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Pacific Northwest
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Hanford Site Groundwater Monitoring for Fiscal Year 2001

Editors
M. J. Hartman
L. F. Morasch
W. D. Webber

March 2002

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL0 1830

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Abstract

This report presents the results of groundwater and vadose zone monitoring and remediation for fiscal year 2001 on the U.S. Department of Energy's Hanford Site, Washington.

The most extensive contaminant plumes are tritium, iodine-129, and nitrate, which all had multiple sources and are very mobile in groundwater. The largest portions of these plumes are migrating from the central Hanford Site to the southeast, toward the Columbia River. Concentrations of tritium, nitrate, and some other contaminants continued to exceed drinking water standards in groundwater discharging to the river in fiscal year 2001. However, contaminant concentrations in Columbia River water remained low and were far below standards.

Carbon tetrachloride and associated organic constituents form a relatively large plume beneath the central part of the Site. Hexavalent chromium is present in smaller plumes beneath the reactor areas along the river and beneath the central part of the site. Strontium-90 exceeds standards beneath each of the reactor areas, and technetium-99 and uranium are present in the 200 Areas. Minor contaminant plumes with concentrations greater than standards include carbon-14, cesium-137, cis-1,2-dichloroethene, cyanide, fluoride, plutonium, and trichloroethene.

Resource Conservation and Recovery Act of 1976 (RCRA) groundwater monitoring continued at 24 waste management areas during fiscal year 2001, including 9 that appear to have contaminated groundwater.

Interim groundwater remediation in the 100 Areas continued with the goal of reducing the amount of chromium (100 K, D, and H Areas) and strontium-90 (100 N Area) reaching the Columbia River. The objective of two interim remediation systems in the 200 West Area is to prevent the spread of carbon tetrachloride and technetium-99/uranium plumes. Groundwater monitoring continued at these sites and at other sites where there is no active remediation.

Vadose zone monitoring, characterization, remediation, and several studies were conducted in fiscal year 2001. Selected wells in single-shell tank farms and other waste sites in the 200 Areas were logged to identify gamma-emitting radionuclides and track their movement. Soil gas monitoring at the 618-11 burial ground helped define the location of tritium contamination and guided the placement of groundwater monitoring wells. Soil gas extraction at a vadose zone remediation site in the 200 West Area resumed after being shut off in fiscal year 2000. The temporary suspension had no negative impact on groundwater quality and resulted in only minimal transport of carbon tetrachloride through the soil to the atmosphere.

In fiscal year 2001, 11 new wells were installed for RCRA monitoring to replace dry wells or to improve monitoring coverage. Thirty-one new wells were installed for activities related to environmental restoration in the 100 D Area and six wells for other projects. Ninety-nine wells were sealed with grout because they were no longer used or were in poor condition.

Groundwater models of groundwater flow and contaminant movement are used to predict future conditions and to assess the effects of remediation systems. The sitewide model was re-calibrated and an alternative case was added that includes interaction between the unconfined and confined aquifer systems. Both of these efforts improved modeling results.

The summary of this report is available on the Internet through the Hanford Groundwater Monitoring Project's web site: http://hanford-site.pnl.gov/groundwater. Inquiries regarding this report may be directed to Ms. Mary J. Hartman, Pacific Northwest National Laboratory, P.O. Box 999, Richland, Washington 99352 or by electronic mail to mary.hartman@pnl.gov.

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This report represents the efforts of dozens of individuals who contribute to the Hanford Groundwater Monitoring Project: planners, schedulers, samplers, laboratory technicians, data management staff, site scientists, editors, text processors, and staff in graphics and duplicating.

John Fruchter and Stuart Luttrell managed the Hanford Groundwater Monitoring Project and the Groundwater Monitoring Task, respectively. Dot Stewart managed the monumental tasks of sampling and analysis, quality control, and data management.

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Mary Hartman
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Bill Webber

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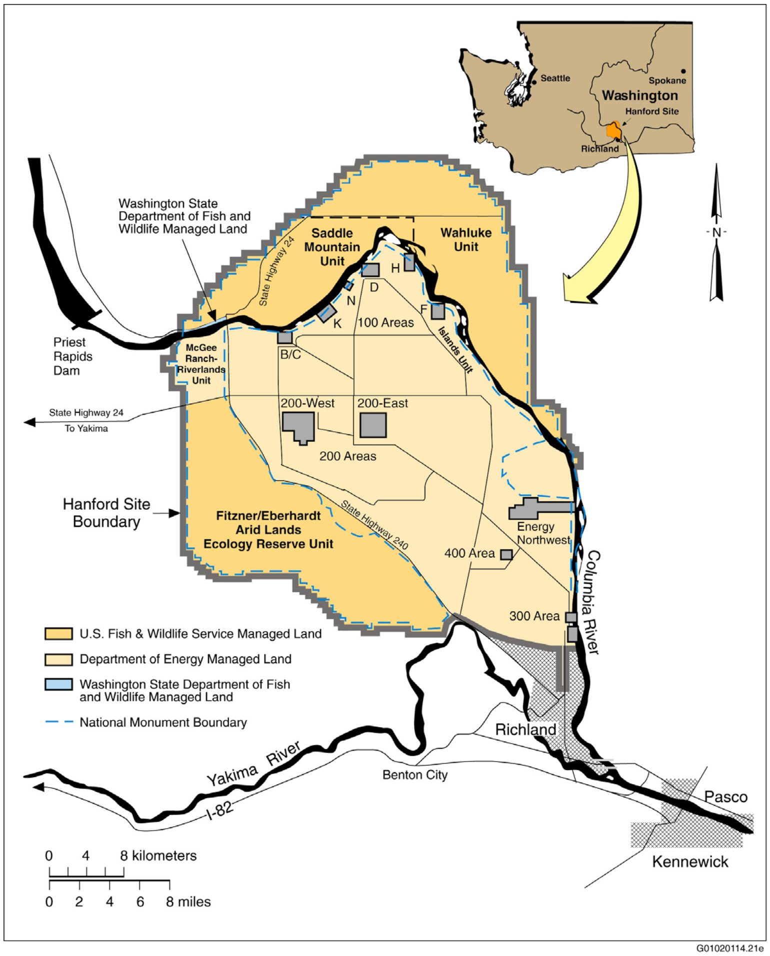
Summary

The Hanford Site, a facility in the U.S. Department of Energy (DOE) nuclear weapons complex, encompasses ~1,517 square kilometers northwest of the city of Richland along the Columbia River in southeastern Washington State. The site was acquired by the federal government in 1943, and until the 1980s was dedicated primarily to the production of plutonium for national defense and the management of resulting waste.

In 1995, all unrestricted discharge of radioactive liquid waste to the ground was discontinued. Today, DOE's mission on the Hanford Site is to restore the Columbia River corridor, transition the central portion of the site toward its long-term waste management role, and prepare for the future.

DOE has monitored groundwater on the Hanford Site since the 1940s to help determine what chemical and radiological contaminants have made their way into the vadose zone and groundwater. As regulatory requirements for monitoring increased in the 1980s, there began to be some overlap between various programs. DOE established the Groundwater Monitoring Project in 1996 to ensure protection of the public and the environment while improving the efficiency of monitoring activities. The Groundwater Monitoring Project is designed to address all

__Groundwater__ is the water that fills the pores or cracks between grains in a layer of sediment or rock. An __aquifer__ is a geologic layer that allows water to pass through easily, with all its pores saturated with water. The top of the saturated zone is called the __water table__. The __vadose zone__ is the soil or rock between the ground surface and the water table. It usually contains some water, but also contains air.



The Hanford Site occupies approximately 1,517 square kilometers of arid land in southeastern Washington.

__Groundwater monitoring__ helps determine what contamination exists beneath the Hanford Site. This information will help regulators and DOE make cleanup decisions based on scientific information and technical capabilities.

groundwater monitoring needs at the site, eliminate regulatory program redundancy, and establish a cost-effective hierarchy for groundwater monitoring activities. Specific objectives include

- maintaining and verifying compliance with all applicable groundwater regulations
- characterizing and defining physical and chemical trends in groundwater
- establishing baselines of groundwater quality
- providing continuing, independent assessment of groundwater remediation activities
- identifying and quantifying new or existing groundwater problems.

This report *is written to meet the requirements in CERCLA, RCRA, the Atomic Energy Act of 1954, and Washington Administrative Code.*

Contamination may reach the Columbia River by moving down through the vadose zone, into the groundwater, and then into the river. The analysis of groundwater samples helps determine the potential effects that contaminants in Hanford soil and groundwater could have on human health and the environment. DOE works with the regulators, such as the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology, to make cleanup decisions based on sound technical information and the technical capabilities available.

Groundwater Monitoring Highlights for Fiscal Year 2001

Notable achievements of the Groundwater Monitoring Project included the following:

- Workers sampled 706 monitoring wells to determine the distribution and movement of contaminants. Many of these wells were sampled multiple times during the year. Data from these samples were used to identify and characterize existing, potential, and emerging groundwater contamination problems.
- Analytical laboratories analyzed nearly 1,000 Hanford groundwater samples for tritium. Over 400 analyses were run for carbon tetrachloride and technetium-99, and over 300 for hexavalent chromium, iodine-129, strontium-90, and uranium.
- The groundwater project continued to monitor 24 *Resource Conservation and Recovery Act of 1976* (RCRA) sites, 5 other regulated units, and 11 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) groundwater operable units.
- RCRA monitoring provided no evidence of new contamination from sites in detection programs. Seven sites continued to be monitored under assessment programs, and two under final-status corrective action.
- The groundwater project evaluated the adequacy of RCRA monitoring networks. At single-shell tank Waste Management Areas A-AX and C, groundwater flow directions have been re-interpreted and the monitoring networks may need to be modified. Because the water table is dropping in the 200 Areas, many monitoring wells have gone dry in recent years. Networks contain fewer than the optimal number of wells at 216-S-10 pond, 216-U-12 crib, and Low-Level Waste Management Areas 3 and 4.
- In January 2001, the Washington State Department of Ecology instructed DOE to cease statistical evaluations of RCRA indicator parameters for the Liquid Effluent Retention Facility near the 200 East Area. Most of the monitoring wells have gone dry and cannot be deepened because there is virtually no

saturated sediment above the basalt bedrock. Only one upgradient and one downgradient well can be sampled. DOE continued to collect and analyze samples from those wells.

- EPA performed a 5-year review to determine whether remedial actions specified under records of decision for the Hanford Site protect human health and the environment. The review identified several action items required to address deficiencies.
- Interim remedial actions continued to limit the movement of contamination in the 100-HR-3, 100-KR-4, 100-NR-2, 200-UP-1, and 200-ZP-1 Operable Units.
- Monitoring provided no evidence of new leaks from fuel storage basins in the 100 K Area. DOE began to remove fuel canisters from the basin during fiscal year 2001.
- Monitoring results at the following regulated units remained within permit limits: 400 Area Process Ponds, Solid Waste Landfill, State-Approved Land Disposal Site, and Treated Effluent Disposal Facility.
- Characterization and monitoring of the tritium plume at the 618-11 burial ground indicated the plume is localized and has a long travel time to the Columbia River. The study included soil gas monitoring, aquifer characterization, and groundwater sampling.
- Monitoring indicated that the tritium plume that originated in the 200 East Area did not move closer to the city of Richland or its water supply wells.
- Average trichloroethene concentrations in compliance wells in the 1100-EM-1 operable unit (Richland North Area) were below the maximum contaminant level for the first time. This contaminant has been attenuating naturally, as expected.
- Drillers completed 11 new RCRA monitoring wells, 31 injection or monitoring wells at the redox site in 100 D Area, and 6 wells for other projects. Ninety-nine wells, mostly near the Columbia River, were sealed with grout because they were no longer needed and posed a potential environmental or safety hazard.
- The sitewide groundwater model was improved by refining input about historical water levels changes, recharge events, and interaction between the unconfined and confined aquifer systems.
- DOE performed an initial assessment using the System Assessment Capability. This set of computer modules simulates movement of contaminants from waste sites through the vadose zone and groundwater.

Groundwater sampling wells *form a monitoring network across the Hanford Site and along the Columbia River. This network provides a picture of the status of groundwater beneath Hanford that will help protect human health and the environment.*

Vadose Zone Highlights for Fiscal Year 2001

DOE's accomplishments in the vadose zone included the following:

- Scientists monitored helium isotopes in soil gas near the 618-11 burial ground to help define distribution of the tritium plume in groundwater (see groundwater highlights).
- Geophysicists logged 113 boreholes with gamma-ray detection equipment at the single-shell tank farms in fiscal year 2001. Results identified possible contaminant movement in four boreholes at the U tank farm and five boreholes at the T tank farm.

- Scientists installed a new vadose zone monitoring device at the single-shell tank farms, the first of its kind at a Hanford Site tank farm. A borehole at the B tank farm was instrumented with tensiometers, heat and water sensors, and a water flux meter.
- Scientists studied alternative methods of monitoring the vadose zone beneath single-shell tanks by simulating tank leakage with a non-hazardous solution at a clean site.
- DOE constructed earthen berms around 200 West Area single-shell tank farms to prevent natural precipitation from running onto the tank farms and possibly mobilizing existing vadose zone contamination. Leaking water pipes also were capped or repaired.
- Leachate monitoring results at the Environmental Restoration Disposal Facility near the 200 West Area met limits defined in the record of decision.
- Soil gas monitoring continued at the Solid Waste Landfill, with no contaminants of concern exceeding reporting limits for air quality. Some contaminants continued to exceed groundwater quality criteria in the leachate.

__Water-table elevations__ are measured across the Hanford Site with an electronic water-level tape once each year. In addition, water levels are measured each time a well is sampled during the year.

Emerging Issues

As monitoring, remediation, and related work progress, new issues of potential concern arise. Some of the issues that DOE will address in coming years include the following:

- **Waste Inventories** – Recent investigations have refined estimates for radioactive waste inventories (i.e., which type of waste went to which disposal facilities in what quantities). In some instances, the new estimates may require a re-examination of groundwater monitoring strategies.
- **Decreasing Water Table Elevation** – Because wastewater discharge to the ground has been reduced in recent years, the water table in the 200 Areas has dropped. The falling water table has caused 32 wells in the 200 Areas to go dry since fiscal year 1997 and changed groundwater flow directions, leaving gaps in monitoring networks. In some areas, the water table has fallen enough that the unconfined aquifer has disappeared and low-permeability basalt or clay extends above the water table. In these areas, routine groundwater monitoring is not applicable, and nontraditional monitoring strategies must be developed.
- **Monitored Natural Attenuation** – The Environmental Protection Agency has published new criteria to identify and quantify natural attenuation processes. These include a more rigorous determination of the level of contamination. For example, additional parameters to be determined are (a) mass and volume of contaminated groundwater; (b) chemical and biological processes likely to reduce the contaminant level; and (c) rate of contaminant recharge from the overlying vadose zone. These determinations are in addition to more traditional methods of monitoring contaminant concentrations at points of groundwater use or exposure.
- **Uranium Mobility** – Evidence from groundwater monitoring, laboratory studies, and remediation evaluations indicates that uranium may be less mobile in the groundwater than previously considered. New information indicates that uranium moves more slowly than groundwater flow. This is an issue for the pump-and-treat system in the 200 West Area and natural attenuation of uranium in the 300 Area. It also must be considered in evaluating the transport of uranium through the vadose zone.

- **Chromium in 100 D Area** – The concentration of hexavalent chromium in a well in the southwestern 100 D Area increased sharply in fiscal year 2001. In August, the concentration reached 4,750 µg/L, the highest concentration on the Hanford Site. The reason for the concentration change and related changes in chromium distribution are unknown.
- **Tritium in 100 K Area** – Tritium concentrations in groundwater near the 100-K burial ground have increased in the past two years. Concentrations exceeded the drinking water standard (20,000 pCi/L) by late 2000 and were nearly 100,000 pCi/L in late 2001. It appears unlikely that past leakage from the KE fuel storage basin or continued movement from the KE condensate crib are the source of this tritium. The source has not been positively determined, but the current hypothesis involves a previously unmapped tritium plume located beneath the 100-K burial ground.

Wells in the 200 Areas that were formerly sampled for the Groundwater Project have gone dry as the water table declined. Most of the wells are in the 200 West Area.

Fiscal Year	200 West	200 East	Both
1997	1	1	2
1998	2	1	3
1999	12	1	13
2000	7	1	8
2001	5	1	6
1997 to 2001	27	5	32

*A **groundwater monitoring network** strategically located across the Hanford Site helps determine changes in the direction of groundwater flow as the site returns to pre-Hanford conditions.*

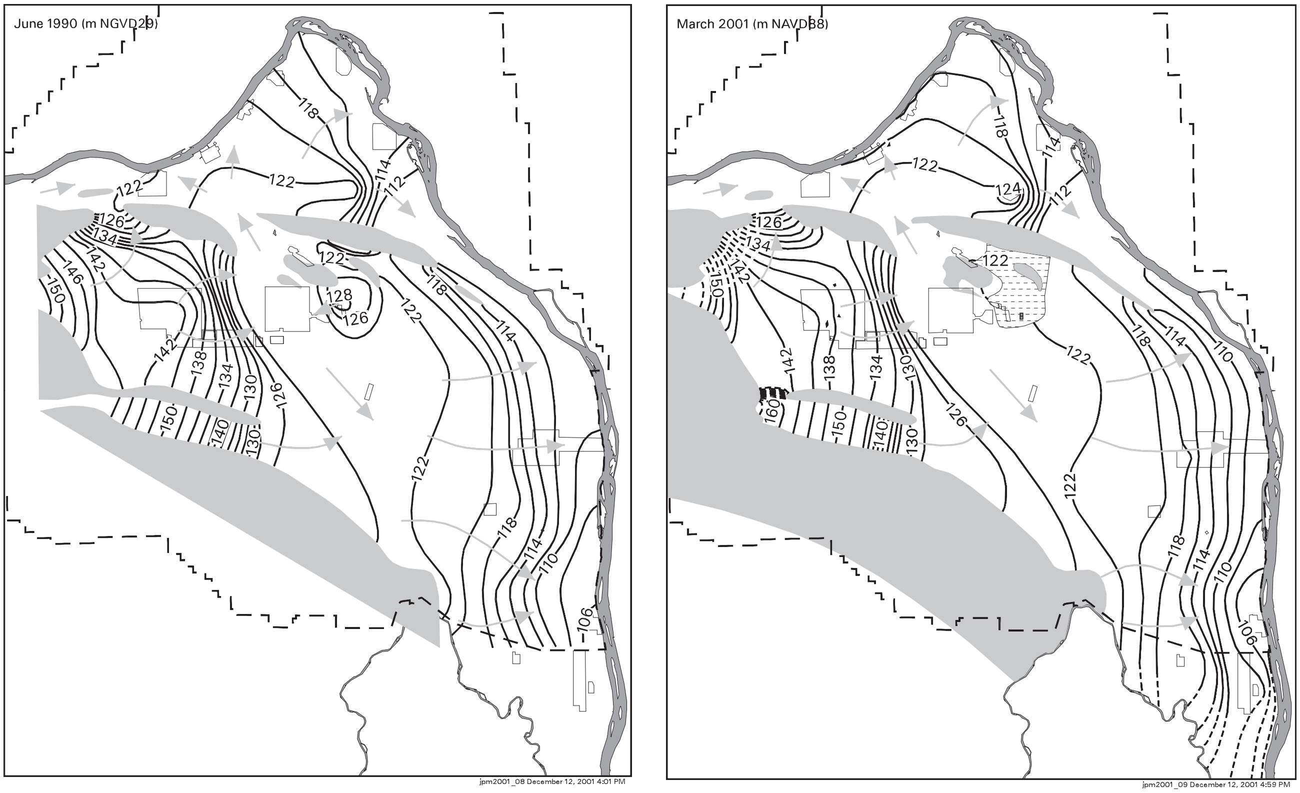
Groundwater Flow and Movement

Groundwater in the unconfined aquifer generally flows from west to east across the Hanford Site to discharge areas along the Columbia River. The direction of groundwater flow is inferred from water-table elevations, barriers to flow (e.g., basalt or mud units at the water table), and the distribution of contaminants.

*The top of an **unconfined aquifer** is the water table. At Hanford, the unconfined aquifer is in a sequence of sandy, gravelly sediment, and depth to the water table ranges from less than 1 meter near the river to more than 100 meters in the center of the Site. **Confined aquifers** are capped by less permeable layers that cannot transmit much water. Confined aquifers at Hanford occur beneath clay or basalt layers.*

General directions of groundwater flow are illustrated on the following map (page xiv) for March 2001. Beneath the reactor areas groundwater flows generally toward the Columbia River. Groundwater seeps appear along the riverbank when river levels are low. Farther inland, north of Gable Mountain, flow is toward the northeast and east. Groundwater beneath the 200 West Area flows eastward beneath the 200 East Area and then flows to the southeast. Groundwater has moved some contaminants from the northern 200 East Area through the gap between Gable Butte and Gable Mountain. This northward flow appears to be diminishing as discussed below. Groundwater converges on the 300 Area from the northwest, west, and southwest and discharges into the Columbia River to the east. Groundwater in the Richland North Area flows generally eastward to the Columbia River.

The natural pattern of groundwater flow was altered during the Hanford Site's operating years by the formation of mounds in the water table. The mounds were created by the discharge of large volumes of wastewater to the ground and were present in each reactor area and beneath the 200 Areas. Since effluent disposal has decreased significantly, these mounds are disappearing. The 1990 water-table map shows groundwater mounds beneath the 200 West and 200 East Areas, which



These maps show the water table and inferred flow directions in June 1990 (National Geodetic Vertical Datum of 1929) and March 2001 (North American Vertical Datum of 1988). NGVD29 is ~1 meter lower than NAVD88. The water table declined beneath most of the Hanford Site during that period. Shaded areas in both maps and the area filled with dashed lines in the 2001 map show where the unconfined aquifer is absent.

created radial flow near the mounds and induced northward flow toward the gap between Gable Mountain and Gable Butte. The 200 East Area mound is gone and the 200 West Area mound is much less prominent in the fiscal year 2001 map. Water levels east of the 200 East Area have dropped below the top of a fine-grained confining unit, thus creating a barrier to movement in the surrounding unconfined aquifer. Beneath this confining unit, the uppermost aquifer is a permeable unit in the Ringold Formation. Groundwater flow in this confined aquifer still is influenced by the recharge mound that formerly created an unconfined aquifer above the fine-grained confining unit in the area.

The end of most effluent discharge changed the direction and rate of groundwater movement, especially in the 200 Areas. The water-table decline continued during fiscal year 2001, causing some monitoring wells to go dry. Drillers installed new wells to replace dry ones at locations agreed upon by DOE and the Washington State Department of Ecology.

Groundwater in the upper basalt-confined aquifer generally flows from west to east across the Hanford Site, up through the unconfined aquifer, and into the Columbia River. Vertical gradients between the basalt-confined aquifer and the unconfined aquifer are upward on most of the Hanford Site. Therefore, there is little potential for contaminants to migrate from the unconfined aquifer into the basalt-confined aquifer, where it could move offsite. Downward gradients are measured beneath the western portion of the site and north and east of the Columbia River.

***Water-table maps** are used to help determine the direction of groundwater flow. Groundwater seeps between the sediment grains in the aquifer from areas where the water-table elevation is high to where it is low.*

Overview of Contaminants

The distribution of nine principal groundwater contamination plumes is shown on the maps on the following pages. The following paragraphs provide some basic information about contaminants on the Hanford Site. More specific information is provided in the sections on the geographic regions of the plume sources.

Tritium – Tritium was common in Hanford Site liquid waste discharged to the soil and is the most mobile and most widely distributed radionuclide onsite. It has a relatively short half-life (12.3 years). The drinking water standard, 20,000 pCi/L, is exceeded in parts of the 100, 200, and 600 Areas. The most prominent tritium plume originated from disposal cribs in the 200 East Area near the PUREX Plant and has migrated downgradient to the southeast where it meets the Columbia River.

Iodine-129 – Iodine-129 is a fission product and was present in waste related to fuel processing. The presence of iodine-129 in groundwater is significant because of its relatively low (1 pCi/L) drinking water standard, its long-term releases from nuclear fuel processing facilities, and its long half-life (16 million years). Iodine-129 is very mobile in groundwater. Waste containing iodine-129 was historically disposed of in the 200 Areas, and groundwater plumes are similar in shape and extent to the tritium plumes, though concentrations above the drinking water standard have not reached the Columbia River.

*The **chemical and physical characteristics** of groundwater vary across areas and time. The interpretation of sampling results must, therefore, be carried out with great care.*

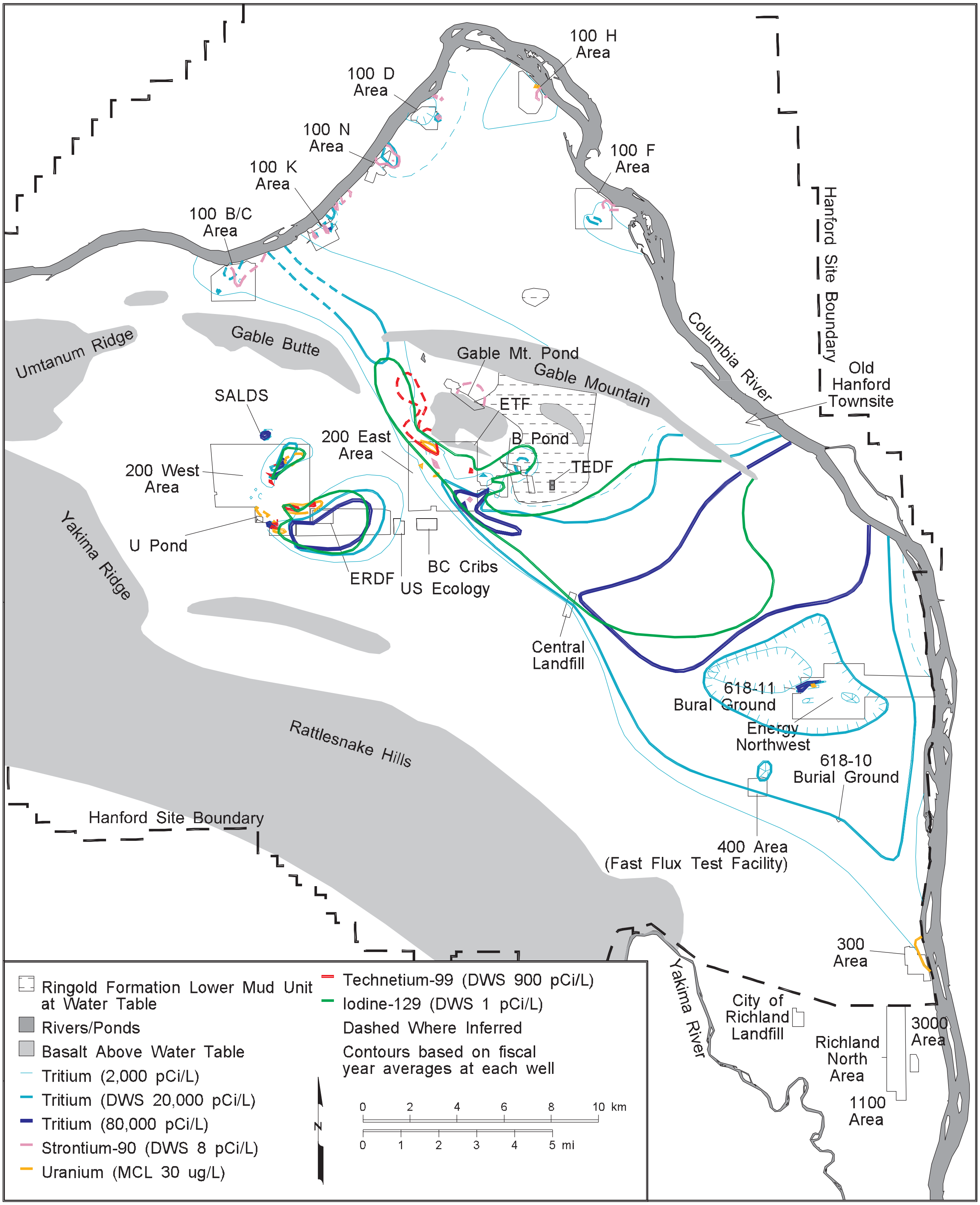
Strontium-90 – Strontium-90 was present in waste associated with fuel processing. It was released also by fuel element failures during reactor operations. Strontium-90 has a half-life of 28.8 years and a drinking water standard of 8 pCi/L. It moves slowly through the vadose zone and in groundwater. A pump-and-treat system in the 100 N Area minimizes its flow into the Columbia River. Strontium-90 also exceeds the drinking water standard beneath the other reactor areas, the 200 Areas, and the former Gable Mountain Pond.

Technetium-99 – Technetium-99 was produced as a high-yield fission product and was present in waste streams associated with fuel processing. It has a half-life of 210,000 years and a drinking water standard of 900 pCi/L. Technetium-99 is very mobile in groundwater and concentrations exceed the drinking water

Area of Contaminant Plumes at Levels Above Drinking Water Standards (square kilometers)

Constituent (drinking water standard)	Fiscal Year 1999	Fiscal Year 2000	Fiscal Year 2001
Carbon tetrachloride (5 µg/L)	11.5	9.8	9.8
Chromium (100 µg/L)	2.7	2.8	2.8
Iodine-129 (1 pCi/L)	87.0	89.6	79.5(a)
Nitrate (45 mg/L)	40.5	36.3	38.4
Strontium-90 (8 pCi/L)	2.7	2.8	2.7
Technetium-99 (900 pCi/L)	2.4	2.3	2.4
Trichloroethene (5 µg/L)	4.5	4.2	4.3
Tritium (20,000 pCi/L)	192	152(a)	151
Uranium (20/30 µg/L)	1.9	2.0	1.6
Combined Plumes	249	210(a)	208
Estimated volume of contaminated groundwater (L)	Not available	1.07 trillion	1.03 trillion

(a) These large changes in estimates of plume area are caused by changing interpretations of the data and changes to the monitoring network. Changes in actual plume size are usually more gradual.



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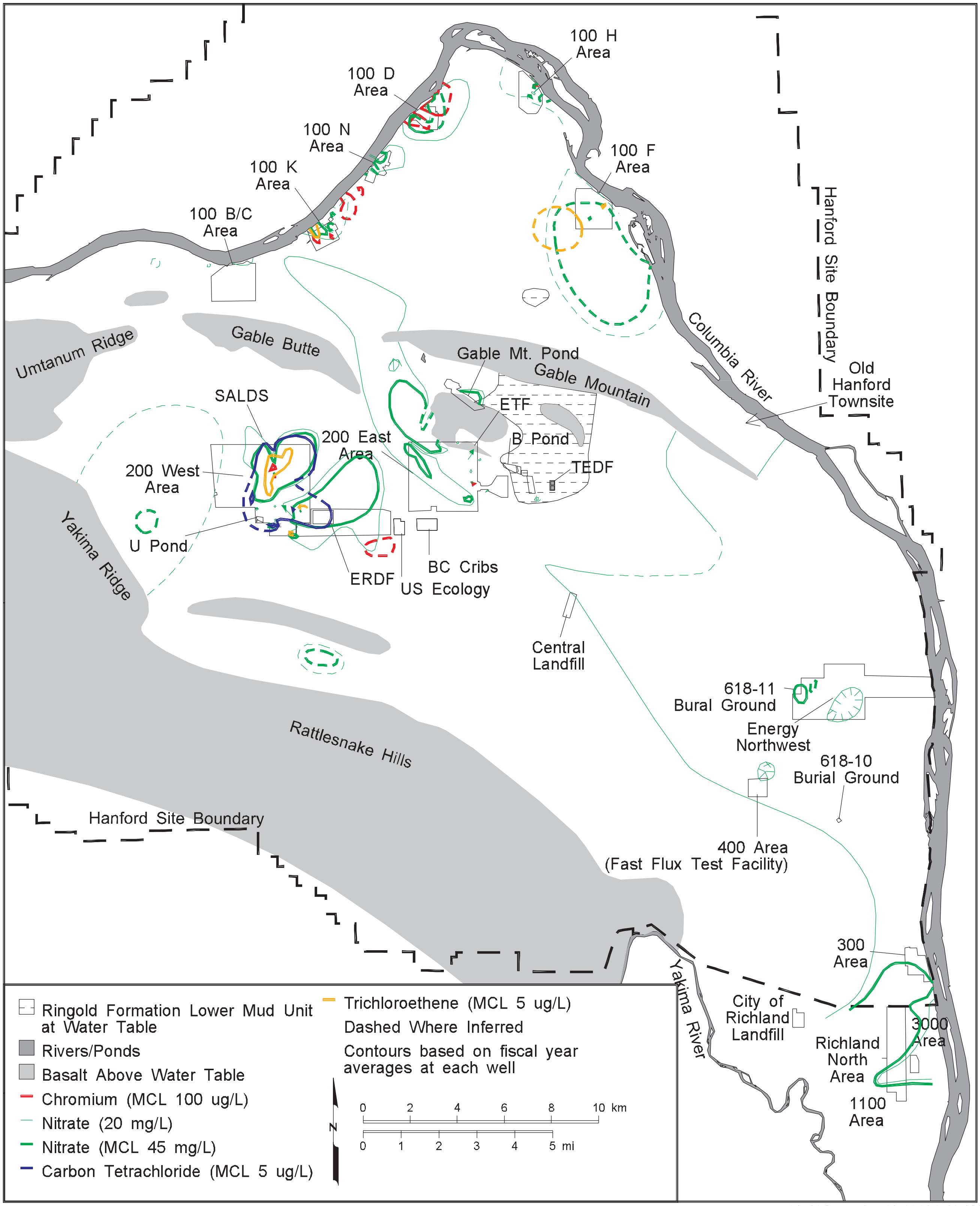
This map shows the distribution of major radionuclides in groundwater at concentrations above maximum contaminant levels or drinking water standards during fiscal year 2001.



This map shows the distribution of major hazardous chemicals in groundwater at concentrations above maximum contaminant levels during fiscal year 2001.

standard beneath portions of the 200 Areas. A technetium-99 plume in the 200 West Area is being contained by a pump-and-treat system. Another plume is located in the northwestern 200 East Area and extends north toward the gap between Gable Butte and Gable Mountain.

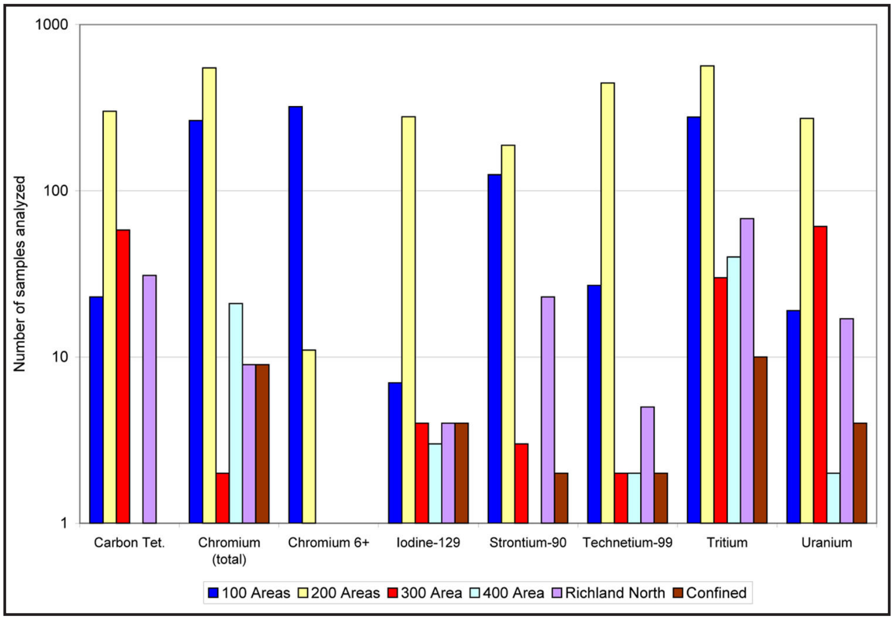
*Because **contaminants** were disposed to the ground or were contained in leaking tanks, groundwater is the major pathway through which contaminants move off the Hanford Site.*

Uranium – Uranium contamination on the Hanford Site had numerous potential sources including fuel fabrication, fuel processing, and uranium recovery from separations activities. Uranium tended to be associated with technetium-99 through the fuel processing cycle, but uranium is less mobile in groundwater on the Hanford Site. The drinking water standard is 30 µg/L. Plumes are detected in the 200 West, 200 East, and 300 Areas.

Chromium – A major source for chromium was the sodium dichromate used as a corrosion inhibitor in cooling water for reactors in the 100 Areas. In the 100 K, 100 D, and 100 H Areas, interim actions are underway to pump and treat groundwater to reduce the amount of chromium reaching the Columbia River. Chromium concentrations continued to exceed the 22 µg/L cleanup goal in all these areas in fiscal year 2001. Another interim action in the 100 D Area is designed to immobilize chromium in the aquifer.

Carbon tetrachloride – Carbon tetrachloride was used in plutonium processing in the 200 West Area, where concentrations in groundwater exceed the 5 µg/L maximum contaminant level. The plume extends beyond the area boundary and forms the most widespread organic contaminant plume on the Hanford Site.

Nitrate – Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical processing operations. Like tritium, nitrate was present in many waste streams and is mobile in groundwater. Agricultural sources of nitrate are located off the Hanford Site to the south and west. Nitrate was measured at concentrations greater than the maximum contaminant level (45 mg/L) in wells in all operational areas except 100 B/C.



The groundwater project requests specific laboratory analyses based on the well's location, historical contaminant trends, and regulatory requirements. This graph shows the number of analyses for some of the primary contaminants of concern during fiscal year 2001.

Trichloroethene – Trichloroethene was used on the Hanford Site in the 1960s and 1970s as a degreasing compound. The drinking water standard is 5 μg/L. The most extensive plume is in the 200 West Area. Trichloroethene also exceeded the standard in the 100 K and 100 F Areas. Annual average concentrations in the 300 and Richland North Areas declined below the standard in all wells in fiscal year 2001.

Cyanide – Cyanide was associated with waste discharged to the BY cribs near 200 East Area. In groundwater, it exceeded the 200 μg/L drinking water standard in three wells and concentrations are increasing because of changing flow directions.

Carbon-14 – Carbon-14 exceeded the 2,000 pCi/L drinking water standard in two small plumes near waste disposal facilities adjacent to the KW and KE Reactor buildings where reactor atmosphere gas condensate was discharged to the ground in the past. The half-life is 5,730 years.

Cesium-137 – Cesium-137 is a high-yield fission product with a half-life of 30 years and a drinking water standard of 200 pCi/L. It was present in waste associated with fuel processing and has been released in reactor areas by fuel element failures. Cesium-137 was present in waste that leaked from underground storage tanks in the past. It is present in the vadose zone near the single-shell tanks, but is rarely detected in groundwater.

Plutonium – Plutonium was present in waste associated with fuel processing. It has a low mobility in groundwater and a long half-life (24,000 years for plutonium-239 and 6,500 years for plutonium-240). The only significant detection of plutonium in recent years was associated with the 216-B-5 injection well in the 200 East Area.

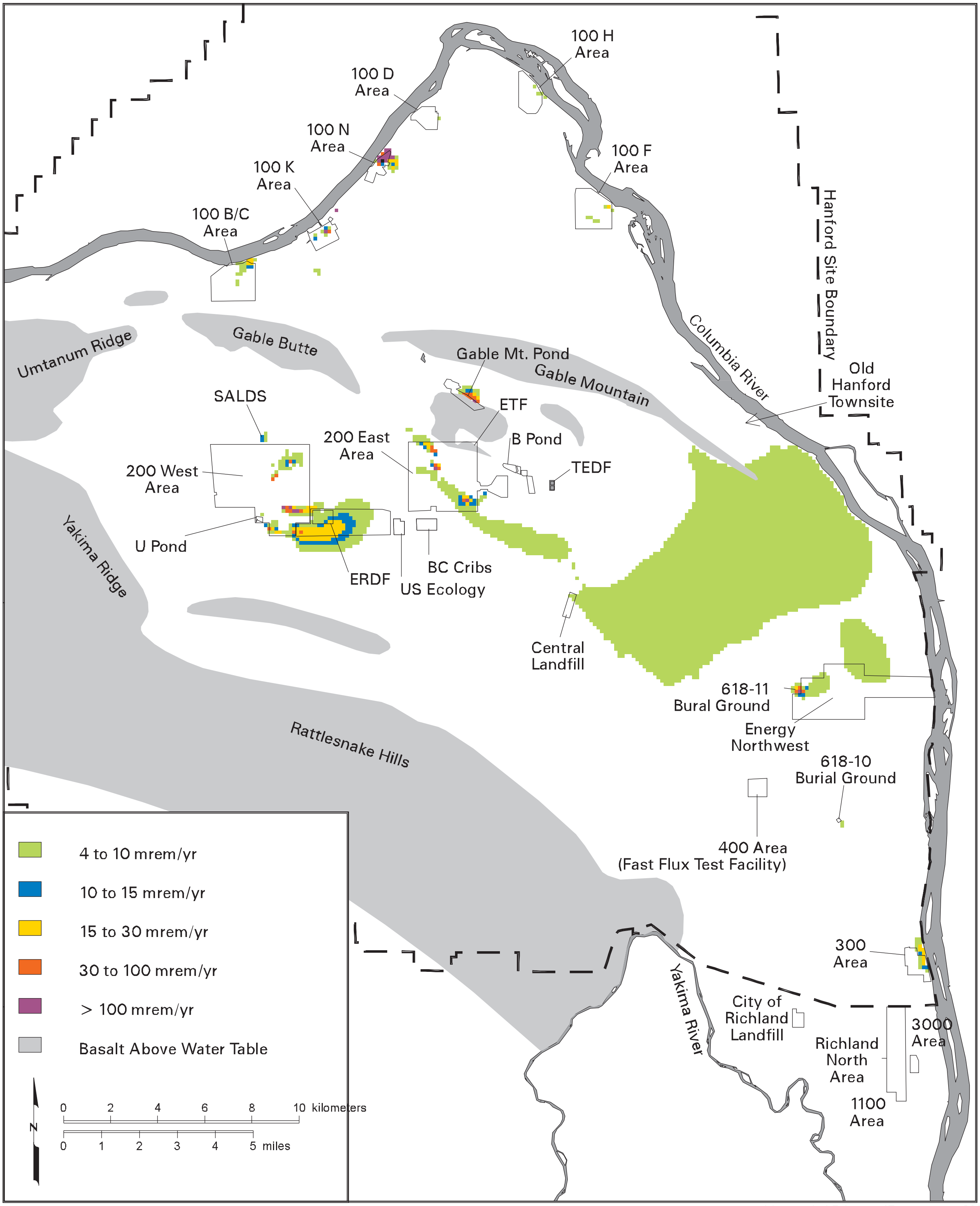
Dose Estimates and Risk Estimates

Groundwater is not a primary source of drinking water for most Hanford Site workers. However, comparison to drinking water standards provides perspective for contaminant levels in groundwater. Drinking water standards use the methods set out in 40 CFR 141, 40 CFR 142, and 40 CFR 143 to estimate the concentration in water that could result in a potential radiological dose of 4 millirem per year from consumption of each individual constituent. Similarly, DOE-derived concentration guides provide estimates of radiological concentration that could result in a 100 millirem per year dose as defined in DOE Order 5400.5. However, the potential dose is actually the sum of the doses from the individual constituents. An estimate of this cumulative dose, which could result from consumption of groundwater from different onsite locations, can be calculated from the extent of contamination.

__Hanford groundwater__ is not a primary source of drinking water, but it flows into the Columbia River, which is a major drinking water source. Therefore, DOE is focusing their remediation efforts on protecting the Columbia River.

DOE estimates the potential dose from ingestion of groundwater by adding the effects of all major radionuclides in Hanford Site groundwater: carbon-14, cesium-137, iodine-129, plutonium, strontium-90, technetium-99, tritium, and uranium. The automatic interpolation process sometimes resulted in peak grid values that were lower than the measured maximum values because it averaged in other lower values. In these cases, the value at the grid node closest to the measured peak value was increased to match the measured peak. Factors to convert activities to ingestion dose equivalents were taken from DOE Order 5400.5.

The dose estimates presented here show that areas above the 100-millirem per year dose standard are restricted to localized parts of the 100 K, 100 N, and



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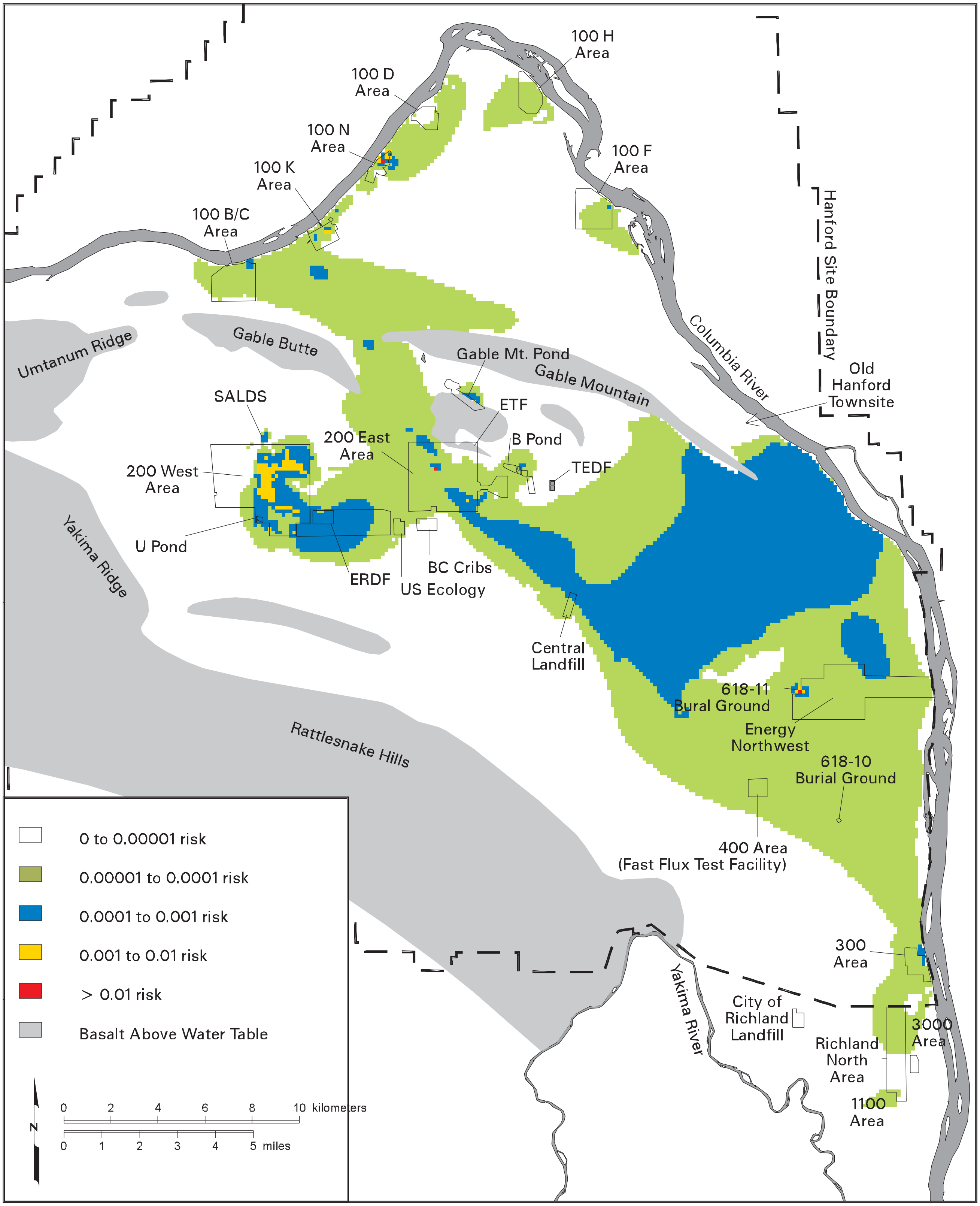
If people drank contaminated groundwater from the Hanford Site, their dose of radioactivity would equal the combined dose from individual radionuclides. However, Hanford Site groundwater is not a major source of drinking water.



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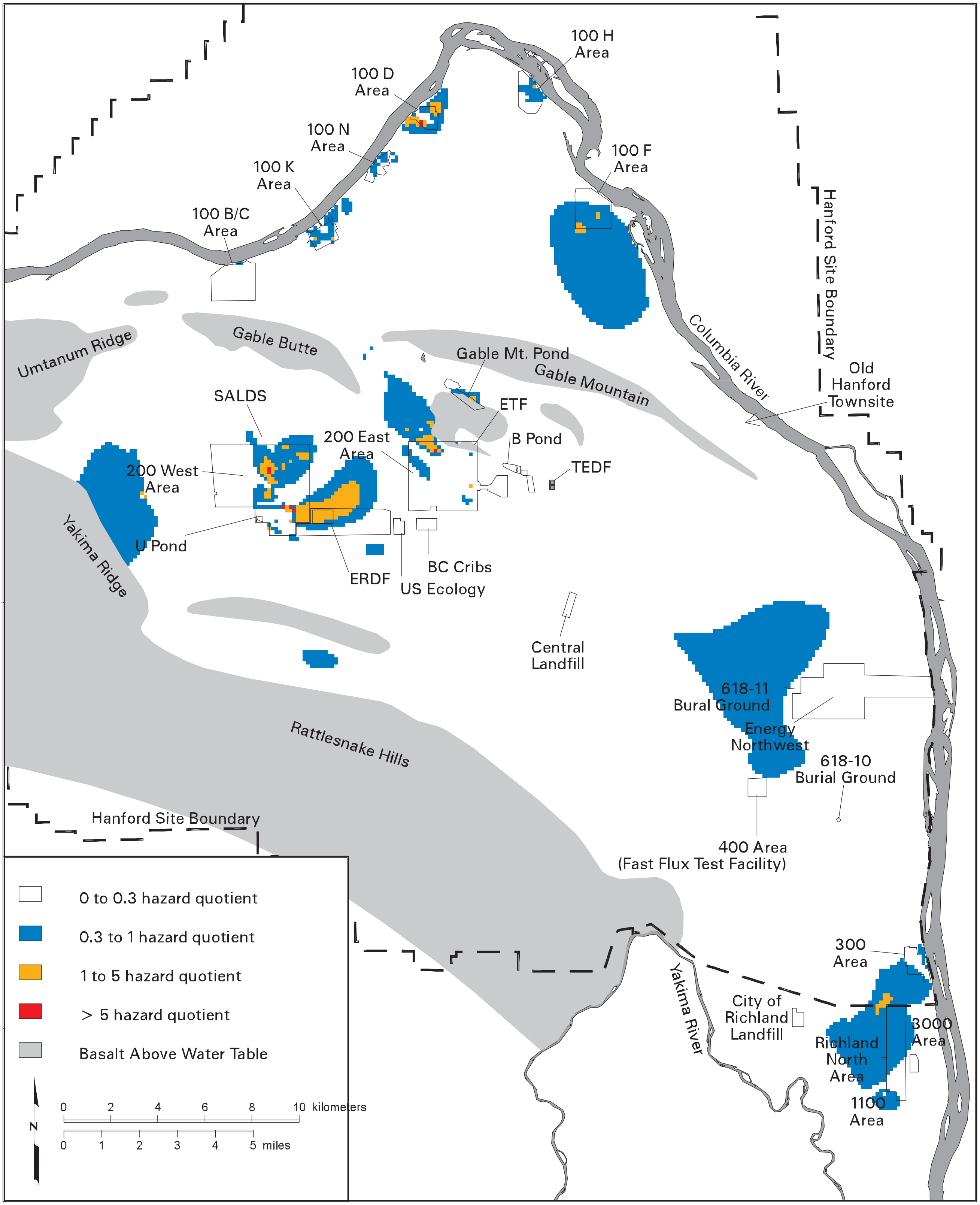
If people drank contaminated groundwater from the Hanford Site for many years, they might increase their risk of cancer. Radiological and chemical contaminants contribute to the total risk.



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Health risks caused by non-radiological, non-carcinogenic contaminants are estimated by the "hazard quotient." Consumption of contaminated groundwater would increase these risks.

200 Areas and a location around a single well downgradient of the 618-11 burial ground. Portions of the 100, 200, 300, and 600 Areas exceed 4 millirem per year.[a]

DOE estimates the likelihood of a person developing cancer over a lifetime as a result of drinking water contaminated with chemicals and radionuclides at concentrations that have been measured in groundwater across the Hanford Site. Cancer-risk estimates were made by adding concentrations of the radionuclides listed above plus carbon tetrachloride, chloroform, cis-1,2-dichloroethene, hexavalent chromium, nitrate, and trichloroethene. The calculation assumes that a person weighing 70 kilograms consumes 2 liters of groundwater every day for 30 years (DOE/RL-91-45; IRIS[b]). Cancer risks exceeding 0.0001 (i.e., 1 in 10,000) are present in portions of the 100, 200, 300, and 600 Areas.

The hazard quotient relates the potential human health hazards associated with exposure to non-carcinogenic substances or carcinogenic substances with systemic toxicity other than cancer (in Hanford Site groundwater, these include hexavalent chromium, nitrate, strontium, and uranium). The calculation assumes that a person weighing 70 kilograms consumes 2 liters of groundwater every day for 30 years (DOE/RL-91-45; IRIS[b]). If the hazard quotient is greater than one, there is a possibility of toxic effects.

Hazard quotients between 1 and 5 are present in the 100 and 200 Areas and from offsite contamination in the Richland North Area. The only locations with hazard quotients above 5 are small portions of the 100 D, 200 West, and 200 East Areas.

100 Areas Groundwater Contamination

***Monitoring well networks** are designed specifically for individual areas based on the type of data needed, the hydrogeologic conditions, geologic conditions, groundwater flow directions, and the expected contaminants.*

During 1944 to 1988, fabricated fuel cylinders were shipped by rail from the 300 Area to the reactors in the 100 Areas for irradiation, the second step in the plutonium production process. The nine plutonium production reactors are ~30 miles from Richland in the northern portion of the Hanford Site along the south bank of the Columbia River. The reactor areas had to be close to the river because large quantities of water were required for cooling.

Today, the most prominent contaminants in 100 Areas groundwater are tritium, strontium-90, hexavalent chromium, and nitrate. These contaminants originated from disposal cribs, trenches, and leaking retention basins. Because these

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(a) EPA drinking water standards for radionuclides in 40 CFR Part 141 were derived based on a 4-millirem-per-year dose standard using Maximum Permissible Concentrations in water specified in National Bureau of Standards Handbook 69 (U.S. Department of Commerce, as amended August 1963). The area exceeding drinking water standards in the plume map is based on the EPA regulatory requirement. However, the areas in the dose estimate map corresponding to a dose >4 millirems per year were calculated using a more recent dosimetry system adopted by DOE and other regulatory agencies (as implemented in DOE Order 5400.5 in 1993). If both dosimetry systems were equivalent, one would expect the area above 4 millirems per year in the dose estimate map to be the same as the area exceeding drinking water standards (see the map of radiological contaminant plumes), or to show a slightly larger area exceeding 4 millirems per year (i.e., if two or more radionuclides were individually below the drinking water standards, but added up to exceed 4 millirems per year). In fact, the areas above 4 millirems per year on the dose estimate map are more restricted than the area above the drinking water standard in the plume map because of differences in the dosimetry systems adopted by EPA and DOE.

(b) *IRIS: Integrated Risk Information System* maintained by the Office of Research and Development, National Center for Environmental Assessment, U.S. Environmental Protection Agency, Washington, D.C. Online manual; available at http://www.epa.gov/iriswebp/iris/index.html.

sites are so close to the Columbia River, all of these contaminants have been detected in springs that discharge to the river.

100 B/C Area. Most of the groundwater contamination in the 100 B/C Area is found in the northern portion of the area, beneath waste trenches and retention basins. Tritium and strontium-90 exceeded drinking water standards in several wells. Nitrate and chromium were somewhat elevated, but were below drinking water standards in fiscal year 2001. Surface waste sites have been excavated and backfilled. There is no active groundwater remediation in the 100 B/C Area.

100 K Area. The primary constituents of concern in 100 K Area groundwater are hexavalent chromium and tritium. The major chromium plume is beneath the 116-K-2 trench, located east of 100 K Area near the Columbia River. This plume is the target of a pump-and-treat system that reduces contaminated flow into the river.

__What is pump-and-treat?__ Several contaminant plumes in the 100 Areas are of special concern because they are so close to the Columbia River. DOE is pumping contaminated groundwater out of strontium-90 and chromium plumes, treating it to remove the contaminants, and injecting the clean water back into the aquifer. The primary purpose of these pump-and-treat systems is to reduce the amount of contamination entering the river until a final cleanup solution is in place.

High concentrations of tritium in very small plumes originated from past leaks in fuel storage basins within the KE Reactor building. The highest concentration was 1.75 million pCi/L in fiscal year 2001. No new leaks have been detected since 1993. One monitoring well near the 100-K burial ground detected a sharp rise in tritium concentrations that appears to indicate the presence of a previously unidentified plume. Other groundwater contaminants in the 100 K Area include carbon-14, nitrate, and trichloroethene.

100 N Area. The primary groundwater contaminant in the 100 N Area is strontium-90. This plume originated at the 1301-N crib near the river, and to a lesser extent, the 1325-N crib. The extent of the plume changed very little over the past 10 years but concentrations increased during the 1990s because of changing water levels and the end of effluent discharge. A pump-and-treat system in the 100 N Area operates to reduce the movement of strontium-90 toward the Columbia

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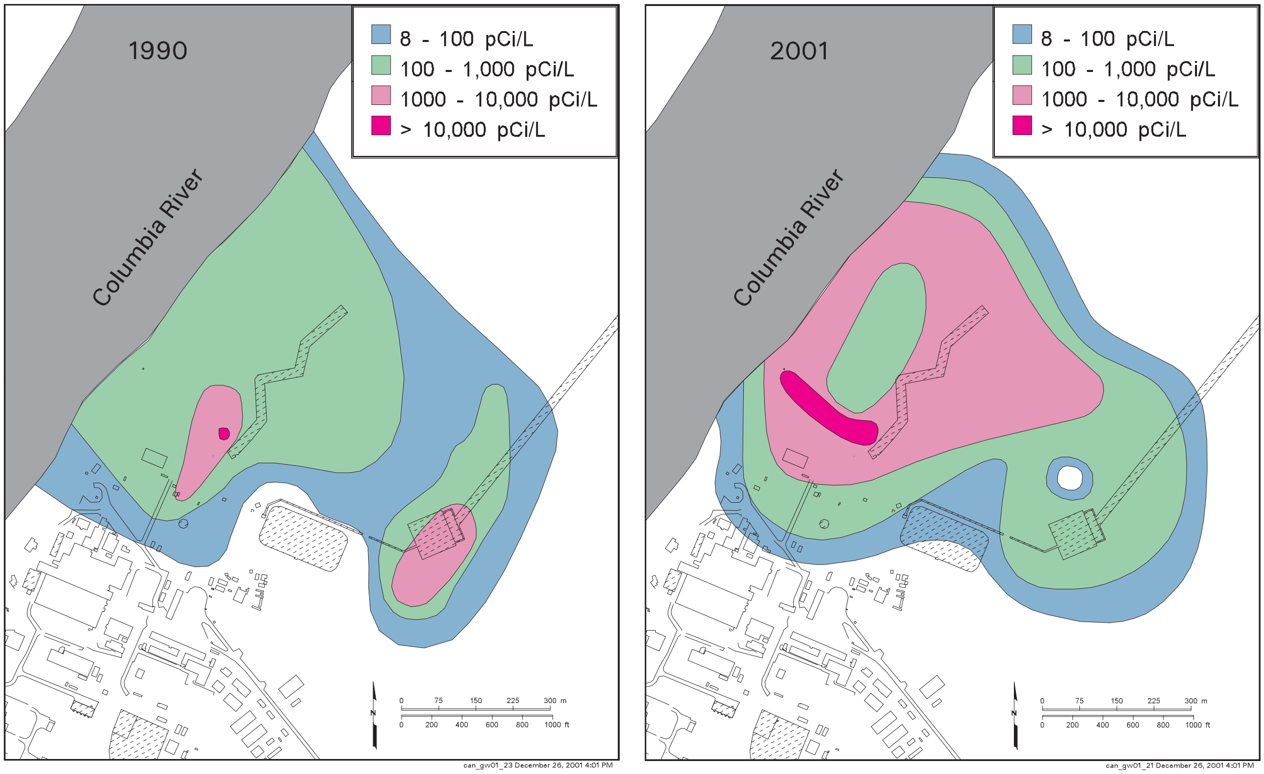
A pump-and-treat system in the 100 K Area reduces the amount of chromium entering the Columbia River. The shape of the plume and concentrations within it have remained fairly stable since 1994.



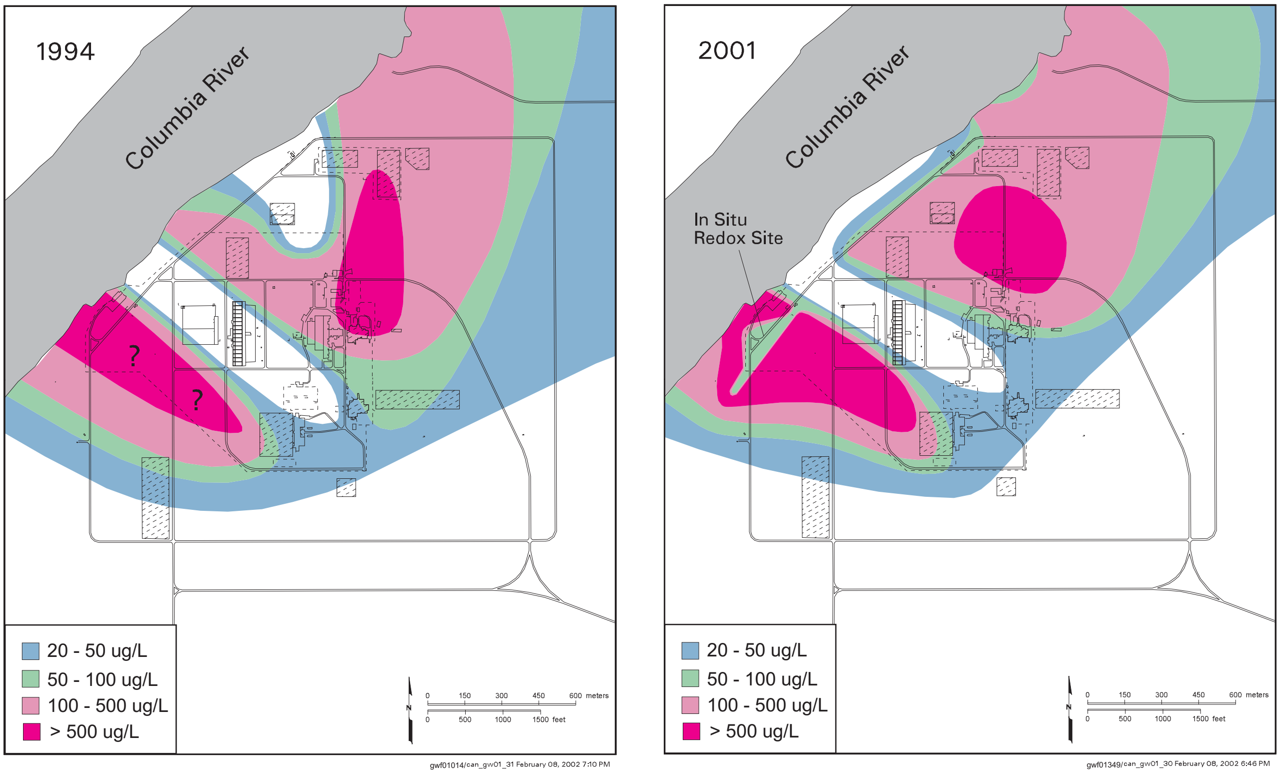
Concentrations of strontium-90 in the 100 N Area increased after 1990, but the shape of the plume remained about the same in 2001. Concentrations near the river decreased because of effects related to a pump-and-treat system.

River. Since strontium-90 binds to sediment grains, pump-and-treat is not an effective way to clean up the aquifer. Tritium also was present in waste discharged to the 100 N cribs. Tritium concentrations in groundwater are declining and the plume is shrinking. Nitrate, sulfate, and petroleum hydrocarbons also are present in 100 N Area groundwater. The 1325-N facility was excavated in fiscal year 2001 and will be backfilled in 2002.

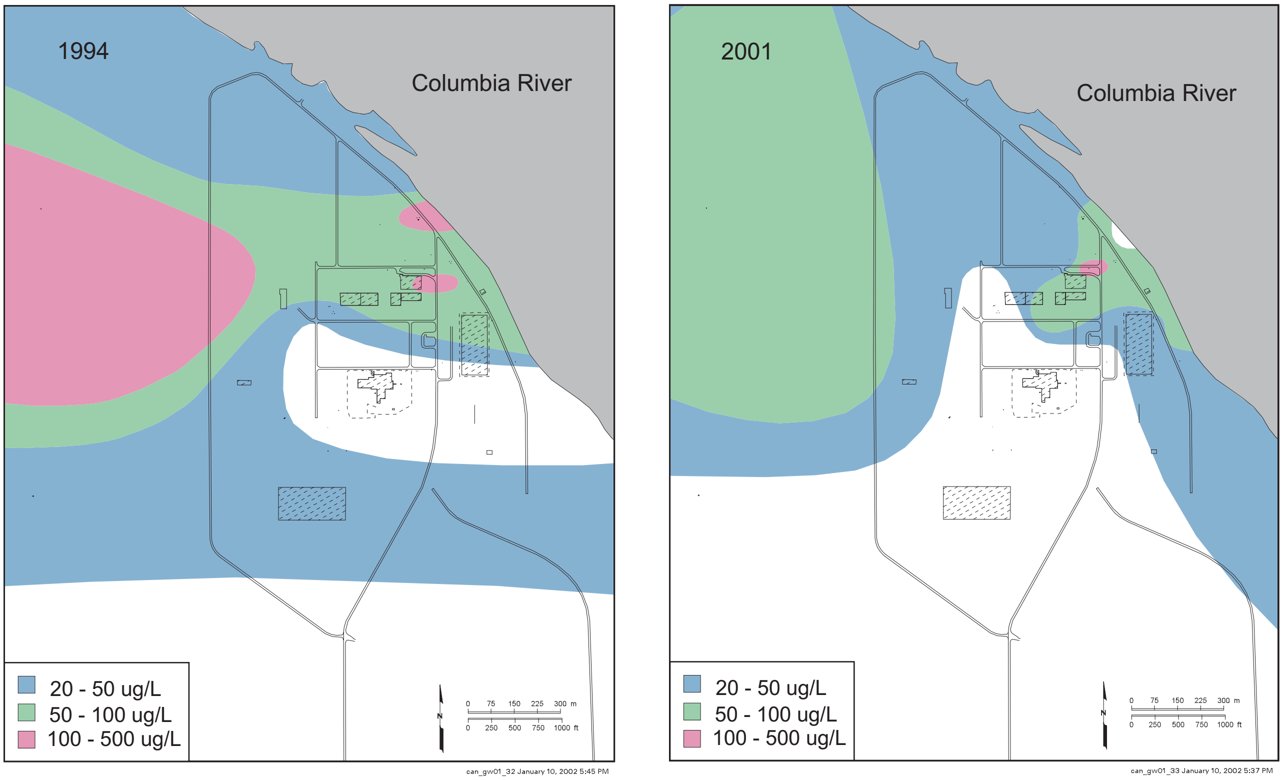
100 D Area. Hexavalent chromium is the primary contaminant of concern in the 100 D Area. The source of this contaminant was sodium dichromate added to cooling water to inhibit corrosion. The water was discharged to cribs and ditches, and some spillage of sodium dichromate also occurred. Hexavalent chromium is highly mobile in groundwater. Chromium is distributed in two plumes beneath the 100 D Area. The northern plume is the target of a pump-and-treat system for the 100-HR-3 operable unit, which also includes the 100 H Area. The southwestern chromium plume is being remediated with an in situ system that immobilizes chromium in the aquifer. This plume had the highest chromium concentrations on the Hanford Site in fiscal year 2001: 4,750 μg/L, which was a large increase from fiscal year 2000.

Nitrate also exceeded drinking water standards in the 100 D Area in a fairly widespread plume, while strontium-90 exceeded the standard in one well. Former waste sites in the 100 D Area were excavated and backfilled in 1999 through 2001.

100 H Area. Hexavalent chromium is present in 100 H Area groundwater, but the plume is smaller and concentrations are lower than in the 100 D Area. The plume is intercepted by pumping wells, treated, and the treated water is injected into an upgradient location. Chromium concentrations have decreased in recent



The shape of the chromium plume in the 100 D Area has changed since 1994, partially as a result of groundwater remediation. The southwestern plume in 1994 had to be estimated because there was only one well monitoring that area.



A pump-and-treat system in the 100 H Area reduces the amount of chromium entering the Columbia River. Between 1994 and 2001, concentrations decreased through most of the plume. Much of the decrease appears to be due to natural processes.

years. Nitrate also is elevated, but concentrations have declined from their peaks. Strontium-90 exceeds the drinking water standard beneath former retention basins. Technetium-99 and uranium are elevated in a small area downgradient of the former 183-H evaporation basins, but were below their drinking water standards in most wells. Former waste sites have been excavated and backfilled.

100 F Area. Nitrate exceeds the drinking water standard beneath much of the 100 F Area and the downgradient region. Strontium-90 exceeds the drinking water standard in a small plume beneath former waste sites in the eastern 100 F Area, near the Columbia River. Groundwater in local plumes or single wells exceeded standards for tritium, uranium, and trichloroethene. Excavation of former waste sites began in fiscal year 2001. There is no active groundwater remediation in the 100 F Area.

Groundwater from the Hanford Site can reach the Columbia River in days, months, or years depending on the geology and how far it has to travel. During this time, many of the contaminants are decreased by natural decay.

200 Areas Groundwater Contamination

After fuel rods were irradiated in the 100 Areas, they were shipped to the 200 Areas. There, between 1944 and 1987, separations (finishing) plants processed the fuel to extract and purify plutonium. The plutonium extraction first took place at the T and B plants and later at the Reduction-Oxidation (REDOX) and PUREX plants. The Plutonium Finishing Plant was used for plutonium purification. U Plant was used to extract uranium from process waste and T Plant was converted to an equipment decontamination facility. Currently, the 200 Areas are used for waste management and disposal.

The 200 Areas are located 20 miles from Richland on a plateau in the center of the Hanford Site, ~5 miles south of the Columbia River. During the finishing process, contaminants such as carbon tetrachloride, chromium, fluoride, iodine-129, nitrate, technetium-99, trichloroethene, tritium, and uranium were disposed to the ground in the 200 Areas. This contamination has moved into the vadose zone and is responsible for groundwater contamination currently detected at these sites.

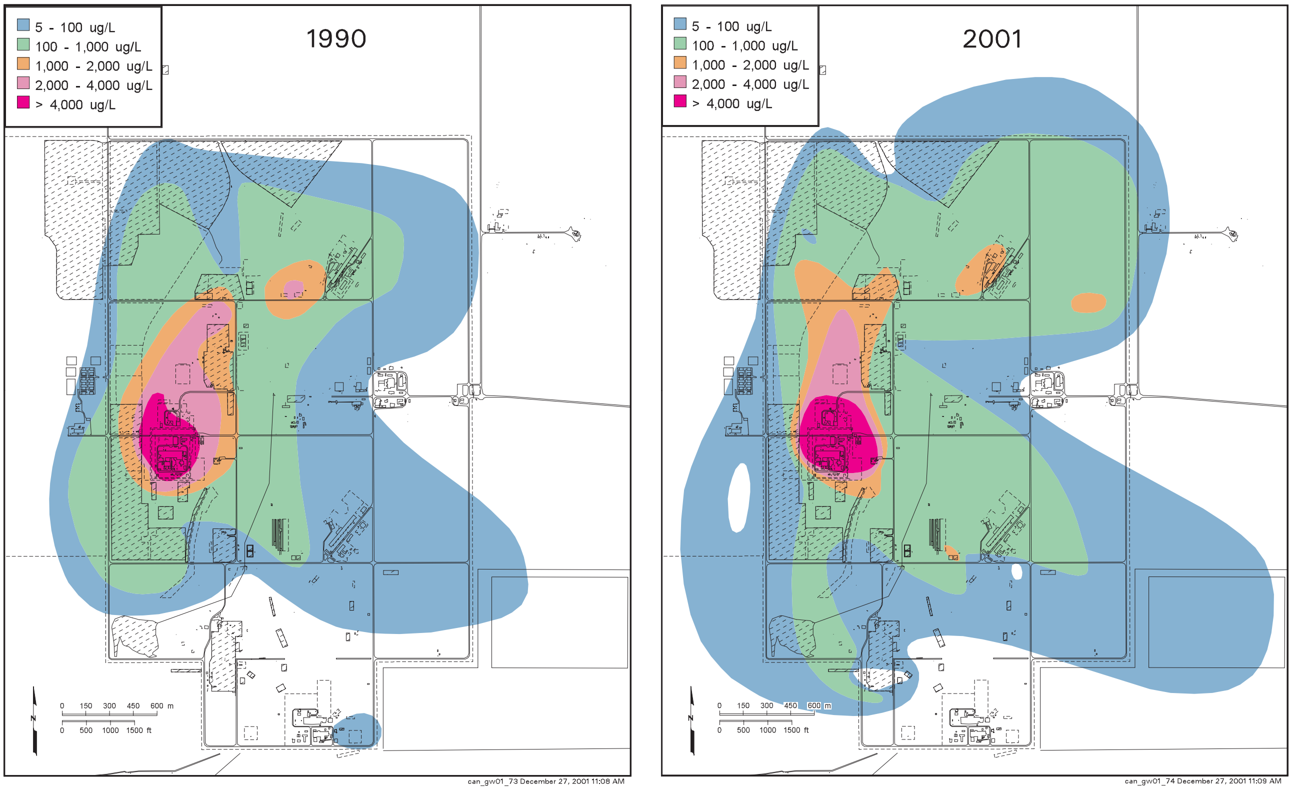
Radioactive and hazardous chemical waste generated from plutonium production and separation activities historically was stored in single-shell tanks in the 200 Areas. These underground tanks were constructed of reinforced concrete and steel in the 1940s. Although most of the free liquid has been removed, some of these tanks leaked in the past and appear to have contributed to groundwater contamination. The tanks still contain ~87 million liters of highly caustic saltcake and 45 million liters of chemical sludge. The tanks are grouped into farms that are regulated under RCRA and monitored to detect new leaks or to define the extent of contamination.

***Cleaning up** contaminated groundwater often takes longer than expected because groundwater systems are complicated and contamination is invisible to the naked eye. Groundwater monitoring is an essential part of remediation because it helps find contaminants and design systems that can treat or destroy the contamination.*

200 West Area. The aquifer beneath the 200 West Area has a lower permeability than beneath the 200 East or 100 Areas, which slows contaminant movement.

The largest plume of chlorinated hydrocarbons on the Hanford Site is beneath the 200 West Area and includes carbon tetrachloride, chloroform, and trichloroethene. The contamination is principally from waste disposal operations associated with the Plutonium Finishing Plant, where organic chemicals were used in plutonium processing. A groundwater pump-and-treat system is operating in this area to prevent the central, high-concentration portion of the carbon tetrachloride plume (>2,000 μg/L) from spreading.

In some areas, concentrations of carbon tetrachloride decrease with depth, but data collected in recent years indicate that in other areas carbon tetrachloride is present at higher concentrations deeper in the Hanford/Ringold sediment than at the water table. Therefore, the extent of the plume at the water table may not reflect the extent in deeper parts of the aquifer system.



The carbon tetrachloride plume beneath the 200 West Area spread between 1990 and 2001. Since 1996, a pump-and-treat system is helping prevent further spreading of the heart of the plume, shown here in pink and red.

The 200 West Area also contains plumes of technetium-99 and uranium from sources near T Plant and U Plant and single-shell tank farms. A groundwater pump-and-treat system is operating near U Plant to contain the technetium-uranium plume there. Contaminant concentrations have declined, and the plumes have shrunk, apparently as a result of remediation and dispersion.

The highest tritium concentrations in the 200 West Area are detected beneath waste facilities associated with T Plant. The maximum concentration detected in fiscal year 2001 was 1.7 million pCi/L, a decrease from the past 2 years. A larger plume (with lower concentrations) originated at sites associated with the REDOX Plant in the southeastern area. It is slowly moving eastward with groundwater flow. Smaller tritium plumes are detected beneath a former waste site in the southwestern area and near an active disposal site north of 200 West Area.

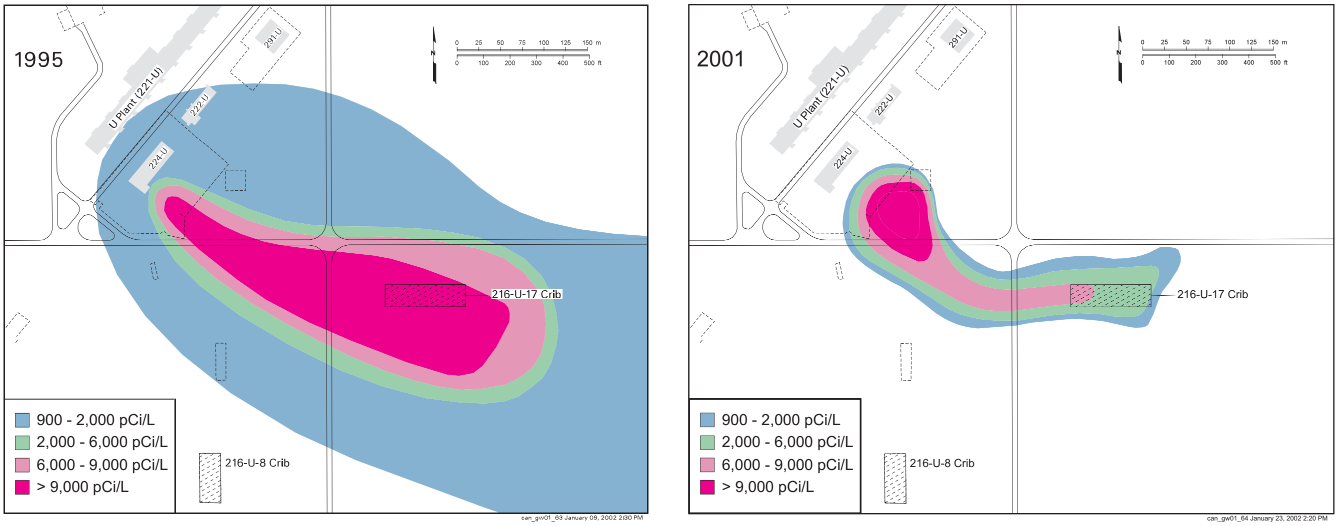
***Pump-and-treat systems** are interim actions for groundwater remediation until a final remedy can be identified.*

Iodine-129 plumes coincide generally with the tritium plumes associated with the T Plant and REDOX Plant. The maximum concentration in fiscal year 2001 was 64 pCi/L.

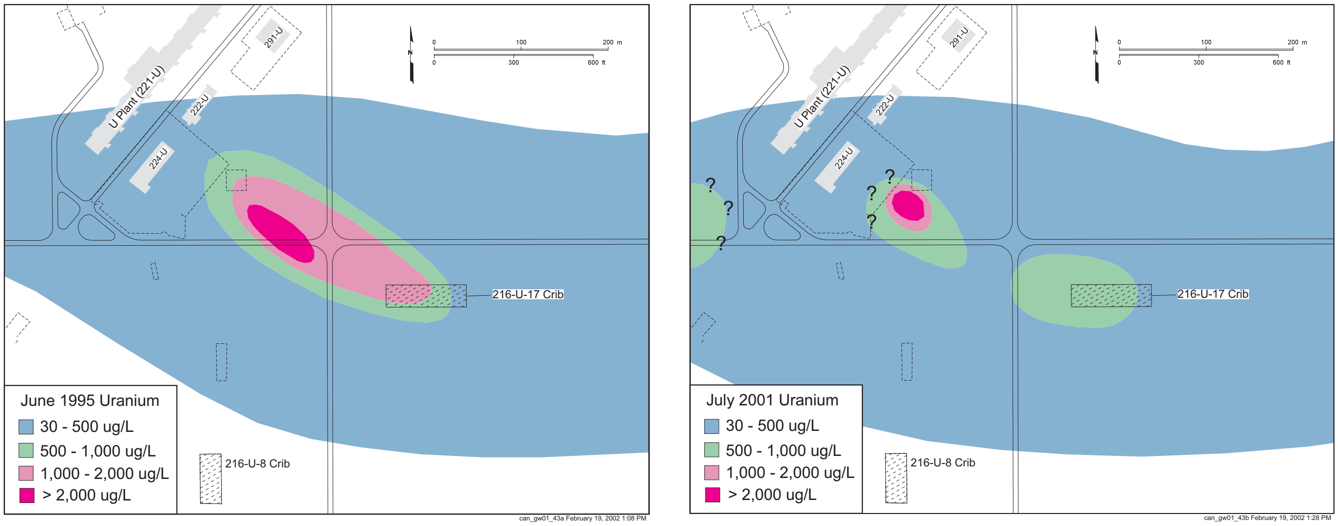
The 200 West Area has two main nitrate plumes: one from the vicinity of U Plant extending into the 600 Area, and another near T Plant. Lower concentrations of contamination are found near the Plutonium Finishing and REDOX plants.

Chromium and fluoride exceeded maximum contaminant levels in several wells near Waste Management Areas T and TX-TY. The plumes are not widespread.

Strontium-90 has been detected in very small areas near facilities that received waste from the REDOX Plant. In fiscal year 2001, only one well had concentrations exceeding the drinking water standard.



A pump-and-treat system at the 200-UP-1 Operable Unit (200 West Area) has decreased the size of the technetium-99 plume. The system began to operate in fall 1995.

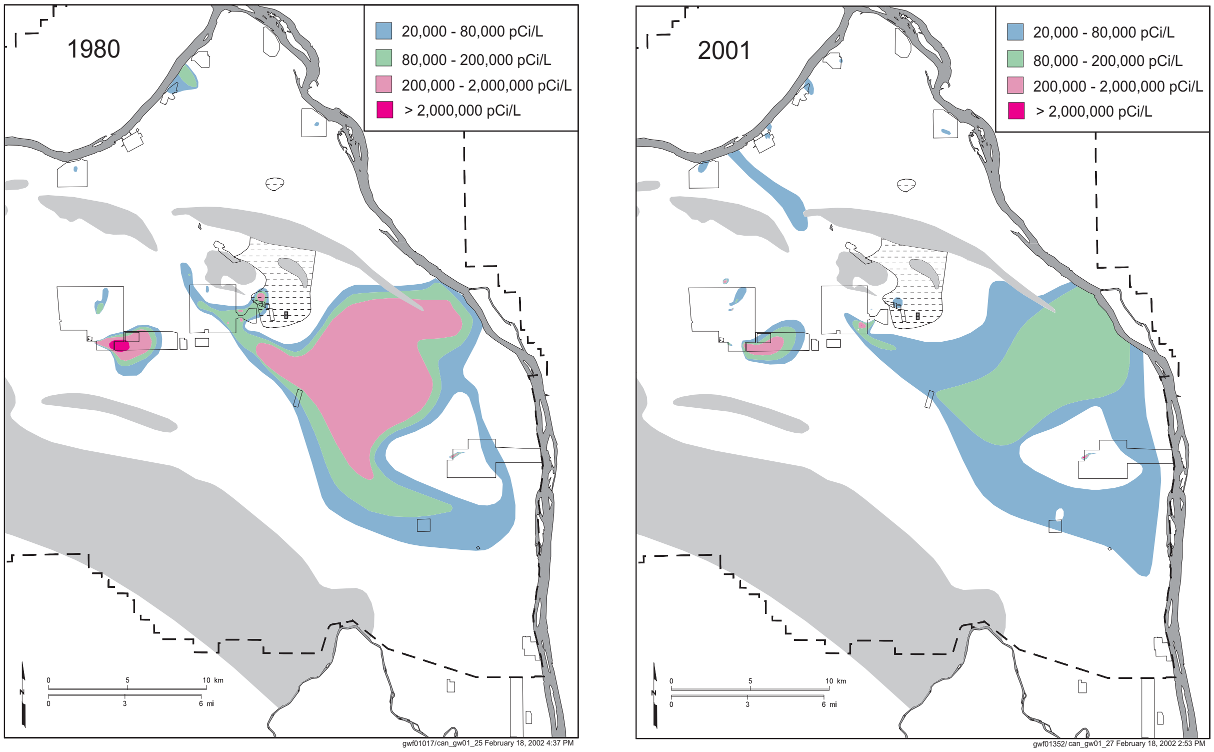


Uranium contamination in the 200-UP-1 Operable Unit is not responding to the pump-and-treat system as quickly as the technetium-99. Also, many monitoring wells in the plume have gone dry, making interpretation of plume size less certain.

200 East Area. Disposal of liquid waste in the 200 Area has contaminated groundwater with tritium, iodine-129, nitrate, and several other contaminants. The most widespread and mobile contaminants have flowed through the permeable aquifer to the Columbia River.

The largest tritium plume originated at waste sites near the PUREX Plant in the southeastern 200 East Area. Concentrations in one well near the former waste sites were up to 4.3 million pCi/L in fiscal year 2001, which is nearly double the highest concentration the previous year.

The movement of the PUREX tritium plume can be traced with historical groundwater data. By 1980, tritium concentrations above 20,000 pCi/L had reached the Columbia River at the Old Hanford Townsite. In the southern portion of the site, the 20,000-pCi/L portion of the plume had apparently flowed around less



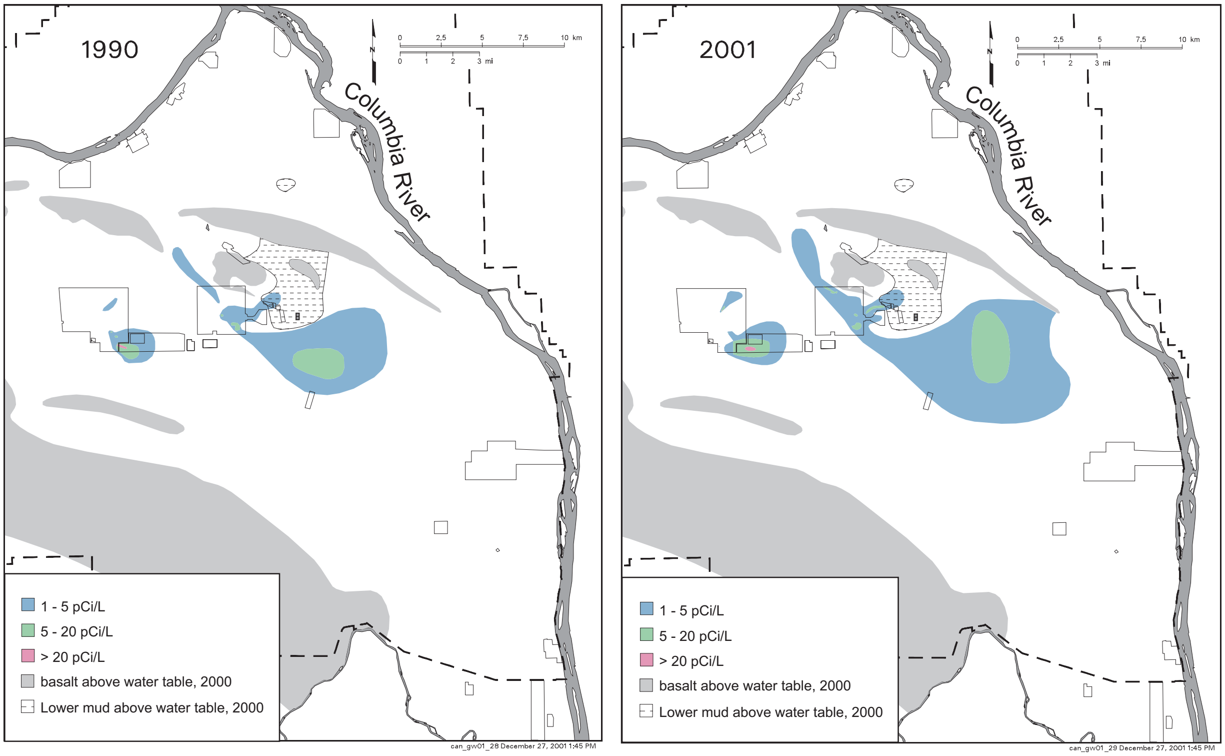
Tritium plumes in 1980 and 2001 are shown in the above maps. Concentrations in the heart of the plume have decreased over the years; in approximately 1995, the southern margin appears to have ceased its southward migration.

transmissive sediment beneath the Energy Northwest site. The core of the plume (concentrations >200,000 pCi/L) had broken off from the source in the southeastern 200 East Area. These high concentrations decreased in the past 20 years and are not seen on the map for fiscal year 2001. The southern margin of the plume appears to have ceased its southward migration in ~1995. Concentrations in the southeastern part of the plume are expected to keep declining because of dispersion and radioactive decay. Concentrations also have declined in the past 10 years in the northwestern 200 East Area, but a plume with its origins in that region is now migrating north between Gable Mountain and Gable Butte.

***Tritium** is very mobile in groundwater and has migrated from sources in the 200 Areas toward the southeast and the Columbia River.*

The iodine-129 plume originating in the 200 East Area is similar to the tritium plume, but concentrations greater than the drinking water standard have not reached the Columbia River. The maximum concentration in fiscal year 2001 was 10 pCi/L with a declining trend. The iodine-129 plume from 200 East Area probably migrated at about the same rate as the tritium plume, but iodine-129 data were not commonly collected until the 1980s. By 1990, the portion of the plume exceeding the 1 pCi/L drinking water standard had traveled more than halfway to the Columbia River. It moved an additional 2.5 kilometers between 1990 and 2001. The plume will continue moving toward the river, but concentrations are expected to decline because of dispersion.

Waste sites near the PUREX Plant in the 200 East Area contributed to extensive nitrate plumes that extend to the southeast, but only proportionally small areas contain nitrate at levels above the maximum contaminant level. This plume extends to wells near the Columbia River at the Old Hanford Townsite, where nitrate concentrations are below the maximum contaminant level and are gradually declining. Another nitrate plume originated from sites in the northwestern 200 East Area and spread northward between Gable Butte and Gable Mountain.



The iodine-129 plume (shown on the above maps) moves similarly to the tritium plume, but it has not moved as far. The plumes have spread between 1990 and 2001.

Elevated technetium-99 levels are associated with the BY cribs in the northwestern 200 East Area. Past leakage from the B-BX-BY single-shell tank farms also appears to be a source of technetium-99 in this area. This plume has migrated toward the north, but preliminary interpretations of recent data indicate that the northward flow from this area has stopped, and groundwater is currently flowing southward. If this interpretation is correct, the northward spread of technetium-99 will cease. The technetium-99 plume is associated with elevated uranium, though the uranium is not as extensive.

***Iodine-129** contamination has not reached the Columbia River at concentrations above the drinking water standard.*

The former 216-B-5 injection well in the northwestern 200 East Area contaminated groundwater with radionuclides including cesium-137, plutonium, and strontium-90. The residual contamination is very localized.

Other groundwater contaminants in the 200 East Area include cobalt-60 and cyanide near the BY cribs in the northwestern area, and strontium-90 beneath the former Gable Mountain Pond.

400 Area Groundwater Contamination

The 400 Area is the location of the Fast Flux Test Facility, the largest test reactor on the Hanford Site. DOE has decided that using the facility is impractical and it will be deactivated. The reactor was designed to test fuels and materials for advanced nuclear power plants as well as for the irradiation testing of fuels, core components and target assemblies for liquid metal fast breeder reactors. Nitrate is the only groundwater contaminant attributable to 400 Area operations. The contamination is believed to have come from a sanitary sewage lagoon that is no longer in use. Nitrite also is detected in groundwater but concentrations are below the maximum contaminant level.

300 Area Groundwater Contamination

During years of production, the 300 Area was where uranium fuel was manufactured before it was sent for irradiation in the reactors in the 100 Areas. The 300 Area was also the location of several test reactors during the Manhattan Project and Cold War periods. During the production process, contaminants such as uranium and trichloroethene were discharged to the ground. These elements, along with breakdown products of trichloroethene, are detected in groundwater, but concentrations are decreasing.

In some areas, DOE and the regulators agree that natural processes will clean up groundwater contamination. For example, dispersion (spreading) and radioactive decay decrease concentrations, while bacteria destroy other types of contaminants. Groundwater is monitored throughout the process to determine if concentrations are falling, as expected. This approach is known as ***monitored natural attenuation*** *and is being applied in the 300 and Richland North Areas.*

An area of elevated uranium concentrations is detected in the 300 Area, downgradient of the 316-5 process trenches and ponds. Uranium contamination is moving from the vicinity of the process trenches toward the southeast, entering the Columbia River. The most heavily contaminated sediment has been removed.

A plume of trichloroethene in the 300 Area is attenuating naturally, and annual average concentrations remained below the 5 μg/L maximum contaminant level in fiscal year 2001. Bacteria naturally present in the subsurface break down the trichloroethene in this area. This degradation produces cis-1,2-dichloroethene as a byproduct, and this contaminant exceeded the maximum contaminant level in a well that monitors the bottom of the unconfined aquifer in fiscal year 2001.

Tritium from the 200 East Area has migrated into the 300 Area at levels below the drinking water standard. The plume has ceased spreading southward. Strontium-90 concentrations are elevated in one well in the 300 Area but were below the drinking water standard in fiscal year 2001.

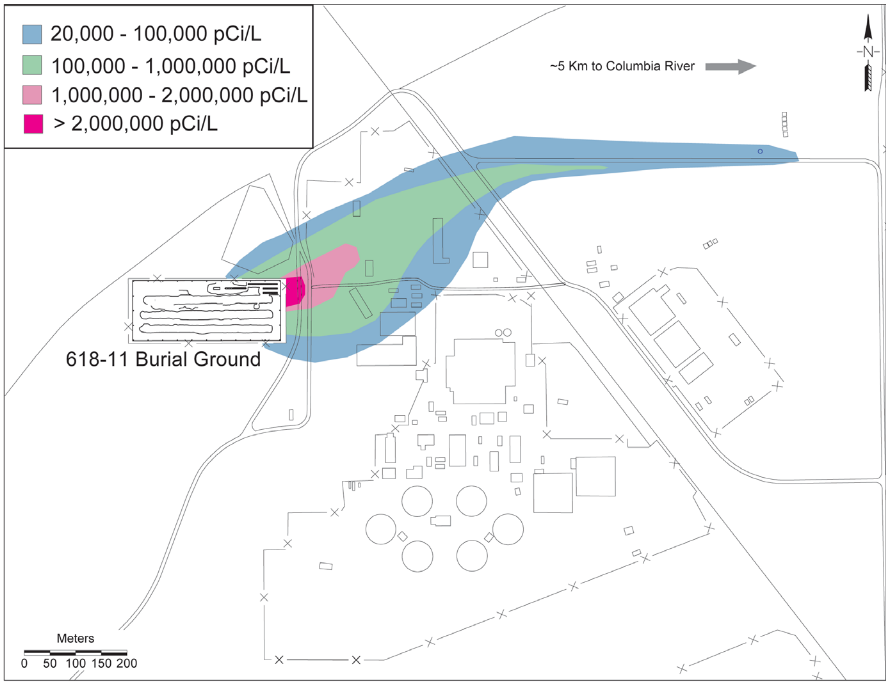
The 300-FF-5 groundwater operable unit includes two "satellite areas" north of the 300 Area proper. These include the 618-11 burial ground, located near the Energy Northwest site, where the highest tritium concentrations currently in Hanford Site groundwater have been detected. Concentrations exceeded 8 million pCi/L in fiscal year 2001. Monitoring of nearby wells and soil gas testing indicate that the contamination is very local. The other satellite area includes the 618-10 burial ground and 316-4 crib. Groundwater near these facilities is contaminated with uranium and hydrocarbons.

Richland North Area Groundwater Contamination

The Richland North Area, located just south of the Hanford Site, contained site support services, such as general stores, shipping, receiving, transportation, maintenance, and general warehouse facilities. In 1998, DOE transferred ownership of portions of the Hanford Site located in the Richland North Area to the Port of Benton.

Groundwater beneath a portion of the Richland North Area is designated the 1100-EM-1 Operable Unit, which contains DOE's inactive Horn Rapids Landfill. A small, narrow plume of trichloroethene, which underlies the landfill and Framatome ANP Richland, Inc. (formerly Siemens Power Corporation), is attenuating naturally. Levels declined below the drinking water standard in fiscal year 2001. Contaminants also flow into the Richland North Area from offsite sources (nitrate from agriculture practices, fluoride, ammonia, and gross beta from Framatome ANP Richland, Inc.).

The city of Richland maintains a well field in the Richland North Area. Wells are monitored frequently to detect any changes in Hanford contaminants near these wells. The tritium plume from the 200 East Area has not been detected in these wells. Low levels of tritium, similar to Columbia River water, continue to be detected.



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The 618-11 burial ground, ~13 kilometers north of Richland, has created a narrow, concentrated tritium plume. Studies indicate that the high concentrations will decay before the plume reaches the Columbia River.

Upper Basalt-Confined Aquifer

Although most of Hanford's groundwater contamination is in the unconfined aquifer, DOE monitors wells in the deeper, basalt-confined aquifer because of the potential for downward migration of contamination from the unconfined aquifer and the potential migration of contamination offsite through the confined aquifer.

Most of the confined-aquifer wells are located near and north of the 200 East Area, where researchers believe there is communication between the two aquifer systems. One well in this region contains technetium-99 at levels above the drinking water standard, and co-contaminants nitrate and cyanide at lower levels. This contamination appears to be localized, but no firm conclusions can be drawn because there are very few wells monitoring the confined aquifer nearby. Another well near the former B Pond detects elevated tritium, but levels are far below the drinking water standard. Confined aquifer wells located farther from the 200 Area (downgradient; nearer areas of potential discharge) are not contaminated.

*Layers of dense, impermeable **basalt rock** prevent Hanford's groundwater contaminants from entering deep confined aquifers beneath most of the site. However, in some places the top impermeable layer of basalt is absent.*

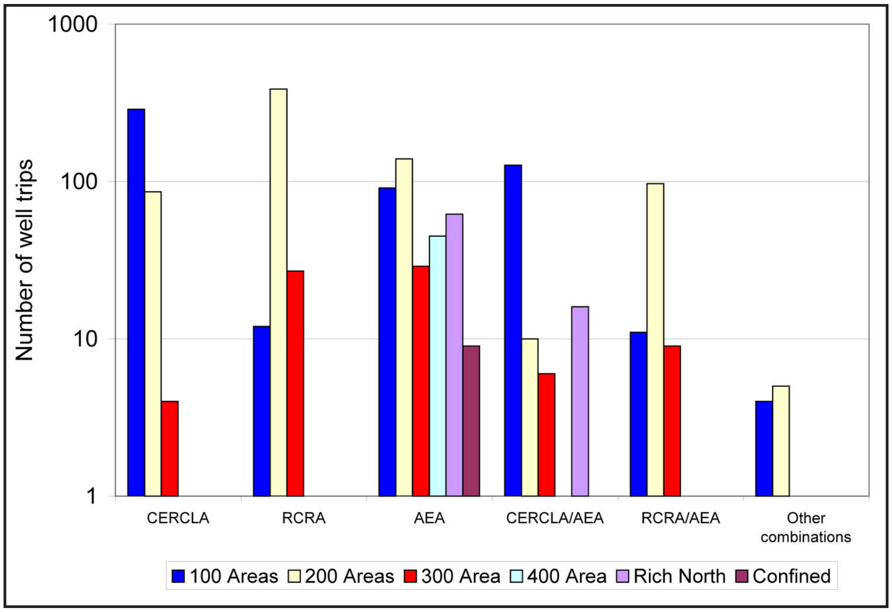
Groundwater Monitoring of RCRA Treatment, Storage, and Disposal Units

DOE monitors groundwater on the Hanford Site to meet the requirements of the RCRA at 24 waste management areas. Fifteen are monitored under indicator evaluation (or detection) programs and do not appear to affect groundwater with hazardous constituents. The others are monitored under assessment or corrective-action programs. Specific highlights are noted below:

- **183-H solar evaporation basins (100 H Area)** – Corrective-action monitoring continued during operation of the 100-HR-3 chromium pump-and-treat system. Leakage from the 183-H basins in the past contaminated the groundwater with chromium, nitrate, technetium-99, and uranium. The CERCLA program directs corrective action.

- **216-B-3 pond (200 East Area)** – In May 2001, the Washington State Department of Ecology issued a guidance letter regarding alternative statistical methods for indicator evaluation monitoring. DOE submitted a proposal for a new monitoring approach in November 2001.
- **216-S-10 pond and ditch (200 West Area)** – A downgradient well went dry in fiscal year 2001, leaving just one useable, shallow, downgradient well.
- **216-U-12 crib (200 West Area)** – Assessment monitoring continued to indicate that nitrate and technetium-99 plumes are mingled from various sources, including the crib. The monitoring network contains just two useable downgradient wells and no upgradient wells.
- **316-5 process trenches (300 Area)** – Corrective-action monitoring continued in fiscal year 2001. The trenches and other nearby sources contaminated groundwater with cis-1,2-dichloroethene, trichloroethene, and uranium. Corrective action is deferred to CERCLA, and involves natural attenuation of the contaminants. Concentrations of trichloroethene declined below the 5 μg/L maximum contaminant level. A new groundwater monitoring plan was written in fiscal year 2001, implementing the use of alternative statistical methods.
- **Liquid Effluent Retention Facility (200 East Area)** – This site is monitored under an indicator evaluation program. However, a downgradient well went dry in fiscal year 2001, leaving just one useable well. Washington State Department of Ecology instructed DOE to cease statistical evaluations.
- **Single-Shell Tanks Waste Management Areas A-AX and C (200 East Area)** – Indicator evaluation monitoring continued. Directions of groundwater flow were re-interpreted and may require modifications to monitoring networks.
- **Single-Shell Tanks Waste Management Area B-BX-BY (200 East Area)** – These tank farms may have contributed to the technetium-99, nitrate, nitrite, and uranium contamination in the northern 200 East Area. However, the assessment monitoring has not clearly identified a source within the tank farms. This waste management area is located near other major sources of contamination (e.g., the BY Cribs and 216-B-8 crib) that produced the bulk of the contamination. In fiscal year 2001, nitrate continued to migrate across the waste management area, with highest concentrations in the north. Technetium-99 concentrations decreased and uranium concentrations rose sharply in the central part of the waste management area. Assessment studies identified tritium as a new contaminant of interest on the west side of the BX tank farm. Three new monitoring wells were installed in fiscal year 2001.
- **Single-Shell Tanks Waste Management Area S-SX (200 West Area)** – Groundwater studies indicate that sources within the tank farms have contaminated groundwater with chromium, nitrate, and technetium-99. A well in the southwest corner of the area shows the impact of a 1960s tank leak, including high concentrations of technetium-99 and uranium. Monitoring results and solute transport modeling indicate the extent of tank waste in groundwater from that leak is very limited. Technetium-99 in other wells suggests longer-term releases from the waste management area in the past. A notable change in fiscal year 2001 was a sharp rise in chromium, nitrate, and technetium-99. This new contaminant occurrence represents a vadose zone source possibly originating in the S tank farm area. Two new monitoring wells were installed in fiscal year 2001.

*The **Resource Conservation and Recovery Act of 1976** (RCRA) regulates facilities used to treat, store, or dispose of hazardous waste. At Hanford, the law applies to sites that contained hazardous or mixed (hazardous and radioactive) waste. RCRA stipulates requirements for monitoring the groundwater beneath these sites.*



Wells were sampled to meet the objectives of CERCLA, RCRA, and the Atomic Energy Act in fiscal year 2001. Many wells are sampled for two or three objectives, so well trips and analyses are coordinated to avoid duplication.

- **Single-Shell Tanks Waste Management Area T (200 West Area)** – Results of assessment monitoring indicate that technetium-99, chromium, and nitrate contamination had a source within the tank farm. The tank-related contaminants are largely restricted to a zone of lower permeability in the upper portion of the aquifer. The lateral extent of this low permeability zone and the extent to which contaminants may be migrating into the deeper zone of higher permeability are uncertain. The lateral extent of contamination also is uncertain because of the lack of monitoring wells north and east of the zone of known contamination.
- **Single-Shell Tanks Waste Management Area TX-TY (200 West Area)** – Assessment monitoring in fiscal year 2001 indicated that a nearby pump-and-treat system has affected groundwater flow and may have an impact on the distribution of contaminants around the waste management area. Technetium-99 may be drawn from beneath the area into the pump-and-treat system. One contaminant plume, containing chromium, iodine-129, nitrate, and technetium-99, originated within the waste management area. A second plume from sources not in the waste management area is superimposed on the tank waste plume. Seven new wells were installed in fiscal years 2000 and 2001.
- **Single-Shell Tanks Waste Management Area U (200 West Area)** – Assessment monitoring continued in fiscal year 2001. Nitrate and technetium-99 concentrations continued to rise, especially in wells on the west side of the area, but concentrations remained below drinking water standards. Three new monitoring wells were installed in fiscal year 2001.

The ***Comprehensive Environmental Response, Compensation, and Liability Act of 1980*** *(CERCLA) regulates waste sites that were active before RCRA took effect. It covers sites where radioactive or hazardous waste were disposed or leaked, and also requires groundwater monitoring where appropriate.*

Groundwater Monitoring of CERCLA Operable Units

DOE monitors groundwater on the Hanford Site to comply with requirements of CERCLA at 11 groundwater operable units. DOE, EPA, and Washington State

Department of Ecology determine methods for remediating contaminated groundwater via formal documents called records of decision.

One operable unit, 1100-EM-1 (Richland North Area), has a final record of decision calling for natural attenuation of volatile organic compounds. Groundwater is monitored to determine the success of this approach. In fiscal year 2001, contaminant concentrations were below their target levels.

At six of the operable units, interim remedial actions are required until final cleanup decisions are made. The environmental restoration contractor monitors groundwater to assess the effectiveness of the interim actions.

- **100-HR-3 (100 D and 100 H Areas) and 100-KR-4 (100 K Area)** – Chromium may pose a threat to aquatic organisms in the Columbia River. Interim records of decision require three interim remedial actions to address chromium contamination. In fiscal year 2001, concentrations remained above cleanup targets.
- **100-NR-2 (100 N Area)** – Strontium-90 concentrations remained much higher than the drinking water standard in wells at the river shore in fiscal year 2001. In 1995, Washington State Department of Ecology instructed DOE to operate a pump-and-treat system for strontium-90 as an expedited response action. The decision was documented in an interim record of decision in 1999.
- **200-UP-1 (200 West Area)** – An interim record of decision required operation of a pump-and-treat system to reduce technetium-99 and uranium contamination. In fiscal year 2001, some concentrations remained above target levels. Many of the wells monitoring this area have gone dry, so the size of the current plumes is uncertain.
- **200-ZP-1 (200 West Area)** – An interim record of decision requires operation of a pump-and-treat system to prevent carbon tetrachloride from spreading. In fiscal year 2001, the system continued to limit migration of the heart of the plume.
- **300-FF-5 (300 Area and satellite areas to the north)** – An interim record of decision calls for natural attenuation of the cis-1,2-dichloroethene, trichloroethene, and uranium plumes. In fiscal year 2001, concentrations of the organic contaminants were low, but uranium remained elevated.

Interim Groundwater Remediation

The goal of groundwater treatment systems on the Hanford Site is to prevent the worst contaminants from spreading. Six pump-and-treat systems removed the following contaminants in fiscal year 2001:

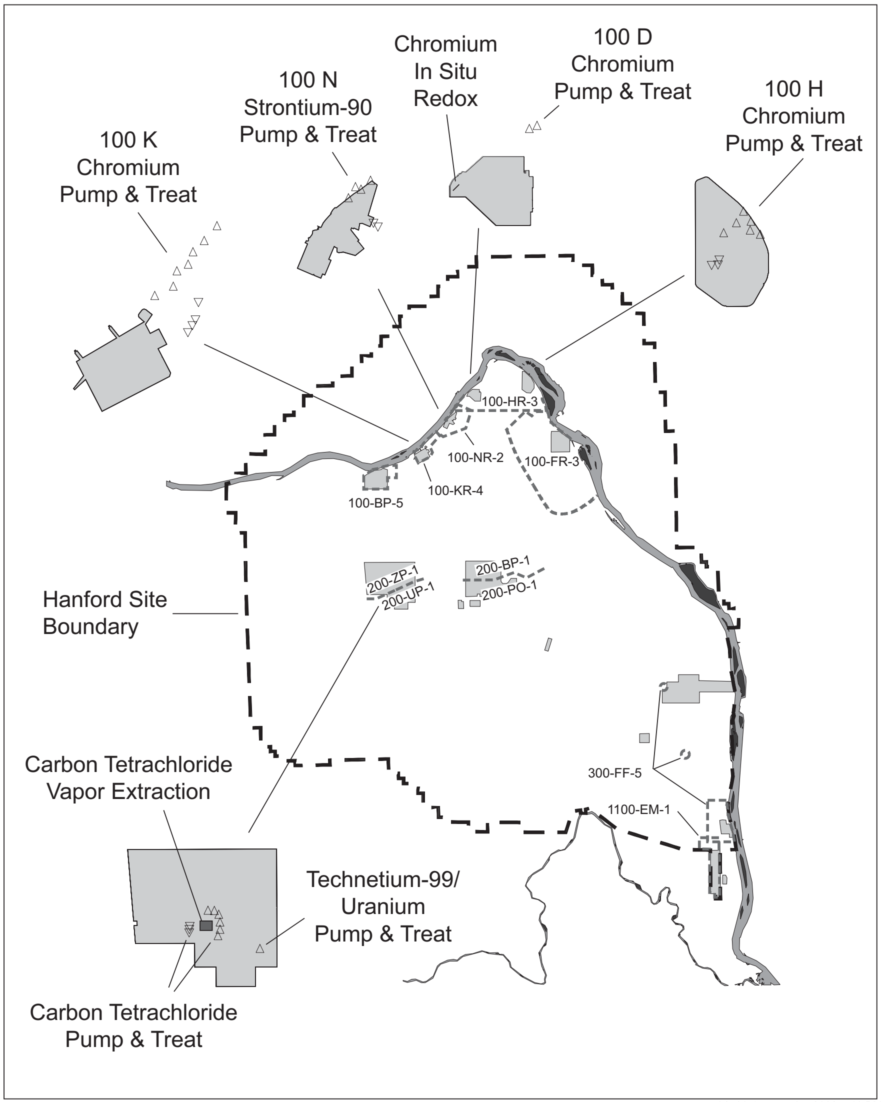
- 100 K (chromium): 37 kilograms
- 100 N (strontium-90): 0.2 curie
- 100 D and 100 H (chromium): 31.5 kilograms
- 200 West (carbon tetrachloride): 1,225 kilograms
- 200 West (technetium-99): 0.142 curie
  (uranium): 17 kilograms.

Also, in the 100 D Area, an in situ remediation system is immobilizing chromium in the aquifer. In the 200 West Area, a soil gas extraction system removed 712 kilograms of carbon tetrachloride from the vadose zone.

At four operable units, there is no imminent threat to human health or the environment so no interim remedial actions are required. These operable units include 100-BC-5 (100 B/C Area), 100-FR-3 (100 F Area), 200-BP-5, and 200-PO-1 (200 East Area). Waste sites and plumes will continue to be monitored until there are final records of decision.

As required under CERCLA, EPA performed a 5-year review to determine whether remedial actions specified under records of decision for the Hanford Site are protective of human health and the environment. The review was published in fiscal year 2001 and included soil and groundwater remedial actions. EPA identified action items to address deficiencies. Actions related to groundwater monitoring include

- Enhance pump-and-treatment operations at 100 K, 100 D, and 100 H Areas, including new extraction wells at 100 K and 100 D Areas, and a new injection well at 100 K Area.
- Investigate alternative remedial action methods for the 100 N Area strontium-90 plume.



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DOE operates six pump-and-treat systems, one in situ remediation system, and one soil gas extraction system to limit movement of contaminants in groundwater and the vadose zone.

When groundwater is pumped from the subsurface, it is treated to remove contaminants before being discharged. This process is often referred to as a pump-and-treat system. This common form of groundwater remediation is being used at Hanford to remove chromium, technetium-99, and uranium. However, because these systems often take a long time to meet cleanup goals, their use is reviewed every 5 years.

- Investigate detection technologies for dense, non-aqueous phase liquids; investigate enhancements to current carbon tetrachloride pump-and-treat system; install a new monitoring/production well near the Plutonium Finishing Plant.
- Develop new monitoring networks for the 200-BP-5, 200-PO-1, 200-UP-1, and 200-ZP-1 Operable Units.
- Update and expand the operations and maintenance plan for 300-FF-5 Operable Unit.

Well Installation

In fiscal year 2001, 11 new wells were completed for RCRA groundwater monitoring. Thirty-one new wells were installed in the 100 D Area to support groundwater remediation for chromium. Six wells were installed for other projects.

Ninety-nine wells were decommissioned (sealed with grout) in fiscal year 2001 because they were no longer used, were in poor condition, or were in the way of construction sites. Approximately 400 well maintenance activities were carried out during fiscal year 2001. These activities included well or pump repair, cleaning, and maintenance.

Modeling

Numerical simulations of groundwater flow and contaminant movement are used to predict future conditions and to assess the effects of remediation systems. Pacific Northwest National Laboratory has responsibility for a sitewide, consolidated groundwater flow and transport model.

In fiscal year 2001, Pacific Northwest National Laboratory re-calibrated a base case of the sitewide groundwater model and an alternative case that includes interaction between the unconfined and confined aquifer systems. The re-calibration significantly improved the model's ability to simulate historical trends in water table changes across the Hanford Site, particularly near the 200 West Area. Incorporating groundwater movement between the unconfined aquifer and the underlying confined aquifer into the model provided a small but measurable improvement in overall model performance.

*Pacific Northwest National Laboratory completed groundwater modeling to support the **Hanford Carbon Tetrachloride Innovative Treatment Remediation Technology Program** in fiscal year 2001. This work was a first step toward implementing innovative technologies to remediate the carbon tetrachloride plume underlying the 200 West Area.*

The Groundwater/Vadose Zone Integration Project is developing the System Assessment Capability as a tool to predict cumulative sitewide effects from all significant Hanford Site contaminants. This tool integrates several linked models, beginning with the waste inventory and simulates release and movement through the vadose zone, groundwater, and Columbia River. In fiscal year 2001, simulated contaminant plumes in groundwater generally covered larger areas and had higher maximum concentrations than historical plumes, except tritium and iodine-129 plumes, which were smaller in area but higher in concentration than the observed

Fifty-eight new wells were drilled on the Hanford Site in fiscal year 2001. Some of them are monitoring wells to replace dry wells or to gather additional information (shown above). Other wells support groundwater remediation.

plumes. Most of the differences were caused by inaccuracies in the inventory, release, or vadose models. Within the groundwater, simulated plumes moving eastward from 200 East Area toward the Columbia River moved more slowly than observed plumes. This delayed movement was consistent with results of the history matching exercise and will be addressed in the future by improvements in the sitewide groundwater model.

Vadose Zone

Liquid waste from past disposal sites, spills, or leaks entered the vadose zone. Not all of this water flowed through to groundwater, so some contaminated sediment or water remains in the vadose zone. This contamination may continue to move downward and into groundwater over time, especially if rain or other sources of water percolate through the contaminated zone.

Subsurface source characterization, vadose zone monitoring, soil-vapor monitoring, sediment sampling, and several technical demonstrations were conducted in fiscal year 2001.

Vadose zone characterization activities at single-shell tank farms in fiscal year 2001 focused on the B, BX, and BY tank farms in the 200 East Area and the S, SX, T, TX, and TY tank farms in the 200 West Area. Two new boreholes were drilled at Waste Management Area B-BX-BY through subsurface contaminant plumes. A third borehole was drilled immediately outside the tank farms to obtain uncontaminated core for comparison with the contaminated material obtained in the tank farms. Analyses of the samples are ongoing and will be reported in next year's annual report.

Steps were taken to minimize the subsurface migration of existing contamination in the single-shell tank farms in 200 West Area. Surface water that could pool around the tank farms was redirected away from the tank farms, and aging water-supply pipelines were capped or tested so they could be repaired.

Characterization of sediment samples from boreholes previously drilled in Waste Management Area SX was reported in fiscal year 2001. Results indicate that cesium, chromium, and pH distributions do not identify the leading edge of contaminant plumes. More mobile indicators, such as electrical conductivity, nitrate, sodium, and technetium identified the leading edges of the contaminant plumes. The bulk of contamination appears to be significantly shallower than the leading edges of the plumes.

Researchers applied mass spectrometry to analyze stable and long-lived isotopes in drill core samples in fiscal year 2001. The purpose of the work was to better understand water and contaminant movement in the vadose zone at the SX tank farm. Results indicated that isotopes of iodine and molybdenum can be used as a tool to fingerprint tank waste leaks. Cesium isotopes were not successful in discerning different leaks. Ratios of several different species also can be used to discern different leaks. Comparison of isotopic and species ratios of contaminants in vadose zone sediment and groundwater can help determine the sources of groundwater contamination.

Other vadose zone studies at the SX tank farm in fiscal year 2001 included a study of water movement inferred from the abundance of stable isotopes of oxygen and hydrogen. These isotopes show where water has undergone significant evaporation, indicating how recently it infiltrated.

Geophysical logging using the spectral gamma technique was performed in 30 boreholes in or near waste sites in the 200 Areas in fiscal year 2001. The method is being used to

Hanford crews drilled a borehole near tank B-110, one of the first single-shell tanks built in the 1940s. Instruments and sensors were installed to measure soil temperature, soil water pressure, and water content.

characterize the vadose zone and to track movement of gamma-emitting radionuclides in the vadose zone. Seven new RCRA wells also were logged.

A comprehensive routine monitoring project using the spectral gamma technique was established in June 2001 in the single-shell tank farms. The goal of the monitoring project is to detect changes occurring since the baseline data were collected. Geophysicists logged 113 boreholes in fiscal year 2001. Possible contaminant movement was identified at the U and T tank farms, so they are being monitored quarterly.

*The results of **vadose zone characterization** studies improve understanding of the distribution of contamination between the ground surface and the water table.*

Analyses of leachate collected from the Environmental Restoration Disposal Facility showed that the liquid collected so far contains no elevated levels of contaminants of concern. Leachate at the Solid Waste Landfill continued to exceed regulatory standards for some constituents, but soil gas monitoring showed no constituents of concern above reporting limits for air quality.

Soil gas monitoring at the carbon tetrachloride expedited-response-action site continued during fiscal year 2001. The temporary suspension of soil-vapor extraction in fiscal year 2001 appears to have caused minimal transport of carbon tetrachloride through the soil surface to the atmosphere and had no negative impact on groundwater quality. Soil gas monitoring at the 618-11 burial ground also continued to help define the extent of tritium contamination in groundwater and the vadose zone. Results were used to help map the plume and to choose locations for groundwater monitoring wells.

During July and August 2001, a borehole with instruments and sensors for vadose zone monitoring was installed at B tank farm in a well next to tank B-110, one of the first tanks built in the 1940s. The instruments will measure soil temperature, soil water pressure, and water content in the vadose zone. This is the first installation of a vadose zone monitoring system in the sand and gravel at Hanford. Also, the sampling is part of the RCRA corrective action program established in 1998.

*The purpose of **spectral gamma logging** is to detect and quantify naturally occurring and man-made gamma-emitting radionuclides in the vadose zone near waste disposal sites.*

Crews installed instruments (left) and completed a GPS survey (right) in preparation for the mock tank demonstration. Scientists tested six leak-detection technologies that could be used to detect leaks outside of a single-shell tank during waste retrieval operations.

This sampling will help characterize the contamination that exists underneath the tank farms and determine how the contamination moves through the soil. Results will help regulators determine what corrective measures may be required to slow the movement of contamination to the groundwater.

Two-dimensional and three-dimensional high-resolution seismic characterization experiments were conducted in May 2001. Information from experiments like these will be used to improve flow and transport models of the vadose zone. The seismic technique did well in identifying hydrologic units. The method achieved vertical imaging from the ground surface to the water table and was used to identify distinct geologic units.

A 3-year DOE Environmental Management Science Program study of clastic dikes and their influence on movement of subsurface contamination began in fiscal year 2000 and continued in fiscal year 2001. The results indicated that even though the air permeability and saturated hydraulic conductivity within the dikes are very low, clastic dikes may still provide transport paths under unsaturated conditions in the vadose zone.

During July and August 2001, scientists deployed six leak-detection technologies that could be used while removing waste from single-shell tanks at the Hanford Site. The demonstration of these methods was designed to provide data that will lead to the development of a way to detect leaks outside of a single-shell tank during waste retrieval operations.

Preliminary results indicate that all six technologies detected leaks from a mock tank but at different levels of ability. The testing done in fiscal year 2001 will allow the selection of two to three of these technologies for further testing in fiscal year 2002 and beyond. This may eventually result in deployment of one or more of these in an actual tank farm, and possibly produce a reliable leak-detection technology for waste retrieval activities.

Air in the vadose zone can become contaminated with gaseous contaminants from landfills or other waste sites. At Hanford, ***soil gas*** *is monitored in the 200 West Area to measure gaseous carbon tetrachloride and to assess how well vadose zone cleanup is working. Soil gas also is monitored beneath two landfills on site.*

Contents

Tables

Figures

1.0 Introduction

The U.S. Department of Energy (DOE) monitors groundwater at the Hanford Site to fulfill a variety of state and federal regulations, including the *Atomic Energy Act of 1954*, the *Resource Conservation and Recovery Act of 1976* (RCRA), the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), and Washington Administrative Code. DOE manages these activities through the Hanford Groundwater Monitoring Project, which is conducted by Pacific Northwest National Laboratory.

1.1 Purpose and Scope

M. J. Hartman

This report describes groundwater conditions on the Hanford Site and fulfills regulatory reporting requirements. It also summarizes groundwater remediation, vadose zone studies, and groundwater modeling.

Hanford Site Groundwater Monitoring for Fiscal Year 2001 presents results of groundwater monitoring, vadose zone monitoring and characterization, and groundwater modeling (Figure 1.1-1). This report also summarizes groundwater remediation and well installation activities for the fiscal year. Monitoring results primarily rely on data from samples collected between October 1, 2000, and September 30, 2001. Data received after November 12, 2001, may not have been considered in the interpretations.

Groundwater monitoring helps the U.S. Department of Energy develop solutions to Hanford Site cleanup issues. The protection of the Columbia River corridor is of primary importance. Pictured above is part of the Hanford Reach.

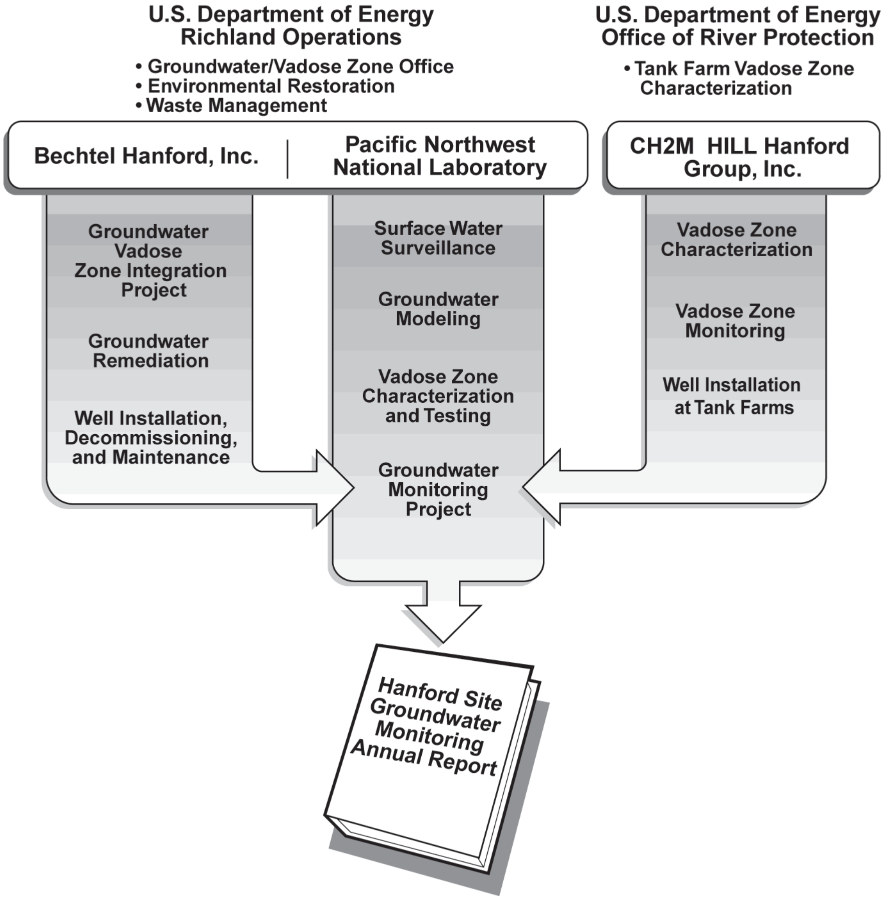

Figure 1.1-1. The Groundwater Monitoring Project Produces the Annual Groundwater Report for the U.S. Department of Energy with Input from Many Contributors

This report is designed to meet the following objectives:

- provide a comprehensive report of groundwater conditions on the Hanford Site and adjacent areas
- fulfill the reporting requirements of RCRA, DOE orders, and Washington Administrative Code
- summarize the results of groundwater monitoring conducted to assess the effects of remediation or interim measures conducted under CERCLA
- describe the results of vadose zone monitoring and characterization
- summarize groundwater modeling activities
- summarize the installation, maintenance, and decommissioning of Hanford Site monitoring wells.

Environmental restoration work, which includes groundwater remediation and associated monitoring of pumping wells, is the responsibility of Bechtel Hanford, Inc. Vadose zone monitoring and characterization are conducted by Bechtel Hanford, Inc.; CH2M HILL Hanford Group, Inc.; and Pacific Northwest National Laboratory.

Supporting information for RCRA, CERCLA, and other waste units regulated under federal and state requirements are presented in Appendix A. Table 1.1-1 summarizes highlights or changes for those units and indicates where to find additional information. Appendix B describes results of the quality control program.

Background information, including descriptions of regulatory requirements, waste sites, analytical methods, regional geology, and statistics is included in a separately-published companion volume, *Hanford Site Groundwater: Setting, Sources and Methods* (PNNL-13080). That document is not updated every year because the information does not change significantly from year to year. Minor updates to the companion document are included in Appendix C. The changes have been incorporated into the compact disk versions of this groundwater monitoring report.

As in previous reports, the enclosed compact disk contains groundwater data for the fiscal year and historical data for selected constituents. Large plate maps show the Hanford Site water table, and the distribution of tritium (the most widespread contaminant) in the uppermost aquifer.

1.2 Related Reports

M. J. Hartman

Other reports and databases relating to Hanford Site groundwater in fiscal year 2001 include the following:

- *Hanford Site Environmental Report for Calendar Year 2000* (PNNL-13487) — This annual report summarizes environmental data, describes environmental management performance, and reports the status of compliance with environmental regulations. Topics include effluent monitoring, surface water and sediment surveillance, soil and vegetation sampling, vadose and groundwater monitoring, radiological surveys, air surveillance, and fish and wildlife surveillance.
- Hanford Environmental Information System (HEIS) — This is the main environmental database for the Hanford Site that stores groundwater chemistry and water-level data, as well as other environmental data (e.g., soil chemistry, survey data).
- Quarterly data transmittals — DOE transmits letters quarterly to the Washington State Department of Ecology after groundwater data collected for the RCRA program have been verified and evaluated. These letters describe changes or highlights of the quarter with reference to HEIS for the analytical results.

Abbreviations and Acronyms

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOE/RL	U.S. Department of Energy, Richland Operations Office
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
DCG	derived concentration guide
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HEIS	Hanford Environmental Information System
MCL	maximum contaminant level
NAVD88	North American Vertical Datam 1988
PUREX	Plutonium-Uranium Extraction (Plant)
RCRA	*Resource Conservation and Recovery Act*
ROD	Record of Decision
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
WAC	Washington Administrative Code

- *Fiscal Year 2001 Annual Summary Report for the 200-UP-1 and 200-ZP-1 Pump-and-Treat Operations* (DOE/RL-2001-53) — This report describes results of remediation and monitoring in two groundwater operable units in the 200 West Area.
- *Calendar Year 2001 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Units and Pump-and-Treat Operations* (DOE/RL-2002-01) — This report describes results of remediation and monitoring in groundwater operable units in the 100 K, 100 N, 100 D, and 100 H Areas.

- *Fiscal Year 2001 Annual Summary Report for the In-Situ REDOX Manipulation Operations* (DOE/RL-2002-05) — This report describes activities related to the remediation system in the southwestern 100 D Area.
- *U.S. DOE Hanford Site First Five Year Review Report* (EPA 2001).

1.3 Groundwater/Vadose Zone Integration Project

E. A. Jenkins

Radionuclides and Their Half-Lives

Symbol	Radionuclide	Half-Lives
^{3}H	tritium	12.35 yr
^{14}C	carbon-14	5,730 yr
^{60}Co	cobalt-60	5.3 yr
^{90}Sr	strontium-90	28.8 yr
^{99}Tc	technetium-99	2.1×10^5 yr
^{106}Ru	ruthenium-106	358.2 d
^{129}I	iodine-129	1.6×10^7 yr
^{137}Cs	cesium-137	30 yr
^{234}U	uranium-234	2.4×10^5 yr
^{239}Pu	plutonium-239	2.4×10^4 yr
^{240}Pu	plutonium-240	6.5×10^3 yr

The U.S. Department of Energy established the Groundwater/Vadose Zone Integration Project (Integration Project) in 1997 as its centerpiece for water resources protection for the Hanford Site. The goal of the Integration Project is to focus and coordinate all projects at Hanford involved in characterizing, monitoring, and remediating the groundwater, the vadose zone (the soil above the groundwater), and the Columbia River.

The project team includes staff from Bechtel Hanford, Inc. and its environmental restoration contractor team; CH2M HILL Hanford Group, Inc.; the Pacific Northwest National Laboratory; and Fluor Hanford, Inc., as well as support from other national laboratories and universities. The Hanford Groundwater Monitoring Project is under the umbrella of the Integration Project.

The Integration Project team's accomplishments in fiscal year 2001 spanned its key focus areas – Sitewide Fieldwork Integration, the System Assessment Capability, Science and Technology, Integration of Information, Technical Review, and Public Involvement. The efforts within these task areas directly support DOE's plan for the Hanford Site.

A major accomplishment within Sitewide Fieldwork Integration was the collection of radioactive and chemical samples from some of Hanford's most hazardous waste sites. This work, which was accelerated to coordinate with other assessment and groundwater remediation work, will provide a significant body of new information and insights that can be used when making safe, cost-effective waste management and remediation decisions.

In fiscal year 2001, pump-and-treat systems along the Columbia River were on line 98% of the time, the highest performance level on record. These systems are used to extract contaminants, such as strontium-90 and chromium, from the groundwater before they reach the river. During the same period, 90 non-essential vadose and groundwater wells in the Columbia River corridor were decommissioned, reducing costs associated with their maintenance.

The environmental restoration contractor completed a large segment of the treatment zone for the in situ reduction oxidation (redox) manipulation site in the 100 D Area by installing 28 wells. Redox treatment involves injecting a chemical into the groundwater, which creates a chemical treatment zone in the aquifer. The redox system prevents a toxic form of chromium from entering the Columbia River and potentially harming young salmon.

Units of Measure

µg/L	micrograms per liter
µS/cm	microsiemens per centimeter
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

An investigation to determine the source and extent of tritium in groundwater near an old radioactive burial site was completed. DOE will use the findings from this work to determine if any action is needed at the burial site to protect public health and environmental safety.

The Integration Project completed the first assessment using the System Assessment Capability in fiscal year 2001. The System Assessment Capability is a suite of computer models and analysis techniques that is used to predict the movement and fate of contaminants that will remain on the Hanford Site after closure. It also is used to estimate the effects of those contaminants to human health, the environment, the Columbia River, and the local economy and cultures. The System Assessment Capability is envisioned as a tool to assess the merits of remediation, isolation, and containment alternatives for specific areas of the Hanford Site.

The National Academy of Sciences completed its 18-month review of the Science and Technology focus area. The committee concluded that there is a long-term and continuing need for science and technology to support cleanup and stewardship of the Hanford Site. In its final report, the committee noted that "The knowledge and technology needed to address the most difficult problems at the site do not yet exist, and advances will not be possible without continuing investments in science and technology."

As part of the project's mission to integrate and provide information to Hanford staff, the Virtual Library was issued as a user-friendly means to review and use site environmental data. Additional data sources will be incorporated into the Virtual Library during the coming year.

Another integration effort the project initiated in 2001 was the Central Plateau Risk Framework Guidance. This effort is aimed at establishing a set of short- and long-term risk parameters, such as site future uses and geographic buffer zones, that will be consistently used to make cleanup and closure decisions by all programs operating on the Hanford Site's Central Plateau.

Technical review and public involvement remained key to the Integration Project's success in the past year. The expert panel, which provides oversight and review of the project, continued to give the effort high marks. Staff met regularly with interested individuals, organizations, and Tribal Nations to obtain feedback about the project. These activities ranged from monthly public meetings to opportunities to learn about the project via the environmental restoration contractor's Internet site.

Conversion Table

The primary units of measurement in this report are metric. To convert metric units to English units, use the information provided in this 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 x 10^{10}	becquerel
picocurie	0.03704	becquerel
rem	0.01	sievert
°Celsius	(°C x 9/5) + 32	°Fahrenheit

1.4 Helpful Information

The companion volume to this report (PNNL-13080), describes techniques used to interpret the data and conventions for plotting. Contaminant plume maps in this report show data from fiscal years 1999 and 2000 if there were no new data for a well in fiscal year 2001. Wells that monitor plumes that change slowly are sampled every 3 years, so this convention allows us to see the most recent data. Trend plots in this report use open symbols to show levels of contaminants that were so low the laboratory could not detect them. These results are typically reported as a value that represents the detection limit of the analytical method or instrument and are flagged "undetected" in the database. Analytical results that appear to be erroneous remain on the plots if they do not distort the scale or obscure the data trends. If the outlying data distort the figure, they are not plotted. All of the data from fiscal year 2001 are included in the data files that accompany this report and in the HEIS database.

Nitrate and nitrite are expressed as the NO_3 and NO_2 ions. Figures showing chromium results include total chromium in filtered samples and hexavalent chromium in filtered or unfiltered samples. Dissolved chromium in Hanford Site groundwater is virtually all hexavalent, so filtered total chromium represents hexavalent chromium.

This report compares contaminant concentrations in groundwater with state or federally enforceable "maximum contaminant levels" and other limits for drinking water. Although Hanford Site groundwater is not generally used for drinking, these levels provide a useful indicator to provide perspective on contaminant concentrations. Standards for arsenic and uranium have changed recently; see Table 5.1 in Appendix C for a complete list of updated standards.

Table 1.1-1. Regulated Units and Groundwater Operable Units on the Hanford Site

Site or Operable Unit	Type of Monitoring Program	Main Text	Influence on Groundwater Quality	Compliance Issues	FY 2001 Highlights
RCRA Units (well location maps, well/constituent tables, statistics tables, and flow rates in Appendix A)					
1301-N facility	Indicator evaluation	2.4.8	2.4.2, 2.4.3	A.1.1	No CIP exceedance
1325-N facility	Indicator evaluation	2.4.8	2.4.2, 2.4.3	A.1.2	No CIP exceedance
1324-N/NA facilities	Indicator evaluation	2.4.9	2.4.4	A.1.3	No CIP exceedance
183-H basins	Corrective action	2.6.7	2.6.2, 2.6.6	A.1.4	Monitoring during IRA. Chromium, nitrate, technetium-99, uranium.
216-A-29 ditch	Indicator evaluation	2.9.2.10	2.9.2.10	A.1.5	No CIP exceedance
216-B-3 pond	Indicator evaluation	2.9.2.11	2.9.2.11	A.1.6	No CIP exceedance; proposed monitoring plan Nov. 2001 with alternative statistics
216-B-63 trench	Indicator evaluation	2.9.1.11	2.9.1.11	A.1.7	No CIP exceedance
216-S-10 pond and ditch	Indicator evaluation	2.8.4.10	None	A.1.8	No CIP exceedance; insufficient wells
216-U-12 crib	Assessment	2.8.3.7	2.8.3	A.1.9	Continued assessment; insufficient wells
316-5 process trenches	Corrective action	2.12.6	2.12.2, 2.12.4	A.1.10	Monitoring during natural attenuation IRA. New monitoring plan.
LERF	Indicator evaluation	2.9.2.12	None	A.1.11	Dry wells; ceased statistical comparisons
LLWMA 1	Indicator evaluation	2.9.1.12	None	A.1.12	No CIP exceedance
LLWMA 2	Indicator evaluation	2.9.1.12	None	A.1.13	No CIP exceedance; dry wells
LLWMA 3	Indicator evaluation	2.8.2.13	None	A.1.14	No CIP exceedance; insufficient wells
LLWMA 4	Indicator evaluation	2.8.1.5	None	A.1.15	No CIP exceedance; insufficient wells
NRDWL	Indicator evaluation	2.11.1.2	None	A.1.16	No CIP exceedance
PUREX cribs	Assessment	2.9.2.7	2.9.2	A.1.17	Continued assessment; iodine-129, tritium, nitrate
SST WMA A-AX	Indicator evaluation	2.9.2.8	2.9.2.8	A.1.18	No CIP exceedance; new interpretation of flow
SST WMA B-BX-BY	Assessment	2.9.1.10	2.9.1	A.1.19	Continued assessment; nitrate, nitrite, technetium-99, uranium. New wells.
SST WMA C	Indicator evaluation	2.9.2.9	2.9.2.9	A.1.20	No CIP exceedance; new interpretation of flow
SST WMA S-SX	Assessment	2.8.4.9	2.8.4	A.1.21	Continued assessment; chromium, nitrate, technetium-99. New wells.
SST WMA T	Assessment	2.8.2.11	2.8.2	A.1.22	Continued assessment; chromium, nitrate, technetium-99. New well.
SST WMA TX-TY	Assessment	2.8.2.12	2.8.2	A.1.23	Continued assessment; chromium, nitrate, technetium-99
SST WMA U	Assessment	2.8.3.8	2.8.3	A.1.24	Continued assessment; nitrate, technetium-99; new wells

Table 1.1-1. (contd)

Site or Operable Unit	Type of Monitoring Program	Main Text	Influence on Groundwater Quality	Compliance Issues	FY 2001 Highlights
Other Regulated Units (well location maps, well/constituent tables in Appendix A)					
100 K fuel storage basins	*Atomic Energy Act*	2.3.8	2.3.4	A.2.1	No leaks detected
200 Areas TEDF	WAC 173-216	2.9.2.13	None	A.2.2	No influence in upper aquifer
4608 B/C process ponds	WAC 173-216	2.10.4	None	A.2.3	No permit limits exceeded
ERDF	CERCLA	A.2.4	A.2.4	A.2.4	No permit limits exceeded
SALDS	WAC 173-216	2.8.5	2.8.5.2	A.2.6	No permit limits exceeded; tritium plume present
SWL	WAC 173-304	2.11.1.3	2.11.1.3	A.2.5	8 constituents exceeded background or standards; low levels of organics
CERCLA Groundwater Operable Units					
100-BC-5	Long-term monitoring	2.2	2.2	A.3.1	None
100-FR-3	Long-term monitoring	2.7	2.7	A.3.2	None
100-HR-3 (D pump and treat)	IRA; interim ROD	2.5.6.1	2.5.2.1	A.3.3	Chromium > cleanup target
100-HR-3 (D redox site)	IRA; interim ROD	2.5.6.2	2.5.2.2	A.3.3	Chromium > cleanup target; new injections
100-HR-3 (H pump and treat)	IRA; interim ROD	2.6.8	2.6.2	A.3.3	Chromium > cleanup target
100-KR-4	IRA; interim ROD	2.3.9	2.3.2	A.3.4	Chromium > cleanup target
100-NR-2	ERA	2.4.11	2.4.2	A.3.5	No decrease in plume size
1100-EM-1	Natural attenuation; final ROD	A.3.11	2.13	A.3.11	TCE <5 in all wells
200-BP-5	Long-term monitoring	A.3.6	2.9.1	A.3.6	None
200-PO-1	Long-term monitoring	A.3.7	2.9.2	A.3.7	None
200-UP-1	Interim action ROD	2.8.3.9	2.8.3.9	A.3.8	Technetium-99 and uranium > cleanup goals
200-ZP-1	Interim action ROD	2.8.1.6	2.8.1.2	A.3.9	Heart of plume contained
300-FF-5 300 Area	Natural attenuation; interim ROD	2.12	2.12.2, 2.12.4	A.3.10	TCE levels decreasing
300-FF-5 northern	Operations and Maintenance plan	2.12.7	2.12.7	A.3.10	618-11 tritium plume defined

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CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*.
CIP = Contamination indicator parameters.
ERA = Expedited response action.
ERDF = Environmental Restoration Disposal Facility.
FY = Fiscal year.
IRA = Interim remedial action.
LERF = Liquid Effluent Retention Facility.
LLWMA = Low-Level Waste Management Area.
NRDWL = Nonradioactive Dangerous Waste Landfill.
PUREX = Plutonium-Uranium Extraction Plant.
RCRA = *Resource Conservation and Recovery Act of 1976*.
ROD = Record of decision.
SALDS = State-Approved Land Disposal Site.
SST = Single-shell tank.
SWL = Solid Waste Landfill.
TCE = Trichloroethene.
TEDF = Treated Effluent Disposal Facility.
WAC = Washington Administrative Code.
WMA = Waste Management Area

2.0 Groundwater

Groundwater contamination at the Hanford Site is associated with a number of sources within its active and inactive operational areas. Liquid waste, discharged to the ground since the 1940s, percolated through the soil and in many locations reached the water table. Very little liquid waste is currently disposed to the soil, and cleanup of existing groundwater contamination, by pump-and-treat systems for example, is occurring at some sites.

This section describes groundwater flow and groundwater contamination in each of the major areas on the Hanford Site. Factors that affect the distribution, migration, and concentrations of groundwater contaminants include

- Source history – groundwater contaminants at the Hanford Site originated from hundreds of disposal sites. These sites were used at different periods of time so the plumes were formed and are dissipating in different ways. In addition, plumes originating from many sources are affected by the discharge of uncontaminated or less contaminated water to nearby facilities.
- Stratigraphy – (a) groundwater tends to flow through sediment with higher hydraulic conductivity rather than less permeable units; (b) in some areas, the shallowest aquifer is connected to deeper aquifers, which could allow contaminants to move into deeper aquifers.
- Declining water table – may affect contaminant concentrations, which may vary with depth.
- Well depth – the depth of the well, the length of the screen, and the depth of the pump intake can affect contaminant concentrations in samples if concentrations vary with depth.
- River stage – (a) affects distribution and trends of contaminants at sites near the Columbia River by changing direction of flow in the aquifer; (b) high water may remobilize contaminants from the vadose zone or may dilute contaminants when river water flows into the aquifer.
- Groundwater remediation – (a) extraction and injection wells affect the direction of groundwater flow locally. This affects contaminant distribution and the ability to monitor other sites (e.g., *Resource Conservation and Recovery Act of 1976* [RCRA] units); (b) treated water is injected back into the aquifer, but may contain residual contaminants or may dilute local groundwater.

This section discusses these factors, as applicable, for individual areas or waste sites in geographic order (north to south, west to east). The results of the monitoring program are discussed, as much as possible, in relation to source areas. In some cases, several potential sources such as cribs, trenches, or other disposal facilities may contribute to a particular groundwater plume, and their individual contributions cannot be readily distinguished. Therefore, they are discussed together. Monitoring of specific storage and disposal facilities, such as RCRA units, is reported within the sections on the geographical areas. The status of groundwater remediation under RCRA or the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) is discussed in the relevant sections.

Waste sites, hydrogeology, and methods of sampling and analysis are described in *Hanford Site Groundwater: Settings, Sources and Methods* (PNNL-13080). That document also explains how water-level and groundwater chemistry data were interpreted and mapped.

2.1 Overview of Hanford Site Groundwater

M. J. Hartman and J. P. McDonald

This section provides a broad picture of groundwater flow and contaminant distribution beneath the Hanford Site. Details for specific locations are included in Sections 2.2 through 2.14. Supporting information for *Resource Conservation and Recovery Act of 1976* (RCRA), *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), and other regulated units is compiled in Appendix A.

The uppermost aquifer beneath most of the Hanford Site is unconfined and is composed of unconsolidated to semiconsolidated sediment of the Hanford and Ringold formations, which were deposited on the basalt bedrock. In some areas, deeper parts of the aquifer are confined locally by layers of silt and clay. Confined aquifers occur within the underlying basalt and associated sedimentary interbeds.

The Hanford Groundwater Monitoring Project sampled over 700 wells during fiscal year 2001. Iodine-129, nitrate, and tritium are the most widespread contaminants.

2.1.1 Groundwater Flow

During March 2001, the Hanford Groundwater Monitoring Project collected 835 water-level measurements across the Hanford Site. This section describes the results of a regional-scale analysis of these data for the unconfined aquifer, including a description of the current water table and changes in the water table during the period from March/April 2000 to March 2001. Most of the water-level data used in this analysis were collected by Duratek Federal Services, Northwest Operations. The environmental restoration contractor provided much of the data used in the vicinity of the pump-and-treat areas from their automated water-level monitoring equipment. Energy Northwest also provided water-level data from their monitoring.

Groundwater monitoring relies on samples from wells across the Hanford Site.

Project staff use measurements of the depth to water in wells to compute water-level elevations (i.e., hydraulic head). Contour maps of water-level elevations indicate the general direction of groundwater movement, because water generally flows perpendicular to the contour lines from high potential (high water-level elevations) to low potential (low water-level elevations). Water-level gradients, in conjunction with the hydraulic properties of the aquifer, are used to estimate the rate of groundwater flow.

Groundwater in the unconfined aquifer generally flows west to east beneath the Hanford Site and discharges to the Columbia River.

Water-level data and water-level maps are used to support the calibration of groundwater flow models and to interpret groundwater sampling results. The unconfined aquifer is the primary focus of this section because it is the most likely groundwater pathway for migration of contaminants off the Hanford Site. However, measurements also are taken annually in the Ringold formation confined aquifer (see Section 2.9.3), the upper basalt-confined aquifer system (see Section 2.14), and in the deep basalt aquifers to support groundwater modeling and to provide a data archive in the event that contamination is discovered in these systems. The *Water-Level Monitoring Plan for the Hanford Groundwater Monitoring Project* (PNNL-13021) contains a detailed description of the water-level monitoring activities, including the methods of data collection and analysis.

2.1.1.1 Current Water Table

Groundwater in the unconfined aquifer flows from regions where the water-table elevation is high (recharge areas) west of the Hanford Site to regions where it is low (discharge areas) near the Columbia River (Figure 2.1-1 and Plate 1). The local geology has a significant influence on the groundwater flow pathways. These geologic controls include the hydraulic conductivity of the sediment comprising the aquifer, the aquifer thickness, and the location of basalt and mud units above the water table, which act as barriers to flow. Steep gradients occur in the western, eastern, and northern regions of the site, while shallow gradients occur within and west of the 100 B/C Area, southeast of the 100 F Area, and in the central portion of the site. This is largely due to differences in hydraulic conductivity and aquifer thickness. Gradients increase as the hydraulic conductivity of the sediments and/or the aquifer thickness decreases.

Recharge to the unconfined aquifer consists of

- infiltration of rain and snowmelt at higher elevations, primarily in the Cold Creek and Dry Creek Valleys and the Rattlesnake Hills
- irrigation of offsite agricultural land in the Cold Creek Valley
- inflowing water from the Columbia River west of the 100 B/C Area and potentially southeast of the 100 F Area
- inflowing water from the Yakima River in the southeast portion of the site
- infiltration of rain and snowmelt across the site
- discharging water from deeper aquifers
- wastewater disposal to the soil column (artificial recharge).

The water table is relatively flat beneath the 200 East Area. Flow is affected by low permeability sediment at the water table.

Steep gradients in the offsite areas north and east of the Columbia River (see Figure 2.1-1) are attributed to recharge associated with irrigation of agricultural land and sediments of low hydraulic conductivity. Regionally, water-table elevations decrease while approaching the Columbia River from either side, indicating that groundwater flow converges and ultimately discharges to the river.

Past wastewater discharges to the ground on the Hanford Site, primarily in the 200 West and 200 East Areas, resulted in groundwater mounding and significantly affected the flow of groundwater. These discharges had largely ceased by the mid-1990s. However, the effects of past discharges at U Pond and lesser discharges to other 200 West Area facilities are still apparent from the shape of the water-table contours passing through the 200 West Area.

Currently, the mound in the 200 West Area is ~13 meters above the estimated pre-Hanford water table. It is expected that when equilibrium conditions are again established, the water table may be ~5 to 7 meters higher than the estimated pre-Hanford water table (PNNL-11801). When the height of the 200 West Area mound peaked in 1984, it was ~24 meters above the estimated pre-Hanford water table. This was determined by examining historical water-level data in conjunction with the estimated pre-Hanford water table from BNWL-B-360. This increase is not entirely due to wastewater discharges, because there was more irrigation in the offsite areas than in pre-Hanford times

The water table in the central portion of the Hanford Site, encompassing the 200 East Area south of Gable Mountain, is relatively flat because of the presence of highly permeable sediment of the Hanford formation at the water table. Groundwater flow in this region also is significantly affected by the presence of low permeability sediment of the Ringold Formation at the water table east and northeast of the 200 East Area. There is a groundwater mound associated with B Pond, where process cooling water and other liquid waste were discharged to the ground until fiscal year 1997. Currently, the mound occurs mainly within and beneath the Ringold Formation mud units and is considered part of the Ringold Formation confined aquifer (see Section 2.9.3). The height of the water table in the 200 East Area peaked in 1969 at ~5.1 meters above the estimated pre-Hanford water table. Water levels declined and then peaked again during 1988 at ~4.9 meters above the pre-Hanford water table. Currently, the water table is elevated by ~2.6 meters. It is estimated that when equilibrium conditions are again established in the 200 East Area, the water table will be near its estimated pre-Hanford elevation (PNNL-11801).

North of Gable Butte and Gable Mountain, groundwater also generally flows from west to east and discharges to the Columbia River. Groundwater enters this region through the gap between Gable Butte and Gable Mountain and the gap between Umtanum Ridge and Gable Butte. The Columbia River recharges the aquifer west of the 100 B/C Area.

The water table continued to decline beneath the central Hanford Site in fiscal year 2001, causing seven wells in the 200 Areas to go dry. Thirty-two wells in the 200 Areas have gone dry since fiscal year 1997.

An apparent groundwater mound exists ~2 kilometers north of Gable Mountain (between Gable Mountain and the 100 F Area). Long before the Hanford Site was established, Jenkins (1922) reported elevated groundwater levels in this area that have persisted to the present. Data suggest that this mound is associated with a subsurface "high" of Ringold Formation sediment having a low hydraulic conductivity (primarily clay). One possible source of recharge is past seasonal use of the Hanford irrigation canal, which traverses the groundwater mound area and was active between 1908 and 1943. Other potential sources of recharge include flow from the upper basalt-confined aquifer system and infiltration from surface runoff. The slow dissipation of the recharge water is attributed to the presence of a significant thickness of clay in the Ringold Formation sediment. There is insufficient information to distinguish whether the groundwater in this area is locally perched or is part of the regional, unconfined flow system.

The elevation of the water table in the region between the Yakima and Columbia Rivers is lower than the Yakima River stage elevation, which is ~122 meters above mean sea level at Wanawish (formerly Horn Rapids) Dam. This implies that infiltration from the Yakima River recharges the Hanford/Ringold aquifer system in this area. During the summer, leakage from the Horn Rapids Ditch and Columbia Canal, which originate from the Yakima River at Wanawish Dam, and irrigation in areas east of the Yakima River also may recharge the Hanford/Ringold aquifer system. Operation of the Richland North Well Field recharge ponds results in a groundwater mound in the Richland North Area.

2.1.1.2 Water-Table Changes from March/April 2000 to March 2001

The water table declined over much of the Hanford Site between March/April 2000 and March 2001 (Figure 2.1-2). The decrease is caused by the decline in wastewater discharges to the ground that have occurred since the peak discharge in 1984. Over the 1 year period, the water table declined by an average of 0.14 meter in the 200 East Area and 0.35 meter in the 200 West Area – outside of the 200-ZP-1 and 200-UP-1 Operable Units groundwater pump-and-treat regions.

The water-table elevation increased in a broad region adjacent to the Rattlesnake Hills and Yakima River, as well as in the Dry Creek Valley. This may be caused by higher than normal precipitation in fiscal years 1993 through 1997, along with higher than normal discharge in the Yakima River during fiscal years 1995 through 2000. Water levels declined in the Cold Creek Valley. The water table in this area is believed to respond to offsite irrigation practices.

Water levels declined in the region north of Gable Butte and Gable Mountain. The decline was greatest along the river due to a lower river stage during March 2001 as compared to March 2000. A slight increase in the water table occurred just south of the 100 H Area.

The water level has been increasing for the past several years in well 699-59-80B along the south side of Gable Butte. Between March 2000 and March 2001, the water level in this well increased 0.42 meter, the largest increase on the Hanford Site. The rate of increase since 1996 averaged 0.46 meter per year, which is a faster rate of increase than at any time since measurements began at this well in 1948. The cause of this increase remains unknown. No maintenance activities were conducted at this well that might explain the increase.

Changes in the water table also occurred beneath active facilities (e.g., the State-Approved Land Disposal Site, near the 200 West Area, and the North Richland Well Field) and within groundwater pump-and-treat areas. These changes are attributed to operation of these facilities. The largest water-level decline in the unconfined aquifer (1 meter) occurred in well 199-K-19 near the 100-KR-2 Operable Unit groundwater pump-and-treat extraction wells in the 100 K Area.

2.1.2 Groundwater Contaminants

During fiscal year 2001, Groundwater Project staff sampled 706 wells for radiological and chemical constituents (Table 2.1-1). Many of the wells were sampled multiple times, for a total of 1,507 well trips. Tritium was the most frequently-analyzed constituent, analyzed 991 times (Table 2.1-2). Anions, hexavalent chromium, metals, iodine-129, technetium-99, strontium-90, and volatile organic compounds were other commonly-analyzed constituents. The data from many wells on the Hanford Site are used to meet the objectives of multiple regulations, including RCRA, CERCLA, and the *Atomic Energy Act of 1954* (see Table 2.1-1). Sampling and analysis are coordinated to avoid unnecessary costs. Well location maps are included in Sections 2.2 through 2.14 and in Appendix A for RCRA units and other sites regulated under the Washington Administrative Code.

The major sources of groundwater contamination on the Hanford Site are former liquid waste facilities in the 100, 200, and 300 Areas.

Tritium, nitrate, and iodine-129 are the most widespread contaminants associated with past Hanford Site operations. Their distribution in the unconfined aquifer are shown in Figures 2.1-3, 2.1-4, and 2.1-5. The distribution of tritium is shown in more detail in Plate 2. The most prominent portions of these plumes originated at waste sites in the 200 Areas and spread toward the southeast. Nitrate and tritium also have significant sources in the 100 Areas.

Chromium contamination is widespread in several of the 100 Areas and extends into the surrounding 600 Area. Strontium-90 contamination is present in the 100 Areas, but the plumes are smaller. Other contaminant plumes include

- carbon tetrachloride and associated trichloroethene in the 200 West Area
- chromium in the 600 Area south of the 200 Areas
- technetium-99 and uranium that extend eastward from the 200 West Area
- technetium-99 and uranium with minor amounts of cyanide and cobalt-60 northwest of the 200 East Area
- uranium in the 300 Area.

Groundwater in the unconfined aquifer on the Hanford Site discharges to the Columbia River. Some samples at the river shore contained contaminants at levels above drinking water standards. Concentrations in river water remained far below standards.

Several other constituents are detected outside the boundaries of the operational areas, but the contamination is clearly linked to operations in the specific areas and is discussed with the source areas. Table 2.1-3 lists contaminants and refers to the sections in this report where they are discussed. The table highlights contaminants that exceed water quality standards. Analytical results including fiscal year 2001 and historical data are included in the data files accompanying this report.

Available data indicate that the vast majority of contamination on the Hanford Site remains near the water table. Relatively few wells are completed deeper in the aquifer, but in most cases, these detect lower levels of contamination than their shallow counterparts. A confined aquifer in the Ringold sediment east of the 200 East Area is contaminated with tritium at levels near those in the unconfined aquifer. However, tritium levels drop sharply a short distance downgradient, as discussed in Section 2.9.3. Deeper still, in the upper basalt-confined aquifer, contamination has been detected in only two wells, both near the 200 East Area (see Section 2.14).

For site characterization and cleanup, waste sites are grouped into source operable units, and the groundwater beneath the sites is divided into groundwater operable units. Groundwater operable unit boundaries are illustrated in Figure 2.1-6.

A number of Hanford waste sites have specific RCRA monitoring requirements (see Appendix A, Figure A.1). The results of monitoring at these facilities are integrated into the following discussions, and specific RCRA reporting requirements, such as indicator parameter evaluations, are included as needed. Appendix A discusses issues related to regulatory compliance and describes results of statistical evaluations for RCRA monitoring requirements. Appendix A also summarizes analytical results for wells monitoring RCRA- and state-permitted facilities that exceeded maximum contaminant levels or drinking water standards.

Groundwater monitoring in the zone of groundwater/Columbia River interaction is accomplished by periodic sampling of (a) aquifer sampling tubes located along the low river-stage shoreline, (b) riverbank seepage, and (c) nearshore river water.

2.1.3 Monitoring at River Shoreline

Groundwater flowing in the uppermost aquifers beneath the Hanford Site ultimately discharges into the Columbia River. A zone of groundwater/river water interaction is created where the approaching groundwater comes under the influence of the river system. Rapidly varying hydraulic gradients, which are caused by river stage fluctuations, and the infiltration of river water into the banks and riverbed sediment, join to create a zone of dynamic physical, chemical, and biological processes. Understanding the features and processes for this zone is essential to estimate and predict contaminant transport.

Groundwater plumes currently beneath the reactor areas and at other shoreline locations have existed for a significant time since their creation by former liquid waste disposal practices. The bulk of these practices ended by 1971, although some disposal continued at 100 N Area until 1987 and at the 300 Area until 1994.

The daily fluctuations of Columbia River flow exert a strong influence on water quality in the aquifer near the river. Contaminants may be diluted significantly prior to their ultimate discharge through the riverbed sediment and into the free-flowing stream.

Since then, infiltration of natural precipitation and continued drainage of moisture from the vadose zone cause residual amounts of contaminated moisture to move slowly downward into groundwater, thus maintaining contaminant plumes.

Because of the length of time since plumes were created by former disposal practices, the highest concentration portions of some plumes may already have migrated past the near-river environment and discharged into the river. For example, discharges from single-pass reactors to liquid waste disposal trenches generally ended by the mid-1960s. The groundwater travel time for non-attenuated contaminants from the trench locations to the groundwater interface is ~10 years or less. Therefore, the concentrations currently seen in plumes associated with these sites represent the waning portions of the plumes. Contamination at the levels seen today are likely to persist for many years as the result of slow leaching of overlying contaminated vadose zone sites.

Groundwater contamination at some shoreline locations is from more distant sources than those described above for the reactor areas. Example areas include the shoreline between the 100 B/C and 100 K Areas and at the Old Hanford Townsite. Evidence suggests that contaminants such as nitrate, tritium, and technetium-99 have traveled from liquid waste disposal sites in the 200 East Area to these shorelines.

The principal features and terminology associated with the zone of groundwater/river water interaction are shown in Figure 2.1-7. Contamination transported via groundwater movement typically resides in the uppermost hydrologic unit, i.e., the unconfined aquifer beneath the water table. For contaminant plumes in the 100 Areas, the thickness of this uppermost unit is reasonably well known, so the interface between the contaminated layer and the adjacent river channel can be defined. This knowledge helps identify the riverbed area that is most at risk from contaminated groundwater entering the river.

Monitoring water movement and chemical/radiological characteristics in the zone of interaction requires several approaches. The various types of sampling sites available are illustrated in Figure 2.1-7. They include near-river monitoring wells, aquifer sampling tubes, riverbank seepage sites, and riverbed sediment pore water sites. Aquifer sampling tubes are polyethylene tubes installed at various depths to monitor near the water table, at mid-depth in the aquifer, and near the bottom of the aquifer (BHI-01153). The tubes are sampled annually to support objectives of the Environmental Restoration Program. The Public Safety and Resource Protection Program and Environmental Restoration Program monitor riverbank seepage annually. River water also is monitored routinely at multiple locations along the shoreline and across several transects of the Columbia River.

Groundwater movement varies dramatically in response to daily river stage cycles. At times of very high river stage, flow is reversed and the infiltration of river water is great enough to dilute contaminant concentrations in groundwater approaching the river. To describe these rapid changes, water levels are recorded at hourly intervals using sensors installed in wells and the river.

Because of infiltrating river water, water quality characteristics in the banks and riverbed sediment varies with river stage fluctuations. Specific conductance, which is a measure of the dissolved salts in water, is used to differentiate river water (lower conductance) from groundwater (higher conductance). Investigations to date have revealed that some mixing, and, therefore, dilution of contaminants, occurs at the interface between groundwater and the free-flowing stream of the river. Consequently, the maximum contaminant concentrations detected in near-river wells, aquifer sampling tubes, and riverbank seepage (see Table 2.1-3) may not represent the maximum concentration in groundwater that approaches the river.

Contaminant concentrations in seeps and aquifer tubes in fiscal year 2001 generally agreed with concentrations detected in monitoring wells, while concentrations in river water remained very low. Five contaminants exceeded drinking water standards in seep samples:

- Tritium exceeded the 20,000 pCi/L standard at the 100 B/C, 100 N, and 100 D Areas and the Old Hanford Townsite.
- Nitrate exceeded the 45 mg/L standard at the 100 B/C, 100 K, 100 D, and 300 Areas and the Old Hanford Townsite (data from the 100 F Area appear erroneous in fiscal year 2001, but seep water had high nitrate in the past)
- Chromium exceeded the 100 μg/L maximum contaminant level at seeps in the 100 K and 100 D Areas. It exceeded the 11 μg/L aquatic standard in each of the 100 Areas.
- Strontium-90 exceeded the 8 pCi/L standard near the shore at the 100 B/C, 100 N, and 100 H Areas.
- Uranium exceeded the 30 μg/L standard at the shoreline in 300 Area.

Table 2.1-1. Groundwater Monitoring Project Well Trips for Various Regulatory Purposes in Fiscal Year 2001

	Hanford Site	100 Areas[a]	200 Areas[a]	300 Area[b]	400 Area	Richland North[c]	Basalt Confined
Number of wells	706	200	378	47	6	66	9
Total well trips	1,507	533	724	75	45	78	9
CERCLA	378	288	86	4	0	0	0
RCRA	467	12	387[d]	27	0	0	0
AEA	375	91	139	29	45	62	9
CERCLA/AEA	159	127	10	6	0	16	0
RCRA/AEA	117	11	97[d]	9	0	0	0
Other combinations	11	4	5	0	0	0	0

(a) Including 600 Area wells around or downgradient of these areas.
(b) Including 618-11 burial ground.
(c) Includes all wells beginning with "1199" or "699-S."
(d) Includes 41 well trips for Nonradioactive Dangerous Waste Landfill.
AEA = *Atomic Energy Act of 1954*.
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*; includes long-term monitoring.
RCRA = *Resource Conservation and Recovery Act of 1976*.
Other combinations include CERCLA/RCRA and CERCLA/RCRA/AEA.
Some well trips also include cosampling for the Washington State Department of Health, Fast Flux Test Facility, and special projects.

Table 2.1-2. Number of Samples (excluding quality control) Analyzed for Selected Constituents in Fiscal Year 2001

Samples Analyzed For	Total Number of Samples	Number of Wells	100 Areas[a]	200 Areas[a]	300 Area[b]	400 Area	Richland North[c]	Basalt Confined
Carbon tetrachloride	414	238	23	301	58	1	31	0
Chromium (total)	855	467	265	549	2	21	9	9
Chromium (hexavalent)	332	106	321	11	0	0	0	0
Iodine-129	301	240	7	279	4	3	4	4
Strontium-90	342	279	125	188	3	1	23	2
Technetium-99	483	224	27	445	2	2	5	2
Tritium	991	596	278	565	30	40	68	10
Uranium	376	203	19	273	61	2	17	4

(a) Including 600 Area wells around or downgradient of these areas.
(b) Including 618-11 burial ground.
(c) Includes all wells beginning with "1199" or "699-S."

Table 2.1-3. Maximum Concentrations of Groundwater Contaminants in Fiscal Year 2001

Contaminant (alphabetical order)	DWS or MCL [DCG][a]	Units	100 B/C Section 2.2		100 K Section 2.3		100 N Section 2.4		100 D Section 2.5		100 H Section 2.6		100 F Section 2.7		200 West Section 2.8
			Wells	Shore[b]	Wells	Shore[b]	Wells	Shore[b]	Wells	Shore[b]	Wells	Shore[b]	Wells	Shore	Wells
Carbon tetrachloride	5	µg/L													**7,400**
Carbon-14	2,000 [70,000]	pCi/L			**16,300**	ND									
Cesium-137	200 [3,000]	pCi/L													
Chloroform	100	µg/L													160
Chromium (dissolved)	100	µg/L	86	48	**1,332**	**110**	**173**	12	**4,750**	**521**	**160**	88	79	19	**248**
Cobalt-60	100 [5,000]	pCi/L													
Cyanide	200	µg/L													
cis-1,2 Dichloroethene	70	µg/L													
Fluoride	4	mg/L									0.32				**4.9**
Gross alpha	15	pCi/L									**33**				**18**
Gross beta	50	pCi/L	**270**	50	**8,670**	**82**	**3,440**	5.9	**75**	14	**278**	27	**80**	10	**28,700**
Iodine-129	1 [500]	pCi/L													**64**
Nitrate (as NO_3)	45	mg/L	34	**67**	**160**	**74**	**125**	22	**86**	**88**	**150**	17	**158**	[c]	**1,300**
Nitrite (as NO_2)	3.3	mg/L							**8.3**						**27**
Plutonium	NA [30]	pCi/L													
Strontium-90	8 [1,000]	pCi/L	**135**	**15.8**	***5,210***	ND	***9,690***	***9,690***	**12**	1.4	**38**	**14**	**38**	1.7	**69**
Technetium-99	900 [100,000]	pCi/L									471				**81,500**
Trichloroethene	5	µg/L			**19**								**16**		**21**
Tritium	20,000 [2,000,000]	pCi/L	**40,700**	**31,300**	**1,750,000**	6,140	**36,900**	**29,700**	18,600	**22,100**	7,740	5,460	**38,600**	1,380	**1,540,000**
Uranium[d]	30 [790]	µg/L									**49**		23		***2,140***

Table 2.1-3. (contd)

Contaminant (alphabetical order)	DWS or MCL [DCG][a]	Units	200 East Section 2.9 Wells	200 East Section 2.9 Shore[b]	400 Section 2.10 Wells	600 Section 2.11 Wells	300 Section 2.12 Wells	300 Section 2.12 Shore[b]	618-11 Section 2.12.8 Wells	Richland North Section 2.13 Wells	Basalt-Confined Section 2.14 Wells
Carbon tetrachloride	5	μg/L				ND					
Carbon-14	2,000 [70,000]	pCi/L									
Cesium-137	200 [3,000]	pCi/L	**1,910**								
Chloroform	100	μg/L				0.43					
Chromium (dissolved)	100	μg/L	**1,640**			17					
Cobalt-60	100 [5,000]	pCi/L	78								ND
Cyanide	200	μg/L	**423**								29
cis-1,2 Dichloroethene	70	μg/L					**190**				
Fluoride	4	mg/L								**15**	**8.5**
Gross alpha	15	pCi/L	**357**				**43**	**88**	8.0	10	3.5
Gross beta	50	pCi/L	**25,700**	36			**282**	33	**84**	24	**330**
Iodine-129	1 [500]	pCi/L	**10**	0.27							ND
Nitrate (as NO_3^-)	45	mg/L	**748**	**100**	**87**	22	**89**	**104**	**93**	**162**	38
Nitrite (as NO_2)	3.3	mg/L			0.36						
Plutonium	NA [30]	pCi/L	***63***								
Strontium-90	8 [1,000]	pCi/L	***12,000***								ND
Technetium-99	900 [100,000]	pCi/L	**13,000**	112							**1,120**
Trichloroethene	5	μg/L					**5.3**			**5.1**	
Tritium	20,000 [2,000,000]	pCi/L	***4,300,000***	**107,000**	**57,600**	**49,800**	**57,700**	11,700	***8,370,000***	551	5,770
Uranium[d]	30 [790]	μg/L	**678**				**205**	**210**	11	23	

Note: Table lists highest concentration for fiscal year 2001 in each geographic region. Concentrations in **bold** exceed drinking water standards. Concentrations in ***bold italic*** exceed DOE derived concentration guides. Blank spaces indicate the constituent is not of concern in the given area.

(a) DWS = drinking water standard; MCL = maximum contaminant level; DCG = DOE derived concentration guide. See PNNL-13080 for more information on these standards.

(b) Shoreline sampling includes aquifer sampling tubes, seeps, and shoreline wells from fall 2000. 200 East Area plumes monitored at Old Hanford Townsite.

(c) Fiscal year 2001 results appear erroneous. Past year's results up to 55 mg/L.

(d) Uranium standard of 30 μg/L becomes effective December 2003.

ND = Not detected.

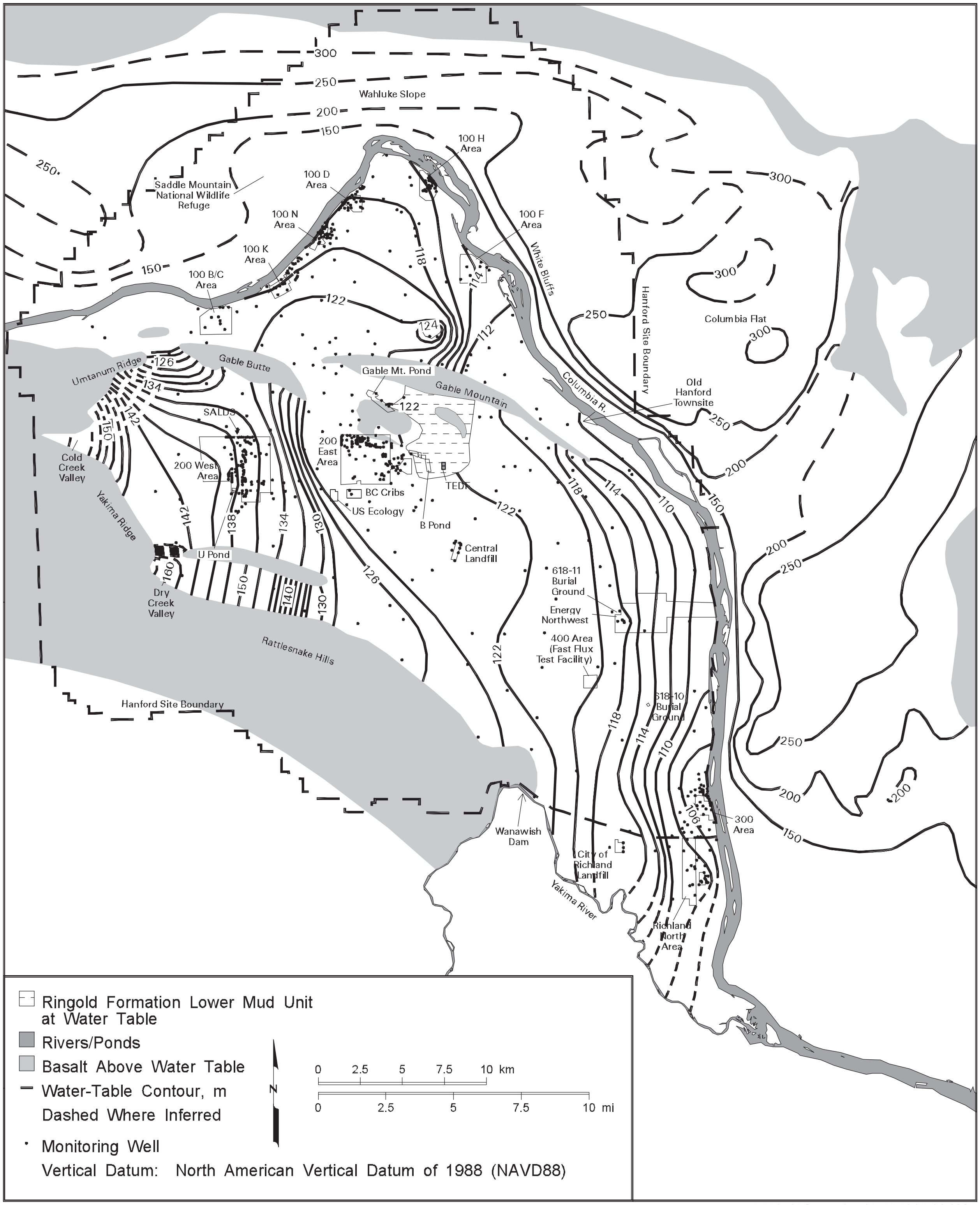

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Figure 2.1-1. Hanford Site and Outlying Areas Water-Table Map, March 2001

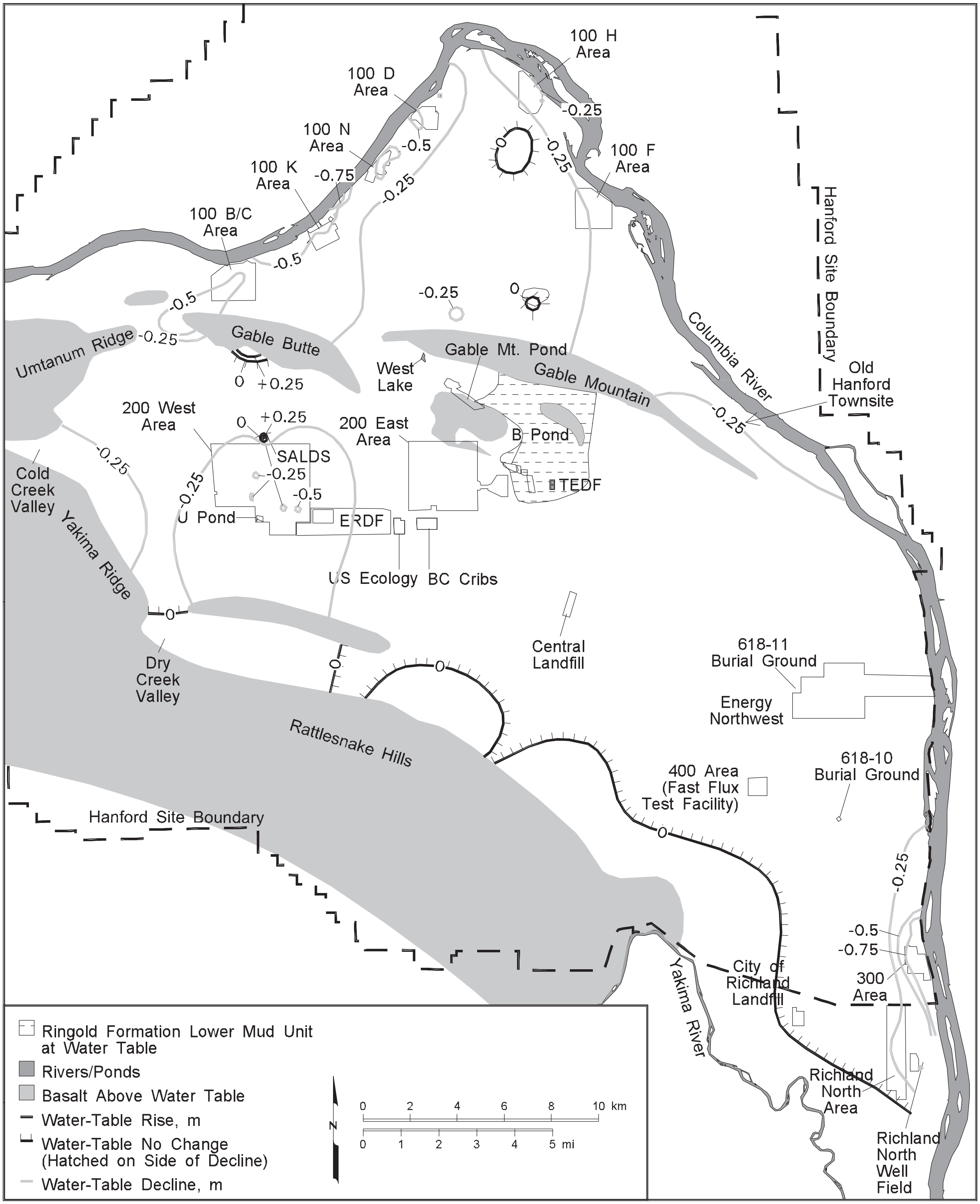

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Figure 2.1-2. Changes in Water-Table Elevations Between March/April 2000 and March 2001

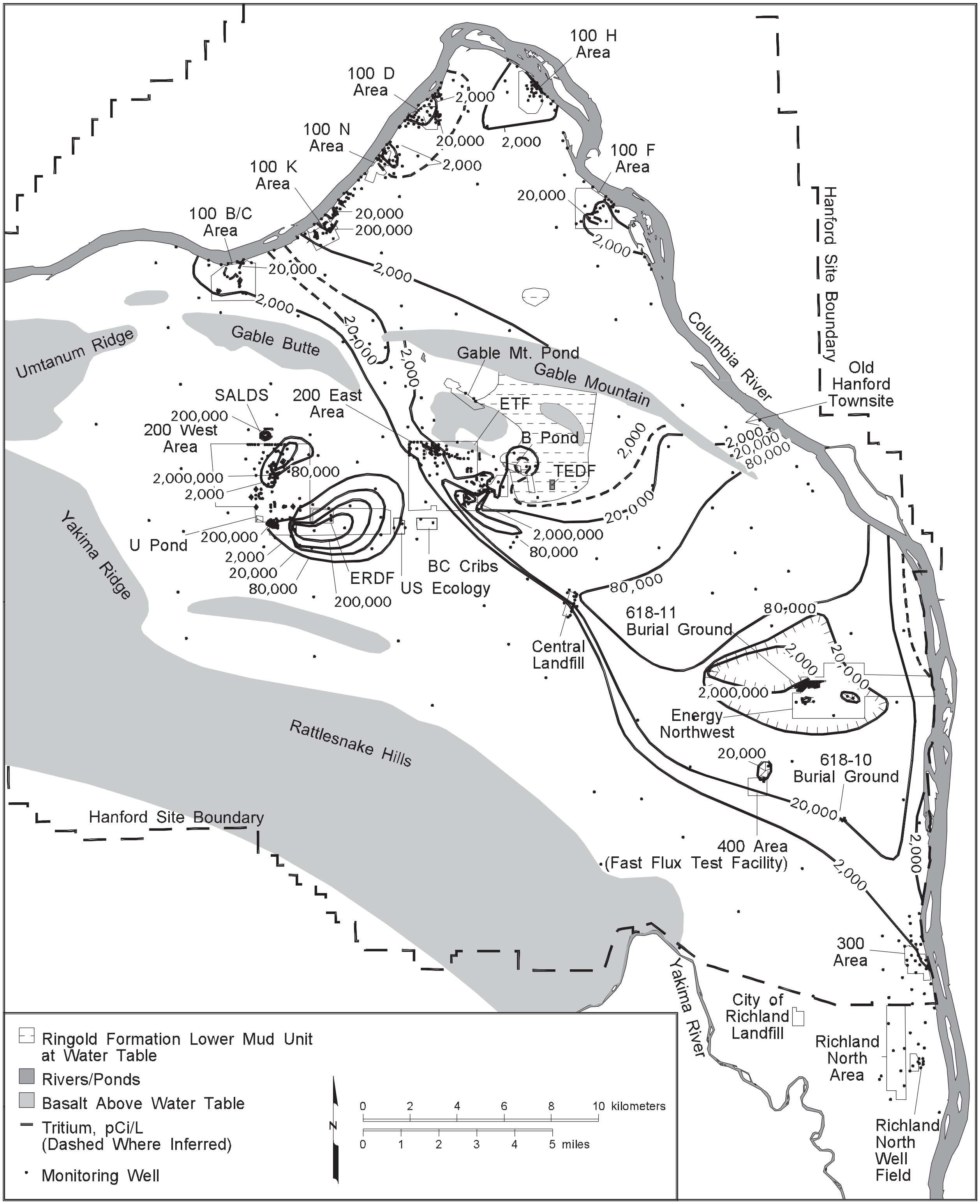

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Figure 2.1-3. Average Tritium Concentrations on the Hanford Site, Top of Unconfined Aquifer

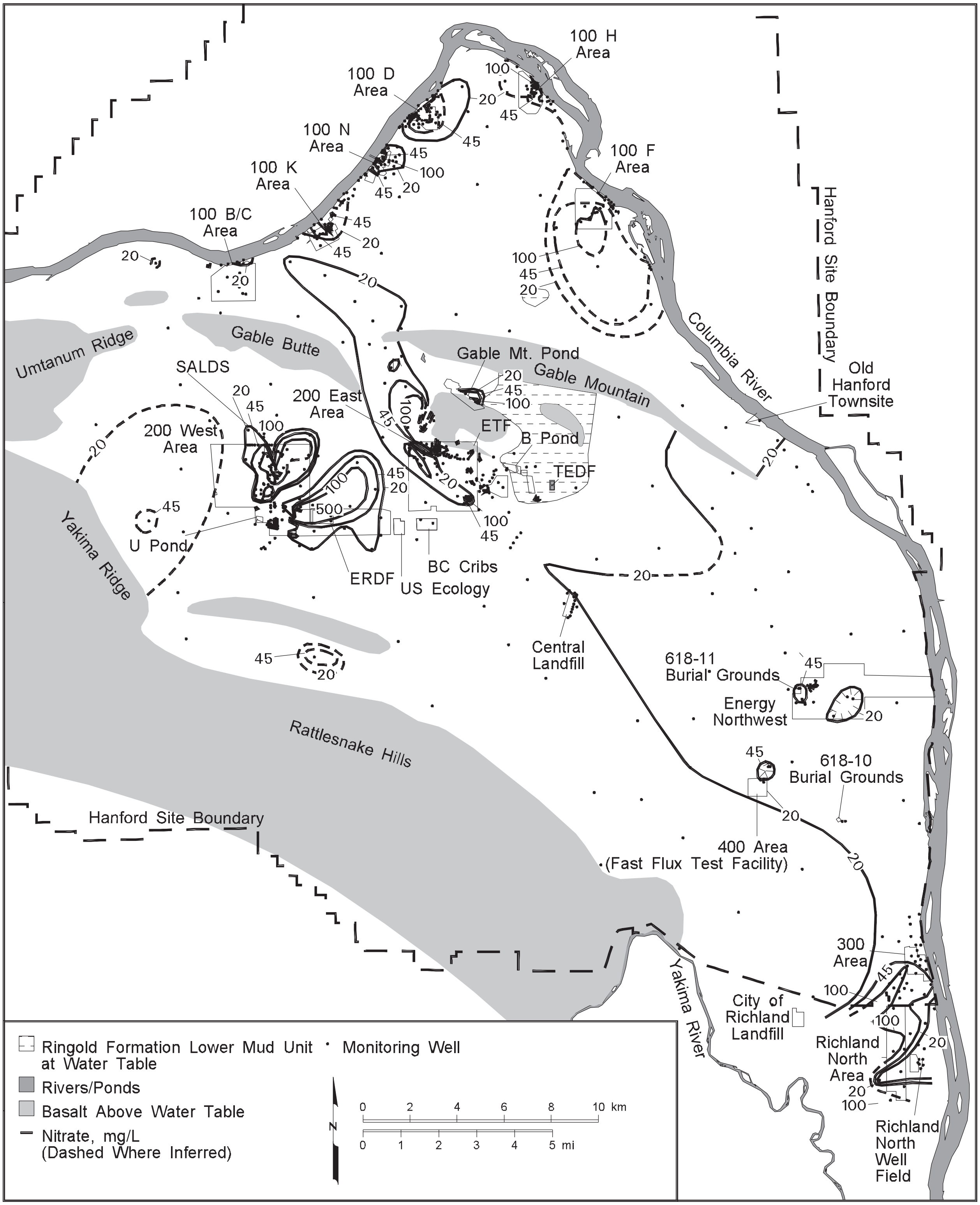

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Figure 2.1-4. Average Nitrate Concentrations on the Hanford Site, Top of Unconfined Aquifer

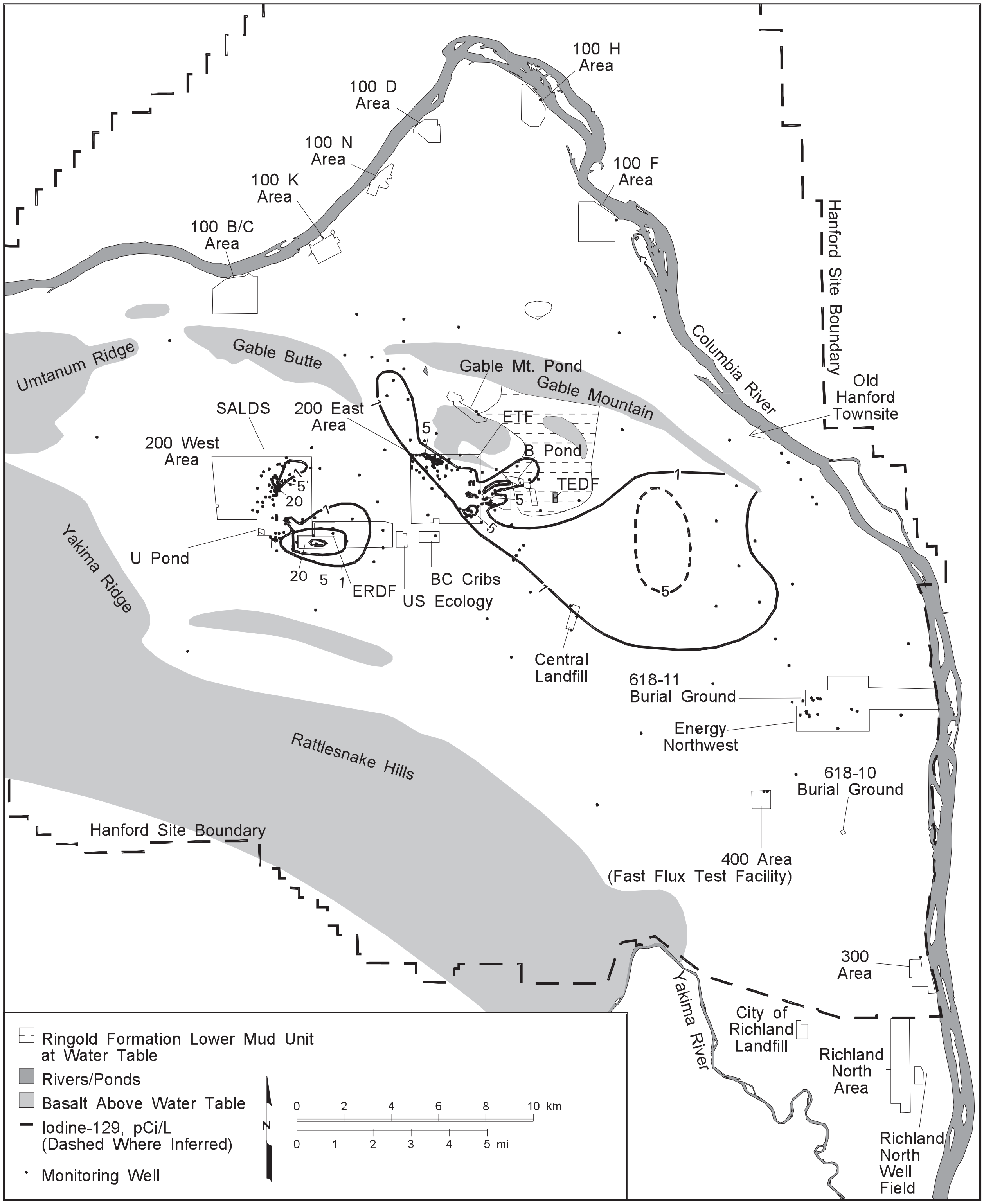

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Figure 2.1-5. Average Iodine-129 Concentrations on the Hanford Site, Top of Unconfined Aquifer

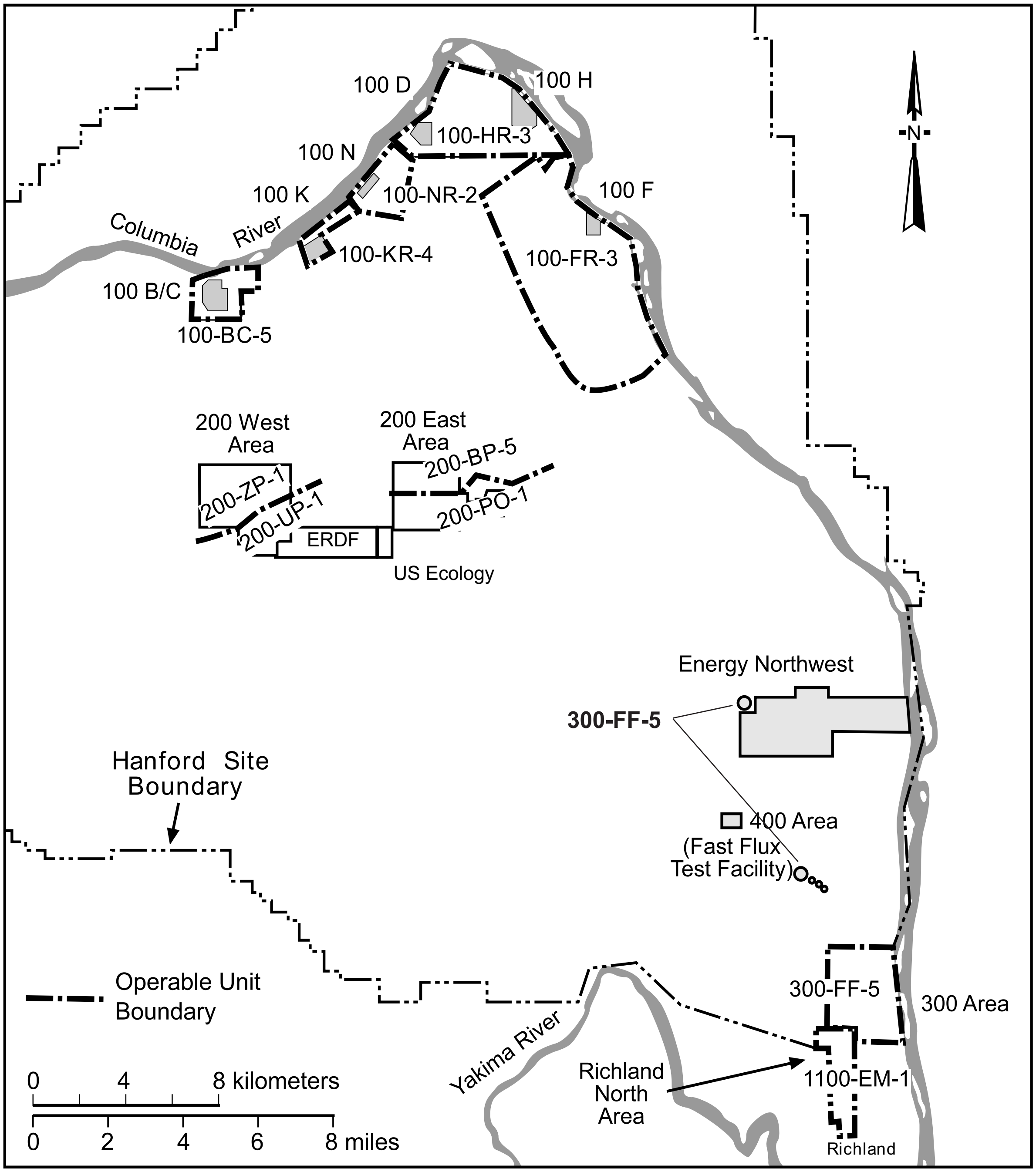

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Figure 2.1-6. Groundwater Operable Units on the Hanford Site

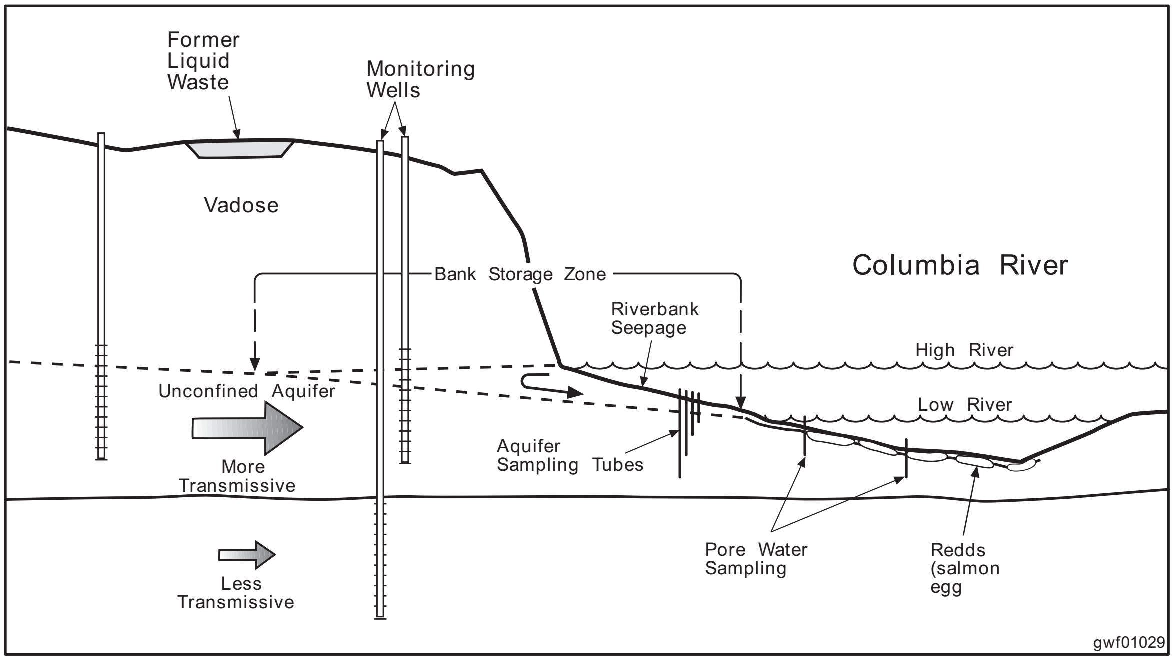

Figure 2.1-7. Principal Features of Groundwater/Columbia River Zone of Interaction

2.2 100 B/C Area

M. D. Sweeney

The 100 B/C Area is the reactor area farthest upstream along the Columbia River. B Reactor was placed in service in 1944 and operated until 1968. C Reactor operated from 1952 to 1969. The B and C Reactors used a single-pass system for cooling water (i.e., cooling water passed through the reactor and was eventually discharged to the Columbia River). Groundwater contaminants include strontium-90 and tritium. Chromium and nitrate are elevated locally. Fiscal year 2001 results indicate that contamination concentrations continue to decline throughout the 100 B/C Area.

Strontium-90 and tritium exceeded drinking water standards in groundwater at the 100 B/C Area in fiscal year 2001.

Figure 2.2-1 shows the location of monitoring wells in the 100 B/C Area. Some wells in the 600 Area also are monitored near the 100 B/C Area and are shown in Figure 2.2-2.

2.2.1 Groundwater Flow

Groundwater flow within the unconfined aquifer was north toward the Columbia River in March 2001 (see Plate 1). The hydraulic gradient in March 2001 was 0.001 near the Columbia River. The average gradient between C Reactor and the Columbia River was ~0.001 in March 2001. The hydraulic conductivity of the unconfined aquifer in the 100 B/C Area ranges from 4.3 to 17 meters per day (BHI-00917). Using these values and an effective porosity of 0.1 to 0.3, the flow rate ranges from 0.014 to 0.17 meter per day.

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Aerial view of the 100 B/C Area, November 2001. Results of fiscal year 2001 sampling indicates that contaminant concentrations continued to decline throughout the 100 B/C Area.

2.2.2 Tritium

Tritium exceeded the 20,000 pCi/L drinking water standard in three wells in the 100 B/C Area and one well east of the 100 B/C Area in fiscal year 2001. The distribution of tritium indicates that tritium had multiple sources within the 100 B/C Area (see Plate 2).

Monitoring Objectives in 100 B/C Area

Groundwater monitoring is conducted in the 100 B/C Area biannually to annually to describe the nature and extent of contamination.

Tritium concentrations continued to decline in most 100 B/C Area wells in fiscal year 2001 (Figure 2.2-3). Well 199-B5-2 dropped below the drinking water standard for the first time since 1995. The only well with a reported rise in concentration is well 699-72-73, located ~1,500 meters east of the 100 B/C boundary (Figure 2.2-4). Tritium concentrations in this well exceeded the drinking water standard for the first time in November 2000. The increasing concentration in well 699-72-73 is believed to come either from the 100 B/C Area or the 200 East Area via Gable Gap.

Well 199-B3-1, scheduled for annual sampling for tritium, was not sampled this year due to sediment buildup in the well. The well will be sampled again in fiscal year 2002 after well maintenance has been completed.

2.2.3 Nitrate

During fiscal year 2001, there were no wells with concentrations above the 45 mg/L drinking water standard. With the exception of wells 199-B3-47 and 699-72-73, the concentrations of nitrate reported in previous years have continuously declined to levels below the regulatory threshold. The two wells that exhibit an increasing trend in concentration are still below the drinking water standard. The likely source of nitrate contamination in the 100 B/C Area is the 200 East Area via Gable Gap.

2.2.4 Strontium-90

Strontium-90 contamination had sources near the B Reactor building and at retention basins and disposal trenches near the Columbia River. The plume has not changed significantly in recent years.

Three wells in the 100 B/C Area continued to exceed the 8 pCi/L drinking water standard for strontium-90. The contaminant sources are in two distinct regions in the 100 B/C Area, but the contamination has mingled to form a single plume. Two wells are located on the northern boundary near the Columbia River, and the last well is located northeast of the 116-B-5 crib (see Figure 2.2-1).

Strontium-90 concentrations have varied in all wells that have exceeded the drinking water standard. The strontium-90 concentration decrease in well 199-B5-2 may be an artifact of remediation activities conducted at the 116-B-5 crib.

2.2.5 Chromium

During fiscal year 2001, hexavalent chromium concentrations in the 100 B/C Area did not exceed the 100-μg/L maximum contamination level.

Hexavalent chromium was a minor contaminant in the 100 B/C Area groundwater in the past. However, concentrations have been declining in recent years. During fiscal years 2000 and 2001, all concentrations were below the maximum contaminant level.

2.2.6 Waste Site Remediation

In fiscal year 2001, waste site remediation in the 100 B/C Area consisted of surface excavation, partial soil remediation activities, and equipment removal

(Table 2.2-1). Excavation began at the 132-C-2 Outfall, the 132-B-6 Outfall, and the 116-B-7 Outfall. All of these facilities are near the river shoreline and were used to discharge reactor cooling water. Partial soil remediation was conducted at the 100-B-8 Pipelines and 100-C-6 Pipelines. The pipelines conveyed effluent from the cooling water retention basins to the outfall areas. At the 100-B-12, Filter Box Radiological Materials Area, the filter boxes were removed from the site without soil remediation.

2.2.7 Monitoring at River Shoreline

Groundwater near the Columbia River is sampled annually in the late fall via aquifer sampling tubes and riverbank seeps. The sampling tubes are polyethylene tubes that were installed in the aquifer at locations near the low water shoreline.

Seeps are natural areas of groundwater discharge above the water line. Six aquifer tubes and two seeps were sampled in the 100 B/C Area in fiscal year 2001 (Table 2.2-2). Samples from two aquifer tubes exceeded the drinking water standard for strontium-90 in fiscal year 2001, both reporting 15.8 pCi/L. The specific conductance of the samples was 349 and 417 µS/cm, indicating the groundwater was relatively undiluted with river water. Tube 05-M is located farther upstream (see Figure 2.2-1) from 100 B/C, and tube 06-M is located downgradient of waste sites in the northern 100 B/C Area that have strontium-90 contaminated groundwater. The concentration in that location indicates that the strontium-90 plume may be slightly larger than previously thought, based on data from monitoring wells alone. However, a seep near tube 05-M had no detectable strontium-90.

Strontium-90 and tritium concentrations continued to exceed drinking water standards in seep or aquifer tubes sampled at the 100 B/C Area in fiscal year 2001.

Tritium concentrations exceeded the drinking water standards (20,000 pCi/L) in one aquifer tube that is within the groundwater tritium plume (see Plate 2). The concentration was 31,300 pCi/L. Chromium concentrations did not exceed the maximum contaminant level for the reporting period (see Table 2.2-2). Nitrate concentrations exceeded the drinking water standard in all three seeps. The concentrations ranged from 45.2 to 66 mg/L.

The shoreline data may indicate that as concentrations of contaminants have declined in wells in and around the reactor areas, the seeps and aquifer tubes are recording the last vestiges of groundwater contamination. An alternative explanation of this phenomenon is that groundwater monitoring well placement is not optimized to capture the remaining contamination plumes.

Table 2.2-1. 100 B/C Area Waste Sites Remediated in Fiscal Year 2001

Waste Site Designation	Fiscal Year Excavated	Fiscal Year Backfilled	Maximum Depth of Excavation (m)
132-C-2 Outfall	2001	2002(a)	~8.5
132-B-6 Outfall	2001	2002(a)	~7
116-B-7 Outfall	2001	2002(a)	~8.8
100-B-8 Pipeline	2001-2004(a)	2004(a)	>6
100-C-6 Pipeline	2001-2004(a)	2004(a)	>6
100 B-12 Filter Box	2001	NA	Surface

(a) Projected.
NA = Not applicable.

Table 2.2-2. Shoreline Monitoring Data for the 100 B/C Area, Fiscal Year 2001

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Chromium (µg/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
01-D	Tube	11/17/00	268	5		3.8	1,120	
03-D	Tube	11/17/00	316	12		5.3	6,000	
04-M	Tube	11/20/00	374	14	-0.2	7.5	8,930	
05-M	Tube	11/20/00	349	39	15.8	49.5	9,030	
06-M	Tube	11/16/00	417(a)	48(a)	15.8	48.8	31,300	
07-D	Tube	11/16/00	394	19	-0.2	27.4	19,100	
SB-037-1	Seep	10/25/00	373	13	0.1	8.1	5,060	66.8
SB-037-1	Seep	05/04/01	350	9	0.0	4.9	6,120	
SB-037-1	Seep	10/22/01	355					
SB-038-3	Seep	10/17/00		10				
SB-038-3	Seep	10/25/00	340(a)	13	0 U(a)	5.3(a)	7,430(a)	45.2
SB-038-3	Seep	10/22/01	347			23.9		
SK-057-3	Seep	10/12/00	242(a)	7.5 U(a)		16.5(a)	2,050(a)	59(a)

Tube = Aquifer sampling tube near the low-river shoreline.
Seep = Natural riverbank seepage site.
U = Below detection limit.
(a) Average of multiple measurements.

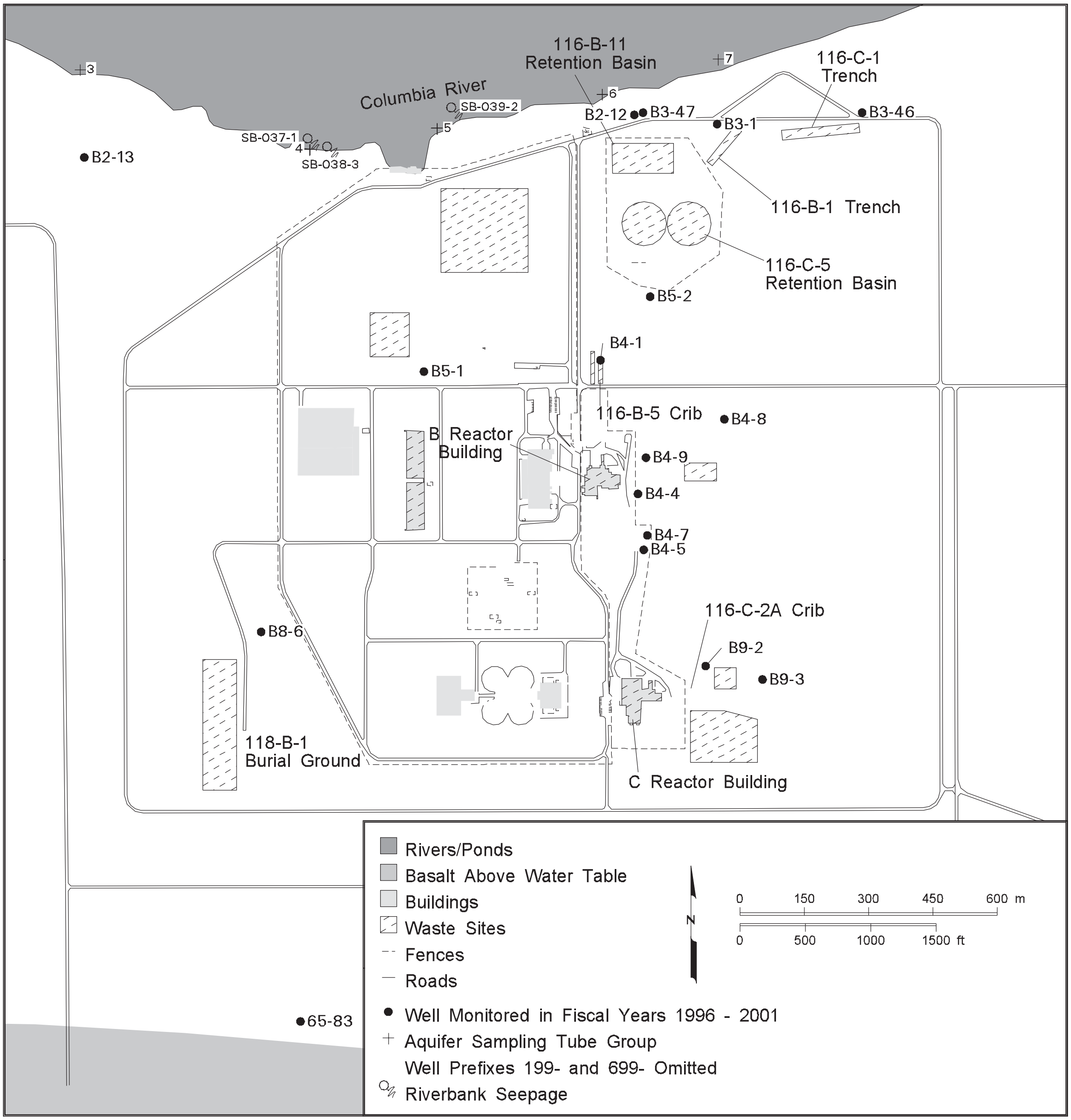

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Figure 2.2-1. Groundwater Monitoring Wells in the 100 B/C Area

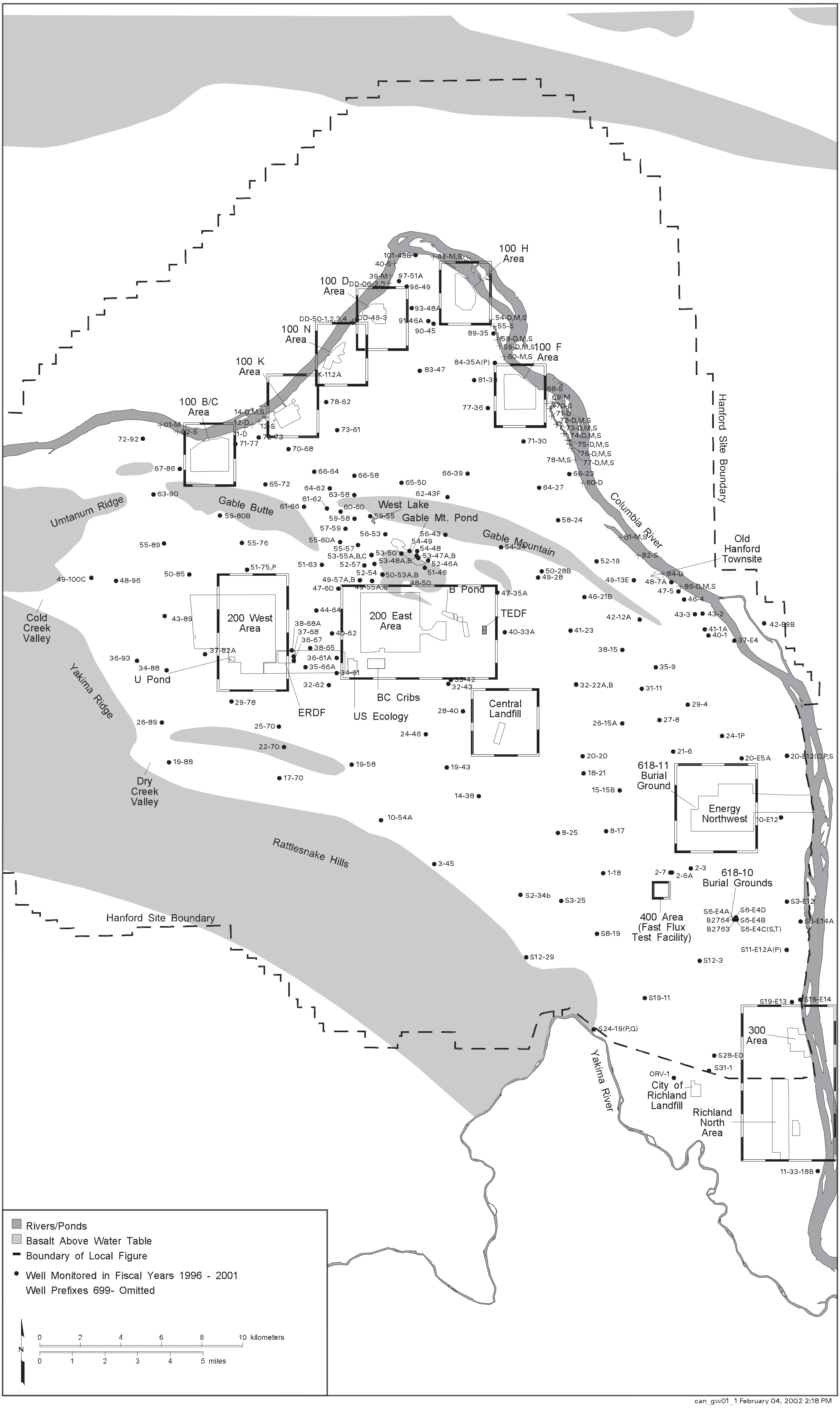


Figure 2.2-2. Groundwater Monitoring Wells in the 600 Area

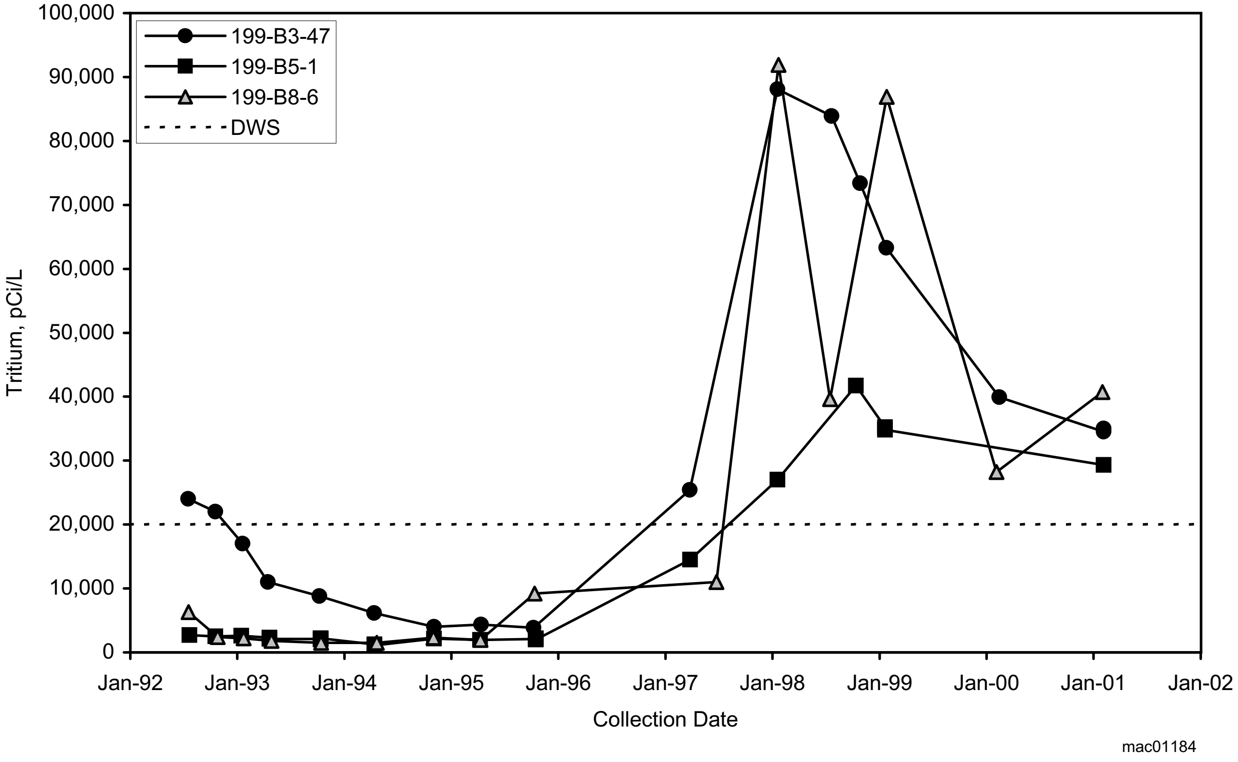


Figure 2.2-3. Tritium Concentrations Inside the 100 B/C Area Boundary

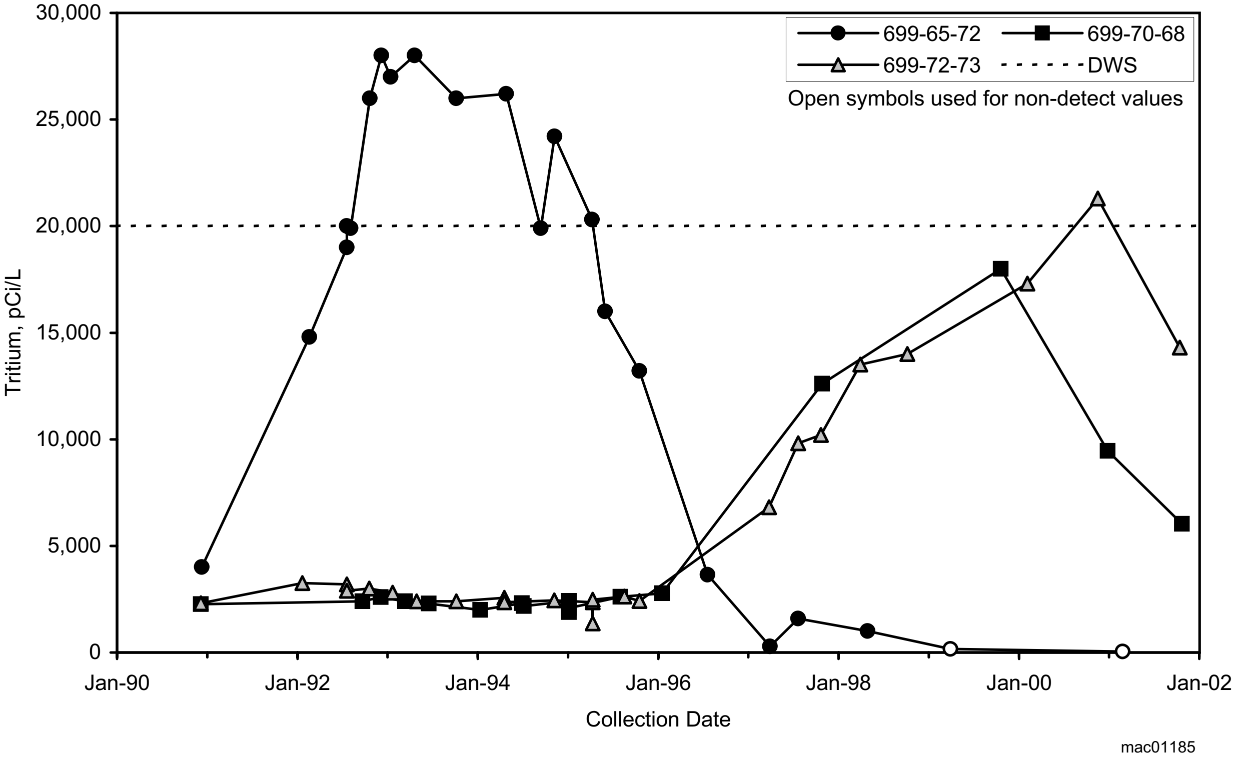


Figure 2.2-4. Tritium Concentrations for Selected Wells North of Gable Gap

2.3 100 K Area

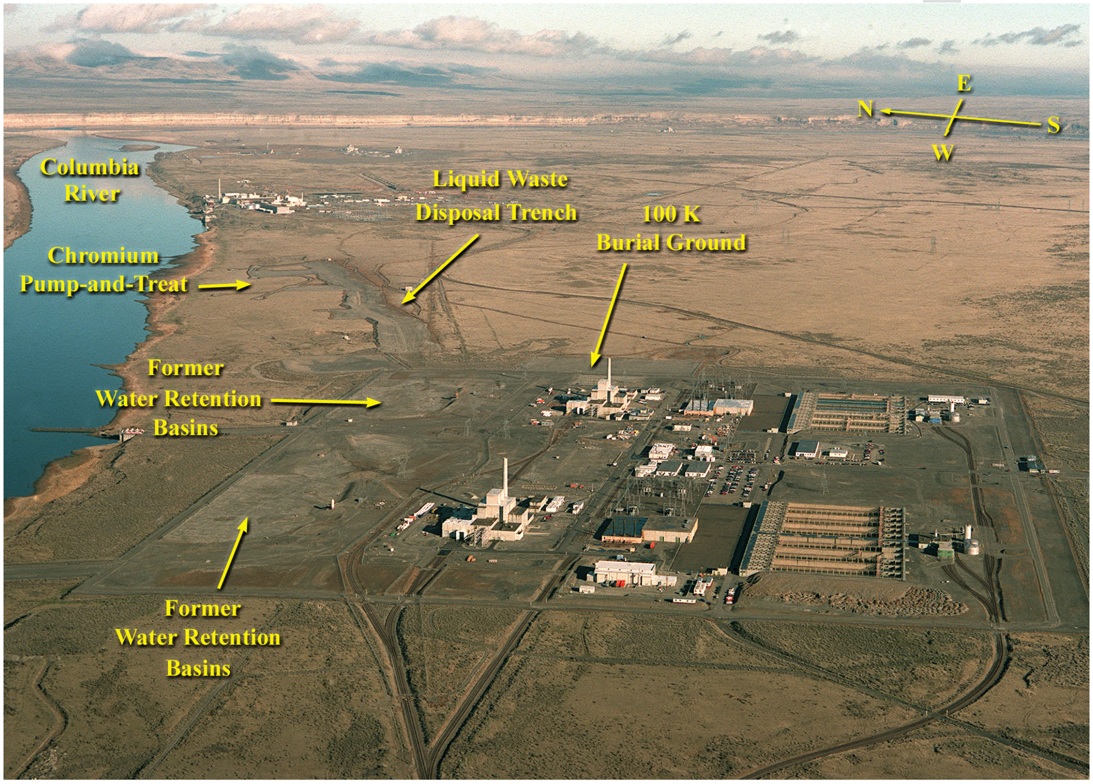
R. E. Peterson and W. J. McMahon

The KE and KW Reactors were the largest of the original group of eight production reactors. They operated between 1955 and 1971. A photo of the 100 K Area taken in November 2001 is shown below. Figure 2.3-1 is an index map that shows existing facilities, former waste disposal sites, monitoring wells, and rivershore monitoring sites. The fuel storage basins that are integral parts of each reactor building are still in use for temporary storage of irradiated fuel, though remediation activities have started that involve moving the fuel to a better storage facility located in the Central Plateau.

The principal groundwater contamination concerns in the 100 K Area today involve (a) chromium in groundwater near the Columbia River; (b) operating facilities that contain highly radioactive spent fuel, shielding water, and sludge; and (c) carbon-14, strontium-90, and tritium associated with past-practice liquid waste disposal sites. The most prominent of these latter sites is the 100-K trench (waste site 116-K-2), which received reactor coolant and decontamination solutions. This liquid waste disposal trench was the largest soil column disposal facility in the 100 Area. An interim remedial action using a pump-and-treat system is in progress to reduce the amount of chromium in groundwater between this trench and the Columbia River. An emerging issue involved an unexplained increase in tritium concentrations near the 100-K burial ground.

Principal groundwater issues in the 100 K Area include (1) a chromium plume that is currently undergoing remediation by a pump-and-treat system, (2) monitoring for potential loss of highly radioactive shielding water from fuel storage basins, and (3) unexplained increasing tritium concentrations in groundwater near the 100-K burial ground.

Several sources exist that could potentially contribute additional contamination to the currently mapped groundwater plumes or possibly create new plumes. These sources include locations where the vadose zone contains significant inventories of radionuclides from disposal of liquid waste during the reactor operating



Aerial view of the 100 K Area, November 2001.

years and from previous leakage of shielding water from the KE Fuel Storage Basin (KE Basin). A second source involves the potential new loss of shielding water from either the KE or KW Fuel Storage Basin (KE or KW Basin). Removing spent nuclear fuel, shielding water, and sludge from the fuel storage basins is a top priority for the Hanford Site and work is underway. Finally, waste sites not previously suspected of contributing to groundwater contamination may be present; an example is the 100-K burial ground (waste site 118-K-1).

Background information on the geology of the 100 K Area, regulatory issues, and monitoring methods are described in PNNL-13080. The operational history and waste sites at 100 K Area are described in the technical baseline report for the 100-KR-4 Operable Unit (WHC-SD-EN-TI-239).

2.3.1 Groundwater Flow

Monitoring Objectives in 100 K Area

Groundwater monitoring is conducted in the 100 K Area:

- annually to describe the nature and extent of contamination in support of environmental restoration issues
- quarterly near the KE and KW Fuel Storage Basins to detect potential leakage and to characterize the movement of past leakage
- various time intervals to evaluate the performance of the pump-and-treat system for chromium near the 100-K trench.

An overview of current groundwater movement beneath the 100 K Area can be inferred from a map of the water-table elevation for March 2001 (see Figure 2.3-1). Groundwater flow is generally toward the north-northwest, i.e., perpendicular to the contour lines shown on the map. The principal sources of uncertainty in describing the shape of the water-table elevation contours are the uneven distribution of monitoring wells and their relatively limited number.

Groundwater flow velocity and plume transport rates are estimated using several methods. Estimates involving the Darcy equation, which gives an average linear flow velocity in the aquifer pore space, are based on hydraulic conductivity, effective porosity, and the hydraulic head gradient. Typical values for 100 K Area aquifer properties and hydraulic gradients are hydraulic conductivity in the range 2 to 30 meters per day, an effective porosity of 20%, and average gradients between 0.003 and 0.006. The Darcy equation indicates velocities in the range 0.03 to 0.90 meters per day for these parameters.

Direct measurements of flow direction and velocity have been made in 100 K Area monitoring wells in the past. A new flowmeter was tested in several 100 K Area wells in 1993[a] and 1994 (WHC-SD-EN-DP-090). The test results indicated a direction of 325 degrees (azimuth clockwise from true north) and a flow velocity of 1.13 meters per day near the KE Reactor building (well 199-K-30). Near the KW Reactor building, results at two wells were 300 degrees and 0.24 meter per day (well 199-K-34) and 342 degrees and 0.63 meter per day (well 199-K-106A). Inland of the KW Reactor, at the southern end of the water treatment plant basins, a direction of 335 degrees and velocity of 0.15 meter per day were measured (well 199-K-35).

Estimates based on the arrival of plume fronts at wells downgradient of contaminant sources also have provided flow velocity estimates. Recent evidence for the area between the KE Reactor complex and the Columbia River suggests a rate of ~0.12 meter per day (PNNL-13404, p. 2.32). This estimate is based on the migration of a tritium plume associated with leakage from the KE Fuel Storage Basin in 1993. Figure 2.3-2 shows tritium concentrations in well 199-K-27, located adjacent to the KE Basin on the downgradient side, and well 199-K-32A, located along the downgradient flowpath from the KE Basin to the Columbia River. The assumption is made that the pulse in tritium concentrations in each well represents the release of shielding water from the KE Basin in early 1993. Its arrival at well

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[a] Letter report from D. B. Barnett (Pacific Northwest National Laboratory) to J. W. Roberts (Westinghouse Hanford Company, Richland, Washington) *Brief Summary of K-Area Flowmeter Applications*, dated May 4, 1993.

199-K-32A ~6 years later is used to infer travel time and flow velocity. Migration of a tritium pulse that appeared in groundwater near the KW condensate crib in 1995 and was subsequently detected at downgradient well 199-K-33 suggests a rate of ~0.89 meter per day (Figure 2.3-3).

Trend-surface analysis of direction and gradient has recently been performed to better define plume movement in the vicinity of the 100 K burial ground.[b] Analysis of water-table elevation data from wells 199-K-30, 199-K-32A, and 199-K-111A for the period 1994 to present indicates an average flow direction of 325 degrees and average gradient of 0.0043, which equates to a flow velocity of 0.22 meter per day (assuming a hydraulic conductivity of 10 meters per day and porosity of 20%). For hourly data collected in September 2001 from these same wells, the average direction is 318 degrees and average gradient is 0.0047, which equates to a flow velocity of 0.24 meter per day (same assumptions). Hourly data for a second triad of wells (199-K-18, 199-K-30, and 199-K-111A) also were analyzed, producing an average direction of 321 degrees and average gradient of 0.0049. These parameters (see Section 2.3.8.1) produce a flow velocity of 0.25 meter per day (same assumptions).

Groundwater flow beneath the K Reactors and disposal sites is toward the river. Travel time to the river is faster at KW Reactor than at KE Reactor. Water-table mounds that developed during operations, and more recently during remediation activities, have influenced flow directions locally.

Although the horizontal movement of groundwater predominates in the flow field, vertical movement also occurs in response to the fluctuating Columbia River stage and possibly the influence of deeper aquifers. The water table typically moves up and down through a range of ~2 meters in 100 K Area wells located within several hundred meters of the river, decreasing to a range of ~0.3 meter in wells located farthest inland (BHI-00917). The vertical movement of the water table may cause remobilization of contaminants held in the normally unsaturated vadose zone, as has been demonstrated previously at the 100 K Area (PNNL-12023) and also the 100 N Area (DOE/RL-98-38).

Monitoring wells in the 100 K Area do not provide extensive and uniform coverage, so the configuration of the water table cannot be described with a high degree of confidence for all portions of the area. The general direction of groundwater flow is fairly clear; however, the fine-scale details for direction and rate of flow between known contaminant sources and the Columbia River are less well defined. The presence of engineered backfill and heterogeneity in hydraulic properties of the aquifer contribute to uncertainty in describing pathways for contaminant transport. Near the Columbia River, the rate and direction of groundwater flow vary through wide ranges because of changing hydraulic gradients caused by the fluctuating river stage.

During the operating years 1955 to 1971, a large mound formed beneath the southwestern end of the 100-K trench (HW-77170). A radial flow pattern developed around the mound and modified the natural flow field beneath the entire 100 K Area. Radial flow distributed hexavalent chromium and tritium widely throughout the area. The implication of the mound with respect to current groundwater conditions is that residual contaminated moisture from the previously saturated mound areas is believed to slowly migrate downward to the water table, thus providing continual recharge to contaminant plumes in groundwater. A more recent mound buildup is occurring beneath the interim action injection wells, which are located south of the 100-K trench. Treated effluent has been injected into these wells since October 1997 (see Section 2.3.9). A recent analysis of the possible extent of the mound was completed in September 2001.[c] The analysis

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(b) Letter report from R. E. Peterson to F. S. Spane (Pacific Northwest National Laboratory, Richland, Washington) *Direction and Rate of Groundwater Movement*, dated September 21, 2001.

(c) Letter report from F. A. Spane to R. E. Peterson (Pacific Northwest National Laboratory, Richland, Washington) *Preliminary Evaluation of the Potential Extent of a Groundwater Mound Associated with the 100-KR-4 Injection Well System*, dated September 14, 2001.

results suggest that hydraulic head increases of ~0.4 meter are possible out to distances of ~500 meters from the injection site.

2.3.2 Chromium

Chromium was introduced to 100 K Area groundwater from multiple sources. Infiltration of reactor coolant that contained 700 μg/L hexavalent chromium created the most widespread contamination because of mounding beneath the southwestern end of the 100-K trench. Additional sources include leakage and/or spillage of sodium dichromate stock solutions near railcar transfer stations, storage tanks, and mixing facilities during the water treatment process. By early 1971, these sources no longer contributed new contamination, and the nearly 30 years of groundwater movement since then has allowed the original plumes to disperse. The hexavalent form of chromium is highly soluble in groundwater as the chromate anion (CrO_3^-) and moves at the same rate as groundwater because the anion is not adsorbed significantly by solid materials in the aquifer. However, residual amounts of chromium remain in vadose zone moisture beneath waste sites.

Groundwater beneath the 100 K Area is contaminated by chromium in three areas: a plume between the 100-K trench and the Columbia River, and two smaller areas of contamination near the reactor buildings.

The current distribution of chromium in 100 K Area groundwater is shown in Figure 2.3-4. Three areas of concern are apparent: (1) a relatively large area of contamination associated with the 100-K trench, (2) a smaller area centered on the KW Reactor, and (3) an area near the south end of the settling basins at the 183-KE water treatment plant. The level of contamination represented by these mapped areas has not changed appreciably in recent years.

The first area is the target plume for interim remedial action using a pump-and-treat system (DOE/RL-99-13). The extent to which this contamination was moved inland by mound buildup during the operating years is not clearly defined, though it appears to have moved at least to well 699-78-62, located 1,600 meters inland. Chromium concentrations in the target plume typically range from 75 to 200 μg/L, thus exceeding the 100 μg/L maximum contaminant level for drinking water supplies in some areas and the 10 μg/L standard set by Washington State for the protection of freshwater aquatic organisms (WAC 173-201A-040; the U.S. Environmental Protection Agency standard is 11 μg/L). The chromium concentrations in the six wells used to extract groundwater for treatment are shown in Figures 2.3-5 and 2.3-6. Concentrations in wells located between the extraction wells and the river are shown in Figure 2.3-7. The treated effluent from the system, which is nearly free of chromium, is returned to the aquifer at wells upgradient of the 100-K trench. Additional information on the operating characteristics and performance of the interim action pump-and-treatment system is presented in the section on groundwater remediation (see Section 2.3.9).

In the second area of concern, i.e., near the KW Reactor, concentrations in recent years have ranged between 200 and 600 μg/L (Figure 2.3-8). The specific source for the chromium in this plume is not known, though the source may be leakage and/or spillage of sodium dichromate stock solution in upgradient areas during the operating years. One potential site is the railcar transfer station and storage tanks located at the southeastern side of the settling basins at the 183-KW water treatment plant. Because of the time that has passed since operations ended, this plume may represent remobilization of residual vadose zone contamination by more recent infiltration of moisture from the surface. The changing trends in wells 199-K-107A and 199-K-34, which are located downgradient of the KW Reactor building, suggest plume movement in this area. The most recent decline in chromium concentrations in well 199-K-108A is believed to be the result of dilution caused by infiltration of clean water from the surface (see Section 2.3.7.4).

The western extent of this plume is uncertain because monitoring wells do not cover that area. The plume does not appear to have reached the Columbia River because similar concentrations are not detected in wells 199-K-31 and 199-K-33, which are located between KW Reactor and the Columbia River. Also, there is no evidence for elevated chromium in riverbank seepage or aquifer sampling tubes along this segment of 100 K shoreline. The travel time between KW Reactor and well 199-K-33 has been previously estimated at between 1.6 and 4.9 years, depending on the assumed groundwater flow rate (WHC-SD-EN-TI-280), though the migration of a tritium plume in this region suggests the shorter time period may be more accurate (see Figure 2.3-3). Increasing concentrations first appeared at KW Reactor in mid-1994, so sufficient time apparently has passed for the plume to move downgradient to well 199-K-33, assuming the well is within the flow path. Because a distinct increase in concentrations in the well is not yet apparent, it appears that the well is either not within the flow path of the chromium plume or the travel time is much longer than expected.

The third area of chromium contamination appears to have originated at the southeastern end of the settling basins at the 183-KE water treatment plant. The source for the chromium is most likely past leaks or spills of sodium dichromate stock solution during railcar transfer operations or from storage tanks located in the area (WHC-SD-EN-TI-239, p. 6-3). Subsequent remobilization of residual sodium dichromate held in the vadose zone may have occurred as the result of water leakage from the nearby settling basins. The maximum chromium concentration detected in groundwater at well 199-K-36 is 2,710 μg/L in January 1996. The most recent concentrations are in the range of 550 to 1,300 μg/L and are generally increasing. An anomalously low concentration was observed for a sample collected in July 2001 (485 μg/L). This may represent dilution of groundwater in the area by clean water from the nearby #5 settling basin, which is known to have lost a significant volume of water during the late summer.

2.3.3 Strontium-90

Strontium-90 is not distributed widely in 100 K Area groundwater, though there are several waste sites where the vadose zone may be contaminated, thereby creating a potential source for future groundwater contamination. Strontium-90 contamination is anticipated wherever liquid effluents associated with irradiated nuclear fuel were disposed. The principal sites for soil column disposal were the 100-K trench and the fuel storage basin drain fields/injection wells associated with each reactor (waste sites 116-KE-3 and 116-KW-2). The radionuclide is partially adsorbed onto sediment particles in the vadose zone and aquifer. It is considered a moderately mobile radionuclide in groundwater and has a radioactive decay half-life of 28.8 years. The drinking water standard is 8 pCi/L and the U.S. Department of Energy (DOE) derived concentration guideline is 1,000 pCi/L.

Strontium-90 in groundwater near the KE Reactor originated from past disposal of effluent from a fuel storage basin to a nearby drain field. Concentrations vary as a consequence of water movement downward through the contaminated vadose zone.

Current levels of strontium-90 contamination in groundwater between the 100-K trench and the Columbia River range up to a maximum near 40 pCi/L (Figure 2.3-9). The radionuclide is a co-contaminant with chromium in this plume, which is undergoing interim remedial action. However, strontium-90 is not removed by the ion exchange resin that removes chromium from extracted groundwater and is, therefore, returned to the aquifer via the injection wells. Strontium-90 in the treated effluent was measured at 4.31 and 4.09 pCi/L on May 8, 2001, and the concentration trend has been constant since startup of the pump-and-treat system in October 1997.

Near the KE Reactor, groundwater samples from well 199-K-109A reveal a variable trend in strontium-90 concentrations with the highest values well above the DOE derived concentration guideline. The highest value observed at this well was 18,600 pCi/L in 1997 and summer 2001 concentrations are ~2,400 pCi/L.

Figure 2.3-10 shows the historical trends, along with data for tritium concentrations. The source for the strontium-90 detected in this well has been previously identified as past-practice disposal to the nearby drain field/injection well (PNNL-12023). This facility (waste site 116-KE-3) received effluent from the KE Basin that may have contained strontium-90 released from damaged fuel elements, as well as tritium. Increased infiltration of water from leaking fire hydrant lines, or possibly an elevated water table during 1997, remobilized contamination held in the normally unsaturated vadose zone (PNNL-12023). For wells most likely to detect current leakage from the KE Basin (i.e., wells 199-K-27, 199-K-28, and 199-K-29), strontium-90 remains undetected. The strontium-90 concentration in KE Basin shielding water is ~1 million pCi/L.

Strontium-90 also is elevated somewhat above the drinking water standard near the KW Reactor, with concentrations ~40 pCi/L in several wells. As for the KE Basin, the suspected source is the adjacent drain field/injection well (waste site 116-KW-2). Concentrations in groundwater at well 199-K-34 show a slightly increasing trend since 1998 to a current level of 42 pCi/L. Strontium-90 concentrations in KW Basin shielding water are ~20,000 pCi/L. Concentration trends are illustrated using gross beta results (Figure 2.3-11) because they are obtained more frequently at these wells. Gross beta activity at this location is caused primarily by strontium-90 from past-practice disposal of fuel storage basin effluent. The concentration of strontium-90 is approximately one-half that of the gross beta concentration.

2.3.4 Tritium

Tritium (hydrogen-3) is a common and widespread radiological contaminant in Hanford Site groundwater, with a radioactive decay half-life of 12.3 years. The distribution of tritium in 100 K Area groundwater is shown in Figure 2.3-12, with the plume shapes reflecting downgradient dispersion from known sources. The principal known locations where tritium was (and still may be) introduced to groundwater include the KE and KW Reactor complexes and the 100-K trench. Two principal past-practices sites are located near the northeastern side of each reactor building, where condensate from reactor atmosphere gas apparently continues to migrate downward through the soil column beneath the KW and KE condensate cribs (waste sites 116-KW-1 and 116-KE-1, respectively). Carbon-14 is a co-contaminant with tritium in the effluent disposed to these cribs.

The tritium distribution in groundwater during fiscal year 2001 illustrates that principal sources include several sites near the reactor complexes, along with the 100-K trench and possibly the 100-K burial ground.

A second source for currently observed plumes is past leakage from the KE Basin (see Section 2.3.8), with the most recent leakage having occurred in early 1993. The plume created by the 1993 leakage moved north-northwest past well 199-K-27 and is believed to have arrived at downgradient well 199-K-32A (see Figure 2.3-2). KE Basin shielding water lost in 1993 also contained technetium-99, which is used to help distinguish this tritium plume from those associated with other sources, such as the condensate cribs.

A rapid rise in tritium concentrations in groundwater at well 199-K-111A, located at the northwest corner of the 100-K burial ground, started in late summer 2000 (Figure 2.3-13). Investigations were immediately undertaken to determine the source for the tritium, because radiological contamination had not been previously observed at this well. Co-contaminants that might help identify the source (e.g., technetium-99 indicates KE Basin shielding water and carbon-14 indicates the KE condensate crib) were not detected at the well. An analysis of groundwater flow direction from known tritium sources suggests that plumes from the KE Basin and KE condensate crib sources are unlikely to pass by well 199-K-111A. Soil gas samples were collected from existing sampling sites near well 199-K-111A

(PNNL-13217) and helium-3, an indicator of nearby tritium, continues to be somewhat elevated in the area, although the cause for this cannot be stated conclusively.

Most evidence to date suggests that the tritium observed in groundwater at well 199-K-111A is from a previously unidentified plume located to the east or southeast of the well. There is circumstantial evidence to indicate that disposal of tritium-producing irradiated metallic waste occurred in silos at the 100-K burial ground (WHC-SD-EN-TI-239). The possibility exists that tritium is being produced by processes analogous to the 618-11 burial ground (PNNL-13675). If a tritium plume is present in groundwater beneath the 100-K burial ground, some way of displacing it laterally to the west to well 199-K-111A is needed. Radial flow associated with the mound buildup beneath the 100-KR-4 treated effluent injection site to the east is one potential mechanism. However, a model for the extent of that mound has thus far produced inconclusive results as to whether buildup to date would be sufficient to influence plume movement at the distance of the burial ground.

In previous annual reports, the cause for the relatively high tritium concentrations detected in the vicinity of monitoring well 199-K-18 and extraction well 199-K-120A (see Figure 2.3-12) was described as being not fully understood. Possible explanations included (a) vadose zone moisture containing tritium from past disposal to the 100-K trench continuing to feed a small groundwater plume in the vicinity of these wells, and (b) shielding water from the KE Basin lost during the period 1976 to 1979 or groundwater from beneath the KE condensate crib. The recent new data from well 199-K-111A, along with new information from the various investigations to identify a source, add a third possibility, i.e., that a tritium plume extending from the 100-K burial ground has reached the two wells.

The relatively low tritium concentrations detected in wells beneath the 100-K trench may represent continued slow downward migration of residual amounts of contaminated moisture from the vadose zone to the current water table. Past disposal to this trench, which ended in 1971, created a mounded water table, causing widespread dispersal of effluent contaminated with tritium and chromium. A minor amount of tritium is being re-introduced to the aquifer upgradient of this trench via injection of treated effluent from the pump-and-treat system. Tritium concentrations in this effluent were measured at 6,740 and 6,630 pCi/L on May 8, 2001. The concentration trend for the effluent has been decreasing since the pump-and-treat system started in October 1997.

2.3.5 Carbon-14

Carbon-14 is present in groundwater at two condensate disposal sites near the KW and KE Reactors. These areas represent the only significant detections of this radionuclide in Hanford Site groundwater.

This radionuclide was present along with tritium in the condensate from reactor atmosphere gas that was disposed to the cribs located on the northeastern side of the KE and KW Reactors (waste sites 116-KE-1 and 116-KW-1). The drinking water standard for carbon-14 is 2,000 pCi/L and the DOE derived concentration guide for this radionuclide is 70,000 pCi/L. The half-life is relatively long (5,730 years), suggesting that the existing plumes will eventually be exposed at the Columbia River before they decay. The radionuclide may disperse more slowly than tritium because of interaction with carbonate minerals, so the distribution patterns for the two contaminants are not necessarily identical (see distribution map in Figure 2.3-12). The different geochemical characteristics for carbon-14 and tritium mean that the ratio of the two constituents cannot be used as an exclusive indicator of effluent from the condensate cribs.

The highest concentrations of carbon-14 in groundwater are found in wells near and downgradient of the condensate cribs. Figure 2.3-14 shows the concentration trends in wells near the KE condensate crib (waste site 116-KE-1) and

Figure 2.3-15 shows concentrations near the KW condensate crib (waste site 116-KW-1). The presence of carbon-14 in groundwater at well 199-K-108A remains unexplained in the absence of tritium at that location, which if present, would point to the KW condensate crib as the source.

2.3.6 Nitrate

Nitrate is widely distributed in groundwater beneath all the reactor areas. There are multiple sources that potentially contribute to the plumes, including septic system drain fields and past-practice disposal to the soil column of decontamination solutions, such as nitric acid (WHC-SD-EN-TI-239). The maximum contaminant level for drinking water supplies is 45 mg/L and this level is exceeded in numerous 100 K Area wells.

Nitrate concentrations in groundwater exceed the drinking water standard at numerous 100 K Area wells. Concentration trends are increasing or decreasing, depending on location.

The fiscal year 2001 values for nitrate in groundwater near the KE Reactor building are shown in Figure 2.3-16. The highest value is ~118 mg/L at well 199-K-30, where the trend has been gradually increasing since 1997. At well 199-K-23, located on the west side of KE Reactor, concentrations have gradually increased to ~70 mg/L during the past 8 years. To the north of the KE Reactor, concentrations have gradually increased to ~66 mg/L at well 199-K-111A, but the trend is not coincident with the recent, rapidly increasing trend for tritium at that well. Near the KW Reactor, nitrate concentrations appear to be gradually decreasing with time (Figure 2.3-17). The highest value is ~67 mg/L at well 199-K-106A, followed by ~50 at well 199-K-33. Near the southwest end of the 100-K trench, concentrations also appear to be gradually decreasing, with a concentration of ~70 mg/L at well 199-K-18 and ~25 mg/L at 199-K-19.

In addition to local 100 K Area sources for nitrate, the distribution is also being affected by the arrival of nitrate plumes from distant sources. Groundwater from the 200 East Area has traveled toward the northwest through Gable Gap and is now passing just to the west of 100 K Area, as indicated by the nitrate plume shown on the sitewide groundwater map (see Figure 2.1-4). Increasing nitrate trends in wells south and west of 100 K Area record the arrival of this plume. Technetium-99 is a co-contaminant with nitrate in this plume.

2.3.7 Other Constituents of Interest

The groundwater constituents described in Sections 2.3.2 through 2.3.6 have been previously identified as contaminants of concern with regard to environmental restoration. Three additional constituents of interest that are detected in several wells in the 100 K Area are discussed in this section, along with a description of two areas where increased infiltration of surface water is suspected.

2.3.7.1 Plutonium

During late May and early April 1999, scientists from Woods Hole Oceanographic Institute completed sampling at wells 199-K-27, 199-K-32A, 199-K-36, and 199-K-110A as part of a plutonium speciation study. The purpose of the research was to study the association of actinides with dissolved organic complexes in subsurface waters. The project was funded by the DOE's Environmental Management Science Program and was a joint effort involving Woods Hole and Pacific Northwest National Laboratory.

The status of the research was presented in late November 2000 during an Environmental Management Science Program workshop at the Hanford Site. The amount of plutonium detected in groundwater at 100 K Area was extremely small and was reported as number of atoms per liter, which ranges from 100,000 to

10 million. The latter value is equivalent to 0.000246 pCi/L, which are the units normally used for environmental monitoring results. Initial results showed that it was possible to differentiate the various sources for plutonium atoms detected in 100 K Area groundwater (e.g., global fallout, KW and KE Reactor fuel, and N Reactor fuel). Analysis of additional samples collected in 1999 is continuing; new samples from 100 N Area groundwater were collected in spring 2001 (see Section 2.4.10).

Analysis for plutonium is not routinely performed as part of groundwater monitoring at 100 K Area. The tools and methods used by the researchers to achieve the ultra-low detection levels are not practical for the current monitoring program. Other contamination indicators (e.g., gross alpha) are monitored routinely that would indicate the loss of basin shielding water, which contains plutonium, to the environment.

2.3.7.2 Trichloroethene

This organic constituent is a minor contaminant of concern resulting from the past disposal/spillage of organic solvents. Groundwater samples from two wells downgradient of the KW Reactor contained trichloroethene at levels above the 5 µg/L maximum contaminant level for drinking water supplies. At well 199-K-106A, the concentration was 19 µg/L in summer 2001 and at well 199-K-33, the concentration was 11 µg/L. Concentrations at those wells remain essentially constant with time.

2.3.7.3 Nickel

Nickel has not been tracked previously as a contaminant of concern for human or ecological health reasons (BHI-00917). However, concentrations in filtered groundwater samples exceeded the 100 µg/L maximum contaminant level in well 199-K-109A (135 µg/L for a filtered sample in fiscal year 2001). In previous years, the 100 µg/L standard also was exceeded in wells 199-K-36 and 199-K-110A (Figure 2.3-18). There is no obvious waste site source for nickel contamination and its occurrence is scattered. Nickel appears to be elevated only in relatively new monitoring wells that have stainless steel casings and screens. Therefore, a sampling anomaly is suspected, perhaps the result of corrosion of the stainless steel (Hewitt 1994). Chloride concentrations also are typically elevated in the wells that show elevated nickel, which supports the suggestion of corrosion.

2.3.7.4 Evidence for Infiltration of Surface Water

The influence of infiltration, because of natural precipitation or leaking underground water lines, has been described previously at several sites at 100 K Area (e.g., PNNL-12023). Continued downward movement of tritium and carbon-14 beneath the KE and KW condensate cribs and remobilization of strontium-90 near the drain field at the KE (and possibly KW) Basin are two examples where above-normal infiltration of water from the surface or near surface is believed to have played an important role in moving contamination.

Two additional sites appear to be influenced by the infiltration of clean water through the vadose zone or possibly by the arrival of groundwater diluted by clean water from an unidentified source. The most clear indication is groundwater at well 199-K-108A near the southeastern corner of the KW Reactor. Rapidly decreasing trends for chloride and nitrate at this well started in late summer 1999 (Figure 2.3-19) and continue as of fall 2001. Because contamination indicators also are decreasing, the overlying vadose zone is believed to be free of contaminants, assuming that infiltration of clean water from above is the cause. However, no potential source for clean water has yet been identified.

Infiltration of water from surface sources, such as precipitation or leaking utility lines, may influence contaminant concentrations in the underlying groundwater. Infiltration is suspected near the KE and KW Reactors during fiscal year 2001.

Groundwater near the northwestern side of KE Reactor also may be influenced by infiltration. At well 199-K-28, a decreasing trend similar to that observed at well 199-K-108A started in late summer 1999. Again, decreasing chloride and nitrate trends provide the clearest evidence for infiltration of clean water; contamination indicators also are lower. At well 199-K-28, this trend reversed itself starting in late summer of 2000. (Note: Well 199-K-28 was decommissioned on October 18, 2001, to make way for construction of the new fuel transfer annex facility at the KE Basin.)

2.3.8 100-K Fuel Storage Basins Monitoring

The Hanford Groundwater Monitoring Project provides services to the Spent Nuclear Fuel Project to (a) help detect the loss of basin shielding water and (b) characterize the impact of lost shielding water on groundwater conditions. A description of the monitoring strategy and data quality objectives for the 100-K fuel storage basins is presented in a groundwater monitoring plan (WHC-SD-EN-AP-174).

Irradiated nuclear fuel from the N Reactor is stored in water-filled basins in the 100 K Area. The shielding water has become highly contaminated and constitutes a potential source for groundwater contamination if a basin leaks. Removal of nuclear fuel from the basins began in December 2000.

The 100-K fuel storage basins are operating facilities that currently store irradiated fuel elements from the N Reactor. The KE Basin contains fuel stored in unsealed canisters, while KW Basin contains fuel stored in sealed containers (HNF-SD-SNF-TI-009). Because of the unsealed containers and greater proportion of damaged fuel elements, the KE Basin is the more contaminated facility. A shielding water re-circulation system includes exchange resins that remove some of the radionuclides, but concentrations of many fuel degradation products remain very high. The concentrations of tritium, strontium-90, and cesium-137 in the KE and KW Basins are shown in Figures 2.3-20 and 2.3-21, respectively.

Removal of fuel from the basins is a high priority Hanford Site cleanup project (ROD 1999a). Actual removal of fuel began in December 2000 at the KW Basin and continued during fiscal year 2001. The removed fuel is dried and repackaged at the Cold Vacuum Drying facility located in the 100 K Area. It is then transported to the Canister Storage Building, which is an interim storage facility located in the 200 Area. Removal of fuel from the basins is scheduled for completion by 2004, followed by removal of sludge and shielding water, and finally demolition of the concrete structure, which should all be completed by 2007 under Tri-Party Agreement Major Milestone M-34-00A (Ecology et al. 1998). Background information on the Spent Nuclear Fuels Project can be found in a feasibility study report that provides detailed information on the fuel, shielding water, and sludge, along with a description of alternatives for cleanup (DOE/RL-98-66).

2.3.8.1 Groundwater Flow Near the Basins

The general movement of groundwater beneath the KE and KW Basins is from the south-southeast to the north-northwest, i.e., toward the Columbia River (see Plate 1). Travel time from the basins to the Columbia River is estimated to be in the range of 5 to 12 years (see Section 2.3.1 for a more complete discussion). Several factors may influence the characteristics of groundwater movement beneath the basins, including currently operating facilities that may lose clean water (e.g., fuel storage basin emergency makeup water stored in clearwells) and heterogeneity in the hydraulic properties of the aquifer. The distribution and rate of downward movement of water infiltrating from the surface may be influenced by backfill associated with building foundations and underground pipelines. Infiltration of water is a concern because of the potential to remobilize contamination from former operations that remains in the vadose zone in some areas.

Travel time for groundwater between the KE Basin and the Columbia River is estimated to be ~12 years, while at the KW Basin, it is somewhat faster.

In an effort to determine the origin of tritium detected in groundwater at well 199-K-111A, located ~260 meters to the north of the KE Basin, an evaluation of flow direction from each of the known tritium sources was undertaken in June 2001. Flow direction corridors were estimated from water-table contours and conceptual representations of tritium distribution from each source were developed, following earlier similar work for the KE Basin (WHC-SD-EN-AP-174). The results are summarized in Figure 2.3-22. The dashed gray lines represent the central path traced by plume movement downgradient from each source. The red outlined areas are where plumes from various sources are expected to be found currently.

Area A in Figure 2.3-22 represents the plume created by the 1993 leakage from KE Basin, which has now migrated downgradient as far as well 199-K-32A. The travel time for this plume from the basin to the well is ~6 years. Technetium-99, a co-contaminant with tritium in shielding water, is detected at well 199-K-32A. Area B represents tritium recently remobilized from the vadose zone associated with the former storage basin drain field/injection well (waste site 116-KE-3). Strontium-90 is a co-contaminant in this plume, which is inferred from groundwater conditions observed at well 199-K-109A. Area C is the presumed distribution of tritium from the KE condensate crib, which operated from 1955 to 1971 and is assumed to still contribute contamination to groundwater via slow downward migration of moisture through the vadose zone. Carbon-14 is a co-contaminant in this plume.

Two additional flow paths from potential, but as yet undocumented, tritium sources are also shown in Figure 2.3-22. One extends from the central portion of the 100-K burial ground, where past disposal of irradiated fuel components may create tritium-producing conditions similar to those observed at the 618-11 burial ground (PNNL-13228, pp. 4.8 to 4.9). The second extends from the southwestern end of the 100-K trench and is presumed to represent residual contamination from past disposal to the trench, which ended in 1971.

2.3.8.2 Tritium as an Indicator of Shielding Water Loss

Tritium is a key constituent for monitoring potential leakage from the KE and KW Basins, because the concentrations in each basin are relatively high and the constituent acts as a good tracer for groundwater movement. Tritium concentrations decrease with distance from the source because of radioactive decay and dispersion, but not by adsorption onto solids as occurs with strontium-90 and cesium-137.

Because of high tritium concentrations in basin shielding water, tritium in groundwater is used as a key indicator of water loss from the basins. Monitoring results for fiscal year 2001 do not suggest leakage from either KE or KW Basins.

Figure 2.3-23 shows the tritium concentrations in wells near the KE Basin. The record for these wells, which were constructed in 1980, suggests that the plume from major leakage during the period 1976 through 1979 must have already passed these wells by the time of their installation because there is no indication of a plume. The volume of water lost during that period is estimated at ~57 million liters (WHC-SD-SNF-TI-013), and the tritium concentration in KE Basin water was ~600,000 pCi/L. A subsequent period of documented leakage in 1993 is clearly revealed by the tritium pulse that passed well 199-K-27. That leakage is estimated at ~341,000 liters (WHC-SD-SNF-TI-013), and the basin water concentration at the time was ~3 million pCi/L. (Note: The cause for the 1990 tritium pulse in well 199-K-27 is not known.)

Tritium concentrations in groundwater near the KW Basin are generally lower than near the KE Basin (Figure 2.3-24). There has been no readily identifiable leakage from the KW Basin. The tritium observed in well 199-K-34 is most likely attributable to the KW condensate crib.

Concentration trends for tritium in groundwater near the KE and KW condensate cribs are included here to illustrate the other major sources for tritium in groundwater near the reactors. Figure 2.3-25 shows the tritium concentrations and specific conductance values for groundwater immediately downgradient of the KE condensate crib. The concentrations at that location are believed to represent the downward migration of tritium (and carbon-14) in vadose zone moisture. The strong positive correlation between tritium concentrations and specific conductance values suggests that downward migration is promoted by increased infiltration of water from the surface. The increase in specific conductance in groundwater at the KE condensate crib has been attributed to infiltration of precipitation (e.g., snow melt) containing ice control salt (WHC-SD-EN-TI-280).

Figure 2.3-26 shows the same constituents for the KW condensate crib. A similar correlation between tritium and specific conductance is absent at this location. There is currently no clear explanation for the tritium peak (~600,000 pCi/L) that occurred during 1995. Leakage from the KW Basin is not considered a possible source because basin water concentrations were only one-tenth the concentrations observed in the well shown in Figure 2.3-26. Specific conductance at the KW crib is significantly higher than natural background (~650 versus ~350 μS/cm for background).

2.3.9 Groundwater Remediation

A groundwater pump-and-treat system began operating in the 100 K Area in October 1997 as an interim remedial action. The primary purpose of this system is to prevent or reduce the movement of hexavalent chromium from the aquifer to the river, thereby protecting aquatic organisms. The extraction wells are located within a chromium plume located between the 100-K trench and the Columbia River. The treatment system removes chromium from the extracted groundwater and the treated effluent is returned to the aquifer at a location upgradient of the trench.

One goal of the pump-and-treat system in the 100 K Area is to reduce the amount of chromium reaching the Columbia River, where the chemical may adversely affect aquatic organisms.

2.3.9.1 Interim Remedial Action Objectives

The record of decision (ROD 1996a) for interim remedial action to address chromium contamination in groundwater at the 100 K Area contains the following objectives for operating the pump-and-treat system:

- protect aquatic receptors in the river bottom substrate 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 record of decision stipulates that the interim action pump-and-treat system will continue to operate until the U.S. Environmental Protection Agency and Washington State Department of Ecology are satisfied that termination (or intermittent operation) is appropriate. Criteria for ending the operation include (a) sampling results demonstrate that the concentration of hexavalent chromium is below 22 μg/L in the compliance wells, and (b) evidence to conclude that the concentration will remain below the compliance value. Other criteria for terminating pump-and-treat operations involve the effectiveness of the treatment technology and the availability of a superior treatment technique (ROD 1996a).

2.3.9.2 Remediation Progress During Fiscal Year 2001

Progress was made toward achieving the remedial action objectives at the 100-KR-4 Operable Unit in fiscal year 2001. The pumping operation captures groundwater that contains hexavalent chromium at concentrations above the standard to protect aquatic organisms, thus preventing further transport of the contaminant to exposure sites within the river. Although designed primarily to prevent or reduce the amount of contaminated groundwater that discharges into the Columbia River, the pump-and-treat system also reduces overall contamination in the operable unit by removing contaminant mass from the aquifer. The pump-and-treat program collects data on hydraulic gradients, contaminant levels (including co-contaminants strontium-90, tritium, carbon-14, and nitrate), and treatment system operating parameters. These data are used to evaluate treatment system performance and to provide a technical basis for selecting a final remedy for groundwater remediation in the operable unit. A complete description of the progress and effectiveness of the interim remedial action to date is presented in the annual summary report for calendar year 2000 (DOE/RL-2001-04).

During fiscal year 2001, the pump-and-treat system at 100 K Area extracted 335.3 million liters of groundwater and removed 37.6 kilograms of hexavalent chromium.

During fiscal year 2001, the pump-and-treat system extracted 335.3 million liters of groundwater and removed 37.6 kilograms of hexavalent chromium (Table 2.3-1). Extraction well operating flow rates averaged between 70 and 169 liters per minute for the year, with maximum sustained pumping rates ranging between 91 and 174 liters per minute at the different wells. Average concentrations for hexavalent chromium in groundwater from the extraction wells ranged between 82 and 174 μg/L, with an average treatment system influent concentration of 113 μg/L. The effluent concentration averaged 6 μg/L hexavalent chromium during calendar year 2000 (DOE/RL-2001-04).

2.3.9.3 Influence on Aquifer Conditions

A variety of parameters can be assessed to help determine the influence of the remedial action on aquifer conditions, including trends in plume areal extent, volume of contaminated groundwater, mass of contaminant in the plume, and decreases in concentrations at various observation points, such as monitoring wells. The areal extent of the 100-KR-4 target chromium plume as mapped has not changed appreciably during recent years. Also, there is considerable uncertainty as to the location of parts of the plume's boundary because of limited monitoring well coverage. Partly for this reason, an accurate description of the volume of contaminated groundwater also is unavailable. However, some information on trends relating to chromium mass is available.

As of the end of fiscal year 2001, the 100-KR-4 pump-and-treat system had removed ~140 kilograms of hexavalent chromium from groundwater (Data source: Project Specific Database for the 100-KR-4 Operable Unit). The breakdown of removal by calendar year is as follows: 1997 (11 kilograms); 1998 (31 kilograms); 1999 (38 kilograms); 2000 (34 kilograms); and 2001 (27 kilograms as of September 30). A rough estimate for the total amount of chromium in the plume targeted for remedial action suggests a mass of 250 kilograms (DOE/RL-94-95). Uncertainty in this estimate is high, primarily as a consequence of limited data on (a) the vertical distribution of chromium in the aquifer; (b) an unknown rate of chromium discharge from the overlying vadose zone to the aquifer; and (c) the distance inland to which the plume extends. However, it does appear reasonable to infer from these numbers that the mass of chromium removed by the treatment system is significant relative to the total mass likely to be present in groundwater.

Work is in progress under the Integration Project Science and Technology program to better define the spatial dimensions and processes associated with the groundwater/river interface at the Hanford Site (PNNL-13674). Part of this effort includes developing improved estimates for the groundwater volume flux and chromium mass flux from the aquifer into the river, using a refined hydrogeologic model and best-available estimates for aquifer hydraulic properties. Initial estimates for the target chromium plume at the 100 K Area have been prepared to represent fiscal year 2000 conditions. These rates are compared to the production rates for the interim action pump-and-treat system in Table 2.3-1. Although the chromium mass estimates are remarkably similar, this may be fortuitous because of the uncertainty associated with the aquifer flux estimates. The values for aquifer flux and pump-and-treat system production are reasonably consistent, however, and provide evidence that the interim remedial action is having a significant impact on aquifer conditions. Whatever chromium is removed by the system is not available for discharge through potentially sensitive habitat at the groundwater/river interface.

The concentration of hexavalent chromium in groundwater from the extraction wells has remained essentially constant or shown a slight but general decline since pumping began ~4 years ago (see Figures 2.3-5 and 2.3-6). The concentrations in extraction wells have not declined below 22 μg/L, which is the target concentration for the compliance wells listed in the record of decision (ROD 1996a). Hexavalent concentrations in wells 199-K-119A and 199-K-125A reveal distinctly decreasing trends, while the decreasing trend in well 199-K-116A appears more gradual. Concentrations in wells 199-K-113A, 199-K-116A, and 199-K-120A do not exhibit long-term decreasing trends, possibly because of changes in plume movement direction as a consequence of the pumping operation, i.e., higher concentration groundwater is being drawn toward the well. Compliance well 199-K-112A was converted to an extraction well in January 2001, which extends the capture zone to the north of the trench. The hexavalent chromium concentration in this well has remained ~100 μg/L since concentrations throughout the aquifer rebounded following the 1996 and 1997 periods of elevated water table (a consequence of unusually high river discharge).

In response to the CERCLA 5-year review of interim remedial actions for groundwater, the pump-and-treat system at 100 K Area will continue to operate. A new extraction well will be installed to provide more complete capture of the target plume.

Concentrations in groundwater at three of the five compliance wells have remained relatively constant during the last 4 years, as illustrated in Figure 2.3-7, with two exceptions. The concentrations in wells 199-K-18 and 199-K-126 (not shown in figure – similar to well 199-K-18) show distinctly increasing trends. The cause for the increasing trends is again likely to be related to changes in plume movement because of the pumping operation, with higher concentration groundwater being drawn toward the wells. Conversion of well 199-K-112A from a compliance well to an extraction well may have influenced plume movement near well 199-K-126. The concentration trend in well 199-K-117A reveals a distinct decrease that is correlated with the pump-and-treat operation. Before pumping began in 1997, the concentration in this well exceeded 150 μg/L, the highest of the compliance wells. Since then, with the extraction wells operating, the concentration typically measures <50 μg/L. This pattern also is present in nearby monitoring well 199-K-21, which also shows a consistent downward trend beginning with a concentration of ~100 μg/L in January 1997 and ending with the most recent measurement of 10 μg/L in November 2000. Concentrations in wells 199-K-20 and 199-K-114A remain relatively constant.

Concentrations of hexavalent chromium remain above the target level of 22 μg/L in the extraction and compliance wells, so the annual summary report for the remedial action (DOE/RL-2001-04) recommends continued operation of the pump-and-treat system. In response to a finding included in the first 5-year review of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remediation activities for the Hanford Site (EPA 2001), plans are underway to (a) install an additional extraction well and injection well, (b) improve the treatment system performance, and (c) increase the treatment system capacity. All of these activities are intended to provide more complete capture of the target plume. The new extraction well is planned for a location between existing extraction wells 199-K-119A and 199-K-120A. It will extract groundwater containing hexavalent chromium that is observed at compliance wells 199-K-18 and 199-K-20.

Reduction of the target chromium plume is occurring as a result of the interim remedial action involving the pump-and-treat system. Reduction also is occurring as a consequence of natural processes, which include dispersion by groundwater movement, dilution at the groundwater/river interface and within the free-stream of the river, and a presumed reduction in the rate of chromium recharge from the vadose zone to the aquifer. However, slow downward diffusion of chromium-contaminated moisture from the vadose zone is likely to continue for many years beneath the footprint of former liquid waste disposal sites, thus maintaining some level of contamination in the aquifer. There is no evidence of chromium-bearing groundwater approaching the 100 K Area from source regions upgradient, other than the groundwater that was pushed upgradient because of radial flow associated with the original mound beneath the 100-K trench.

2.3.10 Monitoring at River Shoreline

Groundwater samples are collected annually from aquifer sampling tubes located near the low river stage shoreline and from riverbank seepage sites during the seasonal low river stage, which occurs during the fall months. The tubes were re-sampled during the October-November time period in 1998, 1999, 2000, and 2001 to support Environmental Restoration program objectives. Samples from aquifer tubes reflect conditions in the zone of interaction between the groundwater flow system and the river flow system, thus providing a representative sample of groundwater from locations close to the point of discharge into the riverbed.

Riverbank seepage is monitored by the Surface Environmental Surveillance Project, with additional sampling and analysis conducted under the Environmental Restoration program in support of groundwater operable unit investigations. River water is collected along the Hanford Site shoreline at least annually, as part of the Surface Environmental Surveillance Project river monitoring task. Table 2.3-2 lists the analytical results for key constituents in samples collected during fall 2000 from aquifer sampling tubes, riverbank seepage, and nearshore river water (when available). Riverbank seepage is typically a mixture of river water and groundwater. When exposed at the surface during low river stage, it presents a potential ecological or human health risk in areas where groundwater is contaminated.

Chromium, beta activity, and tritium were detected in aquifer sampling tubes or groundwater seeps discharging to the Columbia River shore in the 100 K Area in fiscal year 2001.

2.3.10.1 Aquifer Sampling Tubes

Samples collected from the tubes during October and November 2000 were screened for key 100 K Area contamination indicators (i.e., carbon-14, chromium, gross beta, strontium-90, and tritium). Hexavalent chromium concentrations ranged from a high of 110 μg/L downgradient of the 100-K trench (tube 23-D) to lows of <10 μg/L (i.e., near the detection limit) in tubes located opposite the K Reactor complexes. Strontium-90 was not detected in samples from tubes located downgradient of the 100-K trench. The single gross beta result available for this shoreline segment is from a site just upstream of 100 K Area plumes; it probably represents the arrival of technetium-99 with a groundwater plume that has migrated northward through Gable Gap. Tritium and carbon-14 were measured in a tube downgradient from the 100-K burial ground and KE Reactor complex (tube 19-D) but neither was detected, though the specific conductance measurement indicates the sample was primarily river water. Nitrate was not measured in any of the tube samples.

All of the results from the aquifer sampling tubes, with the possible exception of those for tube 26-M, reflect dilution by river water, as indicated by the specific conductance of the samples relative to groundwater. Consequently, the groundwater approaching the river may contain contaminants at greater concentrations than those listed in Table 2.3-2.

2.3.10.2 Riverbank Seepage

Samples of riverbank seepage were collected at three locations adjacent to 100 K Area facilities and waste sites during October 2000 and 2001. Maximum concentrations for contaminants of concern were: 82 μg/L hexavalent chromium; 6.3 pCi/L gross beta; 74 mg/L nitrate; and 6,140 pCi/L tritium (see Table 2.3-2). Strontium-90 was detected at a very low concentration at one seepage area adjacent to the 100-K trench. Concentrations at all seepage sites sampled are consistent with observations in previous years.

Table 2.3-1. Aquifer Flux Compared to Pump-and-Treat Production Rates

Estimates Based on Data from 10/99 to 10/00 (fiscal year 2000)	Flux Across Aquifer Near River Interface(a)	Pump-and-Treat System Production Rates(b)
Water volume (L/yr)	437,532,000	286,663,199
Chromium mass (kg/yr)	34.02	33.54

(a) Work in progress, Groundwater/River Interface Task, Integration Project.
(b) DOE/RL-2001-04, p. 3-31.

Table 2.3-2. Shoreline Monitoring Data for the 100 K Area, Fiscal Year 2001

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Carbon-14 (pCi/L)	Chromium (µg/L)	Gross Beta (pCi/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Tritium (pCi/L)
14-M	Tube	10/30/00	393		8	82.4		-0.1 U	
19-D	Tube	10/30/00	213	2.14 U	6			0.3 U	-133 U
22-M	Tube	10/30/00	301		95				
23-D	Tube	10/31/00	260		110				
25-D	Tube	10/31/00	299		5				
26-M	Tube	10/31/00	412		21				
SK-063-1	Seep	10/17/00	340		49	3.1	74.4	0.02 U	5,370
SK-063-1	Seep	10/25/01	210			4.7			
SK-077-1	Seep	10/25/00	131(a)		5 U(a)	6.7(a)	6.9	2.1	90 U(a)
SK-077-1	Seep	10/25/01	147			5.1			
SK-082-2	Seep	10/17/00	327		63	2.8 U	33.3		5,120
SK-082-2	Seep	05/04/01	342		82	2.8 U		0.03 U	6,140

Tube = Aquifer sampling tube near the low-river shoreline.
Seep = Natural riverbank seepage site.
U = Below detection limit.
(a) Average of multiple measurements.
Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically in the range of 350 to 450 µS/cm and river water 120 to 150 µS/cm.
Chromium includes hexavalent chromium and total chromium for filtered samples.

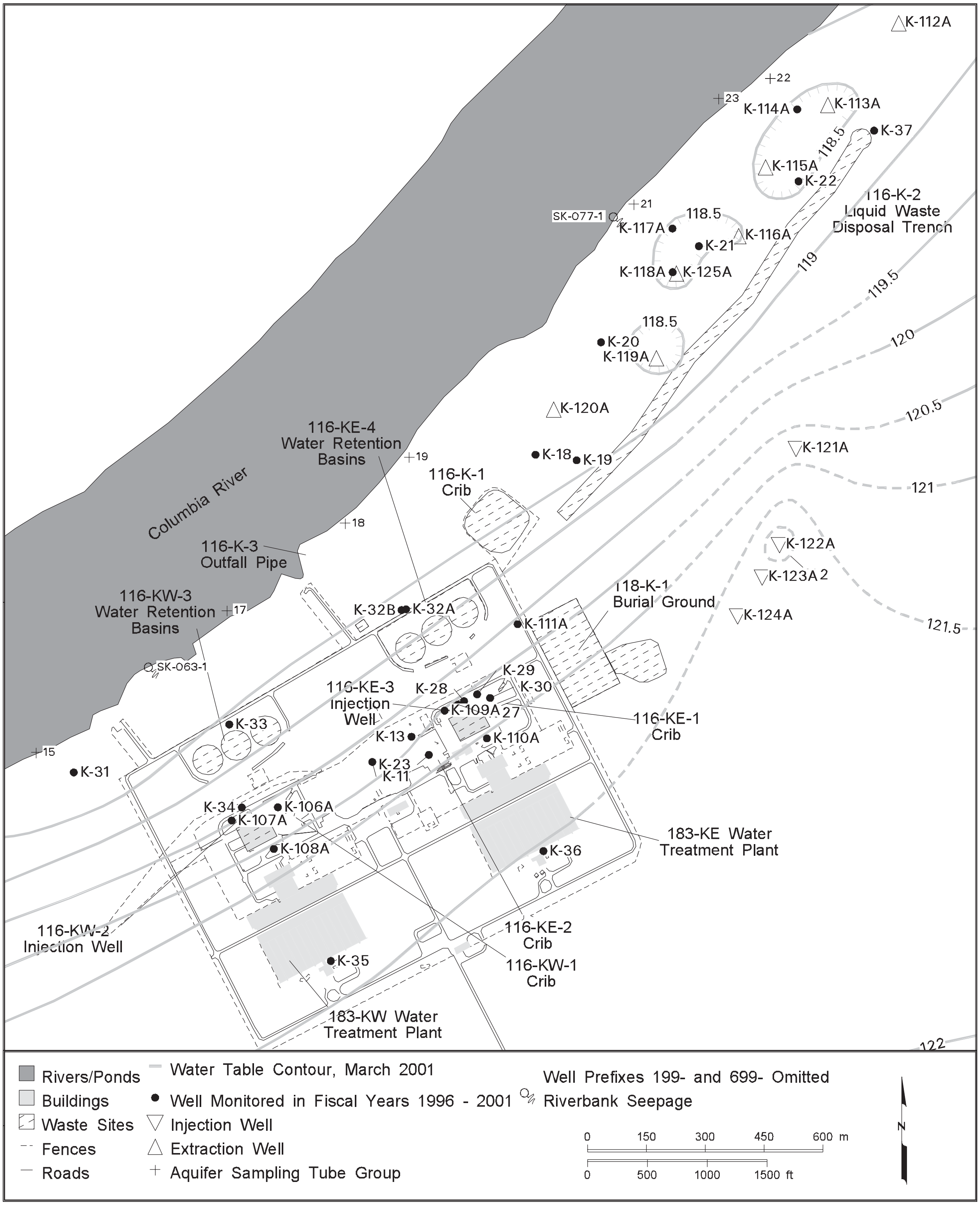

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Figure 2.3-1. Groundwater Monitoring Wells in the 100 K Area

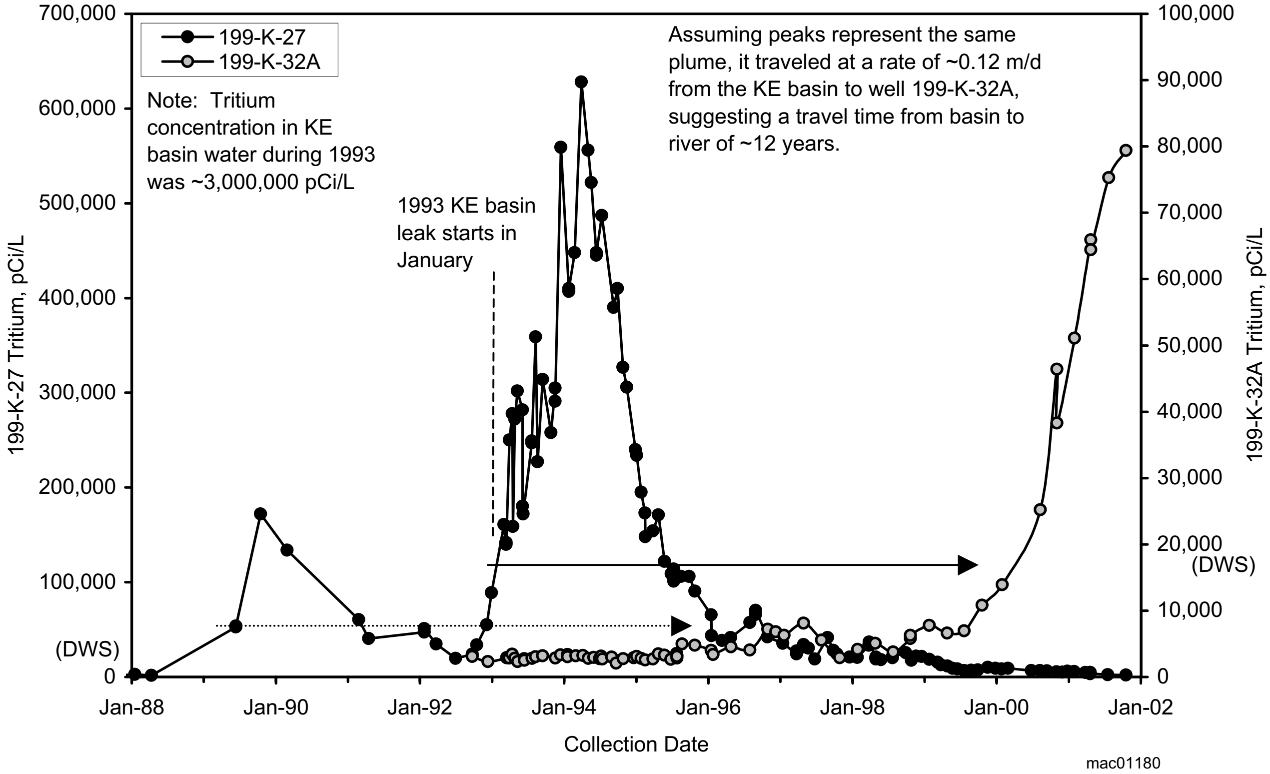

Figure 2.3-2. Tritium Plume Movement Between KE Fuel Storage Basin and the Columbia River

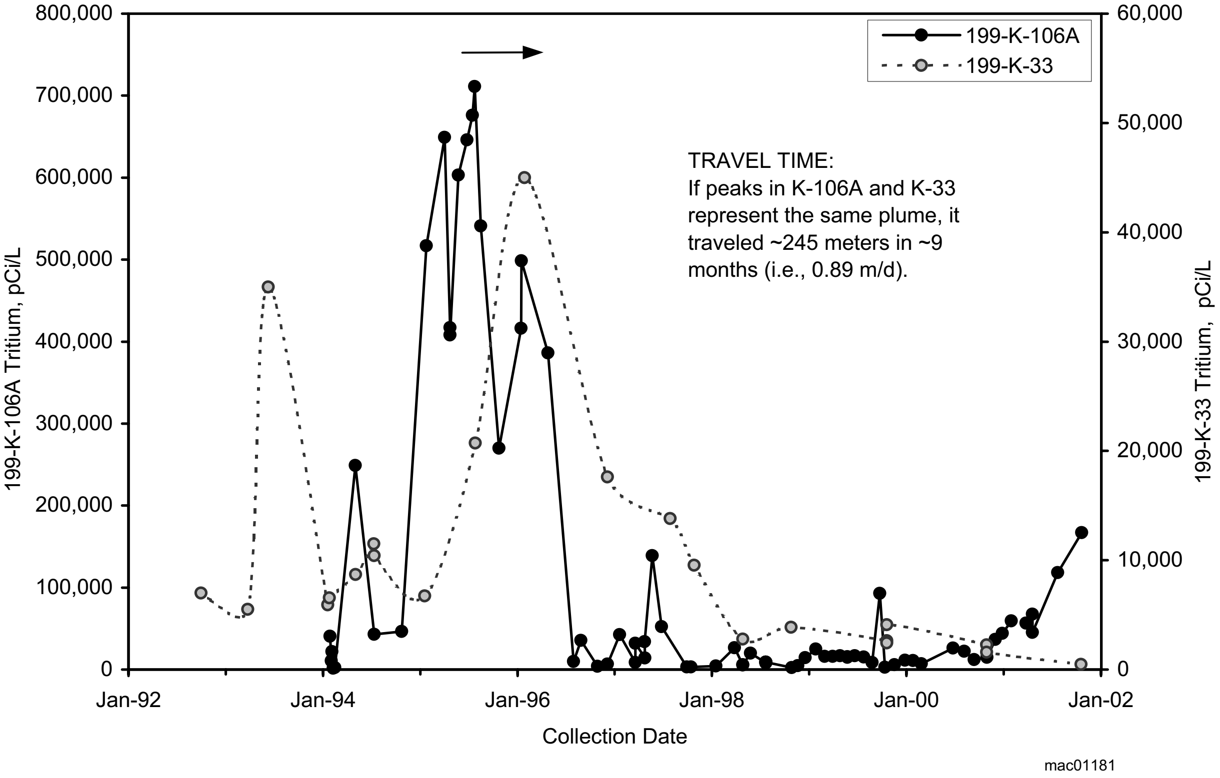

Figure 2.3-3. Tritium Plume Movement Between KW Fuel Storage Basin and the Columbia River

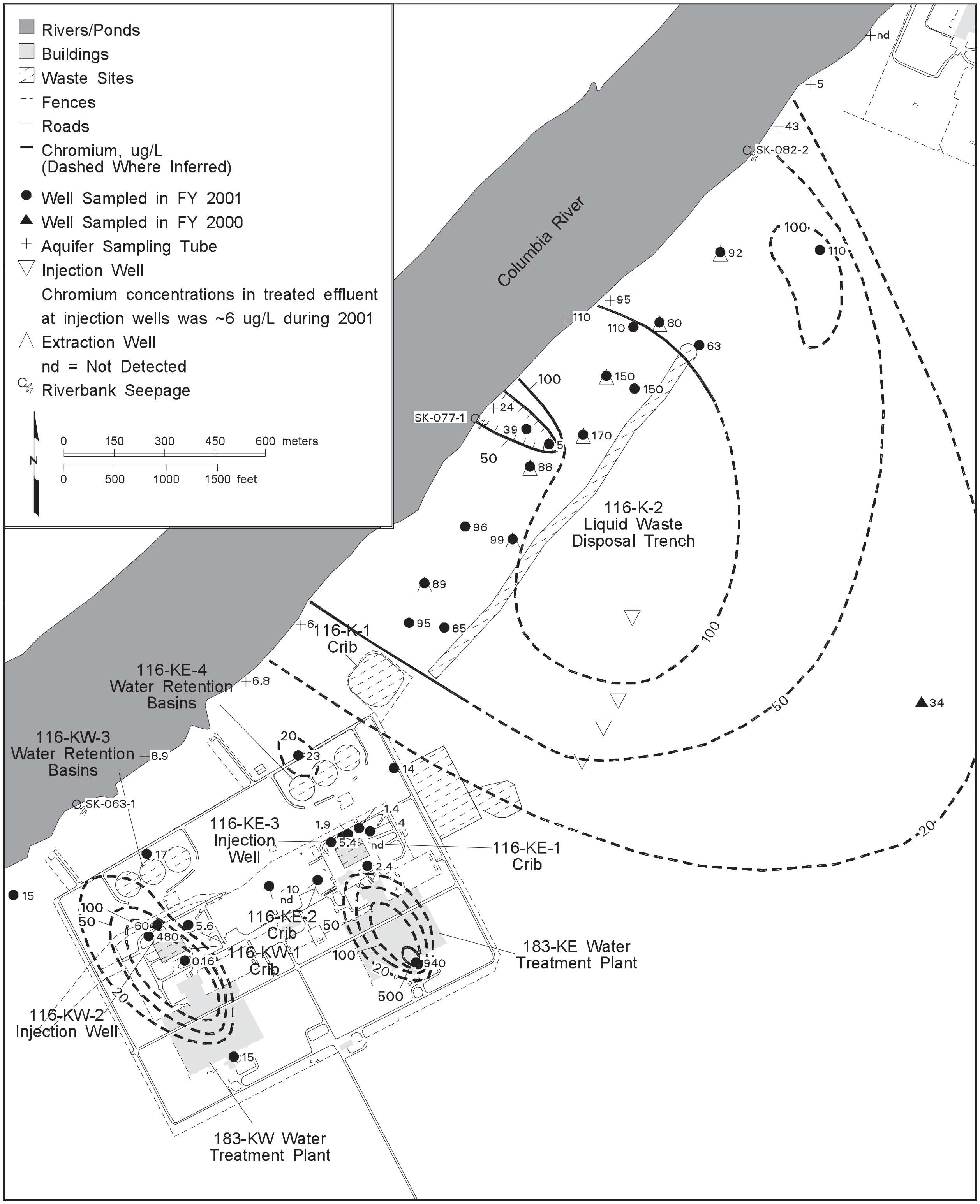

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Figure 2.3-4. Distribution of Chromium in Groundwater Beneath the 100 K Area, Fiscal Year 2001

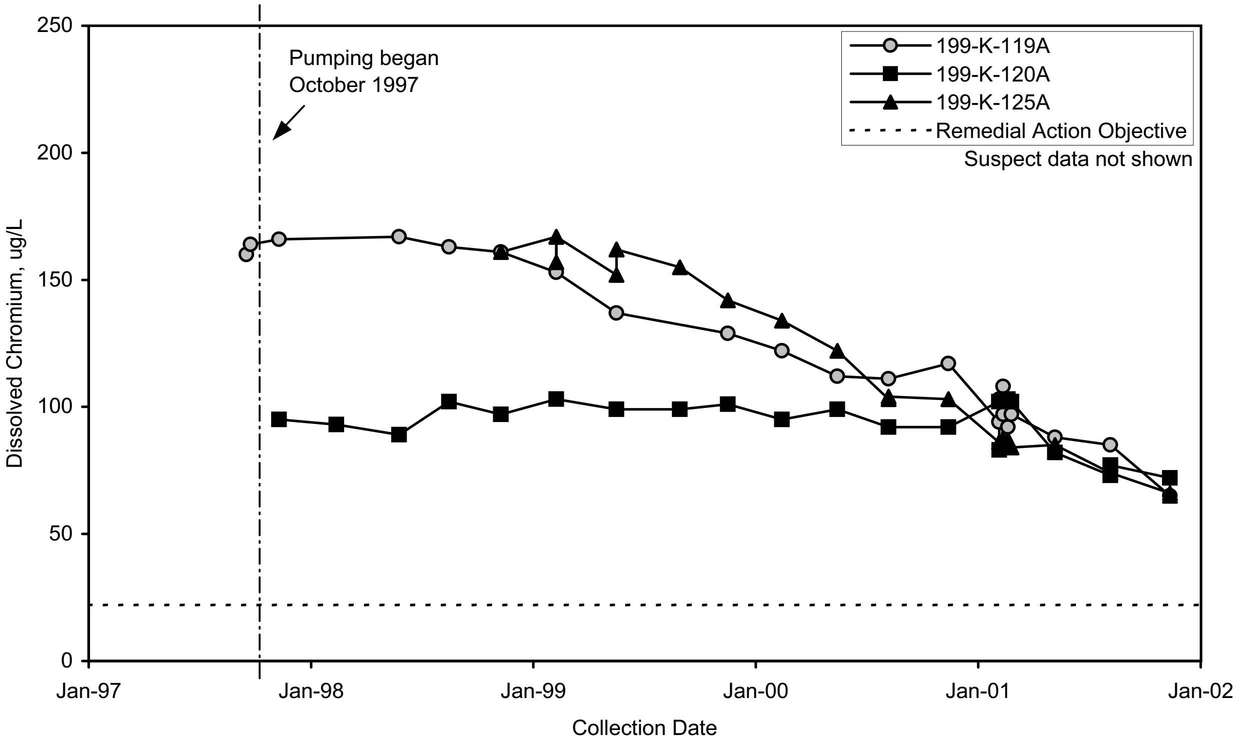

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Figure 2.3-5. Chromium Concentrations in Extraction Wells at the Southwest End of the Liquid Waste Disposal Trench

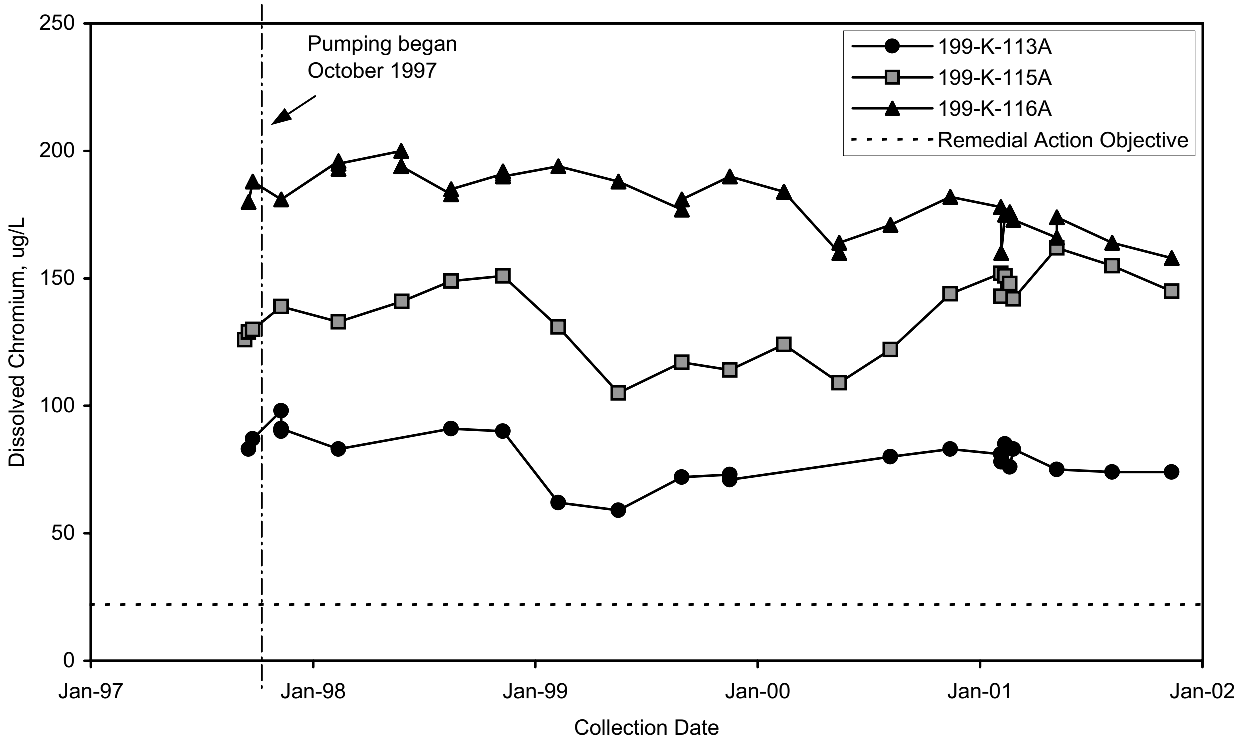

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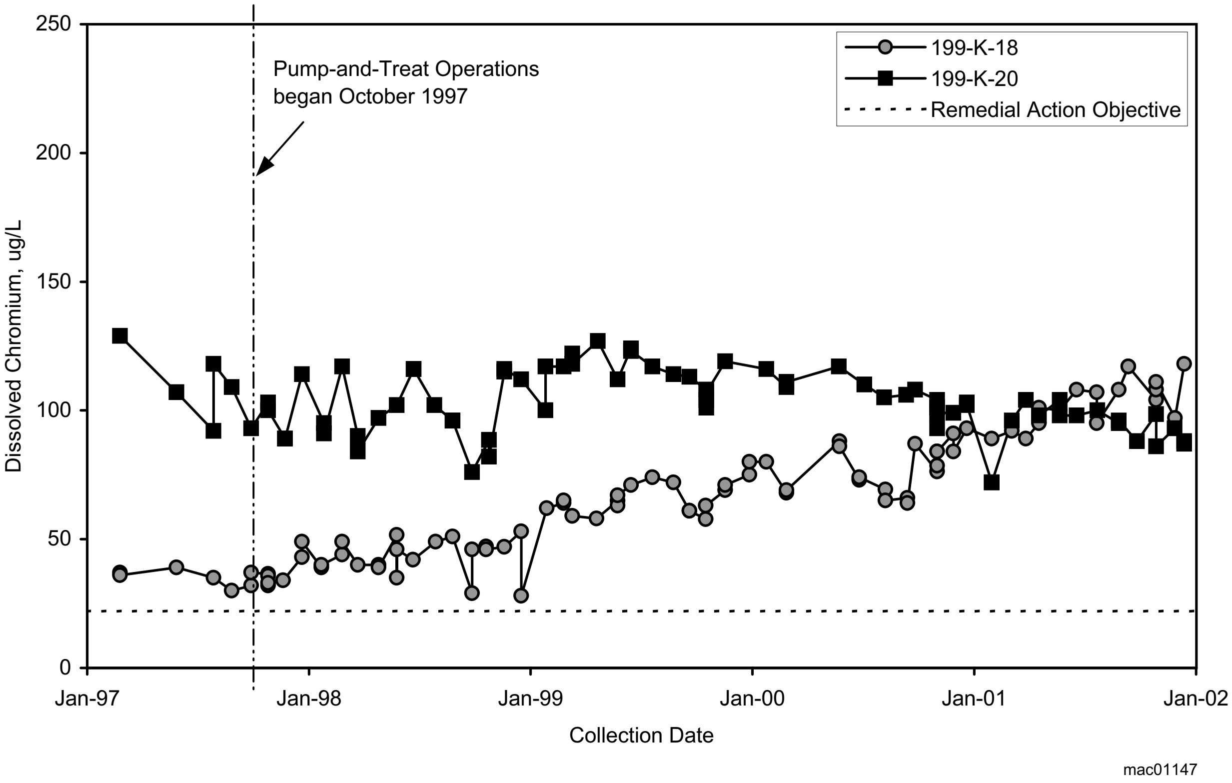
Figure 2.3-6. Chromium Concentrations in Extraction Wells at the Northeast End of the Liquid Waste Disposal Trench



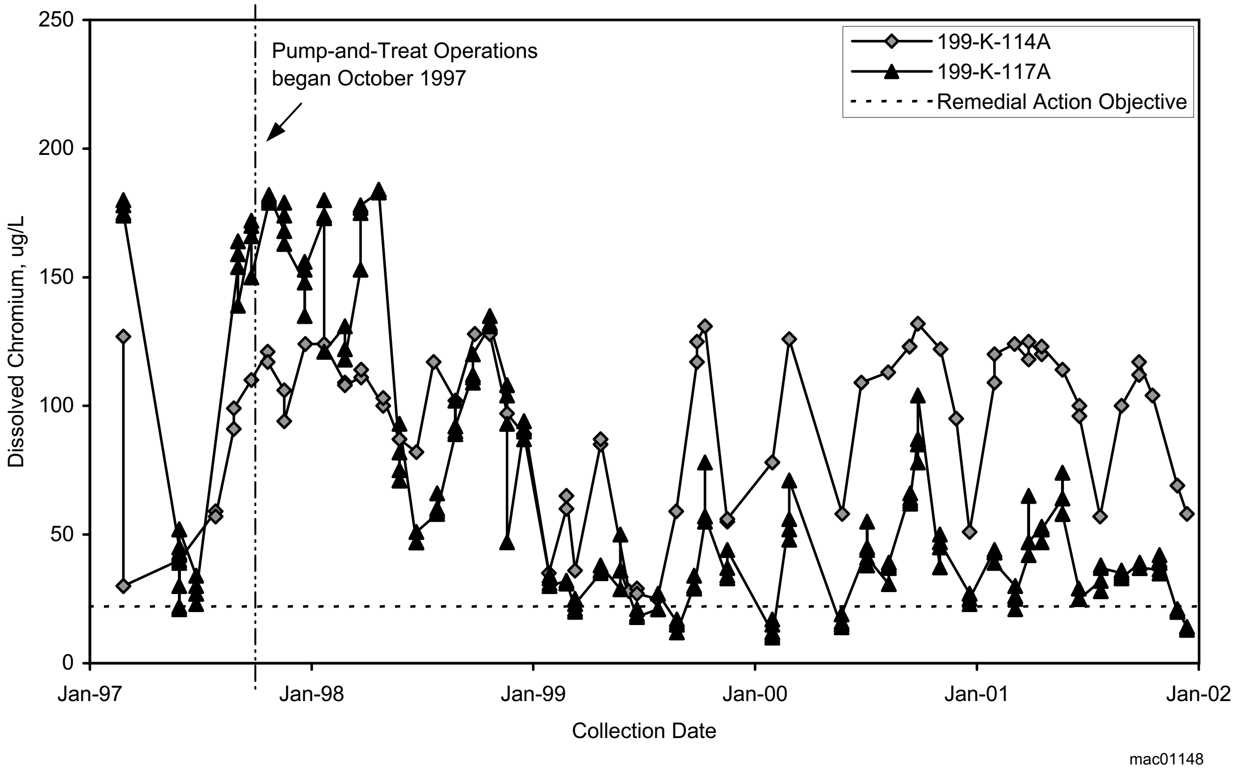


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Figure 2.3-7. Chromium Concentrations Between Extraction Wells and the Columbia River

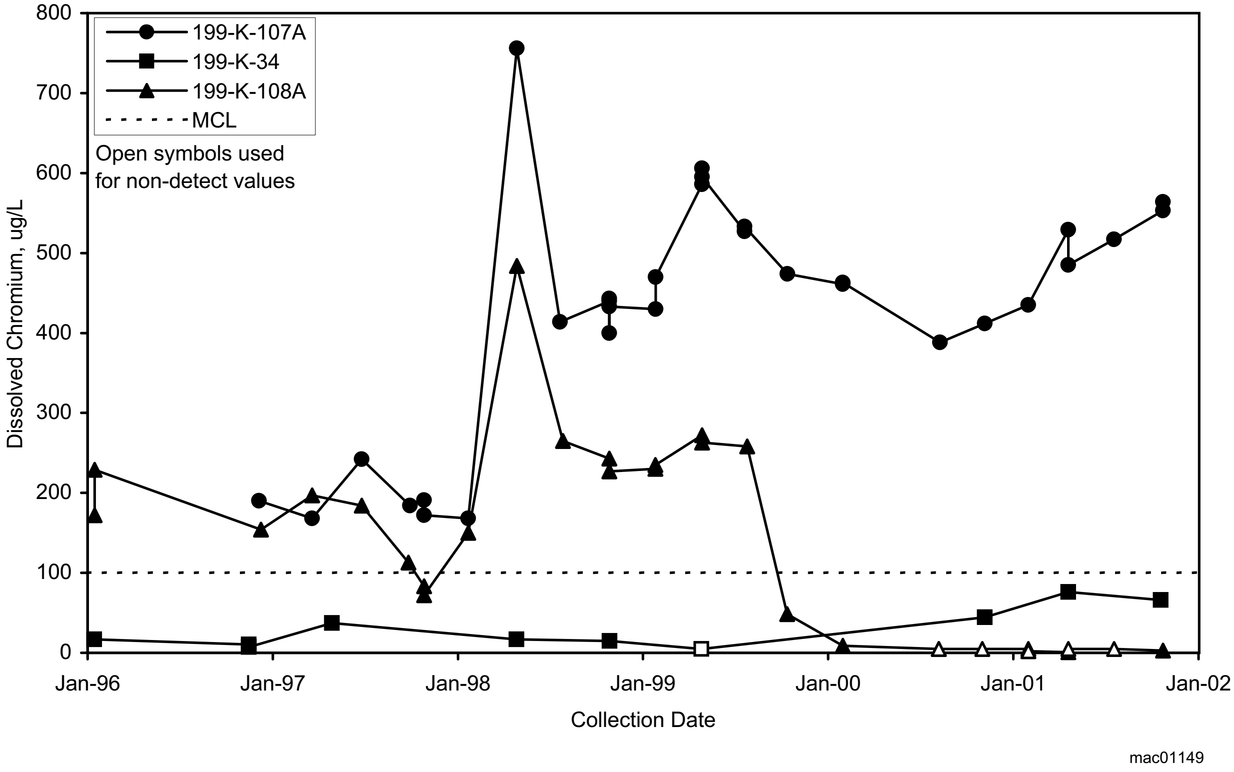

Figure 2.3-8. Chromium Concentrations in Wells Near the KW Reactor

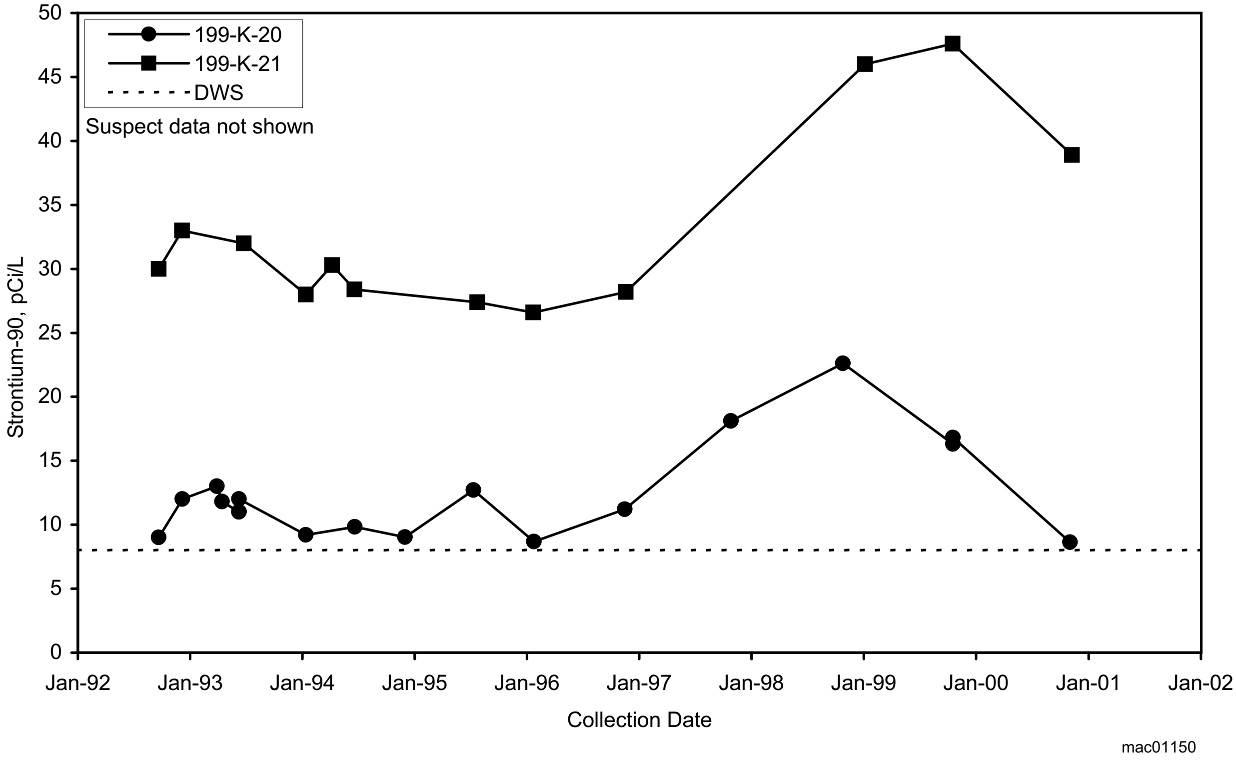

Figure 2.3-9. Strontium-90 Concentrations in Wells Between 100-K Trench and the Columbia River

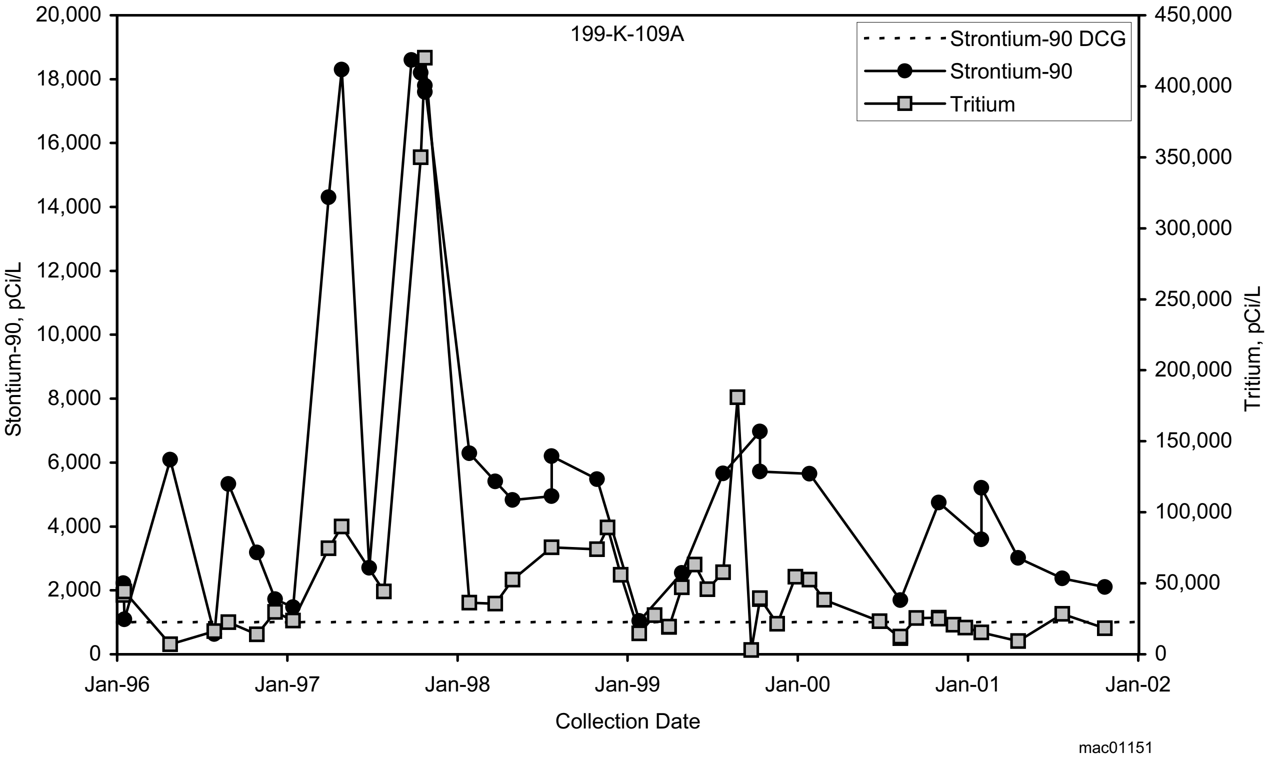

Figure 2.3-10. Strontium-90 and Tritium Concentrations Near the KE Fuel Storage Basin

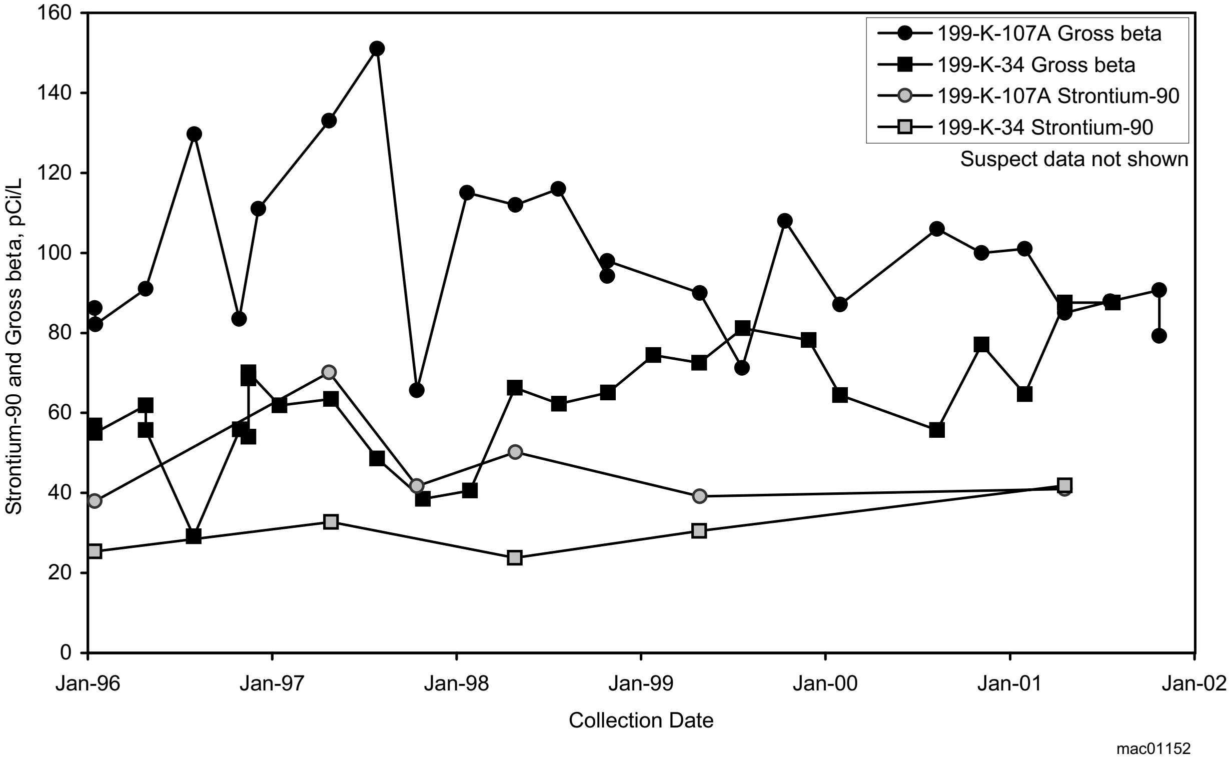

Figure 2.3-11. Strontium-90 and Gross Beta Concentrations in Wells Near the KW Fuel Storage Basin

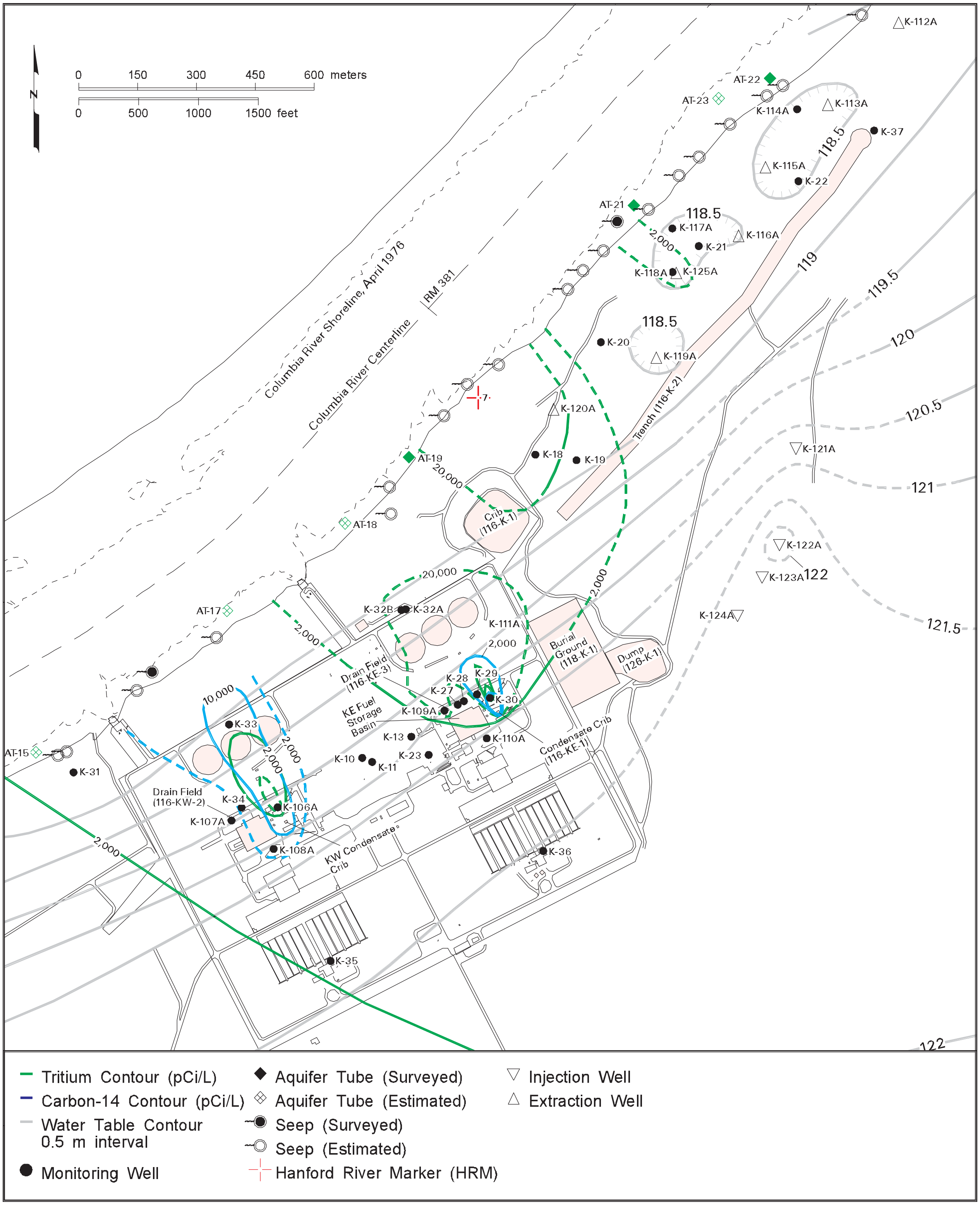

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Figure 2.3-12. Distribution of Tritium and Carbon-14 Beneath the 100 K Area, Fiscal Year 2001

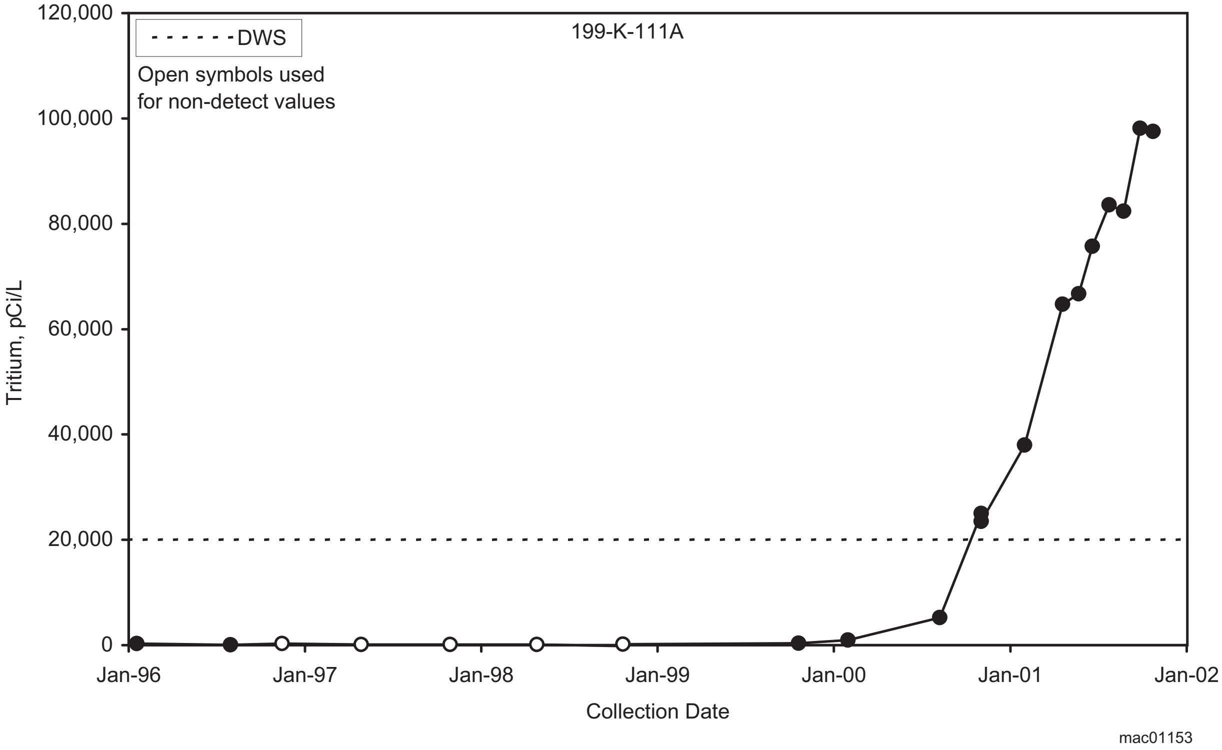


Figure 2.3-13. Tritium Concentrations Near the 100-K Burial Ground

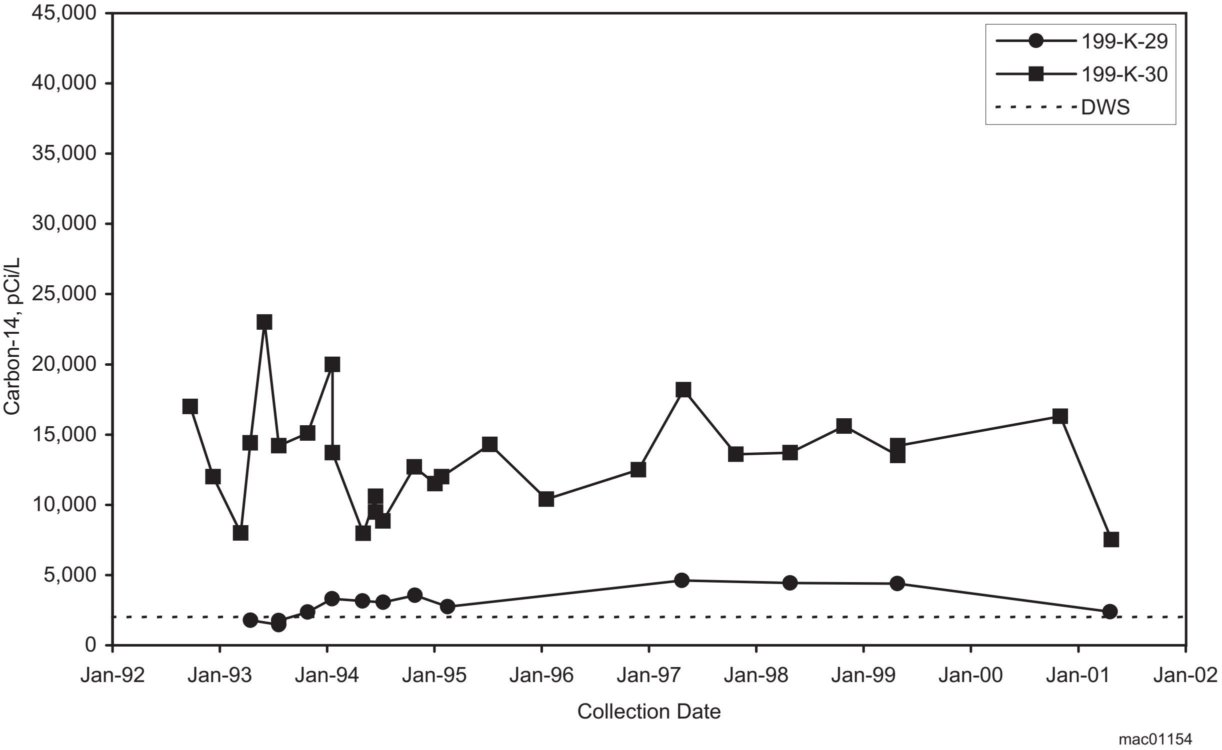


Figure 2.3-14. Carbon-14 Concentrations in Wells Near the KE Condensate Crib

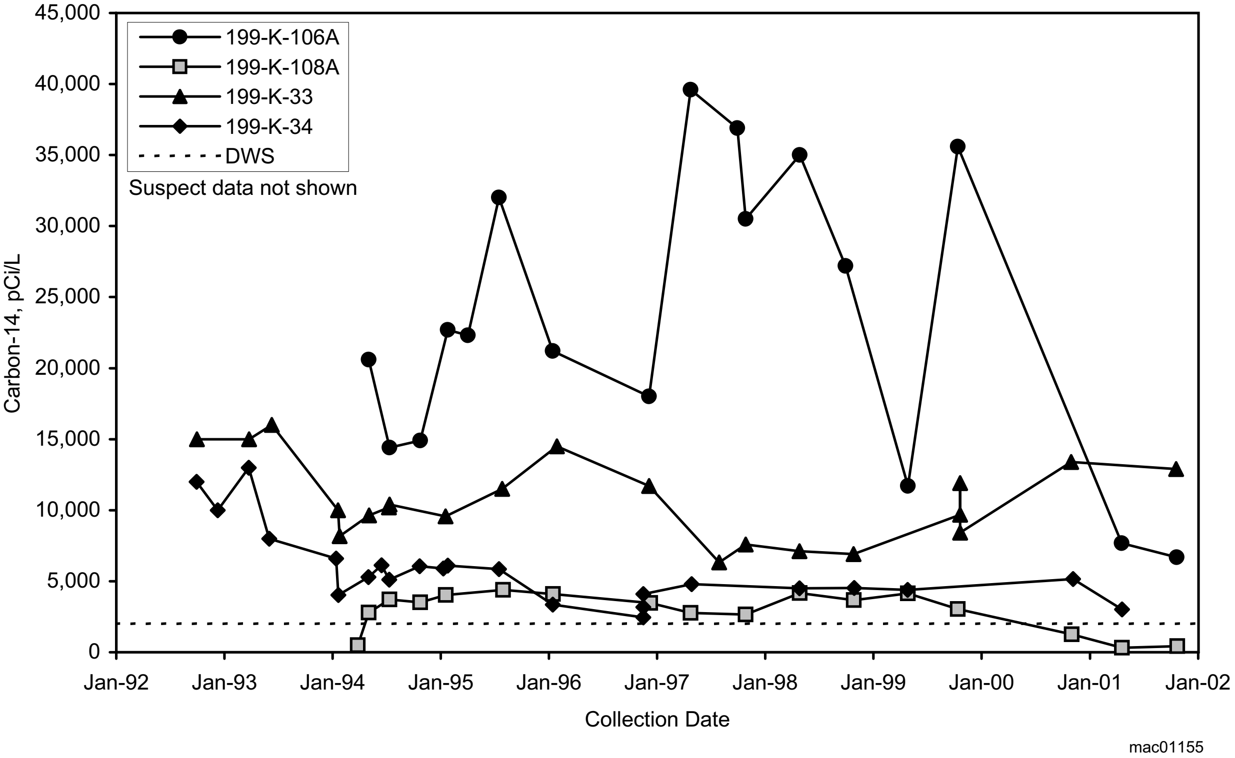


Figure 2.3-15. Carbon-14 Concentrations in Wells Near the KW Condensate Crib

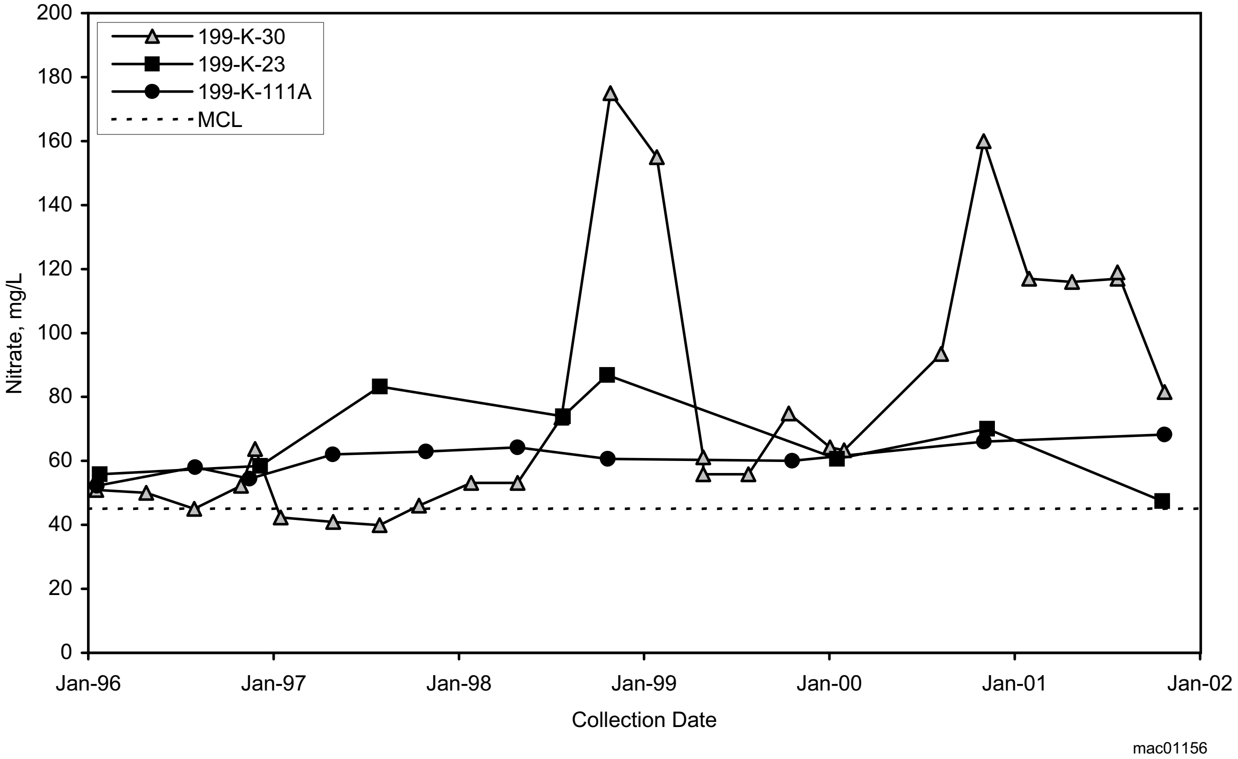


Figure 2.3-16. Nitrate Concentrations in Wells Near the KE Reactor Building

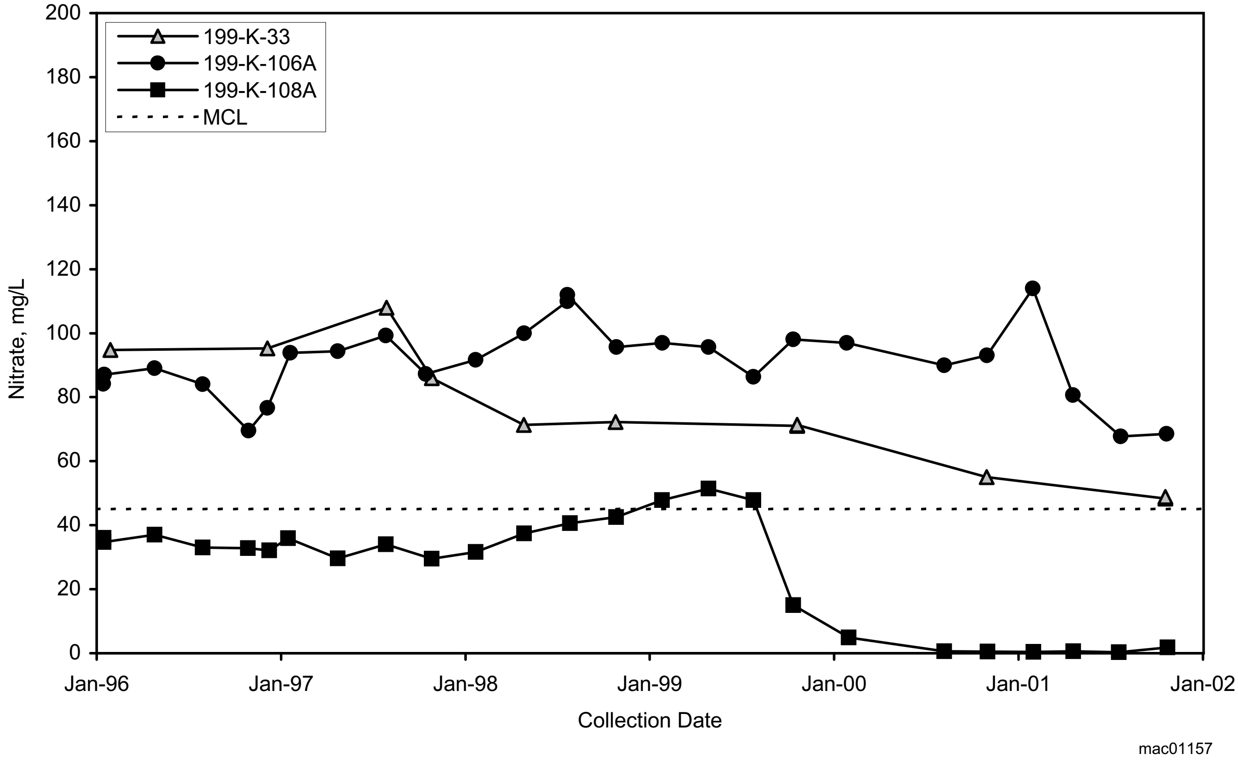
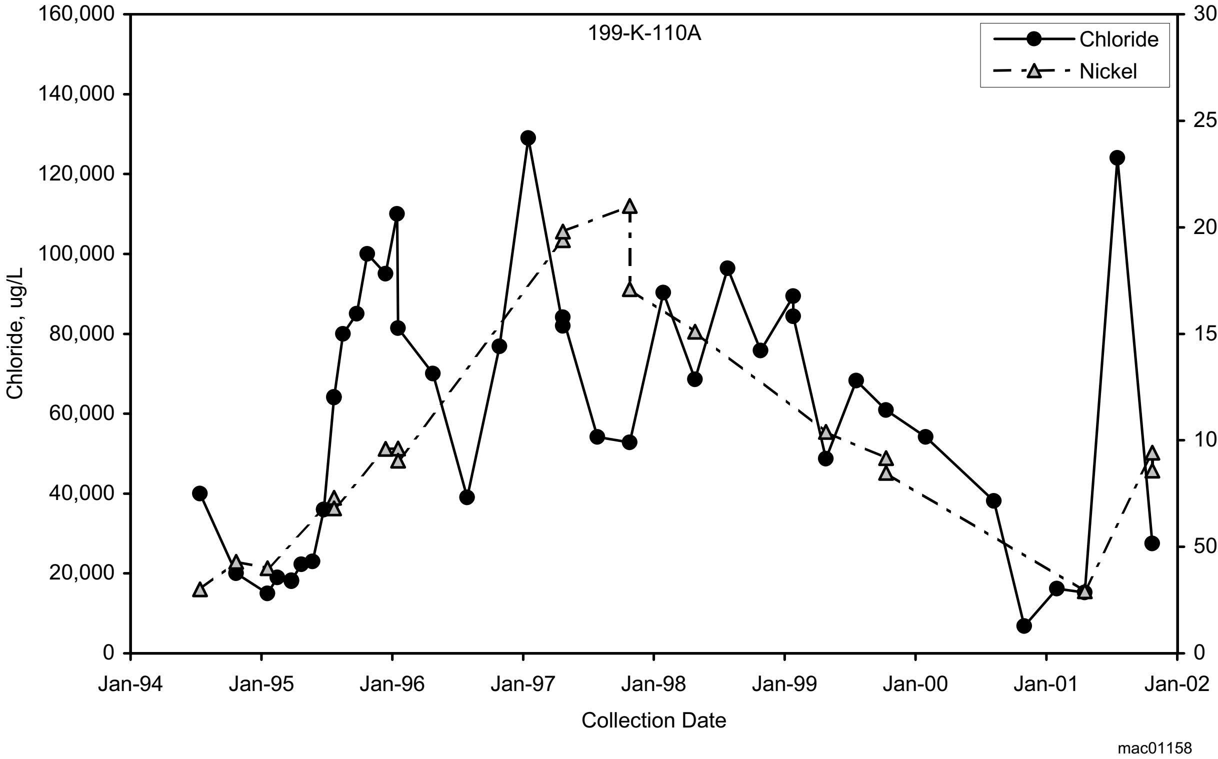


Figure 2.3-17. Nitrate Concentrations in Wells Near the KW Reactor Building



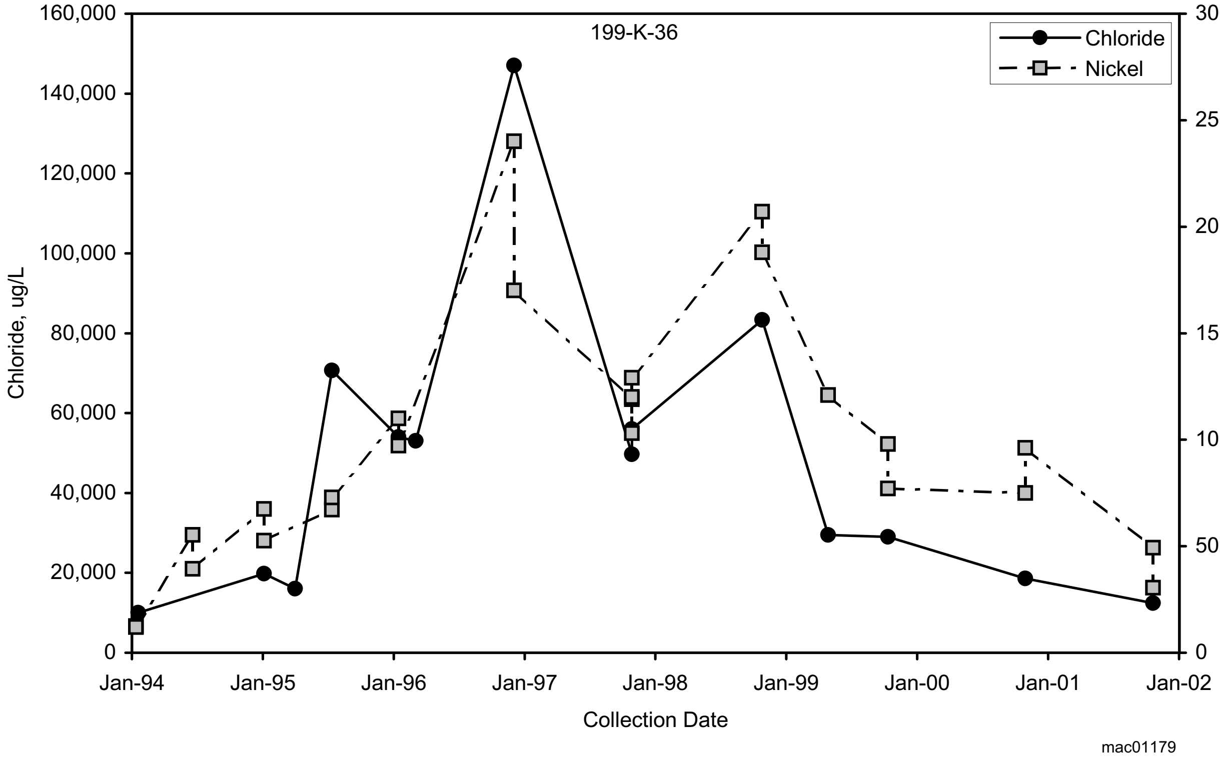


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Figure 2.3-18. Nickel and Chloride Concentrations in Wells Near the KW Reactor Complex

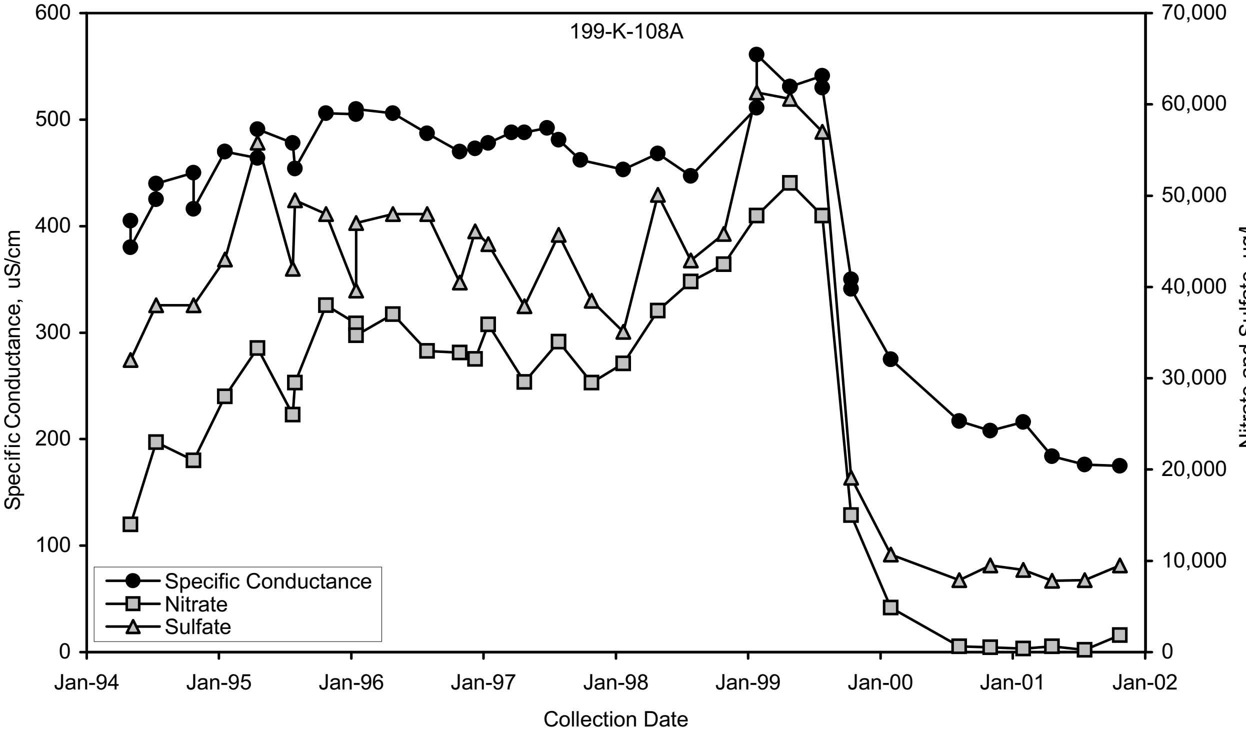


Figure 2.3-19. Evidence for Dilution of Groundwater by Clean Water Near the KW Reactor Building

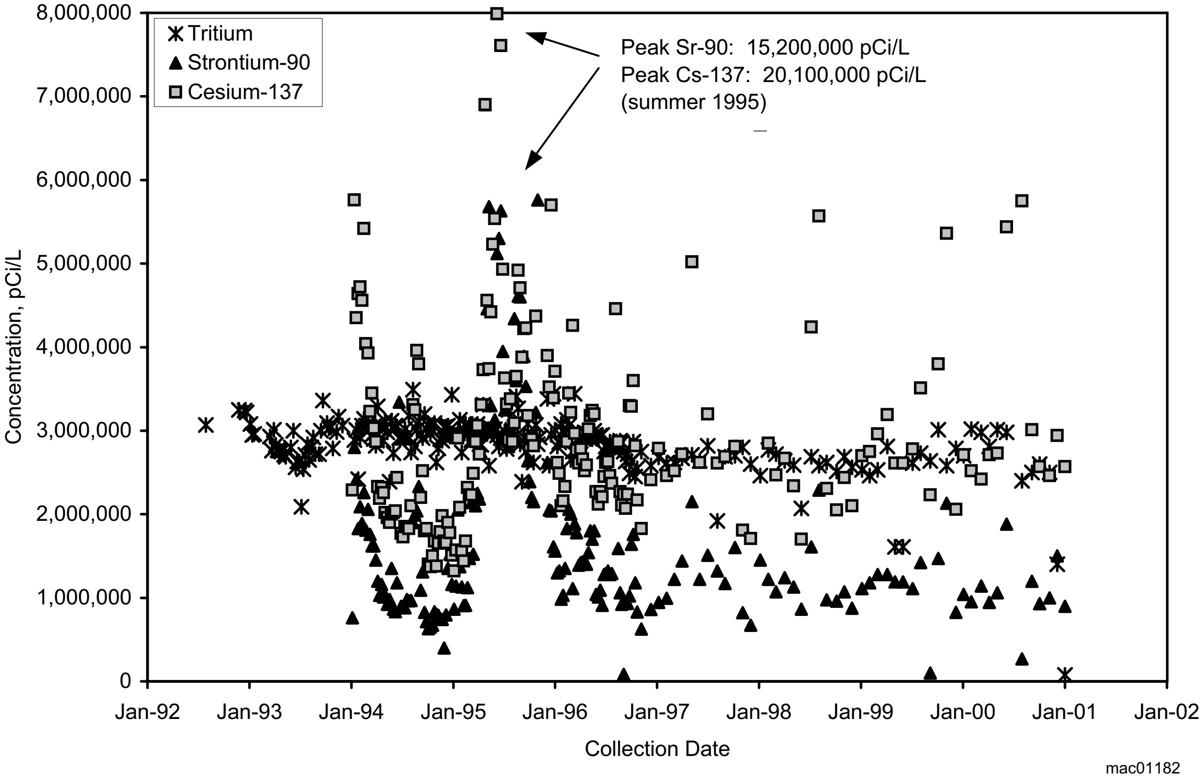


Figure 2.3-20. Tritium, Strontium-90, and Cesium-137 Concentrations in KE Fuel Storage Basin Shielding Water

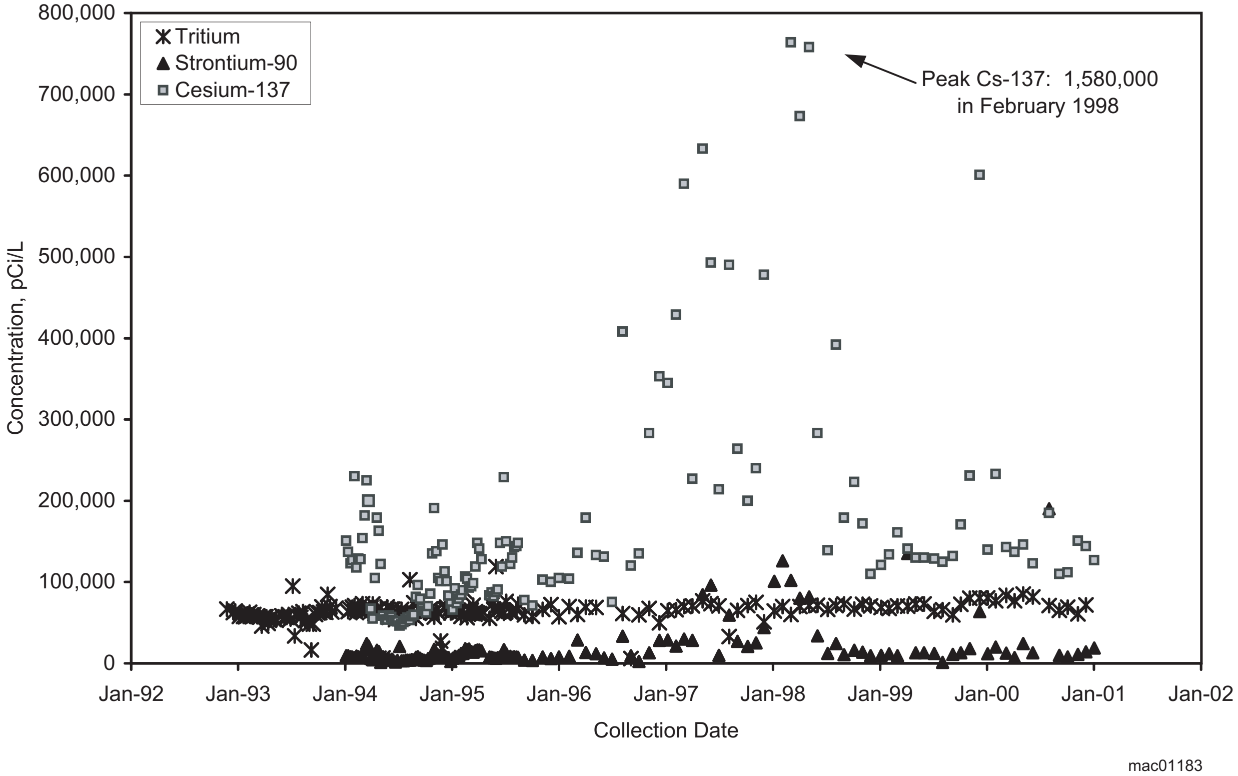


Figure 2.3-21. Tritium, Strontium-90, and Cesium-137 Concentrations in KW Fuel Storage Basin Shielding Water

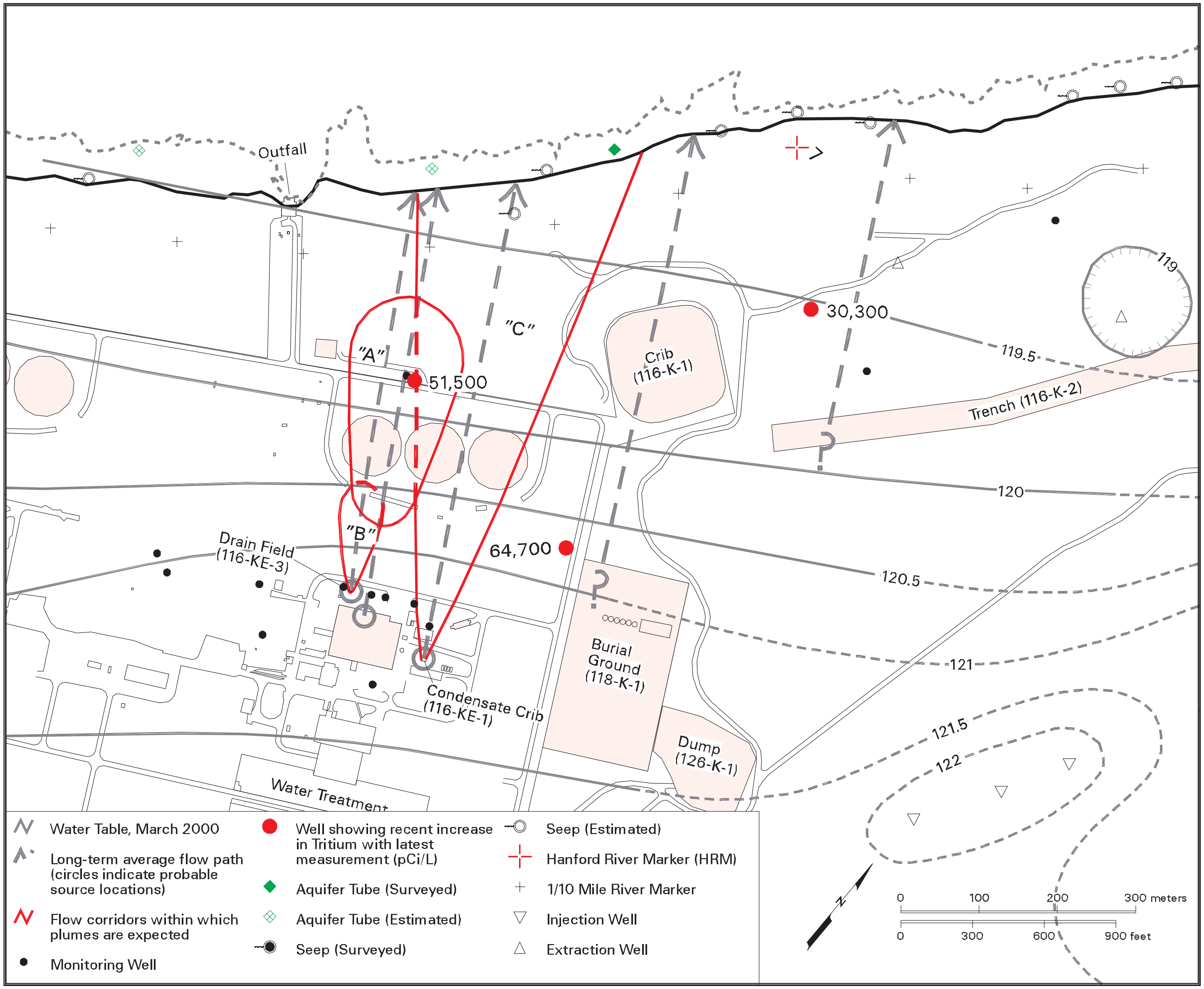
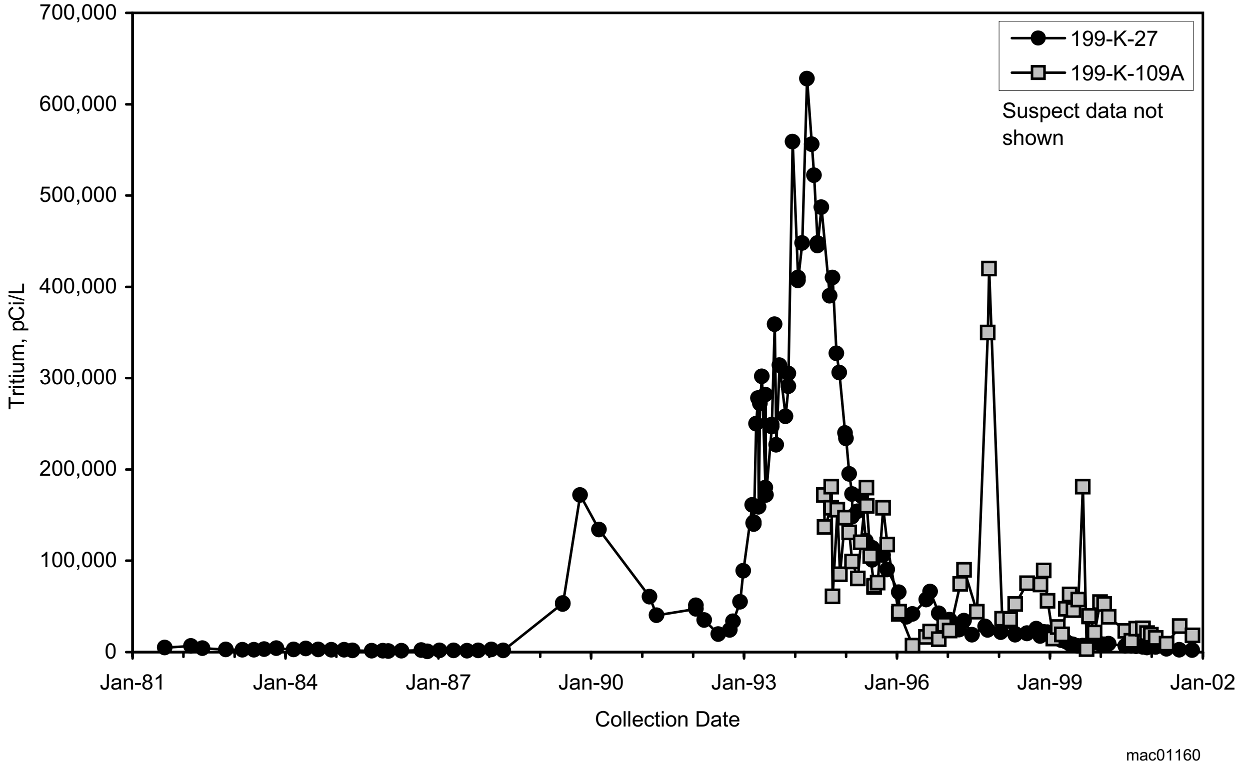


Figure 2.3-22. Flow Direction Corridors from Tritium Sources Near the KE Reactor Complex



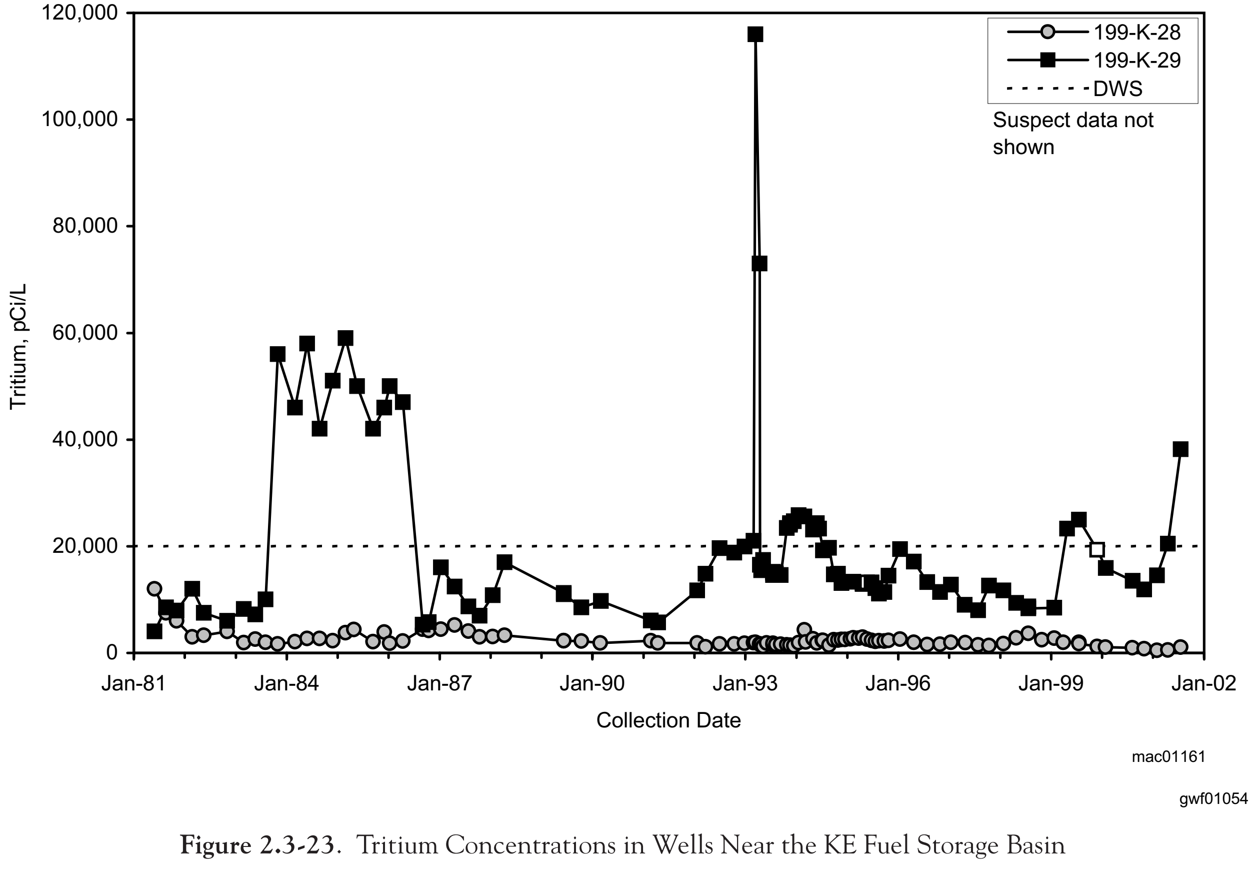


Figure 2.3-23. Tritium Concentrations in Wells Near the KE Fuel Storage Basin

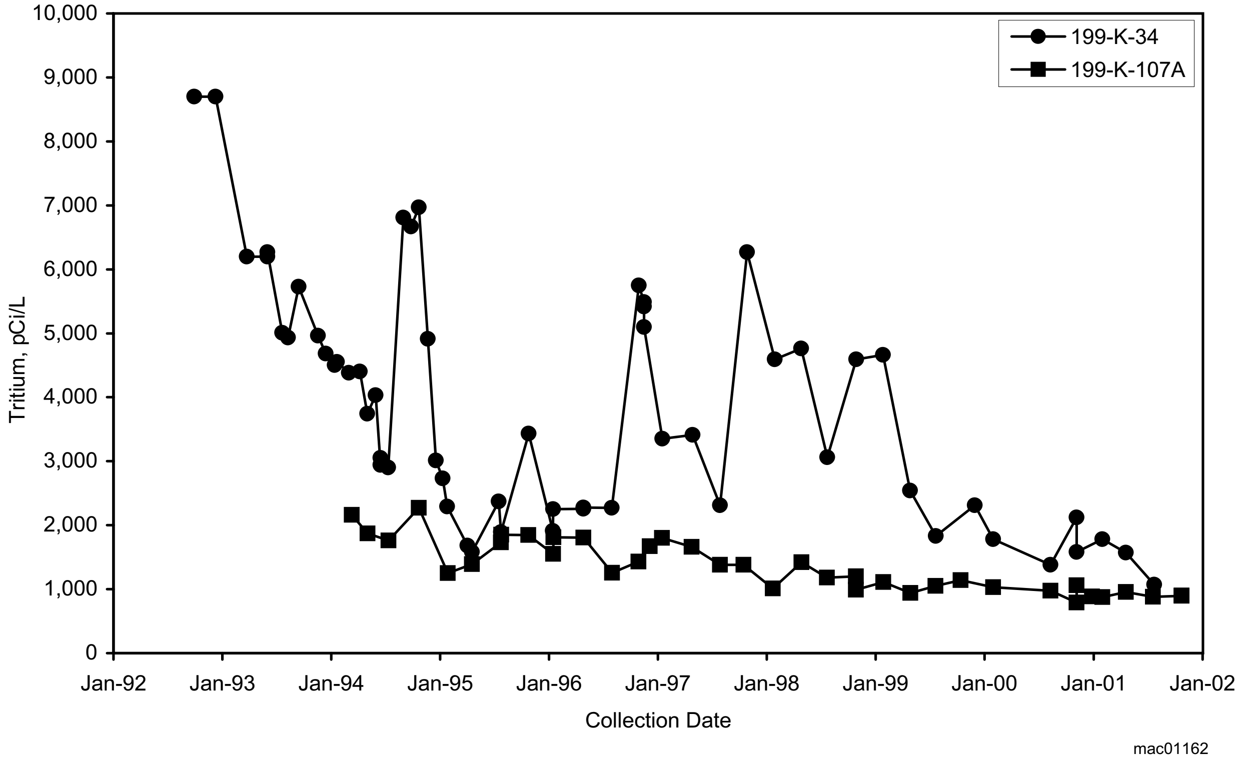


Figure 2.3-24. Tritium Concentrations in Wells Near the KW Fuel Storage Basin

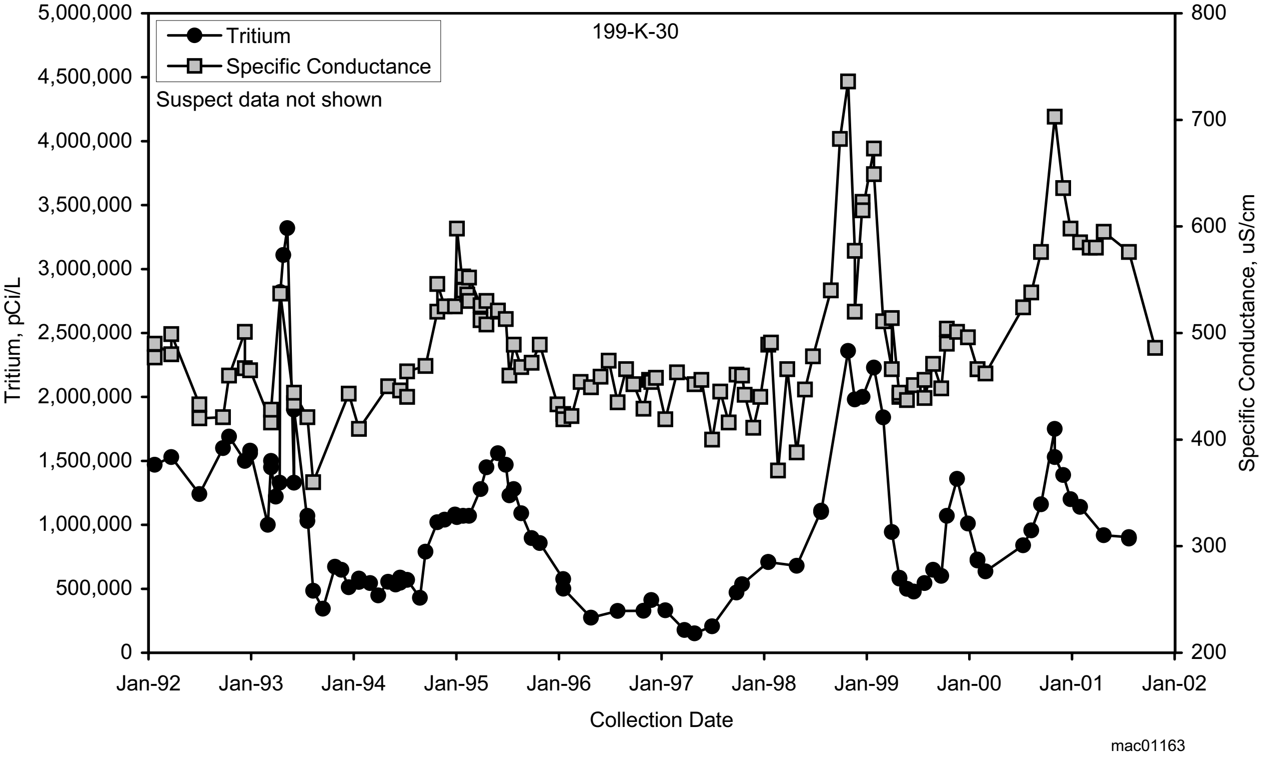


Figure 2.3-25. Tritium Concentrations and Specific Conductance Near the KE Condensate Crib

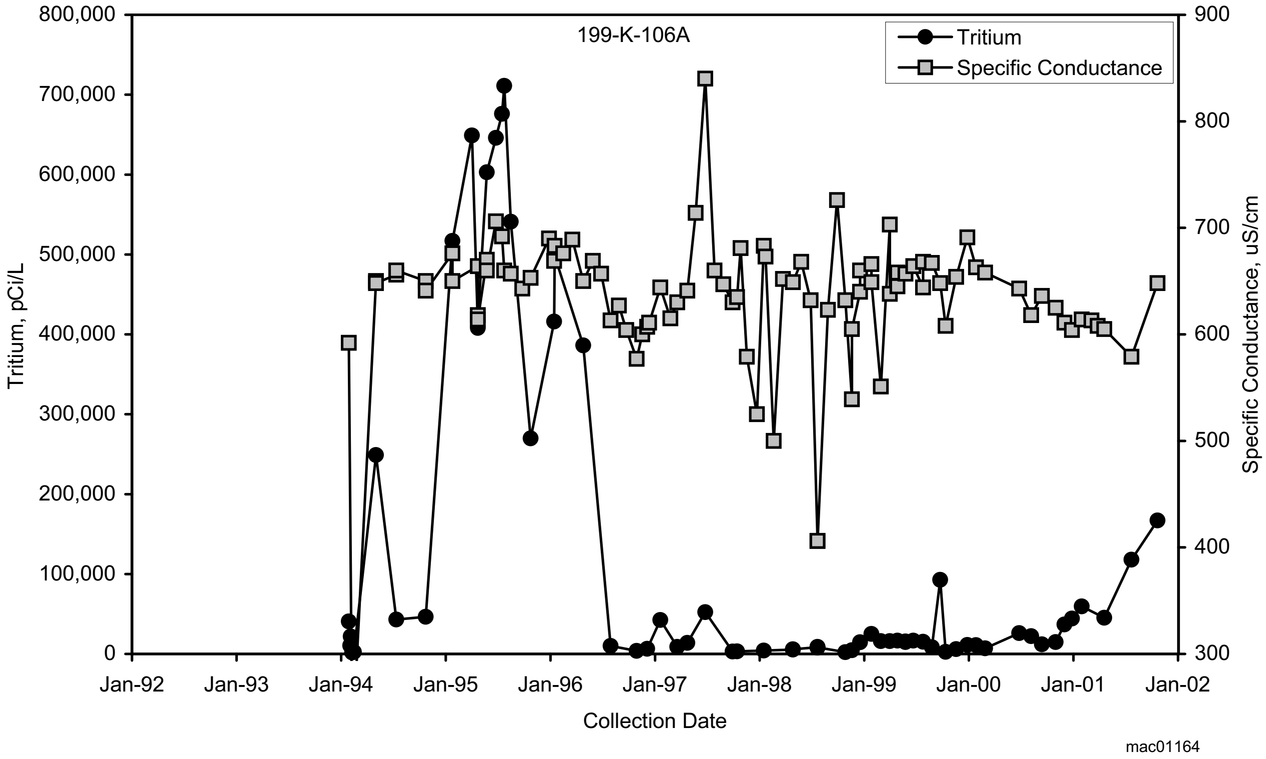


Figure 2.3-26. Tritium Concentrations and Specific Conductance Near the KW Condensate Crib

2.4 100 N Area

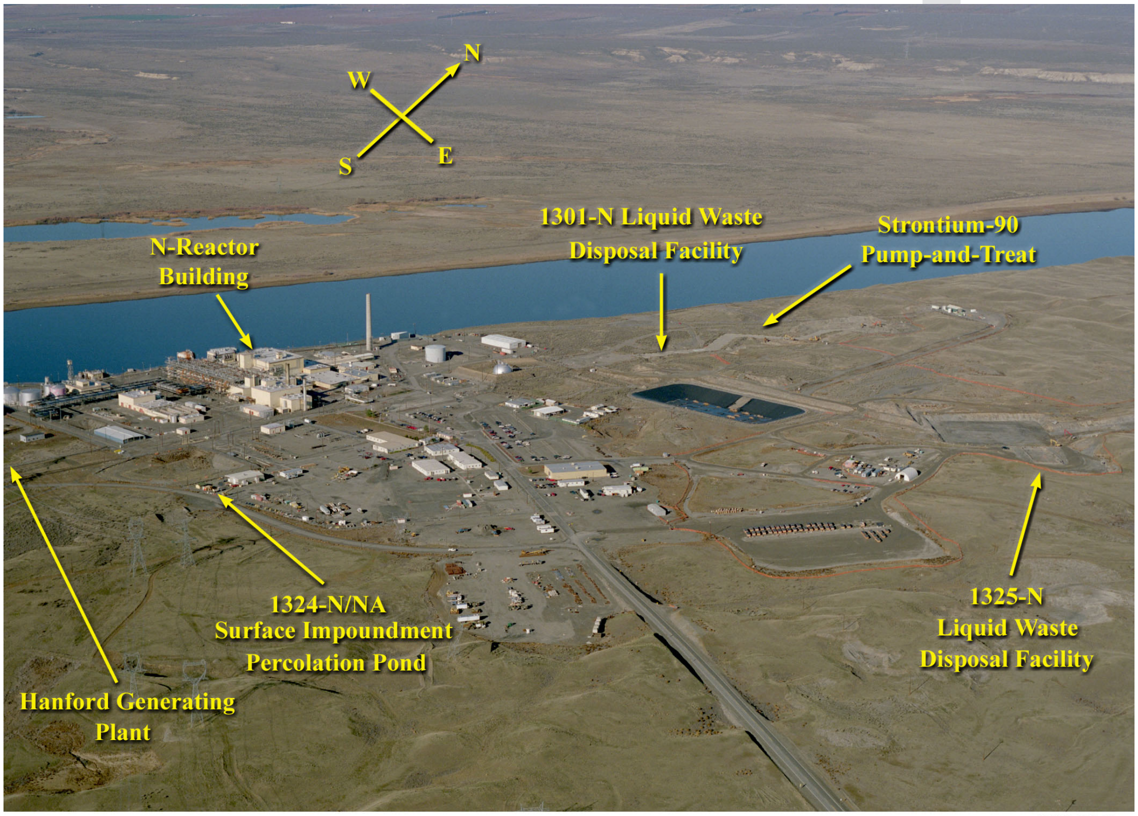
M. J. Hartman and W. J. McMahon

The 100 N Area contains a single reactor that operated from 1963 through 1987. The most significant groundwater contamination is associated with the 1301-N and 1325-N liquid waste disposal facilities (waste sites 116-N-1 and 116-N-3), which are being remediated. Other sources of contamination include the 1324-N/NA facilities (waste sites 120-N-1 and 120-N-2) and various spills or leaks of petroleum products. Waste sites and proposed corrective measures are described in DOE/RL-95-111 and DOE/RL-96-39. Facilities and well locations are shown in Figure 2.4-1.

Strontium-90 is the most significant groundwater contaminant in the 100 N Area. It has a relatively low mobility in the aquifer, and the general shape of the plume has not changed in many years.

2.4.1 Groundwater Flow

Groundwater generally flows to the north and northwest beneath the 100 N Area, toward the Columbia River (see Plate 1). When the stage of the Columbia River is high, the gradient beneath the 1301-N liquid waste disposal facility reverses, creating a potential for groundwater to flow toward the northeast, approximately parallel to the Columbia River. Estimated flow velocities in March 2001 ranged from 0.04 to 1.3 meters per day (see Appendix A, Table A.2). Movement of a peak in specific conductance at the 1325-N site in 1997 to 1999 indicated a flow velocity within the calculated range, 0.3 meter per day.



Aerial view of the 100 N Area, November 2001. In fiscal year 2001, the liner and pipelines were removed from the 1324-N surface impoundment. Soil samples indicate the site is clean and does not require excavation.

Below-normal precipitation in 2000 and 2001 resulted in low river stages, which in turn lowered water-table elevation in the 100 Areas. Well 199-N-2, located between the 1301-N trench and the river, showed decreasing water levels through fiscal years 2000 and 2001 with no seasonal peak in June as is typical for this well (Figure 2.4-2). The water level in September 2001 was the lowest on record in this well. Farther inland, water-table changes lag behind changes in river stage. Water levels in wells near the 1325-N and 1324-N/NA sites are still slightly higher than their minimum levels (1994), but are expected to decline further. Some wells near these facilities went dry in fiscal year 2001.

Monitoring Objectives in 100 N Area

Groundwater monitoring is conducted in the 100 N Area:

- triennially to annually to describe the nature and extent of contamination
- semiannually to detect the possible impact of three RCRA sites
- semiannually to monitor trends in variable constituents/wells
- quarterly to monitor potential effects of surface remediation and dust-control water application
- various time intervals to evaluate the performance of a pump-and treat system for strontium-90.

2.4.2 Strontium-90

Groundwater beneath the 1301-N and 1325-N facilities is contaminated with strontium-90 at levels far above the 1,000 pCi/L DOE derived concentration guide (Figure 2.4-3). Contamination is concentrated in an area between the 1301-N facility and the Columbia River where a pump-and treat system is operating. The contours of Figure 2.4-3 take into account the strontium-90 remaining in the treated water that is injected into wells 199-N-29 and 199-N-104A, near the 1325-N facility. The average strontium-90 concentration of the injected water in fiscal year 2001 was 356 pCi/L.

Although the general shape of the strontium-90 plume in the 100 N Area has remained relatively constant for more than 10 years, concentrations have increased in many parts of the plume (see Summary of this document or Section 2.5 of PNNL-13404). During the same period, concentrations decreased in some wells near the 1325-N facility and near the extraction wells. Factors that may have contributed to these changes include the following:

(a) Beneath the 1325-N facility, water levels dropped after effluent discharge ceased in 1991, leaving much of the strontium-90 above the water table. Therefore, strontium-90 concentrations in groundwater decreased.

(b) After effluent disposal ceased in 1991, groundwater with low specific conductance from effluent recharge was replaced with higher-conductance groundwater from upgradient locations. The calcium in the high-conductance groundwater exchanged for strontium on the sediment grains, thereby releasing the strontium (including strontium-90) to groundwater. This effect was most notable in wells near the 1325-N site as discussed below, but also was observed near the 1301-N facility.

(c) Near the Columbia River and the 1301-N facility, high river stage in 1996 and 1997 caused the water table to rise and mobilized strontium-90 that was formerly in the vadose zone. Thus, concentrations in groundwater increased.

(d) Extraction wells may be inducing flow from the Columbia River into the aquifer, creating a dilution effect.

Strontium-90 concentrations at 100 N Area vary with changing water-level elevations and ion exchange processes.

Groundwater is pumped from three extraction wells in the 1301-N strontium-90 plume: 199-N-75, 199-N-103A, and 199-N-106A. An additional well, 199-N-105A, is an alternate extraction well and was used for 3 months in fiscal year 2001. The performance of the pump-and-treat system is discussed in Section 2.4.11. Strontium-90 concentrations have varied greatly in the extraction wells since pumping began in 1995 (Figure 2.4-4). The highest concentrations are detected in the furthest north well, 199-N-106A. The relatively low values in well 199-N-103A are puzzling because the highest concentrations in monitoring wells are upgradient and downgradient of well 199-N-103A.

In fiscal year 2001, the highest strontium-90 concentration in the 100 N Area was 9,690 pCi/L in well 199-N-46, adjacent to the river (Figure 2.4-5). Well 199-N-67, closer to the 1301-N facility, had detected 18,000 to 24,000 pCi/L in recent years, but because of a low water table, the well could not be sampled in 2001.

Near the 1325-N facility, strontium-90 concentrations continued to decrease in well 199-N-81, with an annual average of 800 pCi/L (see Figure 2.4-5). Strontium-90 concentrations peaked at more than twice this level in 1997. The changes in concentration appear to be related to high-conductance groundwater from the 1324-N/NA site moving through the area and mobilizing strontium that was sorbed to sediment grains. Researchers investigated the potential for this type of chemical interaction in 1993 (see Appendix A of WHC-EP-0675) and concluded that ion exchange is the dominant adsorption mechanism for strontium-90 in 100 N Area sediment. With the influx of the higher-conductance groundwater, more calcium is available to exchange with strontium-90 on the sediment grains, thereby releasing the strontium-90 to solution. Trends for specific conductance and calcium are very similar to the strontium-90 trend, suggesting a correlation. Other chemicals associated with the 1324-N/NA site (sulfate, chloride) follow the same trend, supporting the idea that the high-conductance water originated beneath the 1324-N/NA site when flow directions were different than today (see Section 2.4.4 for a discussion of specific conductance and sulfate).

In general, the strontium-90 plume appears to be limited to the upper few meters of the aquifer. Wells 199-N-69 and 199-N-70, completed at the bottom of the upper unconfined aquifer, have no detectable strontium-90, though they are in the heart of the contaminant plume. Well 199-N-80, located near the 1301-N site and completed below a 5-meter-thick clay layer, also has shown undetectable or very low levels (<1 pCi/L) of strontium-90. The analytical laboratory reported a concentration of 2.9 pCi/L strontium-90 in a sample collected in September 2000. If correct, this would have represented a significant increase in concentration. However, the well was sampled in March and September 2001 and no strontium-90 was detected. The earlier detection is believed to be erroneous.

2.4.3 Tritium

The 1301-N and 1325-N facilities contaminated groundwater with tritium, which forms a plume at levels exceeding the 20,000 pCi/L drinking water standard (see Plate 2). The plume is shrinking, and concentrations are declining in most 100 N Area wells. The general decline is expected to continue because of plume dilution and radioactive decay. The core of the plume (i.e., the highest concentration) was formerly beneath the 1325-N facility and has migrated to the north and northwest. The highest concentrations of tritium currently are near the Columbia River. Tritium also is present in upgradient wells 199-N-74 and 199-N-52, but at levels below the drinking water standard. The upgradient tritium is believed to have been moved inland by mounding during 1325-N operations.

The tritium plume beneath the 100 N Area continued to shrink in fiscal year 2001 because of migration, dilution, and radioactive decay.

Unlike strontium-90, tritium concentrations are fairly constant with depth in the aquifer. Tritium concentrations in wells 199-N-69 and 199-N-70, completed at the base of the unconfined aquifer, are about the same as in nearby shallow wells. Concentrations are declining at about the same rate as in the shallow wells. Tritium is also elevated in well 199-N-80, monitoring a locally confined aquifer in the Ringold Formation (25,600 pCi/L and declining).

2.4.4 Sulfate and Specific Conductance

The 1324-NA percolation pond has added non-hazardous constituents, including sulfate and sodium, to groundwater, creating high specific conductance (>1,000 µS/cm). The plume extends to the north-northwest, presumably discharging to the Columbia River.

Specific conductance and sulfate are declining in wells near the 1324-NA pond. When high conductance waste was being discharged, sulfate concentrations were over 1,500 mg/L. The secondary drinking water standard is 250 mg/L. Sulfate and specific conductance in downgradient wells remain much higher than in upgradient well 199-N-71.

Most of the near-river wells within the high-conductance plume have declining specific conductance trends, with peaks between 1992 and 1996. However, specific conductance is still increasing at the northern end of the plume. The maximum value in the 100 N Area in fiscal year 2001 was in well 199-N-3, with an average of 1,600 µS/cm (Figure 2.4-6).

A plume of relatively high-conductance groundwater, which also originated from past discharges to the 1324-NA percolation pond, is passing beneath the 1325-N facility. The plume apparently passed the location of upgradient well 199-N-74 in the early 1990s (before the well was installed), and passed downgradient wells 199-N-81 and 199-N-41 in 1998 and 1999, respectively (Figure 2.4-7).

2.4.5 Nitrate

Nitrate concentrations declined in many wells in the 100 N Area in fiscal year 2001, but remained above background levels.

Nitrate exceeds the 45 mg/L maximum contaminant level in scattered portions of the 100 N Area, but the sources are unknown. Nitrate concentrations increased in many wells in the 100 N Area (and other 100 Areas) in the late 1990s, but the trends have reversed in most wells as demonstrated by results from well 199-N-72 (Figure 2.4-8).

The largest area of nitrate contamination is near the 1301-N facility, including wells 199-N-2, 199-N-3, and 199-N-105A. The highest concentration in fiscal year 2001 was 110 mg/L in well 199-N-2. Wells 199-N-26 and 199-N-56, southwest and northeast of N Reactor, respectively, also exceeded the maximum contaminant level in fiscal year 2001. Wells near the 1324-N/NA and 1325-N sites formerly exceeded the standard, but concentrations have decreased.

Several wells near an area contaminated with petroleum products have anomalous, low nitrate values. For example, nitrate has been historically below detection limits in well 199-N-18 and is highly variable in well 199-N-16 (Figure 2.4-9). This anomaly appears to be related to reducing conditions brought on by bacterial breakdown of the petroleum products.

2.4.6 Petroleum Products

Contamination from old leaks of petroleum products increased sharply in one well in the 100 N Area in fiscal year 2001.

Petroleum hydrocarbons increased suddenly in one well in the 100 N Area in fiscal year 2001. In September 2001, well 199-N-18, downgradient of the location of a large spill that occurred in 1966, contained 6,800 mg/L total petroleum hydrocarbons diesel range, 4,300 mg/L total petroleum hydrocarbons gasoline range, and 4,460 mg/L oil and grease. These are the highest levels of contamination detected since 1990 (WHC-EP-0258-2). Samplers noted a diesel odor and visible oil in every bailer trip while sampling the well. The reason for the increase is unknown and will be investigated in fiscal year 2002.

Groundwater chemistry in the petroleum-contaminated area suggests that bacterial degradation of the product is taking place, creating reducing conditions in the aquifer. Chemical reduction may explain anomalous, low nitrate and high iron and manganese concentrations in wells 199-N-16 and 199-N-18.

2.4.7 Chromium

Only one well in the 100 N Area consistently has chromium concentrations above the 100 μg/L maximum contaminant level. Well 199-N-80, which is completed in a thin, confined aquifer in the Ringold Formation, typically has chromium concentrations of ~170 μg/L. The source for chromium in this deep horizon is unknown. Chromium was disposed of in the 1301-N crib until the early 1970s, and it was identified as a contaminant of potential concern based on soil data (see Section 2.5 in DOE/RL-96-39). There are no chromium data from wells that monitored the facility in the early 1970s, and chromium was not detected in significant concentrations in wells near the crib in the 1980s. The presence of chromium in well 699-87-55, which is located east of the northern part of the 1325-N facility, illustrates the possible inland influence of past disposal from the 100 N or 100 D Areas.

2.4.8 RCRA Parameters for 1301-N and 1325-N Facilities

Monitoring for the *Resource Conservation and Recovery Act of 1976* (RCRA) in fiscal year 2001 indicated the 1301-N and 1325-N facilities are not contaminating groundwater with non-radioactive, hazardous constituents. Specific conductance and total organic carbon were elevated in some wells, but reflect contaminants from upgradient sources. Appendix A contains more information about these sites.

The 1301-N, 1324-N/NA, and 1325-N RCRA facilities do not appear to have contaminated groundwater with hazardous, non-radioactive constituents.

Specific conductance of groundwater near the 1301-N facility is affected by a plume of high-conductance groundwater from an upgradient source. The sample scheduled for September 2001 (collected October 1) from well 199-N-3 had an average conductance of 1,600 μS/cm, slightly below the critical mean value (see Figure 2.4-6). If the increasing trend continues, this parameter may exceed the critical mean value in fiscal year 2002.

In fiscal year 2000, well 199-N-3 also exceeded the critical mean value for total organic carbon, but concentrations dropped below the critical mean value in fiscal year 2001 (Figure 2.4-10). The contamination is believed to originate at the petroleum leakage site located nearby (see Section 2.4.6).

Specific conductance in 1325-N downgradient well 199-N-41 continued to exceed the critical mean value in March and September 2001. This well first exceeded the critical mean value in September 1999. The high specific conductance is believed to originate at an upgradient source (1324-N/NA facility), passed upgradient well 199-N-74 several years ago, and is declining (see Figure 2.4-7). Because the 1325-N facility is not the source, no assessment is required.

Groundwater at the 1301-N and 1325-N facilities also is analyzed for other constituents discharged to these facilities during their use. These analytes include cadmium, chromium, and nitrate (see Appendix A). Cadmium and chromium (in filtered samples) were not detected in significant concentrations in 1301-N or 1325-N downgradient wells. Nitrate was elevated in some of the downgradient wells, as discussed in Section 2.4.5, but the sources are unclear.

2.4.9 RCRA Parameters for 1324-N/NA Facilities

RCRA monitoring in fiscal year 2001 indicated the 1324-N/NA site has not contaminated groundwater with hazardous constituents. Since monitoring began in 1988, specific conductance has been elevated at this site primarily because of non-dangerous constituents that were present in the waste, such as sodium and sulfate. No additional assessment is required. Total organic carbon, total organic halides, and pH were all below the critical mean value in downgradient wells. Downgradient well 199-N-59 was dry in fiscal year 2001 because the river stage was low for 2 years and the well is relatively shallow. Appendix A contains more information about this site.

2.4.10 Plutonium

In summer 2001, researchers began a study on speciation of plutonium and other actinides in 100 N Area groundwater. Actinides are radioactive elements with atomic numbers 89 through 103, including uranium, plutonium, americium, and neptunium. The study includes the separation of plutonium into particulate, colloidal, and dissolved phases and the determination of redox states and isotopic composition in each fraction. Other objectives of the study are to: (a) characterize groundwater colloids to better understand transport mechanism for actinide-colloid complexes; (b) predict the rate of transport and fate of actinides in the groundwater of the 100 N Area using a three-phase (dissolved-colloid-particulate) model; and (c) test the impact of pumping rates on the formation of colloids and actinide concentrations and the impact of redox condition upon the actinide speciation.

Conventional analytical methods have not detected plutonium in 100 N Area groundwater. The methods used in this study can achieve ultra low detection limits.

This project is part of a joint effort between Woods Hole Oceanographic Institute and Pacific Northwest National Laboratory through the project "Speciation, Mobility and Fate of Actinides in the Groundwater at the Hanford Site" funded by the Environmental Management Science Program. Previous efforts have focused on the 100 K Area.

2.4.11 Groundwater Remediation at the 100-NR-2 Operable Unit

Extraction wells between the 1301-N facility and the Columbia River have created a hydraulic sink, reducing the amount of strontium-contaminated groundwater entering the river. However, the pump-and-treat system has not removed a significant quantity of strontium-90 mass. Since operations began in 1995, the pump-and-treat system has removed 1.1 curies of strontium-90 while ~10 curies of the estimated inventory have decayed naturally.

The pump-and-treat system at the 100-NR-2 Operable Unit, located along the 1301-N facility, is part of an expedited response action that began operating in 1995. An action memorandum (Ecology and EPA 1994) contains the following objectives that pertain to operation of the pump-and-treat system:

- reduce strontium-90 contaminant flux from the groundwater to the Columbia River
- evaluate commercially available treatment options for strontium-90
- provide data necessary to set demonstrable strontium-90 groundwater cleanup standards.

In September 1999, the U.S. Department of Energy (DOE), Washington State Department of Ecology, and the U.S. Environmental Protection Agency signed an interim record of decision for the 100-NR-1 and 100-NR-2 Operable Units (ROD 1999b). This record of decision specifies the selected remedy and activities for the

100-NR-2 Operable Unit, including continued operation of the pump-and-treat system with the objectives listed above.

The pump-and-treat system satisfied the remedial action objectives in fiscal year 2001, but has not affected the distribution or concentration of strontium-90 in the aquifer to any observable extent. The extraction wells create a hydraulic sink between the 1301-N facility and the Columbia River and, thus, reduce or reverse the hydraulic gradient in the groundwater toward the Columbia River. The reduction or reversal of the hydraulic gradient results in less groundwater and strontium-90 discharging to the Columbia River through the N Springs area. However, the pump-and-treat system is not capable of controlling the water discharged because of the cyclical river stage and bank storage effects of the Columbia River. A complete description of the progress and effectiveness of the remedial action is presented in DOE/RL-2001-04.

During fiscal year 2001, the pump-and-treat system extracted over 112 million liters of groundwater and removed ~0.2 curie of strontium-90 (Table 2.4-1). Combined, the extraction wells delivered an average concentration of 1,999 pCi/L to the treatment system during the fiscal year. After treatment, the effluent contained 356 pCi/L, which was returned to the aquifer through wells 199-N-29 and 199-N-104A.

The pump-and-treat system has not reduced the concentration of strontium-90 in the aquifer, nor has it removed a significant quantity of strontium-90 mass compared to the estimated existing inventory. The distribution of strontium-90 in the aquifer remained essentially unchanged in recent years.

Since operations began in 1995, the pump-and-treat system has removed 1.1 curies of strontium-90, compared to a total inventory in the aquifer estimated to exceed 75 curies. Assuming a starting inventory of 75 curies in September 1995, ~10 curies of the estimated inventory have decayed during this time. The pump-and-treat system's removal of strontium-90 is insignificant compared to radioactive decay. Current estimates indicate that it will take >300 years before the strontium-90 concentrations reach permissible levels (DOE/RL-95-110) as a result of radioactive decay. Considering the moderately high adsorption characteristic of strontium-90 and the fact that the plume geometry has remained virtually unchanged for several years, the contaminant may be essentially immobile in the aquifer, and there may be much less discharging into the river than previously estimated. For this reason, DOE is investigating and evaluating alternative remediation technologies.

2.4.12 Waste Site Remediation

The environmental restoration contractor continued excavating the 1325-N facility (waste site 116-N-3) in fiscal 2001 and will complete remediation in fiscal year 2002. The excavation reached a depth of ~4.6 meters. Soil samples were collected from the bottom of the excavation and results will be evaluated to determine whether contaminants remain. Water to control dust was applied as necessary to protect worker health. Application of water was held to a minimum to reduce the potential for mobilizing contaminants from the vadose zone to groundwater. Quarterly groundwater monitoring in well 199-N-81 for strontium-90 and gamma-emitting radionuclides indicated no increased mobilization.

The 1324-N surface impoundment (waste site 120-N-2) was also remediated in fiscal year 2001. The liner and pipelines were removed. Soil samples indicated the site is clean and does not require excavation.

2.4.13 Monitoring at River Shoreline

In fiscal year 2001, strontium-90 and tritium concentrations continued to exceed drinking water standards in wells near the Columbia River shore in the 100 N Area.

Water quality near the Columbia River in the 100 N Area is evaluated by sampling wells near the river (199-N-46, 199-N-92A, 199-N-96A, and 199-N-99A) and riverbank seepage. The sampling points are located on the shoreline downgradient of the 1301-N facility (see Figure 2.4-1). Table 2.4-2 lists constituents of interest for the 100 N Area for fiscal year 2001. The closest aquifer sampling tubes to the 100 N Area are located downstream, between 100 N and 100 D Areas. Aquifer tubes were not installed in the 100 N Area because of the availability of near-river wells and the presence of concrete rubble along the shoreline. Shoreline and river sampling is conducted annually in the fall.

2.4.13.1 Near-River Wells

Strontium-90 concentrations in samples from near-river wells are illustrated with the contaminant plume in Figure 2.4-3. In fiscal year 2001, concentrations ranged from undetected in well 199-N-92A (north of the main plume) to 9,690 pCi/L in well 199-N-46, within the plume.

The highest tritium concentration in fiscal year 2001 in a near-river well was 29,700 pCi/L in well 199-N-92A, a typical value for this well. These concentrations fit the overall distribution of tritium illustrated in Plate 2.

2.4.13.2 Riverbank Seepage

The Sitewide Environmental Surveillance Project collected a sample from one seep along the 100 N Area shoreline in October 2000 and May 2001 (see Table 2.4-2). The sample contained a low level of gross beta, no detectable strontium-90, but relatively high tritium (17,300 pCi/L) and nitrate. Low strontium-90 or gross beta and high tritium concentrations are typical for this seep, because it is located downstream of the main strontium-90 plume. Another seep located in the heart of the strontium-90 plume was not flowing in fiscal year 2001.

The Near-Facility Environmental Monitoring Program, which is mandated primarily by DOE orders, monitors 13 “seep wells” along the 100 N Area shoreline. These structures are metal casings installed in the gravel of the shoreline, designed to enable sampling of seep water. They are located in a section of shoreline approximately parallel to the 1301-N trench. Data from samples collected in October 2000 are listed in PNNL-13487. Results for tritium and strontium-90 are included in Table 2.4-2.

Water from four seep wells exceeded the drinking water standard for strontium-90. Two seep wells exceeded the derived concentration guide. These seeps are located adjacent to well 199-N-46, where the maximum strontium-90 concentration in 100 N Area was detected in fiscal year 2001.

Tritium concentrations in the seep wells were much lower than in the near-river wells or the seep discussed above. The highest tritium concentration in a seep well in fiscal year 2001 was 1,300 pCi/L. Tritium concentrations in most of the seep wells have declined two orders of magnitude since 1987.

Table 2.4-1. Summary of 100 N Area Pump-and-Treat Performance for Fiscal Year 2001

Well ID or Sample Location	Annual Average Flow Rate (L/min)	Total Volume Pumped (x 10^6 L)	Average Strontium-90 Concentration (pCi/L)	Strontium-90 Mass Removed (Ci)
199-N-75	37	14.4	480.5	NA
199-N-103A	54	26.4	230.8	NA
199-N-105A(a)	50	5.4	603.0	NA
199-N-106A	138	65.5	3,943	NA
N-Influent	188	112.5	1,999	0.2
N-Effluent	188	112.5	356	NA

(a) Backup extraction well; operated in place of well 199-N-75 from April 10 to July 9, 2001.
NA = Not analyzed.
Total strontium-90 removed since startup is ~1.1 curies; total remaining in aquifer estimated at 65 curies.

Table 2.4-2. Shoreline Monitoring Data for the 100 N Area, Fiscal Year 2001

Location Name	Sample From	Sample Date	Specific Conductance (μS/cm)	Chromium (μg/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Sulfate (mg/L)	Nitrate (mg/L)
199-N-46	Well	03/23/01	419	NA	9,690	NA	5,010	NA	NA
199-N-92A	Well	09/06/01	254	5.7(a)	0.58(a)	4.8(a)	29,100(a)	32(a)	17(a)
199-N-96A	Well	09/10/01	1,091	4.8 U	3.3	11.4	3,370	97	8.3
199-N-99A	Well	09/06/01	241	4.8 U	1,700	3,440	16,700	17	11
SN-NS8-13	Seep	10/17/00 05/04/01	326 343	11 12	0 U 0 U	5.9 3.7	17,700 17,300	55 NA	96 NA
RN-084 to RN-095	River	09/07/01	NA	NA	01-0.3	NA	NA	9.2-9.6	1.7-2.2
Y301	Seep well	10/01	NA	NA	8.3	NA	1,300	NA	NA
Y302	Seep well	10/01	NA	NA	1.1	NA	280	NA	NA
Y303	Seep well	10/01	NA	NA	1,300	NA	230(a)	NA	NA
Y304	Seep well	10/01	NA	NA	1,800	NA	280	NA	NA
Y305	Seep well	10/01	NA	NA	7.1	NA	200	NA	NA
Y306	Seep well	10/01	NA	NA	4.0	NA	200	NA	NA
Y307	Seep well	10/01	NA	NA	3.3	NA	300	NA	NA
Y308	Seep well	10/01	NA	NA	4.5	NA	240	NA	NA
Y309	Seep well	10/01	NA	NA	2.2	NA	190	NA	NA
Y310	Seep well	10/01	NA	NA	7.0	NA	240	NA	NA
Y311	Seep well	10/01	NA	NA	48	NA	400	NA	NA
Y312	Seep well	10/01	NA	NA	3.8	NA	370	NA	NA
Y313	Seep well	10/01	NA	NA	0.2	NA	250	NA	NA

Well = Monitoring well located adjacent to river.
NA = Not analyzed.
River = River water collected near the shore.
Seep = Natural riverbank seepage site.
Seep well = Metal casing in shoreline gravel; monitors seep water.
U = Below detection limit.
(a) Average of multiple measurements.
Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350 to 450 μS/cm.

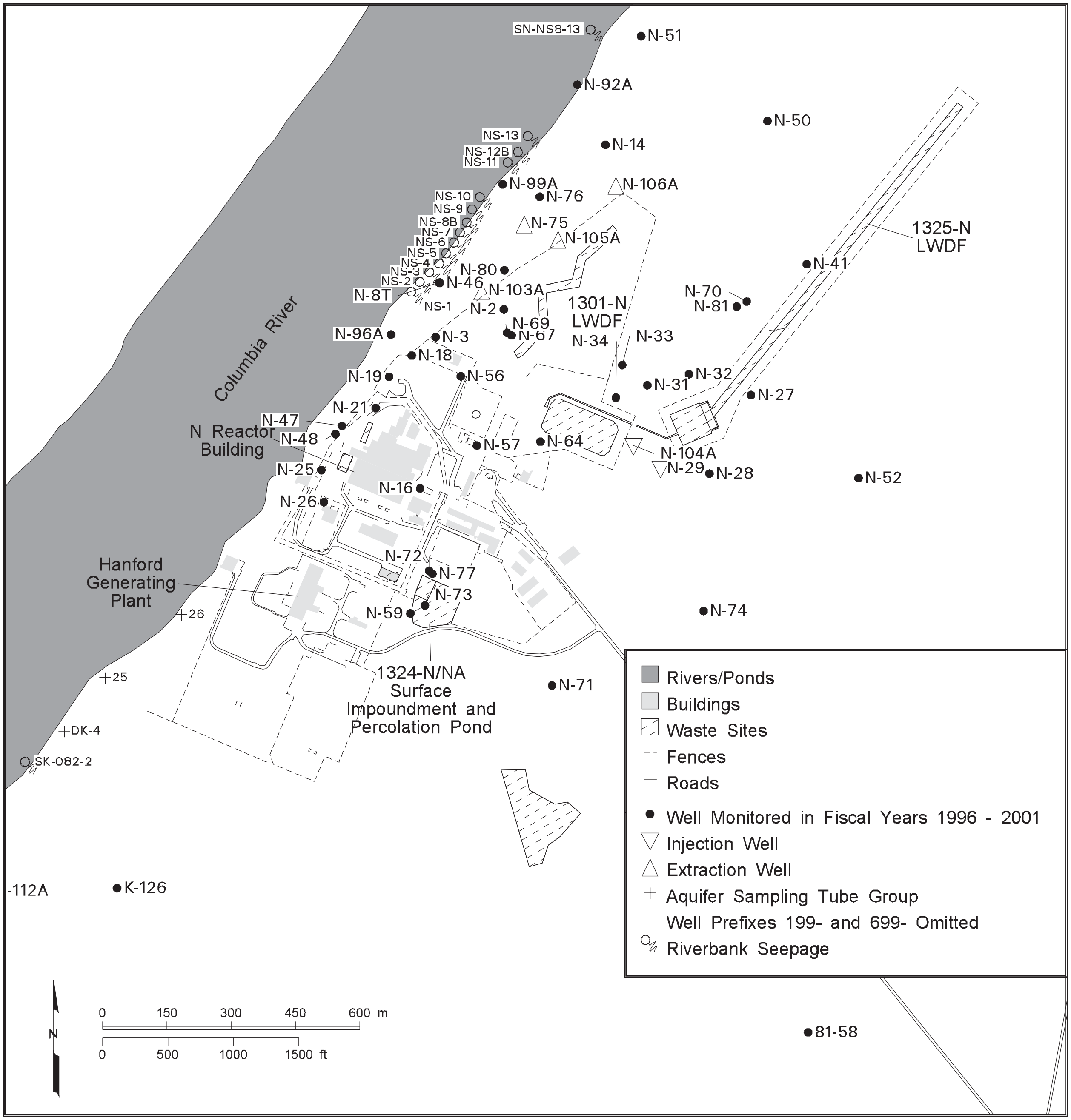


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Figure 2.4-1. Groundwater Monitoring Wells in the 100 N Area

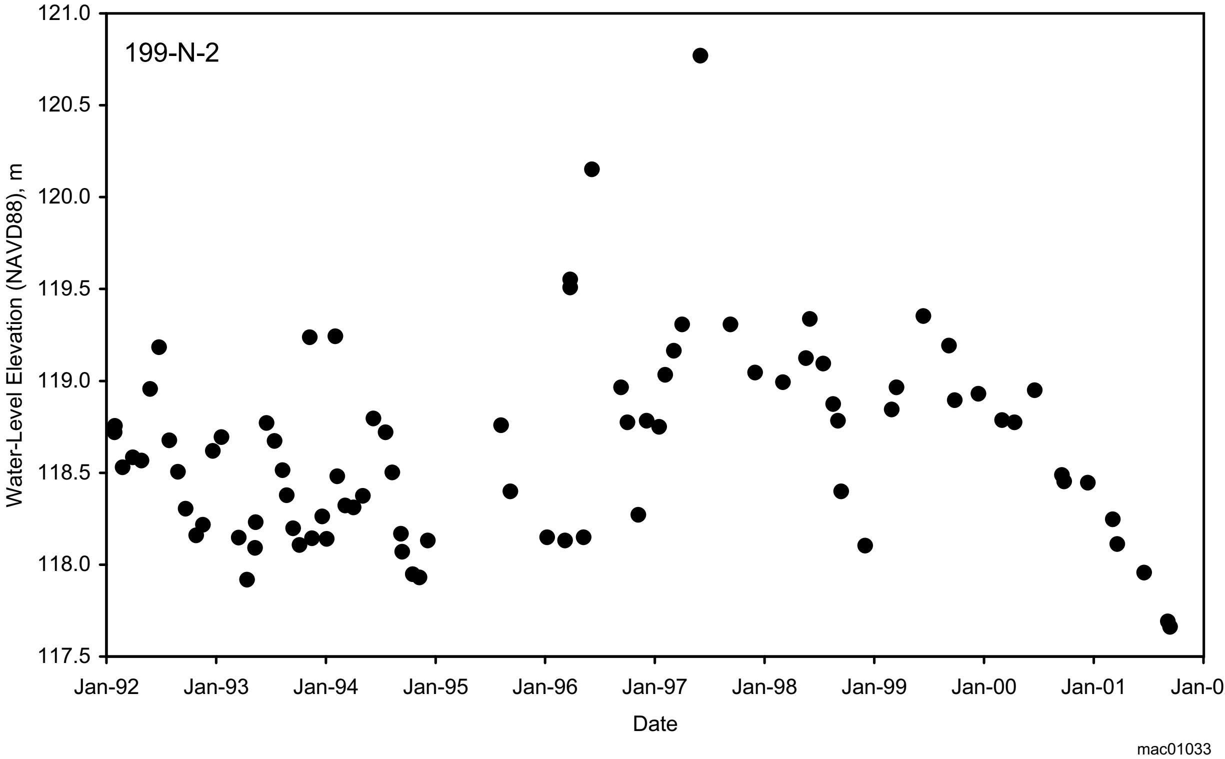

Figure 2.4-2. Water Level Between 1301-N Facility and the Columbia River

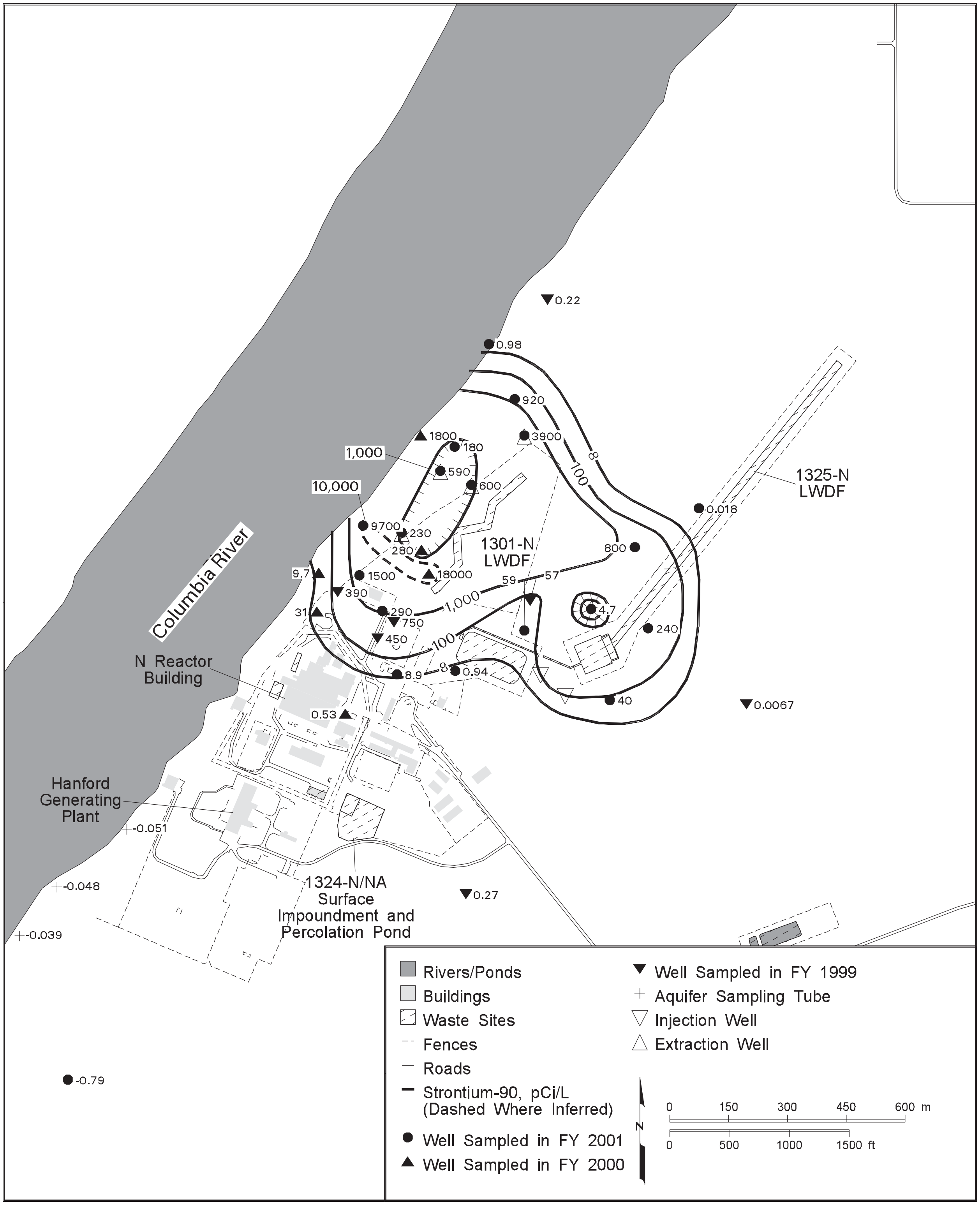

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Figure 2.4-3. Average Strontium-90 Concentrations in the 100 N Area, Top of Unconfined Aquifer

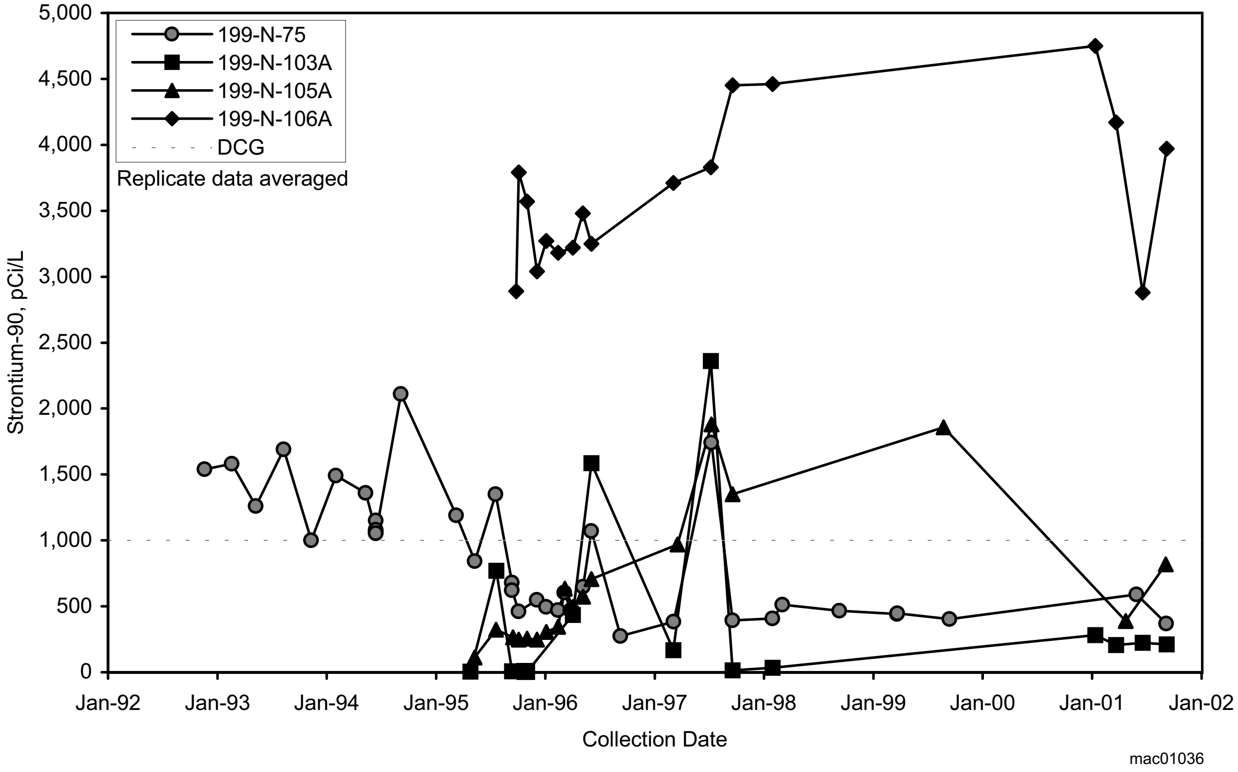
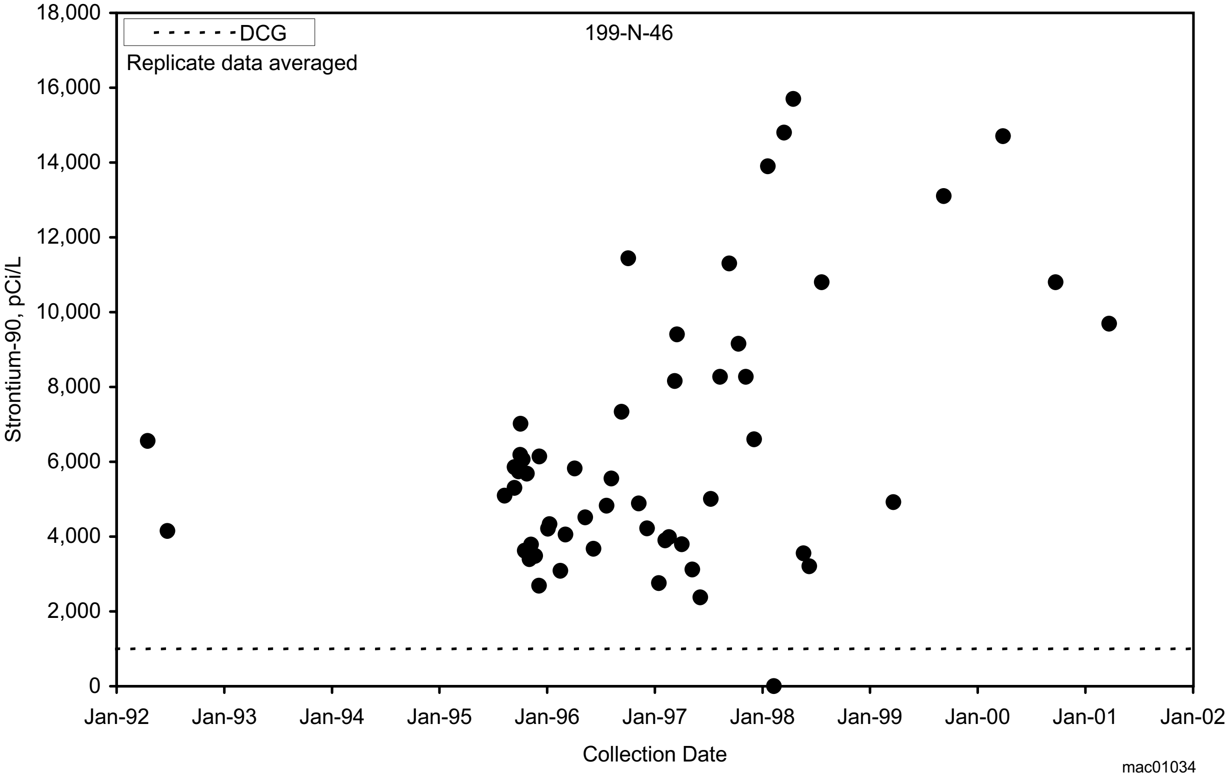


Figure 2.4-4. Strontium-90 Concentrations in 100 N Area Extraction Wells



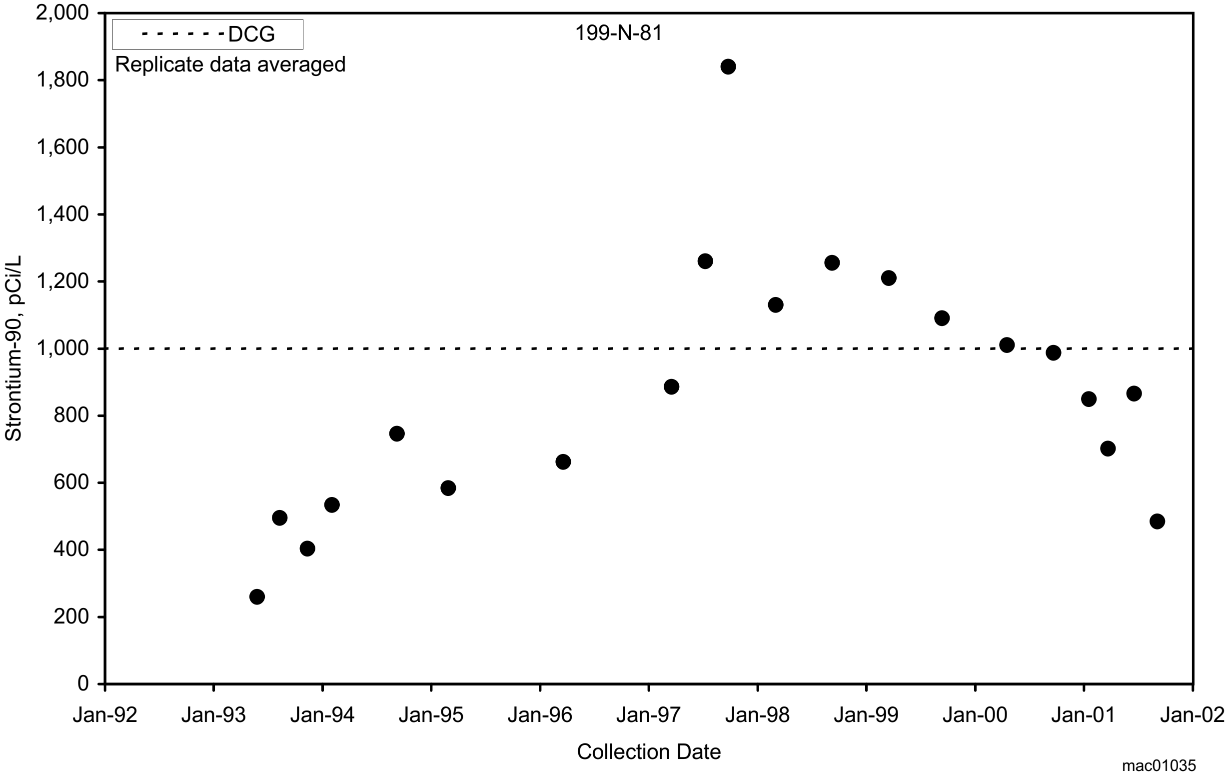


Figure 2.4-5. Strontium-90 Concentrations in Well 199-N-46 Near the 1301-N Facility and Well 199-N-81 Near the 1325-N Facility

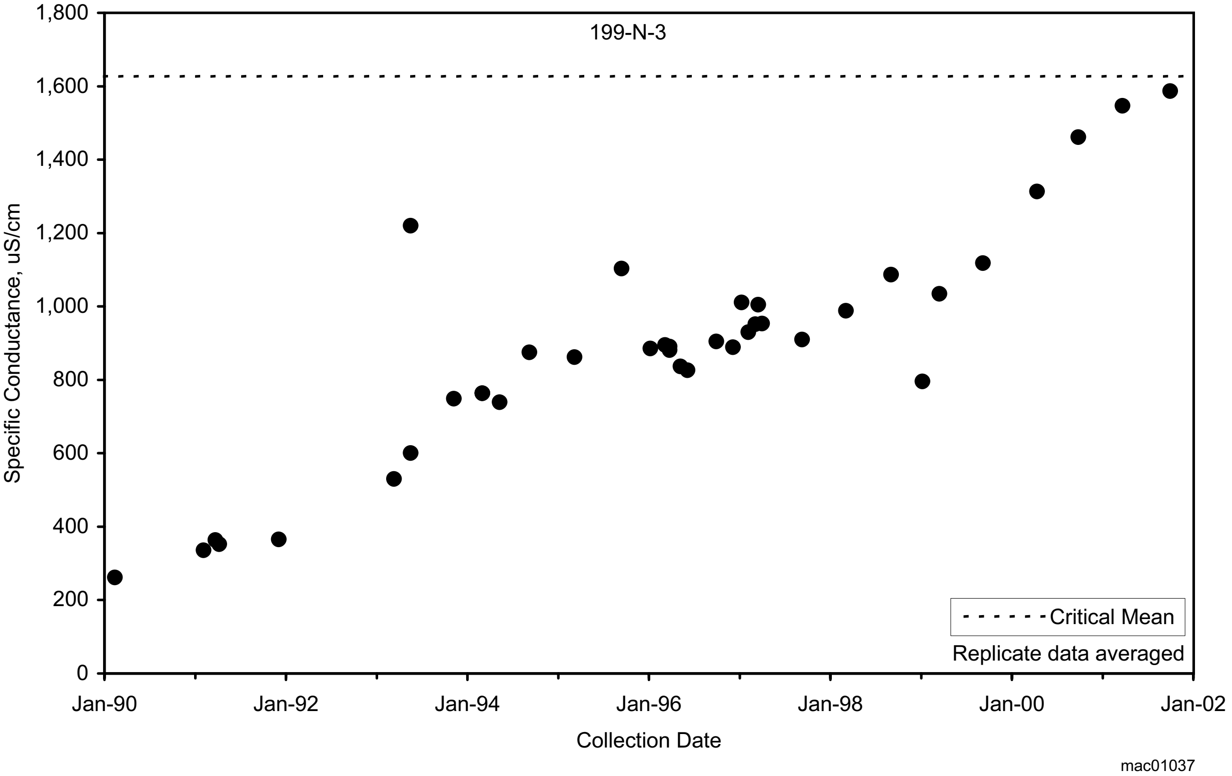


Figure 2.4-6. Specific Conductance Near the 1301-N Facility

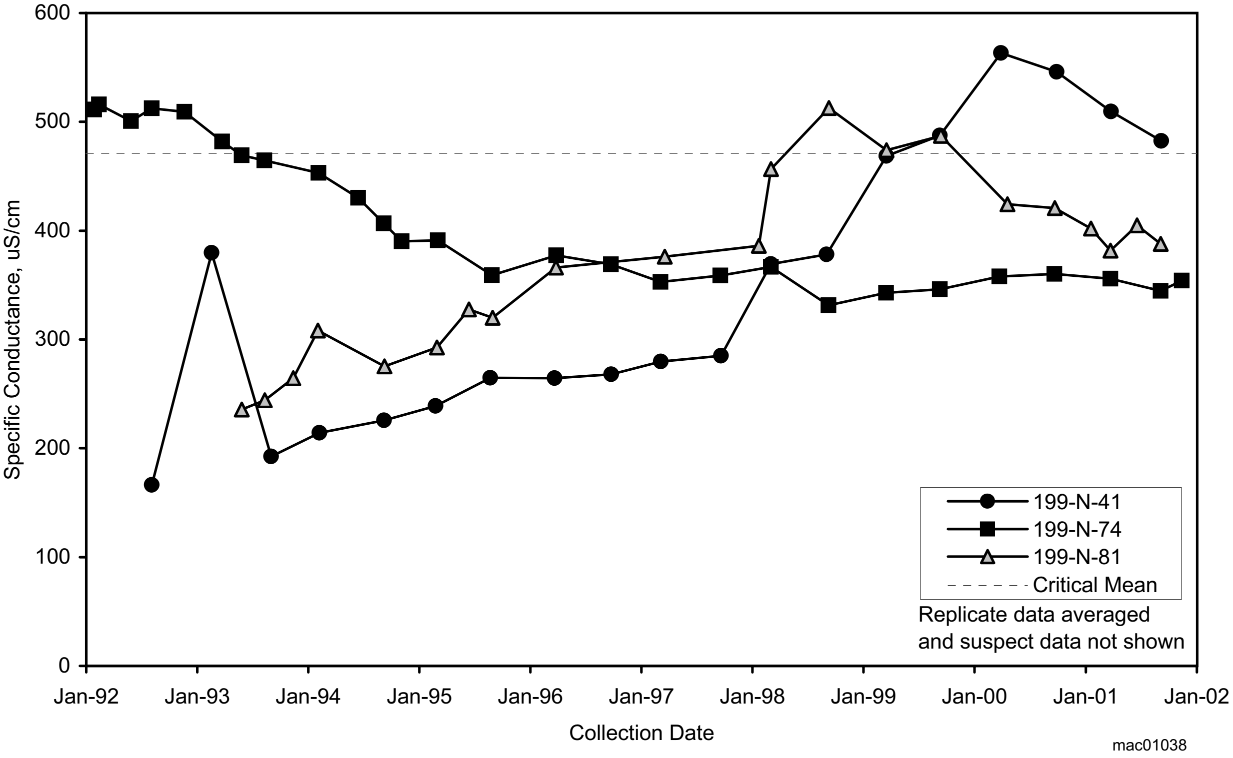


Figure 2.4-7. Specific Conductance in Wells Near the 1325-N Facility

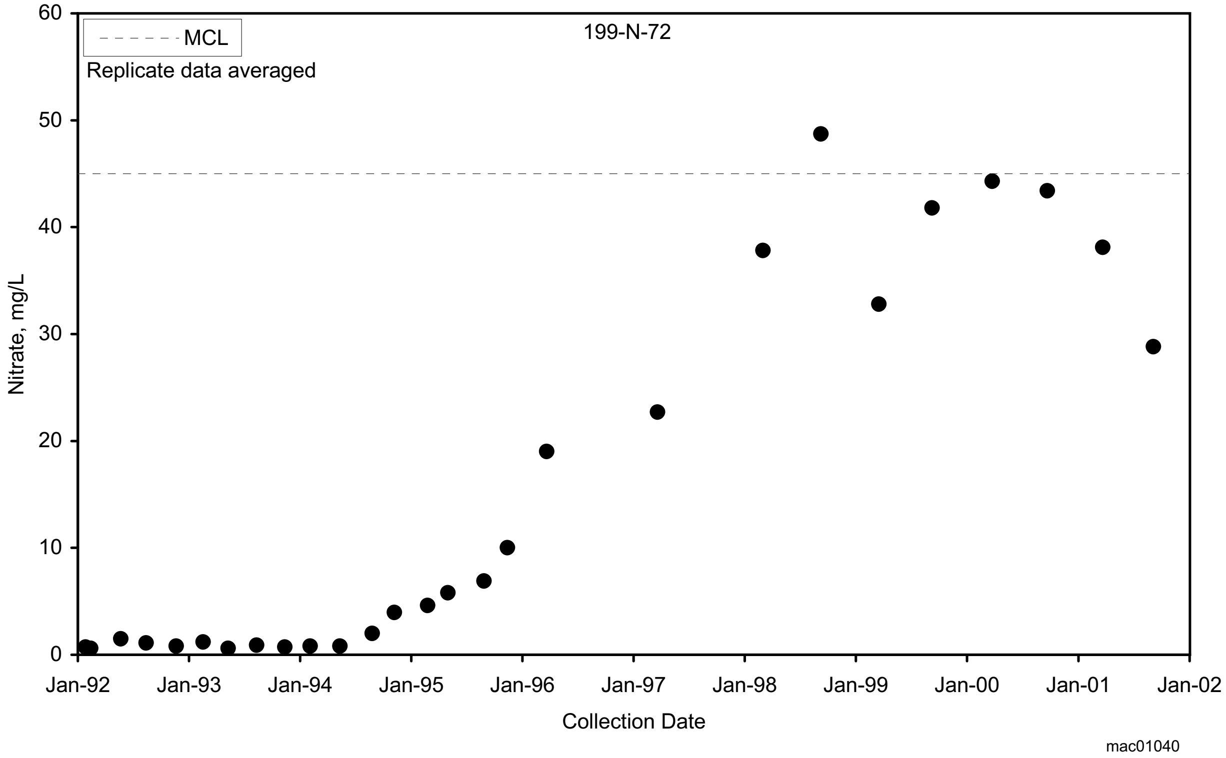


Figure 2.4-8. Nitrate Concentrations Near the 1324-NA Percolation Pond

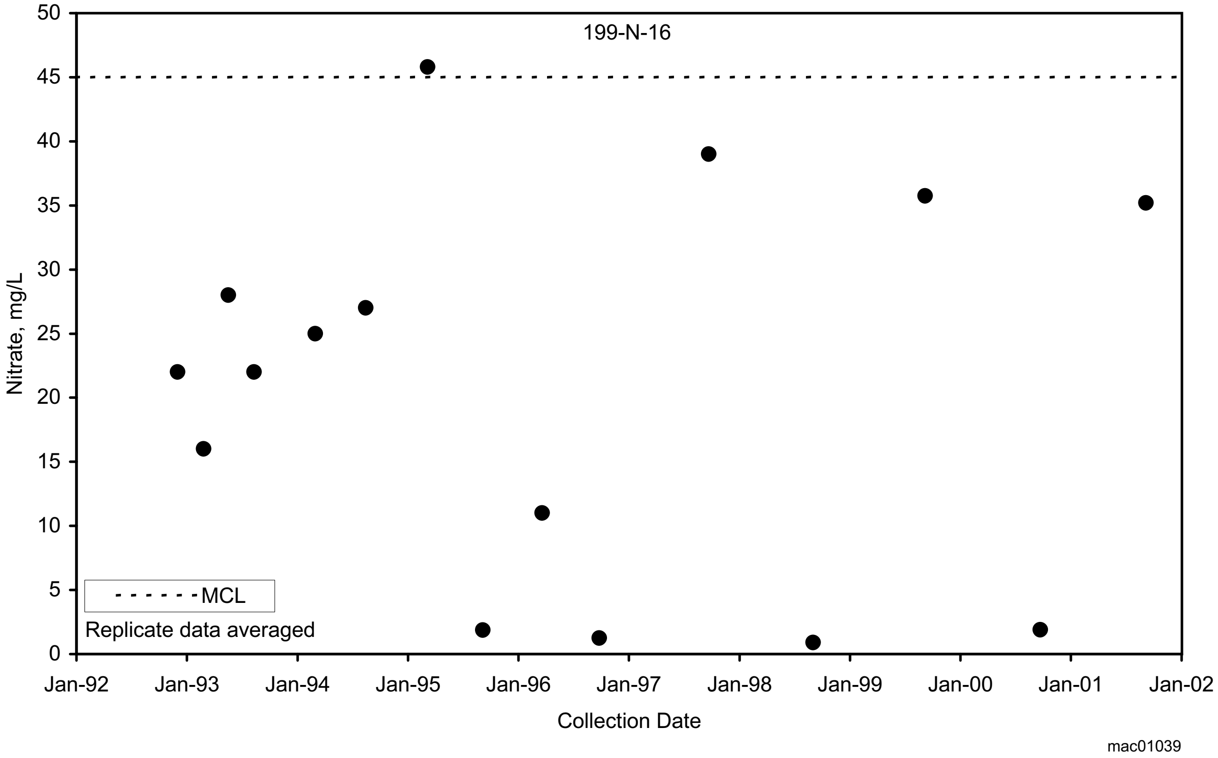


Figure 2.4-9. Nitrate Concentrations Near N Reactor

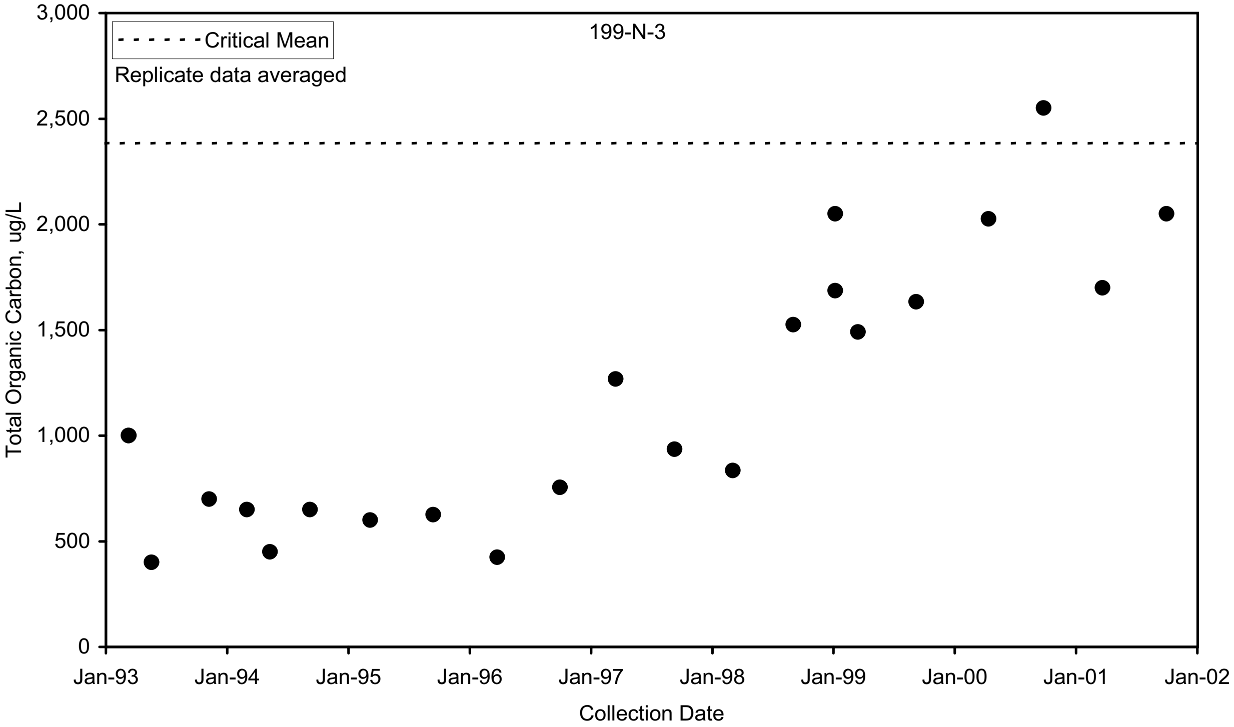


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Figure 2.4-10. Total Organic Carbon Near the 1301-N Facility

2.5 100 D Area

M. J. Hartman, W. J. McMahon, and C. W. Miller

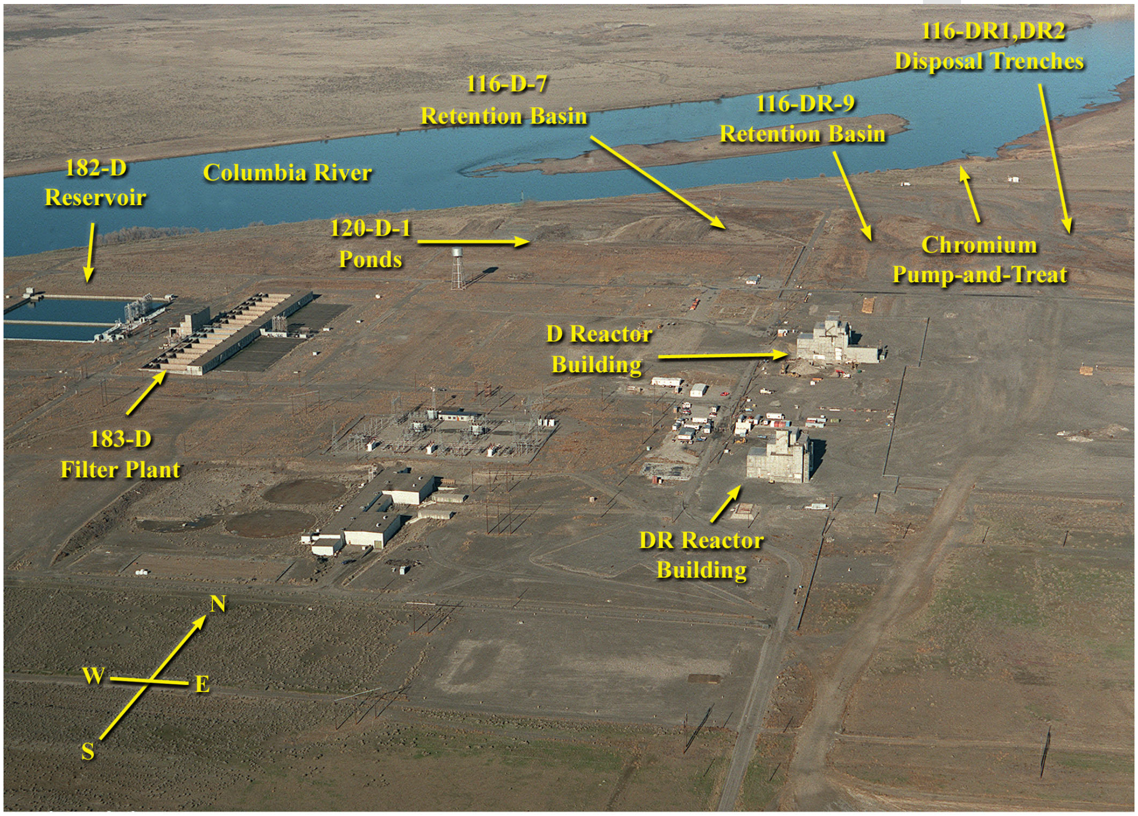
Hexavalent chromium is the contaminant of greatest concern in the 100 D Area. Two remediation systems help reduce the amount of chromium entering the Columbia River: a pump-and-treat system in the northern 100 D Area and in situ remediation in the southwestern 100 D Area.

The 100 D Area contains two former plutonium production reactors. D Reactor operated between 1944 and 1967 and DR Reactor between 1950 and 1964. Descriptions of operations and associated hazardous waste sites for the 100 D Area are presented in WHC-SD-EN-TI-181. Locations of former waste sites and monitoring wells are shown in Figures 2.5-1 and 2.5-2.

Chromium-contaminated groundwater at the 100 D Area flows into the Columbia River where it is a potential threat to some aquatic wildlife. The chromium-contaminated groundwater is believed to well up through the adjacent riverbed gravel used by salmon for spawning habitat. Two interim remedial actions operate to reduce the amount of chromium entering the Columbia River at 100 D Area. A pump-and-treat system is active in the northern 100 D Area near the former retention basins, and an in situ reduction oxidation (redox) manipulation site is being expanded in the southwestern 100 D Area.

2.5.1 Groundwater Flow

A groundwater flow divide bisects the 100 D Area, with flow toward the north and northwest in the western part of the area, and flow to the northeast (across



Aerial view of the 100 D Area, November 2001. During fiscal year 2001, the pump-and-treat system extracted ~106 million liters of groundwater, removing ~27 kilograms of chromium. In addition, an in situ redox technique is successfully immobilizing some of the chromium in groundwater beneath this site.

the horn of the Hanford Site) in the east (see Plate 1). The location of this divide appears to vary somewhat with river stage.

In the central and northern 100 D Area (from D Reactor building to the retention basins), flow is primarily to the north. The gradient in this area was 0.0016 in March 2001. Extraction wells 199-D8-53 and 199-D8-54A have created a local depression in the water table, inducing radial flow toward these wells.

Monitoring Objectives in 100 D Area

Groundwater monitoring is conducted in the 100 D Area:

- triennially to annually to describe the nature and extent of contamination
- semiannually to monitor trends in variable constituents/wells
- quarterly to characterize chromium and sulfate distribution
- quarterly to evaluate the performance of in situ remediation of chromium
- various time intervals to evaluate the performance of a pump-and treat system for chromium.

In the southwestern portion of 100 D Area, near the redox site, the direction of groundwater flow generally is toward the northwest, approximately perpendicular to the Columbia River. The environmental restoration contractor evaluated water levels in wells in this area using a three point solution to estimate changes in apparent groundwater flow direction in fiscal year 2001. These evaluations indicated that the direction of groundwater flow varied over a range of ~90 degrees. The variations appear to be related to river stage.

Two sets of wells were selected for the analysis. All of these wells were equipped with pressure transducers and data loggers to record changes in groundwater surface elevation. Wells 199-D4-20, 199-D4-38, and 199-D5-38 were selected to represent the groundwater flow between the permeable treatment barrier and the Columbia River. Wells 199-D4-20, 199-D5-38, and 199-D5-43 were selected to represent conditions inland of the permeable reactive barrier (see well locations in Figures 2.5-1 and 2.5-2).

The flow direction analysis indicated that the groundwater flow direction deviated from a direction perpendicular to the Columbia River for most of fiscal year 2001 (Figure 2.5-3). From late October 2000 to mid-May 2001, the direction of groundwater flow deviated to the west of perpendicular. The maximum deviations were 22 degrees and 68 degrees from perpendicular for the near-river and inland well sets, respectively. From late May 2001 to mid-August 2001, the direction of groundwater flow deviated to the east of perpendicular with maximum deviations of 10 degrees and 22 degrees for the near-river and inland well sets, respectively.

2.5.2 Chromium

In 100 D Area groundwater, chromium is distributed in two plumes that appear to be merging: a northern plume with sources near the former D Reactor and a southwestern plume with a source near the former 183-DR water treatment facility (Figure 2.5-4). The area of low chromium concentrations between the plumes is believed to be a result of leakage of clean water from the 182-D reservoir, which created an area of dilution and perhaps a groundwater mound. Until 1994, recharge from 120-D-1 ponds also kept contaminant concentrations low. The 182-D reservoir has been in use almost continually since 1947 to store raw process water pumped from the Columbia River. In 1995, it was drained, repaired, and refilled. Changes in the distribution of chromium and other constituents (nitrate, sulfate, specific conductance) suggest that a lower rate of leakage after the repairs is allowing the northern and southwestern plumes to move into this clean area.

Chromium concentrations in wells near the Columbia River increase when the river stage is low and decrease when the river is high. Concentrations in the northern 100 D Area do not show any clear overall trend over the past 3 years.

2.5.2.1 Northern Chromium Plume

Cribs and trenches near the D Reactor building were the primary sources for a chromium plume that extends northward toward the river (see Figure 2.5-4). The former retention basins and disposal trenches in the north also were contaminant sources. The southwestern boundary of the plume has expanded in the past 2 years, and concentrations increased in wells 199-D5-37 and 199-D5-41. The center of this plume, with concentrations >500 µg/L, is moving downgradient (north and northwest) and reached well 199-D5-13 in fiscal year 2001. Concentrations near the reactor building decreased.

A pump-and-treat system in the northern 100 D Area removes chromium-contaminated groundwater to prevent it from reaching the Columbia River (see Section 2.5.6.1). Most years, chromium concentrations vary seasonally, as shown for compliance monitoring wells in Figure 2.5-5. The highest concentrations generally are measured during the late fall and winter months, when the river stage is lowest. The lowest concentrations typically are measured in late spring and early summer months when runoff caused by snow melt drains through the Columbia River and its tributaries. However, drought conditions in 2001 resulted in a lower river stage for the reporting period and the typical seasonal variations in chromium concentrations did not occur. For example, the hexavalent chromium concentrations measured in well 199-D8-68 in June and November 2001 were 274 and 382 µg/L, respectively. By comparison, the hexavalent chromium concentrations measured in well 199-D8-68 in June and September 1999 were 21 and 323 µg/L, respectively. Wells 199-D8-69 and 199-D8-70 also displayed a much more limited range in hexavalent chromium concentrations during fiscal year 2001 compared to fiscal year 2000.

Chromium concentrations in the extraction wells also fluctuate with river stage (Figure 2.5-6). The start of pump-and-treat operations coincided with the second consecutive flood stage years in the Columbia River during 1996 and 1997, and chromium concentrations were low during those years. Chromium concentrations increased in 1998 and were higher during fiscal year 2001 than in fiscal years 1999 and 2000.

2.5.2.2 Southwestern Chromium Plume

The chromium plume in the southwestern 100 D Area is oriented perpendicular to the Columbia River (see Figure 2.5-4). Researchers have been unable to identify the source of this plume with certainty. It may have been the former 183-DR water treatment facility, where sodium dichromate was added to the water as a corrosion inhibitor. Another possible source is a former transfer station where chromate stock solutions were unloaded from railcars and piped to the water treatment facilities. The transfer station was located north of the 183-DR facility. Characterization in these areas failed to locate areas of high chromium contamination in the vadose zone (PNNL-13486; PNNL-13107).

Over the past three years, the southwestern chromium plume appears to have expanded toward the north. Concentrations increased in northern wells and decreased or remained essentially unchanged in southern wells. The most dramatic change was a sharp increase in concentrations in well 199-D5-39 (Figure 2.5-7). The concentration in this well in August 2001 was 4,750 µg/L, which is higher than any concentration previously measured in this plume. The change was accompanied by increases in concentration of all the major ions except sulfate, which is highly variable in this well. The recent changes may be related to the decrease in artificial recharge from the water reservoir, as discussed above.

Chromium concentrations increased sharply in a well in the southwestern 100 D Area, to over 4,000 µg/L the highest level observed in groundwater on the Hanford Site. The plume is the target of an in situ remediation technique.

A groundwater cleanup technique called in situ redox manipulation is being used to remediate the southwestern chromium plume (see Section 2.5.6.2). A chemical solution injected into the aquifer alters sediment chemistry and forms a permeable reactive barrier. As groundwater naturally flows through the barrier, chromium is immobilized. The technique was tested in fiscal years 1997 through 1999, using five injection wells, and was expanded fiscal years 2000 and 2001. Figure 2.5-8 shows the influence of the in situ treatment on the chromium plume near the redox site in August 2001, after a series of new dithionite injection/withdrawals. Chromium concentrations are low along the line of active injection wells, and the effect extends farther downgradient of the center of the barrier, where initial injections occurred.

Wells within the initial reactive barrier (e.g., well 199-D4-7 in Figure 2.5-8) showed sharp declines in chromium concentration after injections in 1997 and 1998. There was an increase in chromium in well 199-D4-7 and some of the other wells in the barrier between September 2000 and May 2001. The increase may have been caused by changes in flow direction, variations in groundwater velocity, heterogeneity of the distribution of reduced sediments within the aquifer, or the effects of air rotary drilling nearby. The environmental restoration contractor prepared a mitigation plan to evaluate potential causes of the increased chromium in these wells and to identify potential responses if the observed conditions are found to decrease the longevity of the barrier.

The redox manipulation technique has decreased the concentration of chromium in groundwater in a portion of the southwestern 100 D Area. Decreases in the concentrations of dissolved oxygen and nitrate have also occurred.

Effects of the chromium reduction reached wells 199-D4-23, 199-D4-38, and 199-D4-39, located downgradient of the barrier (see Figure 2.5-8). All of the wells showed decreases in chromium concentrations in fiscal years 2000 or 2001. Although chromium rebounded in well 199-D4-39 in August 2001, the overall decrease is expected to continue as the influence of the more recent injection/withdrawals moves downgradient.

Other effects of the redox technique on groundwater chemistry include decreases in dissolved oxygen and nitrate, and increases in aluminum, iron, manganese, nitrite, and sulfate. Although iron and manganese are elevated in the treatment zone, they are not expected to be mobile downgradient from the zone because they will re-oxidize and become immobile once they contact untreated sediment. Chromium, however, cannot be re-oxidized to its hexavalent state in the natural oxidizing conditions at the 100 D Area. Increased sulfate in groundwater downgradient of the barrier is a result of incomplete recovery of the reaction products following the reduction treatment.

The presence of chromium in well 699-87-55, located south of the 100 D Area is puzzling. Contamination may have moved south from the 100 D Area in the 1960s and 1970s when a prominent groundwater mound was present beneath the retention basins. Concentrations are lower in 600 Area wells east of the 100 D Area.

2.5.3 Nitrate

Nitrate is widely distributed in the 100 D Area at concentrations exceeding the 45 mg/L maximum contaminant level. Nitrate concentrations decreased in most wells since fiscal year 2000, but long-term trends are variable.

Like chromium, nitrate concentrations are low in the central 100 D Area, especially downgradient of the 182-D water reservoir. Nitrate also is low downgradient of the redox site as a result of treatment.

2.5.4 Tritium

Tritium is above background levels in some 100 D Area wells, but concentrations were below the drinking water standard in fiscal year 2001. Many of the wells in the central 100 D Area continued to have low tritium concentrations (see Plate 2) as a result of the influence of the Columbia River and artificial recharge with fresh water. Tritium in the southwestern 100 D Area may have migrated from the 100 N Area.

2.5.5 Strontium-90

Until its decommissioning in 1999, well 199-D5-12 near D Reactor consistently had elevated strontium-90 (~30 pCi/L). The contamination presumably was related to past disposal of radionuclide-bearing effluent from the D Reactor fuel storage basin to cribs located nearby. The contamination is not widespread; nearby well 199-D5-15 detected a low level of strontium-90 in fiscal year 2001 (2.3 pCi/L) and no strontium-90 was detected in well 199-D5-16.

In the northern 100 D Area, strontium-90 concentrations are above background levels in several wells near the pump-and-treat system but are below the 8-pCi/L drinking water standard with one exception. Samples from the pump-and-treat extraction wells 199-D8-53 and 199-D8-54A contain strontium-90 at concentrations slightly below the 8-pCi/L drinking water standard, and well 199-D8-68 has shown widely variable strontium-90 concentrations that exceeded the drinking water standard in fiscal year 2001 (Figure 2.5-9).

2.5.6 Groundwater Remediation at the 100-HR-3 (D) Operable Unit

Two interim actions for groundwater remediation are underway in the 100 D Area to reduce the amount of hexavalent chromium entering the Columbia River: (1) a pump-and-treat system in the northern 100 D Area, and (2) an in situ treatment system in the southwestern 100 D Area.

2.5.6.1 Pump-and-Treat System

A pump-and-treat system operates in the 100 D Area as part of an interim action for the 100-HR-3 Operable Unit, primarily to protect aquatic receptors in the river bottom substrate by reducing the discharge of chromium to the Columbia River. The system is located north of the former 116-D-7 and 116-DR-9 retention basins and began operating in July 1997. Groundwater is pumped from extraction wells 199-D8-53 and 199-D8-54A, then is piped to the 100 H Area, where it is treated and injected.

During fiscal year 2001, the pump-and-treat system removed ~27 kilograms of chromium from 100 D Area groundwater. The system will continue operating until a final remedy is determined or until the concentration of hexavalent chromium is below 22 µg/L and appears stable.

Interim Remedial Action Objectives

The record of decision (ROD 1996b) contains the following specific remedial action objectives:

- 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 record of decision stipulates that the pump-and-treat system continue operating until the selection of the final remedy, or when the U.S. Environmental Protection Agency and Washington State Department of Ecology are satisfied that termination (or intermittent operation) is appropriate. The system may be shut down when the concentration of hexavalent chromium is below 22 µg/L in the compliance wells (199-D8-68, 199-D8-69, and 199-D8-70), and the data indicate that the concentration will remain low. Other criteria for terminating pump-and-treat operations include the effectiveness of the treatment technology does not justify continued operation or an alternative and superior treatment technique becomes available (ROD 1996b).

Remediation Progress During Fiscal Year 2001

The pump-and-treat system made progress toward achieving the remedial action objectives in 100 D Area during fiscal year 2001. Groundwater that flows beneath the most significant waste sites in this area (retention basins, trenches, and cribs) is prevented from reaching the Columbia River. A complete description of the progress and effectiveness of the remedial action is presented in DOE/RL-2001-04.

Although designed primarily to prevent or reduce the amount of contaminated groundwater discharging into the Columbia River, the pump-and-treat system also is reducing overall contamination in the operable unit by the process of contaminant mass removal. The pump-and-treat program collects hydraulic monitoring data, contaminant monitoring data, and treatment system operation data to assess performance of the treatment system and to provide the basis for selecting the final remedy as part of the record of decision.

Scientists are evaluating methods to improve the pump-and-treat system because the current process may take years to achieve the remediation objectives.

During fiscal year 2001, the pump-and-treat system in 100 D Area extracted ~106 million liters of groundwater, removing ~27 kilograms of chromium (Table 2.5-1). The withdrawn water was sent to the 100 H Area, where it was treated and injected into the aquifer. A total of ~97 kilograms of hexavalent chromium has been removed from the plume targeted for interim action since startup of the pump-and-treat system in July 1997. This is in addition to the ~30 kilograms removed earlier by the pilot test conducted between August 1992 and August 1994 (DOE/RL-95-83). An estimate for the total amount of chromium in the plume suggests a mass of 590 kilograms (DOE/RL-94-95). This estimate was prepared before the discovery of chromium in the southwestern 100 D Area. Uncertainty in this estimate is associated primarily with the sparse distribution of monitoring wells and the lack of data on the vertical distribution of chromium in the aquifer. The value should be viewed as an order-of-magnitude estimate.

Influence on Aquifer Conditions

Chromium trends in compliance and extraction monitoring wells were discussed in Section 2.5.1.2 and illustrated in Figures 2.5-5 and 2.5-6. Because the concentration of chromium shows a cyclical pattern, an overall trend in concentration over the last 4 years is difficult to identify. The concentration has declined below 22 μg/L in the extraction and compliance wells several times since 1996, during summers when the river stage was high. However, the concentration of chromium rebounded above the action level by the following September as river stage declined. No seasonal drop in chromium concentrations was observed during summer 2001 because river stage remained low. Because of the recurring elevated concentration of chromium in the compliance wells, the annual summary report (DOE/RL-2001-04) recommended continued operation of the pump-and-treat system. Contaminant data indicate that many years of pumping may be required before the remedial action objectives have been entirely satisfied. Planning is currently underway to evaluate methods of improving system performance and reducing the amount of time needed to achieve the remedial action objectives.

2.5.6.2 In Situ Redox Manipulation

The amended record of decision for the 100-HR-3 Operable Unit includes use of the in situ redox manipulation technique for interim remediation of groundwater (ROD 1999b). The technique was tested in the 100 D Area in 1997 through 1999 and expanded in fiscal years 2000 and 2001. The redox system creates a permeable reactive barrier in the aquifer by reducing the ferric iron to ferrous iron on the surfaces of sediment grains and within the minerals of the sediment. This reduction was accomplished by injecting a chemical-reducing agent, sodium dithionite, into closely spaced wells. After the aquifer sediment was reduced, reagent and reaction products were pumped out of the wells. The reducing conditions remain in the aquifer because of the change in iron chemistry, and the barrier should remain effective for ~23 years (PNNL-13349). This estimate has an uncertainty of ±15 years because of variability in the aquifer's reducible iron content. Hexavalent chromium is immobilized by reduction of the soluble chromate ion (hexavalent chromium) to insoluble chromium hydroxide or iron chromium hydroxide (trivalent chromium). This transformation is particularly advantageous because chromium is not easily re-oxidized under ambient environmental conditions and will, thus, remain immobile. However, during fiscal year 2001, some of the earliest treated wells had increasing concentrations of hexavalent chromium (see Section 2.5.2). These increases were unexpected based on calculations of the expected barrier lifetime. Several hypotheses for the increase have been formulated. The environmental restoration contractor has prepared a mitigation plan to evaluate these potential causes. Mitigation response actions include re-injection of treatment solution into the affected wells in fiscal year 2002.

Interim Remedial Action Objectives

The objectives of the redox remedial action are the same as for remediation using pump and treat. These objectives are to protect human health and the environment, and include the following three components:

- protect aquatic receptors in the river substrate from contamination 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 goal of this treatment system is to reduce concentrations of hexavalent chromium to 20 μg/L or less in compliance wells. Groundwater monitoring requirements are described in the remedial design report and remedial action work plan (DOE/RL-99-51).

The redox manipulation technique creates a permeable barrier in the aquifer. Sodium dithionite was injected into additional wells in fiscal year 2001 to extend the length of the treatment zone. As groundwater flows through this zone, the hexavalent chromium is converted to the trivalent form, which is virtually immobile in groundwater.

Remediation Progress During Fiscal Year 2001

The environmental restoration contractor continued to expand the permeable reactive barrier in fiscal year 2001. Crews installed and treated new injection wells, extending the total length of the barrier to 433 meters (the barrier will continue to be lengthened to 643 meters by 2002). Twenty-eight wells were treated in fiscal year 2001 (Table 2.5-2). A total of 44 injection/extraction wells have been treated since 1997. The remaining wells identified for the interim remedial action are planned for treatment during fiscal year 2002.

The chromium map of Figure 2.5-8 illustrates which wells were injected in fiscal year 2001 and in previous years. The withdrawn solution was discharged to a lined evaporation pond east of the site.

Influence on Aquifer Conditions

The Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation (DOE/RL-99-51) describes the groundwater monitoring program that is used to assess the effectiveness of the treatment system. The monitoring network includes

- ten barrier injection wells to monitor barrier performance
- seven downgradient wells for compliance monitoring (199-D4-23, -38, -39, -83, -84, -85, and -86).

- thirteen wells throughout the southwestern 100 D Area for general plume tracking
- five aquifer sampling tubes and five river substrate tubes to monitor effects at the Columbia River.

The samples were analyzed for hexavalent chromium, specific conductance, dissolved oxygen, and sulfate to monitor the effects of the remedial action. Additional wells also were sampled for surveillance monitoring (PNNL-13698).

Chromium distribution and trends were discussed in Section 2.5.2 and illustrated in Figure 2.5-8. The effects of the redox treatment are evident in some of the compliance wells. Chromium concentrations in compliance wells 199-D4-23 and 199-D4-84 declined, but concentrations increased in well 199-D4-39 in fiscal year 2001.

2.5.7 Waste Site Remediation

The environmental restoration contractor excavated waste sites in the 100 D Area from 1997 through 2000. These sites included retention basins and associated sites in the northern 100 D Area, cribs, trenches, and drains near the D and DR Reactor buildings, and cooling water pipelines. Contaminated soil was disposed in the 200 Areas Environmental Restoration Disposal Facility, and the sites were backfilled with clean soil. Remediation of these sites lessens the potential for movement of contaminants from the sediment to groundwater in the future. Sites backfilled in fiscal year 2001 are listed in Table 2.5-3.

2.5.8 Monitoring at River Shoreline

Groundwater near the Columbia River is sampled annually in the late fall via aquifer sampling tubes and riverbank seeps. The sampling tubes are polyethylene tubes that were installed in the aquifer at locations near the low water shoreline. Seeps are natural areas of groundwater discharge above the water line. Table 2.5-4 lists constituents of interest for the 100 D Area for fiscal year 2001.

2.5.8.1 Aquifer Sampling Tube Results

Hexavalent chromium continued to exceed water quality standards in aquifer tubes and seeps in the 100 D Area. The maximum value in fiscal year 2001 was 479 µg/L.

Chromium concentrations in the aquifer tubes reflect the distribution of chromium in groundwater (see Figure 2.5-4). All but one of the nine tubes sampled for chromium in November 2000 exceeded the 11 µg/L standard for protecting aquatic organisms. The highest concentrations were in the southwestern chromium plume in tube 166-D-3, at 480 µg/L. Shoreline concentrations in this area are expected to decline in the future, as groundwater flows through the redox remediation system toward the river.

Only one aquifer tube in the 100 D Area was sampled for tritium in fiscal year 2000. Tube DD-50-3, west of well 199-D3-2, detected 22,100 pCi/L. The source of the tritium is believed to be the 100 N Area (see Section 2.5.4).

No aquifer tubes were sampled for gross beta, nitrate, or strontium-90 in fiscal year 2001.

2.5.8.2 Riverbank Seepage Results

Four riverbank seep sites were sampled during fiscal year 2001 (October 2000). Chromium concentrations of seep samples ranged from 22 µg/L in seep SD-098-1, upstream of 100 D Area, to 155 µg/L in seep SD-102-1 in the chromium plume in the southwestern 100 D Area. Near the 100 D Area pump-and-treat compliance wells, seep SD-110-1 contained 87 µg/L of chromium.

Tritium concentrations ranged from undetected in seep SD-102-1 (west-central 100 D Area) to 9,580 pCi/L in the upstream seep, SD-098-1. Two seeps were sampled for strontium-90: SD-102-1 contained 0.1 pCi/L and SD-110-1 (near the retention basins in the northern 100 D Area) contained 1.4 pCi/L.

2.5.8.3 Special Shoreline Investigation

An investigation of the hydraulic characteristics of the uppermost hydrologic unit at the 100 Area shoreline is currently underway as part of a masters' degree research project.[a] The objective of the study is to determine the concentration and extent of hexavalent chromium, the effect of anisotropy on transport of hexavalent chromium, and the relationship between changing river stage and water quality within the hyporheic zone (the area within the sand and gravel riverbed where groundwater meets stream water).

Forty-one piezometers were installed along a 4,000-meter segment of the river at depths ranging from 0.2 to 2 meters below the riverbed. Hexavalent chromium concentrations ranged from undetectable to >700 μg/L, with the highest concentrations in the portion of shoreline along the southwestern chromium plume. Hydraulic conductivity, estimated from slug tests, ranged from 0.02 to 37 meters per day and correlated with chromium concentrations (i.e., high hydraulic conductivity, high chromium concentrations). These results were used to evaluate the effects of heterogeneity on the flow of chromium into the river. Using the October-November 1999 sample results, the estimated hydraulic conductivity values, and considering heterogeneity, the estimated chromium flux was 44 grams per day.

Piezometers were sampled at various times of the year to determine the relationship between changing river stage and chromium, specific conductance, dissolved oxygen, and temperature. As noted in previous studies, higher chromium concentrations tend to be associated with lower river stage.

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[a] Arntzen, E. Master's degree research project in progress: "In Situ Hydraulic Testing and Water Quality Sampling in the Hyporheic Zone of the Columbia River, Hanford Reach, Washington." Portland State University, Portland, Oregon.

Table 2.5-1. Summary of 100 D Area Pump-and-Treat Performance for Fiscal Year 2001

Extraction Well	Annual Average Flow Rate (L/min)	Maximum Sustained Flow Rate (L/min)	Total Volume Pumped (x 10^6 L)	Average Chromium Concentration (µg/L)	Chromium Mass Removed (kg)
199-D8-53	112	150	52.0	213	11.1
199-D8-54A	113	151	54.2	274	15.5
Total	--	--	106.2	--	26.6

Data source: Project specific database for the 100-HR-3 Operable Unit.

Table 2.5-2. Redox Site Injection/Extraction Wells Treated in Fiscal Year 2001

Well Treated	Injection Start Date	Treatment Completion Date
199-D4-32	10/31/00	01/03/01
199-D4-37	04/10/01	05/10/01
199-D4-46	04/12/01	04/22/01
199-D4-14	04/17/01	04/27/01
199-D4-45	04/24/01	05/06/01
199-D4-42	05/01/01	05/11/01
199-D4-48	05/08/01	05/24/01
199-D4-43	05/22/01	06/07/01
199-D4-40	05/30/01	06/20/01
199-D4-47	06/06/00	06/25/01
199-D4-44	06/13/01	Ongoing at end of FY 01
199-D4-41	06/20/01	07/05/01
199-D4-55	07/12/01	07/28/01
199-D4-59	07/17/01	09/05/01
199-D4-51	07/19/01	08/17/01
199-D4-25	07/24/01	08/28/01
199-D4-56	07/31/01	08/19/01
199-D4-49	08/07/01	09/11/01
199-D4-53	08/09/01	08/31/01
199-D4-62	08/21/01	10/05/01
199-D4-57	08/23/01	10/10/01
199-D4-60	08/29/01	Ongoing at end of FY 01
199-D4-54	09/05/01	Ongoing at end of FY 01
199-D4-24	09/07/01	10/04/01
199-D4-52	09/11/00	Ongoing at end of FY 01
199-D4-50	09/14/01	Ongoing at end of FY 01
199-D4-58	09/18/01	10/10/01
199-D4-61	09/20/01	10/18/01

Table 2.5-3. 100 D Area Waste Sites Remediated in Fiscal Year 2001

Waste Site Designation	Fiscal Year Excavated	Fiscal Year Backfilled	Maximum Depth of Excavation (meters)
Cooling Water Effluent Pipeline Sites (from reactor buildings to retention basins and outfall structures)			
100-D-48 (D reactor) cooling water pipelines	1999-2000	2001	7
100-D-49 (DR reactor) cooling water pipelines	1997-2000	2001	6
Sites Located near D Reactor Building			
100-D-52 dry well	2000	2001	7.6
116-D-4 crib or French drain (also known as 116-D-3)	2000	2001	2.8
116-D-6 French drain	2000	2001	4.6
116-D-1A and -1B trenches (and co-located 100-D-46 burial ground)	2000	2001	4.6
116-D-2 crib	2000	2001	4.6
116-D-9 crib	2000	2001	5.5

Table 2.5-4. Shoreline Monitoring Data for the 100 D Area, Fiscal Year 2001

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Chromium (µg/L)	Gross Beta (pCi/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Tritium (pCi/L)
DD-50-3	Tube	11/07/00	301	42				22,100
DD-44-4	Tube	11/14/00	497	273				
DD-43-3	Tube	11/09/00	463	304				
DD-42-3	Tube	11/09/00	371	276				
DD-41-2	Tube	11/09/00	291	211				
166-D-3	Tube	11/08/00	597(a)	479(a)				
166-D-2	Tube	11/13/00	386	78(a)				
166-D-1	Tube	11/13/00	361	420				
DD-17-2	Tube	11/09/00	251					
40-S	Tube	11/15/00	227	5 U				
SD-098-1	Seep	10/12/00		22(a)	2.4 U(a)	43.2(a)		9,580(a)
SD-102-1	Seep	10/17/00		155(a)	2.3(a)	88.1	0.1	146 U(a)
SD-110-1	Seep	10/17/00		87(a)	5.3(a)	50.9(a)	1.4	1,157(a)
SD-110-2	Seep	10/17/00			5.2	5,799(b)		1,120

Tube = Aquifer sampling tube located near the low-river shoreline.
Seep = Natural riverbank seepage site.
U = Below detection limit.
(a) Average of multiple measurements.
(b) Suspected error.

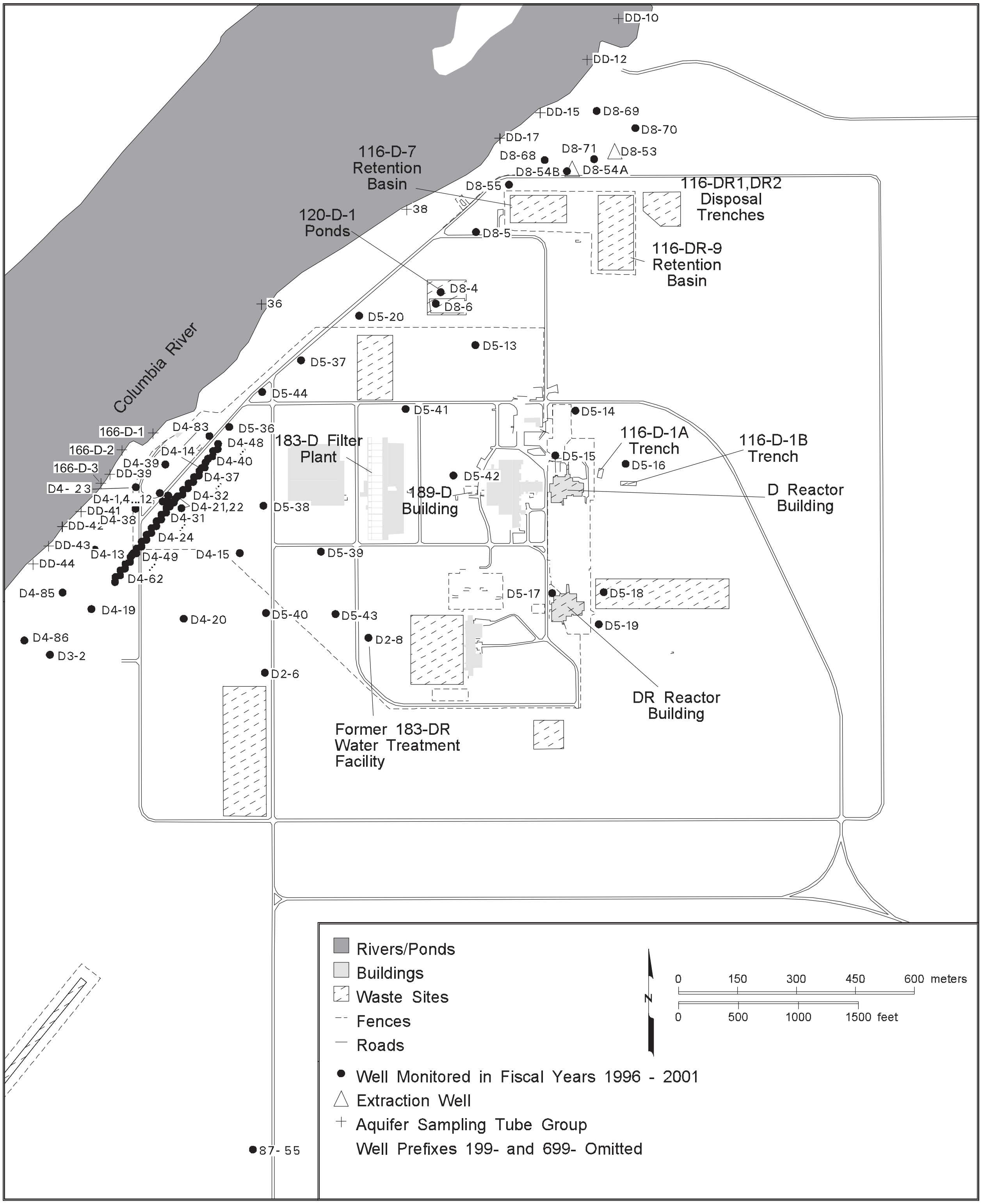

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Figure 2.5-1. Groundwater Monitoring Wells in the 100 D Area

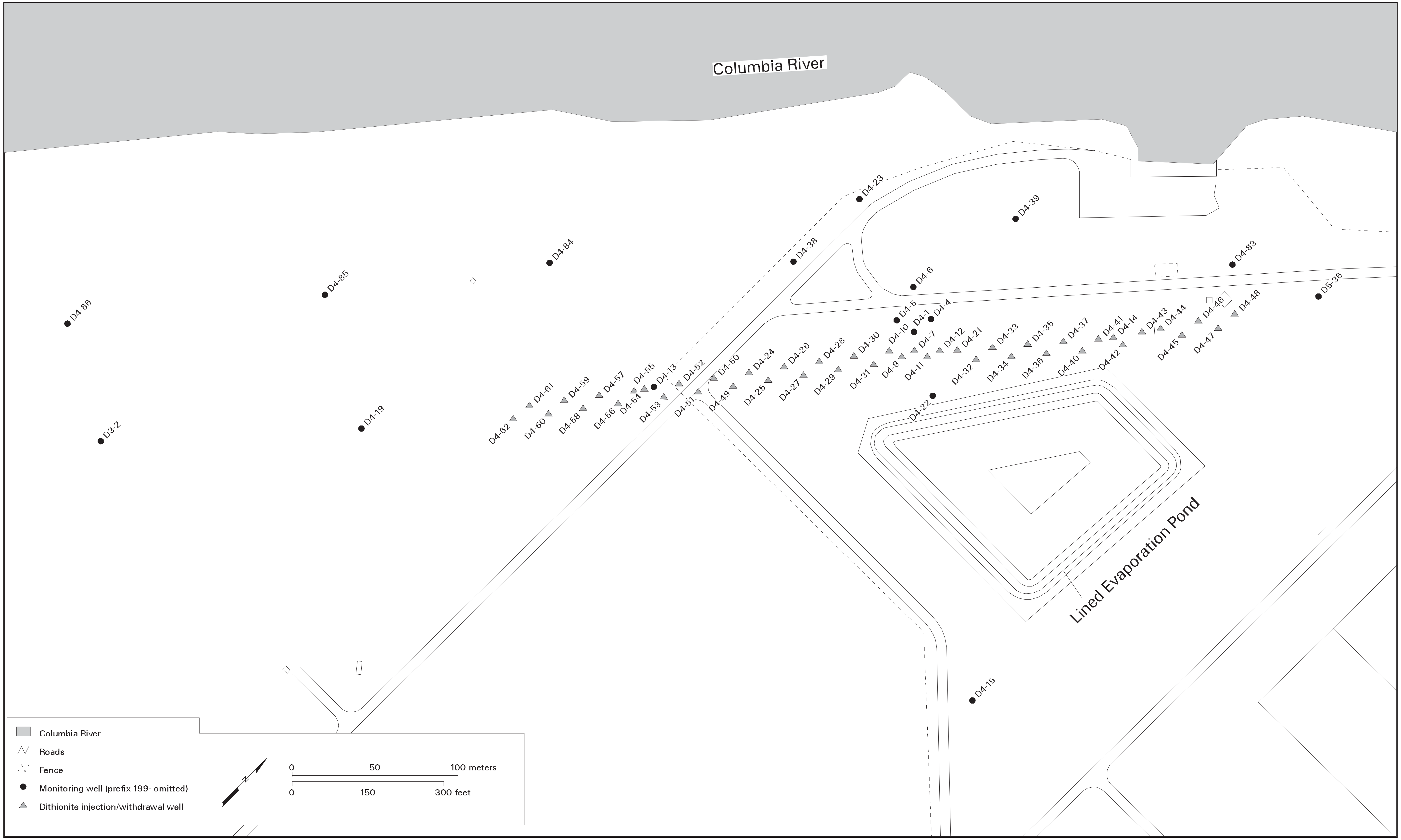

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Figure 2.5-2. Injection/Withdrawal Wells and Groundwater Monitoring Wells Near the Redox Site in 100 D Area

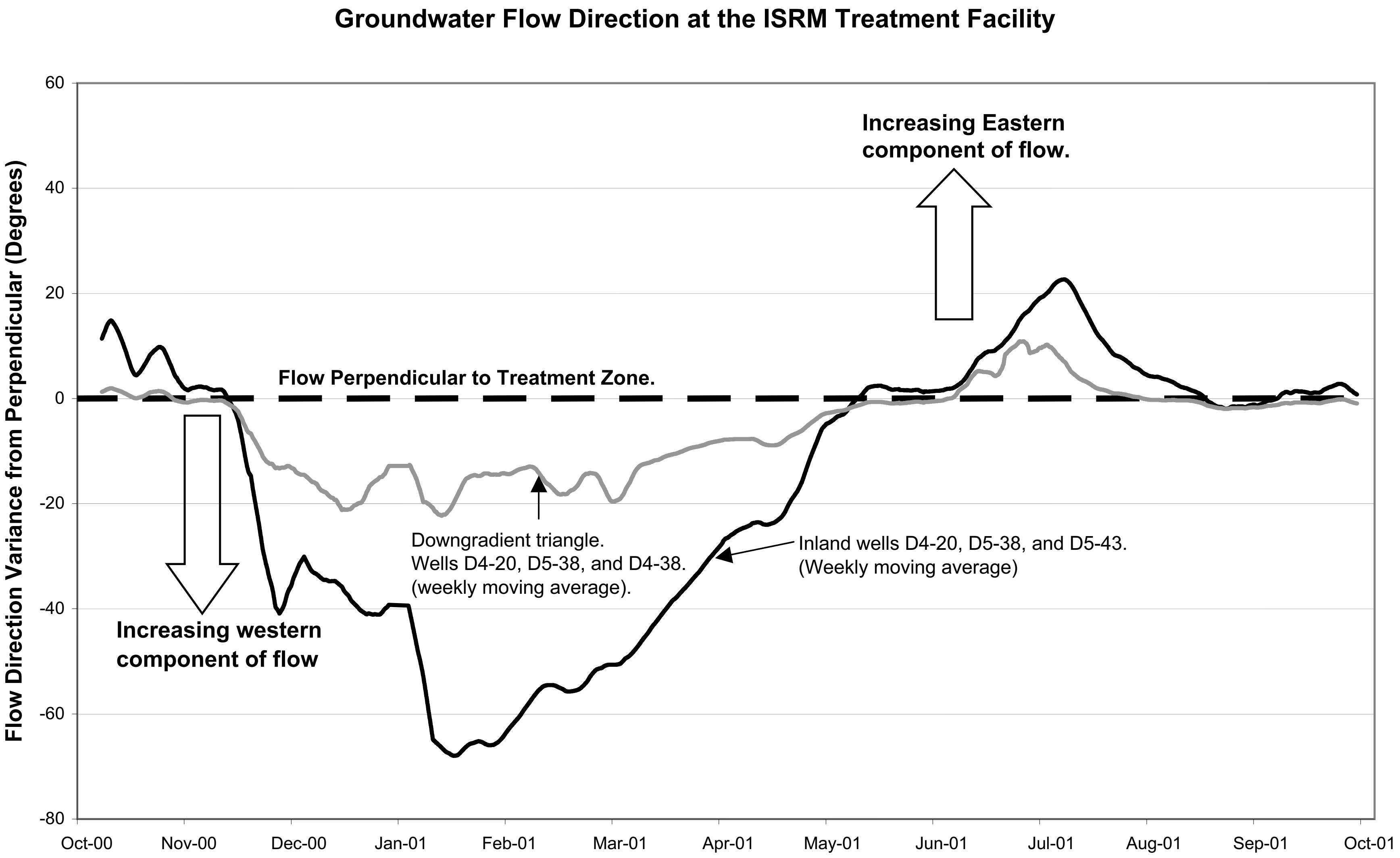

Figure 2.5-3. Variations in Groundwater Flow Direction Observed Near the Redox Site

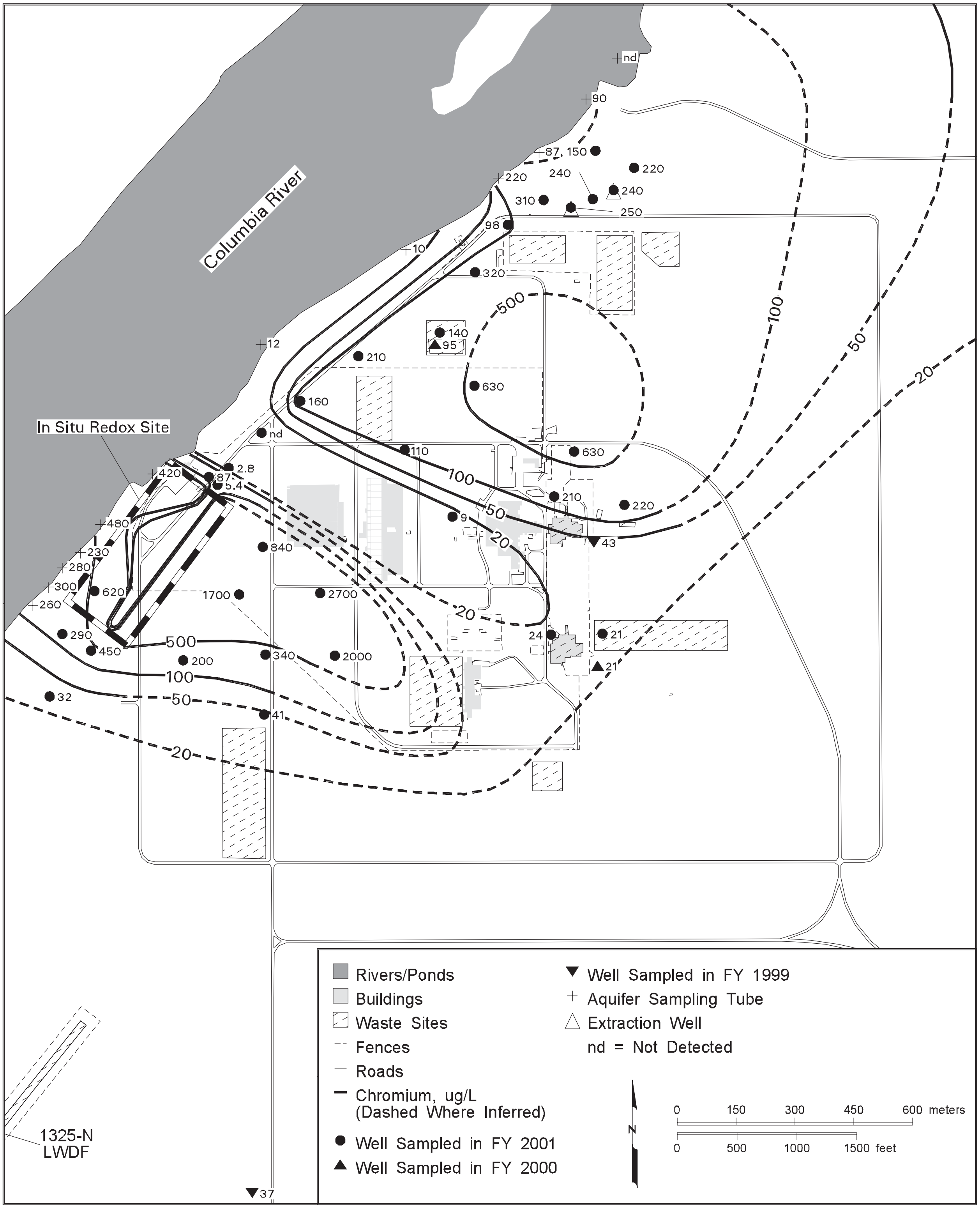

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Figure 2.5-4. Average Dissolved Chromium Concentrations in the 100 D Area, Top of Unconfined Aquifer

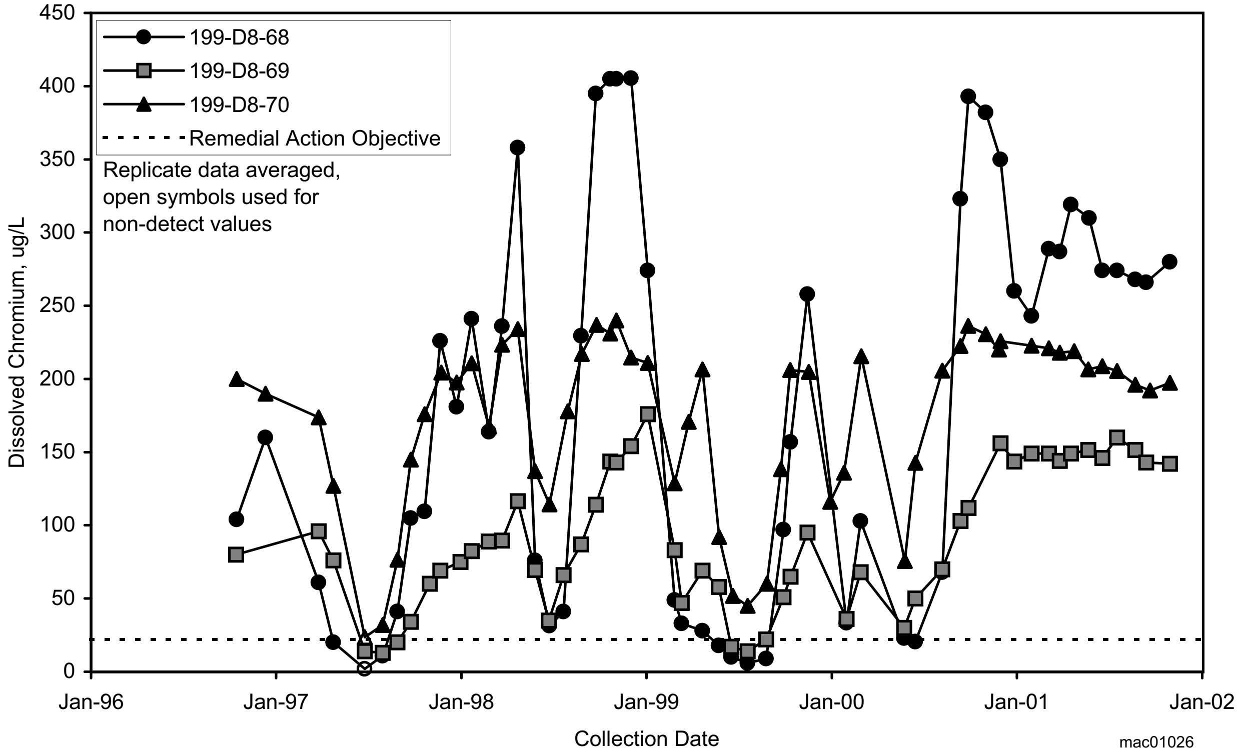

Figure 2.5-5. Dissolved Chromium Concentrations in Compliance Wells for the 100-HR-3 Pump-and-Treat System at 100 D Area

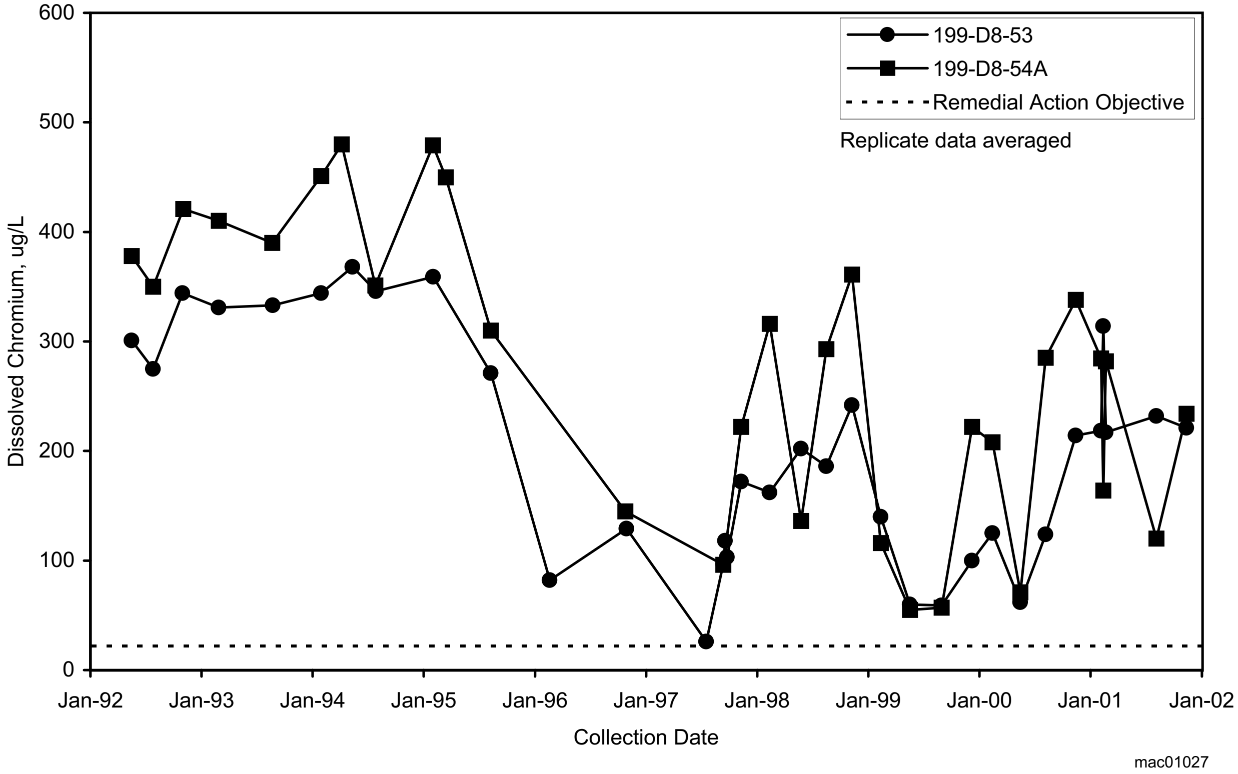

Figure 2.5-6. Dissolved Chromium Concentrations in Extraction Wells for the 100-HR-3 Pump-and-Treat System at 100 D Area

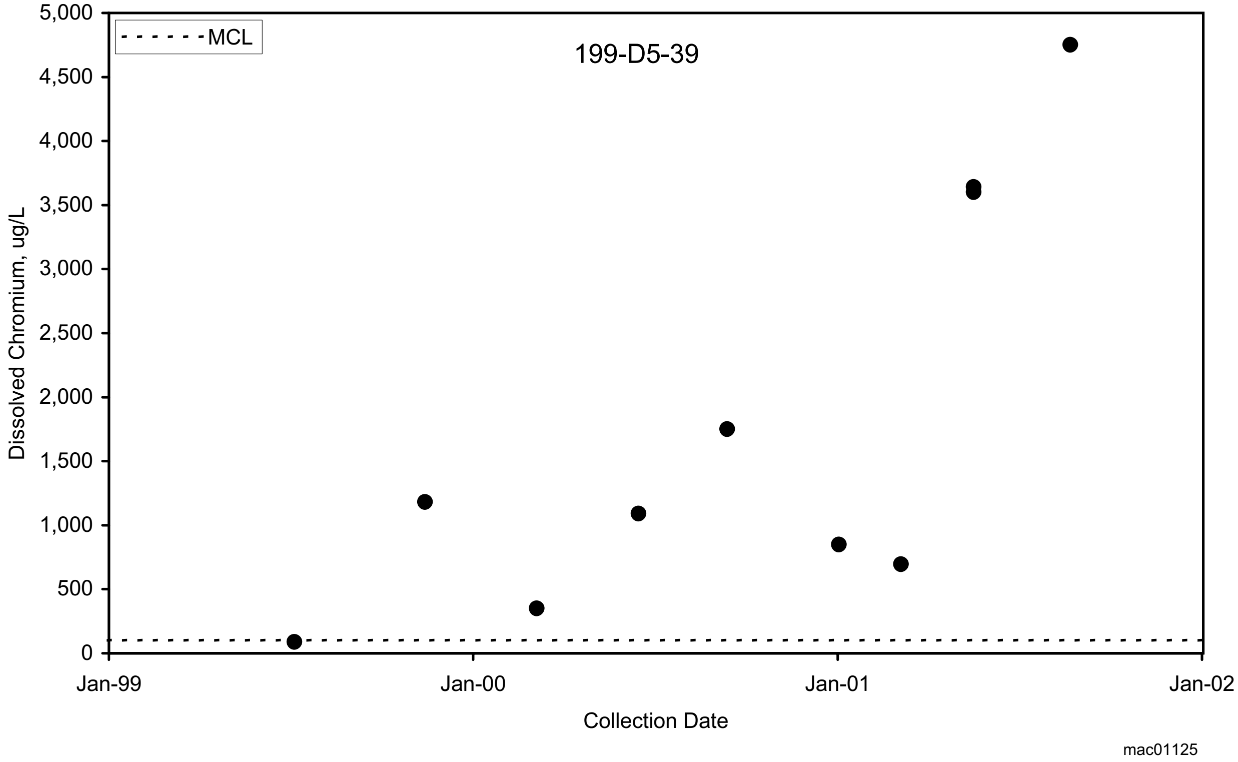

Figure 2.5-7. Dissolved Chromium Concentrations in the Southwestern 100 D Area

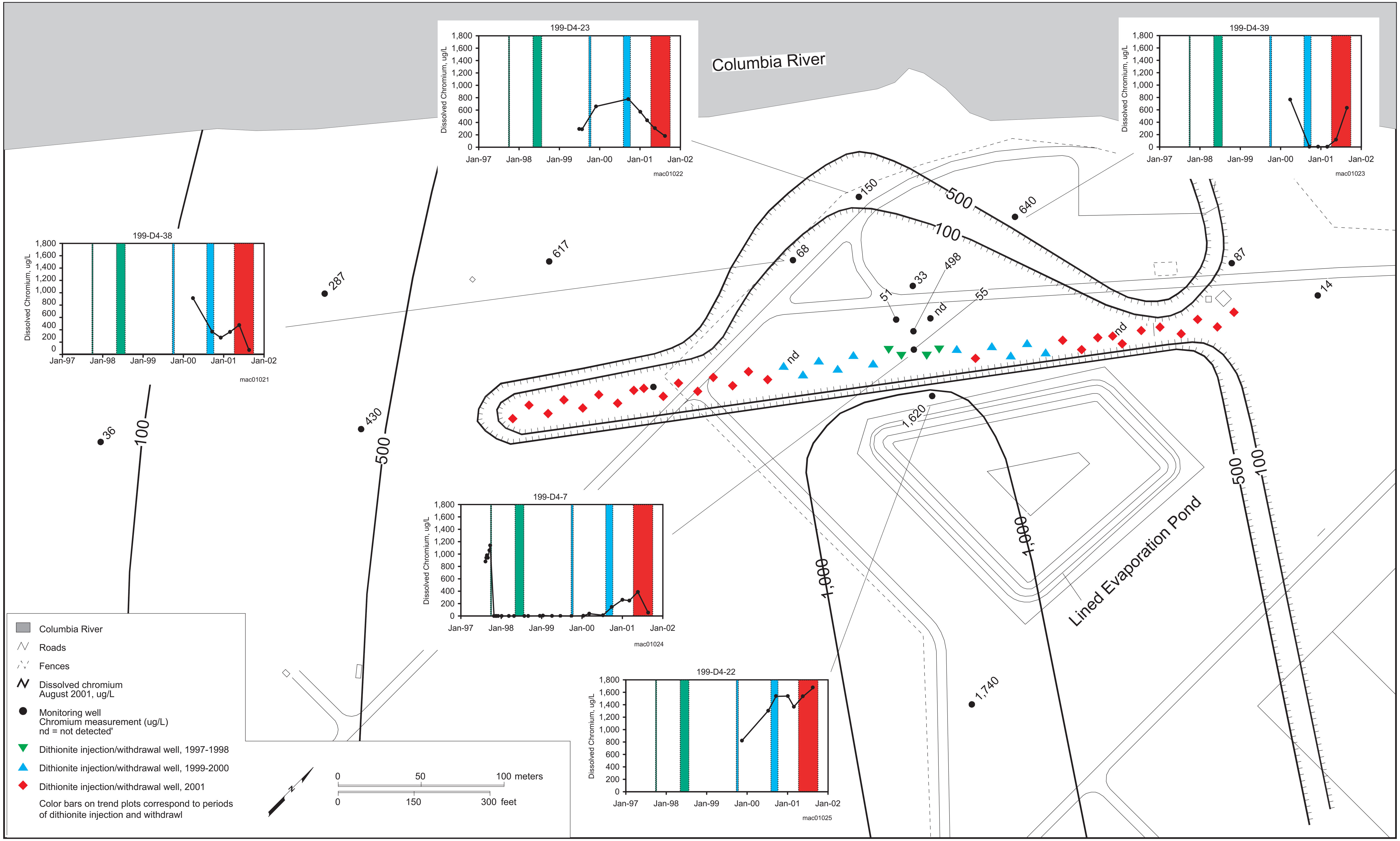

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Figure 2.5-8. Chromium Concentrations in Wells Near the Redox Site, 100 D Area, August 2001

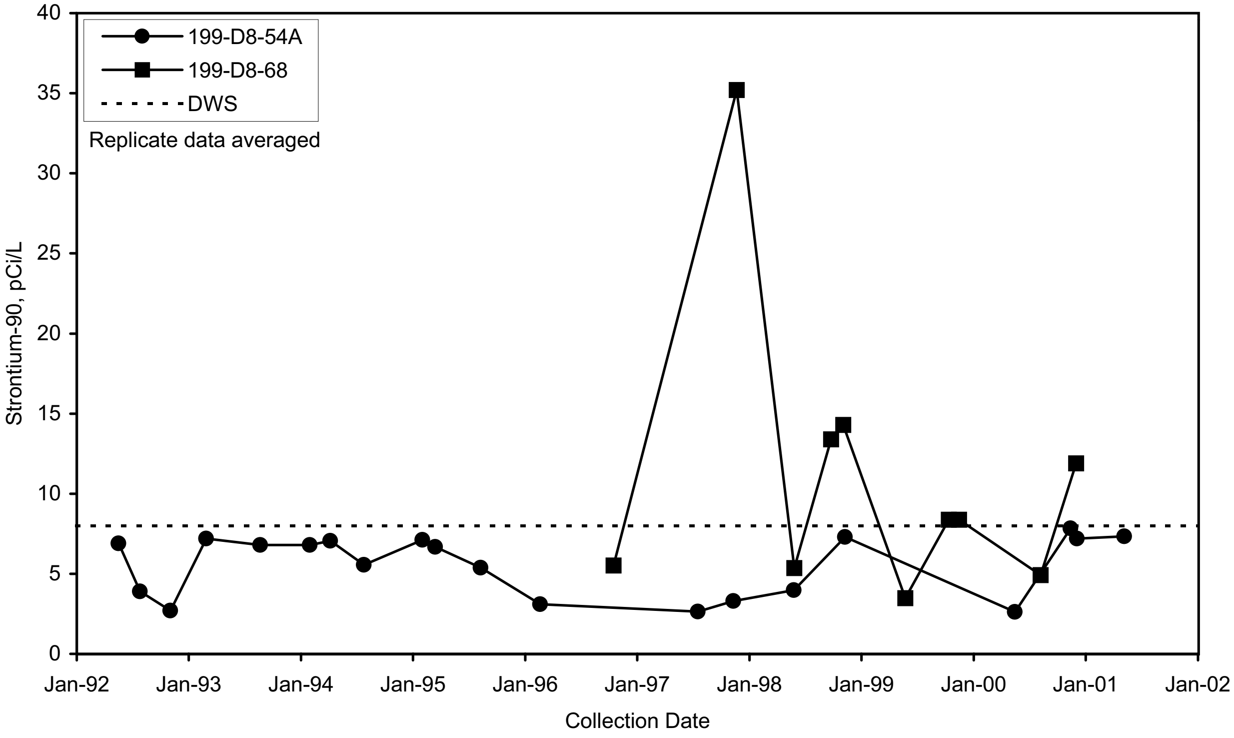

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Figure 2.5-9. Strontium-90 Concentrations in Wells Near the 116-D-7 and 116-DR-9 Retention Basins

2.6 100 H Area

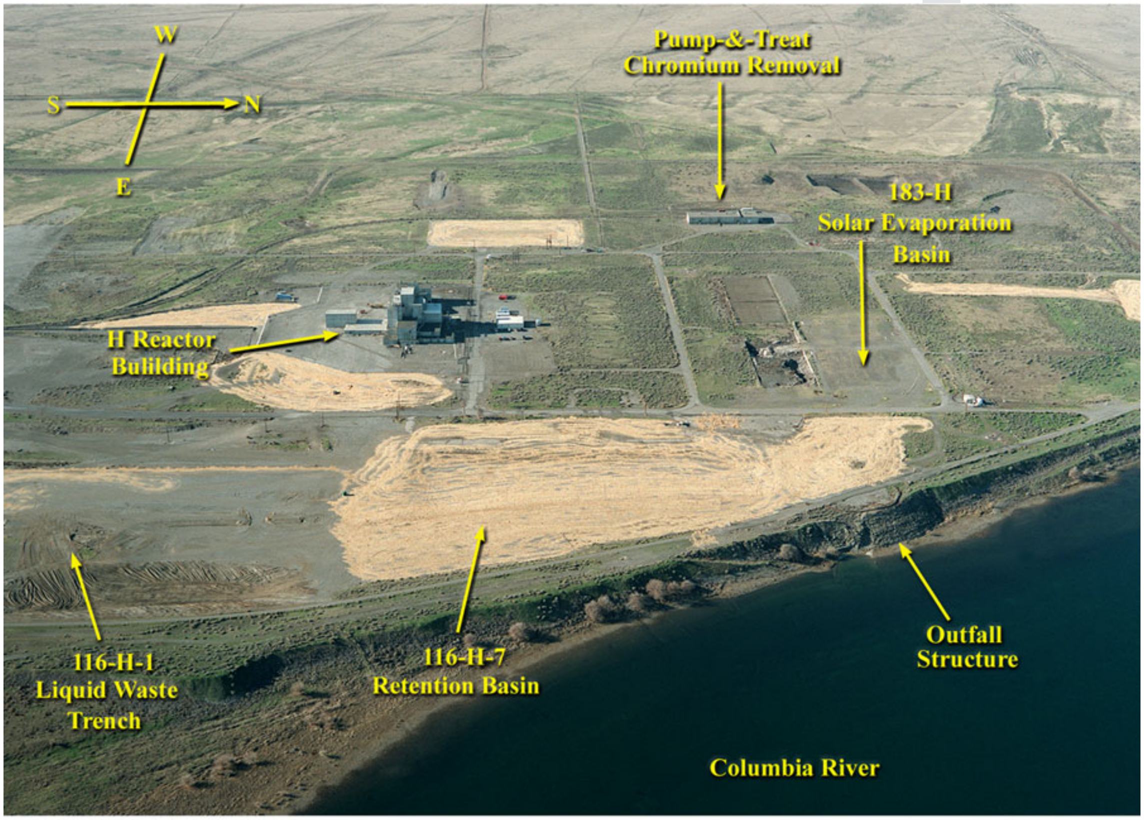
M. J. Hartman and W. J. McMahon

The H Reactor operated between 1949 and 1965 using a single-pass cooling system. Groundwater contaminants include chromium, nitrate, strontium-90, and uranium. Sources of groundwater contamination include the 107-H retention basins and disposal trenches in the eastern part of the area (waste sites 116-H-7 and 116-H-1), and the 183-H solar evaporation basins (waste site 116-H-6), which stored fuel fabrication effluent between 1973 and 1985. A comprehensive description of 100 H Area operations and waste sites is presented in the technical baseline report for the 100-HR-3 Operable Unit (BHI-00127). Facilities and monitoring wells referred to in the text are shown on Figure 2.6-1.

The presence of chromium in 100 H Area groundwater is a concern because the adjacent riverbed is used by salmon for spawning. Additional groundwater contaminants of interest are nitrate, strontium-90, technetium-99, and uranium.

2.6.1 Groundwater Flow

Groundwater movement beneath the 100 H Area is generally southwest to northeast, toward the Columbia River (see Plate 1). Flow through the sandy/gravelly sediment near the water table is relatively rapid and estimated to be within 0.3 to 2 meters per day (DOE/RL-93-43). Groundwater flows generally toward the northeast across the entire horn of the Columbia River north of Gable Mountain, so groundwater approaching the shoreline upstream of 100 H Area and along the area may contain contaminants that originated in the 100 D and 100 N Areas.



Aerial view of the 100 H Area, November 2001. The pump-and-treat system removes chromium from groundwater and also collects data on water levels, contaminant concentrations, and operating data to assess the performance of the system.

Monitoring Objectives in 100 H Area

Groundwater monitoring is conducted in the 100 H Area:

- annually to describe the nature and extent of contamination in support of environmental restoration decisions
- annually to monitor conditions beneath the former 183-H solar evaporation basins, a RCRA site
- semiannually to monitor trends in variable constituents/wells
- various time intervals to evaluate the performance of a pump-and-treat system for chromium.

Daily and seasonal river stage fluctuations create corresponding changes in the elevation of the water table, which causes changes in flow direction and may also influence water quality monitoring results. During periods of high river levels, river water infiltrates the banks along the 100 H Area shoreline, causing variable flow directions and mixing between groundwater and river water. The river stage was low throughout fiscal year 2001, and water levels in monitoring wells did not show the usual spring/summer high. The extraction and injection of groundwater associated with the interim remedial action to address chromium contamination also influences the movement of groundwater in the vicinity of the associated wells.

2.6.2 Chromium

Chromium contamination in 100 H Area groundwater originated from sources within the 100 H Area and from upgradient sources in the 100 D Area (Figure 2.6-2). Chromium concentrations in 100 H Area groundwater are generally below the 100 μg/L drinking water standard, and in fiscal year 2001, only well 199-H4-9, downgradient of the former 183-H solar evaporation basins, had an annual average exceeding the standard. Concentrations exceeded the more stringent standard for protection of freshwater aquatic organisms (11 μg/L) in the northern and eastern 100 H Area. The chromium plume in this area is adjacent to gravelly riverbed areas that are heavily used by salmon for spawning (Dauble and Watson 1997). During previous field studies, samples of pore water were obtained from the spawning gravel in this area and found to contain chromium concentrations as high as 130 μg/L (BHI-00345).

Chromium concentrations have declined in the past 10 years, especially at inland wells. Six wells are currently being used at 100 H Area to extract chromium-contaminated groundwater as part of interim remedial actions, which started in July 1997. Figure 2.6-3 shows chromium concentrations in extracted groundwater from wells nearest the Columbia River. Concentrations in wells located farther inland are shown in Figure 2.6-4. A general decline in concentrations with time is apparent in the inland wells. Concentrations vary appreciably in wells nearest the river, as revealed by trend charts for several compliance monitoring wells (Figure 2.6-5). The performance of this interim remedial action is described more fully in Section 2.6.8.

Chromium concentrations exceeded the maximum contaminant level in only one 100 H well in fiscal year 2001. Concentrations exceeded the more stringent aquatic standard (11 μg/L) beneath most of the 100 H Area.

Well 199-H4-12C, located downgradient of the 183-H basins and completed in a confined unit, has shown relatively high chromium concentrations and a declining trend (Figure 2.6-6). One potential explanation for the elevated chromium involves corrosion of the stainless steel well screen. No other contaminants from the 183-H basins are present and there is no information available to suggest that waste effluents have contaminated this deep aquifer.

West of the 100 H Area (upgradient), chromium in wells 699-96-43 and 699-97-43 is believed to have originated across the tip of the Hanford Site in the 100 D Area. Concentrations have declined since the early 1990s but exceeded the maximum contaminant level in fiscal year 2001 (Figure 2.6-7). These concentrations are higher than in the nearest wells in the 100 H Area.

2.6.3 Strontium-90

The primary source for strontium-90 contamination currently detected in 100 H Area groundwater is past disposal of contaminated reactor coolant to the former 116-H-7 retention basin, 116-H-1 liquid waste disposal trench, and the 116-H-5 sludge burial trench, which have been excavated and backfilled. The strontium-90 plume is located east and southeast of the retention basin (Figure 2.6-8), and has changed very little in the past 10 years. Concentrations are somewhat variable, but there are no clear increasing or decreasing trends. The maximum concentration in fiscal year 2001 was 38 pCi/L in well 199-H4-63.

2.6.4 Tritium

Tritium concentrations in the 100 H Area remained below the 20,000 pCi/L drinking water standard in fiscal year 2001 (see Plate 2). The highest values detected during fiscal year 2001 were 5,740 pCi/L in well 199-H6-1 (southeastern 100 H Area) and 7,740 pCi/L in well 699-96-43, upgradient of 100 H Area.

2.6.5 Nitrate

During fiscal year 2001, numerous wells in the 100 H Area exceeded the 45 mg/L maximum contaminant level (Figure 2.6-9). The highest concentrations occur in groundwater affected by effluent that leaked from the former 183-H solar evaporation basins, which were a source of nitrate (e.g., 122 mg/L in well 199-H4-4). Several wells in the southern 100 H Area also exceeded the maximum contaminant level.

A general increase in nitrate concentration was apparent in the late 1990s for many 100 H Area wells (and also for wells located in other reactor areas). This trend appears to have reversed in most wells (Figure 2.6-10). The cause for the nitrate peak is not known.

2.6.6 Technetium-99 and Uranium

The former 183-H basins were a source of technetium-99 and uranium to groundwater. In fiscal year 2001, technetium-99 did not exceed the 900-pCi/L drinking water standard in any wells, and uranium exceeded the 30 μg/L maximum contaminant level only in wells 199-H4-3 and 199-H4-4.

These two contaminants are mobile in groundwater. Near the Columbia River, their concentrations vary with changes in elevation of the water table, which responds to fluctuations in river stage. This variability is illustrated for well 199-H4-4 in Figure 2.6-11. Typically, low water levels are associated with higher contaminant concentrations. However, though river stage was low throughout fiscal year 2001, concentrations remained relatively low.

2.6.7 RCRA Monitoring at the Former 183-H Solar Evaporation Basins

The former 183-H solar evaporation basins are a RCRA site that has contaminated groundwater with chromium, nitrate, technetium-99, and uranium. Concentrations have declined in recent years.

Groundwater near the former 183-H solar evaporation basins is monitored to meet RCRA final status corrective action requirements. Hazardous waste was removed from the treatment facility during the late 1980s, followed by decontamination and demolition of the structure, which was completed in 1995 (DOE/RL-97-48). Contaminated soil was then removed, though fluoride and nitrate remained elevated in the remaining soil, thus requiring postclosure groundwater monitoring.

Groundwater movement in the vicinity of the basins has been influenced by the interim remedial action under CERCLA that focuses on chromium contamination. While pumping operations are in progress, RCRA monitoring tracks the trends of five contaminants associated with leakage from the basins: chromium, fluoride, nitrate, technetium-99, and uranium (PNNL-11573). All of these, with the exception of fluoride, are elevated in groundwater downgradient of the basins, as discussed in Sections 2.6.2, 2.6.5, and 2.6.6. See Appendix A for supporting information about this RCRA site.

2.6.8 Groundwater Remediation at the 100-HR-3 (H) Operable Unit

A pump-and-treat system began operating in the 100 H Area during July 1997 as an interim remedial action for chromium contamination in groundwater. The primary purpose for this system is to prevent or reduce the movement of hexavalent chromium from the aquifer to the river, thereby protecting aquatic receptors. The extraction network currently includes three wells located within ~50 meters of the river shore, and three additional wells located farther inland. A report is prepared annually that describes the performance of the system for the preceding calendar year (e.g., DOE/RL-2001-04).

The pump-and-treat system in the 100 H Area is reducing the amount of chromium that reaches the Columbia River, where it could potentially harm aquatic organisms. Since 1997, 29 kilograms of chromium have been removed from groundwater.

2.6.8.1 Interim Remedial Action Objectives

The record of decision (ROD 1996a) for the 100-HR-3 Operable Unit contains the following specific remedial action objectives that pertain to operation of the pump-and-treat system that serves the 100 H and 100 D Areas:

- 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 record of decision stipulates that the interim action pump-and-treat system continues to operate until the U.S. Environmental Protection Agency and Washington State Department of Ecology are satisfied that termination (or intermittent operation) is appropriate. Criteria for ending the operation include (a) sampling results indicate that the concentration of hexavalent chromium is below 22 μg/L in the compliance wells and (b) evidence to indicate that concentrations will remain below the compliance value. Other criteria for terminating the pump-and-treat operation involve the effectiveness of the treatment technology and the availability of a superior treatment technique (ROD 1996a).

2.6.8.2 Remediation Progress During Fiscal Year 2001

The pump-and-treat system made progress toward achieving the 100 H Area remedial action objectives during fiscal year 2001. Although designed primarily to prevent or reduce the amount of contaminated groundwater discharging into the Columbia River, the pump-and-treat system also reduces overall contamination in the aquifer by removing contaminant mass. The pump-and-treat monitoring program collects data on water levels, contaminant concentrations, and operating data to assess the performance of the system. These data help to provide a technical basis for selecting a final remedy for environmental restoration of this operable unit.

During fiscal year 2001, the pump-and-treat system extracted over 136 million liters of 100 H Area groundwater and removed ~5.9 kilograms of hexavalent chromium from near the river (Table 2.6-1). The average concentration of hexavalent chromium in the extracted groundwater was 46 μg/L. After treatment, the average effluent concentration was 9 μg/L, with hexavalent chromium being undetected during 25 of the 53 sampling events. The treatment system in 100 H Area receives groundwater from both 100 D and 100 H Areas. The treated effluent was injected back into the aquifer at an upgradient location southwest of the H Reactor.

2.6.8.3 Influence on Aquifer Conditions

Past leakage of hazardous waste from the former 183-H basins contributed to the chromium plume beneath the 100 H Area.

The pump-and-treat system has removed ~29 kilograms of hexavalent chromium from 100 H Area groundwater since July 1997, which appears to represent a significant fraction of the amount likely to be in the aquifer. The amount of chromium in the plume targeted for interim remedial action was estimated to be ~42 kilograms for 1992 conditions (WHC-SA-1674-VA). This estimate was based on the volume of groundwater contaminated by chromium at concentrations >10 µg/L and assumed aquifer porosity to be 20%. Estimates of the mass of chromium in the plume are subject to uncertainty because of (a) lack of data on the vertical distribution of contamination in the aquifer; (b) uncertainty in the rate at which chromium enters from the vadose zone; and (c) difficulty in evaluating the amount of chromium flowing into the area from upgradient sources.

High flow in the Columbia River during 1996 and 1997 caused the water table to be substantially elevated above normal levels. Increases in chromium concentrations were detected in several monitoring wells after the water table receded to more typical levels in 1998. The elevated water table may have increased movement of some contaminants from the vadose zone into the aquifer. Since then, surface remediation of the 183-H solar evaporation basins, which are believed to be an important source for chromium, has been completed and future contributions from this facility are expected to be minimal.

The amount of chromium in the aquifer available to discharge to the river channel is decreased by extraction of groundwater by the pump-and-treat system. Where flow is not captured by the extraction wells (believed to be a small part of the plume), the amount is decreased to levels below the remedial action objective by natural attenuation via dispersion with groundwater flow, followed by discharge to the river channel. However, two processes tend to recharge the plume: movement of chromium-bearing groundwater into the 100 H Area and downward movement from the vadose zone. These processes will likely cause chromium to be detected beneath the 100 H Area for many years into the future, although the concentration may be below the pump-and-treat remedial action objective.

Chromium concentrations in most of the extraction and compliance wells remained above the interim remedial action objective of 22 µg/L during fiscal year 2001. The pump-and-treat system will continue to operate in 2002.

The concentration of chromium in inland extraction well 199-H3-2A has been below the 22 µg/L action level since 1998, with the exception of a few apparently erroneous values that do not agree with results of duplicate samples (see Figure 2.6-4). Concentrations in near-river extraction well 199-H4-4 typically decline below the 22 µg/L action level during the early summer months when river stage is high, and rebound by the following September when river stage drops. However, concentrations remained above the action level in fiscal year 2001 because the river stage did not show a typical early summer high. Concentrations in the other extraction and compliance wells ranged from 24 to 103 µg/L during fiscal year 2001 (see Figures 2.6-3, 2.6-4, and 2.6-5). Because chromium concentrations continue to exceed the action level in the compliance wells, operation of the pump-and-treat system is continuing into fiscal year 2002.

The decrease in chromium concentrations in some extraction wells and compliance wells suggests that the concentration in the aquifer is decreasing in some areas. However, the rate of decline is not consistent throughout the entire targeted plume area. The pump-and-treat system does reduce the amount of chromium in the environment, and prevent it from discharging into the river. Contaminant monitoring results indicate that several years of pumping may be required before the concentration levels required by remedial action are achieved.

2.6.9 Waste Site Remediation

Remedial actions involving excavation of waste sites in the 100 H Area continued during fiscal year 2001, and previously excavated sites were backfilled (Table 2.6-2). Contaminated soil and debris were disposed at the Environmental Restoration Disposal Facility.

Water (obtained from fire hydrants) was applied as necessary to control dust during the excavation process. Application of water was held to the minimum amount necessary for worker safety and preventing airborne dispersal of contaminants. Judicious application of water reduced the potential to mobilize contaminants from the vadose zone to the groundwater.

2.6.10 Monitoring at River Shoreline

Groundwater samples are collected annually from aquifer sampling tubes located near the low river stage shoreline and from riverbank seepage sites during the period of low river stage that occurs during the fall. The tubes are sampled annually to support Environmental Restoration Project objectives. Riverbank seepage is monitored by the Surface Environmental Surveillance Project, with additional sampling and analysis conducted under the Environmental Restoration Project to support investigations of groundwater operable units. Table 2.6-3 lists the analytical results for key constituents in samples collected during fiscal year 2001 from aquifer sampling tubes and riverbank seepage.

2.6.10.1 Aquifer Sampling Tubes

Chromium exceeded its aquatic standard in most shoreline samples from the 100 H Area during fiscal year 2001. Strontium-90 exceeded its drinking water standard in one sample from a shoreline seep.

Samples from aquifer sampling tubes were collected during November 2000 and analyzed for hexavalent chromium, gross beta, nitrate, and strontium-90. Chromium concentrations in sampling tubes generally agreed with concentrations in wells (see Figure 2.6-2). The highest hexavalent chromium concentration was 53 μg/L at a location just upstream of the 100 H Area. Over the rest of the 100 H Area shoreline, values ranged from 21 to 46 μg/L. At two aquifer tubes downstream of 100 H Area, chromium was measured at 49 and 11 μg/L. These concentrations are consistent with hexavalent chromium concentrations in groundwater samples from nearby monitoring wells. The upstream concentrations represent chromium that has migrated across the tip of the Hanford Site, with a probable source at the 100 D Area.

Gross beta, nitrate, strontium-90, and tritium analyses were not requested on most of the aquifer tube samples.

2.6.10.2 Riverbank Seepage

Four riverbank seepage sites were sampled in fiscal year 2001 along the 100 H Area shoreline. All of the seeps were sampled during seasonal low-river discharge conditions (October or November 2000), when seepage is least influenced by bank storage of river water and is most representative of groundwater that discharges into the Columbia River. Two of the seeps also were sampled in April 2001. River stage was still low due to drought conditions in 2001.

As in previous years, chromium concentrations in seeps exceeded the 11 μg/L standard for protection of aquatic organisms in most of the seeps. The highest chromium concentration was 85 μg/L from a seep just upstream of 100 H Area, sampled in April. The source for the upstream chromium most likely was past waste disposal in the 100 D Area. Chromium concentrations were lower downstream of 100 H Area (4 to 12 μg/L).

Strontium-90 was analyzed at two seeps. It was undetected in a seep upstream of 100 H Area and reached a high of 14.2 pCi/L in a seep near the former retention basin, where a contaminant plume is present in groundwater (see Figure 2.6-8). Gross beta was analyzed in all seep samples and ranged from undetected to 27.4 pCi/L in the seep with the high strontium-90 concentration.

Nitrate results appear to be erroneous (see Table 2.6-3). Tritium concentrations in seeps were similar to groundwater, ranging from undetected to 5,460 pCi/L.

Table 2.6-1. Performance Parameters for the 100 H Pump-and-Treat System for Hexavalent Chromium, Fiscal Year 2001

Well or Sample Location	Annual Average Flow Rate (L/min)	Maximum Sustained Flow Rate (L/min)	Total Volume Pumped ($x10^6$ L)	Average Chromium Concentration (µg/L)	Chromium Mass Removed (kg)
199-H3-2A	72	105	36.2	10	0.05
199-H4-11	73	87	36.4	32	1.57
199-H4-12A	39	57	17.9	72	1.85
199-H4-15A	54	69	26.9	63	1.70
199-H4-7	39	60	19.1	46	0.77
199-H4-65[a]	0	0	0	--	0
H Area Influent	273	340	136	46	5.94
Effluent[b]	470	780	243	0.09	--

(a) Water level in well 199-H4-65 too low to operate pump.
(b) Includes treated groundwater originating from 100 H and 100 D Areas.
Data source: Project specific database for the 100-HR-3 Operable Unit.

Table 2.6-2. 100 H Area Waste Sites Excavated Under CERCLA During Fiscal Year 2001

Waste Site Designation	Fiscal Year Excavated	Fiscal Year Backfilled	Maximum Depth of Excavation (meters)
Sites Located in Eastern 100 H Area			
116-H-7 retention basin	1999, 2000	2001	4.8
116-H-1 trench	1999, 2000	2001	4.6
100-H-5 sludge burial ground	1999, 2000	2001	5.1
Cooling Water Effluent Pipeline Sites (from reactor building to retention basins)			
100-H-21 effluent pipelines	2000, 2001	2001	4.6
100-H-22 effluent pipelines leakage site	2000, 2001	2001	4.6
Sites Located near H Reactor			
100-H-1 rod cave	2000	2001	5.6
100-H-2 buried thimble site	2000	2001	2.6
100-H-7 French drain	2000	2001	Not available
100-H-24 substation	2000	2001	4.6
100-H-30 sanitary sewer trench	2000	2001	2.6
116-H-2 liquid waste disposal trench	2000	2001	2.6
116-H-3 French drains	2000	2001	4.6
Sites Located in Northern 100 H Area			
1607-H2 and H4 septic tanks and drain fields	2000	2001	5.6

Table 2.6-3. Shoreline Monitoring Data for the 100 H Area, Fiscal Year 2001

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Chromium (µg/L)	Gross Beta (pCi/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Tritium (pCi/L)
42-D	Tube	11/01/00	298	24				
43-D	Tube	11/01/00	254	26				
44-D	Tube	11/01/00	377	53				
46-D	Tube	11/02/00	306	27				
47-D	Tube	11/02/00	165					
47-M	Tube	11/02/00	165					
48-M	Tube	11/02/00	535	40	6.5		0 U	
49-S	Tube	11/06/00	369	21				
50-M	Tube	11/06/00	506	46				
51-M	Tube	11/06/00	443	49				
55-M	Tube	11/06/00	312	11				
SH-144-1	Seep	10/13/00		30	3.2	66.8(b)		1,240
SH-145-1	Seep	11/01/00		13(a)	2.4(a)	114(b)	0 U	408(a)
SH-145-1	Seep	04/30/01		85(a)	5.3(a)		0 U	5,460
SH-150-1	Seep	11/01/00		6	0.9 U	384(b)		236 U
SH-153-1	Seep	11/01/00		4(a)	13(a)	10.2	5.6	144 U(a)
SH-153-1	Seep	04/30/01		12	27.4		14.2	836

Tube = Aquifer sampling tube located near the low-river shoreline.
Seep = Natural riverbank seepage site.
U = Below detection limit.
(a) Average of multiple measurements.
(b) Suspected error.

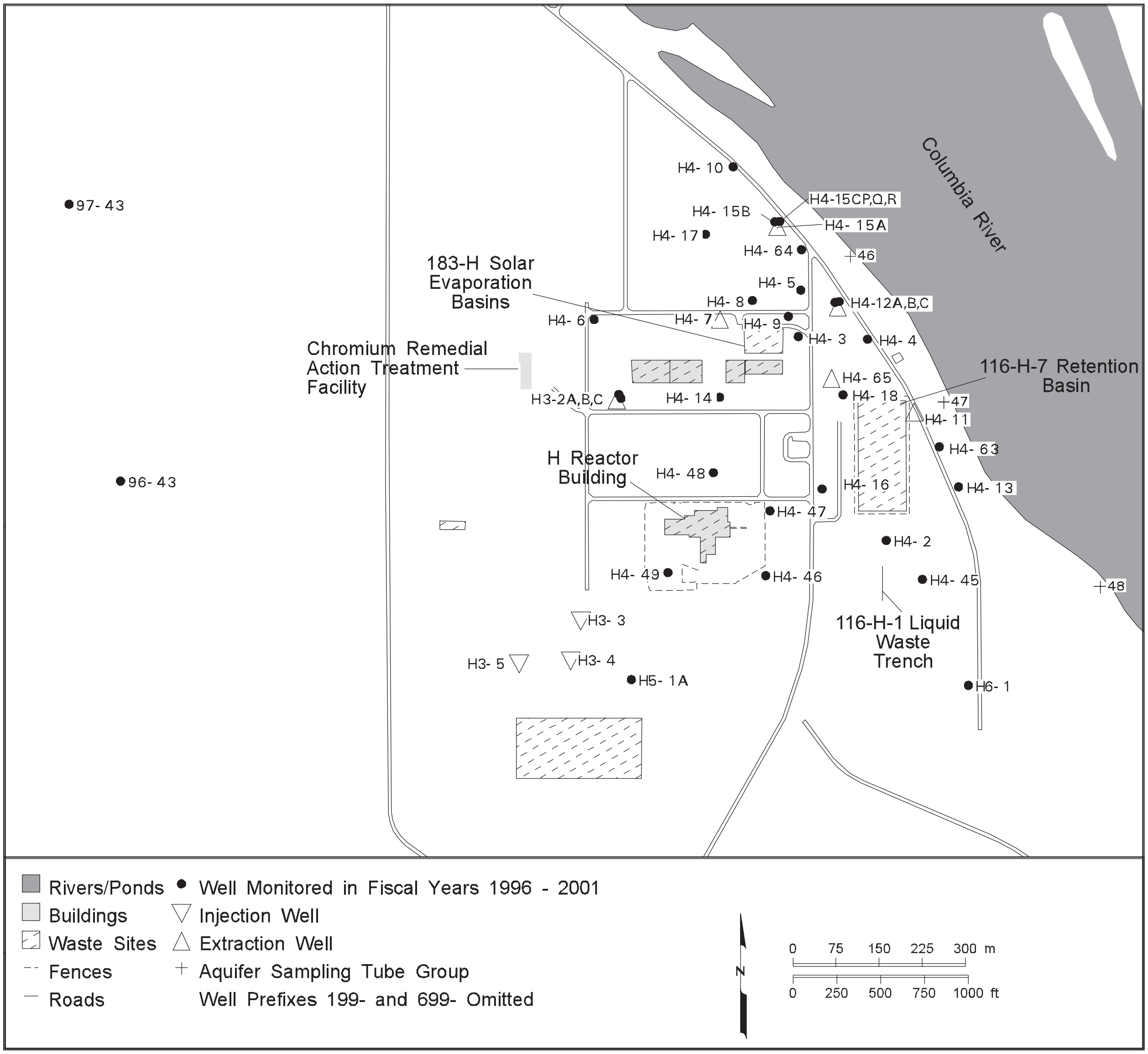


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Figure 2.6-1. Groundwater Monitoring Wells in the 100 H Area

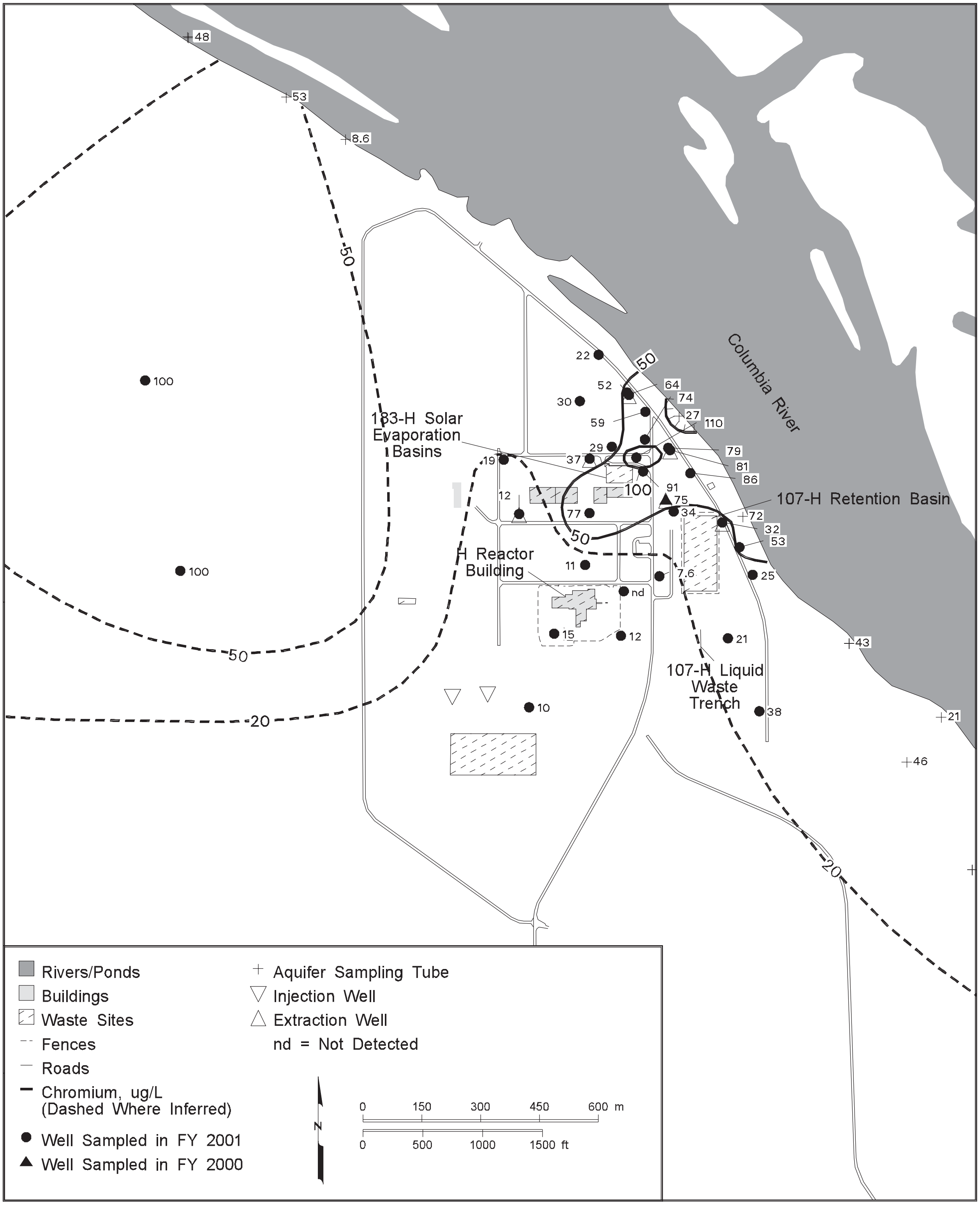

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Figure 2.6-2. Average Chromium Concentrations in the 100 H Area, Top of Unconfined Aquifer

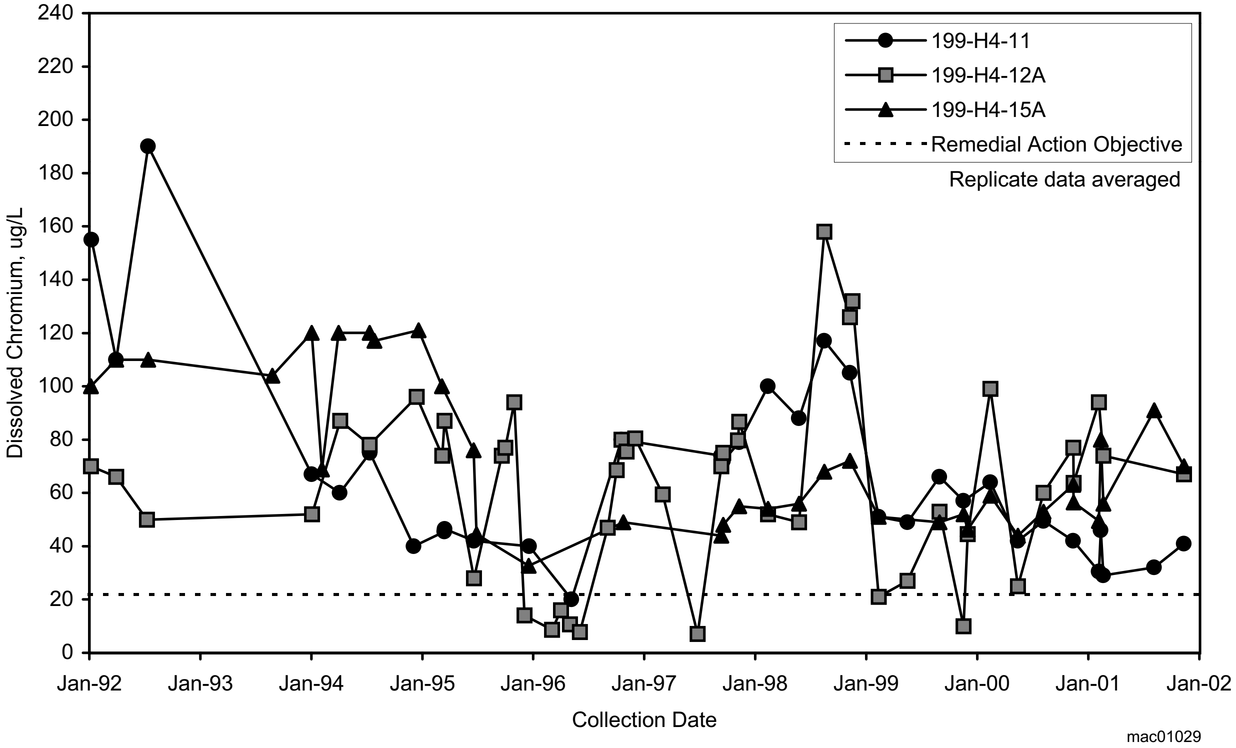

Figure 2.6-3. Dissolved Chromium Concentrations in Extraction Wells Near the Columbia River at the 100 H Area

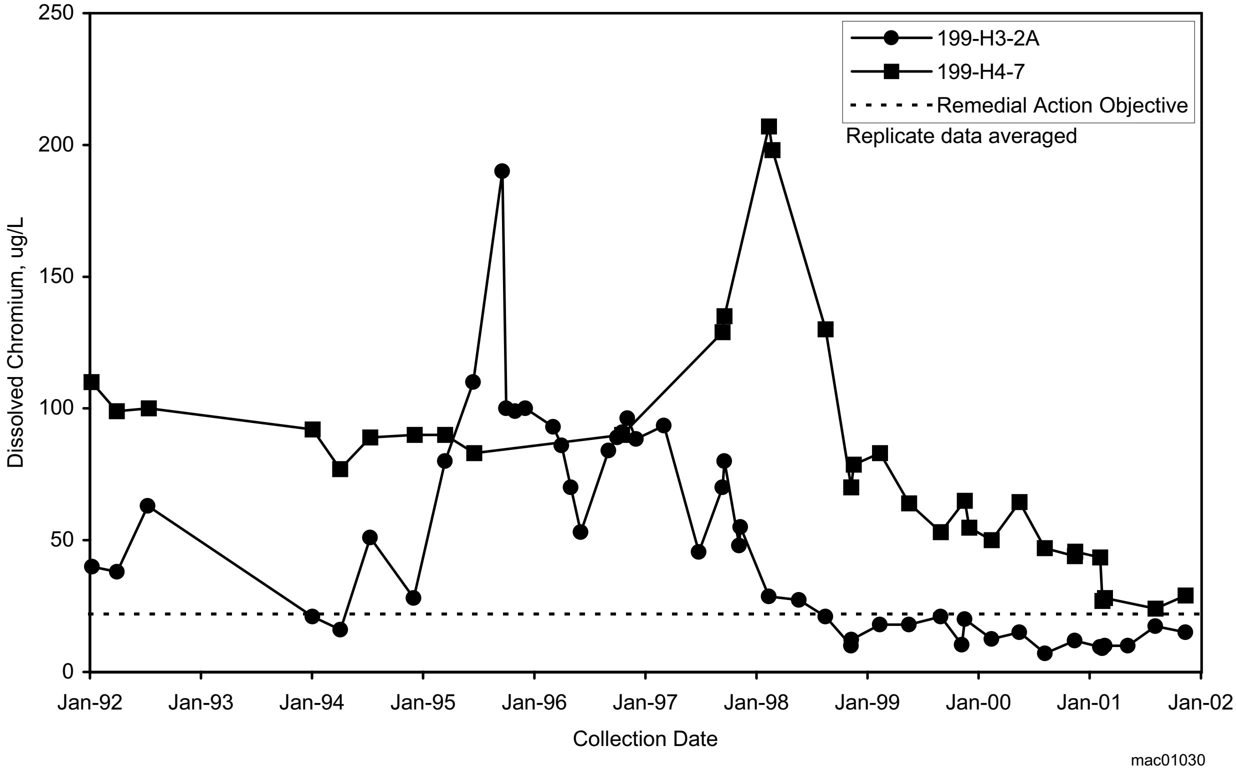

Figure 2.6-4. Dissolved Chromium Concentrations in Extraction Wells Located Inland at the 100 H Area (well 199-H4-65 not shown because it lacks data for fiscal year 2001)

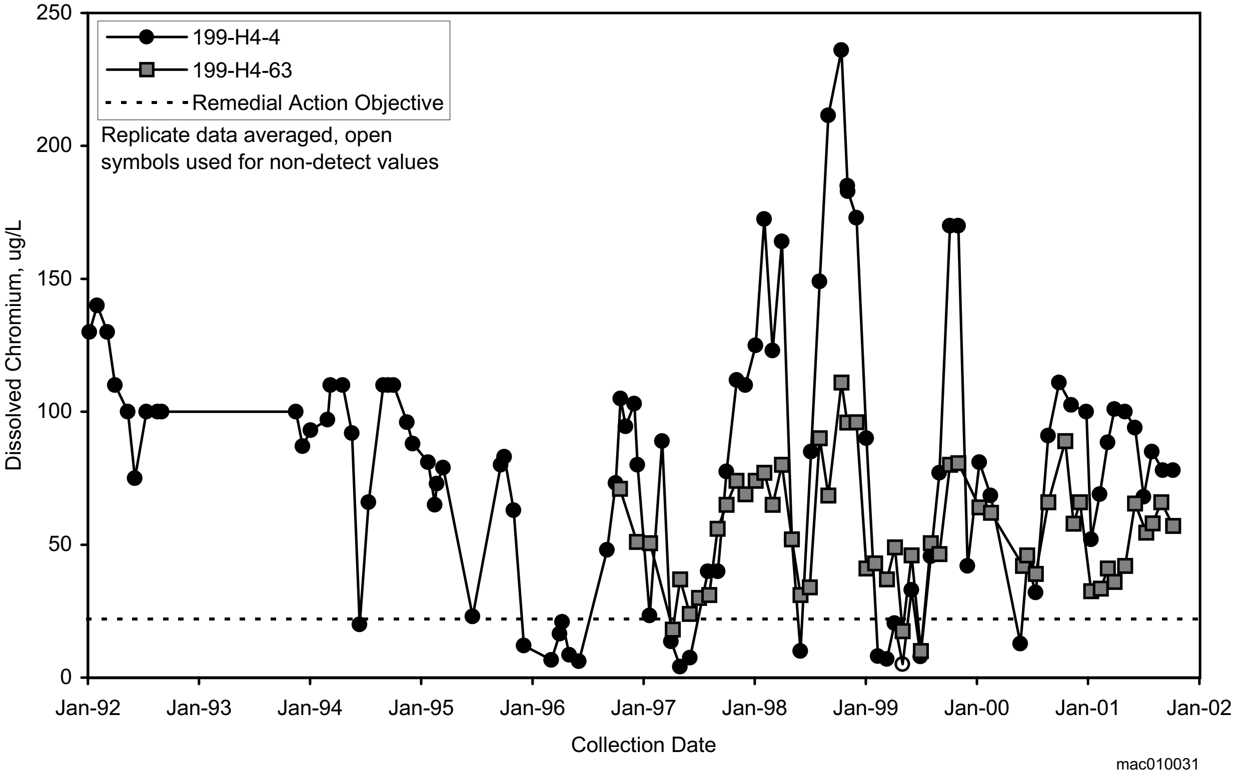

Figure 2.6-5. Dissolved Chromium Concentrations in Groundwater at Interim Action Compliance Wells

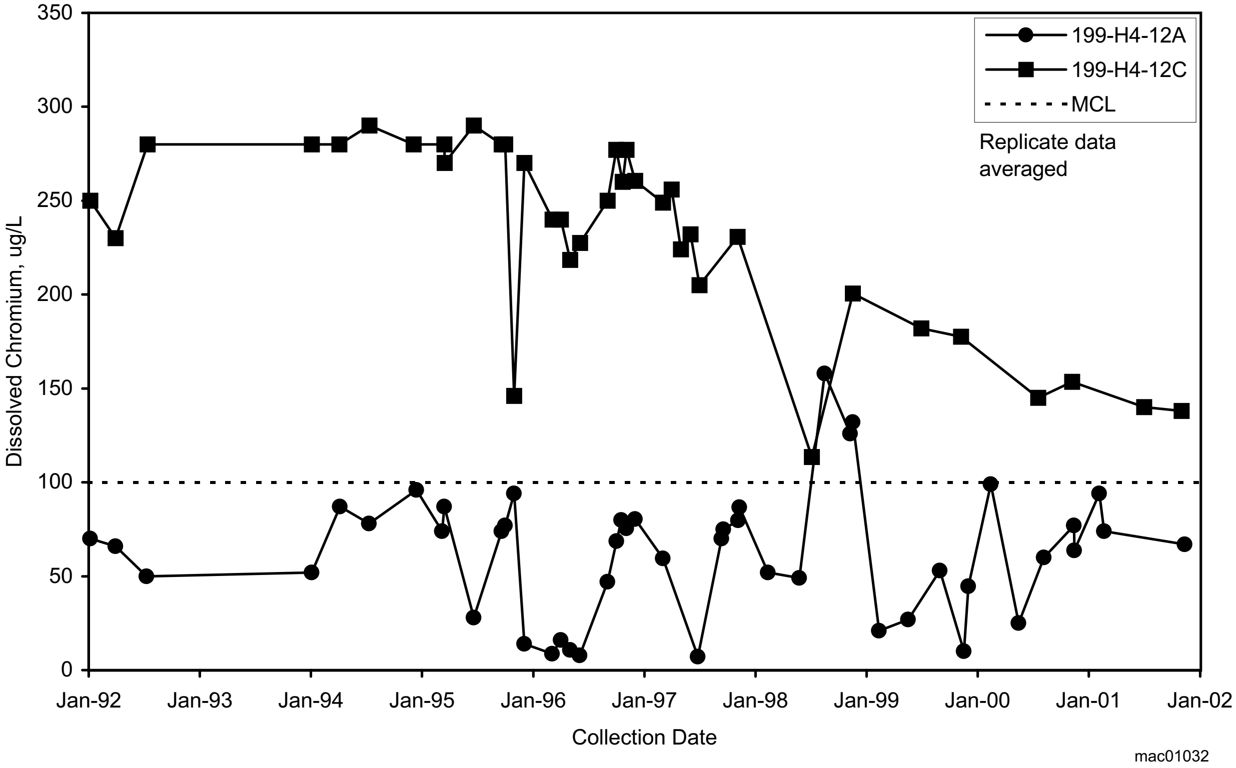

Figure 2.6-6. Dissolved Chromium Concentrations in Groundwater at Well Cluster 199-H4-12

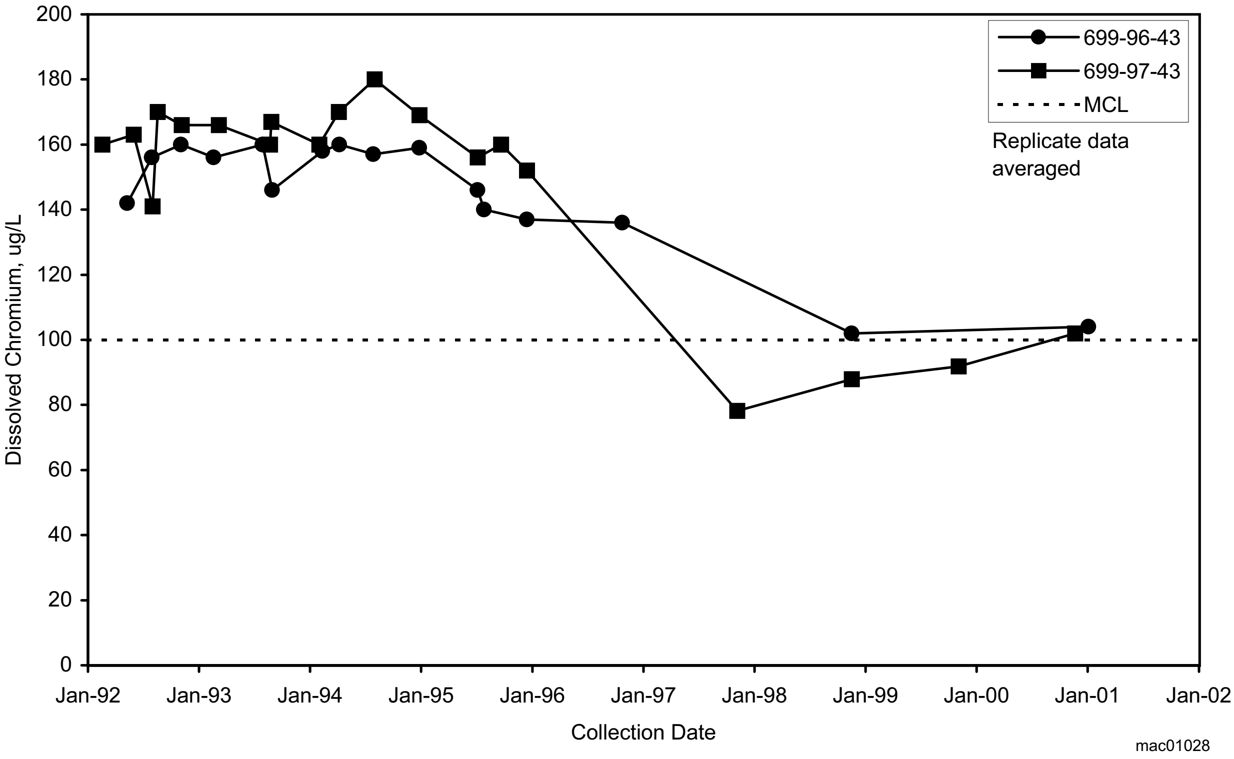

Figure 2.6-7. Dissolved Chromium Concentrations in Wells Upgradient of the 100 H Area

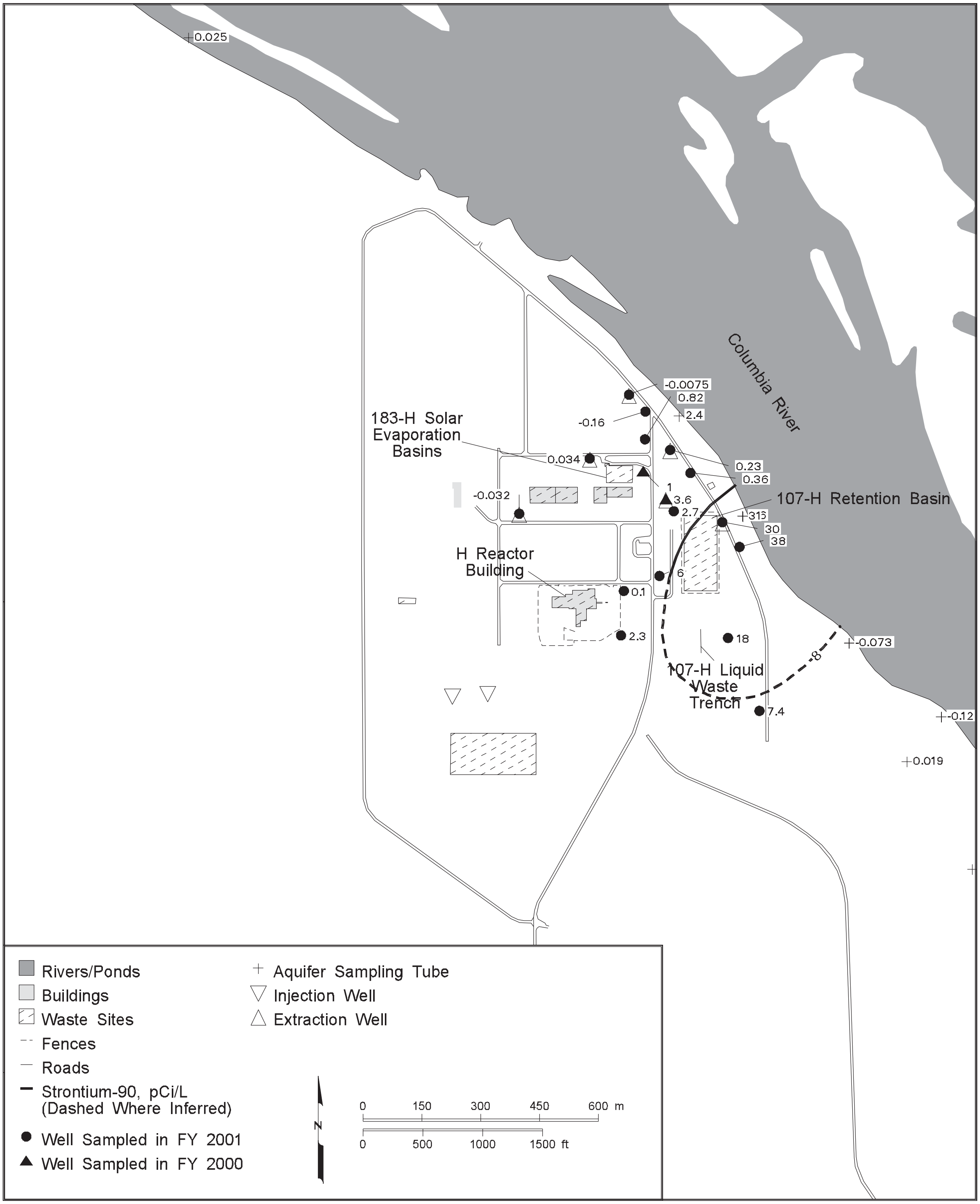

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Figure 2.6-8. Average Strontium-90 Concentrations in the 100 H Area, Top of Unconfined Aquifer

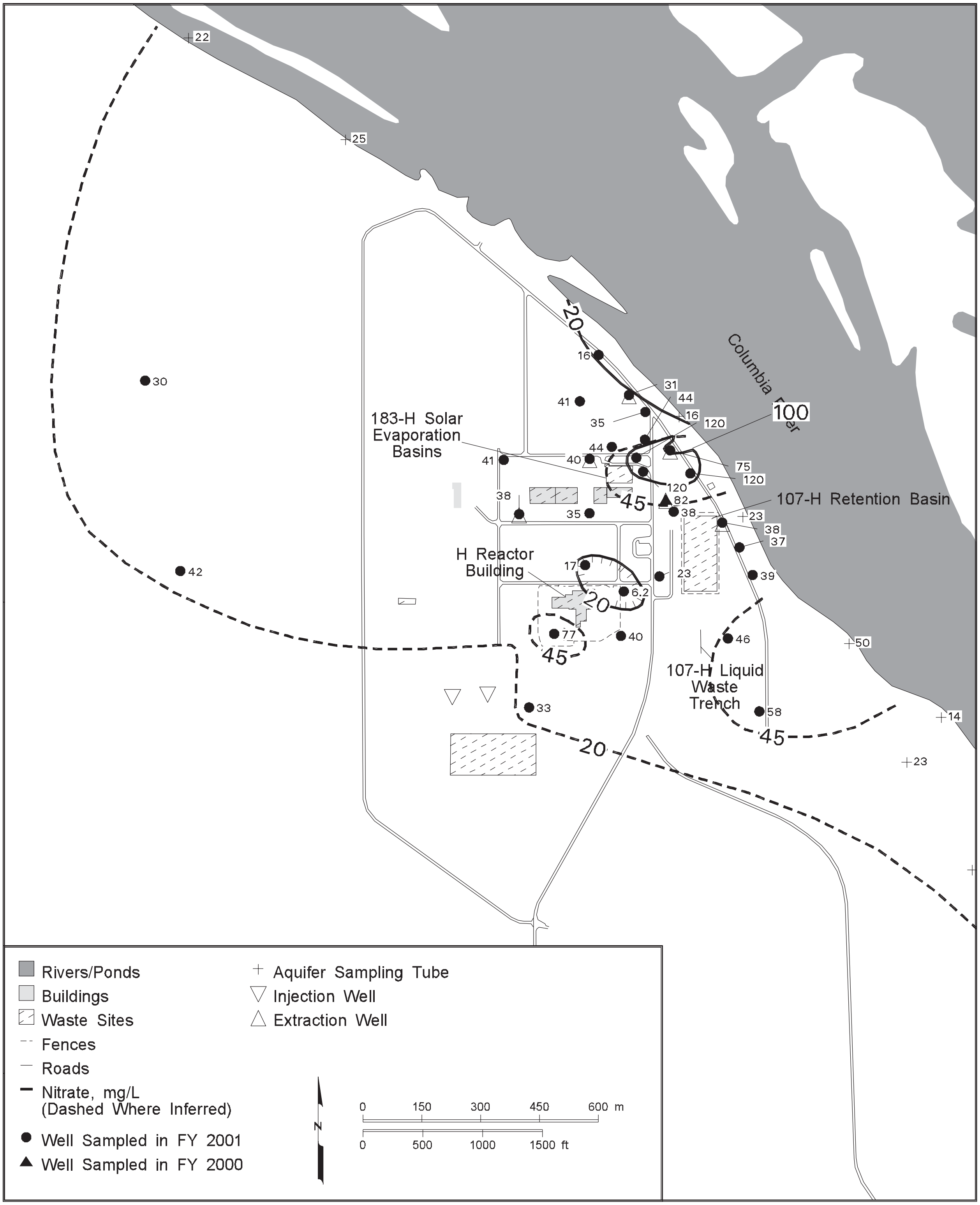

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Figure 2.6-9. Average Nitrate Concentrations in the 100 H Area, Top of Unconfined Aquifer

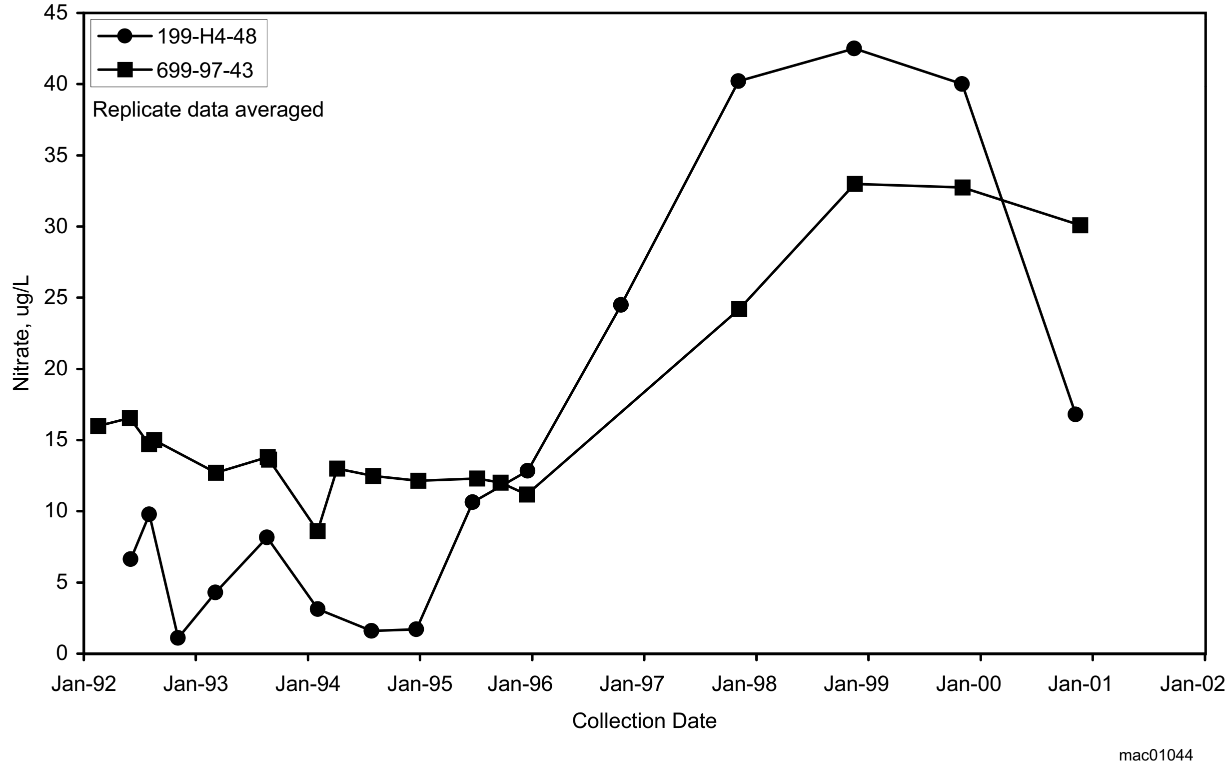


Figure 2.6-10. Nitrate Concentrations in Well 199-H4-48, Near H Reactor, and Well 699-97-43, West of 100 H Area

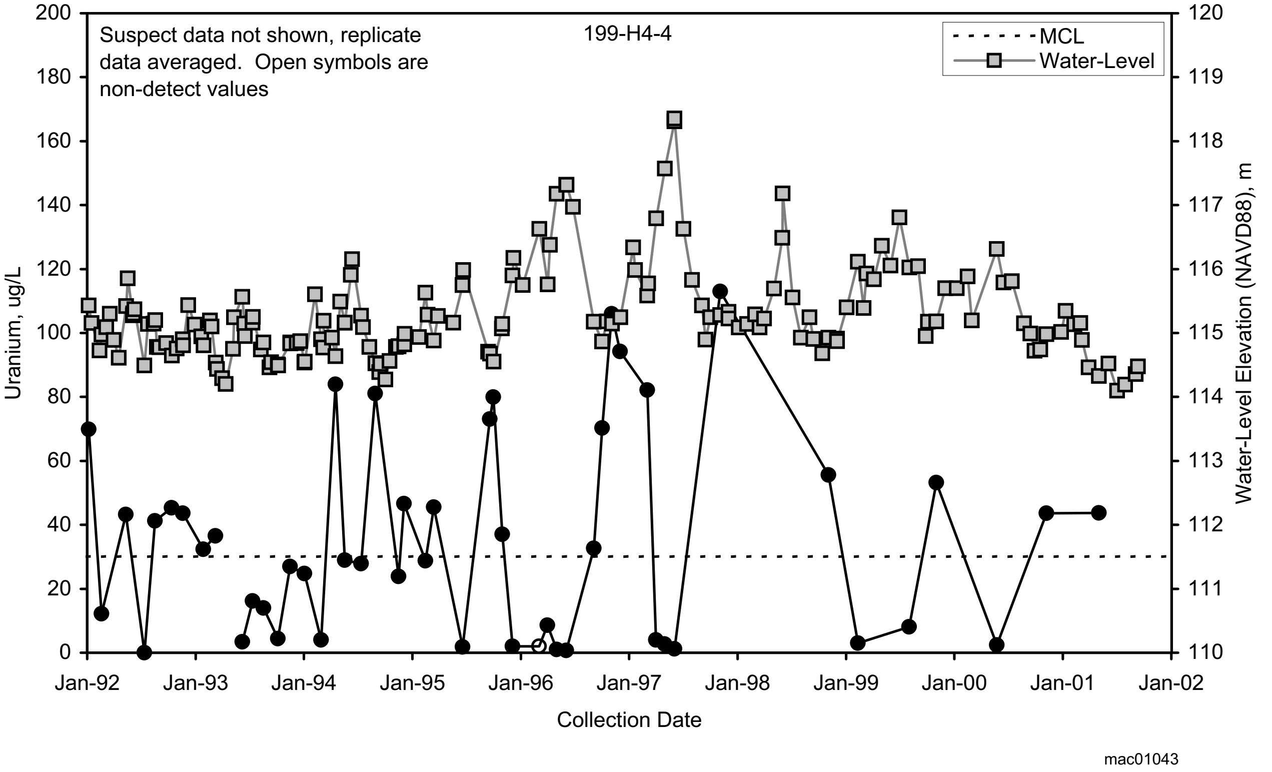


Figure 2.6-11. Uranium Concentrations and Water Levels Downgradient of 183-H Basins

2.7 100 F Area

M. D. Sweeney

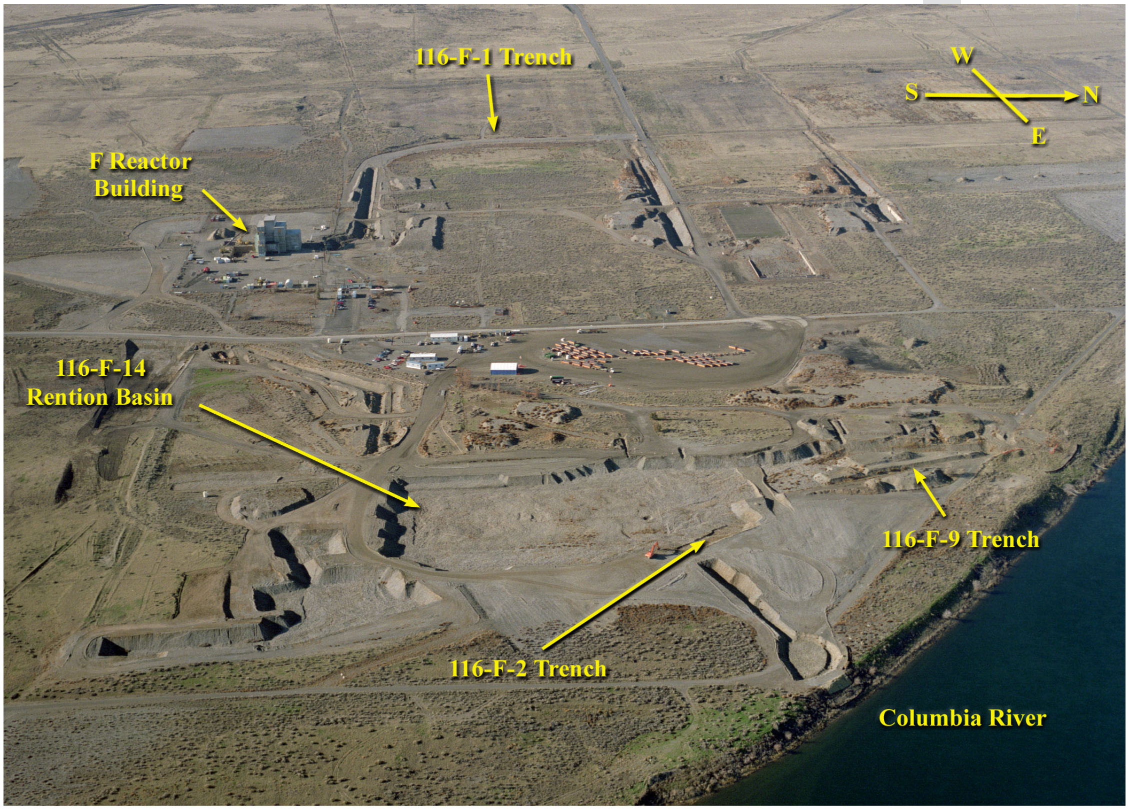
The 100 F Area is located the farthest east and downstream of the reactor areas on the Hanford Site (Figure 2.7-1). F Reactor operated from 1945 to 1965. Like all of the other Hanford Site reactors except N Reactor, F Reactor was cooled by a single-pass system (i.e., cooling water passed through the reactor and was eventually discharged directly to the Columbia River). Waste sites in the 100 F Area include retention basins for reactor coolant, liquid waste disposal trenches, and French drains. Waste sites are described in DOE/RL-95-54 and DOE/RL-95-92. Groundwater contaminants include nitrate, strontium-90, and tritium. Local contamination with chromium, trichloroethene, and uranium is also detected.

Nitrate continued to exceed its maximum contaminant level beneath the 100 F Area and in a fairly large plume extending downgradient to the southeast. Strontium-90, trichloroethene, and tritium exceeded standards in much smaller plumes or single wells.

2.7.1 Groundwater Flow

Groundwater flows toward the east-northeast in the northern 100 F Area and toward the southeast in the southern 100 F Area (see Plate 1). In March 2001, the gradient between wells 199-F5-4 and 199-F8-4 was 0.002. Hydraulic conductivity of the Hanford formation in the 100 F Area ranges from 9.1 to 69 meters per day (BHI-00917). Using these values and an effective porosity of 0.1 to 0.3, the flow rate ranges from 0.06 to 1.4 meters per day toward the southeast.

A plume of groundwater contaminated with tritium, which originates from sources in the 100 F Area, extends to the southeast of the 100 F Area, confirming



Aerial view of the 100 F Area, November 2001. During fiscal year 2001, remediation of waste sites continued; contaminated soil and debris were excavated and taken to the Environmental Restoration Disposal Facility.

the southeastern direction of flow. This plume appears to discharge into the river in the vicinity of the 100 F Area slough and some additional, but uncertain, distance farther downstream. The cause for this preferential pathway may be a buried former river channel that lies parallel to the current channel. Evidence for erosional features on the top of the Ringold Formation (which lies below the water table) was noted during earlier investigations of the hydrogeology of the 100 F Area (Figure 2.7-2).

Monitoring Objectives in 100 F Area

Groundwater monitoring is conducted in the 100 F Area:

- triennially to annually to describe the nature and extent of contamination
- quarterly to monitor trends in variable constituents/wells.

2.7.2 Tritium

Tritium concentrations beneath the 100 F Area are generally low except for one well near the 118-F-1 burial ground (see Plate 2). The tritium concentration appears to have stabilized with the last three annual samples reporting values of 36,900 pCi/L (1999), 24,400 pCi/L (2000), and 38,600 pCi/L (2001). No specific information on the source of the tritium contamination can be found in the Waste Identification Database System.

2.7.3 Uranium

No wells exceeded the new uranium maximum contaminant level of 30 μg/L in fiscal year 2001.

2.7.4 Strontium-90

Two wells exceeded the drinking water standard for strontium-90 in fiscal year 2001. Well 199-F5-1 is near the river ~50 to 100 meters east of the 116-F-2 trench. The second well, 199-F5-6, is located ~320 meters east of the 183-F clearwells. Strontium-90 concentrations in these wells appear to fluctuate with changing river levels near the 100 F Area.

These wells have been used to track a small strontium-90 plume near the 116-F-14 retention basins and the 116-F-2 trench. Two other wells, 199-F5-3 and 199-F5-46, used for plume tracking near these facilities exceeded the drinking water standard in fiscal year 2001.

2.7.5 Nitrate

Nitrate exceeds the 45 mg/L maximum contaminant level in a fairly large plume originating in the 100 F Area and extending downgradient to the southeast. Nitrate varies in concentration across the 100 F Area. Nine wells had concentrations above the maximum contaminant level in fiscal year 2001. Eight of these wells are inside the 100 F Area boundary. Of these wells, three have higher concentrations of nitrate than in their last sampling (Figure 2.7-3). They include wells 199-F5-45, 199-F7-1, and 199-F8-2. Only well 199-F5-45 continues to exhibit an increasing trend, while the remaining two wells have exhibited trends that are best described as stabilized. Five of the eight wells inside the 100 F boundary are decreasing in concentration. Of these wells, only 199-F8-4 exhibits an overall decrease in concentration (Figure 2.7-4). Wells 199-F5-45, 199-F5-46, 199-F5-47, and 199-F7-2 have higher reported values for fiscal year 2001 than when sampling began in the early 1990s (Figure 2.7-5). Well 699-71-30 is located ~1,550 meters west of the southwestern corner of the 100 F Area boundary (see Figure 2.2-2). The concentration has varied considerably since 1996 with the latest result showing an increase of ~20 mg/L from fiscal year 1999.

Nitrate results from the 100 F Area through the last 10 years have shown that concentrations are rising near the facilities inside the 100 F Area boundary and in a few downgradient wells. The persistence of nitrate concentration, and its wide areal distribution, indicate that the source area for this contaminant are from either multiple sources outside the 100 F Area, or from a variety of smaller sources originating from within the 100 F boundary.

2.7.6 Chromium

No wells sampled in fiscal year 2001 exceeded the 100 µg/L maximum contaminant level for hexavalent chromium. The only well (199-F5-46) reporting an exceedance in fiscal year 2000 has exhibited a sharp decline in the current reporting period. No explanation for the sudden shift in concentration can be provided at this time.

Nitrate concentrations increased in many wells in the 100 F Area since the late 1990s. In fiscal year 2001, concentrations declined from their peak values in most wells.

2.7.7 Trichloroethene

Trichloroethene continued to be detected in the southwestern corner of the 100 F Area and in the adjacent 600 Area. Wells 199-F7-1, 199-F7-2, and 699-77-36 exceeded the 5 µg/L maximum contaminant level in fiscal year 2001. Trichloroethene concentrations have increased slightly in wells 199-F7-1 and 199-F7-2 (Figure 2.7-6). The drinking water standard was exceeded for the first time in well 199-F7-2 with a reported concentration of 5.6 µg/L. Well 699-77-36 (see Figure 2.7-1) continues to exhibit a gradual decline in concentration with a fiscal year 2001 result of 15 µg/L (Figure 2.7-7). The two wells with increasing trends are separated by ~850 meters, while well 699-77-36 is located ~800 meters west of the 100 F boundary. The distance between these wells indicates that the source areas for trichloroethene contamination are either widely dispersed throughout the 100 F Area, or they represent a plume that is migrating toward the river with the hydraulic gradient.

2.7.8 Waste Site Remediation

Remedial action at waste sites in the 100 F Area (Table 2.7-1) continued in fiscal year 2001. These activities consisted of excavating contaminated soil and debris for disposal at the Environmental Restoration Disposal Facility. Water (obtained from fire hydrants) was applied as necessary to control dust. Application of water was held to a minimum to reduce the potential for mobilizing contaminants from the vadose zone to the groundwater. After excavation is completed, the sites will be backfilled and re-vegetated.

2.7.9 Monitoring at River Shoreline

Groundwater near the Columbia River is sampled annually in October/November via aquifer sampling tubes and riverbank seeps. The sampling tubes are polyethylene tubes that were installed in the aquifer at locations near the low-water shoreline. Seeps are natural areas of groundwater discharge above the water line. Three aquifer tubes and two seeps were sampled near 100 F Area in fiscal year 2001 (Table 2.7-2).

Nitrate exceeded its maximum contaminant level in two seeps on the shore of the Columbia River downgradient of the 100 F Area.

The highest nitrate concentrations typically are detected in two seeps southeast of the 100 F Area, where the groundwater nitrate plume discharges to the Columbia River. Nitrate data from these two seeps in fiscal year 2001 were erroneous. Other contaminants were present in very low concentrations at the shoreline.

Table 2.7-1. 100 F Area Waste Sites Remediated in Fiscal Year 2001

Waste Site Designation	Fiscal Year Excavated	Maximum Depth of Excavation (m)
100 F pipelines	2001	6.0
116-F-14 retention basin	2001	4.6
116-F-2 liquid waste disposal trench	2001	4.6
116-F-9 animal waste leaching trench	2001	4.6
126-F-1 ash pit	2001	4.6
1607-F2 and 1607-F6 septic tanks	2001	4.6
UPR-100-F-2 basin leak ditch	2001	4.6
116-F-12 french drain	2001	4.6
100-F-34 french drain	2001	4.6
100-F-2 strontium garden	2001	2.0

Table 2.7-2. Shoreline Monitoring Data for the 100 F Area, Fiscal Year 2001

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)	Chromium (µg/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
64-D	Tube	11/15/00	230	9	1.7		152	
66-M	Tube	11/16/00	200	5	0.1		82	
SF-190-4	Seep	11/07/00	126	4	0.9	2.9	-51	11.4
SF-207-1	Seep	11/07/00	365(a)	14(a)	0.0 U(a)	10.4(a)	821(a)	125.3(b)
SF-207-1	Seep	04/30/01	476	19	0.0	10.2	1,380	
SF-207-1	Seep	10/22/01	452			6.4		
SF-211-1	Seep	11/07/00	426	12	0.1	7.7	959	637.5(b)
SF-211-1	Seep	10/22/01	512					

Tube = Aquifer sampling tube near the low-river shoreline.
Seep = Natural riverbank seepage site.
U = Below detection limit.

(a) Average of multiple measurements.

(b) Suspected error. Historical data for SF-207-1 range from 18.6 to 54.9 mg/L and for SF-211-1 average ~5.5 mg/L.

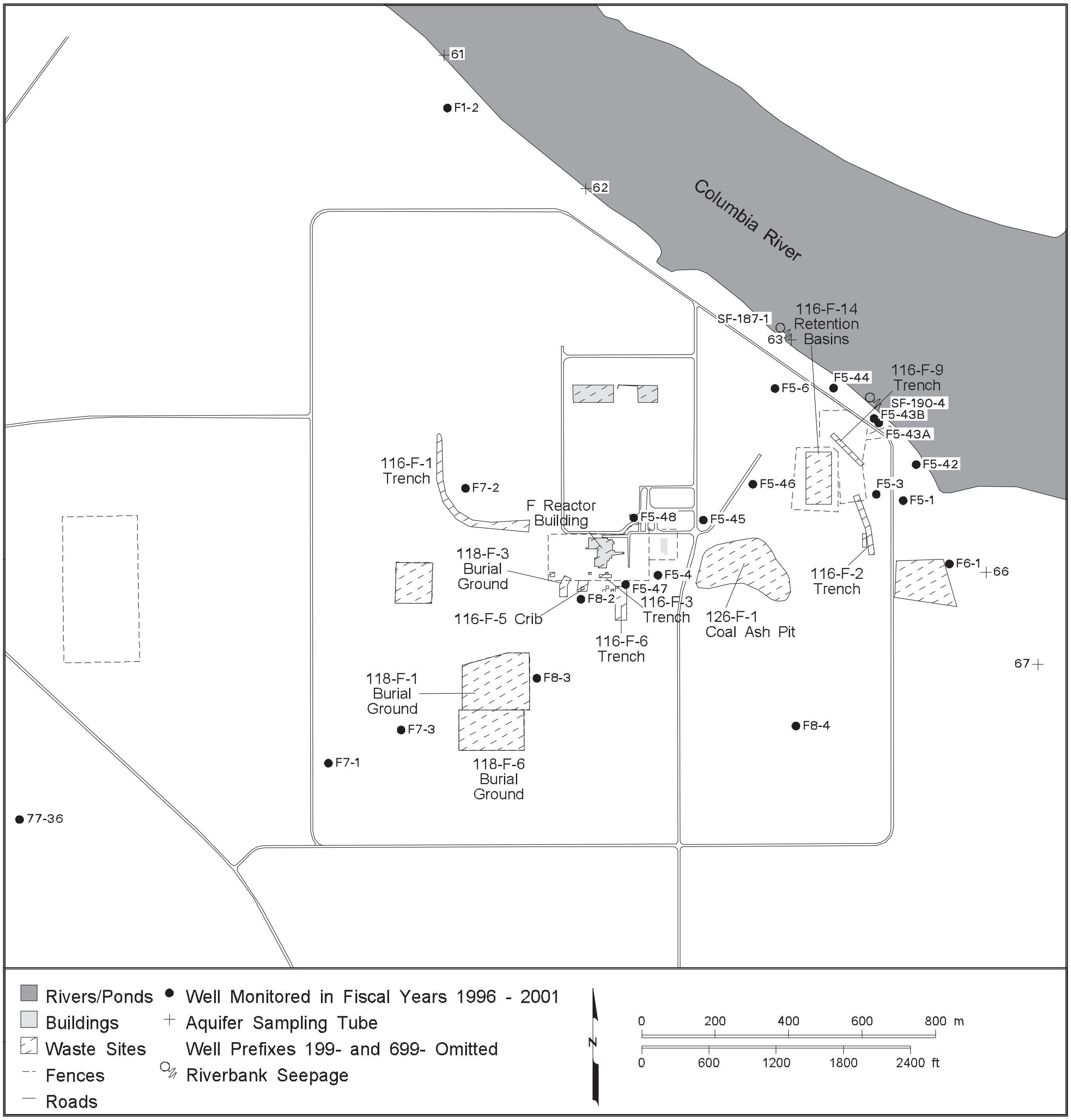


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Figure 2.7-1. Groundwater Monitoring Wells in the 100 F Area

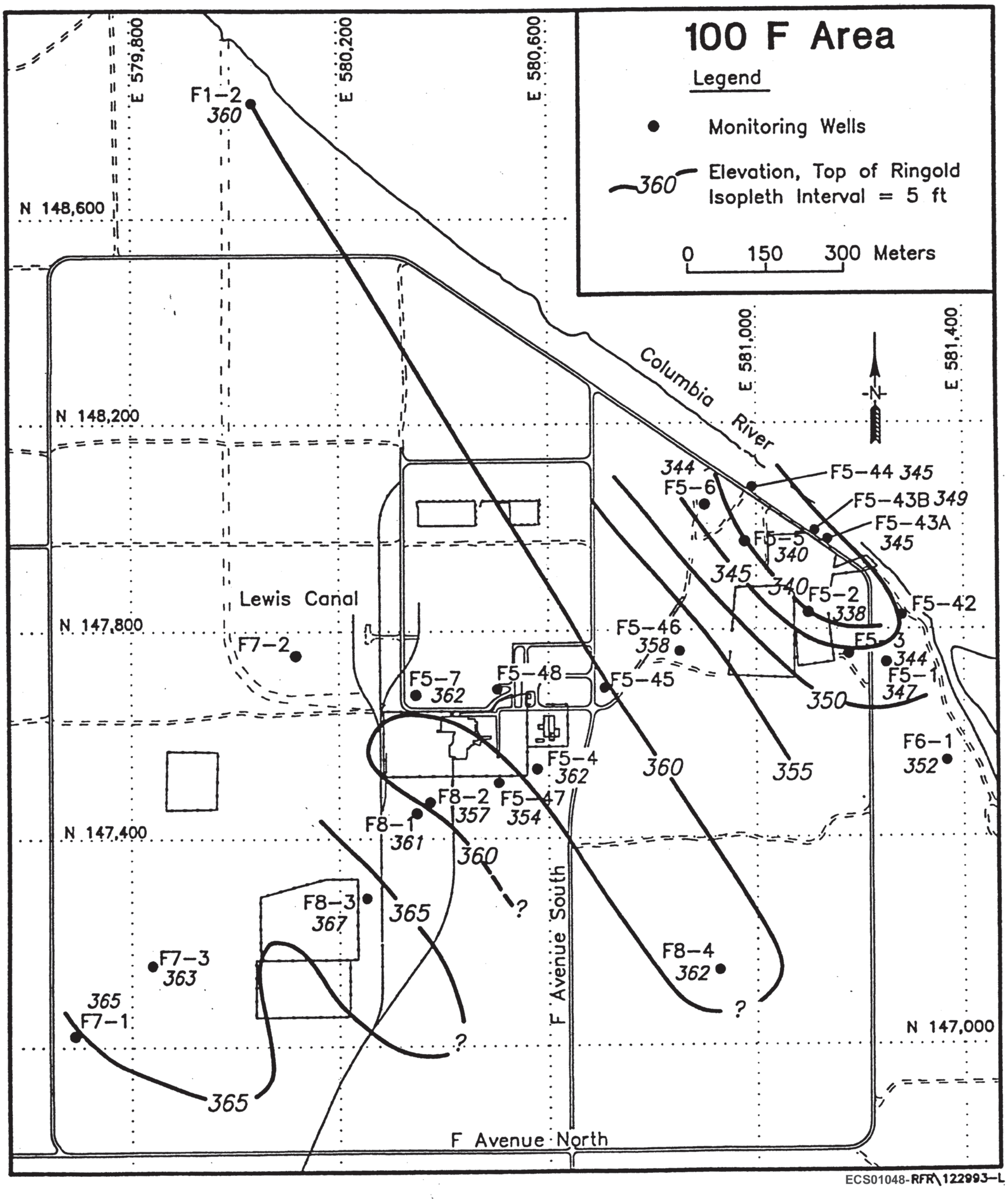


Figure 2.7-2. Elevation Top of Ringold Formation (from WHC-SD-EN-TI-221)

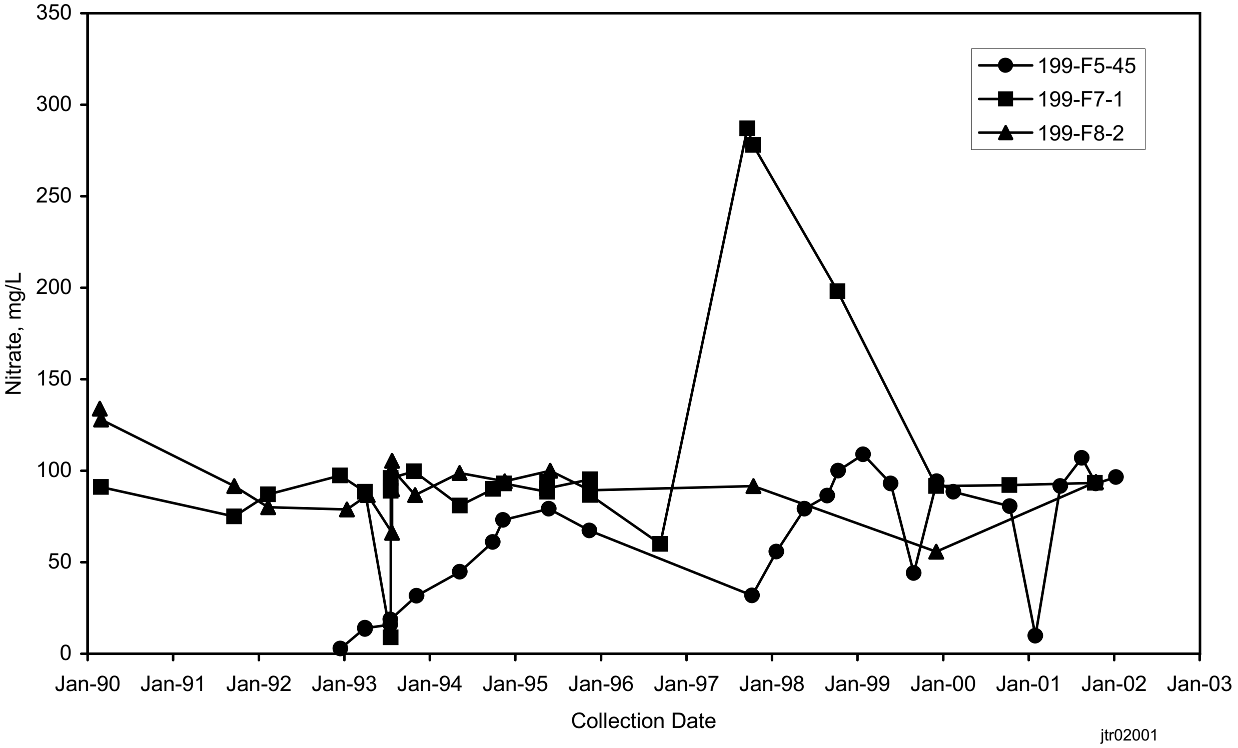


Figure 2.7-3. Nitrate Concentrations in Wells South and East of F Reactor

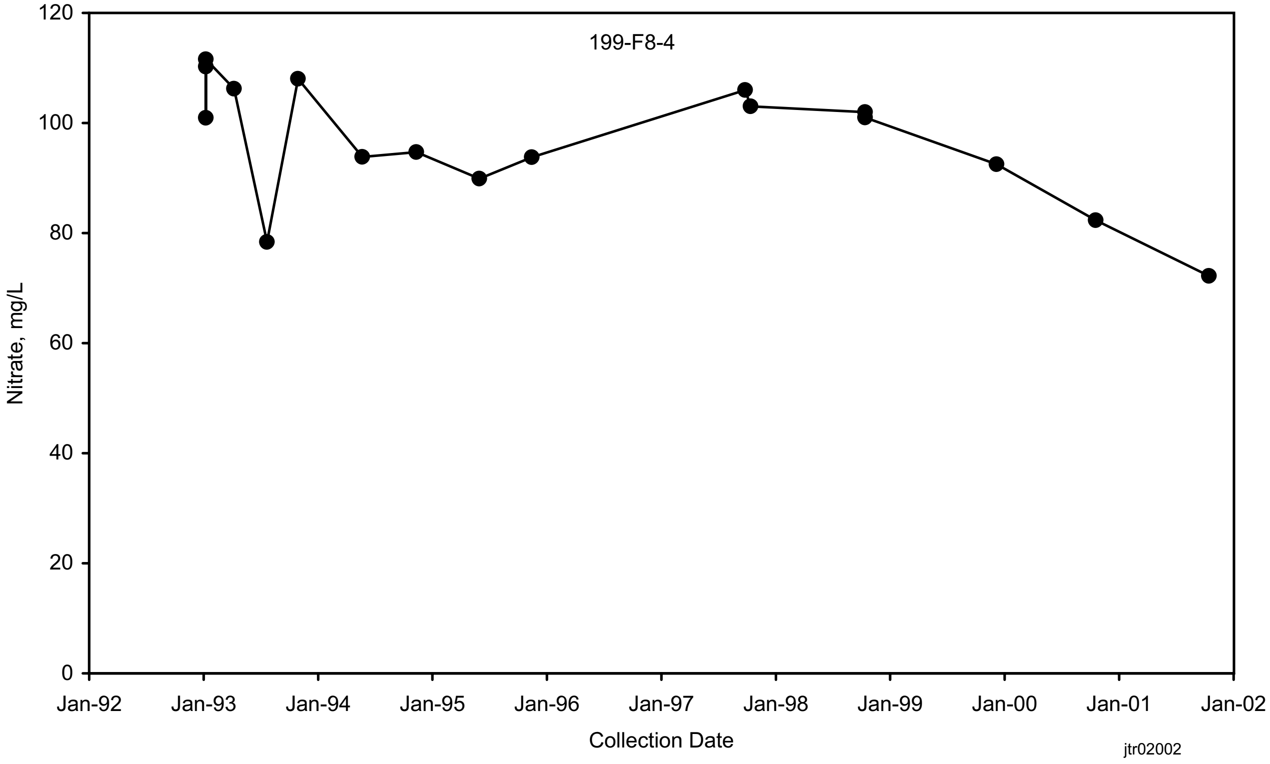


Figure 2.7-4. Nitrate Concentrations in Wells in the Eastern 100 F Area

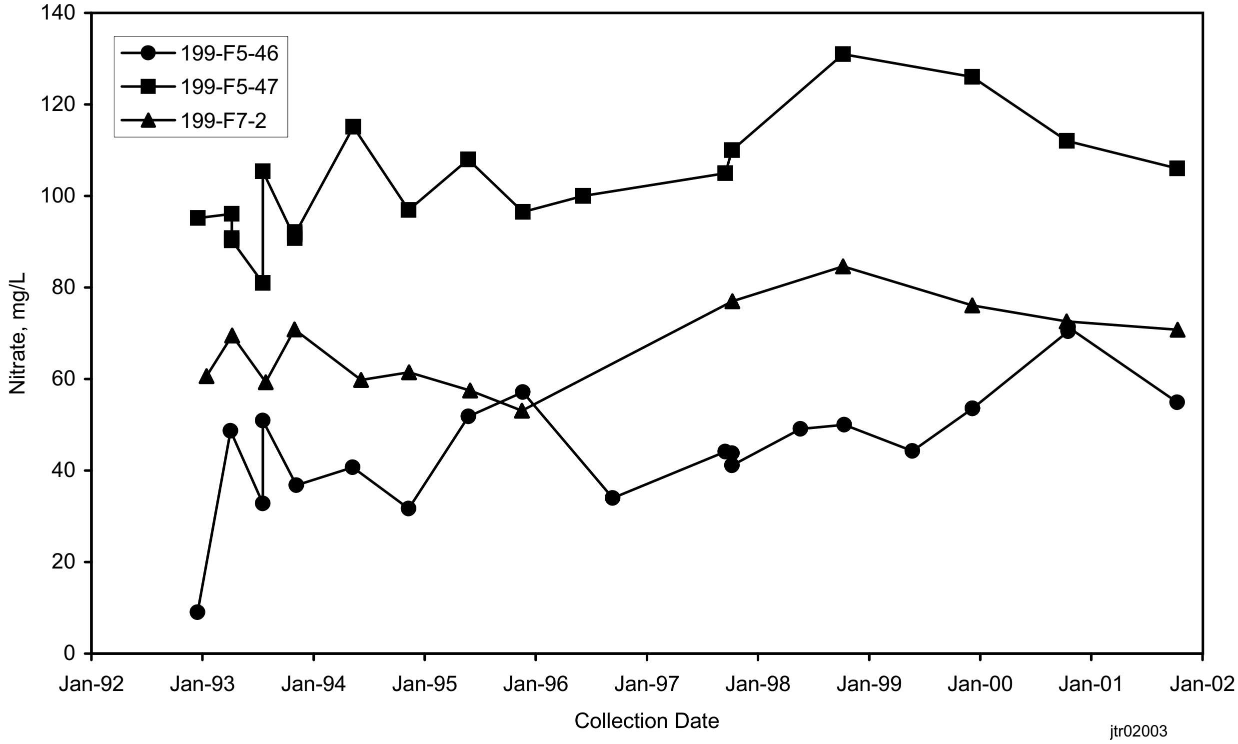


Figure 2.7-5. Nitrate Concentrations in Wells Monitoring 100 F Area

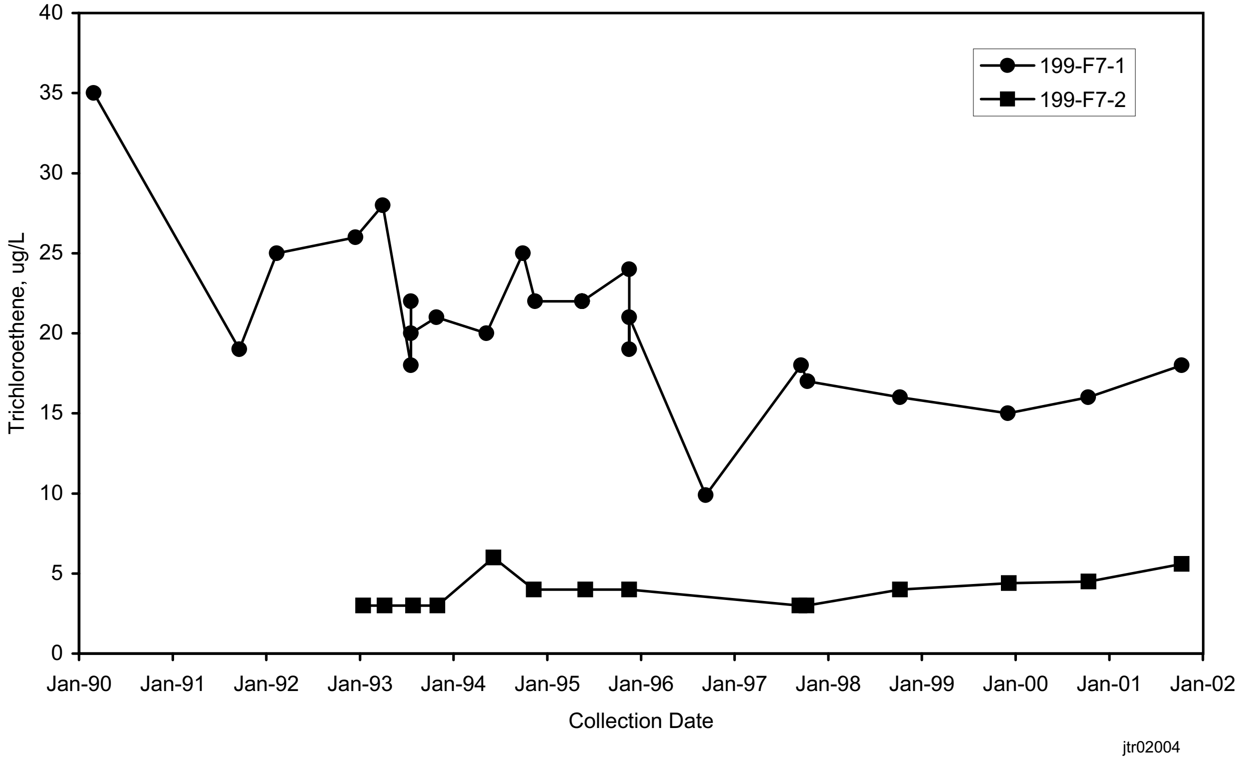


Figure 2.7-6. Trichloroethene Concentrations in Wells in the Western 100 F Area

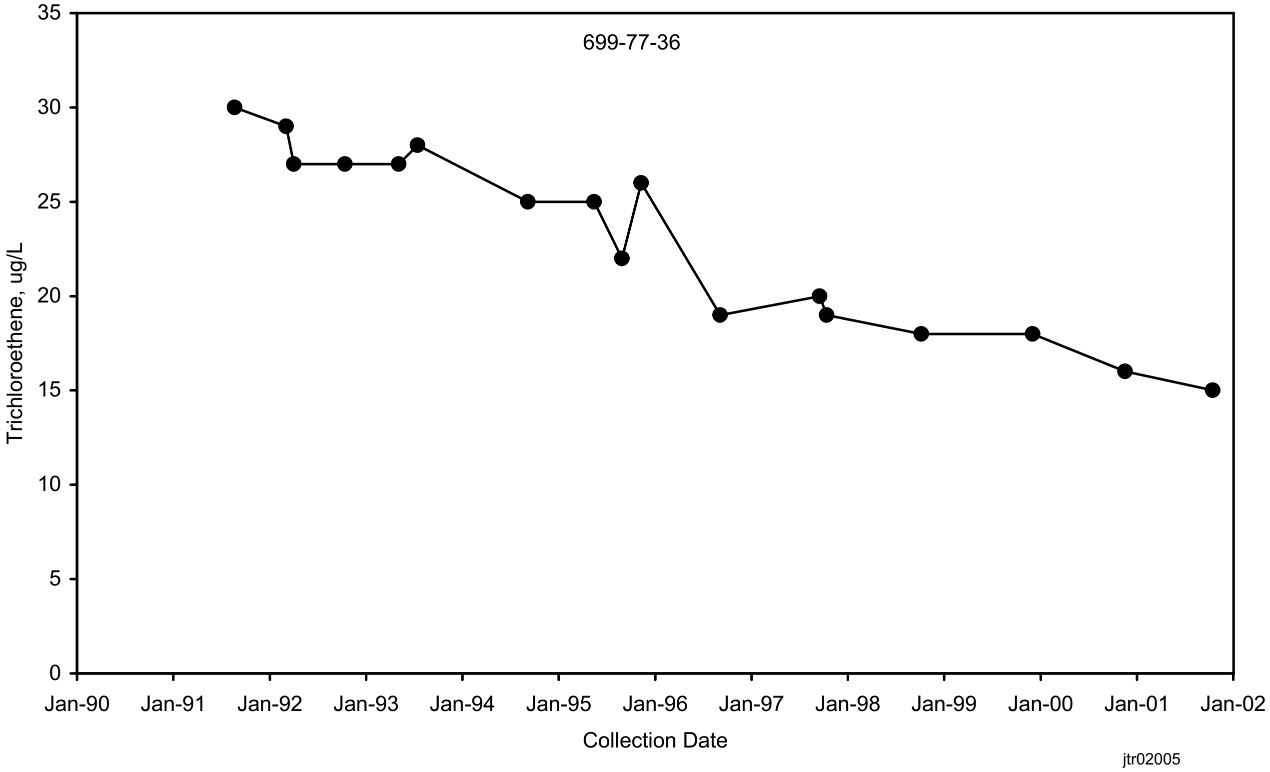


Figure 2.7-7. Trichloroethene Concentrations in a Well 100 Meters West of 100 F Area

2.8 200 West Area

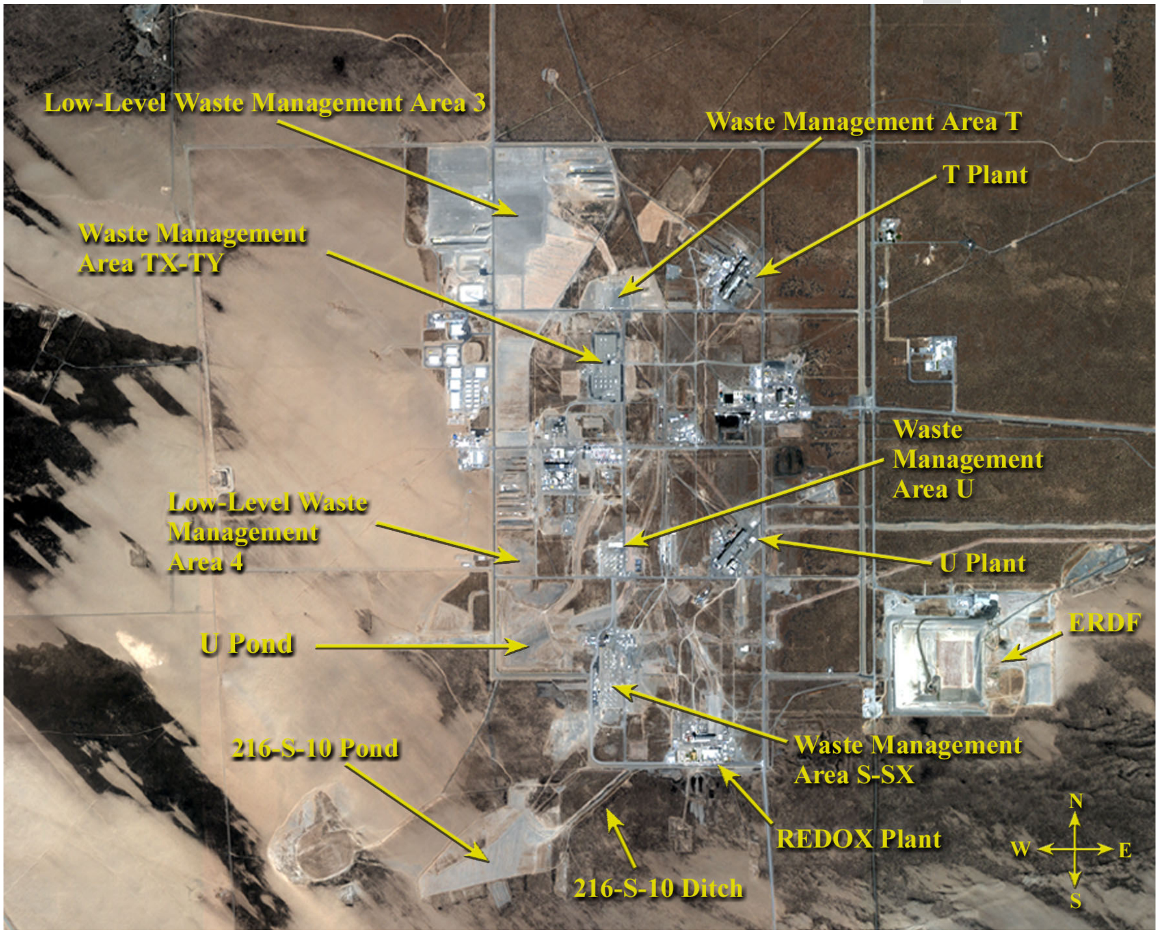
P. E. Dresel, D. B. Barnett, F. N. Hodges, D. G. Horton, V. G. Johnson, R. B. Mercer, R. M. Smith, L. C. Swanson, and B. A. Williams

The 200 West Area, located on the central plateau of the Hanford Site, was used to process irradiated reactor fuel to extract and purify plutonium between 1944 and 1987. The extraction took place at the T Plant and later the Reduction-Oxidation (REDOX) Plant. The Plutonium Finishing Plant was used for plutonium purification. U Plant was used to extract uranium from process waste. Currently, the 200 West Area is used for waste management and disposal. Further details are provided in PNNL-13080.

Groundwater beneath the 200 West Area is contaminated with widespread plumes of carbon tetrachloride, nitrate, tritium, and iodine-129. Chromium, fluoride, technetium-99, trichloroethene, and uranium also are present at levels above their drinking water standards. The eastward spread of contamination from this area is relatively slow because of low-permeability sediment in the aquifer.

The 200 West Area contains two *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) Operable Units, 200-ZP-1 and 200-UP-1, and eight *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and disposal facilities with groundwater monitoring requirements. For the purpose of describing groundwater contamination, the 200 West Area can be divided into five major regions:

- *Plutonium Finishing Plant.* This is the source of carbon tetrachloride, which is the main contaminant plume of concern for the 200-ZP-1 Operable Unit. The carbon tetrachloride and other volatile organic compounds form extensive



Satellite image of the 200 West Area, August 2000.

plumes that have migrated into the area of the 200-UP-1 Operable Unit to the south. The Low-Level Waste Management Area 4 burial ground (a RCRA treatment, storage, and disposal facility) is found in this area. A pump-and-treat system is remediating the carbon tetrachloride contamination in this region.

- *T Plant.* Contaminants within this area are generally considered part of the 200-ZP-1 Operable Unit. RCRA treatment, storage, and disposal facilities, Waste Management Area T single-shell tank farm, Waste Management Area TX-TY single-shell tank farm, and Low-Level Waste Management Area 3 burial ground are located in this area.
- *U Plant.* The main contaminant plumes of concern at the 200-UP-1 Operable Unit, technetium-99 and uranium, have a source from U Plant disposal facilities. Two RCRA treatment, storage, and disposal facilities are located in this area: Waste Management Area U single-shell tank farm and the 216-U-12 crib. A pump-and-treat system is remediating the technetium-99 and uranium contamination in this region.
- *REDOX Plant.* Contaminants within this area are generally considered part of the 200-UP-1 Operable Unit, except when the source is from within 200-ZP-1. Two RCRA treatment, storage, and disposal facilities are located in this area: Waste Management Area S-SX single-shell tank farm and the 216-S-10 pond and ditch.
- *State-Approved Land Disposal Site.* This is a permitted liquid waste disposal system where liquid waste contaminated with tritium is discharged to the ground. This site is regulated under a state of Washington waste discharge permit.

CERCLA Operable Units

Groundwater contamination in the 200 West Area falls under two CERCLA Operable Units, 200-ZP-1 and 200-UP-1.

- 200-ZP-1 includes contamination originating in the Plutonium Finishing Plant and T Plant regions.
- 200-UP-1 includes contamination originating in the U Plant and REDOX Plant regions.

This section discusses groundwater flow, major contaminants, specific RCRA facility monitoring, and performance of remediation systems for each region. The major contaminant plumes found in 200 West Area are carbon tetrachloride, chloroform, iodine-129, nitrate, technetium-99, trichloroethene, tritium, and uranium. Chromium, fluoride, and strontium-90 are also found in small areas. Monitoring well locations in the 200 West Area are shown in Figure 2.8-1.

2.8.1 Plutonium Finishing Plant

The Plutonium Finishing Plant performed the final stages of plutonium purification from 1949 through 1987. Carbon tetrachloride and other volatile organic compounds form the major plumes attributable to the Plutonium Finishing Plant. Relatively widespread nitrate contamination also is present. The Plutonium Finishing Plant has not been a significant contributor to the major radiological contaminant plumes in groundwater. Migration of plutonium contamination from the vadose zone is of considerable concern because large quantities of plutonium, in the presence of organic complexing agents, were disposed to ground in the area. The formation of plutonium-bearing colloids that could enhance mobility is also a concern. No further investigation of the mobility of plutonium was undertaken in fiscal year 2001. Past data suggest minor plutonium groundwater contamination (PNNL-12086), though no new results from fiscal year 2001 indicated the presence of plutonium in 200 West Area groundwater.

The only facilities near the Plutonium Finishing Plant with RCRA monitoring requirements are the burial grounds in Low-Level Waste Management Area 4. These are not believed to contribute to groundwater contamination. Remediation of volatile organic compounds in groundwater and the vadose zone is being undertaken in this area using a pump-and-treat and a vapor extraction system. Carbon tetrachloride continues to be removed from the vadose zone by vapor extraction, reducing this source of groundwater contamination (see Section 3.2). The groundwater pump-and-treat system removes carbon tetrachloride as groundwater is withdrawn, treated, and re-injected. The pump-and-treat extraction and re-injection of the treated groundwater has caused significant changes in groundwater flow and contaminant distribution.

Monitoring Objectives Near Plutonium Finishing Plant

Groundwater monitoring is conducted near the Plutonium Finishing Plant:

- triennially to annually to describe the nature and extent of contamination
- semiannually to detect the possible impact of one RCRA waste management area
- semiannually to monitor trends in variable constituents/wells
- various time intervals to evaluate the performance of a pump-and-treat system for carbon tetrachloride.

2.8.1.1 Groundwater Flow

Groundwater near the Plutonium Finishing Plant flows generally from west to east, but is heavily influenced by the ongoing 200-ZP-1 Operable Unit pump-and-treat activities (see Plate 1). At the start of fiscal year 2001, there were six extraction wells along an arc from north of the Plutonium Finishing Plant to the east and southeast. Use of the southernmost extraction well was suspended in January 2001 (see Section 2.8.1.5). There are also five injection wells (only three are active) located to the southwest of the Plutonium Finishing Plant and to the west of Low-Level Waste Management Area 4. A small groundwater mound is associated with the injection wells, and a region of drawdown is associated with the extraction wells, causing flow to converge on the extraction zone from all directions. These flow conditions are expected to continue until the end of the pump-and-treat program, at which time the flow direction will resume a west to east pattern. Groundwater flow beneath Low-Level Waste Management Area 4 is discussed in Section 2.8.1.5, and flow beneath the pump-and-treat system is discussed in Section 2.8.1.6. The pump-and-treat system also has had an impact on flow at Waste Management Area TX-TY and U tank farms as discussed in Sections 2.8.2.12 and 2.8.3.1.

2.8.1.2 Carbon Tetrachloride

Carbon tetrachloride contamination is present in the unconfined aquifer system beneath most of the 200 West Area and has migrated past the 200 West Area boundary (Figure 2.8-2), covering an area of over 11 square kilometers. The maximum carbon tetrachloride concentration shown in Figure 2.8-2 in the 200 West Area was near the northern extraction wells in well 299-W15-1, where the average concentration was 5,700 μg/L. The allowable maximum contaminant level for carbon tetrachloride in drinking water is 5 μg/L. The interim remedial action goal for the pump-and-treat system, under the interim record of decision (ROD 1995), is to contain the >2,000 μg/L portion of the plume.

Carbon tetrachloride contamination beneath the 200 West Area originated primarily in waste sites near the Plutonium Finishing Plant. In fiscal year 2001, there were significant decreases in concentrations in the core of the plume.

The carbon tetrachloride contamination is believed to be from pre-1973 waste from the Plutonium Finishing Plant. The major identified sources are the 216-Z-9 trench, the 216-Z-1A tile field, and the 216-Z-18 crib. The 216-Z-12 crib, the 216-Z-19 ditch, and the 216-T-19 tile field also may have contributed. These sources are shown in Appendix A, Figure A.23. Vadose zone carbon tetrachloride sources are discussed in Section 3.2.

Carbon tetrachloride concentrations have generally decreased in the center of the plume in fiscal year 2001. Concentrations of carbon tetrachloride decreased in the northernmost extraction wells 299-W15-33, 299-W15-34, and 299-W15-35 and nearby monitoring wells such as well 299-W15-1 (Figure 2.8-3). Concentrations in the southern extraction wells 299-W15-32 and 299-W15-36 and nearby monitoring wells have declined since the start of pump-and-treat operations. Concentrations are declining around the active injection wells as shown by the depression in the contours in Figure 2.8-2.

The part of the carbon tetrachloride plume with concentrations >2,000 μg/L extends to the north, reaching the vicinity of Waste Management Area TX-TY. Several wells in the northern part of the 200 West Area have carbon tetrachloride concentrations exceeding 1,000 μg/L. For example, on the eastern side of Low-Level Waste Management Area 3, well 299-W10-20 has persistent concentrations of carbon tetrachloride near or above 1,000 μg/L, even though it is not located near any known sources. Concentrations were above the 2,000 μg/L interim cleanup level to the west of Waste Management Area TX-TY, in wells 299-W10-5 and 299-W15-40 (Figure 2.8-4).

The greatest concern for transport of carbon tetrachloride is from the northeastern part of the 200 West Area.

The greatest concern for transport of carbon tetrachloride from the 200 West Area remains in the northeastern part of the plume. Carbon tetrachloride concentration changes near the periphery of the plume and at key locations within the plume are shown in Figure 2.8-5. Concentrations declined in well 299-W7-5, in the northwestern part of the plume, while they remained steady, after several years of increase in well 299-W12-1, in the northeast. High concentrations are found near the eastern boundary of the 200 West Area, where carbon tetrachloride reached 1,200 μg/L in well 299-W11-10. The well network is too sparse to define the extent of carbon tetrachloride downgradient of this well. In the southeast, concentrations declined slightly in well 699-36-67 but remain close to the drinking water maximum contaminant level. Along the western boundary, the concentration remained low in well 299-W18-21, after a peak in 1995.

Carbon tetrachloride concentrations have increased markedly in some wells in the vicinity of Waste Management Area S-SX. For example, concentrations in well 299-W23-15, located directly south of the SX tank farm, rose from <5 μg/L in fiscal year 1995 to an average of 130 μg/L in fiscal year 2001 (see Figure 2.8-5). The previously low concentrations in this area could have been caused by the discharge of water free of carbon tetrachloride to portions of the 216-U-14 ditch, north of the tank farms, until 1995. This discharge may have affected groundwater flow, so that carbon tetrachloride spread to the east and west of the tank farms. A number of other wells in the area remain low in carbon tetrachloride.

Carbon tetrachloride concentrations have increased in the southern part of the plume near Waste Management Area S-SX.

Information on the distribution of carbon tetrachloride in the eastern half of the 200 West Area is very sparse. The original monitoring well network had large gaps in this area and several key wells have gone dry. Whether a low concentration area exists in the east-central part of the 200 West Area, as shown on the map (see Figure 2.8-2), is uncertain. This low concentration area may have resulted from past discharges to the 200 West power plant pond and the 216-W laundry waste crib, as is suggested by samples from well 299-W14-10, where carbon tetrachloride was near or below the detection limit. Well 299-W14-10 is an older well that does not appear to have been completed properly to provide representative groundwater samples.

Carbon tetrachloride contamination extends southeast of the Plutonium Finishing Plant to the eastern edge of the Environmental Restoration Disposal Facility, between the 200 West and 200 East Areas. Concentrations in fiscal year 2001 reached the maximum contaminant level of 5.1 μg/L in well 699-37-68.

Overall changes in carbon tetrachloride concentrations in the last year are shown by comparing geostatistical models of the plume for fiscal year 2000 and 2001. A geostatistical model was developed in fiscal year 2000 to increase the efficiency of the monitoring network by eliminating unnecessary samples. Stochastic simulation was used to provide estimates of the concentration (mean value of 100 simulations) at every point in the 200 West and surrounding areas. The results are shown in Figure 2.8-6. The geostatistical evaluation was redone using fiscal year 2001 data and compared to the fiscal year 2000 results. The difference between the results for each year is also shown in the figure. The warm colors (red, orange, yellow shades) in the figure show an increase in carbon tetrachloride in the northern part of the 200 West Area and a small area in the south-central part (near the 216-U-1 and 216-U-2 cribs). The slightly increasing concentrations in the southwest and northeast are shown in green. A significant decrease in carbon tetrachloride is evident in the high concentration core of the plume.

Carbon tetrachloride contamination has been detected to depths >60 meters below the water table. In places, contamination at depth extends greater distances laterally than contamination at the water table, as reported previously (PNNL-12086). Little information is available on the distribution of carbon tetrachloride at depth. Available data are from a few well nests completed at different depths and from depth-discrete samples collected at specific points in RCRA boreholes and in older wells with large open intervals. One disadvantage of the depth-discrete samples within an open well bore is the potential for vertical mixing within the well or along the annulus.

Three borings were drilled through the aquifer in fiscal year 1999, prior to being completed as wells at the water table. The first two of these, located at Waste Management Area T (well 299-W10-24) and Waste Management Area TX-TY (299-W14-14), contained high levels of carbon tetrachloride. The highest concentration detected was 1,600 μg/L at 33 meters below the water table in well 299-W10-24. The deepest sample, at 68 meters below the water table in well 299-W14-14, still contained 590 μg/L of carbon tetrachloride (Figure 2.8-7). At the third location, Waste Management Area S-SX (well 299-W22-50), the highest concentration of carbon tetrachloride was 13 μg/L at the water table, but 5.6 μg/L of carbon tetrachloride also were detected at 53 meters below the water table (Figure 2.8-8). The interim remedial measures at the 200-ZP-1 Operable Unit do not address the deep contamination.

2.8.1.3 Chloroform and Trichloroethene

Two sources of chloroform in Hanford Site groundwater are from chlorination of organic matter during purification of potable water and then its subsequent disposal to ground, or from biodegradation of carbon tetrachloride. Biodegradation is believed to be the major source of chloroform in the 200 West Area. The drinking water standard maximum contaminant level for chloroform is 100 μg/L (total trihalomethanes). In January 2002, the maximum contaminant level for total trihalomethanes was reduced to 80 μg/L. Values for chloroform at the water table were all below the maximum contaminant level in fiscal year 2001, but the concentration was above the drinking water standard in well 299-W14-9, which is open to a long interval in the aquifer. The average concentration in that well for fiscal year 2001 was 123 μg/L, which is slightly higher than the fiscal year 2000 average of 96 μg/L.

The distribution of trichloroethene near the Plutonium Finishing Plant is shown in Figure 2.8-9. The trichloroethene plume is entirely contained within the extent of the carbon tetrachloride plume. Disposal of trichloroethene near T Plant also may have contributed to this plume. The maximum annual average trichloroethene found in fiscal year 2001 was found near the northern extraction wells for the carbon tetrachloride pump-and-treat system, 16 μg/L in well 299-W15-7. This is a decline from 28 μg/L reported the previous year. The maximum contaminant level allowable in drinking water for trichloroethene is 5 μg/L.

2.8.1.4 Nitrate

A nitrate plume originates at Plutonium Finishing Plant disposal facilities. The 216-Z-9 trench received an estimated 1.3 million kilograms of chemicals containing nitrate during its operation from 1955 to 1962. Other liquid waste disposal facilities associated with the Plutonium Finishing Plant received smaller but still significant amounts of nitrate. Additional sources of nitrate from disposal facilities near T Plant also contribute to the contamination downgradient. The extent of nitrate in the 200 West Area is shown in Figure 2.8-10. The highest nitrate concentrations are associated with facilities near T Plant and are discussed in Section 2.8.2.6.

Waste sites near the Plutonium Finishing Plant have contributed to the large nitrate plume in groundwater beneath the 200 West Area.

Nitrate concentrations are increasing in wells downgradient from the injection wells for the 200-ZP-1 pump-and-treat system. This increase is apparently because the injected water was not treated for nitrate removal. Thus, nitrate concentrations in wells 299-W18-23 reached 58 mg/L in fiscal year 2001, though the values fluctuate in response to varying injection rates so the average concentration was 49 mg/L. This nitrate results in an increase in specific conductance for wells upgradient of Low-Level Waste Management Area 4, decreasing the usefulness of specific conductance for RCRA detection monitoring.

2.8.1.5 RCRA Parameters for Low-Level Waste Management Area 4

RCRA monitoring at Low-Level Waste Management Area 4 indicates no groundwater contamination from this facility.

Wells were sampled semiannually for contamination indicator parameters in accordance with RCRA interim status regulations. Monitoring wells and constituents are listed in Appendix A, Table A.27. This monitoring network is marginally adequate to detect releases from Low-Level Waste Management Area 4. Downgradient well 299-W15-18 can no longer be sampled and there have been some sampling problems at well 299-W18-24 related to low water level. The pump has been lowered as far as possible in well 299-W18-24.

Groundwater flow beneath Low-Level Waste Management Area 4 is generally to the east. It is affected to some degree by the 200-ZP-1 pump-and-treat system, which has extraction wells to the east and injection wells to the west of this RCRA site. The groundwater velocity is 0.2 to 0.6 meters per day (see Appendix A, Table A.2).

There is no evidence that Low-Level Waste Management Area 4 has contributed to contaminants found in the groundwater. Downgradient well 299-W15-16 continued to exceed the critical mean for total organic halides. This well is still affected by contamination from other sources and was at one time an upgradient monitoring well. The elevated total organic halide concentrations are attributed to carbon tetrachloride from Plutonium Finishing Plant operations (see Section 2.8.1.2). The U.S. Department of Energy (DOE) reported the exceedance to the Environmental Protection Agency and Washington State Department of Ecology in August 1999. Critical mean values are listed in Appendix A, Table A.28. Contaminant concentrations that exceeded drinking water standards are listed in Appendix A, Table A.3.

Monitoring at Low-Level Waste Management Area 4 is challenging because extraction and injection of groundwater from a nearby remediation system has changed flow directions and contaminant concentrations.

Nitrate continues to exceed the maximum contaminant level (45 mg/L) at many of the Low-Level Waste Management Area 4 monitoring wells. This contamination is not related to waste disposal at the burial grounds. In the southwestern corner of Low-Level Waste Management Area 4, well 299-W18-21 has had elevated nitrate and tritium that have not been associated with the large contaminant plumes in the 200 West Area. This may indicate a preferential pathway or a different source. Only a few trenches have received waste in this part of the burial ground, so it is unlikely that the contamination is related to the burial ground itself.

The 200-ZP-1 pump-and-treat program has caused increased technetium-99 levels in well 299-W15-15 and possibly well 299-W18-23 on the western side of Low-Level Waste Management Area 4 (Figure 2.8-11). Injection wells (299-W15-29 and 299-W18-36) to the west of Low-Level Waste Management Area 4 are injecting water with >100 pCi/L of technetium-99. Tritium in well 299-W15-15 may also be attributed to the 200-ZP-1 pump-and-treat operations. The increase in tritium coincides with the start of the pump-and-treat operations (Figure 2.8-12). Technetium-99 and tritium concentrations remain far below the drinking water standard.

2.8.1.6 Groundwater Remediation at 200-ZP-1 Operable Unit

The pump-and-treat system for the 200-ZP-1 Operable Unit is successfully containing and capturing the high concentration portion of the carbon tetrachloride plume near the top of the aquifer in the immediate vicinity of the Plutonium Finishing Plant. Contamination in the groundwater was reduced in the area of highest concentration through mass removal; additional information was collected through hydraulic monitoring, contaminant monitoring, and treatment system operations that should support the final record of decision.

Groundwater is pumped out of wells in the carbon tetrachloride plume and treated to remove the contamination. The objective of the interim remedial action is to keep the center of the plume from spreading. In fiscal year 2001, ~340 million liters of groundwater were treated and 1,226 kilograms of carbon tetrachloride were removed.

The pump-and-treat system for the 200-ZP-1 Operable Unit, located north of the Plutonium Finishing Plant, was implemented as an interim remedial action. The interim action objectives (ROD 1995) are the following:

- prevent further movement of contaminants from the highest concentration area of the plume (i.e., containing carbon tetrachloride inside the 2,000 to 3,000 μg/L contour)
- reduce contamination in the area of highest carbon tetrachloride concentrations
- provide information that will lead to development of a final remedy that will be protective of human health and the environment.

The following information is summarized from the annual report for pump-and-treat operations (DOE/RL-2001-53). The 200-ZP-1 Operable Unit facilities and Phase III extraction, injection, and monitoring well locations are shown in Appendix A, Figure A.23.

History of Operations

The pump-and-treat system was implemented in three-phases. Phase I operations consisted of a pilot-scale treatability test that ran from August 29, 1994, to July 19, 1996. During that period, contaminated groundwater was removed from a single extraction well, treated using granular activated carbon, and returned to the aquifer through an injection well. For more detailed information about operations during the treatability test, refer to DOE/RL-95-30.

Phase II operations began August 5, 1996, and ended on August 8, 1997, for transition to Phase III operations. During Phase II, three extraction wells were completed in the top 15 meters of the aquifer. The groundwater was treated using an air stripper followed by granular activated carbon treatment of the air stream and returned to the aquifer through a single injection well.

From August 8 to 28, 1997, well-field piping and treatment equipment were upgraded for Phase III operations, which began August 29, 1997, and continue to the present. During Phase III, six extraction wells were completed in the top 15 meters of the aquifer and five injection wells were installed. The Phase III treatment system uses air stripping combined with vapor-phase, granular activated carbon technology to remove the volatile organic compounds from the contaminated groundwater. Extraction wells 299-W15-32, 299-W15-33, 299-W15-34, 299-W15-35, 299-W15-36, and 299-W15-39 were active in fiscal year 2001. In fiscal year 2001, treated water was injected into wells 299-W15-29, 299-W18-36, and 299-W18-37.

Extraction well 299-W15-37 was converted to a monitoring well in January 2001 because it is not needed to contain the high concentration part of the plume.

Extraction well 299-W15-37 was converted to a monitoring well on January 17, 2001, because of the low concentrations in this area and concerns about spreading the high concentration area of the plume to the southeast. Water-level data and previous modeling results (DOE/RL-99-79) show that this well is not necessary to contain the high concentration area of the plume.

Contaminant Removal

Carbon tetrachloride contamination in the upper part of the aquifer was reduced in the area of highest concentrations through mass removal. Approximately 338.9 million liters of contaminated groundwater were treated in fiscal year 2001 at an average flow rate of 689 liters per minute. Production rates for each of the six extraction wells ranged from 40 to 307 liters per minute. The average influent concentration for the six extraction wells was 3,600 μg/L, a decrease from 4,041 μg/L in fiscal year 2000 and less than fiscal year 1999 concentrations (3,788 μg/L). Influent concentrations ranged from 2,800 to 4,300 μg/L.

Treatment of the contaminated water resulted in the removal of 1,226 kilograms of carbon tetrachloride in fiscal year 2001. Since initiation of pump-and-treat operations in August 1994, 1.59 billion liters of water have been treated, resulting in removal of 5,796 kilograms of carbon tetrachloride. Table 2.8-1 shows the volumes of treated water and the mass of carbon tetrachloride removed by quarter since inception of operations.

Extraction well 299-W15-37 was converted to a monitoring well in fiscal year 2001. This well is located southeast of the high concentration portion of the carbon tetrachloride plume (see Appendix A, Figure A.23). It was concluded prior to shutdown that this well was not contributing significantly to hydraulic capture of the high concentration area. Recent sampling results support that conclusion. Since shutdown, carbon tetrachloride concentrations have decreased from 505 μg/L (January 2001) to 315 μg/L (May 2001).

Technetium-99 samples were collected to make sure that the pump-and-treat system is not being negatively affected by radiological contamination. The origin of technetium-99 may be the 216-T-19 crib area or Waste Management Area TX-TY, located north-northeast of extraction wells 299-W15-34 and 299-W15-35. Concentrations at the four northernmost extraction wells ranged from ~32 to 257 pCi/L, very similar to the concentration range measured in fiscal year 2000.

Northeast of primary injection well 299-W15-29, technetium-99 concentrations have increased at well 299-W15-15 from 18 pCi/L in fiscal year 1994 to 103 pCi/L in fiscal year 2001. This change was anticipated based on the average concentrations of ~100 pCi/L that pass through the treatment system and are disposed at the injection wells. None of the results exceed the drinking water standard of 900 pCi/L.

Overall Effectiveness

The >2,000 μg/L center of the carbon tetrachloride plume for fiscal year 2001 has a similar shape and concentration distribution as the fiscal year 2000 plume. High concentrations of carbon tetrachloride present beneath the Plutonium Finishing Plant complex are being drawn toward the extraction wells. In the area of the injection wells, concentrations continue to decline both from injection of treated groundwater into the aquifer, and as hydraulic mounding drives groundwater toward the extraction wells. The high concentration area of the plume in the upper part of the aquifer appears to be shrinking in size, evidenced by decreasing concentrations in monitoring and extraction wells, and decreasing concentrations in the influent tank from 4,041 μg/L in fiscal year 2000 to 3,600 μg/L in fiscal year 2001. Figure 2.8-13 shows details of the July 2001 carbon tetrachloride plume map in the area of the remediation system, and Figure 2.8-14 shows the June 1996 baseline plume map.

Contaminant concentrations appear to have peaked and are declining in extraction wells 299-W15-32, 299-W15-33, 299-W15-34 (slightly), 299-W15-35 (slightly), and 299-W15-36 (Figures 2.8-15 and 2.8-16). Initial increases in carbon tetrachloride concentrations at the extraction wells indicate that a plume is being pulled from beneath the Plutonium Finishing Plant complex northeast to these wells. The recent peak in concentrations and now downward trends implies that the center of this dissolved mass has arrived at the extraction wells.

The highest average fiscal year 2001 concentrations of carbon tetrachloride were measured at the two northernmost extraction wells, 299-W15-33 (4,865 μg/L) and 299-W15-34 (5,355 μg/L) (see Figure 2.8-15). The lowest concentration was at 299-W15-37 at 464 μg/L. Table 2.8-2 compares average carbon tetrachloride concentrations at the extraction wells for fiscal years 1997, 1998, 1999, 2000, and 2001.

Carbon tetrachloride concentrations continue to decrease at extraction well 299-W15-32 (see Figure 2.8-16). Average concentrations have changed from 7,120 μg/L in fiscal year 1997 to 3,255 μg/L in fiscal year 2001. This well is located on the northwestern side of the 216-Z-9 crib, where the highest volumes of carbon tetrachloride were discharged.

There were no significant changes in chloroform and trichloroethene concentrations in the extraction wells for fiscal year 2001. Chloroform concentrations ranged from 12 to 25 μg/L, while trichloroethene concentrations ranged from 2 to 16 μg/L. All chloroform concentrations were below the drinking water standard of 100 μg/L. The drinking water standard for trichloroethene is 5 μg/L.

Monitoring wells near the injection and extraction wells, and around the Plutonium Finishing Plant have declining carbon tetrachloride concentrations. A few examples given below support this conclusion. Appendix A, Figure A.23 shows the locations of these wells.

Monitoring wells near the injection and extraction wells, and around the Plutonium Finishing Plant have declining carbon tetrachloride concentrations.

- **Well 299-W15-15** has changed from ~1,000 μg/L in 1997 to 38 μg/L in 2001 (located northeast of injection well 299-W15-29).
- **Well 299-W15-16** decreased rapidly in 2 years from ~5,400 μg/L in October 1999 to 1,200 μg/L in October of 2001. This well, situated on the west side of the Plutonium Finishing Plant, has had the highest concentrations historically of any groundwater monitoring well (8,700 μg/L in March 1990).
- **Well 299-W15-18** declined from 5,300 μg/L in 1994 to 650 μg/L in early 2000. This well is situated on the southwest side of the Plutonium Finishing Plant. It has been dry since fiscal 2000 and concentrations were declining rapidly at that time.
- **Well 299-W18-24** declined from ~1,400 μg/L in 1998 to 555 μg/L in early 2001 (located south of the Plutonium Finishing Plant).
- **Well 299-W15-7** decreased from a high of 4,900 μg/L in October 1999 to ~3,400 μg/L in October 2001 (located just southeast of extraction well 299-W15-34).
- **Well 299-W15-38** has decreased from a high of 4,000 μg/L in February 2000 to 2,300 μg/L in October 2001. This monitoring well is immediately northeast of extraction well 299-W15-32 near the 216-Z-9 trench. A decline in concentration at this well is consistent with the rapid decline at extraction well 299-W15-32.

Water-Level Impact and Capture-Zone Analysis

Regional groundwater flow in the vicinity of the extraction wells is still east-northeast in this area (see Plate 1). Water levels are estimated to be declining at a rate of ~0.4 meter per year (DOE/RL-2001-53). The extraction wells are apparently influencing water levels and flow direction farther north in Waste Management Area TX-TY (PNNL-13342), Waste Management Area U (to the south), and Low-Level Waste Management Area 4 (to the west).

The entire high concentration area of the plume (>2,000 μg/L) in the immediate vicinity of the Plutonium Finishing Plant was contained hydraulically in fiscal year 2001 (DOE/RL-2001-53), based on the measured radius of influence of the pumping wells across the high concentration area and in monitoring wells situated between the pumping wells. The pumping influence extends over 124 meters from extraction well 299-W15-33 at least to monitoring well 299-W15-31A where a drawdown of 0.11 meter was measured.

Summary

In summary, the high concentration portion of the carbon tetrachloride plume continues to move toward the extraction wells and appears to be hydraulically contained based on the contaminant plume maps, contaminant trends, and hydraulic capture analysis. Contaminant concentrations appear to be declining in most of the extraction wells, implying that the peak of dissolved mass originating beneath the Plutonium Finishing Plant complex has arrived at these wells. The injection wells have diluted the western and southern portions of the plume and are driving dissolved contaminant mass toward the extraction wells. Most monitoring wells in the core area of the plume have decreasing contaminant concentrations, although the rate of change varies from well to well.

2.8.2 T Plant

Monitoring Objectives Near T Plant

Groundwater monitoring is conducted near T Plant:

- triennially to annually to describe the nature and extent of contamination
- semiannually to monitor trends in variable constituents/wells
- semiannually to detect the possible impact of one RCRA waste management area
- quarterly to assess contamination from two RCRA waste management areas.

T Plant operated from 1944 through 1953 to separate plutonium from irradiated fuel using the bismuth phosphate process. The plant subsequently was converted to an equipment decontamination facility. Chlorinated hydrocarbons (carbon tetrachloride and trichloroethene), iodine-129, nitrate, and tritium form the most extensive contaminant plumes in the vicinity of T Plant. The majority of the chlorinated hydrocarbon contamination appears to originate in the vicinity of the Plutonium Finishing Plant, though there may be a contribution from T Plant facilities. Nitrate contamination appears to originate from both T Plant and Plutonium Finishing Plant facilities. Technetium-99 contamination at levels above drinking water standards is not as extensive, but high levels are found near Waste Management Areas T and TX-TY. In addition, minor chromium, fluoride, and uranium contamination is found near T Plant. Groundwater contamination near T Plant is considered part of the 200-ZP-1 CERCLA Operable Unit.

Waste Management Areas T and TX-TY are monitored as RCRA treatment, storage, and disposal facilities. They were both monitored according to interim status assessment requirements in fiscal year 2001. The RCRA groundwater assessments have indicated that Waste Management Areas T and TX-TY are probable sources of some of the groundwater contamination in this vicinity and further assessment is ongoing. Several facilities outside the waste management areas also affected groundwater in this vicinity, so the RCRA assessment must consider those impacts. This section is designed to meet the needs for annual reporting of the RCRA assessments. The specific conclusions of the monitoring regarding the assessment sites are discussed in Sections 2.8.2.11 and 2.8.2.12. Low-Level Waste Management Area 3 was monitored under RCRA interim status detection requirements and is discussed in Section 2.8.2.13.

2.8.2.1 Groundwater Flow

Groundwater in the northern portion of the 200 West Area predominantly flows toward the east-northeast but is locally influenced by the 200-ZP-1 Operable Unit pump-and-treat system and effluent discharges to the State-Approved Land Disposal Site (see Plate 1). The flow direction in this region has changed ~35 degrees over the past decade from a north-northeast direction to a more easterly direction. This is due to decreased effluent discharges to the soil column in the 200 West Area, which is causing flow to return to its pre-Hanford direction.

The water table is influenced locally by the 200-ZP-1 Operable Unit pump-and-treat system. This causes flow in the south-central portion of this region to have a southerly component toward the extraction wells. Also, effluent discharges at the State-Approved Land Disposal Site, just north of the 200 West Area, has resulted in a local groundwater mound beneath this facility. Groundwater flow beneath Waste Management Area T is discussed in Section 2.8.2.11, flow beneath Waste Management Area TX-TY is discussed in Section 2.8.2.12, and flow beneath Low-Level Waste Management Area 3 is discussed in Section 2.8.2.13. Groundwater flow beneath the State-Approved Land Disposal Site is discussed in Section 2.8.5.

Waste sites associated with T Plant have contaminated groundwater with iodine-129, nitrate, technetium-99, tritium, and possibly some carbon tetrachloride. This area also contains minor chromium, fluoride, and uranium contamination.

2.8.2.2 Tritium

A tritium plume lies beneath much of the northern half of the 200 West Area and extends to the northeast (see Plate 2). The plume geometry suggests the major tritium source is near the TY tank farm, the 242-T evaporator, and associated disposal cribs. Other sources may be present in the vicinity of the T tank farm and associated cribs and trenches. Tritium concentrations remain high in the area immediately east of the TY tank farm. In June 1998, tritium concentrations suddenly increased to 3.21 million pCi/L near the 216-T-28 crib, in well 299-W14-2. Tritium concentrations were highly erratic in that well until it went dry after December 2000. Concentrations in nearby well 299-W14-13 peaked at nearly 3 million pCi/L in fiscal year 2000, but the fiscal year 2001 samples were between 1.1 and 1.5 million pCi/L (Figure 2.8-17). Thus, all tritium concentrations measured in the 200 West Area in fiscal year 2001 were less than the 2 million pCi/L DOE derived concentration guide. The hydraulic gradient in this vicinity is flat due to the interaction of the regional gradient and the influence of the 200-ZP-1 Operable Unit pump-and-treat system. Condensate from the 242-T evaporator is a likely source of this tritium contamination; however, the cause for the sudden increase is unknown. The erratic concentration trend in well 299-W14-2 suggests that contamination in the vadose zone could be remobilized by a fresh water source such as a leaking water line, but this has not been confirmed.

Tritium concentrations in wells near the TY tank farm had increased sharply in recent years, but declined in fiscal year 2001. Still, concentrations exceeded 1 million pCi/L.

2.8.2.3 Iodine-129

Iodine-129 near T Plant (Figure 2.8-18) coincides generally with the tritium plume. The interpretation of iodine-129 results is somewhat complicated by a number of samples reported with detection limits greater than the 1 pCi/L drinking water standard. The highest iodine-129 concentration in the northern 200 West Area was 64 pCi/L, measured near the 216-T-28 crib in well 299-W14-2. The 242-T evaporator or cribs that received condensate are likely sources for the iodine-129 contamination.

2.8.2.4 Technetium-99

A technetium-99 plume is present in the T Plant area (Figure 2.8-19), but the concentrations are less than the drinking water standard in most of the area. Technetium-99 is found at concentrations greater than the 900 pCi/L drinking water standard near the northeastern corner of Waste Management Area T and in Waste Management Area TX-TY. The extent of these plumes changed little in fiscal year 2001. The RCRA assessment concluded that Waste Management Areas T and TX-TY were probably the sources of at least some of this technetium-99 (PNNL-11809). Further details on the technetium-99 contamination are discussed with the tank farm assessment summaries in Sections 2.8.2.11 and 2.8.2.12.

2.8.2.5 Uranium and Gross Alpha

Few analyses for uranium were performed on groundwater samples from the vicinity of T Plant in fiscal year 2000 because most wells showed insignificant levels in previous monitoring. Wells monitored near the single-shell tank farms for RCRA compliance are sampled for gross alpha measurements, which would show an increase if uranium contamination appeared. Uranium was detected above the 30 μg/L maximum contaminant level in two wells located near the T Plant. The uranium is detected far from major disposal facilities, so the source of the contamination is unknown. Well 299-W11-14 contained 56.6 μg/L of uranium in the single sample taken in fiscal year 2001, similar to levels found in the past several years. The single sample from well 299-W11-37, located northeast of well 299-W11-14, contained 450 μg/L of uranium. This well had not been sampled for uranium in recent years so a trend cannot be established.

2.8.2.6 Nitrate

Nitrate continued to be present in groundwater at concentrations in excess of the 45 mg/L maximum contaminant level beneath much of the northern part of 200 West Area (see Figure 2.8-10). The maximum concentration in this vicinity in fiscal year 2001 was 990 mg/L near the 216-T-36 crib, south of Waste Management Area T. Concentrations in this well increased sharply through the year, reaching a maximum of 1,300 mg/L in the August 2001 sample. The nitrate contamination is more widespread than the iodine-129, technetium-99, or tritium plumes discussed previously. There probably are multiple sources of nitrate in this area, including disposal facilities near the Plutonium Finishing Plant.

High concentrations of nitrate in groundwater continued to be found in wells near T Plant disposal facilities. The maximum value in fiscal year 2001 was 1,300 mg/L, an increase from fiscal year 2000.

Nitrate is found at concentrations greater than the maximum contaminant level at considerable depth within the unconfined aquifer near T Plant. For example, 300 mg/L of nitrate was detected in a sample from well 299-W6-3 that is completed ~60 meters below the water table. This well is completed above the top of the Ringold lower mud unit.

2.8.2.7 Chromium

Chromium at levels above the 100 μg/L maximum contaminant level in filtered samples is restricted to the immediate vicinity of Waste Management Areas T and TX-TY (Figure 2.8-20). The maximum average annual concentration detected in fiscal year 2001 was 230 μg/L in well 299-W14-13, east of Waste Management Area TX-TY, where concentrations have been generally increasing.

A small chromium plume has been identified in the vicinity of Waste Management Area T. The specific source for this persistent plume has not been identified but the 216-T-36 crib, which received steam condensate and decontamination waste, and miscellaneous waste from the T and U Plants is a likely contributor. Potassium dichromate was frequently used in equipment decontamination. Thus, the crib and the vitreous clay pipe leading to the crib are likely sources of chromium contamination. Chromium is of interest because it has been identified in tank waste and may help form a signature of mobile tank waste components. However, similar waste was disposed to cribs and trenches in the immediate vicinity. Chromium is discussed further in Sections 2.8.2.11 and 2.8.2.12.

2.8.2.8 Fluoride

Fluoride was detected above the 4 mg/L maximum contaminant level near the T Plant waste disposal facilities. The fluoride contamination was found in a number of wells in the vicinity of Waste Management Area T, with the highest value measured in fiscal year 2001, 4.7 mg/L on the eastern side of the tank farm in well 299-W11-42. In fiscal year 2000, well 299-W10-3, located at the northeastern corner of the 216-T-7 crib, had a fluoride concentration of 9.8 mg/L but that well has been decommissioned. Fluoride may be associated with tank waste from leaks or discharged to the cribs.

2.8.2.9 Chlorinated Hydrocarbons

Although the bulk of the carbon tetrachloride plume in the 200 West Area is known to have originated from liquid waste disposal facilities in the vicinity of the Plutonium Finishing Plant, a second source may exist in the vicinity of T Plant. According to WHC-SD-EN-TI-248, the source could be carbon tetrachloride that was dissolved in the 242-T evaporator overhead and discharged from 1973 to 1976 to the 216-T-19 crib. The carbon tetrachloride distribution in the 200 West Area is shown in Figure 2.8-2. Of particular interest are relatively low carbon tetrachloride concentrations in the vicinity of the southeastern corner of Waste Management Area TX-TY, where levels are <500 μg/L but still above the 5 μg/L maximum contaminant level. This area is within the hydraulic influence of the 200-ZP-1 Operable Unit pump-and-treat system discussed in Section 2.8.1.6. Although data are sparse, there appears to be a generally low carbon tetrachloride concentration area in the east-central part of the 200 West Area.

Trichloroethene also is found at levels above the maximum contaminant level in the vicinity of T Plant but at levels considerably lower than carbon tetrachloride. The area of trichloroethene greater than the maximum contaminant level extends from the Plutonium Finishing Plant northeast through the T Plant vicinity (see Figure 2.8-9). The extent of trichloroethene contamination has not changed greatly in the past several years.

2.8.2.10 Manganese, Nitrite, and Iron

High levels of iron, manganese, and nitrite have been reported east of Waste Management Area T in filtered samples. Manganese in well 299-W11-28 reached a fiscal year 2001 maximum level of 397 μg/L. Elevated manganese and iron also were detected in nearby well 299-W11-24. Elevated nitrite was detected at levels (expressed as NO_2^-) up to 26.6 mg/L in well 299-W11-24 and 1.12 mg/L in well 299-W11-28 for fiscal year 2000. Iron was also elevated in these wells but levels were lower than in fiscal year 2000. The high iron, manganese, and nitrite are indicative of reducing conditions; however, the cause of the reducing conditions is unknown.

2.8.2.11 RCRA Assessment Summary for Waste Management Area T

Waste Management Area T, located in the north-central portion of the 200 West Area, consists of the T single-shell tank farm and ancillary equipment (e.g., diversion boxes). Constructed between 1943 and 1944, the tank farm contains twelve 2-million-liter tanks and four 208,000-liter tanks. The tanks began receiving waste in 1944, initially receiving waste from the bismuth phosphate process. During early operations, tank waste was cascaded through sets of three tanks and overflow from the third tank was discharged to the ground in cribs and tile fields to the west of the waste management area. Seven of the tanks in the waste management area are known or suspected to have leaked. See Section 3.2.4 for vadose zone monitoring at Waste Management Area T.

RCRA Waste Management Area T contains single-shell tank farms that have contaminated groundwater with chromium, nitrate, and technetium-99. Assessment monitoring continued in fiscal year 2001.

Waste Management Area T was originally placed in assessment monitoring because of elevated specific conductance in downgradient well 299-W10-15 (WHC-SD-EN-AP-132). However, it remained in assessment because of contaminants observed in downgradient well 299-W11-27 (PNNL-11809). This site continued to be monitored under an assessment program in fiscal year 2001 (PNNL-12057). The well and analyte lists for this unit are given in Appendix A, Table A.38.

Groundwater Flow

The direction of groundwater flow at Waste Management Area T has varied over the life of the facility because of changing effluent discharge patterns within the 200 West Area. The flow direction when the RCRA monitoring network was established was toward the northeast. The groundwater presently flows generally toward the east or slightly north of east, as indicated by the large-scale water-table map (see Plate 1). Groundwater flow velocities calculated using new values for hydraulic conductivity (PNNL-13378) fall in the range of 0.003 to 0.024 meter per day (see Appendix A, Table A.2). This range is in reasonable agreement with velocities of 0.009 to 0.017 meter per day calculated from tracer pumpback tests in well 299-W10-24 (PNNL-13378).

Locally, the direction of groundwater flow may diverge from the regional pattern because variable cementation within the Ringold Formation may result in preferred groundwater flow paths. The pre-Hanford flow direction in the vicinity of Waste Management Area T is believed to have been from west to east, and it was expected that groundwater flow in this area would eventually move to that direction. However, the change has happened fairly rapidly over the past several years and may have been accelerated by operation of the 200-ZP-1 Operable Unit pump-and-treat system <1 kilometer to the south. Results of recent hydraulic testing at Waste Management Area T can be found in PNNL-12057 and PNNL-13378.

Groundwater Contamination

Several contaminants continued to be detected in the vicinity of Waste Management Area T during fiscal year 2001. High carbon tetrachloride, chromium, fluoride, nitrate, tritium, and trichloroethene are from upgradient sources and are components of a contaminant plume crossing the waste management area from west to east. These contaminants were discussed in previous sections. Technetium-99, chromium, and nitrate have a local source within the tank farm and are discussed here.

A narrow technetium-99 plume has been identified northeast of the waste management area. Technetium-99 concentrations began increasing in downgradient well 299-W11-27 in late 1995 and early 1996, soon after effluent discharges to ground stopped in the 200 West Area (Figure 2.8-21). The concentration of technetium-99 peaked at 21,700 pCi/L in February 1997. Technetium-99 subsequently decreased to a low of 6,000 pCi/L when the last sample was taken in March 1999 prior to the well going dry. The chemical signature of the contaminants detected in well 299-W11-27 is particularly clear because it is superposed on a low ionic strength groundwater resulting from leakage along a ~40-centimeter-diameter vitrified clay pipe connecting the 207-T retention basin and the T-4-2 ditch. Cable tool drilling of well 299-W11-27, immediately adjacent to the pipe, may have damaged the pipe. Groundwater constituent concentrations were decreasing in well 299-W11-27 when monitoring was initiated in 1992 and remained below upgradient values until surface water discharge ceased in 1995.

Technetium-99 in replacement well 299-W10-24 (see Figure 2.8-21), drilled immediately adjacent well 299-W11-27, has ranged between 1,340 and 3,660 pCi/L (1,340 to 1,890 pCi/L during fiscal year 2001) with a trend toward lower values. As discussed below, the difference between wells 299-W11-27 and 299-W10-24 may be because of the longer interval open below the water table in the replacement well relative to well 299-W11-27. The sampling pump in well 299-W10-24 is set at a depth of ~4.6 meters below the water table.

Technetium-99 concentrations in well 299-W11-23, a pre-RCRA well located east of well 299-W11-27 at the northeastern corner of the waste management area (see Figure 2.8-21), started to increase in November 1997, reaching a high of 8,540 pCi/L in November 1998. Technetium-99 subsequently showed considerable variability, dropping to a low of 841 pCi/L in March 2000 and rising to 4,470 pCi/L for the last sample in December 2000. The detection in well 299-W11-23 is apparently a result of the change in the direction of groundwater flow from northeast to east. Apparently, the plume that extends northeast from well 299-W11-27 is shifting eastward across well 299-W11-23 (see Figure 2.8-19).

Technetium-99 concentrations in well 299-W11-39, the replacement well for 299-W11-23, ranged from 4,160 to 5,010 pCi/L between February 2001 and August 2001. The highest concentration was measured in August 2001. The concentrations of technetium-99 in this well indicate that technetium is distributed through the upper portion of the aquifer and not just at the very top. The low nitrate concentrations observed indicate that the screened interval in this well does not penetrate the high nitrate zone sampled by nearby well 299-W10-24.

The post-1995 increase in nitrate concentration in well 299-W11-27 was strongly correlated with the technetium-99 trend (Figure 2.8-22), but this correlation does not carry through to the replacement well 299-W10-24. The concentration of nitrate in well 299-W10-24 is much higher than that in well 299-W11-27, whereas the technetium-99 is lower. Deep aquifer sampling during the drilling of well 299-W10-24 in 1998 indicates the presence of a maximum in nitrate (~500 mg/L) at ~20 meters below the water table, with the deeper groundwater chemically resembling the high nitrate groundwater occurring in other parts of the area (PNNL-13116). This suggests that the pulse of nitrate and technetium-99 in well 299-W11-27 is a feature of the very top of the aquifer. The groundwater chemistry detected in well 299-W10-24 is apparently a mixture of two sources: the shallow, high-technetium-99 groundwater seen in well 299-W11-27 and the high-nitrate groundwater from depth. The high-nitrate from the lower portion of the screened interval, where the aquifer is more permeable, dominates the mixture during pumping.

The tank-related contaminants at Waste Management Area T appear to be restricted to a zone of lower permeability in the upper portion of the aquifer. The lateral extent to this low permeability zone is uncertain.

Chromium concentrations in well 299-W11-27 exhibited a peak in fiscal year 1996, reaching 590 μg/L in May 1996 (Figure 2.8-23). Technetium-99 in well 299-W11-27 peaked ~9 months later, reaching 21,700 pCi/L in February 1997. The peak for chromium is quite sharp and well defined, while the later peak for technetium-99 is broader and more diffuse. In well 299-W11-23, chromium and technetium-99 track closely, and there is no indication of a lag between the constituents (Figure 2.8-24). It is uncertain to what extent the chromium concentrations in well 299-W10-24 is related to the regional plume (see Section 2.8.2.7) or to the shallow contaminant plume intercepted in well 299-W11-27.

The tank-related contaminants are apparently largely restricted to a zone of lower permeability in the upper portion of the aquifer. This lower permeability zone is variable in thickness, occurring in the upper portion of the screened interval in well 299-W10-24 and over the entire screened interval in well 299-W11-39. The lateral extent of this low permeability zone and the extent to which contaminants may be migrating into the deeper zone of higher permeability is uncertain. The lateral extent of contamination is uncertain because of the lack of monitoring wells north and east of the zone of known contamination.

Monitoring Network

The original RCRA monitoring network for Waste Management Area T, completed in 1992, consisted of one upgradient and three downgradient wells. All of these original wells have subsequently gone dry, as a result of the falling water table in the area. In addition, a change in groundwater flow direction resulted in gaps in the downgradient coverage. Existing, pre-RCRA wells have been used when possible to meet the needs resulting from a declining water table and changes in the direction of groundwater flow; however, new wells were needed for upgradient and downgradient monitoring and to track the known contaminant plume.

The water table beneath Waste Management Area T continued to decline in fiscal year 2001, and new wells were installed to replace dry wells and to account for changes in the direction of groundwater flow.

Two RCRA compliant monitoring wells were drilled in fiscal year 1999 (PNNL-12125) and four new downgradient wells were drilled in late fiscal year 2000 and early fiscal year 2001 (PNNL-13591). These wells were drilled to replace dry groundwater monitoring wells and fill gaps in the downgradient monitoring network caused by changes in the direction of groundwater flow. In addition, a new upgradient well was completed in early fiscal year 2002. All of the new wells have been completed with 10.7-meter screened intervals to allow for future declines in water-table elevation. The well network is summarized in Appendix A, Table A.38.

2.8.2.12 RCRA Assessment Summary for Waste Management Area TX-TY

RCRA Waste Management Area TX-TY contains single-shell tank farms that may have contaminated groundwater with chromium, nitrate, and technetium-99. Assessment monitoring continued in fiscal year 2001. These plumes may also have sources outside the waste management area.

Waste Management Area TX-TY, located in the north-central portion of the 200 West Area, consists of the TX and TY tank farms and ancillary equipment (e.g., diversion boxes). Constructed between 1944 and 1952, the tank farms contain twenty-four 2.9-million-liter tanks. The tanks began receiving waste in 1944, initially receiving principally waste from the bismuth phosphate process. During early operations, tank waste was cascaded through sets of three tanks and overflow from the third tank was discharged to the ground in cribs and tile fields to the west of the waste management area. Twelve of the tanks in the waste management area are known or suspected to have leaked.

Waste Management Area TX-TY was originally placed in assessment monitoring because of elevated specific conductance in downgradient wells 299-W10-17 and 299-W14-12 (WHC-SD-EN-AP-132). The area remained in assessment because of contaminants detected in downgradient well 299-W14-12 (PNNL-11809). This site continued to be monitored under an assessment program in fiscal year 2001. The well and analyte lists for this unit are given in Appendix A, Table A.39.

Groundwater Flow

The direction of groundwater flow at Waste Management Area TX-TY has been highly variable over the life of the facility. When the RCRA monitoring network was established, the flow direction was toward the northeast. The pre-Hanford flow direction in the vicinity of Waste Management Area TX-TY is believed to have been from west to east, and it is expected that groundwater flow in this area would eventually return to that direction.

The operation of a pump-and-treat system in an area south of Waste Management Area TX-TY has changed flow directions over the past several years. The remediation may have a significant impact on the distribution of contaminants.

Groundwater flow directions have changed fairly rapidly over the past several years as a result of the 200-ZP-1 Operable Unit pump-and-treat system located immediately south of the waste management area combined with the decline of the 200 West Area groundwater mound. The current flow direction is generally toward the east in the northern part of the waste management area, toward the southeast in the central part of the waste management area, and toward the south or slightly west of south in the southern part of the waste management area (see Plate 1). Results of recent hydraulic testing at Waste Management Area T can be found in PNNL-12072 and PNNL-13378. Groundwater flow velocities calculated using new values for hydraulic conductivity (PNNL-13378) fall in the range of 0.003 to 0.59 meter per day (see Appendix A, Table A.2).

Groundwater Contamination

A number of contaminants were detected in the vicinity of Waste Management Area TX-TY during fiscal year 2001. Carbon tetrachloride from upgradient sources was discussed in previous sections of this chapter. Chromium, iodine-129, nitrate, technetium-99, and tritium may have a local source and are discussed in more detail in the following paragraphs.

Contaminant levels (chromium, cobalt-60, iodine-129, nitrate, technetium-99, and tritium) were elevated along the eastern side of Waste Management Area TX-TY in well 299-W14-12 when first sampled in 1992 and remained high for several years. Technetium-99 had a high value of 13,300 pCi/L in November 1992 (Figure 2.8-25). Contaminant concentrations dropped sharply, along with falling water levels in 1995 to 1996 and remained at relatively low levels during 1997 to

1998. In late 1998, contaminant levels began to increase and continued that trend until the last sampling of the well in January 1999 prior to the well going dry. Technetium-99 concentrations in replacement well 299-W14-13 also exhibit an upward trend reaching a maximum of 7,400 pCi/L in March 2000. Technetium-99 concentrations in well 299-W14-13 ranged from 3,360 to 4,910 pCi/L in fiscal year 2001, with the highest concentration occurring in August 2001 (see Figure 2.8-25).

Tritium and iodine-129 were important constituents of the contaminant plume initially detected in well 299-W14-12 (Figure 2.8-26). Tritium peaked at 585,000 pCi/L in February 1995 and iodine-129 peaked at 64 pCi/L in September 1993. During fiscal year 2001, tritium has ranged between 1.1 million pCi/L and 1.4 million pCi/L. A key to the behavior of tritium and iodine-129 is the detection of a contaminant plume adjacent to the 216-T-28 crib in non-RCRA well 299-W14-2 that consists predominately of tritium and iodine-129, with relatively low concentrations of technetium-99 and nitrate. In June 1998, a tritium concentration of 3.2 million pCi/L and an iodine-129 concentration of 81 pCi/L were reported. The last sample from this well before it went dry, taken in December 2000, yielded values of 1.48 million pCi/L for tritium, 64 pCi/L for iodine-129, and 767 pCi/L for technetium-99. The most likely source of the contaminants detected in well 299-W14-2 is condensate leaked from the 242-T evaporator located between the TX and TY tank farms. It is also possible that condensate from evaporator leaks has been a major contributor to tritium and iodine-129 contamination detected in wells 299-W14-12 and 299-W14-13.

Chromium was a prominent co-contaminant in downgradient well 299-W14-12, reaching 600 μg/L in November 1992 (Figure 2.8-27). Subsequently, chromium decreased, reaching a low of 5 μg/L. Chromium continued to increase in replacement well 299-W14-13, reaching 538 μg/L in March 2000. During fiscal year 2001, chromium concentrations in well 299-W14-13 ranged from 202 to 248 μg/L, with the highest concentration occurring in August 2001 (see Figure 2.8-27).

Nitrate was a major constituent of the contaminant plume first detected in well 299-W14-12, peaking at 530 mg/L in November 1992. Nitrate concentrations dropped to 190 mg/L in May 1997 and subsequently rose to 580 mg/L in January 1999, the last sampling of this well. Nitrate concentrations rose in replacement well 299-W14-13, reaching a maximum of 436 mg/L in January 2000 and have ranged between 225 and 309 mg/L in fiscal year 2001.

Technetium-99 levels have increased on the south side of Waste Management Area TX-TY since the initiation of the 200-ZP-1 Operable Unit pump-and-treat operations (see Section 2.8.1.6) (Figure 2.8-28). Technetium-99 in the southwestern corner of Waste Management Area TX-TY, well 299-W15-22, increased significantly in 1998 before the well went dry. Technetium-99 concentrations reached 3,680 pCi/L in May 1998 and 2,940 pCi/L in August 1998. More recently, technetium-99 concentrations in new well 299-W15-41 have ranged between 847 and 1,980 pCi/L, with fiscal year 2001 concentrations ranging from 1,210 and 1,350 pCi/L.

The wells along the southern boundary of the Waste Management Area TX-TY lie directly between the waste management area and the nearest extraction wells of the 200-ZP-1 pump-and-treat operation. The groundwater flow direction is southward from beneath Waste Management Area TX-TY into the pump-and-treat system. Wells 299-W14-5 and 299-W14-6 on the southeastern side of the waste management area and well 299-W15-40 on the southwestern side of the waste management area have low technetium-99, indicating a technetium-99 source beneath the area. These values suggests that the remediation impacts the distribution of contaminants under and around the waste management area and that technetium-99 may be drawn from beneath the area into the pump-and-treat system (see Section 2.8.1.5).

Contaminant distributions along the eastern side of Waste Management Area TX-TY have been affected by changing flow directions. The direction of groundwater flow in the vicinity of well 299-W14-12 was toward the northeast when monitoring was initiated. Flow is currently toward the southeast. Groundwater flow directions indicate that the source for the initial plume detected in well 299-W14-12 was within the TX tank farm. The present direction of groundwater flow at well 299-W14-13 is from the TY tank farm; however, given the low flow rates detected in this area, it is unlikely that contaminants could have arrived from that source in the available time. The most reasonable explanation for the tank waste contaminants in well 299-W14-13 is the presence of a plume north of this well that moved laterally toward the southeast, across this well, as a result of the change in groundwater flow direction in 1998. A second plume, consisting primarily of tritium and iodine-129 from the 242-T evaporator, is superimposed on the tank waste plume. Sampling in wells 299-W14-12 and 299-W14-13 indicate considerable complexity in the vertical distribution of contaminants in the vicinity of the wells. This complexity is increased by the observed strong vertical hydraulic gradient in well 299-W14-13 (PNNL-13378). In a lateral direction, the extent of the contaminant plumes is bounded by wells 299-W14-2 and 299-W14-14. The plumes have not reached intermediate field wells 299-W14-16 and 299-W14-17 located east of the waste management area.

Monitoring Network

The original RCRA monitoring network for Waste Management Area TX-TY, completed in 1992, consisted of one upgradient and three downgradient wells. Three of these wells have subsequently gone dry, as a result of the falling water table in the area, and the fourth will be dry soon. In addition, a change in direction of groundwater flow has resulted in gaps in the downgradient coverage. Existing, pre-RCRA wells have been incorporated into the network when possible.

Four new RCRA compliant monitoring wells were drilled in fiscal year 1999 (PNNL-12124; PNNL-12072) to replace existing groundwater monitoring wells and to fill gaps in the downgradient network resulting from changes in the direction of groundwater flow. In late fiscal year 2000 and early fiscal year 2001, five new downgradient wells (PNNL-12124) were drilled. Three, including a replacement for well 299-W15-4, were installed along the southern margin of the waste management area; two wells were installed farther downgradient. In addition, replacements for upgradient well 299-W15-12 and downgradient well 299-W14-2 were completed in early fiscal year 2002. All wells have been completed with 10.7-meter screened intervals to allow for future declines in water-table elevation. The current monitoring network is summarized in Appendix A, Table A.39. Additional wells, including well clusters to evaluate vertical contaminant distribution and gradient, are being considered.

New monitoring wells have been installed downgradient of Waste Management Area TX-TY to account for the changing flow direction and to monitor contaminants farther from the waste management area.

2.8.2.13 RCRA Parameters for Low-Level Waste Management Area 3

This RCRA site continued to be monitored under interim status indicator evaluation requirements. Groundwater monitoring wells were sampled semiannually in fiscal year 2001. Appendix A, Table A.24 lists the current monitoring wells and constituents. Because of the changing flow direction and the continuing decline in water levels, this network only marginally monitors this waste management area. Four wells (299-W6-2, 299-7-6, 299-W7-10, and 299-W9-1) were determined to be dry. Several other groundwater monitoring wells (notably 299-W7-8, 299-W7-9, and 299-W10-13) are approaching the point where representative sampling will no longer be possible because of the declining water table. No additional wells were installed in calendar year 2001.

The groundwater flow in this portion of 200 West Area is to the east-northeast. The flow direction is returning to the pre-Hanford conditions and will continue to change until the direction is predominately west to east. Groundwater velocity is in the range of 0.0001 to 0.12 meters per day (see Appendix A, Table A.2).

RCRA monitoring at Low-Level Waste Management Area 3 indicates no groundwater contamination from this facility.

There are no indications that Low-Level Waste Management Area 3 has contributed to groundwater contamination. Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. Critical mean values for specific conductance were exceeded in samples collected from upgradient well 299-W10-13 on October 4, 2000. Results from March and September 2001 were below the comparison value and there is a slight downward trend. Other contamination indicator parameters were not exceeded in any wells monitoring this waste management area. There was an elevated total organic carbon value of 6,500 μg/L on October 5, 2000, from the upgradient deep well 299-W10-14. The average for the other three measurements was 317 μg/L, and the high result is suspected to be a measurement error.

Nitrate and carbon tetrachloride routinely exceed the allowed maximum contaminant levels at Low-Level Waste Management Area 3. This contamination is related to widespread plumes originating to the south and are not a result of waste disposal practices at this RCRA site. Trichloroethene was slightly above the 5 μg/L maximum contaminant level in October 2000 (5.9 μg/L), but results from March and September 2001 were below the maximum contaminant level and were on a slightly downward trend.

2.8.3 U Plant

U Plant was built to recover plutonium using the bismuth phosphate process but was never used for that purpose. It was used to recover uranium from bismuth phosphate process waste from 1952 until ~1962.

A groundwater contaminant plume containing iodine-129, nitrate, trichloroethene, technetium-99, and uranium originates from U Plant disposal facilities and extends beyond the 200 West Area fence line to the east. The 216-U-1 and 216-U-2 cribs are the major sources of the plume. Waste from these cribs is believed to have been re-mobilized by disposal of waste to the 216-U-16 crib (WHC-EP-0133). Additional sources of contaminants include the 216-U-17, 216-U-8, and 216-U-12 cribs.

Interim action remediation using a groundwater pump-and-treat system is taking place in the vicinity of U Plant as part of the 200-UP-1 CERCLA operable unit. Because of the effects of remediation and past injection of treated water into the aquifer, the plume maps in this report are somewhat generalized in the area of system influence. This section discusses the contamination from the facilities in the vicinity of U Plant and includes the contamination being remediated in accordance with CERCLA and the specific reporting requirements for RCRA monitoring at the 216-U-12 crib and Waste Management Area U single-shell tank farm.

Monitoring Objectives Near U Plant

Groundwater monitoring is conducted near U Plant:

- triennially to annually to describe the nature and extent of contamination
- quarterly to assess the impact from RCRA Waste Management Area U and the 216-U-12 crib
- various time intervals to evaluate the performance of a pump-and-treat system for technetium-99 and uranium in the 200-UP-1 Operable Unit.

2.8.3.1 Groundwater Flow

Groundwater flow in the vicinity of U Plant in the 200 West Area is primarily toward the east (see Plate 1). The flow direction has changed only slightly (5 to 10 degrees), from east-southeast to a more easterly direction, over the past decade. This is because many of the former liquid effluent disposal sites in the 200 West Area are to the west of U Plant. Groundwater flow in this area is not significantly influenced by the pump-and-treat system at the 200-UP-1 Operable Unit. This is because there is only a single extraction well compared to the six extraction and three injection wells at the 200-ZP-1 Operable Unit pump-and-treat system. As reported in Section 2.8.1.1, the southernmost extraction well in the 200-ZP-1 system was removed from the network, eliminating the effect of the extractions on Waste Management Area U. Groundwater flow beneath the 216-U-12 crib is discussed in Section 2.8.3.7, flow beneath Waste Management Area U is discussed in Section 2.8.3.8, and flow at the 200-UP-1 Operable Unit pump-and-treat system is discussed in Section 2.8.3.9.

2.8.3.2 Uranium

The highest concentrations of uranium in Hanford Site groundwater in fiscal year 2001 were detected near U Plant in wells downgradient from the 216-U-1 and 216-U-2 cribs and adjacent to the 216-U-17 crib (Figure 2.8-29). The extent of contamination appears slightly smaller than in fiscal year 2000. However, many wells in this vicinity have gone dry. The maximum annual average uranium concentration detected near U Plant in fiscal year 2001 was 2,000 μg/L in well 299-W19-36, which is the former pump-and-treat injection well (see Figure 2.8-29). The uranium concentrations for several wells in the U Plant vicinity constitute dose values greater than the DOE derived concentration guide dose level. Assuming natural isotopic abundance, a uranium concentration of 790 μg/L represents the 100 mrem/yr dose equivalent for ingestion of drinking water. Uranium concentrations in wells near the 216-U-1 and 216-U-2 cribs showed a large pulse of uranium in 1986. Trends in uranium concentrations in well 299-W19-3, immediately downgradient from the cribs, are shown in Figure 2.8-30. The uranium levels in this well decreased considerably since the maximum measured in 1986. Uranium in fiscal year 2001 was 1,300 μg/L, a decline from the 1999 concentration of 1,990 μg/L.

Waste sites associated with U Plant have contaminated groundwater with uranium at the highest concentrations currently detected on the Hanford Site. The current extent of contamination appears slightly smaller than in fiscal year 2000. Carbon tetrachloride, iodine-129, nitrate, technetium-99, and trichloroethene contamination is also found in this area.

The uranium distribution in the vicinity of the 216-U-17 crib has been affected by pump-and-treat remediation (discussed in Section 2.8.3.9). The remediation system affected the direction of groundwater flow, both through the pumping and the past injection of treated groundwater upgradient of the pumping well. Because injection ceased in March 1997, its effect on the uranium distribution is decreasing. Uranium concentrations peaked in fiscal year 1999 near the extraction well in well 299-W19-20 but have declined since that time (Figure 2.8-31). The uranium concentration remains above the cleanup goal (480 μg/L). The high concentrations of uranium detected near the former injection well suggest that uranium contamination is moving into the area from upgradient and also may be rebounding from termination of the injection.

2.8.3.3 Technetium-99

Technetium-99 typically followed uranium throughout much of the fuel cycle. Thus, a sizable technetium-99 plume is associated with the 216-U-1, 216-U-2, and 216-U-17 cribs in essentially the same location as the uranium plume (Figure 2.8-32). The distribution of technetium-99 in this vicinity is complex, in part because of the operation of the pump-and-treat system that re-injected treated water until March 1997. The maximum annual average technetium-99 concentration associated with this plume in fiscal year 2001 was 22,000 pCi/L, found in former injection well 299-W19-36. Technetium-99 concentrations in most wells in the central part of the plume have declined during the period of pump-and-treat operations.

Technetium-99 concentrations also declined in downgradient well 699-38-70 (Figure 2.8-33). The data indicate that the technetium-99 plume has split into two lobes, one contained by the pump-and-treat system and a lower concentration portion downgradient of the capture zone.

Technetium-99 remains slightly elevated in wells downgradient of Waste Management Area U, when compared to upgradient wells. However, levels are below the drinking water standard. The concentrations in most downgradient wells declined to values between 200 and 300 pCi/L. In new well 299-W19-41, however, concentrations of technetium-99 averaged 630 pCi/L during fiscal year 2001, nearly the same as in fiscal year 2000.

2.8.3.4 Nitrate

Near U Plant, nitrate contamination at levels greater than the maximum contaminant level is considerably more widespread than technetium-99 or uranium (see Figure 2.8-10). This reflects the multiple sources of nitrate in the area. In particular, the 216-U-1, 216-U-2, 216-U-8, and 216-U-12 cribs contributed to nitrate levels above the maximum contaminant level. Nitrate sources near the REDOX Plant have also contributed to contamination in this vicinity (see Section 2.8.4.5).

Nitrate concentrations in the vicinity of the 216-U-17 crib are among the highest on the Hanford Site. The maximum nitrate concentration in fiscal year 2001 was 550 mg/L in well 299-W19-20, a decline from fiscal year 2000. The main nitrate source is believed to be past disposal to the 216-U-1 and 216-U-2 cribs, the same as the technetium-99 and uranium source.

2.8.3.5 Iodine-129

Iodine-129 at levels above the drinking water standard extends from the immediate vicinity of the 216-U-1 and 216-U-2 cribs to the east beyond the 200 West Area boundary (Figure 2.8-34). The fiscal year 2001 iodine-129 concentration detected in well 299-W19-3 near the cribs was 9.2 pCi/L, nearly twice the fiscal year 2000 result. Downgradient, the iodine-129 plumes from U Plant operations merge with, and become indistinguishable from, the REDOX Plant plume (see Section 2.8.4.3).

2.8.3.6 Trichloroethene

Trichloroethene is found at levels greater than the maximum contaminant level of 5 μg/L in the vicinity of the technetium-99 and uranium plume. Well 299-W19-35 was the only well that contained trichloroethene at levels greater than the maximum contaminant level, with a fiscal year average concentration of 8 μg/L. Thus, there does not appear to be a significant ongoing source of trichloroethene in this area.

2.8.3.7 RCRA Assessment Summary for 216-U-12 Crib

The 216-U-12 crib is located ~609 meters south of U Plant in the southeastern portion of the 200 West Area. The crib is an unlined, gravel-bottom, gravel percolation crib 3 meters by 30 meters, and 4.6 meters deep. The crib received process effluent from U plant including the 224-U Building, operating from 1960 through 1972, and from 1981 until February 1988.

The 216-U-12 crib was placed in assessment monitoring because of elevated specific conductance in downgradient wells 299-W22-41 and 299-W22-42 in 1993 (WHC-SD-EN-AP-108). The results and findings of the assessment monitoring program are presented in PNNL-11574. The elevated levels of specific conductance in the downgradient wells are attributed to calcium and nitrate. Technetium-99 has been detected in downgradient monitoring wells since monitoring began, indicating that the crib was the source. These findings indicated that the crib contributed to groundwater contamination and must remain in interim status assessment monitoring. The objective of the assessment monitoring is to evaluate the flux of constituents into the groundwater beneath the crib and monitor the known constituents until a corrective action is defined or final status monitoring plan is implemented for the crib.

The 216-U-12 crib is a RCRA facility that has contributed to groundwater contamination in the U Plant area. Nitrate and technetium-99 are elevated in downgradient wells. Concentrations of these contaminants are declining.

This site continued to be monitored quarterly under a RCRA assessment monitoring program during fiscal year 2001. The RCRA assessment monitoring well network and analyte lists for this site are provided in Appendix A, Table A.17.

Groundwater Flow

Based on regional groundwater elevations, the direction of groundwater flow continues relatively unchanged to the east-southeast to east. The pre-Hanford flow direction in the vicinity of the 216-U-12 crib is believed to have been from west to east, and it is expected that groundwater flow will eventually return to a more easterly direction.

Groundwater flow rates have not changed significantly since last year and range from 0.02 to 0.08 meter per day (see Appendix A, Table A.2).

Groundwater Contamination

Site-specific parameters selected for the interim status quality assessment monitoring include iodine-129, nitrate, technetium-99, and tritium (see Appendix A, Table A.17). The crib is the source of elevated nitrate and technetium-99 that were detected in downgradient wells 299-W22-41, 299-W22-42, 299-W22-79, and 699-36-70A.

The regional nitrate and technetium-99 plumes are a co-mingled series of smaller plumes with sources from several cribs (216-U-1, 216-U-2, 216-U-8, and 216-U-12) in the U Plant area. Iodine-129 and tritium were detected repeatedly in several monitoring wells downgradient from the 216-U-12 crib, but the sources appear to be the REDOX Plant effluent disposal cribs that are upgradient of the 216-U-12 crib. These plumes are discussed further in Section 2.8.4.

Nitrate continued to be detected at levels greater than the 45 mg/L drinking water maximum contaminant level in downgradient well 699-36-70A (ranging from 109 to 89 mg/L), but has remained below the drinking water maximum contaminant level in well 299-W22-79 during fiscal year 2001. The concentration trend in the nitrate has continued downward in both wells (Figure 2.8-35). Technetium-99 followed a trend similar to nitrate. Technetium-99 concentrations ranged from 20 to 92 pCi/L in downgradient wells during fiscal year 2001, which is well below the 900 pCi/L drinking water standard (Figure 2.8-36). Technetium-99 concentration trends are declining in wells near the crib and increasing farther downgradient.

Tritium has a source upgradient of the 216-U-12 crib. Tritium concentrations remained above the 20,000 pCi/L drinking water standard in downgradient well 699-36-70A during fiscal year 2001. The most recent concentrations are 8,540 and 69,000 pCi/L reported in downgradient wells 299-W22-79 and 699-36-70A, respectively. Tritium concentrations continued to decline in both wells during fiscal year 2001.

Iodine-129 is elevated above the 1 pCi/L drinking water standard in wells 299-W22-79 and 699-36-70A. The most recent iodine-129 concentration reported in these wells is 1.9, and 7.37 pCi/L, respectively. The iodine-129 source is upgradient of the 216-U-12 crib.

Monitoring Network

Some of the wells in the 216-U-12 monitoring network have gone dry in recent years. The network currently includes only two wells.

Declining water levels in the 200 West Area have reduced the 216-U-12 crib monitoring network from the original four wells to just two downgradient wells. The two remaining downgradient wells, 299-W22-79 and 699-36-70A (see Appendix A, Figure A.8), are sampled quarterly for the constituents of interest. The Washington State Department of Ecology and DOE annually negotiate installation of future monitoring wells under an interim milestone agreement (M-24-00M) (Ecology et al. 1998).

2.8.3.8 RCRA Assessment Summary for Waste Management Area U

Waste Management Area U, located in the central portion of the 200 West Area, consists of 16 single-shell underground storage tanks, 8 diversion boxes, and associated pipelines and valve boxes. The tanks were in use from 1946 until 1980 during which time they received high-level radioactive wastes from T Plant, U Plant, and the REDOX Plant. In addition, waste from other tank farms in 200 West Area was transferred to some of the tanks in Waste Management Area U. After a tank was removed from service, as much of its liquid contents were pumped as possible, leaving the tanks in an interim stabilized condition. In this condition, the tanks may contain up to an estimated 117,000 liters of supernatant liquid, but these liquids comprise <10% of the waste volume in the tank and consists of interstitial liquid held within the matrix of the solid contents of the tank that cannot be pumped from the tanks (DOE/RL-91-52).

RCRA assessment monitoring continued at Waste Management Area U in fiscal year 2001. Nitrate and technetium-99 concentrations continued to rise, while chromium either decreased or remained constant.

Over the course of tank farm operations, four of the tanks were declared leakers (DOE/RL-91-52) based on liquid losses or, in the case of one tank, a known tank rupture. In addition to these releases to the surrounding soil, three unplanned releases resulted in the spread of contamination to surface or near surface soil. Soil in the vadose zone surrounding the tanks has been contaminated with tank waste because of these releases. The soil provides a source of contamination for Waste Management Area U in addition to the contents of the tanks. To prevent precipitation from running onto the waste management area and infiltrating through contaminated soil, curbing and gutters were constructed in fiscal year 2001 on the side of Camden Avenue and 16th Street. These structures were designed to divert rainfall and snowmelt water from the roads and surrounding area to an area west of new well 299-W18-40 located on the southwestern corner of the waste management area. The structures should prevent the water from ponding on the waste management area and infiltrating through contaminated vadose zone sediment around the tanks.

Waste Management Area U was placed into assessment status in 2000 when specific conductance in groundwater monitoring wells downgradient of the Waste Management Area exceeded upgradient levels (PNNL-13185). An assessment of that finding determined that the waste management area had affected groundwater quality with elevated concentrations of nitrate, technetium-99, and possibly chromium in wells downgradient of the waste management area (PNNL-13282). The contaminant concentrations did not exceed their respective maximum contaminant levels and the area affected appeared to be limited to the southeastern corner of the waste management area. The resulting groundwater assessment plan (PNNL-13612) focused on:

Three new monitoring wells were installed in fiscal year 2001 to monitor Waste Management Area U.

- continued monitoring of existing wells
- drilling of new wells to provide additional areal monitoring coverage and replace wells that were going dry
- tracking groundwater flow conditions in conjunction with the termination of pumping in well 299-W15-37 that was part of the 200-ZP-1 pump-and-treat remedial action.

Groundwater Flow

Groundwater flow conditions at Waste Management Area U have varied greatly over the past several decades because of changing wastewater disposal in areas surrounding the waste management area. Discharges of water to U Pond, southwest of the area, maintained a northeastern direction of groundwater flow beneath the site while the tanks were in service. When U Pond was decommissioned in 1984, liquid waste discharges from facilities such as the Plutonium

Finishing Plant located northwest of Waste Management Area U continued, shifting the groundwater flow to the east and southeast beneath the waste management area. From 1991 to 1993, discharges of liquid waste to the 216-U-14 ditch, located east and southeast of Waste Management Area U, reversed the direction of groundwater flow beneath Waste Management Area U, causing flow to the west. This flow reversal was indicated in water levels and groundwater chemistry in groundwater monitoring wells surrounding the waste management area and lasted from ~1993 to 1996, at which time groundwater flow to the east was re-established.

Previous interpretations of water levels in the area north of Waste Management Area U indicated that the groundwater flow to the east was affected by the 200-ZP-1 Operable Unit pump-and-treat system located in the area. Pumping of the southernmost extraction well, 299-W15-37, produced a depression in the water table in the area just north of the waste management area, which was interpreted as producing a northerly component of flow from the northern end of the area. On January 17, 2001, well 299-W15-37 was permanently removed from the pump-and-treat system. In anticipation of that action, water levels in groundwater wells in the area were measured weekly and pressure transducers and data loggers were installed at two monitoring wells at Waste Management Area U to record water levels on a continual basis (PNNL-13612). The data indicated that water levels in all monitoring wells at Waste Management Area U responded similarly; therefore, any effect that the pumping well had was equal across the waste management area. The transducer data indicated that the water table on the north end of the waste management area was depressed by only 0.1 meter. When the pump was turned off, water levels recovered fully within one month, at which time, water levels began to drop at the rate of the regional water table in 200 West Area of ~0.4 meter per year. Therefore, while the pumping well 299-W15-37 did have an impact on groundwater in the vicinity of Waste Management Area U, that effect was apparently equal across the entire area and negligible in its effect on groundwater flow direction and velocity.

Cessation of pumping from a CERCLA extraction well did not affect groundwater flow near Waste Management Area U significantly.

Groundwater flow velocities were calculated based on a hydraulic conductivity of 6.12 meters per day and a specific yield of 0.17 determined in well 299-W19-42 (PNNL-13378) and a gradient of 0.0021 in the direction of 5 degrees to 10 degrees north of east. The velocity thus calculated is ~0.08 meters per day (see Appendix A, Table A.2). This flow direction is consistent with the regional groundwater flow interpretation.

Groundwater Contamination

In fiscal year 2001, the groundwater chemistry beneath Waste Management Area U has remained the same as presented in past years with nitrate and technetium-99 concentrations continuing to rise, especially in downgradient wells 299-W19-41 and 299-W19-12, located on the west side of the waste management area (Figures 2.8-37 and 2.8-38). Nitrate and technetium-99 concentrations are still less than their respective drinking water standards, 45 mg/L and 900 pCi/L, but these levels will be exceeded within the next 2 years if the trends continue. In previous annual reports, chromium was reported to have increased along with the nitrate and technetium-99, but chromium concentrations in wells 299-W19-42 and 299-W19-12 have either decreased or remained constant since 2000. It appears that the source of nitrate and technetium-99 contamination does not include chromium in mobile form.

Carbon tetrachloride is found at concentrations well above the drinking water maximum contaminant level in wells on the downgradient side of Waste Management Area U. It appears that the highest carbon tetrachloride concentrations are found on the northern side of the waste management area with lower concentrations to the south. Carbon tetrachloride concentrations are an order of magnitude lower on the upgradient side (well 299-W18-31) of the waste management area than on the downgradient side. Without evaluating this observation in light of the regional distribution of carbon tetrachloride, it might appear that these elevated carbon tetrachloride concentrations are due to releases from the waste management area. When the regional carbon tetrachloride distribution (see Figure 2.8-2) is considered, it becomes clear that the source of carbon tetrachloride is from the northwest where liquid waste disposal sites from the Plutonium Finishing Plant are located. The fact that the carbon tetrachloride source is northwest of Waste Management Area U explains why carbon tetrachloride concentrations decrease from north-to-south along the downgradient side of the waste management area.

Some constituents present naturally in the vadose zone have continued to increase in fiscal year 2001, but only in well 299-W19-12. These constituents are calcium, chloride, magnesium, and sulfate. While these increases are neither large nor hazardous, they indicate that a change of unknown origin is occurring at the waste management area. Because these increases are not detected in well 299-W19-41, where the highest nitrate and technetium-99 concentrations are found, the cause does not appear to be related to tank waste releases from the waste management area.

Monitoring Network

At the start of fiscal year 2001, the monitoring network consisted of one upgradient well (299-W18-31) and four downgradient wells (299-W18-30, 299-W19-12, 299-W19-41, and 299-W19-42). See Appendix A, Figure A.18 for the locations of these wells. Well 299-W19-12 is a pre-RCRA well drilled in 1983, but while not completed in the same fashion as wells currently drilled, the well does meet the requirements for RCRA groundwater monitoring. The well has consistently yielded groundwater with statistically significant higher pH than all of the other monitoring wells in the network. The higher pH has been attributed possibly to cement grout used in the completion of the well. Because of the possible effect of well completion on groundwater chemistry and the need for closer spacing of monitoring wells on the downgradient margin of the waste management area, well 299-W19-12 was replaced with two new wells, 299-W19-44 and 299-W19-45. Upgradient well 299-W18-25 went dry in 2000 and was replaced by well 299-W18-40 in 2001. The three wells drilled in 2001 were completed with 10.7-meter screened intervals. Groundwater modeling indicates that the falling water table will equilibrate at an elevation that is above the bottom of each of the new wells; therefore, their depth of completion should not limit their lifetime (PNNL-13612).

The current monitoring network and schedule for sampling and analyses are documented in the groundwater quality assessment plan (PNNL-13612) published in August 2001. A summary of the monitoring plans is presented in Appendix A, Table A.40.

2.8.3.9 Groundwater Remediation at 200-UP-1 Operable Unit

Groundwater in the U Plant area is pumped and treated to shrink the highest concentration portions of the technetium-99 and uranium plumes. The system operates as an interim action until a final remedy is selected. During fiscal year 2001, 8 grams of technetium-99 and 17 kilograms of uranium were removed.

The goal of the pump-and-treat system at the 200-UP-1 Operable Unit is to reduce contamination in the highest concentration area of the plumes, reduce human health risks through mass removal, hydraulically contain the contaminant plume, and provide information to support a final remedy decision. At the end of fiscal year 2001, technetium-99 remained above the 9,000 pCi/L remediation goal in one monitoring well. Uranium concentrations generally remained above the 480 µg/L remediation goal in almost all wells. However, the loss of many of the monitoring wells the last several years due to declining water levels has created a situation where the contaminant plumes can no longer be tracked accurately. For more detailed information about operations during fiscal year 2001, refer to DOE/RL-2001-53.

Interim Remedial Action Objectives

The pump-and-treat system for this operable unit is located southeast of U Plant (221-U) (see Appendix A, Figure A.22). The interim action objectives (ROD 1997) are the following:

- reduce contamination in the areas of highest concentration of technetium-99 and uranium to below 10 times (480 μg/L) the cleanup level under the *Model Toxics Control Act* (WAC 173-340) for uranium, and 10 times (9,000 pCi/L) the drinking water standard 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 the development and implementation of a final remedy that will protect human health and the environment.

History of Operations

A previous pump-and-treat system operated in 1985 near the 216-U-1 and 216-U-2 cribs to reduce elevated uranium concentrations. For a discussion of this operation, refer to WHC-EP-0133.

The current system was constructed to contain the highest concentration portion of the technetium-99 and uranium plume. Early operations consisted of a treatability test conducted from March 1994 to September 1995. Phase I pump-and-treat operations began September 1995 and consisted of one extraction well and one injection well. This system operated until February 7, 1997. Groundwater was treated onsite using an ion-exchange medium, and treated water was injected upgradient from the extraction well.

On February 25, 1997, an interim action record of decision (ROD 1997) was issued that initiated Phase II for the pump-and-treat system at the 200-UP-1 Operable Unit. The selected remedy consisted of pumping the highest concentration zone of the technetium-99 and uranium groundwater plumes, using the same extraction well and transporting the contaminated groundwater to the Effluent Treatment Facility in the 200 East Area. Since March 1997, contaminated groundwater was pumped from the extraction well, transported in an 11-kilometer pipeline to the Effluent Treatment Facility in the 200 East Area for treatment, and then sent to the State-Approved Land Disposal Site north of the 200 West Area for disposal. Secondary contaminants (carbon tetrachloride and nitrate) are also present and are being removed.

Contaminant Removal

Approximately 102 million liters of contaminated groundwater from the 200-UP-1 system were treated at the Effluent Treatment Facility in fiscal year 2001. A total volume of 523 million liters have been treated since startup in fiscal year 1994. The average extraction flow rate was 189 liters per minute. The amount of contamination removed this fiscal year is summarized in the following list:

- Technetium-99
    - 75.7 grams removed since startup (March 1994)
    - 8.4 grams removed during fiscal year 2001

- Uranium
  - 131.9 kilograms removed since startup (March 1994)
  - 17.1 kilograms removed during fiscal year 2001
- Carbon tetrachloride
  - 20.2 kilograms removed since startup (March 1994)
  - 2.7 kilograms removed during fiscal year 2001
- Nitrate
  - 19,500 kilograms removed since startup (March 1994)
  - 3,924 kilograms removed during fiscal year 2001.

Table 2.8-3 shows additional detail about the amount of contamination removed since startup of operations.

Carbon tetrachloride concentrations again decreased while groundwater was transported along the 11-kilometer pipeline between the extraction well in the 200 West Area to the Effluent Treatment Facility in the 200 East Area. The dissolved carbon tetrachloride is lost to the atmosphere. Given the volume of groundwater pumped in fiscal year 2001 (91 million liters), the estimated amount of carbon tetrachloride mass lost to the atmosphere was 6.6 kilograms. This loss is in addition to the mass removed during treatment.

Overall Effectiveness

As of July 2001, the high concentration portions of the technetium-99 and uranium plumes were hydraulically contained (9,000 pCi/L and 450 µg/L contours, respectively). However, they were not remediated to the levels required by the interim action objectives (ROD 1997). Significant progress was made to reduce the size and concentration of the technetium-99 plume. Less progress has been made to remediate the uranium plume because of its tendency to sorb to the soil.

The general plume configuration for both technetium-99 and uranium is similar to past years, with two distinct high concentration areas: one near extraction well 299-W19-39, and the other near monitoring well 299-W19-36 (Figures 2.8-39 and 2.8-40). Well 299-W19-37, located about halfway between the extraction well and upgradient well 299-W19-36, is the basis for distinguishing between these two areas because of low contaminant concentrations here (<500 pCi/L technetium and <250 µg/L uranium).

Several wells monitoring the progress of the 200-UP-1 pump-and-treat system have gone dry in recent years. This makes it difficult to estimate the current plume configuration.

The capability for monitoring and tracking changes in plume configuration continues to be hampered by the lack of well control in the baseline plume area (see Figures 2.8-39 and 2.8-40), even though another monitoring well, 299-W19-43, was installed the end of the fiscal year. As a result, the plume maps and the discussion on the extent of remediation are based on historical information and a limited amount of data collected this fiscal year. Only three monitoring wells are still viable within the original baseline plume area: 299-W19-20, 299-W19-37, and 299-W19-36. These wells span the target remediation area from the upgradient end, to mid-point to near the extraction well, respectively.

To accelerate remediation in the upgradient plume area, well 299-W19-36 will be converted to an extraction well in fiscal year 2002. This well will be tied into the same cross-site transfer line as well 299-W19-39 for transporting contaminated groundwater to the Effluent Treatment Facility for treatment and disposal.

Technetium-99

Technetium-99 has declined consistently in response to remediation efforts. The remedial action objective of 9,000 pCi/L is thought to have been met in all wells except in upgradient monitoring well 299-W19-36 (see Figure 2.8-39).

Concentrations at the end of the fiscal year were 19,400 pCi/L and were declining rapidly from a peak concentration of 27,700 pCi/L in November 2000.

Technetium-99 concentrations at extraction well 299-W19-39 (see Figure 2.8-39) are below the remedial action objective but above the drinking water standard, and have been relatively constant since 1999. The last sample result in fiscal year 2001 was around 1,400 pCi/L. The drinking water standard for technetium-99 is 900 pCi/L.

Contaminant concentrations at downgradient well 299-W19-40 also remain below the drinking water standard of 900 pCi/L, although the last sample collected in July 2001 increased to 500 pCi/L from 258 pCi/L in April 2001. Even with the higher concentration, it appears that extraction well 299-W19-39 is containing the high concentration area of the plume. This conclusion is further substantiated by the relatively low concentrations measured at cross-gradient monitoring wells 299-W19-35 (northeast) and 299-W19-38 (southwest) (524 and 750 pCi/L, respectively).

The pump-and-treat system appears to have remediated most of the technetium-99 to below its target level. The system has been less successful for uranium.

Uranium

Uranium concentrations have declined in response to remediation efforts, but are still above the 480 µg/L remedial action objective in most monitoring wells located within the baseline remediation area (see Figure 2.8-40). Again, only a few monitoring wells are still available to evaluate contaminant concentrations. The remedial action objective has been met in only one active monitoring well within the target remediation area, well 299-W19-37. All wells outside of the targeted remediation area are also below the remedial action objective.

Concentrations have declined slowly but steadily since 1997 at extraction well 299-W19-39. Initial levels were as high as 366 µg/L in 1997 but had decreased to 146 µg/L at the end of fiscal year 2001. While uranium has never been above the remedial action objective in the extraction well, it is above the remedial action objective of 480 µg/L at nearby monitoring well 299-W19-20. Uranium has declined rapidly in this well since 1999, from 2,800 to 871 µg/L in fiscal year 2001.

Uranium increased significantly at well 299-W19-36 from 170 µg/L in January 2000 to 2,140 µg/L in mid-2001. Prior to going dry in 1999, two upgradient monitoring wells were also above the remedial action objective: 299-W19-28 (560 µg/L) and 299-W19-29 (1,335 µg/L). Concentrations were steady or increasing at that time, so it is unlikely that they have since declined below the remedial action objective.

Uranium concentrations have always been below the remedial action objective at downgradient monitoring well 299-W19-40. They have never been above 480 µg/L at this well. During startup of operations (1995), uranium values changed rapidly, decreasing from near 300 µg/L to around 140 µg/L (mid-1996). They have remained about this level the last 5 years (there was a slight increase from 1998 to 2000 to ~190 µg/L).

In summary, most of the high concentration portion of the technetium-99 plume in the southeastern 200-UP-1 Operable Unit appears to have been remediated to below the 9,000 pCi/L remedial action objective. An area of high concentration is still present in the upper portion of the plume near former injection well 299-W19-36. Technetium-99 concentrations reached 27,700 pCi/L at this well in November 2000, but now appear to be on a downward trend.

Uranium concentrations are above the 480 µg/L remedial action objective in only one well, 299-W19-20, near extraction well 299-W19-39; however, most monitoring wells have gone dry, and determining plume configuration at this time can only be estimated using historical data. Total uranium in well 299-W19-36 has risen rapidly as groundwater diluted by previous injection of treated effluent now moves downgradient. For a detailed discussion on the likely reason why contaminant concentrations have increased so dramatically, refer to DOE/RL-2001-53.

Water-Level Impact and Capture-Zone Analysis

Based on water-level data collected during fiscal year 2001, the water table beneath the 200-UP-1 Operable Unit continues to decline at a rate of ~0.4 meter per year (DOE/RL-2001-53). This is approximately the same rate calculated in fiscal year 2000. The drop in water levels has resulted in the loss of well 299-W19-38 in fiscal year 2001. The loss of this well leaves the monitoring network without well coverage in the south and southwest portions of the contaminant plumes.

The radius of influence of the extraction well is estimated at ~155 meters, essentially unchanged from fiscal years 1998 to 2000. The extraction well appears to be capturing the targeted plume area based on drawdown detected in observation wells located outside of the targeted remediation area, previous modeling results, and the low concentrations of contaminants in downgradient well 299-W19-40 (DOE/RL-2000-71). However, the limited monitoring network is not robust enough to confirm that interior plume concentrations are below the remedial action objectives.

2.8.4 REDOX Plant

The REDOX Plant was used for separating plutonium from irradiated fuel from 1951 through 1967. Groundwater plumes, originating in the vicinity of the REDOX Plant and its associated waste storage and disposal facilities, include chromium, iodine-129, nitrate, technetium-99, trichloroethene, tritium, and uranium at levels above the maximum contaminant levels/drinking water standards. These plumes are considered part of the 200-UP-1 Operable Unit. Strontium-90 was detected at levels above the drinking water standard in only one well in this area in fiscal year 2001. Two RCRA treatment, storage, and disposal facilities in this vicinity, Waste Management Area S-SX and 216-S-10 pond and ditch, have groundwater monitoring requirements. Other facilities appear to have produced the major part of the groundwater contamination, though high concentrations of technetium-99 and other contaminants are attributed to leaking tanks or associated piping in Waste Management Area S-SX.

Monitoring Objectives Near REDOX Plant

Groundwater monitoring is conducted near the REDOX Plant:

- triennially to annually to describe the nature and extent of contamination
- semiannually to detect the possible impact of one RCRA waste management area
- quarterly to assess contamination from one RCRA waste management area.

2.8.4.1 Groundwater Flow

The direction of groundwater flow in the southern portion of the 200 West Area is principally toward the east (see Plate 1). Over the past decade, flow in this area has changed (by ~30 degrees) from a southeasterly direction to mostly east in response to decreased effluent discharges in the 200 West Area. Groundwater flow beneath Waste Management Area S-SX is discussed in Section 2.8.4.9, and flow beneath the 216-S-10 pond and ditch is discussed in Section 2.8.4.10.

2.8.4.2 Tritium

A tritium plume extends eastward from the vicinity of the REDOX Plant in the southern 200 West Area (see Plate 2). The eastern part of the plume curves to the north, but the tritium concentrations in the northern part of this plume are declining, as illustrated by the tritium trend plot for well 699-38-65 (Figure 2.8-41). Concentrations are changing slowly to the east and appear to be declining in some wells to the south and in the center of the plume. The overall picture is of a plume that has nearly stopped spreading in most directions and has started to contract in some areas as radioactive decay dominates over the hydrologic transport. Slowly increasing concentrations are still seen in the eastern part of the plume. Movement within this tritium plume is expected to be slow because of the low-permeability sediment at the 200 West Area and the dissipation of the groundwater mound beneath the 200 West Area since the reduction of effluent discharge.

The tritium plume from the southern 200 West Area extends to US Ecology's low-level radioactive waste disposal facility. The maximum tritium concentration (annual average of 5,870 pCi/L) detected in groundwater at that facility in fiscal year 2001 was in a well located on the western (upgradient) side of the facility. The concentrations in this well, 699-35-59 (US Ecology well 13), have increased slowly due to transport from the 200 West Area. The fiscal year 2000 average tritium concentration for this well was 5,600 pCi/L. These data were provided by US Ecology and are not included on the diskette included with this report.

Waste sites associated with the REDOX plant have contributed to chromium, iodine-129, technetium-99, trichloroethene, tritium, and uranium plumes in groundwater. Contaminant concentrations increased in some wells near Waste Management Area S-SX.

Tritium was found above the drinking water standard upgradient of the REDOX Plant near the 216-S-25 crib and Waste Management Area S-SX (Figure 2.8-42). The source of tritium in this area is attributed to the past-practice disposal sites (e.g., 216-S-4, 216-S-21, 216-S-25 cribs). Tritium concentrations in well 299-W23-9, located near the 216-S-25 crib, declined through fiscal year 2001 after several years of increasing concentrations. In fiscal year 2001, the average concentration for well 299-W23-9 was 190,000 pCi/L, compared to 410,000 pCi/L in fiscal year 2000.

2.8.4.3 Iodine-129

An iodine-129 plume from the 200 West Area extends into the 600 Area to the east and coincides with the tritium plume originating near the REDOX Plant (see Figure 2.8-34). This iodine-129 plume and the iodine-129 contamination originating farther north near U Plant appear to combine downgradient and become indistinguishable at the current level of monitoring detail. The maximum iodine-129 concentration detected in this plume in fiscal year 2001 was 31 pCi/L in well 699-35-70, nearly the same as the fiscal year 2000 value of 34 pCi/L. Iodine-129 concentrations in this well have not changed significantly in the last decade.

2.8.4.4 Technetium-99

Technetium-99 continued to be found at levels above the drinking water standard in three small plumes located near Waste Management Area S-SX (Figure 2.8-43). Evidence from recent years suggests that multiple sources of technetium-99 in the Waste Management Area S-SX tank farm contribute to groundwater contamination (PNNL-11810). The 216-S-13 crib may have contributed to the technetium-99 detected further downgradient of Waste Management Area S-SX, but well 299-W22-21, located next to the 216-S-13 crib, can no longer be sampled due to the declining water table. There is a scarcity of wells to track the migration of technetium-99 downgradient of Waste Management Area S-SX, though recently drilled monitoring wells 299-W22-82 and 299-W22-83 provide some information. Technetium-99 in the vicinity of Waste Management Area S-SX is discussed in Section 2.8.4.9.

2.8.4.5 Strontium-90

Strontium-90 was detected at levels above the 8 pCi/L drinking water standard in only one well in the 200 West Area. This well, 299-W22-10, is located downgradient of the 216-S-1 and 216-S-2 cribs, east of the SX tank farm. A strontium-90 concentration of 69 pCi/L was reported in the sample from 2001. This is slightly lower than the 74 pCi/L value from fiscal year 2000 but higher than concentrations of <30 pCi/L prior to fiscal year 1999.

2.8.4.6 Nitrate

Nitrate was detected in fiscal year 2001 above the maximum contaminant level in two small plumes in the vicinity of the REDOX Plant. The first plume is located near the 216-S-20 crib, which received laboratory waste from the 222-S Building (see Figure 2.8-10). Lower concentrations of nitrate also are associated with the tritium and iodine-129 plumes extending to the east of the REDOX Plant.

Nitrate was detected above the maximum contaminant level in well 299-W23-9 near the 216-S-25 crib and extends past Waste Management Area S-SX (see Figure 2.8-10). Nitrate appears to be associated with the technetium-99 plumes in this vicinity. In particular, 580 mg/L of nitrate was detected in new well 299-W23-19, located in the southwestern corner of Waste Management Area S-SX. The nitrate in this well is much higher than concentrations upgradient so it is likely that the tank farm also is contributing to the nitrate contamination. Nitrate levels are considerably lower in wells downgradient of the tank farm.

2.8.4.7 Chromium

Chromium declined to levels below the maximum contaminant level in fiscal year 2000 near the 216-S-10 pond and ditch, in well 299-W26-7, the upgradient well for the 216-S-10 pond and ditch (see Section 2.8.4.10). Concentrations remained low in fiscal year 2001. The source of the chromium contamination has not been determined, but it is possibly related to the 216-S-10 pond or to earlier disposal to upgradient facilities (termed the "REDOX swamp" in some early reports). There may be a relationship between the chromium detected in well 299-W26-7 and chromium detected farther downgradient, south of the 200 East Area (discussed in Section 2.11.5). Chromium in Waste Management Area S-SX is discussed in Section 2.8.4.9.

2.8.4.8 Trichloroethene

A small trichloroethene plume, with concentrations just above the maximum contaminant level, is found east of the REDOX Plant. The 216-S-20 crib is a likely source of the trichloroethene plume. In fiscal year 2001, trichloroethene stayed nearly the same as in fiscal year 2000 at 9.4 μg/L in well 299-W22-20.

2.8.4.9 RCRA Assessment Summary for Waste Management Area S-SX

Waste Management Area S-SX continued to be monitored under a RCRA assessment program in fiscal year 2001. The groundwater assessment is being conducted concurrently with the vadose zone characterization work for the RCRA field investigation (HNF-5058). The RCRA field investigation report will be used to support decisions concerning the need for a corrective measures study. The site map for this waste management area and a table of wells sampled and associated analytes are included Appendix A (Figure A.18 and Table A.37). Analytes exceeding contaminant standards are listed in Appendix A, Table A.3.

At RCRA Waste Management Area S-SX, technetium-99 and other contaminants continued to increase in a well adjacent to a tank that is known to have leaked in the past. Technetium-99 concentrations reached 74,000 pCi/L, the highest levels detected in Hanford Site groundwater in fiscal year 2001.

Groundwater Flow

Estimates of the rate of groundwater flow, using travel times for tritium between upgradient and downgradient wells in the vicinity of Waste Management Area S-SX, suggest groundwater flow rates of 25 to 50 meters per year or 0.07 to 0.14 meter per day (PNNL-12114). Calculated Darcy flow rates (see Appendix A, Table A.2) based on hydraulic conductivity and tracer test data, also suggest low flow rates (0.013 to 0.04 meter per day).

The water table is declining at the rate of ~0.6 meter per year, which probably accounts for the gradual change in flow direction from 1990 to the present. For example, trend surface analysis of the water-table elevations in the network wells indicates that the flow direction has shifted from a southeastward direction to almost due east at the present time (PNNL-13441). The flow direction inferred from water-table elevation contours suggests southeastward flow over the larger area around the waste management area (see Plate 1). This apparent discrepancy may in part be due to aquifer inhomogeneities.

Solute transport modeling was conducted in an attempt to simulate the movement of tank waste from the southwest corner of the SX farm near tank SX-115 (PNNL-SA-35433). Predicted and observed technetium-99 concentrations at downgradient well locations were in reasonable agreement, suggesting that the groundwater flow rates and directions discussed above are reasonably close to actual conditions. The solute transport modeling also suggested the extent of the contaminant plume is very limited. For example, the predicted 8,000 pCi/L concentration contour covered an area of only ~1,000 square meters (~20 meters by 50 meters). Additional hydrologic characterization is planned by the Tank Farm Vadose Zone Project to assess the feasibility of conducting a pump-and-treat system in the immediate vicinity of tank SX-115 (see also Section 3.1.1.2 for a discussion of efforts to eliminate suspected driving force(s) for transporting vadose zone contamination to groundwater at this location).

Groundwater Contamination

The general distributions of contaminant plumes in the vicinity of Waste Management Area S-SX were discussed earlier in this section. Contaminants have tended to migrate to the east-southeast as also suggested by the water-table contours for this area (see Plate 1). The 12 new wells installed between 1999 and 2001 provide additional information concerning both areal and vertical extent of contamination.

The constituents of interest for this waste management area were identified previously based on process knowledge and results of in-tank sampling and analysis. The radioactive constituents with greatest concentrations in the tanks are cesium-137 and strontium-90. The more mobile components of tank waste that have been identified in groundwater beneath this waste management area include technetium-99 as pertechnetate, chromate, nitrate, and tritium. While upgradient sources exist because of past-practice discharges to adjacent cribs (e.g., 216-S-25 crib), tank farm waste input can be distinguished from upgradient sources by isotopic and chemical ratios (PNNL-12114; HNF-4936; PNNL-13441). For example, ratios of technetium-99 to nitrate in upgradient wells are very low compared to ratios in downgradient wells (~0.01 versus ~0.1, respectively, PNNL-13441).

Chromium, nitrate, and technetium-99 concentrations increased sharply in a well downgradient of the S tank farm. This new contaminant occurrence is believed to represent a vadose zone source remaining after a past leak or spill.

Concentrations of carbon tetrachloride, chromium, iodine-129, nitrate, technetium-99, and tritium exceeded drinking water standards (see Appendix A, Table A.3). Carbon tetrachloride and tritium are attributed primarily to upgradient or non-tank farm related sources. The one exceedance for iodine-129 (6 pCi/L) is believed to be an analytical error. Iodine-129 was not detected in the preceding and following sampling events at this well. Highlights of concentration trends for key tank waste contaminants are summarized as follows.

Technetium-99. As last year, the most significant trend during fiscal year 2001 was the increase in technetium-99 concentrations in well 299-W23-19. This well is located immediately adjacent to tank SX-115 where a documented release to the soil column occurred in the 1960s. The technetium-99 concentration increased from a low of 39,000 pCi/L in October 1999 to a maximum of 81,500 pCi/L in March 2001, dropped abruptly to 36,700 pCi/L in August and then rebounded to 74,000 pCi/L in September. Co-contaminants, chromium and nitrate, exhibited similar trends (Figure 2.8-44) indicating the rapidly changing concentrations are not due to analytical problems.

Technetium-99 levels in wells 299-W22-46 (Figure 2.8-45) and 299-W22-50, east-southeast of the tank SX-115, appear to persist, suggesting a longer-term release source than previously observed in other wells in the waste management area well network. For example, technetium-99 in well 299-W22-45 (see Figure 2.8-45) exhibits a transient concentration-time pattern. The latter suggests a one-time vadose zone transport or leak event.

Another notable change is the sharply rising concentrations of chromium, nitrate, and technetium-99 in downgradient well 299-W22-48 at the S tank farm (Figure 2.8-46). Technetium-99 reached a maximum of 4,050 pCi/L in September 2001. Based on the location of this well and inferred flow directions, this new contaminant occurrence represents a vadose zone source possibly originating in the S tank farm area. For example, spills and leaks of tank waste occurred at single-shell tank S-104 and valve pits in the east-central and central area of the S tank farm. The 216-S-3 crib is also located upgradient from this well. However, the latter received primarily evaporator condensate wastewater, which would have been dominated by tritium. Only very low concentrations of tritium occur in well 299-W22-48 (for example, 1,460 pCi/L was the highest observed during fiscal year 2001).

Nitrate. The highest nitrate concentration (646 mg/L versus the drinking water standard of 45 mg/L) occurred in well 299-W23-19 together with the highest technetium-99 concentration. Most of this nitrate is attributed to the same tank waste source discussed above for technetium-99. However, nitrate is widespread in this area due to past-practice discharge of nitrate-bearing wastewater to upgradient cribs, ditches and ponds. The highest nitrate concentration in the nearest upgradient RCRA well (299-W23-14) was 135 mg/L in March 2000. Similar concentrations have occurred in well 299-W23-9 near the upgradient crib 216-S-25. The crib received treated high-nitrate waste from a groundwater pump and treat that operated in 1985. The process was intended to remove uranium from groundwater extracted near the past-practice U plant cribs (216-U-1 and 216-U-2) that received process condensate containing uranyl nitrate. The process did not remove the nitrate.

Based on the groundwater data collected to date, only the more mobile tank waste constituents (e.g., hexavalent chromium, nitrate, technetium-99, and tritium) have reached groundwater beneath Waste Management Area S-SX. Cesium-137 and strontium-90 were not detected during fiscal year 2001.

Excluding well 299-W23-19, nitrate concentrations in fiscal year 2001 ranged from a low of 753 mg/L (downgradient well 299-W22-80 at the south end of SX tank farm) to a maximum of 95.2 mg/L at well 299-W23-9 near upgradient crib 216-S-25. The widespread and continuous presence of moderate nitrate concentrations is attributed to residual contamination from multiple upgradient sources and to the relatively slow groundwater flow rate.

Chromium. Chromium ranged from 3 to 138 μg/L in network wells during the report period. The highest concentration occurred in well 299-W23-19 in March and was the first time the drinking water maximum contaminant level for this contaminant has been exceeded in a network well at this waste management area. The trend for this constituent in well 299-W23-19 is similar to nitrate and technetium-99 (see Figure 2.8-44). The abrupt change in concentration over a relatively short time and the co-occurrence with other mobile tank waste constituents exhibiting the same pattern is consistent with a localized tank farm source (e.g., the water soluble or extractable fraction from soil cores taken beneath tank SX-115 all contained chromium, nitrate, and technetium-99 (PNNL-13404).

Uranium. Uranium in network wells ranged from 1.1 to 25 μg/L, as compared to a drinking water maximum contaminant level of 30 μg/L. The highest concentration occurred in well 299-W23-19. The second highest concentration (20 μg/L) occurred in upgradient well 299-W23-9 near the 216-S-25 crib. Average background for Hanford Site groundwater is ~2 μg/L. The moderately elevated uranium in the vicinity of Waste Management Area S-SX is attributed primarily to the upgradient past-practice sources.

Cesium-137 and Strontium-90. Except for well 299-W23-19, the collection frequency for these constituents was changed from quarterly to annually during the year. Due to the low groundwater flow rates combined with retardation effects for these constituents, an annual collection frequency for downgradient wells was deemed adequate. However, a quarterly frequency is maintained at well 299-W23-19 because this well intersects groundwater beneath vadose zone contamination near tank SX-115.

Cesium-137 and strontium-90 were not detected in any of the network monitoring wells for Waste Management Area S-SX during fiscal year 2001. As previously noted, evaluation of historical and more recent groundwater data (HNF-4936) showed that results for these two constituents of interest were at or below the routine detection limits (~10 pCi/L for cesium-137 and ~1 pCi/L for strontium-90) and were within the 95% confidence limits for field trip blank results.

Monitoring Network

Two new wells were drilled in calendar year 2001 that extend the spatial coverage at the northern end of S tank farm and midway along the east side of SX tank farm. With all the new wells now installed, the theoretical detection efficiency will be >95% (PNNL-13441). A tabulation of all wells currently in the network is included in Appendix A, Table A.37.

2.8.4.10 RCRA Parameters for 216-S-10 Pond and Ditch

The inactive 216-S-10 pond and ditch was monitored semiannually under RCRA interim status indicator evaluation (see Appendix A, Table A.15). None of the indicator parameter concentrations in downgradient monitoring wells exceeded critical mean values during fiscal year 2001 (see Appendix A, Table A.16). A site-specific constituent, chromium, which had been elevated above the 100 μg/L maximum contaminant level in past years, had dramatically declined during fiscal year 2000 in upgradient well 299-W26-7 (Figure 2.8-47). Chromium values ranged from 5.7 to 25.9 μg/L in fiscal year 2001. Because the upgradient well is located immediately adjacent to the 216-S-10 pond (see Appendix A, Figure A.7), the elevated chromium could have been from an upgradient source or from the pond. A new monitoring plan will be prepared in calendar year 2002 to update and redefine the RCRA monitoring network. Further description of the chromium plume is presented in Section 2.8.4.7.

RCRA monitoring at the 216-S-10 pond and ditch provides no evidence of groundwater contamination from this facility. Another downgradient monitoring well went dry in fiscal year 2001, leaving just one upgradient and one downgradient well.

The water table continued to decline in the 200 West Area during fiscal year 2001. During the year, downgradient well 299-W26-12 went dry and was removed from the monitoring network. The current RCRA monitoring network consists of two remaining wells, one upgradient (299-W26-7) and one downgradient (299-W26-13). RCRA requirements for interim status monitoring specify that a minimum of one upgradient and three downgradient monitoring wells are needed to monitor the site. As a result, at least two additional wells are needed to bring the monitoring network back into compliance with RCRA regulations. The Washington State Department of Ecology and DOE annually negotiate installation of future monitoring wells under and interim milestone agreement (M-24-00M) (Ecology et al. 1998).

Background values of contaminant indicator parameters for the facility have been re-calculated based on one upgradient well, 299-W26-7. Based on regional groundwater elevations, the groundwater flow direction continues toward the east-southeast to east. The indicator parameters provide no evidence of contamination from the 216-S-10 pond and ditch.

Groundwater flow rates have not changed significantly since last year and range between 0.053 and 2.55 meter per day (see Appendix A, Table A.2).

Sample results that exceeded drinking water standards and maximum contaminant levels this year are presented in Appendix A, Table A.3.

2.8.5 State-Approved Land Disposal Site (616-A Crib)

The Hanford Site 200 Areas Effluent Treatment Facility processes contaminated liquids from Hanford Site facilities. The clean water generated by these processes is occasionally enriched in tritium and is discharged to the 200 Areas' State-Approved Land Disposal Site. This site is regulated by State Waste Discharge Permit ST-4500 (Ecology 2000), which is administered under WAC 173-216. Groundwater monitoring for tritium and other constituents is required by the state-issued permit at 22 wells surrounding the facility (Figure 2.8-48).

During fiscal year 2001, discharge volume to the facility totaled ~105 million liters. Over 445 million liters of effluent have been discharged since the State-Approved Land Disposal Site began operating in 1995. The quantity of tritium disposed to the site during fiscal year 2001 totaled slightly <4.7 curies, most of which was discharged during October 2000. This brings the total inventory disposed since 1995 to slightly over 325 curies.

In August 2000, a new state waste discharge permit was signed with the Washington State Department of Ecology, allowing operation of the facility to continue through August 2005. In support of the permit, a revised groundwater monitoring plan (PNNL-13121) was prepared during fiscal year 2000. The most notable changes are that well 299-W8-1 was dropped as an upgradient monitoring location for the State-Approved Land Disposal Site, and ammonia was dropped from the constituent list. Fiscal year 2001 was the first year that this new permit and revised groundwater monitoring requirements were applied to the facility. A discussion of fiscal year 2001 groundwater monitoring results is presented in PNNL-13689 and is summarized below.

The State-Approved Land Disposal Site is used to dispose treated water that occasionally contains tritium. Tritium continued to exceed the drinking water standard in nearby wells in fiscal year 2001, but no new tritium was detected in wells farther from the site.

2.8.5.1 Groundwater Flow

Water levels measured during fiscal year 2001 indicate that a small groundwater mound resulting from operations at the facility persists in the vicinity of the State-Approved Land Disposal Site (see Plate 1). Hydrographs of wells near the 200 West Area, immediately south of the disposal site (Figure 2.8-49), indicate a potential for flow toward the south from the disposal site. Hydraulic head level in well 699-48-77A has consistently surpassed the head in most wells in the tritium-tracking network since late 1997. This is a result of the continuing general decline in water levels in the 200 West Area combined with the increased head near the State-Approved Land Disposal Site. The current exceptions to this relationship are the wells southwest of the State-Approved Land Disposal Site. In these wells, water-level elevations are only intermittently lower than those in well 699-48-77A, depending on the magnitude of discharges to the State-Approved Land Disposal Site. The center of the mound is not necessarily located at well 699-48-77A; its shown location is partially an artifact of well coverage. The actual center is probably located somewhere between well 699-48-77A and the facility. Interpreted flow paths (or the potential for flow) of groundwater in the vicinity of the State-Approved Land Disposal Site indicate that effluent from the site could eventually affect groundwater quality at wells to the south of the facility. It is not known exactly how far south the effluent could actually flow before turning east. The transport southward will ultimately depend on the interplay between discharge volumes and aquifer properties. Downgradient well 699-51-75 is currently in an optimum location for the interception and efficient tracking of tritium in a regionally downgradient direction from the State-Approved Land Disposal Site.

The hydraulic gradient near the State-Approved Land Disposal Site was ~0.004, as measured between wells 699-48-77A and 699-48-77D in March 2001 (see Appendix A, Table A.2). The gradient is probably somewhat higher between well 699-48-77A and the State-Approved Land Disposal Site.

2.8.5.2 Extent of Contamination

Results of tritium analyses in the State-Approved Land Disposal Site tritium-tracking well network for fiscal year 2001 are shown on Figure 2.8-48. Wells in the State-Approved Land Disposal Site proximal network (699-48-77A, 699-48-77C, and 699-48-77D) have been affected by tritium discharges from the State-Approved Land Disposal Site since 1996. Wells 299-W6-7, 299-W6-8, and 299-W6-11 continue to show the effects of the decaying tritium plume originating from the northeast portion of the 200 West Area.

Figure 2.8-50 illustrates the trends in tritium activities in the three State-Approved Land Disposal Site proximal wells. Well 699-48-77A was first affected by discharges in July 1996. Although this well is farthest away from the facility of the three proximal State-Approved Land Disposal Site wells, subsurface geologic features allowed the effluent to reach this well before any others (PNNL-11665; PNNL-13121). This well produced a maximum tritium activity during fiscal year 2001 of 670,000 pCi/L (February 2001), which is more than four times higher than the fiscal year 2000 maximum. The reason for this increase is that significant tritium discharges to the State-Approved Land Disposal Site resumed in September 2000. This resumption followed a hiatus in tritium discharge since April 1999.

The maximum tritium result for well 699-48-77D in fiscal year 2001 was 280,000 pCi/L (November 2000), which is down from a maximum of 420,000 pCi/L in fiscal year 2000. Well 699-48-77D is nearest the State-Approved Land Disposal Site, but showed tritium incursion only as recently as September 1997, ~18 months later than the more distant well 699-48-77A. The reason for this delay is related to the fact that the State-Approved Land Disposal Site drainfield fills from the end of the facility (south end) farthest away from well 699-48-77D and the aforementioned geologic features beneath the State-Approved Land Disposal Site. These two conditions are interpreted to shunt the subsurface flow of effluent away from well 699-48-77D before it reaches groundwater.

Well 699-48-77C is screened ~20 meters deeper in the aquifer than wells 699-48-77A and 699-48-77D. Because of its deeper position, tritium incursions from State-Approved Land Disposal Site operation have been historically lower in concentration and intermittent in this well until recently. During times of high discharge, the hydraulic head beneath the State-Approved Land Disposal Site is increased, and effluent is forced deeper into the aquifer. The historical high tritium concentration of 980,000 pCi/L was measured in well 699-48-77C in February 2001, indicating that the downward-moving State-Approved Land Disposal Site effluent from earlier (prior to April 1999), tritium-rich discharges is still reaching this location in considerable strength. However, the trend shown in Figure 2.8-50, which indicates successively lower concentrations measured in April and July 2001, suggests that the maximum strength of the tritium plume from the early discharges may have reached this well, and concentrations are now declining.

Tritium from the State-Approved Land Disposal Site appears not to have reached wells on the border of the 200 West Area. Concentrations of all constituents remained below permit limits in fiscal year 2001.

A few wells along the border of the 200 West Area, generally southeast of the State-Approved Land Disposal Site, have shown elevated concentrations of tritium as a result of historical disposal practices in the 200 West Area. As shown in Figure 2.8-48, tritium concentrations in these wells have generally decreased or remained the same over the past several years. Well 299-W6-7 experienced a ~50% decline in activity between fiscal year 2000 and fiscal year 2001 measurements for tritium. This rate of decline is much more rapid than the historical rate. Well 299-W7-8 also has shown detectable tritium (as high as 800 pCi/L) prior and subsequent to State-Approved Land Disposal Site operation, but the overall trend in this well for tritium activity is downward.

During fiscal year 2000, results from wells 299-W7-3 and 299-W7-7 were thought to have indicated the first arrival of tritium from the State-Approved Land

Disposal Site in this area (PNNL-13329). Re-analysis of the samples and subsequent sampling shows no conclusive evidence of State-Approved Land Disposal Site effluent in these wells.

In addition to tritium, groundwater from the State-Approved Land Disposal Site proximal wells (699-48-77A, 699-48-77C, and 699-48-77D) are analyzed for a list of 15 constituents required by the State Waste Discharge Permit ST-4500. Enforcement limits were set for most of these constituents (acetone, benzene, total cadmium, chloroform, total copper, total lead, total mercury, pH, sulfate, tetrahydrofuran, total dissolved solids). Gross alpha, gross beta, strontium-90, and tritium are not assigned enforcement limits, but are monitored and reported. Additional parameters, such as alkalinity and dissolved oxygen, were sought for determination of general groundwater characteristics and verifying the quality of analytical results. Maximum concentrations for these constituents, and the corresponding sample months for fiscal year 2001, are listed in Table 1 of PNNL-13689.

Of the 11 constituents with permit limits, all were below the permit enforcement limits for groundwater during fiscal year 2001.[a] As in fiscal year 2000, acetone, benzene, chloroform, and tetrahydrofuran results were below detection limits in all three wells for all of fiscal year 2001.

Fiscal year 2001 maxima for gross alpha and gross beta results in State-Approved Land Disposal Site wells remained within published Hanford Site background (WHC-EP-0595; DOE/RL-96-61) ranges for these two indicators. The highest gross alpha result for fiscal year 2001 of 1.7 pCi/L was recorded from well 699-48-77C in November 2000. Gross beta was highest in well 699-48-77A, with a maximum result of 3.0 pCi/L. These results are lower than maximum results for both indicators in fiscal year 2000.

Strontium-90 is the only radionuclide, other than tritium, that is specifically monitored at the State-Approved Land Disposal Site, and was reported above detection in all three proximal wells during fiscal year 2001, but its concentration decreased from fiscal year 2000. Historically, results for strontium-90 have been subject to high counting errors. During fiscal year 2001, several split samples from State-Approved Land Disposal Site wells were analyzed for this radionuclide independently from the routine analytical laboratory. All of the results from these independent analyses were below detection. Thus, it seems unlikely that strontium-90 is actually present in detectable levels in groundwater beneath the State-Approved Land Disposal Site.

Coincident with the first detection of elevated tritium in late 1996, concentrations of sulfate and a few other parameters were also found to have increased in groundwater from well 699-48-77A. These occurrences were interpreted to be a result of the dilute (clean water) effluent from State-Approved Land Disposal Site dissolving soluble mineral species (such as gypsum) in the vadose zone during infiltration (PNNL-11633; PNNL-11665). More recently, wells 699-48-77C and 699-48-77D have shown similar incursions of these constituents. Figure 2.8-51 shows the trend for sulfate in the proximal wells and in well 299-W8-1 for comparison. Other species, such as calcium, chloride, and sodium, and indicators conductivity and total dissolved solids, show a more subdued response during the same time period. The trends are most pronounced in wells 699-48-77A and 699-48-77D because these wells are screened at the water table. The six parameters have a downward trend for the past 3 years in wells 699-48-77A and 699-48-77D, and are now below initial background concentrations in these two wells. Well 699-48-77C is screened ~20 meters below the water table, so the effects of State-Approved Land Disposal Site discharges in this well are retarded with respect to the two shallow wells.

(a) Period reported is October 1, 2000 through August 31, 2001.

Based on the latest arrival of elevated tritium in well 699-48-77A (between November 2000 and February 2001) and the timing of resumed tritium discharges to the State-Approved Land Disposal Site (September 2000), travel time from the facility to the well is estimated from 74 to 129 days. Actual travel time to groundwater from the facility will be less than the maximum of this range, because the effluent is thought to enter groundwater somewhere between the State-Approved Land Disposal Site and the well (PNNL-13121).

Table 2.8-1. Volume of Groundwater Treated and Mass of Carbon Tetrachloride Removed Since Startup of Operations at the 200-ZP-1 Operable Unit

Reporting Period	Liters Treated	Mass of Carbon Tetrachloride Removed (kg)
August 1994 - July 1996	26,676,000	75.85
August 1996 - September 1996	33,232,327	60.96
October 1996 - December 1996	44,583,715	143.54
January 1997 - March 1997	69,869,604	237.2
April 1997 - June 1997	41,877,094	140.8
July 1997 - September 1997	62,469,305	228.8
October 1997 - December 1997	81,629,000	245.7
January 1998 - March 1998	72,791,000	279.5
April 1998 - June 1998	90,842,900	348.9
July 1998 - September 1998	90,899,200	338.1
October 1998 - December 1998	83,552,570	315.57
January 1999 - March 1999	77,079,156	310.2
April 1999 - June 1999	90,657,196	337.8
July 1999 - September 1999	88,657,486	323.7
October 1999 - December 1999	53,073,724	201.8
January 2000 - March 2000	90,498,074	370.0
April 2000 - June 2000	74,312,707	307.8
July 2000 - September 2000	82,096,586	303.7
October 2000 - December 2000	94,110,990	336.8
January 2001 - March 2001	85,367,099	330.5
April 2001 - June 2001	84,283,176	297.1
July 2001 - September 2001	75,085,163	261.9
Total	1,593,644,072	5,796.2

Table 2.8-2. Average Carbon Tetrachloride Concentrations for Each of the Extraction Wells and the Influent Tank at the 200-ZP-1 Operable Unit, Fiscal Year 2001

Well Name[(a)]	FY 2001 Min. Value (μg/L)	FY 2001 Max. Value (μg/L)	FY 1997 Mean Concentration (μg/L)	FY 1998 Mean Concentration (μg/L)	FY 1999 Mean Concentration (μg/L)	FY 2000 Mean Concentration (μg/L)	FY 2001 Mean Concentration (μg/L)	Mean Flow Rate (L/min)
299-W15-33	1,900	6,400	5,058	6,000	6,218	5,956	4,865	55
299-W15-34	3,200	6,200	2,900	3,770	4,700	5,517	5,355	93
299-W15-35	2,200	4,000	3,351	3,660	3,858	3,842	3,413	307
299-W15-32	1,600	4,100	7,120	6,560	5,023	4,224	3,255	40
299-W15-36	700	1,800	2,820	2,040	1,697	1,779	1,377	131
299-W15-37	340	540	280	235	358	556	464	63
Influent Tank (T-01)	2,800	4,300	3,270	3,530	3,788	4,041	3,600	--

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(a) Wells listed from north to south.

Table 2.8-3. Quantity of Treated Groundwater and Contaminant Mass Removed Since Initiation of 200-UP-1 Pump-and-Treat Operations

Reporting Period	Liters Treated	Mass Technetium-99 Removed (g)	Mass Total Uranium Removed (g)	Mass Carbon Tetrachloride Removed (g)	Mass Nitrate Removed (kg)
March 1994 - November 1994[(a)]	3,898,550	3.41	4,422	Not reported	NA
December 1994 - August 1995	11,391,491	7.79	9,831	992	NA
September 1995 - November 1995	17,198,571	3.95	3,895	630	NA
December 1995 - March 1996	31,311,340	9.05	9,105	1,609	NA
April 1996 - June 1996	22,459,108	5.40	6,845	1,569	NA
July 1996 - September 1996	22,370,327	4.01	5,134	2,790	NA
October 1996 - December 1996	20,300,000	3.33	5,607	2,980	NA
January 1997 - February 1997[(b)]	2,667,600	0.83	963	73	NA
February - March 30, 1997	Shut down	NA	NA	NA	NA
March 31 - September 30, 1997	32,414,481	5.6	11,000	888	2,260
October 1 - December 31, 1997	20,390,054	3.31	6,300	572	1,530
January 1 - March 31, 1998	19,791,765	2.08	4,900	460	1,070
April 1 - June 30, 1998	33,538,750	3.58	8,680	907	2,150
July 1 - September 30, 1998	26,346,466	1.57	3,750	296	900
October 1 - December 31, 1998	22,174,396	1.49	4,910	341	979
January 1 - March 31, 1999	23,720,542	1.89	4,450	601	1,050
April 1 - June 30, 1999	24,369,400	2.29	5,400	600	1,400
July 1 - September 30, 1999	23,206,922	2.14	5,940	460	1,430
October 1 - December 31, 1999	14,858,190	1.25	3,080	286	681
January 1 - March 31, 2000	14,636,480	1.29	3,100	352	645
April 1 - June 30, 2000	18,295,080	1.63	4,050	527	806
July 1 - September 30, 2000	15,439,630	1.45	3,410	494	675
October 1 - December 31, 2000	35,538,203	2.93	6,475	781	1,371
January 1 - March 31, 2001	17,352,328	1.41	3,332	434	631
April 1 - June 30, 2001	24,300,159	2.01	3,798	833	955
July 1 - September 30, 2001	25,284,628	2.02	3,523	696	967
Total	523,254,461	75.71	131,900	20,171	19,500

(a) Data from the treatability test as reported in DOE/RL-95-02.

(b) Estimated values based on 189 L/min flow, running 24 hours/day, at 97.5% efficiency.

NA = Not applicable.

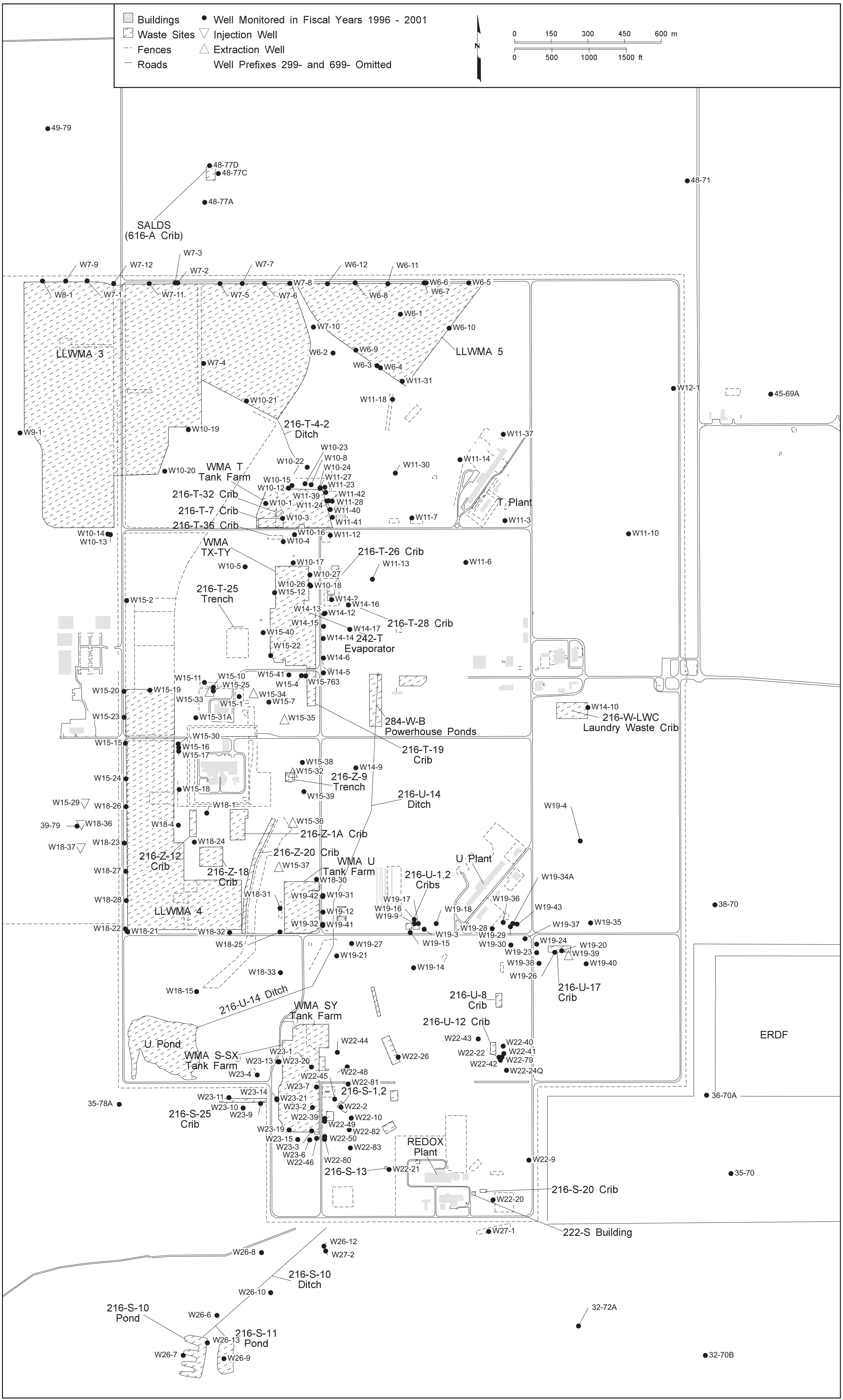

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Figure 2.8-1. Groundwater Monitoring Wells in the 200 West Area

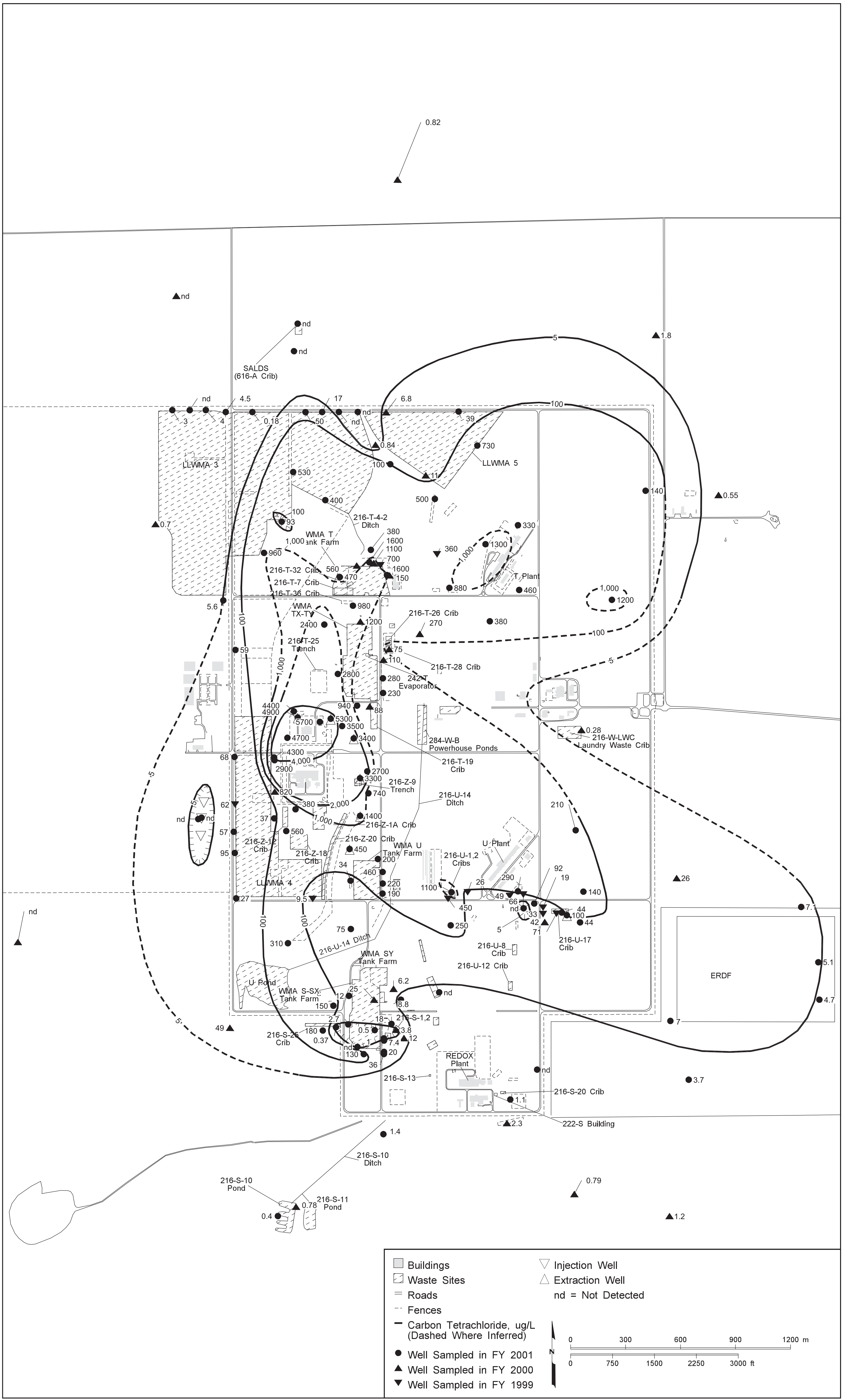

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Figure 2.8-2. Average Carbon Tetrachloride Concentrations in 200 West Area, Top of Unconfined Aquifer

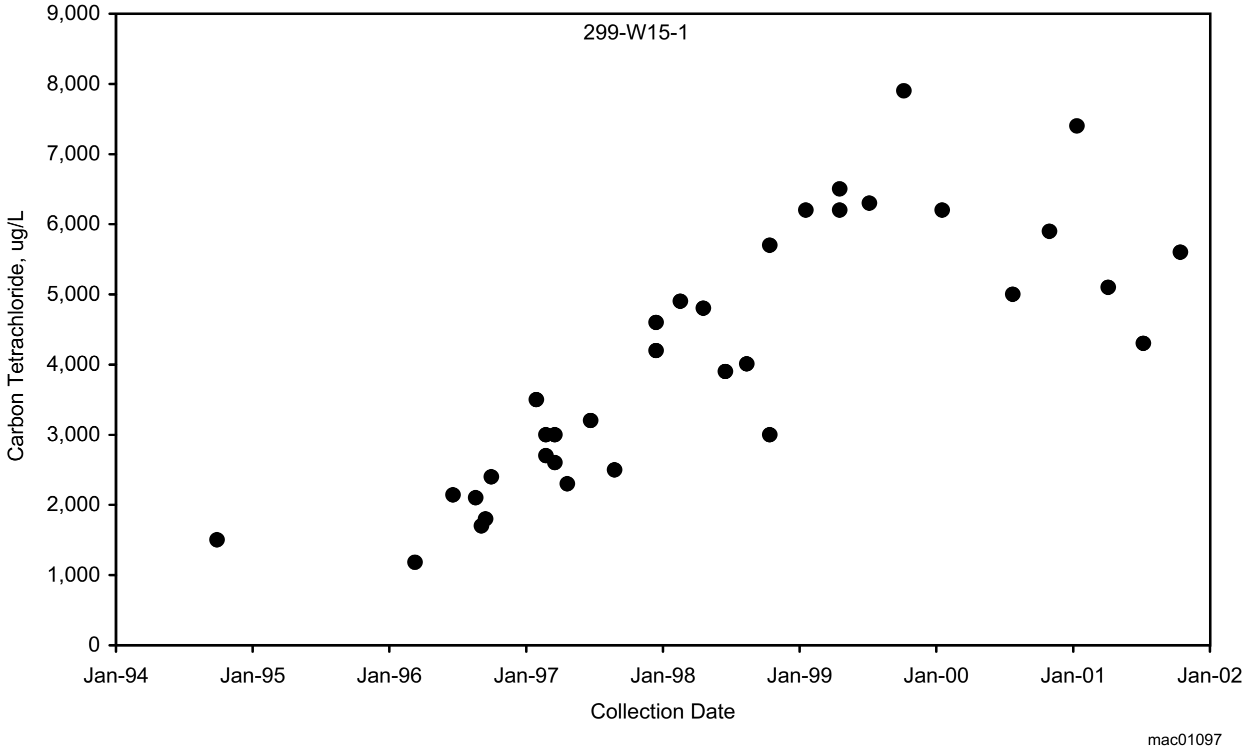

Figure 2.8-3. Carbon Tetrachloride Concentrations Near the Northern Extraction Wells

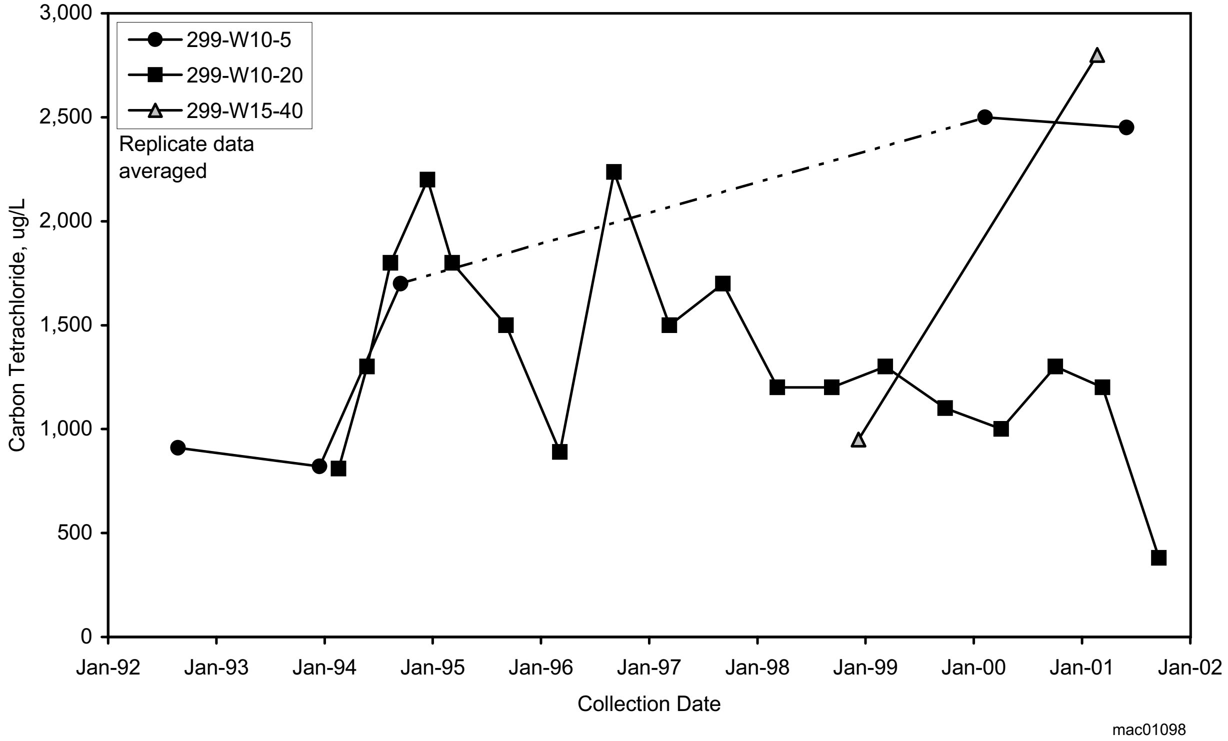

Figure 2.8-4. Carbon Tetrachloride Concentrations in the Northwestern 200 West Area

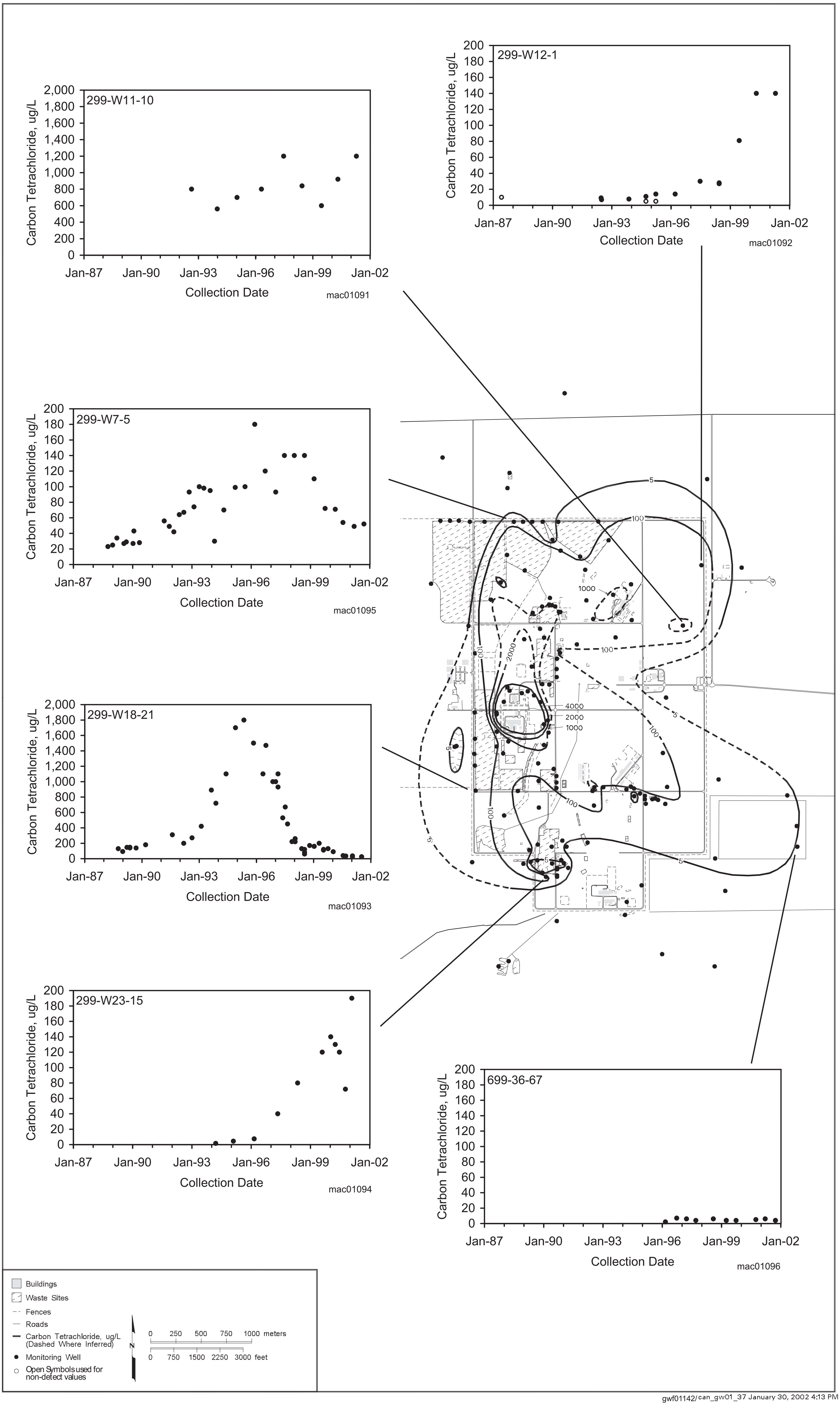

Figure 2.8-5. Carbon Tetrachloride Concentrations in Wells Monitoring 200 West Area, Top of Unconfined Aquifer

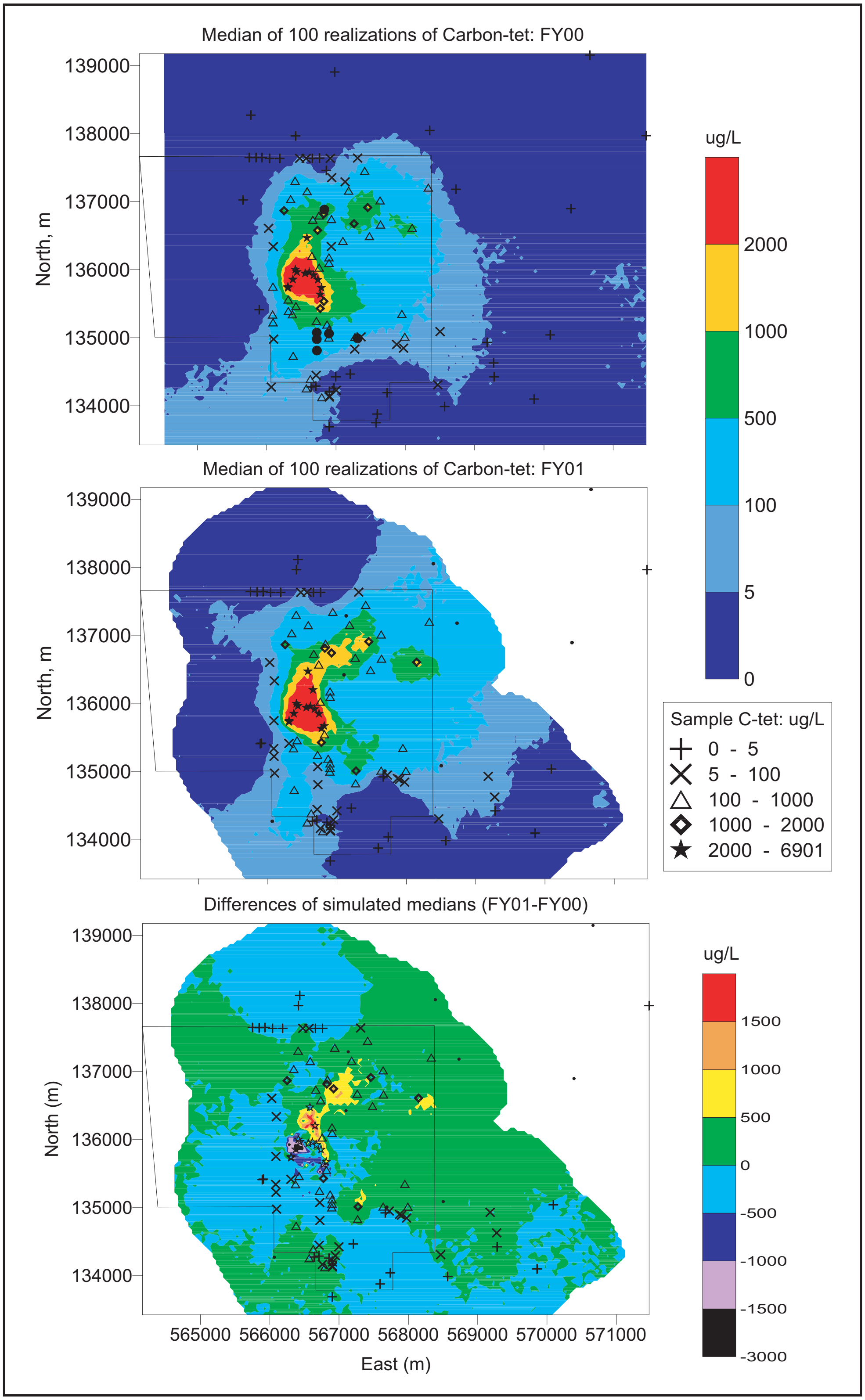

Figure 2.8-6. Geostatistical Comparison of Fiscal Year 2000 to Fiscal Year 2001 Carbon Tetrachloride Plume Showing Areas of Changing Concentrations

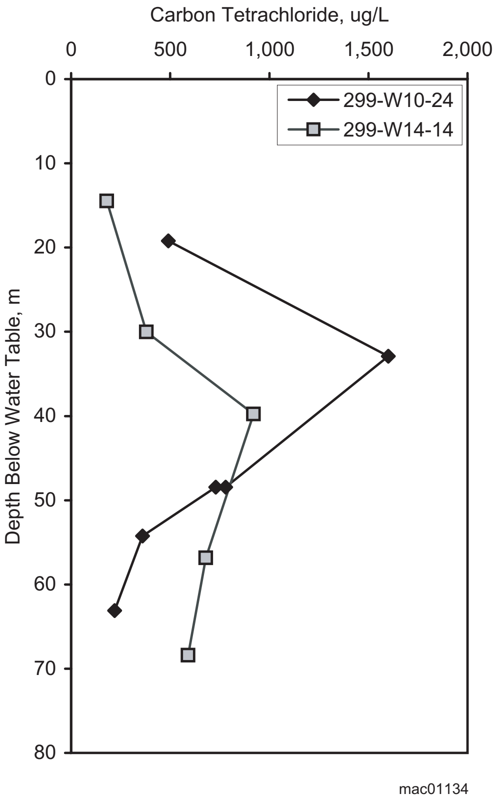

Figure 2.8-7. Depth Distribution of Carbon Tetrachloride Observed During the Drilling at Wells in the Northeastern 200 West Area

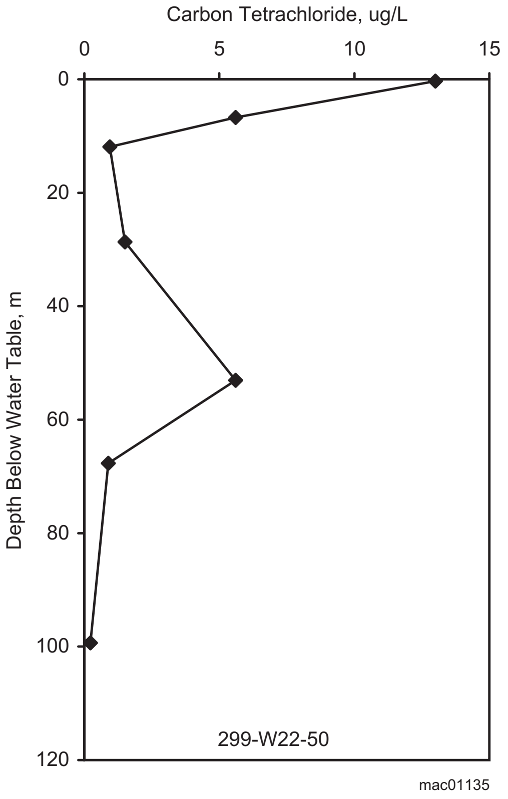

Figure 2.8-8. Depth Distribution of Carbon Tetrachloride Observed During the Drilling in the Southern 200 West Area

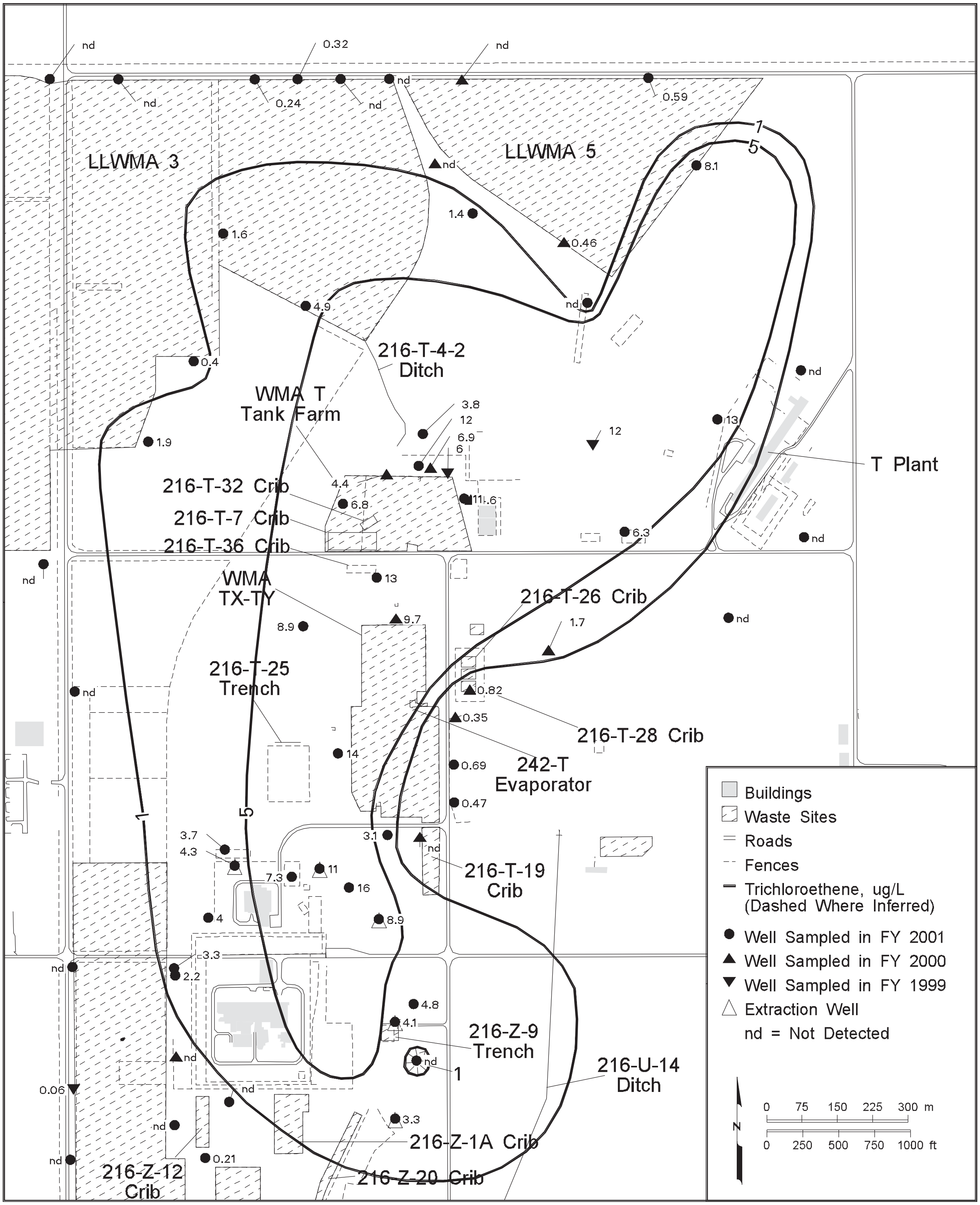

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Figure 2.8-9. Average Trichloroethene Concentrations in Central and Northern 200 West Area, Top of Unconfined Aquifer

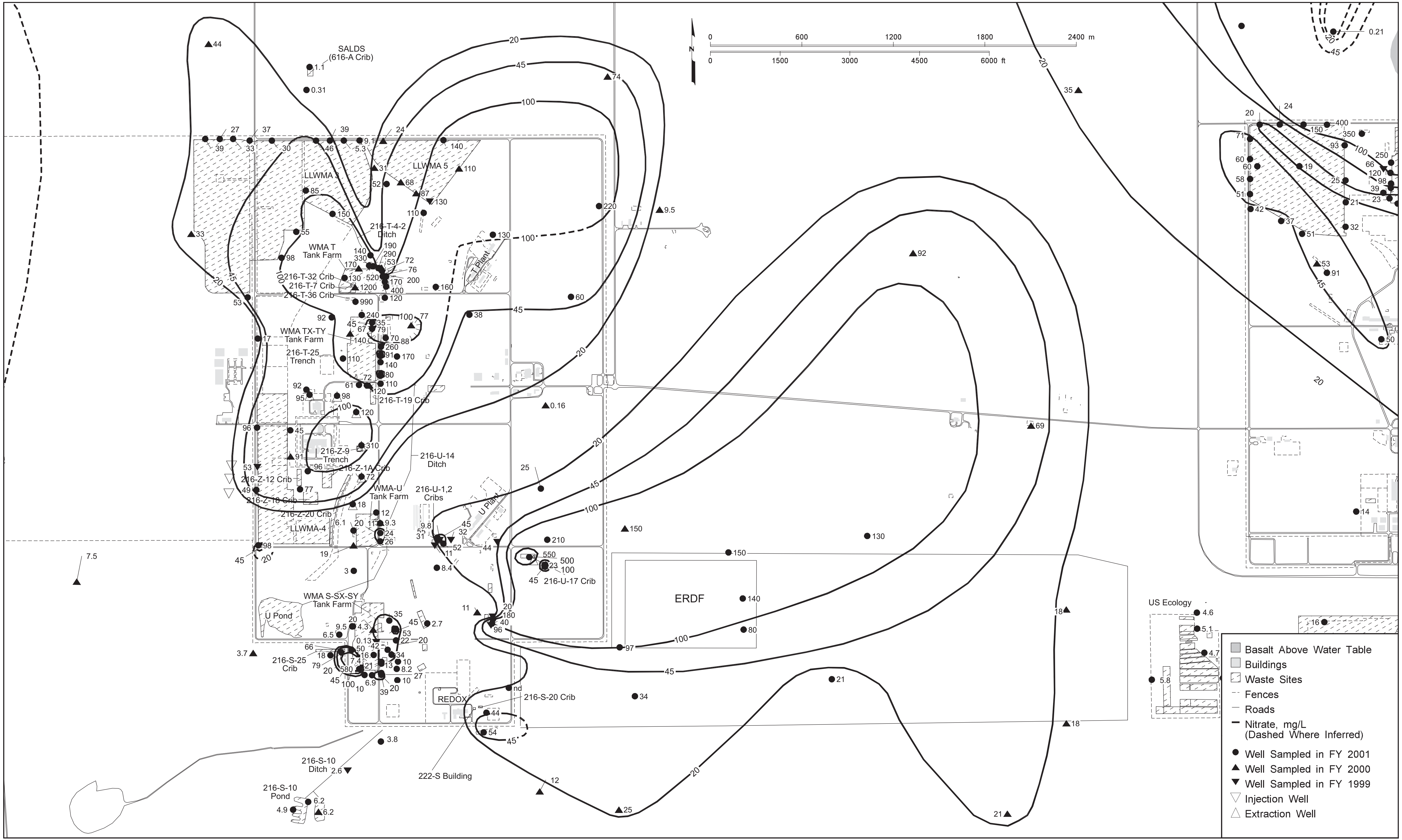

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Figure 2.8-10. Average Nitrate Concentrations in the 200 West Area, Top of Unconfined Aquifer

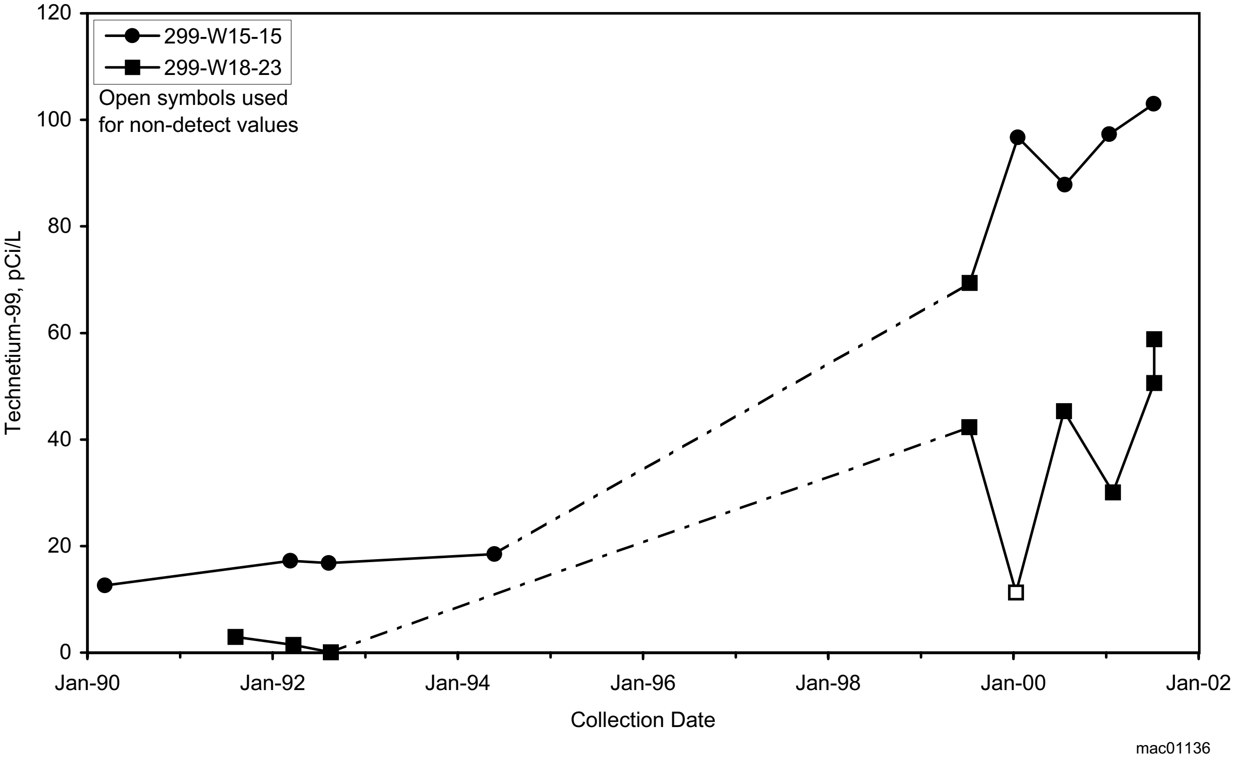

Figure 2.8-11. Technetium-99 Concentrations in Wells West of Low-Level Waste Management Area 4

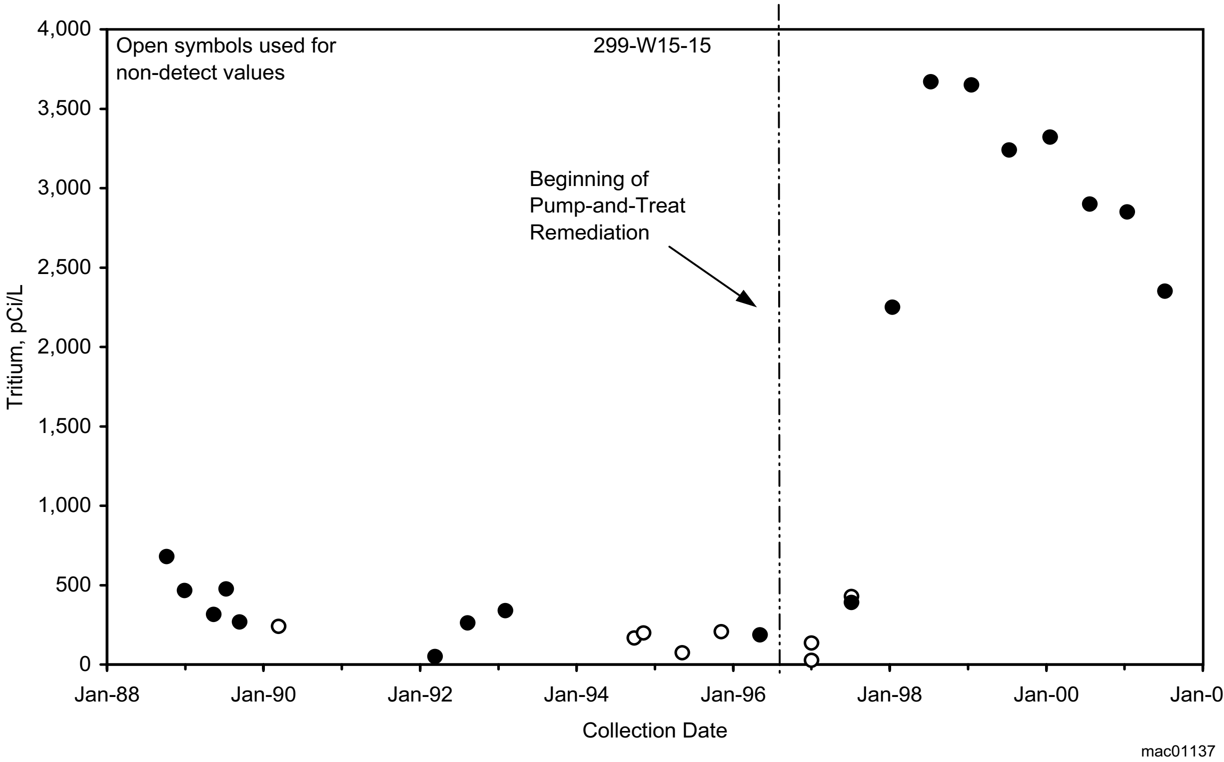

Figure 2.8-12. Tritium Concentrations West of Low-Level Waste Management Area 4

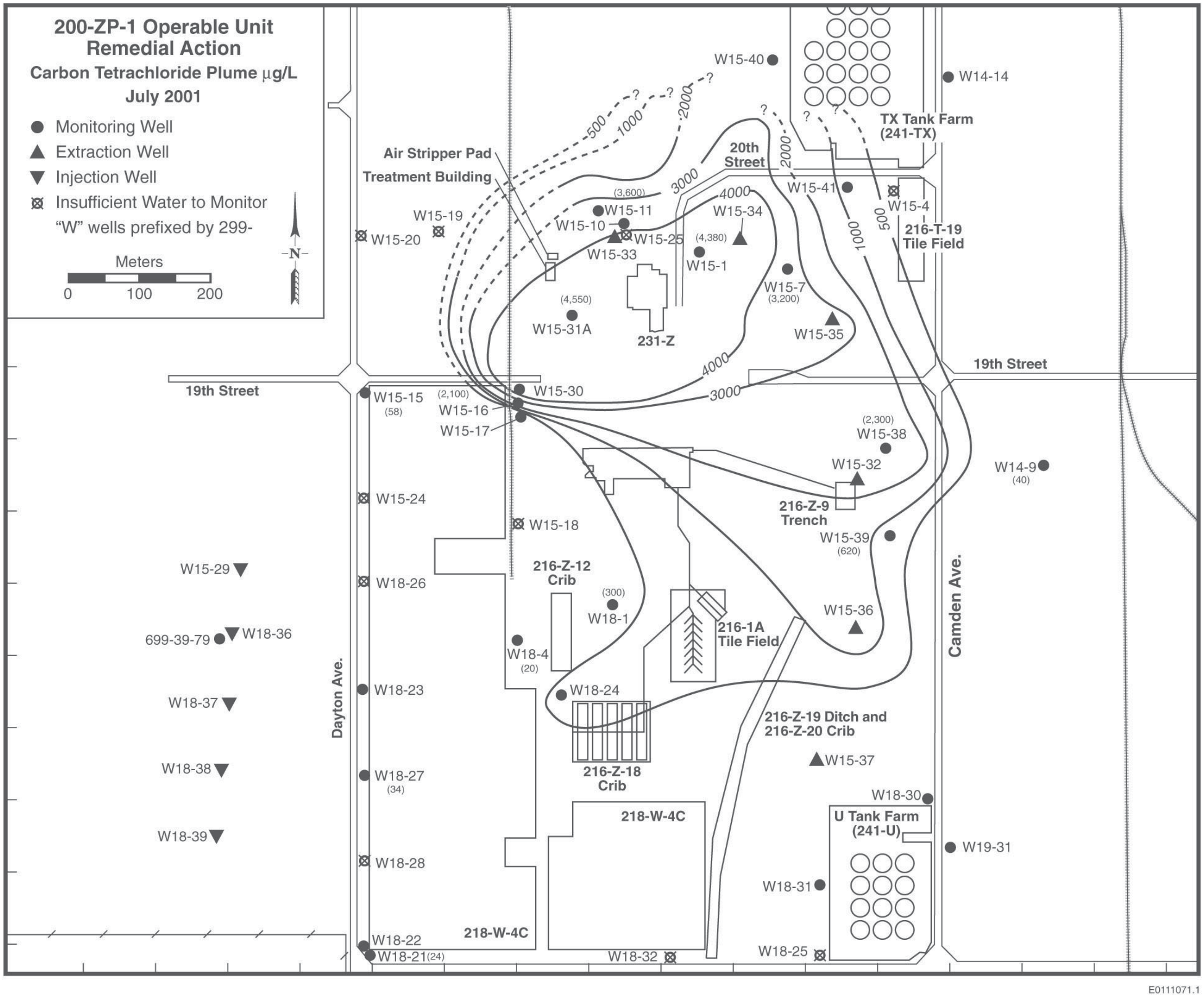

Figure 2.8-13. Carbon Tetrachloride Plume, Top of Unconfined Aquifer, at the 200-ZP-1 Operable Unit Remediation Area, July 2001 (DOE/RL-2000-71)

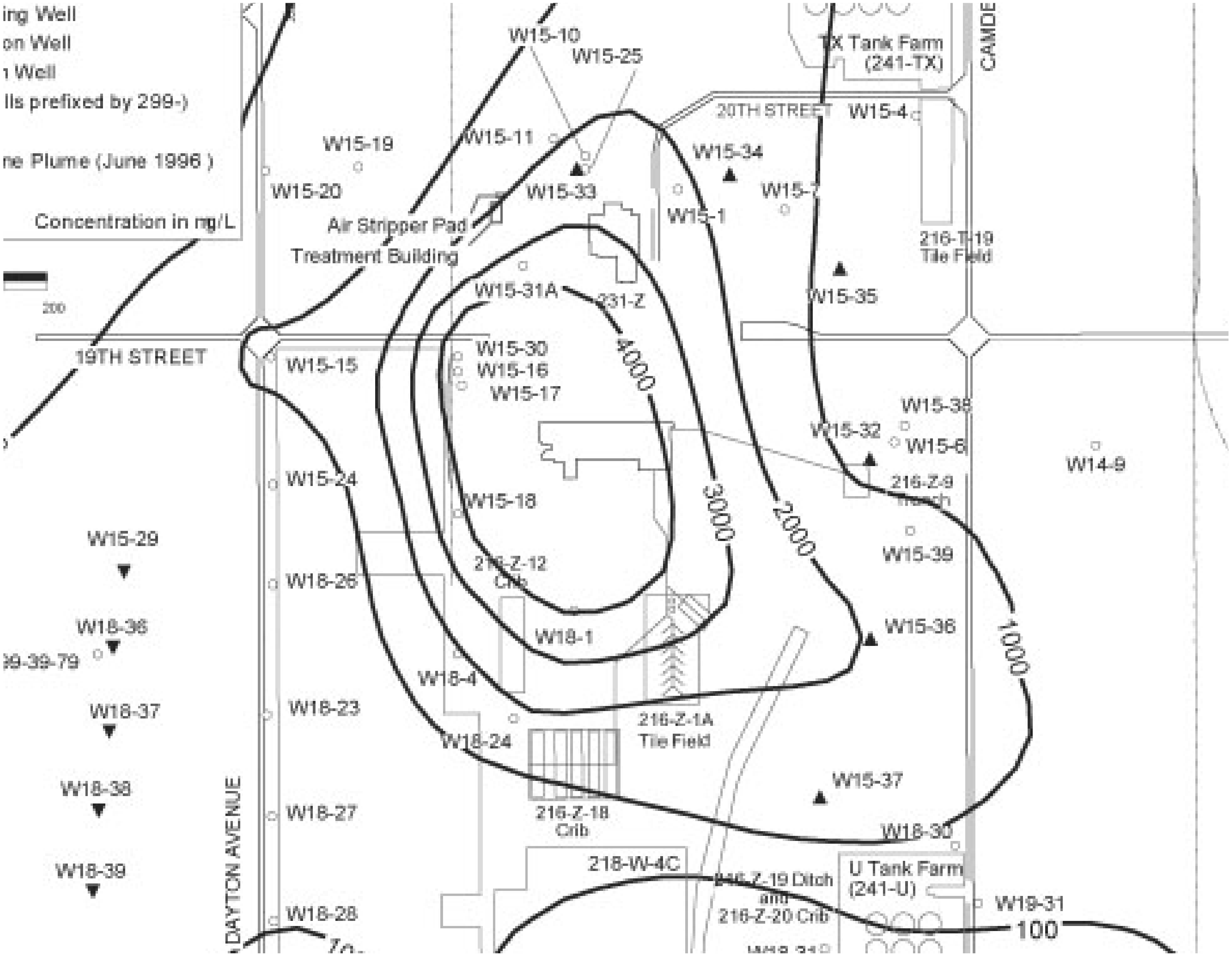

Figure 2.8-14. Carbon Tetrachloride Plume at the 200-ZP-1 Operable Unit Remediation Area, June 1996 (DOE/RL-2000-71)

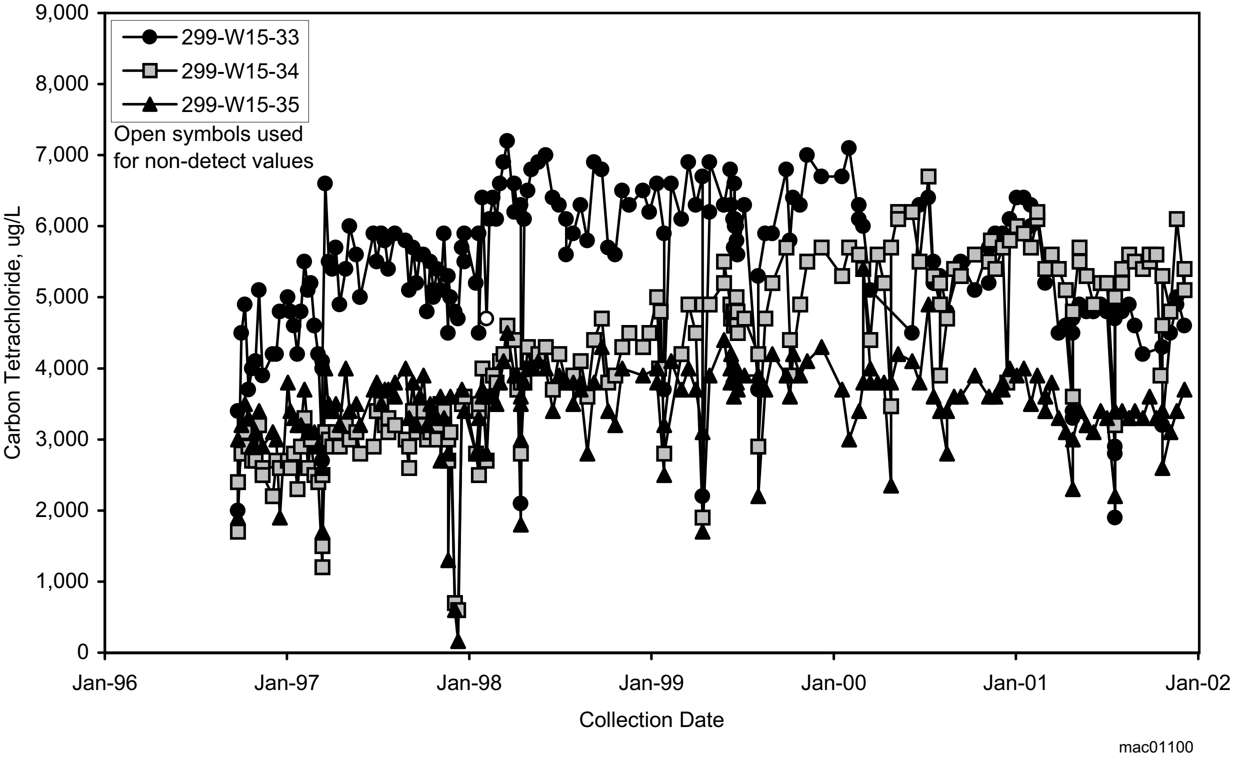

Figure 2.8-15. Carbon Tetrachloride Concentrations in Northern Extraction Wells for the 200-ZP-1 Pump-and-Treat System

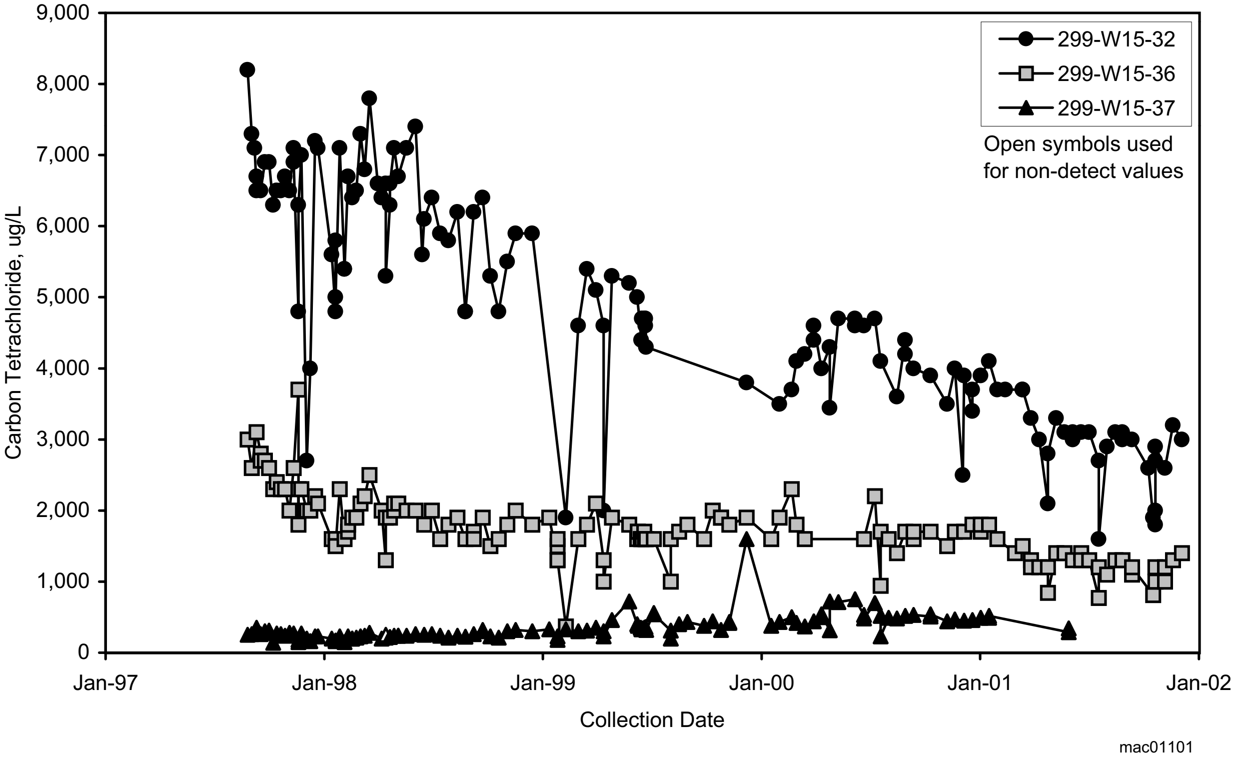

Figure 2.8-16. Carbon Tetrachloride Concentrations in Southern Extraction Wells for the 200-ZP-1 Pump-and-Treat System

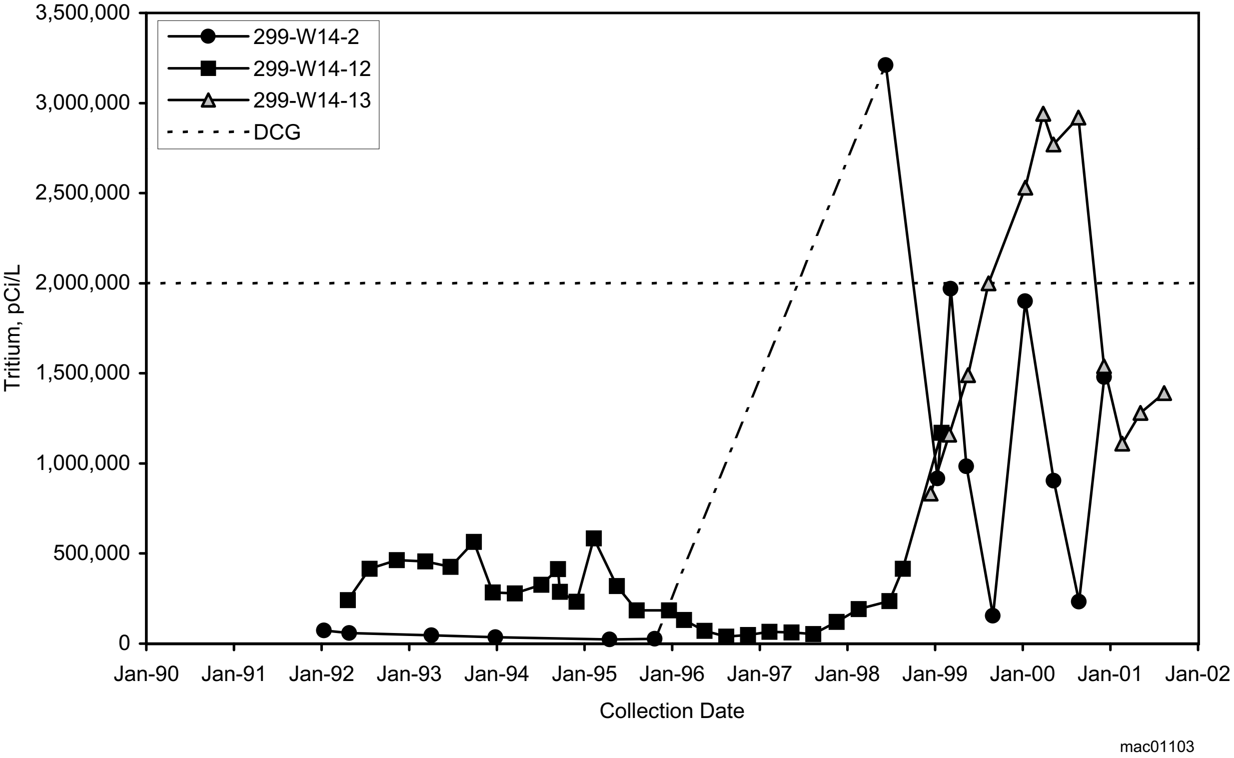

Figure 2.8-17. Tritium Concentrations in Wells East of TY Tank Farm

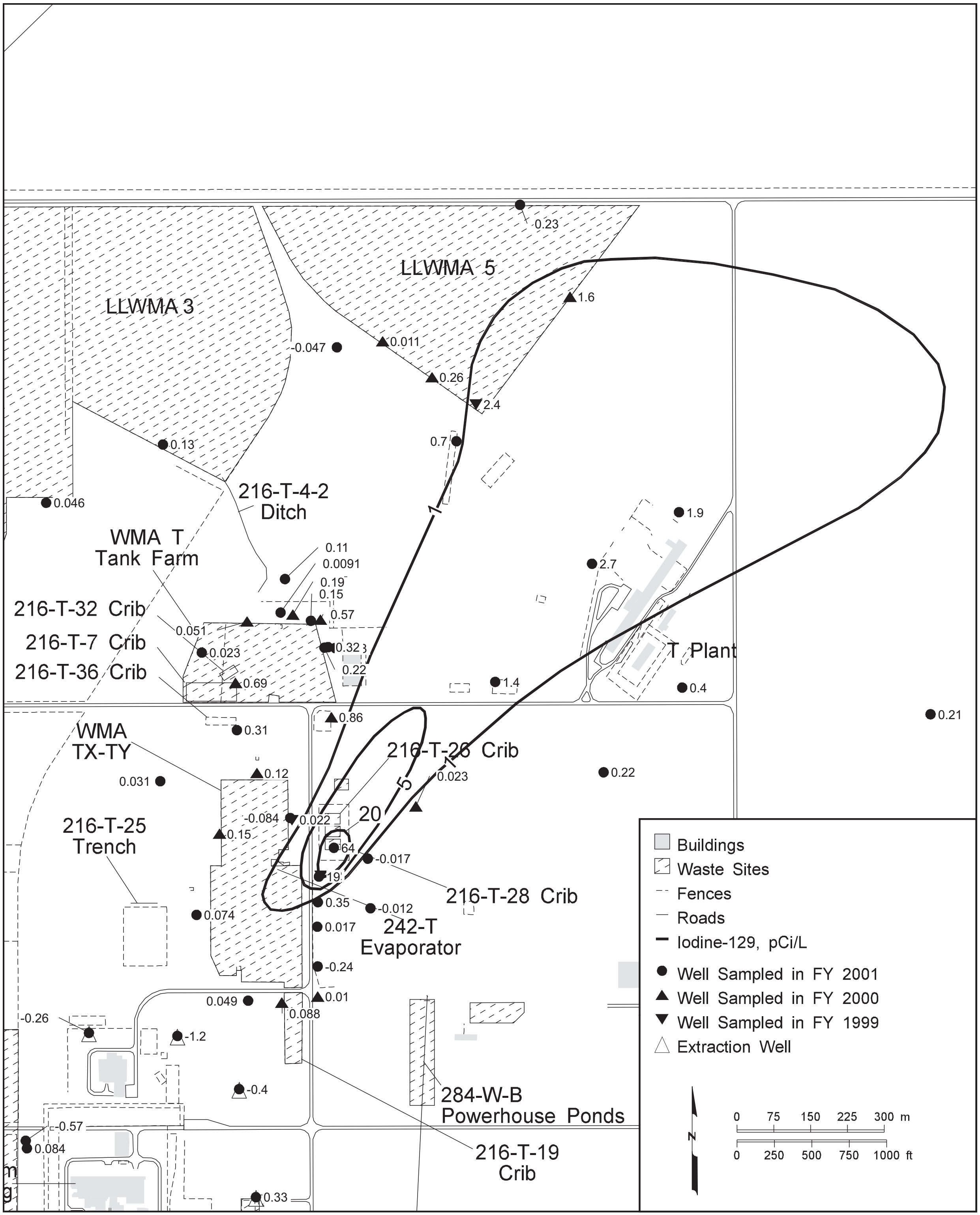

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Figure 2.8-18. Average Iodine-129 Concentrations in the Northern 200 West Area, Top of Unconfined Aquifer

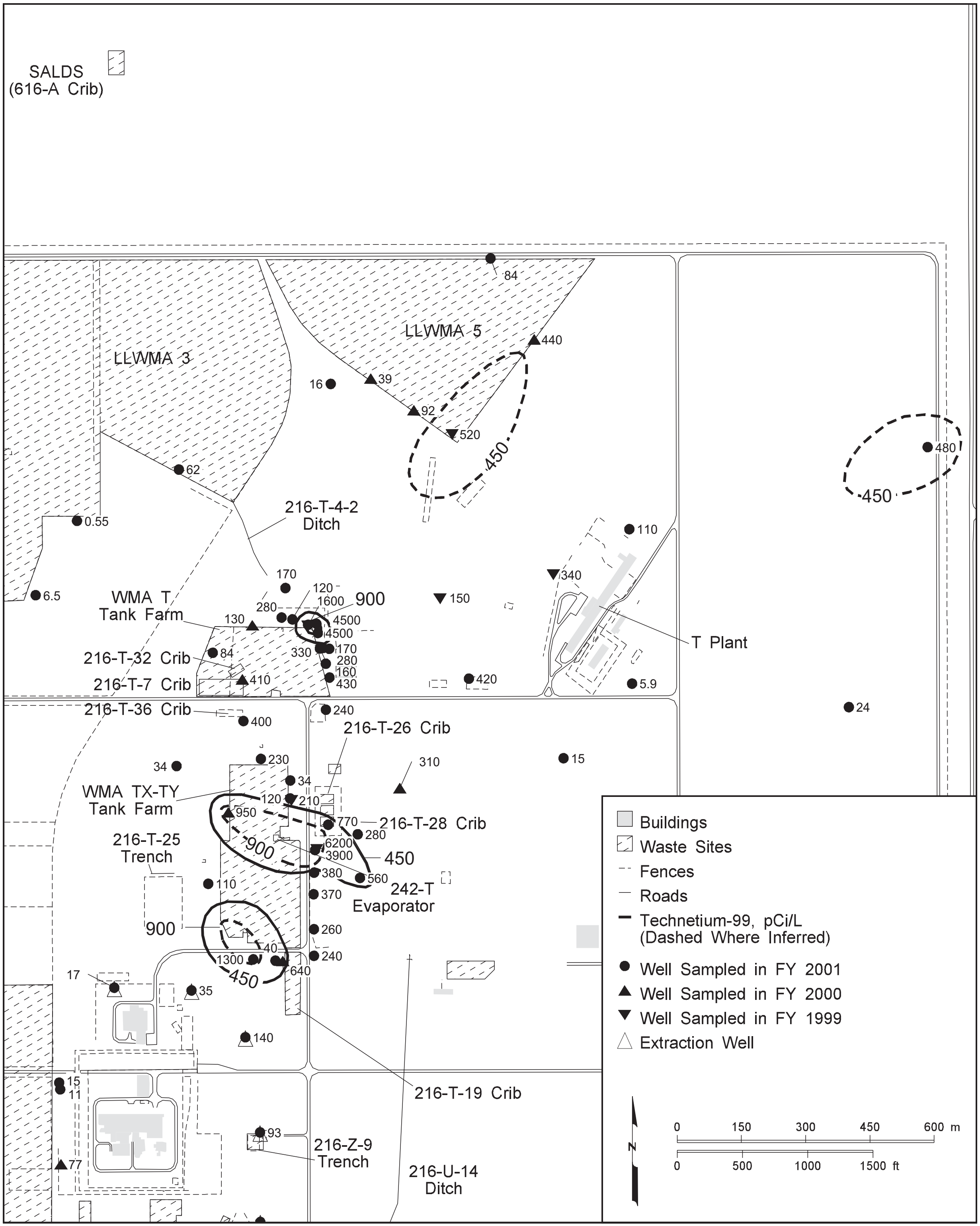

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Figure 2.8-19. Average Technetium-99 Concentrations in the Northern 200 West Area, Top of Unconfined Aquifer

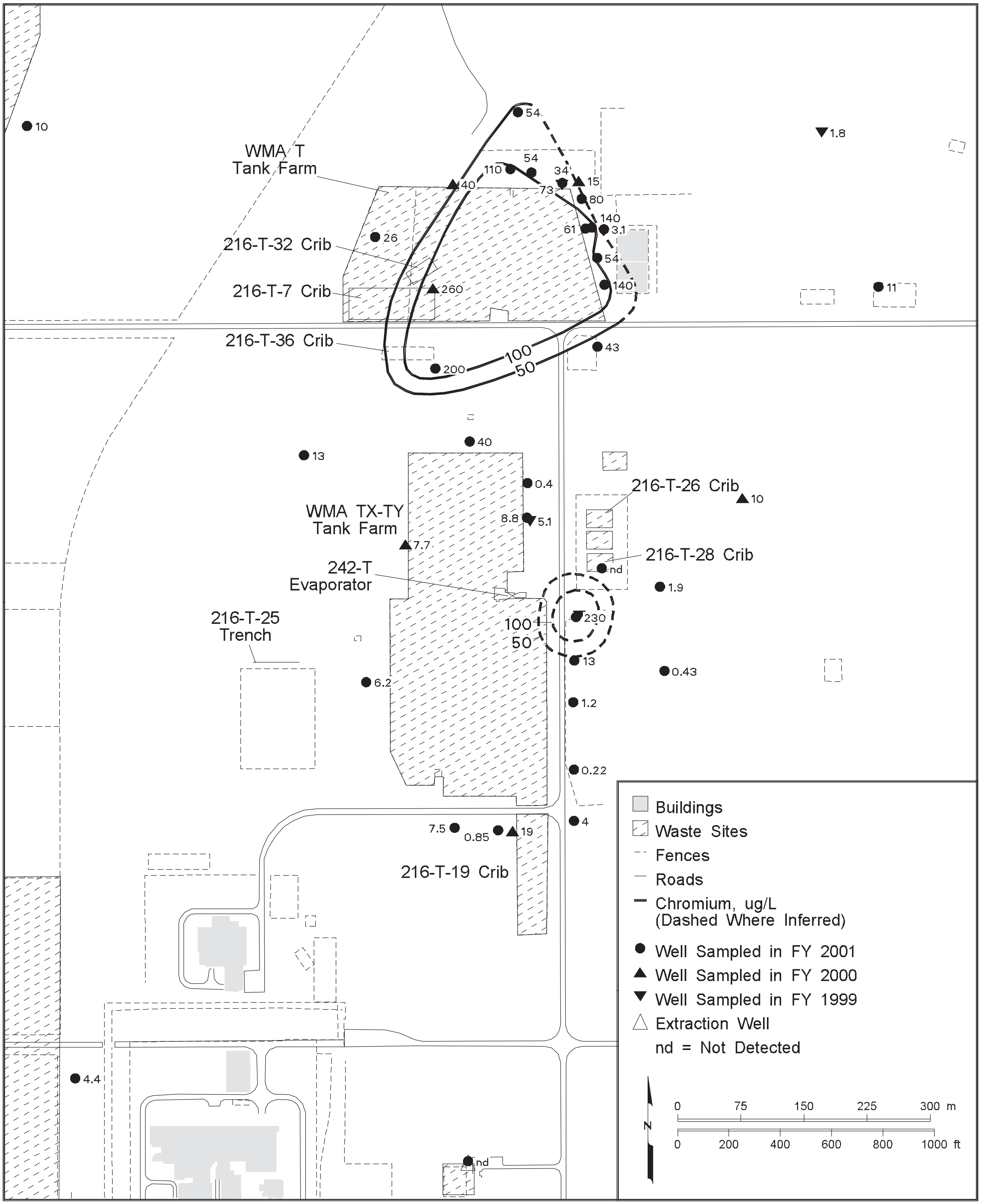

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Figure 2.8-20. Average Dissolved Chromium Concentrations Near Waste Management Areas T and TX-TY, Top of Unconfined Aquifer

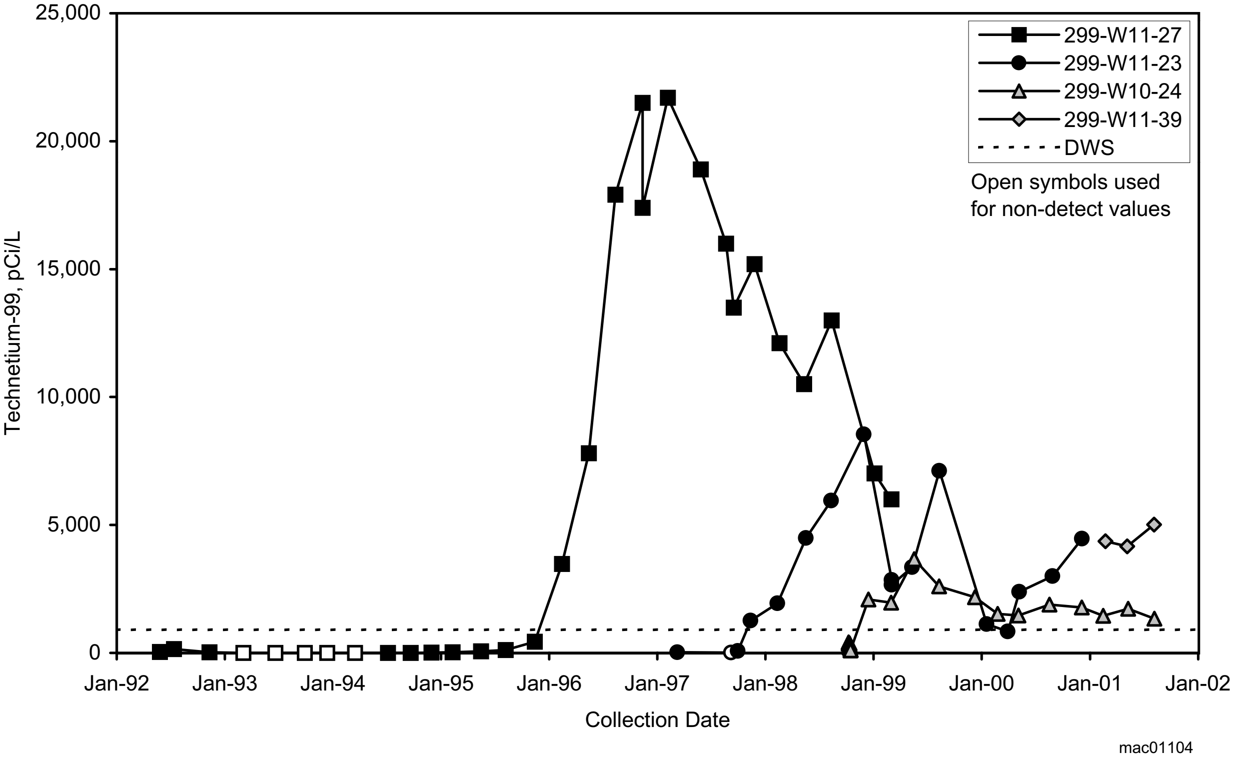

Figure 2.8-21. Technetium-99 Concentrations in Wells North of T Tank Farm

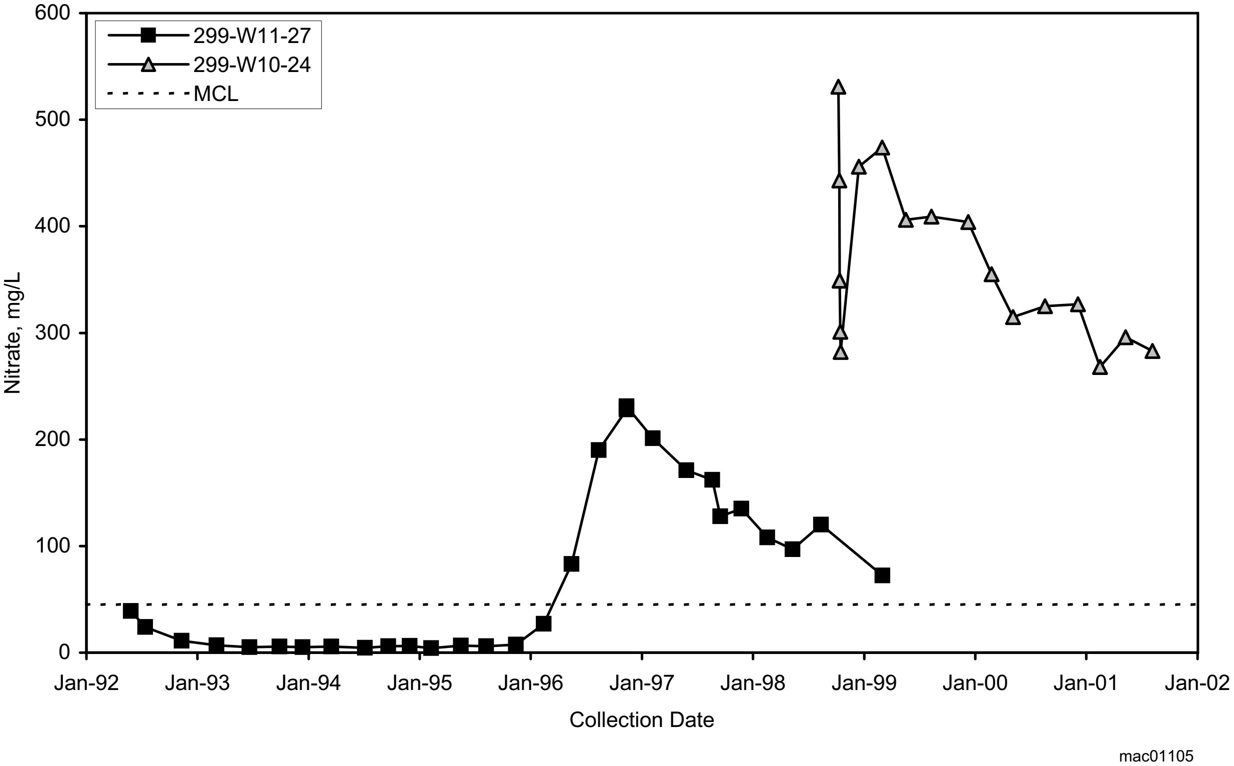

Figure 2.8-22. Nitrate Concentrations in Wells North of T Tank Farm

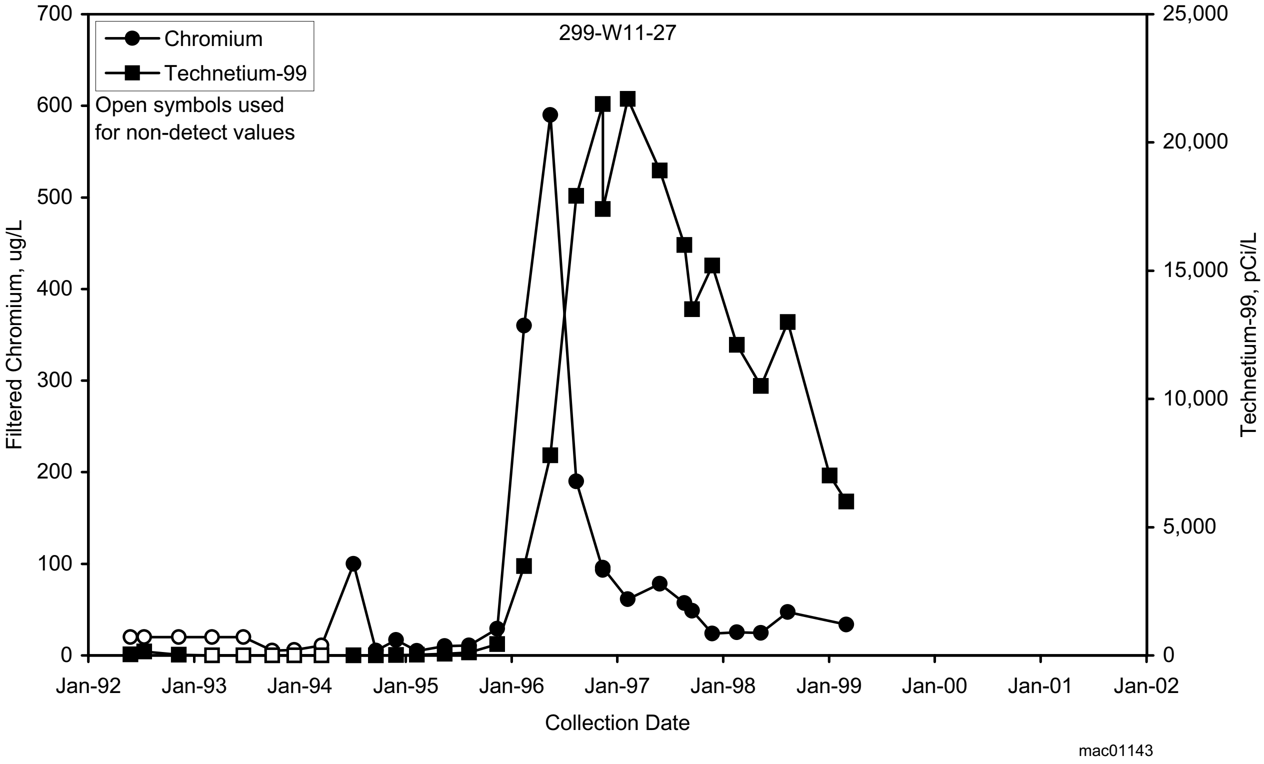

Figure 2.8-23. Technetium-99 and Chromium Concentrations Northeast of Waste Management Area T

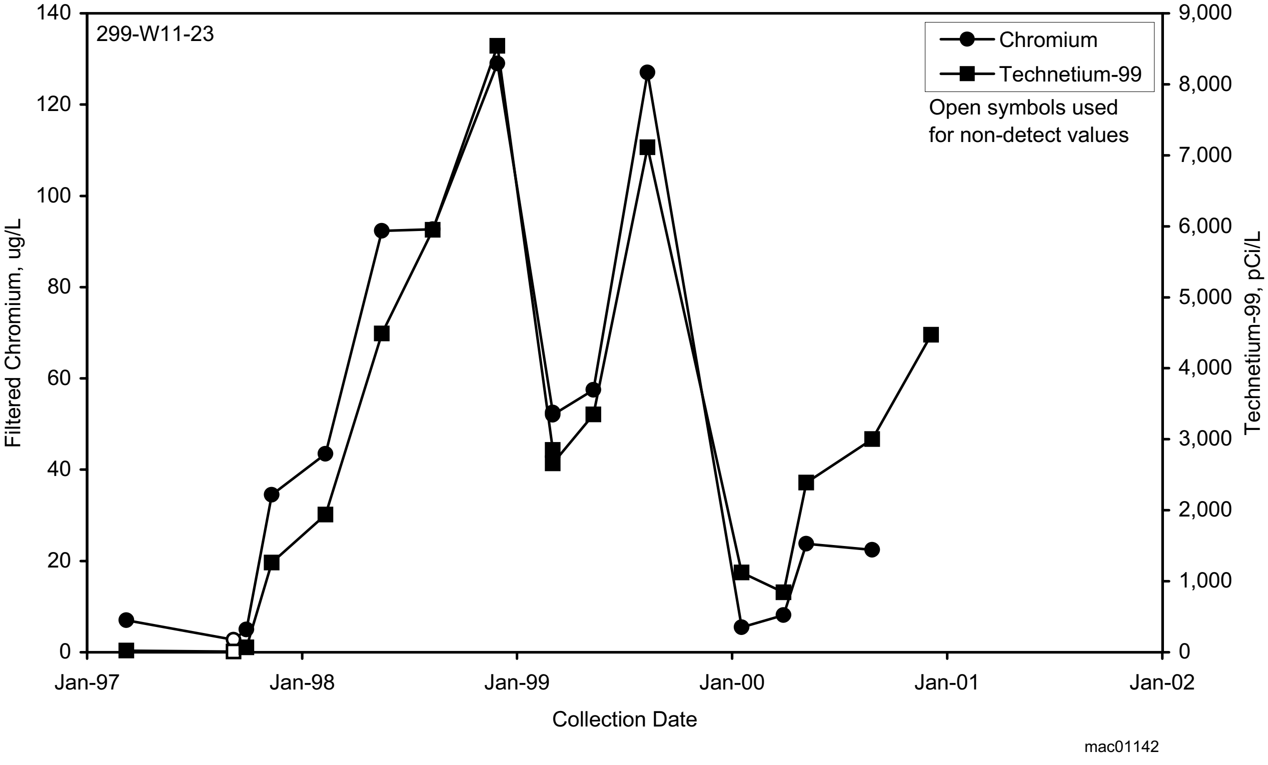

Figure 2.8-24. Technetium-99 and Chromium Concentrations Northeast of Waste Management Area T

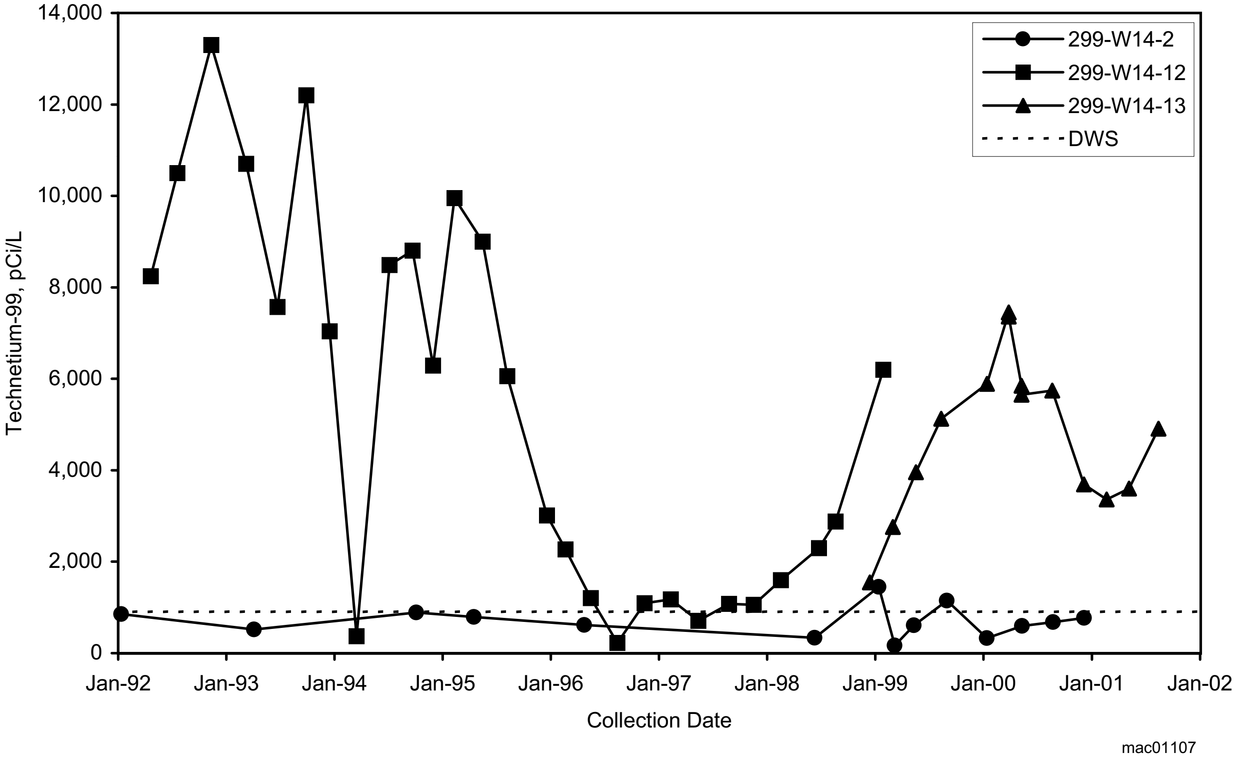

Figure 2.8-25. Technetium-99 Concentrations in Wells East of TX-TY Tank Farms

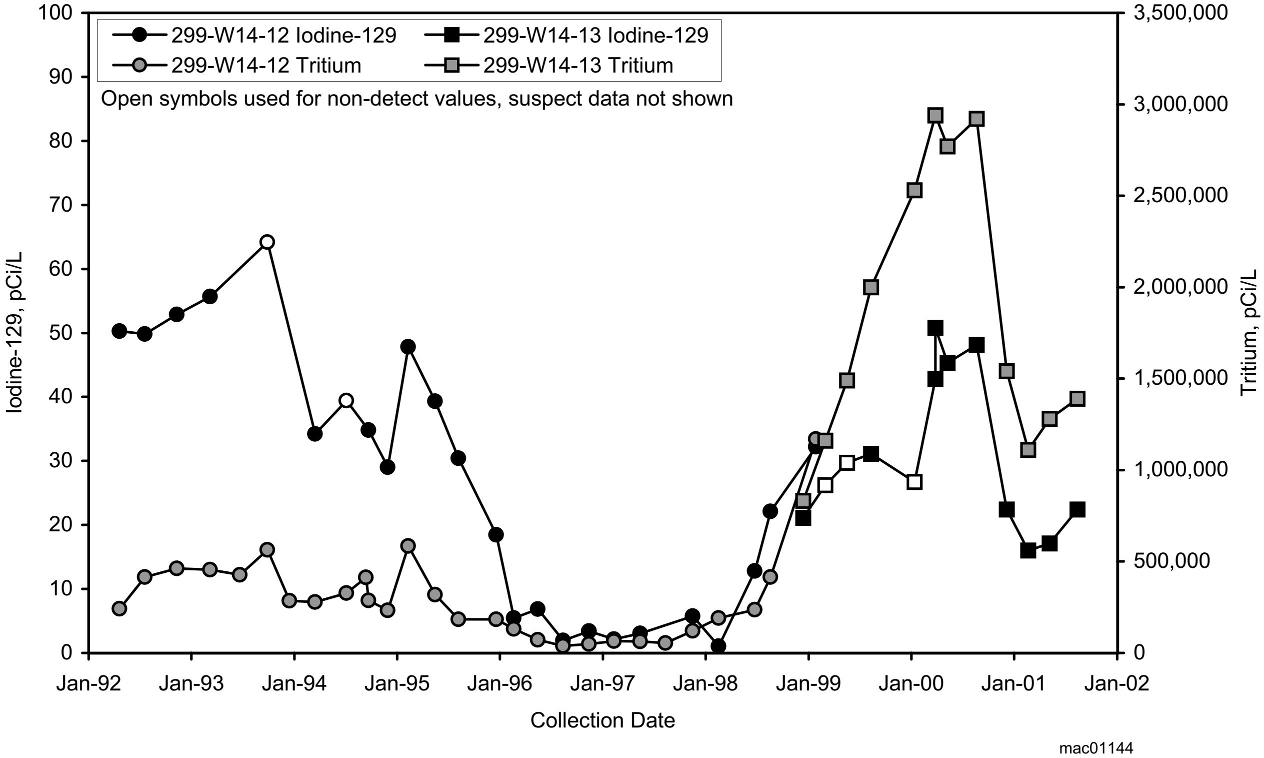

Figure 2.8-26. Tritium and Iodine-129 Concentrations in Wells East of Waste Management Area TX-TY

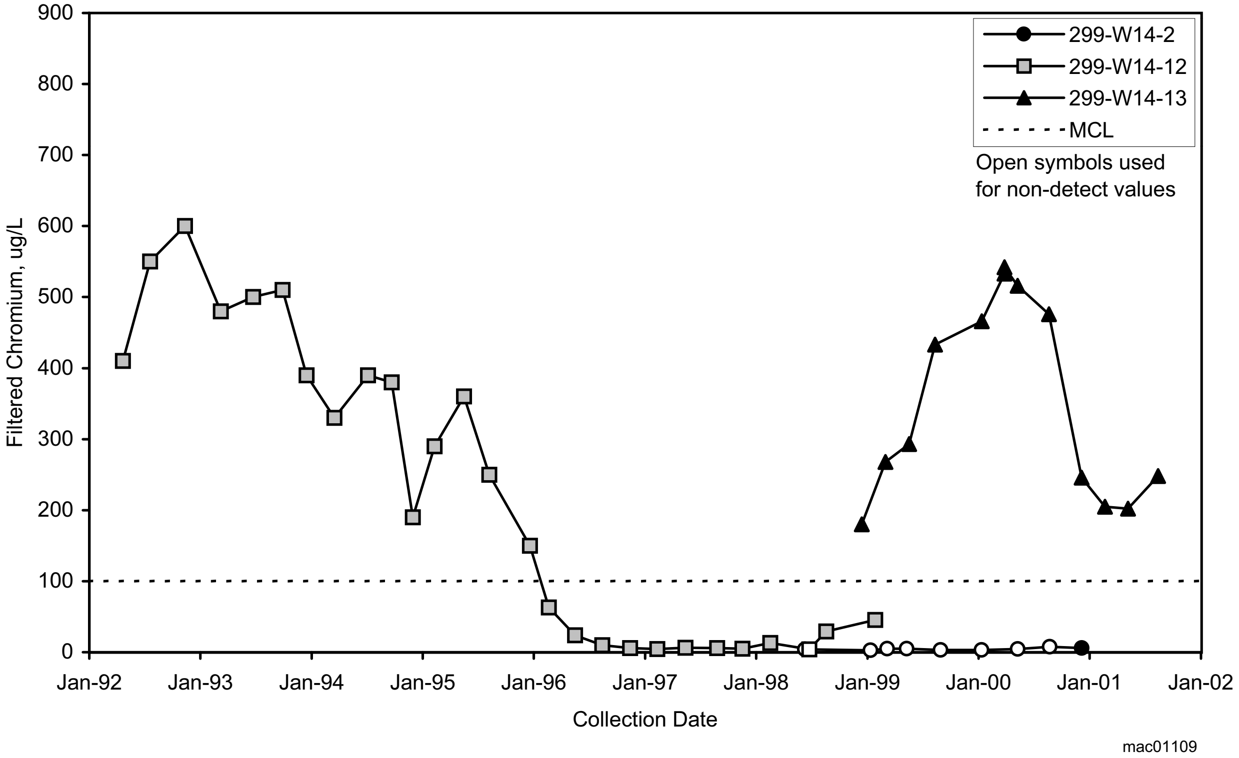

Figure 2.8-27. Chromium Concentrations in Wells East of Waste Management Area TX-TY

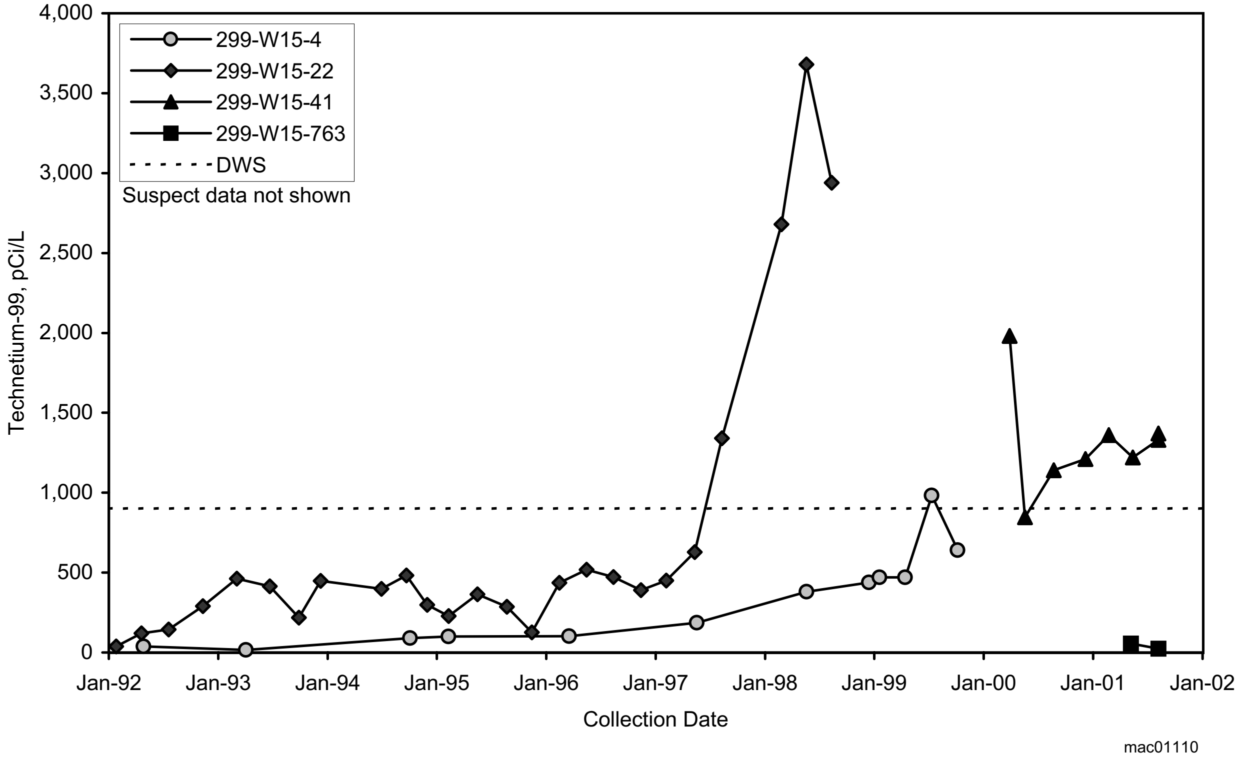

Figure 2.8-28. Technetium-99 Concentrations in Wells South of Waste Management Area TX-TY

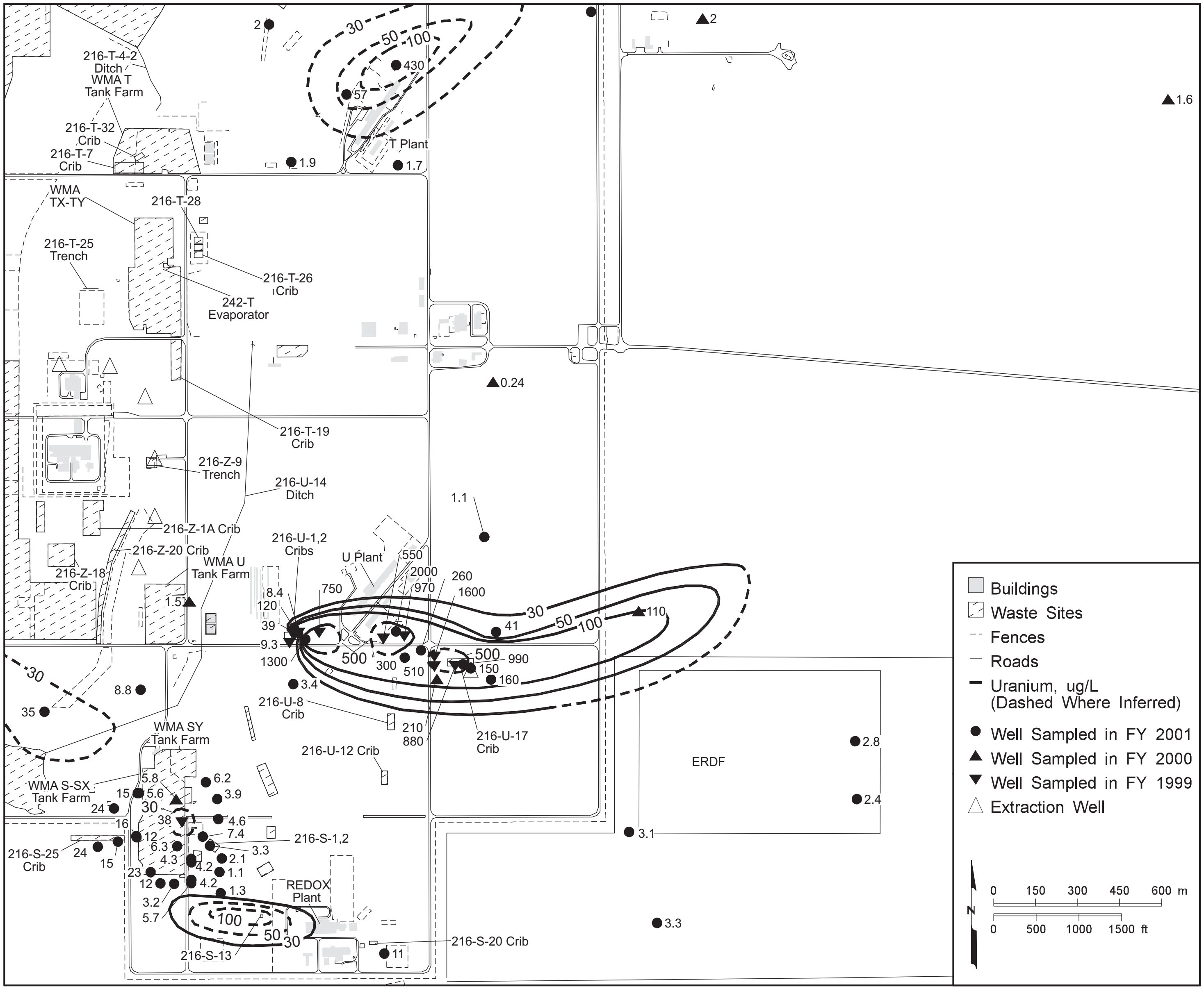

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Figure 2.8-29. Average Uranium Concentrations in the Eastern 200 West Area, Top of Unconfined Aquifer

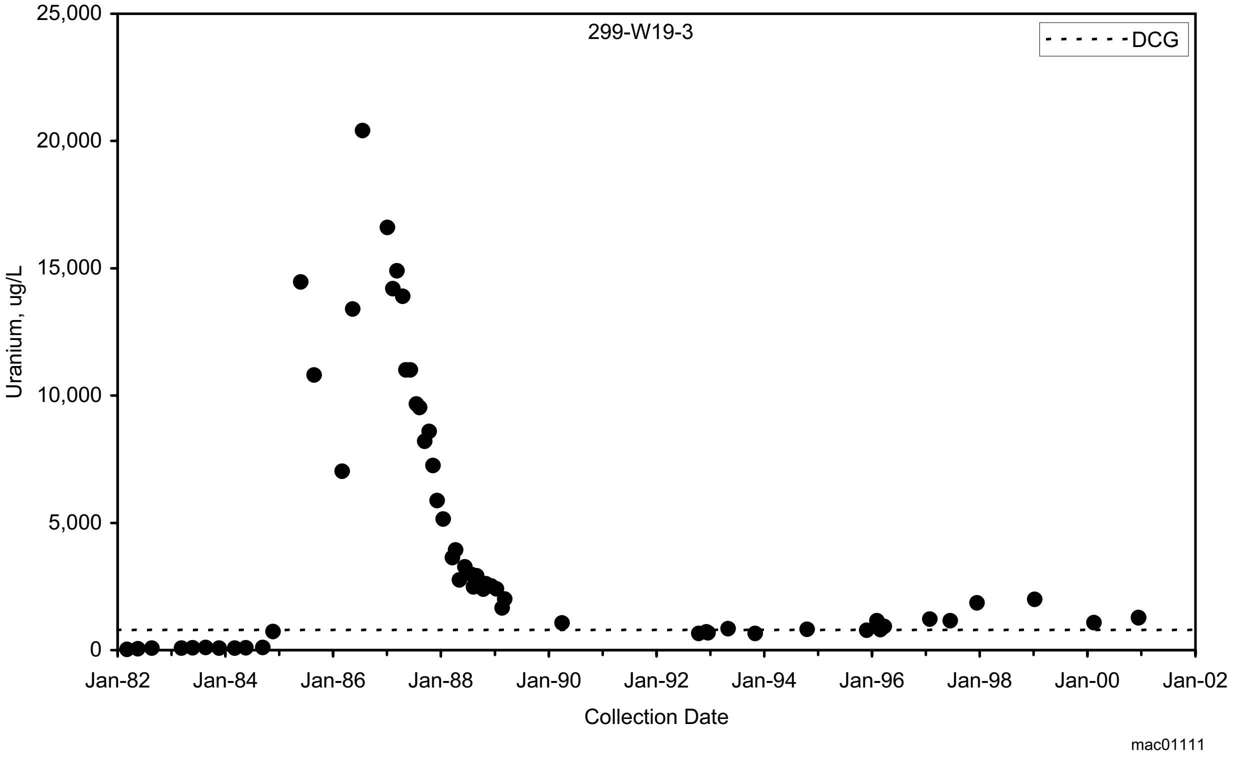

Figure 2.8-30. Uranium Concentrations Near the 216-U-1 and 216-U-2 Cribs

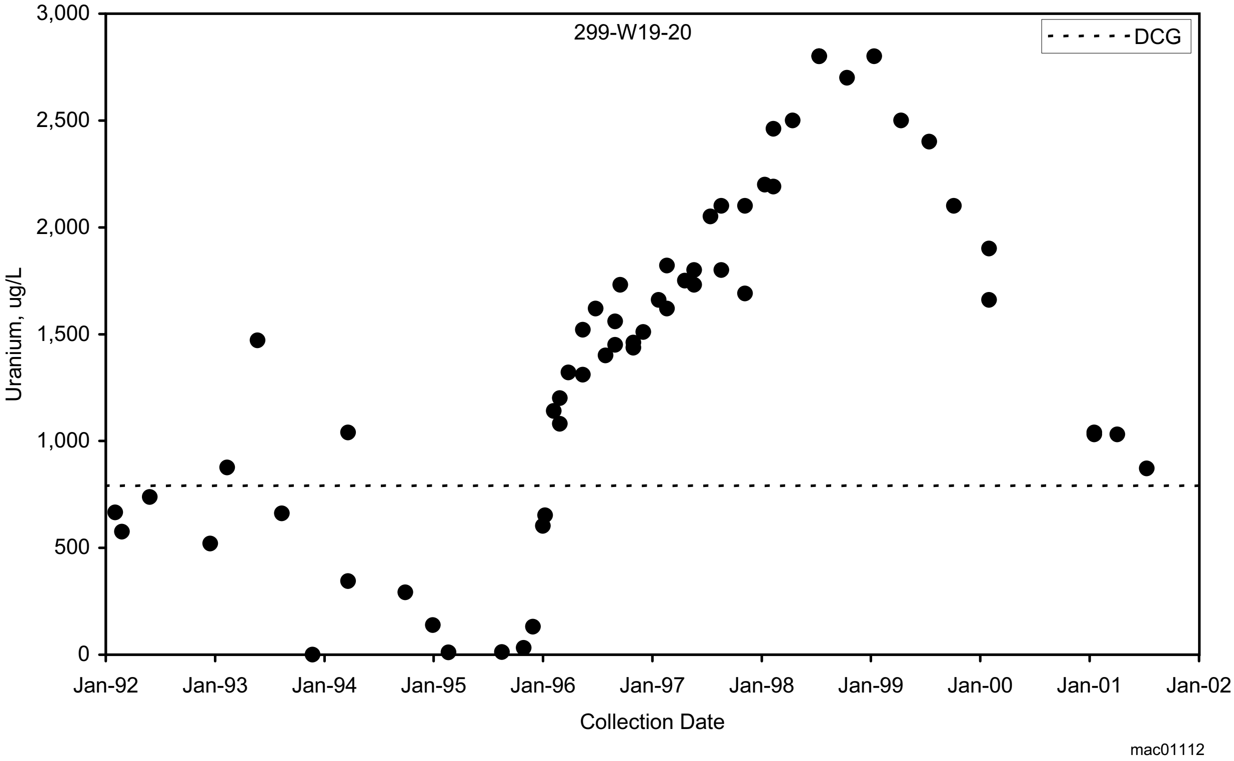

Figure 2.8-31. Uranium Concentrations Near the 200-UP-1 Extraction Well

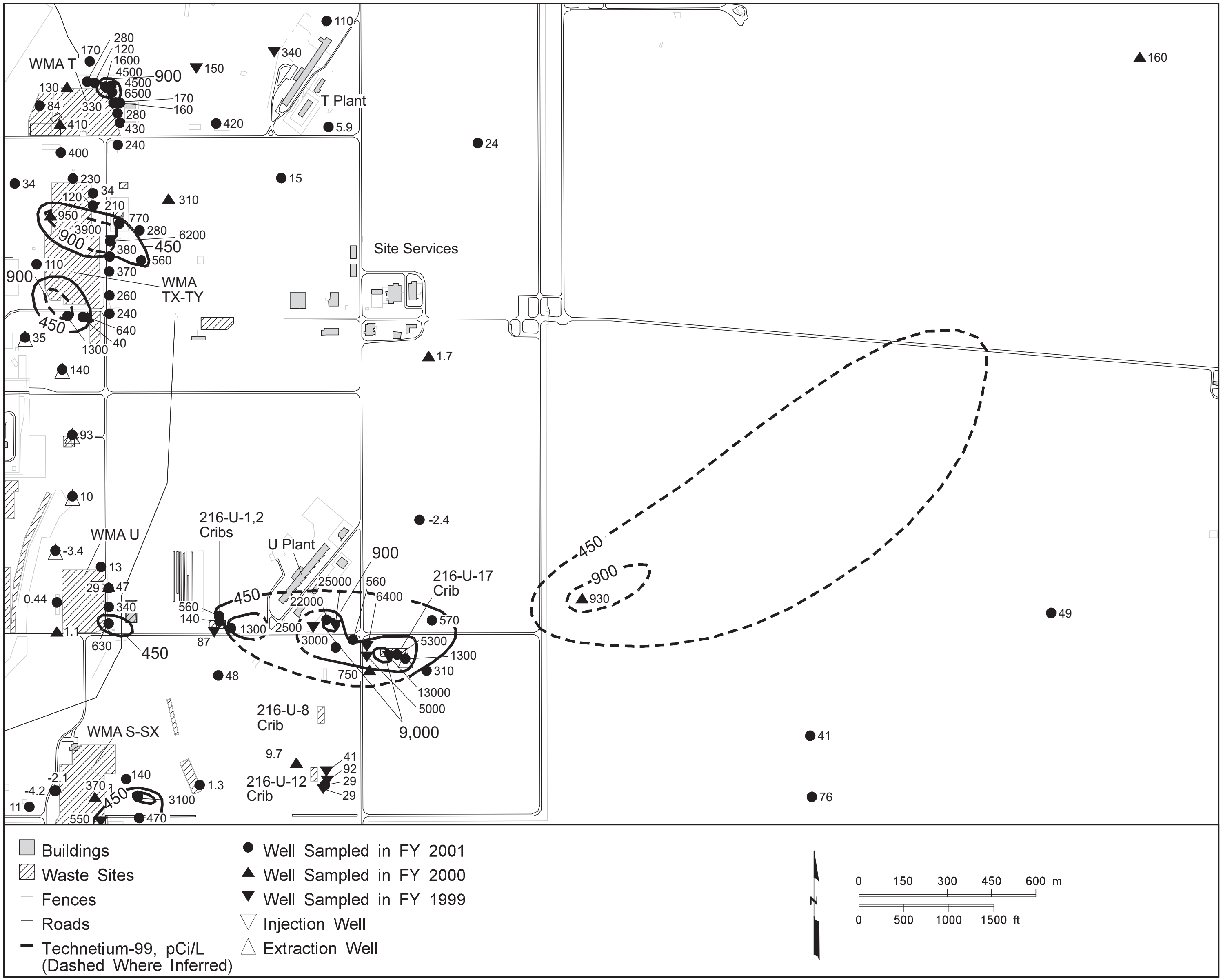

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Figure 2.8-32. Average Technetium-99 Concentrations in the Eastern 200 West Area, Top of Unconfined Aquifer

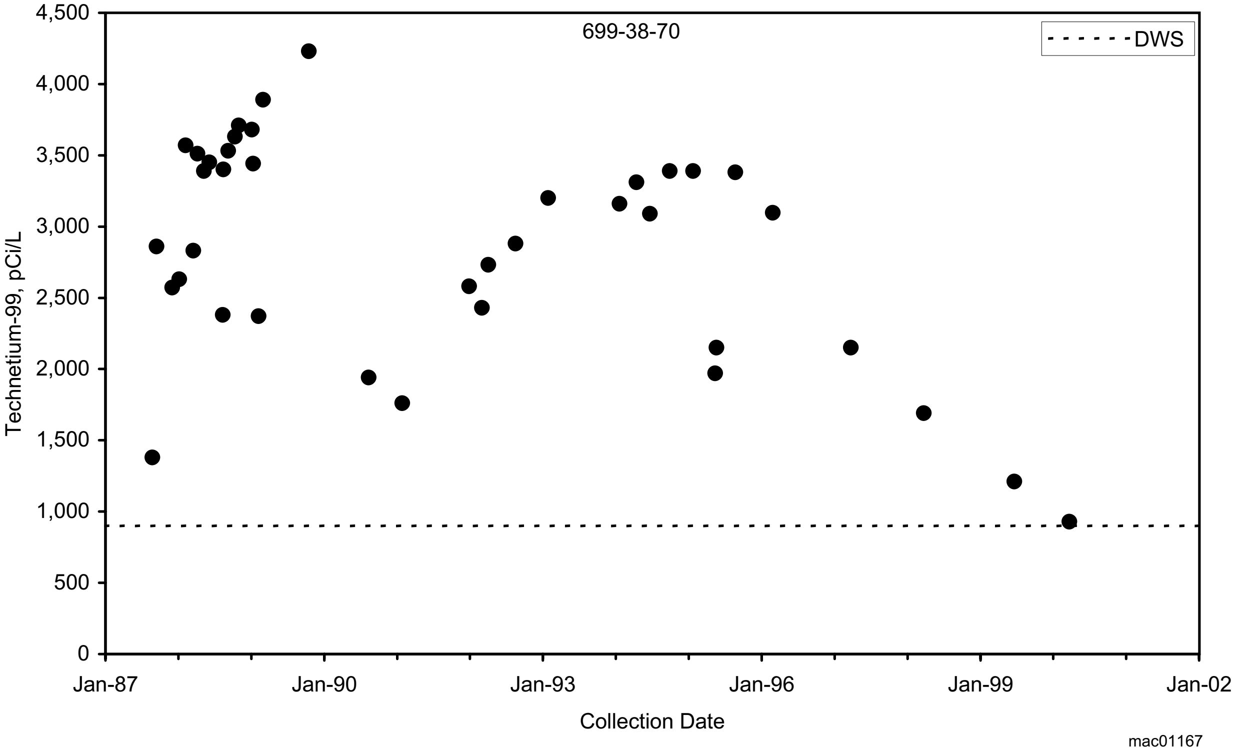

Figure 2.8-33. Technetium-99 Concentrations East of U Plant

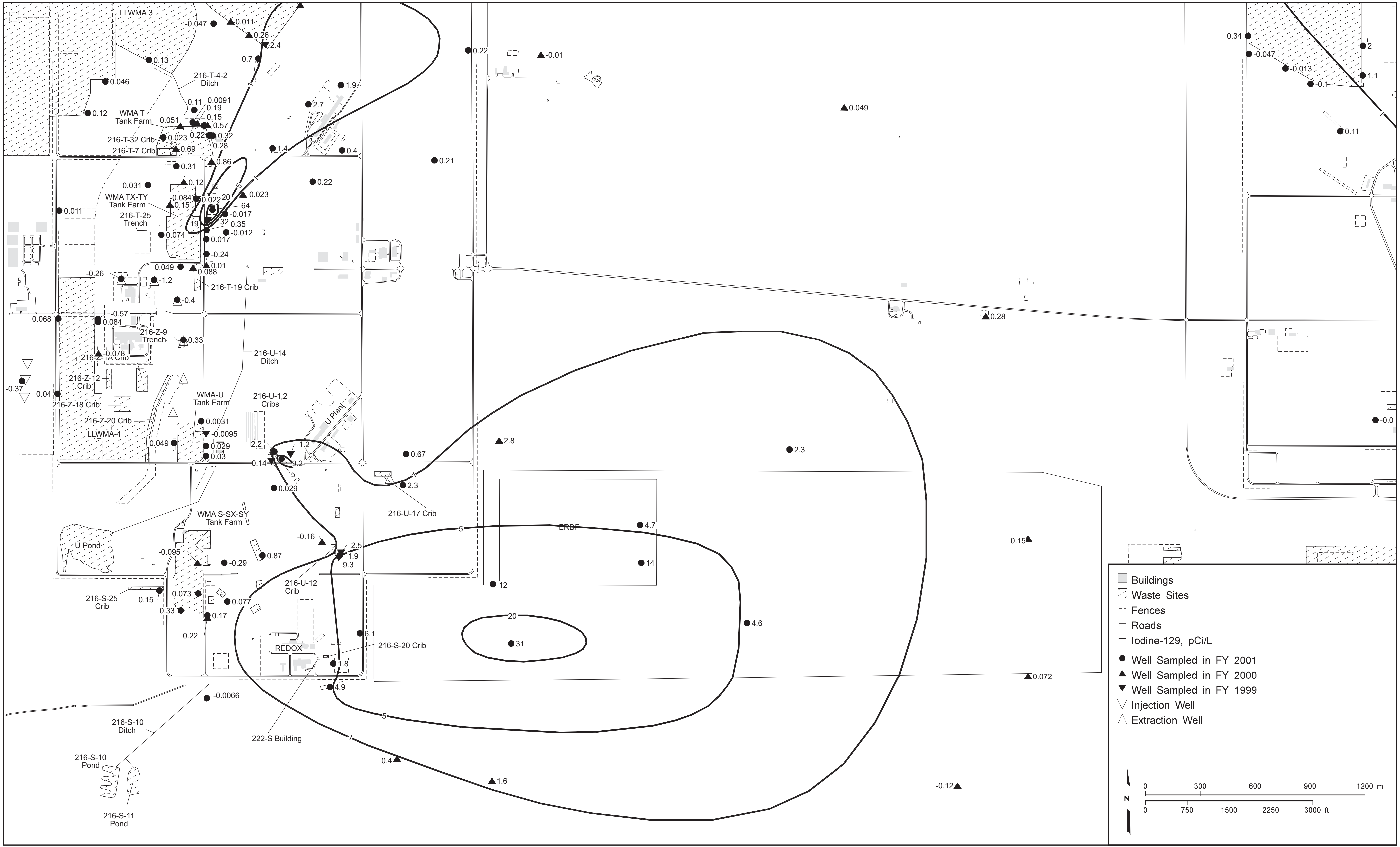

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Figure 2.8-34. Average Iodine-129 Concentrations in 200 West Area, Top of Unconfined Aquifer

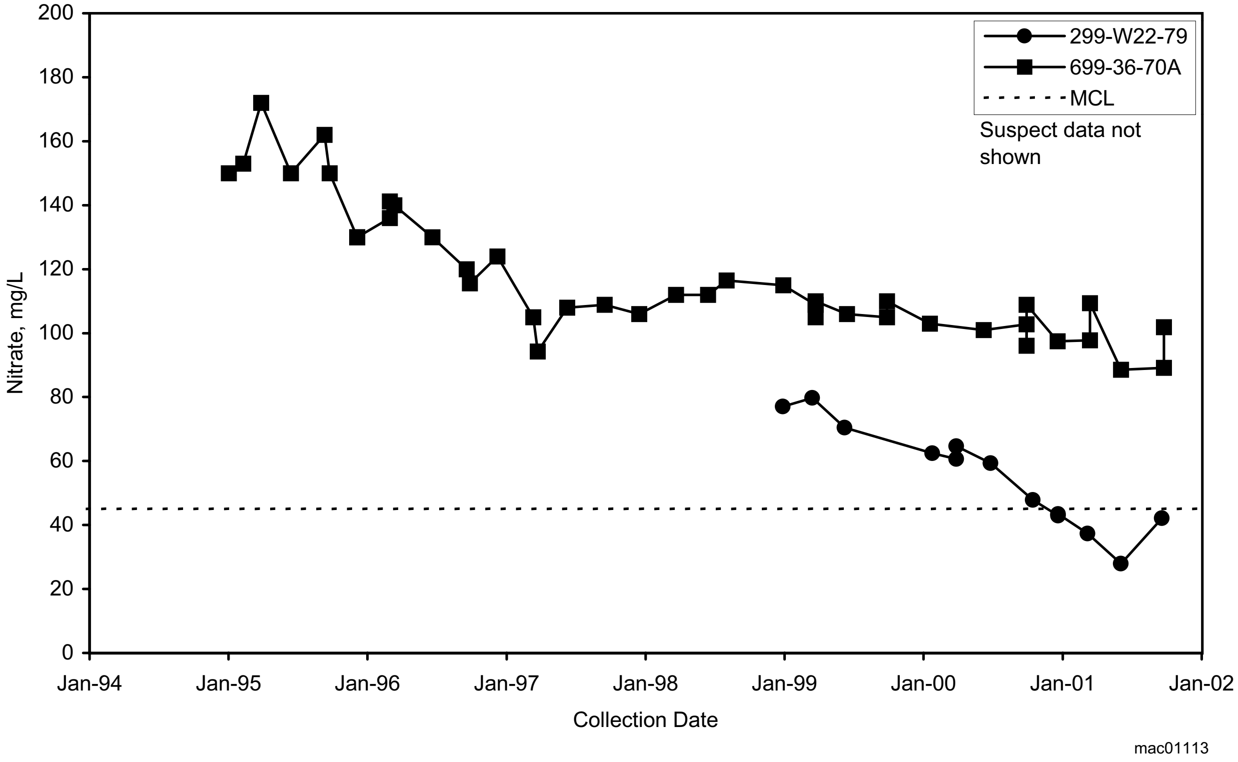

Figure 2.8-35. Nitrate Concentrations in Wells Near the 216-U-12 Crib

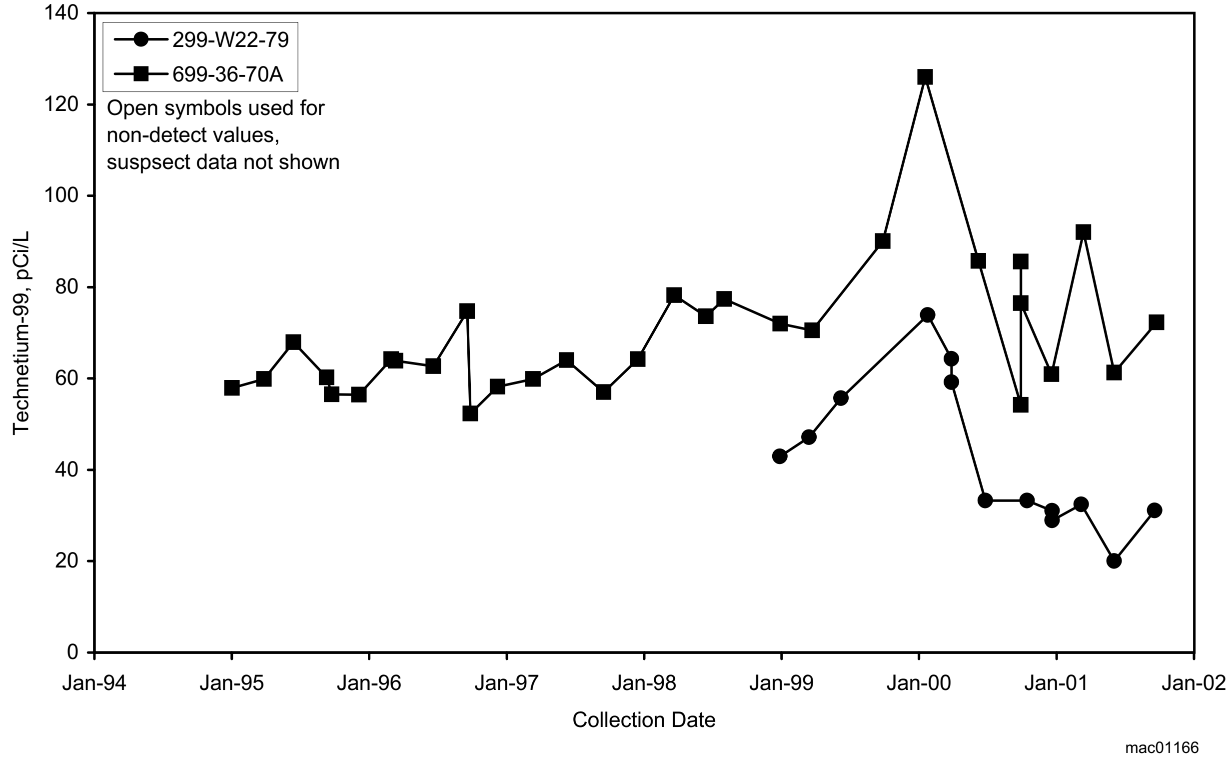

Figure 2.8-36. Technetium-99 Concentrations in Wells Near the 216-U-12 Crib

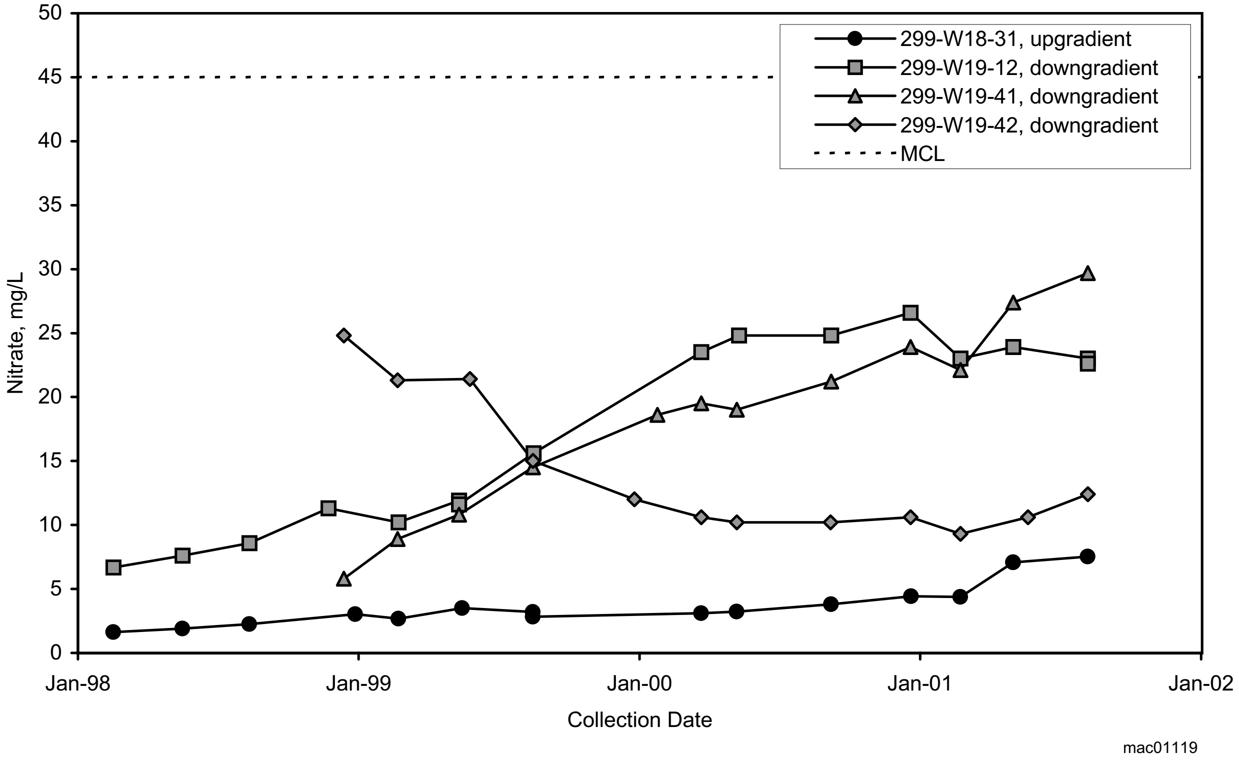

Figure 2.8.37. Nitrate Concentrations in Wells at Waste Management Area U

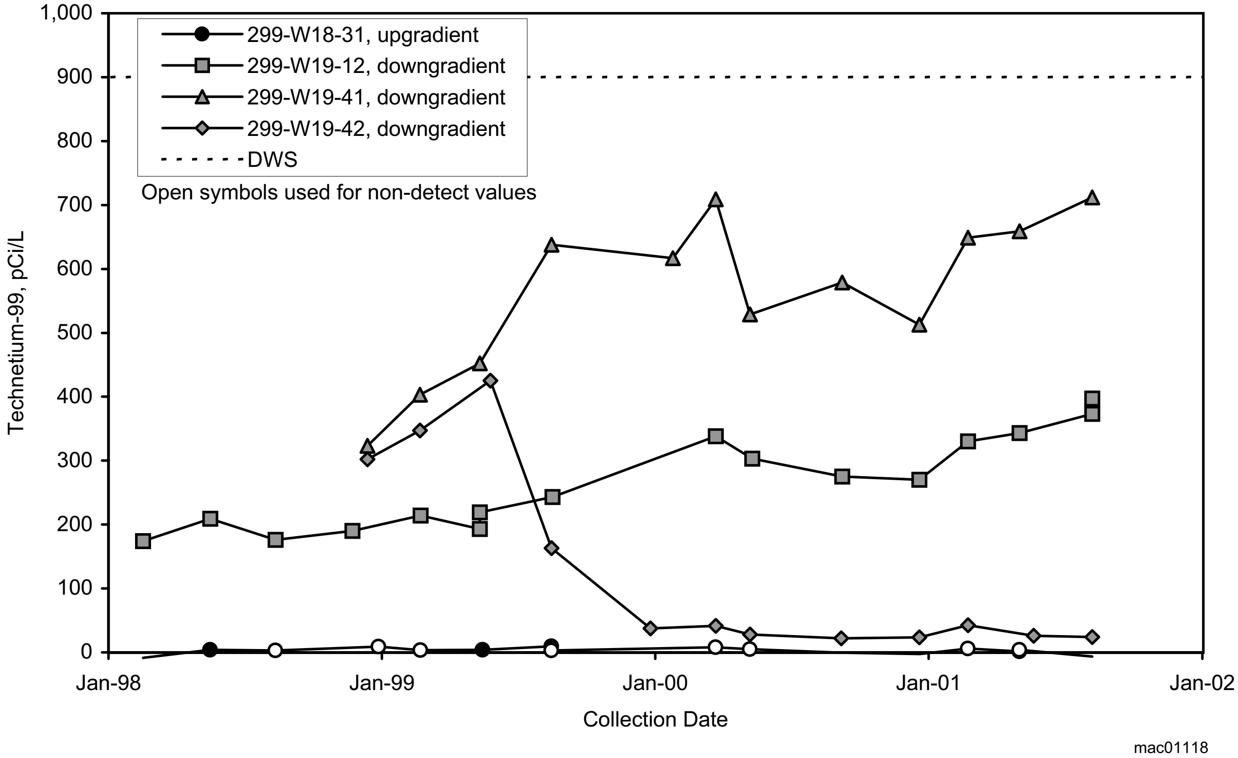

Figure 2.8-38. Technetium-99 Concentrations in Wells at Waste Management Area U

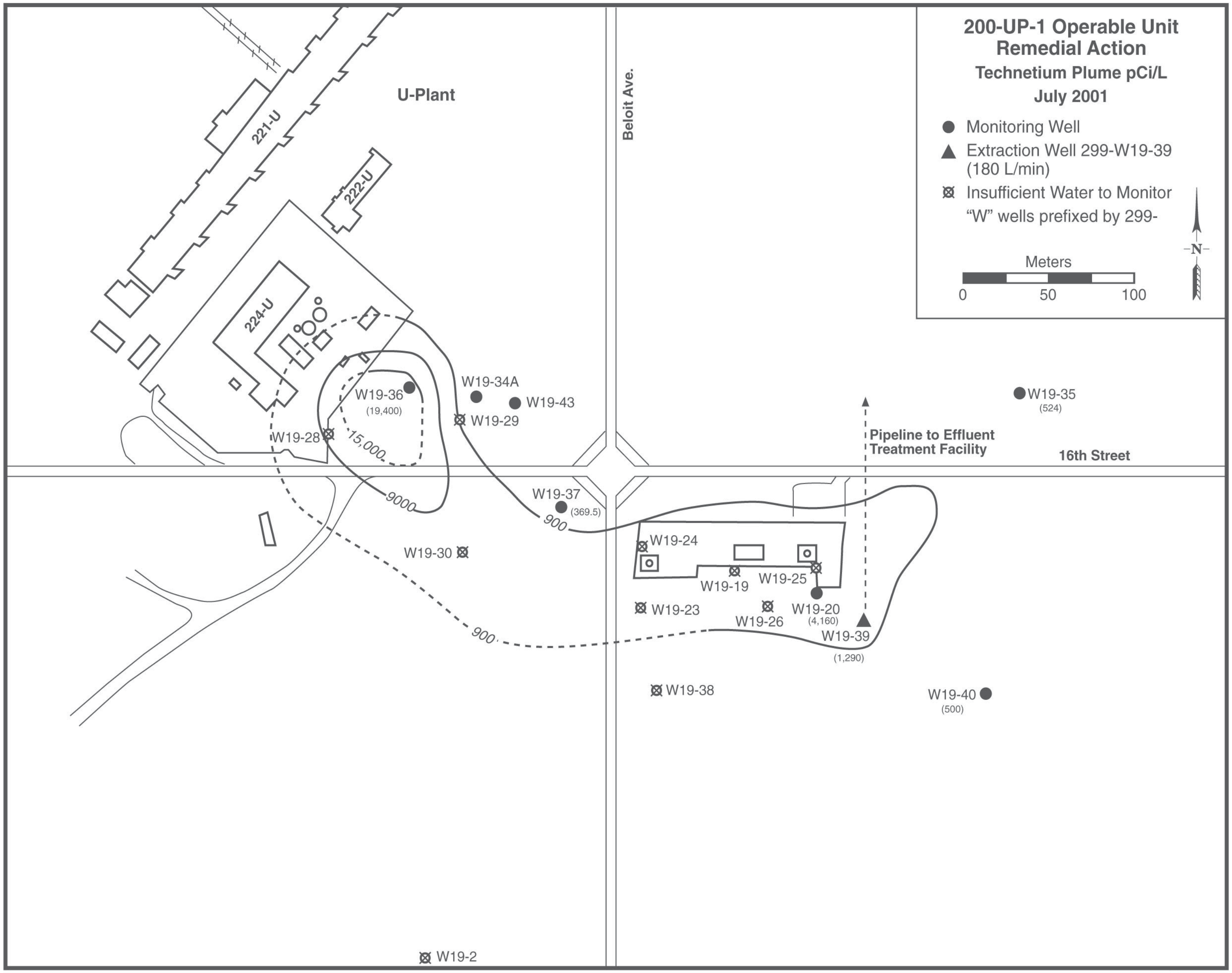

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Figure 2.8-39. Technetium-99 Plume at 200-UP-1 Operable Unit, July 2001 (DOE/RL-2000-71)

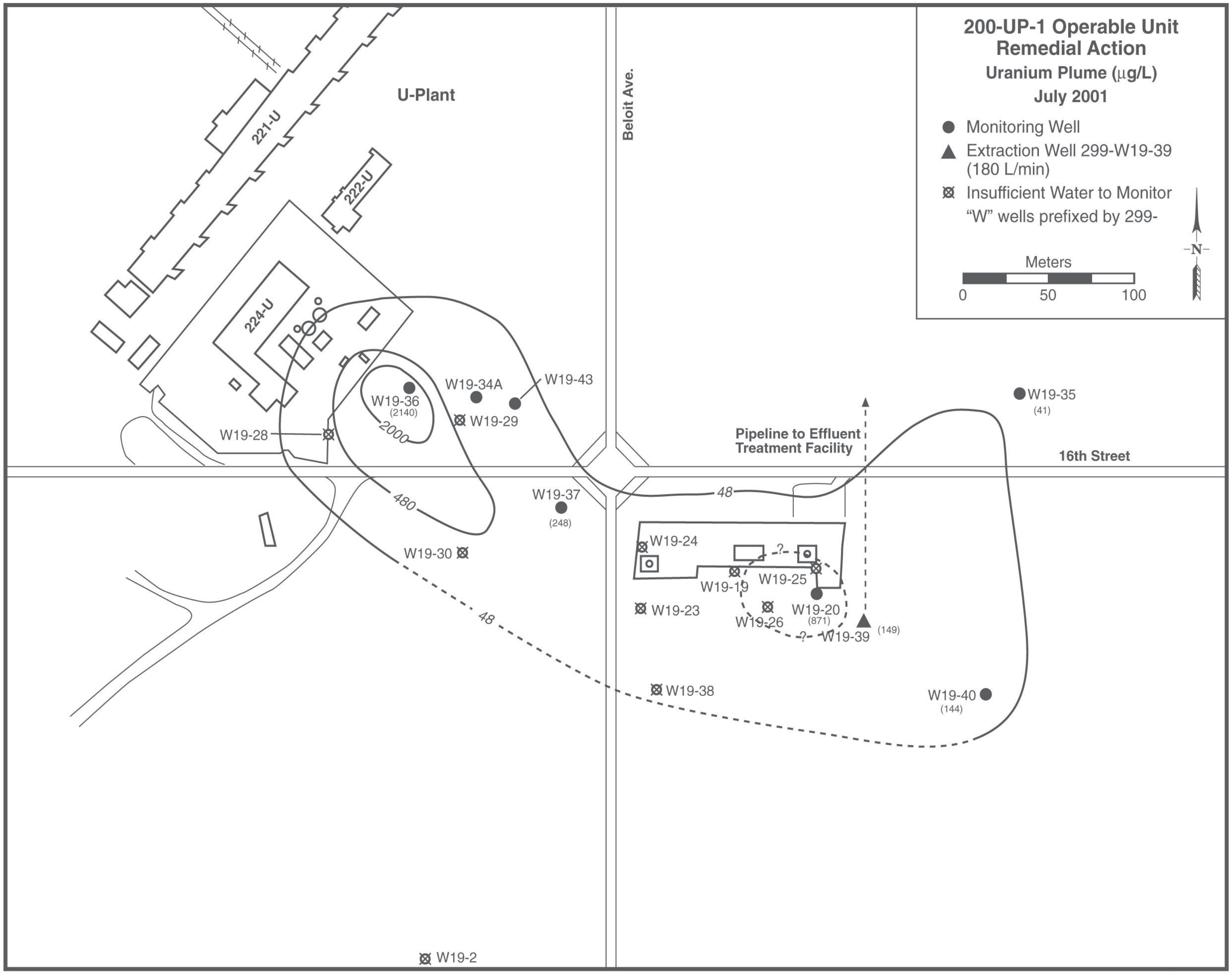

Figure 2.8-40. Uranium Plume at 200-UP-1 Operable Unit, July 2001 (DOE/RL-2000-71)

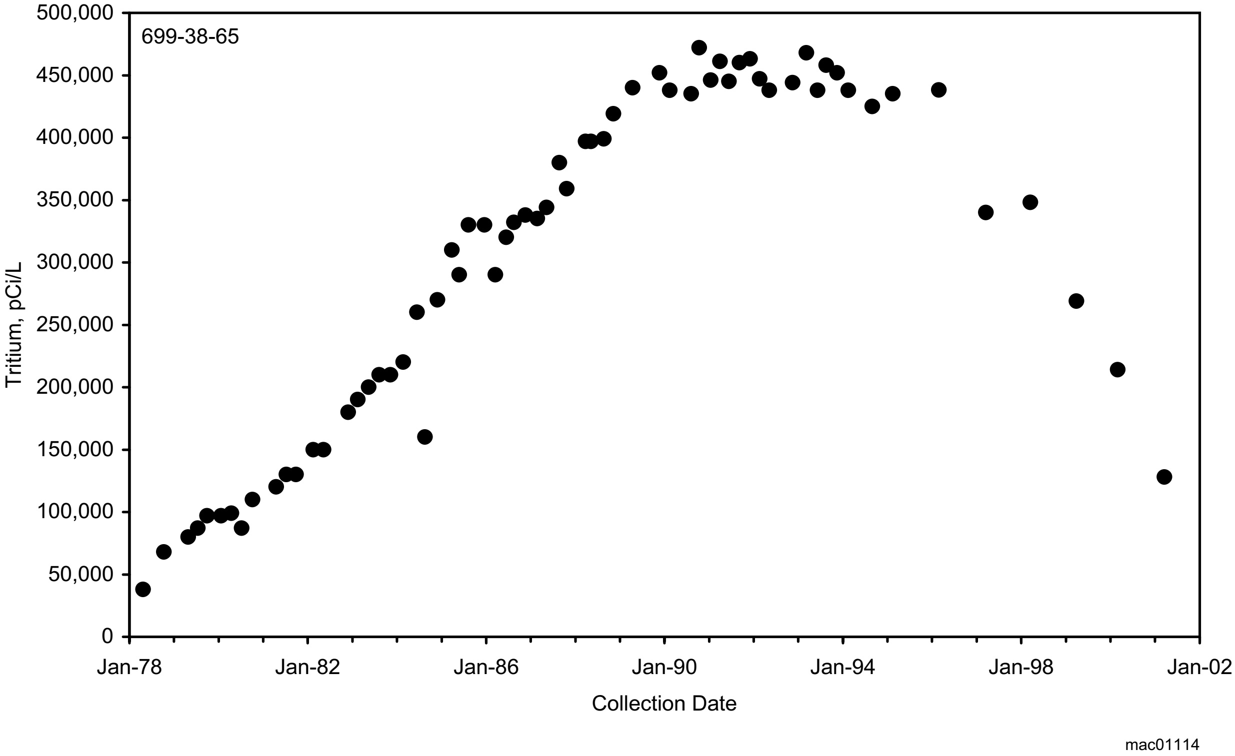

Figure 2.8-41. Tritium Concentrations East of 200 West Area REDOX Plant

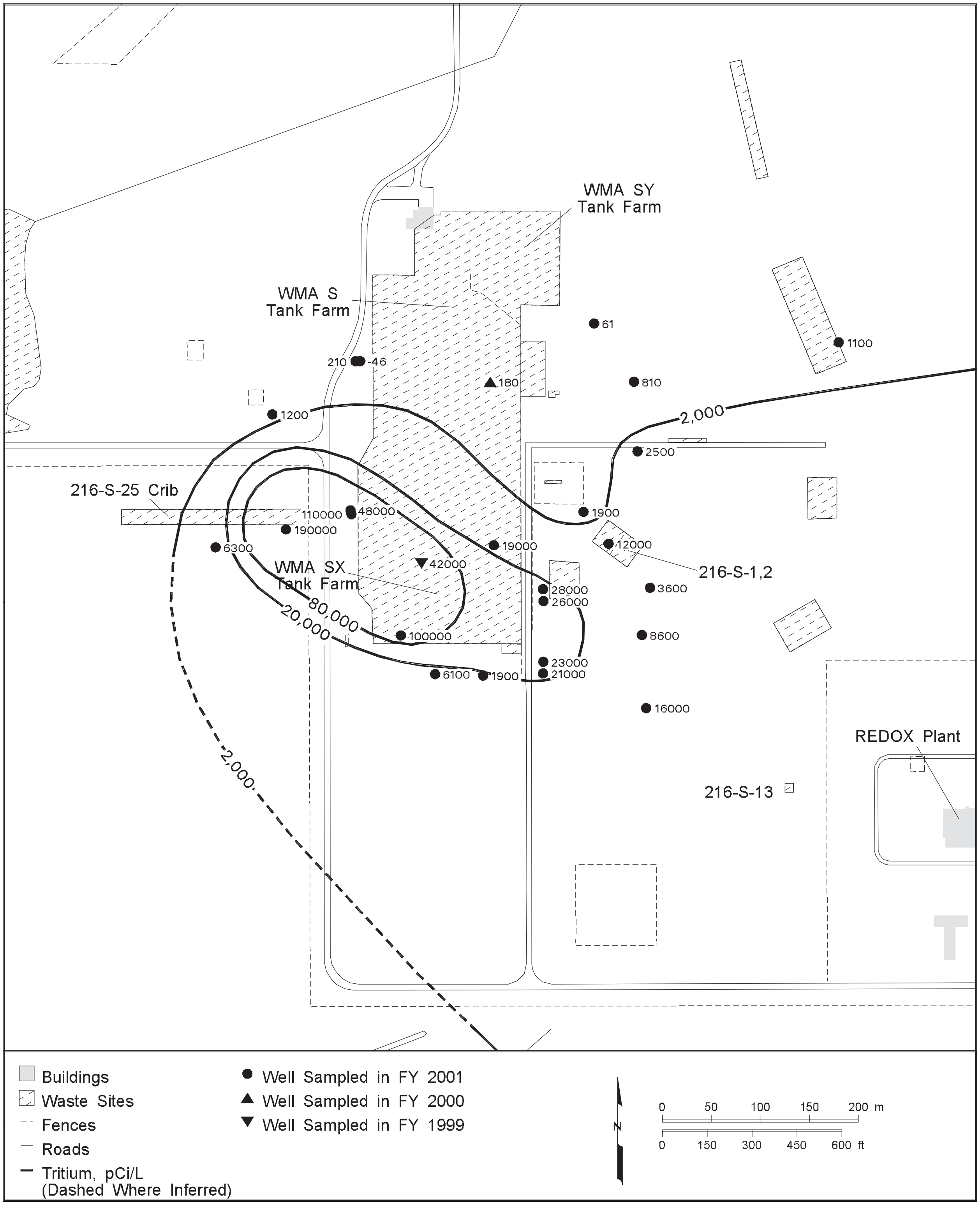

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Figure 2.8-42. Tritium Concentrations in Wells Near the 216-S-25 Crib and Waste Management Area S-SX

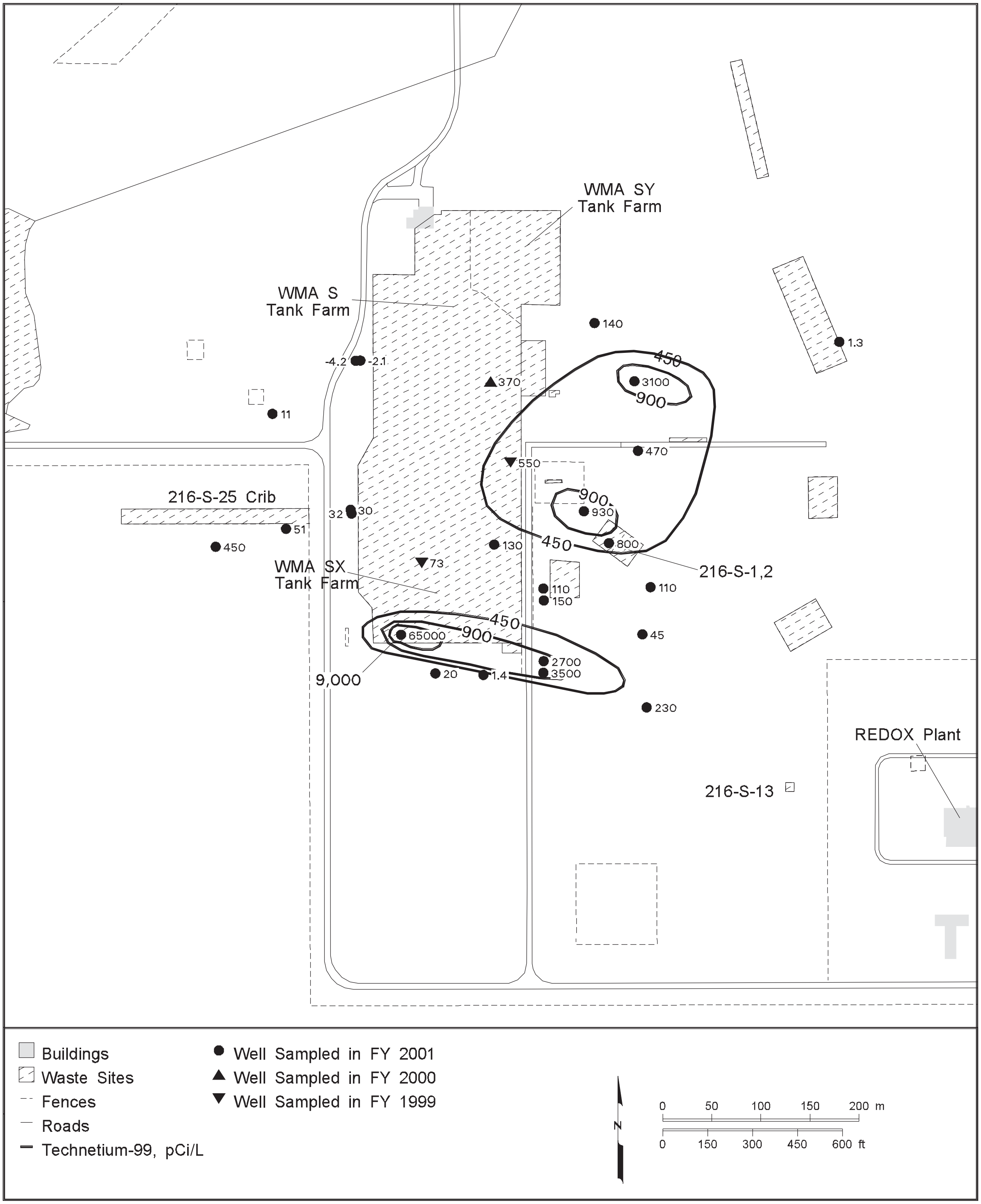

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Figure 2.8-43. Average Technetium-99 Concentrations in Wells Near Waste Management Area S-SX, Top of Unconfined Aquifer

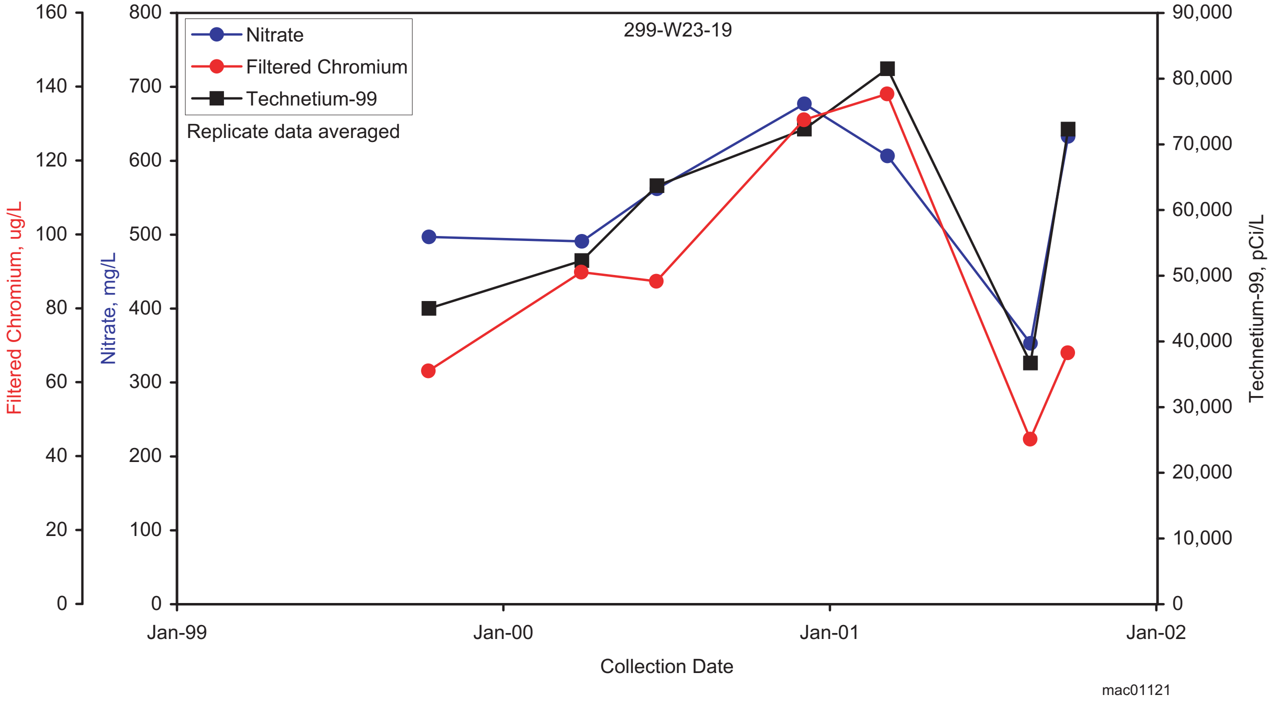

Figure 2.8-44. Technetium-99, Chromium, and Nitrate Concentrations Inside the Southwestern Corner of the SX Tank Farm

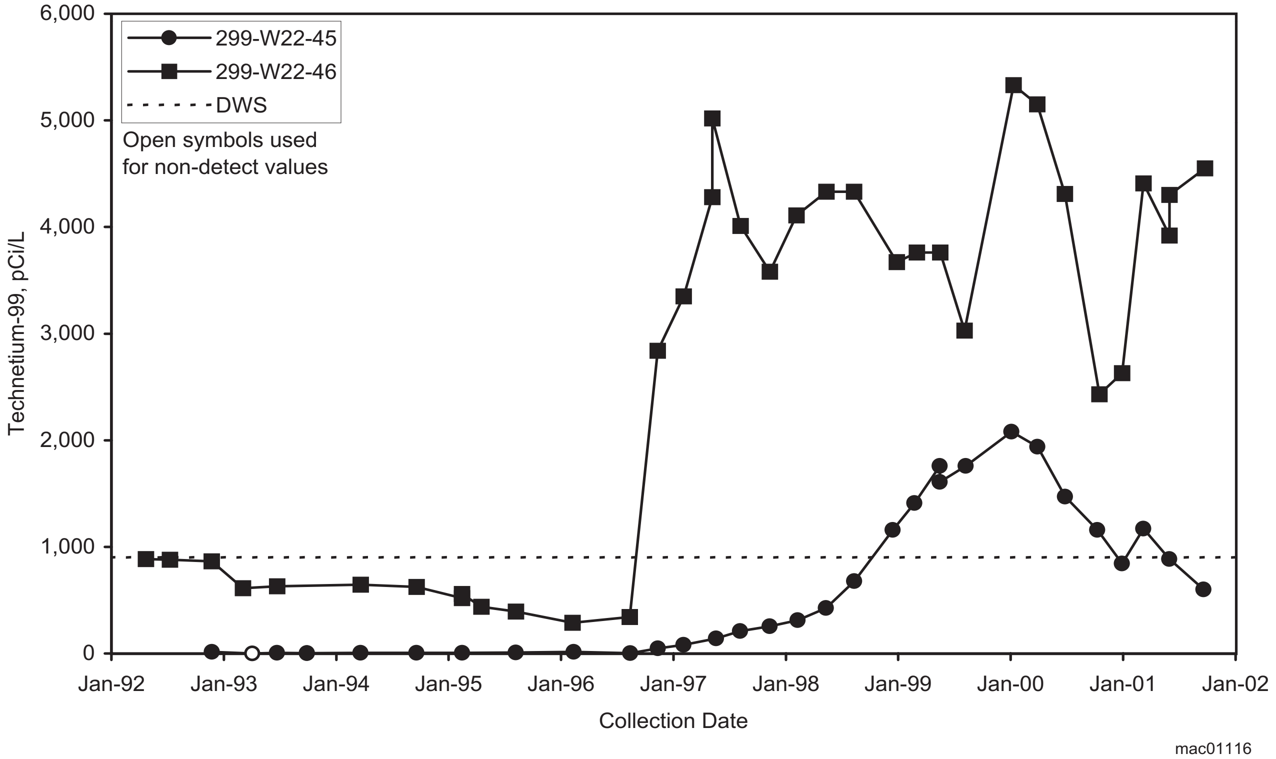

Figure 2.8-45. Technetium-99 Concentrations in Wells Southwest of Waste Management Area SX

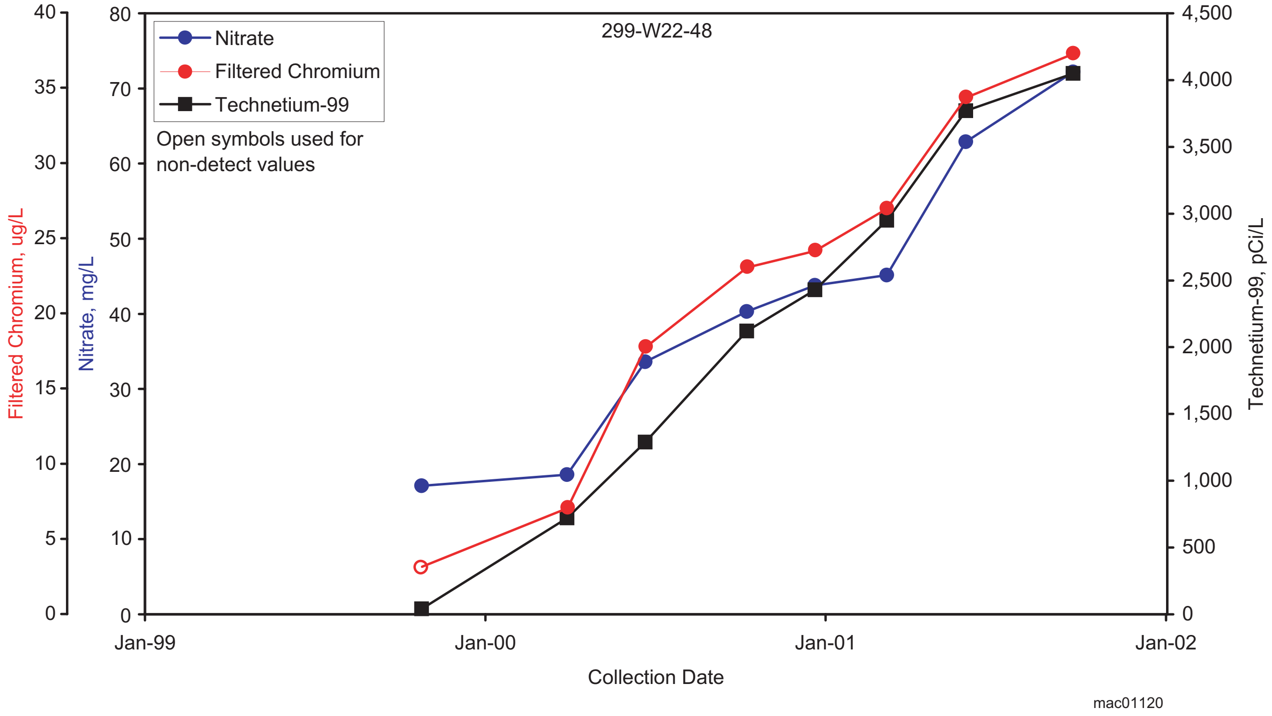

Figure 2.8-46. Technetium-99, Chromium, and Nitrate Concentrations East of the S Tank Farm

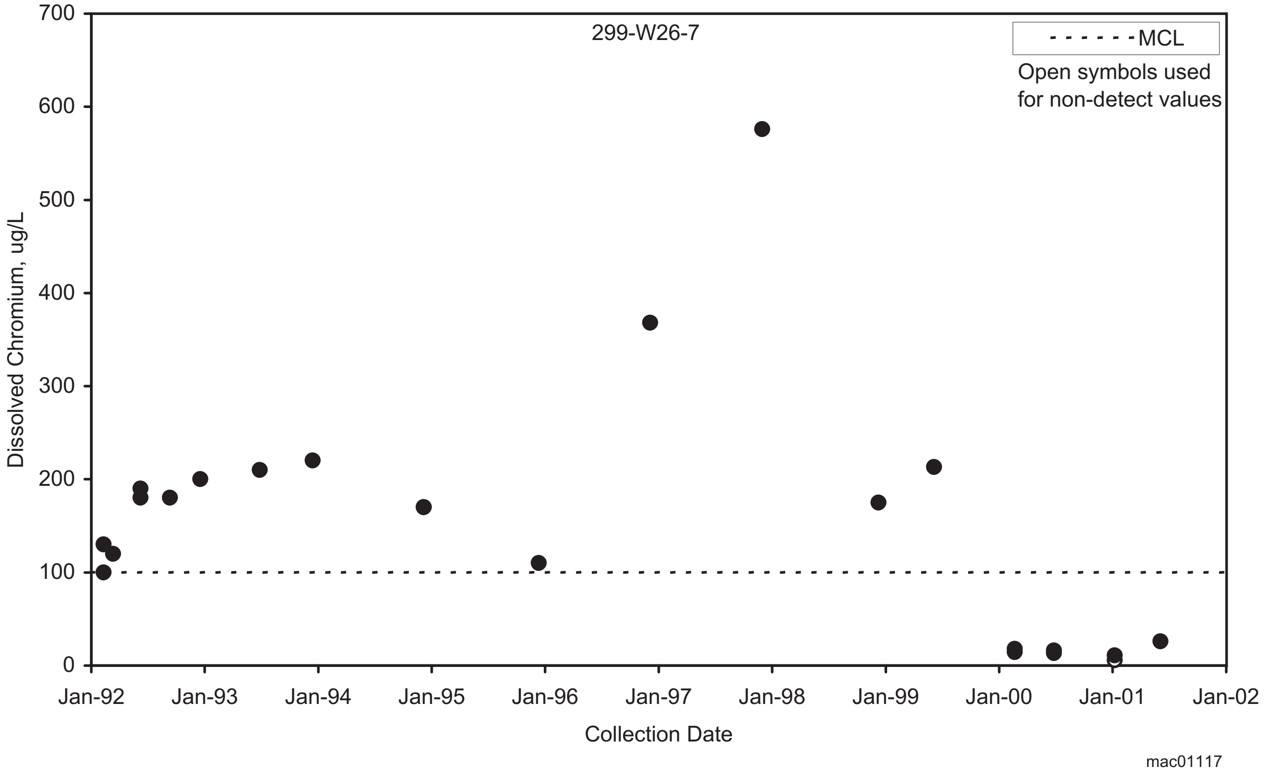

Figure 2.8-47. Chromium Concentrations Near the 216-S-10 Pond and Ditch

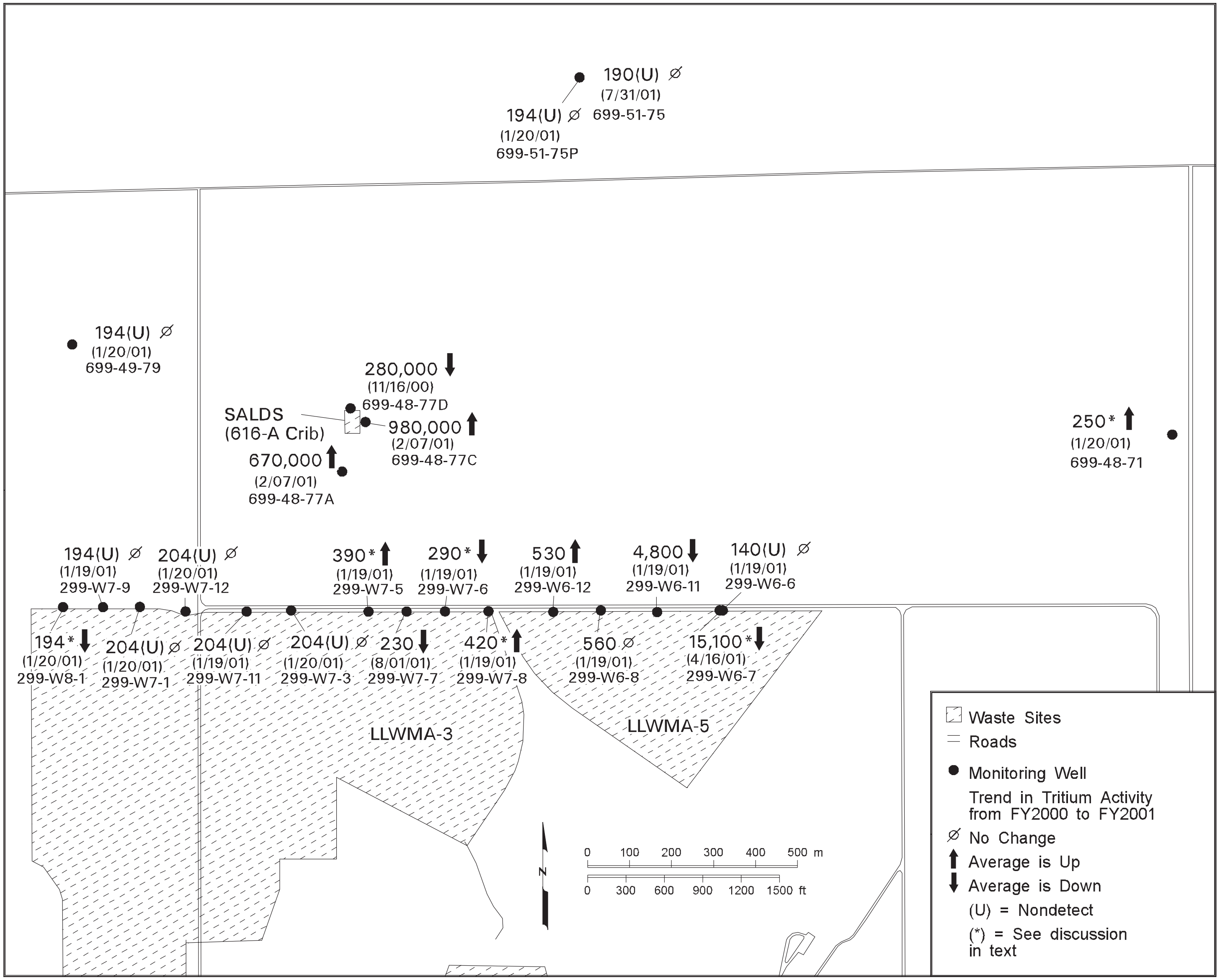

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Figure 2.8-48. Groundwater Monitoring Wells at the State-Approved Land Disposal Site Showing Maximum Tritium Concentrations for Fiscal Year 2001, Indicating Date of Measurement and Change from Fiscal Year 2000

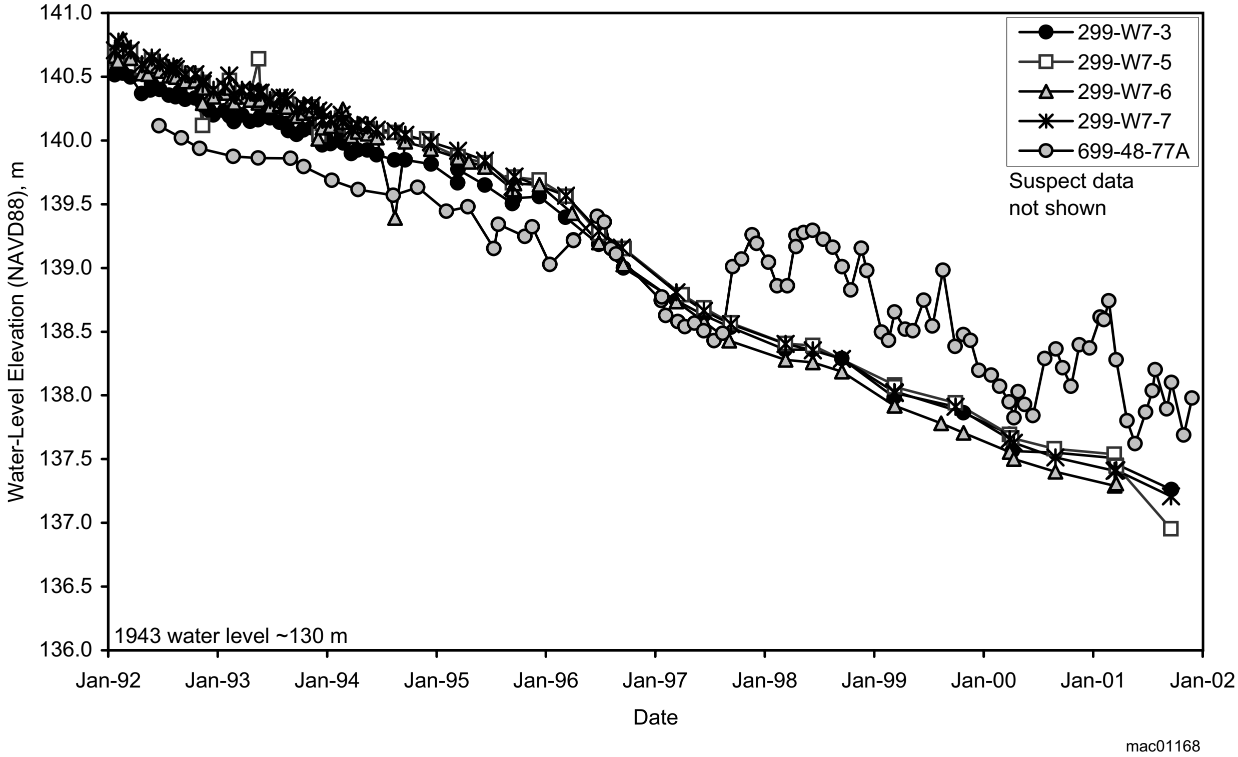


Figure 2.8-49. Water Levels at Tritium Tracking Wells South of the State-Approved Land Disposal Site Compared to Well 699-48-77A

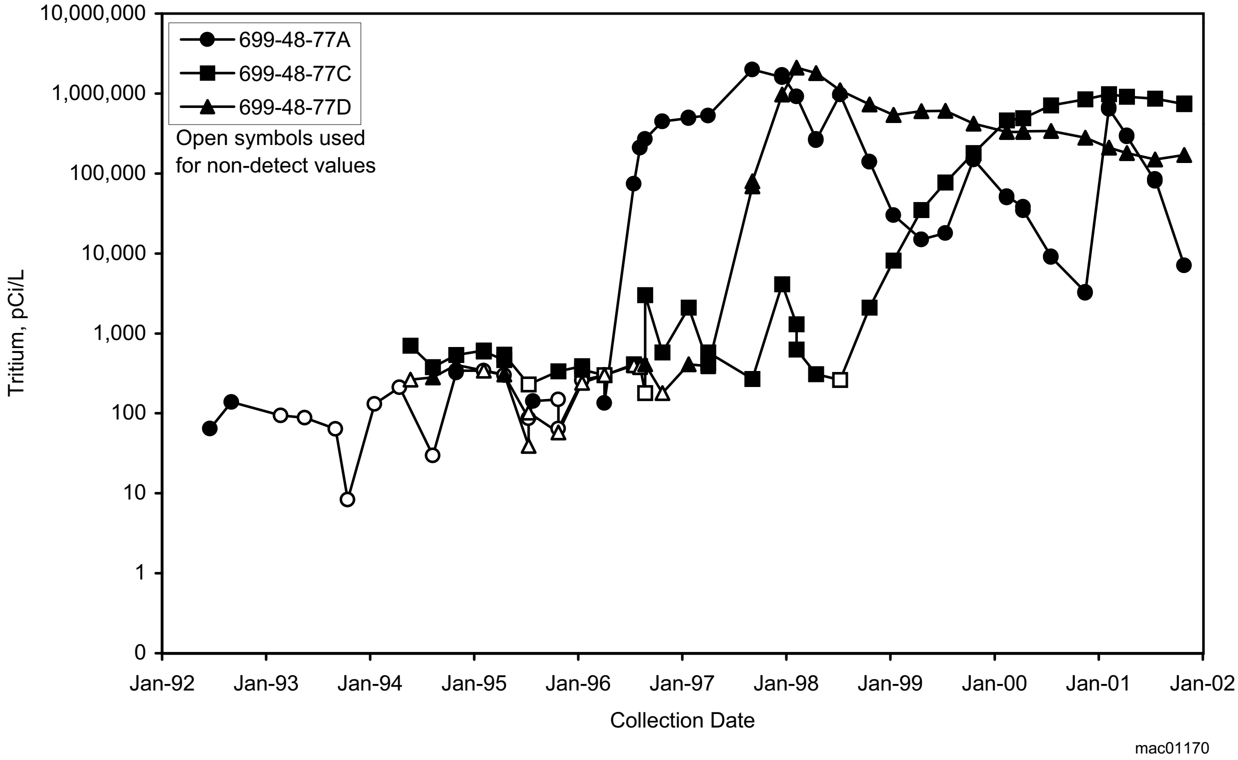


Figure 2.8-50. Tritium Concentration Trends in Wells Nearest to the State-Approved Land Disposal Site Through August 2001. Well 699-48-77C is completed ~20 meters deeper in the aquifer than wells 699-48-77A and 699-48-77D.

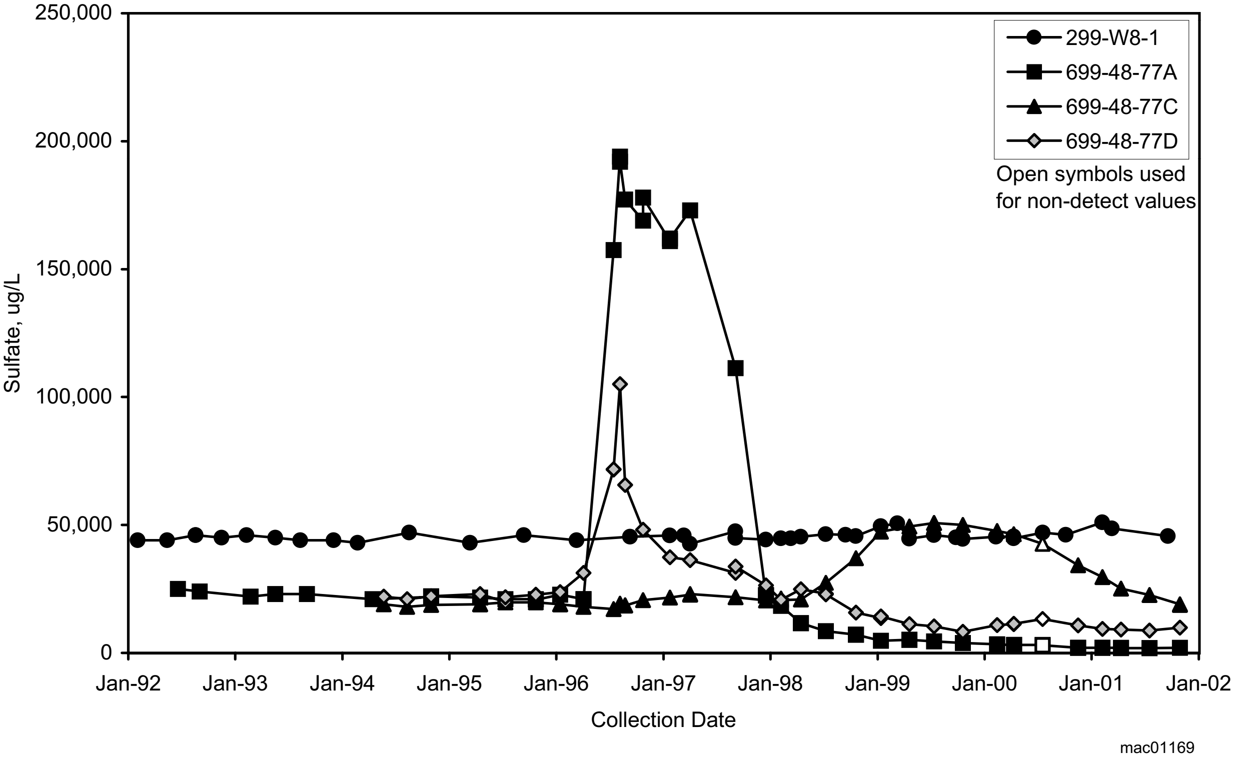


Figure 2.8-51. Sulfate Concentrations in Wells Monitoring the State-Approved Land Disposal Site

2.9 200 East Area

J. W. Lindberg, E. C. Thornton, D. B. Barnett, J. P. McDonald, R. B. Mercer, S. M. Narbutovskih, and M. D. Sweeney

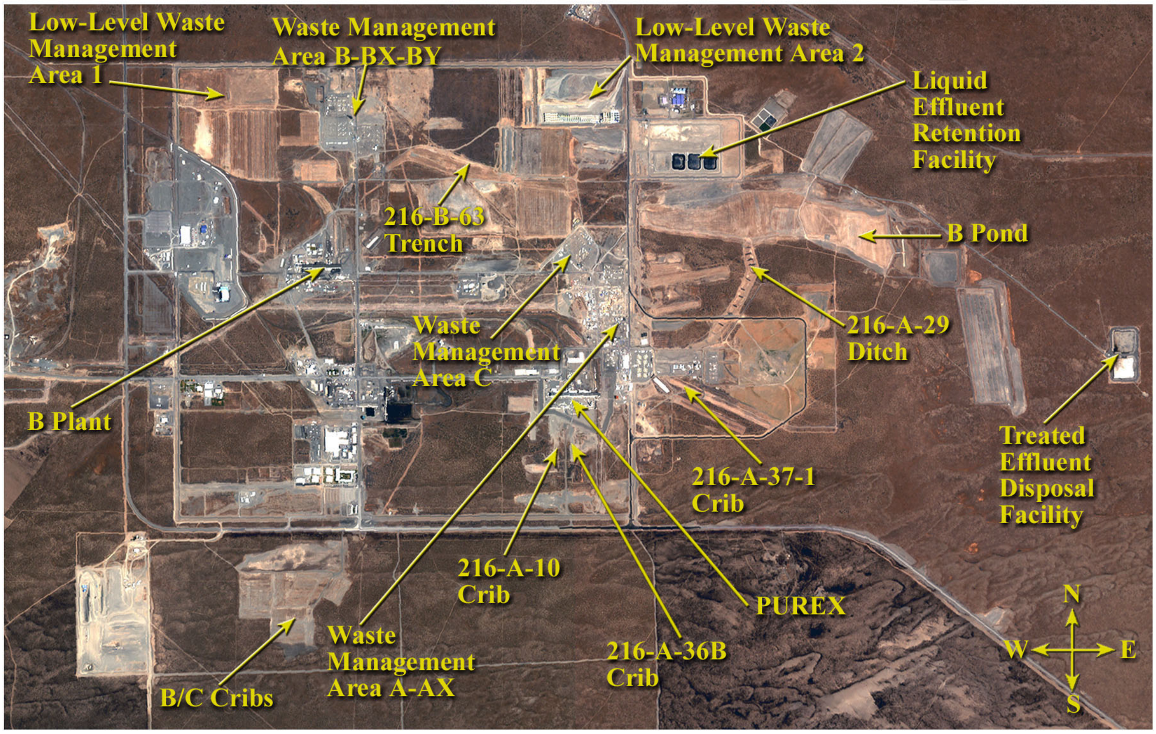
Waste sites in the 200 East Area produced the most widespread contaminant plumes in Hanford Site groundwater: iodine-129, nitrate, and tritium. Locally, cesium-137, chromium, cyanide, fluoride, strontium-90, technetium-99, and uranium also are present at levels above their drinking water standards. The aquifer is very permeable, and groundwater flows toward the southeast or northwest.

The 200 East Area, located on the Central Plateau of the Hanford Site, was used for processing irradiated reactor fuel to extract plutonium between 1944 and 1990. The extraction took place at the B Plant and later at the Plutonium-Uranium Extraction (PUREX) Plant. Currently, the 200 East Area is used for waste management, storage, and disposal. Further details are provided in PNNL-13080.

For the purpose of describing groundwater contamination, the 200 East Area is divided into two parts:

- the B Plant area in the northwestern and northern parts of the 200 East Area (generally the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* [CERCLA] 200-BP-5 Operable Unit)
- the PUREX Plant area in the southeastern and eastern parts of the 200 East Area (generally the CERCLA 200-PO-1 Operable Unit).

Most of the 200 East Area groundwater contamination has its source in these two areas. This chapter also includes a discussion of the extensive tritium, nitrate, iodine-129, technetium-99, and uranium plumes, which extend northwest and southeast of the 200 East Area. These plumes have sources within the 200 East Area. Shoreline monitoring at the Old Hanford Townsite for tritium and other constituents from the 200 East Area also are discussed in this section. Contamination at Gable Mountain Pond and the 216-B-3 pond (B Pond) is considered under CERCLA to be part of a 200 East Area operable unit. Consequently, they



Satellite image of the 200 East Area, August 2000.

also are discussed here. Strontium-90 and nitrate are significant contaminants around Gable Mountain Pond. A section on contamination in the confined aquifer in the Ringold Formation near B Pond is also included.

The discussion in this section is divided into two parts representing these two areas within the overall 200 East Area. Within each section, the general groundwater flow, major contaminants, and specific *Resource Conservation and Recovery Act of 1976* (RCRA) facility monitoring are discussed. The major groundwater contaminants of the 200 East Area are tritium, iodine-129, technetium-99, and nitrate. Also discussed is plutonium and strontium-90 contamination, which is less extensive.

2.9.1 B Plant

This section describes the area surrounding B Plant including waste storage and disposal facilities north of the plant (Figure 2.9-1). B Plant was used to recover plutonium from irradiated fuel using the bismuth phosphate process from 1945 to 1956. Contamination in the B Plant area is the result of waste disposal to the soil at a variety of locations. Throughout the active life of B Plant, the waste that was disposed to these facilities included effluent from process streams, chemicals, cooling water, and condensate. Due to similarity in the chemical makeup of some of the waste, it is difficult to assign regional groundwater contaminants to individual waste sites. However, there are instances where contaminants sources can be assigned to specific waste facilities. The broadly distributed groundwater plumes throughout the eastern Central Plateau, however, are the result of disposal to unspecified waste units within the B Plant area and adjacent PUREX complex (see Section 2.9.2). Monitoring wells within the 200 East Area are shown in Figure 2.9-1.

Monitoring Objectives at B Plant

Groundwater monitoring is conducted near B Plant:

- triennially to annually to describe the nature and extent of regional contamination
- semiannually to monitor trends in various constituents/wells
- semiannually to detect possible impact of three RCRA waste management areas
- quarterly to assess contamination from one RCRA waste management area.

Groundwater in this vicinity is considered part of the 200-BP-5 Operable Unit. Waste sites include past-practice disposal facilities regulated under CERCLA or RCRA. The BY cribs, the 216-B-5 injection well, and Gable Mountain Pond are included in the 200-BP-5 Operable Unit. RCRA facilities include low-level burial grounds Waste Management Areas 1 and 2, the 216-B-63 ditch, and the tank farms in Waste Management Area B-BX-BY. Of the RCRA facilities associated with B Plant, only the Waste Management Area B-BX-BY tank farm is monitored under a groundwater assessment plan because it is believed to have contaminated groundwater with hazardous constituents. Much of the detailed information on contaminant distributions in this area was collected as part of the RCRA assessment for the tank farms. Section 2.9.1.10 on Waste Management Area B-BX-BY is written to support the annual reporting requirements of RCRA regulations. Because of the multiple sources in the area, several of which have affected the groundwater in the immediate vicinity of the tank farm, the groundwater flow and contaminant distributions will be discussed in a general sense first. Then specific conclusions related to the tank farm assessment and other RCRA detection monitoring will be discussed.

2.9.1.1 Groundwater Flow

The small differences in water-table elevation across the B Plant area make it difficult to determine the direction of groundwater flow from water-table maps. Therefore, several other techniques are used to examine groundwater flow in this region. The results based on these techniques are compared for consistency with each other and with groundwater flow theory. The techniques used to determine groundwater flow within the B Plant area consist of plume maps and contaminant trend plots, water-level trend surface analysis, water-level hydrographs for multiple wells, and in situ flow measurements at groundwater wells.

In pre-Hanford times, groundwater in the B Plant area is believed to have flowed toward the southeast. Currently, groundwater entering the 200 East Area from the west divides and flows to the Columbia River along two separate paths: one to the southeast and one to the northwest across a buried anticline and through the gap between Gable Butte and Gable Mountain (i.e., Gable Gap). The pre-Hanford water-table elevation in the 200 East Area vicinity was ~120 meters in the North American Vertical Datum of 1988 (NAVD88). Wells drilled to basalt in the vicinity of the buried anticline show basalt elevations from 119 to 122 meters (NAVD88). Therefore, it is likely that a significant portion of the buried anticline was present above the water table in pre-Hanford times and blocked the northwestern flow pathway resulting in southeasterly flow beneath the B Plant area.

During Hanford operations, a significant quantity of liquid effluent was discharged to the soil column in the 200 East Area. This caused the water table to rise and groundwater beneath the B Plant area to flow toward the northwest. The decline in liquid effluent discharges to the soil in the 200 East Area, and the resulting decline in the water table, is expected to cause groundwater flow in the B Plant area to reverse direction and resume its pre-Hanford flow toward the southeast.

The water-table gradient in the B Plant area is very slight, making it difficult to determine the direction of groundwater flow. A colloidal borescope was used in fiscal year 2000, indicating a generally southward flow direction in much of the area. When B Plant was operating, the water table was higher than it is today, and groundwater flowed toward the northwest.

An in situ flow meter (the colloidal borescope) was used during fiscal year 2000 to determine local groundwater flow directions. The results indicate a generally south to southeast flow direction across the study area; however, considerable variation was observed in flow direction between wells (see PNNL-13404 for a full discussion). Also during fiscal year 2000, a water-level trend surface analysis was conducted for both the 216-B-63 trench and Low-Level Waste Management Area 1. This technique fits a plane to a set of water-level measurements using least squares regression. The results indicate that groundwater flow is to the southwest beneath the 216-B-63 trench, while groundwater flow beneath Low-Level Waste Management Area 1 is toward the northwest (which appears inconsistent with results of the borescope study).

Constituents typically used to track groundwater flow in the B Plant region are tritium, technetium-99, iodine-129, and nitrate because they are not significantly affected by interactions with the aquifer matrix. Contamination from the B Plant area is known to occur to the north and northwest of the 200 East Area, which means that groundwater at some time in the past moved in this direction. Sampling trends for the last 4 years at Waste Management Area B-BX-BY suggest that technetium-99 and nitrate concentrations are increasing in a southerly direction, a result that is consistent with current flow to the south. The movement of contaminants beneath Low-Level Waste Management Area 1, especially tritium, are generally interpreted as supporting northwest flow. To date, the direction of groundwater flow beneath the 216-B-63 trench cannot be determined using groundwater chemistry, since this area has no significant contamination.

Considering the available information on groundwater flow in the B Plant area, the following conceptual model was developed. The generally southern flow beneath Waste Management Area B-BX-BY (based on borescope data, hydrographs, and contaminant movement) and flow to the southwest at the 216-B-63 trench (based on trend surface analysis) is a direct result of the declining water table, as groundwater flows in a perpendicular direction away from the southeast-northwest buried anticline. Farther from the anticline, the saturated thickness and, thus, the transmissivity, increases sharply and flow becomes southeasterly. The flow divide between the southeast and northwest pathways, which was present to the southeast of the B Plant area during Hanford Site operations, is migrating to the northwest in response to the declining water table because less water is being transmitted through Gable Gap. Currently, this flow divide occurs within the

B Plant area somewhere between Waste Management Area B-BX-BY and Low-Level Waste Management Area 1, or perhaps within the southeastern half of Low-Level Waste Management Area 1.

This conceptual model is preliminary and uncertain. The elevation of the basalt across the buried anticline is not well known because wells drilled to basalt in this area are sparse. It is possible that a significant gap was eroded into this anticline, and its presence remains undiscovered. If this were the case, the northwest flow pathway would be much more transmissive than is currently recognized, so the flow divide would not be expected to migrate very far to the northwest. Further, determining the direction of groundwater flow in the 200 East Area using constituent sampling data is difficult. There may be other explanations for this data that are inconsistent with the conceptual model, such as other sources affecting the groundwater or overlapping plumes. In particular, water-line leaks, sanitary septic systems, and leakage from the potable water storage basin may locally affect flow direction and contaminant distribution. Therefore, efforts to verify this conceptual model and better understand groundwater flow in the B Plant area will continue. For a more complete discussion of groundwater flow in the B Plant area, see PNNL-13404.

2.9.1.2 Tritium

Tritium contamination is widespread throughout the northwestern part of the 200 East Area. The contamination extends north through the gap between Gable Mountain and Gable Butte and southeast toward the PUREX Plant (see Plate 2). Tritium contamination from B Plant has declined greatly because of natural decay and dilution. The highest concentrations are in the southern part of the area and represent contamination from the PUREX Plant that moved to the northwest under past flow conditions. Given the widespread, low-level nature of the contamination, it is likely that a number of waste disposal facilities contributed to the plume.

A number of waste sites in the B Plant area contributed to a plume of tritium. One part of this plume has moved north between Gable Mountain and Gable Butte to the 100 B/C Area. Concentrations are declining naturally.

Tritium concentrations in the B Plant area have declined since 1990. One well in the vicinity of the 216-B-5 injection well had concentrations of tritium greater than the drinking water standards in fiscal year 2000. Well 299-E28-24 contained 22,900 pCi/L of tritium in May 2000 but this declined to 19,300 pCi/L in April 2001. Well 299-E28-2 contained tritium at levels above the drinking water standard in fiscal year 1999 but was also below the standard in fiscal year 2001.

Tritium at levels above the drinking water standard can be found between Gable Mountain and Gable Butte and extends to the northwest (see Plate 2). Concentrations in monitoring well 699-61-62 continued to decline with a maximum average concentration for fiscal year 2001 of 33,000 pCi/L. Wells 699-60-60 and 699-64-62 are at fairly constant levels of 34,000 and 25,000 pCi/L, respectively. Well 699-72-73, between the 100 B/C and 100 K Areas, exceeded the drinking water standard for the first time in fiscal year 2001. This tritium is the result of flow through the gap under earlier flow conditions.

The assessment program for Waste Management Area B-BX-BY monitors tritium trends in the surrounding region. For wells north and west of Waste Management Area B-BX-BY, tritium levels tend to be high in the north and decrease to the south. The maximum average tritium value in this region is 17,000 pCi/L in well 299-E33-26, located between the BY cribs and Low-Level Waste Management Area 1 (Figure 2.9-2). It appears that tritium currently has a similar trend in this well and in well 299-E33-7 (at the BY cribs), which may imply groundwater flow from the northeast.

2.9.1.3 Iodine-129

Contamination from iodine-129 is present throughout the B Plant area. Like the tritium plume, the iodine-129 plume extends to the northwest through the

Gable Mountain/Gable Butte gap and southeast toward the PUREX Plant (Figures 2.9-3 and 2.1-5). Iodine-129 concentrations range up to 6 pCi/L in well 299-E33-34. Iodine-129 concentrations have increased slowly in that well but appear to have stabilized in the last several years. A band of elevated iodine-129 concentrations (~5 pCi/L) extends from the vicinity of the 216-B-63 trench, through Waste Management Area B-BX-BY, to the northeastern corner of Low-Level Waste Management Area 1. Interpretation of the iodine-129 configuration in this area is complicated by elevated detection limits that result from interference by technetium-99. In addition, the current laboratory reporting system produced some values reported as not detected at levels greater than the 1 pCi/L drinking water standard.

The iodine-129 plume from the B Plant area is similar to the tritium plume. However, concentrations were below the detection limit in wells north of the gap between Gable Mountain and Gable Butte in fiscal year 2001.

Several wells between Gable Mountain and Gable Butte were sampled for iodine-129 to define the northern plume and to track the movement of this plume out of the 200 Areas (see Figure 2.9-3). The most recent results for these wells were below detection limits, but concentrations were at or above the drinking water standard occasionally in the past.

2.9.1.4 Technetium-99

A plume of technetium-99 extends from the area of the BY cribs and Waste Management Area B-BX-BY to beyond the 200 East Area boundary to the northwest (Figure 2.9-4). The larger part of the plume is to the north and is interpreted to represent early releases of technetium-99 from the BY cribs. Detection of technetium-99 at levels lower than the 900 pCi/L drinking water standard north of the Gable Mountain/Gable Butte gap indicates that in the past, technetium-99 moved north, into, and through the gap. See Figure 2.2-2 for locations of wells in the 600 Area.

Interpretation of the details of the technetium-99 plume north of the 200 East Area is complicated by the variable concentrations seen in wells that are relatively close together. For example, concentrations of technetium-99 less than the drinking water standard were consistently detected in well 699-49-55A since the early 1990s (16 pCi/L in fiscal year 2001). This well was used as the injection well in 1995 for pump-and-treat activities and has had very low technetium-99 values since then. Well 699-49-57A has higher and increasing concentrations (3,200 pCi/L in fiscal year 2001). Well 699-52-57, located north of well 699-49-57A, had consistently low technetium-99 concentrations (<90 pCi/L) throughout the 1990s; however, the water table fell below the screen in 1999 so the well can no longer be sampled. The data from well 699-52-57 remains somewhat suspect due to the shallow penetration into the aquifer. Technetium-99 was not routinely measured in groundwater prior to the late 1980s, limiting the information on the historical trends. Thus, there is considerable uncertainty in the extent of technetium-99 contamination north of the 200 East Area.

One major source of technetium-99 contamination was the BY cribs. Sources within Waste Management Area B-BX-BY also may have contributed. The technetium-99 plume moved toward the north in the past, and now may be moving to the south.

Very high levels of technetium-99, along with cobalt-60, cyanide, and nitrate were found north of the 200 East Area in well 699-50-53A in the late 1980s (Figure 2.9-5). As the water table began to drop in 1988 (Figure 2.9-6), contaminant levels decreased, indicating that the plume had moved out of this area. Technetium-99 levels rose again to almost 10,000 pCi/L during pump-and-treat operations, which were conducted in 1995. Since that time, technetium-99 concentrations in this well have been low as the aquifer has grown thinner. In fact, the aquifer above the basalt surface in this area is presently only a few centimeters thick and the well was not sampled in fiscal year 2001.

In the early 1990s, rising technetium-99 concentrations were seen in the BY crib area in wells 299-E33-7 and 299-E33-38 (see Figure 2.9-5). During late 1997 and 1998, the technetium-99 concentration was higher in well 299-E33-7 than in well 299-E33-38. In early 1999, the trends for both wells began to track together.

Possible explanations for this increase include movement of the contaminant plume back into the 200 East Area from the north and/or transport of contamination from the vadose zone.

Technetium-99 generally decreases from north to south through Waste Management Area B-BX-BY and on the eastern side of Low-Level Waste Management Area 1. This distribution also suggests that the plume is moving toward the south, which agrees with results of in situ flow meter investigations, nitrate trends, and hydrographs from this region. Concentrations are increasing with time in these wells. Technetium-99 levels also have been increasing in recent years in wells 299-E33-33 and 299-E33-36, both located southeast of Waste Management Area B-BX-BY. This increase in technetium-99 may indicate arrival of the plume from the north.

Near the 216-B-8 crib, the ratio of nitrate to technetium-99 is high compared to the BY crib area. This suggests that the nitrate present at the 216-B-8 crib is part of a different group of contaminants from a different source than the BY cribs. Technetium-99 increased in fiscal year 2001 in wells 299-E33-15 and 299-E33-16, as the ratio decreased, possibly indicating the movement of the plume from the BY crib area toward the 216-B-8 crib.

2.9.1.5 Uranium

Uranium contamination in the B Plant area is limited to three isolated areas:

- wells monitoring Waste Management Area B-BX-BY and surrounding cribs
- wells near the 216-B-5 injection well
- wells at the 216-B-62 crib (299-E28-21 and 299-E28-18).

Uranium was associated with technetium-99 in the B Plant area. However, it moves more slowly in groundwater.

Although uranium concentrations have decreased slightly since 1998, many wells in all three of these areas exceeded the 30 μg/L proposed drinking water standard during fiscal year 2001.

Waste Management Area B-BX-BY and Surrounding Cribs

The origin of uranium contamination in the vicinity of Waste Management Area B-BX-BY is somewhat problematic. Currently, the highest uranium concentrations in the B Plant area are found within and to the east of the BY tank farm (Figure 2.9-7). The contamination is present in a narrow northwest-southeast band, but is increasing to the south along the west side of Waste Management Area B-BX-BY. In fiscal year 2001, the highest concentrations were detected in wells 299-E33-9 and 299-E33-44, with annual average concentrations of 560 and 435 μg/L, respectively. Unfortunately, a long sampling history is not available for these wells, which were drilled several years ago. Concentrations began increasing in ~1993 in wells 299-E33-13 and 299-E33-18, located east of the BY cribs and north of the B tank farm, respectively. The later decline in well 299-E33-13 is likely due to a westward shift in groundwater flow. Uranium concentrations rose in well 299-E33-26 located to the northwest and in wells 299-E33-31 and 299-E33-42 to the southwest. Uranium concentrations farther west, in well 299-E33-34, have increased from 16.6 μg/L in 1995 to 45.8 μg/L in 2001. Although uranium is generally increasing in well 299-E33-38, in the southern part of the BY cribs, concentrations only slightly above background have been found in well 299-E33-7, located in the northern part of the BY cribs. Section 2.9.1.10 includes additional discussion of uranium at Waste Management Area B-BX-BY.

The uranium data seem somewhat at odds with the technetium-99 trends. Uranium transport is retarded in groundwater with respect to the water velocity. Concentrations have been increasing in wells along the western edge of Waste Management Area B-BX-BY. The lack of uranium in the northern part of the BY cribs indicates that the uranium is not moving into the area from the north or northwest and that the uranium sources are distinct from the source of the majority of the technetium-99. As discussed in Section 2.9.1.10, at least some of this uranium may be from past releases associated with Waste Management Area B-BX-BY.

216-B-5 Injection Well

Uranium contamination is associated with the cesium-137, plutonium, and strontium-90 contamination found at the former 216-B-5 injection well. The highest uranium concentration detected in fiscal year 2001 was 220 μg/L in well 299-E28-23, located only ~1 meter from the injection well. A uranium value of 30.3 μg/L also was reported for well 299-E28-25, which is the first time a sample from this well has exceeded the maximum contaminant level of 30 μg/L since 1989.

The 216-B-5 injection well created a small plume containing cesium-137, plutonium, and strontium-90.

216-B-62 Crib

Uranium was detected consistently at levels slightly above the proposed drinking water standard in wells monitoring the 216-B-62 crib, located west of B Plant. Uranium concentrations were over 200 μg/L in the mid 1980s, but declined to current levels by the early 1990s. The maximum uranium at the 216-B-62 crib in fiscal year 2000 was 32 μg/L in well 299-E28-18. Uranium also was found along the western side of Low-Level Waste Management Area 1, but no wells exceeded the maximum contaminant level in fiscal year 2001. The uranium detected near Low-Level Waste Management Area 1 probably originated at the 216-B-62 crib.

2.9.1.6 Nitrate

A nitrate plume originating in the 200 East Area extends beyond the boundary fence line, extending northwest to the Columbia River (Figures 2.9-8 and 2.1-4). The plume within the 200 East Area has two parts: (1) a western plume that extends from B Plant to the northwest and (2) an eastern plume extending from the BY and surrounding cribs toward the south and the northwest. The two plumes join northwest of the 200 East Area and extend through the gap between Gable Butte and Gable Mountain to the Columbia River at levels less than the allowable maximum contaminant level for drinking water (45 mg/L).

Nitrate is associated with the tritium plume originating from facilities near B Plant. The plume has reached the Columbia River between the 100 B/C and 100 K Areas, but at concentrations below the maximum contaminant level.

The western part of the nitrate concentration, extending from B Plant, appears to be a portion of a larger plume extending from the PUREX Plant. This plume apparently moved to the northwest under past flow conditions during the period of high discharge to 200 East Area facilities and B Pond.

The highest nitrate concentrations are in the vicinity of the BY and 216-B-8 cribs. High concentrations of nitrate are associated with the cobalt-60, cyanide, and technetium-99 plume originating from the BY cribs. This source is a major contributor to the contamination extending to the northwest. The highest nitrate concentrations measured in fiscal year 2001, however, were found in well 299-E33-16, near the 216-B-8 crib, where the fiscal year 2001 average concentration was 660 mg/L (Figure 2.9-9). The ratio of nitrate to technetium-99 in well 299-E33-16 is high compared to the ratio of nitrate to technetium-99 in wells near the BY cribs, indicating an additional nitrate source in the area.

2.9.1.7 Cobalt-60 and Cyanide

Cobalt-60 and cyanide continue to be detected in a number of wells in the vicinity of B Plant. Cobalt-60 has a relatively short half-life (5.3 years), and is currently only found at levels less than the 100 pCi/L drinking water standard. Cyanide is also a minor contaminant but is found at levels above the 200 μg/L allowable maximum contaminant level for drinking water. These species are useful, however, in distinguishing contaminant groups and contaminant sources. Cyanide and cobalt-60 are generally found together in this vicinity.

Cobalt-60 is not considered a significant contaminant because of its short half-life (5.3 years) and low levels in groundwater.

The maximum cyanide concentrations in this area in fiscal year 2001 were 383 μg/L from well 299-E33-38 and 423 μg/L from well 299-E33-7, both located in the BY cribs. Cyanide contamination in these wells is increasing along with the technetium-99 and nitrate. Thus, the cyanide appears to be related to past discharges of ferrocyanide waste to the BY cribs.

The highest cobalt-60 values in fiscal year 2001 also were detected in wells monitoring the BY cribs, and the cribs are believed to be the source of this contamination. The highest cobalt-60 concentration was in well 299-E33-7, located in the northern part of the BY cribs, where the August 2001 result was 61.3 pCi/L.

2.9.1.8 Cesium-137 and Strontium-90

Cesium-137 and strontium-90 continue to be detected above drinking water standards in the vicinity of B Plant.

Cesium and strontium have relatively low mobility and are generally found near their source. Several wells in the vicinity of B Plant have had elevated concentrations of strontium-90. The highest levels are near the 216-B-5 injection well, which is the source. Four wells (299-E28-2, 299-E28-23, 299-E28-24, and 299-E28-25) had concentrations of strontium-90 above the drinking water standard (8.0 pCi/L) in fiscal year 1999. Two of the wells have had concentrations greater than the U.S. Department of Energy (DOE) derived concentration guide (1,000 pCi/L) in past years and in fiscal year 2001. The highest strontium-90 concentration was reported for well 299-E28- 23, which averaged 11,900 pCi/L in fiscal year 2001.

Well 299-E28-23 near the 216-B-5 injection well has concentrations of cesium-137 greater than the drinking water standard (200 pCi/L). In fiscal year 2001, a value of 1,910 pCi/L was reported for this well, which is similar to previous years.

2.9.1.9 Plutonium

Plutonium-239 and -240 were detected in past years in samples taken from several wells near the 216-B-5 injection well. Plutonium contamination is relatively immobile and, therefore, is found only near the source, which is the injection well. The highest value reported for plutonium in fiscal year 2001 was 63 pCi/L in a sample collected from well 299-E28-23.

2.9.1.10 RCRA Assessment Summary for Waste Management Area B-BX-BY

Underground single-shell tank farms B, BX, and BY, located in the northwestern part of the 200 East Area, comprise Waste Management Area B-BX-BY (see Appendix A, Figure A.16). In 1996, the waste management area was placed in a groundwater quality assessment program, based on specific conductance values that were elevated above the critical mean in downgradient well 299-E33-32 (PNNL-13022). Nitrate, along with calcium and sodium, is the apparent cause of the elevated specific conductance. Elevated concentrations of technetium-99 are associated with the nitrate. The monitoring frequency was increased in 1996 from semiannual to quarterly. In addition, outlying wells were added to the sampling schedule to provide additional coverage for the numerous past-practice liquid effluent discharge facilities located around the waste management area. This additional coverage was needed to identify non-tank farm sources that may have caused the increase in groundwater contamination. Also with the uncertainty in the flow direction in 1996, additional coverage was needed to assure that any contamination from the site would be detected.

During 1997, nitrate, technetium-99, and uranium concentrations rose above the drinking water standards of 45 mg/L, 900 pCi/L, and 30 μg/L, respectively, in well 299-E33-41. This well is located between the B and the BX tank farms. An assessment report (PNNL-11826) concluded that residual waste in the vadose zone possibly related to a tank farm leak in 1951 had, most likely, been driven to the groundwater close to this well by recent fresh water flooding.

Although concentrations of nitrate and technetium-99 were rising in the groundwater along the western side of the waste management area, the source could not be identified. A further determination is being conducted to identify the source of this contamination and to determine the rate and extent of groundwater contamination surrounding Waste Management Area B-BX-BY (PNNL-13022). Three monitoring wells were installed during fiscal year 2001 along the southern and southwestern side of the waste management area (see Appendix A, Figure A.16) to provide basic monitoring for the site.

Groundwater Flow

The hydraulic gradient is nearly flat across Waste Management Area B-BX-BY (see Plate 1), making it difficult to determine upgradient versus downgradient wells from water elevations. Inaccuracies in water elevations become more important when the differences in elevations between wells are small. These inaccuracies result from measurement errors, small deviations from vertical of the borehole, small errors in well elevation surveys, pressure effects associated with changing weather conditions, and lateral changes in sediment grain size distribution across a site causing slight undulations in the water table. Each of these sources of error can affect the water elevation in a well resulting in incorrect interpretation of flow direction (PNNL-13022; PNNL-13023; PNNL-13116). Unless these errors are minimized or corrected, estimates of the direction of groundwater flow based on water elevations alone can be ambiguous when applied to a region as small as Waste Management Area B-BX-BY (PNNL-13022). Consequently, flow directions based on water elevations were supplemented with other techniques (PNNL-13404). Results agreed with local hydrographs, confirming a southerly flow direction across the site. The direction of groundwater flow tends to be southwest from the BY cribs across the BY tank farm; it then swings south to southeast through the BX and B tank farms.

RCRA Waste Management Area B-BX-BY contains single-shell tank farms that may have contaminated groundwater with nitrate, technetium-99, and uranium. Assessment monitoring continued in fiscal year 2001.

The average flow rate, calculated with a form of the Darcy equation, was estimated at 0.98 meter per day in fiscal year 2000 (see Appendix A, Table A.2). This equates to 358 meters of groundwater movement per year. In situ flow measurements conducted in fiscal year 2000 indicate that although this rapid flow rate may be correct for the southern part of the site, the northern section under the BY cribs and the BY Tank farm have a relatively low flow rate. The unconfined aquifer in this region was formed artificially by rising water levels related to intentional and unintentional releases of waste liquids to the ground. Presently, the unconfined aquifer in the north is ~2 meters thick and dropping ~15 centimeters a year. In addition, this thin aquifer is located on a hummocky basalt surface with structural relief that varies from 1.5 to 3.4 meters. This causes the local flow paths to vary markedly as the water flows around basalt highs. The combination of low transmissivity and obstacles to flow cause this northern section to drain slowly as the area returns to pre-Hanford conditions.

Groundwater Contamination

Assessment studies at Waste Management Area B-BX-BY have identified several distinct groups of contaminants based on chemical associations, spatial relationships, historic plume movement, knowledge of process chemistry, and characteristic chemical ratios of contaminant concentrations (PNNL-13116).

1. **Nitrate, Nitrite, Technetium-99, and Uranium**. These contaminants are located under and east of the BY tank farm. Past releases from the waste management area may be the source of this contamination. Further assessment to evaluate this plume is ongoing.

2. **Tritium**. This contamination is found along the southern border of the waste management area. Movement through the vadose zone from a tritium-rich perching zone located ~4.6 meters above the water table under the BX tank farm may be the source of this contamination.
3. **Cobalt-60, Cyanide, Nitrate, and Technetium-99**. These contaminants extend from the north under the BY cribs and are beginning to affect the groundwater under the BY tank farm in the northern section of Waste Management Area B-BX-BY, impinging on the uranium-rich plume under the BY tank farm. These contaminants have moved back into the northwestern section of the 200 East Area after transportation north during the time of maximum discharge in the late 1960s to early 1970s and again during the mid-1980s when B Pond was active. This plume was originally identified in the late 1980s north of the BY cribs centered on well 699-50-53A (WHC-SD-EN-TI-020). The contaminants are attributed to releases from the BY cribs in the mid-1950s.

The discussion in this section centers on the first two contaminant groups because these may emanate from past tank farm-associated sources. Referral is made to the non-tank associated groups as needed to identify possible tanks farm sources from crib-related discharges. Recent analytical results from three new wells installed in fiscal year 2001 south of the waste management area are included.

Nitrate and associated anions, technetium-99, and uranium are the main constituents from processing waste stored in the tanks at Waste Management Area B-BX-BY known to be mobile and used for tracking tank-related waste. Groundwater samples also are analyzed for cobalt-60 and cyanide because, though both constituents are present in some tank waste, these species have been disposed to the ground at the BY cribs. In the case of cobalt-60, there is a well-defined history of the contaminant being found in the groundwater at this site shortly after five of the six BY cribs were used in the mid-1950s. Unfortunately, cyanide was not analyzed in groundwater samples from this area until the late 1980s, when high levels were found along with cobalt-60, nitrate, and technetium-99 in a well north of the BY cribs. The discharges to the BY cribs and to the 216-B-42 trench are the primary sources for cobalt-60 and cyanide in the northeastern corner of the 200 East Area.

Nitrate continues to migrate across Waste Management Area B-BX-BY, with the highest concentrations in the north.

In general, nitrate is still migrating across the waste management area from the highest values in the north to the lowest concentrations along the southern boundary. In August 2001, nitrate concentrations were highest north of the waste management area under the BY cribs (well 299-E33-7) and were lower to the south at well 299-E33-38 (Figure 2.9-10). Values are still lower farther south, ranging from 251 to 21 mg/L (see Figure 2.9-10). In the central region of Waste Management Area B-BX-BY, there is a more significant difference in nitrate concentrations compared to those under the BY cribs (Figure 2.9-11). Concentrations in three centrally located wells (299-E33-9, 299-E33-44, and 299-E33-18) range from 211 to 140 mg/L. Farther south, values drop below the drinking water standard of 45 mg/L, ranging from 24 mg/L (well 299-E33-339) to 7.5 mg/L (well 299-E33-338) south of the waste management area. Although there is a general decrease in nitrate from north to south, the importance of the BY crib relative to other sources is difficult to assess using the nitrate data presented above.

Technetium-99 concentrations generally decreased during fiscal year 2001 around the waste management area (Figure 2.9-12). This figure compares technetium-99 concentrations between well 299-E33-38, located at the BY cribs, with concentrations in wells along the west side of Waste Management Area B-BX-BY. Values range from 3,570 pCi/L at well 299-E33-31 west of the BY tank farm to 195 in well 299-E33-43 to the south. The two new wells completed in early fiscal year 2000 show no upward trend in technetium-99, remaining at low levels below 70 pCi/L for the last 2 years. Although technetium-99 continued to increase early in fiscal year 2001 in the central part of the waste management area, levels have dropped in wells 299-E33-9, 299-E33-44, and 299-E33-41 mirroring the decrease in technetium-99 seen further north at the BY cribs in well 299-E33-38 (Figure 2.9-13). In the south, technetium-99 ranges between 75 and 80 pCi/L in the newly installed wells, 299-E33-339 and 299-E33-337, but drops to 18 pCi/L in the southeast corner of the waste management area in well 299-E33-338. Whether the decrease is caused by local differences in the BY cribs plume or reflects interaction with another source is not presently known.

The ratio of nitrate to technetium-99 is one diagnostic tool used to identify different contaminant plumes with different sources in the groundwater. Tank-related sources are expected to have low ratios because of the large concentrations of technetium-99 with respect to nitrate in tank waste (HNF-SD-WM-TI-740). Ratios based on current estimates of tank waste composition from these farms are typically below 4. Ratios for data related to crib waste range from 40 to 70 for the BY cribs to over 200 for the 216-B-8 crib waste detected in well 299-E33-16 (PNNL-13116). When the technetium-99 and nitrate are low, background ratios are significantly higher (generally over 1,000).

The ratio of nitrate to technetium-99 is a diagnostic tool used to identify contaminant plumes in groundwater. Low ratios mean the contamination probably comes from tank waste, which contains high levels of technetium-99 compared to nitrate.

Nitrate to technetium-99 ratios for data collected from April through June 1999 are mapped in Figure 2.9-14. The current ratios also are mapped for data from May to August 2001 and are shown for comparison in Figure 2.9-15. In the past, ratios within the range from contamination associated with the BY cribs (shown in orange on Figures 2.9-14 and 2.9-15) extended from the BY cribs south along the west side of the BY tank farm and west to the corner of Low-Level Burial Ground 1. Also, the ratios for wells 299-E33-44 and 299-E33-41 were consistently lower (below 30) than those for wells in the surrounding area. The ratio in well 299-E33-16 at the head of the 216-B-8 crib displayed consistent values over time, ranging between 200 and 400. The 1999 values along the boundary of Low-Level Burial Grounds 1, ranging from 221 to 386 reflect low nitrate with very low levels of technetium-99 and are not associated with the 216-B-8 crib.

A comparison of the ratio data from 1999 (see Figure 2.9-14) to that from 2001 (see Figure 2.9-15) indicates southern movement of the BY crib plume is beginning to affect the groundwater chemistry farther to the south. The greatest changes can be seen around the periphery of the mapped area as wells shown in yellow on the 1999 map now display values in orange in 2001. For example, on the eastern side of the mapped area, well 299-E33-15 has dropped from 1,720 to 819 while well 299-E33-17 has dropped from 5,743 to 2,840. The increase in the size of the orange area shows the affect of the southern migration of nitrate and technetium-99, most likely from the BY crib plume.

The apparent southern migration of the area shown in red is due, in part, to the increase in the ratios at wells 299-E33-41 and 299-E33-44 and to the additional ratio data from boreholes 299-E33-45 and 299-E33-46, both of which have very low nitrate to technetium-99 ratios with technetium-99 values over 1,500 pCi/L (drinking water standard, 900 pCi/L). Technetium-99 concentrations just to the south are less than 80 pCi/L. This increase in the nitrate to technetium-99 ratios in the northern part of Waste Management Area B-BX-BY, reflects the increases in nitrate and technetium-99 along with the occurrences of cyanide and cobalt-60, which are markers for the BY crib plume. Thus, the groundwater under the waste management area appears to be experiencing influences from the BY crib plume as it slowly migrates southward.

Cyanide is another constituent that characterizes the BY crib plume as identified in the early 1990s north of the BY cribs (WHC-SD-EN-TI-020; PNNL-13022). August 2001 levels in the BY cribs are currently at 341 μg/L for well 299-E33-7 and 192 µg/L for well 299-E33-38 (Figure 2.9-16). In August 1999, this constituent was first detected south of the cribs in well 299-E33-44 (14 µg/L, August 2001) and later in February 2000, on the western side of the BY tank farm in well 299-E33-31 (28 µg/L, August 2001). During fiscal year 2001, cyanide was detected at low levels farther south on the western side in wells 299-E33-42 and 299-E33-32. Of the three newly installed wells along the southern border of the waste management area, cyanide was detected only in well 299-E33-337 at ~9 µg/L. This southern migration of cyanide is further evidence that the BY crib plume is beginning to negatively affect groundwater chemistry in the region of Waste Management Area B-BX-BY.

Although uranium concentrations have been relatively static in the past and have not reflected the sharp increases seen in cyanide, nitrate, and technetium-99, levels rose sharply in the central part of the waste management area (wells 299-E33-9 and 299-E33-44) after April 2000 to a maximum of 678 µg/L under the BY tank farm (Figure 2.9-17). Uranium at these high levels has not been found either upgradient or downgradient from this central location. Upgradient, under the BY cribs, uranium was found at 165 µg/L during August 2001 in well 299-E33-38 while downgradient, in wells 299-E33-41 and 299-E33-18, values range from 133 µg/L to 24 µg/L. Although there is some variability in values over time, there is no obvious increase in uranium at either of these downgradient wells.

To the west of the waste management area, uranium is increasing steadily (Figure 2.9-18). Values range from 66 µg/L in well 299-E33-31 to 29 µg/L in well 299-E33-42. Because uranium levels, both upgradient and downgradient of the BY tank farm, are either significantly lower or at background levels, the source of the uranium is, most likely, local. The uranium trend seen in well 299-E33-44 also indicates the uranium source is close to the BY tank farm. This well initially showed that uranium was not changing locally until April 2000 when concentrations began to rise sharply. This exponential climb over a short time period indicates that the uranium plume has not experienced much dispersion. Thus, the uranium has not traveled far in the groundwater before affecting the well. The source appears to be either a quasi-stagnant pocket caught in the structural low related to some past tank farm release or is currently moving through the vadose zone driven by some recent flushing event.

BY crib waste in the 1950s was associated with elevated cobalt-60, which today tracks with the cyanide. The high levels of cobalt-60 detected in the groundwater in the late 1950s are evidence that mobile constituents from the BY crib discharges affected groundwater. Although there is no cyanide data available before 1988, the historic uranium data is complete back to the late 1950s. Uranium concentrations associated with breakthrough of the waste effluent from crib discharges into the groundwater are characteristically low. In fact, values were seldom seen above natural background levels. Thus, there were no high concentrations of uranium in the groundwater associated with surrounding crib discharges. Also, the shape of the trend plot for well 299-E33-44 indicates that a steady-state source was operative at this site until concentrations rose sharply after April 2000. This sharp rise to high levels, seen best in well 299-E33-9, suggests the uranium is entering groundwater very close to the well. Multiple depth sampling will be performed in fiscal year 2002 to test if contamination is significantly stratified and if so, to determine the vertical distributions of contaminants.

Increasing uranium west of Waste Management Area B-BX-BY (e.g., wells 299-E33-26, 299-E33-31, and 299-E33-42; see Figure 2.9-18) suggests that uranium may be migrating toward the west or southwest from the waste management area. Alternatively, the increasing uranium seen in wells 299-E33-31 and 299-E33-42 may be related to movement from the BY cribs region.

Nitrite, which is present in processing waste at levels often equal to that of nitrate, is still found in well 299-E33-44 in the central part of the waste management area (1,050 µg/L, August 2001). Nitrite is not usually found in the groundwater, probably because it is oxidized to nitrate before it can be detected in the groundwater. The presence of nitrite might suggest a recent release from the waste management area; however, multiple depth sampling may provide evidence to assist in determining the source of the local contamination is the area.

Recently, tritium has become a contaminant of concern for Waste Management Area B-BX-BY. As shown in Figure 2.9-19, tritium began rising abruptly in wells 299-E33-43 and 299-E33-32 on the western side of the BX tank farm from local background values around 2,000 pCi/L in early 1999. Current values for the two wells are 12,800 pCi/L and 11,100 pCi/L, respectively, in August 2001. This trend is matched in wells 299-E33-334 and 299-E33-335 located in the southwestern corner of the site. The highest value of 21,400 pCi/L is found at the southeastern corner of the BX tank farm in the recently installed well 299-E33-339. This is above the drinking water standard of 20,000 pCi/L. Further to the east, a value of 14,500 pCi/L was detected in well 299-E33-337. To the north, tritium is still at background levels of 2,130 and 2,450 pCi/L in wells 299-E33-41 and 299-E33-42, respectively, indicating that tritium is not migrating into the local area from the north. Tritium values are also low in the southeastern corner of the waste management area in new well 299-E33-338. During the drilling of borehole 299-E33-45, a significant perched water zone was found on a local silt layer ~4.6 meters above the water table. Analyses of the perched water showed tritium levels over 75,000 pCi/L. Although a value of 2,410 pCi/L for tritium was reported for a groundwater sample collected from well 299-E33-45 on January 26, 2001, breakthrough of this contamination to the groundwater in other areas may be the source of the tritium.

New wells at the southern side of Waste Management Area B-BX-BY detected elevated concentrations of tritium, and the concentration in one well exceeded the drinking water standard. This is the first time that tritium has been identified as a contaminant of interest for this waste management area. The contamination may be related to a perched water zone just above the water table.

The historical discharge of effluent to the ground in and around Waste Management Area B-BX-BY has resulted in complex patterns of groundwater contamination with some interaction between multiple plumes. The highest level of technetium-99 is located under the BY cribs to the north and is attributed to discharges to the cribs in the mid-1950s. The technetium-99 is associated with high concentrations of nitrate and cyanide with some cobalt-60. This contamination forms an extensive plume that is moving southward, affecting the groundwater under the northern part of Waste Management Area B-BX-BY. Elevated uranium is found locally under the BY tank farm while a small tritium plume has been found along the southern margin of the waste management area. Although at this time, there is no clearly identified groundwater contamination from the waste management area, it may have contributed to uranium, tritium and other contamination in the vicinity of the BY and BX tank farms. The Waste Management Area B-BX-BY will continue in assessment with quarterly monitoring of the groundwater.

2.9.1.11 RCRA Parameters for the 216-B-63 Trench

Groundwater monitoring continues to provide no evidence that dangerous nonradioactive constituents from the 216-B-63 trench have entered groundwater. The RCRA interim status indicator parameters are pH, specific conductance, total organic carbon, and total organic halides (40 CFR 265.92 [b][3]). Included in the analysis list (see Appendix A, Table A.13) for this trench are alkalinity, gamma scan, gross beta, and turbidity. Statistical analyses revealed no exceedances in pH, specific conductance, total organic carbon, or total organic halides (see Appendix A, Section A.1.7).

RCRA monitoring at the 216-B-63 trench continued to provide no evidence that it has contaminated groundwater.

Groundwater analysis continues to indicate an increase in concentrations of calcium, magnesium, sodium, and sulfate in several wells. The rate of change in concentration, however, has slowed and may indicate that groundwater chemistry has stabilized beneath the trench. The constituent concentrations do not exceed maximum contaminant levels.

The current network is composed of six wells drilled specifically to monitor this trench. The network also includes five upgradient wells drilled to monitor the low-level burial grounds located just north of the trench and one upgradient well drilled to monitor Waste Management Area B-BX-BY. The network currently is considered adequate. The estimated flow rate at the 216-B-63 trench is 0.01 to 0.1 meters per day (see Appendix A, Table A.2).

2.9.1.12 RCRA Parameters for Low-Level Waste Management Areas 1 and 2

The two low-level burial grounds in the 200 East Area, Low-Level Waste Management Area 1 and Low-Level Waste Management Area 2, are monitored under interim status detection monitoring.

RCRA monitoring at Low-Level Waste Management Areas 1 and 2 indicates no groundwater contamination from these facilities.

Low-Level Waste Management Area 1

Groundwater monitoring under interim status requirements continued at this RCRA site in fiscal year 2001. The well network was sampled twice for indicator and site-specific parameters (see Appendix A, Table A.20). The monitoring network meets all RCRA requirements and no additional wells are planned.

The groundwater gradient in this portion of the 200 East Area is almost flat making the determination of groundwater flow direction difficult. Based on contaminant plumes, the flow direction appears to be to the northwest. Recent studies using total surface analysis and colloidal borescope have been inconclusive about flow under Low-Level Waste Management Area 1 (PNNL-13404). The estimated flow rate at Low-Level Waste Management Area 1 is ≤0.5 meter per day (see Appendix A, Table A.2)

Downgradient monitoring well 299-E33-34 continued to exceed the critical mean for specific conductance (617.1 µS/cm) in samples taken in fiscal year 2001 (Figure 2.9-20). This exceedance is related to the nitrate plume and not Low-Level Waste Management Area 1. DOE notified the Washington State Department of Ecology in 1999. Monitoring well 299-E32-10 also exceeded the critical mean for specific conductance in 2001. This was not unexpected, as this well is close to well 299-E33-34. Because no waste has been placed in the northern portion of this site and there is a known nitrate plume from an upgradient source, no further action is necessary. Critical mean values are listed in Appendix A, Table A.21. Results exceeding drinking water standards are listed in Appendix A, Table A.3.

Low-Level Waste Management Area 2

This RCRA site continued in RCRA interim status (indicator-evaluation requirements) in fiscal year 2001. Wells were sampled twice for indicator and site-specific parameters (see Appendix A, Table A.22). The monitoring network for Low-Level Waste Management Area 2 is adequate to detect releases from the facility. However, the continued water-level decline may cause additional wells to go dry.

Groundwater flow appears to be to the west based on small differences in head at wells along the southern boundary of Low-Level Waste Management Area 2. The flow regime in this area is influenced by the basalt subcrop to the north and east. The estimated flow rate at Low-Level Waste Management Area 2 is 0.05 to 0.8 meter per day (see Appendix A, Table A.2).

Statistical evaluations for this area determined that upgradient well 299-E34-7 continued to exceed the critical mean for specific conductance. The major contributors to the increase are sulfate and calcium. The source of these constituents is not known. However, there is only 0.5 meter of water remaining in this well, which is completed at the top of basalt. The increase may be related to the basalt chemistry. This well also exceeded the comparison value for total organic carbon (1,868 μg/L) and total organic halides (9 μg/L) in fiscal year 2001 (Figure 2.9-21). Samples analyzed in fiscal year 2000 for volatile and semivolatile organics in this well did not reveal a likely contaminant. Samples collected in April 2001 were analyzed for oil and grease and total petroleum hydrocarbons (diesel). These results were consistent with the total organic carbon values (1.4 mg/L oil and grease, 0.09 mg/L total petroleum hydrocarbons diesel). Total organic halides also exceeded the critical mean in this well in fiscal year 2001. Additional analyses will be required to identify the source of the elevated total organic halides. Appendix A, Table A.23 lists the critical mean values based on data from the upgradient wells. Appendix A, Table A.3 summarizes constituents exceeding drinking water standards.

2.9.1.13 Gable Mountain Pond (216-A-25 Pond)

Gable Mountain Pond is located in the area between the 200 East Area and Gable Mountain. Beneath the south portion of the pond, basalt bedrock is above the water table. Beneath the north portion of the pond, the groundwater flow direction is probably to the west based on the water-table map.

The former Gable Mountain Pond contaminated groundwater with nitrate and strontium-90.

Between July 1999 and January 2000, contamination was characterized at Gable Mountain Pond as part of the 200-CW-1 Operable Unit remedial investigation (BHI-01367). Although significant amounts of cesium-137 and strontium-90 were detected in vadose zone sediment, the cesium-137 remains higher in the profile and strontium-90 is the most significant groundwater contaminant. The drinking water standard for strontium-90 is 8.0 pCi/L and the DOE derived concentration guide is 1,000 pCi/L. Strontium-90 in the Gable Mountain Pond area apparently resulted from the discharge of waste to that pond during its early use. Wells completed above the basalt in the vicinity of this pond are becoming difficult to sample because of declining water levels.

Strontium-90 concentrations reversed a rising trend during fiscal years 1999 and 2000 in several wells near Gable Mountain Pond. Strontium-90 was detected in groundwater at levels above the DOE derived concentration guide in the only well that was sampled at Gable Mountain Pond in fiscal year 2000. The concentration in the sample from that well, 699-53-47A, was 1,210 pCi/L, considerably higher than the 1999 sample, although concentrations were also above the DOE derived concentration guide in 1997 and 1998. The wells near Gable Mountain Pond were not sampled in fiscal year 2001 owing to the need to develop waste management documentation in support of CERCLA sampling activities.

Nitrate continued to be detected in wells monitoring Gable Mountain Pond at levels above the maximum contaminant level in fiscal years 1999 and 2000 (see Figure 2.9-9). Well 699-53-47A contained 106 mg/L of nitrate in the fiscal year 2000 sample. In fiscal year 1999, 402 mg/L of nitrate was detected in well 699-53-48B, which was not sampled in fiscal years 2000 and 2001.

2.9.2 PUREX Plant

Numerous disposal facilities received waste from PUREX Plant operations. In particular, numerous cribs to the south and east of the PUREX building affected groundwater quality over a large area of the site (see Figure 2.9-1). The most extensive and significant contaminants are iodine-129, nitrate, and tritium. Three cribs (216-A-10, 216-A-36B, and 216-A-37-1) are at least partially responsible for the significant contamination and are monitored in accordance with RCRA. Monitoring results indicate that the impact to groundwater originates from other facilities as well. These other facilities are located generally northeast and east of the plant, and are being addressed under the CERCLA/RCRA past-practice process (216-PO-1 Operable Unit). The 216-A-29 ditch, B Pond, Liquid Effluent Retention Facility, 200 Areas Treated Effluent Disposal Facility, and high-level waste tanks in Waste Management Areas A-AX and C also are monitored in accordance with RCRA. However, to date there is little evidence to suggest that groundwater at these sites has been contaminated with RCRA-regulated waste.

2.9.2.1 Groundwater Flow

Groundwater beneath the PUREX Plant occurs in an unconfined aquifer, one or more confined aquifers overlying basalt bedrock, and confined aquifers within the basalt sequence (see Section 2.14 for more information on the upper-basalt confined aquifer). However, none of the aquifers above the basalt is continuous across the entire PUREX area. Groundwater in the western part of the PUREX Plant area is influenced by a highly-permeable buried Pleistocene flood channel located in the northwest-southeast direction across the 200 East Area. Further influences include the Ringold Formation mud units, the May Junction fault, and past disposal of liquid effluents at the 216-B-3 pond. These features interact to produce a complex flow system. A detailed discussion of the 200 East Area hydrology can be found in PNNL-12261. Consequently, only a brief overview along with new findings for fiscal year 2001 are presented below.

Monitoring Objectives at PUREX Plant

Groundwater monitoring is conducted near PUREX Plant:

- triennially to annually to describe the nature and extent of contamination
- semiannually to monitor trends in variable constituents/wells
- semiannually to detect possible impact of five RCRA waste management areas
- quarterly to assess contamination from one RCRA waste management area
- quarterly or semiannually to detect possible impact of the Treated Effluent Disposal Facility.

The water table in the vicinity of the buried flood channel has a very low gradient (see Plate 1) due to the high permeability of the Hanford formation sediments that predominate in the ancient channel. East of this channel, in the area of the 216-B-3 pond, the lower-permeability Ringold lower mud unit is found at the water table (Figure 2.9-22), creating confining aquifer conditions below. To the south, the lower mud unit, and confined aquifers beneath it, dip below the water table. Consequently, there is no unconfined aquifer in the vicinity of the 216-B-3 pond. Farther east is the north-south-trending May Junction fault, which may be acting as a barrier to groundwater flow.

Groundwater in the unconfined aquifer entering the 200 East Area from the west divides and flows to the Columbia River along two separate paths: one to the southeast and one to the northwest through the gap between Gable Butte and Gable Mountain. The flow is currently thought to divide in the northwestern corner of the 200 East Area (see Section 2.9.1.1). Therefore, flow within the southern part of the PUREX Plant area is currently thought to be toward the southeast within the unconfined aquifer. This is confirmed by the migration of contaminant plumes from the PUREX cribs. In the northern part of the PUREX Plant area, flow is believed to have a significant southern flow direction (southwest to southeast), as groundwater must flow south around the mud units that are located in the vicinity of the 216-B-3 pond.

Past disposal of liquid effluents at the 216-B-3 pond has produced high water levels at wells in the underlying confined aquifer, the Ringold Formation unit A (or unit 9) (see Figures 2.9-22 and 2.9-23). The May Junction fault located east of the 216-B-3 pond may cause the local groundwater flow to be diverted to the south or southwest (PNNL-13367; PNNL-12261). The water in this confined aquifer is believed to discharge to the unconfined aquifer to the south or west at locations where the Ringold lower mud unit (unit 8) is discontinuous. Once the groundwater reaches the highly-permeable buried channel, it flows southeastward. Groundwater flow in the confined aquifers is discussed further in Sections 2.9.2.11, 2.9.2.13, and 2.9.4.1.

Typically, groundwater flow direction and flow rates in the unconfined aquifer can be estimated from water-table maps. However, estimates of flow direction and rate from water maps are difficult in the PUREX Plant area because of the very low water-table gradient. Alternate techniques for characterizing groundwater flow direction and flow rate have been incorporated to supplement the water-table map method. They include groundwater contamination plume maps, contaminant concentration trend plots, and data from use of the colloidal borescope (a down-well flowmeter; Kearl 1997). Results of these techniques are included in the following sections along with discussions of flow direction and flow rate beneath the individual waste facilities in the PUREX Plant area.

The colloidal borescope is an instrument that measures groundwater flow direction and rate in individual wells. In fiscal year 2001, the borescope was used in 20 wells in the PUREX plant region. Borescope results indicated southeastern flow beneath Waste Management Area C. Results were inconclusive in wells around the PUREX cribs and Waste Management Area A-AX .

During fiscal year 2001, an investigation of groundwater flow was conducted in the PUREX Plant area in 20 wells using the colloidal borescope (Kearl 1997). This tool is a down-well probe that can be lowered by a cable into the well screen, and contains a microscope, light source, digital TV camera, and fluxgate magnetometer for orientation. Basically, colloidal-size particles in the groundwater are detected by the digital camera, and a continuous digital image is sent to a computer at the well head via the cable. The image data are processed with time, and the direction and speed of the moving colloidal-size particles are recorded. The underlying assumptions are that the movement of colloidal-size particles within the well screen is the same direction as horizontal groundwater flow direction outside the well screen (in the formation), and that the speed of particle movement is proportional to groundwater flow rate in the formation (proportionality depends on formation hydraulic conductivity).

The 20-well colloidal borescope investigation during fiscal year 2001 was at three sites within the PUREX Plant area, Waste Management Areas A-AX and C, and PUREX cribs. Results of groundwater flow directions (Figure 2.9-24) are generally inconclusive except for groundwater flow in the vicinity of Waste Management Area A-AX where the flow direction appears to be toward the southeast. Further details about the colloidal borescope investigation at the three sites are provided in the discussion of groundwater flow at each of the sites (see Sections 2.9.2.7, 2.9.2.8, and 2.9.2.9).

2.9.2.2 Tritium

The highest tritium concentrations in the 200 East Area continued to be found in wells near cribs that received effluent from the PUREX Plant (see Plate 2). Concentrations of >2 million pCi/L (the DOE derived concentration guide) were detected only in well 299-E17-9 next to the 216-A-36B crib (Figure 2.9-25). The maximum concentration detected in this well in fiscal year 2001 was 4.3 million pCi/L, which is up from the highest fiscal year 2000 reported value of 2.5 million pCi/L. Tritium concentrations that exceed the 20,000 pCi/L drinking water standard continued to be found in many wells affected by cribs near the PUREX Plant. In the area immediately downgradient of the cribs where concentrations are >200,000 pCi/L, tritium is attenuating naturally as a result of radioactive decay and dispersion combined with the decreasing source that resulted from the termination of operations.

A well near the PUREX cribs continued to detect the highest tritium concentrations in the 200 East Area; >4 million pCi/L, an increase over fiscal year 2000.

Prior to fiscal year 1998, tritium levels measured in well 699-37-47A, near the southeastern corner of the 200 East Area and completed in 1996, remained below 20,000 pCi/L (the drinking water standard). In 1998, tritium concentration rose to 36,000 pCi/L (Figure 2.9-26). The rise in tritium concentration was probably due to the reduction in wastewater discharged in the vicinity of B Pond. Well 699-37-47A is very near the mixing area of groundwater from the northwest that has higher tritium concentration and groundwater from the B Pond area that has lower tritium levels. As the influence of wastewater in the B Pond area continued to shrink, the mixing area for groundwater from the two sources (near well

699-37-47A) became more dominated by groundwater from the northwest that has higher tritium concentration. During 1999 and 2000, the concentration of tritium decreased temporarily to as low as 21,000 pCi/L, but in April 2001, it was back up to 30,100 pCi/L.

Two major pulses of the tritium plume from the PUREX cribs were detected in downgradient wells and are related to the two periods of PUREX Plant operation. More tritium contamination was released during the first period of operation during 1956 to 1972.

The widespread tritium plume (see Plate 2), extends from the southeast portion of the 200 East Area to the Columbia River. Separate tritium pulses associated with the two periods of PUREX Plant operations contributed to the plume. The first pulse, which resulted from discharges during 1956 to 1972, can be detected near the Columbia River (e.g., well 699-40-1; Figure 2.9-27). Elevated tritium concentrations measured immediately downgradient from the 200 East Area (within the 80,000 pCi/L isopleth line) represent the second pulse associated with the re-start of operations between 1983 and 1988. Figure 2.9-28 shows the arrival of the plume in early 1987 at well 699-24-33, near the Central Landfill, long after the passage of the plume from the earlier operation. The tritium concentrations in this well during the passage of the first pulse were at least three times the maximum concentrations in the second pulse. Thus, the second pulse is expected to have a significantly lower impact than the first pulse downgradient toward the Columbia River. The overall decline in tritium concentrations throughout this plume indicates that the greatest impact expected at the Columbia River has already occurred.

The zone of lower tritium concentration near Energy Northwest (see Plate 2) may be due to a zone of lower hydraulic conductivity in the unconfined aquifer. At that site, the water table is within the upper portion of the Ringold Formation that locally may have a greater degree of cementation. Tritium at the 618-11 burial ground is discussed in Section 2.12.

2.9.2.3 Iodine-129

The portion of the iodine-129 plume that exceeds the drinking water standard is smaller than tritium and has not reached the Columbia River.

The highest iodine-129 concentrations (drinking water standard of 1.0 pCi/L) detected in the 200 East Area in fiscal year 2001 were near the PUREX Plant cribs (Figures 2.9-29 and 2.1-5). The maximum concentration of iodine-129 detected in fiscal year 2001 was 9.8 pCi/L in well 299-E24-16 near the 216-A-10 crib. Concentrations of iodine-129 in groundwater near the PUREX cribs are generally declining slowly or are stable, as shown for well 299-E17-9 (Figure 2.9-30). The iodine-129 plume extends southeast into the 600 Area and appears to coincide with the tritium and nitrate plumes (see Figures 2.1-3 and 2.1-4).

2.9.2.4 Nitrate

Nitrate originating at the PUREX site forms a broad plume, but most of the plume is below the maximum contaminant level.

High nitrate concentrations continue to be found near liquid waste disposal facilities that received effluent from PUREX Plant operations, and the concentrations are generally decreasing with time. The maximum nitrate concentration detected near the PUREX Plant in fiscal year 2001 was 184 mg/L in well 299-E17-9, which is adjacent to the 216-A-36B crib. The extent of the nitrate plume that originates from the 200 East Area (see Figure 2.1-4) is nearly identical to that of the tritium plume. However, the area with nitrate >45 mg/L (the maximum contaminant level) is considerably more restricted than the area with tritium above its drinking water standard (20,000 pCi/L). Nitrate at levels above the maximum contaminant level north of the 400 Area, within the area impacted by PUREX operations, is attributed to 400 Area disposal (see Section 2.10.2).

2.9.2.5 Strontium-90

A single well (299-E17-14), near the 216-A-36B crib, had a concentration above the drinking water standard (8.0 pCi/L) for strontium-90 (a beta emitter) in fiscal year 2001. The maximum strontium-90 concentration detected in fiscal year 2001 was 17.7 pCi/L, which is slightly lower than the maximum concentration during fiscal year 2000 (19.1 pCi/L). In general, the concentration of strontium-90 has been rising in this well since 1997. The impact is localized because of the lower mobility of strontium-90 compared to iodine-129, nitrate, and tritium. This result is consistent, in part, with a gross beta (drinking water standard of 50 pCi/L) concentration of 56.7 pCi/L in the same well. Strontium-90 was detected at five other wells near the 216-A-10 and 216-A-36B cribs during fiscal year 2001. The concentrations in these four wells have been stable or decreasing since 1994 except for well 299-E24-16 (near 216-A-10 crib), where it has also been increasing since 1997.

The 56.7 pCi/L result for gross beta at well 299-E17-14 during fiscal year 2001 is more than can be accounted for from the 17.7 pCi/L result for strontium-90 in the same well. If the only beta emitter present were strontium-90, gross beta would be ~28 pCi/L. Therefore, the 56.7 pCi/L must include another beta emitter. The higher result for gross beta is probably due to technetium-99 (also a beta emitter). The last technetium-99 result from well 299-E17-14 was 209 pCi/L in fiscal year 1994. Technetium-99 is no longer routinely sampled at well 299-E17-14 because previous results were significantly less than the drinking water standard (900 pCi/L), and gross beta analysis could be used as a screening tool for technetium-99 and other beta emitters.

2.9.2.6 Manganese

Filtered manganese concentrations remained elevated at wells near the 216-A-36B and 216-A-37-1 cribs (PUREX cribs). At the 216-A-37-1 crib, the concentration remained elevated but variable since 1998 in well 299-E25-19 (Figure 2.9-31), but the trend decreased in well 299-E25-17. During fiscal year 2001, the concentrations varied from 52 to 25 µg/L with a general downward trend at well 299-E25-19 (drinking water standard 50 µg/L), whereas at well 299-E25-17 the concentration remained steady at ~27 µg/L.

At the 216-A-36B crib, the concentration in well 299-E17-9 increased to 191 µg/L in October 2000 from the earlier trend below 20 µg/L (Figure 2.9-32). Later, in April 2001, the concentration had decreased to 112 µg/L, and in the fall, the concentration dropped to 50 µg/L. The source of the increased levels of manganese is unknown but presumed to be from the associated PUREX cribs. However, it is possible that the elevated manganese at these wells may be related to corrosion of the well. These wells are of an older type (perforated, carbon steel casing with no screen) and are not compliant with WAC 173-160 (not RCRA compliant).

2.9.2.7 RCRA Assessment Summary for the PUREX Cribs

The PUREX cribs (216-A-10, 216-A-36B, and 216-A-37-1) are monitored in interim status to assess groundwater quality (see Appendix A). Groundwater flow for the two western cribs (216-A-10 and 216-A-36B) is most likely toward the southeast. The flow rate is difficult to determine because the water table is so flat that the hydraulic gradient is difficult to determine. Similarly, the eastern crib (216-A-37-1) is within the area of a flat water table, and the hydraulic gradient is difficult to determine there also. Colloidal borescope results do not provide additional information because they were inconclusive in the PUREX region. Formerly, groundwater flowed mainly to the southwest at the 216-A-37-1 crib when B Pond was in full operation. But with the decreased discharges to B Pond, the flow may revert to more of a southerly or southeasterly direction.

Groundwater downgradient of the 216-A-10, 216-A-36B, and 216-A-37-1 cribs continued to be monitored under a groundwater quality assessment program. These cribs and other waste sites not regulated under RCRA all contributed to the widespread iodine-129, nitrate, and tritium plumes.

The PUREX cribs are located in a region where several groundwater contamination plumes contain constituents that exceed drinking water standards. The similarities in effluent constituents disposed to these cribs, as well as to the 216-A-45 crib, make determining the contribution of the PUREX cribs difficult. During fiscal year 2001, gross beta, iodine-129, filtered manganese, nitrate, strontium-90, and tritium exceeded drinking water standards in at least one well (see Appendix A, Table A.3, and Sections 2.9.2.2 through 2.9.2.6).

Although the concentrations of sulfate and chloride did not exceed drinking water standards, they have increased sharply in wells monitoring the PUREX cribs during the period 1998 through 2001. The reason for these rises in sulfate and chloride concentrations is unknown.

The far-field monitoring well network of the PUREX cribs is integrated with the well network for the 200-PO-1 Operable Unit and the site surveillance well network downgradient of the 200 East Area. These well networks monitor the approximate area of the Hanford Site covered by the tritium plume (above 2,000 pCi/L) from the 200 East Area. Besides the tritium plume, this area also contains the iodine-129 and nitrate plumes. The data from RCRA monitoring of the PUREX cribs are integrated into the assessment of the overall extent of contamination for these constituents (see Sections 2.9.2.2 through Section 2.9.2.6). Contaminant trends of the major plumes (tritium, nitrate, and iodine-129) are generally decreasing in concentration except for localized places where slight increases are observed.

2.9.2.8 RCRA Parameters for Waste Management Area A-AX

This section provides information on the current nature of the unconfined groundwater in the immediate vicinity of the single-shell tanks at Waste Management Area A-AX. The most recent description of stratigraphy for this site can be found in PNNL-13023. Waste Management Area A-AX is regulated under RCRA, and groundwater monitoring is under interim status, indicator-evaluation requirements (WAC 173-303 and by reference 40 CFR 265.92). RCRA monitoring began in 1992.

RCRA Waste Management Area A-AX contains single-shell tank farms. Monitoring data in fiscal year 2001 did not indicate any impact to groundwater. New monitoring wells may be needed in response to a change in the interpretation of groundwater flow direction.

Groundwater Flow

Based on local hydrographs and colloidal borescope measurements, it has been determined that the groundwater flow direction is generally to the southeast (see Figure 2.9-24). In fiscal year 2001, colloidal borescope investigations were conducted in five local wells surrounding the waste management area. A sixth well, 299-E24-19, is deviated from vertical, and the colloidal borescope could not be run in this well. Results from this study indicate a general agreement with water elevation data, which suggest an eastward flow direction in the vicinity of Waste Management Area A-AX (Figure 2.9-33; well 299-E24-20, the upgradient well, is west of well 299-E25-2). Wells located to the west tend to show higher water-table elevations than those southeast of the site.

The existing well network at Waste Management Area A-AX was designed for groundwater flow to the southwest. In response to the change in the interpretation of the flow direction, the Monitoring Efficiency Model (MEMO) was run to assist designing a more complete groundwater network. An interim change notice to the groundwater monitoring plan for this site (PNNL-13023) discusses these model studies and proposed changes in the network. Two new upgradient wells and three additional or replacement downgradient wells have been proposed.

The estimated flow rate at Waste Management Area A-AX is 1.7 to 3.3 meters per day (see Appendix A, Table A.2) depending on the hydraulic conductivity value used in the Darcy equation. Using these estimates of flow rate, the average distance of groundwater flow at the site is 621 to 1,205 meters per year, reflecting the high permeability of the sediment in the aquifer.

Groundwater Chemistry

Although concentrations of indicator parameters, specific conductance, total organic carbon, and total organic halides have not exceeded the critical mean values at Waste Management Area A-AX since 1992, the pH fell below the critical range (6.89 to 9.24) in well 299-E24-19 in July 2001. This well is, at best, crossgradient as it is located on the southwest side of the waste management area (see Appendix A, Figure A.15). Verification sampling was conducted in October 2001 resulting in a pH value of 7.13. Causes for the low pH are discussed below in relation to the elevated chromium found in the groundwater at this location. Groundwater monitoring to date provides no evidence that the site has contaminated groundwater.

Specific conductance values ranged from ~261 to 374 μS/cm during fiscal year 2001 (Figure 2.9-34), reflecting changes primarily in sulfate and nitrate concentrations. The primary cation is calcium. These specific conductance values are well below the critical mean of 534.9 μS/cm. Figures 2.9-35 and 2.9-36 show trend plots for sulfate and nitrate, comparing contaminant levels in groundwater wells monitoring the waste management area network. The specific conductance changes that occurred at Waste Management Area A-AX are generally dominated by sulfate except for well 299-E24-20 (maximum contaminant level 250 mg/L). Although sulfate appears to be increasing in wells on the southwest side of the waste management area, concentration ranges from 37 to 48 mg/L, which is within the Hanford Site background values reported in WHC-EP-0595 (~14 to 60 mg/L). Although in the past, sulfate concentrations above background values were identified in two wells, 299-E25-40 and 299-E25-41, the recent trend appears to be decreasing to values of 55 to 57 mg/L.

Nitrate values currently range from ~4 to 12 mg/L, which falls within the ranges of background values of 3 to 12 mg/L for the Hanford Site (WHC-EP-0595) except for one well. Nitrate concentrations in well 299-E24-20 are ~36 mg/L, which is above the maximum background value of 12 mg/L (see Figure 2.9-36). This well is located south of the 244-AR vault and is the upgradient well for this waste management area. Nitrate values rose from 6 mg/L in February 1996 to 38 mg/L in June 2001.

Technetium-99 concentrations are low (Figure 2.9-37) at this waste management area and there appears to be no correlation between nitrate and technetium-99. There is, however, a distinct correlation between nitrate and tritium in well 299-E24-20, which remained the same from ~9,200 pCi/L in February 2000 to 9,170 pCi/L in December 2000. Most tritium values in other wells at the waste management area range from 3,530 to 5,000 pCi/L. The drinking water standards for tritium and nitrate are 20,000 pCi/L and 45 mg/L, respectively. This local region had extremely high values of tritium (over 200,000 pCi/L) in the late 1960s when PUREX was operating. Also, nitrate concentrations in this well were above 60 mg/L in early 1992. The current elevated nitrate may be this same pocket of nitrate moving back through the well.

One well monitored for Waste Management Area A-AX appears to have a corroding screen, which increases concentrations of chromium, manganese, and nickel in groundwater samples.

In filtered samples from well 299-E24-19, chromium continues to be detected at values above the drinking water standard of 100 μg/L. In July 2001, it was reported at 1,640 μg/L (Figure 2.9-38). This well historically has high concentrations of chromium, nickel (100 μg/L maximum contaminant level), and manganese (50 μg/L maximum contaminant level). The elevated metals concentrations are due most likely to corrosion of the well screen.

Comprehensive purge sampling was conducted during December 2000. Chromium concentrations, specific conductance, and pH were monitored during an extensive purge from the first borehole water removed from the well for over 40 minutes at a pumping rate of 3 gallons per minute. Plots of the chromium concentration and specific conductance are shown in Figure 2.9-39. The results show, as purging began, the chromium content rapidly increased to a maximum of 8,200 μg/L between 2 and 4 minutes. As the purge continued, the chromium concentration sharply declined. Although it initially dropped, specific conductance stayed relatively constant ranging from 230 to 274 μS/cm, indicating that the changes in chromium are not associated with specific conductance.

Figure 2.9-40 shows the same chromium data compared to pH. As the chromium rose sharply, the pH fell from an initial value of 7.08 to a low of 6.17 and then increased as the chromium concentration continued to decrease. During the corrosion of steel, a reduction-oxidation reaction occurs whereby free hydronium ions are produced in the aqueous environment. Thus, the pH is decreased as the metal content is increased, explaining the drop in pH below the critical range for the site. It is important to note that if the chromium flowed with the groundwater over an extended distance from the well screen, the chromium content would not have decreased as the purge progressed. This study provides further support for the premise that the elevated metals historically found in the groundwater at this well are related to corrosion of the screen.

2.9.2.9 RCRA Parameters for Waste Management Area C

RCRA Waste Management Area C contains single-shell tank farms. Monitoring data in fiscal year 2001 did not indicate any impact to groundwater with dangerous waste constituents. New monitoring wells may be needed in response to a change in the interpretation of groundwater flow direction.

This section provides information on the current nature of the uppermost unconfined aquifer in the immediate vicinity of single-shell tanks at Waste Management Area C. Waste Management Area C is regulated under RCRA, and groundwater monitoring is under interim status, indicator-parameter evaluation requirements (WAC 173-303 and by reference 40 CFR 265.92). RCRA monitoring began in 1991.

Groundwater Flow

Based on an integration of colloidal borescope measurements and hydrographs of local wells corrected for vertical deviations, groundwater beneath Waste Management Area C probably flows to the southwest. In fiscal year 2001, colloidal borescope investigations were conducted in four of the five RCRA network wells. The fifth well (299-E27-15) is within a borehole that is deviated too much from vertical to use the colloidal borescope. Results of groundwater flow directions using the colloidal borescope are shown in Figure 2.9-24. Although there were several horizons measured in each of the four wells, only one horizon in each well had stable flow (flow zones). The other horizons measured were either swirling or stagnant. The flow zone in well 299-E27-13 had a southwest flow direction, was measured for over 2 hours, and had little or no vertical component to the flow (mostly horizontal). This result is considered reliable. The flow zone in well 299-E27-14 also had a southwest flow direction and little or no vertical component, but the period of stable flow was measured for only 36 minutes. A measurement period of only 36 minutes with the colloidal borescope is usually considered too short to be reliable. Therefore, the result is accepted with caution. The other two wells, 299-E27-7 and 299-E27-12, had one flow zone each, but the flow zones had large vertical components. Flow zones with large vertical components are not considered reliable indicators of flow direction.

Corrections to water elevations were made for four wells based on the results of gyroscope surveys. Gyroscopic corrections are not available for one well, 299-E27-13. When considered together, water-level data and borescope results indicate a general flow direction to the southwest. In Figure 2.9-41, hydrographs are compared for wells 299-E27-7 and 299-E27-13. Water-table elevations are generally higher (upgradient) at well 299-E27-7 and lower at well 299-E27-13 (downgradient). Well 299-E27-14 is crossgradient while well 299-E27-15 is slightly upgradient (see Appendix A, Figure A.17 for well locations). A flow direction toward the southwest is consistent with the regional water-table map (see Plate 1).

The existing groundwater monitoring well network was designed to monitor groundwater flow toward the west (WHC-SD-EN-AP-012). Groundwater flow models have been constructed to determine the need and the locations for groundwater wells to optimize monitoring at this tank farm. The well network was redesigned. Three additional downgradient wells are recommended with possibly one new upgradient well.

The estimated groundwater flow rates calculated using the Darcy equation range from 1.2 to 2.3 meters per day (see Appendix A, Table A.2). Based on these estimates of flow rate, the groundwater moves from 438 to 840 meters per year. The rate of water table decline beneath Waste Management Area C averaged over the last 3 years is 0.17 meter per year. If this rate continues, wells at this site should be usable for at least 10 years.

Groundwater Chemistry

During fiscal year 2001, critical mean values (or range for pH) were not exceeded for the three indicator parameters of pH, total organic carbon, and total organic halides. However, the critical mean for specific conductance (553.3 μS/cm) was exceeded in well 299-E27-14 at the end of fiscal year 2001 (Figure 2.9-42). An averaged value of 614 μS/cm was reported for this crossgradient well for the September 2001 sampling event. The increase in specific conductance is due primarily to rising sulfate and calcium along with nitrate and chloride (Figure 2.9-43). Sulfate was 135 mg/L while nitrate was 29 mg/L for July 2001. The September 2001 sulfate value is abnormally low and is under review. The nitrate value for September 2001 is 43.8 mg/L, very close to the drinking water standard of 45 mg/L.

Technetium-99 concentrations continue to increase in all wells at Waste Management Area C (Figure 2.9-44). This technetium-99 contamination correlates to the rising specific conductance . Although downgradient well 299-E27-13 had a pulse of technetium-99 (487 pCi/L) seen in 1998, the recent technetium-99 contamination began to increase in 1997 at well 299-E27-14. In July 2001, the reported value was 1,190 pCi/L. The greatest increase in fiscal year 2001 was at well 299-E27-7, which had a maximum value of 2,190 pCi/L in July 2001 (drinking water standard 900 pCi/L). The correlation of the nitrate to the technetium-99 is shown in Figure 2.9-45. As can be seen, nitrate is greater in well 299-E27-14, while technetium-99 is higher in well 299-E27-7. These differences in concentration levels may be due to chemical differences within a larger, regional plume or to different sources.

The increases in well 299-E27-14 are part of a contaminant plume that may be moving into the area from upgradient areas in recent years (1995 to the present). Although the source of this contamination is presently unknown, it may be related to past discharges that moved through the area when the B Pond was in full operation or from the upgradient 216-B-3-1 ditch. As part of a continuous ditch system connected to the 216-B-63 trench, this ditch was decommissioned in 1964 after an accidental release of mixed fission products from the PUREX Plant was discharged directly to the 216-B-3-1 ditch (DOE/RL-89-28).

The technetium-99 level in well 299-E27-7 has risen sharply indicating a short travel time and a short travel distance in the groundwater from the point of entry into the groundwater to the well. Therefore, the 216-B-3-1 ditch is probably not the source of this groundwater contamination. Results from well 299-E27-7 have, in the past 2 years, shown low levels of cyanide with a maximum value of 17 μg/L in June 2000. Ferrocyanide scavenging was conducted in the 244-CR vault with storage in selected tanks at Waste Management Area C (HNF-SD-WM-TI-470). Although well 299-E27-7 is the upgradient well for this waste management area, the only known source for cyanide in this area is the waste stored in the C tank farm. However, cyanide concentrations decreased during fiscal year 2001, and presently, it is not detected in this well or any other network monitoring well.

There does not appear to be other tank-related waste in the groundwater at Waste Management Area C. Tritium levels are low, generally <1,500 pCi/L, except at well 299-E27-7 where values rose from ~600 to 2,500 pCi/L during the late 1990s. Currently, the trend remains steady near 2,480 pCi/L.

2.9.2.10 RCRA Parameters for the 216-A-29 Ditch

The 216-A-29 ditch is a RCRA disposal facility in the 200 East Area and is monitored under an interim status detection program. To date, there is no evidence that the site has contaminated groundwater with regulated constituents. At one time, the site was in assessment monitoring status because of high specific conductance, which was caused by sulfate from the site. However, sulfate is nonhazardous. Specific conductance in well 299-E25-48 continues to exceed the critical mean, but no concomitant rise in hazardous constituents has been observed.

RCRA groundwater monitoring at the 216-A-29 ditch in fiscal year 2001 showed no evidence of contamination from the site.

The direction of groundwater flow beneath the ditch is west-southwest (~240 degrees azimuth) based on tritium and nitrate plume maps (Plate 2 and Figure 2.1-4, respectively) and on water-level elevations in the monitoring wells. The tritium plume map (see Plate 2) shows that the flow direction swings to the southeast as groundwater flows to the southeast corner of the 200 East Area. The calculated gradient is ~0.0004 for the entire length of the ditch and the flow rate is ~0.03 to ~0.09 meter per day (see Appendix A, Table A.2). This estimate of flow rate is lower than the nearby Waste Management Areas A-AX and C because of the much lower estimate of hydraulic conductivity.

The water table beneath the ditch has steadily declined since discharges to the B Pond system were terminated. As an example, Figure 2.9-46 shows the water levels are continuing to decline in two wells monitoring the ditch.

There were no exceedances of contaminant indicator parameters during fiscal year 2001. Water-level measurements were taken during routine sampling throughout the year. The continued regional groundwater decline has made sampling of well 699-43-43 difficult. This particular well may not be functional by the end of fiscal year 2002. The other wells, however, continue to have sufficient water for groundwater monitoring purposes.

2.9.2.11 RCRA Parameters for B Pond

An interim status RCRA facility, the B Pond system originally consisted of a main pond, three expansion ponds, and portions of several ditches leading to the main pond (see Figure 2.9-1 and Appendix A, Figure A.5). Currently, only the main pond and an adjacent portion of the 216-B-3-3 ditch are regulated as a RCRA treatment, storage, and disposal facility.

RCRA groundwater monitoring at B Pond in fiscal year 2001 showed no evidence of contamination from the site.

The B Pond system was placed into assessment in 1990 because of elevated total organic carbon and total organic halides in groundwater from two wells. Following the initial excursion, occurrences of elevated results for total organic carbon and total organic halides were isolated and generally declining with time. Groundwater quality assessment that concluded in 1996 (PNNL-11604) determined that no specific compounds could be identified in sufficient concentration or with consistency that would allow correlation to elevated total organic carbon and total organic halides.

The groundwater monitoring well network in this area was more extensive in the past when groundwater was interpreted to flow radially away from the facility, and the now clean-closed expansion ponds were still part of the regulated facility. The entire historical network and fiscal year 2001 network are shown in Appendix A, Figure A.5. In March 2000, changes in the well network were made to accommodate changes in the water table and potential groundwater flow directions.

Groundwater Flow

Groundwater flow beneath the B Pond, which was historically described as "radial," has now become less defined. Currently, flow appears to be from northeast to southwest across the main pond, and is changing rapidly because of declines in the water table and the shifting patterns of drainage in the aquifer.

In fiscal year 2001, the groundwater flow rate was estimated at 0.02 to 15.4 meters per day (see Appendix A, Table A.2). This range in flow velocities reflects the significant differences in hydraulic conductivities between the relatively permeable Hanford formation gravel and sand, and the less conductive Ringold Formation sediment.

Actual flow may be extremely limited in a southeastern direction (toward the Treated Effluent Disposal Facility) as indicated by tritium concentrations and ionic proportions in groundwater in this area (Figure 2.9-47). Tritium concentrations in this area are well below background levels for surface water (e.g., Columbia River) and the unconfined aquifer elsewhere (~11.7 pCi/L in fiscal year 2001). Major ion proportions, which are sodium bicarbonate dominated, also indicate a more highly evolved groundwater chemistry than typical for the unconfined Ringold aquifer. These two circumstances suggest groundwater in this area is very “old” and was virtually unaffected by B Pond discharges; hence, net groundwater movement from the B Pond area toward the Treated Effluent Disposal Facility is interpreted to be very limited.

Groundwater is considered to flow more readily southwestward out of the confined portions of the aquifer into the unconfined Hanford formation aquifer beneath the southwest extremity of the main pond and the 216-B-3-3 ditch (see Figure 2.9-22 and Section 2.9.3). This groundwater then encounters a highly conductive northwest-southeast channel in the Hanford formation gravel and flows southeastward, eventually flowing over the top of the same layer (Ringold lower mud unit) that confines groundwater in the east and southeast portions of the B Pond facility. This is possible because the strata dip south in this area.

A downward hydraulic gradient is indicated between shallow and deep well pairs in the network. Head measurements during fiscal year 2001 indicated downward-directed gradients of 0.5 between wells 699-43-41E and 699-43-41G (measured in September 2001), 0.3 between wells 699-43-42J and 699-42-42B (measured in March 2001), and 0.12 between wells 699-42-39A and 699-42-39B (measured in January 2001). The downward potential is most likely a result of the remnant groundwater mound beneath the facility, and has been slowly diminishing over the past several years.

Shallow wells continue to go dry in the monitoring network at B Pond because of the subsiding effects of historical discharges. Some wells are predicted to have <1 year of life. The rate of water level decline has slowed in most B Pond wells, however, since 1998.

Groundwater Quality

Chemical parameters sought in B Pond groundwater analyses, which represent both site-specific concerns and regulatory requirements, are listed in Appendix A, Table A.11.

Results for total organic halides, total organic carbon, pH, and conductivity are compared semiannually with calculated background critical means. Because the critical means are below the limits of quantitation for total organic halides and total organic carbon, results from downgradient wells are compared to the limits of quantitation. No critical means or limits of quantitation were exceeded by results in downgradient B Pond wells during fiscal year 2001.

Nitrate displays upward trends in some wells (Figure 2.9-48), but concentrations are all well below the drinking water standard, and most are near or below Hanford Site background as calculated by DOE/RL-96-61. The wells shown in Figure 2.9-48 are still monitored periodically by sitewide groundwater surveillance and/or the B Pond network.

Specific conductance in some wells (Figure 2.9-49) also displayed a recent increase. This increase is interpreted as groundwater returning to equilibrium with the aquifer solids. Past discharges at B Pond mostly diluted the groundwater, artificially depressing specific conductance. This parameter remains below Hanford Sitewide background levels for groundwater in several B Pond wells.

Samples are taken for the radionuclide indicators gross alpha and gross beta because some radionuclides may reside in the soil or groundwater beneath the facility. No trends are apparent in any wells in the B Pond network sampled for these parameters.

Arsenic, iodine-129, nitrate, and tritium are considered of slight potential concern in the B Pond area, but are part of broader Hanford Sitewide groundwater contamination in the same area. Hence, analyses for these parameters were deferred to sitewide surveillance sampling in the appropriate B Pond wells. No apparent trends are seen for arsenic or iodine-129. Tritium concentrations are generally declining.

The B Pond network and constituent list is currently under revision. The revised groundwater monitoring plan will apply methods from the American Society for Testing and Measurement to track trends in conductivity, gross alpha, and gross beta, as indicators of site-specific contamination. This approach will allow a more refined and appropriate evaluation of groundwater contamination potential at B Pond than merely defaulting to the indicators total organic carbon and total organic halides. These two indicators have been determined to have no bearing on groundwater contamination at the B Pond facility (PNNL-11604).

2.9.2.12 RCRA Parameters for Liquid Effluent Retention Facility

Groundwater monitoring at the Liquid Effluent Retention Facility has been guided by the conditions set forth by the operating permit. A RCRA final status detection-monitoring program was in place at the Liquid Effluent Retention Facility until June 1999 when downgradient well 299-E26-9 no longer provided representative groundwater information (i.e., it went dry). A variance was granted by the Washington State Department of Ecology in September 1999 to allow DOE to operate the remaining network wells as the compliance system. This variance gave DOE 18 months, or until the next downgradient well became non-functional, to develop and deploy an alternative monitoring system. The Washington State Department of Ecology rescinded the variance in January 2001 when downgradient well 299-E35-2 no longer produced representative samples. The Washington State Department of Ecology has suspended groundwater monitoring statistical analyses at the Liquid Effluent Retention Facility effective January 14, 2001. The direction of groundwater flow beneath the facility is generally to the southwest, based on regional water-table contours (see Plate 1).

In fiscal year 2001, the Washington State Department of Ecology instructed DOE to cease RCRA statistical evaluations of groundwater data at the Liquid Effluent Retention Facility, because the site has just one downgradient well that can be sampled. The unconfined aquifer is thinning in the area, and effective groundwater monitoring is no longer possible.

Groundwater monitoring (until January 2001) continued to show no evidence that regulated groundwater constituents from the Liquid Effluent Retention Facility entered the groundwater. Exceedances of the critical mean for specific conductance, however, were identified during the reporting period. The exceedances involved well 299-E26-10. The elevations were identified in the past and were associated with an increasing trend in specific conductance in all downgradient wells. The exact nature of the elevation is unknown, but there is speculation that decreasing effluent discharges to B Pond and a return to natural groundwater conditions may be factors. The lack of elevated tritium concentrations in the downgradient wells supports the conclusion that the Liquid Effluent Retention Facility is not the source of the increase. Tritium has been a principle component of effluent stored in the Liquid Effluent Retention Facility basins. Also, the rise in specific conductance concentration began before the basins stored waste.

2.9.2.13 200 Areas Treated Effluent Disposal Facility

Located southeast of the B Pond RCRA site, the 200 Areas Treated Effluent Disposal Facility has been in operation since June 1995. Groundwater monitoring beneath the facility began in late 1992, initially as an unofficial part of the B Pond RCRA monitoring. Three wells were installed in 1992 for the express purpose of monitoring groundwater at the Treated Effluent Disposal Facility (see Appendix A, Figure A.5).

The state waste discharge permit (ST-4502), which sets discharge and groundwater monitoring parameters, was revised in May 2000, and extends the operating period through May 18, 2005. A revised groundwater monitoring plan (PNNL-13032) accompanies this renewed permit.

Discharges to the Treated Effluent Disposal Facility originate from the 200 Areas facilities and consist of clean water and Columbia River water. During fiscal year 2001, ~462 million liters of effluent were discharged to the Treated Effluent Disposal Facility. This is ~50 million liters less than was discharged in fiscal year 2000.

The three monitoring wells at the Treated Effluent Disposal Facility (see Appendix A, Figure A.5) are sampled quarterly for a list of constituents specified by the state waste discharge permit (see Appendix A, Table A.42).

The Ringold confined aquifer (uppermost aquifer), which consists of Ringold units 9A-9C (PNNL-12261), is ~35 meters thick beneath the Treated Effluent Disposal Facility (see Section 2.9.4). The confining unit consists of the Ringold Formation unit 8 (lower mud unit), which is ~26 meters thick near well 699-40-36. Effluent from the Treated Effluent Disposal Facility flows readily downward through the Hanford formation gravel, and is then diverted from the uppermost aquifer by the relatively-impermeable lower mud unit (unit 9B) silt and clay stratum. The effluent is thought to flow generally south along the top of this unit before entering the unconfined Hanford formation aquifer some distance south of the Treated Effluent Disposal Facility.

Since late 1995, hydrographs of the Treated Effluent Disposal Facility wells (Figure 2.9-50) reveal only the continuing decline in hydrostatic pressure from the discontinuation of B Pond discharges. Upgradient well 699-43-37 has experienced the most pronounced decline (~0.25 meter during fiscal year 2001), probably because of its proximity to the source of the B Pond hydraulic mound. No obvious features in the hydrographs can be related to Treated Effluent Disposal Facility operation, which began in June 1995.

The results of monitoring at the Treated Effluent Disposal Facility indicate that groundwater beneath the site has been isolated from Hanford Site influences.

The direction of groundwater flow, or the potential for flow beneath the Treated Effluent Disposal Facility in the confined Ringold aquifer, is south-southwest. Calculations of groundwater flow rate (see Appendix A, Table A.2), from March 2001 measurements, indicate an average linear flow velocity of ~0.004 meter per day. However, groundwater chemistry and recent hydrostratigraphic research suggest that actual flow may be at a very low rate (see Section 2.9.3). Major ion proportions and tritium concentrations ranging from 9.36 to 11.7 pCi/L (fiscal year 2001 results) in this aquifer near Treated Effluent Disposal Facility and eastern portions of B Pond (see Figure 2.9-47) support this inference. Additionally, routine analyses of Treated Effluent Disposal Facility effluent indicates consistently higher amounts of tritium in the effluent (e.g., 165 pCi/L in July 2001), which is more typical of raw Columbia River water, than in groundwater beneath the facility. The results of monitoring suggest that groundwater has been isolated from Hanford Site influences and may be relatively old compared with groundwater elsewhere in the uppermost aquifer.

A list of six constituents is evaluated quarterly and compared with permit enforcement limits. No enforcement limits were exceeded during fiscal year 2001.

In fact, none of these parameters have exceeded enforcement limits or practical quantitation limits since monitoring of Treated Effluent Disposal Facility wells began in 1992 (2+ years prior to operation). Most results for anions, metals, and radionuclide indicators have been near or below Hanford Sitewide background levels calculated by WHC-EP-0595 and DOE/RL-96-61.

Because there was no unconfined aquifer beneath the facility before operation began, wells were installed in the confined Ringold aquifer, even though they are isolated from the effects of operation. Hence, the objective of groundwater monitoring at the Treated Effluent Disposal Facility is to demonstrate that the uppermost aquifer remains unaffected by discharges to the facility.

2.9.3 Confined Aquifer in the Lower Ringold Formation

PNNL-10886 subdivided the Ringold Formation into six hydrogeologic units (units 4 through 9). The Ringold Formation confined aquifer consists of the lowermost hydrogeologic unit (unit 9), which consists of fluvial sand and gravel overlying the uppermost basalt flow. It is confined by hydrogeologic unit 8, also referred to as the lower mud unit, which is the thickest and most laterally continuous mud unit beneath the Hanford Site. The base of the aquifer is the dense interior of the uppermost basalt flow. Previous studies have often included portions of the Ringold confined aquifer when describing and mapping the unconfined aquifer. Interpretations prior to 1999 generally did not differentiate these aquifers and did not attempt to distinguish the groundwater results (i.e., contaminant-plume and potentiometric-surface mapping) for the separate aquifers. Recent re-evaluation of hydrostratigraphy in the 200 East Area and vicinity attempt to refine the interrelationships between confined and unconfined aquifers, and explain nuances in groundwater chemistry between these two systems (PNNL-12261).

An aquifer confined beneath mud units in the Ringold Formation is present near the 200 East Area. Groundwater flow in this area is influenced by a recharge mound related to past discharges to B Pond.

The Ringold confined aquifer is known to be in communication with the unconfined aquifer in the 200 East Area, where they are adjacent to the unconformity created by erosion and subsequent deposition of the Hanford formation (PNNL-12261). Currently, there is no monitoring network designed specifically to monitor conditions within the Ringold confined aquifer. Most of the wells that monitor the Ringold confined aquifer are located east and south of 200 East Area. Therefore, this section focuses on that region.

2.9.3.1 Groundwater Flow

Figure 2.9-23 presents the potentiometric surface for a portion of the confined aquifer in the Ringold Formation. This aquifer occurs within fluvial sand and gravel comprising the lowest sedimentary unit of the Ringold formation (unit 9). It is confined below by basalt and above by the lower mud unit (unit 8). This map is incomplete and subject to uncertainty because only a few wells monitor this aquifer.

Groundwater in the Ringold Formation confined aquifer flows generally west to east in the vicinity of the 200 West Area and west to east along the south boundary of the aquifer. These flow patterns indicate that recharge occurs west of the 200 West Area (Cold Creek Valley) as well as from the Dry Creek Valley and possibly the Rattlesnake Hills. In the central portion of the aquifer, west and south of the 200 East Area, groundwater flow is to the northeast. In addition, a groundwater mound is present northeast of B Pond as a remnant of past wastewater discharges to this facility. This mound causes groundwater to flow southwest beneath B Pond. A stagnation point is believed to exist to the south of B Pond, where the flow of water divides with some moving northwest toward the 200 East Area and some moving toward the east or southeast. Therefore, groundwater flow converges on the 200 East Area where the confining mud unit (unit 8) is absent, so the 200 East Area represents a discharge area for this aquifer. The water flowing toward the east is expected to eventually discharge to the Columbia River.

With the exception of the area immediately around B Pond, there appears to be an upward gradient between unit 9 and the Hanford formation near the 200 East Area in a region where the confining unit (unit 8) is absent (see Figure 2.9-47). Well 299-E25-28 is completed within hydrogeologic unit 9 of the Ringold Formation (below the water table), and well 299-E25-34 is completed across the water table within the overlying Hanford formation (unit 1). These wells are located only 14 meters apart, and their hydrographs are shown in Figure 2.9-46. The hydraulic heads are apparently slightly higher in well 299-E25-28 indicating a small upward gradient, which supports the inference that groundwater discharging from the confined aquifer in the vicinity of the 200 East Area may recharge the overlying unconfined aquifer. After discharging to the unconfined aquifer, the groundwater is interpreted to flow generally southeastward over the top of the confining unit. This is possible because of the southerly dip of the suprabasalt strata.

The contours on Figure 2.9-23 are similar to the potentiometric surface for the upper basalt-confined aquifer (see Section 2.14). Hydraulic head and flow patterns in the central portion of the Hanford Site are very similar in both aquifers. Hydraulic heads differ in the western portion of the aquifers (~3 to 5 meters of head difference in the northern part of the 200 West Area) where a downward hydraulic gradient exists. Hydraulic heads are also interpreted to diverge to the east, and an upward hydraulic gradient is expected in the vicinity of the Columbia River.

Water levels over much of this aquifer declined during the period from March/April 2000 to March 2001. The declining water levels are due to the near cessation of wastewater disposal to the soil column at Hanford.

2.9.3.2 Contaminant Distribution

Most of the available chemical data from the Ringold confined aquifer are from wells on the 200 Areas plateau. This plateau area is one of two areas where contamination can migrate from the unconfined aquifer into the confined Ringold aquifer. The other area of potential downward migration is in the area of the B Pond facility, east of the 200 East Area. However, groundwater chemistry data for the Ringold confined aquifer (in general) are limited because of the lack of well completions in the aquifer.

Tritium concentrations are elevated in the Ringold confined aquifer. The contaminated water flows to the southwest where it enters the unconfined aquifer.

The primary factors contributing to the observed groundwater chemistry are the hydrostratigraphy and groundwater flow patterns. The ion chemistry and tritium concentrations corroborate the interpretation of groundwater flow described in Section 2.9.2.13. Because groundwater flow in the unconfined aquifer is generally isolated from flow in the Ringold confined aquifer (except within the erosional unconformity), the groundwater chemistry must be evaluated for each aquifer independently.

Figure 2.9-47 illustrates proportions of major dissolved ions and shows the extent of tritium penetration into the confined aquifer east of the 200 East Area. The figure illustrates that groundwater chemistry correlates with groundwater flow paths in the unconfined aquifer and in the Ringold confined aquifer (unit 9). The major ion chemistry of groundwater in the Ringold confined aquifer, adjacent to the aquifer juncture, is of the calcium-bicarbonate type and has elevated tritium activities similar to groundwater in the unconfined aquifer. South and east of B Pond toward the May Junction Fault, groundwater in the Ringold confined aquifer has lower tritium concentrations and is of the sodium-bicarbonate type. Tritium concentrations and other chemical data (see PNNL-13032) indicate that groundwater in the Ringold confined aquifer has not been displaced or diluted by wastewater associated with 200 East Area operations.

Tritium was present in discharges to B Pond, which is located directly above the erosional juncture that allows communication between the unconfined and confined aquifers. During active disposal, groundwater mounding increased the driving head and forced groundwater and any associated contamination into the confined aquifer. The groundwater moved laterally within the confined aquifer as long as the head remained high from the overlying groundwater mound. When disposal to B Pond decreased in the late 1980s and then ceased in 1997, water levels and tritium concentrations in the unconfined aquifer decreased significantly. In the case of tritium, decay has contributed significantly to the decline in concentrations. The reduced head has created an upward gradient between the confined and unconfined aquifers. Horizontal flow is toward the southwest, so the high concentrations of tritium in the confined aquifer are expected to move toward the unconfined aquifer.

Similar groundwater mounding has historically occurred within the 200 West Area, and may be responsible for driving contaminants deeper into confined portions of the Ringold aquifer in isolated areas. Wells 299-W7-3 and 299-W6-6, which are deep wells located along the northern boundary of the 200 West Area, have indicated incursions of nitrate during the past 2 to 3 years (from ~8 mg/L in 1994 to ~56 mg/L in fiscal year 2001 in well 299-W6-6). However, the tritium plume that has been identified in this area does not appear in these deeper wells. Well 299-W6-7, which is a shallow companion to well 299-W6-6, produced tritium results of >15,000 pCi/L in fiscal year 2001, and has historically produced elevated nitrate (~143 mg/L in fiscal year 2001). Why nitrate would appear in the adjacent, deeper companion (well 299-W7-6) without the ubiquitous tritium noted elsewhere in this area, is unknown at present.

The State-Approved Land Disposal Site (see Section 2.8.5), which is barely within the areal boundaries of the confined portion of the Ringold aquifer, has intermittently discharged tritium to the ground since late 1995. During the past few years, tritium concentrations of up to 980,000 pCi/L have reached the deepest well located near this facility. Although aquifer tests have indicated confined conditions at depth near this facility, apparently, discharged effluent can be driven into these portions of the aquifer if sufficient head is available. An increase in hydraulic head of up to 1 meter above preoperational conditions has resulted from discharges to the State-Approved Land Disposal Site in the immediate vicinity of the facility.

Groundwater from the 200 East Area flows to the southeast and east, eventually discharging to the Columbia River. One of the major discharge areas is the Old Hanford Townsite. Fiscal year 2001 samples from riverbank seeps contained tritium at levels above the drinking water standard and had low levels of technetium-99 and iodine-129. All contaminants in river samples were below drinking water standards.

2.9.4 Monitoring at River Shoreline (Old Hanford Townsite)

The major plumes of groundwater contamination (iodine-129, nitrate, and tritium) from the 200 East Area entered the Columbia River at the Old Hanford Townsite and elsewhere along the Columbia River to the south. Because of this known groundwater contamination entering the Columbia River along this stretch, groundwater samples are collected annually from riverbank seepage sites located near the shoreline during the seasonal low river stage, which occurs during the fall months. Riverbank seepage is monitored by the Surface Environmental Surveillance Project. Three seepage sites were sampled during fiscal year 2001; no aquifer tubes were sampled. Table 2.9-1 lists the analytical results for key constituents for samples collected from riverbank seepage and from near shore river water along the Old Hanford Townsite shoreline. There are no known local sources for these key constituents, which are believed to have migrated to the Old Hanford Townsite are from the 200 East Area (PNL-8167).

The samples from riverbank seepage had a specific conductance of 292 to 401 µS/cm, indicating that the samples were primarily groundwater, with little dilution by river water in bank storage. The three seepage sites are located near Hanford River Marker #28, with the closest groundwater monitoring wells being 699-45-2, 699-44-4, and 699-46-2. These seepage sites have been monitored for numerous years and have revealed increasing concentration trends for gross beta, tritium, technetium-99, and iodine-129 since 1994 (PNNL-13230). The increasing trends are not reflected in nearby groundwater monitoring wells, where concentrations for these constituents have remained relatively constant or declined in recent years (see Figure 2.9-33).

Gross beta measurements in the seeps range between 32 and 36, which is below the 50-pCi/L drinking water standard. Technetium-99 and iodine-129 are detected in the samples, but at very low concentrations. Tritium is present in the 53,900 to 107,000 pCi/L range, which is above the 20,000 pCi/L drinking water standard. These concentrations are consistent with the groundwater plume that reaches the river along this shoreline. Near shore river water samples show low concentrations, which are generally several orders of magnitude below the groundwater concentrations. Nitrate in seepage is in the range 59 to 100 mg/L, which, is above the 45 mg/L drinking water standard.

Table 2.9-1. Shoreline Monitoring Data for the Old Hanford Townsite Area, Fiscal Year 2001

Location Name	Sample From	Sample Date	Specific Conductance (µS/cm)(a)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Iodine-129 (pCi/L)	Nitrate (mg/L)
SHT-UR28-2	Seep	09/27/00	292		54.1	22.3	53,900	0.27	58.9
SHT-28-2	Seep	09/27/00	303		71.5	27.9	61,100	0.2	92.1
	Seep	04/30/01	401		112.0	35.9	102,000		
SHT-DR28-2	Seep	09/27/00	325		79.7	29.5	79,100	0.1	100.0
		04/30/01	397		81.8	32.2	107,000		
RsHT-260	River	09/18/00		0.1			31		1.3
	River	09/10/01		0.1					1.3
RsHT-270	River	09/18/00		0.1			33		1.4
	River	09/18/00					24		
		09/10/01		0.1					1.4
RsHT-280	River	09/18/00		0.0			4,100		4.1
	River	09/18/00					1,920		
	River	09/10/01		0.1					8.8
RsHT-287-1	River	09/18/00		0.1			382		1.9
	River	09/18/00					500		
	River	09/10/01		0.0					2.4
RsHT-300	River	09/18/00		0.1			114		1.5
	River	09/18/00					157		
	River	09/10/01		0.1					2.7
Rs6-360	River	08/14/01					55		

Seep = Natural riverbank seepage site.
River = River water collected near the shore.
(a) Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350 to 450 µS/cm and river water is 120 to 150 µS/cm.
Data sources: Hanford Environmental Information System and various project records.

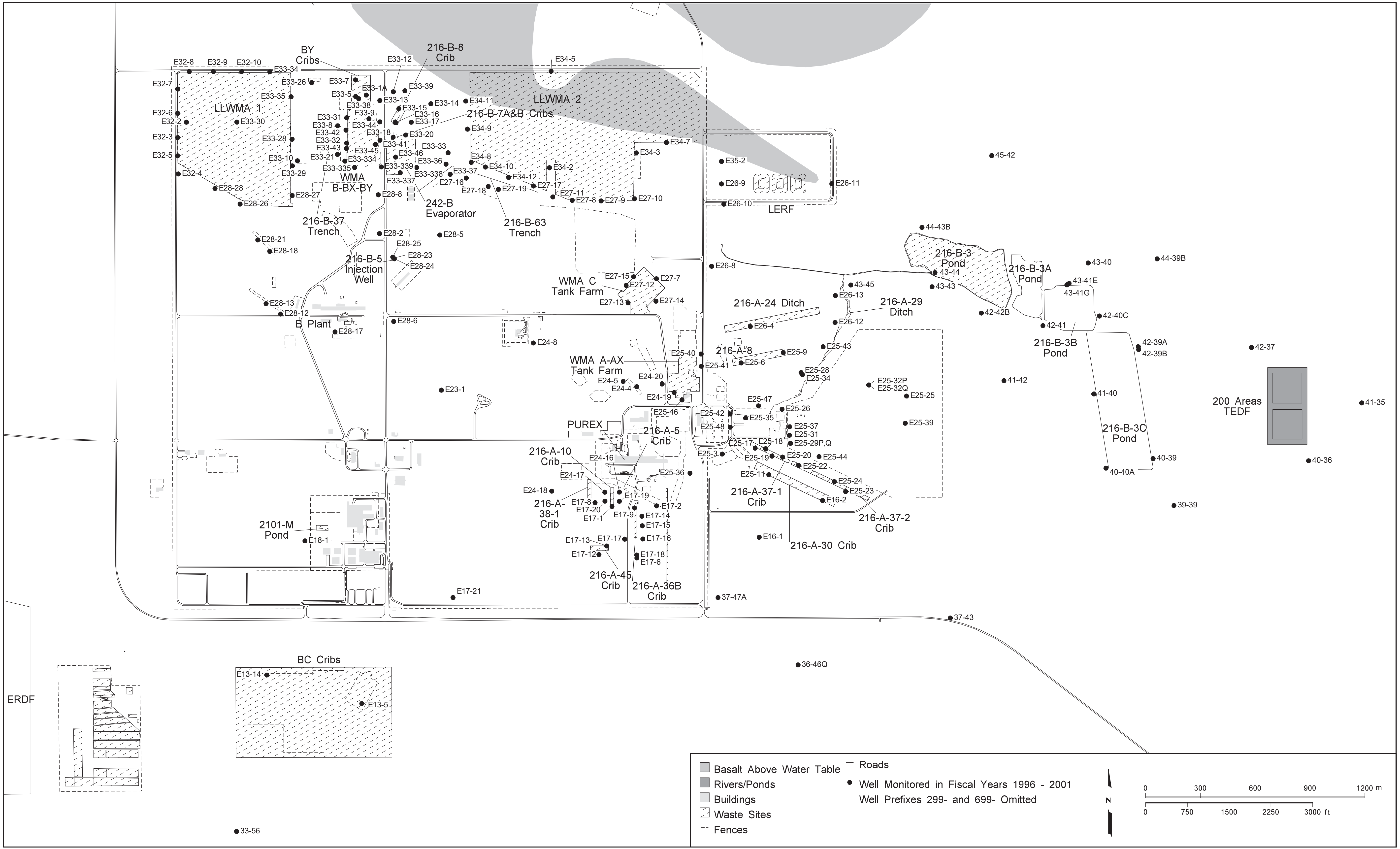


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Figure 2.9-1. Groundwater Monitoring Wells in the 200 East Area

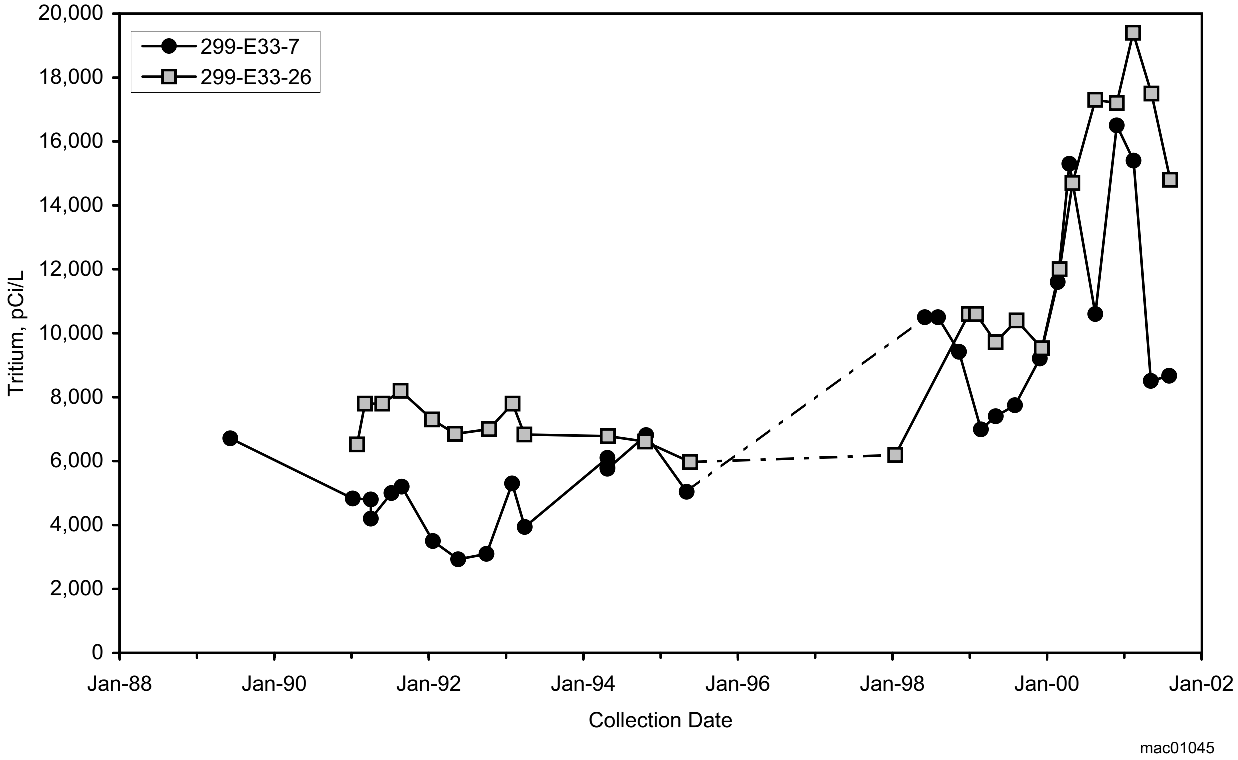

Figure 2.9-2. Tritium Concentrations in Well 299-E33-7 at the BY Cribs and Well 299-E33-26 West of the BY Cribs

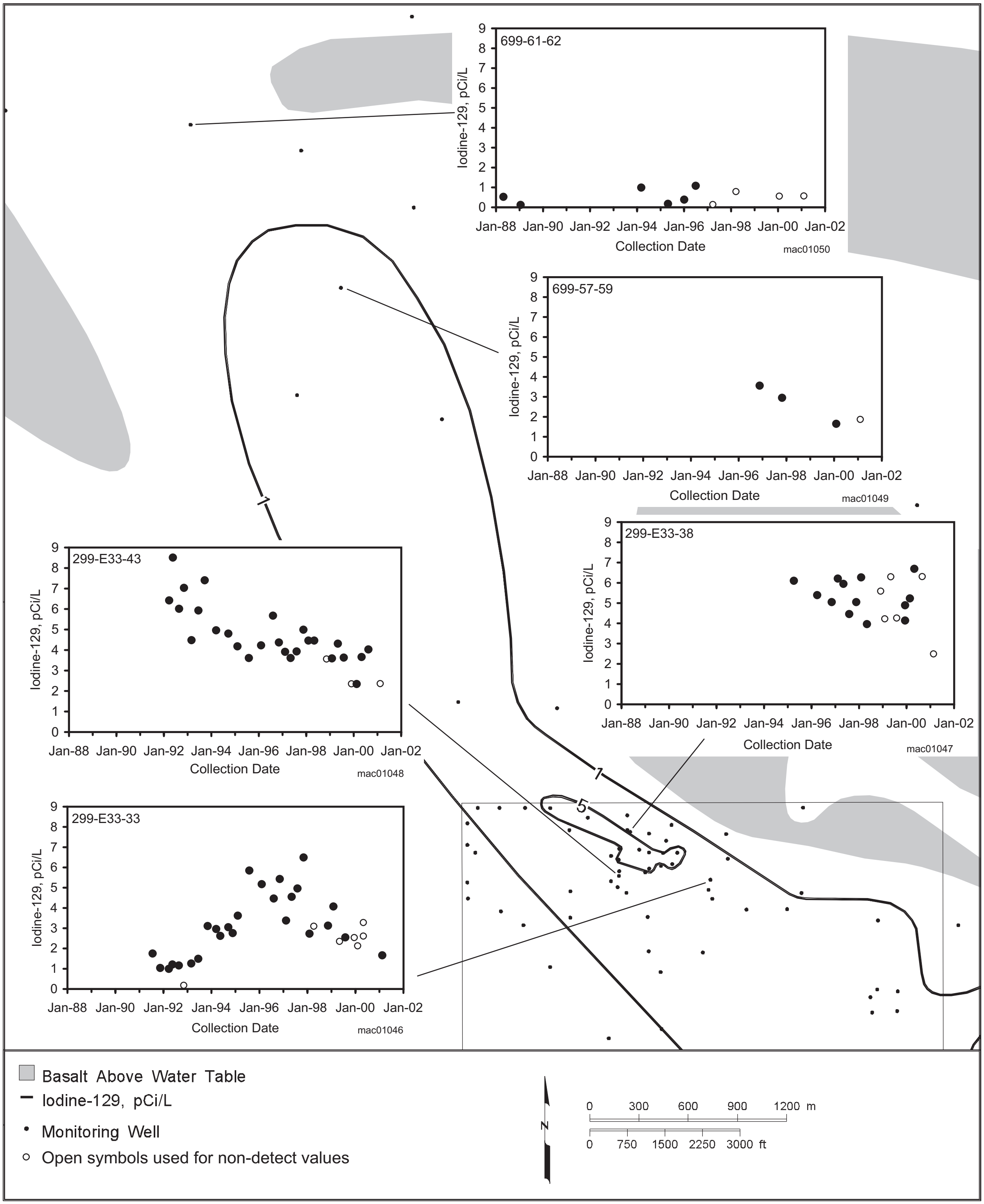

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Figure 2.9-3. Average Iodine-129 Concentrations in the Northern 200 East Area, Top of Unconfined Aquifer

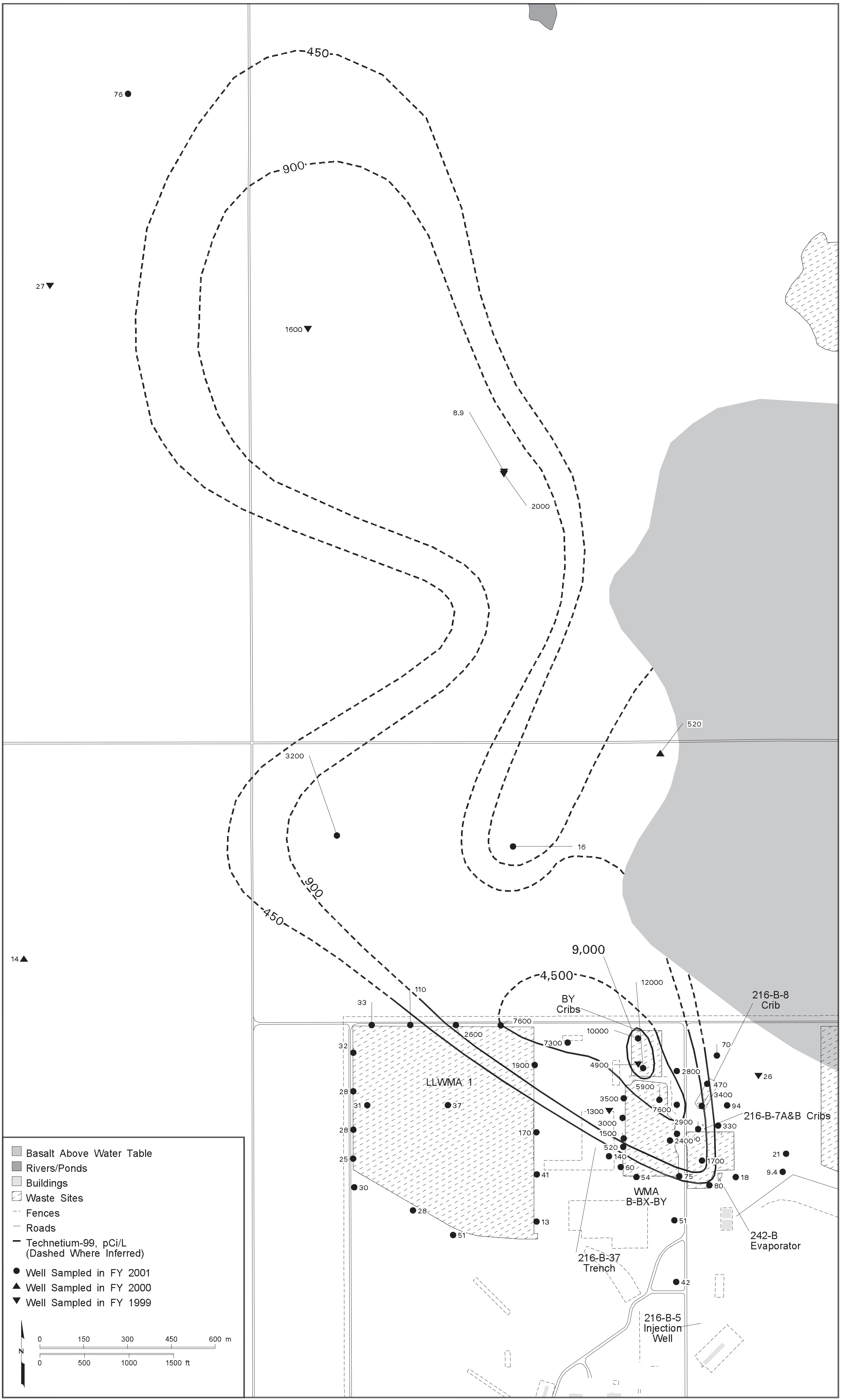

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Figure 2.9-4. Average Technetium-99 Concentrations in the Northern 200 East Area, Top of Unconfined Aquifer

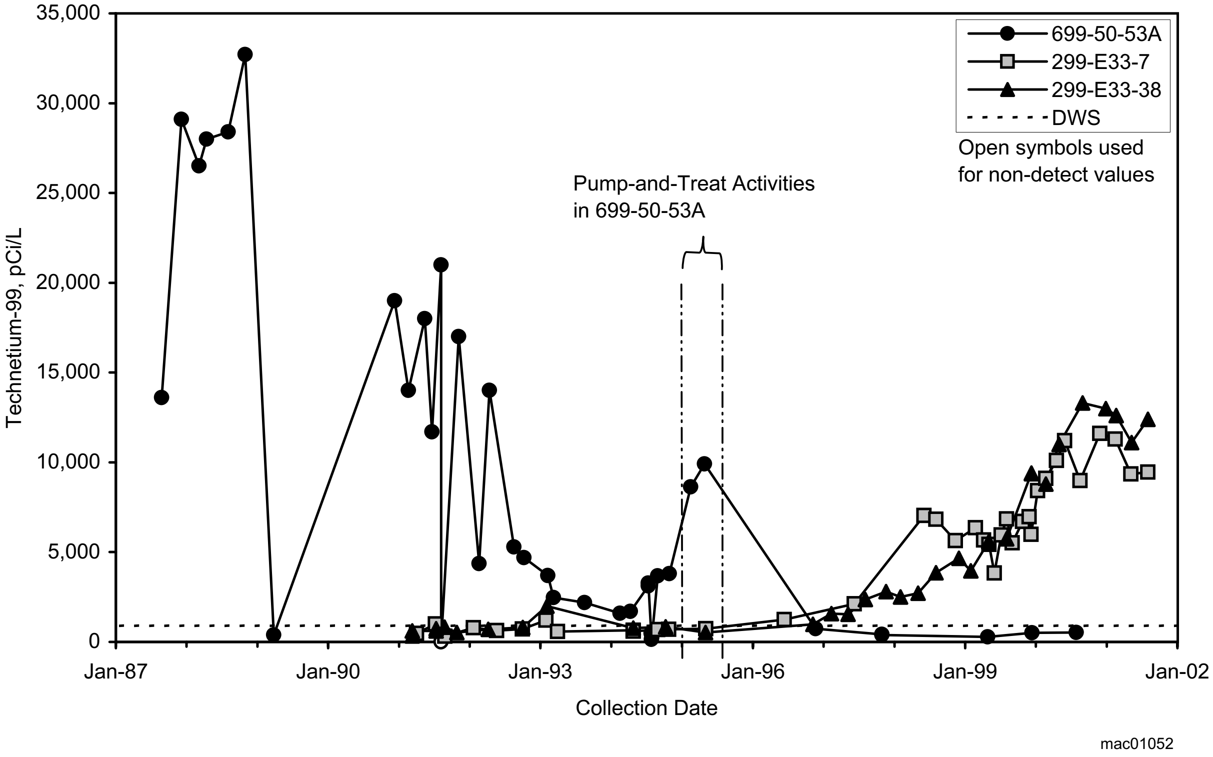

Figure 2.9-5. Technetium-99 Concentrations in Wells 299-E33-7 and 299-E33-38 at the BY Cribs and Well 699-50-53A North of 200 East Area

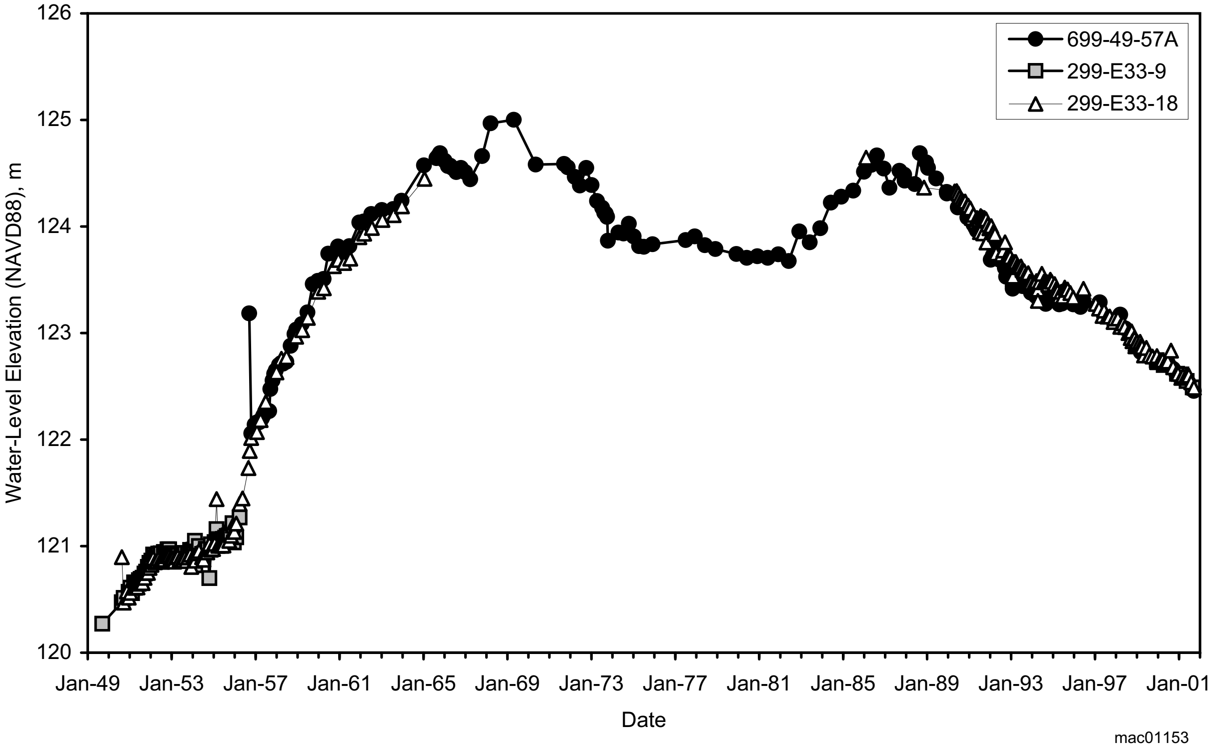

Figure 2.9-6. Water Levels in Wells Monitoring Waste Management Area B-BX-BY

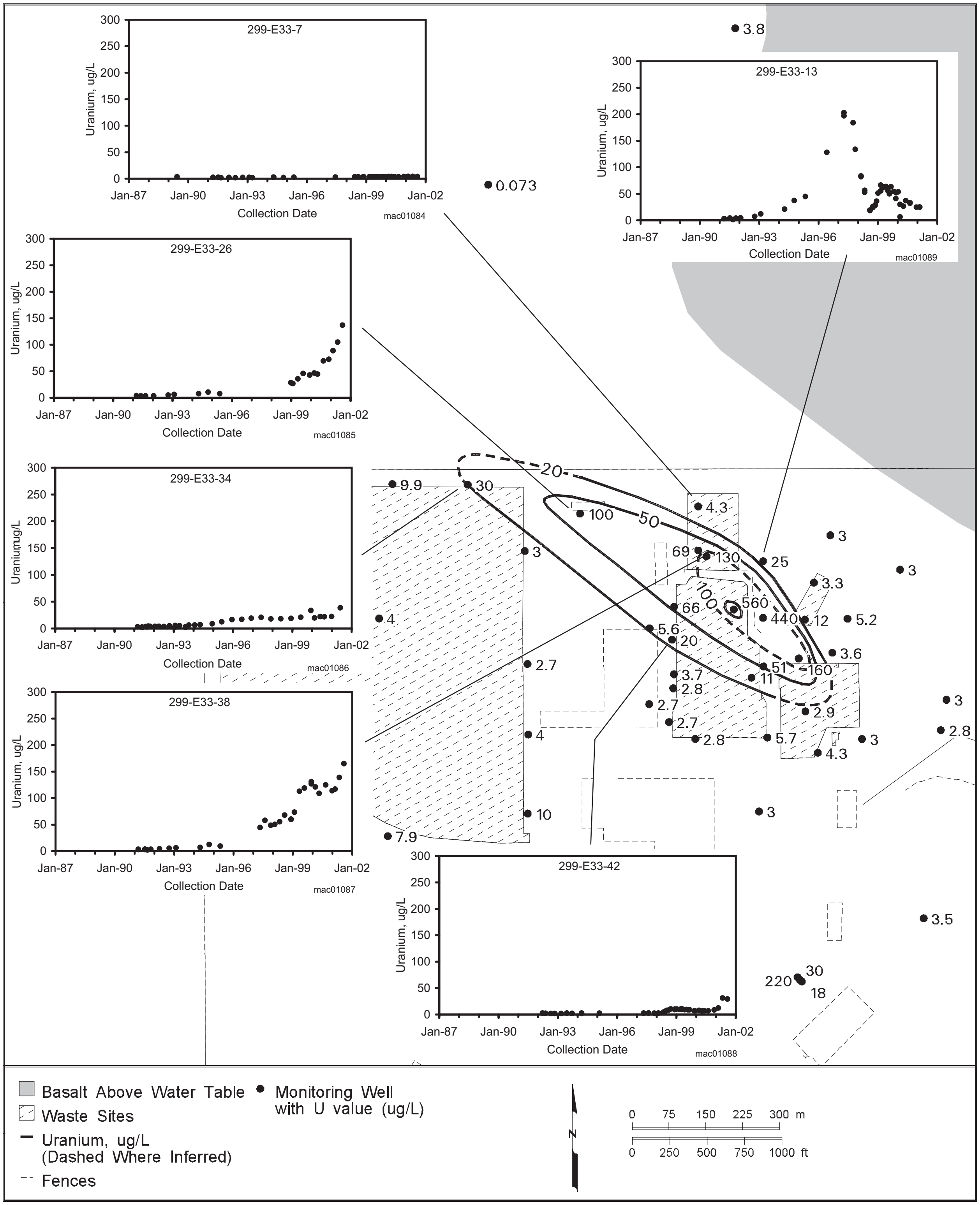

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Figure 2.9-7. Average Uranium Concentrations in the Vicinity of BY Cribs, Top of Unconfined Aquifer

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Figure 2.9-8. Average Nitrate Concentrations in the Northern Part of 200 East Area, Top of Unconfined Aquifer

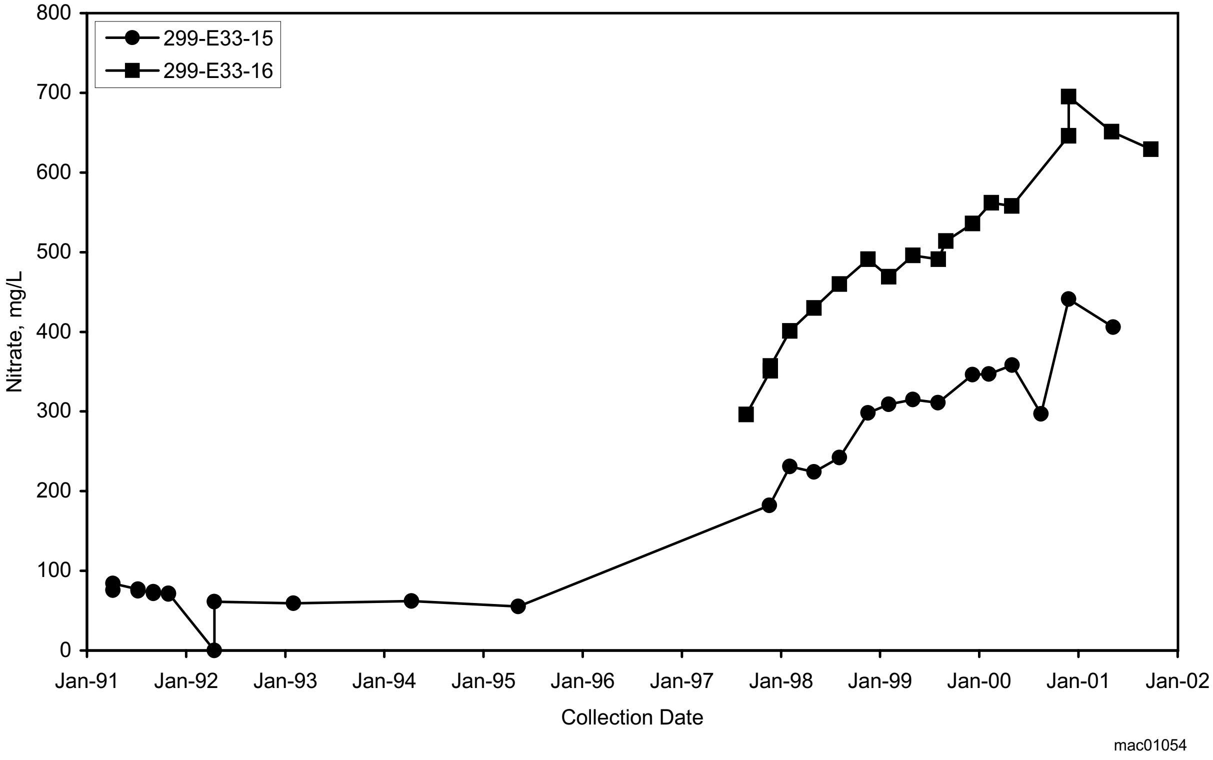

Figure 2.9-9. Nitrate Concentrations in Wells Monitoring 216-B-8 Crib

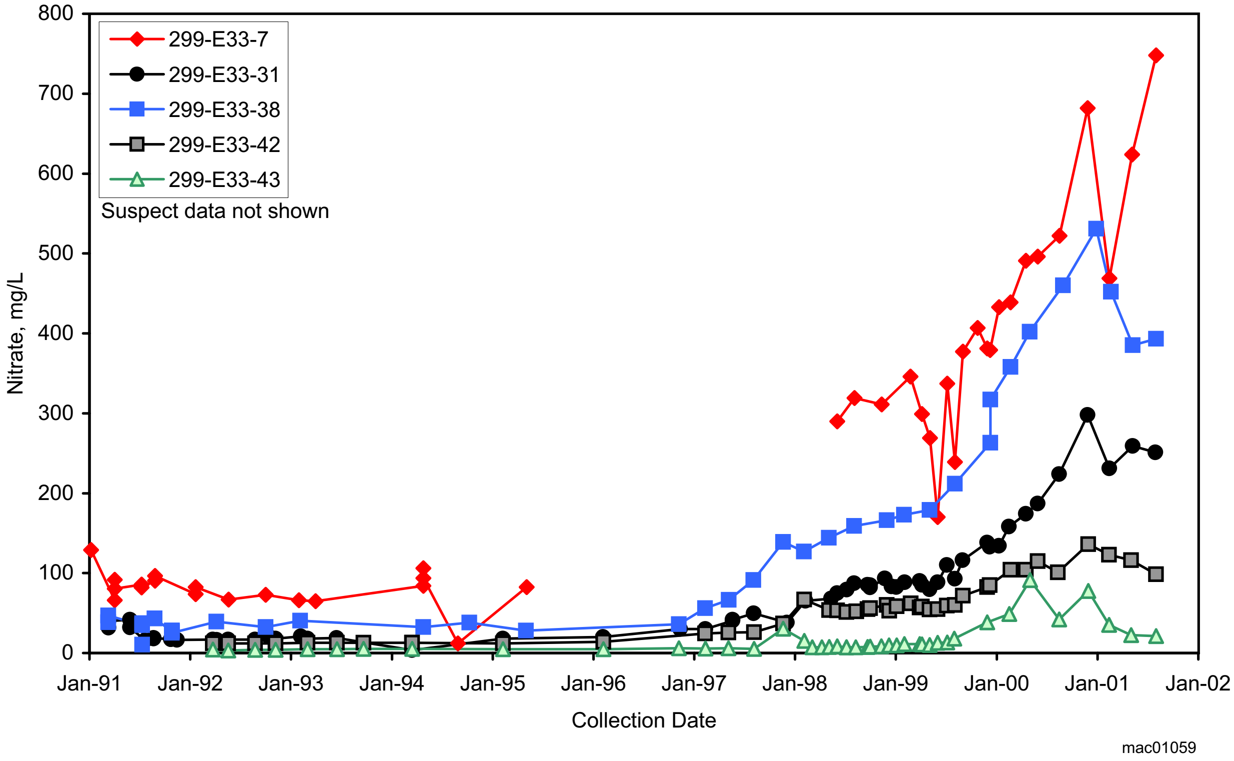

Figure 2.9-10. Nitrate Concentrations in Well 299-E33-7 at the BY Cribs and Wells on the Western Side of Waste Management Area B-BX-BY

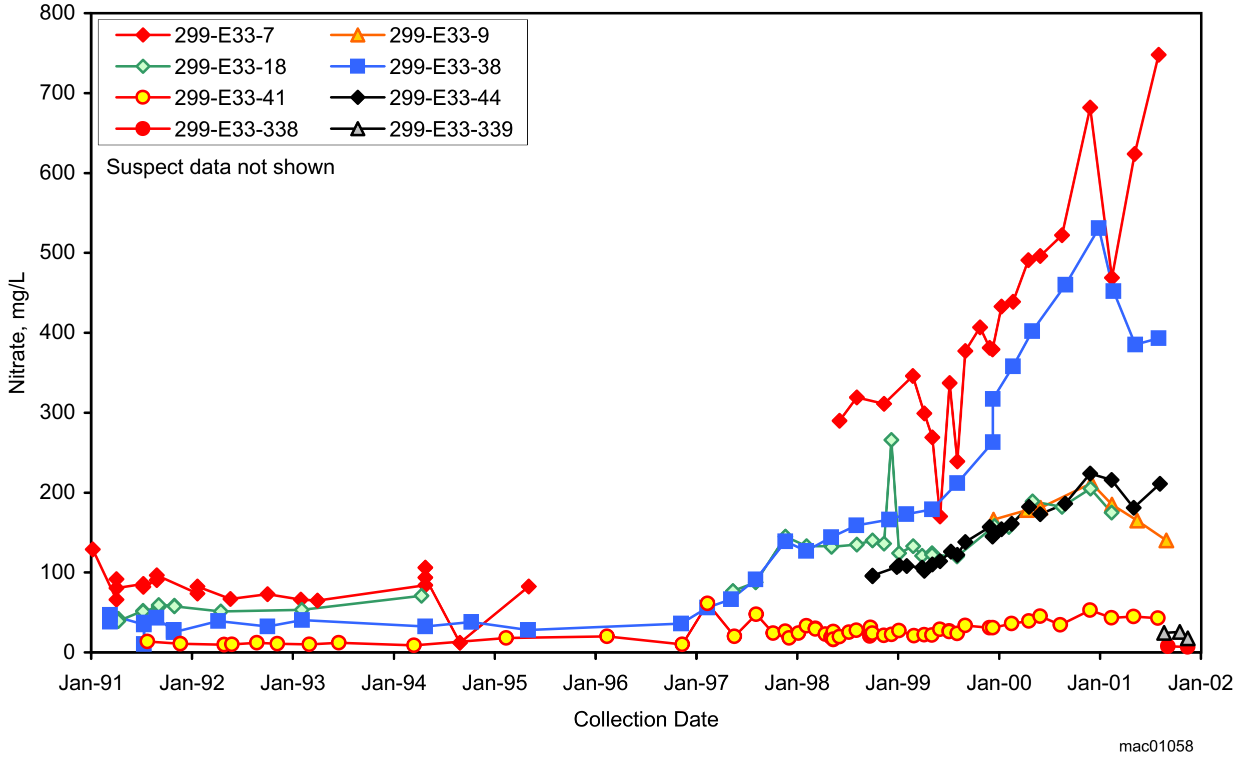

Figure 2.9-11. Nitrate Concentrations at the BY Cribs and Central Waste Management Area B-BX-BY

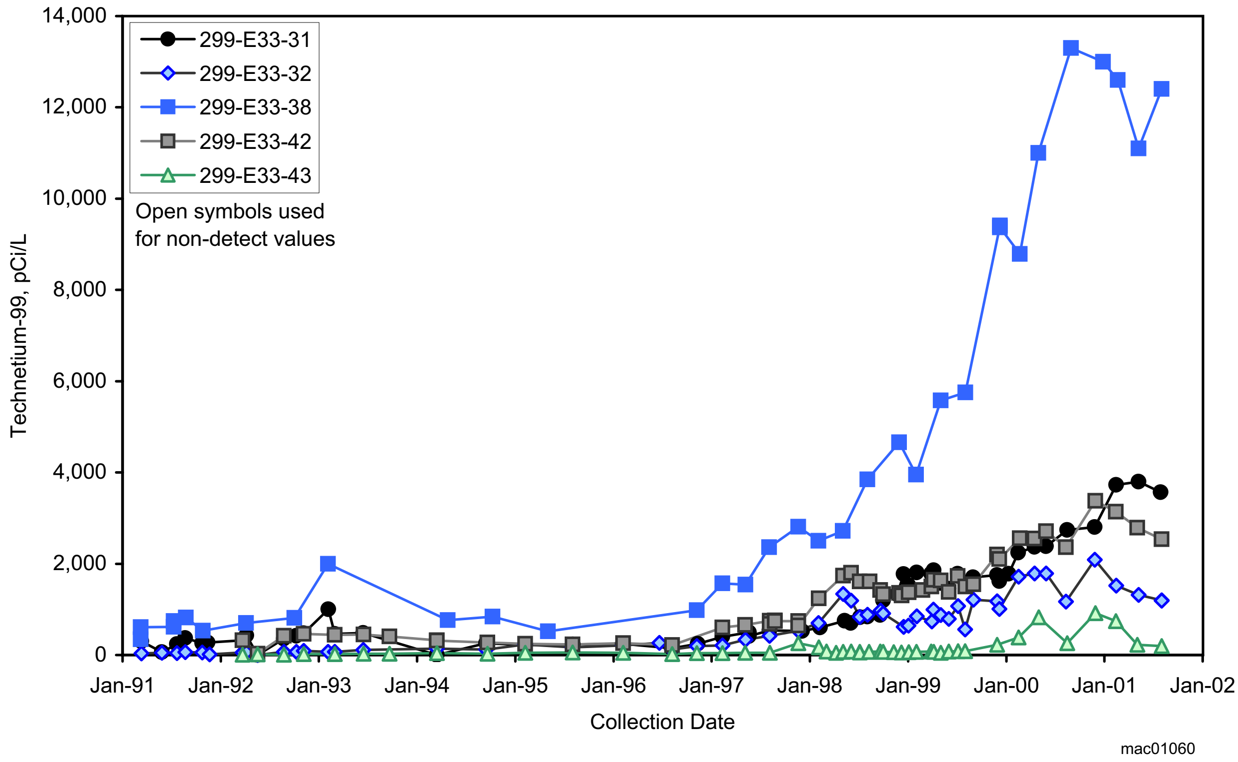

Figure 2.9-12. Technetium-99 Concentrations in Well 299-E33-38 at the BY Cribs and Wells Along the Western Side of Waste Management Area B-BX-BY

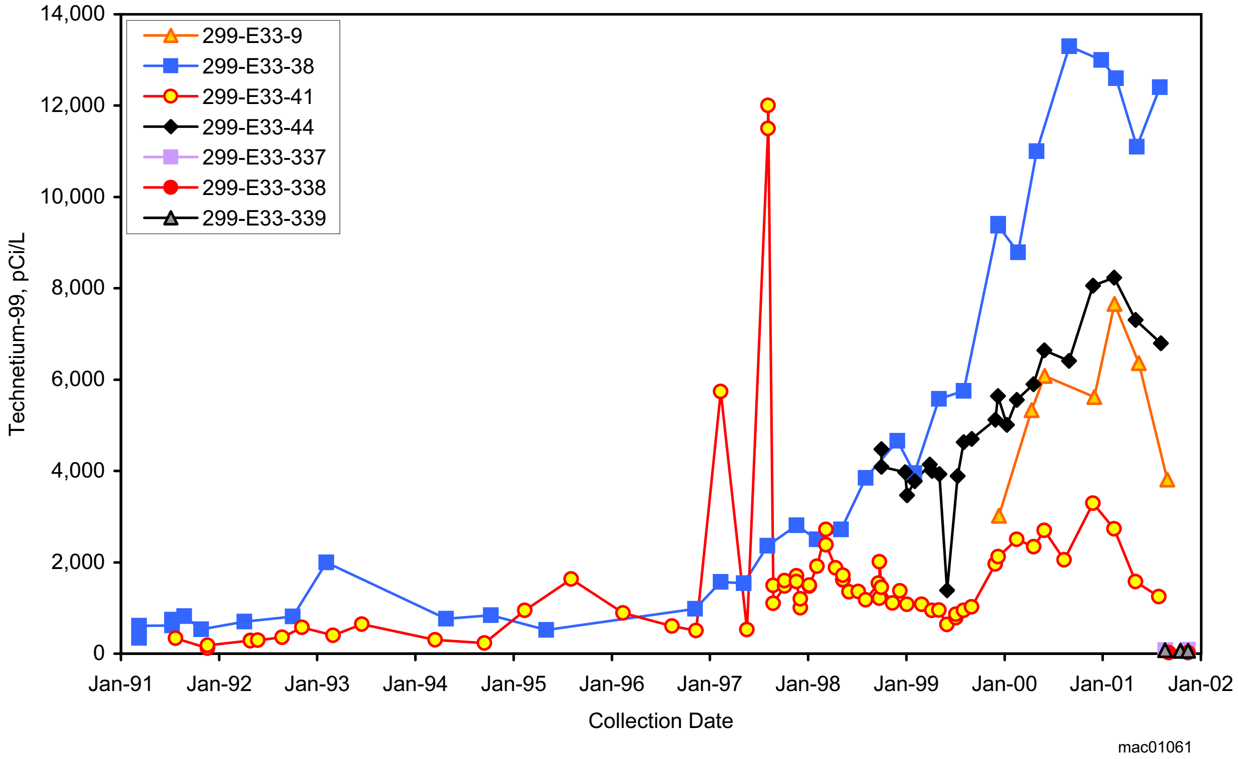

Figure 2.9-13. Technetium-99 Concentrations in Wells at the Central Part of Waste Management Area B-BX-BY

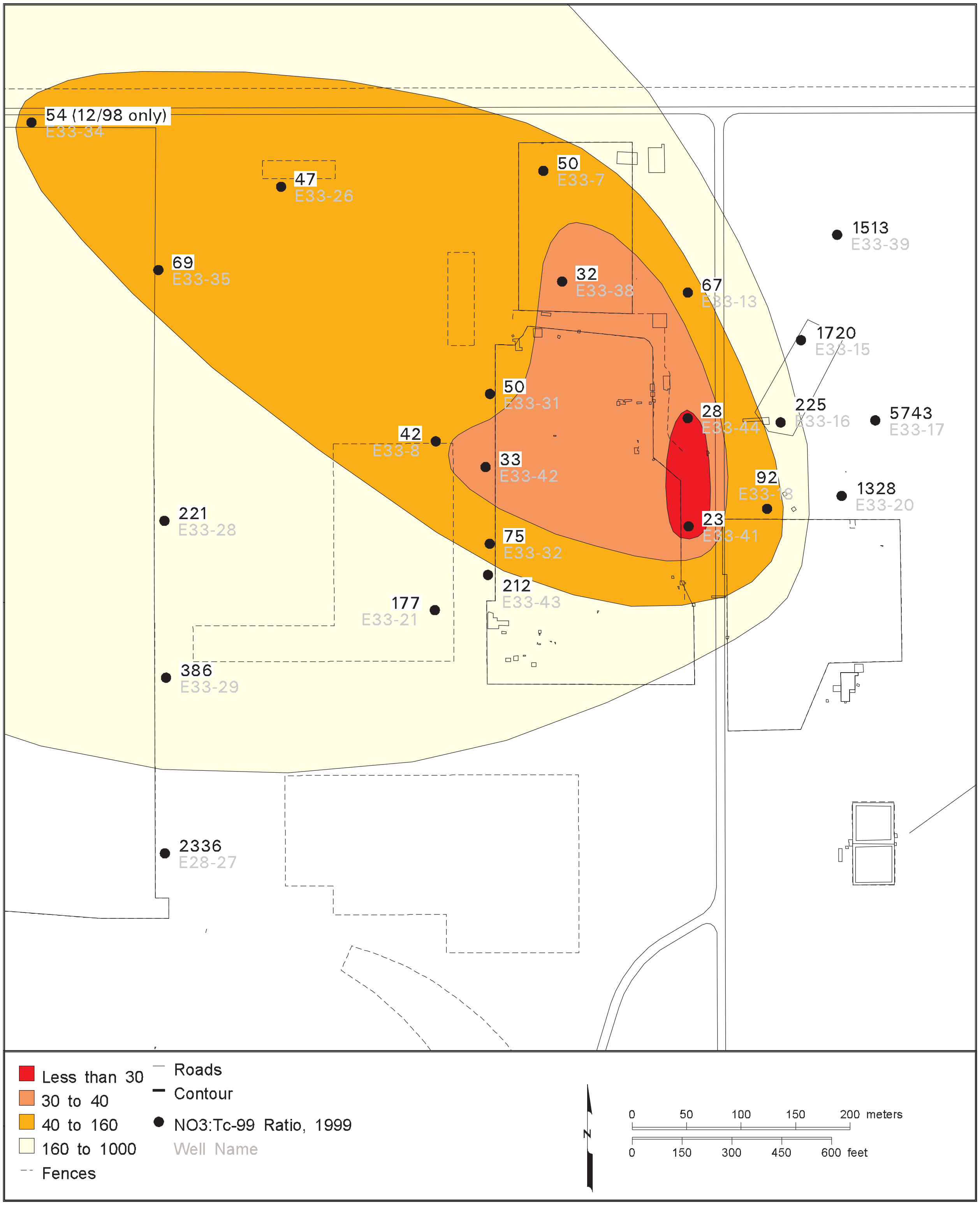

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Figure 2.9-14. Nitrate/Technetium-99 Ratios for Data Collected from April Through June 1999 (given as µg/L over pCi/L) at Waste Management Area B-BX-BY and Low-Level Waste Management Area 1

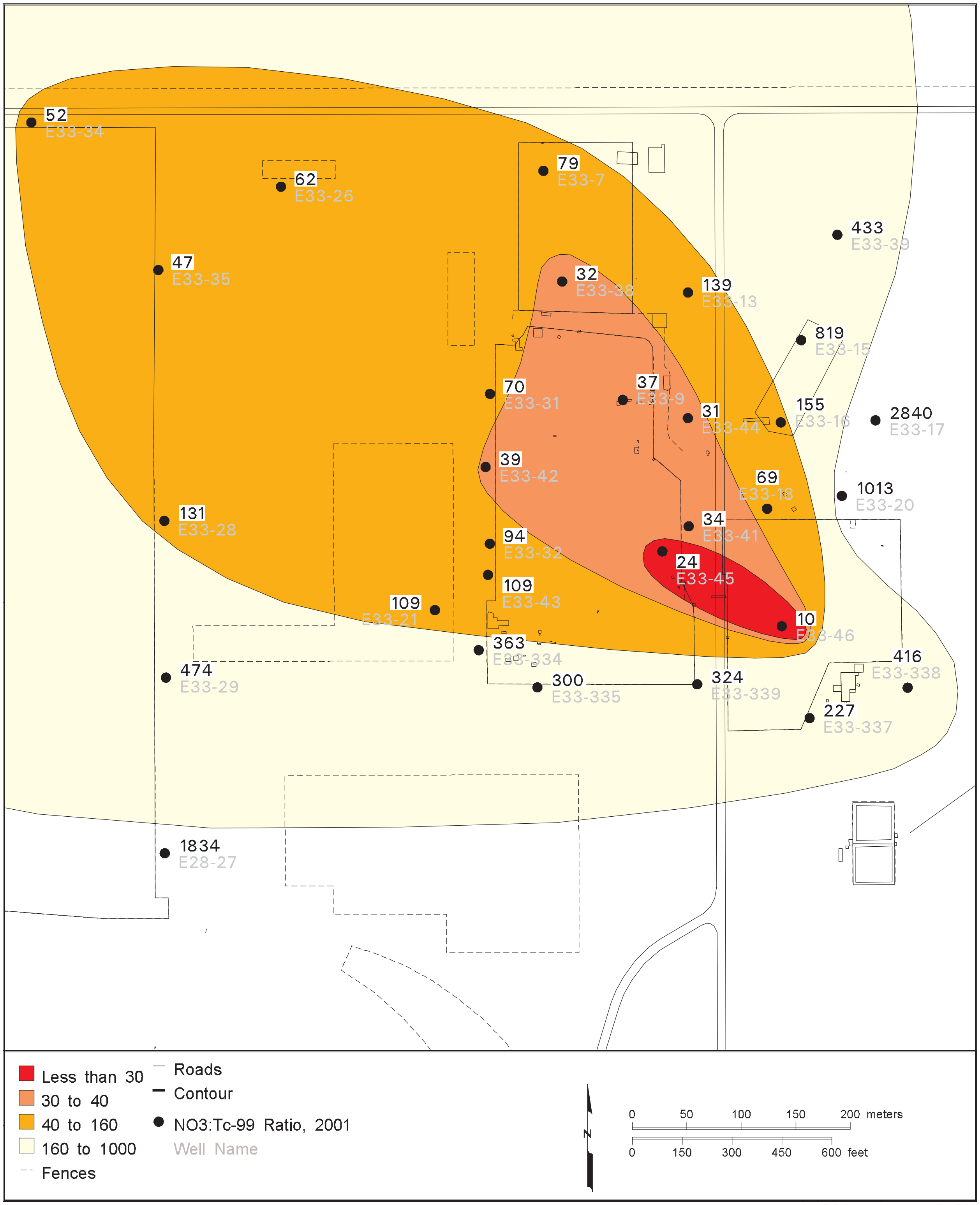

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Figure 2.9-15. Nitrate/Technetium-99 Ratios for Data Collected from May to August 2001 (given as μg/L over pCi/L) at Waste Management Area B-BX-BY and Low-Level Waste Management Area 1

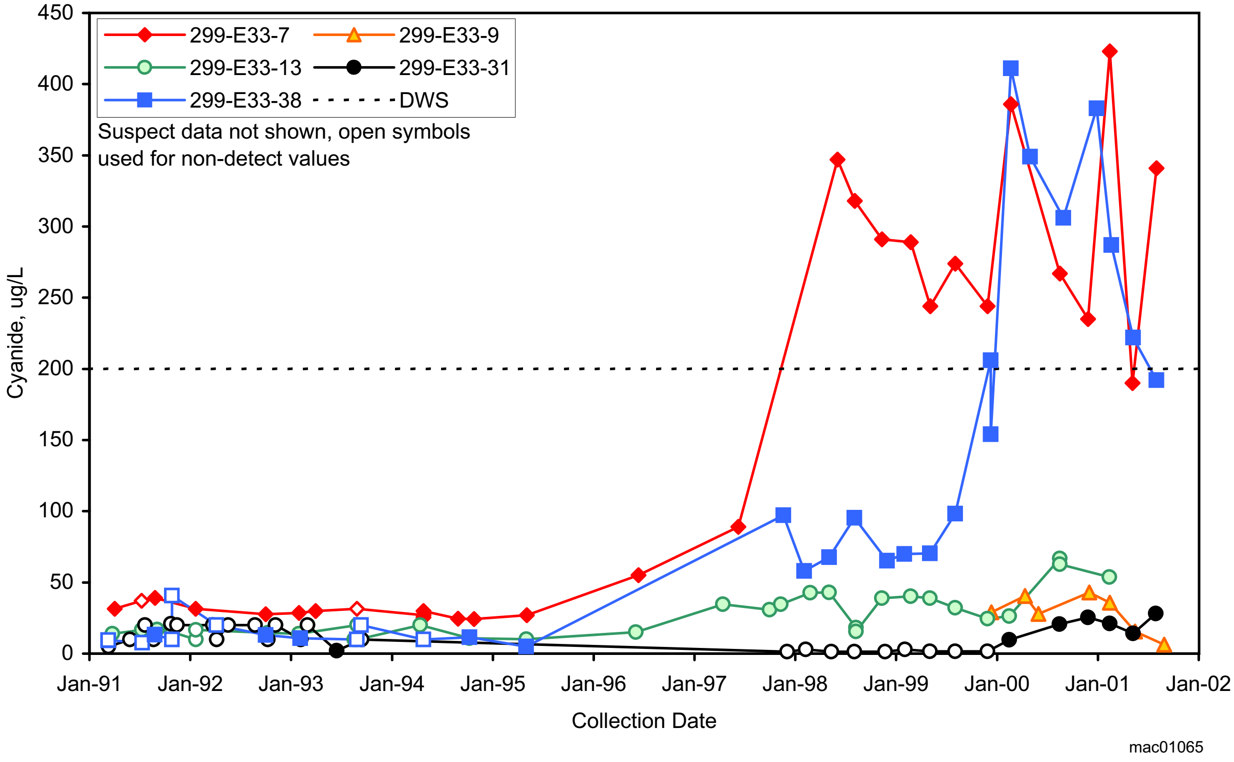

Figure 2.9-16. Cyanide Concentrations in Wells at BY Cribs and Northern Waste Management Area B-BX-BY

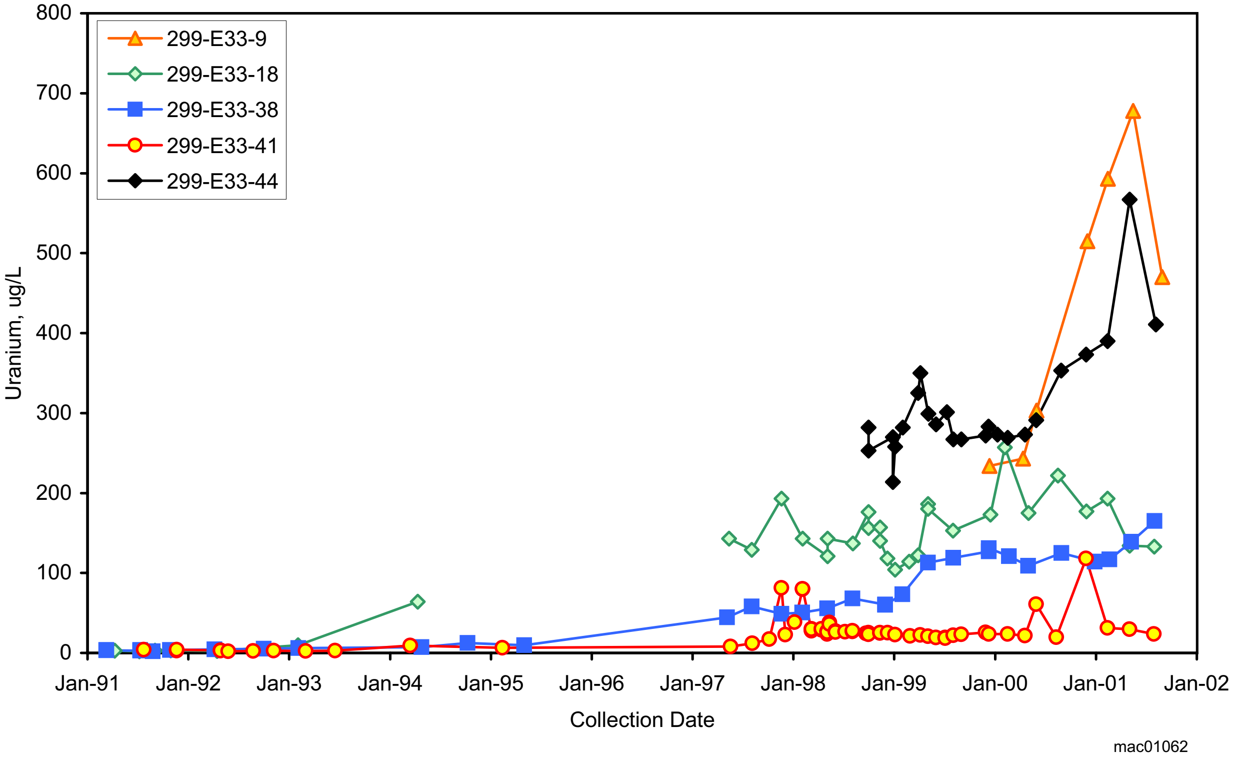

Figure 2.9-17. Uranium Concentrations in Wells at the Central Part of Waste Management Area B-BX-BY

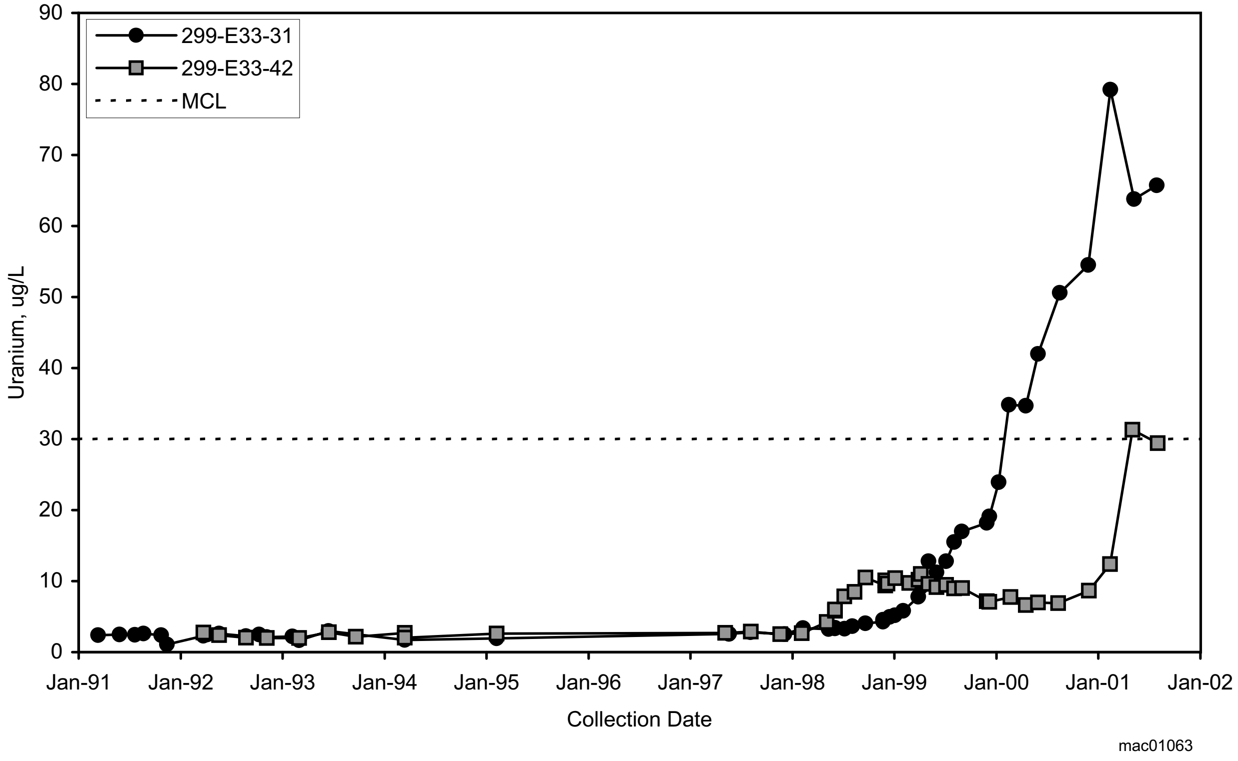

Figure 2.9-18. Uranium Trends in Wells Northwest of Waste Management Area B-BX-BY

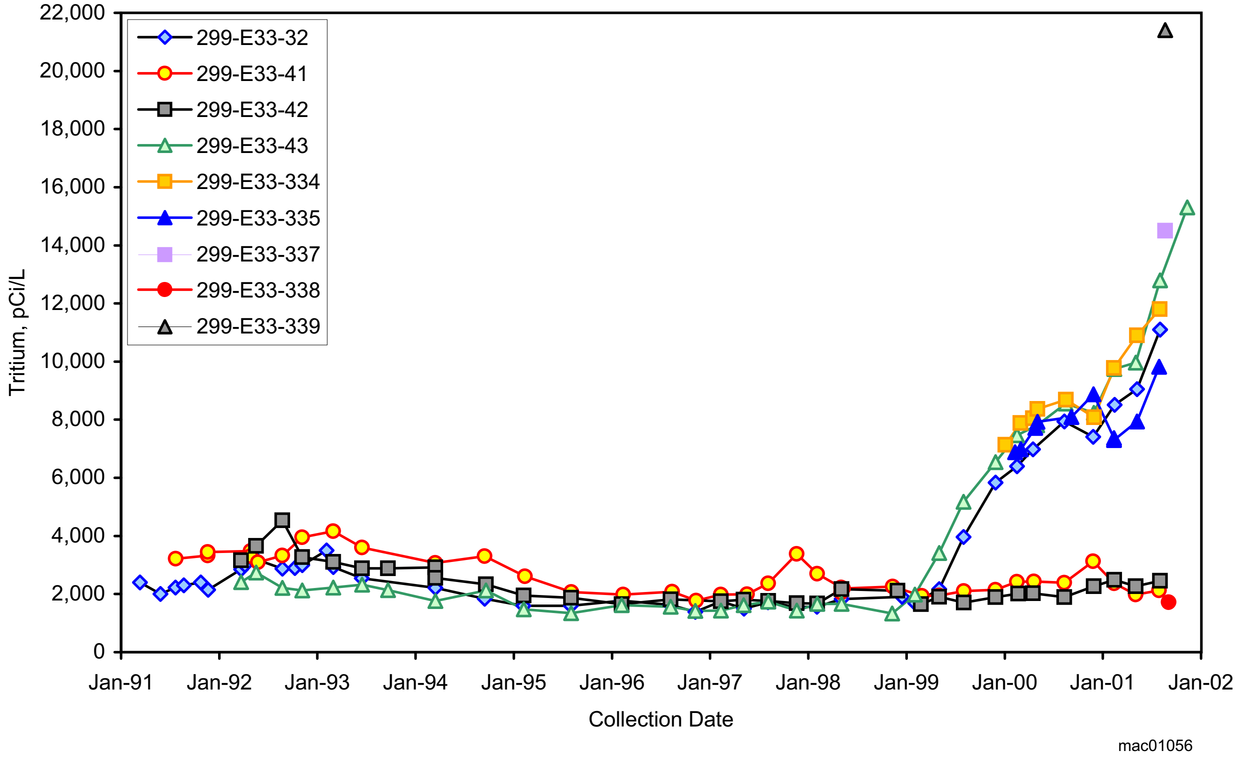

Figure 2.9-19. Comparison of Tritium Concentrations in the Southern Portion of Waste Management Area B-BX-BY to Values Upgradient

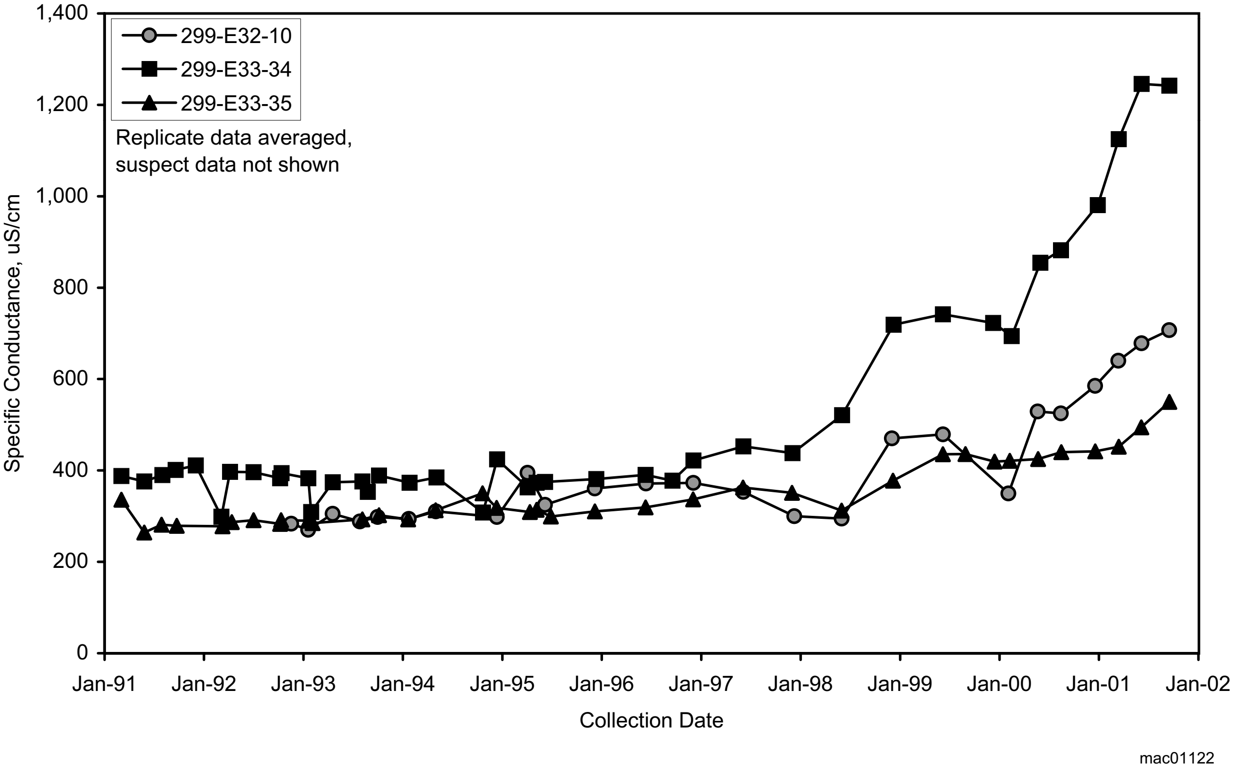

Figure 2.9-20. Specific Conductance in Wells at Low-Level Waste Management Area 1

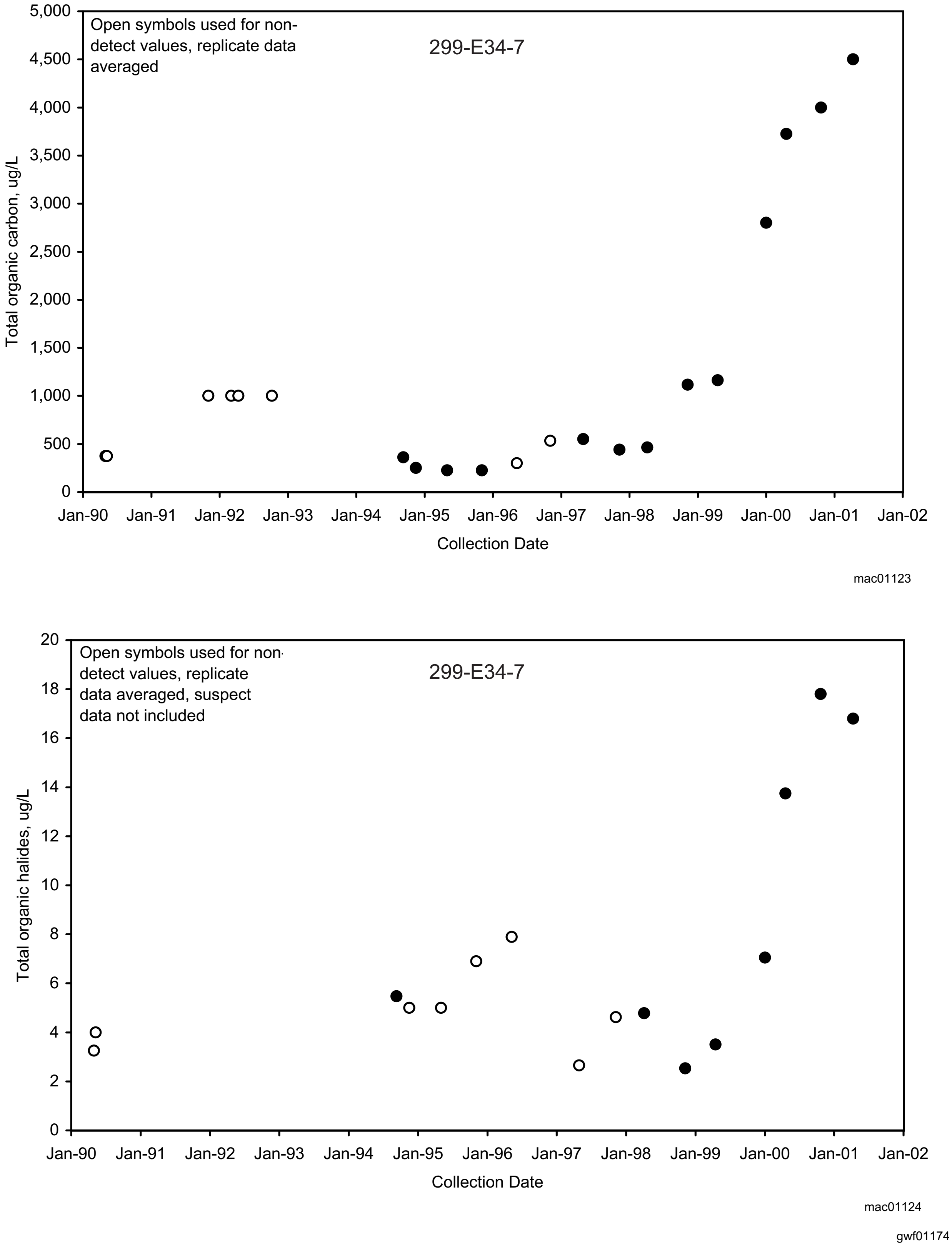

Figure 2.9-21. Total Organic Carbon and Total Organic Halides at Low-Level Waste Management Area 2

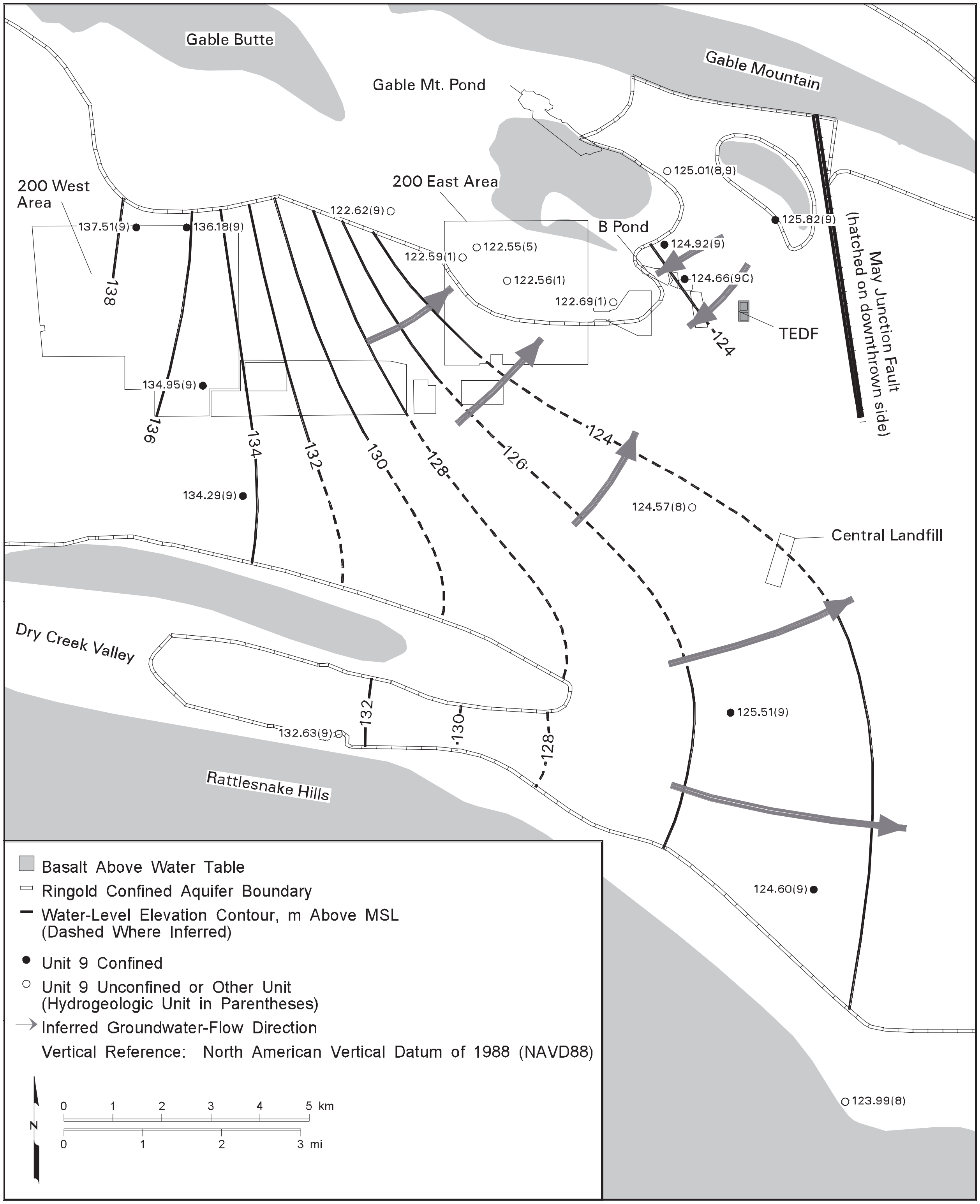

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Figure 2.9-22. Potentiometric Surface Map of Ringold Formation Confined Aquifer (Unit 9), Central Hanford Site, March 2001

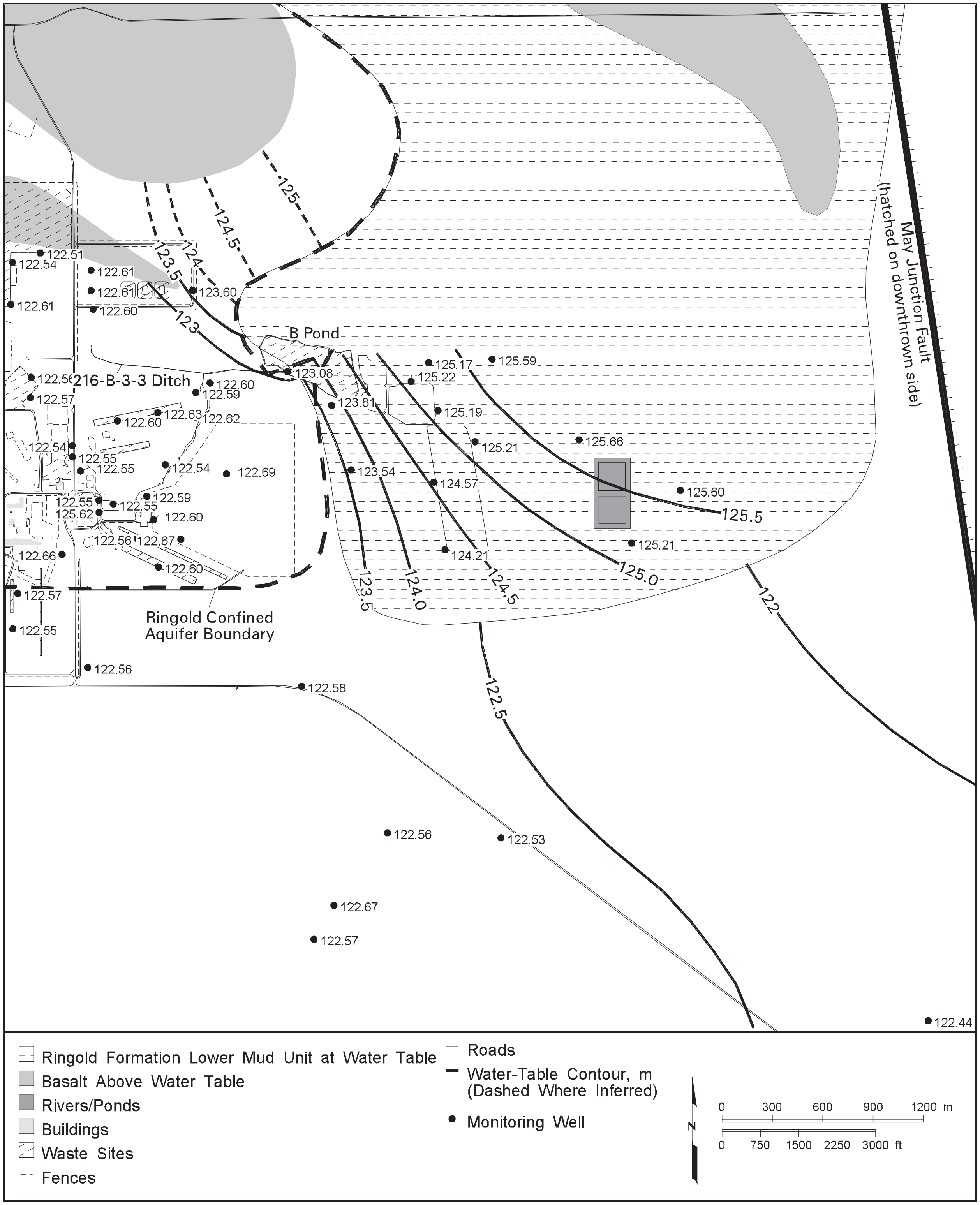

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Figure 2.9-23. March 2001 Water-Table (potentiometric) Map for the Confined and Unconfined Aquifers Near B Pond

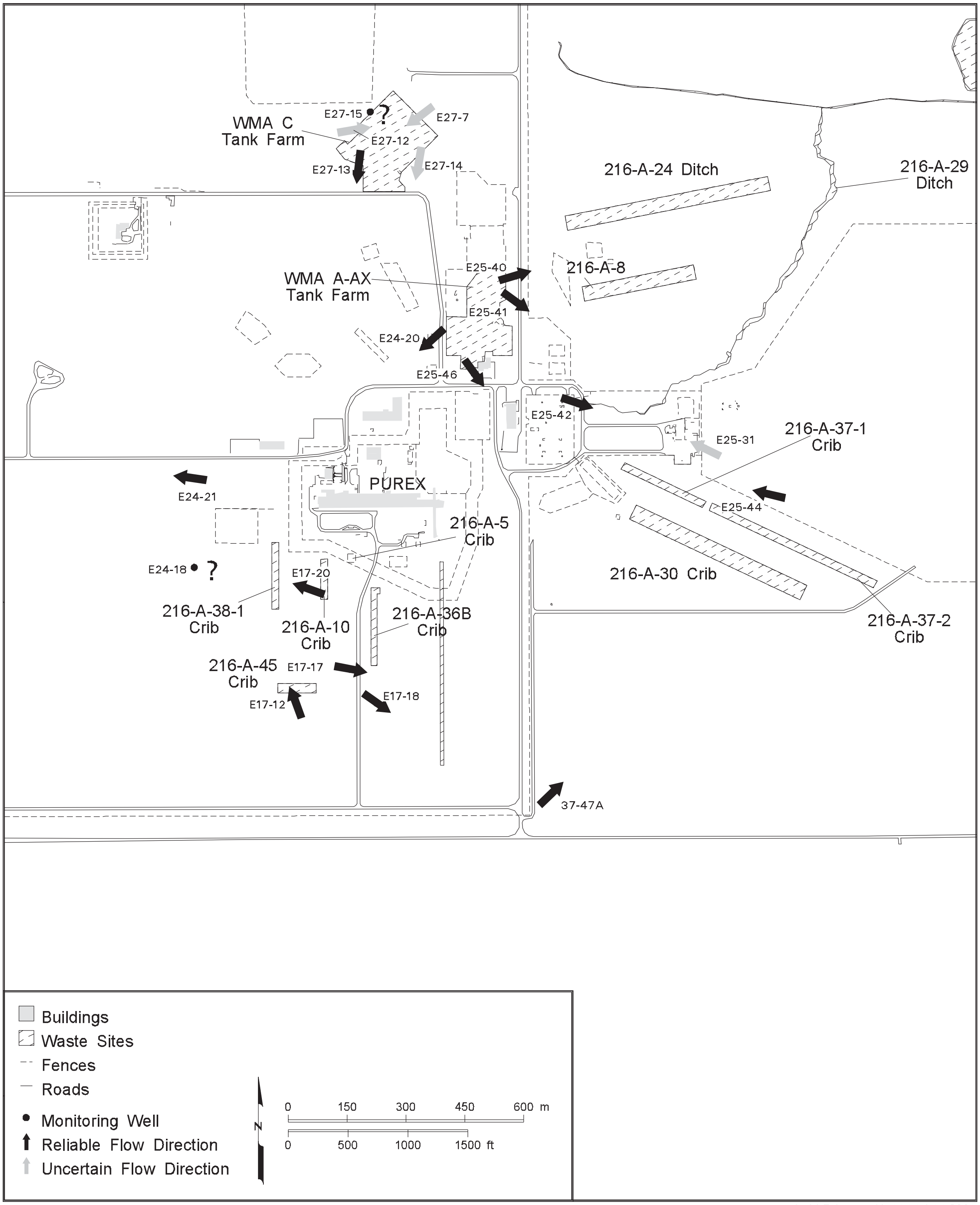

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Figure 2.9-24. Colloidal Borescope Flow Meter Results for the PUREX Plant Area

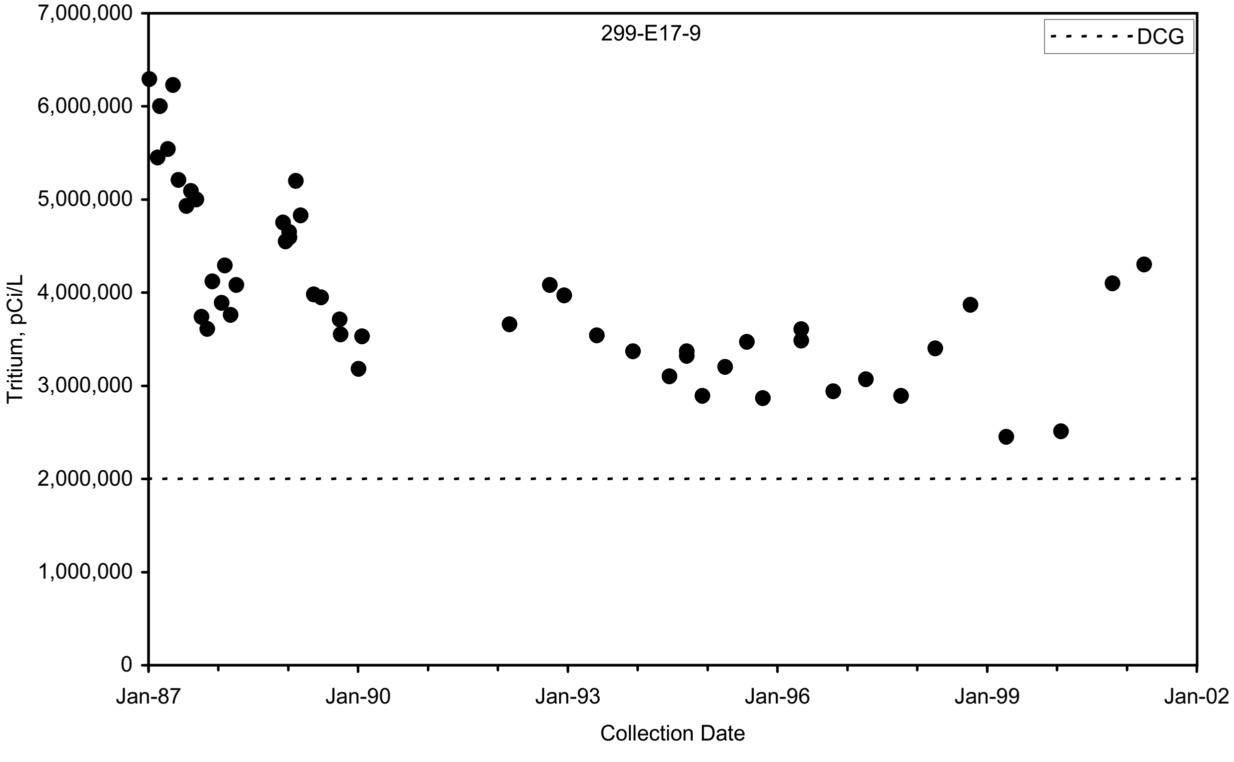

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Figure 2.9-25. Tritium Concentrations at the 216-A-36B Crib

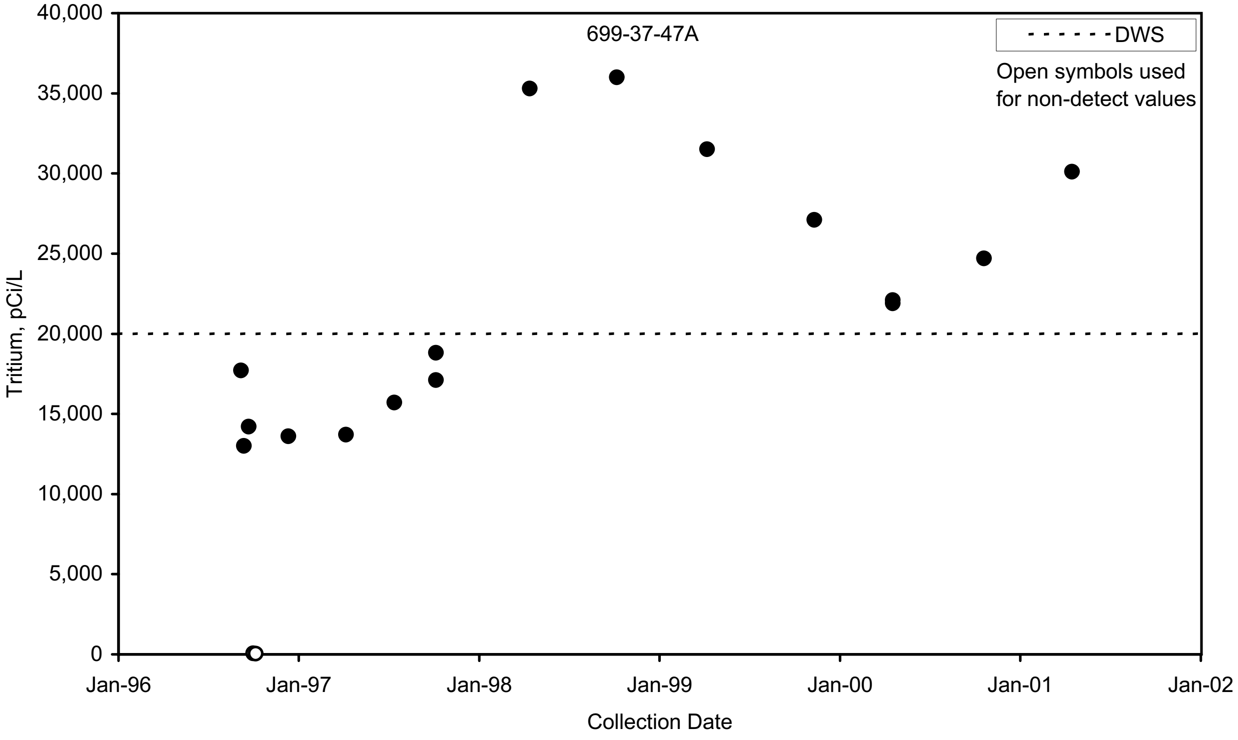

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Figure 2.9-26. Tritium Concentrations Near the PUREX Cribs

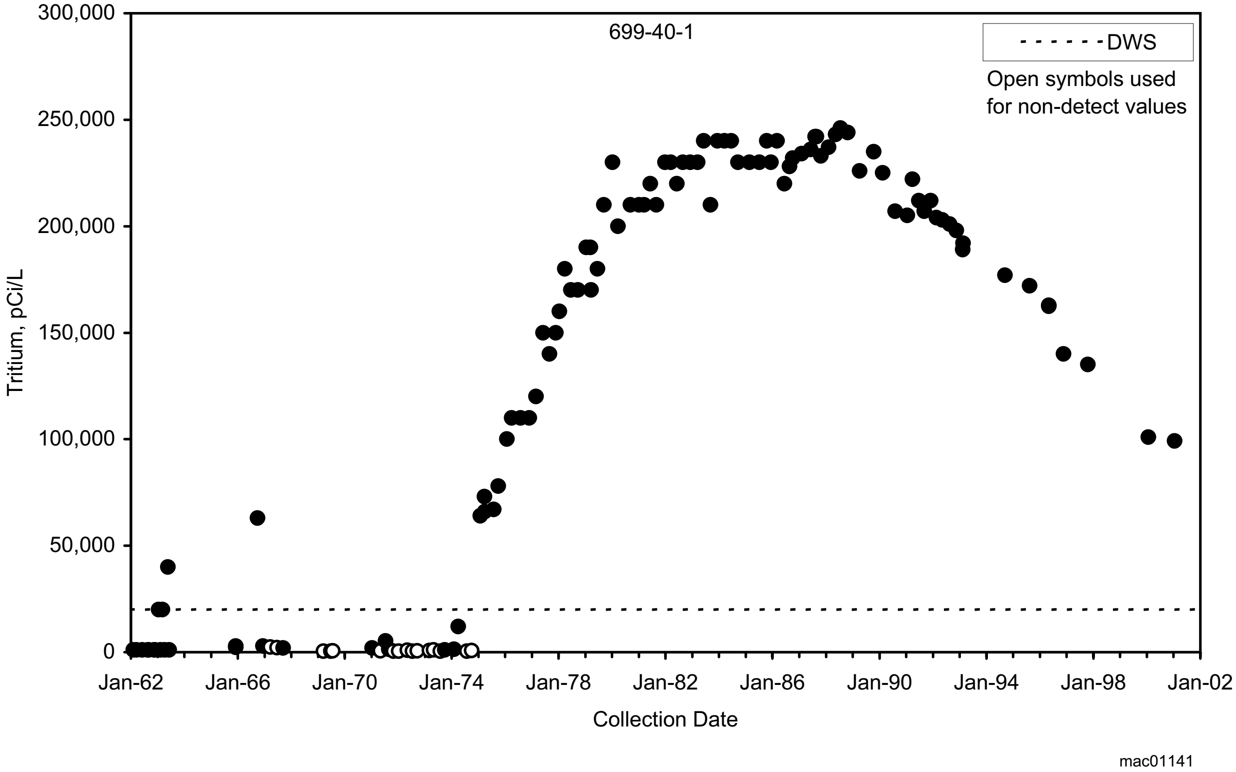

Figure 2.9-27. Tritium Concentrations Within the 200 East Area Plume Near the Columbia River

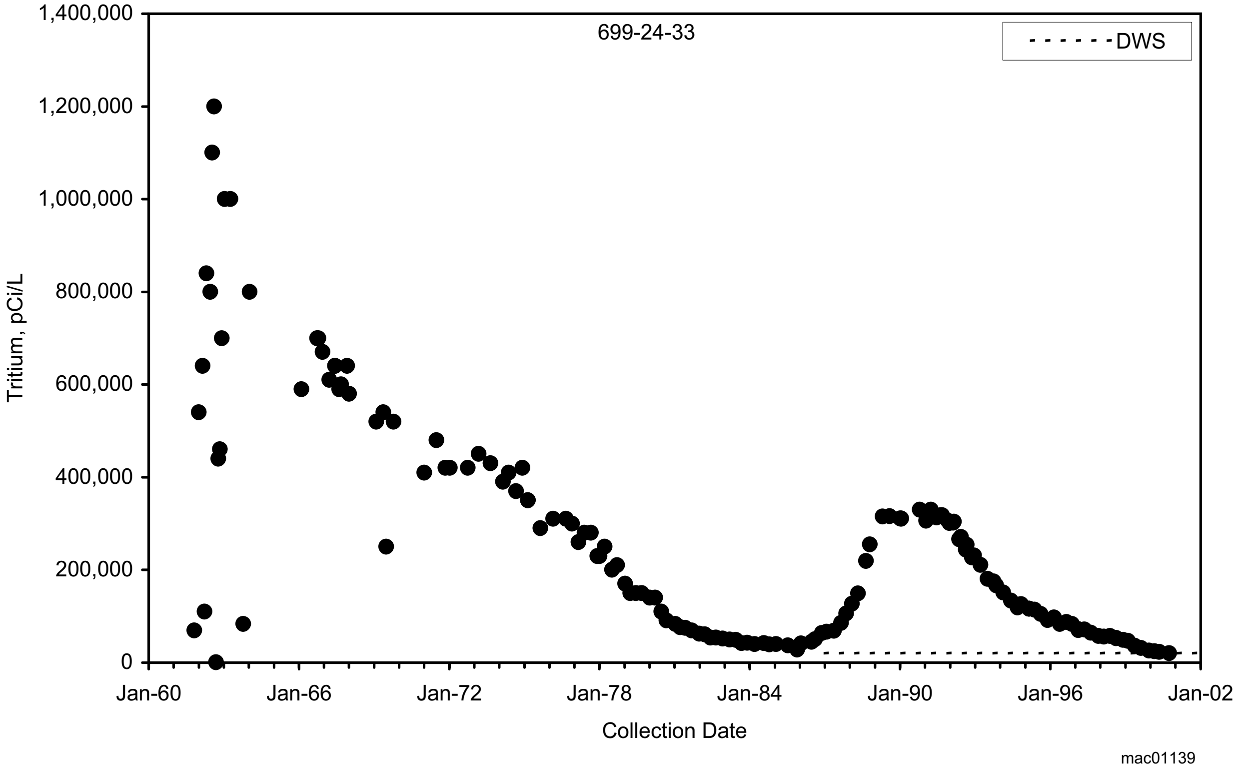

Figure 2.9-28. Tritium Concentrations Within the 200 East Area Plume Near the Central Landfill

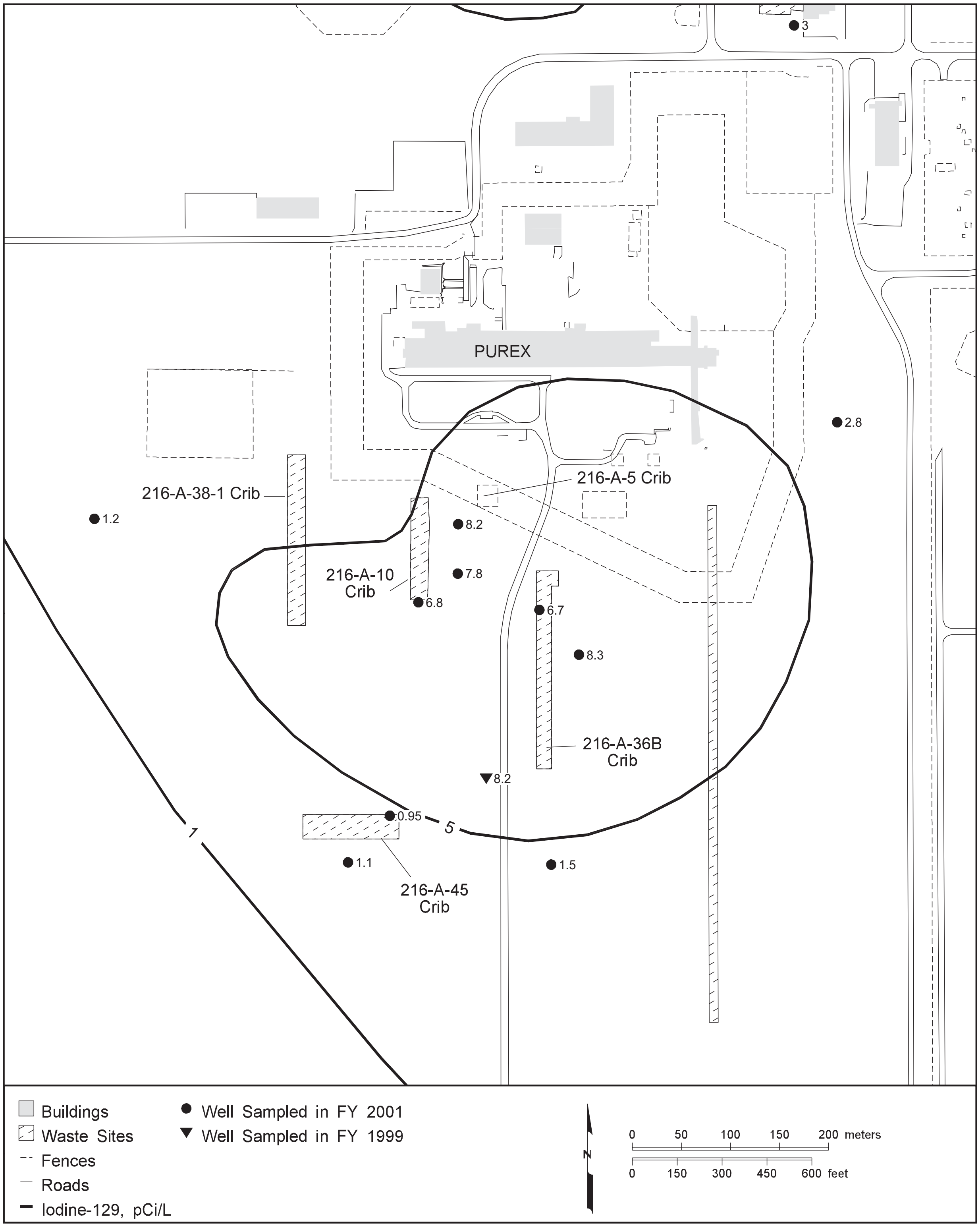

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Figure 2.9-29. Average Iodine-129 Concentrations Near the PUREX Plant, Top of Unconfined Aquifer

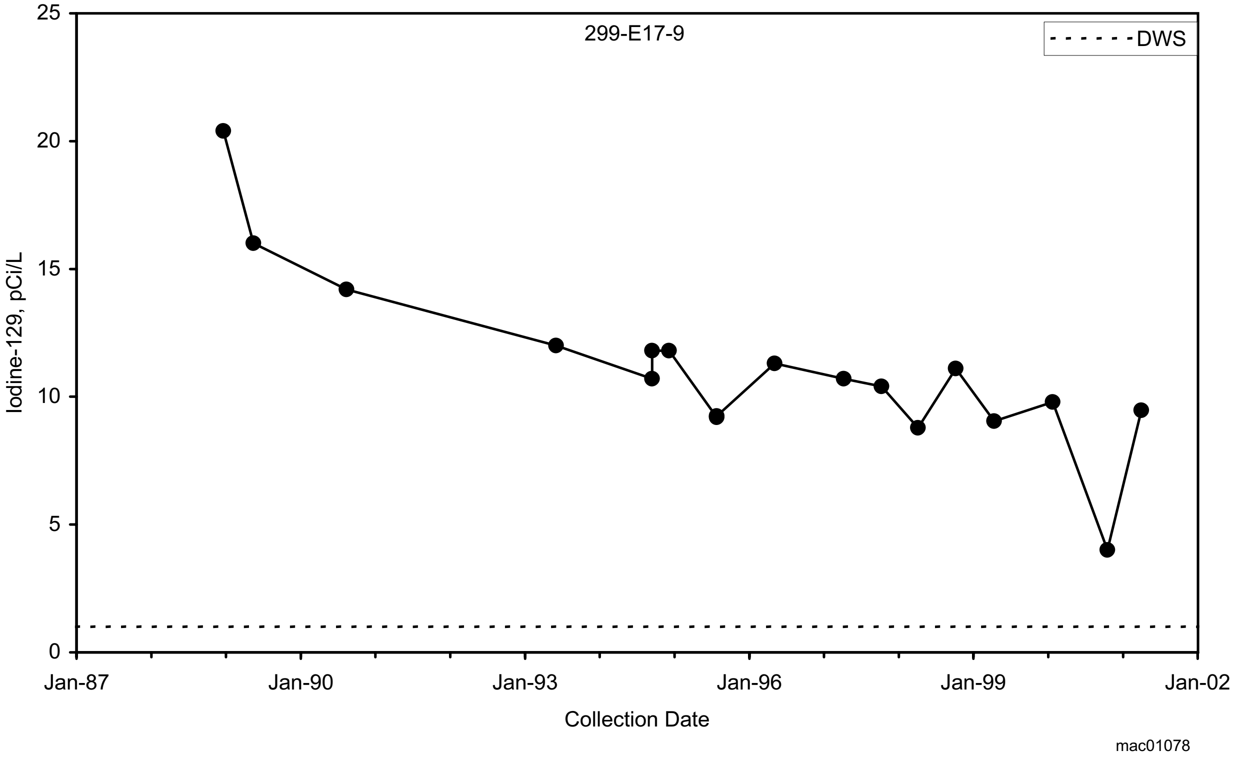

Figure 2.9-30. Iodine-129 Concentrations at the 216-A-36B Crib

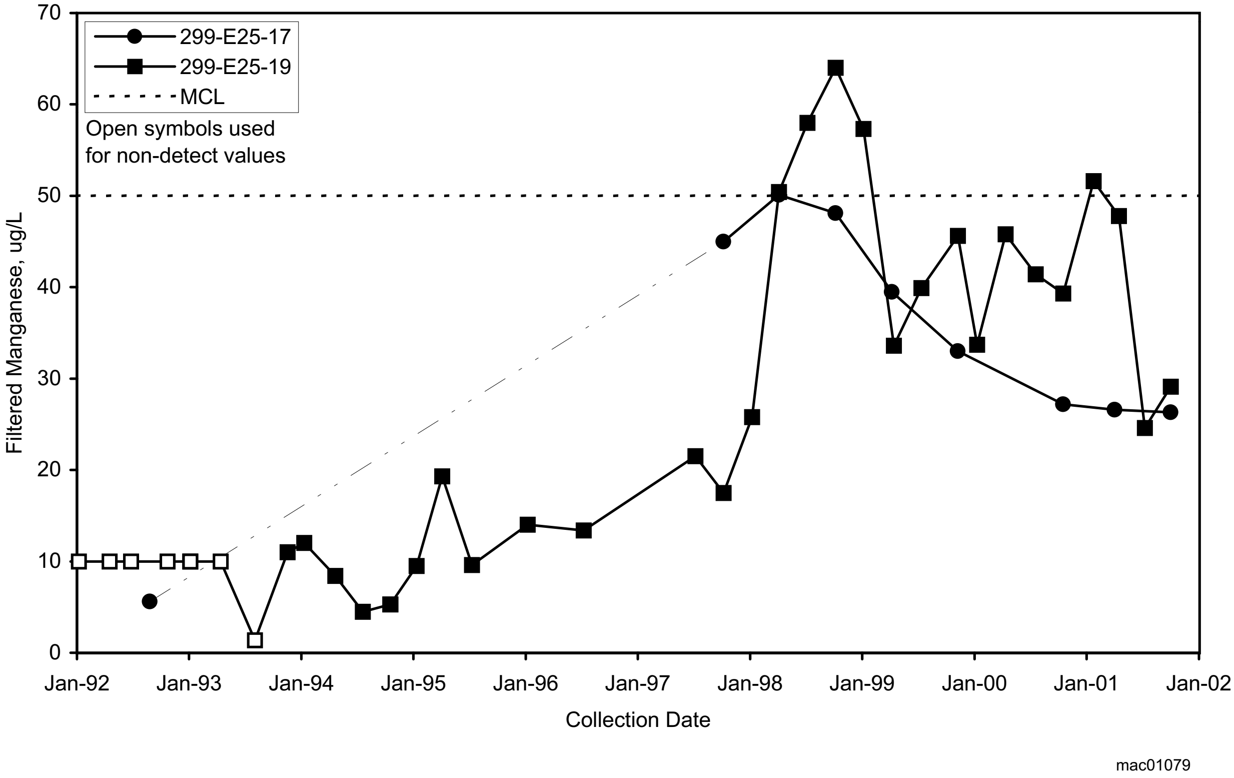

Figure 2.9-31. Manganese Concentrations in Wells Near the 216-A-37-1 Crib

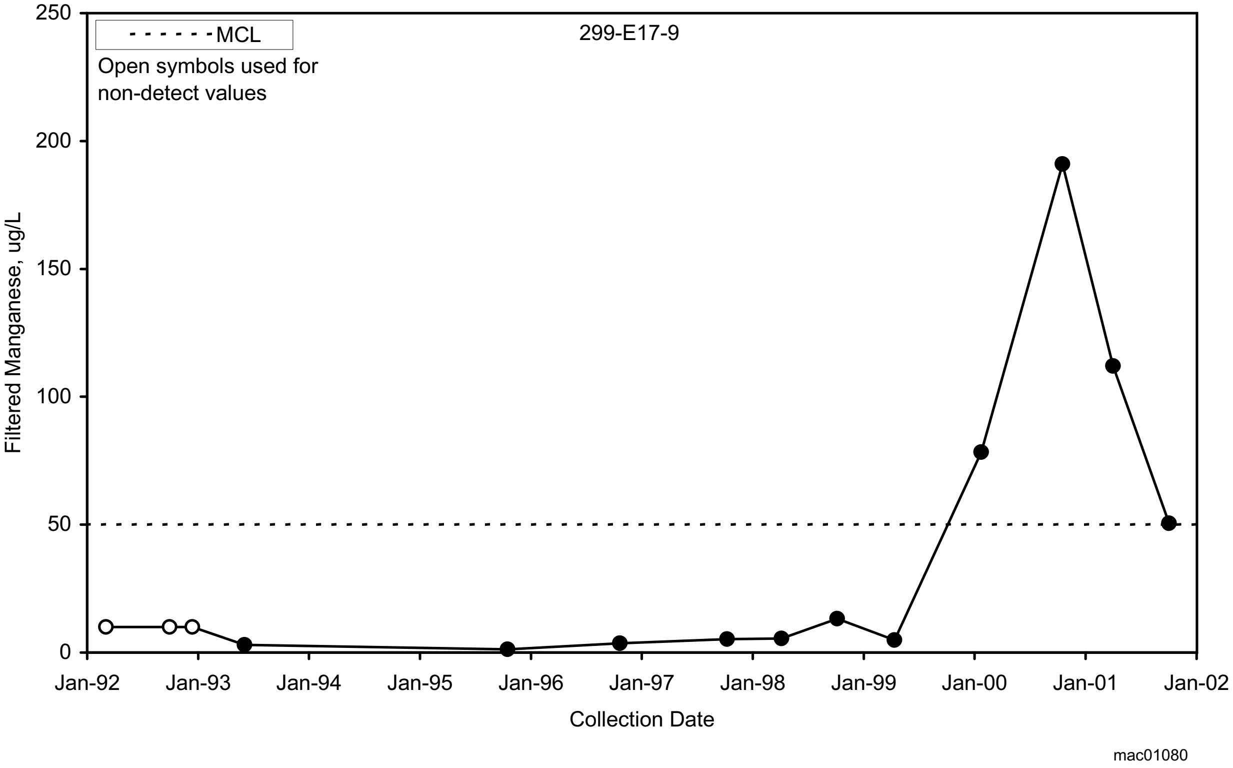

Figure 2.9-32. Manganese Concentrations Near the 216-A-36B Crib

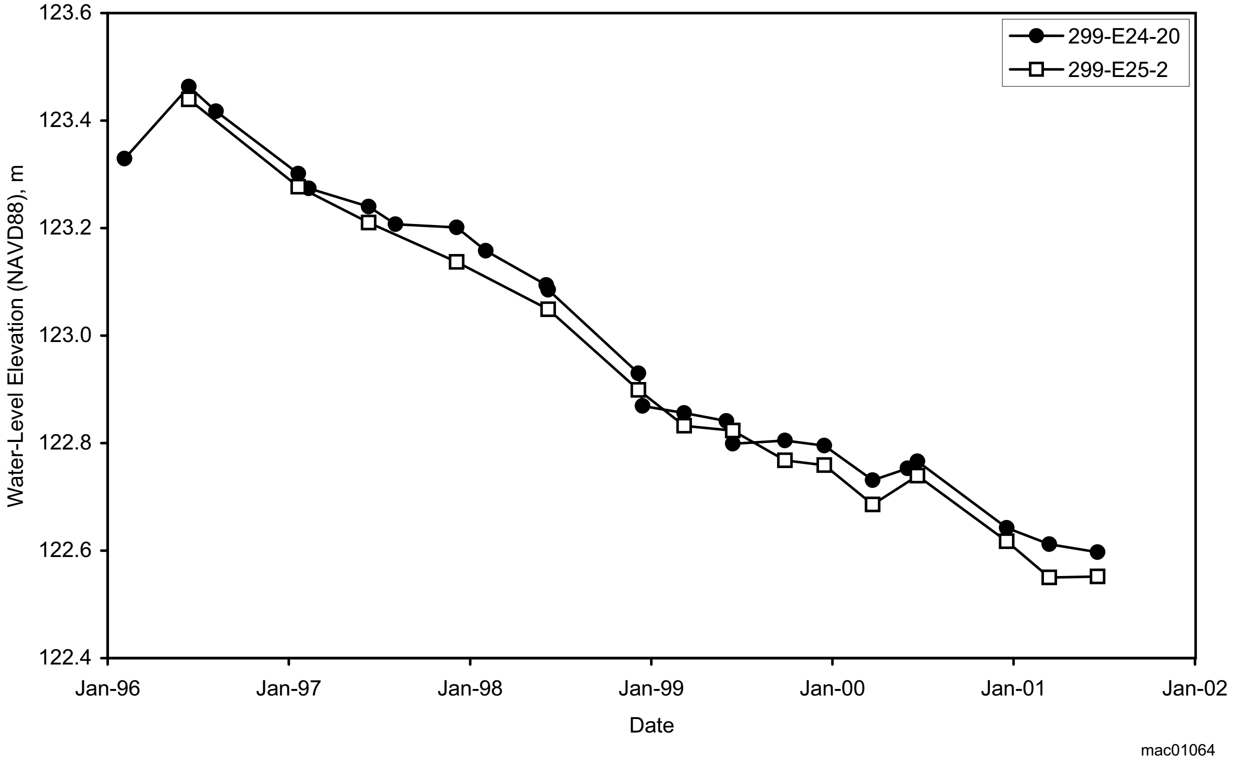

Figure 2.9-33. Water Levels at Waste Management Area A-AX. Well 299-E24-20 is west (upgradient) of well 299-E25-2.

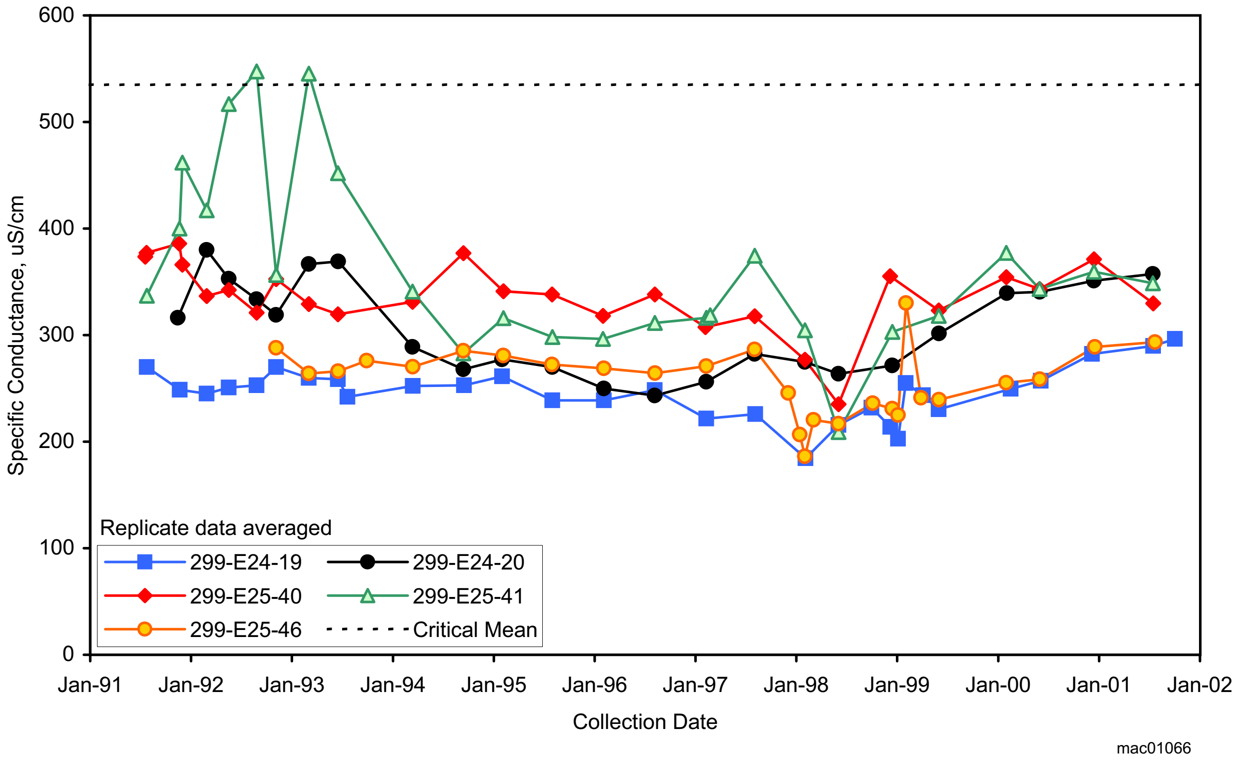

Figure 2.9-34. Specific Conductance in Wells Monitoring Waste Management Area A-AX

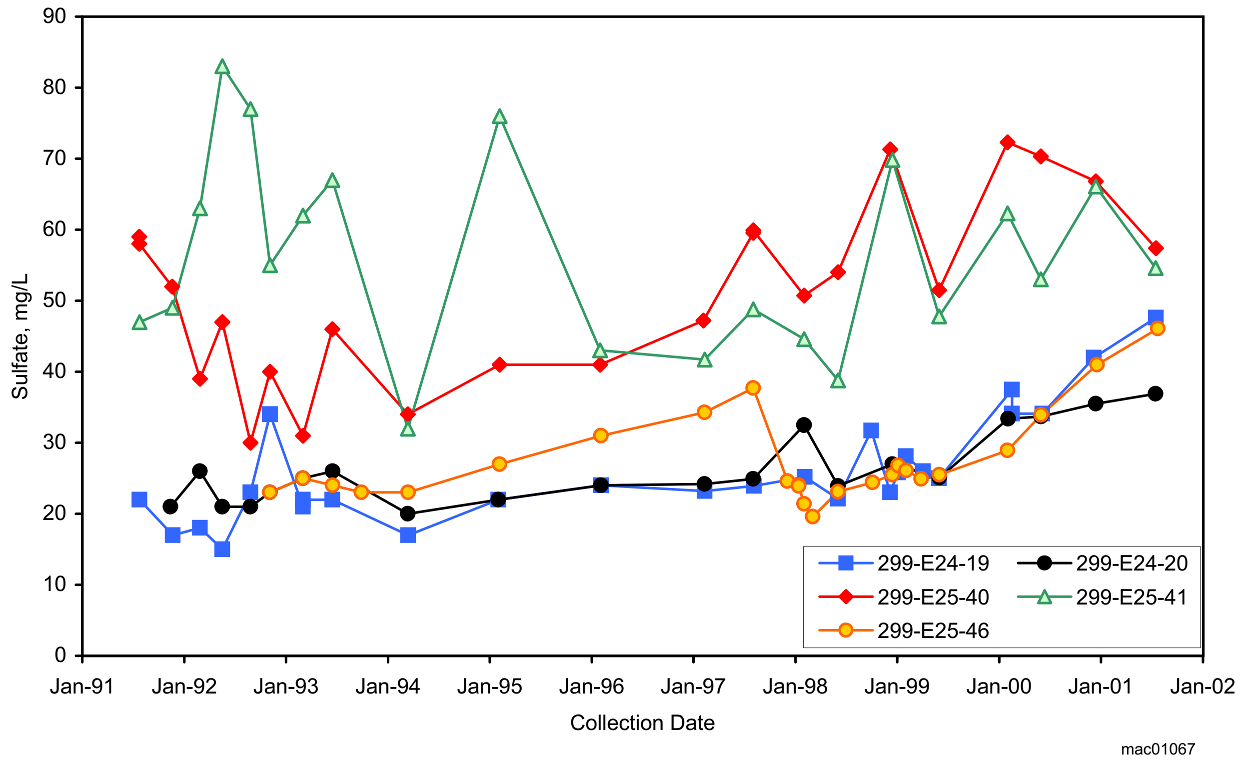

Figure 2.9-35. Sulfate Concentrations in Wells Monitoring Waste Management Area A-AX

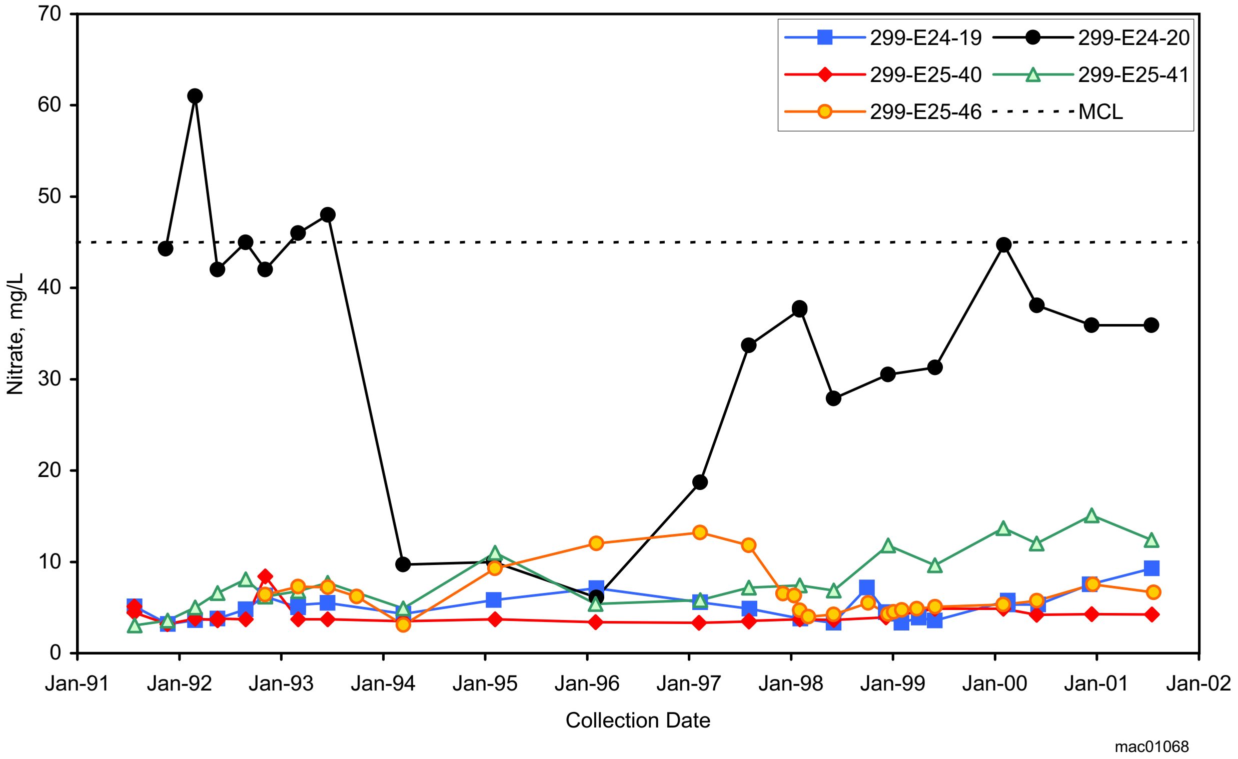

Figure 2.9-36. Nitrate Concentrations in Wells Monitoring Waste Management Area A-AX

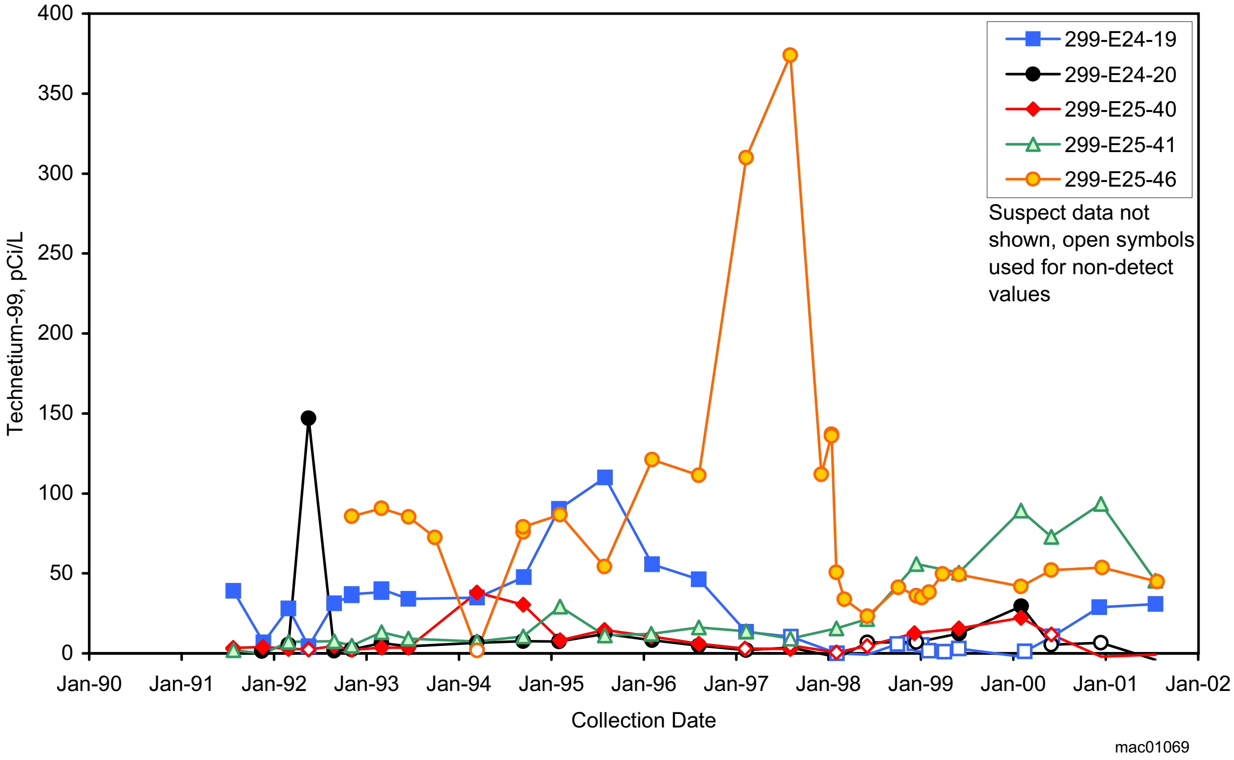

Figure 2.9-37. Technetium-99 Concentrations in Wells Monitoring Waste Management Area A-AX

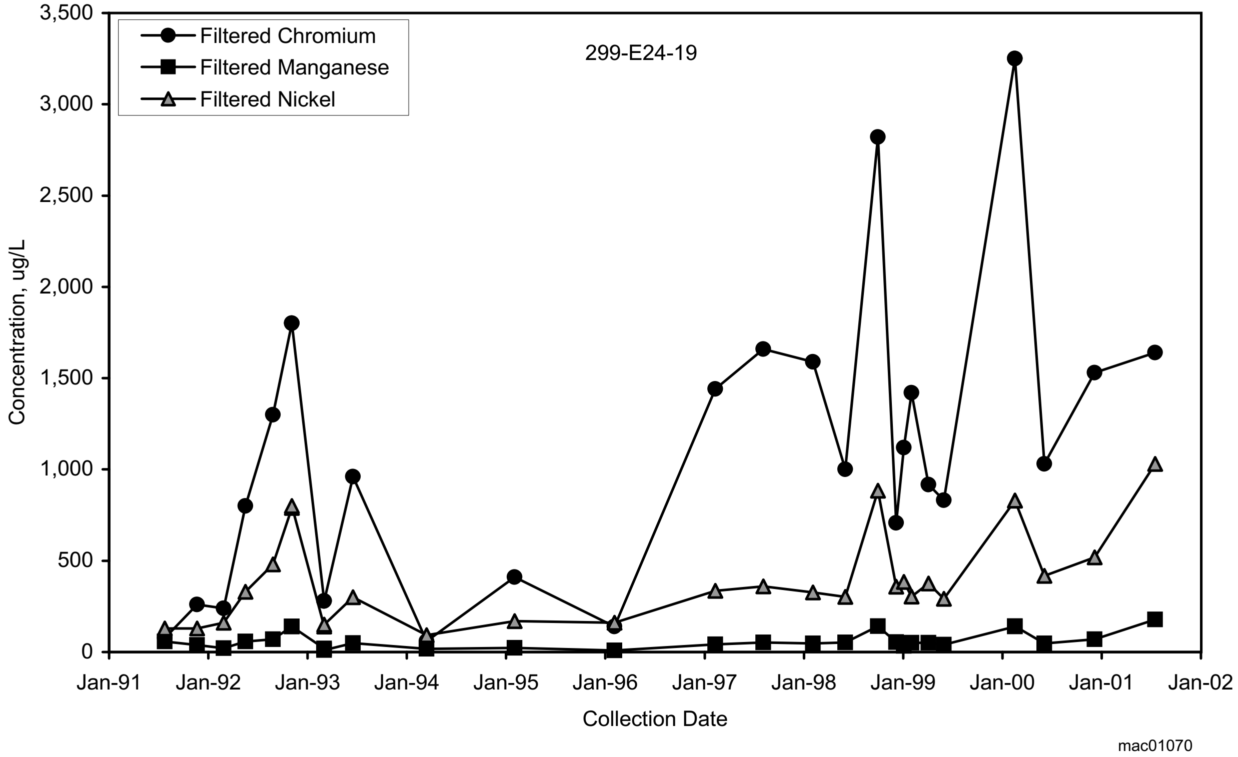

Figure 2.9-38. Chromium, Manganese, and Nickel Concentrations at Waste Management Area A-AX

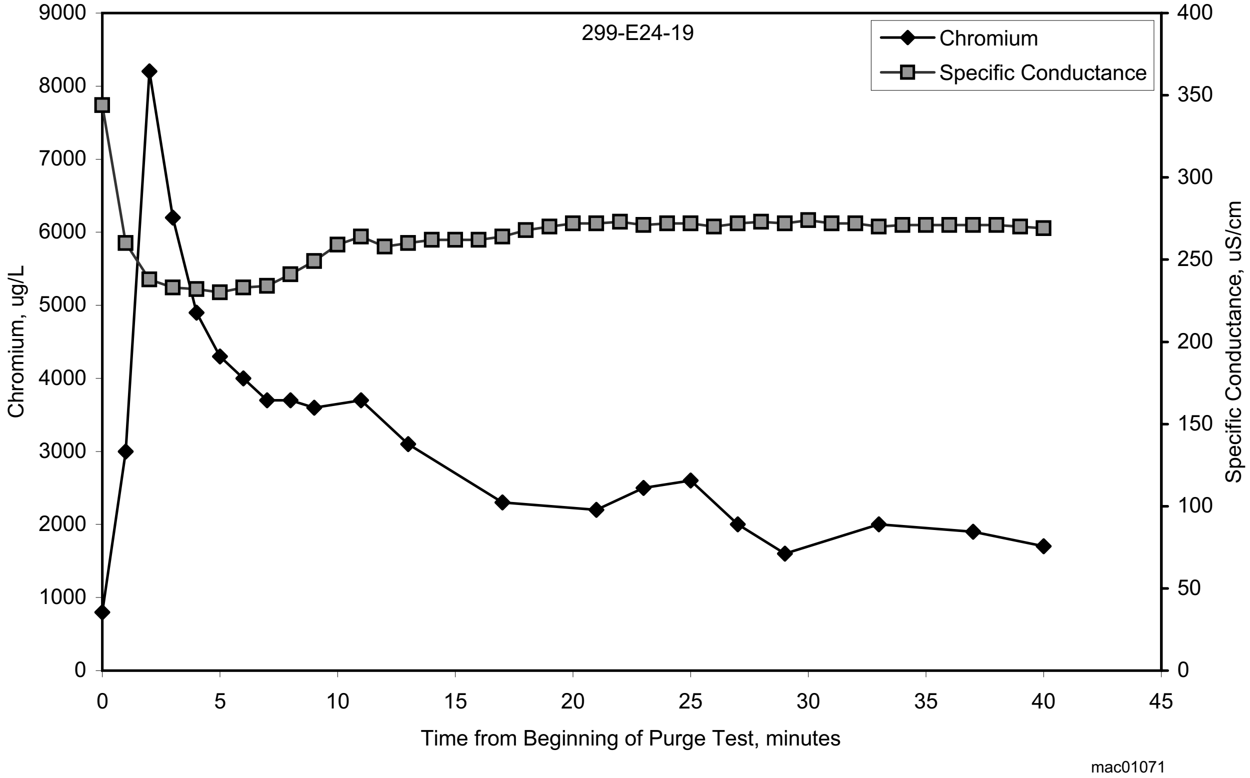

Figure 2.9-39. Chromium Concentrations and Specific Conductance at Waste Management Area A-AX

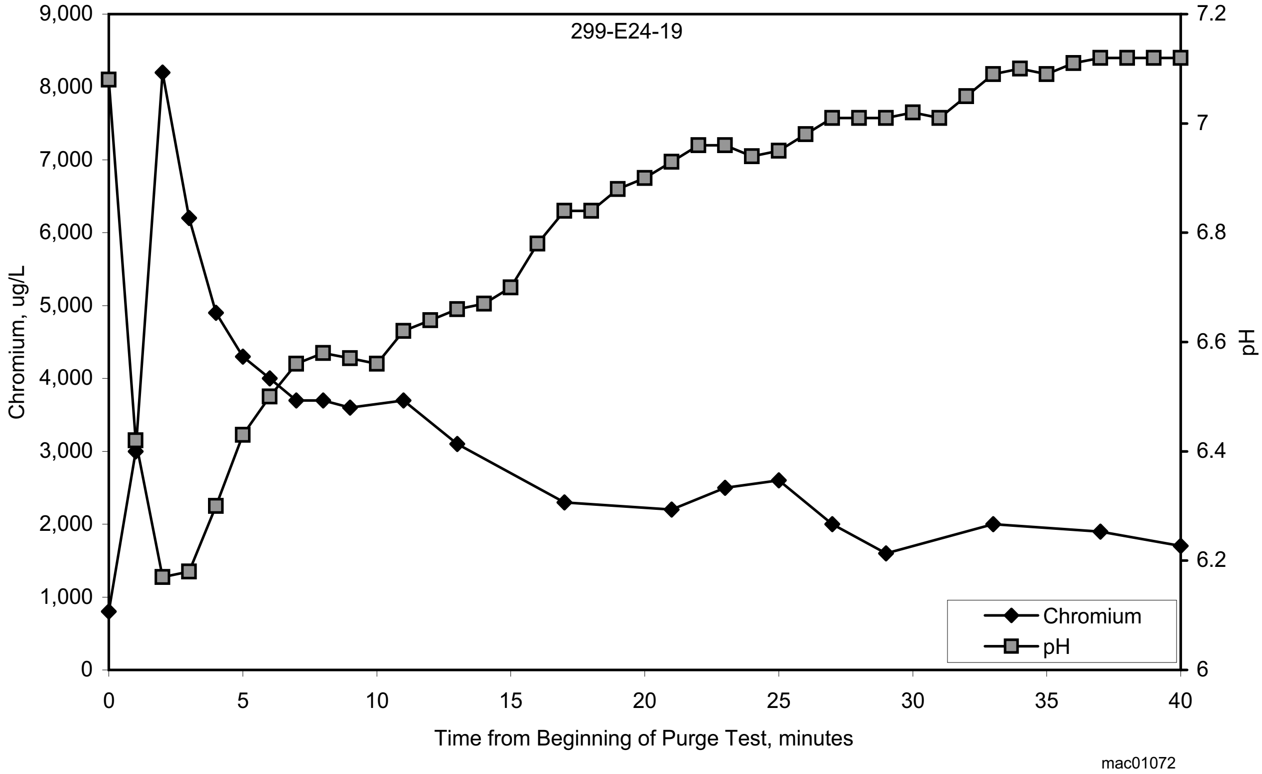

Figure 2.9-40. Chromium Concentrations and pH at Waste Management Area A-AX

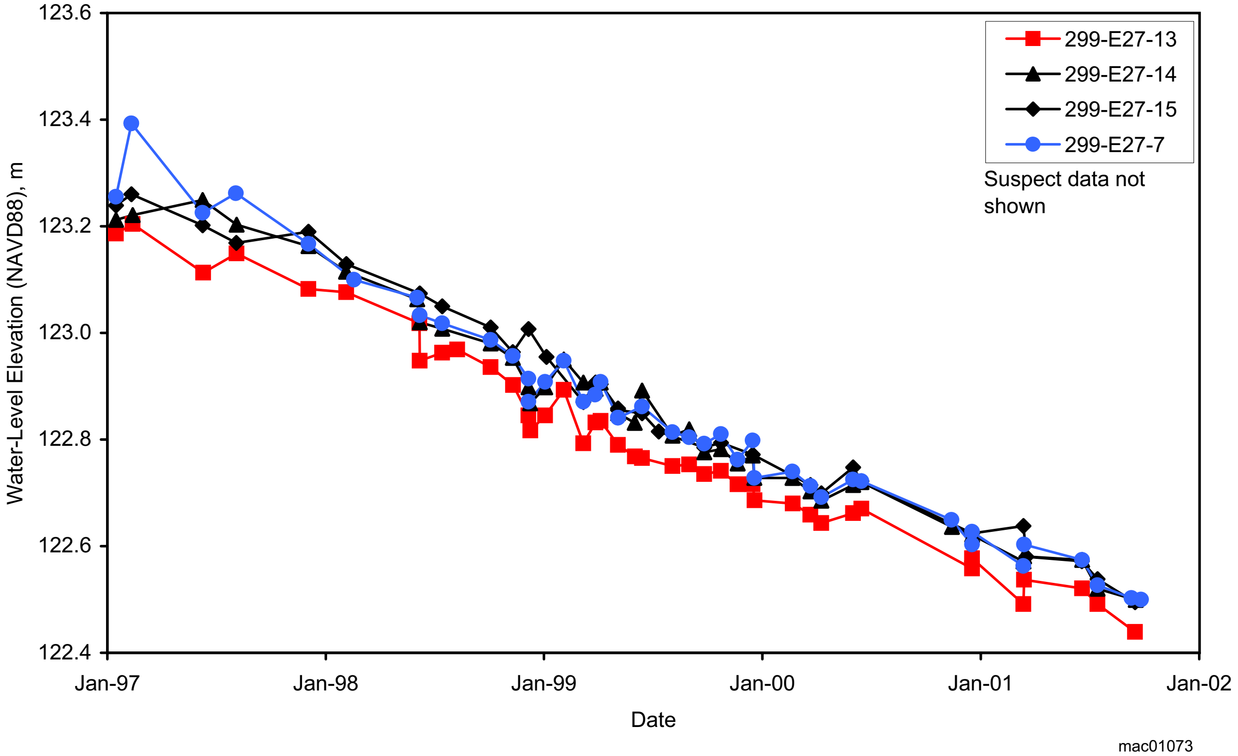

Figure 2.9-41. Water Levels in Wells at Waste Management Area C

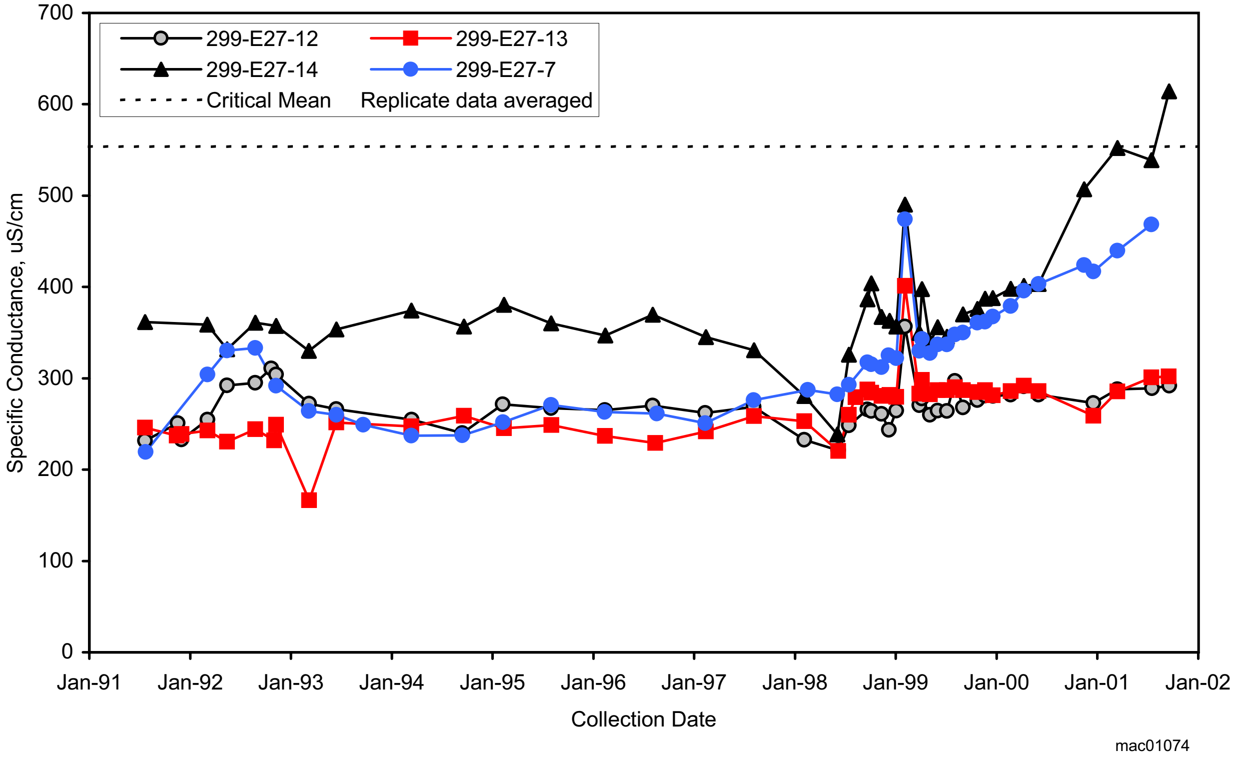

Figure 2.9-42. Specific Conductance in Wells Monitoring Waste Management Area C

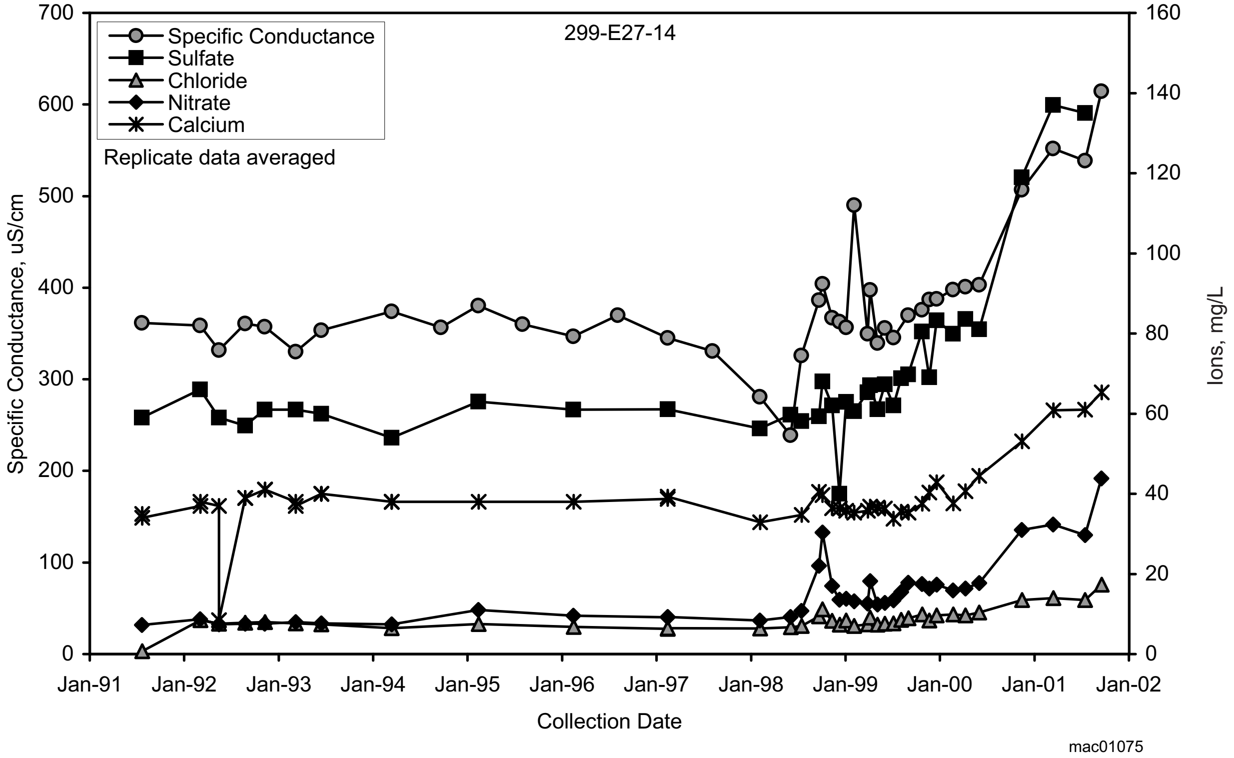

Figure 2.9-43. Specific Conductance Compared to Ions at Waste Management C

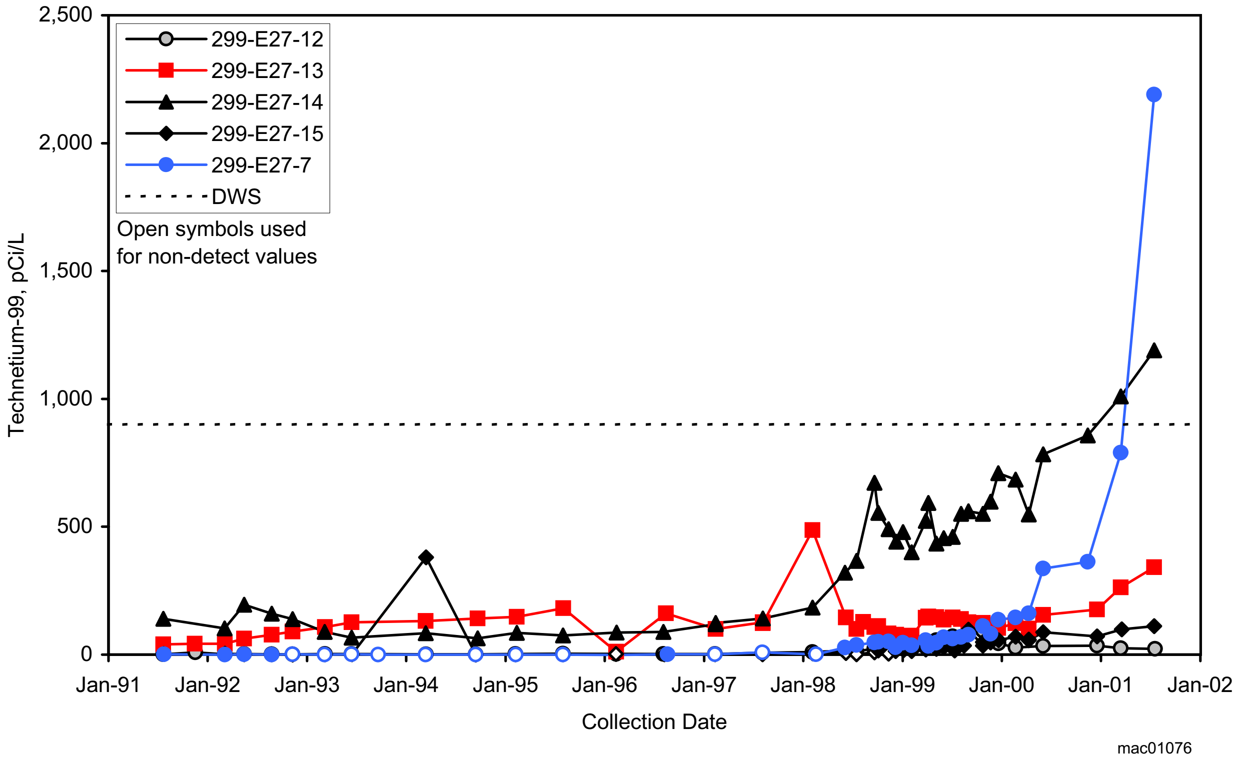

Figure 2.9-44. Technetium-99 Concentrations in Wells Monitoring Waste Management Area C

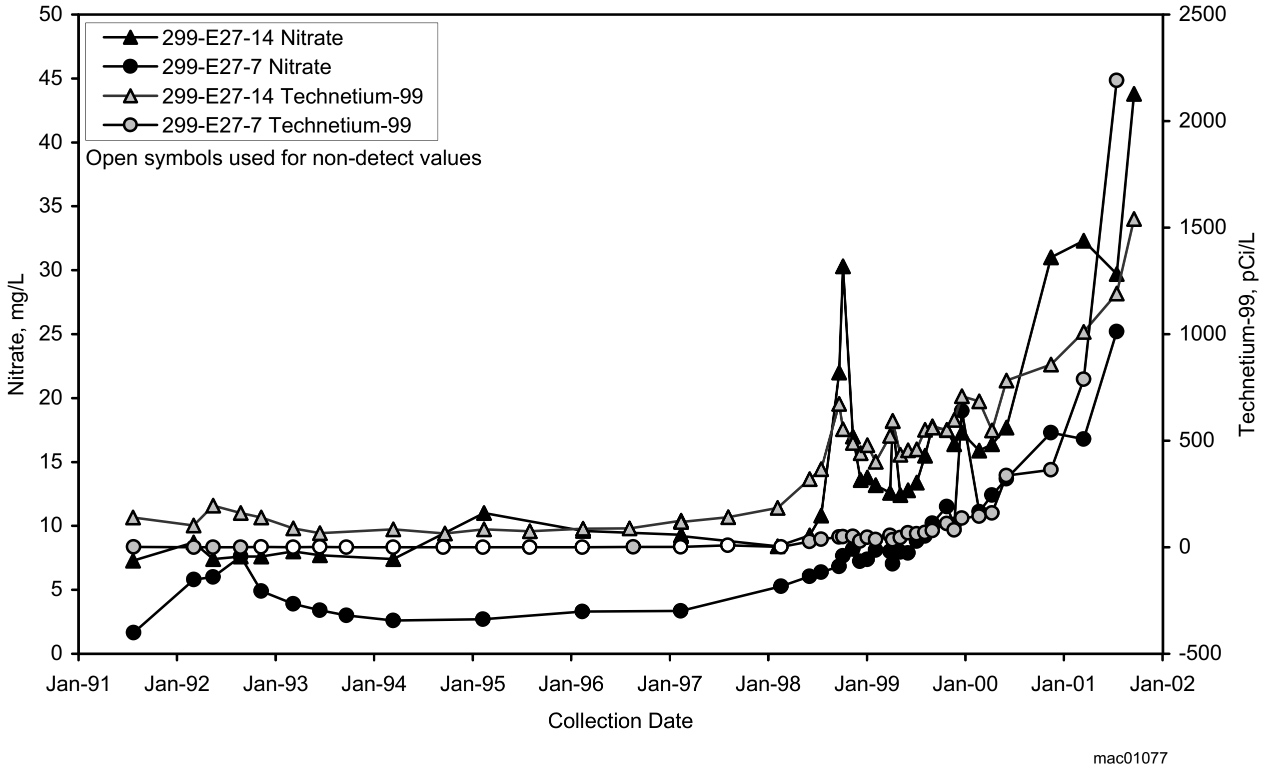

Figure 2.9-45. Nitrate and Technetium-99 Concentrations in Wells at Waste Management Area C

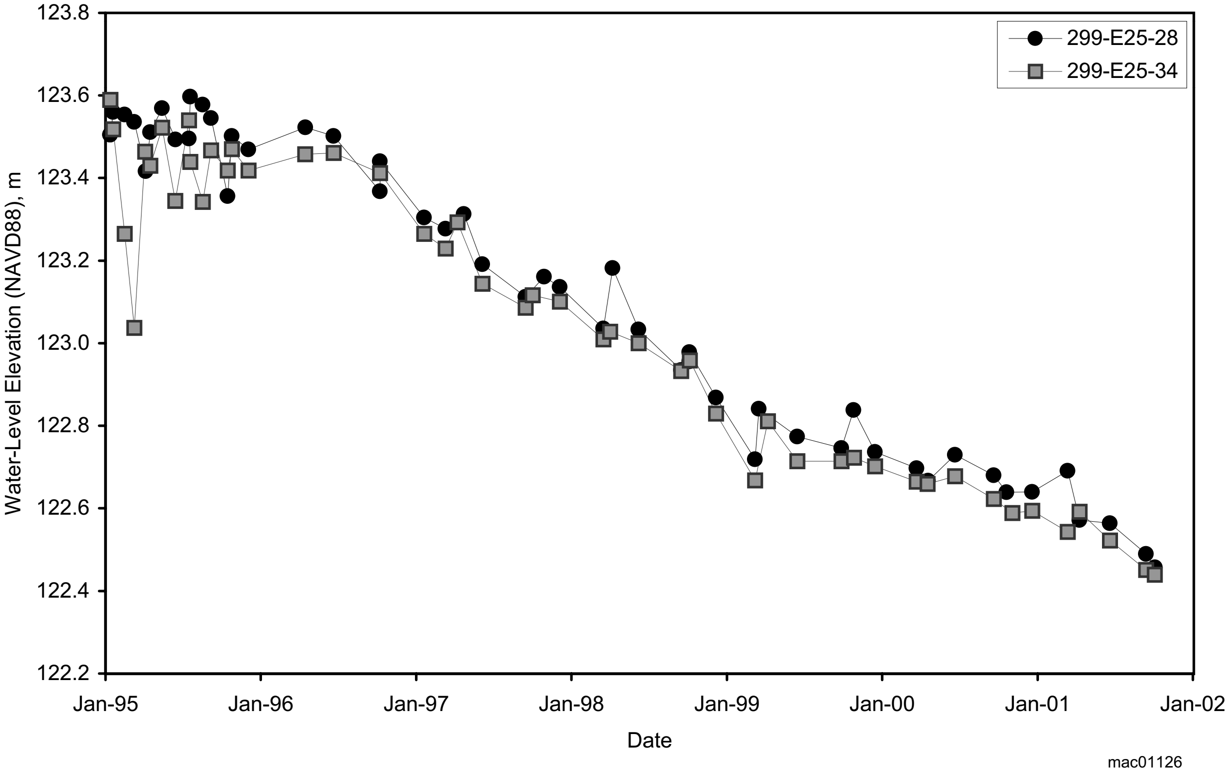

Figure 2.9-46. Water Levels in Well 299-E25-28 in Ringold Formation Unit 9 and Well 299-E25-34 in the Unconfined Aquifer

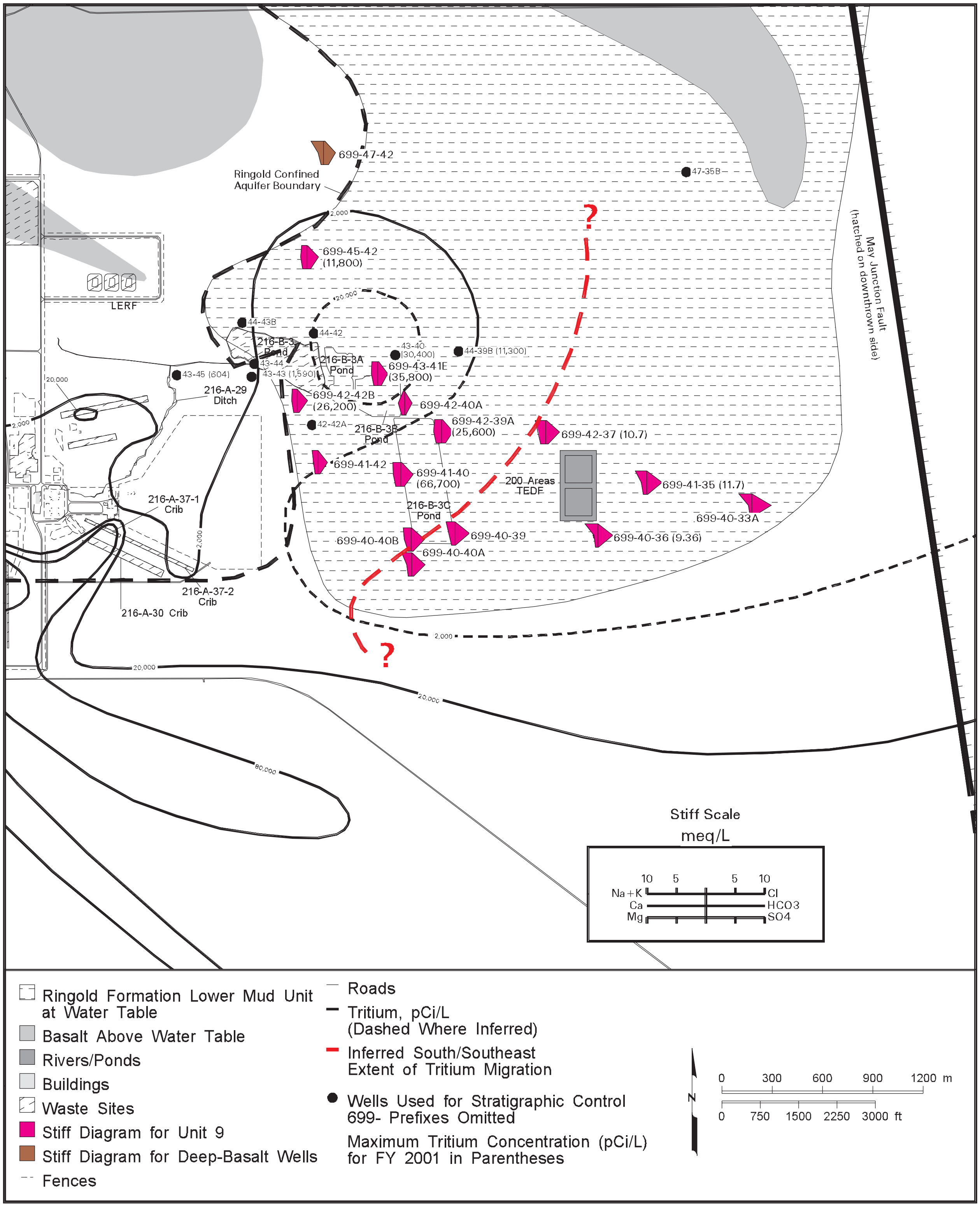

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Figure 2.9-47. Major Ion Chemistry in Wells Completed in the Confined Aquifer in the Vicinity of B Pond (PNNL-12261)

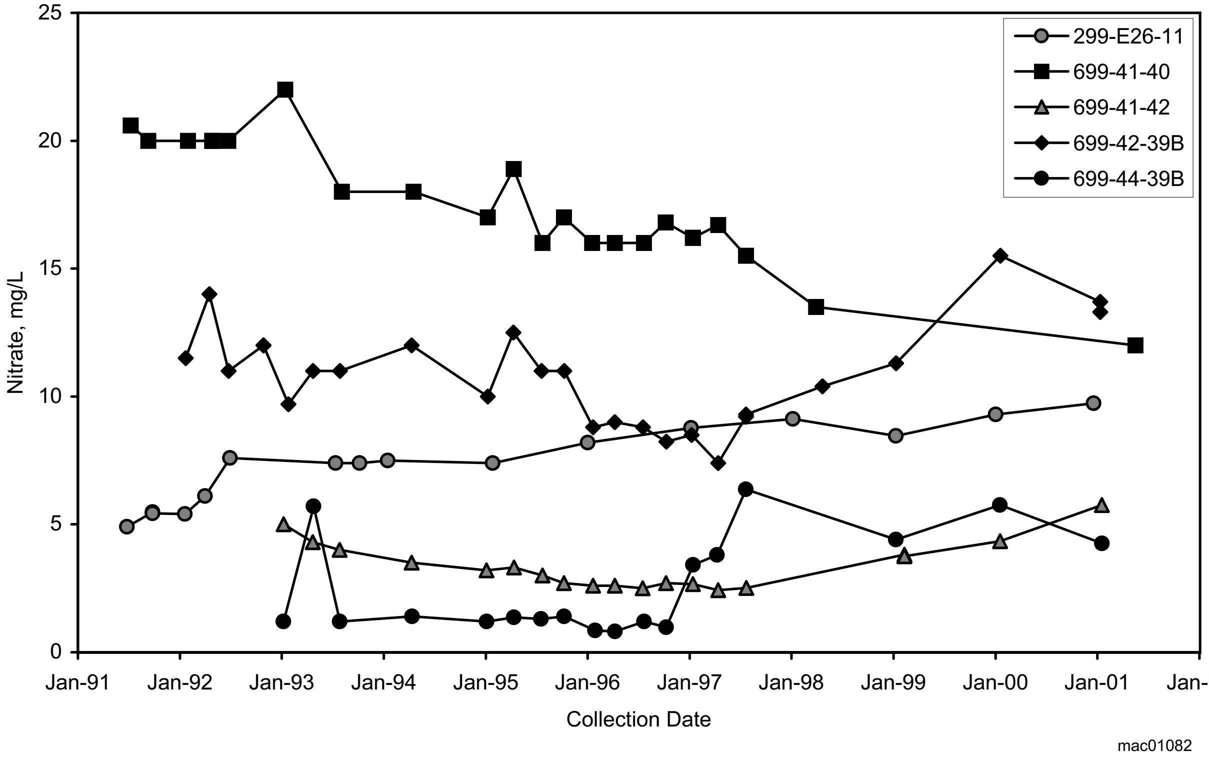


Figure 2.9-48. Nitrate Concentrations at B Pond in Wells Illustrating Significant Trends

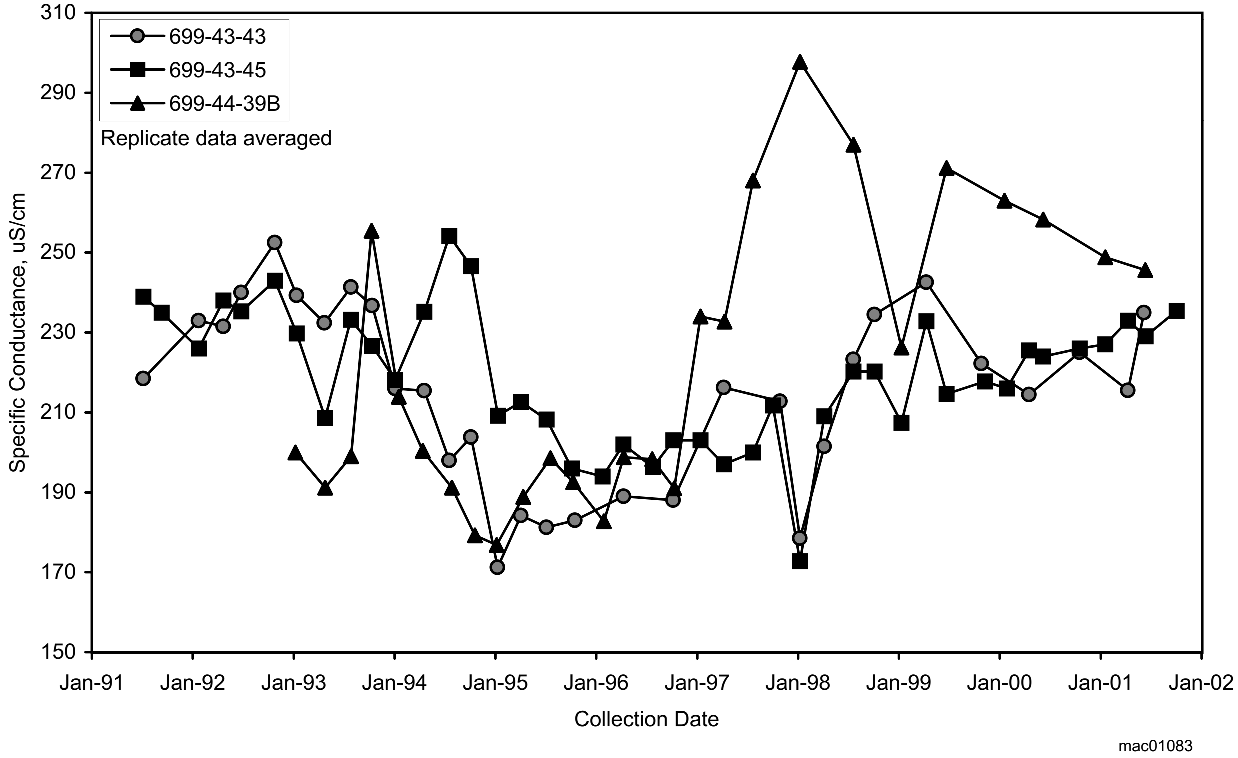


Figure 2.9-49. Specific Conductance in Wells Monitoring B Pond

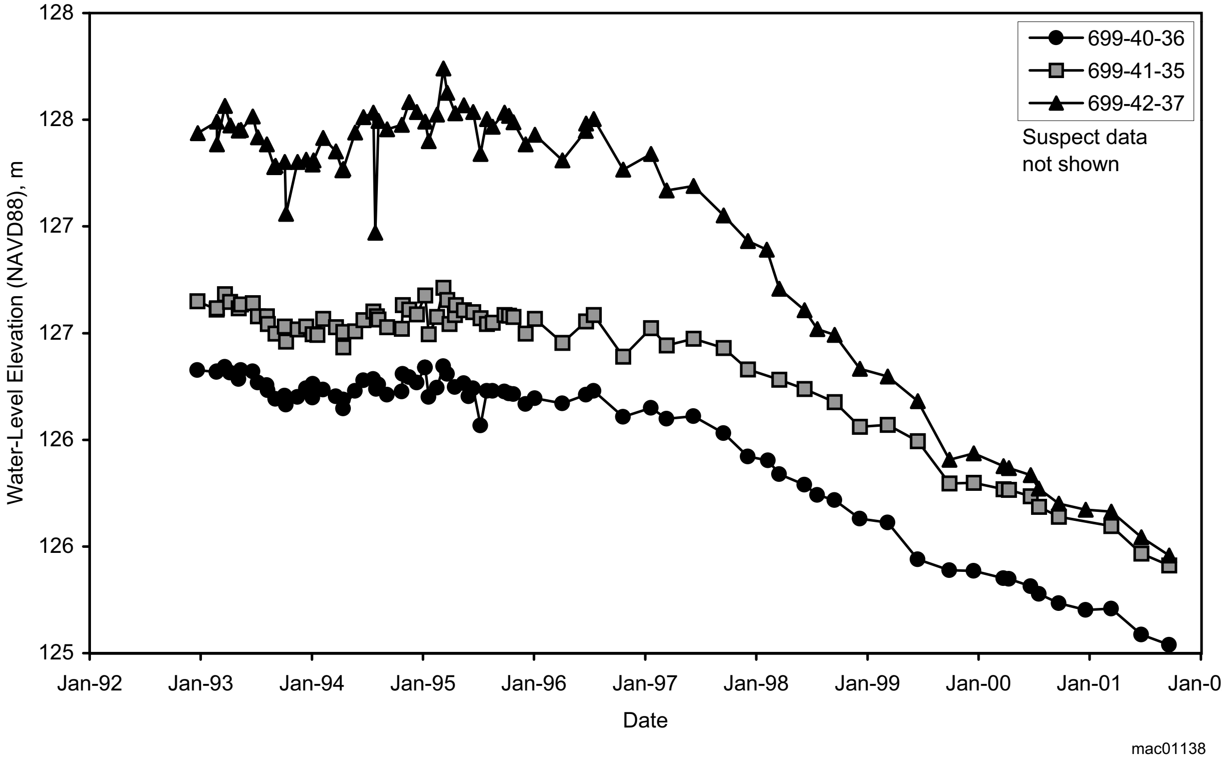


Figure 2.9-50. Water Levels in Wells at the Treated Effluent Disposal Facility

2.10 400 Area

E. C. Thornton

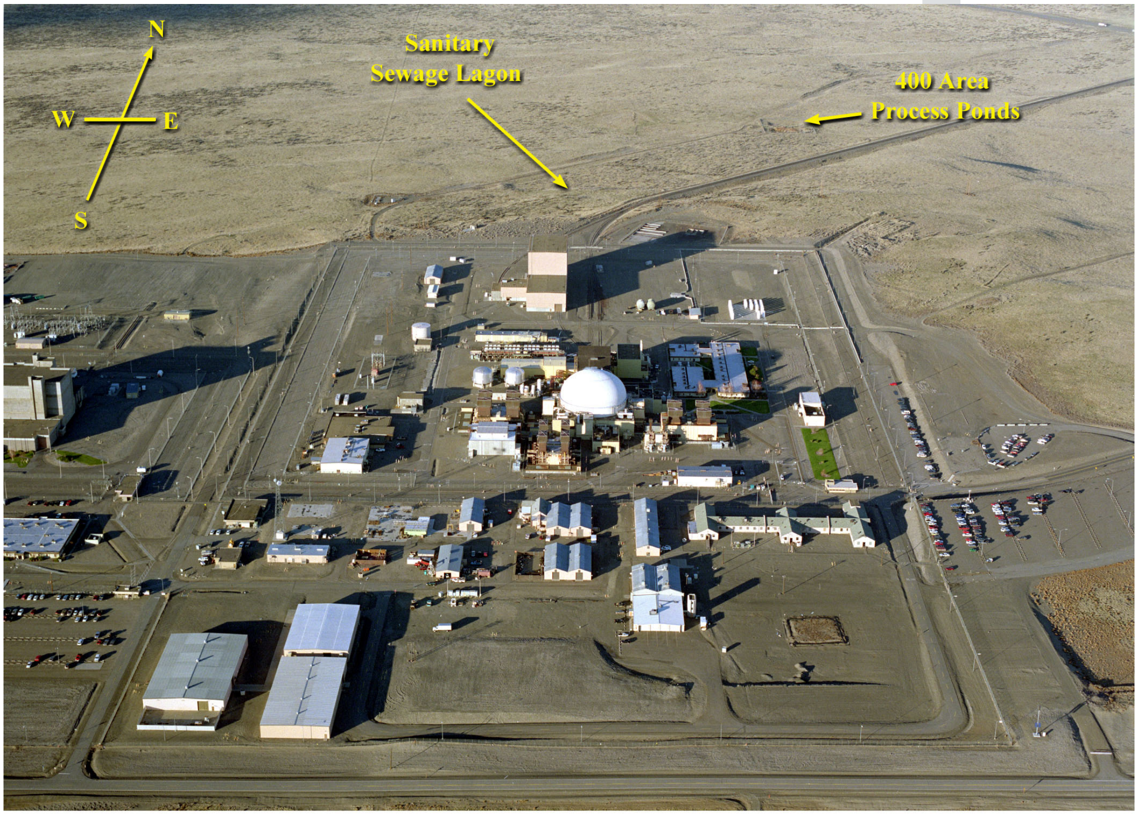
The 400 Area on the Hanford Site is the location of the Fast Flux Test Facility, a liquid sodium-cooled reactor that was being held on standby during fiscal year 2001. In December 2001, the U.S. Department of Energy (DOE) announced that restart of the facility is impracticable and the department will proceed with deactivation of the facility.

Primary groundwater monitoring activities in the 400 Area include monitoring of the 4608 B/C ponds (also called the 400 Area process ponds) for compliance with a waste discharge permit and monitoring of the 400 Area water supply, which is provided by wells completed in the unconfined aquifer system. Monitoring is also conducted to provide information needed to describe the nature and extent of sitewide contamination. The location of groundwater monitoring wells in the 400 Area is shown in Figure 2.10-1.

Wells in the 400 Area supply water and serve as emergency backup. The wells are monitored monthly to ensure that tritium levels remain low.

2.10.1 Groundwater Flow

The Hanford Site water-table map (see Plate 1) shows the groundwater contours for the 400 Area. The water-table map indicates that flow is generally from west to east across the 400 Area. The water table is located near the contact of the Hanford and Ringold Formations, which is ~49 meters below ground surface (WHC-EP-0587). Hanford formation sediment dominates groundwater flow in the 400 Area because of its relatively high permeability compared to that of sediment in the Ringold Formation.



Aerial view of the 400 Area, November 2001.

2.10.2 Nitrate and Nitrite

Nitrate is the only significant contaminant attributable to 400 Area operations and has been detected at elevated levels in one of the wells (699-2-7) downgradient to the process ponds. Elevated nitrate concentrations up to 87 mg/L (45 mg/L maximum contaminant level) were found in well 699-2-7 during fiscal year 2001 and are attributed to a sanitary sewage lagoon formerly located immediately west and upgradient of the process ponds (Figures 2.10-2 and 2.10-3) and later to a drainfield associated with septic tanks located southwest of the ponds. Groundwater samples associated with this well are also frequently elevated with respect to nitrite (Figure 2.10-4), which may have been generated by reduction of nitrate to nitrite due to the natural breakdown of nitrate in the aquifer. All nitrite values are below the 3.3-mg/L maximum contaminant level, however. Disposal to the lagoon was discontinued in 1983 or 1984 and to the drainfield in April 1997. Thus, groundwater contamination from these sources is expected to diminish with time and the average concentration of nitrate in samples collected from well 699-2-7 was, in fact, observed to decrease from 87 to 82 mg/L between fiscal years 2000 and 2001. Nitrate and nitrite concentrations in samples obtained from the new downgradient well 699-2-6A were not significantly elevated relative to the upgradient well 699-8-17.

Nitrate is the only groundwater contaminant attributable to 400 Area operations. The contamination is believed to have come from a sanitary sewage lagoon that is no longer in use.

2.10.3 Tritium

Elevated levels of tritium (Figure 2.10-5) associated with the groundwater plume from the vicinity of the Plutonium-Uranium Extraction Plant in the 200 East Area were identified in 400 Area wells as in previous years. The lower concentrations of tritium north of the 400 Area are probably related to discharge at the process ponds. This source of groundwater contamination is relevant to the water-supply wells, which provide drinking water and emergency supply water for the 400 Area. Well 499-S1-8J serves as the main water supply well, while wells 499-S0-7 and 499-S0-8 are backup supply wells. The tritium concentrations in wells 499-S0-7, 499-S0-8, and 499-S1-8J are compared in Figure 2.10-6 to that of the 400 Area drinking water supply. Tritium was found at levels at or below the 20,000 pCi/L drinking water standard in samples from well 499-S0-7 during fiscal year 2001. Samples collected from well 499-S0-8 exceeded the drinking water standard during the latter part of fiscal year 1999, but all samples collected during fiscal years 2000 and 2001 were well below the drinking water standard. All samples collected from well 499-S1-8J in fiscal year 2001 were below the drinking water standard.

Monitoring Objectives in 400 Area

Groundwater monitoring is conducted in the 400 Area:

- triennially to annually to describe the nature and extent of contamination
- quarterly to detect possible impacts of 400 Area process ponds
- monthly to monitor tritium trends in drinking water wells.

Tritium remained below the 20,000-pCi/L drinking water standard and the 4 mrem/yr dose equivalent in the drinking water supply, sampled at a tap for all sampling events in fiscal year 2001 (see Figure 2.10-6). Nitrate remained below the maximum contaminant level in fiscal year 2001 for the water-supply wells. Data from fiscal year 2001 and earlier from 400 Area and surrounding wells indicates no other constituents are present at levels above their maximum contaminant levels or drinking water standards.

2.10.4 400 Area Process Ponds

The 400 Area process ponds are regulated under a WAC 173-216 state waste discharge permit, which was issued on August 1, 1996, and modified on February 10, 1998. This permit defines groundwater enforcement limitations for the facility. Groundwater monitoring is provided by upgradient well 699-8-17 and downgradient wells 699-2-6A and 699-2-7, and is undertaken quarterly per the requirements presented in Appendix A, Table A.43. Groundwater quality met permit conditions in fiscal year 2001.

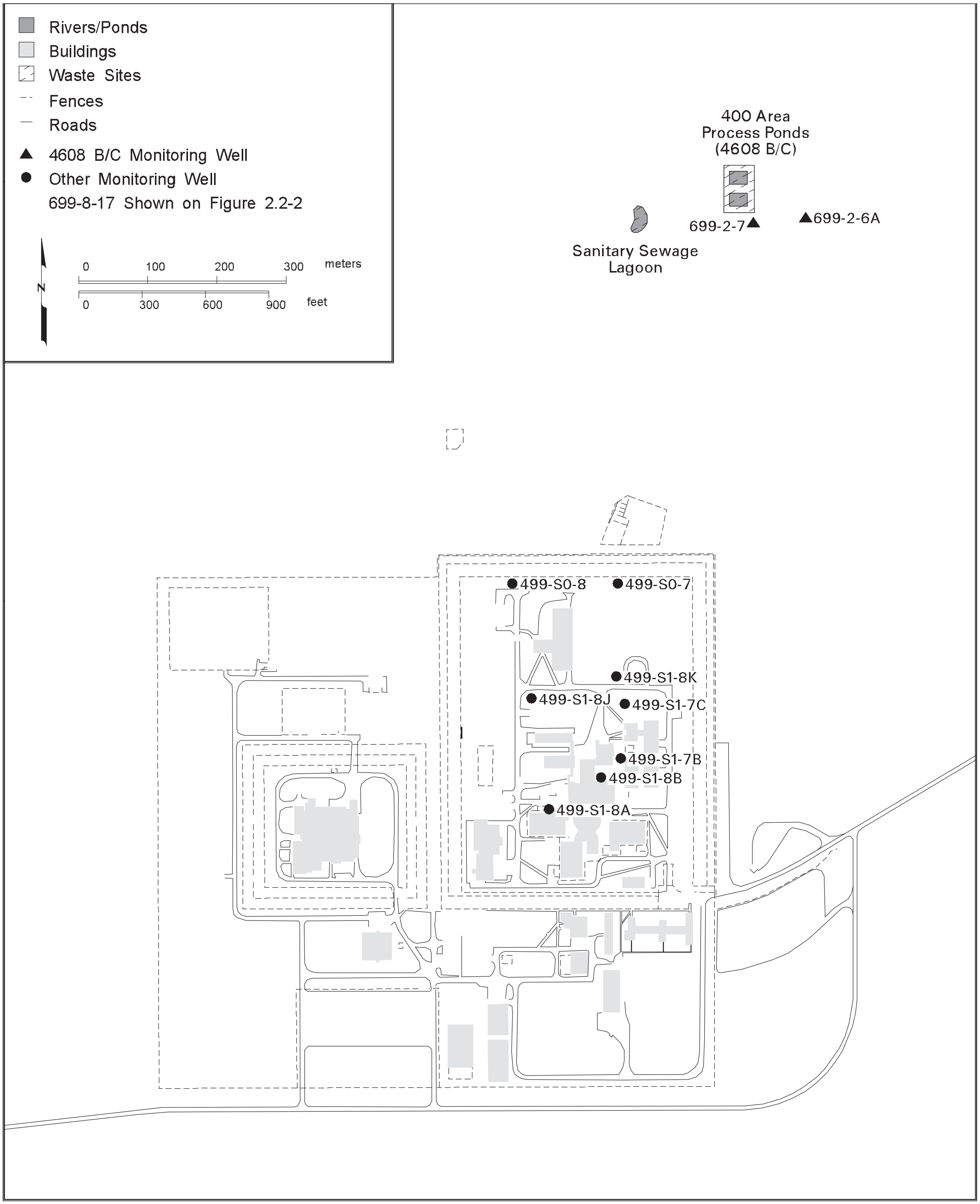


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Figure 2.10-1. Groundwater Monitoring Wells in the 400 Area

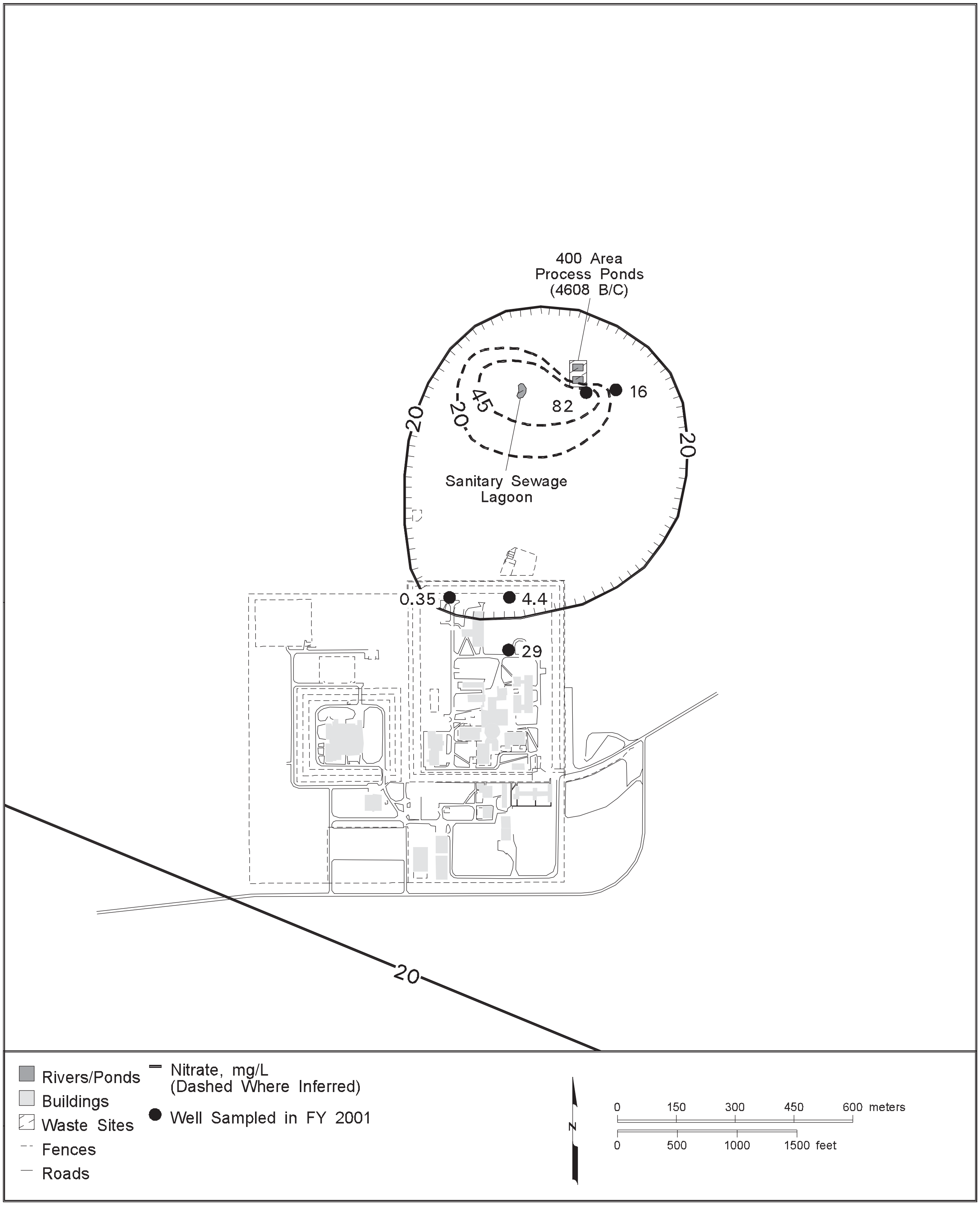

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Figure 2.10-2. Average Nitrate Concentrations in the 400 Area, Top of the Unconfined Aquifer

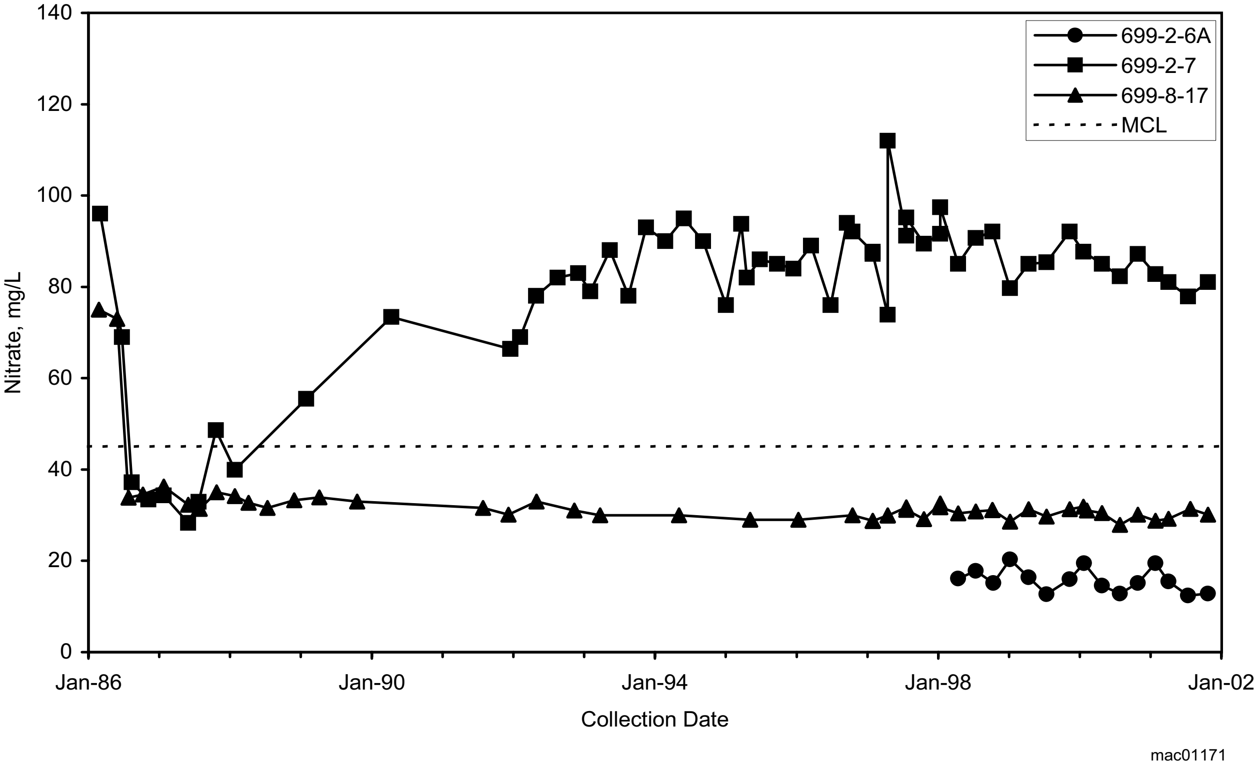

Figure 2.10-3. Nitrate Concentrations in Wells Monitoring the 400 Area Process Ponds

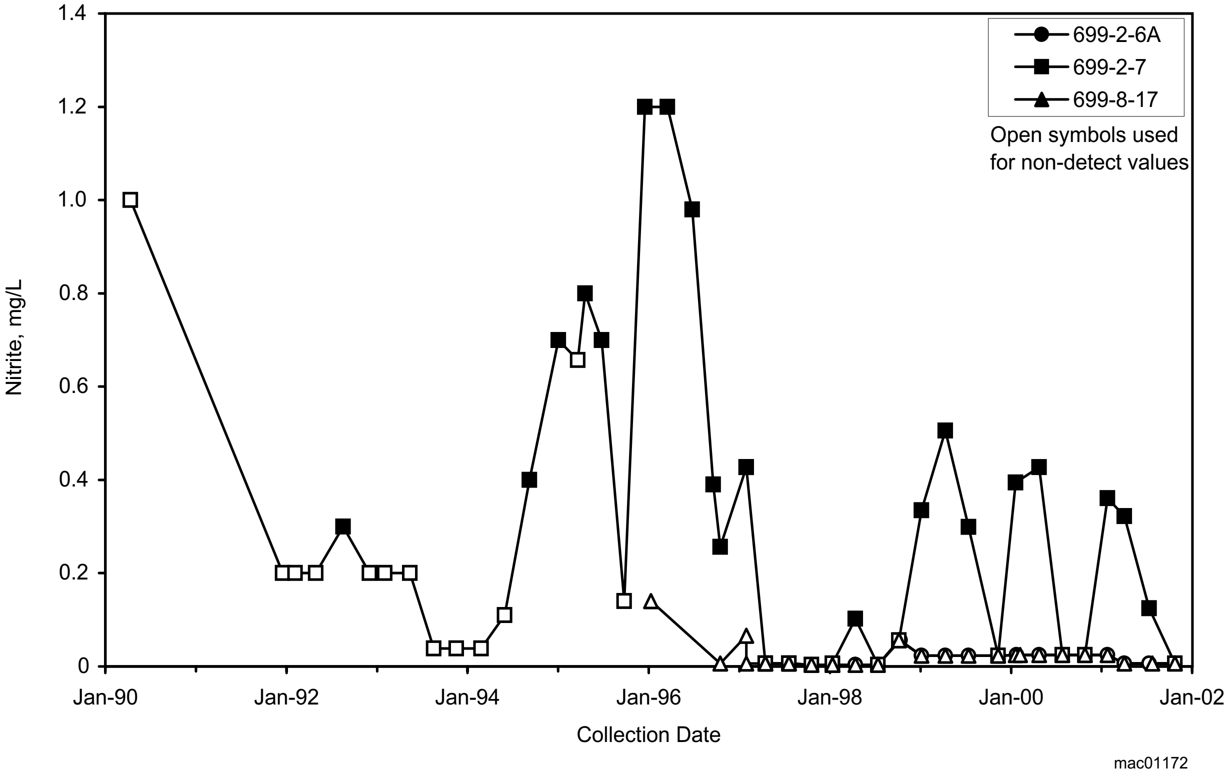

Figure 2.10-4. Nitrite Concentrations in Wells Monitoring the 400 Area Process Ponds

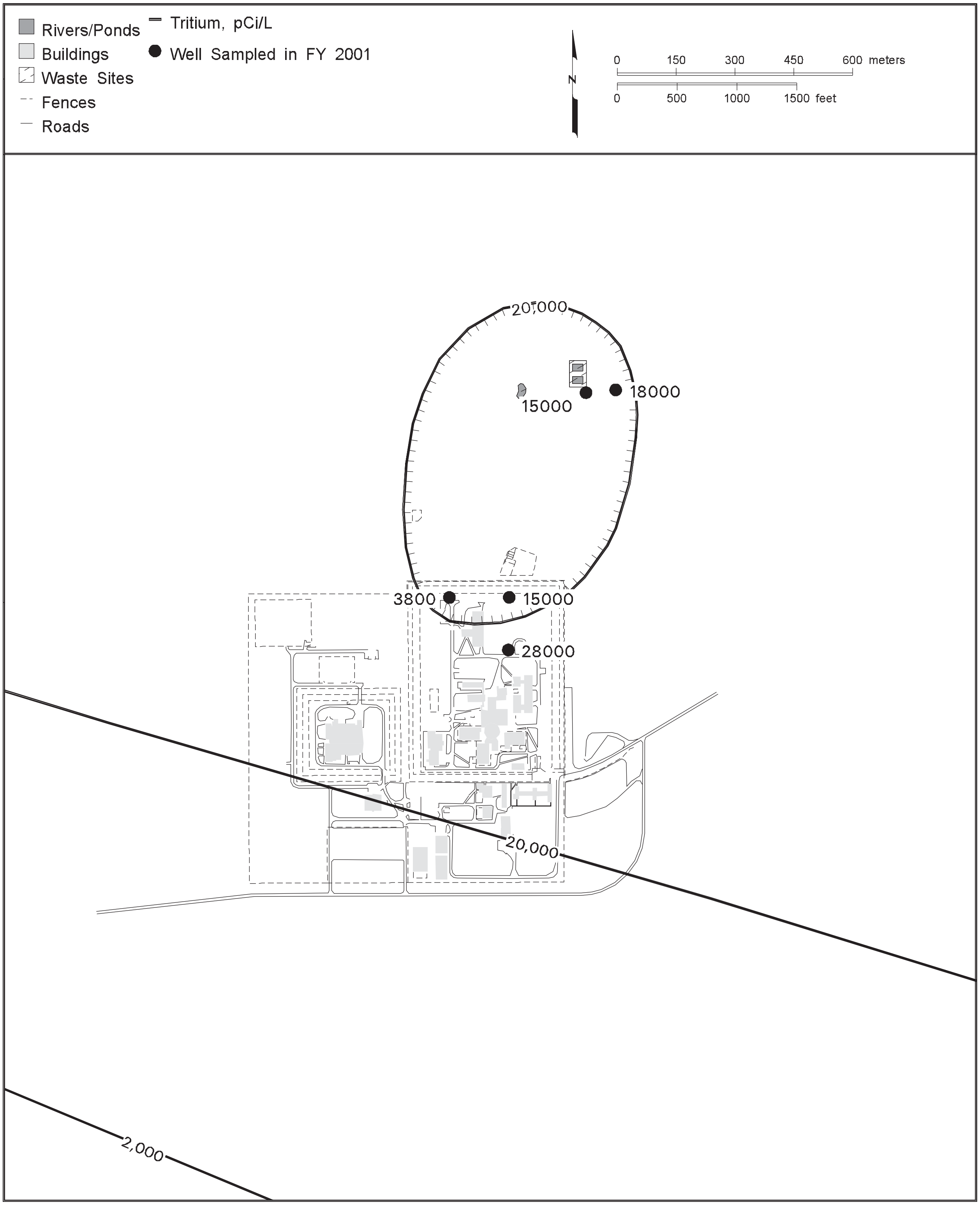

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Figure 2.10-5. Average Tritium Concentrations in 400 Area, Top of Unconfined Aquifer

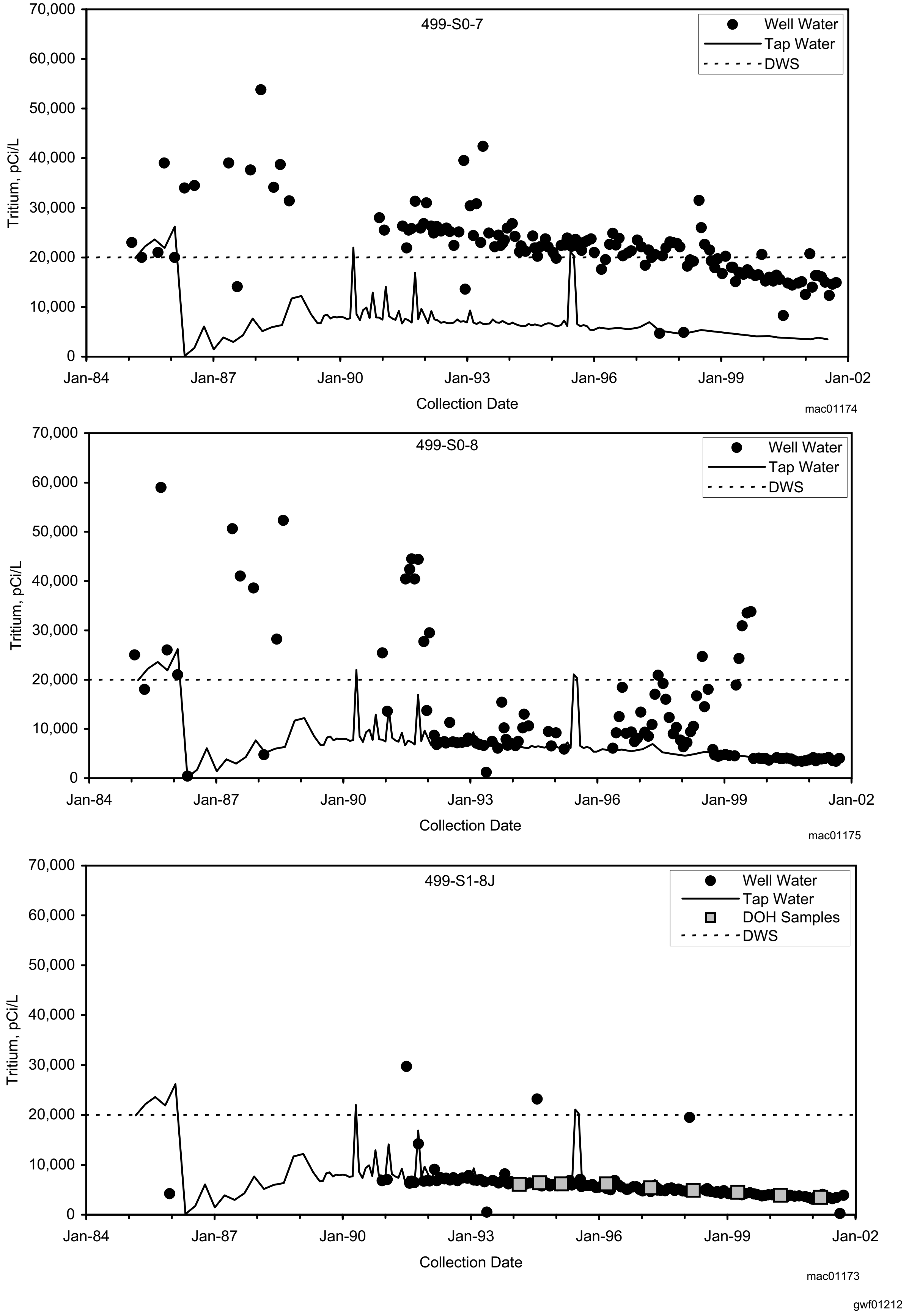


Figure 2.10-6. Comparison of Tritium Concentrations in 400 Area Drinking Water System

2.11 600 Area

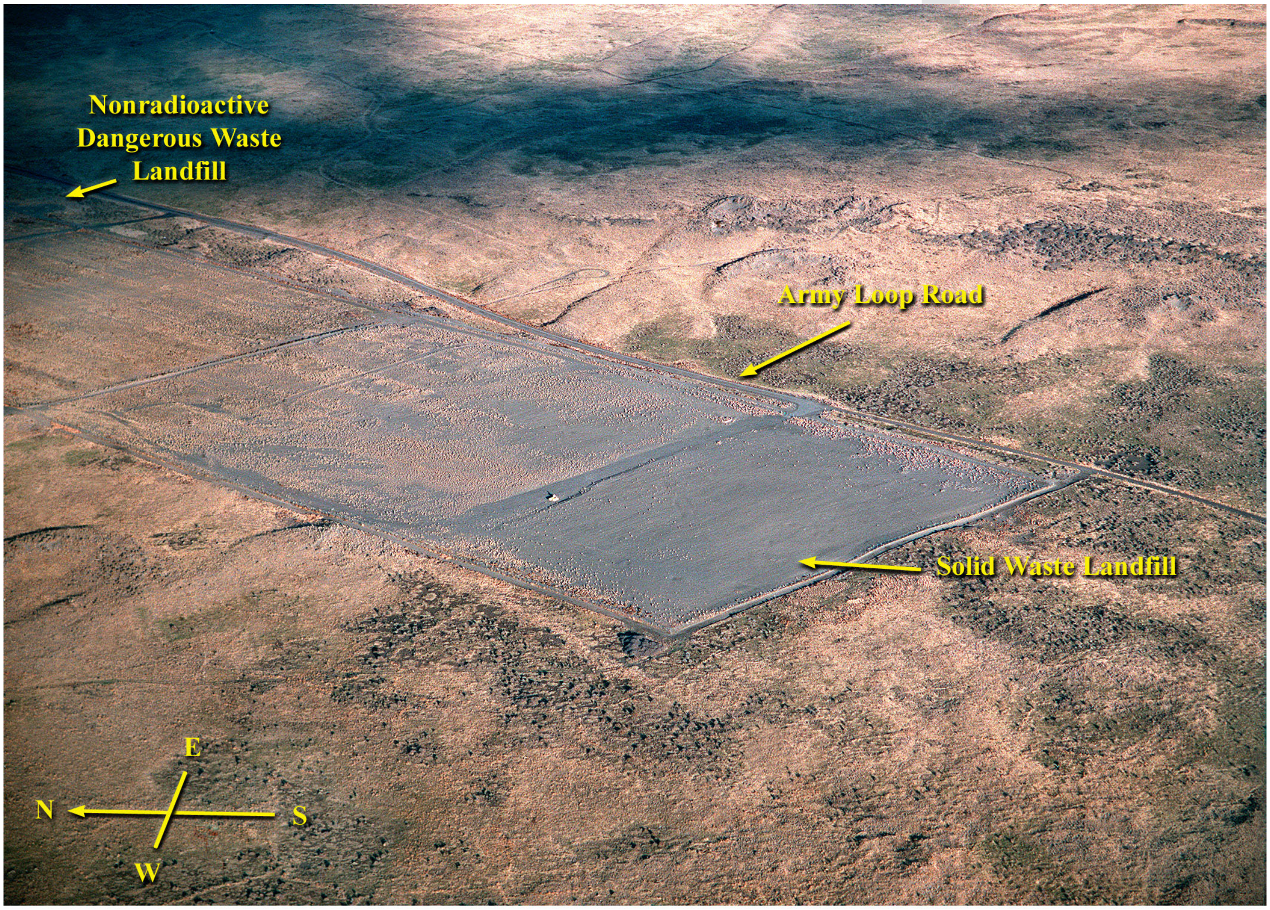
J. W. Lindberg and P. E. Dresel

This section discusses groundwater contamination in the 600 Area including the Central Landfill, Central 600 Area, and Western 600 Area. Other facilities located in the 600 Area are described in the sections relating to their operable units (i.e., 618-10, 618-11, 316-4 are in Section 2.12; Gable Mountain Pond in Section 2.9; PUREX cribs plumes in Section 2.9).

Most of the groundwater contaminants in the 600 Area originated at waste sites in other areas.

2.11.1 Central Landfill

The Central Landfill is located ~5 kilometers southeast of the southeastern corner of the 200 East Area and is composed of two separate landfills, the Nonradioactive Dangerous Waste Landfill and the Solid Waste Landfill. The Nonradioactive Dangerous Waste Landfill is an interim status *Resource Conservation and Recovery Act of 1976* (RCRA) land disposal facility that is monitored under indicator-evaluation requirements. The Solid Waste Landfill is regulated by the Washington State Department of Ecology under WAC 173-304. Originally, in 1973, the area occupied by the two landfills was designated as the Central Landfill. However, in order to segregate "regulated dangerous wastes" such as asbestos and non-radioactive chemical waste, the northern portion of the Central Landfill was isolated from the southern portion (the Solid Waste Landfill).



Aerial view of the Central Landfill, November 2001.

2.11.1.1 Groundwater Flow

Groundwater flow beneath the Central Landfill in fiscal year 2001 was virtually the same as in recent years. The direction and rate of groundwater flow at the Central Landfill are difficult to determine from water-table maps because of the extremely low hydraulic gradient. The best indicators of flow direction are the major plumes of iodine-129, nitrate, and tritium. These plumes flow to the southeast (~125 degrees east of north; see Section 17.0 in DOE/RL-91-03) in the vicinity of the Central Landfill. The decrease in nitrate and tritium concentrations in a southwest-northeast trend across the Central Landfill is due to the location of the Central Landfill on the southern edge of the plumes. The rate of groundwater flow is ~0.31 to 2.7 meters per day (see Appendix A, Table A.2).

Water-level data from one well pair (measured in March 2001), sampling the top of the unconfined aquifer and lower in the aquifer immediately above the low-permeability unit, indicate that the vertical gradient within the upper portion of the unconfined aquifer is negligible.

RCRA monitoring at the Nonradioactive Dangerous Waste Landfill in fiscal year 2001 indicated the site has not had a significant impact on groundwater.

2.11.1.2 RCRA Parameters for the Nonradioactive Dangerous Waste Landfill

Monitoring of the Nonradioactive Dangerous Waste Landfill focuses on the RCRA interim status indicator parameters, pH, specific conductance, total organic carbon, and total organic halides (see Appendix A, Table A.29). Chlorinated hydrocarbons are monitored because they may represent groundwater contamination originating from this landfill. Tritium and nitrate are present in groundwater and have sources in the 200 East Area (see Section 2.9.2). The groundwater quality parameters (chloride, iron, manganese, phenols, sodium, and sulfate) are monitored but are either not detected or not found in concentrations significantly above background concentrations.

Wells at the Nonradioactive Dangerous Waste Landfill (Figure 2.11-1) are sampled on a semiannual basis, usually in February and August. The second sampling of the previous fiscal year (August 2000) was delayed beyond the end of the fiscal year (to October 2000). Therefore, the Nonradioactive Dangerous Waste Landfill wells were sampled three times in fiscal year 2001 (October 2000, February/March 2001, and August 2001).

The values for RCRA indicator parameters did not exceed their critical means (or critical range for pH) in fiscal year 2001 for three of the indicator parameters including, pH, total organic carbon, and total organic halides. However, the critical mean for specific conductance (600.7 µS/cm) was exceeded at two wells during the February/March 2001 sampling period and the August 2001 sampling period. The highest level was 616 µS/cm at well 699-25-34A during March 2001. The increased specific conductance is most likely caused by increases in the concentrations of non-hazardous constituents (bicarbonate, calcium, manganese, and sulfate) from the adjacent Solid Waste Landfill.

Monitoring Objectives in 600 Area

Groundwater monitoring is conducted in the 600 Area:

- triennially to annually to describe the nature and extent of contamination
- semiannually to detect possible impacts of the Nonradioactive Dangerous Waste Landfill RCRA Site
- quarterly to detect possible impacts of the Solid Waste Landfill.

The U.S. Department of Energy notified the Washington State Department of Ecology of the indicator parameter exceedance by letter on June 7, 2001. An accompanying report served as both the assessment plan and assessment report. The assessment plan proposed a continuing detection monitoring program at the site.

During fiscal year 2001, eight volatile organic compounds were detected in wells at the Nonradioactive Dangerous Waste Landfill, but seven of the eight were detected at concentrations below their practical quantitation limits. One volatile organic compound (1,1,1-trichloroethane) was detected at levels above the practical quantitation limit in four downgradient wells and one upgradient well, but the maximum concentration detected was 1.4 μg/L (drinking water standard 200 μg/L). The seven other volatile organic compounds detected below their practical quantitation limits are as follows: 1,1-dichloroethane, acetone, carbon tetrachloride, chloroform, methylene chloride, tetrachloroethene, and trichloroethene. The source of the volatile organic compounds could be either from the Solid Waste Landfill (to the south) or the Nonradioactive Dangerous Waste Landfill (bottom of trenches ~35 meters above water table). For example, tetrachloroethene is present in vadose zone vapor beneath the Solid Waste Landfill (PNL-7147) and also is the principal vadose zone vapor contaminant around the chemical disposal trenches at the Nonradioactive Dangerous Waste Landfill (see Section 5.2 of DOE/RL-93-88). It is possible that both of these sources contribute to the contamination.

Tritium and nitrate continued to be detected in wells at the Nonradioactive Dangerous Waste Landfill during fiscal year 2001. Their sources are upgradient in the 200 East Area. Both tritium and nitrate concentrations continue to decrease with time.

2.11.1.3 Groundwater Monitoring at the Solid Waste Landfill

The Solid Waste Landfill is regulated by the Washington State Department of Ecology under WAC 173-304. WAC 173-304 constituents and site-specific constituents (including volatile organic compounds and filtered arsenic) are analyzed on groundwater samples collected quarterly (see Appendix A, Table A.45). Groundwater flow was described in Section 2.11.1.1. Solid Waste Landfill well locations are shown in Figure 2.11-1.

The Solid Waste Landfill is regulated under state law. Groundwater monitoring has detected only very low levels of chlorinated hydrocarbons.

The Solid Waste Landfill has had little impact on Hanford Site groundwater, except minor chlorinated hydrocarbon contamination (Table 2.11-1) below drinking water standards but above WAC 173-200 levels, which are lower and applicable to the Solid Waste Landfill. Some downgradient wells show higher chloride, specific conductance, and sulfate, and lower field-measured pH than upgradient wells. This apparently is a result of high concentrations of carbon dioxide in the vadose zone resulting from the degradation of sewage material beneath the Solid Waste Landfill (see Section 5.3 of DOE/RL-93-88; PNL-7147; and WHC-SD-EN-TI-199).

WAC 173-304 Parameters

Each WAC 173-304 parameter is discussed separately below. See Appendix A, Table A.46 for a complete list of all results for required constituents at the Solid Waste Landfill during fiscal year 2001. Table 2.11-1 shows the results for the chlorinated hydrocarbon constituents during the same period.

- Temperature – Groundwater temperatures measured during sampling in downgradient wells ranged from 17.1°C to 19.7°C. All measurements were below the background threshold value of 20.7°C. See Appendix A, Table A.47 for a total list of fiscal year 2001 background threshold values for WAC 173-304 required parameters.
- Specific conductance – Specific conductance measurements on samples from all of the Solid Waste Landfill downgradient wells exceeded the background threshold value of 583 μS/cm. The range in downgradient wells was 577 to 867 μS/cm. Six of the eight downgradient wells also exceeded the 700 μS/cm maximum contaminant level (WAC 246-290-310) in fiscal year 2001.
- Field-measured pH – Measured values ranged from 6.5 to 7.5. Reported results were lower than the background threshold range (6.68 to 7.84) in four downgradient wells. They are: 699-23-34A, 699-23-34B, 699-24-34A, and 699-24-34B.

- Total organic carbon – The reported values of total organic carbon ranged from <220 to 56,200 µg/L. The reported value of 56,200 µg/L at well 699-23-34A (May 2001) is the only result exceeding the background threshold value of 1,450.1 µg/L. This result is most likely a laboratory error because it is out of trend for the well, and subsequent results have returned to the former trend (280 µg/L).
- Chloride – Chloride concentrations in downgradient wells ranged from 4,100 to 8,300 µg/L. The reported results at well 699-25-34C ranged from 7,500 to 8,300 µg/L, and three of the four results for fiscal year 2001 exceeded the background threshold value of 7,820 µg/L.
- Nitrate – Nitrate concentrations in the downgradient wells ranged from 10.2 to 17.3 mg/L. Neither the 29.0 mg/L background threshold value nor the 45 mg/L maximum contaminant level were exceeded in any Solid Waste Landfill downgradient well. The source of nitrate contamination at the Solid Waste Landfill is from upgradient sources in the 200 East Area (see Figure 2.1-4).
- Nitrite – Nitrite concentrations in all downgradient wells were less than the method detection limit (24.3 µg/L earlier in the year and 6.6 µg/L later in the year).
- Ammonium – Ammonium concentrations in all downgradient wells were less than the method detection limit (30.1 µg/L earlier and 12.9 µg/L later) except for results for several wells sampled in May 2001. The May 2001 sample results ranged from below the method detection limit to 98.0 µg/L (background threshold value 165 µg/L). The May 2001 results above the method detection limit are probably the result of a laboratory or sampling errors because August 2001 sampling results were all below the method detection limit (12.9 µg/L).
- Sulfate – Reported sulfate concentrations in downgradient wells ranged from 37,900 to 54 mg/L. Reported results from three downgradient wells (699-22-35, 699-23-34A, and 699-23-34B) exceeded the background threshold value of 47 mg/L. None of the samples exceeded the 250 mg/L standard (WAC 173-200).
- Filtered iron – Reported values for filtered iron ranged from less than the method detection limit (14.5 µg/L) to 77 µg/L in downgradient wells. None of the reported values exceeded the 160 µg/L background threshold value.
- Filtered zinc – Reported values for filtered zinc ranged from less than the method detection limit (6 µg/L) to 17.4 µg/L. None of the reported values exceeded the background threshold value of 34.9 µg/L.
- Filtered manganese – Reported values for filtered manganese ranged from less than the method detection limit (0.22 µg/L) to 0.97 µg/L in downgradient wells. None of the reported values exceeded the background threshold value of 10 µg/L.
- Chemical oxygen demand – Except for one reported result of 5.0 µg/L at well 699-25-34C from an October 2000 sample, all other results from downgradient wells were below the method detection limit of 3.1 µg/L. The background threshold value is 5.0 µg/L. The 5.0 µg/L result is probably a laboratory or sampling error because three subsequent samples collected at three separate occasions since then from the same well all have reported results less than the method detection limit (<3.1 µg/L).
- Coliform bacteria (most probable number) – Reported results for coliform bacteria were generally zero colonies per 100 milliliters, and, therefore, less than the background threshold value of 3.7 colonies per 100 milliliters. However, results for two downgradient wells and one upgradient well were above the background threshold value for samples collected only during October 2000. The highest reported result was an average of 315 colonies per 100 milliliters

for two samples collected from well 699-24-35 (an upgradient well). These exceedances are probably in error because they were reported only in the October sampling event. Subsequent results are all zero.

Site-Specific Parameters

Site-specific parameters at the Solid Waste Landfill include chlorinated hydrocarbons (volatile organics) and filtered arsenic. Slightly elevated concentrations of chlorinated hydrocarbons continue to be detected at the Solid Waste Landfill during fiscal year 2001. Two constituents exceeded the groundwater criteria set forth in WAC 173-200. The range of reported concentrations of chlorinated hydrocarbons is given in Table 2.11-1.

Chlorinated hydrocarbons were detected in all of the Solid Waste Landfill monitoring wells, including the upgradient wells. The chlorinated hydrocarbons detected were

- 1,1-dichloroethane
- 1,4-dichlorobenzene
- tetrachloroethene
- trichloroethene
- 1,1,1-trichloroethane.

Of those detected, only 1,1-dichloroethane and tetrachloroethene exceeded the WAC 173-200 concentration limits (1.0 and 0.8 µg/L, respectively). None of the reported results exceeded the maximum contaminant level (drinking water standards) for any of the detected chlorinated hydrocarbons. The results reported for detected chlorinated hydrocarbons are, in general, lower in concentration than the reported results for fiscal year 2000. During fiscal 2000, seven chlorinated hydrocarbons were detected. And during fiscal year 1999, eight chlorinated hydrocarbons were detected, and all but two had concentrations exceeding the WAC 173-200 concentration limits.

The most likely cause of the widespread chlorinated hydrocarbon contamination at the Solid Waste Landfill, including upgradient wells and the adjacent Nonradioactive Dangerous Waste Landfill, is the dissolution of vadose zone vapors into groundwater. However, the source of the vapors is uncertain. The most probable source is chlorinated hydrocarbons dissolved in liquid sewage waste that was discharged to trenches at the site.

Filtered arsenic (maximum contaminant level 50 µg/L, WAC 173-200 limit 0.05 µg/L) is detected at 8 of the 10 wells in the Solid Waste Landfill well network, including both upgradient wells. The highest concentration detected was 2.8 µg/L at well 699-24-35 (an upgradient well). All detections were below the practical quantitation limit of the laboratory analysis, and the instrument detection limit was 1.4 µg/L. Although arsenic was discovered in the trenches leachate collection system, the occurrence of arsenic in groundwater at the Solid Waste Landfill is probably due to natural processes (i.e., occurs naturally in Hanford Site groundwater), or there is an upgradient source (e.g., 200 East Area). The source of the arsenic occurrence being other than the Solid Waste Landfill is supported by (1) the occurrence at 8 of the 10 wells in very low concentrations, and (2) including both upgradient wells.

Another constituent that was discovered in the Solid Waste Landfill trenches leachate collection system was 1,4-dioxane. Therefore, groundwater samples were specifically tested for this constituent. It was not detected in any of the network wells. However, the detection limit for 1,4-dioxane is 13.0 µg/L. The WAC 173-200 limit is 7.0 µg/L.

2.11.2 Central 600 Area

Chromium is frequently detected in filtered samples south of the 200 East Area. Concentrations in well 699-32-62 of 200 μg/L were above the maximum contaminant level in fiscal year 2000 (see Figure 2.2-2 for well locations). This well was not sampled in fiscal year 2001. The chromium concentrations have declined slowly since it was first analyzed in 1992. The sources and extent of this contamination are uncertain; however, chromium is detected in several other wells in this area. Early disposal to the vicinity of the 216-S-10 pond and ditch is one possible source. The extent of chromium contamination to the south of well 699-32-62 is particularly poorly defined.

2.11.3 Western 600 Area

The western 600 Area is the area of the Hanford Site west of the 200 West Area and south of the Columbia River. This area includes the portion of the Hanford Site near the southwestern part of the site along Rattlesnake Ridge.

Nitrate exceeds the maximum contaminant level in two wells in the western Hanford Site. This contamination has sources off the site.

Nitrate was detected at levels above the maximum contaminant level in two wells in the western part of the 600 Area in fiscal year 2001 (see Figure 2.1-4). Nitrate concentrations in these wells have changed little over the past decade. Well 699-36-93, located west (upgradient) of the 200 West Area, contained 46 mg/L of nitrate in the fiscal year 2001 sample. Nitrate concentrations in this well rose during the 1980s and only declined slightly during the 1990s. Well 699-17-70, located 6 kilometers south-southeast of the 200 West Area, contained 59 mg/L of nitrate. Nitrate upgradient of the 200 West Area and in well 699-17-70 north of the Rattlesnake Hills appears to have a source off the Hanford Site, possibly related to agricultural activity. An extension of Yakima Ridge, south of the 200 West Area, forms a partial hydraulic barrier for the unconfined aquifer system, and hydraulic head is considerably higher south of the ridge (see Plate 1). For this reason and the lack of other Hanford Site contaminants such as tritium, nitrate in well 699-17-70, south of the ridge, is not believed to result from Hanford Site activities.

Table 2.11-1. Ranges of Reported Chlorinated Hydrocarbon Concentrations in Solid Waste Landfill Wells During Fiscal Year 2001

Constituent	Limit (µg/L)[(a)]	699-22-35	699-23-34A	699-23-34B	699-24-33	699-24-34A
Carbon tetrachloride	WAC 0.3	<0.33	<0.33	<0.33	<0.33	<0.33
Chloroform	WAC 7.0	<0.38	<3.8	<0.38	<0.38	<0.38
1,1-Dichloroethane	WAC 1.0	<0.36 - **1.6**	<0.36 - **1.3**	<0.36 - **1.4**	<0.36 - 0.81	<0.36 - 0.79
1,2-Dichloroethane	WAC 0.5	<0.34	<0.34	<0.34	<0.34	<0.34
1,4-Dichlorobenzene	WAC 4.0	<0.25	<0.25	<0.25 - 0.28	<0.25	<0.25
cis-1,2-Dichloroethene	MCL 70	<0.33	<0.33	<0.33	<0.33	<0.33
trans-1,2-Dichloroethene	MCL 100	<0.43	<0.43	<0.43	<0.43	<0.43
Tetrachloroethene	WAC 0.8	<0.15 - **1.5**	**1.1 - 1.5**	<0.15 - **1.3**	**1.4 - 2.4**	**1.2 - 1.4**
Total organic halides	NA	8.2 - 12.1	7.5 - 8.4	4.2 - 11.8	<4.3 - 5.0	<3.6 - 9.1
Trichloroethene	WAC 3.0	<0.26 - 0.73	<0.26 - 0.68	<0.26 - 0.59	<0.26 - 0.95	<0.26 - 0.79
1,1,1-Trichloroethane	WAC 200	4.1 - 6.2	2.9 - 4.0	3.1 - 5.5	2.2 - 3.1	2.7 - 4.0
1,1,2-Trichloroethane	MCL 5.0	<0.31	<0.31	<0.31	<0.31	<0.31

Constituent	Limit (µg/L)[(a)]	699-24-34B	699-24-34C	699-24-35	699-25-34C	699-26-35A
Carbon tetrachloride	WAC 0.3	<0.33	<0.33	<0.33	<0.33	<0.33
Chloroform	WAC 7.0	<0.38	<0.38	<0.38	<0.38	<0.38
1,1-Dichloroethane	WAC 1.0	<0.36 - 0.92	<0.36 - 0.72	<0.36 - 0.53	<0.36 - 0.56	<0.36
1,2-Dichloroethane	WAC 0.5	<0.34	<0.34	<0.34	<0.34	<0.34
1,4-Dichlorobenzene	WAC 4.0	<0.25	<0.25	<0.25	<0.25	<0.25
cis-1,2-Dichloroethene	MCL 70	<0.33	<0.33	<0.33	<0.33	<0.33
trans-1,2-Dichloroethene	MCL 100	<0.43	<0.43	<0.43	<0.43	<0.43
Tetrachloroethene	WAC 0.8	**1.6 - 2.3**	**1.2 - 1.9**	<0.15 - **0.94**	<0.15 - **1.6**	<0.15 - 0.62
Total organic halides	NA	<3.6 - 5.0	<4.3 - 8.1	<0.43 - 5.5	<0.43 - 8.5	<4.3 - 6.3
Trichloroethene	WAC 3.0	<0.26 - 0.87	<0.26 - 0.77	<0.26 - 0.53	<0.26 - 0.98	<0.26 - 0.54
1,1,1-Trichloroethane	WAC 200	2.6 - 2.9	1.9 - 2.7	1.8 - 3.1	<0.35 - 1.8	<0.35 - 1.5
1,1,2-Trichloroethane	MCL 5.0	<0.31	<0.31	<0.31	<0.31	<0.31

(a) WAC = Washington Administrative Code.
MCL = Maximum contaminant level.
NA = Not applicable.

Values in **bold** type equal or exceed WAC 173-200-40.

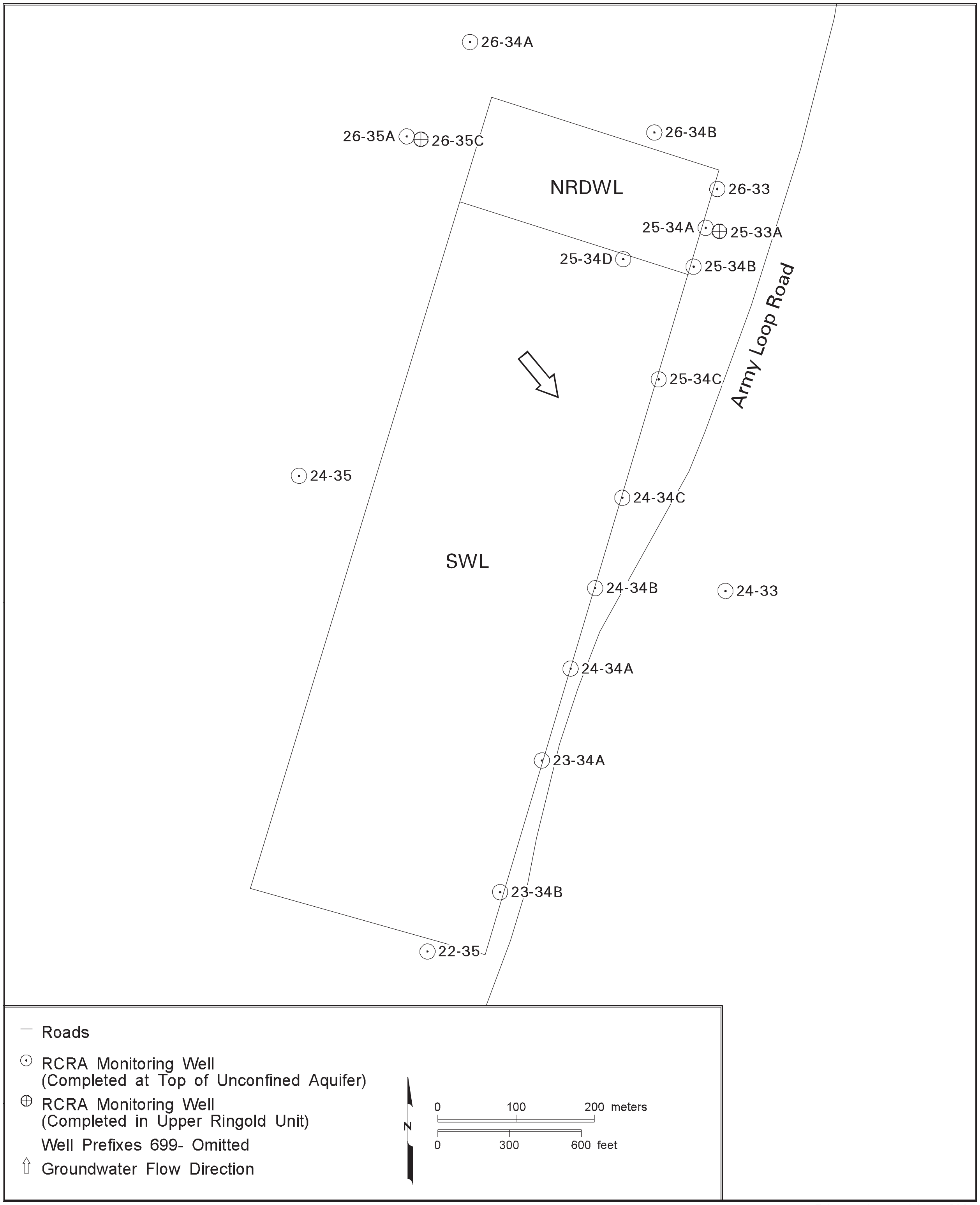


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Figure 2.11-1. Groundwater Monitoring Wells at the Central Landfill and Vicinity. The Nonradioactive Dangerous Waste Landfill (NRDWL) and Solid Waste Landfill (SWL) comprise the Central Landfill.

2.12 300 Area

J. W. Lindberg and P. E. Dresel

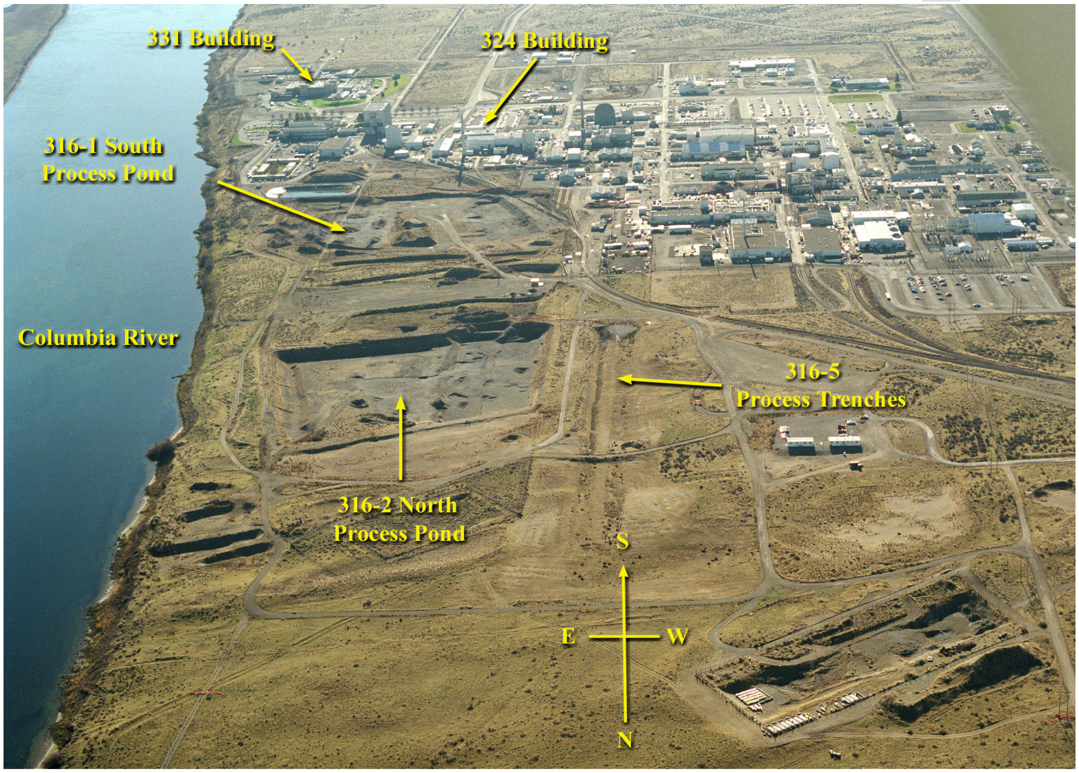
This discussion on the 300 Area is mainly about the 300 Area proper, which includes one *Resource Conservation and Recovery Act of 1976* (RCRA) site (316-5 process trenches) and one groundwater operable unit (300-FF-5). The chapter also includes smaller areas to the north of the 300 Area that are included in the 300-FF-5 Operable Unit. These satellite areas to the north (Figure 2.12-1) include the 618-11 burial ground, 618-10 burial ground, and 316-4 crib and are discussed in Sections 2.12.7.1 and 2.12.7.2.

Uranium in the 300 Area and tritium at the 618-11 burial ground are the major groundwater contaminants of concern in the 300-FF-5 Operable Unit.

Uranium is the major contaminant of concern in the 300 Area. Tritium contamination from the 200 East Area affected the 300 Area at levels less than the drinking water standard of 20,000 pCi/L (see Section 2.13). The 10,000-pCi/L-isopleth line extends through the 300 Area and has retreated slightly from its position last year. Tritium contamination and how it affects the 300 Area is discussed in Sections 2.9.2.2 and 2.13.2. Additional constituents detected during fiscal year 2001 include cis-1,2-dichloroethene, nitrate, and trichloroethene. Figure 2.12-2 shows the locations of groundwater monitoring wells in the 300 Area and Richland North Area. Major contaminants of concern at the 618-10 burial ground and 316-4 crib include uranium, various hydrocarbons, and tributyl phosphate. At 618-11 burial ground, the major contaminant of concern is tritium.

2.12.1 Groundwater Flow

The primary influence on water-table elevation in the 300 Area is the fluctuation in the Columbia River stage. Changes in river-stage elevation can be correlated



Aerial view of the 300 Area, November 2001.

to changes in water-level elevations at wells as far as ~360 meters from the river (PNL-8580). During fiscal year 2001, river-stage fluctuations were typical for an average year, and the water-table elevations and corresponding configuration of the water-table map for March 2001 (see Plate 1) were similar to March water-table maps of previous years. However, the water table during March 2001 was slightly lower in elevation than during March 2000 by 0.5 to 1 meter, which corresponds to a low river stage.

Monitoring Objectives in 300 Area

Groundwater monitoring is conducted in the 300 Area:

- annually to describe the nature and extent of contamination
- annually to determine if contaminants in the groundwater operable unit are reducing in concentration
- semiannually to determine if contaminants at one RCRA site are reducing in concentration
- semiannually for special studies to describe the nature and extent of groundwater contamination at CERCLA operable unit satellite areas to the north of the 300 Area.

Water-table contours in the vicinity of the 300 Area are somewhat concentric, indicating that the 300 Area is a low point or sink in the local unconfined aquifer. Groundwater enters the 300 Area from the northwest, west, and southwest, flows through the 300 Area, and then into the Columbia River. In the immediate vicinity of the 300 Area process trenches (316-5), the flow direction was southeast during March 2001 based on the water-table contours. Flow rate there was 0.32 to 96 meters per day (see Appendix A, Table A.2) based on the March 2001 gradient and calculated hydraulic conductivity from aquifer tests (PNL-6716). The southeast flow direction is typically the direction of groundwater flow in the northern portion of the 300 Area when the river-stage is in a low stage. During higher river stages, the direction of groundwater flow tends to be more south to southwest in the vicinity of the 300 Area process trenches.

2.12.2 Uranium

The uranium distribution in the 300 Area during August and September 2001 is shown in Figure 2.12-3. The highest uranium concentrations are found downgradient of the 300 Area process trenches along the Columbia River shoreline southeast of the South Process Pond (316-1). Because the South Process Pond is downgradient of the process trenches, it is difficult to determine the relative contribution of each facility to the contamination. However, the maximum uranium concentration (30 μg/L maximum contaminant level) detected in the 300 Area during fiscal year 2001 was 205 μg/L at well 399-2-2 during November 2000. Nine months later in August 2001, the concentration at well 399-2-2 was 144 μg/L.

Figure 2.12-4 shows the historical trend for uranium (an alpha emitter) in well 399-1-17A, which is the well closest to the inflow portion of the process trenches while they were operating. Uranium concentrations dropped dramatically in 1991 as a result of the expedited response action, which removed much of the contaminated sediment in the trenches. However, uranium concentrations began to rise sharply again when discharges to the process trenches ceased in December 1994, presumably due to the lack of dilution by the large quantities of process water (5.7 to 9.5 million liters per day). (Note: In the last few years of operation, the process trenches were discharging mostly steam condensate and cooling water, with little or no uranium contamination.) In fiscal years 1996 and 1997, the rise continued, though not at the rapid rate measured in fiscal year 1995. Since 1997, the average uranium levels have been decreasing.

The 316-5 process trenches and 316-1 process pond were waste sites that contaminated groundwater with uranium. The sites have been excavated and contaminant concentrations in groundwater have declined in recent years.

Figure 2.12-4 also shows a yearly cycle for uranium concentration. The peak each year is in the spring with the lowest concentration each year in the fall or early winter. This yearly cycle, or yearly fluctuation, is caused by high Columbia River stages, which mobilize more uranium from the lower vadose zone in spring and less during low flow stages in fall or early winter.

In previous years, another zone of elevated uranium in 300 Area groundwater was found near the 324 Building and well 399-3-11 (PNNL-11470, Figure 6.13-1). The source of this plume may have been the former 307 trenches (later called 316-3), which were decommissioned in 1964. However, in more recent years the elevated zone of uranium moved downgradient (southeast) toward the Columbia River. In fiscal year 1999, the highest concentration of this smaller plume was located at well 399-4-9 (160 µg/L) (see Figure 2.12-1 in PNNL-13116) near the Columbia River. By fiscal year 2001, the highest portion of the plume had moved southeast into the Columbia River, and the remaining portion of the plume is no longer distinguishable from the process trenches plume.

2.12.3 Strontium-90

Strontium-90 has been found as an isolated occurrence at well 399-3-11 in previous years (PNNL-13404, Section 2.12.3). The highest concentration measured in recent years was 8.7 pCi/L in 1995. Since then the concentration levels measured at well 399-3-11 have varied between 3 and 8 pCi/L. Well 399-3-11 was not sampled in fiscal year 2001 because of sampling difficulties at the well head. The source of the strontium-90 is unknown, but it may be the former 307 trenches (316-3) located north-northwest of well 399-3-11.

2.12.4 Chlorinated Hydrocarbons

Trichloroethene was detected at 20 wells in the 300 Area in fiscal year 2001. However, only one of the reported results was at or above the maximum contaminant level of 5.0 µg/L. The single reported result above 5.0 µg/L was at well 399-2-2 (not compatible with WAC 173-160) (see Figure 2.12-2 for well location) in November 2000, which was 5.3 µg/L. However, later in the fiscal year (August 2001) the level had dropped to 2.7 µg/L in this well.

There are two plumes of trichloroethene in the 300 Area:

- a localized plume confined to one well (399-1-16B), which is downgradient of the 300 Area process trenches and at the bottom of the unconfined aquifer
- a plume extending into the 300 Area from the southwest and situated in the upper portion of the unconfined aquifer (Figure 2.12-5).

The 316-5 process trenches contaminated groundwater with trichloroethene. Concentrations are declining naturally, and were below the maximum contaminant level in fiscal year 2001.

The plume downgradient of the process trenches (well 399-1-16B) had a maximum concentration of 3.1 µg/L in March of 2001. Concentration of trichloroethene has decreased steadily in the well since 1997 (Figure 2.12-6).

The other plume of trichloroethene, the one extending into the 300 Area from the southwest (see Figure 2.12-5), is detected at wells screened at the water table. The highest concentration in this plume within the 300 Area during fiscal year 2001 was 5.3 µg/L at well 399-2-2. Since 1997, the concentration of trichloroethene has been variable within a range of 1.7 to 5.3 µg/L (Figure 2.12-7). The only identified source of the trichloroethene in this plume is from offsite, southwest of the Horn Rapids Landfill (see also Section 2.13-4).

A plume of cis-1,2-dichloroethene was detected at four 300 Area wells during fiscal year 2001, but the reported concentrations exceeded the 70 µg/L maximum concentration limit at only one of those wells, 399-1-16B, which is screened at the bottom of the unconfined aquifer. The source of the cis-1,2-dichloroethene was probably the process trenches and potentially is a degradation product of trichloroethene. The concentration is variable in this well but shows an overall slight increase since 1999 (Figure 2.12-8). During fiscal year 2001, the concentration at well 399-1-16B ranged from 130 to 190 µg/L, which is slightly higher than the range in fiscal year 2000 (110 to 170 µg/L).

A plume of tetrachloroethene (i.e., PCE) was detected in the 300 Area during fiscal year 1998, but it has dissipated and was virtually undetected in fiscal year 2001. Its source was in the vicinity of the process trenches and extended southeast toward the Columbia River. The plume continued during fiscal year 1999, but the concentration within the plume decreased dramatically. The maximum reported value at well 399-1-17A, immediately downgradient of the process trenches, was 38 μg/L in fiscal year 1998 (maximum contaminant level 5.0 μg/L). The maximum value at the same well in fiscal year 1999 was 4.0 μg/L. During fiscal year 2001, tetrachloroethene was detected in only one well (399-4-1 in the southern part of the 300 Area, see Figure 2.12-2) with a reported value of 0.36 μg/L.

2.12.5 Nitrate

Nitrate above background levels (WHC-EP-0595, Table A-1-2) was detected in all wells in the 300 Area that sampled the upper portion of the unconfined aquifer during fiscal year 2001 (Figure 2-12.9). However, only one well had reported nitrate results greater than the 45 mg/L drinking water standard. That well was 699-S27-E14 (southern part of 300 Area) with a result of 55.3 mg/L in January 2001. The source of the nitrate is probably offsite industry and agriculture (see also Section 2.13).

2.12.6 RCRA Parameters for the 300 Area Process Trenches

Since December 1996, the 300 Area process trenches have been monitored by a RCRA final status corrective-action network. Corrective action is in conjunction with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) (see Section 2.12.7). The 300 Area Process Trenches modified closure/postclosure plan (DOE/RL-93-73) was approved and incorporated into the Hanford Site RCRA Permit (DOE/RL-88-21) in fiscal year 1997. In May 1998, closure activities at the 300 Area process trenches were completed, and postclosure began. Postclosure will continue for a 30-year period, culminating in postclosure certification in fiscal year 2028. The purpose of groundwater monitoring is to examine the trend of the constituents of concern to determine if they decreased in concentration as expected. Eight wells were monitored during fiscal year 2001 for uranium and volatile organics (including as a minimum, the contaminants of concern, trichloroethene, cis-1,2-dichloroethene, and tetrachloroethene) (see also Appendix A, Table A.18).

The 316-5 process trenches are a RCRA site that has contaminated groundwater and is monitored under a corrective-action program. The corrective action is deferred to the CERCLA operable units and involves natural attenuation of the contaminants.

During fiscal year 2001, uranium remained above the maximum contaminant level (30 μg/L) in the three downgradient wells that monitor the upper portion of the unconfined aquifer (near the water table). Those three wells are 399-1-10A, 399-1-16A, and 399-1-17A. However, since 1997 the uranium concentration has decreased at these three wells. Well 399-1-16B had cis-1,2-dichloroethene levels above the maximum contaminant level (70 μg/L). Trichloroethene and tetrachloroethene exceeded maximum contaminant levels in previous years. During fiscal year 2001, trichloroethene was detected but did not exceed maximum contaminant levels in any of the downgradient wells of the 300 Area process trenches well network. Tetrachloroethene is no longer detected in the well network. For more information about uranium and the volatile organics, see Sections 2.12.2 and 2.12.4.

2.12.7 300-FF-5 Operable Unit

Groundwater monitoring at the 300-FF-5 Operable Unit continued in fiscal year 2001 under the Operation and Maintenance Plan for the 300-FF-5 Operable Unit (DOE/RL-95-73). At the direction of the *Explanation of Significant Difference for the 300-FF-5 Record of Decision* (EPA 2000), the boundaries of the 300-FF-5 Operable Unit were expanded. Correspondingly, groundwater monitoring was expanded to include the areas immediately around the 618-11 burial ground near Energy Northwest and the 618-10 burial ground and 316-4 crib northwest of the 300 Area and south of Energy Northwest (see Figure 2.12-1). A new operations and maintenance plan for the 300-FF-5 Operable Unit is currently being written to include these new satellite areas specified in EPA 2000.

The CERCLA record of decision (ROD 1996b) process required a review by the U.S. Environmental Protection Agency after 5 years from the original time of issuance to assess the progress of the selected remedy. The results of the first 5-year review (EPA 2001) indicated that the 300 Area cleanups were proceeding in a protective and effective manner. The U.S. Environmental Protection Agency still considered that the cleanup goals and remedy selection decisions were appropriate at the time the 5-year review was released. Another U.S. Environmental Protection Agency assessment of the progress of the selected remedy will occur in 5 years (2006).

2.12.7.1 618-10 Burial Ground and 316-4 Crib

Groundwater samples from a well near the 618-10 burial ground and 316-4 crib contain elevated levels of uranium and petroleum products. In fiscal year 2001, up to 5,500 µg/L of hydrocarbon was detected in the oil and grease analysis, suggesting the presence of floating contamination in the well.

This burial ground and adjacent crib are southeast of the 400 Area, adjacent to Route 4S. Based on water-table contours, groundwater flow is to the east (see Plate 1). This site was investigated as part of a CERCLA limited field investigation for the 300-FF-2 Operable Unit (DOE/RL-96-42). In fiscal year 1995, high levels of uranium, 768 µg/L unfiltered, were detected immediately adjacent to the crib in well 699-S6-E4A. The presence of hydrocarbon contamination was detected also in well 699-S6-E4A. Subsequently, tributyl phosphate was detected.

Well locations near the 618-10 burial ground and 316-4 crib are shown in Figure 2.12-10. The CERCLA investigation included re-configuration of well 699-S6-E4A and sampling of two cone penetrometer borings near this well. The conclusions in DOE/RL-96-42 were that uranium and hydrocarbon groundwater contamination are probably localized in the area of well 699-S6-E4A. The source of such contamination is primarily the crib, with possibly some contribution from the burial ground. There are no monitoring wells located immediately downgradient of the 618-10 burial ground.

Uranium in well 699-S6-E4A declined slightly from previous years with a fiscal year 2001 average value of 22 µg/L (Figure 2.12-11). This uranium is highly depleted in uranium-234 and uranium-235 (PNNL-13404). Although details of the disposal to the burial ground and crib have not been researched, the waste is known to have come from 300 Area operations, and depleted uranium is known to have been used there. The presence of a low concentration of uranium-236 suggests that a component of the uranium has been irradiated in a reactor.

The hydrocarbon contamination by the 316-4 crib is primarily high molecular weight compounds. In fiscal year 2001, up to 5,500 µg/L of hydrocarbon was detected in the oil and grease analysis and none detected in the gasoline or diesel range analyses. Previously, diesel range hydrocarbons have been detected. The results suggest the probable presence of light non-aqueous phase liquids in the well. However, the well is not configured to allow the use of an interface probe to check for a floating hydrocarbon layer.

Tributyl phosphate concentrations reported in well 699-S6-E4A have been erratic, with values ranging from 22 to 45 µg/L detected in fiscal year 2001 (Figure 2.12-12). The reasons for the erratic concentrations have not been established but may be related to the petroleum hydrocarbons. When two liquid phases are present in a well, it is common to see erratic results because the composition can vary during pumping.

Information on the vertical distribution of contamination near the 618-10 burial ground and 316-4 crib is available through two deeper monitoring intervals within the Hanford/Ringold aquifer system. During fiscal year 1996, well 699-S6-E4C was re-configured to provide two deep, depth-discrete, monitoring intervals. The two monitored intervals are at 26 meters (well 699-S6-E4CS) and at 50 meters (well 699-S6-E4CT) below the water table, and each interval (26 and 50 meters) is sampled by a piezometer that is open for 2 meters. The tritium concentration at the water table in fiscal year 2001, 19,800 pCi/L in well 699-S6-E4D, declined below the drinking water standard for the first time since 1978. Tritium was not detected in the deeper intervals in fiscal year 2001. This suggests that the earlier samples with detected tritium at depth resulted from intercommunication down the well bore prior to re-configuration. Uranium concentrations were <1 µg/L in the deeper intervals in fiscal year 2001.

2.12.7.2 618-11 Burial Ground

Tritium was detected at a level <1 million pCi/L immediately downgradient of the 618-11 burial ground in January 1999. A special investigation of the groundwater at the 618-11 burial ground carried out in fiscal year 2000 determined that the burial ground was the source of the tritium contamination. The investigation continued through fiscal year 2001 to define the extent of contamination.

The tritium concentration in a well downgradient of the 618-11 burial ground declined between fiscal year 2000 and 2001. This contamination was only recently discovered, and the site was investigated further in fiscal year 2001, defining the lateral and vertical extent of groundwater contamination. Results of the study defined a narrow plume extending ~900 meters east-northeast of the burial ground.

The tritium concentration downgradient of the 618-11 burial ground, in well 699-13-3A, was 1.86 million pCi/L when first measured in January 1999. By January 2000, the level increased to 8.14 million pCi/L. In January 2001, the concentration declined to 5.29 million pCi/L. Nitrate is the only other contaminant that has been detected at levels above drinking water standards. The maximum nitrate detected in fiscal year 2001 was 93 mg/L. Other contaminants detected include technetium-99, very low levels of carbon-14, nickel-63, and traces of carbon tetrachloride.

The 618-11 burial ground is located west of the Energy Northwest reactor complex in the eastern 600 Area. The burial ground was active from 1962 to 1967 and received a variety of low and high activity waste from the 300 Area. The Waste Information Data System description of this site identified contaminants of concern (i.e., cesium, cobalt-60, curium, plutonium, strontium, uranium, and zirconium). Other contaminants that might be encountered include aluminum-lithium, beryllium, carbon tetrachloride, hydrogen gas, sodium-potassium eutectic, and thorium. Potential tritium source materials and source locations within the 618-11 burial ground have not been identified. Possible source materials include fission products and activation products from nuclear operations. In particular, there is a possibility that the tritium is related to tritium production research carried out at the Hanford Site in the 1960s. Although that link has not been established, the hypothesis is consistent with what is known about the research and about burial ground operations.

The water-table gradient at the 618-11 burial ground is nearly due east (see Plate 1). However, the Hanford formation sediment thins at the burial ground and farther east so less permeable Ringold Formation sediment is present at the water table. These lithologic changes suggest that groundwater flow may not be due east, but may divert to the northeast or southeast. The presence of low permeability sediment is believed to explain the area of low tritium concentrations surrounding this region (see Plate 2).

The investigation of tritium at the 618-11 burial ground in fiscal year 2001 defined the lateral and vertical extent of the groundwater contamination. To define the lateral extent, 27 additional soil gas monitoring points were installed and samples collected to measure the helium isotopic ratio. Helium-3 is formed from tritium decay so a high ratio (>1) indicates a tritium source. The measurements are sensitive to helium diffusing upward from contaminated groundwater. Further information on the soil gas sampling is presented in Section 3.2.1 and in PNNL-13675.

Soil boring locations were chosen, based on the results of the helium survey. Six groundwater grab samples were collected from borings drilled to the water table. Four of the borings were completed as wells for future monitoring of the burial ground (BHI-01567). One boring was drilled to the Ringold mud unit 32 meters below ground surface in order to define the vertical extent of contamination.

The fiscal year 2001 study defined a plume that is narrow and extends ~900 meters east-northeast of the burial ground (Figure 2.12-13). Tritium was detected throughout the unconfined aquifer above the silt layer in boring C3254, completed as well 699-13-2D (Figure 2.12-14). Concentrations ranged from 634,000 to 690,000 pCi/L in the uppermost 2 samples (down to ~3 meters below the water table) then doubled to 1.3 million pCi/L in the next two samples (5.5 to 11 meters below the water table). The tritium concentration declined to 503,000 pCi/L in the sample collected just above the Ringold mud unit (13 meters below the water table). The results were consistent with vertical profile sampling of the well immediately east of the burial ground (699-13-3A) where tritium concentrations in discrete-interval samples ranged between 5.8 to 7 million pCi/L through the upper 5 meters of the aquifer. This depth distribution of tritium is not expected from a burial ground source where there is too little recharge to move the contamination deep into the aquifer. The plume is estimated currently to contain 190 to 285 curies of tritium (0.020 to 0.029 gram) based on this extent.[(a)]

The study of tritium at the 618-11 burial ground estimated that it will take ~166 years for this tritium plume to reach the Columbia River. Tritium will most likely decay to less than the drinking water standard before the plume reaches the river.

Water supply wells east of the 618-11 burial ground probably played a large role in determining the current tritium distribution. Wells 699-13-1A and 699-13-1B were used for water supply during construction of the Columbia Generating Station in the 1970s and early 1980s. Tritium was detected at concentrations up to 1.4 million pCi/L in well 699-13-1A in the late 1970s. The narrow plume tracks directly through the location of this well so it appears that the well drew the plume over from the burial ground. The gradients induced by the pumping would cause the transport of tritium down through the unconfined aquifer. The supply wells, in this scenario, would have captured the contamination until the supply of river water to the reactor complex was developed to replace the wells. At that time, the plume would be able to move further east under natural gradients. Groundwater velocity under the natural gradient is considerably slower than under the well pumping.

The conceptual model, above, can be used as a basis to estimate travel time to the Columbia River. Travel time can be estimated by assuming that the 25,400 pCi/L tritium concentration detected in September 2001 in well 699-13-0A (boring C3256) represents first arrival of the plume. In actuality, the mean travel time will be slower since this concentration is still far lower than that detected in well 699-13-1A. The plume velocity can be estimated from the distance between the two wells and the time it took for the plume to travel between them. The plume velocity calculated from these data is 28 meters per year. This velocity can then be used to estimate travel time to the river, the upper-bound concentration expected in groundwater discharge, and the tritium flux to the river. The results of these calculations are shown in Table 2.12-1, along with estimates based on generalized velocity estimates for the Ringold Formation and calculations using the Sitewide (groundwater) Numerical Model. The calculation indicate that the tritium concentration will most likely decay to less than the drinking water standard by the time the plume reaches the Columbia River. The plume is not expected to impact active water supply wells in the vicinity because they are not completed in the flow path.

(a) Letter report from J. V. Borghese, W. J. McMahon, and R. W. Ovink (CH2M HILL) to the U.S. Department of Energy, Richland, Washington. 2001. *Tritium Groundwater Investigation at the 618-11 Burial Ground, September 2001.*

2.12.8 Monitoring at River Shoreline

Groundwater samples are collected annually from riverbank seepage sites during the seasonal low river stage, which occurs during the late summer or early fall months. River bank seepage is monitored by the Surface Environmental Surveillance Project, with additional sampling and analysis conducted under the Environmental Restoration Project in support of the 300-FF-5 Operable Unit investigations. Table 2.12-2 lists the analytical results for key constituents for samples collected during fiscal year 2001 from riverbank seepage sites, tube sampling sites, and near shore river locations.

Fall samples of riverbank seepage were collected at two locations along the 300 Area shoreline during September 2001. The first location (S3-42-2) is adjacent to well 399-1-10 near the former process trenches, and the second (S3-DR42-2) is ~500 meters downstream from the first location, close to wells 399-2-1 and 399-2-3 (see Figure 2.12-2). The specific conductance from the two sites was 412 and 407 µS/cm, respectively, indicating that the seepage samples consisted primarily of groundwater, with little addition of bank storage river water. These seepage sites have been tracked for many years and historical trends of specific conductance are highly variable, with no distinct increase or decrease indicated (PNNL-13230).

Uranium concentrations exceeded the maximum contaminant level in most of the shoreline samples at the 300 Area.

The principal contaminant of concern, uranium, averaged 46 µg/L at location S3-42-2 and 129 µg/L at location S3-DR42-2 (see Figure 2.12-1) during the late summer/early fall sampling periods during fiscal year 2001. Gross alpha measurements reflect the uranium concentrations in these samples. Near shore river water samples collected at several points along the 300 Area shoreline showed that the concentration varied, but could be as high as 87 µg/L near the S3-DR42-2 seep (Rs3-DR42-2-1 sample collected August 27, 2001). In the 10 tube samples collected at four locations, the range of uranium concentration was 95 to 210 µg/L for samples collected September 17-18, 2001. The 210 µg/L result was from a sample collected at depth of 5.5 feet (1.7 meters).

Gross beta (50 pCi/L drinking water standard) measurements at the seeps ranged from 16 to 33 pCi/L, which is similar to previous years. Gross beta typically is detected from daughter products of uranium isotopes. Tritium concentrations (20,000 pCi/L drinking water standard) ranged from 6,300 to 8,380 pCi/L during the late summer/early fall months of fiscal year 2001. Results of tube samples were similar. Tritium samples were not collected in near shore river locations during fiscal year 2001. Nitrate exceeded the 45 mg/L drinking water standard in the seeps, but was nearly undetectable in river water near the shore.

Table 2.12-1. Travel Time, Maximum Concentrations of Tritium, and Tritium Flux at the Columbia River Boundary, Based on Different Travel Estimates

Travel Time (year)	Maximum Concentration at River (pCi/L)	Maximum Tritium Flux to River (Ci/yr)	Scenario
166	700	0.46	From conceptual model
43	730,000	480	Upper limit from generalized Ringold velocities
129	5,800	3.8	Lower limit from generalized Ringold velocities
70-80	5,500	NA	Sitewide numerical model calculations

NA = Not applicable.

Table 2.12-2. Shoreline Monitoring Data for the 300 Area, Fiscal Years 2000 and 2001

Location Name	Sample From	Specific Sample Date	Conductance (µS/cm)$^{(a)}$	Uranium (µg/L)$^{(b)}$	Gross Alpha (pCi/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
A3-Spr-7-1									
(2.5 ft)	Tube	09/18/01		192				7,560	
(4 ft)	Tube	09/18/01		95				8,020	
(6 ft)	Tube	09/18/01		98				8,390	
A3-Spr-7-2									
(2 ft)	Tube	09/18/01		95				8,420	
(4.2 ft)	Tube	09/18/01		106				8,660	
A3-Spr-9-1									
(2 ft)	Tube	09/17/01		101				6,060	
(4 ft)	Tube	09/17/01		149				7,590	
A3-Spr-9-2									
(2 ft)	Tube	09/17/01		163				7,800	
(4.5 ft)	Tube	09/17/01		162				7,620	
(5.5 ft)	Tube	09/17/01		210				7,160	
S3-42-2	Seep	09/27/00	412	75	68.8	0.0923 U	29.1	9,940	104.0
	Seep	05/10/01	440	78	65.2	0.215	25.8	11,700	
	Seep	08/27/01		42	27	0.143	16	6,300	62.9
	Seep	09/18/01		50				7,410	
S3-DR42-2	Seep	09/27/00	407	195	125	0.184	26	9,130	100.0
	Seep	05/03/01	334	110	87.5	0.192	21	6,400	
	Seep	08/27/01		152	86.8	0.202	32.7	8,380	96.1
	Seep	09/17/01		105				6,940	
SRL-444	Seep	05/17/01	284	2					
Rs3-415	River	09/19/00		1		0.0652			1.7
	River	09/13/01		1		0.0818			1.3
Rs3-421	River	09/19/00		1		0.0477			5.7
	River	09/13/01		1		0.0759			4.9
Rs3-42-2-1	River	08/27/01		15					
Rs3-42-2-2	River	08/27/01		5					
Rs3-42-2-3	River	08/27/01		1					
Rs3-42-2-4	River	08/27/01		1					
Rs3-Spr-DR7-1	River	08/27/01		4					
Rs3-Spr-DR7-2	River	08/27/01		2					

Table 2.12-2. (contd)

Location Name	Sample From	Specific Sample Date	Conductance (µS/cm)[a]	Uranium (µg/L)[b]	Gross Alpha (pCi/L)	Strontium-90 (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
Rs3-Spr-DR7-3	River	08/27/01		1					
Rs3-Spr-DR7-4	River	08/27/01		1					
Rs3-4222	River	08/27/01		1					
Rs3-DR42-2-1	River	08/27/01		87					
Rs3-DR42-2-2	River	08/27/01		4					
Rs3-DR42-2-3	River	08/27/01		1					
Rs3-DR42-2-4	River	08/27/01		1					
Rs3-Spr-DR9-1	River	08/27/01		14					
Rs3-Spr-DR9-2	River	08/27/01		15					
Rs3-Spr-DR9-3	River	08/27/01		5					
Rs3-Spr-DR9-4	River	08/27/01		1					
Rs3-4250	River	09/19/00		1		0.055			1.8
	River	09/13/01		1		0.0594			1.3
Rs3-4251	River	08/27/01		2					
Rs3-Spr-11-1	River	08/27/01		14					
Rs3-Spr-11-2	River	08/27/01		2					
Rs3-Spr-11-3	River	08/27/01		4					
Rs3-Spr-11-4	River	08/27/01		2					
Rs3-Spr-DR11-1	River	08/27/01		8					
Rs3-Spr-DR11-2	River	08/27/01		2					
Rs3-Spr-DR11-3	River	08/27/01		1					
Rs3-Spr-DR11-4	River	08/27/01		1					
Rs3-4290	River	09/19/00		1		0.0716			1.5
	River	09/13/01		1		0.0683			1.0
Rs3-4310-1	River	09/19/00		1		0.0552			1.5
	River	09/13/01		1		0.0744			1.0
Rs3-Spr-14-1	River	08/27/01		1					
Rs3-Spr-14-2	River	08/27/01		1					
Rs3-Spr-14-3	River	08/27/01		1					
Rs3-Spr-14-4	River	08/27/01		1					

(a) Specific conductance provides an indication of the amount of river water in the sample; uncontaminated groundwater is typically ~350 to 450 µS/cm and river water is 120 to 150 µS/cm.

(b) Sum of individual isotope concentrations (^{234}U, ^{235}U, and ^{238}U) in pCi/L, divided by 0.68 to convert activity to mass.

Tube = Aquifer sampling tube near shoreline.
Seep = Natural riverbank seepage site.
River = River water collected near the shore.
U = Below detection limit.

Data sources: Hanford Environmental Information System and various project records.

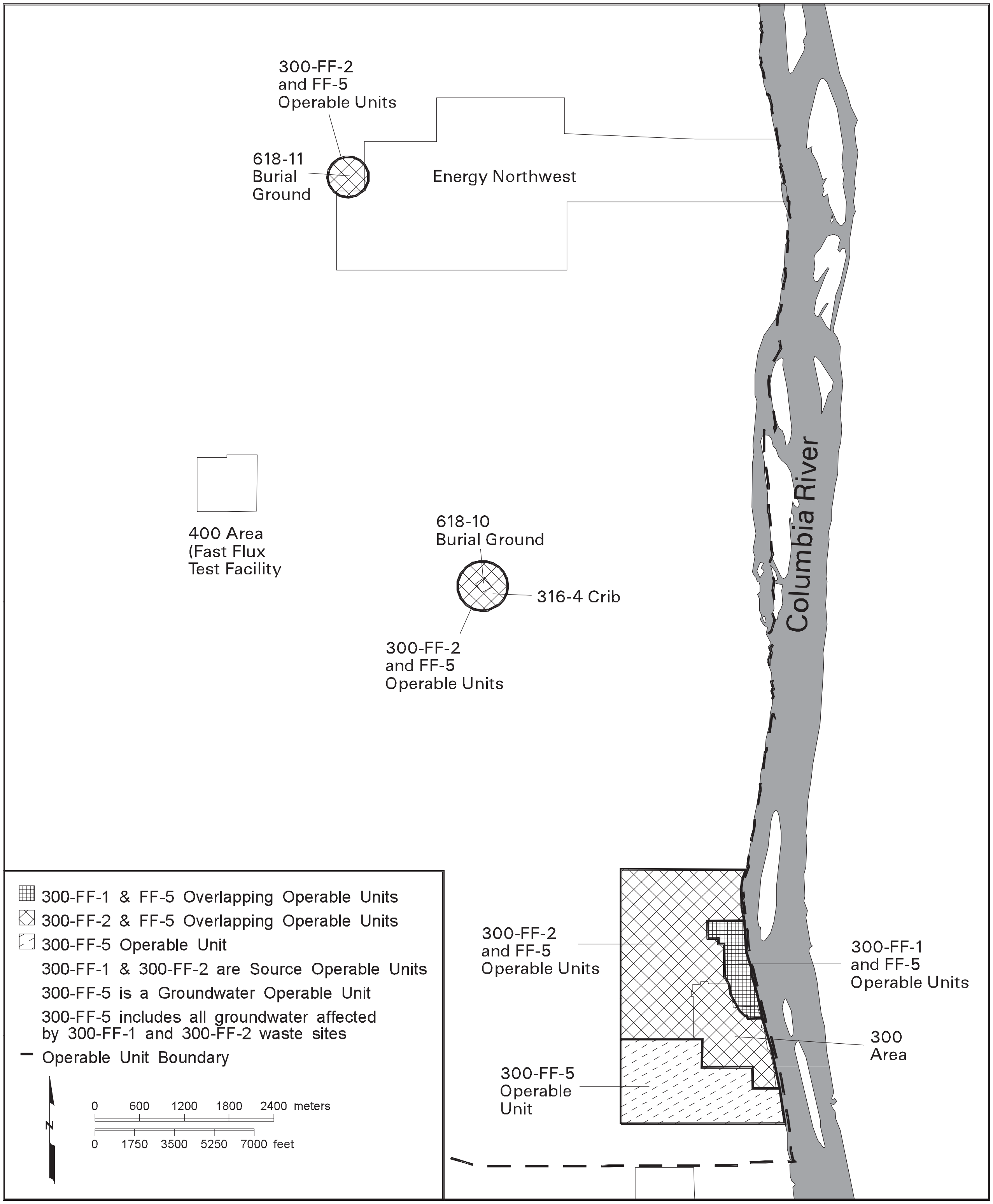


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Figure 2.12-1. Locations of the 300-FF-1, 300-FF-2, 300-FF-5 Operable Units; 618-10 Burial Ground; 316-4 Crib; and 618-11 Burial Ground

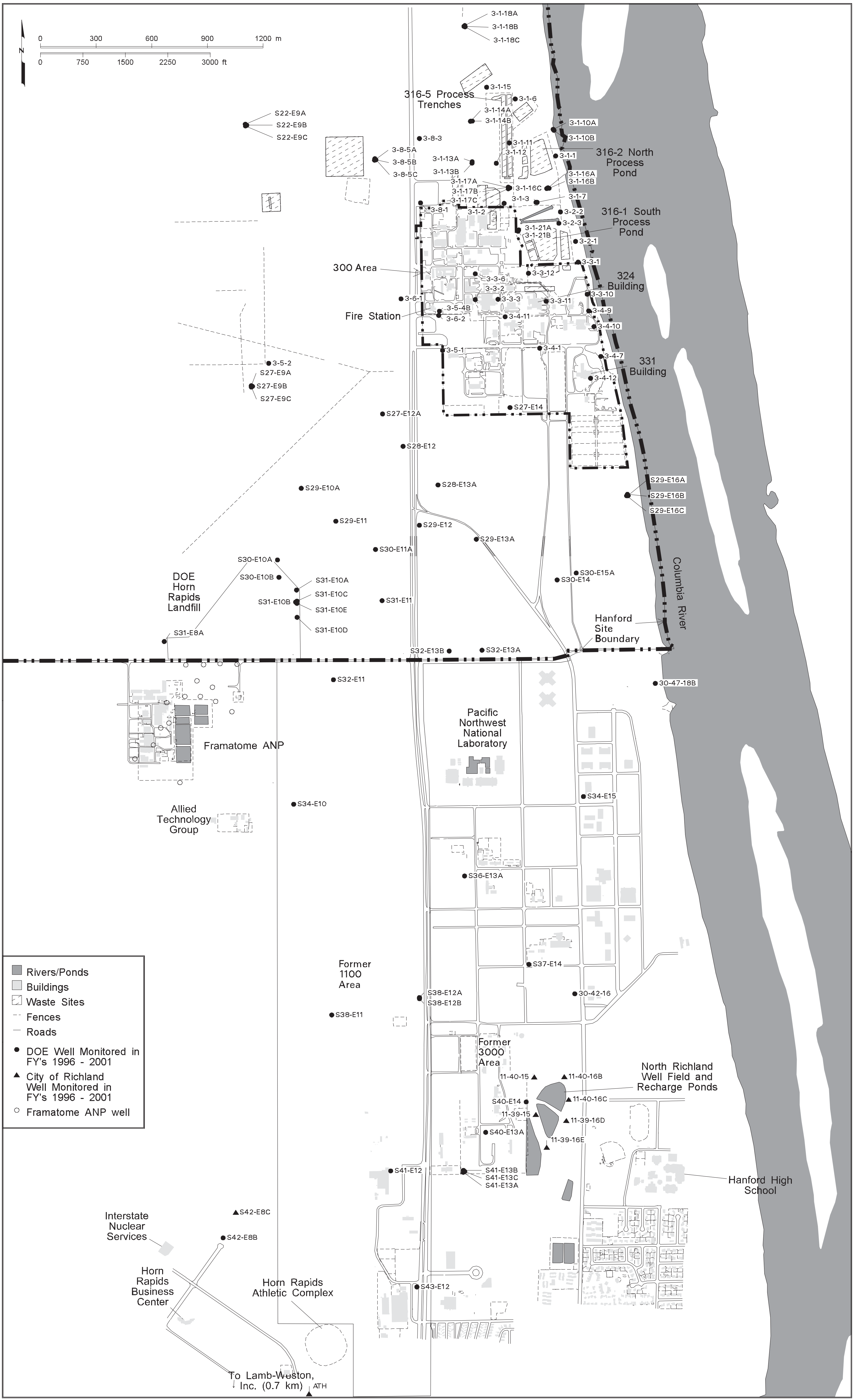

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Figure 2.12-2. Groundwater Monitoring Wells at the 300 and Richland North Areas

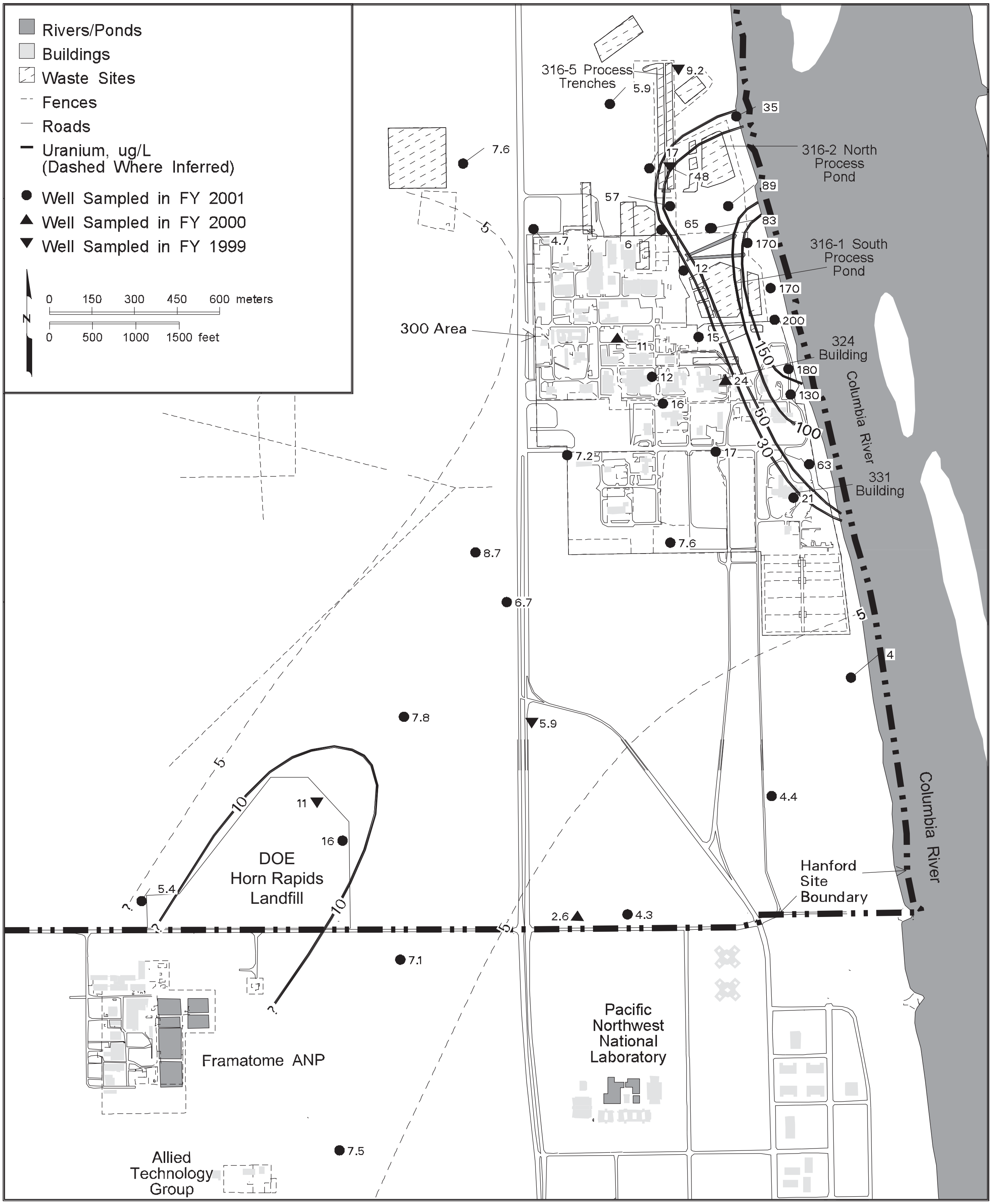

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Figure 2.12-3. Uranium Concentrations in the 300 and Richland North Areas, Top of Unconfined Aquifer, August to September 2001

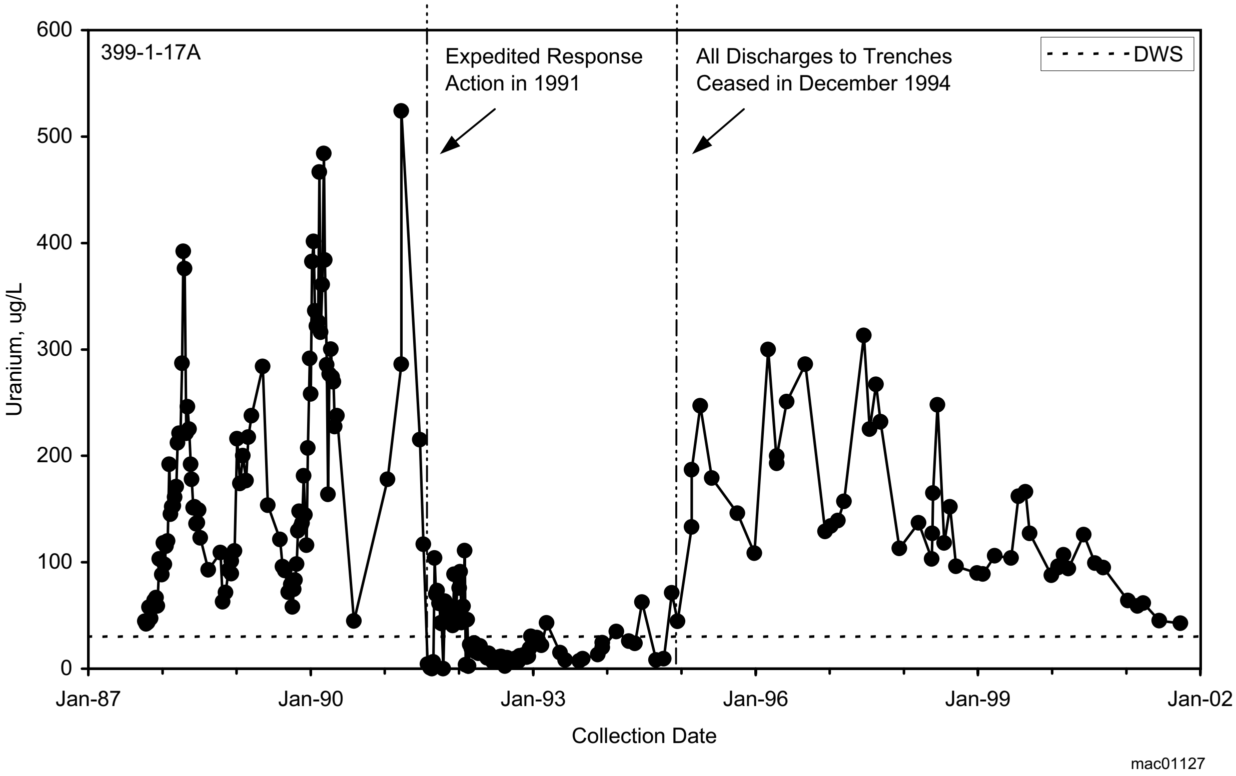

Figure 2.12-4. Uranium Concentrations Near the 316-5 Process Trenches

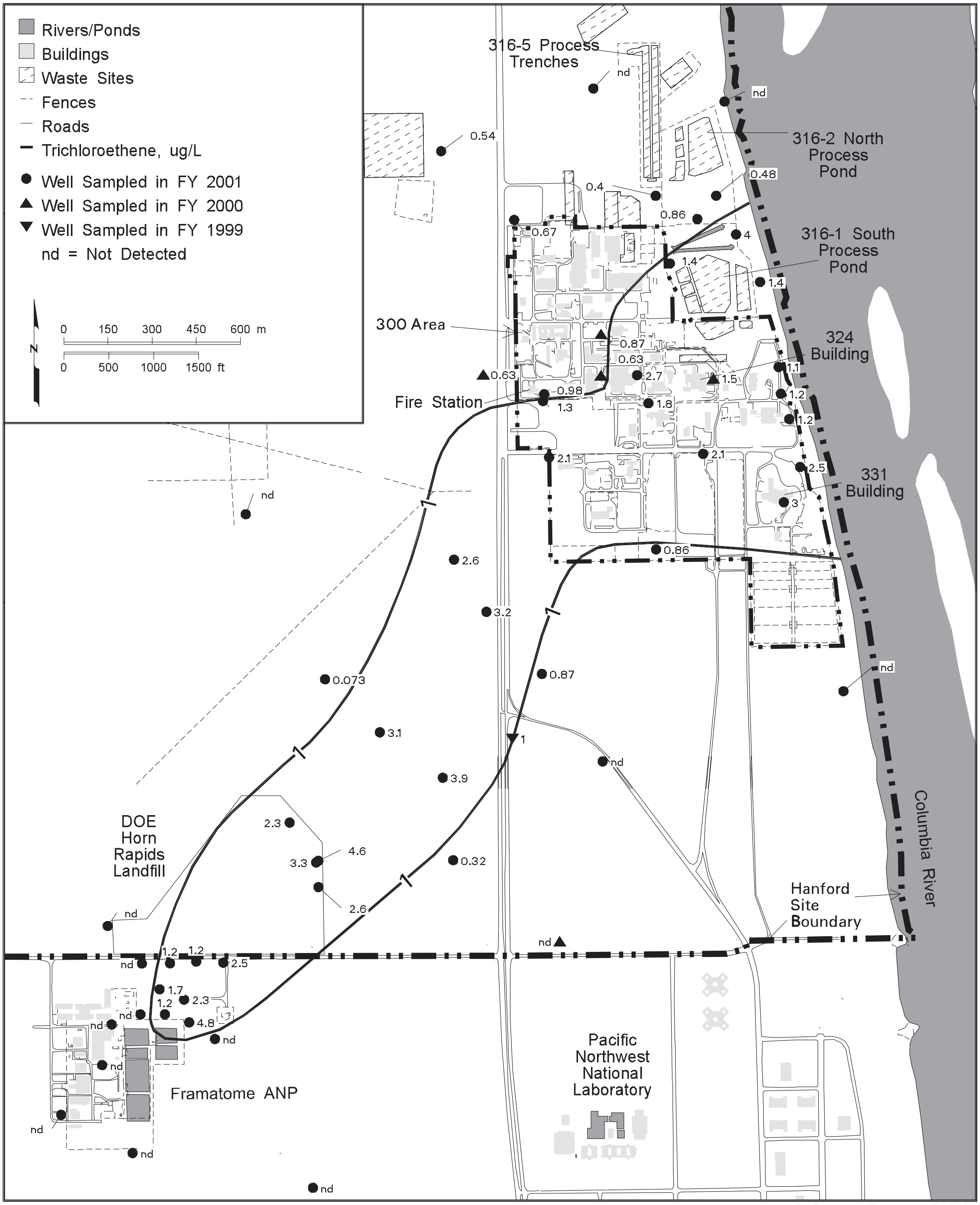

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Figure 2.12-5. Average Trichloroethene Concentrations in the 300 and Richland North Areas, Top of the Unconfined Aquifer

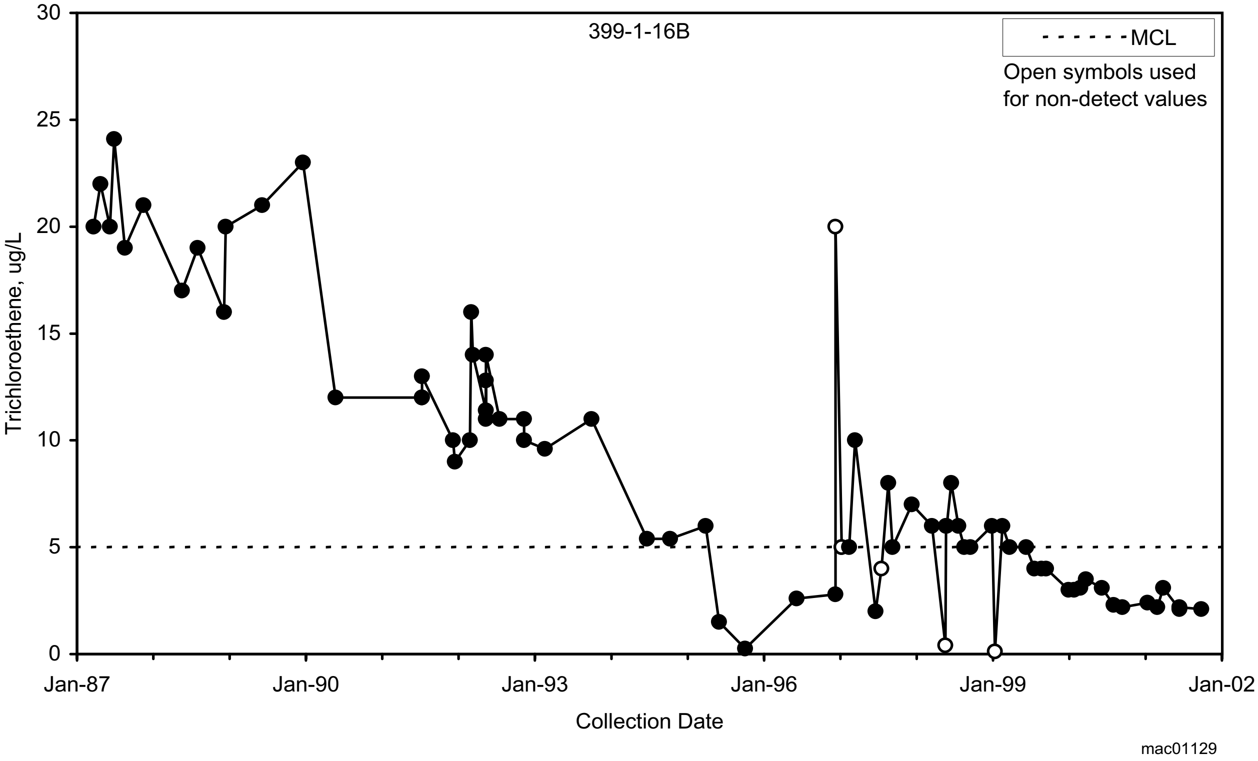

Figure 2.12-6. Trichloroethene Concentrations Near the 316-5 Process Trenches

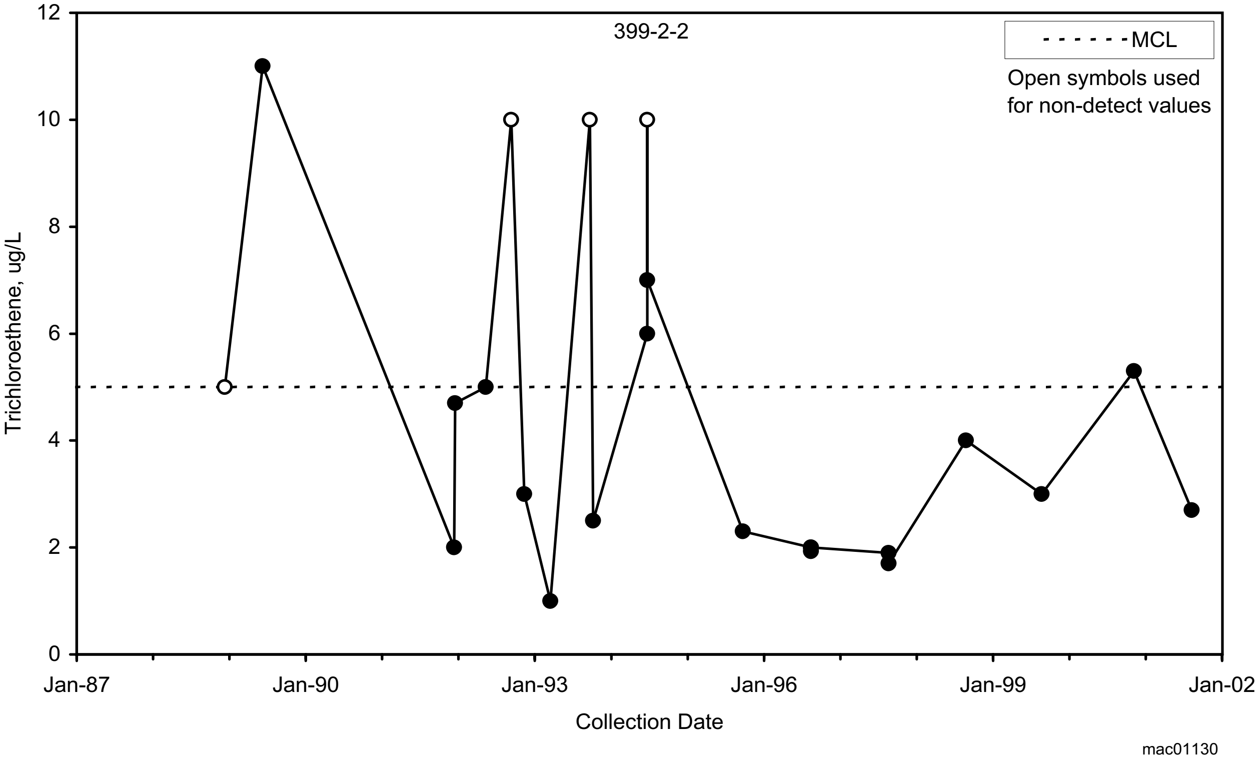

Figure 2.12-7. Trichloroethene Concentrations in the 300 Area

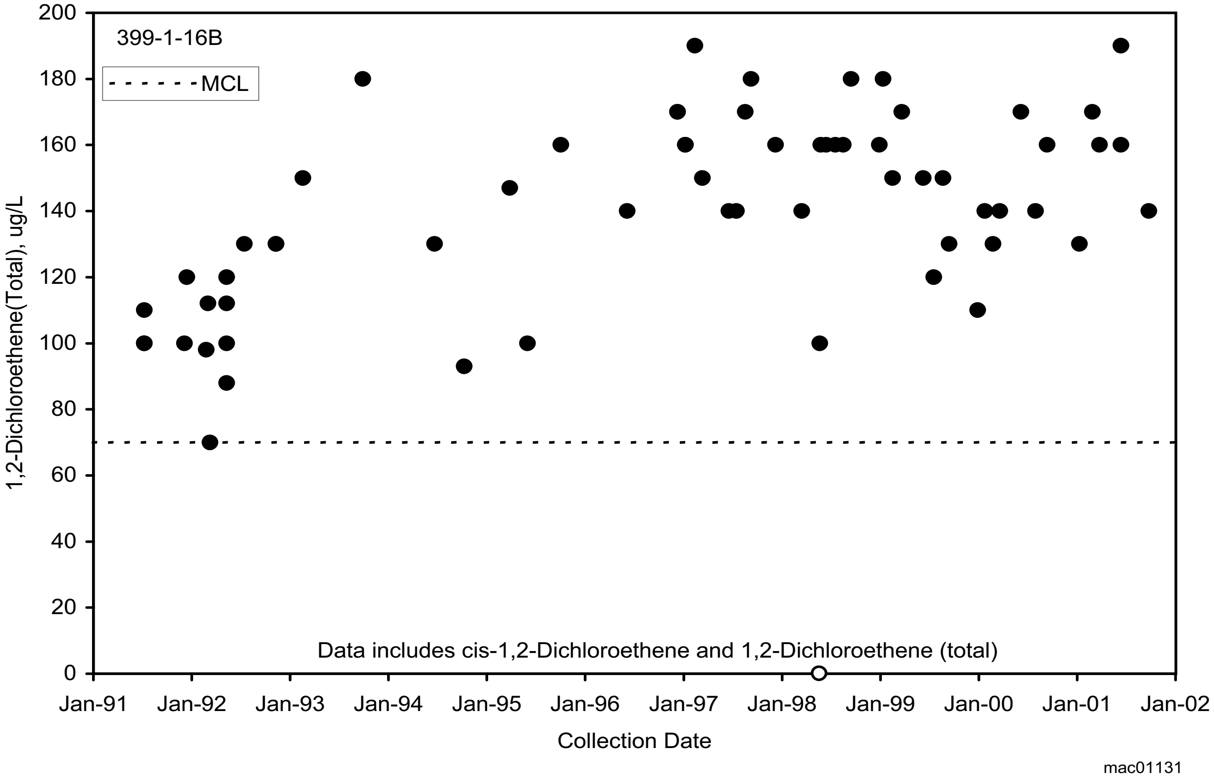

Figure 2.12-8. cis-1,2-Dichloroethene Concentrations Near the 316-5 Process Trenches

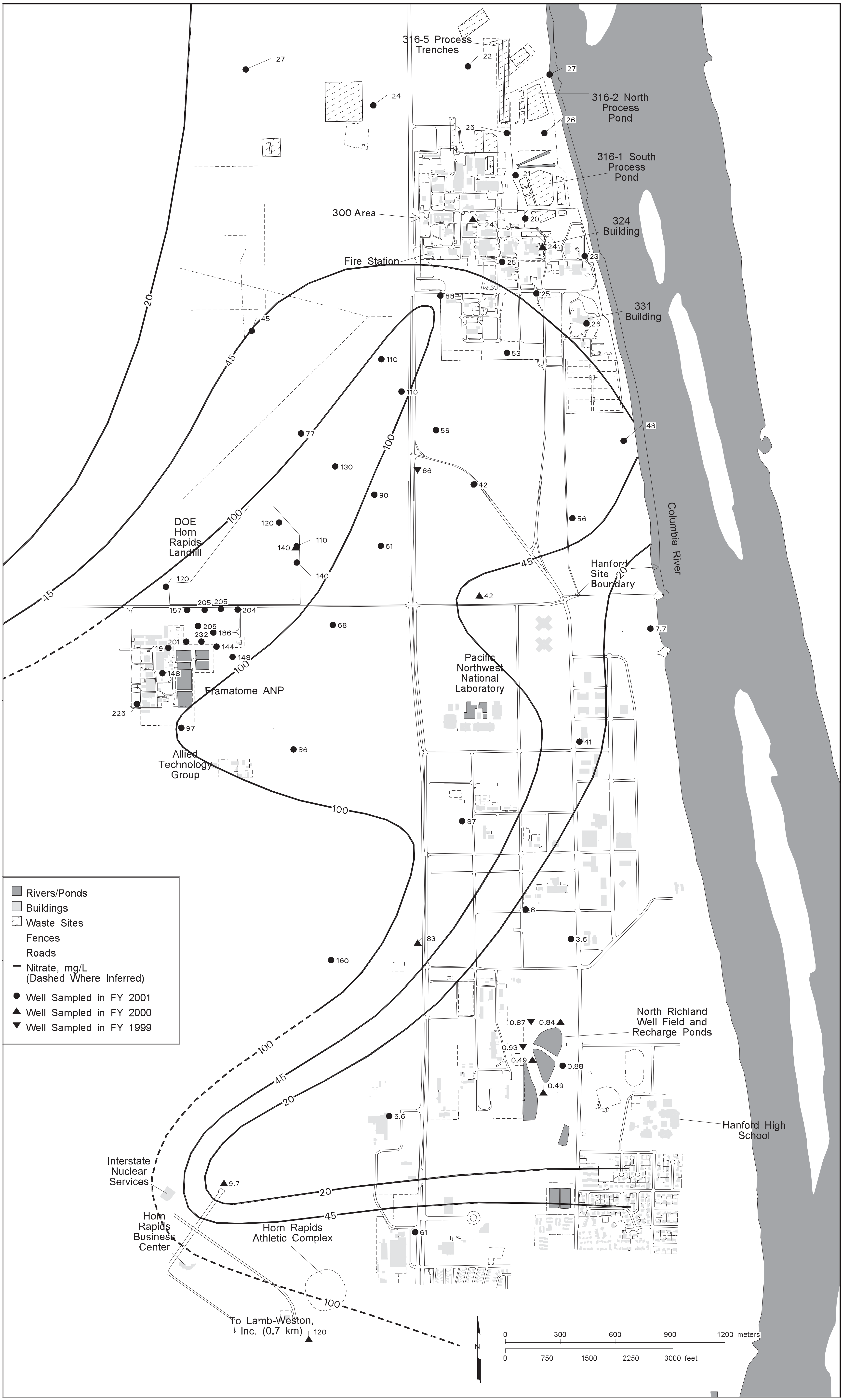

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Figure 2.12-9. Average Nitrate Concentrations in the 300 and Richland North Areas, Top of Unconfined Aquifer

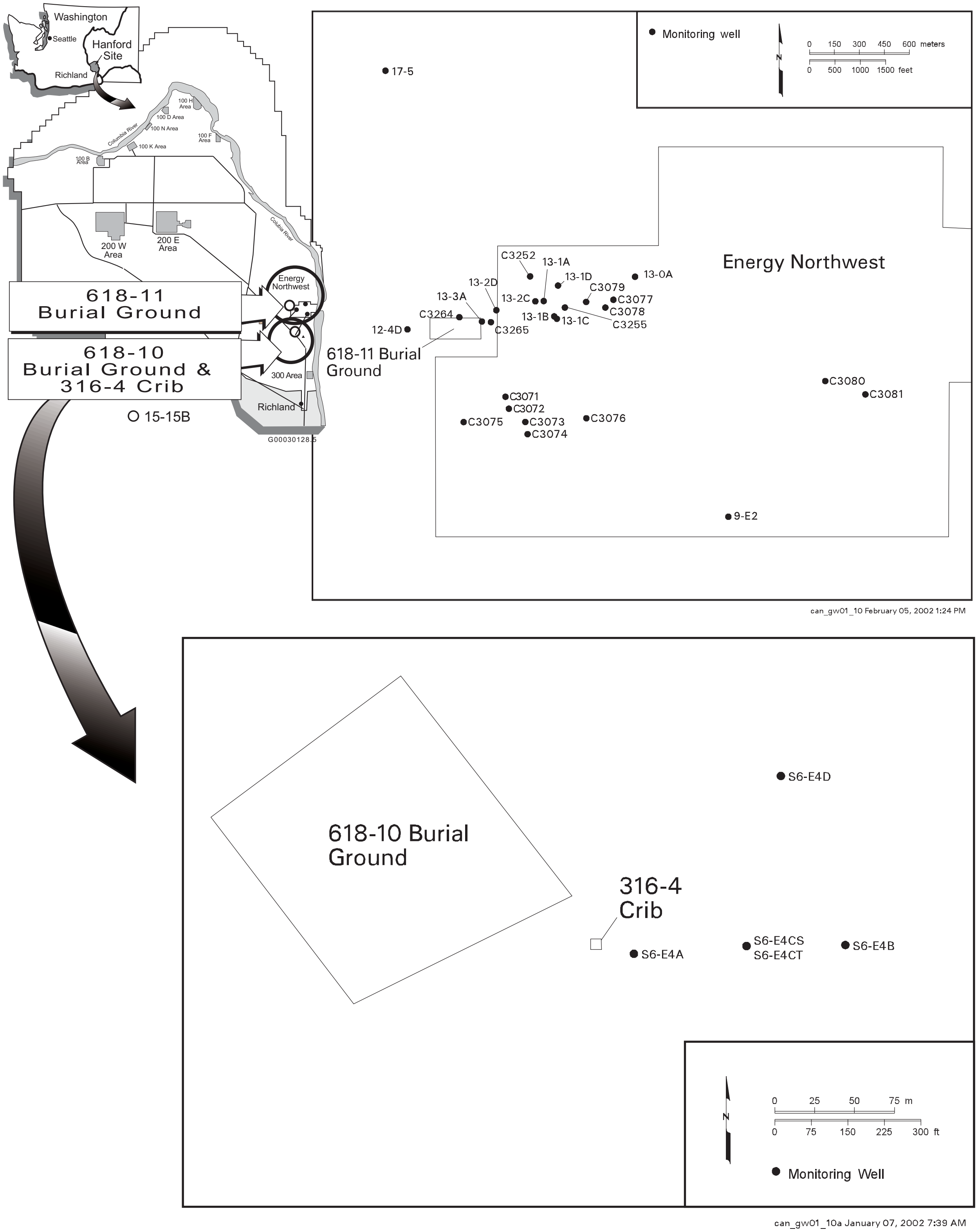


Figure 2.12-10. Groundwater Monitoring Wells Near the 618-10 and 618-11 Burial Grounds and 316-4 Crib (well numbers not beginning with "C" are preceded with 699- prefix)

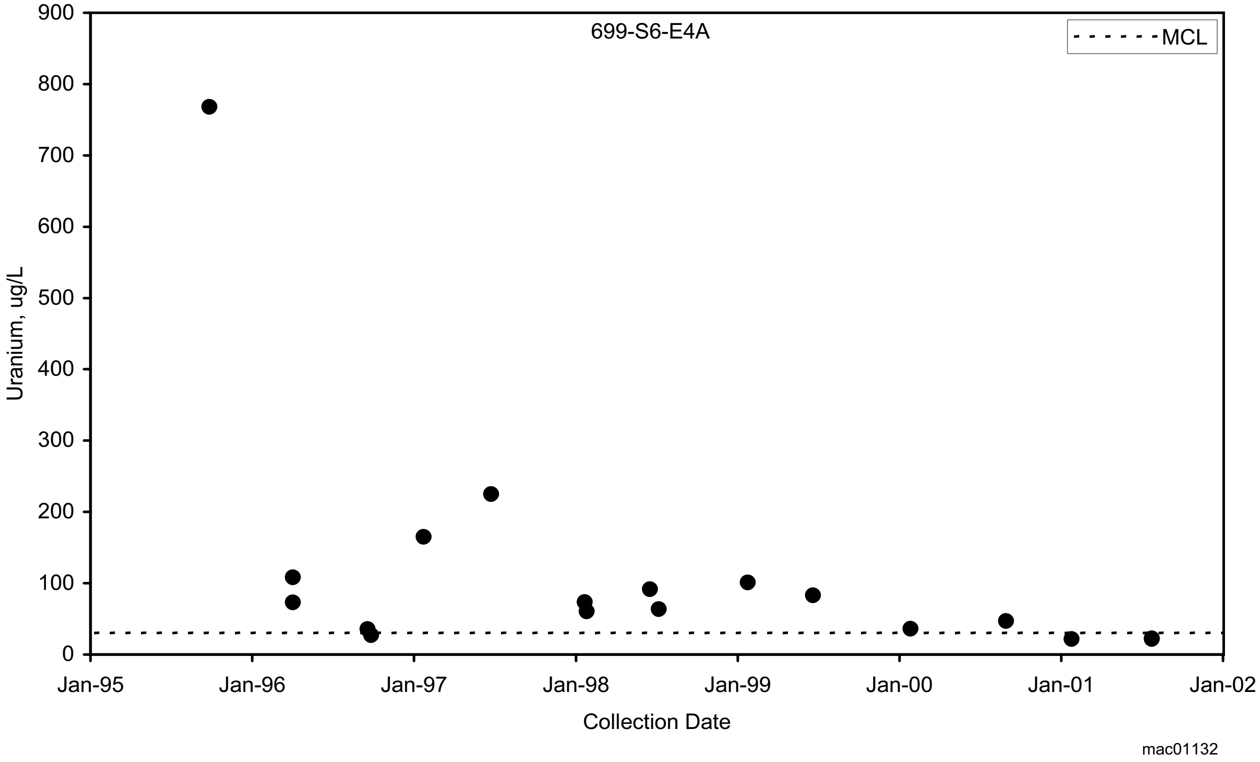


Figure 2.12-11. Uranium Concentrations Near the 618-10 Burial Ground

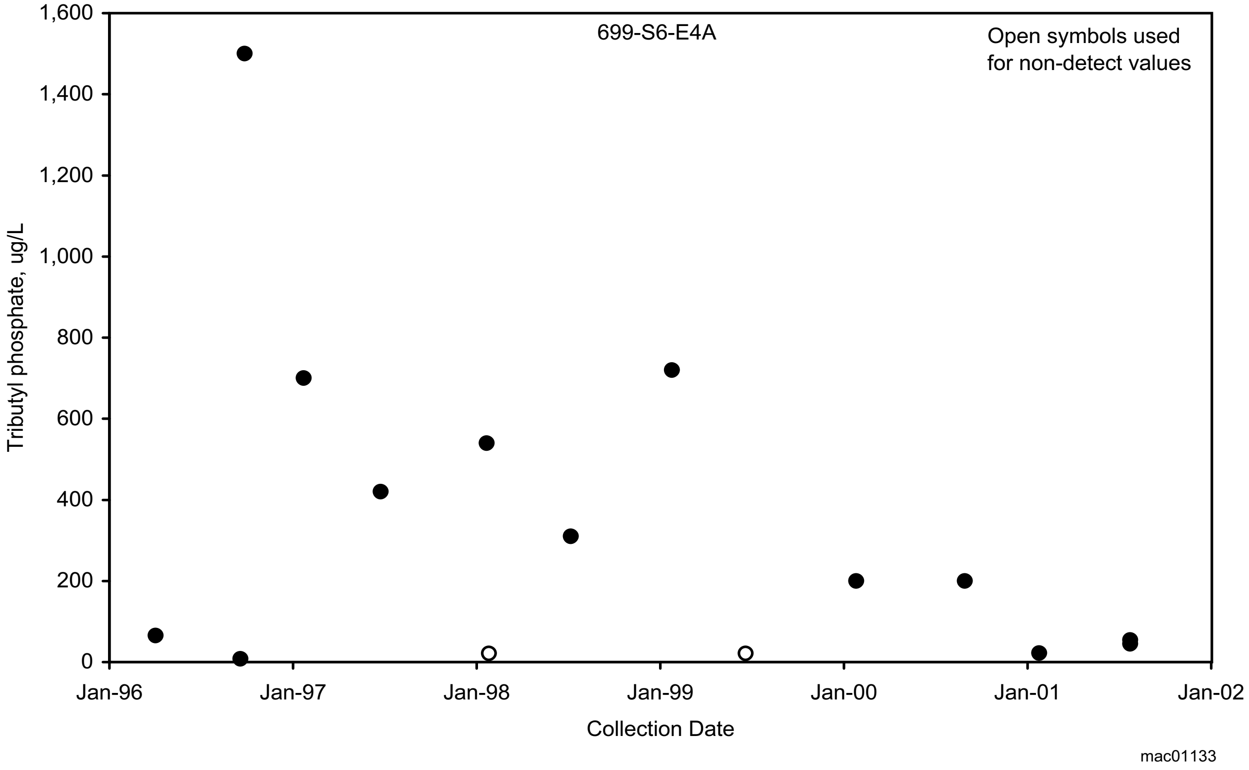
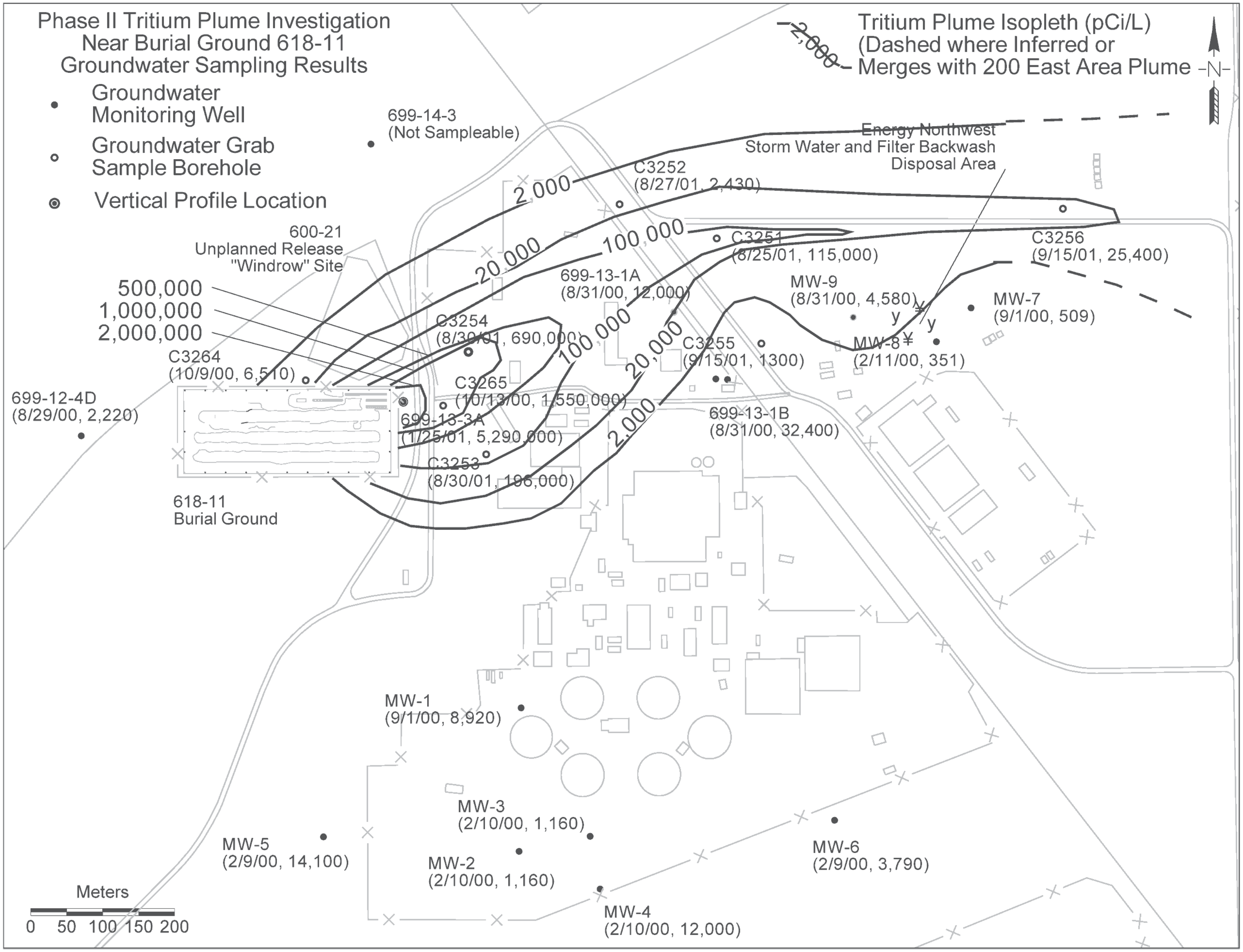


Figure 2.12-12. Tributyl Phosphate Concentrations Near the 618-10 Burial Ground



erc_618-11plume

Figure 2.12-13. Tritium Concentrations Near the 618-11 Burial Ground

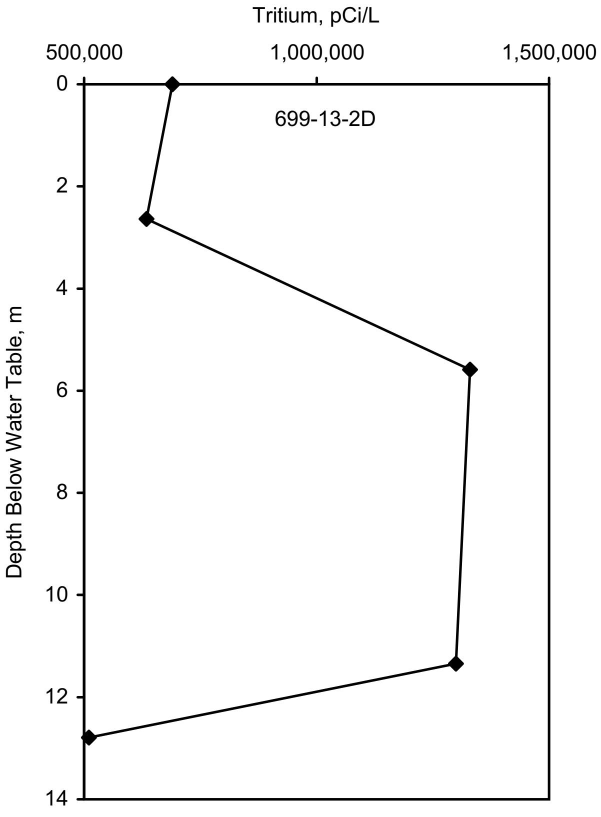


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Figure 2.12-14. Profile of Tritium Concentrations Northeast of 618-11 Burial Ground. The silt layer is immediately below the lowest tritium sample.

2.13 Richland North Area

D. R. Newcomer

The Richland North Area is located in the southern part of the Hanford Site (see Figure 2.12-2). For this report, the Richland North Area is defined as the former 1100 and 3000 Areas, that part of the 600 Area adjacent to the 300 Area, and parts of nearby Richland between the Yakima and Columbia Rivers. Ownership of the 1100 Area was transferred from the U.S. Department of Energy (DOE) to the Port of Benton in 1998. Ownership of the 3000 Area was transferred from DOE to the Port of Benton in 1996.

The area near the city of Richland's North Well Field is monitored closely to detect the possible impact of the tritium plume from the 200 Areas. Monitoring in fiscal year 2001 indicated that the tritium plume in the 300 Area receded to the northeast. Although tritium levels are far below the drinking water standard, frequent monitoring will continue.

2.13.1 Groundwater Flow

Figure 2.13-1 shows the March and April 2001 water-table elevations and illustrates water-level elevation trends for selected areas of the Richland North Area. The water-table elevation decreased ~0.1 to 0.3 meter across most of the Richland North Area between fiscal years 2000 and 2001 in response to a lowered Columbia River stage. Groundwater in the Richland North Area generally flows eastward from the Yakima River and discharges to the Columbia River (see Plate 1). In the northern part of the Richland North Area, groundwater flows northeast and converges with groundwater entering the 300 Area before discharging to the Columbia River. In the southern part of the Richland North Area, groundwater flow from the west is diverted to the northeast and southeast around a recharge mound before discharging to the Columbia River.

01110091-12cn

Aerial view of city of Richland's North Well Field, November 2001.

The Yakima River has a regional effect on groundwater flow and is the primary source of groundwater recharge in the Richland North Area. A higher elevation in Yakima River stage than the water table implies that Yakima River water infiltrates and recharges the unconfined aquifer. Leakage from canals and ditches originating from the Yakima River during the summer months is also a source of groundwater recharge.

Monitoring Objectives in Richland North Area

Groundwater monitoring is conducted in the Richland North Area:

- triennially to annually to describe the nature and extent of contamination
- annually to detect the impact of contamination from off the Hanford Site
- annually or more frequently to ensure the safety of the city of Richland's North Well Field.

The city of Richland's North Well Field, in the south-central portion of the Richland North Area, is the primary local influence on changes in groundwater elevation in this area. The groundwater mound in this area continued to be maintained with at least a 2:1 ratio of recharge to discharge at the well field during fiscal year 2001. Groundwater levels in much of the area near the well field decreased ~0.2 to 0.3 meter between April 2000 and March/April 2001.

Irrigation of agricultural fields in the area between the Yakima River and the former 1100 Area has affected groundwater levels in the Richland North Area. Agricultural irrigation supplied primarily by the Columbia River recharges the unconfined aquifer between the Yakima and Columbia Rivers. This seasonal effect is illustrated from the hydrograph of well 699-S43-E7A in the southern part of the Richland North Area (see Figure 2.13-1) and by water-level fluctuations in well SPC-GM-2 upgradient of Framatome ANP Richland, Inc. in the northern part of the Richland North Area (Figure 2.13-2). Water levels increased in wells west of the Richland North Area near the southern boundary of the Hanford Site between ~1990 and 2000. However, these levels were relatively constant during fiscal year 2001 (Figure 2.13-3).

2.13.2 Tritium

The southern portion of the 200 Area tritium plume extends into the 300 Area and continues to be closely monitored because of its potential impact to the city of Richland's North Well Field (Figure 2.13-4). The tritium distribution in Figure 2.13-4 shows that concentrations decrease from >10,000 pCi/L to <100 pCi/L in a southwesterly direction across the 300 Area. The tritium contours shifted slightly to the northeast, indicating that the tritium plume in the 300 Area decreased in size between fiscal years 2000 and 2001. The shift in the contours is a result of decreasing tritium concentrations in several 300 Area wells. The decreasing tritium concentrations in 2001 are illustrated in Figure 2.13-5. Tritium levels continued to show stable levels just north of the 300 Area (well 699-S19-E13 in Figure 2.13-5).

The 200 Areas tritium plume has not reached the city of Richland's North Well Field or other offsite areas south of the Hanford Site.

South of the 300 Area, tritium levels were slightly elevated above background in wells near the city of Richland's North Well Field and in wells north of the well field during fiscal year 2001 (see Figure 2.13-4). The background geometric mean tritium concentration in the upper part of the unconfined aquifer was determined to be 63.9 pCi/L (DOE/RL-96-61). However, these levels are far below the 20,000 pCi/L drinking water standard. Trends in these tritium concentrations have consistently shown fluctuating levels in the last few years, as shown in Figure 2.13-6. A tritium sampling investigation in 1999 and 2000 indicated there is no statistical difference between most of the tritium results detected in groundwater in this area and tritium in Columbia River water. Columbia River water, which shows slightly elevated tritium levels near the shoreline, is piped to the recharge pond system. Thus, a likely source of the elevated tritium levels is recharge of Columbia River water discharged to the ponds. Slightly elevated tritium levels near Framatome ANP Richland, Inc. and Allied Technology Group appear to be outliers compared to recent trends observed in this area.

Tritium is not migrating in groundwater from the 200 Areas tritium plume to the well field. Several factors limit the migration of the tritium plume into the Richland North Area.

- Groundwater generally flows from west to east between the Yakima River and the Columbia River.
- Artificial recharge from agricultural irrigation west of the Richland North Area contributes to the eastward flow.
- Flow is directed outward from the groundwater mound at the city of Richland's North Well Field recharge ponds.

These factors produce converging flow lines in the 300 Area and discharge to the Columbia River (see Figure 2.13-1 and Plate 1). Thus, there is no indication that the tritium plume is migrating southward and affecting the well field.

Tritium in the top of the unconfined aquifer potentially can migrate to deep parts of the unconfined aquifer or to underlying confined Ringold aquifers. To determine if tritium has reached these depths, tritium is monitored in deep parts of the unconfined aquifer and in underlying confined Ringold aquifers in the Richland North and 300 Areas. This monitoring information is important to evaluate the movement of the unconfined aquifer tritium plume in the 300 Area because of its proximity to offsite areas.

Tritium is monitored in deep parts of the unconfined aquifer at a frequency of one to three years in the Richland North and 300 Areas. The distribution of tritium in these areas is shown in Figure 2.13-7. The wells that are completed in these deeper portions monitor near the middle or bottom of the unconfined aquifer. The bottom of the unconfined aquifer lies above either a clayey silt aquitard or the lower Ringold mud. The only known location where tritium is elevated above background levels in the deep portion of the unconfined aquifer is well 399-1-16B in the northern part of the 300 Area. This well is located in the same area as the tritium plume that resides in the top of the unconfined aquifer. Tritium trends in this well have shown a steady increase in recent years (Figure 2.13-8).

Tritium also is monitored every three years in confined Ringold aquifers below the clayey silt aquitard and below the lower Ringold mud unit. The distribution of tritium in these aquifers in the Richland North and 300 Areas is shown in Figure 2.13-9. The data indicate that tritium levels in the confined aquifers above the basalt are indicative of background concentrations. These concentrations suggest that tritium from the tritium plume in the top of the unconfined aquifer has not reached the confined aquifers in the Richland North and 300 Areas.

2.13.3 Nitrate

Nitrate contamination migrates to the Richland North Area from industrial and agricultural activities off the Hanford Site. Concentrations generally continued to increase in fiscal year 2001.

The nitrate plume in the Richland North Area continued to expand in fiscal year 2001 and migrated east toward the Columbia River. As a result, nitrate concentrations at levels greater than the 45 mg/L maximum contaminant level began to discharge to the Columbia River during fiscal year 2001. This is illustrated by the 45 mg/L contours, which intersect the Columbia River just south of the 300 Area (see Figure 2.12-9).

The nitrate distribution in groundwater is shown in Figure 2.12-9. Nitrate contamination that is found in the Richland North Area is likely the result of industrial and agricultural uses off the Hanford Site. Industrial uses occur at Framatome ANP Richland, Inc. and Lamb-Weston, Inc. Agricultural uses include application of fertilizers onto irrigation circles in the southwestern part of the Richland North Area (see Figure 2.12-2).

Concentrations above the 45 mg/L maximum contaminant level are found over much of the Richland North Area and continued to increase in a number of wells. Some of the highest nitrate levels occur both upgradient and downgradient of Framatome ANP Richland, Inc. Nitrate data for Framatome ANP Richland, Inc. wells are reported in EMF-1865, Addenda 25 and 26. The highest nitrate concentrations were 232 mg/L southwest (upgradient) of Framatome ANP Richland, Inc. and north of Framatome's process lagoons. This nitrate is likely the result of agricultural activities to the west and southwest. Nitrate concentrations continued to be elevated in wells near DOE's inactive Horn Rapids Landfill in fiscal year 2001. The highest average nitrate concentration in this area was 145 mg/L immediately downgradient of the landfill. The shape of the plume (as defined by the 100 mg/L contour) near Framatome ANP Richland, Inc. and DOE's inactive Horn Rapids Landfill indicates that nitrate in these areas continues to migrate in a northeastern direction toward the 300 Area.

Nitrate levels continued to be elevated in an area northwest of the North Richland well field and recharge ponds during fiscal year 2001. These elevated levels are illustrated by the trend plots in Figure 2.13-10. The most likely source of these elevated nitrate levels is the agricultural circles to the west. The shape of the plume indicates that the eastward migration of nitrate is being diverted around the groundwater mound that is in the vicinity of the recharge ponds (see Plate 1). Nitrate levels in wells at the well field continued to be lower than ambient groundwater, a result of recharge from infiltration of river water at the recharge ponds.

2.13.4 Chlorinated Hydrocarbons

Trichloroethene contamination in Richland North Area has sources off the Hanford Site. Concentrations are naturally declining.

Trichloroethene contamination occurs in the Richland North Area beneath DOE's inactive Horn Rapids Landfill and offsite in Framatome ANP Richland, Inc. wells (see Figure 2.12-5). The distribution of trichloroethene shows that the plume has an elongated configuration similar to the 100 mg/L nitrate contour discussed in Section 2.13.3. This configuration indicates a northeast flow direction around the city of Richland's North Well Field recharge ponds and toward the 300 Area. However, trichloroethene concentrations have decreased in essentially all the plume areas near DOE's Horn Rapids Landfill. Trichloroethene concentrations decreased by more than an order of magnitude in this area since monitoring began in 1990 (Figure 2.13-11). In fiscal year 2001, the average trichloroethene concentrations were all <5 µg/L, ranging from less than detection to 4.8 µg/L downgradient of the landfill. The decreased concentrations in the majority of wells downgradient of DOE's Horn Rapids Landfill suggest that some elements of natural attenuation (e.g., volatilization, passive pumping) may have reduced the plume mass. For a discussion of trichloroethene in the 300 Area, see Section 2.12.4.

Average trichloroethene concentrations continued to be <5 µg/L in all Framatome ANP Richland, Inc. wells during fiscal year 2001 (EMF-1865, Addenda 25 and 26). The maximum average trichloroethene concentration was 4.8 µg/L. The past use of solvent to install and maintain process lagoon liners at Framatome ANP Richland, Inc. is the only potential source of trichloroethene identified in the Richland North Area (DOE/RL-92-67).

The city of Richland monitors groundwater quarterly for chemical constituents at their Horn Rapids Sanitary Landfill (formerly Richland Landfill). The landfill is located west of the Richland North Area adjacent to the southern boundary of the Hanford Site (see Plate 1). Chlorinated hydrocarbons were detected in city landfill monitoring wells between ~1 and 1.5 kilometers south of the Hanford Site boundary at levels above their respective maximum contaminant levels during fiscal year 2001 (City of Richland 2001a, 2001b, 2001c, 2001d). The highest average concentrations, which increased during fiscal year 2001, were 57 µg/L

1,1-dichloroethane, 75 μg/L cis-1,2-dichloroethene, 69 μg/L tetrachloroethene, and 26 μg/L trichloroethene. During fiscal year 2001, these constituents were found to be below their respective minimum detection limits at an onsite well (699-S31-1) just northeast of the city's sanitary landfill.

2.13.5 Gross Alpha and Uranium

Elevated levels of gross alpha and uranium occur downgradient of Framatome ANP Richland, Inc. near DOE's inactive Horn Rapids Landfill. The highest gross alpha level was an average of 87 pCi/L in well SPC-GM-8 during fiscal year 2001. This maximum level is an increase from 65 pCi/L in fiscal year 2000. Most of the downgradient Framatome ANP Richland, Inc. wells showed average gross alpha levels that were above the 15 pCi/L maximum contaminant level, which excludes uranium. However, it is probable that the gross alpha levels are largely attributed to uranium because Framatome ANP Richland, Inc., which manufactures nuclear fuel pellets and assemblies for commercial nuclear power plants and processed uranium hexafluoride (UF_6) in the past. If gross alpha is attributed to uranium with natural isotopic abundances, then 87 pCi/L gross alpha is equivalent to ~126 μg/L uranium, which is above the 30 μg/L maximum contaminant level for uranium. Framatome ANP Richland, Inc. is not required to analyze samples collected from their wells for uranium.

Relatively low levels of ammonia, fluoride, and uranium detected near DOE's inactive Horn Rapids Landfill are from industrial sources off the Hanford Site.

The distribution of uranium near DOE's inactive Horn Rapids Landfill is shown in Figure 2.12-3. The map shows a small plume of uranium with levels less than the 30 μg/L maximum contaminant level near the landfill. However, uranium concentrations continued to increase in wells downgradient of the landfill. Uranium concentrations ranged up to 15.7 μg/L, with the highest concentration immediately downgradient of DOE's Horn Rapids Landfill in well 699-S31-E10B. An example of these increases is shown in the trend plot in Figure 2.13-12. At this time, the landfill is not considered a source of the uranium contamination in groundwater because no known uranium sources exist in the landfill. The shape of the uranium contours suggests a uranium source off the Hanford Site.

2.13.6 Other Constituents

Ammonia, fluoride, and gross beta are found at low levels in wells near Framatome ANP Richland, Inc.

Ammonia – Concentrations of ammonia in the Framatome ANP Richland, Inc. wells generally remained steady in fiscal year 2001 (EMF-1865, Addenda 25 and 26). The highest average concentration detected was 16.9 mg/L (as NH_3) in well SPC-GM-10. Ammonia is typically absorbed by plants and soil microorganisms or is taken up as an exchangeable ion on soil particles (Hausenbuiller 1972). However, ammonia is usually less stable than nitrate in a biological system like the soil medium and is rapidly converted to nitrate. Ammonia was detected in six downgradient Framatome ANP Richland, Inc. wells. The fact that ammonia is found in the groundwater suggests that relatively high concentrations reached the soil column.

Fluoride – Two wells downgradient of Framatome ANP Richland, Inc. continued to show fluoride concentrations above the 4 mg/L maximum contaminant level in fiscal year 2001 (EMF-1865, Addenda 25 and 26). The highest average concentration was 4.8 mg/L in well SPC-GM-8. Fluoride contamination is most likely the result of past processing of uranium hexafluoride (UF_6) at the Framatome facility. Average fluoride concentrations in onsite wells for this area continued to be <1 mg/L.

Gross Beta – Gross beta continued to be detected in wells downgradient of Framatome ANP Richland, Inc. during fiscal year 2001 (EMF-1865, Addenda 25 and 26). The highest average gross beta measurement in fiscal year 2001 was 46 pCi/L in well SPC-GM-8. Low levels of technetium-99, detected near DOE's inactive Horn Rapids Landfill, may be related to the gross beta measurements.

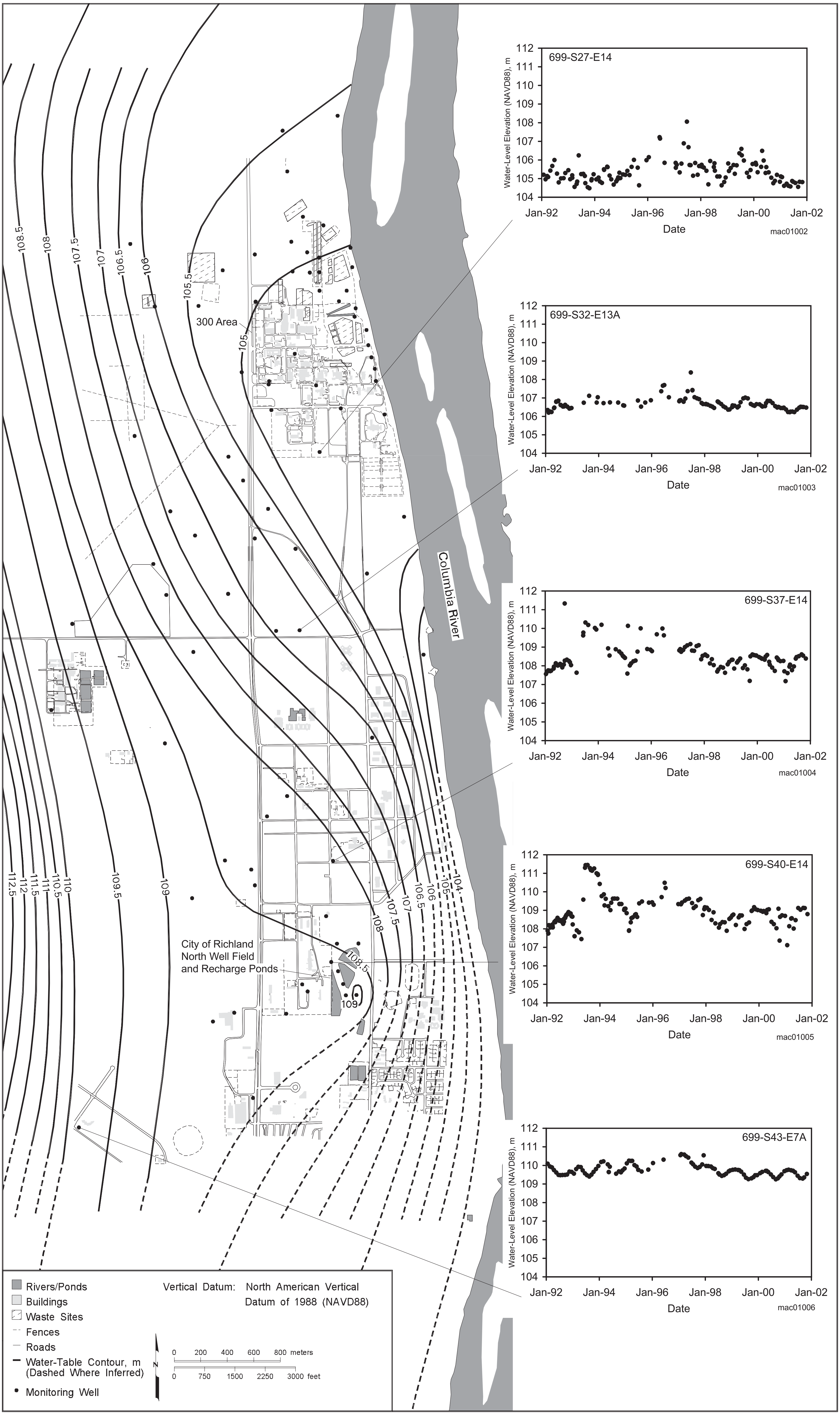

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Figure 2.13-1. Water-Table Map of the Richland North and 300 Areas, March and April 2001

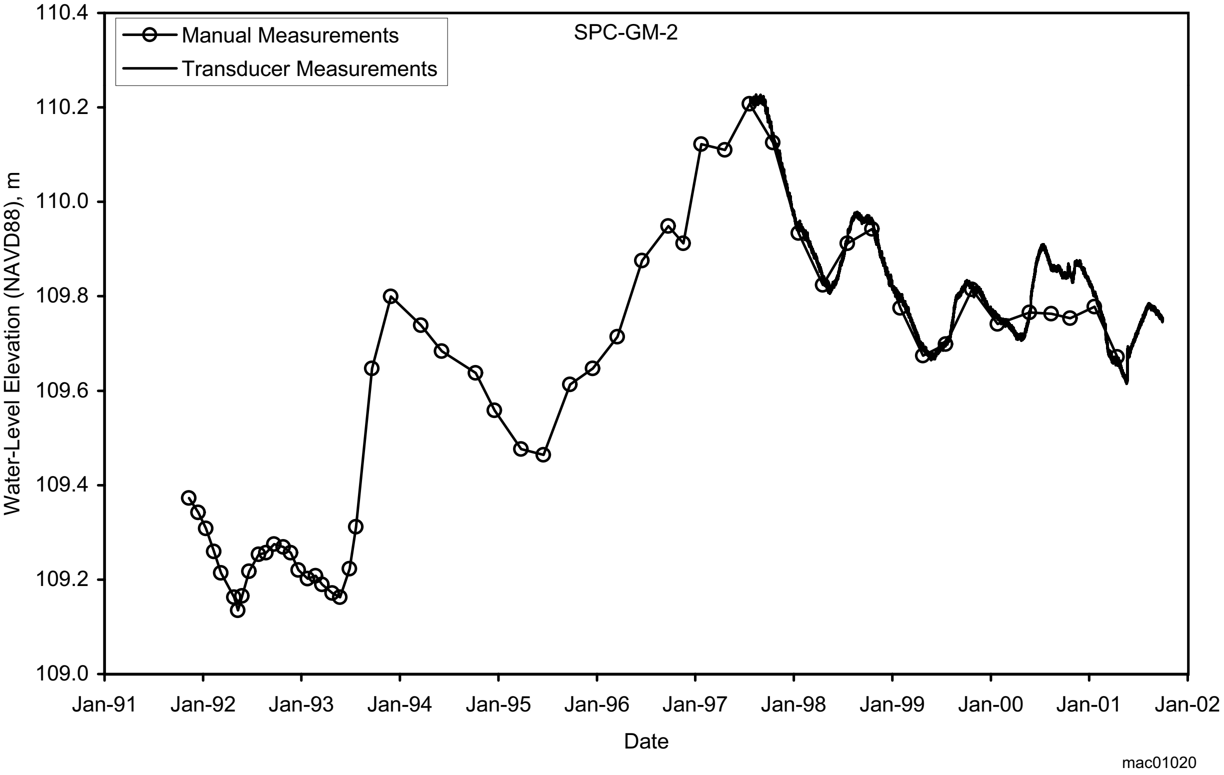

Figure 2.13-2. Water Levels at Framatome ANP Richland, Inc. (manual measurements taken from Framatome quarterly reports, e.g., EMF-1865)

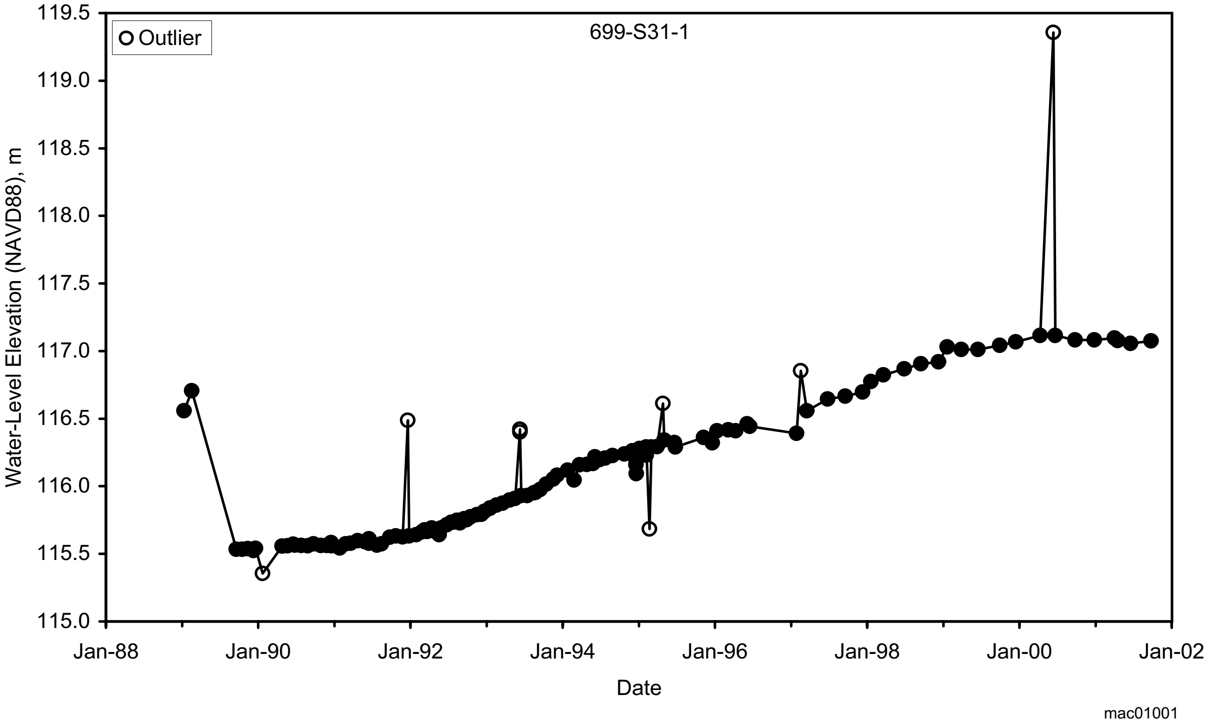

Figure 2.13-3. Water Levels West of Richland North Area

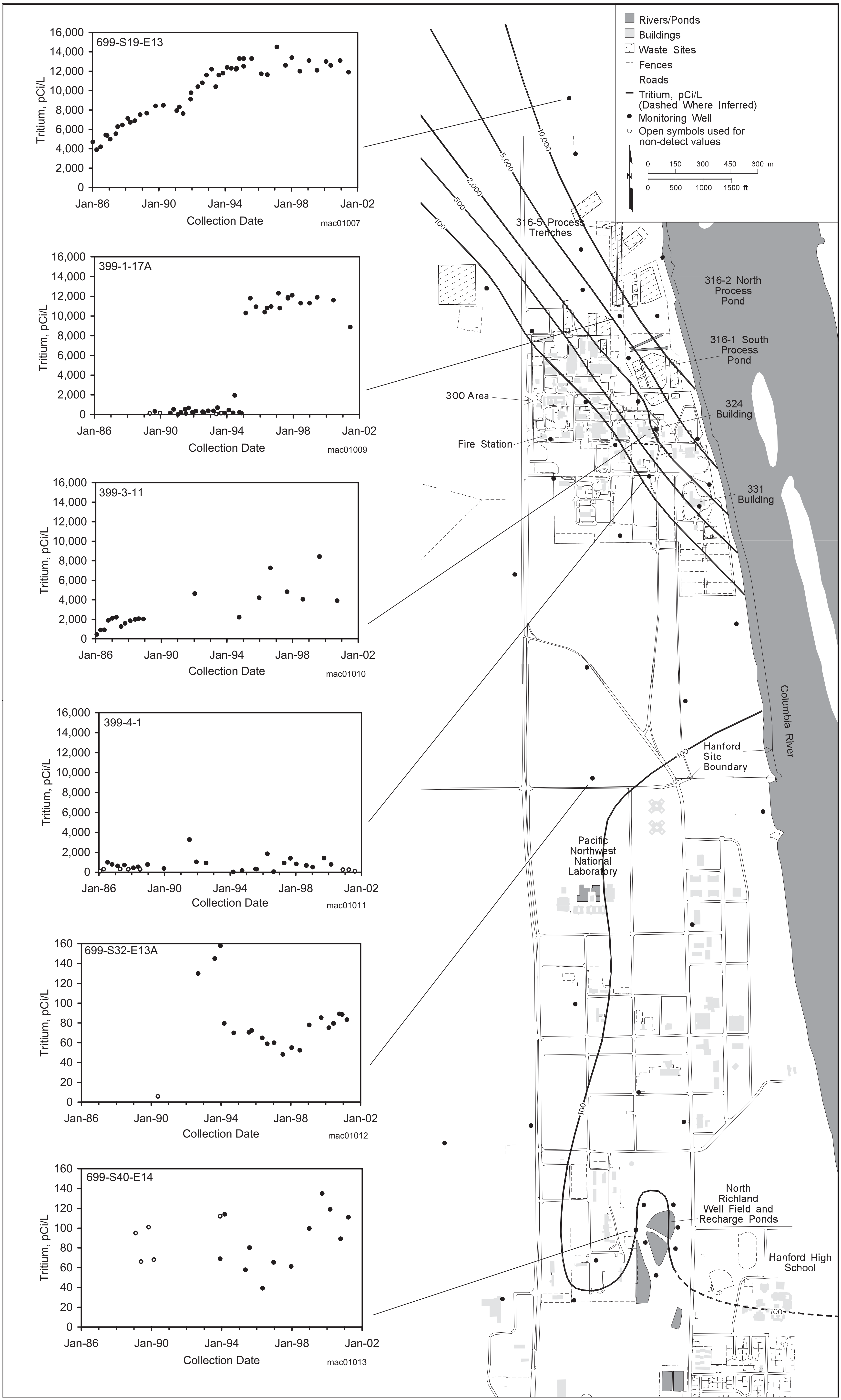

Figure 2.13-4. Tritium Concentrations in Groundwater at 300 and Richland North Areas, Top of Unconfined Aquifer

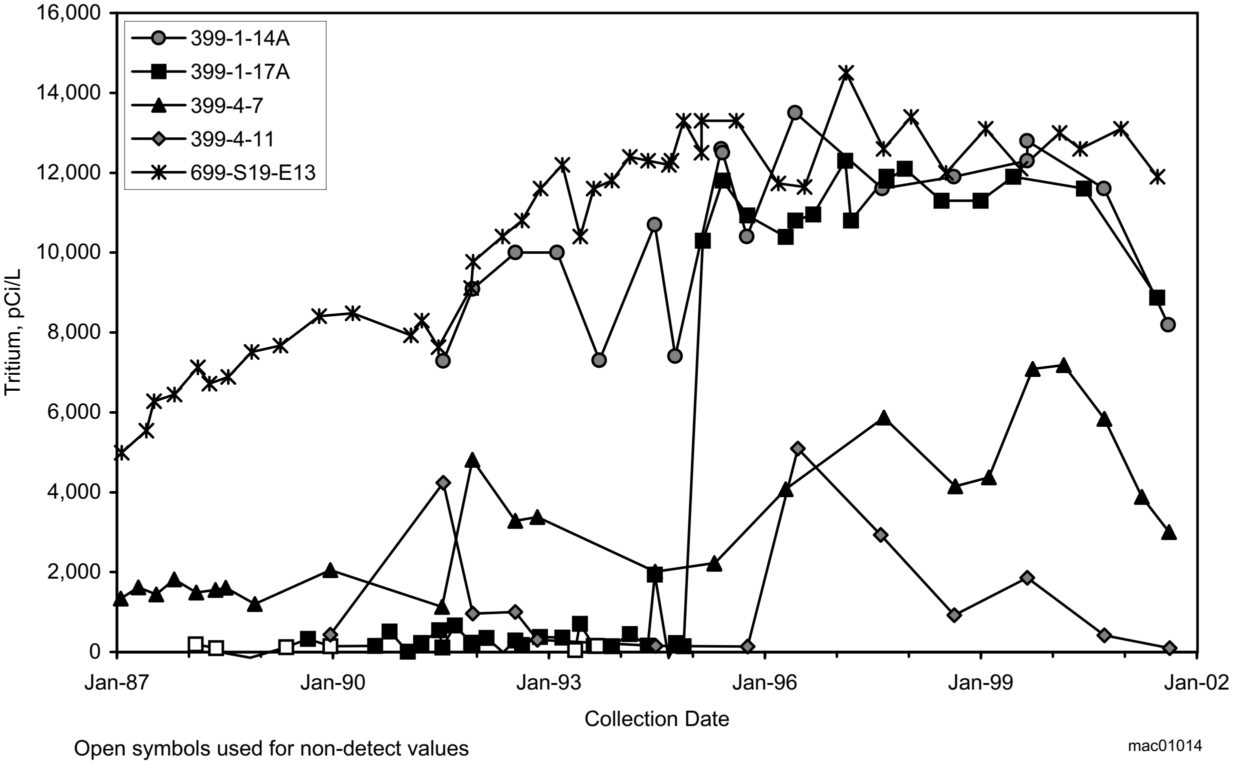

Figure 2.13-5. Tritium Concentrations in Wells Monitoring the 300 Area

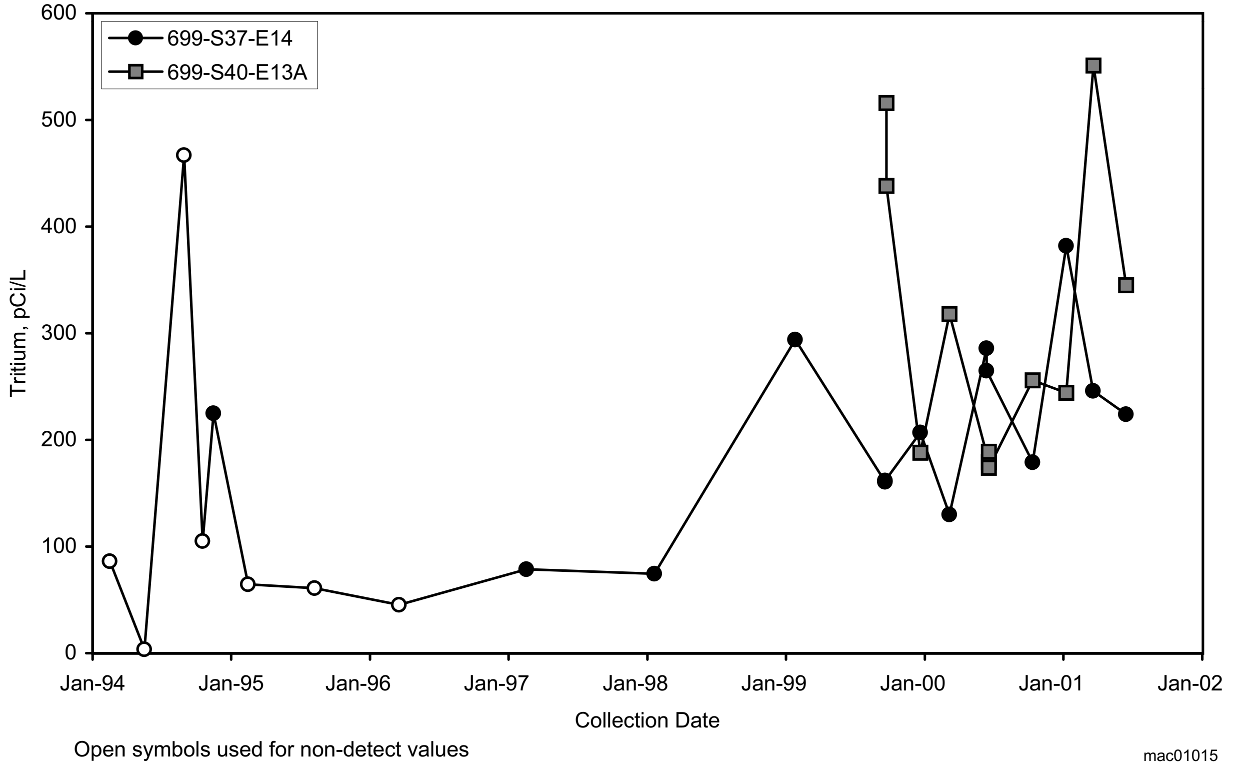

Figure 2.13-6. Tritium Concentrations in Wells Monitoring the Richland North Area

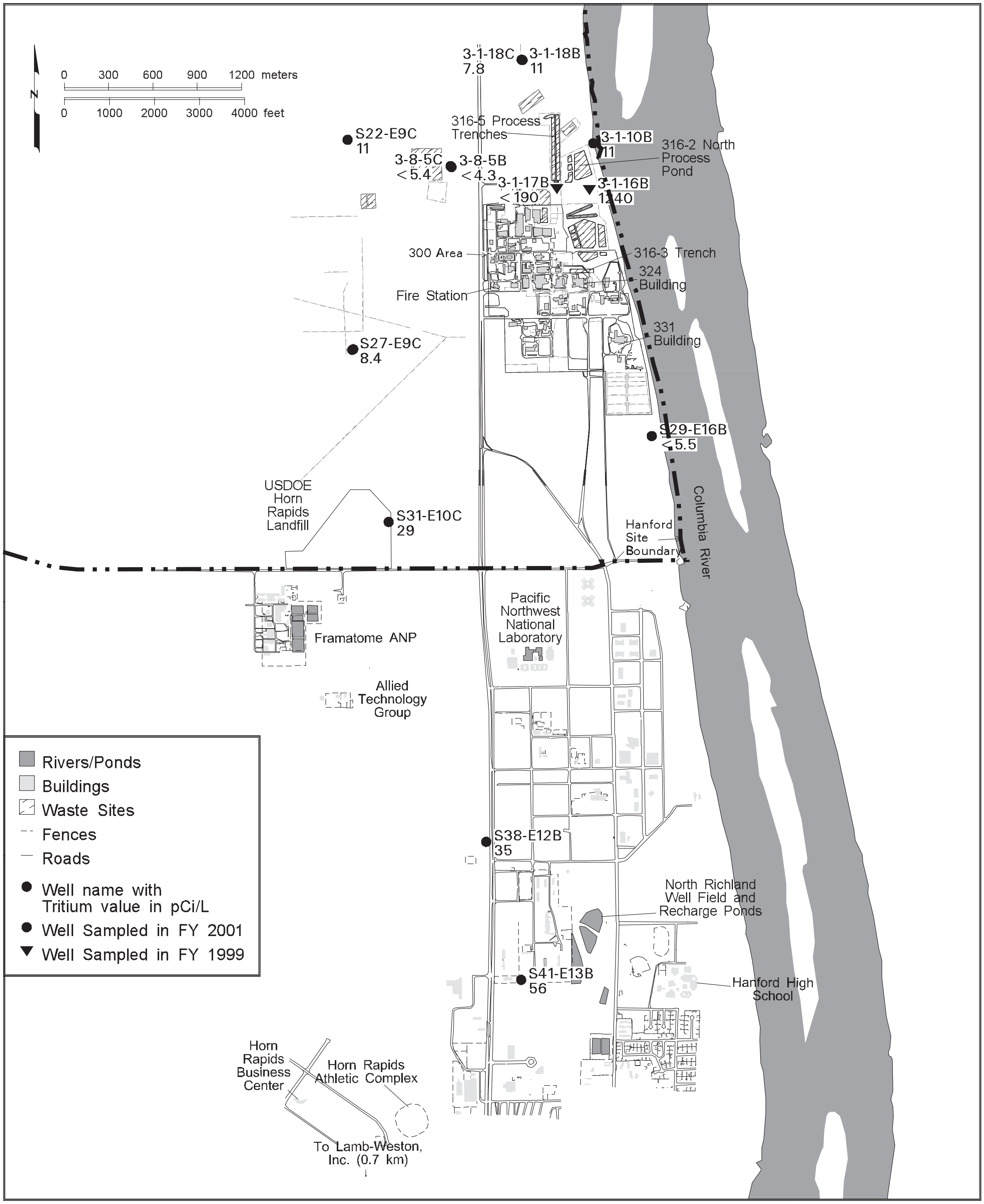

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Figure 2.13-7. Tritium Distribution in the Deep Unconfined Aquifer, Fiscal Year 2001

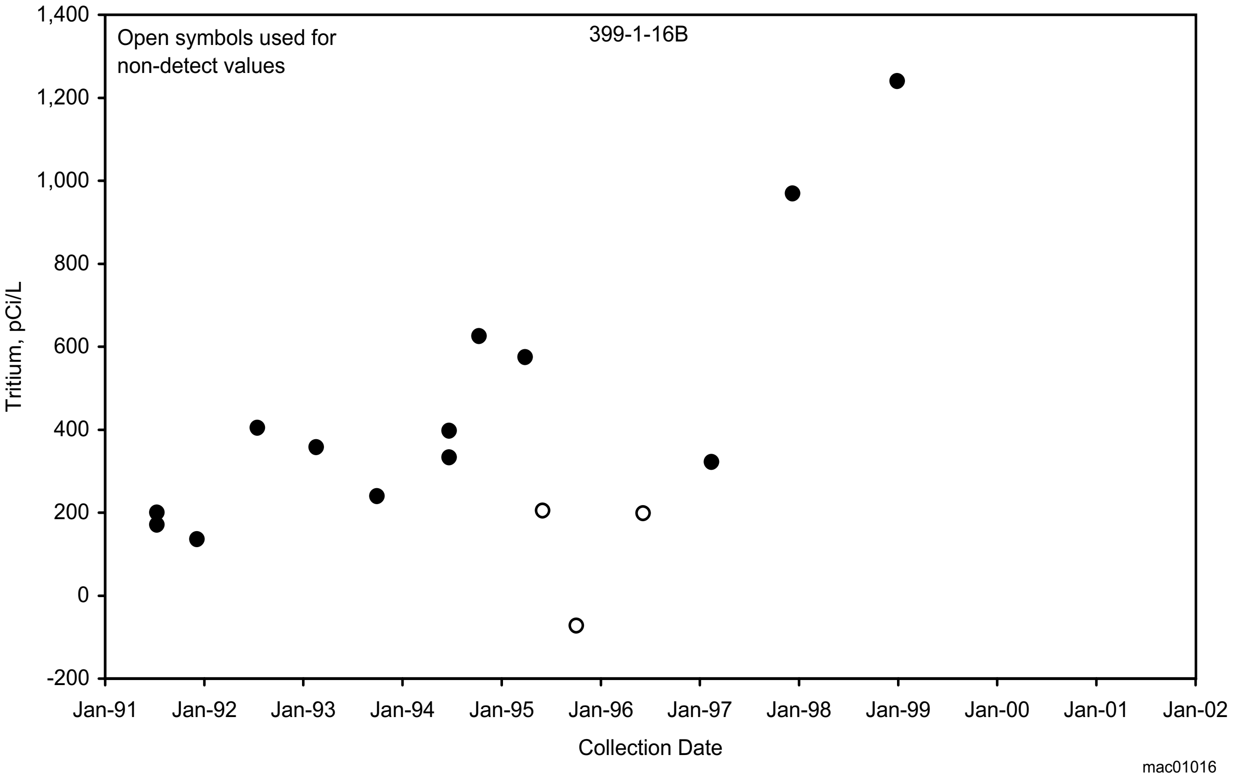

Figure 2.13-8. Tritium Concentrations in the 300 Area, Monitoring the Bottom of the Unconfined Aquifer

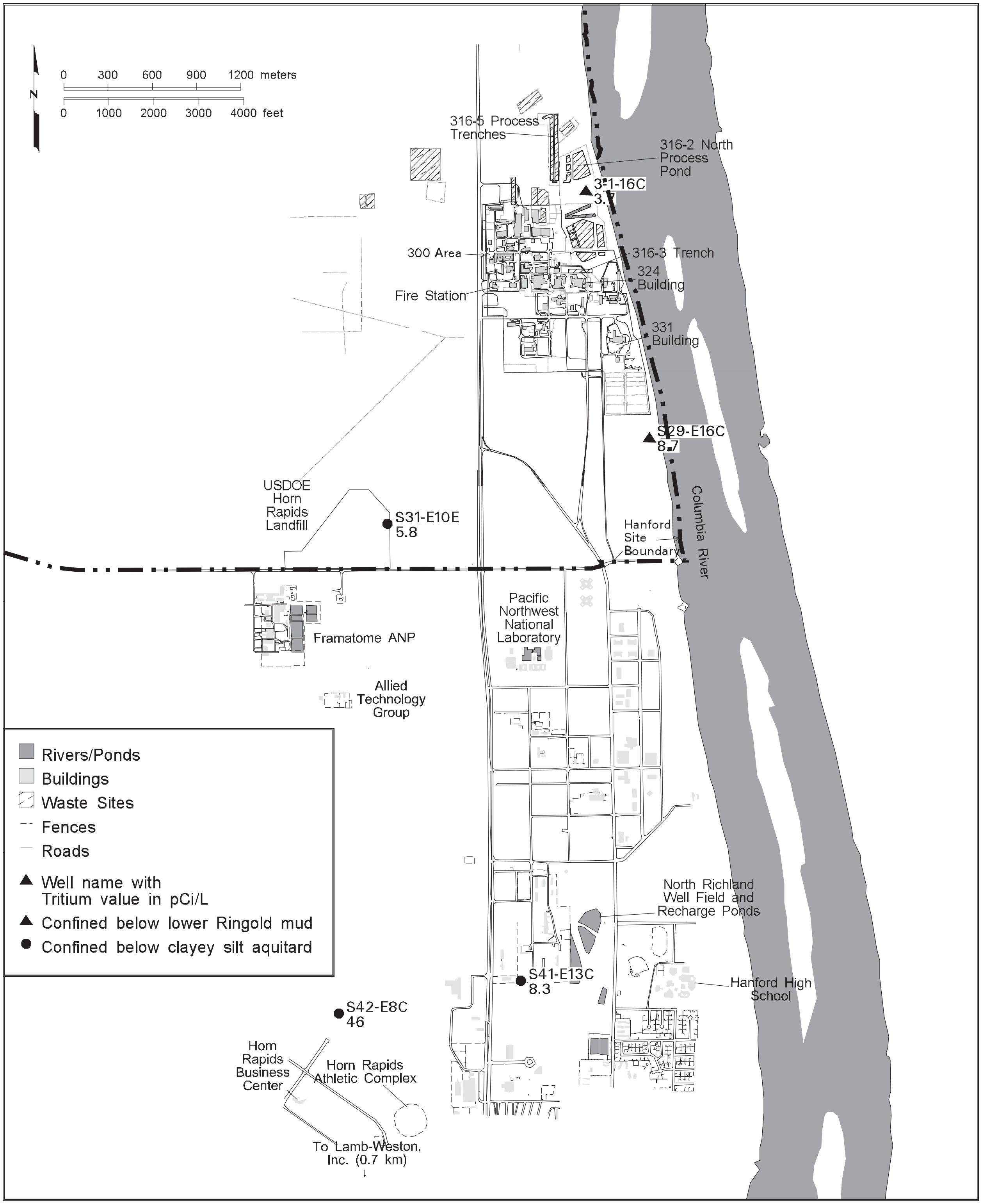

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Figure 2.13-9. Tritium Distribution in the Confined Ringold Aquifers, Fiscal Years 1999-2001

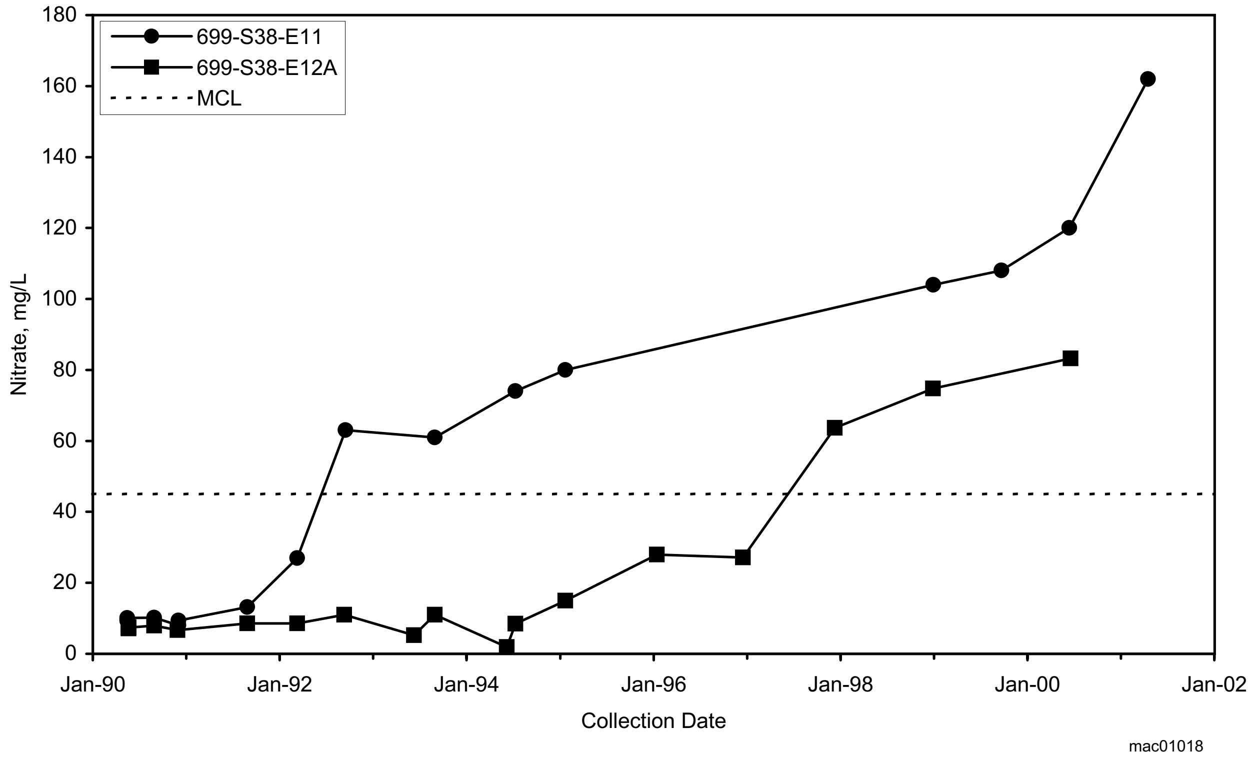

Figure 2.13-10. Nitrate Concentrations in Wells Northwest of the City of Richland's North Well Field

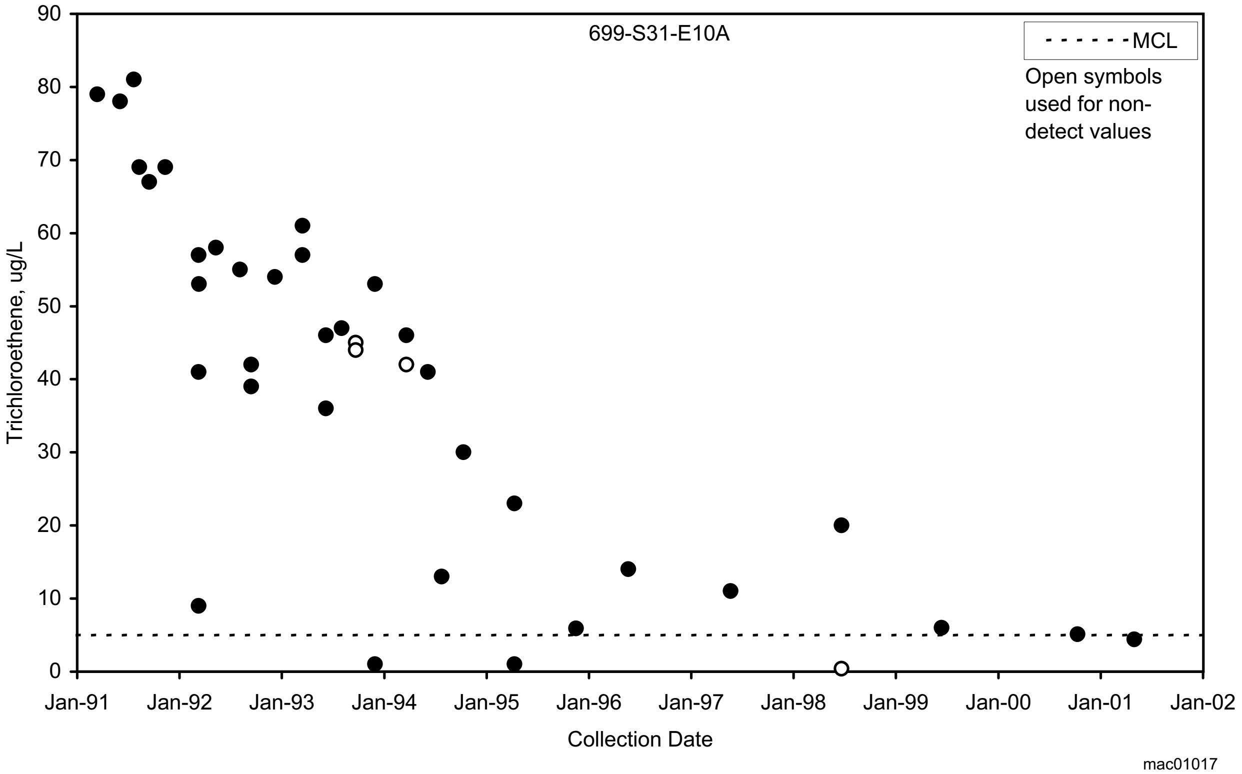

Figure 2.13-11. Trichloroethene Concentrations Near the U.S. Department of Energy's Horn Rapids Landfill

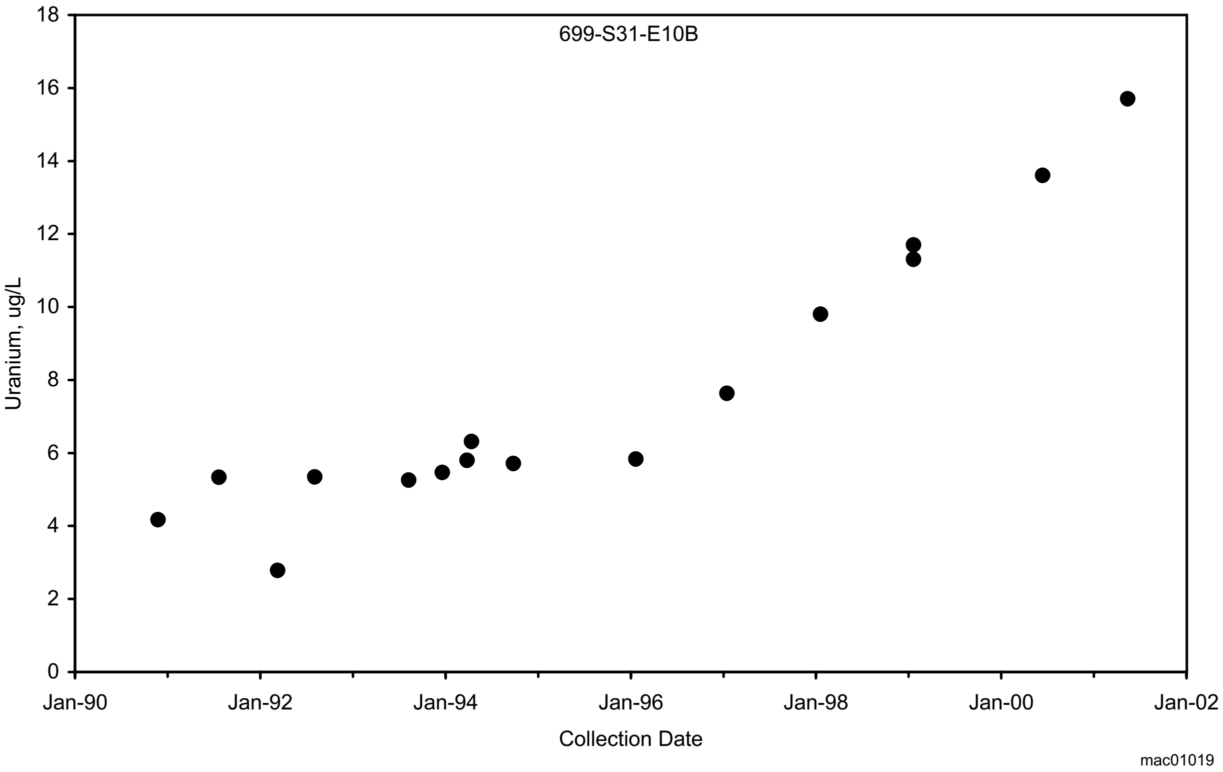

Figure 2.13-12. Uranium Concentrations Near the U.S. Department of Energy's Horn Rapids Landfill

2.14 Upper Basalt-Confined Aquifer

M. J. Hartman, J. P. McDonald, and D. R. Newcomer

Monitoring groundwater within the upper basalt-confined aquifer is important because of the potential for

- downward migration of contamination from the unconfined aquifer system
- migration of contamination off southern portions of the Hanford Site
- migration of contamination onto the Hanford Site from offsite sources.

During fiscal years 2001 and 2002, the groundwater project sampled 25 basalt-confined wells and measured water levels in ~30 wells. Seventeen of the sampled wells are located on the Hanford Site; most of those are sampled every 3 years. Eight basalt-confined wells located off the Hanford Site also were sampled in fiscal year 2001. These wells have not been sampled routinely in the past.

The upper basalt-confined aquifer is much less contaminated than the overlying unconfined aquifer, but a few wells near the 200 East Area contain detectable concentrations of Hanford-derived radionuclides.

2.14.1 Groundwater Flow

Within the upper basalt-confined aquifer system, groundwater occurs within basalt fractures and joints, interflow contacts, and sedimentary interbeds within the upper Saddle Mountains Basalt (see Section 3.1.1 of PNNL-13080). The

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In the area of Gable Mountain, shown above, erosion into the basalt has resulted in isolated communication between the unconfined aquifer and the upper basalt-confined aquifer.

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. An interflow zone occurs within the Elephant Mountain member of the upper Saddle Mountains Basalt, and also may be significant to the lateral transmission of water. This upper basalt-confined aquifer system is confined by the dense, low-permeability, interior portions of basalt flows and in some places by Ringold Formation silt and clay units overlying the basalt. Groundwater flow rates within the Rattlesnake Ridge Interbed have been estimated to be between 0.7 and 2.9 meters per year (PNL-10817). This flow rate is considerably slower than most estimates for the overlying unconfined aquifer system.

Recharge to the upper basalt-confined aquifer system is believed to occur 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 ground surface. Recharge also may occur through the Hanford/Ringold aquifer system in areas where the hydraulic gradient is downward. Recharge also may occur from deeper basalt aquifers where an upward gradient is present. The Columbia River represents a regional discharge area for this aquifer system, at least in the southern portion of the site. Discharge also occurs to the overlying Hanford/Ringold aquifer system in areas where the hydraulic gradient is upward. Discharge to overlying or underlying aquifers in the vicinity of the Gable Butte-Gable Mountain structural area may occur through erosional windows in the basalt.

Confined groundwater generally flows from west to east beneath the Hanford Site, eventually discharging to the Columbia River through the unconfined aquifer.

The groundwater project measures hydraulic heads annually in the upper basalt-confined aquifer system. Figure 2.14-1, constructed by manual contouring, presents an approximation of the March 2001 potentiometric surface for this aquifer system south of Gable Butte and Gable Mountain. The region to the north was not contoured because of insufficient well control. Measurements in the Rattlesnake Ridge Interbed (19 wells), the Levey Interbed (2 wells), and the Elephant Mountain Interflow zone (1 well) were primarily used to construct this map. Additional measurements in the upper Saddle Mountains Basalt (9 wells) were used for general contouring. The monitoring well network used for hydraulic head monitoring is presented in PNNL-13021.

South of the Umtanum Ridge-Gable Mountain area, groundwater in the upper basalt-confined aquifer system generally flows from west to east across the Hanford Site toward the Columbia River. The elevated regions to the west and southwest of the site are believed to be recharge areas for this aquifer system, and the Columbia River represents a discharge area. The Yakima River may also be a source of recharge.

In the vicinity of the 200 East Area, the potentiometric surface in Figure 2.14-1 is similar to the potentiometric surface for the Ringold Formation confined aquifer (compare with Figure 2.9-23). The basalt in this area was significantly eroded by late Pleistocene catastrophic flooding (RHO-BWI-LD-5), which facilitates aquifer intercommunication. During fiscal year 2001, a diagnostic water level-barometric response analysis was conducted at wells 699-49-57A (unconfined aquifer) and 699-49-57B (Rattlesnake Ridge interbed). The results indicate that the Rattlesnake Ridge interbed behaves as an unconfined aquifer in this area. In the vicinity of the 200 East Area and to the immediate north, the vertical hydraulic gradient between the upper basalt-confined aquifer system and the overlying Hanford/Ringold aquifer system is upward (compare the water-level elevations on Figure 2.14-1 with those on Plate 1). Therefore, it is likely the upper basalt-confined aquifer system currently discharges to the overlying Hanford/Ringold aquifer system in this region.

Water-table and potentiometric surface maps of the upper basalt-confined aquifer system (see Figure 2.14-1), the unconfined aquifer (see Figure 2.1-1 and Plate 1), and the Ringold Formation confined aquifer (see Figure 2.9-23) indicate that a downward hydraulic gradient from the Hanford/Ringold aquifer system to the upper basalt-confined aquifer occurs in the western portion of the Hanford Site, in the vicinity of the B Pond recharge mound, as well as in the regions north and east of the Columbia River. In the vicinity of B Pond, however, head decline within the Hanford/Ringold aquifer system may soon lead to a reversal of the vertical hydraulic gradient. Comparison of heads between well 699-42-40C and adjacent wells completed in the unconfined aquifer indicates that the vertical head gradient between the unconfined aquifer system and the upper basalt-confined aquifer system has diminished in recent years and is approaching zero. This is in contrast to historical conditions that indicated a pronounced downward gradient between these two aquifers, presumably due to the effects of the B Pond mound. In other areas of the Hanford Site, the hydraulic gradient is upward from the upper basalt-confined aquifer to the Hanford/Ringold aquifer system.

Water levels in the upper basalt-confined aquifer in the central and western portion of the Hanford Site declined over the period from March/April 2000 to March 2001. Water levels in the eastern portion of the site generally increased during this period. Water levels in the 200 East Area and to the immediate north and east (near B Pond) continue to show a decline; ranging from -0.02 to -0.62 meter over the 12-month period. Water levels near the 200 West Area also continue to show a decline with a range of -0.13 to -0.21 meter. These declines are in response to curtailed effluent disposal activities in the 200 Areas and are consistent with water-level declines in the overlying Hanford/Ringold aquifer system.

The maximum hydraulic head effects of the groundwater mound associated with B Pond have apparently shifted to the northeast since periodic monitoring of the upper basalt-confined aquifer system began in 1991. Figure 2.14-2 shows a trend plot of hydraulic head at well 699-42-40C (located at B Pond and formerly the approximate center of the groundwater mound) and well 699-51-36B (the current approximate center of the groundwater mound). This figure shows that water levels beneath B Pond peaked higher and earlier and are now declining more rapidly than the water level at well 699-51-36B. This more rapid decline beneath B Pond causes the apparent shift in the groundwater mound.

The hydrogeology of the Hanford/Ringold aquifer system in the vicinity of the 200 East Area was extensively investigated in PNNL-12261. This report concluded that the May Junction Fault, located east of B Pond and running north-south, controls groundwater movement from the 200 East Area by impeding the movement of groundwater toward the east. A similar effect also may occur in the upper basalt-confined aquifer system, which would explain why the apparent shift in the B Pond mound is eastward.

2.14.2 Groundwater Quality

The upper basalt-confined aquifer is affected by contamination far less than the overlying unconfined aquifer system because (a) the vertical gradient beneath most of the contaminated areas is upward and (b) low-permeability aquitards separate the two aquifer systems in most regions. Researchers have identified an area of potential communication between the two aquifers north of the 200 East Area (see Section 2.14.1), and two wells near this area contain elevated concentrations of radionuclides. Lower groundwater flow rates probably restrict migration of any contamination that reaches the upper basalt-confined aquifer.

Seventeen wells in the upper basalt-confined aquifer have been sampled in the past two fiscal years. Most of the wells are completed in the Rattlesnake Ridge interbed, and a few are completed in the Levey interbed or the Elephant

Mountain interflow zone. Figure 2.14-3 shows the location of these and other confined-aquifer wells and indicates which stratigraphic unit each well monitors.

Groundwater samples from the basalt-confined wells are sampled for general chemistry (alkalinity, anions, cations) gross alpha, gross beta, tritium, and in some cases, other radionuclides (gamma-emitters, strontium-90, technetium-99). Data for the primary constituents of interest are listed in Table 2.14-1. A full data set is included in the data files that accompany this report.

The general chemistry of confined groundwater evolves as it flows through the aquifer. Figure 2.14-4 shows that near recharge areas at Yakima Ridge and the Rattlesnake Hills, confined groundwater has a calcium-bicarbonate composition, similar to unconfined groundwater. Near the discharge area in the southeastern part of the site, confined groundwater has a sodium-bicarbonate composition. As the water flows through the rock or interbed, calcium exchanges for sodium. Sulfate tends to be reduced and is undetected in wells 399-5-2 and 699-S11-E12AP. Groundwater north of the 200 East Area is the calcium-bicarbonate type, indicating it was recharged quite recently. This area is a region of intercommunication between the two aquifer systems. These hydrochemical patterns are consistent with those presented in 1995 in PNL-10817.

Tritium contamination is not widespread in the basalt-confined aquifer (Figure 2.14-5). Only well 699-42-40C contained elevated levels of tritium (5,770 pCi/L in May 2000). Concentrations have been decreasing in this well since 1996 (Figure 2.14-6). Nearby wells completed in the Ringold formation contain tritium at levels exceeding the 20,000 pCi/L drinking water standard, with declining trends.

One basalt-confined well in the northwestern 200 East Area detects elevated concentrations of cyanide, nitrate, technetium-99, contaminants also present in the overlying unconfined aquifer. Another basalt-confined well near the former B Pond has slightly elevated tritium. Other basalt-confined wells are uncontaminated.

Many of the confined-aquifer wells near the 200 East Area are located beneath the iodine-129 plume, but no iodine-129 is detected in the confined aquifer (see Table 2.14-1).

Technetium-99 continued to exceed the 900-pCi/L drinking water standard in well 299-E33-12, located in the northwestern 200 East Area (1,120 pCi/L in June 2001). Concentrations have been declining gradually in this well since 1992 (Figure 2.14-7). Technetium-99 concentrations are high and variable in the overlying unconfined aquifer.

Well 299-E33-12 also has elevated concentrations of cyanide and nitrate, which are co-contaminants in the unconfined aquifer as well. The contamination apparently does not extend far beyond well 299-E33-12. Wells 299-E33-40, 699-49-55B, and 699-49-57B, located nearby and downgradient, all had undetected technetium-99 in their most recent samples, collected between 1995 and 2001. The vertical hydraulic gradient is believed to be upward now, so it is unlikely that more contamination will move into the confined aquifer.

Nitrate concentrations in the basalt-confined aquifer generally are lower than in the unconfined aquifer because of natural chemical conditions in deep aquifers (see Figure 2.14-5). The highest concentration of nitrate in the confined aquifer was 38 mg/L in well 299-E33-12. Wells 699-50-53B and 699-54-34 also had relatively high nitrate concentrations, perhaps reflecting their location near an area of aquifer intercommunication. Three wells in the eastern portion of the site had undetectable nitrate, affirming the chemically "mature" nature of groundwater with the longest residence times.

Samples from two basalt-confined wells located near the former Gable Mountain Pond (an area of strontium-90 contamination in the unconfined aquifer) were analyzed for strontium-90 in fiscal years 2000 or 2001. Results were below detection limits. Since strontium-90 is only moderately mobile in groundwater, it would be surprising to find significant concentrations in the confined aquifer.

2.14.3 Offsite Monitoring

The primary reason for monitoring groundwater within the upper basalt-confined aquifer is to evaluate the potential for migration of contamination off the southern portions of the Hanford Site. During fiscal year 2001, selected offsite wells completed in the upper Saddle Mountain Basalt were sampled in areas bordering the Hanford Site to the south and southeast. Most of these wells represent groundwater in the upper basalt-confined aquifer. The sampling was limited to eight wells, four in Franklin County to the east and southeast of the 300 Area and four in Benton County near Richland and West Richland (Figure 2.14-8). The purpose of the sampling effort was to evaluate any potential connection between groundwater quality on and off the Hanford Site.

Offsite groundwater quality in the upper basalt-confined aquifer, in the area south and southeast of the Hanford Site, is not affected by contaminated groundwater present on the Hanford Site.

Groundwater analyses were limited to inorganic chemical and radiological constituents. Chemical constituents included dissolved metals, anions, and pH, and radiological constituents included tritium, gross alpha, and gross beta. The inorganic chemical constituents were analyzed to provide information on basic water chemistry, including charge balance, speciation and saturation calculations, and spatial distribution of hydrochemical facies. Tritium was sampled because of its proximity to the onsite tritium plume in the unconfined aquifer. Gross alpha and gross beta were analyzed to provide an indication of radioactivity.

Constituent concentrations were near or within the range of background conditions. It was concluded that offsite groundwater quality in the upper basalt-confined aquifer, in the area south and southeast of the Hanford Site, is not affected by contaminated groundwater present on the Hanford Site. Evaluation of the inorganic and radiological data will be summarized in a report being prepared by Pacific Northwest National Laboratory.(a)

(a) Technical report in preparation: *Groundwater Chemistry and Hydrology of the Upper Saddle Mountains Basalt South and Southeast of the Hanford Site*. D. R. Newcomer, E. C. Thornton, and T. L. Liikala, Pacific Northwest National Laboratory, Richland, Washington.

Table 2.14.1. Potential Contaminants in Upper Basalt-Confined Aquifer

Well	Sample Date	Cobalt-60 (μg/L)	Cyanide (mg/L)	Gross alpha (pCi/L)	Gross beta (pCi/L)	Iodine-129 (pCi/L)	Nitrate (μg/L)	Specific Conductance (μS/cm)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Tritium (pCi/L)
199-H4-2	07/20/00	NA	NA	0.00 U	10.50	NA	80 B	239	0.00 U	NA	0.00 U
299-E26-8	05/03/00	NA	NA	NA	NA	0.09 U	3,900	309	NA	NA	20.80 G
299-E33-12	06/12/01	4.37 U	29.00	2.10	330.00	0.21 U	37,600	341	NA	1,120.00	194.00
399-5-2	06/14/01	NA	NA	0.25 U	9.84	NA	9 U	351	NA	NA	12.40
699-13-1C	02/08/00	2.19 U	NA	0.56 U	7.32	0.12 U	102	330	0.28 U	0.00 UP	110.00 U
699-13-1C	06/28/01	NA	NA	0.83 U	6.82	NA	9 U	336	NA	NA	25.20
699-22-70	05/15/00	NA	NA	NA	NA	NA	9,300	377	NA	NA	3.32 U
699-32-22B	05/15/00	NA	NA	NA	NA	0.05 U	328	366	NA	NA	7.13 J
699-42-40C	05/18/00	NA	NA	NA	NA	0.32 U	4,870	329	NA	NA	5,770.00
699-42-E9B	05/15/01	1.45 U	NA	0.87 U	9.88	0.24 U	9 U	420	NA	NA	4.61 U
699-49-57B	06/13/01	NA	NA	2.18	5.29	0.14 U	1,110	301	NA	0.00 U	21.80
699-50-53B	04/26/00	NA	1.60 U	NA	8.31	0.04 U	11,100	359	NA	0.00 UP	84.00 U
699-52-46A	06/13/01	NA	NA	3.52	8.28	NA	1,640	340	0.18 U	NA	20.60
699-54-34	06/13/01	NA	NA	0.75 U	7.05	NA	16,400 H	315	NA	NA	15.80
699-56-43	06/14/01	NA	NA	2.94	4.35	NA	4,870	321	NA	NA	8.96
699-56-53	05/01/00	1.07 U	1.60 U	NA	8.26	0.06 U	930	362	0.15 U	16.50 P	0.00 U
699-S11-E12AP	05/16/00	NA	NA	0.00 U	6.18	NA	62 B	365	NA	NA	7.98 J
699-S24-19P	07/24/01	NA	NA	NA	NA	NA	1,150	230	NA	NA	NA
Wells Located South and Southeast of the Hanford Site											
699-ORV-1	11/06/00	NA	NA	0.42 U	5.15	NA	102	245	NA	NA	42.70
09N28E04G01	11/06/00	NA	NA	0.07 U	8.87	NA	49 U	377	NA	NA	46.50
09N28E06C02	11/06/00	NA	NA	0.82 U	10.20	NA	2,570	534	NA	NA	55.60
10N27E14F03	11/06/00	NA	NA	0.90 U	7.07	NA	49 U	282	NA	NA	56.20
10N27E14F03	11/06/00	NA	NA	-0.06 U	8.07	NA	49 U	282	NA	NA	56.40
10N28E24R03	10/27/00	NA	NA	0.57 U	12.20	NA	49 U	382	NA	NA	34.60
10N29E02Q01	10/27/00	NA	NA	-0.18 U	10.70	NA	49 U	456	NA	NA	64.30
10N29E06H01	11/03/00	NA	NA	0.77 U	16.40	NA	49 U	907	NA	NA	47.00
10N29E19E01	10/27/00	NA	NA	-0.08 U	11.50	NA	49 U	384	NA	NA	56.10

B = Greater than minimum detection limit but below the analytical laboratory's required detection limit.
G = Result is valid according to further review.
H = Analyzed after recommended holding time.
J = Estimated value.
P = Potential problem; collection/analysis circumstances make value questionable.
U = Below detection limit.
NA = Not analyzed.

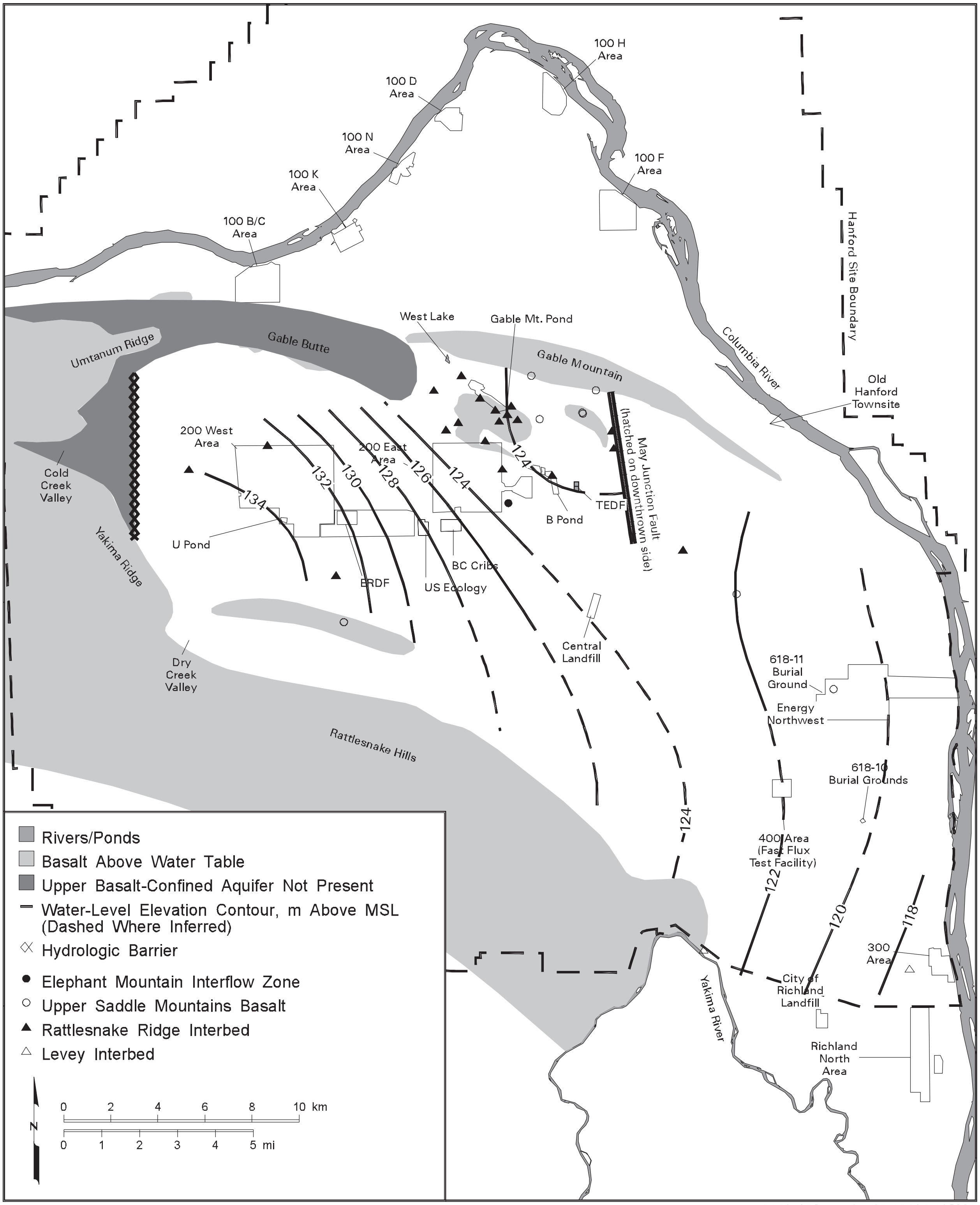

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Figure 2.14-1. Potentiometric Map of Upper Basalt-Confined Aquifer System, March 2001

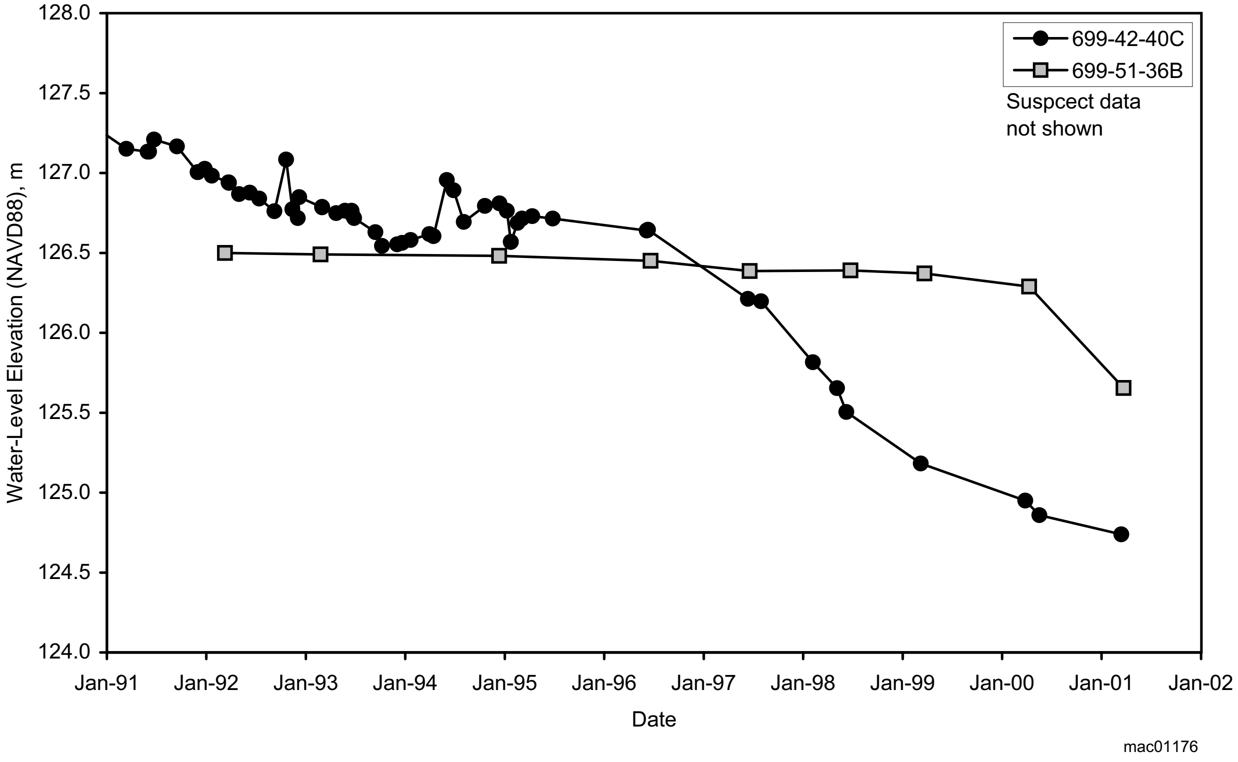

Figure 2.14-2. Water Levels in Upper Basalt-Confined Aquifer in Well 699-42-40C Near B Pond and Well 699-51-36B North of B Pond

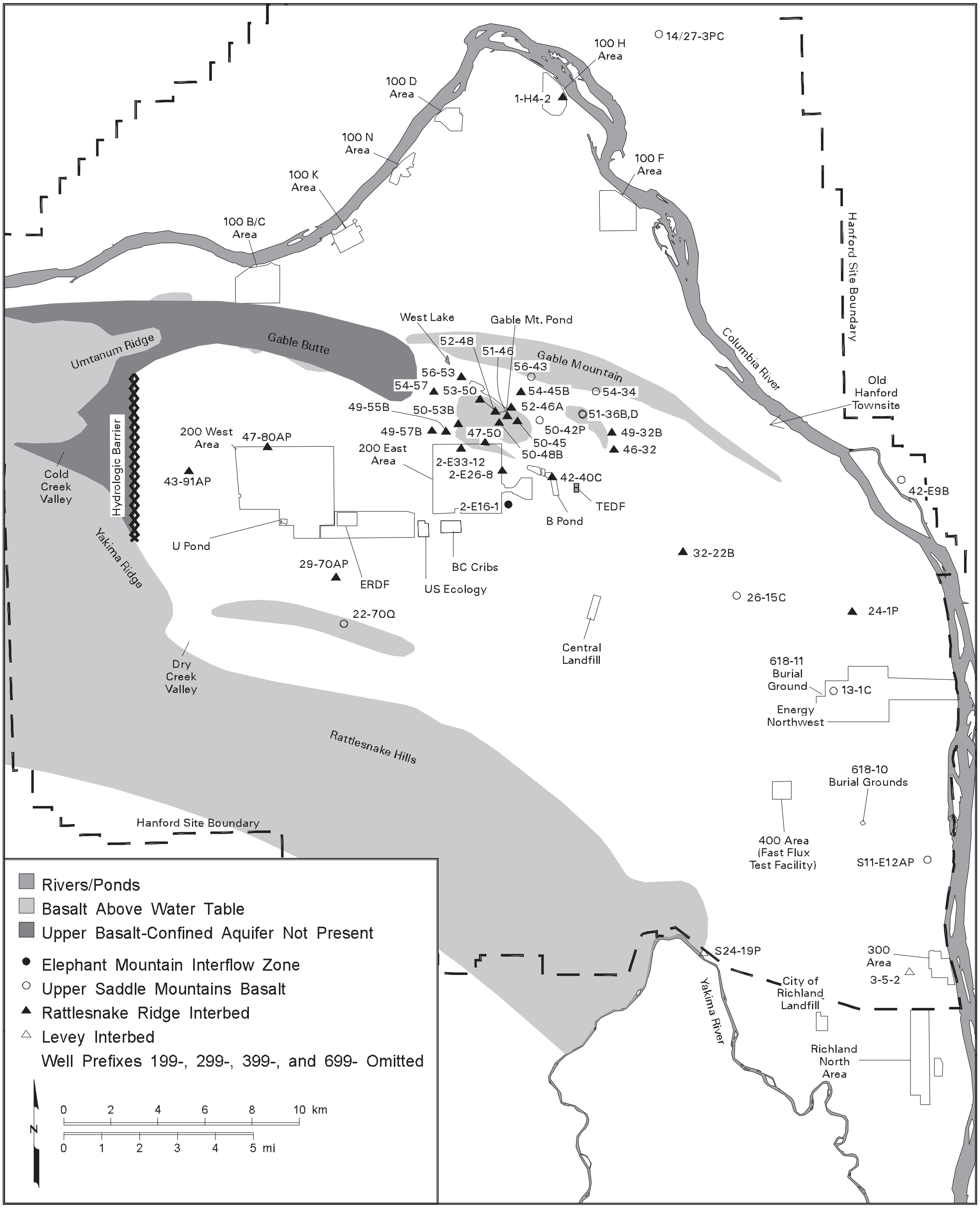

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Figure 2.14-3. Groundwater Monitoring Wells Sampled in the Upper Basalt-Confined Aquifer on the Hanford Site

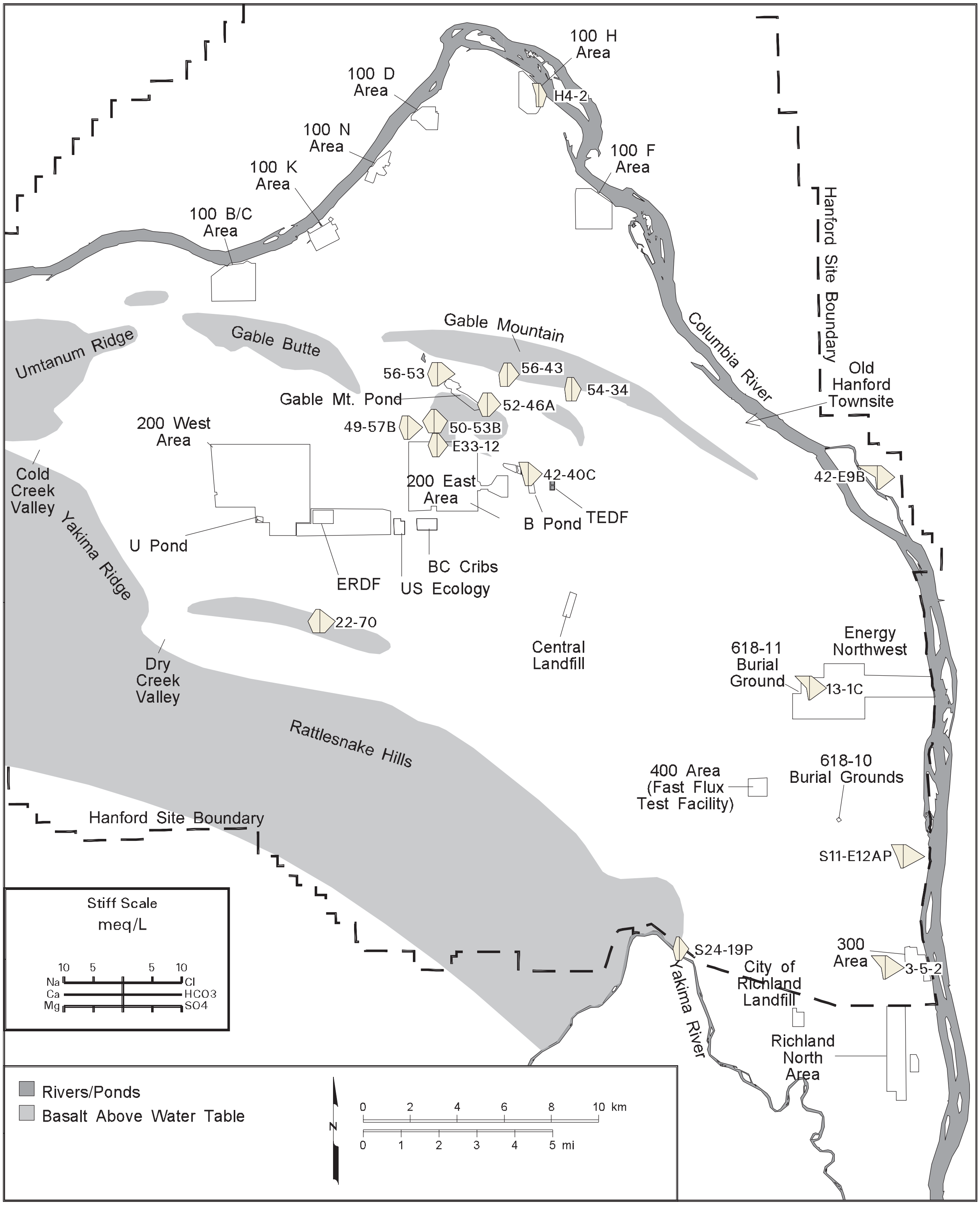

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Figure 2.14-4. Hydrochemical Stiff Diagrams for Groundwater Within the Upper Basalt-Confined Aquifer System, Fiscal Years 2000 and 2001

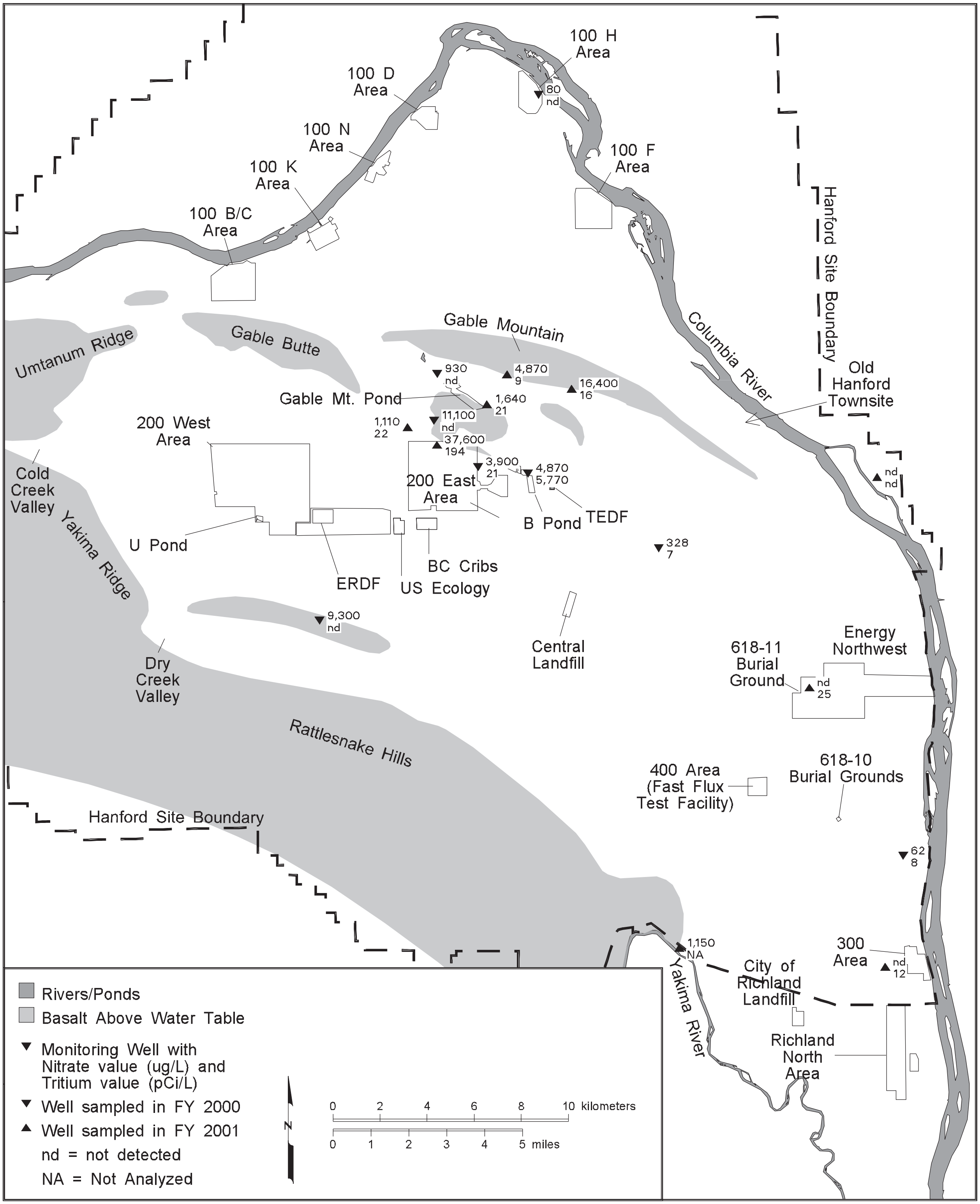

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Figure 2.14-5. Tritium and Nitrate Concentrations in Upper Basalt-Confined Aquifer, Fiscal Years 2000 and 2001

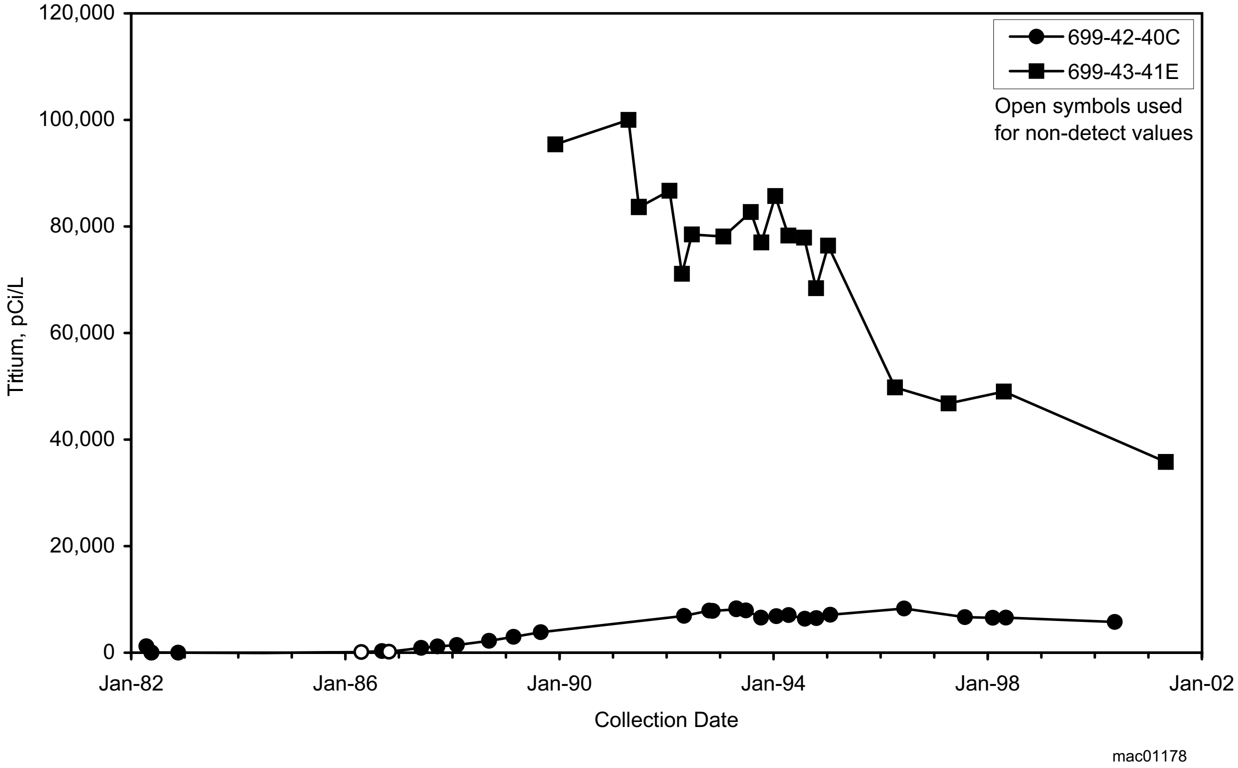

Figure 2.14-6. Tritium Concentrations in Wells 699-42-40C (Basalt-Confined Aquifer) and 699-43-41E (Unconfined Aquifer)

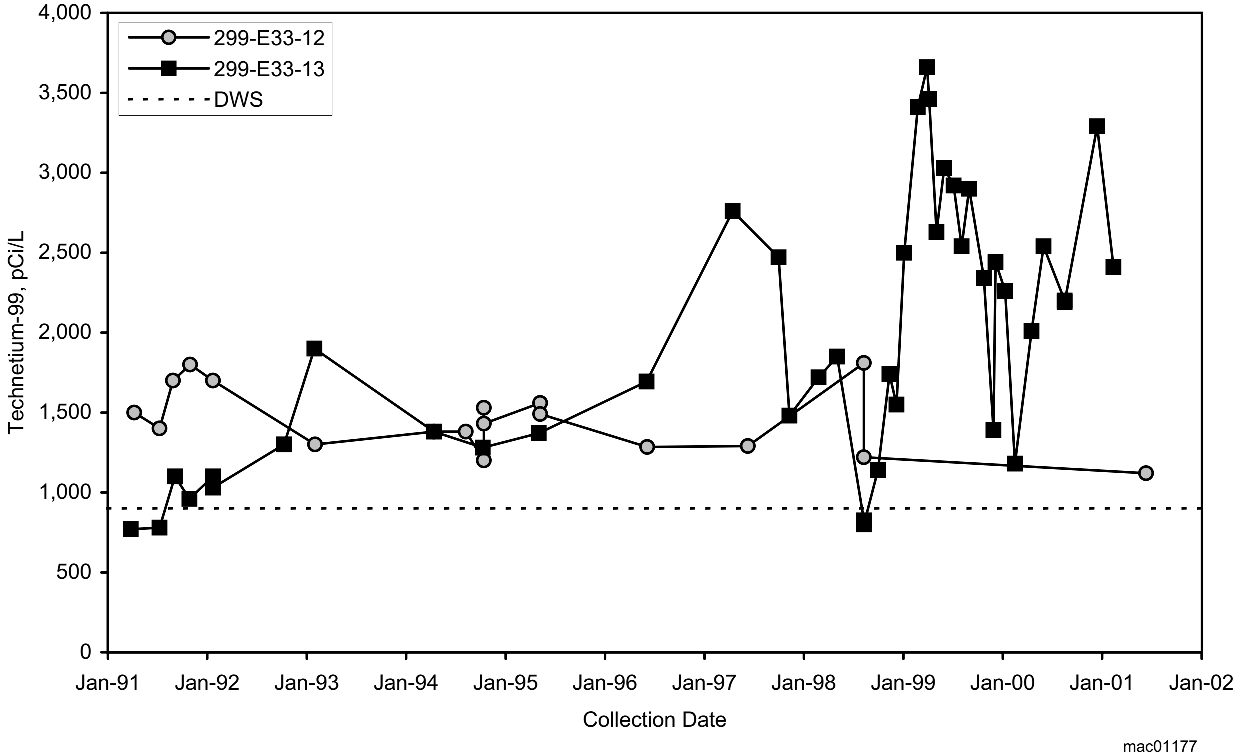

Figure 2.14-7. Technetium-99 Concentrations in Wells 299-E33-12 (Basalt-Confined Aquifer) and 299-E33-13 (Unconfined Aquifer)

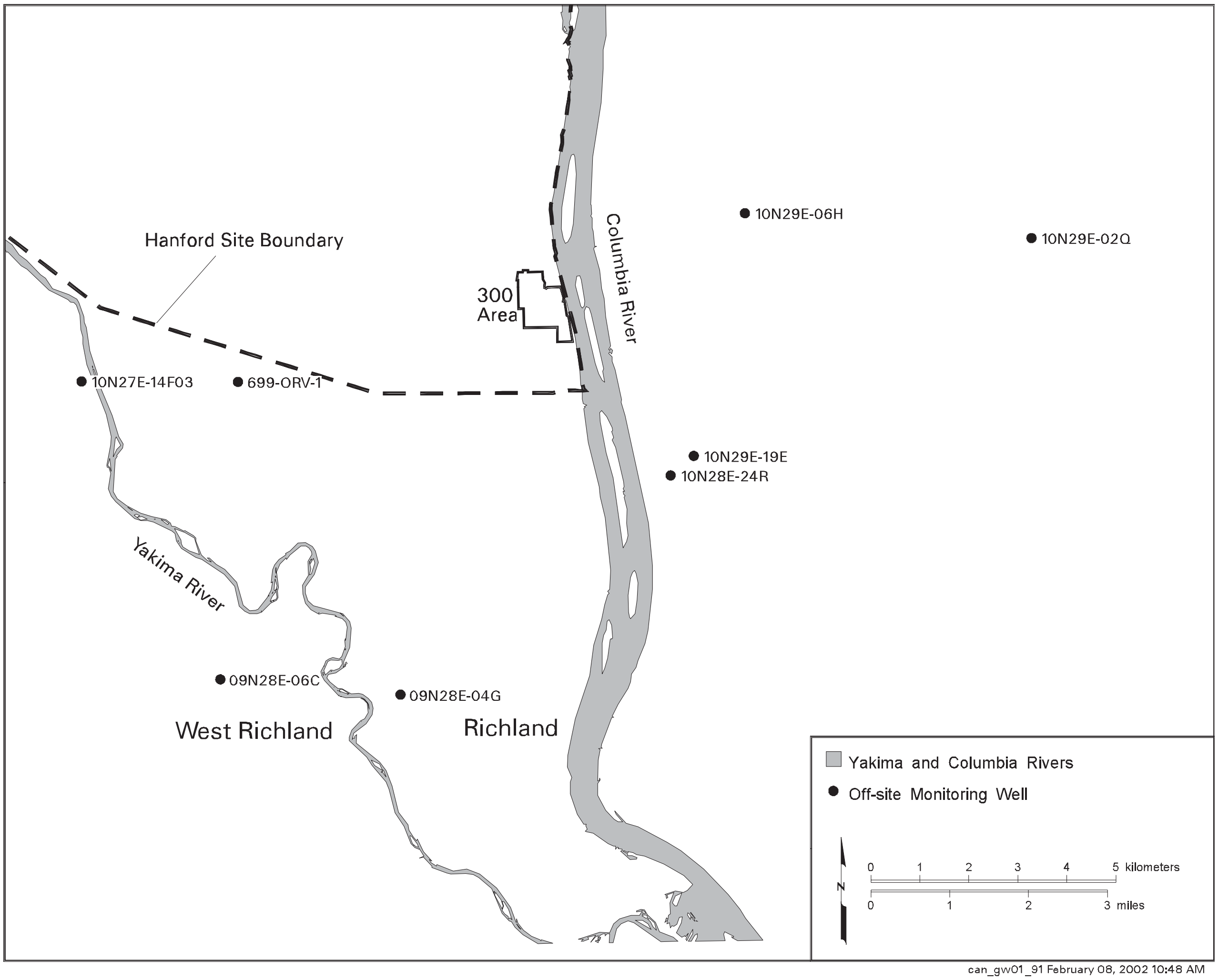

Figure 2.14-8. Offsite Wells Sampled in the Upper Basalt-Confined Aquifer During Fiscal Year 2001

3.0 Vadose Zone

Radioactive and hazardous wastes in the soil column from past intentional liquid waste disposal, unplanned leaks, solid waste burial grounds, and underground tanks at the Hanford Site are potential sources of continuing and future vadose zone and groundwater contamination. Subsurface source characterization, vadose zone monitoring, soil-vapor monitoring, and vadose zone remediation were conducted in fiscal year 2001 to better understand the distribution and mechanisms that control the movement of subsurface contamination. This chapter summarizes major findings from those efforts, focused primarily on vadose zone soil contamination associated with reactor operations, past single-shell tank leaks, and liquid disposal to ground as a result of spent fuel processing. This chapter also summarizes several technical studies whose results could lead to new understandings of contaminant interactions with the soil column and new and improved methods to characterize and monitoring the vadose zone.

An overview of the major soil column sources of groundwater contamination is provided in PNNL-13080. This chapter discusses vadose zone contamination that could affect groundwater in the future. An overall evaluation depends, to a large degree, on integration of vadose zone and groundwater monitoring and characterization data to present a comprehensive picture of contaminant fate and transport. Significant fiscal year 2001 vadose zone results are summarized here. However, the bulk of the data interpretation on the effect to groundwater is presented and discussed in Chapter 2.0.

3.1 Vadose Zone Characterization

D. G. Horton

This section describes significant vadose zone characterization activities that occurred during fiscal year 2001. These characterization activities were done to further the understanding of physical and chemical properties of the vadose zone and vadose zone contamination. During the year, two new characterization boreholes were drilled and sampled at single-shell tank farms in Waste Management Area B-BY-BY to better understand sediment properties, contaminant distribution, and transport mechanisms operating in the vadose zone. Several interim measures were completed at single-shell tank farms in fiscal year 2001 to minimize the subsurface movement of contaminants by preventing surface water from encroaching onto the tank farms.

During fiscal year 2001, baseline spectral gamma logging of selected wells at past-practice, liquid waste disposal facilities was initiated. The results will be a baseline against which future monitoring results can be compared.

Vadose zone characterization activities were done at three sites in the 200 Areas to support remediation of sites that received tank waste (200-TW-1 and 200-TW-2 Operable Units). Characterization activities also were completed at one site in the 100 H Area to support remediation in the reactor areas.

Finally, characterization activities were completed at two burial grounds in the 600 Area, north of the city of Richland. The results of these activities provide a clearer picture of the distribution of subsurface contaminants in this area.

Scientists collected data during a soil gas survey performed during summer 2001. The survey helped determine the direction and extent of tritium groundwater contamination downgradient of the 618-11 burial ground. Results from this survey were used to define the locations for groundwater sampling and monitoring well installation.

3.1.1 Tank Farm Characterization

Vadose zone characterization activities at single-shell tank farms in fiscal year 2000 were concentrated at the B, BX, and BY tank farms in the 200 East Area and the S, SX, T, TX, and TY tank farms in the 200 West Area. Two new boreholes were drilled at Waste Management Area B-BX-BY through subsurface contaminant plumes. A third borehole was drilled immediately outside the tank farms to obtain uncontaminated core for comparison with the contaminated material obtained in the tank farms. Analyses of the samples are ongoing and will be reported in next year's annual report. The description of installation of the boreholes is presented in this report.

Also, steps were taken to minimize the subsurface migration of existing contamination in the single-shell tank farms in 200 West Area. Although these efforts are not strictly characterization efforts, they are important and related because they help minimize the spread of contamination beyond existing contaminated regions.

3.1.1.1 Drilling, Sampling, and Analysis of Soil

D. A. Myers

Two boreholes were drilled in single-shell tank farms at Waste Management Area B-BX-BY to obtain drill cores from contaminated sediment. Analysis of the samples will further our knowledge about contaminant distribution in this area and about subsurface contaminant migration.

BX Tank Farm. Characterization borehole 299-E33-45 was drilled in the BX tank farm east of single-shell tank BX-102 (RPP-7921). The location of the borehole is shown in Figure 3.1-1. The site for this borehole was selected based on information derived from spectral gamma logging of many drywells in the vicinity. The drywell logs indicated numerous radionuclides dispersed through the vadose zone to the full depth of the drywells. The borehole was planned and constructed to characterize those radionuclides and collect samples for chemical and radiochemical analysis to determine the extent of non-gamma emitting radioisotopes.

Characterization of vadose zone contamination beneath single-shell tank farms continued in fiscal year 2001 with the drilling and sampling of two boreholes at Waste Management Area B-BX-BY. The boreholes were located in areas of suspected high contamination.

The borehole was advanced using the cable-tool technique. Thirty-five split-spoon samples were collected with an average recovery of 95%. In addition, 83 composite samples were collected. The composite samples were collected every 0.6 meter, through intervals from which split-spoon samples were not collected, starting from immediately below the first split-spoon sample at ~3.7 meters below ground surface and continuing to 76 meters below ground surface.

A perched water zone was encountered at ~69.2 meters below ground surface. Water samples from the perched zone were collected for chemical and radiological analysis. Groundwater was encountered at a depth of 77.4 meters below ground surface, and the borehole was advanced to a total depth of 79.6 meters. A temporary screen was set and groundwater was sampled to ascertain the technetium-99 concentration and to determine whether or not the borehole should be completed as a RCRA-compliant monitoring well. Technetium-99 concentration was ~1,500 pCi/L and was below the agreed-upon criterion of 4,000 pCi/L for completion as a monitoring well. The borehole was geophysically logged using gross and spectral gamma tools and a neutron-moisture tool.

Some difficulty was experienced in decommissioning the borehole as portions of the hole collapsed as casing was being removed. An agreement with the Washington State Department of Ecology was reached to assure that abandonment of the borehole was consistent with the guidelines and intent of WAC 173-160. The borehole was decommissioned in accordance with the agreed-upon plan.

Analytical data are being collected from the samples obtained in the borehole. The results of those tests will be available in fiscal year 2002 and will be reported in a field investigation report for Waste Management Area B-BX-BY.

B Tank Farm. Characterization borehole 299-E33-46 was drilled in the B tank farm adjacent to the B-110 single-shell tank. The location of the borehole is shown in Figure 3.1-1. The site for this borehole was selected based on data that indicated the possible presence of strontium-90. Initial identification of strontium-90 was based on spectral gamma logging that pointed to a potential source between 21 and 25 meters below ground surface in nearby drywells. Whereas strontium-90 is relatively short-lived and of low mobility, other longer-lived and more mobile radionuclides were likely to be present.

The borehole was advanced using the cable-tool technique (RPP-8633). Thirty-three split-spoon samples were collected with an average recovery of 93.7%. In addition, 102 composite samples were collected. The composite samples were collected every 0.6 meter, through intervals from which split-spoon samples were not collected, starting from immediately below the first split-spoon sample at ~3.7 meters and continuing to 80 meters below ground surface.

Although a perched water zone was anticipated at ~67 meters below ground surface based on drilling experience at the BX tank farm, no drainable water was encountered on the silt/clay zone that extended from 67 to 69 meters below ground surface. Groundwater was encountered at a depth of 78 meters below ground surface, and the borehole was advanced to a total depth of 80.5 meters. A temporary screen was set and groundwater was sampled to ascertain technetium-99 concentration and determine whether or not the borehole should be completed as a RCRA-compliant monitoring well. Technetium-99 concentration was below the agreed-upon criterion of 4,000 pCi/L for completion as a groundwater monitoring well. The borehole was geophysically logged using gross and spectral gamma tools and a neutron-moisture tool.

Borehole 299-E33-46 was completed as a vadose zone monitoring structure (see Section 3.2.5).

3.1.1.2 Interim Measures at 200 West Area Tank Farms

D. A. Myers

The River Protection Project's Vadose Zone Project is finding ways to reduce the movement of tank farm contaminants in the vadose zone. Infiltration of water through the vadose zone has been identified as the primary means by which contaminants are displaced beneath the farms. Two interim measures were taken during fiscal year 2001: placing surface water controls adjacent to tank farms in the 200 West Area, and testing and capping water lines associated with S, SX, and U tank farms in the 200 West Area.

Surface Water Controls. The tank farms in the 200 West Area were originally located in areas that would allow gravity flow of intertank transfer liquids to the farms and minimize the need for supplemental pumping to transfer waste from the point of origin to the storage tanks. Because of this, the tank farms are situated in areas of relatively low elevation. Placement of the farms at a lower elevation was helpful in filling the tanks, but it resulted in the tank farms being potential accumulation points for surface water run-on from major meteorological events or from breaks in waterlines supplying facilities in the 200 Areas. One notable instance of a natural meteorological event occurred in 1978 when a Chinook wind melted a substantial snow pack and water flooded Waste Management Area T tank farm (Figure 3.1-2). An example of a failed waterline occurred in 1993 when a 35-centimeter water main failed during construction activities and released an estimated 2,195,500 liters that ultimately reached the S and SY tank farms.

During fiscal year 2001, berms and other diversion structures were placed in the 200 West Area to redirect run-on away from the tank farms. Whereas precipitation falling directly on the tank farm surfaces remains as a source of recharge, surface water run-on from land adjacent to these farms has been effectively redirected and eliminated from the tank farm. The nature of the run-on controls is illustrated in Figure 3.1-3. Plans are presently being implemented to construct similar controls in the 200 East Area during fiscal year 2002.

Berms were built around 200 West Area single-shell tank farms in fiscal year 2001 to divert natural precipitation from running onto the tank farms and possibly mobilize existing vadose zone contamination.

Testing and Capping of Waterlines. Aging water-supply pipelines in the 200 West Area have been used for up to 2.5 times their design life. These lines that service the tank farms are a major potential source of water that could mobilize contaminants present in the vadose zone. The ongoing water requirements of the single-shell tank farms were assessed to ascertain which lines were essential for operations. Those lines that were determined to be unnecessary are being isolated, cut, and capped (Figure 3.1-4) near the large diameter trunk lines that supply water throughout the 200 Areas. Those lines that were found to be necessary for continued operations are being leak tested; lines found to be leaking will be removed from service and replacement lines constructed.

During fiscal year 2001, two lines leading to the S, SX, and SY tank farms were abandoned by capping. Lines servicing the U tank farm and the 242-S evaporator were tested for leakage. The three lines tested showed no measurable losses when tested for 24 hours.

3.1.1.3 Characterization of Single-Shell Tank Waste Management Area S-SX

Compiled by D. G. Horton

The overall goal of the Tank Farm Vadose Zone Project, lead by CH2M HILL Hanford Group, Inc., is to define risks from past and future single-shell tank farm activities, identify and evaluate interim stabilization measures, and aid decisions about near-term operations, future waste retrieval, and final closure activities for the single-shell tank waste management areas. To this end, the River Protection Project continued characterization activities at the S-SX tank farms in fiscal year 2001.

A series of four reports were issued in fiscal year 2001 describing the sampling and analysis associated with five boreholes drilled in or adjacent to the S-SX tank farms. The boreholes are: 299-W22-48 and 299-W22-50 (PNNL-13757-1), 299-W23-234 also known as 41-09-39 (PNNL-13757-3), 299-W23-19 (PNNL-13757-2), and C3082 (PNNL-13757-4). The work described in these reports has been ongoing for the past three years and preliminary results have been reported in previous annual groundwater reports (PNNL-13116; PNNL-13404). This section summarizes and compares the final results from analyses of samples from the five boreholes. Complete discussions of the sampling, analytical techniques, and results are found in the reports cited above.

Boreholes 299-W22-48 and 299-W22-50 were drilled and completed as RCRA groundwater monitoring wells in fiscal year 2000 east of the SX tank farm (see Figure 2.8-1). They were drilled in uncontaminated sediment and, as such, serve as baseline wells to compare with those drilled in contaminated areas of the tank farm. Both boreholes were continuously cored during drilling. Borehole 41-09-39 was originally drilled in December of 1996 adjacent to the southeast edge of tank SX-109 to a depth of 40 meters. The purpose of the borehole was to determine the presence of cesium-137 at depths of 20 to 40 meters. The borehole was deepened in 1997 to 68.6 meters and split-spoon samples were collected wherever possible. The borehole was decommissioned in 1999 at which time samples were obtained from portions of the borehole that were previously unsampled.

In 1999, borehole 299-W23-19 was drilled 3 meters from the southwestern edge of tank SX-115. The purpose of the borehole was to characterize the vadose zone sediment in the area of a 189,000 liter leak that occurred in the mid-1960s. Near-continuous split-spoon samples were collected down to a depth of ~62.5 meters. The borehole was completed as a groundwater monitoring well in 2000.

Borehole C3082 was installed adjacent to tank SX-108 in 2000. Tank SX-108 had leaked between 9,084 and 132,475 liters in 1962 (HNF-EP-0182). Borehole C3082 was drilled at an angle and aligned to pass beneath the tank, through a zone of high contamination, and terminate at a depth of 45 meters in the Plio-Pleistocene unit. Split-spoon samples were obtained from 16 zones in the borehole.

Boreholes 299-W22-48, 299-W22-50, and 41-09-39 encountered the same stratigraphic and lithologic sequences (Figure 3.1-5); these are (from bottom to top)

1. fluvial, variably cemented sandy gravel to conglomerate of the Ringold Formation, member of Wooded Island, unit E (Lindsey 1996)
2. interbedded fluvial sands and overbank sands and muds of the Ringold Formation member of Taylor Flats
3. basaltic pebbly sand interspersed with layers of mud both containing variable amounts of calcium carbonate representing the lower Plio-Pleistocene unit
4. upper Plio-Pleistocene overbank alluvium and paleosols consisting of fine to very fine-grained sand intercalated with silty fine sand and silt/clay
5. the Hanford formation consisting of a lower fine-grained sand and mud sequence (H2), a middle coarse-grained sand and gravel sequence (H1), and an upper fine-grained sand and mud sequence (H1a)
6. backfill materials consisting of silt, sand, and pebbles from the Hanford formation.

Borehole 299-W23-19 encountered essentially the same stratigraphy and lithologies as the aforementioned boreholes except that the upper Ringold Formation is missing in borehole 299-W23-19. Borehole C3082 penetrated backfill and the Hanford formation and terminated in the upper Plio-Pleistocene unit.

Borehole samples were analyzed for alkali and alkaline earth metals, anions, chromium, electrical conductivity, pH, radionuclides, and water content. Deviations of the analytical results between tank farm boreholes and the baseline boreholes were considered to be indicators of contamination from tank waste.

Water Content. Although there was some correlation between moisture content and the presence of contamination, the relationship was not straightforward because the moisture content also reflects lithology changes. Fine-grained sediment tended to have higher moisture contents than coarse-grained sediment, and those differences were mixed with moisture differences due to leaked fluids. Therefore, moisture by itself was not considered a good indicator of contamination, though moisture content tended to be higher in contaminated zones.

pH. The pH from 1:1 water extracts versus depth for all five boreholes is shown in Figure 3.1-6. The figure shows that natural pH values of uncontaminated sediment are between ~7.0 and 8.5 with a few samples extending to near 9.0. The pH of Hanford formation sediment in equilibrium with atmospheric carbon dioxide and calcite (which is common in Hanford Site sediment) would be 8.3.

The pH values of samples taken from depths above the bottom of tanks SX-109 and SX-115 (<~18.3 meters) are within the range of natural pH values. At both borehole 41-09-39 and C3082, the highest pH values are between 9.2 and 9.8 and occur just below tanks SX-109 and SX-108 to depths of 24.4 to 25.9 meters. In borehole 299-W23-19, elevated pH, from 9.1 to 9.7, occurs between depths of 22.9 and 26.2 meters, similar to tanks SX-108 and SX-109, and between depths of 30.2 and 32 meters. Below about depths of 24.4 to 25.9 meters at tanks SX-108 and SX-109 and below ~32 meters beneath tank SX-115, pH values are within the range of natural, uncontaminated Hanford Site sediment.

In none of the contaminated boreholes is the pH as high as might be expected for tank liquors completely saturating sediment (pH > 13; PNNL-11495). This may result from neutralizing reactions with the sediment and/or carbon dioxide in the vadose zone. Because of these possible neutralizing reactions, pH is not considered a good indicator of the extent of contamination although it is essential in understanding contaminant behavior in the vadose zone.

Electrical conductivity, nitrate, sodium, and technetium-99 were used to map the leading edges of plumes in the S-SX single-shell tank farms. In two cases, the leading edge of the plumes was in the Plio-Pleistocene silt unit with the bulk of contamination in the overlying Hanford formation. In a third case, the bulk of contamination is in the Plio-Pleistocene silt unit with the leading edge possibly extending to groundwater.

Electrical Conductivity. The electrical conductivity results for the five boreholes in the SX tank farm are shown in Figure 3.1-7. The natural, dilution-corrected electrical conductivity in boreholes 200-W22-48 and 299-W22-50 is between ~200 and 6,000 μS/cm. (Because the 1:1 water extract values are dilute with respect to the natural porewater, the diluted value is multiplied by the dilution factor [the amount of water added] to obtain the natural value for the sediment [PNNL-13757-1].) One sample at ~18.3 meters in borehole 299-W22-50 shows pH and electrical conductivity values greater than the other samples from the two uncontaminated boreholes. The electrical conductivity of that sample is considered natural and due to dissolution of evaporite minerals in the sample (PNNL-13757-1).

The electrical conductivity versus depth profiles for boreholes 41-09-39 and C3082 are similar. The profile for 41-09-39 shows that tank fluid dominated porewater to 38.7 meters and is elevated to ~40.3 meters, below which are natural values. Similarly, electrical conductivity shows that tank fluid dominates porewater to a depth of 33.3 meters in borehole C3082, though the two deeper samples still have slightly elevated electrical conductivity. Note that electrical conductivity of the sediment beneath tank SX-108 (C3082) is an order of magnitude greater than that adjacent to tank SX-109 (41-09-39). The data from these two boreholes suggests that the leading edge of the contamination has reached 40.3 meters in borehole 41-09-39 and is below the total depth of 44 meters in borehole C3082. For both boreholes, however, the bulk of the contamination is higher, between 24.4 and 39.6 meters (41-09-39) and 22.9 and 32 meters (C3082).

The profile from borehole 299-W23-19 is somewhat different than that of the other two boreholes. The electrical conductivity in borehole 299-W23-19 is elevated from ~19.8 to 47.6 meters. The profile shows that the contaminant plume has reached the bottom of the upper Plio-Pleistocene unit at 47.6 meters and the bulk of contamination is within the upper Plio-Pleistocene unit between ~36.6 and 47.6 meters. This is deeper than the bulk of contamination shown by electrical conductivity from boreholes 41-09-39 and C3082.

Nitrate and Sodium. Nitrate is the most concentrated anion in tank liquors. Its high concentrations and its high mobility in the vadose zone make nitrate one of the most sensitive indicators of tank waste migrating through the vadose zone. Figure 3.1-8 shows the concentration of nitrate versus depth in the five boreholes at the SX tank farm. Also, sodium is the dominant cation in tank fluids and is mobile in the vadose zone environment. Figure 3.1-9 shows the concentration of sodium versus depth in the SX tank farm boreholes. Both nitrate and sodium closely resemble the electrical conductivity profiles.

In borehole 41-09-39, elevated nitrate is first encountered at a depth of 19.8 meters and is highest between 24.4 and 38.7 meters. Likewise, sodium is elevated from a depth of ~24.4 to 38.7 meters, though moderate sodium values exist to ~47 meters, below which natural sodium concentrations are present. These deeper sodium concentrations, between 39.6 and 47.6 meters, may be due to drag down during drilling of the borehole (PNNL-13757-3). Nitrate in samples from C3082 is elevated throughout the total depth of the borehole (44.2 meters), and sodium has severely affected the vadose zone to a depth of ~39.6 meters. The sodium concentration is near normal in the deepest sample from ~44.5 meters.

Nitrate in borehole 299-W23-19 is elevated from 19.8 meters to ~47.6 meters near the bottom of the upper Plio-Pleistocene unit. Nitrate is <1,000 mg/L and generally <500 mg/L (within natural range) in samples deeper than 47.6 meters except for the deepest two samples. The deepest two samples are from depths below the highest recorded water table during the time that tank SX-115 is suspected to have leaked. Thus, the deepest nitrate concentrations may have resulted from nitrate in a higher-than-current water table. (Historic water levels suggest that the water table was as high as ~61 meters below the S-SX tank farms.) In general, the distribution of nitrate with depth in borehole 299-W23-19 suggests that the leading edge of the nitrate plume is at 47.6 meters.

Figure 3.1-9 shows elevated sodium concentrations begin abruptly at 22.3 meters below ground surface in borehole 299-W23-19 and extend to ~48.3 meters below ground surface near the contact between the Hanford formation H2 and upper Plio-Pleistocene unit. The bottom of the sodium profile is not sharp, but gradually decreases throughout the upper Plio-Pleistocene unit until natural concentrations are attained at ~39.6 meters below ground surface.

In boreholes 41-09-39 and C3082, sodium is slightly elevated throughout the upper part of the boreholes but does not greatly increase until 23.1 to 25.3 meters below ground surface. In borehole 41-09-39, sodium concentration decrease to natural levels at 40.6 meters below ground surface; sodium remains above natural levels in borehole C3082 to total depth. Whereas the bulk of the nitrate contamination is in the Hanford formation H2 unit in boreholes 41-09-39 and C3082 and is in the upper Plio-Pleistocene in borehole 299-W23-19, the bulk of the sodium contamination is in the Hanford formation H2 unit in all three boreholes.

The alkali and alkaline-earth cation profiles for the boreholes impacted by tank waste show evidence of ion exchange in the vadose zone (Figure 3.1-10). This is especially evident for sodium and the alkaline-earth ions. The profiles show that the high sodium concentration in the leaked fluids has replaced the other major cations on exchange sites in the native sediment. The displaced cations are effectively pushed ahead of the sodium bearing fluids as they migrate downward. Each profile of contaminated boreholes in Figure 3.1-10 show a zone of elevated sodium above a zone of relatively high alkaline-earth concentrations.

Chromium and Technetium. The concentration of chromium and technetium-99, two contaminants from leaked tank fluids, were found to be elevated in the vadose zone sediment. Technetium-99 is thought to be extremely mobile in the vadose zone. Figure 3.1-11 shows the distribution of technetium-99 versus depth for the three contaminated boreholes at SX tank farm. The distribution of elevated technetium-99 generally mimics that of electrical conductivity and nitrate. Using the distribution of technetium-99, the leading edge of the contaminant plume is at depths of 41.2 and 42 meters in boreholes 41-09-39 and C3082. In borehole 299-W23-19, the bulk of technetium-99 contamination is above 47.6 meters below ground surface in the upper Plio-Pleistocene unit, but elevated technetium-99 (between 6 and 68 pCi/L) extends to the deepest sample. The deepest sample contains 176 pCi/mL of technetium-99, which may be a result of past interactions with groundwater containing technetium-99.

In summary, chromium and pH distributions do not identify the leading edge of contaminant plumes in the SX tank farm. However, the more mobile indicators, such as electrical conductivity, nitrate, sodium, and technetium, suggest that the leading edge of the contaminant plume is at a depth of 38.7 to 41.2 meters in borehole 41-09-39 and 42 meters to >44.2 meters (deeper than the bottom of the borehole) in borehole C3082. In these two boreholes, the bulk of contamination appears to be significantly shallower than the leading edge of the plume and contamination does not seem to have migrated deeper than the base of the upper Plio-Pleistocene unit. In borehole 299-W23-19, the bulk of contamination is between a depth of 37.2 and 47.6 meters, but some contamination may extend to groundwater.

3.1.2 Vadose Zone Characterization at Past-Practice Liquid Disposal Facilities

S. M. Sobczyk, P. D. Henwood, R. G. McCain, and S. E. Kos

Geophysical logging was conducted in fiscal year 2001 to support

- the 200 Areas Vadose Zone Characterization
- the 200-TW-1 Scavenged Waste Group Operable Unit
- the 200-TW-2 Tank Waste Group Operable Unit Remedial Investigation/Feasibility Study
- installation of new RCRA groundwater monitoring wells.

The DOE Grand Junction Office began spectral gamma logging in existing boreholes near the liquid waste disposal sites and solid waste burial grounds in the Hanford Site 200 Areas during fiscal year 2001. The purpose of the project was to detect and quantify naturally occurring and manmade gamma-emitting radionuclides in the vadose zone. This project is an extension of the baseline characterization work completed in the Hanford Site single-shell tank farms. The newly acquired logs will establish a baseline for comparison of future logs identifying gamma-emitting contaminants and tracking the rate of contaminant movement in the vadose zone.

The spectral gamma logs provided information regarding the nature and extent of vadose zone contamination associated with past practice, liquid waste disposal facilities. Data from each borehole were analyzed to determine concentrations of naturally occurring radionuclides (potassium-40, uranium-238, thorium-232, and associated decay progeny), as well as manmade gamma-emitting radionuclides such as cesium-137, cobalt-60, and europium-152 and -154. Variations in concentrations of naturally occurring radionuclides are used to establish the framework for stratigraphic correlations. The presence of manmade gamma emitters indicates the distribution of past-practice liquid waste.

The logging system, the logging methods, and the data collection and analysis procedures are described in PNNL-13404, PNNL-13080, MAC-HGLP 1.6.5, MAC-VZCP 1.7.9, MAC-HGLP-1.6.2, and MAC-HGLP-1.6.4. Geophysical logging tool calibrations are documented in GJPO-HAN-1; GJO-2001-243-TAR; GJO-99-118-TAR, GJO-HAN-29; and GJO-2001-244-TAR.

During fiscal year 2001, spectral gamma logging system data were collected in 30 boreholes in or near waste sites in the 200 Areas. Fifteen existing boreholes were logged for the 200 Areas Vadose Zone Characterization Project. Eight new characterization boreholes, drilled for the 200-TW-1 Scavenged Waste Group Operable Unit and the 200-TW-2 Tank Waste Group Operable Unit Remedial Investigation/Feasibility Study, were logged. Ten of the boreholes exhibited high gamma flux zones that required the use of the high resolution logging system. In addition, seven new RCRA groundwater monitoring wells, which were installed during fiscal year 2001, were logged. Results of the 200 Areas Vadose Zone Characterization Project will be posted on the Internet at: http://www.gjo.doe.gov/programs/hanf/HTFVZ.html.

The logging done for the 200 Areas Vadose Zone Characterization Project identified deep contamination in borehole 299-E33-20 near the 216-B-11B injection well (see Appendix A, Figure A.16 for location of well 216-B-11B). In this borehole, cesium-137 and cobalt-60 were detected at depths below 73.2 meters (Figure 3.1-12). These depths coincide with historical water levels; the depth to water was reported at 74.1 meters in July 1956, 71.4 meters in November 1989, and 76.5 meters in April 2000. Logging was terminated above the latest reported groundwater level because of waste management issues. The increased water levels in the late 1980s are probably due to the 216-B-3 pond system but the cesium-137 and cobalt-60 may have come from the 216-B-11A and 216-B-11B injection wells located ~4.6 meters northeast of the borehole. The discharges to the B Pond system caused a groundwater mound in this area that has since receded, leaving contaminated soil in the vicinity.

Logging for the 200-TW-1 Scavenged Waste Group Operable Unit and 200-TW-2 Tank Waste Group Operable Unit was done at characterization boreholes at the 216-B-38 specific retention trench (see Appendix A, Figure A.16). The maximum concentration measured to date in any borehole logged outside of tank farms is 300,000 pCi/g of cesium-137 in a characterization borehole (C3104) near the 216-B-38 trench (Figure 3.1-13). This concentration level of cesium-137 is about three orders of magnitude less than the maximum detected in the single-shell tank farms.

Borehole logging for characterization of the 200-TW-1 Operable Unit found a maximum cesium-137 concentration of 300,000 pCi/g at one borehole near the 216-B-38 trench. This is the highest measured cesium-137 concentration to date in the vadose zone outside of the single-shell tank farms.

Seven RCRA groundwater monitoring wells installed during fiscal year 2001 were logged. Four of those wells (299-E33-339, 299-W19-45, 299-W18-40, and 299-W15-765) showed indications of radon in groundwater based on the spectral gamma logging system results. The apparent increase in uranium-238 concentrations below the groundwater level in borehole 299-E33-339 (Figure 3.1-14) is interpreted as an indication of dissolved radon (radon-222) in the groundwater. This interpretation is made because the gamma-ray peaks observed are due to natural uranium-238 and not manmade uranium-238. Radon in a borehole may increase the total gamma counts observed so that, if the gross gamma log is being used for stratigraphic correlation, the presence of radon must be considered.

The 200 Areas Vadose Zone Characterization Project is now in full operation. Gamma spectra are being collected in boreholes and monitoring wells located within and near waste disposal sites (e.g., ponds, ditches, cribs, and burial grounds) in the 200 East and 200 West Areas.

Priority for logging existing boreholes is determined by the data needs of ongoing investigation efforts of the Groundwater/Vadose Zone Integration Project. The data collected in fiscal year 2001 are available to support the Tank Farms Vadose Zone Project, the Groundwater/Vadose Zone Integration Project, and the Hanford Site Groundwater Monitoring Project.

3.1.3 Trench 116-H-1 Characterization

J. J. Kious

Bechtel Hanford, Inc. remediated the 116-H-1 trench in spring 2000. Characterization for site closeout was subsequently completed and documented in fiscal year 2001. Characterization consisted of determining the vertical distribution of contaminants of concern in the vadose zone between the base of the 116-H-1 trench and the water table. This section summarizes the characterization activities and results. A complete description of the work can be found in BHI-01541.

The 116-H-1 trench, located in the 100 H Area (see Figure 2.6-1), received ~90 million liters of reactor cooling water and an unknown volume of water and sludge from the operation and deactivation of the 107-H retention basin. The waste contained 90 kilograms of sodium dichromate.

Borehole C3048 was drilled at the northern end of the trench ~5 meters from the inlet pipe. The borehole was drilled to a total depth of 9.76 meters below the bottom of the trench. The bottom of the trench is 4.9 meters below grade. The sediment encountered during drilling were Hanford formation pebble-cobble gravel with thin interbeds of sand and silt. The water table was encountered at a depth of 8.01 meters.

Eight split-spoon samples were collected at 1-meter intervals between 0.76 and 7.8 meters drilled depth. Samples were sent to the laboratory to measure concentrations of constituents of concern (carbon-14, cobalt-60, cesium-137, europium-152, -154, and -155, plutonium-239/240, uranium-238, arsenic, mercury, hexavalent chromium, and total strontium). Because strontium values are reported in picocuries per gram (pCi/g), it is assumed that total strontium was taken to be strontium-90.

Analytical results show that the concentration of most constituents decreases with increasing depth. For several constituents, there is a sharp decrease in concentration at a depth of 2 meters below the trench bottom. This is most dramatic for cesium-137 and europium-152 (Figure 3.1-15). Cobalt-60 and mercury are detected only above a depth of 2 meters with maxima of 1.4 pCi/g and 0.12 mg/kg at 1 meter. Arsenic, europium-154, plutonium-239/240, strontium-90, and uranium-238 show slight decreases in concentration with depth (Figure 3.1-16). All results for carbon-14 and europium-155 are below the minimum detectable level. Unlike the other constituents, hexavalent chromium shows a maximum concentration below a depth of 2 meters below the trench bottom. The maximum hexavalent chromium concentration is 0.47 to 0.59 mg/kg at 4.1 to 5.2 meters, which is 2.8 to 3.9 meters above the water table. The deepest sample, from a depth of 6.1 meters, contained no detectable hexavalent chromium.

Drilling and sampling activities associated with remediation of the 116-H-1 trench suggest that water used for dust suppression during remediation did not drive contaminants deeper in the vadose zone.

Finally, the moisture content of all samples was below ~10%, which is within the normal range of Hanford formation samples. This indicates that water used for dust control during remediation has not driven contaminants deeper in the soil column.

3.1.4 Helium-3/Helium-4 Ratios in Soil Gas as an Indicator of Subsurface Tritium Contamination at the 618-11 Burial Ground Site

P. E. Dresel and K. B. Olsen

A groundwater sample collected in January 2000 from well 699-13-3A (see Figure 2.12-10), located along the eastern fence line of the 618-11 burial ground, contained 8.1 million pCi/L of tritium. This is the highest concentration of tritium detected at the Hanford Site in recent years. To determine the extent of the groundwater contamination, investigators used helium-3 in the vadose zone as a surrogate tracer for tritium in groundwater. The investigation began in fiscal year 2000 and continued through fiscal year 2001. The fiscal year 2000 investigation established the burial ground as the source of tritium in groundwater and showed that the contamination extended east of the burial ground. A soil gas survey was performed in the summer of 2001 to determine the direction and extent of tritium groundwater contamination downgradient of the burial ground. The results of the soil gas survey were used to define locations for groundwater sampling and monitoring well installation. Section 2.12.7.2 discusses the results of the groundwater investigation at the 618-11 burial ground and contains a plume map for tritium in the area. This section summarizes the soil gas investigation results.

Samples of soil gas collected at the 618-11 burial ground were analyzed for helium isotopes (helium-3 and helium-4) to determine helium-3/helium-4 ratios. The technique is based on the decay of tritium, with a half-life of 12.32 years. Tritium decays to the stable, inert isotope helium-3. As tritium decays, its daughter isotope, helium-3, begins to build up in the vadose zone and groundwater at the rate of tritium decay. The helium-3 then diffuses away from the source and toward the surface. Throughout this process, helium-3 acts as a non-reactive tracer moving through the vadose zone. The soil gas monitoring at the 618-11 burial ground was based on the measurement of helium-3 in the soil gas to identify vadose and/or groundwater sources of tritium in the subsurface environment. The results are expressed as the ratio of helium-3 to helium-4, normalized to the ratio in the atmosphere. Thus, the background value for soil gas that has not been affected by tritium contamination is expected to be close to 1.00.

A soil gas survey using helium isotopes was used to map tritium contamination in groundwater and to determine locations for new groundwater monitoring wells at the 618-11 burial ground. Results of the groundwater monitoring agree with the extent of contamination defined by the soil gas survey.

Fifty-four soil gas sampling points were installed north and east of the 618-11 burial ground in fiscal year 2000. Twenty-seven new soil gas sampling points were installed in fiscal year 2001 east (downgradient) of the 618-11 burial ground (Figure 3.1-17). The points were installed in four transects roughly perpendicular to the hypothesized transport direction in groundwater. All sampling points were completed at 6 meters below ground surface. Soil gas sampling points were installed using a truck mounted Geoprobe™[a] system equipped with a 1.25-inch-diameter probe and a detachable steel tip. Each sampling location was allowed to equilibrate for at least 24 hours before soil gas samples were collected. Several of the fiscal year 2000 sample points were re-sampled in fiscal year 2001 to complete the spatial coverage and to look at temporal changes.

Fifty-milliliter samples were collected for analysis of helium-3 and helium-4 concentrations from each sampling location near 618-11 burial ground. After collection, soil gas samples were sent to the University of Rochester for rare gas analysis. Helium isotope concentrations were analyzed on a rare gas mass spectrometer. All helium-3/helium-4 ratios were reported relative to the atmospheric ratio using air helium as the absolute standard.

The results of analyses of the soil gas samples from the fiscal year 2001 sampling are shown in Figure 3.1-17. Helium-3/helium-4 ratios from samples from the northern and southern ends of the area approach background levels (1.0). The helium-3/helium-4 ratio reaches a maximum of 1.65 in transect 1, closest to the burial ground. The plume width and ratios are smaller in transect 3, to the east. Only one soil gas sampling point in transect 4 showed a signal greater than background. The value at that point is higher than the maximum seen in transect 3, though transect 4 is farther from the source. The higher ratio seen in transect 4 is believed to be because transect 4 is topographically low compared to the other transects; so the soil gas points in transect 4 are closer to the water table and the source of helium-3. The soil gas helium results indicate the centerline of the tritium plume and bound the lateral extent.

Six locations for groundwater samples were chosen, based on the results of the soil gas monitoring. Four of the boreholes drilled for the groundwater sampling were completed as monitoring wells for ongoing sampling of the tritium plume. The results of the groundwater sampling were in excellent agreement with the extent of contamination defined by the soil gas study.

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[a] Geoprobe is a registered trademark of Geoprobe Systems, Salinas, Kansas.

3.1.5 Geophysical and Statistical Investigation of the 618-4 Burial Ground

C. J. Murray, G. V. Last, and Y. Chien

A geophysical and statistical investigation of the 618-4 burial ground was completed in fiscal year 2001. The objective was to use the Enhanced Site Characterization System to integrate and analyze previously collected geophysical data and new geophysical data to map the distribution of buried waste. This section provides a brief summary of the characterization work at the 618-4 burial ground. A full description of the work is given in PNNL-13656.

The Enhanced Site Characterization System uses geostatistical techniques and multivariate statistics to evaluate and model spatially distributed data. This process provided information that will increase the efficiency of remediating the 618-4 burial ground.

The 618-4 burial ground is located north of the 300 Area ~1.6 kilometers north of the city of Richland and 340 meters west of the Columbia River (see Figure 2.12-1 which shows the location of the 618-4 burial ground). The burial ground consists of a single pit that is 160 meters long, 32 meters wide, and 6 meters deep (DOE/RL-88-31). The burial ground received trash and debris contaminated with uranium from nuclear fuel manufacturing processes in the 300 Area between 1955 and 1961.

Geophysical surveys (ground penetrating radar, magnetometer, and metal detector surveys) were conducted over the burial ground in 1991 (WHC-SD-EN-TI-061) revealing metallic waste in the main part of the pit. The burial ground was partly excavated during 1997 and 1998 as part of the environmental restoration at the 300-FF-1 Operable Unit. In April 1998, excavation was stopped after 338 drums containing depleted uranium metal shavings and uranium-oxide powder were exposed.

A re-interpretation of the 1991 ground penetrating radar data in 1999 showed the presence of two anomalies; one coincided with the location of known, buried drums adjacent to the excavated drums, and the second was located ~20 to 30 meters southwest of the buried drums.

3.1.5.1 Study Methods

A detailed geophysical investigation was conducted over the central, unexcavated portion of the burial ground in 2001 to better define the boundaries of the two anomalies identified in 1999. Five variables were incorporated into the Enhanced Site Characterization System analysis: time domain electromagnetic data, magnetic field strength, the thickness of the fill overlying the buried waste (from ground penetrating radar data), the slope of the top of the buried waste (from ground penetrating radar data and surface elevation measurements), and the amplitude of the ground penetrating radar reflection.

The geostatistical methods used included

- discriminant function analysis to differentiate between areas designated by geophysics as containing drummed waste and areas not containing drummed waste
- multiple linear regression analysis to determine relationships among the time domain reflectometry data, the magnetic field strength, and the thickness of fill
- hierarchical cluster analysis and fuzzy adaptive resonance theory analysis to analyze and group similar data points into classes representing the spatial distribution of different geophysical responses.

3.1.5.2 Results

The deployment of the Enhanced Site Characterization System and use of multivariate geostatistical methods allowed construction of a conceptual model of the distribution of buried waste at the 618-4 burial ground. The conceptual model provides information that can increase the efficiency of remediating the burial ground.

The newly acquired geophysical data allowed estimates of the number of drums remaining in the unexcavated parts of the 618-4 burial ground. The number of remaining drums is estimated to be between ~770 and 850 depending on their stacking arrangement and size.

A combination of box plots and discriminant function analysis showed that the area of known drums and the southwest anomaly are similar to one another and different from the rest of the study area. The major differences between the two anomalies and the rest of the study area are that the two anomalies have a higher magnetic field strength, indicating the presence of ferric metals, and a greater thickness of overlying fill material. The time domain electromagnetic data did not appear to be different on either side of the burial pit boundary. Multiple linear regression within the area of known drums found a strong negative correlation between the thickness of fill and the strength of the time domain electromagnetic signal. This suggests that the time domain electromagnetic signal is attenuated by the increased distance and material over the burial site.

Geostatistical analysis of surface geophysical data was used to estimate the number of buried drums at the 618-4 burial ground to be between 770 and 850. This type of information is extremely useful in planning excavation and remediation of buried waste.

Hierarchical clustering analysis was used to partition the geophysical data into clusters or classes reflecting areas having different geophysical responses. That analysis was unsuccessful because, with three classes selected, 98.8% of the data were placed in one class. Because hierarchical clustering was unsuccessful, an alternative neural network classification method, fuzzy adaptive resonance theory, was used to classify the data.

The results produced three classes of data. Class 1 coincided with the known location of buried drums and the anomaly identified to the southwest. This class had

- high magnetic field strength
- intermediate time domain electromagnetic values, ground penetrating reflection amplitudes, and thickness of overlying fill
- low values for the slope on top of the buried waste.

Class 3 appeared to identify areas with much less metallic waste present. This class had the lowest magnetic field strength, time domain electromagnetic values, and ground penetrating radar reflection amplitudes. The greatest concentration of Class 3 occurrences was in the southeastern part of the study area. There were, however, small areas of Class 3 observed within the areas of known buried drums and the southwestern anomaly.

Class 2 had magnetic field strength values similar to Class 1, but time domain electromagnetic and ground penetrating radar reflection magnitudes were far higher than those of Class 1. This class also had the thinnest fill material, which may explain the high time domain electromagnetic values.

The results of the study show that multivariate techniques used by the approach can successfully integrate multiple geophysical variables and group observations into clusters that are relevant for planning the excavation of buried waste. The full evaluation of the Enhanced Site Characterization System, however, cannot be made at this time because of the lack of reliable ground truth data to calibrate the geophysical signals. An effort should be made to provide detailed and accurate locations during excavation of the remaining wastes in the 618-4 burial ground. These data can be used to establish a calibration of the Enhanced Site Characterization System with the geophysical data from the site.

3.1.6 200-TW-1 and 200-TW-2 Characterization

M. E. Todd

The data collected during characterization studies helps evaluate remedial actions for waste sites at Hanford.

Bechtel Hanford, Inc. and CH2M HILL Hanford, Inc. characterized the contaminant distribution at three inactive waste sites in fiscal year 2001 as part of the remedial investigation for the 200-TW-1 and 200-TW-1 Operable Units as defined in the remedial investigation/feasibility study work plan for these operable units (DOE/RL-2000-38). The waste sites that were investigated are the 216-T-26 crib, the 216-B-38 trench, and the 216-B-7A crib (see Appendix A, Figure A.19 for location of the 216-T-26 crib and Figure A.16 for locations of the 216-B-38 trench and the 216-B-7A crib). Characterization activities included installation of new boreholes and drive casings, geologic and geophysical logging, analysis of soil physical properties, and soil sampling and analysis for radiological and non-radiological constituents. The data collected will be used to evaluate remedial actions for these three waste sites and for the 61 other analogous waste sites within the 200-TW-1 and 200-TW-2 Operable Units. The following sections summarize the drilling efforts for the study. The analytical results are not yet available but will be included in the borehole summary and remedial investigation reports for these operable units scheduled to be completed in fiscal year 2002.

The primary objective of the field effort was to characterize the nature and vertical extent of contamination in the vadose zone underlying the waste sites. As part of a combined effort with the Groundwater/Vadose Zone Integration Project, information on possible carbon tetrachloride contamination in the vadose zone and at the water table was collected at the 216-T-26 crib; additional soil samples were collected at the 216-B-7A crib to support plutonium studies for the Science and Technology Project; and archive samples were collected from the 216-B-7A crib for use by the Tank Farm Vadose Zone Project.

The boreholes were drilled using cable tool methods and sampled by split-spoon methods. No water was added to the boreholes during drilling activities. Drilling activities were conducted at night for health and safety reasons. Samples from the zones of high contamination were collected in a containment structure and a glove bag (Figure 3.1-18). The boreholes were geophysically logged using spectral gamma and neutron moisture instruments (see Section 3.1.2). Five additional drive casings were driven and logged at the 216-B-38 trench to assist in selecting the optimum location for the borehole.

3.1.6.1 216-T-26 Crib

The 216-T-26 crib was active between August 1955 and November 1956. During that time, it received 120 million liters of effluent from T Plant. The crib is in a 9.1-by-9.1-meter concrete structure and the distribution piping is a depth of 2.7 meters.

One vadose borehole (C3102) was drilled through the 216-T-26 crib to a total depth of 69 meters below ground surface. Borehole cuttings were logged by a geologist. Soil described as backfill material forms the uppermost soil horizon at the crib. Backfill was identified from 0 to 6 meters below ground surface and consisted mainly of crushed basalt gravel, sand, and silty sandy gravel. Soil typical of Hanford sand- and gravel-dominated sequences lies beneath the backfill. The Hanford formation ranged from 6 to 27 meters below ground surface. The Upper and Lower Plio-Pleistocene Units ranged from 27 to 35 meters below ground surface. The Upper Ringold Formation ranged from 35 to 36.6 meters below ground surface. The Ringold Formation Unit E extended from 36.6 meters to the bottom of the borehole at 69.2 meters below ground surface. The water table was encountered at 68.8 meters below ground surface.

Soil samples were collected for chemical and radiological laboratory analysis and determination of physical properties at discrete intervals ranging from 3 to 69 meters below ground surface. A total of 26 samples were collected from the borehole for chemical and radiological analysis, including eight quality assurance/quality control samples and six physical property samples. Samples were analyzed for metals, anions, and radionuclides, and in some samples, volatile organic compounds. Physical property samples were analyzed for moisture content and grain size analyses; measurements for bulk density were made in the field. In addition, one surface sample was collected from 0 to 0.15 meter and analyzed for chloro-herbicides to support waste designation and disposal. The analytical data results will be provided in the borehole summary and remedial investigation reports scheduled to be completed in fiscal year 2002.

3.1.6.2 216-B-38 Trench

The 216-B-36 trench was active in July 1954 when it received 1.43 million liters of high salt/neutral-basic waste from the 221-B building. The trench was 77 meters long, 3 meters wide, and 3 meters deep.

Five drive casing holes (C3340 through C3344) were installed in the 216-B-38 trench and logged with a spectral gamma tool to identify the area of highest contamination and support placement of a borehole at that location. The resulting borehole (C3104) was drilled through the 216-B-38 trench near the C3340 drive casing location to a total depth of 80 meters using the cable tool method. A geologist logged the borehole cuttings. Soil described as backfill material forms the uppermost soil horizon at the trench. Backfill was identified from 0 to 4.6 meters below ground surface and consisted mainly of crushed basalt gravel, sand, and silty sandy gravel. Soil typical of Hanford sand- and gravel-dominated sequences lies beneath the backfill. The Hanford formation gravel-dominated sequence ranged from 4.6 to 9.3 meters below ground surface. The Hanford formation sand-dominated sequence ranged from 9.3 to 66.6 meters below ground surface. The undifferentiated Hanford formation/Plio-Pleistocene Unit extended from 66.6 meters below ground surface to the bottom of the borehole (80.3 meters below ground surface). The water table was encountered at 80.2 meters below ground surface.

Data collected from the boreholes near cribs and trenches will help determine the nature and extent of vadose zone contamination.

Soil samples were collected for chemical and radiological analysis and determination of physical properties. Samples were collected at discrete intervals from 1 to 80.2 meters below ground surface. A total of 18 samples were collected from the borehole for chemical and radiological analysis, including 3 quality assurance/quality control samples and 2 physical property samples. Samples were analyzed for metals, anions, and radionuclides. Physical property samples were analyzed for moisture content and grain size analyses; measurements for bulk density were collected in the field. In addition, one surface sample was collected from 0 to 0.15 meter and analyzed for chloro-herbicides to support waste designation and disposal. The analytical data results will be provided in the borehole summary and remedial investigation reports scheduled to be completed in fiscal year 2002.

Mercury was detected through field screening at the 216-B-38 borehole at the top of the drill casing in the 0.9 to 1.7 meter interval; however, the level did not exceed action levels in the working area.

The radiological field screening at the 216-B-38 borehole showed elevated beta-gamma counts from 4.4 to 7.6 meters below ground surface. The readings were significantly elevated through this zone with dose readings as high as 6 mrem/hr of beta and 8 mrem/hr of gamma radiation. Radiological field screening is consistent with the geophysical logging results at these depths. The remainder of the field screening generally showed background levels.

3.1.6.3 216-B-7A Crib

The 216-B-7A crib was used from August 1948 through July 1951. The crib received 36 million liters of waste from the 221-B building. The 216-B-7A crib is a hollow structure that is 4.2 meters long, 4.2 meters wide, and 2.4 meters deep.

One vadose borehole (C3103) was drilled through the 216-B-7A crib to a total depth of 67.8 meters below ground surface with cable tool and diesel hammer drill rigs. A geologist logged the borehole cuttings. Soil described as backfill material forms the uppermost soil horizon at the crib. Backfill was identified from 0 to 7 meters below ground surface and consisted mainly of crushed basalt gravel, sand, and silty sandy gravel. Soil typical of Hanford sand- and gravel-dominated sequences lies beneath the backfill. The Hanford formation gravel-dominated sequence ranged from 7 to 10.7 meters below ground surface. The Hanford formation sand-dominated sequence ranged from 10.7 to 66.4 meters below ground surface. The undifferentiated Hanford formation/Plio-Pleistocene silt ranged from 66.4 to 67.8 meters below ground surface (the bottom of the borehole). The water table was not encountered in this borehole; however, drilling was suspended when saturated soil was encountered at 66.8 meters. The stratigraphy encountered in the borehole is consistent with that described in PNNL-12261.

Soil samples were collected for chemical and radiological analysis and determination of physical properties. Samples were collected at discrete intervals from 0.8 to 67.5 meters below ground surface. A total of 22 samples were collected from the borehole for chemical and radiological analysis, including 3 quality assurance/quality control samples and 3 physical properties samples. Samples were analyzed for metals, anions, and radionuclides, and in some samples, volatile organic compounds. Physical property samples were analyzed for moisture content and grain size analyses; measurements were collected for bulk density in the field. In addition, one surface sample was collected from 0 to 0.15 meter and analyzed for chloro-herbicides to support waste designation and disposal. The analytical data results will be provided in the borehole summary and remedial investigation reports scheduled to be completed in fiscal year 2002.

The radiological field screening at the 216-B-7A borehole showed elevated beta-gamma counts from 5.5 to 11.4 meters below ground surface. The readings were significantly elevated through this zone with dose readings as high as 1,500 mrem/hr beta and 20 mrem/hr gamma. Elevated alpha contamination was identified in from 6.8 to 11.4 meters below ground surface. Readings as high as 100 mrem/hr were detected in this zone.

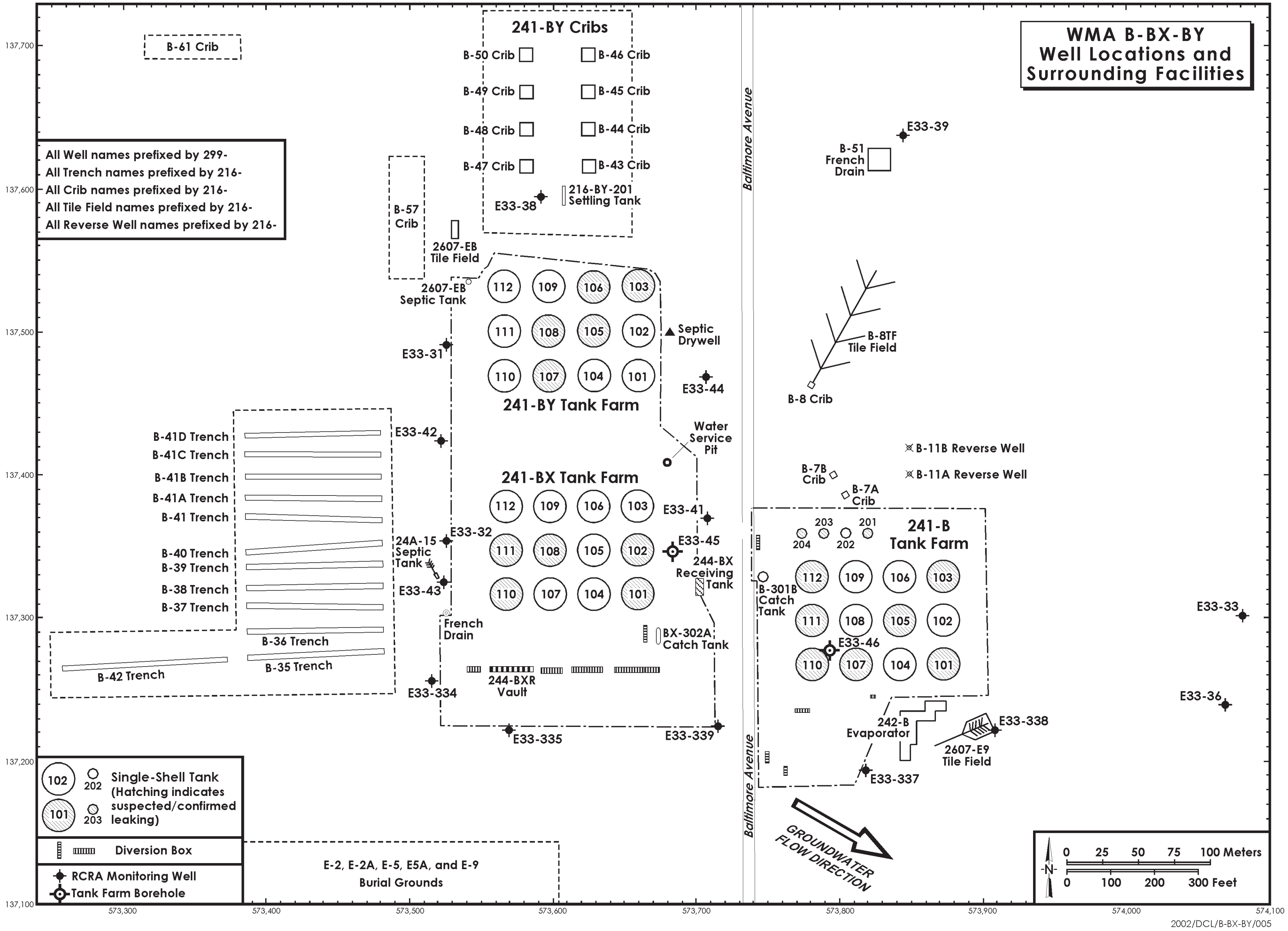

Figure 3.1-1. Locations of New Boreholes 299-E33-45 and 299-E33-46 at Waste Management Area B-BX-BY

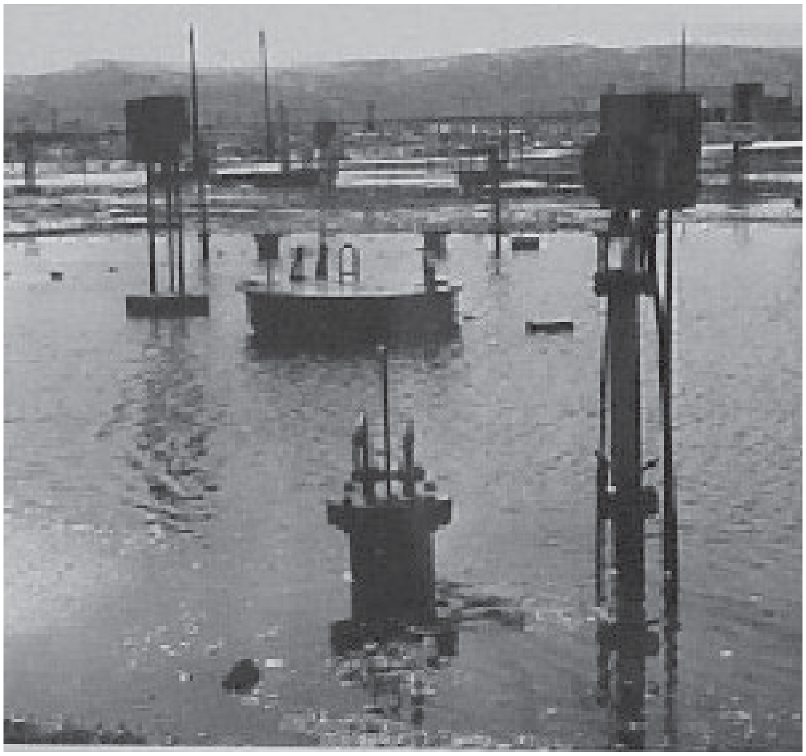

Figure 3.1-2. Photograph of a 1978 Flood at Waste Management Area T Tank Farm as a Result of Melting a Substantial Snowpack by a Chinook Wind

Figure 3.1-3. Photograph of a New Berm Constructed at Waste Management Area TX-TY to Control Run-On

Figure 3.1-4. Example of a Cut and Capped Water Line at Waste Management Area S-SX

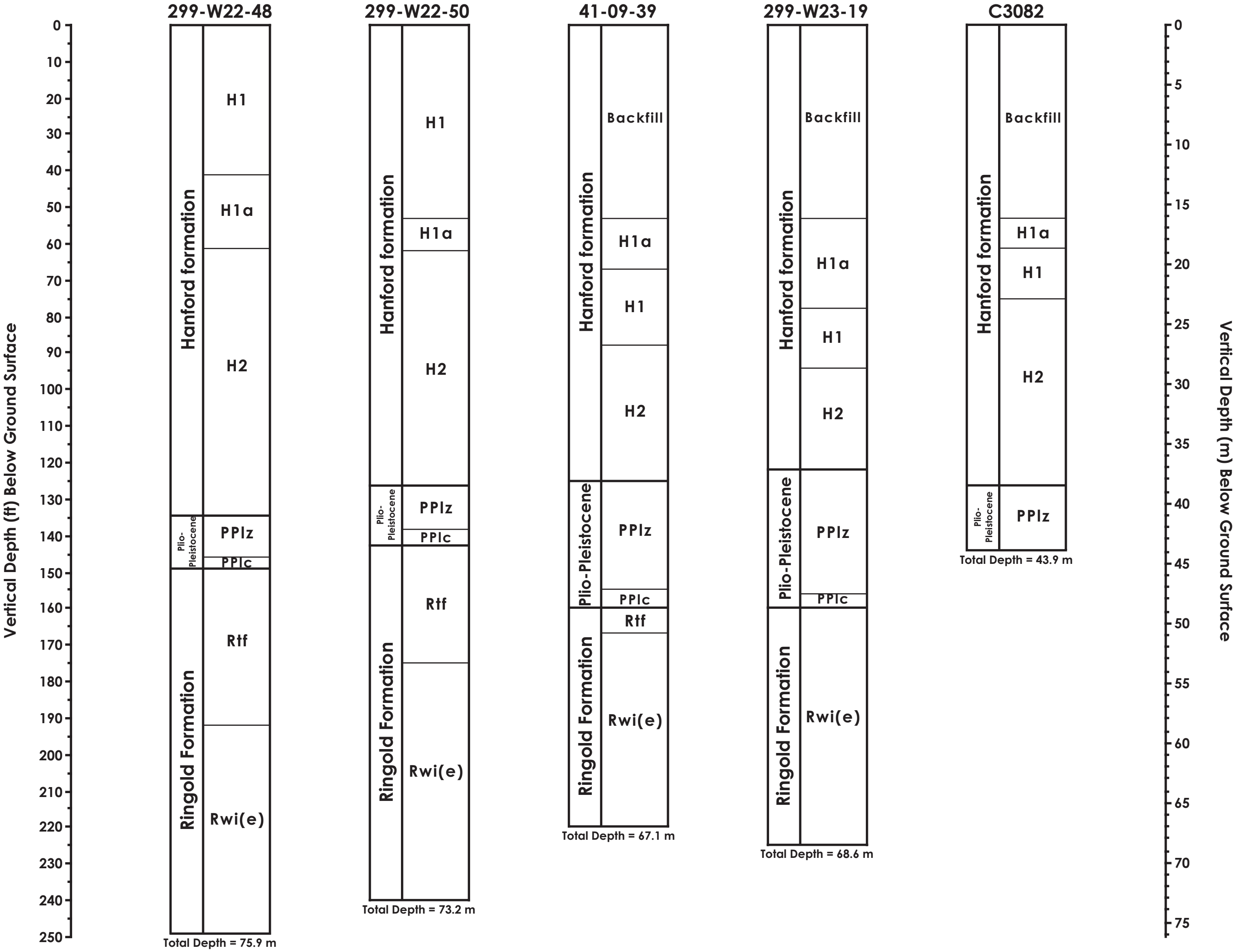

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Figure 3.1-5. Stratigraphy and Lithology Encountered in Five New Boreholes at the SX Tank Farm. The figure is meant to illustrate the types and thickness of lithologies encountered in the boreholes and is not intended as a cross section through the SX tank farm. Rwi(e) = Ringold Formation unit E, Rtf = Ringold Formation member of Taylor Flat, PPlc = lower Plio-Pleistocene unit, PPlz = upper Pilo-Pleistocene unit, H2, H1, and H1a = Hanford formation. See text for descriptions.

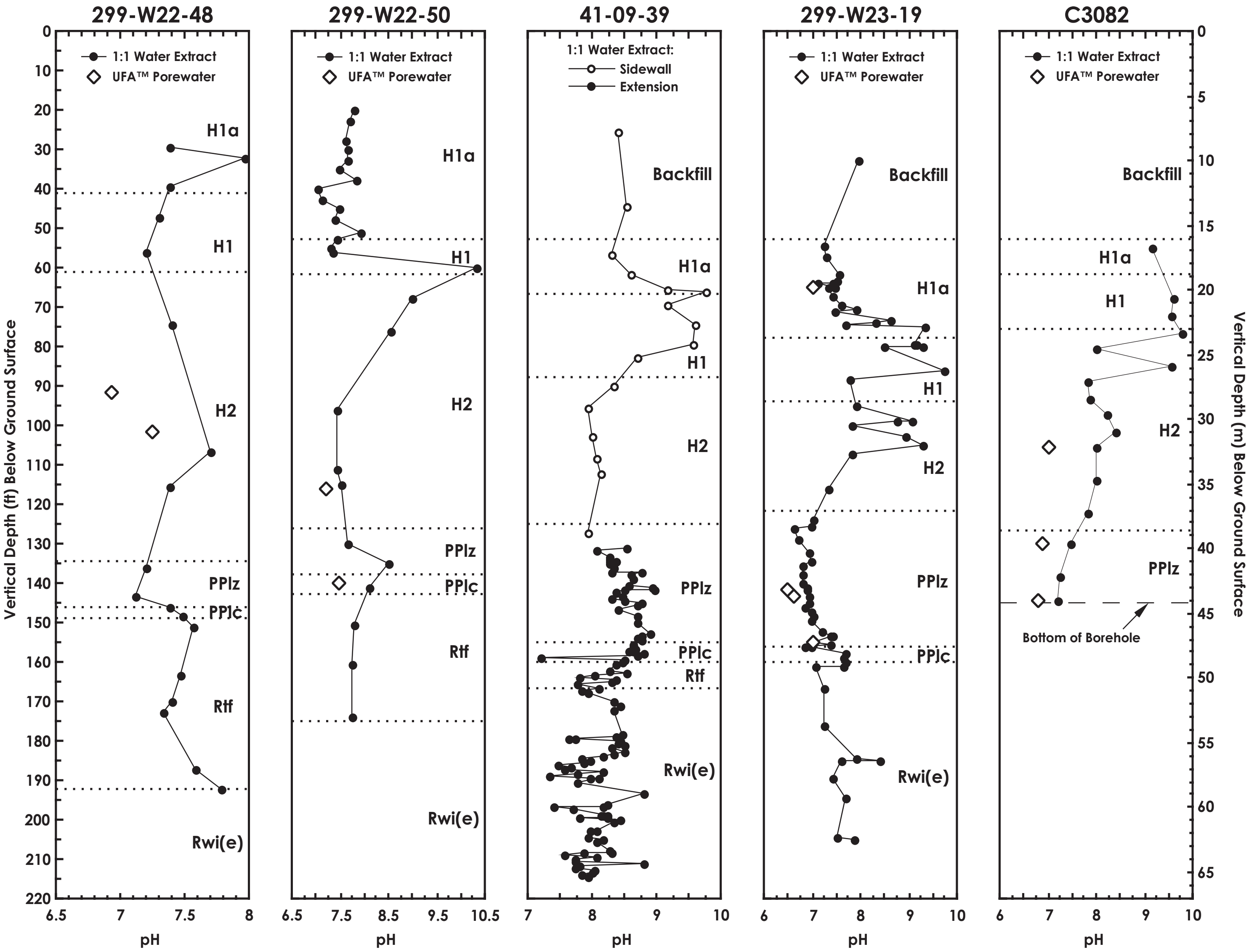

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Figure 3.1-6. pH versus Depth in Five New Boreholes at the SX Tank Farm. See Figure 3.1-5 for definition of stratigraphy (1:1 extract = data from water leached core samples; UFA = data from ultracentrifuged porewater; sidewall = water extract data from sidewall cores; extension = data from core from borehole extensions).

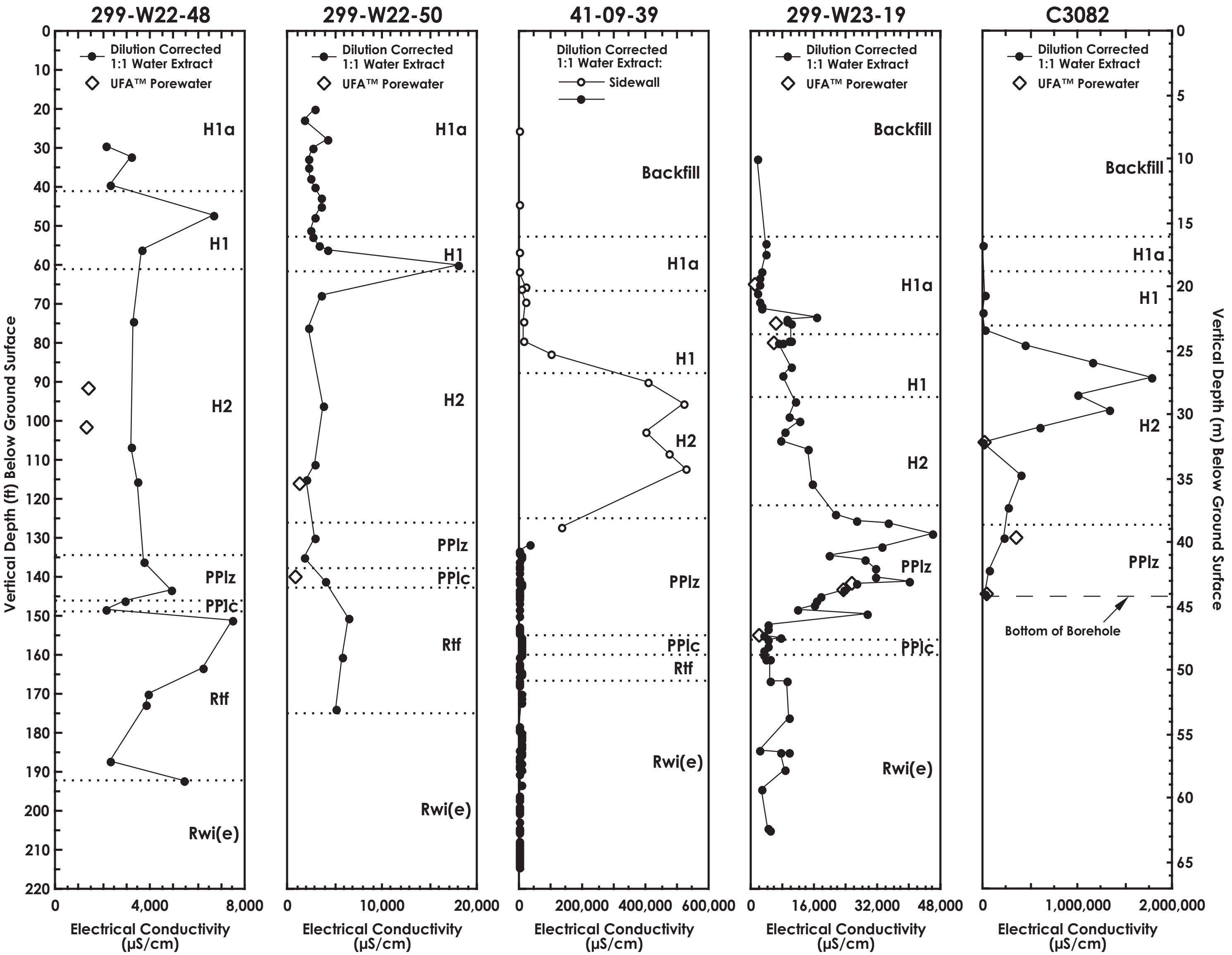

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Figure 3.1-7. Dilution-Corrected Electrical Conductivity versus Depth in Five New Boreholes at the SX Tank Farm. See text for explanation of dilution corrected and Figure 3.1-5 for definition of stratigraphy.

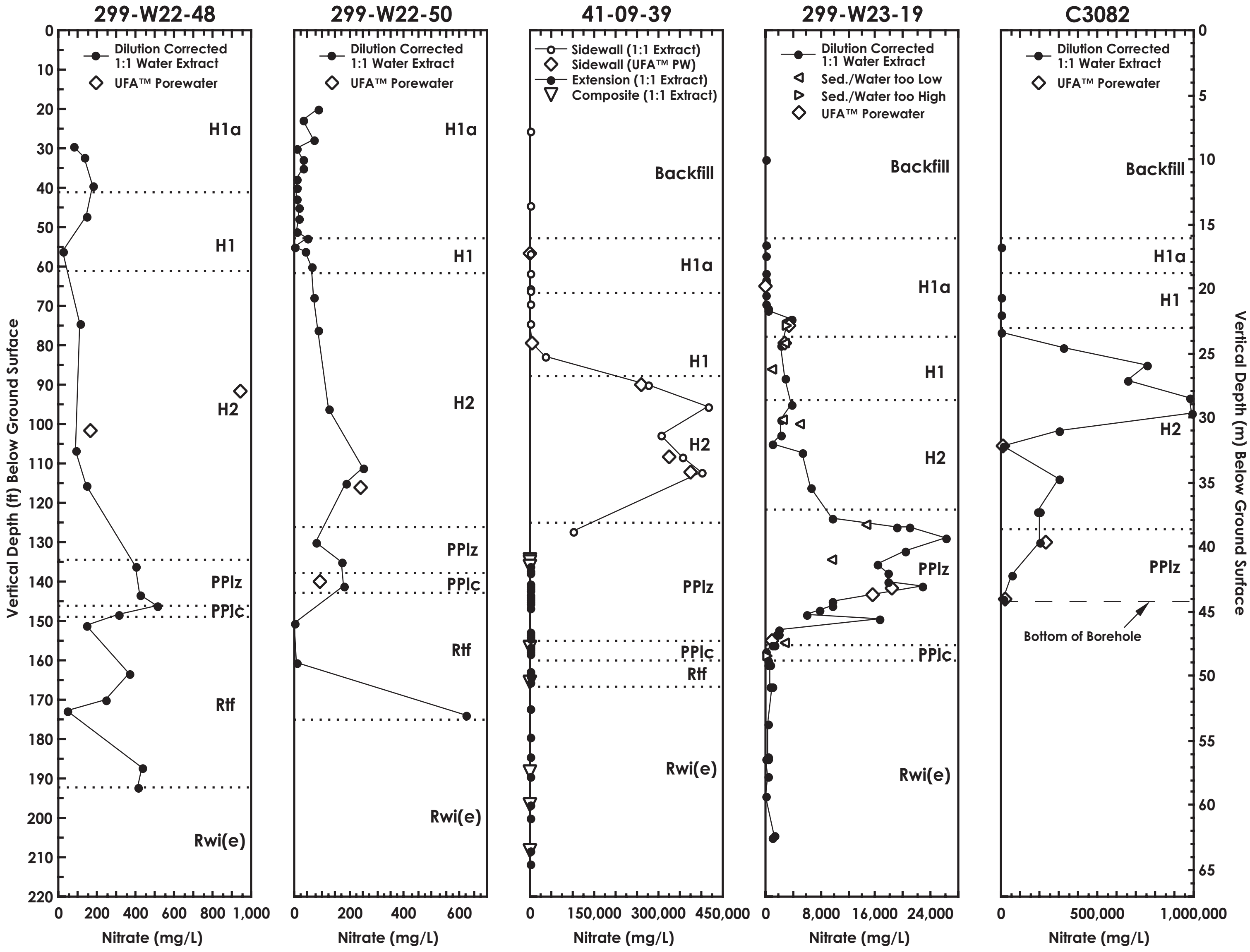

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Figure 3.1-8. Dilution-Corrected Nitrate Concentrations versus Depth in Five New Boreholes at the SX Tank Farm. See text for explanation of dilution corrected and Figure 3.1-5 for definition of stratigraphy.

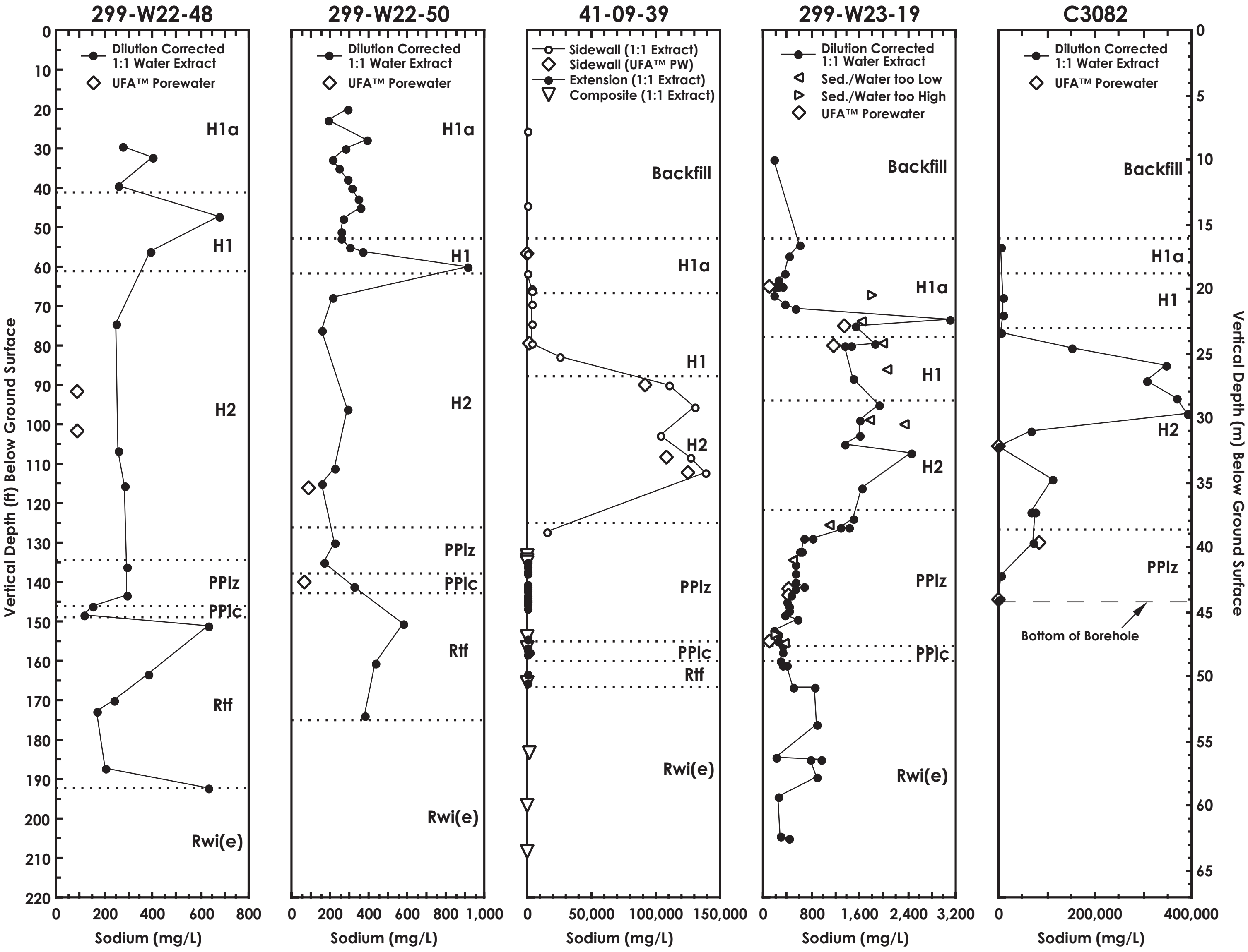

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Figure 3.1-9. Dilution-Corrected Sodium Concentrations versus Depth in Five New Boreholes at the SX Tank Farm. See text for explanation of dilution corrected and Figure 3.1-5 for definition of stratigraphy.

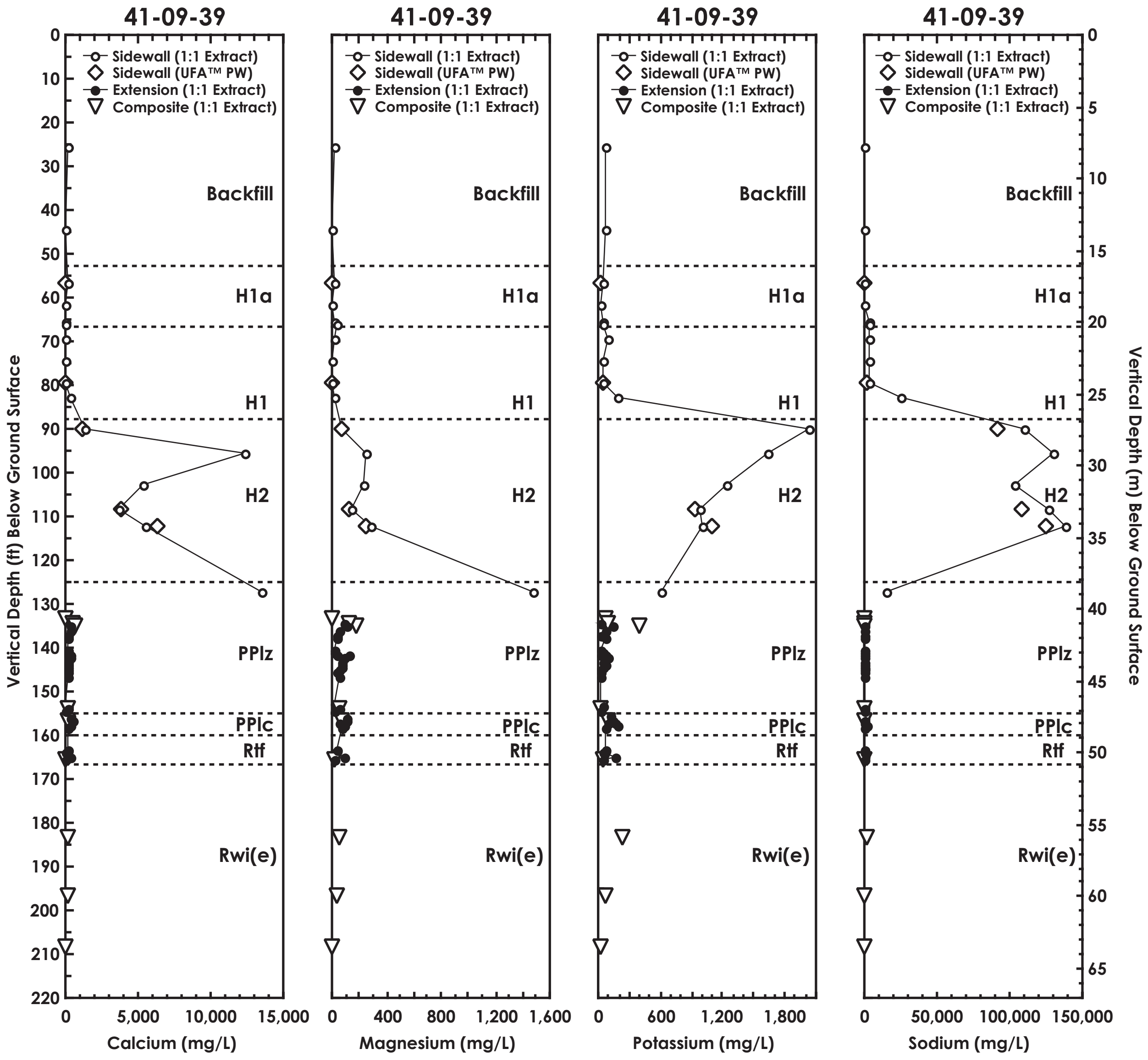

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Figure 3.1-10a. Alkali and Alkaline-Earth Metal Profiles for Five New Boreholes in the SX Tank Farm. The trends show evidence of cation exchange reactions.

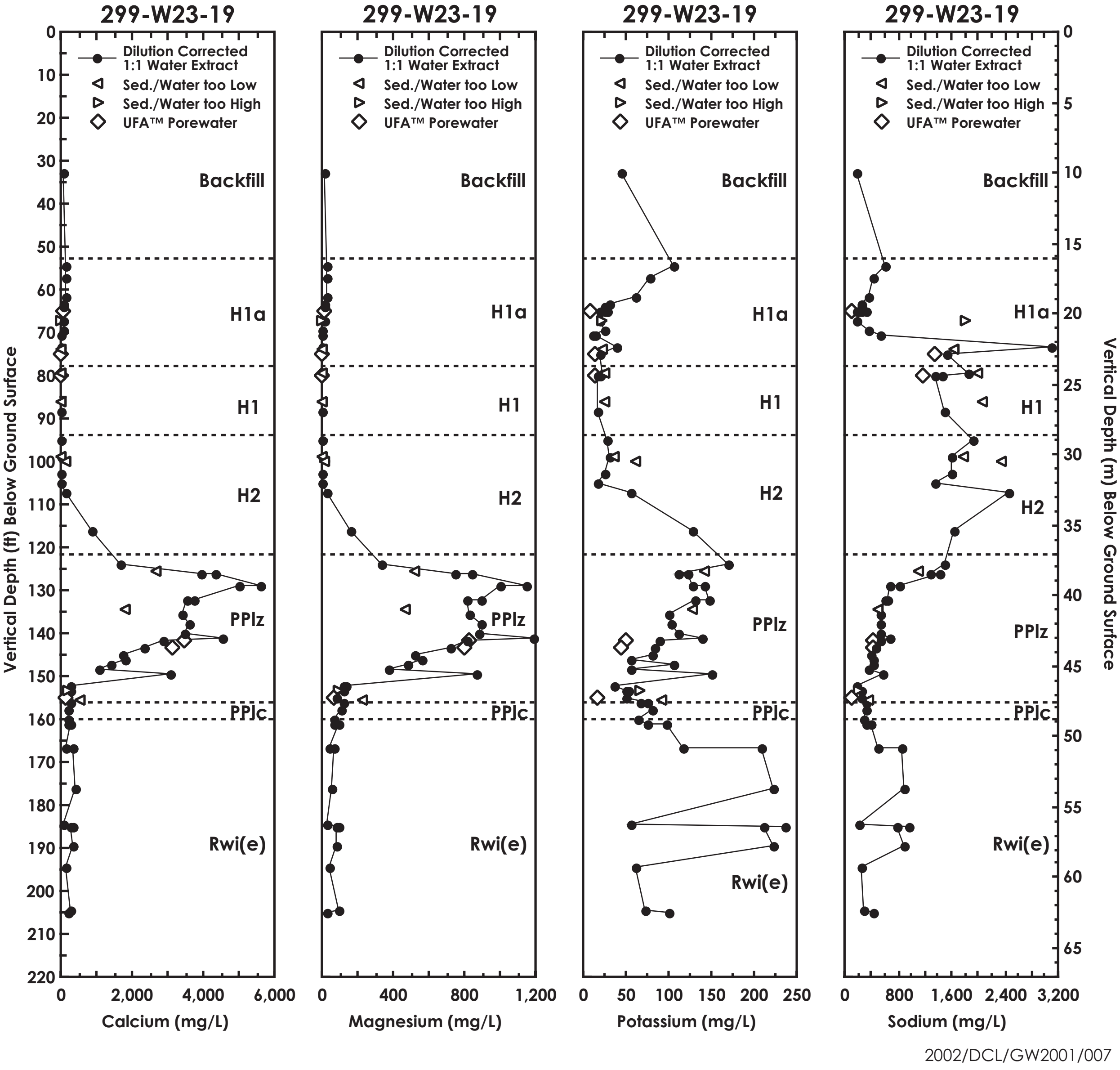

Figure 3.1-10b. (contd)

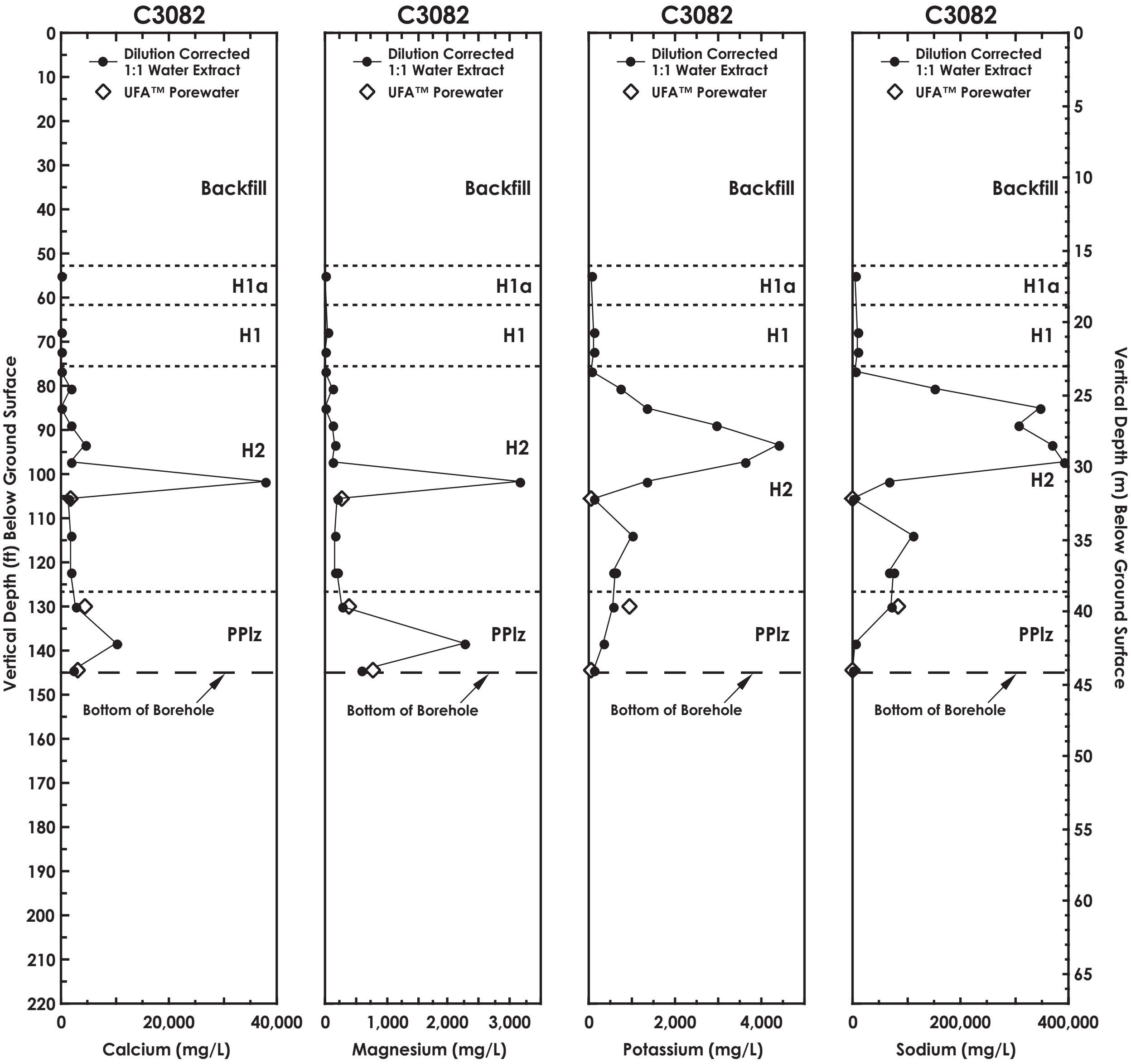

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Figure 3.1-10c. (contd)

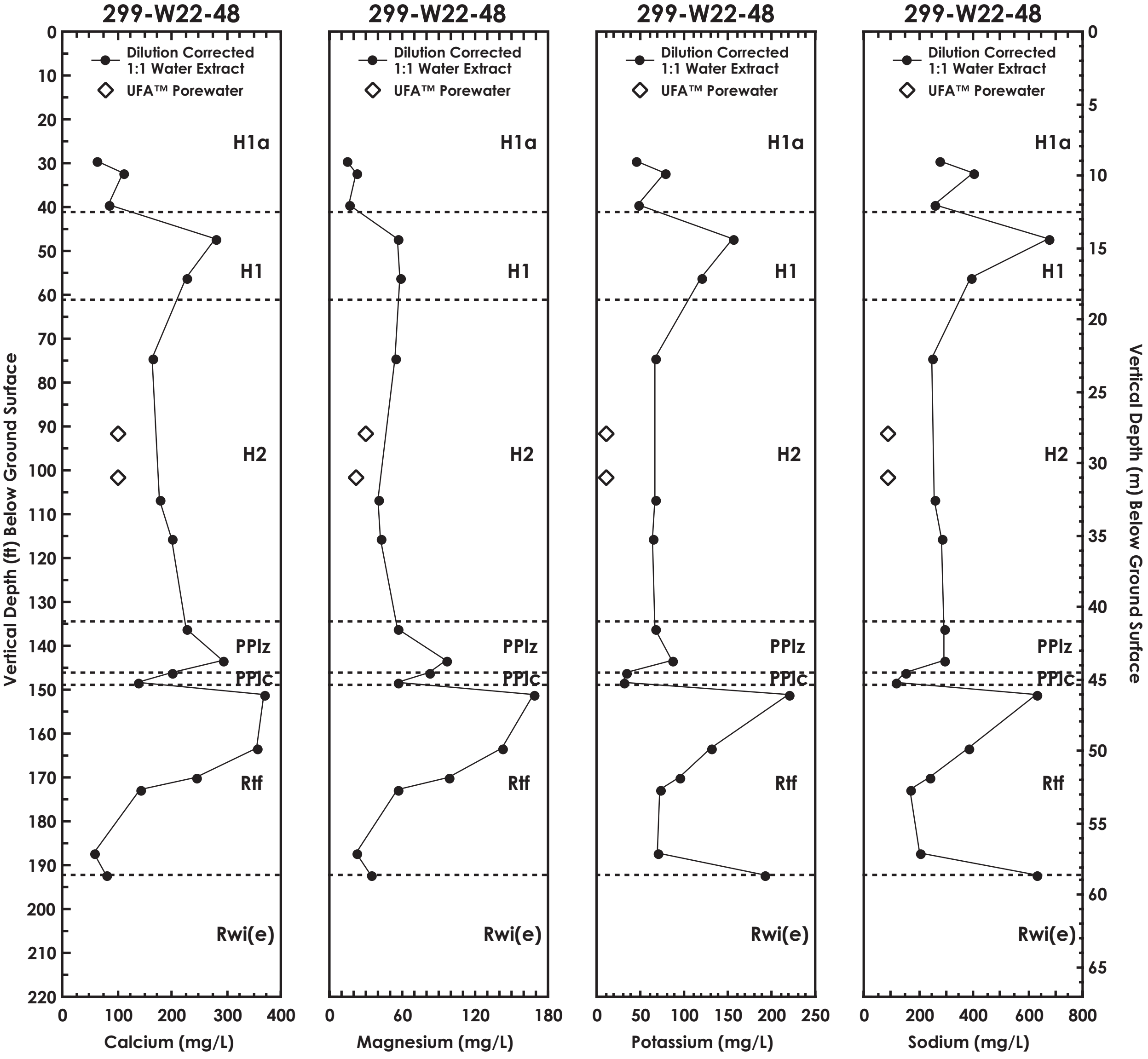

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Figure 3.1-10d. (contd)

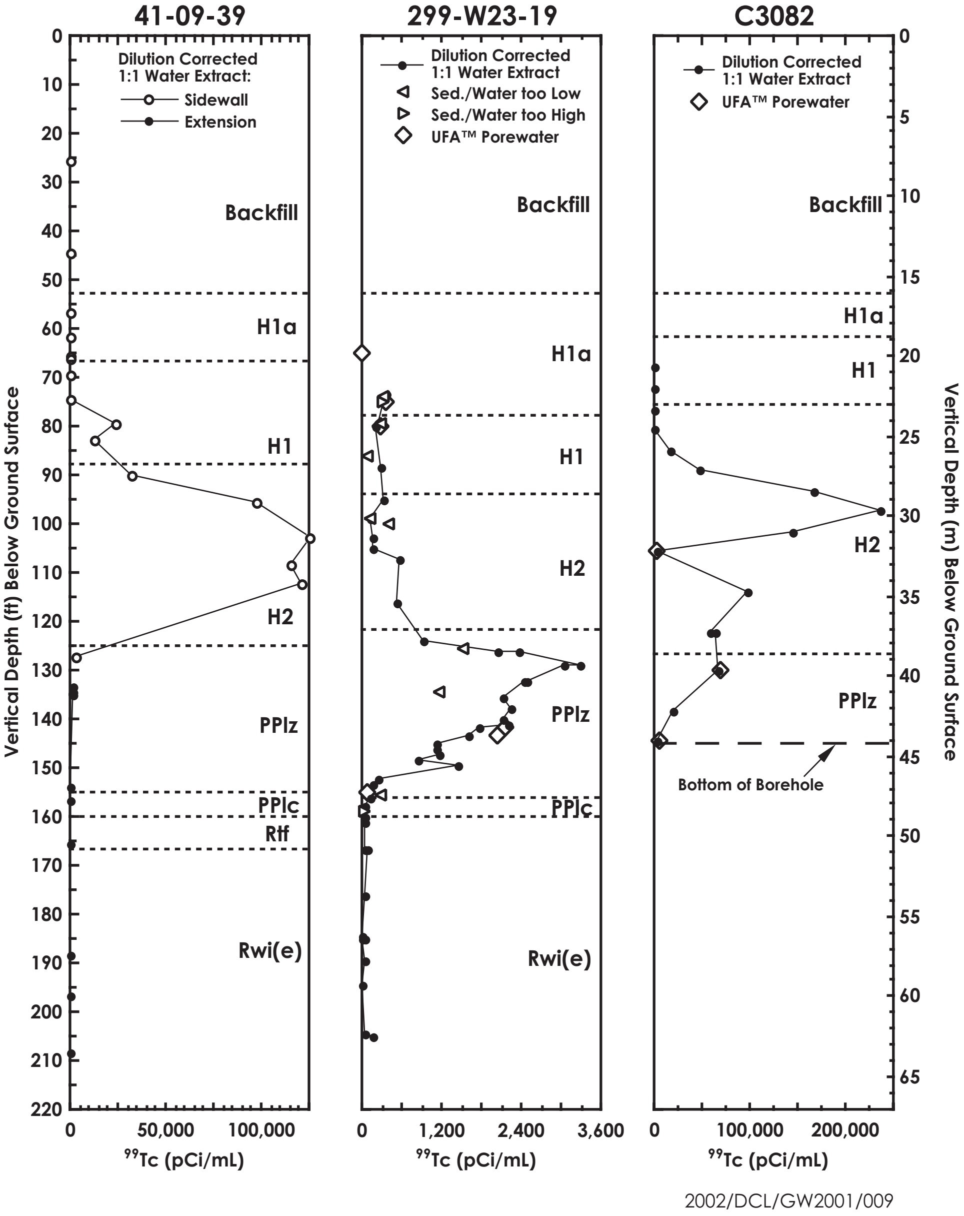

Figure 3.1-11. Dilution-Corrected Technetium-99 Concentrations versus Depth in Three New Boreholes at the SX Tank Farm. See text for explanation of dilution corrected and Figure 2.1.3-1 for definition of stratigraphy.

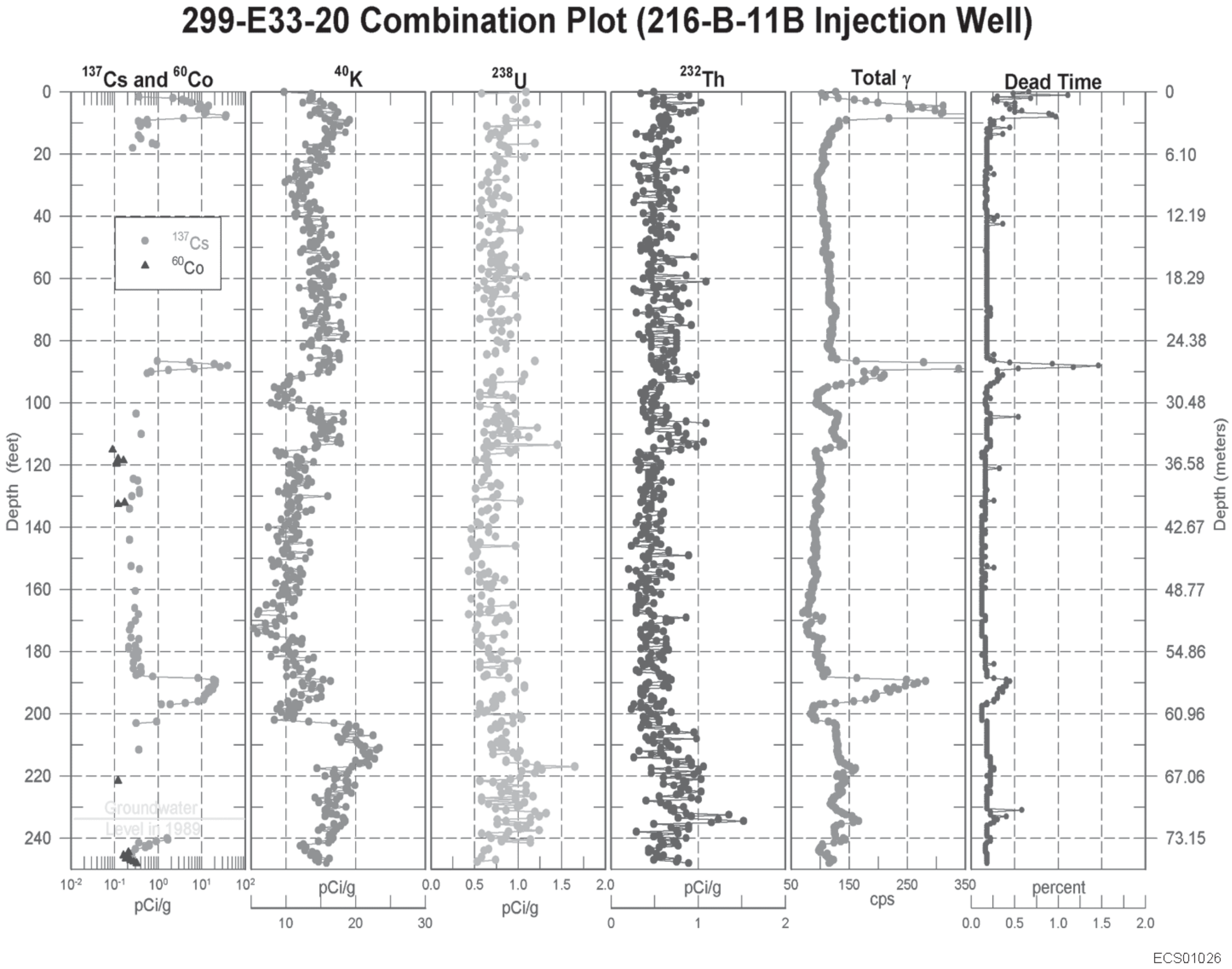

Figure 3.1-12. Spectral Gamma-Ray Log Acquired in Borehole 299-E33-20 Near the 216-B-11B Injection Well, 200 East Area

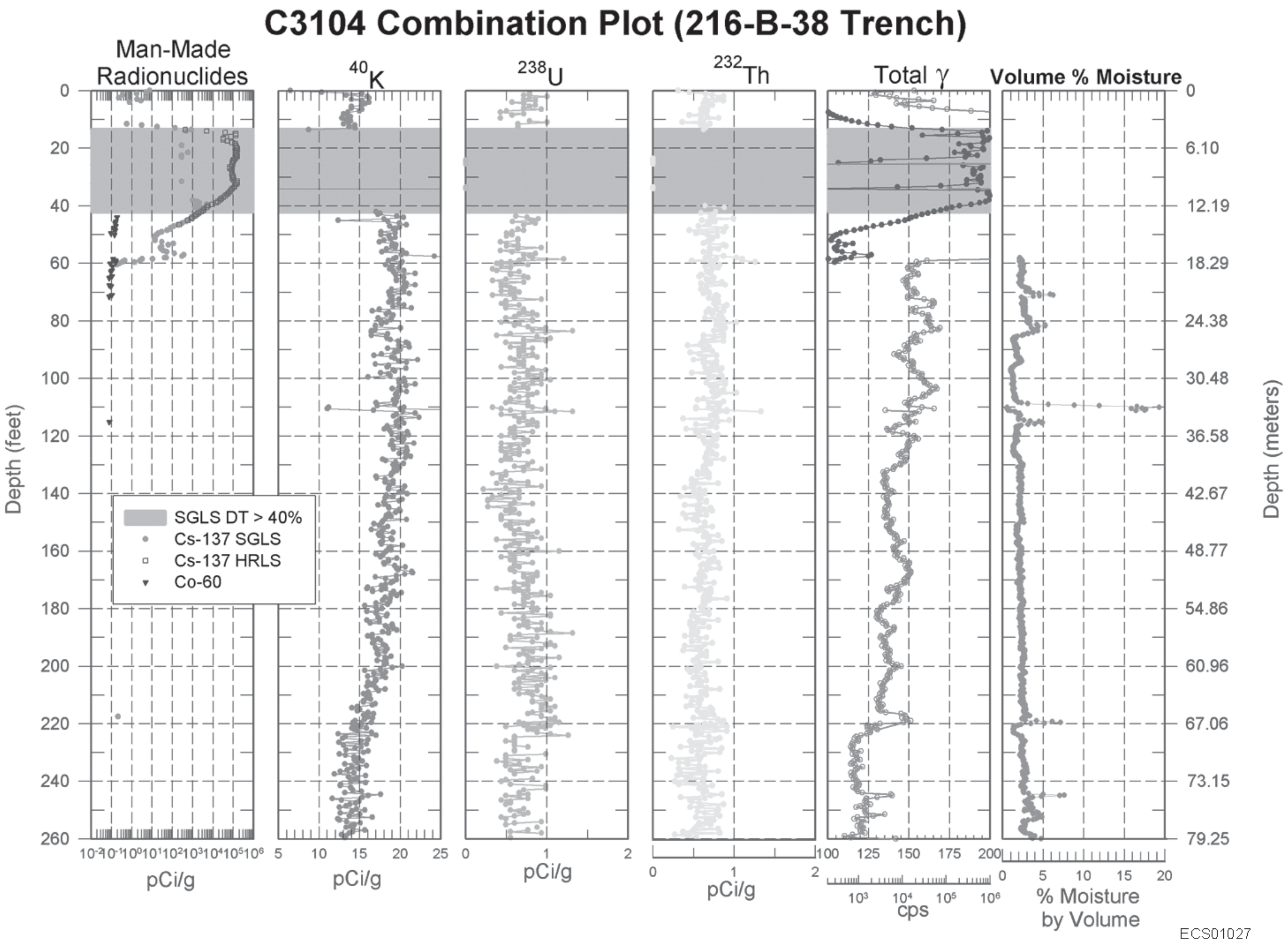

Figure 3.1-13. Spectral Gamma-Ray Log Acquired in Borehole C3104 Near the 216-B-38 Trench, 200 East Area

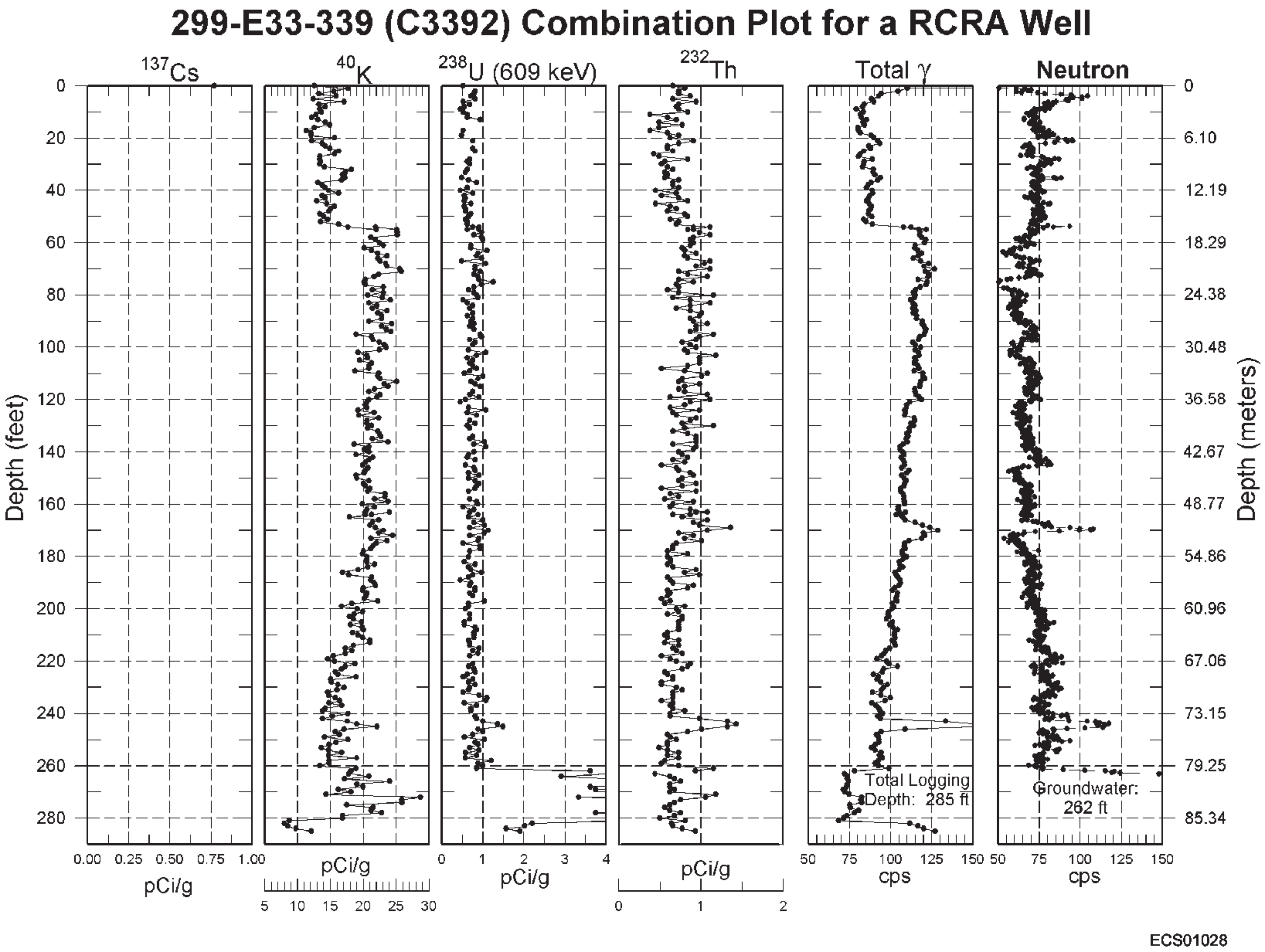

Figure 3.1-14. Spectral Gamma-Ray Log Acquired in Groundwater Monitoring Well 299-E33-339 Near Waste Management Area B-BX-BY

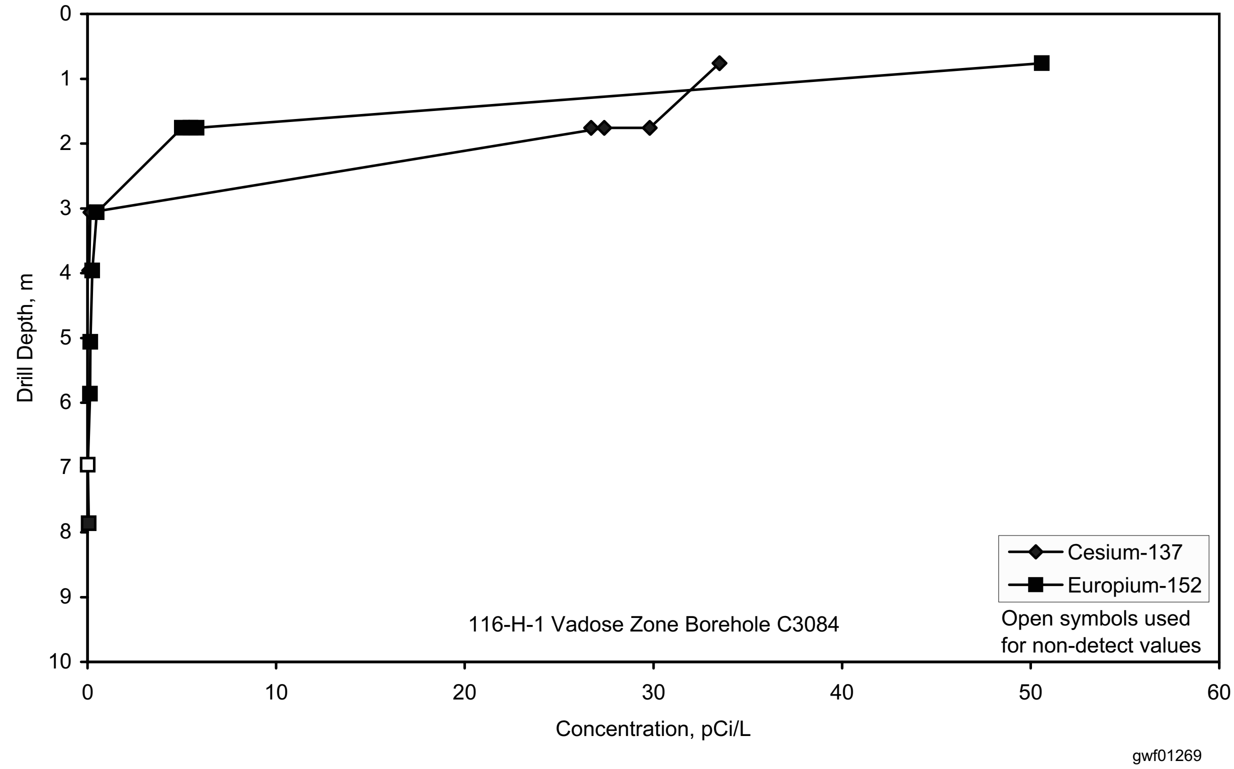

Figure 3.1-15. Concentration versus Depth for Cesium-137 and Europium-152 in Borehole Samples at the 116-H-1 Trench

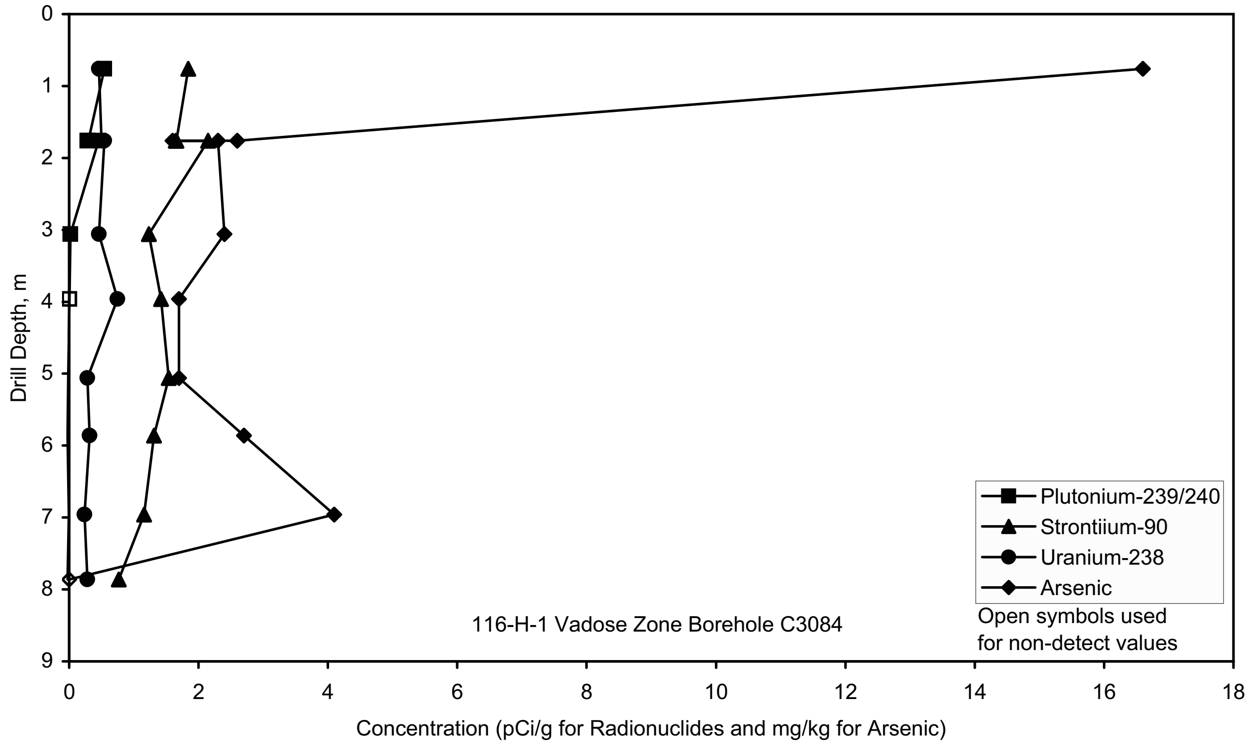

Figure 3.1-16. Concentration versus Depth for Several Constituents in Borehole Samples at the 116-H-1 Trench

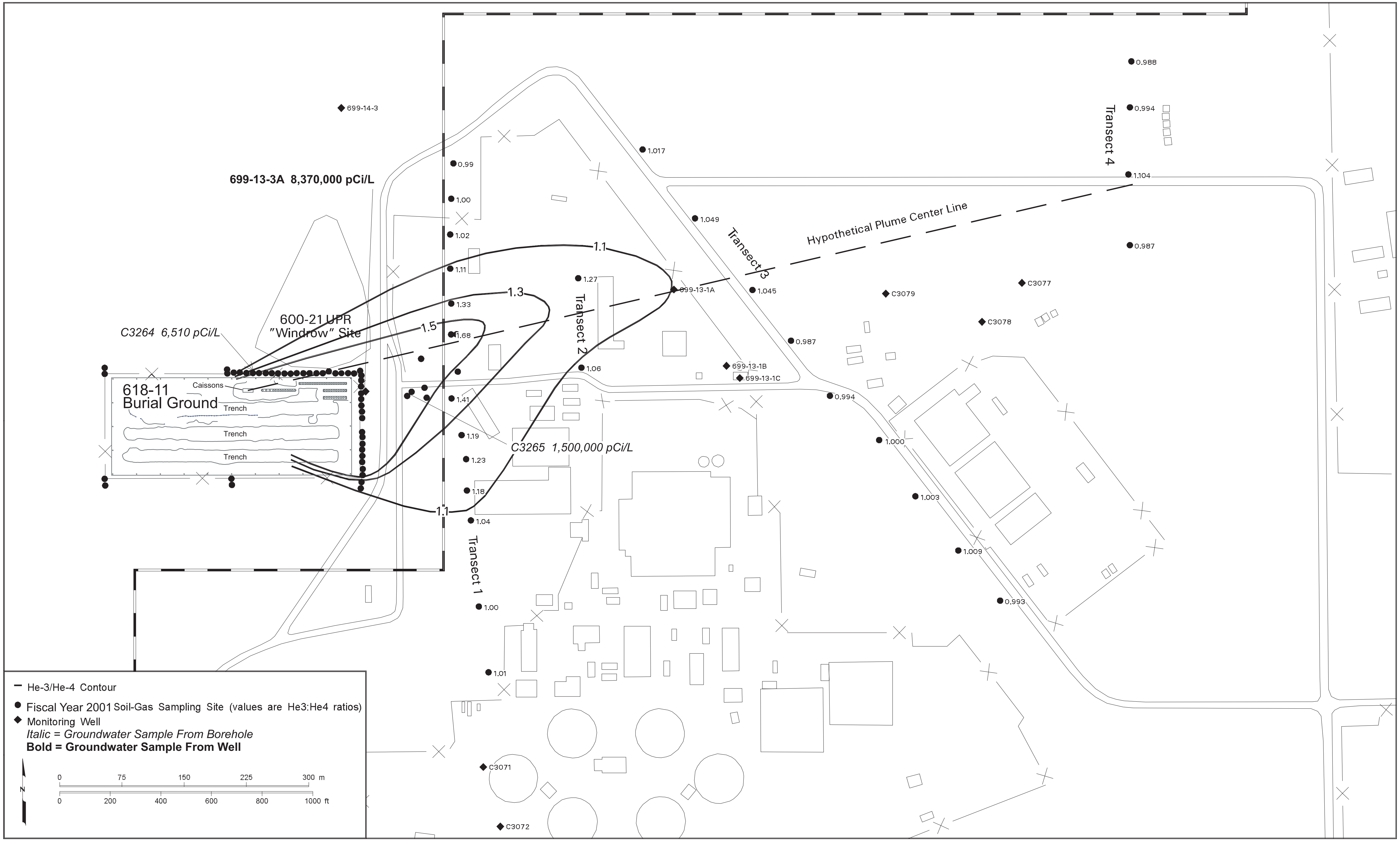

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Figure 3.1-17. Locations of Monitoring Points and Results of Fiscal Year 2001 Helium Ratio Analyses at the 618-11 Burial Ground

Figure 3.1-18. Sampling for 200-TW-1 and 200-TW-2 Remedial Investigations

3.2 Vadose Zone Monitoring

D. G. Horton

Vadose zone monitoring occurred at four major areas on the Hanford Site in fiscal year 2001. Leachate and soil gas monitoring continued at the Solid Waste Landfill and the Environmental Restoration Disposal Facility. Also, soil gas monitoring at the carbon tetrachloride expedited-response-action site continued during fiscal year 2001. Finally, borehole geophysical monitoring of dry wells in single-shell tank farms for leak detection and subsurface contaminant migration continued during the year.

In addition to these monitoring activities, several vadose zone monitoring tools were installed at one borehole at Waste Management Area B-BX-BY tank farms. These instruments will provide continuous soil column monitoring in that tank farm.

Vadose zone monitoring is performed to track the migration of contaminants from tank leaks or other activities related to tank farm operations.

3.2.1 Leachate Monitoring at the Environmental Restoration Disposal Facility

J. M. Faurote

Bechtel Hanford, Inc. operates the Environmental Restoration Disposal Facility to dispose of radioactive, hazardous, dangerous, and mixed waste generated during waste management and remediation activities at the Hanford Site. In fiscal year 2001, Bechtel Hanford, Inc. published the results of groundwater monitoring and sampling at the Environmental Restoration Disposal Facility during the years 1997 through 2000 (BHI-01382). Part of the published results contains laboratory analyses of leachate collected from beneath the facility. This section discusses those results.

The Environmental Restoration Disposal Facility (shown above) is used to dispose of low-level radioactive, hazardous, dangerous, and mixed waste generated during waste management and remediation activities at the Hanford Site.

The Environmental Restoration Disposal Facility began operation in July 1996. Located between the 200 East and 200 West Areas (see Plate 1), the facility is currently operating one cell that became active during June 2000. Two other cells received waste until September 2000. Interim covers were placed over the used parts of those cells. A fourth cell has been constructed but has not been used to date. The four existing cells have an area of ~20 hectares.

Each cell is lined to collect leachate resulting from water added as a dust suppressant and natural precipitation. The liner is sloped to a sump and the leachate is pumped from the sump to the tanks. After ~760,000 liters of leachate are collected, samples are taken and analyzed for 41 volatile organics, 64 semivolatile organics, 23 metals, 9 radionuclides, and gross alpha and gross beta. The number of samples collected during the year depends on the amount of leachate collected.

The purpose of the data is to provide an inventory to the Effluent Treatment Facility, where the leachate is disposed, and to provide quarterly sampling of leachate for delisting analyses. The purpose of the delisting analyses is to enable handling the leachate as non-hazardous waste. The results also are used to determine whether additional analytes should be added to the groundwater monitoring list.

Analyses of leachate from the Environmental Restoration Disposal Facility show that the levels of contaminants in the leachate meet established limits and that no additional analytes are recommended for the groundwater monitoring program at the facility.

Analyses of leachate collected from the Environmental Restoration Disposal Facility indicate that the liquid collected to date meets the limits established in the Environmental Restoration Disposal Facility delisting record of decision amendment (ROD 1999d; BHI-01489). The data also show that the leachate contains several common inorganic ions and metals that are expected to be associated with leachate from a landfill receiving primarily soil (BHI-01489). In addition, the results show the occurrence of several organic compounds that are expected to be present as laboratory contaminants. Except for phthalate ester compounds, the organic compounds detected in the leachate are also detected in the associated analytical blank samples. Most of the phthalate ester detections are not associated with apparent laboratory blank contamination. However, phthalate esters are common plasticizers and are commonly encountered in landfill leachate that has contacted synthetic liner material. Based on the analytical results of leachate samples, no additional analytes are recommended for addition to the groundwater monitoring program at the Environmental Restoration Disposal Facility.

3.2.2 Leachate and Soil Gas Monitoring at the Solid Waste Landfill

R. A. Del Mar

The Solid Waste Landfill is a land disposal facility in the center of the Hanford Site (see Figure 2.11-1). It covers an area of ~26.7 hectares and began operations in 1973 to receive non-hazardous, non-radioactive sanitary waste generated from Hanford Site operations. The Solid Waste Landfill stopped receiving waste in 1996 and an "interim cover" consisting of 0.6 to 1.2 meters of soil was placed over all trenches. Current monitoring at the Solid Waste Landfill consists of quarterly sampling of groundwater, soil gas, and leachate. Recent groundwater monitoring results are discussed in Section 2.11.1.3. This section summarizes leachate and soil gas monitoring results.

In all, the Solid Waste Landfill consists of ~70 single disposal trenches, and 14 double disposal trenches. Based on trench geometry and the thickness of the waste layer, the capacity of a trench per linear meter is ~30.6 cubic meters for the double trenches, and 8.4 cubic meters for the single trenches. Based on this estimation, total design capacity of the Solid Waste Landfill is ~596,400 cubic meters.

3.2.2.1 Leachate Monitoring

One of the double trenches overlies a lined, basin lysimeter designed to collect leachate generated by infiltration through the overlying refuse. This lysimeter covers an area of ~88 square meters. A discharge pipe continuously drains leachate by gravity flow from the basin to a nearby collection pump. However, because the lysimeter only collects leachate from one of 84 trenches, and it is installed under one of the newer trenches built after implementation of regulations restricting land disposal practices, leachate collected from this lysimeter may not be representative of leachate drainage throughout the entire landfill area. Still, it provides some indication of the rate of infiltration and some of the contaminants that may be reaching the groundwater.

Leachate is collected from the basin lysimeter every 10 to 14 days. Figure 3.2-1 shows the rate of leachate generation since routine monitoring was started in 1996. For the past 2 to 3 years, the generation rate has been between 3.8 to 7.6 liters per day, which is consistent with what is expected based on precipitation, soil type, and the vegetative cover.

Figures 3.2-2 and 3.2-3 provide historical data on some of the key metal and organic contaminants found in the leachate. Some of these contaminants (most notably arsenic, manganese, nickel, and 1,4-dioxane) continue to be found in concentrations exceeding groundwater quality criteria (WAC 173-200) and/or maximum contaminant levels (WAC 246-290) in the leachate.

The most notable change occurring during the 2000/2001 sampling period was a brief spike in several non-chlorinated organic constituents, including 2-butanone, 2-pentanone, and 2-hexanone, which were found to be in the 20 to 30 µg/L range. All of these organics were again below detectable limits during the latest sampling period, i.e., third quarter 2001.

3.2.2.2 Soil Gas Monitoring

Soil gas monitoring at the Solid Waste Landfill uses eight shallow monitoring stations located around the perimeter of the landfill. Each station consists of two soil gas probes at depths of ~2.75 and 4.6 meters. Soil gas is monitored quarterly to determine concentrations of oxygen, carbon dioxide, methane, and several key volatile organic compounds. No contaminants of concern were discovered above reporting limits during the 2000/2001 sampling period.

3.2.3 Carbon Tetrachloride Monitoring and Remediation

V. J. Rohay

Soil-vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200 West Area. The U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology authorized the U.S. Department of Energy (DOE) to initiate this remediation in 1992 as a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) expedited response action. The primary focus in the following discussion is on fiscal year 2001 activities associated with the carbon tetrachloride removal. For descriptions of past work, see BHI-00720 and Section 3.2 in PNNL-13404.

There are three soil-vapor extraction systems in use: 14.2, 28.3, and 42.5 cubic meter systems. The 14.2 cubic meters per minute soil-vapor extraction system operated from April 4 through July 18, 2001, at the combined 216-Z-1A/-12/-18 well field and from July 20 through September 30, 2001, at the 216-Z-9 well field (see PNNL-13080 for location maps of the well fields). The system was maintained in standby mode throughout fiscal year 2000 and during the winter in fiscal year 2001 (October 1, 1999, through April 3, 2001). The 28.3 and 42.5 cubic meters per minute soil-vapor extraction systems were maintained in standby mode during fiscal years 2000 and 2001.

To track the effectiveness of the remediation effort, soil-vapor concentrations of carbon tetrachloride were monitored at the inlet to the soil-vapor extraction system and at individual online extraction wells during the 6-month operating period. To assess the impact of non-operation of the soil-vapor extraction system, soil-vapor concentrations of carbon tetrachloride were monitored at off-line wells and probes during the entire fiscal year.

Remediation efforts this fiscal year also included passive soil-vapor extraction and continuation of the carbon tetrachloride Innovative Treatment and Remediation Demonstration Program.

3.2.3.1 Soil-Vapor Extraction

In soil-vapor extraction, compressed air is forced into the ground through an injection well. The incoming air passes through the soil; the contaminants evaporate between the soil particles and are pulled toward the extraction well. The extracted vapor is then treated to remove contaminants.

Soil-vapor extraction to remove carbon tetrachloride from the vadose zone resumed April 4, 2001 at the 216-Z-1A/-12/-18 well field. Initial online wells were selected within the perimeter of the 216-Z-1A tile field. As extraction continued, wells farther away from the tile field and wells within the 216-Z-12 and 216-Z-18 cribs were brought online. Extraction wells open near the less-permeable Plio-Pleistocene Unit, where the highest carbon tetrachloride concentrations have consistently been detected, were selected to optimize mass removal of contaminant. Initial carbon tetrachloride concentrations measured at the soil-vapor extraction system inlet were ~40 ppmv (Figure 3.2-4). After 15 weeks of extraction, concentrations had decreased to ~25 ppmv. The daily mass-removal rate increased significantly at least once during this period as a result of adjustments in the mix of online wells and the flow rate.

Soil-vapor extraction resumed July 20, 2001, at the 216-Z-9 well field. Initial online wells were selected close to the 216-Z-9 trench. As extraction continued, wells farther away from the trench were brought online. Each selection of online wells included wells open near the groundwater and wells open near the Plio-Pleistocene Unit. Initial carbon tetrachloride concentrations measured at the soil-vapor extraction system inlet were ~215 ppmv (see Figure 3.2-4). After 10 weeks of extraction, concentrations had decreased to ~40 ppmv. The daily mass removal rate increased significantly at least once during this period as a result of adjustments in the mix of online wells and the flow rate.

During fiscal year 2001, two existing wells at the 216-Z-9 trench were deepened and completed with screened intervals both above and below the Plio-Pleistocene Unit to enhance vapor extraction. The soil-vapor extraction system was used to conduct a 3-hour soil-vapor extraction test at each of the two wells that were deepened. Well 299-W15-95L was tested on July 20 and well 299-W15-84L on July 23. The objectives of the tests were to observe initial carbon tetrachloride concentrations at these new extraction intervals and to compare soil-vapor samples collected using the soil-vapor extraction system to those collected using a sample pump during drilling.

During each test, only one test well was placed online to the soil-vapor extraction system. A minimum volume of air was extracted initially to obtain a representative sample of the concentration adjacent to the well. Soil-vapor extraction was then continued to determine the carbon tetrachloride concentration at progressive distances from the well. Concentrations were recorded at start-up and at 1-hour intervals following start-up.

Well 299-W15-95L was completed with a screen from 39.3 to 48.5 meters below ground surface. Carbon tetrachloride concentrations in vapor samples collected during drilling through this interval varied from 174 ppmv at 37.2 meters below ground surface to 46 ppmv at 44.8 meters to <1 ppmv at 50.3 meters (BHI-01552). During the soil-vapor extraction test, the carbon tetrachloride concentrations measured at the soil-vapor extraction system inlet increased from 35 to 62 ppmv.

Well 299-W15-84L was completed with a screen from 50.6 to 59.8 meters below ground surface. Carbon tetrachloride concentrations in vapor samples collected during drilling through this interval varied from 1 ppmv at 45.7 meters below ground surface to 35 ppmv at 51.8 meters to 38 ppmv at 55.2 meters to 1 ppmv at 58.9 meters (BHI-01552). During the soil-vapor extraction test, the carbon tetrachloride concentrations measured at the soil-vapor extraction system inlet increased from 27 to 29 ppmv.

During 6 months of soil-vapor extraction in fiscal year 2001, 709 kilograms of carbon tetrachloride were removed from the vadose zone. Of this total, 335 kilograms were removed from the 216-Z-1A/-12/-18 well field during 106 days of operation and 374 kilograms were removed from the 216-Z-9 well field during 74 days of operation.

As of September 2001, 77,169 kilograms of carbon tetrachloride had been removed from the vadose zone since extraction operations started in 1991 (Table 3.2-1). Since initiation, the extraction systems are estimated to have removed 7% of the residual mass at well field 216-Z-1A/-12/-18 and 22% of the mass at well field 216-Z-9. This estimate assumes that all of the mass that has not been lost to the atmosphere (21% of the original inventory), dissolved in groundwater (2% of the original inventory), or biodegraded (1% of the original inventory) is still available in the vadose zone as residual mass (BHI-00720; WHC-SD-EN-TI-101).

Soil-vapor extraction of carbon tetrachloride in 200 West Area continued in fiscal year 2001. By the end of the year, 77,169 kilograms of carbon tetrachloride had been removed from the vadose zone since the remediation began in 1991.

3.2.3.2 Monitoring at Off-Line Wells and Probes

During fiscal year 2001, soil-vapor concentrations of carbon tetrachloride were monitored near the ground surface, near the Plio-Pleistocene Unit (~40 meters below ground surface), and near groundwater (~66 meters below ground surface). Soil-vapor concentrations were monitored near the ground surface and groundwater to assess whether non-operation of the soil-vapor extraction system is allowing carbon tetrachloride to migrate out of the vadose zone. The maximum concentration detected near the ground surface (between 2 and 10 meters below ground surface) was 17 ppmv. Near the groundwater, at a depth of 58 meters below ground surface, the maximum concentration was 9 ppmv.

Soil-vapor concentrations also were monitored above and within the Plio-Pleistocene Unit to provide an indication of concentrations that could be expected during restart of the soil-vapor extraction system. (The Plio-Pleistocene Unit is a geologic stratum that may be a confining layer to carbon tetrachloride vapors.) The maximum concentration detected near the Plio-Pleistocene Unit (between 25 and 41 meters below ground surface) was 360 ppmv in well 299-W15-217 (35 meters below ground surface) at the 216-Z-9 site. During monitoring in fiscal years 1997, 1998, 1999, and 2000, the highest carbon tetrachloride concentrations also were detected in this well.

At the 216-Z-1A/-12/-18 well field, the maximum carbon tetrachloride concentration detected near the Plio-Pleistocene Unit was 306 ppmv in well 299-W18-248 (41 meters below ground surface) adjacent to the 216-Z-1A tile field. During monitoring in fiscal years 1997, 1998, 1999, and 2000, the highest concentrations were detected at wells within the 216-Z-1A tile field.

The temporary suspension of soil-vapor extraction in fiscal year 2001 appears to have caused minimal transport of carbon tetrachloride through the soil surface to the atmosphere. This view is supported because carbon tetrachloride concentrations did not increase significantly at the near-surface probes monitored in fiscal year 2001. In addition, suspending operations of the soil-vapor extraction system appears to have had no negative impact on groundwater quality, because carbon tetrachloride concentrations have not increased significantly near the water table since that time.

3.2.3.3 Passive Soil-Vapor Extraction

Passive soil-vapor extraction is a remediation technology that uses naturally-induced pressure gradients between the subsurface and the surface to drive soil vapor to the surface. In general, falling atmospheric pressure causes subsurface vapor to move to the atmosphere through wells, while rising atmospheric pressure causes atmospheric air to move into the subsurface. Passive soil-vapor extraction systems are designed to use this phenomenon to remove carbon tetrachloride from the vadose zone.

Passive soil-vapor extraction systems were installed at the end of fiscal year 1999 at eight boreholes that are open near the vadose/groundwater interface at the 216-Z-1A/-12/-18 well field. The passive systems are outfitted with check valves that only allow soil vapor to flow out of the borehole (i.e., one way movement), and a canister holding granular activated carbon that adsorbs carbon tetrachloride before the soil vapor is vented to the atmosphere. The check valve prohibits flow of atmospheric air into the borehole during a reverse barometric pressure gradient, which would dilute and spread carbon tetrachloride vapors in the subsurface. Each system also has an inline, replaceable cartridge of granular activated carbon to collect samples upstream of the canister of granular activated carbon.

Soil-vapor extraction is an innovative technology that reduces the concentration of contaminants adsorbed to the soil in the vadose zone. As the name suggests, this treatment extracts contaminants from the soil in vapor form.

Three of eight boreholes have instruments to measure hourly air pressure differentials between the ground surface and the bottom of the borehole, carbon tetrachloride concentrations, temperature, and flow rates. These data can be used to calculate an hourly estimate of the amount of mass removed from the well. The granular activated carbon in the replaceable cartridges at all eight boreholes is sampled monthly and analyzed using laboratory analytical services. Analysis of the granular activated carbon in the cartridge provides a time-integrated estimate of the mass removed while the granular activated carbon was inline.

At the two boreholes with instruments near the 216-Z-1A tile field, 299-W18-6L and 299-W18-252L, the peak carbon tetrachloride concentrations were 40 and 46 ppmv, respectively. Well 299-W18-247L located at the southeastern corner of the 216-Z-18 crib had a peak concentration of 14 ppmv. Flow rates measured at the wells ranged from 0 to as high as 0.4 cubic meters per minute.

3.2.3.4 Innovative Treatment and Remediation Demonstration Program

DOE began an Innovative Treatment and Remediation Demonstration Program for carbon tetrachloride in January 1999. The program is evaluating innovative technologies to characterize and remediate carbon tetrachloride in Hanford soil and groundwater while considering cost, performance, and regulatory issues. During fiscal year 2001, the program began preparation of a report that will summarize its evaluations. Groundwater modeling was performed during fiscal year 2000 to support evaluation of innovative technologies to remediate the carbon tetrachloride groundwater plume. The program completed the review and publication of this report in fiscal year 2001 (PNNL-13560). The Innovative Treatment and Remediation Demonstration Program will continue into fiscal year 2002.

3.2.4 The Hanford Tank Farms Vadose Zone Monitoring Project

S. M. Sobczyk, P. D. Henwood, A. W. Pearson, R. G. McCain, and S. E. Kos

A comprehensive routine monitoring project was established in fiscal year 2001 for selected borehole intervals in the single-shell tank farms. The logging system used for monitoring is the Radionuclide Assessment System. Routine gross gamma logging of monitoring boreholes (drywells) surrounding single-shell tanks was discontinued in 1994, while a baseline characterization of the tank farm boreholes was conducted with the Spectral Gamma Logging System between 1995 and 2000. The baseline project established a record of existing contamination in the vadose zone beneath the single-shell tank farms. The monitoring project is to detect changes occurring since the baseline data were collected.

The general approach of the monitoring project is to prioritize boreholes according to the potential for detectable changes in vadose zone gamma activity and to assist in identifying or verifying future tank leaks. Accordingly, boreholes are weighted according to (1) whether measurements have indicated contaminant movement in the past, (2) whether the borehole is located near a tank containing a significant volume of drainable liquid, or (3) whether the borehole is near a tank that has leaked a significant volumes of liquid. The methods used to prioritize boreholes is described in MAC-HGLP 1.8.1. Monitoring also supports waste retrieval operations and other tank farm activities. When routine monitoring with the Radionuclide Assessment System identifies anomalies, the Spectral Gamma Logging System, the High Resolution Logging System, and the neutron moisture tool may be used for these special investigations.

The Radionuclide Assessment System was built for DOE's Office of River Protection during fiscal year 2001. It consists of a geophysical logging system mounted in a pickup truck. Three sodium iodide detectors are used to cover the range of the anticipated levels of contamination. The Radionuclide Assessment System is designed to detect changes in gamma activity over time. The Radionuclide Assessment System is a simpler, faster, and more cost-effective logging system than is the Spectral Gamma Logging System and is specifically designed for routine monitoring.

The Radionuclide Assessment System was initiated in June 2001 and has been ongoing since that time. The system was used in 113 drywells monitoring the vadose zone at the single-shell tank farm during fiscal year 2001. A summary of logging operations from June 19 to September 30, 2001, is shown in Table 3.2-2. The fiscal year 2001 report on the results of the logging using the Radionuclide Assessment System was issued in November 2001. Routine monitoring reports for the Hanford Tank Farms Vadose Zone Monitoring Project are issued quarterly to summarize the logging results, to provide the status of any ongoing special investigations, and to provide an updated listing of borehole intervals where logging is planned in the coming months.

One hundred thirteen boreholes were logged with gamma-ray detection equipment at the single-shell tank farms in fiscal year 2001. Possible contaminant movement was identified in four boreholes at the U tank farm and five boreholes at the T tank farm.

Since June 2001, Radionuclide Assessment System logging was performed in tank farms A, BX, SX, T, and U. No contaminant movement was detected in tank farms A, BX, and SX. Possible contaminant movement was identified in boreholes 60-07-01, 60-07-10, 60-07-11, and 60-04-08 in the U tank farm and in boreholes 50-06-02, 50-06-03, 50-09-01, 50-09-10, and 50-01-09 in the T tank farm. A special report is being prepared to document contaminant migration at U tank farm to support waste retrieval operations.

Identification of contaminant movement in tank farm U is based on comparison of current Spectral Gamma Logging System logs with baseline data and indicates downward migration of uranium-238 and -235 from 1995 to 2001. In fiscal year 2001, three boreholes in the U tank farm, 60-07-01, 60-07-10, and 60-07-11, were logged with the Spectral Gamma Logging System to identify any contaminant migration in the vicinity that may have occurred since the baseline data were collected in 1995. Comparison of the data collected in 1995 and 2001 shows zones with contamination in 2001 that did not have contamination in 1995. This is interpreted as downward movement of manmade uranium (Figure 3.2-5). The Radionuclide Assessment System was also used to log these three boreholes in addition to other selected boreholes in the farm. Comparison of Radionuclide Assessment System data with Spectral Gamma Logging System data indicates movement in a fourth borehole (60-04-08). These four boreholes are between tanks U-107 and U-104 (Figure 3.2-6). Radionuclide Assessment System monitoring of these boreholes will be implemented on a quarterly basis.

Identification of possible contaminant migration in tank farm T is based on comparison of Radionuclide Assessment System data with baseline data collected with the Spectral Gamma Logging System. Because this involves comparing the responses from two different detectors, each with different response characteristics, the degree of confidence in the identification is somewhat less relative to tank farm U. The boreholes in tank farm T do not define a discrete area as at U tank farm. These boreholes also have been placed on a quarterly monitoring schedule and future comparisons between successive Radionuclide Assessment System logs are expected to provide more definitive information.

3.2.5 An Instrumented Vadose Zone Monitoring Borehole at Waste Management Area B-BX-BY

G. W. Gee, A. L. Ward, J. C. Ritter, J. B. Sisson, J. M. Hubbell, H. Sydnor, and D. A. Myers

The Office of River Protection's Vadose Zone Project drilled borehole 299-E33-46 to 80.5 meters below ground surface in the B tank farm in fiscal year 2001 (see Section 3.1.1.1). Upon reaching final depth, groundwater samples were collected and analyzed for technetium-99. The analyses showed that technetium-99 was <2,000 pCi/L, well below the predetermined criterion for completing the borehole as a groundwater monitoring well. However, researchers at Pacific Northwest National Laboratory and Idaho National Engineering and Environmental Laboratory presented an opportunity to complete the borehole as the first-ever instrumented vadose zone monitoring structure to be constructed in a Hanford Site tank farm. A complete description of the monitoring structure can be found in PNNL-13712. A summary description is given below.

Scientists installed an instrumented vadose zone monitoring structure at the single-shell tank farms, the first of its kind at a Hanford Site tank farm. A borehole at the B tank farm was instrumented with tensiometers, heat and water sensors, water samples, and a water flux meter.

The conventional technology for subsurface characterization is drilling a borehole and collecting soil samples during drilling, then analyzing the samples in a laboratory. The resulting network of drywells installed around each tank was intended for continuous monitoring for leak detection. The maximum detection depth is limited by the drywell depth.

During July and August 2001, a borehole with instruments for vadose zone monitoring and eight sets of sensors were deployed in the B tank farm in a well located adjacent to tank B-110.

Duratek Federal Services, Northwest Operations drilled the 0.2-meter-diameter borehole under the direction of CH2M HILL Hanford Group, Inc. The borehole was steel cased with bentonite and sand at the bottom. A vadose zone monitoring system assembly was lowered to the bottom of the hole. The system included an advanced tensiometer and heat-dissipation probes to measure soil water pressure and monitor for perched water bodies or water-table elevations. Temperature and water-content sensors were installed to measure soil temperature and moisture content. The water-content sensor was set against the borehole wall using its attached lever arm. The process of seating the sensor against the wall was monitored with the aid of a down-hole video system. Table 3.2-3 indicates the types of sensors and their depths in the borehole.

Once the vadose zone monitoring system was placed satisfactorily, the assembly was grouted in place with a silica flour slurry. The grout was allowed to settle a few minutes, and a sand plug was added on top of the grout. This method was repeated up to a depth of 6.2 meters below ground surface, where the backfill materials were switched to sand and native materials. A water flux meter was installed at 6 meters below ground surface and extends to within 20 centimeters of ground surface. A water-flux meter measures infiltration or drainage. A data logger was installed on the surface to collect and store the field data.

The B tank farm installation is the first installation of the vadose zone monitoring system in the sand and gravel at the Hanford Site. Information gained from the B tank farm installation will provide guidance to modify the electrode geometry to better track changes in water content. A preliminary examination of the data collected at borehole 299-E33-46 indicates abnormally high water-content readings at depths of 66.4 and 68.9 meters. A similar behavior has been observed in the laboratory when saline solutions >200 mS/m (2 mmho/cm) were used to calibrate the sensors. Thus, adding a salinity sensor into the vadose zone monitoring system sensor assembly is recommended for future arrays of vadose zone monitoring sensors.

Table 3.2-1. Carbon Tetrachloride Inventory in Primary Disposal Sites

Well Field	Estimated Mass Discharged 1955 to 1973[a] (kg)	Estimated Mass Lost to Atmosphere 1955 to 1990[b] (kg)	Mass Removed Using Soil-Vapor Extraction 1991 to 2001[c] (kg)
216-Z-1A	270,000	56,700	23,846[d]
216-Z-9	130,000 to 480,000	27,300 to 100,800	53,323
216-Z-18	170,000	35,700	
Total	570,000 to 920,000	119,700 to 196,800	77,169

(a) Based on DOE/RL-91-32.
(b) Based on WHC-SD-EN-TI-101.
(c) Based on BHI-00720.
(d) Includes mass removed from 216-Z-18 site; reported as a combined value because the well fields overlap.

Table 3.2-2. Summary of Radionuclide Assessment System Logging Operations in the Single-Shell Tank Farms

	June	July	August	September	FY 2001 Cumulative Total
Total Boreholes	21	35	30	27	113
Main Log Footage	781	1,943	1,860	1,429	6,013
Re-Run Log Footage	104	142	90	78	414
Total Footage	885	2,085	1,950	1,507	6,427

Table 3.2-3. Sensor Placement in Borehole 299-E33-46

Sensor Array Number	Depth (m [ft])	Type of Sensor
1	0.6 and 0.91 (2 and 3)	AT, HDS, WCS, WFM
2	1.8 (6)	AT, HDS, WCS
3	2.7 (9)	AT, HDS, WCS
4	4.6 (15)	AT, HDS, WCS
5	16.1 (53)	AT, HDS, WCS
6	25 (82)	AT, HDS, WCS
7	66.4 (218)	AT, SS, HDS, WCS
8	69 (226)	AT, SS, HDS, WCS

AT = Advanced tensiometer.
HDS = Heat dissipation sensor.
SS = Solution sampler.
WCS = Water content sensor.
WFM = Water flux meter.

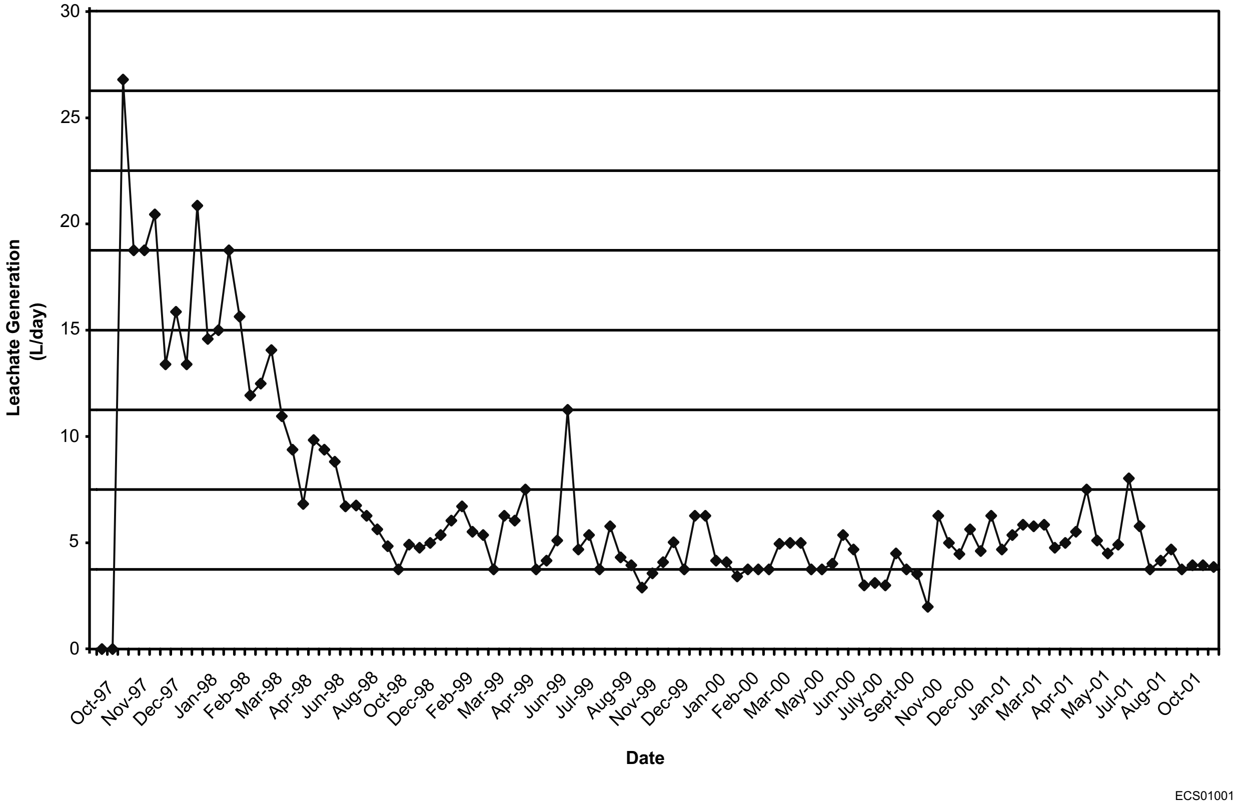


Figure 3.2-1. The Rate of Leachate Generation at the Solid Waste Landfill Since Routine Monitoring Started in 1996

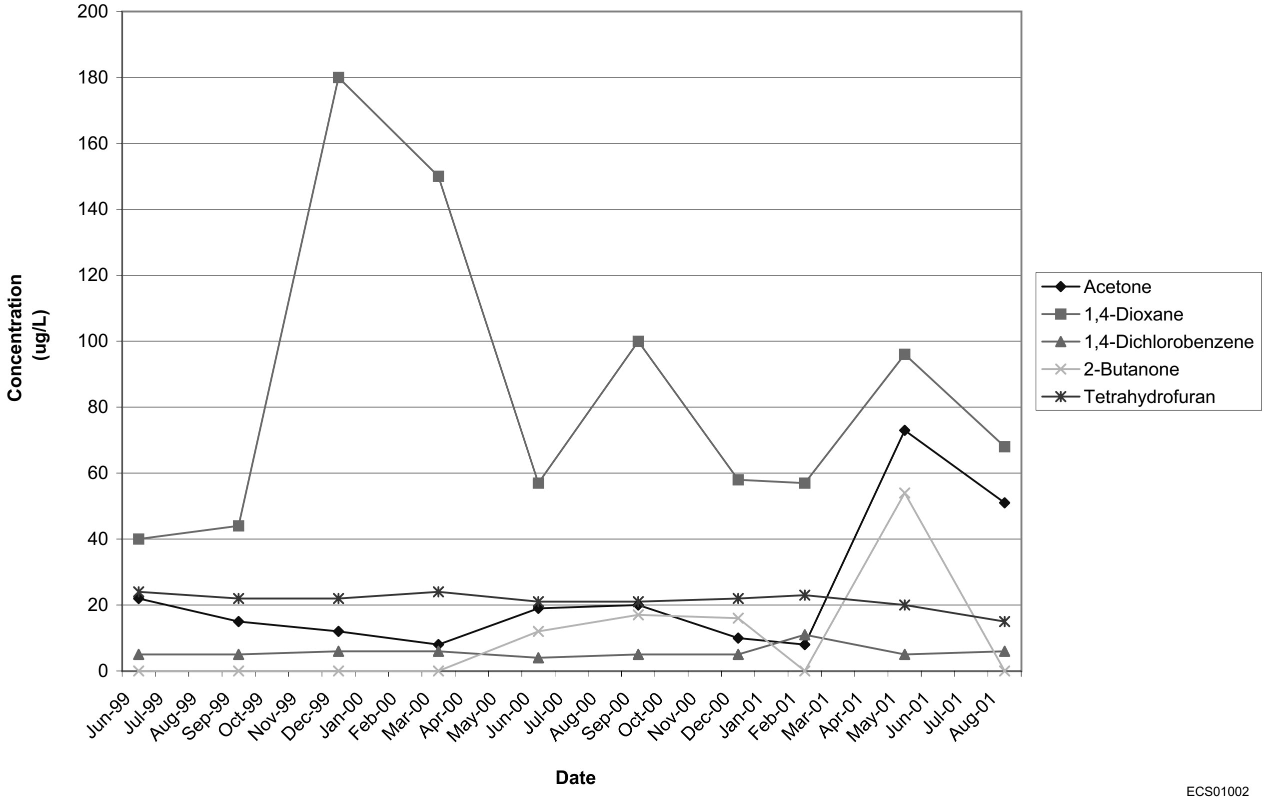


Figure 3.2-2. Key Organic Compounds Found in Leachate from the Solid Waste Landfill

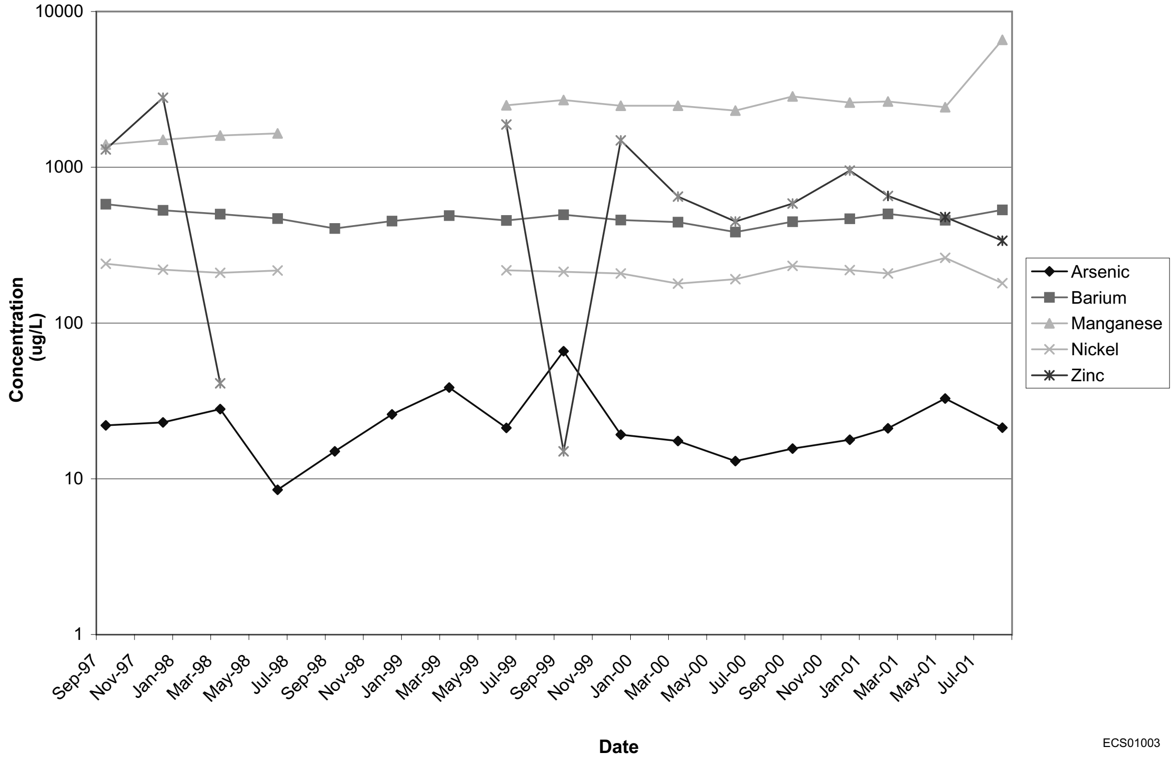


Figure 3.2-3. Key Metals Found in Leachate from the Solid Waste Landfill

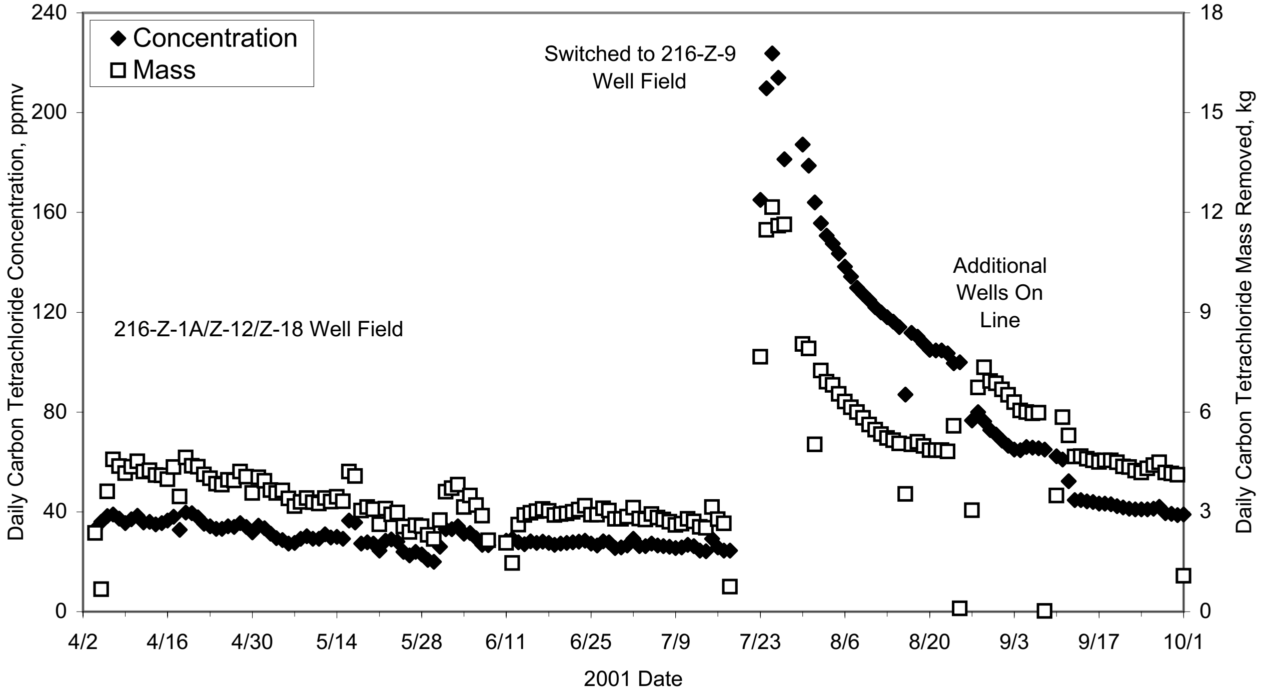


Figure 3.2-4. Time Series Concentrations of Carbon Tetrachloride in Soil Vapor Extracted from the 216-Z-9 Well Field and the 216-Z-1A/-12/-18 Well Field

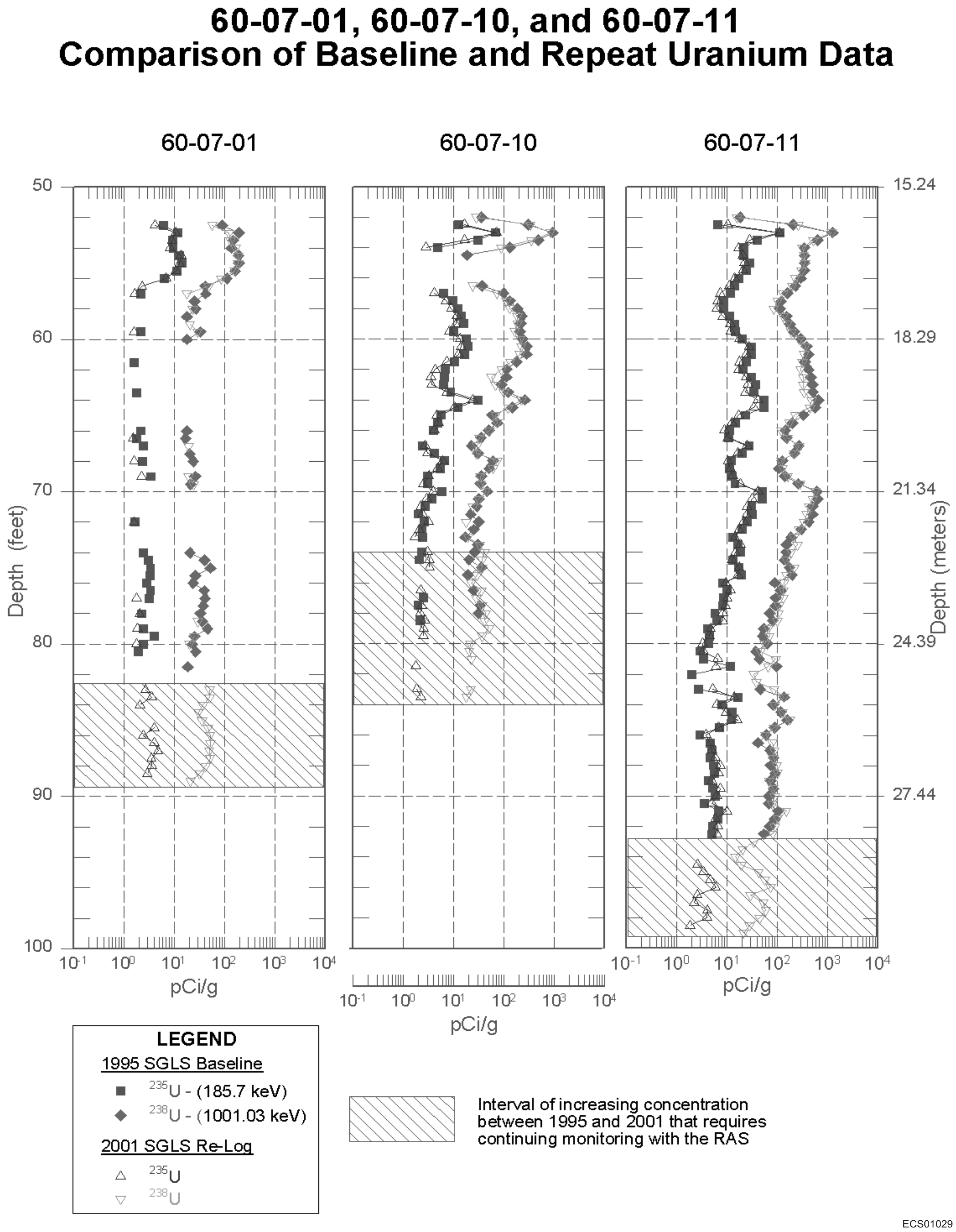


Figure 3.2-5. Examples of 1995 and 2001 Spectral Gamma Logging System Data Obtained in the U Tank Farm, 200 West Area

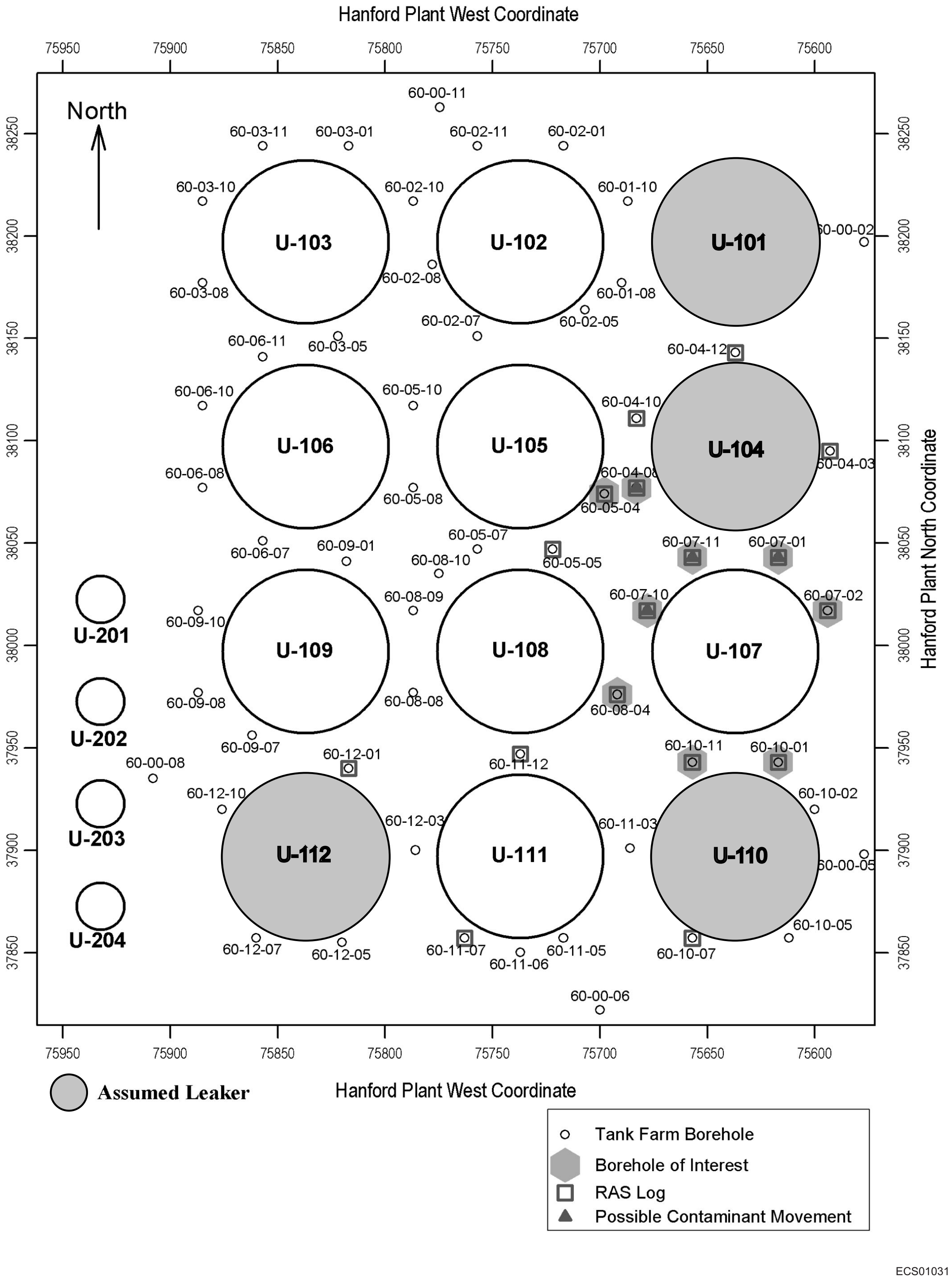


Figure 3.2-6. Location of Monitored Boreholes in U Tank Farm, 200 West Area. The map shows the boreholes in which there may be movement of subsurface contamination.

3.3 Vadose Zone Studies

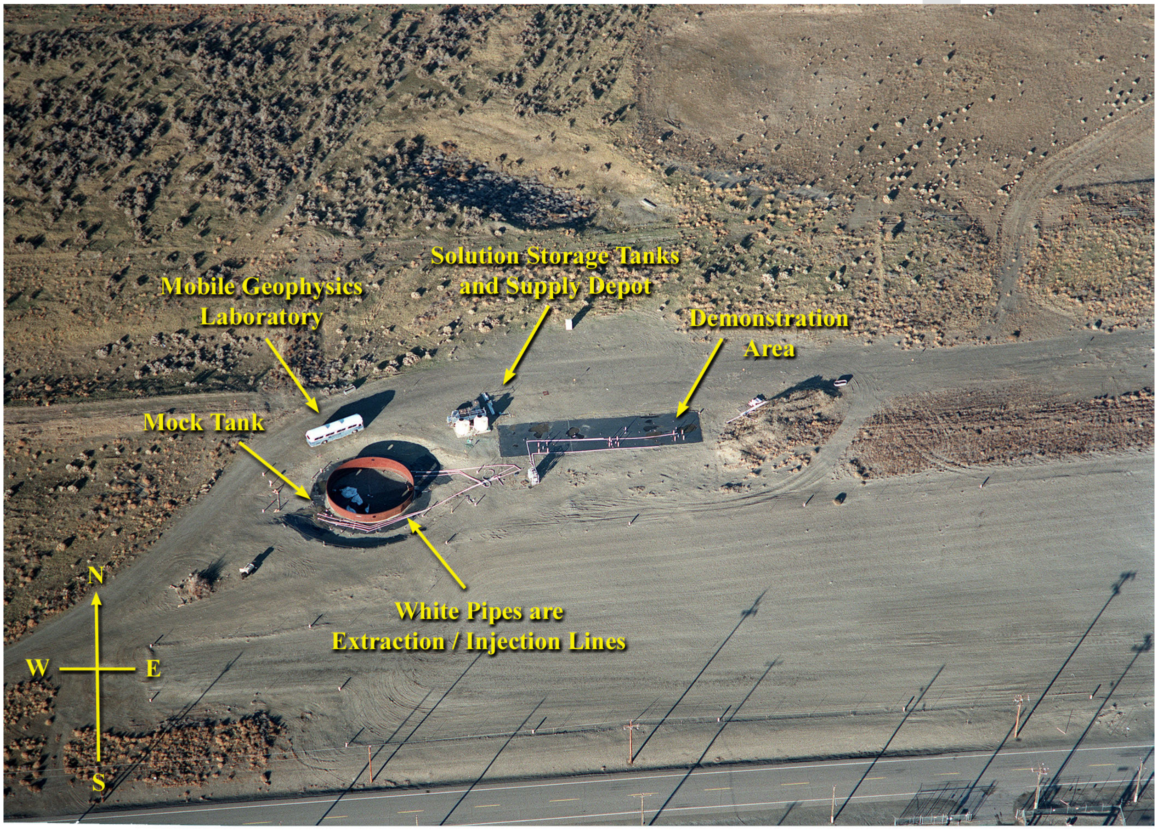
D. G. Horton

This section summarizes the activities and results of technical studies done at the Hanford Site in fiscal year 2001 to better understand the vadose zone and vadose zone contamination. These studies are designed to result in new, innovative methods for cleanup and monitoring at the Hanford Site. These studies include the demonstration and testing of several geophysical methods for monitoring and characterization of the soil column, the isotopic fingerprinting of subsurface waste and subsurface moisture to understand transport processes in the vadose zone, infiltration experiments at a clastic dike site to determine the hydrologic properties of clastic dikes, and development of a model to predict subsurface contaminant migration based on measured infiltration rates.

3.3.1 High Resolution Shallow Seismic Methods for Subsurface Characterization

E. J. Freeman

Two-dimensional and three-dimensional high-resolution seismic characterization experiments were conducted at the Hanford Site in May 2001. The objective was to create an image of the sedimentary units at the selected sites from ground



During July and August 2001, scientists tested six leak detection technologies. The demonstration of these methods was designed to provide data that will lead to the development of a way to detect leaks outside of a single-shell tank during waste retrieval operations.

surface to the water table while retaining sufficient resolution to identify distinct lithologic layers. It is hoped that the continuous images of the sediment layers in the vadose zone can be used to identify field scale heterogeneity with some degree of confidence. Field scale heterogeneities are very important in modeling fluid flow and contaminant transport in the vadose zone. This section presents a brief summary of the experiments and their results. Freeman and Bachrach (2001)[(a)] give a full discussion of the experimental methods and the results.

High-resolution seismic characterization experiments were conducted at four locations on the Hanford Site in 2001. The technique achieved vertical imaging from the surface to the water table with sufficient resolution to identify distinct lithologic units.

Four sites were selected to test the high-resolution seismic method: the Sisson-Lu experimental site, the proposed disposal site for immobilized low-activity waste; an area south of Waste Management Area S-SX; and a clastic dike location south of 200 East Area on Army Loop Road (Figure 3.3-1).

The Sisson-Lu Experimental Site, located southwest of PUREX, was chosen because there is a large quantity of neutron probe moisture data obtained from a dense array of wells completed to 18.6 meters at the site. The sediment in the upper 18 meters at this site is predominantly coarse to medium fluvial sand with interbedded gravel and silt overlain by eolian sands. The three-dimensional survey completed at this site showed reflectors representing changes in lithology to a depth of ~50 meters. Comparing the neutron probe data with the seismic data showed that the best reflectors are the tops of the low moisture zones, which correspond to coarse-grained units. In addition, the data suggest that not all sedimentary layers are continuous along the 14-meter-long profile. Finally, the data also show the strike of what are interpreted to be elongate deposits (possibly a buried channel).

The immobilized low-activity waste site is located west of the Sisson-Lu site. This site was chosen because it is the location of the proposed repository for future vitrified waste storage. The objective of this survey was to image to a depth of ~100 meters. The results of the survey clearly showed the water table at a depth of 90 to 95 meters. This is a significant improvement compared to the depth penetration achieved with previously obtained ground penetrating radar surveys. Additionally, comparison of the seismic profile with the geologist's log from a groundwater well located ~10 meters north of one of the survey lines showed good agreement between the data sources.

In addition to the larger scale features such as lithologic contacts and the water table, smaller scale features were identified in the survey profiles. Potential channels or depressions and fault or slump structures are interpreted from discontinuous and offset reflections.

The area south of the S-SX tank farms was selected because the upper 5 meters of overburden had been removed, permitting greater potential for vertical signal penetration. The sediment beneath the site is predominantly glacial flood deposits of sandy gravel to gravelly sand. There was an attempt to specifically identify a gravel layer previously thought to exist at ~20 meters depth beneath the site. That gravel layer was not positively identified, but a gravel unit at a depth of 45 meters was recognizable in the seismic profile and identified on the geologist's log of a nearby borehole. In addition, the gravel unit appeared to be laterally continuous along the entire 30-meter profile. Other lithologic contacts can be identified on the seismic profile that correspond to lithology changes in the geologist's log.

The clastic dike site is located ~100 meters south of Army Loop Road and 1.6 kilometers east of Goose Egg Hill. (Clastic dikes are vertical, sedimentary

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(a) Letter report from E. Freeman and R. Bachrach (Pacific Northwest National Laboratory, Richland, Washington) to F. M. Mann (CH2M Hill Hanford Group, Inc.), *Application of High Resolution Shallow Seismic Methods for Subsurface Characterization at the Hanford Site*, dated September 25, 2001.

features that crosscut horizontal bedding. See Section 3.3.4 for more on clastic dikes.) The site was selected because of the prominent profile of the dikes in ground penetrating radar surveys previously obtained. The objective was to determine whether the dike would be detected by the survey. The clastic dikes consist of laminated sand and silt, with the laminations oriented subparallel to the dike. The sediment surrounding the dike is dominantly sand. The dike was detected by the seismic survey.

The seismic profiles obtained in 2001 show the capability of the method to image distinct lithologies throughout the entire vadose zone. At locations for which geologist's logs were available, the seismic records match the logs. In addition, other structural features, not previously identified by other means, were identified on the seismic profiles. These features are interpreted to be faults and paleochannels, features that may influence variability of fluid and contaminant flow in the vadose zone. In addition to structural features, the continuity and discontinuity of specific layers was noted in some profiles. At the clastic dike site, the seismic profile did image the dike, but it was not as pronounced as the image previously obtained from ground penetrating radar.

In conclusion, the seismic technique did well in identifying hydrostratigraphic units at the sites where it was deployed. The method achieved vertical imaging from the ground surface to the water table and retained sufficient resolution to identify distinct lithologic units. The seismic profiles correlate well to geologist's logs and neutron probe logs at sites where they are available. The seismic method is much cheaper than drilling boreholes and provides good quality, continuous three-dimensional pictures of the subsurface.

DOE funds research to reduce the uncertainties associated with contaminant movement beneath waste sites at Hanford. These vadose zone transport studies provide the information to help with cleanup decisions.

3.3.2 Vadose Zone Transport Field Studies

G. W. Gee and A. L. Ward

Studies were initiated at the Hanford Site to evaluate the processes controlling the transport of fluids in the vadose zone and to develop a reliable database for testing vadose zone transport models. These models are needed to evaluate contaminant migration through the vadose zone to underlying groundwater at the Hanford Site. Details of the work accomplished in fiscal year 2001 can be found in PNNL-13679. This section summarizes the work completed to date.

A study site, known as the Sisson and Lu site (see Figure 3.3-1), which previously had been characterized extensively using geophysical monitoring techniques, was selected in the 200 East Area. Techniques used previously included neutron probe for water content, spectral gamma logging for radionuclide tracers, and gamma scattering for wet bulk density. Building on the characterization efforts of the past 20 years, instruments were installed at the site to facilitate the comparison of nine vadose zone characterization methods: advanced tensiometers, neutron probe, electrical resistance tomography, high-resolution resistivity, electromagnetic induction imaging, cross-borehole radar, and cross-borehole seismic. Soil coring was used to obtain soil samples for analyzing ionic and isotopic tracers.

Advanced characterization methods all have significant promise as diagnostic tools to define the depth and extent of vadose zone plumes at the Hanford Site, particularly where monitoring wells can be adapted for use by these instruments. Cross-borehole radar requires PVC casing, but high-resolution resistivity and electrical resistance tomography can be adapted for use with steel-cased wells, the typical well at the Hanford Site tank farms. High resolution resistivity appears to be particularly useful to diagnose the lateral extent of a plume. Evaluation of the characterization methods will continue during future field experiments.

Laboratory-scale experiments with hypersaline fluids in Hanford Site sediment suggest that fluid properties may influence transport behavior, to the extent of finger formation, through an interaction between fluid and hydraulic properties. Yet, the importance of these mechanisms to field-scale transport is largely unknown, thereby limiting the accuracy of contaminant-transport predictions. To assess the importance of these interactions in field-scale solute transport, tank leaks were simulated by performing a series of injections with dilute fluids in late spring and early summer of fiscal year 2000 and with hypersaline fluids (36 wt.% sodium thiosulfate) during the spring of 2001. In both tests, a suite of isotopic and ionic tracers was included in the injected fluids. The test in fiscal year 2000 consisted of injecting to ground a series of five 3,875-liter pulses of water and tracers, weekly, for 5 weeks. The fiscal year 2001 test, which was designed partly to evaluate the effects of fluid properties and transport processes, involved the injection of 19,000 liters of hypersaline fluid over the course of 5 weeks. This was followed by 11,400 liters of solute-free water applied in a 2-week period. In fiscal year 2000, infiltration and redistribution were monitored using the nine characterization methods over the course of the injections and for 2 months after the last injection. In fiscal year 2001, all methods except electromagnetic induction imaging were used to monitor the infiltration and re-distribution of the 30,000 liters plume over the course of 3 months.

The Vadose Zone Transport Field Study is assessing the types of tools that can best be used to detect contaminant plumes in the soil with an emphasis on tools that can take advantage of the existing monitoring wells.

Thus far, field-measured distribution of soil water content has been analyzed using three-dimensional spatial-moment analysis. Results clearly show that the subsurface distributions of both the dilute and hypersaline fluids are controlled by interactions between small-scale horizontal stratification and fluid properties. The centers of mass for the two plumes were similar in the lateral and transverse directions, but there was significant difference in depth. After the injection of 20,000 liters, the hypersaline plume had traveled 2.6 times deeper than the dilute plume. Most of the difference occurred during the initial stages of the experiment with the vertical center of mass of the hypersaline plume being twice as deep as that of the dilute plume. The mean velocities were 0.0067 meter per day and 0.0062 meter per day. The mean vertical velocity was 0.0052 meter per day.

Ionic tracer distributions were analyzed using one-dimensional spatial analysis. Concentration profiles were generally asymmetric with a large mass occurring at a depth of 5 to 7 meters, and a smaller mass at a depth of 10 to 12 meters. Also there was a preferred flow path to the southeast. At the test site, there are two relatively fine-textured layers, one at a depth of ~6 meters and one at a depth of ~12 meters. The locations of the mass peaks were coincident with the general depths of finer-textured layers. The fine sand sediment in these layers controlled the migration of the water in both tests and caused a substantial increase in horizontal spreading, while confining the moisture plume to a depth of 13 meters depth in the fiscal year 2000 test. During the fiscal year 2001 tests, elevated water content and tracer concentrations were detected at depths of 16 meters at two monitoring locations in the southeast quadrant of the monitoring site, suggesting that the plume had penetrated below the lower (12 meter) fine-grained layer. However, there appears to be no evidence to support fingering due to fluid properties. The location of the peak concentrations was almost identical for fluoride, chloride, bromide, nitrate, thiosulfate and phosphate but was somewhat larger for sulfate in the fiscal year 2001 tests compared to fiscal year 2000 tests. The distribution of sulfate appeared to be very sensitive to textural changes. Also, the location of centers of mass for the different tracers, however, was somewhat different in the 2001 test and increased from depths of ~5.7 to 8.4 meters in the order phosphate, <bromide, <fluoride,

<thiosulfate, <nitrate, <chloride, <sulfate. The deeper penetration of chloride relative to nitrate and thiosulfate may be indicative of preferential transport due to anion exclusion, a mechanism that would be of great significance to the transport of technetium-99.

These observations emphasize the need to consider local-scale textural discontinuities in conceptual models of field-scale transport at the Hanford Site because they appear to cause lateral spreading of vadose-zone plumes. Lateral spreading of contaminant plumes has been detected in the vadose zone at Hanford Site tank farms and other waste sites. Preliminary modeling of the distribution of the fiscal year 2000 test was performed using Pacific Northwest National Laboratory's Subsurface Transport Over Multiple Phases (STOMP) simulator. The site was modeled as a heterogeneous system with respect to initial water-content distribution and with properties of over 20,000 soil types. To date, these simulations have come closest to reproducing field observations of any of the simulations of experiments performed at this site. Although the general features of the predicted water-content distributions are similar to those observed in the field, the current conceptual and numerical model does not yet adequately describe the extensive lateral spreading observed in the field. At present, there is no model that incorporates the interactions between fluid and hydraulic properties to predict the plume distributions observed in laboratory and field studies. Work is ongoing to evaluate the processes that can cause accelerated transport of hypersaline plumes and to develop techniques to facilitate upscaling and parameterization of field-scale models.

Work in fiscal year 2001 has led to the development of a scaling method that can be coupled with inverse-flow modeling to estimate parameters for heterogeneous soil at the field scale. The method is based on first assigning unique scaling factors to similar soil textures in the field after which field-scale reference values for hydraulic parameters are estimated through inverse modeling of the field experiments. The parameters for individual layers are subsequently obtained through inverse scaling of the reference values using the a priori relationships between the reference parameter values and the specific value for each layer. STOMP was combined with the universal inverse modeling code, UCODE, to estimate the unsaturated hydraulic parameters. Three cases of heterogeneity were used to test the new technique: homogeneous soil, layered soil, and heterogeneous soil. Predictive modeling of drainage from a well-characterized lysimeter site at the Hanford Site with both laboratory and field-measured soil hydraulic properties resulted in an overestimation of soil water content and an underestimation of pressure heads. However, using field-scale values derived from the new scaling technique resulted in significantly better model fits for both water content and pressure head. The simulation of drainage from a layered soil at a well-instrumented field site near the 300 Area at the Hanford Site also resulted in an overestimation of water content and pressure head when local-scale parameter values were used. Again, using field-scale parameter estimates resulted in smaller prediction errors. Application of this technique to the estimation of hydraulic parameters from the Vadose Zone Transport Study field experiments has commenced with a two-dimensional simulation. The prediction of water-content distributions using lab-measured parameter values resulted in poor model fits. However, using inverse scaling improved the fit. Parameters derived from these studies will be compared with those derived from core measurements with the goal of developing an upscaling methodology. Such techniques are critical to the development of long-term, field-scale transport predictions. This type of inverse analysis will be an ongoing effort in fiscal years 2002 and 2003.

A method was developed to scale soil hydrologic properties derived from laboratory measurements up to field scale. Modeling with the field-scale values from the new technique resulted in significantly better simulations for both water content and pressure head.

3.3.3 Fiscal Year 2001 Tank Leak Detection Demonstration

D. B. Barnett, R. J. Cameron, G. W. Gee, M. D. Johnson, and M. D. Sweeney

During July and August 2001, CH2M HILL Hanford Group, Inc. engaged Pacific Northwest National Laboratory to deploy six leak detection technologies at the Hanford Site Mock Tank 105-A (mock tank) (Figure 3.3-2) in a Tank Leak Detection Demonstration using a leak surrogate (sodium thiosulfate solution). Technologies consisted of five geophysical methods and the subsurface airflow extraction test method. The following sections describe the background and basic elements of the fiscal year 2001 testing and provide a summary of results. Preliminary reports of results for the specific test methods, with illustrations and a more comprehensive project overview, are currently available from the authors. Additional analyses are in progress for all methods.

3.3.3.1 Purpose of the Tank Leak Detection Demonstration

Under the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement; Ecology et al. 1998), CH2M HILL Hanford Group, Inc. is demonstrating several retrieval methods as alternatives to past-practice sluicing. These alternative methods use very little, if any, liquid to dislodge, mobilize, and remove the remaining waste from single-shell tanks. As additional assurance of protection of the vadose zone beneath the single-shell tanks, tank waste and tank conditions will be aggressively monitored during retrieval operations.

Six technologies were tested at the Mock Tank Site, 200 East Area, to monitor the progress of a simulated leak. The in-tank tracer approach was the most sensitive method of leak detection and may prove useful during future removal of remaining waste from single-shell tanks.

The Tank Leak Detection Demonstration was designed to provide data about the lower limits of sensitivity, including both minimum detectable effluent volume and time-to-detection, of several geophysical technologies in support of the development of a Leak Detection, Monitoring and Mitigation system for use during waste-retrieval operations.

The six techniques selected for demonstration were (1) electrical resistivity tomography, (2) cross-borehole electromagnetic induction, (3) high-resolution resistivity, (4) cross-borehole radar, (5) cross-borehole seismic tomography, and (6) the subsurface airflow extraction test. Although the work constituted an experimental, initial phase of method evaluation, specific objectives included the following:

- assess each leak detection technology’s sensitivity to leaks (on a total-volume basis)
- determine minimum response time for leak detection by each method
- estimate a rough, “order-of-magnitude” cost to deploy an operating system around a single-shell tank
- determine an optimum system configuration for best performance (borehole placement, electrode placement)
- select the method(s) that offers most promise for eventual deployment in a tank farm.

3.3.3.2 Description of the Field Site

The mock tank (Figure 3.3-3) was constructed in 1994 to 1995 and was previously used to test the applicability and effectiveness of an array of electrical resistivity sensors in providing tomographic imaging of simulated fluid leaks beneath the tank. The original, primary function of the mock tank was to simulate leaks at various points around a single-shell tank. Figure 3.3-4 shows the layout of the mock tank site with the locations of test holes and wells from fiscal year 2001 and previous years.

For the fiscal year 2001 Tank Leak Detection Demonstration, all preparatory drilling was done using a hollow-stem auger and consisted of placing nine PVC wells and three steel-cased wells to a depth of 12.2 meters. Nine of the wells were placed for the tests around the tank, and these were screened at depth to allow air injection/withdrawal. An additional six holes were completed with sealed PVC or carbon steel casing. The intent was to provide fluid (water) containment to allow deployment of seismic techniques. Some of the casings did not contain water efficiently and required lining during seismic testing.

Several cone penetrometer tests were performed around the tank. These tests provided baseline information on soil moisture, density (lithology), electrical resistivity, and air permeability for subsequent geophysical and subsurface airflow extraction tests. Five cone penetrometer holes were placed in the southeastern portion of the test site (see Figure 3.3-4) to characterize stratigraphy and measure infiltration rates and depths as well as preliminary infiltration properties of the sodium thiosulfate solution used to simulate the tank leak.

Soil-sample analysis and cone penetrometer resistivity data were correlated with neutron logging tool data to characterize soil-water saturation. An overall soil-water saturation value of 0.16 (vol/vol) was obtained; this agrees in general with other Hanford Site soil-saturation values at similar levels in the vadose zone. The soil-moisture profile indicates that silt layers are located ~1 meter and 10.4 meters below ground surface as suggested by a higher soil moisture content in these zones.

3.3.3.3 Summary of Fiscal Year 2001 Test Results

Baseline (background) measurements for all methods were conducted during most of July 2001. The first release of the sodium thiosulfate began on August 9, 2001. Table 3.3-1 indicates the volumes and timing for the five solution releases. Release rates ranged from ~38 liters per hour (#2A) to ~90 liters per hour (#4). The releases were scheduled so as to determine if the methods could image initial releases and total discharged volumes, and to demonstrate sensitivity to superimposed releases.

Geophysical Methods

Geophysical methods that were selected for testing in fiscal year 2001 are based on proven technologies that have been used, in one form or another, for many years and within many industries. These methods also have recent application history at the Hanford Site (e.g., PNNL-13451). The principal investigators for the various methods came from Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, private industry, and the Pacific Northwest National Laboratory.

The process of selecting geophysical monitoring technologies that have application to problems at the Hanford Site is described by PNNL-13240. The deployment of multiple methods during the testing at the mock tank allows inter-method comparisons to provide independent verification of results. Detailed descriptions of the techniques discussed are found in PNNL-13240 and PNNL-13451, and descriptions provided by the geophysical researchers (http://vadose.pnl.gov/tldd.stm).

Electrical Resistivity Tomography. The fiscal year 2001 electrical resistivity tomography method used the existing electrode arrays installed around the mock tank site to develop a three-tiered surveying strategy for leak detection. The results show that a system can be developed to detect increases in moisture content with nominal changes to the existing tank farm infrastructure. The early results also show that a low-resolution imaging system can be constructed using the existing wells around the single-shell tanks. An enhanced electrical resistivity network would be able to generate high-resolution tomographic images defining plume geometry, as well as establishing fluid travel time and direction. Figure 3.3-5 is an example of the three-dimensional output from the first solution release. Investigators estimate that the lower limit of detection for their method is ~1,000 liters.

Cross-Borehole Radar. Cross-borehole radar measurements provide information about the sediment, particularly moisture content, between two boreholes. Six sets of individual cross-borehole radar measurements were obtained from July 18 to August 28, 2001. The radar sets included a baseline measurement against which the subsequent measurements are evaluated. Available data indicate that changes in first-arrival amplitude show the greatest change within the first 2 to 3 hours after the injection started. Analysis of results thus far suggests that the method is very sensitive to small volumes of fluids.

Cross-Borehole Seismic. The cross-borehole seismic method involves measuring the travel time of seismic energy transmitted between two or more boreholes to obtain information about the dynamic elastic properties of the porous soil between the two boreholes (Majer et al. 1997). Scientists can then infer lithology, bed geometry and continuity, fracture and fault properties, porosity, and in some cases, interstitial fluid distribution.

Seismic measurements were obtained from three boreholes constructed especially for this exercise (boreholes C3623, C3628, and C3629 on Figure 3.3-4). Four cross-well measurements were gathered — one as a baseline before fluid injection and three following injections of the sodium thiosulfate solution.

Early results from cross-well seismic measurements are inconclusive regarding the capability of this method to detect changes in moisture or fluid content. The change in fluid density was most pronounced at ~4 meters below ground surface. This horizon appears in raw data plots as a distinct change in amplitude in the first arrivals at ~40 to 45 milliseconds. The entire seismic-survey effort, however, was plagued by well seal failures and the necessity of preventing leakage of water from the wells that could hamper the electrical and electromagnetic methods.

Cross-Borehole Electromagnetic Induction. Cross-borehole electromagnetic induction measures the electrical conductivity of the subsurface between two boreholes. Electromagnetic surveys were conducted twice during the scheduled releases at the mock tank site in fiscal year 2001. One set of measurements was made before releasing the sodium thiosulfate solution and one near the end of the test.

Preliminary results for the cross-borehole electromagnetic induction survey roughly coincide with those obtained from the seismic method. A pronounced conductivity change was identified ~6 meters beneath the tank. The method also detected an area of increased conductivity attributed to leakage of water from one of the nearby boreholes prepared for cross-borehole seismic tests. Additional work is still underway to produce full three-dimensional inversions that will provide more detailed and comprehensive imaging of the leak.

High-Resolution Resistivity. High-resolution resistivity surveys are an evolutionary development in direct current electrical resistivity. They differ from conventional, industry-standard approaches by modifying the field-data acquisition procedures and subsequent data processing. High-resolution resistivity is particularly useful in mapping the distribution and time-dependent changes of moisture in the subsurface.

The preliminary results of the high-resolution resistivity survey show that simple plume geometry and volume estimates can be obtained using this method.

The minimum detectable volume is conservatively estimated at 1,800 liters. In spite of some equipment failures that destroyed two sample sets, a nearly continuous set of measurements was obtained during the injection. One of the results indicated not only the change in residual (subtraction of the background potential) electrical potential between the first and third fluid release beneath the mock tank, but also indicated a leaking casing from cross-borehole seismic preparations.

Subsurface Airflow Extraction Test

The subsurface airflow extraction test technology employs the principle of chromatographic separation to quantify substances of interest in a volume of soil through which air is forced. The elution curves of tracer concentration versus time are analyzed in the same manner as elution curves from other types of chromatography (Figure 3.3-6). This method can provide almost real-time quantitative information on leaked tank-waste volume. Additionally, the conservative tracer elution curves may be analyzed for perturbations resulting from leak-induced porosity changes.

For the first in-tank tracer test at the mock tank site, a commercial refrigeration mixture consisting of a 50:50 mixture of difluoromethane and pentafluoroethane was chosen as the tracer.

Three different methods were tested as potential leak detection techniques:

- in-tank tracer (tracer gas is sparged into the solution or water source tank)
- flowfield disturbance
- partitioning tracer.

The three methods tested are very different in concept, but share a common subsurface flowfield and analytical infrastructure (Figure 3.3-7).

In-Tank Tracer. The first in-tank tracer experiment was performed at the development area for the subsurface airflow extraction test using 1,325 liters of clean water saturated with a nitrous oxide tracer. The tracer associated with the water introduced near the surface was detected in the flowfield set at 7.6 to 10.7 meters below ground surface 43 hours after the start of liquid injection. The lag time to detection appeared to be associated primarily with water transport to depth, and the water retained a large burden of tracer until stripped by the subsurface flowfield. Detection sensitivity was several hundred times the instrument detection limit. Based on the favorable results, a series of liquid injections with 36% sodium thiosulfate solutions saturated with one highly soluble compound (difluoromethane) and one minimally soluble compound (pentafluoroethane) were performed at the mock tank. Difluoromethane tracer was observed primarily in the upper interval (3 to 6.1 meters below ground surface) at levels more than three orders of magnitude above the instrument detection limit for three separate leak events. Minor amounts of the soluble tracer were also observed in the 6.1 to 9.1 meters interval, but most of the tracer was stripped out of the liquid during vertical transport through the upper zone. To track vertical transport of the liquid by this method, it would be necessary to operate the flowfield discontinuously.

Flow-Field Disturbance. Several subsurface airflow extraction tests were conducted using a combination of a conservative or non-partitioning tracer (methane) and a partitioning tracer (chlorofluoromethane). Before starting the field studies, it was assumed that permeability changes associated with the introduction of liquid into the vadose zone should be readily detectable through changes in the pattern of conservative tracer recovery alone (this was confirmed by simulation results); however, no experimental verification of the effect had been performed before that time.

Ideally, several baseline subsurface airflow extraction test measurements should have preceded the introduction of brine to fully assess sources of variability. Unfortunately, the test protocol and schedule precluded that. A single baseline subsurface airflow extraction test was performed just before liquid introduction. However, a computer outage occurred at a critical point in the data gathering, rendering the results unusable for that purpose. Subsequent subsurface airflow extraction test runs all showed two or more zones of different permeability in the three intervals likely associated with variations in the stratigraphy of the Hanford formation. The middle zone (6.1 to 9.1 meters) actually appeared to have three different permeabilities represented in the tracer curves. The effect of the leaks was visible as a shift to decreasing tracer residence time as the leak sequence proceeded over a 2-week period. The decreasing trend was particularly evident in the middle zone (6.1 to 9.1 meters). Clearly, more experiments are needed with better establishment of a pre-leak baseline. However, at this point, the flowfield disturbance method can be said to show great promise for qualitative leak detection.

Partitioning Tracer. Four tests were completed using a combination of partitioning and conservative tracers. Analyses performed on both the monitoring well and extraction well data proved inconclusive because of the error estimates associated with the measurements. That result was not unexpected as laboratory experiments performed on concentrated sodium thiosulfate and sodium nitrate solutions in parallel with the field work had already demonstrated that a large decrease in partitioning coefficient was associated with the high-ionic-strength brines for any of the classes of compounds currently available for field use (i.e., chlorofluorocarbons). The decrease associated with the ionic strength effect was almost a full order of magnitude. That was much larger than initially expected. The large decrease causes a corresponding reduction in the sensitivity of the partitioning interwell tracer test method to changes in moisture associated with brine relative to background moisture.

Of the six technologies tested at the Tank Leak Detection Demonstration to monitor the progress of the simulated leak, the in-tank tracer approach was the most sensitive method of leak detection. The in-tank tracer method may prove useful during future removal of remaining waste from single-shell tanks.

3.3.4 Hydrogeologic Influence of Clastic Dikes on Vadose Zone Transport

C. J. Murray, D. G. Horton, A. L. Ward, and G. W. Gee

A 3-year study of clastic dikes and their influence on vertical movement of moisture and contaminants in the vadose zone began in fiscal year 2000 and continued in 2001. The study is funded by DOE's Environmental Management Science Program. The goal is to describe the geometric and hydrologic properties of clastic dikes and dike networks and extrapolate those properties to the vadose zone beneath waste storage and disposal facilities.

Clastic dikes are common sedimentary structures in the vadose zone at the Hanford Site (BHI-01103). The dikes are vertical to subvertical structures that are often contorted and irregular. They crosscut the normal subhorizontal sand and silt beds of the Hanford formation. Clastic dikes generally are composed of multiple layers including an outer skin of silt/clay and coarser grained infilling layers. The dikes vary in width from <1 centimeter to >2 meters and have vertical extents that range from <1 meter to >50 meters, with a large number >20 meters. In plan view, clastic dikes often form 4- to 8-sided polygons arranged in a network. Previous investigators have proposed that the dikes may provide a preferential path for contaminated water leaking from waste tanks to move through the thick unsaturated zone to the unconfined aquifer. However, there is insufficient evidence to determine if that speculation is accurate. One of the goals of the study is to provide information that can be used to evaluate that speculation.

In 2000, the study mapped the large scale geometry of the dikes using remote sensing data and ground penetrating radar data. A clastic dike was excavated near the S-16 pond, southwest of the 200 West Area, and data were collected on properties of the dike and matrix. In addition, infiltration experiments were performed after the excavation was completed.

In 2001, the project extended its study of the small-scale hydrogeologic properties of clastic dikes. The main focus of the project was to study a site near Army Loop Road that initially had been surveyed using ground-penetrating radar in 2000 (see Figure 3.3-1 for the location of the clastic dike site at Army Loop Road). Ground-penetrating radar survey and the air photo and field mapping were used to select a site to trench across a clastic dike. In June 2001, a clastic dike at the Army Loop Road site was trenched with a backhoe to a depth of ~3.5 meters (Figure 3.3-8). The exposed clastic dike is in the sand-dominated facies of the Hanford formation. The dike excavated at the Army Loop Road site was much thicker than the dike excavated in 2000 at the S-16 Pond site (2 meters versus 0.7 meter).

The dike was excavated in three different levels, each ~1 meter high. After the excavation of each level, the slopes surrounding the excavation were pushed back and the excavation taken down another level. In this way, the dike could be imaged and measurements could be taken of the properties of cross sections of the dike and matrix at three different levels that were approximately one on top of the other, without creating a safety hazard in the unstable sediment. The face exposed at each level was mapped and sediment samples were taken for laboratory analysis. Investigators photographed the dike with an infrared camera and a digital camera and took a large number of air permeability measurements at specific points.

The LSAMP II air mini-permeameter developed by New Mexico Institute of Mining and Technology that was employed in the previous fieldwork had a practical range corresponding to a sediment made of fine to medium sand. However, there are numerous silt bands in the dikes as well, but it was not practical to measure the finer-grained units because the measurements took too long to make. In 2001, investigators from New Mexico Tech attempted to modify the system so that it could be used to make measurements in some of the finer-grained sediment. The modifications extended the range of the air mini-permeameter on the lower end by a full order of magnitude.

Two air mini-permeameters, a standard instrument and one with the extended range, were used during the field work at the Army Loop Road site. This allowed substantially more measurements in 2001 than the previous year. During fiscal year 2001, there were a total of ~450 measurements on the three levels, one-third in the dike and two-thirds in the matrix. The results indicate the median air permeability of the dike is about one order of magnitude lower than the permeability in the matrix (Figure 3.3-9), which is similar to the results obtained last year. The variability of the data from the dike is much higher than that of the matrix, with a coefficient of variation (i.e., ratio of standard deviation to the mean) of 1.2 in the dike versus 0.6 in the matrix. The overall variability of air permeability in the dike-matrix system is ~4 orders of magnitude (see Figure 3.3-9). This is an important observation, because some methods used for upscaling permeability data assume the variability in the system is low, about an order of magnitude, which would means it would be questionable to apply those methods to this system.

In addition to making a number of measurements of air permeability, each face in the excavation was imaged using a high-resolution infrared camera. Figure 3.3-10 shows two composite images of the middle level in the trench. The lower image was made with an ordinary digital camera and the upper image was made using the infrared camera. The contrast in the infrared imagery is due to variation in the moisture content of the sediment; darker colors indicate more moisture and tend to be associated with finer-grained units with lower air permeability. The dike can be seen as the banded interval that takes up the middle third of the image, and is ~2 meters wide. An attempt is being made to calibrate the infrared data to the air permeability moisture data.

One feature noted during previous excavations of clastic dikes is that there often appears to be a zone of low permeability in the matrix near the clastic dike. In order to test that hypothesis, air permeability measurements were made across several horizontal transects in the matrix on either side of the dike on several different levels. Several of these transects did, in fact, show a decrease in permeability near the dike. Figure 3.3-11 shows data from a transect on the lowest level of the excavation, which indicates an 80% drop in permeability near the dike. There is no obvious change in grain size near the dike, but grain size analysis will be done to verify that. Also, the matrix sediment will be examined to see if there is an appreciable increase in cementation near the dike.

The continuity of the vertical bands seen within the dike was measured. A transect was laid out on the horizontal exposure of the dike on the floor of the middle layer of the excavation. Each vertical band encountered in the transect was then traced up and down the excavation to see if it was continuous. The vertical bands measured did not include the very thin and very fine-grained clay and silt skins (usually <1 centimeter thick) associated with the major bands. The bands that were characterized had a median thickness of 5 centimeters and ranged from 2.5 to 14 centimeters (Figure 3.3-12). In most cases, the bands could be traced for ~1.6 meters before they pinched out or were obstructed by a clay/silt skin cutting across the band. The range of continuity observed was from 0.2 to 7.7 meters, with all but one of the bands having an apparent continuity of <~2.5 meters. This degree of continuity will affect transport through the clastic dike and will be used to guide construction of models of the properties within the dike.

Infiltration experiments at a clastic dike site showed that even though air permeability and saturated hydraulic conductivity within a dike may be low, clastic dikes may still be fast transport paths under unsaturated conditions in the vadose zone.

A large-scale infiltration experiment was conducted at the Army Loop Road site in fiscal year 2001. A drip irrigation system was used to apply specific fluxes. The application area was centered on the dike and aligned with the longer axis perpendicular to the dike. Three fluxes of water were applied to the clastic dike and surrounding matrix and the progress of the infiltrating water was monitored for each flux rate. Water content, matric potential, and electrical conductivity were measured throughout the tests using a neutron probe, cross-borehole radar, tensiometers, and time domain reflectometry probes. Eight boreholes were emplaced to a depth of ~7 meters and used for the neutron probe and cross-borehole radar measurements. This depth provided significant information because there are no reports of observations of flow within dikes at this large scale. For example, in all of the tests reported in BHI-01103, the maximum depth of observation was <1 meter. The measurement frequency during the infiltration test varied depending on the experimental conditions. The time domain reflectometry probes and tensiometers were installed to a depth of 0.5 meter on a transect oriented perpendicular to the dike.

The three fluxes of ~10^{-3}, 10^{-4}, and 10^{-5} cm/s were applied. Total volume applied was ~15,000 liters. Similar fluxes have been used in prior field tests of surface soils at the Hanford Site (see Appendix C of HNF-4769). Higher fluxes are difficult to maintain because of the water supply; they are also prone to generate ponding and runoff, which degrades the value of the infiltration test. Lower irrigation fluxes more nearly approximate natural fluxes, but they pose problems because of the time required to achieve steady state conditions. Relating each flux to the resulting equilibrium water content will provide a measure of the unsaturated conductivity function (Youngs 1964). The water content and matric potential data provide a direct measure of in situ water retention.

Once steady state was achieved with the third (and lowest) flux rate, the irrigation supply tank was switched to a solution of potassium bromide and the dye known as Brilliant Blue FCF. The presence of the potassium bromide made it easier to detect the wetting front in the subsurface. The flux was continued until the potassium bromide moved below the time domain reflectometry sensing zone (~0.5 meter). Further movement of the water was monitored with neutron probe and cross-borehole radar measurements.

The excavation began after the application of the tracer in the infiltration area. The main excavation face was ~8 to 10 meters from the edge of the infiltration zone, so that the moisture would not affect the air permeability measurements or time domain reflectometry imaging. However, after construction of the main excavation area was complete, an additional face was cut at the edge of the infiltration area so that the distribution of the tracers could be examined. The upper portion of Figure 3.3-13 shows a composite color photographic image of the dye in the sediment and the lower portion of the figure is a map of the moisture distribution in the face of the excavation. The photographic image shows the heterogeneous distribution of the blue dye. The dike is in the center-right area of the image, from 3 to 5 meters, and tended to transmit less dye. However, some of the deepest penetrations of the dye occurred in restricted bands within the dike (see Figure 3.3-13).

The map of the moisture distribution was made using time domain reflectometry probe measurements on a 15 by 15 centimeters grid across the entire face. Although the moisture map captures the main features seen in the photographic image, it is obvious that important heterogeneity in the distribution of dye and moisture is not captured in the map, even with the relatively dense grid of time domain reflectometry measurements. Figure 3.3-14 shows the moisture distribution and indicates quite clearly that much greater levels of moisture are stored within the clastic dike.

One important feature noted in the excavation and infiltration experiment was a clastic sill that emanates from one side of the dike. This sill was detected prior to the excavation, when the access boreholes for the infiltration were being emplaced with a cone penetrometer. Moisture data from the cone penetrometer probe (Figure 3.3-15), which were recorded prior to any activities at the site, indicated the presence of a high-moisture zone at a depth of ~1.5 meters that was present only on the west side of the dike, but not the east side.

Based on previous experience, it was suspected that the feature was a clastic sill. The sill exerted a major influence on the movement of moisture during the experiment. Figure 3.3-16 shows neutron probe measurements for two access holes, one on each side of the dike. Where there is no sill, the moisture appears to have migrated uniformly through the sediment. On the other side of the dike, however, moisture only penetrates below the sill at a relatively late date. Exposing the sill during the excavation showed that moisture had migrated several meters laterally within the sill, carrying moisture well outside of the infiltration zone. This suggests that sills are important controls on vadose zone transport, at least at local scales. The results also indicate that even though the air permeability and saturated hydraulic conductivity within the dike and sill are very low, clastic dikes may still be fast transport paths under unsaturated conditions in the vadose zone.

Data collection will be completed in fiscal year 2002, after which computer simulation of the infiltration experiments will be done. The results of the clastic study will serve as a baseline for future work. Work involving reactive tracer experiments and scaling issues relating the scale of the field tests to the scale of waste sites is planned.

3.3.5 Isotopic Fingerprinting of Radionuclide Sources at Single-Shell Tanks

J. C. Evans, P. E. Dresel, and O. T. Farmer

Researchers from Lawrence Berkeley National Laboratory and Pacific Northwest National Laboratory applied mass spectrometric methods to analysis of stable and long-lived isotopes in drill core samples in fiscal year 2001. The purpose of the work was to show whether isotopic and chemical ratios can differentiate among leak events. This section summarizes the results of that effort. The full text of the experimental methods and results can be found in (Evans et al. March 2001).[b]

Researchers used measurements of stable and radioactive isotopes in samples of drill core from the Hanford Site to show that the isotopes can differentiate among leaks from separate tanks or more than one leak from a single tank.

Sediment core samples were obtained from borehole C3082, the slant borehole at tank SX-108 (see Section 3.1.2 of this chapter). Analyses were made from 1:1 water:sediment or 1:1 8M nitric acid/sediment extracts. Concentrations of trace metals, common anions, and selected radionuclides were measured to differentiate contaminant sources and as indicators of contaminant source compositions. The chosen constituents were the isotopic systems of cesium, molybdenum, and iodine and the relatively mobile constituents chloride, nitrate, sulfate, and technetium-99.

Figure 3.3-17 shows the concentration of cesium-137 and technetium-99 versus depth in borehole C3082. Both isotopes show two peaks in concentration with the more mobile technetium-99 the deeper of the two. Cesium isotopes were measured on selected water and acid extracts from samples near the two peaks in the cesium-137 distribution. The acid extract dissolved large amounts of natural cesium from the sediment so that cesium-133 (the natural isotope) from acid extracts are of little value is studying leaked fluids. The water extracts did show small differences in the cesium-137/cesium-135 ratio between the two peaks but is was unclear whether the differences were a result of the larger measurement error on water leach samples. Thus, cesium data were inconclusive with respect to separating different sources for the two peaks.

Molybdenum has seven stable isotopes four of which are fission products (95, 97, 98, and 100) and three can be regarded as essentially representing naturally occurring molybdenum (92, 94, and 96). Zirconium-95, the parent for molybdenum-95, is likely to have survived the cool-off and chemical processing periods to varying degrees depending on the length of cool-off and chemical processing times. Thus, molybdenum-95 may provide a way to discriminate among different sources of contamination.

Figure 3.3-18 shows the distribution of total molybdenum and molybdenum-100 (as percent of fission products) versus depth. Both analytes show three peaks in concentration at a depth of 20.7, 27.5, and 35.4 meters. The molybdenum data indicate three leak events for molybdenum-bearing waste.

Molybdenum and chromium are in the same group in the periodic table and should have the same geochemical properties; thus, hexavalent molybdenum may be a surrogate for hexavalent chromium. Figure 3.3-19 compares the depth distribution of both molybdenum and chromium. The distribution of both species suggests three separate leak events with the molybdenum maxima slightly retarded with respect to the chromium maxima.

Iodine-129 is considered a very hazardous substance (drinking water standard = 1 pCi/L) and highly mobile in the natural environment. Very little

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(b) Evans, J. C., P. E. Dresel, and O. T. Farmer (Pacific Northwest National Laboratory, Richland, Washington), "ICP/MS Isotopic Determination of Nuclear Waste Sources Associated With Hanford Tank Leaks." Submitted March 27, 2001, to *Journal of Environmental Radioactivity*.

iodine-129 is expected in tank waste because it was largely partitioned into the vapor phase during operations. However, residual fission-derived iodine disposed to tanks is probably in the supernatant and available for release during leaks. Stable iodine (iodine-127) should also be present as a reducing agent during the reduction and oxidation process or as a chemical impurity. Thus, the isotopic ratio of iodine isotopes is likely to vary and can be used as a fingerprint for individual waste streams. Figure 3.3-20 shows the depth profiles for iodine-127 and iodine-129 in samples from borehole C3082. Two peaks are clearly visible and represent iodine from different leak events.

Several non-isotopic species are known to migrate almost unretarded through the vadose zone. These species include chloride, nitrate, sulfate, and technetium. Concentration ratios of these species with very similar geochemical behavior can be used to identify different sources of vadose zone contamination. The distributions of chloride, nitrate, and technetium with depth in borehole C3082 are shown in Figure 3.3-21. The data show two peaks for each constituent.

In conclusion, isotopes of iodine and molybdenum can be used as a tool to isotopically fingerprint tank waste leaks. Cesium isotopes were not successful in discerning different leaks. Ratios of several different unretarded species can also be used to discern different leaks. The separate leaks may be from different tanks or from more than one leak from a single tank. Comparison of isotopic and species ratios of vadose zone sediment can help to determine sources of vadose zone and groundwater contamination.

3.3.6 Water Movement Through the Vadose Zone as Inferred from Isotopic and Chemical Measurements of Borehole Samples

J. C. Evans, P. E. Dresel, and O. T. Farmer

The understanding of how and where water moves in the vadose zone is necessary for evaluation of contaminant transport through the vadose zone to groundwater. An isotopic and chemical study of porewater from cores obtained during drilling of RCRA well 299-W22-48 was done in fiscal year 2001 to address this issue. This section summarizes the full report of the work which is found in RPP-7884.(c)

Stable isotopes of hydrogen and oxygen can help indicate the origin of water in the vadose zone near waste sites. A shift in isotope composition to heavier values indicates that the water was partially evaporated before it entered the ground (evaporation preferentially removes the lighter isotopes of oxygen and hydrogen). Heavier porewater can be indicative of waste from single-shell tanks or waste disposal cribs.

Well 299-W22-48 was drilled located immediately east of Waste Management Area S-SX in 1999 (see Figure 2.8-1). The borehole was drilled in a previously disturbed area in the vicinity (~40 meters) of past-practice disposal facilities). Thirty-two samples were collected from the drill core in 2000. Porewater was extracted from the samples and the water content and the abundances of the stable isotopes of oxygen ($\delta^{18}O$) and hydrogen (δD) were measured at the Lawrence Berkeley National Laboratory.

(c) Draft Report RPP-7884. J. C. Evans, P. E. Dresel, and O. T. Farmer. "Transport Mechanisms Inferred by Isotope Geochemistry." In *Field Investigative Report for Waste Management Area S-SX*, Appendix D.6. CH2M HILL Hanford Group, Inc., Richland, Washington.

Figure 3.3-22 shows the oxygen and hydrogen isotope composition of the porewaters extracted from samples from borehole 299-W22-48. The groundwater samples cluster around the local meteoric water line suggesting that the source for the unconfined aquifer is natural precipitation that has not experienced evaporation processes. The composition of the porewater, however, plots to the right of the local meteoric water line, indicating that these waters have undergone significant evaporation.

The oxygen isotope composition versus depth for porewater samples is shown in Figure 3.3-23. The oxygen isotope composition of the shallowest sample is much heavier than local precipitation or Hanford Site process water derived from the Columbia River, two potential sources of surface water. The shift in the isotope composition to heavier values signifies that the waters have been strongly evaporated. This is typical of near-surface soil waters, especially in arid and semiarid environments. At 2 meters depth, the oxygen isotope composition of the porewater reflects that of precipitation and Columbia River water and, beneath 2 meters, most porewater are shifted to heavier compositions. There are two porewater samples from the deeper part of the core that do not show the effects of evaporation. The deeper sample, from 71.8 meters, is from the saturated zone and has the composition of groundwater in the unconfined aquifer. The other sample, at 44.7 meters depth, is from an extremely moist zone above the lower Plio-Pleistocene caliche layer. Isotopic analyses for uranium-236 and fission derived isotopes of molybdenum show no evidence of nuclear production associated with the moist sediment sample.

The shallow, 0.5-meter-deep, strongly evaporated sample underlain by the 2-meter sample that is essentially the same as unevaporated groundwater, precipitation, or Columbia River water is similar to patterns observed in other studies of shallow, unsaturated soils (Komor and Emerson 1994; Phillips 1995; Melayah et al. 1996; and Barnes and Allison 1988). The unevaporated sample from 2 meters implies that the soil column at 299-W22-48 experienced anomalously high infiltration that allowed unevaporated water to reach that depth. The oxygen isotopic composition allows the possibility that process water was spilled on the surface at this site and there is anecdotal information suggesting that there was an infiltration pond for clean process water in the vicinity.

Data for the water from the moist sediment zone just along the lower Plio-Pleistocene caliche are of great interest in deciphering subsurface water movement. The data show that the water is not derived from direct, vertical infiltration in the vicinity of borehole 299-W22-48 because the isotopic composition of porewater above and below the moist zone are different than that of the water derived from the moist zone. The most likely source for the porewater from this zone is the 216-S-3 crib located ~50 meters west northwest of the borehole although some contribution from the S-SX tank farms is possible.

Stable isotopic composition of porewater collected from sediment in Waste Management Area S-SX was used to distinguish water from liquid disposal sources from natural infiltration.

The stable isotope data can be used to constrain the age of the water in the moist sediment. The oxygen isotope composition is identical to that of Columbia River water and ~2 to 3 per mil lighter than the surrounding waters. Isotopic redistribution by liquid and vapor phase diffusion will dissipate this isotopic anomaly in roughly 25 years. Thus, the water is almost certainly introduced recently.

In summary, the stable isotopic composition of porewater collected from sediment in Waste Management Area S-SX was used to distinguish water from liquid disposal sources from natural infiltration.

3.3.7 Predicting Deep Drainage Using Soil Hydraulic Properties and Soil Texture Data

G. W. Gee and A. L. Ward

Previous studies have shown that movement of contaminants from leaking tanks is accelerated by infiltration of precipitation. Tank farms and other waste sites at Hanford are generally covered with gravel and kept free of vegetation. These factors eased operation of the tanks and prevented uptake of contaminants by plants or animals, but enhanced infiltration of precipitation.

This study used data collected from previous studies to calibrate a simple water balance model that predicts infiltration. The previous studies included Gee et al. 1992, PNNL-13033, Tyler et al. 1999, PNL-6488, PNL-6403, and Gee and Bauder 1986.

An independent set of drainage data was collected to test the model. The independent data were from a 7-meter-deep basin lysimeter at the Hanford Site's Solid Waste Landfill where data have been collected since 1996. At each site, texture of the surface soil was determined using wet sieving and hydrometer analysis (Gee and Bauder 1986).

The Tank Farm Water Balance Model was derived from the data described above. Deep drainage at waste burial sites at Hanford is best analyzed by assessing the complete water balance of the surface soils. Drainage is an integral component of the water balance and in its simplest form is equal to precipitation minus the sum of storage change plus evapotranspiration plus runoff/run-on.

A simple tank farm water balance model predicted average drainage rates of 15% to ~45% of the average annual precipitation at three single-shell tank farms.

Water balance of surface soil is controlled by three main variables, climate, soil and vegetation as described previously. The assessment of net infiltration (drainage) at the waste sites involves the interaction of these three factors. The Tank Farm Water Balance Model is based on the above description of climate, soil, and vegetation and the fact that most waste sites have highly permeable surfaces and are on relatively level ground (little or no runoff or run-on). The model assumes the following conditions:

1. Winter precipitation dominates the net infiltration process.
2. Water runoff and run-on volumes are negligible.
3. Annual water storage changes are negligible.
4. Soil texture (e.g., particle-size distribution) controls the amount of water retained in the surface and influences the overall evaporation rate.
5. The soil surface remains unvegetated (upward water movement is by evaporation only—i.e., no transpiration, or water uptake by plants).

Based on the above assumptions the surface water balance can be written as:

$$D = (P_1 + P_2) - (E_1 + E_2) \qquad (1)$$

where P_1 = winter (November through March) precipitation
P_2 = non-winter (April through October) precipitation
E_1 = winter evaporation
E_2 = non-winter evaporation.

Combining terms leads to the following expression

$$D = P_1 - E_f \qquad (2)$$

where $E_f = (E_1 + E_2) - P_2$ = an evaporation factor-.

E_f is dependent upon soil texture and precipitation.

Based on an analysis of lysimeter records (Gee et al. 1992; PNNL-13033), the impact of precipitation and soil texture on drainage was determined for a range of surface conditions. The following relationship was developed:

$$E_f = E_f^o \text{ for } P_1 > 80 \text{ mm/yr} \qquad (3)$$

$$E_f = E_f^o [P_1/115]^{0.5}, \text{ for } P_1 \leq 80 \text{ mm/yr} \qquad (4)$$

where $E_f^o = 0.0069 f^3 - 0.43 f^2 + 12.64 f + 25.157$ with f being the percent fines (all material <53 micron in size).

Results

Table 3.3-2 shows Darcy's Law drainage estimates compared to actual drainage for the Buried Waste Test Facility sandy soil. The data indicate that the five hydraulic conductivity functions varied widely in their estimates of drainage at a soil-water pressure head of -0.4 meter. There are differences of more than three orders of magnitude between methods. The instantaneous profile method of Watson (1966) provided the best estimate of drainage, whereas the Guelph Permeameter provided the worst estimate.

The performance of the water balance model is shown in Figure 3.3-24, where the model is applied to the lysimeter data from the Buried Waste Test Facility. The agreement between modeled and observed drainage is good. However, it must be kept in mind that the model was not independent of the lysimeter data, because the drainage for the first 15 years from the lysimeter was used in fitting the evaporation factor, E_f, for coarse sand. However, the model then was applied to independent data from the Hanford Solid Waste Landfill lysimeter (HNF-7173). Table 3.3-3 shows measured annual drainage compared to that predicted by the water balance model for a 4-year period. The annual drainage is predicted within 4 millimeters for all 4 years. (The calendar year 1997 winter precipitation exceeds the 1997 annual precipitation because the winter precipitation was calculated from November 1996 to March 1997. Fortuitously, the November to December record precipitation is identical to the entire 1997 annual value, illustrating the extreme variability in Hanford climate.)

Uncertainty in the drainage is dependent on uncertainties in the surface soil texture. Variations in texture (percentage of fines) by several percentage points can alter the drainage estimate by 10 to 20 millimeters per year or more. For example, an increase of fines from 1% to 7% reduces the predicted drainage by a factor of nearly 3, from 80 to 28 millimeters per year.

Drainage predictions were developed for several tank farms, where textural data were available for surface sediment. Table 3.3-4 shows the predicted annual drainage from the Tank Farm Water Balance Model, based on surface texture and the past 20-year climate record. Drainage estimates from the textural data suggest that over a 20-year period, the average drainage rate ranged from 15% to over 50% of the annual average precipitation (28 to 80 millimeters per year).

Discussion

Darcy's Law estimates of drainage, using five different methods to determine the unsaturated hydraulic conductivity, resulted in five distinctly different values of drainage. The two field methods tested provided both the best and worst predictors of drainage. The analysis suggests that when the field drainage data are taken over the range of interest, reliable estimates of drainage can be obtained.

Data available from lysimeter studies at the Hanford Site have shown that winter precipitation and surface textures are the dominant controls to waste site drainage (Gee et al. 1992; PNNL-13033). The calibration data set for the Tank Farm

Water Balance Model contains a 20-year precipitation record and drainage from lysimeters with surfaces ranging from clean gravels to fine silt loams. Combining these data into a water balance model has led to a simple expression for predicting drainage at tank farms and other waste sites that have bare surfaces. Based on the past 20-year record, drainage for tank farms was predicted to range from 20 to 80 millimeters per year. The model does not account for thermal effects on evaporation due to radioisotope heated tank wastes (warmer subsurface temperatures could increase the evaporation rates from tank farms thus decreasing drainage). For this reason, the values reported here may overestimate the actual drainage fluxes. There have been no direct measurements of drainage at Hanford Site tank farms and only one set of measurements for other waste burial grounds (the Solid Waste Landfill), so full verification of the model remains to be completed as additional data are collected.

Table 3.3-1. First Solution Releases

	Volume (liter)	Start	Stop
Release #1	4,247 (blind)	08/09/01 (8:30)	08/13/01 (8:50)
Release #2A	1,772	08/14/01 (11:45)	08/16/01 (11:00)
Release #2B	1,760	08/16/01 (15:13)	08/17/01 (11:50)
Release #3	1,373	08/20/01 (12:04)	08/21/01 (11:37)
Release #4	4,088 (blind)	08/21/01 (14:45)	08/23/01 (12:04)
Release #5	1,435	08/27/01 (13:08)	08/29/01 (08:38)

Table 3.3-2. Darcy's Law Drainage Estimates from Unsaturated Hydraulic Conductivity Functions for Sand at the Buried Waste Test Facility (assumes a unit-gradient condition at the soil water content of 0.09 m^3m^{-3} and the soil water pressure head of -0.40 m)

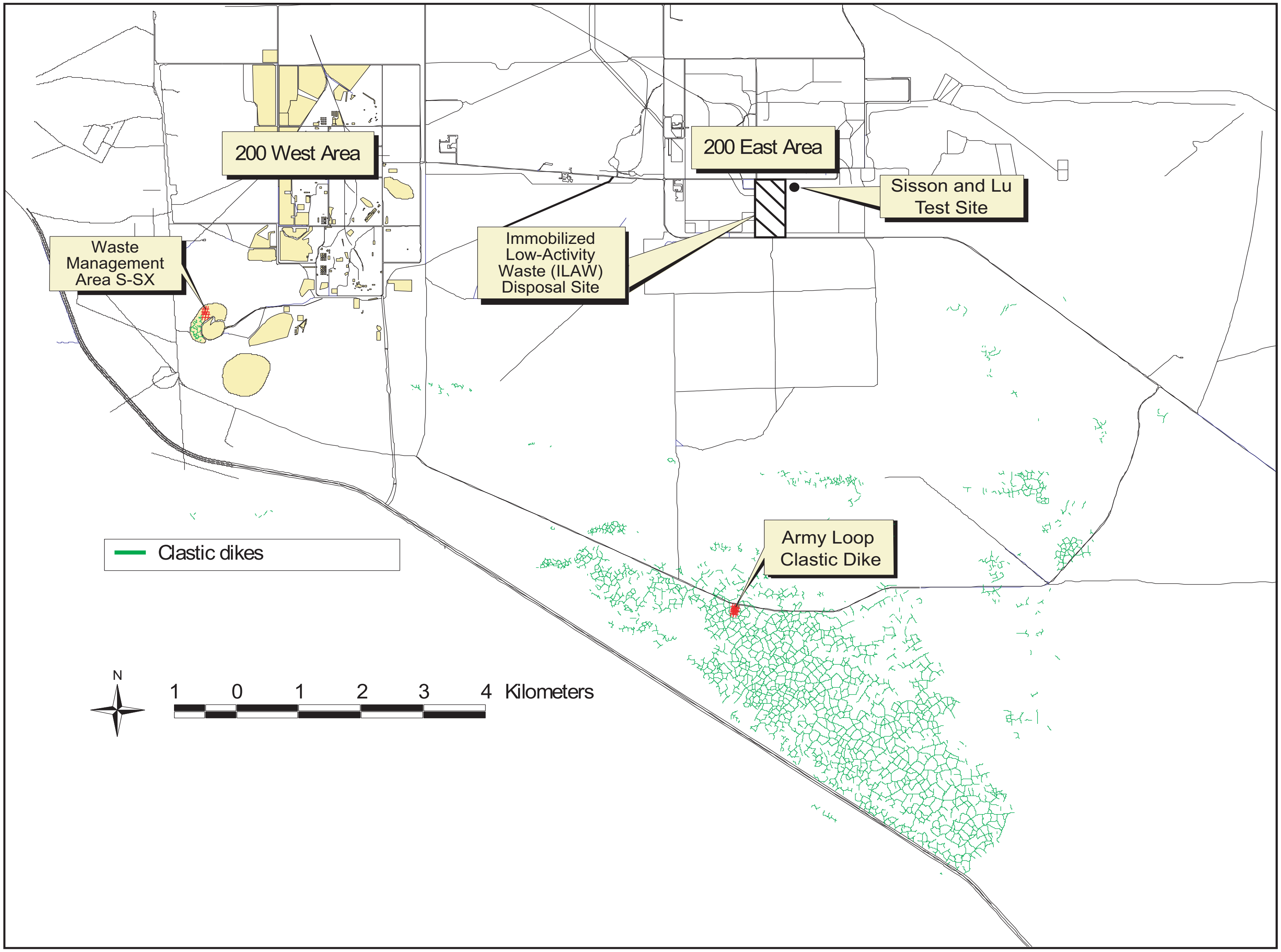
Method	Drainage (mm/yr)
Particle size (Arya and Paris 1981)	3,700
Steady state column (Klute and Dirksen 1986)	20 to 32,000
Guelph permeameter (Reynolds and Elrick 1985)	189,000
Ultracentrifuge (Nimmo et al. 1994)	25,000
Instantaneous profile (Watson 1966)	45 to 55
Direct measure (drainage lysimeter)	56

Table 3.3-3. Measured Drainage at the Hanford Solid Waste Landfill Compared to that Predicted by the Tank Farm Water Balance Model

Year	Annual Precipitation (mm)	Winter Precipitation (mm)	Measured Drainage (mm)	Predicted Drainage (mm)
1997	162	224	162	158
1998	164	107	41	42
1999	95	86	22	21
2000	205	88	19	23

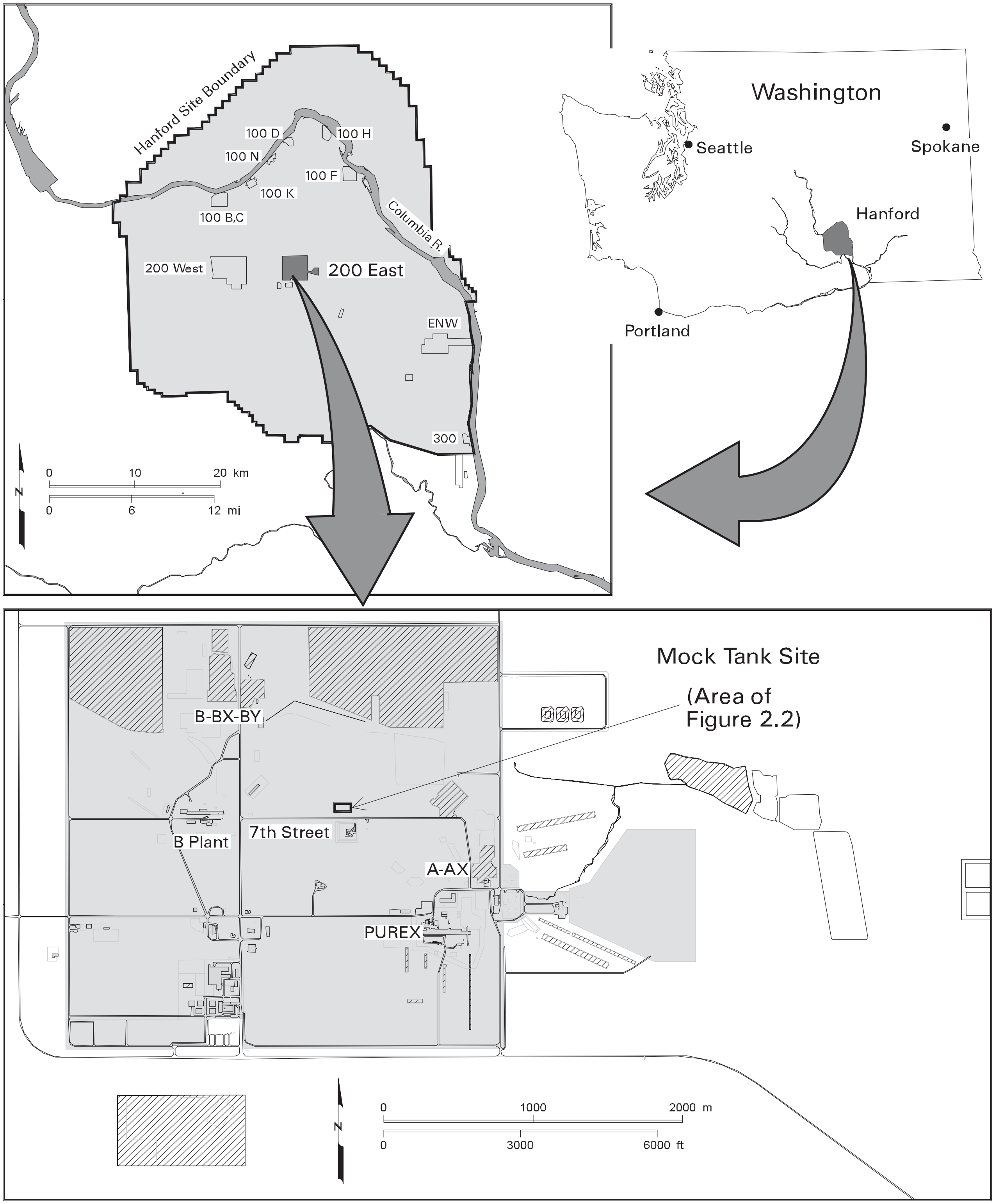
Table 3.3-4. Predicted Drainage Rates from the Tank Farm Water Balance Model Related to Percent Fines in Surface Sediment and Percentage of Annual Precipitation Based on a 20-Year Record

Site/Soil	Percent Fines	Drainage (mm/yr)	Percent Precipitation
AP tank farm	1	80	43
S tank farm	3	56	30
U tank farm	7	28	15
Coarse gravel	0	98	53
Solid Waste Landfill Site	3	56	32
Silt loam	60	0	0



ECS01006

Figure 3.3-1. Location Map of Sites Selected for High-Resolution Seismic Characterization



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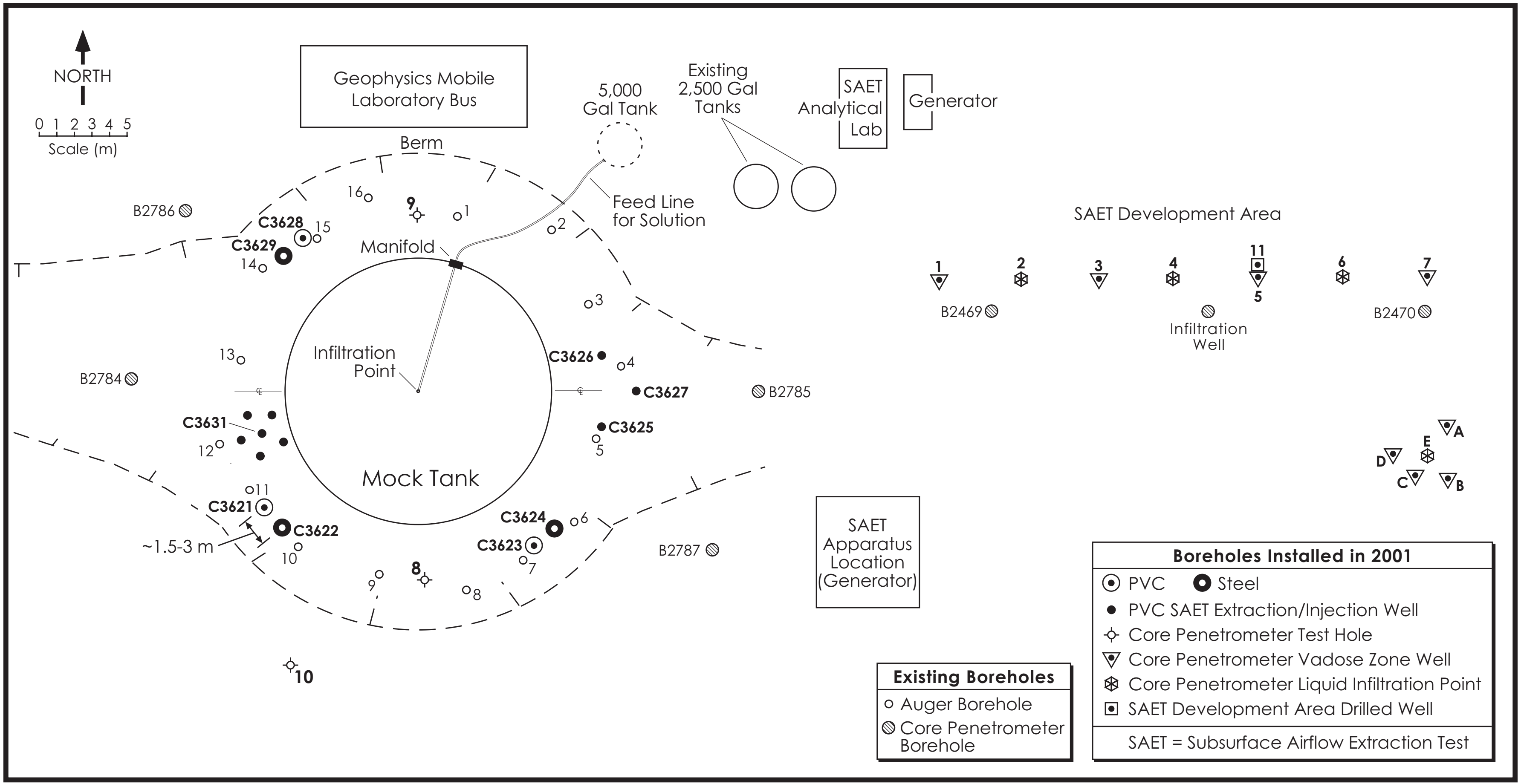
ECS01010

Figure 3.3-2. Location of Mock Tank Site and the Fiscal Year 2001 Tank Leak Detection Demonstration Project

ECS01011

Figure 3.3-3. View of the Mock Tank Site During Fiscal Year 2001. Large PVC pipes are air-extraction lines for the subsurface airflow extraction test. The bus at left is the mobile geophysics laboratory. The large black storage tank contains the sodium thiosulfate solution used to simulate a tank leak. The trailer and RV to the right of the storage tank serve as a field laboratory for the subsurface airflow extraction test.



2002/DCL/Tank 105/001

Figure 3.3-4. Layout of the Mock Tank Site and Adjoining Demonstration Area of the Subsurface Airflow Extraction Test, Showing Old Installations and New Infrastructure for Fiscal Year 2001 Testing

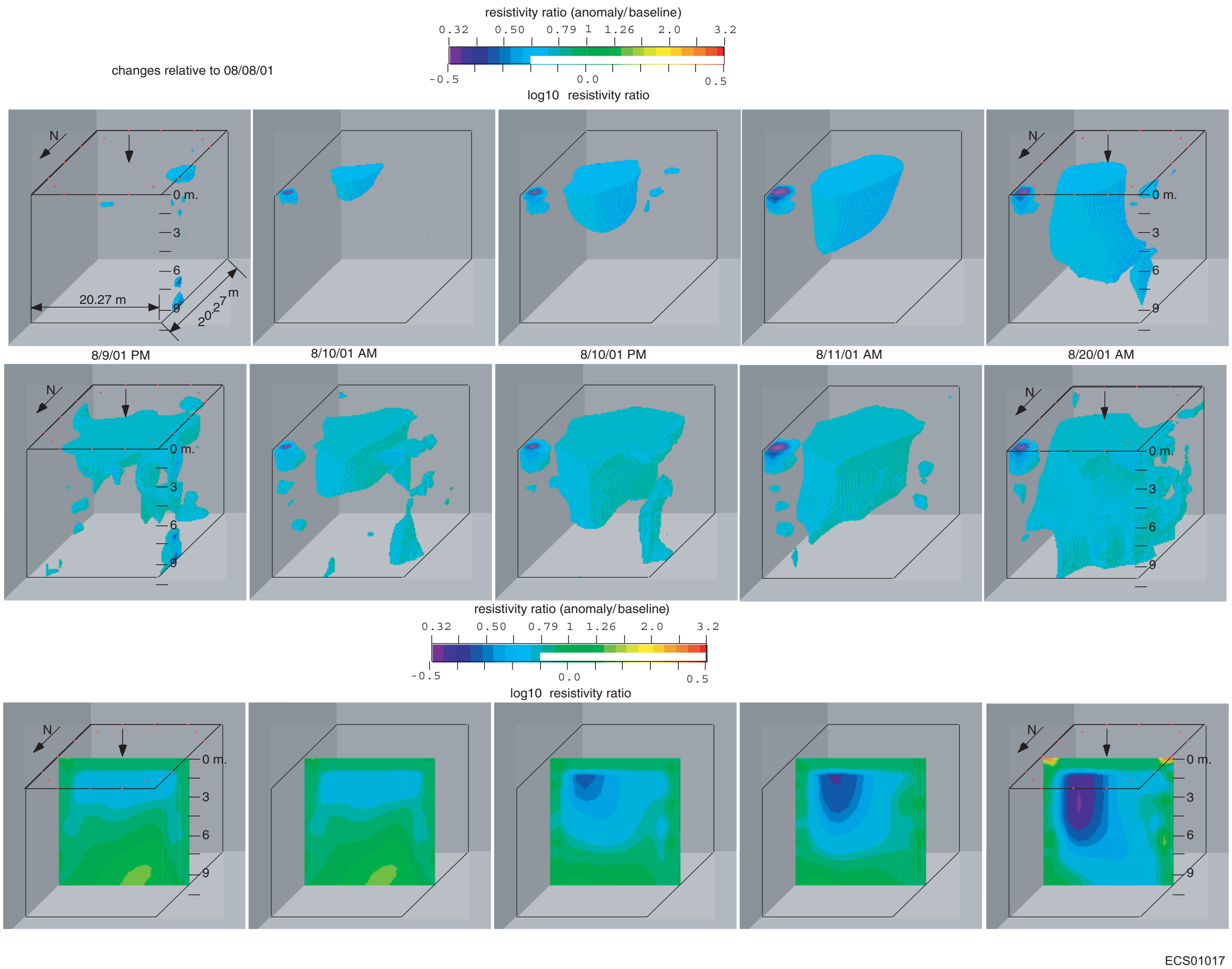
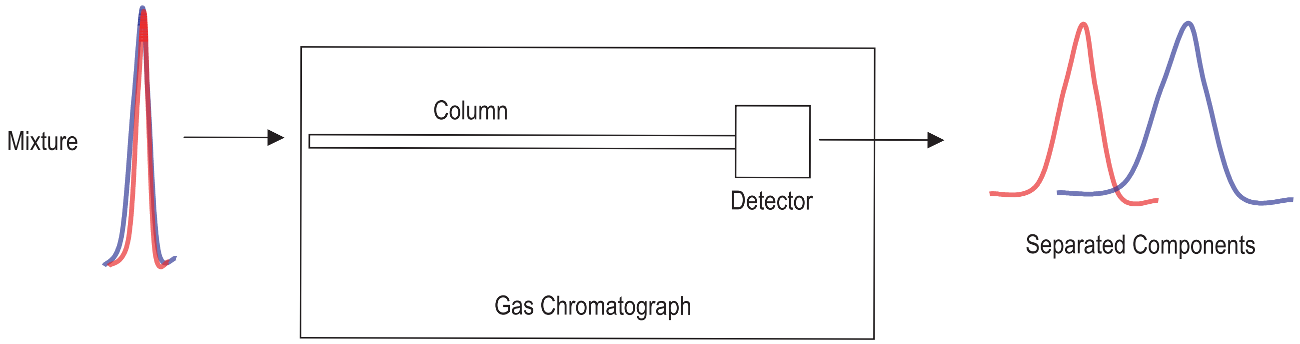


Figure 3.3-5. Three-Dimensional Electrical Resistivity Tomography Showing a History of the First Solution Release. The bottom row shows a single vertical section through the same three-dimensional construction as in the first two rows.



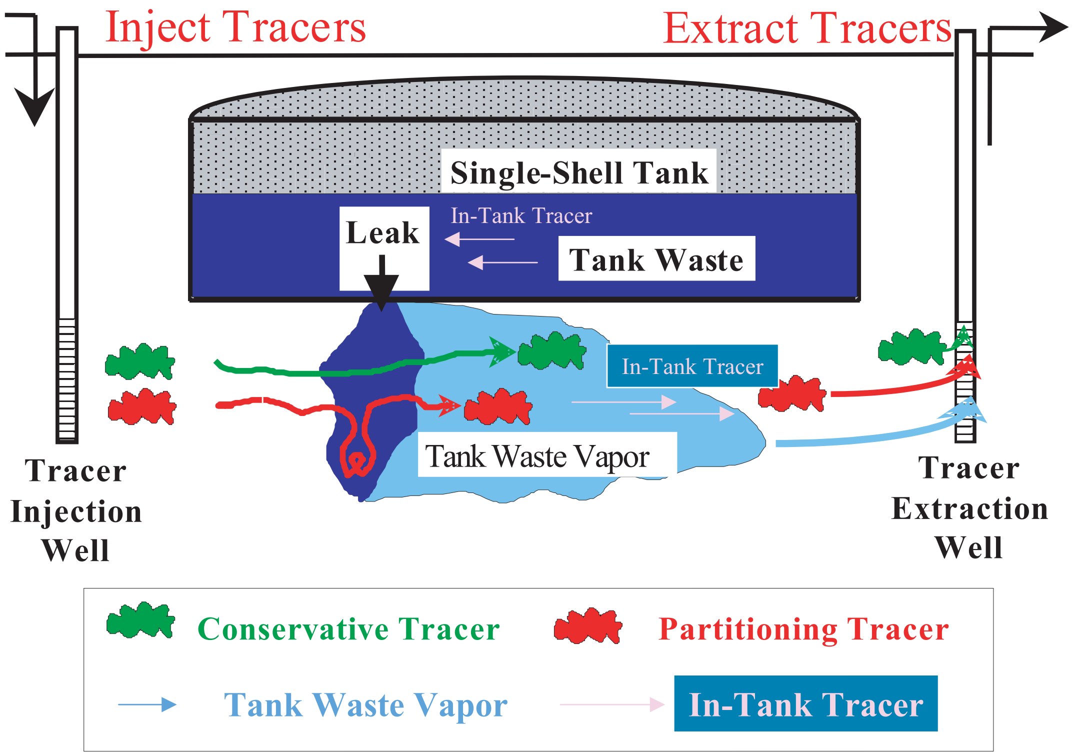
Partitioning relationship between phases described by partition coefficient:

$$K_i = \frac{C_{i,\ \text{Phase A}}}{C_{i,\ \text{Phase B}}} \quad \text{or}$$

Mean residence times of tracers calculated from first temporal moments (centroids of areas under breakthrough curves) $\overline{t}_i$

ECS01019

Figure 3.3-6. Principle of Subsurface Airflow Extraction Tests. Schematic illustration of the transport of conservative and partitioning tracers, in-tank tracers, and tank-waste vapors through an advective flowfield beneath a leaking tank. Partitioning tracers are retarded during passage through the tank waste in the vadose zone. In-tank tracers (chloro/fluorocarbons, N2O) will also be swept through the flowfield and will provide qualitative indication of a leak, as will perturbations of the conservative tracer elution curve caused by leak-induced porosity changes.



ECS01020

Figure 3.3-7. Illustration of Subsurface Airflow Extraction Operation Beneath a Leaking Tank

Figure 3.3-8. Photograph of the Army Loop Road Excavation. Each grid shown in front of the lowest exposed face is 2 meters wide and 1 meter high. Blue tent in the background covers the infiltration test site.

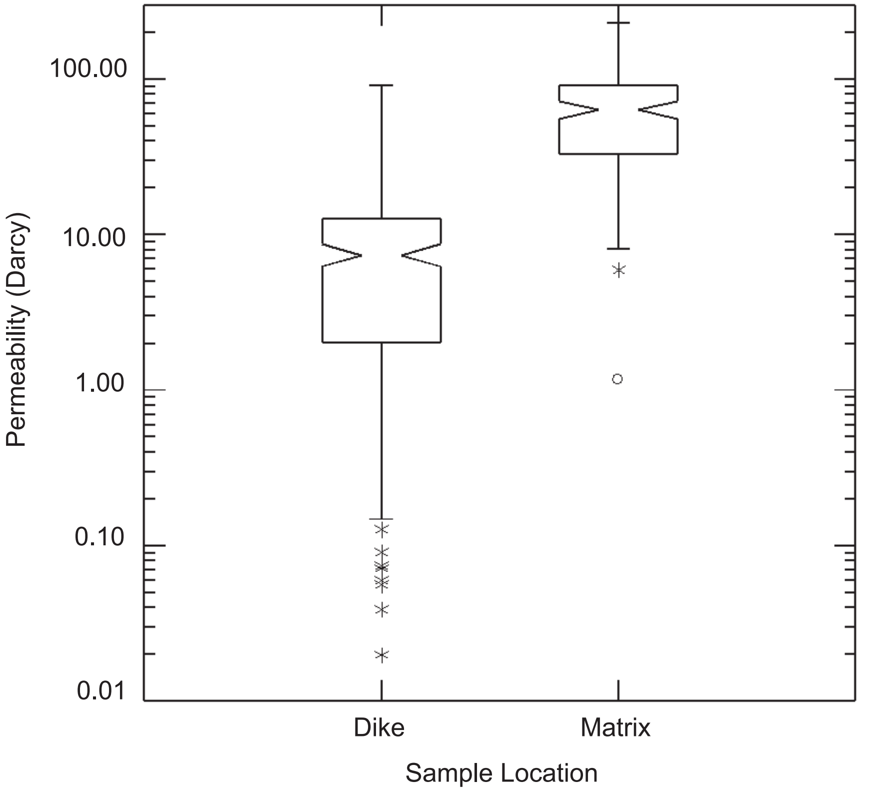


Figure 3.3-9. Box and Whisker Diagram of the Air Permeability of the Dike and Matrix. The notches in the boxes are the median values of air permeability.

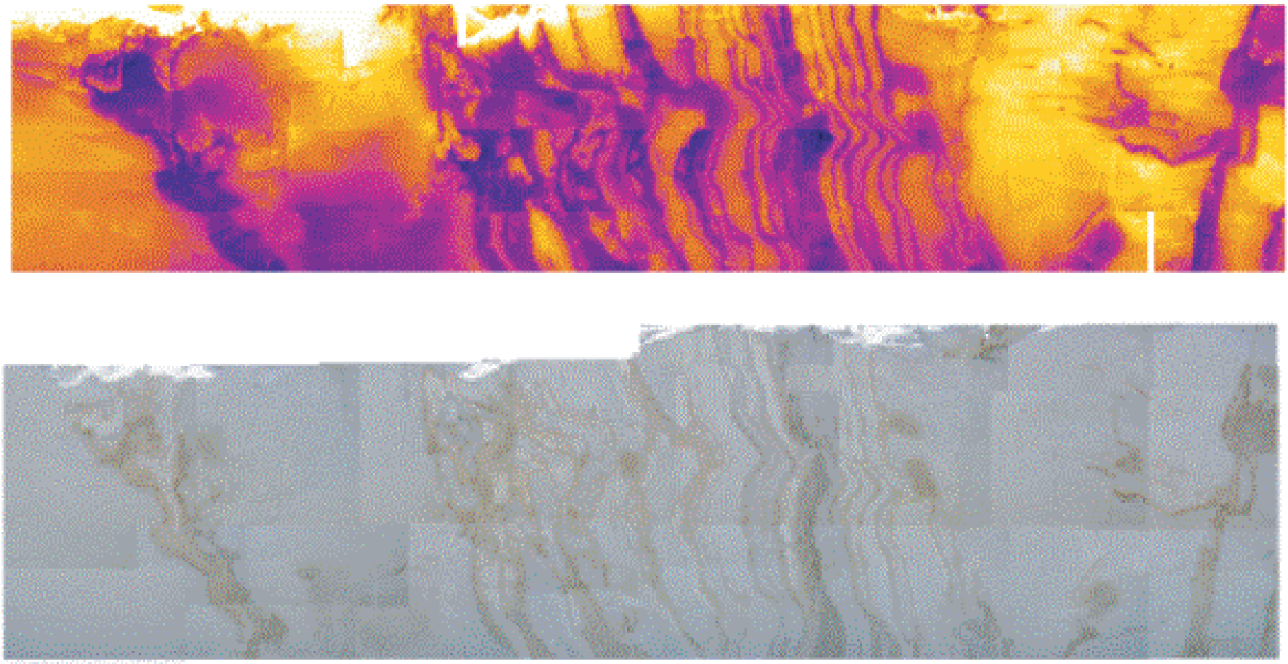


Figure 3.3-10. Composite Photograph of the Dike Exposed in the Army Loop Road Trench. The lower photo is an ordinary digital camera image and the upper image is an infrared image. The major part of the dike is in the center third of the picture.

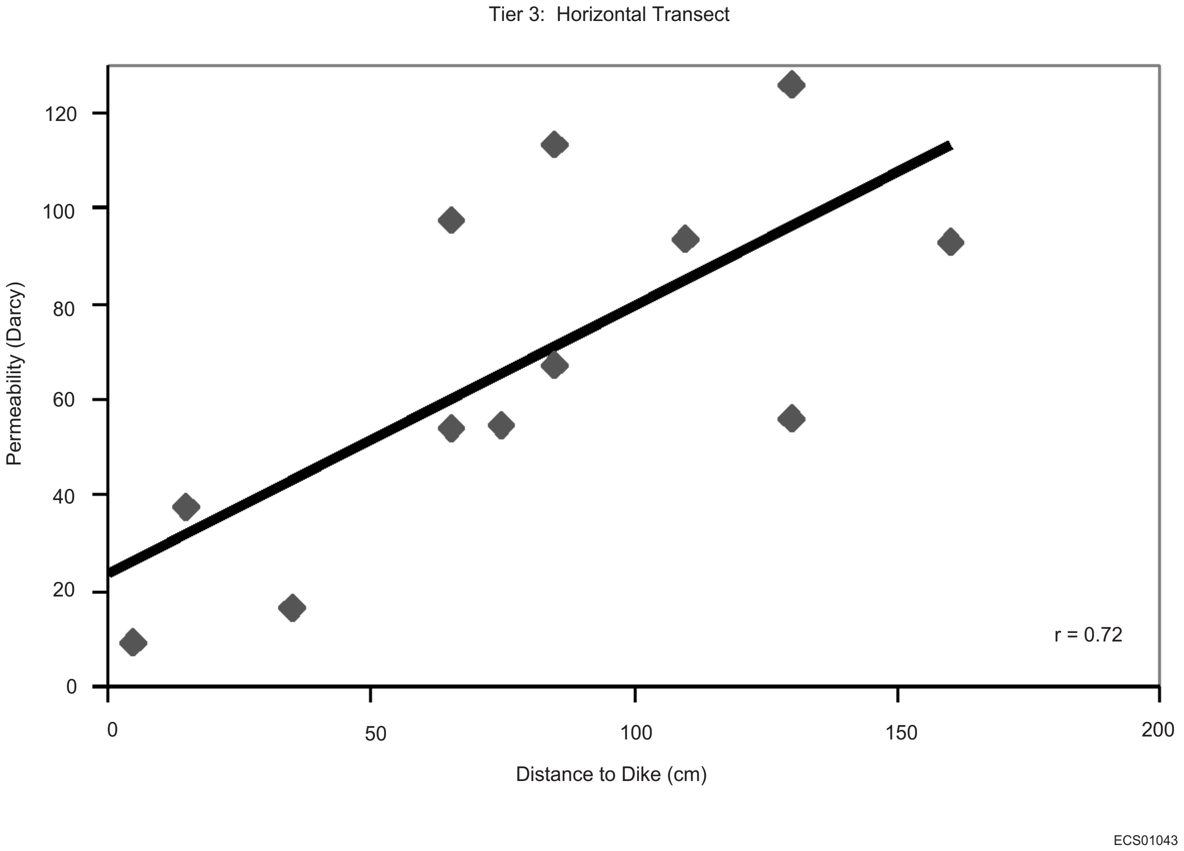
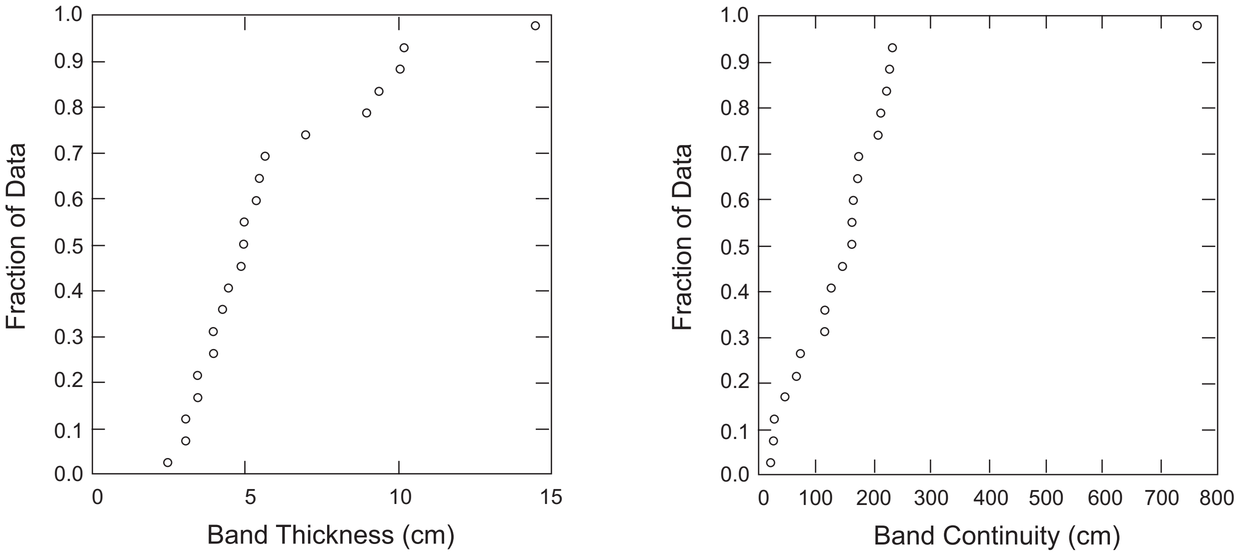
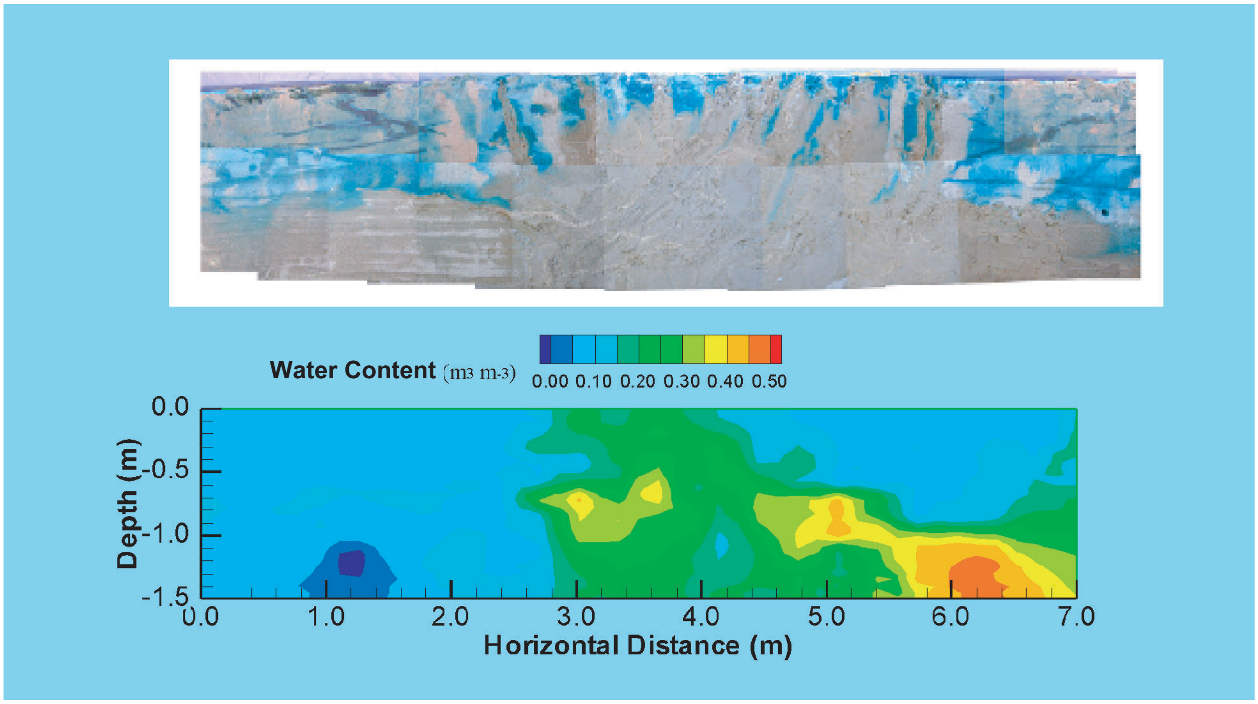


Figure 3.3-11. Air Permeability versus Distance from the Clastic Dike Along a Horizontal Transect in the Host Sediment. The edge of the dike is at 0 cm.



ECS01044

Figure 3.3-12. Thickness and Continuity of Bands within the Clastic Dike Exposed in the Army Loop Road Trench



ECS01045

Figure 3.3-13. Dye Infiltration Experiment at the Clastic Dike in the Army Loop Road Trench. The upper image is a photo of the exposure showing the distribution of the blue dye. The lower image is a computer generated map of moisture distribution in the dike and adjacent sediment. The dike is between about 3 and 5 meters.

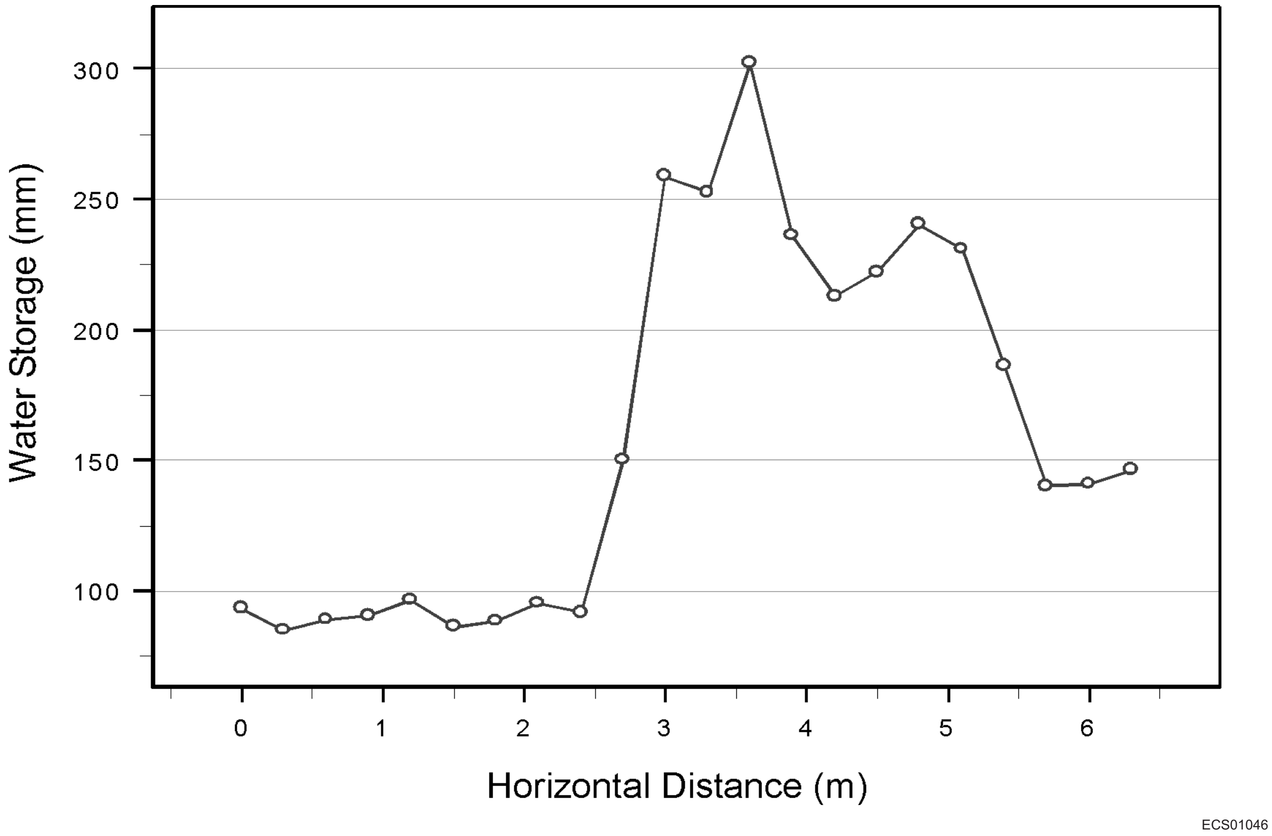


Figure 3.3-14. Moisture Distribution within the Clastic Dike in the Army Loop Road Exposure. The dike is between 3 and 5 meters.

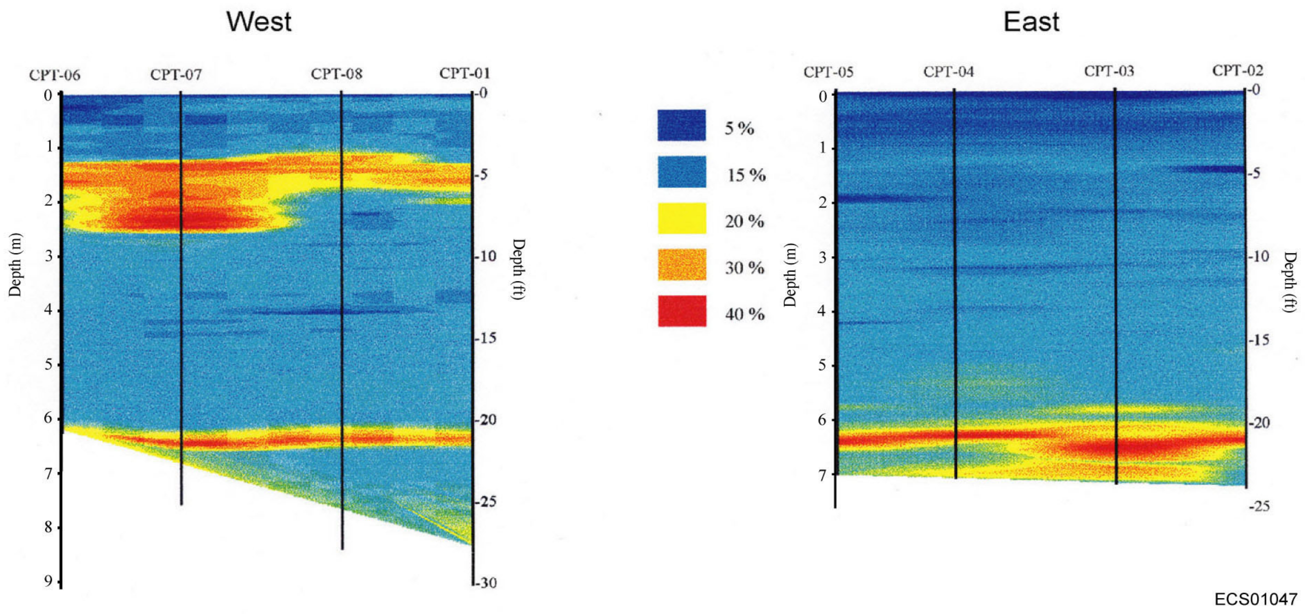
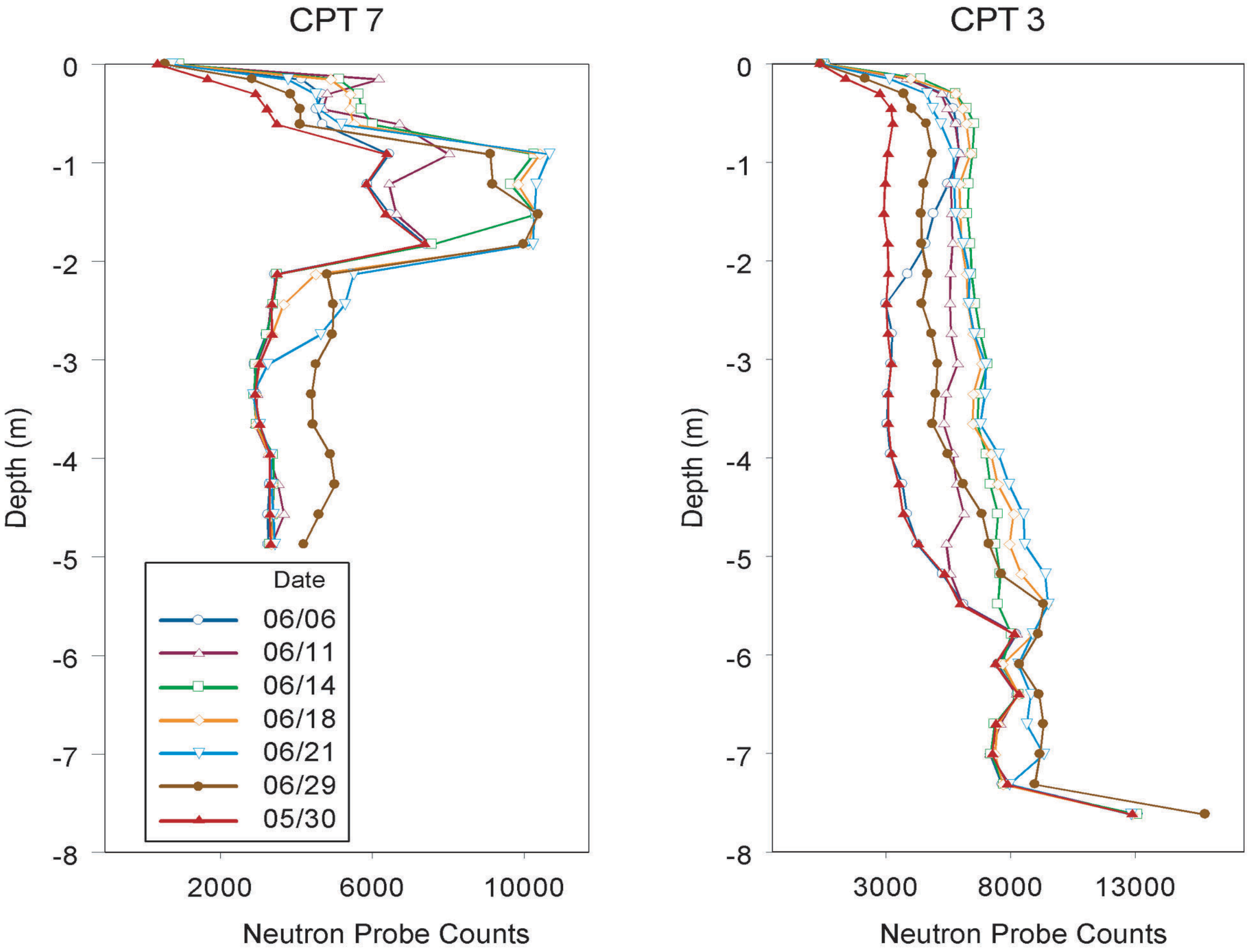


Figure 3.3-15. Vertical Distribution of Moisture Data on the East and West Sides of the Dike



ECS01039

Figure 3.3-16. Neutron Probe Measurements on the East (CPT 3) and West (CPT 7) Sides of the Dike. The sill is at 1 to 2 meters on the west side of the dike.

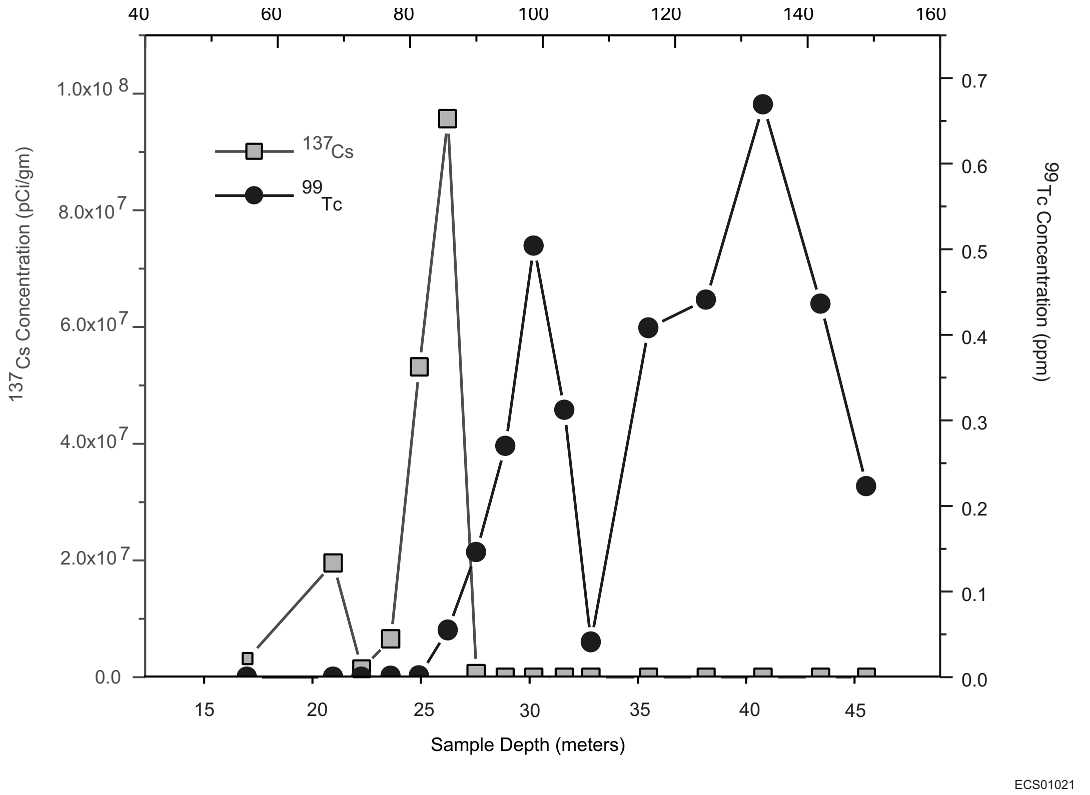


Figure 3.3-17. Concentrations of Cesium-137 and Technetium-99 versus Depth in Samples from Borehole C3082 (data are from PNNL-13757-4)

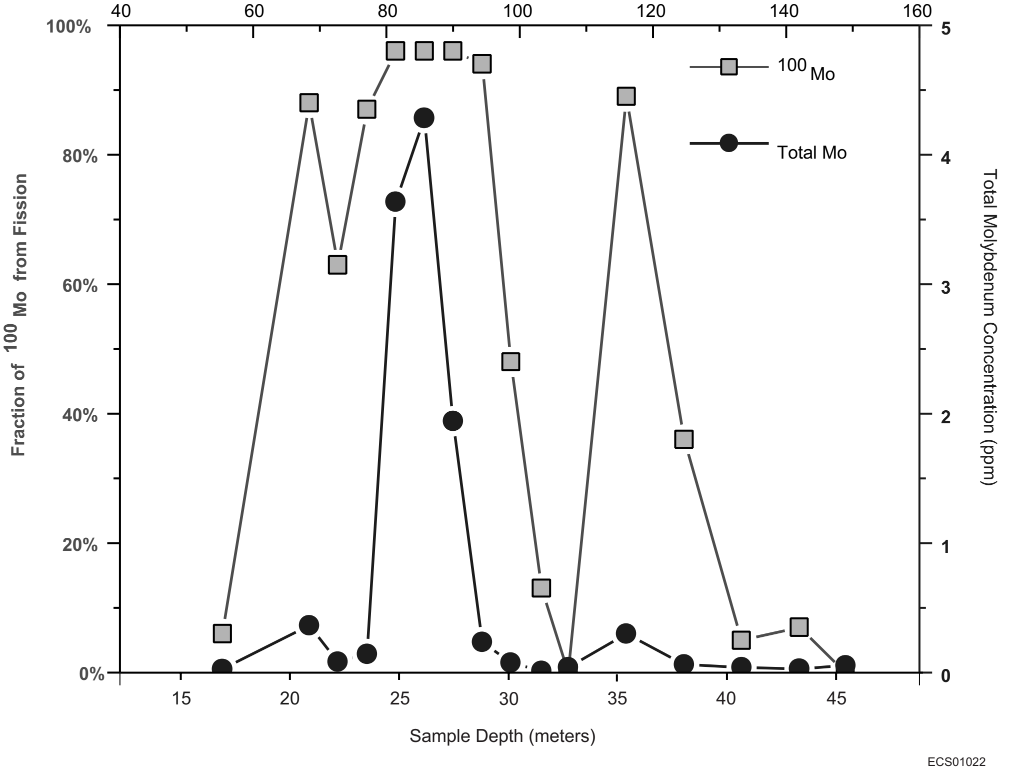


Figure 3.3-18. Concentration of Molybdenum-100 and Total Molybdenum versus Depth in Samples from Borehole C3082

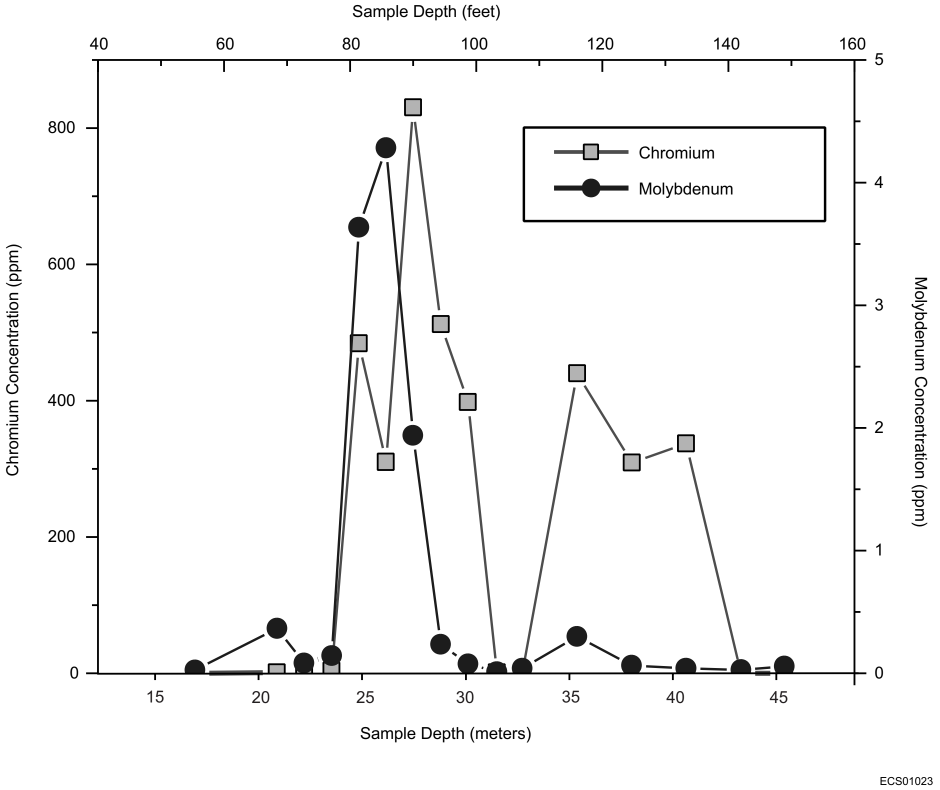


Figure 3.3-19. Depth Distribution of Molybdenum and Chromium in Borehole C3082

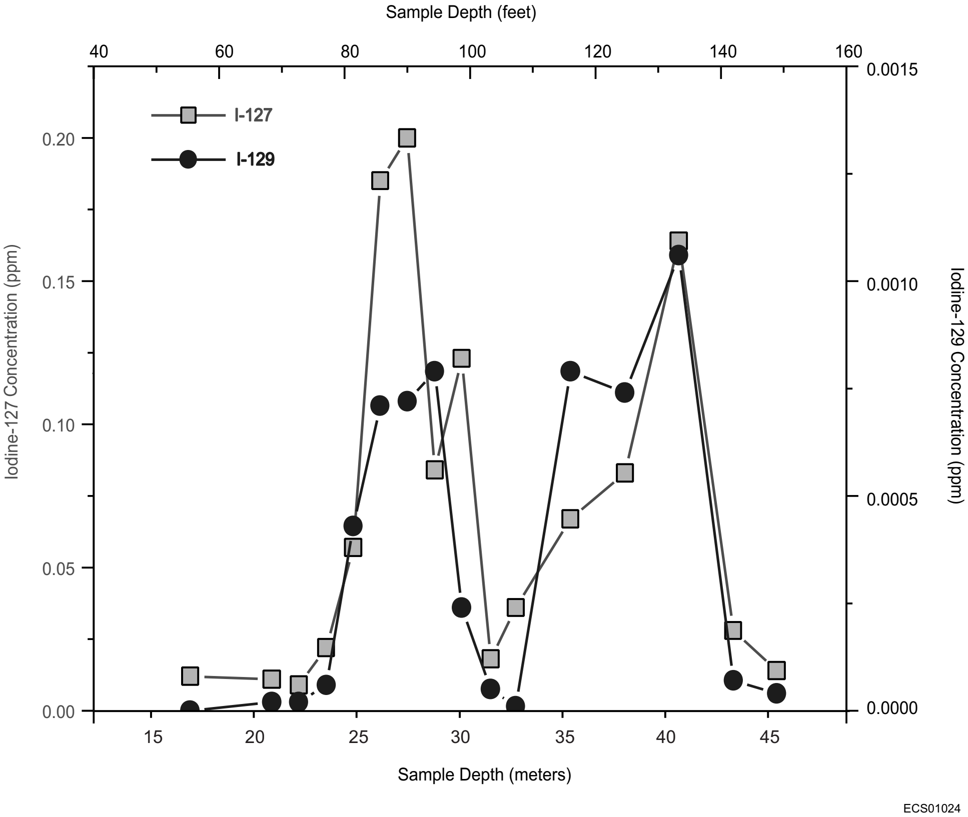


Figure 3.3-20. Depth Profiles for Iodine-127 and Iodine-129 in Samples from Borehole C3082

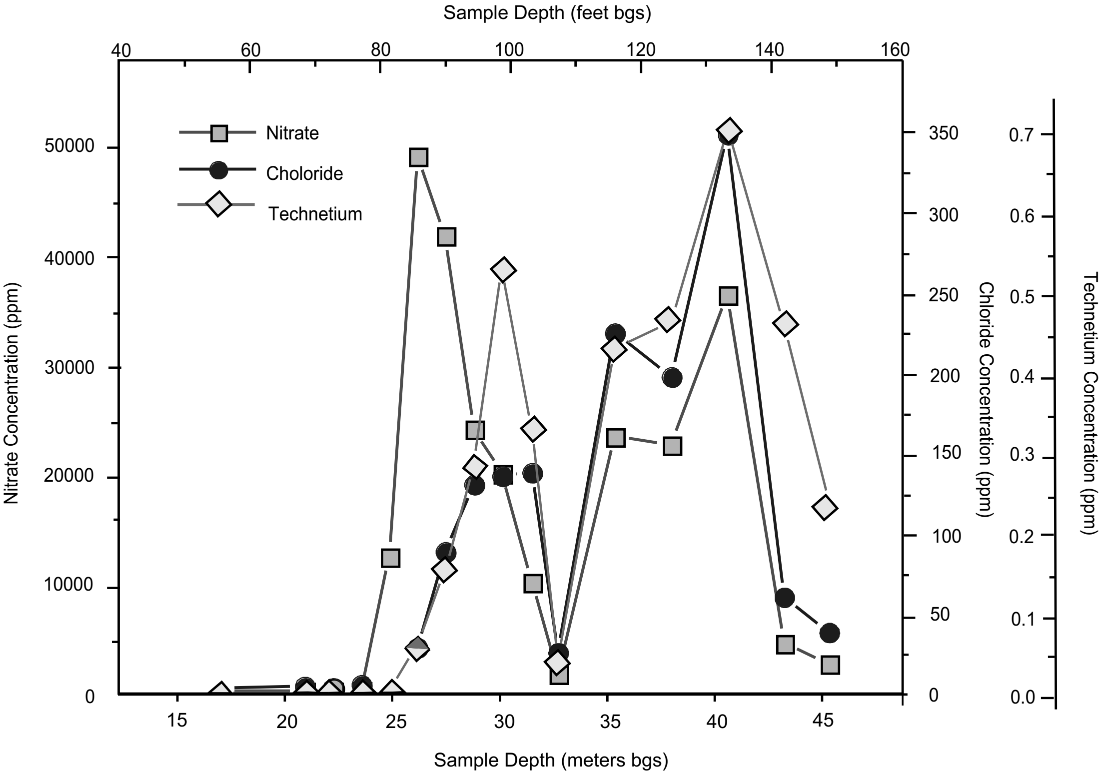


Figure 3.3-21. Depth Distribution of Nitrate, Chloride, and Technetium in Borehole C3082

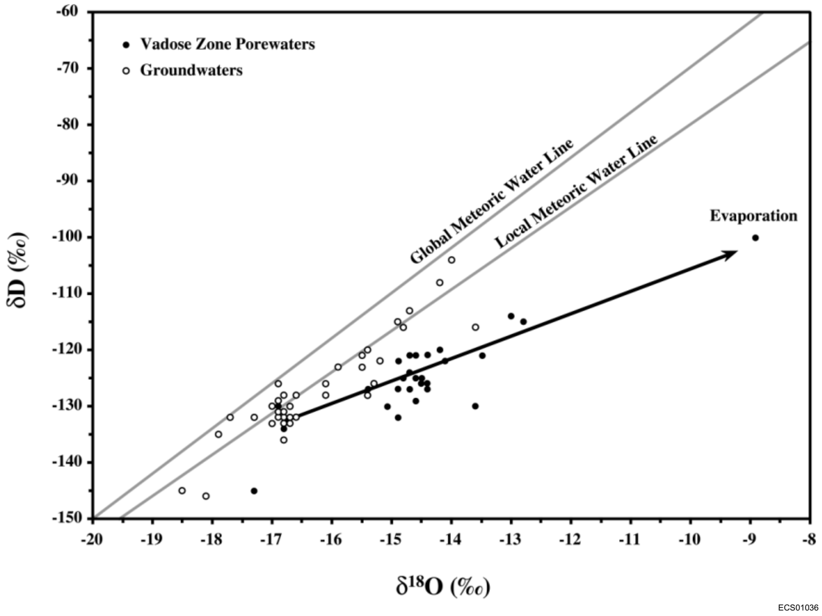


Figure 3.3-22. D versus O for Samples of Porewater from Well 299-W22-48 Core (black circles) and Groundwater Samples from the Hanford Site (open circles). The global meteoric water line, the local meteoric water line, and a characteristic evaporation trend are also shown.

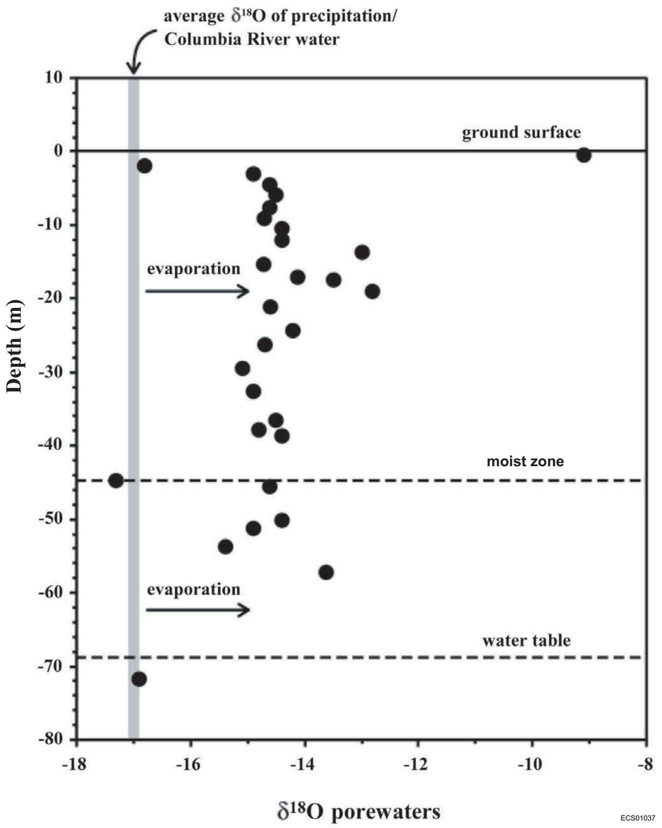


Figure 3.3-23. Oxygen Isotope Composition versus Depth for Samples of Porewater from Well 299-W22-48. The approximate depths of the moist zone above the Plio-Pleistocene caliche layer and the groundwater table are also shown.

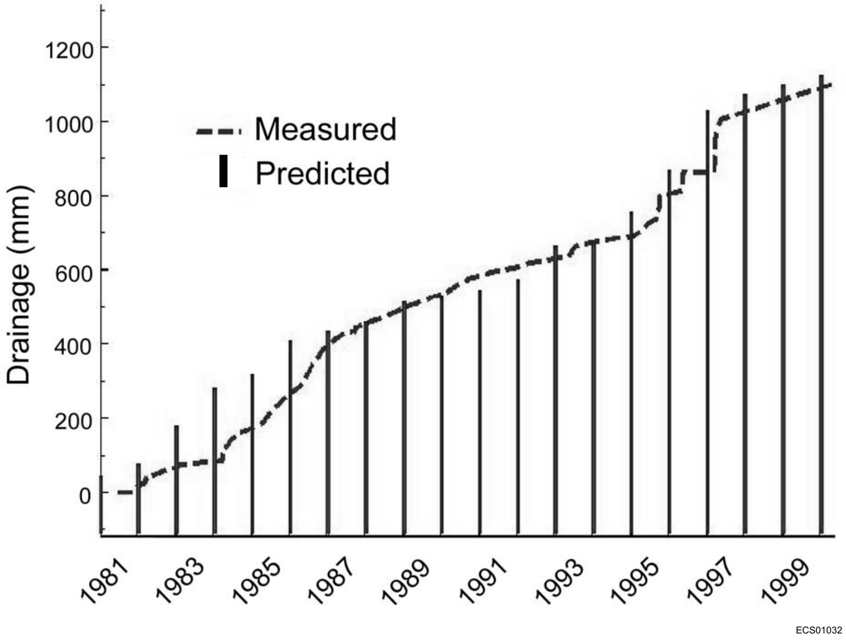


Figure 3.3-24. Twenty-Year Record of Measured and Predicted Drainage from Buried Waste Test Facility Lysimeter. Predictions are from the tank farm water balance model with Hanford Meteorological Station climate record and measured soil texture.

3.4 Groundwater/Vadose Zone Integration Activities

D. G. Horton

Several activities were completed in fiscal year 2001 to support the Groundwater/Vadose Zone Integration Project's (Integration Project) System Assessment Capability modeling efforts. This included gathering data describing the distribution of subsurface contamination for comparison with the results of numerical models describing contaminant distribution. Activities also were completed that describe the features, events, and processes that are important for waste management and remediation efforts at the Hanford Site. This section discusses activities done by the vadose zone module of the System Assessment Capability. The groundwater module is discussed in Section 4.3.

3.4.1 Hanford Site Hydrogeologic Databases

D. G. Horton

The Characterization of Systems Task under the Integration Project is responsible for establishing a consistent set of data, parameters, and conceptual models to support efforts at the Hanford Site to estimate contaminant migration and impact.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Eight facilities were selected for System Assessment Capability history matching including tank T-106 at the T tank farm (shown above). The purpose of the history matching effort was to compare test model predictions with field observations.

As part of these efforts, the Characterization of Systems Task assembled a series of catalogs in fiscal year 2001 that identified the depth and breadth of existing geologic, hydrologic, and geochemical data. These catalogs are the first step in developing a comprehensive, useable, and scientifically defensible database of geologic, hydrologic, and geochemical data.

Fifty-five years of technical data gathering at the Hanford Site has resulted in data scattered among numerous databases, published and unpublished reports, and the technical files of individual contributors. The purpose of the catalogs was to identify these existing data, make an initial cursory assessment of the quality of the data, and gather the sources of the data in one place. Three catalogs were published and a fourth was drafted:

- *A Catalog of Geologic Data for the Hanford Site* (PNNL-13653)
- *A Catalog of Vadose Zone Hydraulic Properties for the Hanford Site* (PNNL-13672)
- *Data Catalog for Models Simulating Release of Contaminants from Hanford Site Waste Sources* (PNNL-13666)
- *Hanford Contaminant Distribution Coefficient Database – FY01 Status Report, Draft.*[(a)]

A compilation of geologic data sources was made in fiscal year 2001. It is estimated that this documentation represents ~90% of the available geologic information collected at the Hanford Site.

The geologic data report includes 2,640 wells and boreholes in the 100 Areas, 200 Areas, and 300 Area from which some kind of geologic data exist. Nearly all of the wells (2,501) have some form of driller's log or geologist's log. Archive samples are available from 1,740 wells. Particle size distribution data are available from 1,124 of the wells, calcium carbonate content from 981 wells, and moisture content data from 423 locations. Most wells have data from numerous samples (e.g., 1.5-meter intervals throughout the well). In addition, some kind of geochemical data (excluding calcium carbonate content) are available from 587 wells, physical property data (other than particle size distribution and moisture) are available for 269 wells, mineralogic information is available from 52 wells, and geochronology data from 23 wells. The report also contains an annotated bibliography of 158 references that contain the geologic data. This compilation of data sources is the most comprehensive made for the Hanford Site. It is believed that >90% of the available geologic data are represented.

The hydraulic property catalogue contains data sources from 182 boreholes and surface locations on the Hanford Site (PNNL-13672). For each sample location, there may be data from multiple depth intervals and many measurements taken at multiple time intervals. Table 3.4-1 shows the types of data available and their locations.

A third report (PNNL-13666) summaries release models used in Hanford Site assessments published over the past 14 years (1987 to 2001). The report (1) provides a summary of descriptions and uses of release models, (2) describes mathematical formulations that commonly have been used in recent years, (3) links release models to data on various waste sources found on the Hanford Site (i.e., saltcake, cement, soil-debris, reactor block, glass, and corrosion), and (4) provides sources of parameter information and data used in the models. The links allow users to quickly locate the specific release model information and data sources they need to apply the models to future site assessments.

A fourth database was compiled containing distribution coefficient data for the sorption of several species on Hanford Site sediments. Table 3.4-2 lists the species for which data are compiled. Included with the distribution coefficients are

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(a) Cantrell, K. J., R. J. Serne, and G. V. Last. 2001. *Hanford Contaminant Distribution Coefficient Database – FY01 Status Report.* Draft Report, Pacific Northwest National Laboratory, Richland, Washington.

pertinent experimental data such as the experimental method, equilibration time, initial concentration of the adsorbate in solution, solution/solid ratio, and source reference. In addition, to these data, more detailed information about the solution composition and the composition and characteristics of the sediment are given in two appendices.

It is believed that ~90% of existing distribution coefficients are represented in the database. A user's guide to the database will be made in fiscal year 2002 to aid users in accessing and selecting distribution coefficients from the database.

3.4.2 Initial Assessment Using the System Assessment Capability — Preliminary Vadose Zone Results

D. G. Horton and G. V. Last

An initial assessment is being conducted with the System Assessment Capability that simulates the transport of 10 different radionuclide and chemical contaminants released from 890 wastes sites, over a time frame from 1944 through 3050. During fiscal year 2001, an initial assessment was performed to demonstrate proof-of-principal for the capability. The follow discussion focuses on some preliminary results from vadose zone simulations conducted at the end of fiscal year 2001.

Three major efforts were associated with the vadose zone portion of the initial System Assessment Capability assessment: data gathering, history matching, and the initial simulations. This section summarizes each of these efforts.

3.4.2.1 Data Gathering

Data were compiled to support vadose zone modeling as part of the initial assessment performed using the System Assessment Capability (Revision 0). The data defined the physical and geochemical parameters for the vadose simulations conducted as part of the initial assessment.

Thirteen aggregate areas were defined based on geographically contiguous areas with relatively homogeneous hydrogeologic characteristics. Each of the six 100 Areas were designated as separate aggregate areas; the 200 Areas were divided into six aggregate areas based on differences in hydrogeologic characteristics; and a single aggregate area was defined for the 300 and 400 Areas.

Generalized hydrostratigraphic columns were defined for each of the 13 aggregate areas. The columns were based on existing information from driller's logs, geologist's logs, geophysical logs, and published interpretive depths of hydrogeologic units. Estimated average strata thicknesses were used for the generalized columns.

Hydraulic property data were assigned to each hydrogeologic stratum present in each of the 13 aggregate areas. The hydraulic parameters assigned were van Genuchten model parameters, saturated hydraulic conductivity, residual water content, bulk density, and longitudinal dispersivity. From these values residual saturation and effective porosity were calculated or estimated. Data were taken from WHC-EP-0883, HNF-4769, RPP-2696, and SAND98-2880.

Six waste chemistry types were previously defined for use in the Composite Analysis (PNNL-11800). (The Composite Analysis is a radiological assessment to estimate dose to hypothetical future members of the public from low-level waste disposal and all other sources of radioactive contamination at the Hanford Site.)

These waste chemistry types describe chemically distinct waste streams that impact the sorption of contaminants. The waste chemistry types are

- high organic/very acidic
- high organic/near neutral
- high salt/very basic
- chelates/high salt
- low organic/low salt/acidic
- log organic/low salt/near neutral.

These same waste chemistry designations were adapted for use in the initial assessment of the System Assessment Capability to assign distribution coefficients to each hydrogeologic stratum in the base templates.

Contaminants were assumed to change mobility characteristics based on buffering of the contaminant solution by the vadose zone sediments and soil water after migrating for some distance through the vadose zone. Thus, distribution coefficients were defined separately for each contaminant in the upper vadose zone (near field or high impact zone) and in the lower vadose zone (far field or intermediate impact zone). Zones in which the organic concentration, pH, or salt concentration in the fluids may have affected the distribution coefficients were designated high-impact and zones in which the acidic or basic nature of the wastes was estimated to have been neutralized by the natural soil were designated intermediate impact. Generally, the hydrogeologic unit into which the waste streams were introduced was designated as high-impact and, if those units were thin, the hydrogeologic unit immediately below was also designated high-impact. All other hydrogeologic units in the profile were designated intermediate impact.

Finally, recharge rates were estimated for all surface conditions under consideration for the initial assessment of the System Assessment Capability, Rev. 0. These conditions include four different barrier designs, degraded barriers, natural conditions, and unique conditions created by human activity. The four barriers included the Hanford barrier, modified RCRA C barrier, standard RCRA C barrier, and modified RCRA D barrier. Four cases were assumed for natural conditions: undisturbed soil and shrub-steppe plant community, undisturbed soil with no vegetation, disturbed soil with no vegetation, and disturbed soil with shrub-steppe vegetation. Also included were estimates for recharge through a surface gravel layer such as that found at tank farms. The resulting recharge estimates ranged from 0.9 to 4 millimeters per year for pre- and post-Hanford Site operations, 4 to 55.4 millimeters per year for the period during which Hanford was operational, and 104 millimeters per year for gravel covers.

3.4.2.2 Vadose Zone History Matching

The Vadose Zone Technical Element used the information gathered through the data gathering process to conducted history-matching exercises in fiscal year 2001 in support of the System Assessment Capability (SAC Rev. 0). The purpose of the history matching effort was to compare test model predictions with field observations. The history matching effort included:

- electing specific test cases to be simulated
- assembling contaminant concentration profile data through time
- comparing the simulated results with field data.

This section briefly describes the history matching exercise and its results.

Eight facilities were selected for System Assessment Capability, Rev. 0, history matching (Table 3.4-3). These facilities were selected because they represented

1. facilities from different aggregate areas
2. facilities with a range in discharge from low volume (216-B-46 crib) to high volume (216-A-8 crib)
3. facilities that received chemically different waste steams
4. facilities that received at least one of the selected constituents of interest (cesium-137, technetium-99, carbon tetrachloride, plutonium 239/240, and tritium)
5. facilities for which historical subsurface contaminant distributions through time were available.

Each facility was assigned an array of attributes that included a base template designation, volume discharged, surface area receiving the discharge, and hydrologic and geochemical properties. Assignment of these attributes is described in Section 3.4.2.1 and in Last et al. 2001.(b) The base template designation contained information about the facility location, the type of facility (e.g., crib, pond, reverse well, tank, etc.) and the stratigraphic column.

Four types of data were used to describe the historic distribution of contamination in the vadose zone: borehole spectral gamma-ray logs, laboratory data obtained from soil samples collected during drilling, gross gamma-ray logs, and groundwater chemistry data. Three criteria were developed with which to judge the success of the System Assessment Capability, Rev. 0, simulations. The criteria were

- Does the simulated result place the center of mass of the contaminant distribution within the same hydrogeologic unit as the measured center of mass for the same time period? If yes then,
- Does the simulated center of mass fall within ±2 meters of the measured center of mass for plutonium-239 or within ±3 meters of the measured center of mass for cesium-137?
- For highly mobile constituents (carbon tetrachloride, technetium-99, tritium), the success criterion was whether the simulation matched the time of first arrival of a surrogate constituent at the water table within ±2 years.

Table 3.4-3 lists the 29 cases tested. Table 3.4-4 shows the results of each history match test.

Figure 3.4-1 shows an example history matching result. The figure shows a comparison of two simulated cesium-137 distributions with the measured concentrations for the 216-A-8 crib. The two simulations include (1) a 1x simulation that used the facility dimensions from the waste inventory data system to define the wet column area beneath the crib and (2) a 2x simulation that used twice the waste inventory data system dimensions to define the wet column area. Adjustments to the wet areas were an attempt to capture the lateral spreading that normally occurs in the vadose zone. Comparing the measured concentrations (field data) with the simulated concentrations for the 1x case shows that the center of mass for the measured contaminant distribution is at a depth of 7.8 meters whereas the simulated center of mass is at a depth of 11.2 meters. Also, the measured center of mass is within the Hanford formation gravel sequence whereas the

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(b) Last, G. V., D. G. Horton, W. E. Nichols, M. J. Fayer, B. N. Bjornstad, T. J Gilmore, K. J. Cantrell, K. M. Krupka, and R. Khaleel. 2001. *Appendix C – Vadose Zone Data for Initial Assessment Performed with the System Assessment Capability (Rev. 0), Draft B*. Pacific Northwest National Laboratory, Richland, Washington.

simulated center of mass is within the Hanford formation sand sequence. Thus, the simulation is outside both acceptance criteria.

Comparing the results for the 2x case shows that the simulated center of mass is at a depth of 8.2 meters and within the Hanford formation gravel sequence. Thus, the 2x simulation is within the acceptance criteria. The 2x infiltration column was needed because the initial simulations using a 1x area resulted in fully saturated, over pressurized vadose zone columns that do not reflect reality. Thus, the large volume of effluent (1.2 billion liters) disposed to the crib required a larger area for infiltration than the crib dimensions to produce the measured distribution in 1995. Also, given the 2x area, the match between the measured and simulated distributions suggests that the hydraulic and geochemical parameters used in the calculations are within a reasonable range.

Figure 3.4-2 shows a comparison between the simulated and measured plutonium-239/240 distributions for the 216-Z-1A tile field in 1998. Also shown are the predicted distributions for years 2050, 2500, and 3000. The 1998 simulation is outside the acceptance criteria with a center of mass at a depth of 8.2 meters in the Hanford formation gravel, whereas the measured center of mass is at a depth of 5.2 meters in the tile field backfill. In addition, the simulated concentration profiles for the years 2050, 2500, and 3000 show much deeper migration of plutonium than past history might suggest. The simulations show that the center of mass moves from a depth of 8.2 meters in 2000 to 12.2 meters in 2050. This 4-meter downward movement is contrary to observations that show that, for the 20-year period between 1979 and 2000, little to no downward movement of plutonium has occurred. This discrepancy is probably due to the assigned hydrostratigraphy, which designated the entire gravel zone beneath the tile field as a high impact zone with an artificially low distribution coefficient. Once the simulated mass reaches the Hanford formation sand (by the year 2050), the distribution coefficients used are much higher resulting in much lower rates of movement (on the order of 0.6 to 0.9 meter per 500 years).

Approximately 30% of the deterministic test cases initially failed to meet the acceptance criteria. However, modifications to the wetted column areas reduced the failure rate to <20%. Those test cases that continued to fall out side the acceptance criteria were associated primarily with either plutonium or carbon tetrachloride.

The reasons the plutonium test cases failed were due in part to the assigned generalized stratigraphy and associated hydraulic properties and in part to the simplified linear sorption algorithms used to simulate plutonium transport. In reality, plutonium in the effluent stream was probably present as both plutonium dioxide particulate that was filtered from the effluent by the sediment directly beneath the facilities and as organo-metallic complexes which transported plutonium deeper in the system (RHO-ST-17), neither of which was accounted for in the simulation.

The carbon tetrachloride simulations failed badly because they considered only aqueous phase transport and not organic (non-aqueous) phase transport.

The overall results of the history match exercise indicated that the System Assessment Capability computer codes were ready for the overall history match and initial assessment.

3.4.2.3 Initial Results of the System Assessment Capability

For the System Assessment Capability, Revision 0, the migration of contaminants through the vadose zone was simulated with the Subsurface Transport Over

Multiple Phases (STOMP) computer code (PNNL-11217; PNL-8637). The original 890 waste sites were reduced to 719 sites, by aggregating proximal solid waste or low volume liquid disposal sites. Each of the 719 sites was individually simulated as one-dimensional, layered columns with stochastically selected hydraulic property and distribution coefficient (K_d) values for each hydrostratigraphic layer (see Section 3.4.2.1).

To simplify the task of preparing model grids for 719 vadose zone sites, the Hanford Site was divided into 13 aggregate areas (see Section 3.4.2.1) for which all encompassed waste sites can be represented with a generalized hydrostratigraphy. For each hydrogeological province, four vadose zone template models were prepared for simulation with the STOMP simulator. These correspond to sites representing surface disposal, shallow land disposal, buried waste tank disposal, and reverse well disposal of contaminants. A total of 67 base templates were prepared. By distributing copies of the base templates, 719 site templates were created, each of which was then modified within the System Assessment Capability model by inserting stochastically selected values for hydrologic and geochemical properties to create the final set of STOMP input files for simulation.

Preliminary results from the initial assessment are available for 25 realizations of 9 contaminants at 719 vadose zone release locations, or a total of 161,775 individual realizations. (In this discussion, realization and simulation are synonymous.) Direct analysis of individual results was impractical, so a flexible data extraction tool was developed that allowed evaluation of accumulated results in various ways. The results were examined at a variety of levels from individual contaminants at an individual waste disposal site to total releases from the Hanford Site as a whole. The results also indicated where improvements to the initial assessment are needed and provided insight in understanding Hanford Site issues.

At the highest level, the total Hanford Site releases from the vadose zone to groundwater were summed over all 719 sites by year, by contaminant, and by realization. An example of this is shown in Figure 3.4-3 for tritium releases. Figure 3.4-4 illustrates a different type of analysis in which the total Hanford Site releases are considered by contaminant species. This figure indicates that nearly all releases from the vadose zone to the groundwater occurred prior to ~1990, except for carbon tetrachloride and hexavalent chromium, which continue to be released for some time into the future.

Simulations of the migration of contaminants through the vadose zone indicate that nearly all releases from the vadose zone to the groundwater occurred prior to ~1990, except for carbon tetrachloride and chromium (Cr-VI).

At an intermediate level of analysis, the mass balance and vadose zone releases to groundwater were summed by hydrogeologic province, by disposal facility type, and by operational area. For example, Figure 3.4-5 illustrates the releases of tritium from the vadose zone to groundwater from the various types of disposal facilities. The results indicate that nearly all releases are from cribs and that they occur before ~1995.

3.4.3 Use of Process Relationship Diagrams in Development of Conceptual Models

G. V. Last, V. J. Rohay, F. J. Schelling, and L. Soler

This section reproduces the abstract of the report PNNL-SA-34515 that describes the strengths and limitations of process relation diagrams. The actual master Process Relationship Diagram and two test case diagrams are presented in the original report. They are not reproduced here because of the complexity of the diagrams.

The Characterization of Systems Task under the Integration Project tested the application of features, events, and processes methodology[c] for documenting the technical knowledge about the Hanford Site and application of that knowledge for performing impact/risk assessments. As part of that effort, Characterization of Systems Task is evaluating the use of process relationship diagrams to document the relationships between features, events, and processes and to assist development, communication, and translation of conceptual models (what is known and not known about a particular environmental problem) into simplified implementation models that can be numerically simulated. A master process relationship diagram was created to describe the most relevant high-level processes and conditions affecting contaminant transport at the Hanford Site.

This diagram graphically represents the logical structure of how the environmental system works and identifies the important processes and their interrelationships. This master diagram was derived from domain-specific diagrams and influence matrixes prepared independently for various components (technical elements) of the system (i.e., inventory, release, vadose zone, groundwater, river, and risk). The diagram was necessarily simplified by focusing on processes, keeping it at a high level, and by not including details of the risk elements. The preparation of this master diagram was intended only as an example or template for the development of problem-specific diagrams.

The master process relationship diagram then was used to analyze two different types of problems from two related operable units. The first problem attempted to identify the dominant, and to some extent the subordinate, processes controlling the fate and transport of all contaminants released from the 200-PW-1 Operable Unit. The second problem attempted to examine different conceptual models for the 200-ZP-1 Operable Unit concerning high carbon tetrachloride concentration in groundwater beneath the Plutonium Finishing Plant, and in doing so, to assist site selection and data collection strategies for a proposed borehole that would test these various conceptual models.

These limited efforts suggest that development and application of process relationship diagrams is a useful approach with the flexibility to facilitate the development and documentation of conceptual models for many types of environmental problems. This approach also can provide a consistent framework and method to facilitate the completeness of those conceptual models. One of its greatest values is to facilitate discussion among the principal project scientists.

However, these diagrams can become very complex and can be difficult for audiences to visualize. It is often difficult to show on one diagram all the necessary levels of detail and important features, conditions, and attributes that affect the processes. Thus, several different diagrams at different levels of detail may be needed to represent a given problem. The use of a master process relationship diagram is not intended as a stand-alone tool, but instead should be used in a facilitated process, in combination with other methods (e.g., graphical illustrations, text, influence matrices, calculations), to fully analyze and document the conceptual models.

(c) Nuclear Energy Agency. December 1999. *Safety Assessment of Radioactive Waste Repositories, An International Database of Feature, Events, and Processes.* A report of the NEA Working Group on the development of a database of features, events, and processes relevant to the assessment of post-closure safety of radioactive waste repositories. Nuclear Energy Agency, Organization for Economic Co-Operation and Development, Washington, D.C.

Table 3.4-1. Types, Abundances, and Locations of Laboratory and Field Hydraulic Data on the Hanford Site

Area	Sieve	Density	Moisture	Unsaturated Conductivity	Saturated Conductivity	Neutron	Storage	Drainage	Water Profile	Air Permeability
100	84	84	84	33	33	--	--	--	--	--
200 East	122	125	108	63	46	36	--	2	--	1
200 West	163	124	60	89	29	--	1	3	1	1
300	--	--	2	--	--	--	1	1	1	--
400	--	--	--	--	--	--	--	1	1	--
600	177	168	149	49	46	--	8	9	8	--
Total	468	501	423	234	154	36	10	16	11	2

Table 3.4-2. Distribution Coefficients Included in the Geochemical Compilation

Species	Am^{3+}	Co^{2+}	Cs^{+}	Ni^{23+}	Pb^{2+}	Pu	Sr^{2+}	CrO_4^{2-}	I^{-}	NO_3^{-}	NpO^{2+}	SeO_4^{2-}	TcO_4^{-}	UO_2^{2+}
Number of Data	60	74	126	50	48	87	220	20	61	12	84	49	83	76

Table 3.4-3. Test Cases for Vadose Zone History Matching

Facility	Constituent	Year Simulated	Facility Area Multiplier	Simulation ID Number
216-A-8 crib	^{137}Cs	1995	1x	1
			2x	2
	^{99}Tc	1945-2050	1x	3
	^{3}H	1945-2050	1x	4
216-B-5 reverse well	^{137}Cs	1979	1x	5
			5x	6
			50x	7
216-B-46 crib	^{137}Cs	1991	1x	8
			0.5x	9
		1996	1x	10
	^{99}Tc	1945-2050	1x	11
	^{3}H	1945-2050	1x	12
241-T-106 tank	^{137}Cs	2000	1x	13
			0.5x	14
216-Z-1A tile field	$^{239/240}Pu$	1998	1x	15
			2x	16
		2050	1x	17
			2x	18
		3000	1x	19
			2x	20
	Carbon Tetrachloride	1992	1x	21
		2050	1x	22
216-Z-12 crib	$^{239/240}Pu$	1998	1x	23
		2050	1x	24
216-U-10 pond	Water	1940-2045	1x	25
			2x	26
			3x	27
216-U-12 crib	^{137}Cs	1991	1x	28
			2x	29

Table 3.4-4. Results of Vadose Zone History Matching[a]

Facility	ID	Stratigraphic (or First Arrived) Criteria	Simulated Stratigraphy (or) First Arrival)	Center of Mass Criteria (depth in m)	Simulated Center of Mass (depth in m)
216-A-8 crib	1	Hanford gravel	*Hanford sand*	7.8	*11.2*
	2		Hanford gravel		8.2
	3	Not determined	*2017*		
	4	Not determined	*1956*		
216-B-5 reverse well	5	Ringold Formation	*Hanford formation/ Plio-Pleistocene*	Not determined	Not determined
	6				
	7				
216-B-46 crib	8	Hanford gravel	Hanford gravel	8.3	*5.1*
	9				5.3
	10			12.3	*5.1*
	11	(1956)	(1956)		
	12	(1956)	(1956)		
241-T-106 tank	13	Hanford gravel	*Hanford gravel*	13.2	12.0
	14				12.1
216-Z-1A tile field	15	Backfill	Hanford gravel	5.2	8.2
	16				7.5
	17		NA[b]		NA
	18		NA		NA
	19		NA		NA
	20		NA		NA
	21	(1963)	*CCL4 did not reach groundwater by 2050*		
	22				
216-Z-12 crib	23	Hanford gravel	*Backfill*	7.2	5.8
	24		NA		NA
216-U-10 pond	25	Simulations for 216-U-10 pond were done only to ensure that the model worked for a pond disposal site			
	26				
	27				
216-U-12 crib	28	Hanford coarse	Hanford coarse	7.3	7.1
	29				6.0

(a) Criteria in *italics* are outside the acceptance criteria.

(b) NA = Not applicable; applies to simulations of future contaminant configurations.

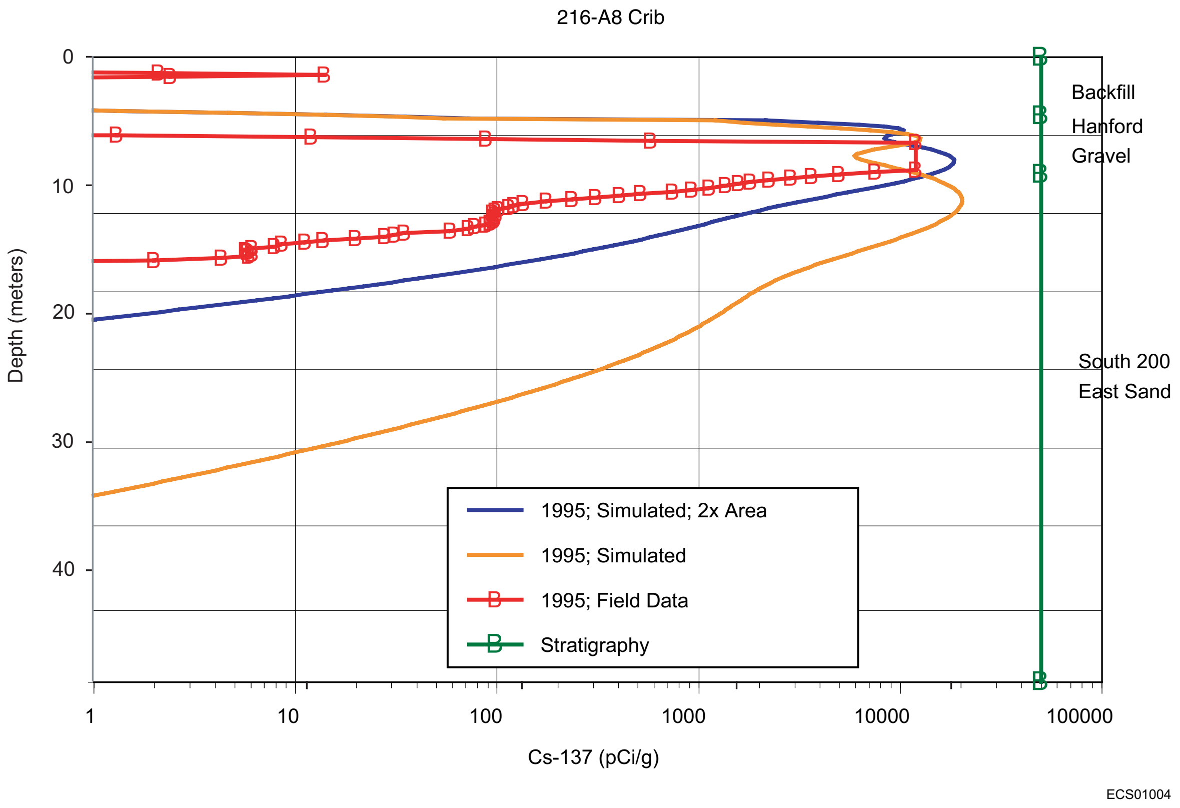

Figure 3.4-1. Cesium-137 History Matching Results for the 216-A-8 Crib

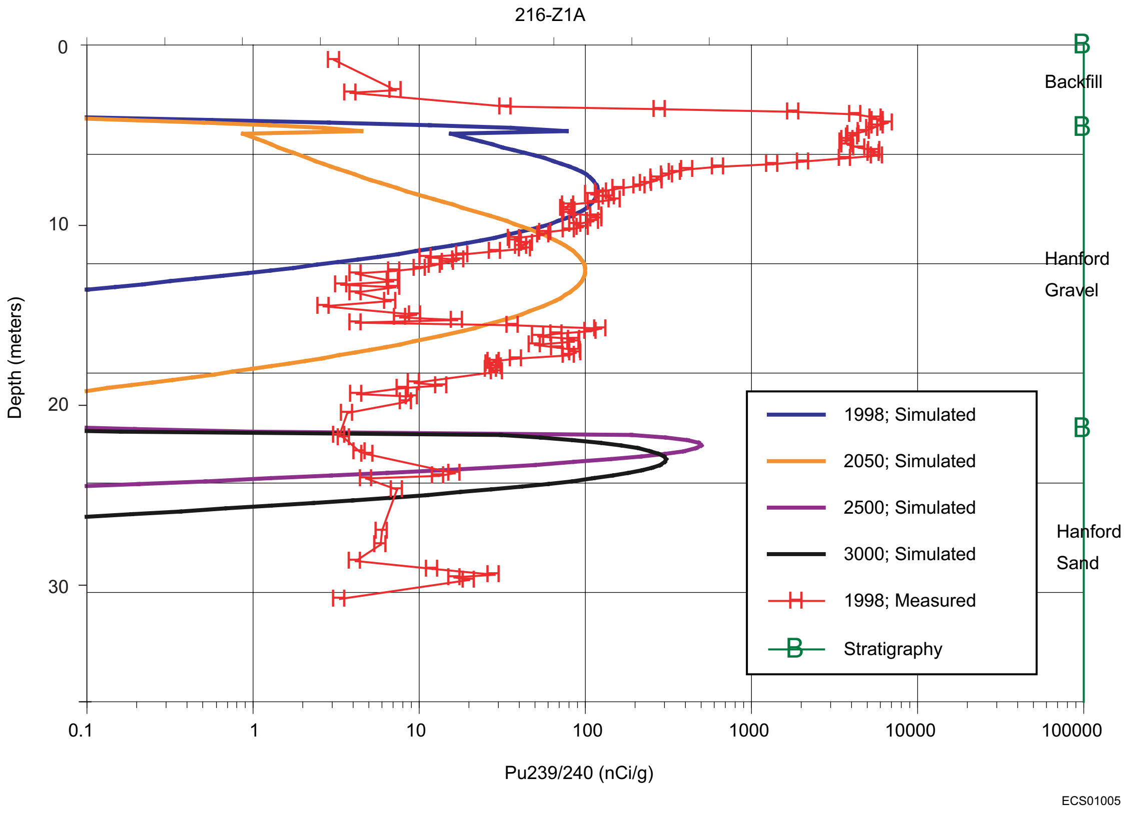

Figure 3.4-2. History Matching Results for Plutonium-239/240 Distributions Beneath the 216-Z-1A Tile Field Using 1x the Facility Footprint Area

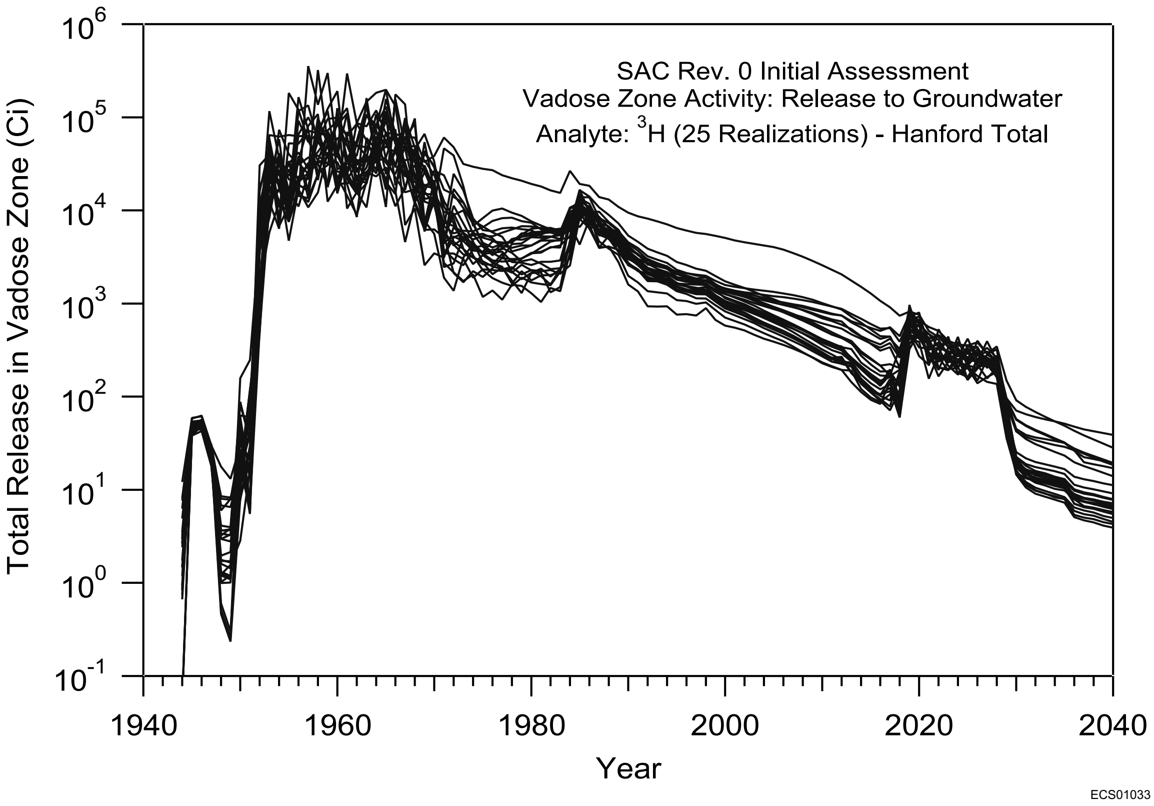

Figure 3.4-3. System Assessment Capability Simulation (25 realizations) of Total Hanford Annual Releases of Tritium from Vadose Zone to Groundwater

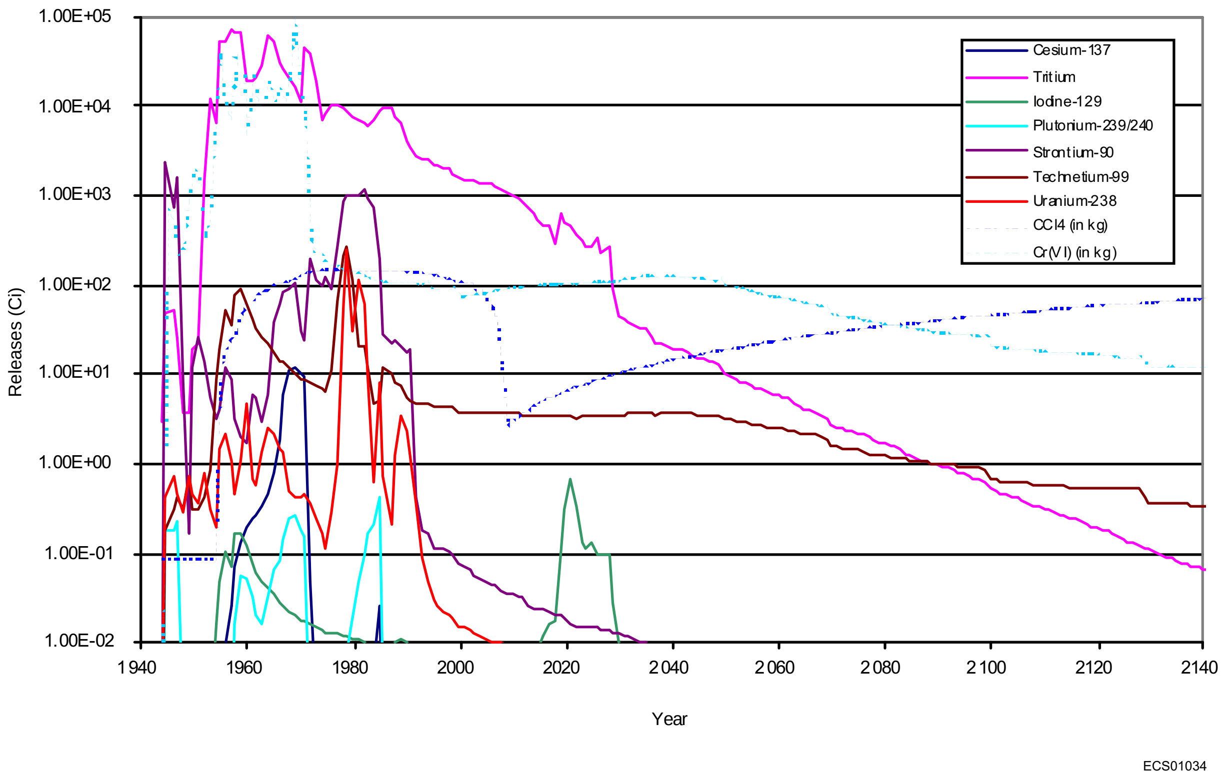

Figure 3.4-4. System Assessment Capability Simulation (realization 5) of Total Hanford Annual Releases from the Vadose Zone to Groundwater by Contaminant Species

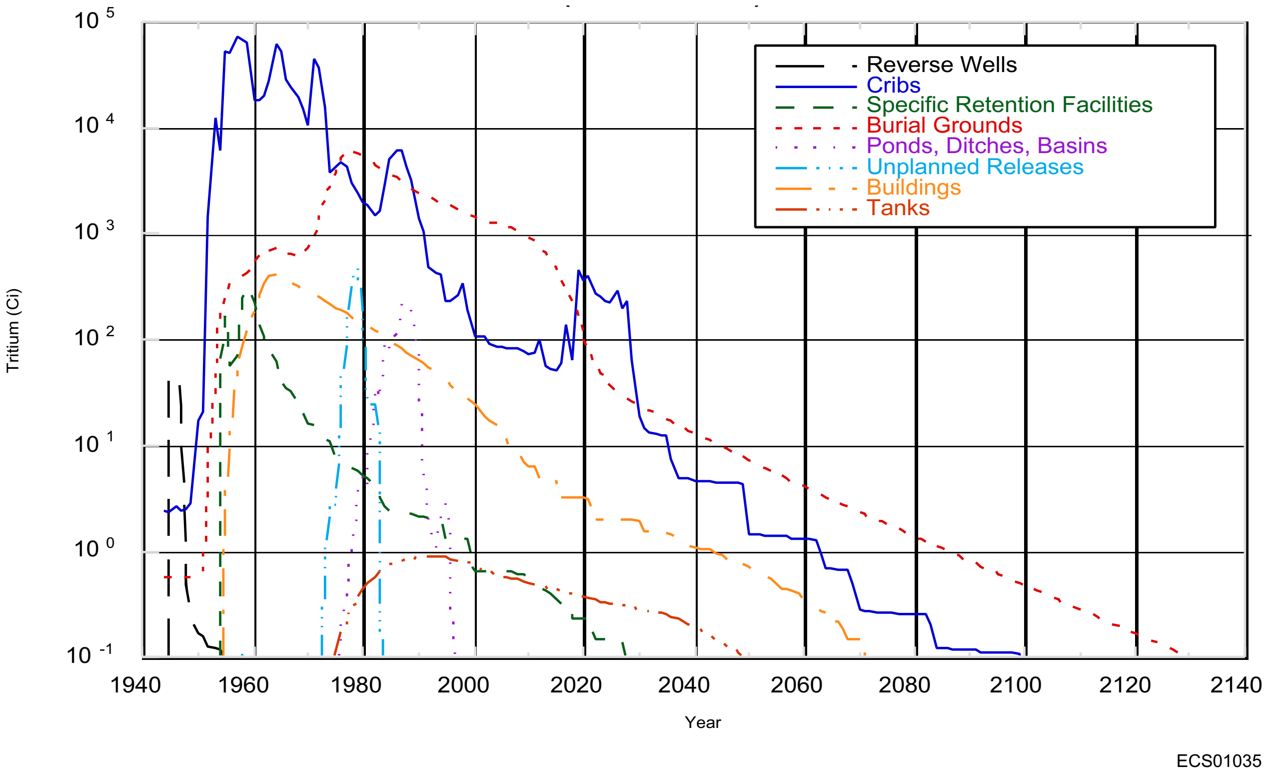

Figure 3.4-5. System Assessment Capability Simulation (realization 5) of Total Hanford Annual Releases from the Vadose Zone to Groundwater by Waste Facility Types

4.0 Groundwater Modeling

P. D. Thorne

Groundwater modeling is conducted to predict future groundwater conditions and the movement of contaminants through groundwater to the accessible environment. Groundwater modeling activities that address sitewide problems have been consolidated under the Hanford Groundwater Monitoring Project to eliminate redundancies and promote consistency. Section 4.1 reports progress on development of the consolidated groundwater model. Sections 4.2 through 4.4 describe specific applications of the consolidated model during the past year. These included

- updating the Hanford Site Composite Analysis
- incorporating a simplified groundwater model into the System Assessment Capability and performing an initial assessment
- modeling of the 200 West Area carbon tetrachloride plume (the consolidated model was used to create a flow field for local-scale transport modeling).

Scientists use groundwater models to predict future groundwater flow conditions and the movement of contaminants through the aquifer beneath the Hanford Site.

Other groundwater models are used for problems at a local scale (i.e., <~10 kilometers). For the past 5 years, local-scale modeling has been performed by the environmental restoration contractor to design and evaluate pump-and-treat systems for groundwater. The Micro-FEM© code was used to model capture and injection zones of extraction and injection wells, respectively, and to estimate the area affected by the pump-and-treat systems over time. The model was used to evaluate the hydraulic effects of the remedial action sites in several different operational areas. The operational areas and the contaminants of concern being treated at each are listed below:

- 100-KR-4 Operable Unit (100 K Area) – hexavalent chromium
- 100-NR-2 Operable Unit (100 N Area) – strontium-90
- 100-HR-3 Operable Unit (includes both 100 D and 100 H Areas) – hexavalent chromium
- 200-UP-1 Operable Unit (200 West Area) – technetium-99 and uranium
- 200-ZP-1 Operable Unit (200 West Area) – carbon tetrachloride.

During fiscal year 2001, these models were only updated to reflect the changing water-table elevation in the aquifer and changes in pumping rates. Additional information on these models is provided in last year's annual groundwater report (PNNL-13404) and in DOE/RL-99-79 and DOE/RL-2000-01.

Groundwater models were used at a local scale to assess and improve the performance of groundwater pump-and-treat systems designed to contain contamination within the unconfined aquifer system.

Local-scale modeling of water movement in the zone of interaction between the unconfined aquifer and the Columbia River also has been conducted over the past few years to support the Groundwater/Vadose Zone Integration Project. The results of this modeling effort were published in PNNL-13674. Groundwater path lines were calculated to illustrate the direction and rate-of-flow within the zone of interaction, using Pacific Northwest National Laboratory's Subsurface Transport Over Multiple Phases (STOMP) code (PNNL-11218). Graphics software was then used to animate water movement and show how the flow field responds to the fluctuating river stage over one complete seasonal cycle of the river. The model was developed for the zone of interaction at the 100 H Area. This two-dimensional simulation of water movement in the near-river unconfined aquifer clearly demonstrated the strong influence exerted by fluctuations in the Columbia River stage. The rise and fall of the river cause the direction and rate of groundwater flow to constantly change, with complete reversals in direction of flow and pore water velocities varying from no motion up to 10 meters per day. The dynamic nature of this flow field has implications for monitoring strategies, environmental restoration remedial actions, and river impact assessments (PNNL-11218).

Objectives of Hanford Site Groundwater Model

A computer model of Hanford Site groundwater must be able to

- predict impact of Hanford activities on groundwater
- assess performance of waste-disposal facilities
- predict movement of contaminants
- evaluate remediation strategies.

4.1 Sitewide Groundwater Flow and Transport Model

Until recently, multiple versions of sitewide models for groundwater flow and contaminant transport were maintained and used by contractors at the Hanford Site. The U.S. Department of Energy (DOE) initiated a sitewide groundwater model consolidation process in 1998. The consolidation of groundwater modeling activities eliminates redundancies and promotes consistency between models. Additional information on the consolidation process is available in DOE/RL-2000-11.

A conceptual model of the sitewide groundwater model was developed from information on the hydrogeologic structure of the aquifer, spatial distributions of hydraulic and transport properties, aquifer boundary conditions, and distribution and movement of contaminants. Development of the basic aspects of this three-dimensional model of the unconfined aquifer system is documented in PNL-8332, PNL-8971, PNL-10195, and PNNL-10886. The groundwater flow system is bounded by the Columbia River on the north and east and by the Yakima River and basalt ridges on the south and west, respectively. A depiction of the surface finite-element grid and boundary conditions used in the three-dimensional flow model is illustrated in Figure 4.1-1. Additional information on the sitewide groundwater model is presented in PNNL-11801 and PNNL-13641.

Local-scale modeling of groundwater movement adjacent to the Columbia River at the 100 H Area clearly demonstrated the strong influence exerted by daily fluctuations in the Columbia River stage on groundwater flow direction and velocity.

4.1.1 Status of the Consolidated Model

A major objective of the consolidation process is to strengthen the technical defensibility of groundwater transport predictions by incorporating uncertainty in the groundwater model. During fiscal year 2001, a document was published on sources of uncertainty and the strategy to address uncertainty in groundwater modeling (PNNL-13641). The method proposed to estimate uncertainty is to develop alternate conceptual models that encompass the identified uncertainties, then apply a transient inverse calibration to each model based on historical observations of water-level changes and contaminant movement. Results of the different calibrated alternative models will then span the range of results expected based on different assumptions.

Calibration of a base-case model and calibration of one alternative model were completed in fiscal year 2001. The alternative model includes interaction between the unconfined aquifer system and the underlying basalt-confined aquifer. Previous sitewide modeling assumed the movement of water between these different systems was negligible. However, it is known that communication takes place, particularly along faults and in the area between Gable Mountain and Gable Butte, where erosion has removed the upper layers of confining basalt.

4.1.2 Uncertainty Analysis

The uncertainty analysis framework, which is presented in PNNL-13641, outlines the strategy to address uncertainty in the sitewide groundwater model. PNNL-13641 also provides a detailed description of the current groundwater conceptual model and describes uncertainties in different components of the model. The initial focus of the effort is to characterize major uncertainties in the conceptual model that affect model predictions. The long-term goals are to estimate uncertainty using stochastic (i.e., probabilistic) methods and alternative conceptual models. This approach is based on recommendations of an external peer review panel convened in 1999. As suggested by the panel, the framework being developed acknowledges the inherent uncertainty in conceptual model representations and associated model inputs. This new framework acknowledges that prescribed processes, physical features, initial and boundary conditions, system stresses, field data, and model parameter values are not known and cannot be known with certainty and, as a result, predictions of groundwater movement and contaminant concentrations over time also will be uncertain.

Uncertainty exists in any prediction of future conditions. Scientists are working to quantify major uncertainties in the consolidated groundwater model by creating feasible alternative conceptual models and by establishing probability distributions for key parameters.

The basic approach to address uncertainty is to use sensitivity analysis for those aspects of the analysis related to vagueness and indefiniteness (e.g., alternative conceptual models and future scenarios) and uncertainty analysis for those situations where the uncertainty (e.g., for parameters) can be represented by a probability density function (PNNL-13641). Steps in this process are outlined below:

1. Identify alternative conceptual models – This effort consists of identifying and documenting the major features and assumptions associated with the Hanford sitewide groundwater model. It also involves periodically revising the set of alternative conceptual models based on any new data or understanding of the groundwater flow system.
2. Develop alternative conceptual models – This will generally involve an inverse modeling step where historical site data on parameters, system responses (e.g., head and concentration), and external driving forces will be used in a parameter identification step to develop the best representation of this model and to help determine the associated uncertainty estimates in some of its parameters.
3. Evaluate alternative conceptual models – This step identifies the plausible conceptual models that will be the subject of subsequent uncertainty assessments. Evaluation will consist of examining statistical measures of overall model fit.
4. Uncertainty assessment – Steps 1 through 3 of above must be completed for all reasonable alternative conceptual models, while this step is carried out only for those determined to be plausible in Step 3. The parameter uncertainty assessment process generally involves: (a) sensitivity studies to identify the important or relevant parameters for the uncertainty analysis, (b) development of the probability density functions for important uncertain parameters including the identification of any correlations among parameters, and (c) propagation of the uncertainties through the model to determine the uncertainty in the model predictions.
5. Estimation of combined conceptual model and scenario uncertainty – This step involves estimating the combined uncertainty by combining the parameter uncertainty associated with each particular scenario and plausible alternative conceptual models.

Identification and development of alternative conceptual models also requires examining and optimizing model complexity (as measured by the number and complexity of processes and parameters included). The complexity should be consistent with the availability of information while also seeking the simplest model parameterization that is consistent with the evidence. While it is important to improve model accuracy and reliability by including as many relevant processes at the fine spatial and temporal scales, there is no guarantee that model reliability will continue to increase with model complexity.

4.1.3 Inverse Calibration — Base Case

The existing (base-case), groundwater flow model was re-calibrated in fiscal year 2001. Results were documented in PNNL-13447. The external peer review panel recommended this three-dimensional transient calibration. It was performed using UCODE, a universal inverse modeling code developed jointly by the U.S. Geological Survey and the International Groundwater Modeling Center of the Colorado School of Mines. The groundwater model was implemented using the Coupled Fluid Energy and Solute Transport code (CFEST). This was the forward model whose parameters are estimated by UCODE. The transient inverse calibration used over 76,000 water-level measurements taken in about 1,200 wells at the Hanford Site since the mid-1940s.

As recommended by an external peer review panel, a three-dimensional transient calibration of the consolidated model was performed in fiscal year 2001.

Because of the long run times required to perform the large number of simulations, an innovative parallel computational approach was implemented using a network of 23 computers. The approach used a recently developed parallel version of UCODE that communicates with a parallel task manager to propagate the multiple simulation tasks (i.e., the forward model runs) for simultaneous computation on the dedicated computers. In addition, a customized version of the forward model code (CFEST) was developed to simplify the specification of inverse model parameters and the large number of observations.

The extended (1943 to 1996) calibration period dataset for the initial transient inverse modeling consisted of new estimates of artificial discharges and river stage variations before 1979 and a complete set of head observations from 1943 to 1996. To evaluate and test these new data, the prior model was used to simulate this time period. This simulation provided some insights into the capability of the prior model to duplicate historical trends in water-table changes and, in particular, groundwater mound building and decline during the entire period of Hanford operations. Results of these preliminary simulations with the prior model indicated that it was not a good predictor of the water-table configuration before 1979. While the prior model was generally capable of replicating overall trends over most of the Hanford Site, its parameter estimates led to a significant over-prediction of the historical growth and decline of groundwater mounds in the 200 West Area. Simulated heads in this area were 10 to 15 meters higher than those detected in wells during the period of maximum discharges and mound building near discharge facilities during the 1950s, 1960s, and 1970s.

Inverse calibration of the consolidated groundwater model utilized in innovative parallel computational approach with a network of 23 computers and a recently developed parallel version of UCODE.

Re-calibrating the prior model using the transient inverse calibration procedures in UCODE significantly improved its ability to simulate historical trends in water-table changes over the entire Hanford Site, but some parameters took on unrealistic values, indicating that parameter zonation and/or conceptual model improvements are needed. The improved inversing methodology provided in UCODE and the additional information provided in the longer calibration period (1943 to 1996) improved the ability of the re-calibrated prior model to simulate historical trends in water-table changes. A comparison of simulated and measured water levels for the entire period of available water-level measurements (1943 to 1996) is shown in Figure 4.1-2. This is a scattergram plot of simulated heads from the inverse model plotted versus the measured head. The 45-degree line represents a perfect match between model and observed data, with the individual plotted points color-coded to indicate the magnitude of the residual error. All goodness-of-fit measures were significantly improved over those for the previously calibrated model for the same simulation period. The most noteworthy improvement by the transient inverse-calibrated prior model is its ability to fit historical trends of water-table changes and mound-building observed near major discharge facilities in the 200 West Area. This improvement in the overall fit resulted in improved statistical performance in all categories (mean residual, range of residuals, and sum of squared residuals) for the 1943 to 1996 period of calibration.

The majority of changes in the parameter estimates derived from the transient inverse calibration of the prior conceptual model using the UCODE methods produced new estimates and linear confidence intervals consistent with prior knowledge. However, estimates for the specific yield of the Hanford formation (from 0.06 to 0.07) and the Ringold Formation (between 0.20 and 0.21) from the three-dimensional transient inverse calibration were not consistent with current understanding of these sediments. The unrealistic estimates for these two parameters, combined with the increased estimates from the inversing for natural recharge as well as boundary fluxes for Cold Creek Valley and Rattlesnake Hills Springs, indicate that the conceptual basis of the prior model is incomplete. This initial three-dimensional transient inverse modeling study indicates that other conceptual model components not considered in the prior model are needed to approximate historical aquifer system behavior. The increased estimates of natural recharge resulting from this initial study, for example, is believed to indicate that recharge to the unconfined aquifer system of the prior model resulting from intercommunication of the unconfined aquifer system with the uppermost confined aquifer associated with the Columbia River Basalt is on the same order of magnitude as natural recharge. Thus, this is the first major conceptual model to be evaluated as studies of alternative conceptual models are undertaken.

Comparisons of the goodness-of-fit measures for the newly calibrated model with those for the prior model illustrate that the new model will strengthen the technical defensibility of the final calibrated model(s) and provide the capability to incorporate uncertainty in model predictions. These initial results, however, indicate that improvements in the conceptual model framework of the prior model are required.

Scientists developed and calibrated an alternative conceptual model of groundwater flow that includes groundwater movement between the unconfined aquifer system, found in the sediment overlying basalt, and the underlying basalt-confined aquifer system.

4.1.4 Inverse Calibration — Case Including Basalt-Aquifer Leakage

The inverse modeling effort described below investigated the effects of groundwater movement between the unconfined aquifer system, which is in the sediment above the basalt bedrock, and the underlying basalt-confined aquifer system. Results of this investigation were documented in PNNL-13623. The objective was to determine whether including groundwater leakage between the unconfined aquifer system and the basalt aquifers could improve model calibration. An improved calibration is reflected by either more reasonable parameter estimates or improved fit of model-predicted heads to observed heads. The calibration process and the codes applied were the same as for the base case calibration described above.

An alternate conceptual model that includes basalt leakage was developed by adding the following leakage mechanisms to the existing model:

- head-dependent leakage of groundwater through the basalt confining layer
- increased leakage at an erosional window near Gable Mountain/Gable Butte
- increased leakage at a smaller erosional feature near B Pond
- increased leakage along two fault zones.

Each feature was added in steps to investigate its sensitivity and relationship with other estimated parameters. The alternative conceptual model that resulted from this stepwise development approach provided reasonable results for the first three mechanisms listed above. However, when fault zone leakage was added, unrealistic flux values occurred from two segments of the Gable Mountain fault close to the Columbia River. One segment was to the northeast of Gable Butte and the other to the southwest of Gable Mountain. These unrealistic fluxes will require additional investigation during future studies of alternative conceptual models. If the anomalous Gable Mountain fault fluxes are disregarded, areal leakage is the dominant intercommunication flux followed by the fault fluxes and the erosional window flux.

Graphical comparisons and summary statistics illustrate that, over the entire prediction period, a slight measurable improvement in overall model fit was realized over that observed for the baseline inverse model. Figure 4.1-3 shows a scattergram comparison of simulated and measured water levels for the entire period of available water-level measurements (1948 to 1996). Residual error statistics indicate that 66.9% of the simulated values were within ±1 meter of measured values, and 99% were within ±5 meters, compared to 65.8% and 98.6%, respectively, for the baseline inverse model. However, the most noteworthy improvements in the transient inverse calibrated model that included basalt leakage is not associated with overall model fit, but with incorporation of (1) a more realistic conceptual model and (2) parameter estimates that are closer to the expected ranges based on previous analysis of available characterization data and our current conceptual understanding of the hydrogeologic system.

However, some parameters continued to take on unrealistic values, indicating that additional conceptual model improvements are needed. The best-fit estimate for the specific yield of the Hanford formation (Unit 1) and the Ringold Formation (Unit 5) (0.06 and 0.2, respectively) and associated confidence limits developed by the inverse calibration were not found to be consistent with reasonable ranges. This was also true for the base case transient calibration discussed above.

For the alternative conceptual model including interaction with the basalt aquifers, a slight improvement in overall model fit was realized compared to the base-case conceptual model.

Inconsistencies between the calibrated values and the prior information for both the Hanford and Ringold Formations suggest that processes other than those considered in the alternative conceptual model require evaluation. Other processes that may be evaluated in future inverse calibration efforts for their ability to provide more realistic specific yield estimates are the inclusion of facies-based zonation of hydraulic properties for the main transmissive model layers and uncertainty in the time required for wastewater discharges applied at ground surface to migrate through the vadose zone.

4.2 Modeling to Support the Composite Analysis Addendum

The sitewide groundwater model was used to simulate transport of contaminants through groundwater from selected waste sites to support the Composite Analysis Addendum (PNNL-11800, Addendum 1). This addendum analysis was required for continued authorization of onsite low-level waste disposal at the Hanford Site. It addressed the impact of the Plutonium Uranium Extraction Plant (PUREX) tunnels, the chemical separations plants, and the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) sites in the 200 East and 200 West Areas that were not considered in the first Composite Analysis (PNNL-11800). The addendum analysis included additional waste-inventory information for these sites developed as part of the System Assessment Capability described in the Section 4.3 of this report.

The addendum analysis provided a best estimate and limited sensitivity analyses for the sites in question. Technetium-99 and iodine-129 were used as representative mobile constituents. Results from the original composite analysis indicated that technetium-99 and iodine-129 were key constituents in the projected doses estimated in the original analysis and that these constituents could be used as general indicator constituents to evaluate potential effects from the sites being considered in this analysis. In addition to inventory estimates from the System Assessment Capability inventory database, the analysis included components for source-term release, vadose zone transport, groundwater transport, atmospheric transport, and exposure and dose calculations.

For groundwater flow and saturated-zone transport of contaminants, the existing three-dimensional sitewide groundwater model was used. Predictions of groundwater flow in the unconfined aquifer focused on the response of the aquifer to the cessation of wastewater discharges from Hanford Site operations. The model was used to simulate transient flow conditions from 1996 through the year 4000. The flow simulations were based on the distribution of hydraulic conductivity from the steady-state calibration to conditions observed in 1979 and the specific yields developed from the transient calibration to conditions observed between 1979 and 1996. All transport calculations used porosity estimates of 0.25 for Hanford formation layers and 0.1 for Ringold Formation layers.

Groundwater modeling to support the Composite Analysis Addendum showed that the additional sites included in the analysis will not significantly increase radiological doses during the next 1,000 years.

Separate transport analyses were performed for each contaminant. Geochemical interactions during contaminant transport were limited to processes represented by the linear sorption isotherm model. This model was selected because it is the only approach for which model parameters (distribution coefficients) were available for the waste sites and radionuclides considered. The distribution coefficients and their corresponding retardation factors were varied spatially in two zones away from the contaminant waste sources in the vadose zone (near field and far field) and assigned a third value in the saturated zone. Results of the groundwater transport simulations for technetium-99 sources indicated that peak predicted concentrations outside of the buffer zone for 2049, 2099, and 2159 would be relatively low at about 1.3, 1.0, and 1.1 pCi/L, respectively. These values are about two to three orders of magnitude below the maximum concentrations for technetium-99 in the original composite analysis (PNNL-11800). Results for iodine-129 sources indicated that peak predicted concentrations outside of the buffer zone at 2049, 2099, and 2159 would be extremely low at about 0.000036, 0.000028, and 0.000026 pCi/L, respectively. These peak values are about four orders of magnitude below iodine-129 concentrations estimated in the original composite analysis (PNNL-11800).

Overall results of the addendum analysis (PNNL-11800, Addendum 1) indicated the effect of the additional sites (PUREX tunnels, chemical separations plants, and added CERCLA sites) will not be significant during the 1,000-year period of analysis, and conclusions of the 1998 version of the Composite Analysis (PNNL-11800) as conditionally approved remain valid. The radiological doses for technetium-99 and iodine-129 for all of the exposure scenarios outside the buffer zone were well below the dose levels estimated in the original Composite Analysis. Previous estimates of the predicted radionuclide concentrations and resulting doses in groundwater within the exclusion and buffer zones demonstrate the need for continued control of land use and monitoring programs at the Hanford Site to meet the primary objective of the long-term protection of human health and the environment. This analysis of future radiological dose to the maximally exposed individual on lands outside the buffer zone supports the concept of retiring the Hanford Site boundary to the buffer zone boundary at the time of Hanford Site closure in 2050.

4.3 System Assessment Capability (SAC) — Preliminary Groundwater Results

The System Assessment Capability integrates several linked models to simulate the movement of contaminants from waste sites through the vadose zone, groundwater, and Columbia River to receptors.

During fiscal year 2001, an initial assessment was performed using the System Assessment Capability. This tool is an integration of several linked computer models designed to simulate the movement of contaminants from waste sites through the vadose zone (see Section 3.4.1), groundwater, and Columbia River to receptors and to then assess the risk to human health, other living systems, the local economy, and cultures. The System Assessment Capability starts with waste inventory and simulates contaminant release from the various waste forms. It also incorporates linked modules to simulate transport through the vadose zone, groundwater, and Columbia River. Additional modules calculate the risks. The assessment uses a stochastic analysis, which means that selected parameters are represented by probability distributions from which values are selected.

For the initial assessment, the transport of 10 different radionuclide and chemical contaminants released from 890 wastes sites from 1944 through 3050 was simulated. The primary objective of the initial assessment was to demonstrate proof-of-principal for the model. The following discussion provides some preliminary results from groundwater simulations conducted at the end of fiscal year 2001.

4.3.1 Groundwater Module

The groundwater module of the System Assessment Capability receives contaminant flux from the vadose zone module. It simulates contaminant movement through the uppermost aquifer system to the Columbia River and other potential exposure locations such as wells or seeps. The concentration of contaminants in groundwater are then used in the risk module calculations and contaminant flux is passed on to the Columbia River module.

An initial assessment was completed using the System Assessment Capability. This effort demonstrated the ability of the approach to predict the cumulative impact of Hanford Site waste on the region.

The groundwater module of the initial assessment completed in fiscal year 2001 used a two-dimensional variable-thickness version of the three-dimensional sitewide groundwater model described above. This two-dimensional model was designed and used to execute the large number of simulations required for probabilistic analyses within a reasonable time period. Groundwater transport simulated by the full three-dimensional model was compared to results of the two-dimensional version as part of a history-matching exercise described below.

4.3.2 Groundwater Module History Matching

The history-matching exercise involved comparing historical transport of contaminants through the Hanford Site groundwater (as measured at wells) with concentrations predicted by the transport simulations. A major objective of the groundwater history-matching exercise was to determine if a simpler, faster-running implementation of the existing sitewide three-dimensional groundwater model was suitable for the System Assessment Capability Rev. 0 initial assessment.

Preliminary analysis of three-dimensional model run-times indicated that the planned 100 realizations would require over 600 days using the planned 10 processors. Therefore, various simpler groundwater model configurations were evaluated in the history-matching exercise. The full three-dimensional model has seven geologic material layers below the water table, divided into a maximum of 27 transport layers. The simpler model configurations considered for the System Assessment Capability Rev. 0 simulations included

- two-dimensional model with variable thickness
- three-dimensional one-layer model (nodes at top and bottom of aquifer)
- three-dimensional two-layer model (Hanford and Ringold Formations)

- three-dimensional five-layer model
- three-dimensional seven-layer model.

Other objectives of the groundwater history-matching exercise were to determine the validity of the groundwater simulations and to identify any problems with the simulations by comparing simulated contaminant movement with historical observations of contaminant concentrations in groundwater.

A two-step approach was used in the groundwater history matching. History matching was initially performed using the existing Hanford sitewide three-dimensional model. This first step included using different values of initial-condition plume thickness to determine the best match to historical measurements of plume movement. The second step was to compare simulation results obtained using the simplified model configurations listed above with results of the full three-dimensional model.

History matching of the groundwater component was based on movement of the tritium plume from the southeastern part of 200 East Area toward the Columbia River and from Gable Mountain Pond to the north. Two major periods of tritium discharge took place from the PUREX disposal facilities in these areas. These periods were 1956 to 1972 and 1983 to 1988. However, tritium was not consistently measured in groundwater before 1970s, when the center of the earlier, and largest, tritium plume was already approximately halfway to the Columbia River. History matching was, therefore, limited to the period after 1974, when adequate historical measurements were available. The PUREX tritium plumes moved relatively quickly and provided the best opportunity for history matching of a plume for a relatively long distance toward the Columbia River, which is a critical component of the System Assessment Capability. However, these history-matching cases have the disadvantage of not simulating transport of contaminant plumes that originate in the 200 West Area. The 200 West Area plumes are within only the saturated Ringold Formation sediment and move much more slowly than plumes within Hanford formation and pre-Missoula gravels. It is also difficult to perform conclusive history matching on the 200 West Area plumes because of the large uncertainties in the contaminant source terms reaching groundwater and slow movement of the plumes.

Modeling and monitoring results are being used to improve our understanding of the Hanford Site. Groundwater monitoring data were an essential part of evaluating the output of the initial System Assessment Capability computer model. The results of this assessment identified areas where our understanding could benefit from additional groundwater monitoring.

Quantitative measures were developed to compare full three-dimensional model runs to the observed PUREX tritium plumes. The same measures were then applied to compare the full three-dimensional model runs with results of the simpler model configurations to determine whether the simpler models were reasonable approximations of the full three-dimensional simulation. History matching for the groundwater component showed that there are significant differences between all of the simplified model implementations and the full three-dimensional model results for the PUREX plumes. However, there were also significant differences between the full three-dimensional simulations and the observed data.

"History matching" showed that a two-dimensional implementation of the consolidated groundwater model was adequate for the initial assessment, which had the objective of demonstrating that an assessment of the scale and scope of the Hanford Site and Columbia River was possible.

Transport of tritium to the Columbia River was significantly slower for the two-dimensional version of the model, which caused simulated tritium (with a 12 year half-life) to decay to much lower than observed concentrations before reaching the river. Only the three-dimensional five-layer and seven-layer models resulted in a significantly better match to the full three-dimensional results than the variable thickness two-dimensional model. However, the time required for running these models (three-dimensional – five and seven layer) for 100 realizations was considered too long. Therefore, the variable thickness two-dimensional model was selected for the System Assessment Capability Rev. 0 simulations. This simplified model provides much faster run times that were needed to complete the many realizations of the System Assessment Capability Rev. 0 assessment in a reasonable time period. The two-dimensional model was determined to be suitable for the groundwater transport calculations in light of the major objective of the initial System Assessment Capability Rev. 0 assessment, which was "to demonstrate that an assessment of the scale and scope of the Hanford Site and the Columbia River can be conducted." However, it was also recognized that future assessments to be conducted using the System Assessment Capability will likely require more accurate groundwater simulations than can be produced by the two-dimensional model. This will require changes in the model implementation and/or hardware upgrades. Future improvements to the full three-dimensional model (i.e., recharge and new calibration) will also require the implementation of a more complex groundwater model so that these improvements can be realized in future versions of the System Assessment Capability. To support the next iteration of the System Assessment Capability, enhancements have been made to decrease the model execution time and additional processors have been acquired.

The System Assessment Capability assembled a complete inventory of selected waste contaminants for the Hanford Site.

4.3.3 Preliminary System Assessment Capability Results

Preliminary groundwater results from the initial assessment are available for 11 realizations for each of the 9 simulated contaminants. Each realization is based on a different selected value of the distribution coefficient from the probability distribution for this parameter, and on differences in waste site inventories, which are also represented by probability distributions.

Simulated plumes generally covered larger areas and had higher maximum concentrations than historical plumes, except tritium and iodine-129 plumes. Some of the major tritium and iodine-129 plumes were smaller in area but higher in concentration than the observed plumes. Most of the differences between groundwater concentrations predicted in the preliminary System Assessment Capability assessment are caused by inaccuracies in the upstream inventory, release, or vadose modules. This causes the releases to the groundwater system to be higher or lower than those observed historically. Within the groundwater module, simulated plumes moving eastward from 200 East Area toward the Columbia River moved more slowly than observed. As an example, Figure 4.3-1 shows the simulated iodine-129 plume for the year 2000. The red contours for each realization are equal to the maximum contaminant level of 1 pCi/L. The observed plume at this concentration for the year 2000 is plotted in blue. Delayed movement of the plume from 200 East Area eastward to the Columbia River was consistent with results of the history matching exercise as was the increased concentrations to the northward through the gap between Gable Mountain and Gable Butte. These problems will be addressed in future System Assessment Capability assessments by both introducing a more complex groundwater model configuration and by ongoing improvements in the sitewide groundwater model. Larger than observed plumes of iodine-129 appearing in the 200 West Area were traced to problems in the upstream modules rather than the groundwater simulation.

4.4 Modeling of the 200 West Area Carbon Tetrachloride Plume

Groundwater modeling of the carbon tetrachloride plume beneath 200 West Area had previously been performed to support the Hanford Carbon Tetrachloride Innovative Treatment and Remediation Demonstration Program. The objective was to determine the source amount of carbon tetrachloride that most likely results in non-compliance at an assumed distance from the source. This work was completed during fiscal year 2001 and is documented in PNNL-13560. Additional work was then performed to compare predictions of carbon tetrachloride plume movement based on realistic and conservative values of distribution coefficient (K_d) and attenuation coefficient (K_a). Results based on different assumptions regarding source remediation were also compared.

4.4.1 Modeling in Support of the Innovative Treatment and Remediation Demonstration Project

Modeling performed to support the Hanford Carbon Tetrachloride Innovative Treatment and Remediation Demonstration Program was a first step toward implementation of innovative technologies for remediation of the carbon tetrachloride plume underlying the 200 West Area. The modeling provided an indication of the potential impact of the carbon tetrachloride source on the compliance boundary ~5,000 meters distant. The primary results of the modeling bracket the amount of carbon tetrachloride source that will most likely result in compliance/non-compliance at the boundary and the relative influence of the various modeling parameters (PNNL-13560).

The modeling was based on the assumption that ~750,000 kilograms of carbon tetrachloride were discharged to the soil in the Z-crib area. Previous work has shown that of this 750,000 kilograms, ~65% cannot be accounted for. Therefore, modeling was performed using 65%, 30%, 10%, and 1% of the 750,000 kilograms as possible source amounts of carbon tetrachloride that could reach the groundwater (~1% to 2% of the original carbon tetrachloride inventory currently exists in the groundwater plume based on averaged carbon tetrachloride groundwater measurements). The modeling simulations examined the migration of carbon tetrachloride from the source area to the compliance boundary. They did not examine migration of the existing plume and did not attempt to match the historical disposal and migration of carbon tetrachloride.

During fiscal year 2001, groundwater modeling was completed for the Innovative Treatment and Remediation Demonstration Project. This work was the first step toward implementing innovative technologies to remediate the carbon tetrachloride plume under the 200 West Area.

Regional flow-modeling results from the Hanford Sitewide Groundwater Model provided groundwater velocity estimates for the simulation. The carbon tetrachloride transport was then simulated as one-dimensional flow in a streamtube 1,000 meters wide by 5,000 meters long. Initially, no vertical or tranverse dispersion or convection was simulated. Along with the varied source amounts, the modeling also varied the groundwater flow velocity; inlet concentration (i.e., the concentration of carbon tetrachloride leaving the source area); porosity; soil/water equilibrium partition coefficient; abiotic degradation rate; dispersivity; and streamtube cross-sectional area. The one-dimensional van Genuchten model simulated convective-dispersive transport of carbon tetrachloride through a homogenous medium along the centerline of the contaminant plume from the 200 West Area source area to the compliance boundary ~5,000 meters distant. One thousand Monte Carlo realizations were carried out. Fixed and deterministic parameters included the following:

- Streamtube length: 5,000 meters.
- Base inventory of contaminant: 750,000 kilograms carbon tetrachloride.
- Base porosity: 0.10 m^3/m^3.
- Bulk density: 1,950 kg/m^3.
- Inlet concentration: 1,500; 2,000; 2,500; or 3,000 mg/L.
- Amount of source remaining: 1%, 10%, 30%, or 65%.
- Groundwater flow velocity: mean, ±s, ±2s.

Stochastic parameters varied by Monte Carlo methods included the following:

- Porosity
- Soil/water equilibrium partition coefficient (K_d)

- Abiotic degradation rate (K_a)
- Dispersivity
- Streamtube cross-sectional area.

Additional simulations that included transverse and vertical dispersion and dilution were conducted to estimate the effect of a three-dimensional flow field. The results showed that in 80% of the simulations the concentration at the compliance boundary was reduced by a factor of >5 and in 20% of these simulations the concentration was reduced by a factor of >10 when compared to the one-dimensional modeling results.

Results of the 1,000 Monte Carlo simulations were analyzed to estimate the area needing remediation in order to meet compliance criteria. The simulations also provided a method for gauging sensitivity of predicted contaminant transport to variations in individual model parameters. The conclusions drawn from the modeling results were:

- If 1% of the discharged carbon tetrachloride is all that ever reaches the groundwater, then it is likely the highest concentration of carbon tetrachloride to arrive at the compliance boundary will not exceed the compliance concentration. However, it is possible the compliance concentration would be exceeded if the actual site parameters correspond to the lower porosity, lower K_d, and lower K_a values used in this study.
- If 10% or more of the discharged carbon tetrachloride reaches the groundwater, then it is likely that the concentration of carbon tetrachloride eventually arriving at the compliance boundary will exceed the compliance concentration unless source removal efforts are used.
- There is a breakpoint between 1% and 10% of the discharged inventory that defines the amount of carbon tetrachloride in the source at which source removal would be required to avoid exceeding the compliance concentration at the compliance boundary.
- Because source inventory remaining appears to be the quantity driving the amount of site cleanup required for compliance, source inventory characterization is needed to resolve compliance issues.

4.4.2 Predictions of Carbon Tetrachloride Plume Movement Based on Different Values of Attenuation Parameters

Additional modeling of the 200 West Area carbon tetrachloride plume was conducted during fiscal year 2001. The objective was to provide scoping simulations to guide planning of additional modeling work. Three sitewide modeling cases were examined to predict concentration distributions at various distances from the assumed source areas utilizing both realistic and conservative values of K_d and K_a. Different assumptions regarding source remediation were also simulated.

The previous Innovative Treatment and Remediation Demonstration modeling study described above was used as a basis for this effort. The three-dimensional distribution of carbon tetrachloride in groundwater in 1993 from the earlier simulations provided initial conditions for the subsequent flow and transport modeling. The Innovative Treatment and Remediation Demonstration simulation that was based on median values of input concentration and median values of attenuation parameters was used for the initial conditions. To support the transport calculations, the sitewide model grid was refined in the area where the plume is predicted to move (i.e., between the source and the Columbia River).

Three cases were evaluated. Case 1 assumed that a continuing source of carbon tetrachloride was in contact with the groundwater. The effects of the continuing source were based on an assumption (also made in the Innovative Treatment and Remediation Demonstration modeling) that the groundwater system close to the source is in equilibrium with the source. Two variations of this case examined different assumptions for K_d and K_a. First these parameters were set to conservative values of K_d = 0.0 m^3/kg (retardation factor = 1.0) and K_a = 0.0 y^{-1} (i.e., no reaction). For the second variation of case 1, the model was rerun with parameters set to best estimate values of K_d = 0.000322 m^3/kg (retardation factor = 2.6) and K_a = 0.00956 y^{-1} (reaction halftime = 72.5 years). These best estimates were based on Appendix C of the Innovative Treatment and Remediation Demonstration report (PNNL-13560). The result of the transport simulation that assumed conservative, although unrealistic, zero values for K_d and K_a is shown in Figure 4.4-1. The result of the variation that assumed best estimate values of K_d and K_a is shown in Figure 4.4-2. These simulations illustrate the dramatic effect of these parameters on plume movement. If the assumption that the source in equilibrium with the existing plume is appropriate, the modeling predicted a source release rate of about 33 kilograms per year. With K_d and K_a set to zero, it was found that:

Comparative modeling showed that natural attenuation parameters, K_d and K_a, are critical in predicting the future movement of carbon tetrachloride from the 200 West Area.

- carbon tetrachloride concentrations will exceed the compliance limit of 5 mg/L outside 200 Areas plateau waste management area (see Figure 4.4-1)
- aquifer source loading and the area of aquifer above the compliance limit of 5 mg/L will continue to grow until the arrival rate at the river reaches the source release rate of 33 kilograms per year (see Figure 4.4-3)

On the other hand if the best estimate values for K_d and K_a are appropriate then:

- concentrations will not exceed the compliance limit of 5 mg/L outside 200 Areas plateau waste management area (see Figure 4.4-2)
- the aquifer source loading and the area/volume of aquifer affected will be limited, as illustrated in Figure 4.4-4, by the removal of carbon tetrachloride through natural attenuation.

Case 2 examined the effect of complete source removal. All of the aquifer volume at or above the held concentration values for the source was set to zero, to simulate complete source removal. Only continued migration of the plume existing outside of the source areas was evaluated. For this case only the conservative natural attenuation parameters (i.e., K_d = 0.0 m^3/kg and K_a = 0.0 y^{-1}) were applied. Results for this case indicated that with complete source removal natural attenuation is sufficient to keep concentrations from exceeding the compliance limit of 5 mg/L outside 200 Areas plateau waste management area.

Case 3 examined the effects of assuming that there is no continuing source of carbon tetrachloride and, therefore, no source removal activities would be needed. For this case, the existing plume provided the initial conditions and only the effects of migration of the existing plume were simulated. Again, only the conservative natural attenuation parameters (i.e., K_d = 0.0 m^3/kg and K_a = 0.0 y^{-1}) were applied. This case indicated that under the assumption of no continuing source (i.e., only an existing plume) natural attenuation is sufficient to keep concentrations from exceeding the compliance limit of 5 mg/L outside the 200 Areas plateau waste management area.

In summary, Figures 4.4-1 and 4.4-2 illustrate that the most important parameters are K_d and K_a. With a K_d and K_a of zero, carbon tetrachloride concentrations will exceed the compliance limit of 5 mg/L outside 200 Area Plateau Waste Management Area and the aquifer source loading and area of the aquifer affected will continue to grow until river arrival rates equal source release rates.

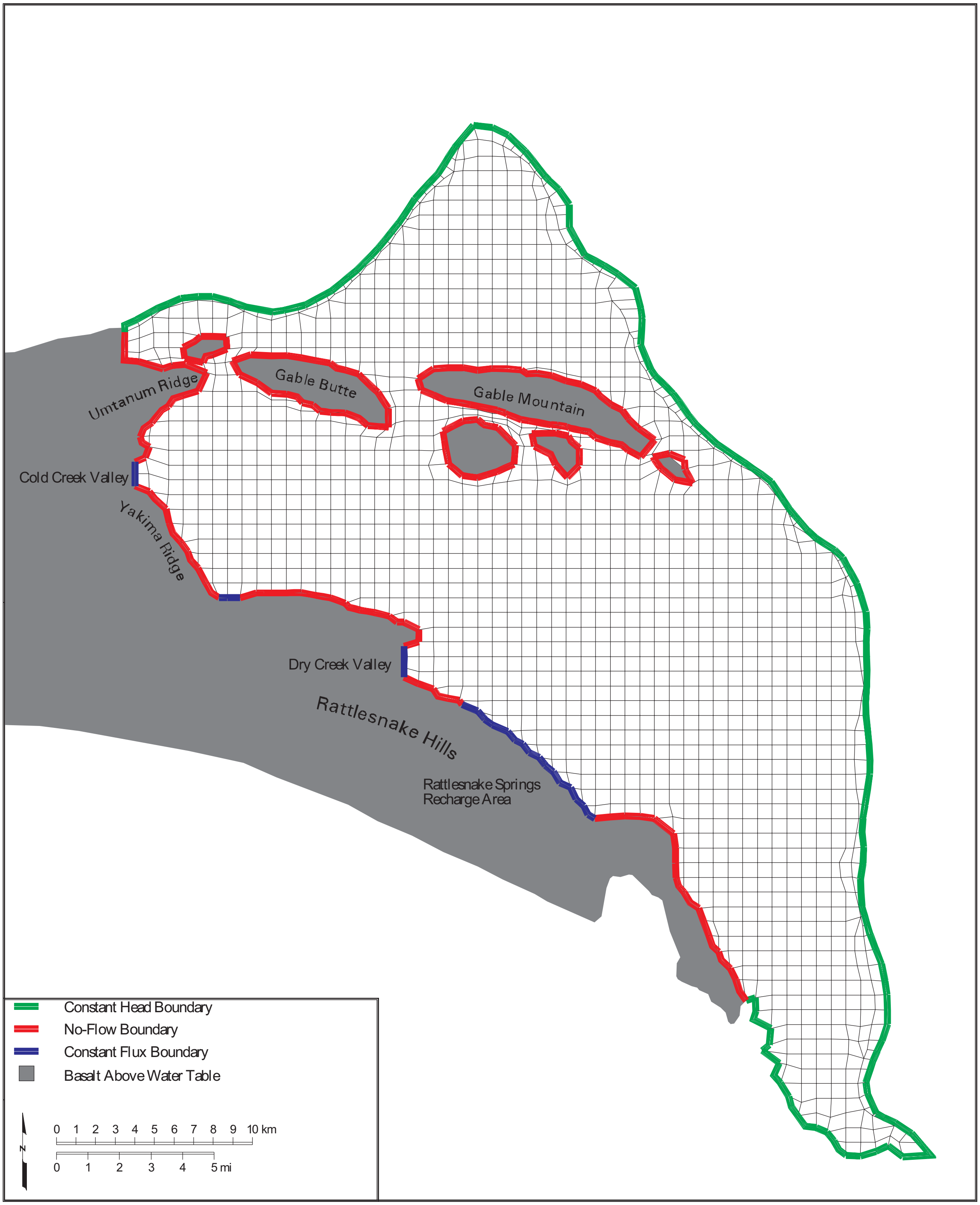

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Figure 4.1-1. Finite Element Grid and Boundary Conditions Used in the Three-Dimensional Sitewide Flow Model (PNNL-13623)

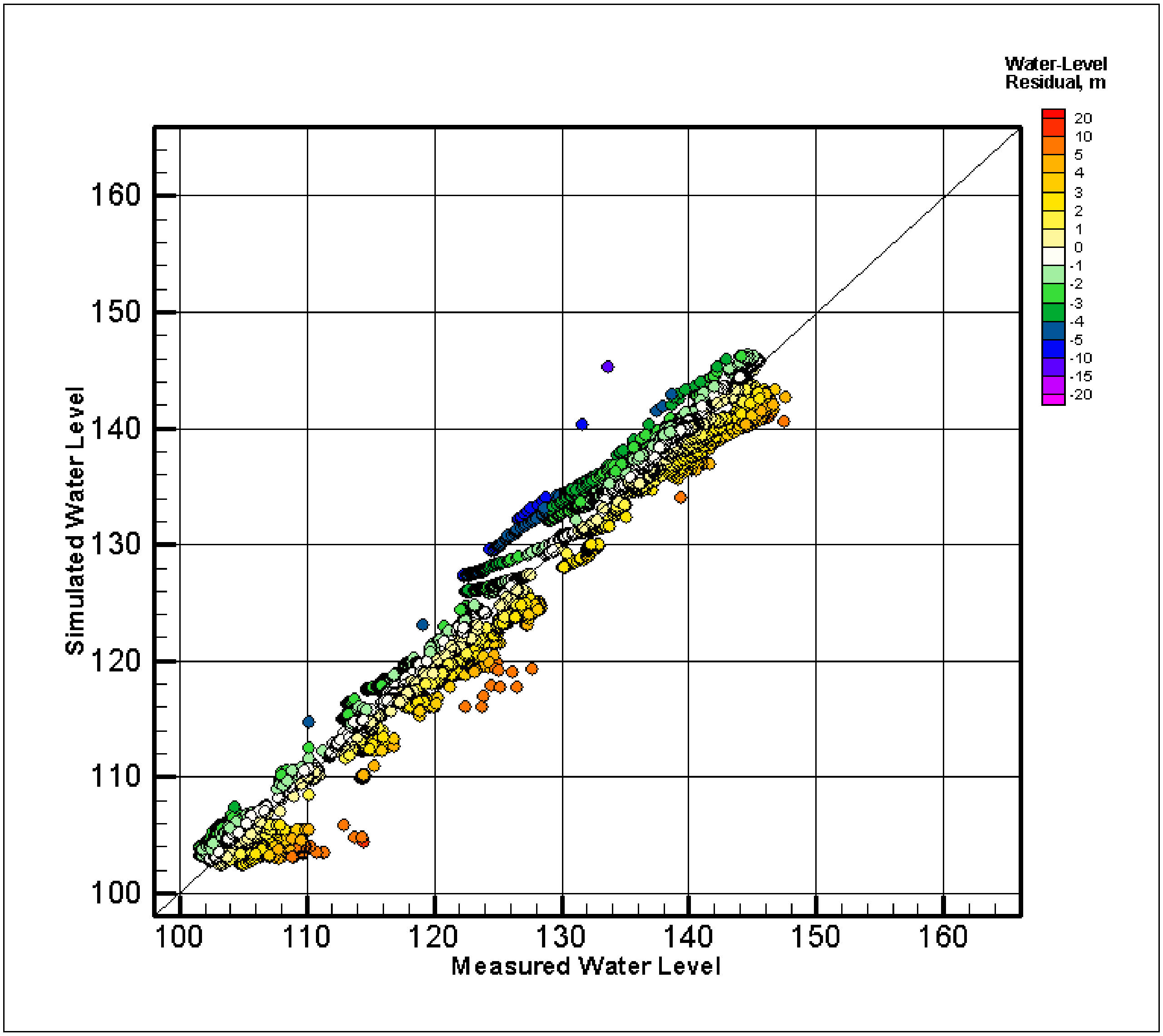


Figure 4.1-2. Base-Case Flow Model Calibration Results – Predicted Hydraulic Heads versus Hydraulic Heads Measured at Wells for 1948 Through 2000 (PNNL-13447)

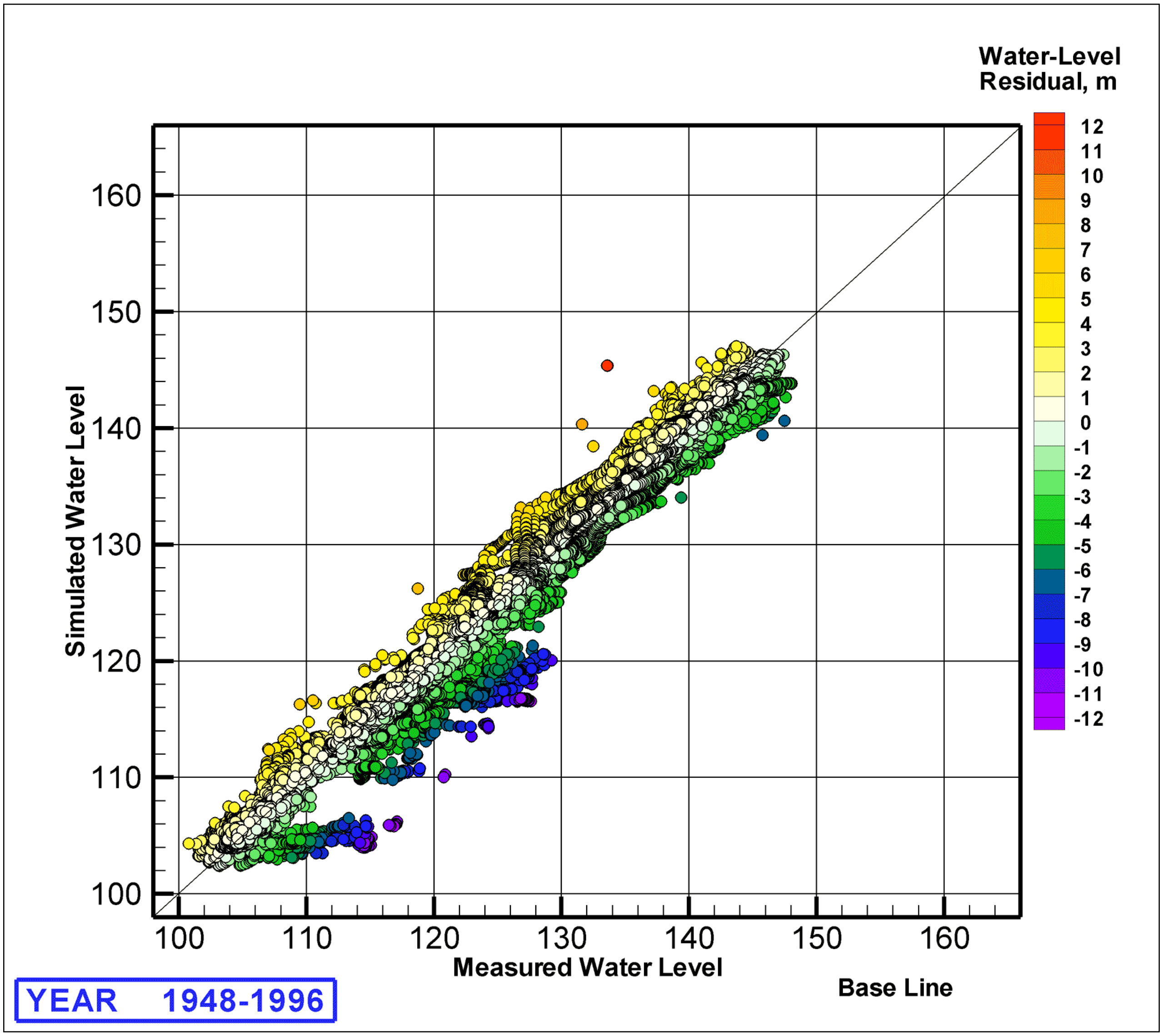


Figure 4.1-3. Calibration Results for the Flow Model with Basalt Aquifer Interaction – Predicted Hydraulic Heads versus Hydraulic Heads Measured at Wells from 1948 Through 2000 (PNNL-13623)

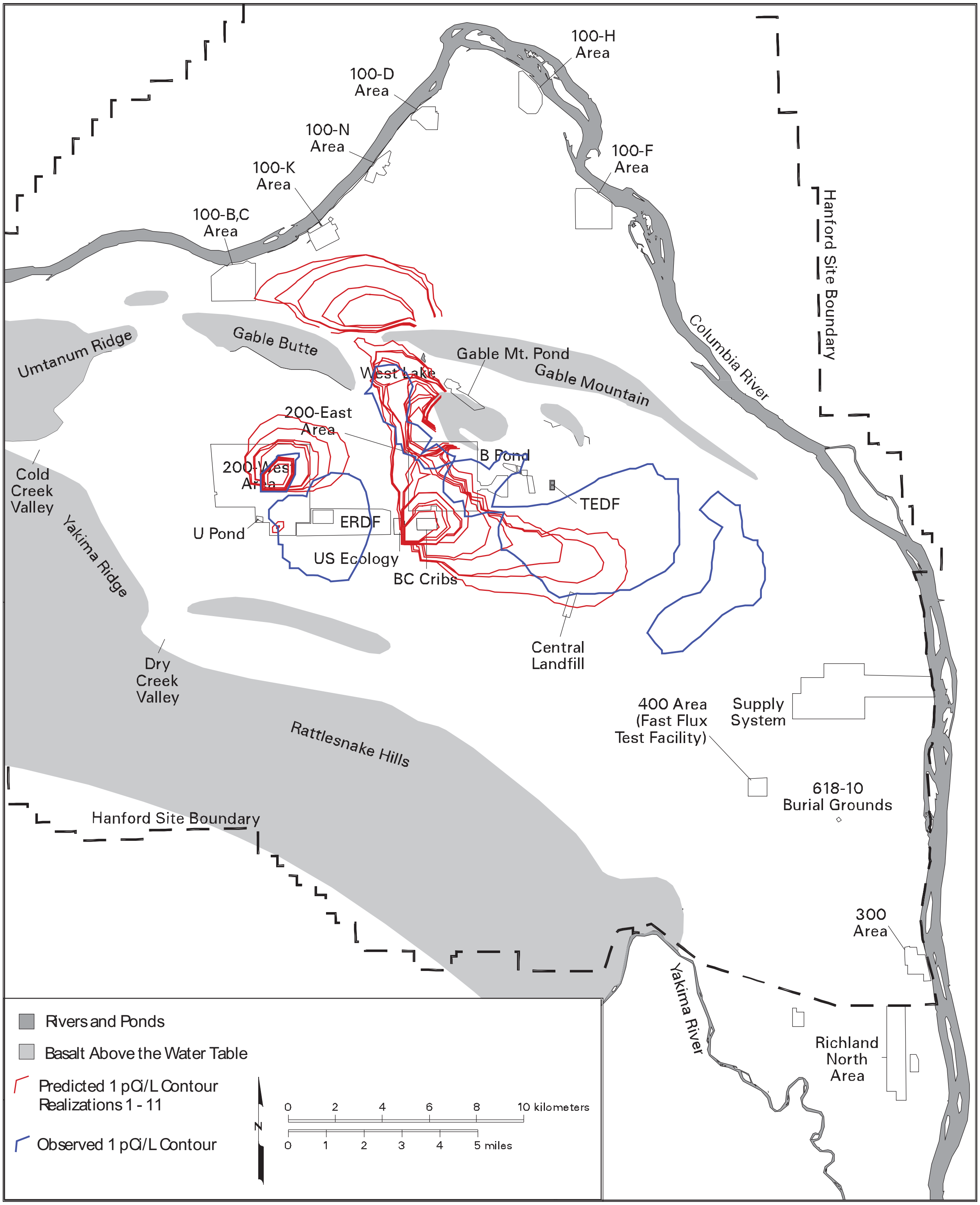


Figure 4.3-1. Preliminary System Assessment Capability Results for Iodine-129 in Groundwater Showing the Observed Plume for Year 2001 in Blue and Plumes Predicted by 11 Different Realizations of the System Assessment Capability in Red

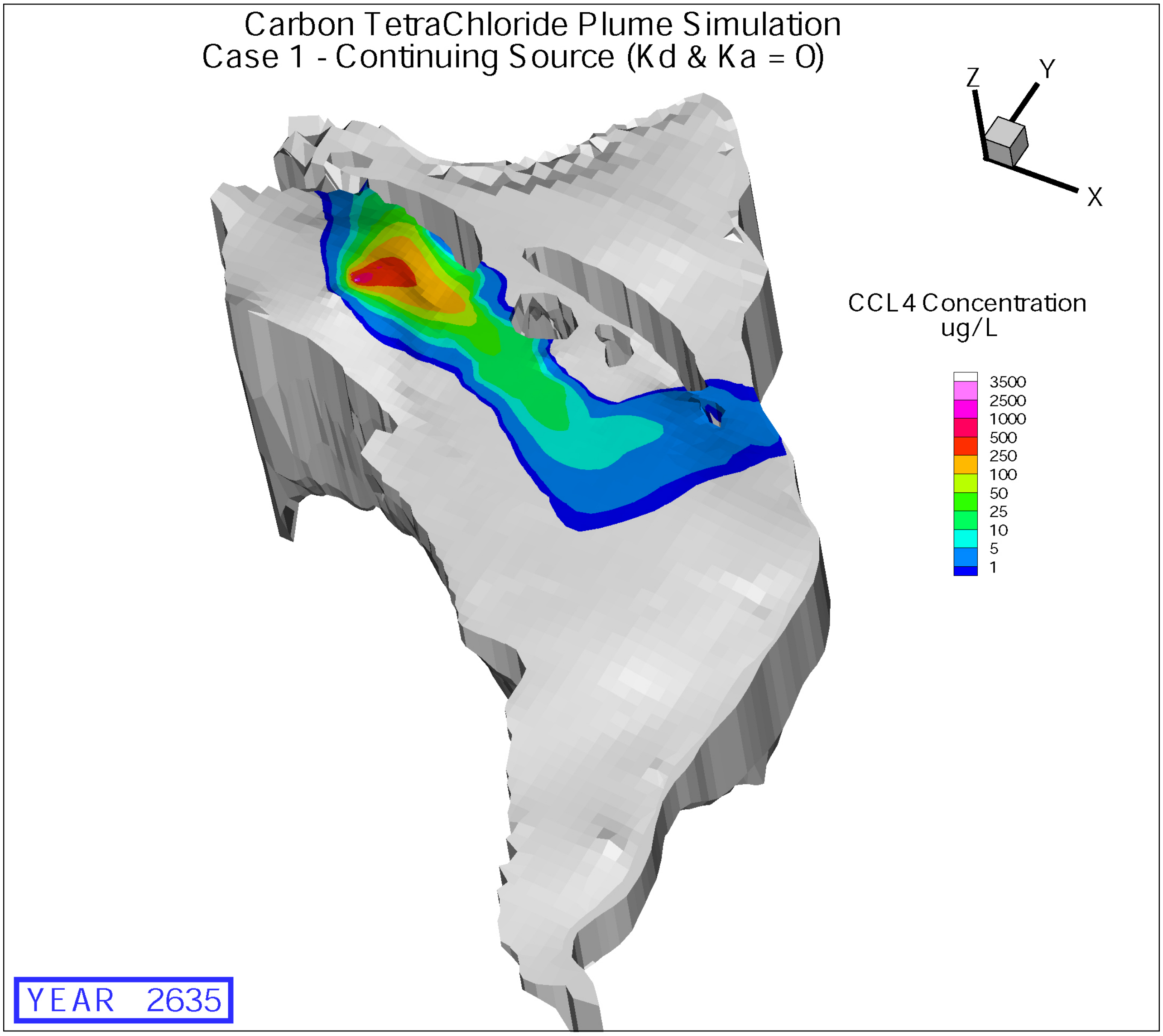


Figure 4.4-1. Predicted Extent of the Carbon Tetrachloride Plume in Year 2635 Based on a Continuing Source and Conservative Attenuation Values of K_d = 0.0 m^3/kg and K_a = 0.0 y^{-1}

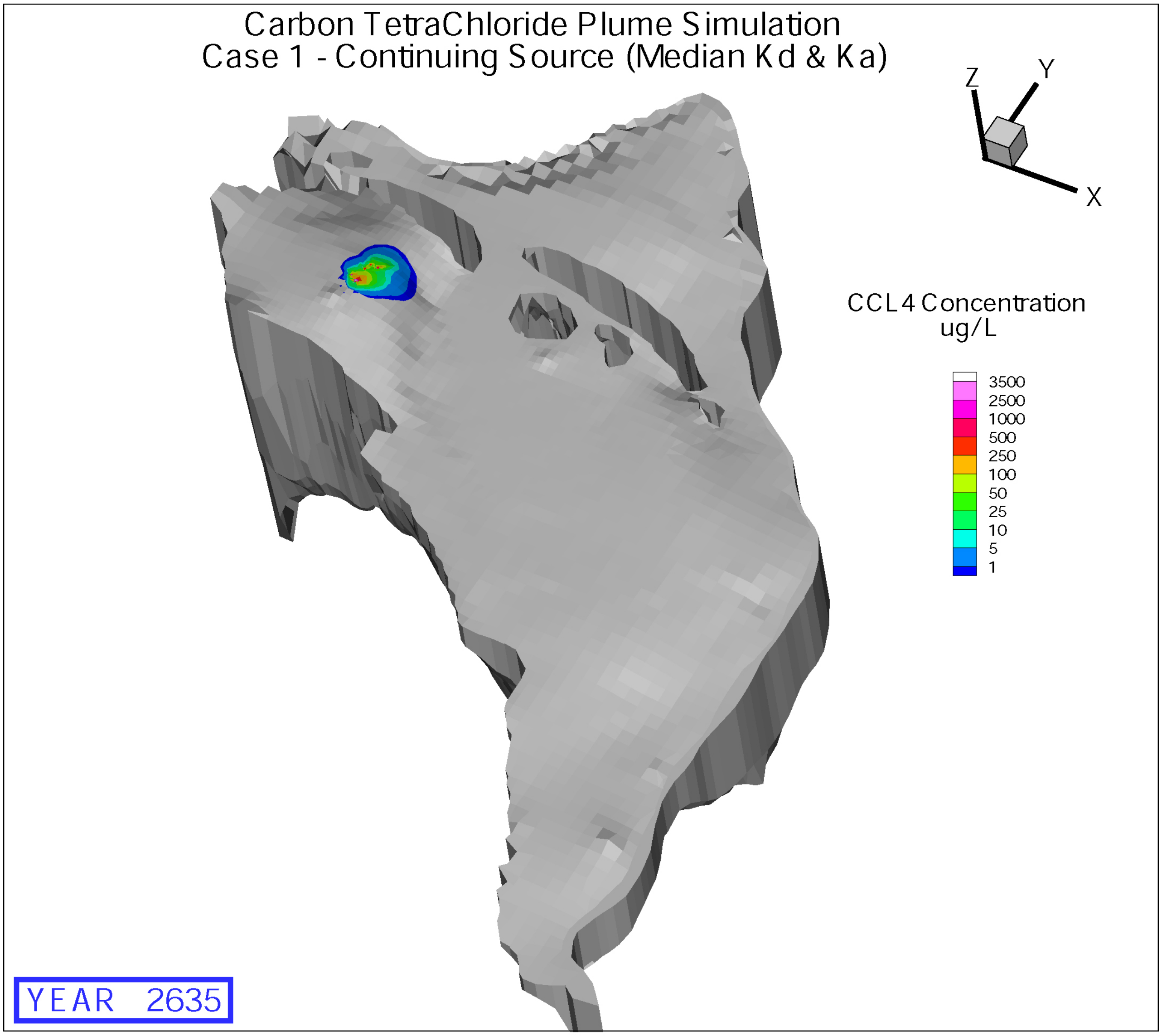
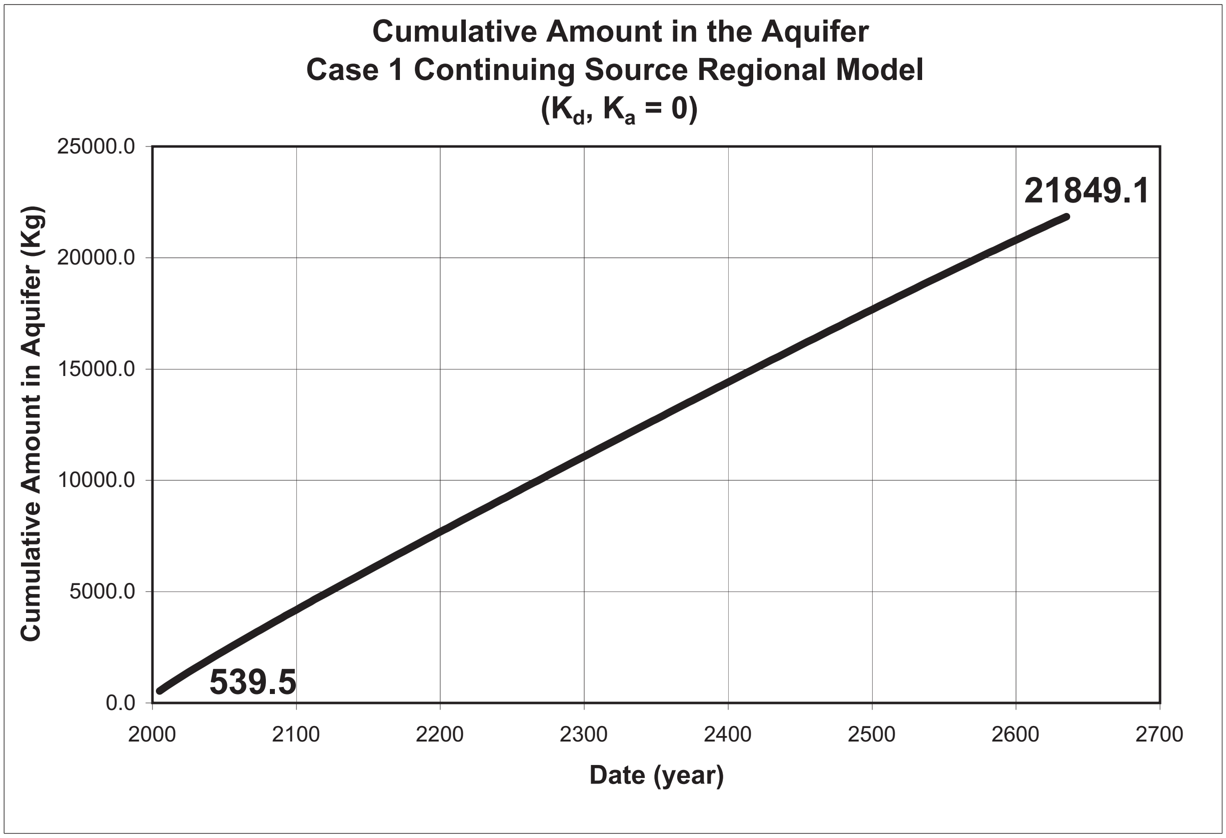


Figure 4.4-2. Predicted Extent of the Carbon Tetrachloride Plume in Year 2635 Based on a Continuing Source and Best-Estimate Attenuation Values of K_d = 0.000322 m^3/kg and K_a = 0.00956 y^{-1} (from Appendix C of PNNL-13560)



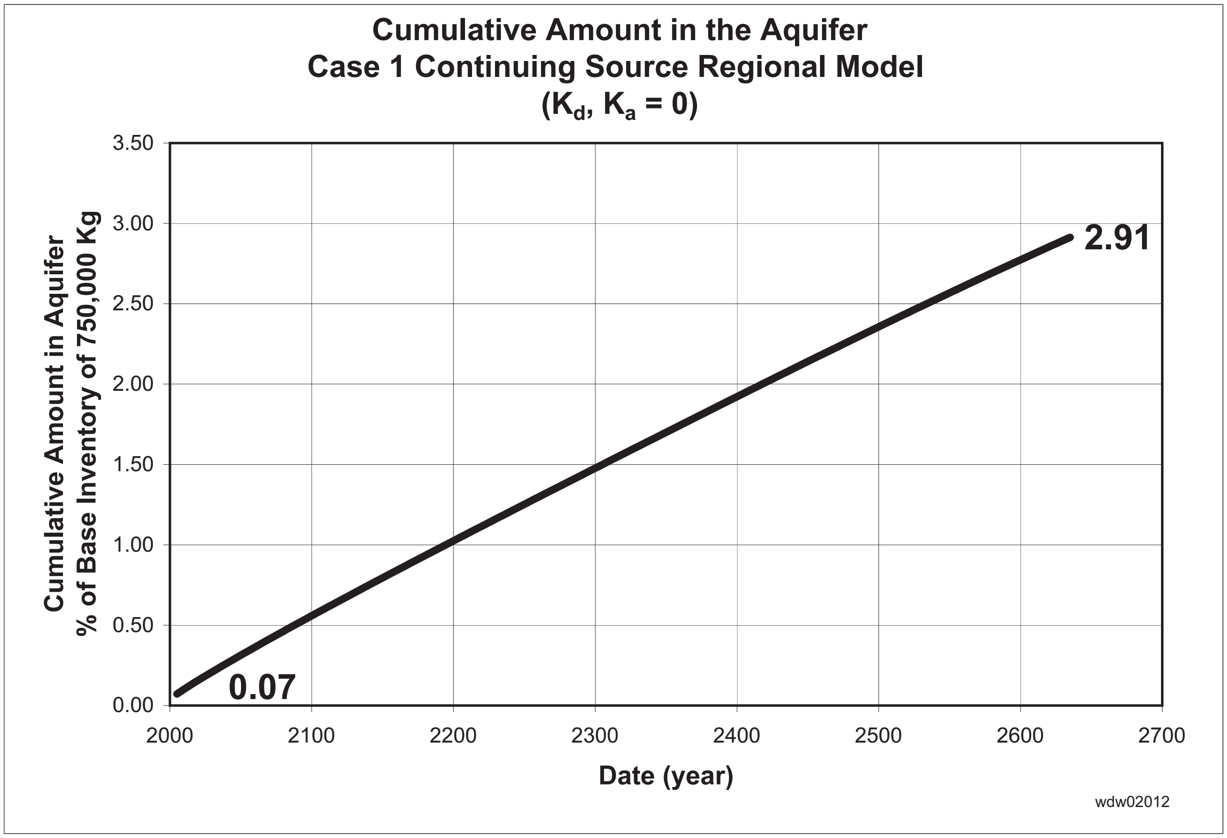
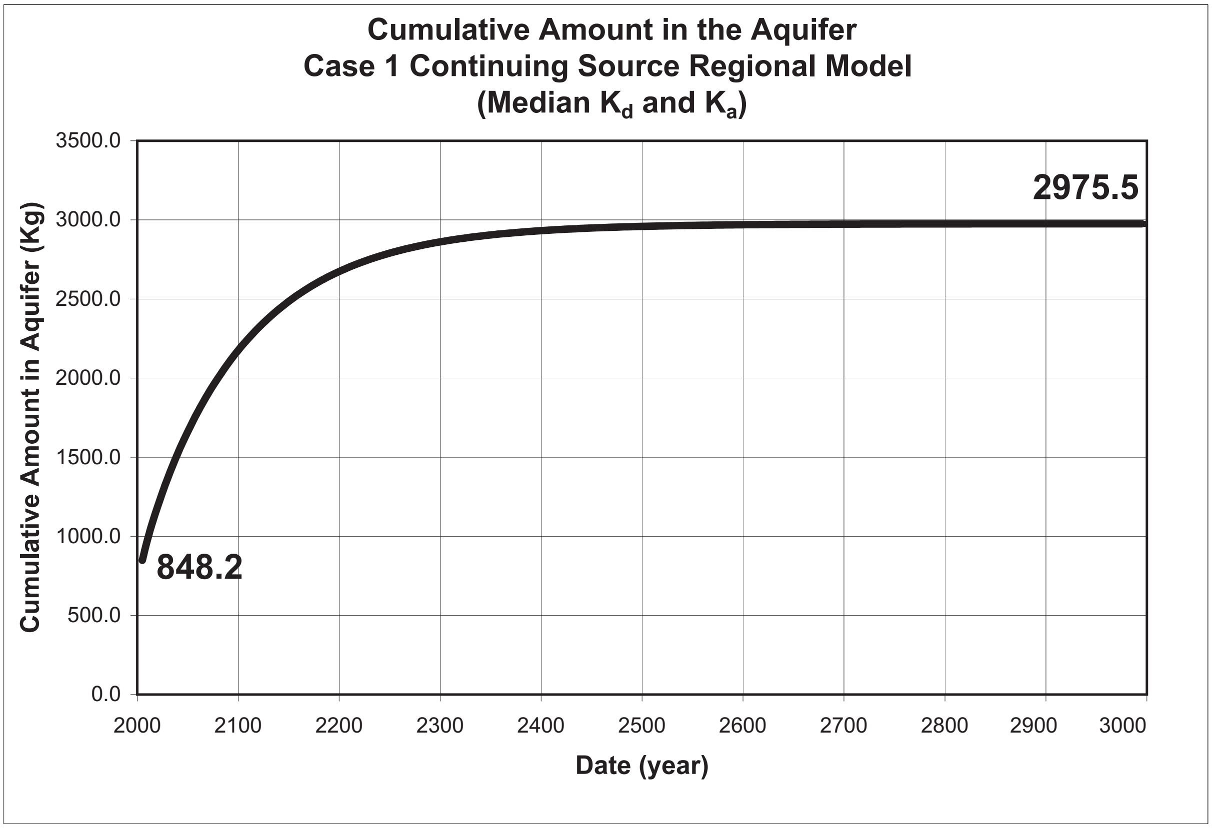


Figure 4.4-3. Predicted Carbon Tetrachloride Plume Loading of the Aquifer for a Continuing Source and Conservative Attenuation Values of K_d = 0.0 m^3/kg and K_a = 0.0 y^{-1}



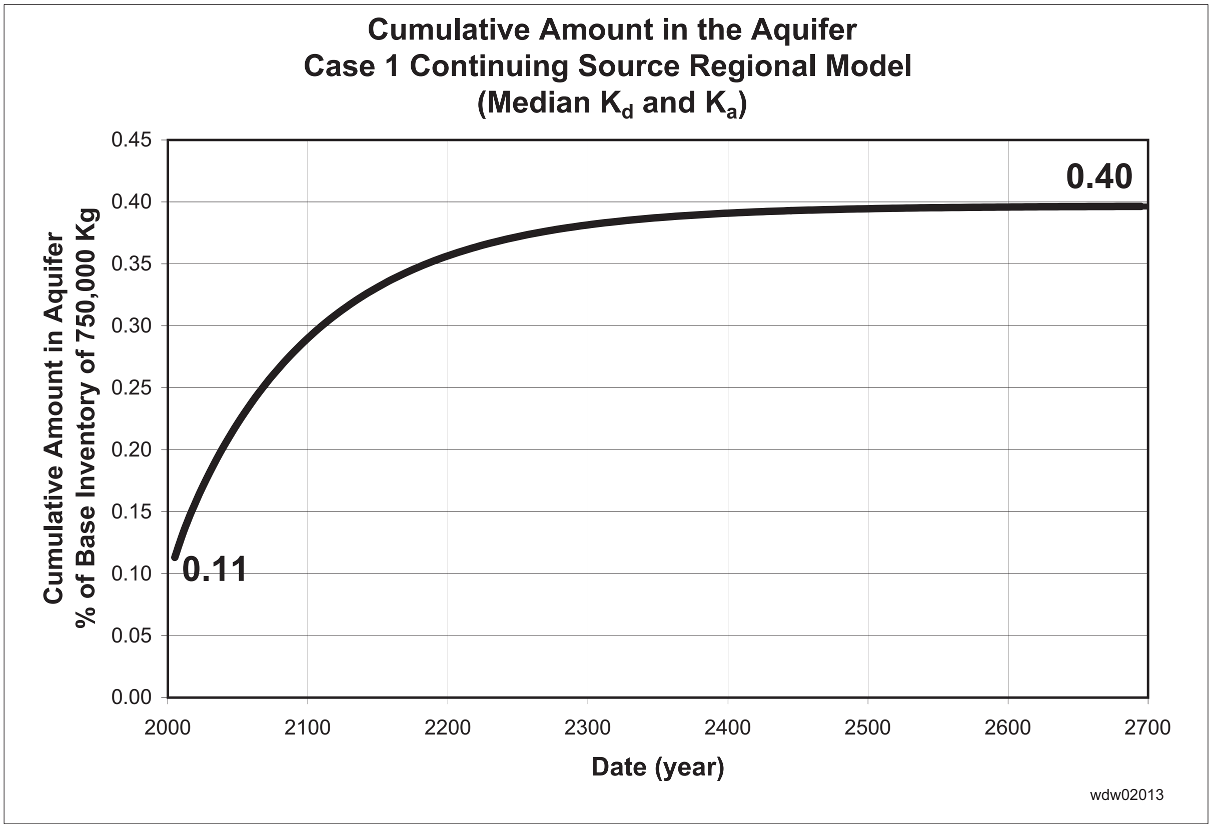


Figure 4.4-4. Predicted Carbon Tetrachloride Plume Loading of the Aquifer for a Continuing Source and Best-Estimate Attenuation Values of $K_d = 0.000322\ m^3/kg$ and $K_a = 0.00956\ y^{-1}$ (from Appendix C of PNNL-13560)

5.0 Well Installation, Maintenance, and Decommissioning

R. B. Mercer, B. A. Williams, and J. E. Auten

This section describes well installation, maintenance, and decommissioning activities conducted on the Hanford Site during fiscal year 2001.

5.1 Well Installation

The Hanford Groundwater Monitoring Project defines needs for new monitoring wells in a description of work between Pacific Northwest National Laboratory and Bechtel Hanford, Inc. Each year, the groundwater project installs new wells to maintain compliance with the *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring requirements and U.S. Department of Energy (DOE) orders. These compliance issues include ongoing RCRA facility groundwater assessments, replacement of monitoring wells that go dry because of the declining water table, replacement of wells that pose contamination risks to the environment, improvement of spatial coverage of the monitoring networks, and vertical characterization of groundwater contamination. The environmental restoration contractor also determines its needs for new wells annually.

Well Installation

Fifty-eight new wells were installed on the Hanford Site in fiscal year 2001:

- 21 for RCRA monitoring
- 36 for CERCLA investigations or remediation
- 1 for the River Protection Project.

Each year DOE and the Washington State Department of Ecology approve RCRA wells through a process that integrates data quality objectives. This process integrates the data needs of various Hanford Site projects in the proposed wells (i.e., *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* and the River Protection Project). New wells needed to monitor environmental restoration projects are approved using a data quality objective process with DOE, Bechtel Hanford, Inc., and the lead regulator (U.S. Environmental Protection Agency or Washington State Department of Ecology).

Groundwater sampling near the Columbia River on the Hanford Site.

Milestone M-24-00M (Ecology et al. 1998) required the installation of eleven new RCRA groundwater monitoring wells by December 31, 2001. Also, ten RCRA wells started in fiscal year 2000 (milestone M-24-00L, Ecology et al. 1998) were completed in fiscal year 2001. Table 5.1-1 lists all new wells completed in fiscal year 2001. Well data packages will be published in fiscal year 2002 with more detailed information about these new wells, including the detailed geologic and geophysical descriptions and a complete set of sampling data results. Thirty-one new wells were installed in the 100 D Area for activities related to environmental restoration (Figure 5.1-1). Five other CERCLA wells were installed in 2001; one in 200 West Area and four near the 618-11 burial ground. One well was installed for the immobilized low-activity waste site in the 200 East Area. Two existing wells (299-W15-84 and 299-W15-85) were deepened for the environmental restoration contractor carbon tetrachloride remediation project (200-ZP-1).

Thirteen boreholes were drilled and immediately decommissioned for investigative purposes (Table 5.1-2). Five were near the 618-11 burial ground as part of the tritium investigation. Six were drilled near the 216-B-38 trench and one near the 216-B-7A crib in the 200 East Area. The remaining borehole was near the 216-T-38 crib in the 200 West Area. The boreholes in the 200 Areas were for vadose characterization. These boreholes were decommissioned as soon as the investigations were completed.

5.2 Well Maintenance

Over 100 wells received routine maintenance, and 99 wells were decommissioned in fiscal year 2001.

Maintenance of groundwater wells is performed to meet regulatory requirements as part of a scheduled preventive maintenance cycle (routine) or in response to problems identified in the field (non-routine). Non-routine maintenance includes both surface and subsurface tasks. Surface tasks include conducting field inspections, well labeling, maintenance and replacement of locking well caps, casing repairs, and diagnosis and repair of surface electrical and pump-discharge deficiencies. Subsurface tasks include repairing and replacing sampling pumps; performing camera surveys; brushing casing perforations or screens; developing wells to improve yield, recovery, and sample quality; or removing sediment accumulation. Routine maintenance is performed on a 5-year cycle to support groundwater sampling and to minimize non-routine maintenance activities. At a minimum, routine maintenance includes the following tasks:

- removing groundwater sampling pump systems or aquifer-testing equipment
- inspecting and repairing or replacing sampling pump systems or aquifer-testing equipment
- brushing or cleaning of well casing perforations or well screens
- removing debris and fill material
- developing the well
- performing borehole video camera survey
- reinstalling sampling or aquifer-testing instrumentation/equipment
- documenting well conditions and maintenance activities.

Non-routine tasks are performed in response to a problem identified in the field or requests. Non-routine maintenance tasks are varied and depend on the specific problem encountered at a well. These activities also include the installation or removal of pumps or monitoring equipment. A summary of maintenance activities by regulatory program is presented in Table 5.2-1.

5.3 Well Decommissioning

Decommissioning activities result in the permanent removal of a well, borehole, or piezometer from service and from the Hanford Site well inventory. Decommissioning is performed in accordance with Washington State Department of Ecology standards (WAC 173-160). Typically, well decommissioning is done by placing sand across the screened interval, perforating the casing across any confining layers, and pressure grouting. The casing is removed if possible. If not, the casing is cut ~1 meter below ground surface. A brass plate is set in the grout below land surface and the hole is backfilled. A well becomes a candidate for decommissioning if its use has been permanently discontinued; if its condition is so poor that its continued use is impractical; or it poses an environmental, safety, or public health hazard.

Decommissioning involves backfilling a well with impermeable material to prevent vertical movement of water or contaminants. Wells that present the risk of being immediate hazards to the public health or safety are categorized into basic risk groups (high, medium, and low). These categories identify wells that have the potential to provide preferential pathways that allow movement of contaminants deeper into the subsurface strata. Well classifications and decommissioned wells are shown in Figure 5.3-1. At this time, decommissioning is generally driven by the long-range environmental restoration schedule (DOE/RL-96-105). Ninety-nine Hanford Site wells were decommissioned during fiscal year 2001 (Table 5.3-1). Wells decommissioned to date on the Hanford Site are illustrated also in Figure 5.3-1.

Table 5.1-1. Well Installations for Fiscal Year 2001

Well Number	Well ID	Program	Project
199-D4-40	C3270	CERCLA	100 D ISRM
199-D4-41	C3271	CERCLA	100 D ISRM
199-D4-42	C3272	CERCLA	100 D ISRM
199-D4-43	C3273	CERCLA	100 D ISRM
199-D4-44	C3274	CERCLA	100 D ISRM
199-D4-45	C3275	CERCLA	100 D ISRM
199-D4-46	C3276	CERCLA	100 D ISRM
199-D4-47	C3277	CERCLA	100 D ISRM
199-D4-48	C3278	CERCLA	100 D ISRM
199-D4-49	C3279	CERCLA	100 D ISRM
199-D4-50	C3280	CERCLA	100 D ISRM
199-D4-51	C3281	CERCLA	100 D ISRM
199-D4-52	C3282	CERCLA	100 D ISRM
199-D4-54	C3284	CERCLA	100 D ISRM
199-D4-55	C3285	CERCLA	100 D ISRM
199-D4-56	C3286	CERCLA	100 D ISRM
199-D4-57	C3287	CERCLA	100 D ISRM
199-D4-58	C3288	CERCLA	100 D ISRM
199-D4-59	C3289	CERCLA	100 D ISRM
199-D4-60	C3290	CERCLA	100 D ISRM
199-D4-61	C3291	CERCLA	100 D ISRM
199-D4-62	C3292	CERCLA	100 D ISRM
199-D4-63	C3293	CERCLA	100 D ISRM
199-D4-64	C3294	CERCLA	100 D ISRM
199-D4-65	C3295	CERCLA	100 D ISRM
199-D4-66	C3296	CERCLA	100 D ISRM
199-D4-67	C3297	CERCLA	100 D ISRM
199-D4-83	C3315	CERCLA	100 D ISRM
199-D4-84	C3316	CERCLA	100 D ISRM
199-D4-85	C3317	CERCLA	100 D ISRM
199-D4-86	C3318	CERCLA	100 D ISRM
299-E24-21	C3177	RPP	ILAW
299-E33-337	C3390	RCRA	B tank farm
299-E33-338	C3391	RCRA	B tank farm
299-E33-339	C3392	RCRA	B tank farm
299-W10-27[(a)]	C3125	RCRA	TX-TY tank farms
299-W10-28	C3400	RCRA	T tank farm
299-W11-39[(a)]	C3117	RCRA	T tank farm
299-W11-40[(a)]	C3118	RCRA	T tank farm
299-W14-16[(a)]	C3120	RCRA	TX-TY tank farms
299-W14-17[(a)]	C3121	RCRA	TX-TY tank farms
299-W14-18	C3396	RCRA	TX-TY tank farms
299-W15-763[(a)]	C3339	RCRA	TX-TY tank farms
299-W15-765	C3397	RCRA	TX-TY tank farms
299-W18-40	C3395	RCRA	U tank farm
299-W19-43	C3381	CERCLA	200-UP-1
299-W19-44	C3393	RCRA	U tank farm
299-W19-45	C3394	RCRA	U tank farm
299-W22-81[(a)]	C3123	RCRA	SX tank farm
299-W22-82[(a)]	C3124	RCRA	SX tank farm

Table 5.1-1. (contd)

Well Number	Well ID	Program	Project
299-W22-83(a)	C3126	RCRA	SX tank farm
299-W22-84	C3398	RCRA	S tank farm
299-W22-85	C3399	RCRA	SX tank farm
299-W23-21(a)	C3113	RCRA	SX tank farm
699-12-2C	C3253	CERCLA	Tritium investigation
699-13-0A	C3256	CERCLA	Tritium investigation
699-13-1E	C3798	CERCLA	Tritium investigation
699-13-2D	C3254	CERCLA	Tritium investigation

(a) Installed under fiscal year 2000 drilling milestone and extensions; completed in fiscal year 2001.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980.*
ILAW = Immobilized low-activity waste.
ISRM = In situ redox manipulation.
RCRA = *Resource Conservation and Recovery Act of 1976.*
RPP = River Protection Project.

Table 5.1-2. Characterization Boreholes for Fiscal Year 2001

Well	Well ID	Program	Project	Facility	Location
C3102	C3102	CERCLA	200-TW-1	216-T-26 crib	200 West
C3103	C3103	CERCLA	200-TW-2	216-B-7A crib	200 East
C3104	C3104	CERCLA	200-TW-2	216-B-38 trench	200 East
C3251	699-13-1D	CERCLA	618-11	618-11 burial ground	600 Area
C3252	C3252	CERCLA	618-11	618-11 burial ground	600 Area
C3255	C3255	CERCLA	618-11	618-11 burial ground	600 Area
C3264	C3264	CERCLA	618-11	618-11 burial ground	600 Area
C3265	C3265	CERCLA	618-11	618-11 burial ground	600 Area
C3340	C3340	CERCLA	200-TW-2	216-B-38 trench	200 East
C3341	C3341	CERCLA	200-TW-2	216-B-38 trench	200 East
C3342	C3342	CERCLA	200-TW-2	216-B-38 trench	200 East
C3343	C3343	CERCLA	200-TW-2	216-B-38 trench	200 East
C3344	C3344	CERCLA	200-TW-2	216-B-38 trench	200 East

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980.*

Table 5.2-1. Well Maintenance Summary for Fiscal Year 2001

Program	Routine	Non-Routine
CERCLA	44	176
LTMC	3	1
RCRA	6	66
Surveillance	61	46
Total	114	289

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980.*
LTMC = Long-Term Monitoring - CERCLA.
RCRA = *Resource Conservation and Recovery Act of 1976.*

Table 5.3-1. Wells Decommissioned in Fiscal Year 2001

Well Name	Well ID	Location
199-B4-9	A4560	100 B
199-D2-5	A4567	100 D
199-K-28	A4654	100 K
299-E25-1000	A6536	200 East
399-1-19	A5034	300 Area
399-1-5	A5038	300 Area
699-10-6	A8177	600 Area
699-1-1	A8119	600 Area
699-11-5	A8211	600 Area
699-11-6	A8212	600 Area
699-11-E8A	A8228	600 Area
699-12-4B	A8250	600 Area
699-13-5	A8266	600 Area
699-14-3	A8292	600 Area
699-14-5	A8293	600 Area
699-15-3	A8316	600 Area
699-15-4	A8317	600 Area
699-16-E4A	A8349	600 Area
699-20-E3	A8427	600 Area
699-20-E5P	A8429	600 Area
699-20-E5Q	A8430	600 Area
699-20-E5R	A8431	600 Area
699-20-E5S	A8432	600 Area
699-2-1	A8121	600 Area
699-24-1T	A5088	600 Area
699-33-6	A8525	600 Area
699-34-8	A8535	600 Area
699-35-3B	A8547	600 Area
699-36-1	A8561	600 Area
699-36-2	A8562	600 Area
699-37-4	A8575	600 Area
699-38-3	A8589	600 Area
699-38-8A	A8590	600 Area
699-38-E0	A8599	600 Area
699-39-1A	A8601	600 Area
699-40-12B	A8628	600 Area
699-40-12D	A8630	600 Area
699-40-12E	A8631	600 Area
699-40-12F	A8632	600 Area
699-40-12G	A8633	600 Area
699-40-12H	A8634	600 Area
699-40-12L	A8635	600 Area
699-40-6	A8621	600 Area
699-4-1	A8127	600 Area
699-41-5	A8648	600 Area
699-42-10	A8662	600 Area
699-4-5	A8128	600 Area
699-46-3	A8725	600 Area
699-5-2	A8133	600 Area
699-5-3	A8134	600 Area
699-5-4	A8135	600 Area

Table 5.3-1. (contd)

Well Name	Well ID	Location
699-5-E6	A8136	600 Area
699-6-1	A8137	600 Area
699-6-2B	A8139	600 Area
699-6-2C	A8140	600 Area
699-65-95	A5304	600 Area
699-6-6	A8141	600 Area
699-67-98	A5314	600 Area
699-6-E6	A8143	600 Area
699-72-88	A5324	600 Area
699-72-98	A5326	600 Area
699-7-3	A8145	600 Area
699-7-E1A	A8147	600 Area
699-7-E1B	A8148	600 Area
699-7-E2	A8149	600 Area
699-7-E6	A8150	600 Area
699-8-E2A	A8155	600 Area
699-8-E2B	A8156	600 Area
699-8-E3C	A8159	600 Area
B2870	B2870	600 Area
B2876	B2876	600 Area
B2877	B2877	600 Area
B2884	B2884	600 Area
B2887	B2887	600 Area
C3182	C3182	600 Area
C3184	C3184	600 Area
C3185	C3185	600 Area
C3320	C3320	600 Area
C3321	C3321	600 Area
C3322	C3322	600 Area
C3323	C3323	600 Area
C3326	C3326	600 Area
C3345	C3345	600 Area
C3346	C3346	600 Area
C3347	C3347	600 Area
C3349	C3349	600 Area
C3361	C3361	600 Area
C3362	C3362	600 Area
C3363	C3363	600 Area
C3378	C3378	600 Area
C3379	C3379	600 Area
C3440	C3440	600 Area
C3509	C3509	200 East
C3510	C3510	200 East
C3511	C3511	200 East
HWDS51	C3352	600 Area
HWDS52	C3351	600 Area
HWDS53	C3353	600 Area
HWDS57	C3358	600 Area

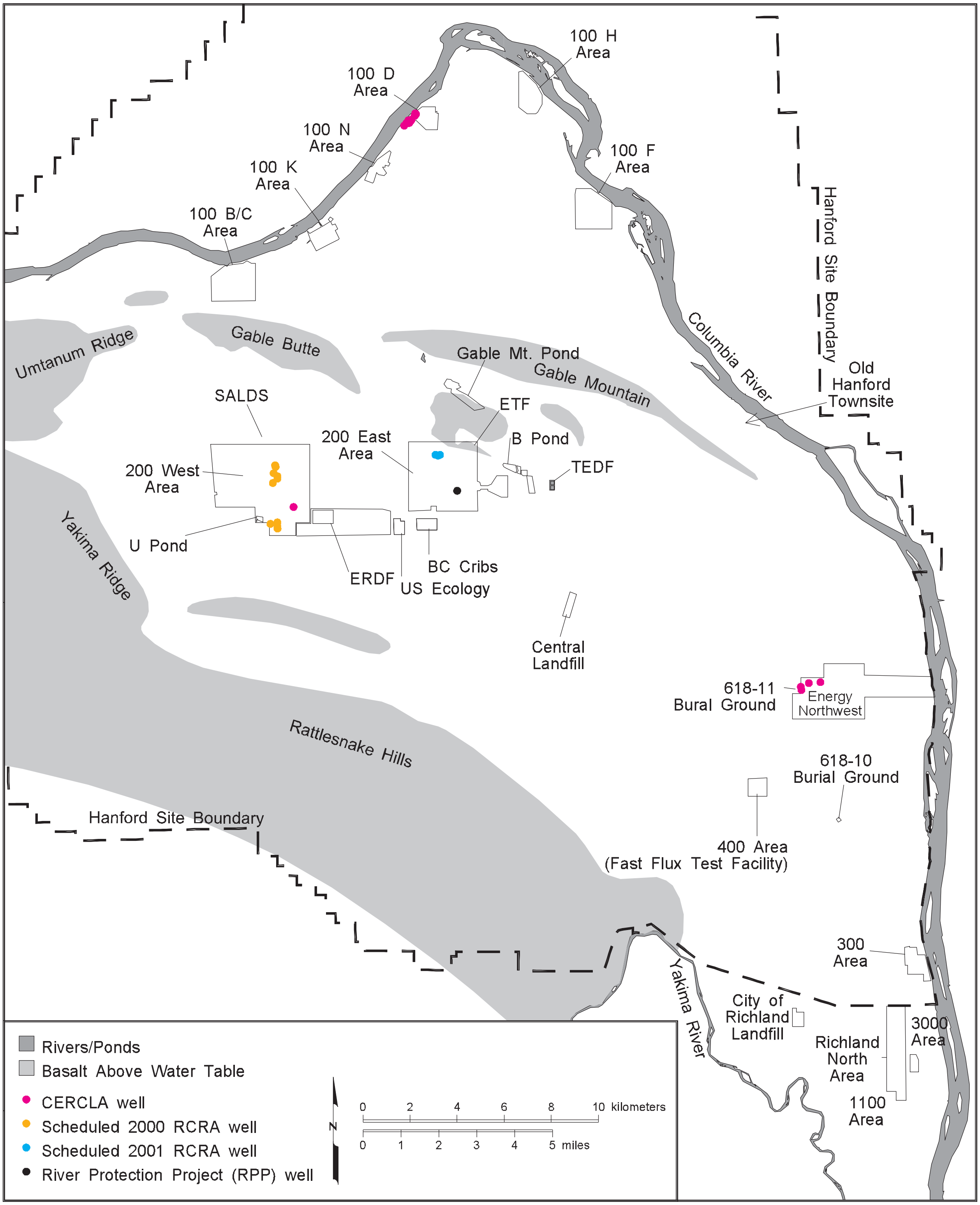


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Figure 5.1-1. Groundwater Monitoring Wells Installed in Fiscal Year 2001

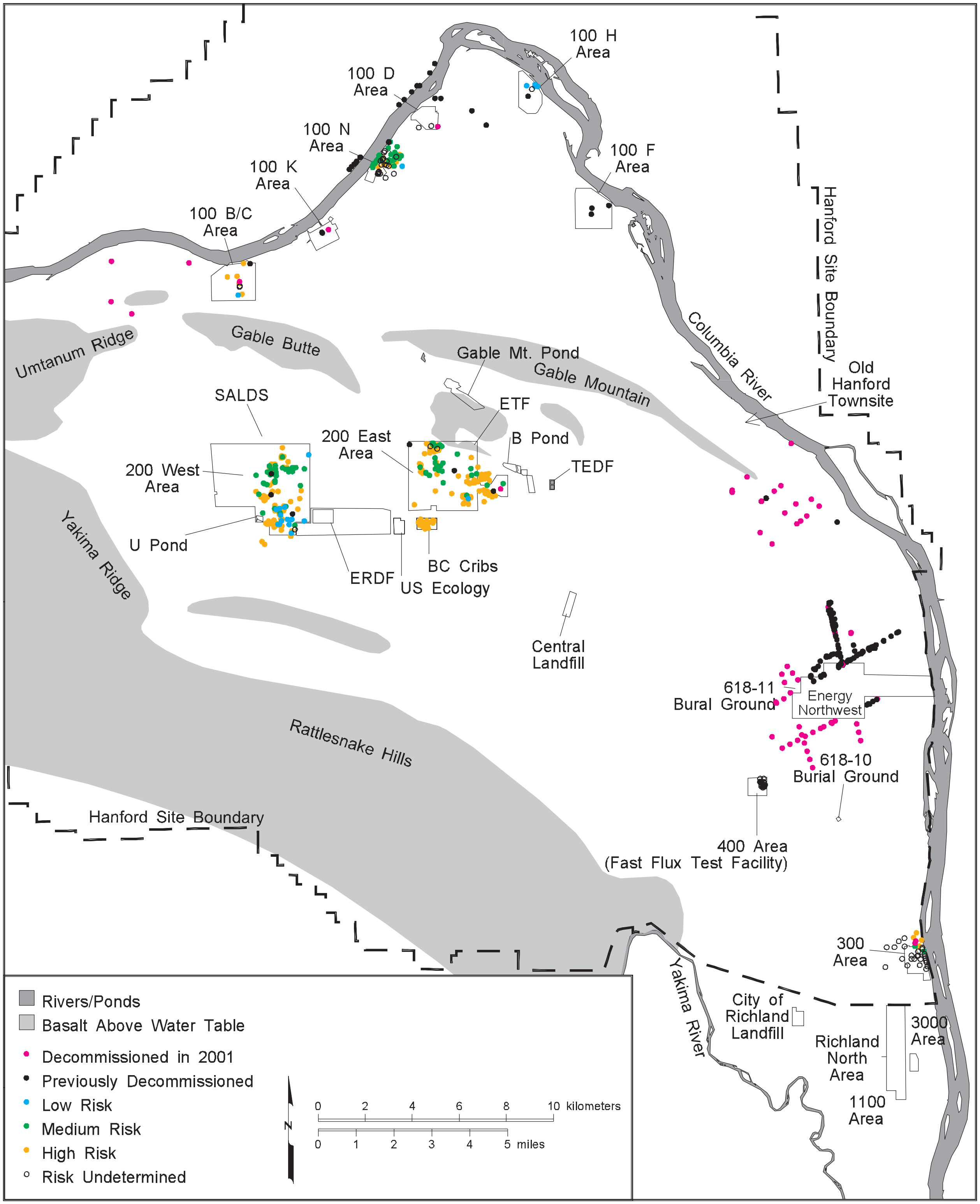

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Figure 5.3-1. Classification of Wells for Decommissioning

6.0 References

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Appendix A

Supporting Information for RCRA Units, Regulated Units, CERCLA Operable Units, and *Atomic Energy Act of 1954* Monitoring

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Appendix A

Supporting Information for RCRA Units, Regulated Units, CERCLA Operable Units, and *Atomic Energy Act of 1954* Monitoring

M. J. Hartman

This appendix contains supplemental information for waste disposal facilities or groundwater operable units on the Hanford Site that require groundwater monitoring. Most of these are regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA) (WAC 173-303), on which this appendix is focused (Figure A.1). Information required by the regulations (e.g., assessing the adequacy of the monitoring networks) is included for each RCRA unit. Three treated effluent disposal facilities (WAC 173-216), one solid waste landfill (WAC 173-304), and various groundwater operable units (*Comprehensive Environmental Response, Compensation, and Liability Act of 1980* [CERCLA]) also are included, and exceedance of drinking water standards and U.S. Department of Energy (DOE) derived concentration guides are summarized.

A.1 RCRA Sites

RCRA groundwater monitoring continued during fiscal year 2001 at 24 waste management areas. Table A.1 lists the monitoring status for RCRA facilities at the end of fiscal year 2001. Estimates of groundwater velocity, and supporting data, are shown for RCRA sites in Table A.2. Table A.3 lists wells exceeding drinking water standards for each regulated unit during fiscal year 2001. RCRA units are discussed below in alphanumeric order.

A.1.1 1301-N Liquid Waste Disposal Facility

The 1301-N liquid waste disposal facility is monitored in accordance with a RCRA interim status indicator evaluation program (40 CFR 265; WAC 173-303-400). The closure plan for this facility was incorporated into a modification of the Hanford Site RCRA Permit in 1999 (Ecology 1994). Remedial actions will be integrated with the 100-NR-1 and 100-NR-2 Operable Units. The closure plan (DOE/RL-96-39) states that RCRA monitoring during and after closure activities will continue, according to the existing interim status monitoring plan (WHC-SD-EN-AP-038).

During fiscal year 2001, upgradient and downgradient wells were sampled twice for contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters (Table A.4 and Figure A.2). Upgradient/downgradient comparison values for indicator parameters have been revised based on recent data for use in fiscal year 2002 comparisons (Table A.5).

Of the dangerous waste constituents or byproduct discharged to this facility, only nitrate exceeded the maximum contaminant level, and the sources are unclear (see Section 2.4.5 of main text). The 1301-N facility has contaminated the groundwater with tritium and strontium-90, but radionuclides are not monitored as part of the RCRA program at these facilities. Table A.3 lists constituents that exceeded drinking water standards in fiscal year 2001.

The current well network adequately monitors the 1301-N Facility, and there are no plans to modify the network in fiscal year 2002.

A.1.2 1324-N/NA Facilities

The 1324-N surface impoundment and 1324-NA percolation pond are monitored in accordance with RCRA interim status indicator evaluation programs (40 CFR 265; WAC 173-303-400). The closure plan for these facilities were incorporated into a modification of the Hanford Site RCRA Permit in 1999 (Ecology 1994). Remedial actions will be integrated with the 100-NR-1 and 100-NR-2 Operable Units. The closure plan (DOE/RL-96-39) states that RCRA monitoring during and after closure activities will continue, according to the existing interim status monitoring plan (WHC-SD-EN-AP-038).

During fiscal year 2001, upgradient and downgradient wells were sampled twice for contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) and groundwater quality and site-specific parameters (see Table A.4 and Figure A.2). Upgradient/downgradient comparison values for indicator parameters were revised based on recent data, for use in fiscal year 2002 comparisons (Table A.6). Table A.3 lists constituents that exceeded drinking water standards in fiscal year 2001.

Average specific conductance values in wells 199-N-72 and 199-N-73 downgradient of the 1324-N/NA site continued to exceed the critical mean value in fiscal year 2001. A previous groundwater quality assessment indicated that the high specific conductance is caused by the non-hazardous constituents sulfate and sodium (WHC-SD-EN-EV-003). Because an assessment has already been completed and non-hazardous constituents caused the high conductance, no further action was needed. Well 199-N-59 contained too little water to sample in fiscal year 2001. Because the pond is small, the remaining two shallow downgradient wells adequately monitor the unit. When the river stage returns to a higher level, well 199-N-59 will be sampled again.

A.1.3 1325-N Liquid Waste Disposal Facility

The 1325-N liquid waste disposal facility is monitored in accordance with RCRA interim status indicator evaluation programs (40 CFR 265; WAC 173-303-400). The closure plan for this facility was incorporated into a modification of the Hanford Site RCRA Permit in 1999 (Ecology 1994). Remedial actions will be integrated with the 100-NR-1 and 100-NR-2 Operable Units. The closure plan (DOE/RL-96-39) states that RCRA monitoring during and after closure activities will continue, according to the existing interim status monitoring plan (WHC-SD-EN-AP-038).

During fiscal year 2001, upgradient and downgradient wells were sampled twice for contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters (see Table A.4 and Figure A.2). Upgradient/downgradient comparison values for indicator parameters were revised based on recent data for use in fiscal year 2002 (Table A.7).

Average specific conductance values in downgradient well 199-N-41 continued to exceed the critical mean value in March and September 2001. This was a continuation of a previous exceedance in 1999 and 2000. DOE notified the Washington State Department of Ecology (Ecology) of that previous exceedance and submitted an assessment report that concluded the exceedance was caused by past discharges of non-hazardous constituents to an upgradient facility.

None of the dangerous waste constituents or byproduct discharged to this facility exceeded the maximum contaminant level in fiscal year 2001. The 1325-N facilities has contaminated the groundwater with tritium and strontium-90, but radionuclides are not monitored as part of the RCRA program at these facilities. Table A.3 lists constituents that exceeded drinking water standards in fiscal year 2001.

The current well network adequately monitors the 1325-N Facility, and there are no plans to modify the networks in fiscal year 2002.

A.1.4 183-H Solar Evaporation Basins

This unit continued to be monitored under a final status corrective-action program during fiscal year 2001 (WAC 173-303-645). The unit was incorporated into the Hanford Site RCRA Permit (Ecology 1994) in 1998. Groundwater remediation is integrated with the 100-HR-3 Operable Unit, where remediation for chromium is underway. While the pump-and-treat system is operating, RCRA monitoring consists of annual sampling of four wells for chromium, fluoride, nitrate, technetium-99, and uranium (PNNL-11573; Table A.8 and Figure A.3). The objective of monitoring during the operation of the pump-and-treat system is to determine whether concentrations of the contaminants of concern are decreasing. The wells were sampled in November 2000. Two semiannual letter reports[a,b] that document the effectiveness of the corrective action program were submitted to Ecology during fiscal year 2001.

The current monitoring network was designed to accommodate groundwater flow imposed by the pump-and-treat system. The network remains adequate, and no changes are planned for fiscal year 2002.

(a) Letter Report 01-GWVZ-019 from J. G. Morse (U.S. Department of Energy, Richland, Washington) to J. Hedges (Washington State Department of Ecology, Olympia, Washington), *Resource Conservation and Recovery Act (RCRA) Final Status/Corrective Action Semiannual Reports*, dated May 4, 2001.

(b) Letter Report 02-GWVZ-003 from J. G. Morse (U.S. Department of Energy, Richland, Washington) to J. Hedges (Washington State Department of Ecology, Olympia, Washington), *Resource Conservation and Recovery Act (RCRA) Final Status/Corrective Action Semiannual Reports*, dated November 14, 2001.

A.1.5 216-A-29 Ditch

The 216-A-29 ditch continued to be monitored under an interim status indicator evaluation program in fiscal year 2001 (Table A.9 and Figure A.4). Indicator parameter data from downgradient wells were compared to values established from the upgradient wells. Average specific conductance values at downgradient well 299-E25-48 exceed the critical mean value and were linked to increases in sulfate, sodium, and calcium. The exceedances were reported previously and indicator evaluation monitoring will continue, because the elevated specific conductance is linked to non-hazardous constituents. Replicate averages for other contamination indicator parameters were below critical mean values or limits of quantitation during fiscal year 2001. Upgradient/downgradient comparison values for fiscal year 2002 comparisons are listed in Table A.10. The current network is adequate for detection monitoring.

A.1.6 216-B-3 Pond

In fiscal year 2001, groundwater monitoring at the 216-B-3 pond (B Pond) continued under an interim status indicator evaluation program. The current network includes eight downgradient wells and one upgradient well (Figure A.5). Samples are collected semiannually in these wells for the list of constituents shown in Table A.11. Water levels are measured semiannually to quarterly and at the time of sampling.

Statistical evaluations of indicator parameters in fiscal year 2001 indicated the site has not adversely affected groundwater quality. All replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during fiscal year 2001. Table A.12 lists upgradient/downgradient comparison values for use in fiscal year 2002.

In May 2001, Ecology issued a letter(c) providing guidance for groundwater monitoring at B Pond because the standard indicator-parameters evaluation and accompanying interim status statistical approach is inappropriate for detecting potential B-Pond-derived contaminants in groundwater. Ecology specified in this guidance letter that certain criteria must be met before they will approve a variance from applying interim status regulations. DOE submitted a proposal that included monitoring network, constituent list, statistical analysis, and reporting for the B Pond system to Ecology in November 2001. The specific elements of the proposal, as per the variance in Ecology's letter,(c) and in agreement with subsequent discussions with Ecology, are provided in Appendix C (see Section 7).

A.1.7 216-B-63 Trench

In fiscal year 2001, monitoring continued to provide no evidence that dangerous, non-radioactive constituents from the 216-B-63 trench have entered groundwater. The well network was sampled twice for the indicator parameters pH, specific conductance, total organic carbon, and total organic halides (Table A.13 and Figure A.6). All replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during fiscal year 2001. Upgradient/downgradient comparison values for statistical evaluations in fiscal year 2002 are listed in Table A.14. The network is adequate for detection monitoring.

A.1.8 216-S-10 Pond and Ditch

During fiscal year 2001, this facility continued to be monitored semiannually under a RCRA interim status indicator evaluation program (Table A.15 and Figure A.7). Statistical evaluation of indicator parameter data from downgradient wells indicates that the site is not contaminating groundwater. Upgradient/downgradient comparison values for fiscal year 2002 are listed in Table A.16. The direction of groundwater flow and estimated flow rate are listed in Table A.2.

Downgradient well 299-W26-12 went dry in fiscal year 2001. Currently, the 216-S-10 pond and ditch are monitored by one upgradient well and one shallow downgradient well because other network wells have gone dry. The groundwater monitoring network requires upgrading to satisfy RCRA interim status requirements. Also, at the current rate of water table decline in the 200 West Area, it is projected that upgradient well 299-W26-7 will go dry in 2002. Ecology and DOE annually negotiate installation of future monitoring wells under an Interim Milestone Agreement (M-24) (Ecology et al. 1998).

(c) Letter from D. Goswami (Washington State Department of Ecology, Olympia, Washington) to M. Furman (U.S. Department of Energy, Richland, Washington), *Statistical Assessment for the 300 Area Resource Conservation and Recovery Act of 1976 (RCRA) Ground Water Monitoring Plan*, dated May 7, 2001.

Sample results that exceeded drinking water standards and maximum contaminant levels are presented in Table A.3. Chromium, which was elevated above the 100 μg/L standard in upgradient well 299-W26-7 since 1992, has remained <30 μg/L since June 1999. Because the upgradient well is located adjacent to the 216-S-10 pond (see Figure A.7), it is unclear if the elevated chromium was from an upgradient source or from past discharges to the pond.

A.1.9 216-U-12 Crib

This RCRA unit continued to be monitored under an interim status groundwater quality assessment program in fiscal year 2001. Assessment monitoring began in 1993 because of high specific conductance in two downgradient wells (299-W22-41 and 299-W22-42) (WHC-SD-EN-AP-108). In fiscal year 2001, network monitoring wells were sampled quarterly for constituents of interest (Table A.17 and Figure A.8).

Based on the results of the assessment investigation (PNNL-11574), the site remains in interim status assessment monitoring because of continued elevated levels of nitrate and technetium-99. Sitewide surveillance monitoring evaluates the extent of these plumes. The objective of RCRA assessment monitoring, rather than delineating the existing plumes, is focused on (1) determining whether the flux of constituents into the groundwater is increasing, staying the same, or decreasing; (2) monitoring the known constituents until a near-term interim corrective action is defined; and (3) monitoring until a final status plan is implemented. The rate and direction of groundwater flow (see Table A.2) and the extent of contamination at this site are discussed in Section 2.8.

The crib will not receive additional effluents and is scheduled, according to provisions of the Hanford Site RCRA Permit (Ecology 1994), to be closed under RCRA final status regulations in 2005.

Currently, the 216-U-12 crib is monitored by only two downgradient wells (299-W22-79, and 699-36-70A). Declining water levels have rendered upgradient well 299-W22-43 dry (last sampled during January 2000); downgradient wells 299-W22-41 and 299-W22-42 went dry in 1999. The groundwater monitoring network needs to be upgraded for RCRA interim status monitoring. Ecology and DOE annually negotiate installation of future monitoring wells under an Interim Milestone Agreement (M-24) (Ecology et al. 1998).

Sample results that exceeded drinking water standards and maximum contaminant levels are presented in Table A.3. Specific conductance (the contaminant indicator for the crib) in downgradient well 299-W22-79 has been below the 457.8 μS/cm critical mean value since 1998 and nitrate, the primary constituent responsible for the elevated specific conductance, was below the 45-mg/L drinking water standard in fiscal year 2001. Both specific conductance and nitrate remain above the critical mean and drinking water standard, respectively, in far field well 699-36-70A.

A.1.10 316-5 Process Trenches

This site continued to be monitored with a final status corrective-action network (Table A.18; Figure A.9). The objective of groundwater monitoring during the corrective-action period is to monitor the trend of the constituents of concern in areas downgradient of the trenches to confirm that the concentrations are attenuating naturally, as expected by the CERCLA record of decision for the 300-FF-5 Operable Unit (ROD 1996a). A new groundwater monitoring plan (PNNL-13645) for corrective action replaced the existing plan (WHC-SD-EN-AP-185) early in fiscal year 2002. The two upgradient wells were eliminated and five other wells were added to the network downgradient of the trenches. These well network changes were made to better accommodate the objective during the corrective-action period. The requirement to collect four time-independent samples from each well during each sampling event was dropped. The new plan requires only one sample per well for each sampling event. Results will be analyzed using the Combined Shewhart-CUSUM Control chart statistical approach (Westgard et al. 1977; Lucas 1982). Also, each well showing an exceedance of maximum contaminant levels by one of the constituents of concern will be sampled quarterly to better follow the trends of contaminant concentration. The other wells in the network will continue to be sampled semiannually. Two semiannual letter reports(d,e) that document the effectiveness of the corrective action program were submitted to Ecology during fiscal year 2001.

(d) Letter Report 01-GWVZ-019 from J. G. Morse (U.S. Department of Energy, Richland, Washington) to J. Hedges (Washington State Department of Ecology, Olympia, Washington) *Resource Conservation and Recovery Act (RCRA) Final Status/Corrective Action Semiannual Reports*, dated May 4, 2001.

(e) Letter Report 02-GWVZ-003 from J. G. Morse (U.S. Department of Energy, Richland, Washington) to J. Hedges (Washington State Department of Ecology, Olympia, Washington) *Resource Conservation and Recovery Act (RCRA) Final Status/Corrective Action Semiannual Reports*, dated November 14, 2001.

Uranium and cis-1,2-dichloroethene continued to exceed concentration limits specified in the permit, and uranium and gross alpha exceeded maximum contaminant levels in one or more wells monitoring near the water table (see Table A.3). In one downgradient well that monitors the base of the unconfined aquifer, cis-1,2-dichloroethene exceeded the maximum contaminant level.

A.1.11 Liquid Effluent Retention Facility

During fiscal year 2001, the Liquid Effluent Retention Facility was monitored by one upgradient and one downgradient well (Table A.19 and Figure A.10) because the other two downgradient wells failed to produce representative groundwater. Negotiations continue between Ecology, DOE, and contractors in an effort to formulate a final status monitoring strategy for the Liquid Effluent Retention Facility. In January 2001, Ecology directed DOE to cease statistical evaluation of groundwater data at the facility.

A.1.12 Low-Level Waste Management Area 1

Groundwater monitoring under interim status requirements continued at this site in fiscal year 2001. The well network was sampled twice for indicator and site-specific parameters (Table A.20 and Figure A.11). Downgradient monitoring well 299-E33-34 continued to exceed the critical mean for specific conductance during fiscal year 2001. This exceedance is related to the nitrate plume and not Low-Level Waste Management Area 1. DOE submitted a letter of notification to Ecology in 1999. Monitoring well 299-E32-10 also exceeded the critical mean for specific conductance in fiscal year 2001. This was not unexpected because this well is close to well 299-E33-34, where the other exceedance occurred. Because no waste has been placed in the northern portion of this site and there is a known nitrate plume from an upgradient source, no further action is necessary. Upgradient/downgradient comparison values for fiscal year 2002 statistical evaluations are listed in Table A.21. Results exceeding drinking water standards are listed in Table A.3.

The groundwater monitoring network for Low-Level Waste Management Area 1 is adequate for the RCRA requirements. No new wells are planned for this area.

A.1.13 Low-Level Waste Management Area 2

This site continued in RCRA interim status indicator evaluation in fiscal year 2001. Wells were sampled twice for indicator and site-specific parameters (Table A.22 and see Figure A.6). Upgradient well 299-E34-7 continued to exceed the critical mean for specific conductance in fiscal year 2001. The major contributors to the increase are sulfate and calcium. The source of these constituents is not known. However, there is only 0.5 meter of water remaining in this well, which is completed at the top of basalt, so the increase may be related to the basalt chemistry. This well also exceeded the comparison value for total organic carbon and total organic halides in fiscal year 2001. Samples analyzed for volatile and semi-volatile organic compounds did not reveal a likely contaminant. Samples collected in April 2001 were analyzed for oil and grease and total petroleum hydrocarbons (diesel). These results were also inconclusive (1.4 mg/L oil and grease, 0.09 mg/L total petroleum hydrocarbons, diesel range). Additional analyses will be required to identify the source of these elevated results. Table A.23 lists the upgradient/downgradient comparison values for fiscal year 2002 statistical evaluations. Table A.3 summarizes constituents exceeding drinking water standards.

The monitoring network for Low-Level Waste Management Area 2 is adequate to detect releases from the facility. However, the continued water-level decline may cause additional wells to go dry. Monitoring wells in this area are all completed at the top of basalt and if more wells become dry, alternatives to groundwater monitoring may be required to detect contamination from this facility.

A.1.14 Low-Level Waste Management Area 3

This RCRA site continued to be monitored under interim status indicator evaluation requirements. Groundwater monitoring wells were sampled twice in fiscal year 2001 (Table A.24 and Figure A.12). Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. Samples from upgradient well 299-W10-13 in October 2000 exceeded the critical mean value for specific conductance. Results from March and September 2001 were below the critical mean value and there is a slight downward trend. Other contamination indicator parameters did not exceed comparison values in any wells monitoring this waste management area. There was an elevated total organic carbon value of 6,500 μg/L in October 2000 from the upgradient deep well 299-W10-14. The average for the other three measurements was 317 μg/L and the high result is considered to be erroneous. Tables A.25 and A.26 list upgradient/downgradient comparison values for fiscal year 2002 statistical evaluations. Contaminant concentrations that exceeded drinking water standards are listed in Table A.3.

Because of the changing flow direction and the continuing decline in water levels, this network only marginally monitors this waste management area. Five wells (299-W6-2, 299-7-6, 299-W7-9, 299-W7-10, and 299-W9-1) have gone dry. Several other groundwater monitoring wells (notably 299-W7-8 and 299-W10-13) are approaching the point where representative sampling will no longer be possible because of the declining water table. No additional wells were installed in calendar year 2001.

A.1.15 Low-Level Waste Management Area 4

Wells were sampled semiannually for contamination indicator parameters in accordance with RCRA interim status regulations (Table A.27 and Figure A.13). Downgradient well 299-15-16 continued to exceed the critical mean value for total organic halides in fiscal year 2001. This well was at one time an upgradient monitoring well and is still affected by contamination from other sources. DOE reported the exceedance to the U.S. Environmental Protection Agency (EPA) and Ecology in 1999. Upgradient/downgradient comparison values for fiscal year 2002 statistical evaluations are listed in Table A.28. Contaminant concentrations that exceeded drinking water standards are listed in Table A.3.

This monitoring network requires upgrading to satisfy RCRA requirements (three upgradient wells and two downgradient wells). Downgradient well 299-W15-18 can no longer be sampled, and there have been some sampling problems at well 299-W18-24 related to low water level. Ecology and DOE annually negotiate installation of future monitoring wells under an Interim Milestone Agreement (M-24) (Ecology et al. 1998).

A.1.16 Nonradioactive Dangerous Waste Landfill

This RCRA site continued to be monitored under an interim status indicator evaluation program in fiscal year 2001 (Table A.29 and Figure A.14). Statistical evaluations indicate the site has not adversely affected groundwater quality. However, average values of specific conductance in downgradient wells 699-25-34A and 699-25-34B have been increasing in recent years and exceeded the critical mean value in fiscal year 2001. DOE notified Ecology of the exceedance. The rise in specific conductance is most likely due to waste discharges at the adjacent Solid Waste Landfill and are not due to the Nonradioactive Dangerous Waste Landfill affecting groundwater quality. Therefore, no further action was taken. Specific conductance (and the other indicator parameters) will continue to be monitored at the Nonradioactive Dangerous Waste Landfill, as well as at the Solid Waste Landfill, to determine if the Nonradioactive Dangerous Waste Landfill is affecting groundwater quality. Table A.30 lists upgradient/downgradient comparison values based on recent data, for use in fiscal year 2002.

A.1.17 PUREX Cribs

The 216-A-10, 216-A-36B, and 216-A-37-1 cribs continue to be monitored under a RCRA interim status assessment program in fiscal year 2001 (Table A.31 and see Figure A.4). The sites are monitored as a single waste management area because they have similar hydrogeology and waste constituents. The groundwater monitoring plan (PNNL-11523) was changed from an indicator parameter evaluation program to a groundwater quality assessment program in 1997 because of evidence of contamination. Combining these cribs into one RCRA groundwater monitoring area saves sampling and analysis costs because the number of near field wells was reduced.

Since fiscal year 2000, two wells (299-E17-9 near the 216-A-36B crib, and 299-E25-17 near the 216-A-37-1 crib) have been difficult to sample because of their age and low water levels. Wells 299-E17-16 and 299-E25-18 will replace the original wells when they can no longer be sampled.

Many of the far-field wells that formerly were sampled annually are now sampled every three years. These wells track the extent and flow rate of the extensive iodine-129, nitrate, and tritium plumes that change very little in a 3-year period. This change was incorporated in two updates of the groundwater monitoring plan along with corrections to outdated procedural references (PNNL-11523).

The rate and extent of contamination are discussed in Section 2.9.2 of the main text. Knowledge of the groundwater flow direction and flow rate in the southeastern portion of the 200 East Area did not change significantly during fiscal year 2001 (see Table A.2). Therefore, the combined near-field and far-field monitoring well networks are generally adequate to continue to monitor both the extent and rate of flow of the contaminant plumes emanating from the PUREX cribs.

During fiscal year 2001, iodine-129, gross beta, manganese, nitrate, strontium-90, and tritium continued to exceed drinking water standards or maximum contaminant levels in areas downgradient of the PUREX cribs (see Table A.3). Tritium exceeded the DOE derived concentration guide of 2,000,000 pCi/L at well 299-E17-9 near the 216-A-36B crib. Strontium-90, a beta emitter, and gross beta exceeded the drinking water standards only in well 299-E17-14, which is also near the 216-A-36B crib. Manganese was elevated in previous years in wells downgradient of the 216-A-37-1 crib, but subsequently has decreased to levels below the maximum contaminant level (50 μg/L) there. However, the concentration of manganese at well 299-E17-9 (near 216-A-36B) increased to a maximum of 191 μg/L in October 2000. Iodine-129, nitrate, and tritium are major plumes that extend beyond the near-field monitoring well network at the PUREX cribs. The far-field monitoring network monitors these more extensive plumes.

A.1.18 Single-Shell Tanks Waste Management Area A-AX

This site continued to be monitored under an interim status indicator evaluation program in fiscal year 2001. Wells were sampled twice for indicator and site-specific parameters (Table A.32 and Figure A.15). Indicator parameter data from upgradient wells were statistically evaluated. Values from downgradient wells were compared to those established from the upgradient wells. The indicator parameters (specific conductance, total organic carbon, pH, and total organic halides) did not exceed upgradient/downgradient comparison values during fiscal year 2001. Table A.33 lists updated upgradient/downgradient comparison values for statistical evaluations in fiscal year 2002, and Table A.3 summarizes results exceeding drinking water standards in fiscal year 2001.

Table A.2 includes the general direction and estimated rate of groundwater flow. A flow direction to the southeast has been established for this site using flow measurements and water elevations taken in the well. Consequently, the network is currently being redesigned. The saturated screen interval ranges from 2 to 4 meters thick in RCRA network wells while the aquifer thickness is ~27.4 meters. The rate of water-table decline was 14 centimeters in 2001. If this rate continues, the RCRA compliant wells at Waste Management Area A-AX will remain usable after the water table returns to a stable elevation.

A.1.19 Single-Shell Tanks Waste Management Area B-BX-BY

RCRA assessment monitoring continued at this waste management area in fiscal year 2001. Exceedances of the critical mean value for specific conductance in February 1996 at well 299-E33-32 initiated assessment monitoring. An assessment monitoring plan (WHC-SD-ENV-AP-002) was issued in September 1996, followed by a groundwater investigation. In a report released in February 1997 (PNNL-11826), it was concluded that waste associated with past operational leaks from this waste management area had reached the groundwater. An updated assessment plan (PNNL-13022) was issued in 2000 that provided guidance for further determination of sources associated with groundwater contamination under the site. This latest plan also guides investigation of the rate of movement and extent of groundwater contamination at this site (see Section 2.9 and Table A.2). Assessment wells were sampled quarterly, and in some cases, semiannually, in fiscal year 2001.

For fiscal year 2001, nitrate, uranium, cyanide, technetium-99 and iodine-129 exceeded maximum contaminant levels or drinking water standards in RCRA compliant wells, with corresponding exceedances of gross beta and gross alpha standards (see Table A.3). Section 2.9.1 discusses contaminant trends.

Originally, the RCRA groundwater monitoring network was designed for groundwater flow toward the northwest, based on regional plume maps. This method was used to determine flow direction because the water table is almost flat in the immediate area of the farms. Assessment studies have determined a southerly flow direction across the site (see Table A.2 and Section 2.9.1 of the main text). Three new wells, 299-E33-337, 299-E33-338, and 299-E33-339, were installed in fiscal year 2001 on the southeast corner of BX tank farm and along the south side of B tank farm to support basic monitoring needs. These wells are scheduled for quarterly monitoring beginning November 2001. Contaminant migration and results from colloidal borescope investigations indicate a southeast flow direction at the southern boundary of the waste management area. Even with these three new wells, additional well coverage may be required (see Section 2.9.1).

In fiscal year 2001, the monitoring network included far-field wells (Table A.34 and Figure A.16). Some of these wells are RCRA compliant, while others are older wells installed to monitor past-practice waste disposal sites. Although water levels are declining through this area, the aquifer still ranges from 2 to 3 meters thick in RCRA-compliant wells. Most of these wells can be used for at least 5 years. The new wells along the southern boundary should be usable after the water table declines to a stable elevation.

A.1.20 Single-Shell Tanks Waste Management Area C

This site continued to be monitored under an interim status indicator evaluation program in fiscal year 2001. Wells were sampled quarterly at the request of Ecology due to rising trends in sulfate, nitrate, and technetium-99 in upgradient and downgradient wells. In addition, the required detection sampling was conducted twice for indicator and site-specific parameters (Table A.35 and Figure A.17).

A general flow direction to the southwest has been established for this site using flow measurements and water elevations taken in the well and corrected for borehole deviations from vertical. Although a revised network is currently being designed, during fiscal year 2001, the site was monitored with the original configuration of wells. Indicator parameter data from upgradient wells were statistically evaluated. Values from downgradient wells were compared to those established from one upgradient well 299-E33-14. The indicator parameters (specific conductance, pH, total organic carbon, and total organic halides) did not exceed the upgradient/downgradient comparison values in downgradient wells during fiscal year 2001. However, conductivity did exceed the critical mean of 553.5 µS/cm in September 2001 in well 299-E33-14 (upgradient) with a value of 614 µS/cm. This exceedance was caused primarily by rising calcium and sulfate, though nitrate also contributed. A further discussion of these chemical trends is included in Section 2.9.2. Table A.36 lists upgradient/downgradient comparison values based on recent data from upgradient wells 299-E27-7 and 299-E27-14, for use in fiscal year 2002. Background values will be re-established after the monitoring network is redesigned based on recent flow interpretations. Table A.3 summarizes results exceeding drinking water standards in fiscal year 2001.

A.1.21 Single-Shell Tanks Waste Management Area S-SX

This site continued to be monitored under an interim status assessment program during fiscal year 2001. DOE initiated the assessment program in response to a directive from Ecology in 1996. The directive cited anomalous trends in technetium-99 and high specific conductance as primary reasons for the assessment. An assessment plan was submitted in August 1996 (WHC-SD-EN-AP-191). A report on the results of the assessment (PNNL-11810) concluded that this waste management area contributed to groundwater contamination. Accordingly, investigation of the rate and extent of the contamination is required. For this purpose, an updated assessment plan (PNNL-12114) was prepared in 1999. Findings for the period November 1997 through June 2000 are documented in PNNL-13441.

Monitoring wells sampled during the report period and constituents analyzed are listed in Table A.37. Three new wells were installed in 1999, six in 2000, and two in 2001 to improve spatial coverage and to replace wells going dry. Technetium-99, nitrate, and chromium, mobile tank farm contaminants with the highest concentrations occur in downgradient wells (299-W23-19, 299-W22-45, 299-W22-46, 299-W22-48, 299-W22-50, and 299-W22-81; Figure A.18) at the SX tank farm. The highest concentrations in the network occur in well 299-W23-19 located adjacent to tank SX-115 in the southwest corner of the SX tank farm. This area appears to be the source of the downgradient occurrences of elevated technetium-99 and nitrate in wells 299-W22-46 and 299-W22-50. The moderately elevated carbon tetrachloride in well 299-W23-15, as well as the lower concentrations in other network wells, are attributed to past-practice upgradient sources (e.g., Plutonium Finishing Plant cribs, ditches and trenches). The nearby upgradient crib, 216-S-25, was a major source of tritium and nitrate that passes beneath the southern end of this waste management area. In addition, rapidly increasing concentrations of technetium-99 and associated mobile tank waste contaminants were observed in well 299-W22-48.

The rate and direction of groundwater flow (see Table A.2) and the extent of contamination at Waste Management Area S-SX are discussed further in Section 2.8 of the main text, and in the updated assessment report for this waste management area (PNNL-13441).

A.1.22 Single-Shell Tanks Waste Management Area T

This site continued to be monitored under an interim status assessment program during fiscal year 2001 (Table A.38 and Figure A.19). Waste Management Areas T and TX-TY began assessment monitoring in 1993 because of high specific conductance in downgradient wells (WHC-SD-EN-AP-132). Assessment findings (PNNL-11809) indicated that contaminants in well 299-W10-15 are a result of sources outside the waste management area. There is strong evidence, however, that contaminants detected in well 299-W11-27, which include chromium, cobalt-60, nitrate, technetium-99, and tritium, are a result of sources within the waste management area; therefore, assessment work has continued. The plume detected in well 299-W11-27 reached well 299-W11-23 in 1998. Well 299-W11-23 is located to the east of 299-W11-27 and apparently, the plume reached this well as a result of changed groundwater flow direction at Waste Management Area T. Well 299-W11-23 is now dry and the plume is being detected in well 299-W11-39, its replacement.

The rate of groundwater flow (see Table A.2) and the extent of contamination at this site are discussed in Section 2.8. One new well, upgradient to the waste management area, was drilled during fiscal year 2001 to improve network coverage.

A.1.23 Single-Shell Tanks Waste Management Area TX-TY

This unit continued to be monitored under an interim status assessment program during fiscal year 2001 (Table A.39 and see Figure A.19). Waste Management Area TX-TY began assessment monitoring in 1993 because of high specific conductance in wells 299-W10-17 and 299-W14-12 (WHC-SD-EN-AP-132). The exceedance in well 299-W14-12 was accompanied by elevated chromium, cobalt-60, iodine-129, technetium-99, and tritium. Assessment results (PNNL-11809) indicated that contaminants in well 299-W10-17 are a result of sources outside the waste management area. Assessment results for well 299-W14-12 indicate that the contamination is consistent with a source within the waste management area. The plume detected in 299-W14-12 is still present in replacement well 299-W14-13. Because there was no evidence for an upgradient source, assessment continues at the site. Sampling results from upgradient well 299-W15-40 eliminated the 216-T-25 trench as a potential source of contamination. Subsequently, a tritium/iodine-129 plume was detected in downgradient well 299-W14-2. This plume, probably originating from the 242-T evaporator, has also been detected in well 299-W14-13.

The rate of groundwater flow (see Table A.2) and the extent of contamination at this site is discussed in Section 2.8. Two new wells were drilled during fiscal year 2001 to improve network coverage.

A.1.24 Single-Shell Tanks Waste Management Area U

This unit was monitored under an interim status groundwater quality assessment program in fiscal year 2001 (Table A.40 and see Figure A.18). The average specific conductance value in downgradient well 299-W19-41 exceeded the critical mean in August 1999, triggering assessment monitoring. DOE transmitted an assessment monitoring plan to Ecology in March 2000 (PNNL-13185). Results of initial assessment studies were published in July 2000 (PNNL-13282). The report concluded that there is evidence that both upgradient sources and sources within the waste management area contributed to the elevated nitrate observed in monitoring wells. Technetium-99 is believed to originate within the southern portion of the waste management area. Thus, assessment monitoring will continue in accordance with the revised plan (PNNL-13612).

The rate of groundwater flow (see Table A.2) and the extent of contamination at this site are discussed in Section 2.8. Three new wells were drilled during fiscal year 2001 to replace an upgradient well that went dry and to improve downgradient coverage.

A.2 Other Treatment/Storage/Disposal Sites

This section describes monitoring results for six facilities used for treatment, storage, or disposal of waste and regulated under regulations other than RCRA.

A.2.1 100 KW and KE Fuel Storage Basins

Groundwater monitoring in fiscal year 2001 revealed no evidence of current leakage from either of these basins. The monitoring network includes 12 wells, as listed in Table A.41. New information was obtained to describe the dispersion of past leakage from the KE Basin, thus improving the conceptual model used to predict where potential future plumes from shielding water loss might travel. DOE monitors groundwater around these facilities to comply with requirements for nuclear fuel and waste storage facilities (DOE Order 5400.1 [IV]9b). The Hanford Site environmental monitoring plan (DOE/RL-91-50) describes the regulatory basis for monitoring these facilities. The implementation of these monitoring and reporting requirements is contained in a groundwater monitoring and assessment plan (WHC-SD-EN-AP-174).

A.2.2 200 Areas Treated Effluent Disposal Facility

A state waste discharge permit (WAC 173-216) governs groundwater sampling and analysis in the three monitoring wells at this facility (Table A.42 and see Figure A.5). The constituent list and frequency of sampling are specified in the permit. A groundwater monitoring plan (PNNL-13032) describes details of the monitoring program. Wells were sampled quarterly during fiscal year 2001.

No permit criteria for constituents in groundwater were exceeded in fiscal year 2001. The groundwater monitoring network demonstrates that effluent from the facility is not taking a direct route to the uppermost aquifer and differentiates the effects of the Treated Effluent Disposal Facility from those of B Pond. The well configuration is currently adequate for this purpose.

A.2.3 4608 B/C Process Ponds and 400 Area Water Supply Wells

The 4608 B/C ponds (also called the 400 Area process ponds), are regulated under WAC 173-216. The permit, issued on August 1, 1996, and modified on February 10, 1998, defines groundwater enforcement limits (Table A.43 and Figure A.20). Groundwater quality met permit conditions in fiscal year 2001.

The water supply in the 400 Area, which comes from wells, is also monitored to maintain compliance with drinking water standards. Tritium was detected at levels above the 20,000-pCi/L standard in the backup water supply wells for this area. Because the backup water supply wells are seldom used, the monthly water supply sampling indicates that tritium in the drinking water is maintained at a level below the 4 mrem/yr dose equivalent standard.

A.2.4 Environmental Restoration Disposal Facility

This facility is a landfill authorized by CERCLA that is designed to meet RCRA requirements of Subpart N, 40 CFR 264. The groundwater monitoring network consists of one upgradient and three downgradient wells that are sampled semiannually (Table A.44). In addition, the facility has a system to collect and remove leachate that helps evaluate whether the liner system is performing within design standards. The sampling plan for groundwater monitoring is documented in BHI-00873, and results for calendar years 1996 through 1999 are published in BHI-01382. Monitoring wells for this facility were sampled in March and September 2001.

A.2.5 Solid Waste Landfill

State dangerous waste regulations (WAC 173-304) govern groundwater monitoring at this landfill. The final closure plan for the site has been implemented. Wells are sampled quarterly for constituents specified in WAC 173-304 plus the site-specific constituents chlorinated hydrocarbons (Table A.45 and see Figure A.14). The groundwater monitoring plan was revised in October 2000 (PNNL-13014). Changes over the previous plan include the elimination of tritium, gross alpha, gross beta, and total organic halides from the list of constituents of concern and some minor changes in the statistical analysis.

Statistical evaluations of the constituents specified in WAC 173-304 for landfills (Tables A.46 and A.47) revealed that five exceeded their background threshold levels (or range for pH) during fiscal year 2001:

1. Specific conductance exceeded its 583 µS/cm threshold level in all eight of the downgradient wells in the monitoring network.
2. Sulfate exceeded its 47.2 mg/L threshold level in three of the eight downgradient wells.
3. Reported results for pH were lower than the background threshold range (6.68 to 7.84) in four downgradient monitoring wells.
4. Chloride exceeded its 7,820 µg/L background threshold level in one downgradient well.
5. The total organic carbon background threshold level (1,168 µg/L) was exceeded in two downgradient wells during one sampling period (May 2001). These results were isolated and results later from these wells returned to historical trends (i.e., below 300 µg/L). Therefore, these exceedances are probably sampling or analytical errors.

Tritium exceeded its drinking water standard at many of the monitoring wells on the eastern side of the landfill, but the source is upgradient. Two chlorinated hydrocarbons exceeded WAC 173-200 groundwater quality criteria in at least one well of the monitoring network. They are as follows, with the number of wells having exceedances and the Washington Administrative Code limit:

- 1,1-dichloroethane (3) (1.0 μg/L)
- tetrachloroethene (9) (0.8 μg/L).

The monitoring network for the Solid Waste Landfill has two upgradient wells and eight downgradient wells and is adequate for meeting the requirements of WAC 173-304.

A.2.6 State-Approved Land Disposal Site

A state waste discharge permit (WAC 173-216) requires groundwater monitoring at this site. The permit was granted in June 1995, and the site began to operate in December 1995. Groundwater monitoring for tritium only is conducted in 19 wells near the facility (Table A.48 and Figure A.21). The permit stipulates requirements for groundwater monitoring and establishes enforcement limits for concentrations of 15 constituents and tritium in 3 additional wells immediately surrounding the facility (see Table A.48).

During fiscal year 2001, tritium concentrations in proximal well 699-48-77A increased (maximum 670,000 pCi/L) as a result of the resumption of tritium disposal in September 2000, which followed a 16-month hiatus in significant tritium discharges. Well 699-48-77C, where tritium results reached a maximum value of 980,000 pCi/L, is reflecting the result of the delayed penetration of effluent deeper into the aquifer from 1999 tritium discharges. Speculation in fiscal year 2000 (PNNL-13329) that tritium may have reached two wells due south of the facility is probably premature. Fiscal year 2001 results indicate no departures from historical levels of tritium in these wells.

No permit enforcement limits were exceeded during fiscal year 2001. Evaluation of the well network indicates that well coverage is currently adequate to satisfy groundwater monitoring requirements.

A.3 CERCLA Groundwater Operable Units

The groundwater and vadose zone beneath contaminated portions of the Hanford Site are divided into 11 groundwater operable units, discussed in alphanumeric order below.

A.3.1 100-BC-5

This operable unit underlies the 100 B/C Area. There is no active groundwater remediation, and monitoring has the same objectives as for the *Atomic Energy Act of 1954*. Sampling schedules and analyte selection are coordinated to meet the requirements of both regulations. The CERCLA well network and constituent list are documented in Federal Facility Agreement and Consent Order (Ecology et al. 1998) Change Control Form No. M-15-99-03, dated July 14, 1999 and in PNNL-13326. Wells are sampled biannually or annually.

A.3.2 100-FR-3

This operable unit underlies the 100 F Area. There is no active groundwater remediation, and monitoring has the same objectives as for the *Atomic Energy Act of 1954*. The CERCLA monitoring network and constituent list are documented in Federal Facility Agreement and Consent Order (Ecology et al. 1998) Change Control Form No. M-15-99-02, dated July 14, 1999 and in PNNL-13327. The Hanford Groundwater Monitoring Project coordinates sampling schedules and analyte selection to meet the requirements of both regulations. Wells are sampled biannually to quarterly.

A.3.3 100-HR-3

This large operable unit encompasses the groundwater and vadose zone beneath the 100 D and 100 H Areas and the horn of the Hanford Site. There are two interim actions for groundwater remediation in the 100-HR-3 Operable Unit: a pump-and-treat system for chromium in the northern 100 D Area and the 100 H Area and an in situ chromium treatment system in the southwestern 100 D Area.

The extraction well network in the northern region of the 100 D Area and in the 100 H Area continued to operate through fiscal year 2001. The purpose for the interim remedial action is to decrease the amount of hexavalent chromium that is entering the Columbia River via groundwater. The key documents that pertain to this interim action are the record of decision (ROD 1996b) and the performance monitoring plan (DOE/RL-96-84).

The specific objectives of the pump-and-treat system are to

- 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 leading to a final remedy.

The performance evaluation and annual summary report (DOE/RL-2001-04) indicated that the pump-and-treat systems reduces contaminant flux to the Columbia River by creating hydraulic barriers. The extraction wells capture and remove contaminants from the groundwater passing under the waste sites that otherwise would enter the Columbia River. Institutional controls prevent access to groundwater, thereby protecting human health. Data on water levels, contaminants, system treatment cost and efficiency, and geology are collected to support the project and to provide a decision basis for the future final remedy. The pump-and-treat systems are discussed in more detail in Sections 2.5 and 2.6 of the main text.

EPA, Ecology, and DOE signed an amended record of decision for the 100-HR-3 Operable Unit in October 1999 (ROD 1999). The amendment adds a requirement for implementing in situ redox manipulation to remediate the chromium plume in the southwestern 100 D Area. The goal of this treatment system is to reduce concentrations of hexavalent chromium to 20 μg/L or less in compliance wells. A design report/work plan defines groundwater monitoring requirements (DOE/RL-99-51). The system made progress toward remedial action objectives in fiscal year 2001. Additional wells were installed for injection/withdrawal and compliance monitoring, and a series of injections/withdrawals was conducted (see Section 2.5 in the main text).

Groundwater monitoring in other 100-HR-3 wells also continued during fiscal year 2001. The list of wells to be sampled and the analyses to be performed were agreed on and are described in National Priorities List Agreement/Change Control Form No. 107, dated November 20, 1996. Most wells are sampled annually, and the samples are analyzed for anions, metals, and radiological indicators. During fall 2000, aquifer sampling tubes and riverbank seepage were sampled. DOE/RL-96-90 and DOE/RL-96-84 describe additional monitoring that is required as part of the interim action.

A.3.4 100-KR-4

This operable unit underlies the 100 K Area. The environmental restoration contractor continued to operate a pump-and-treat system during fiscal year 2001 to treat chromium contamination in 100 K Area groundwater (DOE/RL-2001-04). The system is an interim remedial action stipulated by a 1996 record of decision (ROD 1996b) and is aimed primarily at protecting ecological health in the adjacent river environment.

The objectives of the pump-and-treat system are to

- protect aquatic receptors in the Columbia River bottom substrate from contaminants in groundwater entering the Columbia River
- protect human health by preventing exposure to contaminants in the groundwater
- provide information leading to a final remedy.

The most recent performance evaluation and annual summary report (DOE/RL-2001-04) indicates that the pump-and-treat system reduces contaminant flux to the Columbia River by extracting groundwater from the region between the 100-K trench (waste site 116-K-2) and the river. The extraction wells capture contaminants moving with groundwater, thus reducing the mass of chromium that otherwise would enter the Columbia River. Data on water-levels, contaminants, system treatment cost and efficiency, and geology provide the basis for a future final remedy decision. DOE/RL-96-90 and DOE/RL-96-84 describe the operational and environmental monitoring required as part of the interim action.

CERCLA long-term monitoring of groundwater contamination also continued during fiscal year 2001. Institutional controls are in place to prevent human access to groundwater beneath the 100 K Area, thereby protecting human health. The groundwater monitoring schedule consists predominantly of annual sampling of wells, with analyses for anions, metals, and radiological indicators (BHI-00916). The list of wells, frequency of sampling, and analyses to be performed are described in National Priorities List Agreement/Change Control Form No. 108, dated November 20, 1996.

A.3.5 100-NR-2

This operable unit underlies the 100 N Area. A pump-and-treat system for strontium-90 continued to operate in fiscal year 2001. The environmental restoration contractor operates the system in response to an action memorandum[f] and a record of decision signed in September 1999 (Ecology 1999).

The goals of this pump-and-treat system are to

- reduce strontium-90 contamination flux from the groundwater to the Columbia River
- evaluate commercially available treatment options for strontium-90
- provide data necessary to set demonstrable strontium-90 groundwater cleanup standards.

The system continued to meet these goals in fiscal year 2001 (see Section 2.4 of the main text). The pump-and-treat operation is successfully intercepting and capturing groundwater containing elevated concentrations of strontium-90, and reduces the amount of contamination discharging into the Columbia River (DOE/RL-2001-04). The pump-and-treat program collects hydraulic monitoring data, contaminant monitoring data, and treatment system operation data to assess treatment system performance and to provide the basis for selecting the final remedy.

National Priorities List Agreement/Change Control Form No. 113, dated March 25, 1997, specifies performance monitoring requirements for the N Springs pump-and-treat system. The basic requirement is to sample the process influent and effluent streams monthly for strontium-90 analysis and to place the analytical results in a database to which the regulator has access. An update to the original monitoring plan (BHI-00164) identifies and summarizes all current groundwater monitoring being conducted in the 100 N Area (BHI-01165).

The remedial investigation for the 100-NR-2 Operable Unit also collected groundwater data in fiscal year 2001. Monitoring results, along with information gained by operating the pump-and-treat system, will be used to support selection of a final remediation alternative for the operable unit. Federal Facility Agreement and Consent Order (Ecology et al. 1998) Change Control Form No. M-15-96-08, signed on October 9, 1996, lists the wells and analyses to be performed to satisfy groundwater monitoring requirements for the 100-NR-2 Operable Unit (CERCLA) and the 1301-N, 1325-N, and 1324-N/NA facilities (RCRA).

The Sitewide Environmental Surveillance Project collects riverbank seepage annually. Authority for this activity comes from DOE orders for environmental monitoring. The results are presented in an annual report (e.g., Section 4.2 in PNNL-13487). The Near-Facility Environmental Monitoring Program, which is also mandated primarily by DOE orders, conducts additional groundwater and surface water monitoring. Samples are collected from 13 near-river well casings, which have been driven into the shoreline gravels, and also from a near-river monitoring well. The monitoring supports activities for waste management and environmental restoration and helps determine the effectiveness of effluent treatment and control practices. Results are presented annually (e.g., Appendix 2 of PNNL-13487).

A.3.6 200-BP-5

This CERCLA groundwater operable unit, which encompasses the northern portion of 200 East Area in the vicinity of B Plant, has the same monitoring objectives as monitoring for the *Atomic Energy Act of 1954* (surveillance). Wells and constituents are documented in DOE/RL-2001-49, which is pending regulator approval. The operable unit includes the past-practice sites 216-B-5 injection well, BY cribs, and Gable Mountain Pond. CERCLA groundwater sampling is currently suspended in 200-BP-5 until waste management documentation is completed and approved. See Section 2.9.1 in the main text for additional discussion.

(f) Letter from D. Butler (Washington State Department of Ecology, Olympia, Washington) and R. F. Smith (U.S. Environmental Protection Agency) to R. Izatt (U.S. Department of Energy, Richland Operations Office, Richland, Washington) *Action Memorandum: N-Springs Expedited Response Action Cleanup Plan, U.S. Department of Energy, Hanford Site, Richland, Washington*, dated September 23, 1994.

A.3.7 200-PO-1

This groundwater operable unit, which encompasses the area of the tritium plume southeast of the 200 East Area, has the same monitoring objectives as monitoring for the *Atomic Energy Act of 1954* (surveillance) and RCRA (PUREX cribs assessment). See Section 2.9.1 in the main text for additional discussion.

A.3.8 200-UP-1

During fiscal year 2001, the environmental restoration contractor continued to operate a pump-and-treat system in this operable unit, which underlies the southeastern 200 West Area (Figure A.22).

The interim action objectives (ROD 1997) include the following:

- reduce contamination in the areas of highest concentration of technetium-99 and uranium to below 10 times (480 μg/L) the cleanup level under the *Model Toxics Control Act* (WAC 173-340) for uranium, and 10 times (9,000 pCi/L) the drinking water standard 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 the development and implementation of a final remedy that will be protective of human health and the environment.

Results of the interim action are summarized annually (DOE/RL-2000-71). As of September 2001, the high concentration portions of the technetium-99 and uranium plumes were hydraulically contained. However, they were not remediated to the levels required by the interim action objectives (ROD 1997). The remedial action made progress in reducing the size and concentration of the technetium plume, particularly near extraction well 299-W19-39 where concentrations are less than the remediation objective of 9,000 pCi/L. Near the former injection well, 299-W19-36, technetium-99 concentrations have actually increased to over 25,000 pCi/L. Less progress has been made in remediating the uranium plume because of its tendency to sorb to the soil. The slower response to remediation may also indicate that more uranium is present in the aquifer than originally estimated. Section 2.8.3 of the main text discusses groundwater remediation in more detail.

A.3.9 200-ZP-1

The environmental restoration contractor continued to operate a pump-and-treat system in this operable unit, which underlies the northwestern 200 West Area, in fiscal year 2001 (Figure A.23). The purpose of the pump-and-treat system is to prevent further movement of groundwater contamination from the high concentration portion of the carbon tetrachloride plume and to reduce contaminant mass (ROD 1995).

The interim action objectives (ROD 1995) include the following:

- prevent further movement of contamination from the highest concentration area of the plume (i.e., containing carbon tetrachloride inside of 2,000 to 3,000 μg/L contour)
- reduce contamination in the area of highest carbon tetrachloride concentrations
- provide information that will lead to development of a final remedy that will be protective of human health and the environment.

Results of the interim action are summarized annually (DOE/RL-2000-71). The 200-ZP-1 pump-and-treat system made measurable progress toward meeting its specific objectives in fiscal year 2001. However, the central portion of the carbon tetrachloride plume has expanded to the extraction wells. Spreading of the high concentration area is attributed to the effects of pumping. This situation implies that more carbon tetrachloride mass is present beneath the Plutonium Finishing Plant than originally anticipated. Additional investigative work is needed to characterize contamination in this area. Section 2.8.1 of the main text discusses groundwater remediation in more detail.

A.3.10 300-FF-5

This operable unit includes the groundwater and vadose zone beneath the 300 Area and smaller satellite areas to the north that include the 618-10 and 618-11 burial grounds and the 316-4 crib. Groundwater in the 300 Area is monitored to assess whether the contaminants of concern (cis-1,2-dichloroethene, trichloroethene, and uranium) are naturally diminishing over time. The remedial action is an interim action that involves imposing restrictions on the use of the groundwater until these contaminants meet health-based criteria (ROD 1996a). This is an interim action because there are other constituents (e.g., tritium) migrating into the unit that have not yet been fully addressed and because a portion of the unit is overlain by uncharacterized waste sites in the 300-FF-2 Operable Unit. A final action decision for the 300-FF-5 Operable Unit will be made after these issues have been resolved.

An operation and maintenance plan for the 300-FF-5 Operable Unit (DOE/RL-95-73) will be finalized in fiscal year 2002. The plan identifies tasks necessary to verify the effectiveness of the remedial action. The plan describes the monitoring program and administrative tasks that are part of the remedial action. The planned routine operation and maintenance activities include groundwater, river, and ecosystem monitoring.

The constituents of concern temporarily increased in concentration in the groundwater of the 300-FF-5 Operable Unit immediately after discharges from the process sewers to the 316-5 process trenches stopped. The previously lower concentrations in the groundwater were apparently due to the dilution of the constituents by the large quantities of relatively clean waste cooling water. When use of the trenches ceased and the dilution no longer occurred, the concentrations rose to the high levels discovered in 1995 to 1997. More recently the constituents of concern have begun to decrease in concentration, as was predicted (ROD 1996a).

In June 2000, EPA developed an explanation of significant difference to the 300-FF-5 Operable Unit that expands the scope of the 300-FF-5 groundwater operable unit to include groundwater beneath all 300-FF-2 waste sites and burial grounds. That is, the original 300-FF-5 boundary as it was defined in the 1996 record of decision (ROD 1996a), was expanded to include the 618-10 burial ground and 316-4 crib (between the 300 Area and Energy Northwest) and 618-11 burial ground immediately west of Energy Northwest. The explanation of significant difference also requires an update to the operations and maintenance plan (DOE/RL-95-73) to ensure that adequate groundwater monitoring requirements are in place. The explanation of significant difference did not make any fundamental changes to the 1996 remedy selected.

The CERCLA record of decision (ROD 1996a) process required a review by EPA after 5 years from the original time of issuance to assess the progress of the selected remedy. The results of the first 5-year review (EPA 2001) indicated that the 300 Area cleanups were proceeding in a protective and effective manner. EPA still considered that the cleanup goals and remedy selection decisions were appropriate at the time the 5-year review was released. Another EPA assessment of the progress of the selected remedy will occur in 5 years (2006).

There are several wells in the immediate area of the 618-10 burial ground and 316-4 crib, including one well completed at multiple depths. Monitoring well 699-S6-E4A is located next to the 316-4 crib. During fiscal year 2001, uranium concentrations declined slightly from previous years with a fiscal year 2001 average value of 22 μg/L. Also, tributyl phosphate and tritium continued to be detected. Tributyl phosphate concentrations were less variable than in past years with a high of 54 μg/L detected in July 2001. The tritium concentration at the water table in this area ranged up to 20,200 pCi/L, which is consistent with the regional tritium plume. For more information on the 618-10 burial ground and 316-4 crib, see Section 2.12.

The discovery of high levels of tritium downgradient of the 618-11 burial ground, in well 69-13-3A (1.9 million pCi/L in January 1999; 8.1 million pCi/L in January 2000) resulted in an investigation into the source and extent of the contamination in fiscal years 2000 and 2001 (see Sections 2.12 and 3.1 of the main text). The fiscal year 2001 investigation defined the extent of the tritium contamination and resulted in the installation of four new monitoring wells for ongoing monitoring of the plume. Results of Phase I showed that the extremely high levels of tritium found in well 699-13-3A were not found in any other nearby wells, strongly suggesting a source with the 618-11 burial ground. No other radionuclides were detected at levels above drinking water standards in well 699-13-3A. Nitrate continued to be detected in well 699-13-3A at levels greater than the maximum contaminant level (45 mg/L) with a fiscal year 2001 average of 88 mg/L. No other non-radioactive constituents were detected at levels above primary maximum contaminant levels.

A.3.11 1100-EM-1

The 1100-EM-1 Operable Unit contains DOE's inactive Horn Rapids Landfill. Results of the CERCLA investigation for this operable unit are presented in the final remedial investigation study (DOE/RL-92-67) and the record of decision (ROD 1993). The selected remedy for groundwater is monitored natural attenuation of volatile organic compounds, with institutional controls on drilling of new water supply wells. Monitoring includes analysis for trichloroethene, its breakdown products (vinyl chloride and 1,1-dichloroethene), and nitrate in wells downgradient of DOE's inactive Horn Rapids Landfill, as recommended in the sampling plan (PNNL-12220).

Wells in this operable unit network were sampled twice in fiscal year 2001 because the fiscal year 2000 sampling was delayed to early fiscal year 2001. The delay was caused by issues associated with disposal of sampling-related waste. One monitoring well, 699-S29-E12, was not sampled in fiscal year 2001 because the pump failed.

In fiscal year 2001, average trichloroethene concentrations were below 5 µg/L at point of compliance wells 699-S27-E12A, 699-S28-E13A, and 699-S29-E13A. These wells form a line downgradient of DOE's inactive Horn Rapids Landfill that is approximately perpendicular to the prevailing path of the trichloroethene plume. Groundwater modeling indicated that the trichloroethene plume was expected to attenuate to levels below 5 µg/L by the year 2017 (ROD 1993). Thus, the trichloroethene plume has naturally attenuated 16 years ahead of the predicted date. Vinyl chloride and 1,1-dichloroethene levels continued to be less than their respective minimum detection levels during fiscal year 2001. EPA conducted a 5-year review in 2001 and no groundwater monitoring changes were required at DOE's inactive Horn Rapids Landfill.

Nitrate levels continued to exceed the maximum contaminant level of 45 mg/L in fiscal year 2001. In one well, 699-S29-E13A, nitrate levels rose above 45 mg/L for the first time. The record of decision indicated that nitrate concentrations, some of which were higher in the early 1990s than at current levels, pose a low risk level and do not trigger remedial action.

Although not specified in the record of decision, chromium is monitored annually in one well downgradient of the 1171 Building in the former 1100 Area. The concentration of unfiltered chromium in this well measured 40 µg/L, which is lower than the maximum contaminant level of 100 µg/L, in fiscal year 2001. Filtered chromium continued to be much less than the maximum contaminant level and was less than the minimum detection limit of 3 µg/L in fiscal year 2001.

A.4 Drinking Water Standards and Derived Concentrations Guides

Groundwater is not a primary source of drinking water for most Hanford Site workers. However, comparing groundwater chemistry to drinking water standards provides perspective for contaminant levels. Exceedances of maximum contaminant levels are summarized in Table A.49. Drinking water standards use the methods set out in 40 CFR 141, 40 CFR 142, and 40 CFR 143 to estimate the concentration in water that could result in a potential radiological dose of 4 millirem per year from consumption of each individual radionuclide. Similarly, DOE derived concentration guides provide estimates of radiological concentration that could result in a 100 millirem per year dose as defined in DOE Order 5400.5. Table A.50 summarizes exceedances of these limits by geographic region of the Hanford Site, and the number of wells exceeding the standard at least once during the fiscal year.

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Table A.1. RCRA Interim and Final Status Groundwater Monitoring Projects, September 2001

	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring				
TSD Units, date initiated	Indicator Parameter Evaluation(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated	Groundwater Monitoring Regulations	Year Scheduled for Part B or Closure
1301-N LWDF, December 1987			X(b)			40 CFR 265.93(b) WAC 173-303-400	1999(c)
1324-N/NA LWDF, December 1987			X(b)			40 CFR 265.93(b) WAC 173-303-400	1999(c)
1325-N LWDF, December 1987			X(b)			40 CFR 265.93(b) WAC 173-303-400	1999(c)
183-H solar evaporation basins, June 1985					X, 1998	40 CFR 264 WAC 173-303-645(10)	1994(c)
216-A-29 ditch, November 1988	X					40 CFR 265.93(b) WAC 173-303-400	2006(c)
216-B-3 pond, November 1988	X					40 CFR 265.93(b) WAC 173-303-400	2003(c)
216-B-63 trench, August 1991	X					40 CFR 265.93(b) WAC 173-303-400	2006(c)
216-S-10 pond and ditch, August 1991	X					40 CFR 265.93(b) WAC 173-303-400	2006(c)
216-U-12 crib, September 1991		X, 1993				40 CFR 265.93(d) WAC 173-303-400	2006(c)
316-5 process trenches, June 1985					X, 1998	40 CFR 264 WAC 173-303-645(10)	1996(c,d)
LERF, July 1991						40 CFR 265.93(b) WAC 173-303-400	1998(e,f)
LLWMA 1, September 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002(f,g)

Table A.1. (contd)

	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring				
TSD Units, date initiated	Indicator Parameter Evaluation(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated	Groundwater Monitoring Regulations	Year Scheduled for Part B or Closure
LLWMA 2, September 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002(f,g)
LLWMA 3, October 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002(f,g)
LLWMA 4, October 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002(f,g)
NRDWL, October 1986	X					40 CFR 265.93(b) WAC 173-303-400	2006(c)
PUREX cribs(h) 1988		X, 1997				40 CFR 265.93(d) WAC 173-303-400	TBD(c,i)
WMA A-AX, February 1990	X					40 CFR 265.93(b) WAC 173-303-400	TBD(c,i)
WMA B-BX-BY, February 1990		X, 1996				40 CFR 265.93(d) WAC 173-303-400	TBD(c,i)
WMA C, February 1990	X					40 CFR 265.93(b) WAC 173-303-400	TBD(c,i)
WMA S-SX, October 1991		X, 1996				40 CFR 265.93(d) WAC 173-303-400	TBD(c,i)
WMA T, February 1990		X, 1993				40 CFR 265.93(d) WAC 173-303-400	TBD(c,i)
WMA TX-TY, September - October 1991		X, 1993				40 CFR 265.93(d) WAC 173-303-400	TBD(c,i)

Table A.1. (contd)

	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring				
TSD Units, date initiated (associated [CERCLA] groundwater operable units)	Indicator Parameter Evaluation(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated	Groundwater Monitoring Regulations	Year Scheduled for Part B or Closure
WMA U, October 1990		X, 2000				40 CFR 265.93(b) WAC 173-303-400	TBD(c,i)

(a) Contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) used to determine if a facility is affecting groundwater quality. Exceeding the established limits means that additional evaluation and sampling are required (i.e., groundwater quality assessment). An X in the assessment column indicates whether an evaluation was needed or an assessment was required.
(b) Monitored according to interim status plan as specified in closure plans.
(c) Closure/postclosure plan; TSD unit will close under WAC 173-303-610.
(d) Closure plan pending Washington State Department of Ecology approval.
(e) Statistical evaluations suspended in January 2001 because only one downgradient well is not dry.
(f) Part B permit; TSD unit scheduled to operate under final status regulations beginning in year indicated.
(g) Facility Part B permit and final status groundwater monitoring plan contingent on completion of solid waste environmental impact statement.
(h) 216-A-10, 216-A-36B, and 216-A-37-1 combined into one RCRA monitoring unit. RCRA monitoring will be performed according to interim status groundwater quality assessment requirements.
(i) Unscheduled.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980.*
LERF = Liquid effluent retention facility.
LLWMA = Low-level waste management area.
LWDF = Liquid waste disposal facility.
NRDWL = Nonradioactive Dangerous Waste Landfill.
PUREX = Plutonium-uranium extraction (plant).
RCRA = *Resource Conservation and Recovery Act of 1976.*
TBD = To be determined.
TSD = Treatment, storage, or disposal (unit).
WMA = Waste management area.

Table A.2. Estimates of Groundwater Flow Rates at Hanford Site Facilities

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity(a)	Gradient(b)	Comments
1301-N LWDF	NW	0.07 to 1.3	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0036	Gradient calculated between wells 199-N-66 and 199-N-2.
1324-N/NA	NW	0.07 to 1.3	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0036	Gradient calculated between wells 199-N-72 and 199-N-26.
1325-N LWDF	N	0.04 to 0.76	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0021	Gradient calculated between wells 199-N-28 and 199-N-81.
183-H solar evaporation basins	E	0.10 to 2.7	Darcy	15 to 140 (PNL-6728)	0.1 to 0.3	0.002	Gradient calculated between wells 199-H3-2A and 199-H4-5. Flow meter in wells 199-H4-7 and 199-H3-2A (Section 3.3 in DOE/RL-96-01).
		0.65 to 4.9	Flow meter				
200 Area TEDF	SSW	0.004	Darcy	1.1 (WHC-SD-EN-ES-004)	0.25(c)	~0.001	Gradient calculated between wells 699-41-35 and 699-40-36.
216-A-29 ditch	WSW	~0.03 to ~0.09	Darcy	18 (WHC-SD-EN-DP-047)	0.1 to 0.3	~0.0004	
216-B-3 pond	SW	0.02 to 15.4	Darcy	1 to 640 (WHC-SD-EN-EV-002, PNL-10195)	0.25	~0.006	Gradient calculated between wells 699-44-42 and 699-43-45.
216-B-63 trench	SW	0.01 to 0.1	Darcy	52 to 200 (WHC-SD-EN-EV-002)	0.1 to 0.3	~0.00004	
216-S-10 pond	ESE	0.053 to 2.55	Darcy	10 (WHC-SD-EN-DP-052) 12 to 150 (BNWL-1709)	0.1 to 0.3	0.0016 to 0.0017	Gradient increases to the south. Gradients calculated using water-table contours.
216-U-12 crib contours.	ESE	0.02 to 0.08	Darcy	4.2 to 5.4 (PNNL-13378)	0.1 to 0.3	0.0015	Gradient calculated using water-table
316-5 process trenches	SE	10.7 (PNNL-5408)	Movement of PCE spill				
	S	0.32 to 96	Darcy	150 to 15,000 (PNL-6716)	0.1 to 0.3	0.00064	
LERF	W	0.04 to 6.0	Darcy	6.1 to 120	0.1 to 0.3	0.002 to	

Table A.2. (contd)

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity[a]	Gradient[b]	Comments
				(PNNL-11620)		0.005	
LLWMA 1	NW	≤0.5	Darcy	73 to 760 (PNL-6820)	0.1 to 0.3	≤0.00006	Uncertainty with gradient and rate of flow. Flow direction inferred from plume maps.
LLWMA 2	W	~0.05 to ~0.8	Darcy	430 to 2,000 (PNL-6820)	0.1 to 0.3	~0.00004	Gradient calculated between wells 299-E34-10 and 299-E27-9.
LLWMA 3	ENE	0.0001 to 0.12	Darcy	0.02 to 9.8 (PNL-6820)	0.1 to 0.3	0.0013	
LLWMA 4	E to ENE	0.2 to 0.6	Darcy	24 (PNL-6820)	0.1 to 0.3	0.002	
NRDWL	125° E of N (based on plume maps)	0.031 to 2.74	Darcy	518 to 1,524 (WHC-EP-0021)	0.1 to 0.3	0.00018	
PUREX cribs	See comment	See comment	Plume maps	NA	NA	See comment	Gradient too low to determine flow direction or rate.
SALDS	NE	0.05 to 0.55	Darcy	3.5 to 36.3 (WHC-SD-C018H-RPT-003)	0.25[c]	0.004	Gradient was calculated between wells 699-48-77A and 699-48-77D.
SWL	125° E of N (based on plume maps)	0.38 to 2.30	Darcy	640 to 1,280 (PNL-6820)	0.1 to 0.3	0.00018	
WMA A-AX	SE	1.7 to 3.3	Darcy	1,981 to 2,519 (WHC-SD-EN-TI-019)	0.2 to 0.3	0.00026	
WMA B-BX-BY	SW (north half) SE (south half)	0.98	Darcy	1,615 (WHC-SD-EN-TI-019)	0.3	~0.00018	
WMA C	SW	1.2 to 2.3	Darcy	1,067 to 2,073 (WHC-SD-EN-TI-019)	0.3	0.00030	
WMA S-SX	E to SE	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.
		0.013 to 0.04	Tracer pump back - Darcy (PNNL-13514)	1.8 to 7.6 (pump test data)	0.26 to 0.35	0.0018 to 0.0026	Based on tracer tests in wells 299-W22-48, -49, and -50; flow rate is estimated aquifer rate (see PNNL-13514, Table 6.1).
WMA T	E	0.003 to 0.024	Darcy	1 to 2.4	0.1 to 0.3	0.001	

Table A.2. (contd)

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity[a]	Gradient[b]	Comments
				(PNNL-13378)			
WMA TX-TY	E (north half) S or SW (south half)	0.003 to 0.59	Darcy	0.88 to 19.6 (PNNL-13514)	0.1 to 0.3	0.003	
WMA U	ENE, changing to E	0.008 to 0.20	Darcy	1.2 to 9.5 (PNNL-13378)	0.1 to 0.3	0.0021	Pumping in well 299-W15-37 stopped on January 17, 2001; flow direction changing to east across entire WMA.

(a) Effective porosity assumed to be between 0.1 and 0.3, a representative range for the unconfined aquifer system.
(b) March 2001 unless noted otherwise.
(c) RHO-ST-42, RHO-RE-ST-12 P, PNNL-11801.

LERF = Liquid effluent retention facility.
LLWMA = Low-level waste management area.
LWDF = Liquid waste disposal facility.
NA = Not applicable.
NRDWL = Nonradioactive Dangerous Waste Landfill.
PCE = Tetrachloroethylene.
RCRA = *Resource Conservation and Recovery Act of 1976*.
SWL = Solid Waste Landfill.
WMA = Waste management area.

Table A.3. Monitoring Results Exceeding Maximum Contaminant Levels or Drinking Water Standards (regulated units listed in alphanumeric order)[(a)]

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	DWS[(b)]
			1301-N			
Gross beta, pCi/L	N	199-N-2	Down	1	532	50
	N	199-N-3	Down	3	3,900	50
Nitrate, µg/L	N	199-N-105A	Down	1	45,596.04	45,000
	N	199-N-2	Down	2	10,4029.8	45,000
Strontium-90, pCi/L	N	199-N-2	Down	1	269	8
	N	199-N-3	Down	3	2,310	8
	N	199-N-34	Up	1	59.9	8
	N	199-N-57	Up	1	13.8	8
Tritium, pCi/L	N	199-N-2	Down	1	39,500	20,000
	N	199-N-34	Up	1	22,000	20,000
			1324-N/NA			
Nitrate, µg/L	N	199-N-59	Down	1	67,287.36	45,000
			1325-N			
Antimony, µg/L	Y	199-N-41	Down	1	29.2	6
Gross beta, pCi/L	N	199-N-81	Down	1	1,900	50
Radium-226, pCi/L	N	199-N-32	Down	2	102	5
Strontium-90, pCi/L	N	199-N-28	Down	1	96.8	8
	N	199-N-81	Down	2	1,010	8
Tritium, pCi/L	N	199-N-28	Down	1	24,000	20,000
	N	199-N-32	Down	3	28,700	20,000
	N	199-N-81	Down	1	22,300	20,000
			183-H Solar Evaporation Basins			
Chromium, µg/L	N	199-H4-12C	Down	1	234	100
	N	199-H4-3	Down	2	151	100
	Y	199-H4-12C	Down	1	178	100
	Y	199-H4-3	Down	2	142	100
Gross alpha, pCi/L	N	199-H4-3	Down	2	131	15
Gross beta, pCi/L	N	199-H4-3	Down	2	593	50
Hexavalent chromium, µg/L	Y	199-H4-12C	Down	2	177	100
	Y	199-H4-3	Down	4	153	100
Nitrate, µg/L	N	199-H4-12A	Down	1	59,761.8	45,000
	N	199-H4-3	Down	2	387,345	45,000
	N	199-H4-7	Down	2	52,600	45,000
Technetium-99, pCi/L	N	199-H4-3	Down	1	1,070	900
Uranium, µg/L	N	199-H4-3	Down	1	157	30
			216-A-29 Ditch			
Arsenic, µg/L	Y	299-E25-35	Down	1	12	10
Iodine-129, pCi/L	N	299-E25-34	Down	1	2	1
	N	699-43-43	Up	2	6	1
	N	699-43-45	Up	1	6	1
			216-B-3 Pond			
Iodine-129, pCi/L	N	699-43-45	Down	1	6	1
Tritium, pCi/L	N	699-41-40	Down	1	66,700	20,000
	N	699-42-39A	Down	1	25,600	20,000
	N	699-42-39B	Down	2	42,900	20,000
	N	699-42-42B	Down	1	26,200	20,000
	N	699-43-40	Down	1	30,400	20,000
	N	699-43-41E	Down	1	35,800	20,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS[b] Level
216-B-63 Ditch						
Arsenic, µg/L	Y	299-E33-33	Down	1	11	10
Iodine-129, pCi/L	N	299-E27-18	Down	1	4	1
	N	299-E33-33	Down	1	2	1
	N	299-E33-37	Down	1	3	1
216-S-10 Pond and Ditch						
Antimony, µg/L	Y	299-W27-2	Down	1	7	6
Carbon tetrachloride, µg/L	N	299-W27-2	Down	1	6	5
Nickel, µg/L	Y	299-W27-2	Down	2	133	100
216-U-12 Crib						
Carbon tetrachloride, µg/L	N	699-36-70A	Down	2	7	5
Iodine-129, pCi/L	N	699-36-70A	Down	4	17	1
Methylenechloride, µg/L	N	699-36-70A	Down	1	6	5
Nitrate, µg/L	N	299-W22-79	ND	1	47,800	45,000
	N	699-36-70A	Down	6	109,342	45,000
Tritium, pCi/L	N	699-36-70A	Down	2	69,000	20,000
316-5 Process Trenches						
cis-1,2-dichloroethylene, µg/L	N	399-1-16B	Down	6	190	70
Gross alpha, pCi/L	N	399-1-17A	Down	2	43	15
Uranium, µg/L	N	399-1-10A	Down	4	43	30
	N	399-1-16A	Down	5	100	30
	N	399-1-17A	Down	5	64	30
Low-Level Waste Management Area 1						
Antimony, µg/L	Y	299-E32-10	Down	1	17	6
Cyanide, µg/L	N	299-E33-34	Down	3	333	200
Gross alpha, pCi/L	N	299-E33-34	Down	1	21	15
Gross beta, pCi/L	N	299-E32-10	Down	2	1,200	50
	N	299-E32-9	Down	1	58	50
	N	299-E33-28	Up	1	55	50
	N	299-E33-34	Down	4	3,060	50
	N	299-E33-35	Up	3	658	50
Iodine-129, pCi/L	N	299-E32-9	Down	1	3	1
	N	299-E33-35	Up	1	4	1
Nitrate, µg/L	N	299-E28-26	Up	2	54,900	45,000
	N	299-E32-10	Down	4	178,000	45,000
	N	299-E32-2	Down	2	59,800	45,000
	N	299-E32-3	Down	2	61,100	45,000
	N	299-E32-5	Down	2	55,800	45,000
	N	299-E32-6	Down	2	60,200	45,000
	N	299-E32-7	Down	3	85,400	45,000
	N	299-E33-34	Down	4	456,000	45,000
	N	299-E33-35	Up	4	120,000	45,000
Technetium-99, pCi/L	N	299-E32-10	Down	4	3,490	900
	N	299-E33-34	Down	4	8,170	900
	N	299-E33-35	Up	4	2,420	900
Uranium, µg/L	N	299-E33-34	Down	2	46	30
Low-Level Waste Management Area 3						
Iodine-129, pCi/L	N	299-E27-10	Up	1	4	1
Nitrate, µg/L	N	299-E34-7	Up	2	112,000	45,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS(b) Level
Carbon tetrachloride, µg/L	N	299-W10-13	Up	4	6	5
	N	299-W10-19	Up	3	130	5
	N	299-W10-20	Up	3	1,300	5
	N	299-W10-21	Up	3	530	5
	N	299-W6-2	Down	2	110	5
	N	200-W7-4	Down	3	630	5
	N	299-W7-5	Down	2	52	5
	N	299-W7-7	Down	2	22	5
Nickel, µg/L	Y	299-W7-1	Down	3	211	100
Nitrate, µg/L	N	299-W10-13	Up	3	72,200	45,000
	N	299-W10-19	Up	3	55,8000	45,000
	N	299-W10-20	Up	3	99,600	45,000
	N	299-W10-21	Up	3	156,000	45,000
	N	299-W6-2	Down	2	52,200	45,000
	N	299-W7-4	Down	3	86,800	45,000
	N	299-W7-5	Down	2	47,400	45,000
Trichloroethene, µg/L	N	299-W10-21	Up	1	6	5
Low-Level Waste Management Area 4						
Carbon tetrachloride, µg/L	N	299-W15-15	Up	7	100	5
	N	299-W15-16	Down	4	4,600	5
	N	299-W15-17	Down	2	11	5
	N	299-W18-21	Up	4	36	5
	N	299-W18-23	Up	3	85	5
	N	299-W18-24	Down	2	630	5
	N	299-W18-27	Up	4	170	5
Gross alpha, pCi/L	N	299-W18-21	Up	1	17	15
Nitrate, µg/L	N	299-W15-15	Up	2	97,400	45,000
	N	299-W15-16	Down	1	46,448	45,000
	N	299-W18-21	Up	2	98,700	45,000
	N	299-W18-23	Up	2	58,000	45,000
	N	299-W18-24	Down	1	77,000	45,000
Uranium, µg/L	N	299-W18-21	Up	1	31	30
Nonradioactive Dangerous Waste Landfill						
Tritium, pCi/L	N	699-26-33	Down	1	57,700	20,000
	N	699-26-35A	Up	2	49,800	20,000
Plutonium-Uranium Extraction (PUREX) Cribs						
Gross beta, pCi/L	N	299-E17-14	Down	4	63	50
Iodine-129, pCi/L	N	299-E17-1	Down	3	7	1
	N	299-E17-14	Down	5	10	1
	N	299-E17-19	Down	2	9	1
	N	299-E17-9	Down	1	9	1
	N	299-E24-16	Down	4	10	1
	N	299-E25-17	Down	1	4	1
Nitrate, µg/L	N	299-E17-1	Down	3	82,300	45,000
	N	299-E17-14	Down	4	116,000	45,000
	N	299-E17-9	Down	1	184,000	45,000
Strontium-90, pCi/L	N	299-E17-14	Down	5	19	8
Tritium, pCi/L	N	299-E17-1	Down	3	547,000	20,000
	N	299-E17-14	Down	5	820,000	20,000
	N	299-E17-18	ND	2	104,000	20,000
	N	299-E17-19	Down	2	400,000	20,000
	N	299-E17-9	Down	2	4,300,000	20,000
	N	299-E24-16	Down	4	348,000	20,000
	N	299-E24-18	Up	2	107,000	20,000
	N	299-E25-19	Down	4	211,000	20,000
	N	699-37-47A	Down	2	30,100	20,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS$^{(b)}$ Level
Single-Shell Tanks Waste Management Area A-AX						
Chromium, µg/L	Y	299-E24-19	Down	2	1,640	100
Iodine-129, pCi/L	N	299-E24-19	Down	1	3	1
	N	299-E25-40	Up	1	4	1
	N	299-E25-41	Up	1	3	1
Nickel, µg/L	Y	299-E24-19	Down	2	1,030	100
Single-Shell Tanks Waste Management Area B-BX-BY						
Antimony, µg/L	Y	299-E32-10	Cross	1	17	6
Cyanide, µg/L	N	299-E33-34	Cross	3	333	200
	N	299-E33-38	Up	3	383	200
	N	299-E33-7	Up	3	423	200
Gross alpha, pCi/L	N	299-E33-13	Up	1	16	15
	N	299-E33-18	Up	2	108	15
	N	299-E33-26	Cross	2	53	15
	N	299-E33-31	Down	1	33	15
	N	299-E33-34	Cross	1	21	15
	N	299-E33-38	Up	2	84	15
	N	299-E33-41	Down	2	70	15
	N	299-E33-44	Down	2	245	15
	N	299-E33-9	Down	2	357	15
Gross beta, pCi/L	N	299-E32-10	Cross	2	1,200	50
	N	299-E32-9	Cross	1	58	50
	N	299-E33-13	Up	2	975	50
	N	299-E33-15	ND	1	80	50
	N	299-E33-16	ND	3	1,400	50
	N	299-E33-18	Up	3	1,200	50
	N	299-E33-20	Down	1	103	50
	N	299-E33-26	Cross	3	2,720	50
	N	299-E33-28	Up	1	55	50
	N	299-E33-31	Down	3	1,310	50
	N	299-E33-32	Down	4	739	50
	N	299-E33-34	Cross	4	3,060	50
	N	299-E33-35	Cross	3	658	50
	N	299-E33-38	Up	3	4,600	50
	N	299-E33-41	Down	2	1,140	50
	N	299-E33-42	Down	3	1,190	50
	N	299-E33-43	Down	3	229	50
	N	299-E33-44	Down	3	3,320	50
	N	299-E33-7	Up	3	4,210	50
	N	299-E33-9	Down	3	3,090	50
Iodine-129, pCi/L	N	299-E32-9	Cross	1	3	1
	N	299-E33-35	Cross	1	4	1
Nitrate, µg/L	N	299-E28-26	Cross	2	54,900	45,000
	N	299-E32-10	Cross	4	178,000	45,000
	N	299-E32-2	Cross	2	59,800	45,000
	N	299-E32-3	Cross	2	61,100	45,000
	N	299-E32-5	Cross	2	55,800	45,000
	N	299-E32-6	Cross	2	60,200	45,000
	N	299-E32-7	Cross	3	85,400	45,000
	N	299-E33-13	Up	2	425,000	45,000
	N	299-E33-15	ND	2	441,000	45,000
	N	299-E33-16	ND	4	695,000	45,000
	N	299-E33-17	ND	1	267,000	45,000
	N	299-E33-18	Up	4	205,000	45,000
	N	299-E33-20	ND	3	460,000	45,000
	N	299-E33-26	Cross	4	441,000	45,000
	N	299-E33-31	Down	3	259,000	45,000
	N	299-E33-32	Down	4	98,700	45,000
	N	299-E33-34	Cross	4	456,000	45,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS(b) Level
Nitrate, µg/L (contd)	N	299-E33-35	Cross	4	120,000	45,000
	N	299-E33-38	Up	4	531,000	45,000
	N	299-E33-41	Down	1	52,700	45,000
	N	299-E33-42	Down	4	136,000	45,000
	N	299-E33-43	Down	1	77,500	45,000
	N	299-E33-44	Down	4	224,000	45,000
	N	299-E33-7	Up	4	748,000	45,000
	N	299-E33-9	Down	4	212,000	45,000
Technetium-99, pCi/L	N	299-E32-10	Cross	4	3,490	900
	N	299-E33-13	Up	2	3,290	900
	N	299-E33-16	ND	4	5,780	900
	N	299-E33-18	Up	4	3,810	900
	N	299-E33-26	Cross	4	7,510	900
	N	299-E33-31	Down	4	3,800	900
	N	299-E33-32	Down	5	2,090	900
	N	299-E33-34	Cross	4	8,170	900
	N	299-E33-35	Cross	4	2,420	900
	N	299-E33-38	Up	4	13,000	900
	N	299-E33-41	Down	4	3,290	900
	N	299-E33-42	Down	4	3,380	900
	N	299-E33-43	Down	1	915	900
	N	299-E33-44	Down	4	8,230	900
	N	299-E33-7	Up	4	11,600	900
	N	299-E33-9	Down	4	7,660	900
Tritium, pCi/L	N	299-E33-339	Down	1	21,400	20,000
Uranium, µg/L	N	299-E33-18	Up	4	193	30
	N	299-E33-26	Cross	4	137	30
	N	299-E33-31	Down	4	79	30
	N	299-E33-34	Cross	2	46	30
	N	299-E33-38	Up	4	165	30
	N	299-E33-41	Down	2	118	30
	N	299-E33-42	Down	1	31	30
	N	299-E33-44	Down	4	567	30
	N	299-E33-9	Down	4	678	30
Single-Shell Tanks Waste Management Area C						
Gross beta, pCi/L	N	299-E27-13	Down	1	62	50
	N	299-E27-14	Up	1	264	50
	N	299-E27-7	Up	1	159	50
Iodine-129, pCi/L	N	299-E27-13	Down	1	3	1
Technetium-99, pCi/L	N	299-E27-14	Up	3	1,540	900
	N	299-E27-7	Up	1	2,190	900
Single-Shell Tanks Waste Management Area S-SX						
Carbon tetrachloride, µg/L	N	299-W22-45	Down	1	18	5
	N	299-W22-46	Down	1	36	5
	N	299-W22-48	Down	2	10	5
	N	299-W22-49	Down	2	8	5
	N	299-W22-50	Down	1	20	5
	N	299-W23-13	Up	2	16	5
	N	299-W23-15	Down	2	190	5
Chromium, µg/L	Y	299-W23-19	Down	2	138	100
Gross beta, pCi/L	N	299-W22-45	Down	2	588	50
	N	299-W22-46	Down	2	1,740	50
	N	299-W22-48	Down	2	954	50
	N	299-W22-50	Down	2	1,230	50
	N	299-W23-19	Down	5	28,700	50
Iodine-129, pCi/L	N	299-W23-19	Down	1	6	1
Nitrate, µg/L	N	299-W22-45	Down	2	46,000	45,000
	N	299-W22-46	Down	1	48,300	45,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS$^{(b)}$ Level
Nitrate, μg/L (contd)	N	299-W22-48	Down	3	72,200	45,000
	N	299-W23-14	Up	1	68,600	45,000
	N	299-W23-19	Down	5	677,000	45,000
	N	299-W23-21	Up	3	54,400	45,000
	Y	299-W23-14	Up	1	62,900	45,000
Technetium-99, pCi/L	N	299-W22-45	Down	2	1,170	900
	N	299-W22-46	Down	6	4,550	900
	N	299-W22-48	Down	5	4,050	900
	N	299-W22-50	Down	5	3,530	900
	N	299-W23-19	Down	5	81,500	900
Tritium, pCi/L	N	299-W22-39	Down	2	28,700	20,000
	N	299-W22-46	Down	5	21,900	20,000
	N	299-W22-49	Down	5	27,400	20,000
	N	299-W22-50	Down	5	24,800	20,000
	N	299-W23-14	Up	1	113,000	20,000
	N	299-W23-19	Down	5	115,000	20,000
	N	299-W23-21	Up	3	49,000	20,000
	N	299-W23-14	Up	1	100,000	20,000
Single-Shell Tanks Waste Management Area T						
Carbon tetrachloride, μg/L	N	299-W10-1	Up	1	470	5
	N	299-W10-22	Down	1	380	5
	N	299-W10-23	Down	2	1,600	5
	N	299-W10-4	Up	2	1,400	5
	N	299-W11-42	Down	1	1,600	5
	N	299-W6-10	Up	1	730	5
	N	299-W6-2	Down	2	110	5
Chromium, μg/L	Y	299-W10-23	ND	4	116	100
	Y	299-W10-4	Up	4	209	100
	Y	299-W11-24	Down	1	209	100
	Y	299-W11-41	Down	4	146	100
	Y	299-W11-42	Down	4	148	100
Fluoride, μg/L	N	299-W10-24	ND	4	4,700	4,000
	N	299-W11-42	Down	4	4,900	4,000
Gross beta, pCi/L	N	299-W10-23	ND	3	101	50
	N	299-W10-24	ND	2	598	50
	N	299-W10-4	Up	2	97	50
	N	299-W11-12	Down	2	108	50
	N	299-W11-24	Down	1	63	50
	N	299-W11-39	Down	1	1,420	50
	N	299-W11-40	Down	1	71	50
	N	299-W11-41	Down	2	79	50
	N	299-W11-42	Down	3	87	50
Nitrate, μg/L	N	299-W10-1	Up	3	145,000	45,000
	N	299-W10-19	Down	3	55,800	45,000
	N	299-W10-20	Down	3	99,600	45,000
	N	299-W10-21	Down	3	156,000	45,000
	N	299-W10-22	Down	3	151,000	45,000
	N	299-W10-23	ND	6	376,000	45,000
	N	299-W10-24	ND	4	327,000	45,000
	N	299-W10-4	Up	4	1,300,000	45,000
	N	299-W10-8	Down	3	228,000	45,000
	N	299-W11-12	Down	4	134,000	45,000
	N	299-W11-24	Down	4	540,000	45,000
	N	299-W11-28	Down	2	266,000	45,000
	N	299-W11-39	Down	3	87,700	45,000
	N	299-W11-40	Down	3	194,000	45,000
	N	299-W11-41	Down	4	422,000	45,000
	N	299-W11-42	Down	4	606,000	45,000
	N	299-W6-2	Down	2	52,200	45,000
	N	299-W6-2	Down	1	56,200	45,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS$^{(b)}$ Level
Nitrite, µg/L	N	299-W11-24	Down	3	26,600	3,300
Technetium-99, pCi/L	N	299-W10-24	ND	4	1,770	900
	N	299-W11-23	Down	1	4,470	900
	N	299-W11-39	Down	3	5,010	900
Trichloroethene, µg/L	N	299-W10-1	Up	1	7	5
	N	299-W10-21	Down	1	6	5
	N	299-W10-23	ND	2	12	5
	N	299-W10-4	Up	2	13	5
	N	299-W11-42	Down	1	11	5
	N	299-W6-10	Up	1	8	5
Tritium, pCi/L	N	299-W11-12	Down	4	62,800	20,000
	N	299-W11-24	Down	1	21,000	20,000
	N	299-W11-28	Down	2	23,500	20,000
	N	299-W11-40	Down	3	26,600	20,000
	N	299-W11-41	Down	4	32,500	20,000
Single-Shell Tanks Waste Management Area TX-TY						
Carbon tetrachloride, µg/L	N	299-W14-4	Down	1	280	5
	N	299-W14-6	Down	1	230	5
	N	299-W15-40	Up	1	2,800	5
	N	299-W15-41	Down	1	940	5
Chromium, µg/L	Y	299-W14-13	Down	4	248	100
Gross beta, pCi/L	N	299-W10-17	Down	2	68	50
	N	299-W14-13	Down	2	1,250	50
	N	299-W14-14	Down	2	86	50
	N	299-W14-15	Down	2	85	50
	N	299-W14-2	Down	1	215	50
	N	299-W14-5	Down	1	54	50
	N	299-W14-6	Down	5	71	50
	N	299-W15-41	Down	2	435	50
	Y	299-W14-5	Down	1	59	50
Iodine-129, pCi/L	N	299-W14-13	Down	4	22	1
	N	299-W14-2	Down	1	64	1
Nickel, µg/L	Y	299-W10-26	Down	1	120	100
Nitrate, µg/L	N	299-W10-17	Down	4	263,000	45,000
	N	299-W10-26	Down	5	71,300	45,000
	N	299-W10-5	Up	2	96,900	45,000
	N	299-W14-13	Down	3	309,000	45,000
	N	299-W14-14	Down	4	251,000	45,000
	N	299-W14-15	Down	4	98,700	45,000
	N	299-W14-2	Down	1	70,400	45,000
	N	299-W14-5	Down	3	137,000	45,000
	N	299-W14-6	Down	6	87,200	45,000
	N	299-W15-40	Up	4	126,000	45,000
	N	299-W15-41	Down	5	65,100	45,000
	N	299-W15-763	Down	1	124,000	45,000
	Y	299-W14-5	Down	1	105,000	45,000
Technetium-99-pCi/L	N	299-W14-13	Down	4	4,910	900
	N	299-W15-41	Down	5	1,370	900
Trichloroethene, µg/L	N	299-W15-40	Up	1	14	5
Tritium, pCi/L	N	299-W14-13	Down	4	1,540,000	20,000
	N	299-W14-2	Down	1	1,480,000	20,000
Single-Shell Tanks Waste Management Area U						
Carbon tetrachloride, µg/L	N	299-W18-30	Down	5	310	5
	N	299-W18-31	Up	2	35	5
	N	299-W19-12	Down	1	220	5
	N	299-W19-41	Down	1	190	5
	N	299-W19-42	Down	1	460	5

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS(b) Level
Gross beta, pCi/L	N	299-W19-12	Down	2	81	50
	N	299-W19-41	Down	2	159	50

(a) Samples collected between October 1, 2000 and September 30, 2001. Primary maximum contaminant levels and drinking water standards. Excludes data flagged as undetected, rejected, or suspect.
(b) DWS = Drinking water standard.
ND = Not determined.

Table A.4. Monitoring Wells and Constituents for 100 N Area Units (adapted from WHC-SD-EN-AP-038, Rev. 2)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
1301-N Liquid Waste Disposal Facility				
199-N-2^{64}	Top of unconfined	Semiannual	Quarterly	PRE
199-N-3^{64}	Top of unconfined	Semiannual	Semiannual	PRE
199-N-34^{83}	Top of unconfined	Semiannual	Quarterly	PRE
199-N-57^{87}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-105A^{95}	Unconfined	Semiannual	--	RCRA(a)
1324-N/NA Liquid Waste Disposal Facilities				
199-N-59^{87}(b)	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-71^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-72^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-73^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-77^{92}(c)	Bottom of unconfined	Semiannual	Semiannual	RCRA
1325-N Liquid Waste Disposal Facility				
199-N-28^{83}(c)	Top of unconfined	Semiannual	Quarterly	PRE
199-N-32^{83}	Top of unconfined	Semiannual	Semiannual	PRE
199-N-41^{84}	Top of unconfined	Semiannual	Quarterly	PRE
199-N-74^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
199-N-81^{93}	Top of unconfined	Semiannual	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH (field)	Alkalinity(d)	ICP metals (filtered)(d)
Specific conductance (field)	Anions(d)	Turbidity
Total organic carbon	Gross alpha(e)	
Total organic halides		

(a) Extraction well; screened over entire thickness of aquifer.
(b) Well dry in fiscal year 2001.
(c) Used for supplemental information; no statistical evaluations.
(d) Annually for 1301-N and 1325-N liquid waste disposal facilities.
(e) Gross alpha required for wells 199-N-59 and 199-N-77 only.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.5. Critical Means for 1301-N Liquid Waste Disposal Facility for Fiscal Year 2002 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.4079	507.72	124.56	1,222.2	1,222.2
Field pH	8	7	6.0818	7.89	0.085	[7.34, 8.44]	[7.34, 8.44]
Total organic carbon,(b) µg/L	8	7	5.4079	341.56	252.215	1,788.3	1,788.3
Total organic halides,(b) µg/L	8	7	5.4079	4.43	2.461	18.5	18.5

(a) Based on semiannual sampling events from March 2000 to September 2001 for upgradient wells 199-N-57 and 199-N-34.
(b) Critical means calculated from values reported below vendor's specified method detection limit.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 20 comparisons.

Table A.6. Critical Means for 1324-N/NA Liquid Waste Disposal Facilities for Fiscal Year 2002 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	5	4	8.1216	358.65	31.886	642.3	642.3
Field pH	5	4	9.7291	8.163	0.057	[7.56, 8.77]	[7.56, 8.77]
Total organic carbon,(b) µg/L	5	4	8.1216	259.70	137.393	1,482.0	1,482.0
Total organic halides,(b) µg/L	5	4	8.1216	5.365	1.594	19.5	19.5

(a) Based on semiannual sampling events from September 1999 to September 2001 for upgradient well 199-N-71.
(b) Critical means calculated from values reported below vendor's specified method detection limit.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table A.7. Critical Means for 1325-N Liquid Waste Disposal Facility for Fiscal Year 2002 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, μS/cm	5	4	8.1216	354.5	5.913	407.1	470.9
Field pH	5	4	9.7291	8.096	0.065	[7.41, 8.78]	[7.41, 8.78]
Total organic carbon,(b) μg/L	5	4	8.1216	312.75	216.467	2,238.6	2,238.6
Total organic halides,(b) μg/L	5	4	8.1216	5.925	1.779	21.8	21.8

(a) Based on semiannual sampling events from September 1999 to September 2001 for upgradient well 199-N-74.
(b) Critical means calculated from values reported below vendor specified method detection limit.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table A.8. Monitoring Wells and Constituents for the Former 183-H Solar Evaporation Basins (adapted from PNNL-11573)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
199-H4-3^{74}	Top of unconfined	Annual	Semiannual	PRE
199-H4-7$^{86(a)}$	Top of unconfined	Annual	Semiannual	RCRA
199-H4-12A$^{86(a)}$	Top of unconfined	Annual	Semiannual	RCRA
199-H4-12C^{86}	Mid-depth unconfined	Annual	Semiannual	RCRA

Dangerous Waste Constituents	Site-Specific Parameters	
Chromium (filtered)	Alkalinity	pH
Nitrate	Anions	Specific conductance
Fluoride	ICP metals (filtered)	Turbidity
Technetium-99		
Uranium		

(a) Extraction well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.9. Monitoring Wells and Constituents for the 216-A-29 Ditch (adapted from PNNL-13047)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E25-26^{85}	Upper unconfined	Semiannual	Quarterly	RCRA
299-E25-28^{86}(a)	Deep unconfined	Semiannual	Quarterly	RCRA
299-E25-32P^{88}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E25-34^{88}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E25-35^{88}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E25-48^{92}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E26-12^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E26-13^{91}	Top of unconfined	Semiannual	Quarterly	RCRA
699-43-43^{88}	Top of unconfined	Semiannual	Quarterly	RCRA
699-43-45^{89}	Top of unconfined	Semiannual	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH (field)	Alkalinity	Phenols
Specific conductance (field)	Anions	Turbidity
Total organic carbon	ICP metals (filtered)(b)	
Total organic halides		

(a) Used for supplemental information; no statistical evaluations.
(b) Analyzed annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.10. Critical Means for the 216-A-29 Ditch for Fiscal Year 2002 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.9757	255.094	7.351	271.7	271.7
Field pH	8	7	6.6987	8.503	0.188	[7.17, 9.84]	[7.17, 9.84]
Total organic carbon,(b) µg/L	8	7	5.9757	470.75	219.117	1,859.6	1,859.6
Total organic halides,(b,c) µg/L	8	7	5.9757	2.681	1.310	11.0	15.1

(a) Based on semiannual sampling events from October 1999 to June 2001 for upgradient wells 699-43-43 and 699-43-45.
(b) Critical mean calculated from values reported below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recent determined limit of quantitation (see Table B.22).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 36 comparisons.

Table A.11. Monitoring Wells and Constituents for the 216-B-3 Pond (adapted from WHC-SD-EN-AP-013)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E26-11^{89}	Top of uppermost	Semiannual	Semiannual	RCRA
299-E32-4^{87}	Top of uppermost	Semiannual	Quarterly	RCRA
699-40-39	Lower uppermost	Semiannual	Semiannual	RCRA
699-41-42^{92}	Top of uppermost	Semiannual	Quarterly	RCRA
699-42-39B^{91}	Lower uppermost	Semiannual	Quarterly	RCRA
699-42-42B^{88}	Top of uppermost	Semiannual	Quarterly	RCRA
699-43-41G^{91}	Lower uppermost	Semiannual	Quarterly	RCRA
699-43-44^{99}	Bottom of uppermost	Semiannual	Semiannual	RCRA
699-43-45^{89}	Top of uppermost	Semiannual	Quarterly	RCRA
699-44-39B^{92}	Top of uppermost	Semiannual	Quarterly	RCRA

Contamination Indicator Parameters

pH (field)
Specific conductance (field)
Total organic carbon
Total organic halides

Site-Specific Parameters

Anions(a)
Arsenic(b)
Gross alpha
Gross beta
ICP metals (filtered, unfiltered)(a)
Iodine-129(b)
Nitrate(b)
Phenols(a)
Tritium(b)
Turbidity

(a) Analyzed annually.
(b) Constituents of sitewide concern; selected wells analyzed under surveillance monitoring.
Bold italic = Upgradient well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.12. Critical Means for 216-B-3 Pond for Fiscal Year 2002 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	15	14	4.4995	417.667	7.215	451.2	451.2
Field pH	15	14	4.8656	7.704	0.262	[6.39, 9.02]	[6.39, 9.02]
Total organic carbon,(b,c) µg/L	15	14	4.4995	174.150	123.011	745.8	1,450.1
Total organic halides,(b,c) µg/L	14	13	4.5978	3.980	2.242	14.7	15.1

(a) Based on semiannual sampling events from January 1994 to January 1997 for upgradient well 299-E32-4.
(b) Critical means calculated from values reported below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recent determined limit of quantitation (see Table B.22).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 40 comparisons.

Table A.13. Monitoring Wells and Constituents for the 216-B-63 Trench (adapted from WHC-SD-EN-AP-165)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E27-8^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-9^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-11^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-16^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-17^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-18^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-19^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-33^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-36^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-37^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-8^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-10^{91}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH (field)	Alkalinity(a)	ICP metals (filtered)(a)
Specific conductance (field)	Anions(a)	Phenols(a)
Total organic carbon	Gross alpha	Turbidity
Total organic halides	Gross beta	

(a) Analyzed annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.14. Critical Means for the 216-B-63 Trench for Fiscal Year 2002 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	20	19	4.267	404.384	23.862	508.7	508.7
Field pH	20	19	4.572	8.053	0.079	[7.68, 8.42]	[7.68, 8.42]
Total organic carbon,(c) µg/L	20(b)	19	4.267	523.75	242.809	1,585.5	1,585.5
Total organic halides,(c,d) µg/L	20	19	4.267	2.589	1.082	7.3	15.1

(a) Based on semiannual sampling events from April 2000 to October 2001 for field parameters and from January 2000 to April 2001 for total organic carbon and total organic halides for upgradient wells 299-E27-8, 299-E27-9, 299-E27-11, 299-E27-17, and 299-E34-10.
(b) Excluded one unrepresentative measurement of 11,000 µg/L collected on October 20, 2000, from well 299-E27-9.
(c) Critical mean calculated from values reported below vendor's specified method detection limit.
(d) Upgradient/downgradient comparison value is the most recent determined limit of quantitation (see Table B.22).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 48 comparisons.

Table A.15. Monitoring Wells and Constituents for the 216-S-10 Pond and Ditch (adapted from WHC-SD-EN-AP-018)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W26-7^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W26-12^{91}	Top of unconfined	Semiannual(a)	Semiannual	RCRA
299-W26-13^{99}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W27-2^{92}(b)	Base of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Anions(c)	Phenols(c,d)
Specific conductance	Hexavalent chromium (filtered)(e)	Turbidity
Total organic carbon(d)	ICP metals (filtered)(c)	
Total organic halides(d)		

(a) Sampled twice in fiscal year 2001; now dry.
(b) Used for supplemental information; no statistical evaluation.
(c) Analyzed annually only.
(d) Not analyzed in well 299-W27-2.
(e) Analyzed semiannually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.16. Critical Means for the 216-S-10 Pond and Ditch for Fiscal Year 2002 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	4	3	9.4649	269.375	3.282	304.1	304.1
Field pH	4	3	11.9838	8.266	0.083	[7.16, 9.37]	[7.16, 9.37]
Total organic carbon,(b,c) µg/L	4	3	9.4649	248.25	127.38	1,596.2	1,596.2
Total organic halides,(c,d) µg/L	4	3	9.4649	2.121	0.059	2.7	15.1

(a) Based on semiannual sampling events from June 1999 to January 2001 for upgradient well 299-W26-7, except for total organic carbon that was collected from December 1998 to January 2001.
(b) Excluding unrepresentative measurement of 1,040 µg/L collected on December 1998 from well 299-W26-7.
(c) Critical means calculated from values reported below vendor's specified method detection limit.
(d) Upgradient/downgradient comparison value is the most recent determined limit of quantitation (see Table B.22).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 8 comparisons.

Table A.17. Monitoring Wells and Constituents for the 216-U-12 Crib (adapted from WHC-SD-EN-AP-019 and WHC-SD-EN-AP-108)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W22-79^{98}	Top of unconfined	Quarterly	Quarterly	RCRA
699-36-70A^{94}	Top of unconfined	Quarterly	Quarterly	RCRA

Contamination Indicator Parameters

- pH (field)
- Specific conductance (field)
- Total organic carbon
- Total organic halides

Site-Specific Parameters

- Alkalinity(a)
- Anions
- ICP metals (filtered)(a)
- Iodine-129(b)
- Technetium-99
- Total dissolved solids(a)
- Tritium
- Turbidity

(a) Analyzed annually.
(b) Analyzed semiannually.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.18. Monitoring Wells and Constituents for the 316-5 Process Trenches (adapted from WHC-SD-EN-AP-185)

Well	Hydrogeologic Unit Monitored	Sampling Frequency(a)	Water-Level Measurement	Well Standard
399-1-10A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
399-1-10B^{91}	Bottom of unconfined	Semiannual	Semiannual	RCRA
399-1-16A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
399-1-16B^{87}	Bottom of unconfined	Semiannual	Semiannual	RCRA
399-1-17A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
399-1-17B^{86}	Bottom of unconfined	Semiannual	Semiannual	RCRA
399-1-18A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
399-1-18B^{87}	Bottom of unconfined	Semiannual	Semiannual	RCRA

Field-Measured Parameters

- pH
- Specific conductance
- Turbidity

Site-Specific Parameters

- cis-1,2-dichloroethene
- Tetrachloroethene
- Trichloroethene
- Uranium

(a) Sampled and measured monthly for 4 months for each semiannual sampling period.
Bold italic = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

Table A.19. Monitoring Wells and Constituents for the Liquid Effluent Retention Facility (adapted from WHC-SD-EN-AP-024)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E26-10^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E26-11^{89}	Top of unconfined	Quarterly	Semiannual	RCRA

Contamination Indicator Parameters(a)	Site-Specific Parameters	
pH (field)	Alkalinity(b)	ICP metals (filtered)(b)
Specific conductance (field)	Ammonium(b)	Phenols(b)
Total organic carbon	Anions(b)	Temperature
Total organic halides	Gross alpha(b)	Turbidity
	Gross beta(b)	Volatile organic compounds

(a) Statistical evaluations suspended in January 2001 because only one downgradient well is not dry.

(b) Analyzed annually.

Bold italic = Upgradient well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.20. Monitoring Wells and Constituents for Low-Level Waste Management Area 1 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E28-26^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E28-27^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E28-28^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-2^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-3^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-4^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-5^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-6^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-7^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-8^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-9^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E32-10^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-28^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-29^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-30^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-34^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E33-35^{90}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters

pH (field)
Specific conductance (field)
Total organic carbon
Total organic halides

Site-Specific Parameters

Alkalinity
Anions
Gross alpha
Gross beta
ICP metals (filtered)
Lead (filtered)
Mercury (filtered)
Phenols(a)
Tritium
Turbidity
Uranium

(a) Analyzed annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.21. Critical Means for Low-Level Waste Management Area 1 for Fiscal Year 2002 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	28	27	4.1542	427.643	38.497	590.4	590.4
Field pH	28	27	4.4138	8.06	0.156	[7.36, 8.76]	[7.36, 8.76]
Total organic carbon,(b) µg/L	28	27	4.1542	458.214	256.4	1,542.2	1,542.2
Total organic halides,(b,c) µg/L	28(d)	27	4.1542	2.608	0.830	6.1	15.1

(a) Based on semiannual sampling events from December 1999 to June 2001 for upgradient wells 299-E28-26, 299-E28-27, 299-E28-28, 299-E32-4, 299-E33-28, 299-E33-29, and 299-E33-35.
(b) Critical mean calculated from values reported below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recent determined limit of quantitation (see Table B.22).
(d) Excluding one unrepresentative measurement of 352 µg/L collected from well 299-E33-28 on June 5, 2001.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 68 comparisons.

Table A.22. Monitoring Wells and Constituents for Low-Level Waste Management Area 2 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E27-8^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-9^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-10^{90}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-11^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E27-17^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-2^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-3^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-5$^{87(a)}$	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-7^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-9^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-10^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-11^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E34-12^{92}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters

pH (field)
Specific conductance (field)
Total organic carbon
Total organic halides

Site-Specific Parameters

Alkalinity
Anions
Gross alpha
Gross beta
ICP metals (filtered)
Lead (filtered)
Mercury (filtered)
Phenols[(b)]
Polychlorinated biphenyls
Tritium
Turbidity

(a) Used for supplemental information; no statistical evaluation.
(b) Analyzed annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.23. Critical Means for Low-Level Waste Management Area 2 for Fiscal Year 2002 Comparisons[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, μS/cm	9	8	5.7760	530.0	64.793	924.5	924.5
Field pH	9	8	6.4036	8.1542	0.110	[7.41, 8.90]	[7.41, 8.90]
Total organic carbon, μg/L	9	8	5.7760	567.167	267.020	2,192.9	2,192.9
Total organic halides,[(b,c)] μg/L	9	8	5.7760	2.925	1.045	9.3	15.1

(a) Based on semiannual sampling events from April 1999 to April 2001 for upgradient wells 299-E27-10 and 299-E34-3. Data from well 299-E34-7 are excluded due to elevated levels of all indicator parameters.
(b) Critical mean calculated from values below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recent determined limit of quantitation (see Table B.22).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 48 comparisons.

Table A.24. Monitoring Wells and Constituents for Low-Level Waste Management Area 3 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W7-1^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-3^{87}(a)	Deep unconfined	Semiannual	Semiannual	RCRA
299-W7-4^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-5^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-6^{87}(b)	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-7^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-8^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-9^{90}(b)	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-11^{91}(c)	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-12^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W8-1^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W10-13^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W10-14^{87}(a)	Deep unconfined	Semiannual	Semiannual	RCRA
299-W10-19^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W10-20^{93}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W10-21^{93}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters

- pH (field)
- Specific conductance (field)
- Total organic carbon
- Total organic halides

Site-Specific Parameters

- Alkalinity
- Anions
- Gross alpha
- Gross beta
- ICP metals (filtered)
- Lead (filtered)
- Mercury (filtered)
- Phenols
- Tritium
- Turbidity
- Volatile organic compounds

(a) Used for supplemental information; no statistical evaluations.
(b) Dry well; last sampled March 2001.
(c) Dry well; last sampled September 2001.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.25. Critical Means for Low-Level Waste Management Area 3 (area not affected by upgradient contamination) for Fiscal Year 2002 Comparisons[a]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	6	5	7.1466	590.458	55.308	1,017.4	1,017.4
Field pH	6	5	8.2913	8.208	0.084	[7.46, 8.96]	[7.46, 8.96]
Total organic carbon,[b] µg/L	6	5	7.1466	458.375	215.428	2,121.3	2,121.3
Total organic halides, µg/L	6	5	7.1466	8.223	4.186	40.5	40.5

(a) Based on semiannual sampling events from March 1999 to September 2001 for upgradient well 299-W10-13. Critical means calculated for area not impacted by upgradient source of contamination.
(b) Critical means calculated from values reported below vendor's specified method detection limit.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 24 comparisons.

Table A.26. Critical Means for Low-Level Waste Management Area 3 (area affected by upgradient contamination) for Fiscal Year 2002 Comparisons[a]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	12	11	4.6425	523.048	84.169	929.8	929.8
Field pH	12	11	5.0765	8.102	0.154	[7.29, 8.92]	[7.29, 8.92]
Total organic carbon,[b,c] µg/L	12	11	4.6425	377.167	190.394	1,297.2	1,450.1
Total organic halides, µg/L	12	11	4.6425	379.988	238.759	1,533.7	1,533.7

(a) Based on semiannual events from October 1999 to March 2001 for upgradient wells 299-W10-19, 299-W10-20, and 299-W10-21. Critical means calculated for area impacted by upgradient source of contamination.
(b) Critical means calculated from values reported below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recent determined limit of quantitation (see Table B.22).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 28 comparisons.

Table A.27. Monitoring Wells and Constituents for Low-Level Waste Management Area 4 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W15-15^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W15-16^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W15-17^{87}[a]	Deep unconfined	Semiannual	Semiannual	RCRA
299-W18-21^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W18-22^{87}[a]	Deep unconfined	Semiannual	Semiannual	RCRA
299-W18-23^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
299-W18-24^{87}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters

- pH (field)
- Specific conductance (field)
- Total organic carbon
- Total organic halides

Site-Specific Parameters

- Alkalinity
- Anions
- Gross alpha
- Gross beta
- ICP metals (filtered)
- Iodine-129[c]
- Lead (filtered)
- Mercury (filtered)
- Phenols
- Technetium-99[b]
- Tritium
- Turbidity
- Volatile organic compounds

(a) Used for supplemental information; no statistical evaluations.
(b) Selected wells.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.28. Critical Means for Low-Level Waste Management Area 4 for Fiscal Year 2002 Comparisons[a]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance,[b] µS/cm	10	9	4.7815	431.945	80.188	834.1	834.1
Field pH	12	11	4.8638	7.935	0.139	[7.23, 8.64]	[7.23, 8.64]
Total organic carbon,[c] µg/L	12	11	4.4375	486.458	243.990	1,613.4	1,613.4
Total organic halides, µg/L	12	11	4.4375	49.271	25.9	168.9	168.9

(a) Based on semiannual sampling events from January 2000 to July 2001 for upgradient wells 299-W15-15, 299-W18-21, and 299-W18-23.
(b) Excluding outliers.
(c) Critical means calculated using data below vendor's specified method detection limit.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 20 comparisons.

Table A.29. Monitoring Wells and Constituents for the Nonradioactive Dangerous Waste Landfill (adapted from PNNL-12227)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
699-25-33A^{87}(a)	Top of LPU(b)	Semiannual	Semiannual	RCRA
699-25-34A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
699-25-34B^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
699-25-34D^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
699-26-33^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
699-26-34A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
699-26-34B^{92}	Top of unconfined	Semiannual	Semiannual	RCRA
699-26-35A^{86}	Top of unconfined	Semiannual	Semiannual	RCRA
699-26-35C^{87}(a)	Top of LPU(a)	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH (field)	Anions	Turbidity
Specific conductance (field)	ICP metals (filtered)	Volatile chlorinated hydrocarbons
Total organic carbon	Phenols(c)	
Total organic halides		

(a) Used for supplemental information; no statistical evaluation.
(b) Low-permeability unit in upper Ringold Formation.
(c) Analyzed annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.30. Critical Means for Nonradioactive Dangerous Waste Landfill for Fiscal Year 2002 Comparisons(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, μS/cm	10	9	5.0255	522.25	8.358	566.3	566.3
Field pH	10	9	5.5489	7.320	0.162	[6.38, 8.26]	[6.38, 8.26]
Total organic carbon,(b) µg/L	10	9	5.0255	412.5	244.841	1,703.0	1,703.0
Total organic halides,(b,c) µg/L	10	9	5.0255	3.621	2.071	14.5	15.1

(a) Based on semiannual sampling events from February 2000 to August 2001 for upgradient wells 699-26-34A and 699-26-35A.
(b) Critical means calculated from values reported below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recent determined limit of quantitation (see Table B.22).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 28 comparisons.

Table A.31. Monitoring Wells and Constituents for PUREX Cribs 216-A-10, 216-A-36B, and 216-A-37-1 (adapted from PNNL-11523)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
Upgradient Wells				
299-E24-18^{88}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E25-31^{87}	Top of unconfined	Semiannual	Semiannual	RCRA
Near-Field Wells – 216-A-10 Crib				
299-E17-1^{55}	Top of unconfined	Semiannual	Semiannual	PRE
299-E17-19^{88}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E24-16^{88}	Top of unconfined	Quarterly	Quarterly	RCRA
Near-Field Wells – 216-A-36B Crib				
299-E17-9^{68}	Top of unconfined	Semiannual	Semiannual	PRE
299-E17-14^{88}	Top of unconfined	Quarterly	Quarterly	RCRA
299-E17-18^{88}	Top of unconfined	Semiannual	Semiannual	RCRA
Near-Field Wells – 216-A-37-1 Crib				
299-E25-17^{76}	Top of unconfined	Semiannual	Semiannual	PRE
299-E25-19^{76}	Top of unconfined	Quarterly	Quarterly	PRE
699-37-47A^{96}	Top of unconfined	Semiannual	Semiannual	RCRA
Far-Field Wells				
57 wells	Unconfined	Triannual(a)	Triannual(a)	RCRA, PRE

Contamination Indicator Parameters

pH (field)(b)
Specific conductance (field)(b)

Site-Specific Parameters

Alkalinity
Ammonium ion
Anions(b)
Arsenic (filtered)
Gross alpha
Gross beta
ICP metals (filtered)
Iodine-129(b)
Phenols
Strontium-90
Tritium(b)
Turbidity(b)

(a) Some far-field wells sampled annually.
(b) Far-field wells analyzed for these constituents only.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
PUREX = Plutonium uranium extraction (plant).
RCRA = Well constructed to RCRA standards.

Table A.32. Monitoring Wells and Constituents for Waste Management Area A-AX (adapted from PNNL-13023)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E24-19^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E24-20^{91}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E25-40^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E25-41^{89}	Top of unconfined	Semiannual	Semiannual	RCRA
299-E25-46^{92}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH (field)	Alkalinity	Technetium-99
Specific conductance (field)	Anions	Tritium$^{(a)}$
Total organic carbon	ICP metals (filtered)	Turbidity
Total organic halides	Phenols$^{(a)}$	Uranium

(a) Annually.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.33. Critical Means for Waste Management Area A-AX for Fiscal Year 2002 Comparisons$^{(a)}$

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.4079	353.375	15.651	443.2	443.2
Field pH	8	7	6.0818	8.111	0.086	[7.55, 8.67]	[7.55, 8.67]
Total organic carbon,$^{(b,c)}$ µg/L	8	7	5.4079	525.0	129.629	1,268.5	1,450.1
Total organic halides,$^{(b,c)}$ µg/L	8	7	5.4079	2.439	0.767	6.8	15.1

(a) Based on semiannual sampling events from February 2000 to July 2001 for upgradient wells 299-E25-40 and 299-E25-41.
(b) Critical mean calculated from values reported below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recent determined limit of quantitation (see Table B.22).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 20 comparisons.

Table A.34. Monitoring Wells and Constituents for Waste Management Area B-BX-BY (adapted from PNNL-13022)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
		Near-Field Wells		
299-E28-8^{57}	Unconfined	Semiannual	Quarterly	PRE
299-E33-7^{55}	Unconfined	Quarterly	Quarterly	PRE
299-E33-9^{49}	Unconfined	Quarterly	Quarterly	PRE
299-E33-15^{53}	Unconfined	Semiannual	Quarterly	PRE
299-E33-16^{53}	Unconfined	Semiannual	Quarterly	PRE
299-E33-17^{53}	Unconfined	Annual	Quarterly	PRE
299-E33-18^{50}	Unconfined	Quarterly	Quarterly	PRE
299-E33-20^{56}	Unconfined	Semiannual	Quarterly	PRE
299-E33-21^{57}	Unconfined	Semiannual	Quarterly	PRE
299-E33-31^{89}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-32^{89}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-33^{89}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-36^{90}	Unconfined	Annual	Quarterly	RCRA
299-E33-38^{91}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-39^{91}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-41^{91}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-42^{91}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-43^{91}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-44^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-334^{00}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-335^{00}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-337^{01}	Unconfined	Annual(a)	Annual	RCRA
299-E33-338^{01}	Unconfined	Annual(a)	Annual	RCRA
299-E33-339^{01}	Unconfined	Annual(a)	Annual	RCRA
		Far-Field Wells(b)		
299-E28-27^{87}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-26^{69}	Unconfined	Quarterly	Quarterly	PRE
299-E33-28^{87}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-29^{87}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-34^{90}	Unconfined	Quarterly	Quarterly	RCRA
299-E33-35^{90}	Unconfined	Quarterly	Quarterly	RCRA
		Supplemental Far-Field Wells(b)		
299-E28-26^{87}	Unconfined	Variable	Semiannual	RCRA
299-E28-28^{90}	Unconfined	Variable	Semiannual	RCRA
299-E32-2^{87}	Unconfined	Variable	Semiannual	RCRA
299-E32-3^{87}	Unconfined	Variable	Semiannual	RCRA
299-E32-4^{87}	Unconfined	Variable	Semiannual	RCRA
299-E32-5^{89}	Unconfined	Variable	Semiannual	RCRA
299-E32-6^{91}	Unconfined	Variable	Semiannual	RCRA
299-E32-7^{91}	Unconfined	Variable	Semiannual	RCRA
299-E32-8^{91}	Unconfined	Variable	Semiannual	RCRA
299-E32-9^{91}	Unconfined	Variable	Semiannual	RCRA
299-E32-10^{92}	Unconfined	Variable	Semiannual	RCRA
299-E33-30^{87}	Unconfined	Variable	Semiannual	RCRA

Contamination Indicator Parameters	Site-Specific Parameters(c)	
pH	Alkalinity	Low-level gamma (cobalt-60)
Specific conductance	Anions (nitrate, nitrite)	Strontium-90
Total organic carbon	Cyanide	Technetium-99
Total organic halides	Gross alpha	Total dissolved solids
	Gross beta	Tritium
	ICP metals (filtered)	Turbidity
	Iodine-129	Uranium

(a) New wells sampled once in fiscal year 2001. Will be sampled quarterly in fiscal year 2002.
(b) Far-field wells sampled routinely; supplemental wells sampled periodically for key constituents only.
(c) Constituent list varies by well.

Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.35. Monitoring Wells and Constituents for Waste Management Area C (adapted from PNNL-13024)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-E27-7$^{82(a)}$	Top of unconfined	Semiannual	Quarterly	PRE
299-E27-12^{89}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E27-13^{89}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E27-14^{89}	Top of unconfined	Semiannual	Quarterly	RCRA
299-E27-15^{89}	Top of unconfined	Semiannual	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH (field)	Alkalinity	Technetium-99
Specific conductance (field)	Anions	Total uranium
Total organic carbon	Cyanide	Tritium
Total organic halides	ICP metals (filtered)	Turbidity
	Phenols	

(a) Used for supplemental information; no statistical evaluation.

Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.36. Critical Means for Waste Management Area C for Fiscal Year 2002 Comparisons[(a)]

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	4	3	11.9838	523.05	77.478	1,212.4	1,212.4
Field pH	5	4	8.1216	8.264	0.128	[6.90, 9.63]	[6.90, 9.63]
Total organic carbon, µg/L	4	3	11.9838	676.25	69.597	1,608.7	1,608.7
Total organic halides,[(b,c)] µg/L	4	3	11.9838	3.272	0.815	14.2	15.1

(a) Based on semiannual sampling events from June 2000 to September 2001 for upgradient well 299-E27-14.
(b) Critical mean calculated from values reported below vendor's specified method detection limit.
(c) Upgradient/downgradient comparison value is the most recent determined limit of quantitation (see Table B.22).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table A.37. Monitoring Wells and Constituents for Waste Management Area S-SX (adapted from PNNL-12114)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W22-44^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-45^{92}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-46^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-48^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-49^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-50^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-80^{00}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-81^{00}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-82^{00}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-83^{00}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W22-84^{01}	Top of unconfined	Quarterly(a)	Quarterly	RCRA
299-W22-85^{01}	Top of unconfined	Quarterly(a)	Quarterly	RCRA
299-W23-15^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W23-19^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W23-20^{00}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W23-21^{00}	Top of unconfined	Quarterly	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters(b)	
pH (field)	Alkalinity	Technetium-99
Specific conductance (field)	Anions	Total dissolved solids
	Gamma scan (cesium-137)	Tritium
	Hexavalent chromium	Turbidity
	ICP metals (filtered)	Uranium
	Strontium-90	

(a) New wells will be sampled quarterly in fiscal year 2002.

(b) Constituent list varies by well. Well 299-W23-19 sampled quarterly for all constituents listed. All other wells include gamma scan (cesium-137) and strontium-90 annually.

Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.38. Monitoring Wells and Constituents for Waste Management Area T (adapted from PNNL-12057)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W10-1^{47}	Unconfined	Semiannual	Semiannual	PRE
299-W10-4^{52}	Unconfined	Quarterly	Quarterly	PRE
299-W10-8^{73}	Top of unconfined	Quarterly	Quarterly	PRE
299-W10-22^{94}	Unconfined	Quarterly	Quarterly	RCRA
299-W10-23^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-W10-24^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-W10-28^{01}	Unconfined	Quarterly(a)	Quarterly(a)	RCRA
299-W11-7^{51}	Unconfined	Semiannual	Semiannual	PRE
299-W11-12^{53}	Unconfined	Quarterly	Quarterly	PRE
299-W11-23^{73}	Top of unconfined	Quarterly	Quarterly	PRE
299-W11-24^{73}	Top of unconfined	Dry(b)	Dry	PRE
299-W11-28^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W11-39^{00}	Unconfined	Quarterly	Quarterly	RCRA
299-W11-40^{00}	Unconfined	Quarterly	Quarterly	RCRA
299-W11-41^{00}	Unconfined	Quarterly	Quarterly	RCRA
299-W11-42^{00}	Unconfined	Quarterly	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters(c)	
pH	Alkalinity	Iodine-129
Specific conductance	Anions	Strontium-90
	Gamma scan (cesium-137, cobalt-60)	Technetium-99
		Tritium
	Gross alpha	Turbidity
	ICP metals (filtered)	Volatile organic compounds

(a) New wells will be sampled quarterly in fiscal year 2002.
(b) Dry well; last sampled February 2001.
(c) Constituent list varies by well.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.39. Monitoring Wells and Constituents for Waste Management Area TX-TY (adapted from PNNL-12072)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W10-17^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W10-26^{99}	Unconfined	Quarterly	Quarterly	RCRA
299-W10-27^{01}	Unconfined	Quarterly	Quarterly	RCRA
299-W14-2^{55}	Unconfined	Dry(a)	Dry	PRE
299-W14-5^{74}	Unconfined	Quarterly	Quarterly	PRE
299-W14-6^{74}	Unconfined	Quarterly	Quarterly	PRE
299-W14-13^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-W14-14^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-W14-15^{00}	Unconfined	Quarterly	Quarterly	RCRA
299-W14-16^{00}	Unconfined	Quarterly(b)	Quarterly	RCRA
299-W14-17^{00}	Unconfined	Quarterly(b)	Quarterly	RCRA
299-W14-18^{02}	Unconfined	Quarterly(b)	Quarterly	RCRA
299-W15-40^{98}	Unconfined	Quarterly	Quarterly	RCRA
299-W15-41^{00}	Unconfined	Quarterly	Quarterly	RCRA
299-W15-763^{01}	Unconfined	Quarterly	Quarterly	RCRA
299-W15-765^{02}	Unconfined	Quarterly(b)	Quarterly(b)	RCRA

Contamination Indicator Parameters

- pH (field)
- Specific conductance (field)

Site-Specific Parameters

- Alkalinity
- Anions
- Gamma scan (cesium-137, cobalt-60)
- Gross alpha
- ICP metals (filtered)
- Iodine-129
- Strontium-90(c)
- Technetium-99
- Tritium
- Turbidity
- Volatile organic compounds(c)

(a) Dry well; last sampled February 2001.
(b) New wells will be sampled quarterly in fiscal year 2002.
(c) Limited wells.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.40. Monitoring Wells and Constituents for Waste Management Area U (adapted from PNNL-13612)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W18-30^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W18-31^{91}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W18-40^{01}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W19-12^{83}(a)	Top of unconfined	Quarterly	Quarterly	PRE
299-W19-41^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W19-42^{99}	Top of unconfined	Quarterly	Quarterly	RCRA
299-W19-44^{01}	Top of unconfined	Quarterly(b)	Quarterly	RCRA
299-W19-45^{01}	Top of unconfined	Quarterly(b)	Quarterly	RCRA

Contamination Indicator Parameters	Site-Specific Parameters	
pH (field)	Alkalinity	Iodine-129(c)
Specific conductance (field)	Anions	Technetium-99
	Gamma scan(c)	Tritium(c)
	Gross alpha(c)	Volatile organic compounds(c)
	ICP metals (filtered)	

(a) Used for supplemental information; no statistical evaluations.
(b) New wells will be sampled quarterly in fiscal year 2002.
(c) Annually.

Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.41. Monitoring Wells and Constituents for the 100 KE and 100 KW Basins (adapted from WHC-SD-EN-AP-174)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
199-K-27^{79}	Top of unconfined	Monthly	Monthly	PRE
199-K-28$^{79(a)}$	Top of unconfined	Quarterly	Quarterly	PRE
199-K-29^{79}	Top of unconfined	Quarterly	Quarterly	PRE
199-K-30^{79}	Top of unconfined	Monthly	Monthly	PRE
199-K-32A^{92}	Top of unconfined	Quarterly	Quarterly	RCRA
199-K-34^{92}	Top of unconfined	Quarterly	Quarterly	RCRA
199-K-106A^{94}	Top of unconfined	Monthly	Monthly	RCRA
199-K-107A^{94}	Top of unconfined	Quarterly	Quarterly	RCRA
199-K-108A^{94}	Top of unconfined	Quarterly	Quarterly	RCRA
199-K-109A^{94}	Top of unconfined	Monthly	Quarterly	RCRA
199-K-110A^{94}	Top of unconfined	Quarterly	Quarterly	RCRA
199-K-111A^{94}	Top of unconfined	Quarterly	Quarterly	RCRA

Field Parameters$^{(b)}$		Site-Specific Parameters$^{(b)}$	
pH	Redox potential	Anions	ICP metals (filtered)
Specific conductance	Temperature	Carbon-14	Strontium-90
Dissolved oxygen	Turbidity	Gross alpha	Technetium-99
		Gross beta	Tritium

(a) Well 199-K-28 was decommissioned in October 2001.
(b) Frequency of parameter measurements varies.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.42. Monitoring Wells, Constituents, and Enforcement Limits for the 200 Areas Treated Effluent Disposal Facility (adapted from PNNL-13032)

Well	Hydrogeologic Unit	Sampling Frequency	Water-Level Measurement	Well Standard
699-40-36^{92}	Ringold confined	Quarterly	Quarterly	RCRA
699-41-35^{92}	Ringold confined	Quarterly	Quarterly	RCRA
699-42-37^{92}	Ringold confined	Quarterly	Quarterly	RCRA

Constituent$^{(a)}$	Enforcement Limit (μg/L)
Cadmium	5
Lead	10
pH	6.5 - 8.5 pH units

(a) Also monitored for ICP metals, anions, trace metals, alkalinity, specific conductance, total dissolved solids, turbidity, gross alpha, gross beta, and low-level tritium (annually). No enforcement limits for those constituents.
Bold italic = Upgradient well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.

Table A.43. Monitoring Wells, Constituents, and Enforcement Limits for the 400 Area Process Ponds (specified in state waste discharge permit)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
699-2-6A^{97}	Unconfined aquifer	Quarterly	Quarterly	RCRA
699-2-7^{78}	Unconfined aquifer	Quarterly	Quarterly	PRE
699-8-17^{50}	Unconfined aquifer	Quarterly	Quarterly	PRE

Constituent	Enforcement Limit (μg/L)(a,b)
Cadmium (unfiltered)	10
Chromium (unfiltered)	50
Lead (unfiltered)	50
Manganese (unfiltered)	50
Mercury (unfiltered)	2
pH	Monitor only
Sulfate	Monitor only
Total organic carbon	Monitor only

(a) Defined as the average of four quarterly measurements from a well. Average to be calculated using the four most recent quarterly measurements from a well.

(b) Enforcement limit in groundwater shall be met in point-of-compliance well 699-2-7.

Bold italic = Upgradient well.
Superscript = Year of installation.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.44. Monitoring Wells and Constituents for the Environmental Restoration Disposal Facility (adapted from BHI-00873)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
699-35-66A^{57}	Top of unconfined	Semiannual	Semiannual	PRE
699-36-67^{96}	Top of unconfined	Semiannual	Semiannual	RCRA
699-36-70^{94}	Top of unconfined	Semiannual	Semiannual	RCRA
699-37-68^{96}	Top of unconfined	Semiannual	Semiannual	RCRA

Contamination Indicator Parameters

pH (field)
Specific conductance (field)
Turbidity

Site-Specific Parameters

Alkalinity
Anions
Arsenic (filtered)
Carbon-14
Carbon tetrachloride
Gross alpha
Gross beta
ICP metals (filtered)
Iodine-129
Radium
Technetium-99
Total dissolved solids
Total organic halides
Uranium

Bold italic = Upgradient well.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.45. Monitoring Wells and Constituents for the Solid Waste Landfill (adapted from PNNL-13014)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
699-22-35^{93}	Top of unconfined	Quarterly	Quarterly	RCRA
699-23-34A^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-23-34B^{93}	Top of unconfined	Quarterly	Quarterly	RCRA
699-24-33^{48}(a)	Top of unconfined	Quarterly(b)	Quarterly	PRE
699-24-34A^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-24-34B^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-24-34C^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-24-35^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-25-34C^{87}	Top of unconfined	Quarterly	Quarterly	RCRA
699-26-35A^{86}	Top of unconfined	Quarterly	Quarterly	RCRA

Parameters/Constituents Required by WAC 173-304-490		Site-Specific Parameters	
Ammonia as nitrogen	Nitrate	Anions	Volatile organic compounds
Chemical oxygen demand	Nitrite	ICP metals (filtered)	
Chloride	pH		
Specific conductance	Sulfate		
Dissolved iron	Temperature		
Dissolved zinc	Total coliform		
Manganese	Total organic carbon		

(a) Used for supplemental information; no statistical evaluations.
(b) Well sampled for supporting data.
Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.46. Sampling Results for Required Constituents[a] at the Solid Waste Landfill

Constituent, unit	Tolerance Interval[b]	Date	Well 699-22-35	Well 699-23-34A	Well 699-23-34B	Well 699-24-33	Well 699-24-34A	Well 699-24-34B[c]	Well 699-24-34C	Well 699-24-35	Well 699-25-34C[d]	Well 699-26-35A
Temperature, °C	20.7	October 2000	18.1	[e]	18.2	19.2	[e]	19	19.2	17.2	17.3	19.7
		February 2001	17.6	17.7	17.3	19.4	18.3	18.1	18.6	17.1	18.5	19.7
		May 2001	18.1	18.7	17.8	19.1	18	18.4	18.9	17.7	19.2	19.6
		August 2001	18.1	18.7	18.7	20	18.7	18.9	18.8	18	19.7	19.7
Specific conductance, µS/cm	583	October 2000	867[f]	[e]	800[f]	740[f]	[e]	703[f]	742[f]	586[f]	668[f]	527
		February 2001	867[f]	708[f]	805[f]	756[f]	698[f]	692[f]	743[f]	541	669[f]	522
		May 2001	864[f]	725[f]	814[f]	726[f]	689[f]	710[f]	707[f]	577[f]	650[f]	526
		August 2001	850[f]	726[f]	794[f]	764[f]	690[f]	704[f]	741[f]	607[f]	668[f]	533
Field pH	[6.68, 7.84]	October 2000	7.12	[e]	6.68	6.9	[e]	6.7	6.94	6.87	7.53	7.29
		February 2001	6.85	6.5[f]	6.63[f]	6.84	6.61[f]	6.64[f]	7.4	6.88	7.09	7.25
		May 2001	6.98	6.8	6.66[f]	6.88	6.67[f]	6.66[f]	6.93	6.82	7.3	7.2
		August 2001	6.77	6.56[f]	6.67[f]	6.89	6.68	6.67[f]	6.93	6.83	6.91	7.72
Total organic carbon, µg/L	1,450	October 2000	<200[g]	[e]	<220	540	[e]	230	<220	280	<220	260
	February 2001	360	260	<220	<220	<220	310	<220	520	680	660	
		May 2001	350	56,200[f]	1,300[f]	460	750	1,100	810	370	880	480
		August 2001	190	280	210	130	290	270	170	230	260	150
Chloride, µg/L	7,820	October 2000	5,900	[e]	6,000	6,100	[e]	5,500	6,000	5,400	7,500	6,800
		February 2001	6,900	6,900	7,000	7,500	6,800	6,700	7,300	6,400	8,100[f]	7,600
		May 2001	7,200	6,600	6,700	4,100	6,700	7,000	6,900	6,100	8,300[f]	7,600
		August 2001	6,100	5,600	6,100	6,400	5,900	5,800	6,500	5,800	8,000[f]	6,800
Nitrate, µg/L	29,000	October 2000	14,600	[e]	14,600	14,200	[e]	12,400	14,200	10,600	17,300	19,000
		February 2001	13,700	10,600	13,300	12,800	10,200	12,400	12,400	10,200	17,300	16,800
		May 2001	14,600	11,500	13,700	13,300	10,600	12,000	12,400	9,740	16,800	17,500
		August 2001	15,100	12,400	15,100	13,700	12,000	12,400	13,700	11,100	16,400	17,700
Nitrite, µg/L	359	October 2000	<24.3	[e]	<24.3	<24.3	[e]	<24.3	<24.3	<24.3	<24.3	<24.3
		February 2001	<24.3	<24.3	<24.3	<24.3	<24.3	<24.3	<24.3	<24.3	<24.3	<24.3
		May 2001	<6.6	<6.6	<6.6	<6.6	<6.6	<6.6	<6.6	<6.6	<6.6	<6.6
		August 2001	<6.6	<6.6	<6.6	<6.6	<6.6	<6.6	<6.6	<6.6	<6.6	<6.6
Ammonium, µg/L	90	October 2000	<30.1	[e]	<30.1	<30.1	[e]	<30.1	<30.1	<30.1	<30.1	<30.1
		February 2001	<30.1	<30.1	<30.1	<30.1	<30.1	<30.1	<30.1	<30.1	<30.1	<30.1
		May 2001	98.9	<12.9	52	<12.9	57.6	<12.9	57.1	68	62	<12.9
		August 2001	<12.9	<12.9	<12.9	<12.9	<12.9	<12.9	<12.9	<12.9	<12.9	<12.9
Sulfate, µg/L	47,200	October 2000	54,000[f]	[e]	53,600[f]	40,200	[e]	43,300	40,600	45,000	41,900	39,700
		February 2001	51,300[f]	45,800	50,600[f]	40,300	43,600	43,100	39,900	44,900	41,900	40,300
		May 2001	51,700[f]	46,500	49,800[f]	41,100	43,300	45,300	37,900	44,300	42,300	39,200
		August 2001	52,700[f]	48,600[f]	52,200[f]	42,900	46,000	45,600	41,400	47,400	43,500	40,100

Table A.46. (contd)

Constituent, unit	Tolerance Interval(b)	Date	Well 699-22-35	Well 699-23-34A	Well 699-23-34B	Well 699-24-33	Well 699-24-34A	Well 699-24-34B(c)	Well 699-24-34C	Well 699-24-35	Well 699-25-34C(d)	Well 699-26-35A
Iron, filtered, μg/L	160	October 2000	<34.9	(e)	<34.9	<34.9	(e)	<34.9	<34.9	<34.9	<34.9	<34.9
		February 2001	<20.4	77	50.7	37.5	49	<14.5	43.9	40	23.5	<20.4
		May 2001	15.4	<14.5	15.3	<14.5	20.5	<14.5	<14.5	<14.5	<14.5	36.2
		August 2001	<20.5	<20.5	<20.5	<20.5	27.6	32	27	23.5	28.3	<20.5
Zinc, filtered, μg/L	34.9	October 2000	<14.3	(e)	<14.3	<14.3	(e)	<14.3	<14.3	<14.3	15.7	<14.3
		February 2001	<7.1	<7.1	<7.1	12.3	<7.1	<6	<7.1	<7.1	<6	<7.1
		May 2001	<6	<6	<6	16.9	<6	<6	7.2	<6	<6	6.3
		August 2001	1.6	1.7	0.79	17.4	3	1.7	6.6	4.3	5.7	4.3
Manganese, filtered,	10	October 2000	<1.2	(e)	<1.2	<1.2	(e)	<1.2	<1.2	<1.2	<1.2	<1.2
μg/L	February 2001	<2.9	<2.9	<2.9	<2.9	<2.9	<34	<2.9	<2.9	0.37	<2.9	
		May 2001	<34	0.6	<34	0.59	0.97	<34	<34	0.89	<34	1.5
		August 2001	<22	<22	<22	<22	0.64	<22	<22	0.42	0.41	<22
Chemical oxygen demand, mg/L	5	October 2000	<3.1	(e)	<3.1	<3.1	(e)	<3.1	<3.1	<3.1	5	<3.1
		February 2001	<3.1	<3.1	<3.1	<3.1	<3.1	<3.9	<3.1	<3.1	<3.9	<3.1
		May 2001	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9
		August 2001	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9
Coliform bacteria, Col/100 ml	3.7	October 2000	0	(e)	5(f)	0	(e)	31(f)	0	315(f)	1(f)	0
		February 2001	0	0	0	0	0	0	0	0	0	0
		May 2001	0	0	0	0	0	0	0	0	0	0
		August 2001	0	0	0	0	0	0	0	0	0	0

(a) WAC 173-304.
(b) Number obtained from Table A.47, background threshold value column.
(c) Well actually sampled April 2001.
(d) Well actually sampled March 2001.
(e) Sample not collected.
(f) Exceeding background threshold values.
(g) < = Data values less than the method of detection limit; number given is the respective limit.

Table A.47. Results of Shapiro and Francia Test for Normality and Background Threshold Values for the Solid Waste Landfill

Constituent,(a) unit	Test Statistic, W' Log Value	Test Statistic, W' Raw Data	Critical Value,(b) W'α	Upper Tolerance Limit	Background Threshold Value
Temperature, °C	0.953 s	0.961 s	0.963	20.7(c)	20.7
Specific conductance, µS/cm	0.978 ns	NA	0.960	583(d)	583
Field pH	0.988 ns	NA	0.963	[6.68, 7.84](d)	[6.68, 7.84]
Total organic carbon, µg/L	NC	NC	NC	842(c) 1,143(e)	1,143
Chloride, µg/L	0.954 s	0.962 s	0.963	7,820(c)	7,820
Nitrate (as NO_3^-), µg/L	0.833 s	0.844 s	0.963	29,000(c)	29,000
Nitrite (as NO_2^-), µg/L	NC	NC	NC	359(f)	359
Ammonium (as NH_3^-) , µg/L	NC	NC	NC	90(c) 74.6(f)	90
Sulfate, µg/L	0.983 ns	NA	0.963	47,200(d)	47,200
Iron, dissolved, µg/L	0.960 s	0.802 s	0.962	160(c) 137(f)	160
Zinc, dissolved, µg/L	NC	NC	NC	34.9(e) 19(f)	34.9
Manganese, dissolved, µg/L	NC	NC	NC	10(e) 2.3(f)	10
Coliform bacteria, colonies/100 ml	NC	NC	NC	3.7(g)	3.7
Chemical oxygen demand, µg/L	NC	NC	NC	5,000(g)	5,000

(a) Constituents are specified in WAC 173-304-490(2)(d). Data collected from March 1993 to May 2000 from upgradient well 699-24-35 and 699-26-35A.
(b) Obtained from Table A-9 (Shapiro 1980) for α = 5%.
(c) Maximum value reported.
(d) Based on log-normal distribution.
(e) Based on limit of quantitation using field blank data for the second quarter of fiscal year 2000.
(f) Based on limit of quantitation using method detection limit (see Table B.23).
(g) Based on laboratory practical quantitation limit.
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.

Table A.48. Monitoring Wells, Constituents, and Enforcement Limits for the State-Approved Land Disposal Site (adapted from PNNL-13121)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard
299-W6-6$^{(91)}$	Bottom of unconfined	Annual	Annual	RCRA
299-W6-7$^{(91)}$	Top of unconfined	Annual	Annual	RCRA
299-W6-8$^{(91)}$	Top of unconfined	Annual	Annual	RCRA
299-W6-11$^{(92)}$	Top of unconfined	Annual	Annual	RCRA
299-W6-12$^{(92)}$	Top of unconfined	Annual	Annual	RCRA
299-W7-1$^{(87)}$	Top of unconfined	Annual	Annual	RCRA
299-W7-3$^{(87)}$	Bottom of unconfined	Semiannual	Semiannual	RCRA
299-W7-5$^{(87)}$	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-6$^{(87)}$	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-7$^{(89)}$	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-8$^{(89)}$	Top of unconfined	Annual	Annual	RCRA
299-W7-9$^{(90)}$	Top of unconfined	Annual	Annual	RCRA
299-W7-11$^{(91)}$	Top of unconfined	Semiannual	Semiannual	RCRA
299-W7-12$^{(91)}$	Top of unconfined	Annual	Annual	RCRA
299-W8-1$^{(87)}$	Top of unconfined	Annual	Monthly	RCRA
699-48-71$^{(56)}$	Unconfined	Annual	Annual	PRE
699-48-77A$^{(92)(a)}$	Ringold unit E; upper	Quarterly	Monthly	RCRA
699-48-77C$^{(94)(a)}$	Ringold unit E; mid to lower	Quarterly	Monthly	RCRA
699-48-77D$^{(94)(a)}$	Ringold unit E; upper	Quarterly	Monthly	RCRA
699-49-79$^{(48)}$	Top of unconfined	Annual	Annual	PRE
699-51-75$^{(57)}$	Top of unconfined	Semiannual	Semiannual	PRE
699-51-75P$^{(57)}$	Lower unconfined	Annual	Annual	PRE

Constituent	Enforcement Limit (μg/L)	Constituent	Enforcement Limit (μg/L)
Acetone	160	Lead, total	50
Benzene	5	Mercury, total	2
Cadmium, total	10	pH	6.5 - 8.5 pH units
Chloroform	6.2	Strontium-90	Monitor only
Copper, total	70	Sulfate	250,000
Gross alpha	Monitor only	Tetrahydrofuran	100
Gross beta	Monitor only	Total dissolved solids	500,000
		Tritium	Monitor only

(a) Monitored for full constituent list. Other wells analyzed for tritium only.
Superscript = Year of installation.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.49. Monitoring Results Exceeding Maximum Contaminant Levels by Geographic Region, Fiscal Year 2001

Constituent, units	Primary Maximum Contaminant Level (MCL)	Area with Wells Exceeding MCL	Number of Wells Exceeding MCL	Maximum Concentration in Groundwater
Antimony, μg/L (*filtered and unfiltered samples*)	6	100 B/C	2	7
		100 D	3	29
		100 H	1	19
		100 K	4	21
		200 East[(a)]	2	17
		200 West	1	7
Arsenic, μg/L (*filtered and unfiltered samples*)	10	100 D	5	22
		200 East	7	12
		200 West	1	23
Carbon tetrachloride, μg/L	5.0	200 West	83	7,400
Chloroform	100	200 West	1	160
Chromium, μg/L (*includes total and hexavalent chromium; filtered and unfiltered samples*)	100	Aq. Tubes	7	521
		100 D	53	4,750
		100 H	8	160
		100 K	19	1,332
		100 N	1	173
		200 East	1	1,640
		200 West	8	248
Cyanide, μg/L	200	200 East	3	423
cis-1,2 Dichloroethene, μg/L	70	300	1	190
Fluoride, mg/L	4.0	200 East	1	8.5
		200 West	2	4.9
		Richland North	1	15
		Basalt	1	8.5
Nitrate (as NO_3), mg/L	45	100 D	21	86
		100 F	10	158
		100 H	7	150
		100 K	7	160
		100 N	7	125
		200 East[(a)]	36	748
		200 West	74	1,300
		300	1	89
		400	1	87
		618-11	2	93
		Richland North	22	162
Nitrite (as NO_2), mg/L	3.3	100 D	2	8.3
		200 West	1	27
Trichloroethene, μg/L	5.0	100 F	3	16
		100 K	2	19
		200 West	23	21
		300	1	5.3
		Richland North	1	5.1

(a) Includes wells in the 600 Area affected by contaminants migrating from the 200 East Area.

Table A.50. Monitoring Results Exceeding Drinking Water Standards by Geographic Region, Fiscal Year 2001

Constituent, units	Drinking Water Standard (DWS)	DOE Derived Concentration Guide	Area with Wells Exceeding DWS	Number of Wells Exceeding DWS	Maximum Concentration in Groundwater
Carbon-14, pCi/L	2,000	70,000	100 K	5	16,300
Cesium-137, pCi/L	200	3,000	200 East	1	1,910
Gross alpha, pCi/L	15	NA	100 H	2	33
			200 East[(a)]	13	357
			200 West	2	18
			300	1	43
Gross beta, pCi/L	50	NA	100 B/C	2	270
			100 D	1	75
			100 F	1	80
			100 H	4	278
			100 K	6	8,670
			100 N	7	3,440
			200 East[(a)]	33	25,700
			200 West	33	28,700
			618-11	2	282
			Aq. Tubes	1	82
			Basalt	1	330
Iodine-129, pCi/L	1.0	500	200 East[(a)]	28	10
			200 West	12	64
Strontium-90, pCi/L	8.0	1,000	100 B/C	4	135
			100 D	1	12
			100 F	2	38
			100 H	3	38
			100 K	8	5,210
			100 N	17	9,690
			200 East[(a)]	5	12,000
			200 West	1	69
			Aq. Tubes	2	16
Technetium-99, pCi/L	900	100,000	200 East[(a)]	22	13,000
			200 West	16	81,500
			Basalt	1	1,120
Tritium, pCi/L	20,000	2,000,000	100 B/C	7	40,700
			100 F	1	38,600
			100 K	9	1,750,000
			100 N	12	36,900
			200 East	45	4,300,000
			200 West	28	1,540,000
			400	3	57,600
			618-11	8	8,370,000
Uranium, µg/L	30	790	100 H	2	49
			200 East[(a)]	13	678
			200 West	14	2,140
			300	11	205

(a) Includes wells in the 600 Area affected by contaminants migrating from the 200 East Area.
NA = Not applicable.

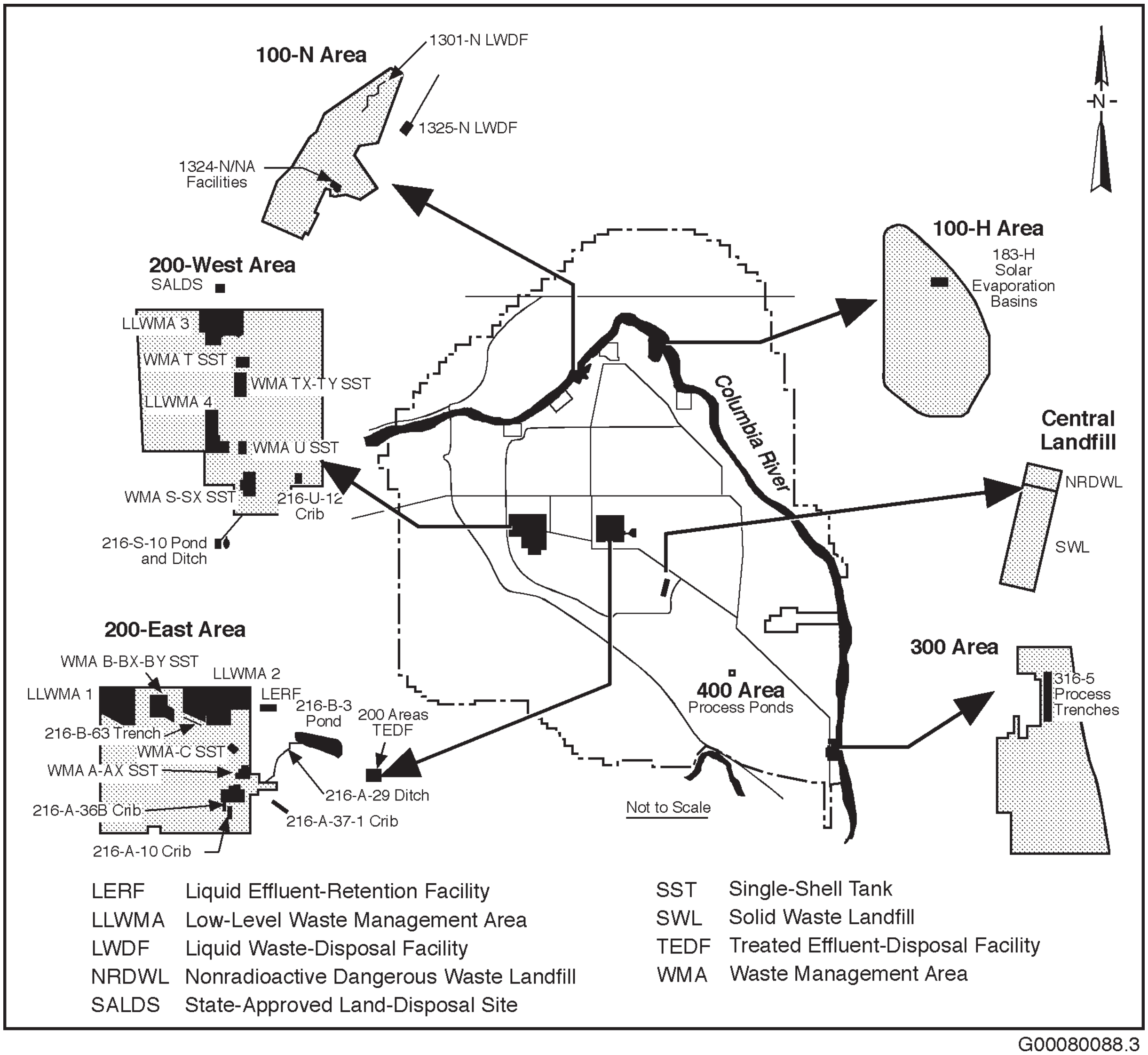

Figure A.1. Regulated Units on the Hanford Site Requiring Groundwater Monitoring. The 216-A-10, 216-A-36B, and 216-A-37-1 cribs are monitored as a single waste management area.

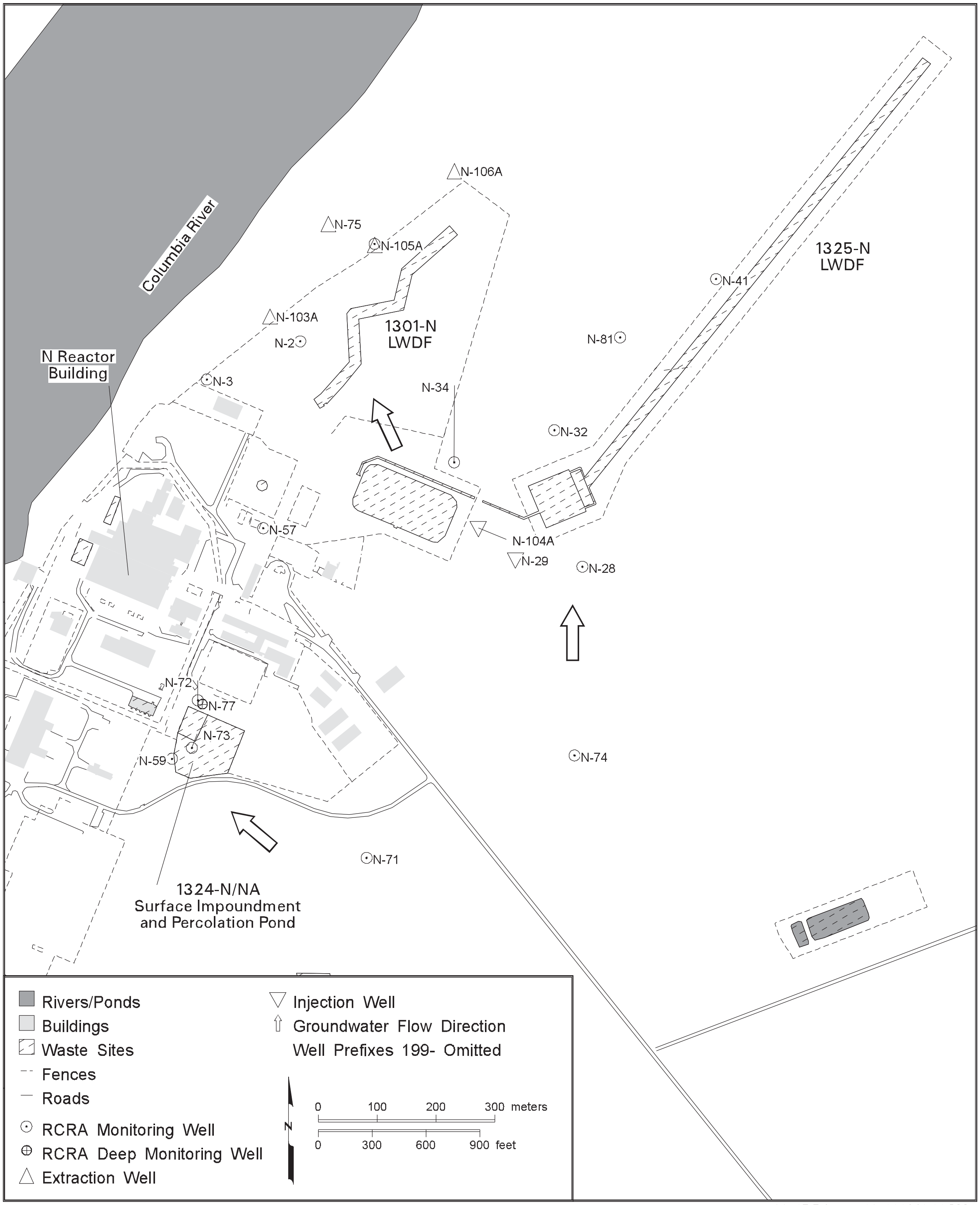

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Figure A.2. Groundwater Monitoring Wells for 100 N Area RCRA Sites

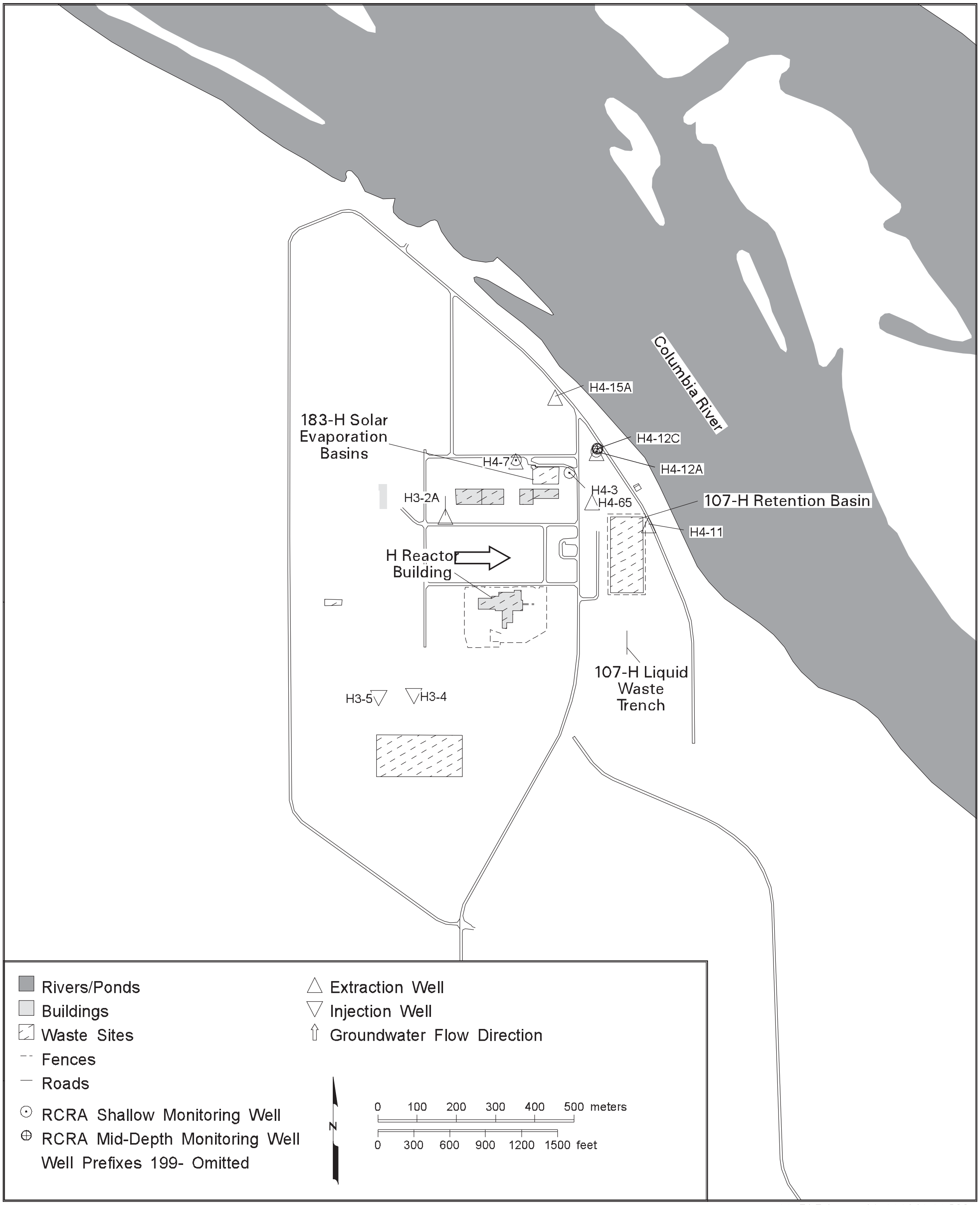

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Figure A.3. Groundwater Monitoring Wells at the Former 183-H Solar Evaporation Basins

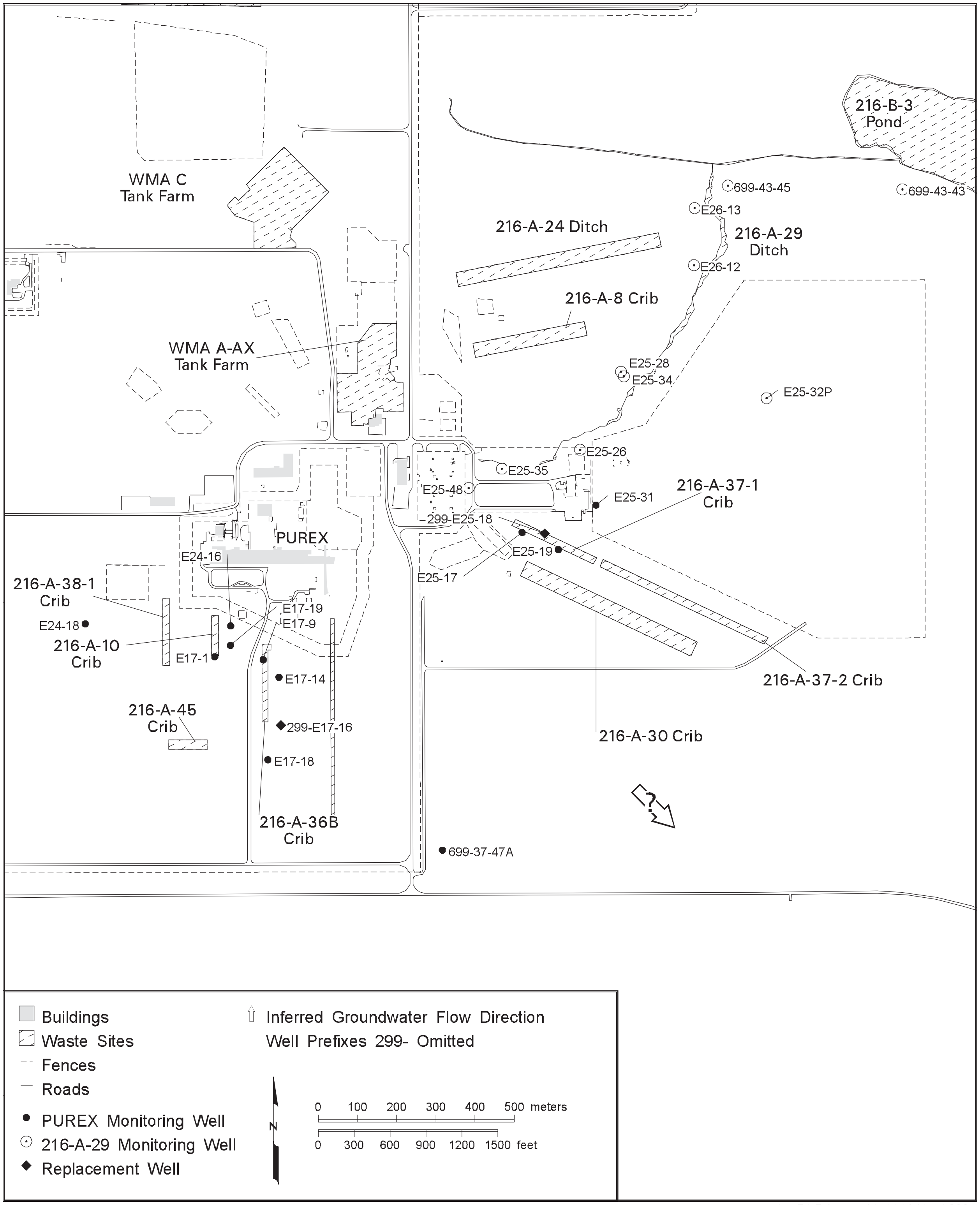

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Figure A.4. Groundwater Monitoring Wells at the 216-A-29 Ditch and PUREX Cribs

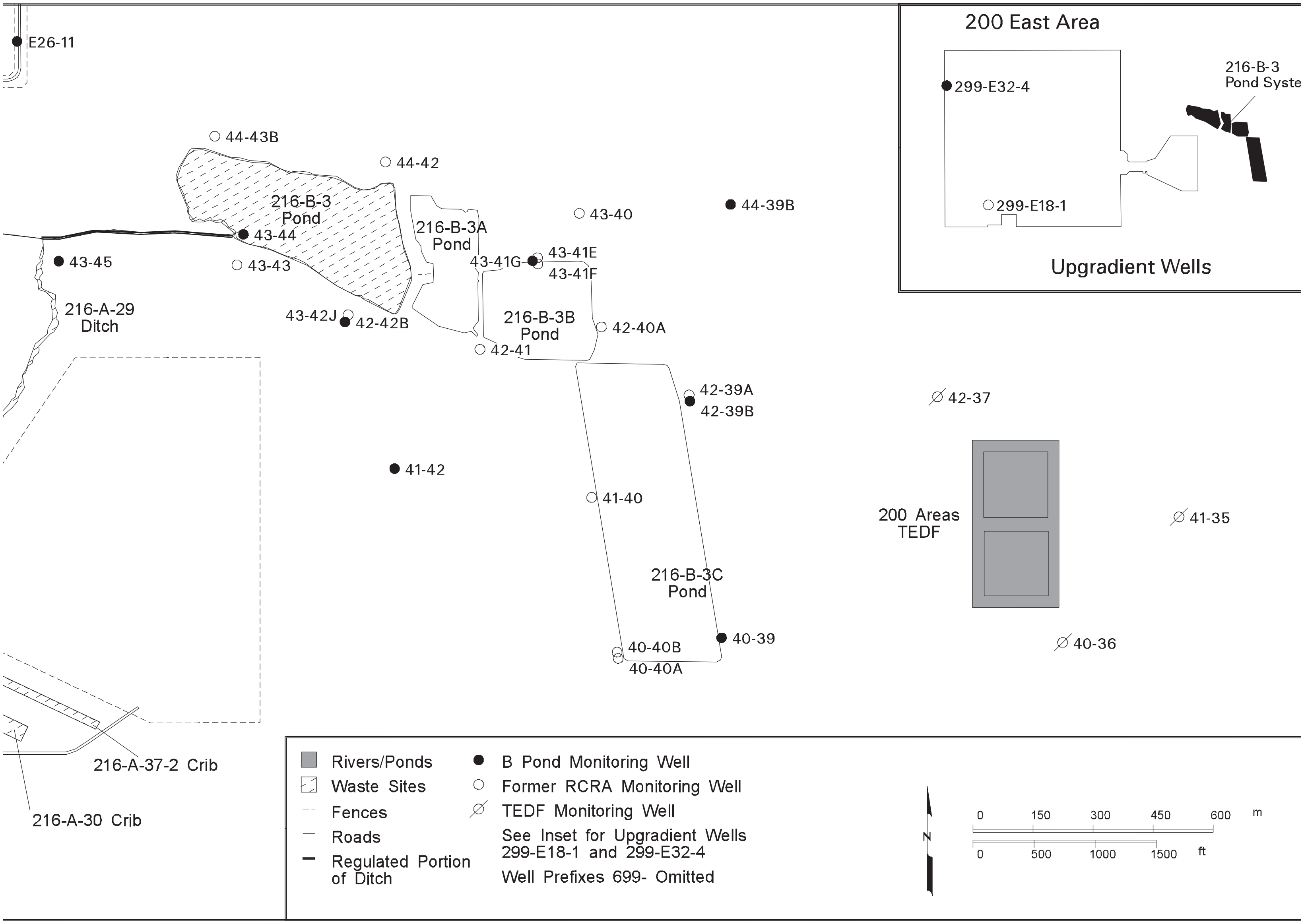

Figure A.5. Groundwater Monitoring Wells at the 216-B-3 Pond and 200 Areas Treated Effluent Disposal Facility

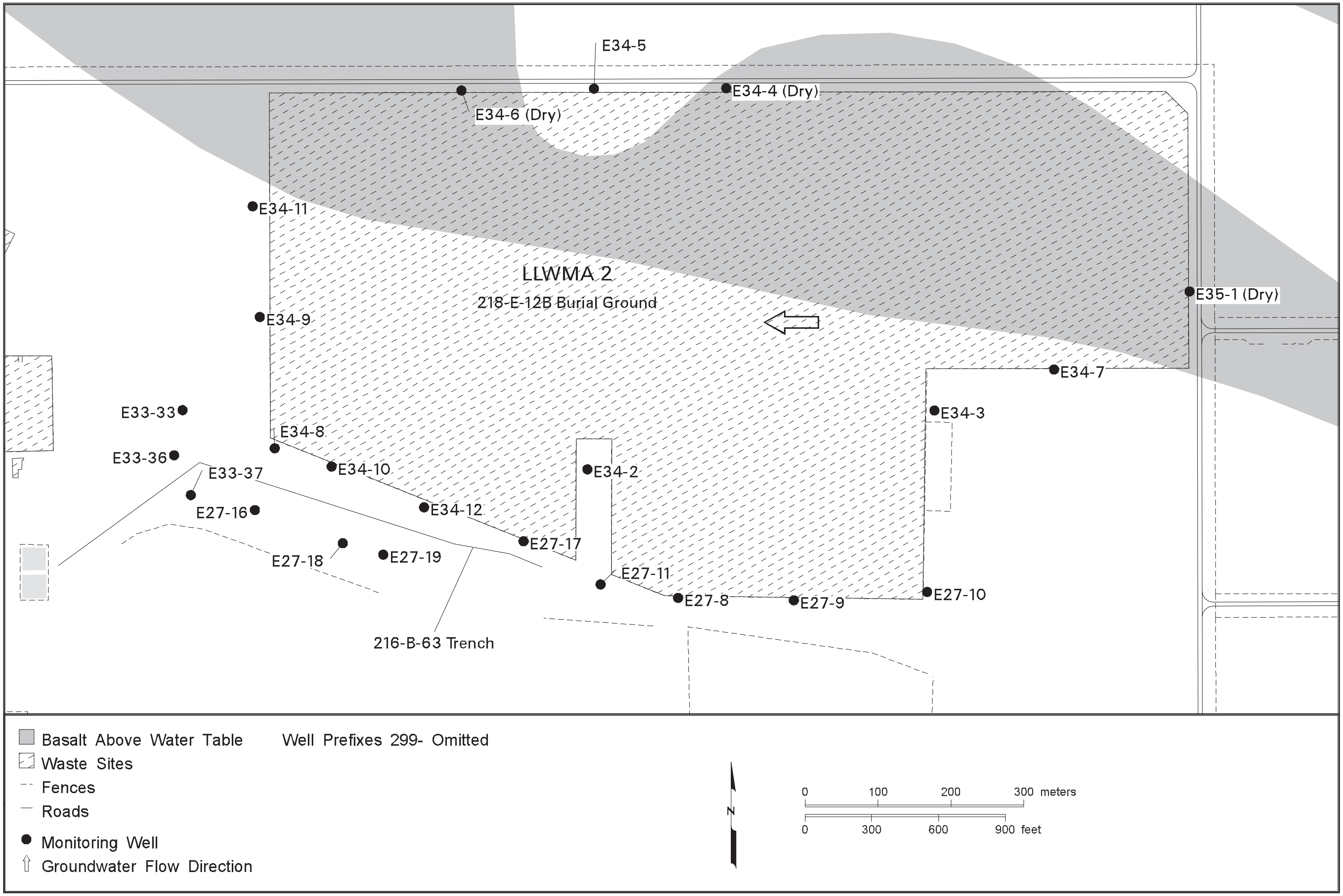

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Figure A.6. Groundwater Monitoring Wells at the 216-B-63 Trench and Low-Level Waste Management Area 2

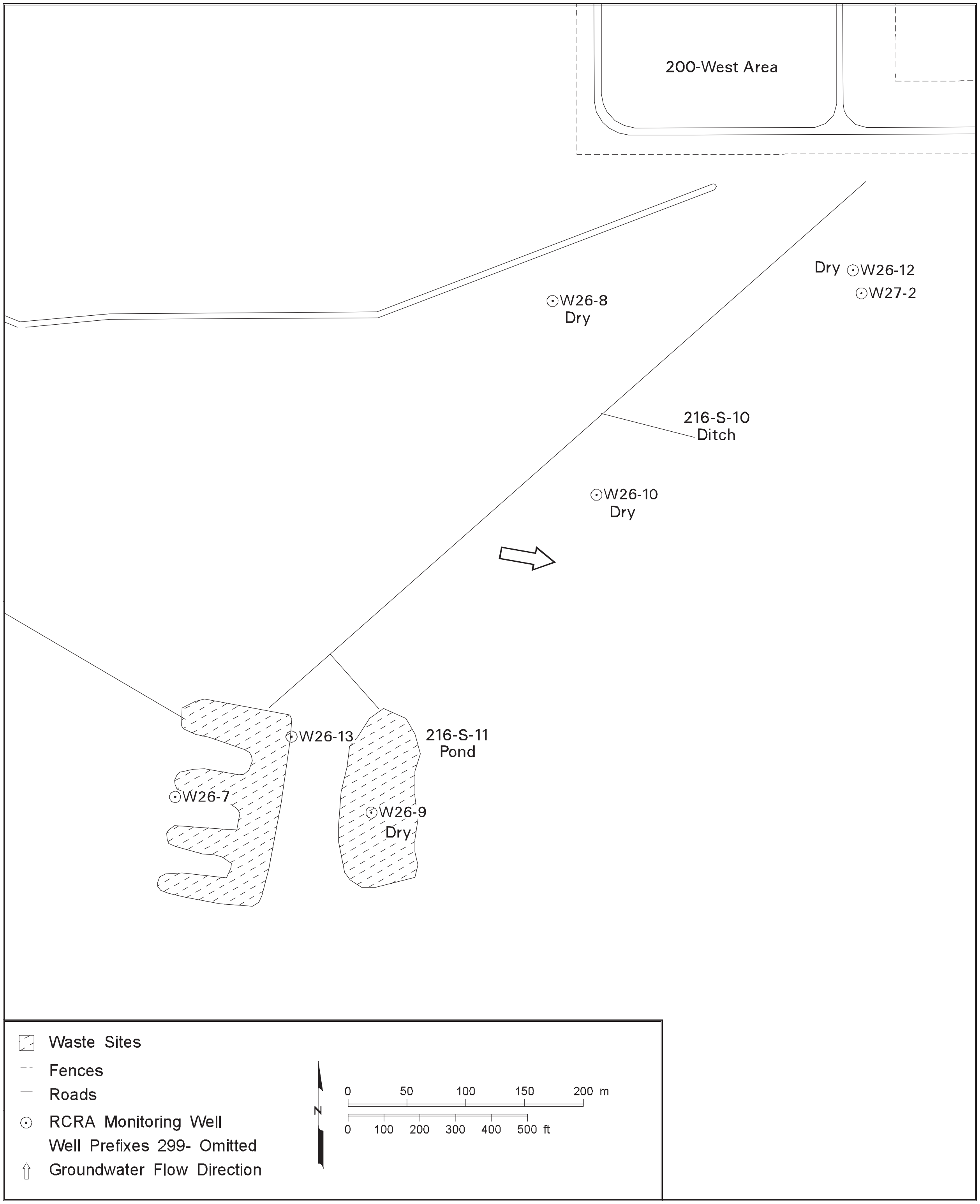

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Figure A.7. Groundwater Monitoring Wells at the 216-S-10 Pond and Ditch

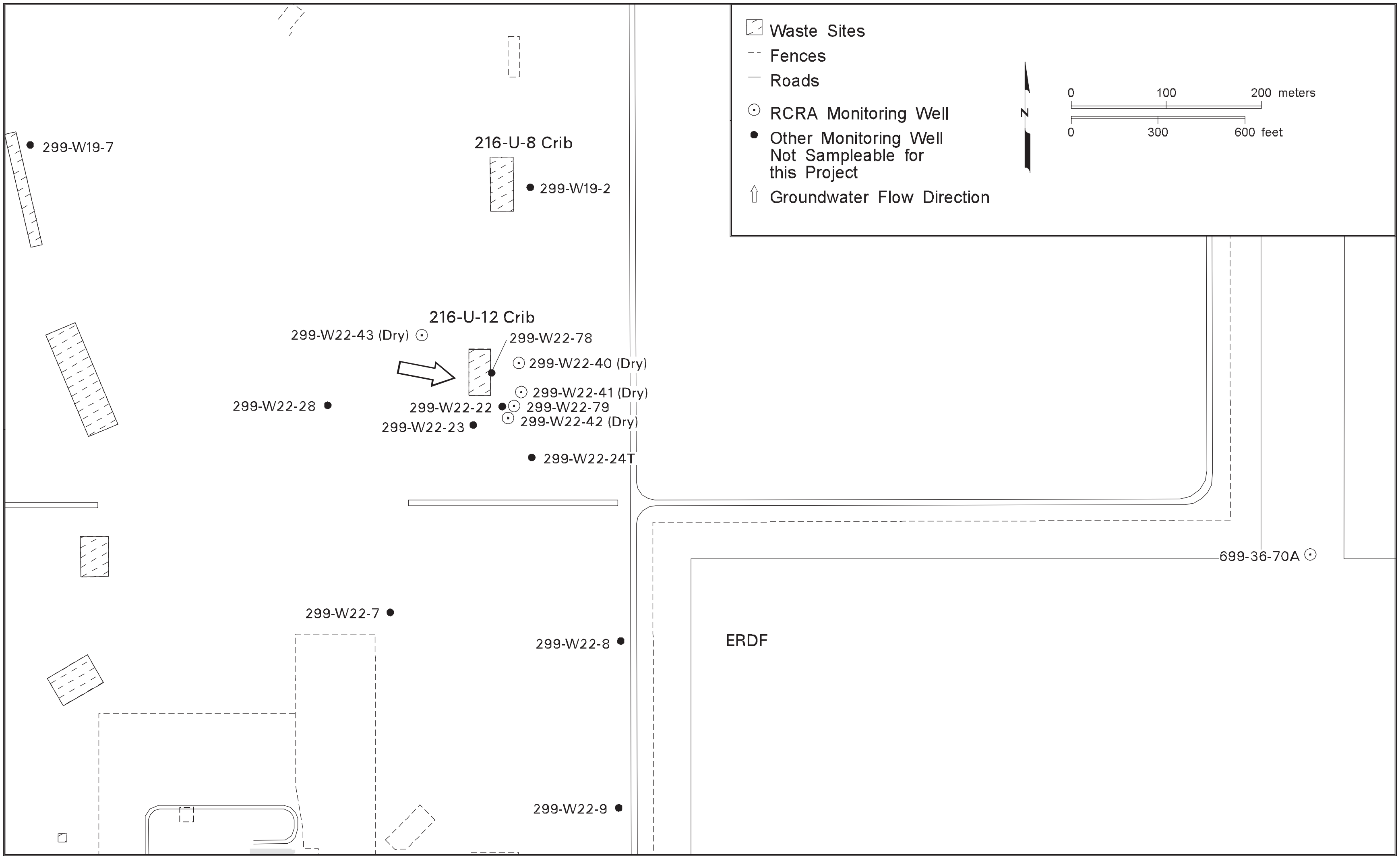

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Figure A.8. Groundwater Monitoring Wells at the 216-U-12 Crib

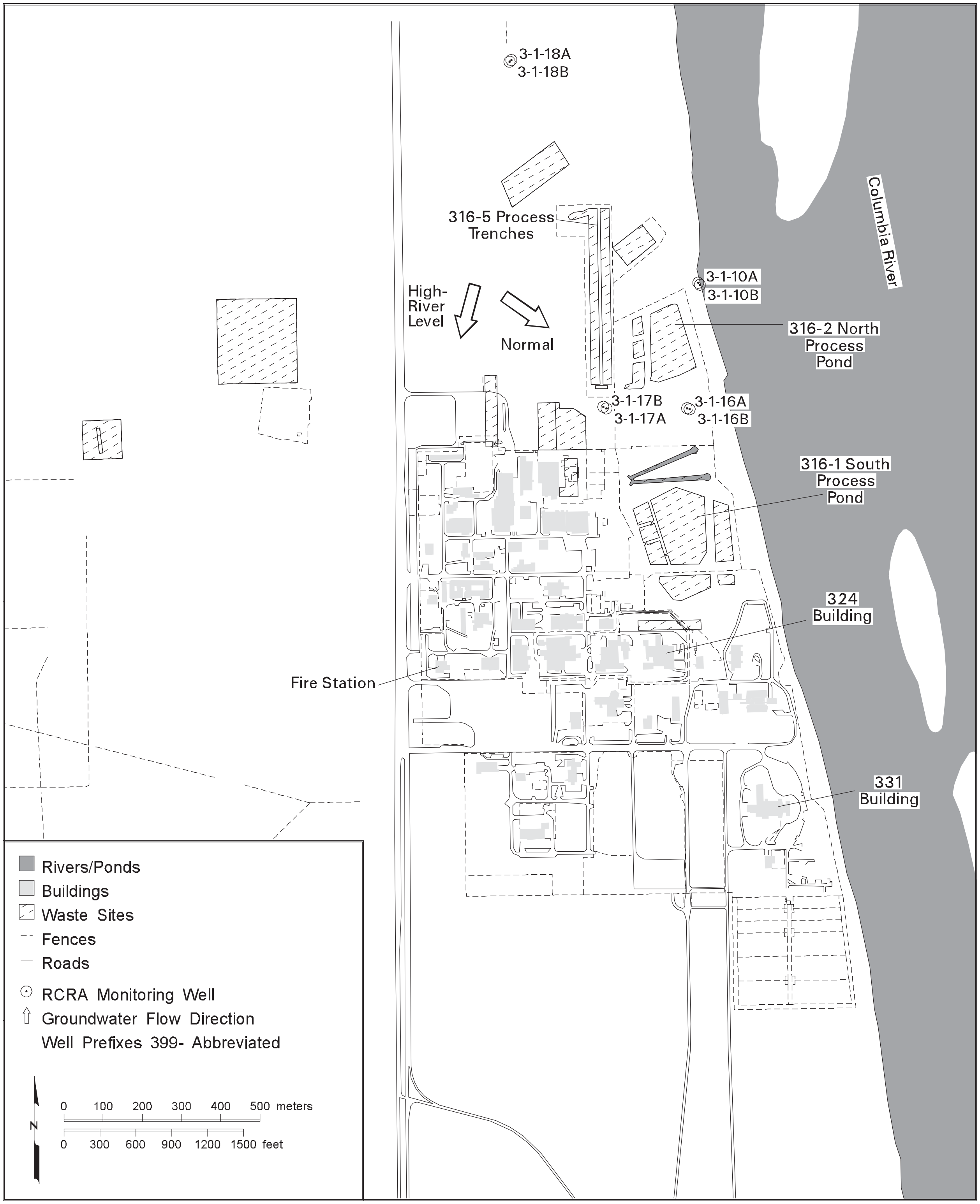

Figure A.9. Groundwater Monitoring Wells at the 316-5 Process Trenches

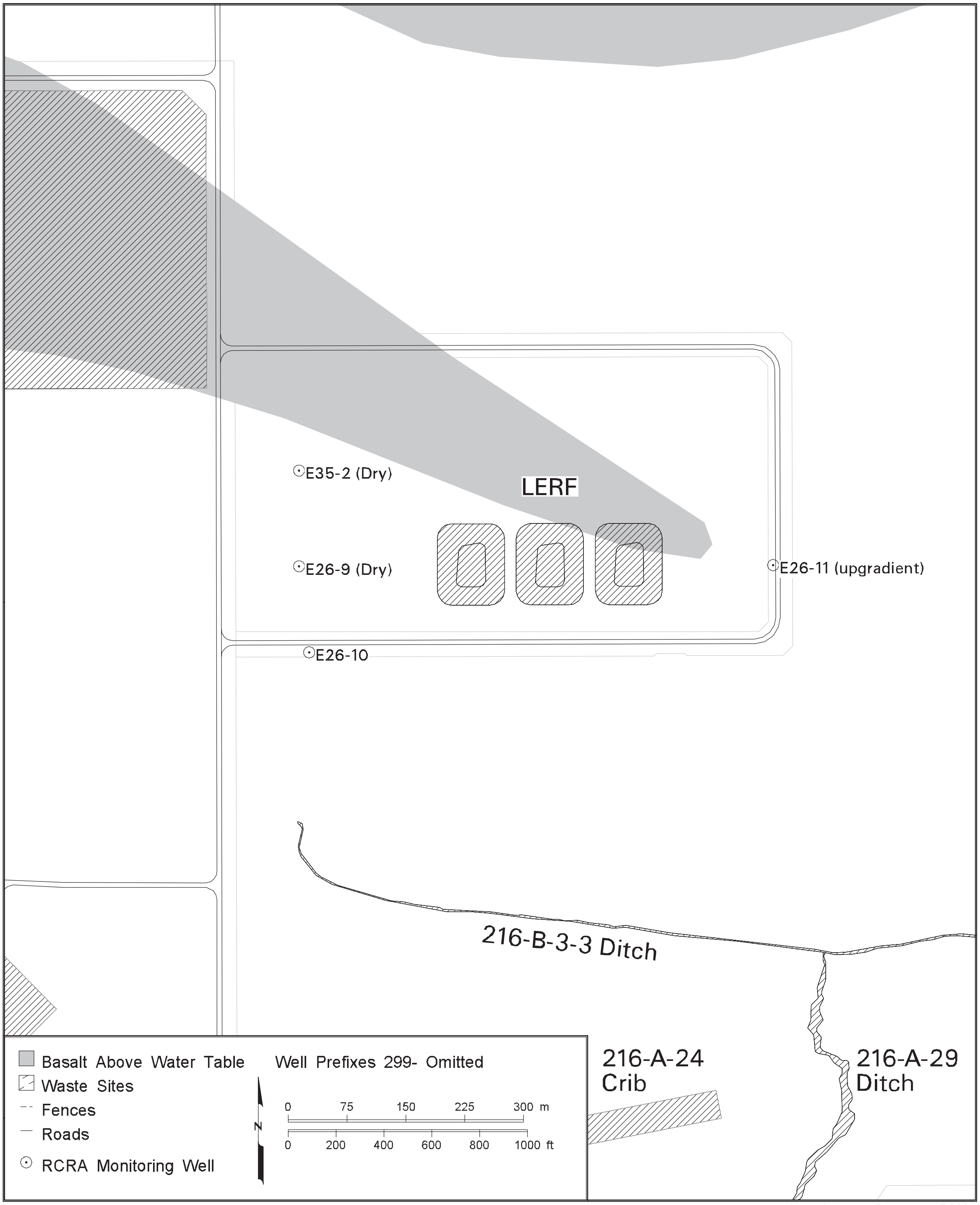

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Figure A.10. Groundwater Monitoring Wells at the Liquid Effluent Retention Facility

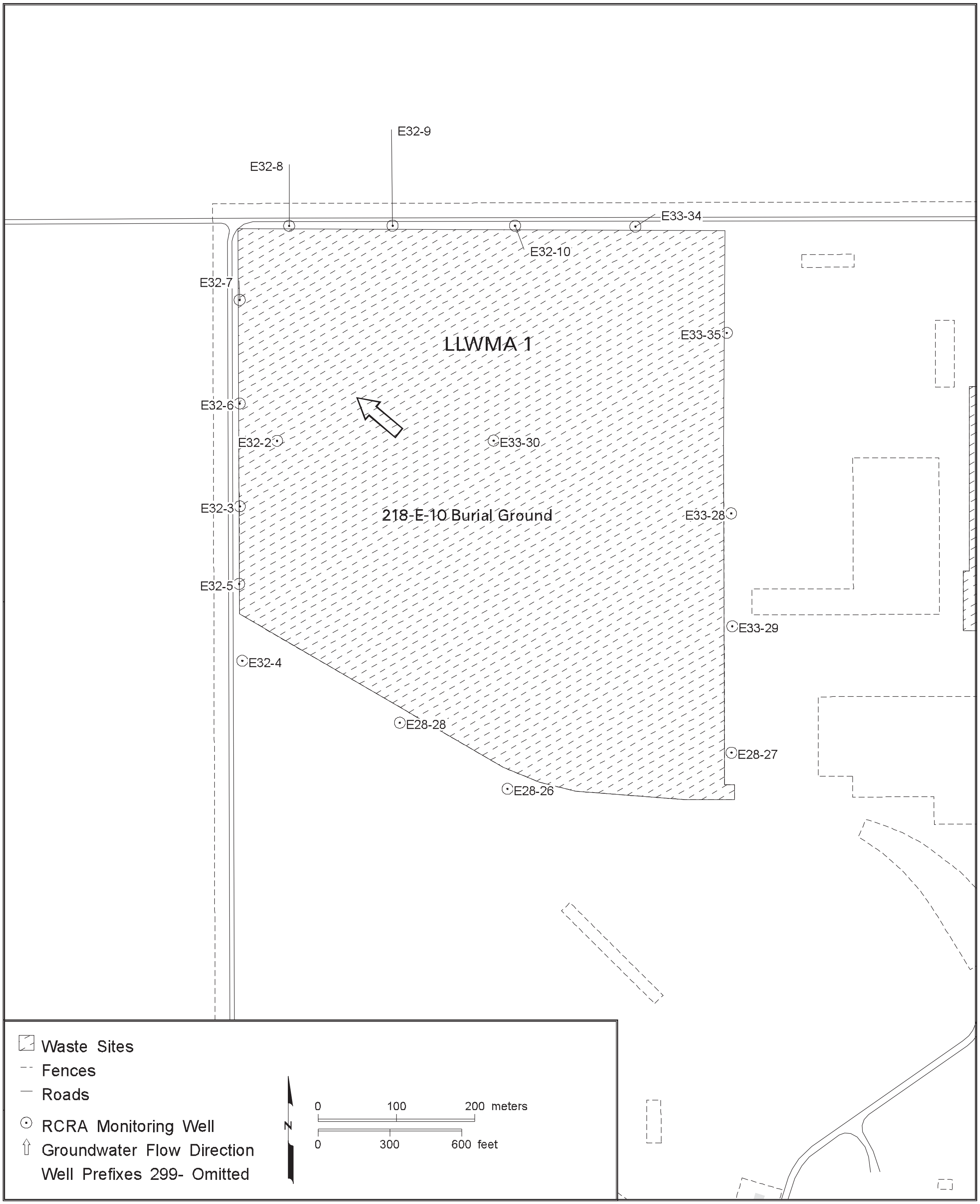

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Figure A.11. Groundwater Monitoring Wells at Low-Level Waste Management Area 1

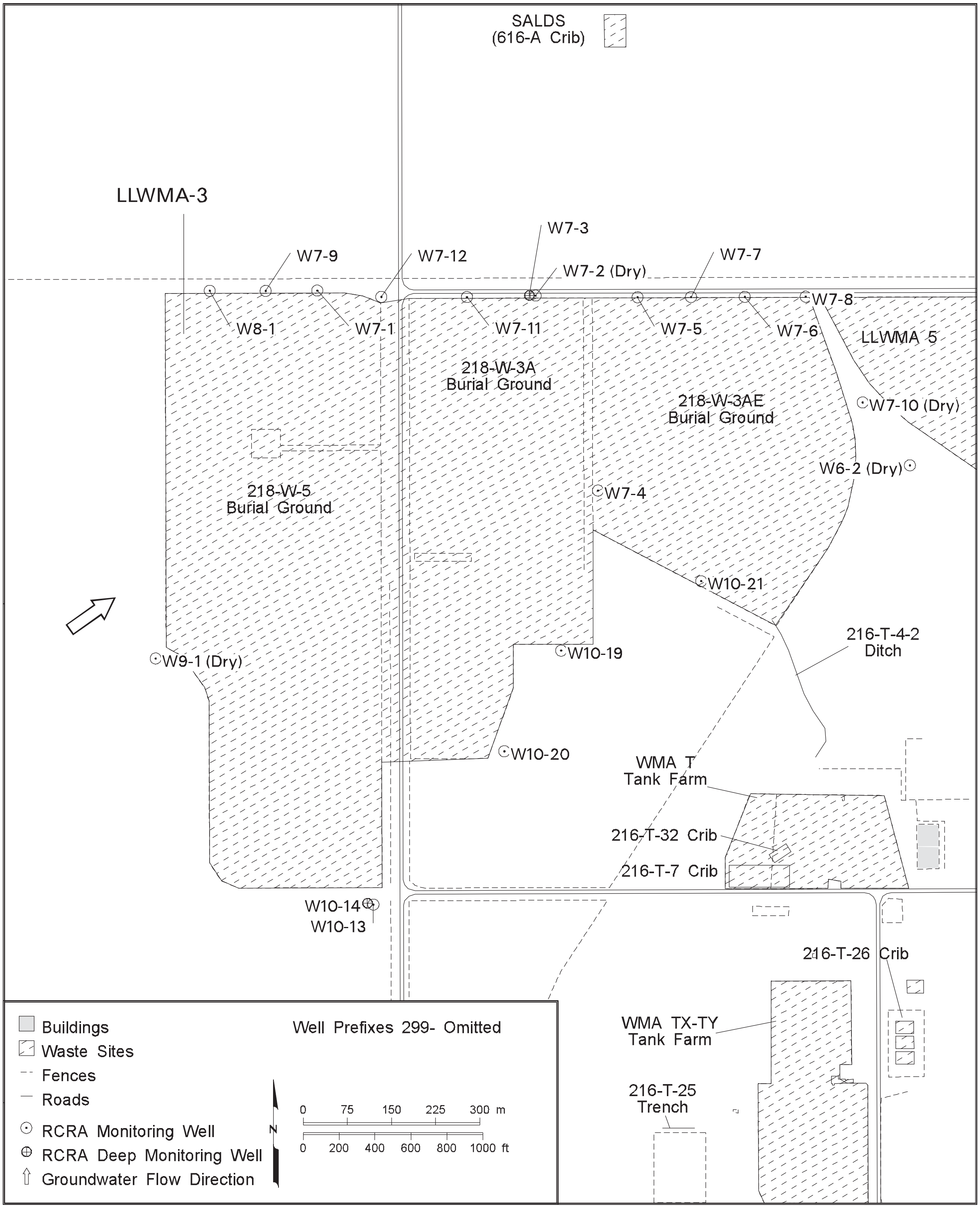

Figure A.12. Groundwater Monitoring Wells at Low-Level Waste Management Area 3

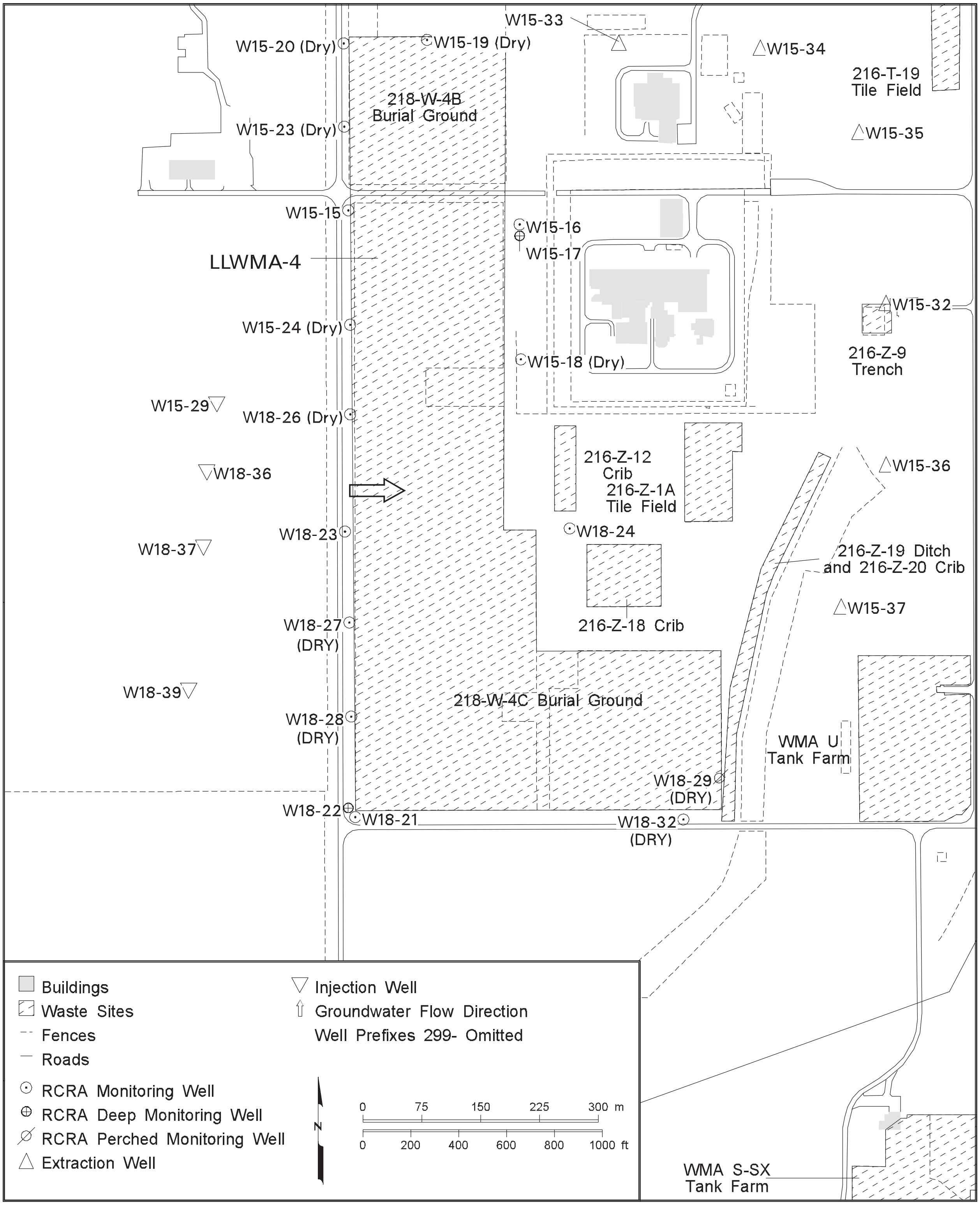

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Figure A.13. Groundwater Monitoring Wells at Low-Level Waste Management Area 4

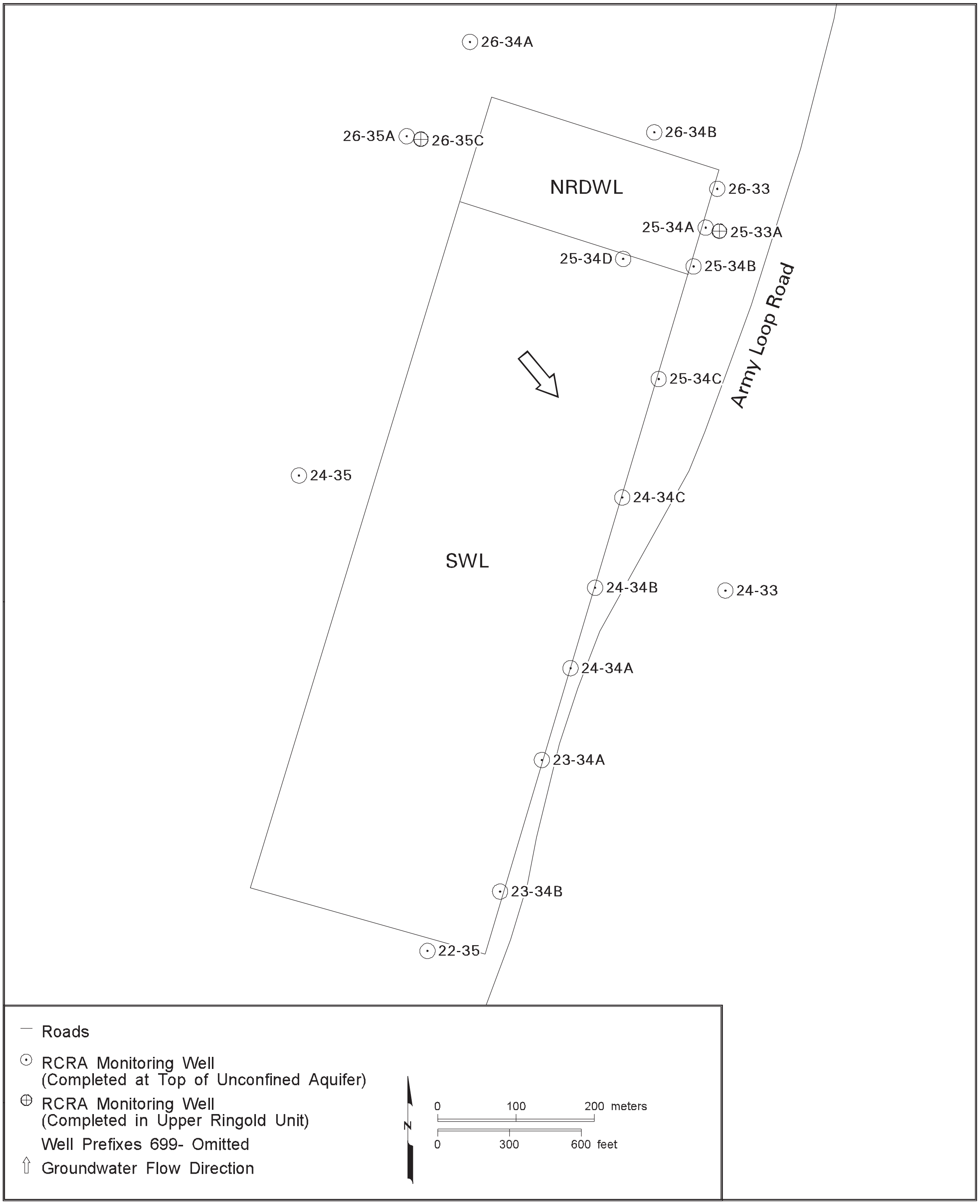

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Figure A.14. Groundwater Monitoring Wells at the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill

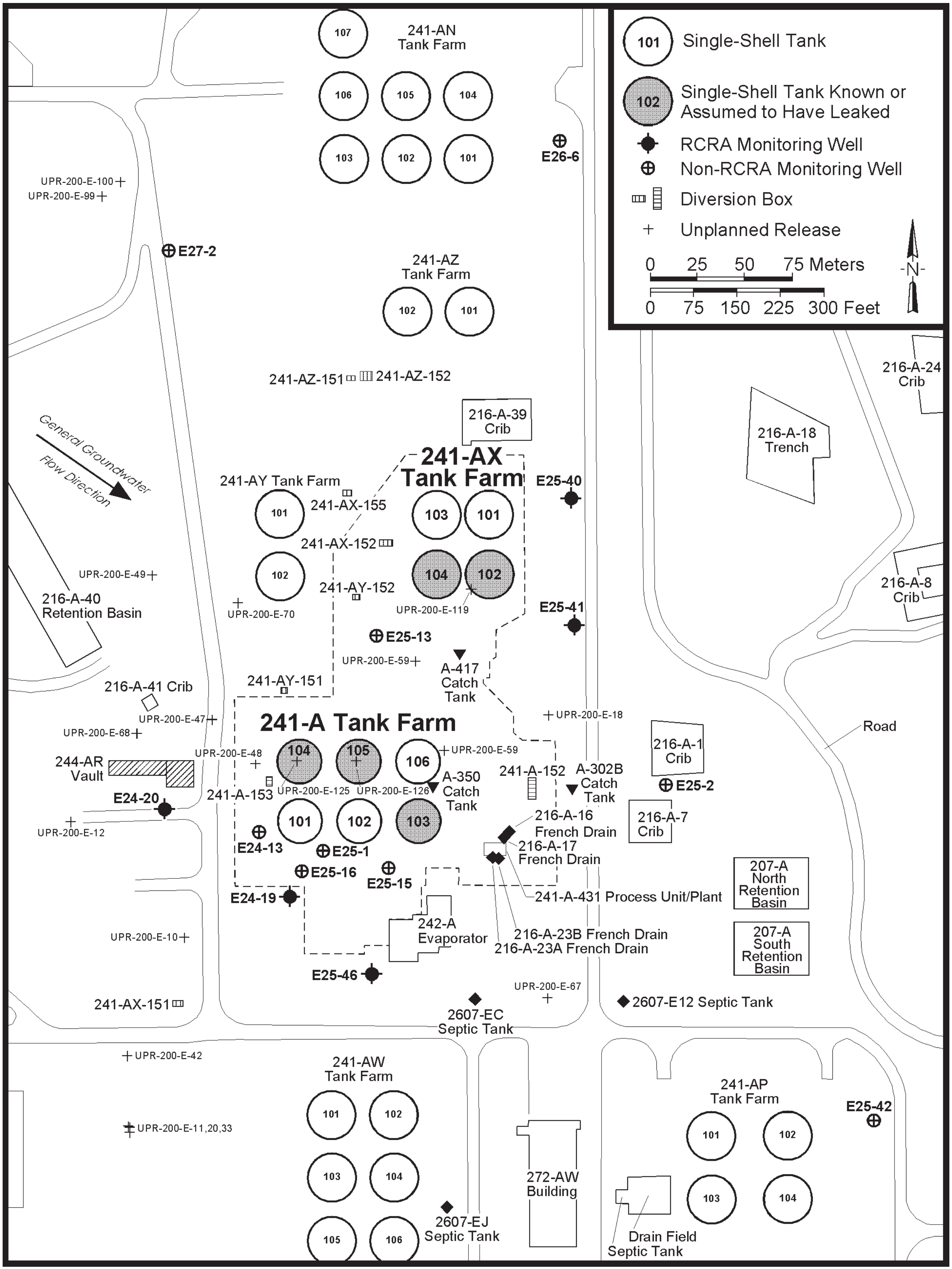

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Figure A.15. Groundwater Monitoring Wells at Waste Management Area A-AX

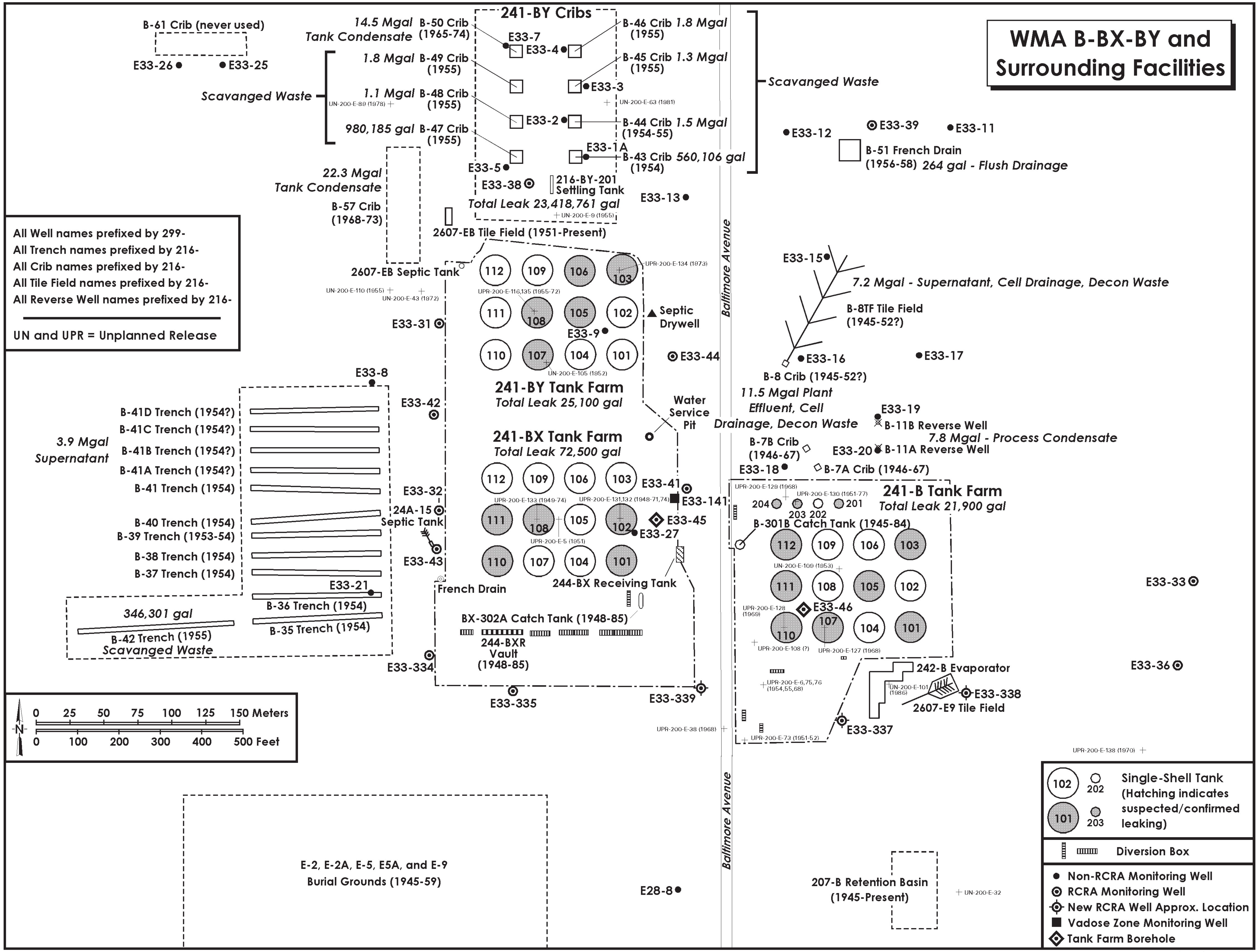

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Figure A.16. Groundwater Monitoring Wells at Waste Management Area B-BX-BY

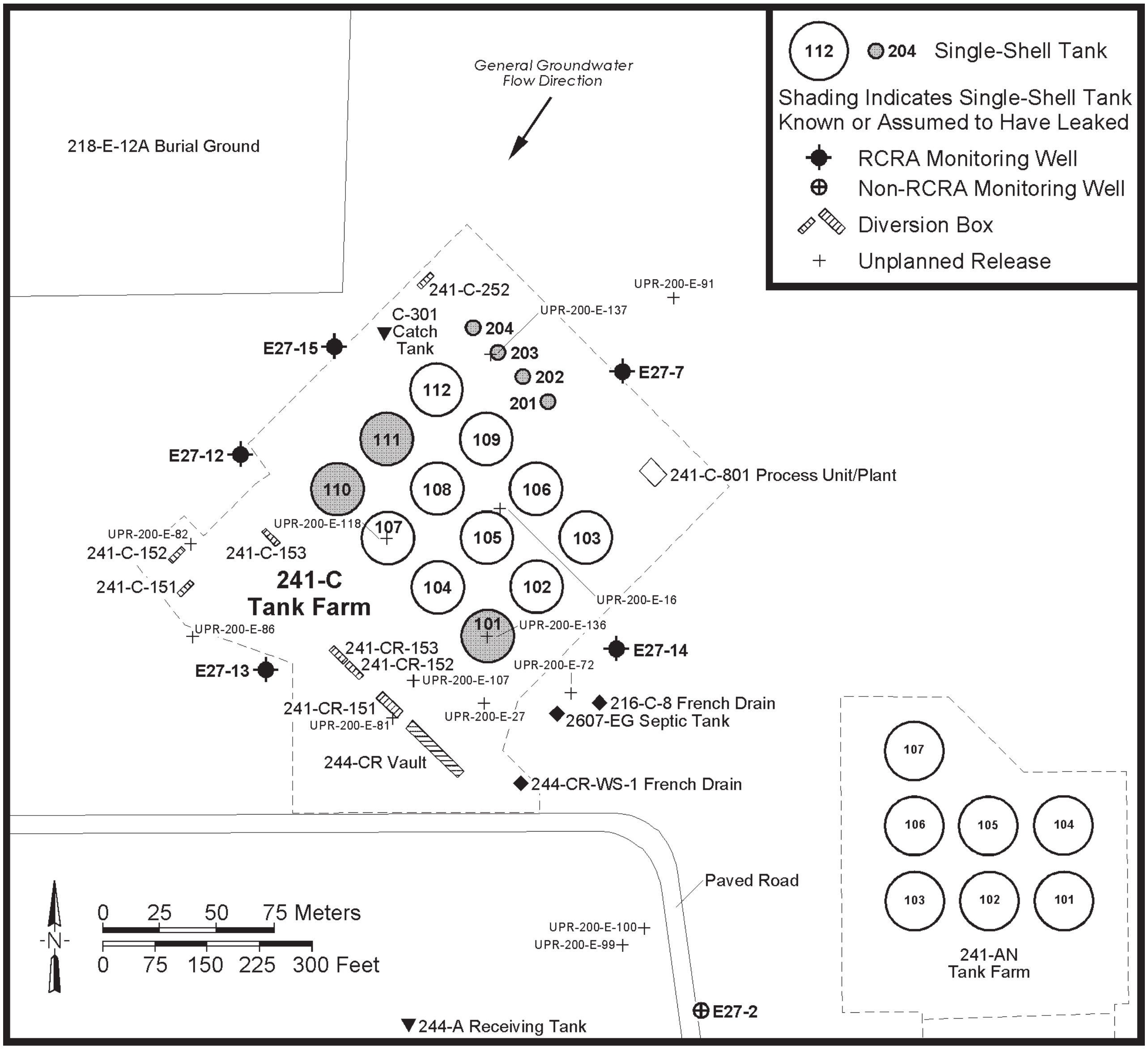

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Figure A.17. Groundwater Monitoring Wells at Waste Management Area C

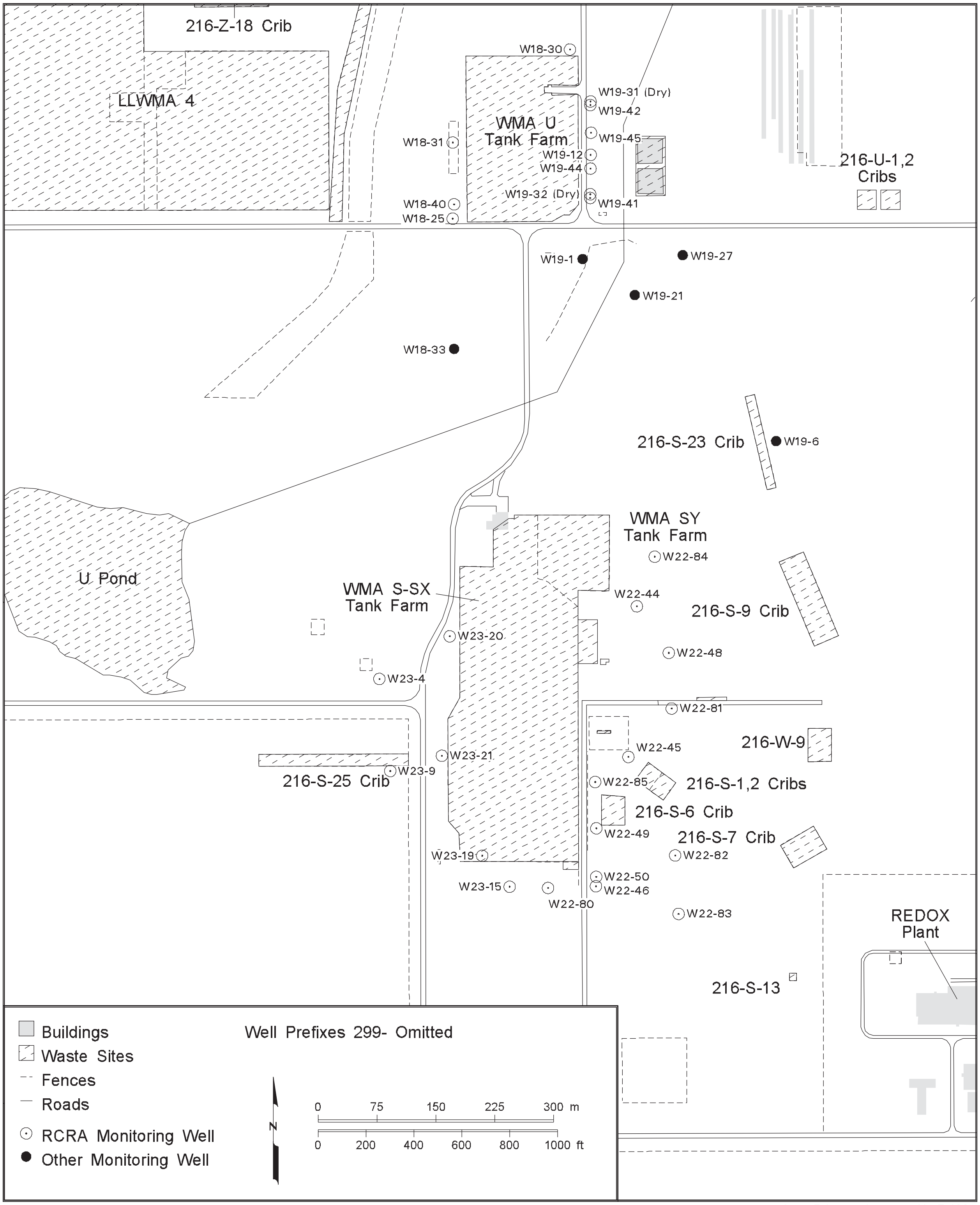

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Figure A.18. Groundwater Monitoring Wells at Waste Management Areas S-SX and U

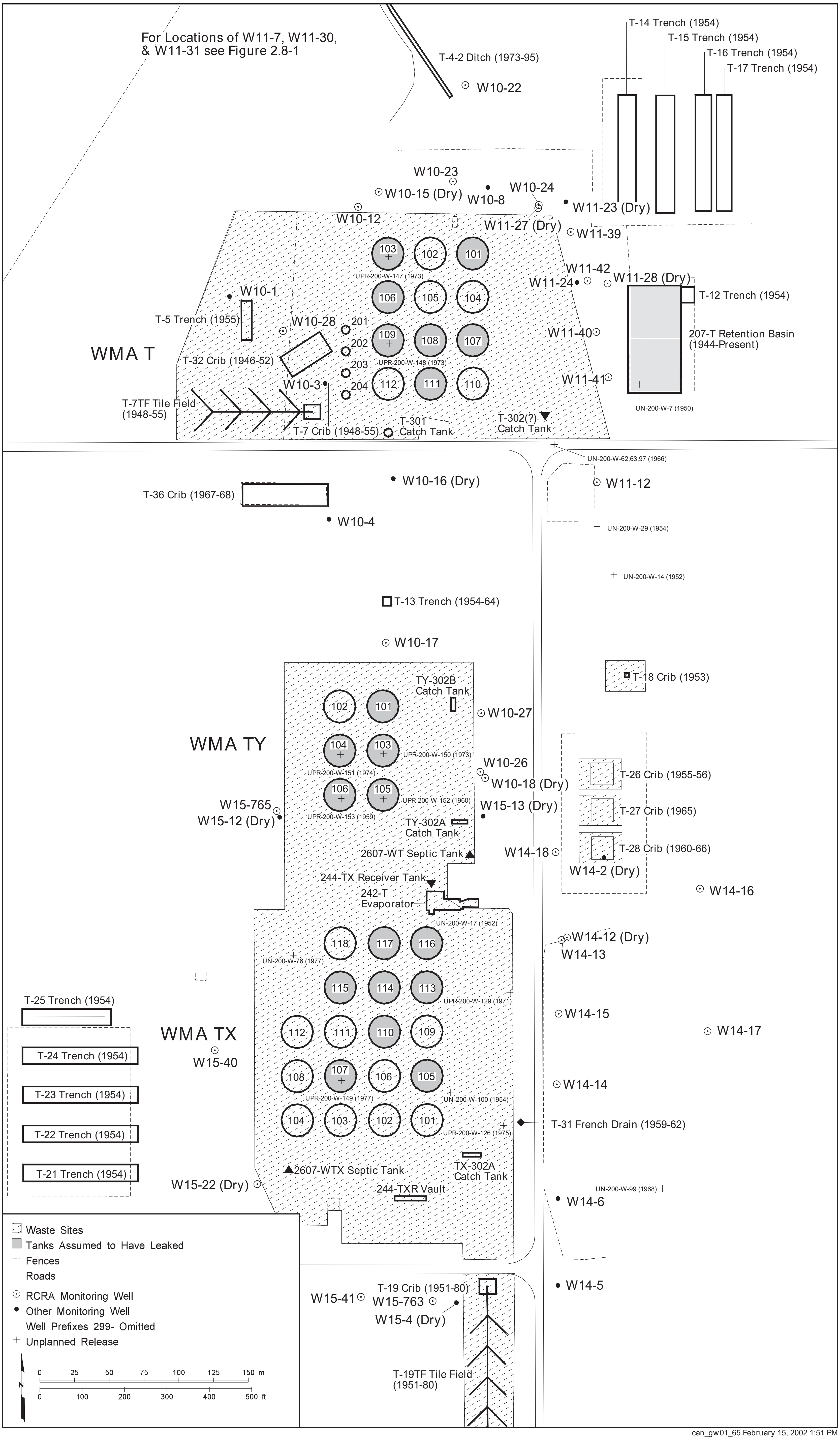

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Figure A.19. Groundwater Monitoring Wells at Waste Management Areas T and TX-TY

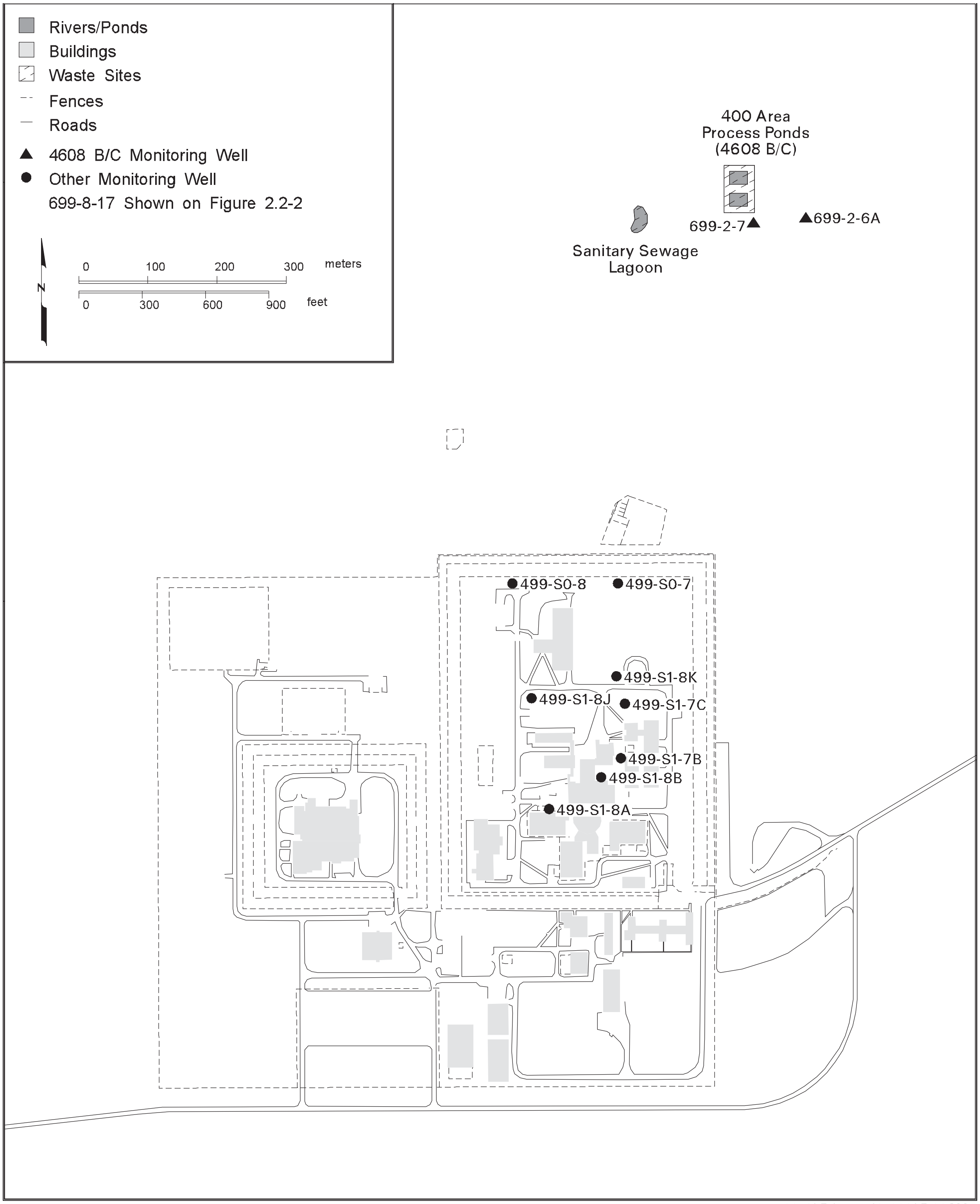

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Figure A.20. Groundwater Monitoring Wells at the 400 Area Process Ponds

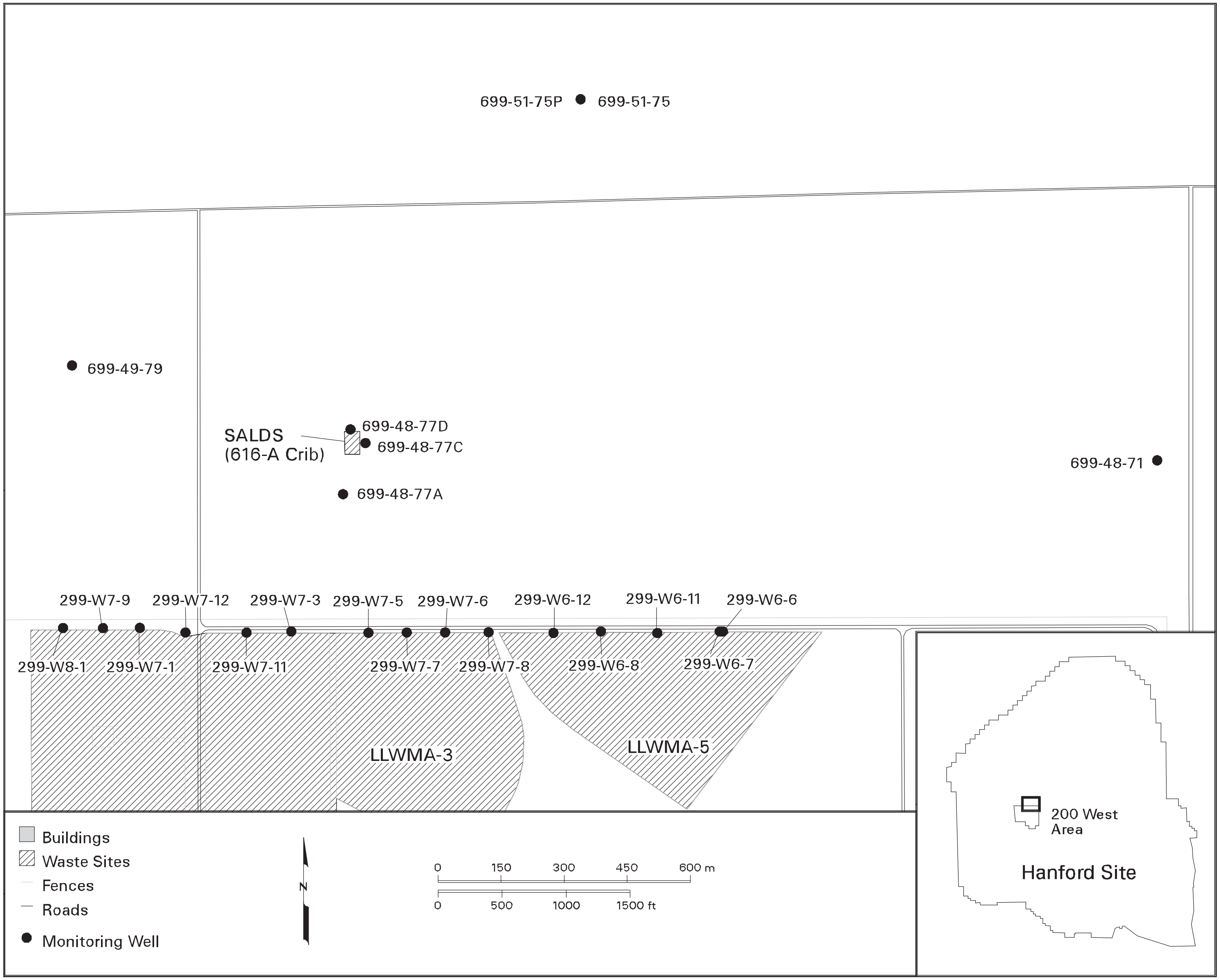

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Figure A.21. Groundwater Monitoring Wells at the State-Approved Land Disposal Site

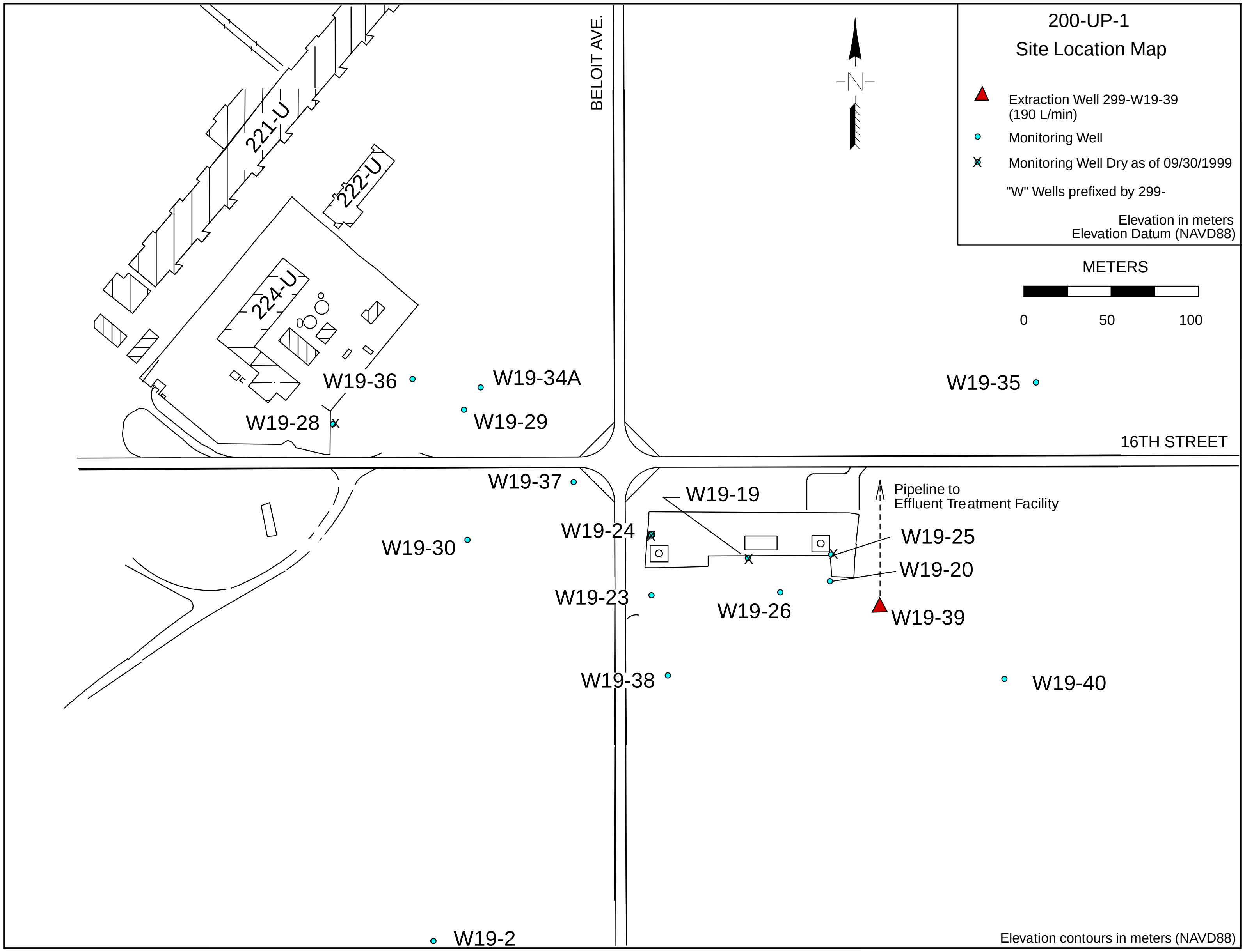

Figure A.22. Groundwater Monitoring Wells at the 200-UP-1 Operable Unit

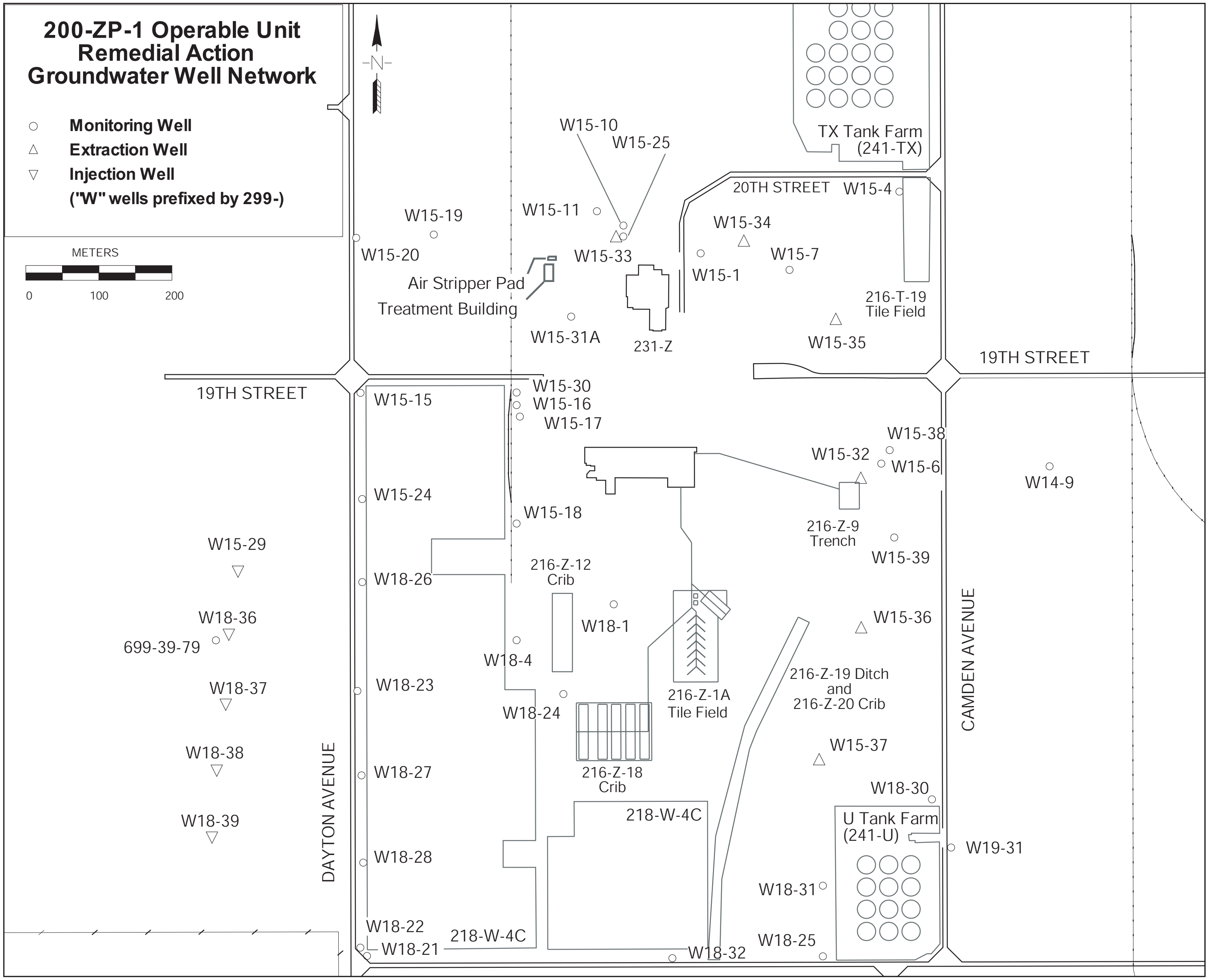

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Figure A.23. Groundwater Monitoring Wells at the 200-ZP-1 Operable Unit

Appendix B

Quality Assurance and Quality Control

Contents

Tables

Appendix B

Quality Assurance and Quality Control

This appendix presents fiscal year 2001 quality assurance/quality control (QA/QC) information for long-term and interim action groundwater monitoring at the Hanford Site. The phrase "long-term monitoring" refers to monitoring performed to meet the requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA) and the *Atomic Energy Act of 1954*. Long-term monitoring also includes monitoring performed at *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) sites with no groundwater remediation. Pacific Northwest National Laboratory (PNNL) manages long-term monitoring via the Hanford Groundwater Monitoring Project (groundwater project). Interim action monitoring encompasses monitoring at sites with active groundwater remediation under CERCLA. Bechtel Hanford, Inc. manages interim action groundwater monitoring.

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 are the primary parameters used to assess data quality (Mitchell et al. 1985). Representativeness, completeness, and comparability may also be evaluated for overall quality. These parameters are evaluated through laboratory QC checks (e.g., matrix spikes, laboratory blanks), replicate sampling and analysis, analysis of blind standards and blanks, and interlaboratory comparisons. Acceptance criteria have been established for each of these parameters. When a parameter is outside the criteria, corrective actions are taken to prevent a future occurrence.

The QA/QC practices for RCRA samples are based on guidance from the U.S. Environmental Protection Agency (EPA) (OSWER-9950.1; SW-846). U.S. Department of Energy (DOE) orders and internal requirements provide the guidance for the collection and analysis of samples for other long-term monitoring. The QA/QC practices for the groundwater project are described in the project-specific QA plan. Guidance for interim action monitoring QA/QC practices is provided in project-specific documents (e.g., BHI-00038; DOE/RL-90-08; DOE/RL-91-03; DOE/RL-91-46; DOE/RL-92-76; DOE/RL-96-07; DOE/RL-96-90; DOE/RL-97-36).

A glossary of QA/QC terms is provided in PNNL-13080.

B.1 Sample Collection and Analysis

C. J. Thompson

Duratek Federal Services, Northwest Operations conducted groundwater sampling for fiscal year 2001. Their tasks included bottle preparation, sample set coordination, field measurements, sample collection, sample shipping, well pumping, and coordination of purgewater containment and disposal. Duratek's statement of work[a] defines quality requirements for sampling activities. Groundwater project staff review all sampling procedures before the procedures are implemented.

Groundwater project staff regularly reviewed sample collection activities performed by nuclear chemical operators from Flour Hanford Inc. under the supervision of Duratek Federal Services, Inc. The purpose of the reviews was to ensure that samples were collected and submitted to the laboratories in accordance with high-quality standards. Periodic surveillances were conducted in the following areas: sample delivery and shipping, bottle preparation, sample collection, calibration of instruments, standard certifications and usage, procedure implementation and control, staff training, equipment decontamination, and paperwork processing. No major problems were identified, and all minor deviations that were noted have been corrected.

Severn Trent Laboratories, Incorporated, St. Louis, Missouri (STL St. Louis), performed most routine analyses of hazardous and non-hazardous chemicals for the groundwater project. Lionville Laboratory, Incorporated, Lionville,

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(a) SOW-243841-A-B2. 1998. Statement of Work between Pacific Northwest National Laboratory and Duratek Federal Services, Inc., Richland, Washington.

Pennsylvania (Lionville Laboratory), served as the project's secondary laboratory for chemical analyses of split samples and blind standards. However, Lionville Laboratory performed the majority of chemical analyses for interim action groundwater monitoring. STL St. Louis also analyzed samples from sites with active groundwater remediation.

Severn Trent Laboratories, Incorporated, Richland, Washington (STL Richland) was the primary radiological laboratory for the groundwater project. Eberline Services, Richmond, California, also performed radiological analyses on long-term monitoring samples. The roles of these laboratories were reversed for interim action groundwater monitoring (i.e., Eberline Services served as the primary laboratory, while STL Richland was used as a backup laboratory).

Standard methods from EPA and American Society for Testing and Materials (ASTM) were used for the analysis of chemical constituents. Methods employed for radiological constituents were developed by the analyzing laboratories and are recognized as acceptable within the radiochemical industry. Descriptions of the analytical methods used are provided in PNNL-13080.

B.2 Data Completeness

C. J. Thompson

Data judged to be complete are data that are not suspect, rejected, associated with a missed holding time, out-of-limit field duplicate or field blank, or qualified to indicate laboratory blank contamination. For fiscal year 2001, 88% of the groundwater project data were considered complete. Potentially invalid data were flagged in the database. The percentages of data flagged were 1.2% for field QC problems, 1.4% for exceeded holding times, 0.0% for rejected results, 0.3% for suspect values, and 10% for laboratory blank contamination. These values are similar to the percentages observed in fiscal year 2000.

Specific evaluation of completeness for interim action groundwater monitoring was not performed for this report. Completeness issues are primarily assessed as part of site-specific validation activities. No validation activities were performed on interim action groundwater monitoring data in fiscal year 2001.

B.3 Field Quality Control Samples

C. J. Thompson and R. L. Weiss

Field QC samples include field duplicates, split samples, and three types of field blanks. The three types of field blanks are full trip, field transfer, and equipment blanks. Field duplicates are used to assess sampling and measurement precision. Split samples are used for confirming out-of-trend results and for interlaboratory comparisons. Field blanks provide an overall measure of contamination introduced during the sampling and analysis process.

B.3.1 Long-Term Monitoring (Hanford Groundwater Monitoring Project)

The groundwater project's criteria for evaluating the analytical results of field QC samples are as follows:

- field duplicates – Results of field duplicates must have precision within 20%, as measured by the relative percent difference. Only those field duplicates with at least one result greater than five times the method detection limit or minimum detectable activity are evaluated.
- split samples – Results must have a relative percent difference <20%. Only those results that are quantitative (i.e., greater than five times the method detection limit or minimum detectable activity) are evaluated.
- field blanks – For most chemical constituents, results above two times the method detection limit are identified as suspected contamination. However, 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 flagged if they are greater than two times the total propagated analytical uncertainty.

If a field blank does not meet the established criteria, it is assumed that there are potential problems with the data for all associated samples. For full-trip and field-transfer blanks, an associated sample is one that was collected on the same day and analyzed by the same method as a full-trip or field-transfer blank. For equipment blanks, an associated sample is one that has all of the following in common with an equipment blank:

- collection date
- collection method/sampling equipment
- analysis method.

Data associated with out-of-limit field blanks are flagged with a Q in the database to indicate a potential contamination problem. A Q is also applied to both duplicate results when their precision exceeds the QC limits.

The percentages of acceptable field blank (97%), split sample (100%), and duplicate (98%) results evaluated in fiscal year 2001 were high, indicating little problem with contamination and good precision overall. Tables B.1 through B.4 summarize the field blank and field duplicate results that exceeded QC limits. To assist with their evaluation, the tables are divided into the following categories, where applicable: general chemical parameters, ammonia and anions, metals, volatile organic compounds, semivolatile organic compounds, and radiological parameters. Constituents not listed in the tables had 100% acceptable field blanks and/or field duplicates.

With the exception of semivolatile organic compounds, all classes of constituents had results that were flagged as potentially contaminated because of out-of-limit field blank results. Most of the out-of-limit blank results were less than five times the method detection limit (i.e., below quantifiable limits). A few constituents such as chloride, nitrate, and sodium had several quantifiable field blank results, but the concentrations were much lower than the levels of these constituents in almost all groundwater samples.

Forty-four percent of the field blank results for total organic carbon exceeded the QC limits. In general, the blank concentrations were low (only three results were greater than the contract required detection limit of 1,000 μg/L), but the values are of concern for RCRA detection monitoring because total organic carbon is an indicator parameter. All but two of the out-of-limit results were for samples collected after the first quarter. The samplers began using a new deionized water system for blank preparation in December 2000, and the new water system may have been less efficient in removing organic carbon from the supply water. Another factor that appears to have contributed to the elevated blank results is the performance of the primary laboratory's total organic carbon analyzer. The instrument required repair during the third quarter, and many of the laboratory's method blanks during the third quarter were out-of-limits, with concentrations as high as 750 μg/L.

Compared to last year, the relative number of out-of-limit field blank results for metals was significantly reduced (2% for fiscal year 2001 versus 8% for fiscal year 2000). Efforts taken by STL St. Louis to reduce the potential for sample contamination during the digestion of samples probably account for the improved data quality. Most of the unacceptable results were within a factor of three of the QC limits. Aluminum, iron, and zinc had one or more method blank results that were comparable to the out-of-limit field blank results, suggesting that the elevated field blank values were caused by false detections or laboratory contamination.

Concentrations of six volatile organic compounds exceeded the QC limits in one or more field blanks. Methylene chloride was the predominant volatile contaminant, accounting for 85% of the out-of-limit results. Levels of acetone were also out-of-limits in two field blanks. Laboratory contamination is the suspected source of these common contaminants, because similar concentrations were also measured in several laboratory method blanks. Four field-transfer blanks had out-of-limit results for carbon tetrachloride, chloroform, cis-1,2-dichlorothene, and trichloroethene. In general, these compounds had low frequencies of detection (i.e., <10%) in field blanks, and the overall impact on the data is minor.

Tritium and uranium were the only radiological constituents with out-of-limit field blank results. Although the blank concentrations were low, they were greater than levels of uranium and tritium in some of the associated groundwater samples. The source of water used to prepare the blanks is the expected source of tritium. Beginning in fiscal year 2002, a source of "dead" water (i.e., water containing little or no tritium) will be used to prepare full-trip blanks for low-level tritium.

Comparison of full-trip and equipment blank results suggests that the use of non-dedicated sampling equipment at some wells did not have a significant impact on data quality. Overall, fewer constituents were detected in equipment blanks, and the concentrations of most constituents were lower in equipment blanks. However, only a limited comparison can be made because only 11 equipment blanks were collected compared to 64 full trip blanks. The percentages of out-of-limit results were slightly higher in equipment blanks for those constituents detected in both types of blanks.

Duplicate results were flagged for all constituent classes except semivolatile organic compounds (see Table B.4). Overall, the relative number of flagged duplicate results was very low (<2%), but the percentages of unacceptable results were high for chromium (24%), iron (36%), manganese (20%), and potassium (17%) based on the number of duplicates that met the evaluation criteria. Most of the metal samples were unfiltered; thus, suspended solids in heterogenous sample fractions may have caused some of the discrepancies in the metal results. Most of the out-of-limit duplicate results appear to be anomalous instances of poor precision based on other QC indicators such as the results from the blind standards and laboratory duplicates (discussed in Sections B.4.2 and B.4.3). In several cases, the laboratory was asked to re-analyze or investigate duplicate results with a very high relative percent difference, but the checks did not reveal the source of the problem. Especially poor agreement was observed between a pair of results for the following: carbon disulfide (non-detection and 2.8 μg/L), chloride (41,700 and 12,100 μg/L), gross alpha (non-detection and 12.2 pCi/L), iron (non-detection and 155 μg/L), nitrogen in nitrate (23,800 and 3,300 μg/L), sodium (23,900 and 8,110 μg/L), sulfate (110,000 and 24,600 μg/L) and total dissolved solids (1,680 and 677 mg/L). Swapped samples or procedural deviations at the laboratory may have caused the unmatched results.

The only split samples collected during fiscal year 2001 for the Hanford Groundwater Monitoring Project were from 100 K Area wells. Thirteen samples were split and submitted to Lionville Laboratory and STL Richland for tritium analyses. Five of the samples contained concentrations that were quantifiable at both laboratories, and the relative percent differences for all of the pairs were <20%. Thus, the laboratories showed excellent agreement overall for tritium.

B.3.2 Interim Action Monitoring

Trained staff collected samples in accordance with approved procedures. In general, field QC samples consisted of field duplicates, splits, equipment blanks, and trip blanks. Field QC data are evaluated as necessary to support decisions that may modify or terminate a remedial action. In fiscal year 2001, no evaluations were necessary for decision-making purposes. Nonetheless, field QC data were examined to monitor laboratory operations and to identify potential problem areas where improvements were necessary. Evaluation criteria were essentially the same as those used for long-term monitoring, except the 20% relative percent difference criterion for field duplicate and split sample results was relaxed for sample analytical results near (i.e., typically within five times) the method detection limits.

For field blank samples, >91% of all results were returned as non-detected. This is a significant improvement over previous years, in which 80% to 85% of results were non-detected. Blank detects are summarized in Table B.5. Approximately 70% of the blank results detected were common metals (e.g., calcium, iron, manganese, sodium) measured by the inductively coupled plasma method at levels close to analysis procedure detection limits. All detected organic constituents were common laboratory contaminants (all but one were for methylene chloride, the most common laboratory contaminant). Only one radiochemical constituent was reported (tritium, one sample), and the result was near analysis detection limits. Evaluation of other field blank sample results showed no evidence of unexpected or excessive contamination of blanks in the field or by the laboratory. The constituents and levels of contamination found should have no impact on decision making for interim action monitoring.

Field duplicate and split results showed ~6% exceeding the criteria used for evaluation. The percentage of out-of-limit splits was ~2 times higher than the relative number of out-of-limit duplicates. It should be noted that the criteria used to evaluate splits are likely more restrictive than necessary because they are based on similar criteria for laboratory replicate evaluation (i.e., analysis of multiple aliquots from the same sample container by the same laboratory in the same analytical batch).

As noted in previous years, metals analysis by the inductively coupled plasma method accounts for most of the analyses (two-thirds of all) exceeding the criteria. Again as in previous years, the only higher concentration results (significantly above analytical quantitation limits) exceeding the criteria were on unfiltered samples. Unfiltered samples accounted for ~80% of all results which exceeded the criteria. Unfiltered samples would be expected to show greater variability because of suspended solids. Field duplicate evaluations are summarized in Table B.6, and interlaboratory split evaluations are summarized in Table B.7.

This year's interlaboratory splits included volatile organic analyses performed in the field and at the commercial (fixed) laboratories. As noted last year, field/fixed splits for carbon tetrachloride with results >~50 μg/L showed significantly lower levels (i.e., approximately one-third lower) reported by the fixed laboratory. No additional information on potential causes for these differences has been developed. The discrepancies in the data did not impact any project decisions during fiscal year 2001.

Previous evaluations noted an apparent non-random variability in interlaboratory splits for analysis of some metals at low levels. This was noted again this year but to a lesser degree. At levels below ~50 µg/L, results reported by STL St. Louis were greater than Lionville Laboratory's corresponding results for the following metals: iron, manganese, vanadium, and zinc. If low concentrations of these metals become of interest, the differences between analytical technologies should be investigated.

Overall evaluation indicates no significant issues between procedures and analyses performed by the laboratories providing services to Bechtel Hanford, Inc. The overall performance for fiscal year 2001 improved slightly from the previous year.

B.4 Holding Times

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Holding time is the elapsed time period between sample collection and analysis. Samples should be analyzed within recommended holding times to minimize the possibility of changes in constituent concentrations caused by volatilization, decomposition, or other chemical changes. Samples are also refrigerated to slow potential chemical reactions within the sample matrix. Maximum recommended holding times for constituents frequently analyzed for the groundwater project are listed in Table B.8. Radiological constituents do not have recommended maximum holding times because these constituents are not typically lost under ambient temperatures when appropriate preservatives are used. Results of radionuclide analysis are corrected for decay from sampling date to analysis date.

During fiscal year 2001, recommended holding times were exceeded for 418 out of 7,534 (5.6%) of the groundwater project's non-radiological sample analysis requests. A sample analysis request is defined as a sample that is submitted for analysis by a particular analytical method. In general, the missed holding times should not have a significant impact on the data. Results for samples with missed holding times are flagged with an H in the database. STL St. Louis exceeded the holding times for 411 out of 7,465 (5.5%) sample analysis requests. Of these, the constituents with the most missed holding times were anions by ion chromatography (235 samples), total dissolved solids (38 samples), cyanide (36 samples), total organic halides (24 samples), total organic carbon (19 samples), conductivity (16 samples), alkalinity (14 samples), and volatile organic compounds by Method 8260 (14 samples). STL Richland exceeded the holding times for 1 out of 33 (3.0%) coliform samples. Lionville Laboratory exceeded holding times for 6 out of the 36 analysis requests (16.7%) for total organic carbon and total organic halides that were processed for the groundwater project. This information was discussed with the laboratories to help them identify areas where improvements are needed.

Specific evaluation of adherence to analytical holding times for interim action monitoring was not performed for this report. Analytical holding times are monitored as part of ongoing sample and data management activities throughout the year. However, interim action monitoring data are not flagged for missed holding times. No remediation decisions were affected by missed holding times in fiscal year 2001.

B.5 Laboratory Performance

D. S. Sklarew, D. L. Stewart, and C. J. Thompson

Laboratory performance is measured by several indicators, including nationally based performance evaluation studies, double-blind standard analyses, laboratory audits, and internal laboratory QA/QC programs. This section provides a detailed discussion of the performance indicators for STL St. Louis and STL Richland. Brief summaries of performance measures for Lionville Laboratory and Eberline Services are also presented throughout this section. The majority of the laboratory's results were within the acceptance limits, indicating good performance overall.

B.5.1 Nationally Based Performance Evaluation Studies

During fiscal year 2001, Environmental Resources Associates, New York State Department of Health, and DOE conducted nationally based studies to evaluate laboratory performance for chemical and radiological constituents. STL St. Louis and Lionville Laboratory participated in the EPA sanctioned Water Pollution and Water Supply Performance Evaluation studies conducted by New York State (Environmental Laboratory Approval Program) and Environmental Resources Associates, respectively. STL Richland and Eberline Services took part in DOE's Quality

Assessment Program. STL Richland participated in the Environmental Resources Associates's InterLaB RadCheM Proficiency Testing Program, which has replaced the National Exposure Research Laboratory studies. All four laboratories took part in DOE's Mixed Analyte Performance Evaluation Program. Results of those studies related to groundwater monitoring at the Hanford Site are described in this section.

B.5.1.1 Water Pollution and Water Supply Studies

The purpose of water pollution and water supply studies is to evaluate the performance of laboratories in analyzing selected organic and inorganic compounds. Every month, an accredited agency such as the New York State Department of Health or Environmental Resource Associates 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, expressed in this report as a percentage of the results that the accredited agency found acceptable, independently verify the level of laboratory performance.

For the three potable and non-potable water chemistry studies in which STL St. Louis participated this year (NY ELAP 237, 240, and 245),(b) the percentage of acceptable results ranged from 92% to 95% (Table B.9). Of the 26 constituents with unacceptable results, only dicamba was out of limits more than once; however, both unacceptable results were caused by reporting errors. Low results for dimethylphthalate and orthophosphate are not significant because dimethylphthalate is not included in the target analyte list for Hanford samples, and an alternate method is used for phosphate analysis. Reporting or calculation errors caused ten unacceptable results. Dichlorodifluoromethane and vinyl chloride results were both high as a result of a calibration bias; laboratory staff believe this result was caused by degradation of the compounds in the calibration standard. Carbon tetrachloride also had a high result associated with a calibration bias. Laboratory staff believe mercury results were low because of sample instability. The low chemical oxygen demand result may have been caused by a dilution error. Aluminum and iron results may have been high because of trace environmental contamination. PCB-1221 was misidentified as PCB-1232 because of extraneous peaks; the laboratory felt this was an isolated incident. The laboratory was unable to identify a cause or determine a corrective action for the low results for total organic carbon, ammonia, 2-chloroethylvinyl ether, endosulfan sulfate, or total hardness. Similarly, no cause or corrective action was reported for the high results for alkalinity, specific conductance, iron, or potassium.

Lionville Laboratory participated in water pollution study WP-66 and water supply study WS-49 this year. The percentage of Lionville's acceptable results ranged from 86% to 94% (Table B.10). Of the 40 constituents with unacceptable results, benzene, 1,2-dichlorobenzene, methylene chloride, and 1,1,2,2-tetrachloroethane were out of limits twice; in one case these were all biased high, in the other case, they were all biased low. Twenty-five other volatiles analyzed by method 502.2 were also biased high. Cyanide results have been unacceptable in this and previous water supply studies; the error appears to be caused by lack of pH control, which is now being corrected. Corrective action has also been taken for persistent unacceptable results for 2,4-D; hydrolysis and derivatization procedures have been modified. Total phosphate may have been incorrect due to poorly controlled pH adjustment. Biological oxygen demand results were corrected during re-analysis. The laboratory believes that there is an ongoing problem with the sample provided for total suspended solids analysis and does not believe that corrective action on their part is necessary; they propose using another performance evaluator for total suspended solids samples.

B.5.1.2 DOE Quality Assessment and Mixed Analyte Performance Evaluation Programs

DOE's Quality Assessment Program evaluates how laboratories perform when they analyze radionuclides in water, air filter, soil, and vegetation samples. This discussion considers only water samples. The program is coordinated by the Environmental Measurements Laboratory in New York. The Environmental Measurements Laboratory provides blind standards that contain specific amounts of one or more radionuclides to participating laboratories. Constituents analyzed can include americium-241, cesium-137, cobalt-60, gross alpha, gross beta, plutonium-238, plutonium-239, strontium-90, tritium, uranium-234, uranium-238, and total uranium. After sample analysis, each participating laboratory forwards the results to the Environmental Measurements Laboratory for comparison with known values and with results from other laboratories. The Environmental Measurements Laboratory evaluates the accuracy

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(b) Letter reports from M. Caruso (Environmental Laboratory Approval Program, State of New York Department of Health, Albany, New York) to W. Deckelmann (Severn Trent Laboratories, St. Louis, Earth City, Missouri). Proficiency Test Reports, ELAP 237, December 15, 2000; ELAP 240, April 5, 2001; and ELAP 245, October 3, 2001.

of the results based on the historical analytical capabilities for the individual analyte/matrix pairs. Using a cumulative normalized distribution, acceptable performance yields results between the 15th and 85th percentiles. Acceptable with warning results are between the 5th and 15th percentile and between the 85th and 95th percentile. Not acceptable results include the outer 10% (<5th percentile or >95th percentile) of historical data (EML-611; EML-613; EML-615).

For the three studies conducted this year, QAP53 (EML-611), QAP54 (EML-613), and QAP55 (EML-615), the percentages of STL Richland's acceptable results were 100%, 100%, and 80%, respectively (Table B.11). The two unacceptable results were for cobalt-60 and cesium-137. Five constituents (42%) in the first study, three constituents (25%) in the second study, and one constituent (10%) in the third study had results that were evaluated as acceptable with warning (see Table B.11).

The percentages of Eberline Services' results that were acceptable for the three studies were 92%, 92%, and 100%, respectively (Table B.12). The constituents with unacceptable results were total uranium and gross alpha. Two constituents (17%) in the first study, one constituent (8%) in the second study, and four constituents (33%) in the third study had results that were evaluated as acceptable with warning (see Table B.12).

DOE's Mixed Analyte Performance Evaluation Program examines laboratory performance in the analysis of soil and water samples containing metals, volatile and 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, and is similar in operation to DOE's Quality Assessment Program discussed above. DOE evaluates the accuracy of the Mixed Analyte Performance Evaluation Program results for radiological and inorganic samples by determining if they fall within a 30% bias of the reference value.

All fiscal year 2001 results (MAPEP-00-W8) for inorganics for STL St. Louis were acceptable (Table B.11). All radiological constituents and organics were also acceptable for STL St. Louis, though 6 were acceptable with warning. Only one result for STL Richland, strontium-90, was not acceptable (see Table B.11). All results for Eberline Services and Lionville Laboratory were acceptable (see Table B.12).

B.5.1.3 InterLaB RadCheM Proficiency Testing Program Studies

The purpose of the InterLaB RadCheM Proficiency Testing Program, conducted by Environmental Resources Associates, is to evaluate the performance of laboratories in analyzing selected radionuclides. The program provides blind standards that contain specific amounts of one or more radionuclides in a water matrix to participating laboratories. Environmental Resources Associates standards were prepared for the following radionuclides/parameters: barium-133, cesium-134, cesium-137, cobalt-60, gross alpha, gross beta, iodine-131, radium-226, radium-228, strontium-89, strontium-90, tritium, uranium, and zinc-65. After sample analysis, the results were forwarded to Environmental Resources Associates for comparison with known values and with results from other laboratories. Environmental Resources Associates bases its control limits on the EPA's National Standards for Water Proficiency Testing Studies Criteria Document (NERL-Ci-0045).

In the 15 studies in which STL Richland participated, 51 constituents were analyzed. Of these, 46 (90%) were acceptable. The unacceptable results were for uranium, strontium-89, cesium-134 (twice), and gross beta (see Table B.11). None of the results were evaluated as acceptable with warning.

Eberline Services does not participate in the Environmental Resources Associates program.

B.5.2 Double-Blind Standard Evaluation

The groundwater project forwarded blind QC standards to STL Richland and St. Louis, Lionville Laboratory, and Eberline Services during fiscal year 2001. Blind spiked standards were generally prepared in triplicate and submitted to the laboratories to check the accuracy and precision of analyses. For most constituents, the standards were prepared in a groundwater matrix from a background well. Cyanide standards for the first three quarters and standards for trace ICP metals were prepared in organic free, deionized water. In all cases, the standards were submitted to the laboratories in double-blind fashion (i.e., the standards were disguised as regular groundwater samples). After analysis, the laboratory's results were compared with the spiked concentrations, and a set of control limits were used to determine if the data were acceptable. Generally, if a result was out of limits, the data was reviewed for errors. In situations where several results for the same method were unacceptable, the results were discussed with the laboratory, potential problems were investigated, and corrective actions were taken if appropriate.

Tables B.13 and B.14 list the number and types of blind standards used in fiscal year 2001 along with the control limits for each constituent. Overall, 83% of the blind spike determinations were acceptable. Eighty-six percent of the results from STL Richland and St. Louis were within the control limits, which is slightly lower than the percentage from last year (90%). Lionville Laboratory's and Eberline Services' overall performance was poor; only 65% of the results from those two labs were acceptable.

Table B.15 lists the blind-standard spike concentrations and the average results for STL Richland and St. Louis. One or more individual results (not listed separately in Table B.15) were unacceptably high for gross beta, selenium, and total organic carbon. Similarly, one or more results were biased low for cadmium, cyanide, technetium-99, and total organic halides.

All of STL St. Louis' results for total organic carbon were biased high, but only two were outside the acceptance limits. Most of the results had recoveries ranging from 110% to 120%. A similar tendency was observed in last year's blind standard results. The standards with the out-of-limit recoveries were spiked at the lowest levels (1,002 μg/L, which is approximately equal to the laboratory's practical quantitation limit). However, the unknown source of bias in these results may also be partially responsible for some of the elevated total organic carbon results for field blanks (discussed in Section B.2.1).

Thirteen of fourteen results for total organic halides from STL St. Louis were out of limits. Two of the unacceptable results were for standards spiked with 2,4,6-trichlorophenol at a concentration near the detection limit, where the precision is expected to be poor. The remaining out-of-limit results were for standards spiked with volatile organic compounds. The groundwater project performed in-house analyses on splits of the standards and confirmed that the standards were spiked at the proper concentrations. Consequently, the reason for the low bias appears to be volatilization or weak retention of the volatile analytes on the charcoal cartridges used in the analysis. The laboratory investigated the out-of-limit results but was unable to determine the source of error. Low-biased total organic halide results are of concern because of the potential for not detecting halogenated organics at RCRA sites. However, even with a 50% negative bias, detection should occur at concentrations well below the limit of quantitation (discussed in Section B.5).

Approximately half of STL St. Louis' cyanide results were biased low by 25% to 50%. Similar results were also obtained last year, and project staff members postulated that the low results were caused by instability of the commercially-prepared cyanide solutions. During the first quarter of this year, two sets of cyanide standards were prepared and submitted to STL St. Louis to check the integrity of the commercial solutions. The first set of standards was prepared in the same manner as those from previous quarters (i.e., by diluting a commercially-prepared stock solution containing cyanide). The second set of standards was prepared gravimetrically using a cyanide salt. The results indicated that the problem was related to the commercial solutions, because the gravimetric standards had acceptable results, while the commercial standards remained low by ~25%. Gravimetric standards were submitted to STL St. Louis during the last 3 quarters of the year, and the second and third quarter results were improved, with recoveries ranging from 96% to 115%. However, during the fourth quarter, the recoveries dropped again to 50% to 75%. The laboratory had some instrumentation problems during the fourth quarter that may have caused the low values.

During the second quarter, a special set of blind standards containing low concentrations of antimony, arsenic, cadmium, lead, selenium, and thallium was submitted to STL St. Louis to evaluate the laboratory's trace-ICP capability. Overall, the laboratory performed well on the trace-metal standards. With the exception of cadmium, all of the results were within the acceptance limits. The cadmium recoveries were ~40%. Possible reasons for the low recoveries were investigated during the fourth quarter by submitting three sets of cadmium-containing blind standards to STL St. Louis. The first set was identical to the second quarter standards and was prepared using the second-quarter stock solution. The second set consisted of one sample that was prepared from a fresh stock solution, and the third set was prepared using a stock solution from a different vendor (Fisher Scientific). Results from the three sets of standards were mixed. Cadmium recoveries in the first set of standards were <20%, suggesting that the second-quarter stock solution was unstable. All other metals had acceptable results except selenium, whose concentrations were within a factor of two of the instrument detection limit. The cadmium standard prepared from the fresh stock solution had an acceptable recovery of 95%. Finally, the cadmium recoveries in the final set of standards ranged from 64% to 69%. Since cadmium in the latter two sets of standards was spiked at concentrations near the instrument detection limit, the results are not unreasonable. Additional blind standards are planned for fiscal year 2002 to further evaluate the laboratory's performance on trace metals.

In general, STL Richland's performance on radiological blind standards was excellent. All results except two from the second quarter were within the QC limits. The out-of-limit results were for gross beta and technetium-99. Since the other second quarter results for these constituents were acceptable, the out-of-limit results appear to have been caused by an isolated procedural error at the laboratory.

STL St. Louis' ability to serve as a backup radiological laboratory was evaluated with blind standards that were analyzed for gross alpha, gross beta, strontium-90, and uranium-238. All of the results for these standards were within the acceptance limits.

Table B.16 provides a detailed summary of Lionville Laboratory's and Eberline Services' blind standard results. In contrast with last year, all of the two labs' results for total organic carbon and gross beta were acceptable. However, Lionville Laboratory continued to have problems with standards for total organic halides. Three of the results were biased high by ~140%. Moreover, eleven total organic halide results had low recoveries that ranged from 38% to 75%. Although the laboratory reanalyzed some of the samples and rechecked the data for the others, no errors were found. The impact of the out-of-limit results is minimal because Lionville Laboratory did not analyze any routine groundwater samples for total organic halides during fiscal year 2001. Two-thirds of Eberline Services' results for gross alpha were outside the QC limits. Individual standard recoveries ranged from 52% to 71%. The laboratory re-analyzed all of the samples with the out-of-limit results, but the re-analysis results did not show better agreement with the spiked concentrations. Eberline Services did not analyze any routine long-term monitoring samples for gross alpha during fiscal year 2001.

Bechtel Hanford, Inc. sent no blind standards as part of interim action monitoring to the commercial laboratories in fiscal year 2001. The great similarity of matrices between the long-term and interim action monitoring samples and common use of the same laboratories make additional analysis of blind standards redundant.

B.5.3 Laboratory Internal QA/QC Programs

STL Richland, STL St. Louis, Eberline Services, and Lionville Laboratory maintain internal QA/QC programs that generate data on analytical performance by analyzing method blanks, laboratory control samples, matrix spikes and matrix spike duplicates, matrix duplicates, and surrogates (see PNNL-13080 for definitions of these terms). This information provides a means of assessing laboratory performance and the suitability of a method for a particular sample matrix. Laboratory QC data are not currently used for in-house validation of individual sample results unless the lab is experiencing unusual performance problems with an analytical method. An assessment of the laboratory QC data for fiscal year 2001 is summarized in this section. STL data are discussed in detail first and are presented in Tables B.17 through B.20. Constituents not listed in these tables did not exceed STL's QC limits. A brief summary of Lionville Laboratory and Eberline Services data is presented at the end of the section.

Most of this year's laboratory QC results were within acceptance limits, suggesting that the analyses were in control and reliable data were generated. Nevertheless, several parameters had unacceptable results, and some were significantly out-of-limits. For method blanks, significantly out-of-limits means some results were greater than twice the QC limit. For laboratory control samples, matrix spikes, and duplicates, significantly out-of-limits means the results were outside the range of the QC limits plus or minus more than 10 percentage points (e.g., if the QC limits are 80% to 120%, significantly out-of-limits would mean <70% or >130%). Results that were significantly out-of-limits are noted in Tables B.17 through B.20.

Evaluation of results for method blanks was based on the frequency of detection above the blank QC limits. In general, these limits are two times the method detection limit for chemical constituents and two times the total propagated error 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.

Table B.17 summarizes method blank results from STL Richland and St. Louis. The general chemistry parameters, ammonia and anions, and metals categories had the greatest percentages of method blank results exceeding the QC limits. The following parameters had >10% of method blank results outside the QC limits: specific conductance, total organic carbon, chloride, cyanide, phosphate, aluminum, iron, sodium, thallium, and methylene chloride. The out-of-limit method blank results for conductance are not a significant problem because the values are much lower than the levels measured in Hanford Site groundwater. Similarly, the highest method blank result for chloride (0.19 mg/L) is lower than the chloride levels measured in Hanford groundwater. The percentage of out-of-limit method blanks for total organic carbon increased significantly over that from last year. As noted in Section B.2.1, the elevated method blank results appear to have been caused by instrumentation problems during the third quarter.

Table B.18 summarizes results for the laboratory control samples from STL Richland and St. Louis. Only semivolatile organic compounds had >2% of their measurements outside the QC limit. The higher than usual failure rate for laboratory control samples for semivolatile organics was mainly the result of one day's analysis of a series of phenols in which the QC limits were exceeded. Three phenols and uranium-235 had >10% of laboratory control samples outside of QC limits. Because phenols are rarely found in Hanford groundwater samples, the phenol results should not have a significant impact. Historical data for uranium-235 in wells associated with the out-of-limits laboratory control samples were too sparse to define trends for uranium-235; thus it is not possible to determine if the out-of-limit laboratory control sample results had an impact on the associated uranium-235 data.

Table B.19 summarizes results for the matrix spikes and matrix spike duplicates from STL Richland and St. Louis. Fewer than 5% of the matrix spikes or matrix spike duplicates for general chemistry parameters, metals, and volatile organic compounds were out of limits. The ammonia and anions, semivolatile organics, and radiochemistry parameters categories had the greatest percentage of matrix spikes/spike duplicates exceeding the QC limits. Table B.19 indicates which constituents had >10% of matrix spikes/spike duplicates out of limits. A spot check of historical data in wells associated with a number of these out-of-limits matrix spike samples indicated that data were generally too sparse to define trends for the constituents; thus, it is not possible to determine if the out-of-limit matrix spikes had an impact on the associated data.

Matrix duplicates were evaluated by comparing the relative percent difference to the QC limit for results that were five times greater than the method detection limit or the minimum detectable activity. Table B.20 lists the constituents that exceeded the relative percent difference limits. All categories had fewer than 4% of their measurements outside the QC limits. Only cyanide and pentachlorophenol had >10% of matrix spikes/spike duplicates out of limits. As with the matrix spikes, it is not possible to determine if the out-of-limit duplicate results had an impact on the associated data.

Surrogate data included eight compounds each for volatile organics and for semivolatile organics. For volatile organic compounds, 1.7% of the surrogate results were outside of QC limits; the corresponding percentage for semivolatile organic surrogates was 6.3%.

QC data for Eberline Services and Lionville Laboratory were limited for fiscal year 2001 because these laboratories did not analyze many samples for the groundwater project. Lionville Laboratory analyzed method blanks, laboratory control samples, matrix spikes, and matrix duplicates for total organic carbon and total organic halides. Most of the results were within QC limits. However, one total organic halide matrix spike and one total organic halide duplicate were outside the limits. Eberline Services QC data were limited to gross alpha and gross beta. All the QC data except one gross beta duplicate were within limits for these parameters.

B.5.3.1 Issue Resolution

Issue resolution forms are documents that are used to record and resolve problems encountered with sample receipt, sample analysis, missed hold times, and data reporting (e.g., broken bottles or QC problems). The laboratories generate the forms and forward them to the groundwater project as soon as possible after a potential problem is identified. The forms provide a means for the project to give direction to the laboratory on resolution with the issues. The documentation is intended to identify occurrences, deficiencies, and/or issues that may potentially have an adverse effect on data integrity. Table B.21 indicates the specific issues identified during fiscal year 2001 and the number of times these occurred. The number of issues identified by the laboratories was small compared to the total number of samples submitted for analyses (~10,200, consisting of ~12,300 bottles). The frequencies of the individual issues increased in some categories and remained the same as last year for other categories. The increases are primarily due to a more complete documentation process being implemented at the laboratory. Previously, the laboratory documented many of the problems via non-conformance memos provided in data packages.

B.5.3.2 Laboratory Audits/Assessments

Laboratory activities are regularly assessed by surveillance and auditing processes to ensure that quality problems are prevented and/or detected. Regular assessment supports continuous process improvement.

Assessments of STL Richland and St. Louis were conducted February 25 to March 1, 2001, and April 24 to 26, 2001, respectively. Representatives from Bechtel Hanford, Inc. performed the Richland audit, and Hanford Site's Integrated Contractor Assessment Team, consisting of representatives from Bechtel Hanford, Inc. and PNNL conducted the St. Louis audit. The purpose of the assessments was to evaluate the continued support of analytical services to Hanford Site contractors as specified in the statement of work between Flour Hanford, Inc. and Severn Trent Laboratories (Fluor Hanford Contract 615, RFSH-SOW-93-0003).(c)

The assessment scope for these audits was based on the analytical and QA requirements for both groundwater and multi-media samples as specified in the statement of work. The primary areas of focus for the STL Richland laboratory

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(c) RFSH-SOW-93-0003, Rev. 6. 1999. *Environmental and Waste Characterization of Analytical Services*. Statement of Work between Fluor Daniel Hanford, Inc. and Severn Trent Laboratories, Richland, Washington.

were personnel training, procedure compliance, sample receipt and tracking, instrument operation and calibration, equipment maintenance, instrumentation records and logbooks, implementation of Severn Trent Laboratories' QA Management Plan in accordance with Hanford Analytical Services Quality Assurance Document (HASQARD, Volumes 1 and 4, DOE/RL-96-98) and the implementation of corrective actions for deficiencies identified in previous audits.

For the laboratory audit at STL St. Louis, emphasis was placed on the implementation of Severn Trent Laboratories' QA program in accordance with the requirements of HASQARD, compliance to laboratory specific administrative and technical operating procedures, and verification of the corrective actions initiated in response to the previous audits. The specific areas reviewed included sample preparation, instrument calibration, quality control sample data and acceptance criteria, logbook review, data reporting, and preventative maintenance.

Two findings and four observations were noted in the assessment of STL Richland, and six findings and six observations were identified during the assessment of STL St. Louis. Improved compliance to HASQARD was noted as evident by the reduced number of deficiencies identified this year. The findings and observations related to deficiencies in the following specific programmatic areas: document control, quality improvement, work processes, sample receipt, procedure development and review, control charting practices, internal audit frequency, preventative maintenance, and calibration. Corrective-action responses to the assessment findings and observations have been evaluated. The STL Richland laboratory has addressed all finding and observations, and the audit findings have been closed. STL St. Louis has addressed all findings and observations; all of the findings except three have been closed.

Quality and technical representatives from Bechtel Hanford, Inc. conducted assessments of Eberline Services, Inc., Richmond, California Laboratory and its subcontractor, Lionville Laboratory (formerly RECRA) on July 10 to 12, 2001, and May 22 to 24, 2001, respectively. The scope of these audits focused on the analytical and QA requirements for sample analyses as specified in the Flour Hanford Contract 630, and associated SOW 93-003, Rev. 6, Environmental and Waste Characterization Analytical Services, with these laboratories. The primary focus of these audits was the implementation of the of their operating procedures to meet the requirements specified in the SOW and verification of the implementation of corrective actions associated with last year's audit of Lionville laboratory.

No findings were noted for Eberline Services. However, two observations were identified during the audit of Eberline Services, Inc. The observations were related to management of sample receipt anomalies and incompleteness of the record control and storage procedure. All corrective-action responses have been addressed by the laboratory and were found acceptable.

Four findings and three observations were noted for Lionville Laboratory. These findings and observations were related to procedural non-compliance, overdue review of procedures, non-compliance to the QA requirements in HASQARD, and an inadequate and ineffective review of corrective-action processes. Closure of the audit findings for 2001 is complete, although the 2000 audit remains open.

Members of the DOE-sponsored Environmental Management Consolidated Assessment Program also conducted audits of STL St. Louis, Eberline Services, and Lionville Laboratory. The dates for these assessments were May 15 to 17, 2001, July 10 to 12, 2001, and August 28 to 30, 2001, respectively. The goal of the Environmental Management Consolidated Assessment Program is to design and implement a program for consolidating site audits of commercial and DOE environmental laboratories providing services to DOE Environmental Management.

The focus of the Environmental Management Consolidated Assessment Program audits included the following areas: general laboratory practices and quality management, data quality for inorganics and organic chemistry and radiochemistry analysis, laboratory information management and electronic data deliverables, and hazardous and radioactive material management. STL St. Louis had findings in the following areas: incomplete or lack of procedures, procedural non-compliance, implementation of the preventative maintenance program, instrument calibration, records storage and management, and incomplete documentation for the handling of hazardous and radioactive materials. Eberline Services, Inc. and Lionville Laboratory had findings related to procedural noncompliance, training, database change control, records management processes, insufficient corrective action management system, and insufficient implementation of their waste disposal/storage program.

Continued assessments of the laboratories are planned for the upcoming year to further evaluate performance and to ensure those corrective actions for the past findings and observations have been implemented.

B.6 Limit of Detection, Limit of Quantitation, and Method Detection Limit

C. J. Chou, D. S. Sklarew, and C. J. Thompson

Detection and quantitation limits are essential for evaluating data quality and usefulness because they provide the limits of a method's measurement. The detection limit is the lower limit at which a measurement can be differentiated from background. The quantitation limit is the lower limit where a measurement becomes quantifiably meaningful. The limit of detection, limit of quantitation, and method detection limit are useful for evaluating groundwater data.

The limit of detection is defined as the lowest concentration level statistically different from a blank (Currie 1988). The concentration at which an analyte can be detected depends on the variability of the blank response. For the purpose of this discussion, the blank is taken to be a method blank.

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, OSWER 9355.0-14). 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% (Miller and Miller 1988). A false-positive error is an instance when an analyte is declared to be present but is, in fact, absent. A false-negative error is an instance when an analyte is declared to be absent but is, in fact, present.

The limit of detection for a radionuclide is typically computed from the counting error associated with each reported result (e.g., EPA 520/1-80-012) and 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 B.22 are based on variabilities that result from both 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, and the values shown in Table B.22 are most useful for assessing long-term variability in the overall 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). The limit of quantitation is calculated as the blank mean plus 10 standard deviations of the blank (EPA/540/P-87/001, OSWER 9355.0-14). The blank-corrected limit of quantitation is simply ten 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% probability that the true concentration of the analyte is within ±25% 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% 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.

For this report, total organic carbon, total organic halides, and radionuclide field blank data are available for limit of detection and limit of quantitation determinations. The field blanks are QC samples that are introduced into a process to monitor the performance of the system. 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. The results of the limit of detection and limit of quantitation determinations are listed in Table B.22.

Because of the lack of blank data for other constituents of concern, it was necessary to calculate approximate limit of detection and limit of quantitation values by using variability information obtained from low-level standards. The data from the low-level standards are obtained from laboratory method detection limit studies. If low-level standards are used, the variability of the difference between the sample and blank response is increased by a factor of √2 (Currie 1988, p. 84). The formulas are summarized below:

$$\mathrm{MDL} = 3.14 \text{ x } s$$

$$\mathrm{LOD} = 3 \text{ x } \left(\sqrt{2} \text{ x } s\right)$$
$$= 4.24 \text{ x } s$$

$$\mathrm{LOQ} = 10 \text{ x } \left(\sqrt{2} \text{ x } s\right)$$
$$= 14.14 \text{ x } s$$

where s = standard deviation from the seven replicates of the low-level standard.

The results of limit of detection, limit of quantitation, and method detection limit calculations for most non-radiological constituents of concern (besides total organic carbon and total organic halides) are listed in Table B.23. The values in the table apply to STL St. Louis only.

Specific evaluation of detection-limit issues for the interim action groundwater monitoring program was not performed for this report. Detection-limit issues are primarily assessed as part of site-specific validation activities. No validation activities were performed on interim action groundwater monitoring data in fiscal year 2001.

B.7 Conclusions

Overall, assessments of fiscal year 2001 QA/QC information indicate that groundwater monitoring data are reliable and defensible. Sampling was conducted in accordance with reviewed procedures. Few contamination or other sampling-related problems were encountered that affected data integrity. Likewise, laboratory performance was excellent in most respects, based on the large percentages of acceptable field and laboratory QC results. Satisfactory laboratory audits and generally acceptable results in nationally-based performance evaluation studies also demonstrated good laboratory performance. However, the following areas of concern were identified and should be considered when interpreting groundwater monitoring results:

- 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 should be identified during data review.
- Several indicator parameters, anions, metals, and volatile organic compounds were detected at low levels in field and/or laboratory method blanks. The most significant contaminants were iron, methylene chloride, total organic carbon, total organic halides, and zinc.
- Maximum recommended holding times were exceeded for ~6% of groundwater project samples that were analyzed by non-radiological methods. Anions and indicator parameters were primarily affected, though the data impacts are considered minor.
- STL St. Louis and Lionville Laboratory had several out-of-limit blind-standard results for total organic halides. Most of the results had a low bias, suggesting that groundwater results for total organic halides may also be biased low. STL St. Louis also had performance problems with cyanide standards, although some of the low values appear to have resulted from problems with the standards. Finally, Eberline Services had several low-biased blind-standard results for gross alpha.

B.8 References

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Table B.1. Long-Term Monitoring Full Trip Blanks Exceeding Quality Control Limits

Constituent	Number Out of Limits	Number of Analyses	Percent Out of Limits	Range of QC Limits(a)	Range of Out-of-Limit Results
General Chemical Parameters					
Total organic carbon	23	58	39.7	74 - 444 μg/L	350 - 1,500 μg/L
Total organic halides	1	54	1.9	7.13 - 8.54 μg/L	8.1 μg/L
Ammonia and Anions					
Chloride	19	52	36.5	20 - 69.2 μg/L	29 - 200 μg/L
Cyanide	2	6	33.3	3.18 - 5.02 μg/L	10.4 - 27.5 μg/L
Fluoride	1	52	1.9	12 - 20.8 μg/L	54 μg/L
Nitrogen in nitrate	4	52	7.7	4 - 22 μg/L	11 - 49 μg/L
Sulfate	1	52	1.9	58 - 216 μg/L	400 μg/L
Metals					
Aluminum	1	38	2.6	83.6 μg/L	220 μg/L
Copper	1	38	2.6	5.6 μg/L	11 μg/L
Iron	5	38	13.2	31.2 μg/L	36.1 - 251 μg/L
Potassium	1	38	2.6	2,930 μg/L	4,650 μg/L
Sodium	11	38	28.9	166 μg/L	318 - 1,060 μg/L
Zinc	2	38	5.3	6.2 μg/L	9.7 - 25.4 μg/L
Volatile Organic Compounds					
Acetone	1	20	5.0	1.5 - 20.1 μg/L	3.1 μg/L
Methylene chloride	2	22	9.1	1.2 - 11.9 μg/L	2.9 - 4.8 μg/L
Radiological Parameters					
Tritium	5	40	12.5	30 - 440 pCi/L(b)	317 - 213 pCi/L
Uranium	1	18	5.6	0.00032 - 0.0072 μg/L(b)	0.0146 μg/L

(a) Because method detection limits 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) The limit for radiological analyses is determined by the sample-specific total propagated uncertainty.

Table B.2. Long-Term Monitoring Field Transfer Blanks Exceeding Quality Control Limits

Constituent	Number Out of Limits	Number of Analyses	Percent Out of Limits	Range of QC Limits(a) (μg/L)	Range of Out-of-Limit Results (μg/L)
Acetone	1	108	0.9	1.5 - 20.1	3.8
Carbon tetrachloride	1	109	0.9	0.46 - 1.3	29
Chloroform	1	109	0.9	0.42 - 0.76	5.1
cis-1,2-Dichloroethlene	1	109	0.9	0.36 - 1.0	1.8
Methylene chloride	24	109	22.0	1.2 - 11.9	1.4 - 11
Trichloroethene	2	109	1.8	0.32 - 0.62	0.58 - 0.76

(a) Because method detection limits 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.

Table B.3. Long-Term Monitoring Equipment Blanks Exceeding Quality Control Limits

Constituent	Number Out of Limits	Number of Analyses	Percent Out of Limits	Range of QC Limits[(a)]	Range of Out-of-Limit Results
General Chemical Parameters					
Total dissolved solids	1	1	100.0	8,456 µg/L	37,000 µg/L
Total organic carbon	5	5	100.0	74 - 444 µg/L	550 - 1,100 µg/L
Total organic halides	4	5	80.0	7.13 - 8.54 µg/L	9.6 - 18.2 µg/L
Ammonia and Anions					
Chloride	3	7	42.9	20 - 100 µg/L	27 - 6,300 µg/L
Fluoride	1	7	14.3	12 - 20.8 µg/L	140 µg/L
Nitrogen in nitrate	1	7	14.3	4 - 22 µg/L	35 µg/L
Sulfate	1	7	14.3	58 - 216 µg/L	150 µg/L
Metals					
Iron	2	6	33.3	31.2 µg/L	36.5 - 70.3 µg/L
Manganese	1	6	16.7	1.8 µg/L	3.5 µg/L
Sodium	1	6	16.7	166.2 µg/L	189 µg/L
Zinc	2	6	33.3	6.2 µg/L	6.5 - 13.7 µg/L
Radiological Parameters					
Tritium	1	6	16.7	40 - 440 pCi/L[(b)]	193 pCi/L
Uranium	1	2	50.0	0.0154 µg/L[(b)]	0.0323 µg/L

(a) Because method detection limits 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) The limit for radiological analyses is determined by the sample-specific total propagated uncertainty.

Table B.4. Long-Term Monitoring 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 Relative Percent Differences[b]
General Chemical Parameters					
Alkalinity	38	38	1	2.6	67.4
Oil and grease	2	1	1	100.0	68.3
Total dissolved solids	17	17	1	5.9	59.5
Ammonia and Anions					
Chloride	54	54	3	5.6	31.7 - 110.0
Fluoride	54	54	1	1.9	58
Nitrogen in nitrate	52	52	3	5.8	25.7 - 151.3
Sulfate	66	66	3	4.5	29.0 - 126.9
Metals					
Calcium	51	51	1	2.0	56.6
Chromium	63	21	5	23.8	27.0 - 68.1
Iron	51	11	4	36.4	40.8 - 126.5
Manganese	51	5	1	20.0	45.4
Potassium	51	18	3	16.7	20.8 - 65.3
Sodium	51	51	1	2.0	98.7
Volatile Organic Compounds					
Carbon disulfide	19	1	1	100.0	161.3
Carbon tetrachloride	20	9	1	11.1	28.6
Radiological Parameters					
Cobalt-60	14	1	1	100.0	26.9
Gross alpha	35	3	2	66.7	27.4 - 169.4
Gross beta	31	22	4	18.2	25.2 - 47.3
Iodine-129	17	5	1	20.0	21.9
Tritium	43	32	1	3.1	29

(a) Duplicates with both results less than five times the method detection limit or minimum detectable activity were excluded from the evaluation.

(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 B.5. Interim Action Monitoring Field Blank Detections

Constituent	Total Number of Detects	Number of Analyses	Percent Out of Limits	RDL[(a)]	Range of Detected Results
General Chemical Parameters					
Total dissolved solids	4	4	100.0	10,000 µg/L	6,000 - 116,000 µg/L
Alkalinity	4	4	100.0	5,000 µg/L	500 - 1,000 µg/L
Anions					
Chloride	2	13	15.4	200 µg/L	400 - 510 µg/L
Nitrate	1	12	8.3	250 µg/L	280 µg/L
Sulfate	1	13	7.7	500 µg/L	290 µg/L
Metals					
Aluminum	6	15	40.0	200 µg/L	22 - 130 µg/L
Barium	4	23	17.4	200 µg/L	0.26 - 3.7 µg/L
Beryllium	2	15	13.3	5 µg/L	0.45 - 0.48 µg/L
Calcium	11	15	73.3	5,000 µg/L	21 - 68 µg/L
Chromium	1	23	4.3	10 µg/L	6.9 µg/L
Iron	11	15	73.3	100 µg/L	5.7 - 130 µg/L
Magnesium	4	15	26.7	5,000 µg/L	28 - 40 µg/L
Manganese	2	15	13.3	15 µg/L	4 - 4.3 µg/L
Nickel	1	15	6.7	40 µg/L	16 µg/L
Sodium	10	15	66.7	5,000 µg/L	44 - 370 µg/L
Zinc	15	23	65.2	20 µg/L	0.9 - 17 µg/L
Volatile Organic Compounds					
Acetone	1	18	5.6	20 µg/L	4 µg/L
Methylene chloride	16	18	88.9	5 µg/L	2 - 15 µg/L
Volatile Organic Compounds - Field Analysis					
Carbon tetrachloride	1	11	9.1	5 µg/L	58 µg/L
Radiological Parameters					
Tritium	1	9	11.1	400 pCi/L	210 pCi/L

(a) Contractually defined required detection limit.

Table B.6. Interim Action Monitoring Field Duplicates Exceeding Quality Control Limits

Constituent	Total Number of Duplicates	Number of Out of Limits	Percent Out of Limits	Range of Relative Percent Differences
General Chemical Parameters				
Total dissolved solids	2	1	50.00	22
Anions				
Chloride	14	1	7.14	21
Metals				
Aluminum	18	6	33.33	23 - 104
Arsenic	4	2	50.00	51 - 78
Chromium	22	3	13.64	20 - 58
Hexavalent chromium	41	1	2.44	164
Iron	18	7	38.89	24 - 132
Lead	4	1	25.00	153
Manganese	18	1	5.56	21
Selenium	4	1	25.00	56
Zinc	22	4	18.18	60 - 155
Radiological Parameters				
Gross beta	8	2	25.00	21 - 94
Technetium-99	11	1	9.09	83

Table B.7. Interim Action Monitoring Interlaboratory Splits Exceeding Quality Control Limits

Constituent	Total Number of Duplicates	Number of Out of Limits	Percent Out of Limits	Range of Relative Percent Differences
Ammonia and Anions				
Chloride	7	1	14.3	23
Sulfate	11	1	9.1	26
Metals				
Aluminum	10	1	10.0	92
Chromium	10	1	10.0	24
Iron	10	2	20.0	52 - 71
Manganese	10	2	20.0	40 - 42
Potassium	10	5	50.0	26 - 102
Sodium	10	1	10.0	26
Zinc	10	3	30.0	25 - 112
Radiological Parameters				
Gross beta	7	1	14.3	42
Technetium-99	4	1	25.0	25
Uranium	2	1	50.0	22
Fixed Laboratory-Field Analyses				
Carbon tetrachloride	7	7	100.0	22 - 72
Hexavalent chromium	33	2	6.1	21 - 43

Table B.8. Hanford Groundwater Monitoring Project Maximum Recommended Holding Times

Method	Constituent	Holding Time
8010/8020/8260 (SW-846)	Volatile organics	14 days
8270 (SW-846)	Semivolatile organics	7 days before extraction; 40 days after extraction
8080 (SW-846)	Pesticides	7 days before extraction; 40 days after extraction
8080 (SW-846)	Polychlorinated biphenyls	7 days before extraction; 40 days after extraction
8040 (SW-846)	Phenols	7 days before extraction; 40 days after extraction
6010 (SW-846)	Inductively coupled-plasma metals	6 months
7060 (SW-846)	Arsenic	6 months
7421 (SW-846)	Lead	6 months
7470 (SW-846)	Mercury	28 days
7740 (SW-846)	Selenium	6 months
7841 (SW-846)	Thallium	6 months
9012 (SW-846)	Cyanide	14 days
9020 (SW-846)	Total organic halides	28 days
9060 (SW-846)	Total organic carbon	28 days
9131 (SW-846)	Coliform	1 day
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
410.4 (EPA-600/4-81-004)	Chemical oxygen demand	28 days

Table B.9. Summary of Severn Trent-St. Louis Water Pollution Performance Evaluation Studies

Accreditation Laboratory	NY ELAP 237 October 2000 Percent Acceptable	NY ELAP 240 January 2001 Percent Acceptable	NY ELAP 245 July 2001 Percent Acceptable
New York Environmental Laboratory Approval Program	91.9[(a)]	94.9[(b)]	93.0[(c)]

(a) Unacceptable results were for total dissolved solids, mercury, carbon tetrachloride, dichlorodifluoromethane, vinyl chloride, isopropylbenzene, and p-isopropyltoluene.

(b) Unacceptable results were for total hardness, specific conductance, total organic carbon, alkalinity, ammonia, 2-chloroethylvinyl ether, dicamba, and endosulfan sulfate.

(c) Unacceptable results were for chemical oxygen demand, orthophosphate (as P), aluminum, iron, potassium, dimethylphthalate, 2,4-D, dicamba, chlordane, endosulfan II, and PCB 1221.

Table B.10. Summary of Lionville Laboratory Water Pollution (WP) and Water Supply (WS) Performance Evaluation Studies

Accreditation Laboratory	WP-66 September 2000 Percent Acceptable	WS-49 October 2000 Percent Acceptable
Environmental Resource Associates	93.8[(a)]	85.6[(b)]

(a) Unacceptable results were for BOD, total suspended solids, total phosphorus as P, benzene, the three dichlorobenzenes, and methylene chloride.

(b) Unacceptable results were for cyanide, dichlorodifluoromethane and 1,1,2,2-tetrachloroethane (by method 524.2), 2,4-D, hexachlorocyclopentadiene, and 27 VOAs by method 502.2 (benzene, chlorobenzene, 1,2-dichlorobenzene, 1,2-dichloroethane, cis-1,2-dichloroethylene, trans-1,2-dichloroethylene, 1,2-dichloropropane, methylene chloride, styrene, tetrachloroethylene, toluene, 1,2,4-trichlorobenzene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethylene, total xylenes, bromodichloromethane, bromoform, chlorodibromomethane, chloroform, total trihalomethanes, 2-chlorotoluene, dibromomethane, 1,1,1,2-tetrachloroethane, 1,1,2,2-tetrachloroethane, 1,2,3-trichloropropane, and 1,2,4-trimethylbenzene).

Table B.11. Summary of Severn Trent Interlaboratory Performance, Fiscal Year 2001

Radionuclides	Number of Results Reported for Each	Number Within Acceptable Control Limits
DOE Quality Assessment Program (QAP53, QAP54, QAP55) Environmental Measurements Laboratory		
Americium-241, gross alpha, gross beta, tritium, plutonium-238, plutonium-239, strontium-90, uranium	3	3[a,b]
Cobalt-60, cesium-137	3	2[a,b]
Uranium-234, uranium-238	2	2[a,b]
DOE Mixed Analyte Performance Evaluation Program (MAPEP-00-W8) Radiological and Environmental Sciences Laboratory		
Americium-241, cesium-134, cesium-137, cobalt-57, cobalt-60, manganese-54, nickel-63, plutoniuim-238, plutonium-239/240, uranium-234/233, uraniium-238, zinc-65	1	1[c]
Strontium-90	1	0[c]
Antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, vanadium, zinc; Americium-241, cesium-134, cesium-137, cobalt-57, cobalt-60, manganese-54, plutonium-238, plutonium-239/240, strontium-90, uraniuim-234/233, uranium-238, zinc-65; Nitrobenzene, 2,4-dimethylphenol, 1,2,4-trichlorobenzene, naphthalene, 2-nitroaniline, 2,4-dinitrotoluene, 4-nitrophenol, diethylphthalate, anthracene, pyrene, benzo(a)anthracene	1	1[d,e]
ERA InterLaB RadCheM Proficiency Testing Program Environmental Resource Associates		
Radium-226, radium-228	5	5[f]
Uranium	5	4[f]
Cobalt-60, cesium-137, gross alpha, strontium-90	4	4[f]
Gross beta, strontium-89	4	3[f]
Cesium-134	4	2[f]
Barium-133, iodine-131, tritium, zinc-65	2	2[f]

(a) Control limits from EML-611 and EML-613.
(b) Two results each for uranium-234 and uranium-238 and one result each for americium-241, cobalt-60, cesium-137, strontium-90, and total uranium were acceptable but outside warning limits.
(c) Results from STL Richland.
(d) Results from STL St. Louis.
(e) One result each for plutonium-238, plutonium-239/240, 1,2,4-trichlorobenzene, naphthalene, 2-nitroaniline, and 2,4-dinitrotoluene were acceptable but outside warning limits.
(f) Control limits from National Standards for Water Proficiency Testing Studies Criteria Document.

Table B.12. Summary of Eberline Services and Lionville Laboratory Interlaboratory Performance, Fiscal Year 2001

Radionuclides	Number of Results Reported for Each	Number Within Acceptable Control Limits
DOE Quality Assessment Program (QAP53, QAP54, QAP55) **Environmental Measurements Laboratory**		
Americium-241, cobalt-60, cesium-137, iron-55, gross beta, tritium, plutonium-238, plutonium-239, strontium-90, uranium-234, uranium-238	3	3(a,b)
Gross alpha, uranium	3	2(a,b)
DOE Mixed Analyte Performance Evaluation Program (MAPEP-00-W8) **Radiological and Environmental Sciences Laboratory**		
Americium-241, cesium-134, cesium-137, cobalt-57, cobalt-60, manganese-54, nickel-63, plutoniuim-238, plutonium-239/240, strontium-90, uranium-234/233, uranium-238, zinc-65	1	1(c)
Antimony, beryllium, cadmium, chromium, copper, nickel, selenium, thallium, vanadium, zinc; 1,3-Dichlorobenzene, 1,4-dichlorobenzene, nitrobenzene, 2,4-dimethylphenol, 1,2,4-trichlorobenzene, naphthalene, 2,6-dichlorophenol, 2-nitroaniline, 2,6-dinitrotoluene, 2,4-dinitrotoluene, 4-nitrophenol, diethylphthalate, anthracene, 1,3-dinitrobenzene, pyrene, benzo(a)anthracene	1	1(d)

(a) Results from Eberline Services. Control limits from EML-611 and EML-613.
(b) Two results each for uranium-238 and uranium and one result each for cesium-137, plutonium-239, and uranium-234 were acceptable but outside warning limits.
(c) Results from Eberline Services.
(d) Results from Lionville Laboratory.

Table B.13. Summary of Severn Trent Laboratories Double-Blind Spike Determinations

Constituent	Laboratory	Sample Frequency	Number of Results Reported[a]	Number of Results Outside QC Limits[b]	Control Limits[c] (%)
General Chemical Parameters					
Specific conductance	St. Louis	Quarterly	12	0	±25
Total organic carbon (potassium hydrogen phthalate spike)	St. Louis	Quarterly	16	2	±25
Total organic halides (2,4,6-trichlorophenol spike)	St. Louis	Quarterly	14	2	±25
Total organic halides (carbon tetrachloride, chloroform, and trichloroethene spike)	St. Louis	Quarterly	14	11	±25
Anions					
Cyanide	St. Louis	Quarterly	15	7	±25
Fluoride	St. Louis	Quarterly	12	0	±25
Nitrogen in nitrate	St. Louis	Semiannually	4	0	±25
Metals					
Antimony	St. Louis	Semiannually	6	0	±25
Arsenic	St. Louis	Semiannually	6	0	±25
Cadmiuim	St. Louis	Semiannually	9	8	±25
Lead	St. Louis	Semiannually	6	0	±20
Selenium	St. Louis	Semiannually	6	3	±25
Thallium	St. Louis	Semiannually	6	0	±25
Volatile Organic Compounds					
Carbon tetrachloride	St. Louis	Quarterly	12	0	±25
Chloroform	St. Louis	Quarterly	9	0	±25
Trichloroethene	St. Louis	Quarterly	12	0	±25
Radiological Parameters					
Gross alpha (plutonium-239 spike)	Richland	Quarterly	12	0	±25
Gross alpha (plutonium-239 spike)	St. Louis	Annually	3	0	±25
Gross beta (strontium-90 spike)	Richland	Quarterly	12	1	±25
Gross beta (strontium-90 spike)	St. Louis	Annually	3	0	±25
Cesium-137	Richland	Annually	3	0	±30
Cobalt-60	Richland	Annually	3	0	±30
Iodine-129	Richland	Semiannually	6	0	±30
Plutonium-239	Richland	Quarterly	12	0	±30
Strontium-90	Richland	Semiannually	6	0	±30
Strontium-90	St. Louis	Annually	3	0	±30
Technetium-99	Richland	Quarterly	12	1	±30
Tritium	Richland	Quarterly	12	0	±30
Uranium-238	Richland	Quarterly	12	0	±30
Uranium-238	St. Louis	Annually	3	0	±30

(a) Blind standards were generally submitted in triplicate or quadruplicate. Additional blind standards for cadmium and cyanide were submitted for special investigations as described in the text.

(b) Quality control limits are given in the Hanford Groundwater Monitoring Project's QA plan.

(c) Each result must be within the specified percentage of the known value to be acceptable.

Table B.14. Summary of Lionville Laboratory, Inc. and Eberline Services Double-Blind Spike Determinations

Constituent	Sample Frequency	Number of Results Reported[(a)]	Number of Results Outside QC Limits[(b)]	Control Limits[(c)] (%)
		General Chemical Parameters		
Total organic carbon (potassium hydrogen phthalate spike)	Quarterly	16	0	±25
Total organic halides (2,4,6-trichlorophenol spike)	Quarterly	10	7	±25
Total organic halides (carbon tetrachloride, chloroform, and trichloroethene spike)	Semiannually	7	7	±25
		Radiological Parameters		
Gross alpha (plutonium-239 spike)	Semiannually	6	4	±25
Gross beta (strontium-90 spike)	Quarterly	12	0	±25

(a) Blind standards were submitted in triplicate or quadruplicate.
(b) Quality control limits are given in the Hanford Groundwater Monitoring Project's QA plan.
(b) Each result must be within the specified percentage of the known value to be acceptable.

Table B.15. Double-Blind Standard Results, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Laboratory	Fiscal Year Quarter	Spike Amount	Average Result	Average Recovery (%)	Relative Standard Deviation (%)
General Chemical Parameters (µg/L)						
Conductivity	St. Louis	Second	445	429	96	1
	St. Louis	Third	445	506	114	1
Total organic carbon[a]	St. Louis	First	2,506	2,925	117	2
	St. Louis	Second	1,002	1,300	130	11
	St. Louis	Third	1,497	1,625	109	8
	St. Louis	Fourth	2,000	2,325	116	2
Total organic halides[b] (phenol)	St. Louis	First	101	80.2	79	6
	St. Louis	Second	900	878	98	6
	St. Louis	Third	13	9.68	74	20
	St. Louis	Fourth	44.4	43.2	97	22
Total organic halides[c] (volatile organic mixture)	St. Louis	First	102	63.0	62	13
	St. Louis	Second	950	631	66	16
	St. Louis	Third	13.6	14.1	103	9
	St. Louis	Fourth	44	28.6	65	3
Anions (µg/L)						
Cyanide	St. Louis	First	100	57.1	57	4
	St. Louis	Second	201.7	167.3	83	29
	St. Louis	Third	308.3	332.3	108	7
	St. Louis	Fourth	51.7	32.57	63	18
Cyanide[d] (gravimetric)	St. Louis	First	102.3	103.9	102	5
Fluoride	St. Louis	First	1,000	1,130	113	5
	St. Louis	Second	5,000	4,650	93	2
	St. Louis	Third	3,000	3,300	110	5
	St. Louis	Fourth	2,000	2,130	107	3
Nitrogen in nitrate	St. Louis	Second	45,180	41,300	91	--
	St. Louis	Third	45,180	46,033	102	0
Metals (µg/L)						
Antimony	St. Louis	Second	40.24	41.2	102	4
	St. Louis	Fourth	40.3	38.7	96	1
Arsenic	St. Louis	Second	16.10	18.2	113	4
	St. Louis	Fourth	16.1	17.4	108	2
Cadmium	St. Louis	Second	2.012	0.82	41	6
Cadmium	St. Louis	Fourth	2.00	1.9	95	--
Cadmium[e] (2nd quarter stock solution)	St. Louis	Fourth	8.07	1.43	18	8
Cadmium[f] (alternate supplier)	St. Louis	Fourth	2.03	1.35	67	5
Lead	St. Louis	Second	8.048	6.67	83	6
	St. Louis	Fourth	8.07	7.2	89	6
Selenium	St. Louis	Second	4.024	4.1	102	0
	St. Louis	Fourth	4.03	5.6	139	6
Thallium	St. Louis	Second	20.12	17.3	86	5
	St. Louis	Fourth	20.2	20.2	100	6
Volatile Organic Compounds (µg/L)						
Carbon tetrachloride	St. Louis	First	108	110	102	9
	St. Louis	Second	499	483	97	3
	St. Louis	Third	5.00	4.23	85	4
	St. Louis	Fourth	20	17.3	87	7
Chloroform	St. Louis	Second	226	243	108	2
	St. Louis	Third	5.00	5.1	102	7
	St. Louis	Fourth	20.0	19.3	97	3

Table B.15. (contd)

Constituent	Laboratory	Fiscal Year Quarter	Spike Amount	Average Result	Average Recovery (%)	Relative Standard Deviation (%)
Trichloroethene	St. Louis	First	7.00	5.67	81	6
	St. Louis	Second	209	190	91	0
	St. Louis	Third	5.00	4.77	95	3
	St. Louis	Fourth	10.0	8.77	88	2
Radiochemical Parameters (pCi/L)						
Cesium-137	Richland	Third	214.4	217.7	102	2
Cobalt-60	Richland	Third	50.04	50.1	100	10
Gross alpha	Richland	First	19.68	21.7	110	11
	Richland	Second	309.0	292	95	12
	St. Louis	Second	309.0	320	103	7
	Richland	Third	15.38	16.2	106	17
	Richland	Fourth	102.2	107	104	2
Gross beta[(g)]	Richland	First	39.97	42.8	107	4
	Richland	Second	28.94	33.6	116	9
	St. Louis	Second	28.94	34.8	120	4
	Richland	Third	68.5	76.6	112	1
	Richland	Fourth	115.6	119	103	1
Iodine-129	Richland	First	29.8	32.0	107	4
	Richland	Third	9.5	9.21	97	5
Plutonium-239	Richland	First	19.68	22.3	113	7
	Richland	Second	1.51	1.47	98	10
	Richland	Third	7.1	8.57	121	8
	Richland	Fourth	2	1.94	97	22
Strontium-90	Richland	Second	20.1	21.8	108	5
	Richland	Fourth	101.2	106	105	6
	St. Louis	Fourth	101.2	124	123	1
Technetium-99	Richland	First	461.0	475	103	3
	Richland	Second	1,006	791	79	56
	Richland	Third	202.7	207	102	2
	Richland	Fourth	102.4	113	110	7
Tritium	Richland	First	258.9	240	93	13
	Richland	Second	202.6	219	108	3
	Richland	Third	20,200	18,200	90	1
	Richland	Fourth	259.2	264	102	4
Uranium-238	Richland	First	62.31	66.4	107	1
	Richland	Second	153.6	159	103	1
	St. Louis	Second	153.6	165	107	2
	Richland	Third	916.8	985	107	0
	Richland	Fourth	332.2	313	94	8

(a) Total organic carbon standards were submitted in quadruplicate each quarter.

(b) Total organic halide (phenol) standards were submitted in quadruplicate during the second and third quarters. The standards were submitted in triplicate in the first and fourth quarters.

(c) Total organic halide (volatile) standards were submitted in quadruplicate during the first and fourth quarters. The standards were submitted in triplicate in the second and third quarters.

(d) Special cyanide standards were prepared gravimetrically from a potassium cyanide salt.

(e) Special cadmium standards were prepared using the same stock solution that was used for the second quarter standards.

(f) Special cadmium standards were prepared from a stock solution purchased from an alternate vendor (Fisher Scientific).

(g) Assuming strontium-90 and yttrium-90 are in equilibrium, spike amount is strontium-90 + yttrium-90.

Table B.16. Double-Blind Standard Results, Lionville Laboratory and Eberline Services

Constituent	Laboratory	Fiscal Year Quarter	Spike Amount	Average Result	Average Recovery (%)	Relative Standard Deviation (%)
		General Chemical Parameters (µg/L)				
Total organic carbon[a]	Lionville	First	2,506	2,600	104	0
	Lionville	Second	1,002	1,150	115	5
	Lionville	Third	1,497	1,700	114	0
	Lionville	Fourth	2,000	2,450	123	4
Total organic halides[b]	Lionville	First	101	241	239	1
(phenol)	Lionville	Second	900	642	71	5
	Lionville	Fourth	44.4	39.6	89	23
Total organic halides[c]	Lionville	Second	950	551	58	11
(volatile organic mixture)	Lionville	Fourth	44	20.6	47	17
		Radiological Parameters				
Gross alpha	Eberline	First	19.68	14.6	74	9
	Eberline	Third	15.38	11.0	72	33
Gross beta[d]	Eberline	First	30.26	41.5	137	4
	Eberline	Second	20.34	27.3	134	19
	Eberline	Third	60.26	67.4	112	2
	Eberline	Fourth	107.8	112	104	3

(a) Total organic carbon standards were submitted in quadruplicate each quarter.

(b) Total organic halide (phenol) standards were submitted in quadruplicate during the second quarter. The standards were submitted in triplicate in the first and fourth quarters.

(c) Total organic halide (volatile) standards were submitted in triplicate during the second quarter and in quadruplicate during the fourth quarter.

(d) Assuming strontium-90 and yttrium-90 are in equilibrium, spike amount is strontium-90 + yttrium-90.

Table B.17. Method Blank Results, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Percent Out of Limit[a]	Number of Analyses	Concentration Range of Out-of-Limit Results
General Chemistry Parameters			
Total General Chemistry Parameters	7.5	452	--
Conductivity	57.1[b]	21	0.43 - 5.9 µS/cm
Total organic carbon	20.2[b]	109	0.28 - 0.75 mg/L
Ammonia and Anions			
Total Ammonia and Anions	6.4	1,161	--
Chloride	23.7[b]	219	0.024 - 0.19 mg/L
Cyanide	15.2[b]	33	3.7 - 11 µg/L
Fluoride	4.2[b]	216	0.04 - 0.07 mg/L
Nitrogen in nitrate	0.9[b]	215	0.0042 - 0.026 mg/L
Phosphate	16.7[b]	6	0.3 mg/L
Sulfate	2.3[b]	220	0.14 - 0.73 mg/L
Metals			
Total Metals	5.6	1,418	--
Aluminum	16.7	66	98.2 - 106 µg/L
Beryllium	7.7[b]	65	1.1 - 2.6 µg/L
Cadmium	9.0[b]	144	0.43 - 2.3 µg/L
Calcium	1.6	63	381 µg/L
Chromium	2.3[b]	128	0.61 - 2.8 µg/L
Iron	23.4[b]	64	32.8 - 111 µg/L
Magnesium	4.8[b]	62	301 - 1,080 µg/L
Manganese	1.6	64	2.7 µg/L
Mercury	5.3[b]	19	0.14 µg/L
Sodium	30.4[b]	69	202 - 1,070 µg/L
Strontium	3.2	62	2.5 - 4.1 µg/L
Thallium	16.7	6	6.7 µg/L
Zinc	3.2[c]	63	11.1 - 38.8 µg/L
Volatile Organic Compounds			
Total Volatile Organic Compounds	0.8	2,864	--
Acetone[c]	7.7[b]	117	2.3 - 4.9 µg/L
Methylene chloride[c]	11.5[b]	122	1.4 - 8.6 µg/L
Semivolatile Organic Compounds			
Total Semivolatile Organic Compounds	0.0	749	--
Radiochemistry Parameters			
Total Radiochemistry Parameters	0.4	1,129	--
Potassium-40	1.8	56	118 pCi/L
Tritium	3.4[b]	118	15.5 - 4,970 pCi/L[d]

(a) Quality control limits are twice the method detection limit.
(b) One or more results were "significantly out of limits" as defined in the text.
(c) Quality control limits are five times the method detection limit.
(d) Range values are from two methods.

Table B.18. Laboratory Control Samples, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total General Chemical Parameters	0.0	560
Ammonia and Anions		
Total Ammonia and Anions	0.2	1,271
Cyanide	4.3(a)	46
Metals		
Total Metals	0.04	2,737
Mercury	3.6	28
Volatile Organic Compounds		
Total Volatile Organic Compounds	0.0	555
Semivolatile Organic Compounds		
Total Semivolatile Organic Compounds	7.5	494
2,3,4,6-Tetrachlorophenol	7.7(a)	26
2,4,5-Trichlorophenol	3.8(a)	26
2,4,6-Trichlorophenol	3.8(a)	26
2,4-Dichlorophenol	3.8(a)	26
2,4-Dimethylphenol	3.8(a)	26
2,4-Dinitrophenol	3.8(a)	26
2,6-Dichlorophenol	3.8(a)	26
2-Chlorophenol	6.9(a)	29
2-Methylphenol	3.8(a)	26
2-Nitrophenol	3.8(a)	26
2-secButyl-4,6-dinitrophenol	11.5(a)	26
4,6-Dinitro-2-methyphenol	7.7(a)	26
4-Chloro-3-methylphenol	6.9(a)	29
4-Nitrophenol	27.6(a)	29
Pentachlorophenol	6.9(a)	29
Phenol	27.6(a)	29
Radiochemistry Parameters		
Total Radiochemical Parameters	1.2	883
Cobalt-60	1.8(a)	56
Iodine-129	3.2	62
Technetium-99	3.8(a)	79
Uranium-235	30.8(a)	13

(a) One or more results were “significantly out of limits” as defined in the text.

Table B.19. Matrix Spikes and Matrix Spike Duplicates, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total General Chemistry Parameters	3.8	158
Total organic halides	8.0[(a)]	75
Ammonia and Anions		
Total Ammonia and Anions	13.2	372
Bromide	15.4[(a)]	13
Chloride	9.7[(a)]	62
Cyanide	34.6[(a)]	26
Fluoride	1.6[(a)]	62
Nitrogen in ammonia	6.7	15
Nitrogen in nitrate	17.7[(a)]	62
Nitrogen in nitrite	11.3[(a)]	62
Phosphate	20.0[(a)]	5
Sulfate	16.9[(a)]	65
Metals		
Total Metals	0.6	2,771
Cadmium	4.0[(a)]	150
Copper	0.8	133
Iron	2.2[(a)]	138
Lead	1.7	60
Silver	4.4[(a)]	136
Volatile Organic Compounds		
Total Volatile Organic Compounds	3.9	388
1,1-Dichloroethene	5.6	18
Benzene	0.9[(a)]	106
Gasoline	50.0	2
Tetrachloroethene	25.0	8
Toluene	1.9[(a)]	106
TPH gasoline	25.0	8
Trichloroethene	5.6[(a)]	108
Semivolatile Organic Compounds		
Total Semivolatile Organic Compounds	8.7	746
2,3,4,6-Tetrachlorophenol	18.4[(a)]	38
2,4,5-Trichlorophenol	7.9[(a)]	38
2,4,6-Trichlorophenol	7.9[(a)]	38
2,4-Dichlorophenol	5.3[(a)]	38
2,4-Dimethylphenol	10.5[(a)]	38
2,4-Dinitrophenol	7.9[(a)]	38
2,6-Dichlorophenol	5.3[(a)]	38
2-Chlorophenol	6.8[(a)]	44
2-Methylphenol	5.3[(a)]	38
2-Nitrophenol	7.9[(a)]	38
2-secButyl-4,6-dinitrophenol	10.5[(a)]	38
4,6-Dinitro-2-methylphenol	7.9[(a)]	38
4-Chloro-3-methylphenol	9.1[(a)]	44
4-Nitrophenol	18.2[(a)]	44
Pentachlorophenol	6.8[(a)]	44
Phenol	18.2[(a)]	44
Pyrene	16.7	6
TPH diesel	20.0	10
Radiochemistry Parameters		
Total Radiochemistry Parameters	25.5	145
Neptunium-237	100[(a)]	1
Strontium-90	100[(a)]	1
Technetium-99	21.1[(a)]	76
Uranium	29.2[(a)]	65

(a) One or more results were “significantly out of limits” as defined in the text.

Table B.20. Matrix Duplicates, Severn Trent Laboratories (Richland and St. Louis)

Constituent	Percent Out of Limit	Number of Analyses
General Chemistry Parameters		
Total General Chemistry Parameters	1.7	465
Alkalinity	1.2[(a)]	84
Conductivity	4.2	24
Total dissolved solids	8.3[(a)]	36
Total organic carbon	1.0[(a)]	192
Total organic halides	0.9	116
Ammonia and Anions		
Total Ammonia and Anions	0.9	1,508
Chloride	0.7[(a)]	280
Cyanide	19.5[(a)]	41
Nitrogen in nitrate	1.1[(a)]	276
Metals		
Total Metals	0.3	1,406
Cadmium	1.3	76
Iron	3.0[(a)]	67
Mercury	2.2	46
Volatile Organic Compounds		
Total Volatile Organic Compounds	0.0	254
Semivolatile Organic Compounds		
Total Semivolatile Organic Compounds	3.3	513
2,3,4,6-Tetrachlorophenol	3.8	26
2,4,5-Trichlorophenol	3.8	26
2,4,6-Trichlorophenol	3.8	26
2,4-Dichlorophenol	3.8	26
2,4-Dimethylphenol	3.8	26
2,4-Dinitrophenol	3.8	26
2,6-Dichlorophenol	3.8	26
2-Chlorophenol	3.3	30
2-secButyl-4,6-dinitrophenol	3.8	26
3-+4-Methylphenol	3.8	26
4,6-Dinitro-2-methylphenol	3.8	26
4-Chloro-3-methylphenol	3.3	30
4-Nitrophenol	3.3	30
Phentachlorophenol	10.0	30
Phenol	3.3	30
Radiochemistry Parameters		
Total Radiochemistry Parameters	0.7	1,125
Cobalt-60	1.8	56
Gross beta	1.4[(a)]	70
Iodine-129	3.3[(a)]	61
Technetium-99	2.7	75
Uranium	1.5[(a)]	66
Uranium-235	7.7	13

(a) One or more results were “significantly out of limits” as defined in the text.

Table B.21. Summary of Issue Resolution Forms Received from Severn Trent Laboratories (Richland and St. Louis) for Fiscal Year 2001

Issue Category	Number of Occurrences Prior to Receipt at the Laboratory	After Receipt at the Laboratory
Hold time missed	182	85
Broken bottles	6	
Missing samples	1	
Temperature deviation	13	
pH variance	12	
Bottle size/type (insufficient volume)	36	
Chain of custody forms incomplete	1	
Laboratory QC out of limits		170
Analytical preparation deviations		2
Method failures/discontinued analyses		56

Table B.22. Summary of Analytical Laboratory Detection/Quantitation Limits Determined from Field Blank Data, Severn Trent Laboratories (Richland and St. Louis)

Period	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
Constituent: Total Organic Carbon (µg/L)					
10/03/00 - 12/13/00	10(a)	157.42	145.58	436.8(b)	1,455.8(b)
02/13/01 - 03/13/01	8(a)	257.78	134.30	402.9	1,343.0
08/18/00 - 06/12/01	25(a,c)	187.10	141.24	423.7	1,412.4
10/03/00 - 08/14/01	24(c)	229.28	145.01	435.0	1,450.1
Summary	24	229.28	145.01	435.0	1,450.1
Constituent: Total Organic Halides (µg/L)					
10/03/00 - 11/16/00	10	1.79	1.65	5.0(b)	16.5(b)
02/13/01 - 03/13/01	10	0.61	1.06	3.2	10.6
09/20/00 - 06/12/01	29(c)	0.91	1.35	4.1	13.5
10/03/00 - 08/14/01	30(c)	1.18	1.51	4.5	15.1
Summary	30	1.18	1.51	4.5	15.1
Constituent: Antimony-125 (pCi/L)					
10/09/00 - 07/30/01	9	0.09	2.04	6.13(b)	20.42(b)
Constituent: Cesium-134 (pCi/L)					
10/09/00 - 07/30/01	9	-0.75	1.39	4.18(b)	13.92(b)
Constituent: Cesium-137 (pCi/L)					
10/09/00 - 07/30/01	9	-0.53	1.07	3.21(b)	10.68(b)
Constituent: Cobalt-60 (pCi/L)					
10/09/00 - 07/30/01	9	0.32	1.20	3.60(b)	12.00(b)
Constituent: Europium-154 (pCi/L)					
10/09/00 - 07/30/01	9	0.31	4.17	12.52(b)	41.74(b)
Constituent: Gross Alpha (pCi/L)					
10/03/00 - 12/20/00	11	0.31	0.25	0.75(b)	2.50(b)
01/08/01 - 03/19/01	12	0.05	0.16	0.48	1.62
04/03/01 - 06/12/01	4	-0.10	0.14	0.42	1.41
07/09/01 - 08/07/01	3	0.17	0.26	0.77	2.58
Summary	30	0.14	0.21	0.62	2.06
Constituent: Gross Beta (pCi/L)					
10/03/00 - 12/20/00	11	0.65	0.95	2.84(b)	9.47(b)
01/08/01 - 03/19/01	12	0.55	0.67	2.02	6.74
04/03/01 - 06/12/01	3	0.86	0.48	1.45	4.82
07/09/01 - 07/19/01	2	0.53	0.31	0.93	3.11
Summary	28	0.62	0.78	2.33	7.78
Constituent: Iodine-129 (pCi/L)					
10/18/00 - 12/20/00	4	0.02	0.112	0.34(b)	1.12(b)
01/08/01 - 03/19/01	6	-0.04	0.060	0.18	0.60
04/05/01 - 07/09/01	3	0.05	0.094	0.28	0.94
Summary	13	-0.00	0.085	0.26	0.85
Constituent: Potassium-40 (pCi/L)					
10/09/00 - 07/30/01	9	1.89	30.05	90.2(b)	300.5(b)
Constituent: Ruthenium-106 (pCi/L)					
10/09/00 - 07/30/01	9	-6.12	7.72	23.2(b)	77.2(b)
Constituent: Strontium-90 (pCi/L)					
10/09/00 - 07/09/01	9	0.07	0.12	0.37(b)	1.24(b)

Table B.22. (contd)

Period	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
		Constituent: Technetium-99 (pCi/L)			
10/09/00 - 12/20/00	6	1.86	4.33	12.98[b]	43.28[b]
01/08/01 - 03/19/01	9	0.57	5.97	17.91	59.70
05/09/01 - 06/04/01	3	-1.88	3.25	9.74	32.45
07/16/01 - 08/07/01	3	-2.35	2.95	8.84	29.47
Summary	21	0.17	4.95	14.86	49.54
		Constituent: Tritium (pCi/L)			
10/03/00 - 12/20/00	9	137.2	96.1	288.2[b]	960.8[b]
01/08/01 - 03/19/01	14	105.9	141.3	423.8	1,412.8
04/03/01 - 06/04/01	5	157.3	88.2	264.7	882.4
07/09/01 - 08/13/01	6	107.1	57.4	172.0	573.5
Summary	34	121.9	112.7	338.0	1,126.8
		Tritium – Low-Level Method			
10/13/00 - 06/15/01	6	191.7	67.9	203.7	679.1
		Constituent: Uranium (µg/L)			
10/09/00 - 12/13/00	4	0.0060	0.0061	0.024[c]	0.067[c]
01/08/01 - 03/19/01	7	0.0074	0.0022	0.014	0.029
05/09/01 - 06/15/01	2	0.0033	0.0039	0.015	0.042
07/16/01 - 08/13/01	4	0.0047	0.0066	0.025	0.071
Summary	17	0.006	0.0047	0.020	0.053

(a) Excluded outliers.

(b) Limit of detection (blank corrected) equals 3 times the blank standard deviation; limit of quantitation (blank corrected) equals 10 times the blank standard deviation.

(c) Limit of detection equals the mean blank concentration plus 3 standard deviations; limit of quantitation equals the mean blank concentration plus 10 standard deviations.

Table B.23. Summary of Detection and Quantitation Limits, Severn Trent Laboratory (St. Louis)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
General Chemical Parameters								
EPA-600/4-81-004, 120.1	Conductivity[b]	0.278	0.375	1.252	04/21/01	0.147	0.198	0.662
EPA-600/4-81-004, 160.1	Total dissolved solids	4,228	5,709	19,039				
EPA-600/4-81-004, 310.1	Alkalinity	2,230	3,011	10,042	04/04/01	1,680	2,269	7,565
EPA-600/4-81-004, 410.4	Chemical oxygen demand	3,067	4,141	13,811	04/04/01	3,940	5,320	17,743
EPA-600/4-81-004, 413.1	Oil and grease	699	944	3,148				
Ammonia and Anions								
EPA-600/4-81-004, 300.0	Bromide	17.4	23.5	78.4	03/01/01	10.0	13.5	45.0
EPA-600/4-81-004, 300.0	Chloride	34.6	46.7	155.8	03/01/01	10	13.5	45.0
EPA-600/4-81-004, 300.0	Fluoride	10.4	14.0	46.8	03/01/01	6	8.1	27.0
EPA-600/4-81-004, 300.0	Nitrogen in nitrate	11	14.9	49.5	03/01/01	2	2.7	9.0
EPA-600/4-81-004, 300.0	Nitrogen in nitrite	7.4	10.0	33.3	03/01/01	2	2.7	9.0
EPA-600/4-81-004, 300.0	Phosphate	34.8	47.0	156.7	03/01/01	35	47.3	157.6
EPA-600/4-81-004, 300.0	Sulfate	108	146	486	03/01/01	29	39.2	130.6
EPA-600/4-81-004, 350.1	Nitrogen in ammonia	30.1	40.6	135.5	04/21/01	12.878	17.4	58.0
SW-846, 9012	Cyanide	1.59	2.15	7.16	04/21/01	2.51	3.4	11.3
Metals								
SW-846, 6010	Aluminum	41.8	56.4	188.2				
SW-846, 6010	Antimony	24.7	33.4	111.2				
SW-846, 6010	Barium	3.9	5.3	17.6				
SW-846, 6010	Beryllium	0.5	0.7	2.3				
SW-846, 6010	Cadmium	2.8	3.8	12.6				
SW-846, 6010	Calcium	122.5	165.4	551.6				
SW-846, 6010	Chromium	4.6	6.2	20.7				
SW-846, 6010	Cobalt	4.3	5.8	19.4				
SW-846, 6010	Copper	2.8	3.8	12.6				
SW-846, 6010	Iron	15.6	21.1	70.2				
SW-846, 6010	Lead	71.5	96.5	322.0				
SW-846, 6010	Magnesium	92.2	124.5	415.2				
SW-846, 6010	Manganese	0.9	1.2	4.1				
SW-846, 6010	Nickel	15.4	20.8	69.3				
SW-846, 6010	Potassium	1,467	1,981.5	6,608.0				
SW-846, 6010	Silver	6.9	9.3	31.1				
SW-846, 6010	Sodium	83.1	112.2	374.2				
SW-846, 6010	Strontium (elemental)	1.2	1.6	5.4				
SW-846, 6010	Tin	35	47.3	157.6				
SW-846, 6010	Vanadium	3.4	4.6	15.3				
SW-846, 6010	Zinc	3.1	4.2	14.0				

Table B.23. (contd)

Method	Constituent	Initial MDL(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 7060	Arsenic	2	2.7	9.0	04/10/01	1.38	1.9	6.2
SW-846, 7131	Cadmium	0.2	0.3	0.9				
SW-846, 7191	Chromium	0.3	0.4	1.4				
SW-846, 7421	Lead	0.8	1.1	3.6	04/10/01	1.01	1.4	4.5
SW-846, 7470	Mercury	0.011	0.015	0.050				
SW-846, 7740	Selenium	0.9	1.2	4.1	04/10/01	1.22	1.65	5.49
SW-846, 7841	Thallium	0.6	0.8	2.7	04/10/01	1.77	2.39	7.97
			Volatile Organic Compounds					
SW-846, 8010	1,1,1-Trichloroethane	0.35	0.47	1.58				
SW-846, 8010	1,1,2-Trichloroethane	0.19	0.26	0.86				
SW-846, 8010	1,1-Dichloroethane	0.36	0.49	1.62				
SW-846, 8010	1,2-Dichloroethane	0.34	0.46	1.53				
SW-846, 8010	1,4-Dichlorobenzene	0.1	0.14	0.45				
SW-846, 8010	Carbon tetrachloride	0.32	0.43	1.44				
SW-846, 8010	Chloroform	0.38	0.51	1.71				
SW-846, 8010	cis-1,2-Dichloroethylene	0.33	0.45	1.49				
SW-846, 8010	Methylene chloride	2.38	3.21	10.72				
SW-846, 8010	Tetrachloroethylene	0.15	0.20	0.68				
SW-846, 8010	trans-1,2-Dichloroethylene	0.43	0.58	1.94				
SW-846, 8010	Trichloroethylene	0.26	0.35	1.17				
SW-846, 8010	Vinyl chloride	0.25	0.34	1.13				
SW-846, 8020	1,4-Dichlorobenzene	0.33	0.45	1.49				
SW-846, 8020	Benzene	0.25	0.34	1.13				
SW-846, 8020	Ethylbenzene	0.12	0.16	0.54				
SW-846, 8020	Toluene	0.21	0.28	0.95				
SW-846, 8020	Xylenes (total)	0.33	0.45	1.49				
SW-846, 8260	1,1,1,2-Tetrachloroethane(c)	0.33	0.45	1.49	08/08/01	0.21	0.28	0.95
SW-846, 8260	1,1,1-Trichloroethane(c)	0.23	0.31	1.04	08/08/01	0.31	0.42	1.40
SW-846, 8260	1,1,2,2-Tetrachloroethane(c)	0.34	0.46	1.53	08/08/01	0.32	0.43	1.44
SW-846, 8260	1,1,2-Trichloroethane(c)	0.31	0.42	1.40	08/08/01	0.27	0.36	1.22
SW-846, 8260	1,1-Dichloroethane(c)	0.19	0.26	0.86	08/08/01	0.25	0.34	1.13
SW-846, 8260	1,1-Dichloroethylene(c)	0.23	0.31	1.04	08/08/01	0.39	0.53	1.76
SW-846, 8260	1,2,3-Trichloropropane(c)	0.25	0.34	1.13	08/08/01	0.28	0.38	1.26
SW-846, 8260	1,2-Dibromomethane(c)	0.28	0.38	1.26	08/08/01	0.29	0.39	1.31
SW-846, 8260	1,2-Dichloroethane(c)	0.17	0.23	0.77	08/08/01	0.27	0.36	1.22
SW-846, 8260	1,2-Dichloroethylene (total)(c)	0.33	0.45	1.49	08/08/01	0.45	0.61	2.03
SW-846, 8260	1,2-Dichloropropane(c)	0.21	0.28	0.95	08/08/01	0.2	0.27	0.90

Table B.23. (contd)

Method	Constituent	Initial MDL[a] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[a] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	1,4-Dichlorobenzene[c]	0.14	0.19	0.63	08/08/01	0.25	0.34	1.13
SW-846, 8260	1-Butanol[c]	6.55	8.84	29.50	08/08/01	4.92	6.64	22.16
SW-846, 8260	2-Butanone[c]	0.7	0.95	3.15	08/08/01	0.39	0.53	1.76
SW-846, 8260	2-Hexanone[c]	0.99	1.34	4.46	08/08/01	0.28	0.38	1.26
SW-846, 8260	4-Methyl-2-pentanone[c]	1.27	1.71	5.72	08/08/01	0.42	0.57	1.89
SW-846, 8260	Acetone[c]	4.02	5.43	18.10	08/08/01	0.3	0.41	1.35
SW-846, 8260	Acetonitrile[c]	2.64	3.56	11.89	08/08/01	2.32	3.13	10.45
SW-846, 8260	Acrolein[c]	2.56	3.46	11.53	08/08/01	1.83	2.47	8.24
SW-846, 8260	Benzene[c]	0.23	0.31	1.04	08/08/01	0.23	0.31	1.04
SW-846, 8260	Bromodichloromethane[c]	0.2	0.27	0.90	08/08/01	0.22	0.30	0.99
SW-846, 8260	Bromoform[c]	0.24	0.32	1.08	08/08/01	0.32	0.43	1.44
SW-846, 8260	Bromomethane[c]	0.23	0.31	1.04	08/08/01	0.52	0.70	2.34
SW-846, 8260	Carbon disulfide[c]	0.3	0.41	1.35	08/08/01	0.29	0.39	1.31
SW-846, 8260	Carbon tetrachloride[c]	0.23	0.31	1.04	08/08/01	0.33	0.45	1.49
SW-846, 8260	Chlorobenzene[c]	0.28	0.38	1.26	08/08/01	0.24	0.32	1.08
SW-846, 8260	Chloroethane[c]	0.23	0.31	1.04		0.39	0.53	1.76
SW-846, 8260	Chloroform[c]	0.23	0.31	1.04	08/08/01	0.21	0.28	0.95
SW-846, 8260	Chloromethane[c]	0.26	0.35	1.17	08/08/01	0.18	0.24	0.81
SW-846, 8260	cis-1,2-Dichloroethylene[c]	0.18	0.24	0.81	08/08/01	0.24	0.32	1.08
SW-846, 8260	cis-1,3-Dichloropropene[c]	0.16	0.22	0.72	08/08/01	0.25	0.34	1.13
SW-846, 8260	Dichlorodifluoromethane[c]	0.13	0.18	0.59	08/08/01	0.45	0.61	2.03
SW-846, 8260	Ethyl cyanide	2.6	3.51	11.71	01/27/01	2	2.70	9.01
SW-846, 8260	Ethylbenzene[c]	0.35	0.47	1.58	08/08/01	0.24	0.32	1.08
SW-846, 8260	Methylene chloride[c]	0.37	0.50	1.67	08/08/01	0.24	0.32	1.08
SW-846, 8260	Styrene[c]	0.33	0.45	1.49	08/08/01	0.24	0.32	1.08
SW-846, 8260	Tetrachloroethylene[c]	0.57	0.77	2.57	08/08/01	0.36	0.49	1.62
SW-846, 8260	Tetrahydrofuran[c]	1.49	2.01	6.71	08/08/01	2.26	3.05	10.18
SW-846, 8260	Toluene[c]	0.33	0.45	1.49	08/08/01	0.23	0.31	1.04
SW-846, 8260	trans-1,2-Dichloroethylene[c]	0.26	0.35	1.17	08/08/01	0.23	0.31	1.04
SW-846, 8260	trans-1,3-Dichloropropene[c]	0.32	0.43	1.44	08/08/01	0.22	0.30	0.99
SW-846, 8260	Trichloroethene[c]	0.16	0.22	0.72	08/08/01	0.29	0.39	1.31
SW-846, 8260	Vinyl acetate[c]	0.29	0.39	1.31	08/08/01	0.24	0.32	1.08
SW-846, 8260	Vinyl chloride[c]	0.17	0.23	0.77	08/08/01	0.32	0.43	1.44
SW-846, 8260	Xylenes (total)[c]	0.61	0.82	2.75	08/08/01	0.66	0.89	2.97
SW-846, 8260	1,4-Dichlorobenzene	0.929	1.25	4.18				
WTPH Gasoline	TPH, gasoline fraction	0.05	0.07	0.23				

Table B.23. (contd)

Method	Constituent	Initial MDL[(a)] (μg/L)	Initial LOD (μg/L)	Initial LOQ (μg/L)	Ending Values, Effective Date	Ending MDL[(a)] (μg/L)	Ending LOD (μg/L)	Ending LOQ (μg/L)
Semivolatile Organic Compounds								
SW-846,8015	TPH, diesel function	92.3	124.6	415.6				
SW-846, 8040	2,3,4,6-Tetrachlorophenol	2.09	2.82	9.41	01/19/01	2.64	3.56	11.89
SW-846, 8040	2,4,5-Trichlorophenol	4.7	6.35	21.16	01/19/01	2.9	3.92	13.06
SW-846, 8040	2,4,6-Trichlorophenol	4.96	6.70	22.34	01/19/01	4.71	6.36	21.21
SW-846, 8040	2,4-Dichlorophenol	1.23	1.66	5.54	01/19/01	3.08	4.16	13.87
SW-846, 8040	2,4-Dimethylphenol	2.87	3.88	12.92	01/19/01	2.52	3.40	11.35
SW-846, 8040	2,4-Dinitrophenol	1.82	2.46	8.20	01/19/01	1.88	2.54	8.47
SW-846, 8040	2,6-Dichlorophenol	1.1	1.49	4.95	01/19/01	3.3	4.46	14.86
SW-846, 8040	2-Chlorophenol	2.13	2.88	9.59	01/19/01	3.16	4.27	14.23
SW-846, 8040	2-Methylphenol (cresol, o-)	2.43	3.28	10.94	01/19/01	2.94	3.97	13.24
SW-846, 8040	2-Nitrophenol	1.92	2.59	8.65	01/19/01	3.1	4.19	13.96
SW-846, 8040	2-secButyl-4,6-dinitrophenol (DNBP)	2	2.70	9.01	01/19/01	2.2	2.97	9.91
SW-846, 8040	3-,4-Methyl phenol	3.54	4.78	15.94				
SW-846, 8040	4,6-Dinitro-2-methyl phenol	1.36	1.84	6.12	01/19/01	2.15	2.90	9.68
SW-846, 8040	4-Chloro-3-methylphenol	1.01	1.36	4.55	01/19/01	2.56	3.46	11.53
SW-846, 8040	4-Nitrophenol	0.92	1.24	4.14	01/19/01	1.62	2.19	7.30
SW-846, 8040	Pentachlorophenol	1.5	2.03	6.75	01/19/01	2.24	3.02	10.09
SW-846, 8040	Phenol	0.54	0.73	2.43	01/19/01	1.69	2.28	7.61
SW-846, 8082	Aroclor-1016	0.105	0.142	0.473	03/16/01	0.68	0.92	3.06
SW-846, 8082	Aroclor-1221	0.105	0.142	0.473	03/16/01	0.68	0.92	3.06
SW-846, 8082	Aroclor-1232	0.105	0.142	0.473	03/16/01	0.68	0.92	3.06
SW-846, 8082	Aroclor-1242	0.105	0.142	0.473	03/16/01	0.68	0.92	3.06
SW-846, 8082	Aroclor-1248	0.105	0.142	0.473	03/16/01	0.68	0.92	3.06
SW-846, 8082	Aroclor-1254	0.252	0.340	1.135	03/16/01	0.5	0.68	2.25
SW-846, 8082	Aroclor-1260	0.252	0.340	1.135	03/16/01	0.5	0.68	2.25
SW-846, 8270	1,2,4,5-Tetrachlorobenzene	1.98	2.67	8.92				
SW-846, 8270	1,2,4-Trichlorobenzene	0.973	1.31	4.38				
SW-846, 8270	1,2-Dichlorobenzene	0.894	1.21	4.03				
SW-846, 8270	1,3-Dichlorobenzene	0.9	1.22	4.05				
SW-846, 8270	2,2'-Oxybis(1-chloropropane)	1.178	1.59	5.30				
SW-846, 8270	2,4,5-Trichlorophenol	0.776	1.05	3.49				
SW-846, 8270	2,4,6-Trichlorophenol	0.663	0.90	2.99				
SW-846, 8270	2,4-Dichlorophenol	1.005	1.36	4.53				
SW-846, 8270	2,4-Dimethylphenol	0.968	1.31	4.36				
SW-846, 8270	2,4-Dinitrophenol	0.969	1.31	4.36				
SW-846, 8270	2,4-Dinitrotoluene	0.675	0.91	3.04				
SW-846, 8270	2,6-Dinitrotoluene	0.709	0.96	3.19				

Table B.23. (contd)

Method	Constituent	Initial MDL(a) (μg/L)	Initial LOD (μg/L)	Initial LOQ (μg/L)	Ending Values, Effective Date	Ending MDL(a) (μg/L)	Ending LOD (μg/L)	Ending LOQ (μg/L)
SW-846, 8270	2-Chloronaphthalene	0.979	1.32	4.41				
SW-846, 8270	2-Chlorophenol	1.118	1.51	5.03				
SW-846, 8270	2-Methylnaphthalene	0.996	1.34	4.49				
SW-846, 8270	2-Methylphenol (cresol, o-)	0.996	1.34	4.49				
SW-846, 8270	2-Nitroaniline	0.587	0.79	2.64				
SW-846, 8270	2-Nitrophenol	1.176	1.59	5.30				
SW-846, 8270	3,3'-Dichlorobenzidine	0.549	0.74	2.47				
SW-846, 8270	3-Nitroaniline	0.499	0.67	2.25				
SW-846, 8270	4,6-Dinitro-2 methyl phenol	1.74	2.35	7.84				
SW-846, 8270	4-Bromophenylphenyl ether	0.776	1.05	3.49				
SW-846, 8270	4-Chloro-3-methylphenol	0.835	1.13	3.76				
SW-846, 8270	4-Chloroaniline	0.883	1.19	3.98				
SW-846, 8270	4-Chlorophenylphenyl ether	1.024	1.38	4.61				
SW-846, 8270	4-Methylphenol (cresol, p-)	0.767	1.04	3.45				
SW-846, 8270	4-Nitroaniline	0.866	1.17	3.90				
SW-846, 8270	4-Nitrophenol	0.478	0.65	2.15				
SW-846, 8270	Acenaphthene	0.869	1.17	3.91				
SW-846, 8270	Acenaphthylene	0.98	1.32	4.41				
SW-846, 8270	Aniline	7.763	10.48	34.96				
SW-846, 8270	Anthracene	0.481	0.65	2.17				
SW-846, 8270	Benzo(a)anthracene	0.579	0.78	2.61				
SW-846, 8270	Benzo(a)pyrene	0.599	0.81	2.70				
SW-846, 8270	Benzo(b)fluoranthene	0.88	1.19	3.96				
SW-846, 8270	Benzo(ghi)perylene	0.953	1.29	4.29				
SW-846, 8270	Benzo(k)fluoranthene	0.737	1.00	3.32				
SW-846, 8270	Benzyl alcohol	1.101	1.49	4.96				
SW-846, 8270	Bis(2-Chloroethoxy)methane	1.141	1.54	5.14				
SW-846, 8270	Bis(2-chloroethyl) ether	1.121	1.51	5.05				
SW-846, 8270	Bis(2-ethylhexyl) phthalate	1.29	1.74	5.81				
SW-846, 8270	Butylbenzylphthalate	0.723	0.98	3.26				
SW-846, 8270	Chrysene	0.415	0.56	1.87				
SW-846, 8270	Di-n-butylphthalate	1.348	1.82	6.07				
SW-846, 8270	Di-n-octylphthalate	1.348	1.82	6.07				
SW-846, 8270	Dibenz[a,h]anthracene	1.433	1.94	6.45				
SW-846, 8270	Dibenzofuran	0.766	1.03	3.45				
SW-846, 8270	Diethylphthalate	1.504	2.03	6.77				
SW-846, 8270	Dimethyl phthalate	3.039	4.10	13.69				

Table B.23. (contd)

Method	Constituent	Initial MDL[(a)] (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL[(a)] (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	Fluoranthene	0.602	0.81	2.71				
SW-846, 8270	Fluorene	0.723	0.98	3.26				
SW-846, 8270	Hexachlorobenzene	0.576	0.78	2.59				
SW-846, 8270	Hexachlorobutadiene	0.907	1.22	4.08				
SW-846, 8270	Hexachlorocyclopentadiene	0.906	1.22	4.08				
SW-846, 8270	Hexachloroethane	0.861	1.16	3.88				
SW-846, 8270	Indeno(1,2,3-cd)pyrene	0.612	0.83	2.76				
SW-846, 8270	Isophorone	0.858	1.16	3.86				
SW-846, 8270	N-Nitroso-di-n-dipropylamine	0.905	1.22	4.08				
SW-846, 8270	N-Nitrosodimethylamine	0.735	0.99	3.31				
SW-846, 8270	N-Nitrosodiphenylamine	0.451	0.61	2.03				
SW-846, 8270	Naphthalene	1.093	1.48	4.92				
SW-846, 8270	Pentachlorophenol	0.866	1.17	3.90				
SW-846, 8270	Phenanthrene	0.457	0.62	2.06				
SW-846, 8270	Phenol	0.554	0.75	2.49				
SW-846, 8270	Pyrene	0.707	0.95	3.18				

(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) µS/cm.

(c) Between January 27, 2001 and August 7, 2001, a third MDL (value not shown in table) was in effect for this compound.

MDL = Method detection limit.
LOD = Limit of detection.
LOQ = Limit of quantitation.

Appendix C

Update of Background Document

Appendix C

Update of Background Document

This appendix contains updates to the report, *Hanford Site Groundwater Monitoring: Setting, Sources and Methods* (PNNL-13080). *Hanford Site Groundwater Monitoring: Setting, Sources and Methods* is a companion volume to this large report; it contains background information that does not change significantly from year to year.

Please remove the pages contained in this appendix and insert them into your document *Hanford Site Groundwater Monitoring: Setting, Sources and Methods* (PNNL-13080). PNNL-13080 will be revised completely and re-issued when major changes are needed. To request a copy of PNNL-13080, contact Mary J. Hartman at mary.hartman@pnl.gov or (509) 373-0028.

Tables

Figures

Table 5.1. Maximum Contaminant Levels and Interim Drinking Water Standards

Constituent	MCL or DWS	Agency(a)	EPA Status
Aluminum(b)	50 µg/L	EPA	Final
Antimony	6 µg/L	EPA	Final
Arsenic	10 µg/L	EPA, DOH	Final
Barium	2,000 µg/L	EPA	Final
	1,000 µg/L	DOH	
Cadmium	5 µg/L	EPA	Final
Carbon tetrachloride	5 µg/L	EPA, DOH	Final
Chloride	250 mg/L(b)	EPA, DOH	Final
Chloroform (THM)(c)	80 µg/L	EPA	Final
Chromium	100 µg/L	EPA, DOH	Final
cis-1,2-Dichloroethene	70 µg/L	EPA	Final
Copper	1,000 µg/L(b)	EPA, DOH	Final
Cyanide	200 µg/L	EPA	Final
1,4-Dichlorobenzene	75 µg/L	EPA	Final
Fluoride	4,000 µg/L	EPA, DOH	Final
	2,000 µg/L(b)	EPA	Final
Iron	300 µg/L(b)	EPA	Final
Lead	15 µg/L(d)	EPA	Final
	50 µg/L	DOH	
Manganese	50 µg/L(b)	EPA, DOH	Final
Mercury (inorganic)	2 µg/L	EPA, DOH	Final
Methylene chloride	5 µg/L	EPA	Final
Nitrate, as NO_3^-	45 mg/L	EPA, DOH	Final
Nitrite, as NO_2	3.3 mg/L	EPA	Final
Pentachlorophenol	1 µg/L	EPA	Final
pH	6.5 to 8.5(b)	EPA	Final
Selenium	50 µg/L	EPA	Final
	10 µg/L	DOH	
Silver	100 µg/L(b)	EPA, DOH	Final
Sulfate	500 mg/L	EPA	Proposed
	250 mg/L(b)	EPA	Final
Tetrachloroethene	5 µg/L	EPA, DOH	Final
Thallium	2 µg/L	EPA	Final
Total dissolved solids	500 mg/L(b)	EPA	Final
1,1,1-Trichloroethane	200 µg/L	EPA	Final
Trichloroethene	5 µg/L	EPA, DOH	Final
Zinc	5,000 µg/L(b)	EPA, DOH	Final
Antimony-125	300 pCi/L(e)	EPA	Interim
Beta particle and photon activity	4 mrem/yr(f)	EPA, DOH	Final
Carbon-14	2,000 pCi/L(e)	EPA	Interim
Cesium-137	200 pCi/L(e)	EPA	Interim
Cobalt-60	100 pCi/L(e)	EPA	Interim
Iodine-129	1 pCi/L(e)	EPA	Interim
Ruthenium-106	30 pCi/L(e)	EPA	Interim
Strontium-90	8 pCi/L(e)	EPA	Interim
Technetium-99	900 pCi/L(e)	EPA	Interim
Total alpha (excluding uranium)	15 pCi/L(e)	EPA, DOH	Final
Tritium	20,000 pCi/L(e)	EPA	Interim
Uranium	30 µg/L	EPA	Final

(a) DOH = Washington State Department of Health at WAC 246-290; EPA = U.S. Environmental Protection Agency at 40 CFR 141, 40 CFR 143, and EPA 822-R-96-001.

(b) Secondary maximum contaminant level.

(c) Standard is for total trihalomethanes (THM).

(d) Action level.

(e) Concentration assumed to yield an annual dose equivalent of 4 mrem/yr.

(f) 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/yr. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/yr. Compliance may be assumed if annual average concentrations of total beta, tritium, and strontium-90 are <50, 20,000, and 8 pCi/L, respectively.

DWS = Drinking water standard.
MCL = Maximum contaminant level.

Table 5.2. Derived Concentration Guides [(a,b,c)] and 4-mrem Effective Dose Equivalent Concentrations for Drinking Water[(d)]

Radionuclide	Derived Concentration Guide, pCi/L	4-mrem Effective Dose Equivalent, pCi/L
Tritium	2,000,000	80,000
Carbon-14	70,000	2,800
Chromium-51	1,000,000	40,000
Manganese-54	50,000	2,000
Cobalt-60	5,000	200
Zinc-65	9,000	360
Krypton-85	NS	NS
Strontium-90	1,000	40
Technetium-99	100,000	4,000
Ruthenium-103	50,000	2,000
Ruthenium-106	6,000	240
Antimony-125	60,000	2,400
Iodine-129	500	20
Iodine-131	3,000	120
Cesium-134	2,000	80
Cesium-137	3,000	120
Cerium-144	7,000	280
Uranium-234	500	20
Uranium-235	600	24
Uranium-238	600	24
Plutonium-238	40	1.6
Plutonium-239	30	1.2
Plutonium-240	30	1.2
Americium-241	30	1.2

(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/yr.

(b) Values in this table represent the lowest, most conservative derived concentration guides considered potentially applicable to Hanford Site operations, and may be adjusted upward (larger) if accurate solubility information is available.

(c) From DOE Order 5400.5.

(d) Concentration of a specific radionuclide in water that would produce an effective dose equivalent of 4 mrem/yr if consumed at average annual rates.

NS = No standard.

7.0 Statistical Methods

Data gathered to support groundwater monitoring at the Hanford Site are used to evaluate the changes noted in groundwater quality from baseline conditions of the various facilities. The methods used for the statistical evaluations are briefly described in this section. The facilities in this evaluation include

- RCRA interim status liquid and solid waste treatment, storage, and/or disposal units
- RCRA final status liquid and solid waste treatment, storage, and/or disposal units
- Variance allowed for the 216-B-3 Pond System
- Solid Waste Landfill
- Liquid effluent receiving facilities where statistical comparisons of groundwater samples were specified in the groundwater monitoring plans.

The RCRA units with a potential to contaminate groundwater require monitoring as prescribed in 40 CFR 265, WAC 173-303-400 (interim status), and 40 CFR 264 Subpart F and WAC 173-303-645 (final status). Groundwater monitoring activities at most of the RCRA units are currently governed by interim status regulations, except for the 183-H solar evaporation basins and the 300 Area process trenches, which were subject to corrective-action programs in accordance with final status regulations. The Solid Waste Landfill, though not a RCRA hazardous waste site, is statistically evaluated according to requirements of WAC 173-304.

In May 2001, Washington State Department of Ecology (Ecology) issued a guidance letter[a] that allows for variance from applying interim status regulations at the 216-B-3 pond system (B Pond) and to denote the requirements for achieving acceptable control limits for the 300 Area process trenches. Prior to receiving approval of a variance, conditions specified in the letter issued by Ecology in May 2001 must be met. The guidance letter[a] provides a path to more efficient and cost effective monitoring at these facilities. Statistical methodology adopted for these two facilities is described in Section 7.3. Criteria specified by Ecology and agreements reached with Ecology for the B Pond system are described in Section 7.4

Operations at the 200 Areas Treated Effluent Disposal Facility and the State-Approved Land Disposal Site began during 1995. Another facility, the 4608 B/C ponds (also called the 400 Area process ponds), consists of unlined infiltration ponds that receive wastewater from the 400 Area facilities. These sites are regulated by WAC 173-216. Because these are discharge permit disposal facilities, they require effluent and groundwater monitoring. Upgradient and downgradient comparisons for constituents of concern were performed at these sites in accordance with groundwater monitoring plans.

7.1 RCRA Interim Status Facilities

The primary objectives of RCRA groundwater monitoring are to comply with regulatory requirements and agreements, to assess potential impact on groundwater quality, and to identify near-term corrective measures, if feasible, for the protection of human health and the environment. In accordance with 40 CFR 265 Subpart F (which was incorporated, by

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[a] Letter from Dib Goswami (Washington State Department of Ecology, Olympia, Washington) to Marvin Furman (U.S. Department of Energy, Richland, Washington), *Statistical Assessment for the 300 Area Resource Conservation and Recovery Act of 1976 (RCRA) Ground Water Monitoring Plan*, dated May 7, 2001.

reference, into WAC 173-303-400), RCRA projects are monitored according to one of three levels of effort:

- background monitoring
- indicator evaluation
- groundwater quality assessment.

All of the RCRA facilities at the Hanford Site have completed their initial background monitoring programs. A general description of the applicable statistical methods that are appropriate for these interim status facilities is provided in this section.

The statistical method used to summarize background data is the averaged replicate t-test method as described in Appendix B of RCRA Groundwater Monitoring Technical Enforcement Guidance Document (OSWER-9950.1). The averaged replicate t-test method for each contamination indicator parameter during each evaluation period is calculated as

$$t = \left(\bar{x}_i - \bar{x}_b\right)/S_b * \sqrt{1 + 1/n_b}$$

where: t = test statistic

x_i = average of replicates from the i^{th} monitoring well

$\surd_b$ = background average

S_b = background standard deviation

n_b = number of background replicate averages.

The guidance documentation (OSWER-9950.1) states that a test statistic larger than the Bonferroni critical value, t_c, (i.e., $t > t_c$) indicates a statistically significant increase (or decrease, for pH) compared to the background data. This increase or decrease would indicate that contamination may have occurred. These Bonferroni critical values depend on the overall false-positive rate required for each sampling period (i.e., 1% for interim status), the total number of wells in the monitoring network, and the number of degrees of freedom (n_b - 1) associated with the background standard deviation. Because of the nature of the test statistic in above equation, sampling results to be compared to background do not contribute to the estimate of the variance, S_b^2. The test can be reformulated, without prior knowledge of the results of the sample to be compared to background, in such a way that a critical mean, CM, can be obtained

$$CM = \bar{x}_b + t_c * S_b * \sqrt{(1 + 1/n_b)}$$

$$CM = \bar{x}_b \pm t_c * S_b * \sqrt{(1 + 1/n_b)}$$

For pH, a two-tailed critical mean (or critical range) is calculated and a one-tailed critical mean is calculated for specific conductance, total organic carbon, and total organic halides. The critical mean (or range for pH) is the value above which (or above/below in the case of pH) a compared value is determined to be statistically different from background.

In the past, the lack of estimates of background variability for total organic carbon and/or total organic halides precluded the determination of critical means for various RCRA facilities. The calculated critical means were used in the statistical evaluations unless the calculated critical means were not quantifiable. In this case, a limit of quantitation was used as the threshold value for the regulatory decision to determine whether a RCRA facility has affected the groundwater quality beneath the facility. The limit of quantitation and limit of detection are determined quarterly and the most recent updated values are used in statistical evaluations.

Finally, if the calculated critical ranges for pH were too large to be meaningful because of the requirement to use four quarters of data to establish background, the upgradient/downgradient comparison value would be revised to the critical range by using more data. The expansion of the background dataset to include more than 1 year's data provides a better estimate of background mean and background standard deviation. More important, it increases the number of degrees of freedom associated with the background standard deviation. Other things being equal, a smaller t_c value and a narrower critical range for pH would result. This approach is preferred because it complies with both the requirements and the spirit of the regulations.

7.2 RCRA Final Status Facilities

Three levels of groundwater monitoring programs are required by the final status regulations (40 CFR 264 Subpart F and WAC 173-303-645): detection monitoring, compliance monitoring, and corrective action. The 183-H solar evaporation basins and the 300 Area process trenches are monitored in accordance with the RCRA final status requirements. Additionally, four permitted treatment, storage, and disposal facilities (i.e., 1301-N Liquid Waste Disposal Facility, 1324-N/NA Liquid Waste Disposal Facilities, 1325-N Liquid Waste Disposal Facility and Liquid Effluent Retention Facility), as of September 30, 1999, also are regulated under final status requirements. Groundwater monitoring, however, is regulated under interim status requirements in accordance with guidance provided by Ecology.

Evaluation of groundwater monitoring data under interim status involves use of a t-test to compare mean concentrations of the four parameters indicating contamination between upgradient and downgradient wells on the four replicate measurements during each sampling event. This required method is flawed (Davis and McNichols 1994; Cameron 1996) because

- The required pooling of background data is not valid when spatial, temporal, and sampling variability constitute a significant portion of the total variability.
- A static background is assumed because one initial set of background samples is collected and statistically compared to downgradient data collected during later monitoring.
- The background data pool does not incorporate any component of spatial variability when only one upgradient well is used.
- The four indicator parameter selected do not serve well as early warning indicators of incipient contamination of groundwater by leachate from the facility.

In final status monitoring, flexibility is allowed in selecting statistical methods as well as constituents used for statistical comparison. Appropriate statistical methods include analysis of variance, tolerance intervals, prediction intervals, control charts, test of proportions, or other statistical methods approved by the regulator. The important factors to consider when selecting appropriate statistical methods are the distribution(s) of monitoring parameters; the nature of the data; and the proportions of non-detections, seasonal, temporal, and spatial variations. The statistical evaluation procedures chosen for final status facilities will be based on guidance given by EPA (PB98-151047; EPA-530/R-93-003), and the American Society for Testing and Materials (ASTM 1996). Specific statistical methods are to be addressed in the unit-specific permit applications and/or in the groundwater monitoring plans.

7.2.1 Detection-Level Monitoring

In a detection-level groundwater monitoring program, the objective is to detect a potential impact from a regulated unit by testing for statistically significant changes in geochemistry in a downgradient monitoring well relative to baseline levels. These baseline levels could be obtained from upgradient (or background) wells, and the comparisons are referred to as interwell (or between-well) comparisons. Alternatively, if baseline values are obtained from historical measurements from that same well, the comparisons are referred to as intra-well (or within-well) comparisons. Groundwater parameter data (e.g., heavy metals, pH, reaction products, specific conductance, total organic carbon, total organic halides, waste constituents) from downgradient, compliance-point wells will be compared semiannually with baseline data to determine whether there is a statistically significant increase (or decrease for pH) over baseline concentrations. Final status, detection-level, groundwater monitoring plans for the Liquid Effluent Retention Facility and low-level burial grounds were proposed and presented to Ecology. However, a decision was made to not incorporate the low-level burial grounds into the permit until 2002. Therefore, these sites continue to be monitored in accordance with interim status requirements. Although the Liquid Effluent Retention Facility was included in the Hanford Site RCRA Permit, groundwater monitoring continued in interim status in accordance with the variance letter granted by Ecology in September 1999.[b] Specifically, the variance letter allowed the monitoring of groundwater in the vicinity of the Liquid Effluent Retention Facility using only two downgradient wells and one upgradient well. In January 2001, one of the downgradient wells went dry and no longer provided groundwater samples representative of the aquifer. As a result, the variance granted earlier is no longer in effect.[c] In addition, Ecology suspended further statistical evaluation of groundwater monitoring results associated with the two remaining yield wells.[c] Currently, Ecology, U.S. Department of Energy, and contractors are working on an alternative monitoring program for the Liquid Effluent Retention Facility.

7.2.2 Compliance-Level Monitoring

A compliance-level, groundwater monitoring program will be established for a RCRA unit if groundwater sampling during detection-level monitoring reveals statistically significant evidence of contamination for constituents of concern at the point of compliance well. In compliance-level monitoring, the objective is to determine whether specified concentration limits (e.g., groundwater protection standards) have been exceeded. This is accomplished by comparing the concentration of a constituent of concern to a concentration limit, such as a risk-based maximum concentration limit; alternative concentration limit; area or natural background; or applicable, relevant, and appropriate requirements. These concentration limits would be applied during compliance monitoring to determine whether corrective action might be necessary.

Maximum concentration limits will be identified for each groundwater monitoring constituent of concern. Alternative concentration limits will be proposed after considering the observed concentrations of chemical constituents in the groundwater that might have originated from the regulated unit in question. The area background, natural background, and other standards that are applicable, relevant, and appropriate will be evaluated when proposing an alternative concentration limit. The parameters monitored, the concentration limits, and the statistical methods were specified in the unit-specific groundwater-monitoring plan and approved by Ecology.

Results of groundwater monitoring indicate that the 300 Area process trenches exceed concentration limits for trichloroethylene, cis-1,2-dichloroethylene, and uranium in some of the downgradient compliance wells. The Washington State Department of Ecology was notified and the site RCRA permit was revised, putting the 300 Area process trenches into corrective action. During FY 2001, the revised groundwater monitoring plan for the 300 Area process trenches that complies with RCRA final status corrective action groundwater monitoring requirements was in place (PNNL-13645). This plan replaces the previous compliance-level plan (WHC-SD-EN-AP-185) that was in effect until August 2001.

7.2.3 Corrective Action

A corrective action program is initiated if a concentration limit at the point of compliance is exceeded. Exceedance is defined as statistically significant evidence of increased contamination [see WAC 173-303-645 (2)(a)(ii)]. Details for the corrective-action

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(b) Letter from Stan Leja (Washington State Department of Ecology, Olympia, Washington) to Marvin Furman (U.S. Department of Energy, Richland, Washington), *Variance from Interim-Status Groundwater Monitoring Requirements at the Liquid Effluent Retention Facility*, dated September 22, 1999.

(c) Letter from Dib Goswami and Fred Jamison (Washington State Department of Ecology, Olympia, Washington) to Kevin Leary and Michael Thompson (U.S. Department of Energy, Richland, Washington), *Liquid Effluent Retention Basin (LERF) Unsaturated Zone Monitoring Alternatives Evaluation, Suspension of Groundwater Monitoring Statistical Evaluation Requirements, LERF RCRA Permit Modification, and Leachate Monitoring Performance Criteria*, dated January 24, 2001.

program will be specified in the unit-specific permit application. In conjunction with a corrective-action program, a groundwater monitoring program must be established and implemented to demonstrate the effectiveness of the corrective-action program. In addition, the corrective-action groundwater monitoring program must be at least as effective as the previous compliance monitoring program in determining compliance with groundwater protection standards. The 183-H solar evaporation basins are monitored under a corrective-action plan.

As described earlier, the 300 Area process trenches groundwater monitoring plan that complies with final status corrective-action requirements was submitted and approved by Ecology in fiscal year 2001 (PNNL-13645). This monitoring plan includes well and constituent lists; summarizes sampling, analytical, and quality control requirements; and incorporates the entire interim changes made since the last revision of the groundwater monitoring plan for the 300 Area process trenches. Changes from the previous monitoring plan include updating the discussion on hydrogeology and conceptual model, redesigning the monitoring well network to include 11 wells rather than the previous eight, and adopting a combined Shewhart-CUSUM control chart approach that will track the contamination trends better than the previous plan with reduced costs. A detailed description of the combined Shewhart-CUSUM control chart procedures are presented in the following section.

7.3 Shewhart-CUSUM Control Chart Procedures

The combined Shewhart-CUSUM control chart approach was first referenced by Westgard et al. (1977) and further developed by Lucas (1982). This method is also discussed in a groundwater context by EPA-600/4-88/040, Gibbons (1994), and ASTM (1996) and first adopted into EPA guidance in 1989 (PB89-151047; EPA-530/R-93-003). Statisticians of Washington State University (WSU) evaluated the efficacy of this method for monitoring groundwater quality on behalf of Ecology (Jandhyala and Zhang 1999). In their report, Jandhyala and Zhang endorsed the control chart method of monitoring groundwater quality. There are several advantages in applying the control chart procedure:

- This method can be implemented with a single observation at any monitoring event (i.e., this method is efficient).
- This method is effective; it could be applied to monitor each well individually and yet maintain desired site-wide false positive and false-negative error rates. The spatial variations that adversely affect the ANOVA procedure do not play a role under the control chart procedure. [Note: Due to the elimination of spatial variability, the uncertainty in measured concentrations is decreased making intra-well comparisons more sensitive to a real release (that is, false negatives) and false positive results (ASTM 1996).

The power of the control chart method could be enhanced by the combined Shewhart and CUSUM procedures. The Shewhart procedure is sensitive to sudden shifts and the CUSUM procedure is sensitive to gradual changes in the mean concentrations. A combined Shewhart and CUSUM procedure, therefore, is well designed to detect both types of changes.

The combined Shewhart–CUSUM method can be implemented following a baseline of eight or more independent sampling periods for a given well (ASTM 1996). The method assumes that the groundwater baseline data and future observations will be independent and normally distributed. The most important assumption is that the data are independent. The assumption of normality can usually be met by log-transforming the data or by other Box-Cox transformations. The method is more fully discussed in Lucas (1982), EPA-600/4-88/040, Gibbons (1994), ASTM (1996), and Montgomery (1997).

The method is a sequential testing procedure to test for an upward shift in the mean concentration of a constituent of interest. The Shewhart portion of the test checks for any sudden upward shift in groundwater quality parameters based on a single observation, while the CUSUM checks for any gradually increasing trend in the groundwater quality parameters. The procedure can be implemented as follows: Let x'_i be a series of independent baseline observations $i = 1, \ldots, b$ ($b = 8$). Let x_i be a series of future monitoring measurements $i = 1, 2, 3\ldots$.

Then, using the baseline data, the following steps are applied:

1. First determine if the x'_i can be assumed to follow a normal distribution with mean m and standard deviation s. If not, transform the x'_i using the appropriate Box-Cox transformation and work with the transformed data.
2. Next use the baseline data to compute the estimates

$$\bar{x}' = \sum_{i=1}^{b} x_i' / b \text{ for } \mu \text{ and } s' = \sqrt{\sum_{i=1}^{b} (x_i' - \bar{x}')^2 / (b-1)} \text{ for } \sigma.$$

3. Determine the upper Shewhart control limit (SCL) for the procedure by calculating $SCL = x' + z_s s'$ where z_s is a percentile from the standard normal distribution used to set the false negative and false positive values of the Shewhart control limit. The value of z_s that is most often suggested for groundwater use is 4.5 by Lucas (1982), EPA-600/4-88/040, PB89-151047, and ASTM (1996). Other values may also be used, depending on the sampling scheme used and whether verification sampling is used to modify the false positive and false negative error rates.
4. Determine the upper CUSUM control limit (CCL), with $CCL = x' + z_s s'$. The value of z_c suggested by Lucas (1982), EPA-600/4-88/040, PB89-151047, is $z_c = 5$. This value can also be adjusted to reach desired false negative and false positive error rates. In practice setting $z_c = z_s = 4.5$ results in a single limits with no compromise in leak detection capabilities (ASTM 1996).
5. Determine the amount of increased shift in the mean of the water quality parameter of interest to detect an upward trend. This value is referenced as k and is usually measured in s units of the water quality parameter. Lucas (1982), EPA-600/4-88/040, and PB89-151047, suggest a value of $k = 1$ if there are less than 12 baseline observations; and a value of $k = 0.75$ if there are 12 or more baseline observations.

Using the monitoring data after the baseline measurements have been established:

6. Compute the CUSUM statistic as $S_i = \max\{0, (x_i - ks') + S_{i-1}s'\}$ as each new monitoring measurement, x_i becomes available, where $i = 1,2,3,\ldots$ and $S_0 = 0$
7. As each new monitoring measurement becomes available, compute the Shewhart and CUSUM tests; a verification sampling will be conducted if either $x_i \geq SCL$ or $S_i \geq CCL$. A well is declared to be out of control only if the verification result also exceeds the SCL or the CCL. If both $x_i <$ SCL and $S_i <$ CCL, then continue monitoring.
8. As monitoring continues and the process is shown to be in control, the baseline mean and standard deviation should be updated periodically (every year or two) to incorporate these new data. This updating process should continue for the life of the monitoring program.

If resampling is implemented during the monitoring, the analytical result from the resample is substituted into the above formulas for the original value obtained, and the CUSUM statistic is updated. Note in the above combined test that the Shewhart portion of the test will quickly detect extremely large deviations from the baseline period. The CUSUM portion of the combined test is sequential; thus, a small shift in the mean concentration over the baseline period will slowly aggregate in the CUSUM statistic and eventually cause the test to exceed the CUSUM control limit CCL.

Various control limits for the 300 Area process trenches constituents of interest were submitted and approved by Ecology and are presented in Table 7.3 of PNNL-13645.

7.4 Variance Allowed for the 216-B-3 Pond System

In May 2001, Ecology issued a letter[d] providing guidance for groundwater monitoring at the B Pond system because the standard indicator-parameters evaluation and accompanying interim status statistical approach is inappropriate for detecting potential B-Pond-derived contaminants in groundwater at this facility. Ecology specified in this guidance letter that certain criteria must be met prior to receiving approval of a variance from applying interim status regulations.

A proposal that included monitoring network, constituent list, statistical analysis, and reporting for the B Pond system was submitted to Ecology in November 2001. The specific elements of the proposal, as per the variance stated in Ecology's letter,[d] and in agreement with subsequent discussions with Ecology, are as follow:

Well Network

1. The well network (see attached map) will consist of one upgradient well (699-44-39B) and three downgradient wells (699-43-42J, 699-43-44, and 699-43-45).
2. Because data from the relatively new well 699-43-44 are limited, data from nearby well 699-43-43 will be used as a historical surrogate for 699-43-44, per letter direction. To establish the degree of data comparability between the wells, well 699-43-43 will be added to the network, and sampled as long as it remains serviceable. Well 699-43-44 is a replacement for well 699-43-43 which is becoming dry.

Constituents List

The constituents will be the same as presented during the May 17 presentation[e] and are shown in Table 7.4-1. This table will replace Table 5.1 in *Groundwater Monitoring Plan for the Hanford Site 216-B-3 Pond RCRA Facility* (PNNL-13367). As agreed, total organic carbon and total organic halides will be eliminated from the list and the total and dissolved concentrations of cadmium, lead, mercury, and silver will be analyzed annually for 4 years. Analysis for these metals will be discontinued after 4 years if no anomalous concentrations or trends are revealed.

Statistical Analysis

1. Only site-specific parameters (gross alpha, gross beta, and specific conductance) will be subject to statistical evaluations on a semiannual basis.
2. The combined Shewhart-CUSUM control chart method will be applied to the three site-specific parameters. The appropriate baseline period for the data will be identified and baseline data evaluated. Outliers will be addressed to avoid bias in the statistical analysis.
3. American Society for Testing and Materials (ASTM 1996) guidance will be used to evaluate non-detect results and outliers.
4. Normal probability plots will be used to verify normal distribution of data.
5. Input parameter values (k, SCL, and CCL) will be proposed and submitted to Ecology for approval prior to implementation of the groundwater monitoring plan. Power curves illustrating probabilities for false positive and false negative will be submitted.

(d) Letter from Dib Goswami (Washington State Department of Ecology, Olympia, Washington) to Marvin Furman (U.S. Department of Energy, Richland, Washington), *Statistical Assessment for the 300 Area Resource Conservation and Recovery Act of 1976 (RCRA) Ground Water Monitoring Plan*, dated May 7, 2001.

(e) Presentation by D. B. Barnett, Pacific Northwest National Laboratory, to Washington State Department of Ecology, May 17, 2001, Richland, Washington.

Reporting

Groundwater analytical and hydrologic data from nearby facilities, such as the Liquid Effluent Retention Facility, Treated Effluent Disposal Facility, and 216-A-29 ditch, will be examined for results that may lend understanding to the B Pond hydrogeologic system and will be discussed in the Hanford Site annual groundwater report, as appropriate. This discussion will be accompanied by recommendations for modifications of the well network and/or constituent list, as necessary.

7.5 Solid Waste Landfill

Groundwater monitoring at the Solid Waste Landfill is regulated in accordance with WAC 173-304-490, requiring no replicate analyses. Thus, the tolerance interval approach, suitable for individual sample comparisons, was used for performing the required comparisons between upgradient and downgradient wells for determining whether a significant change over background occurred for constituents specified in WAC 173-304-490. The statistical evaluations are described as follows.

7.5.1 Calculating Background Summary Statistics

Summary statistics were recalculated for the WAC 173-304-490(2)(d) constituents using quarterly monitoring data collected from March 1993 to May 2000 from upgradient wells. The results were presented in Table 6.1 of PNNL-13014. Some of the background data are below laboratory's specified method detection limit. Following guidance in PB89-151047, EPA-530/R-93-003, and Ecology (1996b), the following procedures were used in handling the non-detects. In cases where the proportion of non-detects is less than 15%, not detected measurements were replaced by half of their method detection limits, and the usual calculations were performed. In cases where the proportion of non-detects is between 15% to 50%, Cohen's method (Cohen 1959, 1961) was used to estimate the mean and standard deviation (dissolved iron, manganese, and zinc). For total organic carbon, Aitchison's adjustment (Aitchison 1955) was used because the fraction of nondetects exceeds 50% and Cohen's method may not give valid results (PB89-151047, pages 27-34). For ammonium, coliform bacteria, chemical oxygen demand, nitrite, and summary statistics are not calculated because these constituents are essentially not detected.

7.5.2 Testing Assumption of Normality of Data

Background water quality is statistically defined as the 95% upper tolerance interval with a 95% confidence (see Ecology 1996b, page 65). The tolerance interval defines a concentration range (from background well data) that contains at least a specified proportion (coverage) of the population with a specified probability (level of confidence). There are two types of tolerance intervals: parametric and non-parametric. Parametric tolerance interval techniques are valid when the assumption that the data are drawn from a normal (or lognormal) population holds. When data is not normally (or log-normally) distributed, a non-parametric tolerance interval is used to estimate background values.

Parametric tolerance intervals are sensitive to the assumption that the data are normally distributed. The statistical tests used to evaluate whether or not the data follow a specified distribution are called goodness-of-fit tests. A recommended test is the Shapiro-Wilk test for normality of the data (Shapiro and Wilk 1965). It is considered one of the best tests of normality available (Miller 1986; Mandansky 1988). The Shapiro-Wilk test statistic (W) will tend to be large when a probability plot of the data indicates a nearly straight line (i.e., normal distribution). Only when the plotted data show significant departure from normality will the test statistic be small. Hence, if the computed value of W is less than the critical value W_α for a prechosen value of α (e.g., $\alpha = 5\%$) shown in statistical table, the hypothesis of normality is rejected. The Shapiro-Wilk test of normality can be used for sample sizes up to 50. When sample size is larger than

50 (up to 98), a slight modification of the procedure called the Shapiro-Francia test (Shapiro and Francia 1972) can be used instead. Like the Shapiro-Wilk test, the Shapiro-Francia test statistic (W') will be small when the probability plot shows significant bends or curves (i.e., non-normality). Procedures are provided in PB98-151047 (pages 9-12) and Shapiro (1980, pages 20-24).

7.5.3 Re-Establishing Background Levels

Background values were established for the WAC 173-304-490(2)(d) constituents based on the tolerance interval approach using monitoring data collected from upgradient wells (699-24-35 and 699-26-35A) during May 1987 to September 1993. Since then more information has been obtained and the analytical laboratory has changed. Therefore, it is deemed appropriate to revise the original background values to reflect the most current site conditions and improve estimates of background mean and standard deviation. Both the upper and lower limits of the interval (two sided) were calculated for pH. Only the upper limits of the intervals (one sided) were calculated for other constituents.

If a lognormal (or a normal) distribution is a reasonable approximation of the background concentrations, a parametric tolerance interval (TI) of the following form is calculated.

$TI = \bar{x}_b \pm kS_b$ (two-sided), or

$TI = \bar{x}_b \pm kS_b$ (one-sided)

where: $\bar{x}_b$ = Background mean

k = a normal tolerance factor, which depends on the number of background samples (n), coverage (P%), and confidence level (Y). Coverage of 95% and confidence of 95% are used. With n = 60, P = 95%, and Y = 95%, k is 2.022 for a one-sided normal tolerance interval (Gibbons 1991).

S_b = Background standard deviation.

If background concentration do not follow a lognormal or normal distribution, or the proportion of non-detects is greater than 15%, a nonparametric tolerance interval is constructed (Conover 1980). A two-sided nonparametric tolerance interval is just the range of the observed data. An upper one-sided nonparametric tolerance limit is the largest observation. With 56 to 60 background samples for chemical oxygen demand, coliform bacteria, iron, manganese, nitrite, total organic carbon, and zinc (see Table 6.2 of PNNL-13014), the upper one-sided tolerance limit defined by the largest observation contains at least 95% of the background population with 95% probability.

In cases where all of the background values are below the contractually established detection limits or where the proportion of nondetects is more than 15%, a limit of quantitation was also calculated using the fiscal year 2000 field blanks data or based on method detection limits (PNNL-13404, Appendix B). Following guidance (OSWER-9950.1; Ecology 1996b), it was decided that for cases where the calculated upper tolerance limit is below the limit of quantitation, the most recently determined limit of quantitation will be used as the background threshold value (comparison value) between data obtained from background and downgradient compliance wells. This approach uses quality control data to target the limits of quantifiable data and provides a realistic approach for background/compliance well comparisons when upgradient wells yield values that are below the detection limit. In cases where the limit of quantitation is not available (e.g., chemical oxygen demand and coliform bacteria), the contractually required quantitation limits were used as the background threshold values. It should be noted that inconsistent values (i.e., outliers) were tested and removed from the background data sets in the statistical evaluations. The exclusion of extreme observation(s) from the background data sets provides smaller variability and lower comparison values. Thus, it is more conservative. The resulting tolerance limits, limits of quantitation, and background threshold values are also presented in groundwater annual reports (PNNL-13404).

7.5.4 Comparisons with Background Levels

Groundwater monitoring results have been and will continue to be compared on a quarterly basis with background levels determined in accordance to methods presented in Section 6.3.3. In addition, when there is a statistically significant increase for parameters or constituents listed in WAC 173-304-490(2)(d), the owner and/or operator needs to determine whether the groundwater performance standard has been exceeded and initiate the notification process. Results of past groundwater monitoring have detected the following primary chlorinated hydrocarbons in the groundwater beneath the Solid Waste Landfill: 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,1,1-trichloroethane (1,1,1-TCA), carbon tetrachloride, trichloroethylene (TCE), tetrachloroethylene (PCE), and 1,4-dichlorobenzene. These contaminants will be compared with WAC 173-200 groundwater quality criteria. If the criterion is exceeded, Ecology will determine whether corrective action program is required. In that case, a new groundwater monitoring plan will be written.

7.6 Liquid Effluent Receiving Facilities

Operation of the 200 Areas Treated Effluent Disposal Facility and the State-Approved Land Disposal Site began during 1995. These facilities are regulated by WAC 173-216; both require effluent and groundwater monitoring. Another facility, the 400 Area process ponds, is designated also as a WAC 173-216 discharge permit site. The permit was issued on August 1, 1996 and modified on February 10, 1998. The principal groundwater quality regulations (WAC 173-200) emphasize the non-degradation of current groundwater quality. These regulations require "Establishment of an enforcement limit as near the natural ground water quality as practical," and establishment of the point of compliance in the groundwater "...as near the source as technically, hydrogeologically, and geographically feasible."

7.6.1 Preoperational Monitoring

Groundwater quality data from the preoperational phases of the 200 Areas Treated Effluent Disposal Facility and the State-Approved Land Disposal Site were used to establish the background (baseline) values for the potential constituents of concern. In essence, background values were calculated using the parametric tolerance-interval approach discussed above because background water quality is statistically defined as the 95% upper tolerance interval with a 95% confidence (Ecology 1996b, p. 65). The baseline values were provided to the regulator to allow the determination of enforcement limits (specified in the permit) for specific constituents in groundwater.

7.6.2 Operational Monitoring

The objectives of collecting and evaluating the groundwater quality data from operational monitoring are (1) to determine if groundwater quality has changed from the baseline, preoperational conditions; (2) to evaluate the impact, if any, that operation of the facility has on the quality of groundwater in the uppermost aquifer; and (3) to demonstrate compliance with the groundwater enforcement limits set forth in the permit.

Statistical approaches used for preoperational and operational monitoring were described in detail in the groundwater monitoring plans for the 200 Areas Treated Effluent Disposal Facility (PNNL-13032) and State-Approved Land Disposal Site (PNNL-13121).

Table 7.1. Constituent List for the B Pond Facility (modified from PNNL-13367)

Indicator Parameters

pH
Specific conductance

Groundwater Quality Parameters(a)

Chloride(b)
Iron(c)
Manganese(c)
Phenols
Sodium(c)
Sulfate(b)

Site-Specific Parameters

Gross alpha
Gross beta
Arsenic(d)
Nitrate(d)
Iodine-129(d)
Tritium(d)
Cadmium(e)
Lead(e)
Mercury(e)
Silver(e)

Field Parameters

Alkalinity
Dissolved oxygen
Turbidity
Temperature

(a) Sampled annually; all others sampled semiannually.
(b) These constituents are part of a larger suite of anions provided in this analysis.
(c) These constituents are part of a large suite of metals provided by this analysis using inductively-coupled plasma methods.
(d) These constituents are also of Hanford sitewide concern, and are scheduled on a periodic basis in coordination with the sitewide surveillance sampling effort.
(e) Total concentrations, to be discontinued following four years (once annually) of analyses with no anomalous concentrations or trends.

and/or strontium-89 determination, yttrium-90 is separated from the strontium by hydroxide and oxalate precipitations. The yttrium oxalate is converted to yttrium oxide, weighed for chemical recovery, and counted by beta-proportional counting for activity.

8.6.10 Technetium-99

Two laboratory-specific methods are used. In the first method, samples are wet ashed with nitric acid and hydrogen peroxide to destroy organic material in the sample. Actinides, lanthanides, alkaline earths, transition metals, and lead are removed by precipitation as hydroxides and carbonates. Technetium, as the pertechnetate ion, is adsorbed from a weak nitric acid solution on a strongly basic anion-exchange column. The technetium is then eluted with a stronger nitric acid solution and determined by liquid scintillation beta counting. In the second method, the sample is evaporated to dryness on a hot plate to remove potential tritium interference. After re-constituting the sample residue with deionized water, the sample is treated with hydrogen peroxide to ensure any technetium is present as the pertechnetate ion. Technetium is then isolated and concentrated by passing the sample solution through a solid-phase extraction disc. The disc is placed directly in a scintillation cocktail, and technetium-99 is determined by liquid scintillation counting.

8.6.11 Total Alpha - Radium

Method 9315 (SW-846) is used to determine the total radium alpha activity. Radium is co-precipitated in water samples with mixed barium and lead sulfates. The carriers are added to an alkaline solution containing citrate, which prevented precipitation during carrier exchange with radium isotopes in the sample. Ammonium sulfate is then used to precipitate the sulfates, which were purified by nitric acid washes. The precipitate is dissolved in an alkaline solution containing EDTA (disodium ethylenedinitriloacetate dihydrate), and the barium and radium sulfates are precipitated by addition of acetic acid, thus separating radium from lead and other radionuclides. The precipitate is dried on a plate, weighed to determine chemical yield, and alpha counted to determine the activity concentration of the radium isotopes.

8.6.12 Uranium - Total

Total uranium analyses are performed by fluorometric or laser kinetic phosphorimetry or by alpha-counting determinations of individual isotopes for activity.

Method 908.1 (EPA-600/4-80-032) is the fluorometric determination of uranium in water. The sample is preconcentrated with aluminum phosphate. The sample is then fused with sodium fluoride and then read in a fluorometer. The technique of standard additions is used by adding a known quantity of uranium to each sample.

In the laser kinetic phosphorimetry method, the water samples are pretreated for organic and halide-quenching interferants (if necessary) and the particulates filtered out. The uranium is complexed with a substance such as phosphoric acid for it to phosphoresce. The concentration is calculated based on the phosphorescence of the sample in a laser phosphorimeter.

In the field, laser kinetic phosphorimetry, using instrument manufacturer's and company-specific methods, is used for total uranium determination.

8.6.13 Tritium

Laboratory-specific methods or Method 906.0 (EPA-600/4-80-032) are used. Sodium hydroxide is added to the tritium sample. The alkaline sample is then distilled, and a fraction (10 milliliters) mixed with scintillation cocktail, allowed to sit while the chemiluminescence decayed, and then counted by liquid scintillation instrumentation.

8.6.14 Tritium - Low-Level

The sample is distilled in the presence of potassium permanganate to eliminate solids and organic material that may cause quenching. The sample is then enriched in a basic medium by electrolysis to a small volume. The enriched volume is transferred to a liquid-scintillation vial with scintillation cocktail and allowed to sit for 24 hours while the chemiluminescence decays and temperature equilibrium is reached. The sample is then counted by liquid scintillation instrumentation.

8.6.15 Uranium Isotopes

Uranium is separated from lead, radium, and thorium on a hydrochloric acid anion-exchange resin column; iron is removed by passing the sample through a nitric acid anion-exchange resin column. The uranium fraction is eluted and electrodeposited on a disk for alpha spectrometry counting.

Table 8.1. (contd)

Analytical Test	User[(a)]	Reference	Analytical Methods
Lead	G	Method 7421 (SW-846)	Graphite furnace atomic absorption
Mercury	G, E	Method 7470 (SW-846)	Cold vapor furnace atomic absorption
Selenium	G, E	Method 7740 (SW-846)	Graphite furnace atomic absorption
Thallium	G	Method 7841 (SW-846)	Graphite furnace atomic absorption
		Radiological Analyses	
Americium-241	G	Laboratory specific	Anion- and cation-exchange resin separation with alpha energy analysis
Carbon-14	G, E	Laboratory specific	Separation and liquid scintillation counting
Gamma spectrometry	G	Laboratory specific Method 901.1 (EPA-600/4-80-032)	Intrinsic germanium counting
Gross alpha and gross beta	G, L E	Method 9310 (SW-846) Method 900.0 (EPA-600/4-80-032)	Gas-flow proportional counting
Iodine-129	G	Laboratory specific	Chemical separation, co-precipitated, and counted on low-energy photon detector
Isotopic plutonium	G	Laboratory specific	Anion-exchange resin separation with alpha energy analysis
Neptunium-237	G	Laboratory specific	Liquid-liquid separation and alpha energy analysis
Nickel-63	E	Laboratory specific	Separation and liquid scintillation counting
Radiostrontium	G G	Method 8040 (SW-846) Method 905.0 (EPA-600/4-80-032)	Gas chromatography
Strontium-90	G, E	Laboratory specific	Nitrate and carbonate co-precipitation, gravimetric yield, and beta gas-flow-proportional counting
Technetium-99	G, E	Laboratory specific	Anion-exchange resin column separation with liquid scintillation counting
	G, E	Laboratory specific	Solid-phase extraction separation with liquid scintillation counting
Total alpha - radium	G, E, L	9315 (SW-846)	Co-precipitation and alpha counting
Tritium - low level	G, E, L	Laboratory specific	Electrolysis to enriched volume and liquid scintillation counting

Table 8.1. (contd)

Analytical Test	User[(a)]	Reference	Analytical Methods
Uranium - isotopic	G	Laboratory specific	Anion-exchange resin separation with alpha energy analysis
Uranium - total	G, E	Laboratory specific	Laser kinetic phosphorimetry or fluorophotometry
	F	Company specific	Laser kinetic phosphorimetry
Tritium	G, E G, E	Laboratory specific Method 906.0 (EPA-600/4-80-032)	Distillation and liquid scintillation counting

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(a) E = Environmental Restoration Contractor, Bechtel Hanford, Inc.
F = Field (all contractors).
G = Groundwater Monitoring Project, Pacific Northwest National Laboratory.
L = Liquid Waste-Processing Facilities, Waste Management Federal Services of Hanford, Inc.
(b) Also analyzed by anion methods.
WTPH = Washington total petroleum hydrocarbons.

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