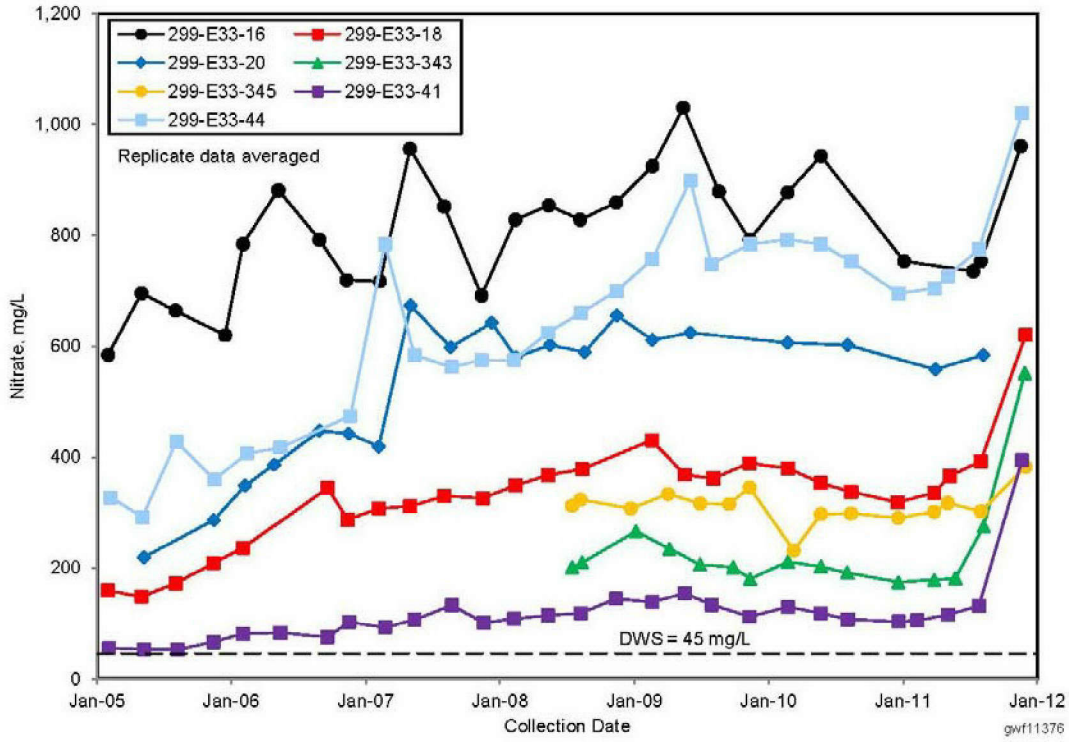

Figure 3.4-9. Nitrate Trend Plot for the East Side of the 241-B Tank Farm

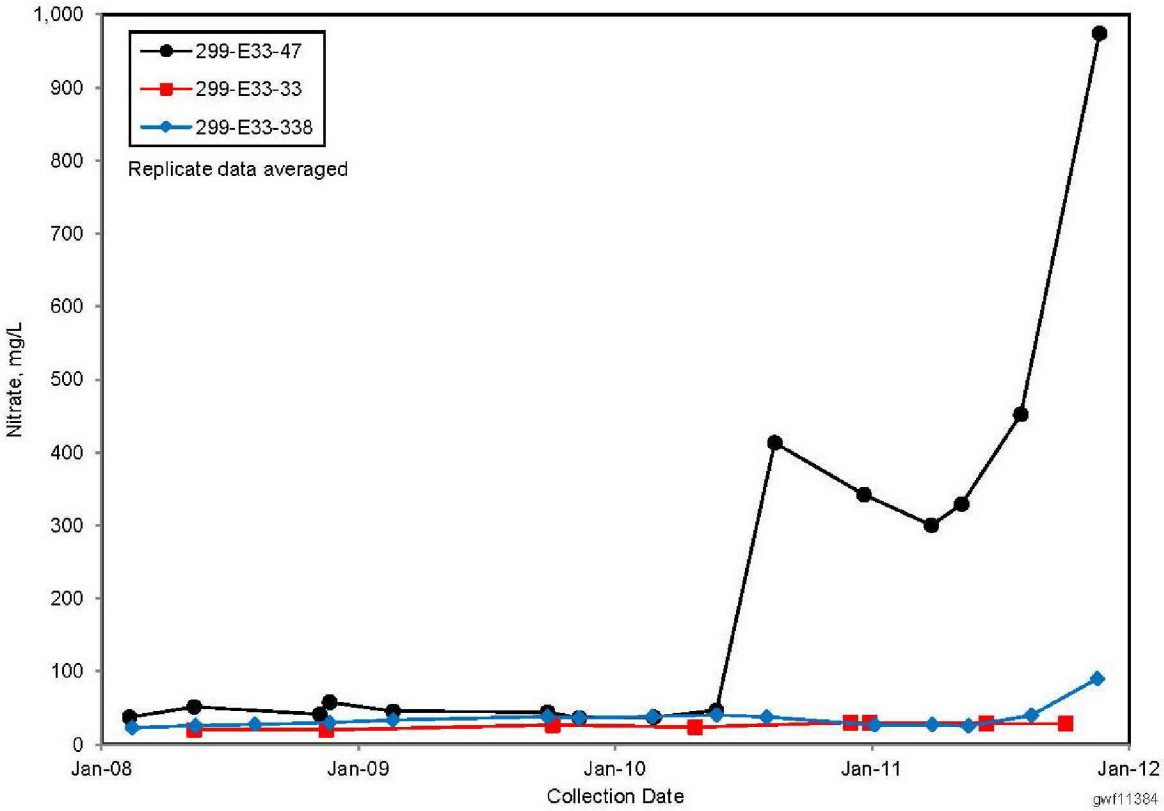

Figure 3.4-10. Nitrate Trend Plot for the South Side of the 241-B Tank Farm

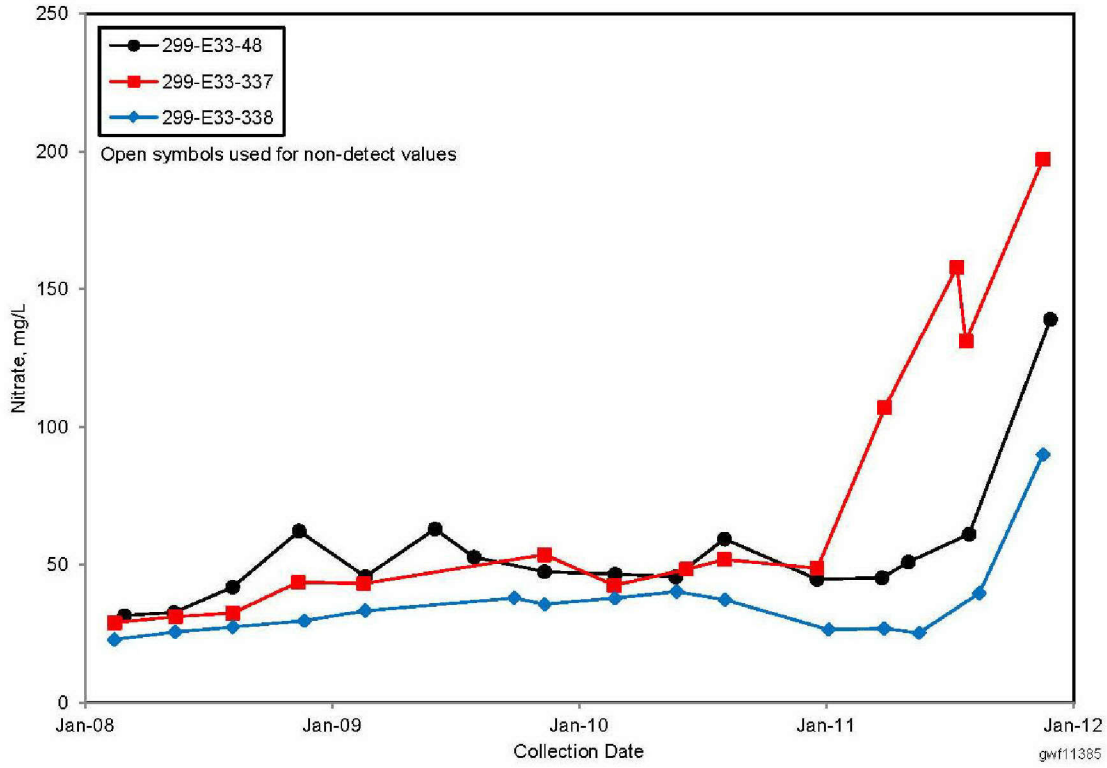

Figure 3.4-11. Nitrate Trend Plot near the East Extent of the 216-B-2 Ditches

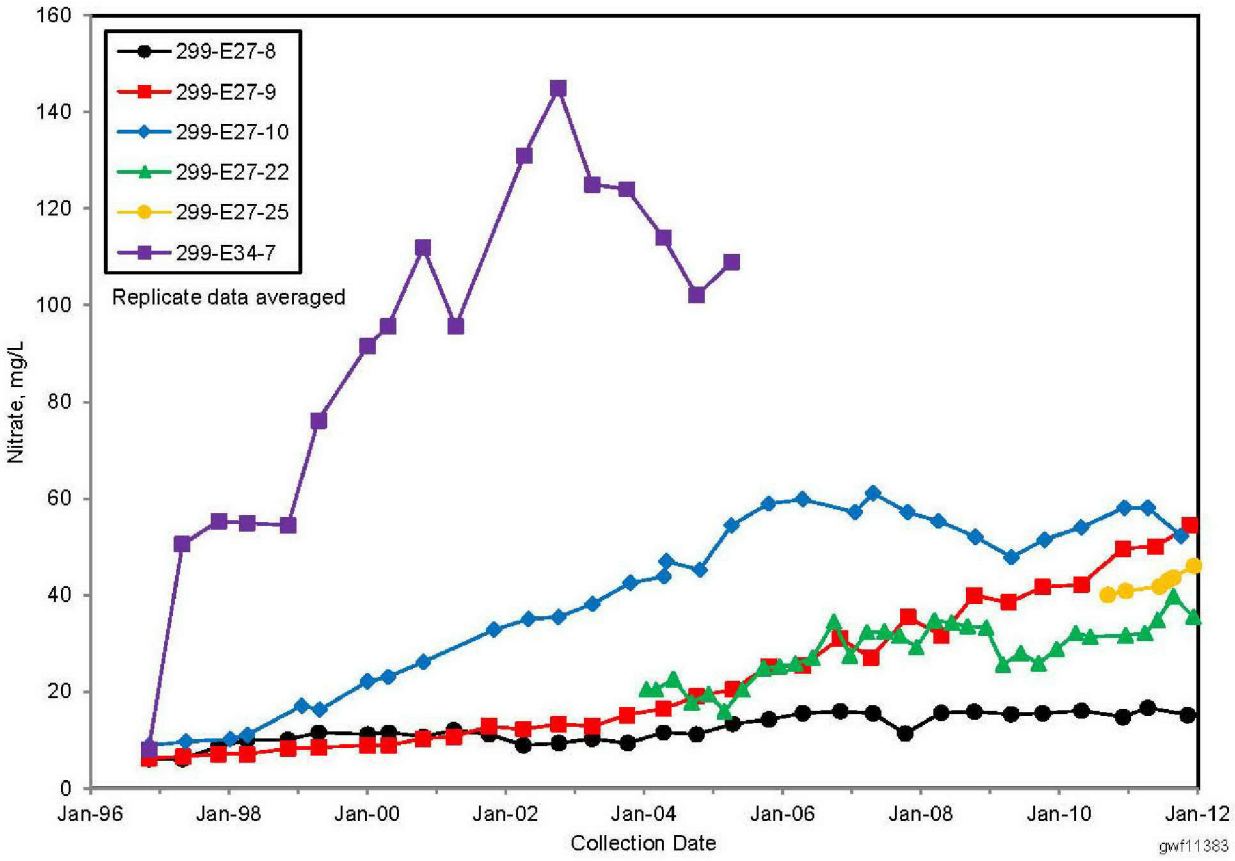

Figure 3.4-12. Average Groundwater Iodine-129 Levels in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

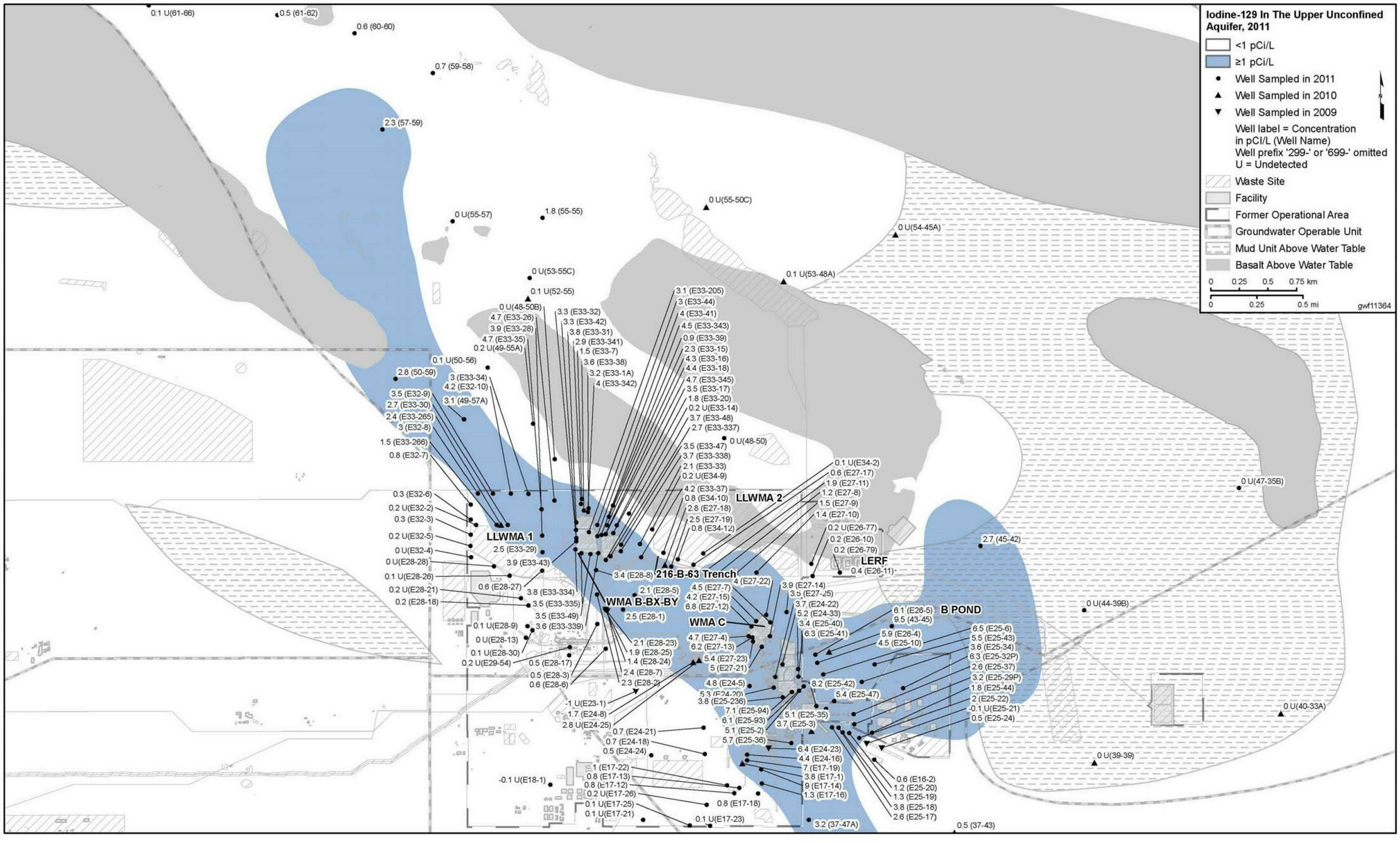

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Figure 3.4-13. Iodine-129 Trend Plots beneath the 216-B-2 Ditches and South-Southeast Side of the 241-B Tank Farm

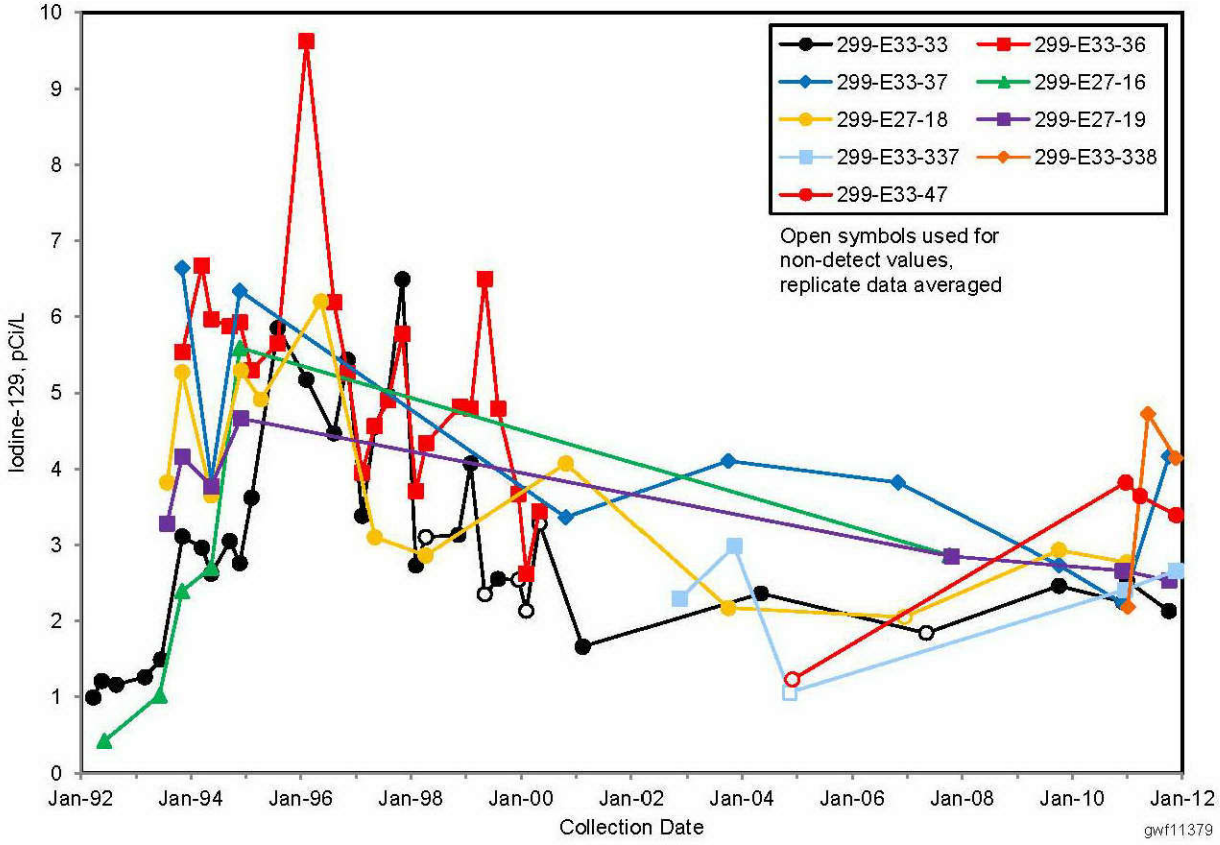

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Figure 3.4-14. Average Groundwater Technetium-99 Levels in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

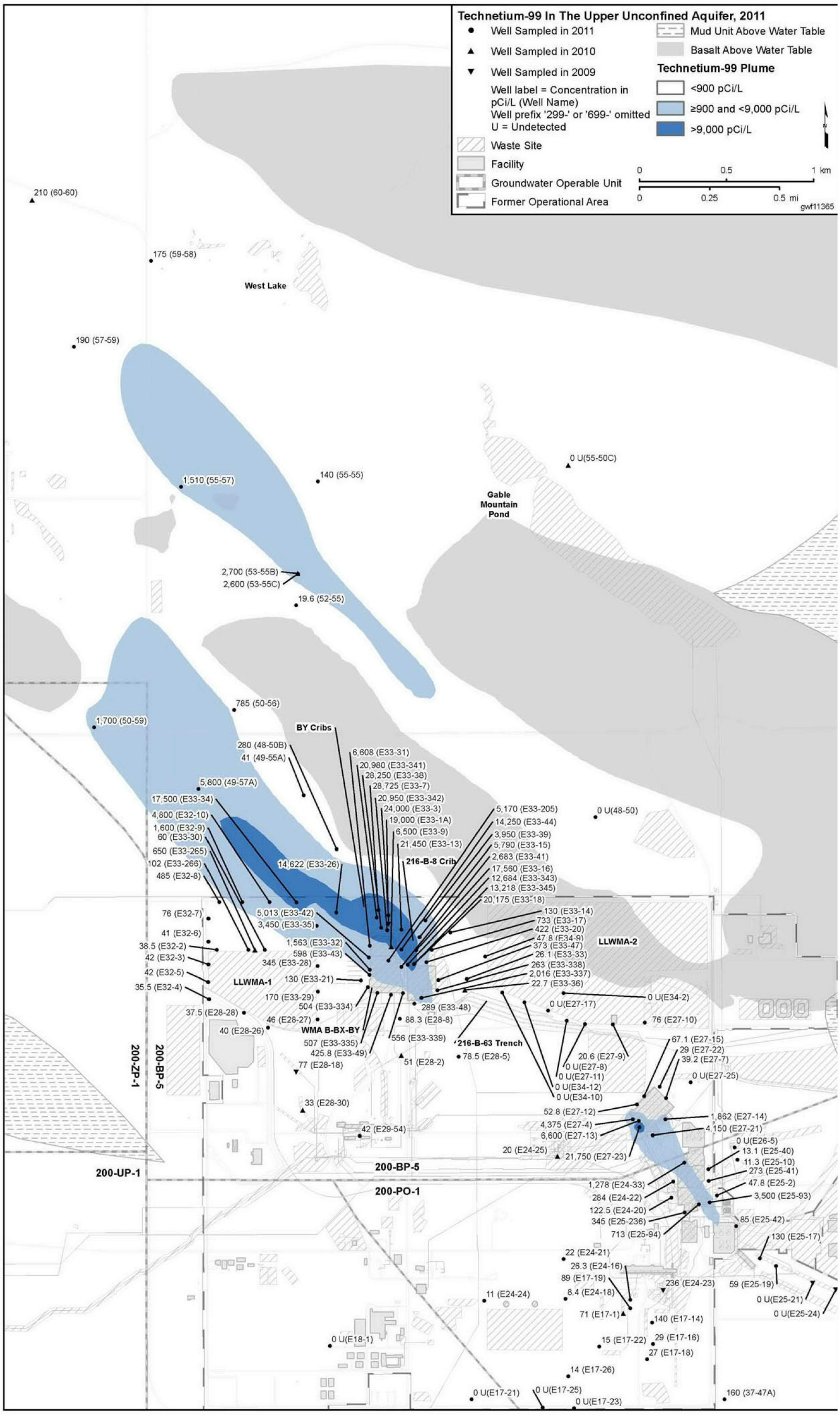

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Figure 3.4-15. Technetium-99 Trend Plot of Wells Located beneath the BY Cribs

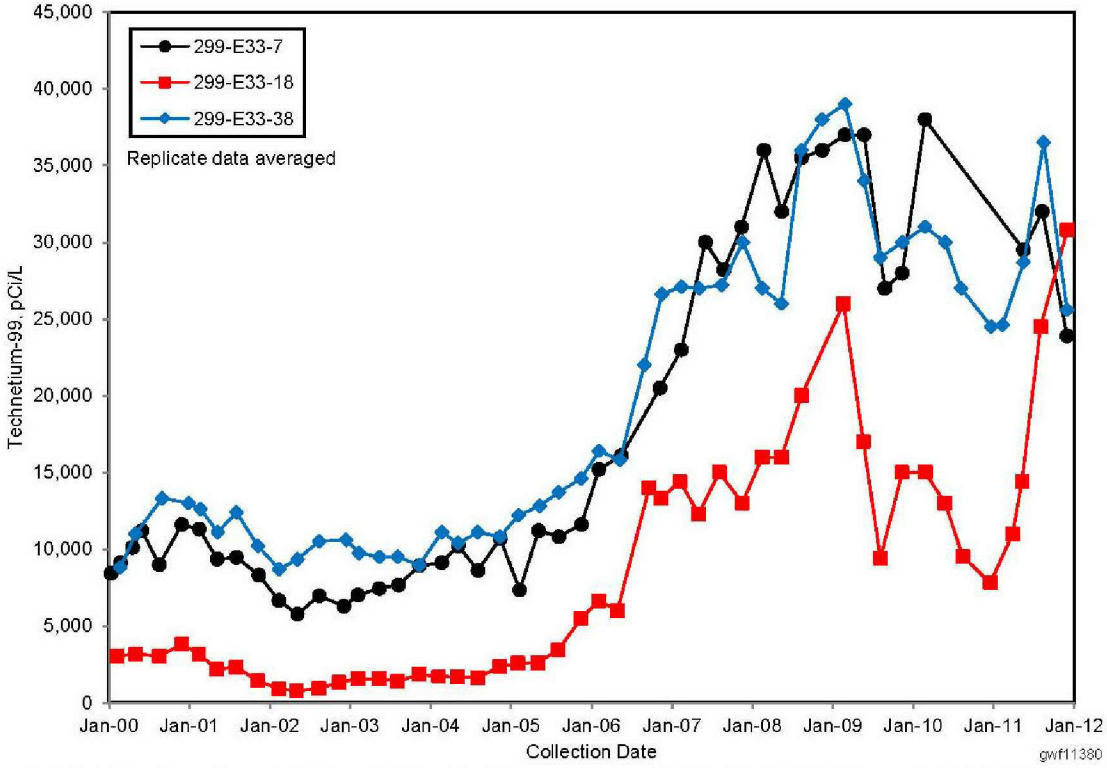

Figure 3.4-16. Technetium-99 Trend Plot for Wells 299-E27-13, 299-E27-23, and 299-E27-4 at WMA C

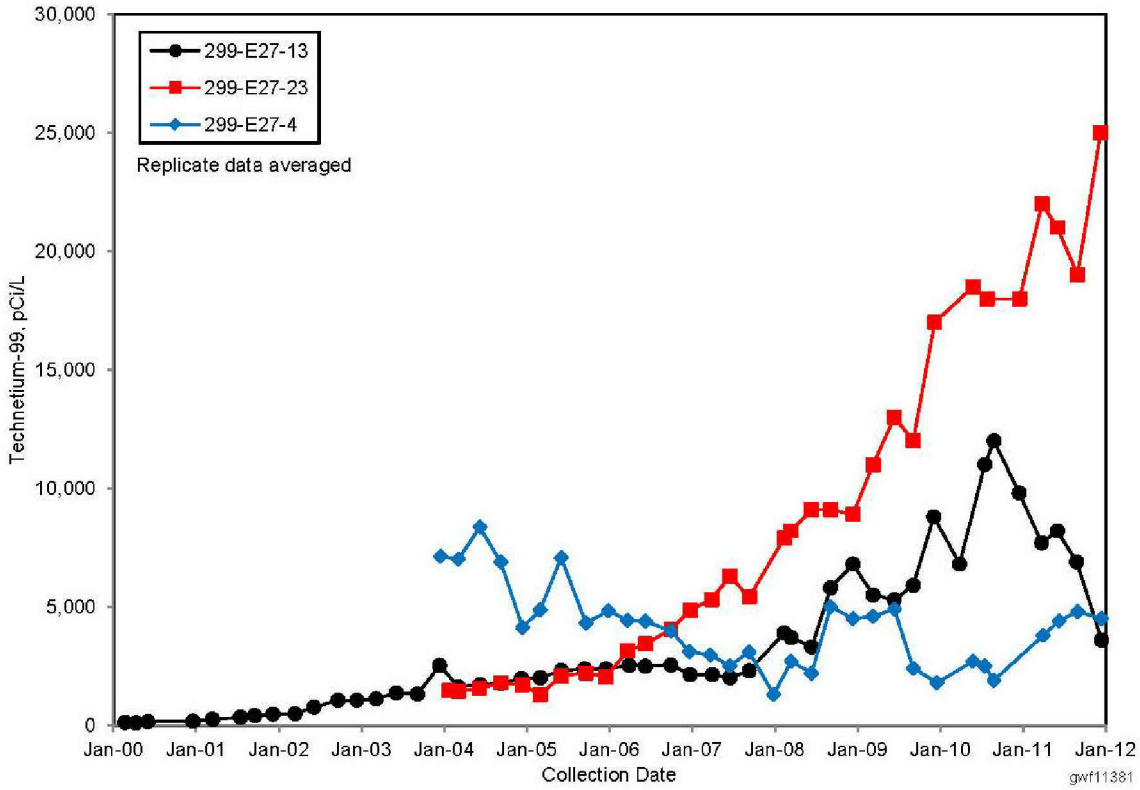

Figure 3.4-17. Average Groundwater Uranium Concentrations in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

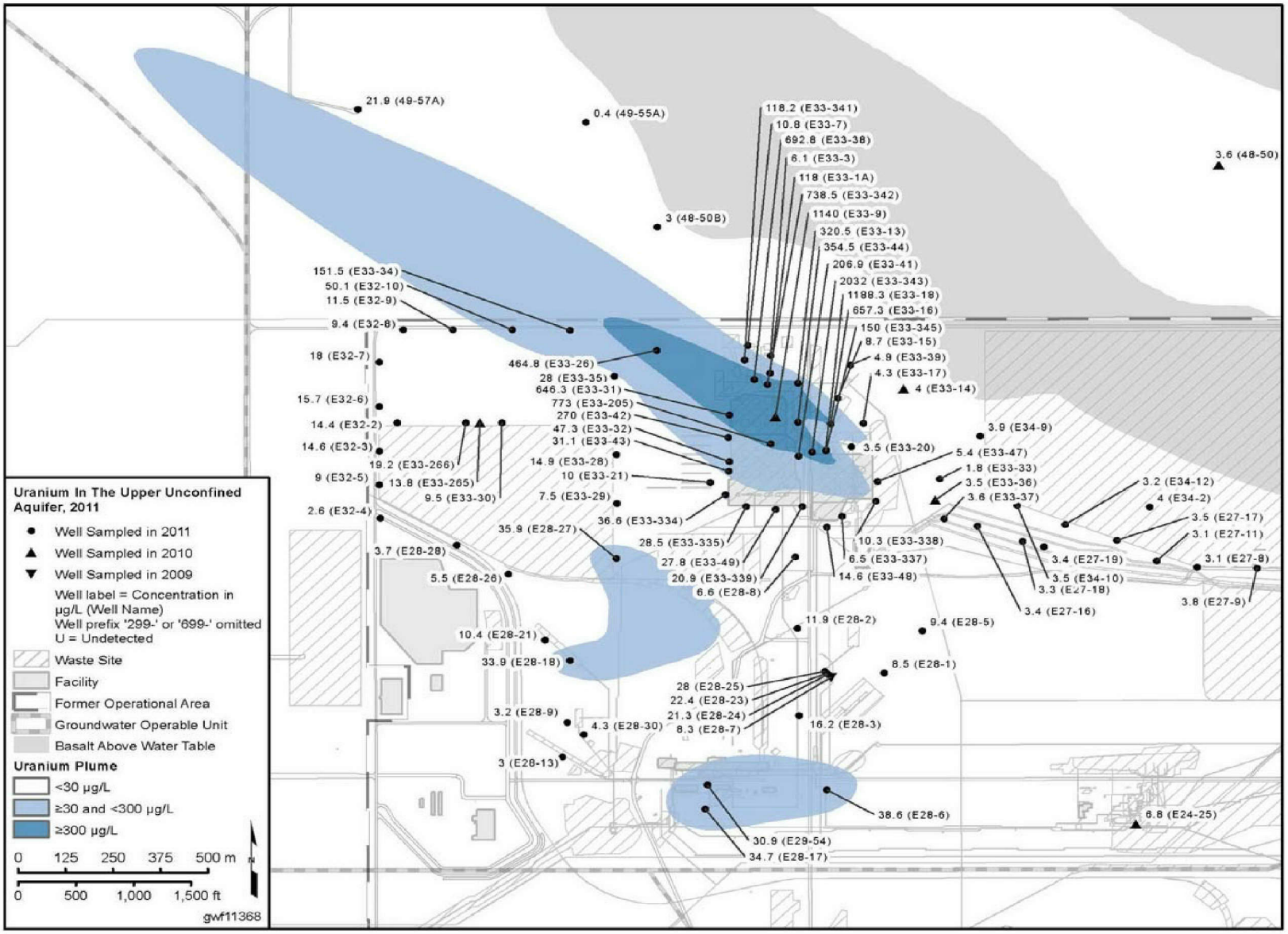

Figure 3.4-18. Uranium Concentrations near the 216-B-5 Injection Well

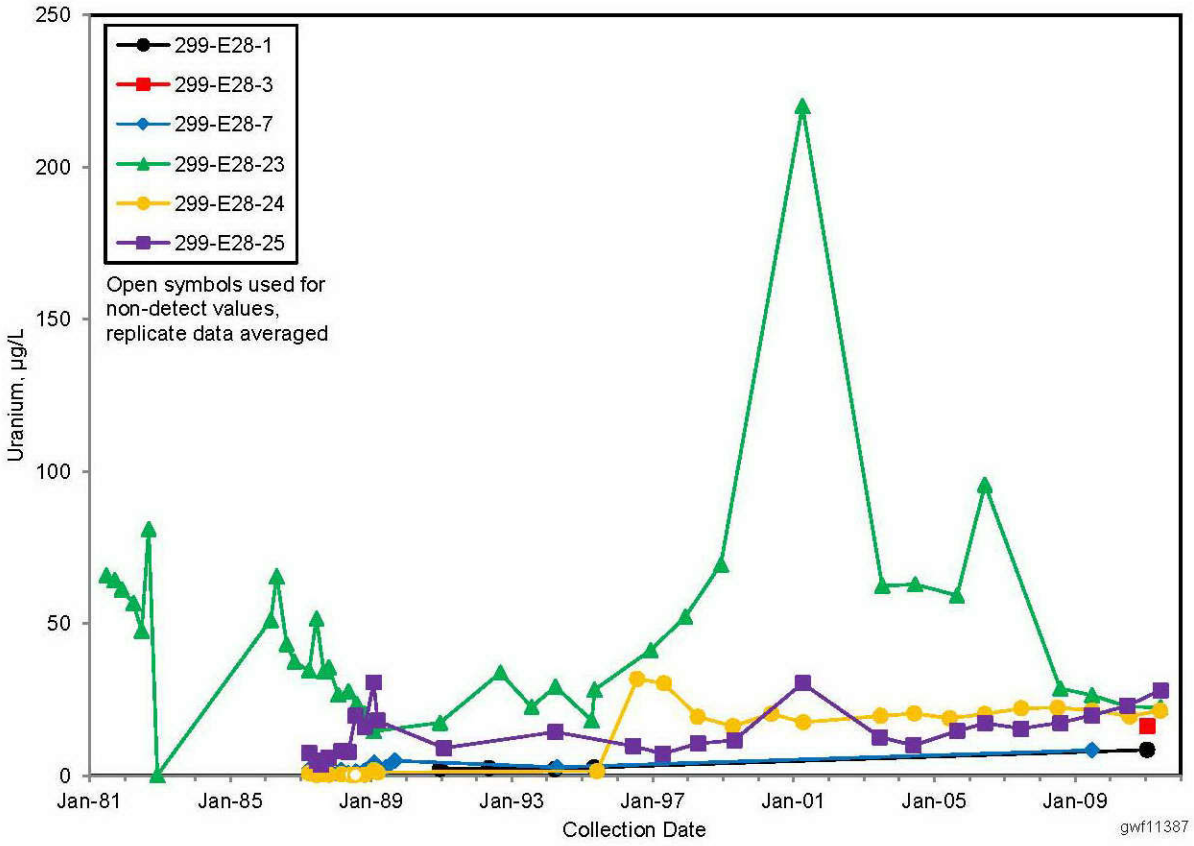

Figure 3.4-19. Average Groundwater Strontium-90 Levels in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

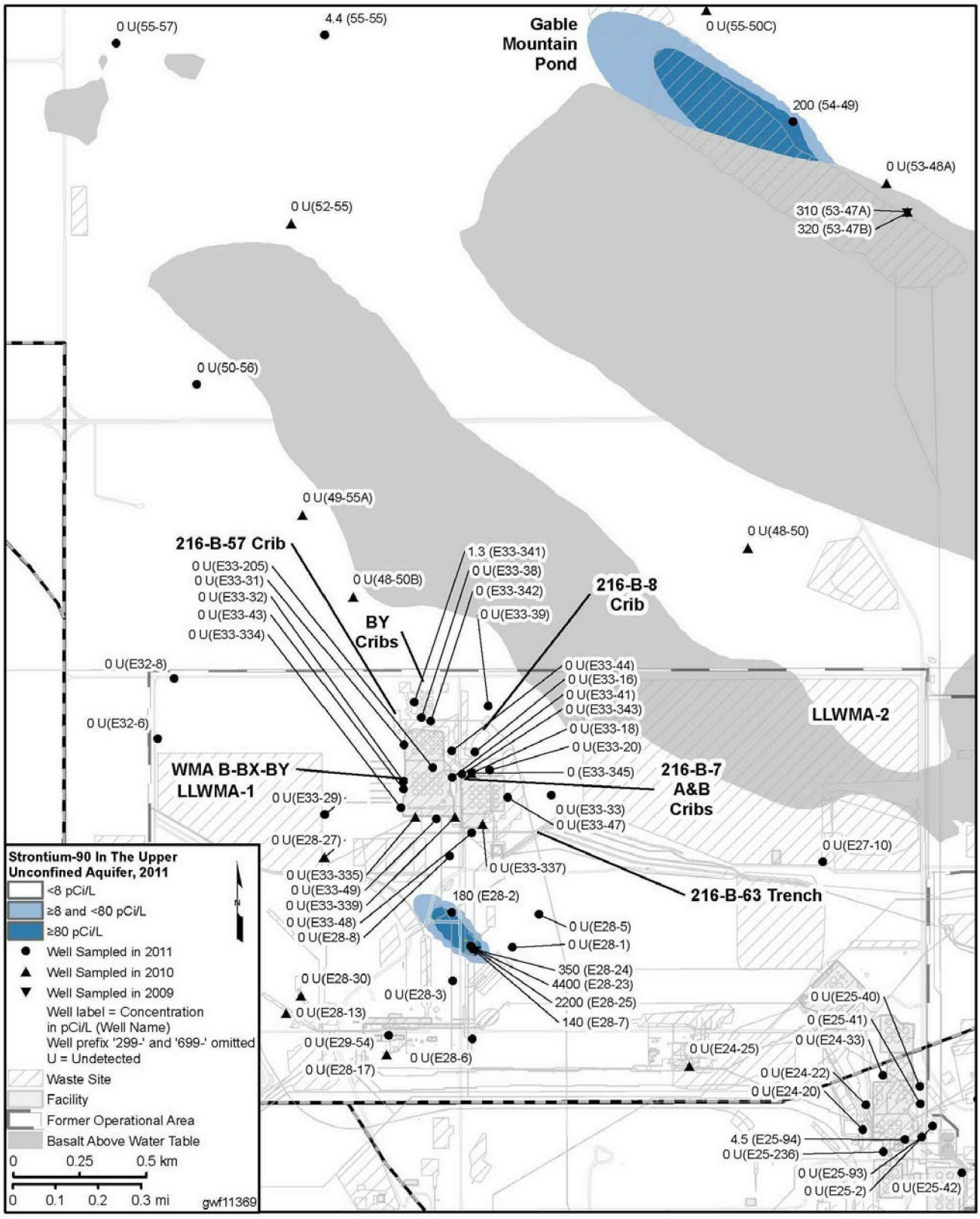

Figure 3.4-20. Cyanide and Iron Trend Plot for the BY Cribs

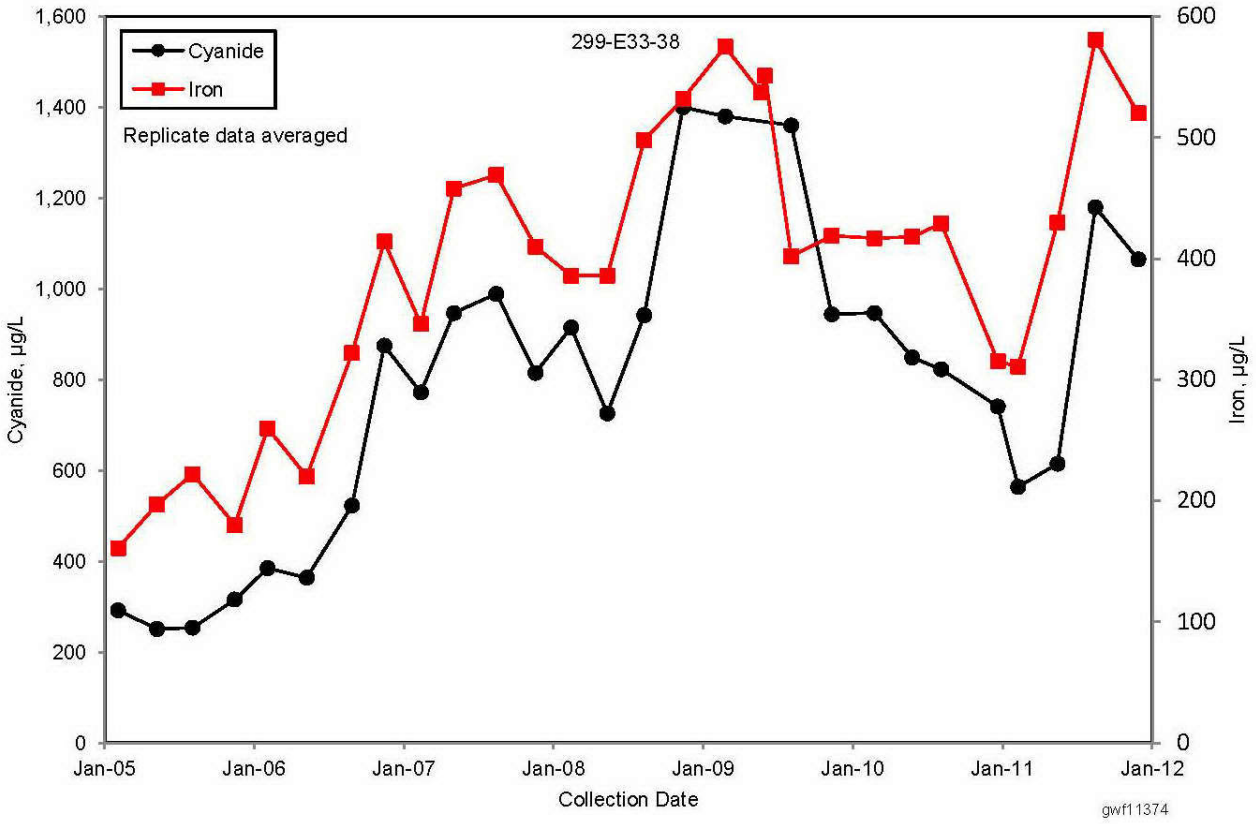

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Figure 3.4-21. Average Groundwater Cyanide Concentrations in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

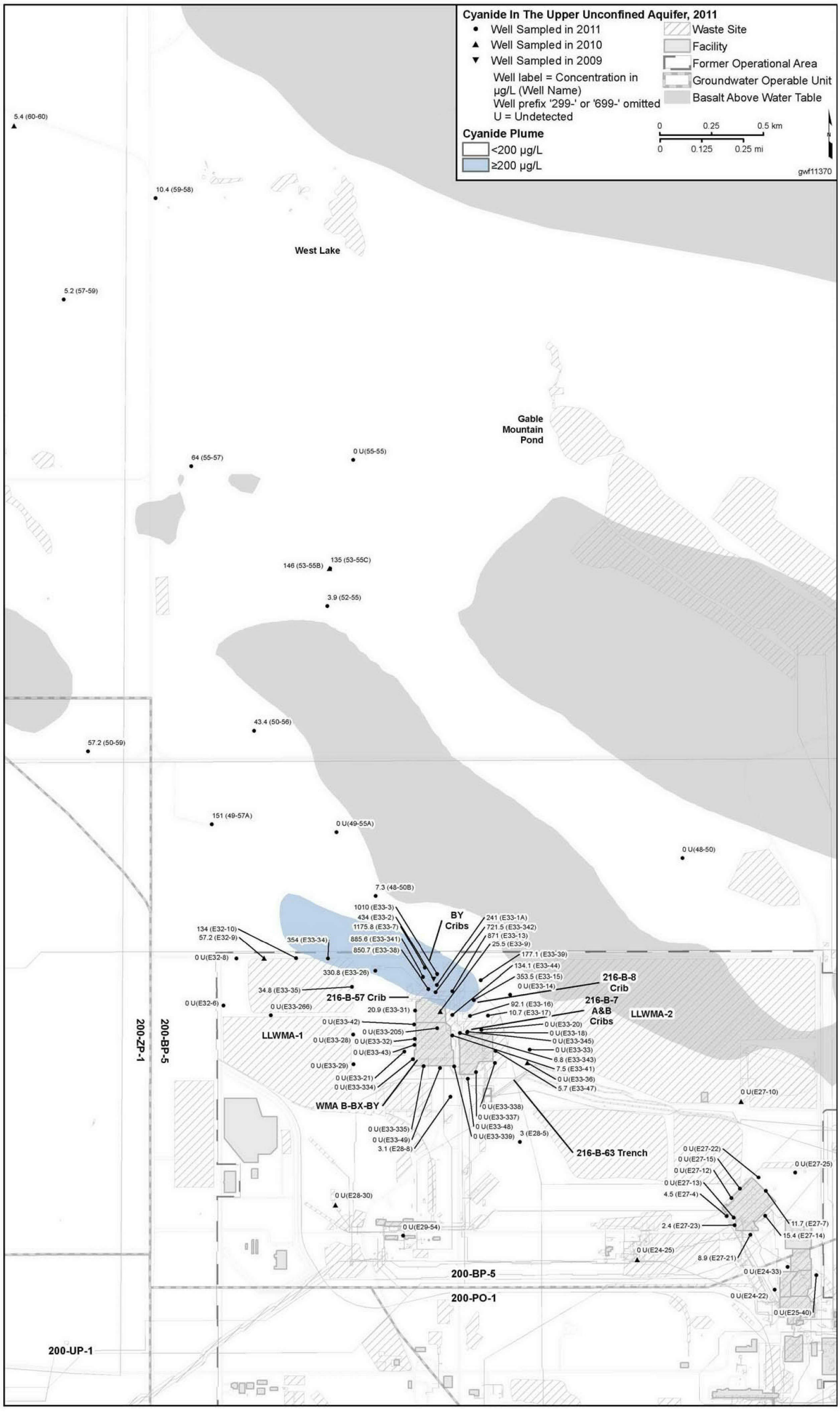


Figure 3.4-22. Average Groundwater Tritium Levels in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

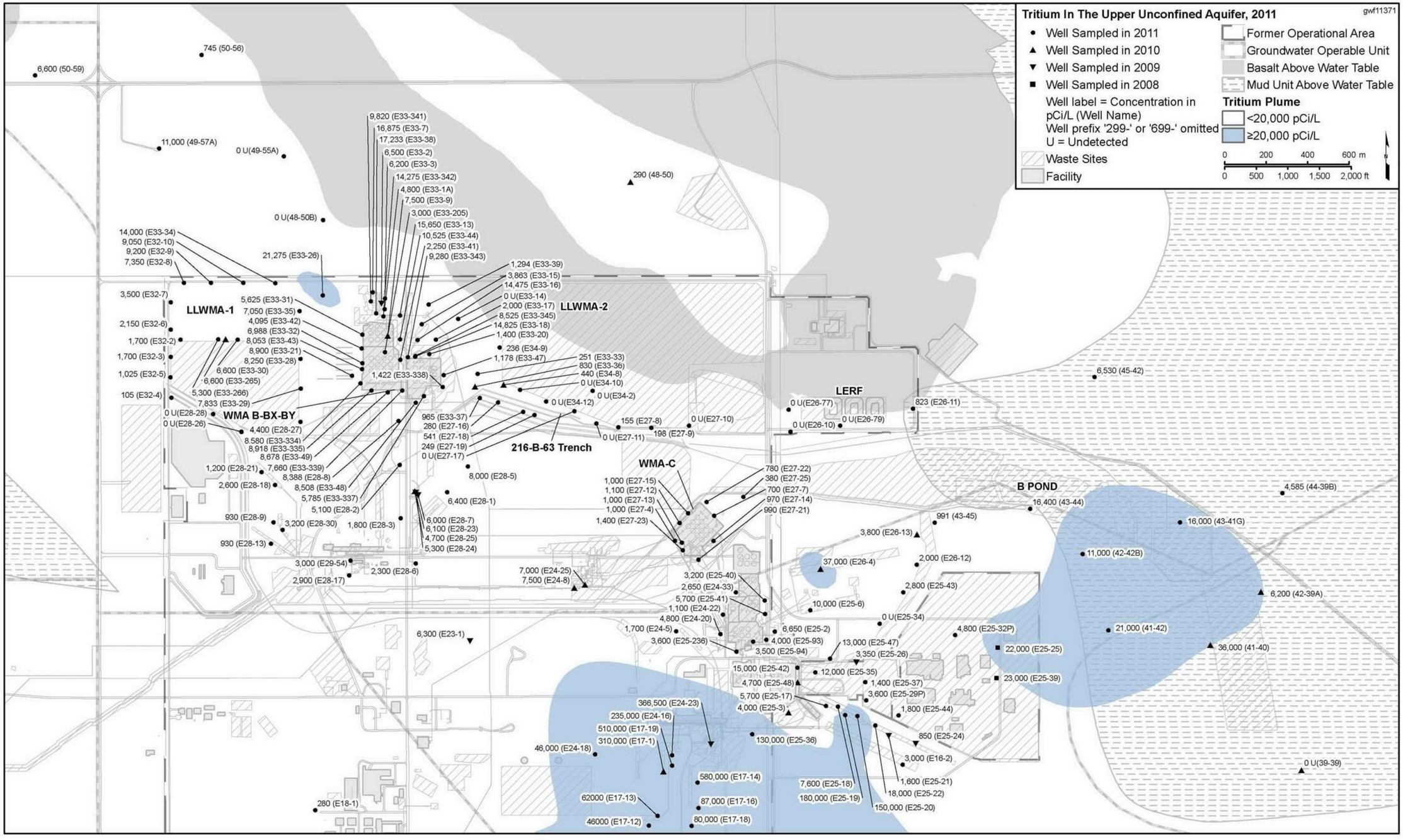


Figure 3.4-23. Average Groundwater Sulfate Concentrations in the 200 East Area and 600 Area of the 200-BP-5 Operable Unit

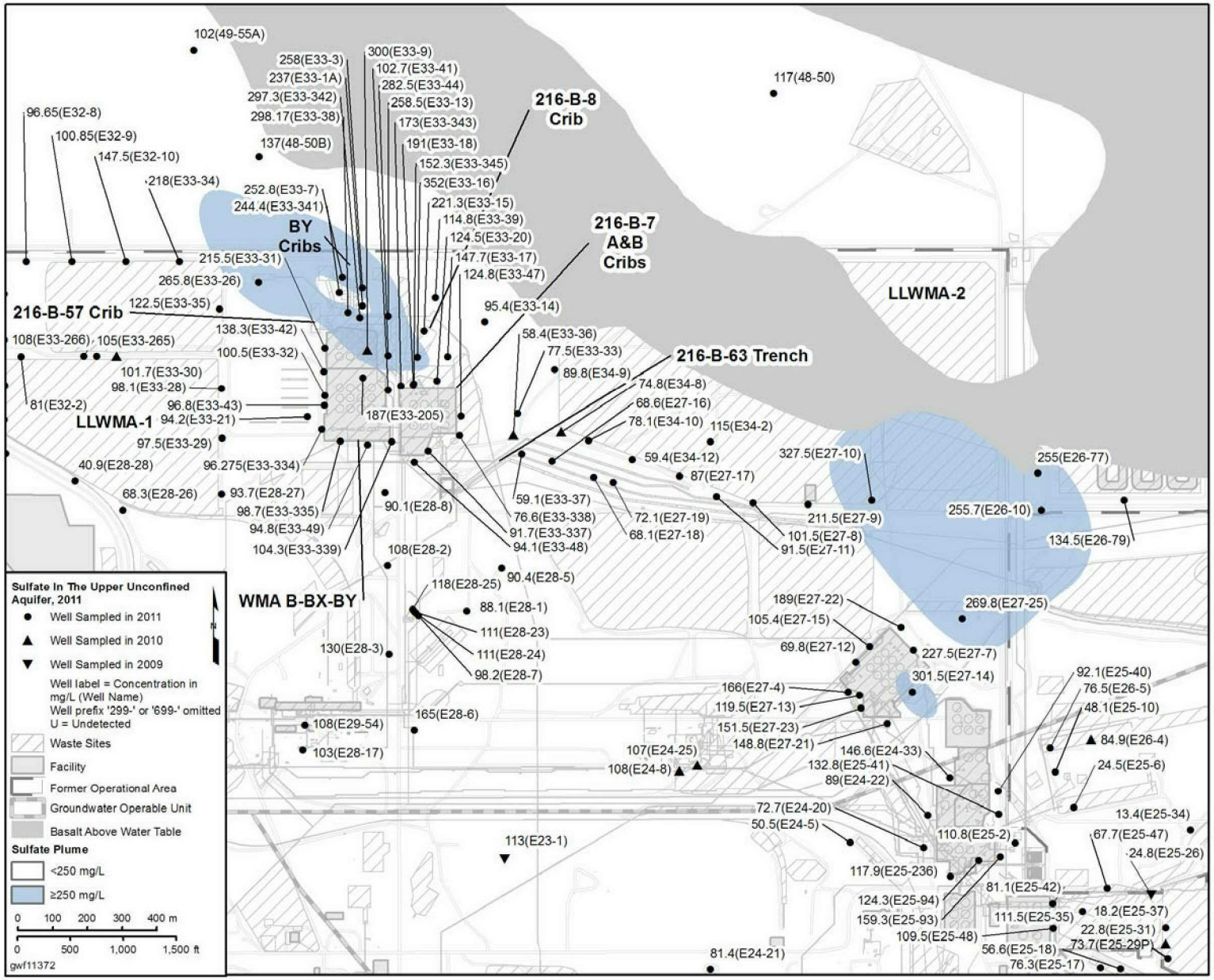
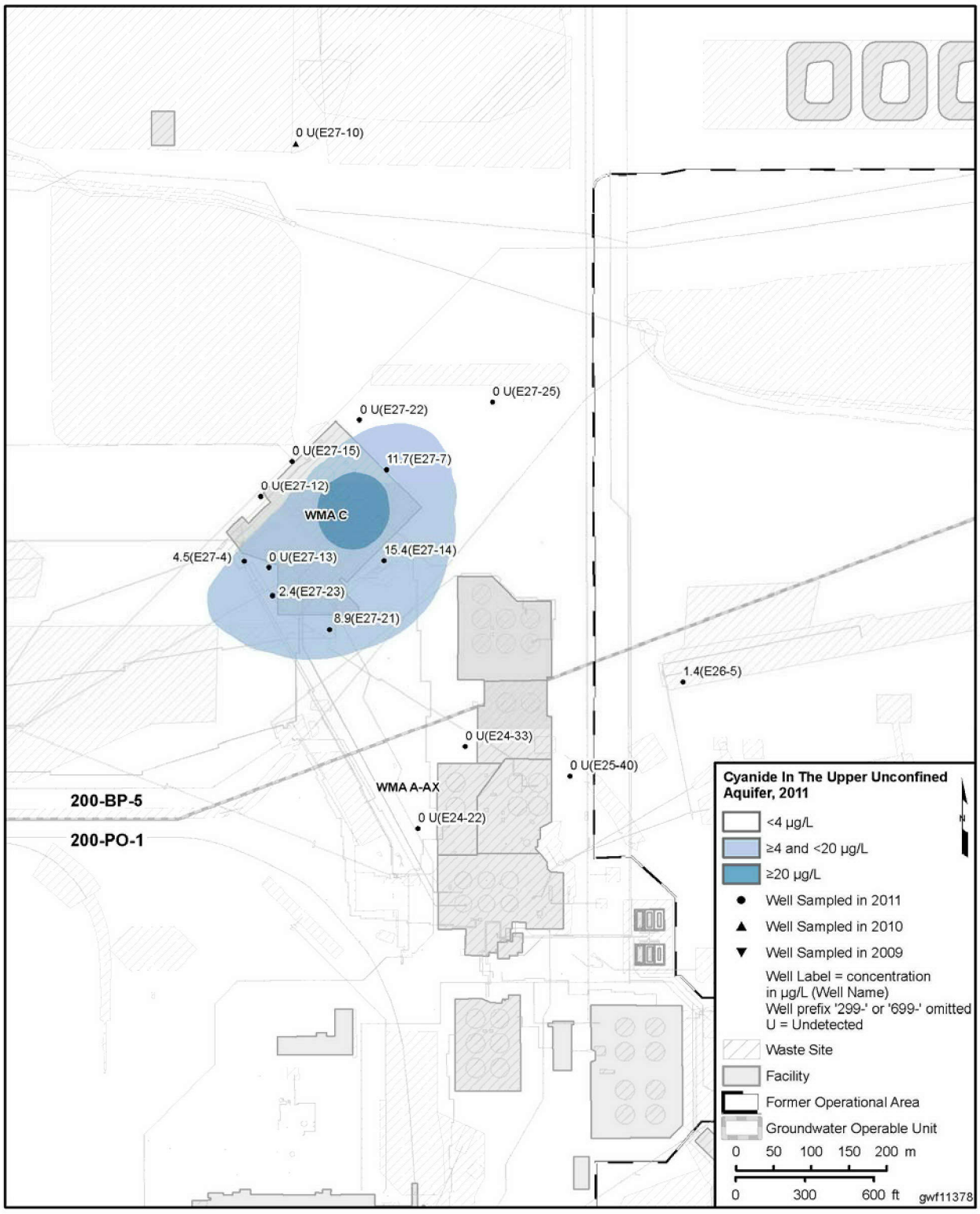


Figure 3.4-24. Average Cyanide Concentrations at WMA C, Upper Part of Unconfined Aquifer, 2011



3.5 200-PO-1

D.C. Weekes and K.M. Hanson

This chapter describes groundwater flow and chemistry for the 200-PO-1 groundwater interest area, which includes the 200-PO-1 Operable Unit (Figure 3.1-1 in Section 3.1). This area encompasses the southern portion of the 200 East Area and a large, triangular-shaped portion of the Hanford Site that extends to the Hanford town site to the east and to the 300-FF-5 groundwater interest area to the southeast. Although the 216-B-3 Pond (B Pond) straddles the boundary of two interest areas, it is considered part of the 200-PO-1 groundwater interest area. The BC Cribs and Trenches are located completely outside of the 200-PO-1 Operable Unit, but are within the 200-PO-1 groundwater interest area. Potential groundwater contamination in this area is discussed in this chapter to ensure that potential groundwater impacts from these cribs and trenches are not overlooked.

The 51 wells located in the 200 East Area (near the major sources for groundwater contamination) are considered to be in the 200-PO-1 near-field area, while the 80 wells located in the 600 Area to the east and southeast are considered to be in the far-field area. In addition, many of the wells sampled for RCRA and WAC-permitted sites are cooperatively sampled with the 200-PO-1 Operable Unit. Figure 3.5-1 shows the location of local facilities and wells used in near-field monitoring of the southern 200 East Area. Figure 3.5-2 provides the locations of wells used in the remainder of the 200-PO-1 far-field area and shoreline monitoring sites within the 600 Area.

Active groundwater remediation is currently not taking place in 200-PO-1. A ROD has not yet been issued.

Groundwater monitoring in 200-PO-1 is designed to meet the requirements of the AEA, CERCLA, RCRA, and the WAC, as directed by DOE orders. Active groundwater remediation is currently not taking place in 200-PO-1. A ROD has not yet been prepared. The immediate goal for 200-PO-1 Operable Unit is to monitor the contaminants of concern and contaminants of potential concern under the CERCLA remedial investigation RI/FS process until final cleanup decisions are made. There are seven RCRA units that are sampled cooperatively with the 200-PO-1 Operable Unit CERCLA sampling. They are:

- Integrated Disposal Facility
- 216-A-36B Crib
- 216-A-37-1 Crib
- WMA A-AX (single-shell tanks)
- 216-A-29 Ditch
- 216-B-3 Pond facility
- Nonradioactive Dangerous Waste Landfill (NRDWL)

Facilities monitored under other WAC requirements include the Solid Waste Landfill (SWL) and the 200 Area Treated Effluent Disposal Facility (TEDF). Water supply wells monitored under AEA include three wells in the 400 Area and two new wells northwest of the 618-10 Burial Ground.

Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit (DOE/RL-2009-85) provides a detailed discussion of geology and hydrogeology within 200-PO-1 and includes geologic cross sections. A hydrostratigraphic cross section for the Central Plateau is shown in Figure 3.1-3 in

Section 3.1. The following paragraphs summarize key characteristics of the aquifers and flow characteristics.

The suprabasalt aquifer system is primarily unconfined; but due to its large extent and overall thickness (up to 215 meters), it includes localized semiconfined and confined intervals within the deeper portion of the sedimentary sequence. The suprabasalt aquifer system is primarily contained within the Ringold Formation, which is composed of silty, sandy gravel interspersed with thick, fine-grained (i.e., silty) intervals such as the Ringold Formation lower mud unit. However, in some regions of 200-PO-1, the very uppermost portion of the unconfined aquifer is actually within the lower portion of the Hanford formation, which overlies the Ringold Formation. The younger, more permeable Hanford formation can result in preferential groundwater flow (e.g., the southeast-trending paleochannel cutting across the northern and eastern portions of the 200 East Area) because of the relatively higher hydraulic conductivity of the Hanford formation compared to the underlying Ringold Formation.

200-PO-1 at a Glance

PUREX Plant Operations: 1956-1972 (Plutonium separation)
1983-1989 (Plutonium separation)

2011 Groundwater Monitoring

Contaminant	Drinking Water Standard	Maximum Concentration	Plume Area* (km^2)
Tritium	20,000 pCi/L	580,000 pCi/L	94.9
Iodine-129	1 pCi/L	9.98 pCi/L	52.8
Nitrate	45 mg/L	158 mg/L	1.8
Strontium-90	8 pCi/L	30 pCi/L	Not calculated
Technetium-99	900 pCi/L	6,500 pCi/L	0.04
Uranium	30 µg/L	68 µg/L	0.13

Remediation

A soil desiccation treatability test was conducted in the cribs region of the BC Cribs and Trenches Area to collect data supporting potential use of desiccation as a deep vadose zone remedy.

Final action record of decision is scheduled for 2016.

* Estimated area above listed drinking water standard.

The Ringold lower mud unit represents the base of the unconfined aquifer throughout the majority of 200-PO-1, except where the Ringold lower mud unit is absent in the northern and central portions of the 200 East Area, where the uppermost basalt is the base of the aquifer.

The Ringold Formation lower mud unit represents the base of the unconfined aquifer throughout the majority of the 200-PO-1 Operable Unit.

The depth to the uppermost unconfined aquifer is more than 91 meters near the southern boundary of the 200 East Area, and it varies in depth to near zero meters below ground surface at the Columbia River. Springs and seeps occur along the riverbanks where the aquifer flows in places laterally out of the ground, directly into the river, and/or down the river shoreline into the river.

In the southern portion of the 200 East Area, where the main contaminant sources are located, the groundwater flow direction ranges from southeast to northeast in the unconfined aquifer before diverting primarily to the southeast upon exiting the 200 East Area (Figure 3.1-5 in Section 3.1 and Figure 3.4-3 in Section 3.4) (see Section 3.1 for further discussion of the water table and groundwater flow).

The southeast flow out of the 200 East Area is influenced by the higher groundwater elevations to the west, the large more permeable paleochannel (trending southeast) incised in the top of the underlying Ringold Formation, and the Ringold Formation lower mud unit situated above the water table in the vicinity of the B Pond. In the central to eastern portion of 200-PO-1, groundwater flow fans outward, flowing northeast, east, and southeast as it approaches the Columbia River. Flow toward the northeast in this region, away from the high conductivity paleochannel, is a result of the locations of the various recharge, discharge, and no-flow boundaries for the aquifer (see Figure 3.1-5 in Section 3.1). There are no-flow boundaries north of the paleochannel (along the mud and basalt subcrops east and northeast of the 200 East Area), and flow is parallel to these boundaries. If this part of the aquifer is considered as a separate region, the paleochannel would be a recharge boundary, so there is a component of flow away from the paleochannel.

Analyses of the propagation of peak tritium concentrations from the southeast corner of the 200 East Area to the Columbia River shows that the travel time for mobile contaminants is ~33 years (Section 3.6.10 of DOE/RL-2009-85). This travel time is based on historical water table conditions, and current travel times are expected to be slightly longer due to the reduced hydraulic gradient.

Principal sources of groundwater contamination included cribs, ponds, pipelines, and potentially leaking single-shell tanks.

Hydraulic head in 200-PO-1 generally increases with depth, forming an upward gradient. In the 200 East Area, the hydraulic head differential between the Ringold confined aquifer and the overlying unconfined aquifer ranges from a few centimeters to one meter, with the head decreasing upward. Along the Columbia River near well 699-20-E12, the vertical head difference is 10 meters, with the 600 Area between the two areas having intermediate head differences. The exception to the general upward gradient is near B Pond where the heads decrease with depth, which is likely a condition remaining from the time that the B Pond system was in operation. A detailed discussion of 200 East Area hydrogeology and groundwater flow characteristics is provided in PNNL-12261.

Other important concepts associated with 200-PO-1 include the following:

- Principal sources of groundwater contamination included cribs, ponds, pipelines, and single-shell tanks that formerly leaked. These facilities are currently inactive, and pumpable liquids have been removed from the tanks; however, the waste sites have not yet been remediated and contamination remains in the vadose zone.
- Tritium, nitrate, and iodine-129 are the principal groundwater contaminants of concern because of their widespread plumes. The area of the iodine-129 plume above 1 pCi/L appears stable, while the tritium plume is shrinking as a result of dispersion and radioactive decay (Figure 3.5-3). Changes in the apparent areal extent of the nitrate plume in Figure 3.5-3 are due mostly to differences in plume interpretation over the years.
- Small plumes of strontium-90, technetium-99, and uranium in the 200 East Area exceed their respective drinking water standards. Concentrations in the local plumes of strontium-90 and technetium-99 are stable or decreasing, but the small uranium plume may be increasing in size.
- The direction of groundwater flow in the 200 East Area is difficult to interpret because of the low hydraulic gradient. An effort to determine the hydraulic gradient near the Plutonium-Uranium Extraction (PUREX) Cribs and the Integrated Disposal Facility (IDF) by improving the accuracy of the water-level measurements began during fiscal year 2008 and continued through 2011. This effort yielded results that are in agreement with the interpreted movement of contaminant plumes.

- Most of the monitoring wells are screened at the top of the unconfined aquifer where the highest levels of groundwater contamination are detected. Twenty wells are screened (or have perforated casings) in deeper portions of the unconfined or confined aquifers. Deeper wells monitored during 2011 continued to show that groundwater contamination is either not detected at depth or that concentrations are much lower than near the water table (in the areas where the deeper wells are located).

Major contaminants of concern in 200-PO-1 groundwater include tritium, iodine-129, nitrate, strontium-90, technetium-99, and uranium.

The cribs, ponds, and ditches surrounding the PUREX Plant are responsible for most of the groundwater contamination in 200-PO-1. The PUREX Plant began operation in 1956, eventually replacing the REDOX Plant as the plutonium-separation facility. The first PUREX operational campaign was from 1956 to 1972. Following an 11-year shutdown, the PUREX Plant operation restarted in 1983, operating for five years until December 1988, when the mission for nuclear weapons production ended. Plant operation briefly restarted again in December 1989 to stabilize material in the system. The plumes that are present primarily contain those species associated with process condensates, including tritium, iodine-129, and nitrate. Some strontium-90 and technetium-99 are also associated with PUREX waste disposal, although technetium-99 is not found above the 900 pCi/L drinking water standard in contaminant plumes from PUREX Cribs. The PUREX Cribs include RCRA sites 216-A-36B Crib and 216-A-37-1 Crib and other cribs not monitored under RCRA. Within the boundaries of 200-PO-1, technetium-99 exceeds the drinking water standard only near WMA A-AX.

The sections that follow describe the major contaminants of concern within 200-PO-1, which include tritium, iodine-129, nitrate, strontium-90, technetium-99, and uranium. Other contaminants of potential concern are also discussed.

3.5.1 Tritium

The PUREX Cribs were the principal source for the large tritium plume that extends from the southeastern portion of the 200 East Area to the Columbia River (Figures 3.5-4 and 3.5-5). The highest concentrations of tritium in this plume remain near these cribs (Figure 3.5-5). The highest reported level of tritium during 2011 was 580,000 pCi/L for a sample collected in April at well 299-E17-14. Figure 3.5-3 illustrates how the sizes of the major plumes have changed since 2003. The tritium plume has decreased in size by approximately 38% since 1996.

The principal source for the large tritium plume is the PUREX Cribs. This plume has decreased in size by ~38% since 1996.

Near-field wells have higher tritium concentrations than wells in the far-field because of their proximity to tritium sources. However, like wells in the far-field areas, some but not all wells in the near-field area generally show decreasing trends. Figure 3.5-6 shows tritium concentration trends in wells at the PUREX Cribs (one well for each of the PUREX Cribs). The wells shown had the highest tritium concentration for their respective cribs during 2011. The generally stable trends in these wells indicate an ongoing source of tritium to the aquifer.

Concentrations of tritium generally continued to decline in the far-field area as the plume attenuates naturally due to radioactive decay and dispersion. The plume eventually discharges with normal groundwater flow to the Columbia River. There is poor well coverage in the region between 699-40-1 and 699-20-E12 along the Columbia River. This is an area of active sand dunes, making it difficult to drill

wells. Three wells in the northeastern portion of 200-PO-1 (699-35-9, 699-29-4, and 699-26-15A) previously had tritium concentrations greater than 80,000 pCi/L (Figure 5-4 in DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2*). In 1997, the 80,000 pCi/L plume configuration was 60 square kilometers in this area. In 2008, the 80,000 pCi/L plume configuration had decreased to 18 square kilometers. Likewise, the tritium results for these three wells has decreased from over 120,000 pCi/L in the mid-1990s to 69,000, 61,000, and 58,000 pCi/L, respectively in 2010, eliminating concentrations greater than 80,000 pCi/L in this area (Figure 3.5-4). The three wells cited were not sampled in 2011.

The zone of lower tritium concentrations near the Energy Northwest complex (Figure 3.5-4) is due to a zone of lower hydraulic conductivity in the unconfined aquifer. In this area, the water table is within the upper portion of the Ringold Formation, which has a greater degree of local cementation. The small but concentrated tritium plume near the Energy Northwest complex is due to tritium from the 618-11 Burial Ground in the 300-FF-5 Operable Unit. Section 2.7 discusses tritium at the 618-11 Burial Ground, which is west of the Energy Northwest complex.

Southeast of the 200 East Area, the tritium plume bends sharply toward the north in the vicinity of well 699-31-31 (Figure 3.5-4). Between the years 2000 and 2001, concentrations in this well decreased abruptly from levels above the 20,000 pCi/L drinking water standard to concentrations an order of magnitude below the drinking water standard. Although the reason for the decline has not been determined, the current sample results from this well were honored when interpreting the tritium plume extent in Figure 3.5-4. However, it is possible the well is not yielding representative samples of the aquifer. It is also possible that the sample results are representative and the decline in concentrations was due to displacement of the plume by water that has been discharged to the Treated Effluent Disposal Facility, located 3.5 kilometers to the northwest. Thus, there is uncertainty in the tritium distribution in this region.

Wells screened (or casings perforated) in the middle or lower portions of the unconfined aquifer had tritium results ranging from non-detect to 21,000 pCi/L. The maximum concentration was at well 699-41-42 (west of B Pond). Well 699-41-42 is in an area where the head decreases with depth, allowing downward flow (see Figure 4-5 in Section 4.0).

Tritium was not detected in the three wells (699-40-36, 699-41-35, and 699-42-37) located near the TEDF, east of the 200 East Area. These wells are screened in the Ringold unit A below the Ringold lower mud unit, which locally confines the groundwater. Tritium was also not detected in five of the six wells monitoring the basalt-confined aquifer that were sampled in 2011 (i.e., not detected in 299-E16-1, 299-E33-40, 699-24-1P, 699-32-22B, and 699-S11-E12AP). The deep basalt-confined aquifer well where tritium was detected was 699-42-40C near B Pond (where the head decreases with depth). Results from both the Ringold Formation and basalt-confined aquifers are discussed further in Chapter 4.0.

3.5.2 Iodine-129

The iodine-129 plume (Figure 3.5-7) extends southeast into the 600 Area from the 200 East Area and appears to coincide with the northern portions of the tritium plume. Although stable since 2003, the plume areal extent (above the 1 pCi/L isopleth line) has decreased over the past 17 years and the maximum concentrations have declined significantly (Figure 5.3 of PNL-10698, *Hanford Site Ground-Water Monitoring for 1994*). Figure 3.5-3 shows the plume areal extent since 2003.

Similar to the tritium plume, the iodine-129 plume bends sharply to the north in the vicinity of well 699-31-31 (Figure 3.5-7). Concentrations decreased substantially in this well during the mid-1990s, from ~8 pCi/L to levels below the 1 pCi/L drinking water standard. As explained in Section 3.5.1, sample results from this well may not be representative of the aquifer, although it is also possible the iodine-129 plume has been displaced in the aquifer by discharges at the Treated Effluent Disposal Facility. Thus, there is uncertainty in the iodine-129 distribution in this region.

The highest concentrations of iodine-129 in 200-PO-1 are near the sources in the 200 East Area and B Pond area. The concentrations in this near-field area in 2011 ranged from non-detect to 9.98 pCi/L at well 699-43-45 (near the 216-A-29 Ditch). Concentrations near the PUREX Cribs reached a maximum of 9.01 pCi/L in well 299-E17-14. The general trend was relatively stable for iodine-129 at this well (Figure 3.5-8), which is typical of the trend for iodine-129 at other wells near the PUREX Cribs.

The iodine-129 plume area has decreased over the past 17 years.

The sources of iodine-129 in the 200 East Area likely contribute to the plume because of the persistence of the plume across the northern portions of 200-PO-1. With a low retardation factor, iodine-129 would be expected to disperse more quickly through natural processes if the plume were not continually replenished. Iodine-129 has a half-life of 15.7 million years and a low distribution coefficient (ranging from 0 to 2 mL/g, depending on aquifer conditions, and averaging 0.2 mL/g) (PNNL-11800, *Composite Analysis of Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*; PNNL-14702).

Iodine-129 was detected in wells screened (or perforated) deeper in the unconfined aquifer, including wells near B Pond, the 216-A-37-1 Crib, and the 216-A-29 Ditch. The highest concentration observed in a deeper unconfined aquifer well was 5.51 pCi/L in 299-E25-32Q near the 216-A-29 Ditch. None of the deep basalt-confined aquifer wells had detectable iodine-129.

3.5.3 Nitrate

The extent of the plume with nitrate concentrations elevated above background mirrors that of the tritium plume; however, the portion of the plume exceeding the 45 mg/L drinking water standard is relatively small by comparison (Figure 3.5-9). During 2011, the highest nitrate concentration in 200-PO-1 was at wells near the PUREX Cribs (Figure 3.5-10). The maximum concentration for samples collected during 2011 was 158 mg/L at well 299-E17-19 (at the 216-A-36B Crib) (Figure 3.5-11). The nitrate plume, with sources in the 200 East Area, appears to be dispersing slightly over time when compared with previous years, except near the PUREX Cribs (Section 2.11 of PNNL-15670; Section 2.11 of DOE/RL-2008-01) and WMA A-AX. Another nitrate plume from an offsite source exists near the 300 Area.

The nitrate plume, with sources in the 200 East Area, appears to have dispersed over previous years, except near the PUREX Cribs.

Many of the wells near the PUREX Cribs in the southeastern portion of the 200 East Area have increasing nitrate concentrations. The cause of the increase in nitrate concentrations in this area is unknown but may be the result of shifting groundwater flow directions related to the cessation of wastewater discharges at B Pond or the discharge of wastewater at the TEDF. These same discharges may have diluted the nitrate concentrations while B Pond was active. Increasing concentrations near the PUREX Cribs and WMA A-AX may also be due to continued seepage from the vadose zone at these locations (Figures 3.5-12, 3.5-13, and 3.5-14).

For the wells screened (or casings perforated) in the middle to lower portions of the unconfined aquifer, nitrate did not exceed the 45 mg/L drinking water standard which implies that the highest concentrations are in the upper portion of the aquifer. The highest nitrate concentration reported in the deeper wells was at well 699-2-7 near the 400 Area Process Ponds, which is a local source of nitrate; the nitrate concentration was 32.8 mg/L. In the main water supply well in the 400 Area (well 499-S1-8J), the nitrate concentration was below the detection limit of 0.17 mg/L. In the Ringold Formation confined

aquifer beneath the TEDF, nitrate concentrations averaged 6.7 mg/L at well 699-42-37, 0.90 mg/L at well 699-41-35, and 0.17 mg/L at well 699-40-36—consistent with regional concentrations. Nitrate concentrations were very low in all of the basalt-confined aquifer wells.

3.5.4 Strontium-90

Well 299-E17-14 (at the 216-A-36B Crib) was the only well with strontium-90 detected above the drinking water standard (8 pCi/L) during 2011 in 200-PO-1. At well 299-E17-14, the trend appeared to be decreasing in 2008 and 2009, when the levels dipped lower than the previously stable concentration of 18 to 20 pCi/L, with concentrations of 14 and 11 pCi/L, respectively. Values have been increasing since 2009. The 2011 result for 299-E17-14 was 30 pCi/L. Other wells in the PUREX area in which strontium-90 was detected, but at concentrations below the drinking water standard were: 3.50 pCi/L in well 299-E17-16, 2.70 pCi/L in well 299-E17-18, and 4.66 pCi/L in well 299-E24-16. Strontium-90 was not detected in any of the deeper unconfined aquifer wells.

3.5.5 Technetium-99

Technetium-99 continues to be detected at WMA A-AX at levels above the 900 pCi/L drinking water standard.

Technetium-99 (a beta emitter) continues to exceed the drinking water standard (900 pCi/L) at only one location within 200-PO-1, WMA A-AX. Technetium-99 is most concentrated at well 299-E25-93, located along the southern boundary of WMA A-AX, with results for 2011 ranging from 1,600 to 6,500 pCi/L; and the source is probably WMA A-AX. Technetium-99 is also above the drinking water standard in WMA A-AX upgradient well 299-E24-33, with results ranging from 890 to 1,500 pCi/L in 2011, suggesting WMA C as another source (Figure 3.5-15). Concentrations at well 299-E25-93 have decreased since 2009, while concentrations at well 299-E24-33 have increased during the same time period (Figure 3.5-16). Technetium-99 was detected in wells at the PUREX Cribs up to a concentration of 140 pCi/L. The technetium-99 activity from these areas extends throughout the northern and central portions of the area occupied by the large tritium plume, with concentrations up to 120 pCi/L.

3.5.6 Uranium

In recent years, uranium concentrations have been increasing in wells near the PUREX Cribs.

Elevated uranium concentrations were found at three locations within 200-PO-1, the PUREX Cribs, the 618-10 Burial Grounds, and the 618-11 Burial Grounds. In recent years, uranium concentrations have been increasing in wells near the PUREX Cribs (Figure 3.5-17). Uranium concentrations at well 299-E17-14 have been stable since 2006, with concentrations near the 30 µg/L drinking water standard (Figure 3.5-18). In two nearby wells, concentrations have been higher in recent years, with the highest concentration at well 299-E24-23 (106 µg/L in 2009) (Figure 3.5-18); however, well 299-E24-23 was not sampled during 2010 or 2011, so it is not known if the upward trend continued. The other well with a higher uranium concentration was 299-E25-36, with a concentration of 68.1 µg/L in 2011.

At the 618-10 Burial Ground, uranium concentrations reached the 14.4 µg/L background concentration (Table ES-1 of DOE/RL-96-61), but these areas are sites of known uranium contamination in the 300-FF-5 Operable Unit (Section 2.7). Elsewhere, including the deeper wells, uranium concentrations are within the background range.

3.5.7 Other Contaminants

Other constituents (i.e., arsenic, chromium, manganese, and vanadium) are contaminants of potential concern at various source sites within 200-PO-1 (DOE/RL-2003-04, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit*). Chromium, cobalt-60, cyanide, and uranium are contaminants of potential concern at the BC Cribs and Trenches. Arsenic was detected in nearly every well sampled in 200-PO-1, but mostly at concentrations below the background concentration of 11.8 µg/L. Volatile organic compounds are constituents of concern at the Nonradioactive Dangerous Waste Landfill (NRDWL), Solid Waste Landfill (SWL), 216-A-36B, 216-A-37-1, and 400 Area wells as well as the southeast and river transect wells.

Manganese exceeded the 50 µg/L secondary drinking water standard in 200-PO-1 groundwater during 2011 in only two wells.

In 2011, manganese exceeded the 50 µg/L secondary drinking water standard in two wells, 699-32-22B and 699-24-1P. In well 699-32-22B, a manganese value of 60.7 µg/L was obtained for an unfiltered sample. Well 699-32-22B is a deep basalt-confined aquifer well that is screened across a basalt interbed at a depth of 236 to 255 meters below ground surface. It is located along the southeast transect (see Section 3.5.8.1) (Figure 3.5-2). The result for the unfiltered sample is anomalous for this well and is an isolated occurrence; it is likely that this result is a sampling or laboratory error, or the deterioration of the well screen or casing. In well 699-24-1P, the average manganese value of 84 µg/L was obtained for the unfiltered samples; and the average manganese value of 64.5 µg/L was obtained for the filtered samples. Since the duplicate of the filtered samples were nearly identical and the duplicate of the unfiltered sample was much higher, a problem with quality control is indicated related to the unfiltered samples. As a result, the unfiltered results are likely not representative.

The vanadium concentration averaged 32.5 µg/L in well 299-E25-22—the highest in 200-PO-1—located near the 216-A-37-2 Crib. This result is typical for well 299-E25-22, and vanadium was detected in many wells throughout 200-PO-1. The background level for vanadium is 19 µg/L. A drinking water standard has not been established for vanadium.

Groundwater monitoring is routinely conducted in four wells at the BC Cribs and Trenches (299-E13-5, 299-E13-11, 299-E13-14, and 299-E13-19). Recent results show that contaminants of potential concern (i.e., chromium, cobalt-60, cyanide, and uranium), as well as the 200-PO-1 major contaminants of concern, were either not detected or were similar to background (upgradient) concentrations in the BC Cribs and Trenches.

Although not a contaminant of concern in 200-PO-1, a fluoride concentration of 8.91 mg/L observed in well 699-S2-34B (the well at the Laser Interferometer Gravitational-Wave Observatory [LIGO]) during 2011 was above the 4 mg/L primary drinking water standard. This well is used for water supply. The results are typical of the historical trend for this well. The well is screened in the Frenchman Springs Member of the Wanapum Basalt, and water from this member generally yields low levels of fluoride. At the LIGO site, the Wanapum Basalt may present upwelling groundwater from the underlying Grande Ronde Basalt, which is known to have fluoride concentrations in the range of 8 to 10 mg/L (Section 4.1 of PNNL-13962, *Natural Gas Storage in Basalt Aquifers of the Columbia Basin, Pacific Northwest USA: A Guide to Site Characterization*).

Volatile organic compounds were constituents of concern in various areas (see Section 3.5.9) within 200-PO-1; however, they were not detected in 2011.

3.5.8 CERCLA Activities

The 200-PO-1 Operable Unit makes up a large portion of the Hanford Site (Figure 3.5-2). The operable unit boundaries are generally defined by the 2,000 pCi/L tritium (200 East Area origin) plume contour, which is the largest contaminant plume on the Hanford Site. Wells at the BC Cribs and Trenches are also within the 200-PO-1 groundwater interest area, even though they are located outside the operable unit boundaries. Wells 299-E13-120 and 299-E13-121 were installed to support soil desiccation treatability testing in the BC Cribs and Trenches Area. Neutron moisture logging of the wells monitors the effectiveness of pore water removal from the vadose zone.

Groundwater monitoring at 200-PO-1 supports the RI/FS process under the direction of a work plan and two sampling and analysis plans (one for routine groundwater sampling, and a second for short-term characterization to supplement routine groundwater monitoring). Work began on a draft RI report in 2009 following completion of RI activities. Draft A of DOE/RL-2009-85 was submitted for regulatory review in May 2010. The work plan, sampling and analysis plans, and RI report documents are briefly described below.

DOE/RL-2003-04, referred to as the "routine" sampling and analysis plan, provides the basis for regular sampling and analysis of 200-PO-1 contaminants of concern for CERCLA and AEA. Revision 1 of this plan was approved in 2005 to provide groundwater data necessary to track the extent and concentration of known contaminant plumes. In 2008, the monitoring well list and groundwater analyte list were updated with additional wells and analytes. Figure 3.5-1 (near-field wells) and Figure 3.5-2 (far-field wells) show the monitoring well locations associated with the routine sampling and analysis plan. Appendix A provides the well and analyte lists for 200-PO-1 near-field and far-field monitoring. Sections 3.5.1 through 3.5.7 and 3.5.8.1 discuss the routine sampling results for 2011.

Remedial Investigation/Feasibility Study Work Plan for the 200-PO-1 Groundwater Operable Unit (DOE/RL-2007-31) was issued in 2008 to further define the conditions within the 200-PO-1 Operable Unit. Work was completed for the characterization sampling and analysis plan in 2009, and the results were reported in the RI report (DOE/RL-2009-85) and in the 2009 Hanford Site Groundwater Annual Report (DOE/RL-2010-11). The RI report was completed in 2010 and, prior to issuance, was submitted for review by the regulatory agencies. Results of the draft RI report were summarized in Section 10.2 of DOE/RL-2011-01. The final RI report will be issued in 2012.

3.5.8.1 CERCLA Groundwater Monitoring

This section discusses the groundwater monitoring results for 2011 for the routine sampling and analysis plan (DOE/RL-2003-04) that were not previously discussed in Sections 3.5.1 through 3.5.7. Of the 60 wells scheduled for sampling during 2011, 57 were successfully sampled. Three well trips were unsuccessful due to a variety of reasons, including maintenance issues, wellhead damage, access problems, or insufficient water.

Most of the results for the primary groundwater plumes and contaminants of concern for 200-PO-1 were discussed previously, but specific details of the guard wells are discussed here. Appendix A provides lists of wells and groundwater constituents analyzed for 200-PO-1.

The 200-PO-1 routine sampling and analysis plan (DOE/RL-2003-04) specifies annual sampling of two lines of guard wells to screen for a comprehensive list of analytes (i.e., additional groundwater constituents that are not usually analyzed on samples collected from far-field wells). One of the lines of guard wells (the southeast transect) is located southeast of the 200 East Area (Figure 3.5-2) and ensures that unexpected contaminants do not migrate undetected from the 200 East Area. The other line (the river transect) is a line of wells located along the Columbia River to assess the concentration of any groundwater contaminants that may reach the river. The comprehensive list of analytes for samples collected from wells of both transects includes tritium, iodine-129, anions (including nitrate), gross alpha and beta, gamma scan, metals, strontium-90, and volatile organic compounds.

The only constituents exceeding drinking water standards in southeast transect wells were tritium and iodine-129.

Most of the anions and metals (e.g., fluoride and arsenic) detected in southeast transect wells during 2011 are naturally occurring or are typical of Hanford Site background values (Table ES-1 of DOE/RL-96-61). The only constituents exceeding their drinking water standard were tritium and iodine-129, but their concentrations were consistent with their respective plumes. Technetium-99 was detected at levels above Site background (0.99 pCi/L), but concentrations were similar to other wells in the area. Gross alpha and gross beta were as high as 2.2 and 14 pCi/L, respectively, in southeast transect wells; and both are typical for wells in this area. Chromium, cobalt, copper, nickel, and vanadium were all detected at levels above Site background levels, but their results were low enough to be flagged by the analytical laboratory as "estimated" only. Nitrate and sulfate exceeded Hanford Site background and are elevated due to 200 East Area liquid waste discharges. The highest reported levels were 21.9 and 55.5 mg/L, respectively.

The only groundwater contaminant exceeding its drinking water standards in the river transect wells was tritium.

Groundwater monitoring results for 2011 at the river transect were similar to those for the southeast transect, although generally lower in concentrations as a result of greater distance from contamination sources. Most of the anions and metals (e.g., fluoride and arsenic) detected in river transect wells are naturally occurring or are typical of Hanford Site background values (Table ES-1 of DOE/RL-96-61). The only constituent exceeding a drinking water standard was tritium (drinking water standard of 20,000 pCi/L) with a high of 66,000 pCi/L at well 699-41-1A. This tritium result is typical for this area of the large tritium plume emanating from the 200 East Area, and the trend for this well is stable. Aluminum, bismuth, molybdenum, and sodium were detected at levels above Site background concentrations. Sodium was above Site background values and had a high of 38.7 mg/L in well 699-S3-E12. The trend in this well is increasing slightly, and the reason for the elevated levels at this location is unknown. Other wells in the area have sodium concentrations ranging from 15 to 30 mg/L.

3.5.8.2 Soil Desiccation at BC Cribs

A soil desiccation treatability test was conducted in the cribs region of the BC Cribs and Trenches Area to collect data supporting potential use of desiccation as a deep vadose zone remedy. Desiccation, in theory, inhibits the migration of contaminants in the deep vadose zone. Desiccation was achieved by the injection of dry, constant temperature nitrogen into the subsurface. Providing a drying gas of constant temperature and humidity (essentially zero) enabled more precise analysis of the dessication effect. The test was conducted at a relatively shallow interval containing high moisture and associated technetium-99 and nitrate contamination. Deep vadose conditions were simulated by covering the contaminated test area with an impermeable barrier. The active desiccation portion of the field test occurred with nitrogen injection at a stable flow rate of 510 m^3/h from January 17, 2011 through June 30, 2011 (164 days), except during a 13-day interval from April 21 through May 4, 2011, when there was no injection. Injection well 299-E13-62 was screened from 9.1 to 15.2 meters below ground surface. Soil gas was extracted from similarly screened well 299-E13-65, positioned 12 meters away. Extraction was maintained for the full test duration at a stable flow rate of 170 m^3/h. The soil gas was routed through a heat exchanger to condense water that was collected and sampled. A clustered monitoring approach was used in the test: a borehole containing sensors, gas-sampling ports, and electrical resistance tomography electrodes were placed nominally adjacent to a cased, unscreened well that was used to conduct neutron

moisture logging. The unscreened well was also used for application of cross-hole ground penetrating radar.

A soil desiccation treatability test was conducted at BC Cribs to dry out the vadose zone by injecting nitrogen gas into the subsurface.

As anticipated, desiccation occurred more rapidly in strata having higher permeability with the combination of in situ sensors and geophysical measurements (electrical resistance tomography, neutron moisture logging, and cross-hole radar) providing data to monitor desiccation progress. Following completion of the active portion of the test, data collection continues to monitor rewetting of the desiccated region. In 2012, a comprehensive report will be issued.

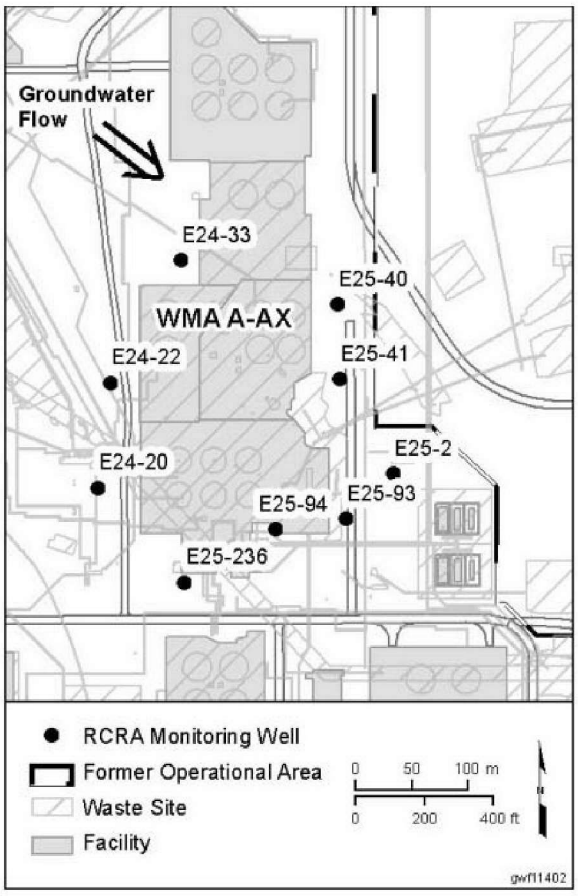
3.5.9 RCRA and Other Facility Monitoring

The following sections describe the results of monitoring at ten individual waste management/disposal facilities within 200-PO-1. Seven of the sites are monitored in accordance with RCRA regulations. Interim status groundwater quality assessment monitoring was conducted at WMA A-AX (40 CFR 265.93[d]), as referenced by WAC 173-303-400. Interim status indicator evaluation monitoring was conducted at the 216-A-36B Crib, 216-A-37-1 Crib, 216-A-29 Ditch, 216-B-3 Pond, and NRDWL (40 CFR 265.92; 40 CFR 265.93[b], as referenced by WAC 173-303-400).

The Integrated Disposal Facility is not operational but is monitored as incorporated into the Hanford Facility RCRA Permit (WA7890008967) to obtain baseline information.

The 200 Area Treated Effluent Disposal Facility (TEDF) is authorized by *State Waste Discharge Permit Number ST 4502* (Ecology, 2000b) and is monitored by three wells. Groundwater monitoring at the SWL was conducted (PNNL-13014, *Groundwater Monitoring Plan for the Solid Waste Landfill*) to accommodate the requirements of WAC 173-304 ("Minimum Functional Standards for Solid Waste Handling") that are similar to WAC 173-350, "Solid Waste Handling Standards." WAC 173-350 superseded WAC 173-304.

The 400 Area water supply wells are monitored for the AEA in accordance with DOE/RL-2003-04. Groundwater data for these facilities are available from the data files accompanying this report and from the Hanford Environmental Information System (HEIS) database, which can be accessed via the internet through the DOE's 2012 Environmental Dashboard Application.



3.5.9.1 Waste Management Area A-AX

WMA A-AX consists of two tank farms: the A Tank Farm and the AX Tank Farm. The A Tank Farm consists of six tanks, each with a capacity of 3.8 million liters. The AX Tank Farm consists of four

tanks, each with a capacity of 3.8 million liters (Section 2.1 of RPP-14430, *Subsurface Conditions Description of the C and A-AX Waste Management Area*). The WMA also includes ancillary equipment consisting of seven diversion boxes, associated piping, valve pits, pumps, and the 244-AR waste transfer vault. Both tank farms received waste generated from PUREX processing operations in the 1950s and 1960s.

WMA A-AX was placed into assessment status in 2005 at the direction of Ecology because of elevated specific conductance in downgradient monitoring well 299-E25-93. The first determination assessment found that sources within the WMA had affected groundwater quality with elevated concentrations of nickel in wells downgradient of the WMA (Section 4, SGW-47538, *Groundwater Quality Assessment Report for Waste Management Area A-AX: First Determination*). The current objective of RCRA monitoring at WMA A-AX is to assess the extent and concentrations of dangerous waste constituents in the groundwater and determine their rate of movement. Radiological constituents from the single shell tanks were discussed in previous sections.

The current monitoring plan is PNNL-15315, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site*. With the installation of well 299-E25-236 in 2008, the groundwater monitoring well network was completed (Section 5.2 of PNNL-15315). A new plan was written as required by 40 CFR 265.93(d)(7) that will continue an interim status groundwater quality assessment program. Ecology is reviewing the new plan, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX* (DOE/RL-2009-70). Until the new plan is approved, groundwater monitoring at WMA A-AX will continue under the current groundwater monitoring plan (PNNL-15315).

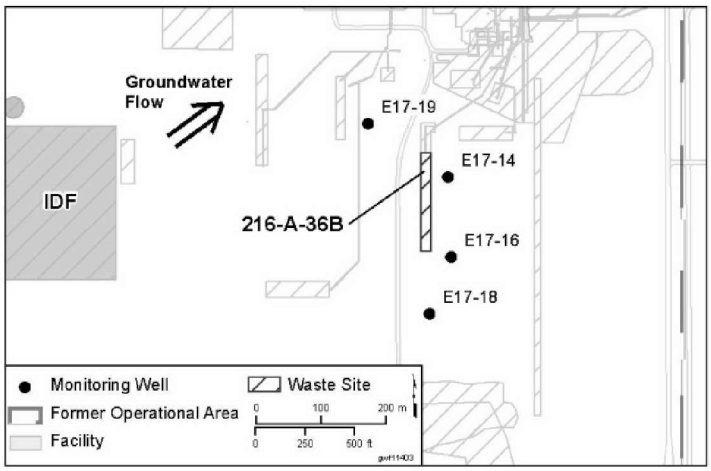
Appendix B includes a well location map (Figure B-4) and a list of wells and constituents monitored for WMA A-AX (Table B-34). With the exception of well 299-E25-94, all required sampling was performed successfully during the year, although a few wells were sampled later than scheduled because of maintenance or other issues. Well 299-E25-94, scheduled for a March sample, was missed as a result of pump problems. The locations of the current wells are appropriately oriented with a southeast groundwater flow direction.

Water-Level and Well Network Evaluation. Groundwater flow direction in the unconfined aquifer is most likely to the southeast, based on slightly higher heads to the northeast, the orientation of the paleochannel, and the configuration of the major contamination plumes. The water table gradient is indeterminate because of a lack of corrected water level measurements, and the hydraulic conductivity of the Hanford sediments is relatively high. Thus, the groundwater flow rate is indeterminate (Appendix B, Table B-1).

Based on the distribution of the monitoring wells compared to the extent of contamination, DOE believes the current well network is capable of monitoring the distribution of contamination at this WMA. The WMA A-AX will remain in interim status groundwater quality assessment monitoring in accordance with 40 CFR 265.93(d), as referenced by WAC 173-303-400 for 2012.

Assessment Results. Groundwater beneath WMA A-AX is contaminated with the dangerous waste constituent nickel and supporting constituent, nitrate. Filtered nickel concentrations ranged from undetected to 20 µg/L (sample in well 299-E25-40). Nickel concentrations were stable but continued to be higher in downgradient wells 299-E25-40 and 299-E25-236 than in the upgradient wells.

Nitrate exceeded the drinking water standard (45 mg/L) in only one WMA A-AX well during 2011 (maximum value of 61.5 mg/L in 299-E25-93). Chromium and lead were detected, but chromium was detected only at very low levels (less than 35.3 µg/L) in two wells. The maximum detection for lead (1.82 µg/L for an unfiltered sample in 299-E25-94) was above the Hanford Site background level (1.3 µg/L) (Table ES-1 of DOE/RL-96-61). The sample result is an outlier and is inconsistent with all other samples in that well.



Sodium and sulfate were detected in all of the WMA A-AX samples and are naturally occurring constituents in Site groundwater. Detected sodium was at or below background levels. Sulfate concentrations were well above Site background levels, but upgradient concentrations are similar to downgradient concentrations.

Total organic carbon was detected in many of the network wells as isolated detections. The highest of these detections was 1,330 µg/L at well 299-E25-94. The cause of these spurious detections is unknown; however, total organic carbon concentrations at well 299-E25-236, which ended the year at 2,520 µg/L in December 2010, significantly decreased to 460 µg/L in December 2011. Like the isolated detections in the other wells, the cause for the rising total organic carbon concentrations in well 299-E25-94 is unknown. Efforts to determine the source of the elevated total organic carbon will continue in 2012.

3.5.9.2 216-A-36B Crib

The 216-A-36B Crib is located in the southeastern portion of the 200 East Area (Figure 3.5-1) and is 7 meters deep, 150 meters long, and 2.3 to 3.4 meters wide at the base; the sides slope at 1:1.5. The crib was originally part of the 180 meters long, 216-A-36 Crib, which received PUREX effluent from September 1965 through March 1966. In March 1966, the northernmost 30 meters of the crib was isolated, and a grout barrier was established between it and the southern portion of the crib, now known as 216-A-36B. The 216-A-36B was operational from March 1966 through October 1972, and it was reactivated in November 1982 for the PUREX Plant restart. It was permanently removed from service in August 1987. The site received discharges of PUREX ammonia scrubber distillate totaling 2.9×10^8 liters.

Since January 2011, the 216-A-36B Crib has been monitored under interim status regulations to determine if dangerous waste constituents have impacted groundwater (DOE/RL-2010-93, *Interim Status Groundwater Monitoring Plan for the 216-A-36B PUREX Plant Crib*). Revision 1 of the plan was released in June 2011 to provide more detail pertaining to the constituent list and sampling frequency. Before 2011, the 216-A-36B Crib, along with two other PUREX Cribs (216-A-10 and 216-A-37-1), were monitored in a RCRA interim status groundwater quality assessment program. However, the 216-A-10 Crib was officially closed March 30, 2010, and was removed from Part A of the Hanford Facility Dangerous Waste Permit. The two remaining cribs, 216-A-36B and 216-A-37-1, will remain in RCRA interim status but were returned to indicator evaluation programs because groundwater constituents detected were not dangerous wastes or dangerous waste constituents. Other nearby cribs also received PUREX waste (e.g., 216-A-45 Crib); however, these other cribs are not regulated as RCRA treatment, storage, and disposal units, but are instead monitored under CERCLA through the 200-PO-1 Operable Unit.

Appendix B includes a well location map (Figure B-4), a list of wells and constituents sampled for the 216-A-36B Crib (Table B-10) and the critical means[1] calculated for 2012 (Table B-11). In the first year of monitoring, initial background concentrations will be established. One well at 216-A-36B Crib is

[1] The critical mean is the value above which a sample result in a downgradient well would be statistically higher than background sample results from the upgradient well. Calculation of the critical mean is based on the Student's t-test at the 0.01 level of significance as required by 40 CFR 265.93(b), referenced by WAC 173-303-400.

sampled on a quarterly schedule to establish background, and the other wells are sampled semiannually. All scheduled groundwater samples were collected from wells at the 216-A-36B Crib during 2011 and critical means calculated (Appendix B).

Water-Level and Well Network Evaluation. The delineations of groundwater flow directions and water table gradients are difficult to calculate for the 200 East Area from water-level data because of a flat water table. Work began in fiscal year 2008 to better understand the groundwater flow direction beneath the PUREX Cribs and the nearby IDF. Gyroscope surveys were completed on eleven monitoring wells near the IDF and PUREX Cribs. Highly accurate casing elevation surveys were also performed on these wells. Water level measurements were collected monthly between June 2008 and March 2009, and quarterly thereafter, and the data were analyzed by trend-surface analysis. The average groundwater flow direction based on measurements collected through 2010 was determined to be east at 80 (±17) degrees, with an average gradient of 2.0×10^{-5} meter per meter ($\pm 0.2 \times 10^{-5}$ meter per meter) (Section 10.3.1 of DOE/RL-2011-01).

During 2011, the effects of barometric pressure fluctuations on the water-level data were analyzed and removed using multiple regression/deconvolution, as described in "Identifying and Removing Barometric Pressure Effects in Confined and Unconfined Aquifers" (Rasmussen and Crawford, 1997). Automated water-level data were collected for a short period from the network wells, and the data were analyzed by multiple regression to determine the water-level response characteristics to barometric pressure changes. Then, the well-specific response functions were used to normalize the manual water-level measurements collected from 2008 through 2011 to a constant barometric pressure using deconvolution. All of the measurements were then reanalyzed by trend-surface analysis. The results indicated an average flow direction of east-northeast at 69 (±11) degrees and a hydraulic gradient magnitude of 2.2×10^{-5} meter per meter ($\pm 0.2 \times 10^{-5}$ meter per meter). Thus, accounting for barometric pressure effects resulted in a slight change in the interpreted flow direction and a reduction in the uncertainty of the results, but it did not appreciably alter the previous flow interpretation.

The well network for the trend-surface analyses extended from wells 299-E24-24 and 299-E17-21 on the west side of IDF to wells 299-E26-36 and 699-37-47A east and southeast of the 216-A-36B Crib. The trend-surface analysis results, indicating an east-northeast flow direction, represent the average hydraulic gradient beneath this region. However, near the edge of the study area, the groundwater flow may already be turning toward the southeast. Thus, the specific groundwater flow direction beneath the 216-A-36B Crib is still subject to some uncertainty: it could be east-northeast, or east, or southeast. The groundwater flow rate is calculated to range between 0.001 and 0.6 meter per day.

The 216-A-36B Crib is located in a region where several groundwater contaminant plumes contain constituents exceeding drinking water standards. The similarities in effluent constituents disposed to these cribs, and other PUREX cribs such as the 216-A-45 Crib, make it difficult to determine the contribution of the individual cribs to these plumes.

The primary constituent of interest at the 216-A-36B Crib is nitrate because it is a breakdown product of nitric acid, which was disposed to the 216-A-10 Crib. Additional groundwater quality constituents required by WAC 173-303-400 and 40 CFR 265.93(d)(3) and (d)(4) include chloride, iron, manganese, phenols, sodium, and sulfate.

The 216-A-36B Crib well network is capable of meeting the groundwater monitoring objectives to determine if groundwater has been impacted with dangerous waste constituents. The upgradient and downgradient wells of the network are aligned appropriately, based on the recent determination of groundwater flow direction.

Sampling Results. Samples were collected to establish initial background concentrations of indicator parameters and groundwater quality parameters during 2011. Subsequent sampling will compare the analyses to the first year baseline (critical means values in Appendix B).

Groundwater quality constituents required by WAC 173-303-400 (i.e., chloride, iron, manganese, phenols, sodium, and sulfate) continue to be lower than their respective drinking water standards during 2011.

3.5.9.3 216-A-37-1 Crib

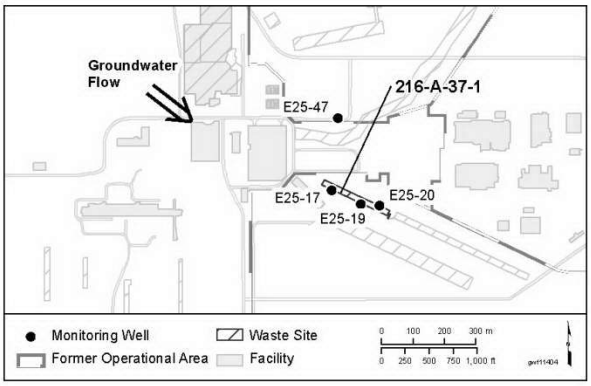
The 216-A-37-1 Crib is located east of the 200 East Area (Figure 3.5-1) and is 5.2 meters deep, 213 meters long, and 3 meters wide at the base; the sides slope at 1:1. The crib was operational from March 1977 through April 1989 and was used for percolation of 242-A evaporator process condensate to the soil column. The crib received spent halogenated and non-halogenated solvents and ammonia. During its operational life, the 216-A-37-1 Crib received a total of 3.7×10^8 liters of process condensate.

Since January 2011, 216-A-37-1 Crib has been monitored under interim status regulations to determine if dangerous waste constituents have impacted groundwater (DOE/RL-2010-92, *Interim Status Groundwater Monitoring Plan for the 216-A-37-1 PUREX Plant Crib*). Revision 1 of the plan was released in June 2011 to provide more detail pertaining to the constituent list and sampling frequency. Before 2011, the 216-A-37-1 Crib, along with two other PUREX Cribs (216-A-10 and 216-A-36B), were monitored in a RCRA interim status groundwater quality assessment program. However, the 216-A-10 Crib was officially closed March 30, 2010, and was removed from Part A of the Hanford Facility Dangerous Waste Permit. The two remaining cribs, 216-A-36B and 216-A-37-1, will remain in RCRA interim status but were returned to indicator evaluation programs because groundwater constituents detected were not dangerous wastes or dangerous waste constituents. Other nearby cribs also received PUREX waste (e.g., 216-A-45 Crib); however, these other cribs are not regulated as RCRA treatment, storage, and disposal units, but are instead monitored under CERCLA through the 200-PO-1 Operable Unit.

Appendix B includes a well location map (Figure B-4), a list of wells and constituents sampled for the 216-A-37-1 Crib (Table B-12), and the critical means calculated for 2012 (Table B-13). One well at 216-A-36B Crib is sampled on a quarterly schedule to establish background, and the other wells are sampled semiannually. All scheduled groundwater samples were collected from wells at the 216-A-36B Crib during 2011.

Water-Level and Well Network Evaluation. Near the 216-A-37-1 Crib, groundwater flow is estimated to be toward the southeast. Flow directions are influenced by (1) the northwest-southeast-trending paleochannel with high permeability Hanford formation sediments cutting across the 200 East Area, (2) the Ringold lower mud unit at the water table east of the 200 East Area, and (3) the higher water table elevations to the west and north. These flow directions are supported mainly by the distribution of plumes emanating from near these cribs and recent efforts to improve the accuracy of water-level measurements in the southeastern portion of the 200 East Area (Section 3.5.9.2). The gradient magnitude is assumed to be the same as at the nearby IDF and 216-A-36B Crib, which is 2.2×10^{-5} meter per meter (Section 3.5.9.2), and the groundwater flow rate ranges between 0.001 and 0.66 meter per day (Appendix B, Table B-1).

The 216-A-37-1 Crib is located in a region where several groundwater contaminant plumes contain constituents exceeding drinking water standards. The similarities in effluent constituents disposed to these cribs, and other PUREX cribs such as the 216-A-45 Crib, make it difficult to determine the contribution of the individual cribs to these plumes.



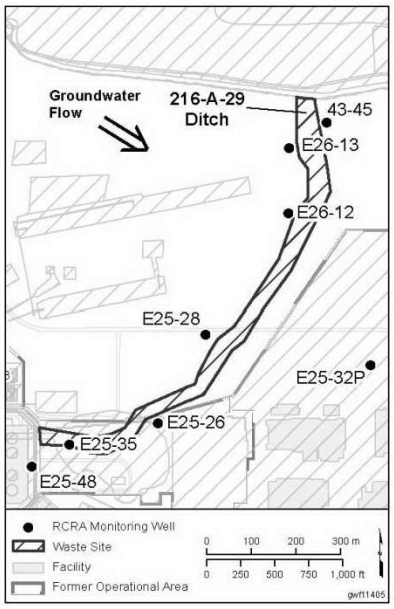
The primary constituent of interest at the 216-A-37-1 Crib is nitrate, a breakdown product of nitric acid, which was disposed to the 216-A-37-1

Crib. Additional groundwater quality constituents required by WAC 173-303-400 and 40 CFR 265.93(d)(3) and (d)(4) include chloride, iron, manganese, phenols, sodium, and sulfate.

The 216-A-37-1 Crib well network is capable of meeting the groundwater monitoring objectives. The upgradient and downgradient wells of the near-field network are aligned appropriately, based on the interpreted groundwater flow direction.

Sampling Results. Samples were collected to establish initial background concentrations of indicator parameters and groundwater quality parameters during 2011. Subsequent sampling will compare the analyses to the first year baseline (critical means values in Appendix B).

Groundwater quality constituents required by WAC 173-303-400 (i.e., chloride, iron, manganese, phenols, sodium, and sulfate) continue to be lower than their respective drinking water standards during 2011, except for the anomalously elevated iron and manganese values in wells with carbon-steel casings.



3.5.9.4 216-A-29 Ditch

The 216-A-29 Ditch is located just east of the 200 East Area fence line (Figure 3.5-1) and is planned for closure. The 216-A-29 Ditch is a regulated unit because it received nonradioactive dangerous waste regulated by 40 CFR 261, "Identification and Listing of Hazardous Waste," after November 19, 1980. The 216-A-29 Ditch is regulated as a surface impoundment, as defined in WAC 173-303-400.

The 216-A-29 Ditch was excavated to convey liquid effluent from the PUREX chemical sewer to the B Pond and was placed in service in November 1955. Flow from the chemical sewer (low-level contaminants) was continuous, with an average flow of 3,671 liters per minute. The 216-A-29 Ditch received continuous discharge of corrosive waste and potentially hazardous spilled chemical materials from the PUREX Plant. The most significant chemical discharges included acidic and caustic effluents associated with backwashing for the regeneration of demineralizer columns. The ditch also received spills from the PUREX Plant chemical sewer (low-level contamination). A complete, estimated inventory of materials discharged to the 216-A-29 Ditch is provided in *Groundwater Monitoring Plan for the 216-A-29 Ditch* (WHC-SD-EN-AP-045, Appendix A).

The 216-A-29 Ditch is currently backfilled with material from the ditch sides and spoils piles in the bottom. The portion of the 216-A-29 Ditch inside the 200 East Area security fence was brought to grade with clean material. The portion of the ditch outside of the 200 East Area security fence was topped with clean material in a series of eleven terraces progressing down the length of the ditch. Both areas have been revegetated and appropriately signed (the 216-A-29 Ditch is an underground radioactive material area).

In compliance with WAC 173-303-400(3) and 40 CFR 265.92, the 216-A-29 Ditch network groundwater wells are monitored semiannually for total organic carbon, total organic halides, pH, and specific conductance. Wells are monitored annually for metals (including cadmium), and phenols. Alkalinity, anions, and water levels are also analyzed semiannually. Alkalinity (and metals and anions) is used to calculate a groundwater charge balance, while anions are included to detect potential nitrate contamination and to provide input for charge-balance calculations. Two sample events were missed for well 299-E25-26 as a result of pump issues and work restrictions because of overhead power lines. With the exception of the well noted above, all wells were sampled during the calendar year as required.

Historically, well 699-43-45 has served as an upgradient well for the 216-A-29 Ditch. With the continual shift in groundwater flow direction from the southwest to the southeast, this well is no longer

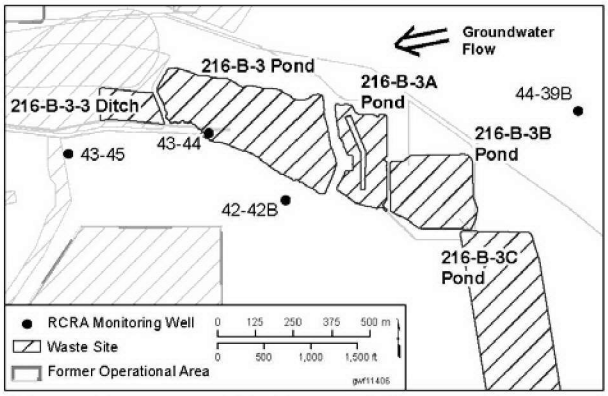
upgradient of the unit. Wells 299-E26-12 and 299-E26-13, which have always been included in the network, became the new upgradient wells starting in 2011.

Wells 299-E25-26, 299-E25-35, and 299-E25-48 are located south of the 216-A-29 Ditch and are downgradient of the inlet end of the ditch. Well 699-43-45 now monitors the distal end of the ditch, while well 299-E25-32P monitors downgradient of the middle of the ditch.

The groundwater beneath the 216-A-29 Ditch is monitored as required by WAC 173-303-400 and 40 CFR 265.93(b) for detection of dangerous waste/dangerous waste constituents impacting groundwater. A groundwater monitoring plan for this unit was issued in March 2010 (DOE/RL-2008-58, *Interim Status Groundwater Monitoring Plan for the 216-A-29 Ditch*). The eight wells of the groundwater monitoring network are sampled semiannually for contamination indicator parameters and annually for groundwater quality parameters (i.e., alkalinity, metals, phenols, and anions) and site-specific constituents (Table 3.1 of DOE/RL-2008-58). Appendix B lists the network wells and the groundwater constituents monitored.

Water-Level and Well Network Evaluation. The magnitude of the water table gradient at the 216-A-29 Ditch is assumed to be similar to that at the PUREX Cribs and IDF at 2.2×10^{-5} meter per meter (Section 3.5.9.2) with a southeastern flow direction interpreted from plume maps. Based on the interpretation of a southeast flow direction, the current network was capable of detecting potential releases from the 216-A-29 Ditch throughout 2011. The average flow velocities range from 0.001 to 0.004 meter per day (Appendix B, Table B-1). In accordance with requirements, the network will be re-evaluated annually.

Sampling Results. To date, no dangerous waste subject to WAC 173-303 from the 216-A-29 Ditch has contaminated groundwater. Therefore, the site remains in an interim status indicator evaluation program, as specified in 40 CFR 265.92(b). As required under WAC 173-303-400 and RCRA (40 CFR 295.93[b]) for interim status facility indicator parameter monitoring, the required indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides) are statistically compared between upgradient and downgradient wells using the most recent data. Specific conductance remained above the critical mean value in downgradient wells 299-E25-35 and 299-E25-48 and upgradient well 299-E26-13 during both semiannual sampling events in 2011. DOE has previously concluded that the exceedances are caused by nondangerous waste constituents sodium, sulfate, and calcium (Section 2.2 of DOE/RL-2008-58). The continued trend of increasing specific conductance coincides with similar increases in sulfate, nitrate, and chloride in these wells. Wells 299-E25-28 (deep completion) and 299-E25-34 appear to be least affected by these trends. Well 299-E25-32P also exceeded the specific conductance critical mean. The constituents have been steadily increasing in this well.



None of the increasing constituents exceed their respective drinking water standards. The remaining three contamination indicator parameters (i.e., pH, total organic carbon, and total organic halides) were below critical means for all wells in the 216-A-29 Ditch network during 2011. Appendix B lists the revised critical mean values to be used for 2012 comparisons (Table B-9).

3.5.9.5 216-B-3 Pond

The inactive 216-B-3 Pond was located east of the 200 East Area. The location was within a natural topographic depression. During operations, the pond covered approximately 40 acres with depth up to 6.1 meters. Total discharge to the pond since 1945 is estimated to have exceeded 1.0×10^{12} liters (260 billion gallons) (PNNL-15479, *Groundwater Monitoring Plan for the Hanford Site 216-B-3 Pond*

RCRA Facility). Waste streams sent to the pond during active operations included: steam condensate and process cooling water from the 221-B Building; 284-E Powerhouse water; 244-AR and 244-CR Vaults cooling water; 242-A Evaporator cooling water; 202-A Building process cooling water; condenser cooling water and air sampling vacuum pumps seal cooling water; 241-BY Tank Farm condenser cooling water; Waste Encapsulation & Storage Facility cooling water; 241-AY and 242-AZ surface condenser; chemical storage and makeup tank overflows; and demineralizer recharge effluents.

Several hazardous, nonradioactive discharges reached the 216-B-3 Pond through the 216-A-29 Ditch. Associated compounds included: demineralizer regenerate, aqueous makeup tank heels, and off-specification batches; N cell prestart testing (oxalic acid, nitric acid, hydrogen peroxide, calcium nitrate); potassium permanganate; sodium carbonate solution; hydrazine solution; potassium hydroxide; sodium nitrate, sodium hydroxide; cadmium nitrate; and sodium nitrite.

The B Pond is classified as a treatment, storage, and disposal unit because it received dangerous waste after implementation of dangerous waste regulations. The dangerous waste received came from three primary sources: corrosive and dangerous waste resulting from regeneration of demineralizer columns at PUREX, spills of dangerous or mixed waste from PUREX and other facilities, and off-specification chemical makeups at PUREX. The last known reportable discharge of chemical waste, sodium nitrite, occurred in 1987.

In accordance with 40 CFR 265.93(b) (as referenced by WAC 173-303-400), the well network was sampled semi-annually for contaminant indicator parameters and supporting constituents (DOE/RL-2008-59, *Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond*). All of the wells were sampled semiannually, as required, during the reporting period. Appendix B includes a list of 216-B-3 Pond wells, constituents monitored, and whether the wells were sampled as schedule (Table B-14). That appendix also includes statistical comparison values used in 2011 and revised values for 2012 (Table B-15).

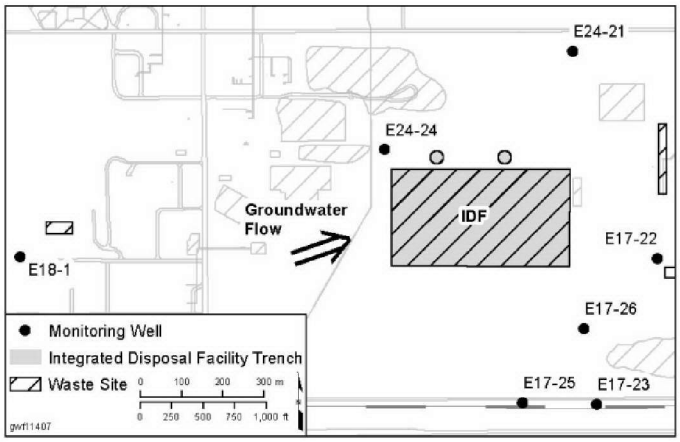
Water-Level and Well Network Evaluation. Groundwater flow direction in the unconfined aquifer is to the west, and the flow rate is estimated to be 0.0048 meter per day (Appendix B, Table B-1).

The network well screens range from 1.66 to 3.99 meters into the aquifer. These water table wells all have adequate water columns in the screened interval available for sampling.

Sampling Results. During 2011, the indicator parameter measurements for pH, specific conductance, total organic carbon, and total organic halides did not exceed the statistically derived background comparison values (e.g., critical mean). The average pH levels for all of the 216-B-3 Pond wells ranged from 7.8 to 8.42, which is within the lower and upper bound of the critical mean (6.9 to 9.17, respectively). The highest average specific conductance level was 299 µS/cm, which is below the critical mean (340 µS/cm). The highest average total organic carbon level was 1,300 µg/L; however, this was in the upgradient well. The highest average total organic carbon level in a downgradient well was 549 µg/L, which is below the critical mean (920 µg/L). The highest average total organic halide concentration was 11.59 µg/L, which is below the critical mean (13.1 µg/L). In addition, the annual groundwater phenol results were all reported as non-detects for the April, 2011 sampling event. Thus, this site remained in interim status indicator evaluation monitoring.

The indicator parameter measurements for the B-Pond downgradient wells for pH, specific conductance, total organic carbon, and total organic halides did not exceed the statistically derived background comparison values.

3.5.9.6 Integrated Disposal Facility



Construction of the IDF began in September 2004 and was completed in April 2006. The DOE submitted a Part B RCRA Permit application to Ecology, which was incorporated into the Hanford Facility RCRA Permit (WA7890008967) on April 9, 2006. The start date for IDF operations is estimated to be December 2016.

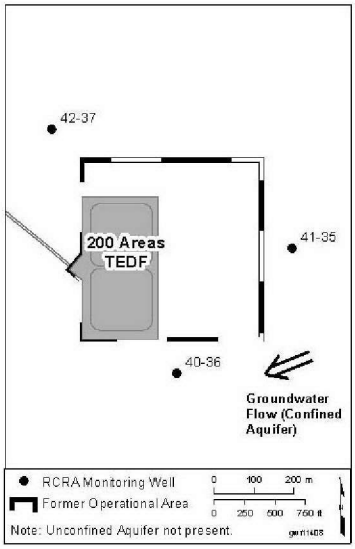
The objective of RCRA and operational monitoring at the IDF will be to determine whether the facility has impacted groundwater quality. The facility is not yet operational, and current monitoring is directed at obtaining baseline values for monitored constituents.

The IDF consists of an expandable, double-lined landfill with ~7 hectares of liner. The facility is located in the south-central portion of the 200 East Area (Figure 3.5-1). The landfill is divided lengthwise (north-south) into two distinct cells: (1) the east cell for the disposal of low-level radioactive waste, and (2) the west cell for the disposal of mixed waste. The facility is a RCRA-compliant landfill (i.e., a double, high-density, polyethylene-lined trench with leachate collection and leak detection system). The constructed liner is ~442 meters wide, 160 meters long, and up to 15 meters deep. The landfill will have four layers of waste containers, separated vertically by 0.9 meter of soil. The current waste disposal capacity is ~163,000 cubic meters.

Water-Level and Well Network Evaluation. The delineations of groundwater flow directions and water table gradients are difficult to calculate for the 200 East Area from water-level data because of a flat water table. Efforts to improve the accuracy of water-level measurements in this region began during 2008, and the results of this work were summarized in Section 3.5.9.2 for the 216-A-36B Crib. The interpreted hydraulic gradient of 2.2×10^{-5} meter per meter toward the east-northeast at 69 (±11) degrees is believed to be representative for the IDF. The groundwater flow rate is estimated to range from 0.005 to 0.02 meter per day (see Appendix B, Table B-1).

All seven network wells were sampled as scheduled during 2011. Starting in 2011, sampling was reduced to annually for each well in the network to maintain the baseline prior to operational status. This change was approved by a Permit modification in 2010 (Section III. 11. E. 1. b of 10-EMD-0080, "Class 1 Modifications to the Hanford Facility Resource Conservation and Recovery Act Permit Quarter Ending June 30 2010").

The current groundwater monitoring network consists of three upgradient wells (299-E18-1, 299-E24-21, and 299-E24-24) and four downgradient wells (299-E17-22, 299-E17-23, 299-E17-25, and 299-E17-26). Groundwater flow direction has been changing since the network was initially planned, and the current network is no longer considered adequate. A revised monitoring network has been provided in a plan that is undergoing Ecology review. All monitoring wells are in compliance with WAC 173-160.



Sampling Results. Nitrate exceeded the drinking water standard (45 mg/L) during 2011 in two wells at the IDF, and the results are comparable to previous years. The maximum nitrate concentration was 69.9 mg/L in well 299-E24-24. This well is in the regional 200 East Area nitrate plume that is presumed to originate from the PUREX Cribs east of the IDF (Section 3.5.3). Contamination

occurred possibly during an earlier time when groundwater flow direction was flowing radially outward from B Pond.

3.5.9.7 Treated Effluent Disposal Facility

J.P. McDonald

The 200 Area Treated Effluent Disposal Facility (TEDF) is authorized by *State Waste Discharge Permit Number ST 4502* (Ecology, 2000b; hereinafter referred to as the "Permit") to receive effluent from a variety of Hanford Site sources. The facility is located ~3 kilometers east of the 200 East Area and 1 kilometer southeast of the 216-B-3 Pond (Figure 3.5-1), and consists of two, 5-acre infiltration basins. Together, the basins have an allowable average monthly discharge limit of ~18.5 million liters per day and an average yearly limit of ~6.5 million liters per day. However, actual discharge volumes are normally well below these limits. During 2011, for instance, 53.8 million liters of effluent were discharged to the basins for an average yearly rate of 102.6 liters per minute; and the highest average monthly rate was 152 liters per minute during May. The TEDF has been operating since June 1995.

Groundwater monitoring at the TEDF is conducted to demonstrate that the uppermost aquifer beneath the facility, the Ringold Formation confined aquifer, continues to be isolated from TEDF discharges.

Water-Level and Well Network Evaluation. Beneath the TEDF, the Ringold Formation lower mud unit occurs above the regional water table, making the confined aquifer in Ringold unit A the uppermost aquifer beneath the facility. TEDF discharges are assumed to infiltrate vertically until encountering the mud unit, then form a thin perched zone with flow toward the south in the down-dip direction. Correlation of well water levels in the 200 East Area to TEDF discharge volumes has confirmed that effluent discharges to the TEDF recharge the regional unconfined aquifer (Section 3.2.1 of DOE/RL-2011-01). The recharge location is probably where the mud unit dips below the water table, which is interpreted to be ~500 meters south of the facility (Plate 6 of PNNL-12261).

During installation of the TEDF monitoring wells in 1992, the confined aquifer was established as the point of compliance for groundwater because it was the uppermost aquifer beneath the facility. Under this paradigm, groundwater monitoring is performed to demonstrate that the mud unit continues to protect the confined aquifer from potential impacts associated with TEDF discharges. However, this situation is not ideal, since the wells are not monitoring the actual TEDF discharges. The Permit is currently undergoing renewal; in the draft revised permit, it is proposed that groundwater monitoring be discontinued and the effluent monitored before discharge to the facility to comply with the Permit.

Three groundwater monitoring wells are located at the TEDF. Well 699-42-73 is the designated

The permit for TEDF is currently undergoing renewal, and it is proposed that groundwater monitoring be discontinued and the point of compliance for groundwater be moved to the effluent.

upgradient well, and wells 699-40-36 and 699-41-35 are designated as downgradient wells. The wells are sampled quarterly for the three constituents with Permit limits (5 µg/L for cadmium, 10 µg/L for lead, and pH ranging from 6.5 to 8.5) in accordance with *Groundwater Monitoring Plan for the Hanford Site 200 Area Treated Effluent Disposal Facility* (PNNL-13032). The Permit (Ecology, 2000b) limits apply only to the downgradient wells. Sampling is also performed for specific conductance, gross alpha and beta, anions, metals, total dissolved solids, trace metals, and tritium to provide information on general

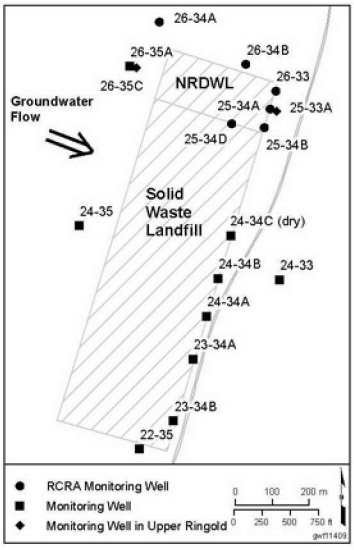
groundwater quality. Appendix B includes a well location map and a list of wells and constituents sampled for the TEDF. During 2011, all three wells were sampled as scheduled.

Groundwater flow in the confined aquifer beneath the TEDF was determined using six sets of water-level measurements collected in the TEDF monitoring wells during the year. The average hydraulic gradient was calculated to be 4.7×10^{-4} meter per meter toward the southwest (213 degrees azimuth). The hydraulic gradient magnitude was used to estimate the groundwater flow rate in the confined aquifer. Using a hydraulic conductivity range of 0.7 to 2.7 meters per day (minimum and maximum results of constant rate discharge tests performed in the monitoring wells, as reported in Section 4.5 of WHC-SD-EN-SE-004, *Site Characterization Report: Results of Detailed Evaluation of the Suitability of the Site Proposed for Disposal of 200 Areas Treated Effluent*), and an assumed effective porosity range of 0.1 to 0.2, the average linear velocity was estimated to range from 0.0016 to 0.013 meter per day (0.60 to 4.6 meters per year). Using a best hydraulic conductivity value of 1.5 meters per day (average of constant-rate discharge tests from all three wells [Section 4.5 of WHC-SD-EN-SE-004]) and an assumed effective porosity of 0.15, the best-estimate average linear velocity is 0.0047 meter per day (1.7 meters per year). Water-levels declined an average of 0.13 meter in the monitoring wells between March 2010 and March 2011. Water levels are still declining in response to dissipation of the B Pond mound. The confined aquifer discharges to the unconfined aquifer along the erosional boundary of the lower mud unit, the edge of which is shown in Figure 3.5-5.

DOE believes the monitoring well network remains capable of demonstrating continued isolation of the confined aquifer from TEDF discharges.

Sampling results during 2011 demonstrated continued isolation of the confined aquifer from TEDF discharges; there were no exceedances of a concentration limit.

Sampling Results. Groundwater sample results for pH, cadmium, and lead from the two downgradient wells exhibited no exceedance of a concentration limit during 2011. The TEDF effluent generally is relatively low in total dissolved solids and has a low ion content compared to the groundwater background. For instance, specific conductance is generally less than 200 µS/cm in the effluent, but sample results from the wells have been stable between 300 and 375 µS/cm since TEDF began operating. Thus, if TEDF effluent were impacting the confined aquifer, it is expected that decreasing trends in specific conductance and major ions would be observed. Sample results of major anions and cations, along with radionuclide indicators, were on trend during 2011 and have exhibited either no changes or only minor changes from initial background values since the TEDF began operating. These results demonstrate continued isolation of the confined aquifer from TEDF discharges.



Beginning in 2010, elevated concentrations of chromium, iron, nickel, and manganese began to be observed in the upgradient well, 699-42-37. These constituents are the primary components of stainless steel, and because this well is constructed of stainless steel, corrosion of the well components was suspected. A camera survey was conducted at the end of the year, and corrosion of the well screen was confirmed. Corrosion has also recently been found in other stainless steel wells at Hanford (e.g., see Sections 3.3.8 and 3.3.10.3).

3.5.9.8 Nonradioactive Dangerous Waste Landfill

The NRDWL is located southeast of the 200 East Area (Figure 3.5-2) next to the SWL. The landfill has an area of 4.5 hectares

consisting of 19 parallel trenches, each ~122 meters long, 4.9 meters wide at the base, and 4.6 meters deep. The landfill received chemical waste, asbestos, and nonhazardous waste between 1975 and 1985. The objective of RCRA monitoring at the NRDWL is to determine if dangerous waste constituents from the landfill have contaminated groundwater (40 CFR 265.93[b], as referenced by WAC 173-303-400) through an interim status indicator evaluation monitoring program.

The NRDWL is underlain by ~40 meters of vadose zone composed mostly of sand, silty-sandy gravel, and gravel of the Hanford formation. The uppermost aquifer below the water table consists of ~9 meters of additional Hanford formation, 8 meters of the Cold Creek unit (a pre-Missoula gravel deposit), and 6 meters of undifferentiated Ringold Formation sandy gravel. Below the 6 meters of Ringold Formation sandy gravel is a low-permeability unit composed of silt and silty sand that forms the base of the unconfined aquifer locally. Two of the wells in the NRDWL network (one upgradient and the other downgradient) reach the top of this low permeability unit to sample groundwater from the lower portion of the local unconfined aquifer.

Water-Level and Well Network Evaluation. Groundwater flow direction is southeast, as determined from the general direction of movement of major contaminant plumes originating in the 200 East Area. Although the water table gradient is very low (9.3×10^{-5}), the hydraulic conductivity of the Hanford sediments is relatively high, allowing average flow velocities ranging from 0.16 to 1.4 meters per day (Appendix B, Table B-1).

The main groundwater constituents of interest at the NRDWL are the RCRA interim status indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halides), and the groundwater quality parameters (i.e., chloride, iron, manganese, phenols, sodium, and sulfate) (Appendix B, Table B-32 and PNNL-12227, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*). The site-specific constituents nitrate and selected volatile organic compounds are also monitored. Groundwater quality parameters are monitored annually, and the indicator parameters and site-specific contaminants of concern are monitored semiannually. Two sample events were missed in 2011: one is for well 699-25-34D and the other one is for well 699-26-34A in July 2011. Both missed events were due to limited maintenance resources. All other wells were sampled in 2011 as scheduled.

The NRDWL well monitoring network consists of nine wells (Appendix B), with two of the wells screened at the bottom of the unconfined aquifer, just above the low-permeability unit. The two deeper wells are monitored for information only and are not used for upgradient/downgradient comparisons. Of the seven wells screened at the water table, two wells are upgradient (west and northwest), and five are downgradient (north, east, and south). The wells are located appropriately to accomplish the objectives of the interim status groundwater indicator parameter evaluation program.

During 2010, a new combination RCRA groundwater monitoring plan was written for the NRDWL and the SWL (DOE/RL-2010-28, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill*). Because the two landfills are adjacent to one another, combining the ultimate remedial action for the two landfills was considered a reasonable option to maximize available resources. In the new plan, NRDWL groundwater monitoring will move into RCRA final status under WAC 173-303-645. The plan is under review by Ecology. Until the plan is approved, NRDWL will continue to be monitored under the current groundwater monitoring plan (PNNL-12227).

Sampling Results. Specific conductance in downgradient wells continued to exceed the critical mean (750 µS/cm) during 2011 but did not require verification sampling or regulator notification. Specific conductance exceedances occurred previously at NRDWL and were determined to be caused by nonhazardous groundwater constituents (e. g., calcium and magnesium) likely from the nearby SWL (Section 2.11 of DOE/RL-2008-01).

The volatile organic compounds, manganese, and phenols were not detected at NRDWL wells during 2011. Chloride, iron, sodium, and sulfate were detected at levels consistent with Hanford Site background

values (Table ES-1 of DOE/RL-96-61). The highest nitrate result was 27 mg/L, which is consistent with nitrate emanating from the 200 East Area (Figure 3.5-9).

3.5.9.9 Solid Waste Landfill

The SWL is located south of the NRDWL (Figure 3.5-2). Between 1973 and 1996, the landfill received paper waste and construction debris primarily, but also received asbestos, sewage, and catch tank liquid waste. Occupying 26 hectares, the landfill consists of a series of parallel trenches that vary in length from 168 to 200 meters, are 5 meters wide at the base (single width) to 16 meters wide at the base (double width), and are 6 meters deep. The landfill is regulated by Ecology in accordance with WAC 173-350, which requires monitoring of leachate, soil gas, and groundwater. However, the groundwater monitoring plan (PNNL-13014, *Groundwater Monitoring Plan for the Solid Waste Landfill*) was written to accommodate the requirements WAC 173-304, which are similar to WAC 173-350. WAC 173-350 superseded WAC 173-304. WAC 173-304 constituents and site-specific constituents (including selected volatile organic compounds and filtered arsenic) are analyzed in groundwater samples collected quarterly. Compliance is determined by comparing results from downgradient monitoring wells with statistically derived background threshold values from upgradient wells.

Water-Level and Well Network Evaluation. The groundwater flow direction is southeast, as inferred from the general direction of movement of major 200 East Area plumes. Hydrogeology is similar to that at the NRDWL (Section 3.5.9.8). The well network for the SWL includes two upgradient wells and seven downgradient wells. Appendix B lists the network wells, their locations, and the groundwater constituents monitored (Table B-46). During 2011, six sampling events were missed because of logistical problems. Well 699-24-34C accounted for three missed events because the well is dry.

Leachate and Soil Vapor Monitoring

A leachate collection system (lysimeter) underlying one set of double trenches within the SWL is sampled quarterly and has detected contamination from the landfill in previous years. The leachate is analyzed for ammonia, metals, anions, total organic carbon, total organic halides, total dissolved solids, and selected volatile organic compounds. Most of the inorganic analytes were detected, but the VOCs were generally not detected. Most of the constituents detected in the leachate during 2011 were also analyzed in groundwater samples from the SWL well network. However, nine of these constituents were not analyzed in groundwater samples: boron, silicon, aluminum, lead, molybdenum, tin, uranium, thorium, and thallium.

Most of the inorganic analytes were detected, but the volatile organic compounds were generally not detected. The results are reported annually. Some of the leachate results exceeded WAC 173-200 standards; however, the fact that contaminants are above compliance levels in the leachate does not necessary mean they are present in the same concentrations in the groundwater.

The soil gas monitoring network consists of eight shallow monitoring stations located around the perimeter of the SWL (a ninth station was damaged beyond repair in a fire event). Each monitoring station consists of two dedicated soil-gas probes driven to depths of about 2.7 and 4.6 meters, respectively. The soil gas is monitored quarterly to determine concentrations of carbon dioxide, methane, and ammonia. The soil gas is also analyzed for several key volatile organic constituents: methylene chloride, 1,1-dichloroethane, chloroform, 1,1,1-trichloroethane, carbon tetrachloride, trichloroethene, 1,1,2-trichloroethane, and tetrachloroethene.

During this reporting period, soil gas at the SWL was analyzed in March and again in June. SWL soils were not tested during the second half of the year because of extreme fire danger in September (which prohibited off-road vehicular traffic) and to staff reductions during the fourth quarter. During 2011, only methane, carbon dioxide, and ammonia were detected in soil vapor samples (no volatile organic compounds were detected). The methane results ranged from nine to 64.54 parts per million (ppm). Carbon dioxide concentrations ranged from 959 to 8,927 ppm (the typical concentration in air is

~387 ppm; concentrations above one percent, or 10,000 ppm, are lethal). Two sample stations produced readings indicating the presence of ammonia: sample station SWL-01B (14.81 ppm) and sample station SWL-02B (34.59 ppm). Both stations are on the east side of the SWL. Concentrations of methane, carbon dioxide, and ammonia at levels greater than normally found in air have possibly resulted from degradation of sewage discharged at the SWL. The 2011 analytical results are typical and consistent with historical trends at the SWL.

Groundwater Monitoring Results

Each WAC 173-304 parameter is discussed separately in the following paragraphs. Appendix B provides a complete list of the results for required constituents at the SWL during 2011 and the background threshold values for 2011. The amount of detail in the discussions of individual groundwater constituents (compared to other sections of this report) is provided to meet the annual reporting requirements of the groundwater monitoring plan (PNNL-13014). Only the filtered results for the metals are presented because WAC 173-304 specifies that the groundwater samples be analyzed for the dissolved metals.

Ammonium. Results for the ammonium ion (background threshold value 90 µg/L) in SWL wells during 2011 ranged from less than the method detection limit (1.8 µg/L) to 31.4 µg/L in well 699-24-34A. Ammonium ion was detected in the upgradient and downgradient wells. Detections of this groundwater constituent have been sporadic in previous years at the SWL and continued during the reporting period.

Chemical Oxygen Demand. Chemical oxygen demand remained below the background threshold value of 10 mg/L at all SWL wells during 2011 except one analysis at 10 mg/L in upgradient well 699-26-35A. Historically, chemical oxygen demand values are sporadic at the SWL. Elevated values of this parameter could be an indication of groundwater contaminated by sewage, which is known to have been discharged to the SWL trenches.

Chloride. Chloride ranged from 8.3 mg/L at downgradient wells 699-22-35 and 699-24-34A to 5.7 mg/L at downgradient well 699-23-34B. The background threshold value of 7.8 mg/L was exceeded during 2011 only in wells 699-22-35 and 699-24-34A. Chloride slightly increased in concentration in most SWL wells until about 2005 and has stabilized thereafter.

Coliform Bacteria. The background threshold value (of one colony per 100 milliliters of groundwater) was exceeded at five SWL wells during 2011. Two of the wells, 699-24-34C and 699-24-35, had values of 111 and 62.7 colonies per 100 milliliters, respectively. The values have been flagged because they are significantly out of trend. The other wells with detections are 699-23-34A, 699-24-34A, 699-24-35, and 699-24-34B, with values of 3.1, 2, 2, and 1 colonies per 100 milliliters, respectively. As with chemical oxygen demand, elevated levels of coliform bacteria have been detected sporadically at the SWL in previous years. Elevated levels of this constituent are expected with the known disposal of sewage at the SWL.

Filtered Iron. Except for one spurious value of 259 µg/L in downgradient Well 699-22-35, none of the filtered iron results exceeded the 160 µg/L background threshold value during 2011. The reported values ranged from less than 19 to 87 µg/L. Elevated filtered iron results have been reported above the background threshold value occasionally at SWL wells in recent years but are not typical of overall historical trends.

Filtered Manganese. Filtered manganese was not detected above the method detection level range of 3.3 to 6.0 µg/L in SWL wells during 2011. The background threshold value is 18 µg/L.

Nitrate. The SWL is located on the western edge of the region of elevated nitrate concentrations emanating from the 200 East Area (Figure 3.5-9). Downgradient wells have levels of nitrate similar to the upgradient wells. During 2011, the highest level of nitrate at the SWL was 20.4 mg/L at downgradient well 699-23-34A, which was significantly lower than the 29 mg/L background threshold value.

Nitrite. There were four detections of nitrite at SWL wells during 2011. Detections range from 519 to 716 µg/L but the analyses are suspect data which are under review (see the nitrite discussion in Section D.6.5.3 in Appendix D). The background threshold value was 266 µg/L, and the analytical laboratory's required detection limit was 131 µg/L.

pH. Two wells at the SWL during 2011 had pH levels lower than the background threshold range (6.68 to 7.84): wells 699-23-34A and 699-23-34B. The lowest pH value reported was 6.52 at well 699-23-34A. The pH trends are relatively steady at the SWL wells.

Specific Conductance. Specific conductance values at all seven downgradient wells exceeded the 583 µS/cm background threshold value during 2011. Specific conductance values at the two upgradient wells did not exceed the background threshold value. Five of the seven downgradient wells also had specific conductance values greater than the 700 µS/cm limit of WAC 246-290-310, "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)." The highest reported value during 2011 was 821 µS/cm at downgradient well 699-22-35. Specific conductance values at the SWL have remained relatively stable since 2001. Elevated specific conductance is principally caused by an increase of carbonate or bicarbonate concentration in groundwater at the SWL (Section 3.4 of DOE/RL-94-143, *Corrective Action Plan for the Hanford Site Solid Waste Landfill*).

Sulfate. The results for sulfate reported ranged from 38.6 mg/L at upgradient well 699-26-35A to 50.7 mg/L at downgradient well 699-23-34A. Only well 699-23-34A had results exceeding the 47.2 mg/L background threshold value. The overall trend for sulfate concentrations at the SWL is stable to slightly increasing.

Temperature. None of the temperatures exceeded the 20.7°C background threshold value during 2011. The highest temperature reported was 20.3°C in well 699-24-34B.

Total Organic Carbon. Six of the wells had total organic carbon results during 2011 that exceeded the 1,200 µg/L background threshold value and are undergoing review. The three wells below the background threshold value are downgradient wells 699-24-34C and 699-24-34B and upgradient well 699-26-35A, with maximum reported values of 292, 1,000 µg/L, and 385 µg/L, respectively. In previous years, elevated total organic carbon results have occurred occasionally. As with chemical oxygen demand and coliform bacteria, elevated total organic carbon could be due to the degradation of the sewage disposed at the site.

Filtered Zinc. During 2011, filtered zinc ranged from less than 4 µg/L (the analytical method detection limit) to a maximum of 15 µg/L at upgradient well 699-24-35. None of the SWL wells had filtered zinc values exceeding the 42.3 µg/L background threshold value.

Site-Specific Parameters. Disposed waste at the SWL has impacted groundwater with minor chlorinated hydrocarbon contamination. However, the concentrations of chlorinated hydrocarbons at the SWL have decreased over the years, and minute chlorinated hydrocarbons concentrations were detected. The maximum value for tetrachloroethene was 3 µg/L in downgradient wells 699-24-33 and 699-699-24-34B. A maximum value of 6.6 µg/L for acetone was detected in well 699-22-35. All of the results have been flagged as suspect and are under review.

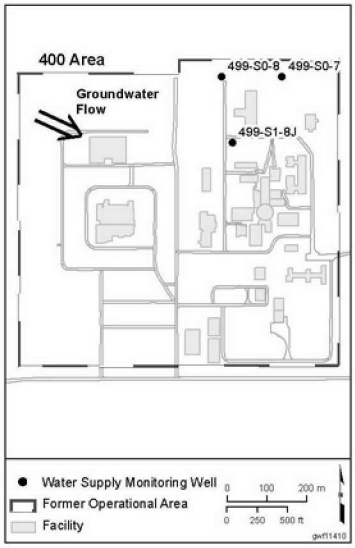
Most of the constituents detected in the leachate were also detected in groundwater but at levels lower than the primary drinking water standards (or secondary drinking water standards, if appropriate) or the limits specified in WAC 173-200-040 ("Water Quality Standards for Ground Waters of the State of Washington," "Criteria"), except for arsenic and iron. Cobalt, copper, and manganese were not detected. The drinking water standard for arsenic is 10 µg/L, but the WAC 173-200-040 limit is 0.05 µg/L. The results for filtered and non-filtered arsenic ranged from 1.69 to 3.96 µg/L, all exceeding the WAC 173-200-040 limit. However, results from downgradient wells were not significantly different than the results from upgradient wells, and the sample results are consistent with Hanford Site background

values. Although none of the filtered iron results exceeded the 300 µg/L drinking water standard, this limit was exceeded in unfiltered samples from downgradient well 699-24-34B with a concentration of 3,320 µg/L, although the value is suspect.

A new RCRA groundwater monitoring plan was written in 2010 that combined SWL groundwater monitoring with that of the NRDWL (DOE/RL-2010-28). Because the two landfills are adjacent to one another, combining the ultimate remedial action for the two landfills was considered a reasonable option to maximize available resources. At the SWL, closure and post-closure groundwater monitoring is subject to WAC 173-350-500 ("Ground Water Monitoring"); however, compliance with groundwater monitoring requirements for the SWL will be achieved through deferral under WAC 173-350-710(8) ("Permit Application and Issuance") to equal or greater requirements within WAC 173-303-645. Some downgradient wells at the SWL continue to show higher coliform bacteria, specific conductance, sulfate, and lower pH. In previous years, some of the SWL wells also showed higher chemical oxygen demand. The lower pH is apparently a result of elevated levels of carbon dioxide in the vadose zone resulting from the degradation of sewage material disposed to the SWL (Section 5.3 in DOE/RL-93-88, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1993*; PNL-7147, *Final Report: Soil Gas Survey at the Solid Waste Landfill*; WHC-SD-EN-TI-199, *Nonradioactive Dangerous Waste Landfill Soil-Gas Survey: Final Data Report*). The coliform bacteria and specific conductance also may be related to sewage disposed at the SWL. Soil vapor analysis shows elevated levels of carbon dioxide, methane, and ammonia.

3.5.9.10 400 Area

The 400 Area is located 16.2 kilometers southeast of 200 East Area and falls within the 200-PO-1 "footprint." The 400 Area includes the Fast Flux Test Facility, ancillary facilities, and waste sites. Waste sites in the 400 Area will be remediated under the 300-FF-2 operable unit (Section ES of DOE/RL-2010-99).



Primary groundwater monitoring activities in the 400 Area involve monitoring of the area's three water supply wells in accordance with the AEA. Monitoring is conducted to provide information on the potential impact of site-wide contamination (primarily tritium, nitrate, and iodine-129) on the water supply wells, which provide drinking water and emergency supply water for approximately 40 people (Section 8.6 of PNNL-19455, *Hanford Site Environmental Report for Calendar Year 2009*). This section discusses monitoring of the 400 Area water supply wells (specifically tritium) and the general aspects of groundwater chemistry in the 400 Area.

Each of the three 400 Area water supply wells (499-S1-8J, 499-S0-7, and 499-S0-8) have a pumping capacity of 757 liters per minute. The wells provide water to a common header that supplies storage tanks. The 400 Area water usage ranges from 757 liters per minute in the summer months to 95 liters per minute in the winter months. Table 3.5-1 provides the characteristics of the well screens for the three water supply wells. Well 499-S1-8J is the main water supply well, but occasionally wells 499-S0-7 and 499-S0-8 are used for water supply.

Since 2009, the water supply wells have been on an annual sampling schedule for 200-PO-1. They were scheduled for sampling in 2011, but sampling was delayed until January 2012. Additionally, a sample was collected from well 499-S1-8J for the Washington State Department of Health Program at the same time. The samples were analyzed for a selected list of volatile organic compounds, ammonium ion, metals, anions, gamma scan, gross alpha and beta, iodine-129, strontium-90, technetium-99, tritium, and uranium.

The water table map (Figure 3.1-5 in Section 3.1) indicates that flow in the unconfined aquifer is generally to the east-southeast across the 400 Area. The water table is located near the contact of the Ringold Formation and overlying Hanford formation and is ~49 meters below ground surface (WHC-EP-0587, *Groundwater Impact Assessment Report for the 400 Area Ponds*). Hanford formation sediments dominate groundwater flow in the 400 Area due to their relatively high permeability compared to the sediments in the underlying Ringold Formation.

Sampling Results. Elevated levels of tritium associated with the groundwater plume originating in the 200 East Area (as compared with Hanford Site background value of 119 pCi/L) were identified in the 400 Area wells (Figure 3.5-4). Well 499-S1-8J has lower tritium levels because it is screened at a greater depth (top of screen 61 meters below the water table) than the other two water supply wells (19 and 9 meters, respectively). Figure 3.5-19 compares the tritium concentrations in the three wells to that of the 400 Area drinking water supply. Tritium was measured at levels below the drinking water standard (20,000 pCi/L) in all three water supply wells. The maximum tritium concentration in well 499-S0-7 during January 2012 was 6,700 pCi/L. Tritium remained below the drinking water standard and the 4 mrem/year dose equivalent in the drinking water supply (sampled at a tap) for all of the sampling events during January 2012 (Figure 3.5-19).

Although many groundwater constituents were detected in samples collected during January 2012, none of the constituents were above drinking water standards. Other constituents detected included bromodichloromethane, bromoform, bromomethane, carbon disulfide, chloroform, chloromethane, cobalt, copper, dibromochloromethane, diethylphthalate, gross alpha, gross beta, iodomethane, lead, molybdenum, thallium, and tritium. All of these constituents, except for gross beta and tritium, were found in very low concentrations; most were either outliers or detected in such low concentrations as to be lower than the laboratory's contract-required detection limit. The gross beta results ranged up to 11 pCi/L in well 499-S1-8J, which is typical for these wells.

Table 3.5-1. Well Screen Characteristics of the Three 400 Area Water Supply Wells

Well	Elevation Top of Screen (m NAVD88)	Elevation Bottom of Screen (m)	Water Table to Screen Distance (m)
499-S1-8J	57	48	61
499-S0-7	100	46	19
499-S0-8	110	81	9

Notes: Depth to water in all three wells approximately 49 meters. Water table elevation approximately 118 meters (NAVD88, *North American Vertical Datum of 1988*).

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Figure 3.5-1. Facilities and Wells in 200 East Area (Near—Field)

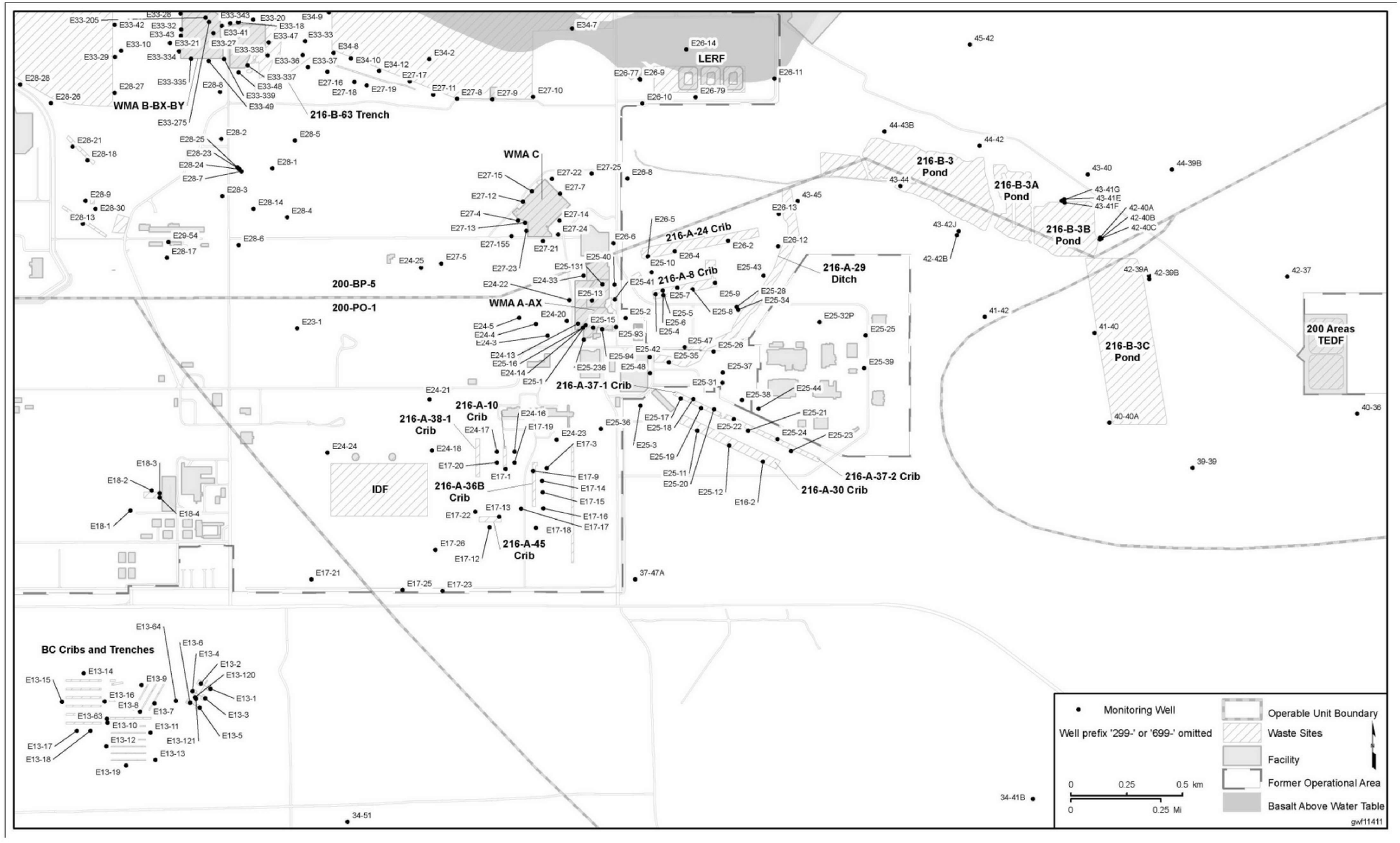

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Figure 3.5-2. Map of 200-PO-1 Operable Unit Boundaries, Far-Field Wells, Shoreline Monitoring Sites, and Transects

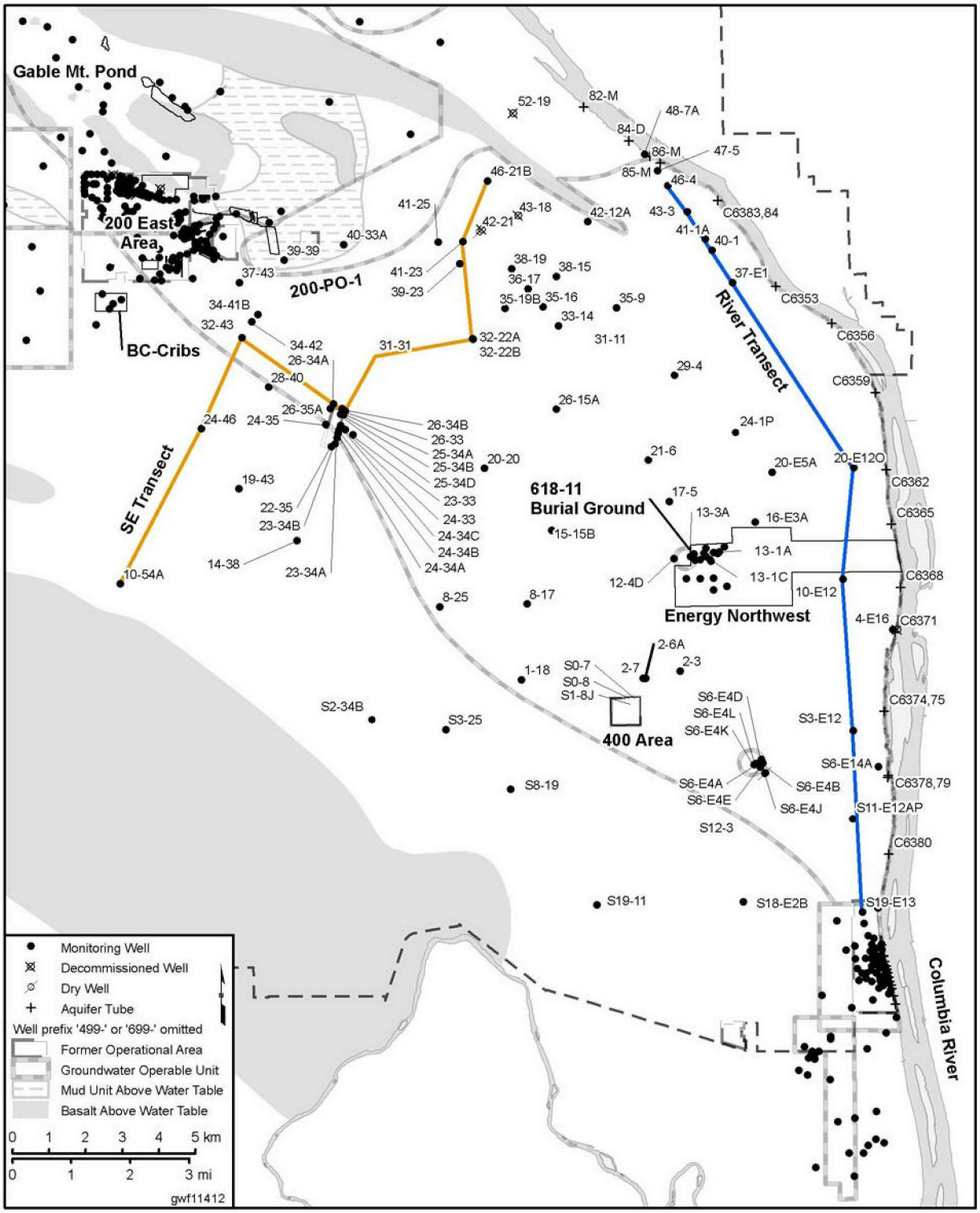

Figure 3.5-3. Changes in 200-PO-1 Plume Areas

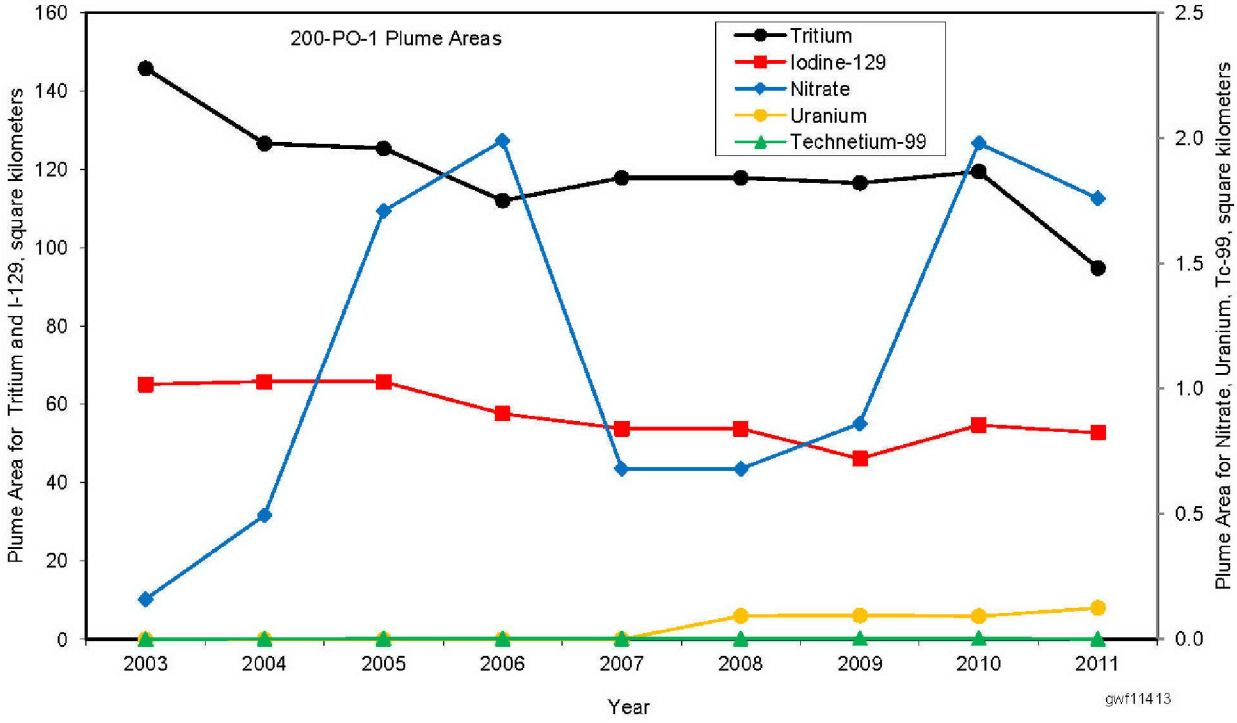

Figure 3.5-4. Tritium Plume Map for 200-PO-1 Operable Unit

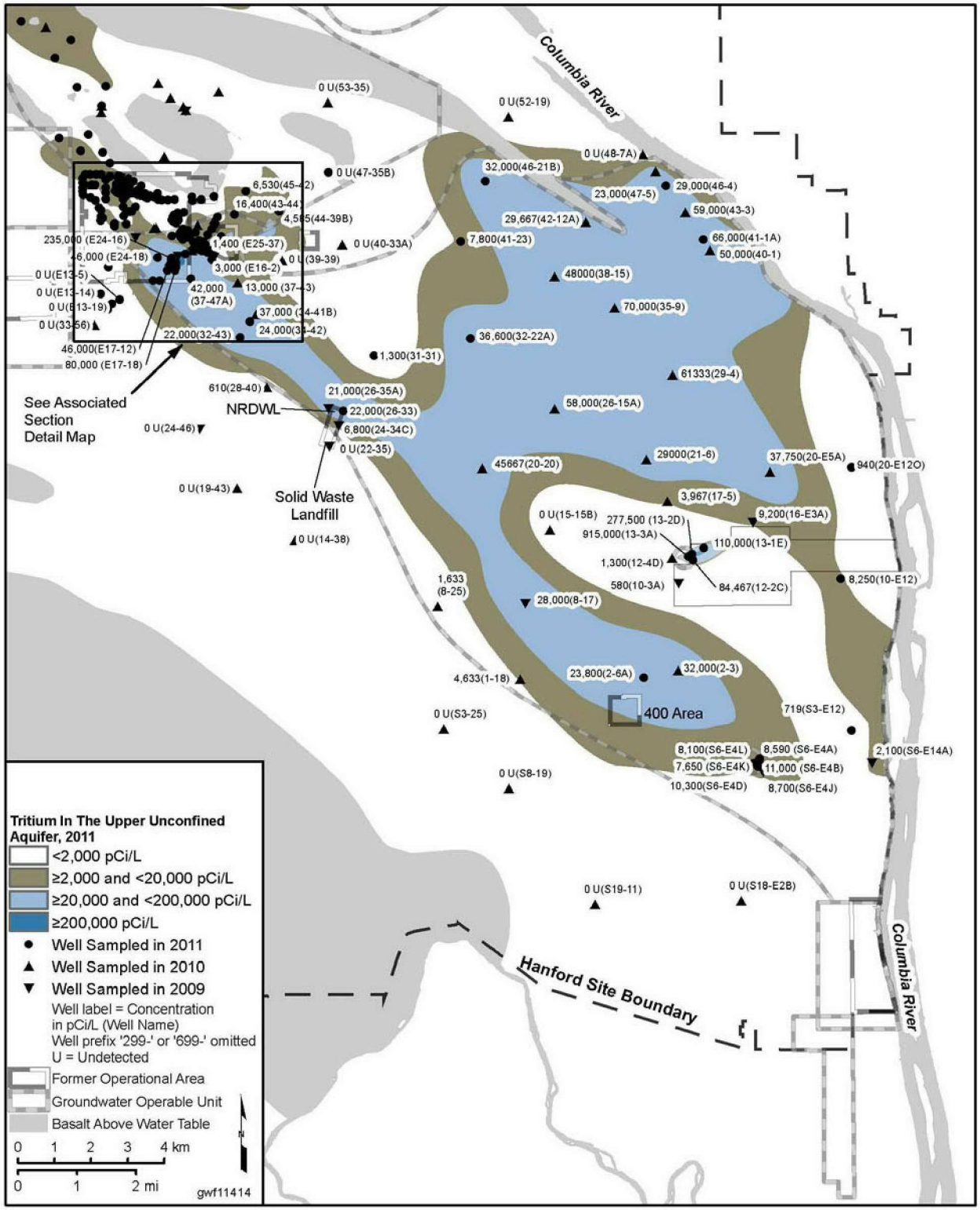

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Figure 3.5-5. Tritium Plume Map (Near-Field)

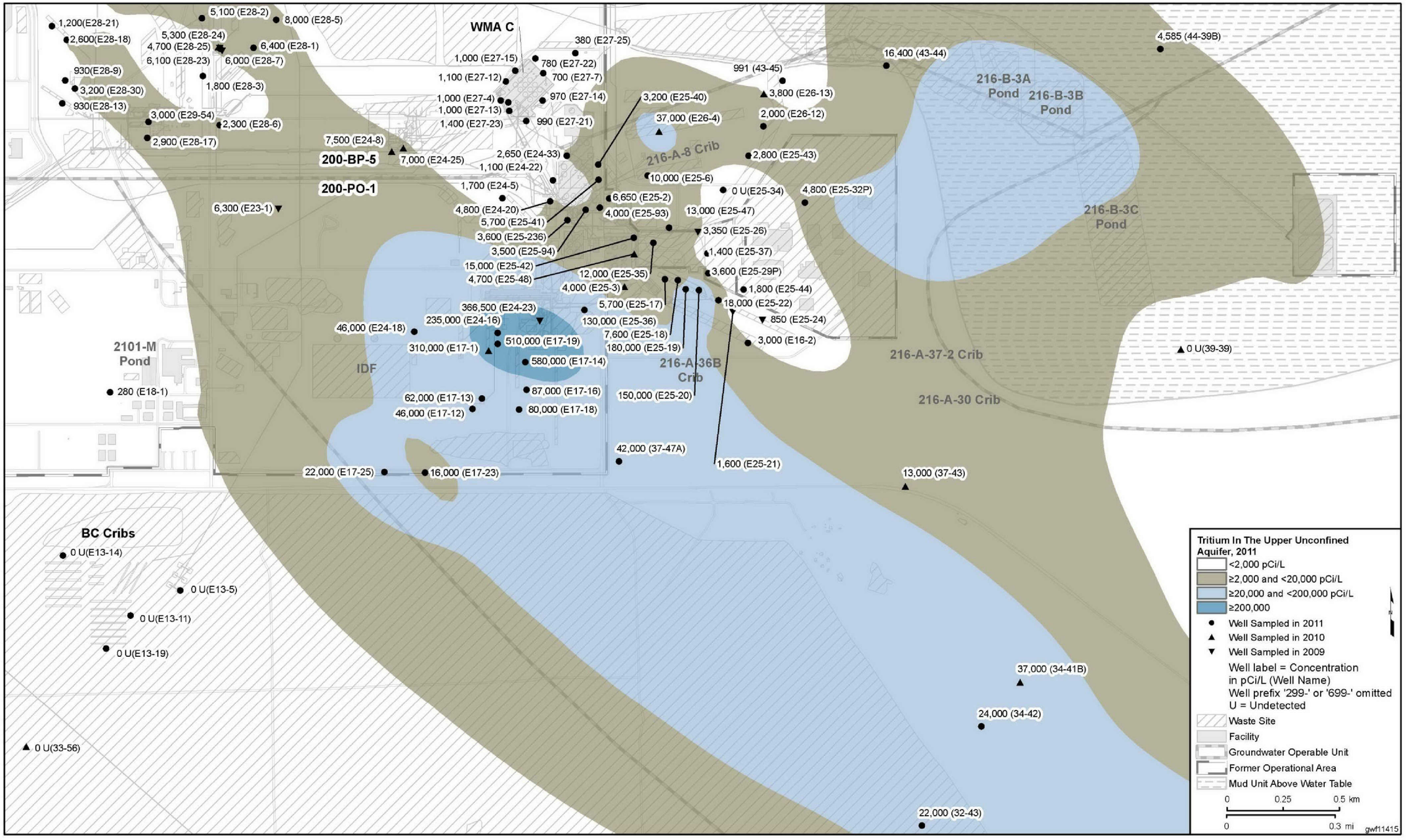

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Figure 3.5-6. Tritium Concentrations in Wells at the PUREX Cribs

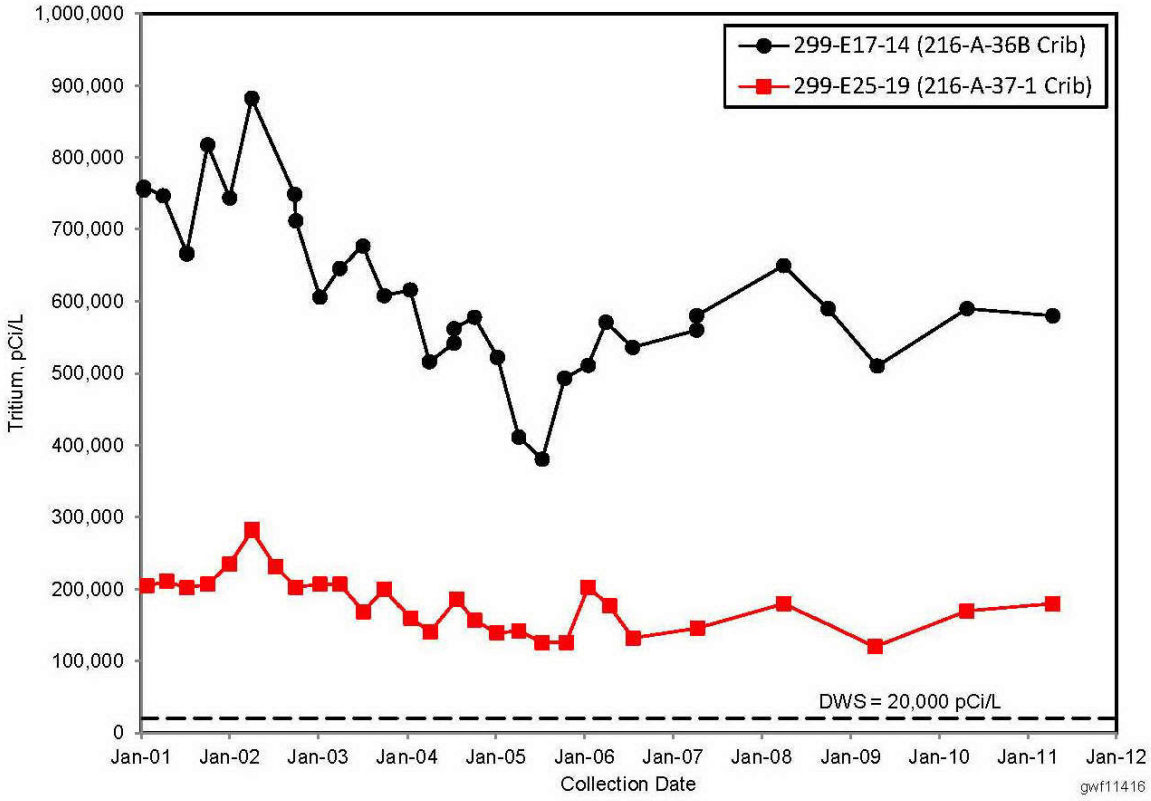

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Figure 3.5-7. Iodine-129 Plume Map for 200-PO-1 Operable Unit

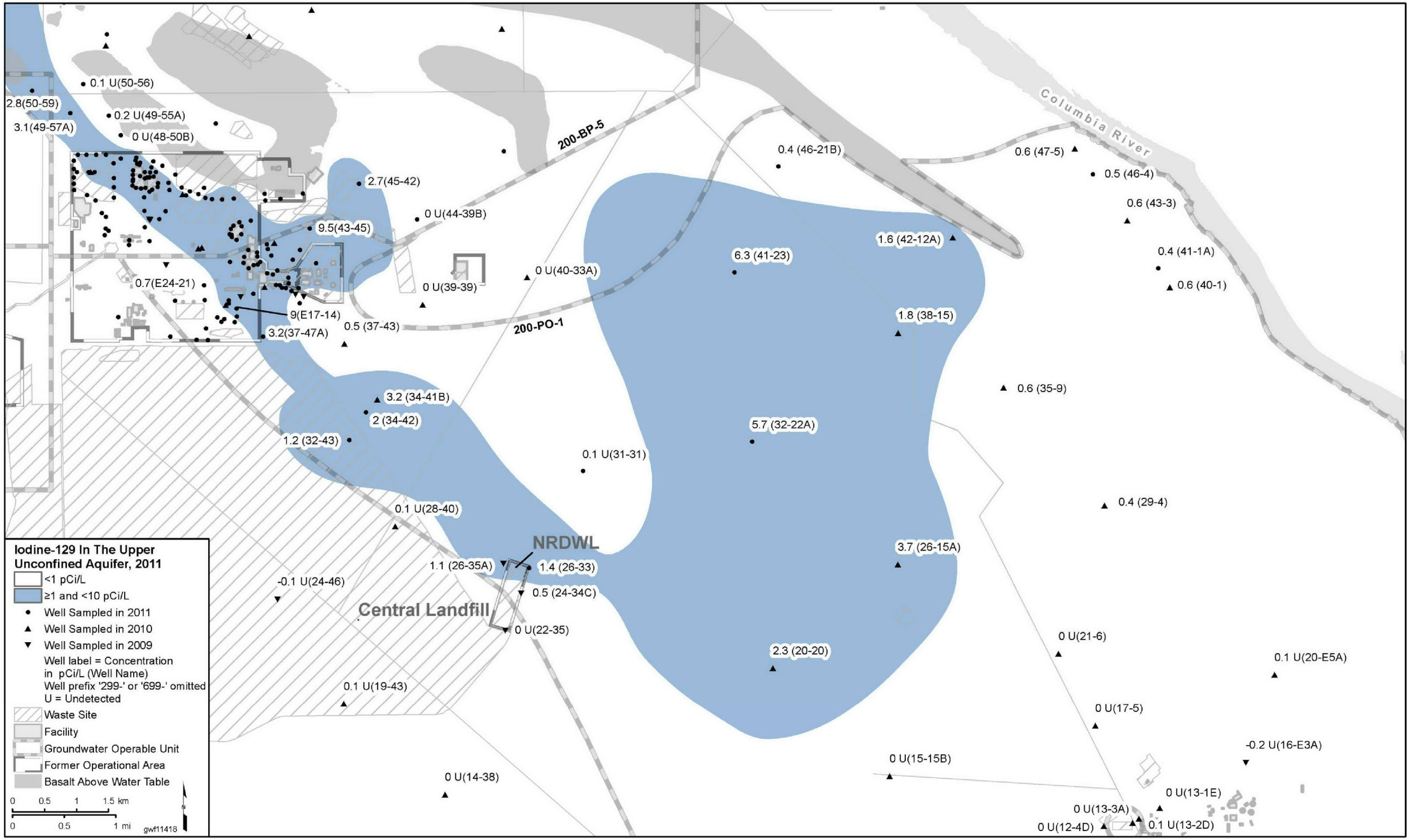

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Figure 3.5-8. Iodine-129 Concentration in Well 299-E17-19 at the 216-A-36B Crib

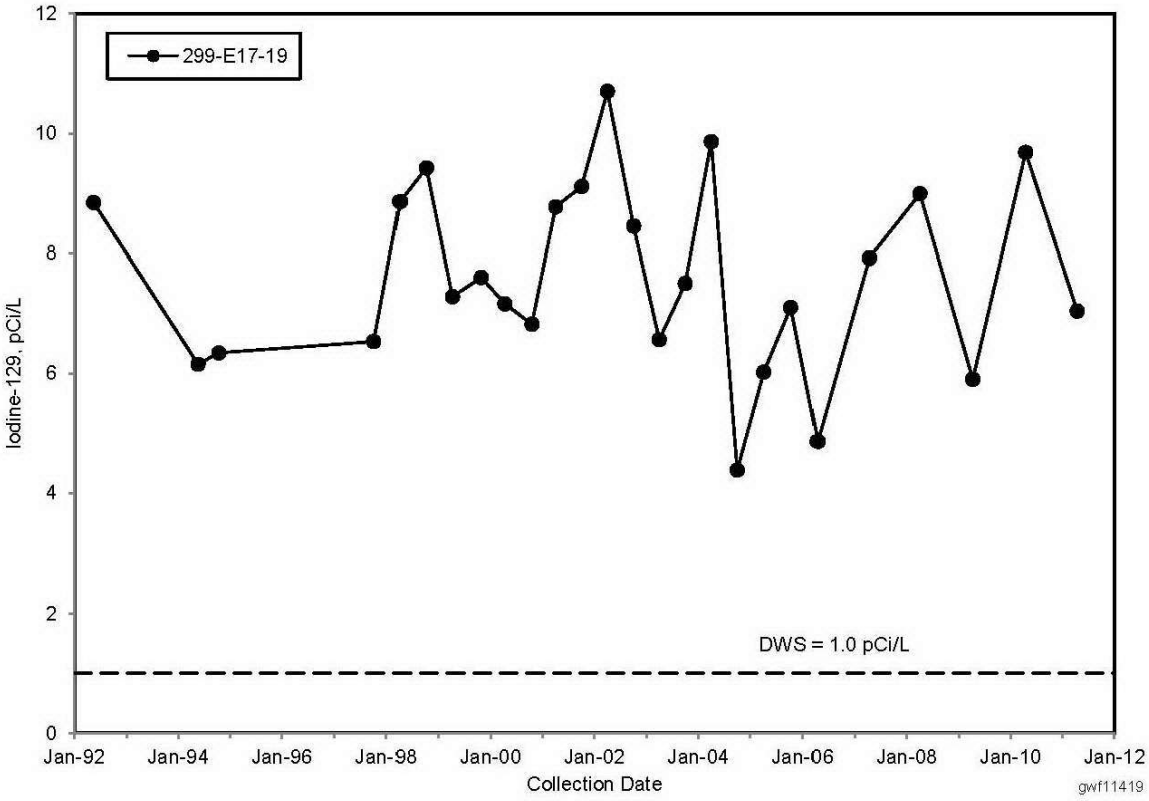


Figure 3.5-9. Nitrate Plume Map—200-PO-1 Operable Unit (Far-Field)

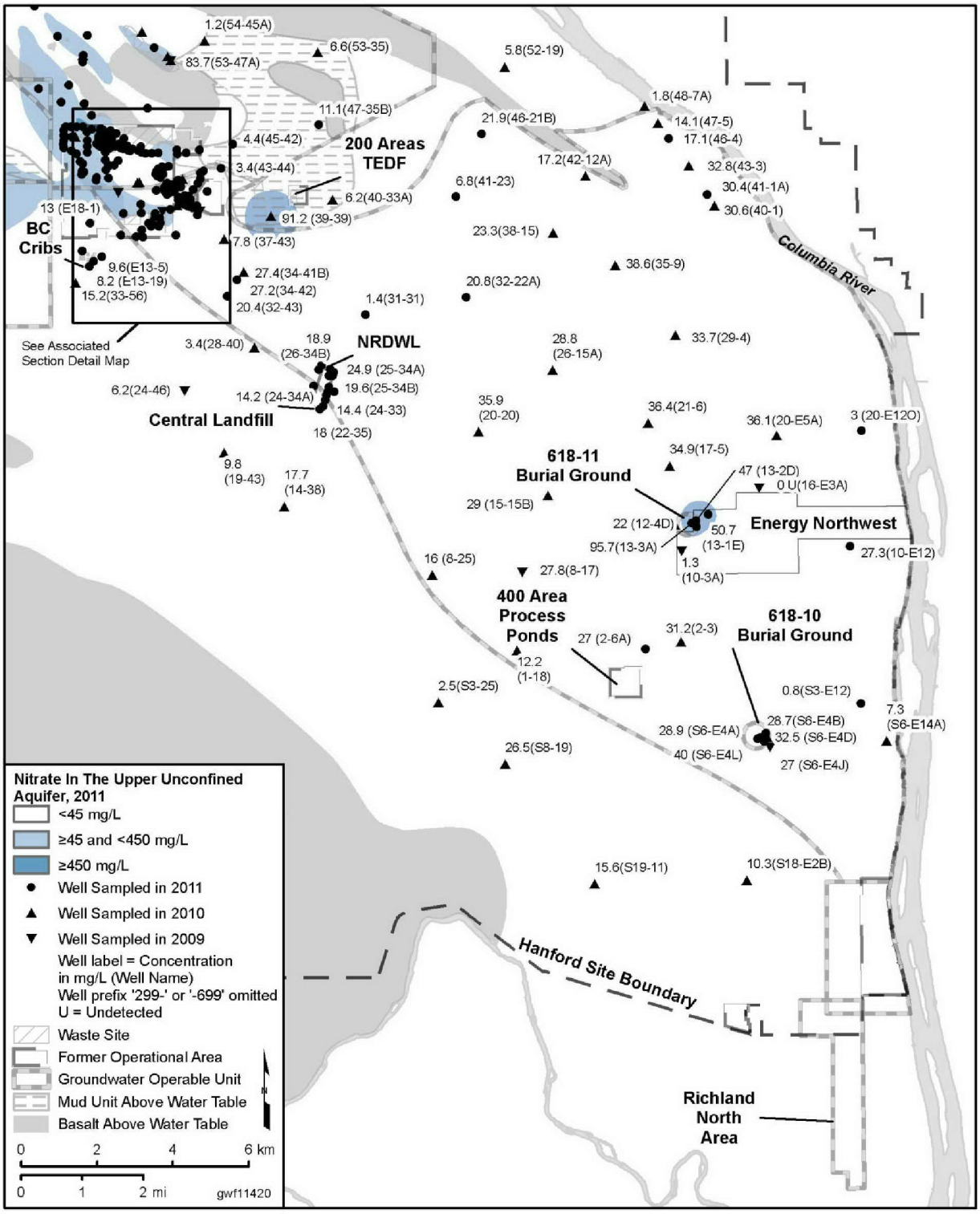


Figure 3.5-10. Nitrate Plume Map—200 East Area (Near-Field)

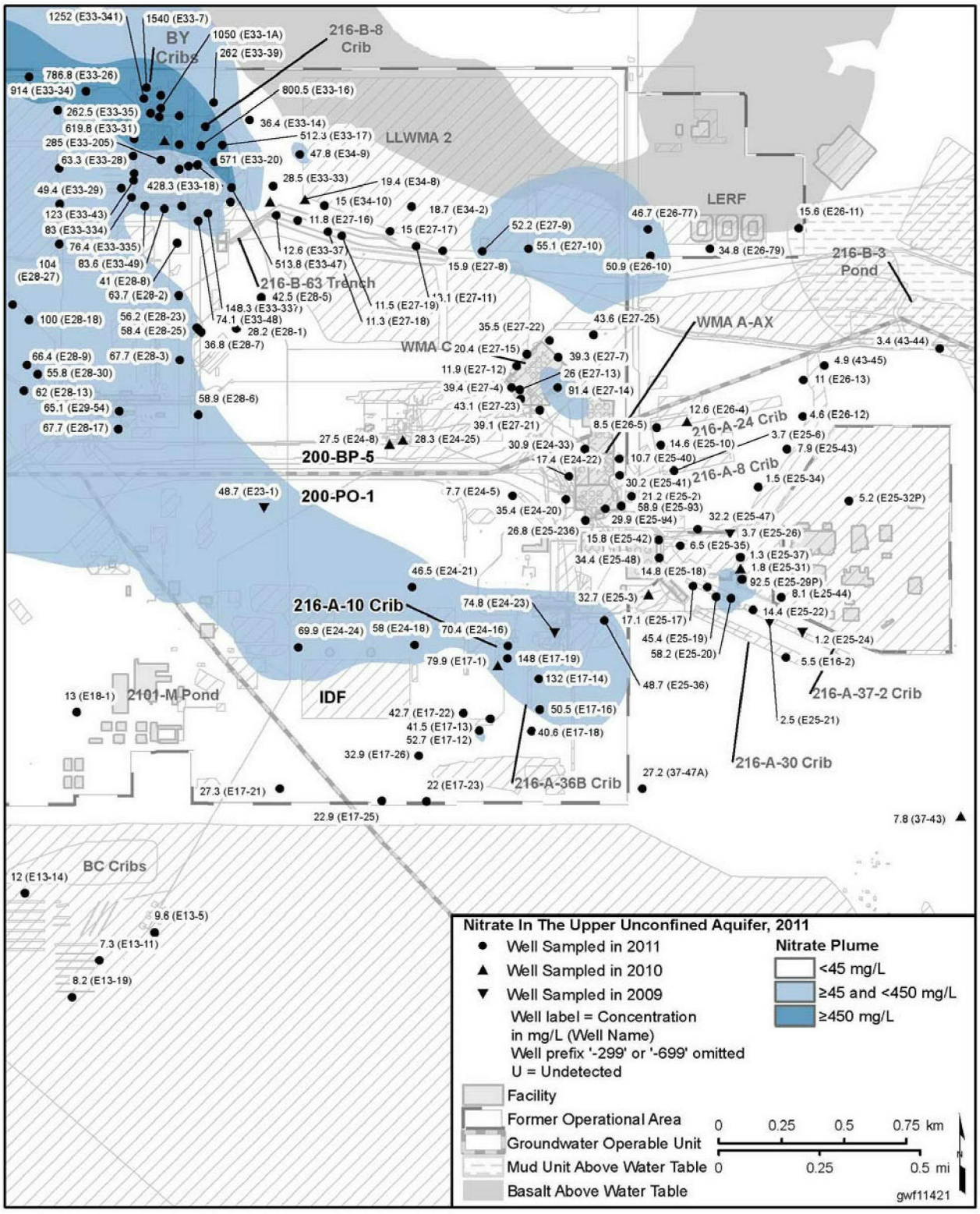


Figure 3.5-11. Nitrate Concentration in Well 299-E17-19 near the 216-A-36B Crib

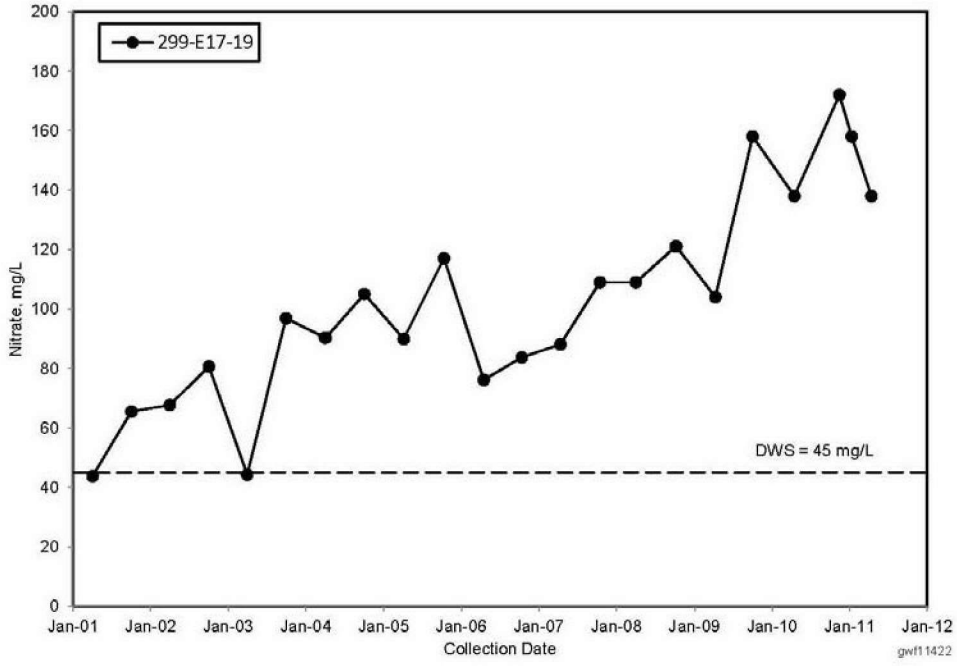


Figure 3.5-12. Nitrate Concentrations in Wells at Waste Management Area A-AX

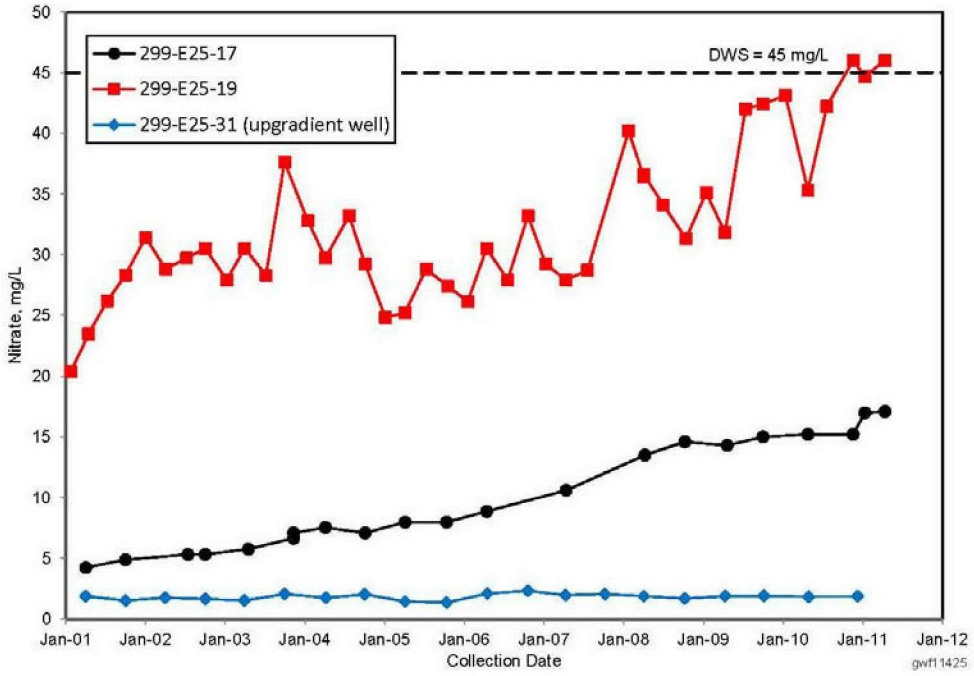


Figure 3.5-13. Nitrate Concentrations in Wells at 216-A-36B Crib

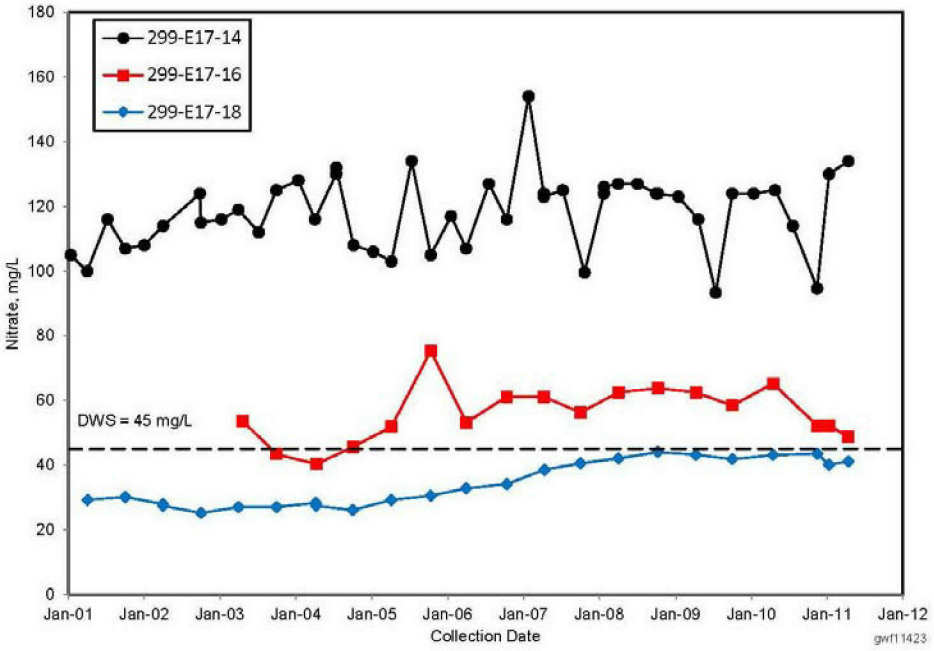


Figure 3.5-14. Nitrate Concentrations in Wells at 216-A-37-1 Crib

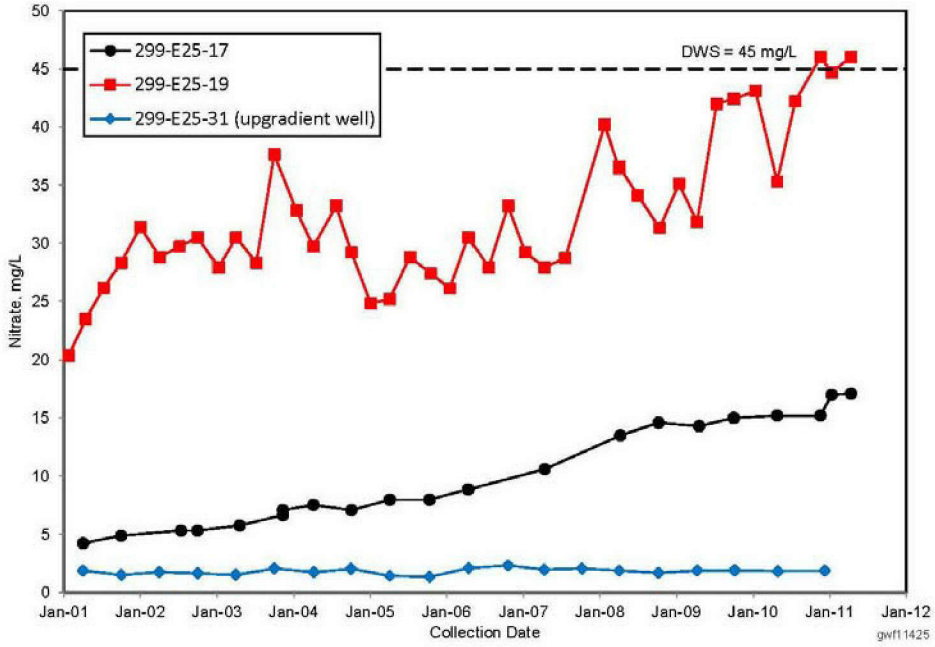


Figure 3.5-15. Technetium-99 Plume Map of Waste Management Area A-AX and Waste Management Area C

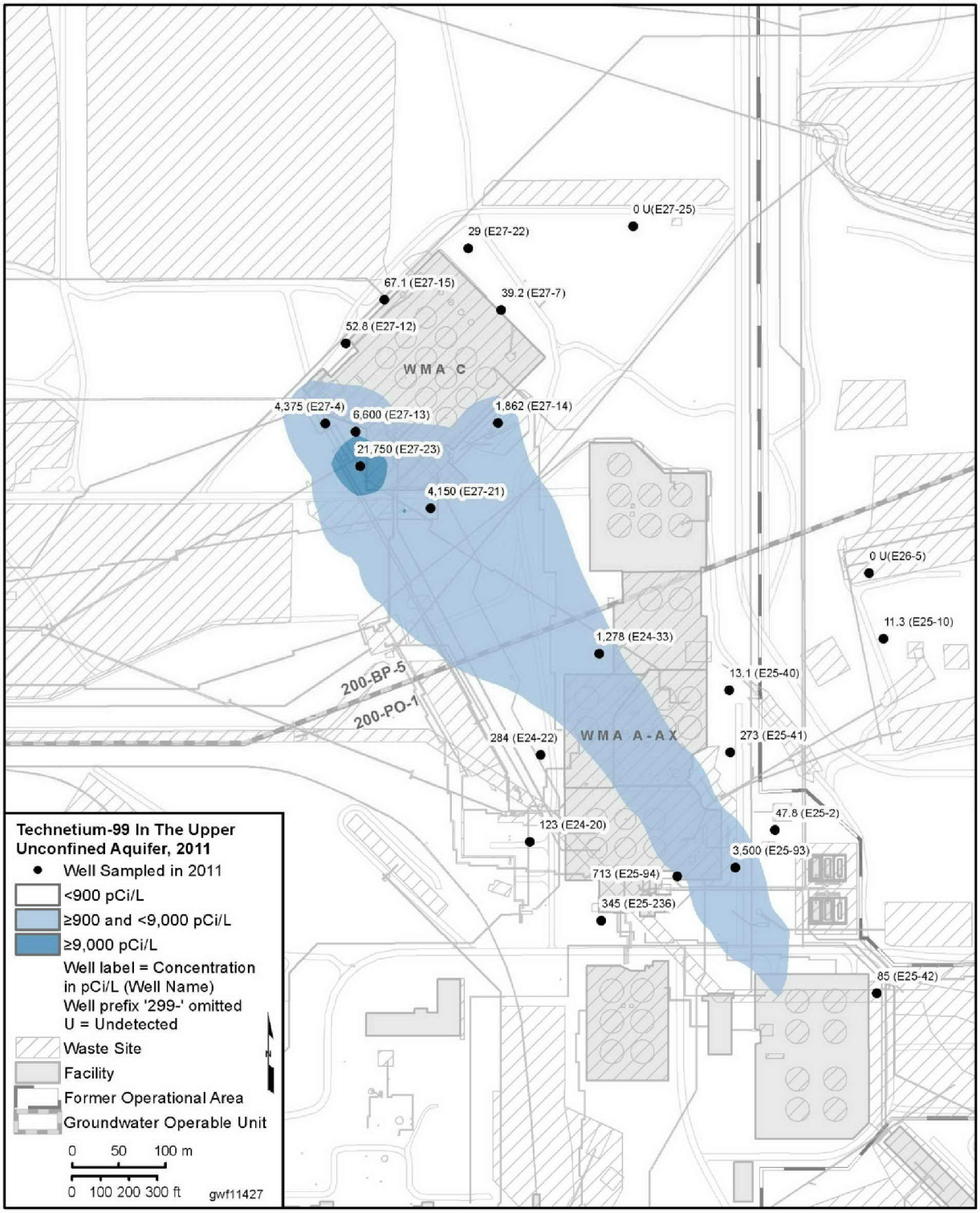


Figure 3.5-16. Technetium-99 Concentrations in Wells at Waste Management Area A-AX

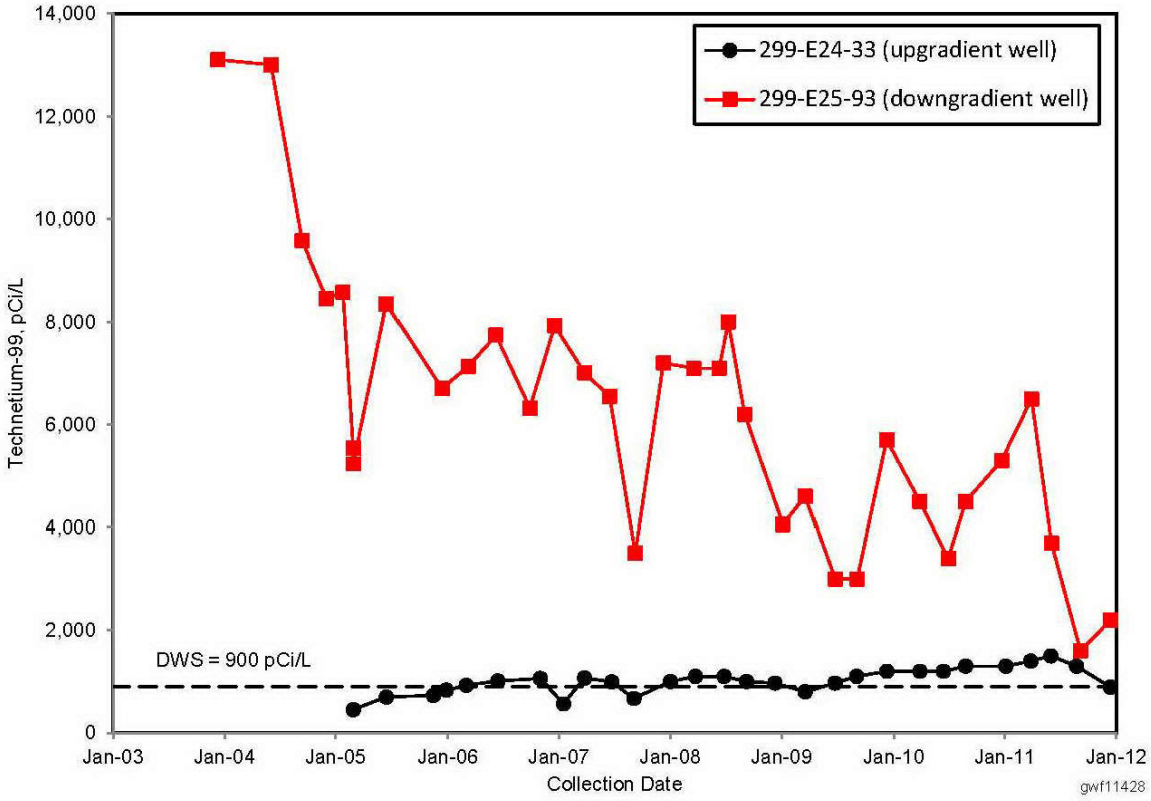


Figure 3.5-17. Local Plume Map for Uranium near the PUREX Cribs

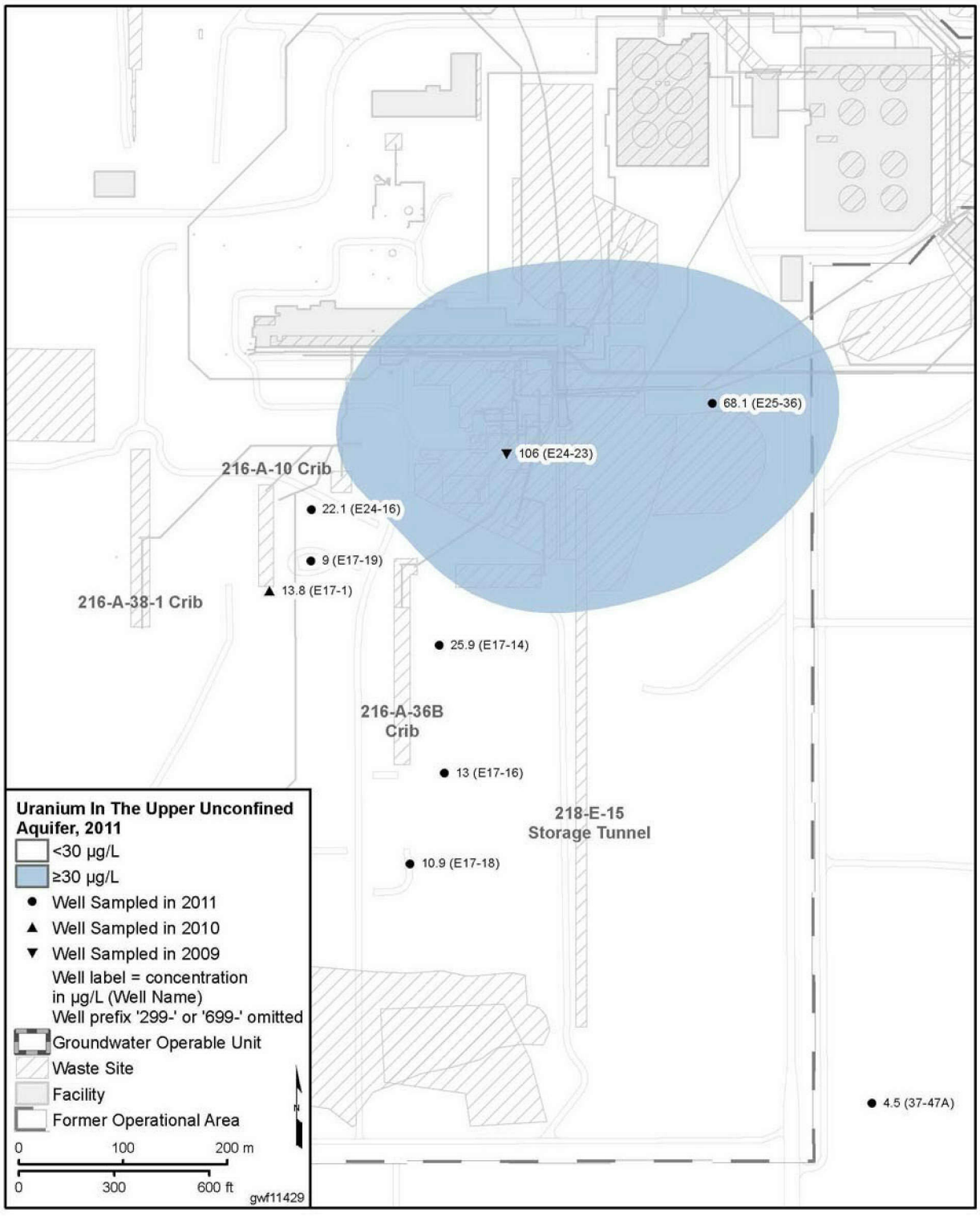


Figure 3.5-18. Uranium Concentration in Wells near the PUREX Cribs

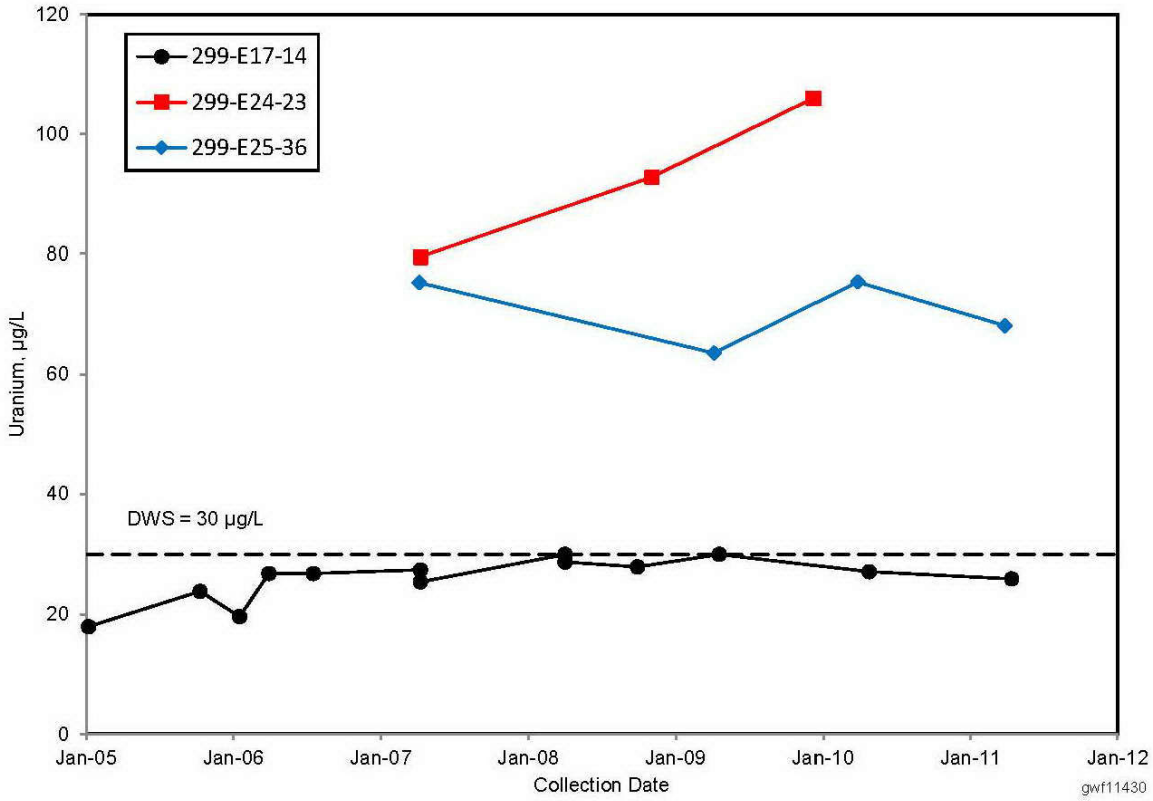
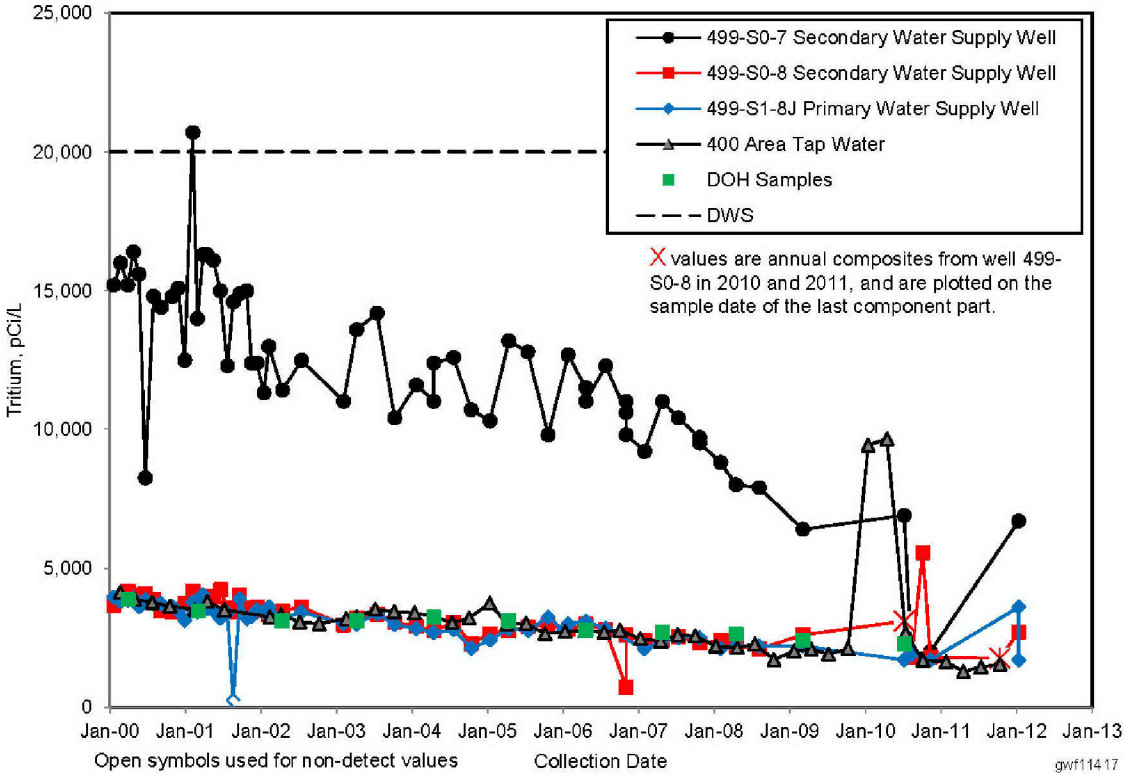


Figure 3.5-19. Tritium Trends in 400 Area Water Supply Wells



3.6 Central Plateau Summary and Recommendations

J.P. McDonald

Spent fuel reprocessing, isotope recovery operations, and associated waste management activities occurred on the Central Plateau within the 200 East and 200 West Areas. The groundwater interest areas associated with this region are 200-ZP-1 and 200-UP-1, addressing the northern and southern parts of the 200 West Area, respectively, and 200-BP-5 and 200-PO-1 for the northern and southern parts of the 200 East Area. This section summarizes the 2011 groundwater monitoring results for these interest areas, as well as groundwater remediation system operations and activities conducted for the deep vadose zone. Recommendations for future groundwater monitoring are also provided.

3.6.1 Groundwater Monitoring Results

Within the Central Plateau, groundwater monitoring during 2011 was conducted under CERCLA to track contaminants throughout the operable units, provide information for remedial investigations, and assess groundwater remediation systems. Groundwater monitoring was also performed to assess potential impacts to groundwater from specific facilities under RCRA and WAC requirements and to track radionuclide contaminants under the AEA. Table 3.6-1 lists the number of wells sampled and number of sample events (i.e., well trips) for each Central Plateau groundwater interest area. The results of this sampling are provided in Table 3.6-2, which lists the maximum concentration for selected groundwater constituents by interest area.

Within the 200 West Area, the overall extent of the carbon tetrachloride plume during 2011 was similar to that observed during 2010. The maximum sample result during 2011 was 3,900 μg/L, and seven wells had concentrations exceeding 2,000 μg/L. The plume has moved into deeper parts of the aquifer as it has migrated east.

Trichloroethene and chloroform occur in groundwater beneath the 200 West Area and are associated with the carbon tetrachloride plume. The maximum trichloroethene sample result during 2011 was 11 μg/L, which is approximately twice the 5 μg/L drinking water standard. This constituent is expected to disperse and possibly degrade to concentrations below the drinking water standard over time. All chloroform sample results were below the 80 μg/L drinking water standard for total trihalomethanes.

Nitrate and tritium occur above drinking water standards within all four Central Plateau groundwater interest areas. These constituents originate from multiple sources. The highest nitrate sample result during 2011 was 2,740 mg/L near the T Tank Farm in the northern 200 West Area, and the highest tritium result was 580,000 pCi/L at the PUREX Cribs in the 200 East Area. The tritium plume from the PUREX Cribs extends east through the 200-PO-1 interest area to the Columbia River, where the plume then discharges. Concentrations of tritium are declining in many of the Central Plateau wells as the plumes attenuate naturally by radioactive decay and dispersion.

The largest iodine-129 plume occurs within 200-PO-1, but the highest concentrations occur in the 200 West Area. At the 1 pCi/L contour level, the 200-PO-1 plume extends 12 kilometers east of the 200 East Area, and its extent has changed very little over the last 17 years. While the contaminant continues to migrate downgradient, concentrations at the leading edge of the plume (at the 1 pCi/L level) are reduced by dispersion such that the contour position is stable (i.e., at steady state). Iodine-129 is detected in wells near the Columbia River shore indicating the contaminant is discharging to the river, but concentrations are diluted well below 1 pCi/L by mixing with river water entering the aquifer during high river stages. There is no significant reduction in concentrations due to radioactive decay, because iodine-129 has a long half-life. The maximum concentration within 200-PO-1 during 2011 was 9.98 pCi/L near B Pond. The maximum iodine-129 sample result within the Central Plateau was 22.5 pCi/L in a well near the TX-TY Tank Farms in 200-ZP-1.

The most substantial uranium plumes occur within the 200-BP-5 and 200-UP-1 interest areas. The 200-BP-5 plume originates from the B Complex where the maximum concentration in the unconfined aquifer was 2,420 µg/L during 2011 (well 299-E33-343). Uranium is entering the aquifer from a perched zone beneath the B Complex, where the maximum measured concentration in the perched zone was 71,500 µg/L during 2011 (well 299-E33-344). DOE performed a successful treatability test within this zone during 2011. The uranium plume in the 200-UP-1 interest area occurs near U Plant and originates from the 216-U-1/2 Cribs.

The largest technetium-99 plume occurs within the 200-BP-5 interest area and originates mainly from the BY Cribs. This plume extends to the northwest beyond the 200 East Area. Technetium-99 plumes also occur in association with the tank farms in both the 200 East and West Areas. The maximum sample result on the Central Plateau during 2011 was 51,000 pCi/L at the SX Tank Farm in the 200 West Area.

A cyanide plume originates from the BY Cribs in the 200-BP-5 interest area and is attributed to disposal of wastes from isotope recovery processes. This plume also extends toward the northwest. The maximum concentration in this plume was 1,500 µg/L beneath the BY Cribs.

Chromium plumes on the Central Plateau are associated with waste sites in the 200 West Area. One plume occurs east-southeast of the 200 West Area and originated from cribs and ponds associated with the REDOX Plant. The maximum concentration in this plume during 2011 was 137 µg/L. Chromium plumes also occur at the 200 West Area tank farms. The largest of these is the plume from the SX Tank Farm, which extends nearly 500 meters downgradient from the source area. The maximum concentration in this plume during 2011 was 1,300 µg/L.

RCRA and WAC-regulated groundwater monitoring continued in 2011 at facilities in all four groundwater interest areas (Table 3.6-3). Results did not reveal any new impacts to groundwater. Two sites, the 216-A-36B and 216-A-37-1 Cribs in the southern 200 East Area, changed from assessment monitoring to indicator evaluation monitoring beginning on January 1, 2011. All the sites will continue to be monitored under existing requirements.

3.6.2 Groundwater Remediation

Within the Central Plateau, both the 200-ZP-1 and U Plant groundwater interim-action pump-and-treat systems operated during 2011. There are no active groundwater remedial actions occurring within the 200 East Area operable units, although a treatability test was performed on the perched zone beneath the B Complex as part of the deep vadose zone operable unit, 200-DV-1.

The 200-ZP-1 system is an interim action designed to address the high concentration portion of the carbon tetrachloride plume in the northern 200 West Area in the vicinity of the Plutonium Finishing Plant. The system consists of an air-stripper treatment plant, 14 extraction wells, and five injection wells. Nine of the 14 extraction wells are currently on line; the remaining wells are not being used because of a combination of declining water levels and low well performance. The current pumping rate for the entire system is 1,400 liters per minute. In 2011, 791.8 kilograms of carbon tetrachloride were removed from 758 million liters of groundwater. Since startup of pump-and-treat operations, 13,503 kilograms of carbon tetrachloride have been removed from 5.8 billion liters of groundwater. The volume of water treated in 2011 was 33 percent more than in 2010. Reduction in carbon tetrachloride contamination within the highest concentration portion of the contaminant plume has been demonstrated by the contaminant removal volumes and a decrease in the extent of the high concentration area over the last 15 years.

Two additional interim-action pump-and-treat system extraction wells are located at the northeast corner of the T Tank Farm. Technetium-99 contaminated groundwater is pumped by these wells and routed to the Liquid Effluent Retention Facility. The water is then treated at the Effluent Treatment Facility and discharged at the State-Approved Land Disposal Site north of the 200 West Area. During 2011, this system pumped 58.2 million liters of groundwater. The average pumping rate for the two extraction wells was 110.7 liters per minute. This system removed 13.3 grams (0.23 Ci) of technetium-99;

57.9 kilograms of carbon tetrachloride; 23,024 kilograms of nitrate; and 6.9 kilograms of chromium during 2011.

A final remedy pump-and-treat system for the 200-ZP-1 Operable Unit, completed in 2011 and scheduled for operations in 2012, will extract carbon tetrachloride, chromium, iodine-129, nitrate, technetium-99, and trichloroethene over a large part of the northern 200 West Area and will capture contamination throughout much of the aquifer thickness. During 2011, six new injection wells were installed, bringing the total number of wells supporting the new system to twenty-six. The new pump-and-treat facility is expected to increase pumping capacity over the current interim-action system by a factor of five.

The U Plant pump-and-treat system remediated the uranium and technetium-99 plume that originated from the 216-U-1/2 Cribs in the 200-UP-1 Operable Unit. One extraction well in this system, 299-W19-43, operated during the first three months of 2011. The other extraction well, 299-W19-36, did not operate as a result of a pump failure. The system was shut down during late March and will no longer be operated because of low flow rates from the extraction wells resulting from the regional water table decline and reduced well efficiency.

The U Plant pump-and-treat system was successful in achieving its remedial action objectives. All uranium and technetium-99 samples from the monitoring wells in the area targeted for remediation had concentrations below the 300 µg/L remedial action objective for uranium and below the 9,000 pCi/L remedial action objective for technetium-99. Since startup of this system in 1994, a total of 220.5 kilograms of uranium were removed from the aquifer and 127.4 grams (2.17 Ci) of technetium-99 were removed. Further remediation of the groundwater contaminant plumes, as required, will be addressed in an interim ROD for the 200-UP-1 Operable Unit scheduled to be completed by September 30, 2012.

3.6.3 Soil Vapor Extraction

Soil vapor extraction to remove carbon tetrachloride from the vadose zone near the Plutonium Finishing Plant in the 200 West Area continued to be performed during 2011. Two soil vapor extraction systems, with a total design capacity of 28.4 cubic meters per minute, were used from March through October. The systems were maintained in standby mode during the winter to allow time for carbon tetrachloride vapor concentrations to rebound. During 2011, the two systems removed 195 kilograms of carbon tetrachloride from the vadose zone and treated 3.7 million cubic meters of vapor. Since startup of operations in 1992, 79,945 kilograms of carbon tetrachloride have been removed from the vadose zone in 115 million cubic meters of soil vapor.

Passive soil vapor extraction systems operated during 2011 at eight wells near the 216-Z-1A Tile Field and 216-Z-18 Crib near the Plutonium Finishing Plant. Passive soil vapor extraction is a naturally occurring process driven by barometric pressure fluctuations. During 2011, this system removed approximately 4 kilograms of carbon tetrachloride from the vadose zone. Since operations began in 2001, the passive systems have removed approximately 104 kilograms of carbon tetrachloride from the vadose zone.

Pacific Northwest National Laboratory conducted a treatability test in 2011 using one of the soil vapor extraction systems and associated vadose zone wells. The purpose of the test was to evaluate the flux of carbon tetrachloride from the vadose zone to the groundwater under site-specific conditions and to refine the conceptual site model of the location of the remaining carbon tetrachloride in the vadose zone. Results of this testing will be evaluated during 2012.

3.6.4 Deep Vadose Zone

During 2011, soil samples were collected from the deep vadose zone near the SX Tank Farm in the 200 West Area, and two treatability tests were conducted: a groundwater extraction test in a perched horizon beneath the B Complex and a soil desiccation test at the BC Cribs. These activities were

performed in support of the 200-DV-1 Operable Unit, which addresses the deep vadose zone. Split-spoon soil samples of the vadose zone were collected from well 299-W22-91 for 200-DV-1, as well as by Washington River Protection Solutions for their Closure and Corrective Measures Project in support of tank farm vadose zone investigations. Most of the samples were collected in the lower Hanford formation and within the Cold Creek unit, and were analyzed for a variety of constituents as well as physical and geochemical parameters. No contamination was found in any of the samples.

The groundwater extraction treatability test was conducted in well 299-E33-344 and was designed to assess the feasibility of pumping uranium-contaminated water from the perched horizon. The test was conducted between August and December and was successful in removing approximately 95,000 liters of water from the perched zone. Uranium concentrations in the purge water increased from an initial value of 4,500 µg/L to 71,500 µg/L in December. Pumping was then shut down temporarily because of the high concentrations.

A soil desiccation treatability test was conducted in the BC Cribs and Trenches Area to evaluate the potential use of desiccation as a remedy to inhibit the migration of contaminants in the deep vadose zone. The test was conducted on a high moisture soil zone containing technetium-99. Soil gas flow was established by injection of nitrogen in a well and extraction of soil gas at a nearby well. Sensors indicated that desiccation occurred more rapidly in the higher permeability zones, as expected. At the end of 2011, data were still being collected during the passive, rewetting portion of the test.

3.6.5 Recommendations for Central Plateau Groundwater

The following recommendations are made regarding future groundwater monitoring and remedial action evaluations. Where possible, these recommendations provide sufficient detail to describe and plan the activity. As with any such recommendation, these warrant further review; and their implementation depends on technical priorities and available funding. In some cases, these recommendations are either planned for implementation in calendar year 2012, or have already been implemented as process improvements.

General Recommendation

- As the Hanford Site moves from describing the extent of contamination to active cleanup, meaningful benchmarks for measuring cleanup progress are under development. As new data evaluation and reduction tools are implemented, establish final long-term benchmarks for measuring the progress of cleanup and remedy performance.

200-ZP-1

- During drilling of future wells, collect depth-discrete groundwater samples to assist in defining the vertical distribution of contamination, appropriate length of well screens, and proper positioning of the screens within the aquifer (will continue during 2012).
- Apply modeling tools to assess the effectiveness of the pump-and-treat well configuration to continue to support plume capture and assess efficiency of sampling frequency for the monitoring well network (will continue during 2012).
- Evaluate all extraction wells to determine any degradation in well efficiency. If well performance is found to have declined, well evaluation and rehabilitation should be performed (planned for 2012).
- Review the current performance monitoring well network to determine if sufficient coverage exists to determine plume extent and movement. Many wells in the monitoring well network went dry as a result of the regionally declining water table, and additional wells will go dry over the next ten years. Large-scale pumping from the new extraction wells will accelerate this in some areas. As the number of available wells decreases, the ability to effectively monitor remediation,

contaminant concentrations, and changes in the plume configuration will be significantly impaired (planned for 2012).

- Evaluate the current water-level monitoring network to determine how many additional wells need automated water-level monitoring equipment installed to support hydraulic monitoring of the new 200 West Area pump-and-treat system (planned for 2012).

200-UP-1

- Revise the monitoring plan for the 200-UP-1 Operable Unit (Appendix A of DOE/RL-92-76) after the remedial investigation/feasibility study (DOE/RL-2009-122) and proposed plan (DOE/RL-2010-05) are finalized. The existing plan (Appendix A of DOE/RL-92-76) was designed to gather information needed for the remedial investigation. Because the remedial investigation is complete, a new plan should be prepared that is optimized for long-term monitoring of the operable unit and assessment of the remedial actions.
- Reconfigure the former extraction wells at the U Plant pump-and-treat system, 299-W19-36 and 299-W19-43, as monitoring wells for use in long-term monitoring of the uranium plume from the 216-U-1/2 Cribs and evaluation of future remedial actions (planned for 2012).

200-BP-5

- In the 200 East Area, continue efforts to correct water-level measurements for barometric response and well deviations, along with performing precision well elevation surveys, to provide definitive flow direction and gradient magnitude determinations in accordance with RCRA site requirements.
- Reevaluate the well, constituent lists, and the monitoring frequency specified in the monitoring plan (DOE/RL-2001-49), and provide updated requirements, including additional wells to monitor the extent and movement of deep-seated plumes. Specifically, it is recommended that monitoring be discontinued for plutonium-239/240, strontium-90, and cesium-137 at locations other than at or adjacent to the 216-B-5 Injection Well and Gable Mountain Pond (planned for 2012).
- Continue pumping of perched water at 299-E33-344 (implemented in 2012).
- Determine ways to investigate residual liquid waste in the deep vadose zone beneath WMA C to understand the extent of continued residual liquid waste drainage of technetium-99.

200-PO-1

- Continue to improve water-level measurements in the eastern and southeastern portions of 200 East Area and at the NRDWL/SWL area by decreasing the amount of measurement error. The water table gradient in these areas is so low that errors in measuring the depth to water can be larger than the differences in water table elevations between wells. Wells in the IDF/PUREX cribs area were previously surveyed to a single benchmark and measured for deviation from vertical. Wells to the north, east, and southeast should have the same work performed to more precisely define the groundwater flow direction in this region.

Table 3.6-1. Groundwater Sampling on the Central Plateau, 2011

Interest Area	Number of Wells Sampled	Number of Successful Well Trips	Number of Aquifer Tubes Sampled	Number of Successful Aquifer Tube Trips
200-ZP-1	90	288	n/a	n/a
200-UP-1	74	173	n/a	n/a
200-BP-5	142	318	5	5
200-PO-1	96	193	0	0
Total	402	972	5	5

Note: A successful sampling trip was determined by presence of data in HEIS. This table includes routine sampling, characterization sampling, and sampling conducted to support groundwater remediation systems.

n/a = not applicable

Table 3.6-2. Maximum Concentrations of Selected Groundwater Constituents in Central Plateau Interest Areas During 2011

Contaminant, Units	DWS (DCS)[a]	200-ZP-1	200-UP-1	200-BP-5	200-PO-1
Radionuclides					
Carbon-14, pCi/L	2,000 (62,000)	8.81	8.28	550	
Cesium-137, pCi/L	200 (3,000)	20		2,140	
Cobalt-60, pCi/L	100 (7,200)	23		55.3	
Gross alpha, pCi/L	15	3.01	2.06	1,000[c]	27
Gross beta, pCi/L	50	4,400	1,600	22,000[c]	4,300
Iodine-129, pCi/L	1 (330)	22.5	11.2	6.82	9.98
Plutonium-239/240, pCi/L	N/A (140)			52	
Strontium-90, pCi/L	8 (1,100)	3.2	2.3	4,400	30
Technetium-99, pCi/L	900 (44,000)	7,600	51,000	36,500[c]	6,500
Tritium, pCi/L	20,000 (1,900,000)	420,000	110,000	39,000[c]	580,000
Uranium, µg/L	30	16.8	374	2,420[c]	68.1
Metals[b]					
Arsenic (filtered), µg/L	10	12.8	5.43	104	11.4
Arsenic, µg/L	10	12.3	5.43	98.8	10.8
Barium (filtered), µg/L	2,000	429	130	220	150
Barium, µg/L	2,000	421	132	220	160
Beryllium (filtered), µg/L	4		0.91	1.6[c]	
Beryllium, µg/L	4		1.5	1.6[c]	
Chromium (filtered), µg/L	100	375	1,300	86[c]	28
Chromium, µg/L	100	522	1,300	356	43
Hexavalent Chromium (filt.), µg/L	48	201	13.5	82.9[c]	
Hexavalent Chromium, µg/L	48	383	865	80.3[c]	
Mercury (filtered), µg/L	2	0.342	0.123	0.0926	
Mercury, µg/L	2	0.34[d]	0.132		
Selenium (filtered), µg/L	50	9.98	21.1	13.2	
Selenium, µg/L	50	10	23.1	6.45	
Anions					
Cyanide, µg/L	200	179		1,500	2.1

Table 3.6-2. Maximum Concentrations of Selected Groundwater Constituents in Central Plateau Interest Areas During 2011

Contaminant, Units	DWS (DCS)[a]	200-ZP-1	200-UP-1	200-BP-5	200-PO-1
Fluoride, mg/L	4	4.75	0.517	3.27[c]	8.91
Nitrate as NO_3, mg/L	45	2,740	409	1,700	158
Nitrite as NO_2, mg/L	3.3	0.526	0.654	0.693	0.401
Organics					
1,1,1-Trichloroethane, µg/L	200				0.54
1,1-Dichloroethene, µg/L	7	0.13			
1,2,4-Trichlorobenzene, µg/L	70	1.1			
1,2-Dichlorobenzene, µg/L	600	2.5			
1,2-Dichloroethane, µg/L	5		1.1		
Benzene, µg/L	5		0.069		
Benzo(a)pyrene, µg/L	0.2				
Carbon tetrachloride, µg/L	5	3,900	980		2.1
Chloroform, µg/L	80	47	24	0.32	0.12
cis-1,2-Dichloroethylene, µg/L	70	0.3			
Ethylbenzene, µg/L	700				2.1
Methylene chloride, µg/L	5	1.5	1.6	1.8	
Tetrachloroethene, µg/L	5	3		0.67	1.1
Toluene, µg/L	1,000	0.087	0.16		
Trichloroethene, µg/L	5	11	8.8	4.6	0.46
Xylenes (total), µg/L	10,000				

Note: Table lists highest value for 2011 for each groundwater interest area, excluding those flagged F, R or Y, or nonroutine samples (e.g. characterization). Blank cells indicate a constituent was not detected or not analyzed. Blue cells exceed drinking water standards. Yellow cells exceed derived concentration standards.

a. References for drinking water standards and derived concentrations standards listed in Table 1-1.

b. Antimony, cadmium, and thallium excluded because detection limits are typically higher than drinking water standards, creating false exceedances near the detection limits. Nickel excluded because it typically indicates corrosion of stainless steel well screens and casing.

c. Maximum result from the unconfined aquifer. A higher result occurred in the perched water zone monitored by 299-E33-344 at WMA B-BX-BY.

d. Excludes outlier.

Table 3.6-3. RCRA Monitoring Status for the Central Plateau, 2011

RCRA Unit	Report Section	Status for Reporting Period
216-A-29 Ditch	Section 3.5.9.4	Continued indicator evaluation;[a] using different upgradient wells starting in 2011.
216-A-36B Crib	Section 3.5.9.2	Changed from assessment to indicator evaluation monitoring on January 1, 2011.
216-A-37-1 Crib	Section 3.5.9.3	Changed from assessment to indicator evaluation monitoring on January 1, 2011.
216-B-3 Pond	Section 3.5.9.5	Continued indicator evaluation.[a]
216-B-63 Trench	Section 3.4.13.3	Continued indicator evaluation.[a]
216-S-10 Pond and Ditch	Section 3.3.10.3	Continued indicator evaluation.[a]
IDF	Section 3.5.9.6	Not yet in use; monitoring results added to baseline data set.
LERF	Section 3.4.13.4	DOE and Ecology pursuing agreement for monitoring; new characterization well installed during 2011.
LLWMA-1	Section 3.4.13.5	Continued indicator evaluation.[a]
LLWMA-2	Section 3.4.13.6	Continued indicator evaluation.[a]
LLWMA-3	Section 3.2.10.3	New upgradient well installed during 2011; statistical evaluations suspended until new background values are established.
LLWMA-4	Section 3.2.10.4	Continued indicator evaluation.[a]
NRDWL	Section 3.5.9.8	Continued indicator evaluation;[a] new monitoring plan that combines monitoring for NRDWL and the Solid Waste Landfill into a single plan is under review by Ecology.
SST WMA A-AX	Section 3.5.9.1	Continued assessment (nickel); new monitoring plan being reviewed by Ecology.
SST WMA B-BX-BY	Section 3.4.13.1	Continued assessment (241-BX-102 tank leak).
SST WMA C	Section 3.4.13.2	Continued assessment (cyanide[b]).
SST WMA S-SX	Section 3.3.10.1	Continued assessment (chromium[b]); new monitoring plan implemented during 2011.
SST WMA T	Section 3.2.10.1	Continued assessment (chromium[b]); new monitoring plan implemented during 2011.
SST WMA TX-TY	Section 3.2.10.2	Continued assessment (chromium[b]); new monitoring plan implemented during 2011.
SST WMA U	Section 3.3.10.2	Continued assessment (chromium[b]); new monitoring plan implemented during 2011.

a. Analysis of RCRA contamination indicator parameters provided no evidence of groundwater contamination with dangerous waste/dangerous waste constituents from the unit.

b. Primary RCRA constituents at this unit.

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4.0 Confined Aquifers

M.J. Hartman and J.P. McDonald

This chapter describes groundwater flow and groundwater quality in confined aquifers within the Ringold Formation and the upper portion of the Columbia River Basalt Group.

4.1 Ringold Confined Aquifers

Confined, water-bearing units are present in the Ringold Formation (Figure 4-1). The most widespread Ringold confined aquifer is where the Ringold Formation lower mud unit confines the underlying sediment of Ringold unit A (see Figure 3.1-2 in Section 3.1). Approximately 30 wells are screened in Ringold unit A, although not all of these have been sampled in recent years. Most of the wells are located in or near the Central Plateau; others are located in the southern Hanford Site (including the 300 Area), and one is in the 100 Area.

Local, water-bearing units in or beneath the Ringold upper mud unit exist in the northern Hanford Site. These are not believed to be interconnected into a regional aquifer. Approximately 19 wells in the 100 Area are screened in water-bearing units within or beneath this unit.

4.1.1 Groundwater Flow in Ringold Confined Aquifers

This section describes groundwater flow in the confined aquifer of Ringold unit A in the region near the 200 Area and farther south. The elevation of this Ringold confined aquifer varies from 34 meters (NAVD88) southwest of 200 West Area (Plate 3 of PNNL-13858) to more than 128 meters (NAVD88) northeast of 200 East Area (Plate 3 of PNNL-12261). There are insufficient data from unit A in the northern part of the Hanford Site to interpret groundwater flow directions. Groundwater flow in the Ringold upper mud is not characterized because the water-bearing units are not known to be interconnected.

Figure 4-2 presents the March 2011 potentiometric surface for a portion of the confined aquifer in the Ringold Formation unit A. This map is subject to uncertainty because only a few wells monitor this aquifer. However, generalized flow patterns can be inferred from available data when the hydrogeologic framework (that is, the extent of the confined unit, presence of basalt subcrops, and influence of the May Junction Fault) is considered.

Groundwater flow in the Ringold confined aquifer is generally west to east near the 200 West Area and west to east along the southern boundary of the aquifer near the Rattlesnake Hills. This flow pattern indicates that recharge occurs west of the 200 West Area in upgradient areas within the Cold Creek Valley, as well as in the Dry Creek Valley, and possibly the Rattlesnake Hills. Near the 200 East Area, flow in the Ringold confined aquifer converges from the west, south, and east before discharging to the unconfined aquifer where the Ringold Formation lower mud is absent (Section 4.2.3 of PNNL-12261). This water is thought to flow southeast over the top of the confining unit (Section 2.4.3 of DOE/RL-2008-59, *Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond*). Near the 200 East Area, water-level elevation data from piezometers 299-E25-32P and 299-E25-32Q (used to monitor different depths in the unconfined aquifer) indicate a slight upward gradient along the confined unit boundary. This upward gradient is consistent with discharge of groundwater from the confined aquifer to the overlying unconfined aquifer.

Artificially elevated water levels are present in the Ringold confined aquifer to the northeast of the 216-B-3 Pond (B Pond). The high water levels reflect mounding from past wastewater discharges and subsequently cause a southwest flow beneath B Pond where mounding is not as prevalent. Eastward flow away from the region of elevated water levels does not occur due to the north-south trending May Junction Fault, located east of the B Pond area (Section 2.4.3 of DOE/RL-2008-59). Hydraulic head and water chemistry differences across this fault indicate it is a barrier to groundwater flow in the confined aquifers (Sections 4.2.3 and 4.3.2 in PNNL-12261). While impermeable units have been juxtaposed

against permeable units along part of the fault, the mud units may also have smeared along the fault zone and sealed it (Plates 8 and 9 in PNNL-12261). South of the B Pond area, the flow of water divides, with some flow moving northwest toward the 200 East Area and some flow moving east or southeast. The exact location of the flow divide is not known because of a lack of water-level data in this area and uncertainty regarding the southward extent of the May Junction Fault.

The potentiometric contours for the Ringold confined aquifer (Figure 4-2) are similar to the potentiometric surface contours for the upper basalt-confined aquifer system, indicating that flow patterns in the central portion of the Hanford Site are similar in both aquifers. Basalt bedrock from the topographic low area at Gable Gap near the 200 East Area was eroded significantly by late Pleistocene catastrophic flooding (Section 7.0 of PNNL-19702), which facilitates intercommunication between the unconfined and confined aquifers. The 200 East Area is a discharge area for both of the confined aquifers, which explains the similar flow patterns.

Water levels declined throughout much of the Ringold confined aquifer from March 2010 to March 2011. The decline in individual wells ranged from 0.02 to 0.26 meter. The largest declines were in the 200 West Area where the potentiometric surface declined an average of 0.24 meter. The potentiometric surface is responding to reduced loading of the confined aquifer (that is, a reduction in external stress) caused by water level declines in the overlying unconfined aquifer. The water table in the unconfined aquifer is declining in response to the reduction of liquid effluent discharges to the ground since the discharge volumes peaked in the mid 1980s.

4.1.2 Groundwater Quality in Ringold Confined Aquifers

Wells monitoring Ringold confined aquifers are sampled in accordance with the objectives of the groundwater operable units in which they are located. Chapters 2 and 3 discuss monitoring results and highlights are summarized in the following text.

With few exceptions, groundwater in the Ringold upper mud unit is not contaminated (Table 4-1). Fourteen wells screened in this unit were sampled at least once between 2009 and 2011. Hexavalent chromium concentrations are greater than 100 µg/L in some Ringold upper mud wells in 100-H (higher than currently observed in the unconfined aquifer). As discussed in Section 2.5, it appears that portions of this unit east of 100-D Area were eroded, allowing contaminated cooling water into the mud. This water moves more slowly than unconfined groundwater so the contamination persists.

Tritium concentrations are elevated, but currently below the drinking water standard, in Ringold mud well 199-N-80, located in 100-N (Section 2.4). This is the only well in 100-N screened in the mud. Attempts to install another well in a similar, water-bearing zone in 2011 were unsuccessful; no water-bearing zone was encountered during drilling.

The Ringold confined aquifer near 200 West is contaminated with carbon tetrachloride, which migrated downward where the lower mud is absent.

Wells monitoring the Ringold confined aquifer of unit A show contamination near the 200 West Area (Table 4-1). Twenty-four wells screened in unit A were sampled at least once between 2009 and 2011. Carbon tetrachloride, nitrate, and technetium-99 apparently reached unit A in a region of the 200 West Area where the lower mud unit is absent. As the groundwater continues to flow toward the east where the lower mud is present, it becomes confined. New wells have been installed in recent years to monitor and remediate the contamination. Section 3.2 discusses contaminant distribution with depth in the 200-ZP-1 Operable Unit.

The Ringold confined aquifer (unit A) is the uppermost aquifer in a region east of 200 East (200-BP-5 and 200-PO-1 Operable Units; Sections 3.4 and 3.5). Regional contaminants iodine-129 and

tritium are detected in wells monitoring this aquifer (Table 4-1). Contamination has not been observed in wells located downgradient of the contaminated wells, indicating it is of limited extent.

4.2 Upper Basalt Confined Aquifer

The upper basalt-confined aquifer groundwater system occurs within basalt fractures and joints, interflow contacts, and sedimentary interbeds within the upper Saddle Mountains Basalt. The thickest and most widespread sedimentary unit in this system is the Rattlesnake Ridge interbed, which is present beneath much of the Hanford Site. Groundwater also occurs within the Levey interbed, which is present only in the southern portion of the Site. A small interflow zone occurs within the Elephant Mountain Member of the upper Saddle Mountains Basalt and may be significant to the lateral transmission of water. The upper basalt-confined aquifer system is confined by the dense, low-permeability interior portions of the overlying basalt flows and in some places by silt and clay units of the lower Ringold Formation that overlie the basalt. Approximately 50 wells screened in the upper basalt-confined aquifer have been sampled or had water levels measured in recent years (Figure 4-3).

An area of intercommunication between the unconfined and upper basalt-confined aquifers exists near the 200 East Area where the confining layers are eroded away or fractured. Several basalt-confined wells have shown evidence of intercommunication with the overlying unconfined aquifer (Section 3.0 of PNL-10817, *Hydrochemistry and Hydrogeologic Conditions within the Hanford Site Upper Basalt Confined Aquifer System*).

4.2.1 Groundwater Flow in Upper Basalt-Confined Aquifer

Figure 4-4 presents the interpreted March 2011 potentiometric surface for the upper basalt-confined aquifer system south of Gable Butte and Gable Mountain, based on measurements from 30 monitoring wells. The region to the north of Gable Butte and Gable Mountain was not contoured because of an insufficient number of wells in this area. Plate 1 of *Preliminary Potentiometric Map and Flow Dynamic Characteristics for the Upper-Basalt Confined Aquifer System* (PNL-8869) provides a generalized potentiometric surface map of this area. The upper basalt-confined aquifer system does not exist in the Cold Creek Valley and along the west portion of the Gable Mountain and Gable Butte structural area because of the absence of the Rattlesnake Ridge interbed.

Recharge to the upper basalt-confined aquifer system likely occurs from upland areas along the margins of the Pasco Basin and results from the infiltration of precipitation and surface water where the basalt and interbeds are exposed at or near ground surface. Recharge may also occur from the overlying aquifers (that is, the unconfined aquifer or confined aquifer in the Ringold Formation) in areas where the hydraulic gradient is downward and from deeper basalt aquifers where an upward gradient is present. The Yakima River may also be a source of recharge to this aquifer system. The Columbia River represents a discharge area for this aquifer system in the southeastern portion of the Hanford Site where the river has a lower head than the upper basalt-confined aquifer, but not for the northern portion of the site where the river head is higher (Section 3.2 of PNL-8869). Discharge also occurs to the overlying aquifers in areas where the hydraulic gradient is upward. Discharge to the overlying unconfined aquifer near the Gable Butte and Gable Mountain structural area is believed to occur through windows eroded in the basalt.

South of Gable Butte and Gable Mountain, groundwater in the upper basalt-confined aquifer system generally flows from west to east across the Hanford Site, toward the Columbia River. The north-south trending May Junction Fault, located east of B Pond, acts as a barrier to groundwater flow in the unconfined aquifer and the confined aquifer within the Ringold Formation (Section 2.4.3 of DOE/RL-2008-59). It may also impede the movement of water in the upper basalt-confined aquifer system by juxtaposing permeable units opposite impermeable units. As with the Ringold confined aquifer, a flow divide is interpreted to exist southeast of the 200 East Area and B Pond in the upper basalt-confined aquifer system, but the exact location of this divide is uncertain because of a lack of wells in the area.

Groundwater flow rates within the Rattlesnake Ridge interbed have been estimated between 0.7 and 2.9 meters per year (Section 4.2 of PNL-10817), which is a considerably lower flow rate than most estimates for the overlying unconfined aquifer system. The sediment comprising the interbed consists mostly of sandstone (with silts and clays) and is much less permeable than the sediment in the unconfined aquifer. In addition, the magnitude of the hydraulic gradient is generally lower than in the unconfined aquifer.

The vertical hydraulic gradient between the upper basalt-confined aquifer system and the overlying aquifer varies spatially, as shown by comparison of observed heads (Figure 4-5). A downward gradient exists in the central portion of the Hanford Site, near the B Pond recharge mound, as well as in regions north and east of the Columbia River. Near the B Pond, the vertical head gradient between the unconfined aquifer system and the upper basalt-confined aquifer system has diminished in recent years but remains downward. In other areas of the Site, the hydraulic gradient is upward from the upper basalt-confined aquifer system to the overlying aquifer system.

In the 200 East Area, the potentiometric surface (Figure 4-4) is similar to the potentiometric surface for the Ringold confined aquifer (Figure 4-2). The basalt in this area was significantly eroded by late Pleistocene catastrophic flooding, which facilitates aquifer intercommunication (Section 7.0 of PNNL-19702). In the 200 East Area and to the immediate north, the vertical hydraulic gradient between the upper basalt-confined aquifer system and the overlying aquifer is upward. It is likely that the upper basalt-confined aquifer system currently discharges to the overlying aquifer in this region.

Water levels in the upper basalt-confined aquifer system declined throughout most of the Hanford Site from March 2010 to March 2011. In the 200 East Area and to the immediate north and east (near B Pond), water-level declines in wells were up to 0.08 meter, and water levels declined up to 0.22 meter in wells near the 200 West Area. In most locations the potentiometric surface is responding to reduced loading of the confined aquifer (that is, a reduction in external stress) caused by water level declines in the overlying unconfined aquifer and Ringold confined aquifer. Where the basalt is not confining, the water-level declines in the deeper aquifer are directly due to the declining water table. The water table in the unconfined aquifer is declining in response to reduced effluent disposal activities in the 200 Area. Water-level increases occurred in 699-32-22B (0.10 meter), located about 8 kilometers east-southeast of the 200 East Area, and in 699-S24-19P (0.14 meter), located near the Yakima River.

4.2.2 Groundwater Quality in Upper Basalt-Confined Aquifer

DOE monitors groundwater quality in the upper basalt-confined aquifer system because of the potential for downward migration of contaminants from the overlying unconfined aquifer in areas where confining units are absent or fractured. The upper basalt-confined aquifer system is not affected by contamination as much as the unconfined aquifer. Contamination found in the upper basalt-confined aquifer system is most likely to occur in areas where the confining units have been eroded away or were never deposited, and where past disposal of large amounts of wastewater resulted in downward hydraulic gradients. Researchers have identified areas of intercommunication between the contaminated unconfined aquifer and the upper basalt-confined aquifer by geochemical signatures and the presence of nitrate and tritium in groundwater in some basalt-confined wells near 200 East Area (Chapter 3.0 of PNL-10817). However, groundwater monitoring data do not indicate that substantial contamination has migrated into the upper basalt-confined aquifer. Because of poor seals in wells constructed prior to implementation of WAC 173-160 ("Minimum Standards for Construction and Maintenance of Wells"), intercommunication between aquifers has permitted groundwater flow from the unconfined aquifer to the underlying confined aquifer in the past, increasing the potential to spread contamination (such as at well 299-E33-12, discussed below). Section 2.14.2 of DOE/RL-2008-01 further discusses communication between the upper basalt-confined aquifer system and the overlying aquifers.

No significant contamination is detected in the basalt-confined aquifer, except that caused by well construction or drilling effects.

Twenty-eight wells screened in the upper basalt-confined aquifer were sampled between 2009 and 2011. Concentrations of contaminants are far below drinking water standards in the basalt-confined aquifer (Table 4-2), except where well construction or drilling effects allowed migration of groundwater from the overlying unconfined aquifer. The highest concentrations of contaminants continued to be observed in well 299-E33-12 in the northwestern 200 East Area. This well was drilled in 1953 and was uncased from just above the bottom of the unconfined aquifer through the Rattlesnake Ridge interbed. Contamination is believed to have migrated from the unconfined aquifer, down the open borehole, to the Rattlesnake Ridge interbed (Section 2.14.2 of DOE/RL-2008-01). The well was sealed from the unconfined aquifer in 1979 with an additional seal placed in the well in 1990 to shorten the open interval. Concentrations of waste indicators cyanide, nitrate, technetium-99, and tritium continued to be elevated in samples from this well (Section 3.4.3.1), and possibly in a small area of the confined aquifer. Well 299-E33-50, located near 299-E33-12, consistently shows levels of technetium-99 between 25 and 50 pCi/L. Some of the initial samples from well 299-E33-340, located in the same region, showed contamination. However, after the well was developed and sampled several times, the contamination disappeared, indicating the contamination was dragged down during drilling and not representative of the basalt-confined aquifer. Other confined wells in this region showed no contamination. The hydraulic gradient is upward in this region (Figure 4-5).

Tritium and iodine-129 continued to be detected at levels below their drinking water standards in well 699-42-40C, located east of 200 East (200-PO-1; see Section 4.4). Iodine-129 concentrations are near or below detection limits and tritium concentrations generally are declining. The hydraulic gradient in this region remains downward (Figure 4-5).

Groundwater in basalt-confined wells in other regions of the Hanford Site is uncontaminated, based on data from a small number of available wells that were sampled in recent years (Table 4-2).

Table 4-1. Groundwater Quality in Ringold Confined Aquifers

Groundwater Interest Area (Report Section)	Wells Sampled	Groundwater Contamination[a]
Wells Screened in Ringold Upper Mud Unit		
100-BC-5 (2.2)	199-B2-12, 199-B2-15	None
100-KR-4 (2.3)	199-K-32B, 199-K-192	None
100-NR-2 (2.4)	199-N-80	Hexavalent chromium: up to 198 µg/L[b] Tritium: up to 16,000 pCi/L
100-HR-3 (2.5)	199-D8-54B, 199-H3-2C, 199-H4-12C, 199-H4-15CS, 699-97-43C, 699-97-45B, 699-97-48C, 199-D5-134, 199-D5-141, 199-H2-1, 199-H3-9, 199-H3-10	Hexavalent chromium: up to 287 µg/L
100-FR-3 (2.6)	199-F5-43B, 199-F5-53	None
Well Screened in Ringold Unit B		
100-HR-3	199-H4-15CR	None
Wells Screened in Ringold Unit A		
100-HR-3 (2.5)	199-H4-15CQ	None
200-ZP-1(3.2)	299-W12-2, 299-W12-3, 299-W14-73, 299-W14-74, 699-42-67, 699-43-67B, 699-43-69, 699-44-67, 699-45-69C	Carbon tetrachloride: up to 1,800 µg/L Chromium (filtered; 699-43-69): up to 48 µg/L[b] Nitrate: up to 298 mg/L Technetium-99: up to 462 pCi/L
200-UP-1 (3.3)	None	N/A
200-BP-5 (3.4)	699-42-40A, 699-43-41G, 699-45-42, 699-47-35B	Iodine-129: up to 3 pCi/L Tritium: up to 46,000 pCi/L
200-PO-1 (3.5)	699-40-36, 699-41-40, 699-42-37, 699-42-39B	Chromium (filtered; 699-42-37): up to 19.7 µg/L[b] Iodine-129: up to 1 pCi/L Tritium: up to 36,000 pCi/L
300-FF-5 (2.7)	399-1-16C, 399-1-17C, 399-1-18C, 399-1-9, 399-8-5C	None
1100-EM-1 (2.8)	699-S29-E16C	None

a. Evaluation based on data 2009 through 2011. For wells with characterization data through fully saturated thickness, only considering data from the confined aquifer.

b. Suspected corrosion product.

Table 4-2. Groundwater Quality in Upper Basalt-Confined Aquifer

Groundwater Interest Area	Wells Sampled	Groundwater Contamination[a]
Wells Screened in Upper Saddle Mountains Basalt Flow Top[b]		
200-BP-5	699-54-34, 699-56-43	None
200-PO-1	299-E16-1, 299-E33-40, 699-13-1C, 699-42-E9B	None
Wells Screened in Rattlesnake Ridge Interbed		
100-BC-5	699-66-91	None
100-HR-3	199-H4-2, 199-H4-15CP	None
200-BP-5	299-E26-8, 299-E33-12, 299-E33-50, 299-E33-340, 699-49-55B, 699-49-57B, 699-50-45, 699-50-53B, 699-52-46A, 699-52-55B, 699-54-45B, 699-54-57, 699-56-53	Chromium (filtered; 699-50-53B): up to 17 µg/L[c] Cyanide: up to 27 µg/L[d] Technetium-99: up to 1,200 pCi/L[d]
200-PO-1	699-24-1P, 699-32-22B, 699-42-40C	Iodine-129: up to 0.289 pCi/L Tritium: up to 4,300 pCi/L
1100-EM-1	699-S24-19P	None
Wells Screened in Levey Interbed		
300-FF-5	399-5-2	None
1100-EM-1	699-S11-E12AP	None

a. Evaluation based on data 2009 through 2011.

b. Some of these wells are screened in the flow top and the Rattlesnake Ridge interbed.

c. Suspected corrosion product.

d. Not representative of basalt-confined aquifer. Migrated down wellbore from unconfined aquifer; see text.

Figure 4-1. Ringold Confined Monitoring Wells

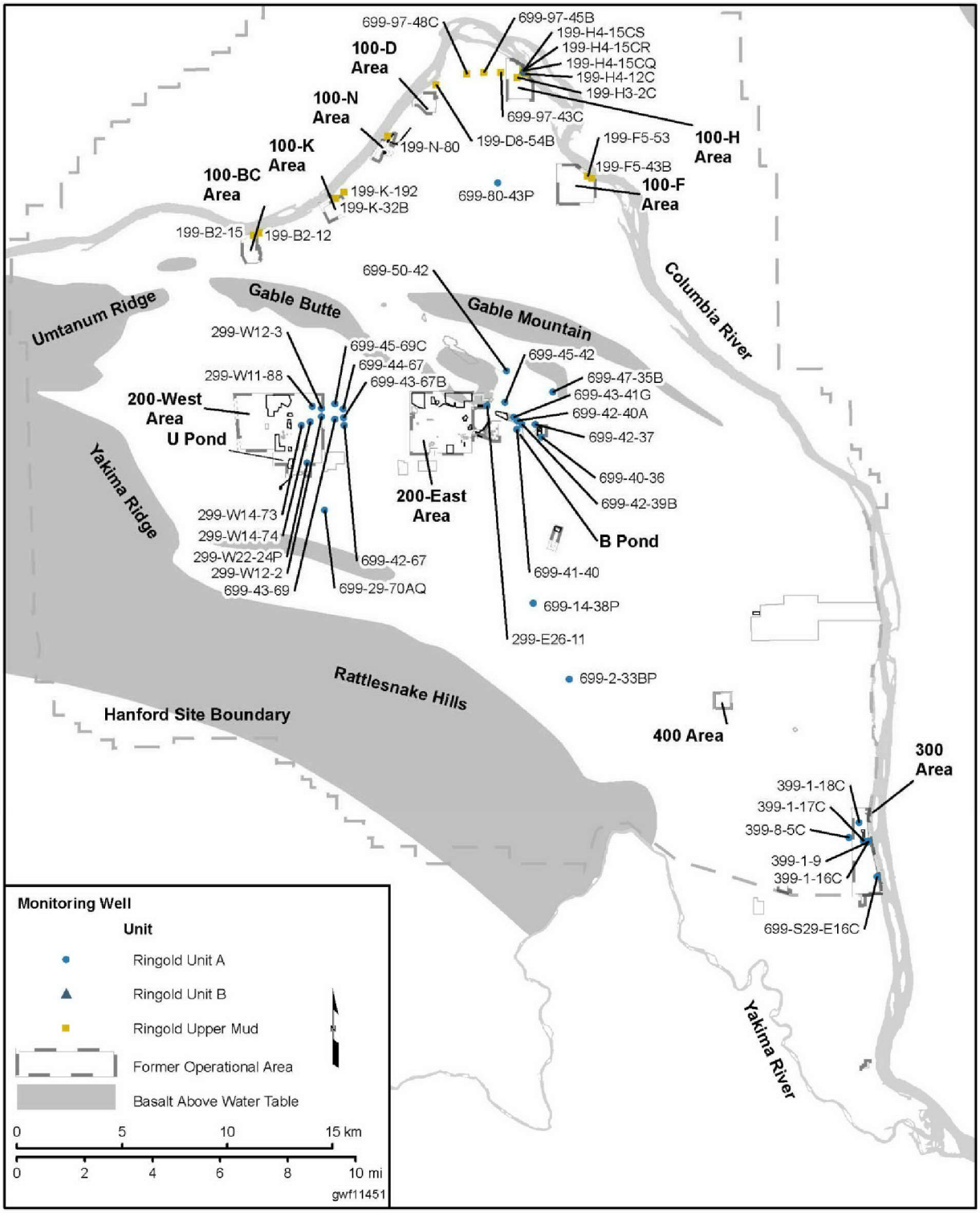


Figure 4-2. Potentiometric Surface for Ringold Unit A, March 2011

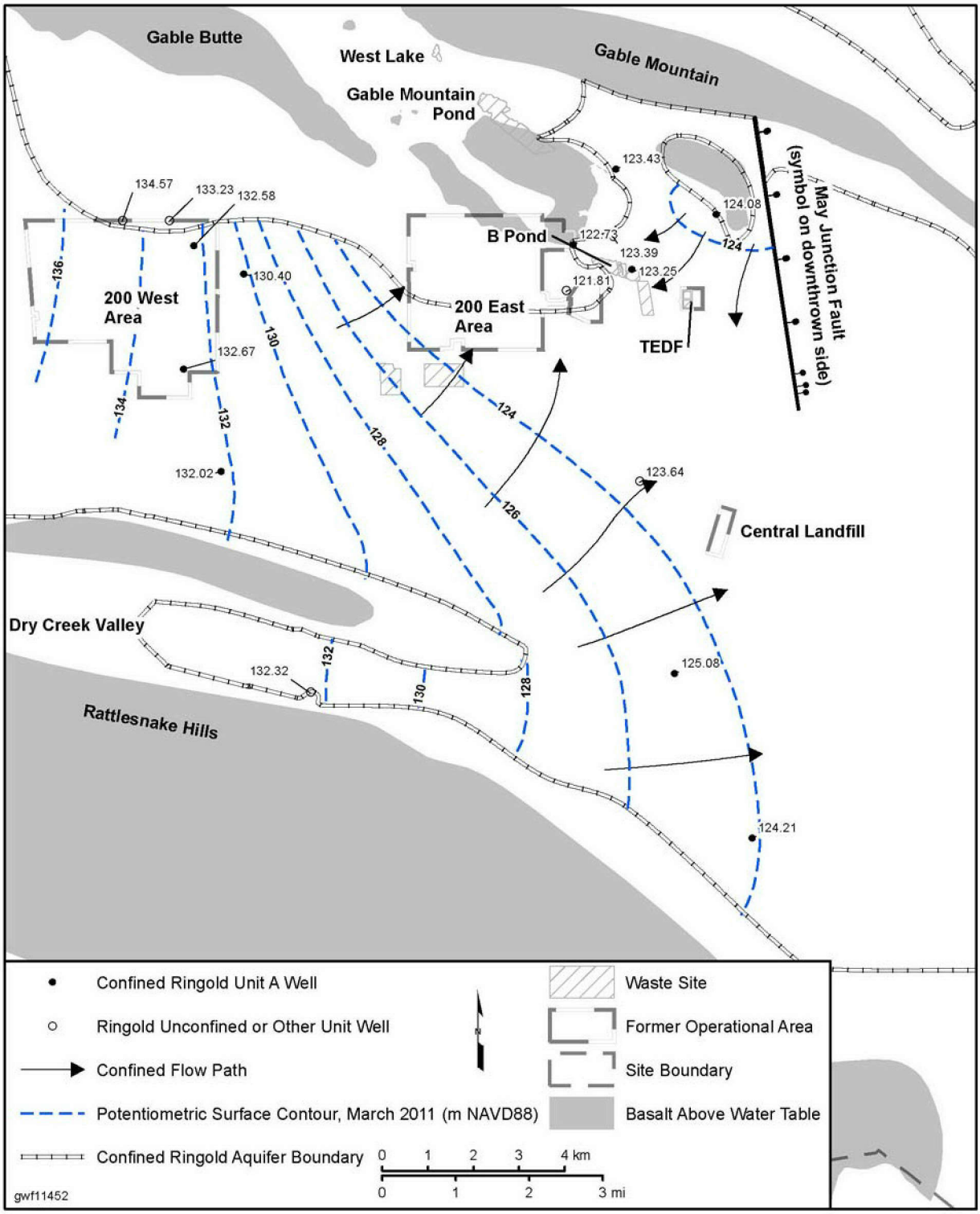


Figure 4-3. Basalt-Confined Monitoring Wells

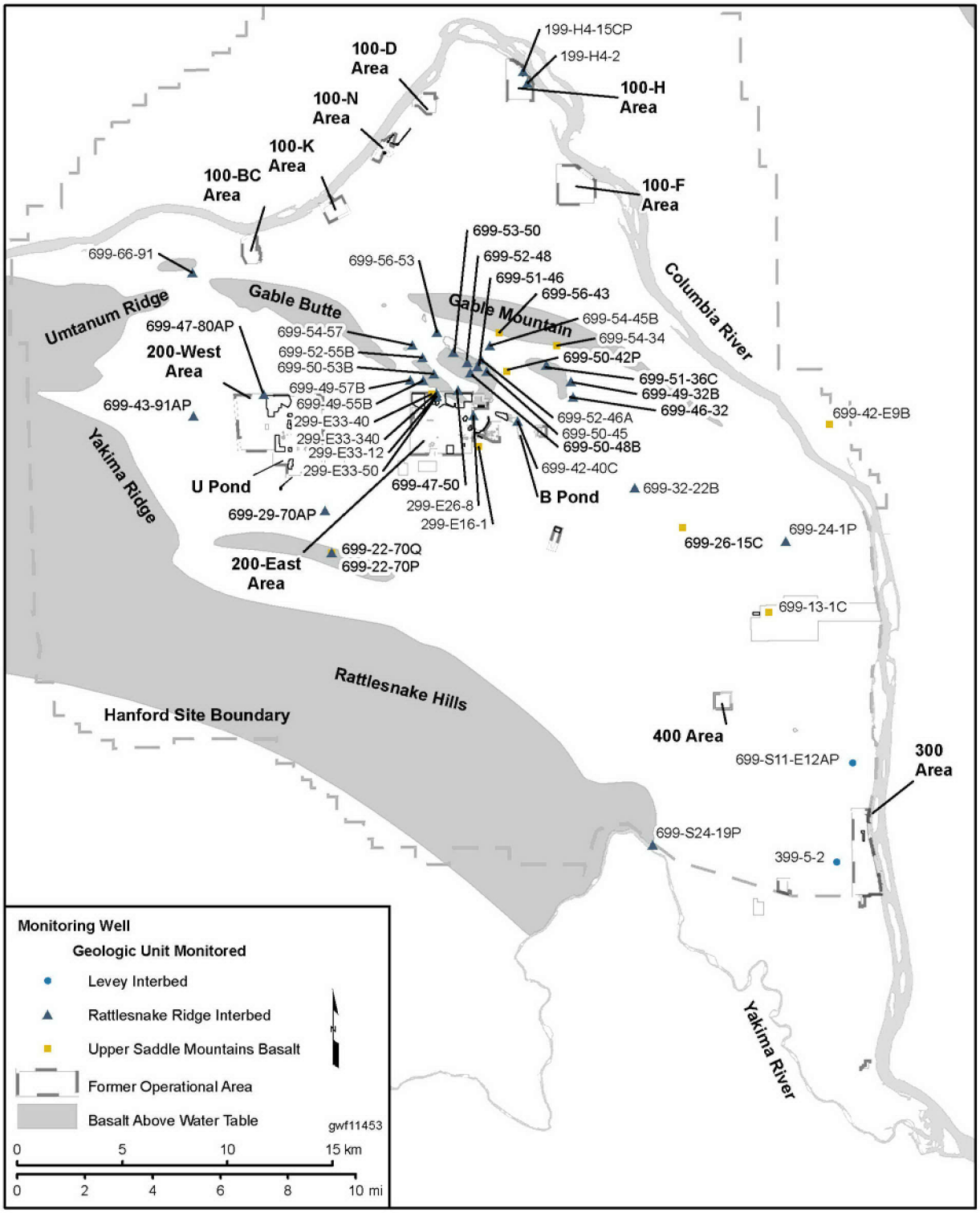


Figure 4-4. Potentiometric Surface for Upper Basalt-Confined Aquifer, March 2011

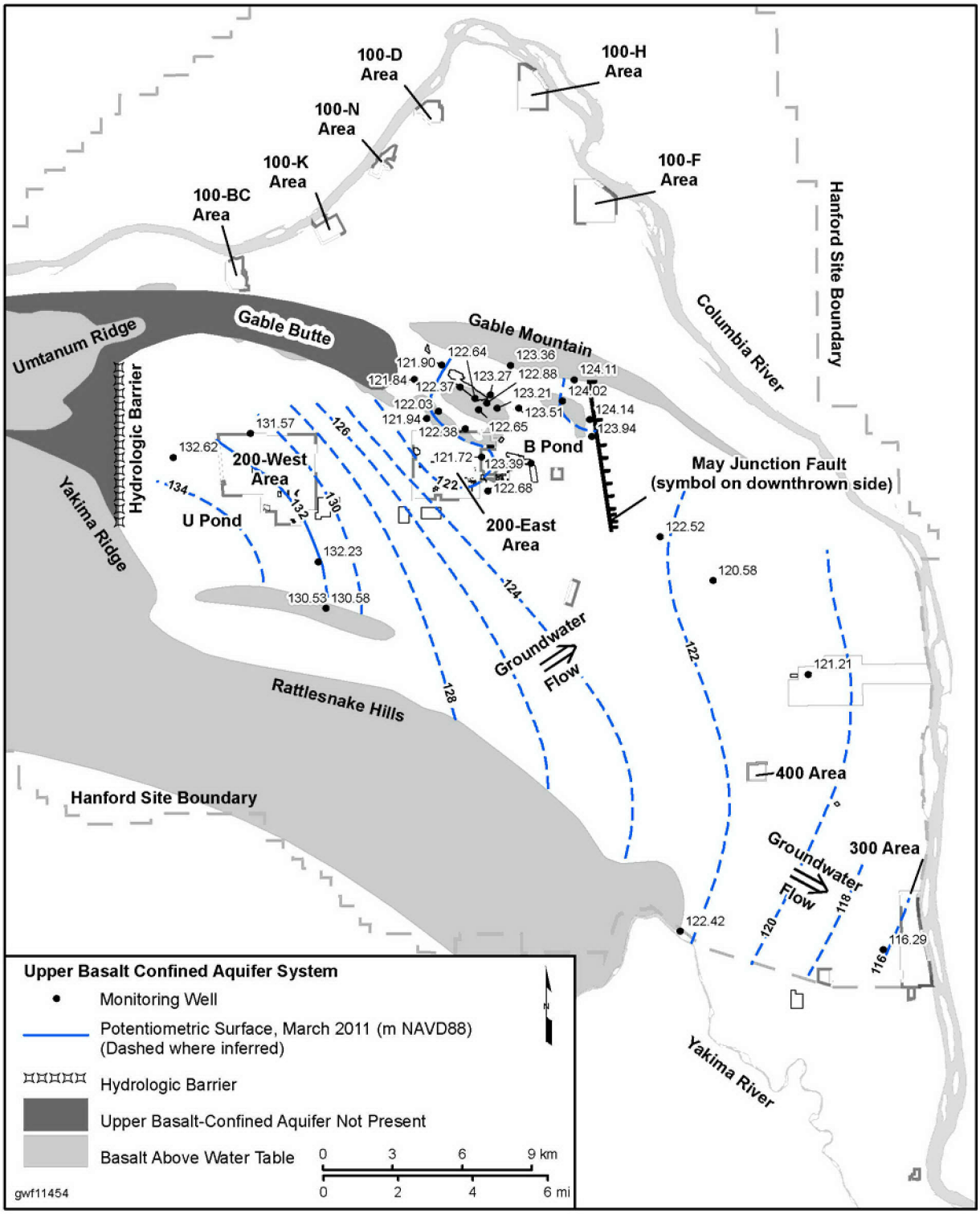
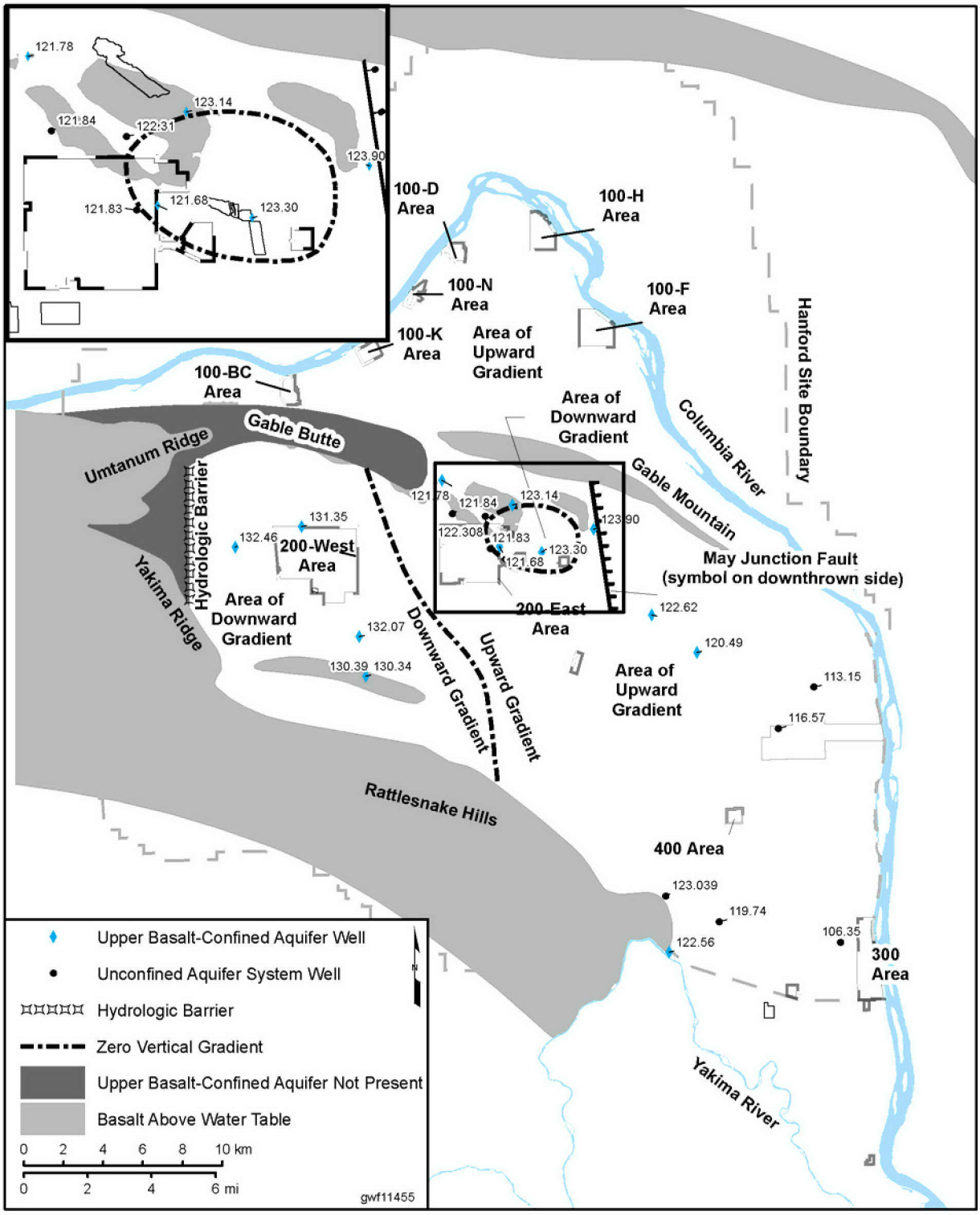


Figure 4-5. Comparison of Observed Heads for Upper Basalt-Confined Aquifer and Overlying Unconfined Aquifer, 2011



5.0 Well Installation, Maintenance, and Decommissioning

L.C. Swanson and B.J. Howard

This chapter describes well installation, maintenance, and decommissioning activities on the Hanford Site in 2011. Numerous water wells were drilled or hand dug by early settlers for drinking water supplies, beginning in the early half of the 20th Century. Several thousand wells have been drilled since the early 1940s to support the Site's nuclear weapons production program. Since the 1990s, many additional wells have been drilled to support the Site's environmental cleanup mission.

All well types are tracked on the Hanford Site through the Well Information and Document Lookup (WIDL) database, which is available to users of the Hanford Local Area Network. Much of this information (borehole geophysical logging reports and data sheets) is also available to the public through DOE's Environmental Dashboard Application (http://environet.hanford.gov/eda). Other data can be accessed via borehole summary reports (report numbers prefixed by SGW) that are generated for each drilling campaign.

Recognized well types on site include aquifer tubes, borings, groundwater wells, hosted piezometers, independent piezometers, piezometer hosts, soil tubes, lysimeters, and vadose wells (Table 5-1). All wells (cased and uncased), borings, aquifer tubes, soil tubes, piezometers, and other subsurface excavations are required to receive a unique Hanford well identification number. A total of 11,382 unique well identification numbers had been assigned on the Hanford Site by the end of 2011. Ecology also assigns a well identification number to each of these well types.

Figure 5-1 presents the categorization of unique well identification numbers taken from the WIDL database and their approximate geographic designations. Figure 1-1 in Chapter 1 shows how the geographic designations are located across the Hanford Site.

During 2011, a total of 4,034 of these unique well identification numbers were documented to be in use, representing 2,951 wells, 122 piezometers within host wells, 78 lysimeters within host lysimeters, 526 aquifer tubes, and 357 soil tubes. Thus, of the 11,382 wells drilled, 7,328 wells are no longer used or have been decommissioned.

5.1 Monitoring Well Installation

DOE works with the appropriate regulatory agencies to define the need for new wells at the Hanford Site. Each year, DOE proposes new wells to meet the requirements of RCRA detection and assessment groundwater monitoring requirements; characterization, remediation, and monitoring for CERCLA; and long-term monitoring of regional groundwater plumes in accordance with DOE orders based on AEA requirements. These efforts may include new or ongoing RCRA assessment of groundwater contamination, replacement of monitoring wells that go dry because of the declining regional water table, replacement of wells that need to be decommissioned, improvement of spatial coverage for different monitoring networks and plume monitoring, and characterization of subsurface contamination.

New RCRA, CERCLA, and AEA well proposals are reviewed, prioritized, and approved annually in accordance with the Tri-Party Agreement (Ecology et al., 1989) Milestone M-024. All new wells are constructed as either Resource Protection Wells or Water Supply wells in accordance with the Washington State provisions of WAC 173-160. Well requirements are integrated, prioritized, and documented through the budget development process, discussions between DOE and the regulatory agencies, and specific monitoring and characterization requirements.

The *American Recovery and Reinvestment Act of 2009* (ARRA) supplemented baseline funding in 2011 for planning and building new groundwater and deep vadose zone monitoring wells, borehole sampling, treatability tests, and remediation systems in order to achieve the Tri-Party Agreement (Ecology et al., 1989) milestones.

In 2011, a total of 89 new groundwater monitoring wells were installed on the Hanford Site.

During 2011, 89 wells were installed[1] at the Hanford Site (Table 5-2). The approximate locations of the new wells are shown in Figures 5-2 through 5-5.

Water well reports for all newly constructed wells, as required by WAC 173-160, were submitted to Ecology. Detailed well information such as geologic and geophysical descriptions, characterization activities (that is, sediment and groundwater sampling, aquifer testing), and construction records for the new wells are stored in WIDL and consolidated in borehole summary reports. Much of this information is also accessible and available through DOE's Environmental Dashboard Application (http://environet.hanford.gov/eda).

5.2 Borings

In 2011, 49 direct-push and characterization boreholes were drilled, sampled, and decommissioned.

During 2011, 49 direct-push and characterization boreholes were installed. The boreholes supported subsurface characterization of radiological constituents, volatile organics (for example, carbon tetrachloride), or vadose zone property determination (such as moisture content or grain-size distribution). In some instances, vadose zone borings were drilled to the top of the groundwater to obtain a one-time water sample as an opportunity for working cross-project to meet data needs. Table 5-3 provides a summary of the number and general location of the direct-push and characterization boreholes. Figure 5-3 shows the approximate locations of the new borings; Figures 5-3 through 5-5 show area specific locations.

5.3 Maintenance

During 2011, well maintenance tasks included surface modifications on the different well types, such as repair or replacement of locking well caps, surface casing, diagnosis and repair of electrical wiring, and modifications to surface pump and riser pipe discharge components and fittings. Subsurface tasks typically included repair and replacement of sampling pumps, downhole camera surveys, pump and equipment retrieval, and replacement of discharge tubing. Well rehabilitation activities included surging, swabbing, screen brushing, chemical treatment, and over-pumping to improve well performance.

Documentation for well maintenance activities is entered into the Well Maintenance Application database, and accessible through WIDL. This information is also accessible externally through the Environmental Dashboard Application (http://environet.hanford.gov/eda).

5.4 Decommissioning

As part of DOE asset management, wells, boreholes, or other subsurface installations are identified for decommissioning when they are no longer useful for achieving the Hanford Site environmental cleanup mission. Well decommissioning is driven by the *Hanford Site Well Decommissioning Plan* (DOE/RL-2005-70). Decommissioning is defined therein as the properly completed and documented sealing of water or resource-protection wells in compliance with state groundwater protection laws

[1] Wells completed (accepted) in 2011. In some cases, drilling began in 2010.

(WAC 173-160). The plan lays out the basis, decision logic, and implementation process for prioritizing and decommissioning Hanford Site wells.

All candidate wells for decommissioning must be reviewed and approved by Hanford Site contractors, DOE, Ecology, EPA, and other potential well users such as the Pacific Northwest National Laboratory prior to decommissioning. The initial phase of decommissioning includes a thorough records review and physical inspection of each well to confirm the well's location and configuration (the well attributes). Normally, a well becomes a candidate for decommissioning under one of the following conditions:

- The well currently is no longer used for water-level or contaminant monitoring, contaminant extraction, in situ remedial treatment of contaminated groundwater, permitted injection of treated effluent from a remedial action, water supply, or is no longer is a research or technology demonstration well.
- The well has no specified future purpose.
- The well is unusable, abandoned, or its use has been permanently discontinued.
- The well is in such disrepair that its continued use is impractical.
- The well is an environmental, safety, or public health hazard (for example, it does not meet WAC 173-160 requirements for well completion; however, there are special provisions for continued use of a non-WAC 173-160 compliant well).
- The well interferes with environmental remediation, excavation, and/or construction activities.

In 2011, 108 wells (Table 5-4) were physically decommissioned. Decommissioning is performed in accordance with WAC 173-160-460 ("What Is the Decommissioning Process for Resource Protection Wells?"), applicable well decommissioning variances, and conditions defined in the Hanford Facility RCRA Permit (WA78900008967).

Wells are decommissioned (filled with grout) when they are no longer useful for monitoring purposes. In 2011, DOE decommissioned 108 wells.

Decommissioning typically involves backfilling a well with impermeable material in both the annular space and the casing to prevent vertical movement of water and/or contaminants into the vadose zone and groundwater. For wells that are constructed according to WAC 173-160 requirements (compliant), decommissioning is performed by filling the well screen and the casing with an impermeable material (e.g., bentonite or cement grout). For older, noncompliant wells, the casing is either removed and the borehole filled with seal material or the casing is perforated and pressure grouted to create an external annular seal and then internally grouted to the surface. As far as possible, all casing is removed from the ground. A brass survey marker identifying the former well is typically set in cement grout at the ground surface over the decommissioned location. Decommissioning activities result in the permanent removal of a well, borehole, or piezometer from service and from the Hanford Site active well inventory.

A completed water well report form is required to be transmitted by the contractor or in-house driller to Ecology when a well is decommissioned. The report provides the details on the well's final construction and the steps taken to decommission the well.

In 2011, in addition to the physical decommissioning of wells, 13 wells were administratively decommissioned. Administratively decommissioned wells may be wells that can no longer be located and are determined to no longer exist, or more generally, are wells that were physically decommissioned but

still require documentation about such in the well database. Field walk-downs for these 13 wells confirmed that these wells cannot be found.

Each year a very limited number of previously unknown wells are also discovered during the conduct of field activities. Once discovered, these wells are assigned a unique well identification number, assigned an appropriate well status, and added to WIDL. In 2011, eight wells were discovered.

Table 5-1. Hanford Site Well Types

Well Category	Description
Aquifer Tube	A groundwater monitoring site installed along the river shoreline. Generally consists of a small diameter tube (less than one inch) and screen installed using push technology near the water table.
Boring	A borehole or direct push that was decommissioned immediately after drilling. Decommissioning generally would have been performed before the drill rig was removed from the site.
Groundwater Well	A well constructed with the open interval extending below the water table. This is the general case and should not be used if the site could be otherwise classified as an aquifer tube, piezometer, or piezometer host.
Hosted Piezometer	Groundwater monitoring well constructed inside of a host well. In most cases, hosted piezometers are one and one-half inch in diameter with the open interval extending below the water table.
Independent Piezometer	Small diameter, independent, groundwater monitoring well not constructed inside of a host well. In most cases, the independent piezometers are one and one-half inch in diameter.
Lysimeter	Generally an in situ open bottom cylindrical core where the top is coincident with the ground surface, and with walls that prevent horizontal movement of moisture. A lysimeter is used to measure moisture or contaminant changes through time over a specific depth interval.
Piezometer Host	A well with one or more piezometers constructed inside it.
Soil Tube	Vadose zone monitoring site. A small diameter tube (less than two inches in diameter) and possibly a screen are left in place after the drilling is completed for sampling.
Vadose Well	A vadose zone monitoring site where casing (greater than two inches in diameter) is left in place after drilling activities are completed. May have a screen, open bottom, or may be closed.

Table 5-2. Wells Installed in 2011

Operable Unit	Well Name	Well ID	Well Purpose	Construction Depth (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
100-BC-5	199-B2-15	C7783	Support RI/FS	171.55	193.8	2/22/2011
100-BC-5	199-B2-16	C7784	Support RI/FS	149.07	155.2	2/22/2011
100-BC-5	199-B3-51	C7785	Support RI/FS	150.92	156.2	3/21/2011
100-BC-5	199-B3-52	C7843	Support RI/FS	59.5	60	12/30/2010*
100-BC-5	199-B4-15	C7846	Support RI/FS	84.2	84.3	12/30/2010*
100-BC-5	199-B5-8	C8244	Support RI/FS	123	230.6	3/21/2011
100-BC-5 Total = 6						
100-FR-3	199-F5-55	C7970	Support RI/FS	50	50	3/15/2011
100-FR-3	199-F5-56	C7972	Support RI/FS	49.45	50.9	3/15/2011
100-FR-3 Total = 2						
100-HR-3	199-D3-5	C7620	Support RI/FS	108.8	112.2	5/10/2011
100-HR-3	199-D5-132	C7622	Support RI/FS	110.84	112	5/10/2011
100-HR-3	199-D5-133	C7621	Support RI/FS	109.96	112	5/10/2011
100-HR-3	199-D5-134	C7624	Support RI/FS	145	270	5/10/2011
100-HR-3	199-D5-140	C7866	Support RI/FS	112.9	111.31	5/10/2011
100-HR-3	199-D5-141	C7625	Support RI/FS	174	316.7	5/10/2011
100-HR-3	199-D5-142	C7857	Support RI/FS	87.3	89.8	2/23/2011
100-HR-3	199-D5-143	C8375	Support RI/FS	109.9	118	5/10/2011
100-HR-3	199-D5-144	C8668	Support RI/FS	113.5	114.7	11/9/2011
100-HR-3	199-D6-3	C7623	Support RI/FS	106.1	110.5	5/10/2011
100-HR-3	199-D8-101	C7852	Support RI/FS	72	72	2/23/2011
100-HR-3	199-H1-3	C7581	100-H Pump-and-Treat	47	48.5	4/28/2011
100-HR-3	199-H1-4	C7604	100-H Pump-and-Treat	46.22	48.5	4/26/2011
100-HR-3	199-H1-6	C7606	100-H Pump-and-Treat	40.86	47	4/27/2011
100-HR-3	199-H3-11	C7863	100-H Pump-and-Treat	52.4	55.8	2/23/2011
100-HR-3	199-H4-83	C7861	100-H Pump-and-Treat	42.2	42.25	2/23/2011
100-HR-3	199-H4-84	C7860	Support RI/FS	48	48.6	2/23/2011
100-HR-3	199-H1-7	C7630	Support RI/FS	36.5	37	5/10/2011
100-HR-3	199-H2-1	C7631	Support RI/FS	76.96	189	5/10/2011
100-HR-3	199-H3-10	C7640	Support RI/FS	115.86	230.8	5/10/2011
100-HR-3	199-H3-6	C7626	Support RI/FS	59.5	61.6	5/10/2011
100-HR-3	199-H3-7	C7627	Support RI/FS	57.28	59	5/10/2011

Table 5-2. Wells Installed in 2011

Operable Unit	Well Name	Well ID	Well Purpose	Construction Depth (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
100-HR-3	199-H3-9	C7639	Support RI/FS	91.14	218.1	5/10/2011
100-HR-3	199-H6-3	C7628	Support RI/FS	67	67.4	5/10/2011
100-HR-3	199-H6-4	C7629	Support RI/FS	61.8	63.6	5/10/2011
100-HR-3 Total = 25						
100-KR-4	199-K-196	C7696	100-K Pump-and-Treat	136.01	139.8	9/29/2011
100-KR-4	199-K-197	C7697	100-K Pump-and-Treat	105.55	108.3	9/29/2011
100-KR-4	199-K-198	C7698	100-K Pump-and-Treat	57.93	101.5	9/30/2011
100-KR-4	199-K-199	C7699	100-K Pump-and-Treat	97	103.1	9/30/2011
100-KR-4	C8205	C8205	Grounding Wells 100-K Substation	181.2	186.4	2/2/2011
100-KR-4	C8226	C8226	Grounding Wells 100-K Substation	191	191	2/2/2011
100-KR-4	199-K-184	C7684	Support RI/FS	167.8	216.1	3/28/2011
100-KR-4	199-K-185	C7685	Support RI/FS	136.5	138.5	3/28/2011
100-KR-4	199-K-186	C7686	Support RI/FS	137.17	167	3/28/2011
100-KR-4	199-K-188	C7688	Support RI/FS	133.1	235	3/28/2011
100-KR-4	199-K-189	C7689	Support RI/FS	159	159	3/28/2011
100-KR-4	199-K-192	C7692	Support RI/FS	188.2	192.9	3/28/2011
100-KR-4	199-K-193	C7693	Support RI/FS	166.3	166.3	3/28/2011
100-KR-4	199-K-194	C7694	Support RI/FS	110.8	147.3	3/28/2011
100-KR-4	199-K-195	C7695	Support RI/FS	128.58	230.5	3/28/2011
100-KR-4 Total = 15						
100-NR-2	199-N-182	C8184	Support RI/FS	109.4	154	9/29/2011
100-NR-2	199-N-183	C8185	Support RI/FS	90.1	117.4	9/29/2011
100-NR-2	199-N-184	C8186	Support RI/FS	84.9	108	9/29/2011
100-NR-2	199-N-185	C8187	Support RI/FS	45.4	92.5	9/29/2011
100-NR-2	199-N-186	C8188	Support RI/FS	91.7	97.3	9/29/2011
100-NR-2	199-N-187	C8189	Support RI/FS	94	94.5	9/29/2011
100-NR-2	199-N-188	C8190	Support RI/FS	83.8	90	9/29/2011
100-NR-2	199-N-189	C8191	Support RI/FS	110.1	117.3	9/29/2011
100-NR-2 Total = 8						
200-BP-5	299-E26-14	C8204	LERF Monitoring Well	218.9	240.6	9/29/2011
100-BP-5 Total = 1						

Table 5-2. Wells Installed in 2011

Operable Unit	Well Name	Well ID	Well Purpose	Construction Depth (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
200-PO-1	299-E13-120	C8387	Support Site Characterization Grounding Truth in the BC Cribs	59.41	65.2	9/21/2011
200-PO-1	299-E13-121	C8388	Support Site Characterization Grounding Truth in the BC Cribs	59.22	65	9/21/2011
200-PO-1 Total = 2						
200-UP-1	299-W22-90	C8095	S-SX Extraction Well for Technetium-99	292.48	317	11/29/2011
200-UP-1	299-W22-96	C8241	S-SX Monitoring Well	280.68	286.1	10/19/2011
200-UP-1	299-W22-91	C8096	S-SX Extraction Well for Technetium-99	295	307.3	10/19/2011
200-UP-1	299-W22-92	C8097	S-SX Extraction Well for Technetium-99	289.94	307.4	10/19/2011
200-UP-1 Total = 4						
200-ZP-1	299-W10-35	C7573	200 West Pump-and-Treat Expansion	459.7	519	1/20/2011
200-ZP-1	299-W10-36	C8066	200 West Pump-and-Treat Expansion	435	457	11/7/2011
200-ZP-1	299-W11-50	C7020	200 West Pump-and-Treat Expansion	430.41	490	1/20/2011
200-ZP-1	299-W6-13	C8064	200 West Pump-and-Treat Expansion	449.94	451	11/7/2011
200-ZP-1	299-W6-14	C8065	200 West Pump-and-Treat Expansion	475	475.8	11/7/2011
200-ZP-1	299-W9-2	C8201	Monitor Mixed-Waste Trenches 31 and 34, Upgradient	324.57	325	9/29/2011
200-ZP-1 Total = 6						
300-FF-5	399-1-60	C7867	Support IFRC	60.05	72.2	4/5/2011
300-FF-5	399-2-33	C7868	Support IFRC	57.7	69.2	4/5/2011
300-FF-5	399-3-34	C7870	Support IFRC	55.02	63.5	4/5/2011
300-FF-5	399-3-37	C7869	Support IFRC	41.55	59.6	4/5/2011
300-FF-5	399-1-54	C7653	Support RI/FS	44.07	118.5	2/15/2011
300-FF-5	399-1-55	C7654	Support RI/FS	43.05	113	2/15/2011
300-FF-5	399-1-56	C7655	Support RI/FS	40	123.5	2/15/2011

Table 5-2. Wells Installed in 2011

Operable Unit	Well Name	Well ID	Well Purpose	Construction Depth (ft bgs)	Drilled Depth (ft bgs)	Acceptance Date
300-FF-5	399-1-57	C7656	Support RI/FS	80	118.5	2/15/2011
300-FF-5	399-1-58	C7657	Support RI/FS	55.55	126	2/15/2011
300-FF-5	399-1-59	C7659	Support RI/FS	62.03	148.7	2/15/2011
300-FF-5	399-1-61	C8026	Support RI/FS	46	58	4/5/2011
300-FF-5	399-1-62	C8027	Support RI/FS	38.24	48	4/5/2011
300-FF-5	399-1-63	C8028	Support RI/FS	41	55.5	4/5/2011
300-FF-5	399-1-64	C8029	Support RI/FS	38.91	48	4/5/2011
300-FF-5	399-2-32	C7660	Support RI/FS	42.8	121	2/15/2011
300-FF-5	399-3-33	C7663	Support RI/FS	55.2	135	2/15/2011
300-FF-5	399-3-38	C8030	Support RI/FS	50.09	56.8	4/5/2011
300-FF-5	399-4-15	C7662	Support RI/FS	62.86	146	2/15/2011
300-FF-5	399-6-3	C7658	Support RI/FS	56.9	128.6	2/15/2011
300-FF-5	399-6-5	C8245	Support RI/FS	58.05	156	2/15/2011
300-FF-5 Total = 20						
Grand Total = 89						

bgs = below ground surface

IFRC = Integrated Field-Scale Subsurface Research Challenge

LERF = Liquid Effluent Retention Facility

RI/FS = Remedial Investigation/Feasibility Study

*Completed in late 2010; reported here because they were not included in 2010 report (DOE/RL-2011-01, *Hanford Site Groundwater Monitoring Report for 2010*).

Table 5-3. Borings Installed in 2011

Operable Unit	Project or Location	Well ID	Drill Depth (ft)	Type of Boring
200-UP-1	216-S-19 Waste Site	C8145	16	Direct-push
200-UP-1	Adjacent to 216-S-19 Waste Site	C8154	16	Direct-push
200-UP-1	Adjacent to 216-S-19 Waste Site	C8155	16	Direct-push
200-UP-1	Adjacent to 216-S-19 Waste Site	C8156	16	Direct-push
200-UP-1	Adjacent to 216-S-19 Waste Site	C8157	16	Direct-push
200-UP-1	Adjacent to 216-S-19 Waste Site	C8158	16	Direct-push
200-UP-1	216-S-19 Waste Site	C8146	16	Direct-push
200-UP-1	216-S-19 Waste Site	C8147	16	Direct-push
200-UP-1	Adjacent to 216-S-19 Waste Site	C8148	16	Direct-push
200-UP-1	200-W-27 Waste Site	C8149	16	Direct-push
200-UP-1	216-S-19 Waste Site	C8150	16	Direct-push
200-UP-1	216-S-19 Waste Site	C8151	16	Direct-push
200-UP-1	216-S-19 Waste Site	C8152	16	Direct-push
200-UP-1	216-S-19 Waste Site	C8153	16	Direct-push
200-UP-1	216-S-19 Waste Site	C8159	16	Direct-push
200-UP-1 Total = 15				
100-HR-3	116-D-7 Waste Site	C7851	69	Characterization
100-HR-3	116-DR-9 Waste Site	C7850	72.3	Characterization
100-HR-3	116-H-1 Waste Site	C7864	50.8	Characterization
100-HR-3 Total = 3				
100-FR-3	118-F-1 Waste Site	C7971	33.5	Characterization
100-FR-3	600-127 Waste Site	C8221	3.2	Direct-push
100-FR-3	600-127 Waste Site	C8222	2.3	Direct-push
100-FR-3	600-127 Waste Site	C8220	5.3	Direct-push
100-FR-3	600-127 Waste Site	C8219	4	Direct-push
100-FR-3	600-127 Waste Site	C8218	4	Direct-push
100-FR-3 Total = 6				
200-UP-1	Underground Diesel Storage Tank at Plutonium Finishing Plant	C8431	13	Direct-push
200-UP-1	Underground Diesel Storage Tank at Plutonium Finishing Plant	C8432	13	Direct-push
200-UP-1	Underground Diesel Storage Tank at Plutonium Finishing Plant	C8433	13	Direct-push

Table 5-3. Borings Installed in 2011

Operable Unit	Project or Location	Well ID	Drill Depth (ft)	Type of Boring
200-UP-1	Underground Diesel Storage Tank at Plutonium Finishing Plant	C8434	13	Direct-push
200-UP-1	Underground Diesel Storage Tank at Plutonium Finishing Plant	C8435	13	Direct-push
200-UP-1 Total = 5				
100-KR-4	100-K-42 Waste Site	C8307	39	Direct-push
100-KR-4	100-K-42 Waste Site	C8308	40	Direct-push
100-KR-4	100-K-42 Waste Site	C8309	40	Direct-push
100-KR-4	100-K-42 Waste Site	C8310	40	Direct-push
100-KR-4	100-K-42 Waste Site	C8311	40	Direct-push
100-KR-4	100-K-42 Waste Site	C8312	38	Direct-push
100-KR-4	100-K-42 Waste Site	C8313	36.5	Direct-push
100-KR-4	100-K-42 Waste Site	C8314	34	Direct-push
100-KR-4	100-K-42 Waste Site	C8315	36.5	Direct-push
100-KR-4	100-K-42 Waste Site	C8316	37	Direct-push
100-KR-4	118-KE-1 Waste Site	C8658	39	Direct-push
100-KR-4	118-KE-1 Waste Site	C8659	24	Direct-push
100-KR-4	118-KE-1 Waste Site	C8660	26.5	Direct-push
100-KR-4	118-KE-1 Waste Site	C8661	39	Direct-push
100-KR-4	118-KE-1 Waste Site	C8662	27	Direct-push
100-KR-4	118-KE-1 Waste Site	C8663	40	Direct-push
100-KR-4	100-K-42 Waste Site	C8664	40	Direct-push
100-KR-4	118-KE-1 Waste Site	C8665	38	Direct-push
100-KR-4	118-KE-1 Waste Site	C8666	20	Direct-push
100-KR-4	118-KE-1 Waste Site	C8667	56	Direct-push
100-KR-4 Total = 20				
Grand Total = 49				

Table 5-4. Wells Decommissioned in 2011

Operable Unit or Location	Well Name	Well ID	Out of Service Date
100-FR-3	699-65-38	A5299	3/30/11
100-FR-3 Total = 1			
100-HR-3	199-D2-8	C3040	6/15/11
100-HR-3	199-D5-140	C7866	6/15/11
100-HR-3 Total = 2			
100-KR-4	199-K-195	C7695	4/29/11
100-KR-4	199-K-29	A5480	1/21/2011
100-KR-4	199-K-30	A4655	1/21/2011
100-KR-4 Total = 3			
100-NR-2	199-N-170	C7035	9/9/11
100-NR-2	199-N-174	C7039	7/6/11
100-NR-2	199-N-175	C7040	7/6/11
100-NR-2	199-N-176	C7041	7/6/11
100-NR-2	199-N-177	C7042	7/6/11
100-NR-2	199-N-178	C7043	7/6/11
100-NR-2	199-N-179	C7044	7/6/11
100-NR-2	199-N-180	C7045	7/6/11
100-NR-2	199-N-181	C7046	7/6/11
100-NR-2	199-N-26	A4675	5/3/11
100-NR-2 Total = 10			
200-BP-5	699-55-40	A5255	5/19/11
200-BP-5	699-56-40A	A8881	5/17/11
200-BP-5	699-56-40B	A8882	5/3/11
200-BP-5	699-56-40C	A8883	5/9/11
200-BP-5	699-56-41	A8884	5/11/11
200-BP-5	699-56-42A	A8885	5/23/11
200-BP-5	699-56-42B	A8886	6/7/11
200-BP-5	699-56-42C	A8887	5/24/11
200-BP-5	699-56-42D	A8888	6/23/11
200-BP-5	699-56-42E	A8889	6/29/11

Table 5-4. Wells Decommissioned in 2011

Operable Unit or Location	Well Name	Well ID	Out of Service Date
200-BP-5	699-56-42F	A8890	6/14/11
200-BP-5	699-57-41B	A8897	4/29/11
200-BP-5	699-57-41C	A8898	6/1/11
200-BP-5	699-57-41D	A8899	6/1/11
200-BP-5	699-57-41E	A8900	4/20/11
200-BP-5	699-57-42	A8902	4/18/11
200-BP-5	699-58-41A	A8908	3/11/11
200-BP-5	699-58-41C	A8910	3/11/11
200-BP-5	699-58-41D	A8911	3/30/11
200-BP-5	699-58-41E	A8912	3/21/11
200-BP-5	699-58-41F	A8913	4/6/11
200-BP-5	C7788	C7788	4/19/11
200-BP-5	C8031	C8031	3/11/11
200-BP-5 Total = 23			
200-PO-1	699-16-5	A8339	5/6/11
200-PO-1	699-17-15	A8356	5/16/11
200-PO-1	699-17-25C	A8360	5/23/11
200-PO-1	699-17-26G	A8367	5/25/11
200-PO-1	699-17-26H	A8368	5/23/11
200-PO-1	699-17-27D	C3545	5/26/11
200-PO-1	699-18-27C	A8385	5/26/11
200-PO-1	699-20-25	A8422	5/16/11
200-PO-1	699-26-28	C5576	5/17/11
200-PO-1	699-26-29A	A8469	5/4/11
200-PO-1	699-28-23	A8483	4/21/11
200-PO-1	699-30-16	A8495	4/6/11
200-PO-1	699-30-25A	A8496	4/20/11
200-PO-1	699-30-25B	A8497	4/15/11
200-PO-1	699-31-23	A8505	4/15/11
200-PO-1	699-33-21B	A8528	4/13/11

Table 5-4. Wells Decommissioned in 2011

Operable Unit or Location	Well Name	Well ID	Out of Service Date
200-PO-1	699-33-30	A8530	4/15/11
200-PO-1	699-34-19	A8536	4/8/11
200-PO-1	699-34-20	A8537	4/12/11
200-PO-1	699-38-34A	A8596	4/28/11
200-PO-1	699-38-9	A8592	5/18/11
200-PO-1	699-39-2A	A8602	5/18/11
200-PO-1	699-39-E2	A8618	5/18/11
200-PO-1	699-40-32	A8640	4/28/11
200-PO-1	699-40-33C	A8642	4/26/11
200-PO-1	699-41-10	A8649	5/16/11
200-PO-1	699-41-20	A8651	3/22/11
200-PO-1	699-42-21	A8665	3/24/11
200-PO-1	699-42-27	A8666	5/18/11
200-PO-1	699-42-29	A8667	5/25/11
200-PO-1	699-43-18	A8680	3/21/11
200-PO-1	699-43-23	A8681	4/4/11
200-PO-1	699-44-27	A8706	5/20/11
200-PO-1	699-44-28	A8707	5/20/11
200-PO-1	699-45-24	A8719	3/29/11
200-PO-1	699-45-26	A8720	3/24/11
200-PO-1	699-46-15	A8728	3/4/11
200-PO-1	699-47-24	A8746	6/8/11
200-PO-1	699-48-17	A8763	3/7/11
200-PO-1	699-48-22	A8765	3/17/11
200-PO-1	699-49-13C	A8786	3/8/11
200-PO-1	699-49-21	A8789	3/18/11
200-PO-1	699-52-17	A8832	3/2/11
200-PO-1	699-52-18B	A8834	3/2/11
200-PO-1	699-54-15A	A8853	3/3/11
200-PO-1	B2882	B2882	7/19/11

Table 5-4. Wells Decommissioned in 2011

Operable Unit or Location	Well Name	Well ID	Out of Service Date
200-PO-1	B8053	B8053	6/14/11
200-PO-1	B8054	B8054	6/20/11
200-PO-1	B8055	B8055	6/13/11
200-PO-1	B8056	B8056	6/14/11
200-PO-1	B8057	B8057	6/16/11
200-PO-1	B8857	B8857	6/3/11
200-PO-1	B8858	B8858	6/3/11
200-PO-1	B8859	B8859	6/3/11
200-PO-1	B8860	B8860	6/3/11
200-PO-1	B8861	B8861	6/3/11
200-PO-1	B8862	B8862	6/3/11
200-PO-1	B8863	B8863	6/3/11
200-PO-1	B8864	B8864	6/3/11
200-PO-1	C3337	C3337	6/8/11
200-PO-1	C3338	C3338	6/10/11
200-PO-1	C3366	C3366	6/14/11
200-PO-1	C3367	C3367	6/14/11
200-PO-1	C3539	C3539	6/10/11
200-PO-1	C3543	C3543	6/20/11
200-PO-1	C3655	C3655	6/21/11
200-PO-1	HWDS49	C3355	6/8/11
200-PO-1 Total = 67			
Monument North (Wahluke Slope)	699-98-54C	A9098	9/17/11
Monument North (Wahluke Slope)	C8450	C8450	9/17/11
Wahluke Slope Total = 2			
Grand Total = 108			

Figure 5-1. Categorization of Unique Well Identification Numbers

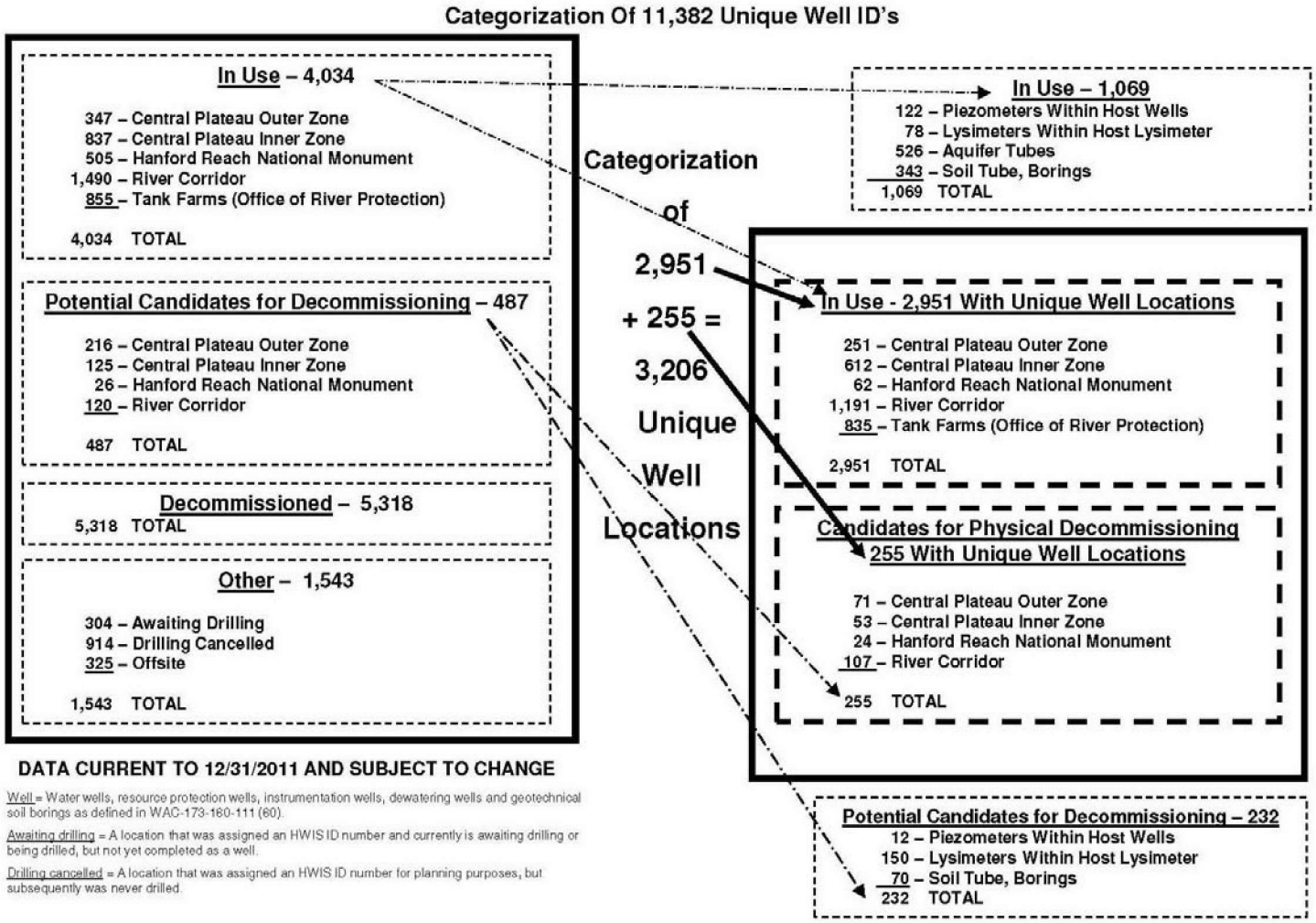
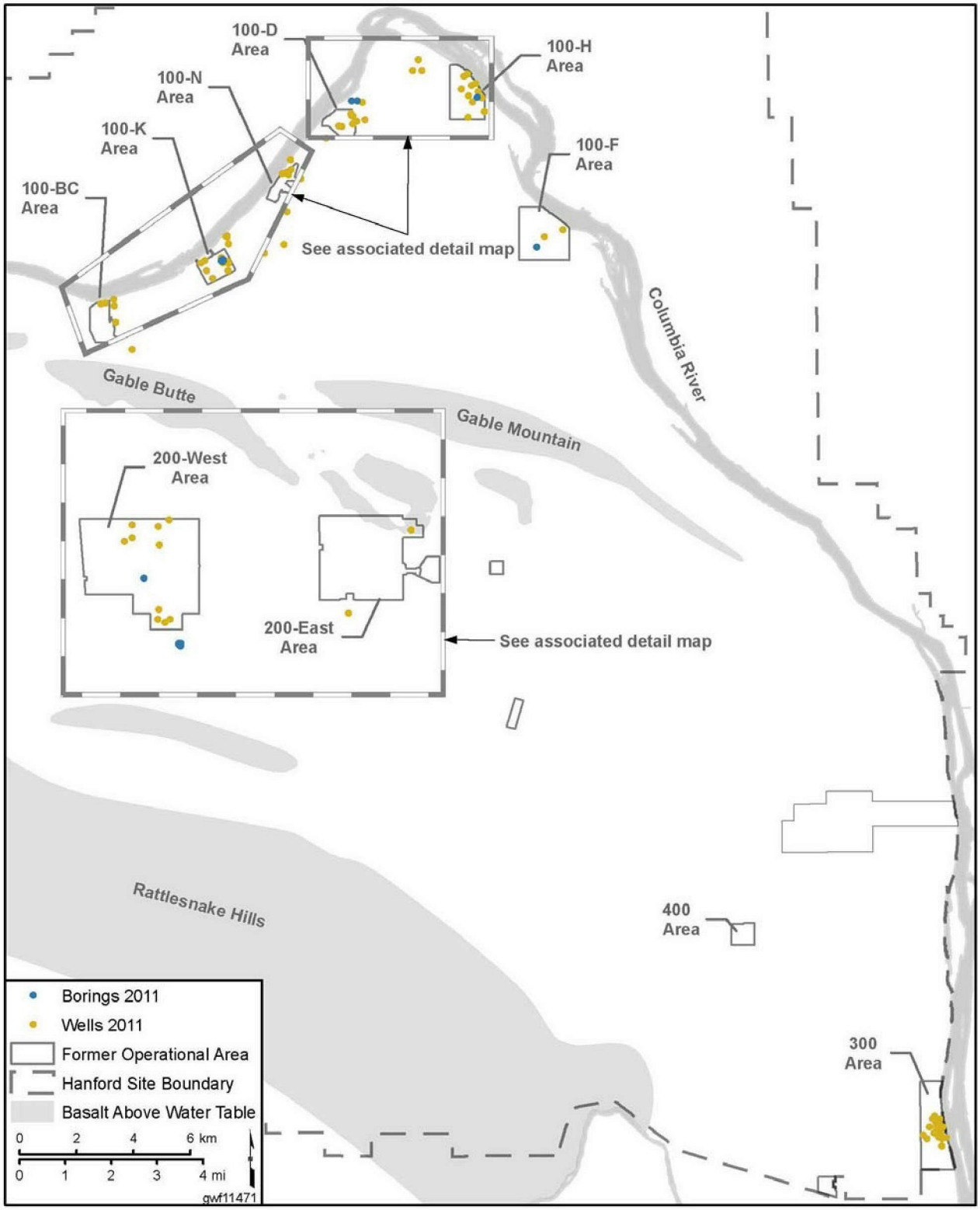


Figure 5-2. Hanford Site Well Installations, 2011



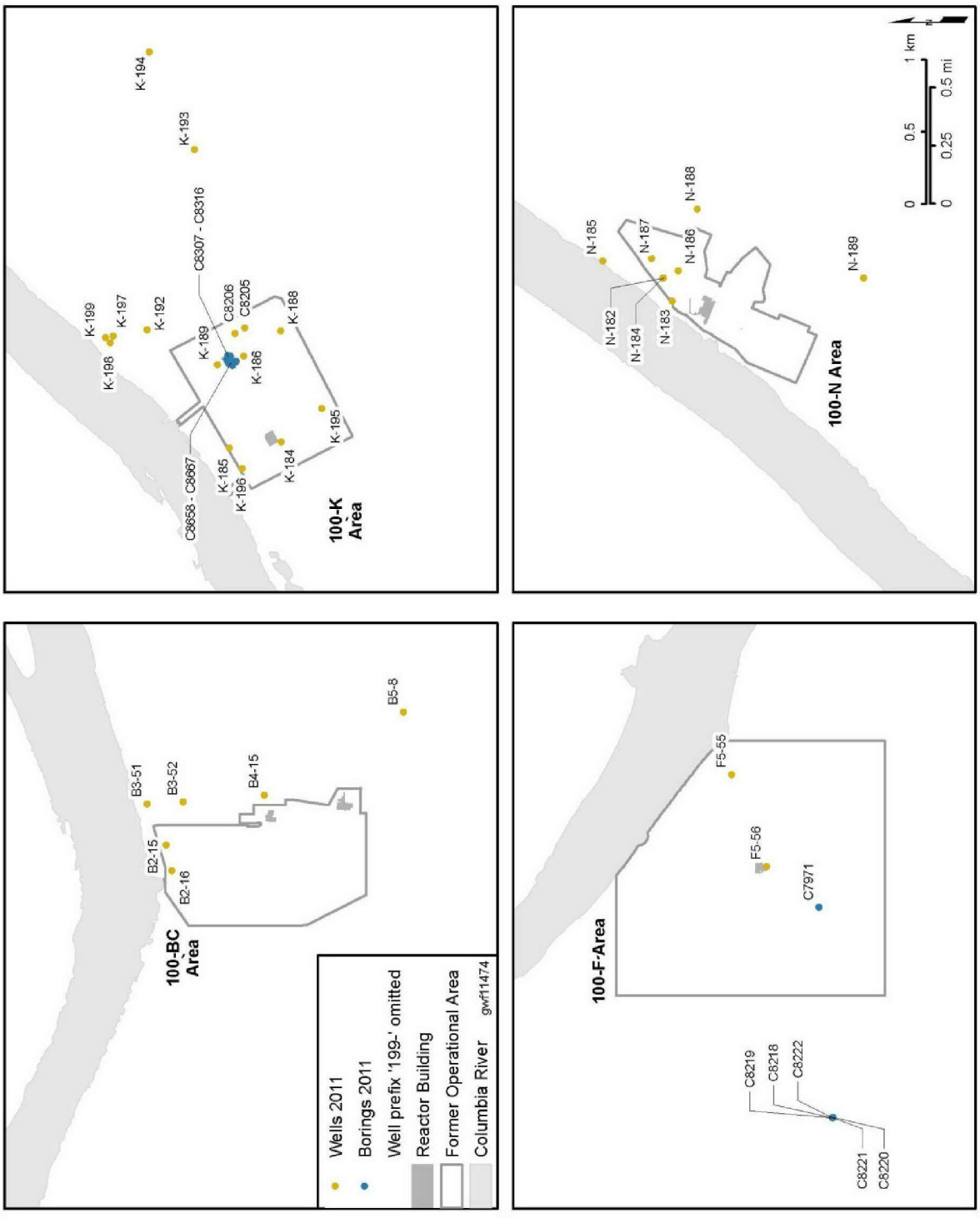


Figure 5-3. 100-BC-5, 100-KR-4, 100-FR-3 and 199-NR-2 Well Installations, 2011

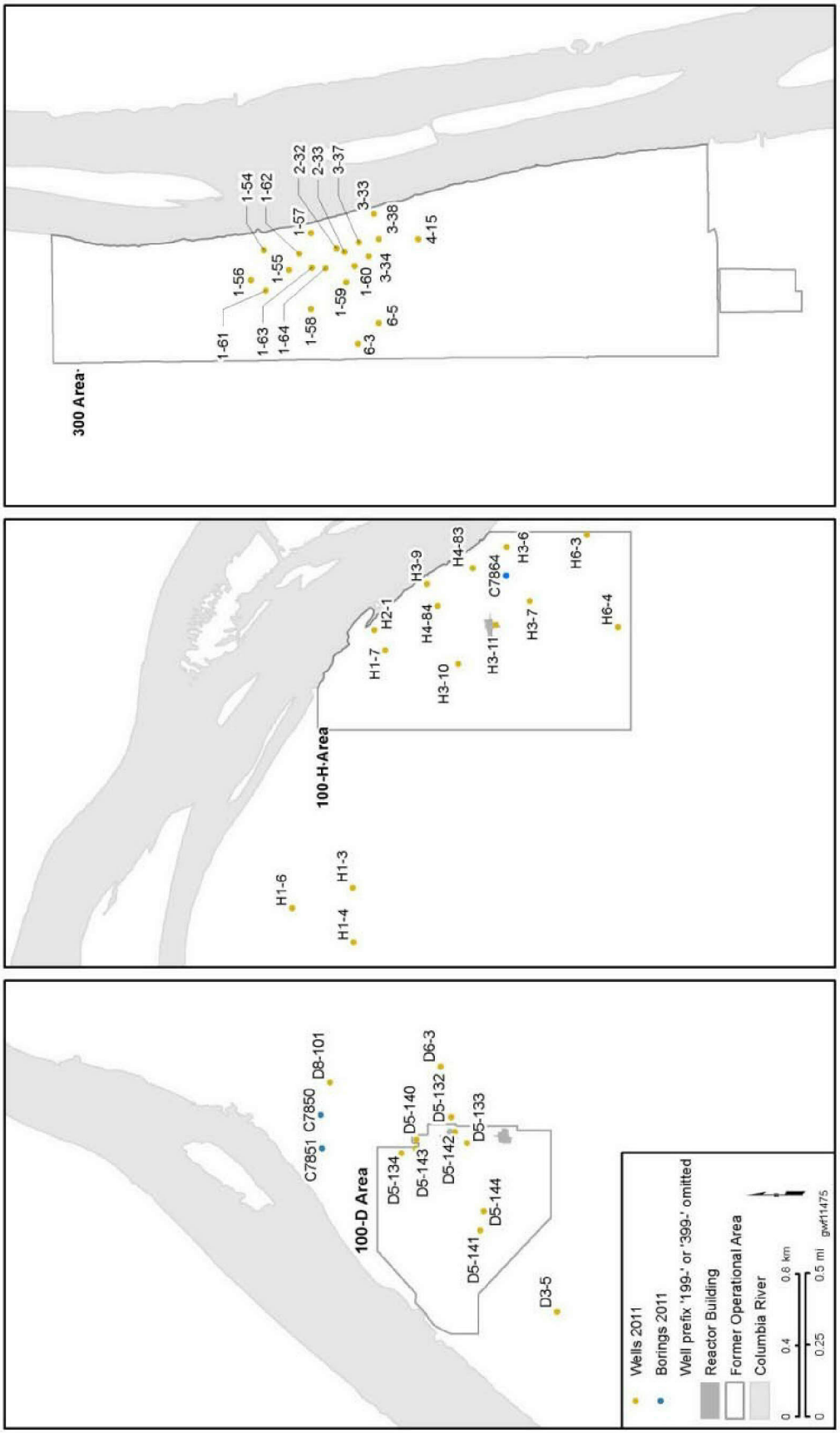


Figure 5-4. 100-HR-3 and 300-FF-5 Well Installations, 2011

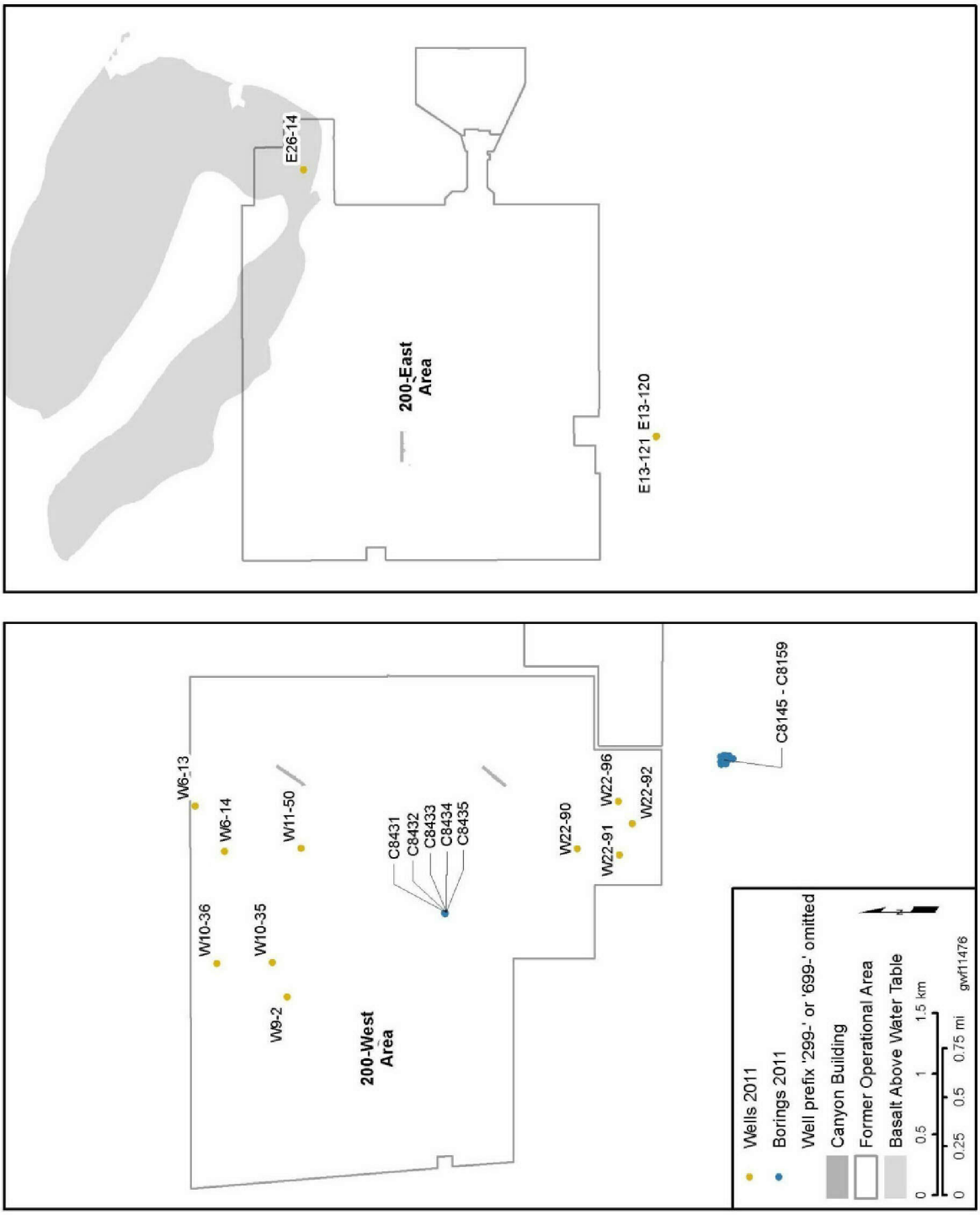


Figure 5-5. 200 East Area and 200 West Area Well Installations, 2011

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Appendix A—Supporting Information for CERCLA Operable Units

M.J. Hartman

Under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), the groundwater beneath contaminated portions of the Hanford Site is divided into 11 groundwater operable units. Figure 2.1-1 in Section 2.1 and Figure 3.1-1 in Section 3.1 show the locations of these units and related groundwater interest areas on the Site. The interest areas are defined informally to aid in planning, scheduling, and data interpretation.

The tables provided in this appendix list the constituents, monitoring wells, and the sampling frequency for each operable unit, as required by their respective sampling and analysis plans or other documentation. The tables also indicate whether the wells were sampled as scheduled during 2011.

In many cases, wells are sampled for additional constituents not strictly required by the plans. Those constituents are not listed in the tables of this appendix, but data files accompanying this report include all of the required and supplemental data.

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Table A-1. Monitoring Wells and Constituents for the 100-BC-5 Operable Unit

Well	Hydrologic Unit Monitored	Alkalinity	Alpha/Beta	Anions	Hexavalent Chromium	Metals	Strontium-90	Tritium	Technetium-99	Sampled as Scheduled in 2011
199-B2-12	Ringold aquitard	BO	--	BO	BO	BO	BO	BO	--	Yes
199-B2-13	Top of unconfined	BE	--	BE	BE	BE	BE	BE	--	Not scheduled
199-B2-14*	Top of unconfined	A	--	A	A	A	A	A	--	Yes
199-B2-15*	Ringold aquitard	Q	--	Q	Q	Q	Q	Q	--	First sampled 4/2011
199-B2-16*	Bottom of unconfined	Q	--	Q	Q	Q	Q	Q	--	First sampled 4/2011; missed 7/2011
199-B3-1*	Top of unconfined	BE	--	BE	A	BE	A	A	--	Yes
199-B3-46	Top of unconfined	BO	--	BO	A	BO	A	A	--	Yes
199-B3-47	Top of unconfined	BE	--	BE	A	BE	A	A	--	Yes
199-B3-50*	Top of unconfined	--	--	--	A	--	A	A	--	Yes
199-B3-51*	Bottom of unconfined	--	--	--	Q		Q	Q	--	First sampled 4/2011
199-B4-1	Top of unconfined	BE	--	BE	A	BE	BE	A	--	Yes
199-B4-4	Top of unconfined	--	--	--	--	--	BE	BE	--	Not scheduled
199-B4-7	Top of unconfined	BO	--	BO	BO	BO	BO	BO	--	Yes
199-B4-8	Top of unconfined	BE	--	BE	BE	BE	BE	BE	--	Not scheduled
199-B4-14*	Top of unconfined	Q	--	Q	Q	Q	Q	Q	--	First sampled 6/2011
199-B5-1	Top of unconfined	BE	--	BE	A	BE	BE	A	--	Yes
199-B5-2	Top of unconfined	--	--	--	A	--	BO	A	--	Yes
199-B5-5*	Bottom of unconfined	A	--	A	A	A	--	A	--	Yes
199-B5-6*[a]	Bottom of unconfined	--	--	--	Q	--	--	Q	--	Yes
199-B5-8*	Top of unconfined	Q	--	Q	Q	Q	Q	Q	Q	First sampled 4/2011
199-B8-6	Top of unconfined	BO	BO	BO	A	BO	BO	A	--	Yes
199-B8-9*	Top of unconfined	Q	Q	Q	Q	Q	A	Q	--	First sampled 1/2011
199-B9-2	Top of unconfined	--	BE	--	BE	--	--	BE	--	Not scheduled

Table A-1. Monitoring Wells and Constituents for the 100-BC-5 Operable Unit

Well	Hydrologic Unit Monitored	Alkalinity	Alpha/Beta	Anions	Hexavalent Chromium	Metals	Strontium-90	Tritium	Technetium-99	Sampled as Scheduled in 2011
199-B9-3	Top of unconfined	BO	BO	BO	BO	BO	--	BO	--	Yes
699-63-90	Unconfined	BE	BE	BE	--	BE	--	BE	--	Not scheduled
699-65-83	Unconfined	--	--	--	--	--	--	BE	--	Not scheduled
699-67-86	Unconfined	--	--	--	--	--	--	BO	--	Yes
699-68-105	Unconfined	BO	--	BO	--	BO	--	BO	--	Yes
699-71-77	Unconfined	BO	--	BO	--	BO	--	BO	BO	Yes
699-72-73	Unconfined	BE	--	BE	--	BE	--	BE	BE	Not scheduled
699-72-92	Unconfined	BO	--	BO	--	BO	--	BO	--	Yes

Note: The sampling requirements are from the following sources:

- DOE/RL-2003-38, *100-BC-5 Operable Unit Sampling and Analysis Plan.*
- TPA-CN-240, *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38, Rev 1 and TPA-CN-182 (September 6, 2007).*
- TPA-CN-293, *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documents and Records: 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38 Rev 1 (as modified by TPA-CN-240, 12/08/2008).*

TPA-CN-293 also includes wells 199-B8-7 and 199-B8-8. However, those wells were decommissioned in 2010 to allow for the remediation of the 100-C-7 waste site.

* New wells installed for 100-BC remedial investigation/feasibility study; not in DOE/RL-2003-38, TPA-CN-240, or TPA-CN-293.

A = to be sampled annually.

BE = to be sampled biennially, even fiscal years.

BO = to be sampled biennially, odd fiscal years.

Q = to be sampled quarterly.

Table A-2. 100-KR-4 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Carbon-14	Hexavalent Chromium	Strontium-90	Tritium	Comment
199-K-13	1	4	1	1	
199-K-18	1	8	1	2	
199-K-19	2	5	2	2	
199-K-20	2	6	2	2	
199-K-21	1	3	1	1	
199-K-22	3	6	3	3	
199-K-23	1	1	1	1	
199-K-31	1	1	1	2	
199-K-32A	4	9	2	6	
199-K-32B	1	1	1	1	
199-K-34	3	6	3	6	
199-K-36		2			
199-K-37	1	7	3	3	
199-K-106A	3	4	3	6	
199-K-107A	1	5	1	5	
199-K-108A	8	15	1	8	
199-K-110A		3		2	
199-K-111A	3	6	2	7	
199-K-112A					
199-K-113A	2	39	3	2	KR-4 Extraction
199-K-114A	2	36	2	2	KR-4 Extraction
199-K-115A	2	38	2	2	KR-4 Extraction
199-K-116A	2	37	2	2	KR-4 Extraction
199-K-117A	4	6	1	1	
199-K-118A					
199-K-119A	2	3	2	2	
199-K-120A	2	39	2	3	
199-K-121A					KR-4 Injection
199-K-122A					KR-4 Injection
199-K-123A					KR-4 Injection

Table A-2. 100-KR-4 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Carbon-14	Hexavalent Chromium	Strontium-90	Tritium	Comment
199-K-124A	1	3	2	2	
199-K-125A	3	14	3	5	
199-K-127	2	39	2	3	KR-4 Extraction
199-K-128A					KR-4 Injection
199-K-129		1			KR-4 Extraction
199-K-130	1	15	1	1	KX Extraction
199-K-131	2	15	2	2	KX Extraction
199-K-132	4	34	2	4	KW Extraction
199-K-137	10	37	3	8	KW Extraction
199-K-138	1	28	1	1	KW Extraction
199-K-139	2	31	2	2	KW Extraction
199-K-140	1	3	1		
199-K-141	7	24	7	7	KX Extraction
199-K-142					
199-K-143					KX Injection
199-K-144	3	40	4	4	KR-4 Extraction
199-K-145	2	38	2	3	KR-4 Extraction
199-K-146	2	18	2	2	KX Extraction
199-K-147	1	15	2	1	KX Extraction
199-K-148	1	17	1	1	KX Extraction
199-K-149	2	2	2	2	
199-K-150	2	7	2	2	
199-K-151	2	3	2	2	
199-K-152	3	39	4	4	KX Extraction
199-K-153	1	14	1	1	KX Extraction
199-K-154	1	16	1	1	KX Extraction
199-K-156					KX Injection
199-K-157	1	3	1	4	
199-K-158					KW Injection
199-K-159					KX Injection

Table A-2. 100-KR-4 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Carbon-14	Hexavalent Chromium	Strontium-90	Tritium	Comment
199-K-160					KX Injection
199-K-161	1	34	2	1	KX Extraction
199-K-162	3	26	4	3	KR-4 Extraction
199-K-163	1	18	1	1	KX Extraction
199-K-164					KX Injection
199-K-165	8	39	3	8	KW Extraction
199-K-166	1	31	1	1	KW Extraction
199-K-168	4	34	2	2	KW Extraction
199-K-169					KX Injection
199-K-170					KX Injection
199-K-171	1	13	1	1	KX Extraction
199-K-172					KX Injection
199-K-173	6	10	1	6	
199-K-174					KW Injection
199-K-175					KW Injection
199-K-178	1	14	1	1	KX Extraction
199-K-179					KR-4 Injection
199-K-180					KX Injection
199-K-181	5	7	5	5	
199-K-182		2	1	1	
199-K-183	3	3	3	3	
199-K-184	3	4	3	3	
199-K-185	4	5	4	4	
199-K-186	2	3	2	2	
199-K-187	6	7	5	5	
199-K-188	1	2	1	1	
199-K-189	3	5	3	3	
199-K-190	3	4	3	3	
199-K-191	3	4	3	3	
199-K-192	3	4	3	3	

Table A-2. 100-KR-4 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Carbon-14	Hexavalent Chromium	Strontium-90	Tritium	Comment
199-K-193	4	6	4	4	
199-K-194	2	3	2	2	
199-K-195	2	4	2	2	Decommissioned
199-K-196	1	1	1	1	
199-K-197	1		1	1	
199-K-198			1	1	
199-K-199					
199-K-200	4	5	4	4	
199-K-201	3	4	3	3	
699-73-61		2	1	2	
699-78-62					

Numbers indicated number of sampling events (dates) for each constituent, excluding characterization sampling.

Table A-3. Monitoring Wells and Constituents for 100-NR-2

Well Name	Field Parameters	Alkalinity	Alpha	Anions	Beta	Gamma	Metals	Oil and Grease	VOA/SVOA	Strontium-90	Total Petroleum Hydrocarbons	Tritium	Sampled as Scheduled in 2011
199-N-2	A	A	--	A	A	--	A	--	--	A	--	A	No beta, strontium-90, or tritium
199-N-3	A	A	--	A	A	--	A	--	--	A	A	A	Yes
199-N-14	A	A	--	A	A	--	A	--	--	A	--	A	Yes
199-N-16	A	A	--	A	A	--	A	A	A	A	A	--	Yes
199-N-18	A	A	--	A	--	--	A	A	A	A	A	--	Yes
199-N-19	A	--	--	A	--	--	A	--	--	A	A	--	Yes
199-N-21	A	--	--	A	--	--	A	--	--	A	A	--	Yes
199-N-26	A	A	--	A	--	--	A	--	--	--	A	--	No; decommissioned 2011
199-N-27	A	A	A	A	A	A	A	--	--	A	--	A	Yes
199-N-28	A	A	A	A	A	--	A	--	--	A	--	--	Yes

Table A-3. Monitoring Wells and Constituents for 100-NR-2

Well Name	Field Parameters	Alkalinity	Alpha	Anions	Beta	Gamma	Metals	Oil and Grease	VOA/SVOA	Strontium-90	Total Petroleum Hydrocarbons	Tritium	Sampled as Scheduled in 2011
199-N-32	A	A	--	A	A	A	A	--	--	A	--	A	Yes
199-N-34	A	A	--	A	--	--	A	--	--	A	--	A	Yes
199-N-41	A	A	--	A	--	--	A	--	--	A	--	A	Yes
199-N-46	S	S	S	S	S	S	S	--	--	S	--	S	Yes
199-N-50	A	--	--	A	A	--	--	--	--	A	--	A	Yes
199-N-51	A	--	--	--	A	--	--	--	--	A	--	A	Yes
199-N-52	A	A	A	A	A	--	A	--	--	A	--	--	Yes
199-N-56	A	A	A	A	--	A	A	--	A	A	A	A	Yes
199-N-57	A	A	A	A	--	A	A	--	--	A	A	A	Yes
199-N-64	A	A	A	A	A	A	A	--	A	A	A	A	Yes
199-N-67	A	A	A	A	A	--	A	--	--	A	--	A	Yes
199-N-69	A	--	--	--	--	--	--	--	--	A	--	A	Yes
199-N-70	A	A	A	A	A	A	A	--	--	A	--	A	Yes
199-N-73	A	A	--	A	--	--	A	--	--	--	--	--	Yes
199-N-74	A	--	A	--	A	A	A	--	--	--	--	--	Yes
199-N-75	A	A	--	A	A	--	A	--	--	A	--	A	No; maintenance required
199-N-76	S	S	--	S	S	S	S	--	--	S	--	S	Yes
199-N-80	A	--	A	A	A	A	A	--	A	A	--	A	Yes, plus additional constituents
199-N-81	A	A	--	A	A	A	A	--	--	A	--	A	Yes
199-N-92A	A	A	--	A	A	--	A	--	--	A	--	A	Yes
199-N-96A	A	A	--	A	A	--	A	A	A	A	A	A	Yes
199-N-99A	A	A	--	A	A	--	A	--	--	A	--	A	Yes
199-N-103A	A	A	A	A	A	A	A	--	--	A	--	A	Yes
199-N-105A	A	A	A	A	A	A	A	--	--	A	--	A	Yes

Table A-3. Monitoring Wells and Constituents for 100-NR-2

Well Name	Field Parameters	Alkalinity	Alpha	Anions	Beta	Gamma	Metals	Oil and Grease	VOA/SVOA	Strontium-90	Total Petroleum Hydrocarbons	Tritium	Sampled as Scheduled in 2011
199-N-106A	A	A	A	A	A	A	A	--	--	A	--	A	Yes
199-N-119	A	A	A	A	A	A	A	--	--	A	--	A	Yes
199-N-120	A	A	A	A	A	A	A	--	--	A	--	A	Yes
199-N-121	A	A	A	A	A	A	A	--	--	A	--	A	Yes
199-N-122	A	--	--	A	--	--	A	--	--	A	--	A	Yes
199-N-123	A	--	--	A	--	--	A	--	--	A	--	A	Yes
199-N-146	A	--	--	A	--	--	A	--	--	A	--	A	Yes
199-N-147	A	--	--	A	--	--	A	--	--	A	--	A	Yes
199-N-167	A	A	--	A	A	--	A	A	A	A	A	A	Yes
199-N-169	A	A	--	A	A	--	A	A	A	A	A	A	Yes
199-N-170	A	A	--	A	A	--	A	A	A	A	A	A	Yes
199-N-171	A	A	--	A	A	--	A	A	A	A	A	A	Yes
199-N-172	A	A	--	A	A	--	A	A	A	A	A	A	Yes
199-N-173	A	A	A	A	A	--	A	A	A	A	A	A	Yes

Note:

1. Monitoring requirements have been modified from *Remedial Design/Remedial Action Work Plan for the 100-NR-2 Operable Unit* (DOE/RL-2001-27).

2. TPA-CN-256, *Change Notice for Modifying Approved Documents/Work plans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: DOE/RL-2001-27, Rev 0, Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit and the Interim Action Waste Management Plan for the 100-NR-2 Operable Unit, DOE/RL-2000-41, Rev. 1*, modified the monitoring requirements, including updating analyses and removing decommissioned wells.

3. Field parameters include pH, temperature, conductivity, and turbidity; with dissolved oxygen and oxidation-reduction potential on some wells.

A = to be sampled annually

S = to be sampled semiannually

Table A-4. Monitoring Wells and Constituents for the 100-NR-2 Apatite Treatability Test Plan

Well Name	Well Type	Anions	Beta	Metals	Sr-90	Sampled as Scheduled in 2011
199-N-122	Compliance	Q	Q	Q	P	Sampled 3 times
199-N-123	Compliance	Q	Q	Q	P	Sampled 3 times
199-N-126	Monitoring	S	S	S	P	Sampled once
199-N-127	Monitoring	S	S	S	P	Sampled once
199-N-128	Monitoring	Q	Q	Q	P	Sampled once
199-N-129	Monitoring	S	S	S	P	Sampled once
199-N-130	Monitoring	S	S	S	P	Sampled once
199-N-131	Monitoring	S	S	S	P	Sampled once
199-N-132	Monitoring	Q	Q	Q	P	Sampled once
199-N-133	Monitoring	S	S	S	P	Sampled once
199-N-136	Barrier	S	S	S	P	Sampled once
199-N-137	Barrier	S	S	S	P	Sampled once
199-N-138	Barrier	S	S	S	P	Sampled once
199-N-139	Barrier	S	S	S	P	Sampled once
199-N-140	Barrier	S	S	S	P	Sampled once
199-N-141	Barrier	S	S	S	P	Sampled once
199-N-142	Barrier	Q	Q	Q	P	Sampled once
199-N-143	Barrier	S	S	S	P	Sampled once
199-N-144	Barrier	S	S	S	P	Sampled once
199-N-145	Barrier	Q	Q	Q	P	Sampled once
199-N-146	Compliance	Q	Q	Q	P	Sampled 3 times
199-N-147	Compliance	Q	Q	Q	P	Yes
199-N-148	Monitoring	Q	Q	Q	P	Sampled once
199-N-149	Monitoring	Q	Q	Q	P	Sampled once
199-N-150	Monitoring	Q	Q	Q	P	Sampled once
199-N-151	Monitoring	Q	Q	Q	P	Sampled once
199-N-152	Monitoring	S	S	S	P	Sampled once
199-N-153	Monitoring	S	S	S	P	Sampled once
199-N-154	Monitoring	S	S	S	P	Sampled once
199-N-155	Monitoring	Q	Q	Q	P	Sampled once

Table A-4. Monitoring Wells and Constituents for the 100-NR-2 Apatite Treatability Test Plan

Well Name	Well Type	Anions	Beta	Metals	Sr-90	Sampled as Scheduled in 2011
199-N-156	Monitoring	Q	Q	Q	P	Sampled once
199-N-159	Barrier	S	S	S	P	Sampled once
199-N-160	Barrier	Q	Q	Q	P	Sampled once
199-N-161	Barrier	S	S	S	P	Sampled once
199-N-162	Barrier	S	S	S	P	Sampled once
199-N-163	Barrier	S	S	S	P	Sampled once
199-N-164	Barrier	Q	Q	Q	P	Sampled once

Note: Requirements from "100/300 Area Unit Managers Meeting Minutes," Attachment 2 (0078408). Additional requirements are applied during injection.

P = periodic splits for strontium-90 during performance monitoring period; full set at least once a year

Q = schedule changed to February, May, August, and November quarterly monitoring in accordance with TPA-CN-271, *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: Treatability Test Plan Addendum for the 100-NR-2 Groundwater Operable Unit, DOE/RL-2005-96 Addendum*)

S = sampled twice each year (at high and low river stages)

Table A-5. 100-HR-3 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Hexavalent Chromium	Nitrate	Strontium-90	Sulfate	Technetium-99	Tritium	Uranium	Comment
199-D2-6	4	2		2		1	1	
199-D2-8	5	3		3		1	2	
199-D2-10								DX injection well
199-D2-11	14	2		2		2		
199-D2-12								DX injection well
199-D3-2	6	4		4		1	2	
199-D4-1	6	3		3		2	2	
199-D4-4	10	6		6		1	3	
199-D4-5	7	4		4		1	3	
199-D4-6	7	4		4		1	3	
199-D4-7	9	5		5		1	3	

Table A-5. 100-HR-3 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Hexavalent Chromium	Nitrate	Strontium-90	Sulfate	Technetium-99	Tritium	Uranium	Comment
199-D4-13	2	2		2		2	2	
199-D4-14	5	3		3		1	2	
199-D4-15	19	13		13		1	1	
199-D4-19	6	4		4		3	3	
199-D4-20	6	4		4		2	3	
199-D4-22	7	5		5		2	4	
199-D4-23	10	4	1	4	1	2	3	
199-D4-31	7	4		4			3	
199-D4-32	9	5		5			4	
199-D4-36	8	5		5			3	
199-D4-38	11							DX extraction well
199-D4-39	12	1	1	1	1	1	1	DX extraction well
199-D4-48	9	5		5			4	
199-D4-62	3	2		2			2	
199-D4-78	8	5		5		4	3	
199-D4-83	1							DX extraction well
199-D4-84	11							DX extraction well
199-D4-85	10							DX extraction well
199-D4-86	5	2	2	2	2	2	2	
199-D4-95	17	1	1	1	1	1	1	DX extraction well
199-D4-96	15	1	1	1	1	1	1	DX extraction well
199-D4-97	16	1	1	1	1	1	1	DX extraction well
199-D4-98	16	1	1	1	1	1	1	DX extraction well
199-D4-99	16	1	1	1	1	1	1	DX extraction well
199-D4-101	2	1	1	1	1	1	1	DX extraction well
199-D5-13	8	2		2		2		
199-D5-14	8	4		4		4		

Table A-5. 100-HR-3 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Hexavalent Chromium	Nitrate	Strontium-90	Sulfate	Technetium-99	Tritium	Uranium	Comment
199-D5-15	4	2		2		2		
199-D5-16	3	1		1		1		
199-D5-17	1	1		1		1		
199-D5-18	2	1		1		1		
199-D5-19	1					1		
199-D5-20	15							DX extraction well
199-D5-32	15	1	1	1	1	1	1	DX extraction well
199-D5-33	5	1		1				
199-D5-34	8	5		5				
199-D5-36	3	2	1	2	1	1	1	
199-D5-37	8	5	3	5			3	
199-D5-38	3	3		3		3	3	
199-D5-39	20	1	1	1	1	1	1	DX extraction well
199-D5-40	5	3		3				
199-D5-42								DX injection well
199-D5-43	11	6		6		2	3	
199-D5-44								DX injection well
199-D5-92	17	1	1	1	1	1	1	DX extraction well
199-D5-93	3	2		2				
199-D5-97	11							
199-D5-98	5	1		1				
199-D5-99	7							
199-D5-101	15	1	1	1	1	1	1	DX extraction well
199-D5-102	12	2		2				
199-D5-103	12	6		6				
199-D5-104	8							DX extraction well
199-D5-106	2	2	2	2	2	2	2	

Table A-5. 100-HR-3 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Hexavalent Chromium	Nitrate	Strontium-90	Sulfate	Technetium-99	Tritium	Uranium	Comment
199-D5-119	12	7		7				
199-D5-120	2							
199-D5-121	14							
199-D5-122	11							
199-D5-123	12							
199-D5-125	12							
199-D5-126	10							
199-D5-127	13	1	1	1	1	1	1	DX extraction well
199-D5-128								DX injection well
199-D5-129								DX injection well
199-D5-130	16	1	1	1	1	1	1	DX extraction well
199-D5-131	16	1	1	1	1	1	1	DX extraction well
199-D5-132	1	1	1	1		1		
199-D5-133	1	1	1	1		1		
199-D5-140	1	1		1		1		
199-D5-141	2	2		2		2		
199-D5-143	1	1		1		1		
199-D6-1								DX injection well
199-D6-2								DX injection well
199-D6-3	1	1	1	1		1		
199-D7-3	16	1	1	1	1	1	1	DX extraction well
199-D7-4								DX injection well
199-D7-5								DX injection well
199-D7-6	15	1	1	1	1	1	1	DX extraction well
199-D8-4	10	3		3		3		
199-D8-5	7	1		1		1		
199-D8-6	4	1	1	1	1	1	1	DX extraction well

Table A-5. 100-HR-3 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Hexavalent Chromium	Nitrate	Strontium-90	Sulfate	Technetium-99	Tritium	Uranium	Comment
199-D8-53	6		1			1		
199-D8-54A	8		1			1		
199-D8-54B	3	1		1		1	1	
199-D8-55								DX injection well
199-D8-68	12	1	1	1	1	1	1	
199-D8-69	16	1	1	1	1	1	1	DX extraction well
199-D8-70	8	2	2	2	2	2	2	
199-D8-71	10		1					
199-D8-72	9	1	1	1		1	1	
199-D8-73	16	1	1	1		1	1	DX extraction well
199-D8-88	11	1	1	1	1	1	1	
199-D8-89	18	2	2	2	2	2	2	DX extraction well
199-D8-90	15	1	1	1	1	1	1	DX extraction well
199-D8-91	16	1	1	1	1	1	1	DX extraction well
199-D8-93								DX injection well
199-D8-94								DX injection well
199-D8-95	16	1	1	1	1	1	1	DX extraction well
199-D8-96	16	1	1	1	1	1	1	
199-D8-97	14	1	1	1	1	1	1	DX extraction well
199-D8-98	16	1	1	1	1	1	1	
199-D8-99								DX injection well
199-D8-101	3	2		2		2		
199-H1-1	7	1	1	1	1	1	1	HX extraction well
199-H1-2	4							HX extraction well
199-H1-3	3							HX extraction well
199-H1-4	4							HX extraction well
199-H1-5	12							DX extraction well

Table A-5. 100-HR-3 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Hexavalent Chromium	Nitrate	Strontium-90	Sulfate	Technetium-99	Tritium	Uranium	Comment
199-H1-6	4							HX extraction well
199-H1-7	1	1	1	1	1	1	1	
199-H1-20								HX injection well
199-H2-21								HX injection well
199-H1-25	7	1	1	1	1	1	1	HX extraction well
199-H1-27	7	1	1	1	1	1	1	HX extraction well
199-H1-32	6	1	1	1	1	1	1	HX extraction well
199-H1-33	6	1	1	1	1	1	1	HX extraction well
199-H1-34	6	1	1	1	1	1	1	HX extraction well
199-H1-35	7	1	1	1	1	1	1	HX extraction well
199-H1-36	6	1	1	1	1	1	1	HX extraction well
199-H1-37	5	1	1	1	1	1	1	HX extraction well
199-H1-38	6	1	1	1	1	1	1	HX extraction well
199-H1-39	5							HX extraction well
199-H1-40	6	1	1	1	1	1	1	HX extraction well
199-H1-42	7	1	1	1	1	1	1	HX extraction well
199-H1-43	7	1	1	1	1	1	1	HX extraction well
199-H1-45	7	1	1	1	1	1	1	HX extraction well
199-H2-1	2	2	2	2	2	2	2	
199-H3-2A	4	1	2	1		2		
199-H3-2C	16	3	3	3	3	3	3	HX extraction well
199-H3-3	4	1	2	1		2		
199-H3-4	12	2	1	2	1	1	1	HX extraction well
199-H3-5	4	1	2	1		1		
199-H3-9	1	1	1	1	1	1	1	
199-H3-25								HX injection well
199-H3-26								HX injection well

Table A-5. 100-HR-3 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Hexavalent Chromium	Nitrate	Strontium-90	Sulfate	Technetium-99	Tritium	Uranium	Comment
199-H3-27								HX injection well
199-H4-2	2	1	1	1	1	1	1	
199-H4-3	3	3	1	3	1	1	1	HX extraction well
199-H4-4	9	2	2	2	2	2	2	HX extraction well
199-H4-5	10	2	2	2	2	2	2	
199-H4-6	4	2		2		2		
199-H4-7								
199-H4-8	1	1	1	1	1	1	1	
199-H4-9	3	2		2	1	1		
199-H4-10	4	1	2	1	2	1	2	
199-H4-11	3							
199-H4-12A	4	2	2	2	2	2	2	
199-H4-12B	2							
199-H4-12C	12	1	1	1	1	1	1	HX extraction well
199-H4-13	4	1	1	1	1	1	1	
199-H4-14								HX injection well
199-H4-15A	14	2	2	2	2	2	2	HX extraction well
199-H4-15B	2							
199-H4-15CP	4	2	1	2	2	2	2	
199-H4-15CQ	5	4	4	4	4	4	4	
199-H4-15CR	4	2	1	2	1	1	1	
199-H4-15CS	4	2	1	2	2	2	2	
199-H4-16	2	1	2	1				
199-H4-17								HX injection well
199-H4-18								HX injection well
199-H4-45	4	1	2	1		1		
199-H4-46	2	1		1		1		

Table A-5. 100-HR-3 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Hexavalent Chromium	Nitrate	Strontium-90	Sulfate	Technetium-99	Tritium	Uranium	Comment
199-H4-48	6	1		1				
199-H4-63	12	2	2	2	2	2	2	HX extraction well
199-H4-64	7	1	1	1	1	1	1	HX extraction well
199-H4-65	5							
199-H4-69	6	1	1	1	1	1	1	HX extraction well
199-H4-70	7	1	1	1	1	1	1	HX extraction well
199-H4-71								HX injection well
199-H4-72								HX injection well
199-H4-73								HX injection well
199-H4-74								HX injection well
199-H4-75	7	1	1	1	1	1	1	HX extraction well
199-H4-76	8	1	1	1	1	1	1	HX extraction well
199-H4-77	6	1	1	1	1	1	1	HX extraction well
199-H4-78								HX injection well
199-H4-79								HX injection well
199-H4-80	12							DX extraction well
199-H4-81	12							DX extraction well
199-H4-82	11							DX extraction well
199-H5-1A	4	1		1				
199-H6-1	1	1	2	1		1		
199-H6-2								HX injection well
699-88-41	3							
699-90-45	1		1					
699-91-46A	3							
699-93-48A	2							
699-94-41	6	2		2		2		
699-94-43	6	2		2		2		

Table A-5. 100-HR-3 Wells Used for Monitoring, Extraction, and Injection, 2011

Well	Hexavalent Chromium	Nitrate	Strontium-90	Sulfate	Technetium-99	Tritium	Uranium	Comment
699-95-45	6	1		1		1		
699-95-48	6	1		1		1		
699-95-51	6	2		2		2		
699-96-43	1	1		1		1		
699-96-52B	11	2	2	2	2	1	2	
699-97-41	5							
699-97-43B	9	3		3		3		
699-97-43C	8	2		2		2		
699-97-45	6	1		1		1		
699-97-45B	8	2		2		2		
699-97-48B	6	2		2		2		
699-97-48C	6	1		1		1		
699-97-51A	6	3		3		3		
699-98-43	6	1		1		1		
699-98-46	8	3		3		3		
699-98-49A	2							
699-98-51	11	2		2		2		
699-99-41	8	4		4		4		
699-99-42B	5	1	1	1	1	1	1	HX extraction well
699-99-44	7	2		2		2		
699-100-43B	6	4		4		2		
699-101-45	6	4		4		2		

Number of sampling events (dates) for each constituent, excluding characterization sampling.

Table A-6. Monitoring Wells and Constituents for the 100-FR-3 Operable Unit

Well	Alkalinity	Alpha	Anions	Hexavalent Chromium	Metals	Strontium-90	Tritium	Trichloroethene (VOA)	Uranium	Sampled as Scheduled in 2011
199-F1-2	BO	--	BO	BO[a]	BO	--	--	--	--	Not scheduled
199-F5-1	A	BE	A	A[a]	A	BE	BE	--	--	Yes
199-F5-4	BO	BO	BO	BO[a]	BO	--	BO	BO	--	Not scheduled
199-F5-6	A	BE	A	A[a]	A	BE	BE	--	--	Yes
199-F5-42	BO	BO	BO	--	BO	BO	BO	--	--	Not scheduled
199-F5-43A	BE	BE	BE	BE[a]	BE	BE	BE	--	--	Yes
199-F5-43B	BE	BE	BE	BE[a]	BE	BE	--	--	--	Yes
199-F5-44	BE	BE	BE	BE[a]	BE	BE	BE	--	--	Yes
199-F5-45	BO	BO	BO	BO[a]	BO	BO	BO	BO	BO	Not scheduled
199-F5-46	BE	A	BE	A[a]	BE	BE	A	BE	A	Yes
199-F5-47	BE	BE	BE	BE[a]	BE	--	BE	--	BE	Yes
199-F5-48[b]	SA	SA	SA	--	SA	--	SA	--	SA	Yes
199-F5-52[c]	A	--	A	A	A	--	A	A	A	Yes
199-F5-53[c]	A	--	A	A	A	--	A	A	A	Yes
199-F5-54[c]	A	A	A	A	A	A	A	A	A	Yes
199-F5-55[d]	SA	SA	SA	SA	SA	SA	SA	SA	SA	Yes
199-F5-56[d]	SA	SA	SA	SA	SA	SA	SA	SA	SA	Yes
199-F6-1	BO	BO	BO	--	BO	BO	BO	--	--	Not scheduled
199-F7-1	BE	--	BE	--	BE	--	--	BE	--	Yes[b]
199-F7-2	BE	BE	BE	--	BE	--	BE	BE	--	Yes
199-F7-3	BE	BE	BE	--	BE	--	BE	BE	--	Yes[b]
199-F8-2	BO	BO	BO	--	BO	--	BO	--	BO	Not scheduled
199-F8-3	BE	BE	BE	--	BE	BE	BE	BE	BE	Yes
199-F8-4	BE	BE	BE	--	BE	--	BE	--	BE	Yes
199-F8-7	A	--	A	A	A	A	A	A	A	Yes
699-58-24	BE	--	BE	--	BE	--	--	--	--	Yes
699-60-32	BO	--	BO	--	BO	--	--	--	--	Not scheduled

Table A-6. Monitoring Wells and Constituents for the 100-FR-3 Operable Unit

Well	Alkalinity	Alpha	Anions	Hexavalent Chromium	Metals	Strontium-90	Tritium	Trichloroethene (VOA)	Uranium	Sampled as Scheduled in 2011
699-62-31	BO	--	BO	--	BO	--	--	--	--	Not scheduled
699-62-43F	BE	--	BE	--	BE	--	BE	--	--	Yes
699-63-25A	BO	--	BO	--	BO	--	BO	--	--	Not scheduled
699-63-55	BO	--	BO	--	BO	--	BO	--	--	Not scheduled
699-64-27	BE	--	BE	--	BE	--	--	--	--	Yes
699-66-23	BE	--	BE	--	BE	--	BE	--	--	Yes
699-67-51	BO	--	BO	--	BO	--	BO	--	--	Not scheduled
699-71-30	BO	BO	BO	--	BO	--	BO	--	--	Not scheduled
699-74-44	BO	--	BO	--	BO	--	--	BO	--	Not scheduled
699-77-36	BE	--	BE	--	BE	--	--	BE	--	Yes
699-77-54	BO	--	BO	--	BO	--	--	--	--	Not scheduled
699-81-38	BE	--	BE	--	BE	--	--	--	--	Yes
699-83-47	BE	--	BE	--	BE	--	--	BE	--	Yes

Note: The sampling requirements are from *100-FR-3 Operable Unit Sampling and Analysis Plan* (DOE/RL-2003-49) as modified by TPA-CN-241, *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: 100-FR-3 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-49, Rev. 1 and TPA-CN-228 (July 14, 2008)*.

All wells are screened in the unconfined aquifer, except wells 199-F5-43B and 199-F5-53, which are screened in the Ringold Formation aquitard.

a. DOE/RL-2003-49 does not require hexavalent chromium for these wells (total chromium in filtered samples is equivalent). However, hexavalent chromium was added to the sampling schedule in 2011.

b. Biennial sampling is required, but the frequency was increased to semiannual in 2011 because of excavation activities at nearby waste site 100-F-57.

c. New wells installed for the 100-F Remedial Investigation/Feasibility Study. Not included in DOE/RL-2003-49 or TPA-CN-241.

d. Temporary wells constructed from vadose boreholes for the RI/FS. Not included in DOE/RL-2003-49 or TPA-CN-241.

A = to be sampled annually.

BE = to be sampled biennially, even fiscal years (note that fiscal year 2012 sampling was scheduled for October 2011; sampling occurred in November and December 2011).

BO = to be sampled biennially, odd fiscal years.

SA = to be sampled semiannually.

VOA = volatile organic analyte.

Table A-7. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 300 Area

Well Name	Hydrologic Unit Monitored	Contaminants of Concern			Contaminants of Potential Concern				Supporting Measurements						Sampled as Scheduled in 2011
		cis-1,2-Dichloroethene	Trichloroethene	Uranium, Total (Unfiltered)	Tetrachloroethene	Strontium-90	Tritium	Nitrate	Anions	Alkalinity	Metals	Volatile Organic Compounds	Alpha/Beta	Uranium, Isotopic	
Near-River Well Group															
399-1-1	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-10A[a]	TU	S	S	Q/M	S	--	A	Q	Q/M	Q/M	S	S	S	A	Missed October and November
399-1-10B	LU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
399-1-16A[a]	TU	S	S	Q/M	S	--	A	Q	Q/M	Q/M	S	S	S	A	Missed October and November
399-1-16B	LU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
399-1-16C	C	A	A	A	A	--	--	A	A	A	A	A	--	--	Yes
399-2-1	TU	S	S	Q	S	--	A	Q	Q	Q	S	S	S	A	Yes
399-2-2	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Second sample delayed until January 2012
399-3-1	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-3-9	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-3-10	TU	S	S	Q	S	--	A	Q	Q	Q	S	S	S	A	Yes
399-3-18[b]	TU	S	S	Q/M	S	--	A	Q	Q/M	Q/M	S	S	S	A	Missed 5 months

Table A-7. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 300 Area

Well Name	Hydrologic Unit Monitored	Contaminants of Concern			Contaminants of Potential Concern				Supporting Measurements						Sampled as Scheduled in 2011
		cis-1,2-Dichloroethene	Trichloroethene	Uranium, Total (Unfiltered)	Tetrachloroethene	Strontium-90	Tritium	Nitrate	Anions	Alkalinity	Metals	Volatile Organic Compounds	Alpha/Beta	Uranium, Isotopic	
399-4-7	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-4-9	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-4-10	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
Central Region – Uranium Plume Transport Corridor Well Group															
399-1-2[c]	TU	S	S	S/M	S	--	--	S	S/M	S/M	S	S	S/M	--	Missed 4 months
399-1-6	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-7	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-8	LU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-9	C	A	A	A	A	--	--	A	A	A	A	A		--	Yes
399-1-11	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-12	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Second sample delayed until January 2012
399-1-17A[a]	TU	S	S	Q/M	S	--	A	Q	Q/M	Q/M	S	S	S	A	Missed October and November
399-1-17B	LU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes

Table A-7. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 300 Area

Well Name	Hydrologic Unit Monitored	Contaminants of Concern			Contaminants of Potential Concern				Supporting Measurements						Sampled as Scheduled in 2011
		cis-1,2-Dichloroethene	Trichloroethene	Uranium, Total (Unfiltered)	Tetrachloroethene	Strontium-90	Tritium	Nitrate	Anions	Alkalinity	Metals	Volatile Organic Compounds	Alpha/Beta	Uranium, Isotopic	
399-1-17C	C	A	A	A	A	--	--	A	A	A	A	A	--	--	Yes
399-1-21A[c]	TU	S	S	Q/M	S		A	Q	Q/M	Q/M	S	S	S/M	A	Missed 4 months
399-1-21B	LU	S	S	S	S	--		S	S	S	S	S	S	--	Yes
399-1-23	TU	S	S	Q	S	--	A	Q	Q	Q	S	S	S	A	Missed 1 quarter
399-2-5	TU	Q	Q	Q	Q	--	A	Q	Q	Q	Q	Q	Q	A	Missed 2 quarters
399-3-11	TU	S	S	Q	S	A	A	Q	Q	Q	S	S	S	A	Decommissioned in 2010
399-3-12	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
399-3-20	TU	S	S	Q	S	A	A	Q	Q	Q	S	S	S	A	Yes
399-3-21	LU	Q	Q	Q	Q	--	A	Q	Q	Q	Q	Q	Q	--	Missed 2 quarters
399-3-22	LU	Q	Q	Q	Q	--	A	Q	Q	Q	Q	Q	Q	--	Missed 1 quarter
Northwest Region – Upgradient Conditions Well Group															
399-1-15	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
399-1-18A	TU	--	--	S	--	--	S	S	S	S	S	--	--	--	Yes
399-1-18B	LU	--	--	S	--	--	S	S	S	S	S	--	--	--	Yes

Table A-7. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 300 Area

Well Name	Hydrologic Unit Monitored	Contaminants of Concern			Contaminants of Potential Concern				Supporting Measurements						Sampled as Scheduled in 2011
		cis-1,2-Dichloroethene	Trichloroethene	Uranium, Total (Unfiltered)	Tetrachloroethene	Strontium-90	Tritium	Nitrate	Anions	Alkalinity	Metals	Volatile Organic Compounds	Alpha/Beta	Uranium, Isotopic	
399-1-18C	C	--	--	A	--	--	--	A	A	A	A	--	--	--	Yes
399-8-1[d]	TU	Q	Q	Q	Q	--	--	Q	Q	Q	Q	Q	Q	--	Yes
399-8-3[d]	TU	Q	Q	Q	Q	--	--	Q	Q	Q	Q	Q	Q	--	Yes
399-8-5A[d]	TU	S	S	S	S	--	--	S	S	S	S	S	S	--	Yes
699-S20-E10	TU	--	--	S	--	--	S	S	S	S	S	--	--	--	Second sample delayed until January 2012
Southwest Region – Upgradient Conditions Well Group															
399-3-2	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
399-3-6	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
399-3-19	TU	S	S	Q	S	--	A	Q	Q	Q	S	S	S	A	Not sampled
399-4-1	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	Sampled once
399-4-12	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes
399-4-14	LU	Q	Q	Q	Q	--	A	Q	Q	Q	Q	Q	Q	--	Yes
399-5-4B	TU	S	S	S	S	--	--	S	S	S	S	S	--	--	Yes

Table A-7. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 300 Area

Well Name	Hydrologic Unit Monitored	Contaminants of Concern			Contaminants of Potential Concern				Supporting Measurements						Sampled as Scheduled in 2011
		cis-1,2-Dichloroethene	Trichloroethene	Uranium, Total (Unfiltered)	Tetrachloroethene	Strontium-90	Tritium	Nitrate	Anions	Alkalinity	Metals	Volatile Organic Compounds	Alpha/Beta	Uranium, Isotopic	
699-S27-E14	TU	A	A	A	A	--	--	A	A	A	A	A	--	--	Sample delayed until January 2012
Wells Installed in 2010-2011[e]															
399-1-54	TU	2	2	2	2	--	2	2	2	2	2	2	2	2	
399-1-55	TU	2	2	2	2	--	2	2	2	2	2	2	2	2	
399-1-56	TU	2	2	2	2	--	2	2	2	2	2	2	2	2	
399-1-57	MU	2	2	2	2	--	2	2	2	2	2	2	2	2	
399-1-58	TU	2	2	2	2	--	2	2	2	2	2	2	2	2	
399-1-59	TU	2	2	2	2	--	2	2	2	2	2	2	2	2	
399-1-61	TU	1	1	1	1	--	--	1	1	1	1	1	--	--	1 sample set during drilling; no routine samples in 2011
399-1-62	TU	1	1	2	1	--	--	2	2	2	2	1	--	--	1 sample set during drilling; 1 routine
399-1-63	TU	1	1	1	1	--	--	1	1	1	1	1	--	--	1 sample set during drilling; no routine samples in 2011
399-1-64	TU	1	1	2	1	--	--	2	2	2	2	1	--	--	1 sample set during drilling; 1

Table A-7. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 300 Area

Well Name	Hydrologic Unit Monitored	Contaminants of Concern			Contaminants of Potential Concern				Supporting Measurements						Sampled as Scheduled in 2011
		cis-1,2-Dichloroethene	Trichloroethene	Uranium, Total (Unfiltered)	Tetrachloroethene	Strontium-90	Tritium	Nitrate	Anions	Alkalinity	Metals	Volatile Organic Compounds	Alpha/Beta	Uranium, Isotopic	
															routine
399-2-32	TU	1	1	1	1	--	1	1	1	1	1	1	1	1	
399-3-33	TU	2	2	2	2	--	2	2	2	2	2	2	2	2	
399-3-38	TU	1	1	2	1	--	--	2	2	2	2	1	--		1 sample set during drilling; 1 routine
399-4-15	TU	7	7	7	7	2	2	7	7	7	7	7	2	2	5 sample sets during drilling; 2 routine
399-6-3	TU	1	1	1	1	--	1	1	1	1	1	1	1	1	
399-6-5	TU	6	6	6	6	--		6	6	6	6	6	1	--	5 sample sets during drilling; 1 routine

Table A-7. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 300 Area

Well Name	Hydrologic Unit Monitored	Contaminants of Concern			Contaminants of Potential Concern				Supporting Measurements						Sampled as Scheduled in 2011
		cis-1,2-Dichloroethene	Trichloroethene	Uranium, Total (Unfiltered)	Tetrachloroethene	Strontium-90	Tritium	Nitrate	Anions	Alkalinity	Metals	Volatile Organic Compounds	Alpha/Beta	Uranium, Isotopic	

Note: The sampling requirements are from *300-FF-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2002-11).

a. *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* supplements *Resource Conservation and Recovery Act of 1976* sampling to provide a full year of monthly monitoring for uranium.

b. Special sampling frequency at near-river well to provide more detailed record of seasonal fluctuations in uranium.

c. Frequency increased to monthly during and following remedial action at former 618-1 Burial Ground.

d. Additional well coverage and sampling frequency to monitor plume that developed downgradient of former 618-7 Burial Ground.

e. Wells installed for the 300 Area Remedial Investigation/Feasibility Study; not in DOE/RL-2002-11. Numbers indicate number of times sampled in 2011.

A = to be sampled annually.

C = uppermost confined aquifer.

LU = lower portion of unconfined aquifer.

MU = middle portion of unconfined aquifer.

Q = to be sampled quarterly.

S = to be sampled semiannually during seasonal high water table and seasonal low water table.

TU = upper portion of unconfined aquifer, including water table.

Table A-8. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 618-10/316-4 Subregion

Well	Contaminants of Potential Concern					Supporting Measurements						Sampled as Scheduled in 2011
	Uranium, Total (Unfiltered)	Tributyl Phosphate	Gross Alpha	Gross Beta	Nitrate	Alkalinity	Metals	VOC and SVOC	Tritium	Technetium-99	Uranium, Isotopic	
Downgradient of 618-10 Burial Ground (Near-Field)												
699-S6-E4K	S	S	S	S	S	S	S	S	S	S	A	Yes
699-S6-E4L	Q	S	Q	Q	Q	S	S	S	S	S	A	2nd delayed until January 2012
Downgradient of 618-10 Burial Ground, Within 316-4 Crib Footprint (Near-Field)												
699-S6-E4A	Q	S	Q	Q	Q	S	S	S	S	S	A	Yes
Background, 618-10 Burial Ground/316-4 Cribs												
699-S6-E4D	A		A	A	A	A	A	--	A	A	--	2nd delayed until January 2012
Downgradient of 618-10 Burial Ground/316-4 Crib												
699-S6-E4B	S	--	S	S	S	S	S	--	S	--	--	1st sample cancelled; 2nd delayed until January 2012
699-S6-E4E	S	--	S	S	S	S	S	--	S	--	--	2nd delayed until January 2012

Note: The sampling requirements are from *300-FF-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2002-11).

Wells were completed at the top of the unconfined aquifer.

A = to be sampled annually.

Q = to be sampled quarterly.

S = to be sampled semiannually.

VOC = volatile organic compound.

SVOC = semivolatile organic compound.

Table A-9. Monitoring Wells and Constituents for the 300-FF-5 Operable Unit, 618-11 Subregion

Well	Contaminants of Potential Concern					Supporting Measurements			2011
	Tritium	Gross Alpha/Beta	Uranium, Total (Unfiltered)	Technetium-99	Nitrate	Alkalinity	Anions	Metals	
Downgradient of 618-11 Burial Ground (Near Field)									
699-12-2C	Q	Q	S	S	S	S	S	S	Missed 1 quarter
699-13-2D	Q	Q	S	S	S	S	S	S	Yes
699-13-3A	Q	Q	S	S	S	S	S	S	Yes
Upgradient Conditions (Near Field)									
699-12-4D	A	A	A	A	A	A	A	A	Not sampled
Downgradient of 618-11 Burial Ground (Far Field)									
699-13-0A	S	S	--	--	S	S	S	S	Yes
699-13-1E	S	S	--	--	S	S	S	S	Yes

Note: The sampling requirements are from *300-FF-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2002-11).

A = to be sampled annually.

Q = to be sampled quarterly.

S = to be sampled semiannually.

Table A-10. Monitoring Wells and Constituents for the Former 1100-EM-1 Operable Unit

Well	1,1-Dichloroethene	Trichloroethene	Vinyl Chloride	Anions*	Sampled as Scheduled in 2011
699-S28-E12	A	A	A	A	Yes
699-S31-E10A	A	A	A	A	Yes
699-S31-E10C	A	A	A	A	Yes

Note: The sampling requirements are from TPA-CN-163, *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: PNNL-12220, "Sampling and Analysis Plan Update for Groundwater Monitoring – 1100-EM-1 Operable Unit".*

* Supplemental analyses.

A = to be sampled annually

Table A-11. Monitoring Wells and Constituents for the 200-ZP-1 Operable Unit

Well	Anions	Alkalinity	Iodine-129	Metals	Hexavalent Chromium	Technetium-99	Tritium	Uranium	Volatile Organic Analytes	Sampled as Scheduled in 2011
299-W6-10	--	--	--	--	--	--	--	--	--	No; dry well
299-W7-4	--	--	--	--	--	--	--	--	--	No; dry well
299-W8-1	--	--	--	--	--	--	--	--	--	No; dry well
299-W10-1	A	A	A	A	A	A	A	A	A	Yes
299-W10-4	A	A	A	A	A	A	A	A	A	Yes
299-W10-5	A	A	A	A	A	A	A	A	A	Yes
299-W10-22	A	--	--	A	--	A	A	--	A	No; dry well
299-W10-23	A	A	--	A	A	A	A	--	A	Yes
299-W10-33	A	A	A	A	--	A	A	--	A	Yes
299-W11-3	A	--	A	A	--	--	A	--	A	No; dry well
299-W11-6	A	--	A	--	--	A	--	--	A	No; dry well
299-W11-7	A	--	A	A	--	A	A	--	A	No; dry well
299-W11-10	A	--	--	--	--	--	--	--	A	No; dry well
299-W11-13	A	--	A	--	--	A	A	--	A	Yes
299-W11-18	A	--	A	--	--	A	A	--	A	Yes
299-W11-34P	A	--	A	A	--	A	A	--	A	Yes
299-W11-37	A	--	A	--	--	--	A	A	A	Yes
299-W11-39	A	A	A	A	A	A	A	--	--	Yes
299-W11-40	A	--	--	A	A	A	A	--	A	Yes
299-W11-42	A	--	A	A	A	A	A	--	A	Yes
299-W11-43	A	--	A	A	--	--	A	A	A	Yes
299-W11-45	A	--	A	A	A	A	A	--	A	Yes
299-W11-46	A	--	A	A	A	A	A	A	A	Yes
299-W11-47	A	A	--	A	A	A	A	--	A	Yes
299-W11-48	A	A	A	A	--	A	A	--	A	Yes
299-W11-87	A	--	A	A	--	A	A	--	A	Yes
299-W11-88	A	A	A	A	--	--	A	A	A	Yes

Table A-11. Monitoring Wells and Constituents for the 200-ZP-1 Operable Unit

Well	Anions	Alkalinity	Iodine-129	Metals	Hexavalent Chromium	Technetium-99	Tritium	Uranium	Volatile Organic Analytes	Sampled as Scheduled in 2011
299-W12-1	A	A	A	A	--	--	A	--	A	Yes
299-W13-1	A	A	--	A	--	A	A	--	A	Yes
299-W14-14	A	A	A	A	A	A	A	A	A	Yes
299-W14-16	A	A	A	A	A	A	A	--	A	Yes
299-W14-71	A	A	--	A	--	--	A	--	A	Yes
299-W14-72	A	A	--	A	--	--	A	--	A	Yes
299-W15-1	A	--	--	--	--	--	--	--	A	Yes
299-W15-2	A	--	--	A	--	--	A	--	A	No; failed pump
299-W15-7	A	--	--	--	--	A	--	--	A	Yes
299-W15-11	A	--	--	--	--	A	A	--	A	Yes
299-W15-15	--	--	--	--	--	--	--	--	--	No; dry well
299-W15-17	A	A	A	A	--	A	--	--	--	Yes
299-W15-30	A	A	A	A	--	A	A	A	A	Yes
299-W15-31A	A	--	--	--	--	A	--	--	A	Yes
299-W15-34	A	--	--	--	--	A	--	--	A	Yes
299-W15-35	A	A	A	A	A	A	A	A	A	Yes
299-W15-36	A	--	--	--	--	--	--	--	A	No; well offline
299-W15-38	--	--	--	--	--	--	--	--	--	No; dry well
299-W15-39	--	--	--	--	--	--	--	--	--	No; dry well
299-W15-40	A	--	A	A	--	A	A	--	A	Yes
299-W15-41	A	--	--	A	--	A	A	--	A	No; dry well
299-W15-42	A	A	--	A	--	A	--	--	A	Yes
299-W15-43	A	A	A	A	--	A	A	--	A	Yes
299-W15-44	A	A	A	A	A	A	A	--	A	Yes
299-W15-45	A	--	--	--	--	A	--	--	A	Yes
299-W15-46	A	--	--	--	--	A	--	--	A	Yes

Table A-11. Monitoring Wells and Constituents for the 200-ZP-1 Operable Unit

Well	Anions	Alkalinity	Iodine-129	Metals	Hexavalent Chromium	Technetium-99	Tritium	Uranium	Volatile Organic Analytes	Sampled as Scheduled in 2011
299-W15-47	A	A	A	--	A	A	A	A	A	No; failed pump
299-W15-49	A	--	--	--	--	A	--	--	A	Yes
299-W15-50	A	A	--	A	--	A	--	--	A	Yes
299-W15-152	A	--	--	--	--	--	--	--	A	Yes
299-W15-763	A	A	--	A	A	A	A	--	A	Yes
299-W15-765	A	--	A	A	--	A	A	--	A	Yes
299-W17-1	A	--	--	A	--	A	A	--	A	Yes
299-W18-16	A	--	--	--	--	--	--	--	A	Yes
299-W18-23	--	--	--	--	--	--	--	--	--	No; dry well
699-43-69	A	--	--	--	--	--	--	--	A	Yes
699-43-89	A	A	A	A	--	A	A	A	A	Yes
699-44-64	A	--	A	--	--	A	--	A	A	Yes
699-45-69A	A	--	A	--	--	--	--	--	A	Yes
699-45-69C	A	--	--	--	--	--	A	--	A	Yes
699-48-71	A	A	A	A	--	A	A	--	A	Yes
699-48-77A	A	A	A	A	A	A	A	A	A	Yes

Note: The sampling requirements have been modified from *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit* (DOE/RL-2003-55).

The following wells (from DOE/RL-2003-55) have gone dry: 299-W6-10, 299-W7-4, 299-W8-1, 299-W10-22, 299-W11-3, 299-W11-7, 299-W11-10, 299-W15-15, 299-W15-38, 299-W15-39, 299-W15-41, and 299-W18-23.

A = to be sampled annually.

Table A-12. Monitoring Wells and Constituents for the 200-UP-1 Operable Unit

Well	Arsenic	Cadmium	Carbon-14	Chromium	Iodine-129	Iron	Manganese	Nitrate and Fluoride	Selenium-79	Strontium-90	Technetium-99	Tritium	Uranium	Volatile Organic Analytes	Sampled as Scheduled in 2011
299-W15-37[a]	A	A	--	--	--	--	--	A	--	--	--	--	A	S	Yes
299-W18-15	S	--	--	--	--	--	--	S	--	--	--	--	S	S	Yes
299-W18-21[a]	A	--	--	--	--	--	--	A	--	--	A	--	A	S	Yes
299-W18-22[a]	A	--	--	--	--	--	--	A	--	--	A	--	A	S	Yes
299-W18-30	A	--	--	--	A	--	--	A	--	--	--	--	A	A	Yes
299-W19-4	--	--	--	--	BO	--	--	BO	--	--	BO	--	BO	BO	Delayed until 01/2012
299-W19-18[b]	--	--	--	--	A	--	--	A	--	--	A	--	A	A	Yes
299-W19-34A	A	--	--	--	A	--	--	A	--	--	A	--	A	A	Yes
299-W19-34B	BE	--	--	--	BE	--	--	BE	--	--	BE	--	BE	BE	Not scheduled
299-W19-35	--	S	--	--	S	--	--	S	--	--	S	--	S	S	Second sample delayed until 01/2012
299-W19-36[d]	--	--	--	--	A	--	--	Q	--	--	Q	--	Q	Q	No; extraction well pump failure
299-W19-43[e]	--	--	--	--	S	--	--	Q	--	--	Q	--	Q	Q	No; extraction well shut down
299-W19-46	--	S	--	--	S	--	S	S	--	--	S	S	S	S	Yes
299-W19-48	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Yes

Table A-12. Monitoring Wells and Constituents for the 200-UP-1 Operable Unit

Well	Arsenic	Cadmium	Carbon-14	Chromium	Iodine-129	Iron	Manganese	Nitrate and Fluoride	Selenium-79	Strontium-90	Technetium-99	Tritium	Uranium	Volatile Organic Analytes	Sampled as Scheduled in 2011
299-W19-49[f,g]	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Second sample missed
299-W19-101[c]	--	--	--	--	A	--	--	A	--	--	A	A	A	A	Yes
299-W19-105[g]	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Yes
299-W19-107[g]	--	--	--	--	S	--	--	S	--	--	S	--	S	S	Yes
299-W21-2[g]	--	--	--	--	S	--	--	S		S	S	S	S	S	First sample missed; second sample delayed until 01/2012
299-W22-26	--	A	--	--	A	--	--	A	A	--	A	A	A	A	Yes
299-W22-45	--	A	--	--	A	--	--	A	--	A	--	A	A	A	Yes
299-W22-48	S	S	--	--	S	--	S	S	--	S	--	S	S	S	Yes
299-W22-49	--	S	--	--	S	S	S	S	--	S	S	S	S	S	Yes
299-W22-69[g]	--	--	--	--	A	--	--	A	--	--	A	A	--	A	Yes
299-W22-72[g]	--	--	S	--	S	--	--	S	--	S	S	S	S	S	Second sample delayed until 01/2012

Table A-12. Monitoring Wells and Constituents for the 200-UP-1 Operable Unit

Well	Arsenic	Cadmium	Carbon-14	Chromium	Iodine-129	Iron	Manganese	Nitrate and Fluoride	Selenium-79	Strontium-90	Technetium-99	Tritium	Uranium	Volatile Organic Analytes	Sampled as Scheduled in 2011
299-W22-83	--	Q	--	--	Q	--	--	Q	Q	Q	Q	Q	Q	Q	Three samples missed due to electric pump issue; 4th sample delayed until 01/2012
299-W22-86[g]	--	--	--	S	S	--	--	S	S	--	--	S	--	S	Second sample delayed until 01/2012
299-W22-87[g]	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Second sample missed
299-W22-88[g]	--	--	--	--	S	--	--	S	--	--	S	S	S		Yes
299-W23-4	S	--	--	--	--	--	--	S	--	--	--	S	S	S	First sample missed
299-W23-15	--	--	--	--	--	S	--	S	--	--	S	S	S	S	Second sample delayed until 01/2012
299-W23-21	--	--	--	--	--	--	--	Q	--	--	Q	Q	Q	Q	First sample missed; 4th sample delayed until 01/2012
299-W26-13	--	--	--	--	BO	--	--	BO	--	--	--	BO	BO	BO	Yes
299-W26-14	--	--	--	--	BE	--	BE	BE	--	--	BE	BE	BE	BE	Not scheduled
699-30-66[g]	--	--	--	S	S	--	--	S	--	--	--	S	S	S	Yes
699-32-62	--	--	--	BO	BO	--	--	BO	--	--	--	BO	--	--	Yes
699-32-72A	--	--	--	--	BO	--	--	BO	--	--	--	BO	--	BO	Yes
699-32-76[g]	--	--	--	BO	BO	--	--	BO	--	--	--	--	--	BO	Yes

Table A-12. Monitoring Wells and Constituents for the 200-UP-1 Operable Unit

Well	Arsenic	Cadmium	Carbon-14	Chromium	Iodine-129	Iron	Manganese	Nitrate and Fluoride	Selenium-79	Strontium-90	Technetium-99	Tritium	Uranium	Volatile Organic Analytes	Sampled as Scheduled in 2011
699-33-74[g]	--	--	--	A	A	--	--	A	--	--	A	A	A	A	Yes
699-33-75[g]	--	--	--	S	S	--	--	S	--	--	--	S	S	S	Yes
699-33-76[g]	--	--	--	A	A	--	--	A	--	--	--	--	--	A	Yes
699-34-72[g]	--	--	S	--	S	--	--	S	--	S	S	S	S	S	First sampled missed
699-35-66A	--	--		BO	BO	--	--	BO	--	--	--	BO	--	BO	Yes
699-35-78A	A	--	--	--	--	--	--	A	--	--	--	--	A	A	Yes
699-36-61A	--	--	--	BE	BE	--	--	BE	--	--	--	BE	--	--	Not scheduled
699-36-70A	--	--	--	--	A	--	--	A	--	--	A	A	A	A	Yes
699-36-70B[g]	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Yes
699-38-65	--	--	--	--	A	--	--	A	--	--	--	A	--	--	Yes
699-38-68A	--	--	--	--	BO	--	--	BO	--	--	BO	BO	BO	BO	Yes
699-38-70B	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Yes
699-38-70C	--	--	--	--	S	--	--	S	--	--	S	S	S	S	Yes
699-40-62	--	--	--	--	BO	--	--	BO	--	--	BO	BO	BO	BO	Yes
699-40-65[g]	--	--	--	--	S	--	--	S	--	--	--	S	--	S	Yes

Table A-12. Monitoring Wells and Constituents for the 200-UP-1 Operable Unit

Well	Arsenic	Cadmium	Carbon-14	Chromium	Iodine-129	Iron	Manganese	Nitrate and Fluoride	Selenium-79	Strontium-90	Technetium-99	Tritium	Uranium	Volatile Organic Analytes	Sampled as Scheduled in 2011

Note: The sampling requirements have been modified from *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit* (DOE/RL-92-76).

Wells listed in DOE/RL-92-76 that are now dry include the following: 299-W18-33, 299-W19-37, 299-W19-40, 299-W22-9, 299-W22-20, 299-W23-9, 299-W23-10, 299-W23-14 (replaced with well 299-W23-21), 699-35-70, and 699-38-70.

Well 299-W19-39 is included in DOE/RL-92-76 but is no longer sampled; the well is configured as an extraction well but is not operating and cannot be sampled.

a. The volatile organic analytes are listed as annual in DOE/RL-92-76; sampled semiannually to support the 200-ZP-1 pump-and-treat system.

b. Not listed in DOE/RL-92-76 but sampled annually to support the 200-UP-1 pump-and-treat system.

c. Listed as "299-W19-50 (new well 'L')" in DOE/RL-92-76; was abandoned during drilling and replaced by 299-W19-101.

d. Frequency specified as annual in DOE/RL-92-76; now a pump-and-treat system extraction well sampled quarterly.

e. Frequency specified as semiannual in DOE/RL-92-76; now a pump-and-treat system extraction well sampled quarterly.

f. Listed as "299-W19-47 (new well 'M')" in DOE/RL-92-76; assumed to be a typographical error. New well "M" is 299-W19-49.

g. Frequency reduced from quarterly after first year of sampling.

A = to be sampled annually.

BE = to be sampled biennially, even fiscal years.

BO = to be sampled biennially, odd fiscal years.

CY = calendar year.

Q = to be sampled quarterly.

S = to be sampled semiannually.

VOA = volatile organic analyte.

Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2011
	Cesium-137	Cobalt-60	Cyanide	Iodine-129	Nitrate	Plutonium-239/240	Strontium-90	Technetium-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Americium-241	Arsenic	Metals (Filtered)	Neptunium-237	TOC/TOX	
299-E24-8	3-10	3-10		3-10	3-10	--	--	--	3-10	--	--	3-10		3-10	--	--	--	Not scheduled
299-E26-10	--	--	--	A	A	--	--	--	A	--	--	--	--	--	--	--	--	Yes
299-E26-11	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	3-10	--	--	--	Not scheduled
299-E27-7	--	--	--	A	A	--	--	A	A	--	--	--	--	A	--	--	--	Yes
299-E27-10	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	3-10	--	--	--	Not scheduled
299-E27-14	--	--	--	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
299-E27-15	--	--	--	--	A	--	--	A	--	--	A	--	--	--	A	--	--	Yes
299-E27-17	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	3-10	--	--	--	Not scheduled
299-E27-18	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	3-10	--	--	--	Not scheduled
299-E27-155*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	--	No As, Am-241, Np-237, Pu-239/240, Sr-90
299-E28-2	A	--	--	A	A	A	A	A	A	--	A	A	--	--	A		--	No alkalinity, Cs-137, Gross Alpha/Beta, metals, Pu-239/240, Tc-99
299-E28-5	A	--	--	3-10	3-10	A	A	--	3-10	A	--	3-10	--	3-10	--	--	--	Yes
299-E28-6	A	A	--	3-10	3-10	A	A	--	3-10	A	--	3-10	--	3-10	--	--	--	Yes

Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2011
	Cesium-137	Cobalt-60	Cyanide	Iodine-129	Nitrate	Plutonium-239/240	Strontium-90	Technetium-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Americium-241	Arsenic	Metals (Filtered)	Neptunium-237	TOC/TOX	
299-E28-8	A	--	--	--	--	A	A	A		A	--	--	--	--	--	--	--	Yes
299-E28-13	--	--	--	3-10	3-10	--	3-10	--	3-10	3-10		3-10	--	--	--	--	--	Not scheduled
299-E28-17	A	--	--	--	A	A	A	--	--	A	--	--	--	--	--	--	--	No Cs-137, Pu-239/240, Sr-90
299-E28-18	--	--	--	A	A	--	--	--	A	A	--	A	--	A	--	--	--	No As, Gross Alpha/Beta
299-E28-21	--	--	--	--	--	--	--	--	--	A	--	--	--	--	--	--	--	Yes
299-E28-23	A	--	--	--	--	A	A	--	--	A	--	A	A	--	--	A	--	No Am-241, Np-237
299-E28-24	A	--	--	--	--	A	A	--	A	A	--	A	A	--	--	A	--	No Am-241, Np-237
299-E28-25	A	--	--	A	A	A	A	--	A	A	--	A	A	A	--	A	--	No Am-241, Np-237, Gross Alpha/Beta, tritium
299-E28-26	--	--	--	3-10	A	--	--	A	3-10	A	--	--	--	3-10	--	--	--	Yes
299-E28-27	A	--	--	A	A	A	A	A	3-10	A	--	--	--	--	--	--	--	No Cs-137, Pu-239/240, Sr-90
299-E28-28	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
299-E32-2	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
299-E32-4	--	--	--	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes

Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2011
	Cesium-137	Cobalt-60	Cyanide	Iodine-129	Nitrate	Plutonium-239/240	Strontium-90	Technetium-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Americium-241	Arsenic	Metals (Filtered)	Neptunium-237	TOC/TOX	
299-E32-5	--	--	--	3-10	3-10	--	--	--	3-10	3-10	--	--	--	--	--	--	--	Not scheduled
299-E32-6	--	--	--	3-10	A	--	--	A	3-10	3-10	--	--	--	--	--	--	--	Yes
299-E32-7	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
299-E32-8	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
299-E32-9	--	--	3-10	A	A	--	--	--	3-10	--	--	--	--	--	--	--	--	Yes
299-E32-10	--	A	A	3-10	3-10	--	--	A	3-10	A	--	--	--	3-10	--	--	--	Yes
299-E33-7	A	A	A	A	A	--	--	A	A	A	--	A	--	--	--	--	--	Yes
299-E33-12	--	--	--	--	--	--	--	3-10	--	--	--	--	--	--	--	--	--	Not scheduled
299-E33-13	--	--	A	--	--	--	--	--	--	A	--	--	--	--	--	--	--	Yes
299-E33-15	--	--	--	--	A	--	--	A	--		--	--	--	--	--	--	--	Yes
299-E33-16	--	--	--	A	A	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-18	--	--	--	A	A	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-26	--	A	A	3-10	3-10	--	--	A	3-10	A	--	3-10	--	--	--	--	--	Yes
299-E33-28	--	--	--	--	A	--	--	A	--	--	--	--	--	--	--	--	--	Yes
299-E33-29	--	--	--	3-10	3-10	--	--	3-10	3-10		--	--	--	--	--	--	--	Not scheduled

Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2011
	Cesium-137	Cobalt-60	Cyanide	Iodine-129	Nitrate	Plutonium-239/240	Strontium-90	Technetium-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Americium-241	Arsenic	Metals (Filtered)	Neptunium-237	TOC/TOX	
299-E33-30	--	--	--	--	A	--	--	A	--	--	--	--	--	--	--	--	--	No nitrate
299-E33-32	--	--	--	3-10	3-10	--	--	3-10	3-10	--	--	--	--	--	--	--	--	Not scheduled
299-E33-33	--	--	--	3-10	3-10	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	Not scheduled
299-E33-34	--	A	A	A	A	--	--	A	A	A	--	--	--	--	--	--	--	Yes
299-E33-35	3-10	3-10	A	3-10	A	--	--	A	3-10	A	--	--	--	--	--	--	--	Yes
299-E33-37	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
299-E33-38	--	A	A	A	A	A	A	A	A	A	--	A	--	A	--	--	--	Yes
299-E33-39	--	--	A	A	A	--	--	A	A	A	--	--	--	--	--	--	--	Yes
299-E33-41	3-10	3-10	3-10	3-10	3-10	--	--	A	3-10	A	--	--	--	--	--	--	--	Yes
299-E33-42	--	--	--	A	--	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-43	--	--	--	A	--	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-44	--	A	--	--	--	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-50*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA		No Am-241, Np-237, Pu-239/240
299-E33-205*	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	--	Only third quarter due to access issue. No Am-241, Np-237, Pu-239/240

Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2011
	Cesium-137	Cobalt-60	Cyanide	Iodine-129	Nitrate	Plutonium-239/240	Strontium-90	Technetium-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Americium-241	Arsenic	Metals (Filtered)	Neptunium-237	TOC/TOX	
299-E33-334	--	--	--	--	A	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-335	--	--	--	--	--	A	--	A	--	--	--	--	--	--	--	--	--	Yes
299-E33-338	--	--	--	--	--	--	--	A	--	A	--	--	--	--	--	--	--	Yes
299-E33-340*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	No Am-241, Np-237, Pu-239/240
299-E33-341*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	No Am-241, Np-237, Pu-239/240
299-E33-342*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	No Am-241, Np-237, Pu-239/240
299-E33-343*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	No Am-241, Np-237, Pu-239/240
299-E33-344*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	No Am-241, Np-237, Pu-239/240
299-E33-345*	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	--	No Am-241, Np-237, Pu-239/240
299-E34-2	--	--	--	A	A	--	--	--	A	--	--	--	--	--	--	--	--	Yes
299-E34-9	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-44-39B	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Not scheduled

Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2011
	Cesium-137	Cobalt-60	Cyanide	Iodine-129	Nitrate	Plutonium-239/240	Strontium-90	Technetium-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Americium-241	Arsenic	Metals (Filtered)	Neptunium-237	TOC/TOX	
699-45-42	--	--	--	3-10	3-10	--	--	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-47-60	--	--	--	A	A	--	--	A	A	--	--	--	--	--	--	--	--	No; maintenance needed
699-48-50B*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	--	No supporting constituents, Sr-90, Pu-239/240
699-49-55A	A	A	A	A	A	A	A	A	A	A	--	A	--	--	--	--	--	No Pu-239/240, Sr-90
699-49-57A	A	A	A	A	A	--	--	A	A	A	--	--	--	A	--	--	--	Yes
699-49-57B	A	A	A	A	A	--	--	A	A	--	--	--	--	--	--	--	--	No sample, scheduling error
699-50-56*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	--	No Am-241, Np-237, Pu-239/240
699-50-59*	--	--	A	A	A	--	--	A	A	A	A	A	--	--	A	--	--	No supporting constituents
699-52-55*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	--	No supporting constituents, gamma, I-129, Pu-239/240, Sr-90, tritium, uranium.
699-52-55B*	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	--	Yes
699-53-47A	--	--	--	--	A	--	A	--	A	--	--	A	--	--	--	--	--	No; schedule constraints

Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2011
	Cesium-137	Cobalt-60	Cyanide	Iodine-129	Nitrate	Plutonium-239/240	Strontium-90	Technetium-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Americium-241	Arsenic	Metals (Filtered)	Neptunium-237	TOC/TOX	
699-53-47B	--	--	--	--	3-09	--	3-09	--	--	--	--	--	--	--	--	--	--	Not scheduled
699-53-48A	--	--	--	A	A	--	A	--	A	--	--	A	--	--	A	--	--	No; scheduling error
699-53-55A	--	A	A	--	A	--	--	A	A	--	--	--	--	--	--	--	--	No; schedule constraints
699-53-55B	--	A	A	--	A	--	--	A	A	--	--	--	--	--	--	--	--	No; schedule constraints
699-53-55C	--	A	A	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
699-54-45A	--	--	--	--	3-09	--	--	--	--	--	--	--	--	--	--	--	--	Not scheduled
699-54-45B	--	--	--	--	3-09	--	--	--	--	--	--	--	--	--	--	--	--	Not scheduled
699-54-48	--	--	--	--	--	--	3-09	--	--	--	--	--	--	--	--	--	--	Not scheduled
699-54-49	--	--	--	--	A	--	A	--	A	--	--	A	--	--	--	--	--	No; schedule constraints
699-55-50C	--	--	--	A	A	--	A	A	A	--	--	--	--	--	--	--	--	No; schedule constraints
699-55-57	--	A	A	A	A	--	--	A	A	--	--	--	--	--	--	--	--	Yes
699-55-60A	--	A	A	A	A	--	--	A	A	--	--	--	--	--	--	--	--	No; schedule constraints
699-57-59	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	No Pu-239/240
699-59-58	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	No gamma, Pu-239/240, Sr-90, TOC/TOX
699-60-60	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	No gamma, Pu-239/240,

Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2011
	Cesium-137	Cobalt-60	Cyanide	Iodine-129	Nitrate	Plutonium-239/240	Strontium-90	Technetium-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Americium-241	Arsenic	Metals (Filtered)	Neptunium-237	TOC/TOX	
																		Sr-90, TOC/TOX
699-61-62	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	No gamma, Pu-239/240, Sr-90, TOC/TOX
699-61-66	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	No Pu-239/240, TOC/TOX
699-64-62	A	A	A	A	A	A	A	A	A	A	A	A	--	--	A	--	A	No gamma, cyanide, Pu-239/240, Sr-90, tritium, uranium, gross alpha/beta, TOC/TOX
699-65-50	--	--	--	--	--	--	--	3-10	--	--	--	--	--	--	--	--	--	Not scheduled
699-65-72	--	--	--	--	--	--	--	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-66-58	--	--	--	--	--	--	--	3-10	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-66-64	--	--	--	--	--	--	--	3-10	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-70-68	--	--	--	--	--	--	--	3-10	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-72-73	--	--	--	--	3-10	--	--	3-10	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-73-61	--	--	--	--	--	--	--		3-10	--	--	--	--	--	--	--	--	Not scheduled

Note: The sampling requirements are from *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit* (DOE/RL-2001-49).

* Well not listed in DOE/RL-2001-49 but added to sampling schedule per the *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit* (DOE/RL-2007-18). Note that wells were also sampled and analyzed for volatile organic analytes and semivolatile organic analytes.

Table A-13. Monitoring Wells and Constituents for the 200-BP-5 Operable Unit

Well	Contaminants of Concern										Supporting Constituents							Sampled as Scheduled in 2011
	Cesium-137	Cobalt-60	Cyanide	Iodine-129	Nitrate	Plutonium-239/240	Strontium-90	Technetium-99	Tritium	Uranium	Alkalinity	Alpha/Beta	Americium-241	Arsenic	Metals (Filtered)	Neptunium-237	TOC/TOX	

3-xx = to be sampled triennially (every 3 years); xx indicates the fiscal year of sampling for a specified analyte.

A = to be sampled annually.

Q = to be sampled quarterly.

SA = to be sampled semiannually.

TOC = total organic carbon.

TOX = total organic halides.

Table A-14. Monitoring Wells and Constituents for 200-PO-1 Operable Unit Near-Field Wells

Well Number[a]	Contaminants of Concern							Supporting Constituents					Sampled as Scheduled in 2011
	Arsenic	Chromium, Manganese, and Vanadium (Filtered)	Iodine-129	Nitrate	Strontium-90	Technetium-99	Tritium	Alpha	Anions[b]	Beta	Metals[c]	Uranium	
299-E16-2	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E17-1	A	A	A	A	A	A	A	A	A	A	A	A	No
299-E17-12	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E17-13	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E17-14	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-16	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-18	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-19	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-23	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E17-25	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E18-1	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E23-1	A	A	A	A	--	--	A	A	A	A	A	--	No
299-E24-16	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E24-18	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E24-20	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E24-22	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E24-23	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E24-33	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E24-5	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-17	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-18	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E25-19	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-2	A	A	A	A	A	A	A	A	A	A	A	--	Yes

Table A-14. Monitoring Wells and Constituents for 200-PO-1 Operable Unit Near-Field Wells

Well Number[a]	Contaminants of Concern							Supporting Constituents					Sampled as Scheduled in 2011
	Arsenic	Chromium, Manganese, and Vanadium (Filtered)	Iodine-129	Nitrate	Strontium-90	Technetium-99	Tritium	Alpha	Anions[b]	Beta	Metals[c]	Uranium	
299-E25-20	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E25-22	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E25-28	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-29P	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-29Q	A	A	A	A	--	--	A	--	--	A	A	--	Yes
299-E25-236	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-3	A	A	A	A	A	--	A	A	A	A	A	--	No
299-E25-32P	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-32Q	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-34	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-35	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-36	A	A	A	A	A	--	A	A	A	A	A	A	Yes
299-E25-37	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-40	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-41	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-42	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-43	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-44	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-47	A	A	A	A	--	--	A	A	A	A	A	--	Yes
299-E25-6	A	A	A	A	A	--	A	A	A	A	A	--	Yes
299-E25-93	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E25-94	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E26-4	A	A	A	A	A	--	A	A	A	A	A	--	No

Table A-14. Monitoring Wells and Constituents for 200-PO-1 Operable Unit Near-Field Wells

Well Number[a]	Contaminants of Concern							Supporting Constituents					Sampled as Scheduled in 2011
	Arsenic	Chromium, Manganese, and Vanadium (Filtered)	Iodine-129	Nitrate	Strontium-90	Technetium-99	Tritium	Alpha	Anions[b]	Beta	Metals[c]	Uranium	
699-37-47A	A	A	A	A	A	A	A	A	A	A	A	A	Yes
699-39-39	A	A	A	A	--	--	A	A	A	A	A	--	No
699-41-42	A	A	A	A	--	--	A	A	A	A	A	--	Yes
699-42-40A	A	A	A	A	--	--	A	A	A	A	A	--	Yes
699-42-42B	A	A	A	A	--	--	A	A	A	A	A	--	Yes
699-43-45	A	A	A	A	--	--	A	A	A	A	A	--	Yes
699-44-39B	A	A	A	A	--	--	A	A	A	A	A	--	Yes

Note: The sampling requirements are from *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2003-04).

a. Some wells added in anticipation of revision of DOE/RL-2003-04.

b. Anions; analytes include, but are not limited to, chloride, nitrate, and sulfate.

c. Metals; analytes include, but are not limited to, chromium, manganese, and vanadium.

A = to be sampled annually

Table A-15. Monitoring Wells and Constituents for the 200-PO-1 Operable Unit Far-Field Wells

Well or Aquifer Tube Name	Contaminant of Concern			Supporting Constituents										Sampled as Scheduled in 2011
	Iodine-129	Nitrate	Tritium	Alpha	Anions[b]	Beta	Cyanide	Gamma	Metals[c]	Strontium-90	Technetium-99	Uranium	Volatile Organic Analytes	
BC Cribs														
299-E13-14	--	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E13-5	--	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E13-11	--	A	A	A	A	A	A	A	A	A	A	A	--	Yes
299-E13-19	--	A	A	A	A	A	A	A	A	A	A	A	--	Yes
Southeast Transect														
699-10-54A	--	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-24-46	A	A	A	A	A	A	--	A	A	A	--	--	A	No
699-26-33	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-31-31	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-32-22A	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-32-43	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-41-23	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-46-21B	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
River Transect														
699-10-E12	--	A	A	A	A	A	--	A	A	A	--	--	A	Yes

Table A-15. Monitoring Wells and Constituents for the 200-PO-1 Operable Unit Far-Field Wells

Well or Aquifer Tube Name	Contaminant of Concern			Supporting Constituents										Sampled as Scheduled in 2011
	Iodine-129	Nitrate	Tritium	Alpha	Anions[b]	Beta	Cyanide	Gamma	Metals[c]	Strontium-90	Technetium-99	Uranium	Volatile Organic Analytes	
699-20-E12O	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-41-1A	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-46-4	A	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-S3-E12	--	A	A	A	A	A	--	A	A	A	--	--	A	Yes
699-S19-E13	--	A	A	A	A	A	--	A	A	A	--	--	A	Yes
Basalt-Confined Aquifer														
299-E16-1	3-09	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not scheduled
699-13-1C	--	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not scheduled
699-24-1P	--	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not scheduled
699-32-22B	3-09	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not scheduled
699-42-40C	3-09	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not scheduled
699-S2-34B	--	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not scheduled
699-S11-E12AP	--	3-09	3-09	3-09	3-09	3-09	--	--	3-09	--	--	--	--	Not scheduled
Far-Field General														
499-S0-7	A	A	A	A	A	A	--	A	A	A	A	A	A	Delayed until January 2012
499-S0-8 [a]	A	A	A	A	A	A	--	A	A	A	A	A	A	Delayed until

Table A-15. Monitoring Wells and Constituents for the 200-PO-1 Operable Unit Far-Field Wells

Well or Aquifer Tube Name	Contaminant of Concern			Supporting Constituents										Sampled as Scheduled in 2011
	Iodine-129	Nitrate	Tritium	Alpha	Anions[b]	Beta	Cyanide	Gamma	Metals[c]	Strontium-90	Technetium-99	Uranium	Volatile Organic Analytes	
														January 2012
499-S1-8J [a]	A	A	A	A	A	A	--	A	A	A	A	A	A	Delayed until January 2012
699-12-4D	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-13-1A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-13-3A	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-14-38	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-17-5	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-19-43	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-20-20	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-20-E12S	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-20-E5A	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-21-6	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-2-3	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-22-35	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-24-34C	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-26-15A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled

Table A-15. Monitoring Wells and Constituents for the 200-PO-1 Operable Unit Far-Field Wells

Well or Aquifer Tube Name	Contaminant of Concern			Supporting Constituents										Sampled as Scheduled in 2011
	Iodine-129	Nitrate	Tritium	Alpha	Anions[b]	Beta	Cyanide	Gamma	Metals[c]	Strontium-90	Technetium-99	Uranium	Volatile Organic Analytes	
699-26-35A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-2-6A [a]	--	A	A	--	A	--	--	--	--	--	--	--	--	Yes
699-2-7 [a]	--	A	A	--	A	--	--	--	--	--	--	--	--	Yes
699-28-40	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-29-4	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-31-11	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-33-56	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-34-41B	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-34-42	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-35-9	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-37-43	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-37-E4	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-38-15	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-40-1	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-40-33A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-40-36	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled

Table A-15. Monitoring Wells and Constituents for the 200-PO-1 Operable Unit Far-Field Wells

Well or Aquifer Tube Name	Contaminant of Concern			Supporting Constituents										Sampled as Scheduled in 2011
	Iodine-129	Nitrate	Tritium	Alpha	Anions[b]	Beta	Cyanide	Gamma	Metals[c]	Strontium-90	Technetium-99	Uranium	Volatile Organic Analytes	
699-41-40	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-41-42 [a]	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-42-12A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-42-39A	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-42-39B	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-42-40A [a]	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Yes
699-43-3	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-45-42	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-47-5	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-48-7A	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-49-13E	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-50-28B	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-52-19	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-8-17	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-8-25	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-9-E2	3-10	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled

Table A-15. Monitoring Wells and Constituents for the 200-PO-1 Operable Unit Far-Field Wells

Well or Aquifer Tube Name	Contaminant of Concern			Supporting Constituents										Sampled as Scheduled in 2011
	Iodine-129	Nitrate	Tritium	Alpha	Anions[b]	Beta	Cyanide	Gamma	Metals[c]	Strontium-90	Technetium-99	Uranium	Volatile Organic Analytes	
699-S12-3	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-S19-E14	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-S3-25	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-S6-E14A	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-S6-E4A	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-S6-E4B	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled
699-S8-19	--	3-10	3-10	--	3-10	--	--	--	--	--	--	--	--	Not scheduled

Note: The sampling requirements are from *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2003-04).

a. Some wells added in anticipation of revision of DOE/RL-2003-04.

b. Anions; analytes include, but are not limited to, chloride, nitrate, and sulfate.

c. Metals; analytes include, but are not limited to, chromium, manganese, and vanadium.

3-xx = to be sampled triennially (every three years); xx indicates the fiscal year of sampling for specified analyte.

A = to be sampled annually.

Appendix B—Supporting Information for RCRA and Other Monitored Facilities

D.C. Weekes

This appendix provides supplemental information for *Resource Conservation and Recovery Act of 1976* (RCRA) and other regulated units on the Hanford Site that require groundwater monitoring, excluding *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* units (discussed in Appendix A). Site-specific descriptions for each facility included in this appendix are provided in the main text of this document under the respective operable unit in which the facility is located.

Groundwater monitoring under RCRA continued during the reporting period at 26 waste management areas (Figure B-1). Estimates of groundwater velocity, hydrologic properties, and associated references are shown in Table B-1 for the RCRA sites. To determine if a waste site has adversely affected groundwater quality under RCRA interim status regulations (WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards;" 40 CFR 265.93, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Preparation, Evaluation, and Response"), concentrations of indicator parameters in downgradient wells are compared to statistically derived critical mean values. The indicator parameters under interim status are specific conductance, pH, total organic carbon, and total organic halides. The critical values to which the indicator parameters are compared represent 99 percent prediction limits, which are calculated for each facility based on samples from upgradient wells. The methodology used to calculate the critical value is the Student's t-test in accordance with 40 CFR 265.93(b). The formula and individual parameters for the test are provided in Section 7.1 of PNNL-13080, *Hanford Site Groundwater Monitoring: Setting, Sources, and Methods*. The upper prediction limits (and lower limit in the case of pH) also are known as critical mean values.

Critical mean values are recalculated annually or if the number of analyses changes. Annual recalculation accounts for changing background conditions. Changes in the number of analyses are usually the result of changes in monitoring well networks (e.g., wells are added or deleted). If changes occur in a monitoring well network, critical mean values for that facility are recalculated for subsequent semiannual sampling events using the new well network.

To reliably indicate potential groundwater effects from a facility, the sample results must be reasonably precise or quantifiable. Specific conductance and pH are field-measured indicator parameters that are reasonably detectable and quantifiable. The parameters of total organic carbon and total organic halides, however, are much more variable and are often below detection levels. Significant imprecision and variability occur when measuring these parameters near detection limits. The variability in laboratory measurements of field blanks is used to estimate laboratory limits of quantitation during the sampling period. The limit of quantitation is defined as ten times the standard deviation of the field blank analyses (Appendix D). For detection monitoring, the statistical comparison values for total organic carbon and total organic halides are the larger of either the critical mean or the limit of quantitation. The direct substitution of the detection limit biases the mean values high and likely decreases the variance used in calculating the critical means. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance* (EPA 530/R-09-007) recommends substitution methods for populations with proportion of non-detects less than 50 percent. For TOC and TOX, if the proportion of non-detects is

greater than this threshold, the measurements at a particular site cannot be estimated; therefore, a critical mean value cannot be calculated. In these cases, the critical mean is reported as NC (not calculable). In this analysis, values reported as being below the detection limit were substituted using robust regression on order statistics (*Nondetects and Data Analysis for Environmental Data* [Helsel, 2005]). Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance (EPA 530/R-09-007) recommends using 8 to 10 independent samples for background limit calculations. If data from 2010 to 2011 did not provide a suitable sample size, earlier data were incorporated until a suitable sample size was reached. For each site, the analyte with the minimum number of samples was considered. Typically, this was either TOX or TOC. The effect of this is that for all analytes at a site, the critical means at each site used data from the same period - although varying number of data points might be used. The period of data to be used at each site was determined before the proportion of non-detects was calculated and substitution methods considered.

The following data were excluded from the analysis.

- Review qualifiers coded with either an F, R, or Y. Definitions for these qualifiers can be found in Appendix D.
- Review qualifiers of Q and QH indicate blanks or duplicates with enough differences to require further evaluation. They are currently excluded from this analysis and may be reviewed at a later date.

The Bonferroni adjustment used to control the overall false-positive error rate while making multiple comparisons is a function of the number of comparisons being made. This analysis assumes that upgradient, as well as downgradient wells, will be compared against the critical means. This is consistent with earlier analysis.

Table B-2 lists the comparison values (critical mean values and limits of quantitation) used during the reporting period. Additional tables list updated critical mean values for use in calendar year 2012 for each RCRA unit where these statistics apply. Tables B-3 through B-41 provide supporting information for the RCRA sites, and Figures B-2 through B-17 show the locations of monitoring wells at RCRA regulated units.

This appendix also provides constituent lists, well network configurations, and other ancillary information for regulated facilities that fall outside of the RCRA program. Some network wells in these facilities are shared with RCRA facilities, and Figure B-18 shows the general locations of these facilities. Locations of monitoring wells for these facilities are shown in Figures B-5, B-14, B-19, B-20, and B-21. Tables B-42 through B-48 list the constituents and/or the results summaries for these facilities.

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Table B-1. Estimates of Groundwater Flow Rates at Hanford Site RCRA Facilities

Site	Flow Direction	Flow Rate (m/day)	Method	Hydraulic Conductivity (m/day) (Source)	Effective Porosity[a]	Gradient[b]	Comments
116-N-1 LWDF	Mar.: East-northeast Sept.: North-northwest	Mar.: 0.01 to 0.13 Sept: 0.05 to 0.84	Darcy	6.1 to 37 (PNL-8335)	--	Mar: 3.5×10^{-4d} Sept: 2.3×10^{-3d}	Trend surface analysis, wells 199-N-2, 199-N-3, 199-N-34, 199-N-57, and 199-N-105A.
120-N-1 and 120-N-2	Mar.: Northeast Sept.: East-northeast	Mar.: 0.01 to 0.19 Sept.: 0.02 to 0.34	Darcy	6.1 to 37 (PNL-8335)	--	Mar: 5.9×10^{-4d} Sept: 9.13×10^{-4d}	Trend surface analysis, wells 199-N-57, 199-N-71, 199-N-72, 199-N-73, and 199-N-165.
116-N-3 LWDF	Mar.: North-northwest Sept.: East-northeast	Mar.: 0.01 to 0.19 Sept.: 0.02 to 0.30	Darcy	6.1 to 37 (PNL-8335)	--	Mar: 5.1×10^{-4d} Sept: 8.0×10^{-4d}	Trend surface analysis, wells 199-N-28, 199-N-32, 199-N-34, 199-N-41, 199-N-71, and 199-N-81 (removed 199-N-28 and 199-N-81 and added 199-N-27 in Sept.).
116-H-6 Evaporation Basins	East	Not calculated	Darcy	15 to 140 (PNL-6728)	--	Not calculated	Flow toward extraction wells east of basins. Water level data not sufficient to calculate gradient.
216-A-29 Ditch	Southeast[c]	0.001 to 0.004	Darcy	18 (WHC-SD-EN-DP-047)	0.25	2.2×10^{-5}	Uncertainty with gradient and rate of flow (see Section 3.1.2).
216-A-36B Crib	East-northeast	0.001 to 0.6	Darcy	18 to 3,000 (PNNL-11523)	--	2.2×10^{-5e}	Trend surface analysis, wells 299-E17-18, 299-E17-21, 299-E17-22, 299-E17-23, 299-E17-25, 299-E24-16, 299-E24-18, 299-E24-21, 299-E24-24, 299-E25-36, and 699-37-47A

Table B-1. Estimates of Groundwater Flow Rates at Hanford Site RCRA Facilities

Site	Flow Direction	Flow Rate (m/day)	Method	Hydraulic Conductivity (m/day) (Source)	Effective Porosity[a]	Gradient[b]	Comments
216-A-37-1 Crib	Southeast	0.06 to 29.46	Darcy	18 to 3,000 (PNNL-11523)	--	9.8×10^{-4}	Uncertainty with gradient and rate of flow due to lack of corrected groundwater level measurements. Flow direction inferred from plume maps.
216-B-3 Pond	West	0.0048	Darcy	1.0 (WHC-SD-EN-EV-002; PNL-10195)	0.25	0.0014[e]	
216-B-63 Trench	Indeterminate	Indeterminate	Darcy	182 (WHC-MR-0207)	0.2	Indeterminate	Uncertainty with gradient and rate of flow due to proximity to flow divide.
216-S-10 Pond and Ditch	East-southeast	0.17	Darcy	10.4 (WHC-SD-EN-DP-052)	0.15	2.5×10^{-3}[d]	Trend surface analysis, wells 299-W26-13, 299-W26-14, 699-32-76, 699-32-77, 699-33-75, and 699-33-76.
316-5 Process Trenches	South-southeast	20	Darcy	9,000 (PNNL-17708)	0.17	3.8×10^{-4}[d]	Trend surface analysis, wells 399-1-6, 399-1-10A, 399-1-12, 399-1-15, 399-1-16A, 399-1-17A, and 399-1-18A
IDF	East-northeast	0.005 to 0.02	Darcy	68 to 75 (PNNL-13652; PNNL-11957)	--	2.2×10^{-5}[e]	Trend surface analysis, wells 299-E17-18, 299-E17-21, 299-E17-22, 299-E17-23, 299-E17-25, 299-E24-16, 299-E24-18, 299-E24-21, 299-E24-24, 299-E25-36, and 699-37-47A
LERF	Southwest	0.02	Darcy	39.8 (PNNL-14804)	0.373	2.6×10^{-4}[e]	Trend surface analysis, wells 299-E26-10, 299-E26-77, and 299-E26-79 (Section 3.4.113)

Table B-1. Estimates of Groundwater Flow Rates at Hanford Site RCRA Facilities

Site	Flow Direction	Flow Rate (m/day)	Method	Hydraulic Conductivity (m/day) (Source)	Effective Porosity[a]	Gradient[b]	Comments
LLWMA-1	Variable	Variable	Darcy	2,500 to 7,500 (PNNL-14753)	0.2	Variable[e]	Variable gradient and rate of flow due to mid-year flow change.
LLWMA-2	Indeterminate	Indeterminate	--	2,500 to 7,500 (PNNL-14753)	0.2	Indeterminate[e]	Uncertainty with gradient and rate of flow due to proximity to flow divide.
LLWMA-3	East-northeast	0.04 to 0.15	Darcy	2.5 to 10 (PNNL-14753)	0.1 (PNNL-14753)	1.5×10^{-3}[d]	Trend surface analysis, wells 299-W7-3, 299-W7-4, 299-W10-29, and 299-W10-31.
LLWMA-4	East	0.08 to 0.32	Darcy	2.5 to 10 (PNNL-14753)	0.1 (PNNL-14753)	3.2×10^{-3}[d]	Trend surface analysis, wells 299-W15-42, 299-W15-94, 299-W15-152, 299-W15-224, 299-W18-16, 299-W18-21, and 299-W18-40.
NRDWL	Southeast	0.16 to 1.4	Darcy	518 to 1,524 (WHC-EP-0021)	--	9.3×10^{-5}[d]	Trend surface analysis, wells 699-8-25, 699-20-20, 699-22-35, 699-24-34C, 699-26-33, and 699-28-40.
WMA A-AX	Southeast	Indeterminate	Darcy	1,981 (PNL-8337; WHC-SD-EN-TI-019)	--	Indeterminate	Uncertainty with gradient and rate of flow due to lack of corrected groundwater level measurements. Flow direction inferred from plume maps.
WMA B-BX-BY	Variable	Variable	Darcy	73 to 2,520 (PNL-6820)	0.3	Variable	Variable with gradient and rate of flow due to mid-year flow change.

Table B-1. Estimates of Groundwater Flow Rates at Hanford Site RCRA Facilities

Site	Flow Direction	Flow Rate (m/day)	Method	Hydraulic Conductivity (m/day) (Source)	Effective Porosity[a]	Gradient[b]	Comments
WMA C	South	Indeterminate	Darcy	1890 to 6,888 (PNNL-14656)	0.3	Indeterminate	Uncertainty with gradient and rate of flow due to lack of corrected groundwater level measurements.
WMA S-SX	East to east-southeast	0.07 to 0.14	Contaminant travel time (PNNL-13441)	NA	NA	NA	Based on inferred contaminant travel time between 216-S-25 Crib and downgradient wells 299-W23-15 and 299-W22-46, and between wells 299-W22-46 and 299-W22-83.
	East	0.10	Darcy	6.1 (PNNL-13514; PNNL-14113, PNNL-14186)	0.12	2.0×10^{-3}[d]	Trend surface analysis, wells 299-W22-44, 299-W22-45, 299-W22-47, 299-W22-48, 299-W22-49, 299-W22-50, 299-W22-80, 299-W22-81, 299-W22-82, 299-W22-83, 299-W22-84, 299-W22-89, 299-W23-15, 299-W23-20, and 299-W23-21.
WMA T	East-northeast	0.12 to 0.19	Darcy	6.11 to 9.69 (PNNL-17732)	0.1	2.0×10^{-3}[d]	Trend surface analysis, wells 299-W10-1, 299-W10-4, 299-W10-8, 299-W10-23, 299-W10-28, 299-W11-12, 299-W11-40, 299-W11-41, and 299-W11-42. Flow direction and gradient influenced by groundwater extraction south and west of the WMA.
WMA TX-TY	Variable	NA	NA	0.07 to 19.9 (PNNL-18279)	0.18 (DOE/RL-2009-38)	NA	Flow direction and rate influenced by 200-ZP-1 pump-and-treat system (Section 3.2.10).

Table B-1. Estimates of Groundwater Flow Rates at Hanford Site RCRA Facilities

Site	Flow Direction	Flow Rate (m/day)	Method	Hydraulic Conductivity (m/day) (Source)	Effective Porosity[a]	Gradient[b]	Comments
WMA U	East-northeast	0.077	Darcy	6.12 (PNNL-13378)	0.17	2.1×10^{-3}[d]	Trend surface analysis, wells 299-W18-30, 299-W18-31, 299-W18-40, 299-W19-12, 299-W19-41, 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47.

Note: Complete citations are provided in the References Section of the main text for the appendix.

a. Effective porosity assumed to be between 0.1 and 0.3, a representative range for the unconfined aquifer system, unless otherwise noted.

b. March 2011, unless noted otherwise.

c. Flow direction is based on those determined on a regional basis.

d. ECF-HANFORD-12-0048, *Hydraulic Gradients and Velocity Calculations for RCRA Sites in 2011.*

e. ECF-HANFORD-12-0061, *Groundwater Hydraulic Gradient and Velocity Calculations for 200 East Area RCRA Sites in 2011.*

NA = not applicable

Table B-2. Upgradient/Downgradient Comparison Values Used for Statistical Comparisons at RCRA Sites, 2011

Quarter	Specific Conductance Critical Mean (µS/cm)	pH Critical Range	TOC Critical Mean[a,b]/LOQ (µg/L)	TOX Critical Mean[a]/ LOQ (µg/L)
116-N-1 (1301-N) Facility				
Jan. to Mar. 2011	1,950	5.39 – 10.15	**2,350**/210	**33.4**/11.8
Apr. to June 2011	1,950	5.39 – 10.15	**2,350**/240	**33.4**/15.0
July to Sept. 2011	1,950	5.39 – 10.15	**2,350**/670	**33.4**/25.5
120-N-1 and 120-N-2 (1324-N/NA) Facilities				
Jan. to Mar. 2011	785	7.34 – 8.59	**860**/210	**15.9**/11.8
July to Sept. 2011	785	7.34 – 8.59	**860**/670	15.9/**25.5**
Oct. to Dec. 2011	785	7.34 – 8.59	860/**1620**	**15.9**/NA
116-N-3 (1325-N) Facility				
Jan. to Mar. 2011	520	7.12 – 8.91	**1,040**/210	**21.5**/11.8
July to Sept. 2011	520	7.12 – 8.91	**1,040**/670	21.5/**25.5**
216-A-29 Ditch				
Apr. to June 2011	336	7.46 – 8.79	**1,970**/240	10.4/**15.0**
July to Sept. 2011	336	7.46 – 8.79	**1,970**/670	10.4/**25.5**
Oct. to Dec. 2011	336	7.46 – 8.79	**1,970**/1620	10.4/**28.1**
216-B-3 Pond				
Apr. to June 2011	340	6.90 – 9.17	**920**/240	13.1/**15.1**
July to Sept. 2011	340	6.90 – 9.17	**920**/670	13.1/**25.5**
Oct. to Dec. 2011	340	6.90 – 9.17	920/**1620**	13.1/NA

Table B-2. Upgradient/Downgradient Comparison Values Used for Statistical Comparisons at RCRA Sites, 2011

Quarter	Specific Conductance Critical Mean (µS/cm)	pH Critical Range	TOC Critical Mean[a,b]/LOQ (µg/L)	TOX Critical Mean[a]/ LOQ (µg/L)
216-B-63 Trench				
Jan. to Mar. 2011	1,030	7.42 – 8.67	**1,000**/210	10.9/**11.8**
Apr. to June 2011	1,030	7.42 – 8.67	**1,000**/240	10.9/**15.0**
Oct. to Dec. 2011	1,030	7.42 – 8.67	1,000/**1620**	10.9/**28.1**
216-S-10 Pond and Ditch				
Jan. to Mar. 2011	350	6.72 – 8.85	**1,510**/210	**17.6**/11.8
Apr. to June 2011	350	6.72 – 8.85	**1,510**/240	**17.6**/15.0
Oct. to Dec. 2011	350	6.72 – 8.85	1,510/**1620**	**17.6**/NA
LLWMA-1				
Jan. to Mar. 2011	1,110	7.43 – 8.57	**1,330**/210	11.1/**11.8**
Apr. to June 2011	1,110	7.43 – 8.57	**1,330**/240	11.1/**15.0**
LLWMA-2				
Apr. to June 2011	1,460	6.72 – 8.89	**2,200**/240	**37.1**/15.0
Oct. to Dec. 2011	1,460	6.72 – 8.89	**2,200**/1620	**37.1**/28.1
LLWMA-3				
No statistical comparisons until new baseline is established.				
LLWMA-4				
Jan. to Mar. 2011	750	7.00 – 8.84	**870**/210	**24.3**/11.8
July to Sept. 2011	750	7.00 – 8.84	**870**/670	24.3/**25.5**
Oct. to Dec. 2011	750	7.00 – 8.84	870/**1620**	**24.3**/NA

Table B-2. Upgradient/Downgradient Comparison Values Used for Statistical Comparisons at RCRA Sites, 2011

Quarter	Specific Conductance Critical Mean (µS/cm)	pH Critical Range	TOC Critical Mean[a,b]/LOQ (µg/L)	TOX Critical Mean[a]/ LOQ (µg/L)
		NRDWL		
Jan. to Mar. 2011	570	6.95 – 7.66	**1,010**/210	**13.9**/11.8
July to Sept. 2011	570	6.95 – 7.66	**1,010**/670	13.9/**25.5**
Oct. to Dec. 2011	570	6.95 – 7.66	1,010/**1620**	13.9/**28.1**

a. Upgradient/downgradient comparison values (in **bold**) for TOC and TOX are the larger of calculated critical mean value and limit of quantitation for the respective quarter.
b. Reported values rounded to the nearest 10 µg/L.
LOQ = limit of quantitation; based on field blanks collected and analyzed in the previous four quarters
NC = not calculated
NA = no blanks data available
TOC = total organic carbon
TOX = total organic halides

Table B-3. Monitoring Wells and Constituents for 100-N Area Units

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters				Other Parameters				Sampled as Scheduled in 2011
			Specific Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Alpha[b]	Anions	Metals (Filtered)	
116-N-1 (1301-N) Liquid Waste Disposal Facility											
199-N-105A	--	C	S	S	S	S	A	--	A	A	Yes
199-N-2	--	P	S	S	S	S	A	--	A	A	Yes
199-N-3	--	P	S	S	S	S	A	--	A	A	Yes
199-N-34	--	P	S	S	S	S	A	--	A	A	Yes
199-N-57	--	C	S	S	S	S	A	--	A	A	Yes
120-N-1 and 120-N-2 (1324-N/NA) Facilities											
199-N-71	--	C	S	S	S	S	A	--	A	A	Yes
199-N-72	--	C	S	S	S	S	A	--	A	A	Yes
199-N-73	--	C	S	S	S	S	A	--	A	A	Yes
199-N-77	Bottom of aquifer; no statistics	C	S	S	S	S	A	S	A	A	Yes
199-N-165	--	C	S	S	S	S	A	A	A	A	Yes
116-N-3 (1325-N) Liquid Waste Disposal Facility											
199-N-28	Information only; no statistics	P	S	S	S	S	A	--	A	A	Yes
199-N-32	--	P	S	S	S	S	S	--	S	S	Yes
199-N-41	--	P	S	S	S	S	A	--	A	A	Yes
199-N-74	--	C	S	S	S	S	A	--	A	A	Yes
199-N-81	--	C	S	S	S	S	A	--	A	A	Yes

Note: Requirements are from *Groundwater Monitoring Plan for the 1301-N, 1324-N/NA, and 1325-N RCRA Facilities* (PNNL-13914).

Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Monitored for the *Atomic Energy Act of 1954.*

A = to be sampled annually

C = well is constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed prior to WAC requirements

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-4. Critical Means for 1301-N (116-N-1) Liquid Waste Disposal Facility for 2012 Comparisons

Constituent (units)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	8	7	7.74	0.42	5%	5.41	5.31 - 10.17	0%
Specific conductance (µS/cm)	8	7	718.34	260.89	36%	5.41	2214.81	0%
TOC* (µg/L)	8	7	570.19	322.15	56%	5.41	2397.92	13%
TOX* (µg/L)	8	7	7.29	45.75	45%	5.41	26.12	47%

Note: Based on semiannual sampling events from March 2010 through September 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 20 comparisons

TOC = total organic carbon

TOX = total organic halides

ND = non-detects

Table B-5. Critical Means for 1324-NA (120-N-1) Percolation Pond and 1324-N (120-N-2) Surface Impoundment for 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	17	16	8.02	0.10	1%	3.91	7.6 - 8.43	0%
Specific conductance (µS/cm)	17	16	471.21	28	6%	3.91	584.64	0%
TOC* (µg/L)	8	7	354.34	58.90	17%	5.20	679.37	0%
TOX* (µg/L)	8	7	5.20	1.40	27%	5.20	12.93	43%

Note: Based on semiannual sampling events from December 2007 through November 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 16 comparisons

TOC = total organic carbon

TOX = total organic halides

ND = non-detects

Table B-6. Critical Means for 1325-N (116-N-3) Liquid Waste Disposal Facility for 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	10	9	8.05	0.12	1%	4.62	7.48 - 8.63	0%
Specific conductance (µS/cm)	10	9	405.20	12.02	3%	4.62	463.45	0%
TOC* (µg/L)	10	9	NC	NC	NC	NC	NC	59%
TOX* (µg/L)	8	7	5.87	2.33	40%	5.20	18.73	36%

Note: Based on semiannual sampling events from March 2008 through September 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

tc = Bonferroni critical t-value for appropriate df and 16 comparisons

TOC = total organic carbon

TOX = total organic halides

ND = non-detects

NC = not calculated because proportion of non-detects is greater than 50%

Table B-7. Monitoring Wells and Constituents for 183-H (116-H-6) Evaporation Basins

Well Number	Comment	WAC-Compliant	Permit-Specified					Other Parameters			Sampled as Scheduled in 2011
			Chromium (Filtered)	Nitrate	Tc-99*	Fluoride	Uranium[a]	Alkalinity	Anions	Metals (Filtered)	
199-H4-12A	Extraction well	C	A	A	A	A	A	A	A	A	Yes
199-H4-12C	Extraction well; RUM	C	A	A	A	A	A	A	A	A	Yes
199-H4-3	Extraction well	P	A	A	A	A	A	A	A	A	Yes
199-H4-8	--	C	A	A	A	A	A	A	A	A	Yes

Notes:

Requirements are from *Groundwater Monitoring Plan for the 183-H Solar Evaporation Basins* (PNNL-11573) and the 2008 Hanford Facility RCRA Permit modification (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*).

Wells completed at the top of the unconfined aquifer unless specified otherwise.

* Radionuclides not typically subject to RCRA monitoring but included in the current Hanford Facility RCRA Permit (WA7890008967) for this facility.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed before WAC requirements

Table B-8. Monitoring Wells and Constituents for 216-A-29 Ditch

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters				Other Parameters				Sampled as Scheduled in 2011
			Specific. Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Anions	Metals	Phenols	
299-E25-26	Upper unconfined	C	S	S	S	S	S	S	A	A	No[b]
299-E25-28	Deep unconfined; no statistics	C	A	A	A	A	A	A	A	A	Yes
299-E25-32P	--	C	S	S	S	S	S	S	A	A	Yes
299-E25-35	--	C	S	S	S	S	S	S	A	A	Yes
299-E25-48	--	C	S	S	S	S	S	S	A	A	Yes
299-E26-12	--	C	A	A	A	A	A	A	A	A	Yes
299-E26-13	--	C	S	S	S	S	S	S	A	A	Yes
699-43-45	--	C	S	S	S	S	S	S	A	A	Yes

Note: Requirements from *Interim Status Groundwater Monitoring Plan for the 216-A-29 Ditch* (DOE/RL-2008-58).

Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. Upgradient well(s) are noted in ***bold italic***.

b. Well was not sampled for the year due to maintenance and pump issues (2 sample events missed).

A = to be sampled annually

C = well is constructed as a resource protection well in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-9. Critical Means for 216-A-29 Ditch for 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	12	11	8.20	0.13	2%	4.72	7.58 - 8.82	0%
Specific conductance (µS/cm)	12	11	270.23	23.67	9%	4.72	386.63	0%
TOC* (µg/L)	12	11	301.61	73.65	24%	4.72	663.75	49%
TOX* (µg/L)	12	11	NC	NC	NC	NC	NC	63%

Note: Based on semiannual sampling events from January 2010 through November 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 32 comparisons

TOC = total organic carbon

TOX = total organic halides

ND = non-detects

NC = not calculated because proportion non-detects is greater than 50%

Table B-10. Monitoring Wells and Constituents for 216-A-36B Crib

Well Number[a]	WAC-Compliant	Other Field Parameters	Indicator Parameters	Supporting Constituents					Sampled as Scheduled in 2011
		Temperature, Turbidity, Water Levels	Specific Conductance, pH, TOC, TOX	Anions[b]	Metals[c]	Alkalinity	Phenols	VOCs[d]	
299-E17-14	C	S	S	A	A	A	--	2	Yes
299-E17-16	C	S	S	A	A	A	--	2	Yes
299-E17-18	C	S	S	A	A	A	--	2	Yes
299-E17-19	C	Q	Q[e]	A	A	A	--	2	Yes

Note:

1. Requirements for 216-A-36B Crib are from *Interim Status Groundwater Monitoring Plan for the 216-A-36B PUREX Plant Crib* (DOE/RL-2010-93).

2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Anions analysis includes, at a minimum, nitrate and the groundwater quality parameters chloride and sulfate.

c. Metals analysis includes, at a minimum, calcium, magnesium, potassium, and sodium, as well as the groundwater quality parameters iron and manganese.

d. Samples analyzed for VOCs for one year (two sampling events).

e. Quadruplicate replicates collected during each sampling event.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

Q = to be sampled quarterly

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-11. Critical Means for 216-A-36B Crib for CY 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	12	11	7.92	0.06	1%	4.30	7.64 - 8.19	0%
Specific conductance (µS/cm)	12	11	574.90	49.07	9%	4.30	794.64	0%
TOC* (µg/L)	4	3	182.49	96.78	53%	11.98	1479.15	25%
TOX* (µg/L)	3	2	5.06	1.98	39%	28.26	69.82	50%

Note: Based on quarterly sampling events from April 2007 through October 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 16 comparisons

TOC = total organic carbon

TOX = total organic halides

ND = non-detects

Table B-12. Monitoring Wells and Constituents for 216-A-37-1 Crib

Well Number[a]	WAC-Compliant	Other Field Parameters	Indicator Parameters	Supporting Constituents					Sampled as Scheduled in 2011
		Temperature, Turbidity, Water Levels	Specific Conductance, pH, TOC, TOX	Anions[b]	Metals[c]	Alkalinity	Phenols	VOCs[d]	
299-E25-17	P	S	S	A	A	A	A	2	Yes
299-E25-19	P	S	S	A	A	A	A	2	Yes
299-E25-20	P	S	S	A	A	A	A	2	Yes
299-E25-47	C	Q	Q[e]	Q	Q	A	A	2	Yes

Notes:

Requirements for 216-A-37-1 Crib are from *Interim Status Groundwater Monitoring Plan for the 216-A-37-1 PUREX Plant Crib* (DOE/RL-2010-92).

Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Anions analysis includes, at a minimum, nitrate and the groundwater quality parameters chloride and sulfate.

c. Metals analysis includes, at a minimum, calcium, magnesium, potassium, and sodium, as well as the groundwater quality parameters iron and manganese.

d. Samples analyzed for VOCs for one year (two sampling events).

e. Quadruplicate replicates collected during each sampling event.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed before WAC requirements

Q = to be sampled quarterly

S = to be sampled semiannually

VOC = volatile organic compounds

TOC = total organic carbon

TOX = total organic halides

Table B-13. Critical Means for 216-A-37-1 Crib for 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	4	3	8.39	0.06	1%	11.98	7.63 - 9.16	0%
Specific conductance (µS/cm)	4	3	419.44	15.95	4%	11.98	633.15	0%
TOC* (µg/L)	3	2	321.11	94.43	29%	28.26	3402.39	0%
TOX* (µg/L)	4	3	5.31	2.06	39%	11.98	32.92	19%

Note: Based on quarterly sampling events from March through October 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation
df = degrees of freedom (n-1)
n = number of background replicate averages
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons
TOC = total organic carbon
TOX = total organic halides
ND = non-detects

Table B-14. Monitoring Wells and Constituents for 216-B-3 Pond

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters				Other Parameters						Sampled as Scheduled in 2011
			Specific Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Alpha[b]	Anions	Beta[b]	Metals	Phenols	
699-42-42B	Bottom of aquifer	C	S	S	S	S	A	A	A	A	A	A	Yes
699-43-44	--	C	S	S	S	S	A	A	A	A	A	A	Yes
699-43-45	--	C	S	S	S	S	A	A	A	A	A	A	Yes
699-44-39B	--	C	S	S	S	S	A	A	A	A	A	A	Yes

Note: Requirements are from *Interim Status Groundwater Monitoring Plan for the 216-B-3 Pond* (DOE/RL-2008-59).

Wells completed at the top of the unconfined aquifer, unless specified otherwise.

a. Upgradient well noted by ***bold italic***.

b. Monitored for the *Atomic Energy Act of 1954*.

A = to be sampled annually
C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"
S = to be sampled semiannually
TOC = total organic carbon
TOX = total organic halides

Table B-15. Critical Means for 216-B-3 Pond for 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	8	7	8.05	0.12	2%	5.20	7.38 - 8.72	0%
Specific conductance (µS/cm)	8	7	269.97	0.12	0%	5.20	344.18	0%
TOC* (µg/L)	8	7	NC	NC	NC	NC	NC	63%
TOX* (µg/L)	8	7	NC	NC	NC	NC	NC	78%

Note: Based on semiannual sampling events from January 2008 through November 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 16 comparisons

TOC = total organic carbon

TOX = total organic halides

ND = non-detects

NC = not calculated because proportion non-detects is greater than 50%

Table B-16. Monitoring Wells and Constituents for 216-B-63 Trench

Well Number	WAC-Compliant	Contamination Indicator Parameters				Other Parameters						Sampled as Scheduled in 2011
		Specific Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Alpha*	Anions	Beta*	Metals	Phenols	
299-E27-11	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E27-16	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E27-17	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E27-18	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E27-19	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E33-37	C	S	S	S	S	A	A	A	A	A	A	Yes
299-E34-10	C	S	S	S	S	A	A	A	A	A	A	Yes

Notes: Requirements are from *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench* (DOE/RL-2008-60).

Wells completed at the top of the unconfined aquifer, unless specified otherwise.

* Monitored for the *Atomic Energy Act of 1954*.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-17. Critical Means for 216-B-63 Trench for 2012 Comparisons

Constituent (unit)	N	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	21	20	8.06	0.10	1%	4.22	7.61 - 8.51	0%
Specific conductance (µS/cm)	20	19	526.06	142.94	27%	4.27	1151.04	0%
TOC* (µg/L)	20	19	359.03	145.58	41%	4.27	995.56	23%
TOX* (µg/L)	20	19	NC	NC	NC	NC	NC	57%

Note: Based on semiannual sampling events from April 2010 through November 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 48 comparisons

TOC = total organic carbon

TOX = total organic halides

ND = non-detects

NC = not calculated because proportion non-detects is greater than 50%

Table B-18. Monitoring Wells and Constituents for 216-S-10 Pond and Ditch

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters				Other Parameters								Sampled as Scheduled During 2011
			Specific Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Anions	Carbon Tetrachloride	Chloroform	Hexavalent Chromium	Metals	Phenols	Mercury	
299-W26-13	--	C	S	S	S	S	S	A	A	A	S	A	A	S	Yes
299-W26-14	--	C	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-W27-2	Bottom of aquifer; no statistics	C	A	A	A	A	A	A	A	A	A	A	A	A	Yes
699-32-76		C	S	S	S	S	S	A	A	A	S	A	A	S	Yes
699-33-75		C	S	S	S	S	S	A	A	A	S	A	A	S	Yes
699-33-76	Quarterly samples – TOC, TOX[b]	C	S	S	S	S	S	A	A	A	S	A	A	S	Yes

Notes: Requirements are from *Interim Status Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch* (DOE/RL-2008-61).

Wells completed at the top of the unconfined aquifer, unless specified otherwise.

a. Upgradient well noted by ***bold italic***.

b. Quarterly samples collected for TOC and TOX for obtaining baseline conditions.

Routine monitoring frequency will be semiannual as shown.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-19. Critical Means for 216-S-10 Pond and Ditch for 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	4	3	7.73	0.08	1%	12.92	6.54 - 8.93	0%
Specific conductance (µS/cm)	4	3	293	3.96	1%	12.92	351	0%
TOC* (µg/L)	4	3	306.60	161.33	53%	12.92	2,638	25%
TOX* (µg/L)	4	3	6.91	3.66	53%	12.92	60	25%

Note: Based on sampling events from March 2011 through December 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation
df = degrees of freedom (n-1)
n = number of background replicate averages
t_c = Bonferroni critical t-value for appropriate df and 20 comparisons
TOC = total organic carbon
TOX = total organic halides
ND = non-detects

Table B-20. Monitoring Wells and Constituents for 316-5 Process Trenches

Well Number	Comment	WAC-Compliant	*cis*-1,2-Dichloroethene	Tetrachloroethene	Trichloroethene	Uranium[a]	Sampled as Scheduled in 2011
399-1-10A	--	C	S	S	S	S	Yes
399-1-10B	Lower unconfined	C	S	S	S	S	Yes
399-1-16A	--	C	S	S	S	S	Yes
399-1-16B	Lower unconfined	C	S	S	S	S	Missed 1 month
399-1-17A	--	C	S	S	S	S	Yes
399-1-17B	Lower unconfined	C	S	S	S	S	Missed 2 months
399-1-18A	--	C	S	S	S	S	Yes
399-1-18B	Lower unconfined	C	S	S	S	S	Missed 2 months

Notes:

Requirements are from *Groundwater Monitoring Plan for the 300 Area Process Trenches* (WHC-SD-EN-AP-185).

2. Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. Radionuclides are not typically subject to RCRA monitoring, but included in the current Hanford Facility RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*) for this facility.

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled four times semiannually (8 months)

Table B-21. Monitoring Wells and Constituents for the Integrated Disposal Facility

Well Number[a]	WAC-Compliant	Indicator Parameters					Other Parameters								Sampled as Scheduled in 2011
		Chromium (Filtered)	Specific Conductance (Field)	pH (Field)	TOC	TOX	Alkalinity	Turbidity (Field)	Anions	Metals	Alpha[b]	Beta[b]	Iodine-129[b]	Technetium-99[b]	
299-E17-22	C	A	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-23	C	A	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-25	C	A	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E17-26	C	A	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E18-1	C	A	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E24-21	C	A	A	A	A	A	A	A	A	A	A	A	A	A	Yes
299-E24-24	C	A	A	A	A	A	A	A	A	A	A	A	A	A	Yes

Notes:

Requirements are from *Hanford Facility Dangerous Waste Permit Application, Integrated Disposal Facility* (DOE/RL-2003-12) and *Integrated Disposal Facility Operational Monitoring Plan to Meet DOE Order 435.1* (RPP-PLAN-26534).

Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Operational parameters are monitored for DOE O 435.1, *Radioactive Waste Management*.

c. The sample frequency on all samples was changed to annually with the approval of Ecology starting in 2011.

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

TOC = total organic carbon

TOX = total organic halides

Table B-22. Monitoring Wells and Constituents for Liquid Effluent Retention Facility

Well Number[a]	WAC-Compliant	Alkalinity	Alpha[b]	Ammonium	Anions	Beta[b]	Metals	Phenols	VOA	Sampled as Scheduled in 2011
299-E26-10	C	A	S	S	A	S	A	A	S	Yes
299-E26-11	C	A	S	S	A	S	A	A	S	Yes
299-E26-14[c]	C	A	S	S	A	S	A	A	S	New well not sampled in 2011
299-E26-77	C	A	S	S	A	S	A	A	S	Yes
299-E26-79	C	A	S	S	A	S	A	A	S	Yes

Notes: Requirements are from *Interim Status Groundwater Monitoring Plan for the 200 East Area Liquid Effluent Retention Facility* (WHC-SD-EN-AP-024).

Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Monitored for the *Atomic Energy Act of 1954*.

c. Well 299-E26-14 was constructed in September 2011 and will be sampled in 2012 for the same analytes as the other wells and will be evaluated for inclusion in the monitoring well network.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

VOA = volatile organic analysis

Table B-23. Monitoring Wells and Constituents for Low-Level Waste Management Area 1

Well Name[a]	Purpose	WAC Compliant	Water Level[d]	RCRA Required Constituents[b]														Sampled as Scheduled in 2011
				Contaminant Indicator Parameters				Groundwater Quality Parameters						Supporting Constituents[c]				
								Anions[e]			Metals, Unfiltered, Filtered[d]							
				pH[d]	Specific Conductance[d]	TOC	TOX	Chloride	Sulfate	Phenols	Iron	Manganese	Sodium	Alkalinity	Dissolved Oxygen[d]	Temperature[d]	Turbidity[d]	
299-E28-26	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E28-27	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E28-28	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-2	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-3	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-4	Cross-gradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-5	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-6	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-7	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-8	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-9	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E32-10	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E33-28	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E33-29	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes

Table B-23. Monitoring Wells and Constituents for Low-Level Waste Management Area 1

Well Name[a]	Purpose	WAC Compliant	Water Level[d]	RCRA Required Constituents[b]										Supporting Constituents[c]				Sampled as Scheduled in 2011
				Contaminant Indicator Parameters				Groundwater Quality Parameters										
								Anions[e]			Metals, Unfiltered, Filtered[d]							
				pH[d]	Specific Conductance[d]	TOC	TOX	Chloride	Sulfate	Phenols	Iron	Manganese	Sodium	Alkalinity	Dissolved Oxygen[d]	Temperature[d]	Turbidity[d]	
299-E33-34	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E33-35	Upgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E33-265	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E33-266	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes

Note: Requirements are from *Interim Status Groundwater Monitoring Plan for LLBG WMA-1* (DOE/RL-2009-75).

a. Upgradient wells are noted in ***bold italic***.

b. Constituents and parameters are required by 40 CFR 265.92, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis."

c. Constituents not required by RCRA but used for geochemical support.

d. Field measurement.

e. For anions, analytes include chloride, fluoride, nitrate, nitrite, and sulfate. For metals, analytes include (but are not limited to) calcium, chromium, iron, manganese, potassium, and sodium.

A = to be sampled annually
RCRA = *Resource Conservation and Recovery Act of 1976*
S = to be sampled semiannually
TOC = total organic carbon
TOX = total organic halides
Y = well is constructed in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," requirements

Table B-24. Critical Means for Low-Level Waste Management Area 1 for 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	26	25	8.03	0.14	2%	4.20	7.42 - 8.64	0%
Specific conductance (µS/cm)	26	25	595.99	165.76	28%	4.20	1305.87	0%
TOC* (µg/L)	26	25	234.55	82.25	35%	4.20	586.79	41%
TOX* (µg/L)	26	25	NC	NC	NC	NC	NC	73%

Note: Based on semiannual sampling events from January 2010 through December 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 68 comparisons

TOC = total organic carbon

TOX = total organic halides

ND = non-detects

NC = not calculated because proportion non-detects is greater than 50%

Table B-25. Monitoring Wells and Constituents for Low-Level Waste Management Area 2

Well Name	Purpose	WAC Compliant	Water Level[c]	RCRA Required Constituents[a]										Supporting Constituents[b]				Sampled as Scheduled in 2011
				Contaminant Indicator Parameters				Groundwater Quality Parameters										
								Anions[d]			Metals, Unfiltered, Filtered[d]							
				pH[c]	Specific Conductance[c]	TOC	TOX	Chloride	Sulfate	Phenols[d]	Iron	Manganese	Sodium	Alkalinity	Dissolved Oxygen[c]	Temperature[c]	Turbidity[c]	
299-E27-8	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E27-9	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E27-10	Cross-gradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E27-11	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E27-17	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E34-2	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E34-9	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E34-10	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes
299-E34-12	Downgradient	Y	S	S	S	S	S	S	S	A	S	S	S	S	S	S	S	Yes

Table B-25. Monitoring Wells and Constituents for Low-Level Waste Management Area 2

Well Name	Purpose	WAC Compliant	Water Level[c]	RCRA Required Constituents[a]										Supporting Constituents[b]				Sampled as Scheduled in 2011
				Contaminant Indicator Parameters				Groundwater Quality Parameters										
								Anions[d]			Metals, Unfiltered, Filtered[d]							
				pH[c]	Specific Conductance[c]	TOC	TOX	Chloride	Sulfate	Phenols[d]	Iron	Manganese	Sodium	Alkalinity	Dissolved Oxygen[c]	Temperature[c]	Turbidity[c]	

Note: Requirements are from *Interim Status Groundwater Monitoring Plan for LLBG WMA-2* (DOE/RL-2009-76).

a. Constituents and parameters are required by 40 CFR 265.92, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis."

b. Constituents not required by RCRA but needed to support interpretation.

c. Field measurement.

d. For anions, analytes include chloride, fluoride, nitrate, nitrite, and sulfate. For metals, analytes include (but are not limited to) calcium, chromium, iron, manganese, potassium, and sodium.

A = to be sampled annually

RCRA= *Resource Conservation and Recovery Act of 1976*

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Y = well is constructed in accordance with requirements of WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells."

Table B-26. Critical Means for Low-Level Waste Management Area 2 for 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	tc	Critical Mean	Proportion ND Site
pH	9	8	7.78	0.17	2%	5.53	6.82 - 8.75	0%
Specific conductance (µS/cm)	9	8	1069.86	55.92	5%	5.53	1395.68	0%
TOC* (µg/L)	8	7	728.34	185.71	25%	5.98	1905.43	0%
TOX* (µg/L)	7	6	5.66	0.64	11%	6.66	10.19	28%

Note: Based on semiannual sampling events from January 2010 through November 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation
df = degrees of freedom (n-1)
n = number of background replicate averages
t_c = Bonferroni critical t-value for appropriate df and 36 comparisons
TOC = total organic carbon
TOX = total organic halides
ND = non-detects

Table B-27. Monitoring Wells and Constituents for Low-Level Waste Management Area 3

Well Number	WAC-Compliant	Contamination Indicator Parameters				Other Chemical Parameters				Sampled as Scheduled in 2011
		pH (Field)	Specific Conductance (Field)	TOC	TOX	Alkalinity	Anions	Metals	Phenols	
299-W7-4	C	S	S	S	S	S	A	A	A	No*
299-W10-29	C	S	S	S	S	S	A	A	A	Yes
299-W10-30	C	S	S	S	S	S	A	A	A	Yes
299-W10-31	C	S	S	S	S	S	A	A	A	Yes

Notes:

Requirements are from *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3* (DOE/RL-2009-68).

Wells completed at the top of the unconfined aquifer unless specified otherwise.

* Well 299-W7-4 went dry in 2011.

A = to be sampled annually
C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"
S = to be sampled semiannually
TOC = total organic carbon
TOX = total organic halides

Table B-28. Indicator Parameter Averages for 2010 and 2011 at LLWMA-3 Downgradient Wells

Well	pH		Specific Conductance		Total Organic Carbon		Total Organic Halides	
	2011	2010	2011	2010	2011	2010	2011	2010
299-W10-29	7.91	7.91	386	384	436	1,766	19.1	22.7
299-W10-30	7.76	7.84	419	419	1,696	2,059	10.7	9.2
299-W10-31	7.84	8.01	596	504	615	463	36.0	50.0

Source: Environmental Dashboard Application, 2012. Available at: http://environet.hanford.gov/eda/.

Table B-29. Monitoring Wells and Constituents for Low-Level Waste Management Area 4

Well Number[a]	Comment	WAC Compliant	Contamination Indicator Parameters				Other Chemical Parameters				Sampled as Scheduled in 2011
			pH (Field)	Specific Conductance (Field)	TOC	TOX	Alkalinity	Anions	Metals	Phenols	
299-W15-17	Deep unconfined; no statistics	C	S	S	S	S	S	A	A	A	Yes
299-W15-30	--	C	S	S	S	S	S	A	A	A	Yes
299-W15-83	--	C	S	S	S	S	S	A	A	A	Yes
299-W15-94	--	C	S	S	S	S	S	A	A	A	Yes
299-W15-152	--	C	S	S	S	S	S	A	A	A	Yes
299-W15-224	--	C	S	S	S	S	S	A	A	A	No[b]
299-W18-21	Went dry in mid-2010	C	S	S	S	S	S	A	A	A	No[c]
299-W18-22	Deep unconfined; no statistics	C	S	S	S	S	S	A	A	A	Yes

Notes:

Requirements are from *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4* (DOE/RL-2009-69).

Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. Well 299-W15-224 was not sampled in July as scheduled due to electrical problems with the well pump.

c. Well 299-W18-21 was not sampled in 2011 as it went dry in July 2010.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semiannually

TOC = total organic carbon

TOX = total organic halides

Table B-30. Critical Means for Low-Level Waste Management Area 4 for 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	11	10	7.86	0.09	1%	4.98	7.38 - 8.34	0%
Specific conductance (µS/cm)	11	10	430.09	73.12	17%	4.98	810.24	0%
TOC* (µg/L)	9	8	259.48	75.07	29%	5.53	696.88	28%
TOX* (µg/L)	9	8	NC	NC	NC	NC	NC	64%

Note: Based on semiannual sampling events from February 2009 through November 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 36 comparisons

TOC = total organic carbon

TOX = total organic halides

ND = non-detects

NC = not calculated because proportion non-detects is greater than 50%

Table B-31. Indicator Parameter Averages for 2010 and 2011 at LLWMA-4 Wells

Well	pH		Specific Conductance		Total Organic Carbon		Total Organic Halides	
	2011	2010	2011	2010	2011	2010	2011	2010
299-W15-17[a]	8.04	7.86	374	381	125	300	6	5
299-W15-30[a]	8.17	8.45	522	503	283	422	46	71
299-W15-83[a]	7.88	7.77	533	548	374	440	18	19
299-W15-94[a]	7.85	7.89	536	532	376	394	24	48
299-W15-152[a]	7.72	7.82	562	536	379	497	17	25
299-W15-224[a]	7.83	7.80	510	523	269	721	26	31
299-W18-21[b]	7.90	7.87	530	483	265	357	5	6
299-W18-22[b]	7.82	7.95	384	372	274	300	5	5

Source: Environmental Dashboard Application, 2012. Available at: http://environet.hanford.gov/eda/.

a. downgradient well

b. upgradient well

Table B-32. Monitoring Wells and Constituents for the Nonradioactive Dangerous Waste Landfill

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters				Other Chemical Parameters				Sampled as Scheduled in 2011
			pH (field)	Specific Conductance (Field)	TOC	TOX	Anions	Metals	Phenols	VOA	
699-25-33A	Top of LPU; no statistics	C	S	S	S	S	S	A	A	S	Yes
699-25-34A	--	C	S	S	S	S	S	A	A	S	Yes
699-25-34B	--	C	S	S	S	S	S	A	A	S	Yes
699-25-34D	--	C	S	S	S	S	S	A	A	S	No[c]
699-26-33	--	C	S	S	S	S	S	A	A	S	Yes
699-26-34A	--	C	S	S	S	S	S	A	A	S	No[b]
699-26-34B	--	C	S	S	S	S	S	A	A	S	Yes
699-26-35A	--	C	S	S	S	S	S	A	A	S	Yes
699-26-35C	Top of LPU; no statistics	C	S	S	S	S	S	A	A	S	Yes

Notes: Requirements are from *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill* and corresponding Interim Change Notice 1 (PNNL-12227 and PNNL-12227-ICN-1).

Wells completed at the top of the unconfined aquifer unless otherwise specified.

a. ***Bold italic*** indicates upgradient well.

b. The second semiannual sample was not collected for well 699-26-34A because of limited maintenance resources to remove the sampling pump.

c. The second semiannual sample was not collected for well 699-25-34D because of limited maintenance resources to lower the sampling pump.

A = to be sampled annually
C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"
LPU = low-permeability unit in upper portion of Ringold Formation (within member of Taylor Flat)
S = to be sampled semiannually
TOC = total organic carbon
TOX = total organic halides
VOA = volatile organic analysis

Table B-33. Critical Means for Nonradioactive Dangerous Waste Landfill for 2012 Comparisons

Constituent (unit)	n	df	Mean	Standard Deviation	CV (%)	t_c	Critical Mean	Proportion ND Site
pH	18	17	7.48	0.27	4%	4.12	6.36 - 8.61	0%
Specific conductance (µS/cm)	18	17	502.49	49.79	10%	4.12	713.26	0%
TOC* (µg/L)	18	17	369.56	269.32	73%	4.12	1509.73	46%
TOX* (µg/L)	18	17	NC	NC	NC	NC	NC	81%

Note: Based on semiannual sampling events from January 2010 through December 2011.

* Non-detects were imputed using the population of upgradient results to estimate values reported as non-detects. This implicitly assumes that values from all upgradient wells come from the same underlying population.

CV = coefficient of variation

df = degrees of freedom (n-1)

n = number of background replicate averages

t_c = Bonferroni critical t-value for appropriate df and 28 comparisons

TOC = total organic carbon

TOX = total organic halides

ND = non-detects

NC = not calculated because proportion non-detects is greater than 50%

Table B-34. Monitoring Wells and Constituents for Waste Management Area A-AX

Well Number[a]	WAC-Compliant	Site-Specific Constituents										Sampled as Scheduled in 2011
		Nitrate	Sodium	Sulfate	TOC	Chromium	Lead	Alkalinity	Anions	Metals	Technetium-99[b]	
299-E24-20	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E24-22	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E24-33	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E25-2	P	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E25-40	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E25-41	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E25-93	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
299-E25-94	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No[c]
299-E25-236	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes

Notes:

Requirements are from *RCRA Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site* (PNNL-15315).

Wells completed at the top of the unconfined aquifer unless specified otherwise.

a. ***Bold italic*** indicates upgradient well.

b. *Atomic Energy Act of 1954* parameter.

c. Sample not collected in first quarter due to pump problem.

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells

P = constructed before WAC requirements

Q = to be sampled quarterly

TOC = total organic carbon

Table B-35. Monitoring Wells and Constituents for Waste Management Area B-BX-BY

Well Number*	WAC-Compliant	RCRA Parameters				AEA Parameters				Sampled as Scheduled in 2011
		Alkalinity	Anions	Cyanide	Metals	Gamma	Technetium-99	Tritium	Uranium	
299-E28-8	P	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-7	P	Q	Q	Q	Q	Q	Q	Q	Q	Missed first quarter due to maintenance issues
299-E33-9	P	A	A	A	A	A	A	A	A	Sample missed due to work stoppage.
299-E33-15	P	S	S	S	S	S	S	S	S	Yes
299-E33-16	P	Q	Q	Q	Q	S	Q	Q	Q	First quarter sample missed due to schedule oversight.
299-E33-17	P	S	S	S	S	--	S	S	S	Yes
299-E33-18	P	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-20	P	S	S	S	S	--	S	S	S	Yes
299-E33-21	P	A	A	A	A	--	A	A	A	Yes
299-E33-26	C	Q	Q	Q	Q	S	Q	Q	Q	Fourth quarter sample missed due to maintenance issues.
299-E33-31	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-32	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-38	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-39	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-41	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-42	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-43	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-44	C	Q	Q	Q	Q	S	Q	Q	Q	Yes
299-E33-47	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-48	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-49	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-334	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-335	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-337	C	Q	Q	Q	Q	--	Q	Q	Q	Yes

Table B-35. Monitoring Wells and Constituents for Waste Management Area B-BX-BY

Well Number*	WAC-Compliant	RCRA Parameters				AEA Parameters				Sampled as Scheduled in 2011
		Alkalinity	Anions	Cyanide	Metals	Gamma	Technetium-99	Tritium	Uranium	
299-E33-338	C	Q	Q	Q	Q	--	Q	Q	Q	Yes
299-E33-339	C	Q	Q	Q	Q	--	Q	Q	Q	Yes

Note: Requirements from *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area B-BX-BY at the Hanford Site* (PNNL-13022-ICN-3).

Wells completed at the top of the unconfined aquifer.

* Indeterminate flow direction due to flow direction change; no upgradient wells defined.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed before WAC requirements

Q = to be sampled quarterly

S = to be sampled semiannually

Table B-36. Monitoring Wells and Constituents for Waste Management Area C

Well Name[a]	Purpose	Well Construction Standard	pH	Specific Conductance	Alkalinity	Anions	Cyanide	Metals[b], Unfiltered, Filtered	Water Level	Sampled as Scheduled in 2011
299-E27-4	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-7	Upgradient	N	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-12	Upgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-13	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-14	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-15	Upgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-21	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-22	Upgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-23	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-155	Cross- to downgradient	C	SA	SA	SA	SA	SA	SA	SA	Yes
299-E27-24	Downgradient	C	Q	Q	Q	Q	Q	Q	Q	Yes
299-E27-25	Cross-gradient	C	Q	Q	Q	Q	Q	Q	Q	Yes

Note: Requirements are from *Groundwater Quality Assessment Plan for the Single-Shell Waste Management Area C* (DOE/RL-2009-77).

a. ***Bold italic*** indicates change from cross gradient to upgradient determination.

b. Metals for groundwater quality include iron, manganese, and sodium.

C = well constructed as a WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," resource protection well

N = well constructed before requirements of WAC 173-160 were applicable at the Hanford Site

Q = quarterly

SA = semiannually

Table B-37. Groundwater Assessment Volatile Organic Compound Monitoring at Waste Management Area C

Dangerous Waste Constituent Name	CAS #	Wells											
		299-E27-4	299-E27-7	299-E27-12	299-E27-13	299-E27-14	299-E27-15	299-E27-21	299-E27-22	299-E27-23	299-E27-155	299-E27-24	299-E27-25
1,1-Dichloroethane	75-34-3	X	X	X	X	X	X	X	X	X	X	X	X
1,1-Dichloroethylene	75-35-4	X	X	X	X	X	X	X	X	X	X	X	X
1,1,1-Trichloroethane	71-55-6	X	X	X	X	X	X	X	X	X	X	X	X
1,1,2,2-Tetrachloroethane	79034-5	X	X	X	X	X	X	X	X	X	X	X	X
1,1,2-Trichloroethane	79-00-5	X	X	X	X	X	X	X	X	X	X	X	X
1,2-Dibromoethane	106-93-4	X	X	X	X	X	X	X	X	X	X	X	X
1,2-Dichloroethane	107-06-2	X	X	X	X	X	X	X	X	X	X	X	X
1,2-Dichloropropane	78-87-5	X	X	X	X	X	X	X	X	X	X	X	X
1,2,4-Trichlorobenzene	120-82-1	X	X	X	X	X	X	X	X	X	X	X	X
1,4-Dichlorobenzene	106-46-7	X	X	X	X	X	X	X	X	X	X	X	X
1,4-Dioxane	123-91-1	X	X	X	X	X	X	X	X	X	X	X	X
2-Butanone (MEK)	78-93-3	X	X	X	X	X	X	X	X	X	X	X	X
2-Hexanone	591-78-6	X	X	X	X	X	X	X	X	X	X	X	X
2-Propanone (Acetone)	67-64-1	X	X	X	X	X	X	X	X	X	X	X	X
3-Chloropropene	107-05-1	X	X	X	X	X	X	X	X	X	X	X	X
4-Methyl-2-petanone	108-10-1	X	X	X	X	X	X	X	X	X	X	X	X
Acetonitrile	75-05-8	X	X	X	X	X	X	X	X	X	X	X	X
Acrolein	107-02-8	X	X	X	X	X	X	X	X	X	X	X	X
Acrylonitrile	107-13-1	X	X	X	X	X	X	X	X	X	X	X	X
Benzene	71-43-2	X	X	X	X	X	X	X	X	X	X	X	X
Bromomethane	74-83-9	X	X	X	X	X	X	X	X	X	X	X	X
Carbon disulfide	75-15-0	X	X	X	X	X	X	X	X	X	X	X	X
Carbon tetrachloride[a]	56-23-5	X	X	X	X	X	X	X	X	X	X	X	X
Chlorobenzene	108-90-7	X	X	X	X	X	X	X	X	X	X	X	X
Chloroethene	75-01-4	X	X	X	X	X	X	X	X	X	X	X	X
Chloroform[a]	67-66-3	X	X	X	X	X	X	X	X	X	X	X	X

Table B-37. Groundwater Assessment Volatile Organic Compound Monitoring at Waste Management Area C

Dangerous Waste Constituent Name	CAS #	Wells											
		299-E27-4	299-E27-7	299-E27-12	299-E27-13	299-E27-14	299-E27-15	299-E27-21	299-E27-22	299-E27-23	299-E27-155	299-E27-24	299-E27-25
Chloromethane	74-87-3	X	X	X	X	X	X	X	X	X	X	X	X
cis-1,3-dichloropropene	10061-01-5	X	X	X	X	X	X	X	X	X	X	X	X
Dichlorodifluoro-methane	75-71-8	X	X	X	X	X	X	X	X	X	X	X	X
Dichloromethane	75-09-2	X	X	X	X	X	X	X	X	X	X	X	X
Ethylbenzene	100-41-4	X	X	X	X	X	X	X	X	X	X	X	X
Ethyl cyanide	107-12-0	X	X	X	X	X	X	X	X	X	X	X	X
Methacrylonitrile	126-98-7	X	X	X	X	X	X	X	X	X	X	X	X
Styrene	100-42-5	X	X	X	X	X	X	X	X	X	X	X	X
Tetrachloroethene	127-18-4	X	X	X	X	X	X	X	X	X	X	X	X
Toluene	108-88-3	X	X	X	X	X	X	X	X	X	X	X	X
trans-1,3-dichloropropene	10061-02-6	X	X	X	X	X	X	X	X	X	X	X	X
Trichloroethene	79-01-06	X	X	X	X	X	X	X	X	X	X	X	X
Trichlorofluoro-methane	75-69-4	X	X	X	X	X	X	X	X	X	X	X	X
Xylenes	1330-20-7	X	X	X	X	X	X	X	X	X	X	X	X

a. Constituents collected and analyzed during 2011 for continued assessment.

X = Constituent collected and analyzed for in 2011.

CAS = Chemical Abstract Services

Table B-38. Monitoring Wells and Constituents for Waste Management Area S-SX

Well Number[a]	WAC-Compliant	RCRA	Supporting Constituents									Sampled as Scheduled in 2011
		Chromium	Nitrate	Alkalinity	Anions	Metals	Selenium-79	Technetium-99	Tritium	Uranium	Gamma	
299-W22-26	P	S	S	S	S	S	A	S	A		--	Yes
299-W22-44	C	Q	Q	Q	Q	Q	A	Q	A	A	--	Yes
299-W22-45	C	S	S	S	S	S	--	S	A		--	Yes
299-W22-47	C	Q	Q	Q	Q	Q	A	Q	A		--	Yes
299-W22-48	C	S	S	S	S	S	--	S	A		--	Yes
299-W22-49	C	S	S	S	S	S	--	S	A		--	Yes
299-W22-50	C	Q	Q	Q	Q	Q	A	Q	A	A	--	Yes
299-W22-69	C	A	A	A	A	A	--	A	A		--	Yes
299-W22-72	C	A	A	A	A	A	--	A	A		--	Yes
299-W22-80	C	A	A	A	A	A	--	A	A		--	Yes
299-W22-81	C	A	A	A	A	A	--	A	A		--	Yes
299-W22-82	C	A	A	A	A	A	--	A	A		--	Yes
299-W22-83	C	A	A	A	A	A	--	A	A		--	No; missed due to electric sample pump safety issue
299-W22-84	C	A	A	A	A	A	--	A	A		--	Yes
299-W22-85	C	S	S	S	S	S	--	S	A		--	Yes
299-W22-86	C	A	A	A	A	A	--	A	A		--	Yes
299-W22-89	C	A	A	A	A	A	--	A	A		--	Yes
299-W23-15	C	A	A	A	A	A	--	A	A		--	Yes
299-W23-19	C	Q	Q	Q	Q	Q	A	Q	A	A	A	Yes
299-W23-20	C	A	A	A	A	A	A	A	A	A	--	Yes
299-W23-21	C	A	A	A	A	A	A	A	A	A	--	Yes

Table B-38. Monitoring Wells and Constituents for Waste Management Area S-SX

Well Number[a]	WAC-Compliant	RCRA	Supporting Constituents									Sampled as Scheduled in 2011
		Chromium	Nitrate	Alkalinity	Anions	Metals	Selenium-79	Technetium-99	Tritium	Uranium	Gamma	

Note: Requirements from *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area S-SX* (DOE/RL-2009-73).

Wells completed at the top of the unconfined aquifer.

a. ***Bold italic*** indicates upgradient well.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed before WAC requirements

S = to be sampled semiannually

Q = to be sampled quarterly

Table B-39. Monitoring Wells and Constituents for Waste Management Area T

Well Number*	Comment	WAC-Compliant	RCRA Dangerous Constituent	Supporting Parameters			Field-Measured Parameters					Sampled as Scheduled in 2011
			Hxavalent Chromium	Nitrate and Other Anions	Alkalinity	Metals, Unfiltered	pH	Specific Conductance	Turbidity	Temperature	Dissolved Oxygen	
299-W10-1	--	P	A	A	A	A	A	A	A	A	A	Yes
299-W10-4	--	P	SA	SA	A	SA	SA	SA	SA	SA	SA	Yes
299-W10-8	--	P	A	A	A	A	A	A	A	A	A	Yes
299-W10-23	--	C	A	A	A	A	A	A	A	A	A	Yes
299-W10-24	--	C	SA	SA	A	A	SA	SA	SA	SA	SA	Yes
299-W10-28	--	C	A	A	A	A	A	A	A	A	A	Yes
299-W11-12	Well is dry	P	A	A	A	A	A	A	A	A	A	No
299-W11-39	--	C	SA	SA	A	SA	SA	SA	SA	SA	SA	Yes
299-W11-40	--	C	Q	SA	A	SA	Q	Q	Q	Q	Q	Yes
299-W11-41	--	C	Q	SA	A	SA	Q	Q	Q	Q	Q	Yes
299-W11-42	--	C	Q	SA	A	SA	Q	Q	Q	Q	Q	Yes
299-W11-45	Extraction well; screened 8.5 to13 meters below water table	C	Q	SA	A	SA	Q	Q	Q	Q	Q	Yes
299-W11-46	Extraction well; screened 6 to 12 meters below water table	C	Q	SA	A	SA	Q	Q	Q	Q	Q	Yes
299-W11-47	Screened 9 to 18 meters below water table	C	Q	SA	A	SA	Q	Q	Q	Q	Q	Yes

Notes:

Requirements are from *Interim Status Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area T* (DOE/RL-2009-66).

Wells completed at the top of the unconfined aquifer unless specified otherwise.

* ***Bold italic*** indicates upgradient well.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed prior to WAC requirements

Q = to be sampled quarterly

RCRA = *Resource Conservation and Recovery Act of 1976*

SA = to be sampled semiannually

Table B-40. Monitoring Wells and Constituents for Waste Management Area TX-TY

Well Number[a]	Comment	WAC-Compliant	RCRA Dangerous Parameter	Supporting Parameters			Field-Measured Parameters					Sampled as Scheduled in 2011
			Hexavalent Chromium	Nitrate and Other Anions	Alkalinity	Metals, Unfiltered	pH	Specific Conductance	Turbidity	Temperature	Dissolved Oxygen	
299-W10-26	--	C	Q	SA	SA	SA	Q	Q	Q	Q	Q	Yes
299-W10-27	--	C	Q	SA	SA	SA	Q	Q	Q	Q	Q	Yes
299-W14-11	Screened 11 to 14.6 m below water table	C	Q	SA	SA	SA	Q	Q	Q	Q	Q	Yes
299-W14-13	Pump required lowering; not sampled in first and second quarters	C	Q	SA	SA	SA	Q	Q	Q	Q	Q	No
299-W14-14	--	C	SA	SA	SA	SA	SA	SA	SA	SA	SA	Yes
299-W14-15	--	C	Q	SA	SA	SA	Q	Q	Q	Q	Q	Yes
299-W14-16	--	C	SA	SA	SA	SA	SA	SA	SA	SA	SA	Yes
299-W14-17	--	C	SA	SA	SA	SA	SA	SA	SA	SA	SA	Yes
299-W14-18	--	C	Q	SA	SA	SA	Q	Q	Q	Q	Q	Yes
299-W14-19	--	C	SA	SA	SA	A	SA	SA	SA	SA	SA	Yes
299-W15-40	Extraction well; well offline due to low water	C	Q	SA	SA	SA	Q	Q	Q	Q	Q	Yes
299-W15-41	Well is dry	C	SA	SA	SA	SA	SA	SA	SA	SA	SA	No
299-W15-44[b]	--	C	SA	SA	SA	SA	SA	SA	SA	SA	SA	Yes
299-W15-763	--	C	SA	SA	SA	SA	SA	SA	SA	SA	SA	Yes
299-W15-765	Extraction well; offline Mar 2011 due to low water	C	Q	SA	SA	SA	Q	Q	Q	Q	Q	No

Note: Requirements are from *Interim Status Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area TX-TY* (DOE/RL-2009-67).

Wells completed at the top of the unconfined aquifer, unless specified otherwise.

a. Bold italic indicates upgradient well.

b. Well 299-W15-44 was taken out of service as an extraction well and converted to a monitoring well by third quarter CY 2010.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed before WAC requirements

Q = to be sampled quarterly

SA = to be sampled semiannually

Table B-41. Monitoring Wells and Constituents for Waste Management Area U

Well Number[a]	WAC-Compliant	RCRA	Supporting Parameters							Sampled as Scheduled in 2011
		Chromium	Nitrate	Alkalinity	Anions	Metals	Technetium-99	Gross Alpha/ Beta	Gamma	
299-W18-30	C	Q	Q	Q	Q	Q	S	A	A	Yes
299-W18-40	C	Q	Q	Q	Q	Q	S	A	A	No; 2nd and 3rd quarter samples missed due to electric sample pump safety issue
299-W19-12	C	Q	Q	Q	Q	Q	S	A	A	Yes
299-W19-41	C	Q	Q	Q	Q	Q	S	A	A	Yes
299-W19-42	C	Q	Q	Q	Q	Q	S	A	A	Yes
299-W19-45	C	Q	Q	Q	Q	Q	S	A	A	Yes
299-W19-47	C	Q	Q	Q	Q	Q	S	A	A	Yes

Note: Requirement is from *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U* (DOE/RL-2009-74).

Wells completed at the top of the unconfined aquifer.

a. Bold italic indicates upgradient well.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

S = to be sampled semi-annually

Q = to be sampled quarterly

Table B-42. Monitoring Wells, Constituents, and Enforcement Limits for 200 Area Treated Effluent Disposal Facility

Well Number*	WAC-Compliant	Constituents with Enforcement Limits			Other Constituents								Sampled as Scheduled in 2011
		pH (6.5 to 8.5)	Cadmium (5 µg/L)	Lead (10 µg/L)	Specific Conductance	Alpha	Anions	Beta	Metals	Total Dissolved Solids	Trace Metals	Tritium	
699-40-36	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	A	Yes
699-41-35	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	A	Yes
699-42-37	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	A	Yes

Notes:

Requirements are from *Groundwater Monitoring Plan for the Hanford Site 200 Area Treated Effluent Disposal Facility* (PNNL-13032).

All wells completed at the top of the Ringold Formation confined aquifer.

* ***Bold italic*** indicates upgradient well.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

Q = to be sampled quarterly

Table B-43. Monitoring Wells and Constituents for Environmental Restoration Disposal Facility

Well Number[a]	WAC-Compliant	Alkalinity	Alpha	Anions	Beta	Carbon-14	Iodine-129	Metals	Radium[b]	Total Dissolved Solids	Technetium-99	TOX	Uranium	VOA	Sampled as Scheduled in 2011
699-35-66A	P	S	S	S	S	S	S	S	S	S	S	S	S	S	Yes
699-36-66B	C	S	S	S	S	S	S	S	S	S	S	S	S	S	Yes
699-36-70A	C	S	S	S	S	S	S	S	S	S	S	S	S	S	Yes
699-37-66	C	S	S	S	S	S	S	S	S	S	S	S	S	S	Yes

Notes:

Requirements are from *Groundwater Protection Plan for the Environmental Restoration Disposal Facility* (WCH-198).

Wells completed at the top of the unconfined aquifer.

a. ***Bold italic*** indicates upgradient well.

b. Total alpha energy emitted from radium.

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed before WAC requirements

S = to be sampled semiannually

TOX = total organic halides

VOA = volatile organic analyte

Table B-44. Monitoring Wells and Constituents for the KE and KW Basins

Well	WAC Compliant	Gross Alpha	Anions	Gross Beta	Carbon-14	Metals	Strontium-90	Technetium-99	Tritium	Sampled as Scheduled in 2011
KE Basins										
199-K-32A	C	Q	Q	Q	A	--	--	A	Q	Yes
199-K-110A	C	S	S	S	--	A	--	--	S	Yes
199-K-111A	C	Q	Q	Q	A	A	--	A	Q	Yes
199-K-141*	C	Q	Q	Q	A	S	A	A	Q	Yes
199-K-142*	C	Q	Q	Q	A	S	A	A	Q	Not sampled
KW Basins										
199-K-31*	P	S	S	S	A	--	A	A	S	Yes
199-K-34	C	Q	Q	Q	A	S	A	A	Q	Yes
199-K-106A	C	Q	Q	Q	A	S	--	--	Q	No metals
199-K-107A	C	Q	Q	Q	A	S	A	A	Q	Yes
199-K-108A	C	S	S	S	--	S	--	--	S	Yes
199-K-132*	C	S	S	S	A	S	--	--	S	Yes

Notes: Requirements are modified from *Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins* (PNNL-14033).

The following were listed in PNNL-14033 but were decommissioned before 2011: 199-K-27, 199-K-29, 199-K-30, and 199-K-109A (KE Basins) and 199-K-33 (KW Basins).

* Wells not listed in PNNL-14033.

Sampling abbreviations used in this table are as follows:

A = to be sampled annually

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standard for Construction and Maintenance of Wells"

P = constructed before WAC requirements

Q = to be sampled quarterly

S = to be sampled semiannually

Table B-45. Monitoring Wells, Constituents, and Enforcement Limits for State-Approved Land Disposal Site

Well	Comment	Constituents with Enforcement Limits												Other Constituents					Sampled as Scheduled in 2011
		WAC Compliant	pH	Acetone	Benzene	Cadmium *	Chloroform	Copper *	Lead *	Mercury *	Sulfate	Tetrahydrofuran	Total Dissolved Solids	Specific Conductance	Alpha	Beta	Strontium-90	Tritium	
299-W6-6	Bottom of unconfined	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
299-W6-11	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
299-W6-12	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
299-W7-3	Bottom of unconfined	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	Yes
299-W8-1	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	No- dry
699-48-71	Unconfined	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
699-48-77A	Ringold Formation unit E, upper	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No- 4th quarter missed; dry
699-48-77C	Ringold Formation unit E, middle to lower	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-48-77D	Ringold Formation unit E, upper	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-49-79	--	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes
699-51-75	--	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S	Yes
699-51-75P	Lower unconfined	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	Yes

Table B-45. Monitoring Wells, Constituents, and Enforcement Limits for State-Approved Land Disposal Site

Well	Comment	Constituents with Enforcement Limits												Other Constituents					Sampled as Scheduled in 2011
		WAC Compliant	pH	Acetone	Benzene	Cadmium *	Chloroform	Copper *	Lead *	Mercury *	Sulfate	Tetrahydrofuran	Total Dissolved Solids	Specific Conductance	Alpha	Beta	Strontium-90	Tritium	

Notes: Requirements are from *Groundwater Monitoring and Tritium-Tracking Plan for the 200 Area State-Approved Land Disposal Site* (PNNL-13121).

Wells are completed at the top of the aquifer unless specified otherwise

* Filtered and unfiltered samples.

A = to be sampled annually

C = well is constructed as a resource protection well under WAC-173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed before WAC requirements

Q = to be sampled quarterly

S = to be sampled semiannually

Table B-46. Monitoring Wells and Constituents for Solid Waste Landfill

Well Number[a]	Comment	WAC-Compliant	Contamination Indicator Parameters													Other Parameters				Sampled as Scheduled in 2011
			Ammonia/Ammonium ion	Chemical Oxygen Demand	Chloride	Iron (Filtered)	Manganese (Filtered)	Zinc (Filtered)	Nitrate	Nitrite	pH (Field)	Specific Conductance (Field)	Sulfate	Temperature (Field)	Coliform Bacteria	TOC	Anions	Metals (Filtered)	Arsenic (Filtered)	VOA	
699-22-35	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No[b]
699-23-34A	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-23-34B	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-24-33	Information only; no statistics	P	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-24-34A	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-24-34B	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No[b]
699-24-34C	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No[c]
699-24-35	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Yes
699-26-35A	--	C	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	No[b]

Notes:

Requirements from *Groundwater Monitoring Plan for the Solid Waste Landfill* (PNNL-13014).

Wells completed at the top of the unconfined aquifer.

a. Bold italic indicates upgradient well.

b. Well not sampled as scheduled due to sampling priorities. One sampling event was missed in each well.

c. Sampling attempted in April 2011; well appears to be dry.

C = well is constructed as a resource protection well under WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"

P = constructed before WAC requirements

Q = to be sampled quarterly

TOC = total organic carbon

VOA = volatile organic analysis

Table B-47. Analytical Results for Required Constituents at the Solid Waste Landfill

Constituent[a]	Date	699-22-35	699-23-34A	699-23-34B	699-24-33	699-24-34A	699-24-34B	699-24-34C	699-24-35	699-26-35A
Ammonium ion (µg/L) BTV = 90 µg/L[b]	1/12/11	SNC	9.92	<3.09	13.3	<3.09	SNC	10.6	12	<3.09
	4/13 to 4/14/11	<1.8	<1.8	31.4	19.2	47.3	71	SNC	30.7	SNC
	7/13/11	<1.8	<1.8	<1.8	22.2	<1.8	<1.8	SNC	15.8	31.4[c]
	11/3 to 11/7	SNC	SNC	SNC	SNC	SNC	SNC	SNC	SNC	SNC
Chemical oxygen demand (mg/L) BTV = 10 mg/L	1/12/11	SNC	<10	<10	<10	<10	SNC	<10	<10	<10
	4/13 to 4/14/11	<10	<10	<10	<10	<10	<10	SNC	<10	SNC
	7/13/11	<10	<10	<10	<10	<10	<10	SNC	<10	10[c]
	11/3 to 11/7	<10	<6.5	<6.5	<6.5	<6.5	<6.5	SNC	<6.5	<6.5
Chloride (mg/L) BTV = 7.82 mg/L	1/12/11	SNC	6.92	6.52	7.29	7.28	SNC	7.16	6.34	7.35
	4/13 to 4/14/11	6.85	6.85	6.31	7.00	7.23	6.80	SNC	6.17	SNC
	7/13/11	7.12	6.79	5.71	6.86	6.67	6.32	SNC	5.80	7.70[c]
	11/3 to 11/7	**8.30**	7.30	6.50	7.10	**8.30**	7.00	SNC	6.30	7.10
Coliform bacteria (colonies/100mL) BTV = 1 col./100 ml	1/12/11	SNC	≤1	≤1	≤1	**2**	SNC	**111[d]**	≤1	≤1
	4/13 to 4/14/11	≤1	≤1	≤1	≤1	≤1	≤1	SNC	≤1	SNC
	7/13/11	≤1	**3.1**	≤1	≤1	≤1	≤1	SNC	**62.7[d]**	≤1[c]
	11/3 to 11/7	≤1	≤1	≤1	≤1	≤1	≤1	SNC	**2**	≤1
Iron (filtered) (µg/L) BTV = 160 µg/L	1/12/11	SNC	<38	<38	<38	<38	SNC	66	<38	<38
	4/13 to 4/14/11	32	<20	22	<20	27	87	SNC	<20	SNC
	7/13/11	**259[d]**	22	<20	<20	28	79	SNC	32	<19[c]
	11/3 to 11/7	68.5	<28.2	56.6	<28.2	<28.2	67.9	SNC	<28.2	<28.2

Table B-47. Analytical Results for Required Constituents at the Solid Waste Landfill

Constituent[a]	Date	699-22-35	699-23-34A	699-23-34B	699-24-33	699-24-34A	699-24-34B	699-24-34C	699-24-35	699-26-35A
Manganese (filtered) (µg/L) BTV = 18 µg/L	1/12/11	SNC	<6	<6	<6	<6	SNC	<6	<6	<6
	4/13 to 4/14/11	<4	<4	<4	<4	<4	<4	SNC	<4	SNC
	7/13/11	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	SNC	<4.1	<4[c]
	11/3 to 11/7	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	SNC	<3.3	<3.3
Nitrate (mg/L) BTV = 29 mg/L	1/12/11	SNC	19.4	17.1	14.8	13.7	SNC	14.5	12.4	17.8
	4/13 to 4/14/11	17.6	18.5	17.2	14.4	13.5	14.7	SNC	12.8	SNC
	7/13/11	17.9	19.0	17.4	14.2	14.0	15.4	SNC	12.7	19.5[c]
	11/3 to 11/7	18.6	20.4	18.1	14.2	15.5	16.4	SNC	13.7	18.6
Nitrite (µg/L) BTV = 266 µg/L	1/12/11	SNC	<118	<118	<118	<118	SNC	<118	<118	<118
	4/13 to 4/14/11	<131	<131	<131	<131	<131	<131	SNC	<131	SNC
	7/13/11	<131	<131	**897[d]**	<131	**716[d]**	**657[d]**	SNC	**519[d]**	<9.85[c]
	11/3 to 11/7	<9.85	<9.85	<9.85	<9.85	<9.85	<9.85	SNC	<9.85	<9.85
pH measurement BTR = 6.68-7.84	1/12/11	SNC	6.80	6.86	6.98	6.80	SNC	6.90	6.94	7.33
	4/13 to 4/14/11	7.23	6.95	6.74	6.92	6.80	6.78	SNC	6.87	SNC
	7/13/11	6.9	**6.63**	6.79	6.85	6.80	6.78	SNC	6.86	7.30[c]
	11/3 to 11/7	6.83	**6.52**	**6.54**	6.79	6.71	6.73	SNC	6.88	7.24
Specific conductance (µS/cm) BTV = 583 µS/cm	1/12/11	SNC	**762**	**748**	**749**	**658**	SNC	**729**	579	533
	4/13 to 4/14/11	**821**	**769**	**760**	**756**	**663**	**682**	SNC	582	SNC
	7/13/11	**815**	**764**	**760**	**750**	**660**	**662**	SNC	558	556[c]
	11/3 to 11/7	**818**	**769**	**752**	**758**	**675**	**668**	SNC	564	532

Table B-47. Analytical Results for Required Constituents at the Solid Waste Landfill

Constituent[a]	Date	699-22-35	699-23-34A	699-23-34B	699-24-33	699-24-34A	699-24-34B	699-24-34C	699-24-35	699-26-35A
Sulfate (mg/L) BTV = 47.2 mg/L	1/12/11	SNC	**47.5**	44.8	43.7	46.0	SNC	43.9	43.8	39.9
	4/13 to 4/14/11	41.9	45.9	44.4	43.9	45.2	45.4	SNC	43.8	SNC
	7/13/11	42.8	46.4	44.0	43.3	45.4	46.4	SNC	44.7	38.6[c]
	11/3 to 11/7	42.7	**50.7**	44.7	46.0	46.3	46.0	SNC	47.1	42.0
Temperature (^{0}C) BTV = 20.7 ^{0}C	1/12/11	SNC	16.1	17.3	19.2	18.0	SNC	16.6	16.2	19.0
	4/13 to 4/14/11	16.9	18.1	17.5	19.2	15.9	17.8	SNC	17.1	SNC
	7/13/11	19.7	19.5	19.4	19.9	19.5	20.3	SNC	19.1	19.2[c]
	11/3 to 11/7	17.9	17.8	18.1	19.4	18.2	18.7	SNC	17.3	18.9
TOC (µg/L) BTV = 1,200 µg/L	1/12/11	SNC	287	335	296	307	SNC	292	215	159
	4/13 to 4/14/11	453	482	321	273	267	246	SNC	200	SNC
	7/13/11	**1,890[d]**	**1,870[d]**	512	1160	460	330	SNC	352	353[c]
	11/3 to 11/7	**2,400[d]**	**2,800[d]**	**3,100[d]**	**2,800[d]**	**2,000[d]**	1000	SNC	**2,200[d]**	1,000
Zinc (filtered) (µg/L) BTV = 42.3 µg/L	1/12/11	SNC	<4	<4	10	<4	SNC	9	7	4
	4/13 to 4/14/11	<4	<4	<4	11	<4	<4	SNC	13	SNC
	7/13/11	<4.1	<4.1	<4.1	7	<4.1	<4.1	SNC	15	<5[c]
	11/3 to 11/7	<7	<7	<7	8.9	<7	<7	SNC	11.8	<7

Note: Results in **bold** exceed background threshold values.

a. WAC 173-304, "Minimum Functional Standards for Solid Waste Handling."

b. 2010 Background threshold values were obtained from Table C-41 of *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* (DOE/RL-2010-11).

c. Sample collected on December 5, 2011 to the July constituent list.

d. Analysis flagged because it is out of trend and higher than BTV.

BTV = background threshold value

SNC = sample not collected

TOC = total organic carbon

Table B-48. Results of Shapiro and Francia Test for Normality and Background Threshold Values for the Solid Waste Landfill

Constituent[a] (unit)	W-test Statitic[b] (Log Value)	W-test Statistic[b] (Raw Data)	W-test[b] Critical Value, Wα[c]	Upper Tolerance Limit	Background Threshold Value
Ammonium (as NH_3^-) (µg/L)	NC	NC	NC	90[d] 19.7[e] WSCF 27.5[e] STL	90
Chemical oxygen demand (µg/L)	NC	NC	NC	10,000[f]	10,000
Chloride (µg/L)	0.954 s	0.962 s	0.963	7,820[d]	7,820
Coliform bacteria (colonies/100 mL)	NC	NC	NC	1[f]	1
Field pH	0.988 ns	NA	0.963	[6.68, 7.84][g]	[6.68, 7.84]
Iron, dissolved (µg/L)	0.960 s	0.802 s	0.962	160[d] 174[e] WSCF 129[e] STL	174
Manganese, dissolved (µg/L)	NC	NC	NC	10[d] 27.5[e] WSCF 15.1[e] STL	27.5
Nitrate (as NO_3^-) (µg/L)	0.833 s	0.844 s	0.963	29,000[d]	29,000
Nitrite (as NO_2^-) (µg/L)	NC	NC	NC	165[e] WSCF 14[e] STL	165
Specific conductance (µS/cm)	0.978 ns	NA	0.960	583[g]	583
Sulfate (µg/L)	0.983 ns	NA	0.963	47,200[g]	47,200
Temperature (degrees C)	0.953 s	0.961 s	0.963	20.7[d]	20.7
Total organic carbon (µg/L)	NC	NC	NC	842[d] 210[e]	842
Zinc, dissolved (µg/L)	NC	NC	NC	42.3[d] 18.3[e] WSCF 32.1[e] STL	42.3

a. Constituents are specified in WAC 173-304-490(2)(d), "Minimum Functional Standards for Solid Waste Handling," "Groundwater Monitoring Requirements." Data collected from March 1993 to May 2000 from upgradient wells 699-24-35 and 699-26-35A.

b. From "An Approximate Analysis of Variance Test for Normality" (Shapiro and Francia, 1972).

c. Obtained from Table A-9 in "How to Test Normality and Other Distributional Assumptions," *The ASQC Basic References in Quality Control: Statistical Techniques* (Shapiro, 1990) for α = 5%.

d. Maximum value reported.

e. Based on limit of quantitation determined from field blanks (for total organic carbon) or laboratory blanks.

f. Based on laboratory lowest detected result.

g. Based on log-normal distribution.

NA = not applicable
NC = not calculated; insufficient measured values
ns = not significant at 0.05 level of significance
s = significant at 0.05 level of significance
STL = Severn Trent Laboratories (St. Louis)
WSCF = Waste Sampling and Characterization Facility

Figure B-1. RCRA Units on the Hanford Site Requiring Groundwater Monitoring

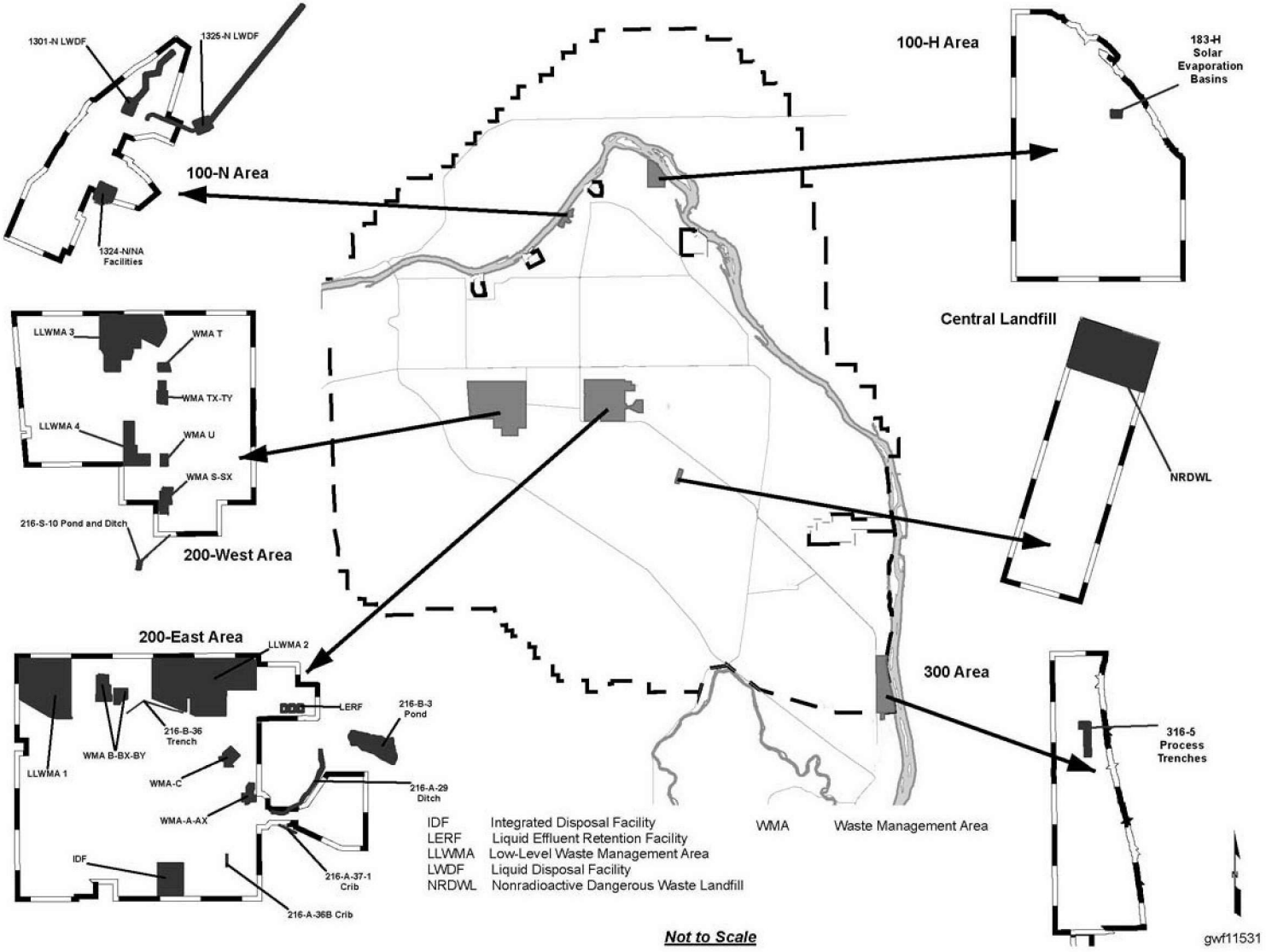


Figure B-2. Groundwater Monitoring Wells for 100-N Area RCRA Sites

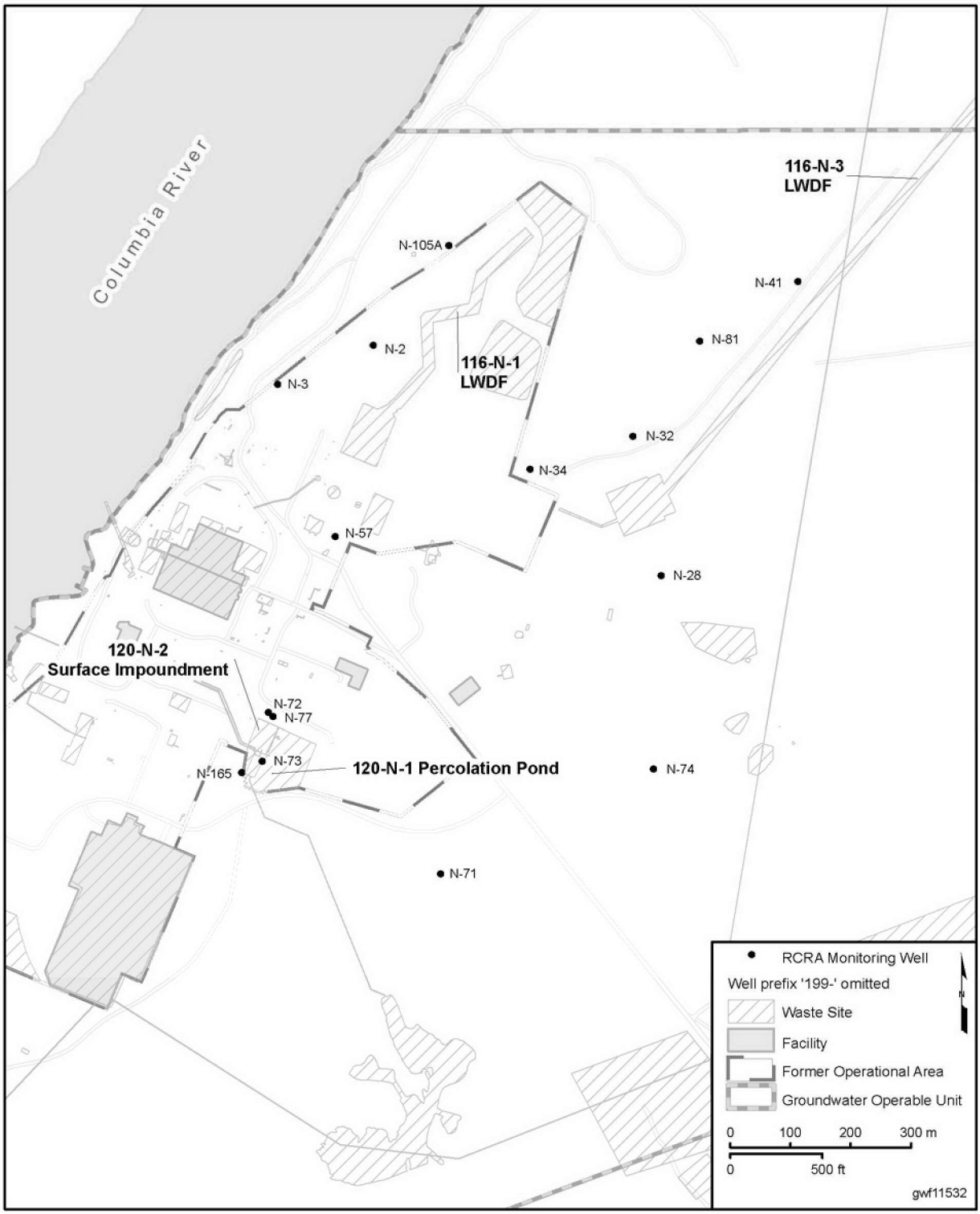


Figure B-3. Groundwater Monitoring Wells at 116-H-6 Evaporation Basins

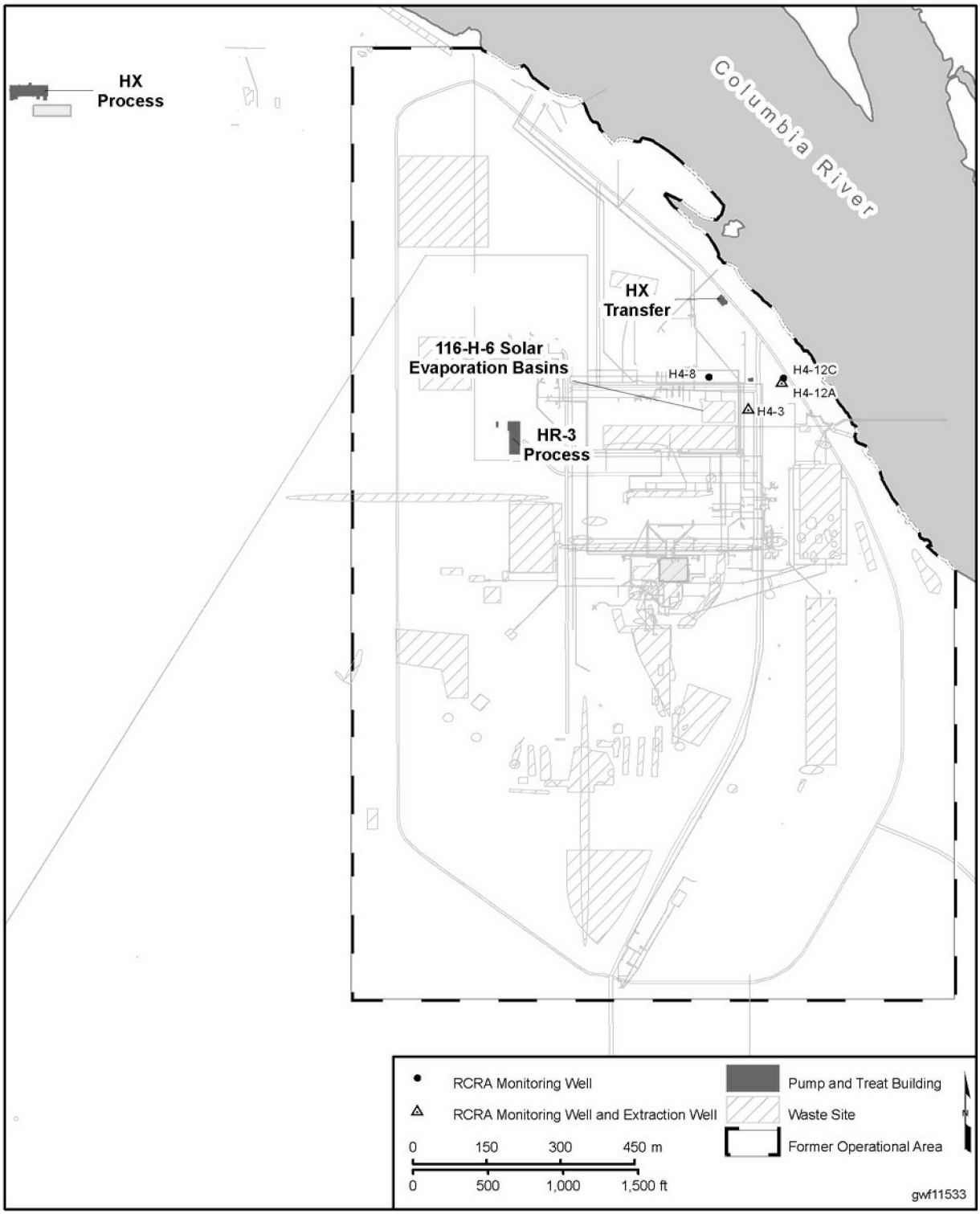
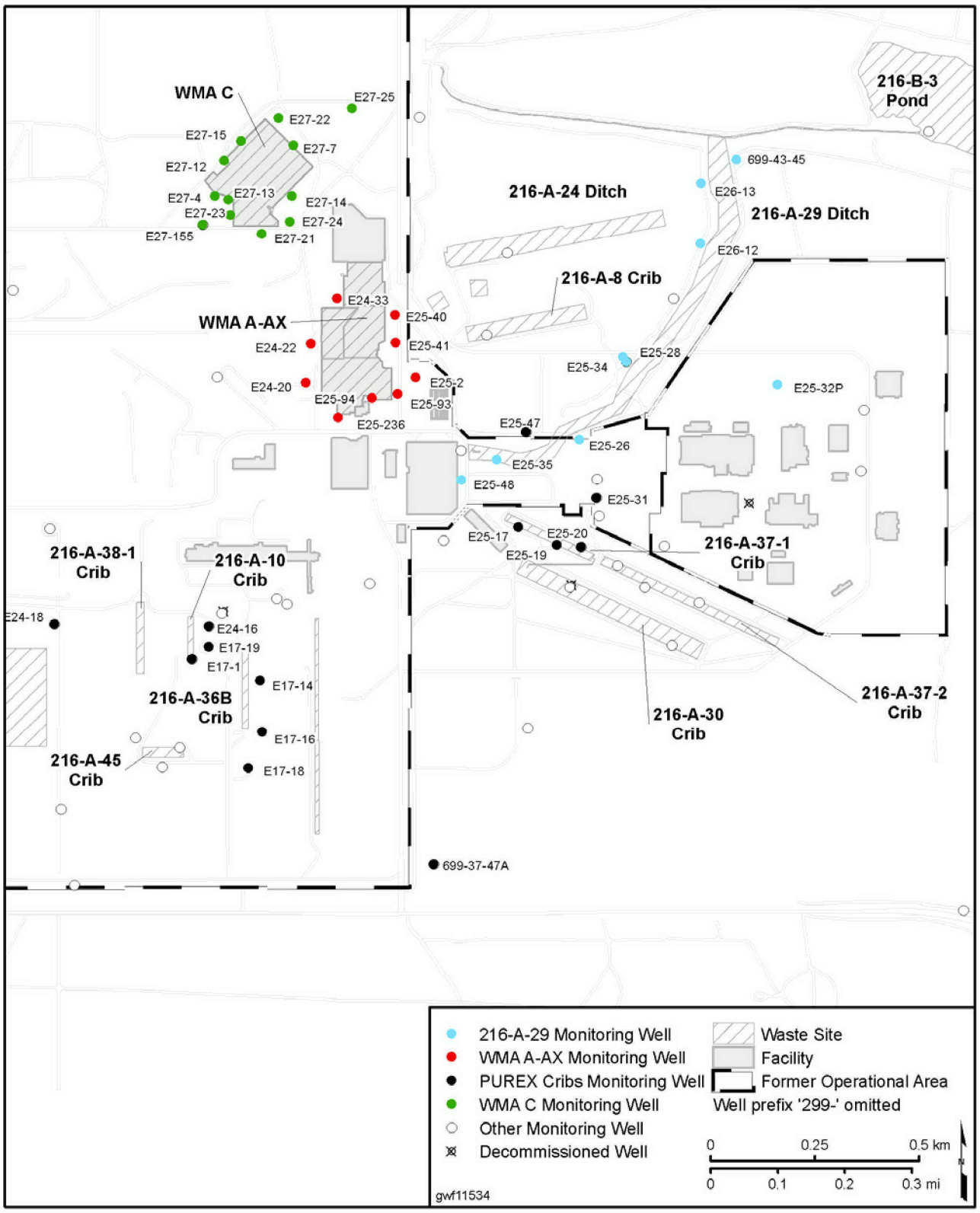


Figure B-4. Groundwater Monitoring Wells at 216-A-29 Ditch, PUREX Cribs, and Waste Management Areas A-AX and C



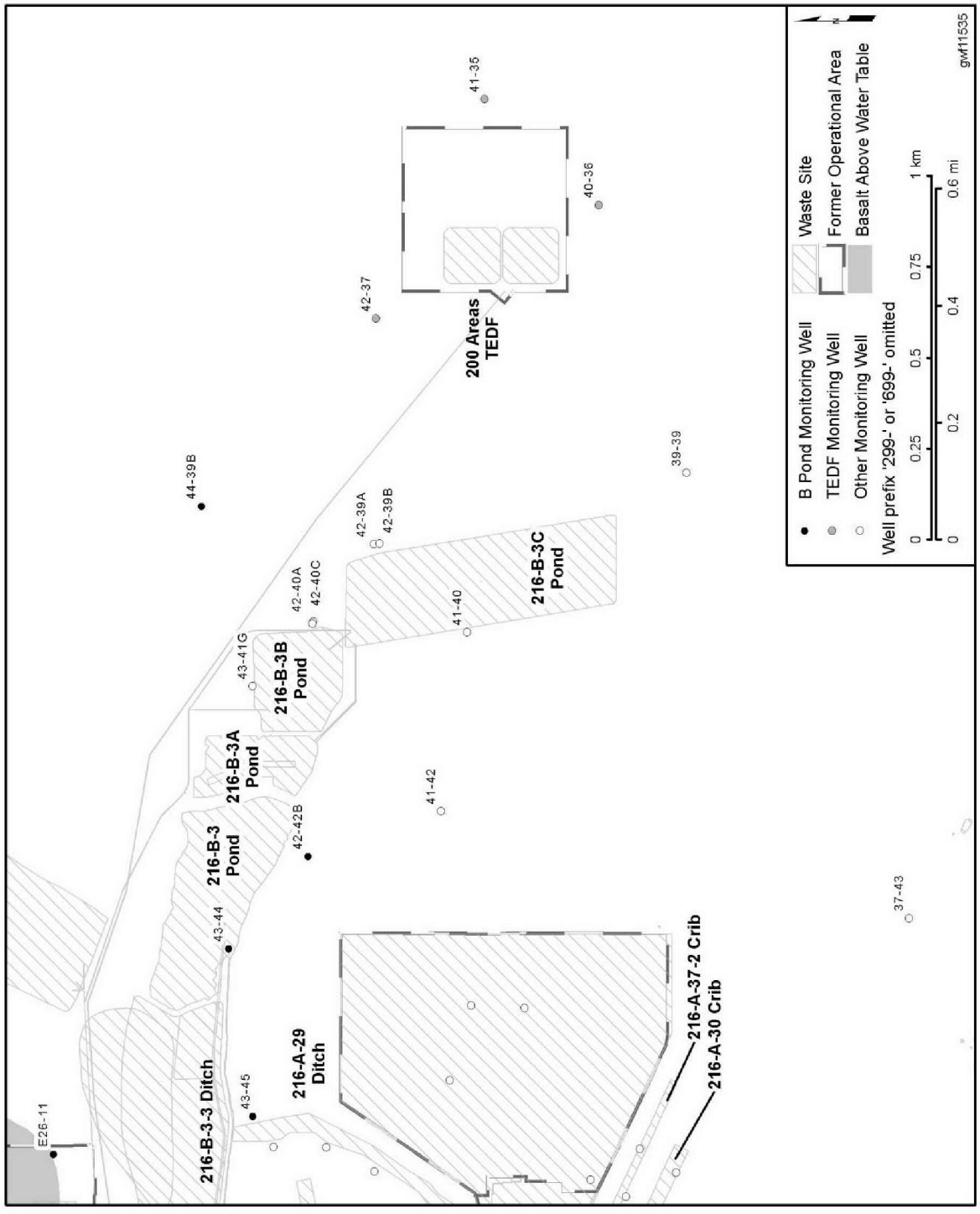


Figure B-5. Groundwater Monitoring Wells at 216-B-3 Pond and 200 Areas Treated Effluent Disposal Facility

Figure B-6. Groundwater Monitoring Wells at 216-S-10 Pond and Ditch

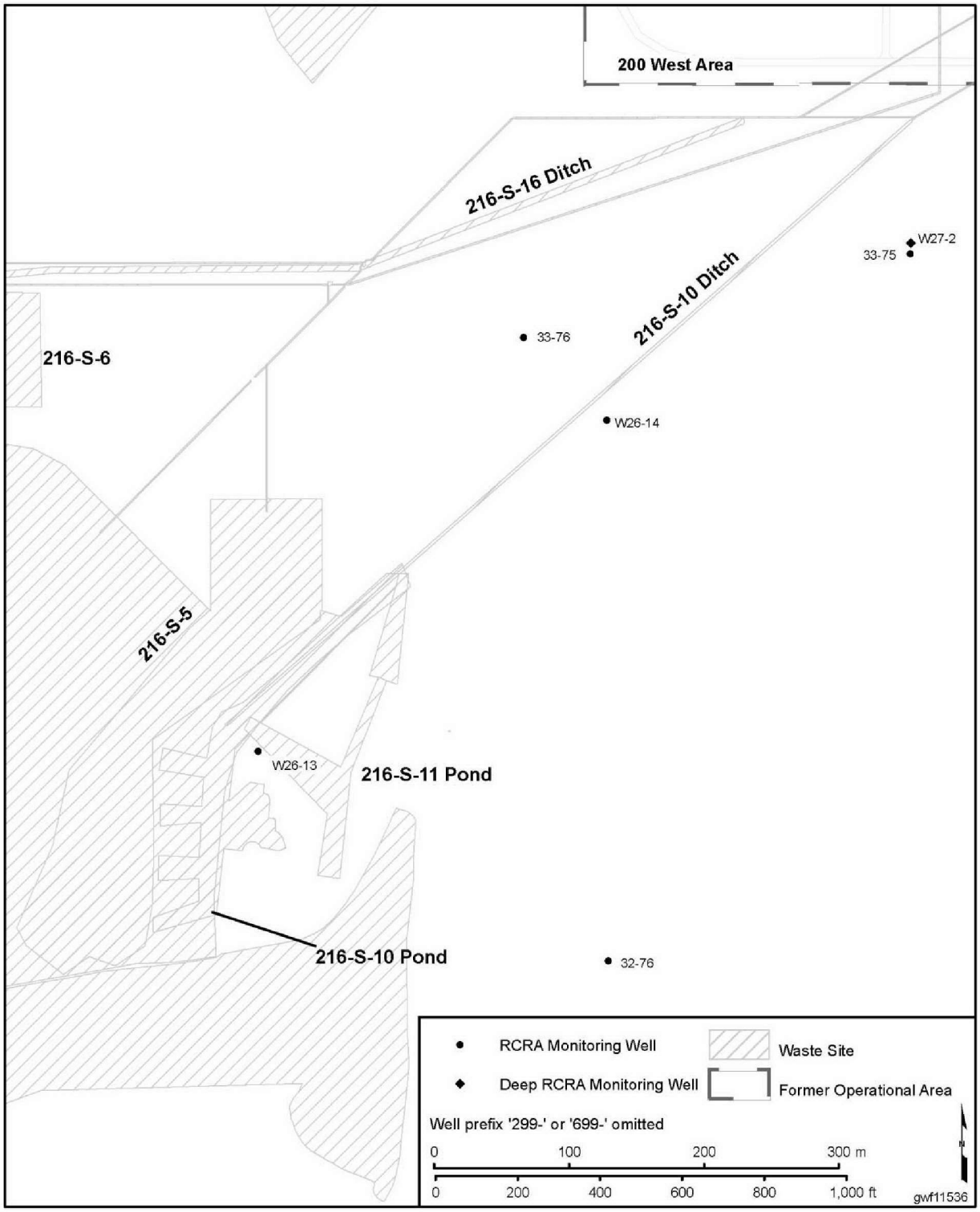
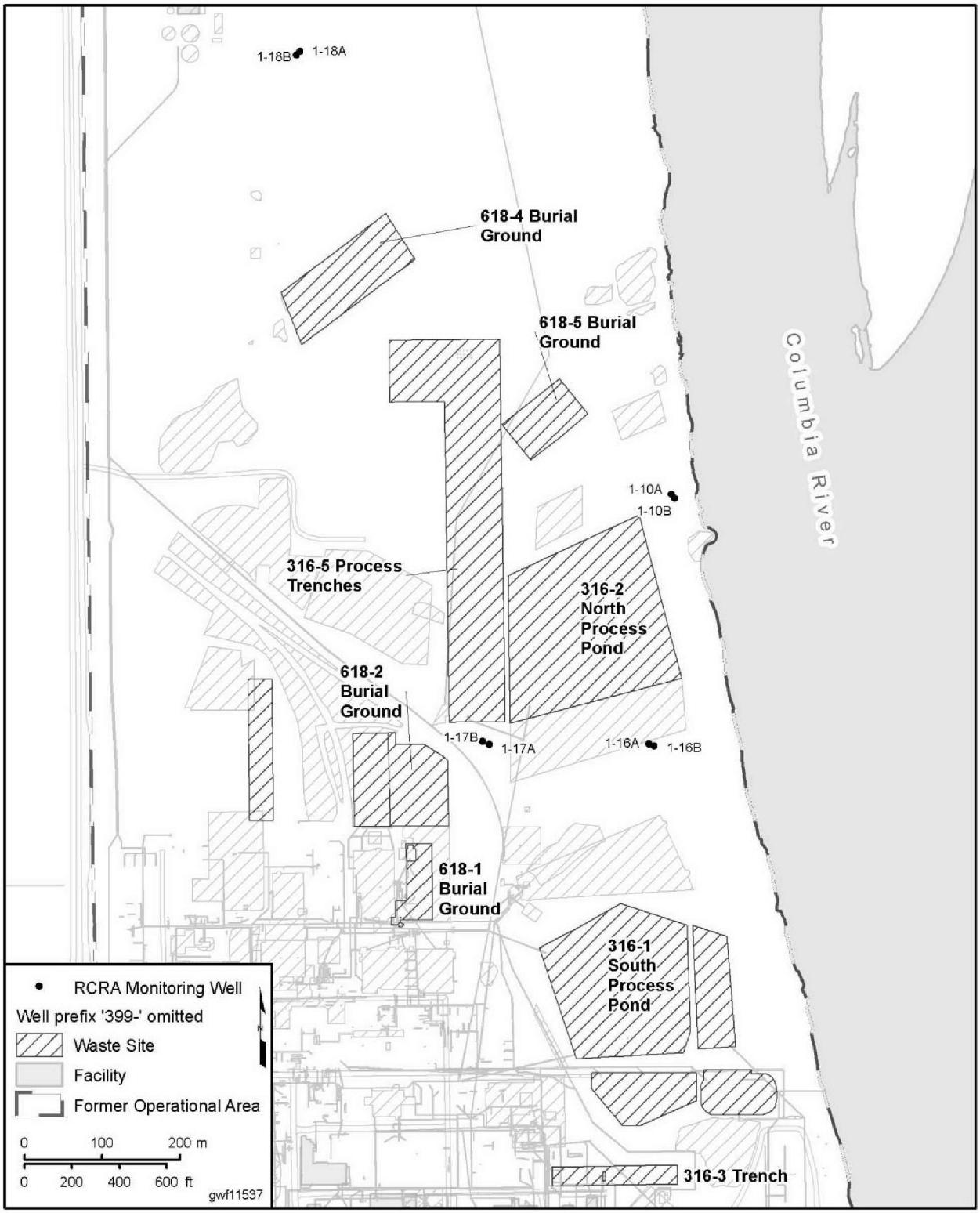


Figure B-7. Groundwater Monitoring Wells at 316-5 Process Trenches



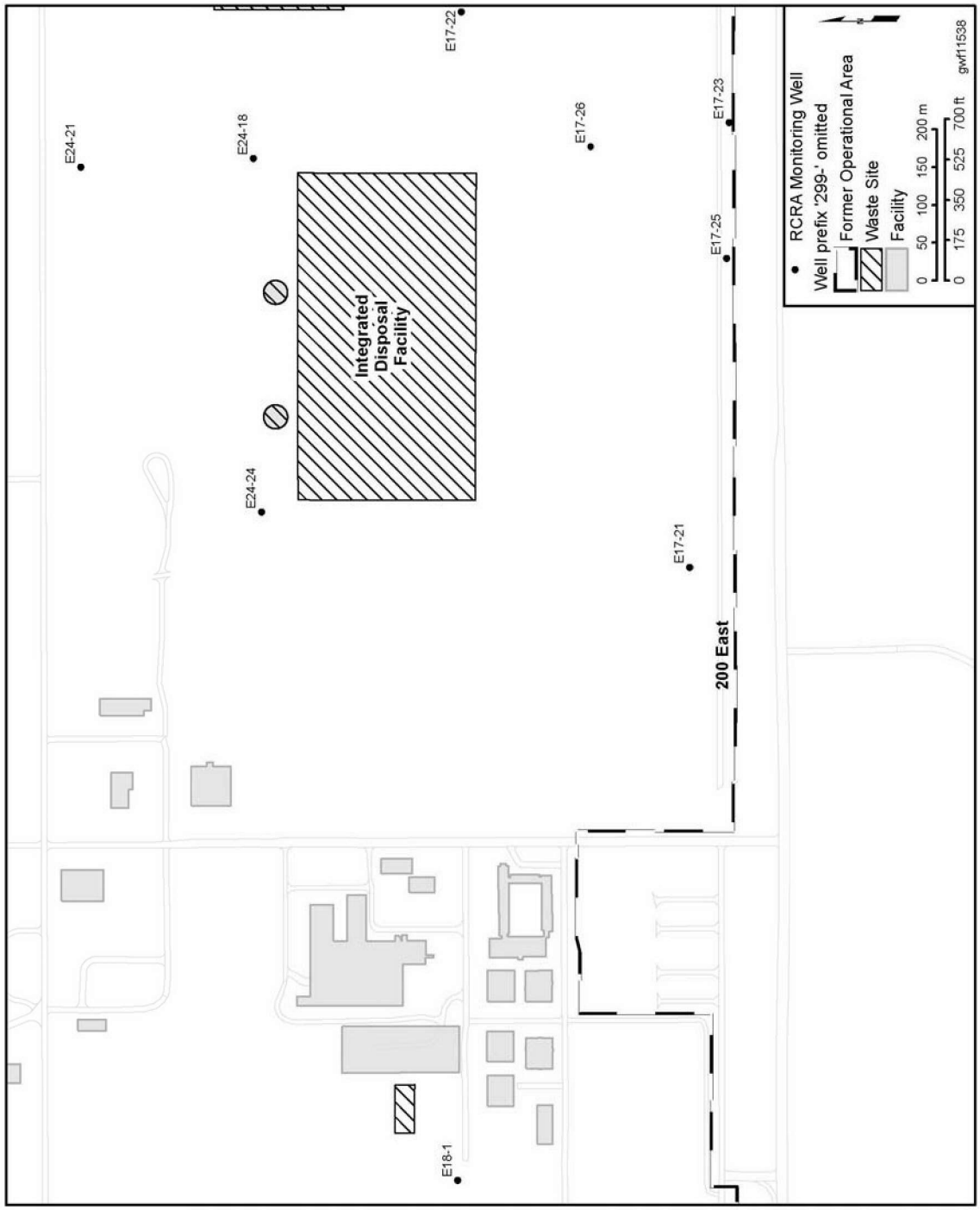


Figure B-8. Groundwater Monitoring Wells at Integrated Disposal Facility

Figure B-9. Groundwater Monitoring Wells at Liquid Effluent Retention Facility

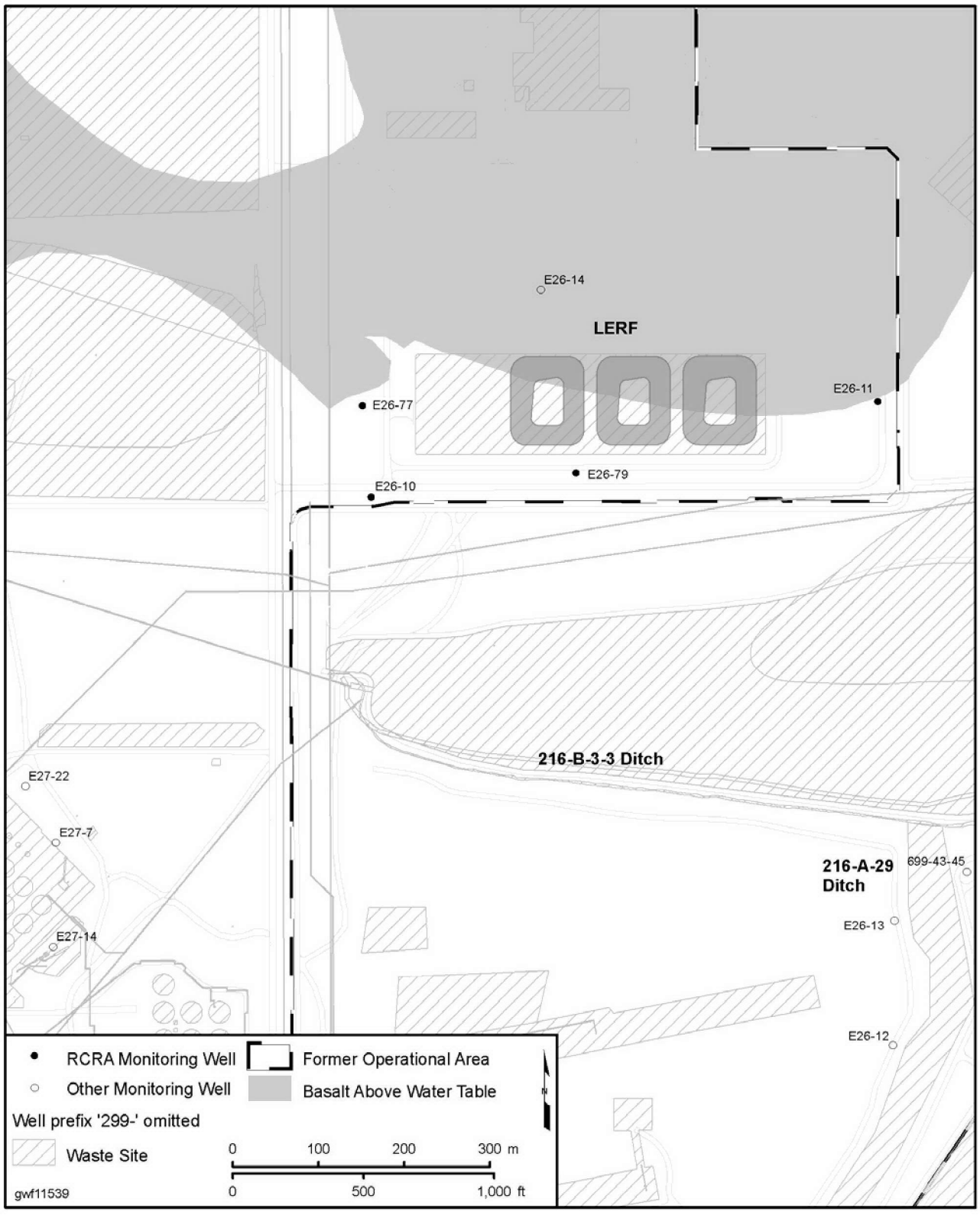
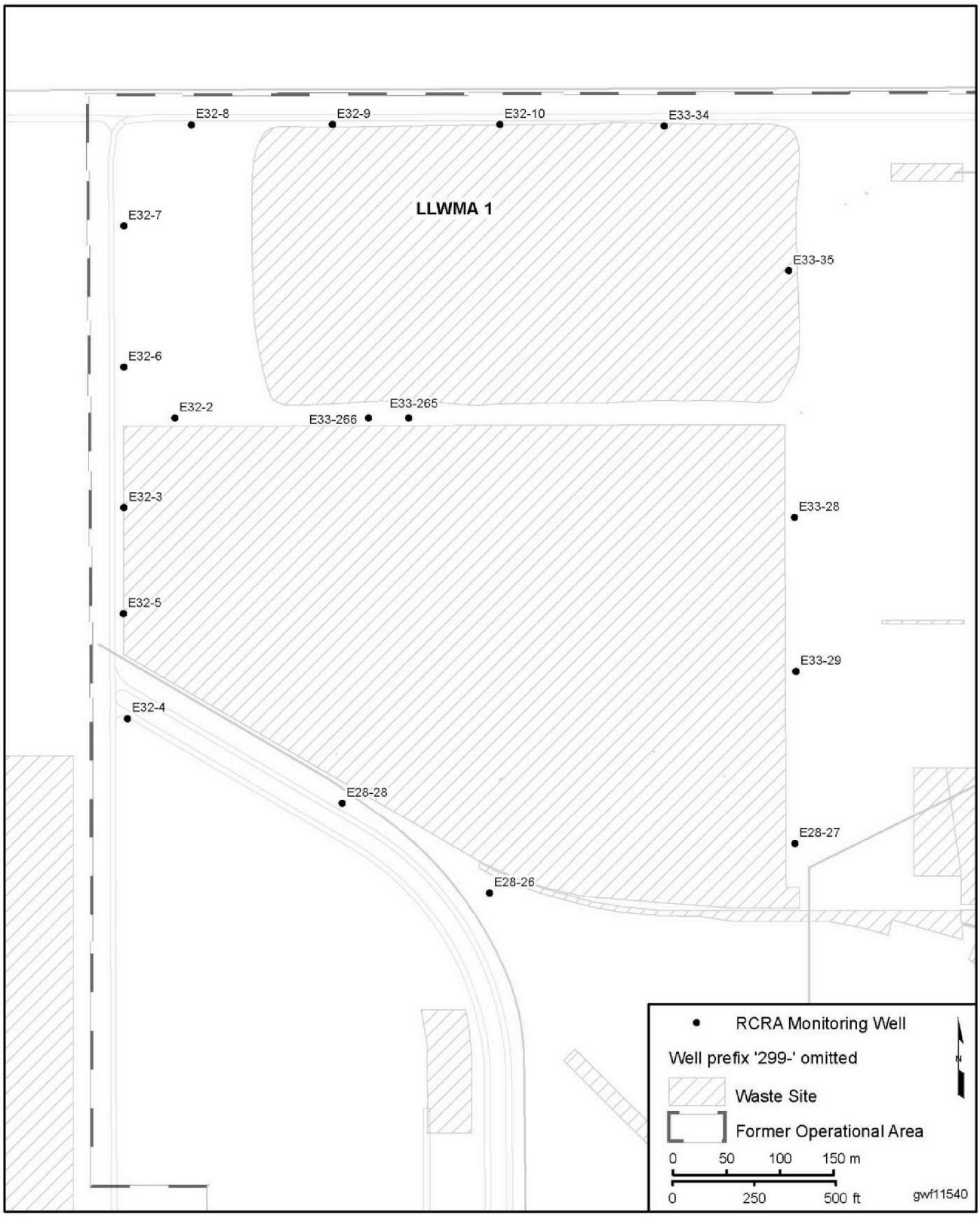


Figure B-10. Groundwater Monitoring Wells at Low-Level Waste Management Area 1



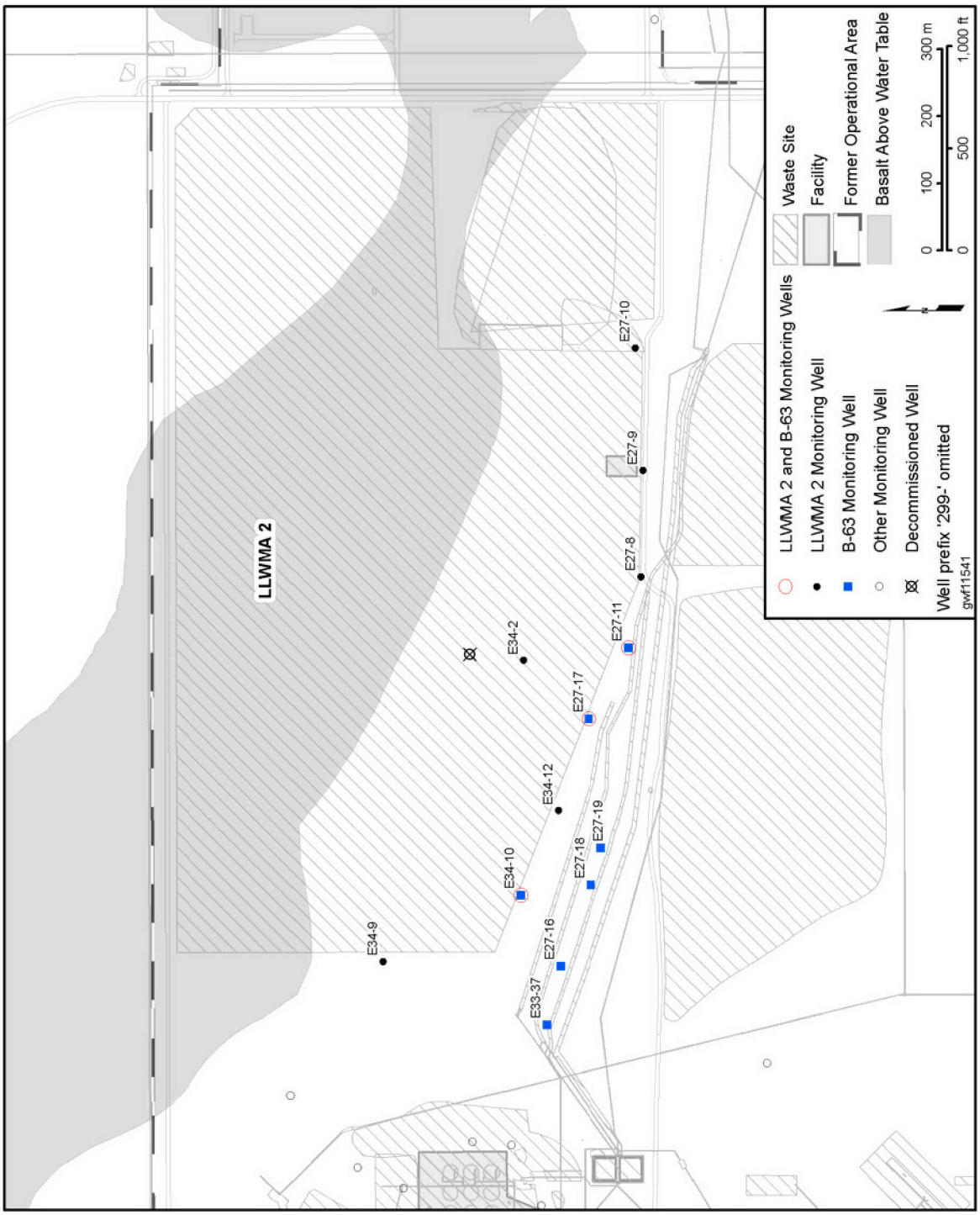


Figure B-11. Groundwater Monitoring Wells at 216-B-63 Trench and Low-Level Waste Management Area 2

Figure B-12. Groundwater Monitoring Wells at Low-Level Waste Management Area 3

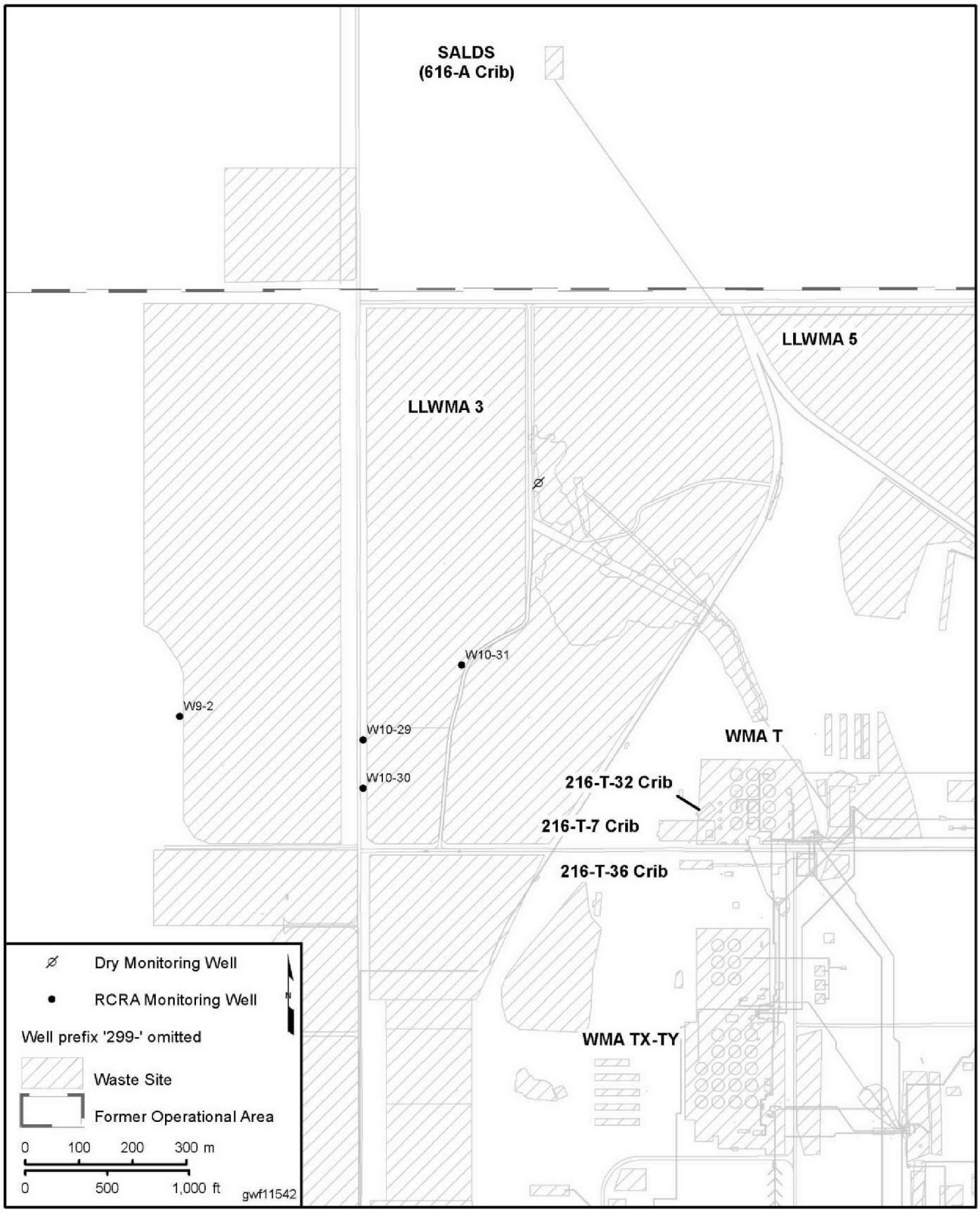


Figure B-13. Groundwater Monitoring Wells at Low-Level Waste Management Area 4

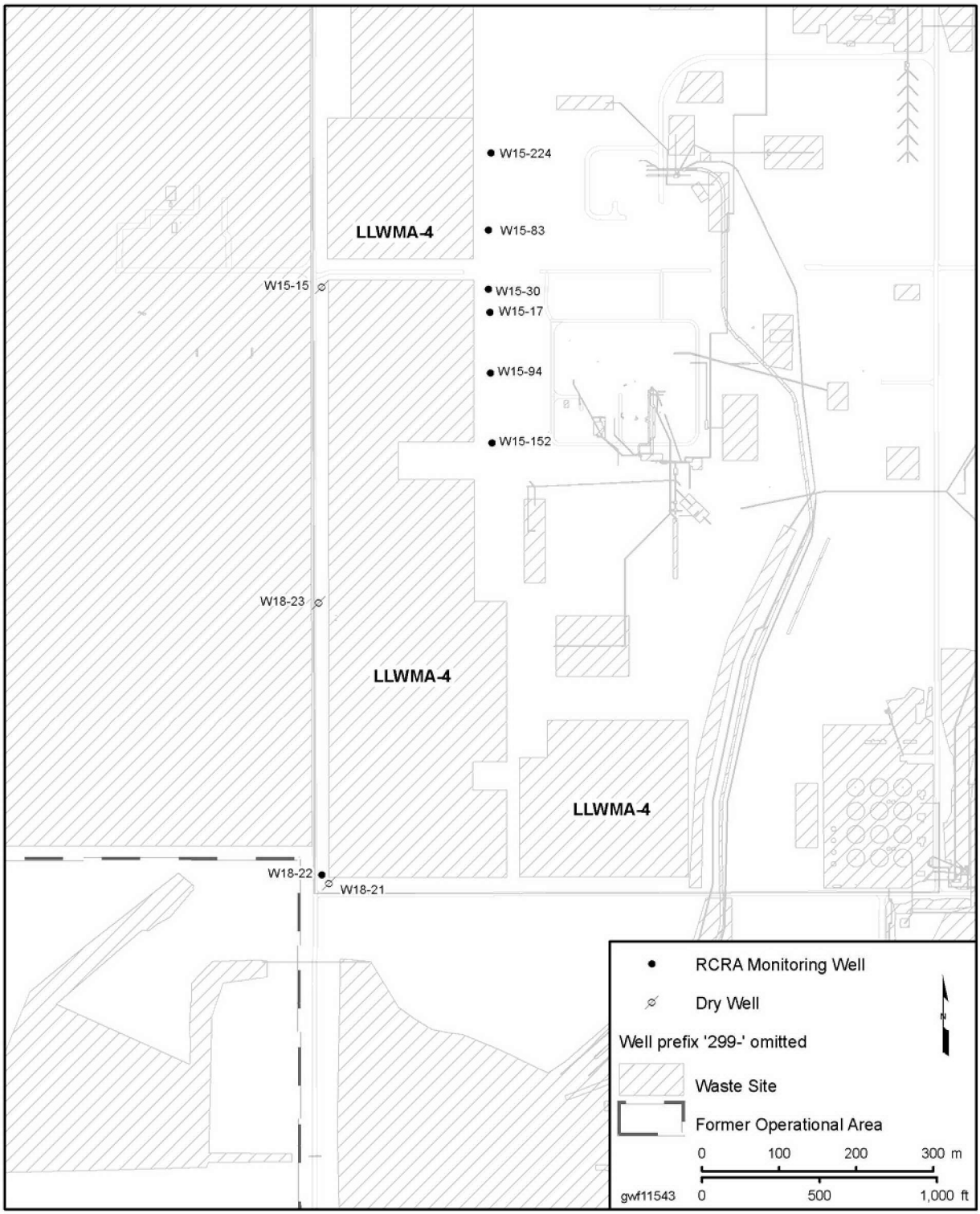


Figure B-14. Groundwater Monitoring Wells at Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill

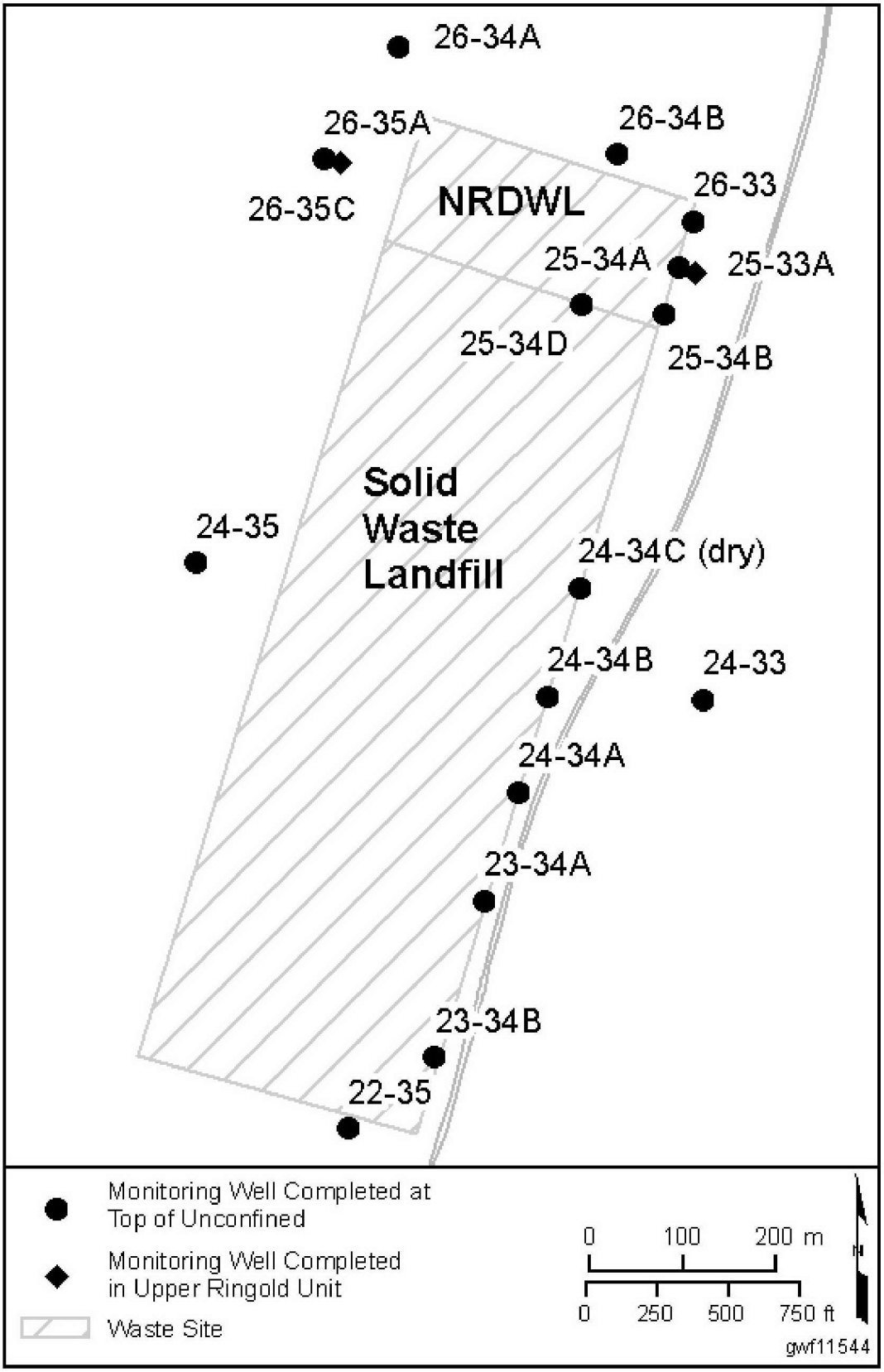


Figure B-15. Groundwater Monitoring Wells at Waste Management Area B-BX-BY

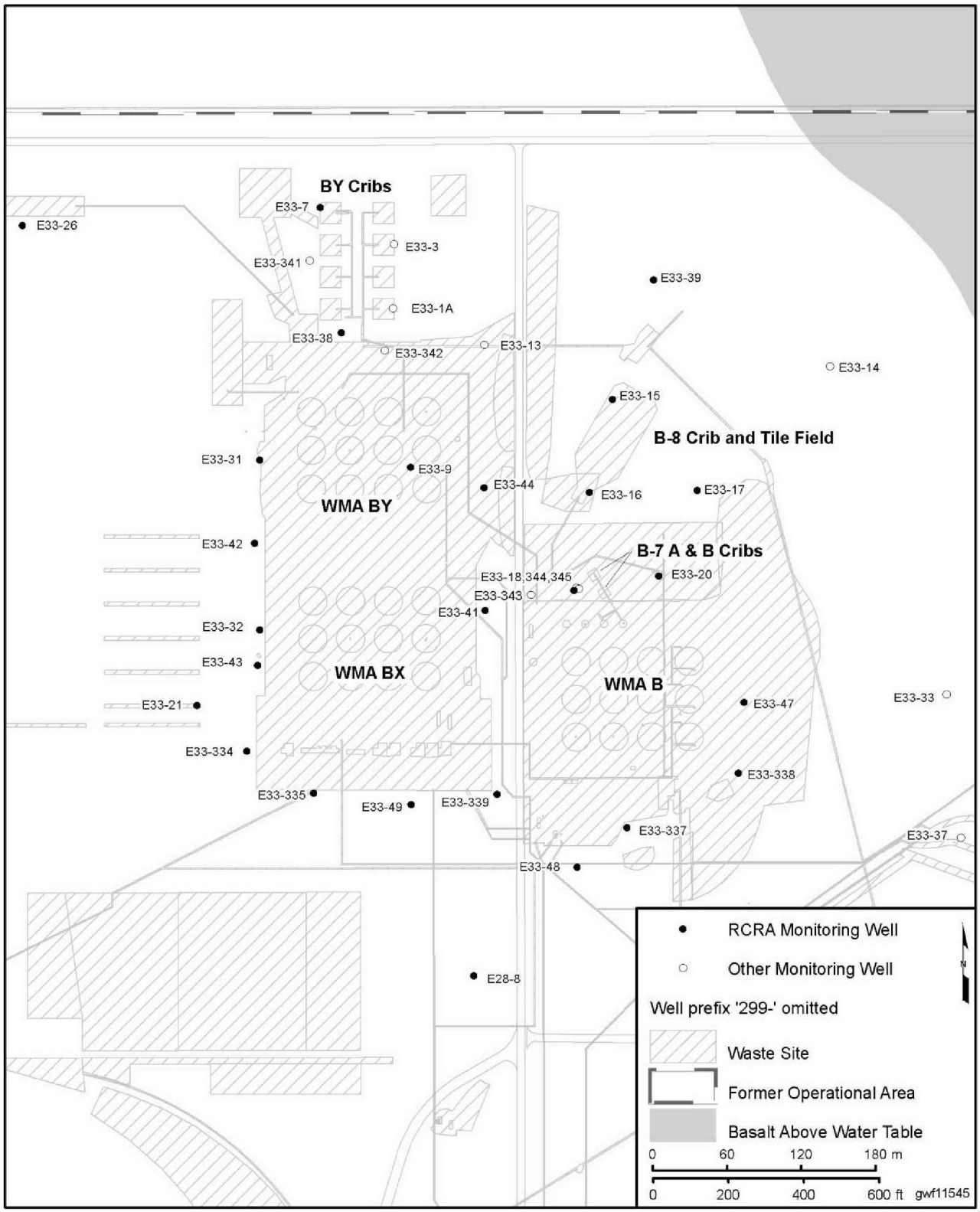


Figure B-16. Groundwater Monitoring Wells at Waste Management Areas S-SX-U

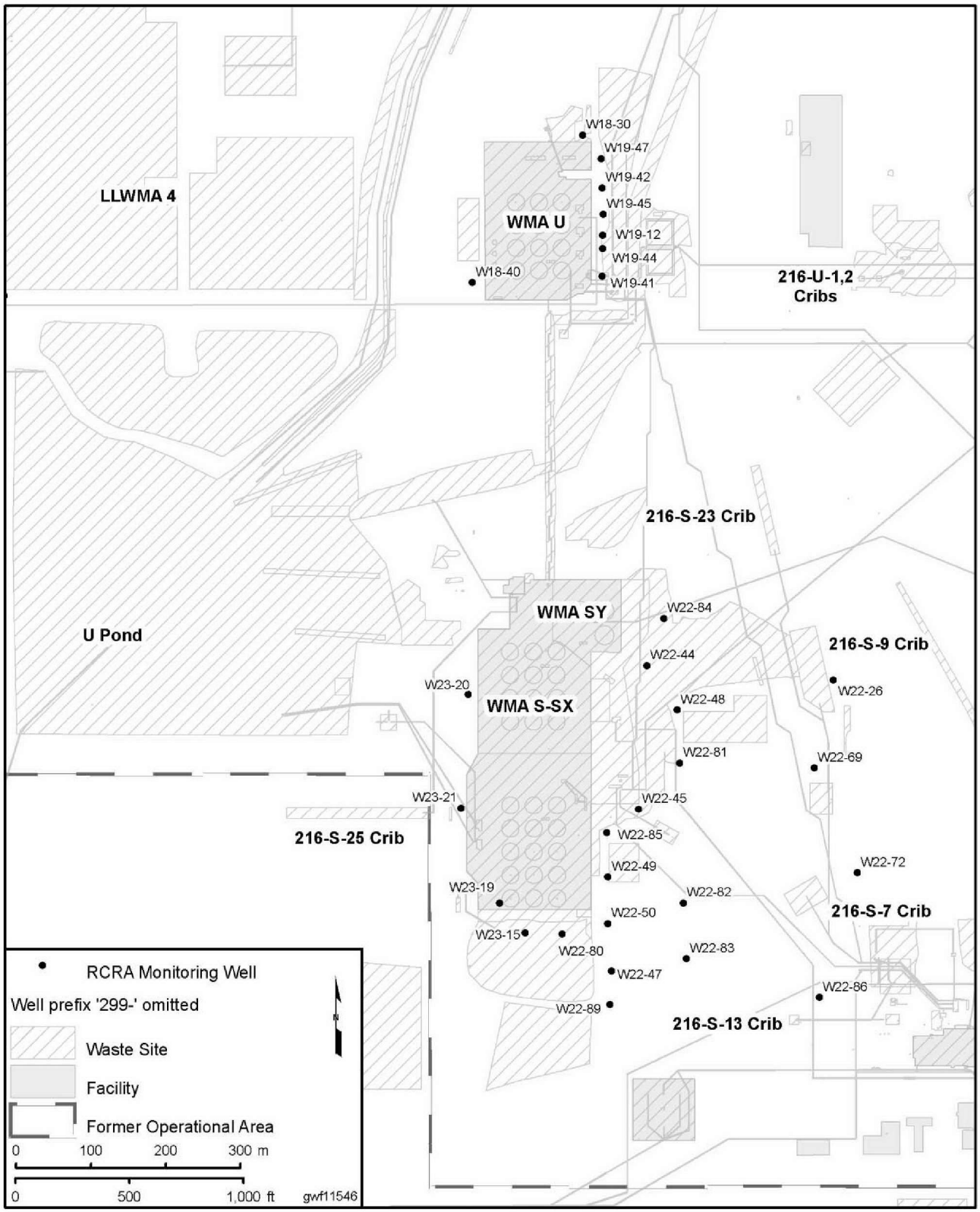


Figure B-17. Groundwater Monitoring Wells at Waste Management Areas T and TX-TY

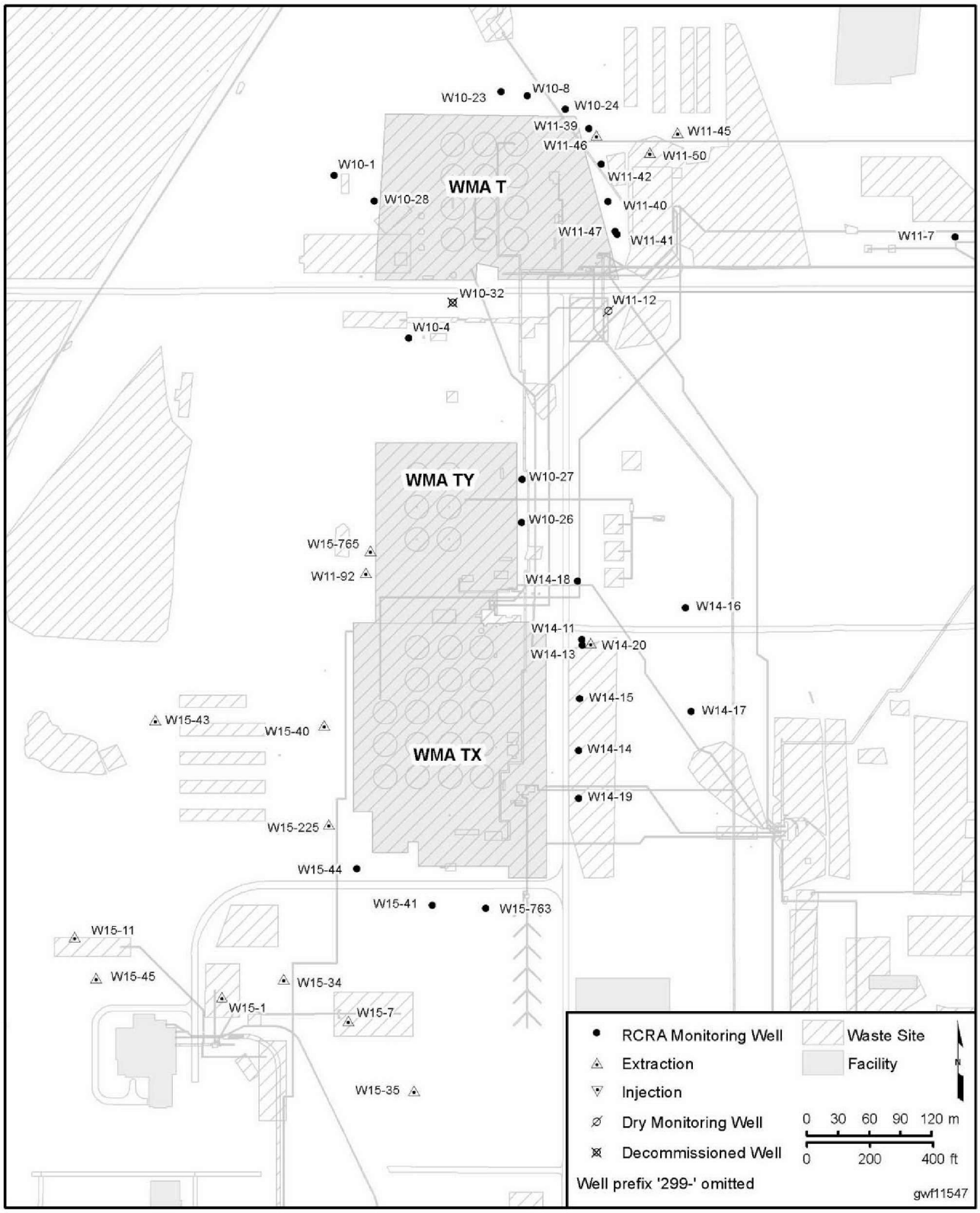


Figure B-18. Non-RCRA Regulated Units on the Hanford Site Requiring Groundwater Monitoring

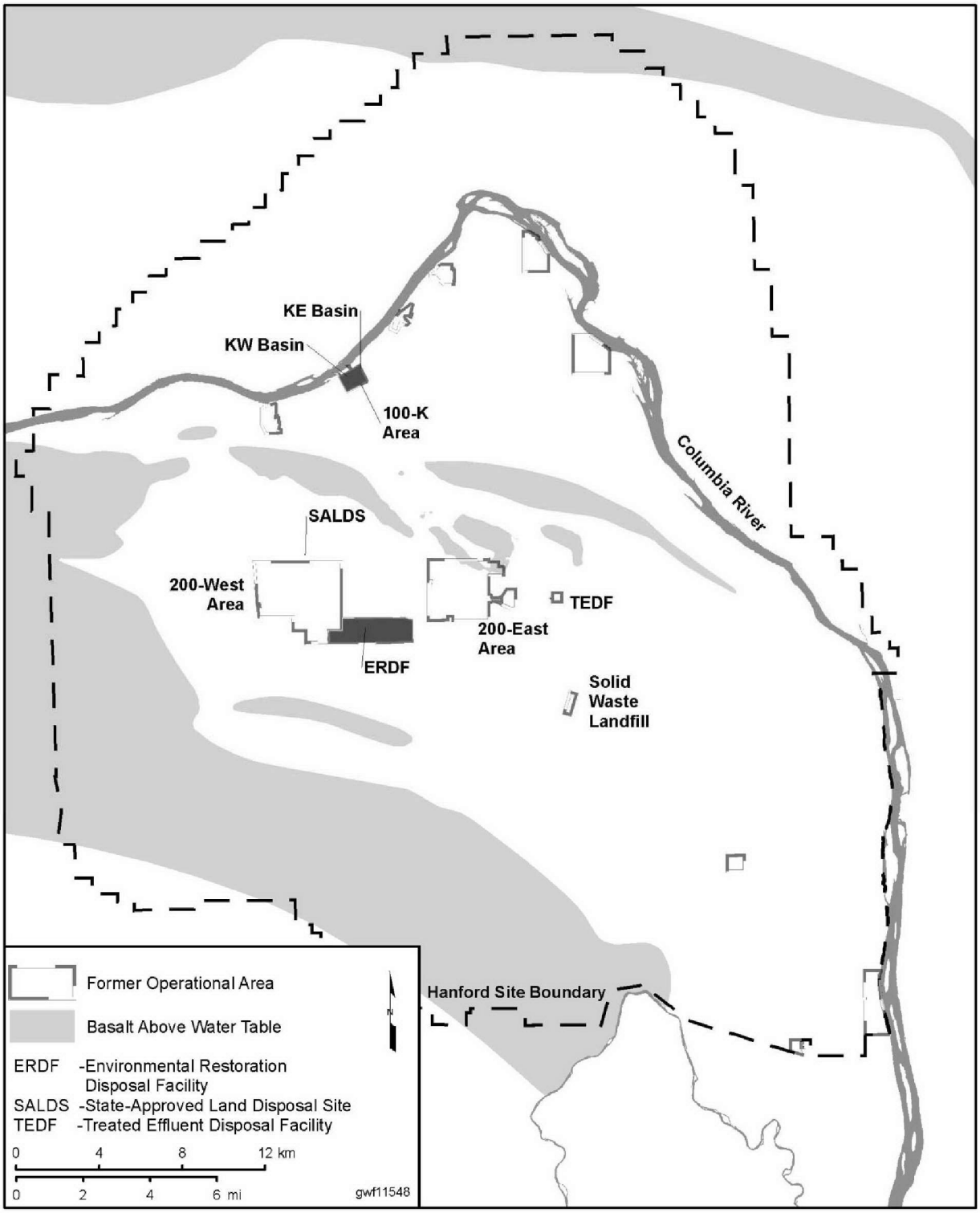
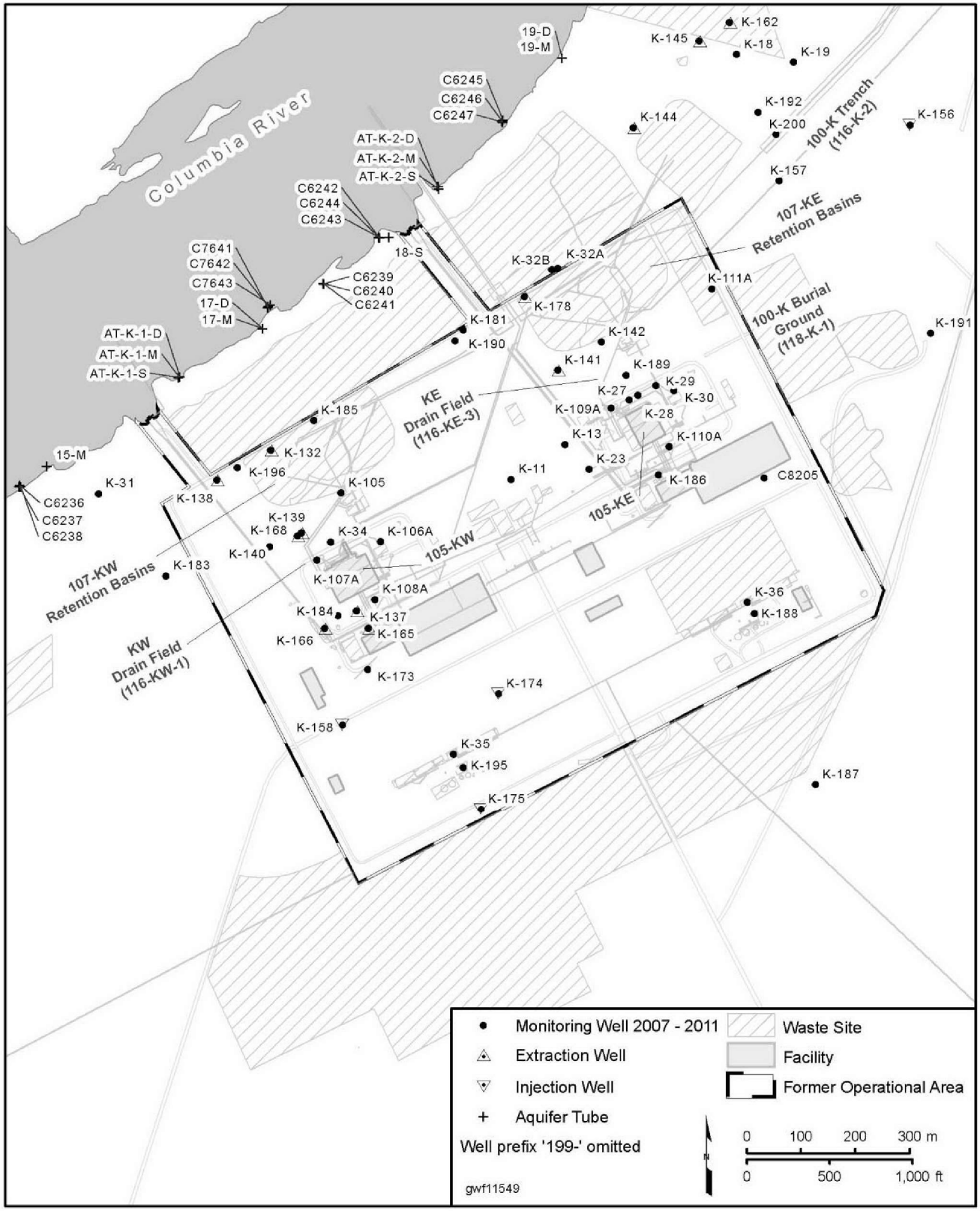


Figure B-19. Groundwater Monitoring Wells at 100-K Basins



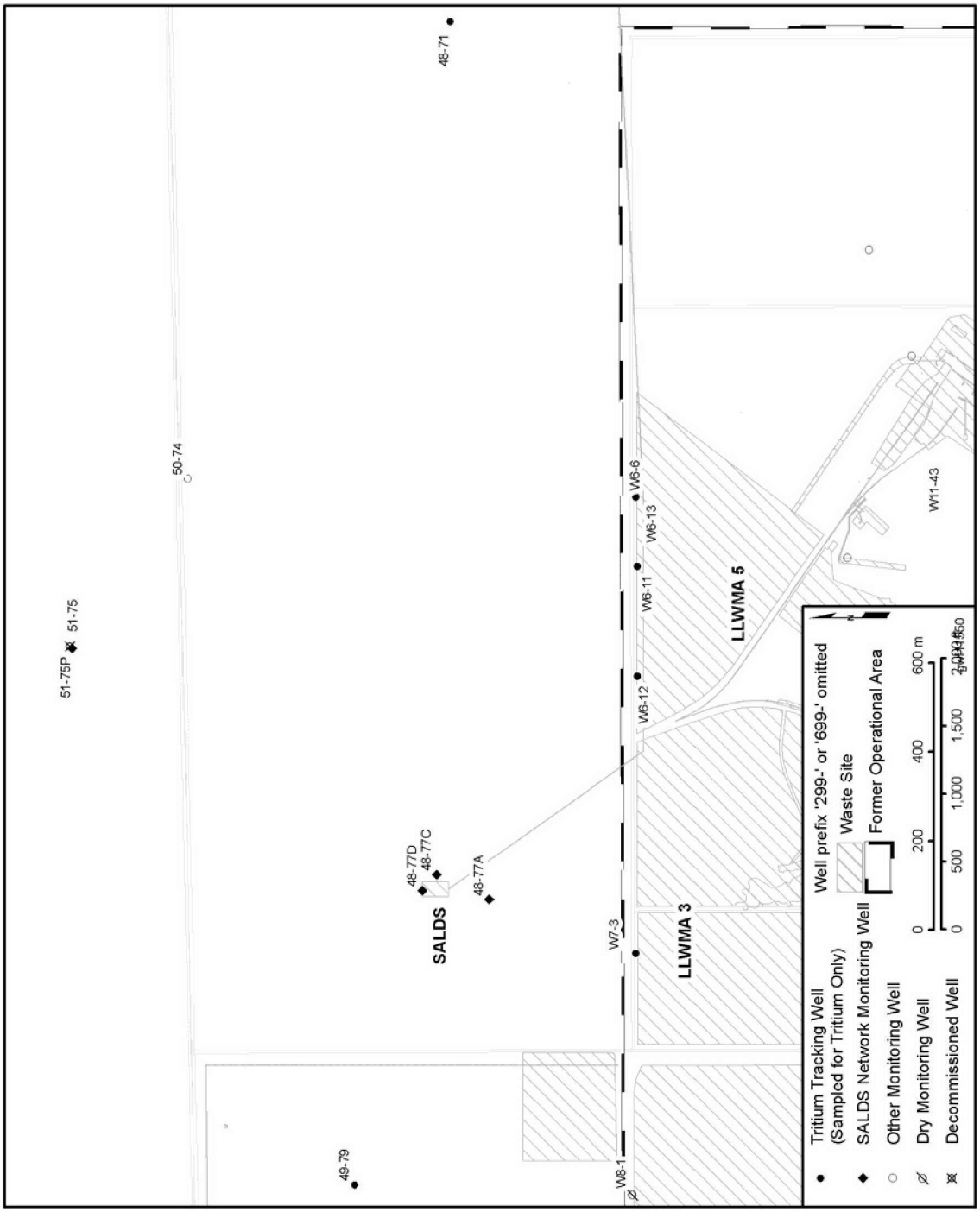
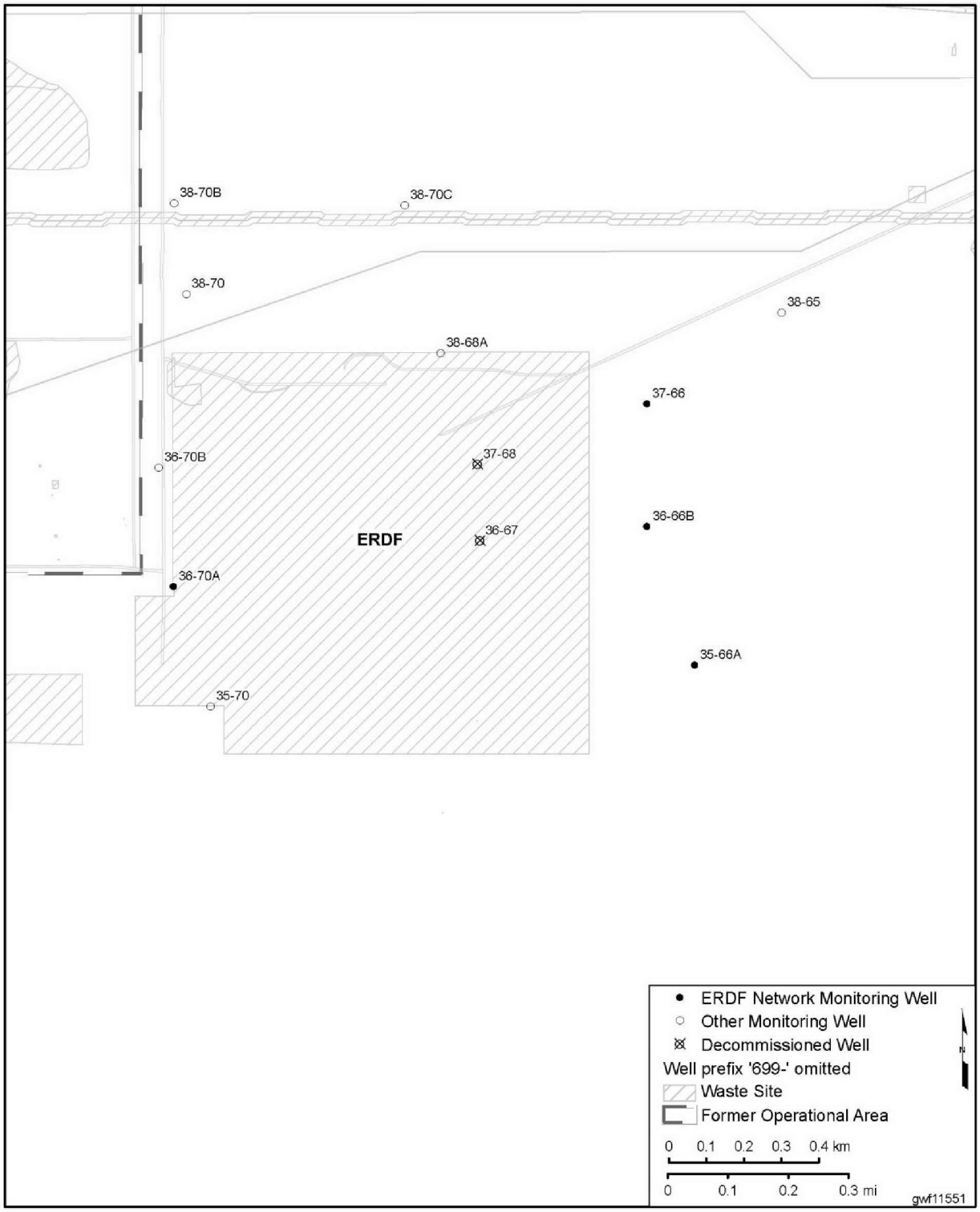


Figure B-20. Groundwater Monitoring Wells at State-Approved Land Disposal Site

Figure B-21. Groundwater Monitoring Wells at the Environmental Restoration Disposal Facility



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Appendix C—Supporting Information for Aquifer Sampling Tubes

M.J. Hartman

Aquifer tubes are small-diameter, flexible tubes that have a screen on one end. The tubes are installed in the aquifer along the Columbia River shoreline by driving a temporary steel casing into the ground adjacent to the river. The temporary casing is filled with water to keep sediment from coming up into the casing, and then the drive-tip on the casing end is knocked out and the screened end of a tube is inserted into the casing. The steel casing is then pulled out, leaving the tube in place. Water is withdrawn from the tube using a peristaltic pump. Most aquifer tube sites include two or three separately installed tubes monitoring different depths, from ~1 to 8 meters. The tube sites cover the Hanford Site shoreline, from just upstream of 100-BC to downstream at the 300 Area. Sites are more closely spaced along some segments where higher density spatial resolution of contaminant plumes is needed.

A total of 562 aquifer tubes were installed on the Hanford Site. A subset of tubes is selected for sampling. *Sampling and Analysis Plan for Aquifer Sampling Tubes* (DOE/RL-2000-59) contains a list of tubes and constituents scheduled to be sampled in fiscal year 2009. The same list of tubes and constituents were scheduled for sampling in fiscal years 2010 through 2012. The sampling and analysis plan also summarizes the history of the Site's aquifer tube installation and describes tube site nomenclature.

Table C-1 summarizes the total number of tubes and clusters in each segment of shoreline, the number of tubes sampled, and the number of sampling trips in 2011. A total of 290 aquifer tubes were sampled in 2011 under the routine shoreline monitoring program (Table C-2), and many of the tubes were sampled more than once, for a total of 566 sampling trips.[1] Additional samples were collected from some 100-N aquifer tubes in support of the apatite barrier performance evaluation (Table C-3).

Most of the aquifer tubes are sampled once per year, generally in the fall, but the annual events were not comprehensive in 2010 and 2011. As stated in the 2010 annual report, fall 2010 sampling was delayed into calendar year 2011 because of a stop-work order and other factors. Not all of the tubes were sampled before the river stage rose and sampling was either cancelled or delayed until late summer. Fall 2011 sampling started slowly because of competing priorities for sampling personnel, and sampling continued into 2012.

Until fall 2011, at most aquifer tube sites, if the specific conductance of the water was less than 160 µS/cm, the conductance was recorded and water was not collected for laboratory analyses because the samples contain more river water than groundwater. This practice was changed in fall 2011, and samples are collected from all scheduled tubes, regardless of the specific conductance.

C.1 References

DOE/RL-2000-59, 2009, *Sampling and Analysis Plan for Aquifer Sampling Tubes*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

[1] These numbers include sampling trips where only field parameters were measured, either by design or because specific conductance was low. The sampling trip tallies in the main text of this report are based on samples collected, as reflected by data in HEIS.

Table C-1. Inventory of Hanford Site Aquifer Tubes as of December 31, 2011

Segment	Total Tubes/Sites	Tubes Not in Service	Tubes Sampled, 2011	Sites Sampled, 2011	Tube Trips, 2011
100-BC	53/21	1	15	8	21
100-K	70/28	1	44	19	58
100-N	84/40	1	42	22	124*
100-D	97/37	11	71	30	190
100-H	97/41	12	57	28	71
100-F	81/29	16	31	15	49
200-PO-1	28/17	4	2	2	2
300 Area	52/25	3	28	12	51
Total	**562/238**	**58**	**290**	**136**	**566**

* Does not include sampling trips made for performance monitoring of the 100-N apatite barrier. See Table C-3 for additional information.

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
100-BC-5				
	01-M	A	3/7/2011	Delayed from fall 2010
		A	12/7/2011	
	03-D	A		Underwater 12/7/2011
	AT-B-1-M	A	12/7/2011	
	AT-B-2-D	A		Underwater 12/7/2011
	04-D	A	3/7/2011	Delayed from fall 2010
		A	12/7/2011	
	C6227	A		Underwater 12/7/2011
	C6228	A		Underwater 12/7/2011
	C6229	A		Underwater 12/7/2011
	05-S	A	3/7/2011	Delayed from fall 2010
		A		Frozen line 12/9'2011; missing PVC end cap.
	05-M	A	3/7/2011	Delayed from fall 2010
		A	12/9/2011	
	05-D	A	3/7/2011	Delayed from fall 2010
		A	12/9/2011	
x	C7718	A		Tubing pulled too far down 12/12/2011
x	C7719	A		Tubing pulled too far down 12/12/2011
x	C7720	A		Tubing pulled too far down 12/12/2011

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	AT-B-3-S	A		
	AT-B-3-M	A		
	AT-B-3-D	A		
x	C7724	A	12/9/2011	
x	C7725	A		Frozen line 12/9/2011; missing PVC end cap
x	C7726	A	12/9/2011	Missing PVC end cap
	06-S	A	3/7/2011	Delayed from fall 2010
	06-M	A	3/7/2011	Delayed from fall 2010
	06-D	A	3/7/2011	Delayed from fall 2010
	C6230	A		
	C6231	A		
	C6232	A		
	C6233	A		
	C6234	A		
	C6235	A		
x	C7780	A	5/11/2011	Delayed from fall 2010
x			12/9/2011	
x	C7781	A	5/11/2011	Delayed from fall 2010
x				Frozen line 12/9/2011.
x	C7782	A	5/11/2011	Delayed from fall 2010
x			12/9/2011	
	AT-B-7-M	A		
	AT-B-5-D	A		
	12-D	A	12/12/2011	Needs to be labeled w/ well ID
100-KR-4				
	14-D	A	9/6/2011	Delayed from fall 2010
	C6236	A	9/6/2011	Delayed from fall 2010
	C6237	A	9/6/2011	Delayed from fall 2010
	C6238	A	9/6/2011	Delayed from fall 2010
	AT-K-1-D	A	12/16/2010	Delayed from fall 2010
	17-D	A		
x	C7641		2/22/2011	Field readings only; low SC
x		Q	5/3/2011	Field readings only; low SC
x		Q	9/6/2011	Field readings only; low SC
x	C7642		2/22/2011	
x		Q	5/3/2011	
x		Q		Under water 8/23/2011
x	C7643		2/22/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
x		Q	5/3/2011	
x		Q	9/6/2011	Under water 8/23/2011
	C6239	A	1/28/2011	Field readings only; low SC; Delayed from fall 2010
	C6240	A	1/28/2011	Field readings only; low SC; Delayed from fall 2010
	C6241	A	1/28/2011	Delayed from fall 2010
x		Q		Not attempted
x		Q	5/12/2011	
x		Q	8/23/2011	
	C6242	A	2/22/2011	Field readings only; low SC; Delayed from fall 2010
	C6243	A	2/22/2011	Delayed from fall 2010
	C6244	A	2/22/2011	Delayed from fall 2010
x	18-S	A	1/28/2011	Delayed from fall 2010
	AT-K-2-D	A		
	C6245	A	9/12/2011	Delayed from fall 2010
	C6246	A	9/12/2011	Delayed from fall 2010
	C6247	A	9/12/2011	Delayed from fall 2010
	19-M	A	9/12/2011	Delayed from fall 2010
	19-D	A	9/12/2011	Delayed from fall 2010
	AT-K-3-S	A	9/12/2011	Delayed from fall 2010
	AT-K-3-M	A	9/12/2011	Delayed from fall 2010
	AT-K-3-D	A		
	C6248	A	5/3/2011	Delayed from fall 2010
	C6249	A	5/3/2011	Delayed from fall 2010
	C6250	A	5/3/2011	Delayed from fall 2010
x		Q		
x		Q		
x		Q	8/23/2011	
	C6251	A	9/26/2011	Delayed from fall 2010
	C6252	A	9/26/2011	Delayed from fall 2010
	C6253	A	9/26/2011	Delayed from fall 2010
	21-S	A	9/26/2011	Delayed from fall 2010
	21-M	A	9/26/2011	Delayed from fall 2010
	C6254	A	9/26/2011	Delayed from fall 2010
	C6255	A	9/26/2011	Delayed from fall 2010
	C6256	A	9/26/2011	Delayed from fall 2010
	C6257	A		
	C6258	A	9/9/2011	Delayed from fall 2010
	C6259	A	9/9/2011	Delayed from fall 2010

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	22-M	A	3/31/2011	Field readings only; low SC; Delayed from fall 2010
	22-D	A	3/31/2011	Delayed from fall 2010
	AT-K-4-S	A		
	AT-K-4-M	A		
x	AT-K-4-D	A		
	23-M	A		
	23-D	A		Removed 3/28/2011
	C6260	A		
	C6261	A		
	AT-K-5-S	A		
	AT-K-5-M	A		
	AT-K-5-D	A		
	DK-04-2	A		
	25-D	A	3/17/2011	Field readings only; low SC; Delayed from fall 2010
	AT-K-6-S	A	3/17/2011	Field readings only; low SC; Delayed from fall 2010
	AT-K-6-M	A	3/17/2011	Field readings only; low SC; Delayed from fall 2010
	AT-K-6-D	A	3/17/2011	
	26-S	A	3/17/2011	Field readings only; low SC; Delayed from fall 2010
x		Q		
x		Q	5/4/2011	Field readings only; low SC
x		Q	8/23/2011	Field readings only; low SC
	26-M	A	3/17/2011	Field readings only; low SC; Delayed from fall 2010
x		Q		
x		Q	5/4/2011	Field readings only; low SC
x		Q	8/23/2011	
	26-D	A	3/17/2011	
x		Q		
x		Q	5/4/2011	
x		Q	8/23/2011	
	C6263	A		
	C6264	A		
	C6265	A		
100-NR-2				
	C6317	A	9/23/2011	Delayed from fall 2010
	C6318	A	9/23/2011	Delayed from fall 2010
	C6319	A	9/23/2011	Delayed from fall 2010
x	C7934	1		

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
x	C7935	1		
x	C7936	1		
x	C7937	1		
x	C7938	1		
x	C7939	1		
	C6320	A		
	C6321	A		
	C6352	A	2/23/2011	Field readings only; low SC; Delayed from fall 2010
	C6322	A		
	C6132	Q	2/23/2011	Delayed from fall 2010
		Q		No yield 3/15/2010
		Q	6/1/2011	
		Q	9/2/2011	
	N116mArray-0A	Q	6/1/2011	
		Q	9/2/2011	
	C6135	Q	2/23/2011	Delayed from fall 2010
		Q	3/15/2011	
		Q		
		Q	9/2/2011	
	N116mArray-1A	Q	3/23/2011	
		Q	6/1/2011	
		Q	9/2/2011	
	N116mArray-2A	Q	2/8/2011	Delayed from fall 2010
		Q	3/15/2010	
		Q	6/1/2011	
		Q	9/2/2011	
	N116mArray-3A	M	1/31/2011	
		M	2/8/2011	
		M	3/15/2011	
		M	4/14/2011	
		M	5/4/2011	
		M	6/1/2011	
		M	7/12/2011	
		M	8/15/2011	
		M	9/2/2011	
	N116mArray-4A	M	1/31/2011	
		M	2/8/2011	
		M	3/15/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
		M	4/14/2011	
		M	5/4/2011	
		M	6/1/2011	
		M	7/12/2011	
		M	8/15/2011	
		M	9/7/2011	
	NVP1-1	Q	2/8/2011	Delayed from fall 2010
		Q	3/16/2011	
		Q	6/2/2011	
		Q		Lost flow 9/7/2011
	NVP1-2	Q	2/8/2011	Delayed from fall 2010
		Q	3/16/2011	
		Q	6/2/2011	
		Q	9/7/2011	
	NVP1-3	Q	2/8/2011	Delayed from fall 2010
		Q	3/16/2011	
		Q	6/2/2011	
		Q	9/7/2011	
	NVP1-4	Q	2/8/2011	Delayed from fall 2010
		Q	3/16/2011	
		Q	6/1/2011	
		Q	9/7/2011	
	NVP1-5	Q	2/8/2011	Delayed from fall 2010
		Q	3/16/2011	
		Q	6/2/2011	
		Q	8/31/2011	
	NVP2-116.3	Q		No yield 3/16/2011
		Q	6/1/2011	
		Q		No yield 8/31/2011
	NVP2-116.0	M	1/31/2011	
		M	2/8/2011	
		M	3/16/2011	
		M	4/14/2011	
		M	5/4/2011	
		M	6/1/2011	
		M	7/12/2011	
		M	8/15/2011	
		M	8/31/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	NVP2-115.7	Q	2/8/2011	Delayed from fall 2010
		Q	3/16/2011	
		Q	6/1/2011	
		Q	8/31/2011	
	NVP2-115.4	Q	2/8/2011	Delayed from fall 2010
		Q	3/16/2011	
		Q	6/1/2011	
		Q	8/31/2011	
	NVP2-115.1	Q	2/8/2011	Delayed from fall 2010
		Q	3/16/2011	
		Q	6/1/2011	
		Q	8/31/2011	
	N116mArray-6A	M	1/31/2011	
		M	2/8/2011	
		M	3/16/2011	
		M	4/14/2011	
		M	5/4/2011	
		M	6/2/2011	
		M	7/12/2011	
		M	8/15/2011	
		M	8/31/2011	
	N116mArray-7A	Q		Not scheduled; destroyed
x	C7881	Q	6/2/2011	Replaced Array-7A
x		Q	8/31/2011	
	N116mArray-8A	Q	2/8/2011	Delayed from fall 2010
		Q	3/10/2011	
		Q	6/2/2011	
		Q	8/31/2011	
	N116mArray-8.5A	Q	2/7/2011	Delayed from fall 2010
		Q	3/10/2011	
		Q	6/2/2011	
		Q	8/31/2011	
	N116mArray-9A	Q	2/7/2011	Delayed from fall 2010
		Q	3/10/2011	
		Q	6/2/2011	
		Q	8/31/2011	
	N116mArray-10A	Q	2/7/2011	Delayed from fall 2010
		Q	3/10/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
		Q		
		Q		8/31/2011 can't see poly tube in PVC protective casing
	N116mArray-11A	Q	2/7/2011	Delayed from fall 2010
		Q	3/10/2011	
		Q	6/2/2011	
		Q	8/31/2011	
	N116mArray-12A	Q		No yield 3/10/2011
		Q	6/2/2011	
		Q	8/31/2011	Very slow flow
	N116mArray-13A	Q		No yield 3/10/2011
		Q		No yield 6/2/2011
		Q		No yield 8/31/2011
	C6323	A	2/8/2011	Delayed from fall 2010
	C6324	A	2/8/2011	Delayed from fall 2010
	C6325	A	2/8/2011	Delayed from fall 2010
	N116mArray-14A	Q		No yield 3/10/2011
		Q		No yield 6/2/2011
		Q		No yield 8/31/2011
	N116mArray-15A	Q	2/7/2011	Delayed from fall 2010
		Q		
		Q	6/2/2011	
		Q	8/31/2011	
	C6326	A	2/23/2011	Scheduled for field readings only; delayed from fall 2011
	C6327	A	2/23/2011	Scheduled for field readings only; delayed from fall 2011
	C6328	A	2/23/2011	Delayed from fall 2010
	C6329	A	9/23/2011	Scheduled for field readings only; delayed from fall 2011
	C6330	A	9/23/2011	Scheduled for field readings only; delayed from fall 2011
	C6331	A	9/23/2011	Delayed from fall 2010
	C6332	A	2/23/2011	Scheduled for field readings only; delayed from fall 2011
	C6333	A	2/23/2011	Scheduled for field readings only; delayed from fall 2011
	C6334	A	2/23/2011	Delayed from fall 2010
100-HR-3 -- 100-D				
x	C7645	A	12/20/2011	
x	C7646	A	12/20/2011	
x	C7647	A	12/20/2011	
x	C7648	A	12/20/2011	
	DD-50-1	A	1/6/2011	Delayed from fall 2010

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
			12/15/2011	
	DD-50-2	A	1/6/2011	Delayed from fall 2010
			12/15/2011	
	DD-50-3	A	1/6/2011	Delayed from fall 2010
			12/15/2011	
	DD-50-4	A	1/6/2011	Delayed from fall 2010
			12/15/2011	
	DD-49-1	A	1/6/2011	Delayed from fall 2010
			12/15/2011	
	DD-49-2	A	1/6/2011	Delayed from fall 2010
			12/15/2011	
	DD-49-3	A	1/6/2011	Delayed from fall 2010
			12/15/2011	
	DD-49-4	A	2/18/2011	Delayed from fall 2010
			12/15/2011	
	C6266	Q	1/6/2011	Delayed from fall 2010
		Q	2/1/2011	
		Q	4/20/2011	
		Q	8/3/2011	
		Q	12/15/2011	
	C6267	Q	1/6/2011	Delayed from fall 2010
		Q		No yield 2/1/11
		Q	4/20/2011	
		Q	8/3/2011	
		Q	12/15/2011	
	C6268	Q	1/6/2011	Delayed from fall 2010
		Q		Under water 2/1/11
		Q	4/20/2011	
		Q	8/3/2011	
		Q	12/15/2011	
	C6269	Q	1/6/2011	
		Q	4/20/2011	Field readings only; low SC
		Q	8/3/2011	Field readings only; low SC
		Q	12/15/2011	
	C6270	Q	1/6/2011	
		Q	4/20/2011	Field readings only; low SC
		Q	8/3/2011	
		Q	12/15/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	C6271	Q	1/6/2011	
		Q	4/20/2011	
		Q	8/3/2011	
		Q	12/15/2011	
	DD-44-3	Q	1/6/2011	Field readings only; low SC; Delayed from fall 2010
		Q	2/18/2011	Field readings only; low SC
		Q	4/20/2011	
		Q	8/3/2011	
		Q	12/16/2011	
	DD-44-4	Q	1/6/2011	Field readings only; low SC; Delayed from fall 2010
		Q	2/18/2011	
		Q	4/20/2011	
		Q	8/3/2011	
		Q	12/16/2011	
	DD-43-2	Q	1/6/2011	Field readings only; low SC; Delayed from fall 2010
		Q	2/18/2011	Field readings only; low SC
		Q	4/20/2011	
		Q	8/10/2011	Field readings only; low SC
		Q	12/16/2011	
	DD-43-3	Q	1/6/2011	Delayed from fall 2010
		Q	2/18/2011	Field readings only; low SC
		Q	4/20/2011	Field readings only; low SC
		Q	8/10/2011	
		Q	12/16/2011	
	DD-42-2	Q	1/6/2011	Field readings only; low SC; Delayed from fall 2010
		Q	2/18/2011	Field readings only; low SC
		Q	4/20/2011	
		Q	8/10/2011	
		Q	12/16/2011	
	DD-42-3	Q	1/6/2011	Field readings only; low SC; Delayed from fall 2010
		Q	2/18/2011	Field readings only; low SC
		Q	4/20/2011	
		Q	8/10/2011	
		Q	12/16/2011	
	DD-42-4	Q	1/6/2011	Field readings only; low SC; Delayed from fall 2010
		Q	2/18/2011	
		Q	4/20/2011	
		Q	8/10/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
		Q	12/16/2011	
	DD-41-1	Q	1/6/2011	Delayed from fall 2010
		Q	2/18/2011	Field readings only; low SC
		Q	4/19/2011	
		Q	8/18/2011	Field readings only; low SC
		Q	12/16/2011	
	DD-41-2	Q	1/6/2011	Field readings only; low SC; Delayed from fall 2010
		Q		No yield 2/18/2011
		Q	4/19/2011	
		Q	8/18/2011	
		Q	12/16/2011	
	DD-41-3	Q	1/6/2011	Delayed from fall 2010
		Q	2/18/2011	
		Q	4/19/2011	Field readings only; low SC
		Q		No yield 8/10/2011
		Q	12/16/2011	
	REDOX-4-3.0	Q	1/26/2011	Field readings only; low SC
		Q	4/19/2011	
		Q	8/18/2011	Field readings only; low SC
		Q	12/13/2011	
	REDOX-4-6.0	Q	1/26/2011	Field readings only; low SC
		Q	4/19/2011	
		Q	8/18/2011	Field readings only; low SC
		Q	12/13/2011	
	REDOX-3-3.3	Q		No yield 1/26/11
		Q	4/26/2011	Not sampled 4/21 b/c no label!
		Q	8/18/2011	Field readings only; low SC
		Q		No yield 12/13/2011
	REDOX-3-4.6	Q	1/26/2011	Field readings only; low SC
		Q	4/21/2-11	
		Q	8/18/2011	Field readings only; low SC
		Q		No yield 12/13/2011
	DD-39-1	Q	1/26/2011	Field readings only; low SC
		Q	4/21/2011	
		Q	8/18/2011	
		Q	12/13/2011	
	DD-39-2	Q	1/26/2011	Field readings only; low SC
		Q	4/21/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
		Q	8/18/2011	
		Q	12/13/2011	
	DD-39-3	Q	1/26/2011	
		Q	4/26/2011	
		Q	8/18/2011	
		Q		Tube broken; cancelled
	REDOX-2-3.0	Q		Not scheduled; destroyed
	REDOX-2-6.0	Q	1/26/2011	
		Q	4/26/2011	
		Q	8/18/2011	
		Q	12/13/2011	
	REDOX-1-3.3	Q	1/26/2011	Field readings only; low SC
		Q	4/26/2011	
		Q	8/18/2011	
		Q	12/13/2011	
	REDOX-1-6.0	Q	1/26/2011	
		Q	4/26/2011	
		Q	8/18/2011	
		Q	12/13/2011	
	AT-D-1-S	A	2/18/2011	Delayed from fall 2010
		A	12/13/2011	
	AT-D-1-M	A	2/18/2011	Delayed from fall 2010
		A	12/13/2011	
	AT-D-1-D	A	2/18/2011	Delayed from fall 2010
		A	12/13/2011	
	C6272	A	3/18/2011	Delayed from fall 2010
		A	12/13/2011	
	AT-D-4-S	A	3/18/2011	Delayed from fall 2010
		A	12/14/2011	
	AT-D-4-M	A	3/18/2011	Scheduled for field readings only; delayed from fall 2011
		A	12/14/2011	Scheduled for field readings only
	AT-D-4-D	A	3/18/2011	Scheduled for field readings only; delayed from fall 2011
		A	12/14/2011	Scheduled for field readings only
	AT-D-2-S	A	3/18/2011	Delayed from fall 2010
		A	12/14/2011	
	AT-D-2-M	A	3/18/2011	Field readings only; low SC; Delayed from fall 2010
		A	12/14/2011	
	36-S	A	12/15/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	36-M	A	12/15/2011	
	36-D	A	12/15/2011	
	AT-D-3-S	A	3/18/2011	Delayed from fall 2010
		A	12/14/2011	
	AT-D-3-M	A	3/18/2011	Delayed from fall 2010
		A	12/14/2011	
	AT-D-3-D	A	3/18/2011	Delayed from fall 2010
		A	12/14/2011	
	C6275	A	3/18/2011	Delayed from fall 2010
		A	12/16/2011	
	38-M	A		
		A	12/13/2011	
	38-D	A		Scheduled for field readings only
		A	12/13/2011	Scheduled for field readings only
	C6278	A	9/13/2011	Delayed from fall 2010
		A	12/21/2011	
	DD-17-2	A	9/13/2011	Delayed from fall 2010
		A	12/21/2011	
	DD-17-3	A	9/13/2011	Delayed from fall 2010
		A	12/21/2011	
	DD-16-3	A	3/18/2011	Field readings only; low SC; Delayed from fall 2010
		A	12/16/2011	
	DD-16-4	A	3/18/2011	Field readings only; low SC; Delayed from fall 2010
		A	12/16/2011	
	DD-15-2	A	3/18/2011	Field readings only; low SC; Delayed from fall 2010
		A	12/21/2011	
	DD-15-3	A	3/18/2011	Delayed from fall 2010
		A	12/21/2011	
	DD-15-4	A	3/18/2011	Field readings only; low SC; Delayed from fall 2010
		A	12/21/2011	
	DD-12-2	A	9/13/2011	Field readings only; low SC; Delayed from fall 2010
		A		Tubing disconnected & PVC broken 12/21/2011
	DD-12-4	A	9/13/2011	Delayed from fall 2010
		A	12/21/2011	
	AT-D-5-M	A	4/26/2011	Field readings only; low SC; Delayed from fall 2010
		A	12/19/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	AT-D-5-D	A	4/26/2011	Field readings only; low SC; Delayed from fall 2010
		A	12/19/2011	
	DD-06-2	A	12/19/2011	
	DD-06-3	A	9/13/2011	Delayed from fall 2010
		A	12/19/2011	
	C6281	A	9/13/2011	Field readings only; low SC; Delayed from fall 2010
		A	12/19/2011	
	C6282	A	9/13/2011	Delayed from fall 2010
		A	12/19/2011	
100-HR-3 -- Horn and 100-H				
	C6284	A	9/15/2011	Delayed from fall 2010
	C6285	A	9/15/2011	Delayed from fall 2010
	C6286	A	9/15/2011	Delayed from fall 2010
	C5632	A	2/9/2011	Field readings only; low SC; Delayed from fall 2010
	C5633	A	2/9/2011	Delayed from fall 2010
	C5634	A	2/9/2011	Delayed from fall 2010
	C5635	A	2/9/2011	Delayed from fall 2010
	C5636	A	2/9/2011	Delayed from fall 2010
	C5637	A	2/9/2011	Delayed from fall 2010
	C5638	A	2/9/2011	Delayed from fall 2010
	C6287	A		
	C6288	A	9/15/2011	Delayed from fall 2010
	C5641	A	2/9/2011	Delayed from fall 2010
	C5644	A	2/9/2011	Delayed from fall 2010
	44-M	A		
	44-D	A		
	C5673	A	3/3/2011	Field readings only; low SC; Delayed from fall 2010
	C5674	A	3/3/2011	Delayed from fall 2010
	C5676	A	3/3/2011	Delayed from fall 2010
	C5677	A	3/3/2011	Delayed from fall 2010
	C5678	A	3/3/2011	Delayed from fall 2010
	C5679	A	3/3/2011	Field readings only; low SC; Delayed from fall 2010
	C5680	A	3/3/2011	Delayed from fall 2010
	C5681	A		
	45-S	A	12/29/2011	
	45-M	A	12/29/2011	
	45-D	A	12/29/2011	
	C5682	A	9/15/2011	Delayed from fall 2010

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	C6290	A	9/16/2011	Delayed from fall 2010
	C6291	A	9/16/2011	Delayed from fall 2010
	C6293	A	9/22/2011	Delayed from fall 2010
	AT-H-1-S	A	12/29/2011	
	AT-H-1-M	A	12/29/2011	
	AT-H-1-D	A	12/29/2011	
	AT-H-2-S	A	9/22/2011	Scheduled for field readings only; delayed from fall 2011
			12/29/2011	
	AT-H-2-M	A	9/22/2011	Scheduled for field readings only; delayed from fall 2011
			12/29/2011	
	AT-H-2-D	A	9/22/2011	Delayed from fall 2010
			12/29/2011	
	AT-H-3-S	A	9/16/2011	Delayed from fall 2010
			12/28/2011	
	AT-H-3-D	A	9/16/2011	Delayed from fall 2010
			12/28/2011	
	47-M	A	4/28/2011	Delayed from fall 2010
		A	12/27/2011	
	47-D	A		No yield 12/27/2011
x	C7649	A	12/28/2011	
x	C7650	A	12/28/2011	
	C6296	A	9/16/2011	Delayed from fall 2010
			12/27/2011	
	C6297	A	9/16/2011	Delayed from fall 2010
			12/27/2011	
	48-S	A	2/4/2011	Field readings only; low SC; Delayed from fall 2010
			12/27/2011	
	48-M	A	2/4/2011	Delayed from fall 2010
			12/27/2011	
	C6299	A	9/14/2011	Delayed from fall 2010
			12/27/2011	
	C6300	A	9/14/2011	Delayed from fall 2010
			12/27/2011	
	C6301	A	9/14/2011	Delayed from fall 2010
			12/27/2011	
	49-D	A	2/4/2011	Delayed from fall 2010
			12/27/2011	
	50-S	A	2/4/2011	Delayed from fall 2010

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	50-M	A	2/4/2011	Delayed from fall 2010
	51-S	A	2/4/2011	Delayed from fall 2010
	51-M	A	2/4/2011	Delayed from fall 2010
	51-D	A	2/4/2011	Delayed from fall 2010
	52-S	A	2/4/2011	Delayed from fall 2010
	52-M	A	2/4/2011	Delayed from fall 2010
	52-D	A	2/4/2011	Delayed from fall 2010
	54-S	A	4/28/2011	Delayed from fall 2010
	54-M	A	4/28/2011	Delayed from fall 2010
	54-D	A	4/28/2011	Delayed from fall 2010
100-FR-3				
	62-M	A	2/10/2011	Delayed from fall 2010
		A	12/5/2011	missing PVC pipe
	C6302	A	9/14/2011	Delayed from fall 2010
				lower priority; sampled 9/2011
	C6303	A	9/14/2011	Delayed from fall 2010
				lower priority; sampled 9/2011
	64-S	A	2/10/2011	Field readings only; low SC; Delayed from fall 2010
		A	11/14/2011	Field readings only; low SC
	64-M	A	2/10/2011	Field readings only; low SC; Delayed from fall 2010
		A	11/14/2011	Field readings only; low SC
	64-D	A	2/10/2011	Delayed from fall 2010
		A	11/14/2011	
	C6305	A	11/16/2011	Field readings only; low SC
	C6306	A	11/16/2011	
	C6307	A	11/16/2011	
	C6308	A	11/15/2011	
	C6309	A	11/15/2011	Field readings only; low SC
	C6311	A	11/15/2011	
	C6312	A	11/15/2011	
	C6314	A	3/8/2011	Field readings only; low SC; Delayed from fall 2010
		A	11/28/2011	
	C6315	A	3/8/2011	Delayed from fall 2010
		A	11/28/2011	
	C6316	A	3/8/2011	Delayed from fall 2010
		A	11/28/2011	
	AT-F-1-S	A	3/8/2011	Field readings only; low SC; Delayed from fall 2010
		A	11/28/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	AT-F-1-M	A	3/8/2011	Field readings only; low SC; Delayed from fall 2010
		A	11/28/2011	
	AT-F-1-D	A	3/8/2011	Delayed from fall 2010
		A	11/28/2011	
	66-S	A	3/8/2011	Scheduled for field readings only; delayed from fall 2011
		A	12/2/2011	
	66-M	A	3/8/2011	Scheduled for field readings only; delayed from fall 2011
		A	12/2/2011	
	66-D	A	3/8/2011	Delayed from fall 2010
		A	12/2/2011	
	67-S	A	3/9/2011	Scheduled for field readings only; delayed from fall 2011
		A	12/2/2011	Scheduled for field readings only
	67-M	A	3/9/2011	Delayed from fall 2010
		A	12/2/2011	
	68-S	A	3/9/2011	Scheduled for field readings only; delayed from fall 2011
		A	12/2/2011	
	68-M	A	3/9/2011	Scheduled for field readings only; delayed from fall 2011
		A	12/2/2011	
	68-D	A	3/9/2011	Delayed from fall 2010
		A	12/2/2011	
	AT-F-2-M	A		
	74-D	A	12/6/2011	
	75-D	A	12/6/2011	
	76-D	A	12/6/2011	
	77-D	A	12/6/2011	
200-PO-1 (Hanford Town Site)				
	85-D	A	2/17/2011	Field readings only; low SC; Delayed from fall 2010
	86-D	A		Cap melted to tube 2/17/2011
	C6383	A		Scheduled for field readings only
	C6384	A		
	C6353	A		
	C6356	A		
	C6359	A		
	C6362	A		
	C6365	A		
	C6368	A		
	C6371	A		
	C6374	A		Scheduled for field readings only

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	C6375	A		
	C6378	A	9/28/2011	
	C6380	A		
300-FF-5				
	AT-3-1-S	A	3/25/2011	Delayed from fall 2010
		A	11/18/2011	
	AT-3-1-M	SA	3/25/2011	
		SA	11/17/2011	
	AT-3-1-D(1)	A	3/25/2011	Delayed from fall 2010
		A	11/17/2011	
	AT-3-2-S	A	3/25/2011	Field readings only; low SC; Delayed from fall 2010
		A		11/17 - SC did not stabilize; no sample
	AT-3-2-M	SA	3/25/2011	
		SA		11/17 - Field readings only; SC low
	C6341	SA	3/25/2011	
		SA	11/29/2011	
	C6342	SA	3/25/2011	
		SA	11/29/2011	
	C6343	SA	3/25/2011	
		SA	11/29/2011	
	AT-3-3-S	SA	3/25/2011	Field readings only; low SC
		SA		11/18 - Field readings only; SC low
	AT-3-3-M	SA	3/25/2011	
		SA	11/18/2011	
	AT-3-3-D	SA	4/7/2011	No yield 3/25/2011; Fixed 3/28/2011
		SA	11/18/2011	
	C6344	SA	3/25/2011	
		SA	11/21/2011	
	AT-3-4-S	SA	3/25/2011	
		SA	11/21/0211	
	AT-3-4-M	SA	4/13/2011	SC declined during sampling
		SA		Insufficient yield 11/21/2011
	AT-3-4-D	SA	3/25/2011	
		SA	11/21/0211	
	C6347	SA	3/29/2011	
		SA	11/29/2011	
	C6348	SA	3/29/2011	
		SA	11/29/2011	

Table C-2. Aquifer Tube Sampling Dates, 2011

Supp.[a]	Tube Name	Frequency[b]	2011 Sample Dates[c]	Comments
	AT-3-5-S	SA	3/29/2011	
		SA	11/30/2011	
	C6350	SA	3/29/2011	
		SA	11/30/2011	
	C6351	SA	3/29/2011	
		SA	11/30/2011	
	AT-3-6-S	SA	3/29/2011	
		SA	11/30/2011	
	AT-3-6-M	A	3/29/2011	Delayed from fall 2010
		A	11/30/2011	
	AT-3-6-D	SA	3/29/2011	
		SA	11/30/2011	
	AT-3-7-S	A	3/29/2011	Delayed from fall 2010
		A	12/1/2011	
	AT-3-7-M	SA	3/29/2011	
		SA		No yield 12/1/2011
	AT-3-7-D	SA	3/29/2011	
		SA	12/1/2011	Tube mislabeled (PVC correct)
	AT-3-8-S	SA	3/29/2011	
		SA	12/1/2011	
	AT-3-8-M	A	3/29/2011	Delayed from fall 2010
		A	12/1/2011	
	AT-3-8-D	A		Not scheduled; no yield previous years

Note: Aquifer tubes are listed in order of location, upstream to downstream. Clusters of tubes are indicated by alternating shades.

a. An x in this column indicates tubes or sampling events that are not included in the aquifer tube SAP (*Sampling and Analysis Plan for Aquifer Sampling Tubes*, DOE/RL-2000-59, Rev. 1). These include aquifer tubes installed for River Corridor remedial investigation/feasibility studies, and increased sampling frequency at the discretion of project staff.

b. Abbreviations are as follows:

A = to be sampled annually
M = to be sampled monthly
Q = to be sampled quarterly
SA = to be sampled semiannually

c. This column includes dates sampled in 2011, without regard to when the tube was scheduled to be sampled. A blank in this column means the tube was not sampled in 2011. If both date and comment are blank, it means a sampling trip was not attempted because of schedule constraints or other factors.

SC = specific conductance
PVC = polyvinyl chloride

Table C-3. Nonroutine Aquifer Tube Sampling at 100-N Apatite Barrier, 2011

Tube Name	Sample Date	Comment
N116Array-1A	9/16/2011	
	9/28/2011	
	10/13/2011	
N116Array-2A	6/27/2011	
	9/16/2011	
	9/28/2011	
	10/13/2011	
APT-1	5/2/2011	
N116Array-3A	6/27/2011	
		Unsuccessful 11/10/2011
N116Array-4A	6/27/2011	
	11/10/2011	
NVP2-116.0	6/27/2011	
	11/10/2011	
N116Array-6A	6/27/2011	
	11/10/2011	
APT-5	6/27/2011	
C7881	6/27/2011	
	9/27/2011	
	10/12/2011	
	10/27/2011	
C7882	6/27/2011	
N116Array-8A	9/27/2011	
	10/12/2011	
	10/27/2011	

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Appendix D – Quality Assurance and Quality Control

J.G. Douglas and S.L. Fitzgerald

This appendix presents 2011 quality assurance/quality control (QA/QC) information for groundwater monitoring at the Hanford Site. CH2M HILL Plateau Remediation Company (CHPRC) managed groundwater monitoring activities through the Soil and Groundwater Remediation Project. This includes monitoring performed to meet the requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA); the *Atomic Energy Act of 1954*; and the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*. The QA/QC practices used by the groundwater project assess and enhance the reliability and validity of field and laboratory measurements conducted to support these programs. Accuracy, precision, and detection limits are the primary parameters used to assess data quality (Mitchell et al., 1985, "Determination of Measurement Data Quality and Establishment of Achievable Goals for Environmental Measurements"). Representativeness, completeness, and comparability can also be evaluated for overall quality; however, representativeness and comparability are considered qualitative and do not have specific evaluation criteria in this report. These six parameters are evaluated through laboratory QC such as matrix spikes and laboratory blanks, replicate sampling and analysis, analysis of blind standards and field blanks, and inter-laboratory comparisons. Acceptance criteria have been established for each of these QC checks. When QC results are outside the criteria, groundwater analytical support staff review the data and ensure that appropriate data qualifying flags are entered in the Hanford Environmental Information System (HEIS) database. When a recurring problem is identified, corrective actions are taken.

This appendix summarizes the overall QA/QC program for the groundwater project. Through a comprehensive review of performance indicators, the groundwater project identifies and resolves issues with data quality and initiates process improvements. The annual QA/QC appendix is a tool for data users in determining usability of specific datasets for decision making purposes.

Several comparisons to 2010 performance are made throughout the appendix. Comparisons between 2010 and 2011 are provided to help indicate relative quality trends in the data.

The QA/QC practices for RCRA samples are based on guidance from the U.S. Environmental Protection Agency (EPA) *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* (SW-846). The U.S. Department of Energy (DOE) orders and internal requirements provide guidance for the collection and analysis of samples for other long-term monitoring. The QA/QC practices for the groundwater project are described in *CH2M HILL Plateau Remediation Company Quality Assurance Program Plan* (CHPRC-00189). A glossary of QA/QC terms is provided in Section D.9. Additional information about the QA/QC program and data for 2011 (results of individual QC samples or associated groundwater samples) are available upon request. Referenced data from the previous reporting period can be found in DOE/RL-2011-01, *Hanford Site Groundwater Monitoring Report for 2010.*

D.1 Sample Collection and Analysis

Tasks related to groundwater sampling included bottle preparation, sample set coordination, measurement of field parameters, sample collection, sample shipping, well pumping, and coordination of purge water containment and disposal.

The Waste Sampling and Characterization Facility (WSCF) is an onsite laboratory managed by Mission Support Alliance. The WSCF was the primary analytical laboratory supporting the groundwater project during 2011. WSCF performed 62 percent of the laboratory analyses for groundwater monitoring during the reporting period (not including field measurements; 56 percent if field measurements are included) compared to 83 percent during 2010. The smaller portion of analyses performed at WSCF during 2011 versus 2010 is largely due to a safety outage that occurred at WSCF during most of

September through December of 2011. During that period, groundwater samples were diverted from WSCF to the other laboratories listed below for analysis.

Besides WSCF, several other laboratories provided additional analytical services for the groundwater monitoring program:

- 222-S Laboratory (Hanford Site, managed by Advanced Technologies and Laboratories International, Inc.) (222-S) provided sample analysis for chemical constituents; 222-S generated less than 1 percent of the analytical results.
- Eberline Services (Richmond, California) provided sample analysis for radiochemical constituents; Eberline Services generated less than 1 percent of the analytical results.
- Lionville Laboratory (Exton, Pennsylvania) provided sample analysis for chemical constituents; Lionville Laboratory generated less than 1 percent of the analytical results.
- TestAmerica Richland (Richland, Washington) provided sample analysis for chemical and radiochemical constituents; TestAmerica Richland generated 4 percent of the analytical results.
- TestAmerica St. Louis (St. Louis, Missouri) provided sample analysis for chemical constituents; TestAmerica St. Louis generated 33 percent of the analytical results.

Standard methods from EPA, ASTM International (formerly the American Society for Testing and Materials), and *Standard Methods for the Examination of Water and Wastewater* (AWWA/APHA/WEF, 1998) were used for the analysis of chemical constituents. For radiological constituents, the analyzing laboratories developed methods that are recognized as acceptable within the radiochemical industry. Descriptions of the analytical methods used are available upon request.

D.2 Data Review and Validation

Groundwater staff review and validate groundwater data according to an established process. Validation produces an electronic dataset with suspect or erroneous data corrected or flagged. The validation process includes the following activities:

- Review of sampling documents and analytical data verification
- Project scientists' evaluations
- Resolution of data issues (Request for Data Review)

D.2.1 Sample Issue Resolution, Review of Sampling Documents, and Data Verification

Sampling documents include the groundwater sampling record, chain-of-custody forms, field logbook pages, and other paperwork associated with sampling and shipping. Groundwater staff reviews these forms to determine whether the documents are filled out completely, signed appropriately and legible, and to determine whether problems arose during sampling that may affect the data. Staff also verifies that analytical data from the laboratories are complete and reported correctly. Moreover, staff reviews laboratory documents to check the condition of the samples upon receipt at the laboratory and determine whether problems arose during analysis that may have affected the data. Identified issues are documented, investigated, and resolved (Sections D.2.3 and D.2.4).

D.2.2 Project Scientists' Evaluation

Data management staff generates routine data reports for project scientists to review. These reports include biweekly data reports for analytical data loaded into the HEIS database since the previous reporting period. The tables are organized by groundwater interest area, RCRA site, or special project (for

example, confined aquifer data). As soon as practical after receiving a report, the project scientists review the data, typically by viewing trend plots, to determine the following:

- Changes in contaminant concentrations or distribution
- Data points that appear erroneous (for example, significantly out of trend)

Project scientists also review quarterly compilations of the data. The quarterly review provides a method for groundwater staff to check for problems with sampling, to confirm all requested analyses were received, and to verify that the data represent actual groundwater quality. Unlike biweekly reports, the quarterly reports include a full dataset (that is, all data from the wells sampled during the previous quarter that have been received and loaded into the HEIS database). This review also includes water-level data, preliminary maps of selected contaminant distribution (plume maps), and a partial listing of sampling comments. When specific questions arise about field measurements, analytical results, dates of analysis or sampling, or sample or well numbers, the project scientist requests a formal data review. Section D.2.3 describes the process for data reviews.

D.2.3 Resolution of Data Issues (Request for Data Review)

Requests for data reviews are the formal mechanism used by the groundwater project to resolve specific issues with data. A single request for data review may cover multiple analytes and samples from multiple sources. When potential anomalies are encountered during a review of analytical data or water-level measurements, the groundwater project support staff or the project scientist reviewing the data will initiate a request for data review. Depending on the type of data issue identified, groundwater analytical support staff resolves the request for data review through some or all of the following actions:

- Request a laboratory recheck, recount, or re-analysis.
- Review laboratory hardcopy data.
- Review sampling documents for data entry errors or other problems.
- Flag the affected data with one of the flags described in Table D-1.

A review of the sampling documents or hardcopy data from the laboratory can sometimes provide an explanation for unusual results (for example, data entry errors or samples swapped in the field). Laboratory rechecks involve an internal laboratory review of the data. When the laboratory discovers discrepancies, the corrected data are re-reported in place of the original data. The original data are removed from the HEIS database, the corrected data are loaded into HEIS, and the data are flagged appropriately. However, when a laboratory re-analysis or recount is requested, the laboratory re-analyzes or recounts the original sample and reports the new results. If a discrepancy occurs between the original and new results, groundwater staff determines which results appear to be more representative. If the new results appear more representative, the old results are removed from HEIS and the new results loaded instead. Finally, whether the old results are retained or the new results are accepted, an appropriate review code is assigned to the reviewed results in the HEIS database to indicate that the review is complete.

Requests for data reviews are most commonly resolved by assigning G, Y, or R flags to the HEIS data. If a review determines that the result is valid, the result is flagged with a G. If clear, documented evidence exists that a result is erroneous, the result is flagged with an R. If a review was unable to determine the validity of the result, the result is considered suspect and flagged as Y. Data flagged with a Y or R is typically excluded from statistical evaluations, maps, and other interpretations, but the data are not deleted from the HEIS database. Occasionally, a request for data review is submitted on data that are not managed by the groundwater project. In those cases, the data owner is notified, but no further action is taken by the groundwater project.

Table D-2 lists the number of analytical and water-level results for groundwater monitoring samples acquired in 2011 that were flagged because of the request for data review process. As of March 5, 2012, requests for data reviews have been filed on 1,406 of 175,221 analytical results (~1 percent). Requests for data reviews of water-level measurements have been filed on 70 of 3,718 measurements (less than 2 percent). The resolution of 456 analytical requests for review is pending, and additional requests may yet be filed on data from the reporting period. There are no pending water-level measurement requests for data review. During the reporting period, WSCF analyses generated ~56 percent of the analytical results (including laboratory and field results) for groundwater monitoring. WSCF data had 79 percent of the requests for data review. The bulk of the requests for data review (57.5 percent) were filed on metals results. Requests for data review also were filed on WSCF results from wet chemistry methods (18.5 percent), organic methods (14.4 percent), and radiological methods (9.6 percent). Requests for data review to the field and other laboratories were scattered among a varied group of methods and issues. No other trends in data review requests from the field or other laboratories were identified.

D.2.4 Sample Issue Resolution

The Sample Issue Resolution (SIR) process is used to record and resolve problems encountered with sample receipt, sample analysis, missed holding times, and data reporting (for example, broken bottles or QC problems) that may adversely affect data integrity. The SIR system was expanded in April 2011 to incorporate the previously used Issue Resolution Form. For this report, the term SIR refers to the SIR process and the Issue Resolution Form process used during 2011. The laboratories or Sample Management and Reporting personnel may generate SIR requests, depending on the nature of the issue. The SIR process also allows the groundwater project to direct the laboratories to resolve problems. During 2011, 191 SIR requests concerning groundwater monitoring samples were processed.

Table D-3 indicates the specific issues identified during the reporting period. The issues included the following:

- Analysis holding times exceeded
- Chain-of-custody issues (for example, missing or incorrect dates, broken chains)
- Broken sample bottles
- Incorrect sample preservation
- Other general laboratory direction (such as clarification of requested analyses for samples diverted from one lab to another)
- QC failures (such as laboratory control sample recovery outside QC limits)
- Data package turnaround time or due date modifications

Most of the other general laboratory direction issues were generated because of the diversion of samples from WSCF to offsite laboratories during the fourth quarter of 2011. The offsite laboratories receiving these diverted samples frequently had analytical methods that differed in name from the WSCF analytical methods requested on the chains-of-custody. In those cases, SIRs were generated to translate the WSCF method name to the offsite lab method name in order that the offsite lab could perform the correct sample analysis.

SIR issues are tracked, and when adverse trends are identified, corrective actions are initiated. For example, TestAmerica Richland submitted several SIR requests about incorrect sample preservation because some sample temperatures were not at 4°C at the time of sample receipt. The issue was forwarded to the field sampling organization for resolution. The resolution was that the samples were transported to TestAmerica Richland's sample receiving area very shortly after sample collection, and the

samples had not had sufficient time to cool to 4°C before sample receipt. In those cases, the direction to TestAmerica Richland was to proceed with sample analysis as requested.

D.3 Data Completeness

Groundwater monitoring data judged to be complete are not suspect, rejected, associated with a missed holding time, an out-of-limit field duplicate, or qualified to indicate laboratory blank contamination. For this completeness determination, 140,437 groundwater monitoring results consisting of field measurements, laboratory sample results, field blank results, and blind standards results were considered. Table D-4 provides a summary of data completeness. For 2011, 96.8 percent of the groundwater data were considered complete. The percentages of potentially invalid data were 0.5 percent for suspect values, less than 0.1 percent for rejected data, 1.9 percent for field QC problems, 0.4 percent for exceeding holding times, and 0.4 percent for laboratory method blank contamination. These percentages reflect an improvement over the 2010 data completeness. For 2010, 89.5 percent of the groundwater data were considered complete, with a failure rate of 0.2 percent for suspect values, less than 0.1 percent for rejected data, 2.4 percent for field QC problems, 0.5 percent for exceeding holding times, and 7.4 percent for laboratory blank contamination.

D.4 Field Quality Control Samples

Field QC samples include three types of field blanks (full trip, field transfer, and equipment blanks), field duplicate samples, and field split samples. The glossary in Section D.9 provides definitions for these QC samples. Field QC samples are used to assess precision, repeatability, and potential contamination related to sampling and laboratory activities. The criteria for evaluating field QC samples are given in DOE/RL-91-50, *Environmental Monitoring Plan United States Department of Energy Richland Operations Office*, and are outlined in the subsections below. Those field QC results that do not meet the QC criteria are given a review qualifier of Q in the HEIS database (DOE/RL-91-50). Tables D-5 through D-7 and Tables D-9 and D-10 summarize the field QC results that exceeded QC limits. Constituents not listed in the tables had 100 percent acceptable field QC. The tables are divided into the following six categories as applicable: general chemistry parameters, ammonia and anions, metals, volatile organic compounds, semivolatile organic compounds, and radiological parameters. Table D-8 provides additional information on the method categories.

D.4.1 Field Blanks

Field blanks are used to assess potential contamination associated with sampling and laboratory activities. The percentage of acceptable field blank results evaluated during this reporting period were 98 percent (compared to 97 percent for 2010), indicating little problem with contamination. Tables D-5 through D-7 summarize the field blank QC results that exceeded QC limits.

Field blank results greater than two times the method detection limit are identified as suspected contamination. For common laboratory contaminants such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the limit is five times the method detection limit. For radiological data, blank results are identified as potentially contaminated if they are greater than two times the minimum detectable activity. Results for samples associated with field blanks that are above these criteria are flagged with a Q in the Review Qualifier field of the HEIS database to indicate potential contamination issues. For full trip and field transfer blanks, an associated sample is defined as being collected on the same day and analyzed by the same method as the corresponding full trip or field transfer blank. For equipment blanks, an associated sample is one that has the same collection date, collection method, sampling equipment, and analysis method as the equipment blank. Data users must evaluate the usability of data associated with quality issues based on the data quality objective requirements established for the specific monitoring campaign.

Of the 12,271 field blank results generated for 2011, 73 (0.6 percent) were flagged as suspect (Y-flagged) in the Review Qualifier field because of the Request for Data Review process. Because most of the Y-flagged values were attributed to well samples that had been substituted for blank samples, either in the field or at the lab, these Y-flagged results were not included in this field blank assessment. In most of these cases, uncertainty exists as to if the well samples had been substituted for the blanks in the field or in the laboratory; therefore, no attempt was made to reassign the suspect blank data to well samples.

The 2011 field blank data consisted of 12,198 results, of which 247 (2 percent) exceeded QC limits. Of the 253 general chemical parameter results, 23 results (9 percent) exceeded QC limits, including 10 alkalinity measurements and 8 total organic halide determinations. Of the 603 ammonia/anion results, 18 (3 percent) exceeded QC limits, including 5 chloride and 5 sulfide results. Of the 3,591 metals results, 84 (2 percent) exceeded QC limits, including 32 sodium, 16 magnesium, and 14 calcium results.

Of the 6,158 volatile organic compound results, 115 (2 percent) exceeded QC limits and included 103 methylene chloride results. A total of 80 methylene chloride results exceeded the drinking water standard of 5 µg/L; this result limits the usability of data with low-level detections for methylene chloride in groundwater monitoring samples.

During 2011, a study was begun to elucidate the likely source(s) of volatile organic compounds in field blanks. The study looked at field blank data and laboratory method blank data, and included observations of sample collection in the field and the volatile organic analysis of field samples at WSCF. This study resulted in the publication of a white paper that outlined possible sources of volatile organic compounds in field blanks and samples (SGW-52194, *Volatile Organic Compound Contamination in Groundwater Samples and Field Blanks*). The major results of the study were:

- Methylene chloride, and to a lesser extent carbon tetrachloride and chloroform, appear as volatile organic carbon contaminants in the field blanks associated with groundwater samples; the source of this contamination is likely the deionized water used to generate the field blanks.
- The appearance of acetone, bromomethane, carbon disulfide, chloromethane, tetrachloroethene, and toluene in laboratory method blanks indicates that these volatile organic analytes may appear as spurious contaminants in groundwater samples introduced during laboratory sample preparation and analysis.
- The vendor for the 40 mL volatile organic compound sample vials used by both Field Sampling Operations and WSCF typically certifies the vials only to 0.5 µg/L for many of the groundwater project's volatile organic compounds of interest. This means that the presence of volatile organic compounds with detected concentrations less than 0.5 µg/L in groundwater samples and blanks may not be distinguishable from sample vial background levels.

Several corrective actions resulted from field observations associated with the report. Groundwater analytical support staff continues to work with field sampling operations and the laboratories to decrease the frequency and magnitude of methylene chloride contamination.

Of the 1,050 semivolatile organic compound results, only 2 (less than 1 percent) exceeded QC limits. Of the 543 radiochemical parameter results, 5 (1 percent) exceeded QC limits, of which 3 were total beta radiostrontium (strontium-90).

For 2010, the largest percentage of out-of-limit blank results was associated with metals analysis at 4.9 percent.

D.4.2 Field Duplicate Samples

Field duplicate samples (field duplicates) are replicate samples sent to the same laboratory. Field duplicates are used to assess field sampling and laboratory measurement precision. The results of field duplicates must have precision less than or equal to 20 percent as measured by the relative percent

difference (RPD). Field duplicates with at least one result greater than five times the method detection limit or minimum detectable activity were evaluated. Field samples for total organic carbon and total organic halides are usually taken in quadruplicate. For those analytes, relative standard deviation was calculated for the results of the quadruplicate sample set and compared to the precision limit of 20 percent. The results for the primary sample and its associated field duplicate that have greater than 20 percent RPD are flagged as Q in the Review Qualifier field of the HEIS database to indicate potential precision issues. Field duplicate values with a Y in the Review Qualifier field were included in the assessment of duplicate precision.

Of the 1,191 duplicate results for 2011, 218 duplicates met the criteria to be evaluated. Of these 218 duplicates, 207 (95 percent) were acceptable, indicating reasonable field sampling and intra-laboratory precision. For comparison, the 2010 percentage of acceptable duplicate results was 93 percent, and the 2009 reporting period acceptable results percentage was 99 percent. Table D-9 presents the duplicate results that exceeded quality control limits.

The seven out-of-limit duplicates for the metals were roughly divided equally between unfiltered and filtered samples. For the unfiltered samples, suspended solids in the samples may have caused some of the discrepancies in the results.

D.4.3 Field Split Samples

Field split samples (field splits) are duplicate samples that are sent to two different laboratories to allow interlaboratory comparisons of analytical results. These interlaboratory comparisons are used to evaluate the performance of the laboratories, to determine the extent of any analytical problems, and to confirm out-of-trend results. Results from the field splits must have an RPD less than or equal to 20 percent. Only those field splits with at least one result greater than five times the method detection limit or minimum detectable activity at both laboratories were evaluated. If the laboratory reported an estimated quantitation limit instead of a method detection limit, the evaluation criterion was one times the estimated quantitation limit instead of five times the method detection limit. For total organic carbon and total organic halides, field splits frequently consisted of two groups of replicate samples; that is, multiple matching samples were submitted to each laboratory. The two sets of replicate samples were evaluated by comparing the average concentration from each laboratory.

For 2011, 391 field splits were analyzed for 110 different analytes generating 1,524 pairs of field splits data. Of the 1,524 pairs, 355 pairs met the evaluation criterion. For the evaluated field splits, 16 percent (57 pairs) exceeded the 20 percent RPD criterion. For comparison, the percentage of out-of-limit results was 22 percent for 2010 and 23 percent for the 2009 reporting period. Table D-10 summarizes the results for field splits that exceeded the 20 percent RPD limit.

The metals analyses constituted 58 percent of the split failures. Most of these failures occurred on unfiltered samples; hence, suspended solids in the samples may have caused some of the discrepancies in the results. After the metals analyses, the radiochemical parameter results accounted for 30 percent of the split sample failures, with carbon-14 and tritium constituting most of the failures. All the carbon-14 failures showed TestAmerica Richland biased low with respect to Eberline Services. TestAmerica Richland also reported carbon-14 blind standard results that were less than the lower control limit (see Section D.6.2). This likely indicates a low bias for TestAmerica Richland's carbon-14 results. For the failed tritium results, TestAmerica Richland tended to show a high bias compared to Eberline Services and WSCF. While not greater than the upper recovery limit for the tritium blind standards (see Section D.6.2), most of the tritium blind standard results reported by TestAmerica Richland had recoveries greater than 100 percent. This may indicate a slightly high bias for TestAmerica Richland's tritium results. The two nitrite split failures between TestAmerica St. Louis and WSCF are because of a possible high-nitrite bias at WSCF (see Section D.6.5.3). Groundwater project personnel will continue to monitor these issues and will initiate corrective actions as required.

D.5 Holding Times

Holding time is the time that elapses between sample collection and sample analysis. Samples are required to be analyzed within recommended holding times to minimize the possibility of changes in constituent concentrations caused by volatilization, decomposition, or other chemical or biological processes. Samples are also refrigerated to slow potential chemical reactions or biological degradation within the sample matrix. Maximum recommended holding times for constituents frequently analyzed for the groundwater project are listed in Table D-11. Results for samples with missed holding times are flagged as H in the HEIS database.

Radiological constituents do not have recommended maximum holding times because these constituents are not typically lost under ambient conditions when appropriate preservatives are used. The results of radionuclide analysis are decay-corrected from the sampling date to analysis date. As a practical matter, the laboratories are typically requested to complete radiochemical analyses within six months of sample collection.

For 2011, recommended holding times were met for more than 99 percent of nonradiological results (Table D-4); this outcome is comparable to the more than 99 percent holding time compliance observed for 2010. Holding times were exceeded for 533 nonradiological results. Missed holding times for anions, mainly nitrate/nitrite (48-hour holding time), contributed the single largest fraction of the missed holding times at 53 percent. Missed holding times were attributed to late sample delivery to the laboratories, high sample loads at the laboratories, or other laboratory issues.

D.6 Laboratory Performance

Several indicators, including national performance evaluation studies, blind standard analyses, laboratory audits, and internal laboratory QA/QC programs, measure laboratory performance. This section provides a detailed discussion of the performance indicators for TestAmerica Richland, TestAmerica St. Louis, and WSCF. Brief summaries of performance measures for Lionville Laboratory and Eberline Services are also presented in this section. At the time of this writing, performance evaluation data were not available from 222-S and will not be discussed; however, 222-S generated less than 1 percent of the analytical results for groundwater monitoring during 2011.

D.6.1 National Performance Evaluation Studies

During 2011, Environmental Resources Associates (ERA) and DOE conducted national studies to evaluate laboratory performance for chemical and radiological constituents. TestAmerica St. Louis, TestAmerica Richland, and WSCF participated in the EPA-sanctioned water pollution/supply performance evaluation (WP/WS) studies conducted by ERA. TestAmerica Richland, TestAmerica St. Louis, WSCF, and Eberline Services participated in ERA's InterLaB RadCheM Proficiency Testing Program (RAD). All five laboratories supporting the groundwater project (WSCF, TestAmerica St. Louis, TestAmerica Richland, Lionville Laboratories, and Eberline Services) took part in DOE's Mixed Analyte Performance Evaluation Program (MAPEP). The results of those studies related to groundwater monitoring at the Hanford Site are described in this section.

D.6.1.1 Water Pollution/Supply Performance Evaluation Studies

The purpose of water pollution/supply performance evaluation studies is to evaluate the performance of laboratories in analyzing selected organic and inorganic compounds in water matrices. An accredited agency, (e.g., ERA) distributes standard water samples to participating laboratories. These samples contain specific organic and inorganic analytes at concentrations unknown to the participating laboratories. After analysis, the laboratories submit results to the accredited agency, which uses regression equations to determine acceptance and warning limits for the study participants. The results of these

studies are expressed in the following section as a percentage of the results that the accredited agency found acceptable and independently verify the level of laboratory performance. If there is an unacceptable result, the laboratories may order an ERA QuiK™Response sample to verify successful corrective action. QuiK™Response samples are similar to water pollution/water supply samples, and results are reported in a comparable fashion.

For the two water pollution performance evaluation studies (ERA WP-194 and WP-198) in which WSCF participated during the reporting period, the percentage of results within the acceptance limits was 98 percent (167 results) (Table D-12). Three different constituents had unacceptable results.

For the five water pollution/supply and three QuiK™Response performance evaluation studies in which TestAmerica St. Louis participated during 2011 (ERA WP-191, WP-192, WP-198, and WS-183), the percentage of results within the acceptance limits was 99 percent (811 results) (Table D-13). Eleven different constituents had unacceptable results, none of which was repeated across studies or in more than one WP/WS study during 2011. As noted, the number of constituents reported by TestAmerica St. Louis in the water pollution studies was considerably greater than those constituents reported by WSCF; therefore, the percentages from the two laboratories are not directly comparable.

For the one water pollution performance evaluation study (ERA WP-192) in which TestAmerica Richland participated during the reporting period, the percentage of results within the acceptance limits was 100 percent (2 results). As noted, the number of constituents was very limited; therefore, the percentage of results is not comparable to that of the other two laboratories.

D.6.1.2 InterLaB RadCheM Proficiency Testing Program Studies

The purpose of the RAD Proficiency Testing Program (also conducted by ERA) is to evaluate the performance of laboratories in the analysis of selected radionuclides. This program provides blind standards that contain specific amounts of one or more radionuclides in a water matrix to participating laboratories. After sample analysis, the results are forwarded to ERA for comparison with the known values and with results from other laboratories. ERA bases its control limits on *National Standards for Water Proficiency Testing Studies, Criteria Document* (EPA NERL-Ci-0045).

During the reporting period, WSCF participated in two studies, RAD-84 and RAD-86 (Table D-12), with an acceptance percentage of 80 percent (5 results with 1 unacceptable).

TestAmerica Richland participated in three studies, RAD-84, RAD-85, and RAD- 86 (Table D-13), with an acceptance percentage of 92 percent (39 results with 3 unacceptable).

TestAmerica St. Louis participated in three studies, MRAD-15, RAD-85, and RAD-87 (Table D-13), and analyzed a total of 44 constituents with an acceptance percentage of 86 percent (6 unacceptable results).

Eberline Services participated in four studies (RAD-84, RAD-85, RAD-86, and RAD-800), and analyzed a total of 36 constituents with an acceptance percentage of 94 percent (2 unacceptable results) (Table D-14).

D.6.1.3 DOE Mixed Analyte Performance Evaluation Program

DOE's Mixed Analyte Performance Evaluation Program (MAPEP) examines laboratory performance in the analysis of soil and water samples containing metals, semivolatile organic compounds, and radionuclides. This report considers only water samples. The program is conducted at the Radiological and Environmental Sciences Laboratory in Idaho Falls, Idaho. DOE evaluates the accuracy of the MAPEP results for radiological, inorganic, and organic analytes by determining if they fall within 30 percent of the reference value. Three studies were available for all labs during the reporting period (MAPEP-10-23, MAPEP-11-24, and MAPEP-11-25). For the MAPEP-10-23 and MAPEP-11-24 studies, WSCF analyzed

radionuclides, including gross alpha/beta, inorganics, and semivolatile organics (Table D-12). Of 180 analytes, 4 had unacceptable results yielding a 98 percent acceptable result rate. The missed analytes were copper, nickel, thallium, and hexachlorobenzene. All these constituents had acceptable results in the previous studies. For the MAPEP-10-23, MAPEP-11-24, and MAPEP-11-25 studies, TestAmerica St. Louis analyzed radionuclides, including gross alpha/beta, inorganics, and semivolatile organics (Table D-13). Of 342 analytes, four had unacceptable results, resulting in 99 percent acceptable results. The missed analytes were uranium-235, acenaphthene, nickel-63, and iodine-129. Except iodine-129, which was a new constituent, all of these constituents were within limits in the preceding study.

TestAmerica Richland reported results for radionuclides, including gross alpha/beta, for the MAPEP-10-23, MAPEP-11-24, and MAPEP-11-25 studies (Table D-13). Of 58 constituents, 2 had unacceptable results, resulting in 97 percent acceptable results. The missed analytes were iron-55 and iodine-129. The iron-55 was also unacceptable in the preceding study and the iodine-129 was a new constituent.

For the MAPEP-11-25 study, Lionville Laboratory analyzed inorganics and semivolatile organics (Table D-14). Of 73 constituents, 100 percent had acceptable results. For the MAPEP-10-23, MAPEP-11-24, and MAPEP-11-25 studies, Eberline Services analyzed radionuclides, including gross alpha/beta (Table D-14). Of 58 analytes, 2 had unacceptable results yielding a 97 percent acceptable result rate.

D.6.2 Quarterly Blind Standard Evaluation

The groundwater monitoring program issues blind standards to the supporting laboratories to provide a measure of inter- and intra-laboratory precision and accuracy. These standards help groundwater staff troubleshoot analytical problems identified through data reviews and QC evaluations. The blind standards also may be used to confirm the adequacy of corrective actions to resolve analytical problems. The *Soil and Groundwater Remediation Quality Assurance Project Plan* appendix of CHPRC-00189 lists the quality requirements and control limits for the groundwater monitoring blind standards.

During the first three quarters of 2011, the groundwater project sent blind standards to Eberline Services, Lionville Laboratory, TestAmerica Richland, TestAmerica St. Louis, and WSCF. Because WSCF, the primary analytical laboratory for the groundwater project, was unable to receive samples for most of the fourth quarter of 2011, blind standards were not prepared or submitted to the laboratories for that quarter.

Blind standards were generally prepared in triplicate and submitted to the laboratories to check the accuracy and precision of analyses. For most constituents, the blind standards were prepared in a groundwater matrix from an appropriate background well to simulate actual groundwater samples. Standards for specific conductance were commercially prepared in deionized water. The blind standards were submitted to the laboratories as regular groundwater samples.

After analysis, the laboratories' results were compared with the spiked concentrations to generate percent recoveries for the results, and the percent recoveries were compared to the control limits to determine whether the data were acceptable. Out-of-limit results were reviewed for errors. In situations where several results for the same method were unacceptable, the Request for Data Review process was invoked for reanalysis of the samples (if within holding times) or for recheck of the results. Any remaining out-of-limit results were discussed with the laboratory, potential problems were investigated, and corrective actions requested when appropriate.

In summary, the evaluation of the double-blind standards for 2011 indicates that each of the participating laboratories meets or nearly meets the 80 percent acceptable results requirement for the groundwater monitoring project. Eberline Services and TestAmerica Richland acceptable results rate was 79 percent. Overall, the performance of the laboratories as measured with the blind standards stayed

roughly the same between 2011 and 2010. Eberline Services showed some improvement over 2010. Specific analytical areas at each laboratory continue to be identified for process improvements.

Tables D-15 through D-19 summarize the number and types of blind standards generated and analyzed during 2011, along with the number of unacceptable results and control limits for each constituent. Of the total for all laboratories for 2011, 84 percent of the blind sample determinations were acceptable. This percentage is comparable to the 84 percent rate for 2010 but is lower than the 87 percent rate for the 2009 reporting period.

The most notable blind standard failures for 2011 were the following:

- Lionville Laboratory failed 6 of 12 total organic carbon blind standards; the six failed determinations all failed high. For the third quarter of 2011, Lionville Laboratory failed all four replicate total organic carbon blind standards with recoveries greater than 250 percent. TestAmerica St. Louis and WSCF also returned results for the total organic carbon blind standards during 2011: TestAmerica St. Louis failed 2 of 12 determinations and WSCF failed 3 of 12 determinations. WSCF will continue to be the primary laboratory for total organic carbon determinations, and TestAmerica St. Louis will be the backup laboratory.
- Eberline Services failed all six of its total-uranium blind standards; the triplicate samples sent first quarter 2011 all failed high, and the triplicate samples sent third quarter 2011 all failed low. Eberline Services used a kinetic phosphorescence method for these determinations. TestAmerica Richland and WSCF had acceptable recoveries for these same uranium blind standards. For their uranium determinations, TestAmerica Richland also used kinetic phosphorescence while WSCF used inductively coupled plasma – mass spectrometry.
- TestAmerica St. Louis reported a number of metals values with percent recoveries that fell outside blind standard recovery criteria. The TestAmerica St. Louis metal results were determined by inductively coupled plasma – atomic emission spectroscopy or by inductively coupled plasma – mass spectrometry. The failures included the following:
    - Boron by inductively coupled plasma – mass spectrometry (three of three failed high)
    - Magnesium by inductively coupled plasma – atomic emission spectroscopy (two of three failed high)
    - Potassium by inductively coupled plasma – atomic emission spectroscopy (three of three failed, one high, and two low). WSCF reported potassium values by inductively coupled plasma – atomic emission spectroscopy with percent recoveries that exceeded blind-standard acceptance criteria (three of three failed high)
    - Thallium by inductively coupled plasma – mass spectrometry (three of three failed high)
    - Zinc by inductively coupled plasma – atomic emission spectroscopy (six of six failed high). Lionville Laboratory and WSCF had acceptable recoveries for all zinc values they reported.
- TestAmerica St. Louis and WSCF continued to report low recoveries for the volatile organic compound blind standards. This trend has been observed historically for this analysis and has been attributed in part to volatile losses of the volatile organic compounds from those blind standards during standards make-up and sample handling. TestAmerica St. Louis and WSCF reported identical overall volatile organic compound blind standard success rates of 53 percent for 2011; for 2010, the two laboratories both reported 78 percent success rates.

- TestAmerica Richland failed all nine of its carbon-14 blind standards. All nine failures had recoveries less than 50 percent. Eberline Services passed all nine of its carbon-14 determinations within acceptance criteria.
- Eberline Services, TestAmerica Richland, and WSCF all reported gross alpha results with failure rates during 2011. Eberline Services reported four of nine results with recoveries outside acceptance criteria (two high and two low). TestAmerica Richland reported six of nine results with recoveries outside acceptance criteria (all six low). WSCF reported seven of nine results with recoveries outside acceptance limits (all seven low).

Groundwater project personnel will continue to monitor identified failures and will initiate corrective actions as required.

The blind standards program also revealed some notable improvements in 2011 over 2010:

- For the total organic halides blind standards, WSCF reported an 86 percent acceptance rate. For 2010, WSCF reported a 62 percent acceptance rate. TestAmerica St. Louis had comparable acceptance rates for both years: 90 percent for 2011 and 100 percent for 2010.
- For hexavalent chromium, TestAmerica Richland showed an improvement in the acceptance rate of blind standard results in 2011 over 2010: 100 percent for 2011 and 71 percent for 2010. This may be attributed to a TestAmerica Richland procedural change that requires dilution and reanalysis of samples with initially determined hexavalent chromium concentrations greater than 1,000 µg/L. Samples with concentrations greater than 1,000 µg/L appear to exceed the linear calibration range of the TestAmerica Richland hexavalent chromium method. Hence, diluting and reanalyzing the sample brings the sample concentration within the linear range of the method and provides more accurate results.
- For iodine-129, Eberline Services showed an improved acceptance rate in 2011 over 2010: 78 percent for 2011 and 33 percent for 2010. TestAmerica Richland had an acceptance rate of 83 percent for 2011 and 100 percent for 2010. TestAmerica Richland will remain the primary laboratory for the determination of iodine-129, especially for low-level determinations.

D.6.3 Laboratory Internal Quality Assurance/Quality Control Programs

This section provides a brief assessment of the laboratory QC data for 2011. The 222-S Laboratory, Eberline Services, Lionville Laboratory, TestAmerica Richland, TestAmerica St. Louis, and WSCF maintain internal QA/QC programs to monitor the laboratory's analytical performance. As part of their QA/QC programs, each laboratory analyzes a variety of QC samples in the same batch as customer samples. These QC samples may consist of method blanks, laboratory control samples, matrix spikes and matrix spike duplicates, sample duplicates, and surrogates (see Section D.9 for definitions of these terms). When the laboratories detect failures in these QC samples, the laboratories apply a laboratory QC flag to the data as noted in the remainder of this section.

Laboratory QC data are not used for groundwater monitoring validation of individual sample results unless the laboratory is experiencing unusual performance problems with an analytical method. All the laboratories supporting the groundwater monitoring project except Lionville Laboratory submit their laboratory QC data electronically. Only those QC data electronically available are reported here; hence, the Lionville QC data are not considered in this report.

Data from laboratory QC samples were evaluated against the acceptance limits for each type of QC sample (CHPRC-00189); the acceptance limits are stated in Tables D-22 through D-43. These evaluations provide a means to assess laboratory performance and the suitability of a method for a particular sample matrix. Laboratory QC samples provide three different types of information regarding the analytical process:

- Laboratory method blanks provide a measure of the cleanliness of the analytical process. The appearance of measurable analytes in the method blank may indicate contamination of customer samples during sample preparation and analysis.
- Laboratory control samples, matrix spike samples, and surrogates provide a measure of the accuracy of the analytical process. Percent recovery is the metric used to determine analytical accuracy. Percent recoveries consistently less than or greater than 100 percent may indicate a bias in the analytical process.
- Laboratory control sample duplicates, matrix spike duplicates, sample duplicates, and surrogate duplicates provide a measure of the reproducibility of the analytical process. Relative percent difference is the metric used to determine reproducibility.

Approximately 99 percent of the laboratory QC results for 2011 were within the acceptance limits and is similar to the 98 percent reported in the 2010 and 2009 annual reports. This percentage indicates that the analyses were in control and reliable data were generated. Table D-20 summarizes the laboratory QC data for 222-S Laboratory, Eberline Services, TestAmerica Richland, TestAmerica St. Louis, and WSCF. Table D-21 summarizes the laboratory QC data by analyte category. Additional details are presented by individual laboratory and QC sample type in Tables D-22 through D-43. Constituents not listed in these tables did not exceed the QC limits.

D.6.3.1 Laboratory Method Blanks

Evaluation of results for method blanks was based on the frequency of detection above the blank QC limits. Except as noted, these limits are two times the method detection limit for chemical constituents and two times the sample-specific minimum detectable activity for radiochemistry parameters. For common laboratory contaminants such as 2-butanone, acetone, methylene chloride, phthalate esters, and toluene, the QC limit is five times the method detection limit. Results associated with out-of-limit blank results are flagged in the laboratory qualifier field in the HEIS database. For inorganic analytes (including the indicator analytes total organic carbon and total organic halides), results associated with an out-of-limit blank are flagged with a C. For organic analytes, results associated with an out-of-limit blank are flagged with a B.

Tables D-22 through D-26 summarize the method blank results for 2011. Overall, 99.5 percent of the results were acceptable; this is similar to that reported in 2010. The method blank results may be summarized by analyte category as follows:

- General chemical parameters had the largest method blank percentage out of limits at 5.1 percent. Most of these failures were traceable to the total organic halides results from TestAmerica St. Louis; the laboratory recognized this issue and took corrective actions to resolve the problem.
- Ammonia/anions had a method-blank failure rate of 0.8 percent. Most of these failures were traceable to the TestAmerica St. Louis laboratory with cyanide, nitrogen-in-ammonia, and sulfide determinations having the highest failure rates.
- Metals had the second greatest percentage of method blank results outside the QC limits at 0.9 percent; this is similar to the 1.1 percent reported for 2010.
- Volatile organic compounds had a blank failure rate of 0.1 percent with method blank results exceeding QC limits for three volatile organic compounds: acetone, methylene chloride, and tetrachloroethene. TestAmerica St. Louis and WSCF reported QC data for volatile organic compounds. TestAmerica St. Louis reported all the volatile organic compound method blank failures; however, the method detection limits that TestAmerica St. Louis reported were typically an order of magnitude lower than those for WSCF. Acetone and methylene chloride

are common laboratory contaminants, and low-level detections of these analytes in Hanford Site groundwater samples may be considered suspect.

- Semivolatile organic compounds had a blank failure rate of 0.1 percent with method blank results exceeding QC limits for three semivolatile organic compounds: acenaphthylene, bis(2-ethylhexyl) phthalate, and hexachlorophene. TestAmerica St. Louis and WSCF reported QC data for semivolatile organic compounds. As with the volatile organic compounds, TestAmerica St. Louis reported all the semivolatile organic compound method blank failures. Again, the method detection limits that TestAmerica St. Louis reported were typically an order of magnitude lower than those for WSCF were.
- Radiochemical parameters had a blank failure rate of 0.5 percent. TestAmerica Richland and WSCF reported method blank results for radiochemical parameters. Of the radiochemical parameter blank failures, 42 percent were attributed to five total beta radiostrontium (strontium-90) blank failures at WSCF.

D.6.3.2 Laboratory Control Samples and Laboratory Control Sample Duplicates

Tables D-27 through D-31 summarize the laboratory control sample and laboratory control sample duplicate results for 2011. Overall, 99 percent of the laboratory control sample percent recoveries were acceptable and 98 percent of the laboratory control sample duplicate relative percent differences were acceptable. The laboratory control sample recoveries give a measure of the accuracy of an analytical result, and the duplicate relative percent difference gives a measure of the repeatability of the analytical result. Laboratories may apply a laboratory QC flag of X and an accompanying explanatory note when laboratory control sample recoveries or laboratory control sample duplicate relative percent differences are outside QC limits. Laboratory control sample duplicate results were available primarily for volatile and semivolatile organic compounds.

The laboratory control sample results may be summarized by analyte category as follows:

- General chemical parameters, ammonia/anions, and radiochemical parameters had no laboratory control sample QC failures.
- Metals had a laboratory control sample QC failure rate of 0.1 percent; all seven of the QC failures failed high. These QC failures were nearly evenly distributed among beryllium, boron, mercury, potassium, and sodium.
- The volatile organic compounds had a laboratory control sample QC failure rate of 1 percent. Of these QC failures, 5 percent failed low and 95 percent failed high. Of the two laboratories reporting these QC data electronically, TestAmerica St. Louis had a failure rate of 1.5 percent and WSCF reporting no failures. The failures were distributed over 31 compounds with acrolein having the highest failure rate at 19.5 percent.
- The semivolatile organic compounds had the largest percentage of laboratory control sample QC failures at 3.9 percent. Of these QC failures, 27 percent failed low and 73 percent failed high. Of the two laboratories reporting these QC data electronically, TestAmerica St. Louis had a failure rate of 4.2 percent and WSCF's failure rate was 1.4 percent. The failures were distributed over 56 compounds; 4-chloroanaline had the highest failure rate at WSCF with 100 percent failures on three samples. The next highest failure rate was 70 percent for 10 determinations of delta-BHC at TestAmerica St. Louis.

Most of the unacceptable results were associated with high recoveries. This may suggest that some of the associated groundwater results may be biased high. Matrix spikes (Section D.6.3.3) and surrogates (Section D.6.3.5) also showed high recoveries.

The laboratory control sample duplicate relative percent differences were available primarily for volatile and semivolatile organic compounds. These QC results may be summarized as follows:

- For the volatile organic compounds, 2 percent of the laboratory control sample relative percent differences exceeded QC limits. The out-of-limit results were associated with 1,4-dioxane (31.9 percent failure rate), acetone (25 percent failure rate), and 1-butanol (12.5 percent failure rate) at TestAmerica St. Louis. The WSCF laboratory did not report any laboratory control sample duplicate data for volatile organic compounds.
- For the semivolatile organic compounds, 1.9 percent of the laboratory control sample relative percent differences exceeded QC limits. The out-of-limit results were associated with two acenaphthylene laboratory control sample duplicates at TestAmerica St. Louis. WSCF did not report any out-of-limits laboratory control sample duplicate data.

D.6.3.3 Matrix Spikes and Matrix Spike Duplicates

Tables D-32 through D-36 summarize the matrix spike and matrix spike duplicate results for 2011. Only those samples that were spiked at a level at least one-fourth of the original sample concentration were included in the evaluation. Approximately 98.5 percent of the results were acceptable, similar to the 99 percent acceptance rates for 2010 and 2009. For matrix spike/matrix spike duplicate recovery failures, the laboratories apply a laboratory QC flag of N for non-gas chromatography – mass spectrometry methods, and a flag of T for gas chromatography – mass spectrometry methods.

The matrix spike recovery results may be summarized by analyte category as follows:

- General chemical parameters had the second highest matrix spike recovery failure rate at 2 percent; 82 percent of the spikes failed high and 18 percent failed low. Five of the nine high failures were from alkalinity determinations at TestAmerica St. Louis. The remaining high failures were two each for total organic carbon and total organic halide determinations at WSCF.
- The ammonia/anions category had 36 matrix spikes out with a failure rate of 0.8 percent. Of the out-of-limit matrix spikes, 19 percent failed high and 81 percent failed low. TestAmerica St. Louis had four out-of-limits matrix spikes for a failure rate of 1.1 percent. WSCF had 32 out-of-limits matrix spikes for a failure rate of 0.8 percent. Most of the WSCF matrix spike failures were from chloride determinations (91 percent failed low) and sulfate determinations (88 percent failed low).
- Metals had the lowest matrix spike failure rate at 0.7 percent; 62 percent of the failures failed high and 38 percent failed low. The metals most affected by these out-of-limits matrix spikes were calcium at TestAmerica St. Louis and potassium at WSCF. Of the calcium matrix spike failures at TestAmerica St. Louis, 62 percent failed high. Of the potassium failures at WSCF, 80 percent failed high.
- Volatile organic compounds had a matrix spike failure rate of 1.6 percent with 69 percent of the failures high and 31 percent low. TestAmerica St. Louis reported all the matrix spike failures. Of these, acrolein had 18 failed matrix spike recoveries; 94 percent of the failed recoveries failed high.
- The semivolatile organic compounds had the highest matrix spike failure rate at 3.6 percent. Of the failures, 63 percent failed high and 37 percent failed low. At TestAmerica St. Louis, the matrix spike recovery failure rate for individual semivolatile compounds ranged from 1.2 to 35 percent with pesticides having the highest out-of-limits rates. At WSCF, the overall matrix spike failure rate was 3.1 percent; this is much improved over the 20.1 percent failure rate reported in 2010. The semivolatile organic compound matrix spike out-of-limits rate at

WSCF ranged from 3.8 to 13 percent with the highest failure rate for petroleum hydrocarbons – diesel range.

- Only four radiochemical parameter matrix spikes were reported out of limits. Eberline Services reported one tritium matrix spike low, and TestAmerica Richland reported three technetium-99 matrix spikes outside QC limits, with one high and two low.

The matrix spike duplicate relative percent difference results were available for all the analytical categories except for the radiochemical parameters. Three of the categories, general chemical parameters, ammonia/anions, and metals, had negligible failure rates. Observations for the matrix spike duplicate failures for the volatile organic compounds and semivolatile organic compounds may be summarized as follows:

- The volatile organic compounds had a matrix spike duplicate failure rate of 3.9 percent. For TestAmerica St. Louis, the compounds with the greatest failure rates were primarily polar species such as cyclohexanone, 1,4-dioxane, diethyl ether, and so forth. These failures are almost undoubtedly caused by the greater solubility of these compounds in water, thus making them more difficult to volatilize from an aqueous matrix than non-polar compounds. In addition, these failures are likely caused by the tendency for these compounds to stick to any active polar sites during chromatography. WSCF did not report any matrix spike duplicate failures for the volatile organic compounds.
- The semivolatile organic compounds had a matrix spike duplicate failure rate of 3.2 percent. For TestAmerica St. Louis, the compounds with the greatest failure rate were Endrin aldehyde, 2,4-dinitrophenol, 3,3'-dichlorobenzidine, and total petroleum hydrocarbons – diesel range. Again, WSCF did not report any matrix spike duplicate failures for the semivolatile organic compounds.

D.6.3.4 Laboratory Sample Duplicates

For laboratory sample duplicates, only those sample results with values five times greater than the method detection limit or the minimum detectable activity, or one times the estimated quantitation limit were considered. Quantifiable sample duplicates were evaluated by comparing the relative percent difference with an acceptable relative percent difference maximum for each constituent. Laboratories may apply a laboratory QC flag of X and an accompanying explanatory note when laboratory sample duplicate relative percent differences are outside QC limits. The failure rate over all sample duplicates was less than 1 percent, which demonstrates good analytical reproducibility. TestAmerica St. Louis delivered the largest failure rate for laboratory sample duplicates at 2.9 percent. Tables D-37 through D-41 list the constituents by laboratory that exceeded the relative percent difference limits. Sample duplicate data were not available for semivolatile organic compounds and sample duplicate failures were negligible for the metals and volatile organic compounds. The following are observations for the categories of general chemical parameters, ammonia/anions, and radiochemical parameters:

- For the general chemistry parameters, TestAmerica St. Louis had three total organic halide sample duplicates that exceeded the relative percent difference criterion.
- For ammonia/anions, TestAmerica St. Louis reported a 20 percent failure rate for sulfide sample duplicates. Other analytes with higher failure rates were fluoride (TestAmerica St. Louis, 4.2 percent failure rate) and nitrogen in ammonia (WSCF, 6.3 percent failure rate).
- For the radiochemical parameters, TestAmerica Richland had an overall sample duplicate failure rate of 1 percent; see Table D-39 for the breakdown by radionuclide. WSCF had an overall failure rate of 1.6 percent; see Table D-41.

D.6.3.5 Surrogates and Surrogate Duplicates

Surrogate and surrogate duplicate data were available only for the volatile organic compounds and semivolatile organic compounds from TestAmerica St. Louis and WSCF. Laboratories may apply a laboratory QC flag of X and an accompanying explanatory note when laboratory surrogate/surrogate duplicate percent recoveries or relative percent differences are outside QC limits. Tables D-42 and D-43 list the constituents by laboratory that exceeded the QC criteria for surrogates and surrogate duplicates. For TestAmerica St. Louis, 96.5 percent of the surrogate recovery data were within QC acceptance limits compared to 98 percent reported for 2010. For WSCF, 98.7 percent of the surrogate recovery data were within QC acceptance limits compared to 97 percent for 2010. By category, 1.5 percent of the volatile organic compound surrogate recoveries were outside QC acceptance limits and was attributed to TestAmerica St. Louis. WSCF did not report any surrogate recovery failures for volatile organic compounds. Of the out-of-limit recoveries, 91.5 percent were greater than the upper recovery limit. For the semivolatile organic compounds, 4.4 percent of the surrogate recoveries were outside QC limits. Of the failed semivolatile organic compound surrogate recoveries, 52 percent failed high. TestAmerica St. Louis had a failure rate of 3.7 percent for semivolatile organic compound surrogate recoveries, and WSCF had a failure rate of 7.1 percent.

For the surrogate duplicate data, both TestAmerica St. Louis and WSCF had ~98 percent of the surrogate duplicate relative percent differences within QC acceptance limits. By category, 0.7 percent of the volatile organic compound surrogate duplicate relative percent differences was outside QC acceptance limits. Most of these surrogate duplicate failures was attributed to TestAmerica St. Louis, which had a 1.1 percent failure rate; WSCF had a 0.2 percent failure rate. For the semivolatile organic compound surrogate duplicates, 96.2 percent of the duplicate relative percent differences were within QC acceptance limits. Most of the failures were attributed to WSCF with an 8.3 percent failure rate; TestAmerica St. Louis had a 2.8 percent failure rate.

D.6.4 Laboratory/Field Audits, Assessments, and Surveillances

Laboratory and field activities were regularly evaluated by audits, assessments, and surveillances to ensure that quality problems are identified and corrected. Evaluation of laboratory and analytical activities is performed by various oversight organizations, with each using slightly differing criteria and terminology.

During 2011, five formal reviews (audits and/or assessments) were conducted on laboratories that routinely analyzed Hanford Site groundwater samples. These formal reviews included four audits performed on commercial laboratories by the DOE Consolidated Audit Program. In addition to the formal reviews, 13 surveillances were performed on sampling, well construction, and analytical data verification activities. Corrective actions were initiated for all findings associated with surveillances, and process improvements were evaluated.

D.6.4.1 DOE Consolidated Audit Program Audits

The goal of the DOE Consolidated Audit Program is to design and implement a program to consolidate site audits of commercial and DOE environmental laboratories providing services to DOE Environmental Management. To support this goal, audits were performed on four commercial laboratories. Audit objectives of the DOE Consolidated Audit Program were to assess the ability of the laboratories to produce data of acceptable and documented quality through analytical operations that follow approved and technically sound methods, and the handling of DOE samples and associated waste in a manner that protects human health and the environment. The DOE Consolidated Audit Program audits were performed at the following laboratories:

- TestAmerica St. Louis, Earth City, Missouri, March 22-24, 2011 (110324-TAS)

- Eberline Services, Richmond, California, March 1-3, 2011 (110303-ESR)
- Lionville Laboratory, Inc, Lionville, Pennsylvania, May 3-5, 2011 (110505-LLI)
- TestAmerica Richland, Richland, Washington, June 14-16, 2011 (110616-TAR)

The scope of the DOE Consolidated Audit Program assessment included the following specific functional areas:

- QA management systems and general laboratory practices
- Data quality for organic analyses
- Data quality for inorganic and wet chemistry analyses
- Data quality for radiochemistry analyses
- Laboratory information management systems/electronic data management
- Hazardous and radioactive materials management
- Verification of corrective action implementation from previous audit findings

A total of 28 new findings, 10 open findings from previous audits, and 26 observations resulted from the four DOE audits. All corrective actions have been accepted, and verification of the corrective actions will be performed in future audits. The DOE Consolidated Audit Program has recommended all of the laboratories for continuation to provide analytical services for samples generated at DOE sites.

D.6.4.2 Integrated Contractor Audit Team

The goal of the Integrated Contractor Audit Team (ICAT) audit program is to use resources from the multiple Hanford contractors to ensure that onsite laboratories supporting the Hanford Site are meeting DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Documents (HASQARD)*. To this end, an ICAT audit was performed at WSCF from July 11 to 15, 2011 (MSA-AVS-11-23).

The scope of the ICAT assessment included the functional areas of the laboratory governed by volumes one and two of the HASQARD. The audit team identified a total of nine findings and eleven observations. All corrective actions have been accepted and verification of the corrective actions will be performed in future audits.

D.6.4.3 Groundwater Project Surveillance

Groundwater project QA personnel performed nineteen groundwater project surveillances on various field sampling, well construction, and data management verification activities during 2011. Surveillances identified a total of two findings and nine opportunities for improvement. A list of the surveillances performed is provided below:

- Groundwater Project surveillances on field sampling activities:
  - *Chemical Analysis of Water Samples at the Pump and Treat Facilities*, September 1 to September 22, 2011 (SGRP-2011-SURV-9565)
  - *QA Verification of Installed Depths of 7 New 100-HX Extraction Wells Pumps and Transducers*, May 17 to May 23 and June 21, 2011 (SGRP-2011-SURV-10620)
  - *QA Verification of Installed Depths of 3 New 100-DX Extraction Wells Pumps and Transducers*, May 18, 2011 (SGRP-2011-SURV-10619, Rev. 1)
  - *SGRP Sample Storage Units*, March 2011 (SGRP-2011-SURV-9564)

  - *QA Verification of Installed Depths of 24 New 100-HX Extraction Wells Pumps and Transducers*, February 2011 to May 2011 (SGRP-2011-SURV-10592)
  - *QA Verification of Installed Depths of 3 New 100-DX Extraction Wells Pumps and Transducers*, February 2011 to May 2011 (SGRP-2011-SURV-10591, Rev. 1)
  - *Chemical Analyses of Water Samples at the Pump and Treat Facilities*, September 1 to September 22, 2011 (SGRP-2011-SURV-9565)
- Groundwater Project surveillance on well construction activity:
  - *Final Acceptance of Three Groundwater Wells in the 100-FR-3 OU*, December 2010 to January 2011 (QA-SGRP-SURV-11-016)
  - *Special Inspection Implementation at the 200 West Pump-and-Treat*, February 22 to February 28, 2011 (SGRP-2011-SURV-9551)
  - *Final Acceptance of 11 Pump-and-Treat Wells in the 200-ZP-1 Operable Unit*, September 2010 to March 2011 (SGRP-2011-SURV-10521)
  - *Final Acceptance of 16 Groundwater RI/FS Wells in the 100-HR-3 Operable Unit*, May 2010 to June 2011 (SGRP-2011-SURV-10664)
  - *Final Acceptance of 6 Groundwater RI/FS Wells in the 100-BC-5 Operable Unit*, December 2010 through July 2011 (SGRP-2011-SURV-10604)
  - *Well Maintenance* June 1 to June 6, 2011 (SGRP-2011-SURV-9558)
  - *Final Acceptance of 13 Groundwater Monitoring Wells in the 100-KR-4 Operable Unit*, November 18, 2010 to June 9, 2011 (SGRP-2011-SURV-10607)
  - *Final Acceptance of 4 IRFC Wells in the 300-FF-5 Operable Unit*, March 2011 to June 2011 (SGRP-2011-SURV-10643)
  - *Final Acceptance of 2 Groundwater Supply Wells in the 300-FF-2 Operable Unit*, November 2010 to May 2011 (SGRP-2011-SURV-10642, Rev. 1)
- Groundwater Project surveillances on data management and verification activities:
  - *QA Surveillance of Well Maintenance Activities*, December 01 to December 08, 2011 (SGRP-2012-SURV-10845)
  - *Data Verification*, June 20 to June 27, 2011 (SGRP-2011-SURV-9552)
  - *Chain of Custody Documentation*, March 29, 2011 (SGRP-2011-SURV-9545)

D.6.5 Analytical Method Issues

This section outlines three analytical issues that were identified during 2011: zinc contamination at WSCF, a positive bias in low-level strontium-90 at WSCF resulting in multiple false positives, and many low-level positive detections for nitrite occurring at WSCF.

D.6.5.1 Zinc Contamination

In May 2011, a high bias for zinc was identified in data reported by WSCF. The zinc results were determined using EPA method 6010 (inductively coupled plasma – atomic emission spectroscopy). The bias was caused by zinc contamination found in a filtration system the lab had recently begun using. The contamination issue was not immediately recognized by the laboratory because method blanks were not being filtered, as were customer samples. The date range of the affected zinc data was January 31 through April 14, 2011. In most cases, the affected data were rerun and re-reported by the laboratory, or reported by EPA method 200.8 (inductively coupled plasma – mass spectrometry) when data were available. In cases where samples were not available for rerun, the data were R-flagged as unusable.

Because of this issue, the laboratory put corrective actions in place to ensure that analytical batch QC samples are run through all the same preparation steps as customer samples.

D.6.5.2 Positive Bias in Low-Level Strontium-90 Results

During 2011, groundwater project scientists noticed an elevated number of false positive strontium-90 results reported by the WSCF lab at or near the minimum detectable activity. Upon notification, WSCF investigated this issue and determined that method changes to meet more rapid turnaround requests were the source of the false positives. The method changes included decreased sample size, shorter in-growth times, and shorter count times. These changes increased the associated uncertainty in the strontium-90 measurement and effectively increased the minimum detectable activity for strontium-90. The increase in the minimum detectable activity resulted in the false positives because WSCF was still reporting to the minimum detectable activity associated with the original method before the method changes. At the end of the 2011, WSCF returned to their original strontium-90 analytical method. Where possible, the identified false positive samples were rerun and the resulting non-detects were reported. For those samples that could not be rerun and where historical data supported it, the strontium-90 data were flagged as suspect.

WSCF recently eliminated another source of uncertainty in the strontium-90 determination by switching from a strontium-85 tracer to a gravimetrically measured cold-strontium carrier to determine strontium recovery. Initial results indicate that this method change will further reduce the number of strontium-90 false positive results.

D.6.5.3 Low-Level Detections for Nitrite

In August 2011, groundwater project scientists began noting a trend of low-level nitrite detected results from WSCF for a number of wells in which nitrite had historically not been detected. These nitrite results were generated in conjunction with other anion results using ion chromatography. Most of these low-level results were just above the method detection limit for nitrite. Further investigation indicated that this trend began in early June 2011. The laboratory was notified and began investigating the issue. WSCF personnel have proposed that when high chloride concentrations are present, nitrite elutes on an elevated baseline produced by the tail of the chloride peak; this chloride peak tailing effect artificially inflates the area of the nitrite peak and results in an overestimate of the nitrite concentration. WSCF personnel have also proposed that recent improvements in ion chromatography instrumentation now allow lower levels of nitrite to be detected and quantitated in Hanford Site groundwater where previously nitrite could not be detected with older, less capable instrumentation.

Working with the instrument manufacturer, the lab has recently implemented a new nitrite peak integration protocol that seems to produce more accurate nitrite concentrations. The application of the new integration protocol to the out-of-trend nitrite data is being evaluated.

D.7 Limit of Detection, Limit of Quantitation, and Method Detection Limit

Detection and quantitation limits are essential for evaluating data quality and usefulness because they provide the limits of a method's measurement. The limit of detection is the lower limit at which a measurement can be differentiated from background. The limit of quantitation is the lower limit at which a measurement becomes quantifiably meaningful. The limit of detection, limit of quantitation, and method detection limit are all useful for evaluating groundwater data.

The limit of detection is defined as the lowest concentration level statistically different from a blank (Currie, 1988, *Detection in Analytical Chemistry: Importance, Theory, and Practice*). The concentration at which an analyte can be detected depends on the variability of the blank response.

In general, the limit of detection is calculated as the mean concentration in the blank plus three standard deviations of that concentration (EPA/540/P-87/001, *A Compendium of Superfund Field Operations Methods*). The blank-corrected limit of detection is simply three times the blank standard deviation. At three standard deviations from the blank mean, the false-positive and the false-negative error rates are each ~7 percent (Miller and Miller, 1988, *Statistics for Analytical Chemistry*). A false-positive error is an instance when an analyte is declared present but is absent; a false-negative error is an instance when an analyte is declared absent but is present.

The limit of detection for a radionuclide is typically computed from the counting error associated with each reported result (EPA 520/1-80-012, *Upgrading Environmental Radiation Data*). The limit represents instrumental or background conditions at the time of analysis. In contrast, the limit of detection and limit of quantitation for the radionuclides shown in Table D-44 for the TestAmerica Laboratories and Table D-45 for WSCF are based on variabilities that result from counting errors and uncertainties introduced by sample handling. In the latter case, distilled water (submitted as a sample) is processed as if it were an actual sample. Thus, any random cross-contamination of the blank during sample processing will be included in the overall error. The values shown in Tables D-44 and D-45 are most useful to assess long-term variability in the overall measurement process.

The limit of quantitation is defined as the level above which quantitative results may be obtained with a specified degree of confidence (Keith, 1991, *Environmental Sampling and Analysis: A Practical Guide*). The limit of quantitation is calculated as the blank mean plus 10 standard deviations of the blank (EPA/540/P-87/001). The blank-corrected limit of quantitation is simply 10 times the blank standard deviation. The limit of quantitation is most useful for defining the lower limit of the useful range of concentration measurement technology. When the analyte signal is 10 times larger than the standard deviation of the blank measurements, there is a 95 percent probability that the true concentration of the analyte is within 25 percent of the measured concentration.

The method detection limit is defined as the minimum concentration of a substance that can be measured and reported with a 99 percent confidence that the analyte concentration is greater than zero. The method detection limit is determined from analysis of a sample in a given matrix containing the analyte (Currie, 1988). The method detection limit is 3.14 times the standard deviation of the results of seven replicates of a low-level standard. Note that the method detection limit, as defined above, is based on the variability of the response of low-level standards rather than on the variability of the blank response. This is the reporting limit most commonly provided from the analytical laboratories with groundwater data (that is, the reporting limit in the HEIS database).

For this report, uncensored data for total organic carbon, total organic halides, and radionuclides are available from field blanks for calculating limits of detection and limits of quantitation. Uncensored blank data are those actual concentration values produced by the method for a blank sample, as opposed to reporting method detection limits when measured concentration values are less than the method detection limits. Uncensored field blank data for total organic carbon and total organic halides are available from laboratory bench sheets. These bench sheets are requested quarterly from the participating laboratories. Uncensored field blank data for the radiological species are available directly from HEIS. The use of field blanks to calculate the limit of detection and the limit of quantitation is preferred over the use of laboratory blanks because field blanks include error contributions from sample preparation and handling, in addition to analytical uncertainties. Methods to calculate the limit of detection and the limit of quantitation are described in detail in Appendix A of DOE/RL-91-03, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site for 1990.*

Because of the lack of uncensored blank data for other constituents reported to the groundwater monitoring project, approximate limit-of-detection and limit-of-quantitation values were derived from laboratory-reported method detection limits. These method detection limits were assumed to have been generated using low-level standards. When low-level standards are used, the variability of the difference

between the sample and blank response is increased by a factor of $2^{0.5}$ (Currie, 1988). The method detection limit, limit of detection, and limit of quantitation were calculated as follows:

$$MDL = 3.14 * s$$

$$LOD = 3(2^{0.5} * s) = 4.24 * s$$

$$LOQ = 10(2^{0.5} * s) = 14.14 * s$$

Where:

MDL = method detection limit

s = standard deviation from the seven replicates of the low-level standard

LOD = level of detection

LOQ = level of quantitation

The results of limit of detection, limit of quantitation, and method detection limit calculations for total organic carbon, total organic halides, and the radiological constituents, are provided in Table D-44 for the TestAmerica Laboratories and Table D-45 for WSCF. The same information for most nonradiological constituents of concern (other than total organic carbon and total organic halides) is listed in Tables D-46 and D-47. The values in Table D-46 apply to TestAmerica Richland and TestAmerica St. Louis and the values in Table D-47 apply to WSCF.

D.8 Conclusions

Overall, assessments of QA/QC information from the reporting period indicate that groundwater monitoring data are reliable and defensible. Little contamination or other sampling-related problems were encountered that affected data integrity. Likewise, laboratory performance was good in most respects, based on the large percentages of acceptable field and laboratory QC results. Laboratory audits and generally acceptable results in nationally based performance evaluation studies also demonstrated acceptable laboratory performance for the groundwater project. However, the following areas of concern were identified and should be considered when interpreting groundwater monitoring results from the current reporting period.

A few QC samples were probably swapped in the field or at the laboratory based on a small number of unusually high field-blank results and duplicate results with poor precision. The same problem likely occurred for a small number of groundwater samples. Mismatched results for key constituents are identified during data review and flagged when appropriate.

Several indicator parameters, anions, metals, volatile organic compounds, and radiological parameters were detected at low levels in field or laboratory method blanks. Results associated with this QC issue are flagged in the HEIS database. Data users must consider data flags when making decisions about data usability.

Several analytical areas have been identified for continued evaluation and follow up. These include analyte issues identified via the blind standards program, especially total organic carbon at Lionville Laboratories, total uranium analyses at Eberline Services, gross alpha at several laboratories, and carbon-14 and tritium at TestAmerica Richland. Additional tracking will continue for the analyte method issues at WSCF with low-level strontium-90 and nitrite.

D.9 Glossary

Accuracy: Closeness of agreement between an observed value and a true value. Accuracy is assessed by means of reference samples and percent recoveries. Laboratory matrix spikes; laboratory control

samples; EPA water pollution, water supply, and inter-laboratory comparison programs; and blind standards are all used to assess accuracy.

Blank spike: See *Laboratory control sample.*

Blind standard: Sample that contains a concentration of analyte known to the supplier but unknown to the analyzing laboratory. Blind standards are used to evaluate analytical accuracy and precision as a measure of laboratory performance and are submitted to the analyzing laboratory as field samples. Blind standards may or may not include groundwater matrix matching.

Comparability: Degree to which one set of data can be compared to another. For example, the results from samples analyzed by more than one laboratory may or may not be comparable. Ideally, comparability should be evaluated using identical samples to ensure that valid comparisons can be made.

Completeness: Number of acceptable data divided by the total number of data points. The groundwater project determines completeness by calculating the number of unflagged data resulting from the validation process, dividing by the total number of data evaluated, and multiplying by 100. The calculated percentages used in reporting completeness are conservative because all data flagged for blank contamination (B for organics or C for inorganics), H, Q, R, or Y are used in calculating the percentage complete; however, flagged data may still be valid.

Data management staff: groundwater project staff responsible for tracking samples and data from sample planning through data receipt. This title includes staff responsible for management of the databases and electronic tools used to support data management activities.

Equipment blank: Sample that contains reagent water and any required preservatives. An equipment blank is filled by pumping or washing reagent water through non-dedicated sampling equipment. The equipment blank is analyzed for all constituents scheduled for the sampling event. Equipment blanks are used to monitor contamination resulting from improperly cleaned equipment.

Field duplicate sample (field duplicate): Replicate sample to determine the precision of the sampling and analytical measurement process by comparing results from identical samples collected at the same time and location. Matching field duplicates are stored in separate containers and are analyzed independently by the same laboratory.

Field matrix spike: See *Blind standard.*

Field split sample (field split): Samples sequentially collected from the same location in the same sampling event and analyzed by different laboratories. Field split samples are used to evaluate inter-laboratory precision and comparability.

Field transfer blank: Sample that contains reagent water and any required preservatives. At the time of sample collection, the field transfer blank is filled at the sampling site by pouring reagent water from a cleaned container into sample vials. After collection, the field transfer blank is treated in the same manner as the samples collected during the sampling event. Field transfer blanks are collected only on days when other samples are collected for volatile organic analysis and are analyzed only for volatile organic constituents. Field transfer blanks are used to check for volatile organic contamination associated with sampling activities.

Flags (as qualifiers): Codes that alert data users to limitations on reported data values. Data flags may be assigned by the laboratory or by groundwater project analytical support staff. A complete list of review flags is provided in Table D-1.

Full trip blank: Sample that contains reagent water and any required preservatives. A full trip blank is used to check for contamination in sample bottles and sample preparation. A full trip blank is analyzed for all constituents of interest and is collected in all types of sample bottles used during that sampling period. The full trip blank is filled during bottle preparation using the same sample preparation procedures

as those for regular well samples. The full trip blank is then handled the same as all other samples through delivery to the laboratory but is not opened in the field.

Groundwater project analytical support staff: Groundwater project staff responsible for reviewing and assessing the quality of data and analytical services. This group performs quarterly and annual reviews of QC data and ensures appropriate data flags are applied. They monitor the qualification and performance of the laboratories supporting the groundwater project.

Groundwater project: The Hanford Site Groundwater Monitoring Program.

Groundwater staff: Employees of the groundwater project, including project scientists, analytical support staff, data management staff, field staff, and others.

Laboratory control sample: Sample of reagent water spiked with a known amount of the target analyte. The sample is extracted (if appropriate) and analyzed to monitor the performance of the analytical method.

Matrix spike/matrix spike duplicate: Samples prepared at the analytical laboratory by adding known quantities of one or more target analytes to a sample before extraction and analysis. Comparison of the original (that is, unspiked) sample and matrix spike results provides information about the suitability of an analysis for the sample matrix. For example, unusually high or low recoveries of the spiked compounds may indicate that components in the sample matrix interfere with the analysis. Matrix spike duplicates are replicate matrix spike samples that are used to assess the precision of an analysis. The maximum limit of precision expected for matrix spike duplicates is 20 percent.

Method blank: Sample of reagent water prepared in the laboratory, extracted (if appropriate), and analyzed as if it were a regular sample. Method blanks are used to monitor the possible introduction of contaminants during sample preparation and analysis at the laboratory.

Precision: Agreement among individual measurements of the same property, usually under prescribed similar conditions. For a set of duplicate measurements, precision is calculated by the RPD of the duplicate results. For the groundwater project, results from laboratory duplicates, matrix spike duplicates, blind standards, split samples, and field duplicates are used to evaluate precision.

Project scientist: Groundwater project scientist responsible for the technical evaluation of data for a specific well or set of wells.

Reagent water: Distilled or deionized water free of contaminants that may interfere with analytical tests.

Relative percent difference (RPD): Calculated as follows:

$$RPD = \frac{|D1 - D2|}{(D1 + D2) / 2} \times 100$$

where: $D1$ = original sample value and $D2$ = duplicate sample value

Representativeness: Expression of the degree to which samples represent the actual composition of the material tested (for example, groundwater in the aquifer). Representativeness is addressed qualitatively by the specification of well construction, sampling locations, sampling intervals, and sampling and analysis techniques specified in monitoring plans.

Sample duplicate: Replicate sample preparation and analysis of a customer sample performed as part of a laboratory's analytical batch quality control. Sample duplicates and matrix spike duplicates are used to evaluate the precision of an analysis method. For the groundwater program, the maximum limit of precision expected for matrix duplicates is 20 percent.

Split samples: See *Field split samples*.

Surrogates: Organic compounds similar to analytes of interest in chemical composition, extraction, and analytical properties but that are not normally found in environmental samples. Surrogates are spiked into method blanks, samples, and matrix spikes. They are then extracted and analyzed to monitor the effectiveness of sample preparation and analysis on individual samples.

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Table D-1. Data Review Flags

Flag	Definition
A	Administrative issue, usually a chain-of-custody issue (e.g., broken chain).
F	Result is being reviewed as part of the RDR process. This flag is assigned when an RDR is initiated.
G	Result is valid according to further review.
H	Holding time exceeded before the sample was analyzed.
P	Potential problem. Collection/analysis circumstances make value questionable.
Q	Associated quality control sample is out of limits.
R	Result is not valid according to further review.
Y	Result is suspect. Review had insufficient evidence to show result valid or invalid.
Z	Miscellaneous circumstance exists. See project file.

RDR = Request for data review

Table D-2. Requests for Data Review for 2011

Flag G	Flag Y	Flag R	Flag P	Other Action	Pending	Number of Results with an Assigned RDR
Analytical Results*						
284	661	2	0	13	456	1406
Water-Level Measurements						
18	43	8	1	0	0	70

* The software used to track RDRs underwent a major upgrade during 2010. Some values in this table may be slightly low due to problems encountered during the upgrade.

G = Result was reviewed and determined to be correct or data was corrected.

P = Potential problem with the well, collection, or analysis that makes the result questionable.

R = Result was reviewed and found to be unusable.

RDR = Requests for data review

Y = Result is suspect.

Table D-3. Summary of Sample Issue Resolutions for 2011

Issue Category	Number of SIRs Generated						
	Totals	Field	222-S	LVL	TARL	TASL	WSCF
Addition of Analyses	3	---	---	1	---	1	1
Analysis Holding Time Exceeded	27	---	---	---	4	15	8
Broken Sample Bottle	2	---	---	---	---	2	---
Cancellation of Analyses	1	---	---	---	---	1	---
Chain of Custody Issue (Field)	43	---	---	---	6	6	31
Chain of Custody Issue (Laboratory)	6	---	---	---	---	2	4
Clarification of Direction	4	---	---	1	1	---	2
Incorrect Method Analysis Requested	1	---	---	---	1	---	---
Incorrect Sample Preservation	19	---	---	---	11	6	2
Instrument Failure/Facility Outage	2	---	---	---	---	1	1
Other Field Sampling Issue	1	---	---	---	---	---	1
Other General Laboratory Direction	39	---	1	---	15	11	12
Other Laboratory Issue	6	---	---	---	3	1	2
Other Sample Management and Reporting Issue	1	---	---	---	---	1	---
Quality Control Failure	20	1	---	---	3	7	9
Reporting Issue	1	---	---	---	---	---	1
Sample Collection Issue	3	1	---	---	1	---	1
Sample Re-Analysis	1	---	---	---	---	1	---
Turnaround Time and Due Date Modification	11	---	---	---	8	2	1
Total SIRs Processed:	**191**	**2**	**1**	**2**	**53**	**57**	**76**

Table D-4. Data Completeness Summary

	Suspect Data	Rejected Data	Field QC	Holding Time	Method Blank	Total
Number of Results Flagged	667	41	2,699	531	534	4,472
Percent Flagged Data	0.5%	0.03%	1.9%	0.4%	0.4%	3.2%
Percent Acceptable Data	99.5%	100.0%	98.1%	99.6%	99.6%	96.8%

Note: Total number of reported results was 140,437.

Table D-5. Full Trip Blanks Exceeding Quality Control Limits

Constituent	Number of Analyses	Number Out of Limits	Percent Out of Limits	Range of QC Limits[a]	Range of Out-of-Limit Results
General Chemistry Parameters					
Alkalinity[b]	99	9	9%	1,080 - 2,000 µg/L	2,100 - 125,000 µg/L
Total dissolved solids	4	1	25%	7,000 - 20,000 µg/L	36,000 µg/L
Total organic carbon	59	4	7%	200 - 520 µg/L	204 - 476 µg/L
Total organic halides	53	8	15%	3.6 - 10 µg/L	3.9 - 12.1 µg/L
Ammonia and Anions					
Chloride	85	4	5%	40 - 3,800 µg/L	110 - 302 µg/L
Cyanide	15	1	7%	3 - 8 µg/L	4 µg/L
Sulfate	85	1	1%	100 - 7,200 µg/L	1,600 µg/L
Sulfide	7	4	57%	200 - 1,600 µg/L	1,600 µg/L
Metals					
Arsenic	54	1	2%	0.8 - 100 µg/L	2.2 µg/L
Calcium	140	12	9%	56 - 212 µg/L	106 - 254 µg/L
Hexavalent Chromium	64	3	5%	4 - 7.4 µg/L	5.3 - 22.7 µg/L
Magnesium	143	12	8%	8 - 264 µg/L	14.5 - 121 µg/L
Manganese	143	1	1%	0.4 - 12 µg/L	0.43 µg/L
Mercury	14	1	7%	0.12 - 0.2 µg/L	0.13 µg/L
Potassium	140	5	4%	146 - 3,300 µg/L	153 - 647 µg/L
Silver	150	3	2%	0.08 - 14 µg/L	11 - 21 µg/L
Sodium	140	23	16%	20 - 648 µg/L	21 - 893 µg/L
Thallium	16	2	13%	0.2 - 98 µg/L	1.3 - 1.9 µg/L
Uranium	54	1	2%	0.1 - 0.46 µg/L	0.79 µg/L
Zinc	140	3	2%	8 - 14 µg/L	9 - 98 µg/L
Volatile Organic Compounds					
Carbon tetrachloride	35	1	3%	0.24 - 2 µg/L	0.48 µg/L
Methylene chloride	35	14	40%	0.55 - 5 µg/L	2.2 - 79 µg/L

Table D-5. Full Trip Blanks Exceeding Quality Control Limits

Constituent	Number of Analyses	Number Out of Limits	Percent Out of Limits	Range of QC Limits[a]	Range of Out-of-Limit Results
Radiological Parameters					
Technetium-99	40	1	3%	11.6 - 20.4 pCi/L	29.2 pCi/L
Total beta radiostrontium	23	3	13%	2.8 - 4.8 pCi/L	4 - 7.4 pCi/L
Tritium	61	1	2%	52.6 - 814 pCi/L	710 pCi/L

a. Because method detection limits are specific to the laboratory and may change throughout the year, the limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

b. Alkalinity includes total alkalinity, bicarbonate, carbonate, and hydroxyl ion determinations.

QC = quality control

Table D-6. Field Transfer Blanks Exceeding Quality Control Limits

Constituent	Number of Analyses	Number Out of Limits	Percent Out of Limits	Range of QC Limits*	Range of Out-of-Limit Results
Volatile Organic Compounds					
1,2-Dichloroethane	160	1	1%	0.2 - 2 µg/L	0.88 µg/L
Acetone	160	2	1%	1.7 - 5 µg/L	2.4 - 3.2 µg/L
Carbon tetrachloride	160	2	1%	0.24 - 2 µg/L	2.1 - 2.4 µg/L
Chloromethane	5	1	20%	0.154 µg/L	0.27 µg/L
Methylene chloride	160	84	53%	0.55 - 5 µg/L	1.7 - 50 µg/L
Trichloroethene	160	1	1%	0.5 - 2 µg/L	0.85 µg/L

* Because method detection limits are specific to the laboratory and may change throughout the year, the limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

QC = quality control

Table D-7. Equipment Blanks Exceeding Quality Control Limits

Constituent	Number of Analyses	Number Out of Limits	Percent Out of Limits	Range of QC Limits[a]	Range of Out-of-Limit Results
General Chemistry Parameters					
Alkalinity[b]	19	1	5%	100 - 7,000 µg/L	2,100 µg/L
Total dissolved solids	4	1	25%	7,000 - 20,000 µg/L	36,000 µg/L
Total organic carbon	59	4	7%	200 - 520 µg/L	204 - 476 µg/L
Total organic halides	53	8	15%	3.6 - 10 µg/L	3.9 - 12.1 µg/L
Ammonia and Anions					
Chloride	22	1	5%	40 - 240 µg/L	361 µg/L
Cyanide	5	2	40%	3 - 8 µg/L	3.9 - 5.9 µg/L
Nitrogen in Nitrate	22	2	9%	17.2 - 75.9 µg/L	39 - 110 µg/L
Sulfate	22	1	5%	100 - 440 µg/L	220 µg/L
Sulfide	1	1	100%	166 µg/L	400 µg/L
Metals					
Calcium	35	2	6%	56 - 212 µg/L	125 - 217 µg/L
Copper	36	1	3%	0.9 - 10.2 µg/L	15 µg/L
Iron	36	1	3%	38 - 76 µg/L	126 µg/L
Magnesium	36	4	11%	8 - 264 µg/L	8.5 - 44 µg/L
Sodium	35	9	26%	20 - 648 µg/L	28 - 428 µg/L
Volatile Organic Compounds					
Chloroform	19	3	16%	0.2 - 2 µg/L	2.3 - 4.4 µg/L
Chloromethane	4	1	25%	0.154 µg/L	0.16 µg/L
Methylene chloride	19	4	21%	0.55 - 5 µg/L	1.1 - 12 µg/L
Tetrachloroethene	19	1	5%	0.36 - 2 µg/L	0.41 µg/L
Semivolatile Organic Compounds					
Benzo(a)pyrene	3	1	33%	0.15 µg/L	2.2 µg/L
Naphthalene	4	1	25%	0.4 - 1.8 µg/L	2.8 µg/L

a. Because method detection limits are specific to the laboratory and may change throughout the year, the limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

b. Alkalinity includes total alkalinity, bicarbonate, carbonate, and hydroxyl ion determinations.

QC = quality control

Table D-8. Summary of Analytical Method Categories

Category	HEIS Method Name	Description
General Chemistry Parameters	120.1_CONDUCT	Specific Conductivity, Conductance Bridge
	160.1_TDS	Total Dissolved Solids
	2320_ALKALINITY	Alkalinity
	2540C_TDS	Total dissolved solids: Standard Method 2540C filter and dry and 180C
	310.1_ALKALINITY	Alkalinity, Titrametric
	360.1_OXYGEN	Dissolved Oxygen
	360.1_OXYGEN_FLD	Dissolved Oxygen (DO)
	410.4_COD	Chemical Oxygen Demand (COD), Automated; Manual
	420.2_PHENOLIC	Phenolics, Automated Colorimetric
	9020_TOX	Total Organic Halides (TOX)
	9060_TOC	Total Organic Carbon
	9070_OILGREASE	Total Recoverable Oil and Grease, Gravimetric
	9223_COLIFORM	Coliform by Enzyme Substrate Test
	CONDUCT_FLD	Field conductivity by instrument manufacturer instructions
	PH_ELECT_FLD	PH Analysis by Electrode, Field Measurement
	REDOX_PROBE_FLD	Oxidation-Reduction Potential by platinum electrode
	TEMP_FLD	Temperature, Field Measurement
	TURBIDITY_FLD	Nephelometric Turbidity, Field Measurement
	WTPH_DIESEL	Total Petroleum Hydrocarbons, SE/GC-FID, Washington State Dept. of Ecology
	WTPH_GASOLINE	Total Petroleum Hydrocarbons, P&T/GC-FID, Washington State Dept. of Ecology
Ammonia and Anions	300.0_ANIONS_IC	Anions by Ion Chromatography
	300.7_CATIONS_IC	Cations by ion chromatography (Nitrogen in ammonium)
	335.2_CYANIDE	Total Cyanide, Titrametric, Spectrophotometric
	350.1_AMMONIA	Ammonia, Automated Phenate
	4500E_CN	Cyanide
	9012_CYANIDE	Cyanide, Automated Colorimetric
	9014_CYANIDE	EPA 9014 cyanide (222-S method = microdistillation + colorimetric determination)
	9030_SULFIDE	Sulfide by Titration

Table D-8. Summary of Analytical Method Categories

Category	HEIS Method Name	Description
	9056_ANIONS_IC	Anions by Ion Chromatography
Metals	200.8_METALS_ICPMS	Metals by ICPMS
	6010_METALS_ICP	Metals by ICP
	6010_METALS_ICP_TR	Metals by ICP, trace
	6020_METALS_ICPMS	Metals by ICPMS
	7196_CR6	Chromium(Hex) - Cr+6, Colorimetric
	7470_HG_CVAA	Mercury (Hg) by CVAA
Volatile Organic Compounds	8015_VOA_GC	Non-Halogenated Volatiles by GC
	8260_VOA_GCMS	Volatile Organics by GC/MS Capillary Column
Semivolatile Organic Compounds	8040_PHENOLIC_GC	Phenols by GC
	8081_PEST_GC	Organochlorine pesticides by GC
	8082_PCB_GC	PCBs BY GC
	8270_SVOA_GCMS	Semivolatiles by GCMS
	8310_SVOA_HPLC	SemiVOAs by HPLC (PAHs)
Radiological Parameters	900.0_ALPHABETA_GPC	Gross Alpha/Beta by GPC
	906.0_H3_LSC	Tritium in Drinking Water, Liquid Scintillation
	906.0ML_H3_LSC	Tritium in Drinking Water, Mid-Level, Liquid Scintillation
	9310_ALPHABETA_GPC	Gross Alpha and Gross beta by GPC
	ALPHA_GPC	Gross Alpha, GPC
	BETA_GPC	Gross Beta GPC
	C14_CHEM_LSC	C-14, Chemical Oxidation/LSC
	C14_LSC	C-14 analysis by unknown method
	GAMMA_GS	Gamma Spectroscopy, Germanium High Energy Detectors
	GAMMALL_GS	Gamma spectroscopy, low-level, germanium high-energy detector
	I129LL_SEP_LEPS_GS	Iodine-129, low-level, separation, precipitation, LEPS detection
	NP237_LLE_PLATE_AEA	Neptunium Isotopic, Liquid-Liquid Extraction, Electroplated, Alpha Spec
	PUISO_IE_PRECIP_AEA	Isotopic Plutonium, Ion Exchange Separation, Precipitated on Disk, Alpha Spec
	PUISO_PLATE_AEA	Isotopic Plutonium, Unknown Separation, Electroplated, Alpha Spec

Table D-8. Summary of Analytical Method Categories

Category	HEIS Method Name	Description
	SE79_SEP_IE_LSC	Selenium-79, separated, ion exchange resin, Liquid Scintillation
	SRISO_SEP_PRECIP_GPC	Strontium beta isotopic, chemical separation, precipitated, GPC
	SRTOT_SEP_PRECIP_GPC	Total Beta Strontium, chemical separation, precipitation, GPC
	TC99_3MDSK_LSC	Technetium-99, 3M Disk separation, LSC
	TC99_ETVDSK_LSC	Technetium-99, Eichrome Teva Disk separation, LSC
	TC99_SEP_LSC	Technetium-99, ppt. and ion exchange resin separation, LSC
	TC99_TR_SEP_GPC	Technetium-99, separated, tracer yield, GPC
	TRITIUM_EIE_LSC	Tritium in water, purification by Eichrome ion exchange, LSC
	UISO_IE_PRECIP_AEA	Uranium isotopic, purification by ion exchange, precipitated, Alpha Spectrometry
	UISO_PLATE_AEA	Uranium isotopic, separation unknown, electroplated, Alpha Spectrometry
	UTOT_KPA	Total Uranium, unknown separation, Laser Phosphorimetry

Table D-9. Field Duplicates Exceeding Quality Control Limits

Constituent	Total Number of Duplicates	Number of Duplicates Evaluated[a]	Number Out of Limits	Percent Out of Limits	Range of Out-of-Limit Relative Percent Difference[b]
Metals					
Aluminum	10	1	1	100	148
Cobalt	24	1	1	100	138
Iron	20	4	1	25	129
Manganese	20	5	2	40	77 - 139
Potassium	20	20	1	5	20.1
Zinc	20	3	1	33	177
Volatile Organic Compounds					
Acetone	4	2	2	100	133 - 142
Radiological Parameters					
Tritium	9	2	1	50	73
Uranium-233/234	2	2	1	50	21

Note: Duplicate control limit is a relative percent difference less than or equal to 20%.

a. Duplicates with at least one result five times greater than the method detection limit or minimum detectable activity were evaluated.

b. In cases where a non-detected result was compared with a measured value, the method detection limit or minimum detectable activity was used for the non-detected concentration.

Table D-10. Field Splits Exceeding Quality Control Limits

Constituent	Total Number of Splits	Number of Splits Evaluated[a]	Number Out of Limits	Percent Out of Limits	Range of Out-of-Limit Relative Percent Differences[b]
General Chemistry Parameters					
Alkalinity	10	10	1	10	37
Total petroleum hydrocarbons - diesel range	6	2	2	100	157 - 166
Ammonia and Anions					
Fluoride	25	4	1	25	22
Nitrogen in Nitrite	23	2	2	100	80 - 174
Metals					
Aluminum	10	1	1	100	36
Calcium	26	26	3	12	20.4 - 26
Chromium	50	16	1	6	61
Hexavalent Chromium	37	21	4	19	30 - 38
Iron	26	5	4	80	41 - 132
Lead	22	8	7	88	23 - 111
Manganese	26	4	2	50	28 - 32
Potassium	26	2	2	100	28 - 39
Strontium	26	26	5	19	20.2 - 32
Vanadium	26	1	1	100	41
Zinc	26	4	3	75	23 - 153
Volatile Organic Compounds					
Xylenes (total)	9	1	1	100	74
Radiological Parameters					
Carbon-14	14	9	9	100	31 - 77
Gross beta	11	6	2	33	21 - 43
Technetium-99	15	4	1	25	26
Tritium	18	8	5	63	21 - 36

Note: Field split control limit is a relative percent difference less than or equal to 20%.

a. Field splits with at least one result five times greater than the method detection limits or minimum detectable activities at both laboratories were evaluated.

b. When a non-detected result was compared with a measured value, the method detection limit or minimum detectable activity was used for the non-detected concentration.

Table D-11. Hanford Groundwater Monitoring Project Maximum Recommended Holding Times

Method	Constituent	Holding Time
120.1 (EPA-600/4-81-004)	Conductivity	28 days
160.1 (EPA-600/4-81-004)	Total dissolved solids	7 days
300.0 (EPA-600/4-81-004)	Bromide	28 days
300.0 (EPA-600/4-81-004)	Chloride	28 days
300.0 (EPA-600/4-81-004)	Fluoride	28 days
300.0 (EPA-600/4-81-004)	Nitrate	48 hours
300.0 (EPA-600/4-81-004)	Nitrite	48 hours
300.0 (EPA-600/4-81-004)	Phosphate	48 hours
300.0 (EPA-600/4-81-004)	Sulfate	28 days
310.1 (EPA-600/4-81-004)	Alkalinity	14 days
350.1 (EPA-600/4-81-004)	Ammonia	28 days
410.4 (EPA-600/4-81-004)	Chemical oxygen demand	28 days
6010 (SW-846)	Inductively coupled plasma metals	6 months
6020 (SW-846)	Inductively coupled plasma-mass spectrometry metals	6 months
7196 (SW-846)	Hexavalent chromium	24 hours
7470 (SW-846)	Mercury	28 days
8015M (SW-846)	Total petroleum hydrocarbons	14 days
8040 (SW-846)	Phenols	7 days before extraction 40 days after extraction
8081 (SW-846)	Pesticides	7 days before extraction 40 days after extraction
8082 (SW-846)	Polychlorinated biphenyls	1 year before extraction 1 year after extraction
8260 (SW-846)	Volatile organics	14 days
8270 (SW-846)	Semivolatile organics	7 days before extraction 40 days after extraction
9012 (SW-846)	Cyanide	14 days
9020 (SW-846)	Total organic halides	28 days
9030 (SW-846)	Sulfides	7 days
9060 (SW-846)	Total organic carbon	28 days
9223 (AWWA et al., 2005)	Coliform	24 hours

Table D-12. Summary of WSCF Performance Evaluation Studies

Study Number	Date	Correct Results / Total Results
WatR™ Pollution/WatR™ Supply Performance Evaluation Studies, Environmental Resource Associates		
WP-194	March 2011	83/83
WP-198	March 2011	81/84[a]
DOE Mixed Analyte Performance Evaluation Program, Radiological and Environmental Sciences Laboratory		
MAPEP-10-MaW23	January 2011	28/31[b]
MAPEP-10-GrW23	January 2011	2/2
MAPEP-10-OrW23	January 2011	56/57[c]
MAPEP-11-MaW24	July 2011	31/31
MAPEP-11-GrW24	July 2011	2/2
MAPEP-11-OrW24	July 2011	57/57
InterLaB RadCheM Proficiency Testing Program, Environmental Resource Associates		
RAD-84	March 2011	4/4
RAD-86	September 2011	0/1[d]

Sources: AWWA/APHA/WEF, 2005, *Standard Methods for the Examination of Water and Wastewater*.

EPA-600/4-81-004, *Environmental Radioactivity Laboratory Intercomparison Studies Program Fiscal Year 1981-1982*.

SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*.

a. Unacceptable results were for Aroclors 1016 and 1232 and hexavalent chromium.

b. Unacceptable results were for copper, nickel, and thallium.

c. Unacceptable result was for hexachlorobenzene.

d. Unacceptable result was for tritium.

Table D-13. Summary of TestAmerica Performance Evaluation Studies

Study Number	Date	Correct Results / Total Results	
		TA St. Louis	TA Richland
WatR™ Pollution/WatR™ Supply Performance Evaluation Studies, Environmental Resource Associates			
WP-191	January 2011	2/2	--
020911D Quick Response	February 2011	21/21	--
WP-192	March 2011	383/392[a]	2/2
030111C Quick Response	March 2011	4/5[b]	--
0318110 Quick Response	March 2011	1/1	--
WP-198	September 2011	327/328[c]	--
WS-183	November 2011	62/62	--
DOE Mixed Analyte Performance Evaluation Program, Radiological and Environmental Sciences Laboratory			
MAPEP-10-MaW23	January 2011	36/36	17/17
MAPEP-10-GrW23	January 2011	2/2	2/2
MAPEP-10-OrW23	January 2011	75/75	--
MAPEP-11-MaW24	August 2011	35/36[d]	16/16
MAPEP-11-GrW24	August 2011	2/2	2/2
MAPEP-11-OrW24	August 2011	74/75[e]	--
MAPEP-11-MaW25	December 2011	35/36[f]	17/18[j]
MAPEP-11-GrW25	December 2011	2/2	2/2
MAPEP-11-XaW25	December 2011	0/1[g]	0/1[g]
MAPEP-11-OrW25	December 2011	77/77	--
InterLaB RadCheM Proficiency Testing Program, Environmental Resource Associates			
MRAD-15	November 2011	11/13[m]	--
RAD-84	March 2011	--	15/15
RAD-85	May 2011	18/20[h]	17/19[k]
RAD-86	September 2011	--	4/5[l]
RAD-87	November 2011	9/11[i]	--

Table D-13. Summary of TestAmerica Performance Evaluation Studies

Study Number	Date	Correct Results / Total Results	
		TA St. Louis	TA Richland

a. Unacceptable results were for total solids, iron, copper, manganese, mercury, hexavalent chromium, and PCBs (2 Aroclors).

b. Unacceptable result was for cobalt-60

c. Unacceptable result was for sulfide.

d. Unacceptable result was for uranium-235.

e. Unacceptable result was for acenaphthene.

f. Unacceptable result was for nickel-63.

g. Unacceptable result was for iodine-129.

h. Unacceptable results were for stontium-90 (2).

i. Unacceptable results were for cesium-137 and gross alpha.

j. Unacceptable result was for iron-55.

k. Unacceptable results were for radium-226 and iodine-131.

l. Unacceptable result was for gross beta.

m. Unacceptable results were for plutonium -238 and plutonium-239.

Table D-14. Summary of Eberline Services and Lionville Laboratory Performance Evaluation Studies

Study Number	Date	Correct Results / Total Results	
		Eberline	Lionville
DOE Mixed Analyte Performance Evaluation Program, Radiological and Environmental Sciences Laboratory			
MAPEP-10-MaW23	January 10, 2011	16/17[a]	--
MAPEP-10-GrW23	January 10, 2011	2/2	--
MAPEP-11-MaW24	July 5, 2011	17/17	--
MAPEP-11-GrW24	July 5, 2011	2/2	--
MAPEP-11MaW25	August 2011	17/17	16/16
MAPEP-11-GrW25	August 2011	1/2[b]	--
MAPEP-11-OrW25	August 2011	--	57/57
MAPEP-11-XaW25	August 2011	1/1	--
ERA InterLaB RadCheM Proficiency Testing Program, Environmental Resource Associates			
RAD-84	March 2011	13/15[c]	--
RAD-85	May 2011	6/6	--
RAD-86	September 2011	6/6	--
RAD-800	September 2011	9/9	--
Water Proficiency Testing Program, Wibby Environmental			
WS0711	July 2011	--	18/18
WP0711	July 2011	--	294/295[d]

a. Unacceptable result was for tritium.

b. Unacceptable result was for gross alpha.

c. Unacceptable results were for barium-133 and strontium-89.

d. Unacceptable result was for fluoride.

Table D-15. Summary of Blind Standard Determinations: Eberline Services

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b] (%)
Total for 2011	—	72	15	79%	—
Metals					
Uranium	Quarterly	6	6	0%	±20
Radiological Parameters					
Carbon-14	N/A	9	0	100%	±30
Cesium-137	Semiannually	3	0	100%	±30
Cobalt-60	Semiannually	3	0	100%	±30
Gross alpha	Quarterly	9	4	56%	±30
Gross beta	Quarterly	12	1	92%	±30
Iodine-129	Semiannually	9	2	78%	±30
Neptunium-237	Annually	3	0	100%	±30
Plutonium-239	Quarterly	6	2	67%	±30
Strontium-90	Annually	3	0	100%	±30
Technetium-99	Quarterly	6	0	100%	±30
Tritium	Semiannually	3	0	100%	±30

a. Blind standards were generally submitted in triplicate or quadruplicate.

b. The recovery of each result must be within the specified percentage of the known value to be acceptable.

Table D-16. Summary of Blind Standard Determinations: Lionville Laboratory

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b] (%)
Total for 2011	—	39	7	82%	—
General Chemical Parameters					
Total organic carbon (potassium hydrogen phthalate)	Quarterly	12	6	50%	±25
Ammonia and Anions					
Chloride	Quarterly	9	1	89%	±25
Fluoride	Quarterly	9	0	100%	±25
Nitrate as Nitrogen	Quarterly	3	0	100%	±25
Nitrite as Nitrogen	Quarterly	3	0	100%	±25
Metals					
Selenium	N/A	See footnote c			±20
Zinc	Annually	3	0	100%	±20

a. Blind standards were generally submitted in triplicate or quadruplicate.

b. The recovery of each result must be within the specified percentage of the known value to be acceptable.

c. Blind standard for selenium was submitted to lab but no results returned.

krm 8/27/12

Table D-17. Summary of Blind Standard Determinations: TestAmerica Richland

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b](%)
Total for 2011	—	105	22	79%	—
Metals					
Hexavalent chromium	Quarterly	12	0	100%	±20
Uranium	Quarterly	9	3	67%	±20
Radiological Parameters					
Carbon-14	N/A	9	9	0%	±30
Cesium-137	Semiannually	3	0	100%	±30
Cobalt-60	Semiannually	3	0	100%	±30
Gross alpha	Quarterly	9	6	33%	±30
Gross beta	Quarterly	12	0	100%	±30
Iodine-129	Semiannually	12	2	83%	±30
Neptunium-237	Annually	3	0	100%	±30
Plutonium-239	Quarterly	9	0	100%	±30
Strontium-90	Annually	6	0	100%	±30
Technetium-99	Quarterly	9	2	78%	±30
Tritium	Semiannually	9	0	100%	±30

a. Blind standards were generally submitted in triplicate or quadruplicate.

b. The recovery of each result must be within the specified percentage of the known value to be acceptable.

Table D-18. Summary of Blind Standard Determinations: TestAmerica St. Louis

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b] (%)
Total for 2011	—	219	39	82%	—
General Chemical Parameters					
Specific conductance	Quarterly	9	0	100%	±25
Total organic carbon (potassium hydrogen phthalate)	Quarterly	12	2	83%	±25
Total organic halides (2,4,5-trichlorophenol)	Semiannually	11	0	100%	±25
Total organic halides (carbon tetrachloride, chloroform, and trichloroethene)	Semiannually	10	2	80%	±25
Ammonia and Anions					
Chloride	Quarterly	9	0	100%	±25
Cyanide	Semiannually	9	0	100%	±25
Fluoride	Quarterly	9	0	100%	±25
Nitrate as Nitrogen	Quarterly	9	0	100%	±25
Nitrite as Nitrogen	Quarterly	9	0	100%	±25
Metals					
Aluminum	N/A	3	0	100%	±20
Antimony	N/A	6	2	67%	±20
Arsenic	Annually	3	0	100%	±20
Barium	Annually	6	0	100%	±20
Beryllium	N/A	6	0	100%	±20
Boron	N/A	3	3	0%	±20

Table D-18. Summary of Blind Standard Determinations: TestAmerica St. Louis

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b] (%)
Cadmium	Semiannually	6	0	100%	±20
Calcium	N/A	3	0	100%	±20
Chromium (total)	Quarterly	9	0	100%	±20
Cobalt	Semiannually	6	0	100%	±20
Copper	Semiannually	6	0	100%	±20
Iron	Semiannually	3	0	100%	±20
Lead	N/A	3	0	100%	±20
Magnesium	Annually	3	2	33%	±20
Manganese	Annually	3	0	100%	±20
Mercury	N/A	See footnote c			±20
Nickel	Annually	3	0	100%	±20
Potassium	Annually	3	3	0%	±20
Selenium	N/A	6	2	67%	±20
Silver	N/A	3	0	100%	±20
Sodium	Annually	3	0	100%	±20
Strontium	N/A	3	0	100%	±20
Thallium	N/A	3	3	0%	±20
Vanadium	Annually	3	0	100%	±20
Zinc	Annually	6	6	0%	±20

Table D-18. Summary of Blind Standard Determinations: TestAmerica St. Louis

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b] (%)
Volatile Organic Compounds					
Carbon tetrachloride	Quarterly	9	4	56%	±25
Chloroform	Semiannually	9	1	89%	±25
Tetrachloroethene	N/A	3	3	0%	±25
Trichloroethene	Quarterly	9	6	33%	±25

a. Blind standards were generally submitted in triplicate or quadruplicate.

b. The recovery of each result must be within the specified percentage of the known value to be acceptable.

c. Mercury blind standards were submitted to laboratory but were not analyzed.

Table D-19. Summary of Blind Standard Determinations: WSCF

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b] (%)
Total for 2011	—	288	35	88%	—
General Chemical Parameters					
Specific conductance	Quarterly	9	0	100%	±25
Total organic carbon (potassium hydrogen phthalate)	Quarterly	12	3	75%	±25
Total organic halides (2,4,5-trichlorophenol)	Semiannually	11	1	91%	±25
Total organic halides (carbon tetrachloride, chloroform, and trichloroethene)	Semiannually	10	2	80%	±25
Ammonia and Anions					
Chloride	Quarterly	9	0	100%	±25
Cyanide	Semiannually	9	0	100%	±25
Fluoride	Quarterly	9	1	89%	±25
Nitrate as Nitrogen	Quarterly	9	0	100%	±25
Nitrite as Nitrogen	Quarterly	9	0	100%	±25
Metals					
Aluminum	N/A	9	0	100%	±20
Antimony	N/A	3	0	100%	±20
Arsenic	Annually	3	0	100%	±20
Barium	Annually	6	0	100%	±20
Beryllium	N/A	6	0	100%	±20
Cadmium	Semiannually	6	0	100%	±20
Calcium	N/A	3	0	100%	±20

Table D-19. Summary of Blind Standard Determinations: WSCF

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b] (%)
Chromium (total)	Quarterly	9	0	100%	±20
Cobalt	Semiannually	6	0	100%	±20
Copper	Semiannually	6	0	100%	±20
Hexavalent chromium	Quarterly	12	0	100%	±20
Iron	Semiannually	3	0	100%	±20
Lead	N/A	3	0	100%	±20
Magnesium	Annually	3	0	100%	±20
Manganese	Annually	3	0	100%	±20
Mercury	N/A	See footnote c			±20
Nickel	Annually	3	0	100%	±20
Potassium	Annually	3	3	0%	±20
Selenium	N/A	3	0	100%	±20
Silver	N/A	3	0	100%	±20
Sodium	Annually	3	0	100%	±20
Strontium	N/A	3	0	100%	±20
Thallium	N/A	3	0	100%	±20
Uranium	Quarterly	9	0	100%	±20
Vanadium	Annually	3	1	67%	±20
Zinc	Annually	6	0	100%	±20
Volatile Organic Compounds					
Carbon tetrachloride	Quarterly	9	5	44%	±25

Table D-19. Summary of Blind Standard Determinations: WSCF

Constituent	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits	Acceptable Results	Control Limits[b] (%)
Chloroform	Semiannually	9	4	56%	±25
Tetrachloroethene	N/A	3	0	100%	±25
Trichloroethene	Quarterly	9	5	44%	±25
Radiological Parameters					
Cesium-137	Semiannually	3	1	67%	±30
Cobalt-60	Semiannually	3	0	100%	±30
Gross alpha	Quarterly	9	7	22%	±30
Gross beta	Quarterly	12	0	100%	±30
Neptunium-237	Annually	3	1	67%	±30
Plutonium-239	Quarterly	6	1	83%	±30
Strontium-90	Annually	3	0	100%	±30
Technetium-99	Quarterly	9	0	100%	±30
Tritium	Semiannually	3	0	100%	±30

a. Blind standards were generally submitted in triplicate or quadruplicate.

b. The recovery of each result must be within the specified percentage of the known value to be acceptable.

c. Mercury blind standards were submitted to laboratory but were not analyzed.

Table D-20. Laboratory Quality Control Results by Laboratory

QC Parameter	222-S Laboratory	Eberline Services	TestAmerica Richland	TestAmerica St. Louis	WSCF	Total
Method Blanks Total	43	80	1,256	9,822	12,511	23,712
Method Blanks Out	1	0	4	47	63	115
Method Blanks Out Percent	2.3	0.0	0.3	0.5	0.5	0.5
Lab Control Samples Total	48	45	725	9,076	9,838	19,732
Lab Control Samples Out	0	0	0	187	11	198
Lab Control Samples Out Percent	0.0	0.0	0.0	2.1	0.1	1.0
Lab Control Sample Duplicates Total	—	—	—	1,810	23	1,833
Lab Control Sample Duplicates Out	—	—	—	37	0	37
Lab Control Sample Duplicates Out Percent	—	—	—	2.0	0.0	2.0
Matrix Spikes Total	10	16	211	15,760	17,955	33,952
Matrix Spikes Out	0	1	4	415	95	515
Matrix Spikes Out Percent	0.0	6.3	1.9	2.6	0.5	1.5
Matrix Spike Duplicates Total	—	—	67	15,269	8,706	24,042
Matrix Spike Duplicates Out	—	—	0	510	1	511
Matrix Spike Duplicates Out Percent	—	—	0.0	3.3	0.0	2.1
Sample Duplicates Total	10	70	1,202	385	3,419	5,086
Sample Duplicates Out	0	0	11	11	21	43
Sample Duplicates Out Percent	0.0	0.0	0.9	2.9	0.6	0.8
Surrogates Total	—	—	—	6,675	5,192	11,867
Surrogates Out	—	—	—	232	67	299
Surrogates Out Percent	—	—	—	3.5	1.3	2.5

Table D-20. Laboratory Quality Control Results by Laboratory

QC Parameter	222-S Laboratory	Eberline Services	TestAmerica Richland	TestAmerica St. Louis	WSCF	Total
Surrogate Duplicates Total	—	—	—	1,717	789	2,506
Surrogate Duplicates Out	—	—	—	32	17	49
Surrogate Duplicates Out Percent	—	—	—	1.9	2.2	2.0

Table D-21. Laboratory Quality Control Results by Analyte Category

QC Parameter	General Chemical Parameters	Ammonia / Anions	Metals	Volatile Organic Compounds	Semivolatile Organic Compounds	Radiochemical Parameters	Total
Method Blanks Total	276	2,448	6,733	6,764	5,269	2,222	23,712
Method Blanks Out	14	19	60	5	5	12	115
Method Blanks Out Percent	5.1	0.8	0.9	0.1	0.1	0.5	0.5
Lab Control Samples Total	465	2,363	6,588	5,548	3,468	1,300	19,732
Lab Control Samples Out	0	0	7	57	134	0	198
Lab Control Samples Out Percent	0.0	0.0	0.1	1.0	3.9	0.0	1.0
Lab Control Sample Duplicates Total	2	—	—	1,726	105	—	1,833
Lab Control Sample Duplicates Out	0	—	—	35	2	—	37
Lab Control Sample Duplicates Out Percent	0.0	—	—	2.0	1.9	—	2.0
Matrix Spikes Total	554	4,412	12,453	9,962	6,334	237	33,952
Matrix Spikes Out	11	36	82	155	227	4	515
Matrix Spikes Out Percent	2.0	0.8	0.7	1.6	3.6	1.7	1.5
Matrix Spike Duplicates Total	237	2,011	7,575	8,267	5,952	—	24,042
Matrix Spike Duplicates Out	0	0	1	320	190	—	511
Matrix Spike Duplicates Out Percent	0.0	0.0	0.0	3.9	3.2	—	2.1
Sample Duplicates Total	150	2,325	410	36	—	2,165	5,086
Sample Duplicates Out	3	13	0	0	—	27	43
Sample Duplicates Out Percent	2.0	0.6	0.0	0.0	—	1.2	0.8
Surrogates Total	—	—	—	7,773	4,094	—	11,867
Surrogates Out	—	—	—	117	182	—	299

Table D-21. Laboratory Quality Control Results by Analyte Category

QC Parameter	General Chemical Parameters	Ammonia / Anions	Metals	Volatile Organic Compounds	Semivolatile Organic Compounds	Radiochemical Parameters	Total
Surrogates Out Percent	—	—	—	1.5	4.4	—	2.5
Surrogate Duplicates Total	—	—	—	1,517	989	—	2,506
Surrogate Duplicates Out	—	—	—	11	38	—	49
Surrogate Duplicates Out Percent	—	—	—	0.7	3.8	—	2.0

Table D-22. Method Blank Results: 222-S

Constituent	Number of Blanks	Percent Out of Limit*	Concentration Range of Out-of-Limit Results
Ammonia and Anions			
Total Ammonia and Anions	43	2.3	—
Cyanide	1	100.0	8.2 µg/L

* Quality control limits are twice the method detection limit.

Table D-23. Method Blank Results: Eberline Services

Constituent	Number of Blanks	Percent Out of Limit*	Concentration Range of Out-of-Limit Results
Metals			
Total Metals	1	0.0	—
Radiological Parameters			
Total Radiochemistry Parameters	79	0.0	—

* Quality control limits are twice the method detection limit or minimum detectable activity.

Table D-24. Method Blank Results: TestAmerica Richland

Constituent	Number of Blanks	Percent Out of Limit*	Concentration Range of Out-of-Limit Results
General Chemistry Parameters			
Total General Chemistry Parameters	8	0.0	—
Metals			
Total Metals	81	1.2	—
Uranium	15	6.7	1.11 µg/L
Radiological Parameters			
Total Radiochemistry Parameters	1,167	0.3	—
Carbon-14	50	2.0	18 pCi/L
Iodine-129	58	1.7	2.83 pCi/L
Uranium-234	2	50.0	0.12 pCi/L

* Quality control limits are twice the method detection limit or minimum detectable activity.

Table D-25. Method Blank Results: TestAmerica St. Louis

Constituent	Number of Blanks	Percent Out of Limit[a]	Concentration Range of Out-of-Limit Results
General Chemistry Parameters			
Total General Chemistry Parameters	93	14.0	—
Specific Conductance	1	100.0	0.31 µS/cm
Total organic carbon	12	16.7	710 µg/L
Total organic halides	17	58.8	4.2 – 13.3 µg/L
Ammonia and Anions			
Total Ammonia and Anions	289	6.2	—
Chloride	47	6.4	41 – 100 µg/L
Cyanide	10	70.0	3.1 – 4.9 µg/L
Nitrogen in ammonia	4	25.0	23.1 µg/L
Nitrogen in nitrite	47	2.1	11 µg/L
Sulfate	47	2.1	350 µg/L
Sulfide	20	25.0	200 – 400 µg/L
Metals			
Total Metals	1,678	0.4	—
Beryllium (ICP-AES)	59	1.7	1.4 µg/L
Potassium (ICP-AES)	59	1.7	4,930 µg/L
Strontium (ICP-AES)	59	1.7	1.7 µg/L
Boron (ICP-MS)	26	7.7	21.5 – 32.5 µg/L
Mercury (CVAA)	12	8.3	0.15 µg/L
Volatile Organic Compounds			
Total Volatile Organic Compounds	3,141	0.2	—
Acetone[b]	62	1.6	1.8 µg/L
Methylene chloride	62	4.8	1.4 – 2.4 µg/L
Tetrachloroethene	61	1.6	0.67 µg/L
Semivolatile Organic Compounds			
Total Semivolatile Organic Compounds	4,621	0.1	—
Acenaphthylene	43	2.3	11 µg/L
Bis(2-ethylhexyl) phthalate[b]	37	5.4	7.0 – 8.8 µg/L

Table D-25. Method Blank Results: TestAmerica St. Louis

Constituent	Number of Blanks	Percent Out of Limit[a]	Concentration Range of Out-of-Limit Results
Hexachlorophene	28	7.1	60 – 61 µg/L

a. Quality control limits are twice the method detection limit.

b. Quality control limits are five times the method detection limit.

CVAA = cold-vapor atomic absorption

ICP-AES = inductively coupled plasma - atomic emission spectroscopy

ICP-MS = inductively coupled plasma - mass spectrometry

Table D-26. Method Blank Results: WSCF

Constituent	Number of Blanks	Percent Out of Limit*	Concentration Range of Out-of-Limit Results
General Chemistry Parameters			
Total General Chemistry Parameters	175	0.6	—
Chemical Oxygen Demand	4	25.0	147 mg/L
Ammonia and Anions			
Total Ammonia and Anions	2,116	0.0	—
Metals			
Total Metals	4,973	1.1	—
Calcium (ICP-AES)	157	4.5	60 – 983 µg/L
Copper (ICP-AES)	160	0.6	11 µg/L
Iron (ICP-AES)	155	0.6	48.6 µg/L
Magnesium (ICP-AES)	163	2.5	9.3 – 28 µg/L
Potassium (ICP-AES)	154	0.6	158 µg/L
Silicon (ICP-AES)	33	18.2	74 – 168 µg/L
Silver (ICP-AES)	162	1.2	14 – 19.8 µg/L
Sodium (ICP-AES)	158	4.4	21.9 – 67 µg/L
Zinc (ICP-AES)	163	3.7	13 – 530 µg/L
Aluminum (ICP-MS)	65	4.6	12.1 – 27.1 µg/L
Barium (ICP-MS)	70	1.4	1.31 µg/L
Chromium (ICP-MS)	87	2.3	0.22 – 0.31 µg/L
Copper (ICP-MS)	70	5.7	0.22 – 1.02 µg/L
Manganese (ICP-MS)	53	3.8	0.21 – 0.45 µg/L
Tin (ICP-MS)	49	2.0	0.66 µg/L

Table D-26. Method Blank Results: WSCF

Constituent	Number of Blanks	Percent Out of Limit*	Concentration Range of Out-of-Limit Results
Vanadium (ICP-MS)	52	5.8	0.49 – 1.11 µg/L
Zinc (ICP-MS)	45	4.4	2.07 – 2.14 µg/L
Volatile Organic Compounds			
Total Volatile Organic Compounds	3,623	0.0	—
Semivolatile Organic Compounds			
Total Semivolatile Organic Compounds	648	0.0	—
Radiological Parameters			
Total Radiochemistry Parameters	976	0.9	—
Potassium-40	39	5.1	510 pCi/L
Total beta radiostrontium	85	5.9	3.4 – 5.0 pCi/L
Uranium-233/234	10	20.0	0.15 – 0.17 pCi/L

* Quality control limits are twice the method detection limit or minimum detectable activity.

ICP-AES = inductively coupled plasma - atomic emission spectroscopy

ICP-MS = inductively coupled plasma - mass spectrometry

Table D-27. Laboratory Control Sample Results: 222-S

Constituent	Number of LCS	Percent Out of Limit	Number of LCSD	Percent RPD Out of Limit
General Chemistry Parameters: Recovery Limits = 80% - 120%				
Total General Chemistry Parameters	4	0.0	—	—
Ammonia and Anions: Recovery Limits = 80% - 120%				
Total Ammonia and Anions	44	0.0	—	—

LCS = laboratory control sample

LCSD = laboratory control sample duplicate

RPD = relative percent difference

Table D-28. Laboratory Control Sample Results: Eberline Services

Constituent	Number of LCS	Percent Out of Limit	Number of LCSD	Percent RPD Out of Limit
Metals: Recovery Limits = 80% - 120%				
Total Metals	1	0.0	—	—
Radiological Parameters: Recovery Limits = 70% - 130%				
Total Radiochemistry Parameters	44	0.0	—	—

LCS = laboratory control sample
LCSD = laboratory control sample duplicate
RPD = relative percent difference

Table D-29. Laboratory Control Sample Results: TestAmerica Richland

Constituent	Number of LCS	Percent Out of Limit	Number of LCSD	Percent RPD Out of Limit
Metals: Recovery Limits = 80% - 120%				
Total Metals	96	0.0	—	—
Radiological Parameters: Recovery Limits = 70% - 130%				
Total Radiochemistry Parameters	629	0.0	—	—

LCS = laboratory control sample
LCSD = laboratory control sample duplicate
RPD = relative percent difference

Table D-30. Laboratory Control Sample Results: TestAmerica St. Louis

Constituent	Number of LCS	Percent Out of Limit	Number of LCSD	Percent RPD Out of Limit
General Chemistry Parameters: Recovery Limits = 80% - 120%, RPD Limit = 20%				
Total General Chemistry Parameters	139	0.0	2	0.0
Ammonia and Anions: Recovery Limits = 80% - 120%				
Total Ammonia and Anions	298	0.0	—	—
Metals: Recovery Limits = 80% - 120%				
Total Metals	1,678	0.1	—	—
Beryllium (ICP-AES)	59	1.7	—	—
Mercury (CVAA)	12	8.3	—	—

Table D-30. Laboratory Control Sample Results: TestAmerica St. Louis

Constituent	Number of LCS	Percent Out of Limit	Number of LCSD	Percent RPD Out of Limit
Volatile Organic Compounds: Recovery and RPD Limits = Laboratory Specific (Statistically Derived)				
Total Volatile Organic Compounds	3,920	1.5	1,726	2.0
1,1,1,2-Tetrachloroethane	57	1.8	28	0.0
1,1-Dichloroethane	78	1.3	34	0.0
1,1-Dichloroethene	78	1.3	34	0.0
1,2-Dichloroethene (Total)	64	3.1	28	0.0
1,2-Dichloropropane	65	1.5	30	0.0
1,4-Dichlorobenzene	75	4.0	32	0.0
1,4-Dioxane	80	2.5	38	31.6
1-Butanol	74	0.0	32	12.5
2-Butanone	79	3.8	36	5.6
2-Hexanone	63	1.6	28	7.1
4-Methyl-2-pentanone	76	1.3	32	0.0
Acetone	77	1.3	32	25.0
Acrolein	57	19.3	28	7.1
Acrylonitrile	38	2.6	20	0.0
Benzene	76	2.6	32	0.0
Bromodichloromethane	66	1.5	30	0.0
Bromoform	65	3.1	30	0.0
Bromomethane	63	4.8	28	0.0
Chlorobenzene	65	4.6	29	0.0
Chloroform	79	3.8	34	0.0
Chloroprene	57	1.8	28	0.0
cis-1,2-Dichloroethene	76	3.9	32	0.0
Ethyl cyanide	77	1.3	34	0.0
Ethyl methacrylate	57	1.8	28	0.0
Ethylbenzene	78	1.3	34	0.0
Isobutyl alcohol	57	1.8	28	7.1
Methacrylonitrile	57	1.8	28	0.0
Methylene chloride	78	1.3	34	0.0

Table D-30. Laboratory Control Sample Results: TestAmerica St. Louis

Constituent	Number of LCS	Percent Out of Limit	Number of LCSD	Percent RPD Out of Limit
Tetrachloroethene	78	3.8	27	3.7
Tetrahydrofuran	76	0.0	32	6.3
Vinyl acetate	57	1.8	28	0.0
Semivolatile Organic Compounds: Recovery and RPD Limits = Laboratory Specific (Statistically Derived)				
Total Semivolatile Organic Compounds	3,041	4.2	82	2.4
2,3,4,6-Tetrachlorophenol	30	6.7	—	—
2,4,5-Trichlorophenol	61	9.8	—	—
2,4,6-Trichlorophenol	61	8.2	—	—
2,4-Dichlorophenol	71	4.2	2	0.0
2,4-Dimethylphenol	61	4.9	—	—
2,4-Dinitrophenol	61	13.1	—	—
2,4-Dinitrotoluene	31	3.2	—	—
2,6-Dichlorophenol	30	10.0	—	—
2,6-Dinitrotoluene	31	3.2	—	—
2-Chlorophenol	61	9.8	—	—
2-Methylphenol (cresol, o-)	71	4.2	2	0.0
2-Nitroaniline	31	3.2	—	—
2-Nitrophenol	71	4.2	2	0.0
3+4 Methylphenol (cresol, m+p)	63	4.8	2	0.0
4,4'-DDD (Dichlorodiphenyldichloroethane)	10	20.0	—	—
4,4'-DDT (Dichlorodiphenyltrichloroethane)	10	10.0	—	—
4,6-Dinitro-2-methylphenol	61	3.3	—	—
4-Chloro-3-methylphenol	61	6.6	—	—
4-Chlorophenylphenyl ether	31	3.2	—	—
4-Nitrophenol	61	4.9	—	—
Acenaphthylene	48	4.2	4	50.0
Anthracene	48	4.2	4	0.0
Benzo(a)anthracene	48	2.1	4	0.0
Benzo(a)pyrene	48	4.2	4	0.0
Benzo(b)fluoranthene	48	2.1	4	0.0

Table D-30. Laboratory Control Sample Results: TestAmerica St. Louis

Constituent	Number of LCS	Percent Out of Limit	Number of LCSD	Percent RPD Out of Limit
Benzo(ghi)perylene	48	2.1	4	0.0
Bis(2-chloroethyl) ether	31	3.2	—	—
Butylbenzylphthalate	31	3.2	—	—
Chrysene	48	2.1	4	0.0
Delta-BHC	10	70.0	—	—
Dibenz[a,h]anthracene	48	6.3	4	0.0
Dibenzofuran	31	3.2	—	—
Dieldrin	10	10.0	—	—
Dimethyl phthalate	31	6.5	—	—
Di-n-butylphthalate	31	3.2	—	—
Di-n-octylphthalate	31	3.2	—	—
Dinoseb(2-secButyl-4,6-dinitrophenol)	30	16.7	—	—
Endosulfan II	10	10.0	—	—
Endosulfan sulfate	10	10.0	—	—
Endrin	10	10.0	—	—
Fluoranthene	48	6.3	4	0.0
Fluorene	48	2.1	4	0.0
Gamma-BHC (Lindane)	10	10.0	—	—
Heptachlor	10	20.0	—	—
Hexachlorobenzene	31	3.2	—	—
Hexachlorobutadiene	31	9.7	—	—
Methoxychlor	10	10.0	—	—
n-Nitrosodi-n-dipropylamine	31	3.2	—	—
Pentachlorophenol	71	18.3	2	0.0
Phenanthrene	48	2.1	4	0.0
Phenol	71	2.8	2	0.0
Pyrene	48	2.1	4	0.0
trans-Chlordane	4	25.0	—	—

Table D-30. Laboratory Control Sample Results: TestAmerica St. Louis

Constituent	Number of LCS	Percent Out of Limit	Number of LCSD	Percent RPD Out of Limit

BHC = benzene hexachloride (This is an erroneous name for hexachlorocyclohexane.)
CVAA = cold-vapor atomic absorption
ICP-AES = inductively coupled plasma - atomic emission spectroscopy
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
RPD = relative percent difference

Table D-31. Laboratory Control Sample Results: WSCF

Constituent	Number of LCS	Percent Out of Limit	Number of LCSD	Percent RPD Out of Limit
General Chemistry Parameters: Recovery Limits = 80% - 120%				
Total General Chemistry Parameters	322	0.0	—	—
Ammonia and Anions: Recovery Limits = 80% - 120%				
Total Ammonia and Anions	2,021	0.0	—	—
Metals: Recovery Limits = 80% - 120%				
Total Metals	4,813	0.1	—	—
Potassium (ICP-AES)	173	0.6	—	—
Sodium (ICP-AES)	154	1.3	—	—
Boron (ICP-MS)	1	100.0	—	—
Mercury (ICP-MS)	69	1.4	—	—
Volatile Organic Compounds: Recovery Limits = Laboratory Specific (Statistically Derived)				
Total Volatile Organic Compounds	1,628	0.0	—	—
Semivolatile Organic Compounds: Recovery and RPD Limits = Laboratory Specific (Statistically Derived)				
Total Semivolatile Organic Compounds	427	1.4	23	0.0
4-Chloroaniline	3	100.0	—	—
4-Nitrophenol	16	6.3	1	0.0
Aroclor-1254	24	4.2	2	0.0
Total petroleum hydrocarbons - diesel range	25	4.0	1	0.0
Radiological Parameters: Recovery Limits = 70% - 130%				
Total Radiochemistry Parameters	627	0.0	—	—

Table D-31. Laboratory Control Sample Results: WSCF

Constituent	Number of LCS	Percent Out of Limit	Number of LCSD	Percent RPD Out of Limit

ICP-AES = inductively coupled plasma - atomic emission spectroscopy
ICP-MS = inductively coupled plasma - mass spectrometry
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
RPD = relative percent difference

Table D-32. Matrix Spike Results: 222-S

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
General Chemistry Parameters: Recovery Limits = 75% - 125%, RPD Limit = 20%*				
Total General Chemistry Parameters	2	0.0	—	—
Ammonia and Anions: Recovery Limits = 75% - 125%, RPD Limit = 20%*				
Total Ammonia and Anions	8	0.0	—	—

*Sample duplicate RPD limit was used to evaluate matrix spike duplicates.
MS = matrix spike
RPD = relative percent difference

Table D-33. Matrix Spike Results: Eberline Services

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
Radiological Parameters: Recovery Limits = 60% - 140%*				
Total Radiochemistry Parameters	16	6.3	—	—
Tritium	3	33.3	—	—

* Recovery limits for technetium-99 and uranium were applied to all radiochemical parameters.
MS = matrix spike
RPD = relative percent difference

Table D-34. Matrix Spike Results: TestAmerica Richland

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
Metals: Recovery Limits = 75% - 125%, RPD Limit = 20%				
Total Metals	149	0.7	67	0.0
Uranium	15	6.7	—	—
Radiological Parameters: Recovery Limits = 60% - 140%*				
Total Radiochemistry Parameters	62	4.8	—	—
Technetium-99	62	4.8	—	—

* Recovery limits for technetium-99 were applied to all radiochemical parameters.

MS = matrix spike

RPD = relative percent difference

Table D-35. Matrix Spike Results: TestAmerica St. Louis

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
General Chemistry Parameters: Recovery Limits = 75% - 125%				
Total General Chemistry Parameters	78	9.0	—	—
Alkalinity	35	20.0	—	—
Ammonia and Anions: Recovery Limits = 75% - 125%				
Total Ammonia and Anions	370	1.1	—	—
Fluoride	60	1.7	—	—
Nitrogen in ammonia	3	33.3	—	—
Nitrogen in Nitrate	64	1.6	—	—
Phosphorus in phosphate	11	9.1	—	—
Metals: Recovery Limits = 75% - 125%, RPD Limit = 20%				
Total Metals	3,040	1.4	3,040	0.0
Calcium (ICP-AES)	112	18.8	112	0.0
Iron (ICP-AES)	110	1.8	110	0.0
Magnesium (ICP-AES)	112	1.8	112	0.0
Potassium (ICP-AES)	110	3.6	110	0.0
Silicon (ICP-AES)	4	50.0	4	0.0
Sodium (ICP-AES)	112	4.5	112	0.0

Table D-35. Matrix Spike Results: TestAmerica St. Louis

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
Strontium (ICP-AES)	108	2.8	108	0.0
Boron (ICP-MS)	48	6.3	48	0.0
Magnesium (ICP-MS)	14	14.3	14	0.0
Volatile Organic Compounds: Recovery and RPD Limits = Laboratory Specific (Statistically Derived)				
Total Volatile Organic Compounds	6,658	2.3	6,615	4.8
1,1,1,2-Tetrachloroethane	98	2.0	98	4.1
1,1,1-Trichloroethane	138	1.4	138	2.9
1,1,2,2-Tetrachloroethane	108	1.9	108	3.7
1,1,2-Trichloroethane	138	1.4	138	2.9
1,1-Dichloroethane	138	0.7	138	2.9
1,1-Dichloroethene	138	2.2	131	3.1
1,2,3-Trichloropropane	36	0.0	36	5.6
1,2-Dibromo-3-chloropropane	94	0.0	91	11.0
1,2-Dibromoethane	98	3.1	95	4.2
1,2-Dichloroethane	138	3.6	138	2.9
1,2-Dichloroethene (Total)	112	2.7	112	3.6
1,2-Dichloropropane	108	2.8	108	3.7
1,4-Dichlorobenzene	128	1.6	128	1.6
1,4-Dioxane	124	2.4	124	30.6
1-Butanol	126	3.2	126	17.5
2-Butanone	138	2.2	138	4.3
2-Chloroethyl vinyl ether	2	100.0	2	0.0
2-Hexanone	108	0.9	108	3.7
4-Methyl-2-pentanone	138	1.4	138	7.2
Acetone	138	2.9	138	10.1
Acetonitrile	100	2.0	100	10.0
Acrolein	98	18.4	98	4.1
Allyl chloride	98	1.0	98	4.1
Benzene	138	1.4	138	2.9
Bromodichloromethane	112	2.7	112	3.6

Table D-35. Matrix Spike Results: TestAmerica St. Louis

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
Bromoform	108	2.8	108	1.9
Bromomethane	108	6.5	102	3.9
Carbon disulfide	138	1.4	138	2.9
Carbon tetrachloride	112	2.7	112	3.6
Chlorobenzene	112	0.9	112	1.8
Chloroethane	108	0.9	108	3.7
Chloroform	142	0.7	142	4.2
Chloromethane	108	1.9	108	3.7
Chloroprene	98	0.0	98	2.0
cis-1,2-Dichloroethene	124	3.2	122	3.3
cis-1,3-Dichloropropene	108	1.9	108	3.7
Cyclohexanone	10	20.0	10	40.0
Dibromochloromethane	108	2.8	103	3.9
Dichlorodifluoromethane	98	3.1	98	4.1
Diethyl ether	10	20.0	10	20.0
Ethyl acetate	10	20.0	10	20.0
Ethyl cyanide	128	2.3	128	6.3
Ethyl methacrylate	98	1.0	98	4.1
Ethylbenzene	134	1.5	134	1.5
Iodomethane	98	0.0	98	2.0
Isobutyl alcohol	98	2.0	98	10.2
Methacrylonitrile	98	2.0	98	4.1
Methyl methacrylate	98	2.0	98	6.1
Methylene chloride	138	1.4	138	2.9
Styrene	108	0.9	108	1.9
Tetrachloroethene	138	4.3	132	1.5
Tetrahydrofuran	128	3.9	128	6.3
Toluene	138	0.7	138	1.4
trans-1,2-Dichloroethene	124	3.2	122	4.9
trans-1,3-Dichloropropene	108	0.9	108	3.7

Table D-35. Matrix Spike Results: TestAmerica St. Louis

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
trans-1,4-Dichloro-2-butene	98	2.0	98	12.2
Trichloroethene	140	2.9	131	3.1
Trichloromonofluoromethane	98	1.0	98	2.0
Vinyl acetate	100	3.0	100	4.0
Vinyl chloride	138	1.4	138	2.9
Semivolatile Organic Compounds: Recovery and RPD Limits = Laboratory Specific (Statistically Derived)				
Total Semivolatile Organic Compounds	5,614	3.7	5,614	3.4
1,2-Dichlorobenzene	58	1.7	58	0.0
1,3-Dichlorobenzene	58	1.7	58	3.4
2,3,4,6-Tetrachlorophenol	58	6.9	58	6.9
2,4,5-Trichlorophenol	116	5.2	116	5.2
2,4,6-Trichlorophenol	116	4.3	116	5.2
2,4-Dichlorophenol	132	3.0	132	4.5
2,4-Dimethylphenol	116	4.3	116	5.2
2,4-Dinitrophenol	114	6.1	114	19.3
2,4-Dinitrotoluene	58	3.4	58	0.0
2,6-Dichlorophenol	58	6.9	58	6.9
2,6-Dinitrotoluene	58	3.4	58	0.0
2-Chloronaphthalene	58	1.7	58	0.0
2-Chlorophenol	116	6.0	116	5.2
2-Methylphenol (cresol, o-)	132	3.8	132	4.5
2-Nitroaniline	58	0.0	58	3.4
2-Nitrophenol	132	3.8	132	4.5
3,3'-Dichlorobenzidine	58	0.0	58	13.8
3+4 Methylphenol (cresol, m+p)	116	3.4	116	10.3
4,4'-DDD (Dichlorodiphenyldichloroethane)	20	10.0	20	10.0
4,4'-DDE (Dichlorodiphenyldichloroethene)	20	5.0	20	10.0
4,4'-DDT (Dichlorodiphenyltrichloroethane)	20	20.0	20	10.0
4,6-Dinitro-2-methylphenol	116	4.3	116	3.4
4-Bromophenylphenyl ether	58	1.7	58	0.0

Table D-35. Matrix Spike Results: TestAmerica St. Louis

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
4-Chloro-3-methylphenol	116	3.4	116	5.2
4-Chloroaniline	58	0.0	58	6.9
4-Chlorophenylphenyl ether	58	1.7	58	0.0
4-Nitroaniline	58	0.0	58	3.4
4-Nitrophenol	116	4.3	116	10.3
Acenaphthene	84	4.8	84	0.0
Aldrin	20	10.0	20	10.0
Alpha-BHC	20	5.0	20	10.0
Anthracene	84	3.6	84	0.0
Benzo(a)anthracene	84	2.4	84	0.0
Benzo(a)pyrene	84	1.2	84	0.0
Benzo(b)fluoranthene	84	2.4	84	0.0
Benzo(ghi)perylene	84	1.2	84	0.0
Benzo(k)fluoranthene	84	1.2	84	0.0
beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	20	10.0	20	10.0
Bis(2-chloroethyl) ether	58	6.9	58	0.0
Bis(2-ethylhexyl) phthalate	74	1.4	74	0.0
Butylbenzylphthalate	58	1.7	58	0.0
Chrysene	84	4.8	84	2.4
Delta-BHC	20	35.0	20	10.0
Dibenz[a,h]anthracene	84	4.8	84	0.0
Dibenzofuran	58	3.4	58	0.0
Dieldrin	20	10.0	20	10.0
Diethylphthalate	58	6.9	58	0.0
Dimethyl phthalate	58	1.7	58	0.0
Di-n-butylphthalate	58	1.7	58	0.0
Di-n-octylphthalate	58	1.7	58	0.0
Dinoseb(2-secButyl-4,6-dinitrophenol)	58	8.6	58	6.9
Diphenylamine+N-Nitrosodiphenylamine	28	3.6	28	7.1
Endosulfan I	20	10.0	20	10.0

Table D-35. Matrix Spike Results: TestAmerica St. Louis

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
Endosulfan II	20	10.0	20	10.0
Endosulfan sulfate	20	5.0	20	10.0
Endrin	20	10.0	20	10.0
Endrin aldehyde	20	20.0	20	20.0
Fluoranthene	84	3.6	84	0.0
Fluorene	84	2.4	84	0.0
Gamma-BHC (Lindane)	20	10.0	20	0.0
Heptachlor	20	25.0	20	10.0
Heptachlor epoxide	20	10.0	20	10.0
Hexachlorobenzene	60	1.7	60	0.0
Hexachlorobutadiene	58	10.3	58	0.0
Hexachlorocyclopentadiene	58	0.0	58	6.9
Hexachloroethane	58	0.0	58	3.4
Indeno(1,2,3-cd)pyrene	84	0.0	84	2.4
Isophorone	58	1.7	58	0.0
Methoxychlor	20	10.0	20	0.0
Naphthalene	100	2.0	100	0.0
n-Nitrosodi-n-dipropylamine	58	5.2	58	0.0
n-Nitrosodiphenylamine	36	5.6	36	0.0
Pentachlorophenol	134	8.2	134	3.0
Phenanthrene	84	4.8	84	0.0
Phenol	132	1.5	132	7.6
Pyrene	84	3.6	84	2.4
Total petroleum hydrocarbons - diesel range	16	0.0	16	12.5

BHC = benzene hexachloride (This is an erroneous name for hexachlorocyclohexane.)
ICP-AES = inductively coupled plasma - atomic emission spectroscopy
ICP-MS = inductively coupled plasma - mass spectrometry
MS = matrix spike
RPD = relative percent difference

Table D-36. Matrix Spike Results: WSCF

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
General Chemistry Parameters: Recovery Limits = 75% - 125%, RPD Limit = 20%[a]				
Total General Chemistry Parameters	474	0.8	237	0.0
Total organic carbon	222	0.9	111	0.0
Total organic halides	248	0.8	124	0.0
Ammonia and Anions: Recovery Limits = 75% - 125%, RPD Limit = 20%[a]				
Total Ammonia and Anions	4,034	0.8	2,011	0.0
Chloride	662	1.7	330	0.0
Cyanide	54	3.7	27	0.0
Nitrogen in ammonium	32	6.3	16	0.0
Sulfate	662	2.6	330	0.0
Metals: Recovery Limits = 75% - 125%, RPD Limit = 20%				
Total Metals	9,264	0.4	4,468	0.0
Hexavalent Chromium	326	0.6	—	—
Aluminum (ICP-AES)	50	2.0	25	0.0
Iron (ICP-AES)	308	1.0	154	0.0
Potassium (ICP-AES)	308	3.2	154	0.0
Silicon (ICP-AES)	64	1.6	32	3.1
Silver (ICP-AES)	308	0.6	154	0.0
Sodium (ICP-AES)	308	0.3	153	0.0
Strontium (ICP-AES)	308	1.3	154	0.0
Thallium (ICP-AES)	42	4.8	21	0.0
Zinc (ICP-AES)	308	0.3	154	0.0
Barium (ICP-MS)	136	1.5	68	0.0
Boron (ICP-MS)	2	100.0	1	0.0
Mercury (ICP-MS)	138	1.4	69	0.0
Strontium (ICP-MS)	60	3.3	30	0.0
Uranium (ICP-MS)	198	1.0	99	0.0
Volatile Organic Compounds: Recovery and RPD Limits = Laboratory Specific (Statistically Derived)				
Total Volatile Organic Compounds	3,304	0.0	1,652	0.0

Table D-36. Matrix Spike Results: WSCF

Constituent	Number of Matrix Spikes	Percent MS Recovery Out of Limit	Number of Matrix Spike Duplicates	Percent MS RPD Out of Limit
Semivolatile Organic Compounds: Recovery and RPD Limits = Laboratory Specific (Statistically Derived)				
Total Semivolatile Organic Compounds	720	3.1	338	0.0
1,2,4-Trichlorobenzene	26	11.5	12	0.0
2,4-Dichlorophenol	26	11.5	12	0.0
2-Chlorophenol	26	3.8	12	0.0
2-Nitrophenol	26	3.8	12	0.0
2-Picoline	26	7.7	12	0.0
4-Nitrophenol	26	3.8	12	0.0
Naphthalene	26	3.8	12	0.0
Pentachlorophenol	26	3.8	12	0.0
Pyrene	26	3.8	12	0.0
Total petroleum hydrocarbons - diesel range	46	13.0	23	0.0
Tributyl phosphate	26	7.7	12	0.0
Radiological Parameters: Recovery Limits = 60% - 140%[b]				
Total Radiochemistry Parameters	159	0.0	—	—

a. Sample duplicate RPD limit was used to evaluate matrix spike duplicates.

b. Recovery limits for technetium-99 and uranium were applied to all radiochemical parameters.

ICP-AES = inductively coupled plasma - atomic emission spectroscopy

ICP-MS = inductively coupled plasma - mass spectrometry

MS = matrix spike

RPD = relative percent difference

Table D-37. Laboratory Sample Duplicate Results: 222-S

Constituent	Number of Laboratory Duplicates	Percent Relative Percent Difference Out of Limit
General Chemistry Parameters: Relative Percent Difference Limit = 20%		
Total General Chemistry Parameters	2	0.0
Ammonia and Anions: Relative Percent Difference Limit = 20%		
Total Ammonia and Anions	8	0.0

Table D-38. Laboratory Sample Duplicate Results: Eberline Services

Constituent	Number of Laboratory Duplicates	Percent Relative Percent Difference Out of Limit
Metals: Relative Percent Difference Limit = 20%*		
Total Metals	1	0.0
Radiological Parameters: Relative Percent Difference Limit = 20%		
Total Radiochemistry Parameters	69	0.0

* Derived from the matrix spike/matrix spike duplicate relative percent difference limit for inductively coupled plasma metals.

Table D-39. Laboratory Sample Duplicate Results: TestAmerica Richland

Constituent	Number of Laboratory Duplicates	Percent Relative Percent Difference Out of Limit
General Chemistry Parameters: Relative Percent Difference Limit = 20%		
Total General Chemistry Parameters	4	0.0
Metals: Relative Percent Difference Limit = 20%*		
Total Metals	82	0.0
Radiological Parameters: Relative Percent Difference Limit = 20%		
Total Radiochemistry Parameters	1,116	1.0
Carbon-14	50	10.0
Cobalt-60	74	1.4
Iodine-129	58	5.2
Strontium-90	44	2.3
Uranium-235	2	50.0

* Derived from the matrix spike/matrix spike duplicate relative percent difference limit for inductively coupled plasma metals.

Table D-40. Laboratory Sample Duplicate Results: TestAmerica St. Louis

Constituent	Number of Laboratory Duplicates	Percent Relative Percent Difference Out of Limit
General Chemistry Parameters: Relative Percent Difference Limit = 20%		
Total General Chemistry Parameters	80	3.8
Total organic halides	18	16.7
Ammonia and Anions: Relative Percent Difference Limit = 20%		
Total Ammonia and Anions	305	2.6
Fluoride	48	4.2
Nitrogen in Nitrate	50	2.0
Sulfide	25	20.0

Table D-41. Laboratory Sample Duplicate Results: WSCF

Constituent	Number of Laboratory Duplicates	Percent Relative Percent Difference Out of Limit
General Chemistry Parameters: Relative Percent Difference Limit = 20%		
Total General Chemistry Parameters	64	0.0
Ammonia and Anions: Relative Percent Difference Limit = 20%		
Total Ammonia and Anions	2,012	0.2
Fluoride	340	0.6
Nitrogen in ammonium	16	6.3
Nitrogen in Nitrate	334	0.6
Metals: Relative Percent Difference Limit = 20%*		
Total Metals	327	0.0
Hexavalent Chromium	327	0.0
Volatile Organic Compounds: Relative Percent Difference Limit = Laboratory Specific (Statistically Derived)		
Total Volatile Organic Compounds	36	0.0
Radiological Parameters: Relative Percent Difference Limit = 20%		
Total Radiochemistry Parameters	980	1.6
Gross alpha	127	2.4
Gross beta	158	0.6
Plutonium-239/240	9	11.1
Total beta radiostrontium	86	2.3
Tritium	100	4.0
Uranium-233/234	10	10.0
Uranium-238	10	40.0

* Derived from the matrix spike/matrix spike duplicate relative percent difference limit for inductively coupled plasma metals.

Table D-42. Surrogate Results: TestAmerica St. Louis

Constituent	Number of Surrogate Results	Percent Surrogate Recovery Out of Limit	Number of Surrogate Duplicates	Percent Surrogate Relative Percent Difference Out of Limit
Volatile Organic Compounds: Recovery and Relative Percent Difference Limits = Laboratory Specific (Statistically Derived)				
Total Volatile Organic Compounds	3,527	3.3	920	1.1
1,2-Dichloroethane-d4	872	1.8	227	2.6
4-Fluorobromobenzene	874	1.9	227	0.0
Dibromofluoromethane	873	5.0	228	1.8
Toluene-d8	875	4.6	228	0.0
Semivolatile Organic Compounds: Recovery and Relative Percent Difference Limits = Laboratory Specific (Statistically Derived)				
Total Semivolatile Organic Compounds	3,148	3.7	797	2.8
2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl	102	1.0	22	0.0
2,4,5,6-Tetrachloro-m-xylene	88	3.4	19	0.0
2,4,6-Tribromophenol	614	5.7	156	3.8
2-Fluorobiphenyl	391	6.4	98	2.0
2-Fluorophenol	612	4.4	156	5.1
Nitrobenzene-d5	391	1.8	98	0.0
o-Terphenyl	65	0.0	20	20.0
Phenol-d5	391	1.8	98	2.0
p-terphenyl	103	3.9	32	0.0
p-terphenyl-d14	391	1.5	98	0.0

Table D-43. Surrogate Results: WSCF

Constituent	Number of Surrogate Results	Percent Surrogate Recovery Out of Limit	Number of Surrogate Duplicates	Percent Surrogate Relative Percent Difference Out of Limit
Volatile Organic Compounds: Recovery and Relative Percent Difference Limits = Laboratory Specific (Statistically Derived)				
Total Volatile Organic Compounds	4,246	0.0	597	0.2
Ethylene Bromohydrin	51	0.0	12	8.3
Semivolatile Organic Compounds: Recovery and Relative Percent Difference Limits = Laboratory Specific (Statistically Derived)				
Total Semivolatile Organic Compounds	946	7.1	192	8.3
2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl	140	14.3	27	11.1
2,4,5,6-Tetrachloro-m-xylene	140	8.6	27	0.0
2,4,6-Tribromophenol	75	2.7	17	11.8
2-Fluorobiphenyl	75	1.3	17	0.0
2-Fluorophenol	75	4.0	17	11.8
Nitrobenzene-d5	75	5.3	17	0.0
o-Terphenyl	196	6.1	30	13.3
Phenol-d5	75	16.0	17	23.5
Terphenyl-d14 (7CI)	75	1.3	17	5.9

TableD-44. Summary of Analytical Laboratory Detection / Quantitation Limits Determined from Field Blanks Data: TestAmerica Laboratories

Period	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
Total Organic Carbon (µg/L)					
Apr-2010 - Mar-2011	14	35.07	162.32	487	1,620
Jul-2010 - Jun-2011	—	—	—	—	—
Oct-2010 - Aug-2011	—	—	—	—	—
Jan-2011 - Dec-2011	12	2.92	202.66	608	2,030
Total Organic Halides (µg/L)					
Apr-2010 - Mar-2011	—	—	—	—	—
Jul-2010 - Jun-2011	—	—	—	—	—
Oct-2010 - Aug-2011	—	—	—	—	—

TableD-44. Summary of Analytical Laboratory Detection / Quantitation Limits Determined from Field Blanks Data: TestAmerica Laboratories

Period	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
Jan-2011 - Dec-2011	12	3.33	3.41	10.2	34.1
Cesium-137 (pCi/L)					
Jan-2011 - Dec-2011	10	0.63	0.53	1.58	5.27
Cobalt-60 (pCi/L)					
Jan-2011 - Dec-2011	10	-0.20	1.07	3.22	10.7
Europium-152 (pCi/L)					
Jan-2011 - Dec-2011	10	-0.12	1.70	5.11	17.0
Europium-154 (pCi/L)					
Jan-2011 - Dec-2011	10	0.20	2.84	8.52	28.4
Europium-155 (pCi/L)					
Jan-2011 - Dec-2011	10	-0.24	1.85	5.54	18.5
Gross alpha (pCi/L)					
Jan-2011 - Dec-2011	7	0.0622	0.238	0.715	2.38
Gross beta (pCi/L)					
Jan-2011 - Dec-2011	7	1.01	1.03	3.10	10.3
Iodine-129 (pCi/L)					
Jan-2011 - Dec-2011	31	0.0250	0.0762	0.229	0.762
Strontium-90 (pCi/L)					
Jan-2011 - Dec-2011	5	0.0173	0.312	0.936	3.12
Technetium-99 (pCi/L)					
Jan-2011 - Dec-2011	10	2.10	2.68	8.03	26.8
Tritium (pCi/L)					
Jan-2011 - Dec-2011	14	12.3	81.5	244	815

Note: Total organic carbon and total organic halides data are from TestAmerica St. Louis. Radiological data are from TestAmerica Richland.

µg/L = micrograms per liter

pCi/L = picoCuries per liter

Table D-45. Summary of Analytical Laboratory Detection / Quantitation Limits Determined from Field Blanks Data: WSCF

Period	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
Total Organic Carbon (µg/L)					
Apr-2010 - Mar-2011	8	-4.52	23.5	71	240
Jul-2010 - Jun-2011	24	-10.6	67.0	201	670
Oct-2010 - Aug-2011	15	24.0	82.1	246	820
Jan-2011 - Dec-2011	3	42.9	97.6	293	980
Total Organic Halides (µg/L)					
Apr-2010 - Mar-2011	4	1.37	1.18	3.5	11.8
Jul-2010 - Jun-2011	8	1.75	1.50	4.5	15.0
Oct-2010 - Aug-2011	24	3.23	2.55	7.7	25.5
Jan-2011 - Dec-2011	13	3.86	2.81	8.4	28.1
Cesium-137 (pCi/L)					
Jan-2011 - Dec-2011	10	0.63	0.53	1.58	5.27
Cobalt-60 (pCi/L)					
Jan-2011 - Dec-2011	6	-0.12	6.21	18.6	62.1
Europium-152 (pCi/L)					
Jan-2011 - Dec-2011	6	-2.83	21.1	63.4	211
Europium-154 (pCi/L)					
Jan-2011 - Dec-2011	6	-0.95	10.2	30.5	102
Europium-155 (pCi/L)					
Jan-2011 - Dec-2011	6	10.3	17.7	53.2	177
Gross alpha (pCi/L)					
Jan-2011 - Dec-2011	28	-0.401	0.616	1.85	6.16
Gross beta (pCi/L)					
Jan-2011 - Dec-2011	40	0.742	1.34	4.03	13.4
Total beta radiostrontium (pCi/L)					
Jan-2011 - Dec-2011	19	0.705	1.96	5.89	19.6
Technetium-99 (pCi/L)					
Jan-2011 - Dec-2011	28	-3.71	3.78	11.3	37.8
Tritium (pCi/L)					
Jan-2011 - Dec-2011	46	7.77	122	365	1,215

µg/L = micrograms per liter
pCi/L = picoCuries per liter

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
General Chemical Parameters								
EPA-600/4-81-004, 310.1	Alkalinity	540	729.01	2,430.02	—	—	—	—
EPA-410.4	Chemical Oxygen Demand	6,500	8,775.08	29,250.26	—	—	—	—
EPA-600/4-81-004, 413.1	Oil and grease	2,100	2,835.03	9,450.09	—	—	—	—
EPA-420.2	Phenols	14	18.90	63.00	—	—	—	—
EPA-600/4-81-004, 120.1	Specific Conductance (µS/cm)	0.097	0.13	0.44	—	—	—	—
Anions								
EPA-600/R-93/100, 300.0	Bromide	25	33.75	112.50	—	—	—	—
EPA-600/R-93/100, 300.0	Chloride	20	27.00	90.00	—	—	—	—
EPA-600/R-93/100, 300.0	Fluoride	10	13.50	45.00	—	—	—	—
EPA-600/R-93/100, 300.0	Nitrogen in Nitrate	8.6	11.59	38.63	—	—	—	—
EPA-600/R-93/100, 300.0	Nitrogen in Nitrite	3	4.05	13.50	—	—	—	—
EPA-600/R-93/100, 300.0	Phosphorus in phosphate	54	72.90	243.00	—	—	—	—
EPA-600/R-93/100, 300.0	Sulfate	50	67.50	225.00	—	—	—	—
SW-846, 9012	Cyanide	1.5	2.03	6.75	—	—	—	—
EPA-600/R-93/100, 350.1	Nitrogen in Ammonium	9.2	12.42	41.40	—	—	—	—
SW-846, 9030	Sulfide	83	112.05	373.50	—	—	—	—
Metals								
SW-846, 6010	Aluminum	79.9	107.87	359.55	—	—	—	—
SW-846, 6010	Antimony	4	5.40	18.00	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 6010	Arsenic	2.7	3.65	12.15	—	—	—	—
SW-846, 6010	Barium	4	5.40	18.00	—	—	—	—
SW-846, 6010	Beryllium	0.61	0.82	2.75	—	—	—	—
SW-846, 6010	Bismuth	105	141.75	472.50	—	—	—	—
SW-846, 6010	Boron	10.8	14.58	48.60	—	—	—	—
SW-846, 6010	Cadmium	0.91	1.23	4.10	—	—	—	—
SW-846, 6010	Calcium	106	143.10	477.00	—	—	—	—
SW-846, 6010	Chromium	3.1	4.19	13.95	—	—	—	—
SW-846, 6010	Cobalt	4	5.40	18.00	—	—	—	—
SW-846, 6010	Copper	4.6	6.21	20.70	—	—	—	—
SW-846, 6010	Iron	28.2	38.07	126.90	—	—	—	—
SW-846, 6010	Lead	1.5	2.03	6.75	—	—	—	—
SW-846, 6010	Lithium	9.6	12.96	43.20	—	—	—	—
SW-846, 6010	Magnesium	132	178.20	594.01	—	—	—	—
SW-846, 6010	Manganese	3.3	4.46	14.85	—	—	—	—
SW-846, 6010	Molybdenum	5	6.75	22.50	—	—	—	—
SW-846, 6010	Nickel	13.3	17.96	59.85	—	—	—	—
SW-846, 6010	Phosphorus	75	101.25	337.50	—	—	—	—
SW-846, 6010	Potassium	1,650	2,227.52	7,425.07	—	—	—	—
SW-846, 6010	Selenium	5	6.75	22.50	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 6010	Silicon	40	54.00	180.00	—	—	—	—
SW-846, 6010	Silver	6	8.10	27.00	—	—	—	—
SW-846, 6010	Sodium	324	437.40	1,458.01	—	—	—	—
SW-846, 6010	Strontium	0.54	0.73	2.43	—	—	—	—
SW-846, 6010	Thallium	4	5.40	18.00	—	—	—	—
SW-846, 6010	Tin	13.5	18.23	60.75	—	—	—	—
SW-846, 6010	Vanadium	4.1	5.54	18.45	—	—	—	—
SW-846, 6010	Zinc	7	9.45	31.50	—	—	—	—
SW-846, 6020	Aluminum	12.9	17.42	58.05	—	—	—	—
SW-846, 6020	Antimony	1.7	2.30	7.65	—	—	—	—
SW-846, 6020	Arsenic	0.95	1.28	4.28	—	—	—	—
SW-846, 6020	Barium	0.2	0.27	0.90	—	—	—	—
SW-846, 6020	Beryllium	0.35	0.47	1.58	—	—	—	—
SW-846, 6020	Boron	10	13.50	45.00	—	—	—	—
SW-846, 6020	Cadmium	0.1	0.14	0.45	—	—	—	—
SW-846, 6020	Calcium	68.1	91.94	306.45	—	—	—	—
SW-846, 6020	Chromium	3.3	4.46	14.85	—	—	—	—
SW-846, 6020	Cobalt	0.22	0.30	0.99	—	—	—	—
SW-846, 6020	Copper	0.45	0.61	2.03	—	—	—	—
SW-846, 6020	Iron	20.4	27.54	91.80	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 6020	Lead	0.17	0.23	0.77	—	—	—	—
SW-846, 6020	Magnesium	5.2	7.02	23.40	—	—	—	—
SW-846, 6020	Manganese	0.24	0.32	1.08	—	—	—	—
SW-846, 6020	Molybdenum	0.41	0.55	1.85	27-May-11	1	1.35	4.50
SW-846, 6020	Nickel	0.4	0.54	1.80	—	—	—	—
SW-846, 6020	Potassium	41.6	56.16	187.20	—	—	—	—
SW-846, 6020	Selenium	1.6	2.16	7.20	—	—	—	—
SW-846, 6020	Silicon	17.8	24.03	80.10	—	—	—	—
SW-846, 6020	Silver	0.04	0.05	0.18	—	—	—	—
SW-846, 6020	Sodium	15	20.25	67.50	—	—	—	—
SW-846, 6020	Strontium	1	1.35	4.50	—	—	—	—
SW-846, 6020	Thallium	0.55	0.74	2.48	—	—	—	—
SW-846, 6020	Tin	1	1.35	4.50	—	—	—	—
SW-846, 6020	Titanium	2	2.70	9.00	—	—	—	—
SW-846, 6020	Uranium	0.23	0.31	1.04	—	—	—	—
SW-846, 6020	Vanadium	2.4	3.24	10.80	—	—	—	—
SW-846, 6020	Zinc	8.3	11.21	37.35	—	—	—	—
EPA-7196	Hexavalent Chromium	3.7	5.00	16.65	—	—	—	—
EPA-7074	Mercury	0.05	0.07	0.23	13-Jul-11	0.06	0.08	0.27
UTOT-KPA	Uranium	0.14	0.19	0.63	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
Volatile Organic Compounds								
SW-846, 8260	1,1,1,2-Tetrachloroethane	0.09	0.12	0.41	—	—	—	—
SW-846, 8260	1,1,1-Trichloroethane	0.069	0.09	0.31	—	—	—	—
SW-846, 8260	1,1,2,2-Tetrachloroethane	0.098	0.13	0.44	—	—	—	—
SW-846, 8260	1,1,2-Trichloro-1,2,2-trifluoroethane	0.1	0.14	0.45	—	—	—	—
SW-846, 8260	1,1,2-Trichloroethane	0.15	0.20	0.68	—	—	—	—
SW-846, 8260	1,1-Dichloroethane	0.068	0.09	0.31	—	—	—	—
SW-846, 8260	1,1-Dichloroethene	0.083	0.11	0.37	—	—	—	—
SW-846, 8260	1,1-Dichloropropene	0.079	0.11	0.36	—	—	—	—
SW-846, 8260	1,2,3-Trichlorobenzene	0.087	0.12	0.39	—	—	—	—
SW-846, 8260	1,2,3-Trichloropropane	0.15	0.20	0.68	—	—	—	—
SW-846, 8260	1,2,4-Trichlorobenzene	0.078	0.11	0.35	—	—	—	—
SW-846, 8260	1,2,4-Trimethylbenzene	0.084	0.11	0.38	—	—	—	—
SW-846, 8260	1,2-Dibromo-3-chloropropane	0.41	0.55	1.85	—	—	—	—
SW-846, 8260	1,2-Dibromoethane	0.13	0.18	0.59	—	—	—	—
SW-846, 8260	1,2-Dichlorobenzene	0.06	0.08	0.27	—	—	—	—
SW-846, 8260	1,2-Dichloroethane	0.1	0.14	0.45	—	—	—	—
SW-846, 8260	1,2-Dichloroethene (Total)	0.15	0.20	0.68	—	—	—	—
SW-846, 8260	1,2-Dichloropropane	0.097	0.13	0.44	—	—	—	—
SW-846, 8260	1,3,5-Trimethylbenzene	0.081	0.11	0.36	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	1,3-Dichlorobenzene	0.078	0.11	0.35	—	—	—	—
SW-846, 8260	1,3-Dichloropropane	0.072	0.10	0.32	—	—	—	—
SW-846, 8260	1,4-Dichlorobenzene	0.12	0.16	0.54	—	—	—	—
SW-846, 8260	1,4-Dioxane	7.6	10.26	34.20	—	—	—	—
SW-846, 8260	1-Butanol	12	16.20	54.00	—	—	—	—
SW-846, 8260	2,2-Dichloropropane	0.14	0.19	0.63	—	—	—	—
SW-846, 8260	2-Butanone	0.52	0.70	2.34	—	—	—	—
SW-846, 8260	2-Chloroethyl vinyl ether	0.16	0.22	0.72	—	—	—	—
SW-846, 8260	2-Chlorotoluene	0.078	0.11	0.35	—	—	—	—
SW-846, 8260	2-Hexanone	0.22	0.30	0.99	—	—	—	—
SW-846, 8260	2-Nitropropane	0.4	0.54	1.80	—	—	—	—
SW-846, 8260	4-Chlorotoluene	0.081	0.11	0.36	—	—	—	—
SW-846, 8260	4-Methyl-2-pentanone	0.12	0.16	0.54	—	—	—	—
SW-846, 8260	Acetic acid, methyl ester	0.37	0.50	1.67	—	—	—	—
SW-846, 8260	Acetone	0.34	0.46	1.53	—	—	—	—
SW-846, 8260	Acetonitrile	2	2.70	9.00	—	—	—	—
SW-846, 8260	Acrolein	2.8	3.78	12.60	—	—	—	—
SW-846, 8260	Acrylonitrile	0.58	0.78	2.61	—	—	—	—
SW-846, 8260	Allyl chloride	0.11	0.15	0.50	—	—	—	—
SW-846, 8260	Benzene	0.064	0.09	0.29	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	Bromobenzene	0.076	0.10	0.34	—	—	—	—
SW-846, 8260	Bromochloromethane	0.13	0.18	0.59	—	—	—	—
SW-846, 8260	Bromodichloromethane	0.088	0.12	0.40	—	—	—	—
SW-846, 8260	Bromoform	0.17	0.23	0.77	—	—	—	—
SW-846, 8260	Bromomethane	0.25	0.34	1.13	—	—	—	—
SW-846, 8260	Carbon disulfide	0.051	0.07	0.23	—	—	—	—
SW-846, 8260	Carbon tetrachloride	0.12	0.16	0.54	—	—	—	—
SW-846, 8260	Chlorobenzene	0.15	0.20	0.68	—	—	—	—
SW-846, 8260	Chloroethane	0.099	0.13	0.45	—	—	—	—
SW-846, 8260	Chloroform	0.1	0.14	0.45	—	—	—	—
SW-846, 8260	Chloromethane	0.077	0.10	0.35	—	—	—	—
SW-846, 8260	Chloroprene	0.097	0.13	0.44	—	—	—	—
SW-846, 8260	cis-1,2-Dichloroethene	0.087	0.12	0.39	—	—	—	—
SW-846, 8260	cis-1,3-Dichloropropene	0.073	0.10	0.33	—	—	—	—
SW-846, 8260	Cyclohexane	0.067	0.09	0.30	—	—	—	—
SW-846, 8260	Cyclohexanone	5.8	7.83	26.10	—	—	—	—
SW-846, 8260	Dibromochloromethane	0.13	0.18	0.59	—	—	—	—
SW-846, 8260	Dibromomethane	0.21	0.28	0.95	—	—	—	—
SW-846, 8260	Dichlorodifluoromethane	0.084	0.11	0.38	—	—	—	—
SW-846, 8260	Diethyl ether	0.26	0.35	1.17	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	Ethyl acetate	0.18	0.24	0.81	—	—	—	—
SW-846, 8260	Ethyl cyanide	1.4	1.89	6.30	—	—	—	—
SW-846, 8260	Ethyl methacrylate	0.11	0.15	0.50	—	—	—	—
SW-846, 8260	Ethylbenzene	0.086	0.12	0.39	—	—	—	—
SW-846, 8260	Hexachlorobutadiene	0.087	0.12	0.39	—	—	—	—
SW-846, 8260	Hexane	0.11	0.15	0.50	—	—	—	—
SW-846, 8260	Iodomethane	0.092	0.12	0.41	—	—	—	—
SW-846, 8260	Isobutyl alcohol	8.7	11.75	39.15	—	—	—	—
SW-846, 8260	Isopropylbenzene	0.083	0.11	0.37	—	—	—	—
SW-846, 8260	Methacrylonitrile	0.5	0.68	2.25	—	—	—	—
SW-846, 8260	Methyl cyclohexane	0.1	0.14	0.45	—	—	—	—
SW-846, 8260	Methyl methacrylate	0.26	0.35	1.17	—	—	—	—
SW-846, 8260	Methyl tert-butyl ether	0.11	0.15	0.50	—	—	—	—
SW-846, 8260	Methylene chloride	0.11	0.15	0.50	04-Jul-11	0.27	0.36	1.22
SW-846, 8260	Naphthalene	0.16	0.22	0.72	—	—	—	—
SW-846, 8260	n-Butylbenzene	0.25	0.34	1.13	—	—	—	—
SW-846, 8260	n-Propylbenzene	0.062	0.08	0.28	—	—	—	—
SW-846, 8260	o-Xylene	0.063	0.09	0.28	—	—	—	—
SW-846, 8260	p-Cymene	0.085	0.11	0.38	—	—	—	—
SW-846, 8260	Pentachloroethane	0.34	0.46	1.53	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	sec-Butylbenzene	0.086	0.12	0.39	—	—	—	—
SW-846, 8260	Styrene	0.074	0.10	0.33	—	—	—	—
SW-846, 8260	tert-Butylbenzene	0.11	0.15	0.50	—	—	—	—
SW-846, 8260	Tetrachloroethene	0.18	0.24	0.81	—	—	—	—
SW-846, 8260	Tetrahydrofuran	1.1	1.49	4.95	—	—	—	—
SW-846, 8260	Toluene	0.072	0.10	0.32	—	—	—	—
SW-846, 8260	trans-1,2-Dichloroethene	0.083	0.11	0.37	—	—	—	—
SW-846, 8260	trans-1,3-Dichloropropene	0.083	0.11	0.37	—	—	—	—
SW-846, 8260	trans-1,4-Dichloro-2-butene	0.29	0.39	1.31	—	—	—	—
SW-846, 8260	Trichloroethene	0.25	0.34	1.13	—	—	—	—
SW-846, 8260	Trichloromonofluoromethane	0.11	0.15	0.50	—	—	—	—
SW-846, 8260	Vinyl acetate	0.18	0.24	0.81	—	—	—	—
SW-846, 8260	Vinyl chloride	0.084	0.11	0.38	—	—	—	—
SW-846, 8260	Xylenes (total)	0.2	0.27	0.90	—	—	—	—
SW-846, 8015	TPH, gasoline fraction	10	13.50	45.00	—	—	—	—
Semivolatile Organic Compounds								
SW-846, 8040	2,3,4,6-Tetrachlorophenol	2	2.70	9.00	—	—	—	—
SW-846, 8040	2,4,5-Trichlorophenol	2.2	2.97	9.90	—	—	—	—
SW-846, 8040	2,4,6-Trichlorophenol	2.2	2.97	9.90	—	—	—	—
SW-846, 8040	2,4-Dichlorophenol	2.1	2.84	9.45	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8040	2,4-Dimethylphenol	2.1	2.84	9.45	—	—	—	—
SW-846, 8040	2,4-Dinitrophenol	2.4	3.24	10.80	—	—	—	—
SW-846, 8040	2,6-Dichlorophenol	2.1	2.84	9.45	—	—	—	—
SW-846, 8040	2-Chlorophenol	2.2	2.97	9.90	—	—	—	—
SW-846, 8040	2-Methylphenol (cresol, o-)	2.2	2.97	9.90	—	—	—	—
SW-846, 8040	2-Nitrophenol	2.3	3.11	10.35	—	—	—	—
SW-846, 8040	3+4 Methylphenol (cresol, m+p)	2.2	2.97	9.90	—	—	—	—
SW-846, 8040	4,6-Dinitro-2-methylphenol	2.2	2.97	9.90	—	—	—	—
SW-846, 8040	4-Chloro-3-methylphenol	2.4	3.24	10.80	—	—	—	—
SW-846, 8040	4-Nitrophenol	2.2	2.97	9.90	—	—	—	—
SW-846, 8040	Dinoseb(2-secButyl-4,6-dinitrophenol)	2.4	3.24	10.80	—	—	—	—
SW-846, 8040	Pentachlorophenol	2.4	3.24	10.80	—	—	—	—
SW-846, 8040	Phenol	2.3	3.11	10.35	—	—	—	—
SW-846, 8081	4,4'-DDD (Dichlorodiphenyldichloroethane)	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	4,4'-DDE (Dichlorodiphenyldichloroethene)	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	4,4'-DDT (Dichlorodiphenyltrichloroethane)	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Aldrin	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Alpha-BHC	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	0.013	0.02	0.06	—	—	—	—
SW-846, 8081	Chlordane	0.23	0.31	1.04	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8081	Delta-BHC	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Dieldrin	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Endosulfan I	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Endosulfan II	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Endosulfan sulfate	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Endrin	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Endrin aldehyde	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Gamma-BHC (Lindane)	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Heptachlor	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Heptachlor epoxide	0.01	0.01	0.05	16-May-11	0.017	0.02	0.08
SW-846, 8081	Methoxychlor	0.01	0.01	0.05	—	—	—	—
SW-846, 8081	Toxaphene	0.66	0.89	2.97	—	—	—	—
SW-846, 8082	Aroclor-1016	0.24	0.32	1.08	—	—	—	—
SW-846, 8082	Aroclor-1221	0.24	0.32	1.08	—	—	—	—
SW-846, 8082	Aroclor-1232	0.24	0.32	1.08	—	—	—	—
SW-846, 8082	Aroclor-1242	0.24	0.32	1.08	—	—	—	—
SW-846, 8082	Aroclor-1248	0.24	0.32	1.08	—	—	—	—
SW-846, 8082	Aroclor-1254	0.17	0.23	0.77	—	—	—	—
SW-846, 8082	Aroclor-1260	0.17	0.23	0.77	—	—	—	—
SW-846, 8270	1,2,4,5-Tetrachlorobenzene	1	1.35	4.50	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	1,2,4-Trichlorobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	1,2-Dichlorobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	1,3-Dichlorobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	1,4-Dichlorobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	1,4-Dioxane	1	1.35	4.50	—	—	—	—
SW-846, 8270	1,4-Naphthoquinone	1	1.35	4.50	18-Jul-11	2.3	3.11	10.35
SW-846, 8270	1-Naphthylamine	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,3,4,6-Tetrachlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,4,5-Trichlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,4,6-Trichlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,4-Dichlorophenol	1	1.35	4.50	18-Jul-11	1.1	1.49	4.95
SW-846, 8270	2,4-Dimethylphenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,4-Dinitrophenol	2	2.70	9.00	—	—	—	—
SW-846, 8270	2,4-Dinitrotoluene	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,6-Dichlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,6-Dinitrotoluene	2.2	2.97	9.90	—	—	—	—
SW-846, 8270	2-Acetylaminofluorene	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Chloronaphthalene	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Chlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Methylnaphthalene	1	1.35	4.50	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	2-Methylphenol (cresol, o-)	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Naphthylamine	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Nitroaniline	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Nitrophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Picoline	2	2.70	9.00	—	—	—	—
SW-846, 8270	3,3'-Dichlorobenzidine	1	1.35	4.50	18-Jul-11	1.3	1.76	5.85
SW-846, 8270	3,3'-Dimethylbenzidine	2.6	3.51	11.70	—	—	—	—
SW-846, 8270	3+4 Methylphenol (cresol, m+p)	2	2.70	9.00	—	—	—	—
SW-846, 8270	3-Methylcholanthrene	1	1.35	4.50	—	—	—	—
SW-846, 8270	3-Nitroaniline	1	1.35	4.50	—	—	—	—
SW-846, 8270	4,6-Dinitro-2-methylphenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	4-Aminobiphenyl	1	1.35	4.50	—	—	—	—
SW-846, 8270	4-Bromophenylphenyl ether	1	1.35	4.50	—	—	—	—
SW-846, 8270	4-Chloro-3-methylphenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	4-Chloroaniline	1	1.35	4.50	18-Jul-11	2.2	2.97	9.90
SW-846, 8270	4-Chlorophenylphenyl ether	1	1.35	4.50	—	—	—	—
SW-846, 8270	4-Methylphenol (cresol, p-)	10	13.50	45.00	23-Sep-11	1	1.35	4.50
SW-846, 8270	4-Nitroaniline	1	1.35	4.50	—	—	—	—
SW-846, 8270	4-Nitrophenol	2	2.70	9.00	—	—	—	—
SW-846, 8270	4-Nitroquinoline-1-oxide	5	6.75	22.50	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	5-Nitro-o-toluidine	1	1.35	4.50	—	—	—	—
SW-846, 8270	7,12-Dimethylbenz[a]anthracene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Acenaphthene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Acenaphthylene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Acetophenone	1	1.35	4.50	18-Jul-11	1.1	1.49	4.95
SW-846, 8270	alpha,alpha-Dimethylphenethylamine	22	29.70	99.00	—	—	—	—
SW-846, 8270	Aniline	1	1.35	4.50	18-Jul-11	1.3	1.76	5.85
SW-846, 8270	Anthracene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Aramite	20	27.00	90.00	23-Sep-11	2	2.70	9.00
SW-846, 8270	Azobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Benzo(a)anthracene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Benzo(a)pyrene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Benzo(b)fluoranthene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Benzo(ghi)perylene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Benzo(k)fluoranthene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Benzothiazole	1	1.35	4.50	—	—	—	—
SW-846, 8270	Benzyl alcohol	1	1.35	4.50	—	—	—	—
SW-846, 8270	Bis(2-chloro-1-methylethyl)ether	1	1.35	4.50	—	—	—	—
SW-846, 8270	Bis(2-Chloroethoxy)methane	1	1.35	4.50	—	—	—	—
SW-846, 8270	Bis(2-chloroethyl) ether	1	1.35	4.50	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	Bis(2-ethylhexyl) phthalate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Butylbenzylphthalate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Carbazole	1	1.35	4.50	—	—	—	—
SW-846, 8270	Chlorobenzilate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Chrysene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Diallate	2	2.70	9.00	—	—	—	—
SW-846, 8270	Dibenz[a,h]anthracene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Dibenzofuran	1	1.35	4.50	—	—	—	—
SW-846, 8270	Diethylphthalate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Dimethoate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Dimethyl phthalate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Di-n-butylphthalate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Di-n-octylphthalate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Dinoseb(2-secButyl-4,6-dinitrophenol)	2	2.70	9.00	—	—	—	—
SW-846, 8270	Diphenylamine+N-Nitrosodiphenylamine	1	1.35	4.50	—	—	—	—
SW-846, 8270	Disulfoton	1	1.35	4.50	—	—	—	—
SW-846, 8270	Ethyl methanesulfonate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Famphur	1.7	2.30	7.65	—	—	—	—
SW-846, 8270	Fluoranthene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Fluorene	1	1.35	4.50	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	Hexachlorobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Hexachlorobutadiene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Hexachlorocyclopentadiene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Hexachloroethane	1	1.35	4.50	—	—	—	—
SW-846, 8270	Hexachlorophene	10	13.50	45.00	—	—	—	—
SW-846, 8270	Hexachloropropene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Indeno(1,2,3-cd)pyrene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Isodrin	1	1.35	4.50	—	—	—	—
SW-846, 8270	Isophorone	1	1.35	4.50	—	—	—	—
SW-846, 8270	Isosafrole	1.3	1.76	5.85	—	—	—	—
SW-846, 8270	Kepone	20	27.00	90.00	—	—	—	—
SW-846, 8270	m-Dinitrobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Methapyrilene	1.3	1.76	5.85	—	—	—	—
SW-846, 8270	Methyl methanesulfonate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Methyl parathion	1	1.35	4.50	—	—	—	—
SW-846, 8270	Naphthalene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Nitrobenzene	1	1.35	4.50	18-Jul-11	1.1	1.49	4.95
SW-846, 8270	Nitrosopyrrolidine	1	1.35	4.50	—	—	—	—
SW-846, 8270	n-Nitrosodiethylamine	1	1.35	4.50	18-Jul-11	1.1	1.49	4.95
SW-846, 8270	n-Nitrosodimethylamine	2	2.70	9.00	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	n-Nitrosodi-n-butylamine	1	1.35	4.50	—	—	—	—
SW-846, 8270	n-Nitrosodi-n-dipropylamine	1	1.35	4.50	—	—	—	—
SW-846, 8270	n-Nitrosodiphenylamine	1	1.35	4.50	—	—	—	—
SW-846, 8270	n-Nitrosomethylethylamine	1	1.35	4.50	—	—	—	—
SW-846, 8270	n-Nitrosomorpholine	1	1.35	4.50	18-Jul-11	1.2	1.62	5.40
SW-846, 8270	n-Nitrosopiperidine	1	1.35	4.50	—	—	—	—
SW-846, 8270	O,O,O-Triethyl phosphorothioate	1	1.35	4.50	29-Jul-11	1.1	1.49	4.95
SW-846, 8270	O,O-Diethyl O-2-pyrazinyl phosphorothioate	1	1.35	4.50	—	—	—	—
SW-846, 8270	o-Toluidine	1	1.35	4.50	—	—	—	—
SW-846, 8270	Parathion	1	1.35	4.50	—	—	—	—
SW-846, 8270	p-Dimethylaminoazobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Pentachlorobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Pentachloroethane	1	1.35	4.50	18-Jul-11	1.3	1.76	5.85
SW-846, 8270	Pentachloronitrobenzene (PCNB)	1	1.35	4.50	—	—	—	—
SW-846, 8270	Pentachlorophenol	1.3	1.76	5.85	—	—	—	—
SW-846, 8270	Phenacetin	1	1.35	4.50	—	—	—	—
SW-846, 8270	Phenanthrene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Phenol	2	2.70	9.00	—	—	—	—
SW-846, 8270	Phorate	1	1.35	4.50	—	—	—	—
SW-846, 8270	p-Phenylenediamine	1	1.35	4.50	—	—	—	—

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	Pronamide	1	1.35	4.50	—	—	—	—
SW-846, 8270	Pyrene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Pyridine	2	2.70	9.00	—	—	—	—
SW-846, 8270	Safrol	1	1.35	4.50	—	—	—	—
SW-846, 8270	sym-Trinitrobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Tetraethyl dithiopyrophosphate (Sulfotepp)	1	1.35	4.50	—	—	—	—
SW-846, 8270	Total cresols	3	4.05	13.50	—	—	—	—
SW-846, 8270	Tributyl phosphate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Tris-2-chloroethyl phosphate	1	1.35	4.50	—	—	—	—
SW-846, 8310	Acenaphthene	0.65	0.88	2.93				
SW-846, 8310	Acenaphthylene	0.4	0.54	1.80				
SW-846, 8310	Anthracene	0.02	0.03	0.09				
SW-846, 8310	Benzo(a)anthracene	0.063	0.09	0.28				
SW-846, 8310	Benzo(a)pyrene	0.075	0.10	0.34				
SW-846, 8310	Benzo(b)fluoranthene	0.051	0.07	0.23				
SW-846, 8310	Benzo(ghi)perylene	0.16	0.22	0.72				
SW-846, 8310	Benzo(k)fluoranthene	0.074	0.10	0.33				
SW-846, 8310	Chrysene	0.035	0.05	0.16				
SW-846, 8310	Dibenz[a,h]anthracene	0.15	0.20	0.68				
SW-846, 8310	Fluoranthene	0.18	0.24	0.81				

Table D-46. Summary of Detection and Quantitation Limits: TestAmerica Laboratories

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8310	Fluorene	0.071	0.10	0.32				
SW-846, 8310	Indeno(1,2,3-cd)pyrene	0.14	0.19	0.63				
SW-846, 8310	Naphthalene	0.2	0.27	0.90				
SW-846, 8310	Phenanthrene	0.1	0.14	0.45	08-Jul-11	0.3	0.41	1.35
SW-846, 8310	Pyrene	0.083	0.11	0.37				
SW-846, 8015	TPH, diesel range	17	22.95	76.50				
SW-846, 8015	TPH, kerosene range	10	13.50	45.00				

Sources: EPA-600/4-81-004, *Environmental Radioactivity Laboratory Intercomparison Studies Program Fiscal Year 1981-1982*.

EPA/600/R-93/100, *Methods for the Determination of Inorganic Substances in Environmental Samples*.

SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*.

Note: Includes analytes from the TestAmerica Richland and TestAmerica St. Louis laboratories.

a. MDLs for many constituents changed during the fiscal year. For these constituents, the initial MDL, LOD, and LOQ were in effect until the date the values were updated (ending values, effective date). In cases where the MDL did not change, no ending values are listed.

b. These MDLs are adjusted to a dilution factor of one and the most commonly used sample volume. The MDLs reported with actual groundwater sample data are usually adjusted for the sample dilution factor or sample aliquot volume. Consequently, the MDLs reported with groundwater sample data may differ from those shown in this table.

BHC = benzene hexachloride (This is an erroneous name for hexachlorocyclohexane.)

LOD = limit of detection

LOQ = limit of quantitation

MDL = method detection limit

TPH = total petroleum hydrocarbons

Table D-47. Summary of Detection and Quantitation Limits: WSCF

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
General Chemical Parameters								
SM 2320B	Alkalinity	1,000	1,350.01	4,500.04	—	—	—	—
EPA-410.4	Chemical Oxygen Demand	10,000	13,500.12	45,000.41	—	—	—	—
EPA-600/4-81-004, 120.1	Specific Conductance (µS/cm)	0.50	0.68	2.25	—	—	—	—
Ammonia / Anions								
EPA-600/R-93/100, 300.0	Bromide	55	74.25	247.50	28-Jan-11	110	148.50	495.00
EPA-600/R-93/100, 300.0	Chloride	42	56.70	189.00	10-Feb-11	60	81.00	270.00
EPA-600/R-93/100, 300.0	Fluoride	44	59.40	198.00	10-Feb-11	23	31.05	103.50
EPA-600/R-93/100, 300.0	Nitrogen in Nitrate	9.5	12.81	42.70	10-Feb-11	19	25.62	85.39
EPA-600/R-93/100, 300.0	Nitrogen in Nitrite	18	24.25	80.85	10-Feb-11	20	26.93	89.75
EPA-600/R-93/100, 300.0	Phosphorus in Phosphate	70	94.50	315.00	28-Jan-11	42	56.70	189.00
EPA-600/R-93/100, 300.0	Sulfate	85	114.75	382.50	10-Feb-11	110	148.50	495.00
EPA-600/R-93/100, 335.2	Cyanide	4	5.40	18.00	—	—	—	—
EPA-600/R-93/100, 300.7	Nitrogen in Ammonium	2.4	3.24	10.80	2-Feb-11	1.4	1.89	6.30
Metals								
SW-846, 6010	Aluminum	19	25.65	85.50	—	—	—	—
SW-846, 6010	Antimony	47	63.45	211.50	19-May-11	36	48.60	162.00
SW-846, 6010	Arsenic	50	67.50	225.00	—	—	—	—
SW-846, 6010	Barium	4	5.40	18.00	—	—	—	—
SW-846, 6010	Beryllium	4	5.40	18.00	—	—	—	—

Table D-47. Summary of Detection and Quantitation Limits: WSCF

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 6010	Bismuth	37	49.95	166.50	—	—	—	—
SW-846, 6010	Boron	41	55.35	184.50	—	—	—	—
SW-846, 6010	Cadmium	4	5.40	18.00	—	—	—	—
SW-846, 6010	Calcium	28	37.80	126.00	19-May-11	49	66.15	220.50
SW-846, 6010	Chromium	14	18.90	63.00	19-May-11	5	6.75	22.50
SW-846, 6010	Cobalt	4	5.40	18.00	—	—	—	—
SW-846, 6010	Copper	5	6.75	22.50	28-Jul-11	4	5.40	18.00
SW-846, 6010	Iron	38	51.30	171.00	19-May-11	19	25.65	85.50
SW-846, 6010	Lead	42	56.70	189.00	—	—	—	—
SW-846, 6010	Lithium	4	5.40	18.00	—	—	—	—
SW-846, 6010	Magnesium	14	18.90	63.00	19-May-11	4	5.40	18.00
SW-846, 6010	Manganese	6	8.10	27.00	19-May-11	4	5.40	18.00
SW-846, 6010	Molybdenum	4	5.40	18.00	—	—	—	—
SW-846, 6010	Nickel	4	5.40	18.00	—	—	—	—
SW-846, 6010	Phosphorus	72	97.20	324.00	—	—	—	—
SW-846, 6010	Potassium	73	98.55	328.50	19-May-11	76	102.60	342.00
SW-846, 6010	Selenium	47	63.45	211.50	—	—	—	—
SW-846, 6010	Silicon	25	33.75	112.50	—	—	—	—
SW-846, 6010	Silver	7	9.45	31.50	19-May-11	4	5.40	18.00
SW-846, 6010	Sodium	11	14.85	49.50	19-May-11	10	13.50	45.00

Table D-47. Summary of Detection and Quantitation Limits: WSCF

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 6010	Strontium	4	5.40	18.00	28-Jul-11	9	12.15	40.50
SW-846, 6010	Thallium	49	66.15	220.50	—	—	—	—
SW-846, 6010	Tin	49	66.15	220.50	—	—	—	—
SW-846, 6010	Titanium	4	5.40	18.00	—	—	—	—
SW-846, 6010	Vanadium	17	22.95	76.50	19-May-11	5	6.75	22.50
SW-846, 6010	Zinc	4	5.40	18.00	28-Jul-11	5	6.75	22.50
EPA-600/R-94/111, 200.8	Aluminum	5	6.75	22.50	—	—	—	—
EPA-600/R-94/111, 200.8	Antimony	0.3	0.41	1.35	—	—	—	—
EPA-600/R-94/111, 200.8	Arsenic	0.4	0.54	1.80	9-Sep-11	0.2	0.27	0.90
EPA-600/R-94/111, 200.8	Barium	0.2	0.27	0.90	—	—	—	—
EPA-600/R-94/111, 200.8	Beryllium	0.05	0.07	0.23	9-Sep-11	0.1	0.14	0.45
EPA-600/R-94/111, 200.8	Boron	0.5	0.68	2.25	—	—	—	—
EPA-600/R-94/111, 200.8	Cadmium	0.1	0.14	0.45	26-Jun-11	0.05	0.07	0.23
EPA-600/R-94/111, 200.8	Chromium	0.5	0.68	2.25	26-Jun-11	0.1	0.14	0.45
EPA-600/R-94/111, 200.8	Cobalt	0.05	0.07	0.23	—	—	—	—
EPA-600/R-94/111, 200.8	Copper	0.1	0.14	0.45	—	—	—	—
EPA-600/R-94/111, 200.8	Lead	0.1	0.14	0.45	9-Sep-11	0.05	0.07	0.23
EPA-600/R-94/111, 200.8	Manganese	0.1	0.14	0.45	—	—	—	—
EPA-600/R-94/111, 200.8	Mercury	0.05	0.07	0.23	28-Jul-11	0.03	0.04	0.14
EPA-600/R-94/111, 200.8	Molybdenum	0.05	0.07	0.23	—	—	—	—

Table D-47. Summary of Detection and Quantitation Limits: WSCF

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
EPA-600/R-94/111, 200.8	Nickel	0.2	0.27	0.90	—	—	—	—
EPA-600/R-94/111, 200.8	Selenium	0.6	0.81	2.70	9-Sep-11	1	1.35	4.50
EPA-600/R-94/111, 200.8	Silver	0.1	0.14	0.45	26-Jun-11	0.05	0.07	0.23
EPA-600/R-94/111, 200.8	Strontium	0.1	0.14	0.45	—	—	—	—
EPA-600/R-94/111, 200.8	Thallium	0.05	0.07	0.23	—	—	—	—
EPA-600/R-94/111, 200.8	Thorium	0.1	0.14	0.45	—	—	—	—
EPA-600/R-94/111, 200.8	Tin	0.05	0.07	0.23	—	—	—	—
EPA-600/R-94/111, 200.8	Uranium	0.05	0.07	0.23	—	—	—	—
EPA-600/R-94/111, 200.8	Vanadium	0.2	0.27	0.90	—	—	—	—
EPA-600/R-94/111, 200.8	Zinc	0.8	1.08	3.60	—	—	—	—
EPA-7196	Hexavalent Chromium	2	2.70	9.00	—	—	—	—
Volatile Organic Compounds								
SW-846, 8015	1-Propanol	2,000	2,700.02	9,000.08	—	—	—	—
SW-846, 8015	Diethyl ether	2,000	2,700.02	9,000.08	—	—	—	—
SW-846, 8015	Ethanol	2,000	2,700.02	9,000.08	—	—	—	—
SW-846, 8015	Ethyl acetate	2,000	2,700.02	9,000.08	—	—	—	—
SW-846, 8015	Ethylene glycol	2,000	2,700.02	9,000.08	—	—	—	—
SW-846, 8015	Methanol	2,000	2,700.02	9,000.08	—	—	—	—
SW-846, 8260	1,1,1-Trichloroethane	1	1.35	4.50	—	—	—	—
SW-846, 8260	1,1,2-Trichloroethane	1	1.35	4.50	—	—	—	—

Table D-47. Summary of Detection and Quantitation Limits: WSCF

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	1,1-Dichloroethane	1	1.35	4.50	—	—	—	—
SW-846, 8260	1,1-Dichloroethene	1	1.35	4.50	—	—	—	—
SW-846, 8260	1,2-Dichloroethane	1	1.35	4.50	—	—	—	—
SW-846, 8260	1,4-Dichlorobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8260	1-Butanol	100	135.00	450.00	—	—	—	—
SW-846, 8260	2-Butanone	1	1.35	4.50	—	—	—	—
SW-846, 8260	4-Methyl-2-pentanone	1	1.35	4.50	—	—	—	—
SW-846, 8260	Acetone	1	1.35	4.50	—	—	—	—
SW-846, 8260	Benzene	1	1.35	4.50	—	—	—	—
SW-846, 8260	Carbon disulfide	1	1.35	4.50	—	—	—	—
SW-846, 8260	Carbon tetrachloride	1	1.35	4.50	—	—	—	—
SW-846, 8260	Chlorobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8260	Chloroform	1	1.35	4.50	—	—	—	—
SW-846, 8260	cis-1,2-Dichloroethene	1	1.35	4.50	—	—	—	—
SW-846, 8260	Ethyl cyanide	2	2.70	9.00	—	—	—	—
SW-846, 8260	Ethylbenzene	1	1.35	4.50	—	—	—	—
SW-846, 8260	Methylene chloride	1	1.35	4.50	—	—	—	—
SW-846, 8260	Tetrachloroethene	1	1.35	4.50	—	—	—	—
SW-846, 8260	Tetrahydrofuran	2	2.70	9.00	—	—	—	—
SW-846, 8260	Toluene	1	1.35	4.50	—	—	—	—

Table D-47. Summary of Detection and Quantitation Limits: WSCF

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	trans-1,2-Dichloroethene	1	1.35	4.50	—	—	—	—
SW-846, 8260	Trichloroethene	1	1.35	4.50	—	—	—	—
SW-846, 8260	Vinyl chloride	1	1.35	4.50	—	—	—	—
SW-846, 8260	Xylenes (total)	1	1.35	4.50	—	—	—	—
NWTPH-G	TPH, gasoline fraction	50	67.50	225.00	—	—	—	—
Semivolatile Organic Compounds								
EPA-8082	Aroclor 1016	0.1	0.14	0.45	—	—	—	—
EPA-8082	Aroclor 1221	0.2	0.27	0.90	—	—	—	—
EPA-8082	Aroclor 1232	0.1	0.14	0.45	—	—	—	—
EPA-8082	Aroclor 1242	0.1	0.14	0.45	—	—	—	—
EPA-8082	Aroclor 1248	0.1	0.14	0.45	—	—	—	—
EPA-8082	Aroclor 1254	0.1	0.14	0.45	—	—	—	—
EPA-8082	Aroclor 1260	0.1	0.14	0.45	—	—	—	—
EPA-8082	Aroclor 1262	0.1	0.14	0.45	—	—	—	—
EPA-8082	Aroclor 1268	0.1	0.14	0.45	—	—	—	—
SW-846, 8270	1,2,4-Trichlorobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	1,4-Dichlorobenzene	1	1.35	4.50	—	—	—	—
SW-846, 8270	1,4-Dioxane	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,3,4,6-Tetrachlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,4,5-Trichlorophenol	1	1.35	4.50	—	—	—	—

Table D-47. Summary of Detection and Quantitation Limits: WSCF

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	2,4,6-Trichlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,4-Dichlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,4-Dimethylphenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,4-Dinitrophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,4-Dinitrotoluene	1	1.35	4.50	—	—	—	—
SW-846, 8270	2,6-Dichlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Chlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Methylphenol (cresol, o-)	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Nitrophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	2-Picoline	1	1.35	4.50	—	—	—	—
SW-846, 8270	3+4 Methylphenol (cresol, m+p)	1	1.35	4.50	—	—	—	—
SW-846, 8270	4,6-Dinitro-2-methylphenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	4-Chloro-3-methylphenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	4-Nitrophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	Acenaphthene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Benzothiazole	1	1.35	4.50	—	—	—	—
SW-846, 8270	Bis(2-ethylhexyl) phthalate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Dinoseb(2-secButyl-4,6-dinitrophenol)	1	1.35	4.50	—	—	—	—
SW-846, 8270	Naphthalene	1	1.35	4.50	—	—	—	—
SW-846, 8270	n-Nitrosodimethylamine	1	1.35	4.50	—	—	—	—

Table D-47. Summary of Detection and Quantitation Limits: WSCF

Method	Constituent	Initial MDL[a,b] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a,b] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	n-Nitrosodi-n-dipropylamine	1	1.35	4.50	—	—	—	—
SW-846, 8270	Pentachlorophenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	Phenol	1	1.35	4.50	—	—	—	—
SW-846, 8270	Pyrene	1	1.35	4.50	—	—	—	—
SW-846, 8270	Total cresols	1	1.35	4.50	—	—	—	—
SW-846, 8270	Tributyl phosphate	1	1.35	4.50	—	—	—	—
SW-846, 8270	Tris-2-chloroethyl phosphate	1	1.35	4.50	—	—	—	—
NWTPH-Dx	TPH, diesel fraction	70	94.50	315.00	—	—	—	—
NWTPH-Dx	TPH, kerosene fraction	70	94.50	315.00	—	—	—	—

Sources: EPA-600/4-81-004, *Environmental Radioactivity Laboratory Intercomparison Studies Program Fiscal Year 1981-1982*.

EPA/600/R-93/100, *Methods for the Determination of Inorganic Substances in Environmental Samples*.

EPA-600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement I*.

SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*.

a. MDLs for many constituents changed during the fiscal year. For these constituents, the initial MDL, LOD, and LOQ were in effect until the date the values were updated (ending values, effective date). In cases where the MDL did not change, no ending values are listed.

b. These MDLs are adjusted to a dilution factor of one and the most commonly used sample volume. The MDLs reported with actual groundwater sample data are usually adjusted for the sample dilution factor or sample aliquot volume. Consequently, the MDLs reported with groundwater sample data may differ from those shown in this table.

LOD = Limit of detection

LOQ = Limit of quantitation

MDL = Method detection limit

TPH = total petroleum hydrocarbons

Appendix E—Overview of Hanford Hydrogeology and Geochemistry

C.J. Martin

This Appendix discusses the hydrogeologic setting of the Hanford Site. The deposition and later removal of sedimentary units in certain areas by cataclysmic flooding contribute to the complex hydrogeology. The regional geologic setting of the Pasco Basin and the Hanford Site has been described in the documents listed in Section 2.6. The following sections provide a basic summary of Hanford Site geology, hydrology, and geochemistry.

E.1 Stratigraphic Setting

This section discusses the geology of the Hanford Site. The Hanford Site lies within the Pasco Basin (Figure E-1). The geology of the Site has been studied extensively over the years. The simplified "layer cake" depositional model of basalt bedrock that is overlain by Ringold Formation sediments, overlain by Cold Creek sediments, overlain by Hanford formation sediments has been complicated by the method of deposition, and later removal, of some of the sedimentary units. During deposition of the Ringold Formation sediments, actions of the ancestral Columbia and Salmon/Clearwater River systems resulted in deposition of a thick sequence of alternating river gravels and sands, as well as overbank flood deposits, and alluvial fans shed from the surrounding hillsides. During the Cold Creek depositional cycle, while the activities in the ancestral river systems continued, large portions of the Pasco Basin remained stable. This stability allowed for the formation of structured soil horizons that can still be identified today in certain areas as the "early Palouse soil." During the last ice age, cataclysmic flooding deposited the coarse gravel to boulder sediments of the Hanford formation, while simultaneously scouring channels of varying depth into the previously deposited Cold Creek and Ringold sediments. As the multiple flooding events waned, and slack water conditions prevailed, fine sands to silts and clays were deposited over much of the Pasco Basin. All of these events contribute to the complex hydrogeology of the Hanford Site.

Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington (BHI-00184) provides a stratigraphic interpretation for the Ringold Formation based on facies associations and defines the areal extent of these suprabasalt units in the Pasco Basin. *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin* (DOE/RL-2002-39) presents the standardized stratigraphic nomenclature for post-Ringold Formation sediments. A generalized stratigraphic column showing the nomenclature is provided in Figure E-2. The following subsections discuss the various stratigraphic layers, from oldest (deepest) to youngest (shallowest).

E.1.1 Columbia River Basalt Group

The lowest geologic unit of interest for this report is the Columbia River Basalt Group. Within the Pasco Basin, the Elephant Mountain flows of the Saddle Mountains Basalt formation are generally the uppermost basalt flows. Beneath the Hanford Site's 200 Area, the Elephant Mountain Member consists of two flows and ranges in thickness from 20 to 30 meters (RHO-BWI-ST-14, *Subsurface Geology of the Cold Creek Syncline*). The earlier basalt flows below the Elephant Mountain Member are locally important but will not be discussed here.

The uppermost surface of the Elephant Mountain Member (basalt) is considered the base of the suprabasalt aquifer system (bedrock) because of its low permeability relative to the overlying sediments. This surface can be interpreted as either a groundwater no-flow boundary or a prescribe-flux boundary, depending on whether leakage between the confined and unconfined aquifers is considered significant (PNL-8971, *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System,*

FY 93 Status Report). In areas where the Elephant Mountain Basalt has been partially eroded (e.g., north of the 200 East Area), a similar boundary exists at the contact between the Rattlesnake Ridge interbed to the top of the Pomona basalt. In some areas, the upper surface of the Elephant Mountain Basalt is sufficiently fractured or rubbly to allow it to transmit water. In these areas the unconfined aquifer may extend into the upper portion of the basalt, and the massive flow interior acts as the no-flow boundary.

The basalt surface beneath the 200 Area dips south, forming the southern limb of the Gable Mountain anticline/northern limb of the Cold Creek syncline ("Paleodrainage of the Columbia River System on the Columbia Plateau of Washington State: A Summary" [Fecht et al., 1987]). Two smaller basalt folds or anticlinal ridges trending northwest-southeast extend above the water table and create barriers to groundwater flow (Figure E-3).

Sedimentary interbeds, collectively referred to as the Ellensburg Formation, were deposited between many of the flows of the Saddle Mountains Basalt. The Ellensburg Formation includes fluvial and lacustrine sediments consisting of muds, sands, and gravels. The Rattlesnake Ridge interbed is the uppermost and most laterally extensive of these interbeds on the Hanford Site, and several wells are completed in this confined aquifer.

Intercommunication of groundwater between the uppermost basalt-confined aquifer (the Rattlesnake Ridge interbed) and overlying suprabasalt aquifer system has been documented in some areas of the Hanford Site, most notably beneath the B Pond (RHO-BWI-ST-14) (see Chapter 15.0). Another area of intercommunication is near Gable Gap, where the upper basalt units have been eroded, exposing the lower units and interbeds to the uppermost unconfined aquifer (PNL-10817, *Hydrochemistry and Hydrogeologic Conditions Within the Hanford Site Upper Basalt Confined Aquifer System*). The dominant vertical flow is now upward in most of these intercommunication areas.

E.1.2 Ringold Formation

The thick sedimentary sequence of the Ringold Formation overlies the basalt. The Ringold Formation can be divided into three broad facies types, depending on the proximity to the ancient river systems and basaltic ridges of the time (Figure E-4):

- **Type I facies:** Consists of gravel and associated sand and silt representing a migrating channel deposit of the ancestral Columbia and/or Salmon/Clearwater River systems. This type of sediment is generally confined to the central portion of the Pasco Basin.
- **Type II facies:** Comprises mainly overbank sand, silt, and clay deposited around the margins of the basin, away from the main fluvial channel system.
- **Type III facies:** A fanglomerate facies comprising angular basaltic debris derived from side-stream alluvium shed from the flanks of the basalt ridges. This facies occurs only locally around the extreme margins of the basin.

To date, two separate Hanford Site stratigraphic classifications have been used to describe Ringold Formation sediments. One classification, developed in BHI-00184, is based on lithology; the second classification, developed by Pacific Northwest National Laboratory (PNL-10886, *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report*; PNL-8971), is based primarily on hydrostratigraphy. This report uses the hydrostratigraphic classification because it is more applicable to the issue of addressing groundwater movement in the suprabasalt sediments (Figure E-2). A hydrogeologic summary of these units is presented below.

The Ringold Formation is broadly divided into two units: an upper unit, consisting of lacustrine deposits and intercalated fluvial sands; and a lower unit that is subdivided into five subunits. BHI-00184 provides a detailed description of the upper Ringold unit. The upper Ringold unit forms the bluffs along the Columbia River north and east of the Hanford Site but has largely been removed by erosion from the site itself.

The lower Ringold Formation is subdivided into five subunits (units 5 through 9) and is discussed below, from deepest to shallowest.

E.1.2.1 Ringold Formation Unit 9

The deepest Ringold sediments belong to unit 9, which is a mixture of clay, silt, fine- to coarse-grained sand, and granule to cobble gravel. In the eastern portion of the 200 East Area, unit 9 can be further subdivided into three hydrogeologic units based on markedly different lithologies and hydraulic properties. The primary subunit is characterized as a silt to clay-rich confining zone with low permeability, classified as unit 9B. Subunits 9A and 9C have much higher permeabilities and lower clay content. Subunits 9A, 9B, and 9C can be differentiated and mapped as separate units using geophysical logs, lithologic logs, and drillers' reports based on the correlation of unit 9B where it is laterally continuous.

Unit 9 dips consistently to the south-southwest, roughly comparable to the basalt structure. Unit 9 increases in thickness from north to south into the Cold Creek syncline, suggesting deposition of Ringold unit 9 in an environment of continued structural growth of the Pasco Basin (SD-BWI-DP-039, *Suprabasalt Stratigraphy Within and Adjacent to the Reference Repository Location*; DOE/RW-0164, *Site Characterization Plan, Reference Repository Location, Hanford Site, Washington*).

The north-northeastern extent of unit 9 is approximate and is delineated as the erosional limit of cataclysmic flooding that traversed across the uplifted Gable Butte anticlinal area (PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*). In the scoured area (interpreted to be north of the erosional boundary), most of the Ringold Formation has been all or partially removed and/or reworked within the area of erosion. Data from north and east of the B Pond suggest that only portions of units 9A/9C and 9B are preserved on the lee side and between the smaller anticlinal ridges within this erosional area (PNNL-12261).

In the northern Hanford Site, unit 9 is present beneath the 100-B/C, 100-K, and 100-N Areas.

E.1.2.2 Ringold Formation Lower Mud Unit (Unit 8)

The Ringold lower mud unit is composed of a thick sequence of fluvial overbank, paleosol, and lacustrine silts and clay, with minor sand and gravel. A more detailed description of the lower mud unit is presented in BHI-00184.

The Ringold lower mud unit is the most significant confining unit within the suprabasalt aquifer system on the Central Plateau. The lower mud unit separates the saturated sediments of the suprabasalt aquifer system into (1) an uppermost unconfined aquifer system often referred to as the Hanford unconfined aquifer, and (2) a lower confined aquifer system referred to as the confined Ringold aquifer system. In the 200 East Area, a secondary confined Ringold aquifer system is composed of subunit 9A/9C gravels separated by subunit 9B. The uppermost unconfined aquifer system includes saturated sediments above the lower mud unit or the top of subunit 9B, or the top of basalt in the areas where the lower mud unit is absent.

BHI-00184 indicates that east of B Pond and south of the 200 East Area, the lower mud unit is regionally continuous throughout the Pasco Basin. However, as BHI-00184 and other publications describe, the lower mud unit is not present on the Gable Mountain anticline, including Gable Gap and the region to the south, extending to the northern boundary of the 200 West Area and including most of the 200 East Area. BHI-00184 suggests that the absence of the lower mud unit is due to either depositional thinning onto the basalt structure or truncation by Ringold unit 5 or Hanford formation sediments. Geologic, geophysical, and hydraulic data indicate that where channeling occurs, erosion appears to have scoured into and/or completely removed all the lower mud unit and unit 5, with the possible exception of small, localized remnants (Figure E-5).

Where the lower mud unit is present, the maximum thickness is between 26 meters (in the 200 West Area) and up to 29 meters (in the 200 East Area), and it dips south to southwest into the Cold Creek

syncline, roughly paralleling the basalt structure. The revised structural map of the Ringold lower mud unit illustrates that it is elevated above the groundwater surface east and south of the B Pond and between the 200 East and 200 West Areas (Figure E-6). In these areas where the Ringold lower mud unit is at or above the water table, it is mapped as a hydraulic barrier similar to the basalt surface (PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*).

The hydrogeologic continuity and thickness of the lower mud unit indicate that groundwater within the Hanford unconfined aquifer and confined Ringold aquifer system does not flow vertically through this unit. However, flow along the lateral boundary of the lower mud unit does occur, and where it has been removed by erosion, groundwater from the confined Ringold aquifer system may be in communication with groundwater from the uppermost unconfined aquifer. Along the May Junction Fault where uplift has juxtaposed the lower mud unit adjacent to the unconfined aquifer, intercommunication between the Ringold confined and the upper unconfined aquifers may also occur.

E.1.2.3 Ringold Formation Units 6 and 7, Overbank Deposits and Upper Mud Unit

Unit 7 consists of fluvial gravels overlain by the fine-grained overbank and lacustrine deposits (clay, silt, silty fine-grained sand, and paleosols) of Ringold unit 6. The shallowest overbank deposits are known informally as the Ringold upper mud unit in the 100 Area, where this unit forms the bottom of the unconfined aquifer. These units have been largely removed by later flooding from beneath the 200 Area or were possibly never deposited in this area.

E.1.2.4 Ringold Formation Unit 5

Unit 5 is the uppermost of the Ringold Formation units in the unconfined aquifer (Figure E-2) and is composed primarily of fluvial gravels that grade upward into the interbedded fluvial sand and silt of the upper Ringold unit (BHI-00184). The unconfined aquifer resides in Ringold unit 5 beneath the 100-B, 100-N, and 100-K Areas; most of the 200 West Area; and the southern and western portions of the 200 East Area.

In the 200 Area, unit 5 overlies the lower mud unit and is present everywhere, except the very northeastern portion of the 200 West Area and in the northern portion of the 200 East Area. Within the 200 East Area, unit 5 is present only in the southern portion because the unit has been removed by erosion (PNNL-13858).

Ringold unit 5 has also been removed from the Gable Gap and most of the 200 East Area to approximately the May Junction Fault. Unit 5 was not removed from the downthrown side of the fault because of structural displacement into the basin and distance away from the highest forces of the Pleistocene floods (PNNL-12261).

Ringold unit 5 is also absent beneath the eastern part of the "horn" area of the Hanford Site (i.e., the 100-H and 100-F Areas) and beneath the 300 Area.

E.1.3 Cold Creek Unit

After deposition of the Ringold Formation sediments, a period of regional incision occurred, followed by soil development and deposition of windblown sediments during the late Pliocene to early Pleistocene ("Late-Cenozoic Stratigraphy and Tectonic Evolution Within a Subsiding Basin, South-Central Washington" [Bjornstad, 1985]). These deposits are referred to as the Cold Creek unit (CCU). In the eastern portion of the Pasco Basin, the CCU is not found and, therefore, was either not deposited or was eroded later by the Columbia River or cataclysmic flooding.

Several different facies associations are represented by the CCU, including (1) mainstream alluvial, (2) calcic-paleosol, (3) side-stream-alluvial, (4) colluvial, and (5) overbank-eolian facies associations (Figure E-7). The CCU in the 200 West Area is represented by the calcic paleosol (the early Palouse soil) and overbank/eolian facies (Cold Creek silt unit [CCU_z]), which is a silt and/or well-sorted, fine sand.

In much of the 200 East Area and elsewhere in the Pasco Basin, a quartzo-feldspathic sandy gravel above the Ringold Formation and below the more basaltic Hanford formation has been identified. This intermediate gravel is referred to as the Cold Creek gravel unit (CCU_g) (PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and into the Upper Unconfined Aquifer Below the B-Complex*). The CCU_g is mineralogically similar to the Ringold Formation, with the exception that it often caves and heaves during drilling. The loose, unconsolidated nature of these sediments suggests that they are post-Ringold in age and belong to a mainstream gravel facies of the CCU. These most likely represent fluvial deposits from the ancestral Columbia River, perhaps equivalent to the pre-Missoula gravels (*Skagit/Hanford Nuclear Project, Preliminary Safety Analysis Report* [PSPL, 1982]) identified east of the 200 Area. The upper surface of the CCU_g unit shows ~10 meters of relief.

E.1.4 Hanford Formation

The "Hanford formation" is the informal name given to Pleistocene-age cataclysmic flood deposits in the Pasco Basin (DOE/RL-2002-39; RHO-BWI-ST-4, *Geological Studies of the Columbia Plateau – A Status Report*; DOE/RW-0164; "Quaternary Geology of the Columbia Plateau" [Baker et al., 1991]; "Geohydrologic Setting of the Hanford Site, South-Central Washington" [Lindsey et al., 1994]). Sources for the floodwaters included Glacial Lake Missoula, pluvial Lake Bonneville, and ice-margin lakes that formed around the margins of the Columbia Plateau (Baker et al., 1991). These floods periodically inundated the Pasco Basin during the Pleistocene, often eroding existing sediments ("Pre-Wisconsin Glacial Outburst Floods: Pedogenic and Paleomagnetic Evidence from the Pasco Basin and Adjacent Channeled Scabland" [Bjornstad and Fecht, 1989]). As the floodwaters encountered restricted flow through Wallula Gap, both coarse- and fine-grained sediments entrained in the floodwaters were deposited within the basin. As the floodwaters gradually drained away, both deposition and erosion occurred. This sequence of events occurred a number of times, leaving behind distinct geomorphic features (Figure E-8) and creating a complex stratigraphy within the Hanford formation, with lenses of sand and silt surrounded by sand and gravel. However, fine-grained sediments are mainly found near the margins of the basin, and coarse-grained sediments are found in the central portion where the flood currents were stronger.

The Hanford formation forms a nearly continuous blanket over the entire Hanford Site, except near flood-scoured Gable Butte/Gable Mountain and other basalt outcrops. In the northern portion of the 200 West Area, the Hanford formation directly overlies basalt; further to the south, it overlies the CCU and Ringold Formation. The Hanford formation consists predominantly of unconsolidated sediments covering a wide range in grain size: from boulder-size gravel to sand, silty sand, and silt. Gravel clasts are composed of mostly sub-angular to sub-rounded basalt. Mineralogically, the sand fraction of the Hanford formation averages ~50% mafic rock fragments (i.e., basalt) and ~50% quartz feldspar (RHO-ST-23, *Geology of the Separations Areas, Hanford Site, South-Central Washington*).

Cataclysmic flood deposits of the Hanford formation have been classified into three facies types (gravel, sand, and interbedded sand- and silt-dominated), which grade into one another both vertically and laterally. The three facies may interfinger with or grade from gravel to sand, or sand to fine-grained facies, but rarely from gravel to fine-grained facies.

E.1.4.1 Gravel-Dominated Facies

The gravel-dominated facies of the Hanford formation (designated as "H1" in the cross sections) consists of coarse-grained basaltic sand and granule- to boulder-size gravel. These deposits display an open-framework texture, plane to low-angle massive bedding, and large-scale planar cross-bedding in outcrop. Gravel-dominated beds sometimes grade upward into sand- and silt-dominated facies. Gravel clasts are dominantly basalt with lesser amounts of Ringold Formation clasts, granite, quartzite, and gneiss (WHC-SD-EN-TI-012, *Geologic Setting of the 200-East Area: An Update*). The gravel-dominated facies was deposited by high-energy floodwaters in or immediately adjacent to the main cataclysmic flood channels (i.e., the Pasco Basin channel way [Figures E-8, E-9, and E-10]).

E.1.4.2 Sand-Dominated Facies

The sand-dominated facies of the Hanford formation (designated as "H2" in the cross sections) consists of fine- to coarse-grained sand and granule gravel. The sands typically have high basalt content and are commonly referred to as black, gray, or "salt-and-pepper" sands. The sands may contain small pebbles and rip-up clasts, pebble-gravel interbeds, and often grade upward into thin (less than 1 meter) zones of silt-dominated facies. This facies commonly displays plane lamination and bedding, and also less flood channels during the waning stages of flooding. This facies is transitional between the gravel-dominated facies and the silt-dominated facies, and it is the major component of the Hanford sand plain (Figures E-8 and E-11).

E.1.4.3 Interbedded Sand- and Silt-Dominated Facies

The interbedded sand and silt-dominated facies of the Hanford formation (designated as "H3" but not occurring in any of the cross sections) consists of thin-bedded, plane-laminated, and ripple cross-laminated silt and fine- to coarse-grained sand. Beds are typically a few centimeters to a meter in thickness and commonly display normally graded bedding (WHC-SD-EN-TI-012). Sediments of this facies were deposited under slack water conditions and in back-flooded areas (DOE/RW-0164; Baker et al., 1991). This facies is typified by the stratigraphy found through the various flood bars (Figure E-8).

E.1.5 Clastic Dikes

Clastic dikes are vertical to sub-vertical sedimentary structures that crosscut normal sedimentary layering. Clastic dikes are a common geologic feature of the Hanford formation in the 200 Area, especially in the sand- and silt-dominated facies. Clastic dikes are much less common in the gravel-dominated facies of the Hanford formation.

Clastic dikes occur in swarms and form four types of networks (BHI-01103, *Clastic Injection Dikes of the Pasco Basin and Vicinity*): (1) regular-shaped polygonal patterns, (2) irregular-shaped polygonal patterns, (3) pre-existing fissure fillings, and (4) random occurrences. Regular polygonal networks resemble four- to eight-sided polygons and typically range from 3 centimeters to 1 meter in width, 2 meters to greater than 20 meters in depth, and 1.5 to 100 meters along strike. Smaller dikelets, sills, and small-scale faults and shears are commonly associated with master dikes that form the polygons.

In general, a clastic dike has an outer skin of clay with coarser infilling material. Clay linings are commonly 0.03 to 1.0 millimeters in thickness, but linings up to ~10 millimeters are known. The width of individual infilling layers ranges from as little as 0.01 millimeters to more than 30 centimeters, and their length can vary from ~0.2 meters to more than 20 meters. Infilling sediments are typically poorly sorted to well-sorted sand but may contain clay, silt, and gravel (HNF-4936, *Subsurface Conditions Description for the S-SX Waste Management Area*). The importance of clastic dikes in determining the migration potential of contaminants from the near-surface disposal facilities to the water table is still debated.

E.1.6 Holocene Surficial Deposits

Holocene surficial deposits consisting of silt, sand, and gravel form a thin (less than 5-meter) veneer across much of the Hanford Site. In the 200 West Area and the southern portion of the 200 East Area, these deposits consist dominantly of laterally discontinuous sheets of windblown silt (loess) and fine-grained sand (PNNL-12086, *Hanford Site Groundwater Monitoring for Fiscal Year 1998*).

E.2 Tectonic Setting

Tectonic activity has occurred in the Pasco Basin throughout its history but has become fairly stable since the deposition of the CCU sediments. The Columbia River Basalt and Ringold Formation sediments both show extensive structural development in the form of anticlines and synclines (folded ridges and valleys). The larger of these structures on the Hanford Site are shown in Figure E-3. From a hydrogeologic perspective the Umtanum Ridge-Gable Mountain anticline is the more important feature. This anticline is an upward flexure of the Columbia River Basalt that creates Gable Butte and Gable

Mountain and has smaller anticlines associated with its limbs that place the basalt at or above the water table in areas to the southwest.

As an additional visual guide to the key stratigraphic elements, three cross sections from *Hydrogeologic Model for the Gable Gap Area, Hanford Site* (PNNL-19702) are provided in this chapter. Although of limited extent, these cross sections provide a view of the complex geology of the Hanford Site resulting from structural deformation as well as from cataclysmic floods during the last ice age. Cross-section 1 (A-A') (Figure E-10) is along a roughly north-south line from the upstream edge of the horn flood bar south through Gable Gap to the southern end of Waste Management Area B-BX-BY (Figure E-9). Cross-section 2 (B-B') (Figure E-11) is an east-west line across Gable Gap showing the paleochannels incised into the basalts. Cross-section 3 (C-C') (Figure E-5) is another roughly east-west line located further south than cross-section 2; it clearly shows how the incised paleochannels left remnants of Ringold Formation sediments and places Hanford formation sediments in direct communication with the basalt-confined aquifers.

E.3 Hydrologic Setting

Both unconfined and confined aquifer systems lie beneath most of the Hanford Site. The unconfined aquifer system is located in unconsolidated to semiconsolidated sediments of the Hanford and Ringold formations overlying the basalt bedrock. In some areas, the unconfined aquifer extends into the fractured upper zone of the underlying basalt. Parts of this aquifer are locally semiconfined or confined (confined Ringold). However, because the entire suprabasalt aquifer system is interconnected on a Hanford Site-wide scale, this system has commonly been referred to as the Hanford unconfined aquifer. Aquifers located within the Columbia River Basalt Group are referred to as the basalt-confined aquifer system.

E.3.1 Confined Aquifer

Confined aquifers within the Columbia River Basalt Group are composed of relatively permeable sedimentary interbeds and the brecciated tops of basalt flows. The horizontal hydraulic conductivities of most of these aquifers range from 10^{-4} to 10^{-10} meters per second. Dense interior sections of the basalt flows have horizontal hydraulic conductivities ranging from 10^{-9} to 10^{-15} meters per second, about five orders of magnitude lower than those of the confined aquifers (DOE/RW-0164). Groundwater in the confined aquifers underlying the Hanford Site results mainly from infiltration of precipitation and stream flow, within recharge areas along the periphery of the Pasco Basin (DOE/RW-0164). Hydraulic head information indicates that groundwater in the confined aquifers flows generally toward the Columbia River and, in some places, toward areas of enhanced vertical flow communication with the unconfined system (*Maps Showing Ground-Water Levels in the Columbia River Basalt and Overlying Materials, Spring 1983, Southeastern Washington* [Bauer et al., 1985]; SD-BWI-TI-335, *Fresh-Water Potentiometric Map and Inferred Flow Direction of Ground Water Within the Mabton Interbed, Hanford Site, Washington State -- January 1987*; DOE/RW-0164).

With regard to development of a conceptual model for groundwater flow and contaminant migration in the unconfined aquifer, the confined aquifer system is important because the two systems are known to be in hydraulic communication in the area northwest of the 200 East Area (RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Area of the Hanford Site*; DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*). Although the dominant gradient is now upward in the confined aquifer system (flow moving from the confined to the unconfined aquifer), the potential also exists for significant downward groundwater leakage between the two systems in areas where hydraulic heads in the unconfined aquifer were artificially increased (see Chapter 15.0, Section 15.2).

E.3.2 Unconfined Aquifer

Groundwater in the unconfined aquifer at the Hanford Site generally flows from recharge areas in the elevated region near the western boundary of the Site, toward the Columbia River on the eastern and

northern boundaries. The Columbia River is the primary discharge area for the unconfined aquifer. The Yakima River borders the Hanford Site on the southwest and is generally regarded as a source of recharge. Natural areal recharge across the entire Hanford Site depends on a number of variables, most notably soil type and vegetation cover. Thus, recharge ranges from a general low of 1.5 millimeters per year for areas with a natural shrub-steppe vegetation cover to a high of 52 centimeters per year for unvegetated areas in the 100-H Area and eastern 200 Area (PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*). It should also be noted that recharge can be artificially reduced/enhanced to as low as 0.04 millimeters per year for engineered evapotranspiration covers or as high as 92 millimeters per year for unvegetated gravel areas. Since 1944, the artificial recharge from Hanford Site wastewater disposal operations has been greater than the natural recharge, estimated at 17.2 millimeters per year (PNNL-18807, *Soil Water Balance and Recharge Monitoring at the Hanford Site – FY09 Status Report*). An estimated 1.68×10^{12} liters of wastewater were discharged to disposal ponds, trenches, and cribs to date. The volumes of wastewater discharged to the ground surface have steadily declined, from ~14 billion liters in 1990, to ~0.6 billion liters by 2000. The greatest decreases occurred in 1996, when all major waste streams were discontinued and combined into very few Washington State Permitted liquid discharges. In calendar year 2010 ~333 million liters of wastewater were discharged to the ground surface. The two largest discharge locations are on the Central Plateau at the 200 Area Treated Effluent Disposal Facility (~93% of the total site-wide discharge) and the State-Approved Land Disposal Site (~6% of the total). The remaining ~1% of artificial recharge comes from releases to the 400 Area process ponds and the 100-N Area filter backwash pond and sanitary sewage lagoon.

The unconfined aquifer at the Hanford Site lies mainly within the Ringold Formation and Hanford formation. Horizontal hydraulic conductivities of sand and gravel facies within the Ringold Formation generally range from $\sim 10^{-4}$ to 10^{-5} meters per second (DOE/RW-0164). Because the Ringold sediments are more heterogeneous and consolidated, contain more silt, and are not as well sorted, these sediments are approximately three times less permeable than the sediments of the overlying Hanford formation along the River Corridor and up to 1,000 times less permeable than the Hanford formation sediments in the Central Plateau. Wastewater discharges increased the water table elevation and created groundwater mounds under the two main wastewater disposal areas near the 200 East and 200 West Areas. Because of the increased groundwater elevation during site operations, the unconfined aquifer extended upward into the Hanford formation. This change resulted in increased transmissivity. Because large wastewater discharges ceased, water levels have declined and are approaching pre-Hanford conditions, as well as an associated decrease in transmissivity.

From 1944 through 1989, the largest water table increase of ~24 meters occurred under the 216-U-10 Pond in the 200 West Area, while an increase of ~9 meters occurred under the 216-B-3 Ponds near the 200 East Area. The volume of water discharged to the ground at the 200 West Area is actually less than that discharged at the 200 East Area; however, the lower permeability of the aquifer in the vicinity of the 200 West Area has inhibited groundwater movement in this area and resulted in a higher groundwater mound. The presence of the groundwater mounds also affected the direction of groundwater movement, causing radial flow from the discharge areas. In *Hanford Site Water-Table Changes, 1950 Through 1980 -- Data Observations and Evaluation* (PNL-5506), changes documented in the water table elevation showed that the edge of the mounds migrated outward from the sources over time until about 1980. Water levels have declined in most areas since 1980 due to decreased wastewater discharges (PNL-7498, *Evaluation of Hanford Site Water-Table Changes -- 1980 to 1990*).

Because non-permitted discharges of wastewater to unlined ponds ceased in 1996, groundwater levels have been declining across the Hanford Site. The water table has decreased 3 meters in the 200 East Area and 13 meters in the 200 West Area. Although some permitted discharges continue today (e.g., Treated Effluent Disposal Facility and State-Approved Land Disposal Site), the water table continues to decline. As a result, groundwater flow directions around the Hanford Site are also changing to a more regional direction (see discussion in Chapter 3.0).

In the 1950s through 1960s, groundwater mounds of 6 to 9 meters were present in each of the 100 Areas (WHC-SD-EN-TI-023, *Hydrologic Information Summary for the Northern Hanford Site*). A mound persisted in the 100-N Area until 1991.

E.3.3 Vadose Zone

The Hanford formation and CCU comprise most of the vadose zone. The CCU (both CCU_z and CCU_g) represents relatively thin, but significant, depositional units of post-Ringold and pre-Hanford sedimentation. The vadose zone ranges in thickness from less than 1 meter near the Columbia River to greater than 50 meters beneath the Central Plateau.

E.3.4 Groundwater/River Interactions

It is widely accepted that the typical groundwater flow system is influenced by the river flow system near the Columbia River. This influence takes the form of a dynamic "zone of interaction," where mixing of groundwater and river water occurs. Physical, chemical, and biological processes occur within the zone of interaction that potentially alter the characteristics of the approaching groundwater. Physical processes include layering and mixing of groundwater and river water (tending to dilute contaminants to lower concentrations), which infiltrates the banks and riverbed sediments, as well as varying hydraulic gradients caused by river-stage fluctuations. Chemical processes may change the characteristics of a contaminant in groundwater so it becomes less mobile (e.g., adsorbs to sediment or precipitates) or more mobile (bonds to non-ionic organic material). Biological activity in the zone may capture and immobilize contaminants, or it may introduce the contaminants into the food chain. Current information to date suggests that physical processes are the dominant influence on contaminant concentrations and fluxes at locations of discharge of the unconfined aquifer at the Hanford Site into the free-flowing stream of the Columbia River.

A number of reports have been issued that address various aspects of the zone of interaction. One of the more detailed of reports (PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River*, discusses modeling the flow and determining the mixing efficiencies within the zone of interaction. PNNL-13674 notes that discharge into the river environment occurs across two primary interfaces: (1) the region between high and low river stage, generally referred to as the "riparian zone;" and (2) an interface that exists within the river channel substrate that is constantly submerged (i.e., at elevations below the lowest river stage), known as the "hyporheic zone."

Within the riparian zone, river water infiltrates the banks during periods of high river stage and forms either a layered system or a mixture during interaction with the approaching groundwater. As seepage from the bank occurs during the period of low river stage, the composition of the seepage may change dramatically from nearly pure river water to primarily groundwater.

In the hyporheic zone, sediment porewater is influenced by the entrainment of river water and the gradual influx of groundwater that upwells from the underlying aquifer. As this zone is constantly submerged, the composition is thought to be more stable, although it is possible for areas of preferential upwelling to be present.

Groundwater flow near the river is strongly influenced by fluctuations in Columbia River stage, which in turn is controlled by dams. River stage can vary 1.8 to 2.4 meters daily and 2.4 to 3.0 meters seasonally (PNNL-13674). As a result of these fluctuations, the dynamics of groundwater flow near the river change on multiple scales (hourly, daily, and seasonally). Normal peak discharge occurs during June, and normal low flow occurs in October and November. During low river stage in the fall and winter, the groundwater flow is toward the river; as the river stage increases in the spring and summer, the gradient becomes less and may even reverse direction in response (SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*). These observations suggest that the Columbia River is primarily a gaining reach during times of low flow and may become primarily a losing reach during times of high flow.

While the aquifer response is most pronounced near the shoreline within several tens of meters of the Columbia River, effects can extend inland of the shore up to several hundreds of meters or more. River-stage fluctuations can be detected in wells up to 610 meters inland from the river. Because of the very flat gradient between the river and the 200 East Area, the resulting pressure head changes during the highest stages can effect water levels (and the subsequent gradient) as far as 11 kilometers from the river (see Chapter 3.0, Section 3.2).

The importance of groundwater/river interactions in the 100 Area was the subject of a 3-day workshop where an expert panel of scientist from academia, government, and the consulting industry, not associated with Hanford, reviewed the current understanding of interactions at Hanford (SGW-39305, *Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area*). A total of twelve recommendations were made on topics from the base conceptual model framework, network design, data acquisition, and analysis, as well as the role of modeling in understanding of groundwater/river interactions and the role that the interactions have on the selection of remedial alternatives. One important concern was regarding the conceptual model. The two-dimensional model results presented in PNNL-13674 indicated that "mixing" occurred throughout the thickness of the unconfined aquifer and provided a 1:1 dilution of contaminated groundwater. This model does not account for the potential existence of an armored layer along the riverbed or the role that geologically controlled preferential pathways might play. The concern was that riverbed armoring and/or aquifer heterogeneities leading to preferential pathways may "short circuit" the mixing zone and allow discharge of contaminated groundwater directly into the Columbia River.

E.4 Physical and Hydraulic Properties

The determination of physical and hydraulic properties and parameters for use at the Hanford Site has a long history dating back to the late 1950s with publication of *Hydraulic Characteristics of Hanford Aquifers* (HW-48916). A number of flow and transport parameters are needed for characterizing and modeling contaminant movement in the subsurface. In general, the physical and hydraulic properties of the sediments present in the subsurface at the Hanford Site have not changed over the Site's operational history; therefore, it could be assumed that the assignment of a single, site-wide, best-estimate value to an individual stratigraphic unit would not be difficult to determine. However, as new data are collected and new methods for determining the properties are developed, the values applied to these properties may change, in some cases significantly. This has been further complicated by (1) the many different contractors and principal investigators that have performed studies at the site over its operational lifetime, (2) the changing nomenclature and descriptions of stratigraphic units and how those descriptions are applied, and (3) the differing approaches used to estimate these properties. In addition to the complications stated above is the tremendous spatial variability and geologic heterogeneity inherent among the various units across the Hanford Site. Determining these properties is also traditionally driven by site-specific workscope and project funding. Therefore, the assignment of a single, site-wide value to an individual stratigraphic unit is difficult.

Because of the difficulties in assigning a single value to any one property (as noted in the previous paragraph), this section introduces the range of values for select physical and hydraulic properties and the parameters encountered at the Hanford Site that affect contaminant fate and transport in both the vadose zone and in the unconfined aquifer. Another key issue when reviewing the physical and hydraulic properties and the parameters on the Hanford Site is that these properties can vary significantly within hydrogeologic formations, making the collection and derivation of these properties location-specific. Many of the properties and parameters are not only location-specific but also scale-specific. Values for some of these properties that are made in the laboratory can bear little resemblance to the same parameter when defined at the field scale. Therefore, it is critical to be aware of how the small-scale laboratory measurements were obtained and what, if any, upscaling techniques are needed to adequately characterize and/or model the large-scale flow and transport behavior.

E.4.1 Vadose Zone Properties

A number of physical and hydraulic properties are necessary to characterize and/or model the movement of contaminants in the vadose zone. All of these properties relate to how moisture containing a contaminant, usually as a component of some type of fluid (e.g., wastewater), moves through the vadose zone. Properties such as bulk density, effective porosity, saturated and unsaturated hydraulic conductivity, and soil moisture content as a function of matric potential have traditionally been defined using a best estimate based on the average of the individual samples tested. Historically, the extent of this testing is based on site-specific workscope and project funding. Factors complicating the derivation of a general site-wide value for any one property arise for many reasons, as noted above. Considering these differences, the Soil and Groundwater Remediation Project set out to re-evaluate and establish a set of consistent and defensible values that could be traced back to their raw data sets, which was completed in 2009 (PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses*). Tables E-1 and E-2 present the hydrostratigraphic units for which the various properties are defined, as well as the range in values for a few select properties from that report.

Other references containing information on vadose zone properties include the following:

- PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*
- PNNL-17154, *Geochemical Characterization Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*
- RPP-23748, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*
- RPP-RPT-35222, *Far-Field Hydrology Data Package for the RCRA Facility Investigation (RFI) Report*
- WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site*

E.4.2 Saturated Zone (Unconfined Aquifer) Properties

A similar number of physical and hydraulic properties is also necessary for the saturated zone (the zone below the water table) to characterize and/or model contaminant movement. Properties such as transmissivity, hydraulic gradient, effective porosity, adsorption coefficients, and both horizontal and vertical hydraulic conductivity relate directly to the movement of a contaminant, again usually as a component of some type of fluid (e.g., wastewater), through the porous material of the saturated zone. Other parameters such as storativity and specific yield have to do with the physical property of the aquifer itself. As for the vadose zone these properties have traditionally been extrapolated from individual well samples and/or testing. Historically, the extent of this testing was based on site-specific workscope and project funding. The overriding factor complicating the derivation of a general site-wide value for any one saturated zone property comes from an increased understanding of the complexity of the Hanford Site's subsurface, which reduces the distance that values can be reliably extrapolated from for any given test well. Similar to vadose zone properties, the key properties for the unconfined aquifer sediments cover a range of values linked to the sediment type and contaminants present, and also vary with the particular location, both vertically and horizontally, within the aquifer.

To aid in predicting future contaminant spread and the effectiveness of remedial actions to be used when assessing past practice sites at the Hanford Site, the Soil and Groundwater Remediation Project began developing a site-wide groundwater model in 2005. An initial effort for this work involved reviewing and compiling aquifer testing data to date for use in the 2005 site-wide groundwater model. This information was published in *Groundwater Data Package for Hanford Assessments* (PNNL-14753). Figure E-12 shows the hydrogeologic units present at the water table in 2005. Table E-3 presents the minimum and maximum values for horizontal hydraulic conductivity for the different hydrogeologic units that make up the unconfined aquifer, while Table E-4 presents minimum and maximum values for other selected saturated parameters. As an example of the variability of these properties, Figure E-13 shows the

distribution of horizontal hydraulic conductivity within the upper 10 meters of the hydrogeologic units at the water table, while Figure E-14(a and b) shows the vertical distribution of hydraulic conductivity along the two cross sections marked in Figure E-13.

Additional references containing information on aquifer properties include the following:

- PNNL-14058, *Prototype Database and User's Guide of Saturated Hydraulic Properties for the Hanford Site*
- PNNL-14753, *Groundwater Data Package for Hanford Assessments*
- PNNL-15837, *Data Package for Past and Current Groundwater Flow and Contamination Beneath Single-Shell Tank Waste Management Areas*
- SGW-42736, *Geohydrologic Data Package in Support of 200-ZP-1 Modeling*
- SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*
- SGW-47040, *Geohydrologic Data Package in Support of 100-FR-3 Modeling*

E.5 Geochemical Overview of Selected Hanford Site Groundwater Contaminants

J. Blount

The groundwater of the unconfined aquifer at the Hanford Site can be generally described as a calcium-magnesium-bicarbonate-type water that is approximately saturated with respect to calcium carbonate. The groundwater is typically slightly basic with a pH range generally between 7.5 and 8.5. Dissolved oxygen (DO) concentrations generally range between 6 to 12 mg/L, but localized low DO conditions are present in some areas. Exceptions to all of these general characteristics are observed locally as a result of previous waste disposal practices, as well as leaks and spills of contaminated solutions during operations, affecting local groundwater chemistry where applicable.

Although the extent of groundwater contamination for any given Hanford Site contaminant will vary in response to the nature of the waste site and the underlying vadose zone, once a contaminant enters the groundwater, the nature and extent of the resulting plume is controlled by the geochemical characteristics of the contaminant under the local aquifer conditions. Consequently, the fate and transport of the primary groundwater contaminants of concern at the Hanford Site will vary across the Site. It is important to understand the nature of these local and regional variations to develop valid conceptual site models. These models help identify chemical sources for the plumes and guide the development of remedial solutions or identify the need for alternative remediation. Thus, understanding the groundwater chemistry is key to moving toward final cleanup of a site.

The mobility of constituents such as uranium, chromium, and nitrate are sensitive to the reduction-oxidation state of the aquifer. These constituents are typically highly mobile under the oxidizing conditions of the unconfined aquifer. These constituents, however, can undergo chemical or biochemical transformations to much less mobile forms in areas of the aquifer where reducing conditions predominate. The fate and transport characteristics of some contaminants are not directly affected by changes in groundwater reduction-oxidation conditions, but these characteristics are affected by other factors (e.g., changes in groundwater pH or aquifer matrix composition). For example, changes in groundwater pH can increase or decrease the extent of sorption of iodide or the precipitation of strontium-90 as a solid carbonate or phosphate phase. The following subsections present a general overview of the geochemical characteristics of groundwater contaminants in the Hanford unconfined aquifer.

E.5.1 Uranium

During the period of active Hanford Site operations, large amounts of uranium metal were used to fuel the reactors and to produce plutonium. Large-scale reprocessing of spent fuel rods and related waste disposal activities generated hundreds of thousands of kilograms of dissolved uranium in large volumes of waste solutions that were primarily released to the vadose zone in the 200 and 300 Areas (PNNL-17031, *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site*). Based in part on the high volume of the waste solutions discharged, the generally high concentrations in those waste solutions, and the mobility of uranium, a substantial component of the discharged uranium was transported through the vadose zone and into the unconfined aquifer. The component of uranium retained in the vadose zone remains a potential future source of groundwater contamination. A simplified summary of the geochemical characteristics of uranium that contributed to the development of large uranium plumes in the unconfined aquifer are summarized below.

Depending on the reduction-oxidation/pH conditions, dissolved uranium in aqueous solutions can exist in the +3, +4, +5, and +6, oxidation states. In most groundwater environments, uranium will exist predominantly in the tetravalent (+4) or in the hexavalent (+6) states (uranium[IV] or uranium[VI]). The high pH (greater than 7.5) and calcium bicarbonate concentrations in most Hanford Site groundwater, combined with the prevalent oxidizing conditions, suggest that uranium(VI) should predominately occur as carbonate complexes; this form of uranium is relatively mobile. However, carbonate complexes of uranium(VI) are sensitive to spatial or temporal changes in groundwater pH. For example, the dominant aqueous uranium species will generally change from the neutral uranyl mono-carbonate complex (UO_2CO_3) at a pH of ~5.5 to 6, to the divalent anionic uranyl di-carbonate complex [$(UO_2(CO_3)_2^{-2}$] at a pH of ~7 to 8, and to the anionic tetravalent uranyl tri-carbonate complex [$(UO_2(CO_3)_3^{-4}$] at a pH above 8.5 (EPA 402-R-99-004B, *Understanding Variation in Partition Coefficient, K_d, Values: Volume II: Review of Geochemistry and Available K_d Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (^3H), and Uranium*). All of these neutral to anionic complexes are slightly absorbing on the aquifer matrix materials, resulting in some degree of retardation of uranium but generally allowing uranium to be mobile enough to form groundwater plumes within the Hanford Site aquifer.

Under reducing conditions with pH values near 8.0, aqueous complexes of uranium(VI) convert to uranium(IV), which tends to precipitate insoluble uranium oxides. Thus, the resulting groundwater concentrations of uranium are very low when uranium(IV) complexes dominate. However conditions sufficiently reducing to convert uranium(VI) to uranium(IV) are rare in any aquifer, especially at the Hanford Site, which has almost universally oxygen-rich groundwater. Several small uranium plumes exist in the groundwater within the 200 West Area with a larger plume under the B Complex in the 200 East Area. Both areas were the sites of chemical processing plants, where plutonium and eventually uranium were separated from irradiated fuel rods. The plume with the greatest areal extent is located under the 300-FF-5 Operable Unit area, where uranium rich fuels rods were manufactured for use in the Hanford Site reactors.

E.5.2 Chromium

Chromium typically occurs in the natural environment as trivalent chromium (chromium[III]). Hexavalent chromium (chromium[VI]) is the common form in waste streams and is the most mobile form of chromium. The aqueous mobility of chromium introduced into the unconfined aquifer at the Hanford Site is highly dependent upon (1) the valence state of the chromium in the waste solution, (2) the chemical characteristics and volume of the waste solution that is transporting the chromium into the aquifer, and (3) the chemistry of the groundwater and associated aquifer matrix.

Cationic chromium(III) species (e.g., $[Cr(OH)]^{2+}$) are stable in strongly acidic solutions, while anionic chromium(III) species ($[Cr(OH)_6]^{3-}$) are stable in strongly basic aqueous solutions. Chromium(III) species are not stable in typical Hanford Site groundwater, with a pH range that is intermediate between these two extremes (e.g., pH between 6.5 and 9). Consequently, if chromium(III) in a disposal area's soil

or waste material is mobilized by either a strongly acidic (e.g., less than pH 5) or basic (e.g., greater than pH of 12) solution and subsequently transported to the unconfined aquifer, the chromium(III) will begin to precipitate as low-solubility solid phases, such as $Cr(OH)_3$. This is the result of either the strongly acidic or basic pH of the waste solution being neutralized by interaction with the groundwater and the aquifer matrix. However, the presence of organic acids and other organic complexing agents in the waste solution or in the local groundwater can increase the solubility of chromium(III) somewhat in near neutral groundwater ("The Role of Metal-Organic Complexes in the Treatment of Chromium Containing Effluents in Biological Reactors" [Remoudaki et al., 2003]). Barring the presence of elevated concentrations of organic complexing agents (e.g., acetate), the precipitation of very low solubility chromium(III) phases (e.g., $Cr[OH]_3$) should keep the concentrations of dissolved chromium(III) below the drinking water standard ("Environmental Chemistry of Chromium" [Rai et al., 1989]). Thus, carbonate-buffered aquifers, such as the Hanford unconfined aquifer, are unlikely to support dissolved chromium(III) plumes, even if the aquifer was receiving substantial volumes of acidic or strongly basic waste solutions with elevated concentrations of dissolved chromium(III).

The aqueous chemistry of chromium(VI) is very different than chromium(III); and chromium(VI) forms very stable, highly mobile anionic species (typically chromate [CrO_4^{2-}]) in oxidizing soil pore water and groundwater over a range of pH conditions.

The vadose zone and the unconfined aquifer at the Hanford Site contain very little natural organic material, and the vadose zone pore water and underlying groundwater are not sufficiently reducing to convert mobile chromium(VI) to the relatively immobile chromium(III). Consequently, oxidizing waste solutions have the potential to transport substantial amounts of chromium(VI) into the vadose zone where subsequent natural or manmade recharge events can transport much of the chromium(VI) to the unconfined aquifer. The stability and mobility of chromium(VI) complexes in the vadose zone and in the unconfined aquifer at the Hanford Site are supported by (1) the results of saturated flow-leaching tests performed on Hanford soils containing chromium(VI) (PNNL-17674, *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site*), and (2) by the existence of the extensive and long-lived hexavalent chromium plumes within the groundwater operable units in the 100 and 200 Areas.

Although chromium(VI) is stable under oxidizing groundwater conditions, it may be readily converted to chromium(III) if sufficiently reducing conditions are either naturally present in the aquifer or if reducing conditions are imposed on the aquifer system by the implementation of an engineered system. Numerous studies and field applications have demonstrated that the addition of simple organic carbon compounds (e.g., lactate or ethanol) to an aquifer contaminated with chromium(VI) will stimulate the natural microbial assemblage in an aquifer to produce reducing conditions. This bioremediation approach has been used at numerous sites to convert toxic and mobile chromium(VI) to less toxic and much less mobile chromium(III). In situ chemical methods can also be used to create reducing conditions. The injection of zero-valent iron at the 100-HR-3 Operable Unit has been shown to create reducing conditions and convert chromium(VI) to chromium(III) (DOE/RL-2009-35, *Treatability Test Report on Mending the In Situ Redox Manipulation Barrier Using Nano-Size Zero Valent Iron*). Once chromium(VI) is converted to chromium(III), it will typically rapidly precipitate as a highly insoluble phase such as $Cr(OH)_3$ that will not redissolve once treatment is terminated.

E.5.3 Nitrate

Nitrate occurs naturally in soil when free-living or symbiotic bacteria combine gaseous nitrogen with hydrogen to produce ammonia. This process of fixation is an integral part of the nitrogen cycle. Whether by decomposition of organic material or by nitrogen-fixing bacteria in legume root nodules, the ammonium is further converted to nitrite (NO_2^-) and then nitrate (NO_3^-). Nitrogen as nitrate is stable and mobile in oxygenated environments, and the amount not taken up by plants is leached to the local aquifer.

The elevated nitrate concentrations observed in some Hanford groundwater are primarily the result of plutonium and uranium separations waste streams released to the ground in very large volumes in the

early days of processing. Nitric acid was used to declad and dissolve the irradiated fuel rods throughout the history of Hanford Site operations. During the time that waste was retrieved from the single-shell tanks for use in the uranium recovery process and to recover strontium-90 from the B Plant waste fractionization campaign, nitric acid was also used to dissolve solids in the feed stock solution.

Additional sources of nitrate result from many of the later plutonium separations processes used at the Hanford Site. Although the reduction-oxidation process (active from 1952 to 1958) used methyl isobutyl ketone as the solvent extractor, aluminum nitrate nonanhydrate was used as the source for the nitrate ion (DOE/RL-2000-60, *Uranium-Rich/General Process Condensate and Process Waste Group Operable Units RI/FS Work Plan and RCRA TSD Unit Sampling Plan Includes: 200-PW-2 and 200-PW-4 Operable Units*). Aluminum nitrate nonanhydrate was added to the processing stream to drive uranium and plutonium into a solution phase for later chemical removal. Another example of nitrate added to the waste stream is during the uranium recovery process. The final product from the tri-butyl phosphate uranium recovery process was uranyl nitrate hexahydrate. By using calcinators, the uranyl nitrate hexahydrate was converted to uranium trioxide for shipment to plants that processed it to the metal form of uranium for use in reactors. Thus, nitrates were part of the waste streams resulting from the nitrification of the uranyl nitrate hexahydrate to uranium trioxide. This process was conducted at U Plant from 1958 until 1972, and the again from 1984 to 1988.

The only other source of nitrate may be upgradient agricultural use of nitrogen-rich fertilizers. However results from wells monitoring upgradient of the 100 Area and the 200 West Area Central Plateau do not show agricultural activities as a major nitrate source, although several have shown steady increases in nitrate levels that remain below regulatory levels. In the southern Hanford Site around the 300 and 1100 Areas, elevated nitrate is from offsite agricultural and industrial sources. However, nitrate in the groundwater beneath most of the Hanford Site is primarily the result of Hanford operations.

E.5.4 Carbon-14

Carbon-12 and carbon-13 are stable nonradioactive isotopes of carbon that account for ~99% and 1%, respectively, of all carbon. Carbon-14 is a radioactive isotope of carbon that is produced naturally in the upper atmosphere, primarily by the interaction of cosmic rays and atmospheric nitrogen, that make up less than one trillionth (1×10^{-10}) of natural carbon. Carbon-14, which decays to nitrogen-14 by beta emission, has a half-life of ~5,700 years.

At the Hanford Site, carbon-14 was produced as a byproduct during plutonium production at the reactors in the 100 Area. Sources of carbon-14 contaminated groundwater include wastes associated with previous reactor operation decommissioning activities (ANL-1472, *Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas*). Several other radioactive isotopes of carbon exist, but their half-lives are extremely short; and they are not a health concern for DOE environmental management sites (ANL-1427).

The environmental chemistry of carbon-14 is virtually identical to that of common carbon, and it can migrate either as a gas (i.e., carbon dioxide) or in solution as carbonate or bicarbonate species (INEEL/EXT-04-01793, *Multiphase Carbon-14 Transport in a Near-Field-Scale Unsaturated Column of Natural Sediments*). The fate and transport characteristics of carbon-14 as carbon dioxide in the vadose zone within or beneath a waste site will reflect a range of factors, including unsaturated water content, extent of microbial biomass production, microbial carbon dioxide production, temperature, diffusion rates, and carbonate equilibriums. These and other factors that affect the transport of carbon dioxide into or out of the vadose zone will be subject to the same gas/water/solid exchange processes as carbon dioxide containing only stable carbon.

Once carbon-14 reaches the water table, the effects of retardation processes such as adsorption and gas/water exchange rates are influenced by the pH and carbonate alkalinity of the groundwater. For example, depending on the pH, carbon-14 in a groundwater plume may be present primarily as

carbonic acid, bicarbonate, or carbonate; each of these carbonate species would be subject to somewhat different retardation factors in the aquifer.

E.5.5 Technetium-99

Technetium-99 is a radioactive metal with a half-life of 210,000 years. Technetium-99 is found primarily in radioactive wastes from nuclear processing facilities as a byproduct (or fission product) of reactor operations. Technetium can exist in valence states ranging from 1- to 7+ and is strongly sensitive to oxidation-reduction conditions. Under oxidizing conditions typical of the Hanford Site aquifer, technetium-99(VII) forms the chemically stable pertechnetate anion (TcO^{4-}). Pertechnetate is generally not adsorbed by inorganic aquifer materials under near neutral or higher pH conditions, so is highly mobile in groundwater under these conditions.

When pertechnetate is exposed to reducing conditions, technetium-99 changes from 7+ to 4+ valance state and normally precipitates to the solid TcO_2, removing technetium-99 from the groundwater. This reduction could occur in a natural environment (e.g., groundwater passing through an area enriched in organic material) or an imposed one. A common remediation technique for a contaminant that behaves in this manner is to reduce the aquifer by injecting a chemical reductant, or by introducing a carbon source into the aquifer, which stimulates indigenous microbes that in turn create reducing conditions in the groundwater and aquifer materials. This will reduce the technetium-99(VII) to technetium-99(IV), which is largely immobile in groundwater. Unlike hexavalent chromium, which remains in the reduced state when conditions return to oxidizing, reduced technetium-99(IV) readily returns to the mobile pertechnetate ion under oxidizing conditions.

E.5.6 Tritium

Tritium is a radioactive isotope of hydrogen with a half-life of 12.3 years that is created naturally in the upper atmosphere and by anthropogenic sources such as nuclear reactors and nuclear weapons testing. The nucleus of a tritium atom consists of one proton and two neutrons and undergoes beta decay to form stable helium-3. The chemistry of tritium is essentially identical to common hydrogen, and it can migrate in soils as a gas and readily reacts with oxygen to form what is known as heavy water (H_3O). Once tritium atoms have been incorporated into water molecules, they will be subject to the same dispersive, advective, and other transport processes as common water and will migrate at the same average velocity (EPA 402-R-99-004B).

The fate and transport of tritium in the subsurface at the Hanford Site is primarily controlled by radioactive decay and by the hydrologic characteristics of the affected vadose or groundwater systems. Although no sorption or precipitation processes are known to retard the movement of tritiated water in the environment, some studies have reported a small but notable retardation of tritium relative to bromide during long-term (~500 days) column testing (INEEL/EXT-04-01793). The modest retardation of tritium (estimated distribution coefficient of ~0.08) in these column tests was speculated to be due to the fixation of tritiated water on clays and other hydrated soil minerals. The 12.3-year half-life of tritium is relatively long compared to the groundwater travel times in many areas of the unconfined aquifer. Consequently, for a given waste site, the extent and magnitude of tritium activity that defines the resulting plume primarily reflects the age and longevity of the contamination event and the local hydraulic properties of the aquifer (e.g., groundwater velocity).

E.5.7 Strontium-90

Strontium is an alkaline earth element that occurs naturally in only the divalent state (2+). Because of the similar size and charge to calcium, these two elements can and commonly do substitute for each other in natural systems. Strontium has four naturally occurring stable isotopes (strontium-84, -86, -87, and -88). Of these, strontium-88 comprises ~82.5% of the total mass of strontium. Numerous short-lived strontium isotopes have been identified as byproducts of nuclear fission (fission products), but strontium-90 (with a half-life of 28.78 years by beta decay) is the only strontium isotope identified as a potential health concern in Hanford Site groundwater.

Strontium forms weak complexes with most inorganic anions (e.g., carbonate, sulfate, chloride, and nitrate) (EPA 402-R-99-004B), and the uncomplexed Sr^{2+} ion typically predominates in groundwater over a wide range of pH conditions. In sufficiently high pH, carbonate-rich environments, the precipitation of strontium carbonate may serve as control on the maximum concentrations in groundwater. Ion exchange of divalent strontium (Sr^{2+}) onto clays and other aquifer phases is a significant mechanism of retardation of strontium transport in groundwater. Although strontium has a higher affinity than calcium for the exchange site of many minerals, the much greater abundance of calcium in most groundwater commonly results in the preferential displacement of Sr^{2+} from exchange sites by Ca^{2+}. This effect would appear to be substantially more pronounced for strontium-90, which would be several orders of magnitude lower in concentration than common strontium and calcium (EPA 402-R-99-004B). Studies on contaminated soils taken from the 100-N Area indicate that because of strong strontium-90 absorption by ion exchange to sediments (distribution coefficient is 25 cm^3/g in groundwater, yielding a retardation factor of approximately 100 (PNNL-16891, *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO4 Solution Injection and Sr-90 Immobilization in 100-N Sediments*), approximately 1% of the strontium-90 is in groundwater, and 99% is adsorbed onto sediments. The strong affinity for Sr^{2+} to exchange with Ca^{2+} is the basis for the success of the apatite barrier in the 100-N Area (see Chapter 6.0, Section 6.2.4).

E.5.8 Iodine-129

Iodine has one stable isotope (iodine-127) and 36 known radioactive isotopes. Iodine-129 is by far the longest lived, with a half-life of 15.7 million years. The other isotopes have half-lives ranging from about 100 microseconds (iodine-109) to 59 days (iodine-125). Iodine-129 is produced in small quantities in nature (e.g., by spontaneous fission of natural uranium) but in much larger quantities as a fission product in nuclear reactors. Iodine occurs in +7, +5, +3, +1, and -1 valence states and typically occurs as the diatomic molecule (I_2) in the atmosphere. In groundwater, iodine most commonly occurs as iodide (I^-), although in marine environments the prevalent form is as I^{5+} in the iodate (IO_3^{-1}) complex. As with other similar anionic halogen species (e.g., Cl^-), iodine is relatively mobile in most groundwater environments and displays very little sorption on the organic-poor sediments and moderately basic groundwater in the unconfined aquifer at the Hanford Site ("Linearity and Reversibility of Iodide Adsorption on Sediments from Hanford, Washington Under Water Saturated Conditions" [Um et al., 2004]).

E.5.9 Carbon Tetrachloride

Carbon tetrachloride is a semi-volatile organic liquid that was used in the Plutonium Finishing Plant in association with plutonium production at the Hanford Site. The carbon tetrachloride molecule is nonpolar, which makes it only sparingly soluble in water (approximately 800 milligrams per liter of water). That characteristic, along with a density of 1.6 g/cm^3, classifies it as a dense, nonaqueous phase liquid. Partition coefficients published in the literature for carbon tetrachloride in groundwater range from 0 to 0.83 liters per kilogram; values obtained from contaminated Hanford sediments range from 5.21×10^{-5} to 0.367 liters per kilogram (PNNL-16100, *Carbon Tetrachloride Partition Coefficients Measured by Aqueous Sorption to Hanford Sediments from Operable Units 200-UP-1 and 200-ZP-1*).

Carbon tetrachloride in the subsurface can exist as a vapor phase, as a dissolved aqueous phase, as an absorbed phase on solid matrices, and as a separate organic phase as a dense, nonaqueous phase liquid. In the Hanford Site vadose zone, all of these phases have been detected, although only a very small amount of dense, nonaqueous phase liquid is present. In groundwater, only the dissolved phase has been detected.

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Table E-1 Hydrostratigraphic Units for Which Physical, Hydrologic, and Geochemical Data Can be Defined

Formation /Unit	Subunit (Symbol)	Representative Hydraulic Property Sediment Class		Qualitative Sediment Description
		PNNL-14702, Rev. 1	After RPP-17209, Rev. 1; RPP-13310, Rev. 1	
Holocene deposits	Backfill (Bf)	Bf	Backfill	Poorly sorted sand and gravel mixed with finer fraction.
Hanford formation	Unit H1a (H1a)	Hfs, Hcs	NA	Mostly sand-dominated sediment with some silt, but may contain some gravelly sediments.
	Unit H1 (H1)	Hgs, Hg	Gravelly sand H1	Gravel-dominated sediments with coarse sand found in 200 West Area.
	Unit H2 (H2)	Hfs, Hcs	Sand H2	A mixture of sandy and silty sediment in 200 West Area.
	Unit H2a (H2a)	--	--	A transitional sand and gravel unit between H2 and H3.
	Unit H3 (H3)	Hgs, Hg	Gravelly sand H3	Laterally discontinuous gravelly sediment at the base of the Hanford formation.
	Unit H4 (H4), undifferentiated Hanford/ Cold Creek unit (Hf/CCU)	Hss, Hcs	NA	Laterally discontinuous silty sediment at the base of the Hanford formation, including undifferentiated silty Hanford/CCU sediments.
Cold Creek unit (CCU)	Cold Creek unit silt (CCUz)	PPlz	Cold Creek (Unit 4)	Stratified very fine sand to clayey silt at least partially correlative with the "early Palouse soils."
	Cold Creek unit carbonate (CCUc)	PPlc	Cold Creek (Unit 4)	Calcium-carbonate cemented clay, silt, sand, and/or gravel.
	Cold Creek unit gravels (CCUg)	NA	Cold Creek (pre-Missoula gravels)	Gravelly sand to gravel equivalent to the pre-Missoula gravels.
Ringold Formation	Member of Taylor Flat (Rtf)	PPlc	NA	Well-bedded fine to coarse sand to silt.
	Member of Wooded Island, subunit E (Rwi(e))	Rg	Ringold sandy gravel	Fluvial gravel, moderate to strongly cemented, and interstratified with finer-grained deposits.
	Ringold Formation lower mud unit (Rlm)	NA	NA	--
	Member of Wooded Island, subunit A (Rwi(a))	NA	NA	--
Saddle Mountains formation	Elephant Mountain Member (Tem)	NA	NA	--

Sources: PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*.

RPP-13310, *Modeling Data Package for an Initial Assessment of Closure of the C Tank Farm*.

RPP-17209, *Modeling Data Package for an Initial Assessment of Closure of the S and SX Tank Farms*.

Note: The information provided in this table is from PNNL-18564, *Selection and Traceability of Parameters To Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report*.

Table E-2. Best Estimate for Site-Wide Vadose Zone Properties

Sediment Class - Description	Bulk Density (g/cm^3)				Total Porosity (cm^3/cm^3)				Effective Porosity (cm^3/cm^3)				Saturated Water Content, Θ_s (cm^3/cm^3)[b]				Saturated Hydraulic Conductivity, K_s, (cm/sec)[b]			
	Min.	Max.	Min. Location	Max. Location	Min.	Max.	Min. Location	Max. Location	Min.	Max.	Min. Location	Max. Location	Min.	Max.	Min. Location	Max. Location	Min.	Max.	Min. Location	Max. Location
Bf – Backfill	2.13	2.13	S-SX Tank Farms	S-SX Tank Farms	NA[c]	NA[c]	--	--	NA	0.158	--	d	0.138	0.2688	South, S-SX Tank Farms	North, B-BX-BY Tank Farms	5.60E-04	5.94E-04	South, S-SX; North B-BX-BY, & C Tank Farms	d
Hss – Hanford formation silty sand	1.58	1.8	S 200 W	N 200 W	0.329	0.392	N 200 W	S 200 W	0.282	0.326	N 200 W	S 200 W	0.351	0.437	North, 200-ZP-1; 200NW	South, 200-U1 & U2	6.55E-06	2.40E-04	North, 200-ZP-1	North, B-BX-BY Tank Farms
Hfs – Hanford formation fine sand	1.65	1.76	S 200 E	S-SX Tank Farms	0.318	0.422	N 200 W	BC	0.277	0.388	N 200 W	BC	0.347	0.394	South, 200-U1 & U2	South, IDF	1.71E-05	4.15E-03	South, 200-U1 & U2	South, IDF
Hcs – Hanford formation coarse sand	1.56	1.67	N 200 W	S 200 E	0.384	0.41	200 W	N 200 W	0.348	0.395	200 W	N 200 W	0.292	0.357	North, 200-ZP-1	South, BC	1.09E-03	5.32E-03	200 W	South, BC
Hgs – Hanford formation gravelly sand	1.81	1.94	200 W	S-SX Tank Farms	0.3	0.335	BC	200 W	0.26	0.305	BC	200 W	0.2126	0.273	South, S-SX Tank Farms	200 W	2.35E-04	5.15E-04	200 W	North, B-BX-BY & C Tank Farms
Hg – Hanford formation sandy gravel	1.79	2.09	N 200 W	S 200 W	0.231	0.237	S 200 W	N 200 W	0.202	0.218	S 200 W	N 200 W	0.15	0.2126	South, 200-U1 & U2	South, S-SX; North B-BX-BY, & C Tank Farms	2.62E-04	3.65E-03	South, S-SX; North B-BX-BY, & C Tank Farms	North, 200-ZP-1
Hrg – Hanford formation gravel (>60% gravel)	0	0	--	--	0	0	--	--	NA	0.239	--	d	0.102	0.138	d	South, IDF	5.60E-04	1.46E-03	South, IDF	d
CCUz – Cold Creek unit silt	1.58	1.71	N 200 W	S 200 W	0.355	0.452	S 200 W	N 200 W	0.308	0.42	S 200 W	N 200 W	0.398	0.448	South, 200-U1 & U2	North, 200-ZP-1	7.27E-06	7.11E-04	South, 200-U1 & U2; 200WS	North, 200-ZP-1
CCUc – Cold Creek unit carbonate	1.65	1.71	S-SX Tank Farms	200 W	0.34	0.352	200 W	N 200 W	0.288	0.297	200 W	N 200 W	0.281	0.286	200 W	South, S-SX Tank Farms	5.00E-04	1.03E-03	200 W	North, 200-ZP-1
CCUg – Cold Creek unit gravels	2.13	2.13	C Tank Farm	C Tank Farm	0	0	--	--	NA	NA	--	--	0.138	0.138	North, C Tank Farm	North, C Tank Farm	5.60E-04	5.60E-04	North, C Tank Farm	North, C Tank Farm
Rg – Ringold Formation sandy gravel	1.82	2.13	S 200 W	S-SX Tank Farms	0.299	0.313	200 W	S 200 W	0.258	0.266	200 W	S 200 W	0.138	0.315	South, S-SX; North B BX-BY, & C Tank Farms	South, 200-U1 & U2	7.83E-05	5.60E-04	South, 200-U1 & U2	South, S-S; North B-BX-BY, & C X Tank Farms

a. Values shown are from PNNL-18564, *Sediments and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report*. See Table gwt10021 and Table 6.1 in PNNL-18564 for details on the sediment classes.
b. Saturated water content and saturated hydraulic conductivity values are from the limited data set of samples tested to date.
c. "NA" indicates not available; total porosity has not been determined for the various types of backfill.

Table E-3. Ranges of Horizontal Hydraulic Conductivity (K_h) Values for Each Hydrostratigraphic Unit

Unit[a]	Unit Description	Minimum K_h[c]	Maximum K_h
1	Hanford formation sands, silts, and gravels	6.06	20195
2	Cold Creek unit fluvial facies (CCU_c)	NAd	NA
3	Cold Creek unit coarse grained facies (CCU_z)	1.84	5717
4	Upper Ringold Formation silts and clays	0.0005	0.0005
5	Upper Ringold Formation sands and gravels	0.239	2562
6	Ringold Formation middle fines	0.01	0.01
7	Ringold Formation middle coarse	0.0227	101
8	Ringold Formation lower mud unit	0.00001	0.00001
9	Ringold Formation basal sands and gravels	0.00051	4.24

a. Units are as defined in PNNL-14753, *Groundwater Data Package for Hanford Assessments*.

b. Unit descriptions are from Figure E-2.

c. K_h = horizontal hydraulic conductivity. Values are in meters per day.

d. "NA" indicates that unit is not found below the water table.

Figure E-1. Location of the Pasco Basin and Hanford Site

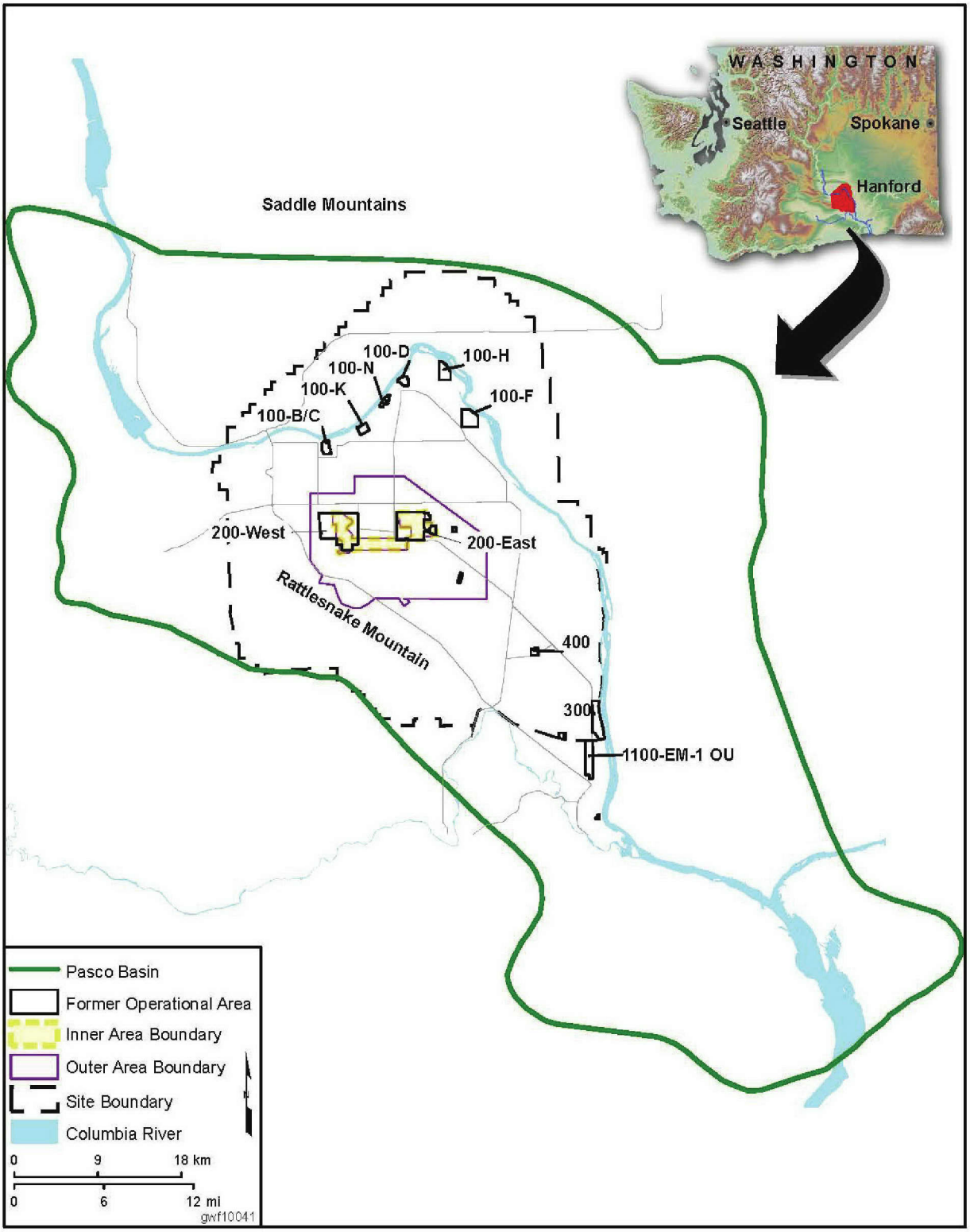
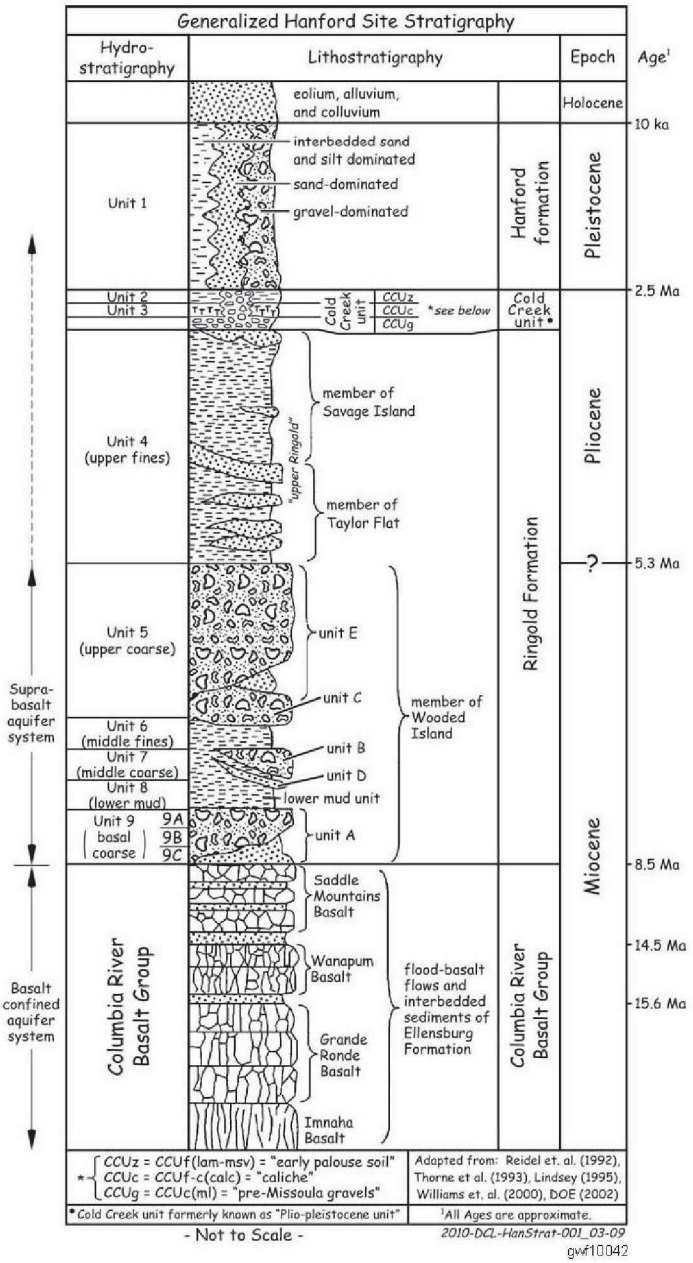


Figure E-2. Stratigraphic Column for the Hanford Site Showing Nomenclature



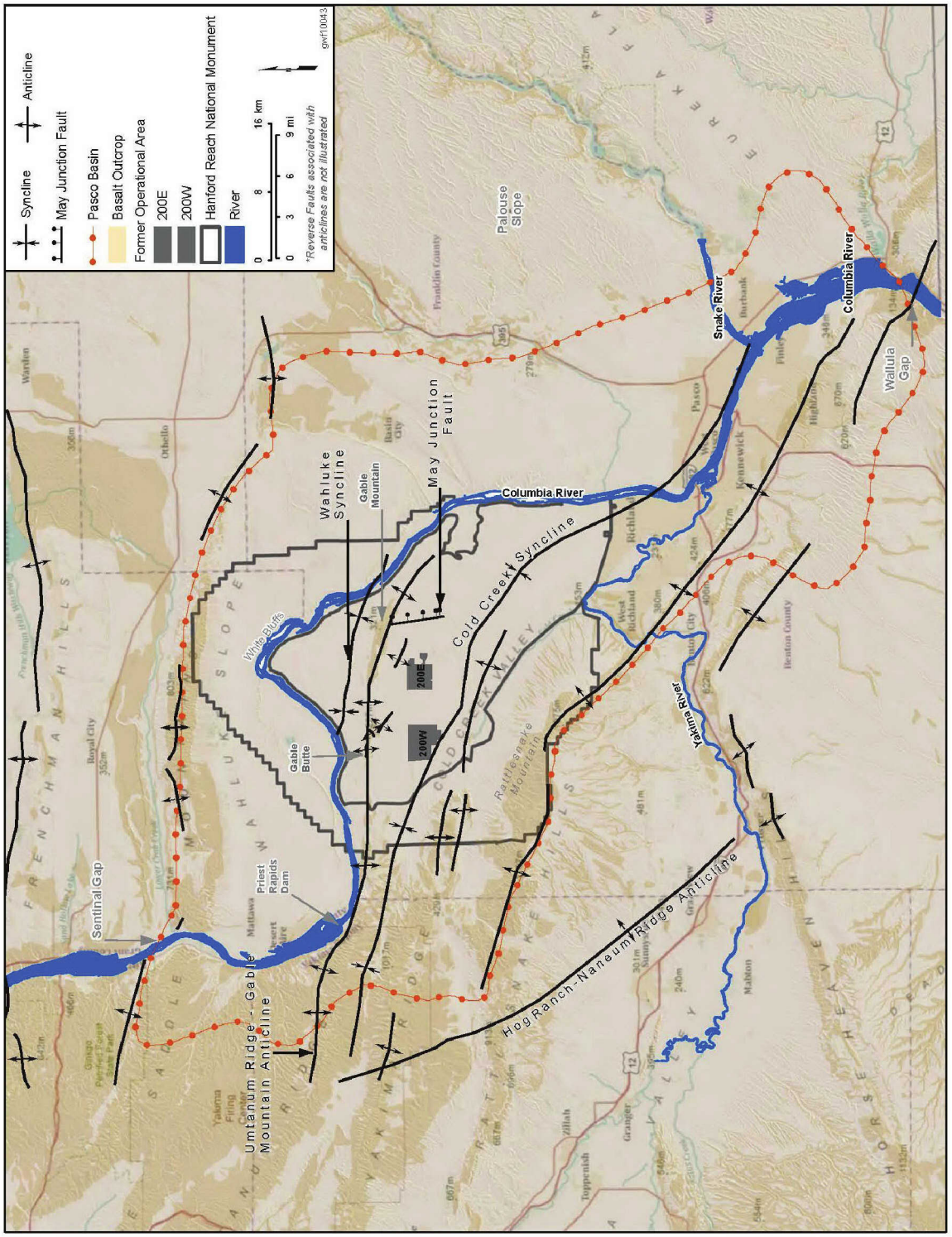
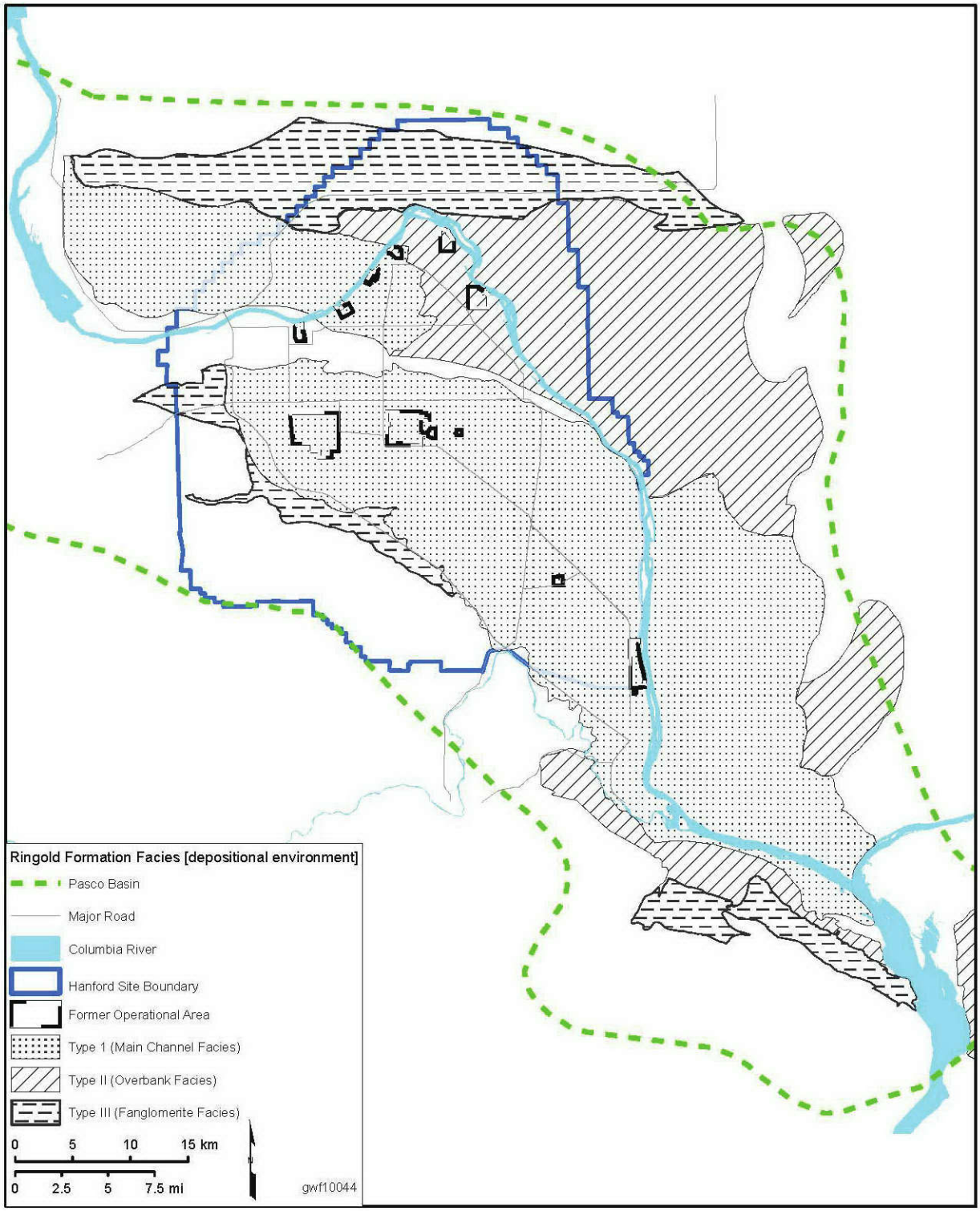


Figure E-3. General Geologic Structures of the Pasco Basin and Hanford Site

Figure E-4. Facies of the Ringold Formation Within the Central Pasco Basin



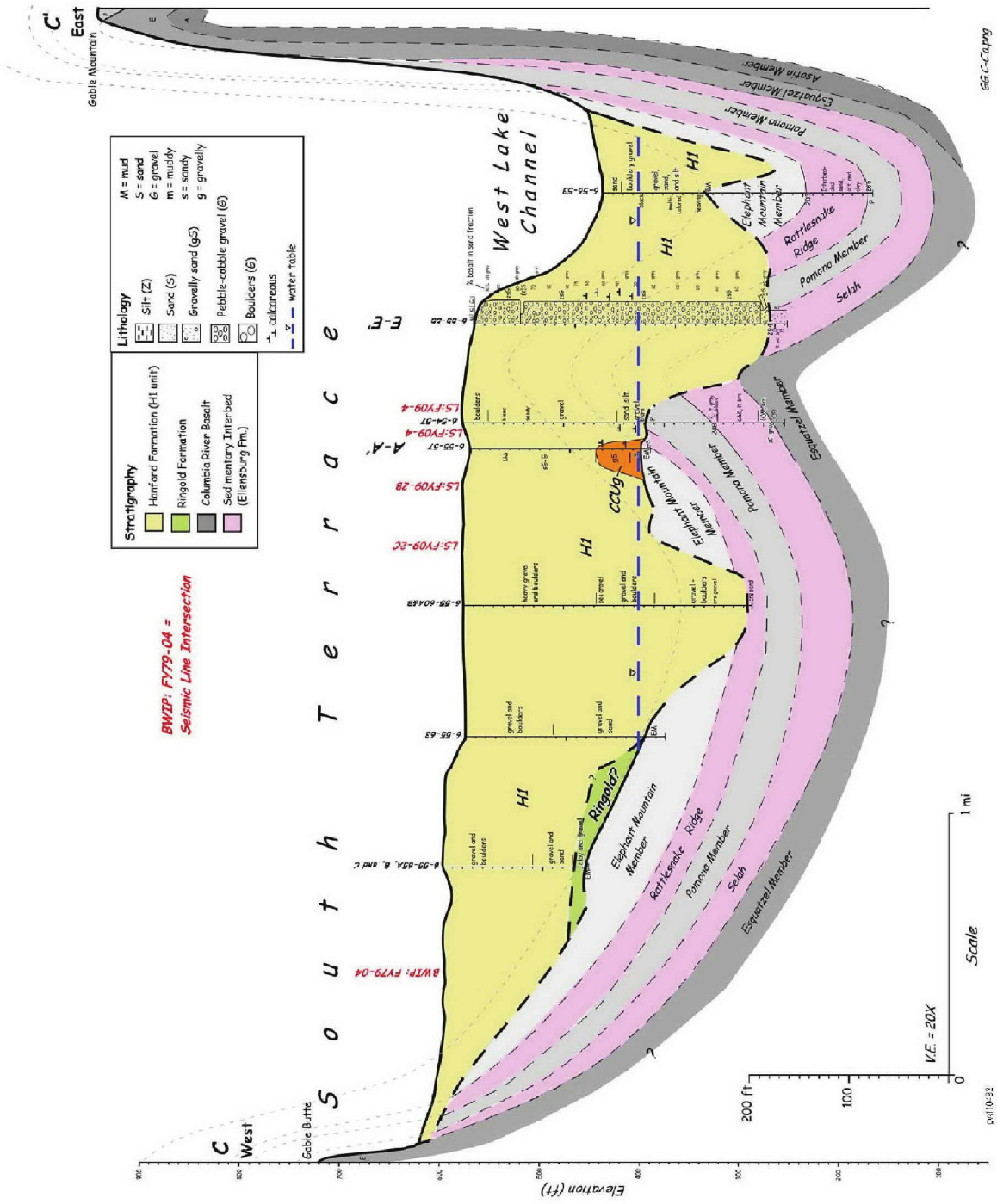


Figure E-5. Hydrogeologic Cross-Section 3 (C-C')

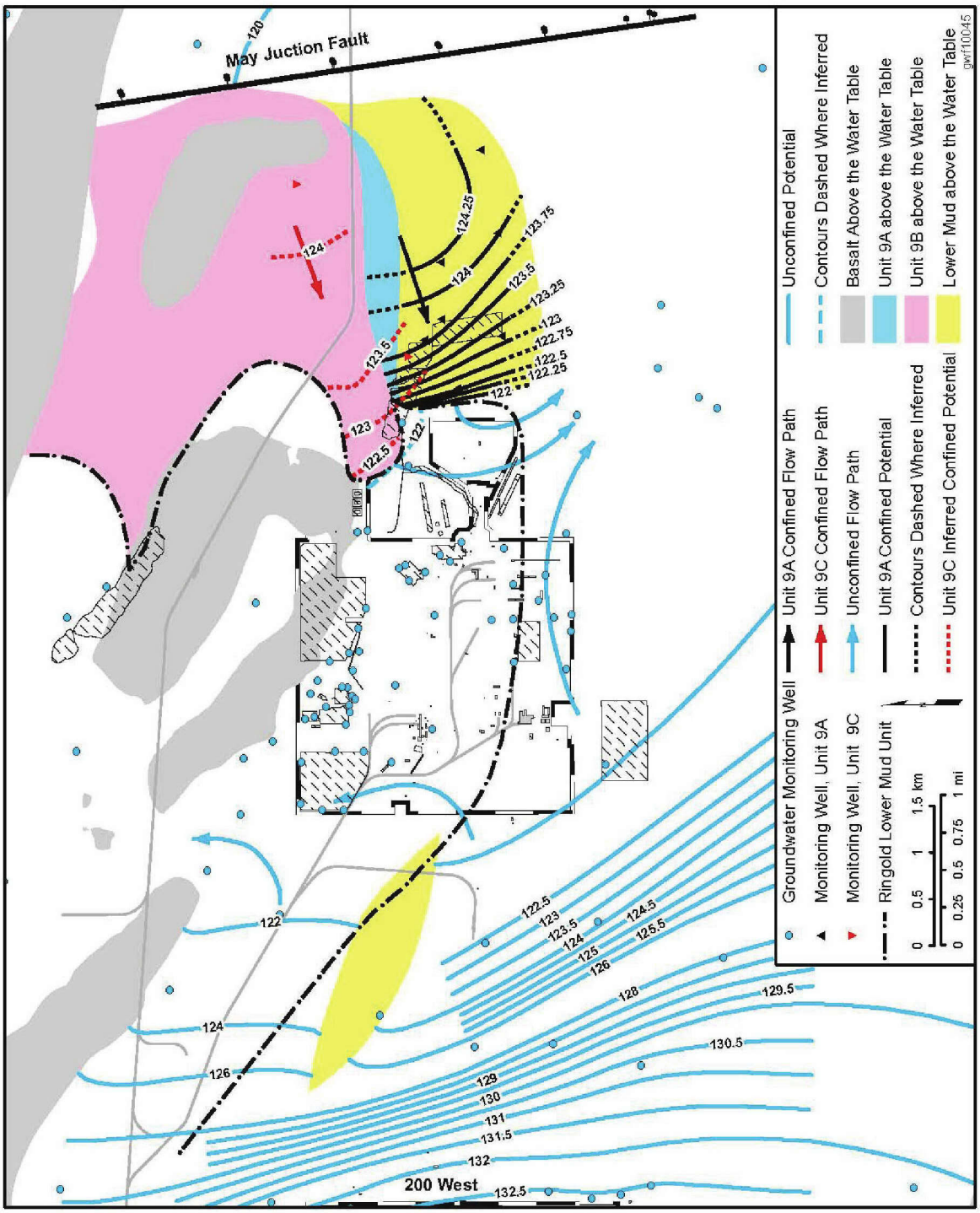


Figure E-6. Lower Ringold Formation Beneath the 200 East Area

Figure E-7. Facies Distribution for the Cold Creek Unit Within the Central Pasco Basin

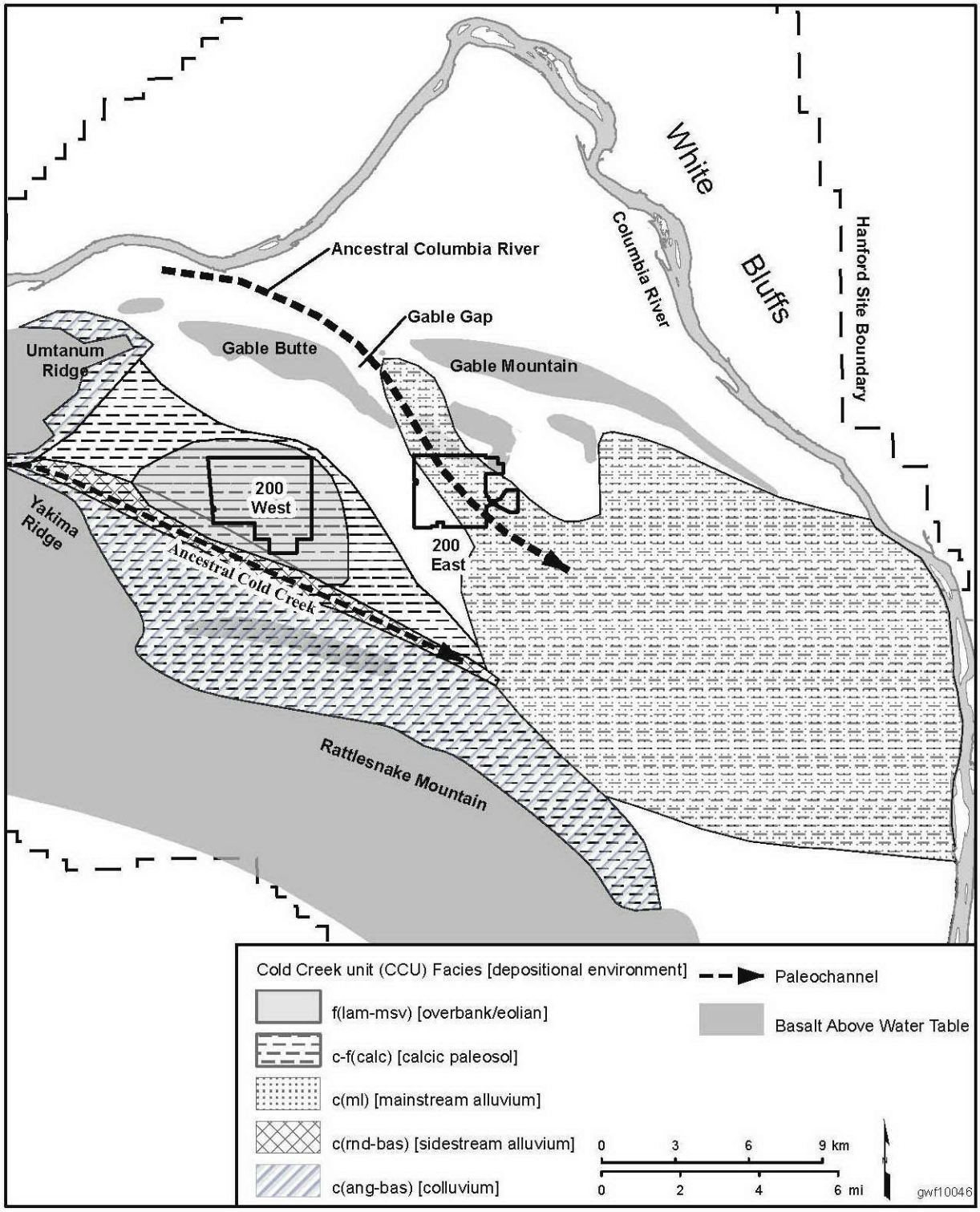
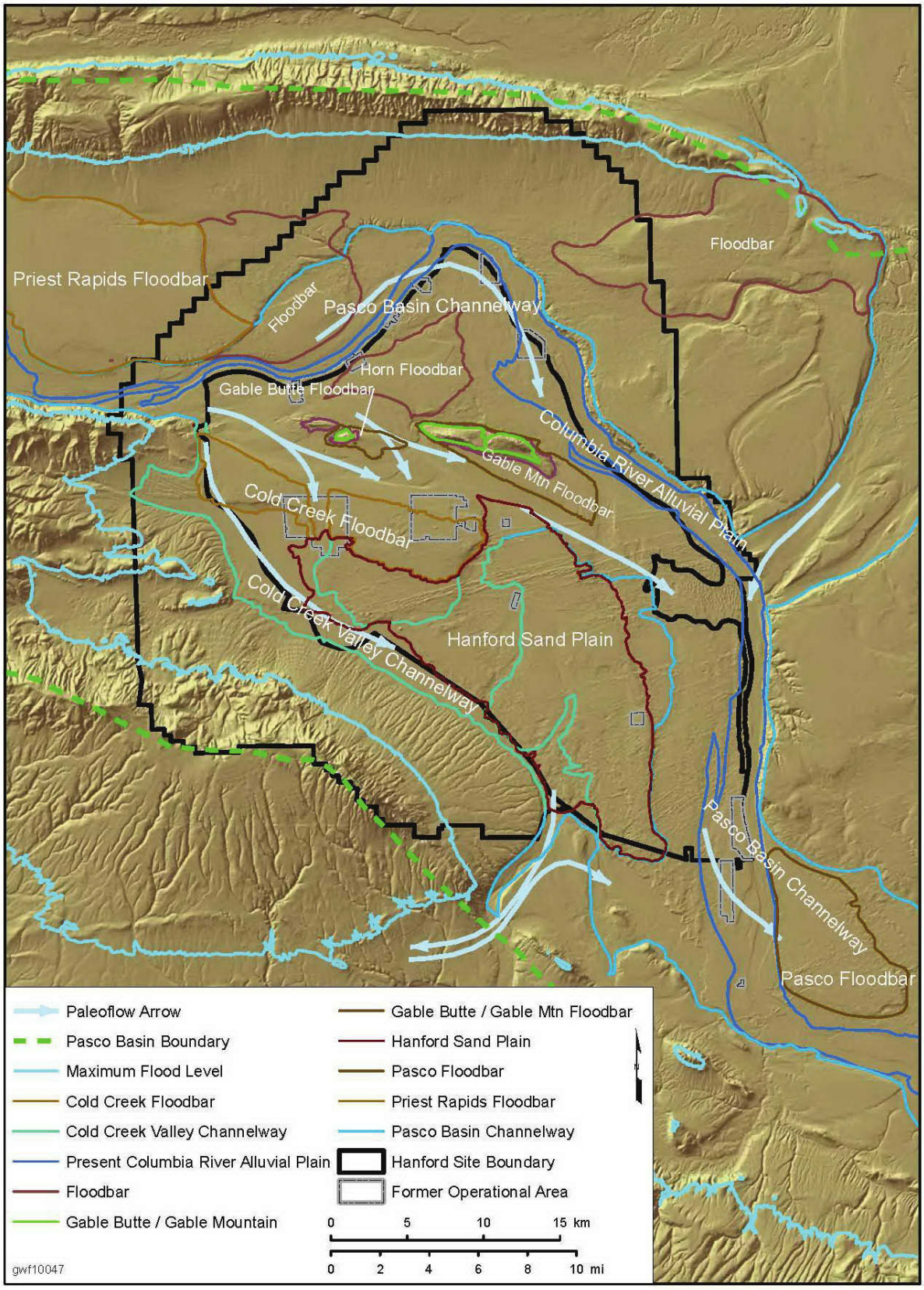


Figure E2-8. Ice Age Flood Geomorphic Features of the Pasco Basin



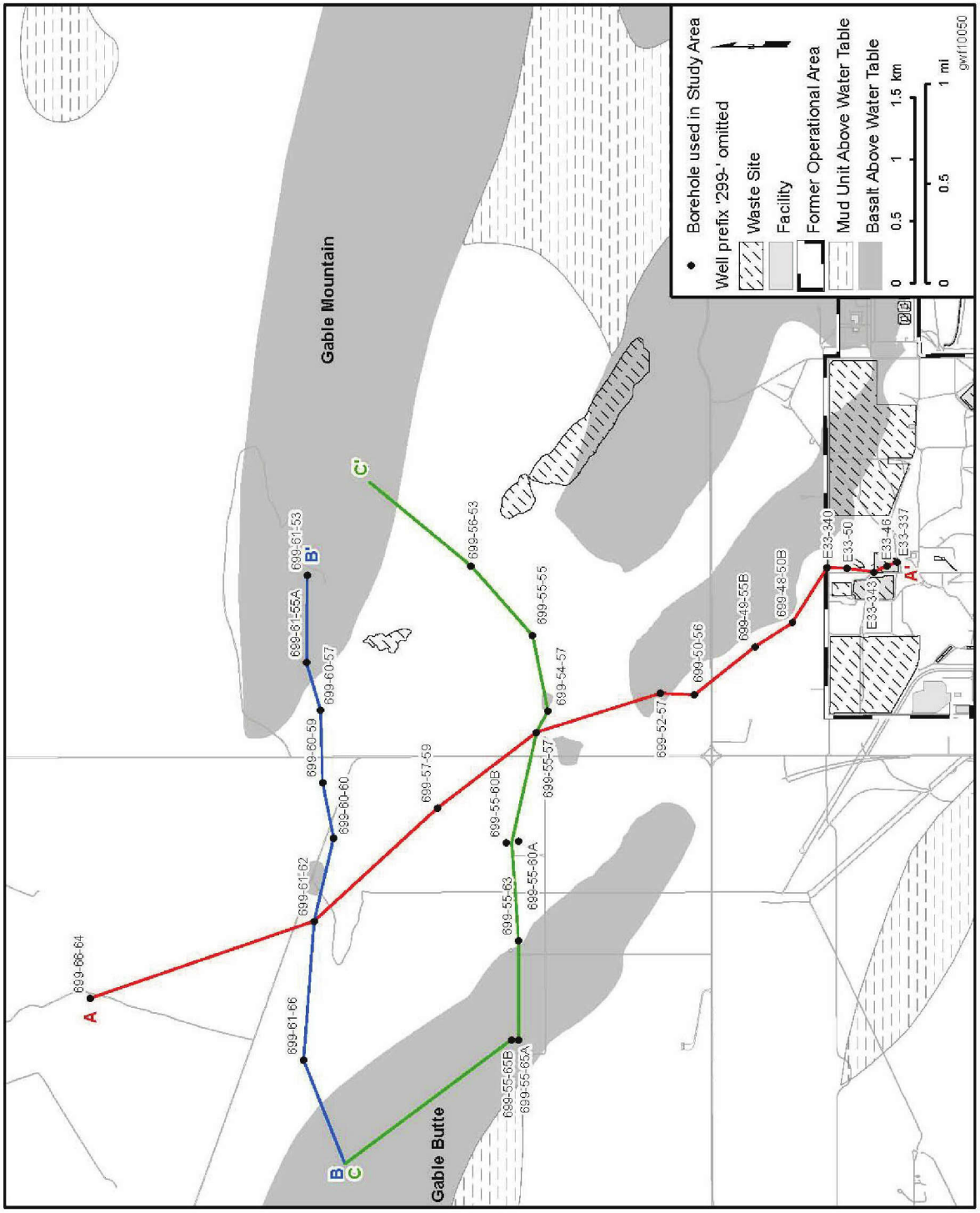


Figure E-9. Cross-Section Location Map

Figure E-10. Hydrogeologic Cross-Section 1 (A-A')

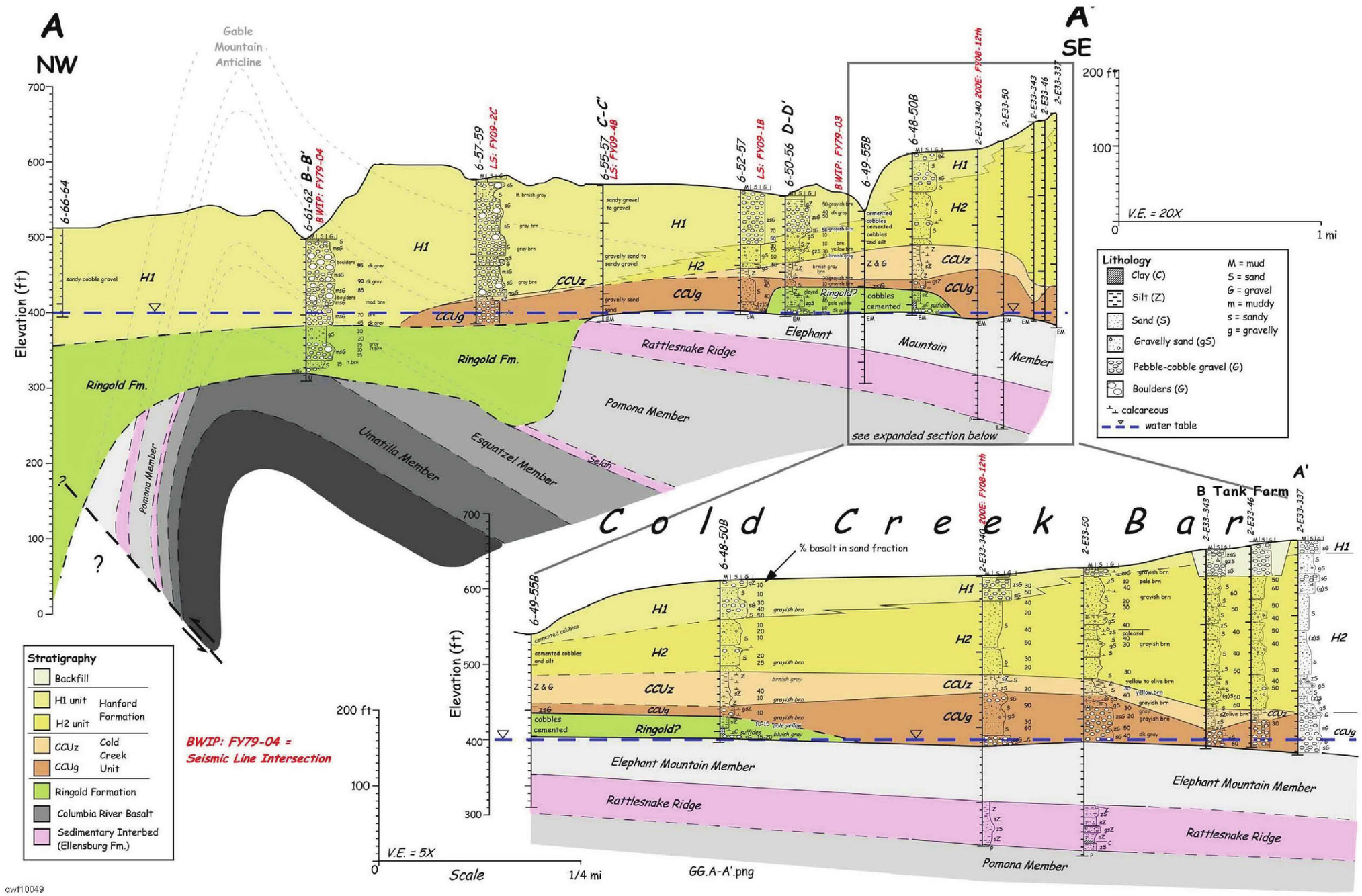


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Figure E-11. Hydrogeologic Cross-Section 2 (B-B')

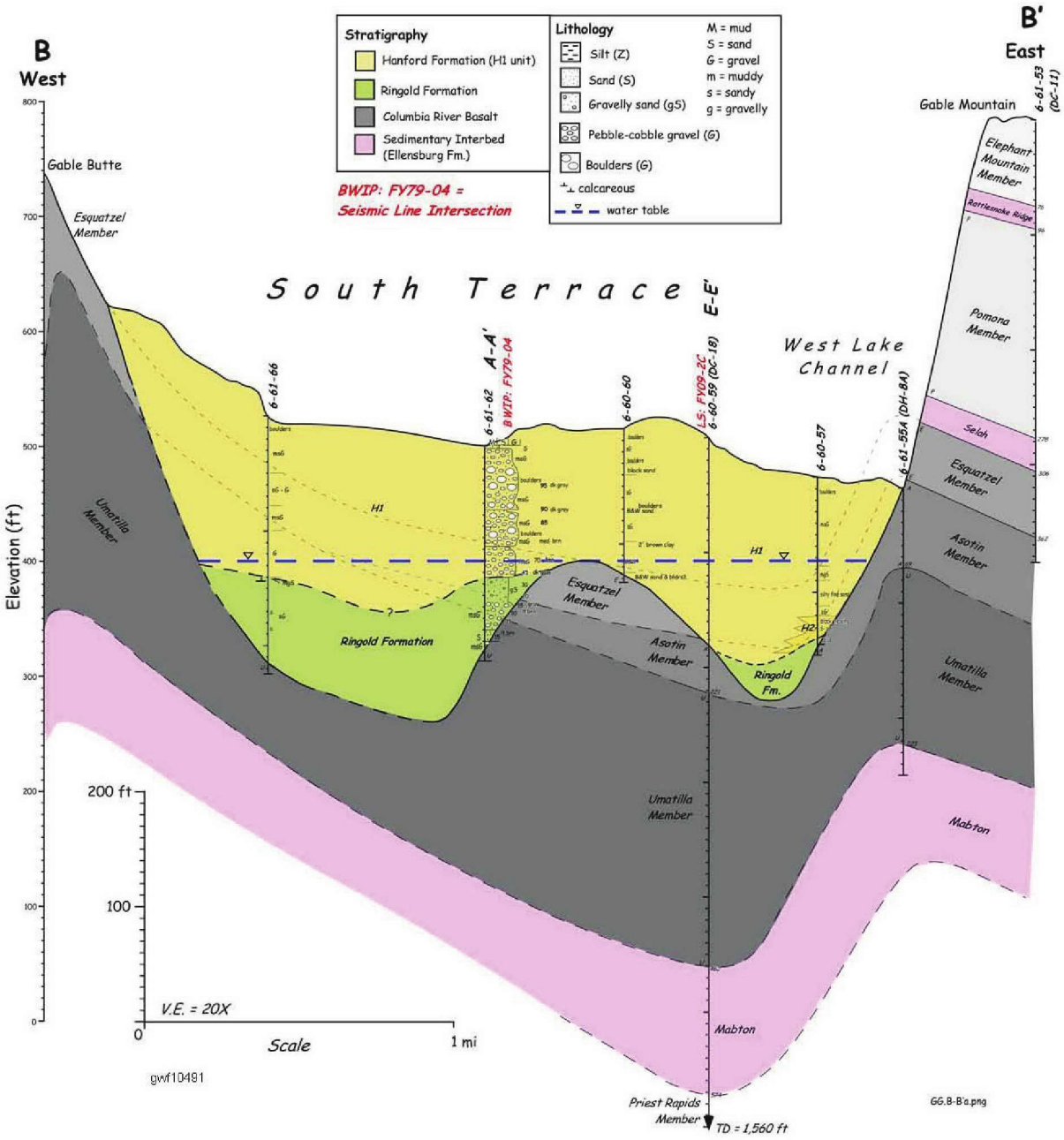


Figure E-12. Distribution of Hydrogeologic Units at Maximum Water Table (after PNNL-14753)

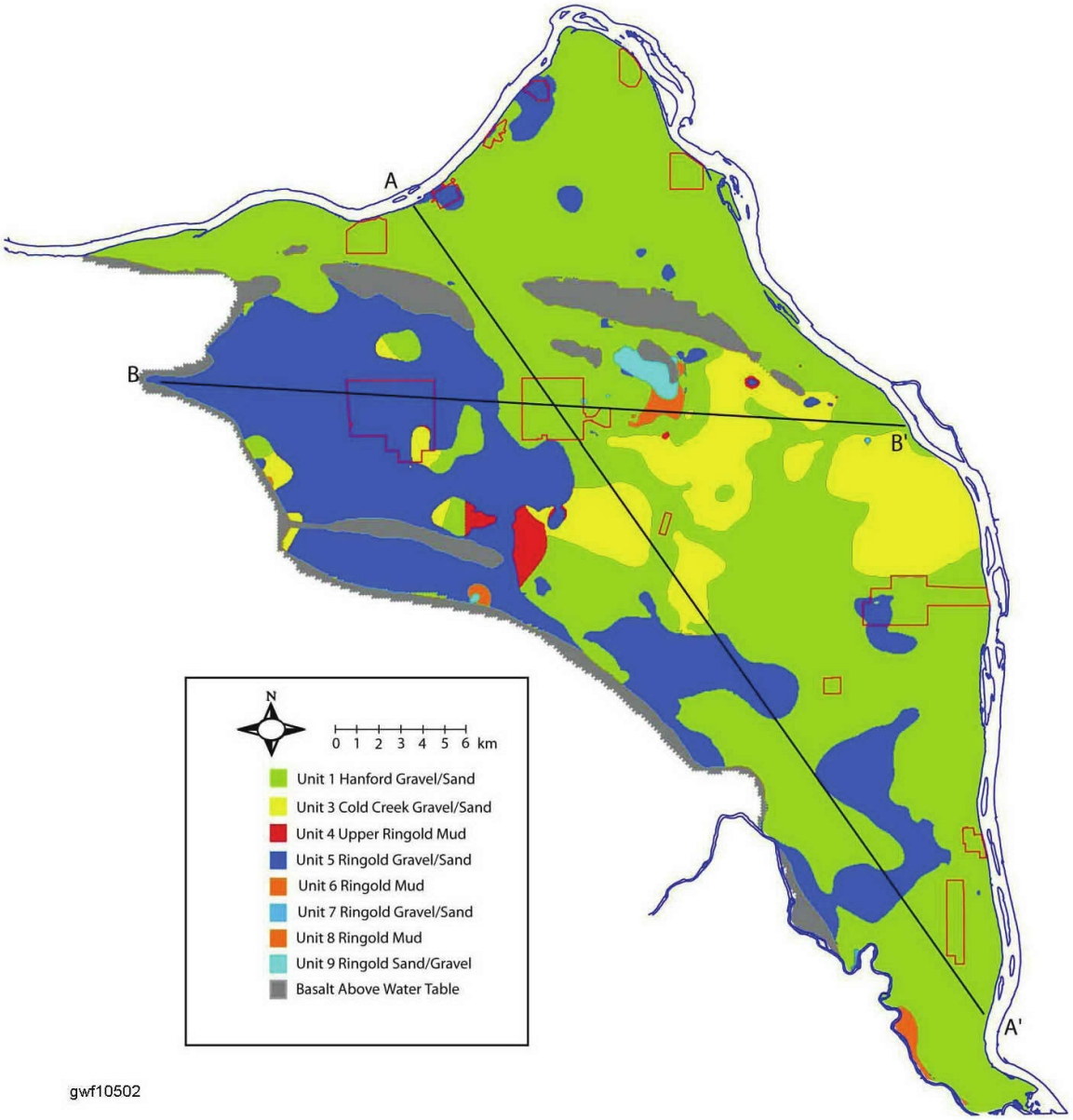


Figure E-13. Hydraulic Conductivity Distribution at Maximum Water Table (after PNNL-14753)

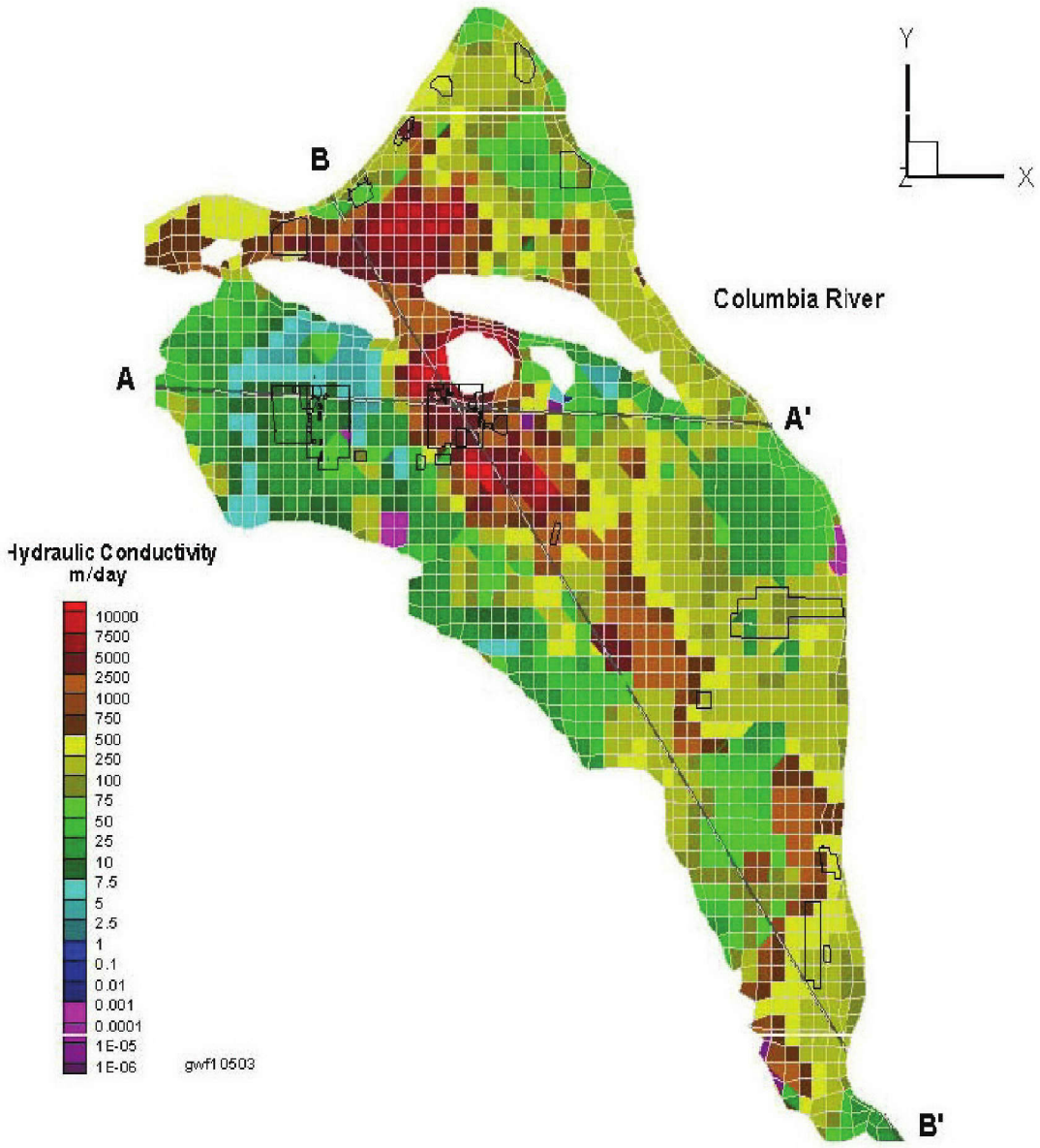
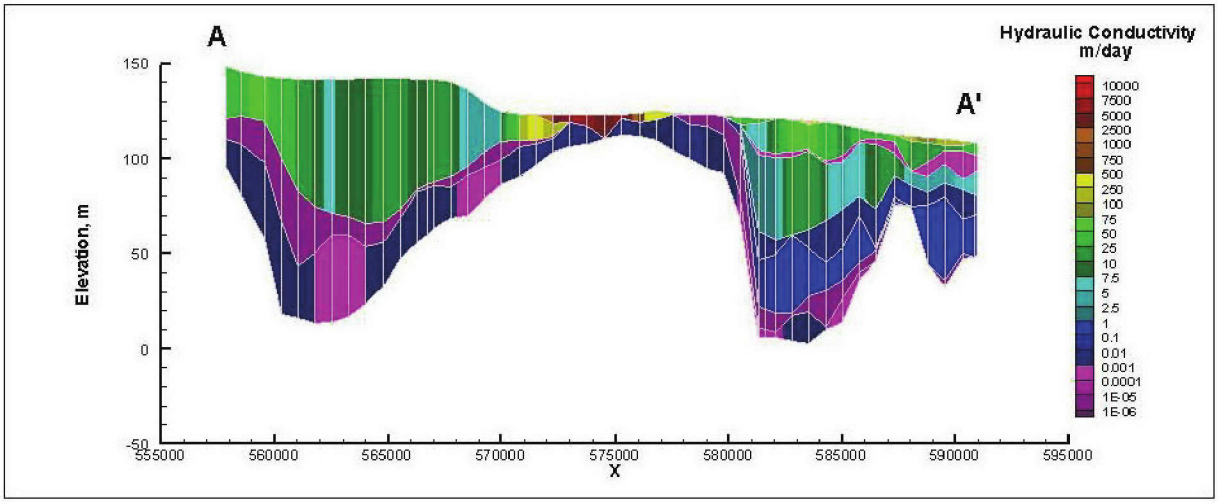
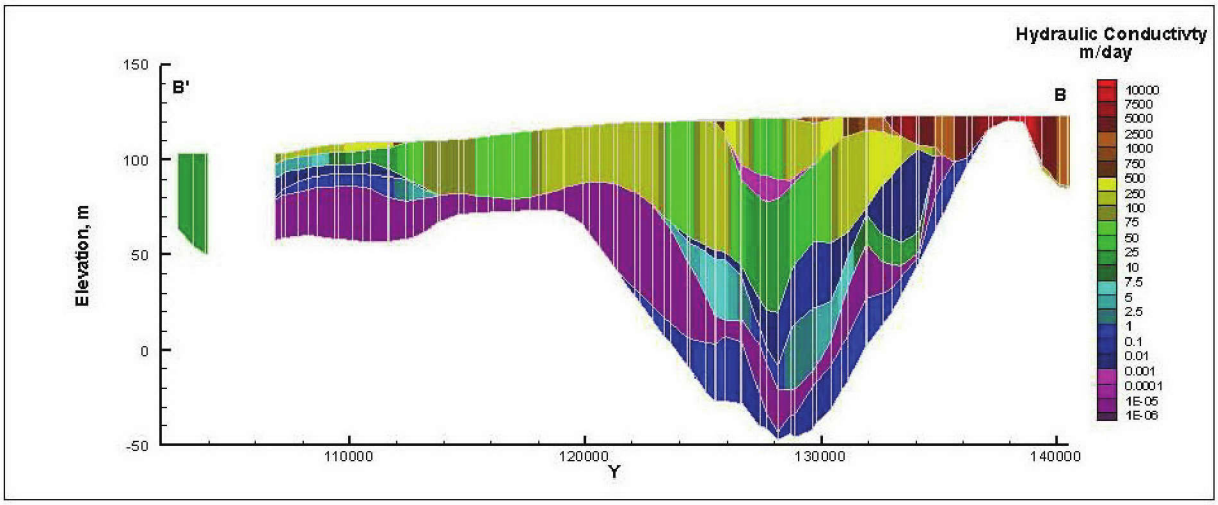


Figure E-14. Hydraulic Conductivity Distribution Along Cross-Section (a) A-A' and (b) B-B' at the Maximum Water Table (after PNNL-14753)



(a)



(b)