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**Hanford Site
Groundwater Monitoring
for Fiscal Year 1999**

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Abstract

This report presents the results of groundwater and vadose zone monitoring and remediation for fiscal year 1999 on the U.S. Department of Energy's Hanford Site, Washington.

Water-level monitoring was performed to evaluate groundwater flow directions, to track changes in water levels, and to relate such changes to evolving disposal practices. Measurements for site-wide maps were conducted in June in past years and are now measured in March to reflect conditions that are closer to average. Water levels over most of the Hanford Site continued to decline between June 1998 and March 1999.

The most widespread radiological contaminant plumes in groundwater were tritium and iodine-129. Concentrations of carbon-14, strontium-90, technetium-99, and uranium also exceeded drinking water standards in smaller plumes. Cesium-137 and plutonium exceeded standards only near the 216-B-5 injection well. Derived concentration guide levels specified in U.S. Department of Energy Order 5400.5 were exceeded for plutonium, strontium-90, tritium, and uranium in small plumes or single wells.

Nitrate and carbon tetrachloride are the most extensive chemical contaminants. Chloroform, chromium, cis-1,2-dichloroethylene, cyanide, fluoride, and trichloroethylene also were present in smaller areas at levels above their maximum contaminant levels. Metals such as aluminum, cadmium, iron, manganese, and nickel exceeded their maximum contaminant levels in filtered samples from numerous wells; however, in most cases, they are believed to represent natural components of groundwater.

Resource Conservation and Recovery Act of 1976 groundwater monitoring continued at 25 waste management areas during fiscal year 1999:

- 16 under detection programs and data indicate that they are not adversely affecting groundwater

- 6 under interim status groundwater quality assessment programs to assess contamination
- 2 under final status corrective-action programs.

Another site, the 120-D-1 ponds, was clean closed in fiscal year 1999, and monitoring is no longer required.

Groundwater remediation in the 100 Areas continued with the goal of reducing the amount of chromium (100 K, D, and H) and strontium-90 (100 N) reaching the Columbia River. The objective of two 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.

Subsurface source characterization and vadose zone monitoring, soil-vapor monitoring, sediment sampling and characterization, and vadose zone remediation were conducted in fiscal year 1999. Baseline spectral gamma-ray logging at two single-shell tank farms was completed, and logging of zones at tank farms with the highest count rate was initiated. Spectral gamma-ray logging also occurred at specific retention facilities in the 200 East Area. These facilities are some of the most significant potential sources of remaining vadose zone contamination. Finally, remediation and monitoring of carbon tetrachloride in the 200 West Area continued, with an additional 972 kilograms of carbon tetrachloride removed from the vadose zone in fiscal year 1999.

This report is available on the internet through the Hanford Groundwater Monitoring Project's web site: <http://hanford.pnl.gov/groundwater>. Inquiries regarding this report may be directed to Ms. Mary J. Hartman or Dr. P. Evan Dresel, Pacific Northwest National Laboratory, P.O. Box 999, Richland, Washington 99352 or by electronic mail to mary.hartman@pnl.gov or evan.dresel@pnl.gov.

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Report Contributors

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Summary

Billions of liters of liquid waste, some containing radionuclides and hazardous chemicals, have been released to the ground on the Hanford Site since 1944. A portion of these contaminants was trapped above the water table and some reached groundwater. The U.S. Department of Energy (DOE) monitors groundwater on the Hanford Site to track the spread of these contaminants. Groundwater is being remediated at seven sites that were identified as requiring immediate action. This report summarizes results of monitoring for fiscal year 1999.

State and federal regulations require groundwater monitoring for protection of human health and the environment. This report fulfills reporting requirements of the *Resource Conservation and Recovery Act of 1976 (RCRA)*, specific Washington Administrative Codes, and the *Atomic Energy Act of 1954* as implemented by DOE orders. This report also summarizes results of groundwater monitoring conducted to assess the effects of remediation or interim measures conducted in accordance with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)*.

Groundwater Flow

The water-table map for March 1999 indicates that groundwater in the unconfined aquifer generally moves from recharge areas along the western boundary of the site to the east and north toward the Columbia River, which is the major discharge area. This natural flow pattern was altered by the formation of groundwater mounds created by the discharge of large volumes of wastewater at disposal facilities. These mounds are declining, and groundwater flow is gradually returning to earlier patterns. During fiscal year 1999, water levels continued to drop beneath the 200 Areas, causing some monitoring wells to go dry. Replacement wells were installed in the most critical locations.

In part of the 200 East Area, water levels have dropped below the top of a fine-grained confining unit so that there is no unconfined aquifer. The uppermost aquifer there is a confined aquifer in the Ringold Formation. Groundwater flow in this confined aquifer is affected by a mound remaining from past discharges to the B Pond. There seems to be an upward gradient between this aquifer and the unconfined aquifer.

Water levels declined beneath the central Hanford Site in fiscal year 1999, causing some wells to go dry. Replacement wells are needed.

The fiscal year 1999 potentiometric map for the upper basalt-confined aquifer is similar to previous maps. The potentiometric map indicates that, south of Umtanum Ridge and Gable Mountain, groundwater generally flows from west to east across the Hanford Site, through the overlying sediment, and into the Columbia River. In the region northeast of Gable Mountain, there is insufficient well coverage to clearly define flow directions. The groundwater is believed to flow southwest and discharge primarily to underlying confined aquifer systems in the Umtanum Ridge-Gable Mountain structural area. A region of increased hydraulic head associated with recharge from agricultural activities north and east of the Columbia River has been observed for deeper, confined aquifer systems and is believed to be mirrored in the upper basalt-confined aquifer system north of Gable Mountain. Water levels in this aquifer in the central and western portions of the Hanford Site declined in fiscal year 1999, responding to a reduction in artificial recharge from liquid waste disposal. Water levels in the eastern portion of the Hanford Site increased in fiscal year 1999 because of large-scale irrigation activities in areas east of the Columbia River.

Groundwater Contamination

Monitoring wells were sampled during fiscal year 1999 to satisfy requirements of RCRA, CERCLA, Washington Administrative Code, and DOE orders. There were 623 wells sampled during the period.

Most of the contamination in the groundwater today resulted from the discharge of high volumes of relatively low-concentration effluents into cribs, ponds, and ditches in the past. New groundwater contamination may result from these inactive sources if contamination that has been immobile in the vadose zone is mobilized by increased infiltration of water from man-made or natural sources, e.g., in areas of gravel cover with no vegetation. Though there may be short-term variability in the concentrations of contaminants derived from these past sources, concentrations are expected to decline overall through radioactive decay, chemical degradation, and dispersion. A few sites still have the potential to add new contamination to groundwater, e.g., single-shell tanks, K Basins, and state-permitted disposal facilities. In the past few years, mobile fractions of waste from leaking single-shell tanks have been detected in groundwater. Tritium leaks from K Basins also have been detected in the past decade.

The Hanford Groundwater Monitoring Project sampled 623 wells during fiscal year 1999. Tritium, nitrate, and iodine-129 are the most widespread contaminants.

The extent of major radionuclides at levels above the interim drinking water standards is shown in Figure S.1. The map is based on data from wells that monitor near the top of the unconfined aquifer. Iodine-129, strontium-90, technetium-99, tritium, and uranium were present at levels above the standards. Minor radiological contamination included carbon-14 (100 K Area) cesium-137 and plutonium (200 East Area near

the 216-B-5 injection well). Derived concentration guide^(a) levels were exceeded for strontium-90 in the 100 K, 100 N, and 200 East areas (near the 216-B-5 injection well). The derived concentration guide for uranium was exceeded near U Plant. The derived concentration guide for tritium was exceeded in one well that monitors fuel storage basins in the 100 K Area and in one well near cribs that received effluent from the Plutonium-Uranium Extraction (PUREX) Plant. The derived concentration guide for plutonium was exceeded in one well in the 200 East Area (near the 216-B-5 injection well). Results for individual constituents are summarized below.

In fiscal year 1999, ~254 square kilometers of the aquifer were contaminated at levels above drinking water standards. This is a slightly larger area than in fiscal year 1998.

The extent of major chemical constituents at levels above the primary maximum contaminant levels is shown in Figure S.2. The map is based on data from wells near the top of the unconfined aquifer. Carbon tetrachloride, nitrate, and trichloroethylene were the most widespread. Chloroform, chromium, cis-1,2-dichloroethylene, cyanide, fluoride, and other metals also were present at levels above their maximum contaminant levels. Results for individual constituents are summarized below.

The area of contaminant plumes with concentrations exceeding a maximum contaminant level or drinking water standard was estimated to be ~254 square kilometers in fiscal year 1999. This is an increase of ~4% compared to fiscal year 1998. The fiscal year 1999 plumes equate to a volume of ~1.4 billion cubic meters. The volume estimate has a high uncertainty because of a lack of knowledge about the vertical extent of contaminant plumes. Plume thickness is estimated to

(a) The derived concentration guide is based on an exposure standard of 100 millirem per year and is the amount of an individual radionuclide that would lead to that dose through ingestion under specified intake scenarios.

be 20 meters, except in the 100, 300, and Richland North areas, where it is estimated to be 5 meters. The porosity of the aquifer is not well-characterized; for the purpose of the calculation, the porosity was assumed to be 30%. The estimate did not include water in the vadose zone.

Limited data are available on contamination deeper in the Ringold Formation near the 200 Areas. Carbon tetrachloride and tritium have been detected in these deeper units.

Tritium

Tritium was present in many Hanford Site waste streams discharged to the soil column and is the most mobile and most widely distributed radionuclide onsite. It has a relatively short half-life (12.3 years).

The most prominent tritium plume originated in the 200 East Area near the PUREX Plant and is migrating downgradient to the southeast. This plume discharges to the Columbia River along a stretch that extends from the Old Hanford Townsite to the 300 Area. Tritium concentrations near the Columbia River are highest in wells near the Old Hanford Townsite, where they are greater than 100,000 pCi/L. Concentrations in these wells are about half of what they were in the 1980s and are expected to continue to decline.

Tritium is very mobile in groundwater. The largest plume originates in the 200 East Area and extends to the southeast, where concentrations exceed the drinking water standard near the Columbia River. Levels are generally declining due to radioactive decay.

Another tritium plume from the 200 East Area has moved northward between Gable Mountain and Gable Butte. A smaller plume between the 200 East and 200 West Areas has its source near the 200 West Area's Reduction-Oxidation (REDOX) Plant. This

plume is moving relatively slowly because the aquifer has a relatively low permeability. Additional plumes of tritium originated in the 100 Areas, exceeding the drinking water standard locally.

Tritium exceeded its 2 million pCi/L derived concentration guide in one well near cribs that received effluent from the PUREX Plant (3.87 million pCi/L) and in one well in 100 K Area (2.36 million pCi/L). Concentrations in the PUREX well appear to be decreasing gradually, while concentrations in the 100 K Area well are highly variable. One well at Waste Management Area TX-TY equalled the derived concentration guide for tritium.

In January 1999, a sample from well 699-13-3A, located downgradient of the 618-11 burial ground in the southeastern 600 Area, contained 1.86 million pCi/L of tritium. This value was the first tritium data from this well and was far higher than concentrations in surrounding wells. The concentration was confirmed by re-analysis, and a sample collected in January 2000 contained 8.1 million pCi/L of tritium. A special investigation of the groundwater at the 618-11 burial ground is being undertaken in fiscal year 2000 to define the source of the high tritium results.

Tritium contamination has been detected in confined aquifers beneath the 200 Areas. Concentrations exceeded the drinking water standard in several wells that monitor a confined aquifer in the Ringold Formation near 200 East Area. Levels below the standard were detected in the upper basalt-confined aquifer.

Iodine-129

The presence of iodine-129 in groundwater is significant because of its relatively low, 1-pCi/L interim drinking water standard; its long-term releases from nuclear fuel processing facilities; and its long half-life (16 million years). However, iodine-129's relatively low-fission yield and long half-life limit its concentration in Hanford Site groundwater. Iodine-129 is transported in groundwater as the anionic iodide (I⁻) species that is very mobile. Waste containing iodine-129 was historically disposed of in the 200 Areas. Extensive

plumes exceed the drinking water standard in the 200 Areas and in downgradient portions of the 600 Area. The major plume extends toward the south-east from the 200 East Area. Concentrations remain below the drinking water standard in wells near the Columbia River, but may increase in the future as the plume moves downgradient. A smaller plume of iodine-129 is moving toward the north between Gable Mountain and Gable Butte.

The highest concentration of iodine-129 detected in fiscal year 1999 was 47 pCi/L at Waste Management Area TX-TY.

Extensive plumes of groundwater contaminated with iodine-129 exceeded the drinking water standard in the 200 Areas and in downgradient portions of the 600 Area.

Technetium-99

Technetium-99 is produced as a high-yield fission product and is present in waste streams associated with fuel processing. Technetium-99 is transported in groundwater as an anionic pertechnetate (TcO_4^-) species that is highly mobile. Technetium-99 tended to be associated with uranium through the fuel processing cycle, but uranium is less mobile in groundwater on the Hanford Site.

The 200 West Area had the highest technetium-99 concentrations detected in fiscal year 1999 (48,000 pCi/L). In this area, the largest plume is associated with U Plant, and the plume is migrating to the east into the 600 Area. A groundwater pump-and-treat system is operating near U Plant in an attempt to contain the plume. Technetium-99 also is elevated in wells monitored for the B, BX, BY, S, SX, T, TX, and TY single-shell tank farms. These sites are undergoing RCRA assessment investigations.

Elevated technetium-99 levels apparently associated with the BY cribs (200 East Area) continued to

be detected in fiscal year 1999. The maximum annual average near the BY cribs in fiscal year 1999 was 5,700 pCi/L.

A well completed in the basalt-confined aquifer near the BY cribs had technetium-99 at levels above the 900-pCi/L drinking water standard in fiscal year 1998 (average of 1,500 pCi/L, which is within the historical range). However, this well was not sampled in fiscal year 1999.

Technetium-99 is a mobile contaminant that exceeds the drinking water standards in small plumes. The highest concentrations in fiscal year 1999 were in the 200 West Area, where uranium is also present. The goal of a groundwater pump-and-treat system in that area is to prevent the plume from spreading.

Uranium

Uranium contamination on the Hanford Site has numerous potential sources, including fuel fabrication, fuel processing, and uranium recovery from separations activities. Uranium mobility is dependent on Eh, pH, and the presence of carbonate; its migration is slower than that of tritium and technetium-99. At the Eh/pH conditions found in the unconfined aquifer, U(VI) is the most mobile state.

The U.S. Environmental Protection Agency (EPA) proposed a 20- $\mu\text{g/L}$ maximum contaminant level for uranium. Uranium was detected at concentrations above this level in the 100 H, 100 F, 200, and 300 areas. Contamination in the 100 H, 100 F, and 200 East areas is very localized.

The highest concentrations detected in fiscal year 1999, exceeding the derived concentration guides for uranium isotopes, were in the 200 West Area near the 216-U-1 and 216-U-2 cribs. This plume extends into the 600 Area to the east. Like technetium-99, this plume is the target of a pump-and-treat system.

Another area of elevated uranium concentrations is observed in the 300 Area, downgradient of the 316-5 process trenches and ponds. Uranium contamination appears to be moving from the vicinity of the process trenches toward the southeast.

Strontium-90

Strontium-90 is produced as a high-yield fission product and is present in waste streams associated with fuel processing; it was released also by fuel element failures during reactor operations. Strontium-90 is of concern because of its moderately long half-life (28.8 years), its potential for concentrating in bone tissue, and the relatively high energy of the beta decay from its yttrium-90 radioactive decay product.

In fiscal year 1999, strontium-90 exceeded the 8-pCi/L interim drinking water standard in wells in all of the 100 and 200 areas and near the former Gable Mountain Pond. Strontium-90 exceeded the 1,000-pCi/L derived concentration guide in wells in the 100 K, 100 N, and 200 East areas. Levels declined to just below the derived concentration guide near the former Gable Mountain Pond.

The most widespread strontium-90 contamination is in the 100 N Area, and is the target of a pump-and-treat system. The plume did not change significantly in fiscal year 1999. Strontium-90 is of concern because of its moderately long half-life (28.8 years) and its potential to concentrate in animal and human bones.

The most widespread, high strontium-90 concentrations continued to be detected in the 100 N Area. The overall extent of the strontium-90 plume in the 100 N Area is not changing perceptibly but concentrations in seeps discharging to the Columbia River continue to exceed the drinking water standard. The goal of a pump-and-treat system in the 100 N Area is to reduce the movement of strontium-90 toward the Columbia River.

Carbon-14

Carbon-14 exceeded the 2,000-pCi/L interim drinking water standard in two small plumes near waste disposal facilities adjacent to the KW and KE reactor buildings. The maximum concentration in fiscal year 1999 was 15,600 pCi/L, about the same as in recent years.

Cobalt-60

Cobalt-60 is a neutron activation product typically associated with waste generated by the processing of irradiated fuel or with reactor cooling water. Cobalt-60 is predominantly present as a divalent cation that is strongly adsorbed onto Hanford Site sediment and is rarely observed in groundwater unless combined with other chemicals. Wells consistently show the presence of detectable cobalt-60 north of the 200 East Area, in an area that is affected by waste disposed to the BY cribs. However, levels have declined because of its relatively short half-life (5.3 years).

In fiscal year 1999, cobalt-60 continued to be detected north of the 200 East Area but remained below the drinking water standard.

In fiscal year 1999, the maximum annual average cobalt-60 detected in this vicinity remained below the 100-pCi/L interim drinking water standard. Cobalt-60 in this area appears to be highly mobile, probably because of the presence of a soluble cobalt-cyanide (or ferrocyanide) complex associated with the plume originating in the BY cribs.

Cesium-137

Cesium-137 is produced as a high-yield fission product, is present in waste streams associated with fuel processing, and has been released in reactor areas by fuel element failures. The concentration of cesium-137 in fiscal year 1999 reached 1,840 pCi/L in a well near the 216-B-5 injection well, which is in line with

the historical trend for the well. The interim drinking water standard for cesium-137 is 200 pCi/L.

Cesium-137 is a potential contaminant of concern at the S and SX single-shell tank farms. However, it was not detected in fiscal year 1999 in this area. It appears that the contamination is dominantly sorbed to particulate matter and does not seem to be a significant groundwater contaminant.

Plutonium

Plutonium was present in waste streams associated with fuel processing. The derived concentration guide for plutonium-239 is 30 pCi/L. There is no explicit interim drinking water standard for plutonium-239; however, the maximum contaminant level for gross alpha (15 pCi/L) is applicable. Alternatively, if the derived concentration guide, which is based on a 100-millirem dose standard, is converted to the 4-millirem dose equivalent used for the interim drinking water standard, 1.2 pCi/L would be the relevant guideline. Plutonium generally binds strongly to sediment, so its mobility in groundwater is limited.

Plutonium contamination is limited to an area adjacent to the 216-B-5 injection well in the 200 East Area.

The only significant detection of plutonium in fiscal year 1999, as in previous years, was associated with the 216-B-5 injection well in the 200 East Area. The maximum plutonium-239/-240 concentration detected near this injection well in fiscal year 1999 was 66 pCi/L, about the same as last year.

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. Additional sources of nitrate are located off the Hanford Site to the south and west.

Nitrate is the widest spread chemical contaminant in groundwater on the Hanford Site. However, the largest portions of the plumes are below the drinking water standard.

Nitrate was measured at concentrations greater than the maximum contaminant level (45 mg/L) in wells in all operational areas. Although elevated nitrate levels were found throughout the extensive plume that originates from the vicinity of the PUREX Plant in the 200 East Area, only proportionally small areas contained nitrate at levels above the maximum contaminant level. Concentrations in wells near the Columbia River at the Old Hanford Townsite are below the maximum contaminant level and have been steady for the past 10 years. Another plume originates at facilities associated with B Plant and migrates northward.

Extensive nitrate contamination extends into the 600 Area from the vicinity of U Plant in the 200 West Area. A large nitrate plume in the 200 West Area is located near T Plant, while smaller amounts of contamination are found near the Plutonium Finishing and REDOX plants. Two relatively small areas greater than the maximum contaminant level were detected near the 400 Area and Energy Northwest (formerly the Washington Public Power Supply System). Nitrate contamination in the Richland North Area apparently has a source off the Hanford Site.

Chromium

A major source for chromium was the sodium dichromate used as a corrosion inhibitor in cooling water for reactors in the 100 Areas. Chromium also was used for decontamination in the 100, 200, and 300 areas and for oxidation-state control in the REDOX Plant processes in the 200 West Area. Chromium was elevated in each of the 100 Areas, but the major plumes

exceeding the 100- $\mu\text{g/L}$ maximum contaminant level are related to operations in the 100 K, 100 D, and 100 H Areas.

Hexavalent chromium is a hazard to some aquatic life. Therefore, interim actions are under way to pump and treat groundwater in 100 K, 100 D, and 100 H areas to reduce the amount of chromium reaching the Columbia River.

Hexavalent chromium was detected in the Columbia River substrate adjacent to these areas and is a hazard to some aquatic life. Therefore, interim actions are under way to pump and treat groundwater in these areas to reduce the amount of chromium reaching the Columbia River. Data from new wells in the southwestern 100 D Area helped define the chromium plume in that region in fiscal year 1999. That plume, with concentrations greater than 1,000 $\mu\text{g/L}$, is being treated in situ by a method of reduction/oxidation manipulation.

Chromium concentrations also exceeded the maximum contaminant level near T Plant and the 216-S-10 pond and ditch in the 200 West Area. Chromium continued to exceed the maximum contaminant level in one well south of the 200 East Area. Other wells in the area also have elevated chromium, though levels are below the maximum contaminant level. The source of this plume has not been identified.

Data from new wells in fiscal year 1999 helped define the chromium plume in the southwestern 100 D Area. An innovative method to clean up this plume will be expanded in fiscal year 2000.

Carbon Tetrachloride

Carbon tetrachloride contamination exceeds the 5- $\mu\text{g/L}$ maximum contaminant level beneath much of

the 200 West Area. The plume extends beyond the area boundary and forms the most widespread organic contaminant plume on the Hanford Site. The contamination is principally from waste disposal operations associated with the Plutonium Finishing Plant, where it was used in plutonium processing. Concentrations in the central part of the plume remained above 2,000 $\mu\text{g/L}$ in fiscal year 1999. A groundwater pump-and-treat system is operating in this area to prevent the central portion of the plume from spreading. There appears to be a shift in the maximum concentrations toward the pumping wells, and the treated water is displacing the plume in the vicinity of the injection wells, located west of the area.

Groundwater beneath the 200 West Area is contaminated with carbon tetrachloride. A pump-and-treat system prevents the center of the plume from spreading.

The total area of the carbon tetrachloride plume at the top of the unconfined aquifer in fiscal year 1999 (5- $\mu\text{g/L}$ contour) was ~11.5 square kilometers, compared to 11.4 in fiscal year 1998. 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.

Carbon tetrachloride has been detected in wells that monitor far below the water table. Further study is needed to determine its distribution with depth.

Chloroform

The 200 West Area chloroform plume is associated with the carbon tetrachloride plume and is

believed to be a degradation product of carbon tetrachloride. A concentration of 140 µg/L was detected in 200 West Area in fiscal year 1999. The maximum contaminant level for chloroform is 100 µg/L (total trihalomethanes).

Trichloroethylene

Trichloroethylene was used on the Hanford Site in the 1960s and 1970s as a degreasing compound. Concentrations of trichloroethylene exceeded the 5-µg/L maximum contaminant level in fiscal year 1999 in wells in the 100 K, 100 F, 200 West, 300, and Richland North areas. It also was detected in wells near the Solid Waste Landfill, but levels were below the maximum contaminant level.

Trichloroethylene was used to remove grease. It is present in small plumes in the 100 K, 100 F, 200 West, 300, and Richland North areas.

Concentrations of trichloroethylene exceeded the maximum contaminant level in the 200 West Area to the west of T Plant and east of U Plant. Trichloroethylene is also associated with the carbon tetrachloride plume near the Plutonium Finishing Plant.

Trichloroethylene exceeded the maximum contaminant level in one of the point-of-compliance wells for the 1100-EM-1 Operable Unit and was detected in other wells near Siemens Power Corporation and Horn Rapids Landfill. The plume appears to be moving toward the northeast and concentrations are declining.

cis-1,2-Dichloroethylene

Concentrations of cis-1,2-dichloroethylene remained high in a well that monitors the bottom of the unconfined aquifer near the 316-5 process trenches in the 300 Area. The average cis-1,2-dichloroethylene concentration in this well in fiscal year 1999 was

150 µg/L (maximum contaminant level is 70 µg/L). The source of this constituent is believed to be anaerobic biodegradation of trichloroethylene.

Tetrachloroethylene

Tetrachloroethylene exceeded the 5-µg/L maximum contaminant level in a single well in the 300 Area in fiscal year 1999, with a concentration of 7 µg/L. A plume of tetrachloroethylene was detected in six wells in the 300 Area in fiscal year 1998, but rapidly decreased.

Cyanide

Cyanide contamination is present north of the 200 East Area and is believed to have originated from wastes containing ferrocyanide that were disposed in the BY cribs. Wells containing cyanide often contain concentrations of several radionuclides, including cobalt-60. Cobalt-60 appears to be chemically complexed and mobilized by cyanide or ferrocyanide. Cyanide concentrations exceeded the 200-µg/L maximum contaminant level in only one well in fiscal year 1999, with a maximum value of 291 µg/L, a slight decrease from fiscal year 1998.

Cyanide was associated with waste discharged to the BY cribs near 200 East Area. In groundwater it exceeded the drinking water standard in one well in fiscal year 1999.

Fluoride

Fluoride was detected above the 4,000-µg/L maximum contaminant level in one well near the T Plant waste disposal facilities in the 200 West Area. The highest concentration was 4,960 µg/L. A concentration of ~5,000 µg/L from a source off the Hanford Site was detected in a well in the Richland North Area.

Ingestion Risk and Dose Estimate

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. Interim 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, 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.

A person's potential dose from drinking contaminated water is the sum of the doses from the individual radionuclides. The highest dose estimates on the Hanford Site are restricted to parts of the 100 K, 100 N, and 200 areas. Groundwater is not used for drinking in these areas.

Figure S.3 shows the cumulative dose estimates from ingestion of groundwater from the unconfined aquifer on the Hanford Site. These estimates were made 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 in Figure S.3 show that areas above the 100-millirem per year dose standard are restricted to localized parts of the 100 K, 100 N, and 200 areas and a location around a single well down-gradient of the 618-11 burial ground. Portions of the 100, 200, 300, and 600 areas exceed 4 millirem per year.^(a)

The hazard quotient describes health hazards associated with noncarcinogenic substances. The highest hazard quotient on the Hanford Site is in a small part of the 200 West Area.

Figure S.4 illustrates the estimated lifetime incremental cancer risk that would be experienced by a person 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-dichloroethylene, hexavalent chromium, nitrate, and trichloroethylene. The calculation assumes that a person weighing 70 kilograms consumes 2 liters of groundwater every day for

(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 Figure S.1 is based on the EPA regulatory requirement. However, the areas in Figure S.3 corresponding to a dose greater than 4 millirem 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 millirem per year in Figure S.3 to be the same as the area exceeding interim drinking water standards (see Figure S.1), or to show a slightly larger area exceeding 4 millirem per year (i.e., if two or more radionuclides were individually below the drinking water standards, but added up to exceed 4 millirem per year). In fact, the areas above 4 millirem per year on Figure S.3 are more restricted than the area above the drinking water standard in Figure S.1 because of differences in the dosimetry systems adopted by EPA and DOE.

30 years (DOE/RL-91-45, Rev. 3; IRIS 1997). Cancer risks exceeding 0.0001 are present in portions of the 100, 200, 300, and 600 areas.

Figure S.5 shows the estimated hazard quotient that would be experienced by an individual drinking water contaminated with chemicals at concentrations that have been measured in groundwater across the Hanford Site. The hazard quotient relates the potential human health hazards associated with exposure to noncarcinogenic 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, Rev. 3; IRIS 1997). The only locations with hazard quotients above 5 are small portions of the 100 H and 200 West areas. Values between 1 and 5 are present in the 100 K, 100 D, 100 F, 200 West, and 200 East areas and from offsite contamination in the Richland North Area.

Groundwater Remediation

Groundwater remediation conducted in accordance with CERCLA was performed at the following sites:

100-KR-4 Operable Unit, 100 K Area — An interim action to address chromium contamination near the 116-K-2 trench continued in fiscal year 1999. Groundwater is extracted from six wells between the trench and the Columbia River, treated to remove chromium, and injected into wells upgradient of the trench. A capture zone model indicates that significant portions of the plume are being captured. The mass of chromium in the aquifer also is being reduced.

100-NR-2 Operable Unit, 100 N Area — Groundwater continued to be extracted from wells near the 1301-N liquid waste disposal facility, treated to remove strontium-90, and injected into wells near the 1325-N liquid waste disposal facility. The extraction wells create a hydraulic barrier intended to reduce the volume of contaminated groundwater reaching the Columbia River.

Pump-and-Treat System

The goal of the pump-and-treat systems on the Hanford Site is to prevent the worst contaminants from spreading. These systems removed the following contaminants in fiscal year 1999:

- ▶ 1,300 kilograms of carbon tetrachloride
- ▶ 63 kilograms of hexavalent chromium
- ▶ 4,900 kilograms of nitrate
- ▶ 0.2 curie of strontium-90
- ▶ 22 kilograms of uranium
- ▶ 7.8 kilograms of technetium-99.

100-HR-3 Operable Unit, 100 D Area — An interim action pump-and-treat system continued in fiscal year 1999. The system removes chromium-contaminated groundwater from wells near the Columbia River and pipes it to the 100 H Area for treatment and injection. The hydraulic effects of groundwater extraction are estimated to result in containment of the plume along ~400 meters of shoreline. A demonstration of in situ redox manipulation technology continued in fiscal year 1999 and the technology will be expanded in fiscal year 2000. The project's goal is to create a permeable treatment zone in the subsurface where chemical-reducing agents will turn the highly soluble hexavalent chromium to an insoluble state.

A test of an in situ method to immobilize chromium in groundwater in the 100 D Area was successful, and the method will be expanded in fiscal year 2000.

100-HR-3 Operable Unit, 100 H Area — An interim action pump-and-treat system continued in fiscal year 1999. The system removes chromium from wells in the central 100 H Area, treats it to remove chromium, and injects the water into wells in the southwestern part of the area. Computer simulations indicate that most of the plume is being captured, but a

portion continues to pass between the extraction wells into the Columbia River. An additional extraction well was installed in fiscal year 1999 and is scheduled to begin operating in 2000 to improve contaminant capture.

200-UP-1 Operable Unit, 200 West Area —

An interim action pump-and-treat system, designed to contain and treat the elevated technetium-99 and uranium, continued to operate in fiscal year 1999. Technetium-99 concentrations are below the remediation goal of 9,000 pCi/L in all but two wells. Uranium concentrations remained above the remediation goal of 480 µg/L in almost all wells, even after treatment of 425.6 million liters of groundwater and 5 years of operation.

200-ZP-1 Operable Unit, 200 West Area —

An interim action pump-and-treat system continued to operate to prevent further movement of carbon tetrachloride, chloroform, and trichloroethylene from the high concentration portion of the carbon tetrachloride plume and to reduce contaminant mass. Treatment of the contaminated water resulted in the removal of 1,290 kilograms of carbon tetrachloride in fiscal year 1999. Since initiation of pump-and-treat operations, August 1994 through September 1999, more than 864.2 million liters of water have been treated, resulting in removal of 3,386 kilograms of carbon tetrachloride. The system appears to be containing and capturing the portion of the plume with the highest concentrations.

Groundwater Monitoring of RCRA Treatment, Storage, and Disposal Units

RCRA groundwater monitoring continued at 25 waste management areas. At the end of fiscal year 1999, 16 were being monitored under indicator evaluation programs and do not appear to adversely affect groundwater with hazardous constituents. One (120-D-1 ponds) was clean closed in fiscal year 1999, meaning that no waste was left in place and no further groundwater monitoring is required. The others were

monitored under assessment or corrective-action programs. The following summarizes the highlights of RCRA monitoring during fiscal year 1999.

Four single-shell tank waste management areas were monitored under interim status assessment investigations. At the T, TX, and TY single-shell tank farms (200 West Area), technetium-99 and other contaminants are increasing in many wells, apparently as a result of changing directions of groundwater flow. Waste Management Area S-SX (200 West Area) had increases and decreases in technetium-99 as a result of movement of the contaminant plume. No cesium-137 or strontium-90 was detected in any of the RCRA wells at Waste Management Area S-SX. Waste Management Area B-BX-BY (200 East Area) appears to have three distinct areas of contamination, based on chemical fingerprints, plume locations, and trends.

The 183-H solar evaporation basins (100 H Area) and the 316-5 process trenches (300 Area) were monitored under final status requirements during fiscal year 1999. The 183-H basins have contaminated the groundwater with chromium, nitrate, technetium-99, and uranium at levels exceeding applicable concentration limits. Corrective action is directed by the CERCLA program, and an interim remedial action (pump-and-treat system) for chromium continued in fiscal year 1999. Groundwater monitoring to meet RCRA requirements continues during the remediation.

The 316-5 process trenches and other nearby sources contaminated groundwater with cis-1,2-dichloroethylene, trichloroethylene, and uranium at

RCRA Monitoring

RCRA monitoring at the Hanford Site included

- ▶ 2 sites under corrective action
- ▶ 6 sites under groundwater quality assessments
- ▶ 1 site clean closed in fiscal year 1999
- ▶ 16 sites under indicator evaluation.

levels above their respective concentration limits. However, the corrective-action monitoring plan has not been approved, and monitoring continues under the compliance plan. Natural attenuation of the contaminants is the corrective action chosen in the CERCLA record of decision. Groundwater monitoring continues in accordance with RCRA.

Changing water levels have affected the adequacy of some RCRA groundwater monitoring networks. In some areas, flow directions have changed since the networks were designed, and some wells have gone dry because of a declining water table. In the 200 West Area, monitoring networks for Waste Management Areas T and TX-TY could be inadequate for RCRA monitoring and need additional wells. Dry wells at the 216-S-10 pond and ditch and the 216-U-12 crib have caused their monitoring networks to be considered inadequate, and replacement wells may be required. In the 200 East Area, the Liquid Effluent Retention Facility is monitored by only two downgradient wells because the water table is dropping to near the bottom of the aquifer. Ecology has granted a waiver from the requirements for three downgradient wells while alternative methods of monitoring are being investigated. The adequacy of monitoring networks for Waste Management Areas A-AX and C are uncertain because of uncertainties in flow direction. Resolution of these uncertainties will be addressed in revised monitoring plans. Inadequacies in existing monitoring networks, where identified, are being evaluated on the basis of regulatory compliance, technical efficacy in terms of actual risk, and in the context of the closure or corrective-action plans of the respective facility.

Well Installation

In fiscal year 1999, eight new wells were installed (or begun) for RCRA groundwater monitoring. Sixteen new wells were installed in the 100 Areas for activities related to environmental restoration. One well was installed to support characterization for a proposed immobilized low-activity waste repository and another for vadose zone characterization at the SX Tank Farm.

Six wells were decommissioned (sealed with grout) in fiscal year 1999 because they were no longer used or were in poor condition. Approximately 110 well maintenance activities were carried out during fiscal year 1999. These activities included well or pump repair, cleaning, and maintenance.

Twenty-six new wells were installed in fiscal year 1999 and six old wells were sealed.

Modeling

Numerical simulations of groundwater flow and contaminant movement are used to predict future conditions and to assess the effects of remediation systems. One site-wide model and several local-scale models were applied to the Hanford Site in fiscal year 1999.

The site-wide, three-dimensional model underwent an external technical peer review in fall 1998. Pacific Northwest National Laboratory (PNNL) plans to implement the following modifications to the model to address peer review comments:

- (1) Investigate alternative conceptual models that reflect different credible combinations of boundary conditions and interpretations of the hydrogeologic framework.
- (2) Develop a model framework that includes uncertainties associated with prescribed processes, physical features, initial and boundary conditions, system stresses, field data, and model parameter values. This framework will ultimately be used to assess uncertainty in results produced by the range of alternative site-wide groundwater conceptual and numerical models.
- (3) Repeat the inverse calibration of the site-wide groundwater model to incorporate many of the changes arising from the peer review and incorporate new information. In addition, perform an inverse calibration of each alternative conceptual model.

Other groundwater models were applied in the design and evaluation of pump-and-treat activities aimed at remediation of contaminated groundwater in the 100 and 200 West areas. These models were used to estimate the area affected by the pump-and-treat operations at different times. Results of the models were used to optimize pumping rates and to choose locations for additional pumping wells.

Vadose Zone

Subsurface source characterization and vadose zone monitoring, soil-vapor monitoring, sediment sampling and characterization, and vadose zone remediation were conducted in fiscal year 1999.

Waste sites in the 100 Areas are being excavated to remove contaminated sediment. Significant activities related to the vadose zone during fiscal year 1999 included

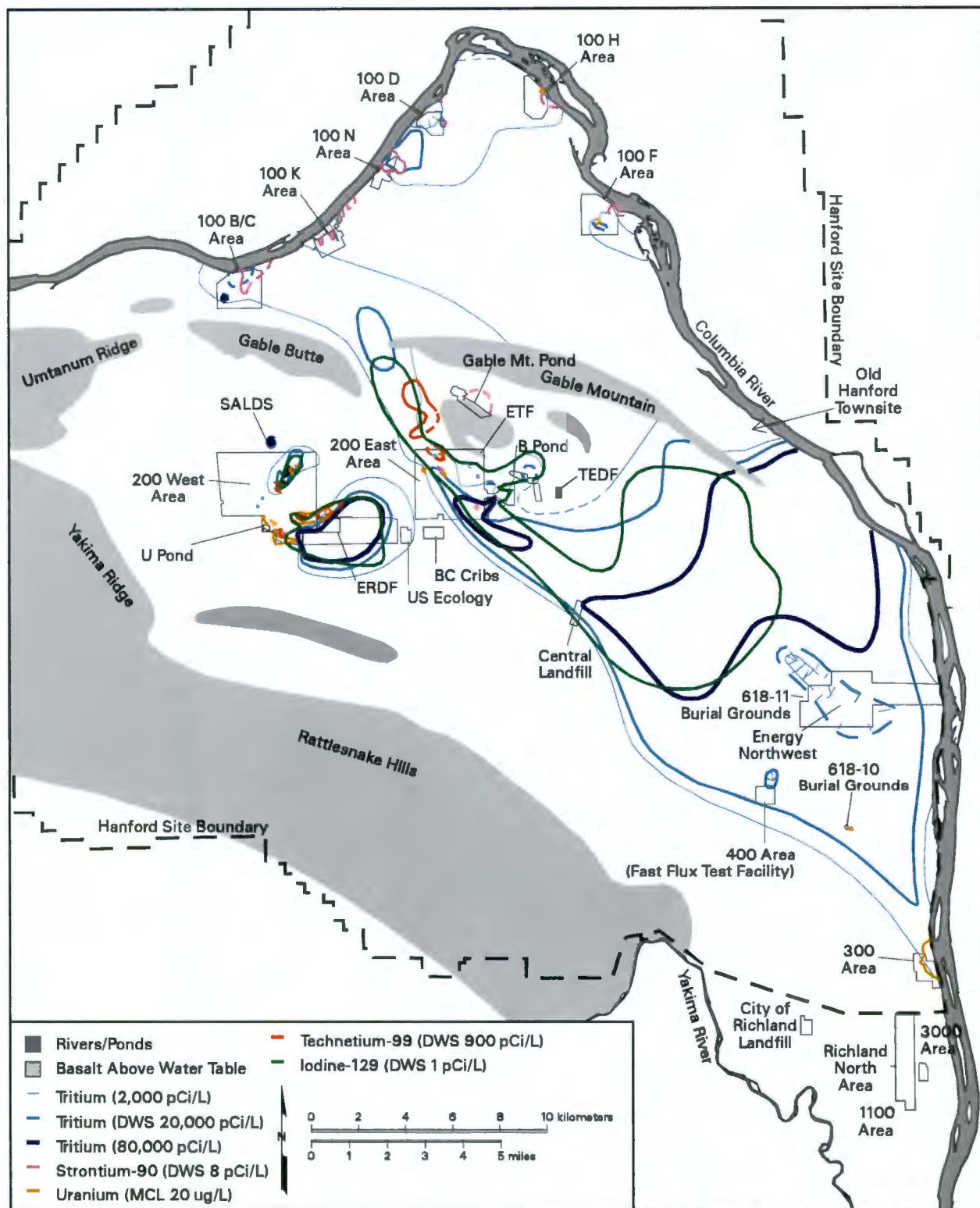
- soil sampling and analysis to support remediation of the 116-C-1 process effluent trench and the 1301-N and 1325-N cribs and trenches
- sampling and analysis to select a waste site for initial deployment of technology for in situ reduction of hexavalent chromium
- laboratory studies to measure the distribution coefficient and the leachability of chromium in 100 Areas sediment to support future remedial action goals and plans.

Several vadose zone characterization and monitoring activities were undertaken at the 200 Areas in fiscal year 1999, including

- sample collection and characterization of deep vadose zone contamination at the SX Tank Farm
- preliminary temperature and neutron capture borehole logging at the SX Tank Farm
- baseline spectral gamma-ray logging at two single-shell tank farms
- spectral gamma-ray logging at specific retention facilities in the 200 East Area, which are some of the most significant potential sources of remaining vadose zone contamination
- remediation and monitoring of carbon tetrachloride in the 200 West Area, where 972 kilograms of carbon tetrachloride were removed from the vadose zone in fiscal year 1999.

In fiscal year 1999, several vadose zone related activities were accomplished which have potential applicability across the Hanford Site:

- 175 lysimeters were inventoried and described.
- Four years of field data from the Hanford Site prototype surface barrier were analyzed and interpreted. Those data have important applicability to contaminated sites that may be left in place and monitored during natural attenuation.
- Tritium and helium-3/helium-4 were obtained from vadose zone sediment to extrapolate concentrations in the soil to concentrations in groundwater.



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Figure S.1. Distribution of Major Radionuclides in Groundwater at Concentrations Above Maximum Contaminant Levels or Interim Drinking Water Standards, Fiscal Year 1999

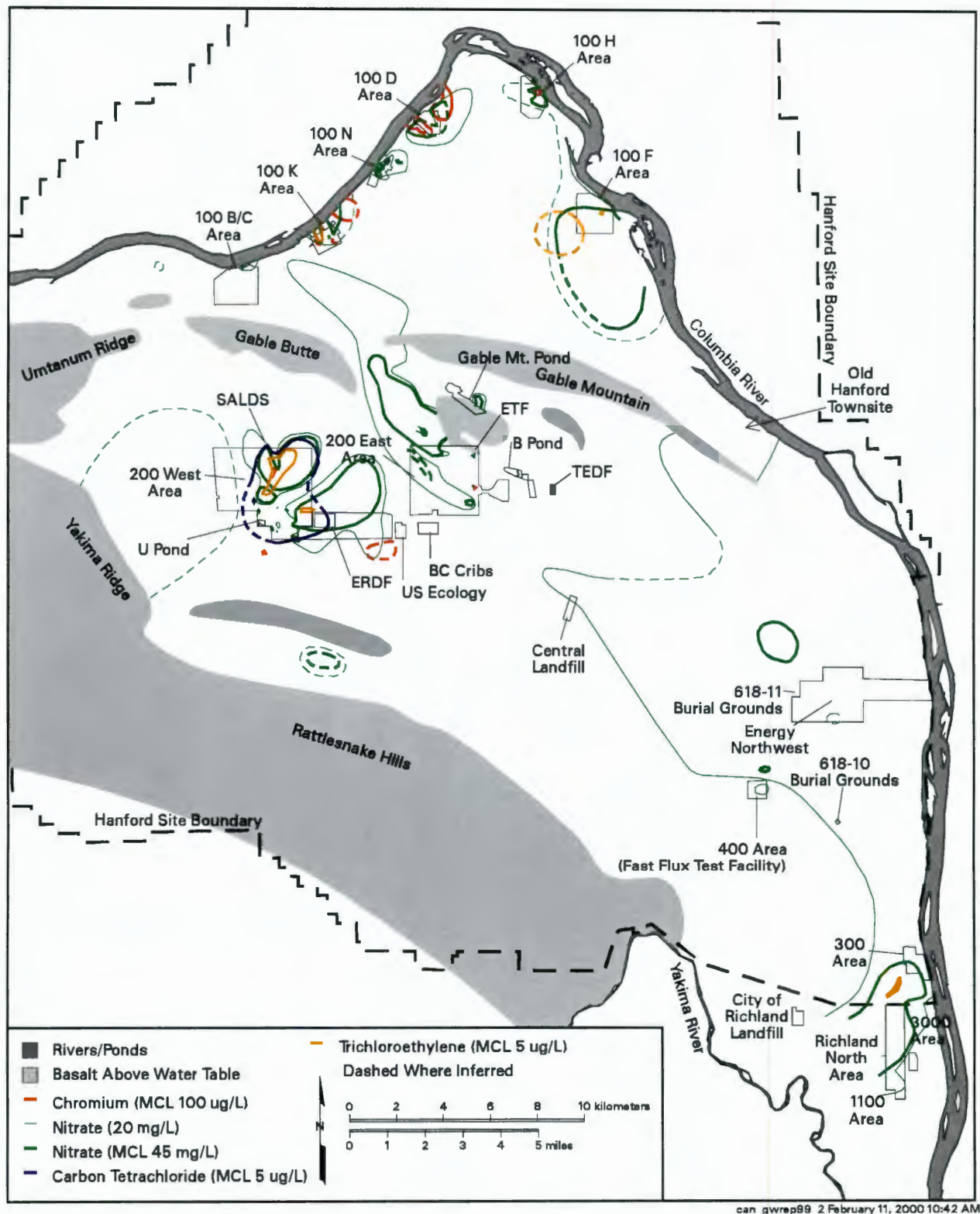
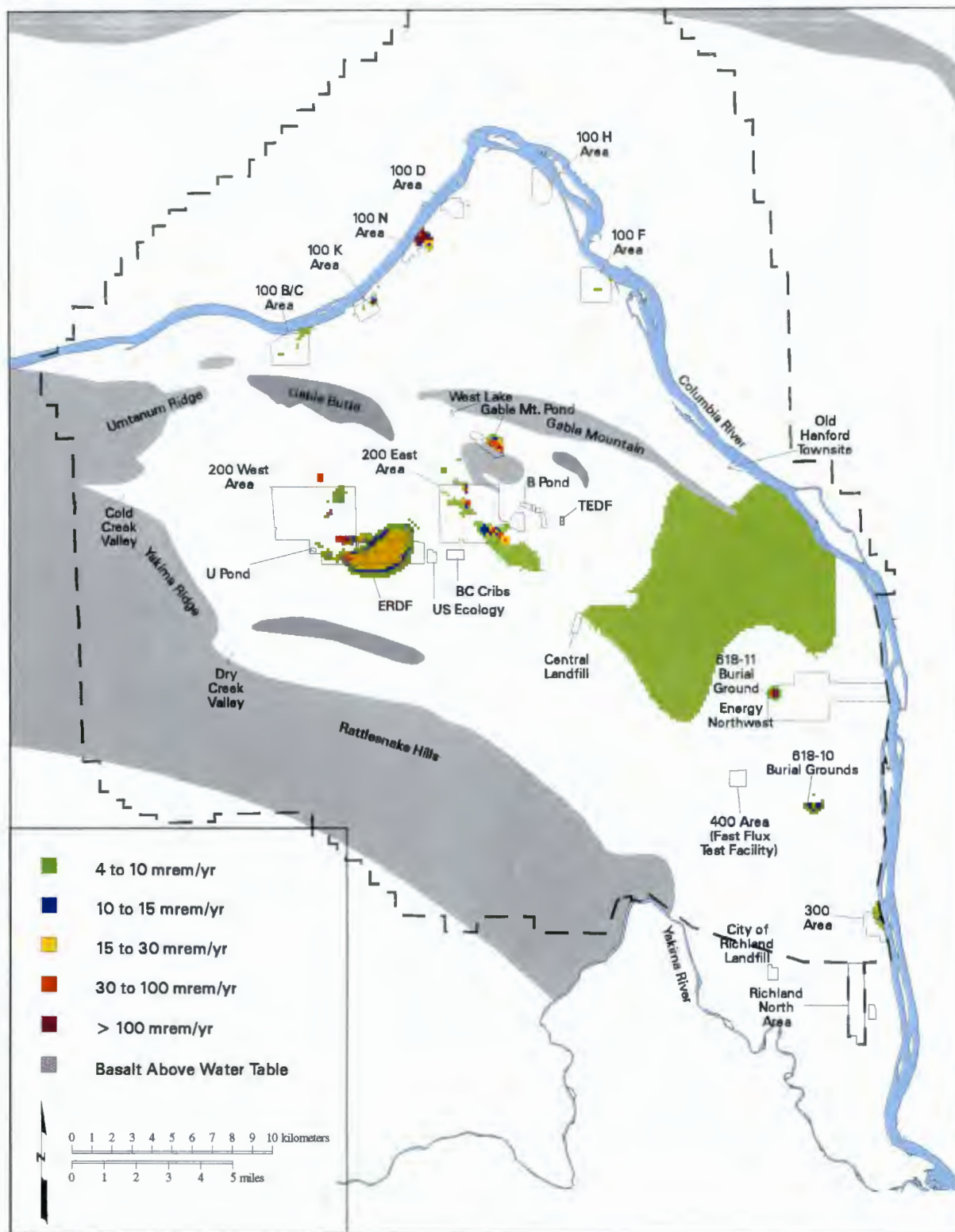
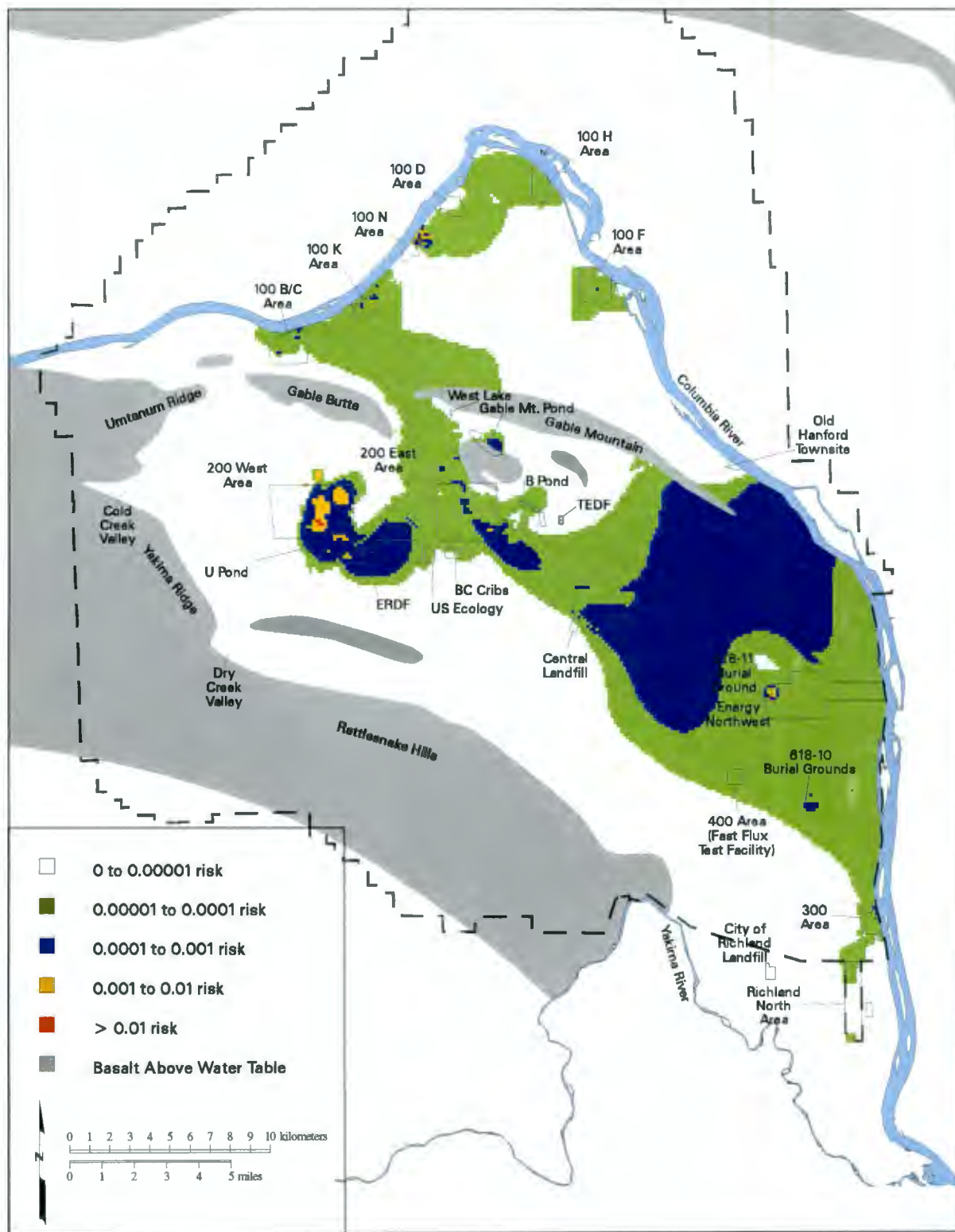


Figure S.2. Distribution of Major Hazardous Chemicals in Groundwater at Concentrations Above Maximum Contaminant Levels, Fiscal Year 1999



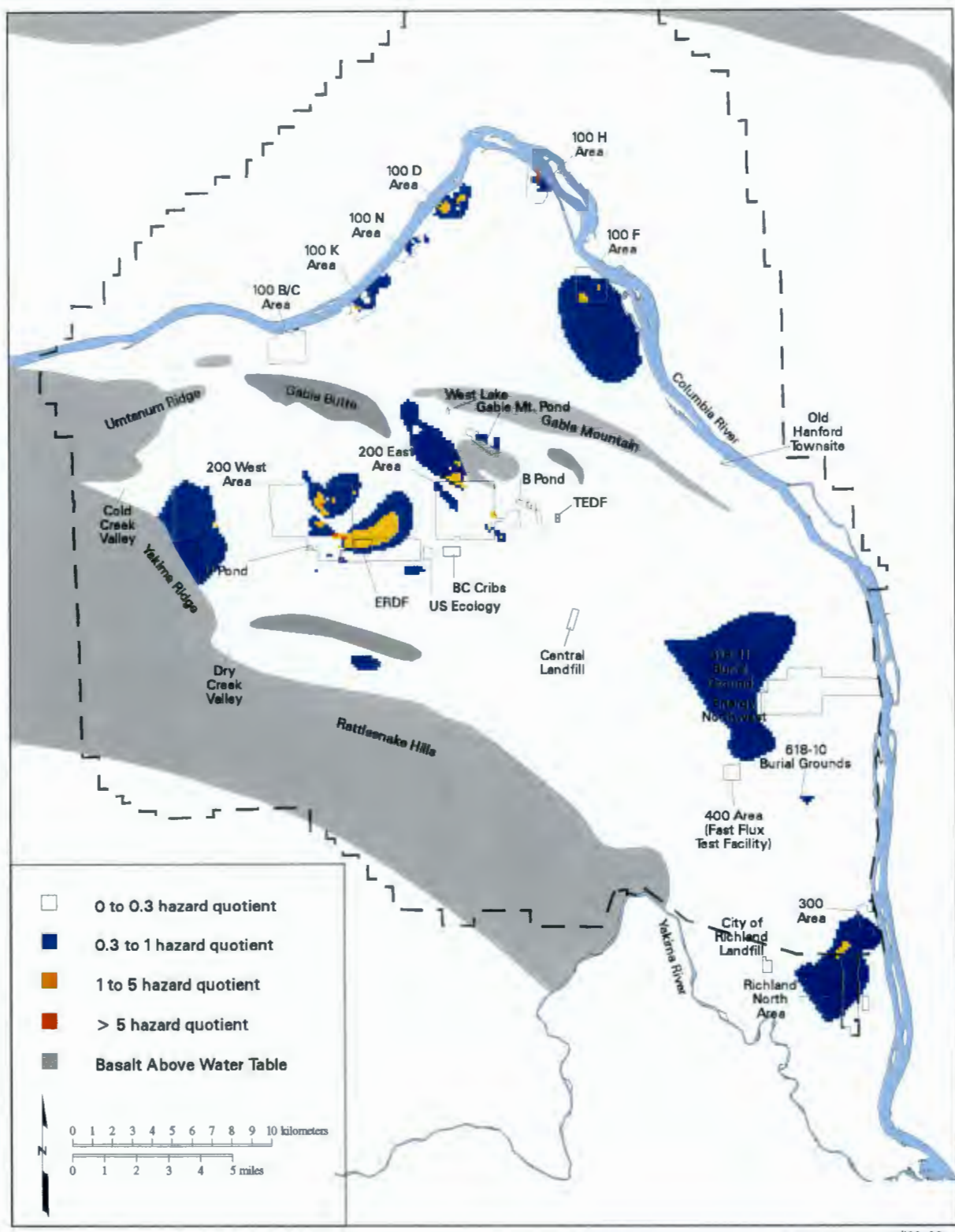
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Figure S.3. Potential Dose Estimates from Ingestion of Groundwater, Fiscal Year 1999



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Figure S.4. Cancer-Risk Estimates from Ingestion of Groundwater, Fiscal Year 1999



pdt00_03a

Figure S.5. Hazard Quotient Estimates from Ingestion of Groundwater, Fiscal Year 1999

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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.

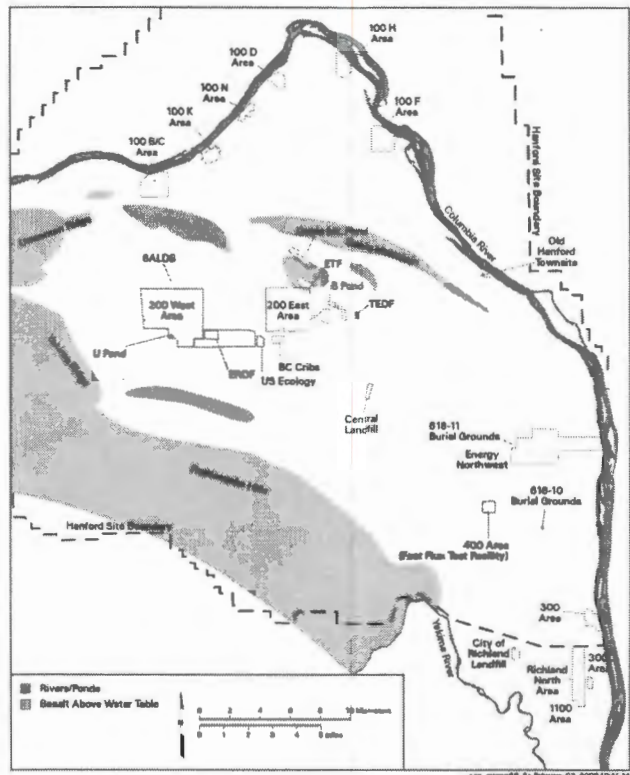
1.1 Purpose and Scope

M. J. Hartman

Hanford Site Groundwater Monitoring for Fiscal Year 1999 presents results of monitoring. These results primarily rely on data from samples collected between October 1, 1998, and September 30, 1999. Data received from the laboratory after November 8, 1999, may not have been considered in the interpretations.

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 Fluor Hanford, Inc., Bechtel Hanford, Inc., and Pacific Northwest National Laboratory.

This year's report has been reorganized to make it easier to use. Annual reports for fiscal years 1996, 1997, and 1998 contained descriptions of regulatory requirements, waste sites, analytical methods, regional geology, and statistics. This background information was important but repetitive, and readers found that it impeded their ability to find the substance of the report. This year that background information was published

in a separate report, *Hanford Site Groundwater: Setting, Sources and Methods* (PNNL-13080). That document will not be updated every year and will be available as a reference companion to the annual reports such as this one.

The discussions of groundwater flow and groundwater chemistry are combined in this year's report. Supporting information in the appendices has also been consolidated this year. Compliance issues, statistical evaluations, monitoring networks, and maps for regulated units are included in Appendix A.

Finally, the physical layout of the report has been redesigned to include more white space, inset sketch maps to orient the reader, and textboxes to emphasize key points.

Please note two changes in the way data are displayed in figures. Maps in this year's report show data from fiscal years 1997 and 1998 if there were no new data for a well in fiscal year 1999. Wells that monitor plumes that change slowly are sampled every 3 years, so this change allows us to see the most recent data. Trend plots in this year's report use open symbols to show data that were reported below laboratory detection limits.

As in previous reports, the enclosed computer diskette contains groundwater data for the fiscal year. Large plate maps show the wells used for monitoring, the Hanford Site water table, and the distribution of tritium (the most widespread contaminant) in the uppermost aquifer.

This report, PNNL-13080, and the fiscal year 1998 report are available on the internet through the groundwater project's web site: <http://hanford.pnl.gov/groundwater>.

1.2 Related Reports

M. J. Hartman

Other reports and databases relating to Hanford Site groundwater in fiscal year 1999 include the following:

- *Hanford Site Environmental Report for Calendar Year 1998* (PNNL-12088) — 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).

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	3.7×10^{10}	becquerel
picocurie	0.03704	becquerel
rem	0.01	sievert
°Celsius	$(^{\circ}\text{C} \times 9/5) + 32$	°Fahrenheit

- 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.
- *Fiscal Year 1999 Annual Summary Report for the 200-UP-1, 200-ZP-1, and 100-NR-2 Pump-and-Treat Operations and Operable Units* (DOE/RL-99-79) — This report describes results of remediation and monitoring in three groundwater operable units.
- Annual report for 100-KR-4 and 100-HR-3 interim remedial action (in preparation) — This report describes results of remediation and monitoring in two groundwater operable units, including 100 K, 100 D, and 100 H areas.

1.3 Groundwater/Vadose Zone Integration Project

T. M. Wintczak

DOE established the groundwater/vadose zone integration project (integration project) in late 1997 to provide a new approach for protecting the Columbia River. DOE directed the integration project to be science-based, to include strong participation from DOE's national laboratories, to incorporate rigorous technical reviews, and to engage diverse stakeholders in project decisions in a meaningful way. The Hanford Groundwater Monitoring Project is under the umbrella of the integration project.

In March 1998, the General Accounting Office issued the report *Understanding of Waste Migration at*

Hanford is Inadequate for Key Decisions (GAO/RCED-98-80). The report concluded that the DOE's understanding of how waste moves through the vadose zone to groundwater was inadequate for making key technical decisions on how to clean up the Hanford Site in an environmentally sound and cost-effective manner. The report also highlighted DOE's inability to credibly estimate the Hanford Site's long-term risk to the public, and underscored the need to investigate vadose zone conditions. DOE and the integration project have made significant progress in meeting the challenges described in the report.

Another significant focus of the integration project involves the preparation of a cumulative impact assessment of the Hanford Site radioactive and hazardous contaminants that have affected, or may affect, use of the Columbia River. The Columbia River Comprehensive Impact Assessment (CRCIA) Part II report (DOE/RL-96-16, Rev. 1) established the basis for this type of holistic assessment. The Systems Assessment Capability will support cleanup decisions and actions, such as the eventual completion of a final record of decision for the cleanup of the overall Hanford Site.

Ultimately, the integration project must work to ensure the protection of all the Hanford Site's water resources (i.e., vadose zone/soils and groundwater) and all the users of the Columbia River. To be successful, the integration project must

- adopt a site-wide approach to planning and funding
- ensure that management attention is maintained on the subsurface and river resources
- be recognized for technical and scientific excellence in all products
- establish and ensure effective two-way communications with diverse project participants.

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 of the Hanford Site. Factors that affect the distribution, migration, and concentrations of groundwater contaminants include

- Residual contamination in the vadose zone – provides a continuing source of groundwater contamination in some areas, and may be moved by increased natural or artificial recharge.
- 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 – (a) some monitoring wells have gone dry, which affects adequacy of *Resource Conservation and Recovery Act of 1976* (RCRA) or other monitoring; (b) 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; (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., 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 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 operational 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 Over view of Hanford Site Groundwater

J. P. McDonald, M. J. Hartman

This section provides a broad picture of groundwater flow and contaminant distribution on the Hanford Site. Details for specific locations are included in Sections 2.2 through 2.14.

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.

2.1.1 Groundwater Flow

The Hanford Groundwater Monitoring Project measures water-level elevations in aquifers beneath the Hanford Site annually. Water-level elevations indicate the potential for groundwater movement, because groundwater flows from areas of high potential (high

Beginning in fiscal year 1999 water levels are measured during March because the March water table is expected to represent the annual average water table.

water-level elevations) to areas of low potential (low water-level elevations). Contour maps indicate the general direction of groundwater movement, because water generally flows perpendicular to the contour lines from high to low potential. Water-level gradients are used to estimate the rate of groundwater flow.

Water-level maps are used to interpret contaminant plume patterns and to support the calibration of groundwater flow models. The Hanford/Ringold aquifer system is the primary focus because it is the most

likely groundwater pathway for migration of contaminants off the Hanford Site. However, measurements also are taken annually in the upper basalt-confined aquifer system (Section 2.14) and in the deep basalt aquifers to support modeling activities 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.

In past years, the groundwater project collected annual water-level measurements during June. However, beginning in fiscal year 1999, the annual measurements were taken during March, because the March water table is expected to be more representative of the annual average water table (PNNL-13021).

The following sections describe groundwater flow in the unconfined aquifer and changes in the water table during the past year. Flow in a confined aquifer in the Ringold Formation is described in Section 2.9.3. Groundwater flow in the basalt-confined aquifer is discussed in Section 2.14.

2.1.1.1 Current Water Table

Groundwater in the unconfined aquifer flows from areas where the water table is higher (west of the Hanford Site) to areas where it is lower, near the Columbia River (Figure 2.1-1 and Plate 2). Steep gradients in the western region of the Hanford Site are caused by

- groundwater recharge
- lower hydraulic conductivity than in the eastern region of the site
- a decrease in the aquifer thickness from west to east.

Possible sources of recharge include infiltration of rain and snowmelt at higher elevations, primarily in the Cold Creek and Dry Creek Valleys, as well as irrigation of offsite agricultural land in the Cold Creek Valley. Steep gradients north and east of the Columbia River (see Figure 2.1-1) are attributed to recharge associated with irrigation of agricultural land. Regionally, water-table elevations decrease while approaching the Columbia River from either side, indicating that groundwater flow converges and ultimately discharges to the river.

Wastewater discharged to the ground on the Hanford Site resulted in groundwater mounding and significantly affected the flow system. Past discharges at U Pond and lesser discharges to other 200 West Area facilities still are apparent from the shape of the water-table contours passing through the 200 West Area. The steep gradient just east of the 200 West

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

Area results partially from this mounding and partially from the relatively low transmissivity. The hydraulic gradient decreases abruptly between the 200 West and 200 East areas, corresponding to an increase in transmissivity. The steep gradient between Umtanum Ridge and Gable Butte results partially from recharge coming from Cold Creek Valley, mounding in the 200 West Area, and restriction of the Hanford/Ringold aquifer system by the underlying basalt to a thin, narrow zone in the gap.

The water table in the central portion of the Hanford Site, 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 up until fiscal year 1997, but currently it occurs mainly within the Ringold Formation mud units and is considered to be part of the Ringold Formation confined aquifer (Section 2.9.3). The mud units of the Ringold Formation at the water table east and northeast of the 200 East Area are represented differently in the June 1998 (PNNL-12086) and March 1999 water-table maps. This is due to evolving interpretation of the hydrogeology of this region.

North of Gable Butte and Gable Mountain, groundwater also generally flows from west to east and discharges to the Columbia River. Recharge to the aquifer in this region comes primarily from the Columbia River west of the 100 B/C Area. Recharge also comes from groundwater flowing north through the gaps between Umtanum Ridge and Gable Butte and between Gable Butte and Gable Mountain.

A local 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, which have persisted to the present. Data suggest that this mound is associated with a subsurface topographic "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 upwelling 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 city of Richland's North Well Field recharge ponds results in a groundwater mound in the Richland North Area.

2.1.1.2 Water-Table Changes from June 1998 to March 1999

A contour map of the change in the water table from June 1998 to March 1999 is shown in Figure 2.1-2. The water table declined over much of the Hanford Site during this period. This is due to the decline in wastewater discharges to the ground that have occurred since the peak discharge in 1984. Over the 9-month period, the water table declined by an average of 0.19 meter (equivalent to 0.25 meter per year) in the 200 East Area and 0.34 meters (0.45 meter per year) 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 declined beneath the central Hanford Site in fiscal year 1999, causing some wells to go dry.

The decline in the water table along the Columbia River from west of the 100 B/C Area to the Old Hanford Townsite is due to seasonal differences in river discharge caused by changing the month in which the measurements are collected from June to March. The largest water-level decline (1.87 meters) on the Hanford Site occurred in well 699-68-105 (west of the 100 B/C Area).

The water-table elevation increased in a broad region adjacent to the Rattlesnake Hills and Yakima

River. This may be caused by higher than normal precipitation in fiscal years 1993 through 1997, along with higher than normal Yakima River discharge in fiscal years 1995 through 1998.

The water-table elevation increased along the Columbia River in the 300 Area. The 300 Area water-level measurements are collected at the end of the month in which the annual measurements are taken. The increase in the water table in the 300 Area is attributed to a higher river stage in late March 1999 as compared to late June 1998. The largest water table increase on the Hanford Site (0.38 meter) occurred in well 399-4-10, which is located adjacent to the Columbia River in the 300 Area.

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 Richland North Well Field) and within groundwater pump-and-treat areas. These changes are attributed to operation of these facilities. The largest water-table increase in the unconfined aquifer (0.58 meter) occurred in well 1199-41-15 at the Richland North Well Field.

2.1.2 Groundwater Contaminants

During fiscal year 1999, Hanford Site staff sampled 623 wells for radiological and chemical constituents. Of the wells sampled, 253 were sampled once, 178 were sampled twice, 20 were sampled three times, 117 were sampled four times, and 55 were sampled more frequently. Well locations for the Hanford Site are shown on Plate 1. A number of wells are sampled to meet Resource Conservation and Recovery Act of 1976 (RCRA) or Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) requirements. More detailed maps of well locations are included in Appendix A for RCRA units and other sites regulated under the Washington Administrative Code.

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 also is shown in Plate 3. The

most prominent portions of these plumes derive from 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 extensive contaminant plumes include carbon tetrachloride and associated chloroform and trichloroethylene in the 200 West Area, chromium in the 600 Area south of the 200 Areas, technetium-99 and uranium that extend

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

eastward from the 200 West Area, and technetium-99 with minor amounts of cyanide and cobalt-60 northwest of the 200 East Area. 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. A few smaller sources within the 600 Area are discussed in Section 2.11. Table 2.1-1 lists contaminants and refers to the sections in this report where they are discussed. The table highlights contaminants

that exceed water quality standards. All analytical results for fiscal year 1999 are included on the data diskette included with this report.

Available data indicate that the vast majority of contamination on the Hanford Site remains near the water table, but information on the depth of the contaminant plumes is lacking for much of the site. Contamination in deeper aquifers of the Hanford/Ringold sediment is discussed for the 200 East Area in Section 2.9.3. Contamination in the upper basalt-confined aquifer is discussed in 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 (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 interim drinking water standards.

Table 2.1-1. Maximum Concentrations of Groundwater Contaminants in Fiscal Year 1999 (data on diskette included with this report)

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	
			Wells	Shore ^(b)	Wells	Shore ^(b)	Wells	Shore ^(b)	Wells	Shore ^(b)	Wells	Shore ^(b)
Carbon tetrachloride	5	µg/L										
Carbon-14	2,000 [70,000]	pCi/L			15,600	680						
Cesium-137	200 [3,000]	pCi/L										
Chloroform	100	µg/L										
Chromium (filtered)	100	µg/L	108	50	606	112	176		2,155	783	259	73
Cobalt-60	100 [5,000]	pCi/L										
Cyanide	200	µg/L										
cis-1,2 Dichloroethylene	70	µg/L										
Fluoride	4,000	µg/L									309	
Gross alpha	15	pCi/L									42	
Gross beta	50	pCi/L	141	52	23,800	55		2.3	255	23	260	97
Iodine-129	1 [500]	pCi/L										
Manganese (filtered)	50	µg/L					5,780					
Nitrate (as NO ₃)	45	mg/L	50	43	175	29	150	21	91	49	216	50
Nitrite (as NO ₂)	3,300	µg/L							4,640			
Plutonium	NA [30]	pCi/L			(c)							
Strontium-90	8 [1,000]	pCi/L	135	5.7	5,660	0.03	19,500	13,100	32		45	
Sulfate	250	mg/L					390		735			
Technetium-99	900 [100,000]	pCi/L									561	56
Tetrachloroethylene	5	µg/L										
Trichloroethylene	5	µg/L			23							
Tritium	20,000 [2,000,000]	pCi/L	86,900	66,000	2,360,000	11,900	51,600	24,400	35,500	4,100	6,630	3,800
Uranium	20 [790]	µg/L									57	

Table 2.1-1. (contd)

Contaminant (alphabetical order)	DWS or MCL [DCG] ^(a)	Units	100 F Section 2.7		200 West Section 2.8	200 East Section 2.9		400 Section 2.10	600 Section 2.11	300 Section 2.12		Richland North Section 2.14
			Wells	Shore ^(b)	Wells	Wells	Shore ^(b)	Wells	Wells	Wells	Shore ^(b)	Wells
Carbon tetrachloride	5	µg/L			7,000				0.5			
Carbon-14	2,000 [70,000]	pCi/L										
Cesium-137	200 [3,000]	pCi/L			undetected	1,840						
Chloroform	100	µg/L			140				1			
Chromium (filtered)	100	µg/L	96	29	433	2,820			NS ^(d)			
Cobalt-60	100 [5,000]	pCi/L				62						
Cyanide	200	µg/L				291						
cis-1,2 Dichloroethylene	70	µg/L								180		
Fluoride	4,000	µg/L			4,960							5,000
Gross alpha	15	pCi/L			1,380	37	3.22		8	67	55.6	77
Gross beta	50	pCi/L	553	7.4	5,490	20,800	23.3		17		21	50
Iodine-129	1 [500]	pCi/L			47	12.5	0.22					
Manganese (filtered)	50	µg/L			1,380	152			9.2			
Nitrate (as NO ₃)	45	mg/L	198	49	823	514	36	92	402	112		168
Nitrite (as NO ₂)	3,300	µg/L			1,862			154	4,340			
Plutonium	NA [30]	pCi/L			undetected	65.8						
Strontium-90	8 [1,000]	pCi/L	329		1	10,800			948	4		
Sulfate	250	mg/L							56			
Technetium-99	900 [100,000]	pCi/L			8,540	6,850	105					
Tetrachloroethylene	5	µg/L								7		
Trichloroethylene	5	µg/L	18		33				0.8	6		6
Tritium	20,000 [2,000,000]	pCi/L	32,700	1,100	1,970,000	3,870,000	120,000	68,400	1,860,000	13,000	9,590	516
Uranium	20 [790]	µg/L	20		2,800	69			99	322	^(e)	12

Note: Table lists highest concentration for fiscal year 1999 in each geographic region. Concentrations in blue exceed drinking water standards. Concentrations in red exceed derived concentration guides. Blank spaces indicate the constituent is not of concern in the given area.

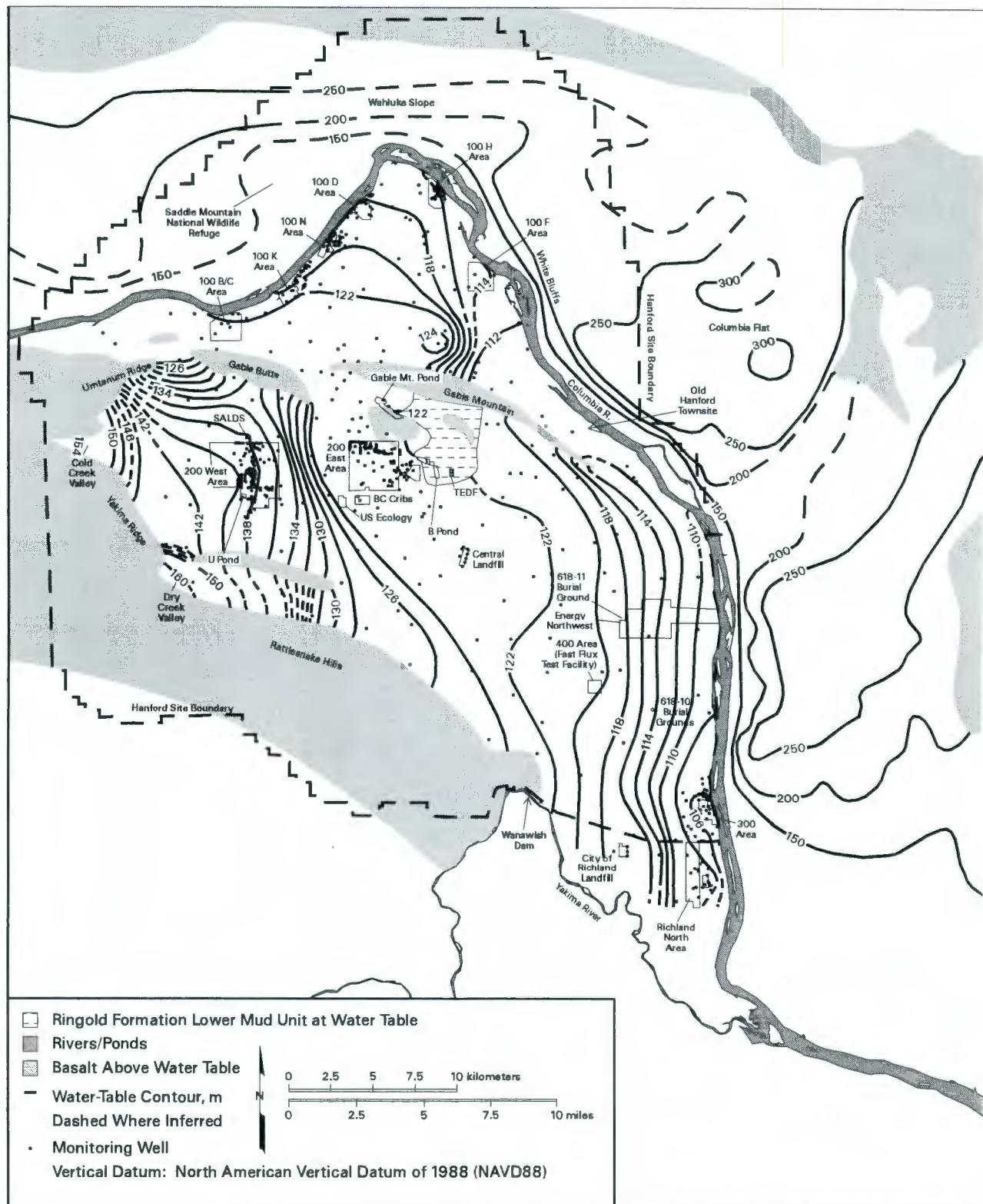
(a) DWS = drinking water standard; MCL = maximum contaminant level; DCG = derived concentration guide. See PNNL-13080 for more information on these standards.

(b) Shoreline sampling includes aquifer sampling tubes, seeps, and shoreline wells from fall 1998. 200 East Area plumes monitored at Old Hanford Townsite.

(c) A special study using ultra-low detection limits detected plutonium at levels far below standard detection limits.

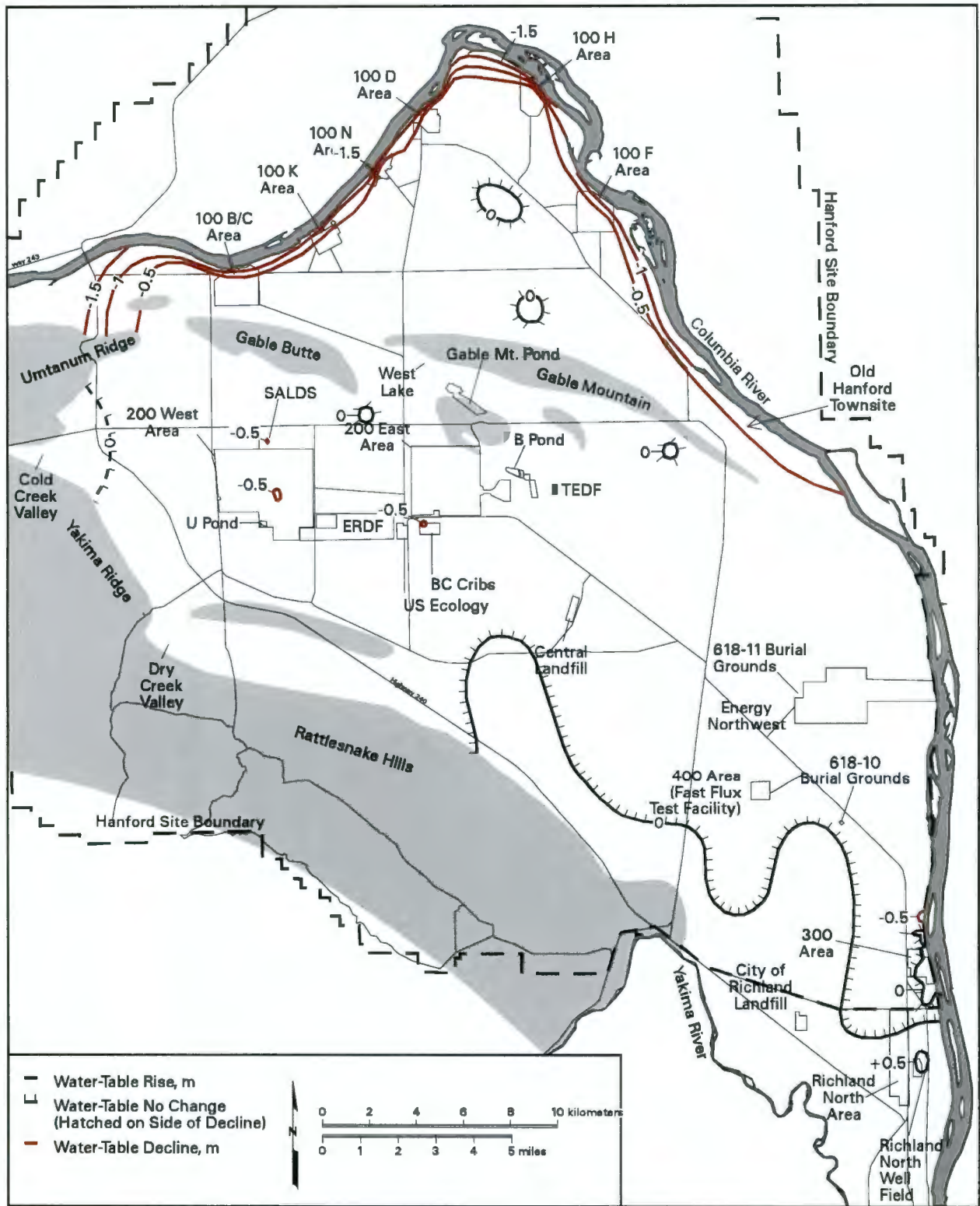
(d) Has had MCL exceedances in the past; well not sampled in fiscal year 1999.

(e) Uranium-234 at 26.2 pCi/L. Uranium-238 at 26.2 pCi/L.



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Figure 2.1-1. Hanford Site and Outlying Areas Water-Table Map, March 1999



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Figure 2.1-2. Changes in Water-Table Elevations Between June 1998 and March 1999

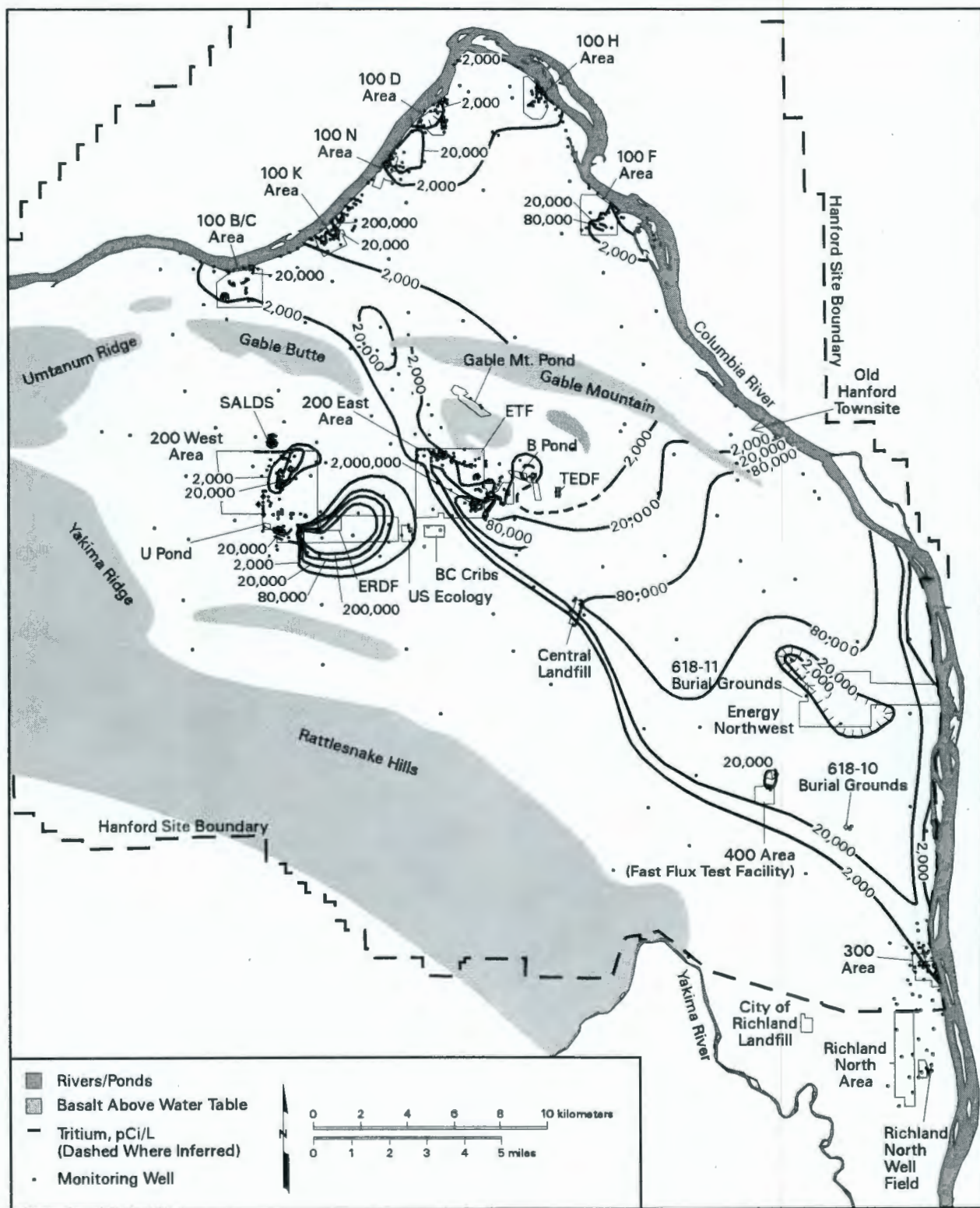
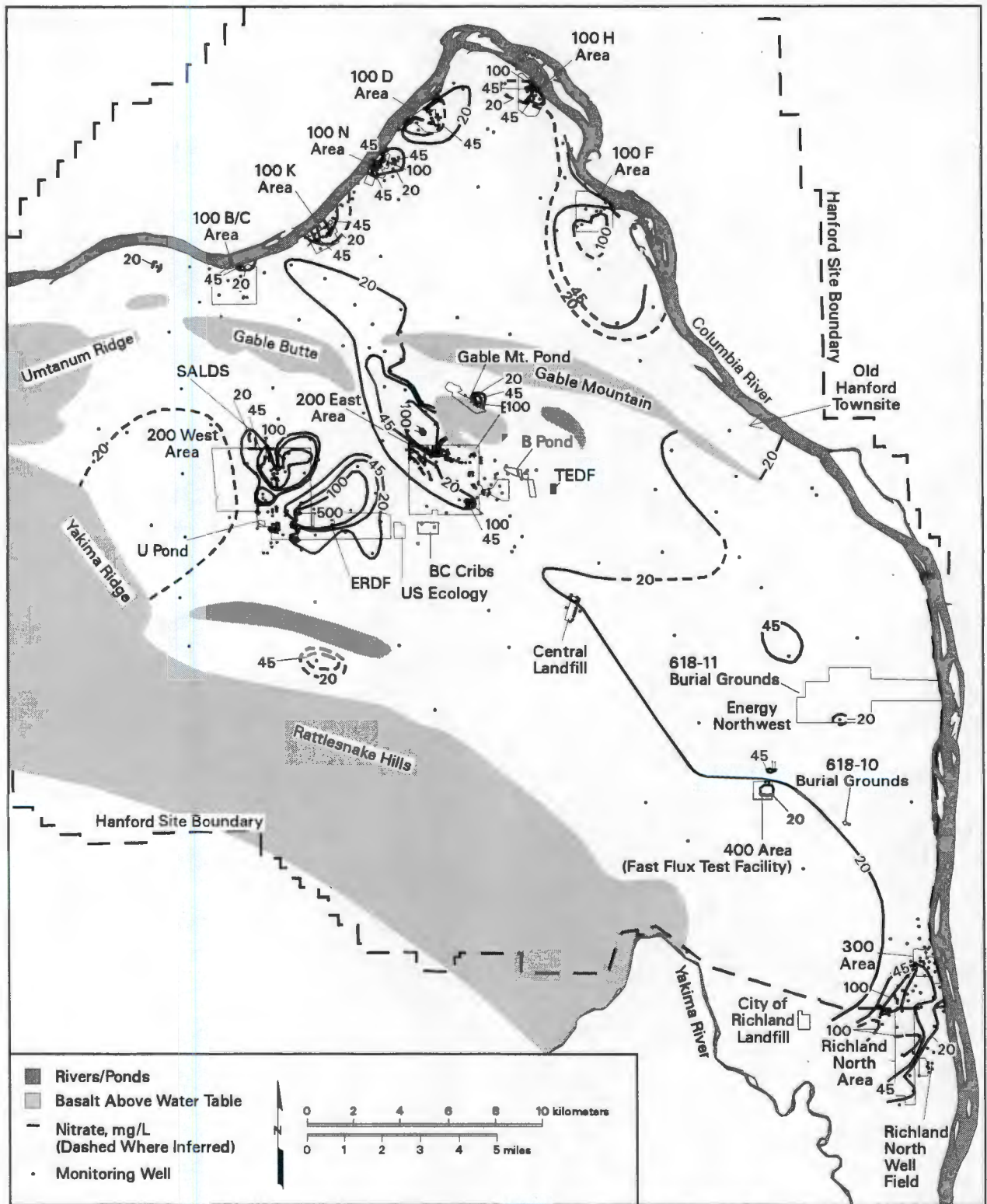


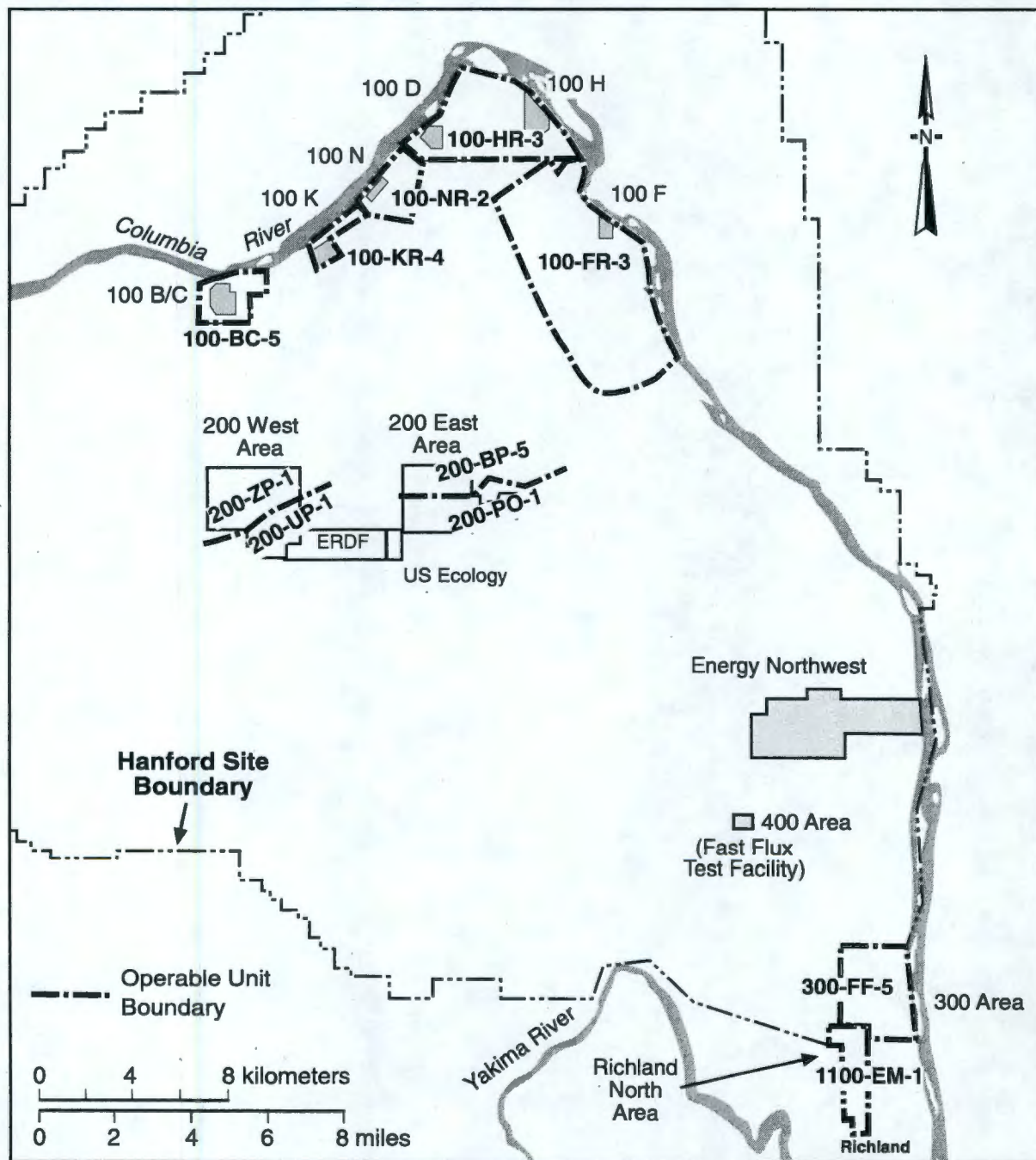
Figure 2.1-3. Average Tritium Concentrations on the Hanford Site, Top of Unconfined Aquifer



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

2.13



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

2.2 100 B/C Area

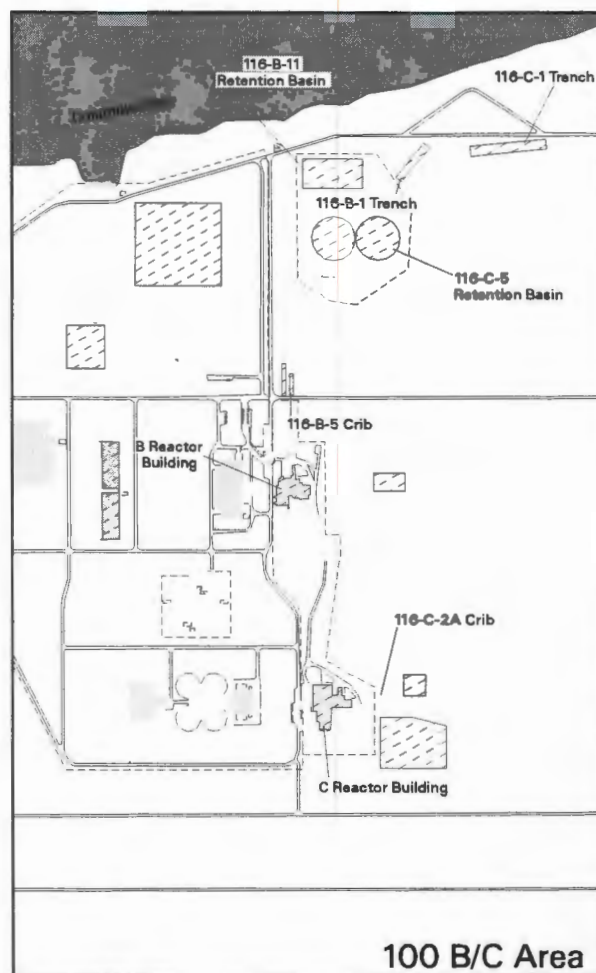
M. D. Sweeney, R. F. Raidl

The 100 B/C Area is the reactor area farthest upstream along the Columbia River. B Reactor was placed into 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 discharged to the Columbia River). Groundwater contaminants include strontium-90 and tritium. Chromium and nitrate are elevated locally.

Extensive restoration of former waste sites continued in fiscal year 1999. Activities consisted of removing and stockpiling clean overburden soil and removing contaminated soil/debris for disposal at the Environmental Restoration Disposal Facility. Water was applied as necessary to control dust during remediation activities. Application of water was held to a minimum to reduce the potential for mobilizing contaminants from the vadose zone to the groundwater. Excavation of the 116-B-11 retention basin and 116-B-13 trench, located in the northern 100 B/C Area, was completed in November 1998 at a maximum depth of 4.6 meters. Twelve smaller sites, including cribs and French drains, were excavated near the 100 B and 100 C reactor buildings in spring 1999. The depths of these excavations ranged from 2.4 to 9.2 meters.

2.2.1 Groundwater Flow

Groundwater flow within the unconfined aquifer was north toward the Columbia River in March 1999 (see Plate 2). The hydraulic gradient was ~ 0.002 near the Columbia River, and much lower farther inland near the reactors. The average gradient between C Reactor and the Columbia River was ~ 0.001 . 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 meters per day.



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2.2.2 Tritium

Several wells in the northern 100 B/C Area and one well in the southwestern 100 B/C Area had tritium concentrations that exceeded the 20,000 pCi/L drinking water standard (see Plate 3). The distribution in fiscal year 1999 was similar to fiscal year 1998.

In fiscal year 1998, some wells in the 100 B/C Area had spikes in tritium concentration. Levels declined again in most of these wells in fiscal year 1999 (Figure 2.2-1), but remained higher than in the early 1990s. Some of the wells with recent tritium peaks are located near waste sites that were remediated in

fiscal years 1997 through 1999, leading to speculation that they were caused by infiltration of dust-control water through contaminated sediment (Section 5.3 of PNNL-12086). However, other wells (e.g., 199-B5-1 and 199-B8-6; see Figure 2.2-1) are not located near surface remediation sites, yet showed similar increases in tritium concentrations. Other wells that did not show spikes in concentrations show gradual declines in tritium.

Monitoring Objectives in 100 B/C Area

Groundwater monitoring is conducted in the 100 B/C Area:

- ▶ triennially to annually to describe the nature and extent of contamination
- ▶ quarterly to monitor trends near inactive waste sites.

2.2.3 Strontium-90

Strontium-90 continues to exceed the 8.0 pCi/L drinking water standard in wells near the 116-B-11 and 116-C-5 retention basins, nearby trenches, and waste disposal facilities near the B reactor building. The distribution is approximately the same as in fiscal year 1998. There are no obvious increasing or decreasing trends in strontium-90 concentration. The highest average concentration in fiscal year 1999 was 77 pCi/L in well 199-B3-46.

2.2.4 Chromium

As in the past, two wells, 199-B3-47 and 199-B5-1, had chromium results above the 100 µg/L maximum contaminant level in fiscal year 1999. These wells have shown a large variability in chromium in the past two years, with a general increase in concentrations. Well 199-B3-47 monitors the 116-B-11 retention basin. The source of chromium at well 199-B5-1 is believed to be sodium dichromate transfer facilities (BHI-00917).

2.2.5 Nitrate

One well, 199-B3-47, exceeded the 45 mg/L maximum contaminant level in fiscal year 1999 with a result of 50.4 mg/L. Concentrations are generally increasing in this well (Figure 2.2-2).

Some wells had high nitrate concentrations in fiscal years 1997 or 1998. Concentrations decreased in these wells in fiscal year 1999, but in some cases remain above earlier levels (Figure 2.2-3). Other wells show no obvious increasing or decreasing trends.

2.2.6 Water Quality at Shoreline Monitoring Locations

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 driven into the aquifer at locations near the low-water shoreline. Seeps are locations where groundwater discharges above the river level.

2.2.6.1 Aquifer Sampling Tube Results

The highest concentrations of contaminants of concern from the fall 1998 sampling round were as follows: 52 pCi/L gross beta, 49.5 µg/L hexavalent chromium (filtered sample), 43 mg/L nitrate, and 66,000 pCi/L tritium. These values are consistent with groundwater contaminant concentrations in monitoring wells near the Columbia River shoreline.

2.2.6.2 Riverbank Seepage Results

The integrated *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* and *Surface Environmental Surveillance* projects collected samples from two seeps along the 100 B/C Area shoreline during October 1998. The highest contaminant concentrations were as follows: 21 µg/L chromium (filtered sample), 21.5 pCi/L gross beta, 15 mg/L nitrate, 5.73 pCi/L strontium-90, and 14,200 pCi/L tritium.

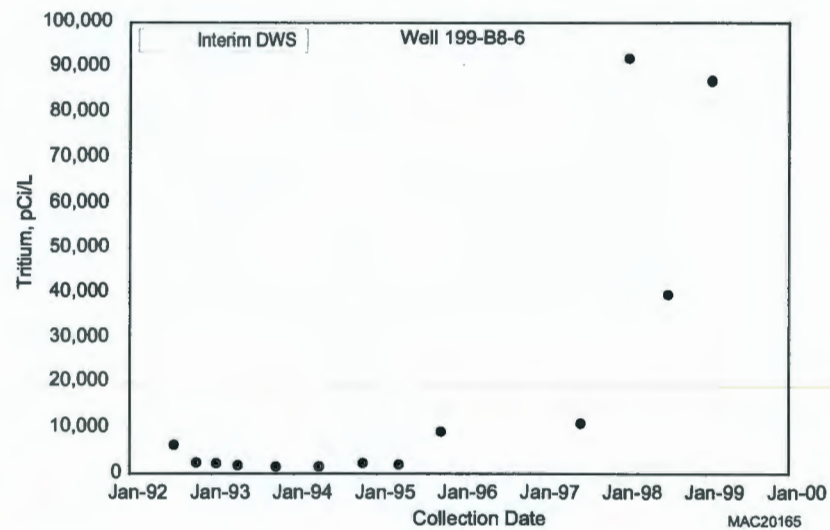
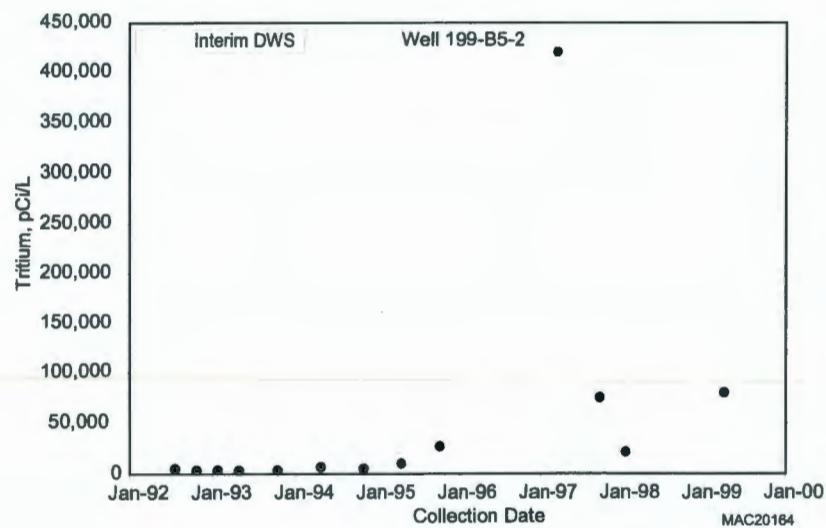
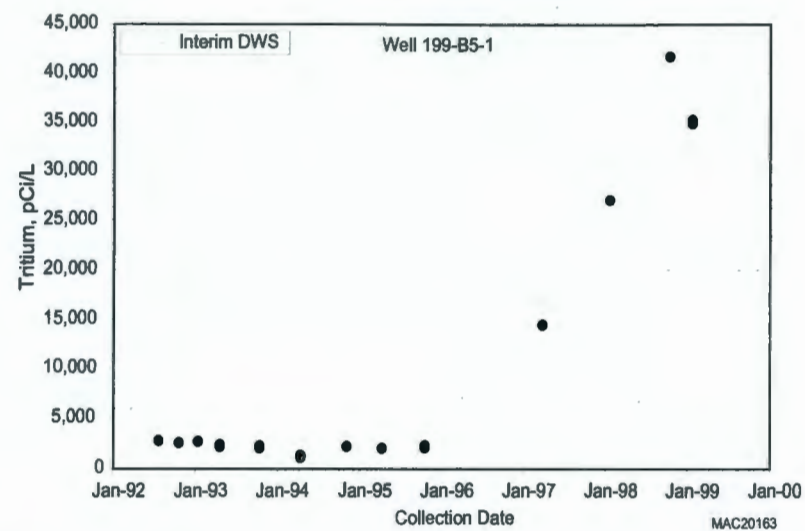
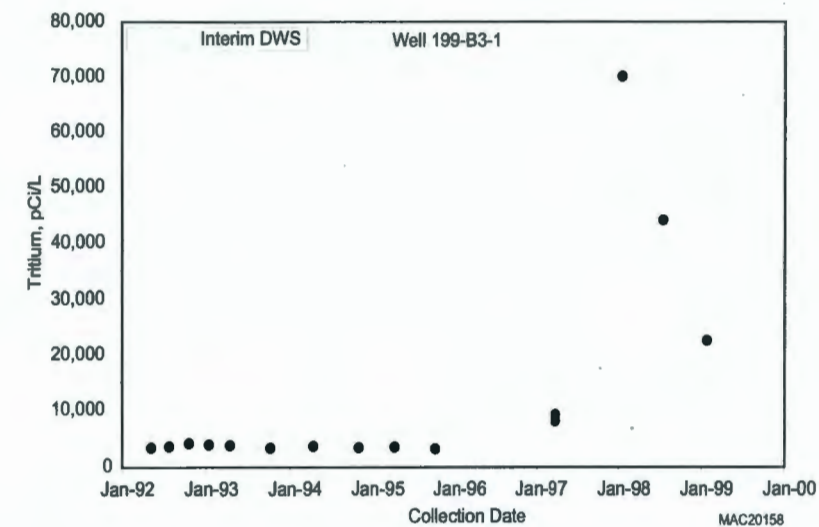


Figure 2.2-1. Tritium in Wells at 100 B/C Area

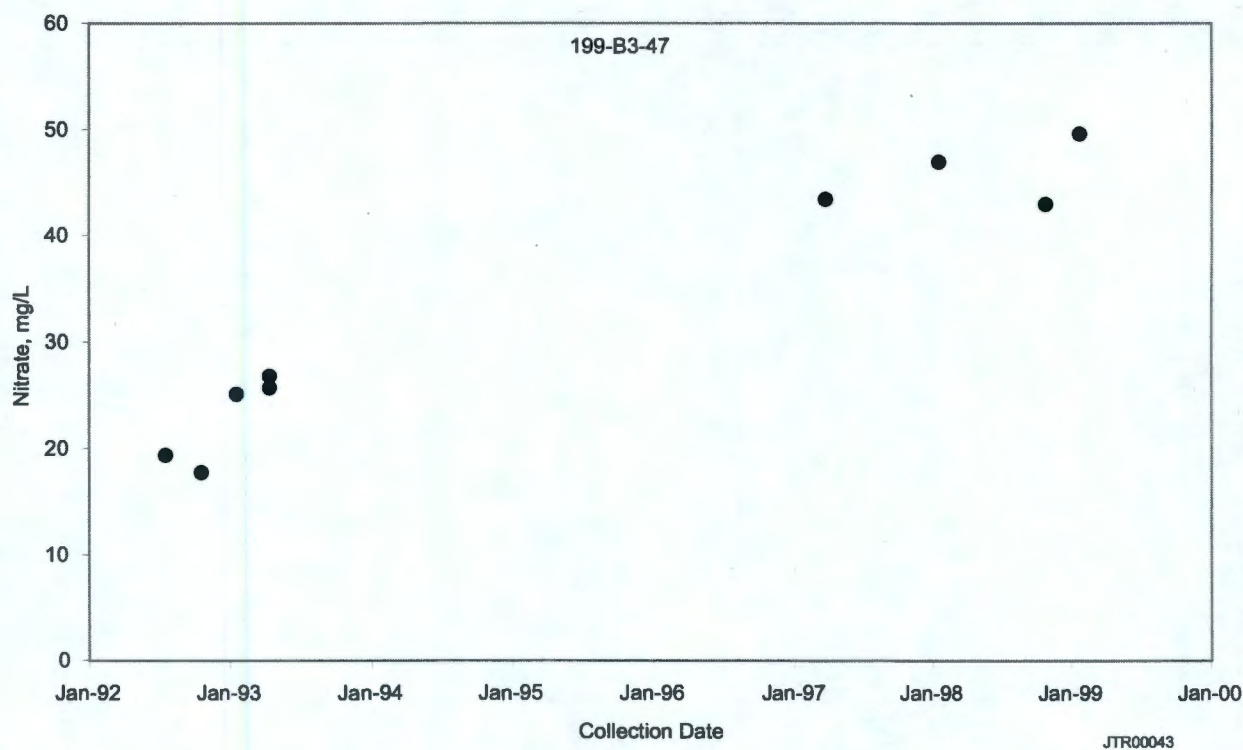


Figure 2.2-2. Nitrate in Well 199-B3-47 Near 116-B-11 Retention Basin

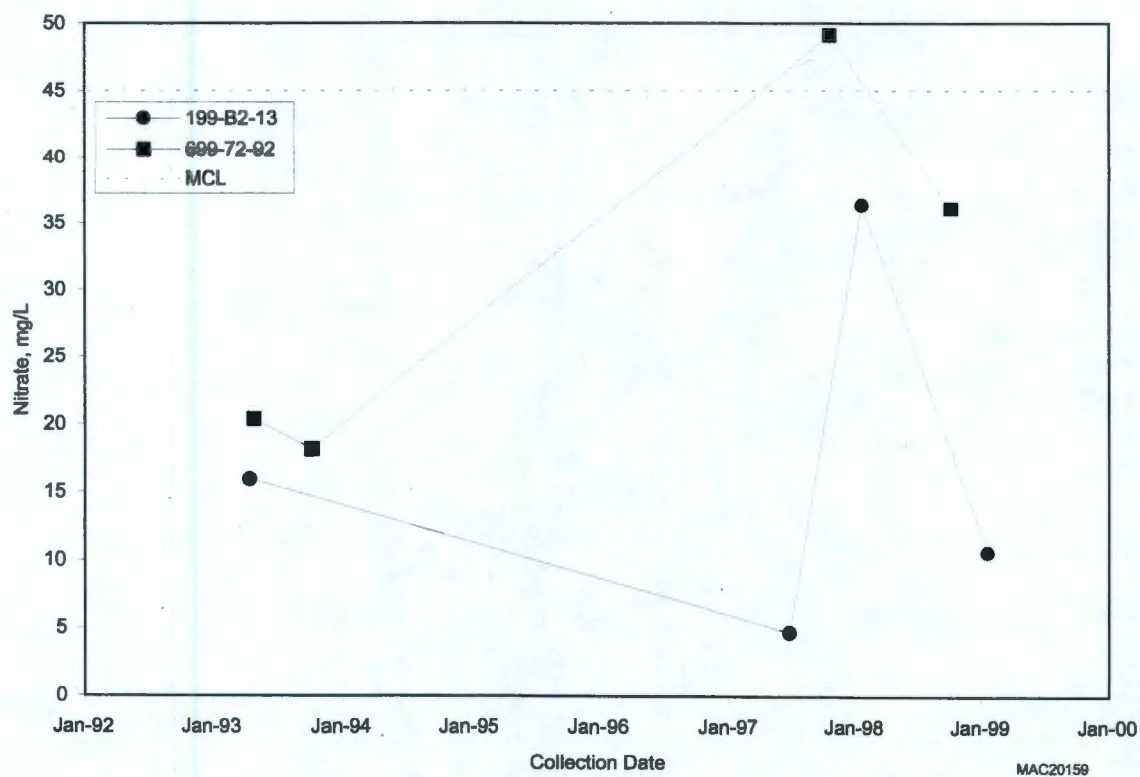


Figure 2.2-3. Nitrate in Wells 199-B2-13 and 699-72-92, West of 100 B/C Area

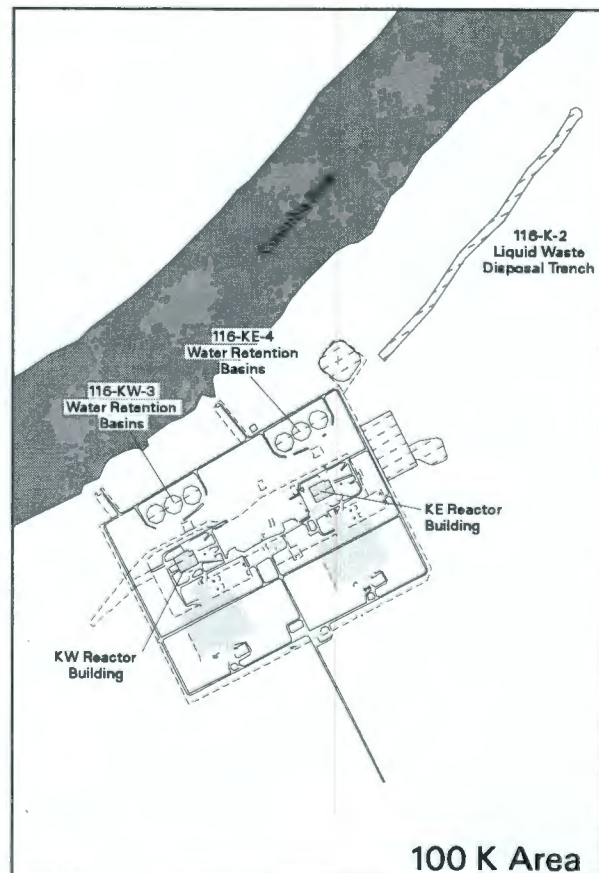
2.3 100 K Area

R. E. Peterson, W. J. McMahon, R. F. Raidl

The KE and KW reactors were the largest of the original group of eight production reactors. They operated between 1955 and 1971. The 116-K-2 liquid waste disposal trench, which received used reactor coolant and decontamination solutions, was the largest soil column disposal facility in the 100 Areas.

The principal issues associated with groundwater contamination in the 100 K Area today involve a chromium plume located near the Columbia River; operating facilities that contain highly radioactive liquid and sludge; and carbon-14, strontium-90, and tritium contamination from past-practice disposal sites. An interim remedial action is in progress to reduce the amount of chromium reaching the Columbia River via groundwater flow. Removal of spent nuclear fuel, shielding water, and sludge from the 100-K Fuel Storage Basins is a top priority project for the Hanford Site and work is underway.

There are several potential sources of contamination that may add to existing groundwater plumes or



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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 decisions
- ▶ monthly near the KE and KW Fuel Storage Basins to detect potential leakage
- ▶ various time intervals to evaluate the performance of the pump-and-treat system for chromium.

create new plumes. These sources include locations where the vadose zone contains significant inventories of radionuclides from past disposal practices and the potential loss of shielding water and sludge from the KE and KW Fuel Storage Basins, located in the reactor buildings.

Additional information on current groundwater issues at the 100 K Area is available on the Internet at <http://pnl45.pnl.gov/100k> or at <http://hanford.pnl.gov/groundwater>. Information on the history of operations and waste sites at 100 K Area is presented in the technical baseline report for the 100-KR-4 Operable Unit (WHC-SD-EN-TI-239).

2.3.1 Groundwater Flow

Groundwater movement beneath the 100 K Area is generally toward the north-northwest, as suggested by contours for the water-table elevation (see Plate 2). The unconfined aquifer is contained within the gravely sediment of Ringold Formation Unit E, which is generally considered a transmissive aquifer. Groundwater flow velocity in this aquifer between the reactors and the Columbia River is estimated to be between 0.01 and 0.4 meter per day (WHC-SD-EN-AP-174). The estimate assumes a hydraulic conductivity in the range 0.95 to 16 meters per day; gradients in the range 0.003 to 0.005; and an effective porosity of 0.2. Using a representative rate of 0.3 meter per day, a travel time of ~4 years is indicated for the pathway between the reactors and the river. In the vicinity of the 116-K-2 liquid waste disposal trench, the extraction and injection of water as part of the interim action pump-and-treat system influences the direction and rate of groundwater movement in the immediate vicinity of the associated wells (Section 2.3.9).

Because monitoring wells in the 100 K Area do not provide complete coverage, the configuration of the water table cannot be accurately described in some areas. Although the general direction of groundwater flow is fairly clear, the fine-scale details for direction and rate of flow between known sources and the Columbia River are less well understood. Also, the presence of engineered backfill and heterogeneity in hydraulic properties of the aquifer sediment contribute to uncertainty in describing pathways for contaminant transport. Near the river, flow rate and direction vary considerably in response to the fluctuating river stage.

In addition to lateral groundwater movement in response to the hydraulic gradient, there is also vertical movement in response to the fluctuating Columbia River stage. The water table typically moves up and down through a range of ~2 meters in wells located within several hundred meters of the Columbia River, decreasing to a range of ~0.3 meter in the 100 K Area

wells located farthest inland (BHI-00917). Water-level fluctuations in these wells are even greater during years of extremely high river discharge (e.g., 1996 and 1997). The vertical movement of the water table may cause remobilization of contaminants held in the normally unsaturated vadose zone (PNNL-12023).

During the operating years 1955 to 1971, a large mound was created beneath the southwestern end of the 116-K-2 liquid waste disposal trench (HW-77170). The mound created a radial flow pattern that modified the flow field beneath the entire 100 K Area. The influence of the mound can be seen in historical monitoring trends for well 699-78-62, which is located ~1,600 meters inland from the trench (Figure 2.3-1). The gross beta contamination in this well is believed to be the result of groundwater flow reversal caused by the mound. The implication of the mound with respect to current groundwater conditions is that residual contaminated moisture from the previously saturated mound areas continues to slowly migrate downward to the water table, thus contributing to groundwater plumes.

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 116-K-2 liquid waste disposal trench. Additional sources include leakage and/or spillage of sodium dichromate stock solutions near rail-car transfer stations, storage tanks, and mixing facilities during the water treatment process. By early 1971, these sources no longer contributed to contamination and the nearly 30 years of groundwater movement since then have allowed the original plumes to disperse. The hexavalent form of chromium is highly soluble in groundwater as chromate (CrO_4^{2-}) and moves at the same speed as groundwater because the anions are not sorbed significantly to the sediment.

The current distribution of chromium in 100 K Area groundwater is shown in Figure 2.3-2. Three areas of concern are apparent: (1) a large area of contamination between the 116-K-2 liquid waste disposal trench and the Columbia River, (2) a smaller area centered on the KW Reactor, and (3) an area near the 183-KE water treatment plant. The first area is the target plume for interim remedial action using a pump-and-treat system (DOE/RL-99-13). Chromium concentrations in this plume typically range from 75 to 150 $\mu\text{g/L}$, which is only slightly above the 100- $\mu\text{g/L}$ maximum contaminant level for drinking water supplies. However, these concentrations are significantly above the 11- $\mu\text{g/L}$ standard set by Washington State for the protection of freshwater aquatic organisms (WAC 173-201A-040). The concentration trends in this plume are described further in the section on groundwater remediation (Section 2.3.9).

The 100 K Area has three areas of chromium contamination: a plume between the 116-K-2 trench and the Columbia River and two smaller areas of contamination near the reactor buildings.

In the second area of concern, i.e., near the KW Reactor, concentrations range between 200 and 600 $\mu\text{g/L}$ as illustrated in Figure 2.3-3. The specific source for the chromium in this plume is not known, though the source is likely to be leakage and/or spillage of sodium dichromate stock solution in upgradient areas. One potential site is the railcar transfer station and storage tanks located at the southeastern side of the 183-KW water treatment plant. A second potential source area is the vicinity of the coolant storage clearwells located on the southeastern side of the KW Reactor.

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 observed in wells 199-K-31 and 199-K-33, which are located

between KW Reactor and the Columbia River (Figure 2.3-3). The increasing trends in wells 199-K-107A and 199-K-108A suggest plume movement in this area. The travel time between KW Reactor and well 199-K-33 has been estimated at between 1.6 and 4.9 years, depending on the assumed groundwater flow rate (WHC-SD-EN-TI-280, Rev. 0). Additional near-river sites are available to monitor the arrival of this plume. They include aquifer sampling tubes (BHI-01153) and riverbank seepage sites near the KW water intake structure.

The third area of chromium contamination appears to originate near well 199-K-36, located at the southeastern end of the 183-KE water treatment plant. In the previous annual groundwater report (PNNL-12086), relatively high chromium concentrations were reported for samples from this well, with a maximum value of 2,710 $\mu\text{g/L}$ on January 16, 1996. The source for the chromium is most likely past leaks or spills of sodium dichromate stock solution during railcar transfer operations and from storage tanks located near that well. Remobilization of sodium dichromate from the vadose zone may occur in association with water leakage from the nearby KE filter plant. Chromium concentrations in well 199-K-36 averaged 210 $\mu\text{g/L}$ during fiscal year 1999.

2.3.3 Strontium-90

Strontium-90 is not distributed widely in 100 K Area groundwater, though there are several waste sites where contamination in the vadose zone is expected, 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 116-K-2 liquid waste disposal trench and the fuel storage basin drain fields/injection wells associated with each reactor. The radionuclide is 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 29.1 years. The drinking water standard is 8 pCi/L.

The current levels of strontium-90 contamination between the 116-K-2 liquid waste disposal trench and the Columbia River range up to a maximum near 50 pCi/L (well 199-K-21). Trends for two wells are illustrated in Figure 2.3-4. The radionuclide is a co-contaminant with chromium in this area. However, it 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 analyses on treated effluent revealed concentrations of 3.83 and 4.1 pCi/L during the period February 1, 1998, and December 31, 1998 (DOE/RL-99-13).

Near the KE Reactor, samples from well 199-K-109A reveal a variable trend in strontium-90 levels. Figure 2.3-5 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 basin that may have contained strontium-90 released from damaged fuel elements, as well as tritium. Increased infiltration of water from the surface, caused by leaking fire hydrant utility lines, apparently remobilized contamination held in the normally unsaturated vadose zone.

Strontium-90 is also elevated somewhat above the drinking water standard near the KW Reactor (Figure 2.3-6). Again, the suspected source is the adjacent drain field/injection well (waste site 116-KW-2).

2.3.4 Tritium

The distribution of tritium in 100 K Area groundwater is shown on Plate 3. The shapes of the contours drawn to describe the plumes for fiscal year 1999 have been modified somewhat compared to previous representations. The revised shapes reflect the most current information on groundwater flow direction and the presumed locations where tritium was (and still

is) introduced to groundwater. These locations and their associated sources include

- northeastern side of each reactor building, where condensate from reactor atmosphere gas apparently continues to migrate downward through the soil column beneath the 116-KW-1 and 116-KE-1 cribs (carbon-14 is a co-contaminant with tritium in this effluent).
- past leakage from the KE basin; the most recent event occurred in 1993, and the plume moved north-northwest past well 199-K-27, but has apparently not yet arrived in downgradient wells 199-K-32A and 199-K-111A (Figure 2.3-7), or the plume is too small to be detected by the existing well network.
- past disposal to the 116-K-2 liquid waste disposal trench, which created a mound that left contaminated moisture in the vadose zone, when waste disposal ended in 1971.

The tritium distribution map for fiscal year 1999 shows contamination near the 116-K-2 trench as separate from the plume near the reactor buildings.

The source for the relatively high tritium concentrations in the vicinity of pump-and-treat extraction well 199-K-120A is not fully understood. One explanation is that residual vadose zone moisture containing tritium from past disposal to the 116-K-2 liquid waste disposal trench continues to feed a small groundwater plume in the vicinity of wells 199-K-18, 199-K-19, and 199-K-120A. An alternative explanation is that the tritium represents shielding water from the 116-KE-1 basin lost during the period 1976 to 1979, or alternatively, groundwater from beneath the 116-KE-1 gas condensate crib. However, if either of these sources is responsible, similar concentrations would be expected in wells along the pathway between those sources and

well 199-K-120A, (i.e., wells 199-K-18 and 199-K-19), which is not the case (Figure 2.3-8). Also, long-term water-level data do not suggest a gradient directed from the KE Reactor toward well 199-K-120A, so a circuitous route would be required to link the well to those sources.

A field sampling program was conducted during summer 1999 to determine whether a tritium plume in groundwater could be detected by analyzing soil gases sampled from the overlying vadose zone. A grid of locations was sampled in the 100 K Area that covered the general area north and east of the KE Reactor (see Figure 3.3-7). No tritium was detected in the soil moisture samples. Analyses for helium-3, which would indicate the presence of tritium in the underlying groundwater, also did not suggest the presence of a plume (Section 3.3.3).

2.3.5 Carbon-14

This radionuclide was included 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 (116-KE-1 and 116-KW-1). Carbon-14 disperses more slowly than does tritium because of interaction with carbonate minerals, so the distribution pattern is not exactly the same as for tritium (PNNL-12023). Unfortunately, the different geochemical characteristics for carbon-14 and tritium limited attempts to use the ratio of the two constituents as an exclusive indicator of effluent from these gas condensate cribs, though some patterns are evident (PNNL-12023).

The highest concentrations of carbon-14 are found in wells near and downgradient of the condensate cribs. Figure 2.3-9 illustrates the concentrations found in wells associated with the 116-KE-1 crib and Figure 2.3-10 illustrates concentrations associated with the 116-KW-1 crib. The derived concentration guide for this radionuclide is 70,000 pCi/L. The half-life is very long (5,730 years), suggesting that some of the existing plume will eventually be exposed at the Columbia River before it decays, although a portion will likely remain fixed in carbonate minerals.

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 past-practice disposal to the soil column of decontamination solutions, such as nitric acid (WHC-SD-EN-TI-239) and septic system drain fields. The maximum contaminant level is 45 mg/L. This level is exceeded in numerous 100 K Area wells. The fiscal year 1999 maximum observed value near the reactor buildings is ~175 mg/L (well 199-K-30) and near the 116-K-2 liquid waste disposal trench is ~130 mg/L (well 199-K-19).

Nitrate levels have been gradually rising in numerous wells in the 100 Areas for as yet unexplained reasons. There are no current operations that would account for the increase. Examples of changing concentrations in 100 K Area wells are presented in Figure 2.3-11. The prominent increase in nitrate that occurred in many wells during 1985 is also not fully understood.

2.3.7 Other Constituents of Interest

Three other constituents detected in one or two wells in the 100 K Area are discussed in this section.

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 research is funded by the U.S. Department of Energy's (DOE) Environmental Management Science Program and is in its third year (EMSP Project No. DE-FG07-96ER14733). The research is a joint project between Woods Hole and Pacific Northwest National Laboratory. The purpose for the research is "...to study the association of actinides with dissolved organic complexes in subsurface waters."

These researchers analyzed groundwater from the 100 K Area in 1998. Because of the atom ratios, they concluded that the plutonium detected in the samples is

from a local source rather than from atmospheric fallout. The concentrations they report represent extremely small amounts of plutonium. For example, the largest value reported was 1.87 femtogram per liter for plutonium-239, which in units commonly used to report monitoring results equates to 0.00000000187 µg/L or 0.000116 pCi/L. The results for samples collected in April 1999 are expected by April 2000.

A specific analysis for plutonium is not performed during the periodic sampling events conducted at 100 K Area. The tools and methods used by the researchers to achieve their ultra-low detection levels are not practical for producing the quantity of environmental data typically used to support decisions. Other contamination indicators are monitored that would indicate the presence of plutonium at concentrations of environmental concern.

2.3.7.2 Trichloroethylene

This organic constituent is a minor contaminant of concern resulting from the past disposal/spillage of organic solvents. Two wells downgradient of the KW reactor building revealed samples containing trichloroethylene at levels above the 5 µg/L maximum contaminant level for drinking water supplies (Figure 2.3-12). Concentrations appear to be decreasing with time.

2.3.7.3 Nickel

Nickel has not been tracked as a contaminant of concern for human or ecological health reasons (BHI-00917). However, concentrations exceed the 100 µg/L maximum contaminant level in wells 199-K-36 and 199-K-110A. 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, which have stainless steel casing and screens. Therefore, a sampling anomaly is suspected, perhaps the result of corrosion of the stainless steel (Hewitt 1994). There is a tendency for nickel concentrations to increase with increasing chloride concentrations in well 199-K-36 (Figure 2.3-13). A similar correlation is observed in well 199-K-108A (also stainless steel construction) between chromium

and chloride concentrations, thus suggesting corrosion of the steel, which would be enhanced by the presence of chloride.

2.3.8 100-K Fuel Storage Basins Monitoring

The 100-K fuel storage basins are operating facilities that are used to store irradiated fuel elements from the N Reactor. The KE basin contains ~1,150 metric tons of fuel stored in unsealed canisters, while KW basin contains ~953 metric tons 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 focused feasibility study is available that provides detailed information on the fuel, shielding water, and sludge, along with a description of alternatives for cleanup (DOE/RL-98-66, Rev. 0). Following this study, a proposed plan for interim remedial action at the basins was issued for public review and comment (DOE/RL-98-71, Rev. 0). Finally, a record of decision has been signed that describes the selected remedial action (ROD 1999a). Work began in fiscal year 1999 with equipment that will be used to move the fuel canisters. The schedule for activities is described under Tri-Party Agreement Major Milestone M-34-00A (Ecology et al. 1989).

The Hanford Groundwater Monitoring Project provides monitoring services to the Spent Nuclear Fuel Project in support of basin leak detection efforts. In addition, the groundwater project maintains baseline information on the characteristics of groundwater movement throughout the 100 K Area. A complete description of the monitoring strategy and data quality objectives for the 100-K fuel storage basins is presented in a monitoring plan (WHC-SD-EN-AP-174).

2.3.8.1 Groundwater Flow

The general movement of groundwater beneath the KE and KW Fuel Storage Basins is from the south-southeast to the north-northwest, i.e., toward the Columbia River (see Plate 2). Several factors may

influence the details 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 sediment. The distribution and rate of downward movement of water infiltrating from the surface may be influenced by engineered backfill associated with buildings and pipelines.

2.3.8.2 Tritium

Tritium is a key constituent for monitoring potential leakage from the KE and KW Fuel Storage Basins. The tritium concentration for KE basin shielding water is 2.64 million pCi/L and for KW basin is 59,500 pCi/L (September 1999 measurements). Additional nearby sources for tritium are past-practice disposal sites located at the eastern side of each reactor building. These soil infiltration sites (referred to as gas condensate cribs or French drains) received condensate from reactor atmosphere gases. The condensate contained significant quantities of carbon-14 and tritium. These constituents continue to migrate downward beneath the disposal sites and to contaminate the underlying groundwater. The levels of tritium in gas condensate are comparable to, or even exceed, basin water concentrations, thus complicating the ability to identify the specific source for tritium observed in groundwater near the basins.

Figure 2.3-14 shows the tritium concentrations in KE basin wells that are most likely to detect basin leaks. The entire record for these wells illustrates that leakage during the period 1976 through 1979 must have already passed these wells by the time of their installation because there is no evidence of a tritium pulse. The volume of water lost during that period is estimated at ~57 million liters (WHC-SD-SNF-TI-013, Rev. 0) and the basin water tritium concentration was ~600,000 pCi/L. A subsequent period of 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, Rev. 0) and the basin water concentration at that time was ~3 million pCi/L. (The cause for the 1990 tritium pulse in 199-K-27 is

not known). Well 199-K-28 apparently does not produce samples that are fully representative of aquifer conditions because it appears to be sufficiently close to well 199-K-27 to have also detected the 1993 leakage.

Tritium is monitored in wells near operating fuel-storage basins. The basins leaked in the past, but there is no evidence of leaks in fiscal year 1999.

Tritium concentrations in groundwater near the KW Fuel Storage Basin are generally lower than near the KE basin (Figure 2.3-15; note order-of-magnitude scale difference). There has been no documented leakage from the KW basin. The tritium observed in well 199-K-34 is most likely attributable to the KW gas condensate crib.

Concentration trends for tritium in groundwater near the KE and KW gas condensate cribs are included here to illustrate the other major sources for tritium in groundwater near the reactors. Figure 2.3-16 shows the tritium concentrations and specific conductance values for groundwater immediately downgradient of the KE gas 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 gas condensate crib has been attributed to infiltration of precipitation (e.g., snow melt) containing ice control salt (WHC-SD-EN-TI-280, Rev. 2).

Figure 2.3-17 shows the same constituents for the KW gas condensate crib. A similar correlation between tritium and specific conductance is absent at this location, and there is currently no clear explanation for the tritium peak (~600,000 pCi/L) that occurred during 1995. Leakage from the KW Fuel Storage Basin is not a possibility because basin water concentrations

were only one-tenth the concentrations observed in the well shown in Figure 2.3-17. Specific conductance at the KW crib is significantly higher than natural background (~650 versus ~350 $\mu\text{S}/\text{cm}$ for background).

2.3.9 Groundwater Remediation

A groundwater pump-and-treat system began operating in the 100 K Area in October 1997. The extraction wells are located between the 116-K-2 liquid waste disposal trench and the Columbia River. The treatment system removes chromium from the extracted groundwater. The treated effluent is injected back into the aquifer at an upgradient location. This interim remedial action is described in a record of decision for the 100-KR-4 Operable Unit (ROD 1996b), which also includes remedial actions in the 100 D and 100 H Areas (100-HR-3 Operable Unit).

The 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 might harm young salmon.

2.3.9.1 Interim Remedial Action Objectives

The record of decision (ROD 1996b) contains the following specific remedial action objectives that pertain to operation of 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 selection of a final remedy, or when U.S. Environmental Protection Agency and Washington State Department of Ecology are satisfied that termination

(or intermittent operation) is appropriate. Conclusion of the pump-and-treat system occurs when sampling results indicate that the concentration of hexavalent chromium is below 22 $\mu\text{g}/\text{L}$ in the compliance wells, and the data indicate that the concentration will remain below the compliance value. Other criteria for terminating pump-and-treat operations include the effectiveness of the treatment technology not justifying further operation or the availability and feasibility of an alternate and superior treatment technique (ROD 1996b).

2.3.9.2 Remediation Progress During Fiscal Year 1999

Progress was made toward achieving the remedial action objectives at the 100-KR-4 Operable Unit in fiscal year 1999. The pump-and-treat operation is successfully intercepting and capturing groundwater containing elevated concentrations of hexavalent chromium. This prevents that groundwater from discharging into the Columbia River. Figure 2.3-18 shows the flow lines and hydraulic capture estimated to occur during a low-flow period in the Columbia River (November 1998), when groundwater flow to the Columbia River is greatest. A description of the numerical modeling used to create this figure is presented in DOE/RL-99-13.

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 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 treatment system performance and to provide the basis to select the final remedy as part of the record of decision.

During fiscal year 1999, the pump-and-treat system extracted 296.2 million liters of groundwater and removed 37.6 kilograms of hexavalent chromium (Table 2.3-1). Extraction well operating flow rates averaged between 95.5 and 106.5 liters per minute for the year, with maximum sustained pumping rates

ranging between 115.1 and 174.4 liters per minute at the different wells. Average concentrations for hexavalent chromium in the extraction wells ranged between 74 and 185 $\mu\text{g/L}$, with an average influent concentration of 136 $\mu\text{g/L}$ delivered to the treatment system during the fiscal year. The effluent concentration averaged 9 $\mu\text{g/L}$ during the year, with hexavalent chromium being undetected during 16 of the 55 individual effluent sampling events.

A total of 69.7 kilograms of hexavalent chromium has been removed since startup of the pump-and-treat system in October 1997. An estimate for the total amount of chromium in the plume targeted for remedial action suggests a mass of 250 kilograms (DOE/RL-94-95, Rev. 1). Uncertainty in this estimate is primarily associated with the lack of data on the vertical distribution of chromium in the aquifer and the distance inland to which the plume extends. An order-of-magnitude estimate for the rate at which chromium is discharging to the Columbia River via groundwater flow is 0.04 kilograms per day (BHI-00469). This equates to a total mass flux of ~29 kilograms that would have entered the Columbia River since October 1997. The actual flux is believed to be less because of the pump-and-treat system.

2.3.9.3 Influence on Aquifer Conditions

The concentration of hexavalent chromium measured in several of the six extraction wells exhibited a slight downward trend during the last 2 years. However, the concentration has not declined below 22 $\mu\text{g/L}$, the target concentration listed in the record of decision. After rebounding from consecutive flood stage years in the Columbia River in 1996 and 1997, the concentration of hexavalent chromium exhibited a downward trend in five of the six extraction wells between May 1998 and July 1999, and then a reversal of trend began in several wells (Figures 2.3-19 and 2.3-20). An explanation for the reversal to an increasing trend is not currently available. Extraction well 199-K-120A has exhibited a constant trend since operations began.

Concentrations have remained relatively constant or increased slightly over the last 2 years in three of

the five compliance wells (Figure 2.3-21). Concentrations averaged 61, 115, and 97 $\mu\text{g/L}$, in wells 199-K-18, 199-K-20, and 199-K-112A, respectively, during fiscal year 1999. Except for the most recent sampling results, the trends observed in the other two compliance wells, 199-K-114A and 199-K-117A, appear to behave similarly.

Because the elevated concentration of hexavalent chromium persisted in the compliance wells, the annual summary report (DOE/RL-99-13) recommended continued operation of the pump-and-treat system. A new monitoring well (199-K-126A) was installed northeast of the trench following a recommendation to define the downgradient extent of the plume (DOE/RL-97-96). Additional plans are in progress to convert compliance well 199-K-112A to an extraction well and thereby increase the capture area beyond the northern end of the trench. The declining concentration of hexavalent chromium measured in the extraction wells indicates that the pump-and-treat system is lowering the concentration of hexavalent chromium in the aquifer, but the rate of decline indicates that many years of pumping may be required before the remedial action objectives have been entirely satisfied.

2.3.10 Water Quality at Shoreline Monitoring Locations

Groundwater samples are collected annually from riverbank seepage sites during the seasonal low river stage and from aquifer sampling tubes located near the low-river stage shoreline.

2.3.10.1 Aquifer Sampling Tubes

The Environmental Restoration Contractor installed aquifer sampling tubes at ~300-meter intervals along the 100 K Area shoreline during the fall 1997. One to three polyethylene tubes were installed at various depths at each tube site near the low-water shoreline. Samples collected from the tubes during the fall 1998 sampling were screened for carbon-14, gross beta, hexavalent chromium, nitrate, and tritium.

Hexavalent chromium concentrations ranged from a high of 112 $\mu\text{g/L}$ (filtered sample) downgradient of

the 116-K-2 trench to undetected from a tube sample slightly upriver of the 100 K Area. Nitrate concentrations from samples collected downgradient of the 116-K-2 trench ranged from 10 mg/L to undetected. Tritium concentrations ranged from 4,500 pCi/L from a tube site upstream of the 100 K Area to undetected downgradient of the 116-K-2 trench. Gross beta concentrations ranged from 4 pCi/L downgradient of the KW Reactor to 55 pCi/L downgradient of the 116-K-2 trench.

The maximum carbon-14 concentration was 680 pCi/L in a sample collected from a tube downgradient of the KW retention basins. This tube site is also downgradient of well 199-K-33 where samples have contained over 10,000 pCi/L carbon-14.

2.3.10.2 Riverbank Seepage

The CERCLA monitoring project collected samples from one riverbank seepage site (SK-062) along the 100 K Area shoreline during October 1998. This site is near the river water intake structure for KW Reactor. Maximum concentrations of contaminants of concern were: 4.95 pCi/L gross beta, 29 mg/L nitrate,

0.03 pCi/L strontium-90, and 11,900 pCi/L tritium. Results for chromium are not available. Tritium has declined in concentration at this seepage site. The median concentration during the period 1993 to 1997 was 18,000 pCi/L (PNNL-12088, Table A.7).

2.3.10.3 Special Shoreline Studies

Independent researchers from the Government Accountability Project sampled mulberry bush leaves from a shoreline location near the southwestern end of the 116-K-2 liquid waste disposal trench (GAP 1999a). They speculate that the radioactivity observed in their samples is related to an underground stream that transports strontium-90 very rapidly from past-practice sources to the Columbia River. No field data exist to support their speculation, other than the vegetation samples. The bushes sampled are located in an area of extensive former surface contamination caused by breakouts from the nearby 116-K-1 crib and 116-K-2 liquid waste disposal trench (WHC-SD-EN-TI-239; historical photo is available on the internet at <http://pnl45.pnl.gov/100k>).

Table 2.3-1. Summary of 100 K Area Pump-and-Treat Performance for Fiscal Year 1999

Well or Sample Location	Annual Average Flow Rate (L/min)	Maximum Sustained Flow Rate (L/min)	Total Volume Pumped ($\times 10^6$ L)	Average Hexavalent Chromium Concentration ($\mu\text{g/L}$)	Hexavalent Chromium Mass Removed (kg)
199-K-113A	95.5	115.1	46.3	74	3.0
199-K-115A	103.2	157.2	53.3	130	6.4
199-K-116A	106.5	174.4	54.5	185	9.6
199-K-119A	95.5	100.7	40.8	155	6.0
199-K-120A	101.2	163.6	52.2	105	5.0
199-K-125A	102.9	157.4	49.1	161	7.5
K-Influent	574	745	296.2	136	37.6
K-Effluent	574	745	296.2	9	--

Data Source: Project Specific Database for the 100-KR-4 Operable Unit.

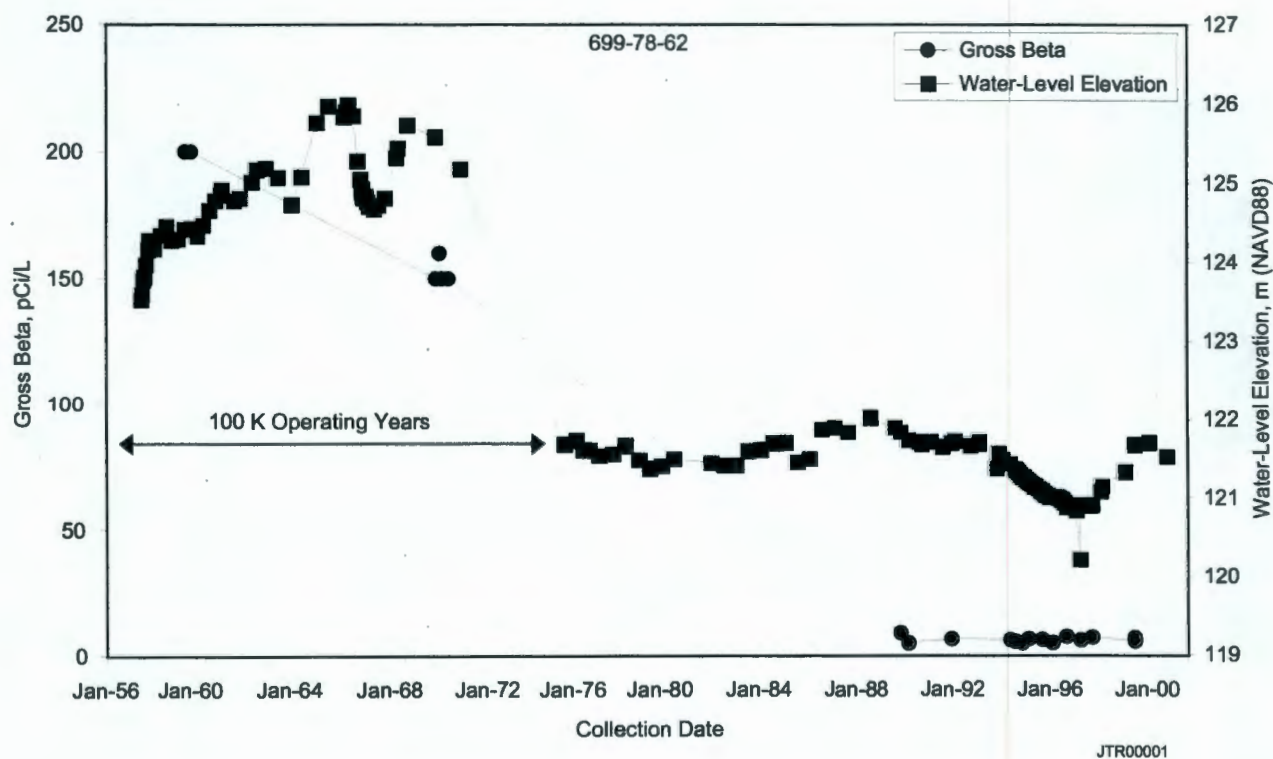
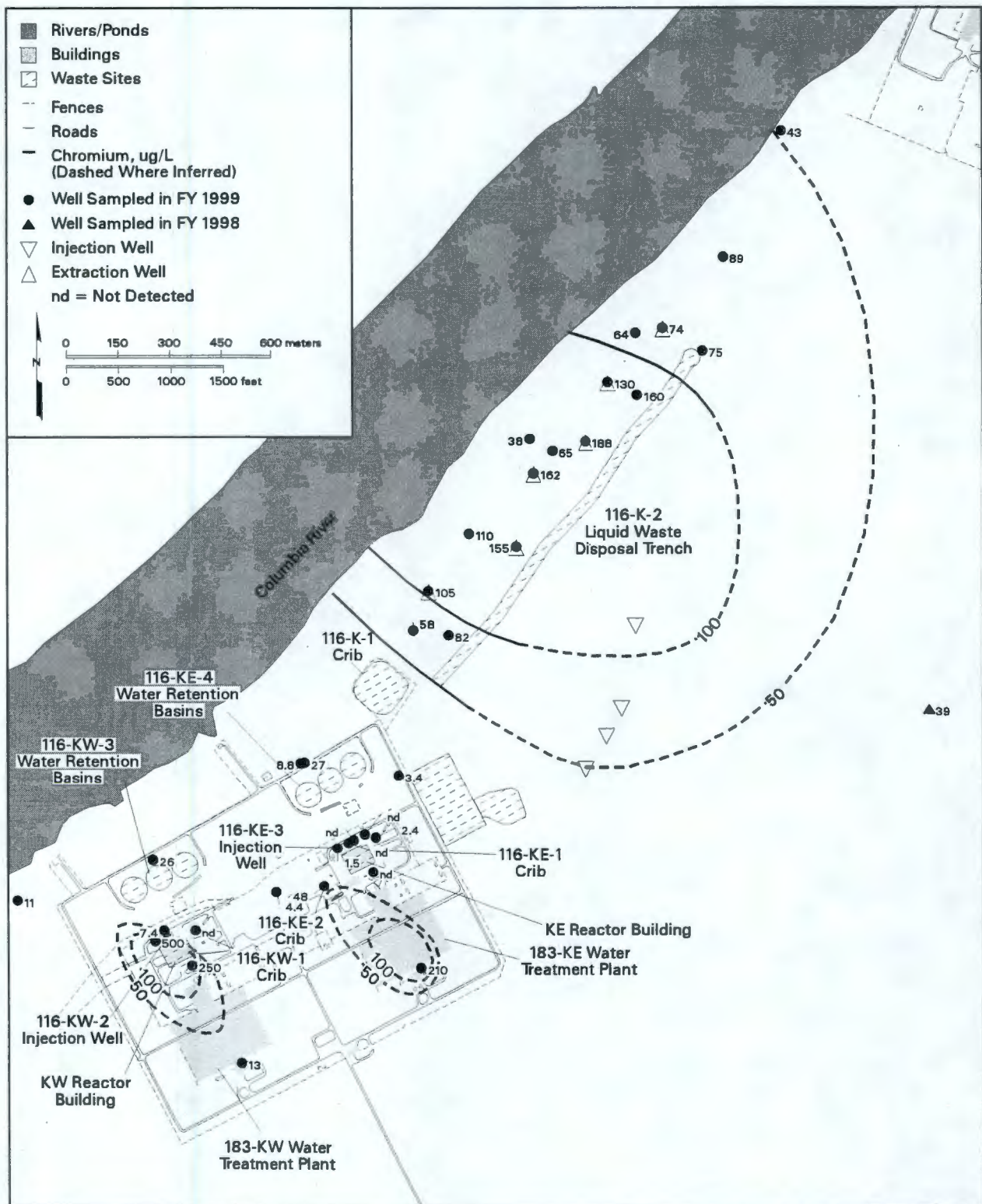


Figure 2.3-1. Influence of Groundwater Mound During the 100 K Operating Years, 1955 to 1971



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Figure 2.3-2. Average Chromium Concentrations in 100 K Areas, Top of Unconfined Aquifer

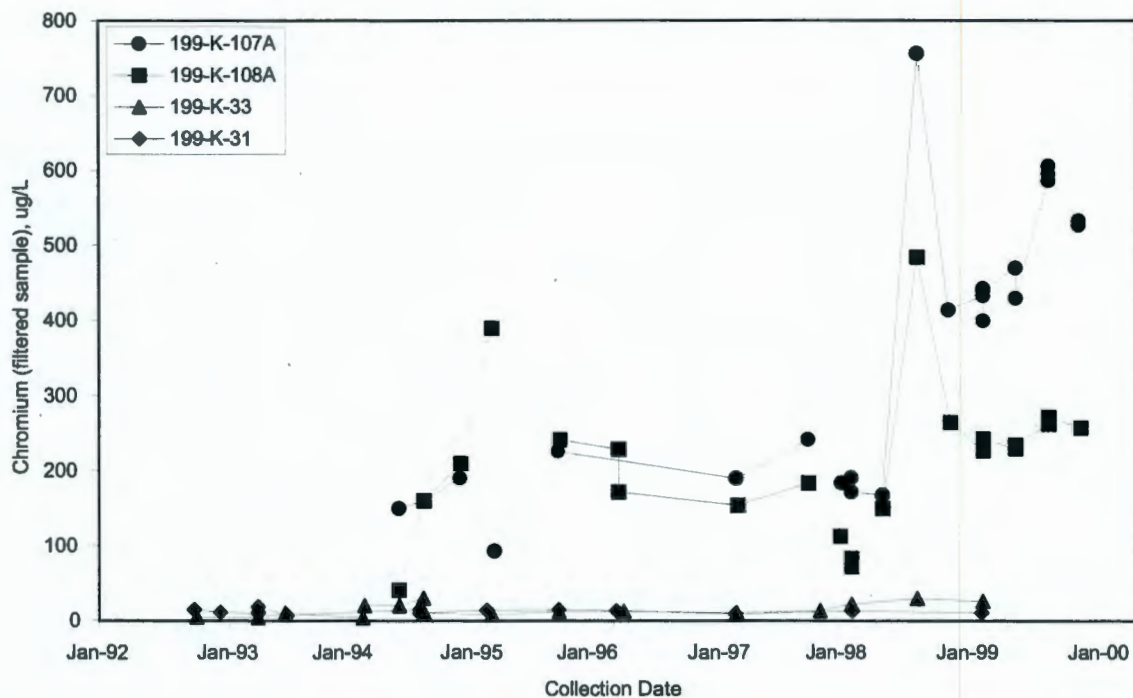


Figure 2.3-3. Chromium in Wells Near KW Reactor

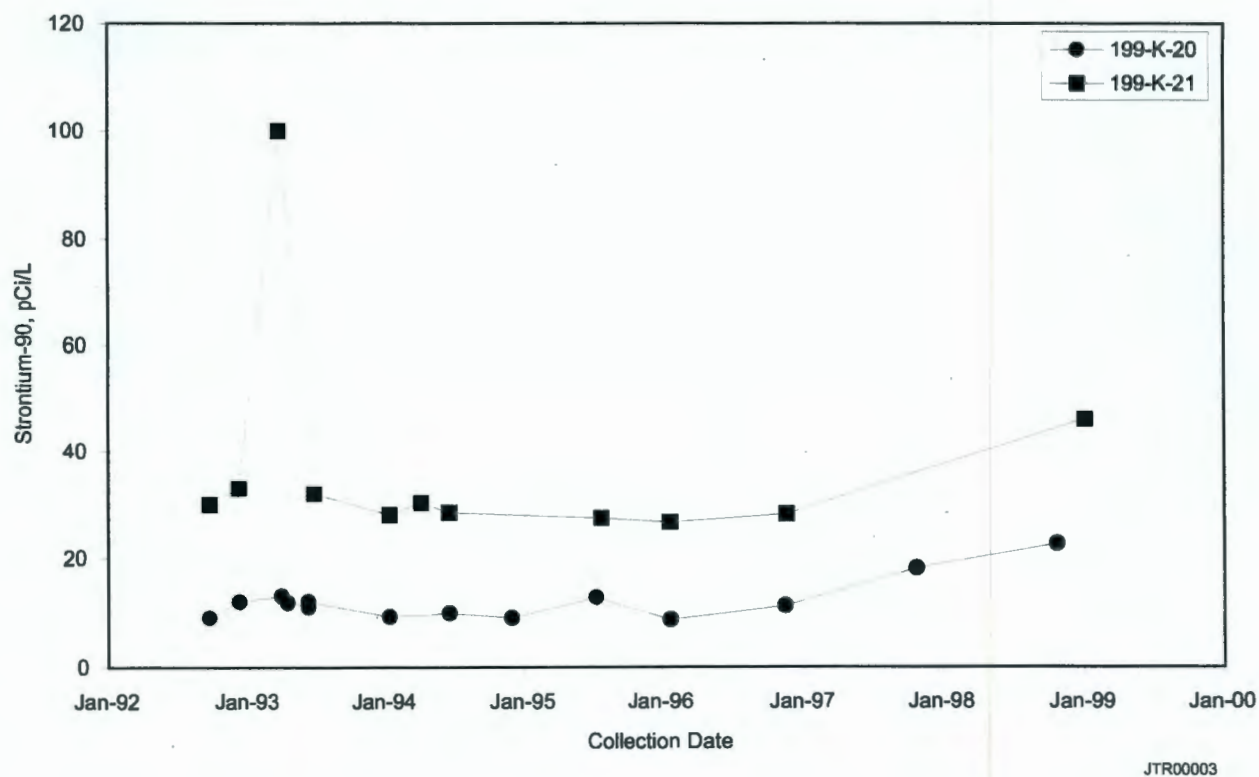


Figure 2.3-4. Strontium-90 in Wells Near 116-K-2 Liquid Waste Disposal Trench

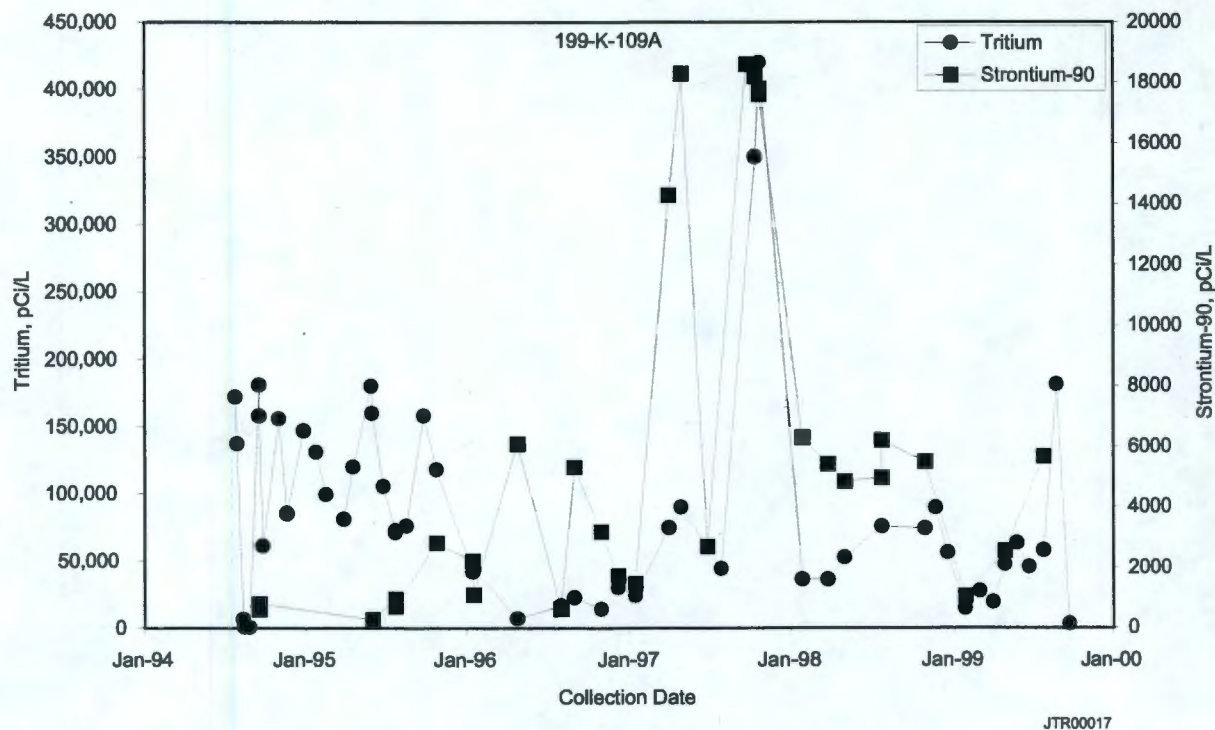


Figure 2.3-5. Strontium-90 and Tritium in Wells Near KE Reactor

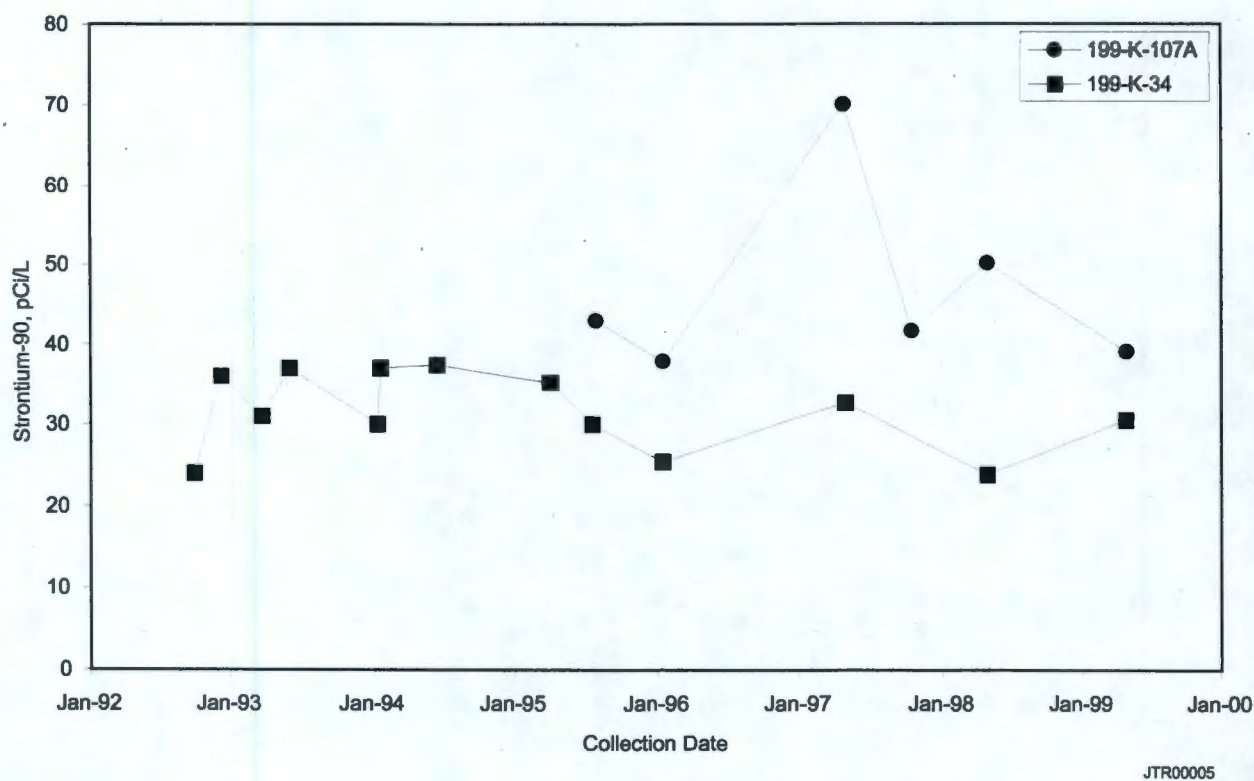
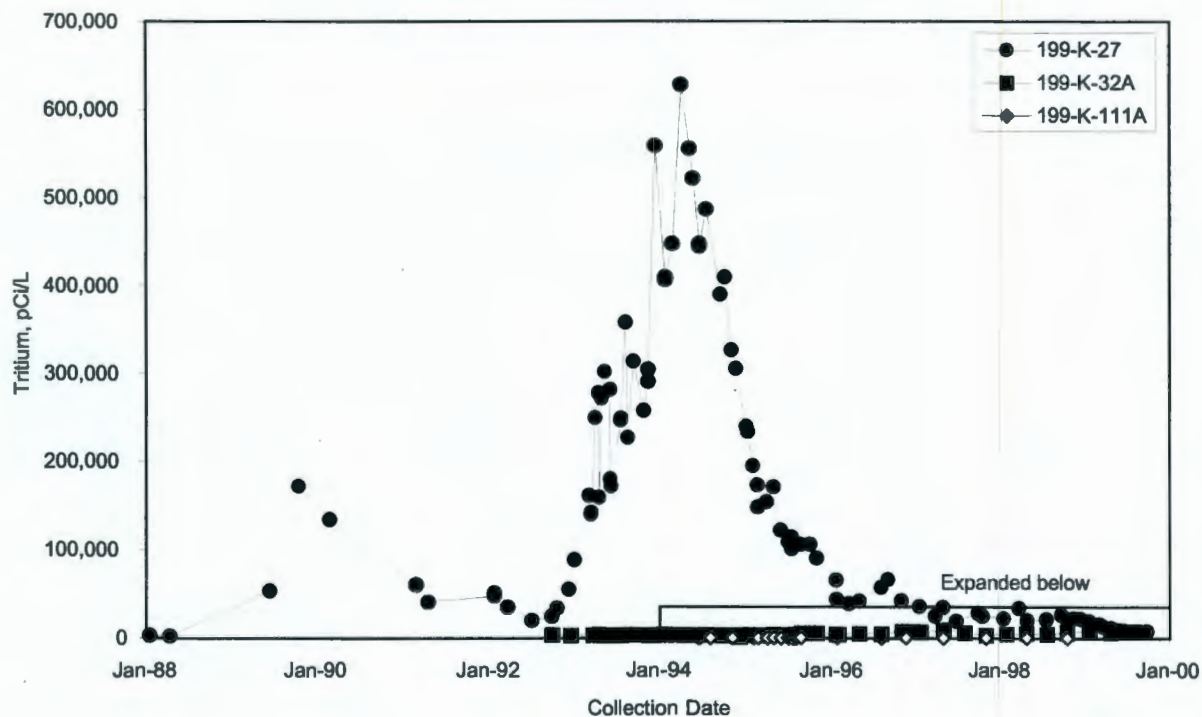
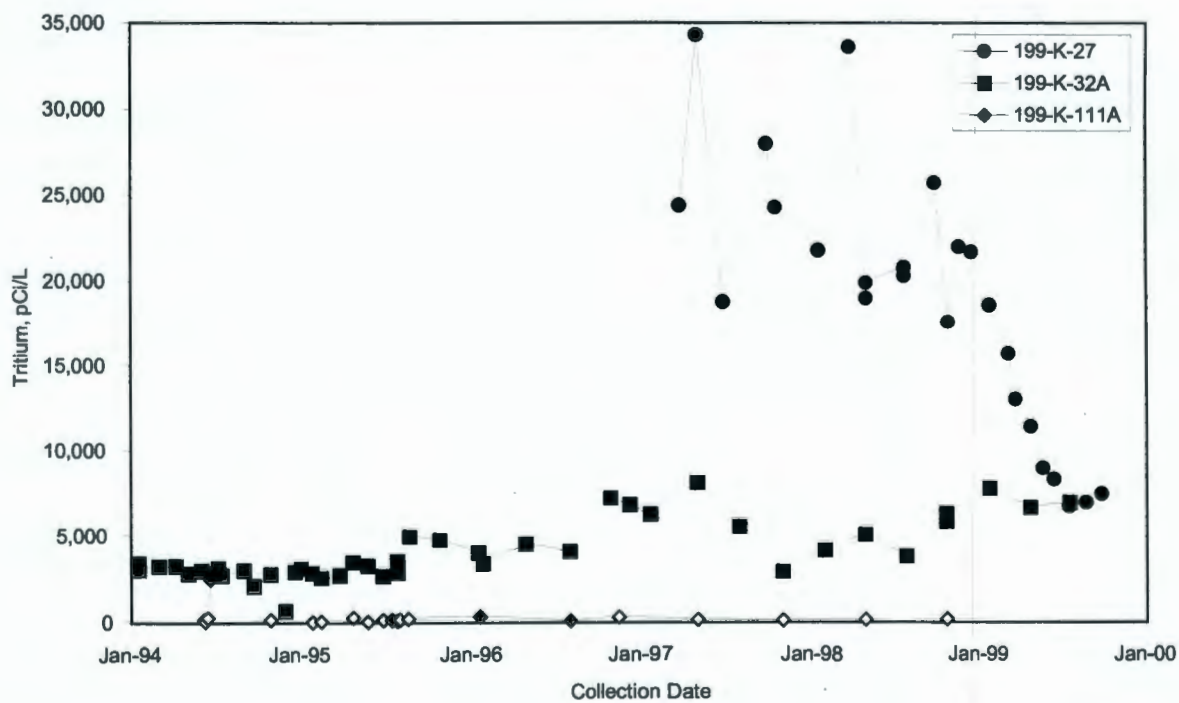


Figure 2.3-6. Strontium-90 in Wells Near KW Reactor



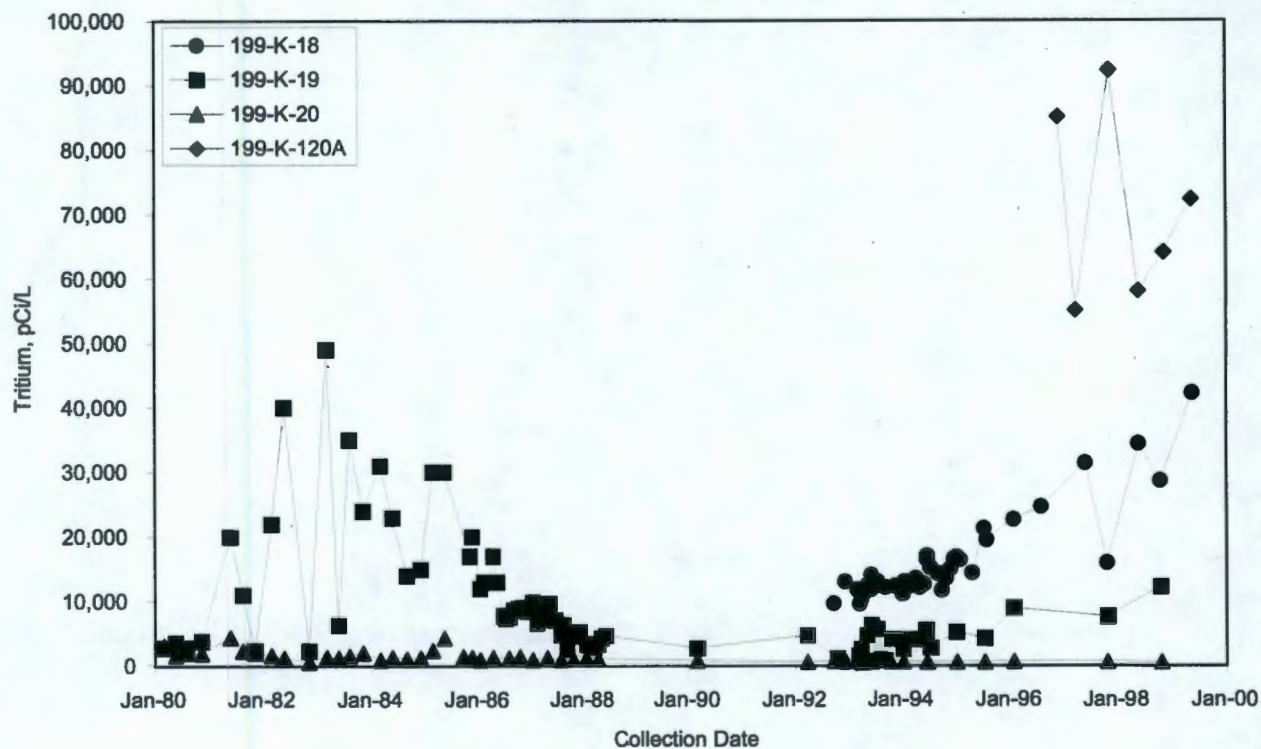
JTR00006



JTR00045

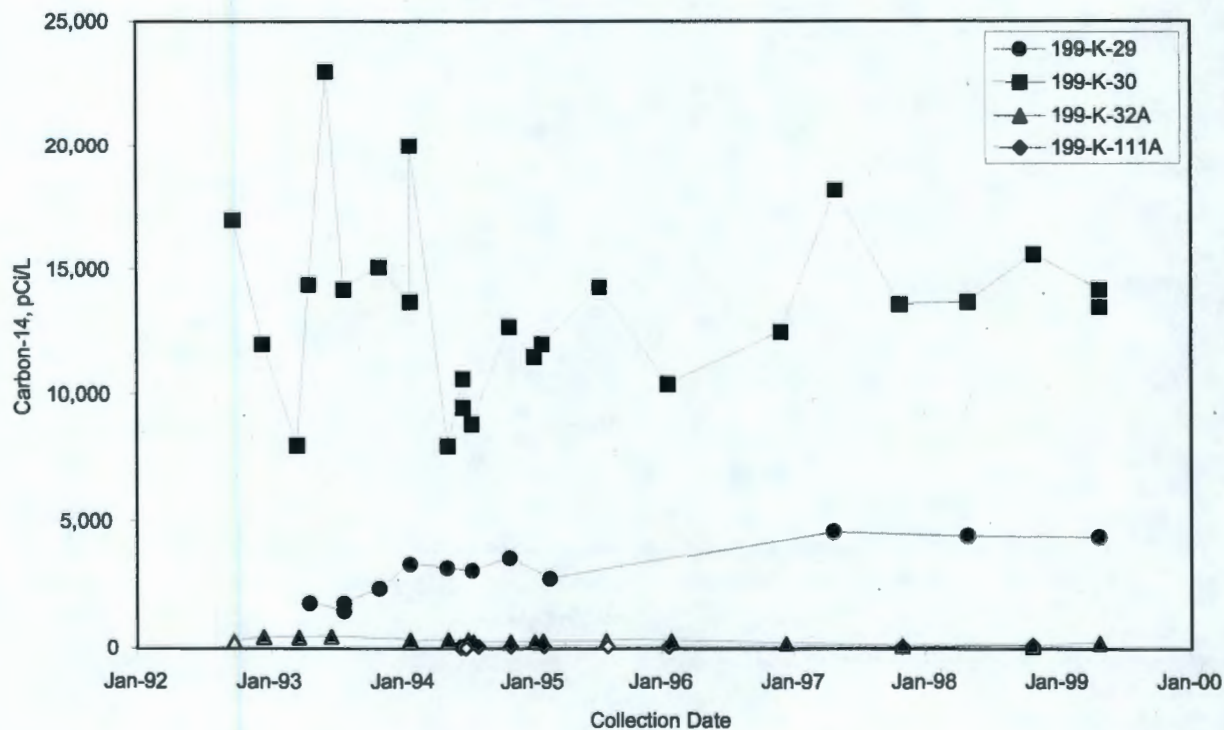
Jtr00049

Figure 2.3-7. Tritium in Wells Downgradient of KE Fuel Storage Basin



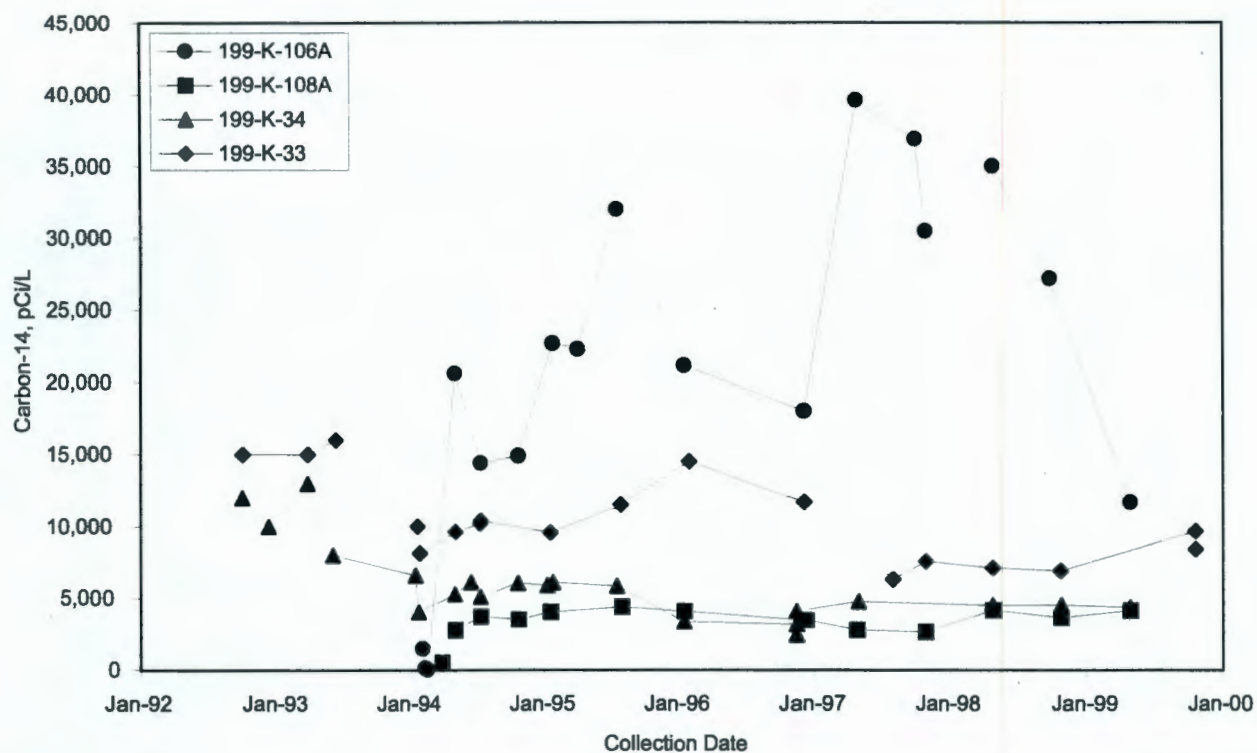
JTR00007

Figure 2.3-8. Tritium in Wells Northeast of KE Reactor



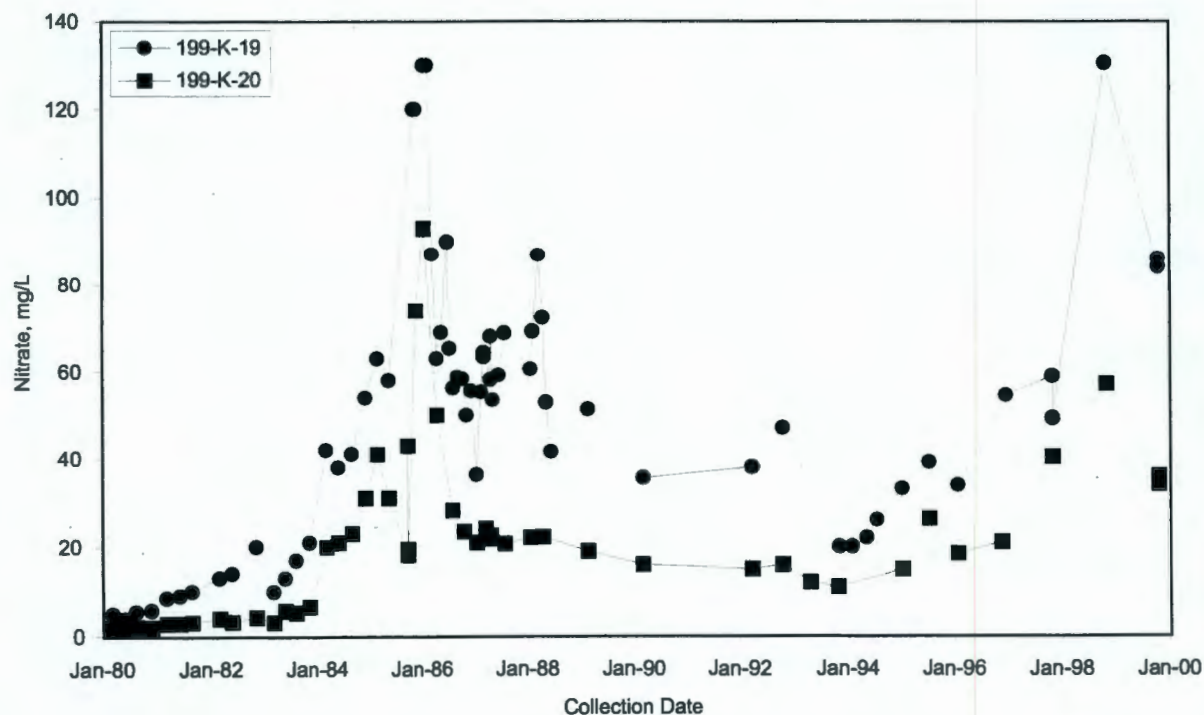
JTR00008

Figure 2.3-9. Carbon-14 in Wells Near KE Gas Condensate Crib



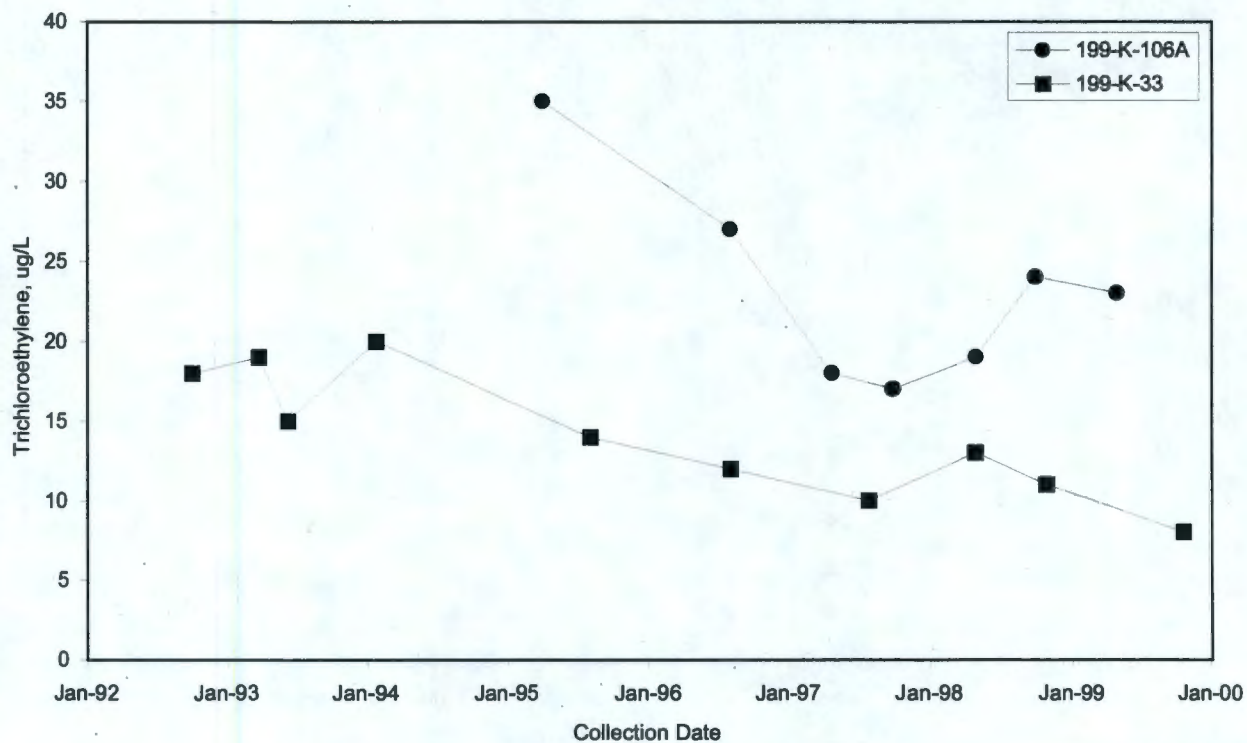
JTR00009

Figure 2.3-10. Carbon-14 in Wells Near KW Gas Condensate Crib



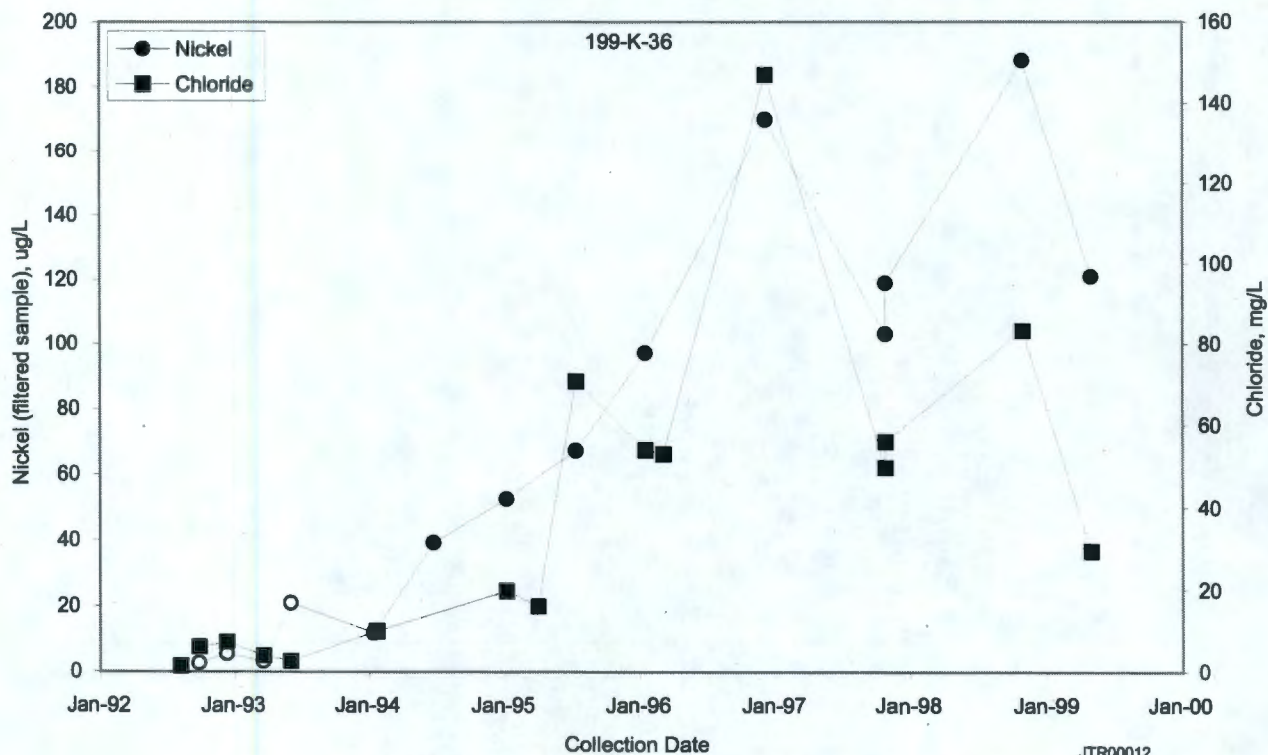
JTR00010

Figure 2.3-11. Example of Increasing Nitrate in Wells at 100 K Area



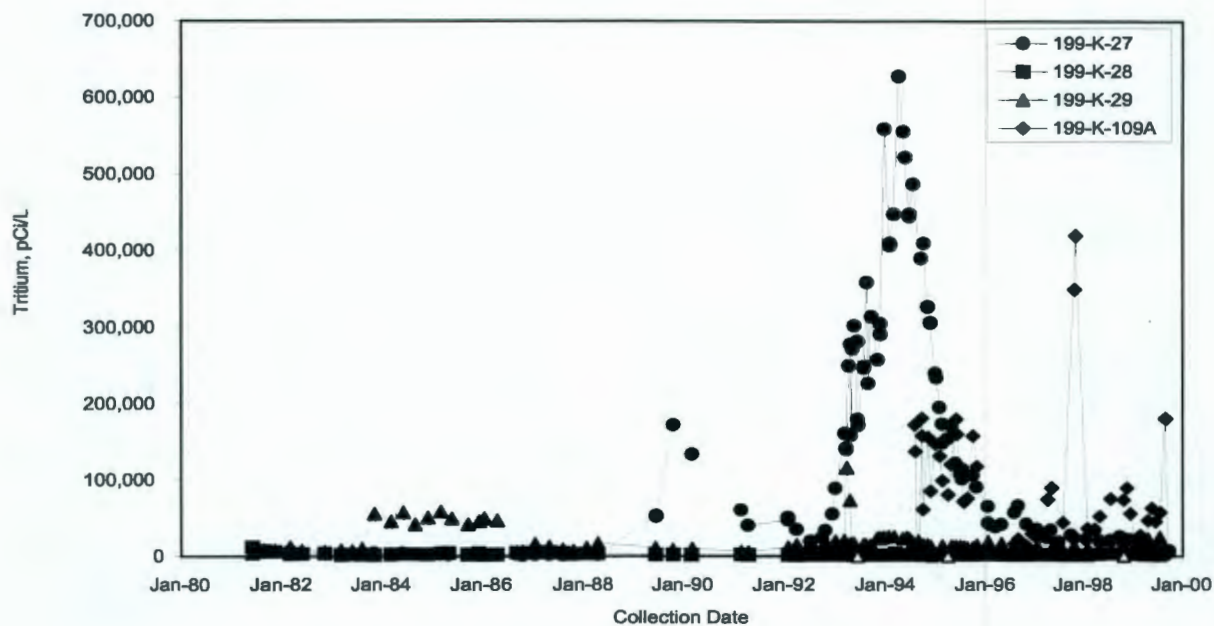
JTR00011

Figure 2.3-12. Trichloroethylene in Wells Near KW Reactor

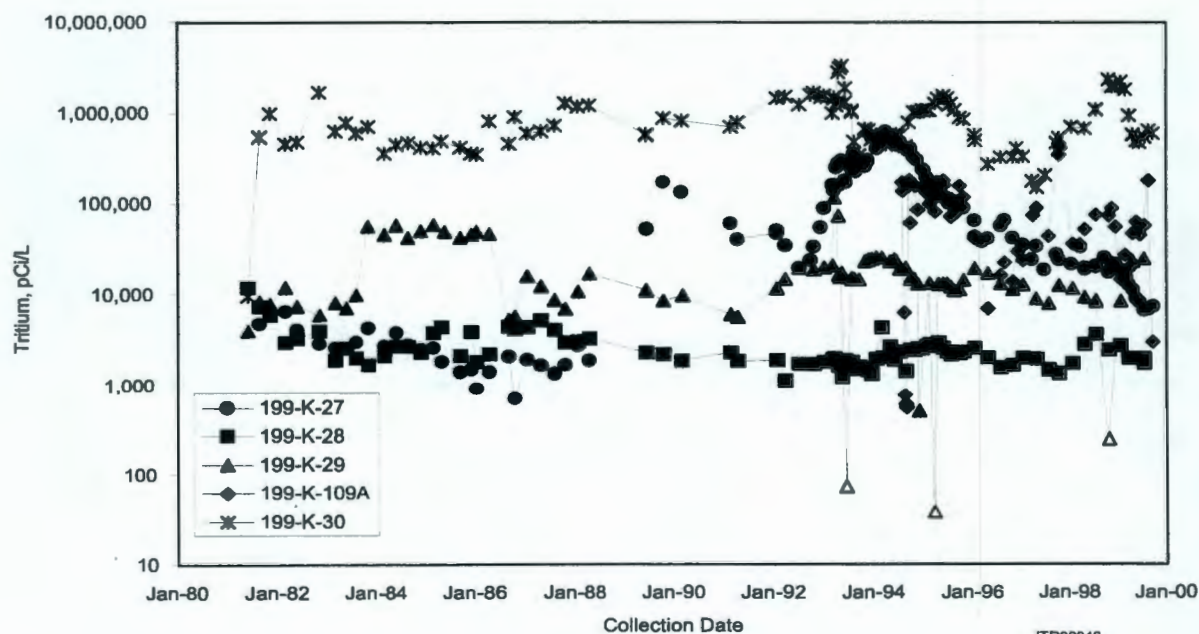


JTR00012

Figure 2.3-13. Nickel in Well 199-K-36

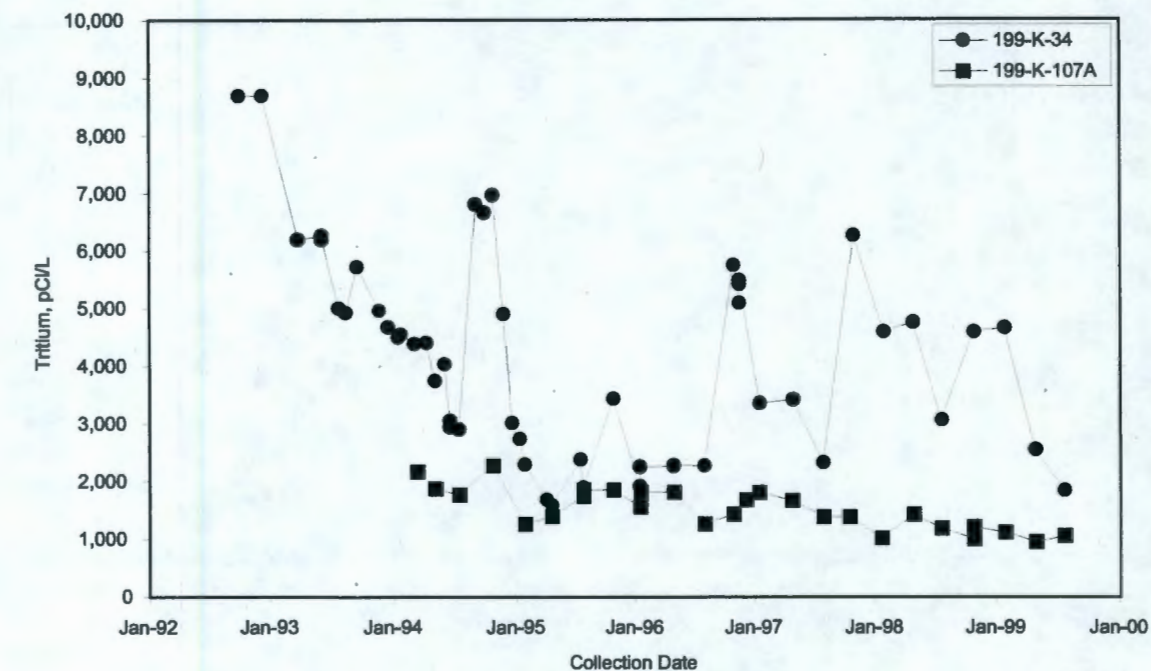


JTR00013

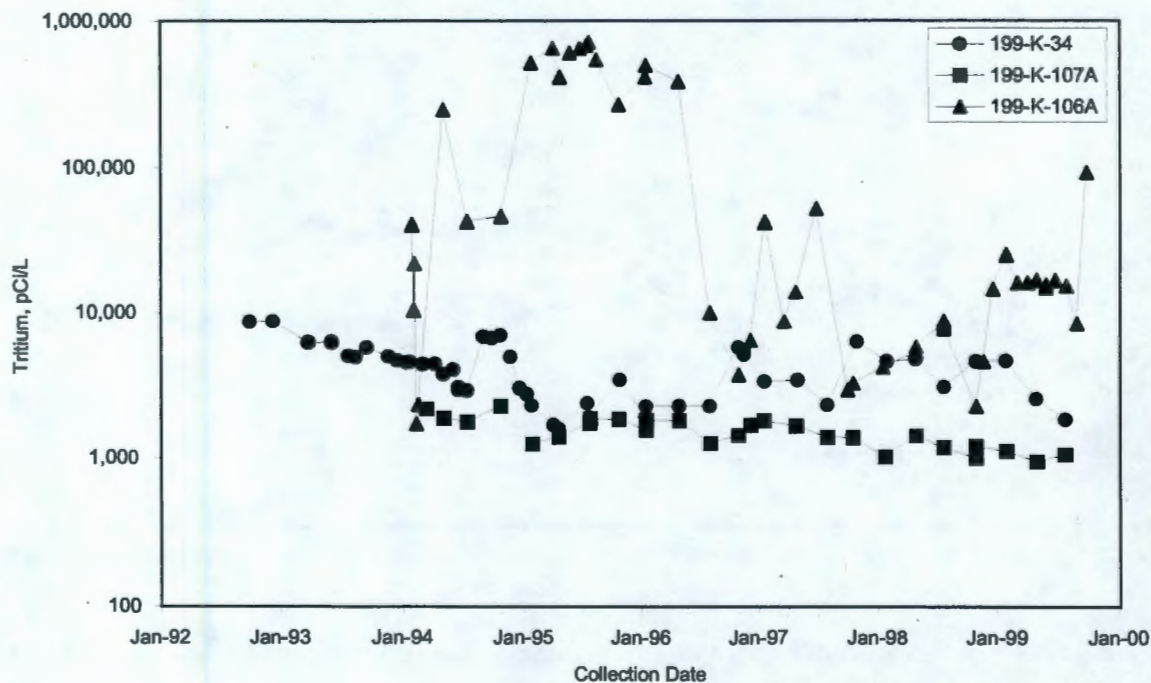


JTR00046

Figure 2.3-14. Tritium in Wells Adjacent to KE Fuel Storage Basin (note logarithmic scale on lower plot)

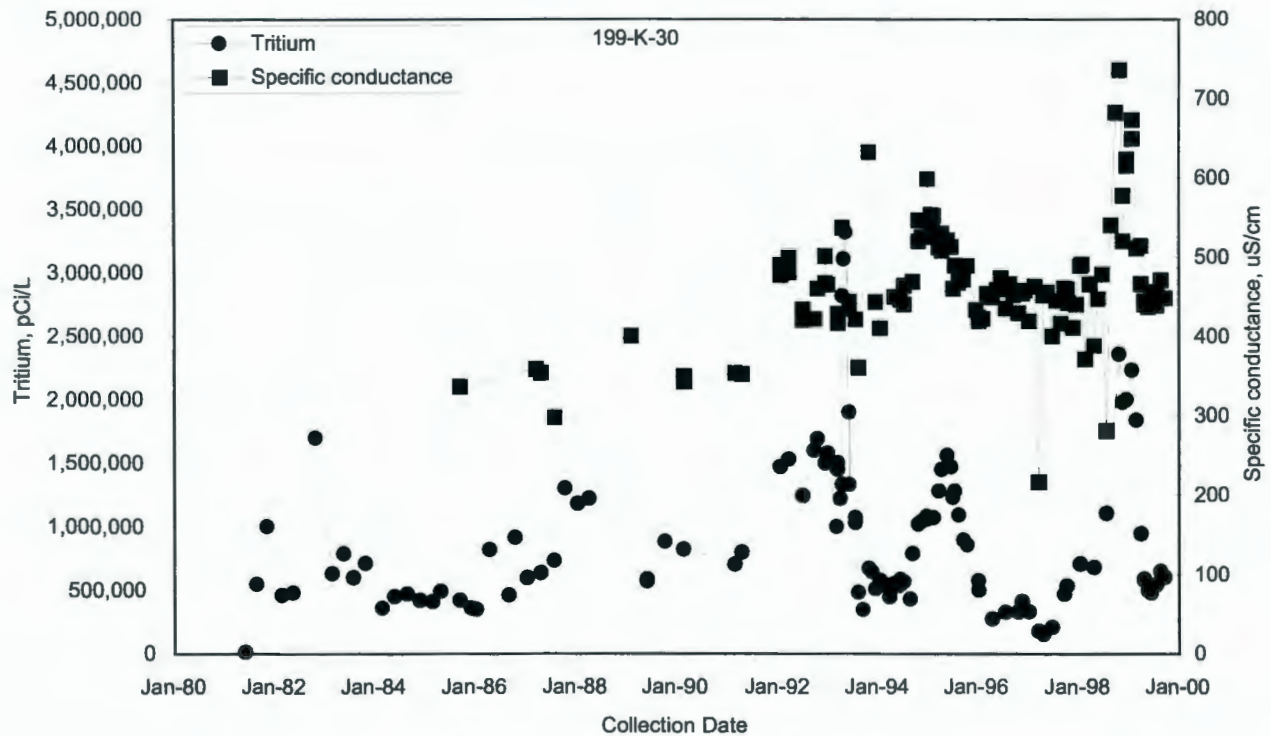


JTR00014



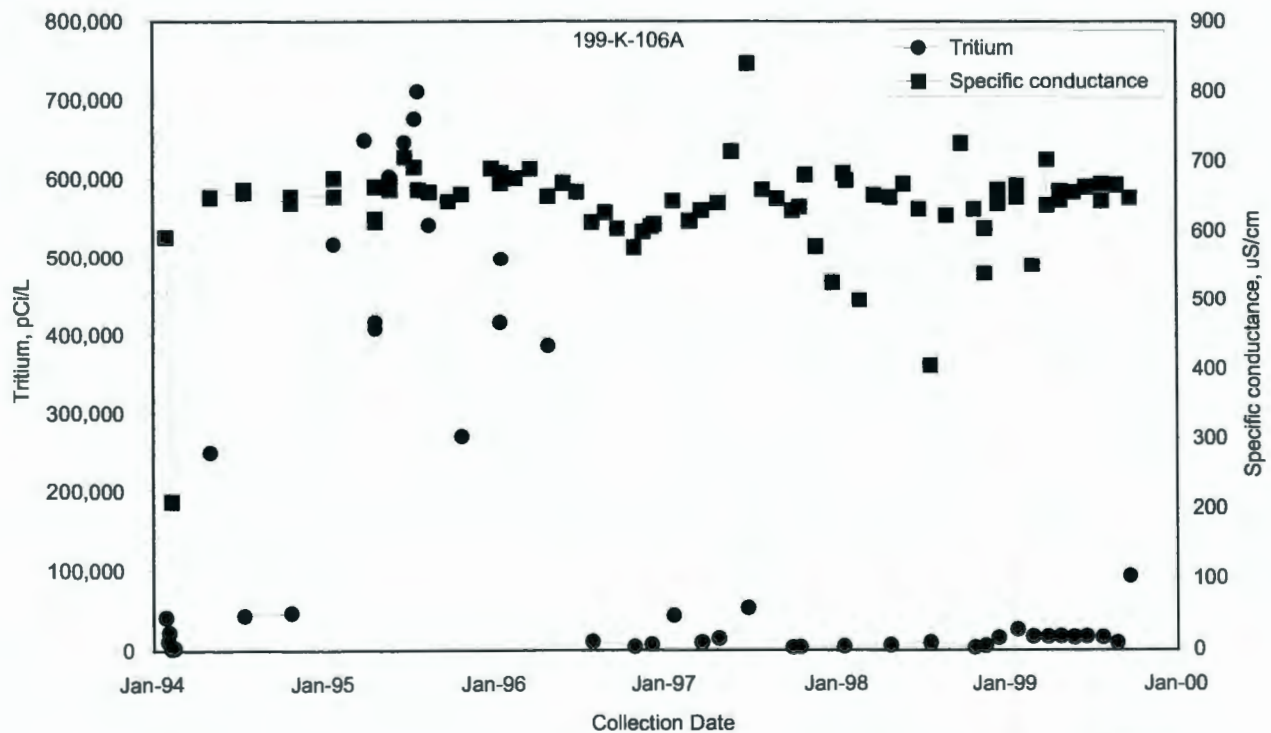
JTR00047

Figure 2.3-15. Tritium in Wells Adjacent to KW Fuel Storage Basin (note logarithmic scale on lower plot)



JTR00015

Figure 2.3-16. Tritium and Specific Conductance in Wells Near KE Gas Condensate Crib



JTR00016

Figure 2.3-17. Tritium and Specific Conductance in Wells Near KW Gas Condensate Crib

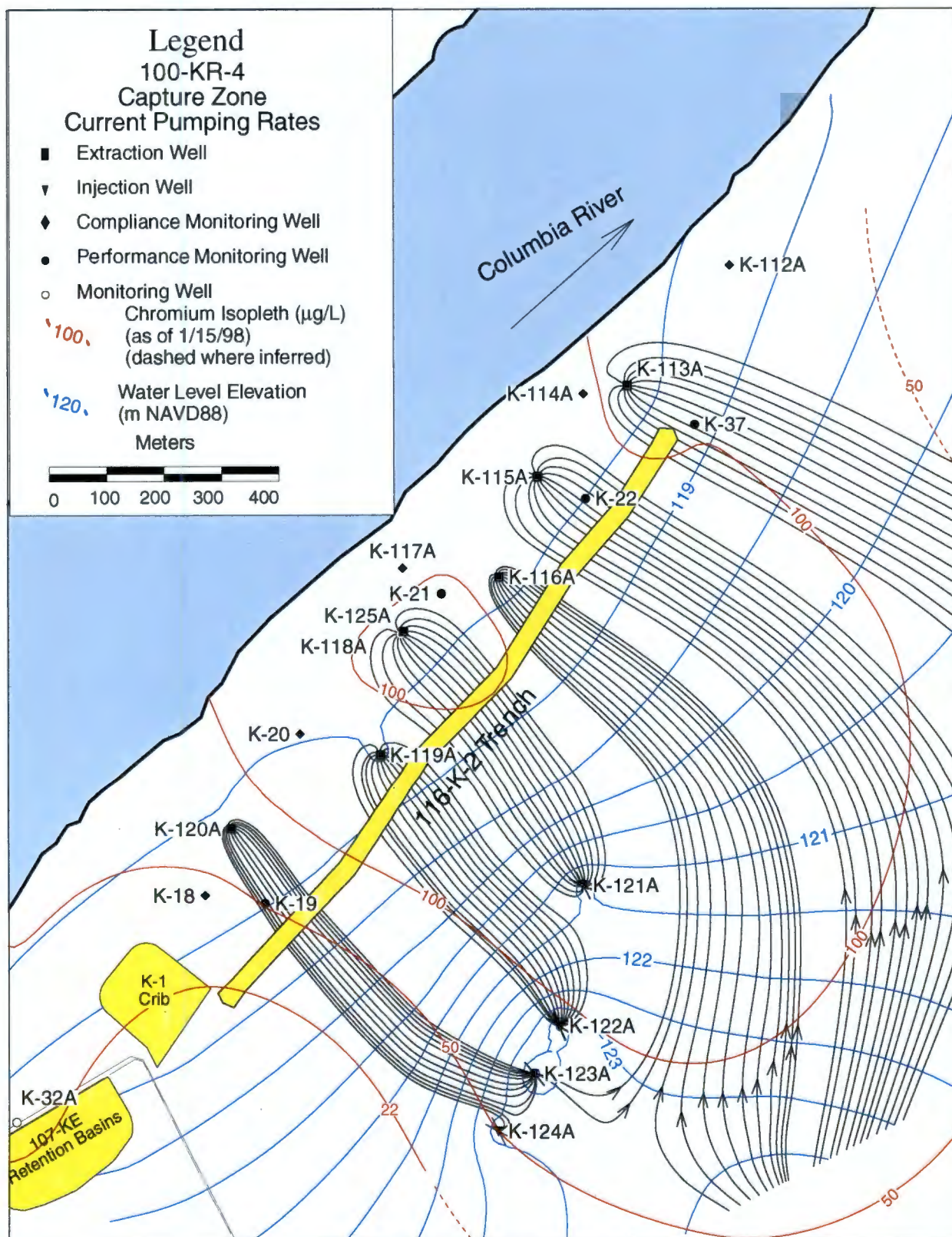


Figure 2.3-18. Capture Zone from 100-KR-4 Pump-and-Treat System (DOE/RL-99-13)

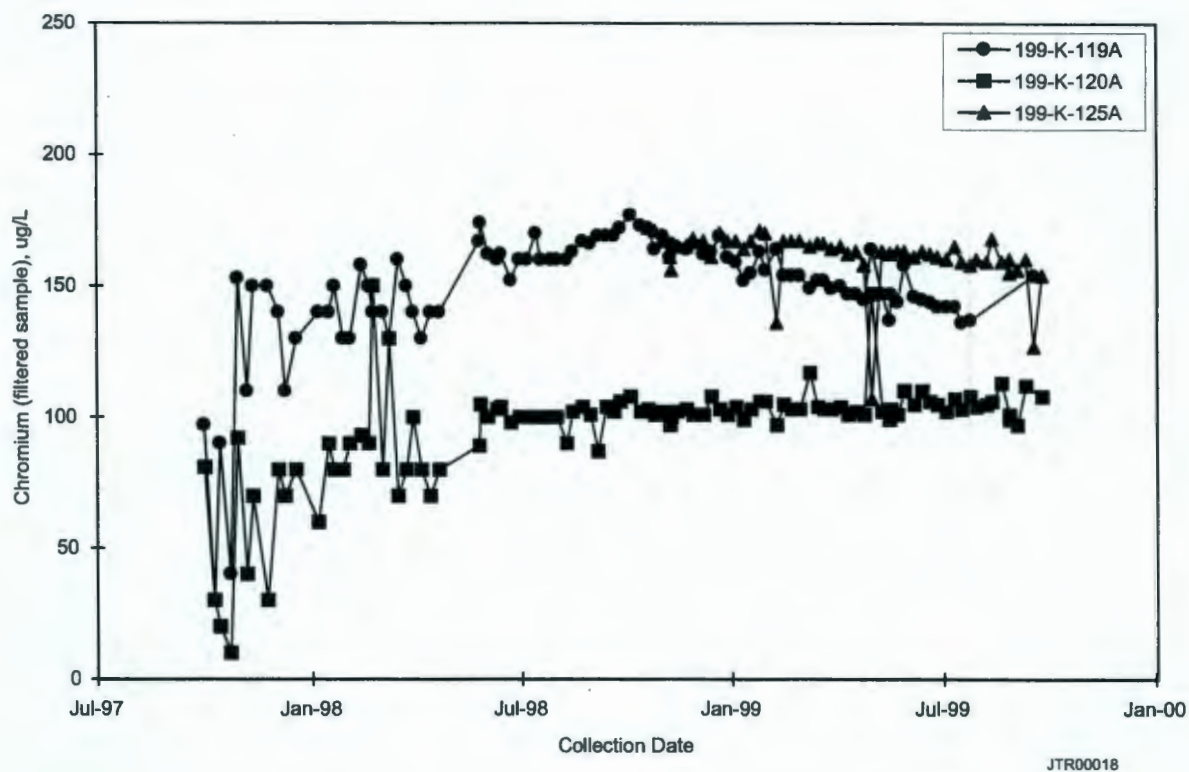


Figure 2.3-19. Chromium in Upstream Near-River Extraction Wells

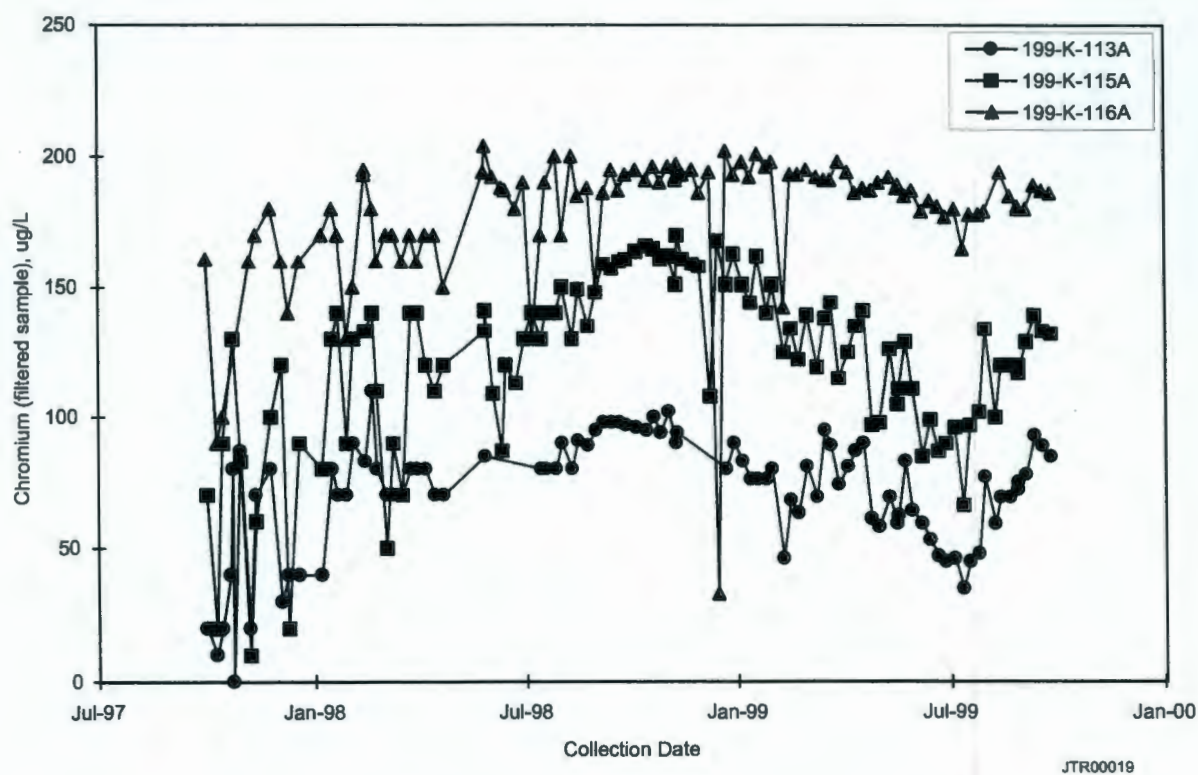
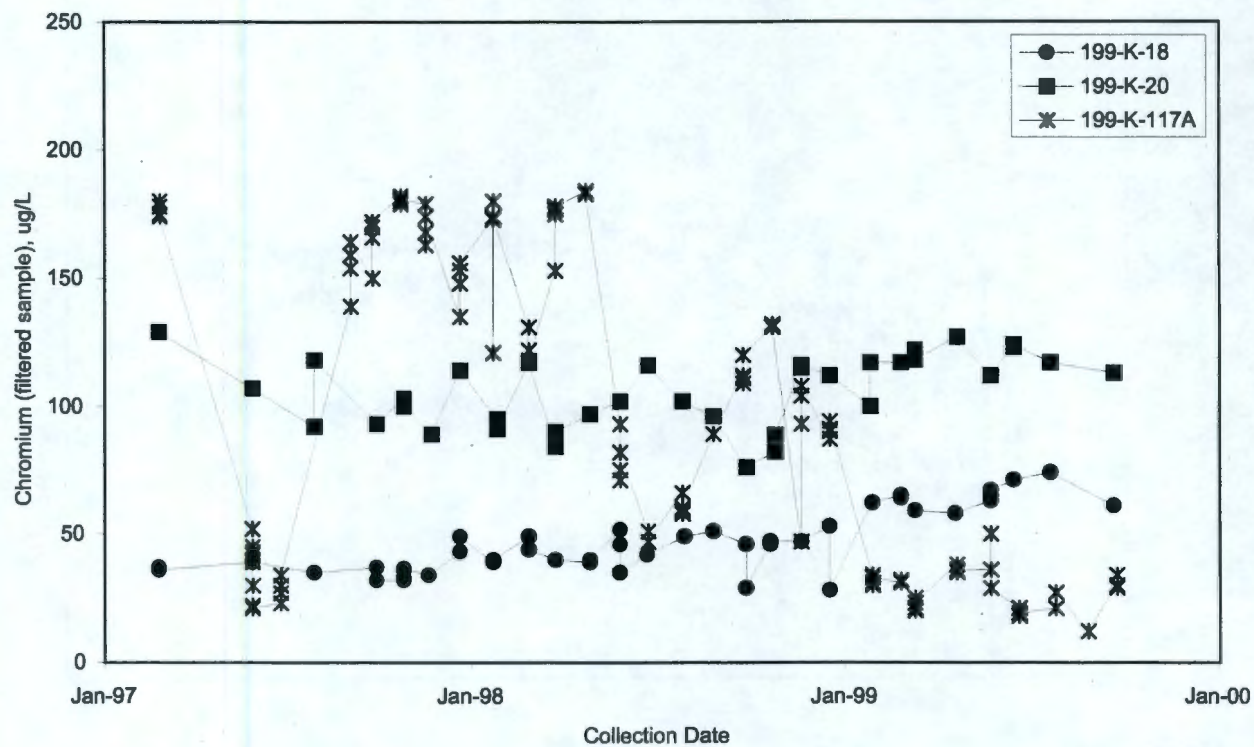


Figure 2.3-20. Chromium in Downstream Near-River Extraction Wells



JTR00020

Figure 2.3-21. Chromium in Compliance Wells

2.4 100 N Area

M. J. Hartman, W. J. McMahon, R. F. Raidl

The 100 N Area contains a single reactor that operated from 1963 through 1987. Waste sites and proposed corrective measures are described in DOE/RL-95-111 and DOE/RL-96-102. The most significant groundwater contamination is associated with the 1301-N and 1325-N facilities, which will be remediated in coming years. Characterization of sediment from those facilities is described in Section 3.1.2. Other sources of contamination include the 1324-N/NA facilities and various spills or leaks of petroleum products. Groundwater flow and contamination for each of these contaminant source areas are discussed in the following sections.

2.4.1 1301-N and 1325-N Liquid Waste Disposal Facilities

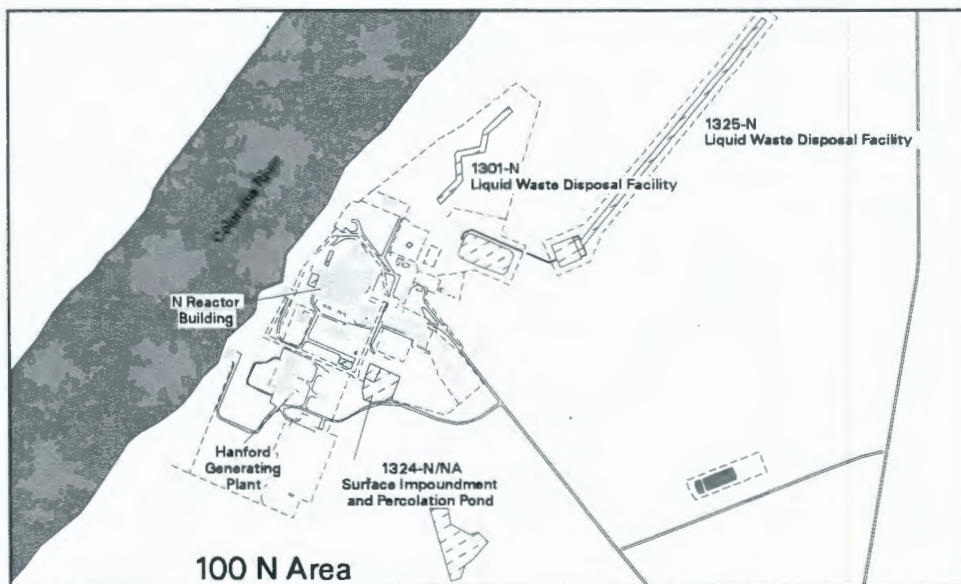
This section describes groundwater flow and contamination beneath the 1301-N and 1325-N facilities. The principal groundwater contaminants are strontium-90 and tritium. Groundwater remediation and riverbank water sampling also are discussed. Fiscal year

1999 data indicate few changes in groundwater quality beneath these facilities compared to previous years.

2.4.1.1 Groundwater Flow

Groundwater generally flows to the northwest, toward the Columbia River, beneath the 1301-N site and toward the north beneath the 1325-N site (see Plate 2). When the stage of the Columbia River is high, the gradient beneath the 1301-N facility reverses, creating a potential for groundwater to flow toward the northeast, approximately parallel to the Columbia River. Estimated flow velocities in March 1999 were 0.04 to 0.82 meter per day at 1301-N and 0.02 to 0.38 meter per day at 1325-N (see Table A.2). Movement of a peak in specific conductance indicates a flow velocity at the upper end of this range at the 1325-N site, 0.3 meter per day.

Extraction of groundwater from wells near the 1301-N facility, and injection of treated water near 1325-N, affect groundwater flow. These effects are clearly visible on the water-table map (see Plate 2) and are discussed in Section 2.4.1.6.



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Water levels beneath both facilities fluctuate with the stage of the Columbia River. In Figure 2.4-1, water levels near the 1301-N facility are represented by well 199-N-2. Because the well is relatively close to the Columbia River, the well shows the greatest fluctuation in the elevation of the water table. Well 199-N-34, representing water levels near the 1325-N facility, showed slightly less variation. The range of water levels was smaller than in the previous several years when river stage was unusually high.

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
- ▶ various time intervals to evaluate the performance of a pump-and treat system for strontium-90.

2.4.1.2 Tritium

The 1301-N and 1325-N facilities contaminated groundwater with tritium, which forms a widespread plume at levels exceeding the 20,000-pCi/L drinking water standard (see Plate 3). 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 is also present in upgradient wells 199-N-74 and 199-N-52. The current upgradient tritium is believed to have been moved inland by mounding during 1325-N operations.

Tritium concentrations are declining in most 100 N Area wells (Figure 2.4-2). The general decline is expected to continue because of plume migration and radioactive decay.

2.4.1.3 Strontium-90

Groundwater beneath the 1301-N and 1325-N facilities is contaminated with strontium-90 at levels up to 18,000 pCi/L (Figure 2.4-3). Contamination is concentrated in an area between the 1301-N facility and the Columbia River and its distribution has not changed significantly in recent years. 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 1999 was 382 pCi/L.

Concentrations in the heart of the plume near the 1301-N facility remained about the same as last year (Figure 2.4-4). However, strontium-90 levels in well 199-N-67 are four or five times higher than they were from 1991 through 1995. The high water table in 1996-1997 may have caused the increase by mobilizing strontium-90 that had been sorbed to sediment in the vadose zone. Changes in flow direction caused by the pump-and-treat system, which began to operate in 1995, also may have contributed to the rise in concentrations.

The pattern of seasonal fluctuation in wells farther from the 1301-N facility, where the vadose zone is not contaminated with strontium-90, is illustrated

Strontium-90 concentrations in 100 N Area groundwater continued to be among the highest on the Hanford Site in fiscal year 1999. Levels were more than 1,000 times the drinking water standard in wells near the Columbia River. This plume is the target of a pump-and-treat system.

by well 199-N-14. Concentrations increased in this well in the mid-to-late 1980s as the plume migrated toward the north. Since then, strontium-90 has ranged from 500 to 1,500 pCi/L, with no overall increasing or decreasing trend. Concentrations tend to be lower when the river stage is higher, because of a dilution effect from the Columbia River.

Near the 1325-N facility in recent years, strontium-90 levels have increased in well 199-N-81 (Figure 2.4-5). The peak level in this well was about the same as the peak in well 199-N-29, adjacent to the crib, when waste was being disposed, and the recent increase may represent movement of the contamination downgradient. This would equate to a transport rate of ~0.1 meter per day for strontium-90. The rate of movement of strontium-90 would be expected to be less than the rate of groundwater flow (0.3 meter per day) because strontium-90 sorbs to the sediment. Strontium-90 levels in well 199-N-81 also may be affected by the influx of water from wells 199-N-29 and 199-N-104A, which are used to inject treated water from the pump-and-treat system. This water may mobilize strontium-90, causing it to migrate northward to well 199-N-81. Other wells near 1325-N neither confirm nor refute this idea. The only well between 199-N-29 and 199-N-81 that can be sampled is 199-N-32, which has always had very low strontium-90 concentrations and does not appear to be representative of concentrations in the larger area.

The strontium-90 plume in groundwater 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.

2.4.1.4 Chromium

In fiscal year 1999, dissolved chromium exceeded the maximum contaminant level in only one well, which is completed in a thin, confined aquifer in the Ringold Formation. Concentrations in well 199-N-80 are steady at ~180 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 (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.

A filtered sample from well 199-N-64, located upgradient of the 1301-N facility, contained 124 µg/L of chromium in fiscal year 1998. The result from a sample collected in September 1999 was 26 µg/L.

2.4.1.5 RCRA Parameters

Monitoring for the *Resource Conservation and Recovery Act of 1976* (RCRA) in fiscal year 1999 indicated the 1301-N and 1325-N facilities are not contaminating groundwater with hazardous constituents.

Total organic carbon exceeded the critical mean value in one well (199-N-3) downgradient of the 1301-N facility in September 1998. Results from January 1999 confirmed the exceedance, and the U.S. Department of Energy (DOE) notified Washington State Department of Ecology (Ecology). No organic constituents of concern have been identified in 1301-N waste or sediment, and the contamination is assumed to come from a source other than the 1301-N facility. The elevated total organic carbon is probably related to the detection of petroleum products in other wells near 199-N-3 (Section 2.4.3). Total organic carbon levels remained fairly stable in well 199-N-3 in fiscal year 1999. For the September 1999 evaluation, the critical mean value was revised based on more recent upgradient data (see Table A.5). The new value is higher (2,383 µg/L) and was not exceeded.

Specific conductance of groundwater near the 1301-N facility is relatively low (200 to 300 µS/cm) compared to typical Hanford Site groundwater because the facility is close to the Columbia River. A plume of high-conductance (500 to 1,000 µS/cm) groundwater

from an upgradient source affects groundwater chemistry in downgradient well 199-N-3 and upgradient well 199-N-57.

Critical mean values for the 1301-N and 1325-N facilities were revised in December 1999, based on recent data from the upgradient wells (1997 through 1999; see Tables A.5 and A.7). The new values were used to evaluate data from July through September 1999. Specific conductance in two downgradient wells at the 1325-N facility (199-N-41 and 199-N-81) exceeded the new critical mean value. The previous critical mean value was 689.9 $\mu\text{S}/\text{cm}$ (Table B.6 in PNNL-12086), based on data from upgradient well 199-N-74 from March 1992 through March 1993, when specific conductance was ~ 500 $\mu\text{S}/\text{cm}$. Specific conductance declined in well 199-N-74 from 1993 to 1995. The new critical mean value is 470.9 $\mu\text{S}/\text{cm}$.

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

DOE notified Ecology of the exceedance and submitted an assessment report. The report concluded that the source of the high specific conductance was not the 1325-N facility, as evident from the following:

- Specific conductance exceeded the critical mean value only after the critical mean value was revised (lowered) based on 1997 to 1999 concentrations in the upgradient well. The older critical mean value was not exceeded.
- Downgradient wells 199-N-41 and 199-N-81 are in a plume of high-sulfate groundwater that was observed in the upgradient well from 1991 to 1995. Based on the rate of groundwater flow in the area, the plume will pass the downgradient wells in 2 to 4 years.

No further assessment of the high specific conductance at 1325-N is needed. The site should remain in

detection monitoring as described in the existing monitoring plan (WHC-SD-EN-AP-038, Rev. 2).

Groundwater at the 1301-N and 1325-N facilities is also 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 2.4.3, but the sources are unclear.

2.4.1.6 Groundwater Remediation

The 100-NR-2 Operable Unit pump-and-treat system, 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.

On September 29, 1999, DOE, Ecology, and U.S. Environmental Protection Agency (EPA) signed an interim record of decision for the 100-NR-1 and 100-NR-2 Operable Units (Ecology 1999). 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 made progress toward the remedial action objectives in fiscal year 1999. Figure 2.4-6 shows the flow lines and hydraulic capture estimated to occur during a low-flow period in the Columbia River (November 1998), when groundwater flow to the Columbia River is greatest. The flow lines

represent simulations of the paths that groundwater would follow from upgradient locations, including the injection wells. The flow paths curve toward the extraction wells, which capture the groundwater from beneath much of the 1301-N strontium-90 plume (DOE/RL-99-79).

During fiscal year 1999, the pump-and-treat system extracted over 108 million liters of groundwater and removed ~0.2 curies of strontium-90 (Table 2.4-1). Combined, the three active extraction wells delivered an average concentration of 2,276 pCi/L to the treatment system during the fiscal year. After treatment, the effluent contained 382 pCi/L, which was returned to the aquifer through wells 199-N-29 and 199-N-104A.

A pump-and-treat system in the 100 N Area is intended as an interim remedial measure to reduce strontium-90 contamination reaching the Columbia River. It is not an efficient way to remove strontium-90 from the aquifer.

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.

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, with concentrations returning to the levels observed prior to the 1996 and 1997 high water years in the Columbia River. Since operations began in 1995, the pump-and-treat system has removed 0.7 curie of strontium-90, compared to a total inventory in the aquifer estimated to exceed 75 curies. Current estimates indicate that the

pump-and-treat system would have to operate for more than 300 years before the strontium-90 concentrations reach permissible levels (DOE/RL-95-110). For this reason, DOE is investigating and evaluating alternative remediation technologies.

2.4.1.7 Water Quality at Shoreline Monitoring Locations

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. The fiscal year 1999 environmental restoration report for the 100-NR-2 Operable Unit (DOE/RL-99-79) provides details of samples analyzed from the near-river sampling points. The following are brief summaries.

Near-River Wells

Strontium-90 concentrations in samples from these wells in fiscal year 1999 ranged from undetected in well 199-N-92A to 13,100 pCi/L in well 199-N-46. Well 199-N-99A, near the middle of the plume, detected a peak of strontium-90 in 1996 (19,000 pCi/L). Levels of strontium-90 remain above the 1,000-pCi/L derived concentration guide (1,890 pCi/L in September 1999).

The highest tritium concentration in fiscal year 1999 in a near-river well was 10,300 pCi/L in well 199-N-92A. Concentrations also were relatively high in well 199-N-46 (9,190 pCi/L in September 1999). Tritium averaged ~1,000 pCi/L in well 199-N-96A, and was undetected in well 199-N-99A.

Riverbank Seepage

The Sitewide Environmental Surveillance Project collected a sample from one seep along the 100 N Area shoreline in October 1998. The sample contained 2.3 pCi/L gross beta, 24,400 pCi/L tritium, and 21 mg/L nitrate. The specific conductance of the sample was 290 μ S/cm, suggesting that there was relatively little dilution of the groundwater by river water in bank storage. Low gross beta and high tritium concentrations are typical for this seep, located downstream of

the main strontium-90 plume. Another seep located in the heart of the strontium-90 plume could not be sampled in fall 1998.

2.4.2 1324-N Surface Impoundment/ 1324-NA Percolation Pond

Groundwater near these RCRA facilities contains high levels of sodium and sulfate, caused by past influence of the percolation pond. Nitrate increased in fiscal year 1999, but its source is unknown.

2.4.2.1 Groundwater Flow

Groundwater flows toward the northwest beneath the 1324-N/NA site, perpendicular to the Columbia River (see Plate 2). The average rate of flow is 0.09 to 1.6 meters per day (see Table A.2). Movement of the sulfate plume between 1990 and 1993 indicated a flow velocity of ~0.5 meter per day (Section 3.2 in DOE/RL-93-88). The gradient in those years was approximately the same as it was in March 1999, so the flow estimate is still valid.

Water levels are influenced by the stage of the Columbia River. In Figure 2.4-1, well 199-N-72 represents water levels near the 1324-N/NA site. Water levels were higher than normal in 1996 through 1998, and declined to more normal conditions in fiscal year 1999.

2.4.2.2 RCRA Parameters

RCRA monitoring in fiscal year 1999 indicated the 1324-N/NA site has not contaminated groundwater with hazardous constituents. Specific conductance and total organic carbon were elevated in downgradient wells but were not caused by dangerous constituents from the site.

Specific conductance has been elevated at this site since monitoring began in 1988, primarily caused by non-dangerous constituents that were present in the waste, such as sodium and sulfate. Specific conductance and sulfate are discussed in Section 2.4.2.3.

Total organic carbon in downgradient well 199-N-59 exceeded the critical mean value in March 1999, continuing a previously reported trend (Figure 2.4-7). Critical mean values were revised for the September 1999 sampling, based on more recent upgradient data (see Table A.6). The critical mean value for total organic carbon at the 1324-N/NA site increased from 1,373.2 to 1,840.1 µg/L. In September 1999, total organic carbon in well 199-N-59 averaged 1,535 µg/L, which is below the revised critical mean though still above the previous mean.

The groundwater at the 1324-N/NA RCRA site does not appear to be contaminated with hazardous constituents. However, this site has added non-hazardous constituents, such as sulfate and sodium, to groundwater.

The source of organic contamination in well 199-N-59 is not the 1324-N/NA site. Organic constituents were not included in waste disposed to the site. Oil and grease were detected in this well in fiscal years 1998 and 1999. This contamination is believed to have originated at one of several nearby storage tanks or waste sites (PNNL-11885).

2.4.2.3 Sulfate and Specific Conductance

The 1324-NA percolation pond has added non-hazardous constituents, including sulfate and sodium, to groundwater, creating high specific conductance (more than 1,000 µS/cm) (Figure 2.4-8). The plume extends in a wedge shape to the north-northwest, presumably discharging to the Columbia River.

Specific conductance and sulfate have declined from their peaks (Figure 2.4-9). 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 well 199-N-59 and other downgradient wells remain much higher than in upgradient well 199-N-74.

2.4.3 Other Groundwater Contamination

This section describes miscellaneous contaminants in 100 N Area: petroleum products, nitrate, and manganese.

2.4.3.1 Petroleum Hydrocarbons

Petroleum hydrocarbons are present as dissolved and free-product phases at several locations in the 100 N Area. Wells 199-N-8T, 199-N-16, 199-N-17, 199-N-18, and 199-N-54 monitor the most prominent area. During fiscal year 1999, most of these wells had detectable oil and grease, ranging from 1 mg/L in wells 199-N-8T and 199-N-54 to 34 mg/L in well 199-N-18. Total petroleum hydrocarbons were only detected in well 199-N-18 (5.4 mg/L). Field samplers look for an oil sheen or odor each time they sample wells in this area of diesel contamination. The samplers noted an oil odor at wells 199-N-17 and 199-N-18 during sampling in fiscal year 1999.

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 manganese concentrations in wells 199-N-16 and 199-N-18 (see discussions below).

As mentioned in Section 2.4.2, well 199-N-59 in the 1324-N/NA monitoring network has elevated total organic carbon. No volatile organic constituents have been detected in this well, but oil and grease were detected at 2 and 26 mg/L in duplicate samples in September 1999. The data are being evaluated to explain the large difference between duplicates. Oil and grease were detected in fiscal year 1998. This contamination is believed to have originated at one of several nearby storage tanks or waste sites (PNNL-11885).

2.4.3.2 Nitrate

Nitrate exceeds the 45-mg/L maximum contaminant level in three portions of the 100 N Area, but the sources are unknown (Figure 2.4-10). Virtually the entire area has nitrate at levels above 20 mg/L.

The first area with nitrate above the maximum contaminant level is in the southern 100 N Area, near the 1324-N/NA site and to the north and west of this site. Nitrate or related constituents were not discharged in significant quantities to this facility (DOE/RL-96-39). Nitrate increased to ~100 mg/L in fiscal year 1999 in well 199-N-59, but decreased in well 199-N-19, where it reached a peak of >200 mg/L in 1996 (Figure 2.4-11).

Wells 199-N-2 and 199-N-32 represent the second and third regions of nitrate contamination (see Figure 2.4-11). These trend plots are typical of many wells in the 100 N Area, showing peaks in nitrate in the mid 1980s and in 1997 and 1998. The 1301-N and 1325-N facilities received nitrate-bearing waste while they were in use, which could explain the 1980s peaks. No satisfactory explanation has been made for the recent nitrate peaks. See Section 5.5 of PNNL-12086 for more discussion of elevated nitrate.

Several wells with anomalous, low nitrate values appear to separate the southern part of the plume from the portion near the 1301-N facility. Nitrate has been historically below detection limits in well 199-N-18, which is very unusual in the unconfined aquifer. Nitrate is highly variable in well 199-N-16, ranging from 0.9 mg/L in September 1998 to >35 mg/L in September 1999 (Figure 2.4-12). Groundwater is not diluted by the Columbia River or leaking utility lines in this area, as evident from the specific conductance, which is >1,000 $\mu\text{S}/\text{cm}$ in these wells. Low nitrate may be related to chemical reduction of petroleum hydrocarbons in the aquifer, as discussed above.

2.4.3.3 Manganese

Manganese exceeds the 50- $\mu\text{g}/\text{L}$ maximum contaminant level in several 100 N Area wells, and may be associated with reducing conditions in the aquifer (Figure 2.4-13). Well 199-N-16 had fairly stable manganese concentrations in recent years, at ~1,000 $\mu\text{g}/\text{L}$. Well 199-N-18 has more limited data, but reached 5,780 $\mu\text{g}/\text{L}$ in fiscal year 1999.

Table 2.4-1. Summary of 100 N Area Pump-and-Treat Performance for Fiscal Year 1999

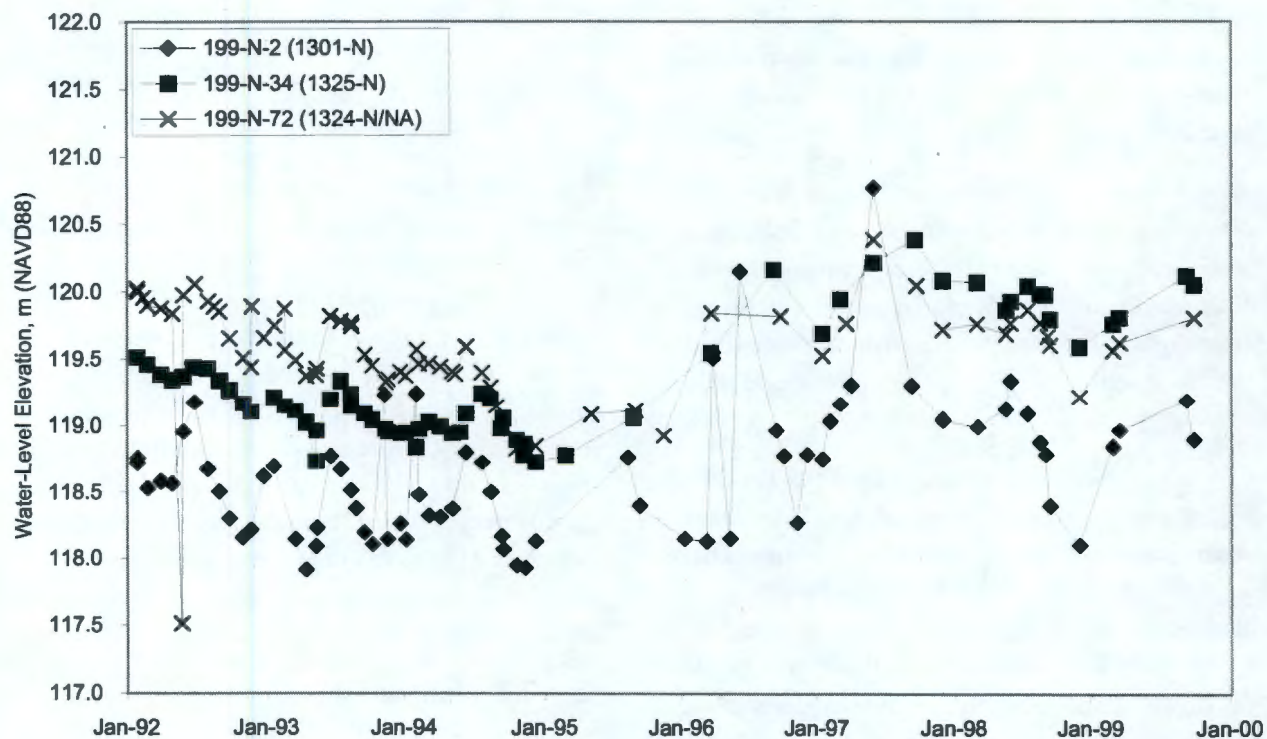
Well ID or Sample Location	Annual Average Flow Rate (L/min)	Total Volume Pumped ($\times 10^6$ L)	Average Strontium-90 Concentration (pCi/L)	Strontium-90 Mass Removed (Ci)
199-N-75	49.4	104.5	445	NA
199-N-103A	64.6	136.6	NS	NA
199-N-105A ^(a)	0	0	1,857	0
199-N-106A	109	230.6	NS	NA
N-Influent	223	108	2,276	0.2
N-Effluent	223	108	382	NA

(a) Backup extraction well; not operating in fiscal year 1999.

NA = Not applicable.

NS = Not sampled.

Total strontium-90 removed since startup is ~0.7 curie. Total in aquifer estimated at 75 curies.



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Figure 2.4-1. Water Levels in Wells Monitoring 100 N Area

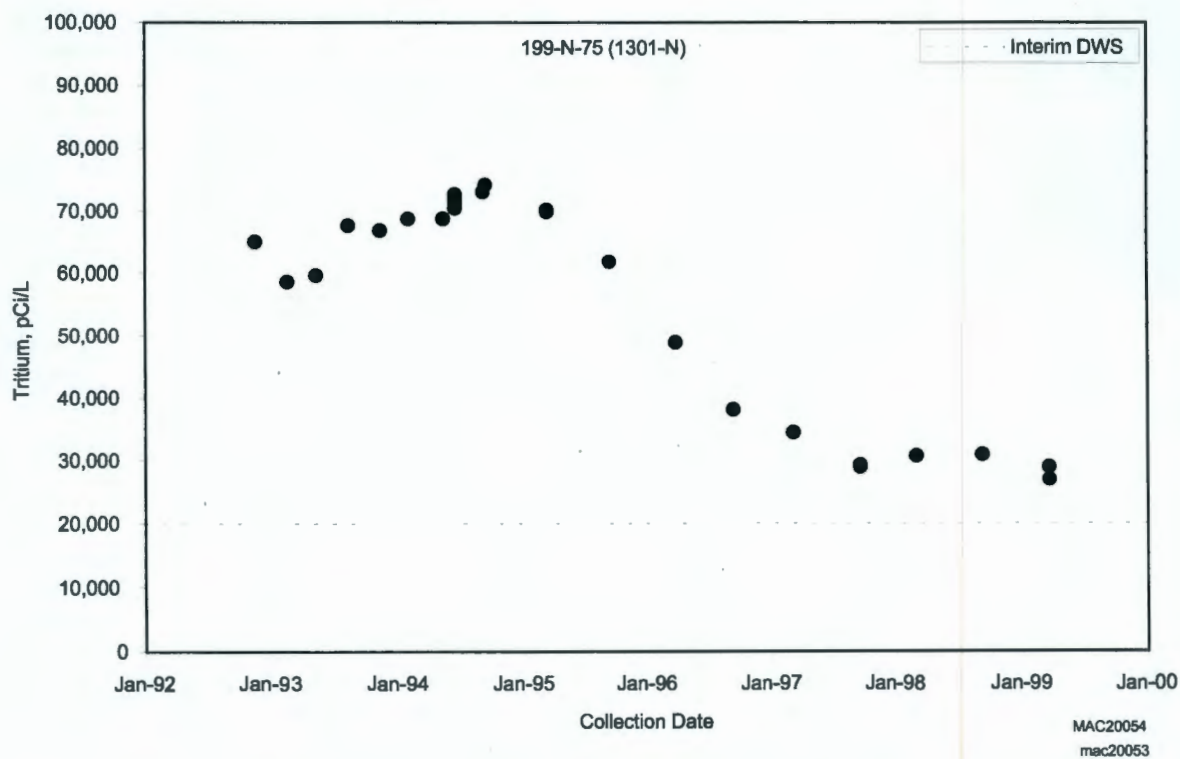
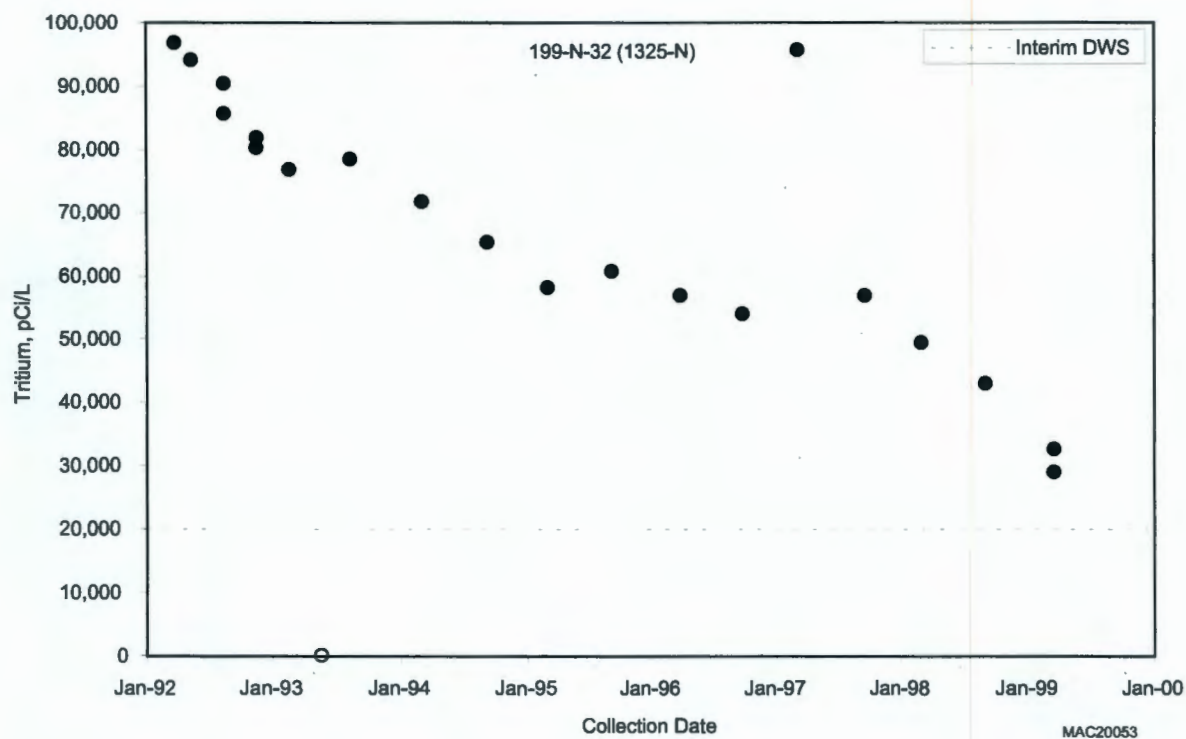


Figure 2.4-2. Tritium in Wells Monitoring 100 N Area



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

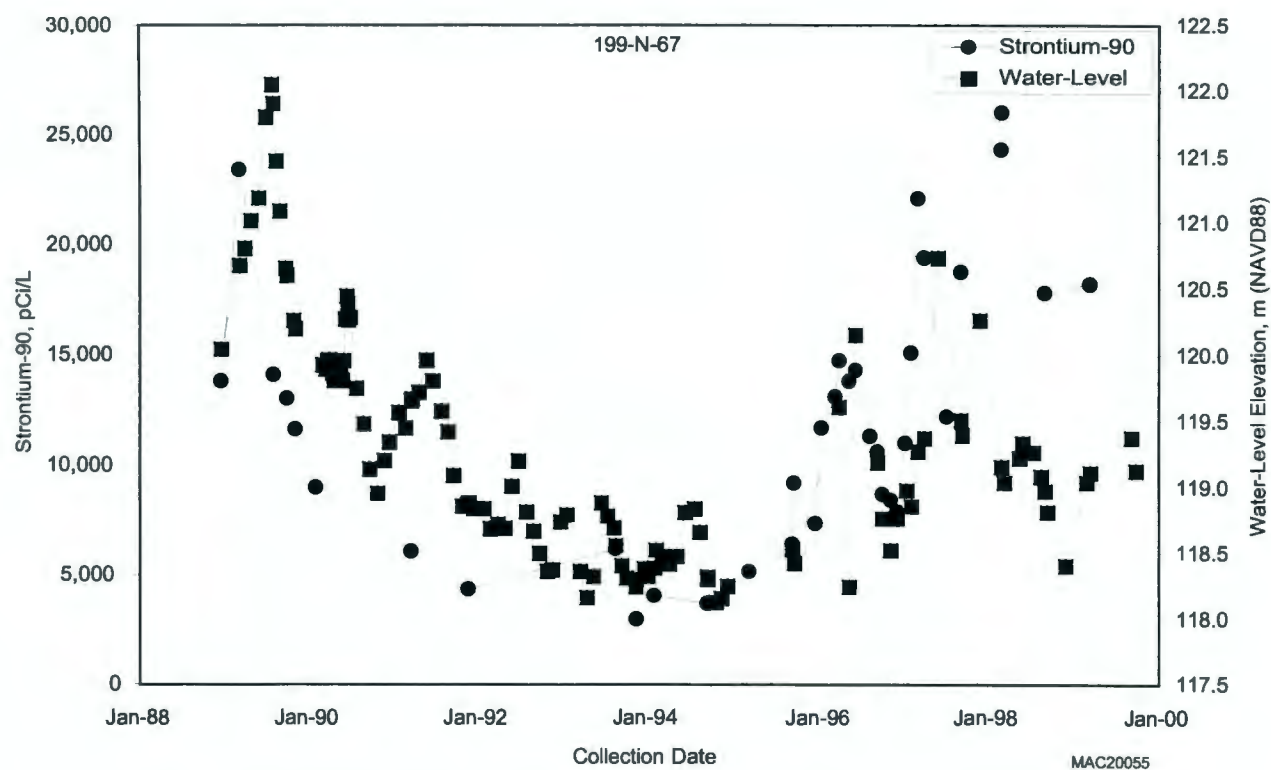


Figure 2.4-4. Strontium-90 and Water Levels in Well 199-N-67 Near 1301-N Facility

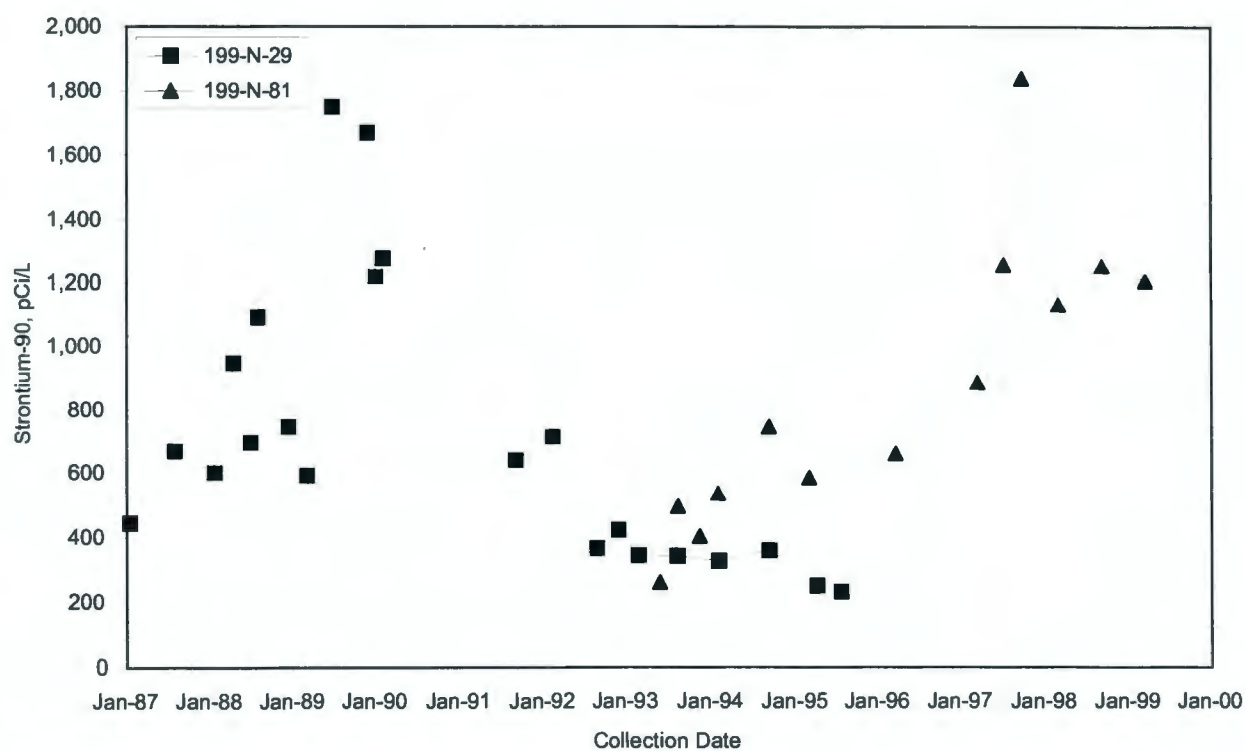


Figure 2.4-5. Strontium-90 in Wells Near 1325-N Facility

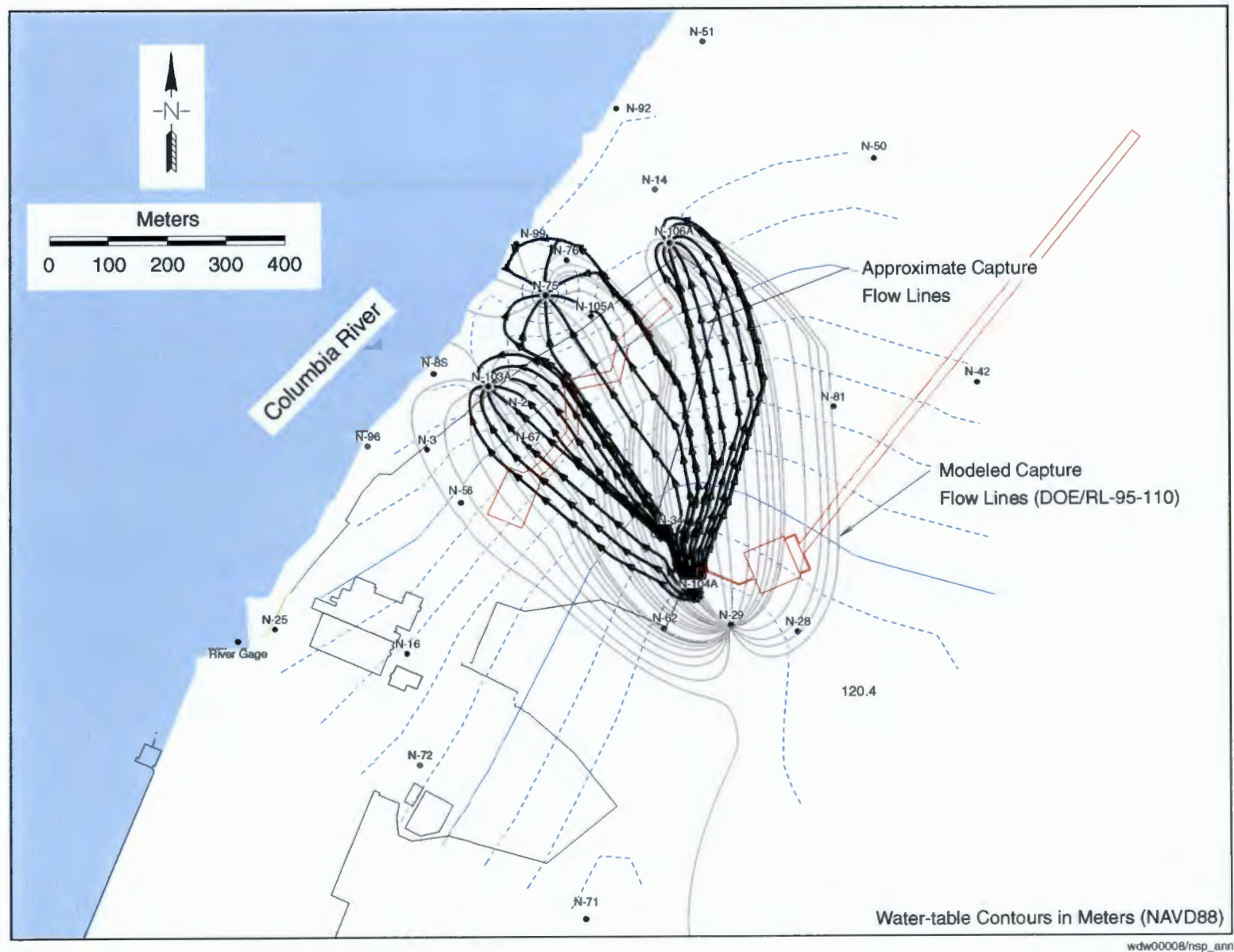


Figure 2.4-6. Groundwater Capture Zone from 100 N Area Pump-and-Treat System (DOE/RL-99-79)

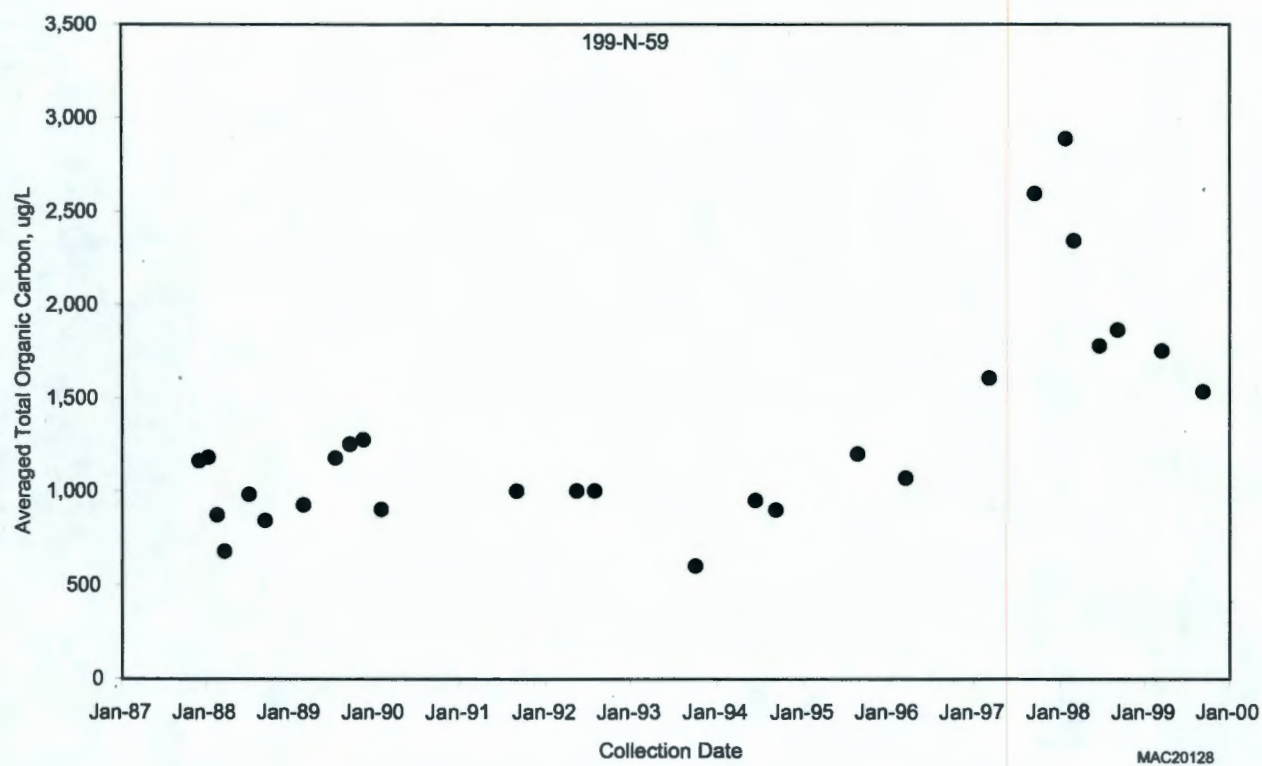
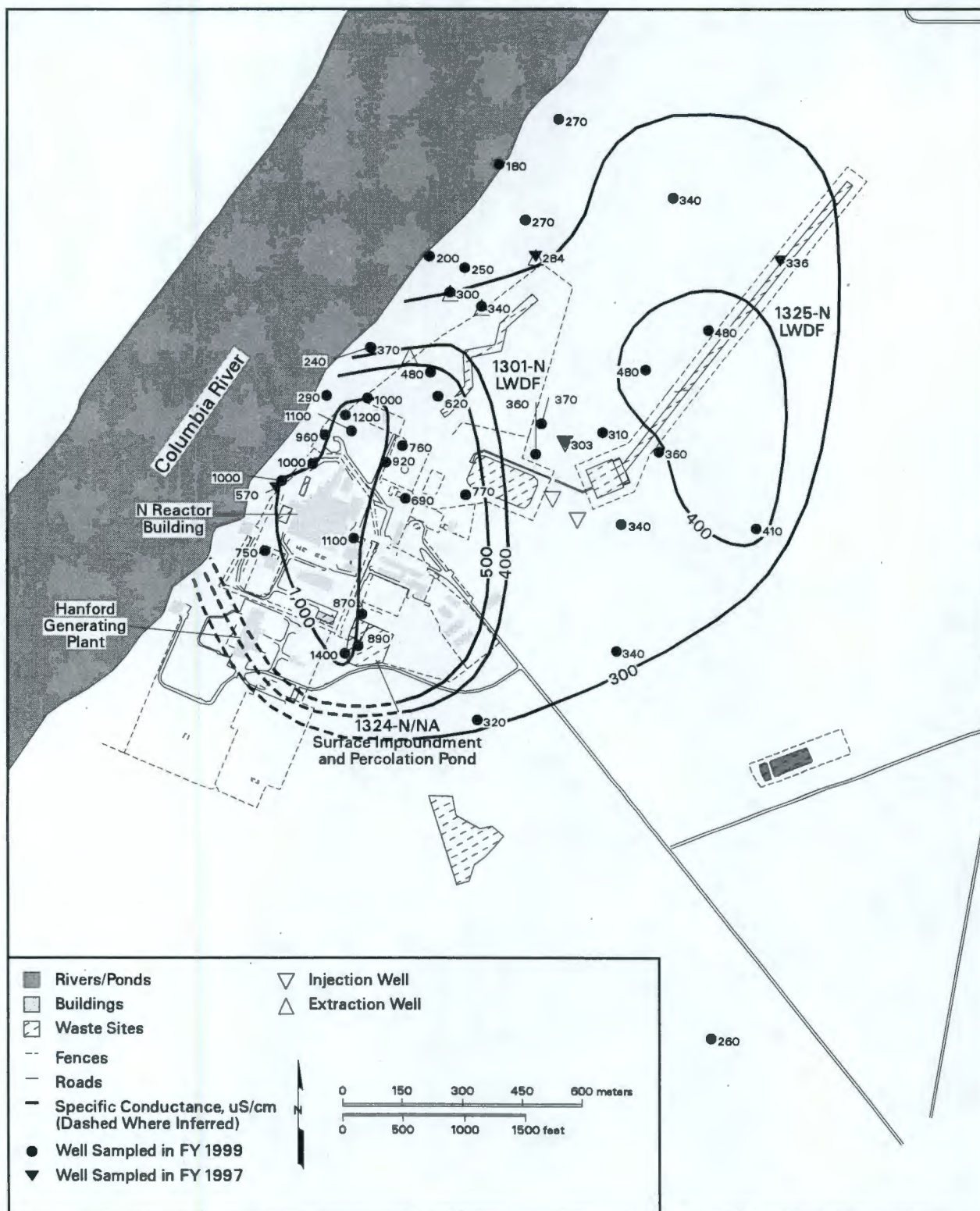


Figure 2.4-7. Total Organic Carbon in Well 199-N-59 Monitoring 1324-N/NA Site



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Figure 2.4-8. Specific Conductance in 100 N Area, Top of Unconfined Aquifer

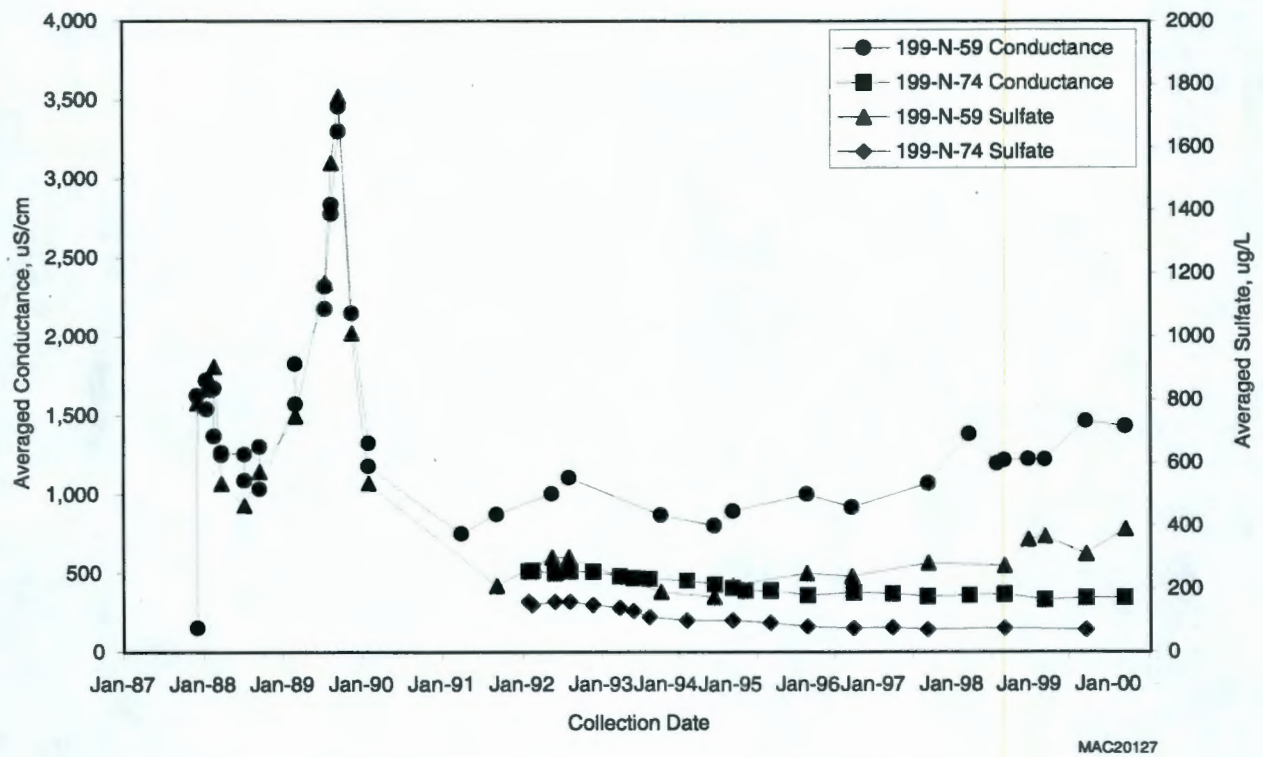
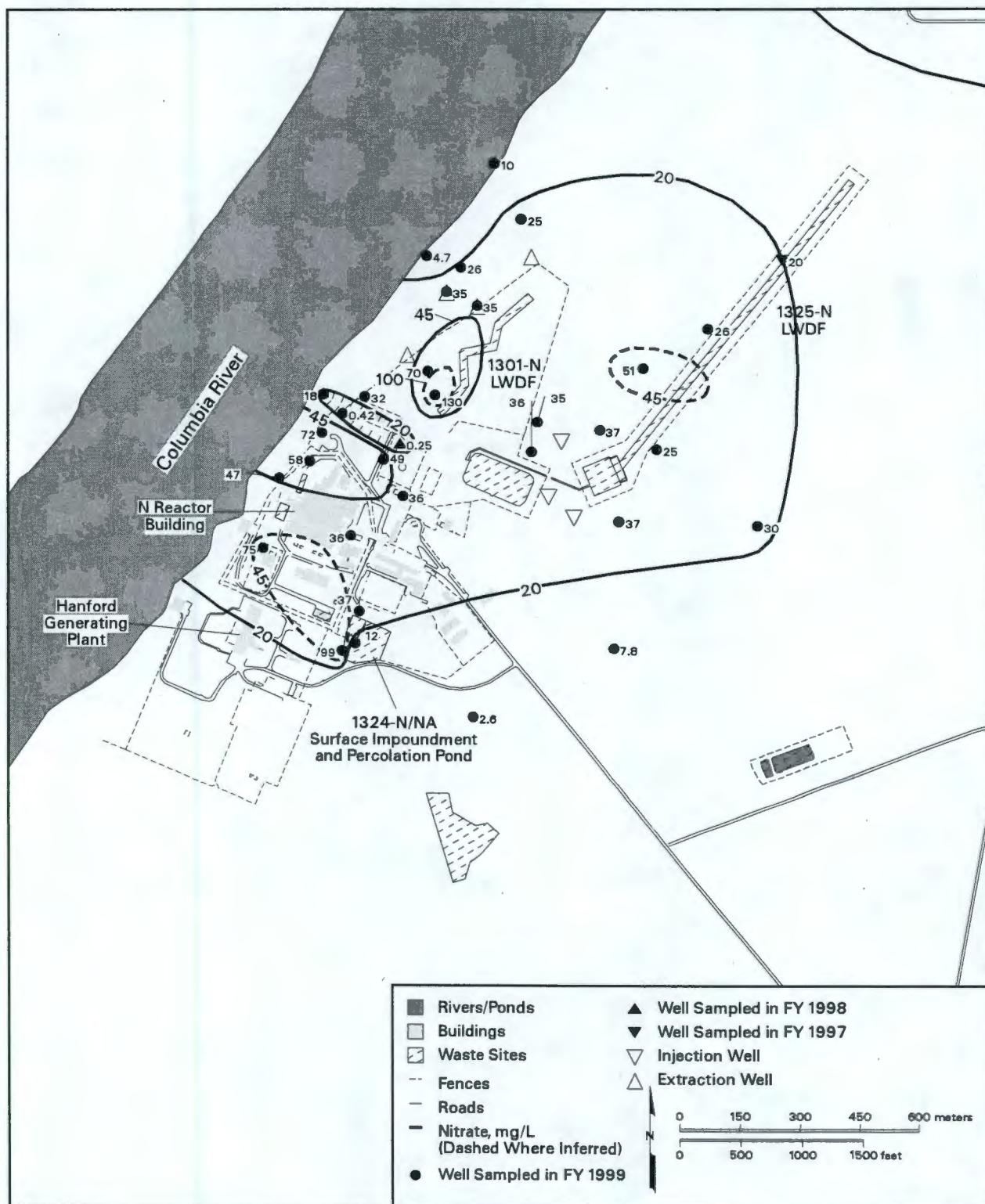


Figure 2.4-9. Specific Conductance and Sulfate in Wells Monitoring 1324-N/NA Facilities



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Figure 2.4-10. Nitrate Concentrations in 100 N Area, Top of Unconfined Aquifer

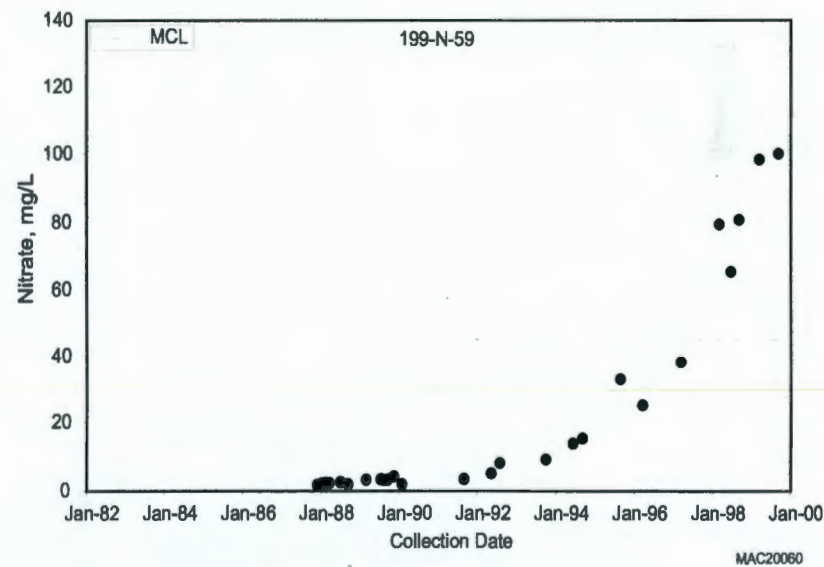
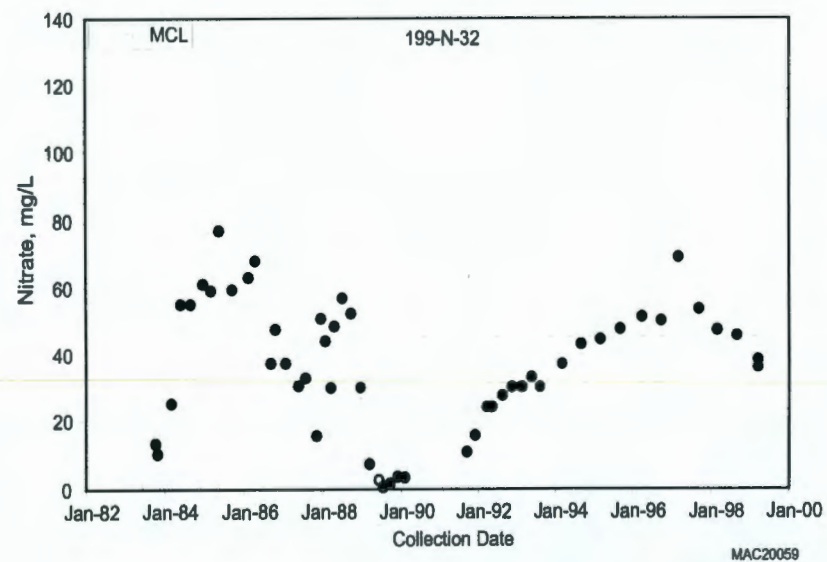
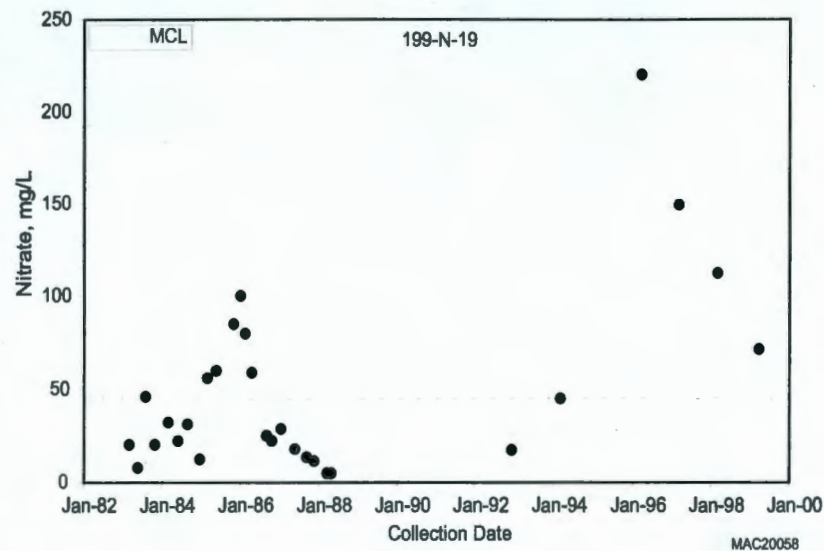
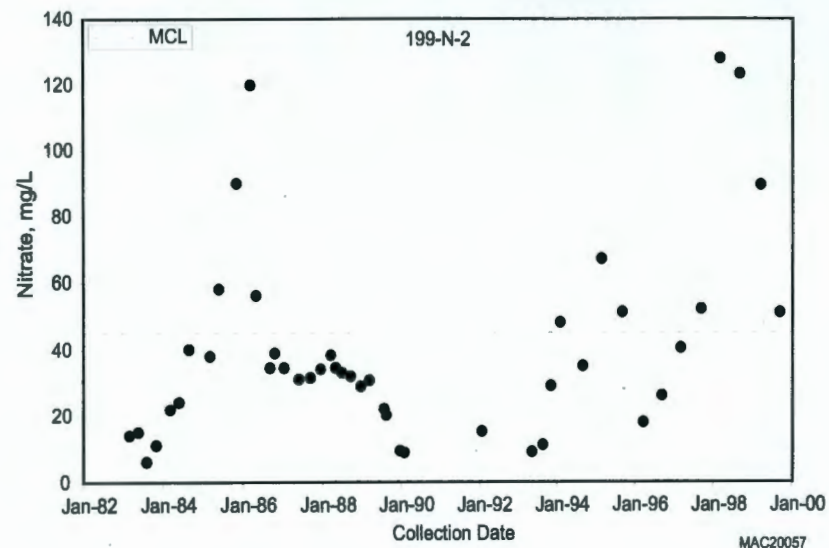


Figure 2.4-11. Nitrate in Wells Monitoring 100 N Area

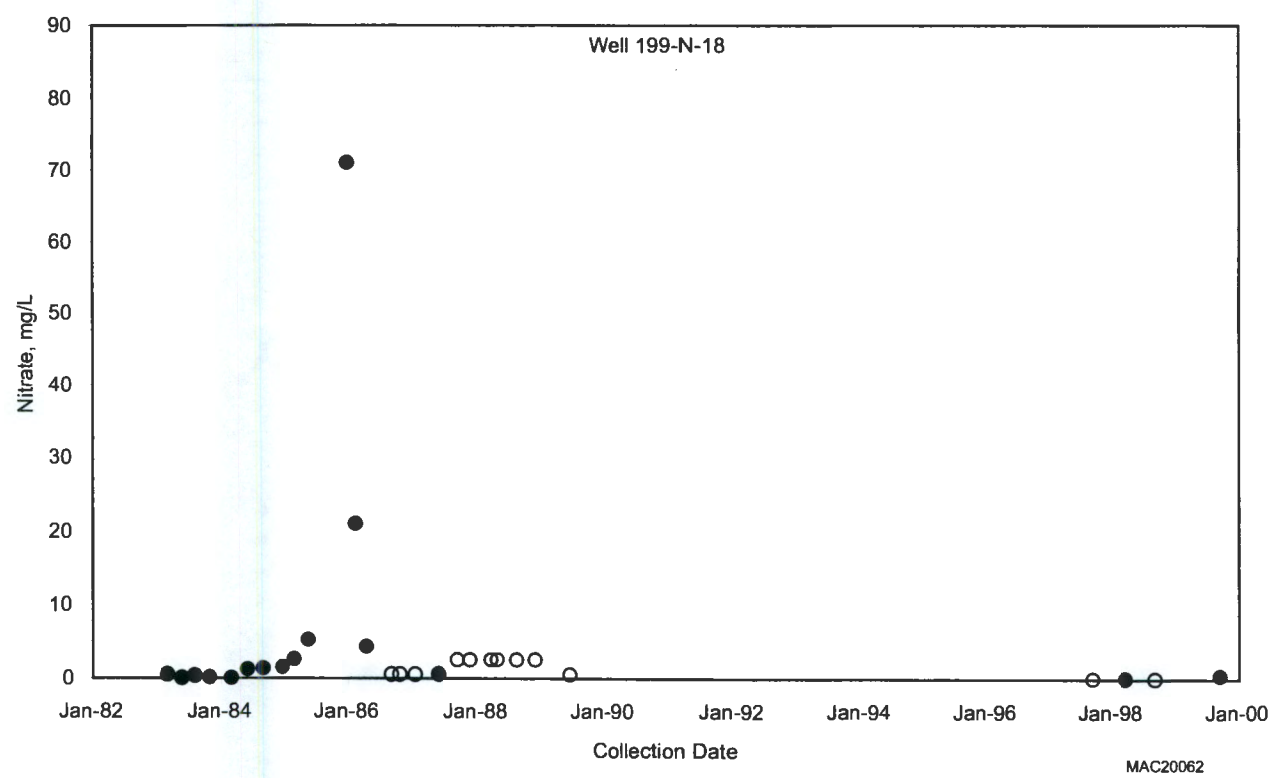
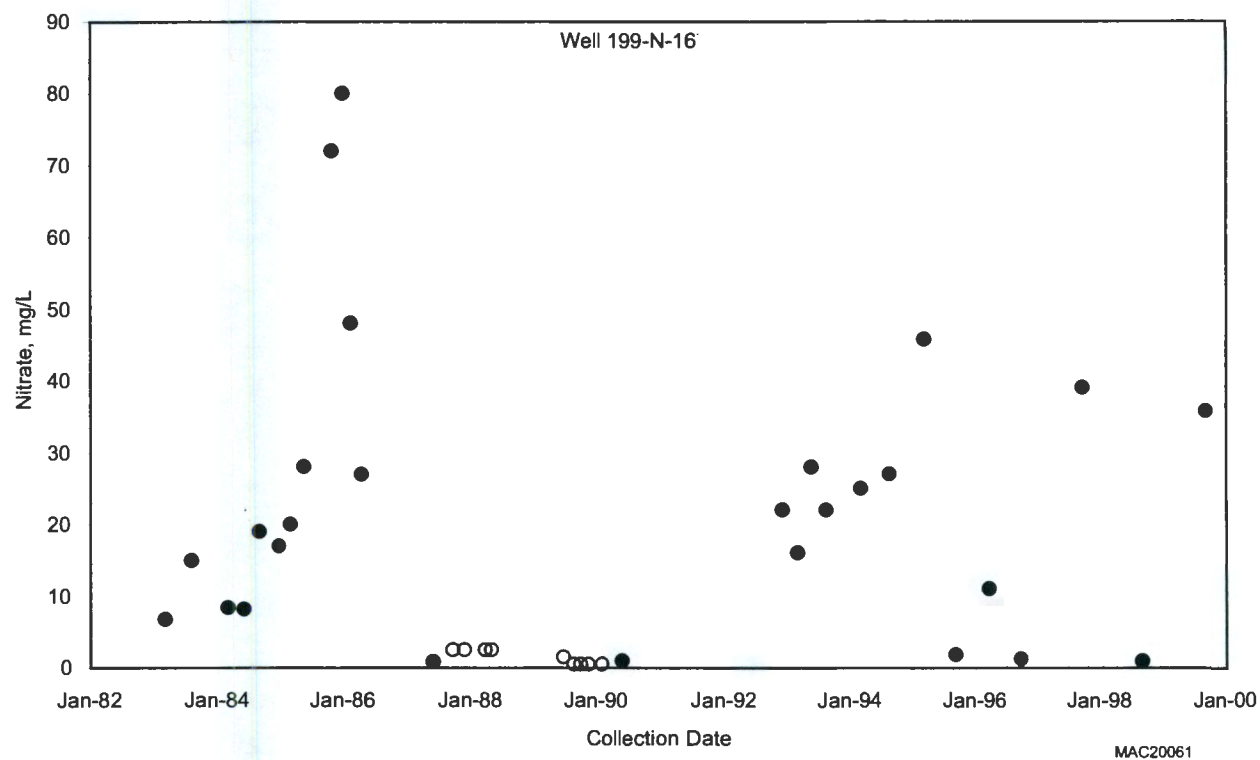


Figure 2.4-12. Nitrate in Wells 199-N-16 and 199-N-18

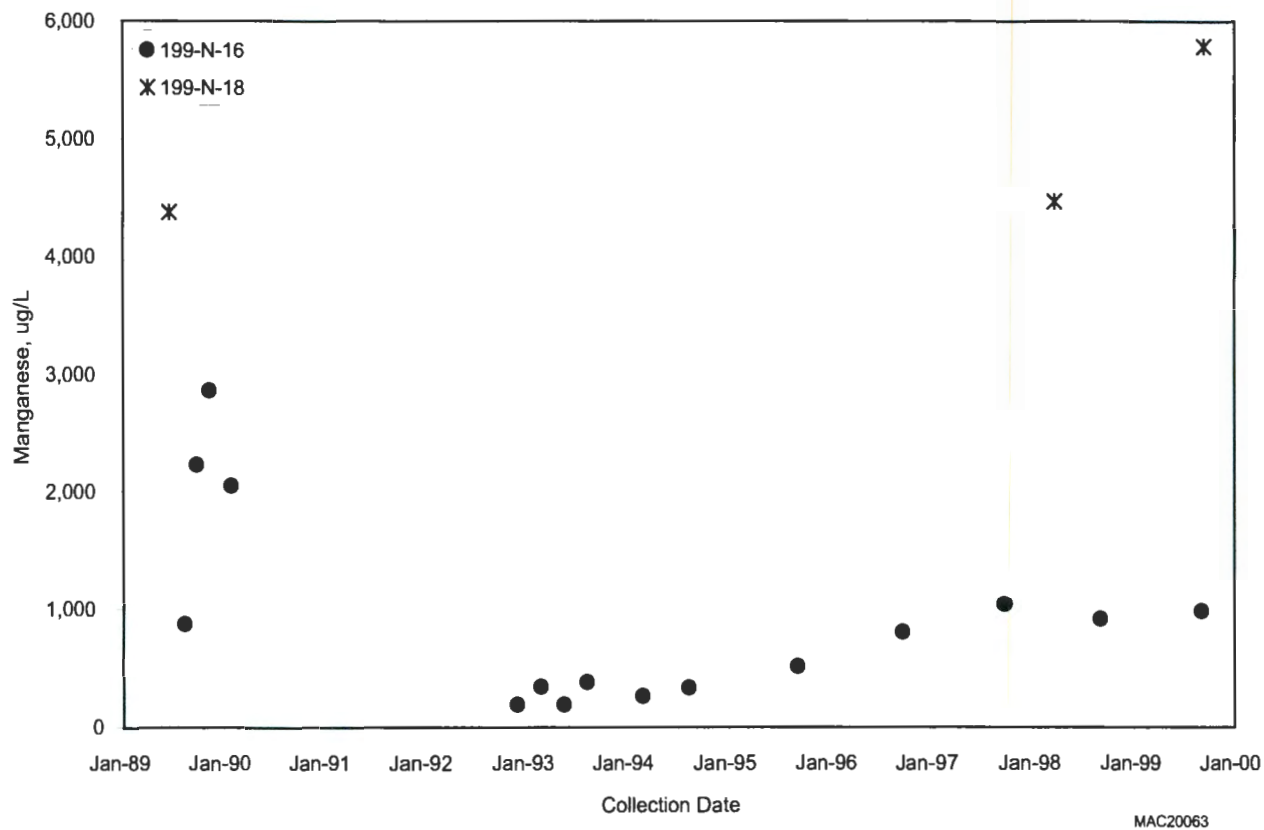


Figure 2.4-13. Manganese in Wells 199-N-16 and 199-N-18

2.5 100 D Area

M. J. Hartman, W. J. McMahon, R. F. Raidl

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. Recent activities to characterize the vadose zone in the 100 D Area are summarized in Section 3.1.3.

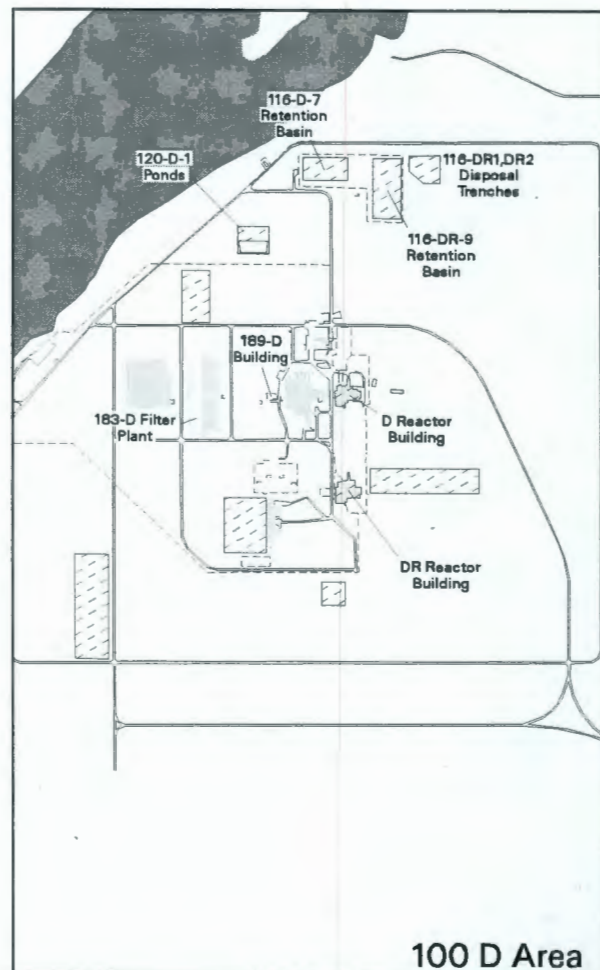
This section discusses groundwater in four general areas: the region around D and DR reactors and to the north, the 120-D-1 ponds RCRA unit, the southwestern 100 D Area, and the river shore.

2.5.1 D and DR Reactors

This section describes groundwater flow and contamination associated with waste sites in the central 100 D Area, near the D and DR reactors. The most prevalent contaminant is chromium. Nitrate and tritium are also elevated in broad plumes, while strontium-90 is above drinking water standards locally. Contamination associated with downgradient waste sites (116-DR-1 and 116-DR-2 disposal trenches; 116-D-7 and 116-DR-9 retention basins) is also discussed in this section. A pump-and-treat system near the retention basins removes chromium from groundwater.

2.5.1.1 Groundwater Flow

Groundwater flows to the north-northwest beneath the D and DR reactor buildings (see Plate 2). The distribution of contaminant plumes with sources near the reactor buildings confirms this direction of flow. During periods of high river stage in the spring and early summer, groundwater may flow toward the northeast (Section 3.5 in PNNL-12086). This effect, which is generally short-lived, is more pronounced in the north and northwest, closer to the Columbia River.



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Extraction wells 199-D8-53 and 199-D8-54A have created a depression in the water table north of the retention basins (see Plate 2). Section 2.5.1.6 describes the capture zone for these wells.

2.5.1.2 Chromium

The area around the D reactor building is a primary source area for a chromium plume that extends northward toward the Columbia River (Figure 2.5-1). The former retention basins and disposal trenches in the north also were contaminant sources. Previous interpretations (e.g., Section 5.6 of PNNL-12086) showed the entire 100 D Area underlain by a continuous area

of chromium contamination. In fiscal year 1999, data from new wells indicated that there are two separate plumes. The northeastern plume, originating near the reactor buildings, did not change significantly in fiscal year 1999. The center of this plume had annual average concentrations up to 630 µg/L in well 199-D5-14.

Chromium concentrations declined sharply in well 199-D5-15, north of the D reactor building, during the past year (Figure 2.5-2). The recent decrease, and a similar dip in the winter of 1996-97, were associated with lower specific conductance. Nitrate, a co-contaminant, also declined during these periods. These low chromium concentrations may be related to infiltration of fresh water from the surface. The 1996 low was linked to a leaking water line near the well. That line was blocked and is currently not in use. Well 199-D5-15 and two nearby wells were used to withdraw groundwater for a pilot-scale treatability test for removing chromium from 1994 to 1996 (DOE/RL-95-83). This pump-and-treat system may have caused declines in chromium during that time.

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 detect the possible impact of one RCRA site, through March 1999
- ▶ 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.

The northern chromium plume in the 100 D Area extends from the reactor buildings toward the Columbia River.

2.5.1.3 Nitrate

Nitrate is widely distributed in the 100 D Area at concentrations up to approximately twice the 45-mg/L maximum contaminant level (see Figure 2.1-4). The highest concentrations were measured in wells near the reactor buildings. Concentrations did not change significantly in fiscal year 1999.

2.5.1.4 Tritium

Tritium is above background levels in the 100 D Area, but exceeds the drinking water standard in only a few wells (see Plate 3). Two wells near the D reactor building had the highest average concentrations, 28,000 pCi/L. Many of the wells in the northwestern 100 D Area continued to have low tritium concentrations (less than 2,000 pCi/L) as a result of the influence of the Columbia River and, possibly, artificial recharge with fresh water.

2.5.1.5 Strontium-90

Strontium-90 exceeds the drinking water standard in one well near D Reactor and sporadically in one well near the retention basins. Well 199-D5-12 is the only well that consistently has elevated strontium-90 (~30 pCi/L). Well 199-D5-15 had an increase in gross beta levels in November 1999 (14.4 pCi/L), but the sample was not analyzed for strontium-90. The reason for this increase is not known. Groundwater in this area is presumably influenced by past disposal of radionuclide-bearing effluent from the D Reactor fuel storage basin, which is located nearby.

In the northern 100 D Area, strontium-90 is above background levels in several wells near the pump-and-treat system but is below the drinking water standard

with one exception. Well 199-D8-68 has shown widely variable strontium-90 concentrations during its 3-year history (Figure 2.5-3). Strontium-90 data are sparse in this well, so the possibility of a seasonal variation is difficult to assess. Some of the increases in strontium-90 (e.g., late 1997, late 1998) appear to follow mid-year increases in water level. Another possible explanation relates to the well's proximity to waste sites that were excavated and remediated in fiscal years 1997 through 1999 (see Section 2.5.4). It is possible that groundwater recharge increased because of the application of dust-control water or natural precipitation collecting in the excavations. The increased recharge may have mobilized or desorbed strontium-90 in the vadose zone and carried it to groundwater. If that is the case, levels are expected to decrease after remediation is completed.

2.5.1.6 Groundwater Remediation

A pump-and-treat system operates in the 100 D Area as part of an interim action for the 100-HR-3 Operable Unit. 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 two extraction wells (199-D8-53 and 199-D8-54A) and treated and discharged in the 100 H Area.

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

Chromium-contaminated groundwater is pumped from two wells in the northern 100 D Area in an attempt to prevent the plume from reaching the Columbia River, where it could harm young salmon.

- 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 not justifying further operation, or the availability and feasibility of an alternative and superior treatment technique (ROD 1996b).

Remediation Progress During Fiscal Year 1999

The pump-and-treat system made progress toward achieving the remedial action objectives in 100 D Area during fiscal year 1999. Figure 2.5-4 shows the flow lines and hydraulic capture estimated to occur during a low-flow period in the Columbia River (November 1998), when groundwater flow to the Columbia River is greatest. The flow lines represent simulations of the paths that groundwater would follow. The flow paths curve toward the extraction wells, which capture the groundwater from beneath most of the high chromium area. In this simulation, groundwater that flows beneath the most significant waste sites in this area (retention basins, trenches and cribs) is prevented from reaching the Columbia River (DOE/RL-99-13).

Although designed primarily to prevent or reduce the amount of contaminated groundwater discharging into the Columbia River, the pump-and-treat system is also 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 treatment system performance and to provide the basis for selecting the final remedy as part of the record of decision.

During fiscal year 1999, the pump-and-treat system in 100 D Area extracted ~128 million liters of groundwater (Table 2.5-1). The treatment system conveys the influent to the 100 H Area, where it was treated and injected into the aquifer. A total of ~51 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-scale 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, Rev. 1). Uncertainty in this estimate is primarily associated with the lack of data on the vertical distribution of chromium in the aquifer, and the value should be viewed as an order-of-magnitude estimate. The rate at which chromium is discharging to the Columbia River via groundwater flow has also been estimated at ~0.07 kilograms per day (BHI-00469). This equates to a total mass flux of ~57 kilograms that would have entered the Columbia River via natural groundwater flow since July 1997. The actual flux is believed to be less because of the pump-and-treat system.

Influence on Aquifer Conditions

Chromium concentrations in the extraction wells and other monitoring wells vary seasonally (Figure 2.5-5). The highest concentrations are measured during the late fall and winter months, when the river stage is lowest. The lowest concentrations are measured in late spring and early summer months when runoff caused by snowmelt drains through the Columbia River and its tributaries. The concentrations of chromium measured in wells 199-D8-68, 199-D8-69, and 199-D8-70 around the beginning of fiscal year 1999 were the highest since the pump-and-treat system began in 1997. The cause of the increase is unclear, but probably is an artifact of the changes caused by the high river stages in 1996 and 1997. The concentrations returned to more typical values in the spring and summer of 1999.

The start of pump-and-treat operations coincided with the second of consecutive flood stage years in the Columbia River during 1996 and 1997. Seasonal variations mask long-term trends in chromium concentration. The maximum concentration in the extraction wells since 1997 is less than the average concentration in those wells before the first high river year (1996) (Figure 2.5-6). Wells 199-D8-53 and 199-D8-54A were originally installed as *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) monitoring wells in 1991 and converted to pump-and-treat extraction wells in 1997.

Because the concentration of chromium in the extraction and compliance wells shows a cyclical pattern, an overall trend in concentration over the last 2 years is difficult to identify. The concentration has declined below 22 µg/L in the extraction and compliance wells twice, during the summer 1997 (all five wells) and the summer 1999 (all except compliance well 199-D8-70), but both times the concentration rebounded above the action level by the following September. Because of the recurring elevated concentration of chromium in the compliance wells, the annual summary report (DOE/RL-99-13) 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.

2.5.2 120-D-1 Ponds

The 120-D-1 ponds (commonly known as D ponds) received effluent from a water treatment plant and related facilities from 1977 until 1994. The site was clean closed in fiscal year 1999. This means that all dangerous waste constituents or residues have been removed and no *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring is required in the future. The following discussion finalizes RCRA interpretation for this site.

2.5.2.1 Groundwater Flow

Groundwater generally flows toward the north beneath D Ponds (see Plate 2). When the stage of the Columbia River is high, flow direction is inferred to be toward the northeast. The rate of flow was estimated to be between 0.002 and 0.2 meter per day in March 1999 (see Table A.2).

2.5.2.2 RCRA Parameters

None of the indicator parameters exceeded critical mean values in fiscal year 1999, indicating the ponds have not contaminated groundwater.

Specific conductance has increased beneath the ponds since dilution effects dissipated (Figure 2.5-7). Groundwater chemistry in the vicinity of the ponds was affected by dilution while the ponds were in use. The dilution effect influenced groundwater chemistry even in upgradient well 199-D5-13. After discharges to the ponds ceased in 1994, groundwater from upgradient sources with high specific conductance flowed past the well and specific conductance increased. This parameter continued to increase in downgradient wells during fiscal year 1999.

Groundwater beneath the ponds has relatively high pH because of the influence of underlying ash (Figure 2.5-8). The elevated pH is caused by pond discharge reacting with materials in the ash that underlies the ponds to within 10 meters of the water table (WHC-EP-0666, WHC-SD-EN-EV-033).

The only regulated dangerous waste that may have been discharged to D ponds was mercury. No mercury has ever been detected in groundwater downgradient of the ponds.

2.5.3 Southwestern 100 D Area

This section describes groundwater flow and contamination in the southwestern 100 D Area, which contains the highest concentrations of chromium measured in groundwater on the Hanford Site. Twelve new wells were installed in fiscal year 1999, which helped

define the boundaries of the chromium plume. An innovative technique for groundwater remediation, using chemical redox principles, was tested in fiscal years 1997 through 1999. Test results indicate that the technique is effective at transforming hexavalent chromium to a less toxic, less mobile form (trivalent chromium).

2.5.3.1 Groundwater Flow

The direction of groundwater flow in the southwestern 100 D Area varies with river stage. Estimates range from 0.1 to 0.3 meter per day toward the northwest during normal river stage. Flow was toward the northeast when the river stage was high. These estimates were based on water-level measurements near the redox site in 1997, 1998, and 1999, an estimated hydraulic conductivity of 16.5 meters per day, and an average porosity of 0.14. The latter terms were obtained from hydraulic tests of site wells and laboratory analyses of site sediment.

2.5.3.2 Chromium

The chromium plume in the southwestern 100 D Area is long and thin, oriented perpendicular to the Columbia River (see Figure 2.5-1). The highest average concentrations in fiscal year 1999 were over 1,000 $\mu\text{g/L}$ in wells 199-D4-15 and 199-D5-43. Twelve new wells that were drilled in fiscal year 1999 provided data that helped define plume boundaries and concentrations. The suspected source of contamination is sodium dichromate stock solution that was used in the 190-DR building or nearby waste sites.

Estimates for the total volume of contaminated groundwater and total mass of chromium in the chromium plume in the southwestern corner of the 100 D Area suggest values that exceed 536 million liters and 233 kilograms, respectively (BHI-01309, Rev. 0). This plume has been the target for a remediation test using a reduction/oxidation (redox) manipulation method (PNNL-12153), which converts the hexavalent chromium in situ to a less soluble form (trivalent chromium). The record of decision for the 100-HR-3

Operable Unit has been amended to include use of the redox method for interim remedial action (ROD 1999b).

The redox technique appears to be successful in chemically reducing hexavalent chromium to a less toxic, less mobile form (trivalent chromium) and will be expanded in fiscal year 2000. Results of a treatability study in 1997 through 1999 show that chromium concentrations have declined in downgradient wells.

Testing of an innovative technique for cleaning groundwater in the 100 D Area was completed in fiscal year 1999. The technique appears to be successful in chemically reducing chromium to a less toxic form. The system will be expanded in fiscal year 2000.

The method created a permeable treatment zone in the aquifer to remediate contaminants that are sensitive to chemical reduction. The treatment zone was created by reducing the ferric iron to ferrous iron within the minerals of the aquifer 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 ± 6 years. 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 reoxidized under ambient environmental conditions, and will thus remain immobile.

Concentrations of hexavalent chromium are below the detection limit (less than 7 $\mu\text{g/L}$) in the treatment zone (e.g., 199-D4-1 and 199-D4-7), and have declined in downgradient wells (e.g., 199-D4-4, 199-D4-5, and 199-D4-6; Figure 2.5-9). Dithionite was injected into

a single well, 199-D4-7, in October 1997, creating a narrow treatment zone estimated at ~15 meters in diameter. Chromium concentrations dropped sharply in downgradient wells, and have remained below the detection limit in the injection well and other wells in the treatment zone. Chromium concentrations in the downgradient wells rebounded somewhat in the first half of 1998, possibly because of changes in the direction of groundwater flow. Chromium concentrations in the downgradient wells dropped again following the second series of injections during May to July 1998. This series of injections included wells 199-D4-9, 199-D4-10, 199-D4-11, and 199-D4-12, and created a longer treatment zone. Chromium concentrations continued to be low until spring and summer 1999. At that time, high river stage reversed the flow direction, causing chromium to increase in wells 199-D4-5 and 199-D4-6. This revised gradient can also be seen by the decrease in chromium concentrations in well 199-D4-2, which is upgradient of the site during normal conditions. Residual effects of redox treatment cause the groundwater to have high specific conductance, while ambient groundwater and river water have lower specific conductance. Thus specific conductance varies inversely with chromium (see Figure 2.5-9). The changes in specific conductance are evidence of changes in flow direction.

Dithionite was injected into well 199-D4-21 in September 1999, lengthening the treatment zone. Effects of that injection will be monitored in fiscal year 2000.

Although chromium concentrations have declined significantly, it is too early to tell how the redox method will perform at this site in the long term. Not enough time has elapsed since the July 1998 injection for groundwater migrating through the treatment zone to fully influence the aquifer downgradient.

Other effects of the redox method include decreases in dissolved oxygen and nitrate and increases in aluminum, iron, manganese, and nitrite. Although iron and manganese are elevated in the treatment zone, they are not expected to be mobile downgradient from the zone because they will reoxidize, and become

immobile, once they contact untreated sediment. Chromium, however, cannot be reoxidized to its hexavalent state in the natural oxidizing conditions at the 100 D Area.

Wells in and downgradient of the treatment zone also show residual effects of the injected reagent. Although much of the reacted reagent (sodium dithionite with potassium carbonate/bicarbonate as a buffer) was pumped from the test wells, some of it remained in the aquifer. Residual effects included elevated carbonate/bicarbonate, potassium, sodium, and sulfate. These constituents cause elevated specific conductance. High gross beta activity that was observed in well 199-D4-1 was caused by potassium-40, a natural component of potassium. Gross beta levels will decline as the residual reagent dissipates. Another potential source of potassium was from tracer tests conducted before the initial injection and in 1999.

Sulfate increased in well 199-D4-13 in most of fiscal year 1999 (Figure 2.5-10). The increase is probably caused by disposal of withdrawn water containing spent reagent and reaction products, which was dripped to the ground near this well. The increase in sulfate probably does not reflect an influx of residual reagent, because well 199-D4-13 is not in the flow path of the redox test site and increases in sulfate were not observed in nearby wells 199-D4-14 and 199-D4-15.

In addition to the monitoring wells, five sets of sampling tubes, each with multiple depths, are used to monitor water in the substrate of the Columbia River downgradient of the site (Section 2.5.5). These data will be used to help assess the performance and side effects of the redox method. However, it is too soon to see effects at the Columbia River.

The redox demonstration will be expanded to a full-scale remediation system beginning in fiscal year 2000. Fourteen new injection/withdrawal wells are planned for fiscal year 2000 to expand the redox barrier. Expansion will continue until the barrier is long enough to prevent groundwater exceeding 20 µg/L chromium from reaching compliance wells near the Columbia River (ROD 1999b).

2.5.3.3 Tritium

Tritium in the southwestern 100 D Area may have migrated from the 100 N Area (Figure 2.5-11). Concentrations in well 699-87-55, located upgradient of 100 D Area, were much higher in the 1970s and 1980s than they are now and have declined for the last 10 years. Well 199-D2-6, in the southwestern 100 Area, showed increases in tritium in 1996 and 1997. This well is downgradient of well 699-87-55, so it is likely that the peaks in well 199-D2-6 are related to previous high values in well 699-87-55. Tritium levels declined in well 199-D2-6 in fiscal year 1999, but remained at 4,600 pCi/L, slightly above pre-1996 levels. Well 199-D3-2, west of the 100 D Area, appears to be linked to the 100 N tritium plume and had concentrations of 35,000 pCi/L in fiscal year 1999.

2.5.4 Waste Site Remediation

Remedial action of waste sites in the northern 100 D Area continued in fiscal year 1999. These activities consisted of removing and stockpiling clean overburden soil and excavating contaminated soil and debris for disposal. 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. The sites have not yet been back-filled with clean soil, so the excavations remain open, and water will be applied as needed to control dust until they are stabilized. Groundwater in the 100 D Area is 16 to 20 meters below the ground surface. The waste sites that were excavated in fiscal year 1999 include the following:

- 116-D-7 and 116-DR-9 retention basins (and associated sludge pits) — Excavation began in fiscal year 1998 and was completed during the first quarter of fiscal year 1999 (October 1998 for 116-D-7 and December 1998 for 116-DR-9). The maximum depths of the excavations were 4.6 to 4.7 meters. In the 116-D-7 basin, results of soil analyses for hexavalent chromium ranged from below the detection limit up to 18 mg/kg on the floor of the excavation.

- 116-DR-1 and 116-DR-2 trenches — Excavation continued from fiscal year 1998. Limited areas of contamination were excavated in fiscal year 1999. The remaining contamination will be excavated in fiscal year 2000. The maximum depth was ~4.6 meters.
- 1607-D2 septic tank — Excavation began in fiscal year 1998 and was completed in October 1998. The maximum depth was 4.7 meters.
- North process effluent pipelines — These pipelines, located north of D Reactor, were removed in fiscal year 1999. The depths of the resulting trenches ranged from 2 to 6 meters.

2.5.5 Water Quality at Shoreline Monitoring Locations

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. Spacing between tubes installed in 1996 and 1997 ranges from 70 to 350 meters. Tube sites completed in 1996 included only one sampling tube; sites completed in 1997 includes up to three tubes installed at different depths to a maximum of 8.8 meters. Seeps are locations where groundwater discharges above the river level.

2.5.5.1 Aquifer Sampling Tube Results

Analyses of samples collected in fall 1998 had concentrations of hexavalent chromium ranging from undetected in tubes from the downstream end of the 100 D Area to 783 µg/L within the chromium plume

in the southwestern 100 D Area. The highest nitrate concentrations (49 mg/L) also were detected in samples collected from a tube in the southwestern chromium plume. Results were consistent with earlier sampling rounds and with analytical results from nearby groundwater monitoring wells.

The highest tritium concentrations (2,600 and 3,200 pCi/L) were detected in samples collected from two sampling tubes along the downstream end of the 100 D Area. The same locations were characterized by the highest gross beta concentrations, at 8.6 and 23 pCi/L. These tubes are downgradient of the 116-DR-9 retention basins and 116-DR-1 and 116-DR-2 liquid waste disposal trenches.

2.5.5.2 Riverbank Seepage Results

Three riverbank seep sites were sampled during fall 1998. Specific conductance ranged from 160 to 245 µS/cm. These relatively low levels suggest that the samples contained substantial river water draining from bank storage.

Chromium concentrations of seep samples ranged from 111 µg/L near the upstream limit of the chromium plume in the southwestern 100 D Area to 21 µg/L downstream near the 100 D pump-and-treat compliance wells. Nitrate concentrations ranged from 7 mg/L at the upstream location to 16 mg/L near the 100 D Area pump-and-treat compliance wells.

Tritium concentrations ranged from 4,100 pCi/L in the upstream seep, nearest 100 N Area, to undetected in the downstream seep. Gross beta concentrations were near the method detection limit at all sites.

Table 2.5-1. Summary of 100 D Area Pump-and-Treat Performance for Fiscal Year 1999

Well or Sample Location	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	132.6	153.2	58.4	137	8.0
199-D8-54A	156.8	172.3	69.2	162	11.2
D-Influent	288.1	312.1	127.6	150.4 ^(a)	19.2

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

(a) Influent was not sampled. This number was calculated from concentrations and volumes in individual wells.

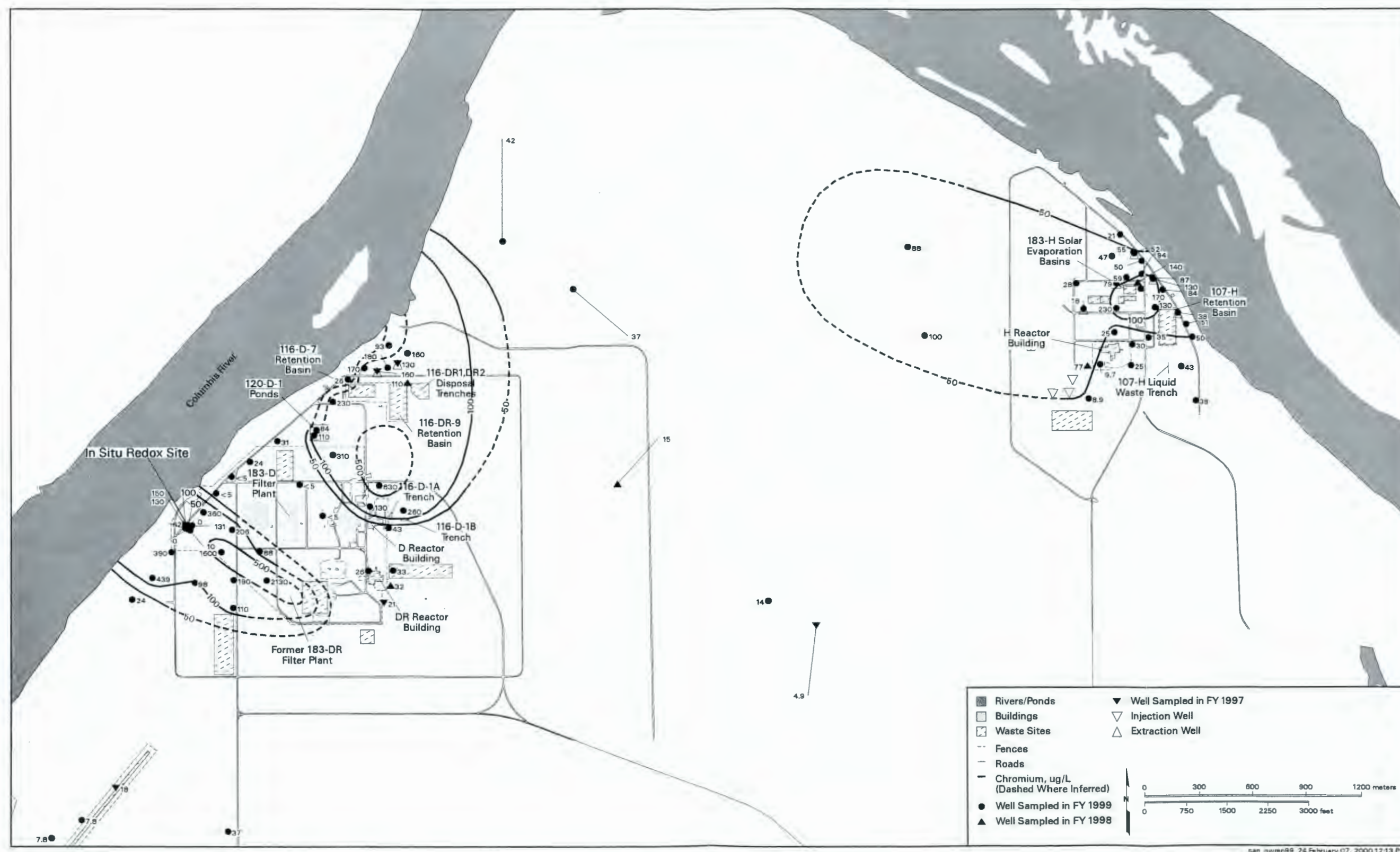


Figure 2.5-1. Average Chromium Concentrations in 100 D and 100 H Areas, Top of Unconfined Aquifer

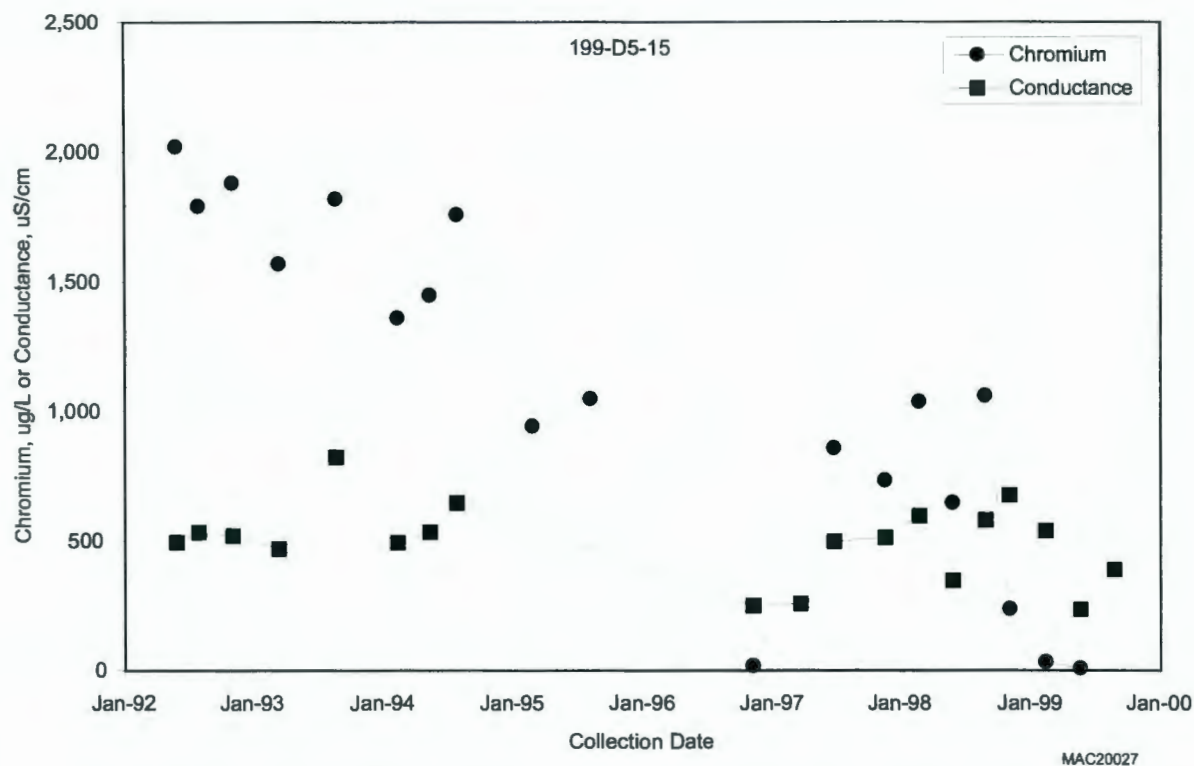


Figure 2.5-2. Chromium and Specific Conductance in Well 199-D5-15, North of D Reactor

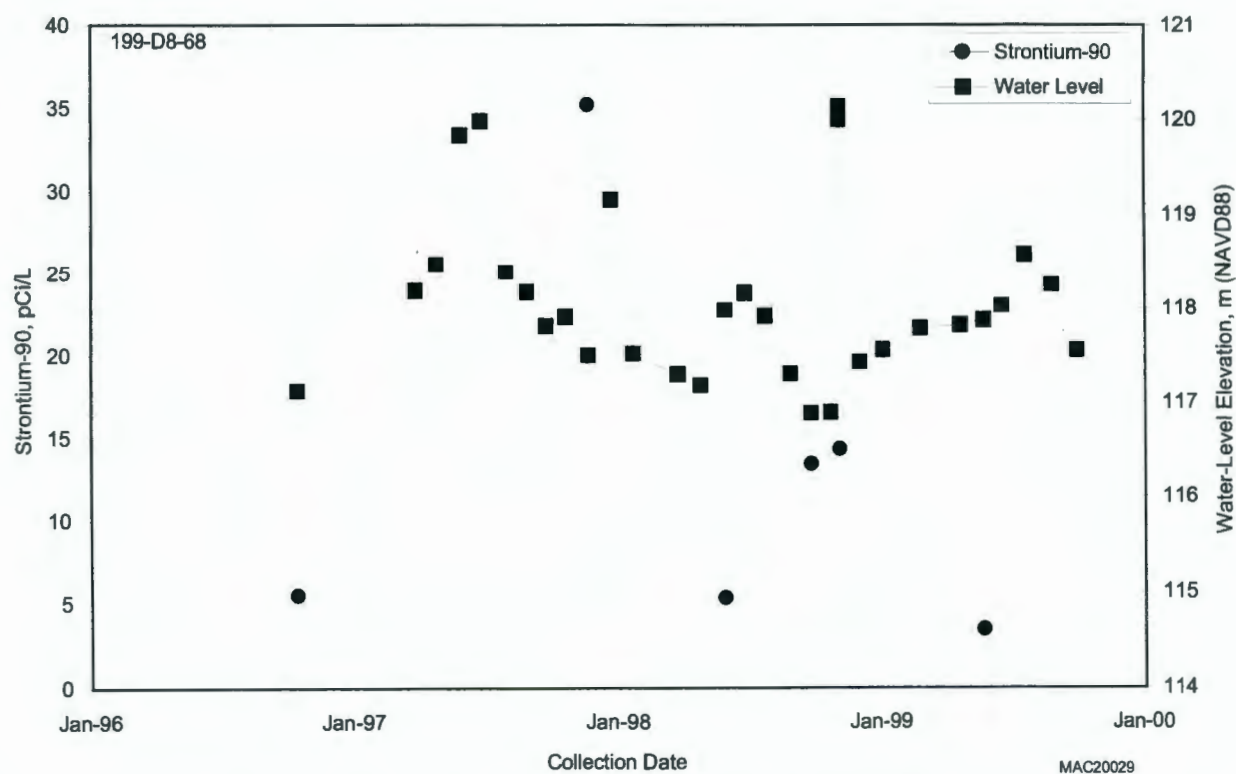


Figure 2.5-3. Strontium-90 and Water Levels in Well 199-D8-68, Northern 100 D Area

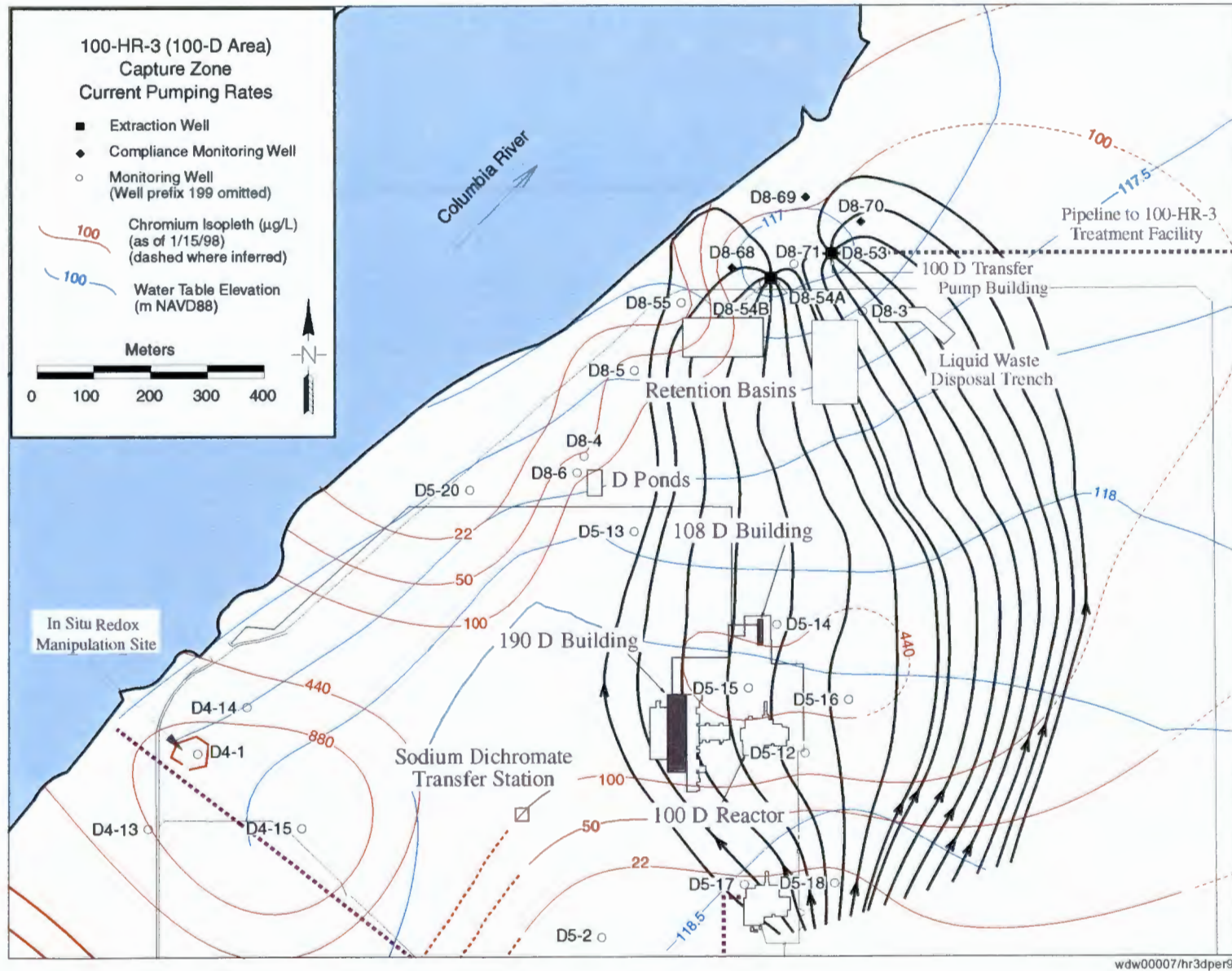


Figure 2.5-4. Capture Zone from 100-HR-3 (100 D Area) Pump-and-Treat System (DOE/RL-99-13)

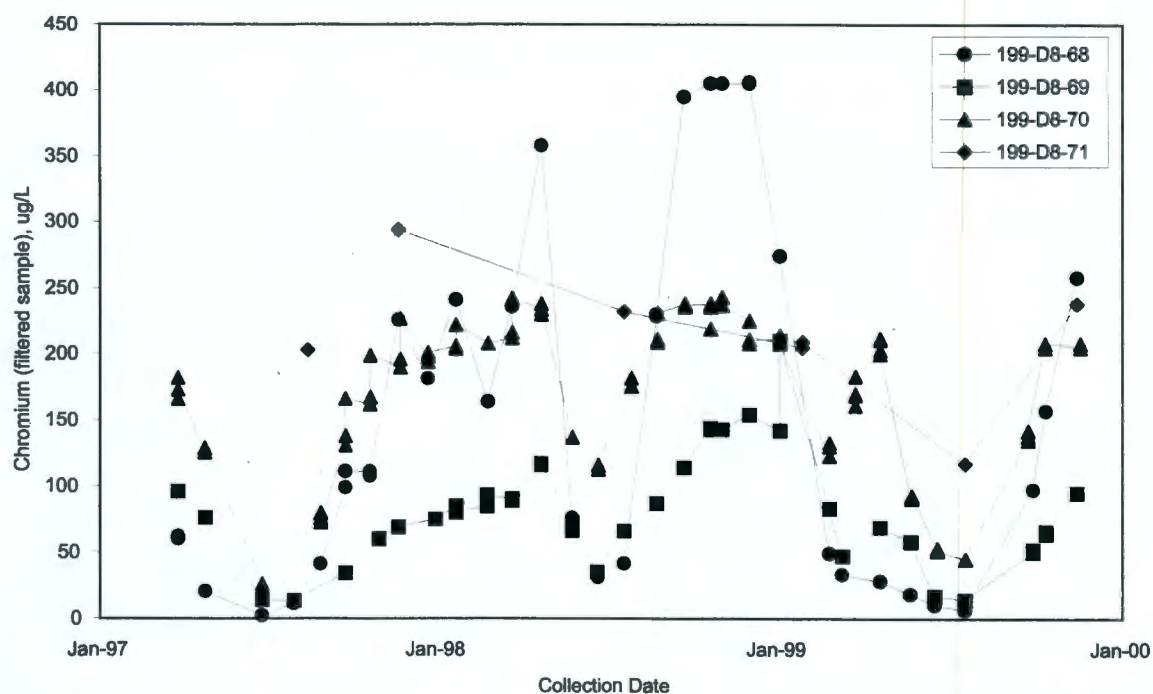


Figure 2.5-5. Chromium in Compliance Wells for the 100-HR-3 (100 D Area) Pump-and-Treat System

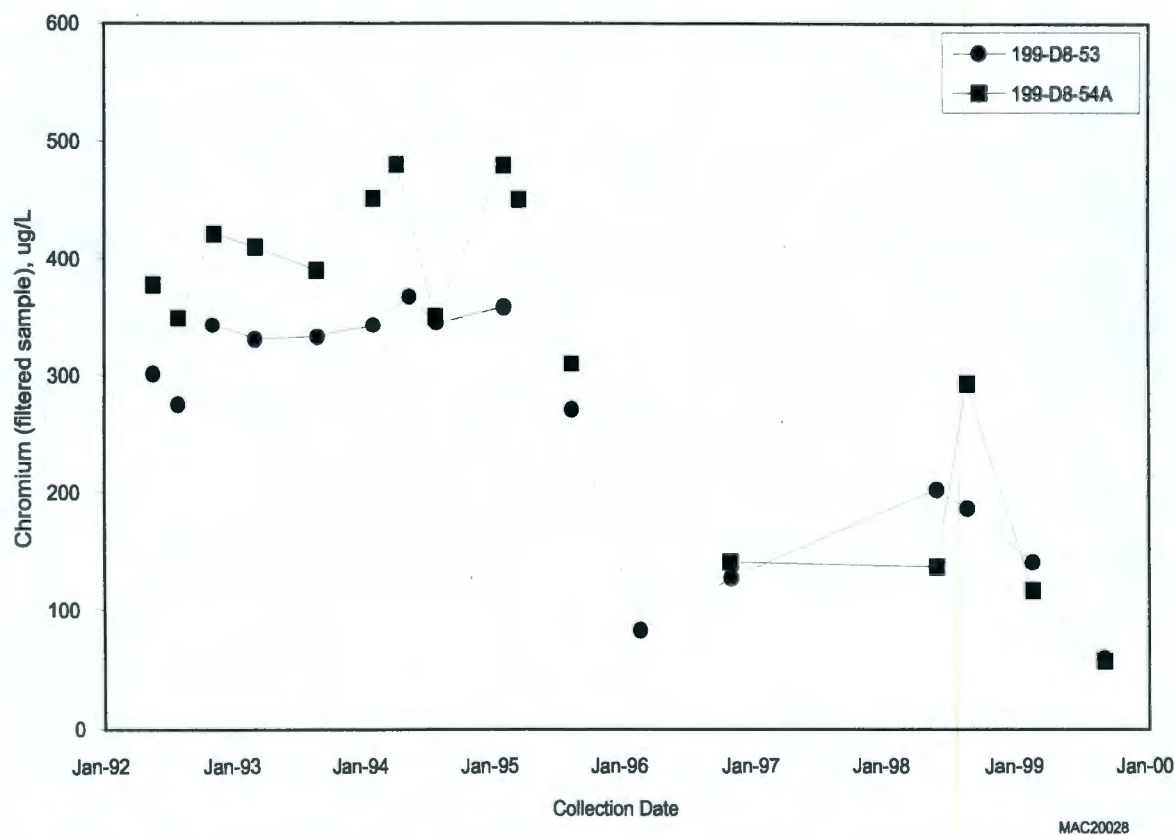
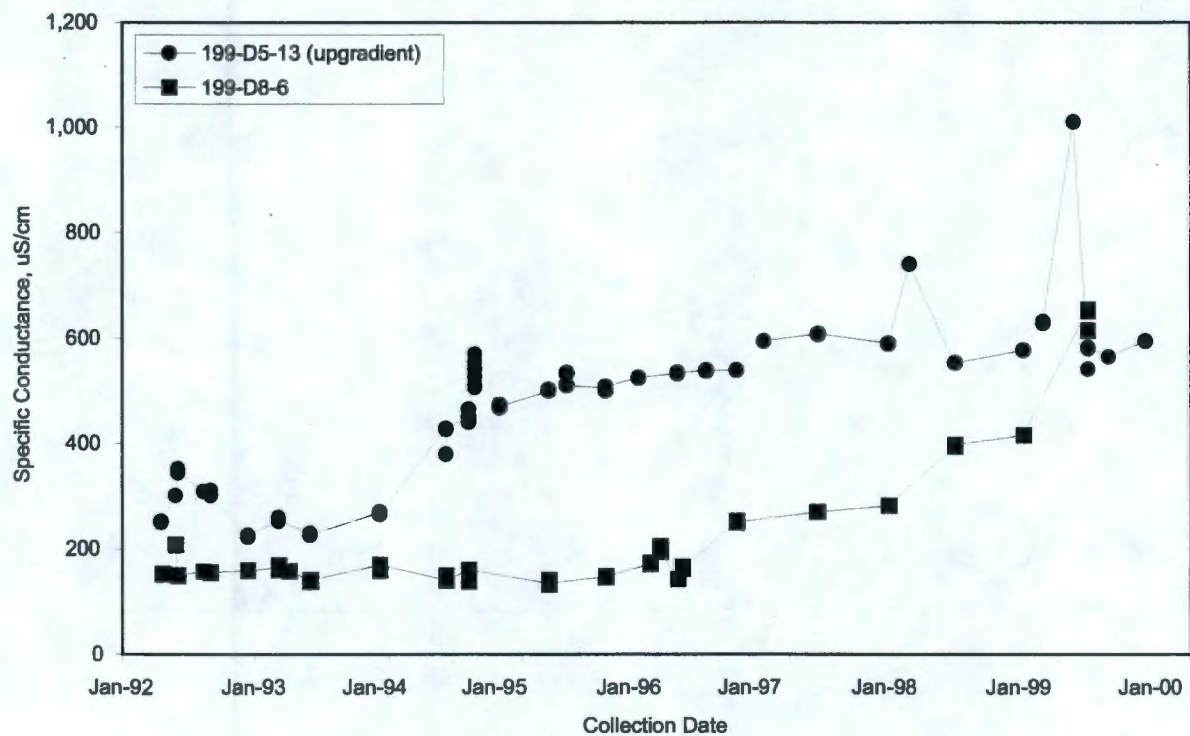
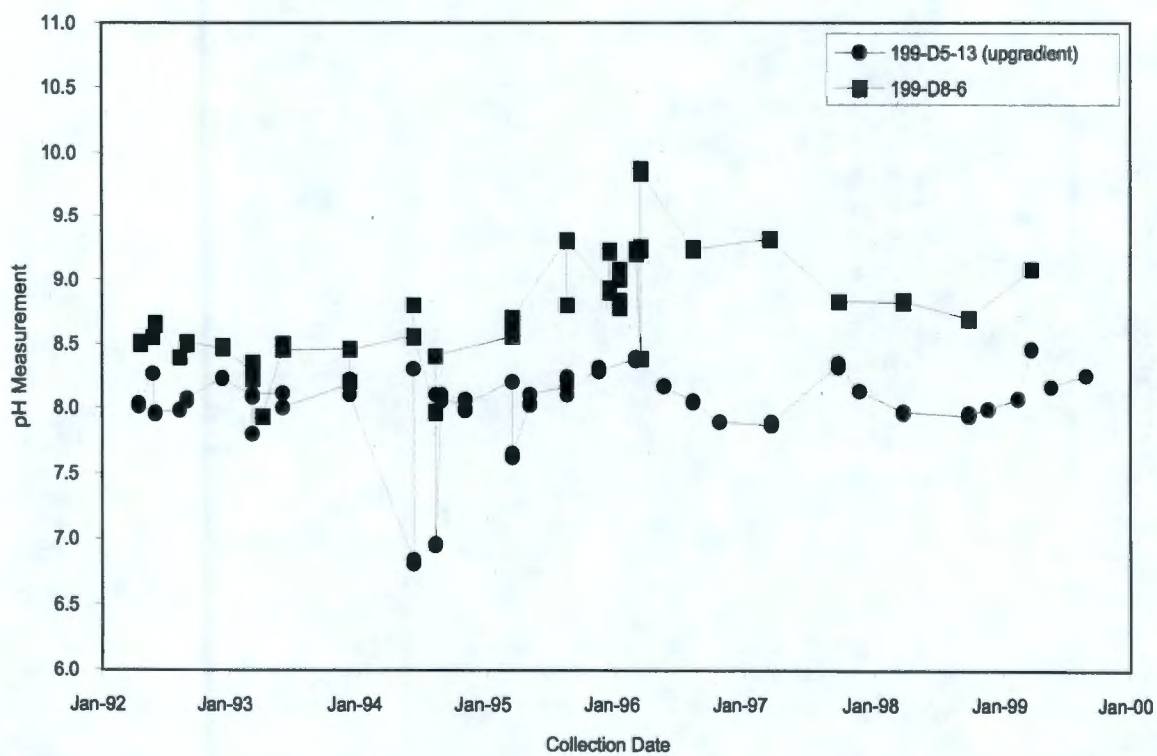


Figure 2.5-6. Chromium in Extraction Wells for 100-HR-3 (100 D Area) Pump-and-Treat System



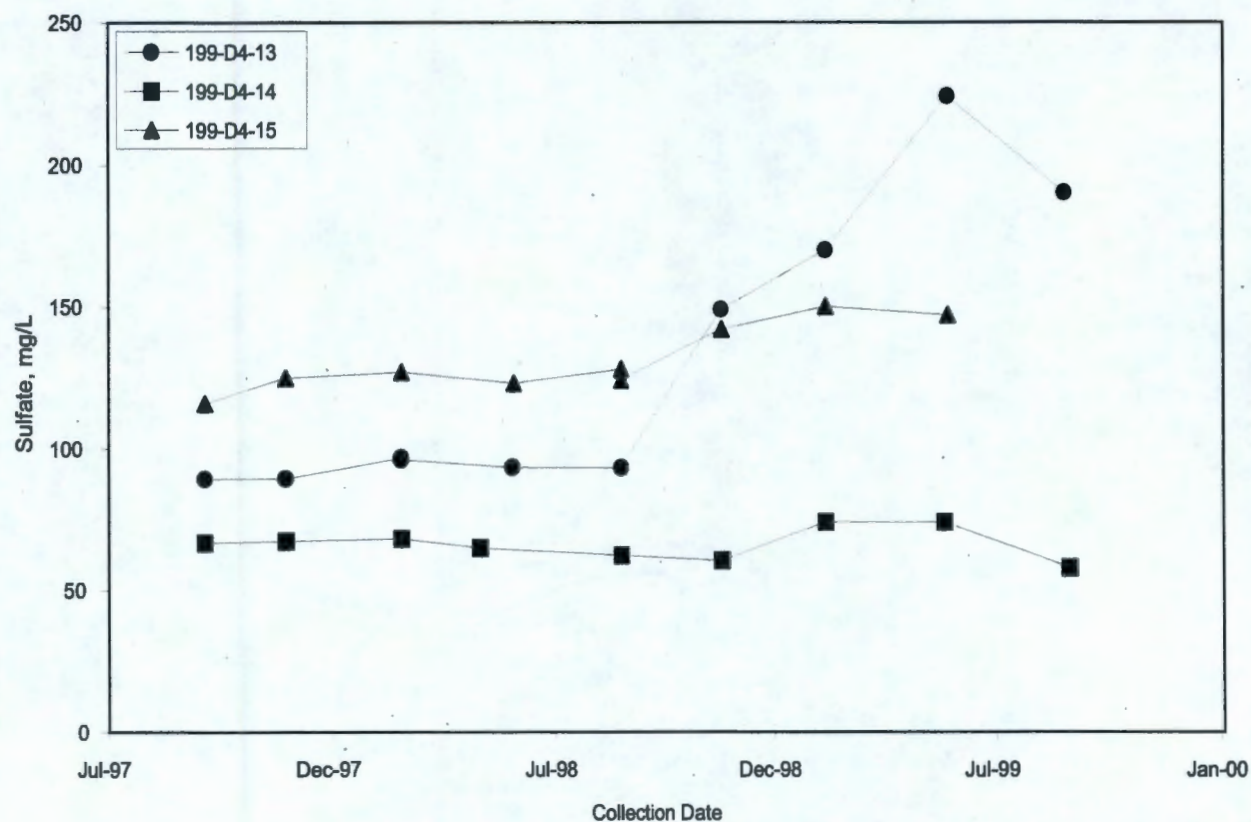
MAC20030

Figure 2.5-7. Specific Conductance in Wells Monitoring D Ponds



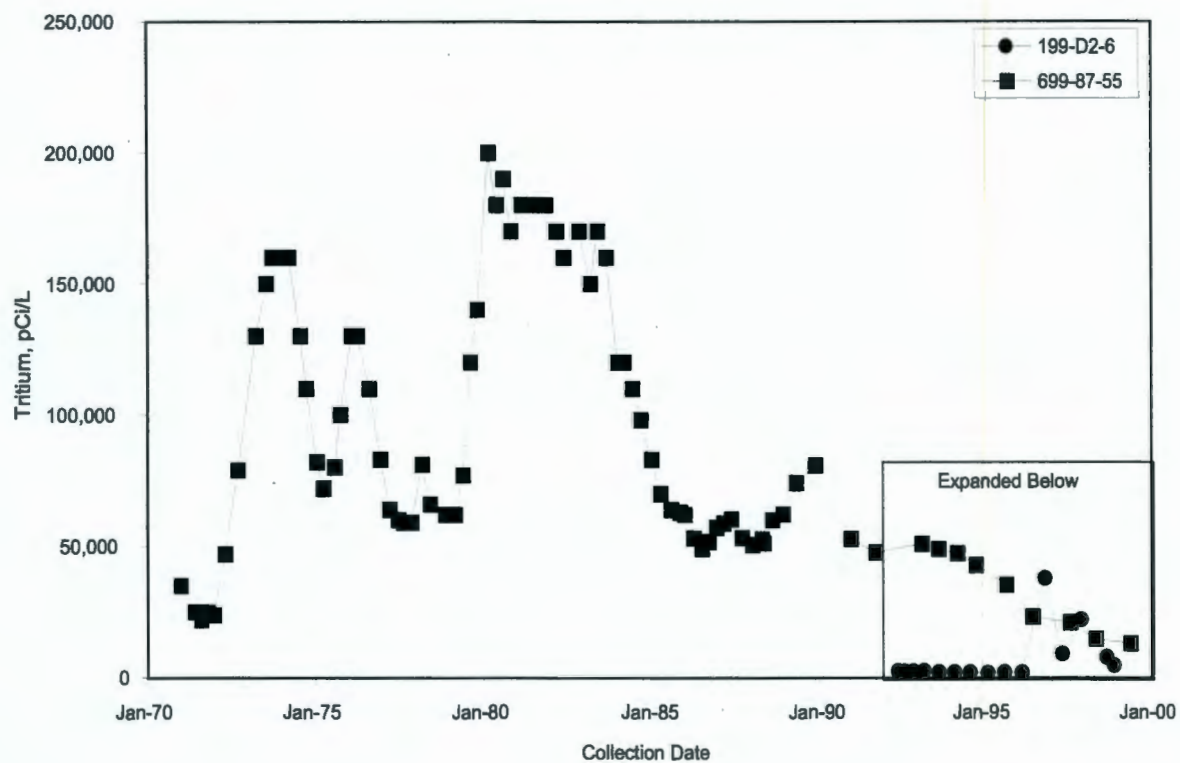
MAC20031

Figure 2.5-8. pH in Wells Monitoring D Ponds

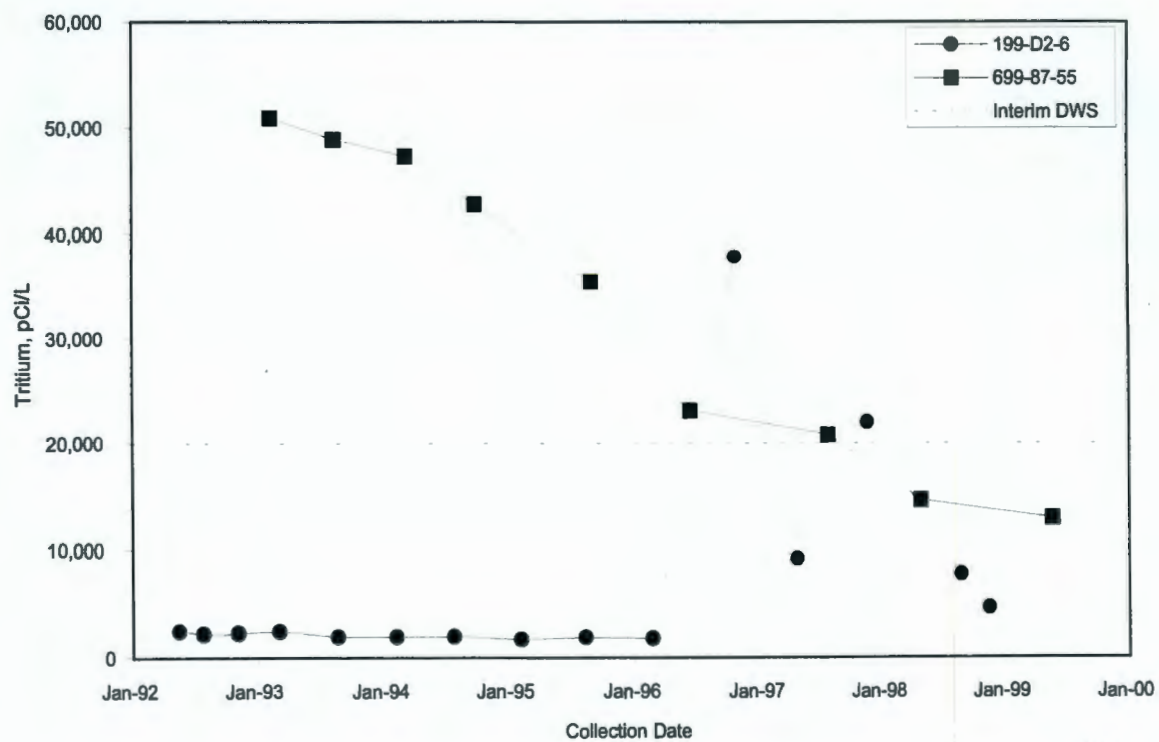


MAC20032

Figure 2.5-10. Sulfate in Wells 199-D4-13, 199-D4-14, and 199-D4-15 Near Redox Demonstration



MAC20033



MAC20043

Figure 2.5-11. Tritium in Wells 199-D2-6 and 699-87-55 at 100 D Area, South of 100 D Area

2.6 100 H Area

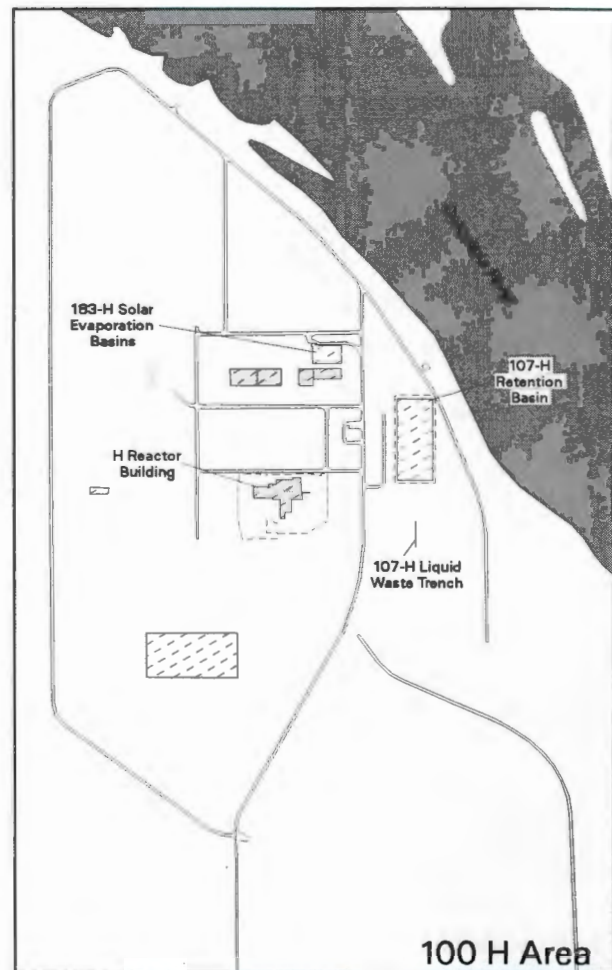
*R. E. Peterson, M. J. Hartman,
W. J. McMahon, R. F. Raidl*

The H Reactor operated between 1949 and 1965 using a single-pass cooling system. This configuration resulted in large volumes of used coolant being released to the soil column, which had significant implications with regard to vadose zone contamination and groundwater movement. An additional source for groundwater contamination was leakage of fuel fabrication effluent stored in solar evaporation basins during the period 1973 to 1985 (Section 2.6.3). Groundwater approaching the 100 H Area from the west is contaminated by chromium and tritium, originating from past disposal in the 100 D Area and possibly the 100 N Area.

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 included on Plate 1.

The presence of chromium in groundwater at the 100 H Area is an environmental restoration issue. In particular, there is concern over chromium in groundwater from 100 H Area that upwells through the adjacent riverbed gravel used by salmon for spawning habitat. Pore water samples collected from gravelly areas used for redds (groups of egg pockets) (BHI-00345, Rev. 1) revealed chromium at concentrations well above the 11 µg/L standard for protecting aquatic organisms. A pump-and-treat system is operating currently to reduce the rate at which chromium enters the Columbia River and also the amount of chromium in near-river groundwater (Section 2.6.4).

Additional remedial actions are underway in the 100 H Area to address vadose zone contamination beneath the 107-H retention basins and adjacent liquid waste disposal trench. These facilities and their underlying soil may contain contaminants that pose a threat to groundwater. The contaminated concrete and soil are being transported to the Environmental



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Restoration Disposal Facility in the 200 Areas plateau. The H reactor building is scheduled for remediation beginning in fiscal year 2000.

The contaminants of potential concern in groundwater beneath the 100 H Area include chemical constituents chromium and nitrate, and radiological constituents strontium-90, technetium-99, tritium, and uranium. Organic constituents are not present at levels of concern. The following sections describe contaminants in their order of relative significance to environmental restoration issues.

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 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.

2.6.1 Groundwater Flow

Groundwater flow beneath the 100 H Area is generally southwest to northeast, toward the Columbia River (see Plate 2). Flow through the sandy/gravelly sediment near the water table is relatively rapid and estimated to be in the range 0.3 to 2.0 meters per day (DOE/RL-93-43, Rev. 0). Because groundwater flows toward the northeast across the entire northern tip of the Hanford Site, groundwater approaching the shoreline upstream of 100 H and along 100 H may contain contaminants whose origin was liquid effluent disposal at the 100 D and 100 N areas.

During periods of high river discharge, significant bank storage of river water takes place along the 100 H shoreline. When combined with a possible preferential pathway created by a former river channel in the sediment of the unconfined aquifer, this promotes groundwater flow that is parallel to the Columbia River. This condition is observed in water-table contour maps drawn for the seasonal high water period during May and June (PNNL-11573) and affects groundwater movement up to a distance of ~300 meters inland. Daily and seasonal river stage fluctuations create corresponding changes in the elevation of the water table, which may cause changes in water quality monitoring results.

The extraction and injection of groundwater associated with the interim remedial action to address chromium contamination also influence the movement of groundwater in the vicinity of the associated wells. This influence is described in Section 2.6.7.

2.6.2 Chromium

Chromium contamination currently observed in 100 H Area groundwater (see Figure 2.5-1) includes a significant component of chromium-bearing groundwater from upgradient sources, such as waste sites in the 100 D Area in addition to 100 H sources. Evidence for this is (1) the groundwater flow direction inferred from water-table elevation maps and (2) chromium concentration trends in wells located along the flow path between 100 D Area and 100 H Area (Figure 2.6-1). Several 100 H Area wells show recent changes in chromium that may be associated with the arrival of chromium- and tritium-bearing groundwater from west of the 100 H Area. These include wells near the H reactor building (Figure 2.6-2). Injection of treated effluent from the chromium pump-and-treat system (Section 2.6.7) may also influence the groundwater flow pattern in that area, thus contributing to the observed changes.

Chromium concentrations in 100 H groundwater are generally 100 µg/L or less, with several exceptions, indicating that the groundwater is typically below the 100 µg/L drinking water standard. However, the more stringent standard for protection of freshwater aquatic organisms (11 µg/L) is exceeded along a portion of the groundwater/river interface 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 gravels in this area and found to contain chromium concentrations as high as 130 µg/L (BHI-00345, Rev. 1).

Chromium concentrations near the approximate center of mass for the plume are illustrated by trend charts for wells 199-H4-14, 199-H4-18, and 199-H4-16 (Figure 2.6-3) and the map shown in Figure 2.6-16.

Chromium concentrations in well 199-H4-14 have historically been higher than in surrounding wells, presumably because of chromium releases at the former water treatment facility located near the well. Figure 2.6-3 shows the concentration trend for well 199-H4-14 and for two wells located downgradient-199-H4-16 and 199-H4-18. Concentration changes observed in 199-H4-18 may be the result of southward displacement of the contaminant plume associated with the former 183-H solar evaporation basins because of high water-table conditions during 1996 and 1997.

Chromium is elevated in groundwater beneath the 100 H Area. Sources include waste sites in the area and upgradient in the 100 D Area.

Several anomalous occurrences of chromium are being tracked. The first involves well cluster 199-H3-2A, -2B, and -2C (trend plots for these wells are shown in Figure 2.6-4). Well 199-H3-2C is completed in a confined aquifer beneath the overlying unconfined aquifer, which is monitored by wells 199-H3-2A and -2B. In late summer 1996, the water quality observed in 199-H3-2C became very similar to that of water from the shallower wells, as illustrated by the change in chromium concentrations. The change occurred at about the same time as pumping began in well 199-H3-2A, as part of the interim remedial action for chromium. An explanation for this change is not yet available.

A second anomaly is found in well 199-H4-12C, which is also completed in a confined unit beneath the unconfined aquifer. This well has shown relatively high chromium concentrations ($\sim 300 \mu\text{g/L}$) since it was constructed in 1986 (Figure 2.6-5) though no other contamination indicators are present. One current explanation for these results involves corrosion of the stainless steel well screen (Hewitt 1994; Oakley and Korte 1996). There is no other evidence suggesting that waste effluents have contaminated this deep aquifer.

2.6.3 Strontium-90

The primary source for strontium-90 contamination observed currently in groundwater is past disposal of highly contaminated reactor coolant to the 107-H retention basin and 107-H liquid waste disposal trench, which is located nearby. Also, highly contaminated sludge from the retention basin was placed in an adjacent trench (107-H sludge burial trench), which is located between the basin and the Columbia River. The vadose zone beneath the basin and trenches is potentially contaminated with strontium-90, some of which has dispersed downward and entered groundwater. The upper portion of the vadose zone beneath these facilities is being excavated during 1999, with the contaminated soil being trucked to the Environmental Restoration Disposal Facility in the 200 Areas plateau.

Typical groundwater concentrations for strontium-90 are illustrated by the trend chart for well 199-H4-11 (Figure 2.6-6), which is located between the retention basin and the Columbia River. The concentration trend for gross beta has also been included in the figure. Where strontium-90 is the principal beta emitter present, the concentration of strontium-90 is approximately one-half that of gross beta.

Strontium-90 is present in groundwater near the Columbia River in the 100 H Area but was not detected in pore water from the river bottom.

Independent researchers have recently inferred that strontium-90 is present in mulberry bushes along the 100 H shoreline and also speculated that strontium-90 is present in riverbed gravel used by salmon for spawning (GAP 1999b). Pore water samples that were still available from an earlier investigation of these gravels (BHI-00345, Rev. 1) were subsequently analyzed for strontium-90, and none was detected (see Section 2.6.9.3). More complete descriptions of the results are presented in PN\NL-13177, along with a discussion of strontium-90 in the 100 Areas and its ecological implication.

2.6.4 Tritium

Tritium concentrations in the 100 H Area are below the 20,000 pCi/L drinking water standard (see Plate 3). The maximum value observed during fiscal year 1999 was ~8,400 pCi/L. During the last several years, tritium has increased in concentration at some 100 H Area wells in an area northeast of the H reactor building (Figure 2.6-7). While concentrations are typically in the range 4,000 to 5,000 pCi/L, the increasing trend may be indicative of contaminant plume movement across the northern tip of the Hanford Site. Upgradient of the wells shown in Figure 2.6-7, tritium concentrations are decreasing in two wells that monitor groundwater from 100 D and 100 N area sources (Figure 2.6-8). This suggests that the higher concentration core of the plume has passed these wells. A second possibility is that injection of treated effluent from the chromium pump-and-treat system at wells 199-H3-3, 199-H3-4, and 199-H3-5 may influence the direction of groundwater flow near the H reactor building, causing a redistribution of the plume.

An increase in tritium concentrations occurred in well 199-H3-2C beginning in mid-1996, from very low concentrations to a peak of ~3,200 pCi/L (Figure 2.6-9). The change is significant because this well monitors a confined aquifer that is separate from the overlying unconfined aquifer; the confined unit is not known to have received any contamination. Other water quality indicators changed in well 199-H3-2C at the same time (e.g., chromium; see Section 2.6.2), with the characteristics of water from 199-H3-2C looking very similar to those for water from the shallower wells. An explanation for this condition has not yet been established.

2.6.5 Nitrate

During fiscal year 1999, 14 wells in the 100 H Area exceeded the 45 mg/L maximum contaminant level. Concentrations were measured to a high of 217 mg/L in well 199-H4-4, which is located within the 183-H plume. The average value for nitrate in 100 H Area wells is 49 mg/L.

A general increase in nitrate concentrations is apparent in the historical trends for numerous 100 H Area wells, and also for wells located in other reactor areas. This trend is illustrated in Figure 2.6-10. The cause for the gradual increase is not known.

2.6.6 183-H Solar Evaporation Basins RCRA Monitoring

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

The 183-H basins are a RCRA site that has contaminated groundwater with chromium, nitrate, technetium-99, and uranium. Groundwater is monitored in conjunction with an interim remedial measure at the 100-HR-3 Operable Unit.

Groundwater movement in the vicinity of the basins has been modified by the interim remedial action to address chromium. While pumping operations are in progress, RCRA monitoring is conducted to track the trends of five contaminants associated with leakage from the basins: chromium, fluoride, nitrate, technetium-99, and uranium (PNNL-11573).

Groundwater chemistry near these former basins is characterized by elevated levels of chromium, nitrate, sodium, sulfate, technetium-99, and uranium. All of these constituents were present in waste discharged to the basins when they were in use. Concentrations in fiscal year 1999 were lower than in recent years. See Appendix A for supporting information about this RCRA site.

2.6.6.1 Groundwater Flow

As indicated on the March 1999 water-table map (see Plate 2), groundwater beneath the former basins flows generally to the east-northeast, toward the Columbia River. Technetium-99 and uranium plumes originating at the basins have migrated primarily toward the east (see Section 5.7 of PNNL-12086). The rate of flow in March 1999 is estimated to be between 0.12 to 3.2 meters per day (see Table A.2).

Groundwater levels fluctuate with the stage of the Columbia River (Figure 2.6-11). Water levels were measured monthly in well 199-H4-4 and ranged in elevation from 114.51 meters in October 1998 to 116.77 meters in July 1999. Periods of high river stage influence flow velocity in the area temporarily, creating a potential for flow toward the south. Groundwater flow around the 183-H solar evaporation basins is also influenced by the pump-and-treat system, as discussed in Section 2.6.7.

2.6.6.2 Technetium-99 and Uranium

Concentrations of technetium-99 and uranium were lower in fiscal year 1999 than in recent years as illustrated by concentrations in wells 199-H4-3 and 199-H4-4 (Figure 2.6-12). These basin contaminants are very mobile in groundwater, and concentrations fluctuate in response to changes in the stage of the Columbia River. Usually concentrations are highest when river stage is low. However, in November 1998, river stage was low, and concentrations were also low, especially in well 199-H4-3. These changes may represent a shift in the contaminant plume caused by the influence of the pump-and-treat system.

Only three wells exceeded the 20- $\mu\text{g/L}$ maximum contaminant level for uranium in fiscal year 1999: 199-H4-3, 199-H4-4, and 199-H4-12A. The highest annual average was $\sim 31 \mu\text{g/L}$ in well 199-H4-4. Well 199-H4-4 also had the highest concentration of technetium-99, with an annual average of $\sim 550 \text{ pCi/L}$. This was below the 900 pCi/L drinking water standard.

Well 199-H4-5 had peaks in concentrations of chromium, nitrate, technetium-99, and uranium in

fiscal year 1998. Levels declined again in fiscal year 1999 (Figure 2.6-13). Changing directions of groundwater flow caused by the pump-and-treat system may have caused the spikes.

Well 199-H4-18 is located near the southern boundary of the contaminant plume attributable to the 183-H solar evaporation basins. During periods of high water-table conditions, the plume appears to be displaced slightly to the south, as indicated by a change in the direction of water-level gradients. This is reflected in well 199-H4-18 by increased concentrations of technetium-99 and nitrate, which are 183-H plume indicators, during the summer of each year (Figure 2.6-14). This was especially apparent during 1996, a year of an usually high water table.

2.6.6.3 Nitrate

Leakage from the basins contributed to a more widespread plume of nitrate (see Section 2.6.5). The highest concentrations in 100 H Area in fiscal year 1999 were observed in downgradient well 199-H4-4 at 217 mg/L. Like technetium-99 and uranium, concentrations in wells downgradient of the basins were generally lower in fiscal year 1999 than in the previous several years.

2.6.6.4 Chromium

Leakage from the 183-H solar evaporation basins also contributed to the widespread plume of chromium (see Figure 2.5-1 and Section 2.6.2). Unlike co-contaminants, chromium appears to have increased in recent years in well 199-H4-3 (Figure 2.6-15). Seasonal fluctuations are evident in well 199-H4-4, where chromium is analyzed monthly. High river stage in the spring and early summer was accompanied by low concentrations of chromium. Specific conductance of those samples was also low, indicating possible dilution by river water.

Chromium declined in well 199-H4-5 after a 1998 peak (see Figure 2.6-14). The changes in concentration may be related to changes in groundwater flow caused by the pump-and-treat system (Section 2.6.7).

Chromium remains elevated, but is gradually declining, in well 199-H4-12C (see Figure 2.6-5). This well is completed in a deeper part of the aquifer than the other wells nearby. The well is monitored as part of the *Resource Conservation and Recovery Act of 1976* (RCRA) network to ascertain whether pumping the shallow aquifer (i.e., well 199-H4-12A) affects the chromium concentrations observed in the deeper aquifer (PNNL-11573). The average concentration for well 199-H4-12C in fiscal year 1999 was ~200 µg/L. Other contaminants that are characteristic of 183-H waste are not elevated, and the cause for this elevated chromium is currently not understood.

2.6.6.5 Fluoride

This constituent was detected in the vadose zone beneath the basins during remediation activities in 1996, making it a constituent of interest for RCRA postclosure care (DOE/RL-97-48, Rev. 0; PNNL-11573). Recent and historical values for fluoride are an order of magnitude lower than the 4 mg/L maximum contaminant level. Fluoride concentrations in down-gradient wells were lower than in upgradient wells during fiscal year 1999, suggesting no addition of fluoride to groundwater as it passes beneath the footprint of the former basins.

2.6.7 Groundwater Remediation

A pump-and-treat system, located in the 100 H Area, began operating in 1997 as an interim action for the 100-HR-3 Operable Unit. Three of the extraction wells are located within ~50 meters of the river shore, two others are located farther inland near the 183-H solar evaporation basins. Four compliance wells are located within ~100 meters of the river shore.

2.6.7.1 Interim Remedial Action Objectives

The record of decision (ROD 1996b) contains the following specific remedial action objectives that pertain to operation of the pump-and-treat system:

- 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 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 pump-and-treat system may be shut down when

- sampling results indicate that the concentration of hexavalent chromium is below 22 µg/L in the compliance wells
- data indicate that the concentration will remain below the compliance value
- effectiveness of the treatment technology does not justify further operation
- an alternative and superior treatment technique becomes available and feasible (ROD 1996b).

2.6.7.2 Remediation Progress During Fiscal Year 1999

The pump-and-treat system made progress toward achieving the remedial action objectives during fiscal year 1999. Figure 2.6-16 shows the flow lines and hydraulic capture estimated to occur during a low flow period in the Columbia River (November 1998), when groundwater flow to the river is greatest. This simulation estimates that much of the contaminated groundwater is prevented from discharging to the Columbia River (DOE/RL-99-13).

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 operable unit by removing contaminant mass. The pump-and-treat program collects hydraulic monitoring data, contaminant monitoring data, and operating data to

assess the performance of the system and to provide the basis to select the final remedy as part of the record of decision.

The goal of a pump-and-treat system in the 100 H Area is to prevent chromium from reaching the Columbia River, where it could harm young salmon. Since 1997, 15 kilograms of chromium have been removed from groundwater.

During fiscal year 1999, the pump-and-treat system extracted over 131.0 million liters of groundwater and removed over 6.1 kilograms of hexavalent chromium in the 100 H Area (Table 2.6-1). The average concentration of hexavalent chromium from 100 H Area wells was 50.6 $\mu\text{g/L}$. After treatment, the average effluent concentration was 2 $\mu\text{g/L}$, with hexavalent chromium being undetected during 45 of the 52 sampling events. A total of 15.0 kilograms of hexavalent chromium has been removed since startup of the pump-and-treat system in July 1997. Published estimates for the total amount of hexavalent chromium in the plume targeted for remedial action range between 42 and 250 kilograms (Peterson and Connelly 1992; DOE/RL-94-95, Rev. 1). A principal reason for uncertainty in these estimates is the lack of data on the vertical distribution of contamination in the aquifer. An order-of-magnitude estimate for the rate at which chromium is discharging to the Columbia River via groundwater flow is 0.05 kilogram per day (BHI-00469). This equates to a total mass flux of ~41 kilograms that would have entered the Columbia River since July 1997. The actual flux is believed to be less because of the pump-and-treat system.

2.6.7.3 Influence on Aquifer Conditions

The concentration of chromium declined below the 22- $\mu\text{g/L}$ action level in some of the extraction and compliance wells during all three summers that the pump-and-treat system operated. Each time, the concentration rebounded over the action level by the following September. In September 1999, chromium

was measured at 77, 48, and 37 $\mu\text{g/L}$ in compliance wells 199-H4-4, 199-H4-63, and 199-H4-64, respectively (Figure 2.6-17).

Because of the recurring elevated concentration of hexavalent chromium in the compliance wells, the annual summary report (DOE/RL-99-13) recommended continued operation of the pump-and-treat system. The cyclical pattern in the hexavalent chromium trend plots makes it difficult to quantify the effectiveness of the pump-and-treat system in lowering the concentration of hexavalent chromium in the aquifer. The concentration in the compliance wells falls close to or below the 22 $\mu\text{g/L}$ remedial action objective level during the summer, but rebounds greatly over it in the fall and winter. The decrease in concentration in certain extraction wells (Figure 2.6-18) and compliance wells indicates that the concentration throughout the aquifer is decreasing in some areas, but the rate of decline is inconsistent throughout the targeted plume area. The pump-and-treat system reduces the total amount of chromium in the environment, but a review of the contaminant data indicates that many years of pumping may be required before the remedial action objectives have been entirely satisfied.

2.6.8 Waste Site Remediation

Remedial action excavation of waste sites in the 100 H Area continued in fiscal year 1999. Activities consisted of removing and stockpiling clean overburden soil and removing contaminated soil/debris for disposal at the Environmental Restoration Disposal Facility. Water from the Columbia River was used for dust control; it was applied as necessary during remediation activities. Application of water was held to a minimum to reduce the potential for mobilizing contaminants from the vadose zone to the groundwater. Groundwater in the 100 H Area is 15 to 18 meters below the ground surface. Waste sites excavated in fiscal year 1999 included

- 107-H retention basin (waste site 116-H-7) — Excavation began in March 1999 and continued

throughout fiscal year 1999. Excavation is scheduled to be completed during the first quarter of fiscal year 2000. The depth of the excavation will be ~10 meters below ground surface.

- 100-H-5 sludge burial site — This site is located just east of the retention basin. Excavation began in September 1999 and is scheduled to be completed during the second quarter of fiscal year 2000. The depth of the excavation will be ~5 meters below ground surface.
- 107-H Liquid Waste Disposal Trench (waste site 116-H-1) — Excavation began in July 1999 and is scheduled to be completed during the first quarter of fiscal year 2000. The depth of the excavation will be ~5 meters below ground surface.
- Reactor process piping — Overburden removal began in August 1999 and is scheduled to be completed during the second quarter of fiscal year 2000. The depth of excavation ranges from 2 to 10 meters below ground surface.

2.6.9 Water Quality at Shoreline Monitoring Locations

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 near the low-water shoreline. Riverbank seepage appears at numerous locations when the river level is low. In fiscal year 1999, special studies of shoreline vegetation and pore water samples were conducted in 100 H Area.

2.6.9.1 Aquifer Sampling Tubes

Samples collected during the fall 1998 sampling round were screened for hexavalent chromium, gross beta, nitrate, technetium-99, and tritium. Hexavalent chromium concentrations ranged from 11 µg/L downstream of the 100 H Area to a maximum of 73 µg/L near the 107-H retention basin. This concentration is consistent with hexavalent chromium concentrations in samples from nearby well 199-H4-11.

Tritium concentrations ranged from 1,000 to 3,800 pCi/L. Gross beta concentrations in the same locations ranged from undetected downstream of the 100 H Area to 97 pCi/L near the 107-H retention basin. These concentrations are consistent with gross beta and tritium concentrations in samples from groundwater monitoring wells near the 100 H shoreline. Technetium-99 was detected in samples from three tubes near the 107-H retention basin, with a maximum concentration of 56 pCi/L.

Nitrate concentrations ranged from 13 mg/L downstream of the 100 H Area to 50 mg/L near the retention basin. These concentrations are consistent with nitrate detected in groundwater samples from monitoring wells near the Columbia River shoreline.

2.6.9.2 Riverbank Seepage

Five riverbank seeps were sampled in the fall 1998 for the 100-HR-3 Operable Unit. These seeps were sampled during low-river discharge, when seepage is least influenced by bank storage of river water and is most representative of groundwater that discharges into the Columbia River. The specific conductance of the collected seep samples ranged from 154 to 280 µS/cm, indicating a mix of groundwater and river water drains back to the river from bank storage.

Chromium concentrations ranged from 6.7 to 57.6 µg/L. The highest chromium concentration was detected in a sample from a seep near the 107-H retention basin and is consistent with aquifer sampling tube and groundwater well sample analytical results.

Gross beta ranged from 3.1 pCi/L upstream of the 100 H Area to a maximum of 38.8 pCi/L near the 107-H retention basin. Gross beta observed at this location is most likely the result of strontium-90 in the groundwater. The maximum tritium concentration was detected in a sample from a seep upstream of the 100 H Area.

2.6.9.3 Special Shoreline Studies

Analysis of radioactivity in shoreline vegetation at the 100 H Area led to speculation that strontium-90

might be present in riverbed pore water where chromium had been observed previously (GAP 1999b). In an attempt to test this hypothesis, archived samples of pore water from the original study (BHI-00345, Rev. 1) were reanalyzed for strontium-90. Strontium-90 was not detected in any of the samples (Table 2.6-2). The pore water sampling locations are in the nearshore area adjacent to the former 107-H retention basin.

Analysis of shoreline vegetation reveals the presence of radionuclides of Hanford Site origin at very low concentrations (WDOH/320-023). The roots of mulberry bushes are bathed in a mixture of groundwater and river water in the zone of bank storage and, thus, provide insight on possible contaminants in groundwater near the Columbia River.

Table 2.6-1. Performance Statistics for the 100 H Pump-and-Treat System for Chromium, Fiscal Year 1999

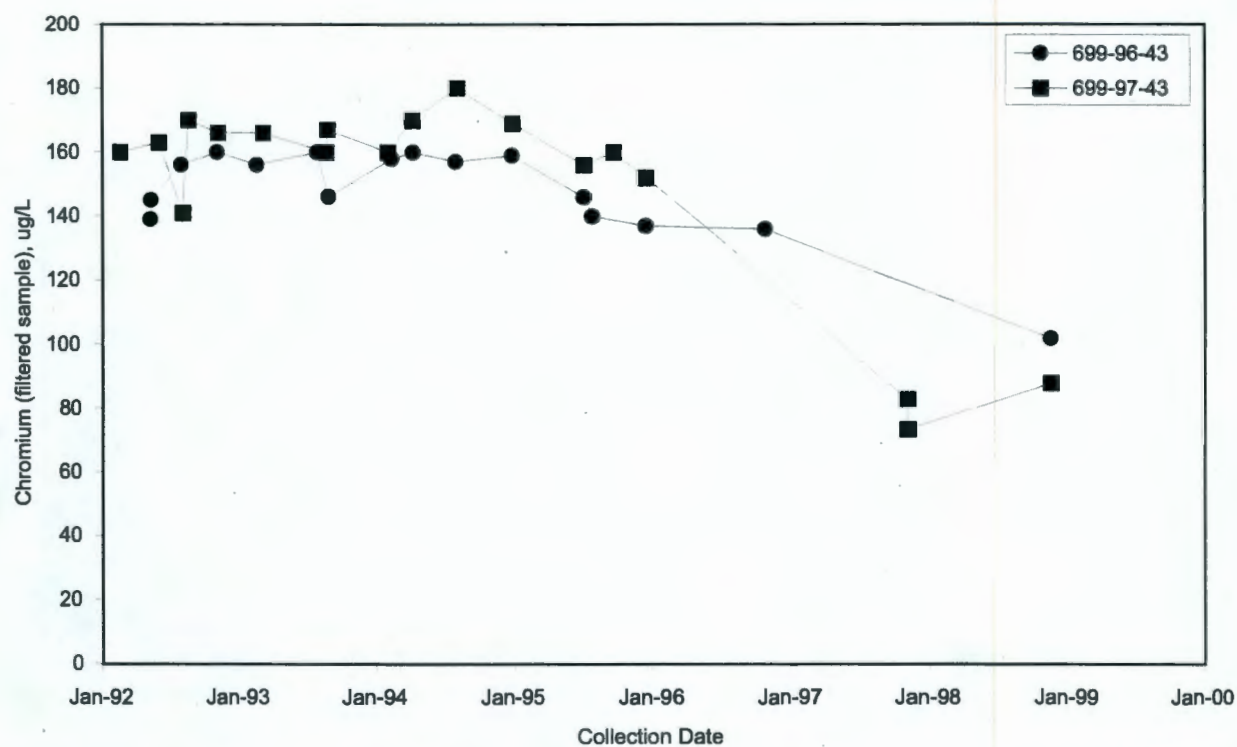
Well or Sample Location	Annual Average Flow Rate (L/min)	Maximum Sustained Flow Rate (L/min)	Total Volume Pumped ($\times 10^6$ L)	Average Chromium Concentration ($\mu\text{g/L}$)	Chromium Mass Removed (kg)
199-H3-2A	69.2	78.1	32.8	16.2	0.5
199-H4-7	46.2	52.2	19.7	63.6	1.3
199-H4-11	83.3	91.6	37.1	61.0	2.3
199-H4-12A	49.4	52.5	22.0	62.6	1.4
199-H4-15A	47.6	51.4	19.3	51.8	1.0
H-Influent	279.6	317.3	131.0	50.6	6.6
H-Effluent	548.8	601.5	258.6	2.1	--

Data Source: Project Specific Database for the 100-HR-3 Operable Unit.

Table 2.6-2. Chromium and Strontium-90 Results for River Substrate Pore Water Samples

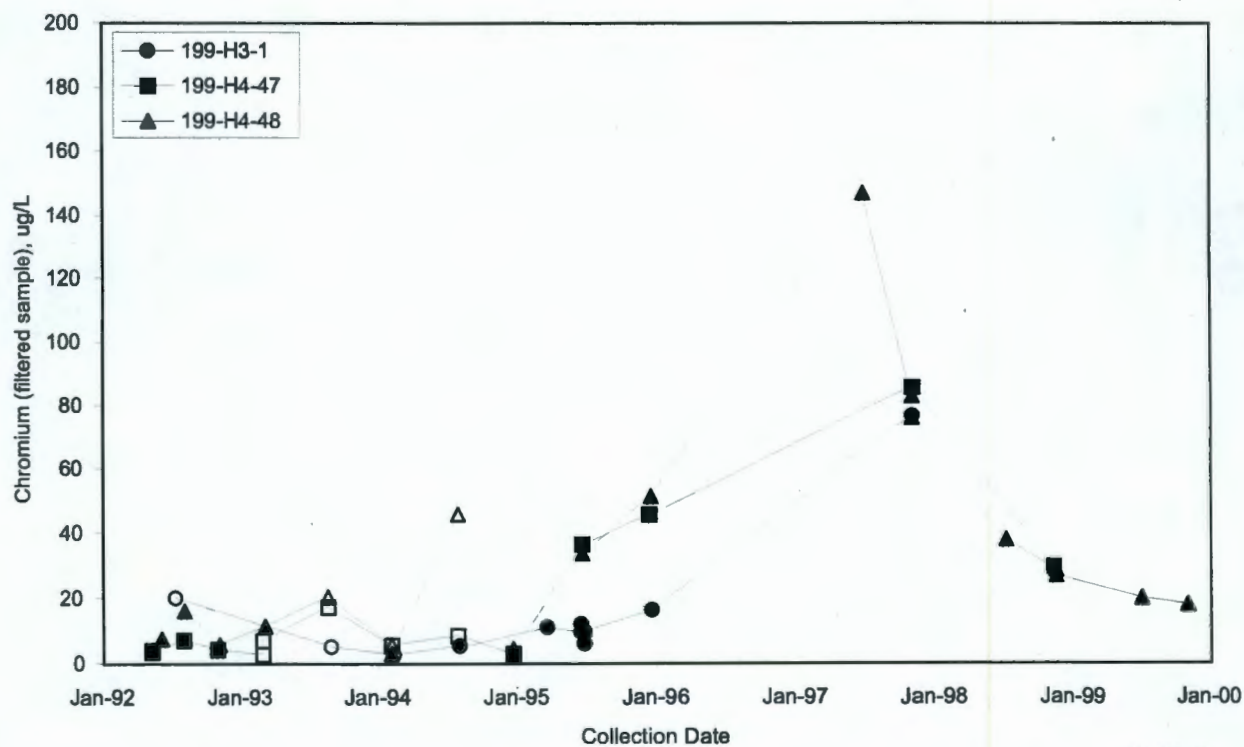
Riverbed Sampling Site	Distance Offshore (m)	Sample Specific Conductance ($\mu\text{S/cm}$)	Hexavalent Chromium ($\mu\text{g/L}$)	Strontium-90 (pCi/L)	Minimum Detection Level (pCi/L)
TH-1A	21	207	100	-0.436	3.2
TH-1A (dupl)	21	198	130	0.931	7.72
TH-1B	30	155	52	-1.02	3.14
TH-1B (dupl)	30	183	103	-4.2	9.01
TH-2A	30	149	<1	-0.751	4.62
TH-2B	43	137	<1	-0.034	3.83
TH-3A	12	175	1.2	0.523	4.77
TH-3B	24	147	9	3.27	3.83
TH-13A	7	177	2.6	0.23	3.85
TH-14A	7	190	73	-0.551	3.1

Note: The specific conductance of river water measured just above the pore water sampling sites ranged between 149 and 155 $\mu\text{S/cm}$. The pore water sample specific conductance indicates the sample was primarily river water, with only a minor added component of groundwater. Strontium-90 analyses were performed on archived pore water samples during August 1999. All results for strontium-90 indicate non-detection.



MAC20138

Figure 2.6-1. Chromium in Wells 699-96-43 and 699-97-43 Between 100 H and 100 D Areas



MAC20139

Figure 2.6-2. Chromium in Wells 199-H3-1, 199-H4-47, and 199-H4-48 Near H Reactor

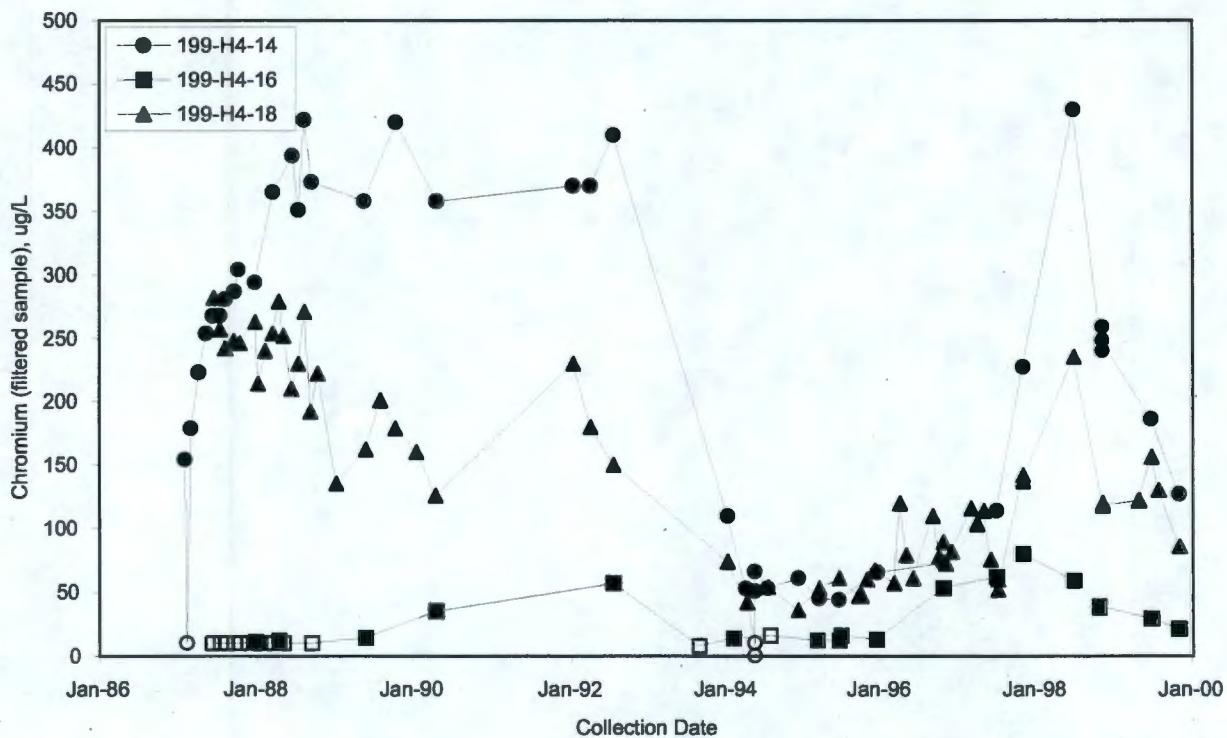


Figure 2.6-3. Chromium in Wells 199-H4-14, 199-H4-16, and 199-H4-18 at 100 H Area

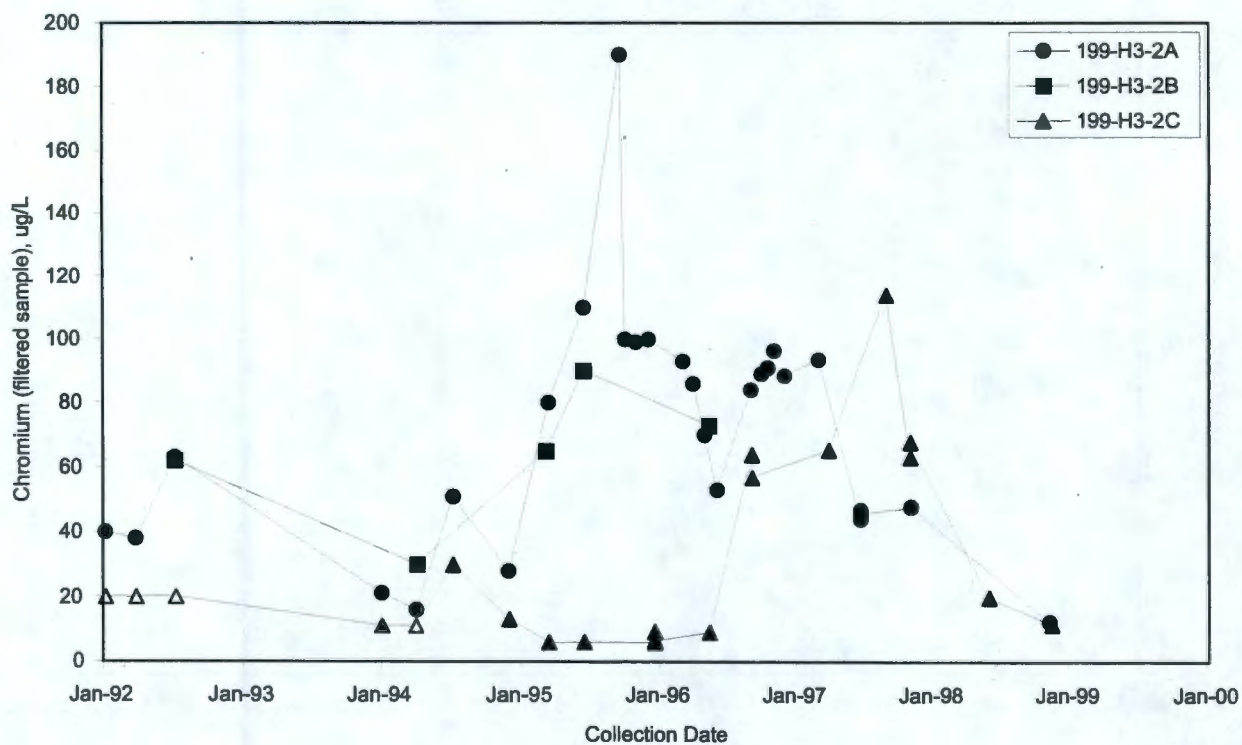
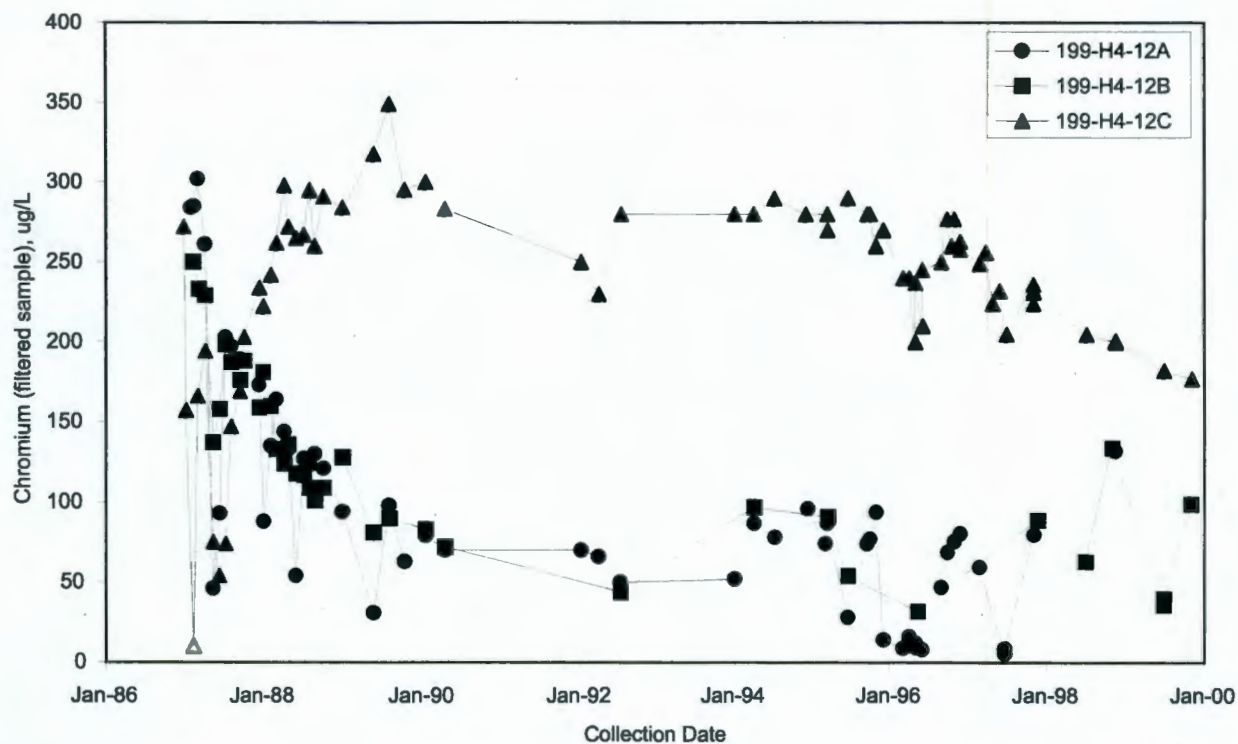
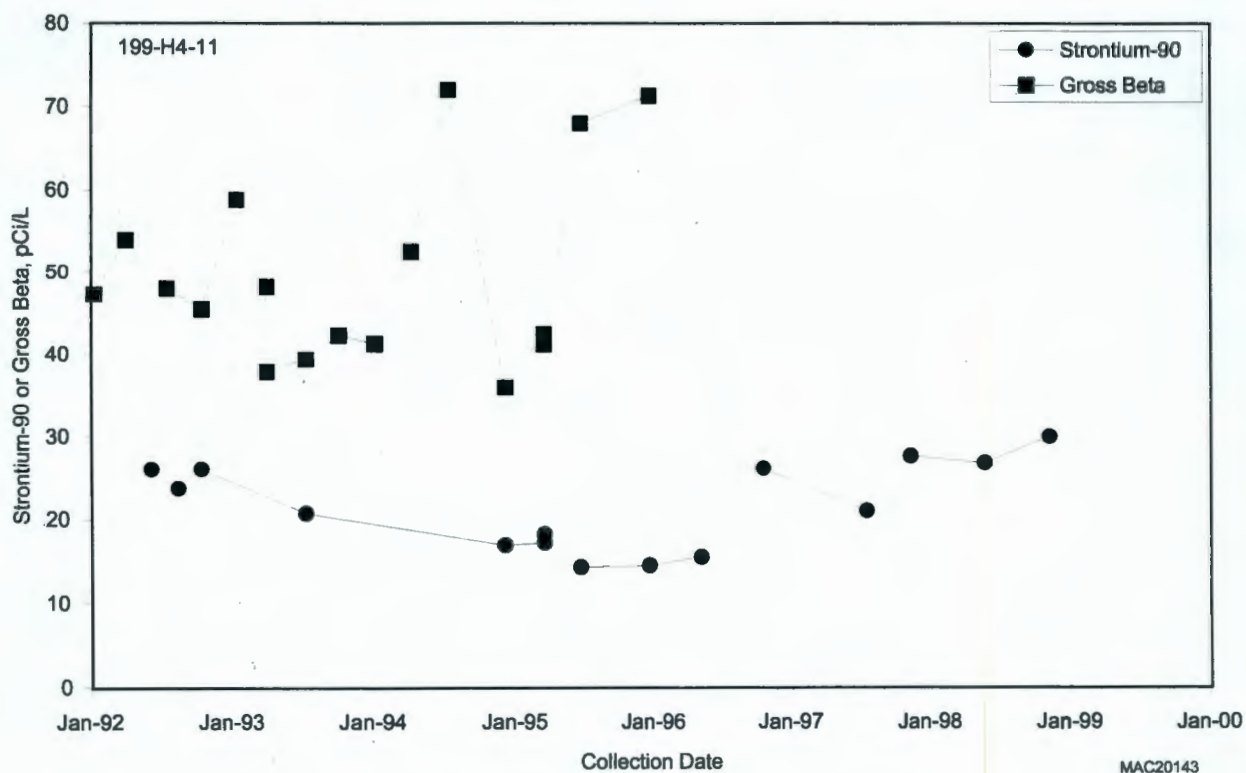


Figure 2.6-4. Chromium in Wells 199-H3-2A, 199-H3-2B, and 199-H3-2C at 100 H Area



MAC20141

Figure 2.6-5. Chromium in Wells 199-H4-12A, 199-H4-12B, and 199-H4-12C at 100 H Area



MAC20143

Figure 2.6-6. Strontium-90 and Gross Beta in Well 199-H4-11

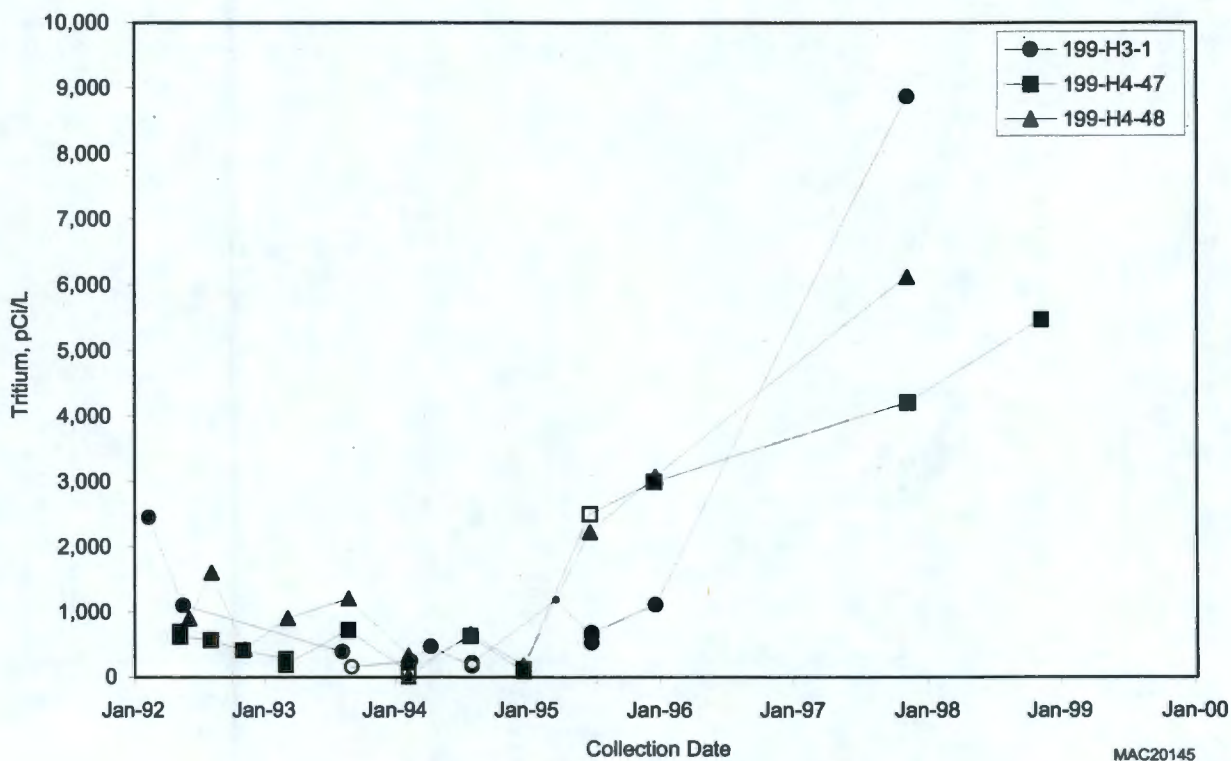


Figure 2.6-7. Tritium in Wells 199-H3-1, 199-H4-47, and 199-H4-48, Northeast of H Reactor

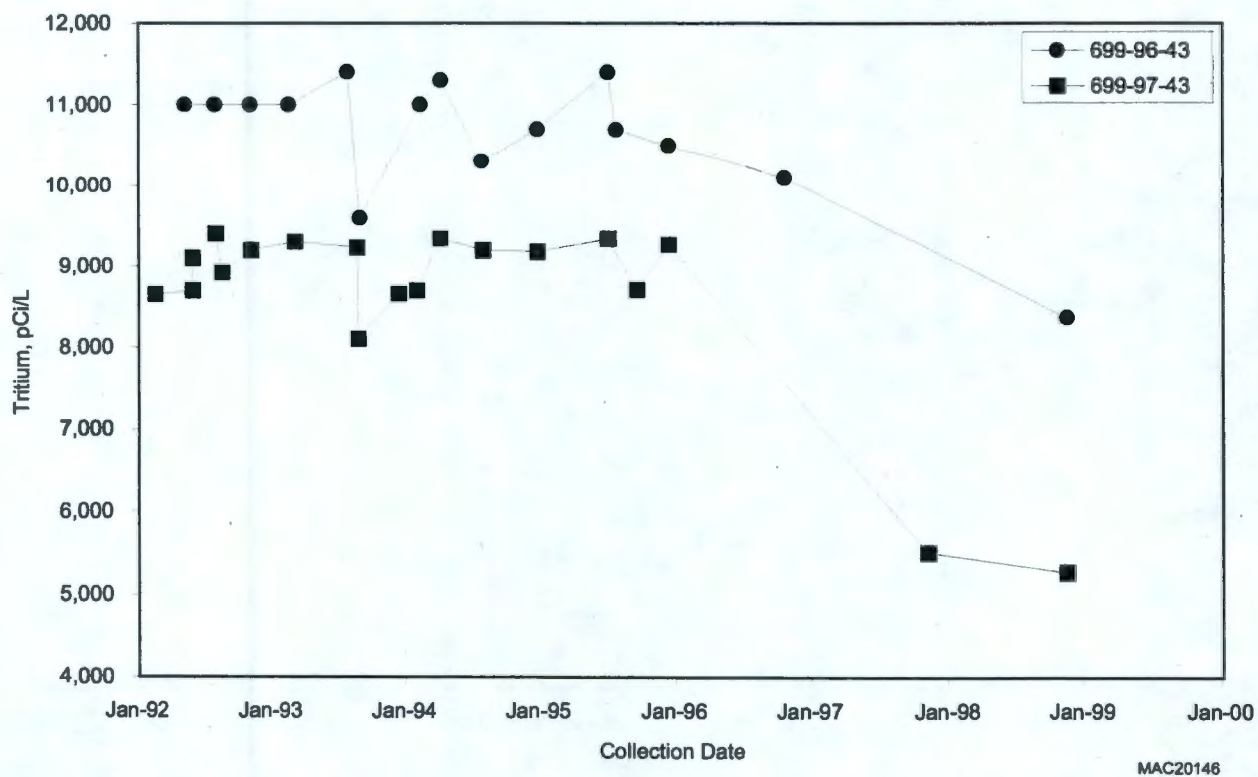
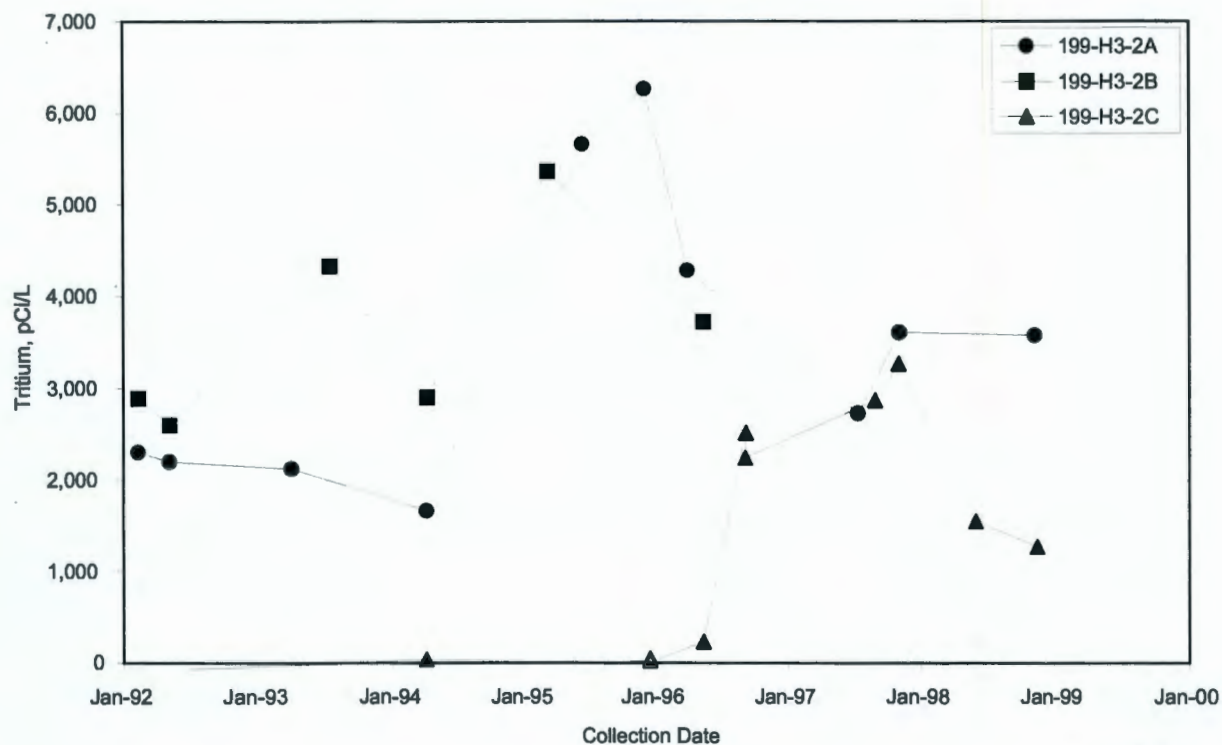
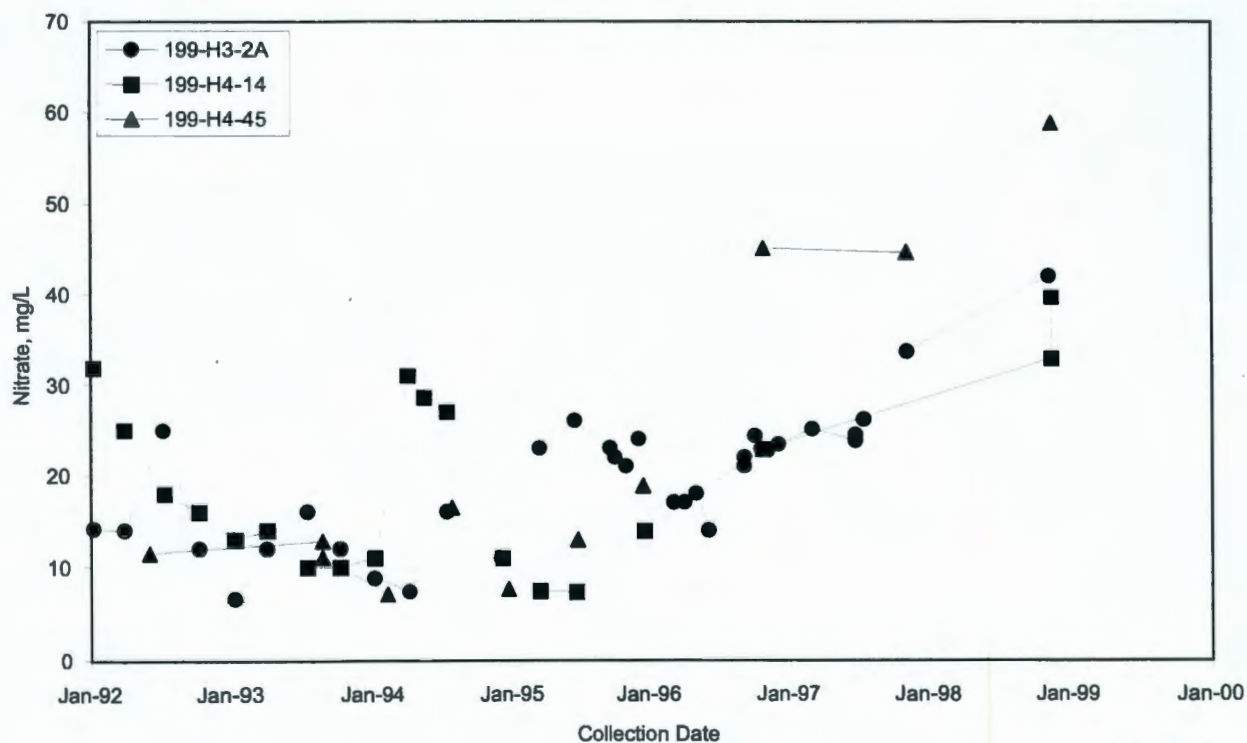


Figure 2.6-8. Tritium in Wells 699-96-43 and 699-97-43 Between 100 D and 100 H Areas



MAC20147

Figure 2.6-9. Tritium in Wells 199-H3-2A, 199-H3-2B, and 199-H3-2C, Western 100 H Area



MAC20148

Figure 2.6-10. Example of Increasing Nitrate in Wells at 100 H Area

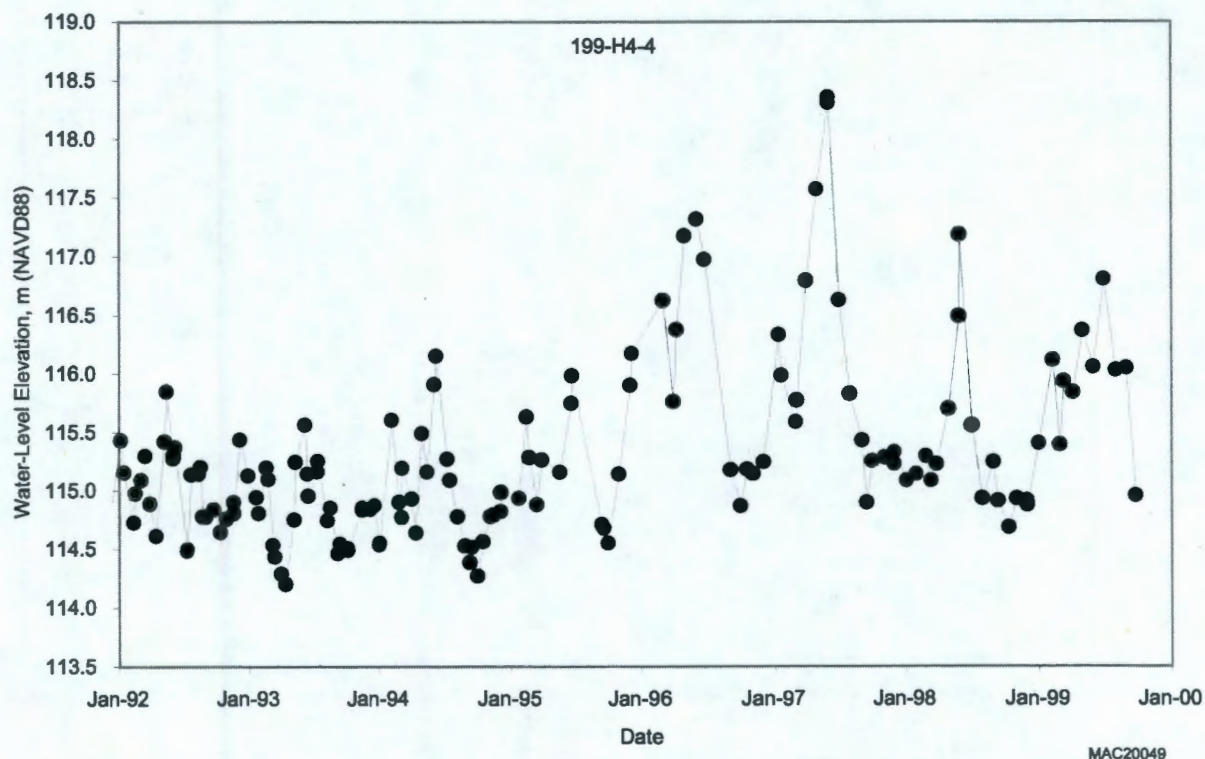
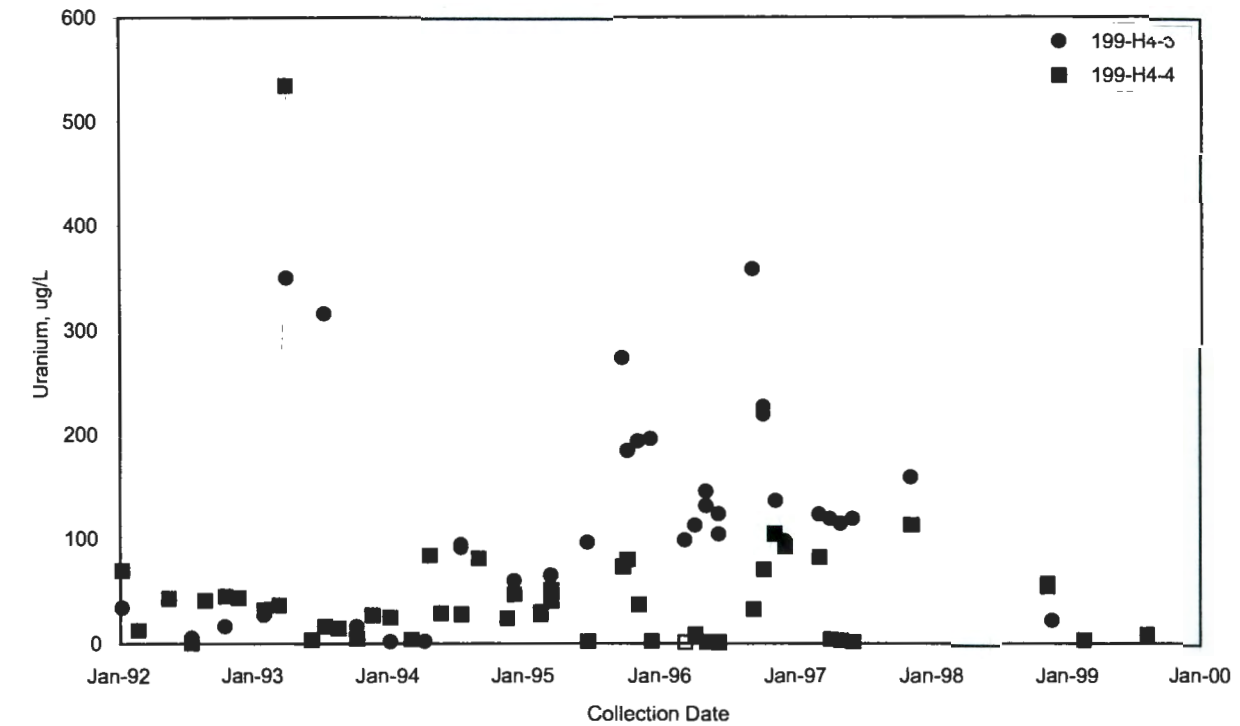
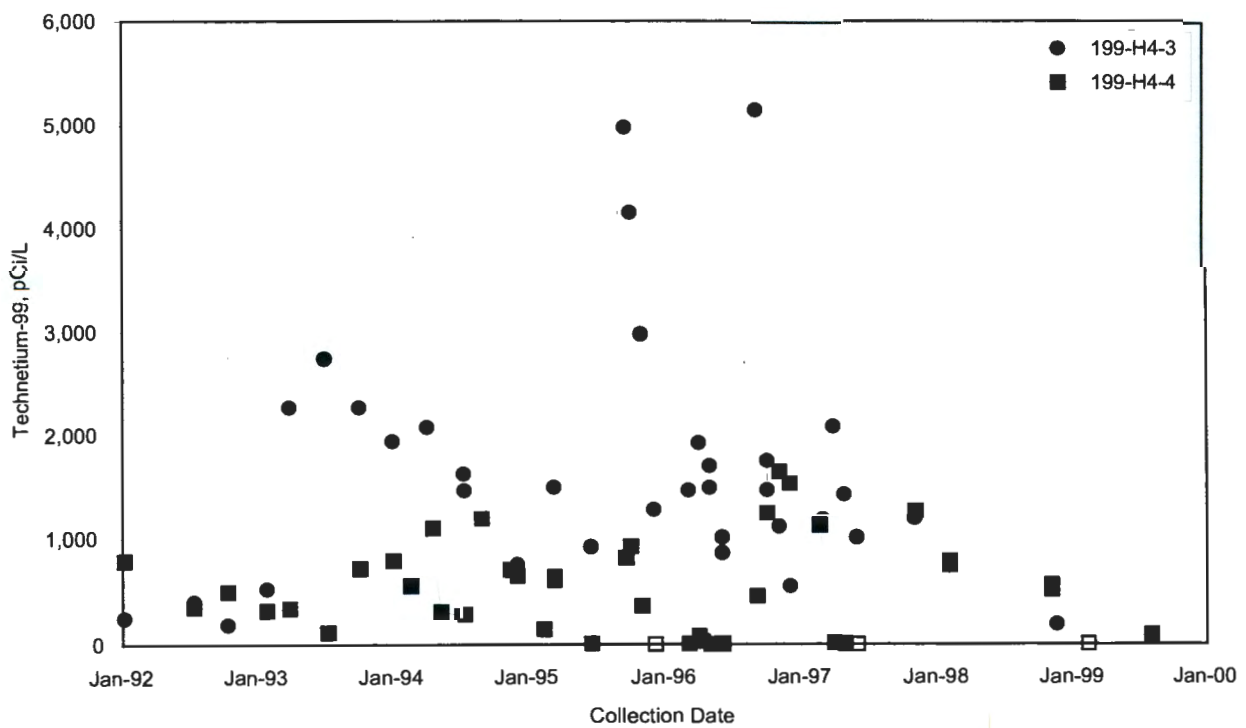


Figure 2.6-11. Water Levels in Well 199-H4-4 Monitoring 183-H Solar Evaporation Basins



MAC20050



MAC20150

Figure 2.6-12. Technetium-99 and Uranium in Wells 199-H4-3 and 199-H4-4 Monitoring 183-H Solar Evaporation Basins

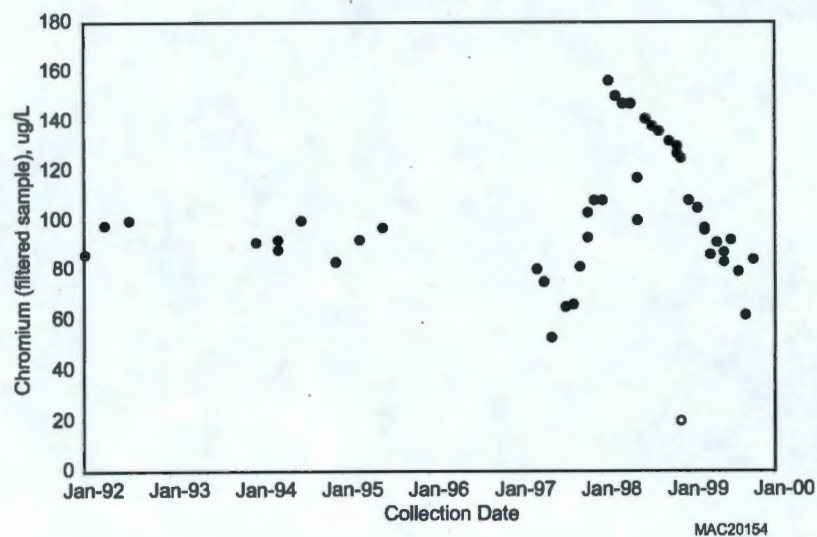


Figure 2.6-13. Contaminants in Well 199-H4-5 Near 183-H Solar Evaporation Basins

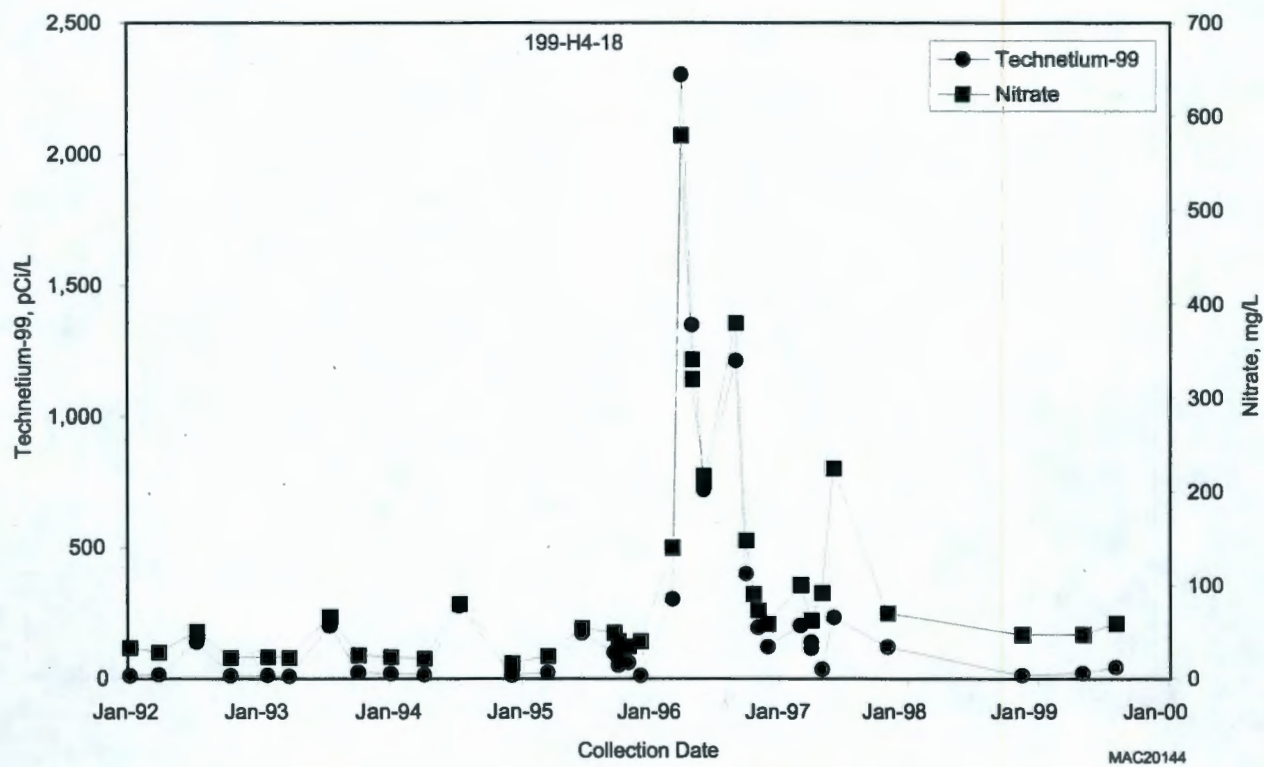
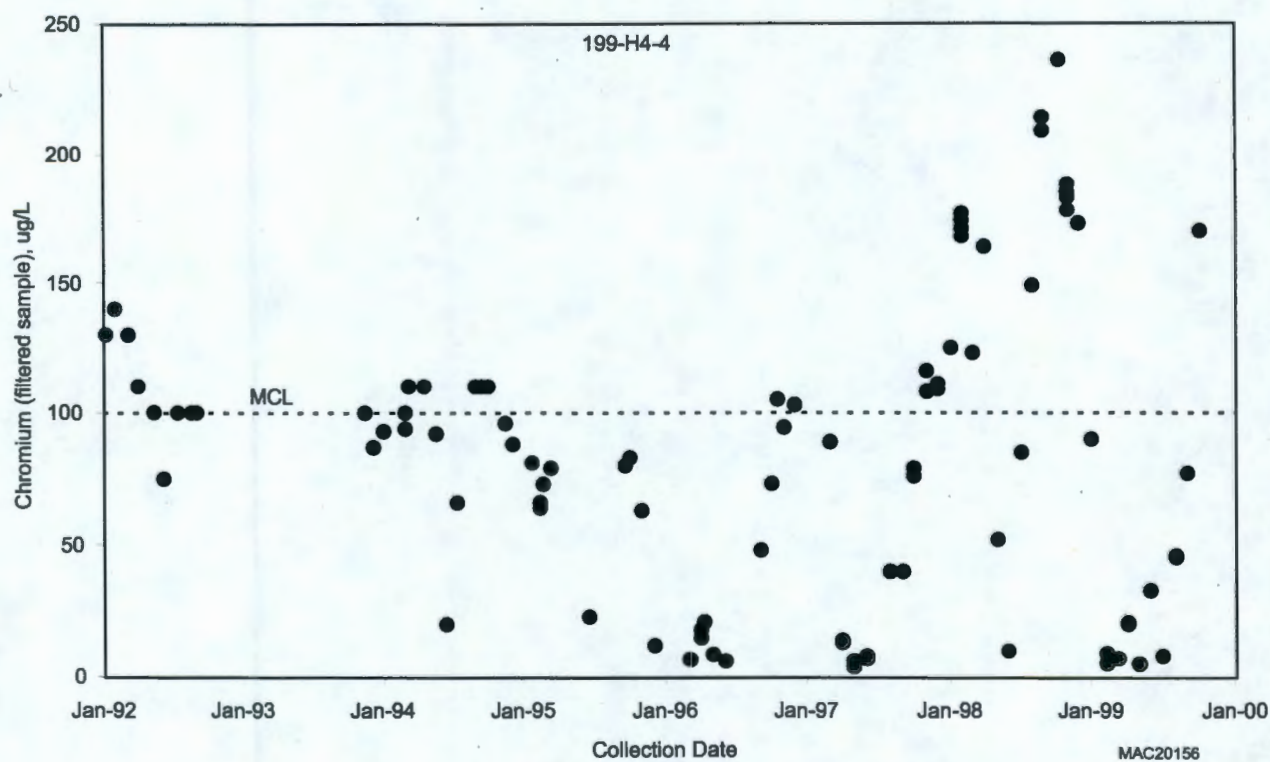


Figure 2.6-14. Technetium-99 and Nitrate in Well 199-H4-18



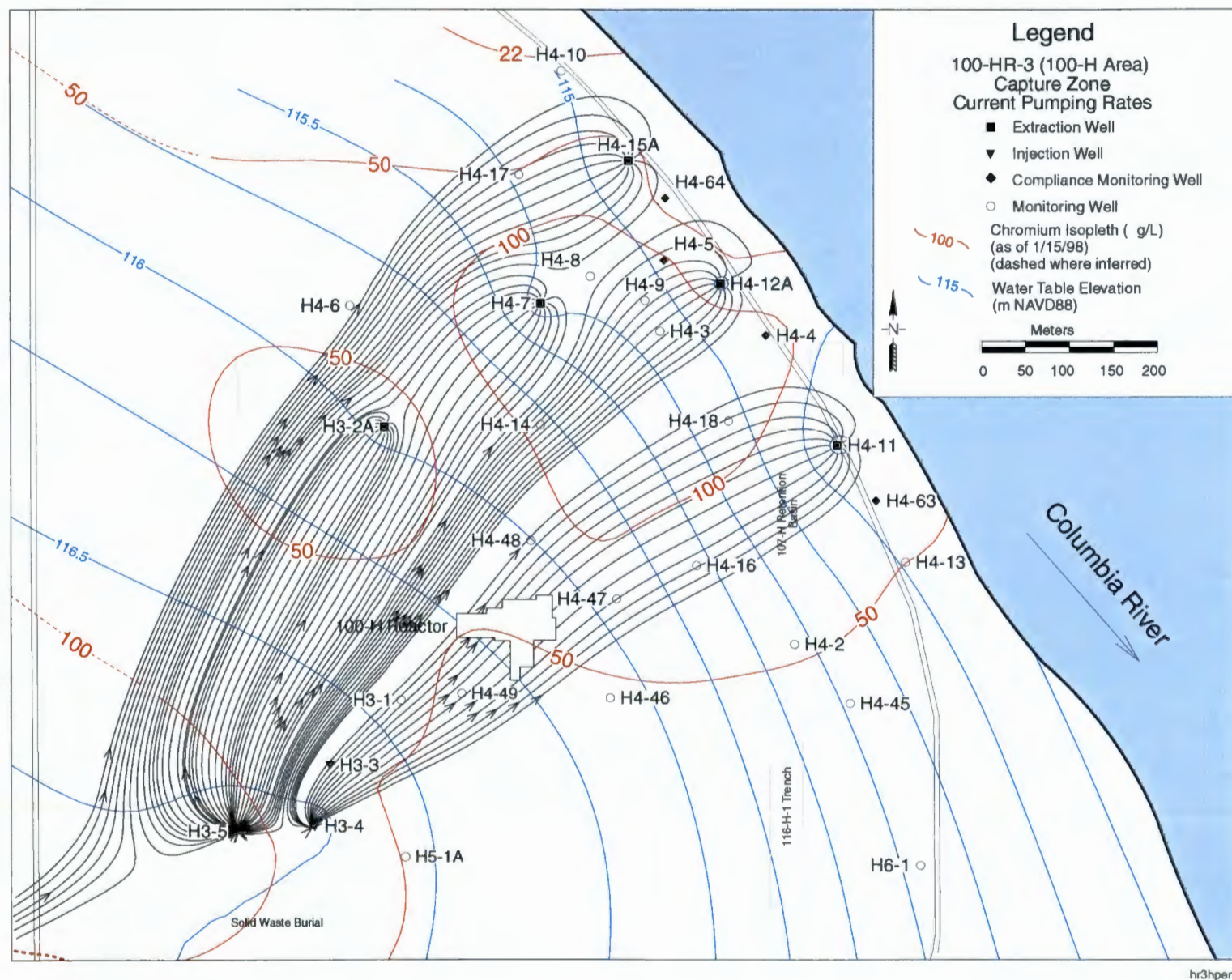


Figure 2.6-16. Capture Zone from 100-HR-3 Pump-and-Treat System (DOE/RL-99-13)

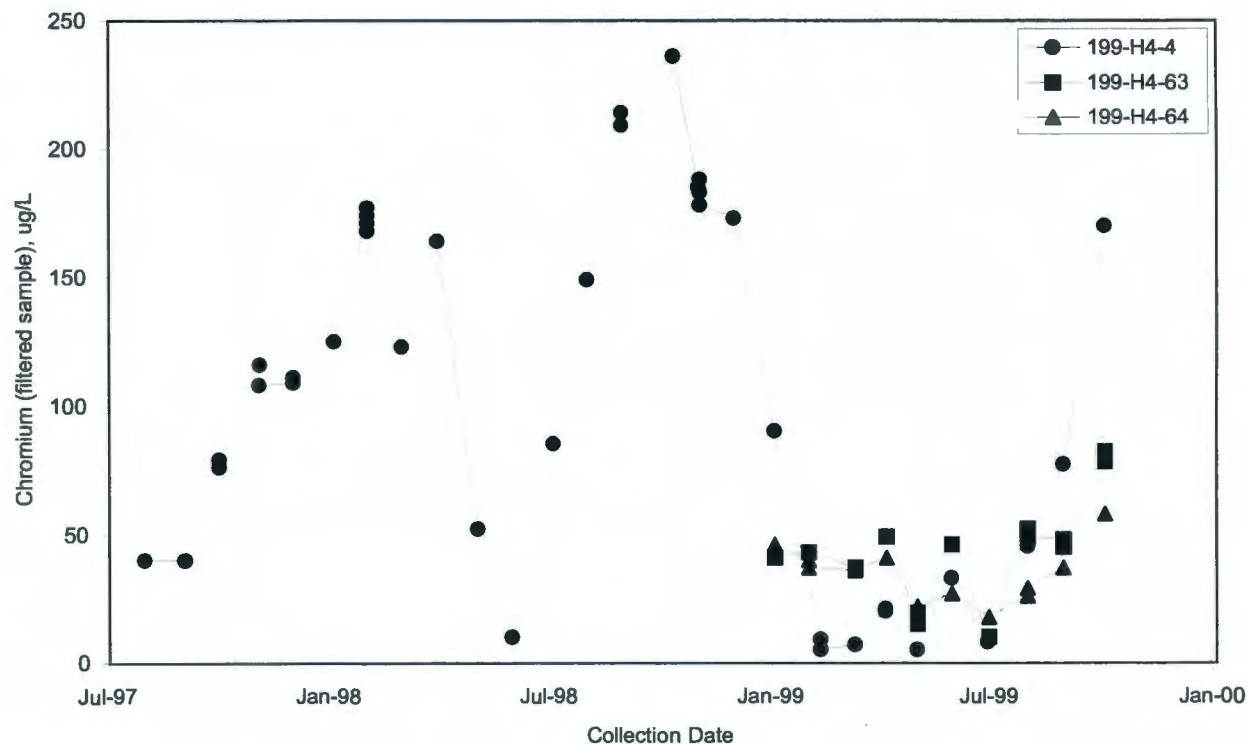


Figure 2.6-17. Chromium in Pump-and-Treat Compliance Wells

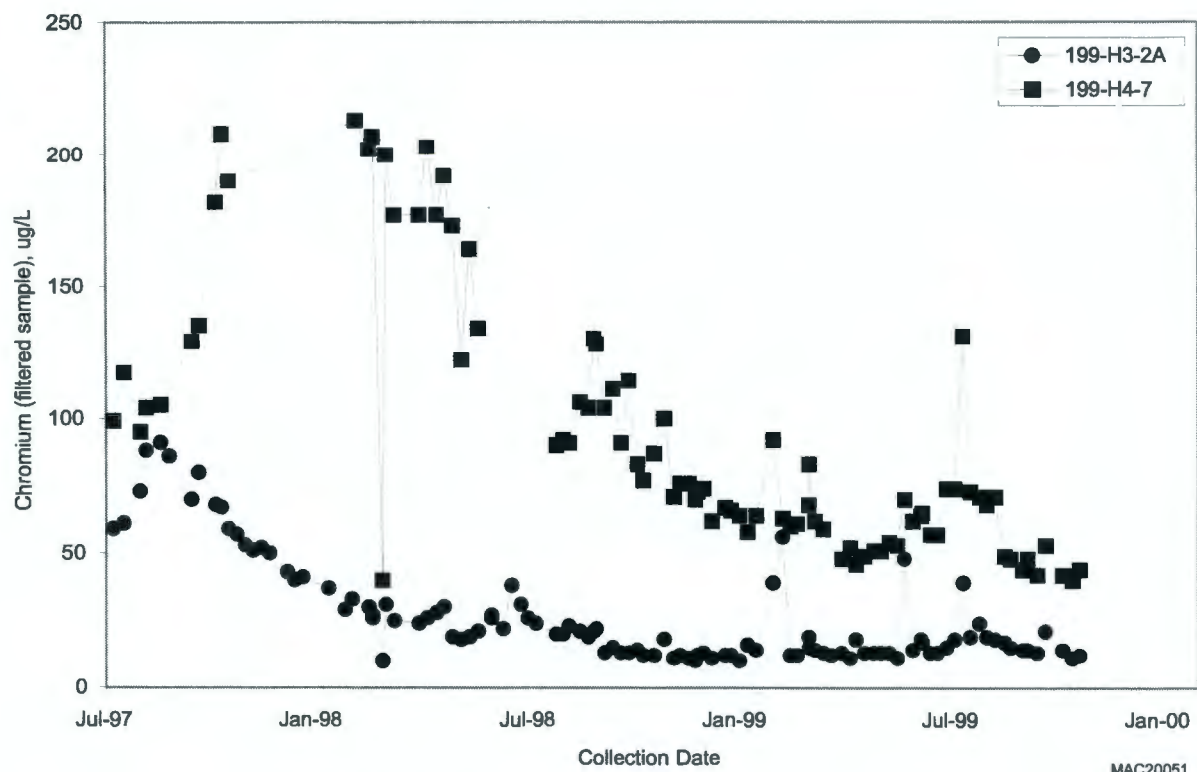


Figure 2.6-18. Chromium in Pump-and-Treat Extraction Wells

2.7 100 F Area

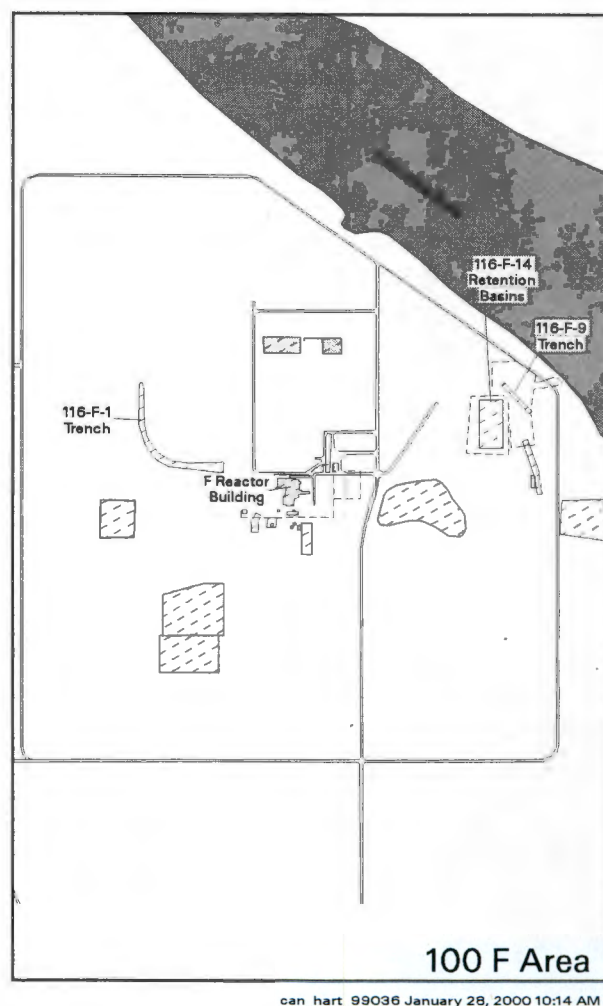
M. D. Sweeney, R. F. Raidl

The 100 F Area is located the farthest east and downstream of the reactor areas on the Hanford Site. 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 discharged directly to the Columbia River). Waste sites in the 100 F Area included leaking 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, trichloroethylene, and uranium is also detected.

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 2). In March 1999, the gradient between wells 199-F5-4 and 199-F8-4 was 0.0016. 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 0.05 to 1.1 meters per day toward the southeast.

A plume of groundwater contaminated with nitrate and tritium, which originates from sources in the 100 F Area, extends to the southeast of the 100 F Area, confirming 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 (see Figures 2.1-3 and 2.1-4). 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 8 in WHC-SD-EN-TI-221, Rev. 0).

2.7.2 Tritium

Results from sampling at 100 F Area in fiscal year 1999 indicated a general decline in tritium concentration. Only one well, 199-F8-3, exceeded the 20,000 pCi/L drinking water standard, with a result of 32,700 pCi/L in October 1998 (see Plate 3). The tritium concentration had declined to 16,300 pCi/L in April 1999.

2.7.3 Uranium

Low levels of uranium are detected in the 100 F Area, but only one result exceeded the proposed 20 µg/L maximum contaminant level in fiscal year 1999. Well 199-F8-2 reported a result of 20.3 µg/L in October 1998. The well is located near the 118-F-3, -4, and -5 burial grounds and downgradient of the 116-F-1 trench. The result represents a slight increase in concentration in this well.

2.7.4 Strontium-90

A plume of strontium-90 exceeding the 8 pCi/L drinking water standard is centered on the 116-F-14 retention basins and the 116-F-2 and 116-F-9 trenches. The distribution in fiscal year 1999 was the same as in 1998 (see Figure 5.8-1 in PNNL-12086).

Most of the wells with detectable strontium-90 either exhibited a decline in concentration, or no significant change. The highest concentration continued to be in well 199-F5-3, with an annual average of 194 pCi/L (Figure 2.7-1). Concentrations in this well have been declining since 1997.

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.

2.7.5 Nitrate

Nitrate continues to have the widest distribution of any contaminant in the 100 F Area. The highest concentrations continued to be in the southwestern corner of the 100 F Area in well 199-F7-1 (Figure 2.7-2). This well had a peak in nitrate in fiscal

year 1998 and decreased this year. Well 199-F5-45, located near the reactor building, showed a peak in nitrate concentrations early in fiscal year 1999, but declined later in the year.

2.7.6 Chromium

Most of the wells in the 100 F Area have low but detectable chromium concentrations. All results were below the 100 µg/L maximum contaminant level in fiscal year 1999. The highest concentrations were reported in wells 199-F5-46 (51 to 96 µg/L) and 199-F5-6 (66 µg/L). The chromium results from both of these wells show variable concentrations. Both wells are downgradient from the 100 F Reactor cooling water effluent lines (100-F-19), which may be the source of the elevated chromium.

2.7.7 Trichloroethylene

Trichloroethylene continued to be detected in the southwestern corner of the 100 F Area and in the adjacent 600 Area. Wells 199-F7-1 and 699-77-36 both exceeded the 5-µg/L maximum contaminant level in October 1998, at 16 and 18 µg/L, respectively. Both wells show declining trends.

Wells 199-F5-45 and 199-F5-46 consistently detect low levels of trichloroethylene. In October 1998, they both measured 5 µg/L.

2.7.8 Water Quality at Shoreline Monitoring Locations

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 driven into the aquifer at locations near the low-water shoreline. Seeps are locations where groundwater discharges above the river level.

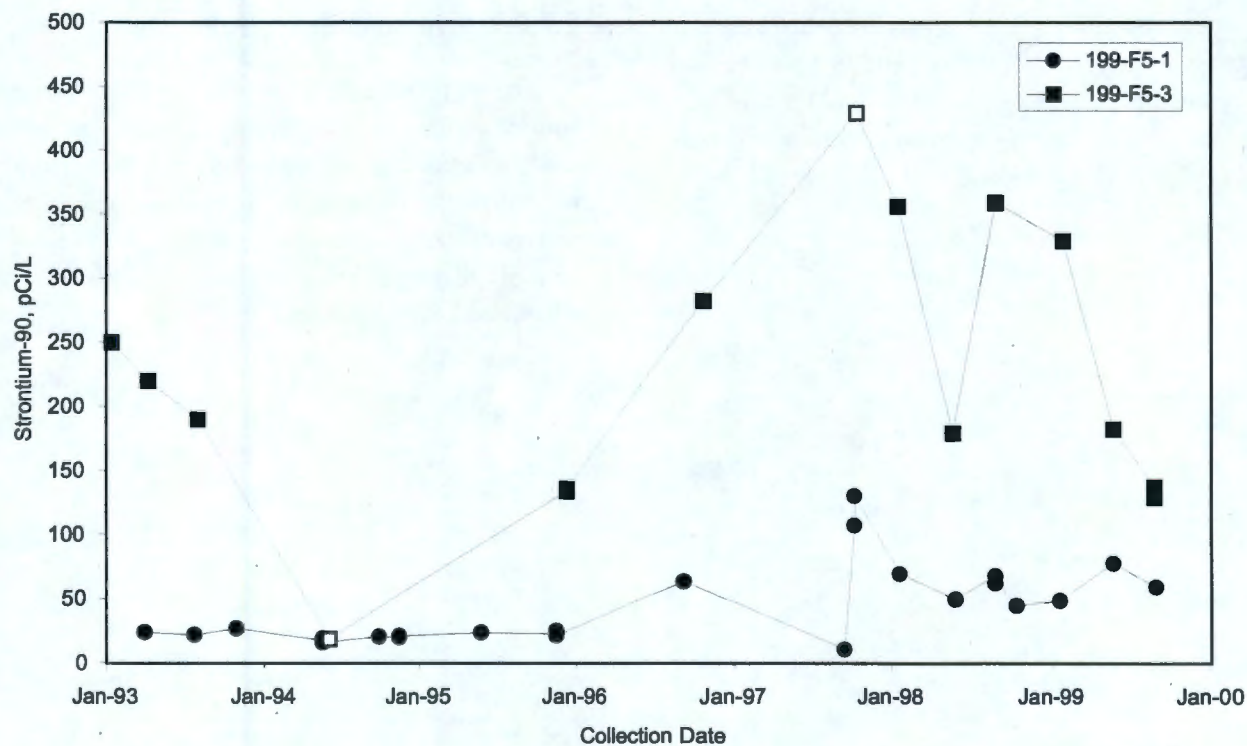
2.7.8.1 Aquifer Sampling Tube Results

Samples collected during the fall 1998 sampling were screened for hexavalent chromium, gross beta,

nitrate, and tritium. The highest contaminant concentrations were: 7.4 pCi/L gross beta, 29.4 µg/L hexavalent chromium, 49 mg/L nitrate, and 1,100 pCi/L tritium. All of the highest concentrations were detected in samples collected along the 100 F Area slough.

2.7.8.2 Riverbank Seepage Results

One seep site along the 100 F Area shoreline was sampled during October 1998. The specific conductance of the sample was 364 µS/cm, indicating that it was primarily groundwater. The maximum concentrations of the contaminants of concern are as follows: 39 mg/L nitrate, 898 pCi/L tritium, 17.6 µg/L chromium, and 5.87 pCi/L gross beta.



JTR00042

Figure 2.7-1. Strontium-90 in Wells 199-F5-1 and 199-F5-3 Near 116-F-2 Trench

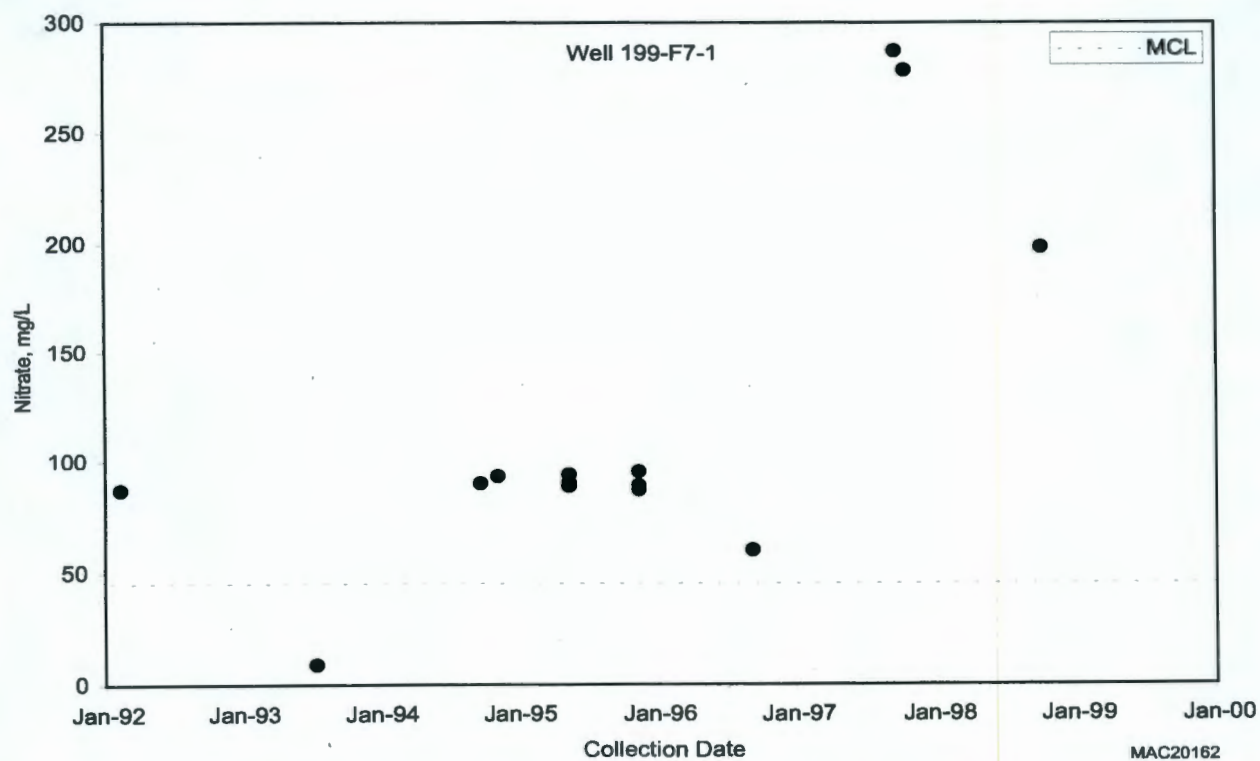
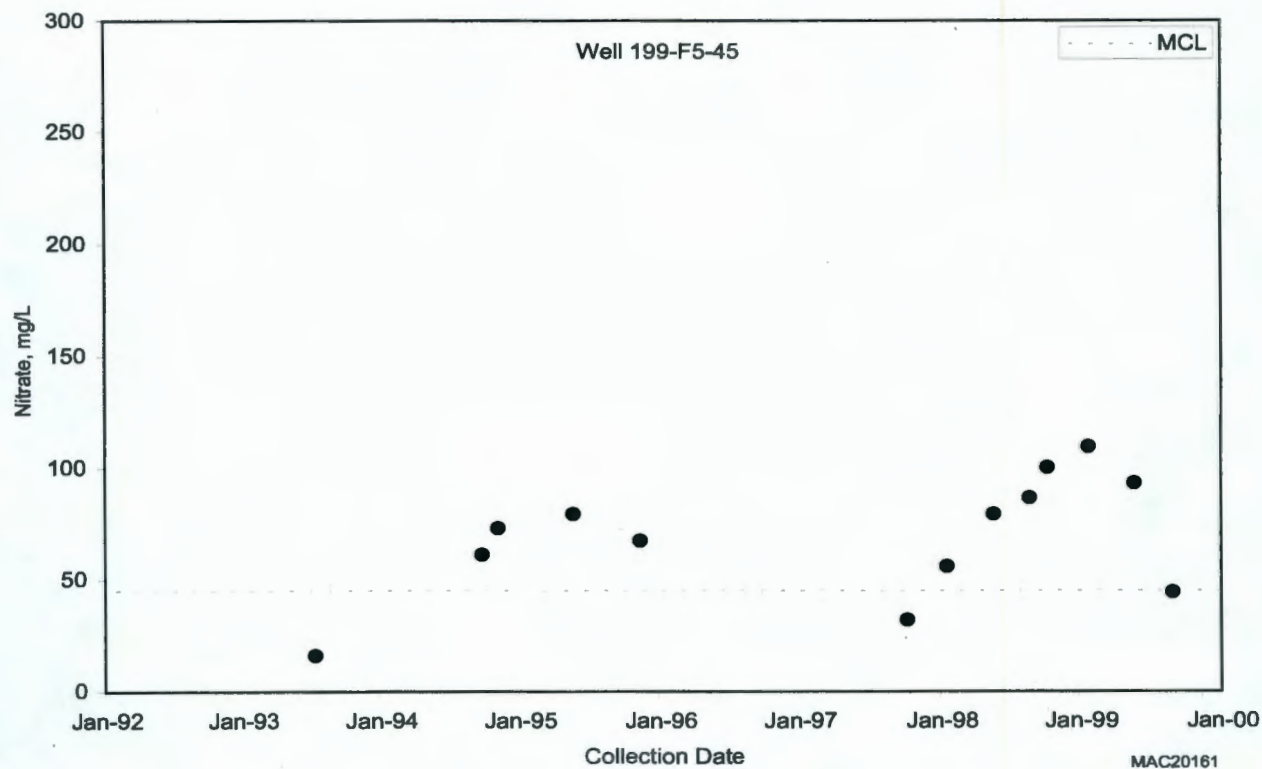


Figure 2.7-2. Nitrate in Well 199-F7-1, Southwestern 100 F Area, and Well 199-F5-45, Northeast of F Reactor

2.8 200 West Area

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

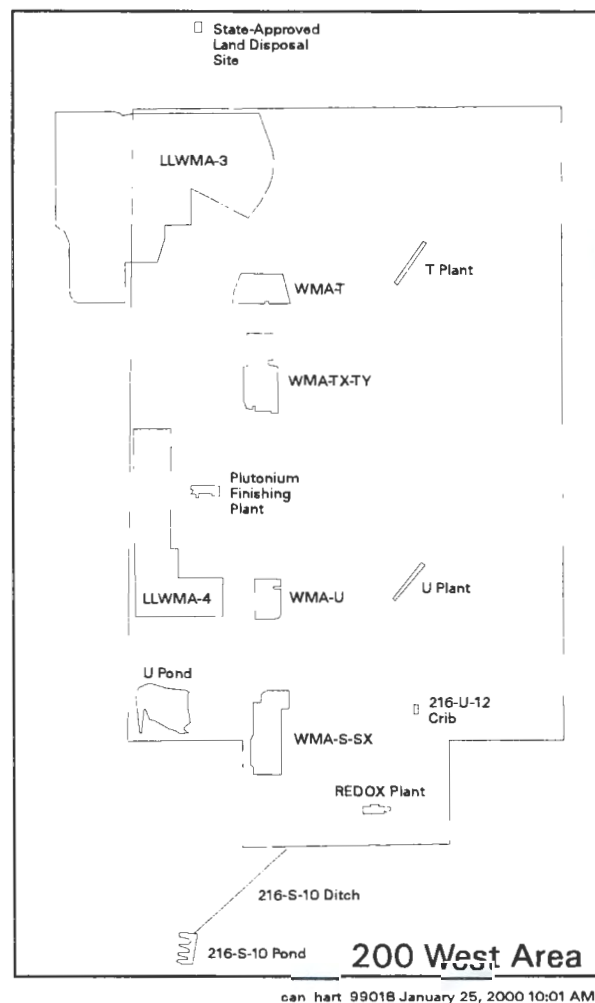
Contamination in 200 West Area can be divided into five major regions:

- Plutonium Finishing Plant
- T Plant
- U Plant
- REDOX Plant
- State-Approved Land Disposal Site.

The discussion in this section is divided into groundwater flow, the major radioactive and non-radioactive hazardous contaminants, and specific *Resource Conservation and Recovery Act of 1976 (RCRA)* facility monitoring. Where appropriate, groundwater remediation is also discussed. The major contaminant plumes found in 200 West Area are carbon tetrachloride, iodine-129, nitrate, technetium, trichloroethylene, tritium, and uranium. Chromium is also found in small, scattered areas.

2.8.1 Plutonium Finishing Plant

The Plutonium Finishing Plant operated from 1949 through 1987 for the final stages of plutonium purification. The Plutonium Finishing Plant was not a significant contributor to the iodine-129 or tritium plumes. Migration of plutonium contamination from the vadose zone is of 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 1999. Carbon tetrachloride and other volatile organic compounds form the major plumes discussed in this section. Relatively widespread nitrate contamination is also present.



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 system. Large masses of carbon tetrachloride continue to be removed from the vadose zone, reducing this source of groundwater contamination. The groundwater pump-and-treat system removes smaller amounts of carbon tetrachloride as groundwater is withdrawn

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.

and re-injected. As a result, significant changes in groundwater flow and contaminant distribution are occurring.

2.8.1.1 Groundwater Flow

Groundwater near the Plutonium Finishing Plant flows generally from west to east (see Plate 2). Flow is heavily influenced by the ongoing 200-ZP-1 Operable Unit pump-and-treat activities. Six extraction wells to the north, east and south of the Plutonium Finishing Plant and five injection wells to the west of Low-Level Waste Management Area 4 have created an area of flow converging on the extraction zone. These conditions are expected to continue until the end of the pump-and-treat program, at which time the flow direction will become generally eastward.

Details of groundwater flow beneath the pump-and-treat system and Low-Level Waste Management Area 4 are discussed below.

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 2.8-1), covering an area of over 11 square kilometers. The contamination is believed

to be from pre-1973 waste associated with the Plutonium Finishing Plant. The maximum carbon tetrachloride concentration detected in the 200 West Area in fiscal year 1999 was in extraction well 299-W15-32, where the annual average concentration was 6,600 µg/L. Data from extraction wells are taken from project-specific data files and, thus, are not included on the diskette provided with this report. The allowable maximum contaminant level for carbon tetrachloride in drinking water is 5 µg/L.

The major identified sources of carbon tetrachloride 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 may also have contributed. These sources are shown in Figure A.12. Vadose zone carbon tetrachloride sources are discussed in Section 3.2.2.1.

A large plume of carbon tetrachloride under the 200 West Area originates mainly from waste sites associated with the Plutonium Finishing Plant. The area of the plume increased slightly during the past year.

In the central part of the plume, the area within the 4,000 µg/L contour has increased during the period of pump-and-treat operations. Concentrations of carbon tetrachloride are increasing 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 2.8-2). Concentrations in the southern extraction wells 299-W15-32 and 299-W15-36 and nearby monitoring wells are declining slowly. BHI-01311, Rev. 0 discusses in more detail the continued existence of high concentrations in the area of pump-and-treat remediation, which supports the presence of a continuing source of carbon tetrachloride, such as non-aqueous phase liquid below the water table or continued recharge from the vadose zone. Concentrations are declining around the active injection wells as shown in Figure 2.8-1.

The part of the plume greater than 1,000 $\mu\text{g/L}$ extends to the north and northeast reaching the vicinity of Low-Level Waste Management Area 3 burial ground and T Plant. Well 299-W10-20, for example, has persistent concentrations of carbon tetrachloride near or above 1,000 $\mu\text{g/L}$, even though it is not located near any known sources. Other wells in the vicinity also have high carbon tetrachloride values, with the exception of well 299-W10-19, where the concentrations have declined sharply since 1997 (Figure 2.8-3). The reason for this localized decline is unknown but suggests variability that may be related to contaminant or water source distribution. It is possible that past discharges to the 200 West power plant pond and the 216-W laundry waste crib, located in the east-central part of the 200 West Area, resulted in the nearly due north and northeastward transport of the carbon tetrachloride. As suggested by BHI-01311, Rev. 0 further investigation of possible sources and historical flow directions in the northwestern 200 West Area is warranted.

Carbon tetrachloride concentrations greater than 1,000 $\mu\text{g/L}$ also are found near T Plant northeast of the known carbon tetrachloride sources near the Plutonium Finishing Plant. High concentrations persist in well 299-W11-14 but have declined in upgradient well 299-W11-7, suggesting a pulse of contamination is moving downgradient (Figure 2.8-4). Concentrations in well 299-W12-1, located in the northeastern corner of the 200 West Area, have increased since 1997 to a maximum of 8 $\mu\text{g/L}$ (Figure 2.8-5). The carbon tetrachloride plume has been divided into two lobes on its northern boundary, likely because of the discharge of relatively clean water to the 216-T-4-2 ditch. Concentrations of a number of contaminants are increasing in that vicinity since that discharge ceased in 1995 (Section 2.8.2).

Carbon tetrachloride concentrations have been increasing markedly 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 less than 5 $\mu\text{g/L}$ in fiscal year 1995 to 120 $\mu\text{g/L}$ in fiscal year 1999 (see Figure 2.8-5). The

previously low concentrations in this area could have been caused by the discharge of carbon tetrachloride-free water 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.

Information on the distribution of carbon tetrachloride in the eastern half of the 200 West Area is very sparse. The original well network had large gaps in this area and several key wells have gone dry. Whether or not a low concentration area exists in the east-central part of the 200 West Area 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 two 1990 samples from well 299-W14-10 where carbon tetrachloride was below the detection limit.

Carbon tetrachloride contamination extends a considerable distance southeast of the Plutonium Finishing Plant to the eastern edge of the Environmental Restoration Disposal Facility. Concentrations in fiscal year 1999 were slightly below the maximum contaminant level but were greater than the maximum contaminant level in fiscal year 1998 (see Figure 2.8-5).

Carbon tetrachloride contamination has been observed to depths greater than 60 meters in the aquifer. In places, contamination at depth extends greater distances laterally than at the water table, as reported previously (PNNL-12086). Little information is available on the distribution of carbon tetrachloride at depth. Available data consist of a few well nests and depth discrete samples collected from older wells with large open intervals. One disadvantage of the depth discrete samples is the potential for vertical mixing within the well or along the annulus. A discussion of depth distribution of carbon tetrachloride is presented in the fiscal year 1998 annual groundwater report (PNNL-12086). A detailed summary of the available data on the depth distribution of carbon tetrachloride has recently been published in BHI-01311, Rev. 0. Two figures from that report showing the carbon tetrachloride distribution in two deeper zones of the:

unconfined aquifer are reproduced here and compared to carbon tetrachloride contours at the top of the aquifer (Figure 2.8-6 and Figure 2.8-7).

2.8.1.3 Chloroform and Trichloroethylene

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 by biodegradation of carbon tetrachloride. Biodegradation is believed to be the major source of chloroform in the 200 West Area. The maximum contaminant level for chloroform is 100 µg/L (total trihalomethanes), which is 20 times higher than that for carbon tetrachloride. The distribution of chloroform is shown in Figure 2.8-8. Values for chloroform are all below the maximum contaminant level.

The distribution of trichloroethylene near the Plutonium Finishing Plant is shown in Figure 2.8-9. Disposal near T Plant may have also contributed to this plume. The plume is fairly extensive but concentrations are only slightly above the 5 µg/L maximum contaminant level.

2.8.1.4 Plutonium and Americium

The single well, 299-W15-8, near the 216-Z-9 crib, where plutonium and americium have been detected in groundwater, has not been monitored since 1991 when the well went dry. No replacement well has been funded. The fiscal year 1998 annual report (PNNL-12086) presents the latest information on plutonium and americium in groundwater and the vadose zone in this vicinity. Report WHC-SD-EN-TI-248 discusses how complexants may mobilize transuranics in the vadose zone.

2.8.1.5 Nitrate

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 significant amounts of nitrate. There is, thus, a nitrate plume originating

in this area, but additional sources of nitrate from disposal facilities near T Plant also contribute to the contamination. The extent of nitrate in the western and northern 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.

Nitrate concentrations are increasing in wells downgradient from the injection wells for the 200-ZP-1 pump-and-treat system. This increase appears to be from nitrate in the injected water that was not treated for nitrate removal. Thus, nitrate concentrations in wells 299-W18-23 and 299-W18-26 are now greater than the maximum contaminant level (Figure 2.8-11). This nitrate results in an increase in specific conductance of water from wells that are now upgradient of Low-Level Waste Management Area 4, decreasing the usefulness of specific conductance for RCRA detection monitoring.

2.8.1.6 Low-Level Waste Management Area 4 RCRA Parameters

The standard detection monitoring system, using upgradient versus downgradient comparisons of indicator parameter concentrations, is of limited use at Low-Level Waste Management Area 4. Water from the 200-ZP-1 pump-and-treat project has been reinjected into groundwater wells located immediately west of Low-Level Waste Management Area 4, changing the groundwater chemistry baseline. Background levels for the contamination indicator parameters were re-established in the second quarter of 1999. There does not appear to be any contaminant release from Low-Level Waste Management Area 4. Wells and analytes monitored are listed in Appendix A.

RCRA monitoring at Low-Level Waste Management Area 4 indicates no groundwater contamination from this facility. Monitoring this area is challenging because of extraction and injection of groundwater from a nearby remediation system.

At the inception of RCRA monitoring at Low-Level Waste Management Area 4 in 1988, groundwater flow was primarily from east to west. However, as the effects of past liquid disposal practices began to dissipate, groundwater flow beneath this facility began to return to the west to east conditions that pre-dated the Hanford Site. The groundwater flow conditions are also being influenced by the ongoing 200-ZP-1 pump-and-treat program, which has extraction wells to the east and injection wells to the west of Low-Level Waste Management Area 4. Groundwater flow is expected to remain in the easterly direction after the pump-and-treat activities are completed.

Carbon tetrachloride, nitrate, and trichloroethylene are the major contaminants in monitoring wells surrounding Low-Level Waste Management Area 4. These constituents are not related to the disposal of waste in this facility. They are attributed to contaminant plumes originating to the east of Low-Level Waste Management Area 4 that have spread over the 200 West Area.

All of the wells in the monitoring network contain carbon tetrachloride above the 5 µg/L maximum contaminant level. In contrast, only monitoring well 299-W15-16 exceeded the 5 µg/L maximum contaminant level for trichloroethylene in April 1999, with a value of 6 µg/L. Subsequent results were below the maximum contaminant level.

Nitrate exceeded the 45 mg/L maximum contaminant level in wells 299-W15-15, 299-W15-16, 299-W15-18, 299-W18-21, 299-W18-23, 299-W18-24, and 299-W18-26. With the exception of 299-W18-21, this contamination is related to the recognized nitrate plume in the 200 West Area. The elevated nitrate levels in well 299-W18-21 appear to be isolated from the main body of this nitrate plume. However, this may simply indicate a preferential flow path in this direction.

2.8.1.7 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. Contamination in the groundwater was reduced in the area of highest concentrations through mass removal, and additional information was collected through hydraulic monitoring, contaminant monitoring, and treatment system operation.

Groundwater is pumped and treated in the 200 West Area to prevent carbon tetrachloride contamination from spreading. In fiscal year 1999, 1,290 kilograms of carbon tetrachloride were removed.

Interim Remedial Action Objectives

The pump-and-treat system for the 200-ZP-1 Operable Unit, located north of the Plutonium Finishing Plant, was implemented as an interim 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 DOE/RL-99-79. The 200-ZP-1 Operable Unit facilities and Phase III extraction, injection, and monitoring well locations are shown in Figure A.12.

History of Operations

The pump-and-treat operations were implemented in a three-phase approach. Phase I operations, which have been terminated, 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 commenced August 5, 1996 and ended on August 8, 1997 for transition to Phase III operations. The well configuration during Phase II operations consisted of three extraction wells, all completed in the top 15 meters of the aquifer. The groundwater was treated using an air stripper followed by granular activated carbon 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 were initiated on August 29, 1997. The well configuration was expanded to six extraction wells, in the top 15 meters of the aquifer, and five injection wells. 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.

Contaminant Removal

Carbon tetrachloride contamination in the groundwater was reduced in the area of highest concentrations through mass removal. Approximately 339.9 million liters of contaminated groundwater were treated in fiscal year 1999 at an average flow rate of 707 liters per minute. Production rates for the six extraction wells ranged from 27 to 310 liters per minute. The average influent concentration for the six extraction wells was 3,788 $\mu\text{g/L}$, ranging from 3,300 to 4,400 $\mu\text{g/L}$.

Treatment of the contaminated water resulted in the removal of 1,290 kilograms of carbon tetrachloride in fiscal year 1999. Since initiation of pump-and-treat operations in August 1994, ~954.8 million liters of water have been treated, resulting in removal of 3,386 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.

The most significant system shutdowns in fiscal year 1999 occurred when sporadic, elevated carbon tetrachloride concentrations (exceeding the 5 $\mu\text{g/L}$ maximum contaminant level) were detected in the water exiting the treatment system. Normally, carbon tetrachloride concentrations are at or below the 2 $\mu\text{g/L}$ detection limit after treatment and before injection. The reason for the increased concentrations was identified as an algae buildup in the air-stripper packing material, which interferes with the air-stripping efficiency. While concentrations of carbon tetrachloride in the effluent tank exceeded the maximum contaminant level of 5 $\mu\text{g/L}$ during those exceptions, concentrations measured at the injection wells were never above the detection limit. It appears that carbon tetrachloride volatilizes from the return water while the water is transported through the pipeline to the injection wells.

To deal with the algae problem, chlorine was injected into the influent tank to reduce the algae content. Since concentrated chlorine (~3,000 mg/L) was injected into the system on May 27, 1999, the carbon tetrachloride concentrations in the effluent tank have been below the maximum contaminant level of 5 $\mu\text{g/L}$. The system is scheduled for cleaning and replacement of the packing in early fiscal year 2000, which will increase air-stripping efficiency.

The environmental restoration contractor sampled for coliform contamination at extraction well 299-W15-35, located nearest to the Z Plant septic field, and in the treatment influent tank on August 4, 1999. The effluent from the Z Plant septic system was suspected to have been impacting the groundwater in the area of the 200-ZP-1 Operable Unit. Coliform was not detected in these samples.

Technetium-99 was measured in special samples collected in fiscal year 1999. The technetium-99 results ranged from a minimum of 20 pCi/L measured at extraction well 299-W15-37 to 286 pCi/L measured at extraction well 299-W15-32. None of the results exceeded the drinking water standard of 900 pCi/L .

Overall Effectiveness

Carbon tetrachloride concentrations increased at all three of the northern extraction wells, but were stable or decreased slightly in the three southern wells (Figure 2.8-12 and Figure 2.8-13). The greatest average fiscal year 1999 concentrations were measured at the two northernmost extraction wells (299-W15-33 [6,218 $\mu\text{g/L}$] and 299-W15-34 [4,700 $\mu\text{g/L}$]) and the lowest average concentrations were observed at the southernmost well (299-W15-37 [358 $\mu\text{g/L}$]). Table 2.8-2 compares average carbon tetrachloride concentrations at the extraction wells for fiscal year 1997, fiscal year 1998, and fiscal year 1999, the mean flow rate for each extraction well, and the relative concentration changes.

There were no significant changes in chloroform and trichloroethylene concentrations in the extraction wells for fiscal year 1999 when compared to fiscal year 1998 concentrations. Chloroform concentrations ranged from 17 to 38 $\mu\text{g/L}$, while trichloroethylene concentrations ranged from 5 to 16 $\mu\text{g/L}$.

As discussed above, the influent tank concentrations of carbon tetrachloride increased to an average of 3,788 $\mu\text{g/L}$. The hydraulic gradient created by the extraction wells is moving significant quantities of dissolved organic mass from the high concentration area of the plume to the extraction wells. Figure 2.8-14 shows the detail of the fiscal year 1999 carbon tetrachloride plume map in the area of the remediation system, and Figure 2.8-15 shows the June 1996 baseline plume map.

Several conclusions can be drawn from changes in the carbon tetrachloride plume maps (refer to DOE/RL-99-79 for additional details and discussion).

- The plume center (greater than 3,000 $\mu\text{g/L}$) is moving primarily in a northerly and easterly direction toward the four northernmost extraction wells.
- The concentrations of carbon tetrachloride east of the pumping wells may be decreasing indicated by a decrease in concentrations in monitoring well 299-W14-9, from ~ 100 $\mu\text{g/L}$ in mid-1997 to ~ 20 $\mu\text{g/L}$ at the end of fiscal year 1999.

- The area of the 4,000 $\mu\text{g/L}$ contour has apparently increased in size, noted by comparing the fiscal year 1999 plume map with the June 1996 baseline plume map. Spreading of the 4,000 $\mu\text{g/L}$ contour is attributed to the effects of pumping.
- Concentrations of carbon tetrachloride south and east of injection well 299-W15-29 are decreasing, as demonstrated by the indentation in the 1,000 $\mu\text{g/L}$ contour on Figure 2.8-14. This implies that injection of the treated water is displacing the plume to the east.

Water-Level Impact and Capture-Zone Analysis

General groundwater flow in the vicinity of the extraction wells is still east-northeast in this area (Figure 2.8-16). Water levels are estimated to be declining in this area at a rate of about 0.47 meter per year (DOE/RL-99-79).

The entire high concentration area of the plume (greater than 2,000 $\mu\text{g/L}$) was contained hydraulically in fiscal year 1999 (DOE/RL-99-79). Based on numerical modeling results, the radius of influence of the pumping wells across the high concentration area extends over 124 meters from extraction well 299-W15-33 (Figure 2.8-17).

2.8.2 T Plant

T Plant operated from 1944 through 1953 to separate plutonium contaminated fuel using the bismuth phosphate process. It was subsequently converted to an equipment decontamination facility. Chlorinated hydrocarbons (carbon tetrachloride and trichloroethylene), 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

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.

Management Area T and Waste Management Area TX-TY. In addition, minor uranium, chromium, and fluoride contamination is found near T Plant.

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 1999. The status of the assessment monitoring is 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 flow in the northern portion of the 200 West Area is predominantly to the east-northeast, with the flow direction more to the east in the area immediately around and to the east of T Plant (see Plate 2). In the past, the flow direction in this part of the 200 West Area was strongly influenced by liquid waste disposal practices at other facilities in 200 West Area. As little as 5 years ago, the flow direction was mainly north-northeast. As the influence of past liquid disposal practices continues to decline, groundwater flow is expected to approach pre-Hanford conditions and become primarily eastward. Pump-and-treat operations at the 200-ZP-1 Operable Unit are impacting flow directions in the southern part of this area.

Sections 2.8.2.11, 2.8.2.12, and 2.8.2.13 on RCRA monitoring contain additional discussion of groundwater flow.

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 3). The plume geometry suggests the major tritium source is near the TY Tank Farm, the 242-T evaporator, and associated disposal cribs. Tritium concentrations remain extremely high in the area immediately east of the TY Tank Farm. In June 1998, tritium concentration suddenly increased to 3.21 million pCi/L in well 299-W14-2, adjacent to the 216-T-28 crib. In fiscal year 1999, concentrations in this well dropped, but concentrations increased in nearby wells 299-W14-12 and its replacement well 299-W14-13 (Figure 2.8-18). The August sample from well 299-W14-13 contained the maximum concentration detected in fiscal year 1999, 2 million pCi/L, which is equal to the derived concentration guide. The hydraulic gradient in this vicinity is very 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 contamination; however, the cause for the sudden increase is unknown.

Waste sites associated with T Plant have contaminated groundwater with high concentrations of tritium. The contaminant is associated with iodine-129 and technetium-99.

In an area north of Waste Management Area T, tritium is consistently found at levels much lower than the surroundings, which may be related to past discharge of relatively clean water to the 216-T-4-2 ditch (WHC-EP-0815). Discharge of water to the 216-T-4-2 ditch ceased in 1995, followed by an increase in tritium concentrations in nearby wells.

2.8.2.3 Iodine-129

The extent of iodine-129 above the interim drinking water standard near T Plant (Figure 2.8-19) coincides generally with the technetium-99 and tritium (see Plate 3) plumes. The interpretation of iodine-129 results is somewhat complicated by analytical difficulties at the primary laboratory that affected numerous higher concentration values. The analytical issues are being addressed in discussions with the laboratory. High concentrations of iodine-129 were measured in well 299-W14-2 with a maximum concentration of 47.4 pCi/L for data that are not associated with analytical problems (annual average from this well was 32 pCi/L). Concentrations from this well appeared to decline during the course of the year.

2.8.2.4 Technetium-99

A technetium-99 plume is present in the T Plant area (Figure 2.8-20), but the concentrations are less than the drinking water standard in most of the area. The two areas with technetium-99 greater than the drinking water standard are near the northeastern corner of Waste Management Area T and in the Waste Management Area TX-TY. The RCRA assessment concluded that Waste Management Area 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 in the vicinity of T Plant in fiscal year 1999 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. Because uranium is typically the source of most elevated gross alpha measurements seen at the Hanford Site, it is discussed in this section. Uranium was detected above the proposed maximum contaminant level in only one well in the T Plant area.

Well 299-W11-14 contained 49.7 $\mu\text{g/L}$ of uranium in the single sample taken in fiscal year 1999. The value continues the slow decline seen for the past several years. This well is located immediately northwest of T Plant, and the source of the uranium has not been determined.

Elevated levels of gross alpha concentration were noted in well 299-W11-27, north of the T Tank Farm prior to its going dry. Although a gross alpha concentration of 90 pCi/L was detected in 299-W11-27 in March, it was not detected in the replacement well 299-W10-24 in March or in samples collected later. Thus, the elevated gross alpha levels in 299-W11-27 are suspected to be related to high turbidity and particulate matter in the samples. High turbidity is often encountered in wells that are nearly dry because the water must be collected near the bottom of the well, and the well often cannot be purged sufficiently to remove the particulate matter. In these cases, the concentrations of contaminants such as uranium, which may be found within or sorbed to particulates, are not representative of aquifer conditions.

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 1999 was 823 mg/L in well 299-W10-4. Concentrations of nitrate in this well have been rising since 1997. The nitrate contamination is more widespread than the iodine-129, technetium-99, or tritium plumes discussed previously. It is probable that there are multiple sources of nitrate in this area, including disposal facilities near the Plutonium Finishing Plant.

2.8.2.7 Chromium

Chromium at levels above the 100 $\mu\text{g/L}$ maximum contaminant level in filtered samples is restricted to the immediate vicinity of Waste Management Area T and TX-TY (Figure 2.8-21). The maximum average annual concentration detected in fiscal year 1999 was

294 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 T Tank Farm. The source for this persistent plume has not been identified. Chromium is of interest because it has been identified in tank waste and may help form a signature of mobile tank waste components. A recent increase in chromium to levels above the maximum contaminant level near Waste Management Area TX-TY is discussed in more detail in Section 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 annual average measurements in wells 299-W10-4 (4.6 mg/L) and 299-W10-12 (4.1 mg/L) greater than the maximum contaminant level. Fluoride may be associated with tank waste.

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 2.8-1. Carbon tetrachloride concentrations in the vicinity of T Plant are highly variable. Of particular interest are relatively low carbon tetrachloride concentrations (less than 500 µg/L but still above the 5-µg/L maximum contaminant level) in the vicinity of the southeastern corner of Waste Management Area TX-TY. This area is within the hydraulic influence of the 200-ZP-1 Operable Unit pump-and-treat system discussed previously.

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.

Trichloroethylene is also 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 trichloroethylene greater than the maximum contaminant level extends from the Plutonium Finishing Plant northeast through the T Plant vicinity (see Figure 2.8-9).

2.8.2.10 Iron, Manganese, and Nitrite

Wells 299-W11-24 and 299-W11-28, located to the east of Waste Management Area T, have had reported high values of iron and manganese in filtered samples. Iron jumped suddenly to a maximum of 9,500 µg/L in well 299-W11-24 in fiscal year 1999 but increased slowly to a fiscal year 1999 maximum of 394 µg/L in well 299-W11-28. Manganese in well 299-W11-24 reached a fiscal year 1999 maximum level of 1,380 µg/L, while the fiscal year maximum value for well 299-W11-28 was 209 µg/L. The manganese trends closely follow those of iron. Elevated nitrite has also been detected at levels (expressed as µg/L NO₂) up to 1,862 µg/L in well 299-W11-24 and 295 µg/L in well 299-W11-28 for fiscal year 1999 but does not follow the same trend as the iron and manganese. The high nitrite, iron, and manganese are indicative of reducing conditions; however, the cause of the reducing conditions is unknown.

2.8.2.11 Waste Management Area T RCRA Assessment Summary

Waste Management Area T, located in the north-central portion of the 200 Area, consists of the T 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 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. Seven of the tanks in the waste management area are known or suspected to have leaked.

This site continued to be monitored under an assessment program in fiscal year 1999. The well and analyte lists for this unit are given in Appendix A.

Groundwater Flow

Groundwater flow directions at Waste Management Area T have been highly variable 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 present flow direction is generally toward the east as indicated by the large scale water-table map (see Plate 2). However, locally flow directions may diverge from the regional pattern because variable cementation within the Ringold aquifer 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 less than 1 kilometer to the south.

RCRA Waste Management Area T contains single-shell tank farms that may have contaminated groundwater with technetium-99 and nitrate. Two new wells were drilled in 1999, but more wells are needed to replace those that are going dry.

Groundwater Contamination

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 2.8-22). 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 as water levels dropped in the well. Technetium-99 in replacement well 299-W10-24, drilled immediately adjacent 299-W11-27, has ranged between 1,960 and 3,660 pCi/L with little apparent trend. This may be because of the longer interval open below the water table in the replacement well or residual effects of well drilling and development. The sampling pump in 299-W10-24 is set at a depth of ~4.6 meters below the water table.

Technetium-99 concentrations in well 299-W11-23 started to increase in November 1997, reaching a high of 8,540 pCi/L in November 1998. Technetium-99 subsequently dropped to 2,755 pCi/L in March 1999 before springing back to 7,110 pCi/L in August 1999. The detection in 299-W11-23 is apparently a result of the change in groundwater flow direction from northeast to east. Apparently, the plume, stretching northeast from 299-W11-27, is moving eastward across 299-W11-23. The location and concentrations of the plume inside the waste management area that initially impacted 299-W11-27 are unknown at this time.

Nitrate concentration trends in well 299-W11-27 and its replacement 299-W10-24 are shown in Figure 2.8-23. The recent increase in nitrate concentration in well 299-W11-27 is strongly correlated with the technetium-99 trend (compare to 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 299-W11-27 whereas the technetium-99 is lower. This suggests that the pulse in nitrate and technetium-99 in well 299-W11-27 is a feature of the very top of the aquifer. However, the highest nitrate concentrations are somewhat deeper, with a different source. Given the widespread nature of the nitrate plume, much of the nitrate appears to be from liquid waste disposal facilities, but the nitrate/technetium-99 association may represent shallow release from T Tank Farm operations.

Chromium concentrations in well 299-W11-27 exhibited a peak in fiscal year 1996, earlier than the peak in technetium-99. The chromium in replacement well 299-W10-24 is higher than currently found in well 299-W11-27, indicating the chromium may not be associated with the technetium-99 source since the technetium-99 was higher in well 299-W11-27.

Monitoring Network

The original RCRA monitoring network for Waste Management Area T, 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 groundwater flow direction has resulted in gaps in the downgradient coverage. Existing, pre-RCRA wells were used to the extent possible to meet the needs resulting from a declining water table and changing groundwater flow directions; however, new wells are needed to meet both the needs of downgradient monitoring and for tracking the known contaminant plume.

Two new RCRA compliant monitoring wells were drilled in fiscal year 1999 to replace existing groundwater monitoring wells and to fill gaps in the downgradient network resulting from changes in groundwater flow directions (PNNL-12125). Well 299-W10-23 was drilled as a replacement for well 299-W10-15 and 299-W10-24 was drilled as a replacement for well 299-W11-27; both were completed with 10.7-meter screened intervals to allow for future declines in water-table elevation. In addition, 299-W10-24 was drilled to a depth below the Ringold lower mud unit before being backfilled and completed as a monitoring well at the top of the aquifer.

Well 299-W10-24 was drilled to an initial depth of 131.8 meters, ending below the lower mud, a confining unit within the lower Ringold Formation but above the top of the basalt. During drilling discrete level groundwater samples were taken at depths of 87.5, 99.1, 116.7, 122.5, and 131.4 meters. The discrete sampling detected significant levels of carbon

tetrachloride, nitrate, technetium-99, and tritium throughout the thickness of the aquifer (Table 2.8-3), including beneath the lower mud, which is generally considered to be a confining layer and the bottom of the unconfined aquifer. Technetium-99 generally decreases downward through the aquifer; however, carbon tetrachloride reaches a maximum concentration of 1,600 µg/L at a depth of 99.1 meters, and nitrate and tritium peak at a depth of 87.5 meters.

2.8.2.12 Waste Management Area TX-TY RCRA Assessment Summary

Waste Management Area TX-TY continued to be monitored under an assessment program in fiscal year 1999. The well and analyte lists for this area are given in Appendix A.

Groundwater Flow

Groundwater flow directions at Waste Management Area TX-TY have been highly variable 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 pre-Hanford flow direction in the vicinity of Waste Management Area TX-TY 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, 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 operation located immediately to the south of the waste management area. 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

RCRA Waste Management Area TX-TY contains single-shell tank farms that may have contaminated groundwater with technetium-99 and nitrate. Four new wells were drilled in 1999 to replace those that have gone dry.

of the waste management area, and toward the south in the southern part of the waste management area (see Plate 2). However, locally flow directions may diverge from the regional pattern because variable cementation within the Ringold aquifer may result in preferred groundwater flow paths.

Groundwater Contamination

Contaminant levels (chromium, cobalt-60, iodine-129, nitrate, technetium-99, and tritium) were elevated 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 2.8-24). 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. Concentrations in replacement well 299-W14-13 appear lower but also exhibit an upward trend reaching a maximum of 5,130 pCi/L in August 1999 (see Figure 2.8-24).

High chromium concentrations were also found several years ago in well 299-W14-12, east of Waste Management Area TX-TY. Concentrations have been lower for several years (Figure 2.8-25). Well 299-W14-12 has gone dry and replacement well 299-W14-13 exhibits increasingly higher concentrations of filtered chromium, ranging from 180 to 433 µg/L in fiscal year 1999.

The groundwater flow direction in the vicinity of 299-W14-12 was toward the northeast when monitoring was initiated. Flow is currently toward the southeast. Thus, it seems likely that 299-W14-13 intersects a plume that is distinct from the plume first sampled by 299-W14-12. The location and extent of the earlier plume is uncertain because of the lack of monitoring wells to the east of the line of compliance at Waste Management Area TX-TY.

Technetium-99 levels have increased in well 299-W15-4 since the initiation of the 200-ZP-1 Operable Unit pump-and-treat operations (see Section 2.8.1)

south of the waste management area (Figure 2.8-26). Concentrations exceeded the drinking water standard of 900 pCi/L in July 1999, though the most recent sample in October 1999 was below the drinking water standard. Well 299-W15-4, originally constructed to monitor the 216-T-19 crib, is directly south of the waste management area in a direct flow path between the waste management area and the nearest extraction well. It is possible that the waste management area is the source of the technetium-99 observed in 299-W15-4. This small increase is important for evaluating the impact of the pump-and-treat remediation on contaminants in the T Plant area and for potential future impact of increasing technetium-99 on the operation of the pump-and-treat system. Technetium-99 in well 299-W15-22, located in the southwestern corner of Waste Management Area TX-TY was increasing in fiscal year 1998 to an average activity of 3,100 pCi/L. However, this well could not be sampled because of declining water levels and has not yet been replaced. This suggests that the remediation may have a larger impact on the plume geometry than can be detected by the current monitoring network. Technetium-99 reached a concentration of 286 pCi/L in northern extraction well 299-W15-32 in fiscal year 1999 (see Section 2.8.1.7).

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 groundwater flow direction has resulted in gaps in the downgradient coverage. Existing, pre-RCRA wells were used to the extent possible to meet the needs resulting from a declining water table and changing groundwater flow directions; however, new wells are needed to meet both the needs of downgradient monitoring and for tracking of the known contaminant plume.

Four new RCRA compliant monitoring wells were drilled in fiscal year 1999 to replace existing groundwater monitoring wells. The new wells fill gaps in the downgradient network resulting from changes in groundwater flow directions. Well 299-W10-26 was drilled as a replacement for downgradient monitoring well 299-W10-18 and 299-W14-13 was drilled as a replacement for downgradient monitoring well 299-W14-12. Well 299-W14-14 was drilled along the southeastern boundary of the waste management area to provide monitoring coverage resulting from changes in groundwater flow direction. Well 299-W15-40 was drilled both as a replacement for upgradient monitoring well 299-W15-22 and to monitor the 241-T-25 trench, which was considered a potential source for contaminants detected in well 299-W14-12. All four wells were completed with 10.7-meter screened intervals to allow for future declines in water-table elevation. In addition, 299-W14-14 was drilled to a depth of 135 meters before being completed as a top-of-the-water-table monitoring well.

Well 299-W14-14 was drilled to an initial depth of 135 meters, ending below the lower mud, a confining unit within the lower Ringold Formation, but above the top of the basalt. During drilling, discrete level groundwater samples were taken at depths of 14.5, 30.1, 39.8, 56.9, and 68.5 meters below the water table. The discrete sampling detected significant levels of carbon tetrachloride, nitrate, technetium-99, and tritium, throughout the thickness of the aquifer (Table 2.8-4), including beneath the lower mud, which is generally considered to be a confining layer, and the bottom of the unconfined aquifer. Technetium-99 generally decreases downward through the aquifer; however, it does seem to peak at a depth of 14.5 meters. Carbon tetrachloride reaches a maximum concentration of 920 µg/L at a depth of 39.8 meters.

2.8.2.13 Low-Level Waste Management Area 3 RCRA Parameters

This site continued to be monitored under a detection program in fiscal year 1999. Concentrations of the indicator parameters, pH, specific conductance,

total organic carbon, and total organic halogen, in downgradient wells did not exceed levels in upgradient wells during this reporting period. There are no indications that Low-Level Waste Management Area 3 has contributed to groundwater contamination. Wells and analytes monitored at this site are listed in Appendix A.

RCRA monitoring at Low-Level Waste Management Area 3 indicates no groundwater contamination from this facility.

The maximum contaminant level for carbon tetrachloride and nitrate are consistently exceeded at Low-Level Waste Management Area 3. These constituents are not related to the disposal of waste in this facility. They are attributed to contaminant plumes originating to the south of Low-Level Waste Management Area 3. Trichloroethylene continues to exceed the 5 µg/L maximum contaminant level in well 299-W10-21.

Groundwater flow beneath Low-Level Waste Management Area 3 is generally to the northeast trending more to the east-northeast under the 218-W-3AE burial ground. The flow direction in this area has been influenced by past liquid disposal practices in other portions of the 200 West Area. As these influences continue to decline, the flow direction is expected to return to the pre-Hanford conditions, with groundwater flowing from west to east.

2.8.3 U Plant

U Plant was built for plutonium recovery using the bismuth phosphate process but was never used for that purpose. It was used for recovery of uranium from bismuth phosphate process waste from 1952 until approximately 1962.

A groundwater contaminant plume, containing iodine-129, nitrate, 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 remobilized by disposal 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.

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 detect the possible impact of one RCRA waste management area
- ▶ quarterly to monitor trends in contaminants from one RCRA site
- ▶ various time intervals to evaluate the performance of a pump-and-treat system for technetium-99 and uranium.

Interim action groundwater pump-and-treat remediation is taking place in the vicinity of U Plant. 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.

2.8.3.1 Groundwater Flow

Groundwater flow in the vicinity of U Plant in the 200 West Area is primarily to the east (see Plate 2). Water levels in this portion of the 200 West Area are higher than the pre-Hanford conditions, but the flow direction has been relatively unchanged over the last 10 or more years. This is because the facilities which were the main contributors to the elevated water levels are to the west of U Plant.

Details of groundwater flow at RCRA sites are discussed in Sections 2.8.3.6 and 2.8.3.7. Details of the effects of groundwater remediation are discussed in Section 2.8.3.8.

2.8.3.2 Uranium

The highest concentrations of uranium in Hanford Site groundwater in fiscal year 1999 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 2.8-27). 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 2.8-28. The uranium levels in this well decreased considerably since the maximum measured in 1986 but have increased again in recent years. Levels in fiscal year 1999 reached 1,990 µg/L. Technetium-99 concentrations, however, have not shown the recent increase. This suggests that the cribs are not currently providing an ongoing source of technetium-99 from the vadose zone. The uranium behavior is different than technetium-99 because of its stronger sorption to the sediment and a greater proportion of the uranium remains at or near the source area.

Groundwater beneath U Plant waste facilities had the highest concentrations of uranium on the Hanford Site in fiscal year 1999. Levels increased in some wells this year, but have declined from their peak in 1986.

The maximum annual average uranium concentration detected near U Plant in fiscal year 1999 was 2,600 µg/L in well 299-W19-20, located near the pump-and-treat extraction well (see Figure 2.8-27). The uranium concentrations for several wells in the U Plant vicinity represent dose values greater than the derived concentration guide dose level. Assuming natural isotopic abundance, a uranium concentration

of 790 $\mu\text{g/L}$ represents the 100-mrem/yr dose equivalent for ingestion of drinking water.

The uranium distribution in the vicinity of the 216-U-17 crib has been affected by pump-and-treat remediation (discussed in Section 2.8.3.8). The remediation system impacted 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. As expected, uranium concentrations decreased downgradient of the injection well and increased near the pumping well as the plume is drawn toward the pumping well. In fiscal year 1999, however, high concentrations of uranium were detected near the former injection well. This suggests that uranium contamination is moving into the area from upgradient but may also 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. The distribution of technetium-99 in this vicinity is complex, in part because of the operation of the pump-and-treat remediation system that reinjected treated water until March 1997. The maximum annual average technetium-99 concentration associated with this plume in fiscal year 1999 was 25,300 pCi/L, found in well 299-W19-29. This well is located downgradient of the former injection well, and for several years prior to fiscal year 1999, the technetium-99 reflected the low concentrations in the injected water (Figure 2.8-29). The technetium-99 levels are currently higher than they were prior to the start of the remediation. However, 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 2.8-30).

Technetium-99 remains slightly elevated in wells downgradient of Waste Management Area U, as 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 increased from 323 to 638 pCi/L during the course of the year.

The distribution of technetium-99 is similar to uranium in the U Plant area. Nitrate is also present, but is more widespread.

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 (Figure 2.8-31). This reflects the multiple sources of nitrate in the area. In particular, the 216-U-12 crib contributed to nitrate at levels slightly above the maximum contaminant level.

Nitrate concentrations in the vicinity of the 216-U-17 crib are among the highest on the Hanford Site but are not typically monitored because nitrate is not a performance indicator for the pump-and-treat system. In fiscal year 1998, a concentration of 1,700 mg/L nitrate was detected in well 299-W19-26. This well was not sampled for nitrate in fiscal year 1999. The 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 was found above the interim drinking water standard in the immediate vicinity of the 216-U-1 and 216-U-2 cribs (Figure 2.8-32). Several of the wells that previously contained iodine-129 at levels above the drinking water standard were not sampled in fiscal year 1999. Downgradient, the iodine-129 plumes from U Plant operations merge with, and

become indistinguishable from, the REDOX Plant plume (see Section 2.8.4.2).

2.8.3.6 216-U-12 Crib RCRA Assessment Summary

RCRA groundwater monitoring continued in an assessment program in fiscal year 1999. 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 site that may have contaminated groundwater with nitrate. New wells are needed to replace those that are going dry.

Declining water levels in the 200 West Area reduced the monitoring network from the original five wells to just three wells (one upgradient and two downgradient). This included one new well that was installed in September 1998. While the wells are sampled quarterly for the constituents of interest (see Table A.17) only two downgradient wells remain active, 299-W22-79 and 699-36-70A (see Figure A.8 and Plate 1). Washington State Department of Ecology (Ecology) and U.S. Department of Energy (DOE) agreed in the form of a Tri-Party Agreement interim milestone M-24-00J that new wells would not be added during calendar year 1999. However, two replacement wells, one upgradient and one downgradient, may be installed in calendar year 2000.

New well 299-W22-79 was sampled for the first time in the first quarter of fiscal year 1999. The well is located approximately halfway between downgradient wells 299-W22-41 and 299-W22-42, both of which went dry and were last sampled in March 1999. Well 299-W22-79 was installed to replace 299-W22-42. Well 299-W22-40 was removed from the network in the first quarter of 1999 after it went dry. Well 299-W22-40 will not be replaced because it was not located directly downgradient of the crib, and no contaminants were detected in the well.

Based on regional groundwater elevations, the groundwater flow direction continues east-southeast to easterly. New wells will be located appropriately to maximize the downgradient coverage of the 216-U-12 crib.

Groundwater flow rates have not changed significantly since last year and are presented in Table A.2.

Site-specific parameters selected for the interim status quality assessment monitoring include gross alpha, gross beta, iodine-129, nitrate, technetium-99, and tritium (see 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 nitrate and technetium-99 plumes are a 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 216-U-12 crib downgradient monitoring wells, 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 maximum contaminant level in all the downgradient wells. However, the concentration trend in the nitrate has been downward (Figure 2.8-33). Technetium-99 followed a trend similar to nitrate. Technetium-99 activities ranged from 21.2 to 103 pCi/L in downgradient wells, well below the 900 pCi/L

drinking water standard (Figure 2.8-34). Technetium-99 concentration trends are declining in wells near the crib and increasing farther downgradient in well 699-36-70A. This suggests that the plume is moving downgradient farther east, away from the crib.

During fiscal year 1999, the center of the tritium plume appears to have moved farther east, away from the crib. Tritium concentrations remained above the 20,000-pCi/L interim drinking water standard in downgradient wells 299-W22-42, 299-W22-79, and 699-36-70A during fiscal year 1999. The most recent concentrations are 21,600 and 83,300 pCi/L reported in wells 299-W22-79 and 699-36-70A, respectively.

Iodine-129 is elevated above the 1 pCi/L drinking water standard in wells 299-W22-42, 299-W22-79, and 699-36-70A. Iodine-129 in these wells is 7.64, 2.58, and 15.2 pCi/L, respectively. The iodine-129 source is upgradient of the 216-U-12 crib.

2.8.3.7 Waste Management Area U RCRA Parameters

This waste management area has remained in detection level monitoring since RCRA interim status monitoring began in 1989. Total organic halides exceeded the critical mean value but have an upgradient source. Recalculation of the critical mean for specific conductance (Appendix A) lowered the value from 533 $\mu\text{S}/\text{cm}$ to 273 $\mu\text{S}/\text{cm}$. The August 1999 specific conductance for downgradient well 299-W19-41 exceeded this new critical mean. DOE notified Ecology of this exceedance and an assessment plan is being prepared.

Groundwater flow directions at Waste Management Area U have been highly variable 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. Prior to establishment of the Hanford Site, groundwater in the vicinity of Waste Management Area U is believed to have flowed from west to east, and it was expected that groundwater flow in this area would eventually move to that direction. However, groundwater flow directions have been altered over the past several years as a result of the 200-ZP-1 Operable Unit pump-and-treat operation located immediately to the north of the waste management area. The present flow direction is generally toward the east in most of the waste management area but has a northeasterly component in the northern part of the waste management area (see Plate 2). This northeasterly component is a result extraction well 299-W15-37. The waste management area is outside of the capture zone of this well, but near enough to experience deflection of groundwater flow trajectories. Locally flow directions may diverge from the regional pattern because variable cementation within the Ringold aquifer may result in preferred groundwater flow paths.

Total organic halides have exceeded the comparison value in a number of samples at Waste Management Area U because of the carbon tetrachloride plume originating at cribs associated with the Plutonium Finishing Plant. Large effluent discharges to the 216-U-14 ditch in the early 1990s, coupled with changes in groundwater flow patterns caused by the 200-ZP-1 pump-and-treat operation, have resulted in concentrations in downgradient wells exceeding the comparison value calculated from the upgradient well. Carbon tetrachloride is not a significant tank component, and the total organic halides exceedances are not related to the waste management area.

Technetium-99 is consistently present in downgradient wells at levels less than the drinking water standard of 900 pCi/L. A number of instances where gross beta values exceed the maximum contaminant level are a result of technetium-99.

Waste Management Area U contains single-shell tanks and is a RCRA site. Specific conductance exceeded its critical mean value in one well in August 1999.

The original RCRA groundwater monitoring network established at Waste Management Area U consisted of two upgradient and three downgradient wells (see Table A.13). One pre-RCRA well (299-W19-12) is used for indication only to fill a gap between RCRA wells 299-W19-41 and 299-W19-42. Three of the RCRA wells were constructed with 4.6-meter screened intervals and two with 10.7-meter screened intervals. Two of the three wells with the shorter screened intervals have gone dry and the third will not be able to be used within a year. The two that have gone dry have been replaced with new wells.

Well 299-W19-41 was constructed to replace downgradient well 299-W19-32 and well 299-W19-42 was constructed to replace downgradient well 299-W19-31. Both wells were constructed with 10.7-meter screened intervals to allow for future declines in water-table elevation.

Well 299-W18-25 will be dry in the near future, leaving one upgradient well for the waste management area. There are no plans to replace 299-W18-25. Time will tell whether one upgradient well is sufficient to capture the variability of upgradient groundwater. Well 299-W19-12 is an older, non-RCRA compliant well that consistently yields anomalous, high pH values, probably as a result of construction materials.

2.8.3.8 Groundwater Remediation at 200-UP-1 Operable Unit

The goal of the 200-UP-1 pump-and-treat system 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. The most notable success in fiscal year 1999 was the reduction of technetium-99 to below the 9,000-pCi/L remediation goal in all but two wells. Uranium concentrations remained above the 480-µg/L remediation goal in almost all wells, even after treatment of 425.6 million liters and 5 years of operation.

Groundwater in the U Plant area is pumped and treated to prevent contamination from spreading. The highest concentration portions of the technetium-99 and uranium plumes have shrunk since 1995.

Interim Remedial Action Objectives

The pump-and-treat system for this operable unit is located on the northern side of the 216-U-17 crib (see Figure A.11). 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 mg/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.

For more detailed information about operations during fiscal year 1999, refer to DOE/RL-99-79.

History of Operations

A separate pump-and-treat remediation 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, with treated water injected upgradient from the extraction well.

On February 25, 1997, an interim action record of decision was issued (ROD 1997) that initiated Phase II for the 200-UP-1 Operable Unit pump-and-treat operations. 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 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 93.5 million liters of contaminated groundwater were treated at the Effluent Treatment Facility in fiscal year 1999. The average extraction flow rate was 182 liters per minute.

Table 2.8-5 details the volumes of treated water and the carbon tetrachloride, nitrate, technetium-99, and uranium removed by quarter since inception of operations (March 1994). Table 2.8-6 shows the contaminant trends.

Carbon tetrachloride concentrations decrease while groundwater is transported along the 11-kilometer pipeline between extraction wells in the 200 West Area and the Effluent Treatment Facility in the 200 East Area because of outgassing and loss of volatiles. Given the volume of pumped groundwater in fiscal year 1999 (93.5 million liters), the estimated amount of mass lost to the atmosphere was 9.3 kilograms. This loss is in addition to the mass removed during treatment.

Overall Effectiveness

As of July 1999, 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). Significant progress was made in reducing the size and concentrations of the technetium-99 plume. Less progress has been made in remediating the uranium plume because of its tendency to sorb to the soil.

The following conclusions were drawn from these plume maps and from information contained in DOE/RL-99-79.

Technetium-99

- The extent of the plume with high concentrations of technetium-99 was reduced in comparison to the original baseline area (Figures 2.8-35 and 2.8-36). Note that the July 1999 900 pCi/L plume covers about the same area as the June 1995 plume of 9,000 pCi/L.
- Technetium-99 concentrations are below the 9,000-pCi/L remediation criterion, with the exception of only two monitoring wells (299-W19-26 and 299-W19-29) (see Figure 2.8-35).
- A localized technetium-99 "hot-spot," originating upgradient of the targeted plume area, appears to be moving downgradient from well 299-W19-28 through wells 299-W19-29 and 299-W19-36.
- Technetium-99 concentrations increased significantly in well 299-W19-36 from 1,470 pCi/L in 1998 to 8,230 pCi/L in 1999. It is likely that technetium-99 will exceed the remediation action objective of 9,000 pCi/L during the next scheduled sampling. This well is the former injection well that was shut down in early 1997.

Uranium

- The extent of the plume with high concentrations of uranium (more than 480 µg/L) appears to be slightly smaller than the June 1995 baseline plume (Figures 2.8-37 and 2.8-38).

- Continued low uranium concentrations (~200 mg/L) in the monitoring well directly downgradient of the extraction well (299-W19-40) indicate that the high concentration portions of the plumes are contained, thereby preventing downgradient migration.
- Uranium concentrations in four monitoring wells and the extraction well have remained above the 480-µg/L remediation objective. The much slower response to remediation compared to technetium is due to uranium's tendency to sorb to soil, making it more difficult to extract.
- Uranium concentrations increased in wells 299-W19-29 and 299-W19-36. The increase in concentrations is attributed to recovery associated with termination of injection well operations. Prior to shutdown of the injection well, contaminants were diluted from injection of treated water.

Water-Level Impact and Capture-Zone Analysis

Water levels declined ~0.56 meter in fiscal year 1999, as the overall 200 West Area water table decreased. Two of the monitoring wells in the 200-UP-1 Operable Unit (299-W19-24 and 299-W19-28) went dry during fiscal year 1999 because of declining water levels. In addition, wells 299-W19-23, 299-W19-26, and 299-W19-38 were switched to a bailer-sampling method because groundwater returns could not be sustained using pumps. It is expected that similar modifications will be made to other monitoring wells in fiscal year 2000, as water levels continue to decline.

Groundwater modeling indicates that the targeted plume is captured under the current well configuration (Figure 2.8-39). It is estimated that one pore volume has been extracted from the original high concentration portion of the plume based on the original baseline plume map (DOE/RL-99-79) (Figure 2.8-40).

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, trichloroethylene, tritium, and uranium, at levels above the maximum contaminant levels/drinking water standards. Strontium-90 was not detected at levels above the interim drinking water standard in this area in fiscal year 1999. Two facilities in this vicinity, Waste Management Area S-SX and 216-S-10 pond and ditch, have RCRA monitoring requirements. Other facilities appear to have produced the major part of the groundwater contamination, although 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 groundwater flow in the southern portion of the 200 West Area is principally to the east, with a slight southeastern component (see Plate 2). The southeastern trend is more apparent in the area of the decommissioned U Pond. Flow directions in this area have shifted more to the east as the impact of past liquid disposal activities have declined. This shift to the east will continue as these influences continue to abate.

Flow beneath RCRA sites is discussed in Sections 2.8.4.8 and 2.8.4.9.

2.8.4.2 Tritium

A tritium plume extends eastward from the vicinity of the REDOX Plant in the southern part of the 200 West Area (see Plate 3). 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).

The tritium plume from the 200 West Area extends to US Ecology's low-level radioactive waste disposal facility. The maximum tritium concentration (4,565 to 4,907 pCi/L) detected in groundwater at that facility in fiscal year 1998 was in well 699-35-59 (US Ecology well no. 13). Tritium concentrations in that well, located on the western (upgradient) side of the facility, continued to increase over the past several years. These data were provided by US Ecology and are not included on the diskette included with this report or shown in Plate 3.

Movement of this tritium plume is expected to be slow because of the low-permeability sediment in the area and the dissipation of the groundwater mound beneath the 200 West Area since the reduction of effluent discharge.

Tritium was found above the interim drinking water standard upgradient of the REDOX Plant near the 216-S-25 crib and Waste Management Area S-SX. The source of tritium in wells in this area is attributed to the past-practice disposal sites (e.g., 216-S-4, 216-S-21, 216-S-25). Tritium concentrations in well 299-W23-9, located near the 216-S-25 crib, have risen in recent years but have not reached the levels seen in the late 1980s. The tritium pulse seen since 1995 in well 299-W22-46 may be the downgradient expression of the discharge from the 216-S-25 crib (Figure 2.8-42).

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 2.8-32). This iodine-129 plume and

the iodine-129 contamination originating farther north near U Plant appear to coalesce downgradient and become indistinguishable at the current level of monitoring detail. The maximum iodine-129 concentration detected in this plume in fiscal year 1999 was 38 pCi/L in well 699-35-70. However, well 299-W22-9, which previously has had the maximum iodine-129 concentrations, could not be sampled due to declining water levels.

2.8.4.4 Technetium-99

Technetium-99 was above the drinking water standard in two small plumes located near Waste Management Area S-SX (Figure 2.8-43). In addition, groundwater samples from a borehole drilled in early fiscal year 2000 just inside the southwestern corner of Waste Management Area SX, showed technetium-99 concentrations of 48,000 pCi/L, currently the highest on the Hanford Site. This borehole was subsequently completed as a groundwater monitoring well (well 299-W23-19). Evidence from recent years suggests that multiple sources of technetium-99 in the Waste Management Area S-SX tank farm are contributing to groundwater contamination (PNNL-11810). It should be noted that past data suggest that the 216-S-13 crib may have contributed to the technetium-99 detected further downgradient of Waste Management Area S-SX. Well 299-W22-21, located next to the 216-S-13 crib, could no longer be sampled in fiscal year 1999. Therefore, there is a scarcity of wells to track the migration of technetium-99 downgradient of Waste Management Area S-SX. Technetium-99 in the vicinity of Waste Management Area S-SX is discussed in Section 2.8.4.8.

2.8.4.5 Nitrate

Nitrate was detected in fiscal year 1999 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 2.8-31). Lower concentrations of nitrate are also 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 2.8-31). It also appears that a low concentration of nitrate is associated with the technetium-99 plumes in this vicinity.

2.8.4.6 Chromium

Chromium continues to be detected at levels above the maximum contaminant level in well 299-W26-7, the upgradient well for the 216-S-10 pond and ditch (Figure 2.8-44). Chromium concentrations in this well have decreased to 175 µg/L in fiscal year 1999 from 576 µg/L in fiscal year 1998. 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 observed in well 299-W26-7 and chromium detected farther downgradient, south of the 200 East Area (discussed in Section 2.11.5).

2.8.4.7 Trichloroethylene

A small trichloroethylene plume, with concentrations just above the maximum contaminant level, has been found in past years to the east of the REDOX Plant. Trichloroethylene was not detected at levels above the maximum contaminant level in this vicinity in fiscal year 1999. The 216-S-20 crib is a likely source of the trichloroethylene plume.

2.8.4.8 Waste Management Area S-SX RCRA Assessment Summary

Waste Management Area S-SX continued to be monitored under a RCRA assessment program in fiscal year 1999. A new groundwater quality assessment plan for continued investigations at this waste management area was prepared during the year (PNNL-12114) to cover ongoing groundwater characterization efforts being conducted concurrently with the RCRA facility investigation corrective measures study (HNF-5085,

Rev. 0). Results of the continued groundwater assessment findings are scheduled for release as a topical report in September 2000. The wells and analytes for this area are listed in Appendix A.

RCRA Waste Management Area S-SX contains single-shell tanks that may have contaminated groundwater with technetium-99. Four new wells were drilled in fiscal year 1999 to help characterize the contaminant plume.

Groundwater Flow

Flow rate estimates, 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). Contours of water-table elevation suggest a general southeasterly flow direction (see Plate 2). Calculated Darcy flow rates (see Table A.2) from 0.0023 to 0.43 meter per day bracket the travel time-based estimates above. The water table is gradually declining at the rate of ~0.6 meter per year, which may result in a future shift to a more easterly flow direction and decreased flow rates as the gradient declines.

Assuming the contaminant-based flow rate estimates noted above are the most representative, the average arrival time from an imaginary north-south centerline through the waste management area to the nearest downgradient RCRA monitoring wells is ~3 to 6 years at 25 meters per year or 1.5 to 3 years at 50 meters per year. At 50 meters per year, it would take over 20 years for a contaminant plume to migrate from within Waste Management Area S-SX to the nearest downgradient 200 West Area fence line location and much longer to reach the Columbia River.

Groundwater Contamination

The general distributions of contaminant plumes in the vicinity of Waste Management Area S-SX are

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 2). In addition to estimates of the extent of groundwater contamination based on the somewhat limited number of near-field monitoring wells in the area, additional information concerning both areal and vertical extent of contamination is emerging from the new wells installed in late 1999.

The constituents of interest for this waste management area have been 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 the 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, tank farm waste input can be distinguished from upgradient sources by isotopic and chemical ratios (PNNL-12114; HNF-4936, Rev. 0). For example, upgradient ratios of technetium-99 to nitrate are very low compared to occurrences in downgradient wells (~ 0.01 versus ~ 0.1 to 0.2 , respectively).

The occurrence of nitrate, chromium, and technetium-99 in groundwater at the SX Tank Farm is consistent with the high percentage of these mobile constituents in the water extracts from contaminated soil samples near tanks SX-108 and -109 (see Tables 3.2-2 and 3.2-3). While a direct link between the above tank source and groundwater cannot be made at this time, the high percentage of water extractable nitrate, technetium-99, and chromium suggests there is potential for transport of this type of waste through the vadose zone to groundwater. In contrast, cesium-137 is not detected in groundwater. This is consistent with a very low percentage of this radionuclide in the water leach fraction (Table 3.2-3) of contaminated sediment from borehole 41-09-39.

Technetium-99, Nitrate, Chromium, and Tritium. Concentration trends for three primary mobile constituents of concern (chromium, nitrate

and technetium-99) have undergone changes during the past year (Figure 2.8-45). Technetium-99 levels in well 299-W22-46, southeast of the SX Tank Farm, declined slightly, with a fiscal year 1999 average of 3,600 pCi/L (Figure 2.8-46). Chromium has declined more rapidly than technetium-99 in well 299-W22-46 and no longer appears to be co-variant with nitrate and technetium-99. This pattern may be a result of overlapping plumes from two different sources that converge in the vicinity of well 299-W22-46. The technetium-99/nitrate ratios for samples from the new wells as discussed above also suggest multiple sources. Another notable change is the rising concentrations of chromium, nitrate, and technetium-99 in downgradient well 299-W22-45 at the SX Tank Farm (see Figure 2.8-45). Based on the location of this well, and inferred flow directions, this new groundwater occurrence represents a different vadose zone source, possibly originating in the northeastern area of the SX Tank Farm. The well is located downgradient from diversion boxes and valve pits that have been sources of surface spills in the past. Single-shell tanks are less likely sources in this area than the ancillary waste systems because of flow direction considerations (see Figure A.5). Technetium-99 concentrations in new well 299-W23-19, located on the southeastern side of tank SX-115, were up to 48,000 pCi/L in screening samples.

Cesium-137 and Strontium-90. Except for non-RCRA well 299-W23-7, located inside and along the eastern side of SX Tank Farm, cesium-137 and strontium-90 were not detected in the monitoring well network for Waste Management Area S-SX during fiscal year 1999. Evaluation of historical and recent groundwater data (HNF-4936, Rev. 0) 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. Also, a special study reduced the cesium-137 detection limit. For example, samples from the two wells with the highest technetium-99 concentrations (299-W23-19, the SX-115 well, and new well 299-W22-50) were less than 0.02 to 0.047 pCi/L, respectively).

A maximum cesium-137 concentration of 49 pCi/L in non-RCRA well 299-W23-7 has been previously reported and discussed (PNNL-12114). However, this occurrence is primarily particulate and is thought to be an artifact of past well installation and maintenance methods (HNF-4936, Rev. 0). Older gamma logs for this well indicate the presence of surface soil contamination at the wellhead. Thus, contaminated soil may have fallen into the well during construction or during subsequent maintenance activities. Also, water can no longer be pumped from this well. It is now on the priority list for decommissioning because it could provide a conduit for downward migration of contaminants.

Gross Alpha. Elevated gross alpha (120 pCi/L) was detected during the year in the same well (299-W23-7) that has exhibited elevated cesium-137 prior to the well going dry. Previous investigation of elevated gross alpha in this well (PNNL-12114) included an analysis of uranium and selected alpha emitters that were reported as non-detections (americium-241, plutonium-238 and 239). Uranium accounted for most, if not all, the alpha emitters present. As with the cesium-137 in this well, the source is likely a result of contamination during well maintenance or other tank farm activities in the past. Additional characterization will be performed during decommissioning of this well. A more complete isotopic analysis of the alpha emitters (e.g., all the uranium isotopes as well as transuranics) may be useful in understanding the origin of the contamination.

Anomalous Metal Occurrences. High concentrations of chromium and iron occurred during the year in well 299-W23-15, located immediately south of the southwestern corner of the SX Tank Farm. This well has previously (1992-1994) exhibited moderately elevated chromium and iron. During fiscal year 1999, iron concentrations (filtered) peaked at over 900 µg/L on May 13, 1999, and total chromium of 42 µg/L was measured on August 9, 1999. Sample splits for the August 9, 1999 sampling were analyzed by the standard method (inductively coupled plasma emission spectroscopy metals analysis using both filtered and unfiltered

samples) and by a hexavalent specific method (unfiltered sample). Results are shown in Table 2.8-7.

Table 2.8-7 indicates that most of the iron was particulate in the August 9, 1999, sample. This suggests the previous high iron concentration of over 900 µg/L for a filtered sample involved filter failure (i.e., a submicron colloidal phase of iron passed through the 0.45-micron membrane filter).

The elevated aluminum for the unfiltered samples, but not for the filtered samples (see Table 2.8-7), suggests the presence of an aluminosilicate mineral phase. For example, the routine practice of acidification of unfiltered samples for metals analysis results in partial dissolution and release of aluminum and silicon from clay minerals such as bentonite or related mineral phases. Table 2.8-7 also indicates that a large fraction (over 60%) of the total chromium was present as hexavalent chromium. In this case, a particulate or submicron colloidal phase cannot explain the elevated chromium result because the hexavalent chromium method is specific for dissolved chromate. Further investigation is needed to understand this anomalous occurrence.

Monitoring Network

Four new wells were drilled in calendar year 1999 to assess both areal and vertical distribution of contaminants near the waste management area. One well was drilled for the RCRA facility investigation remedial measures study (HNF-5085, Rev. 0) as a vadose characterization borehole near tank SX-115. This well was then deepened and completed as a groundwater monitoring well (299-W23-19). The other three wells were installed downgradient from S and SX tank farms in accordance with the RCRA groundwater assessment plan for Waste Management Area S-SX (PNNL-12114). Groundwater samples were collected from selected depths during drilling. Depths sampled included the very top of the aquifer (0 to 0.5 meter) and at 6 meters in all three RCRA compliant wells. In addition, samples were collected from 12, 30, 60, 90 (top of Ringold mud) and 120 meters (below the lower

mud unit) in new well 299-W22-50, installed at the southeastern corner of SX Tank Farm. Groundwater samples from the latter well were collected for both tank waste constituents and volatile organic compounds.

Special sampling in fiscal year 1999 indicated contaminant concentrations are highest at the very top of the aquifer.

New well 299-W23-19 (located on the southwestern side of tank SX-115) was initially completed with a temporary 1.5-meter screen at the top of the aquifer. After discovery of high concentrations of technetium-99 (up to 48,000 pCi/L), the well was completed with a longer permanent well screen. This will allow further characterization of the nature of the groundwater contamination at this location. Initial measurements at the water table in this well resulted in concentrations of technetium-99 and nitrate (31,000 pCi/L) that were ~25% higher than concentrations obtained when the well was pumped at ~1 meter below the static water level. The observation of higher concentrations near the water table is consistent with a well located very near the source where contaminants initially enter the aquifer from the vadose zone. Thus sampling from wells located very near vadose zone contamination must allow for the potential occurrence of higher concentrations at or near the water table where the vadose zone contaminants are transported down to groundwater under unsaturated flow conditions.

Installation of one new downgradient well (299-W22-48) improved spatial coverage at the S Tank Farm. Only very low nitrate (~20 mg/L) and technetium-99 (less than 50 pCi/L) concentrations were detected at this location. In addition, there were no differences in concentrations between the top of the aquifer and at 6 meters below the water table. Previously observed occurrences of elevated nitrate and technetium-99 in an older upgradient well (299-W23-1), located near tank S-107, indicated that contamination from within S Tank Farm reached

groundwater upgradient of new well 299-W22-48 sometime in the past. For example, a technetium-99 transient increase in well 299-W23-1 occurred in 1985 and again in 1997.

New well 299-W22-48 was also cored to near the water table. The core samples will be used to clarify contaminant sorption mechanisms and moisture movement through the vadose zone in the vicinity of single-shell tank farms. The information acquired will also help to better define the stratigraphy in the S Tank Farm portion of this waste management area. One important finding during the coring was the discovery of a section of clastic dike at 52 meters below ground surface. Clastic dikes have been suggested as one type of preferential pathway for transport of moisture and contaminants to groundwater beneath Waste Management Area S-SX.

New well 299-W23-49, located midway and downgradient of SX Tank Farm, was installed as a replacement for well 299-W22-39 that is going dry. Samples of the very top of the aquifer, at 6 meters, and development water pumped from the 4.6 meters of screened interval, all indicated low nitrate (10 mg/L) and very low technetium-99 (less than 50 pCi/L). Thus, there was no indication of a very shallow plume of contaminants at the top of the aquifer or more deeply distributed contamination (below 6 meters). A field screening method for technetium-99 (and cesium-137) was successfully demonstrated for the first time at the Hanford Site. During this RCRA drilling, the screening method was used to determine if there was an indication of increasing tank waste contamination with depth. The drilling plans included a provision to extend the borehole another 15 meters if there was an indication of increasing concentrations with depth.

New well 299-W22-50 is located at the far southeastern corner of the SX Tank Farm and ~15 meters north of well 299-W22-46. This well is a multipurpose well intended to

- replace the existing well when it goes dry in 2 to 3 years

- conduct a two-well test to reduce the uncertainty in hydraulic conductivity
- evaluate depth distribution of contaminants.

The vadose zone portion was also cored to improve understanding of the fine structure stratigraphy in this area and to obtain sample media for laboratory tests (sorption tests, moisture content, porosity, hydraulic conductivity). Field screening results for samples collected during drilling indicated elevated nitrate (52 mg/L) and technetium-99 (~12,000 pCi/L) at the top of the aquifer that declined rapidly with depth. The concentrations of technetium-99 and nitrate were four to five times lower at 6 meters below the static water level in the well than at the top (0 to 0.5 meter). The technetium-99-to-nitrate ratio (200 pCi/mg) based on field screening measurements suggests this newly discovered groundwater contamination is from a different tank farm source than the source responsible for groundwater contamination observed at either the new well near tank SX-115 or at nearby well 299-W22-46. For example, the technetium-99/nitrate ratios for the latter are both ~100 pCi/mg. The ratio for the new occurrence at 299-W22-50 appears to more closely match the water leachate results (210 pCi/mg) for contaminated soil beneath tank SX-108. The RCRA well observations suggest there are at least two different tank farm source areas or types that account for groundwater contamination downgradient from the southern end of this waste management area.

2.8.4.9 216-S-10 Pond and Ditch RCRA Parameters

The inactive 216-S-10 pond and ditch was monitored semiannually under RCRA interim status indicator evaluation (see Tables A.1 and A.15). None of the indicator parameter concentrations in downgradient monitoring wells exceeded critical mean values during fiscal year 1999 (see Table A.3). However, a site-specific constituent, chromium, continued to exceed the 100 µg/L maximum contaminant level in

upgradient well 299-W26-7 (175 µg/L in the December 1998 and 216 in June 1999) (see Figure 2.8-44). Because the upgradient well is located immediately adjacent to the 216-S-10 pond (see Figure A.7), the elevated chromium could be from an upgradient source or from the pond. A new monitoring plan will be prepared to reclassify this well as a downgradient well and replace it with a new upgradient well in calendar year 2000. Further description of the chromium plume is presented in Section 2.8.4.6.

RCRA monitoring at the 216-S-10 pond and ditch provides no evidence of groundwater contamination from this facility. Declining water levels have left this site without adequate well coverage.

The water table continued to decline in the 200 West Area during fiscal year 1999. This continuing decline reduced the 216-S-10 monitoring network from one upgradient and three downgradient wells to just one upgradient well (299-W26-7) and one downgradient well (299-W26-12). Downgradient wells 299-W26-9 and 299-W26-10 went dry during the first half of the year. RCRA interim status monitoring requirements specify that a minimum of one upgradient and three downgradient monitoring wells are needed to monitor the site. As a result, two additional wells are needed to bring the monitoring network back into compliance with RCRA regulations. If well 299-W26-7 is designated as a downgradient well, one upgradient and one downgradient well needs to be constructed. Ecology recommended that only one of the wells be drilled, the replacement for 299-W26-10, and approved this direction in the form of Tri-Party Agreement milestone M-24-00K.^(a) New well 299-W26-13 was installed in December 1999 at a location directly downgradient of the 216-S-10 pond. Two new wells have been proposed to DOE and Ecology to be installed in

(a) Letter from Dib Goswami, Washington State Department of Ecology, to M. J. Furman, U.S. Department of Energy, Richland, Washington, dated April 12, 1999, "Site-Wide Resource Conservation and Recovery Act Well Installation for Milestone M-24-00."

calendar year 2000 as part of a revised groundwater monitoring network. Background values for the facility have been recalculated based on just one upgradient well (299-W26-7). Based on regional groundwater elevations, the groundwater flow direction continues east-southeast to easterly. New wells will be located appropriately to maximize the downgradient coverage of the 216-S-10 pond and ditch.

Groundwater flow rates have not changed significantly since last year and are presented in Table A.2.

Sample results that exceeded drinking water standards and maximum contaminant levels this year are presented in Table A.3. Besides chromium, only carbon tetrachloride and nickel exceeded maximum contaminant levels. Carbon tetrachloride has been detected above or near the drinking water standard across the area. This is due primarily to the spreading of the regional plume across 200 West (see Section 2.8.1.2). The 216-S-10 pond is not the source of this constituent.

2.8.5 State-Approved Land Disposal Site

The State-Approved Land Disposal Site (also known as the 616-A crib) is located ~500 meters north of the northern boundary of 200 West Area (see Plate 1). The site receives, clean, treated water that occasionally contains high levels of tritium (up to ~10 million pCi/L) from the 200 Areas Effluent Treatment Facility. Operation of the site began in December 1995. By the end of September 1999, ~304 curies of tritium and over 270 million liters of effluent had been discharged. However, recent discharges have not contained appreciable tritium; only ~10 curies of tritium have been sent to the site since February 1998.

The State-Approved Land Disposal Site is used to dispose treated water that occasionally contains tritium. Tritium is detected in the wells closest to the site at levels above the drinking water standard.

A new state waste discharge permit is being planned for the facility, to take effect in mid-2000. The groundwater analytical constituent list will be adjusted to reflect effluent character and improved understanding of the groundwater system near the facility. Wells and analytes for this facility are listed in Appendix A.

2.8.5.1 Groundwater Flow

Effluent discharges have created a limited groundwater mound in the immediate vicinity of the State-Approved Land Disposal Site. This is reflected in the hydrograph of well 699-48-77A in Figure 2.8-47. The local mounding effect is superimposed on the general decline of groundwater levels in the 200 West Area and vicinity, as reflected in the hydrographs of wells 699-48-77D and C, and in well 699-48-77A prior to April 1997. This general decline is a response to the discontinuation of effluent disposal activities in the 200 West Area in the late 1980s.

The hydraulic gradient beneath the site in March 1999 was calculated to range from 0.04 between proximal wells 699-48-77A and D near the facility to ~0.0018 between the facility and the 200 West Area. Average linear groundwater flow velocity is estimated to be between 0.03 and 5.8 meters per day (see Table A.2). The higher velocity would occur near the infiltration area of the site and would move generally outward ("radially") from the slight groundwater mound at that location. The lower flow rate would apply to areas removed from the vicinity of the mound.

2.8.5.2 Extent of Contamination

Tritium is monitored in 21 wells near the facility on a semiannual to annual basis, and additional constituents are measured in three nearby wells (699-48-77A, C, and D) and one background well, 299-W8-1, on a quarterly schedule (see Figure A.13). Water levels are measured annually at the time of sample collection in these wells and monthly in the three nearby wells.

During fiscal year 1999, groundwater monitoring wells immediately surrounding the State-Approved Land Disposal Site continued to show the effects of

effluent containing high levels of tritium that were discharged to the facility over the last few years. Concentrations of tritium in groundwater are generally less than in fiscal year 1998, reflecting the reduced concentrations in the effluent over the past ~2 years (PNNL-13058). The highest tritium level observed in groundwater at the State-Approved Land Disposal Site during fiscal year 1999 (730,000 pCi/L) was measured in a sample from well 699-48-77D in October 1998. Figure 2.8-48 illustrates the trends in tritium concentrations in the wells since monitoring began at the facility. Wells 699-48-77A, C, and D are the only wells affected thus far by tritium from disposal to the area.

Monitoring for additional constituents in groundwater also occurs quarterly in the three nearby wells. Approximately 6 months following the startup of operation, analyses began to reveal elevated levels of tritium and other constituents and indicators in well 699-48-77A, the nearby well farthest from the State-Approved Land Disposal Site (see Figure 2.8-48). Further research indicated that the clean water discharged to the site was dissolving soluble components of the soil in the vadose zone, such as gypsum, resulting in elevated concentrations of sulfate, chloride, calcium, and sodium, and abrupt rises in conductivity and total dissolved solids (PNNL-11633; PNNL-11665).

Figure 2.8-49 illustrates the trend for sulfate in the nearby wells and the background well. This event also revealed that the focus of infiltration of effluent was displaced to the south (nearer well 699-48-77A), most likely by the same geologic feature (a caliche horizon) that is responsible for the elevated dissolved solids. The rise of sulfate in well 699-48-77D occurred without a corresponding rise in tritium, thus indicating that this well was affected by dissolved soil salts from a test discharge released several months prior to operation. Tritium-bearing effluent did not affect well 699-48-77D until ~1.5 years after well 699-48-77A detected tritium. This apparent paradox is the result of the limited volume of the test discharge, the location of the infiltration point of effluent, and ambient groundwater flow.

Predictions of hydraulic head by a groundwater numerical model prepared in 1997 (PNNL-11665) compare favorably with current conditions. The same model apparently slightly overestimates the extent of the tritium plume in groundwater near the facility. The probable reason for the overestimation is that the quantity of tritium disposed to the facility thus far is ~50% of the projected quantity through 1999, as assumed by the model.

Table 2.8-1. Volume of Groundwater Treated and Mass of Carbon Tetrachloride Removed Since Startup of Operations at 200-ZP-1

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
Total	954,816,553	3,386.5

Table 2.8-2. Average Carbon Tetrachloride Concentrations for Each of the Extraction Wells and the Influent Tank at 200-ZP-1 During Fiscal Year 1999

Well Name ^(a)	FY 1999 Min. Value (µg/L)	FY 1999 Max. Value (µg/L)	FY 1997 Mean Concentration (µg/L)	FY 1998 Mean Concentration (µg/L)	FY 1999 Mean Concentration (µg/L)	FY 1999 Mean Flow Rate ^(b) (L/min)	Overall Change
299-W15-33	5,300	7,100	5,058	6,000	6,218	57.0	Higher
299-W15-34	3,800	5,700	2,900	3,770	4,700	82.8	Higher
299-W15-35	3,100	4,400	3,351	3,660	3,858	310.0	Higher
299-W15-32	4,300	5,900	7,120	6,560	5,023	27.0	Lower
299-W15-36	1,300	2,100	2,820	2,040	1,697	94.6	Lower
299-W15-37	210	720	280	235	358	57.8	Higher
Influent Tank	3,300	4,400	3,270	3,530	3,788	--	Higher

(a) Wells listed from north to south.

(b) Some discrepancies in discharge rate at the different measurement locations were observed. These are still being resolved. Flow rates may actually be higher by ~10% to 20%.

Table 2.8-3. Results from Discrete Level Groundwater Sampling During Drilling of Well 299-W10-24^(a)

Depth Below Surface (m)	Depth Below Water Table (m)	Carbon Tetra- chloride ($\mu\text{g/L}$)	Technetium-99 (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
70.9 ^(b)	0.3	Not analyzed	13,000	7,380	120
75.2 ^(c)	4.6	Not analyzed	2,090	20,600	456
87.5	16.9	490	358	29,600	531
99.1	30.8	1,600	374	26,700	443
116.7	46.3	760	212	19,500	349
122.5	52.2	360	126	12,700	301
131.4 ^(d)	61.0	220	96	9,220	282

(a) Sampled October 9 through October 16, 1998.

(b) Sampled with Kabis Sampler in well 299-W11-27 on August 13, 1998.

(c) Sampled in well 299-W10-24 after completion on December 15, 1998.

(d) Collected below Ringold lower mud unit.

Table 2.8-4. Results of Discrete Level Sampling During Drilling of Well 299-W14-14^(a)

Depth Below Surface (m)	Depth Below Water Table (m)	Carbon Tetra- chloride ($\mu\text{g/L}$)	Technetium-99 (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)
70.5 ^(b)	4.3	140	110	4,230	120
80.8	14.5	180	556	893	226
96.3	30.1	380	81	5,380	41
106.1	39.8	920	32	9,010	33
122.5	56.9	380	29	7,180	43
134.7 ^(c)	68.5	590	33	8,460	40

(a) Samples taken October 24 through November 9, 1998.

(b) Sample taken from screened interval after well completion on December 10, 1998.

(c) Collected below Ringold lower mud unit.

Table 2.8-5. 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
Total ^(c)	357,180,798	61.74	101,132	15,768	12,770

(a) Data from the treatability test as reported in DOE/RL 95-02, Rev. 0.

(b) Estimated values based on 189 liters per minute flow, running 24 hours per day, at 97.5% efficiency.

(c) Fiscal year 1998 total was reported incorrectly as 338,413,037 liters and should have been reported as 264,078,503 liters.

NA = Not applicable.

Table 2.8-6. Summary of Contaminant Trends in the Extraction Well at 200-UP-1

Contaminant	FY 1997	Average FY 1998	Average FY 1999
Technetium-99	>3,000 pCi/L	2,050 pCi/L	1,400 pCi/L
Uranium	275 µg/L	265 µg/L	210 µg/L
Carbon tetrachloride	18 µg/L	24 µg/L	18 µg/L
Nitrate	75 mg/L	63 mg/L	48 mg/L

Table 2.8-7. Comparison of Filtered and Unfiltered Metal Results on August 9, 1999
for Well 299-W23-15

Method	Chromium ($\mu\text{g/L}$)	Iron ($\mu\text{g/L}$)	Aluminum ($\mu\text{g/L}$)
Filtered (ICP)	16	25	27 U
		131	46
Unfiltered (ICP)	41	1,700	727
	42	1,500	627
Unfiltered (hexavalent-chromium)	25	NA	NA
	25	NA	NA

ICP = Inductively coupled plasma emission spectroscopy.

U = Result is a non-detection; the value shown is the vendor assigned method detection limit.

NA = Not applicable.

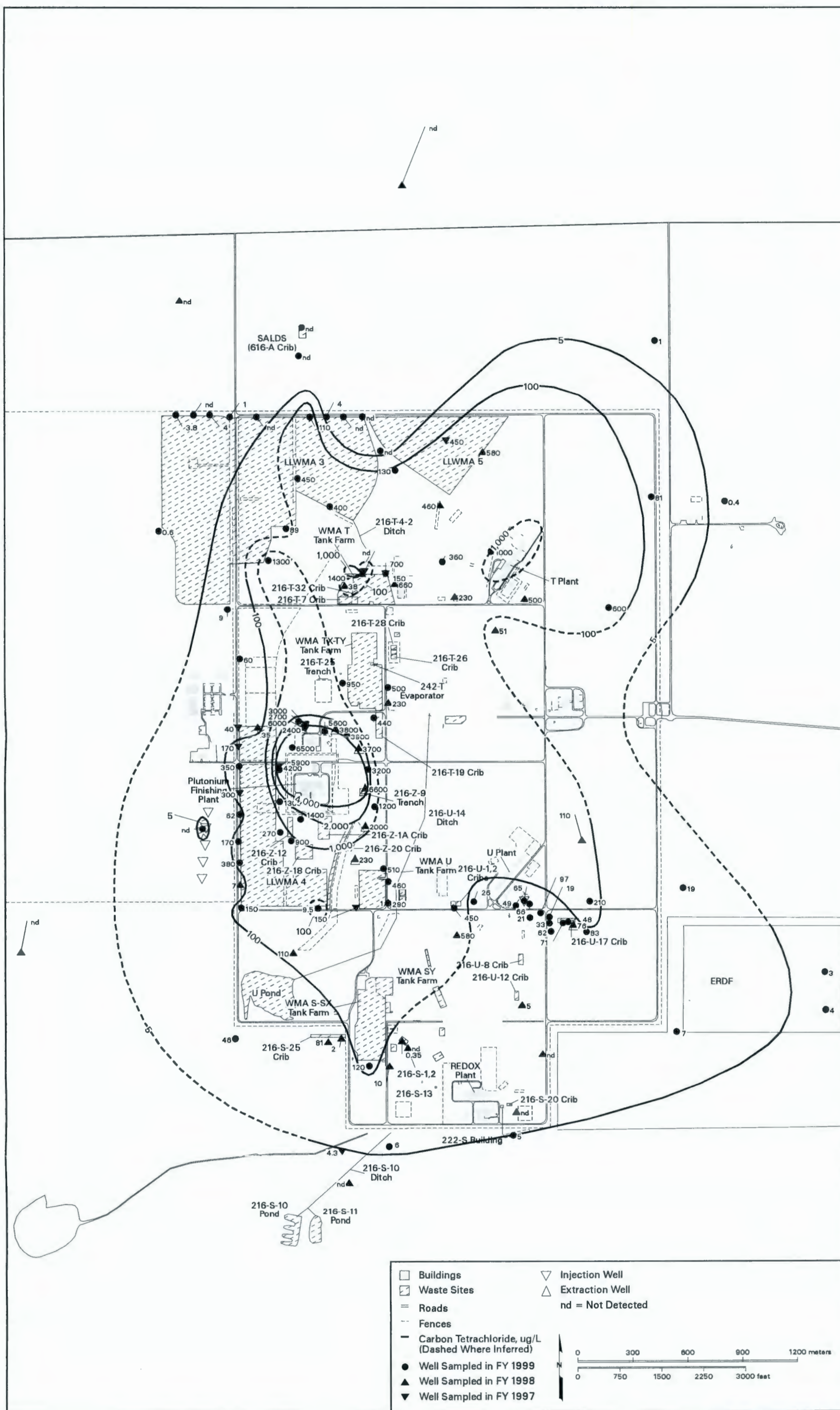


Figure 2.8-1. Average Carbon Tetrachloride Concentrations in 200 West Area, Top of Unconfined Aquifer

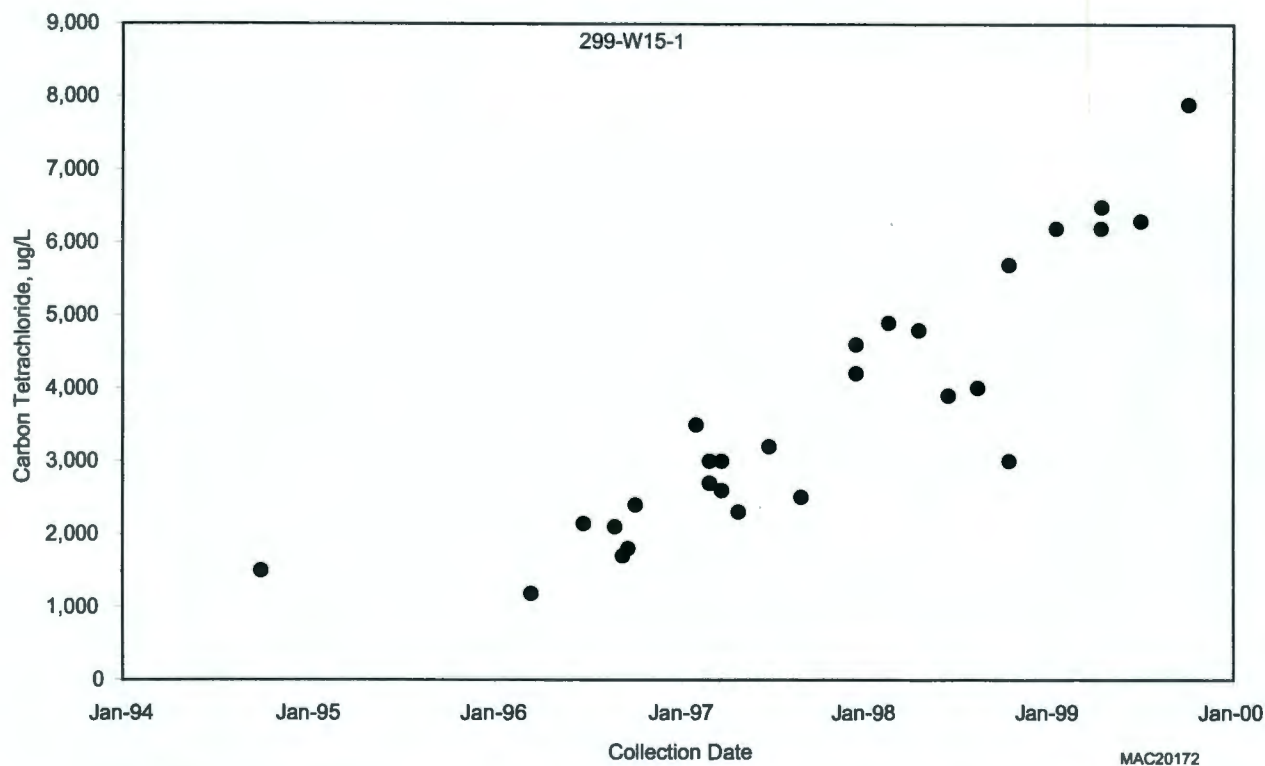


Figure 2.8-2. Carbon Tetrachloride in Well 299-W15-1 Near Northern Extraction Wells

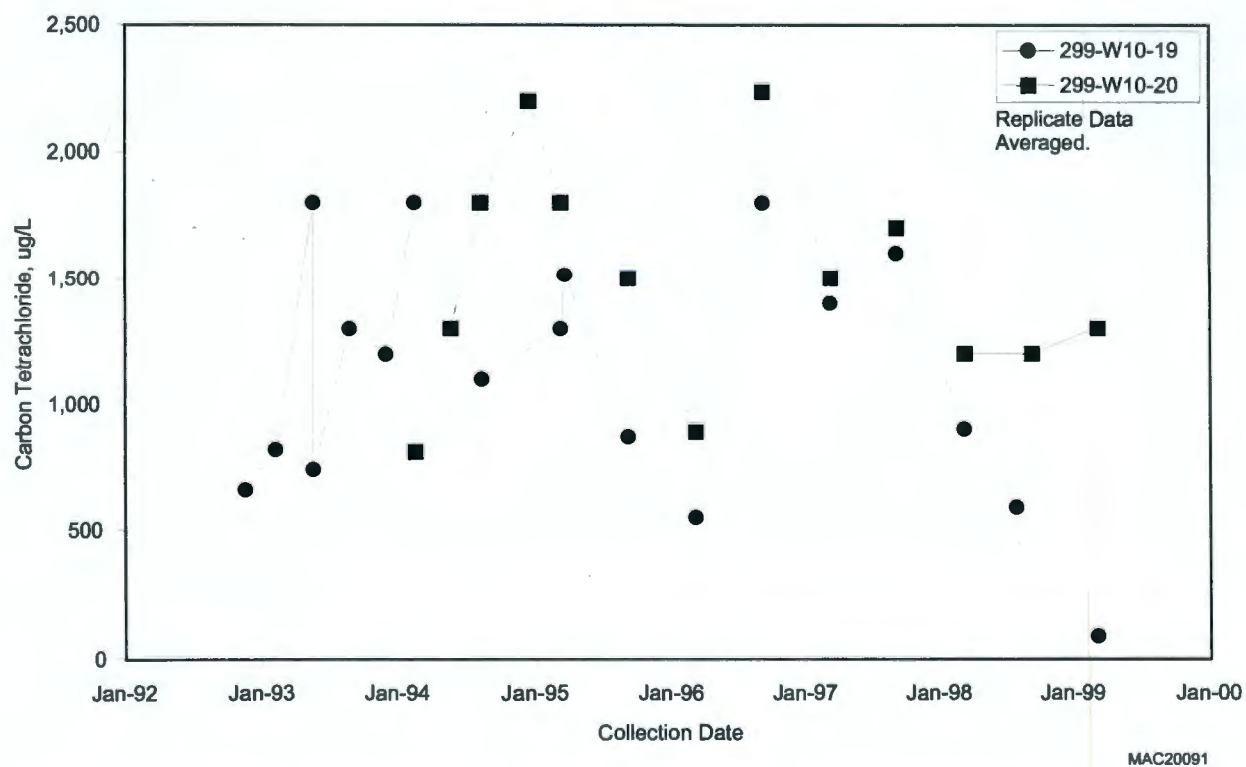
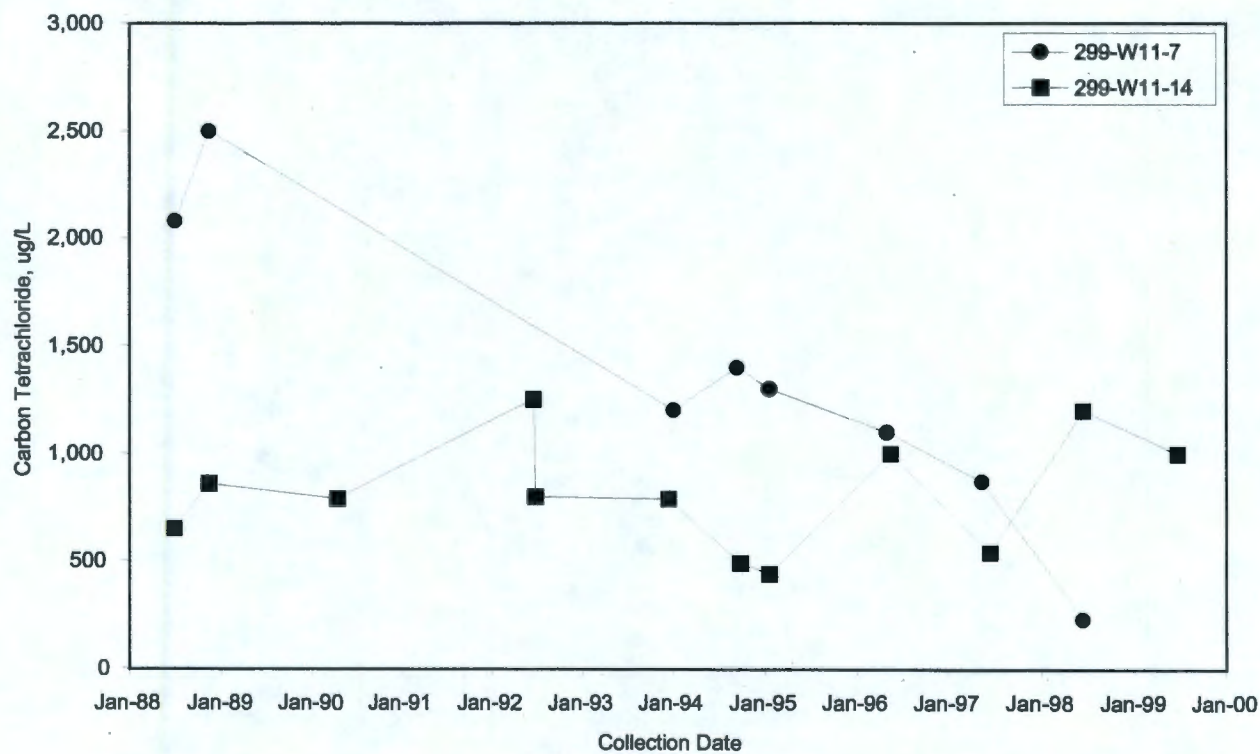


Figure 2.8-3. Carbon Tetrachloride in Wells 299-W10-19 and 299-W10-20, Northwestern 200 West Area



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Figure 2.8-4. Carbon Tetrachloride in Wells 299-W11-14 and 299-W11-7, Northwestern 200 West Area

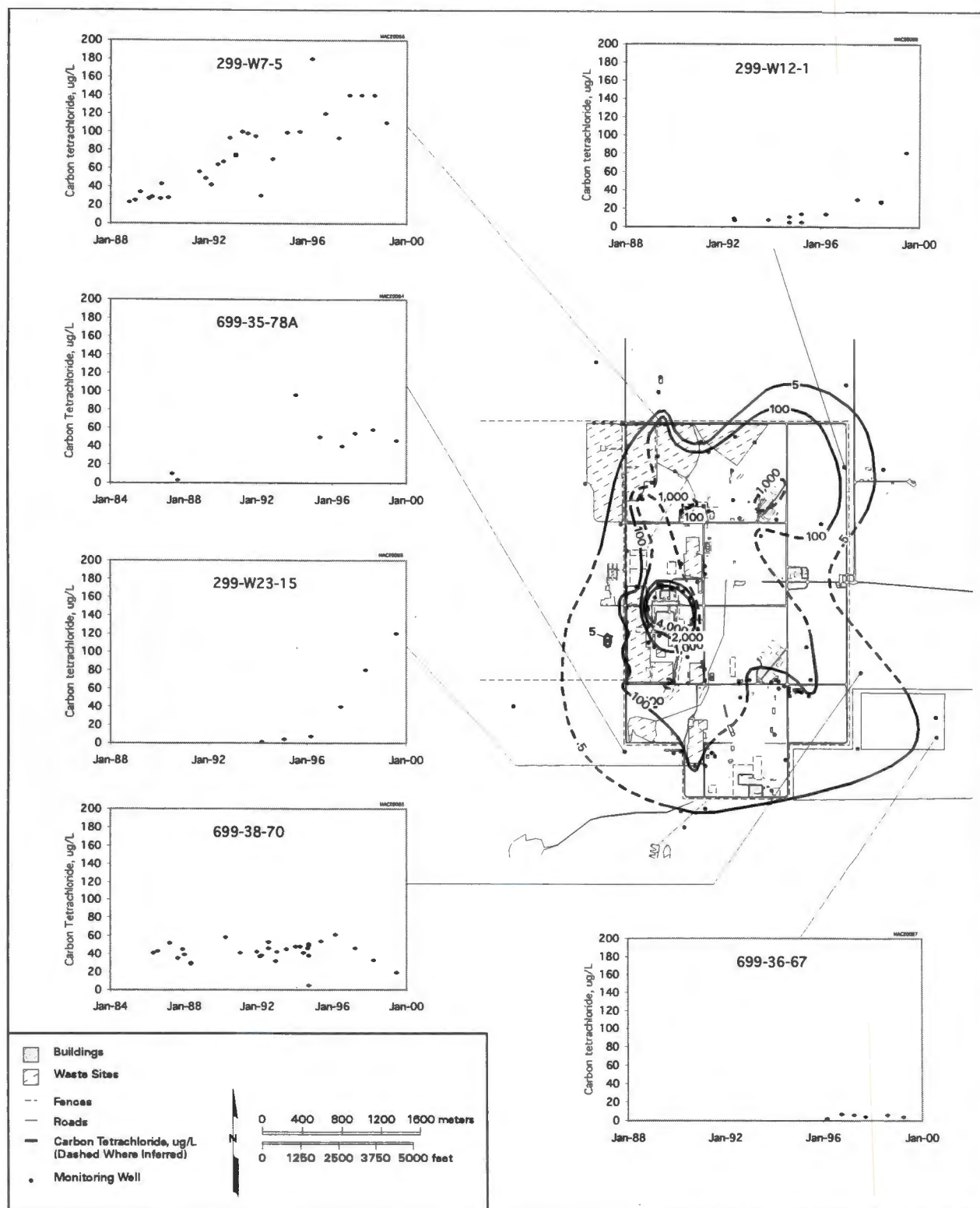


Figure 2.8-5. Carbon Tetrachloride Concentrations in Wells Monitoring 200 West Area, Top of Unconfined Aquifer

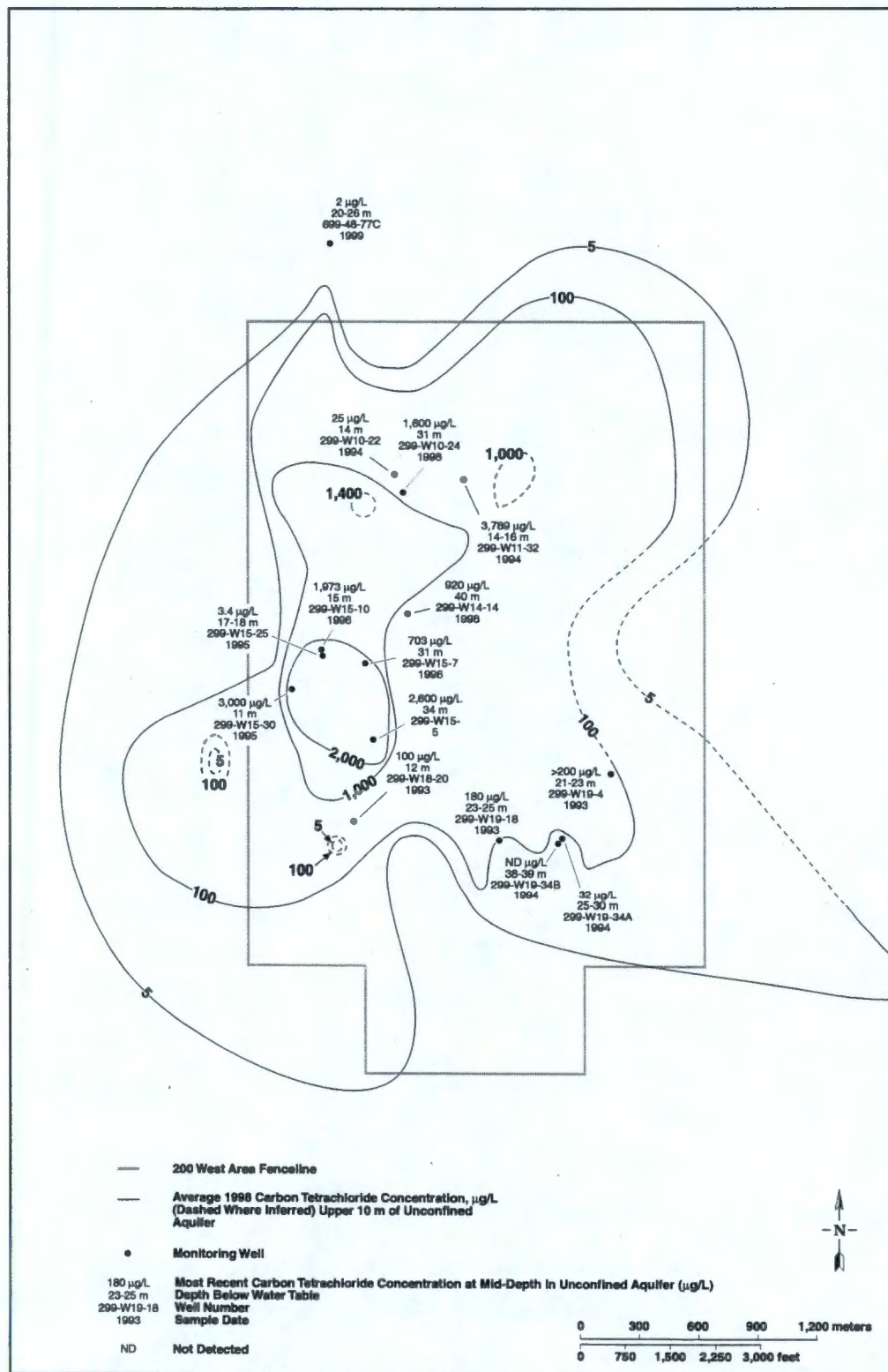


Figure 2.8-6. Carbon Tetrachloride Concentrations in the Middle Unconfined Aquifer, 200 West Area, Compared to Concentration Contours at the Top of the Unconfined Aquifer (DOE/RL-99-79)

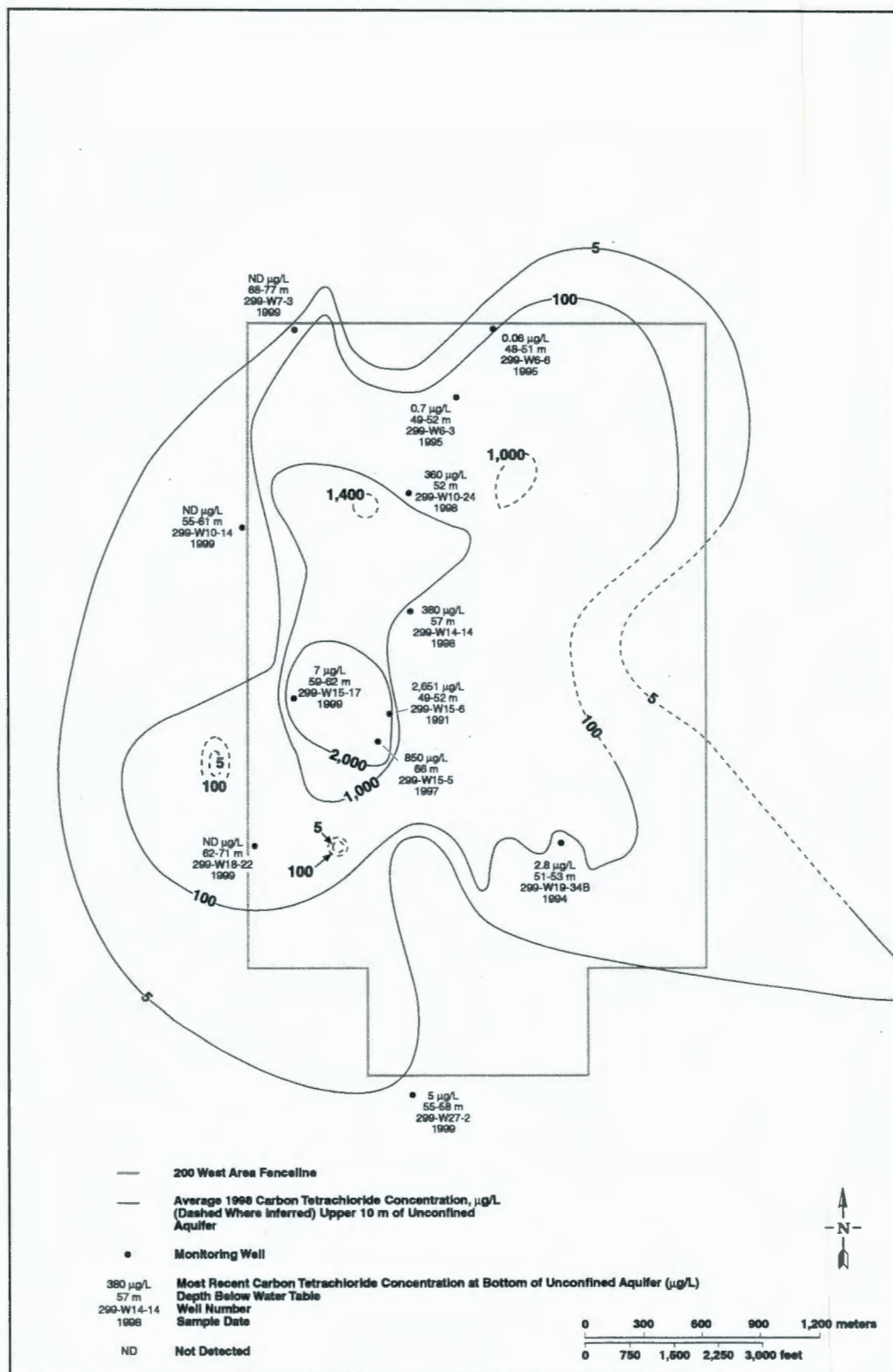


Figure 2.8-7. Carbon Tetrachloride Concentrations in the Lower Unconfined Aquifer, 200 West Area, Compared to Concentration Contours at the Top of the Unconfined Aquifer (DOE/RL-99-79)

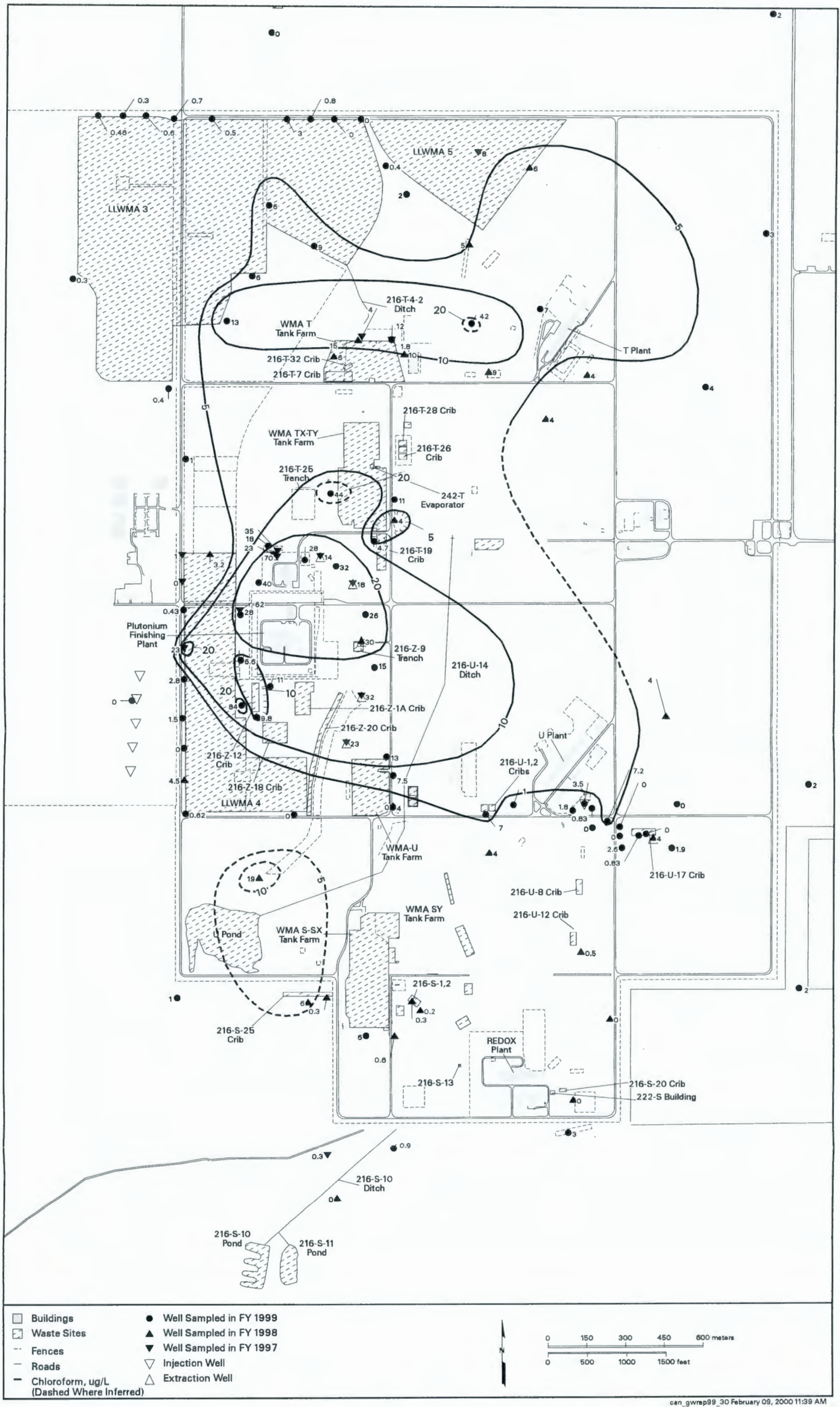
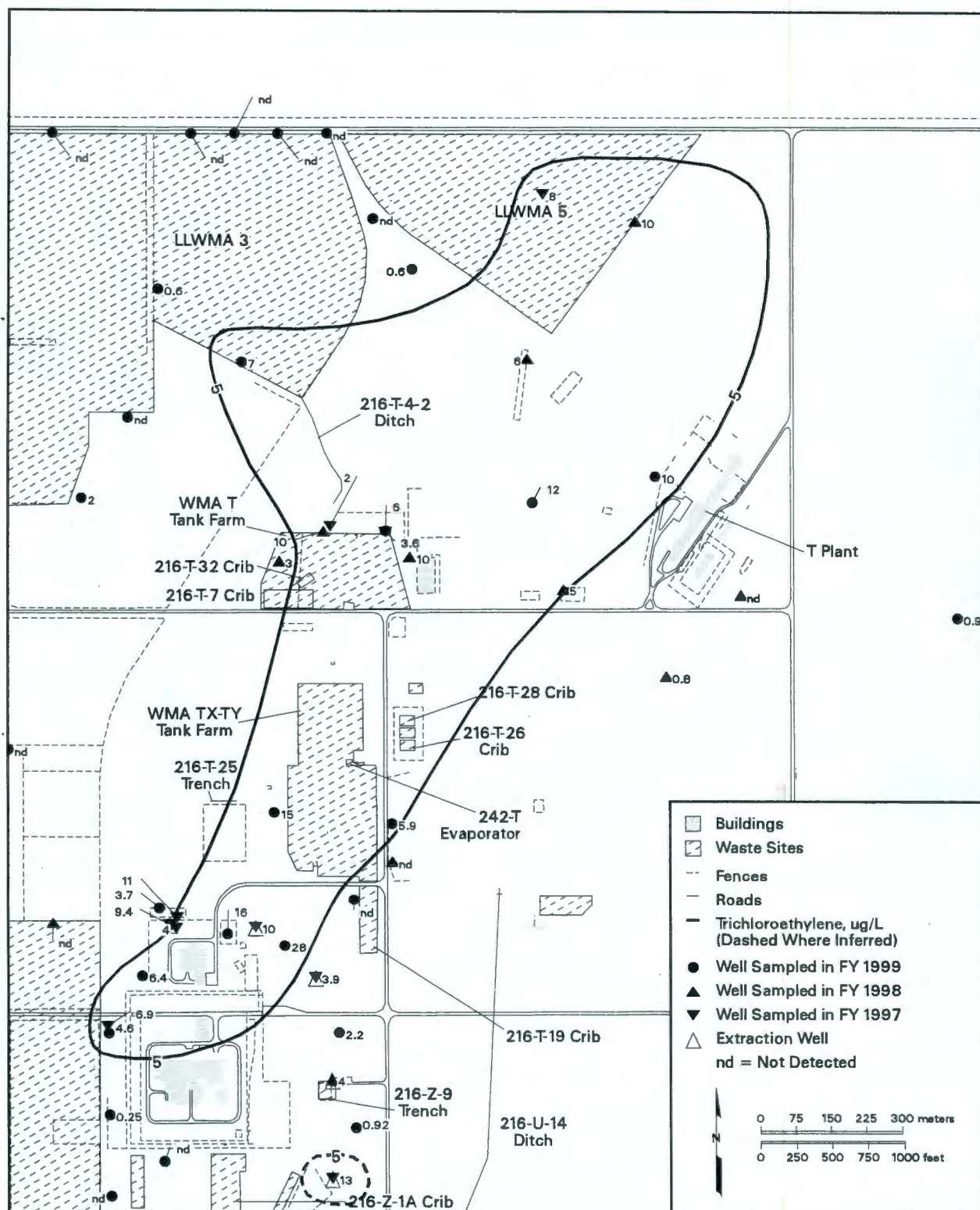
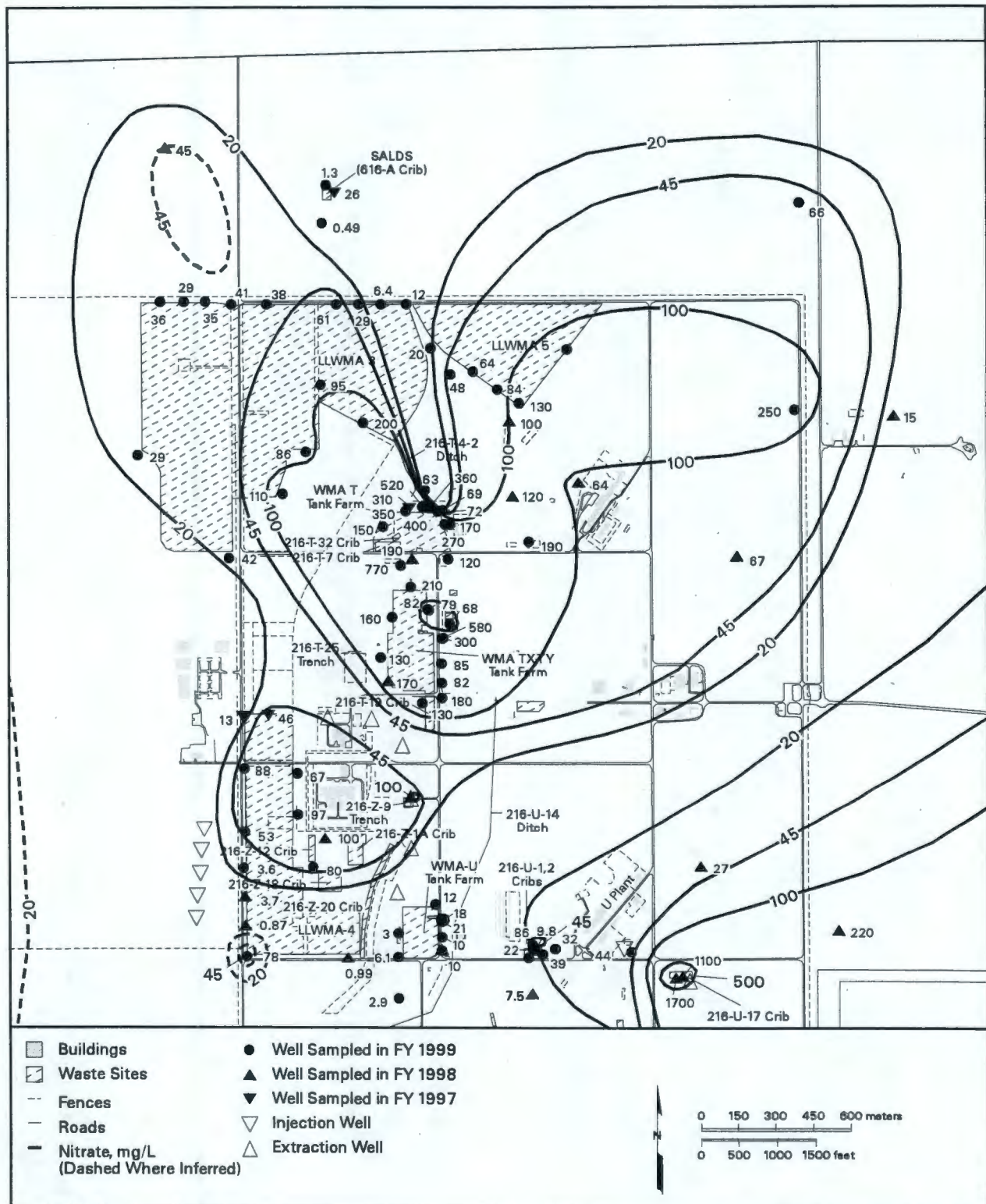


Figure 2.8-8. Average Chloroform Concentrations in 200 West Area, Top of Unconfined Aquifer



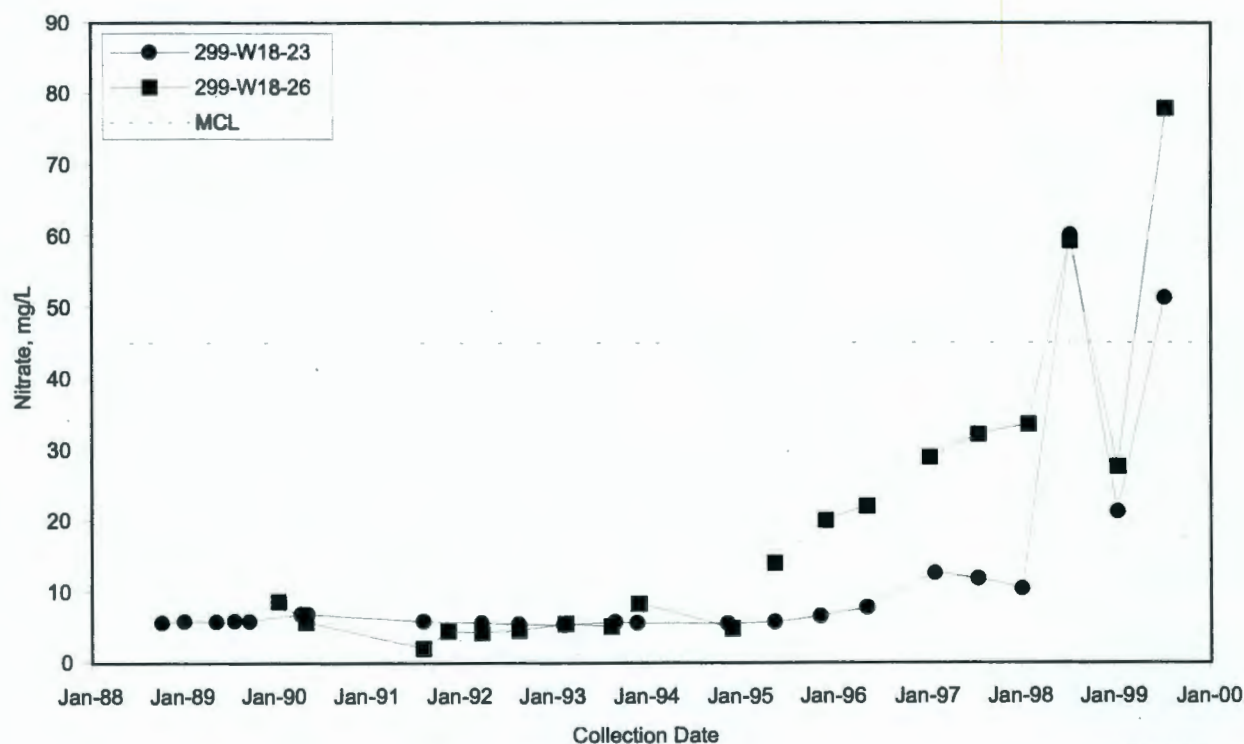
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Figure 2.8-9. Average Trichloroethylene Concentrations in 200 West Area, Top of Unconfined Aquifer



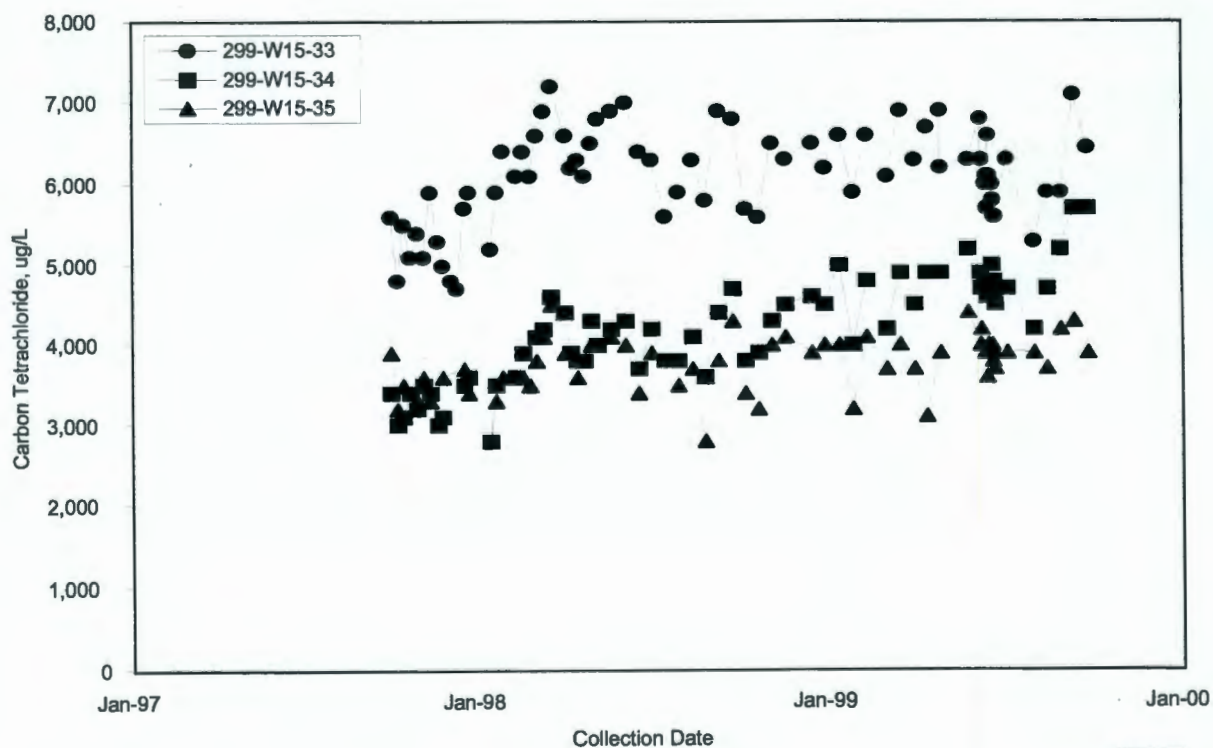
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Figure 2.8-10. Average Nitrate Concentrations in the Western and Northern 200 West Area, Top of Unconfined Aquifer



MAC20083

Figure 2.8-11. Nitrate in Wells 299-W18-23 and 299-W18-26, Western 200 West Area



JTR00027

Figure 2.8-12. Carbon Tetrachloride in Northern Extraction Wells for 200-ZP-1 Pump-and-Treat System

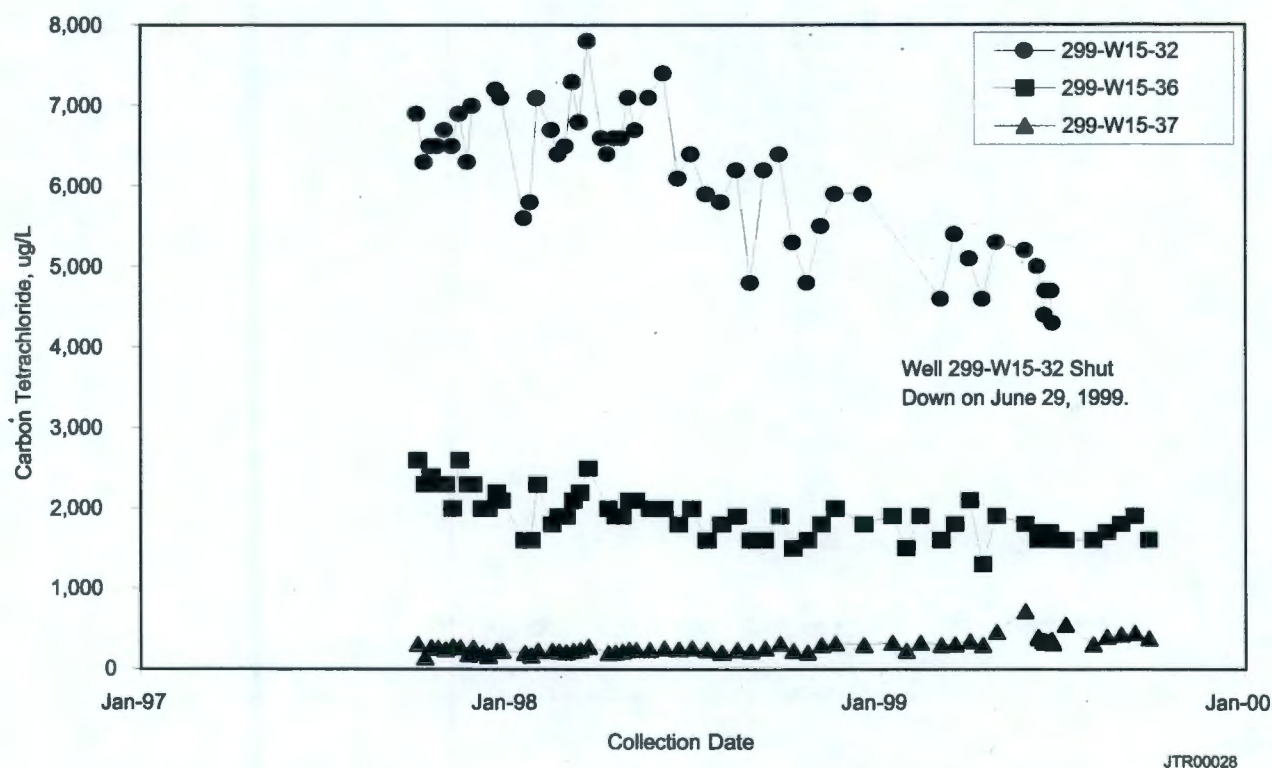


Figure 2.8-13. Carbon Tetrachloride in Southern Extraction Wells for 200-ZP-1 Pump-and-Treat System

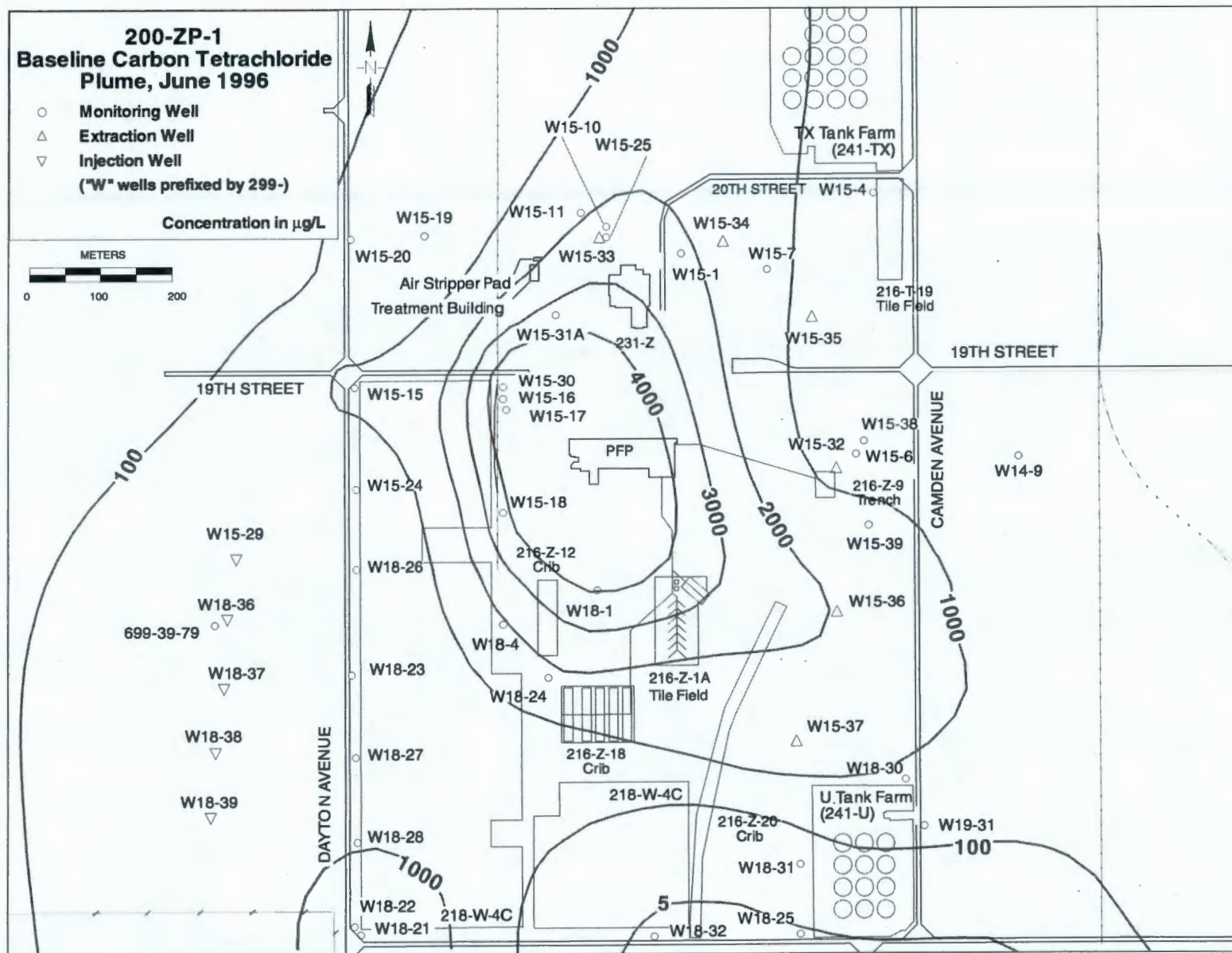


Figure 2.8-15. 200-ZP-1 Carbon Tetrachloride Baseline Plume for the Remediation Area, June 1996 (DOE/RL-99-79)

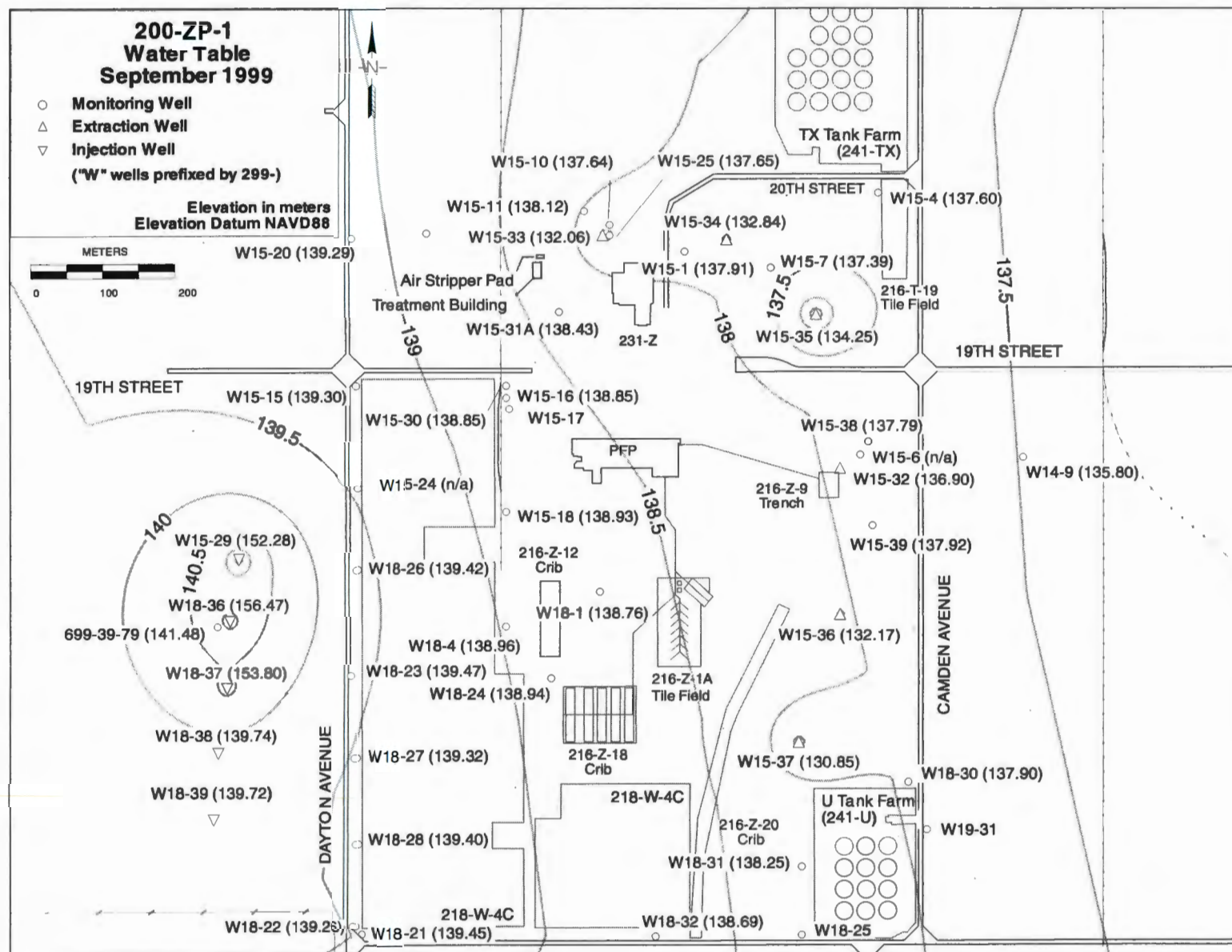


Figure 2.8-16. Water Table for September 1999, Vicinity of the 200-ZP-1 Remediation (DOE/RL-99-79)

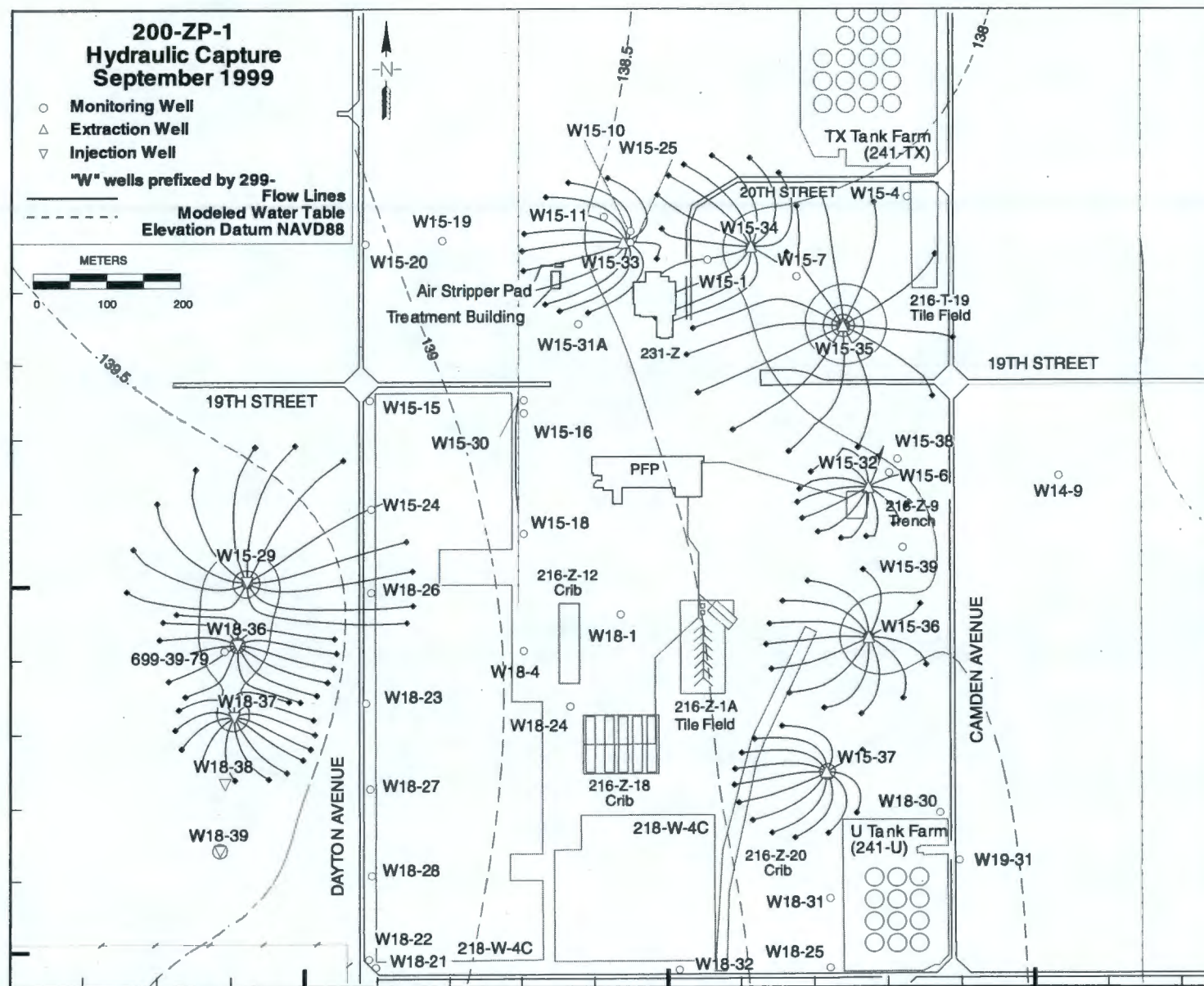
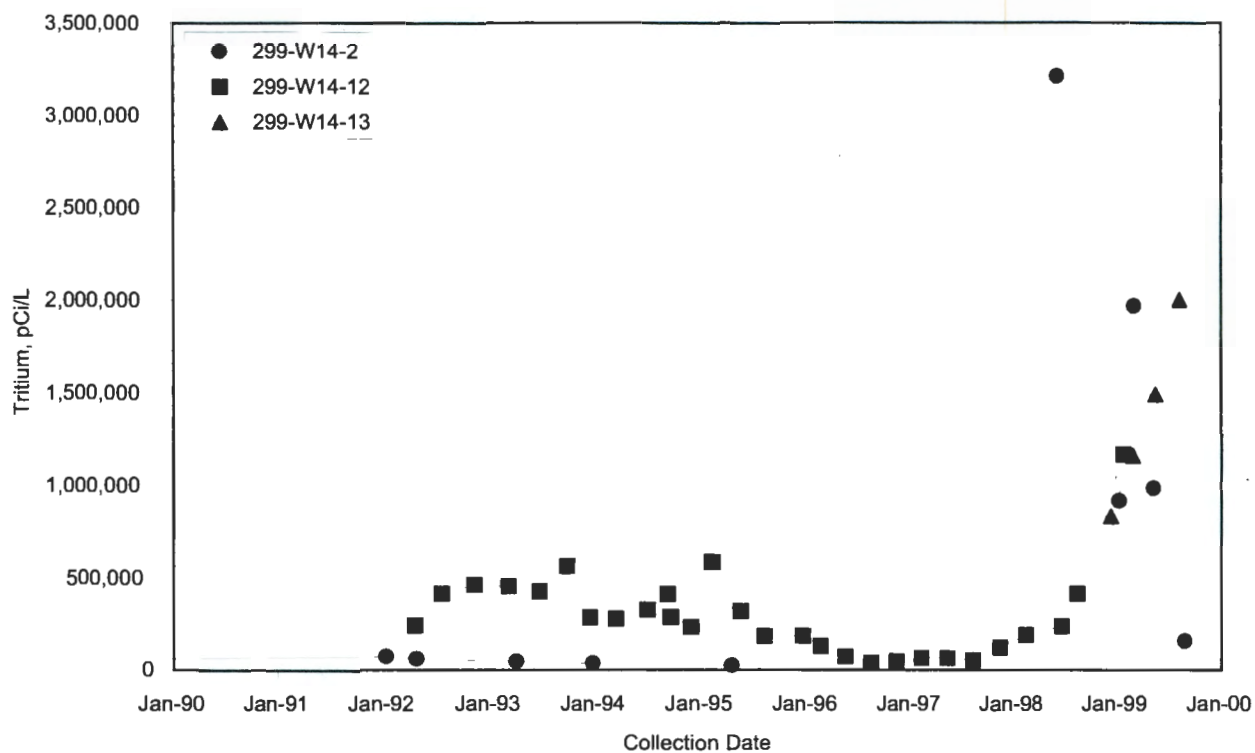


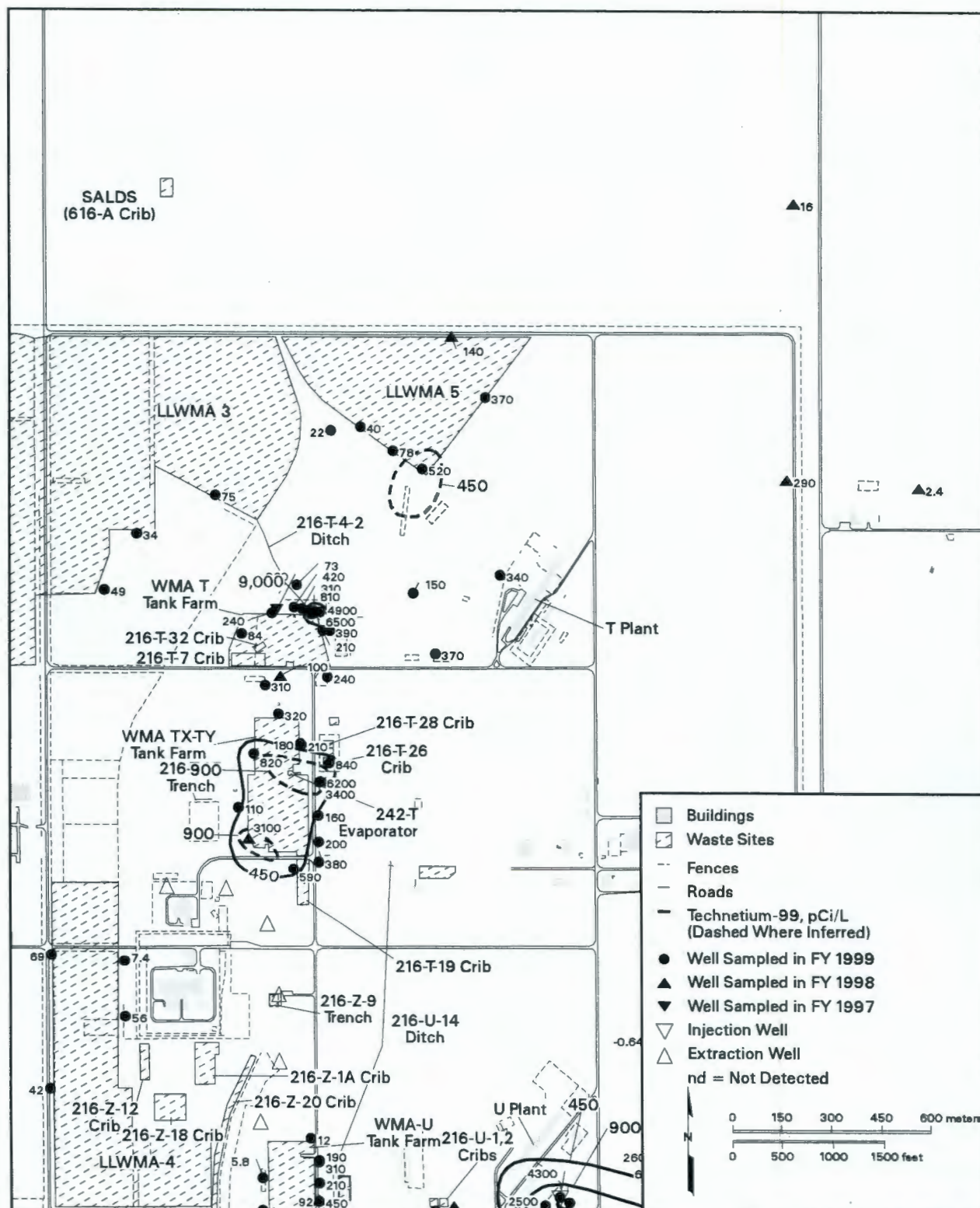
Figure 2.8-17. 200-ZP-1 Pump-and-Treat System Estimated Area of Hydraulic Capture as of September 1999 (DOE/RL-99-79)



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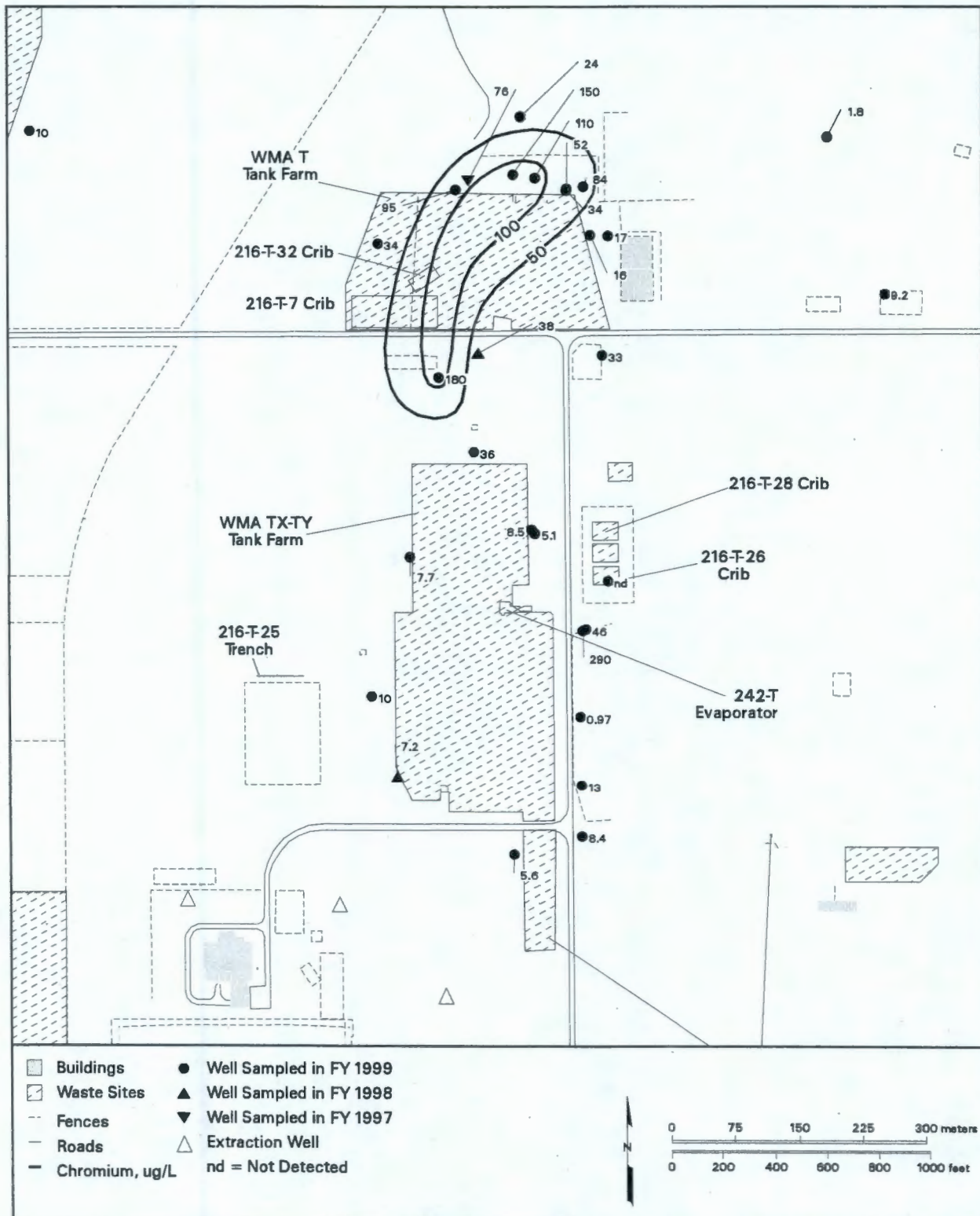
Figure 2.8-18. Tritium in Wells 299-W14-2, 299-W14-12, and 299-W14-13, East of TY Tank Farm





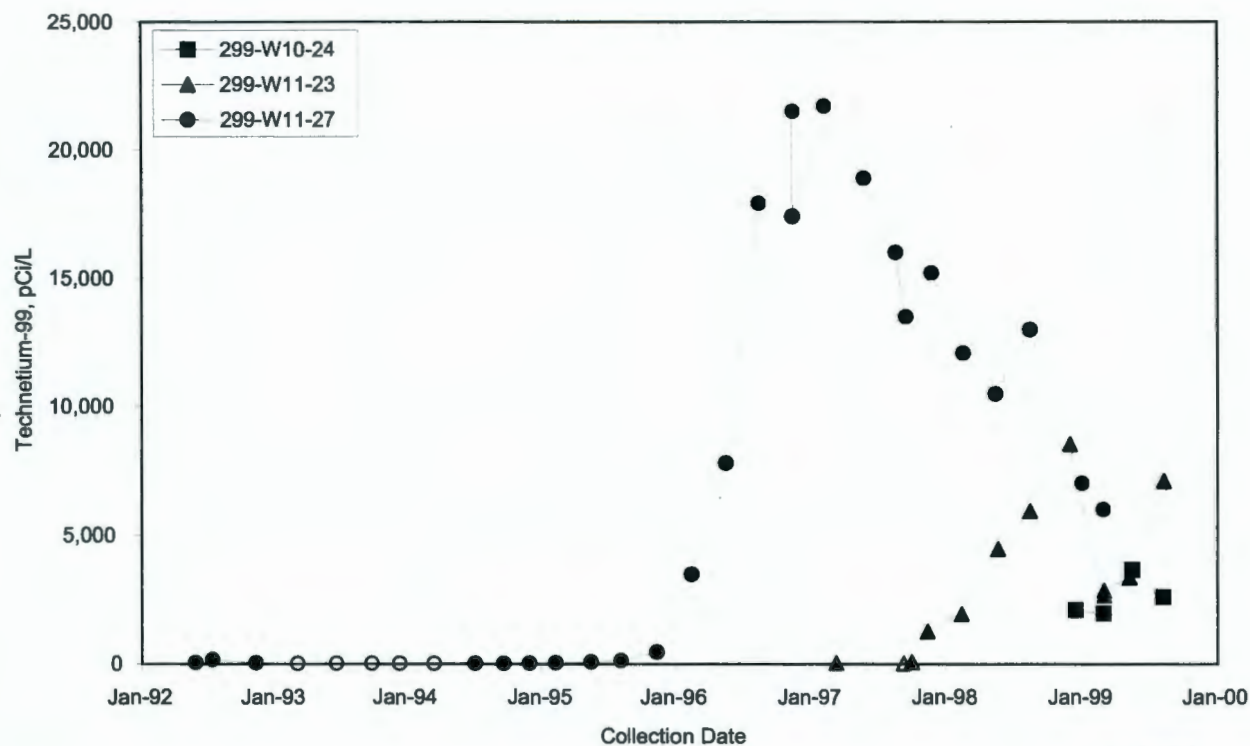
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Figure 2.8-20. Average Technetium-99 Concentrations in Northern 200 West Area, Top of Unconfined Aquifer



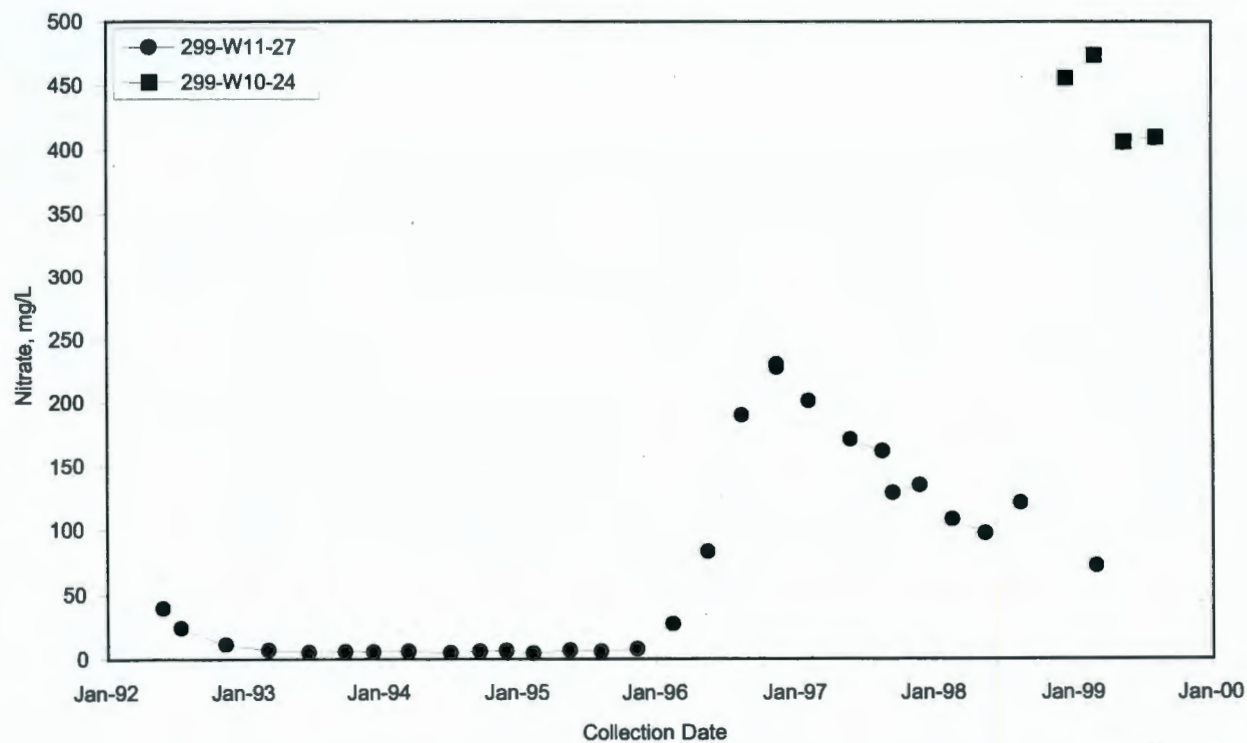
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Figure 2.8-21. Average Filtered Chromium Concentrations Near Waste Management Areas T and TX-TY, Top of Unconfined Aquifer



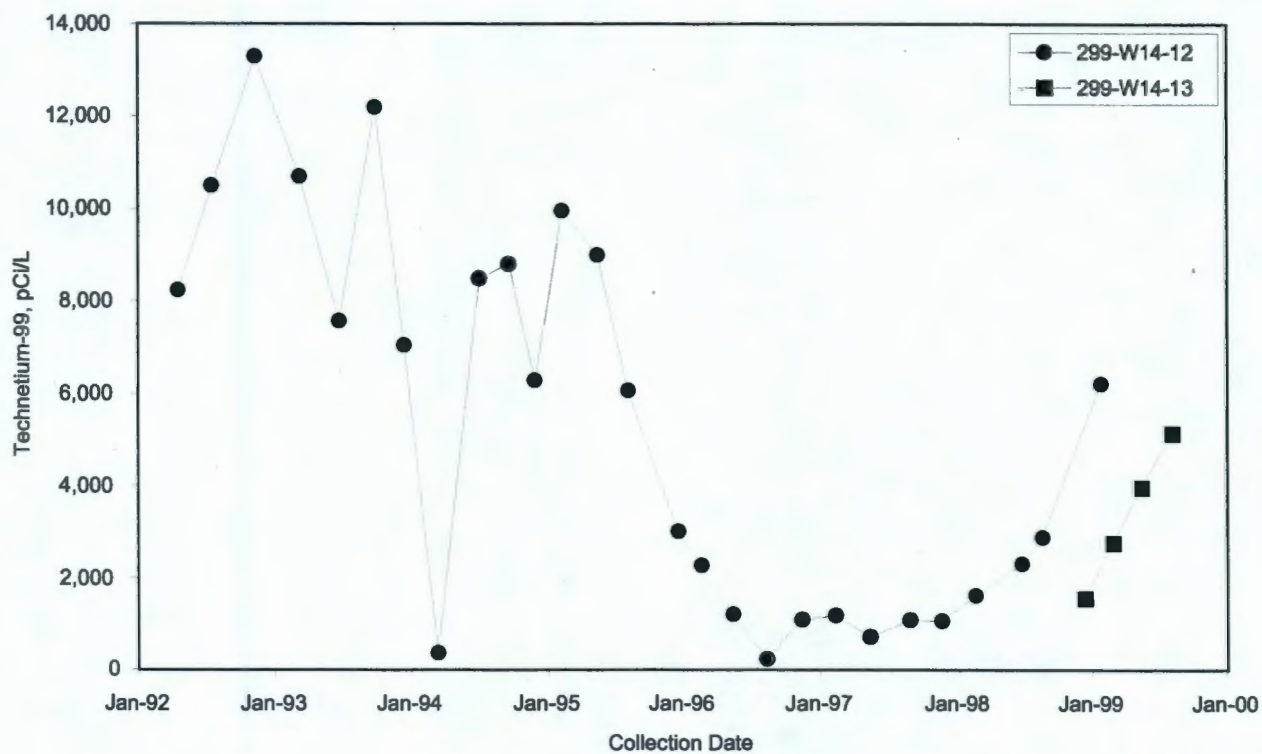
MAC20098

Figure 2.8-22. Technetium-99 in Wells 299-W11-27, 299-W11-23, and 299-W10-24, North of T Tank Farm



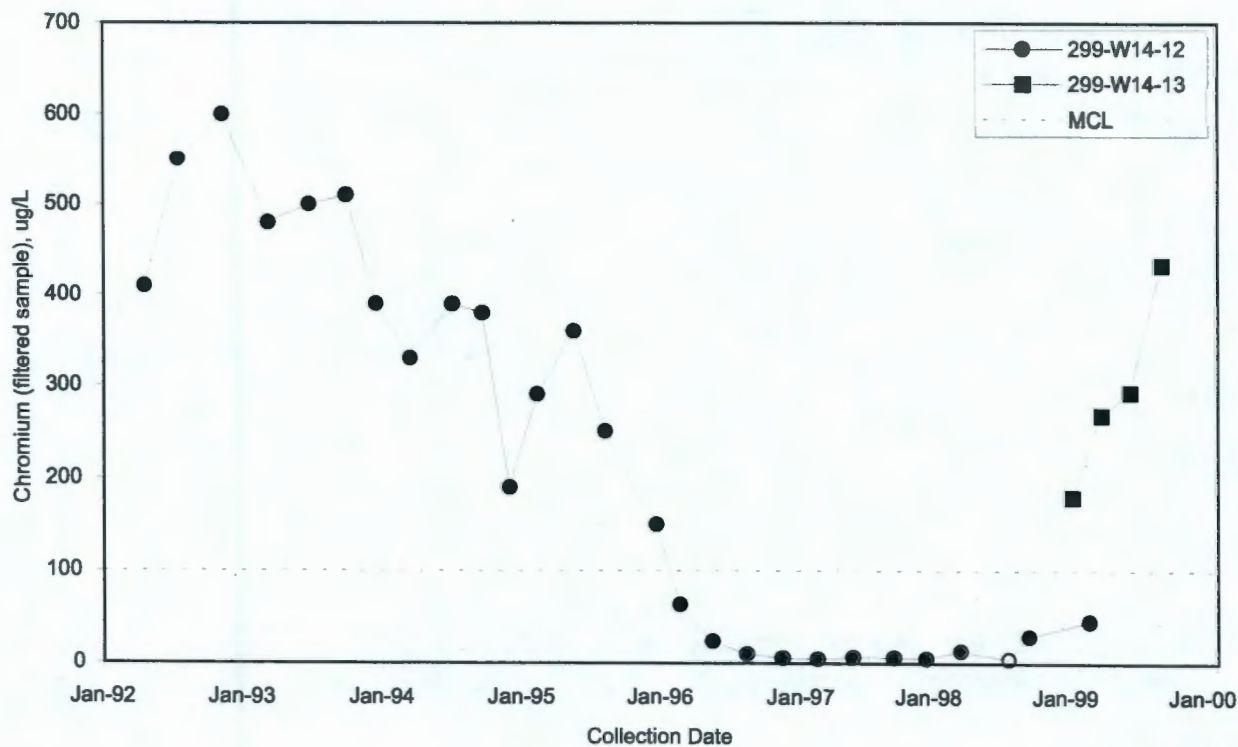
MAC20097

Figure 2.8-23. Nitrate in Wells 299-W11-27 and 299-W10-24, North of T Tank Farm



MAC20082

Figure 2.8-24. Technetium-99 in Wells 299-W14-12 and 299-W14-13, East of TX-TY Tank Farms



MAC20096

Figure 2.8-25. Chromium in Wells 299-W14-12 and 299-W14-13, East of TX-TY Tank Farms

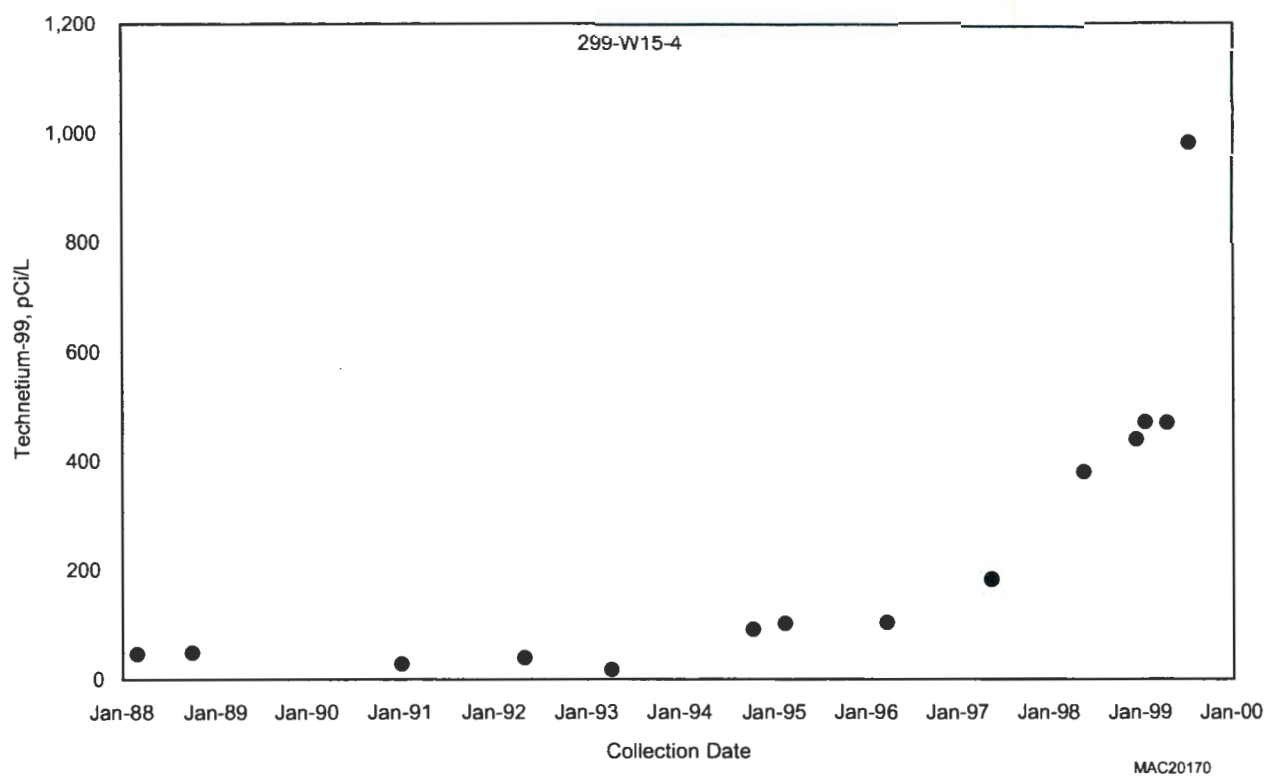
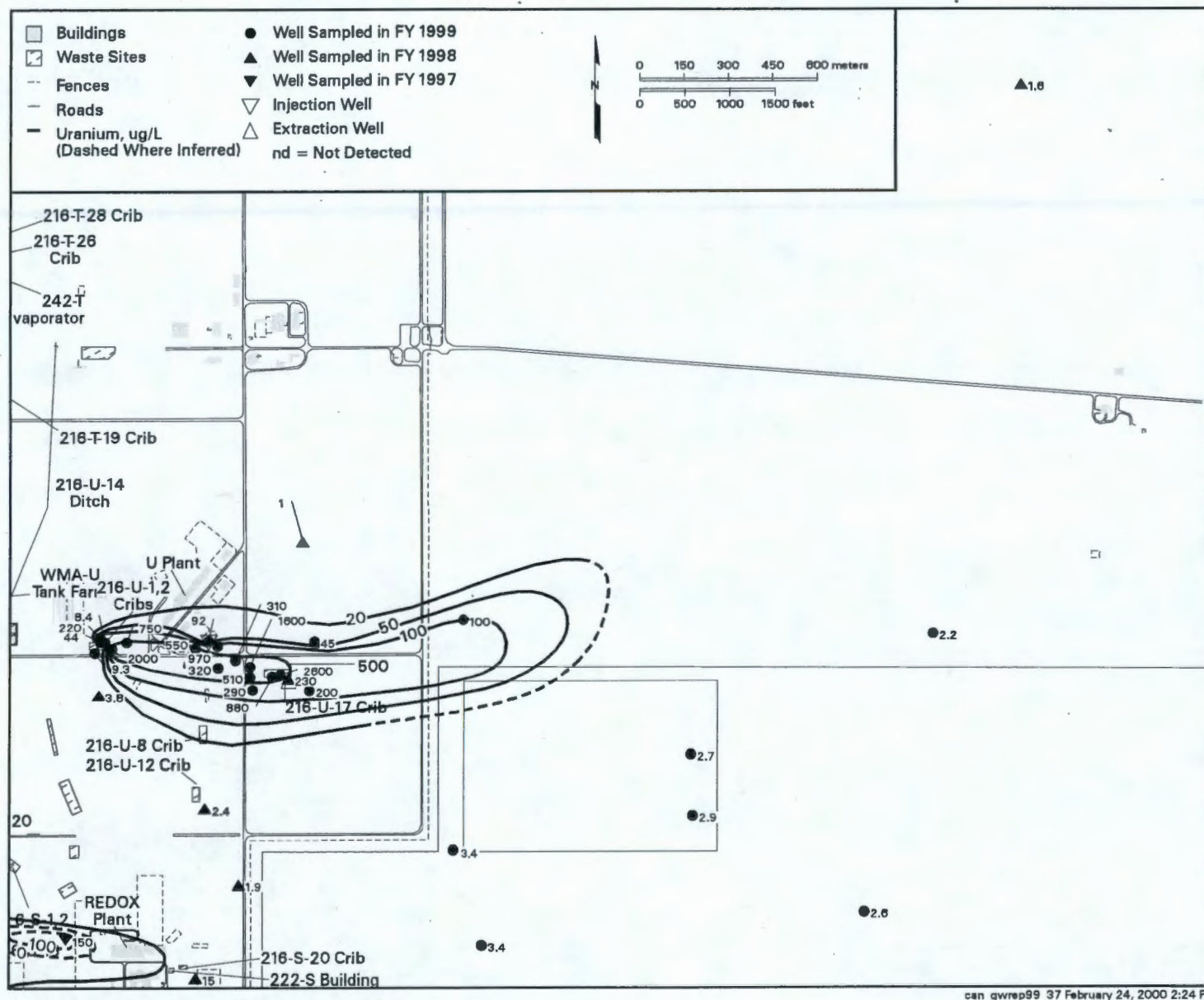
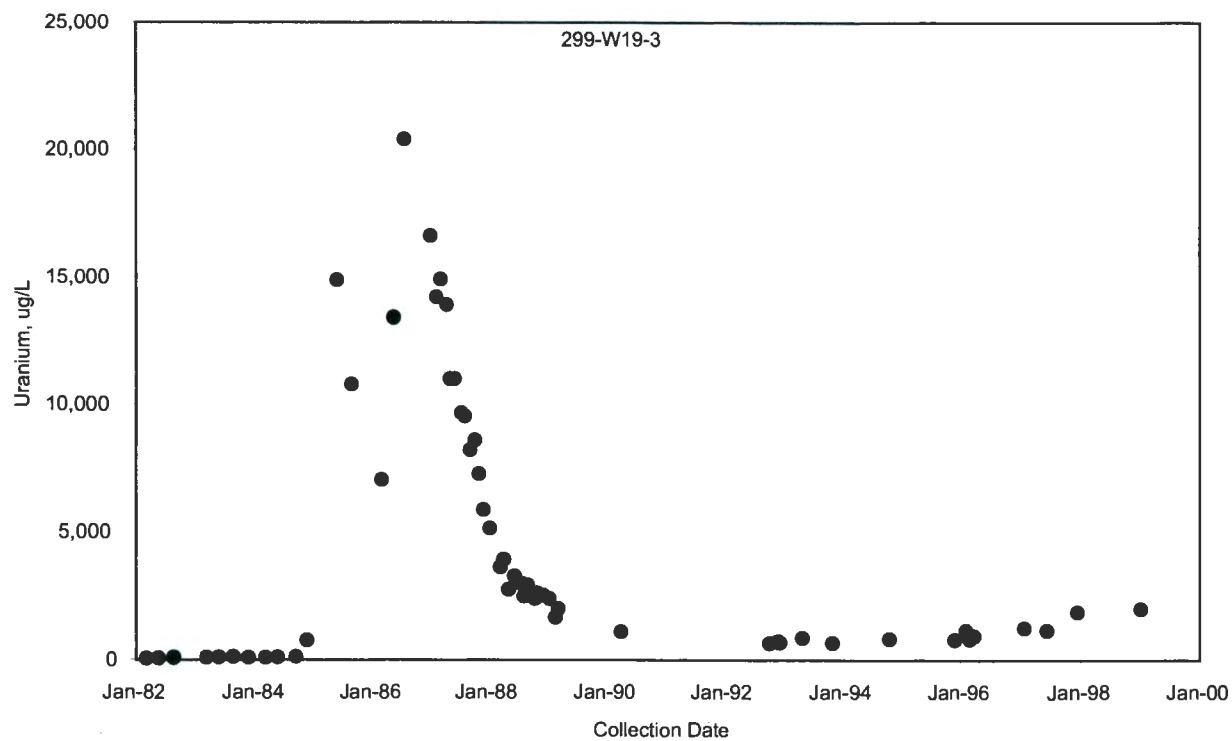


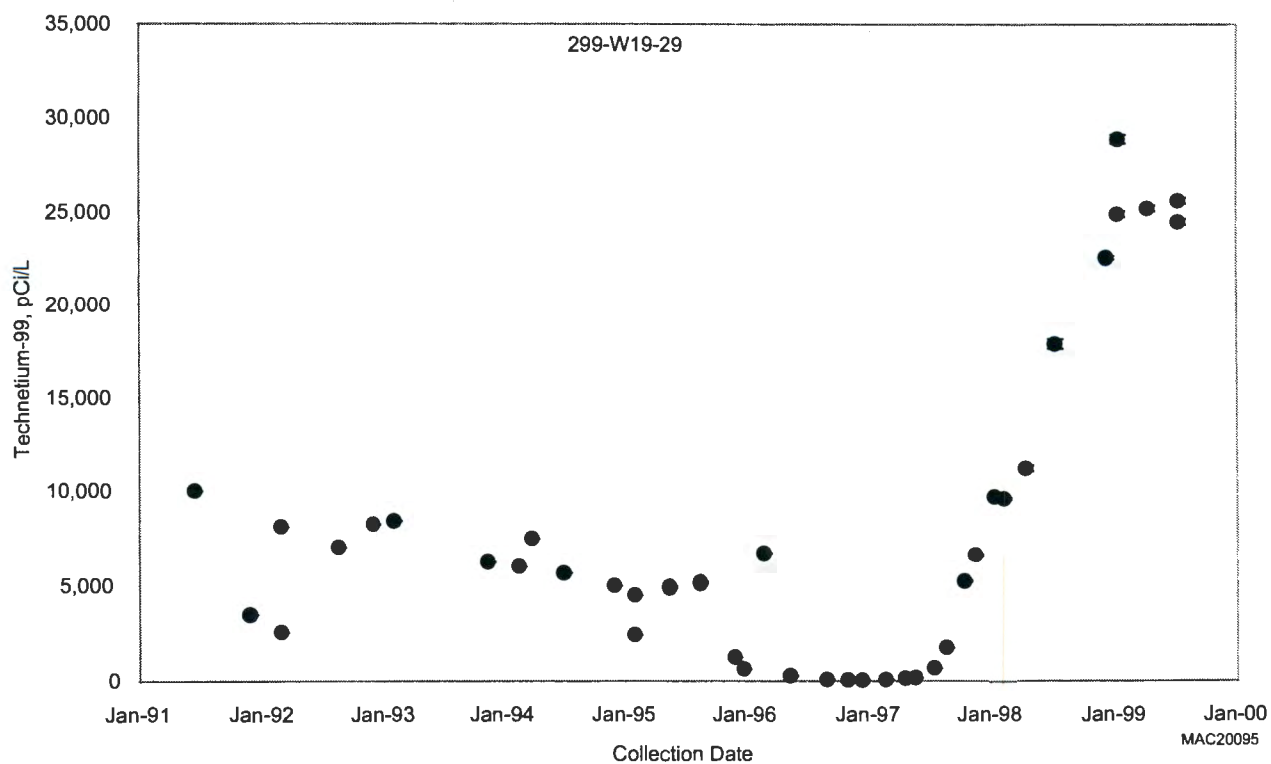
Figure 2.8-26. Technetium-99 in Well 299-W15-4, South of TX-TY Tank Farms





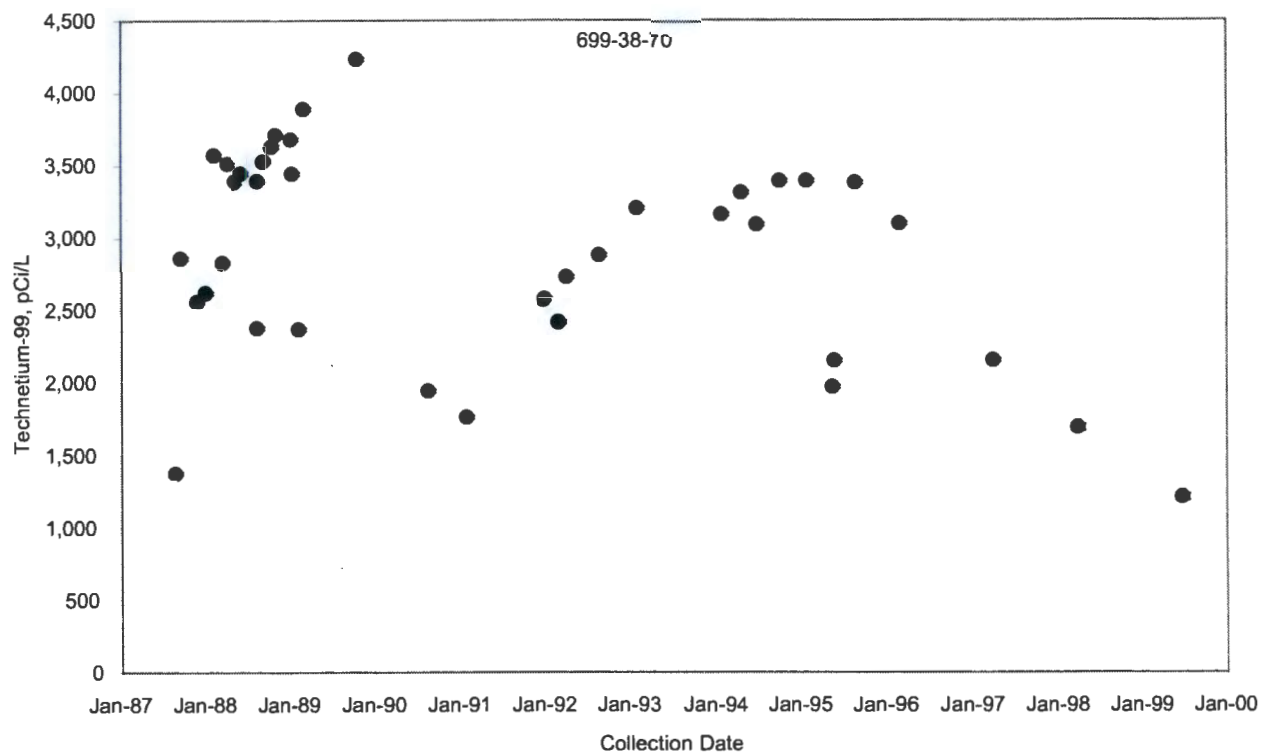
MAC20126

Figure 2.8-28. Uranium in Well 299-W19-3 Near the 216-U-1 and 216-U-2 Cribbs



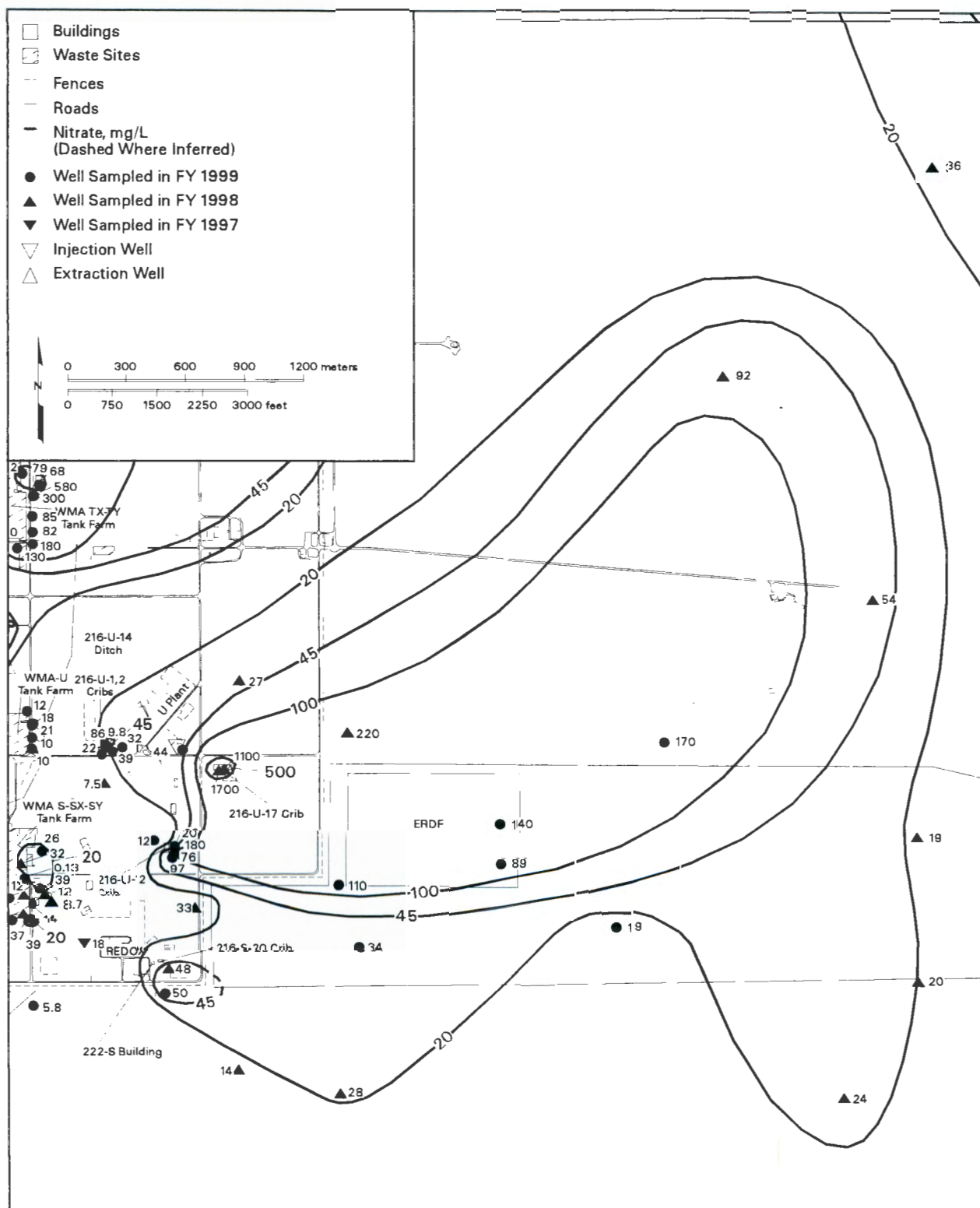
MAC20095

Figure 2.8-29. Technetium-99 in Well 299-W19-29 Near U Plant



MAC20094

Figure 2.8-30. Technetium-99 in Well 699-38-70, East of U Plant



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Figure 2.8-31. Average Nitrate Concentrations in Southern and Eastern 200 West Area, Top of Unconfined Aquifer

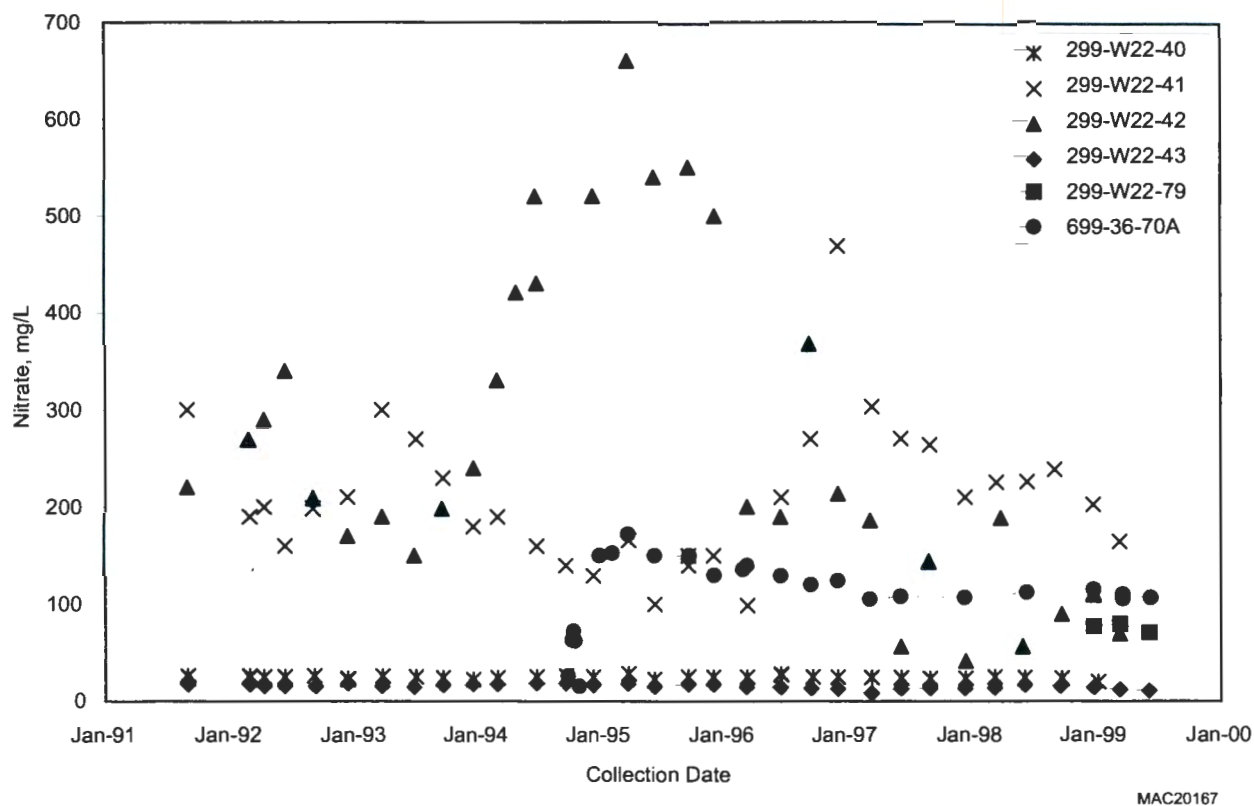


Figure 2.8-33. Nitrate in Wells Near the 216-U-12 Crib

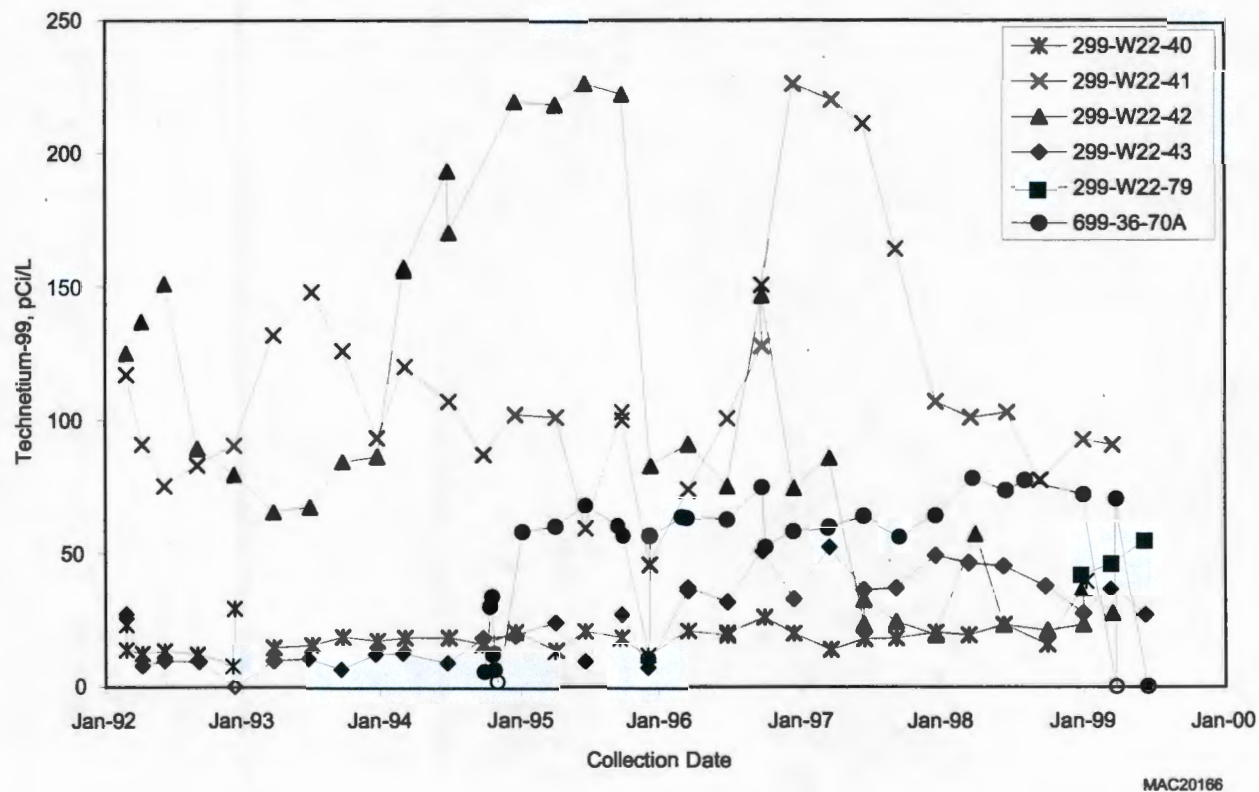


Figure 2.8-34. Technetium-99 in Wells Near the 216-U-12 Crib

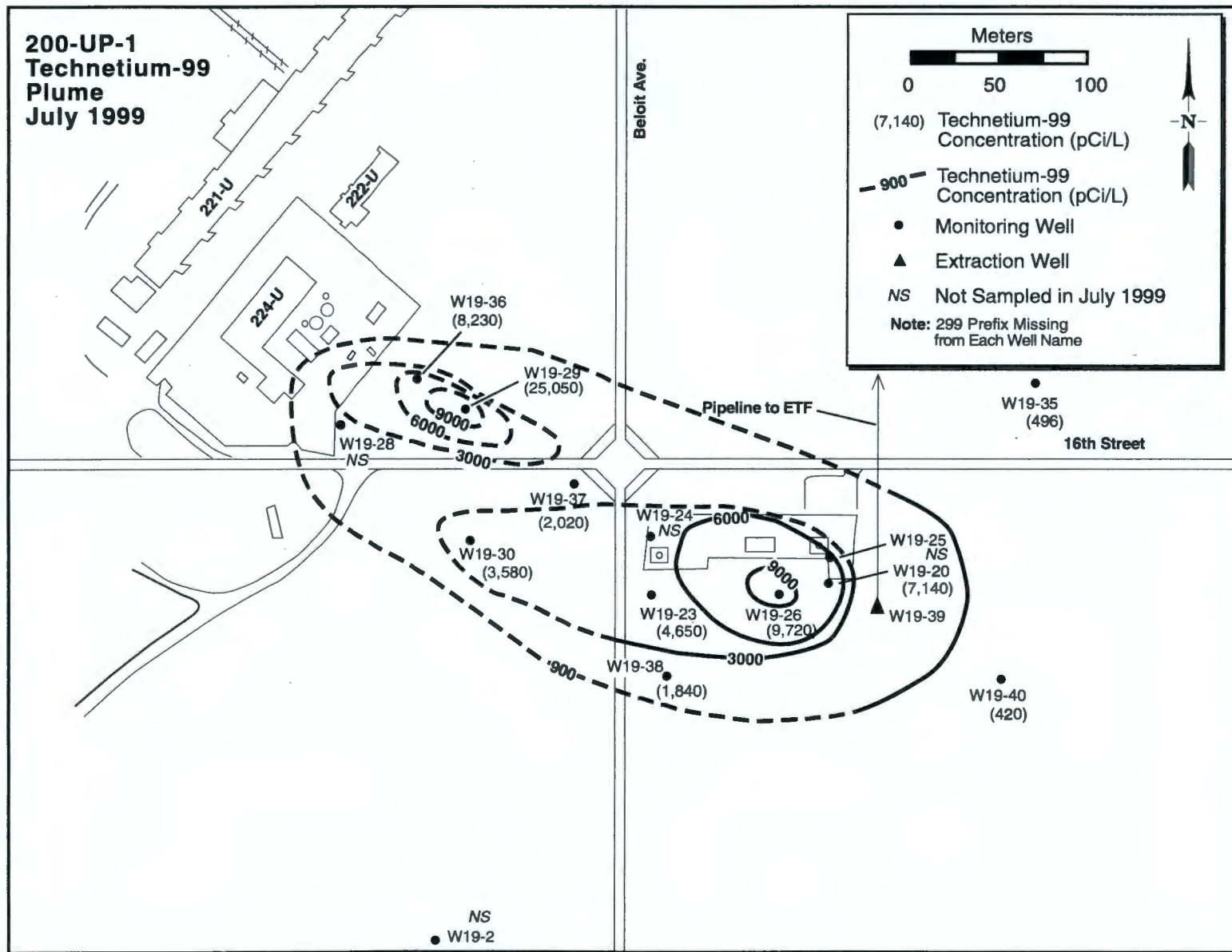


Figure 2.8-35. 200-UP-1 Technetium-99 Plume, July 1999 (DOE/RL-99-79)

E0001136_2

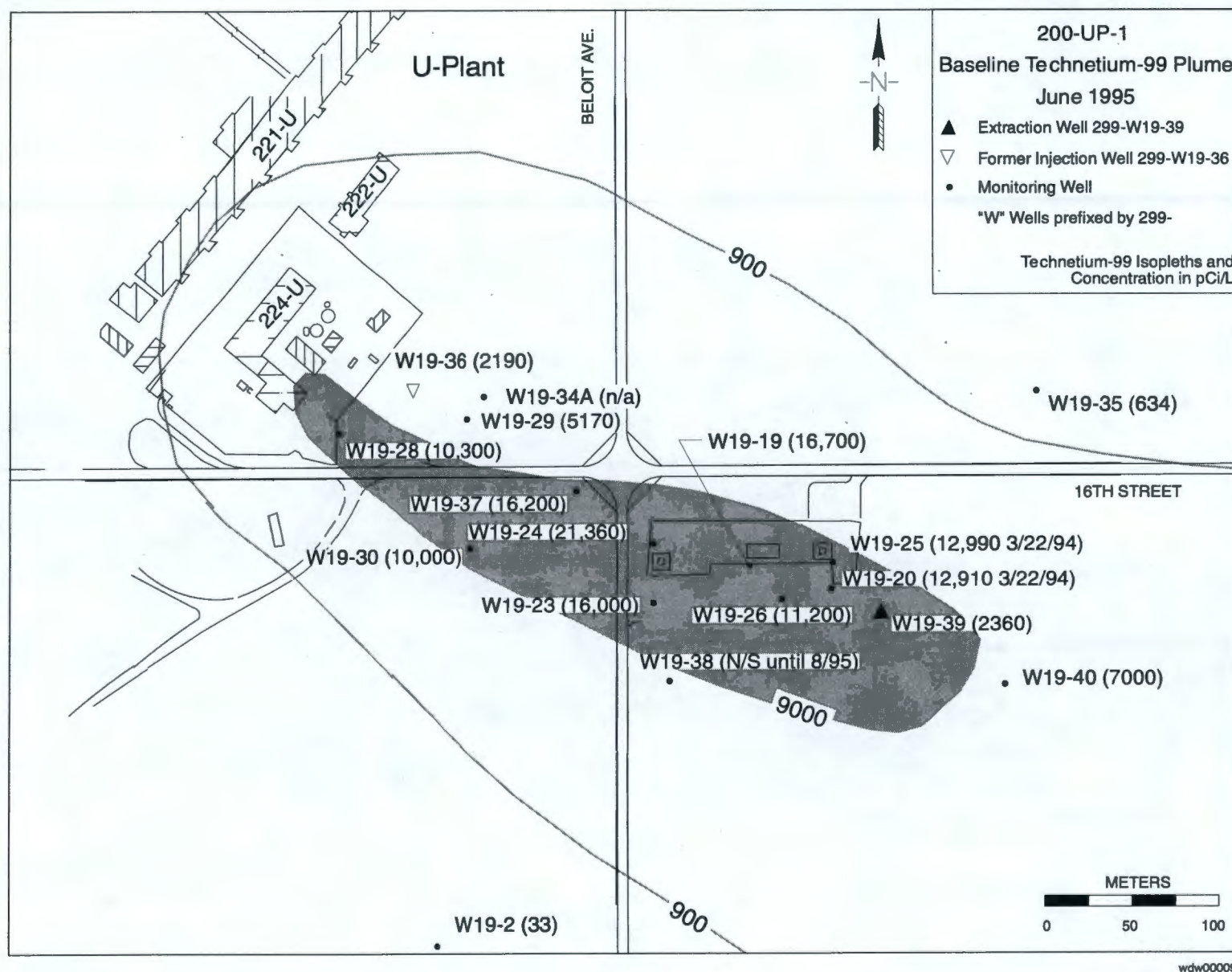
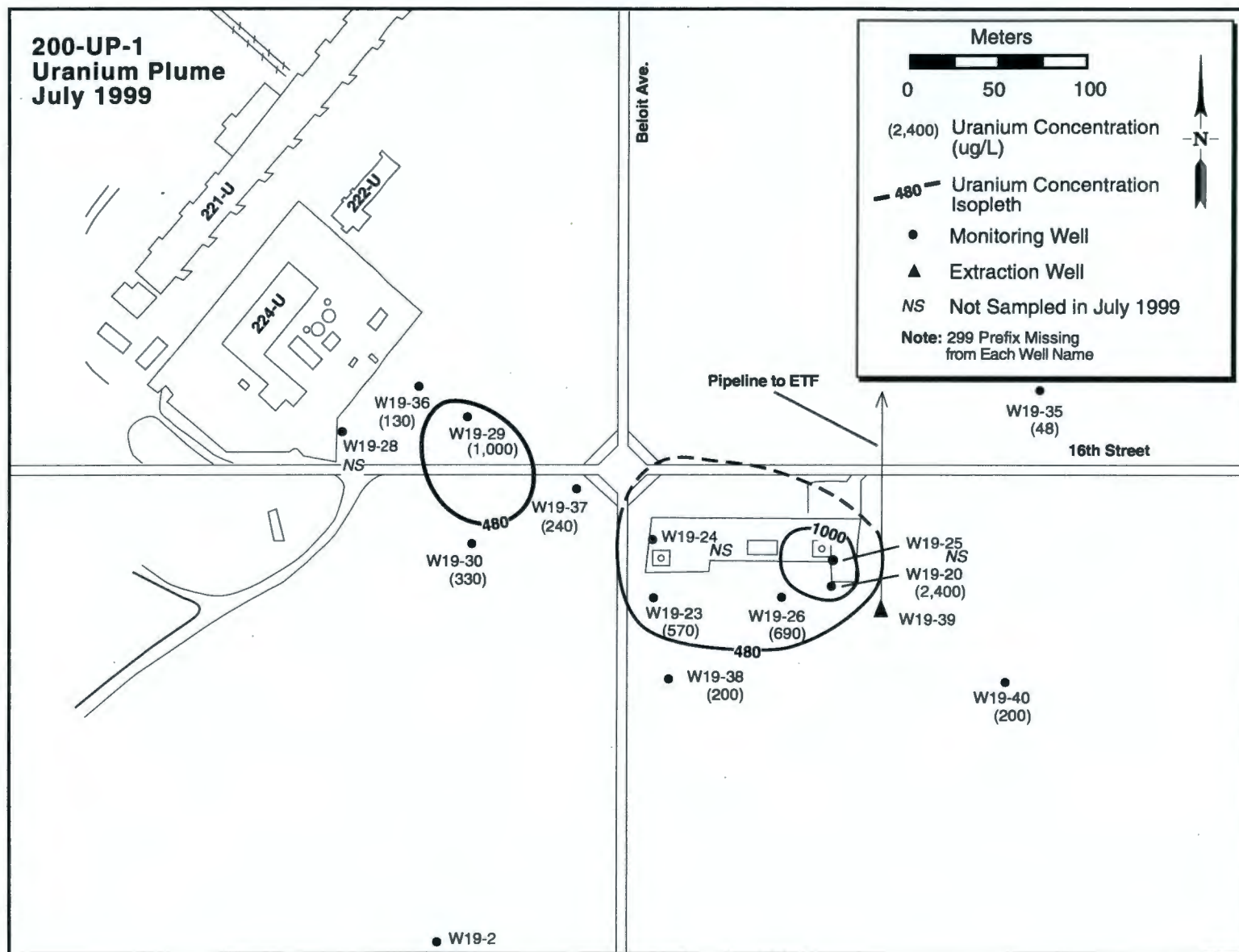


Figure 2.8-36. 200-UP-1 Technetium-99 Baseline Plume, June 1995 (DOE/RL-99-79)



E0001136_1

Figure 2.8-37. 200-UP-1 Uranium Plume, July 1999 (DOE/RL-99-79)

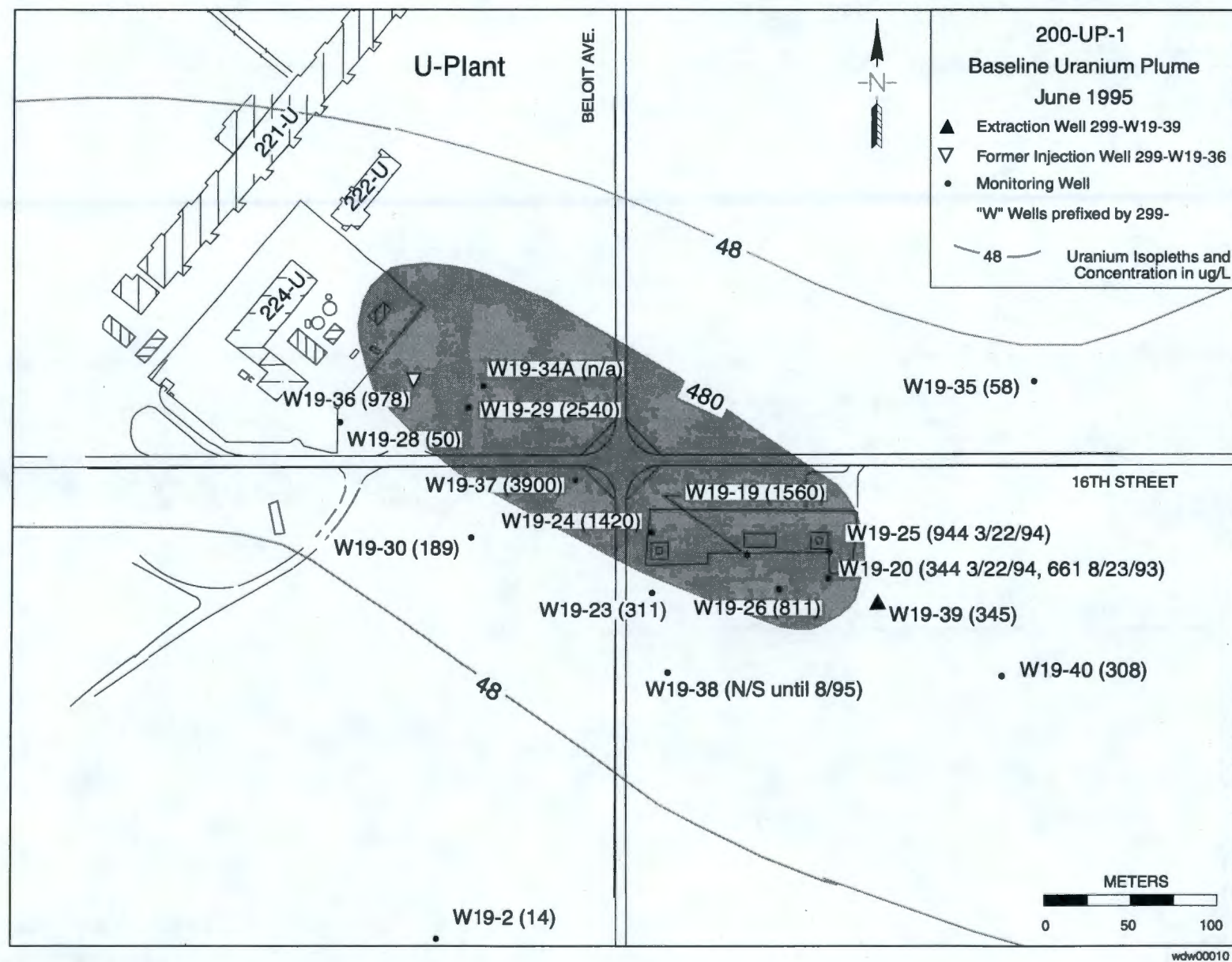


Figure 2.8-38. 200-UP-1 Uranium Baseline Plume, June 1995 (DOE/RL-99-79)

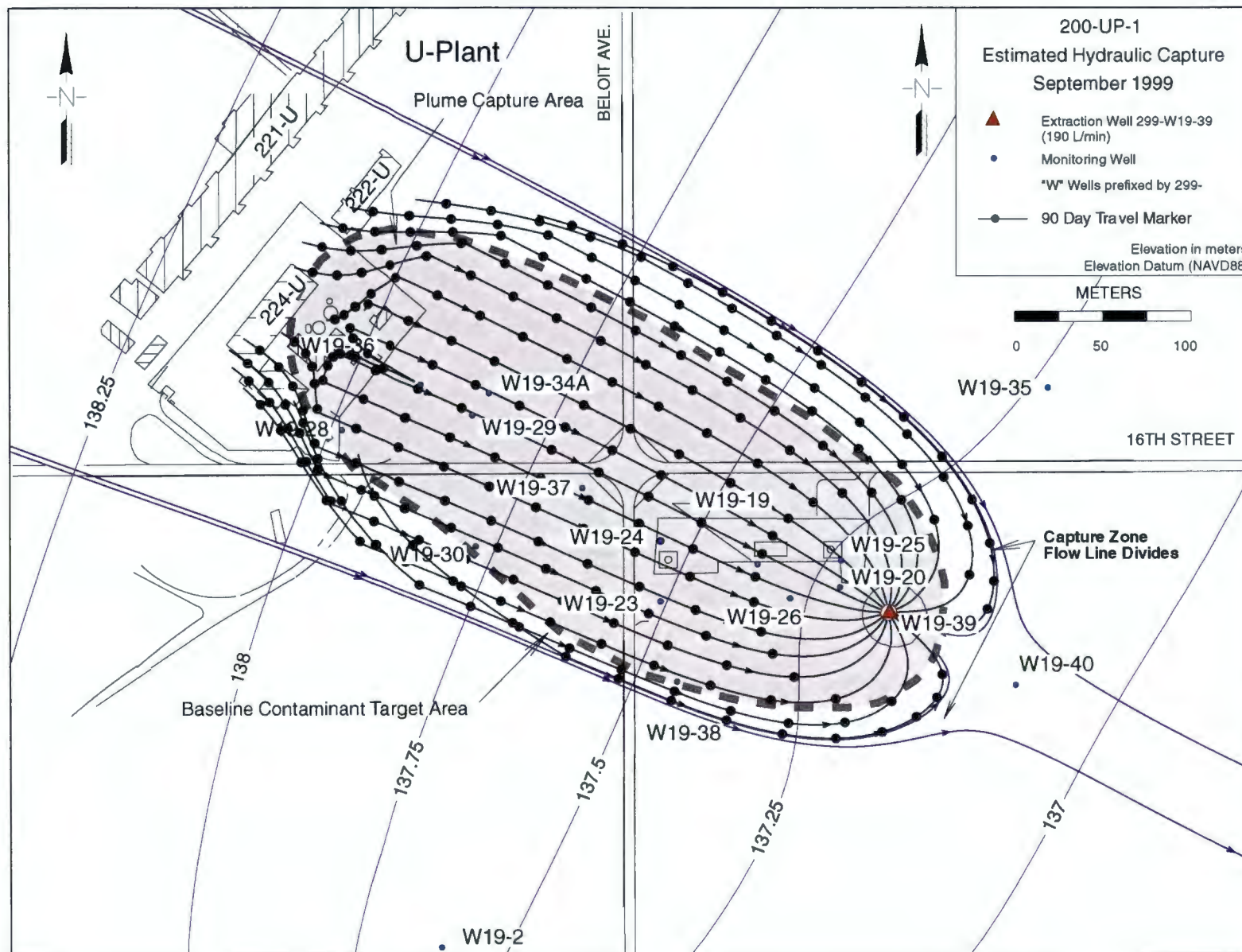


Figure 2.8-39. 200-UP-1 Pump-and-Treat System Estimated Area of Hydraulic Capture as of September 1999 (DOE/RL-99-79)

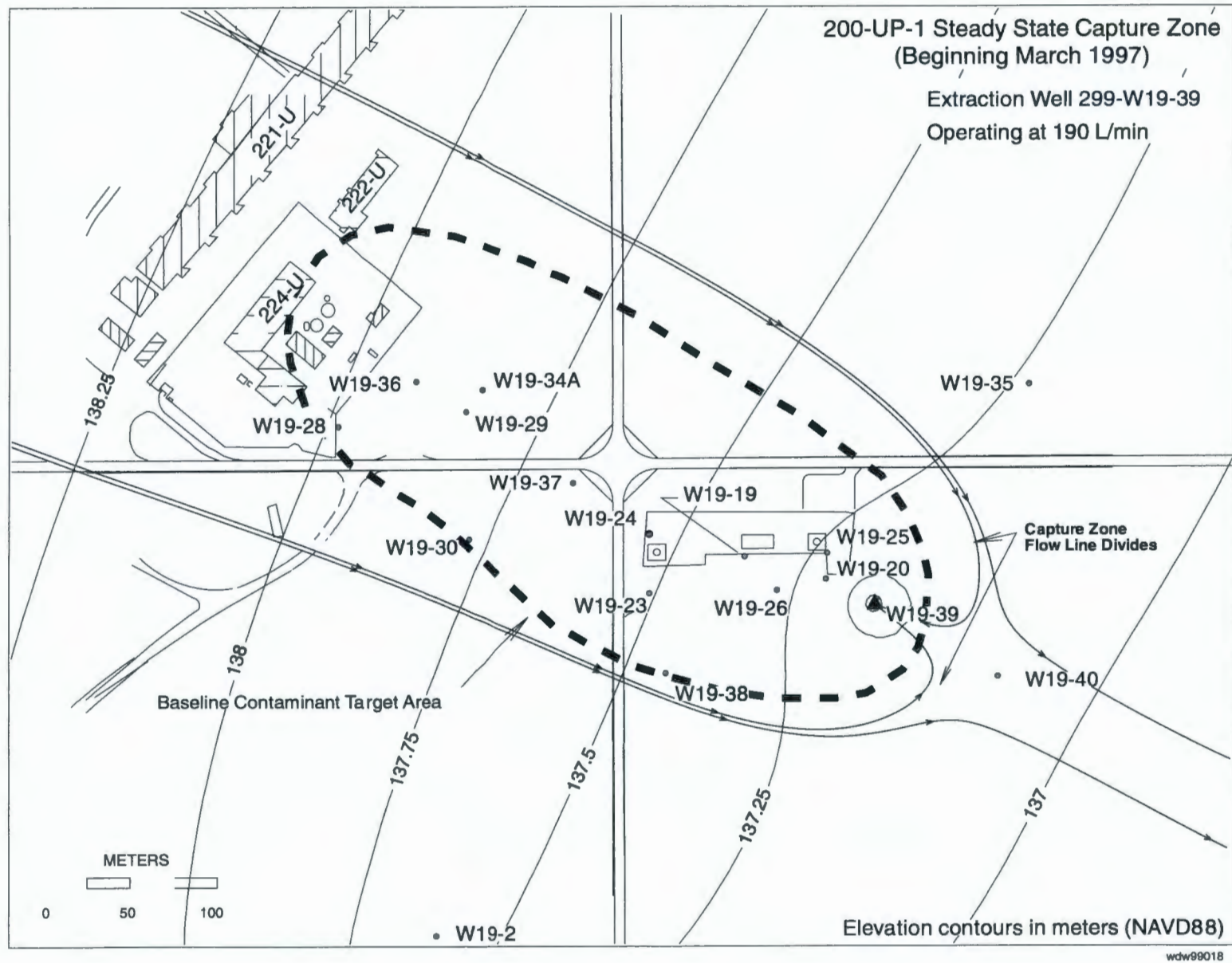


Figure 2.8-40. 200-UP-1 Pump-and-Treat System Steady State Hydraulic Capture Zone Beginning March 1997 (adapted from DOE/RL-99-79)

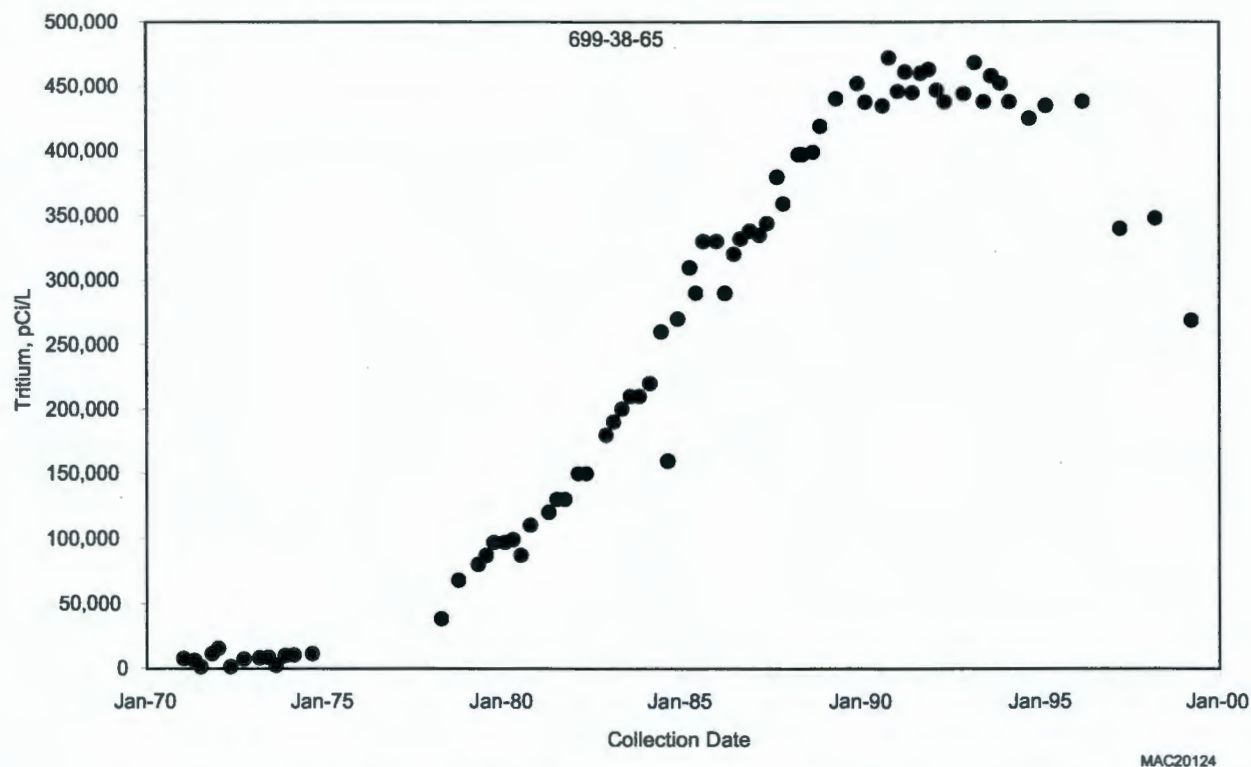


Figure 2.8-41. Tritium in Well 699-38-65, East of 200 West Area REDOX Plant

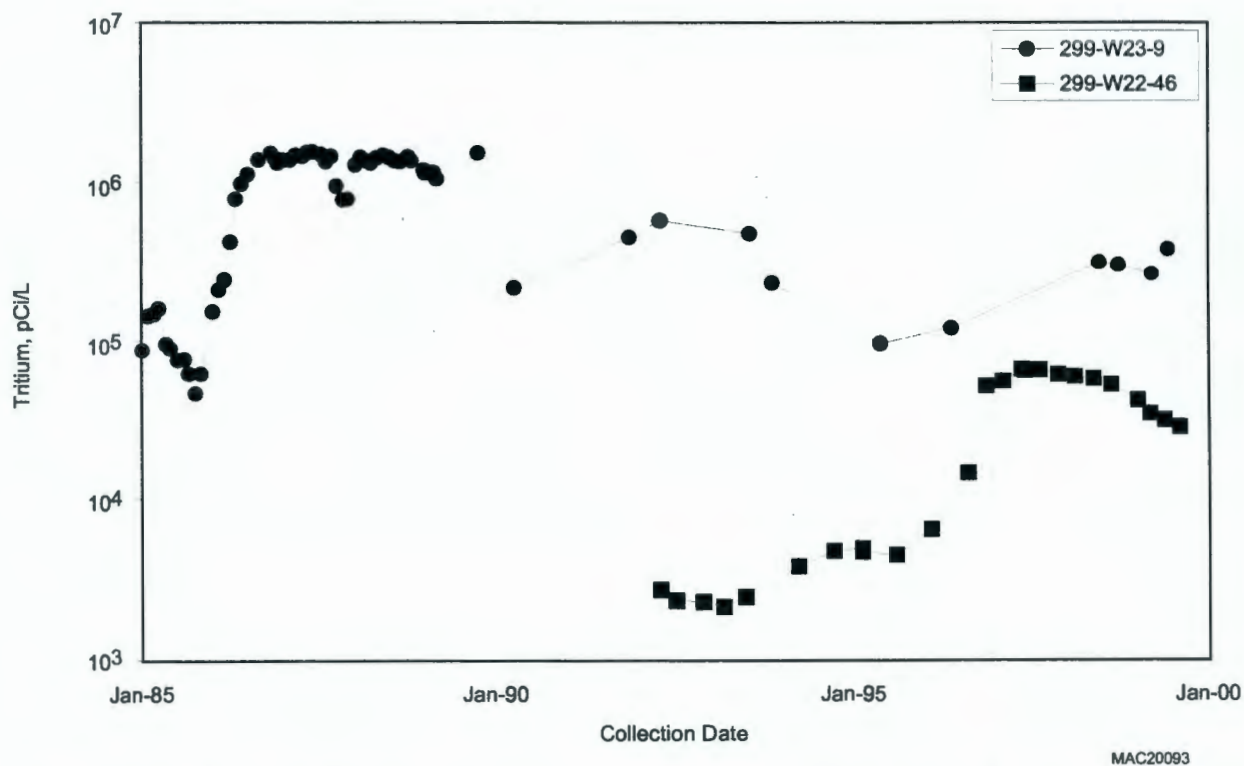
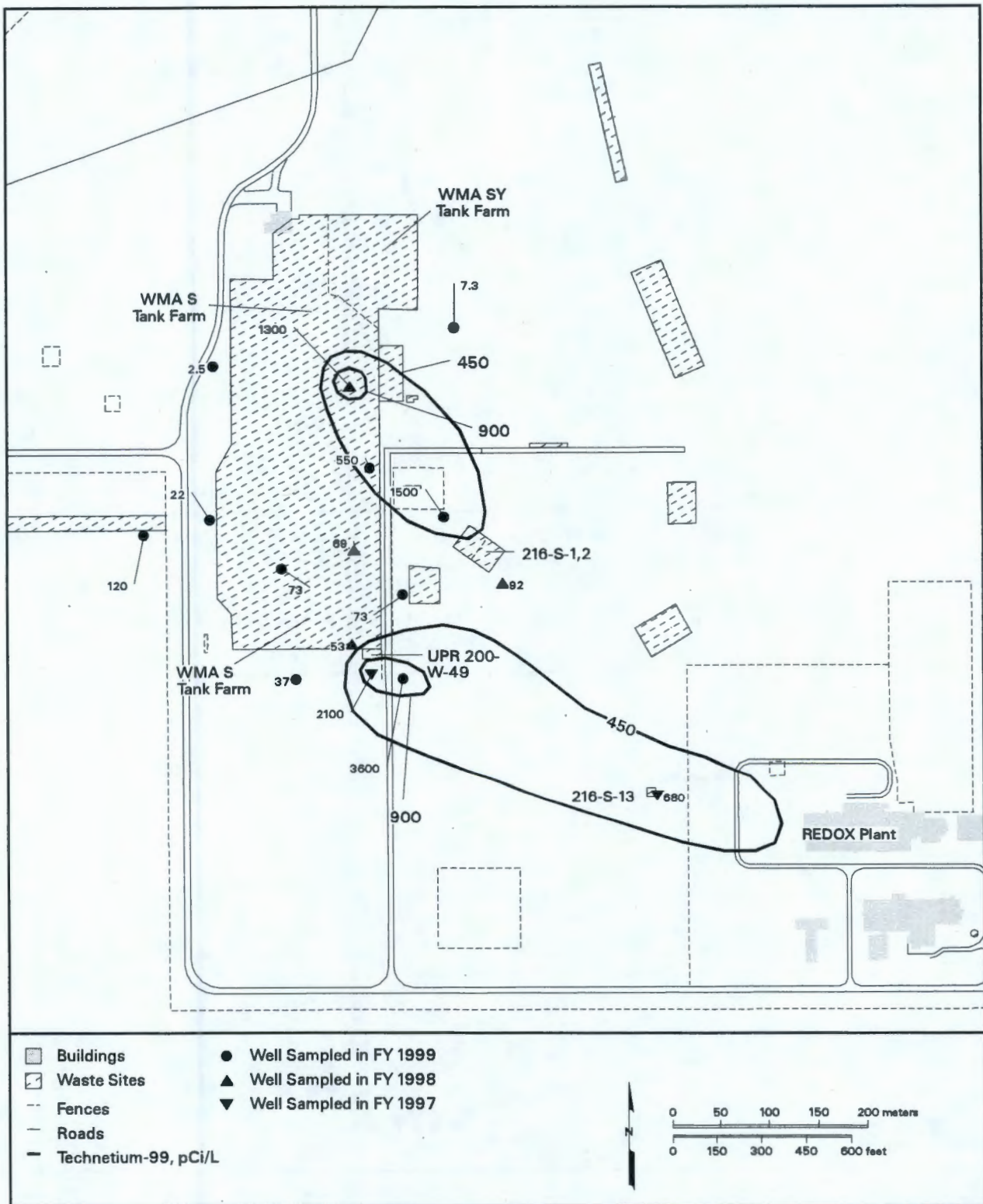


Figure 2.8-42. Tritium in Wells 299-W23-9 and 299-W22-46 Near the 216-S-25 Crib and S-SX Tank Farms



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Figure 2.8-43. Average Technetium-99 Concentrations Near S-SX Tank Farms, Top of Unconfined Aquifer

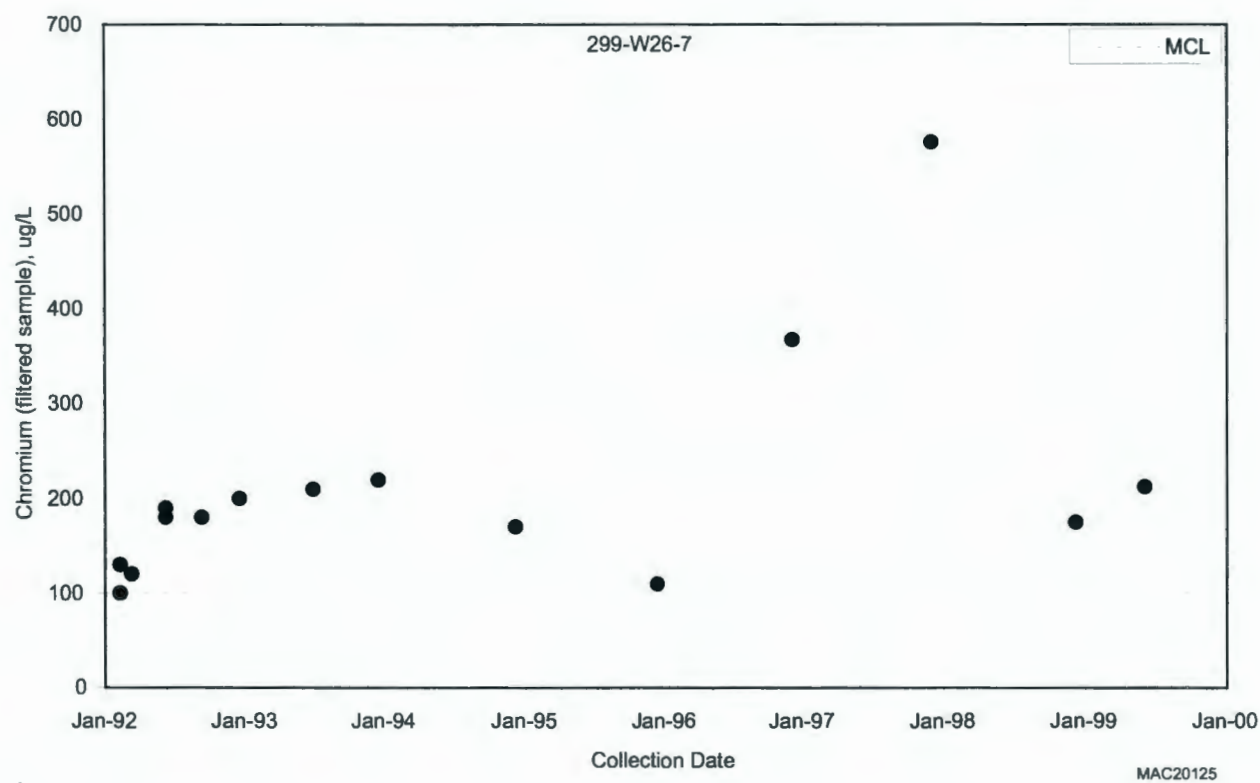


Figure 2.8-44. Chromium in Well 299-W26-7, Monitoring 216-S-10 Pond and Ditch

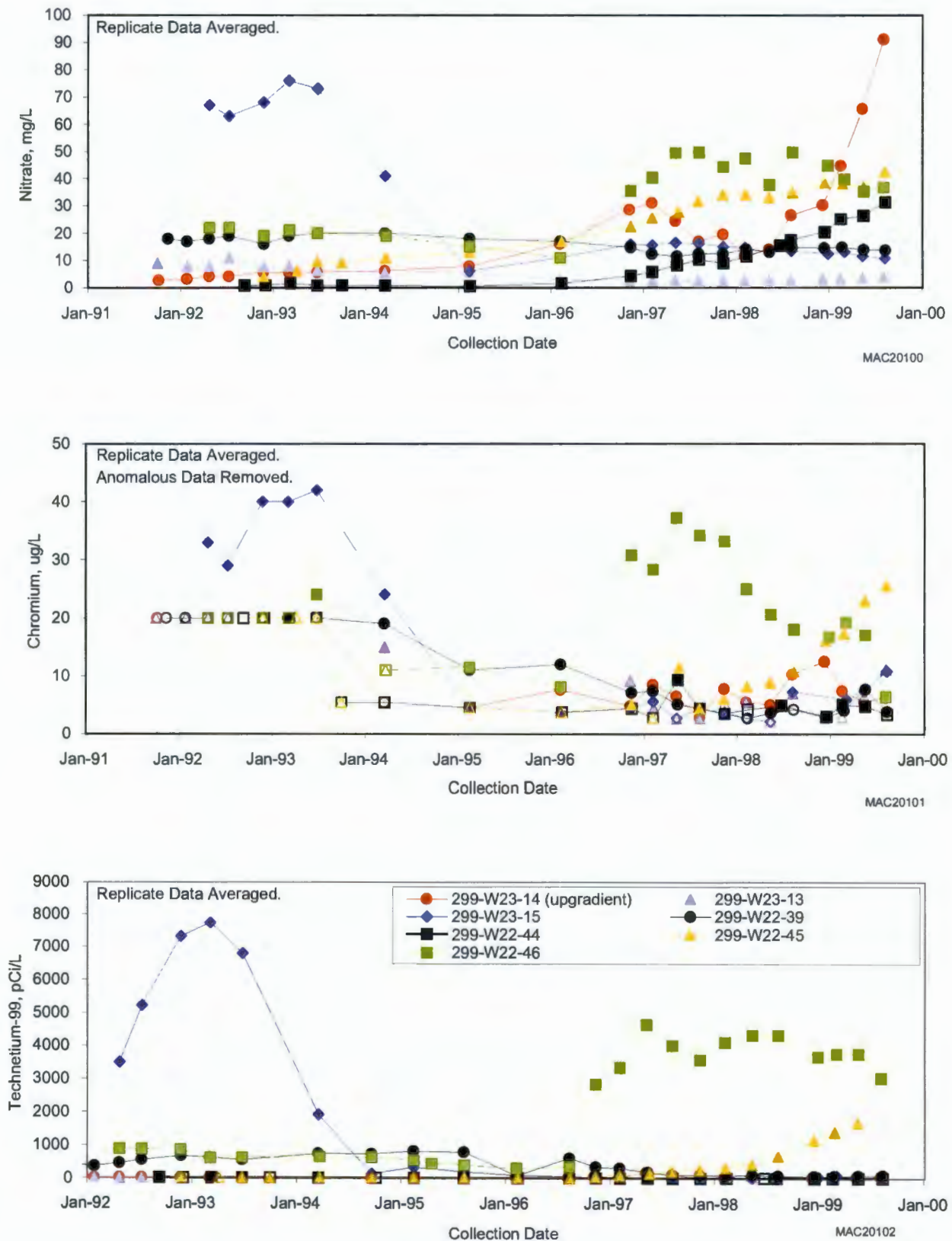
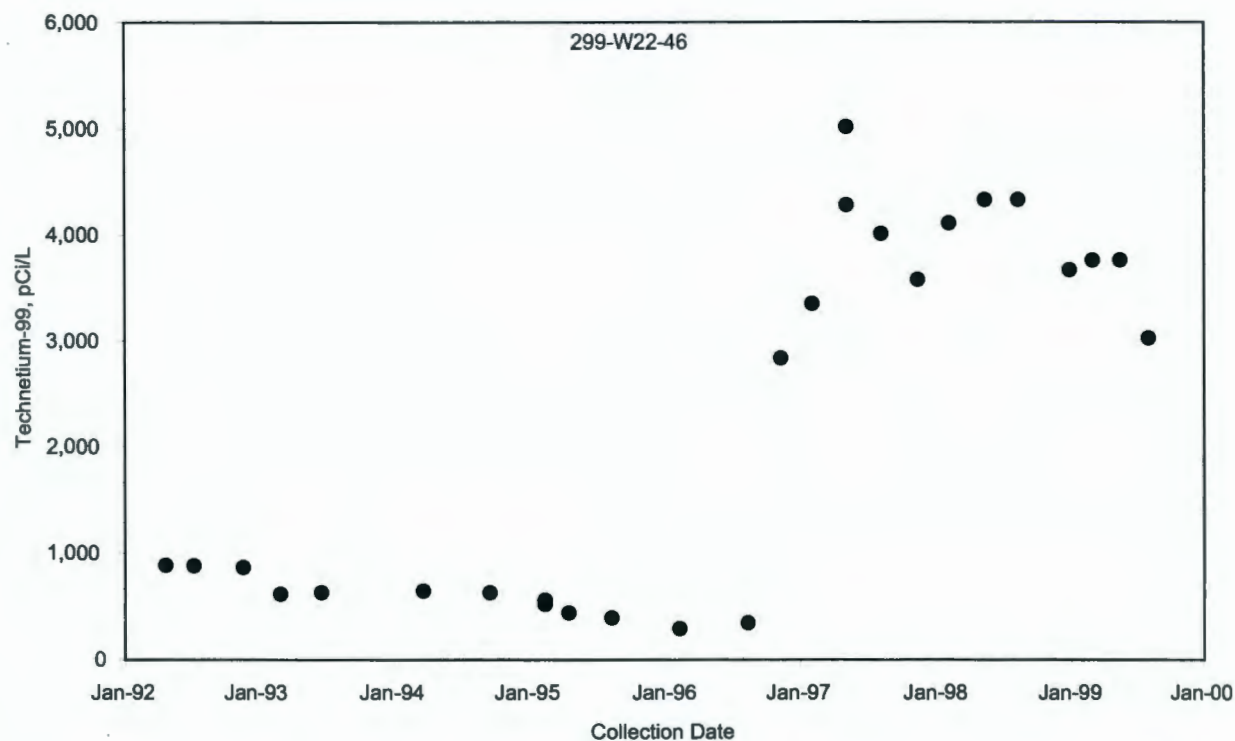
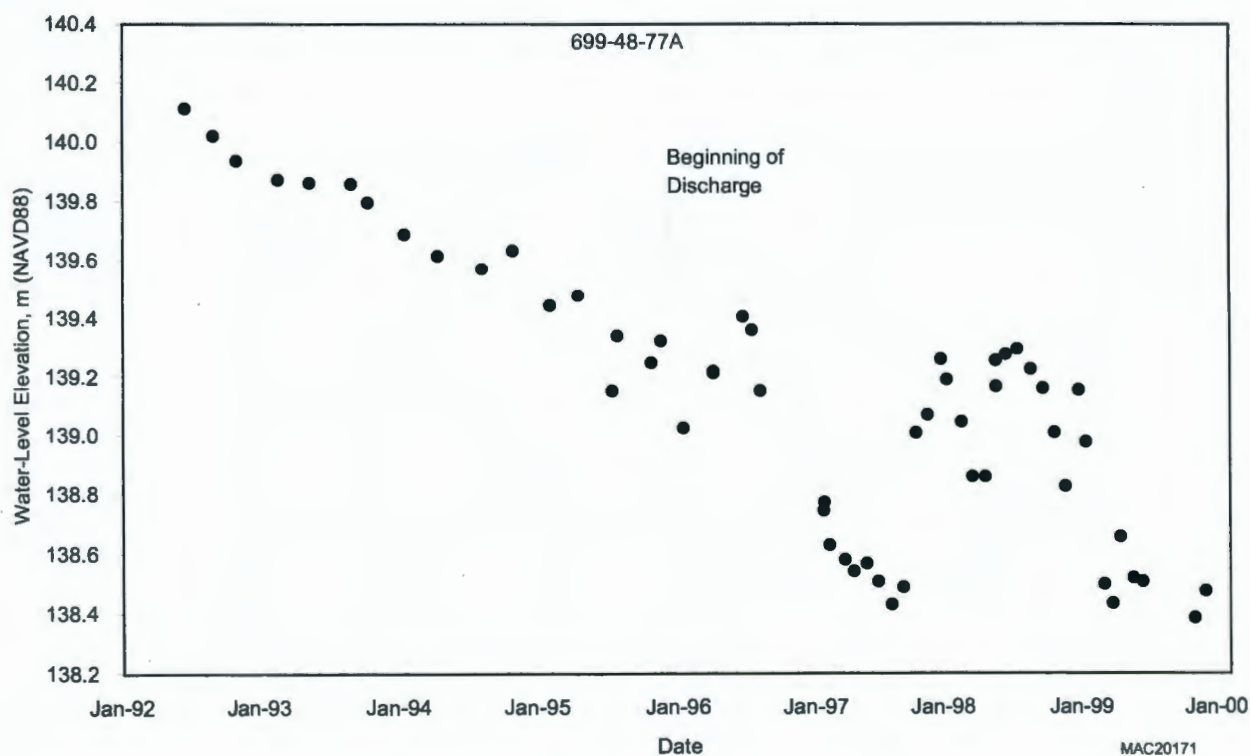


Figure 2.8-45. Technetium-99, Chromium, and Nitrate in Wells at Waste Management Area S-SX



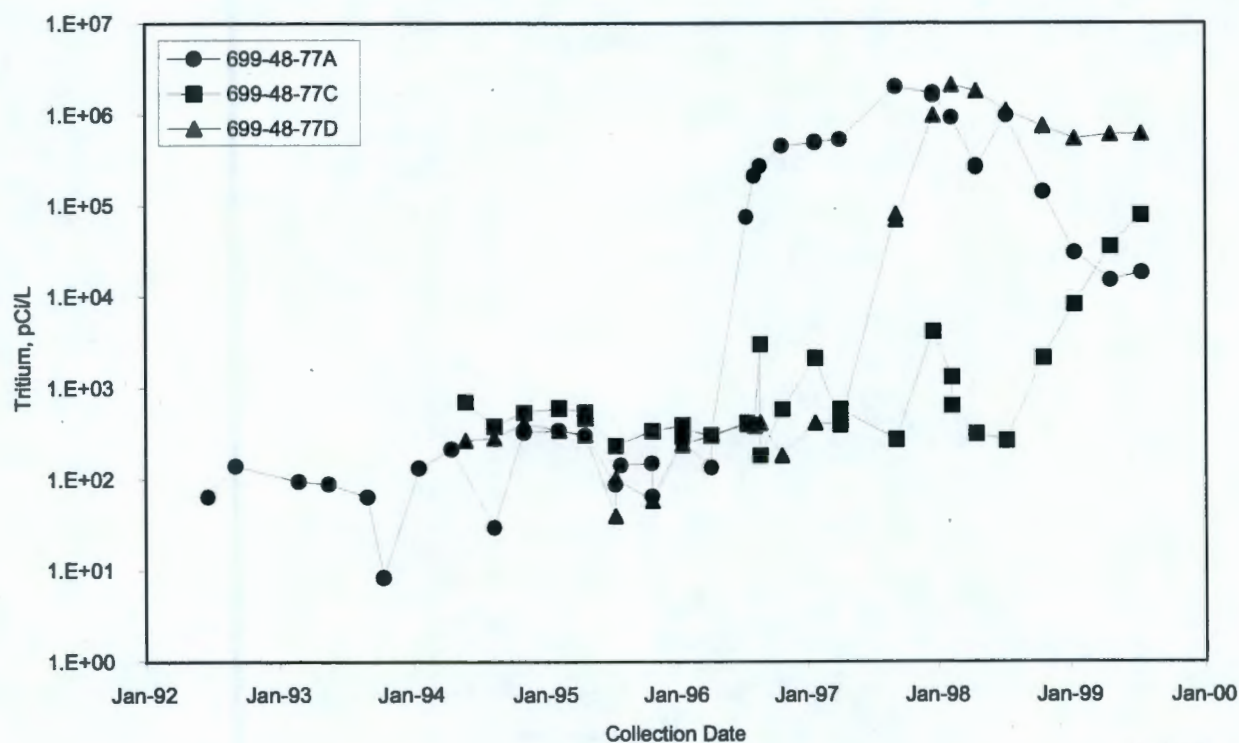
MAC20092

Figure 2.8-46. Technetium-99 in Well 299-W22-46, Southeast of Waste Management Area SX



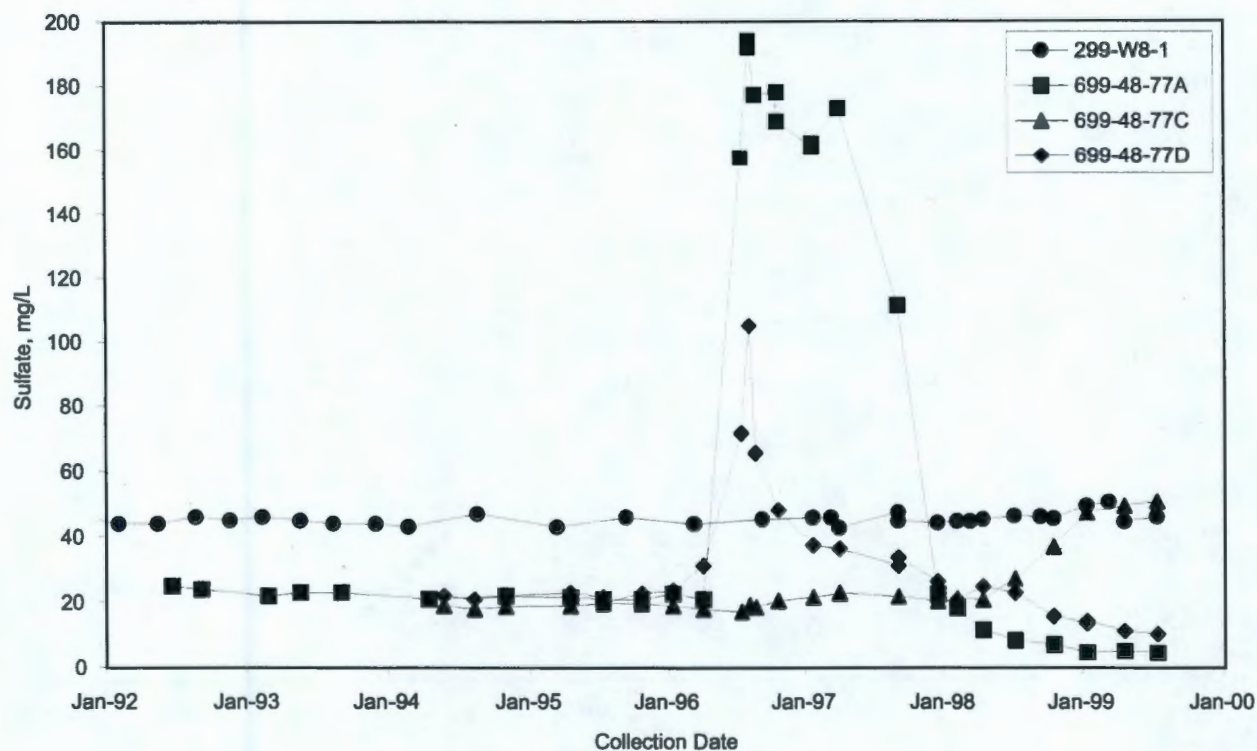
MAC20171

Figure 2.8-47. Water Levels for Well 699-48-77A



MAC20038

Figure 2.8-48. Tritium in Wells Monitoring the State-Approved Land Disposal Site



MAC20037

Figure 2.8-49. Sulfate in Wells Monitoring the State-Approved Land Disposal Site

2.9 200 East Area

J. W. Lindberg, D. B. Barnett, J. P. McDonald,
R. B. Mercer, S. M. Narbutovskih,
M. D. Sweeney, B. A. Williams

For the purpose of describing groundwater contamination, the 200 East Area is divided into two parts:

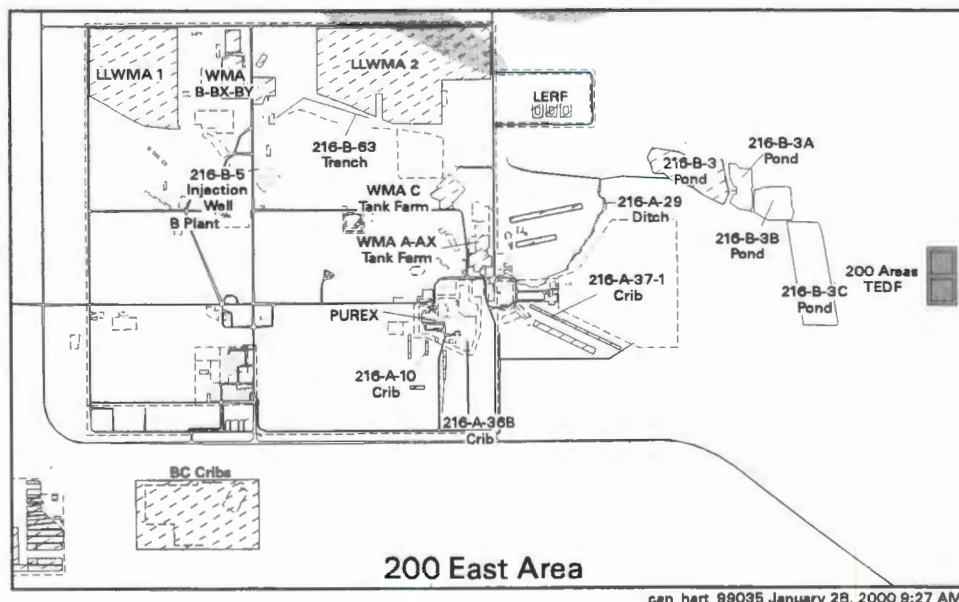
- the B Plant area in the northwestern and northern parts of the 200 East Area
- the Plutonium-Uranium Extraction (PUREX) Plant area in the southeast and eastern parts of the 200 East Area.

The vast majority of the 200 East Area groundwater contamination has its source in these two areas.

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, uranium, strontium-90, plutonium, and nitrate.

2.9.1 B Plant

This section describes the area associated with facilities surrounding B Plant and extends north to the perimeter fence. B Plant was used to recover plutonium from irradiated fuel using the bismuth phosphate process from 1945-1956. Contamination in the B Plant area is the result of waste disposal to the soil column at a variety of locations. The sources of waste actively monitored for contamination include the 216-B-5 injection well, the Waste Management Area B-BX-BY, 216-B-63 ditch, and Low-Level Burial Grounds Waste Management Areas 1 and 2. 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 these waste streams, it is difficult to assign specific groundwater contaminants to individual receiving sites. Certainly there are instances where generally high contaminant concentrations can be assigned to waste facilities (e.g., tank farms versus low-level burial grounds). 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 (Section 2.9.2).

Monitoring Objectives at B Plant

Groundwater monitoring is conducted near B 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 three RCRA waste management areas
- ▶ quarterly to assess contamination from one RCRA waste management area.

2.9.1.1 Groundwater Flow

The difference in water-table elevation across the B Plant area and the northwestern part of the 200 East Area is very small, making it difficult to determine groundwater flow direction and rate from water-table maps. Much of what is known about flow direction can be derived from plume maps and multiple trend plots of water levels at wells. In general, groundwater elevations in the unconfined aquifer continue to decline throughout the B Plant area, a result of the subsiding groundwater mound at 216-B-3 pond (see Section 2.9.2.11).

In the past, groundwater flow in the B Plant area was to the northwest, which was responsible for the contaminant plumes such as tritium and technetium-99 that extend northwest toward the gap between Gable Butte and Gable Mountain. Part of the reason groundwater flow was to the northwest was the large volume of wastewater discharged at 216-B-3 pond. However, after discharges at 216-B-3 pond ceased (Section 2.9.2.11), its influence on groundwater flow in the B Plant area decreased. More recently, groundwater flow has changed from a northwestern flow to a western

flow (see Section 2.9.1.10 and Table A.2) or southwestern flow (see Section 2.9.1.9).

2.9.1.2 Tritium

Tritium contamination is widespread throughout the northwestern part of the 200 East Area and extends north through the gap between Gable Mountain and Gable Butte and southeast toward the PUREX Plant (see Plate 3). Tritium contamination from B Plant has declined greatly because of natural decay. The peak concentrations are receding to the southeast

Although tritium concentrations in the B Plant area have declined since 1990, two wells in the B Plant vicinity continue to have tritium exceeding the drinking water standard (Plate 3 and Figure 2.9-1). Well 299-E28-2 had a reported concentration of 23,000 pCi/L in April 1999. During April 1998, the reported value was 34,000 pCi/L. The tritium concentration in well 299-E28-24 was 30,700 pCi/L. This well was not sampled for tritium in fiscal year 1998. The last time this well was sampled (in September 1993), the reported tritium value was 57,000 pCi/L.

Another pulse of tritium at levels above the interim drinking water standard can be found between Gable Mountain and Gable Butte (see Plate 3). Monitoring well 699-61-62 indicated a maximum average concentration for fiscal year 1999 of 42,000 pCi/L and 54,000 pCi/L for fiscal year 1998. Like tritium concentrations farther south by B Plant, tritium concentrations between Gable Mountain and Gable Butte have declined with time. Peak concentrations do not appear to be moving. Sources of the tritium have not been defined, but are presumed to be B Plant facilities.

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 (Figure 2.9-2). Twenty-one wells had concentrations of iodine-129 above the drinking water standard (1.0 pCi/L) during fiscal year

1999. Four of the wells have iodine-129 values that are increasing. The remaining 17 wells had concentrations that declined or remained unchanged from fiscal year 1998 reported values. Iodine-129 concentrations range up to 6.5 pCi/L in well 299-E33-42.

Several wells between Gable Mountain and Gable Butte are sampled for iodine-129 to define the northern plume and to track the movement of this plume out of the 200 Areas (see Figure 2.9-2). The most recent results for these wells were below detection limits, but concentrations have been at or above the drinking water standard occasionally in the past (Figure 2.9-3).

2.9.1.4 Technetium-99

A plume of technetium-99 (interim drinking water standard 900 pCi/L) extends from the area of Waste Management Area B-BX-BY to beyond the 200 East Area boundary to the northwest (Figure 2.9-4). The plume has two parts. The larger part of the plume is to the north and possibly represents early releases of technetium-99 from the BY cribs. Detection of technetium-99 at levels lower than the interim drinking water standard (900 pCi/L) north of the Gable Mountain-Gable Butte gap indicates that technetium-99 has moved north, into, and through the gap. The southern portion of the plume lies mostly within the boundary of the 200 East Area. This portion of the plume may be associated with west-southwest groundwater flow and movement of more recent BY cribs contamination. For a more detailed discussion, see Section 2.9.1.9).

Overall, technetium-99 in the B Plant area is increasing in concentration. In the area of Waste Management Area B-BX-BY, 17 wells exceeded the interim drinking water standard for technetium-99 in fiscal year 1999. Fourteen of those wells show a significant increase in concentration. The concentration of technetium-99 ranges to more than 5,000 pCi/L within the BY cribs area.

2.9.1.5 Uranium

Uranium contamination in the B Plant area is limited to three isolated areas (refer to Plate 1 for locations):

- wells monitoring Waste Management Area B-BX-BY
- wells near the 216-B-5 injection well
- wells at the 216-B-62 crib (299-E28-21 and 299-E28-18).

Although the trend is decreasing slightly since 1998, many wells in all three of these areas exceeded the 20- μ g/L proposed drinking water standard during fiscal year 1999. Section 2.9.1.9 discusses uranium contamination at Waste Management Area B-BX-BY in more detail.

2.9.1.6 Strontium-90 and Cesium-137

Several wells in the vicinity of B Plant have trends indicating historical concentrations of strontium-90, but the highest levels are near the 216-B-5 injection well. Four wells (299-E28-2, 299-E28-23, 299-E28-24, and 299-E28-25) had concentrations of strontium-90 above the interim drinking water standard (8.0 pCi/L) in fiscal year 1999. Two wells (299-E28-23 and 299-E28-25) are the only ones exceeding the derived concentration guide (1,000 pCi/L). The samples were a mixture of filtered and unfiltered groundwater but the data do not show any significant difference in concentration.

Strontium-90 values that exceed the drinking water standard in the B Plant area range in concentration from 32 to 10,000 pCi/L. The highest concentration (10,000 pCi/L) was reported from well 299-E28-23, which is near the 216-B-5 injection well. Of the four wells exceeding the drinking water standard, well 299-E28-23 is the only well that shows a steady increase in levels of strontium-90 since 1990. Well 299-E28-2 had rising strontium-90 concentrations until early 1999, when it dropped suddenly. Concentrations in wells 299-E28-24 and 299-E28-25 have declined since 1990.

During fiscal year 1999, of the four wells with concentrations of strontium-90 greater than the drinking water standard (8 pCi/L), only one well (299-E28-23) had concentrations of cesium-137 greater than the drinking water standard (200 pCi/L). The concentration of cesium-137 at well 299-E28-23 during December 1998 was 1,840 pCi/L. None of the wells had concentrations exceeding the derived concentration guide (3,000 pCi/L). The trends for cesium-137 for all four of the wells have been relatively stable since 1994.

Cesium-137, strontium-90, and uranium are present in groundwater near the former 216-B-5 injection well. Plutonium is also present, but levels are declining.

2.9.1.7 Plutonium

Plutonium-239 and -240 concentrations continue to be detected in unfiltered groundwater samples taken near the 216-B-5 injection well. The plutonium concentration in well 299-E28-23 was 65.8 pCi/L, the maximum level for the B Plant area, in fiscal year 1999. The concentration has been rising in this well since 1994 but showed no increase in concentration during fiscal year 1999. Wells 299-E28-24 and -25 also had concentrations above background. However, plutonium-239 and -240 concentrations in these wells have declined since 1994. Plutonium-239 and -240 adsorb well onto soil particles and, therefore, do not migrate far from the discharge source (i.e., the 216-B-5 injection well).

2.9.1.8 Nitrate

A nitrate plume originating in the 200 East Area extends beyond the boundary fence line, extending northwest to the Columbia River (Figure 2.9-5). The plume has two parts: (1) a western plume that extends from B Plant to the northwest, which appears to be a portion of a larger plume extending from the PUREX Plant, and (2) an eastern portion of the plume extending from the BY cribs toward the northwest. The two

portions of the plume join northwest of the 200 East Area and extend northwest to the Columbia River.

Significant concentrations of nitrate can be found throughout the 200 East Area, but those exceeding the drinking water standard in the vicinity of B Plant extend northwest from the BY cribs and Waste Management Area B-BX-BY. Twenty-six wells reported nitrate results above the drinking water standard in fiscal year 1999, and fourteen increased in concentration. The highest nitrate concentration was found in well 299-E33-16 near the 216-B-8 crib. Groundwater samples from this well had a yearly average of 490 mg/L for fiscal year 1999, nearly double the nitrate concentration since fiscal year 1997. Nitrate groundwater contamination surrounding Waste Management Area B-BX-BY and the BY cribs is discussed further in Section 2.9.1.9.

2.9.1.9 Waste Management Area B-BX-BY Assessment Summary

Waste Management Area B-BX-BY includes underground single-shell tank farms B, BX, and BY located in the eastern part of the 200 East Area. In fiscal year 1991, a system of RCRA-compliant wells was installed around this area to monitor the quality of the groundwater (WHC-SD-EN-AP-012, WHC-SD-EN-AP-012, Rev. 1). In 1996, the waste management area was placed in a groundwater quality assessment program as required (WHC-SD-EN-AP-002), based on specific conductance values that were elevated above the critical mean (365.7 $\mu\text{S}/\text{cm}$) in downgradient well 299-E33-32 (see Figure A.15). The monitoring frequency was increased from semiannually to quarterly.

During 1997, nitrate and technetium-99 concentrations were above the drinking water standards of 45 mg/L and 900 pCi/L, respectively, in well 299-E33-41, between the B and BX Tank Farms. It was concluded that waste from the waste management area had, most likely, entered the groundwater and was detected in this well (PNNL-11826).

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 rate and extent of groundwater contamination at Waste Management Area B-BX-BY.

RCRA Waste Management Area B-BX-BY contains single-shell tanks that may have contaminated groundwater with technetium-99 and nitrate. The hydraulic gradient is very flat, and the direction of groundwater flow is not known with certainty.

Groundwater Flow

The hydraulic gradient is nearly flat across the 200 East Area (Plate 2), making it difficult to determine upgradient versus downgradient locations from water-level measurements at wells. Part of this difficulty is related to surveying errors that create potential errors in water levels. In 1998, the Hanford Groundwater Monitoring Project changed the datum to which water levels are referenced (PNNL-12086, Section 3.3.2.1) to the North American Vertical Datum of 1988 (NAVD88). Previously, it had been the National Geodetic Vertical Datum of 1929 (NGVD29). Converting older survey data to elevations based on a NAVD88 datum can contribute to vertical errors as much as ~1 centimeter. Another source of error is introduced by specific surveys used to calculate vertical elevation. Even greater error than introduced by datum converting is introduced by using survey data from separate surveys. The overall result is that discrepancies between the data (datums) used have resulted in ambiguity in groundwater levels measured at wells.

However, a general flow direction can be estimated from water levels. Figure 2.9-6 shows hydrographs for 11 wells that are used to monitor the water table at

Waste Management Area B-BX-BY and nearby Low-Level Waste Management Areas 1 and 2. Most of the water elevations reference a survey commonly referred to as NGVD29-2. This survey was used in preference to multiple surveys based on NAVD88.

In addition, as part of the RCRA assessment work, vertical plumbness was measured in several wells that appeared to complicate the interpretation of local flow. Well 299-E33-39 was surveyed in fiscal year 1999 because data from that well consistently displayed anomalously low water elevations. Based on deviations from vertical, determined with a downhole gyroscope, a 12-centimeter correction was added to the water levels in this well.

The data from selected wells shown in Figure 2.9-6 depict general, local, water-level trend. Spurious and outlying data were removed from the individual well trends to facilitate interwell comparisons. The upgradient water elevations are in wells to the north, indicating a southwest flow direction. Although there are data from a few wells in this area that do not agree with this trend, the majority of wells investigated appear to mirror this general southwestern flow. This direction is consistent with recent interpretations of plume movement and with in situ flowmeter results (BHI-00442).

As can be seen in the hydrographs, it could be misleading to determine the direction of groundwater flow by using water-table elevations at several wells collected over a very small time interval. Consequently, it may not be appropriate to provide a three-point solution. However, based on observations of recent contaminant movement and on wells that consistently appear to be at the same relative elevations, an estimated flow direction lies between 200 and 250 degrees azimuth.

The average linear flow rate is calculated to be 0.9 meter per day (see Table A.2). This equates to 324 meters of effective groundwater movement per year. If discrete, highly permeable, flow channels are considered as the prime avenues of contaminant transport, then a flow rate of 0.9 meter per day may be low.

This relatively high flow velocity has implications that relate to the optimal sampling frequency at which the groundwater is monitored. Because the waste management area is less than 305 meters across, contamination related to leaking tank waste might move through the area in less than 1 year. Given the rapid movement of contaminate events seen in the past at well 299-E33-41 and Waste Management Area S-SX, semiannual or even quarterly sampling may not be sufficient to clearly identify and differentiate tank-related waste from background contamination left from discharges to the surrounding cribs, trenches, and reverse wells (PNNL-11810, PNNL-11826). As part of the RCRA Waste Management Area B-BX-BY assessment, a study is being conducted to determine the best sampling frequency for monitoring this area.

Groundwater Contamination

A discussion of the state of contamination surrounding Waste Management Area B-BX-BY is presented in this section, including historic constituent trends that depict the temporal and spatial distribution of contaminants. Several distinct groups of contaminants are recognized, based on spatial relationships and on identifying ratios of co-contaminants.

Although the primary inorganic constituents in tank waste at Waste Management Area B-BX-BY include aluminum, cesium-137, cyanide, nitrate, strontium-90, sulfate, technetium-99, uranium, and other heavy metals, most tank constituents are not mobile. The main tank constituents known to be mobile and used for tracking tank-related waste are nitrate and associated anions, technetium-99 (as TcO_4^-), and uranium. Groundwater samples are also analyzed for cobalt-60, which can be mobile in the presence of the cyanide anion.

Assessment monitoring at Waste Management Area B-BX-BY suggests there are three distinct plumes.

The following discussion centers on those constituents used to track contamination moving through the waste management area and to identify groups of contamination that, most likely, have different source histories. Rather than discuss each contaminant species separately, it is more constructive to discuss groups of constituents that appear centered on three different wells. The first group is centered on well 299-E33-7, where the primary constituents are cobalt-60, cyanide, nitrate, technetium-99, and tritium. The second group is centered on well 299-E33-16 that has high nitrate, elevated technetium-99, and slightly elevated chromium. The third set of contaminants is located at well 299-E33-44, just east of the BY Tank Farm. This group has elevated nitrate, nitrite technetium-99, and uranium. The nature of contamination observed at each of these locations is described below. The location map is found in Appendix A (Figure A.15).

Well 299-E33-7. The highest recent values of technetium-99 (7,030 pCi/L) are observed in the northern area of the BY cribs at well 299-E33-7. The drinking water standard is 900 pCi/L. Technetium-99, however, has risen in wells farther south in the BY cribs and along the western side of the waste management area (Figure 2.9-7). The elevated nitrate apparently migrated with the technetium-99 and was also found in wells at the northeastern corner of Low-Level Waste Management Area 1 (Figure 2.9-8). Nitrate concentrations in all the wells noted in Figures 2.9-7 and 2.9-8 are above the 45 mg/L maximum contaminant level. The July 1999 concentration of nitrate in well 299-E33-7 was 337 mg/L. Analyses of groundwater from wells at Waste Management Area Low-Level Burial Grounds 1 indicate that technetium-99 is also rising at the northwest corner of the 200 East Area and contamination appears to be moving in a southwestward direction, recently impacting well 299-E33-35 (Figure 2.9-9). High values of tritium (maximum of 10,500 pCi/L at well 299-E33-7) are consistent with the elevated technetium-99.

With the recent data collected for the RCRA assessment, it appears that nitrate and technetium-99 have been rising since the early 1990s. This observation

is consistent with the recent analysis of the groundwater flow direction from the northeast to the southwest. This plume movement implies that the source is the original BY crib plume moving back through the area with the lowering of the water table farther to the east. Nitrate, along with chloride, sulfate, and associated cations, is the apparent cause of the elevated specific conductance value first observed in well 299-E33-32 in 1996.

Cobalt-60 and cyanide are also detected in the groundwater underneath the BY cribs in wells 299-E33-7, -38 and -5. The highest values were found in June 1998 at well 299-E33-7 (66 pCi/L for cobalt-60 and 347 µg/L for cyanide). The drinking water standards for cobalt-60 is 100 pCi/L and for cyanide is 200 µg/L. Cyanide and, possibly, cobalt-60 were also found southeast of the BY cribs in samples from well 299-E33-13. Contamination observed in well 299-E33-13 recently assumed a character similar to that at well 299-E33-7. Cyanide and cobalt-60 were not found in other wells in the area. Consequently, it is not yet clear whether these constituents are moving with the nitrate, technetium-99, and tritium or are entering the groundwater from the vadose zone.

Well 299-E33-16. The main characteristic of contamination detected in the groundwater at this well is an extremely high nitrate concentration, close to 500 mg/L (Figure 2.9-10). Associated with the nitrate is technetium-99 above the drinking water standard, at ~2,000 pCi/L in June 1999 (see Figure 2.9-10). Also, chromium is elevated at 53.5 µg/L but below the 100-µg/L maximum contaminant level. Nitrate, elevated above the maximum contaminant level, was also detected at surrounding wells 299-E33-15, -17, and -20. However, the elevated technetium-99 and chromium are not found in the groundwater at these wells, suggesting that the contamination at well 299-E33-16 is localized.

Well 299-E33-44. This well was constructed in 1998 to sample groundwater between high levels of technetium-99 (12,000 pCi/L in August 1997) and uranium (maximum of 81 µg/L in November 1998)

detected at well 299-E33-41 and elevated nitrate, technetium-99, and uranium found in wells 299-E33-13 and -38. The relationship between the technetium-99 and uranium in well 299-E33-41 is shown in Figure 2.9-11. Similar increases in chloride and sulfate correlated with the high frequency technetium-99 pulses. The associated uranium traveled through the local area at a retarded flow rate, with respect to the more mobile anions, but repeated the same high frequency pattern. These events are discussed in detail in PNNL-11826 and PNNL-11793.

Initial groundwater samples from well 299-E33-44, collected in October 1999, revealed that technetium-99 and nitrate are above the drinking water standard (4,480 pCi/L and 95 mg/L, respectively). The highest levels of uranium in the area were found here. The maximum concentration was found in April 1999 (350 µg/L). Unlike the technetium-99 and nitrate observed to the north, the groundwater in this well has neither cyanide nor cobalt-60 in detectable quantities. Also, relatively high levels of nitrite (400 to 600 µg/L) were found in the groundwater samples from this well. A check for coliform proved to be negative. Efforts are currently under way to sample well 299-E33-9 inside the BY Tank Farm to ascertain if this contamination suite is local to well 299-E33-44 or if there is a small plume located under Waste Management Area B-BX-BY.

Contaminant Ratios. One diagnostic tool for identifying different contaminant plumes in the groundwater surrounding Waste Management Area B-BX-BY is the ratio of nitrate to technetium-99. Tank-related sources are expected to have low ratios because of the large concentrations of technetium-99 with respect to nitrate estimates in tank wastes (HNF-SD-WM-TI-740). For example, the ratio of nitrate (in mg/L) to technetium-99 (in pCi/L) for the pulses of contamination shown in Figure 2.9-11 are approximately four. Ratios based on current estimates of tank waste are typically below four. These ratios are low compared to background values, which are in the thousands.

Nitrate to technetium-99 ratios for data collected during the second quarter of 1999 are mapped in Figure 2.9-12. For contamination associated with well 299-E33-7, ratios generally range from 40 to 50. Ratios within this range cover the BY cribs, the western side of the waste management area, and extends to the west at wells 299-E33-26, -34, and -35. With nitrate and technetium-99 increasing in wells 299-E33-28, -32, and -43, the region displaying this signature is expected to increase.

During the time of northward movement, prior to the early 1990s, the highest concentrations of nitrate and technetium-99 were found in well 699-50-53A, located north-northeast of the study area. The nitrate to technetium-99 ratio from this well during the early 1990s was 42, for a technetium-99 value of 17,000 pCi/L and 716 mg/L of nitrate. This ratio is very similar to that of the contamination currently moving through the northern part of this waste management area.

The nitrate to technetium-99 ratio at well 299-E33-16 is above 200 because of high nitrate levels with low technetium-99 values (less than half that observed at wells 299-E33-7 or -44). As can be seen in Figure 2.9-12, none of the surrounding wells have a similar ratio. Wells immediately to the north, east, and south have high nitrate values but do not have technetium-99 above the drinking water standard, resulting in much higher ratios. The contamination detected in this well appears to have a limited spatial extent. It may be that at least part of the aquifer at this site is locally isolated by structure on the basalt. The relief on the top of the basalt can be as much as 4.3 meters, which is similar to the aquifer thickness at this well. If the basalt surface is locally depressed, then the contamination found in the groundwater may be residual from liquid waste discharged to the 216-B-8 crib.

Finally, the ratios at wells 299-E33-44 and -41 (~25) are noticeably lower than those wells in the surrounding area. The nitrate and technetium-99 levels at well 299-E33-41 are significantly low, both currently below the drinking water standard. If a groundwater

sample can be collected from well 299-E33-9, located west of well 299-E33-44 but within the tank farm boundaries, further conclusions may be possible concerning the source of this groundwater contamination at well 299-E33-44.

Correlation with Possible Sources

The contamination discharged to the ground at the BY cribs appears to be migrating from the north in a southwesterly direction, impacting the groundwater under the BY cribs and the northwestern part of Waste Management Area B-BX-BY. This plume, consisting of nitrate, technetium-99, and tritium, is monitored as it moves through the BY and BX tank farms into the northeastern corner of Low-Level Waste Management Area 1. It is unclear whether the cobalt-60 and cyanide associated with the original plume are moving through the area. Although these contaminants are detected in the groundwater under the BY cribs, as of May 1999 they have not been detected farther to the west or south, except in well 299-E33-26.

The elevated chromium, nitrate, and technetium-99 that are detected in the groundwater at well 299-E33-16 appear to be local. This region of the groundwater has only recently been monitored, when assessment level monitoring began. Consequently, it is not known how long the nitrate and technetium-99 have been above the drinking water standard. If the local aquifer is hydraulically isolated from the BY crib plume, it may be difficult to determine trends or changes in the groundwater chemistry at well 299-E33-16.

The origins of the contamination at well 299-E33-44 are, as yet, not understood. The lower nitrate to technetium-99 ratio and the high uranium values may indicate the contamination is from tank waste. It may be possible to determine the source of the contamination after groundwater samples from well 299-E33-9 are analyzed.

2.9.1.10 216-B-63 Trench RCRA Parameters

Groundwater monitoring continues to provide evidence that no dangerous non-radioactive constituents

from the site have entered groundwater from this trench (see Appendix A). 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 for this trench are a gamma scan, alkalinity, gross beta, and turbidity. Analytical results have revealed no contamination that could be attributed to this facility. Groundwater analysis continued to indicate an increase in concentrations of calcium, magnesium, sodium, and sulfate in several wells. However, the concentration of these constituents did not exceed maximum contaminant levels. The reason(s) for these increases are unknown, but they probably indicate the addition of relatively clean wastewater to the groundwater system possibly from 216-B-3 pond. The rate of change in concentration, however, has slowed and may indicate that groundwater chemistry is stabilizing beneath the facility.

*RCRA monitoring at the 216-B-63
crib indicates the site has not contaminated
groundwater.*

2.9.1.11 200 East Low-Level Burial Grounds

The two low-level burial grounds in east area, Low-Level Waste Management Area 1 and Low-Level Waste Management Area 2, are monitored under interim status detection monitoring.

Low-Level Waste Management Area 1

The groundwater monitoring network for Low-Level Waste Management Area 1 continues to meet all RCRA requirements. Sampling is done semiannually at 16 monitoring wells for the constituents listed in Table A.39. Water levels are continuing to decline in the 200 East Area, but none of the monitoring wells in Low-Level Waste Management Area 1 are expected to go dry within the next 10 years. Based on contaminant plume movement in previous years, groundwater flow direction was interpreted to be toward the northwest with flow rates less than 0.5 meter per day

(Table A.2). However, in recent years, the direction of groundwater flow in the northwestern part of the 200 East Area is changing from a northwestern flow to a more southern or southwestern flow. See Section 2.9.1.9 for a detailed discussion of groundwater flow direction and flow rates at Waste Management Area B-BX-BY.

The upgradient/downgradient comparison value for specific conductance was consistently exceeded in well 299-E33-34 in fiscal year 1999. Nitrate at levels well above the 45 mg/L maximum contaminant level was the major contributor to this exceedance (see Figure 2.9-5). Nitrate levels in nearby wells 299-E32-10 and 299-E33-28 also exceeded the maximum contaminant level. The source of the nitrate contamination is assumed to be from the cribs to the east of Low-Level Waste Management Area 1. Elevated nitrate is also present in wells on the southern and western sides of this area. Values exceeded the maximum contaminant level in wells 299-E28-26, 299-E32-2, 299-E32-3, and 299-E32-6. These high levels were associated with the nitrate plume originating from southeast of Low-Level Waste Management Area 1 (see Section 2.9.1.8).

Low-Level Waste Management Area 2

Contamination indicator parameters were sampled semiannually (see Table A.41) in compliance with RCRA interim status regulations at this facility. Groundwater flows to the west at 0.06 to 0.8 meter per day (see Table A.2). The groundwater monitoring network continues to provide adequate coverage. However, if the decline in water levels in the area continues at the current rate additional wells are expected to go dry in ~3 years. Additional wells may be required in some instances, but many of the monitoring wells

*Low-level waste management areas 1
and 2 are monitored as RCRA sites. Data
from fiscal year 1999 indicated they have
not contaminated groundwater.*

in this network are at or near the top of basalt. Alternative methods to monitor this waste management area may be necessary to determine contaminant releases.

There is no evidence of groundwater contamination from Low-Level Waste Management Area 2. The upgradient/downgradient comparison value for specific conductance is consistently exceeded in upgradient well 299-E34-7. The major causes of increased conductivity are sulfate, nitrate, and calcium. Nitrate exceeded the 45 mg/L maximum contaminant level in this well. There are no apparent sources of sulfate or nitrate in Low-Level Waste Management Area 2 near well 299-E34-7. The source of these constituents is unknown.

The quadruplicate averages for total organic carbon at well 299-E27-10 and for total organic halogen at well 299-E34-3 exceeded the established upgradient/downgradient comparison values in the January 1999 sampling events. Both of these exceedances were attributed to suspicious values reported by the laboratory. The values for both constituents returned to normal ranges in samples collected in April 1999.

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 impacted groundwater quality over a large area of the site. 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 were monitored in accordance with RCRA in fiscal year 1999. 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, that are being addressed under the CERCLA/RCRA past-practice process. The 216-A-29 ditch, B Pond, 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 no evidence to indicate that these sites have contaminated groundwater.

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.

2.9.2.1 Groundwater Flow

In the 200 East Area, groundwater flows primarily in two general directions: to the northwest through Gable Gap (located between Gable Mountain and Gable Butte) and to the southeast and east toward the Columbia River (see Plate 2). These flow directions are based on contaminant-plume maps and water-elevation data. However, the location of the divide between flow to the northwest and flow to the southeast is not discernible because the water table in the 200 East Area is nearly flat, which is primarily the result of a zone of high transmissivity in this region.

Groundwater flow rate and direction beneath the individual waste facilities vary and are discussed in the following sections on RCRA monitoring.

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 3). Activities of more than 2 million pCi/L (the derived concentration guide) were detected only in well

299-E17-9 next to the 216-A-36B crib (Figure 2.9-13). The maximum concentration detected in this well in fiscal year 1999 was 3.87 million pCi/L in October 1998, which was also the maximum tritium concentration detected in any well on the Hanford Site during fiscal year 1999. Tritium concentrations that exceeded the 20,000-pCi/L interim drinking water standard continued to be found in many wells affected by cribs near the PUREX Plant.

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 April 1998, October 1998, and April 1999 levels were 35,000, 36,000, and 31,000 pCi/L, respectively. The rise in tritium in this well is probably due to the reduction in wastewater volume discharged in the vicinity of 216-B-3 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 216-B-3 pond area that has lower tritium levels. As the influence of wastewater volumes in the 216-B-3 pond area continues to shrink, the mixing area for groundwater from the two sources (near well 699-37-47A) becomes more dominated by groundwater from the northwest that has higher tritium concentrations.

The movement of the widespread tritium plume (see Plate 3), extending from the southeastern portion of the 200 East Area to the Columbia River, was consistent with patterns noted in fiscal year 1998 (see Section 5.10.3.2 of PNNL-12086). Separate tritium pulses associated with the two periods of PUREX Plant operations contributed to the plume. The first pulse, which resulted from discharges from 1956 to 1972, can be detected near the Columbia River (e.g., well 699-40-1, Figure 2.9-14). Elevated tritium concentrations measured immediately downgradient from the 200 East Area represent the second pulse associated with the restart of operations between 1983 and 1988. The area immediately downgradient of the cribs, where concentrations are greater than 200,000 pCi/L, is naturally attenuating as a result of radioactive decay and dispersion combined with the decreasing source

that resulted from the termination of operations. Figure 2.9-15 clearly 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 concentrations throughout this plume indicates that the greatest impact expected at the Columbia River have already occurred.

Waste facilities associated with the PUREX Plant contaminated groundwater with tritium, iodine-129, and nitrate. The tritium plume has reached the Columbia River at levels above the drinking water standard, but concentrations are generally declining.

The zone of lower tritium concentrations near Energy Northwest (see Plate 3) may be due to discharges (over 75 liters per minute) of drinking water filter backwash water, various wash-water systems, and storm runoff that dilute the plume. Another possibility is that the zone of lower tritium concentration corresponds 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.

2.9.2.3 Iodine-129

The highest iodine-129 (interim drinking water standard of 1.0 pCi/L) concentrations observed in the 200 East Area in fiscal year 1999 were near the PUREX Plant cribs (see Figures 2.1-5 and 2.9-2). The maximum concentration of iodine-129 detected in fiscal year 1999 was 12.5 pCi/L in well 299-E17-14 during October 1998. This well monitors the 216-A-36B 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 2.9-16). The iodine-129 plume extends southeast into the 600 Area and appears to coincide with the tritium and nitrate plumes (see Plate 3 and Figure 2.1-4). Iodine-129 is measured in wells at the Old Hanford Townsite, the area of the 200 Areas plume with the highest tritium concentrations near the Columbia River. These wells show no clear increasing or decreasing trends in iodine-129, and have never been detected above the drinking water standard (see Figure 2.9-3). Recent results have been below detection limits (note that open symbols in Figure 2.9-3 indicate the result was less than analytical error and thus was undetected).

2.9.2.4 Nitrate

High nitrate concentrations continued to be found near liquid waste disposal facilities that received effluent from PUREX Plant operations. The maximum nitrate concentration detected near the PUREX Plant in fiscal year 1999 was 191 mg/L in well 299-E17-9, which is adjacent to the 216-A-36B crib. The extent of the nitrate plume that emanates from the 200 East Area (see Figures 2.1-4) is nearly identical to that of the tritium plume. However, the area with nitrate greater than 45 mg/L (the maximum contaminant level) is considerably more restricted than the area with tritium above the interim 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 attributable to 400 Area disposal (discussed in Section 2.10.2).

2.9.2.5 Strontium-90

A single well (299-E17-14) near cribs south of the PUREX Plant had a concentration above the interim drinking water standard (8.0 pCi/L) for strontium-90 (a beta emitter) in fiscal year 1999. The maximum strontium-90 concentration detected in fiscal year 1999 was 17.2 pCi/L from well 299-E17-14 next to the 216-A-36B crib during April 1999. The impact is very 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 (interim

drinking water standard of 50 pCi/L) concentration of 68.6 pCi/L in the same well. Strontium-90 was detected at four other wells near the 216-A-10 and 216-A-36B cribs during fiscal year 1999. The concentrations have been stable since 1994.

The 68.6 pCi/L result for gross beta at well 299-E17-14 during fiscal year 1999 is more than can be accounted for from the 17.2 pCi/L result for strontium-90 in the same well. 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 (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 the gross beta analysis could be used as a screening tool for technetium-99 and other beta-emitters.

2.9.2.6 Manganese

Manganese concentrations decreased in fiscal year 1999 in two wells (299-E25-17 and 299-E25-19) south of the 216-A-37-1 crib after a fiscal year 1998 peak. The concentration increased in early fiscal year 1998 to levels not reached since 1993 and continued to rise throughout the remainder of the year (Figure 2.9-17). The concentration continued to increase to a maximum of 64 µg/L (at well 299-E25-19) in October 1998 and then began to decrease. After January 1999, the concentration of manganese remained below the secondary maximum contaminant level (50 µg/L) in both wells. The source of the increased levels of manganese is unknown but presumed to be the 216-A-37-1 crib.

2.9.2.7 PUREX Cribs RCRA Parameters

The PUREX cribs (216-A-10, 216-A-36B, and 216-A-37-1 cribs) 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 toward the southeast at ~0.003 to 0.48 meter per day. For the eastern crib (216-A-37-1), groundwater flow is southwest at ~0.018 to 0.18 meter per day. The PUREX cribs are located in a region

where several groundwater 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 very difficult. However, during fiscal year 1999, the following constituents exceeded drinking water standards in at least one well in the near-field well network:

- gross beta (one well only, 299-E17-14)
- iodine-129
- nitrate
- manganese (secondary maximum contaminant level)
- strontium-90 (one well only, 299-E17-14)
- tritium.

Three of the cribs associated with the PUREX Plant are monitored together as a RCRA waste management area. They contributed to the contaminant plume that extends toward the southeast.

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 an 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 (Sections 2.9.2.2 through 2.9.2.6).

2.9.2.8 Waste Management Area A-AX RCRA Parameters

This section provides information on the current nature of the unconfined uppermost aquifer in the immediate region of Waste Management Area A-AX.

Aquifer properties were determined from the stratigraphic interpretations, current water elevations, previous aquifer tests, and regional groundwater table provided in PNNL-12086.

Groundwater Flow

The water table is extremely flat across the 200 East Area. In areas with flat water tables, the choice of surveys may affect the relative position of the water elevation in a well with respect to other network wells. A switch in the relative water elevations of wells used to determine direction would change the interpretation of the flow direction.

When the groundwater project switched from using the NGVD29 vertical control datum to the NAVD88 datum, the hydrographs gave a more realistic estimate of flow direction. In one of the five wells used to monitor the water table, a comparison between hydrographs referenced to NGVD29 versus NAVD88 indicate a survey error on the same scale as the water level difference across the Waste Management Area A-AX site. This well was eliminated from interpretation of flow direction because it is not known which survey may be in error.

RCRA Waste Management Area A-AX contains single-shell tanks. Monitoring data from fiscal year 1999 did not indicate any impact to groundwater. Because of changes in flow direction, the well network may need revising.

Although well 299-E24-19 is used to monitor the groundwater quality, water-table elevations for this well appear abnormally low on a hydrograph. This well may be slightly out of plumb, explaining the abnormal trough in the water-table surface there. The hydrograph for the four remaining wells is shown in Figure 2.9-18 (for well locations, see Figure A.14). As can be seen, the flow direction appears to be toward the east. However, given the uncertainties in water

elevations, it is probably not possible to use water elevations alone to determine local flow at this site.

The original groundwater monitoring network, which is still in use today, was designed for a narrowly focused southwestern groundwater flow direction. The consequences of having a potentially eastern flow in the RCRA compliance network is under investigation. The monitoring plan for this site is being revised. Recommendations are made to resolve the discrepancy between the flow directions based on water levels and that based on plume movement. If the flow is found to be other than to the southwest, a new well network will be designed. Depending on which hydraulic conductivity value is used, the effective flow rate at Waste Management Area A-AX is estimated to be between 0.52 to 0.66 meter per day (see Table A.2 for specific values used in these calculations). This equates to 189 to 245 meters of groundwater movement per year.

Groundwater Chemistry

This section provides information on the results of RCRA groundwater monitoring at Waste Management Area A-AX for fiscal year 1999. Information on recently occurring and past contaminant issues is provided. Routine, interim detection groundwater sampling began at Waste Management Area A-AX in fiscal year 1992. Indicator parameters have not been exceeded at this site during this time. Specific conductance values generally range from 220 to 300 $\mu\text{S}/\text{cm}$, reflecting changes in chloride, nitrate, and sulfate concentrations. Calcium and sodium are the principal balancing cations. Figure 2.9-19 shows trend plots for nitrate, sulfate, and technetium-99, comparing contaminant levels between the five RCRA groundwater monitoring wells. The specific conductance changes that occurred at Waste Management Area A-AX are dominated by sulfate. For most of the wells, sulfate values range from 23 to 30 mg/L, which is close to the Hanford Site background values reported in WHC-EP-0595 (~14 to 60 mg/L). Nitrate values range from ~4 to 8 mg/L, which falls within the ranges of background values of 3 to 12 mg/L for the Hanford Site (WHC-EP-0595). The maximum contaminant levels for nitrate and sulfate are 45 and 250 mg/L, respectively.

Sulfate concentrations above background values were identified in two wells, 299-E25-40 and 299-E25-41, where values reach ~70 mg/L. Speculation on the source of the elevated sulfate is probably not useful until the flow direction can be determined with more confidence.

Nitrate concentrations in well 299-E24-20 are ~38 mg/L, which is above the maximum background value of 12 mg/L (Figure 2.9-20). This well is located south of the 244-AR vault. Nitrate values rose from 6 mg/L in February 1996 to 38 mg/L in February 1998. Although there is no elevated technetium-99 associated with this increase in nitrate, there is a distinct correlation with tritium. Values rose from 4,180 pCi/L of tritium in February 1996 to ~7,200 pCi/L in February 1998. Most tritium values at the waste management area range from 2,800 to 4,000 pCi/L. The drinking water standards for tritium and nitrate are 20,000 pCi/L and 45 mg/L, respectively. Without more complete knowledge of the local groundwater flow direction, it is not possible to speculate on the source of this isolated, elevated nitrate.

Chromium, nickel, and manganese are detected in well 299-E24-19 (Figure 2.9-21). Chromium has sporadically exceeded the 100 $\mu\text{g}/\text{L}$ maximum contaminant level since fiscal year 1991. Values range from 140 $\mu\text{g}/\text{L}$ in early fiscal year 1994 to 2,820 $\mu\text{g}/\text{L}$ in October 1998. The concentration dropped to 707 $\mu\text{g}/\text{L}$ in December 1998. Nickel and manganese also exceeded the 100 $\mu\text{g}/\text{L}$ and 50 $\mu\text{g}/\text{L}$ drinking water standards, respectively. In October 1998, the maximum concentrations of 883 $\mu\text{g}/\text{L}$ for nickel and 141 $\mu\text{g}/\text{L}$ for manganese were detected. Historically, iron only slightly correlates with chromium except for the recent October 1998 maximum.

Nitrate concentrations in well 299-E24-19 also increased in October 1998 from 3,320 to 7,171 $\mu\text{g}/\text{L}$. This is the first occurrence in this well of any non-metal constituents correlating with changes in chromium. Because there are no other correlations with other constituents at this well except the metals, nickel and manganese, and no other local occurrences

of chromium have been documented in other wells, the elevated metals are, most likely, due to corrosion of the screen. Further sampling is required to address the significance of the slightly elevated nitrate.

Technetium-99 declined to low levels (36 pCi/L in December 1998) in well 299-E25-46 after an increase to 374 pCi/L in August 1977 (Figure 2.9-22). The increase in technetium-99 concentrations correlates with a rise in nitrate values during the same time period. Until issues relating to the direction of groundwater flow are resolved, no further speculation on contaminant source is useful.

The drinking water standard of 1 pCi/L is exceeded for iodine-129 in all monitoring wells at Waste Management Area A-AX. This area sits within a large, regional, iodine-129 plume that extends to the southeast. The source is apparently associated with the PUREX cribs (PNNL-12086).

2.9.2.9 Waste Management Area C RCRA Parameters

This section provides information on the current nature of the unconfined, uppermost aquifer in the immediate region of Waste Management Area C. Aquifer properties were determined from the stratigraphic and lithologic interpretations, current water elevations, previous aquifer test results, and from the regional groundwater map provided in PNNL-12086.

RCRA Waste Management Area C contains single-shell tanks. Monitoring data from fiscal year 1999 did not indicate any impact to groundwater.

Groundwater Flow

The water table is extremely flat across the 200 East Area. In areas with flat water tables, the choice of surveys may actually affect the relative position of the water elevation in a well with respect to other network wells. A switch in the relative water elevations of wells could affect the interpretation of the flow direction.

Figure 2.9-23 shows hydrographs for four of the five RCRA network wells that are used to monitor the water table at Waste Management Area C. The data from well 299-E27-15 is historically inconsistent with data from the other wells in the Waste Management Area C network and is, most likely, deviated from vertical. A gyroscopic survey may alleviate the problems with water-level data from the well.

The data from the other four wells are plotted on Figure 2.9-23. Well 299-E27-7 is historically the upgradient well and 299-E27-13 is the downgradient well. Well 299-E27-12 appears to be slightly elevated with respect to well 299-E27-13. Thus, the direction of groundwater flow at Waste Management Area C appears to be toward the southwest. The flow is consistent with the regional water-table map (see Plate 2).

The original groundwater monitoring network, which is still in use today, was designed for a localized western flow direction (WHC-SD-EN-AP-012, Rev. 1). A new groundwater monitoring plan is being prepared that will propose an approach to better determine flow direction.

Depending on which hydraulic conductivity value is used, the effective flow rate at Waste Management Area C is estimated to be between 0.7 to 1.4 meter per day (see Table A.2 for specific values used in these calculations). This equates to 267 to 534 meters of groundwater movement per year.

Currently in RCRA network wells, the open intervals within the aquifer range from 3.2 to 2.4 meters. In well 299-E27-7, the open interval is 14.3 meters. The rate of water-table decline has increased from 9.1 centimeters per year in June 1997 to ~30.5 centimeters per year in March 1999. If this current rate continues, well 299-E27-13, one of the downgradient wells with less than 3 meters of water, may become unusable in 6 or 7 years.

Groundwater Contamination

Critical mean values of the indicator parameters (pH, conductivity, total organic carbon, and total

organic halides) were not exceeded during fiscal year 1999. As sluicing operations were conducted at tank C-106, this site was temporarily placed on monthly monitoring to assist in detecting effects of waste retrieval operations on groundwater quality.

All wells showed concentrations of iodine-129 above the 1-pCi/L interim drinking water standard. The single-shell tank resides within the regional iodine-129 plume that extends throughout this area. Although tritium continues to be elevated in upgradient well 299-E27-7 at 2,520 pCi/L in February 1999, values across the waste management area remain well below the 20,000-pCi/L drinking water standards.

Nitrate rose in well 299-E27-14 from 11 mg/L in July 1998 to 30 mg/L in October 1998. (Figure 2.9-24). If the flow direction to the south-southwest is correct, then well 299-E27-14 may be downgradient from Waste Management Area C. Consequently, this rise in nitrate may be associated with tank farm concentrations. Both the specific conductance and nitrate, however, are below the critical mean set for this RCRA site, and the drinking water standard for nitrate of 45 mg/L. As can be seen in Figure 2.9-24, both upgradient and downgradient wells experienced a slight but steady increase in nitrate levels. A comparison is made between chloride, nitrate, and sodium for well 299-E27-14 in Figure 2.9-25. Both chloride and sodium can be seen to track with the nitrate. However, neither the sulfate nor the calcium show similar trends.

Along with an increase of nitrate at well 299-E27-14 is a corresponding increase in technetium-99 shown in Figure 2.9-26. Technetium-99 contamination rose from 184 pCi/L in February 1998 to 672 pCi/L in September 1998. The July 1999 value was 460 pCi/L. Although elevated with respect to the surrounding area, values are still below the drinking water standard of 900 pCi/L. Similar to the increases in nitrate, the technetium-99 levels are steadily increasing in all the surrounding wells. The September 1999 value for well 299-E27-15 is 98 pCi/L. Figure 2.9-27 shows the direct correlation between nitrate and technetium-99 in well 299-E27-14. As can be seen, the nitrate and technetium-99 concentrations are highly correlated.

With the uncertainty in the current direction of groundwater flow, it is not possible to determine the source of increasing contamination observed at Waste Management Area C. However, it is important to note that, unlike the other single-shell tanks in the 200 East Area, Waste Management Area C is not surrounded with past-practice liquid effluent disposal facilities. Consequently, with no nearby sources and no known local plumes that might be moving through the area, it becomes even more important that the flow direction be determined by a direct, in situ method. Because waste retrieval operations have ceased, the area will be monitored every other month during fiscal year 2000 and will be returned to semiannual monitoring beginning in fiscal year 2001.

2.9.2.10 216-A-29 Ditch RCRA Parameters

The direction of groundwater flow beneath the ditch is west-southwest, based on nitrate and tritium plume maps (see Figures 2.1-4, 2.9-5, and Plate 3) and on water-level elevations in the monitoring wells. The tritium plume map (see Plate 3) shows that the flow direction swings to the southeast as groundwater flows to the southeastern corner of the 200 East Area. The calculated gradient is ~ 0.0005 for the entire length of the ditch and yielded a flow rate of ~ 0.03 to ~ 0.09 meter per day (see Table A.2).

RCRA monitoring at the 216-A-29 ditch in fiscal year 1999 indicated the site has not contaminated groundwater.

The water table beneath the ditch has steadily declined since discharges to the B Pond system were terminated. Figure 2.9-28 shows the water levels are continuing to decline in wells monitoring the head and discharge ends of the ditch. The change in water-table elevation resulted in a flattened water table at both the head and discharge ends of the ditch.

Indicator parameters were not exceeded during fiscal year 1999. Water-level measurements were taken during routine sampling throughout the year. Although

groundwater levels continue to decline regionally, there is sufficient water in network wells for groundwater monitoring purposes.

In the past, sulfate was elevated at 216-A-29 ditch network wells, but reduced dramatically as sulfate bearing wastewater was reduced from 216-A-29 ditch effluent. In the last few years, two wells (299-E25-35 and 299-E25-48) (Figure 2.9-29) have shown a slight increase in sulfate concentration but they remain less than 70 mg/L. Background is ~10 mg/L.

2.9.2.11 216-B-3 Pond Parameters

The 216-B-3 pond system consisted of a main pond, three expansion ponds (3A, 3B, and 3C), and portions of several ditches leading to the main pond (see Figure A.17). In 1994, the main pond and adjoining ditches were decommissioned and filled, and three expansion ponds were clean closed under RCRA regulations. Currently, only the main pond and an adjoining segment of the 216-B-3-3 ditch are subject to RCRA groundwater monitoring requirements.

The B Pond system was placed into assessment monitoring status in 1990 because of elevated total organic carbon and total organic halides in two wells (699-43-41E and 699-43-41F). Since 1990, these two indicators have been below limits of quantitation. The only contaminants consistently detected in groundwater that could be attributed to B Pond operations were nitrate (maximum 22.5 mg/L) and tritium (maximum 232,000 pCi/L). In January 1998, a detection-level program was restored.

Groundwater monitoring is based on two types of potential contamination:

- contamination potentially entrained in the groundwater that has moved away from the point of infiltration
- potential contamination entering groundwater from the vadose zone.

The configuration of the monitoring well network is based on these assumed modes of contaminant occurrence and on monitoring discrete depths within the

The 216-B-3 pond is a RCRA site that formerly created a large recharge mound, affecting groundwater flow in a broad area. This mound has recently dissipated. Groundwater monitoring in fiscal year 1999 showed no evidence of contamination.

aquifer. During fiscal year 1999, the monitoring well network was revised to accommodate changes in groundwater flow direction and additional insights on the potential for contaminant transport. One new well was installed to increase coverage at the southwestern edge of the facility. The monitoring well network for fiscal year 1999 is given in Table A.31; the location of the new well is shown in Figure A.17. As indicated in Figure A.17, the well network was more extensive in the past when the expansion ponds were part of the regulated unit and before constraints on groundwater flow were recognized as discussed below (PNNL-12261, PNNL-11986).

Groundwater Flow

Groundwater flow around B Pond has historically been described as radial, away from the center of a groundwater mound that formed beneath the facility (see Plate 2). In recent years, this mound has become less defined, primarily because of the discontinuation of discharges. The direction of groundwater flow near B Pond altered in response to the changes in hydraulic head. Also, recent hydrogeologic investigations (PNNL-12261) have indicated that actual flow to the south and southeast of B Pond is very limited because of the relatively impermeable character of the sediment in these areas (see Section 2.9.3). In fiscal year 1999, a range of groundwater flow velocity was estimated at 0.01 to 19.2 meters per day (see Table A.2) was detected. The higher end of this range (and hydraulic conductivity range) would apply to the limited portion of the permeable Hanford formation that hosts the uppermost aquifer. As head drops, and the water table declines into the less permeable Ringold Formation, the higher groundwater flow estimates may decrease.

Water levels in B Pond wells have dropped since the mid-1980s, as discharges to the facility decreased and then ended in 1994 (the clean closed 3C expansion pond continued to receive reduced amounts of clean water until August 1997). Figure 2.9-30 is a hydrograph of four wells in the B Pond monitoring network that illustrates the nature of water-level drop

The monitoring network for B Pond was revised in fiscal year 1999 to reflect recent changes in flow patterns.

in most B Pond wells. During a period from 1996 to 1997, several wells in the network experienced a precipitous drop in water levels that has slackened somewhat since about late 1997. Calculations of rates of water-level decline during fiscal year 1999 indicate that rates of decline have slowed in most wells in the current network. Based on these calculations, the estimated service lives of the wells range from 2.4 and 5.2 years in wells 299-E26-11 and 699-43-45, respectively, to >100 years in well 699-40-39. Most of the remaining wells have expected lives of 20 to 40 years. Wells such as 699-43-45 (see Figure 2.9-30) have shown a more steady decline over time, perhaps because they are completed in less permeable portions of the aquifer or farther from the effluent source, thus dampening the hydraulic response to changes in discharges.

Groundwater Quality

The B Pond site-specific contaminants and contamination indicator parameters are given in Table A.31. The site-specific contaminants, radionuclide indicators gross alpha and gross beta, are monitored. These are monitored because of the known or potential radionuclides sent to B Pond in the past. Specific conductance, though also a general indicator parameter of contamination, is given special site-specific importance because of the anionic components of the known waste discharged to B Pond.

Groundwater samples from the B Pond network were collected semiannually during fiscal year 1999,

mostly in January and June. No critical means of contamination indicator parameters were exceeded during fiscal year 1999.

Well 699-42-39B produced the highest gross alpha and gross beta results during fiscal year 1999, 3.78 and 13.1 pCi/L, respectively. Most gross alpha results are less than 4.0 pCi/L, and most gross beta results are less than 10 pCi/L. No trends are apparent in any of the downgradient B Pond wells for these indicators, but gross beta shows a slight upward trend in upgradient well 299-E32-4. The highest result thus far in this well is 15.4 pCi/L in December 1998.

Historically, concentrations of some metals have exceeded primary or secondary drinking water standards, but are mostly thought to be a result of well construction or natural groundwater conditions. These metals included chromium, iron, and manganese. Although unfiltered samples of these metals exceeded the drinking water standards, this was in particulate form and an artifact of the sampling process. The elevated levels were not found in filtered samples.

Tritium concentrations in groundwater at the B Pond remain above the drinking water standard, but continue to decrease. Nitrate was present historically in concentrations above site-wide background estimates, but below drinking water standards. These constituents are tracked in selected B Pond wells for surveillance monitoring and are sampled on a triennial basis. Well 699-41-40 (not in the current B Pond network) has historically produced the highest tritium results in the B Pond area, with a maximum of 232,000 pCi/L in 1988, and a March 1998 result of ~100,000 pCi/L. Well 699-42-39B produced a tritium result of ~60,000 pCi/L in the most recent (April 1998) analysis for this radionuclide. Trends for tritium concentrations in all B Pond wells continue generally downward. Nitrate is sampled annually, according to the recent revision of the network and constituent list, and is scheduled for sampling as of this writing. Historical results for nitrate, as recent as 1997, indicate a continuing decline in nitrate concentrations at B Pond.

The groundwater monitoring plan and network will likely be revised in fiscal year 2000, primarily because of the dynamic hydrologic circumstances at the facility and new information on hydrostratigraphy in the immediate vicinity of the B Pond (PNNL-12261).

2.9.2.12 Liquid Effluent Retention Facility

The Liquid Effluent Retention Facility is monitored in a final status detection evaluation program and is included in the Hanford Site RCRA Permit. Until the final status monitoring plan is approved by the regulators, the site will continue to operate under the existing interim status groundwater monitoring plan (WHC-SD-EN-AP-024). The RCRA indicator parameters are pH, specific conductance, total organic carbon, and total organic halides (40 CFR 265.92[b][3]). Included in the analysis list for this facility are alkalinity, gamma scan, gross beta, and turbidity (see Table A.37). No indicator parameters (and other parameters) were exceeded in fiscal year 1999.

RCRA monitoring at the Liquid Effluent Retention Facility shows no evidence of groundwater contamination from the site. The aquifer beneath the site is very thin, and alternative approaches to monitoring are being investigated.

The direction of groundwater flow beneath the facility is generally to the southwest, based on the regional water-table contours (see Plate 2). However, using only water-level data from wells monitoring the facility, the local flow direction is generally to the west. The gradient is 0.002 to 0.005 and reflects the effects of the B Pond groundwater mound to the east. The flow rate is estimated to range from 0.04 to 6.0 meters per day (see Table A.2).

Groundwater monitoring shows no evidence that dangerous, non-radioactive constituents from the Liquid Effluent Retention Facility entered the groundwater. The critical mean for specific conductance was exceeded in January 1999 and triggered a confirmation

sampling in February. The wells affected by the exceedance included 299-E26-9 and 299-E26-10. Results of an assessment indicated that a return to natural background conditions was the source of the elevated specific conductance. A regional dilution of groundwater had occurred due to long-term discharges to the 216-B-3 Pond. The effect of this dilution has only recently abated and several regional wells east of the 200 East Area fence line have shown increasing specific conductance. Specific conductance background levels for the facility were re-calculated based on recent data.

The current network is composed of three wells, one of which is upgradient. The network was temporarily out of compliance when, in June 1999, well 299-E26-9 was declared dry. The well still has ~0.5 meter of water in the casing, but retrieving a representative sample is not possible. The Washington State Department of Ecology (Ecology) was notified on July 1, 1999, of the loss of a downgradient well. After negotiations between DOE and Ecology, the state of Washington issued a variance letter on September 22, 1999, giving DOE time (18 months) to design and implement a new monitoring network. The eighteen month timeframe discussed in the September letter may be preempted by the loss of another downgradient well. Well 299-E35-2 has less than 1 meter of water. In less than 1 year, it may not be possible to sample the groundwater from this well.

2.9.2.13 200 Areas Treated Effluent Disposal Facility

The 200 Areas Treated Effluent Disposal Facility is a non-RCRA waste disposal site built to provide an infiltration bed for treated liquid effluent from the generating facilities in the 200 Areas. The facility is located ~600 meters east of the 216-B-3C expansion pond (see Figure A.17). In operation since June 1995, the facility allows infiltration of steam condensate and other clean water to the soil column. The facility is regulated by State Waste Discharge Permit ST-4502 (WAC 173-216). Groundwater sampling and analysis in the three monitoring wells at the facility are also governed by ST-4502. The constituent list and frequency

of sampling are specified in the permit and are provided in Table A.43. Currently, all three Treated Effluent Disposal Facility wells are sampled quarterly and semiannually.

Groundwater monitoring at the Treated Effluent Disposal Facility began ~2.5 years prior to the construction of the infiltration basins. The three monitoring wells (699-40-36, 699-41-35, and upgradient well 699-42-37) were completed in 1992 and were sampled as an unofficial portion of the B Pond groundwater monitoring network until April 1995. At that time, sampling and analysis of wells at the Treated Effluent Disposal Facility was conducted according to provisions of the state waste discharge permit.

Infiltration from the Treated Effluent Disposal Facility flows along the top of a clay-rich layer of sediment and does not reach the uppermost aquifer beneath the site.

Groundwater in the uppermost aquifer beneath the Treated Effluent Disposal Facility occurs under confined conditions within Ringold unit A gravels. The Ringold lower mud unit forms an effective aquitard between the vadose zone (Hanford formation) and the uppermost aquifer. Thus, effluent discharged to the Treated Effluent Disposal Facility does not reach the uppermost aquifer in the area but is diverted laterally by the lower mud unit. This condition was recognized during construction of the wells at the facility. Consultation with regulators determined that these wells would be monitored to confirm that effluent was not taking a direct route to groundwater. Ongoing collection and analysis of hydrologic and hydrogeochemical data corroborate this assumption (PNNL-11986).

The potentiometric surface in the vicinity of the Treated Effluent Disposal Facility (Figure 2.9-31) is influenced by the decaying effects of a hydraulic mound created by the nearby B Pond. The hydrographs of

Figure 2.9-32 illustrate the decline in hydraulic head in Treated Effluent Disposal Facility wells as a result of the subsiding mound. Although the rate of decline in the hydraulic head increased in recent years, linear calculations between fiscal years 1998 and 1999 indicate that the wells still have from ~55 years (699-42-37) to ~100 years (699-40-36 and 699-41-35) of service life before going dry.

The average linear groundwater flow rate is 0.004 meter per day (see Table A.2). Contouring of head values in the vicinity of the facility (see Figure 2.9-31) indicate that flow direction is south-southwest.

Recent work on the hydrostratigraphy and groundwater geochemistry in the vicinity of the Treated Effluent Disposal Facility indicates that groundwater flow in the uppermost aquifer is extremely slow and displays a unique geochemical composition and greater age compared with other portions of the uppermost aquifer on the Hanford Site (PNNL-11986; PNNL-12261). This uppermost aquifer is probably the Ringold Formation confined aquifer (see Section 2.9.3). Low-level tritium analyses have indicated a maximum concentration of 8.69 pCi/L of tritium in the three wells monitoring this facility. This level of tritium is anomalously low compared with both the expected values in the uppermost aquifer and Columbia River. These studies also indicate that the lower mud unit effectively blocks any infiltration of effluent to the uppermost aquifer in the vicinity of the facility. No permit enforcement limits in groundwater were exceeded in the facility's wells during fiscal year 1999.

Future groundwater monitoring at the Treated Effluent Disposal Facility will need to incorporate the constraints of the unique hydrogeologic circumstances beneath the facility. Currently, the state waste discharge permit (WAC 173-216) and groundwater monitoring plan for the facility are being revised to account for new knowledge of the hydrogeologic and hydrogeochemical setting of the facility. The new permit is scheduled to take effect in April 2000.

2.9.2.14 Water Quality at Shoreline Monitoring Locations

Seven aquifer sampling tubes are located near the Old Hanford Townsite. The sampling tubes are polyethylene tubes that were installed in the aquifer at locations near the low water shoreline. One of the seeps was sampled in fall 1998. The sample had concentrations of 2,800 pCi/L tritium, 3.9 pCi/L gross beta concentration, and no detectable gross alpha. The sample was not analyzed for iodine-129. The specific conductance of the sample was 262 $\mu\text{S}/\text{cm}$, a value that may indicate a mixture of groundwater and river water from bank storage.

A seep in the riverbank near the Old Hanford Townsite also was sampled in fall 1998. The seep is located ~1 mile downstream of the aquifer sampling tube. The seep sample had concentrations of 120,000 pCi/L tritium and 36 mg/L nitrate. These values are about the same as concentrations in groundwater in the vicinity. Gross alpha and gross beta concentrations were 3.22 and 23.3 pCi/L, respectively. The concentration of iodine-129 was 0.22 pCi/L, and the concentration of technetium-99 was 105 pCi/L. Specific conductance measured 394 $\mu\text{S}/\text{cm}$. This relatively high value indicates the sample was primarily groundwater, not river water draining back from bank storage.

2.9.3 Confined Aquifer in the Lower Ringold Formation

PNNL-10886 subdivided the Ringold Formation into 6 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 upper basalt flow. It is confined by hydrogeologic unit 8, also referred to as the lower mud sequence, 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 upper basalt flow. Previous studies have often included portions of the Ringold confined aquifer when describing and mapping the

unconfined aquifer. Interpretations prior to 1999 do not differentiate these aquifers and do not attempt to separate the groundwater results (i.e., plume mapping and potentiometer surfaces) for the separate aquifers.

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 not a specific monitoring network designed 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

The groundwater project has constructed a preliminary potentiometric surface for a portion of the confined aquifer in the Ringold Formation (Figure 2.9-33). This map is incomplete and subject to uncertainty because only a few wells are monitored within 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 southern 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. In the central portion of the aquifer, 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 groundwater flow divides between flowing toward the 200 East Area and flowing toward the east. Therefore, groundwater flow converges on the 200 East Area where the confining mud unit (unit 8) is absent and flow discharges to the unconfined aquifer.

There appears to be an upward gradient between the confined and unconfined aquifers near the 200 East Area in a region where the confining unit (unit 8) is absent (Figure 2.9-34). 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). This figure shows that hydraulic heads are apparently higher in well 299-E25-28. This supports the concept of groundwater discharging from the confined aquifer in the vicinity of the 200 East Area may recharge the overlying unconfined aquifer.

A confined aquifer in the lower Ringold Formation contains a "mound" in water levels. Tritium contamination has been detected in this aquifer near its juncture with the unconfined aquifer.

The contours on Figure 2.9-33 are similar to the potentiometric surface for the upper basalt-confined aquifer (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 4 meters of head difference in the northern part of the 200 West Area) where a downward hydraulic gradient exists. Hydraulic heads are also expected to diverge to the east and an upward hydraulic gradient is expected in the vicinity of the Columbia River.

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 is believed to be the only area where contamination can migrate from the unconfined aquifer into the confined aquifer.

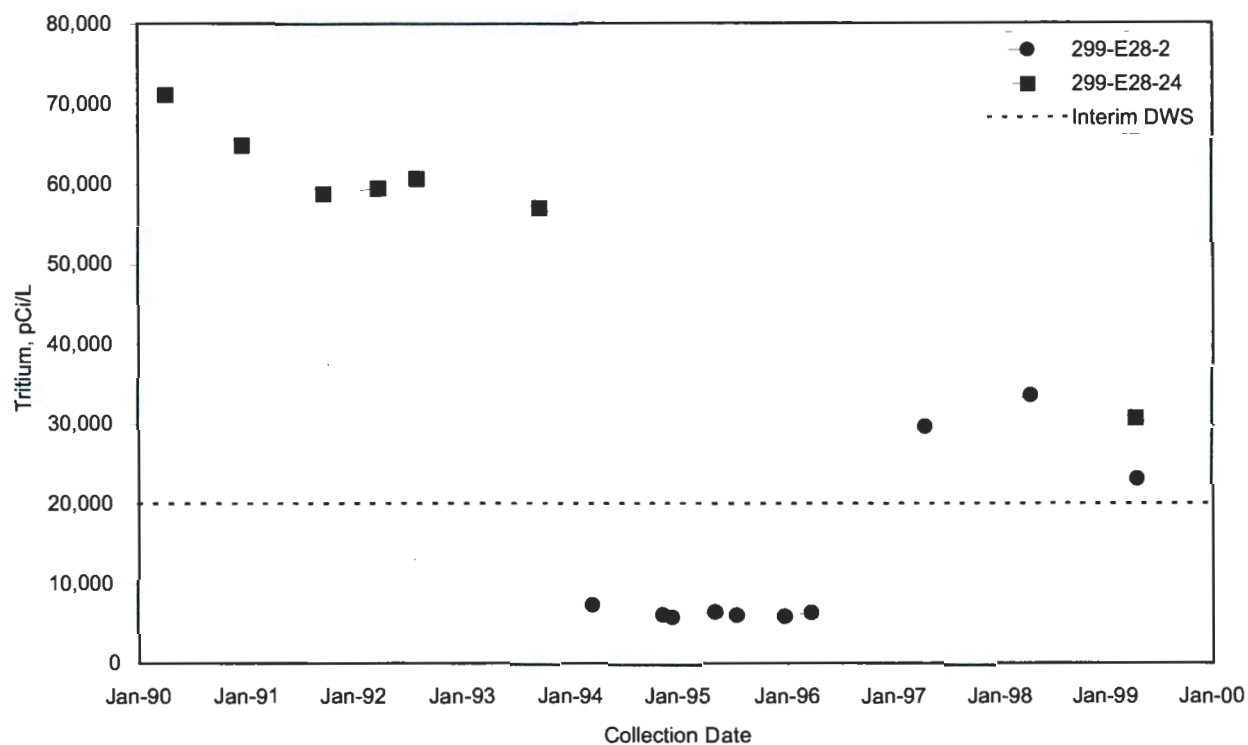
The primary factors contributing to the observed groundwater chemistry are the hydrostratigraphy and groundwater flow patterns. The ion chemistry and tritium concentrations corroborate the interpretation

of groundwater flow described in Section 2.9.3.1. Because groundwater flow in the unconfined aquifer is isolated from flow in the Ringold confined aquifer (except within the erosional unconformity), the groundwater chemistry must be evaluated for each aquifer independently.

Tritium has been detected in the Ringold confined aquifer near the 200 East Area. Figure 2.9-35 illustrates major ion chemistry using Stiff diagrams (Stiff 1951) and also includes tritium concentrations. The figure illustrates that groundwater chemistry correlates with groundwater flow paths in the unconfined aquifer and in the Ringold confined aquifer (unit 9).

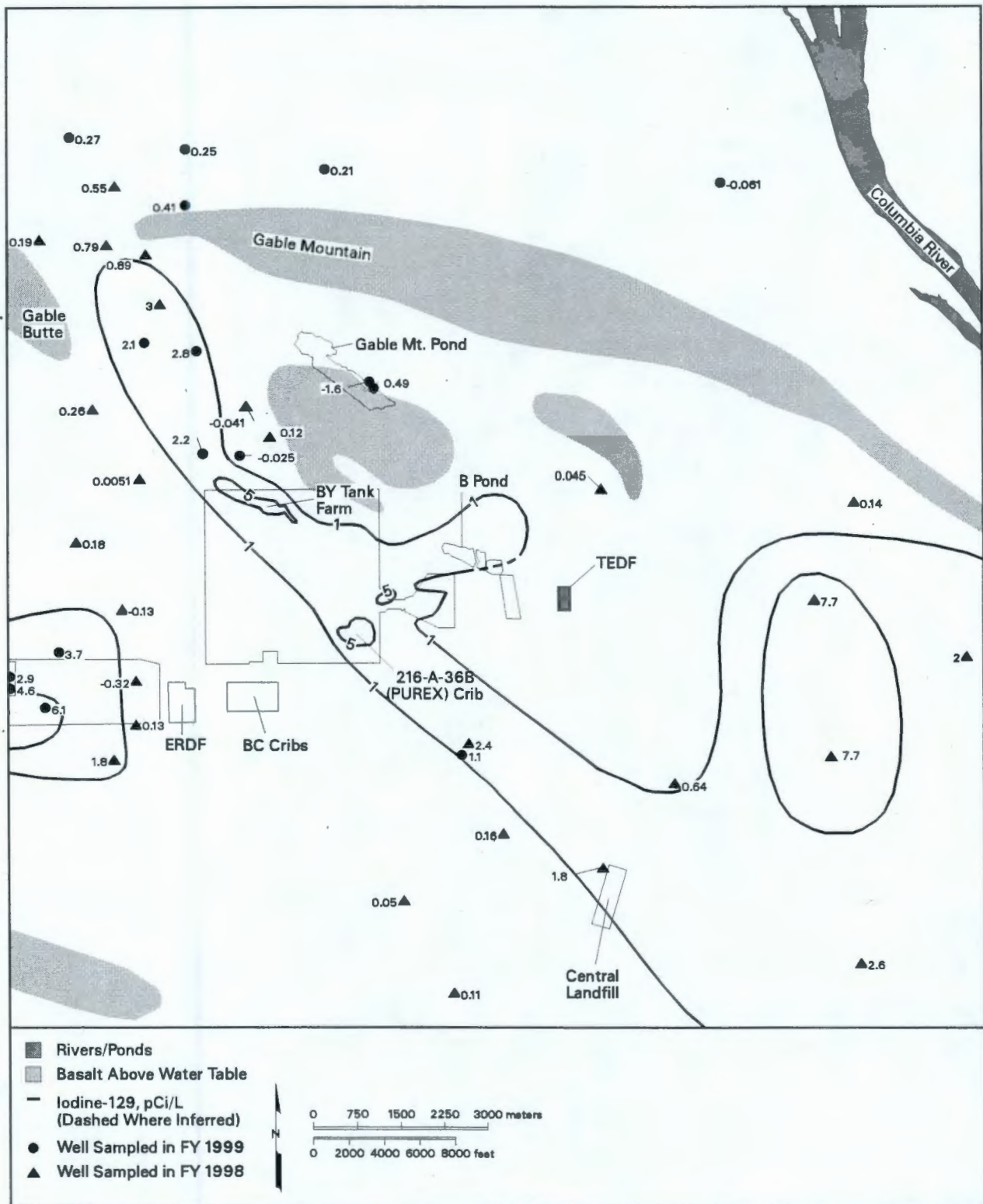
The major ion chemistry of groundwater in the Ringold confined aquifer, adjacent to the aquifer juncture, is of the calcium-bicarbonate type and has elevated tritium activities similar to groundwater in the unconfined aquifer (see Figure 2.9-35). South and east of B Pond toward the May Junction Fault, groundwater in the Ringold confined aquifer has lower tritium concentrations and is of the sodium-bicarbonate type. Tritium concentrations and other chemical data indicate that groundwater in the Ringold confined aquifer near the fault 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 and the potentiometric head increased to equilibrium with the overlying recharge mound. Disposal to B Pond ceased in 1994, and since that time, water levels and tritium concentrations in the unconfined aquifer have decreased significantly. This 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.



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Figure 2.9-1. Tritium in B Plant Area



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Figure 2.9-2. Average Iodine-129 Concentrations in 200 East Area, Extending Northwest Toward Gable Gap, Top of Unconfined Aquifer

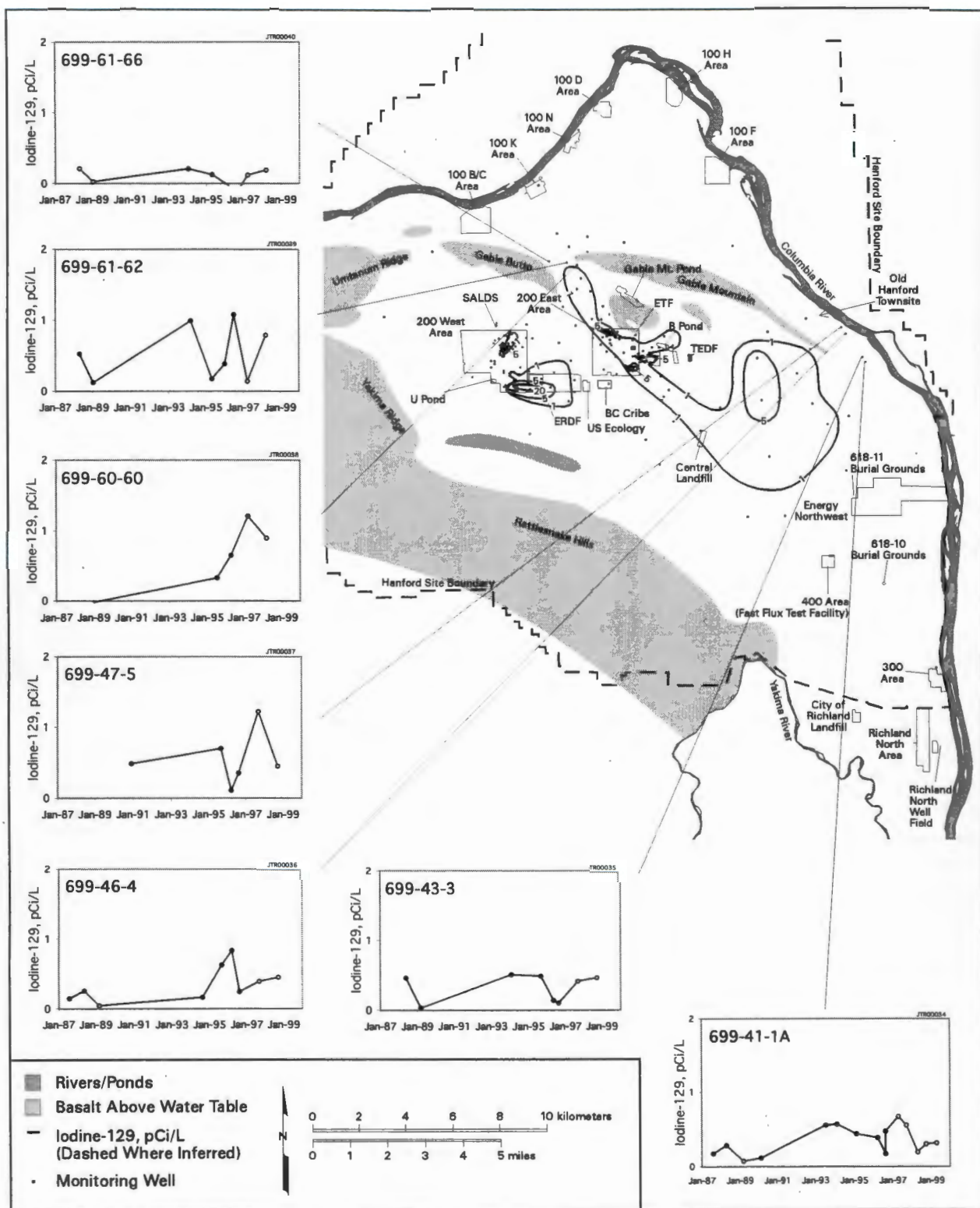
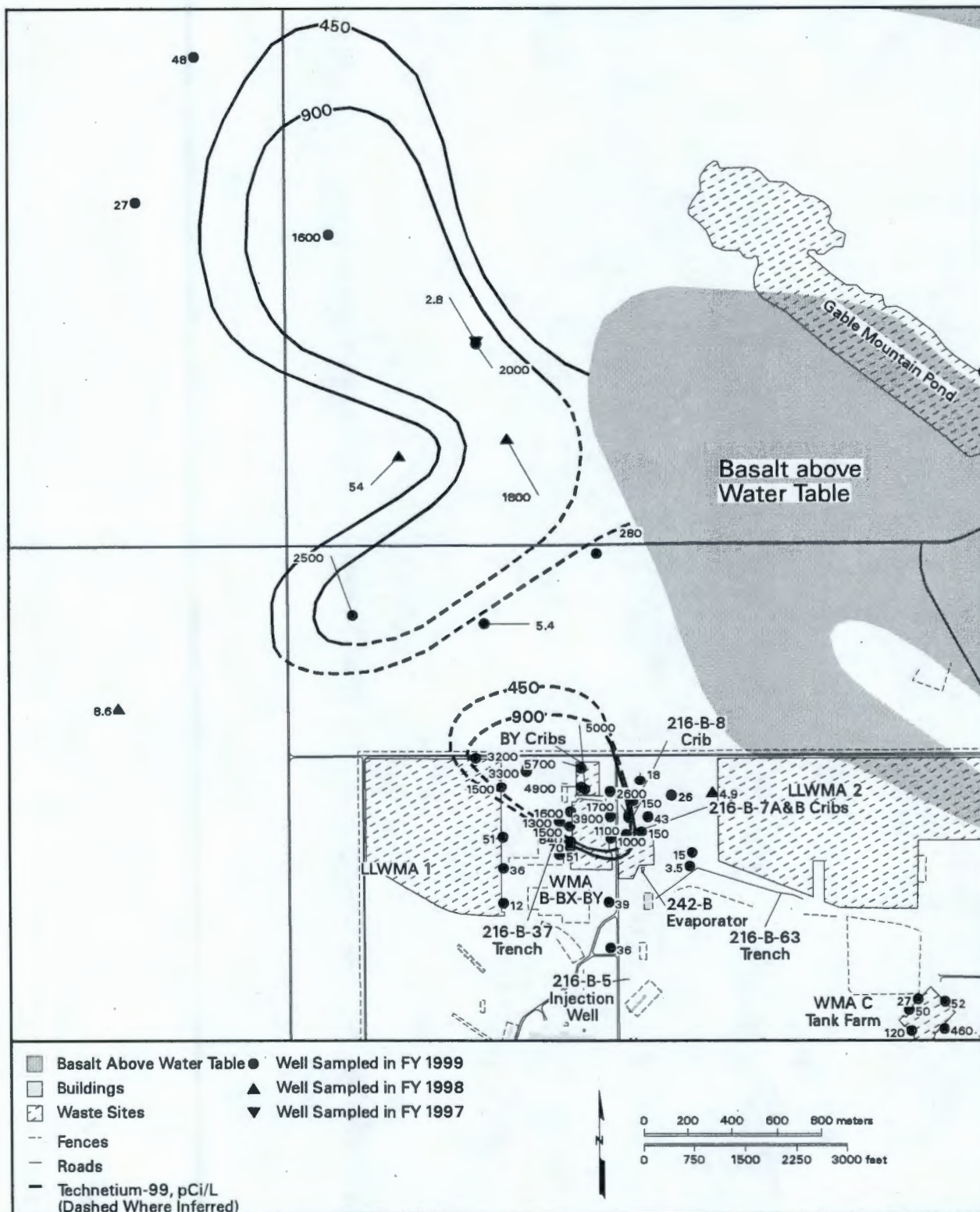
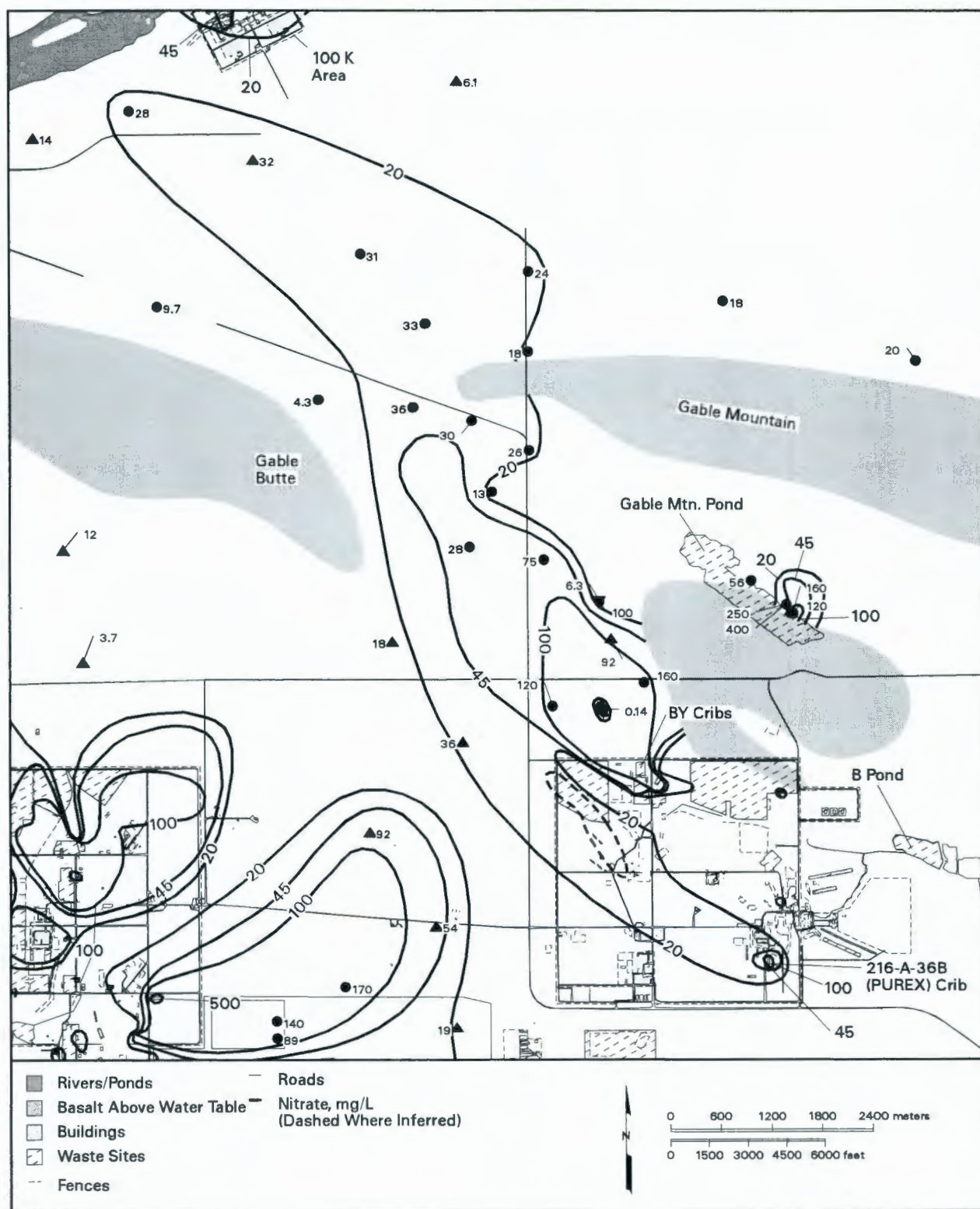


Figure 2.9-3. Iodine-129 in the Gable Gap and Old Hanford Townsite Areas



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Figure 2.9-4. Average Technetium-99 Concentrations, Northern 200 East Area, Top of Unconfined Aquifer



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Figure 2.9-5. Average Nitrate Concentrations in 200 East Area, Top of Unconfined Aquifer

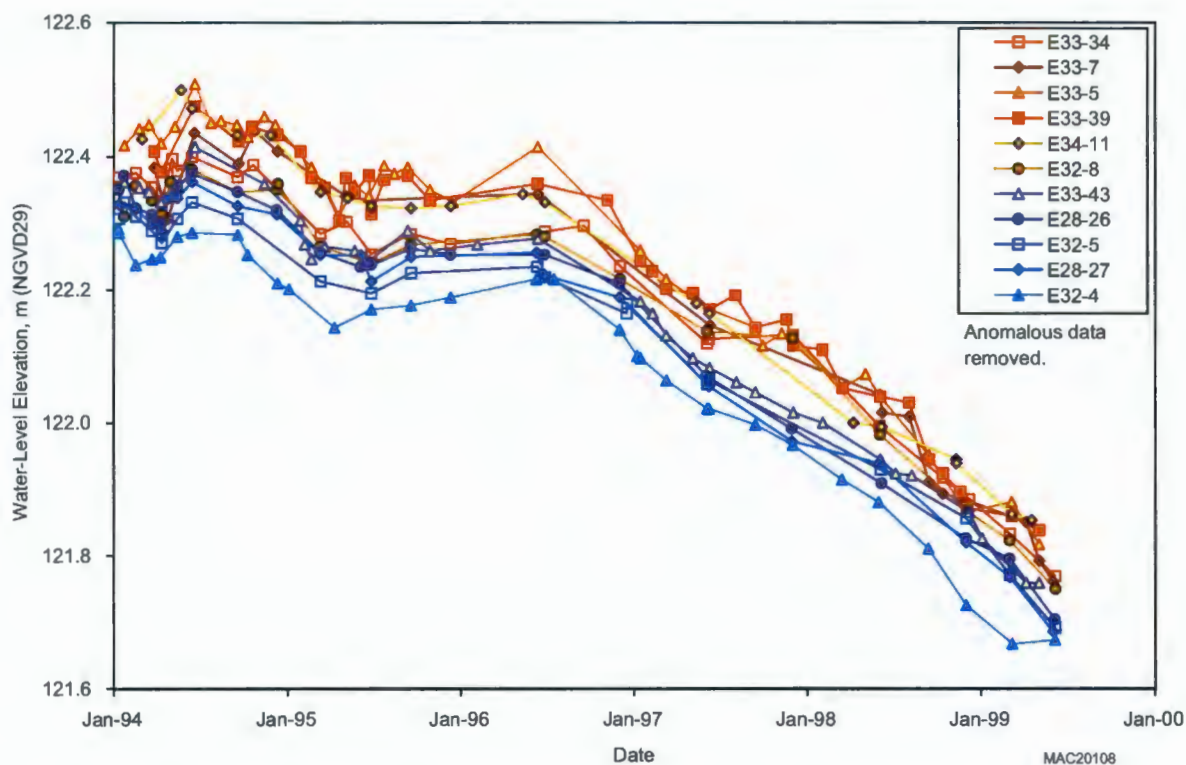


Figure 2.9-6. Hydrographs of Wells Located North, East, West and Southwest of Waste Management Area B-BX-BY

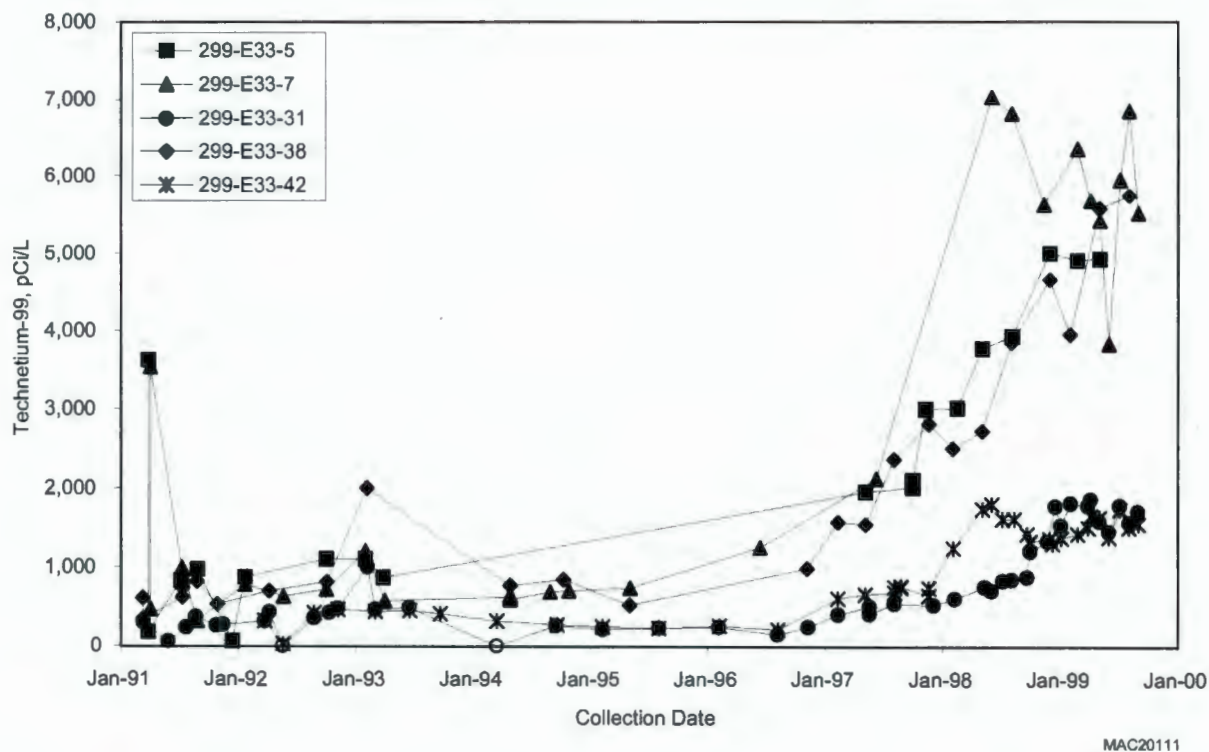


Figure 2.9-7. Technetium-99 in Wells at Waste Management Area B-BX-BY

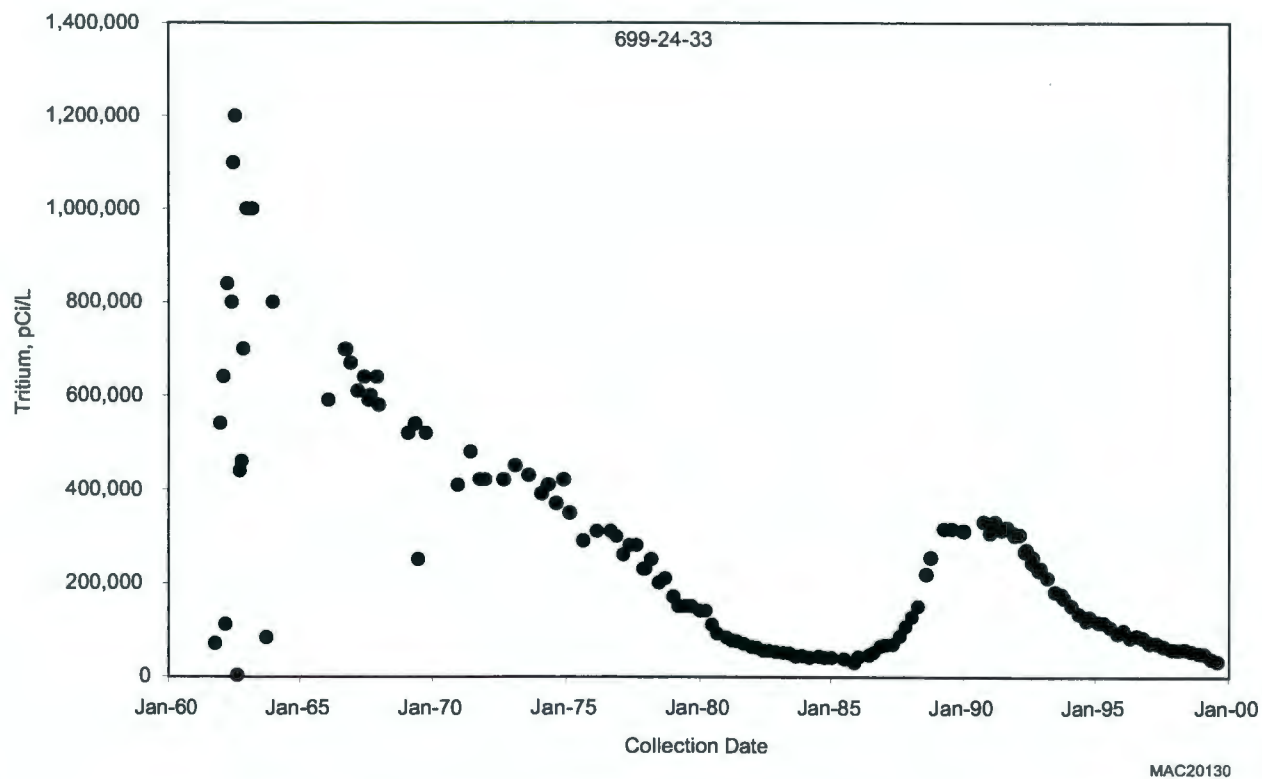


Figure 2.9-15. Tritium in Well 699-24-33 Near the Central Landfill

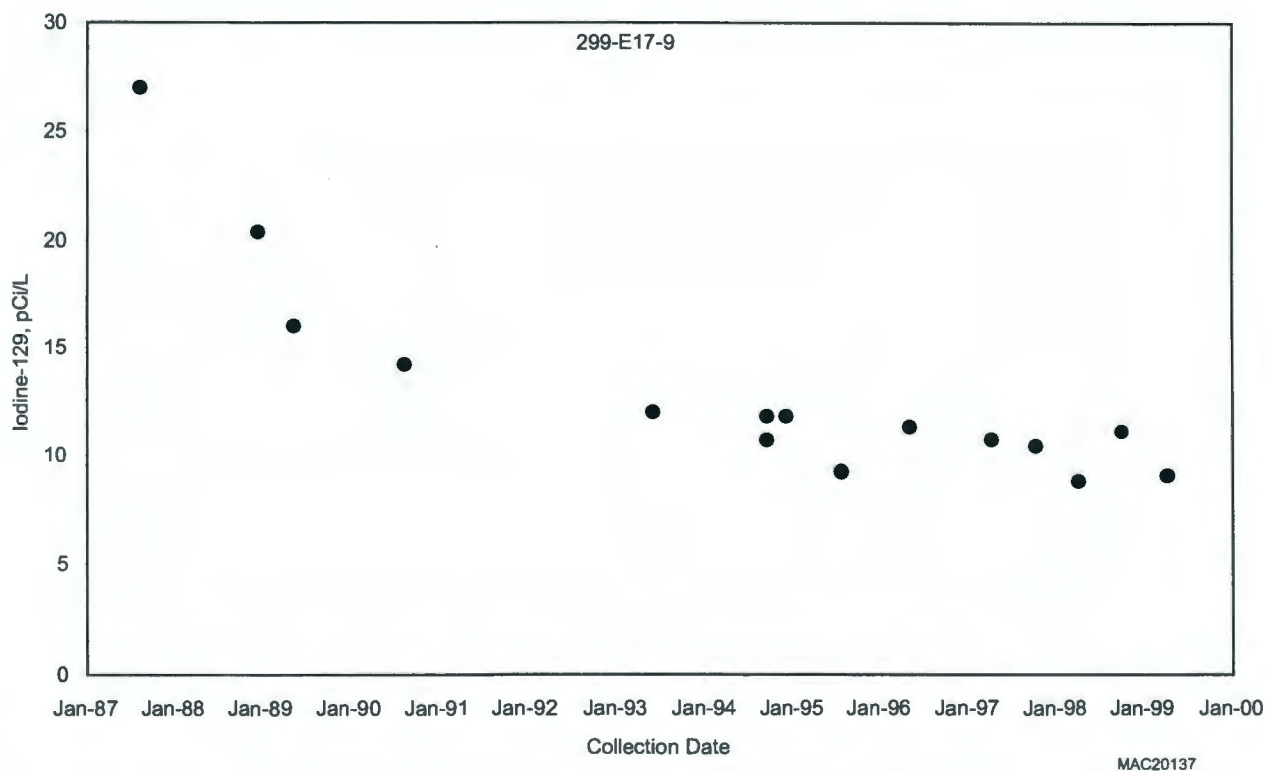


Figure 2.9-16. Iodine-129 in Well 299-E17-9 at 216-A-36B Crib

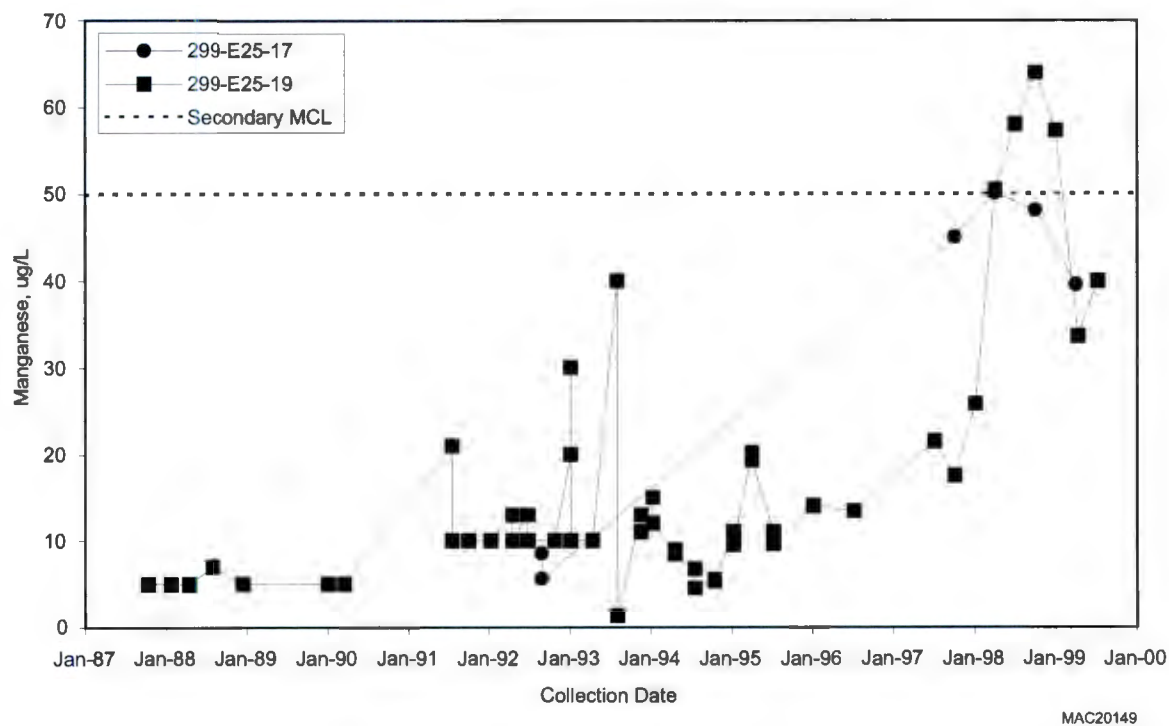


Figure 2.9-17. Manganese at 216-A-37-1 Crib

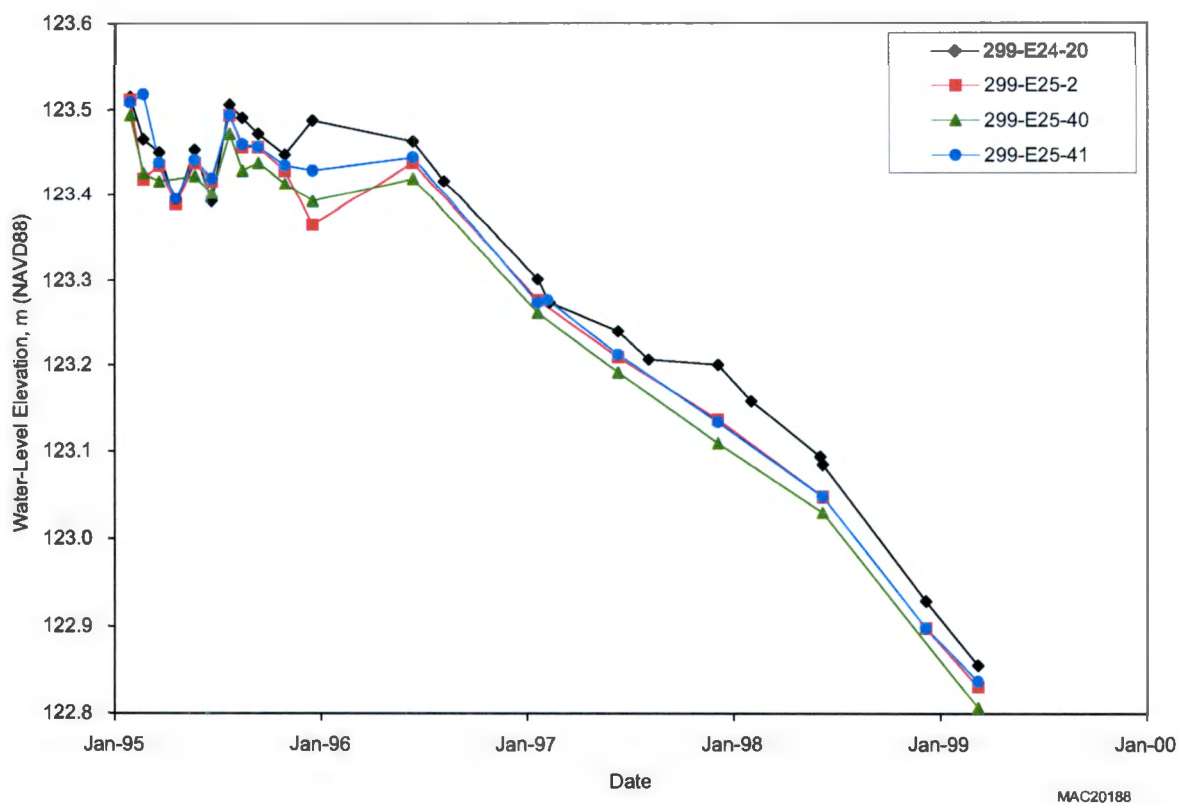


Figure 2.9-18. Hydrographs of Wells at Waste Management Area A-AX Using NAVD88

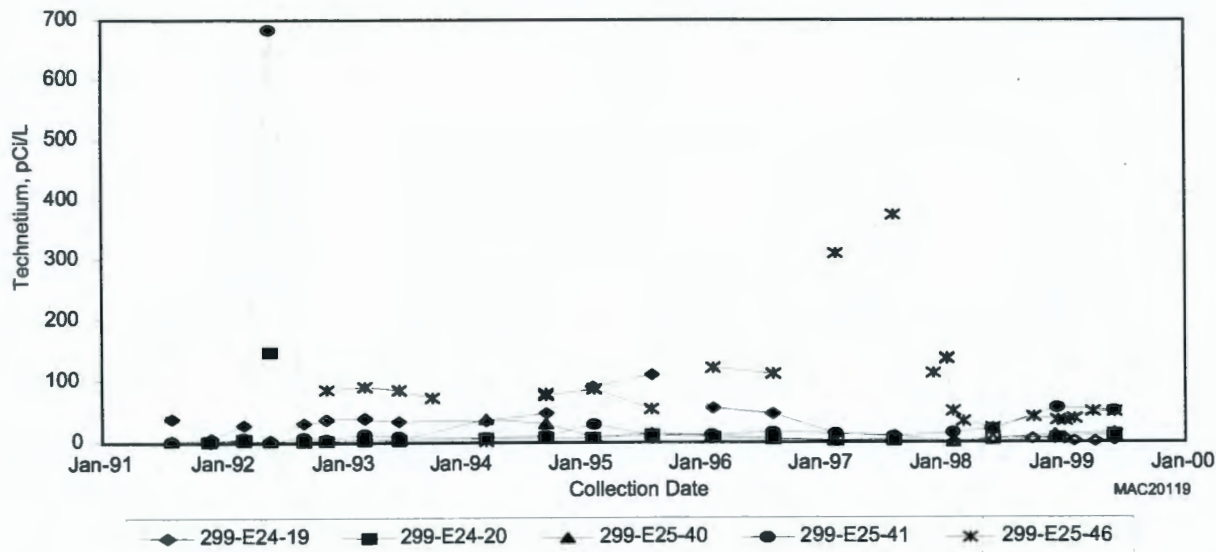
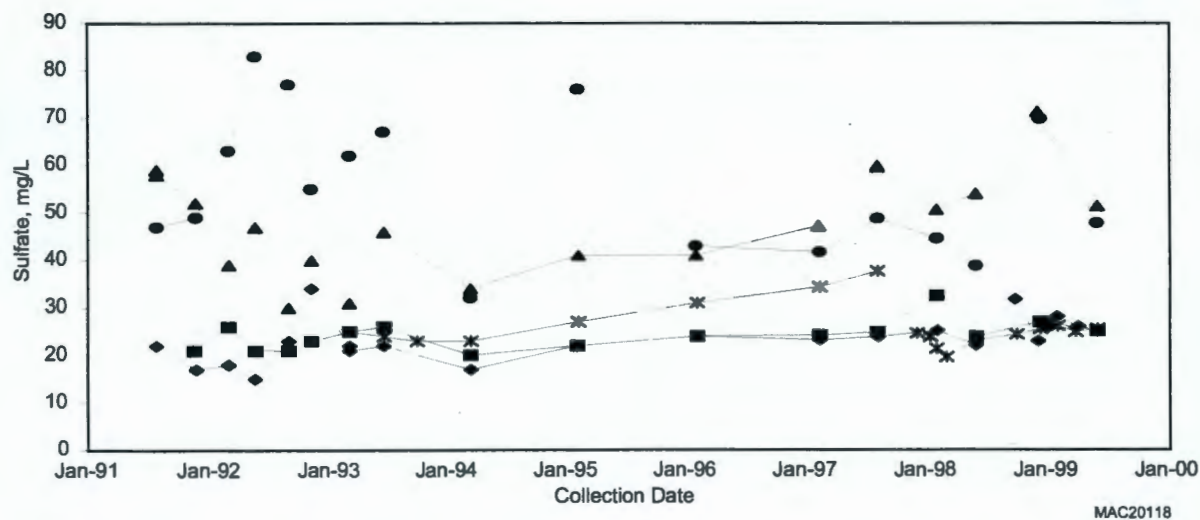
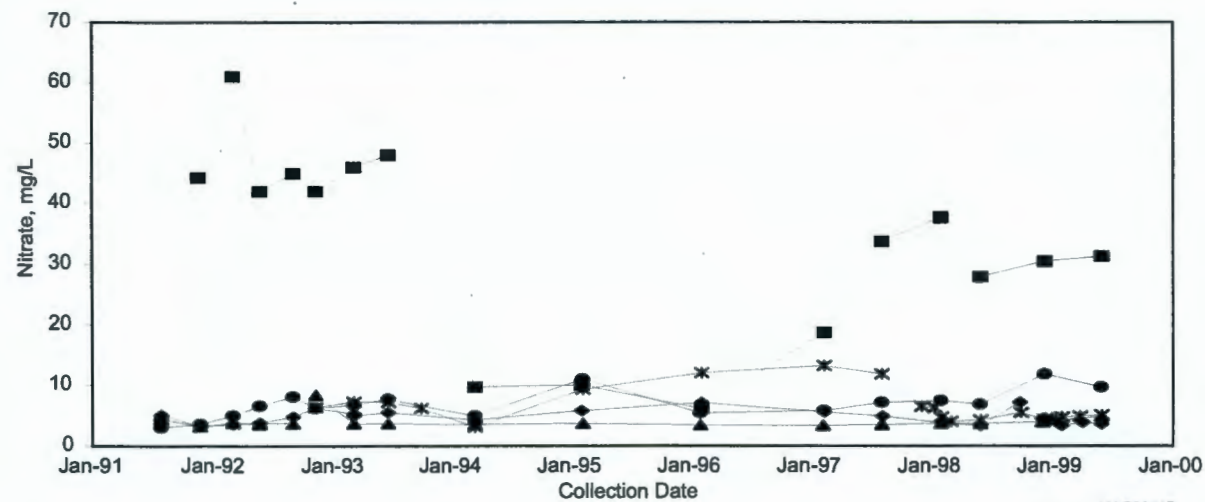


Figure 2.9-19. Nitrate, Sulfate, and Technetium-99 in Wells at Waste Management Area A-AX

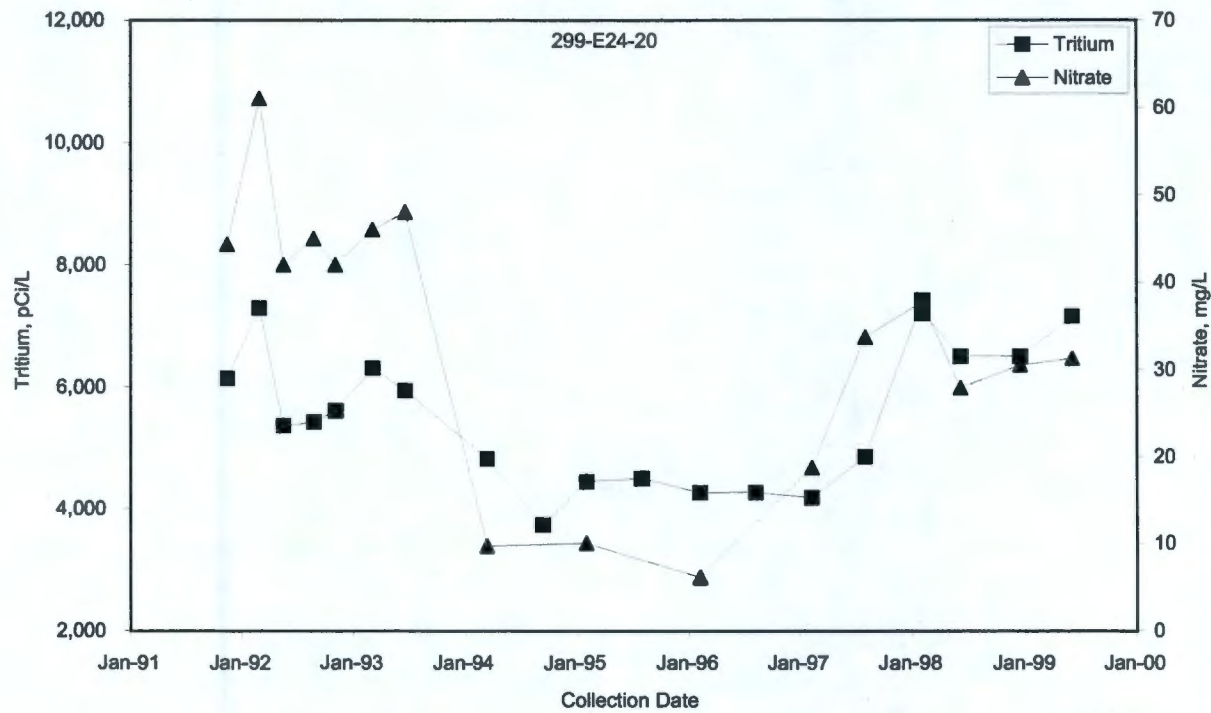


Figure 2.9-20. Tritium and Nitrate in Well 299-E24-20 at Waste Management Area A-AX

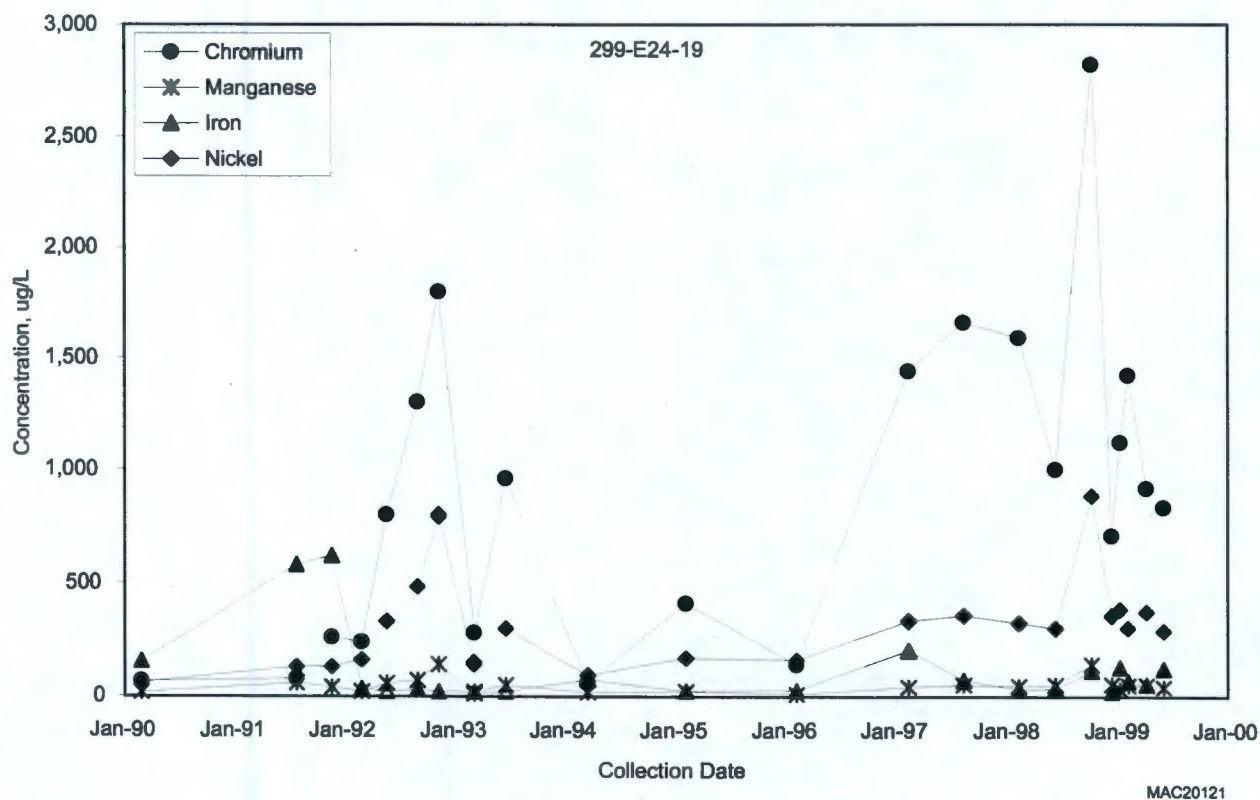
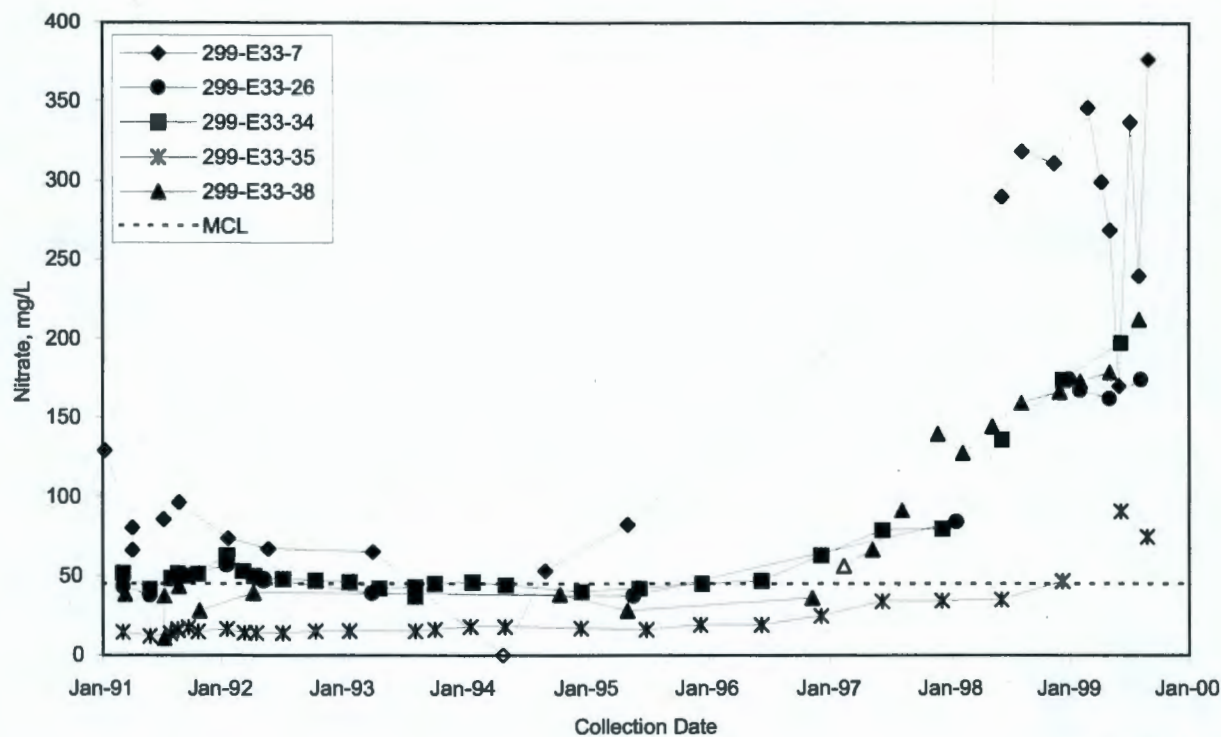
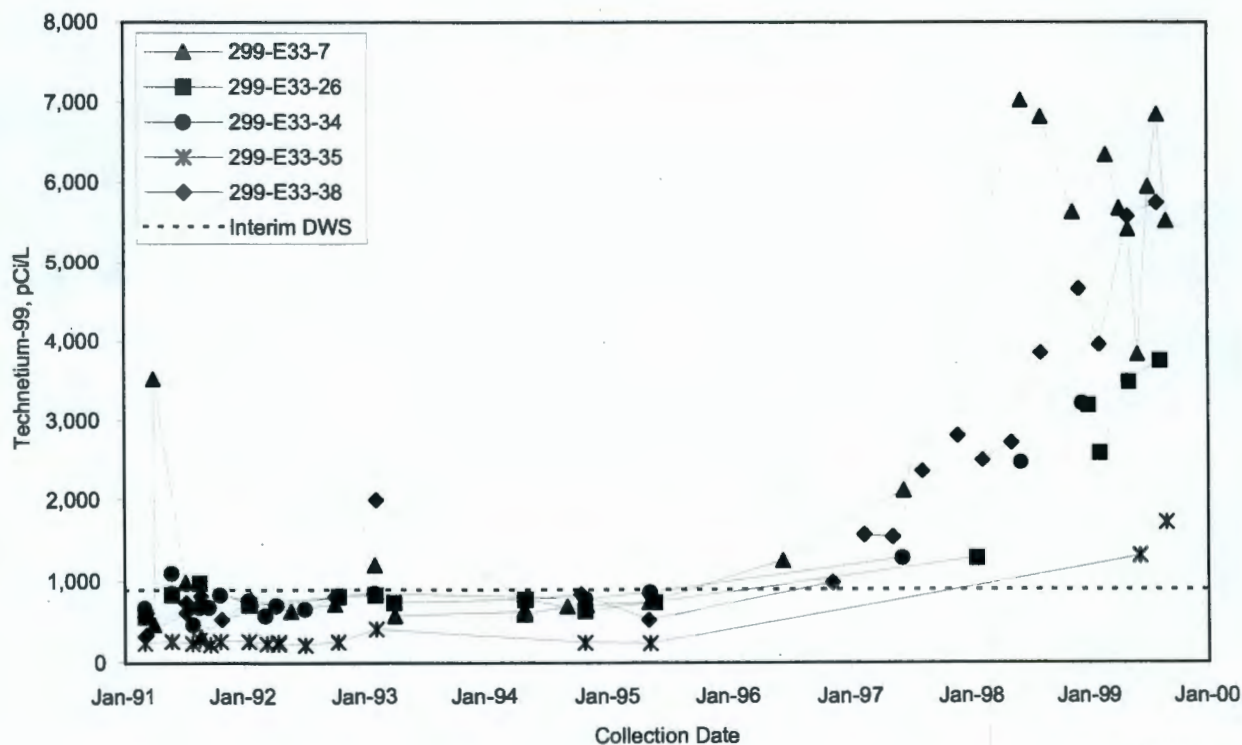


Figure 2.9-21. Chromium, Iron, Manganese, and Nickel in Well 299-E24-19 at Waste Management Area A-AX



MAC20110

Figure 2.9-8. Nitrate in Wells at Waste Management Area B-BX-BY



MAC20112

Figure 2.9-9. Technetium-99 at Waste Management Area B-BX-BY

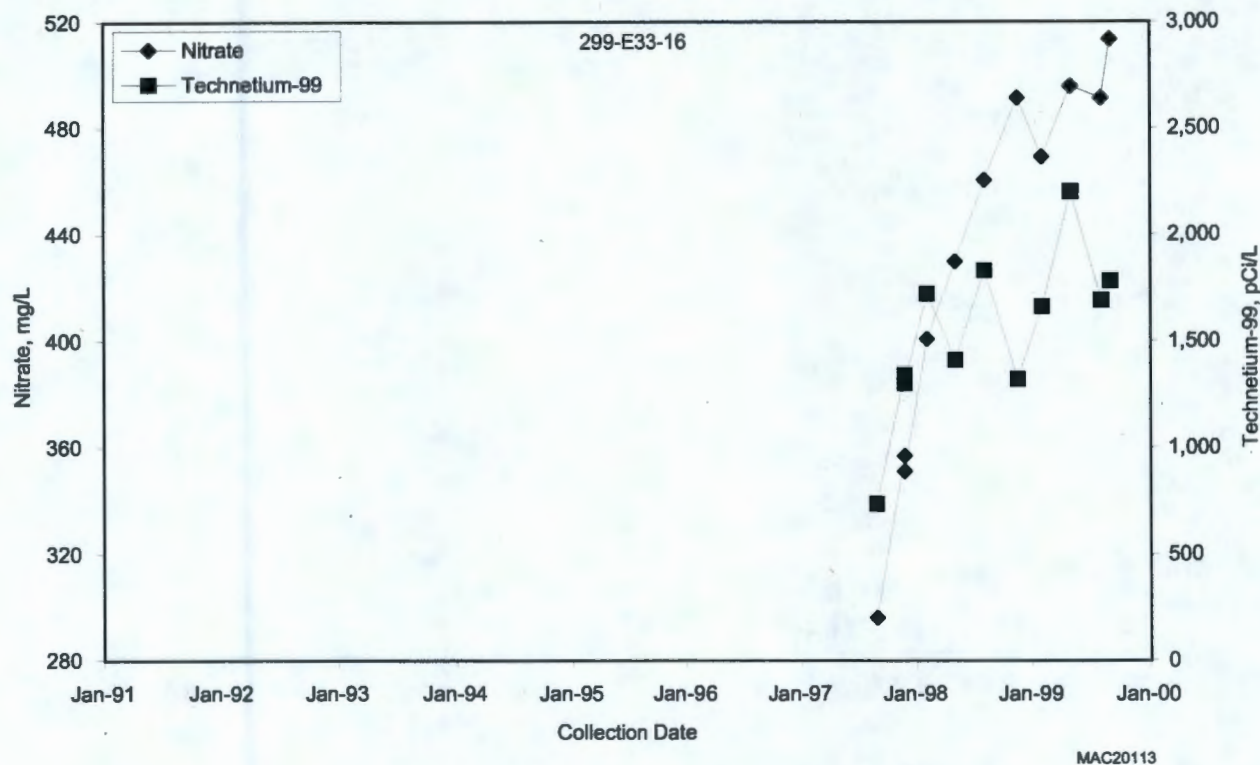


Figure 2.9-10. Nitrate and Technetium-99 in Well 299-E33-16 at Waste Management Area B-BX-BY

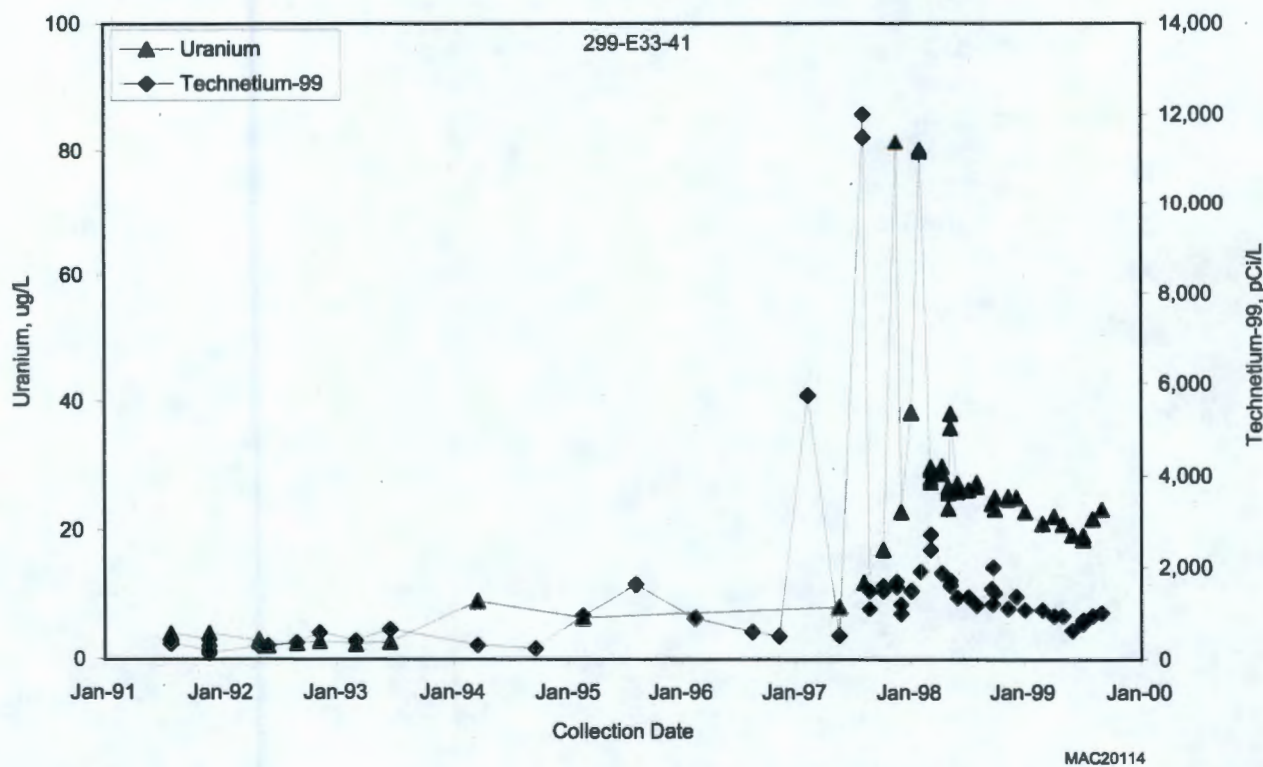


Figure 2.9-11. Technetium-99 and Uranium in Well 299-E33-41 at Waste Management Area B-BX-BY

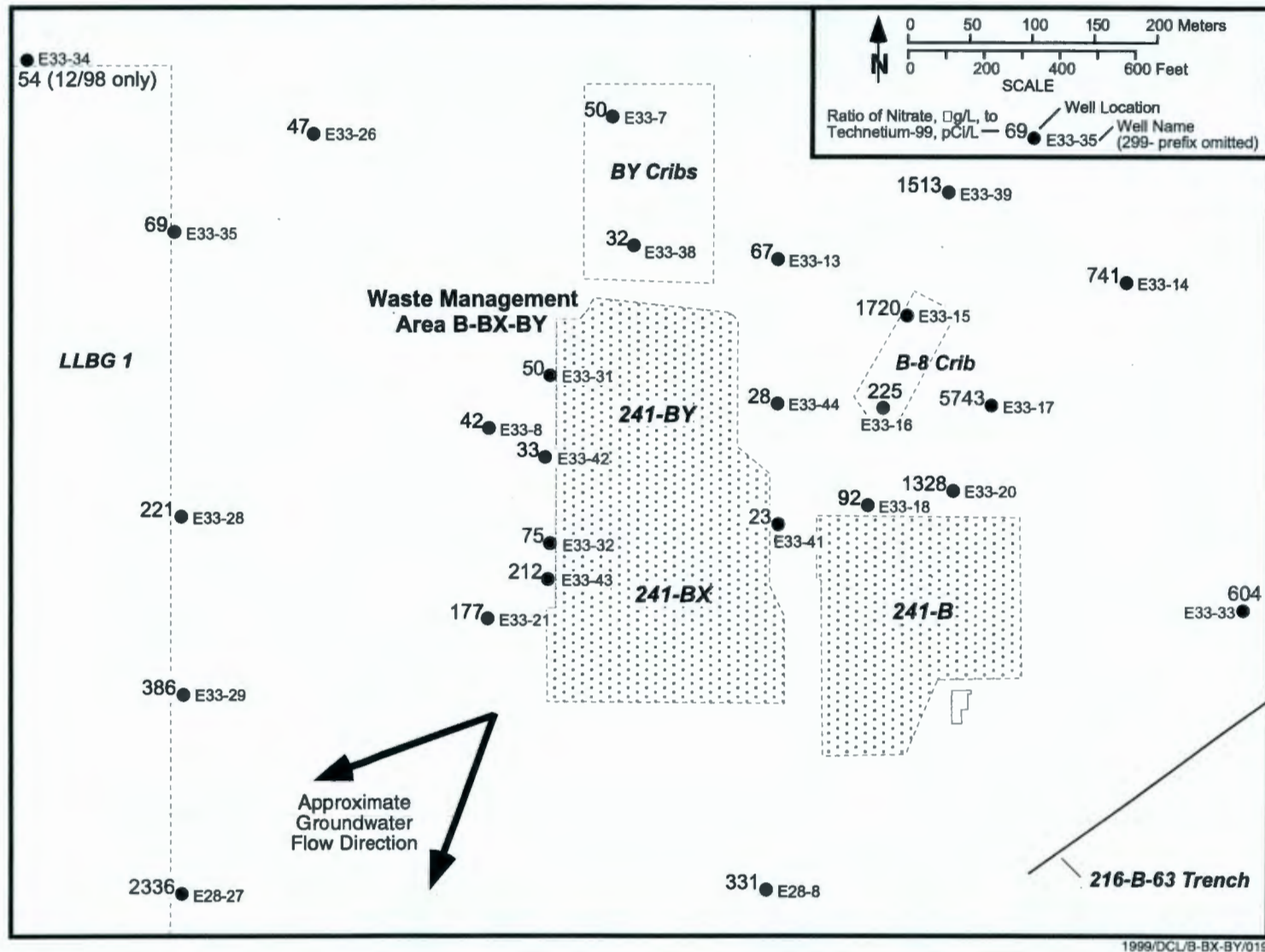


Figure 2.9-12. Ratio of Nitrate to Technetium-99, April through June 1999

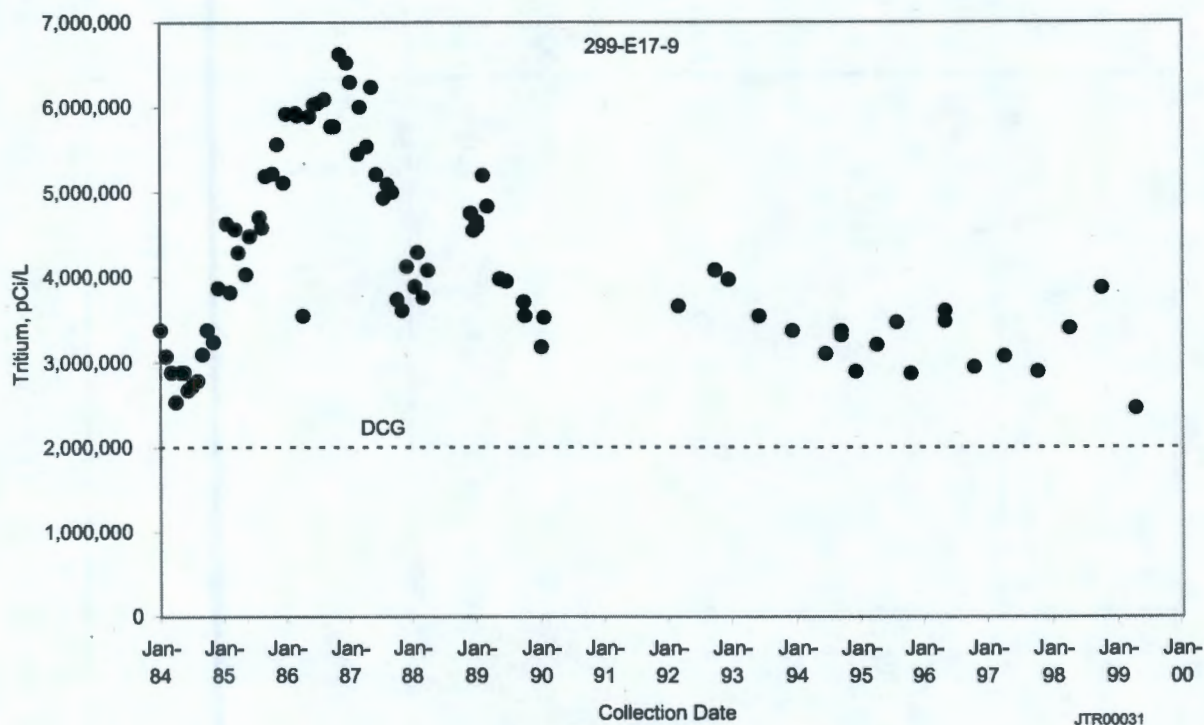


Figure 2.9-13. Tritium in Well 299-E17-9 at 216-A-36B Crib

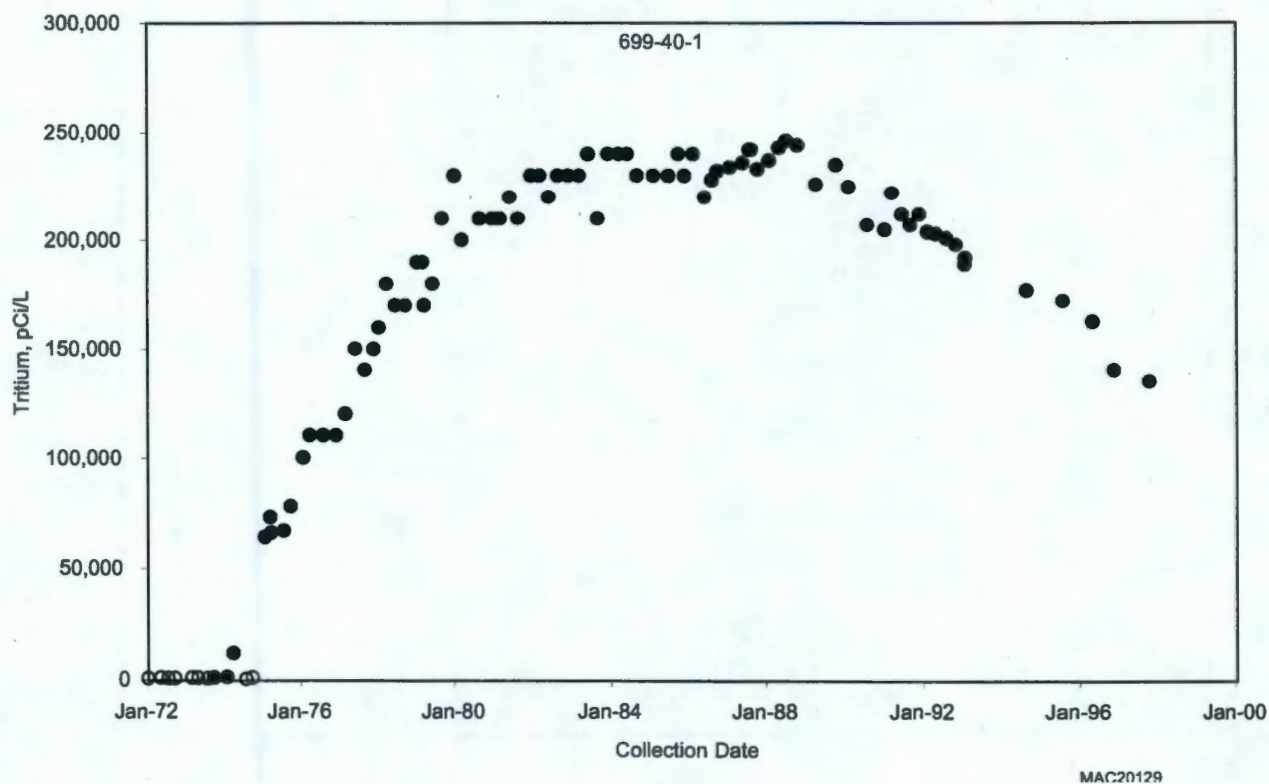


Figure 2.9-14. Tritium in Well 699-40-1 at the 600 Area Near the Old Hanford Townsite

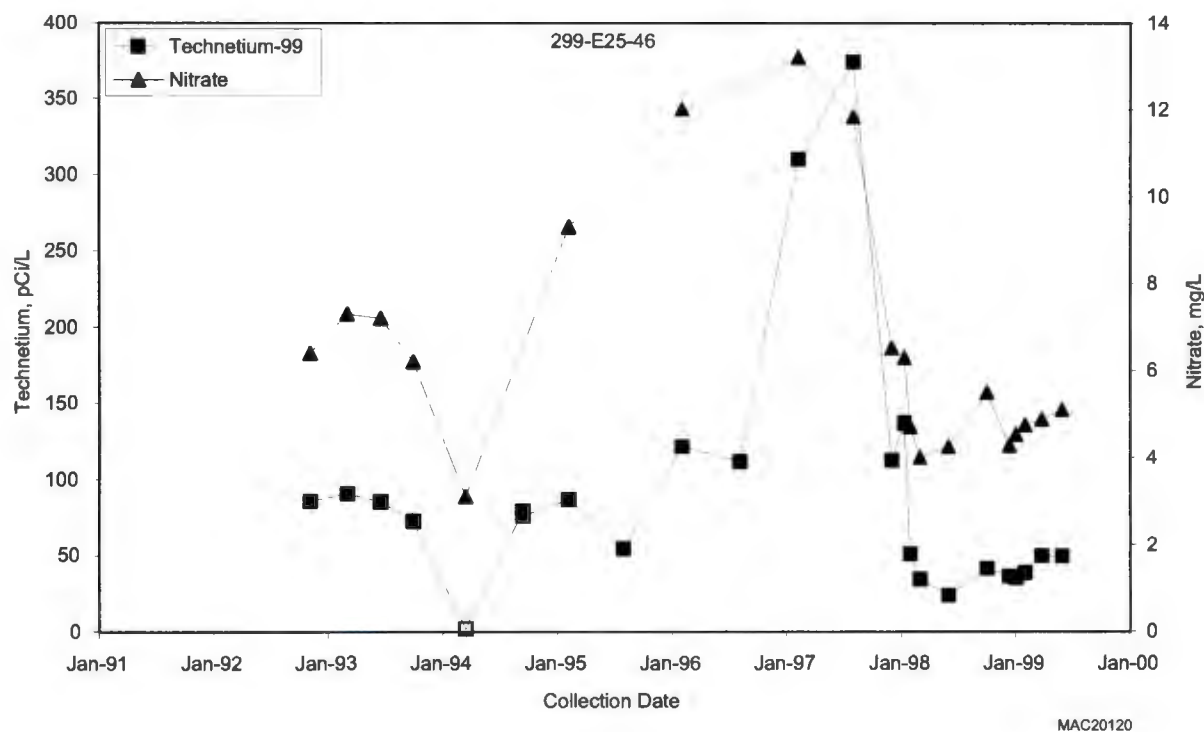


Figure 2.9-22. Tchnetium-99 and Nitrate in Well 299-E25-46 at Waste Management Area A-AX

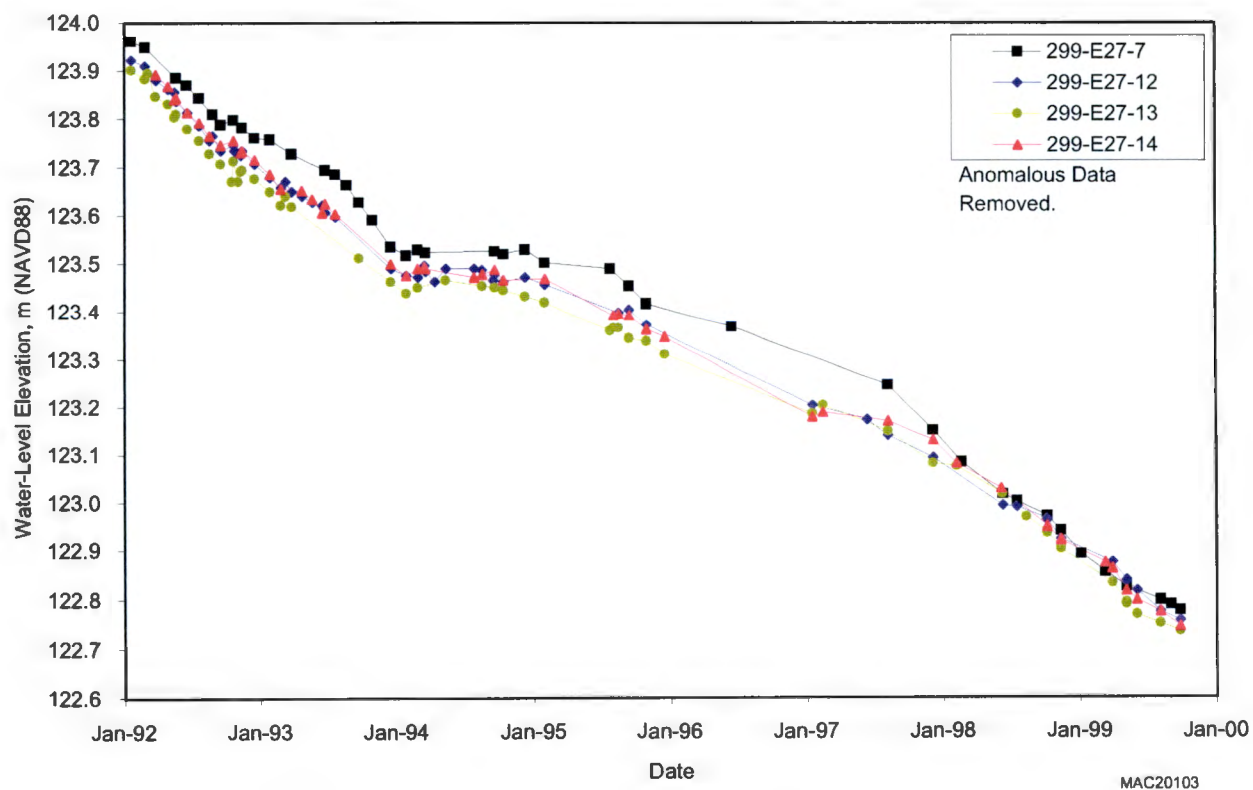
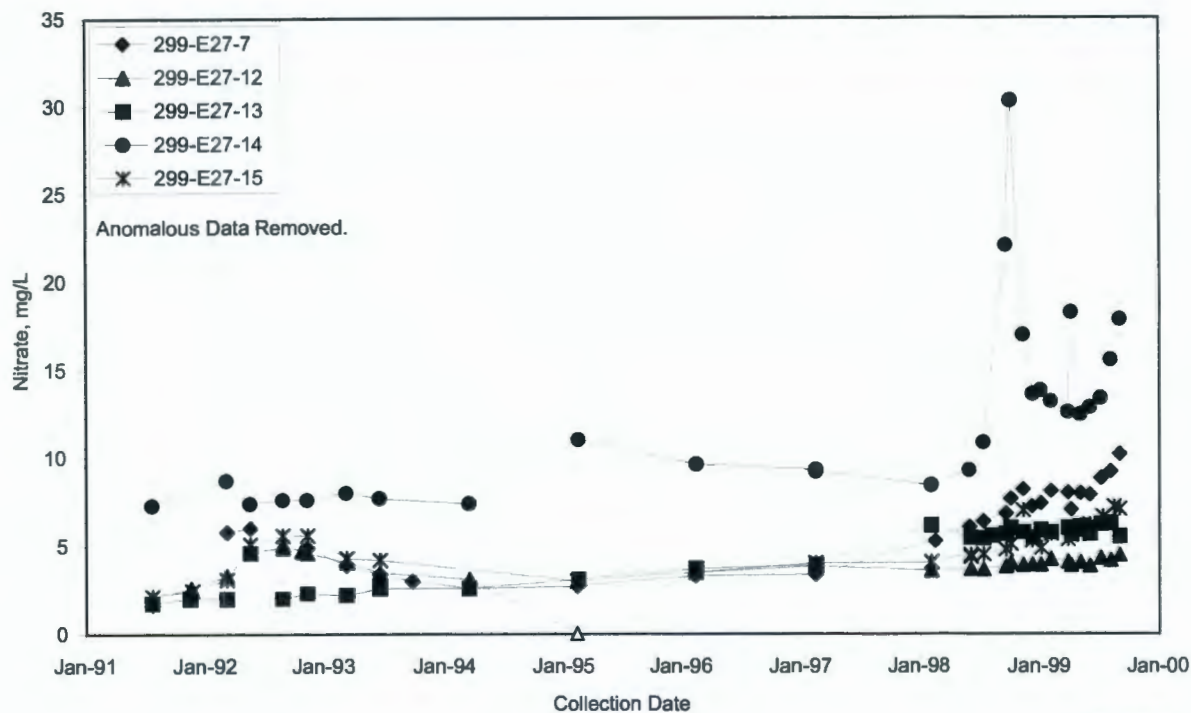
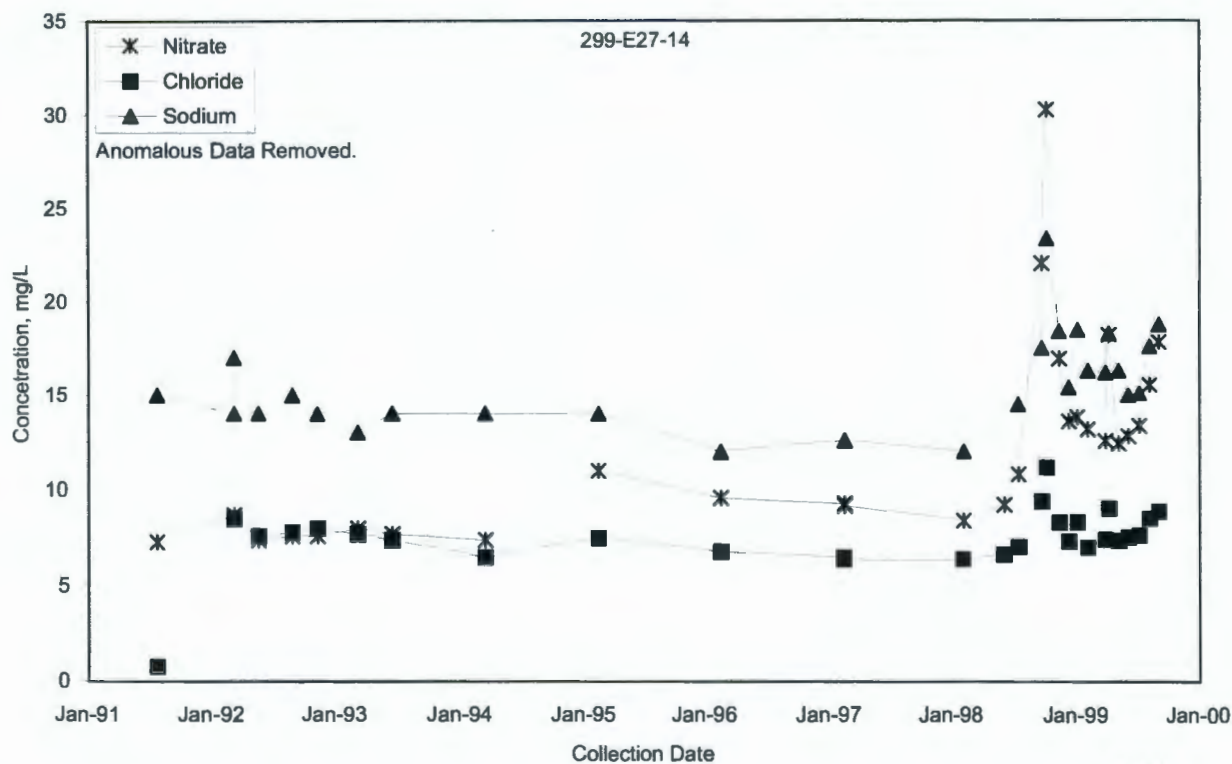


Figure 2.9-23. Hydrographs of Wells at Waste Management Area C



MAC20104

Figure 2.9-24. Nitrate at Waste Management Area C



MAC20105

Figure 2.9-25. Nitrate, Chloride, and Sodium in Well 299-E27-14 at Waste Management Area C

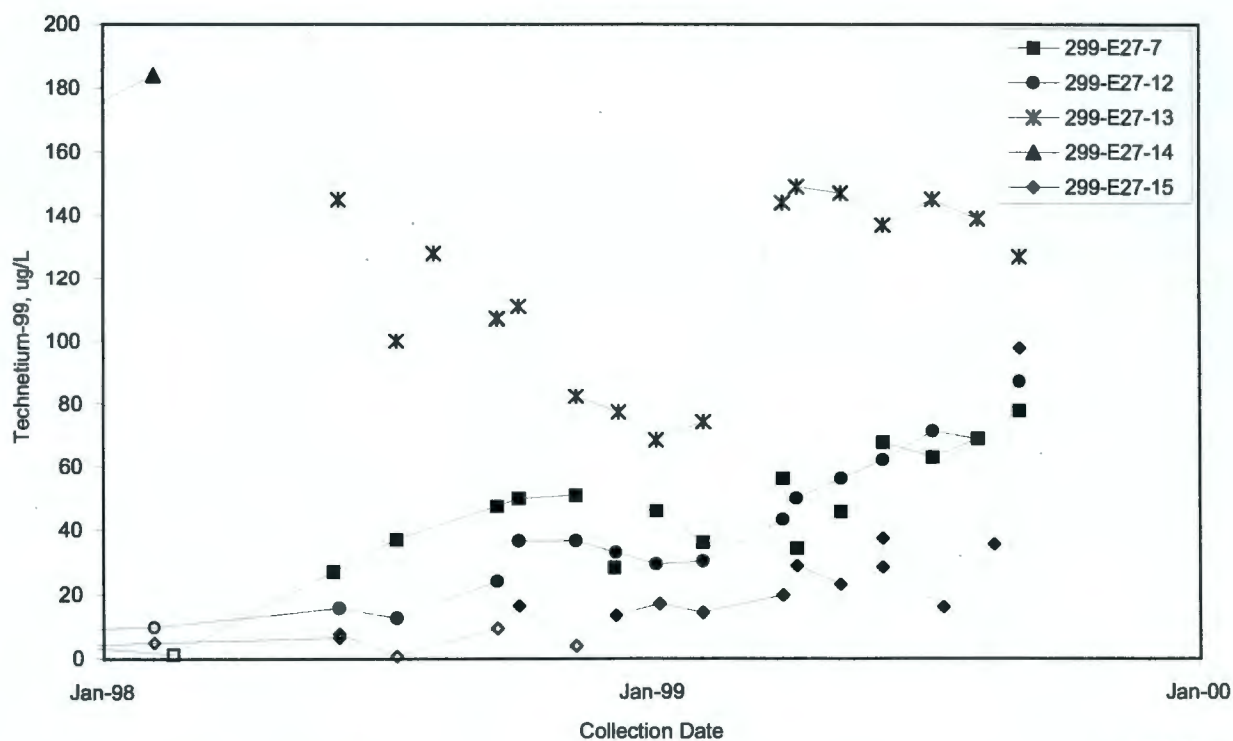
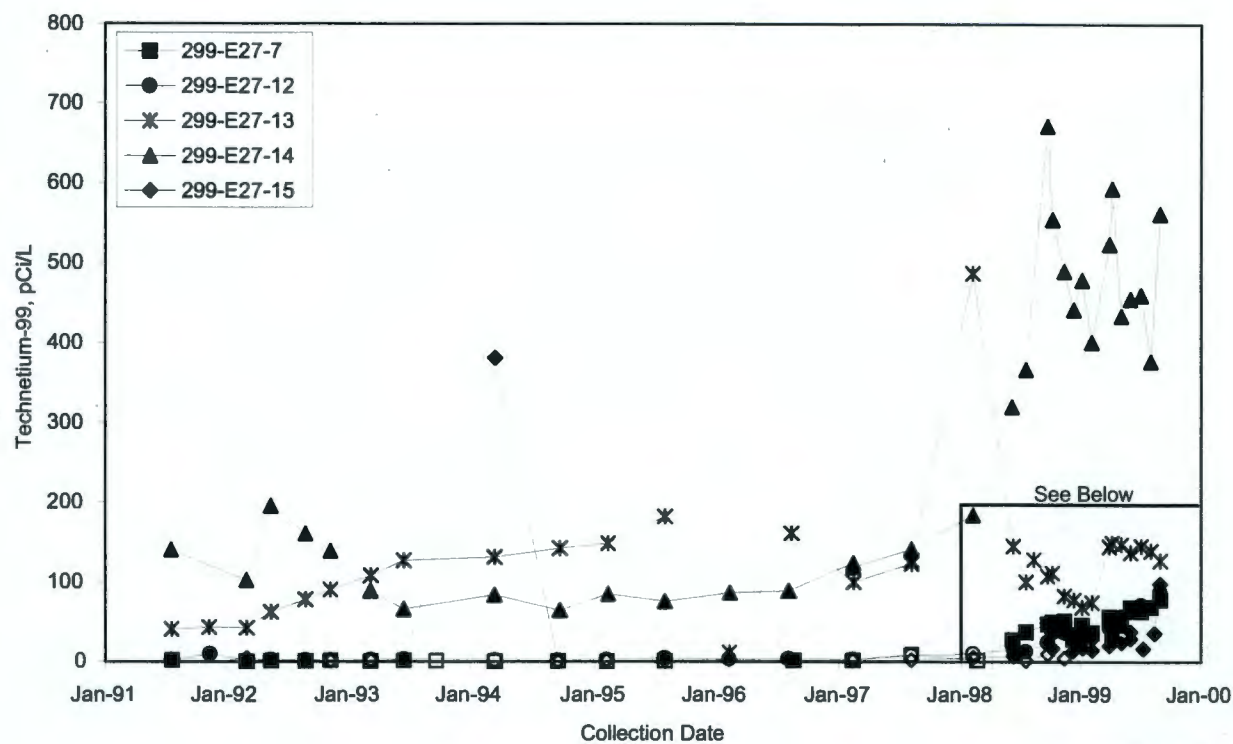


Figure 2.9-26. Technetium-99 at Waste Management Area C

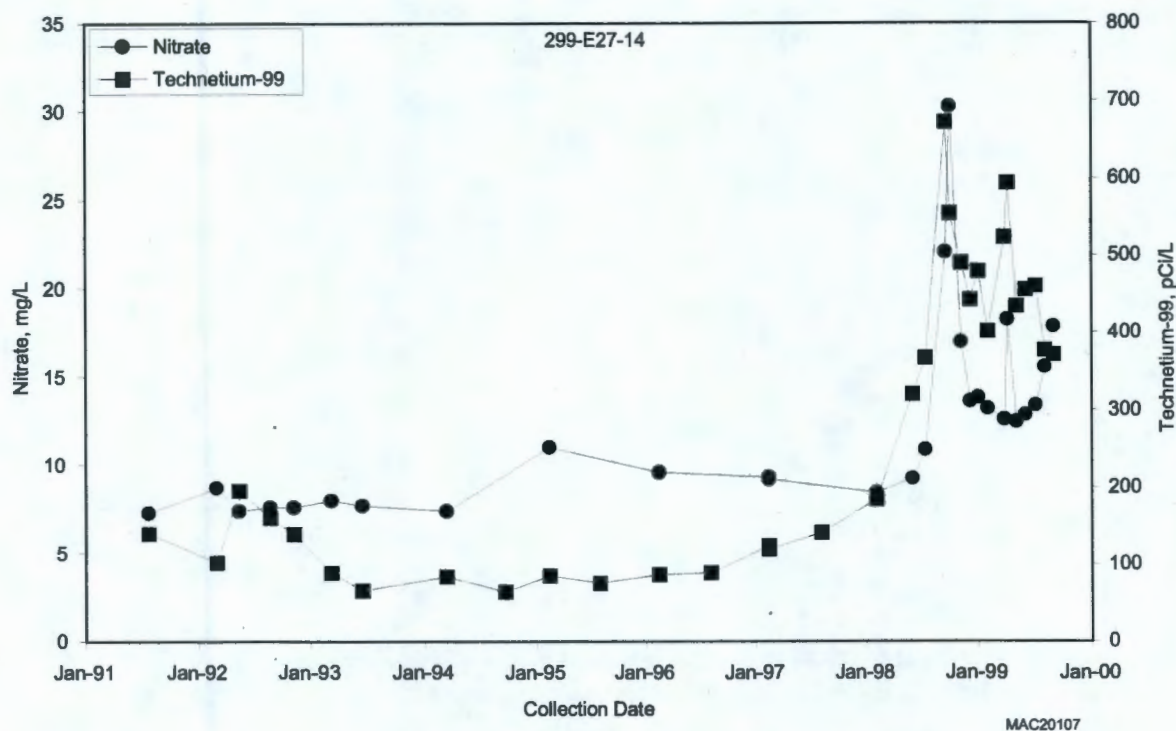


Figure 2.9-27. Nitrate and Technetium-99 in Well 299-E27-14 at Waste Management Area C

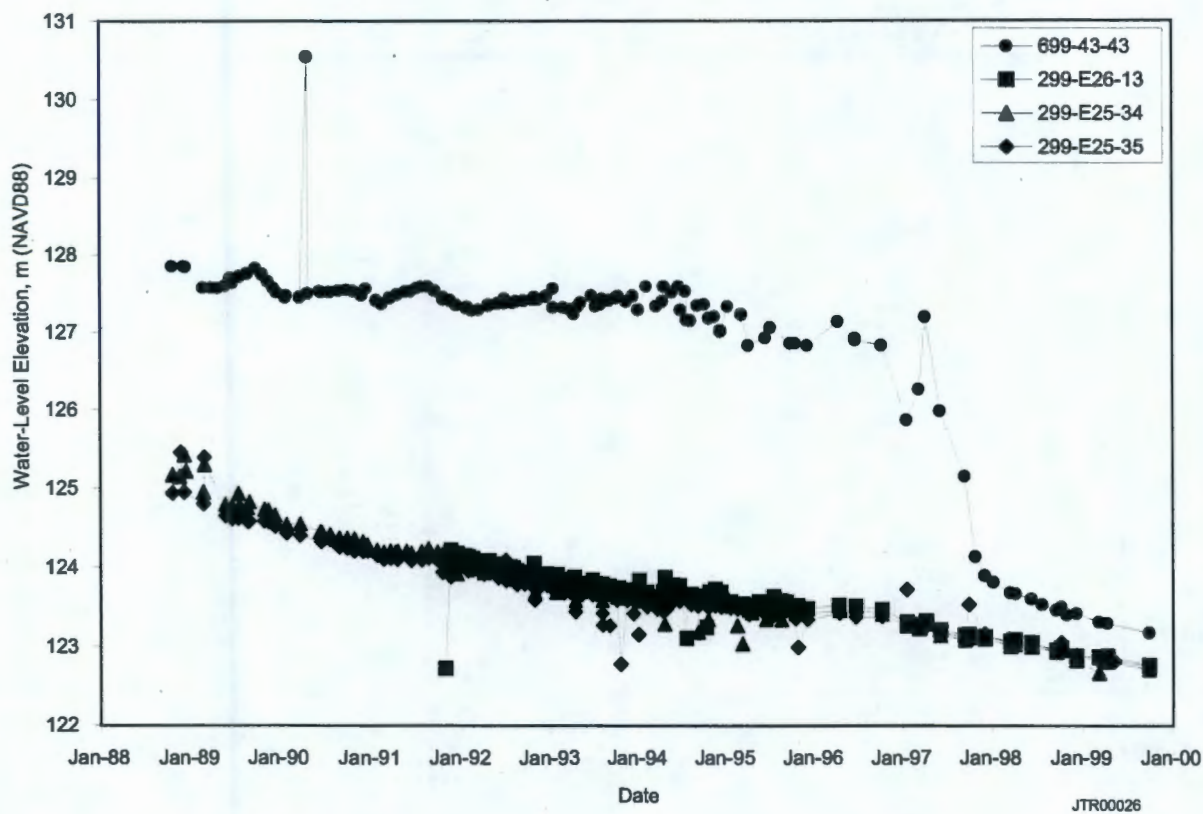
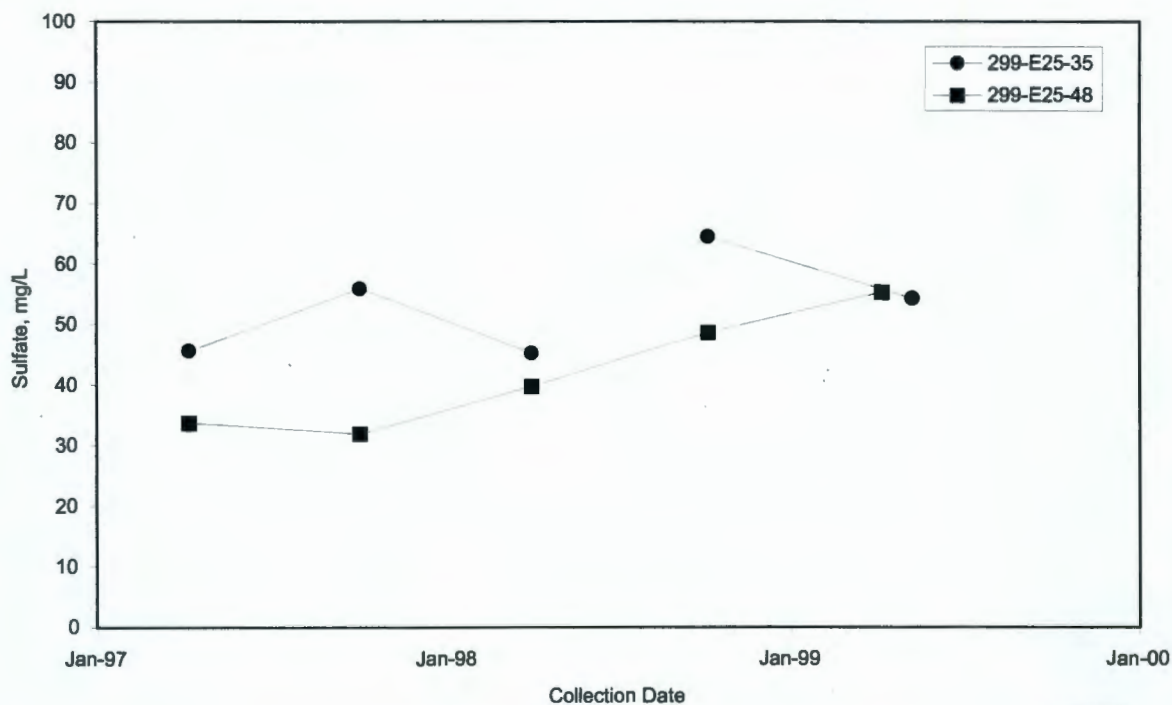
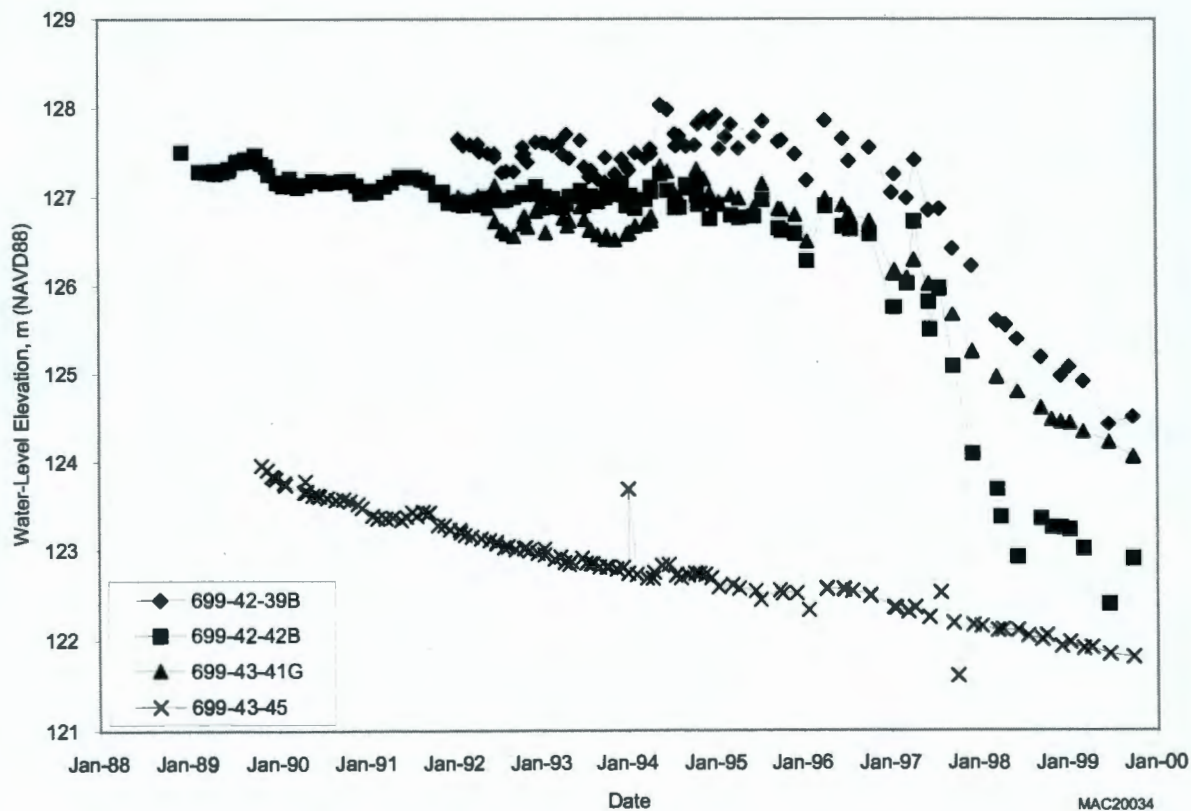


Figure 2.9-28. Hydrographs of Wells at 216-A-29 Ditch



JTR00032

Figure 2.9-29. Sulfate in Wells Monitoring 216-A-29 Ditch



MAC20034

Figure 2.9-30. Hydrographs of Wells at 216-B-3 Pond

2.230

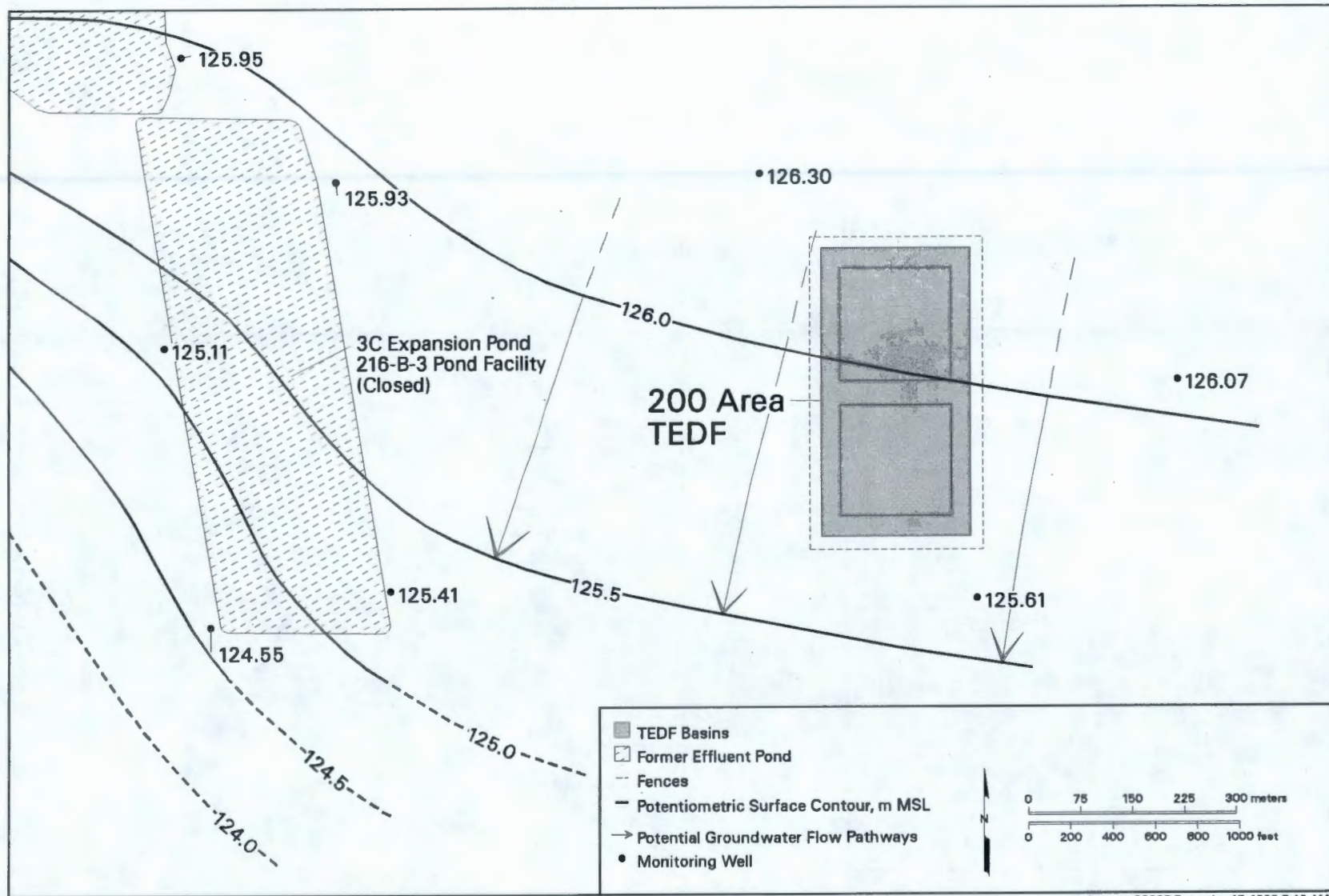


Figure 2.9-31. Potentiometric Surface Map of Unit 7 for the Vicinity of the Treated Effluent Disposal Facility

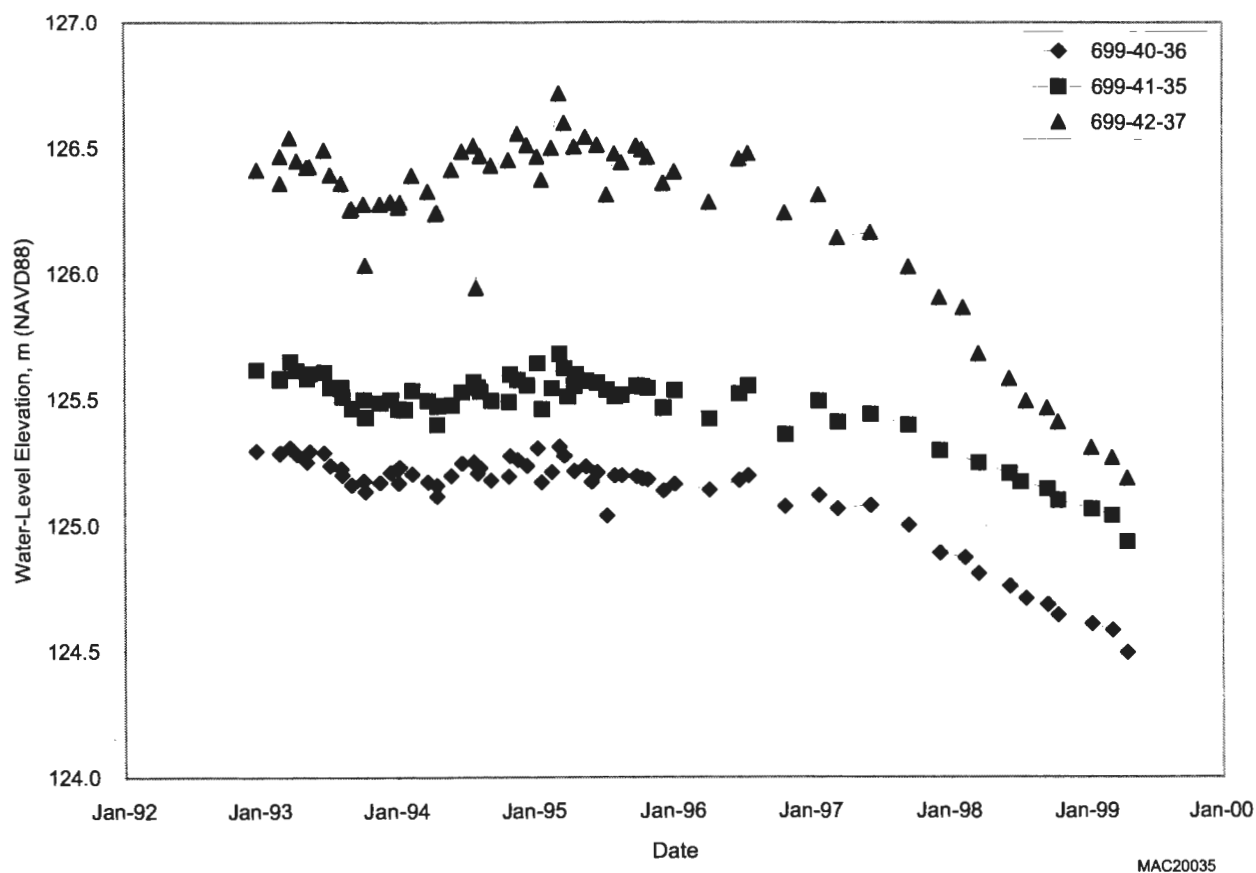
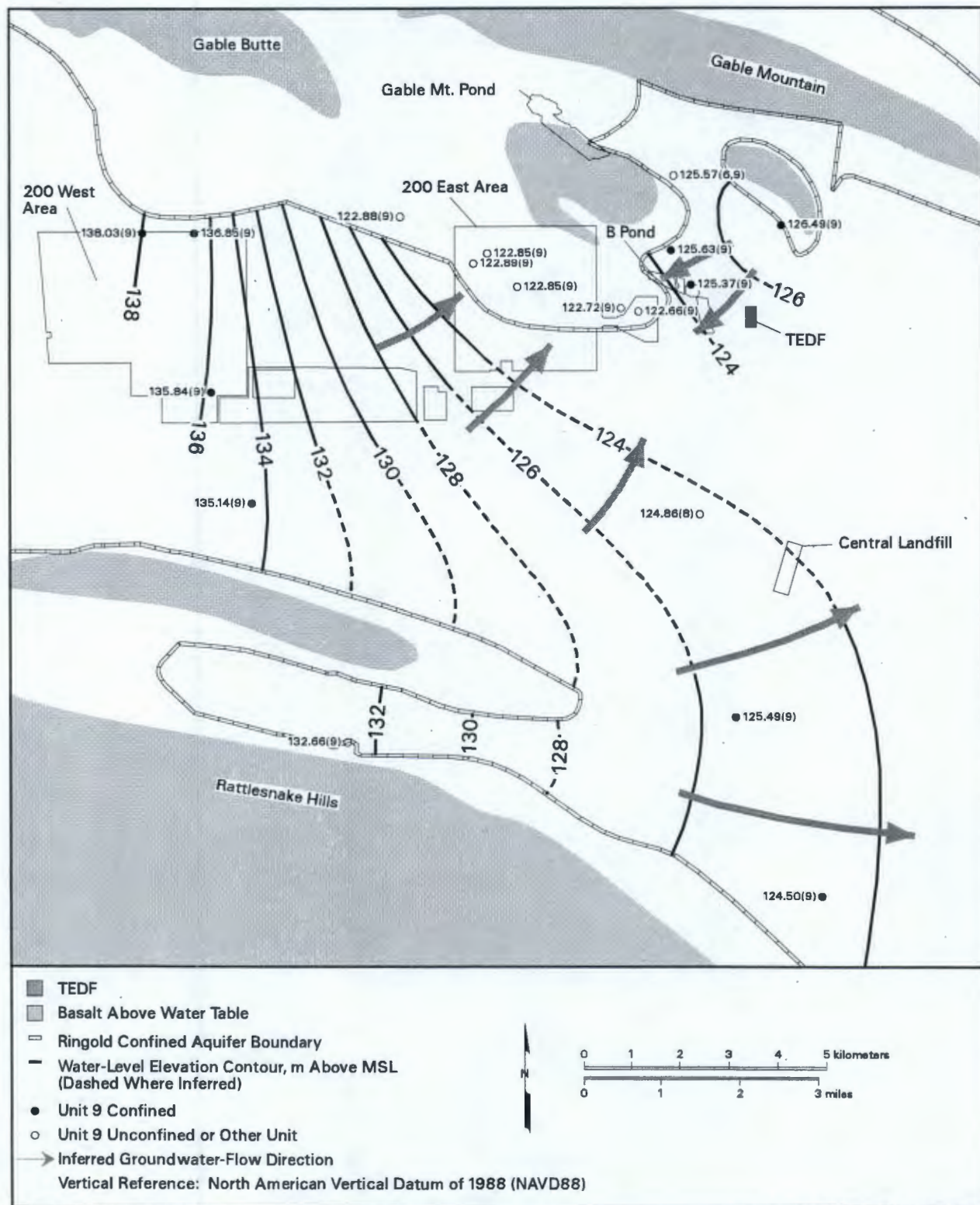


Figure 2.9-32. Hydrographs of Wells at the Treated Effluent Disposal Facility



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Figure 2.9-33. Potentiometric Surface Map of Ringold Formation Confined Aquifer (Unit 9), Central Hanford Site, March 1999

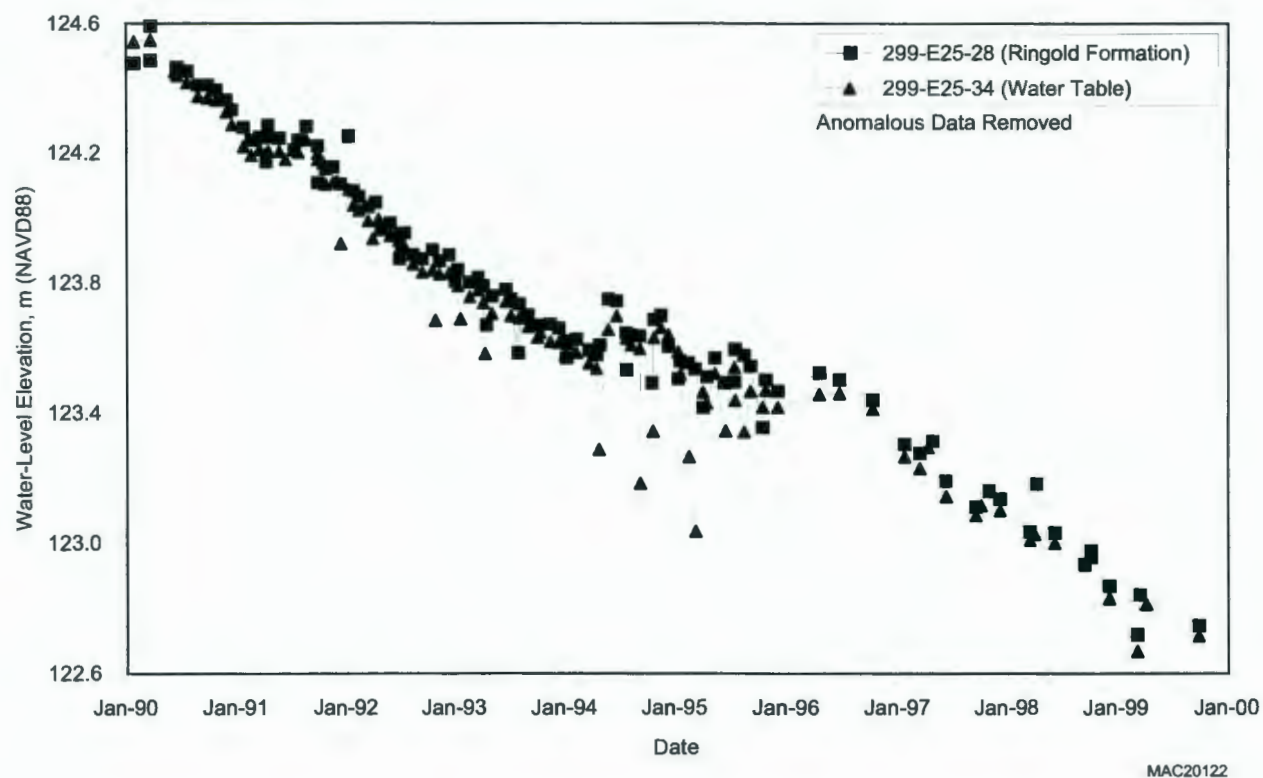
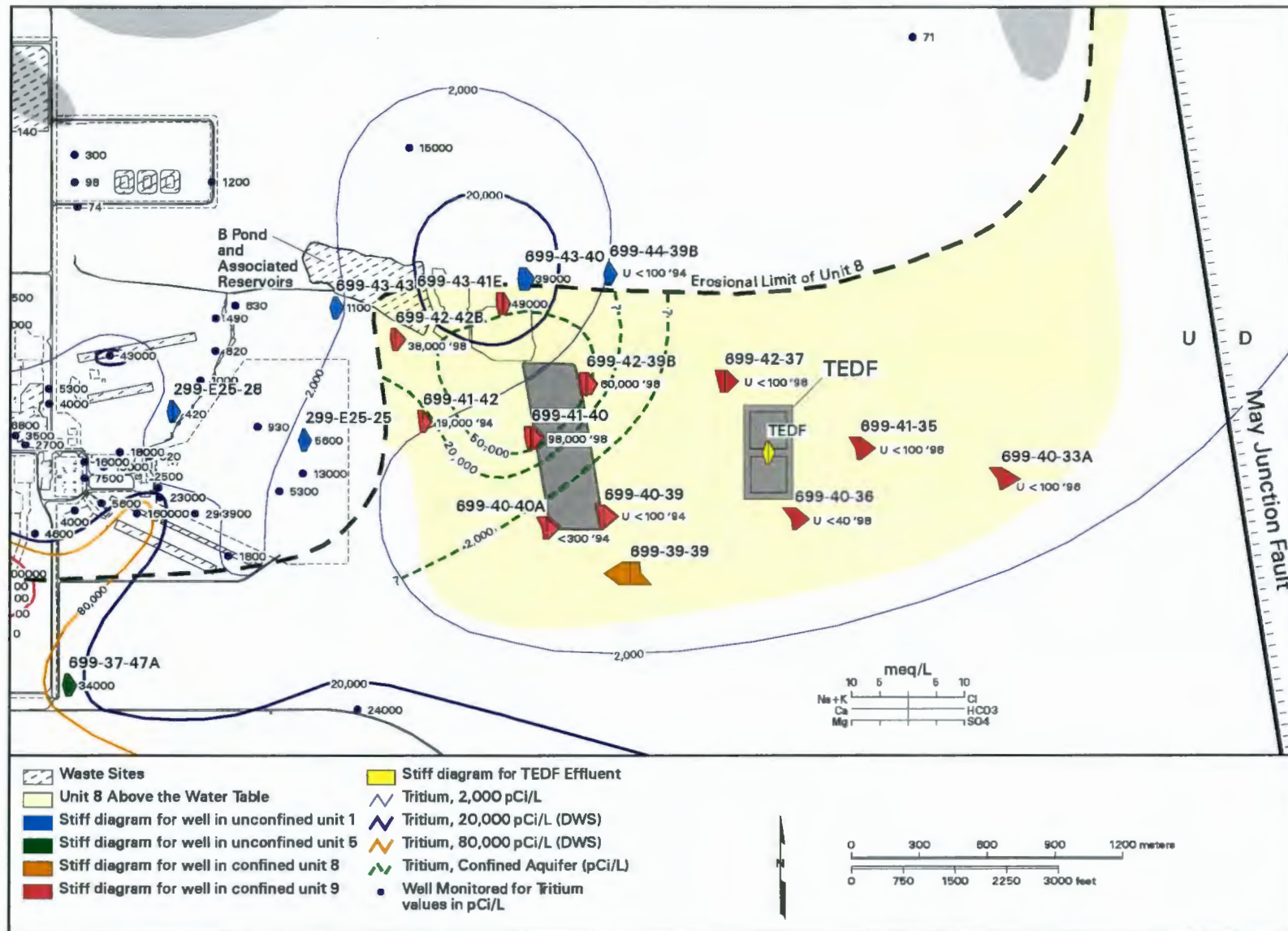


Figure 2.9-34. Water Levels in Wells 299-E25-28 (Ringold Formation Confined Aquifer) and 299-E25-34 (Unconfined Aquifer)



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Figure 2.9-35. Major Ion Chemistry and Tritium Concentrations for Confined and Unconfined Groundwater Near 216-B-3 Pond and 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. The reactor is on standby, pending a decision to restart it for the production of medical isotopes. Assessment efforts associated with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* 300-FF-2 Operable Unit will extend to include groundwater contamination in the 400 Area. 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 site-wide contamination.

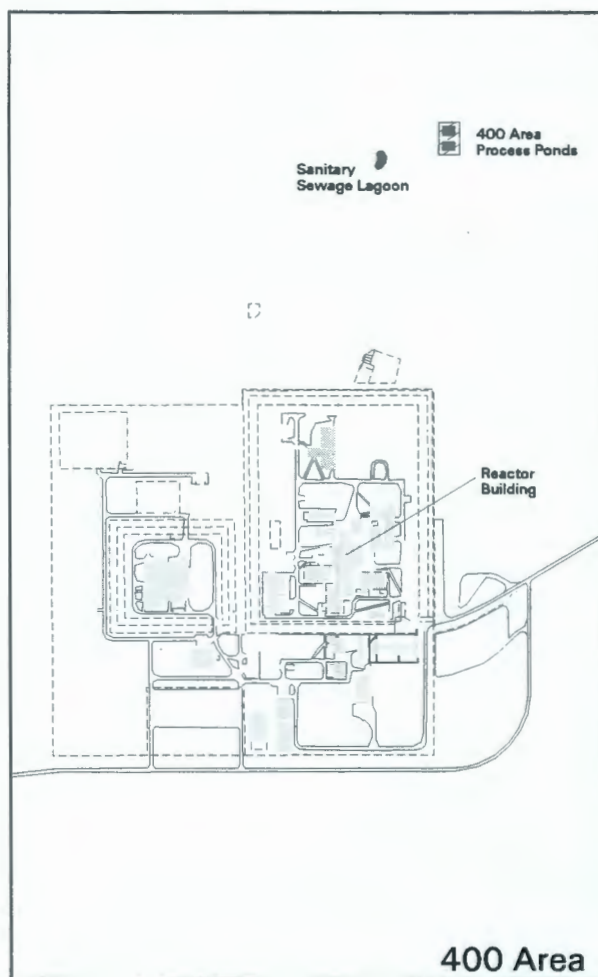
2.10.1 Groundwater Flow

The Hanford Site water-table map (see Plate 2) shows the groundwater-level 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

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.



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(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.

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) down-gradient to the process ponds. Elevated nitrate concentrations up to 92 mg/L (45-mg/L maximum contaminant level) were found in well 699-2-7 during fiscal year

1999 and are attributed to the sanitary sewage lagoon immediately west and upgradient of the process ponds (Figures 2.10-1 and 2.10-2). Groundwater samples associated with this well are also frequently elevated with respect to nitrite (Figure 2.10-3), which may have been generated by reduction of nitrate to nitrite as part of denitrification. All nitrite values are below the 3.3-mg/L maximum contaminant level, however. Disposal to the lagoon has been discontinued, and the

The 400 Area lies within the contaminant plume from the 200 Areas. Nitrate is the only contaminant with a source in the 400 Area.

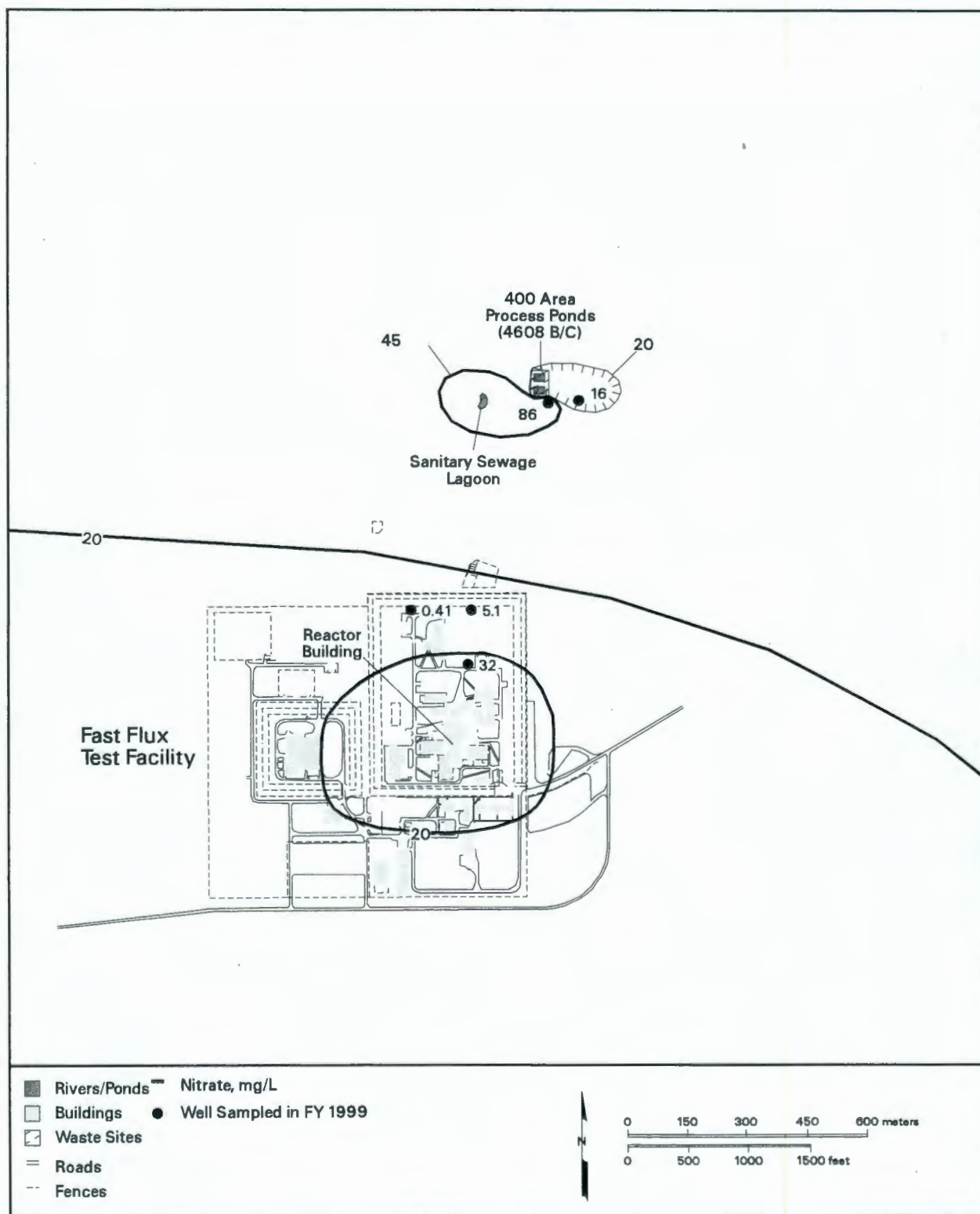
lagoon has been backfilled. Thus, groundwater contamination from this source is expected to diminish with time. Nitrate and nitrite concentrations in samples obtained from the new downgradient well 699-2-6A have not been significantly elevated relative to the upgradient well 699-8-17.

2.10.3 Tritium

Elevated levels of tritium (Figure 2.10-4) 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

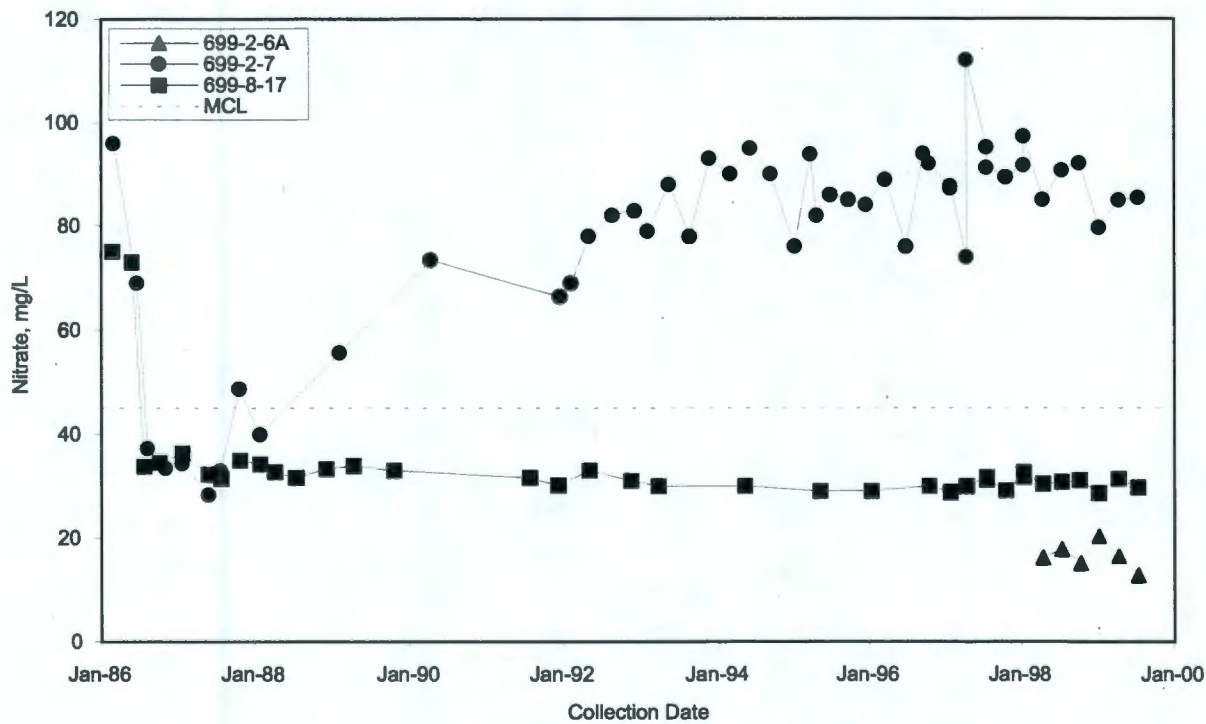
in previous years. This source of groundwater contamination is relevant to the water-supply wells, which provide drinking water and emergency supply water for the 400 Area. The tritium concentrations in wells 499-S0-7, 499-S0-8, and 499-S1-8J are compared in Figure 2.10-5 to that of the 400 Area drinking water supply. Tritium was found at levels at or above the 20,000-pCi/L interim drinking water standard in most samples from well 499-S0-7 during fiscal year 1999. Samples collected from well 499-S0-8 also exceeded the interim drinking water standard during the latter part of fiscal year 1999. All samples collected from well 499-S1-8J in fiscal year 1999 were below the interim drinking water standard. The lower concentrations of tritium north of the 400 Area are probably related to discharge at the process ponds.

Tritium remained below the 20,000-pCi/L interim 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 1999 (see Figure 2.10-5). Nitrate remained below the maximum contaminant level in fiscal year 1999 for the water-supply wells. Data from fiscal year 1999 and earlier from 400 Area and surrounding wells indicates no other constituents are present at levels above their maximum contaminant levels or interim drinking water standards.



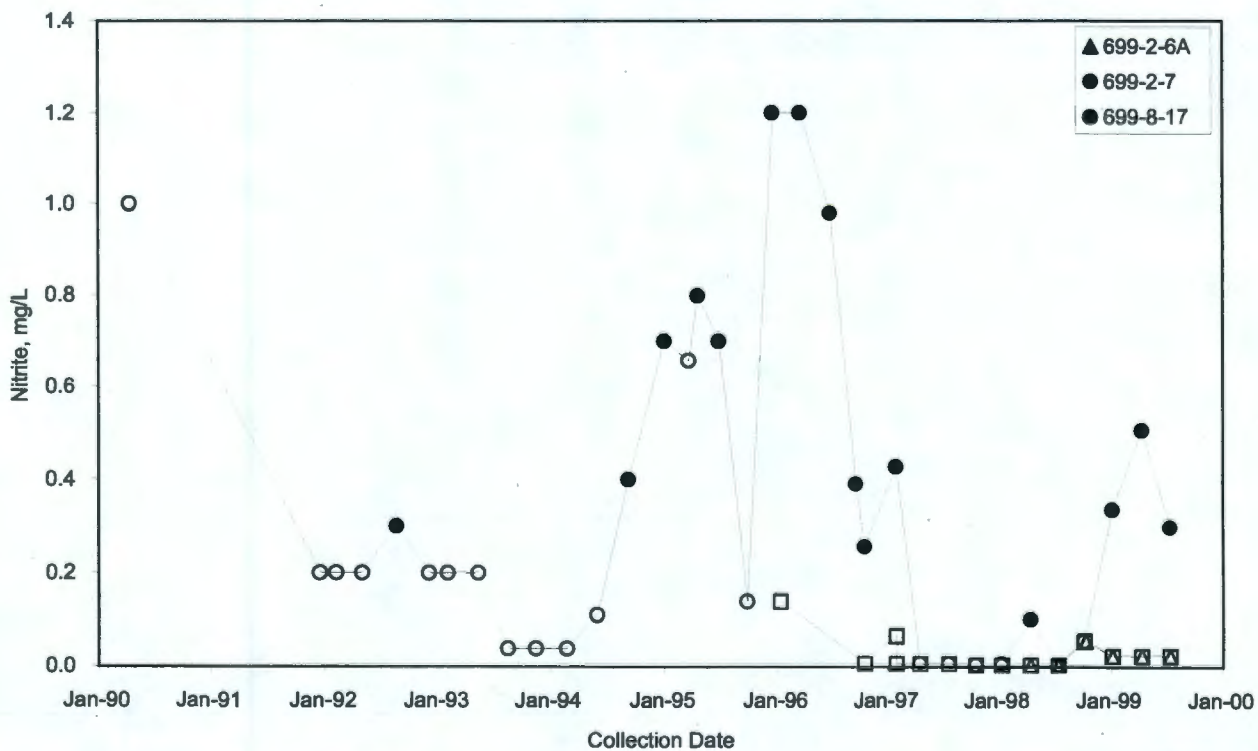
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Figure 2.10-1. Average Nitrate in Wells at 400 Area



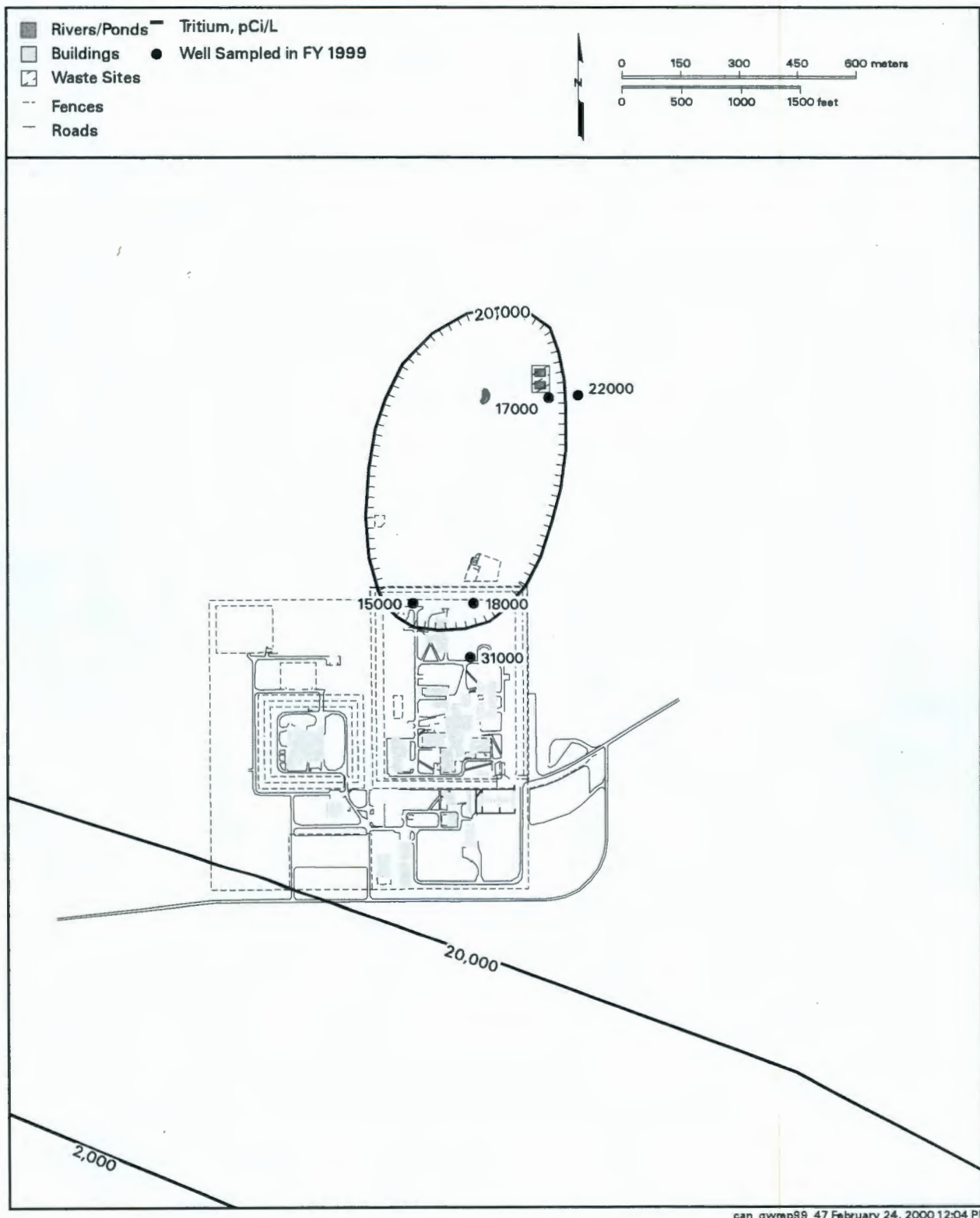
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Figure 2.10-2. Nitrate in 600 Area Wells Near 400 Area



MAC20045

Figure 2.10-3. Nitrite in 600 Area Wells Near 400 Area



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Figure 2.10-4. Average Tritium in Wells at 400 Area

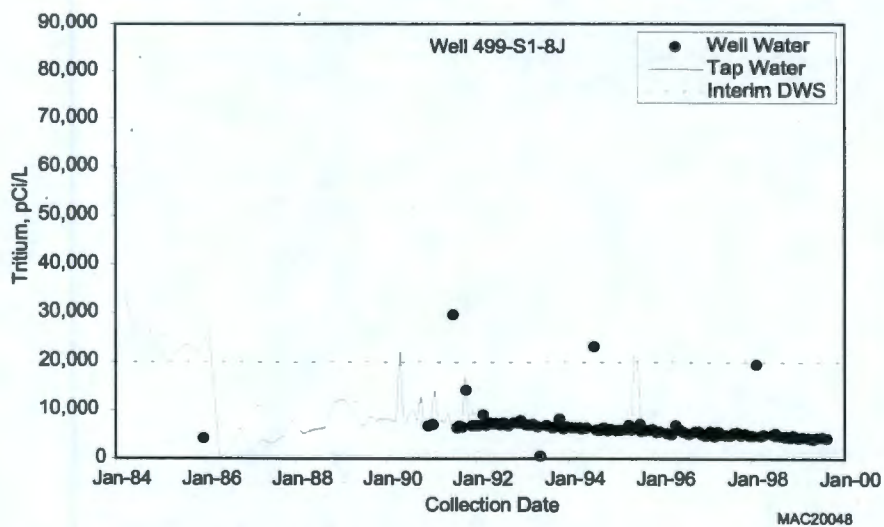
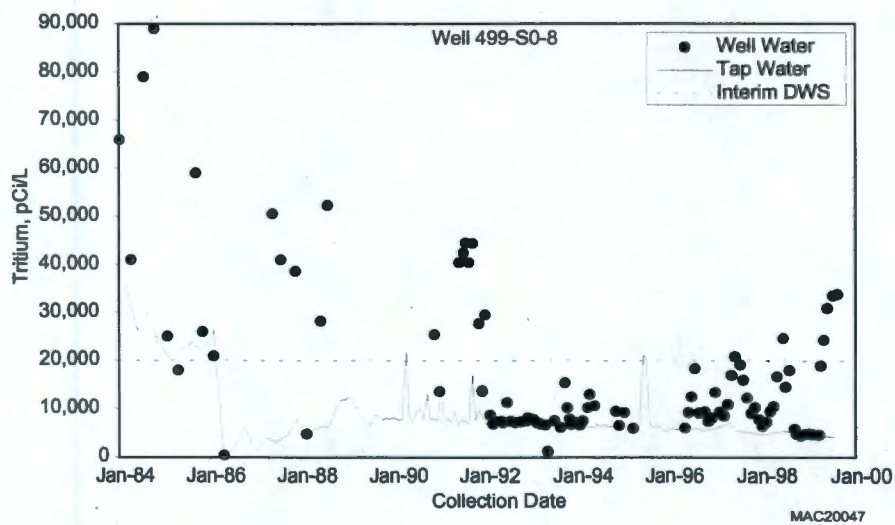
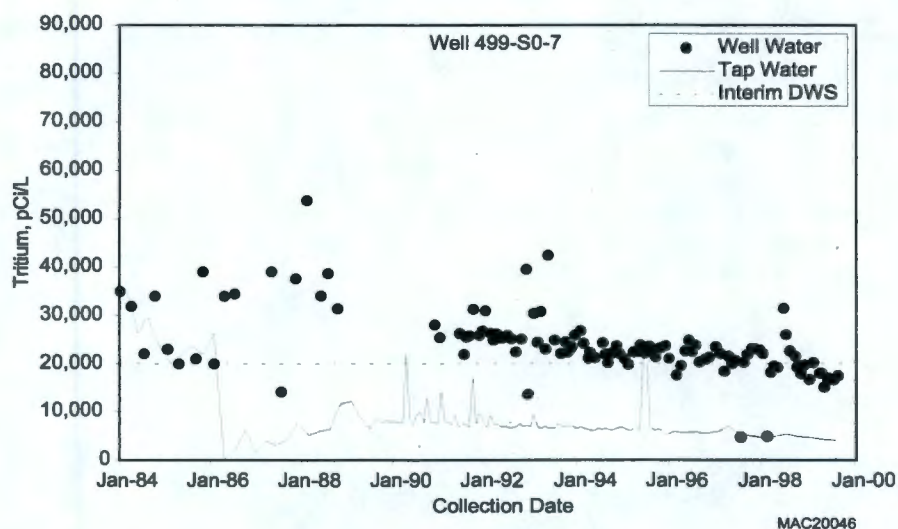


Figure 2.10-5. Comparison of Tritium Concentrations in 400 Area Drinking Water System

2.11 600 Area

J. W. Lindberg, P. E. Dresel

This section discusses groundwater contamination in the 600 Area including the following specific facilities: Nonradioactive Dangerous Waste Landfill, Solid Waste Landfill, Gable Mountain Pond, 618-10 burial ground, and 316-4 crib. Additional constituent information is provided for the Central plateau, western 600 Area, and 200-PO-1 Operable Unit.

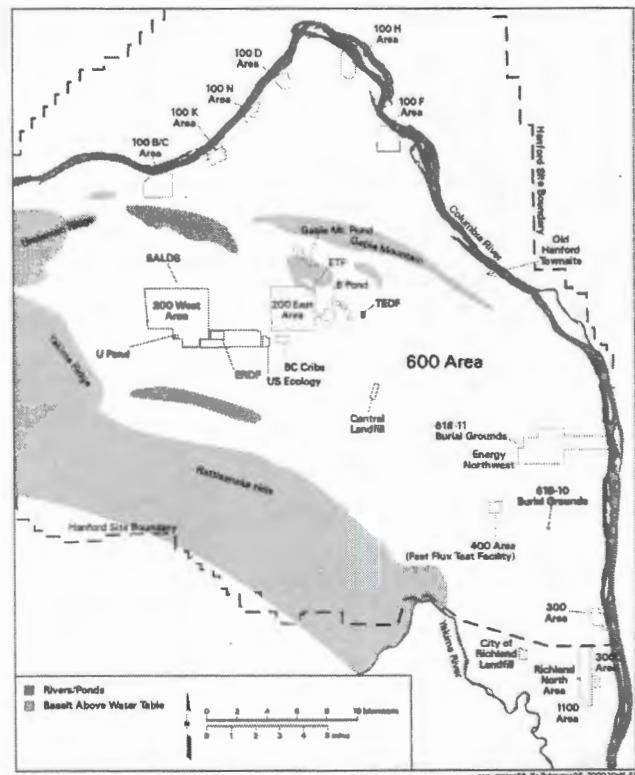
Monitoring Objectives in 600 Area

Groundwater monitoring is conducted in the 600 Area:

- ▶ triennially to annually to describe the nature and extent of contamination
- ▶ annually in "guard wells" to ensure that no unexpected contaminants migrate beyond the 200 Areas or into the Columbia River
- ▶ semiannually to detect possible impacts of the Nonradioactive Dangerous Waste Landfill RCRA Site
- ▶ quarterly to detect possible impacts of the Solid Waste Landfill.

2.11.1 Nonradioactive Dangerous Waste Landfill

The Nonradioactive Dangerous Waste Landfill is a Resource Conservation and Recovery Act of 1976 (RCRA) treatment, storage, and disposal facility regulated under an interim status, indicator parameters program. The Nonradioactive Dangerous Waste Landfill and the adjacent Solid Waste Landfill make up what is known as the Central Landfill.



2.11.1.1 Groundwater Flow

No new data concerning groundwater flow at the Central Landfill became available during fiscal year 1999.

Groundwater flow directions and flow rates 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, Section 17.0 in DOE/RL-91-03) in the vicinity of the Central Landfill. The flow rate estimated by the decrease in nitrate and tritium concentrations across the site is ~6 meters per day. For more information on groundwater flow rate and flow direction, see Table A.2.

Water-level data from two well pairs, sampling the top of the unconfined aquifer and the top of the Ringold Formation, indicate that the vertical gradient within the upper portion of the aquifer is negligible. The well pairs are 699-25-33A and 699-25-34A and 699-26-35A and 699-26-35C.

2.11.1.2 Resource Conservation and Recovery Act of 1976 Parameters

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). Chlorinated hydrocarbons are monitored because they may represent groundwater contamination originating from the Nonradioactive Dangerous Waste 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 above background.

The Nonradioactive Dangerous Waste Landfill, a RCRA site, showed no evidence of significant contamination under interim status monitoring.

The values for RCRA indicator parameters did not exceed their critical means in fiscal year 1999.

Six chlorinated hydrocarbons were detected in Nonradioactive Dangerous Waste Landfill network wells during fiscal year 1999 but none at concentrations exceeding the maximum contaminant levels. They include 1,1-dichloroethane, 1,2-dichloroethane, 1,1,1-trichloroethylene, carbon tetrachloride, tetrachloroethylene, and trichloroethylene. The source of the chlorinated hydrocarbons could be either from the Solid Waste Landfill (to the south) or the Nonradioactive Dangerous Waste Landfill. For example, tetrachloroethylene 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 (Section 5.2 of DOE/RL-93-88). It is possible that both of these sources potentially contribute to the contamination.

Tritium and nitrate were detected in all Nonradioactive Dangerous Waste Landfill network wells. Concentrations increase from the southwestern wells, lowest concentrations, to the northeast where concentrations are highest. The Nonradioactive Dangerous Waste Landfill is on the edge of the major tritium and nitrate plumes emanating from the 200 East Area (see Plate 3 and Figures 2.1-3 and 2.1-4). Both tritium and nitrate concentrations in the Nonradioactive Dangerous Waste Landfill network wells are decreasing with time.

2.11.2 Solid Waste Landfill

The Solid Waste Landfill is regulated by the Washington State Department of Ecology under WAC 173-304, *Washington Solid Waste Regulations*. WAC 173-304 parameters and site-specific parameters (including alkalinity, chlorinated hydrocarbons, gross alpha, gross beta, and tritium) are analyzed on groundwater samples collected quarterly. Groundwater flow was described in Section 2.11.1.

The Solid Waste Landfill has had little negative impact on Hanford Site groundwater, except minor chlorinated hydrocarbon contamination below drinking water standards but above WAC 173-200 levels, which are lower and applicable to the Solid Waste Landfill. Downgradient wells show higher specific

The Solid Waste Landfill is regulated under the Washington Administrative Code. The landfill has had little negative effect on groundwater quality. Low levels of hydrocarbons are detected in groundwater near this site and the adjacent Nonradioactive Dangerous Waste Landfill.

conductance, lower pH, and higher sulfate than upgradient wells. This is apparently a result of high concentrations of carbon dioxide in the vadose zone resulting from the degradation of sewage material beneath the Solid Waste Landfill (Section 5.3 of DOE/RL-93-88).

2.11.2.1 WAC 173-304 Parameters

Each WAC 173-304 parameter is discussed separately below. See Table A.48 for a complete list of all results for required constituents at the Solid Waste Landfill during fiscal year 1999.

- Temperature — Average values for replicate temperature determinations measured during sampling in downgradient wells ranged from 17.3 to 19.9 degrees Celsius. All measurements were below the background threshold value of 21 degrees Celsius. See Table A.49 for a total list of fiscal year 1999 background threshold values for WAC 173-304-required parameters.

- Specific conductance — Due to laboratory errors, many of the field measurements through May 1999 were determined to be unreliable. However, each time replicate field samples were collected, an additional sample was collected and analyzed in the laboratory as a backup. Therefore, laboratory derived data are used for specific conductance for three quarters of the data collected during fiscal year 1999.

Specific conductance measurements on samples from all of the Solid Waste Landfill downgradient wells exceeded the background threshold value of 550 $\mu\text{S}/\text{cm}$. The range was from 576 to 826 $\mu\text{S}/\text{cm}$. Monitoring wells 699-22-35 and 699-23-34B also exceeded the 700 $\mu\text{S}/\text{cm}$ standard (WAC 246-290-310) in fiscal year 1999 as they have in previous years. The August 1999 result for specific conductance also exceeded the 700 $\mu\text{S}/\text{cm}$ standard in well 699-24-34C.

- Constituent pH — Average values for replicate pH measurements in downgradient wells ranged from 6.6 to 7.4. None of the pH measurements exceeded the background threshold range of 6.2 to 8.46.

- Total organic carbon — The average of replicates for total organic carbon concentrations in downgradient wells ranged from below the method detection level, less than 220 to 965 $\mu\text{g}/\text{L}$. None of the reported values exceeded the 1,140 $\mu\text{g}/\text{L}$ background threshold value.
- Chloride — Chloride concentrations in downgradient wells ranged from 5,190 to 7,430 $\mu\text{g}/\text{L}$. The 9,045 $\mu\text{g}/\text{L}$ background threshold value was not exceeded.
- Nitrate — Nitrate concentrations in the downgradient wells ranged from 11 to 22 mg/L . Neither the 33.8 mg/L background threshold value nor the 45 mg/L maximum contaminant level were exceeded in any downgradient well. The source of nitrate at the Solid Waste Landfill is from upgradient sources in the 200 East Area.
- Nitrite and ammonium — Nitrite and ammonium concentrations in all downgradient wells were less than the method detection levels, 70 $\mu\text{g}/\text{L}$ for nitrite and 37 $\mu\text{g}/\text{L}$ for ammonium.
- Sulfate — Reported sulfate concentrations in downgradient wells ranged from 39 to 56 mg/L . Three samples from well 699-22-35 and four samples from well 699-23-34B exceeded the background threshold value of 51.5 mg/L . None of the samples exceeded the 250 mg/L standard (WAC 173-200).
- Filtered iron — Reported values for filtered iron ranged from 31.2 to 117.0 $\mu\text{g}/\text{L}$ in downgradient wells. None of the reported values exceeded the 160.0 $\mu\text{g}/\text{L}$ background threshold value.
- Filtered zinc — Reported values for filtered zinc ranged from 3.9 to 36.2 $\mu\text{g}/\text{L}$ in downgradient wells. Only the reported value of 36.2 $\mu\text{g}/\text{L}$ in well 699-24-34C in December 1998 exceeded the 34.0 $\mu\text{g}/\text{L}$ background threshold value.
- Filtered manganese — Reported values for filtered manganese in downgradient wells ranged from less than 3 to 9.2 $\mu\text{g}/\text{L}$. None of the reported values in downgradient wells exceeded the 11.0 $\mu\text{g}/\text{L}$ background threshold value.

- Chemical oxygen demand — Values for chemical oxygen demand in downgradient wells were reported to be less than 3,820 µg/L, the method detection limit, except for those samples collected in May 1999. The May 1999 values were all above the 5,000 µg/L background threshold values, but are suspect due to laboratory errors.
- Coliform bacteria (most probable number) — The reported values for coliform bacteria were all non-detections (i.e., 0.0 colonies per 100 milliliters), and, therefore, the background threshold value of 16 colonies per 100 milliliters was not exceeded in any downgradient wells.

2.11.2.2 Site-Specific Parameters

Site-specific parameters at the Solid Waste Landfill include chlorinated hydrocarbons, gross alpha, gross beta, and tritium. Elevated concentrations of chlorinated hydrocarbons continue to be detected at the Solid Waste Landfill during fiscal year 1999. Several 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

- carbon tetrachloride
- 1,1-dichloroethane
- 1,4-dichlorobenzene
- trichloroethylene
- chloroform
- 1,2-dichloroethane
- tetrachloroethylene
- 1,1,1-trichloroethane.

Of those detected, only chloroform and 1,4-dichlorobenzene did not equal or exceed 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.

Gross alpha and gross beta were detected in most of the upgradient and downgradient wells at the Solid Waste Landfill. However, neither exceeded the interim drinking water standards, 15 pCi/L for gross alpha and 50 pCi/L for gross beta. The range of reported gross alpha values was 2.27 to 7.95 pCi/L. The range for gross beta was 9.9 to 17.1 pCi/L.

Tritium, which has a source in the 200 East Area (see Section 2.9.2.2), is highest in concentration in the northeast and lowest to the southwest, corresponding to position on the edge of the major plume emanating from the 200 East Area. Although the overall levels are decreasing gradually with time, five Solid Waste Landfill monitoring wells have tritium levels that remain greater than the 20,000 pCi/L interim drinking water standard. The maximum concentration level reported during fiscal year 1998 was 91,400 pCi/L. During fiscal year 1999, the maximum reported was 73,700 pCi/L.

2.11.3 Gable Mountain Pond

Gable Mountain Pond is located in the area between the 200 East Area and Gable Mountain. Beneath the southern portion of the pond, basalt bedrock is above the water table. Beneath the northern portion of the pond, the groundwater flow direction is probably to the west based on the water-table map (see Plate 2).

Strontium-90 concentrations reversed a rising trend over the last few years in several wells near Gable

The former Gable Mountain Pond contaminated groundwater with strontium-90. Levels declined in fiscal year 1999.

Mountain Pond. No wells sampled in fiscal year 1999 had concentrations greater than the derived concentration guide (Figure 2.11-1), though concentrations were greater than the derived concentration guide in fiscal year 1998. Examples of the trends are shown for wells 699-53-47B and 699-53-48A in Figure 2.11-2. The maximum annual average strontium-90 concentration detected in the pond area in fiscal year 1999 was 948 pCi/L in well 699-53-47B. The interim drinking water standard is 8.0 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.

Nitrate continued to be detected in wells monitoring Gable Mountain Pond at levels above the maximum contaminant level in fiscal year 1999. Well 699-53-48B contained 402 mg/L of nitrate, which was the maximum detected in Gable Mountain Pond vicinity. This sample also contained 4.3 mg/L nitrite (as NO_2^-), slightly above the maximum contaminant level. Nitrite, however, was not detected in nearby well 699-53-48A suggesting that the presence of nitrite may be affected by highly localized reducing conditions.

2.11.4 618-10 Burial Ground and 316-4 Crib

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 2). This site was investigated as part of a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) limited field investigation for the 300-FF-2 Operable Unit (DOE/RL-96-42). In fiscal year 1995, high levels of uranium, 768 $\mu\text{g/L}$ unfiltered, were detected in well 699-S6-E4A, which is adjacent to both the burial ground and crib. The presence of hydrocarbon contamination was detected also in well 699-S6-E4A and included

- 104 mg/L total petroleum hydrocarbon
- ~770 to 1,800 $\mu\text{g/L}$ alkane and assorted decanes
- ~3,200 $\mu\text{g/L}$ unknown volatile organics.

Subsequently, tributyl phosphate was detected in well 699-S6-E4A. 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, and the source of such contamination is primarily the crib, with possibly some contribution from the burial ground.

Uranium in well 699-S6-E4A appears to have leveled off at a fiscal year 1999 average value of 92 $\mu\text{g/L}$ (Figure 2.11-3). This uranium is highly depleted in uranium-234 and uranium-235. The uranium isotopic composition for this well is compared to natural abundance and to an average of 24 samples from 200 Area wells in Table 2.11-2. 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.

Tributyl phosphate concentrations reported in well 699-S6-E4A have been highly erratic (Figure 2.11-4). The reasons for the erratic concentrations have not been established but may be related to the petroleum hydrocarbons detected in the past.

During fiscal year 1996, well 699-S6-E4C (previously completed in multiple zones) was re-configured to provide two deep, depth-discrete, monitoring intervals within the Hanford/Ringold aquifer system that, in conjunction with shallow monitoring wells 699-S6-E4B and 699-S6-E4D, provided information on the vertical distribution of contaminants at this location. The two monitored intervals are piezometers 699-S6-E4CT at 26 meters below the water table and 699-S6-E4CS at 50 meters below the water table. Tritium concentrations at the water table in fiscal year 1999 were 23,600 pCi/L in well 699-S6-E4D. Tritium concentrations in piezometer 699-S6-E4CT declined from 27,800 pCi/L shortly after reconfiguration in fiscal year 1996 to 6,691 pCi/L in fiscal year 1999. Tritium

values for piezometer 699-S6-E4CS were still lower at 421 pCi/L in fiscal year 1999. This suggests that the earlier value resulted from intercommunication down the well bore prior to reconfiguration. Continued monitoring, as the well effect dissipates, is needed to determine the tritium value at these depths. However, preliminary results indicate that the highest concentrations of tritium are near the water table and concentrations decrease with depth.

2.11.5 618-11 Burial Ground

In January 1999, a sample from well 699-13-3A, located along the eastern (downgradient) fence line of the 618-11 burial ground, contained 1.86 million pCi/L of tritium (see Plate 3). This value is far higher than data found from the surrounding wells. The value was confirmed by re-analysis. A January 2000 sample contained 8.1 million pCi/L of tritium. This is the highest concentration of tritium detected onsite in recent years. The January 1999 sample collected from this well was the first sample to find tritium. A special investigation of the groundwater at the 618-11 burial ground is being undertaken in fiscal year 2000 to define the source of the high tritium results.

This 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., uranium, cesium, strontium, curium, cobalt-60, zirconium, and plutonium). Other contaminants that might be encountered include thorium, beryllium, aluminum-lithium, carbon tetrachloride, hydrogen gas, and sodium-potassium eutectic.

Well 699-13-3A was drilled and first sampled in 1995. Radionuclides analyzed at least once in this well include tritium, uranium, cesium-137, cobalt-60, europium-152, europium-154, and europium-155. No radionuclides have been detected at levels above drinking water standards except for the tritium discussed above. Gross alpha measurements have all been less

than 9 pCi/L. Gross beta measurements are all less than 30 pCi/L but have shown a slight increasing trend (Figure 2.11-5). No organic chemical constituents have been detected. No other constituents have been detected at levels above primary maximum contaminant levels. Aluminum, iron, and manganese have been detected at levels above secondary maximum contaminant levels in unfiltered samples. Only aluminum was above the secondary maximum contaminant level in fiscal year 1999. Manganese was detected in filtered samples at levels above the secondary maximum contaminant level in fiscal year 1996 (64.5 to 69.3 µg/L).

2.11.6 Central Plateau

Chromium is frequently detected in filtered samples south of the 200 East Area. In recent years, concentrations in well 699-32-62 have been above the maximum contaminant level, but this well was not sampled in fiscal year 1999. The sources and extent of this contamination are uncertain. 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 is particularly poorly defined. See PNNL-13080 for further details.

2.11.7 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 was detected in wells in the western part of the site, but the levels remained lower than the maximum contaminant level in fiscal year 1999 with the exception of well 699-17-70 (54 mg/L), located 6 kilometers south-southeast of the 200 West Area (Figure 2.11-6). 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 to the south of the ridge (see Plate 2). 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.

2.11.8 200-PO-1 Operable Unit

The 200-PO-1 Operable Unit encompasses the area bounded by the 2,000 pCi/L isopleth of the major Hanford Site tritium plume originating from the

200 East Area and extending eastward and southeastward to the Columbia River (see Plate 3). This area also contains the far-field well network of the PUREX cribs RCRA facility (see Section 2.9.2.7). The purpose of the 200-PO-1 Operable Unit and PUREX cribs well networks is to monitor the extent and concentration of the three major plumes of groundwater contamination extending east and southeastward from the 200 East Area. The three major plumes are iodine-129 (see Figure 2.1-6), nitrate (see Figure 2.1-4), and tritium (see Plate 3). They are described with their source area in Section 2.9.2.

Table 2.11-1. Ranges of Chlorinated Hydrocarbon Concentrations (µg/L) in Groundwater at the Solid Waste Landfill, December 1998 to August 1999

Constituent	Limit (µg/L)	699-22-35	699-23-34A	699-23-34B	699-24-33	699-24-34A
Carbon tetrachloride	WAC 0.3	<0.02 - 0.2	<0.2 - <0.45	<0.02 - 0.5	<0.02 - <0.45	<0.02 - <0.45
Chloroform	WAC 7.0	0.6 - 0.8	<0.03 - 0.4	<0.03 - 1.0	<0.03 - 0.3	<0.03 - 0.2
1,1-Dichloroethane	WAC 1.0	2.0 - 3.0	2.0 - 4.0	2.0 - 5.0	1.0 - 2.0	0.6 - 2.0
1,2-Dichloroethane	WAC 0.5	<0.02 - <0.22	<0.02 - <0.22	<0.22 - 1.0	<0.02 - <0.22	<0.02 - <0.22
1,4-Dichlorobenzene	WAC 4.0	<0.03 - <0.17	0.2 - 1.0	<0.03 - <0.17	<0.03 - <0.17	<0.03 - <0.17
cis-1,2-Dichloroethylene	MCL 70	<0.02 - <0.37	<0.02 - <0.37	<0.02 - <0.37	<0.02 - <0.37	<0.02 - <0.37
trans-1,2-Dichloroethylene	MCL 100	<0.03 - <0.33	<0.03 - <0.33	<0.03 - <0.33	<0.03 - <0.33	<0.03 - <0.33
Tetrachloroethylene	WAC 0.8	1	2.0 - 10.0	1.0 - 7.0	2.0 - 11.0	2.0 - 9.0
Total organic halides	NA	2.7 - 11.5	3.05 - 8.7	6.7 - 16.3	3.5 - 7.9	<2.38 - 8.85
Trichloroethylene	WAC 3.0	0.8	0.7 - 3.0	0.6 - 2.0	1.0 - 3.0	0.7 - 2.0
1,1,1-Trichloroethane	WAC 0.2	5.0 - 7.0	4.0 - 13.0	4.0 - 16.0	3.0 - 9.0	3.0 - 10.0
1,1,2-Trichloroethane	MCL 5.0	<0.04 - <0.27	<0.04 - <0.27	<0.04 - <0.27	<0.04 - <0.27	<0.04 - <0.27
Constituent	Limit (µg/L)	699-24-34B	699-24-34C	699-24-35	699-25-34C	699-26-35A
Carbon tetrachloride	WAC 0.3	<0.02 - <0.45	<0.02 - 0.2	<0.02 - <0.45	<0.02 - 0.4	<0.2 - 0.5
Chloroform	WAC 7.0	<0.03 - 0.3	<0.03 - 0.3	<0.03 - <0.29	<0.03 - 0.6	<0.03 - 1.0
1,1-Dichloroethane	WAC 1.0	<1.0 - 2.0	<1.0 - 2.0	0.4 - 0.8	0.4 - 1.0	<0.18 - 0.3
1,2-Dichloroethane	WAC 0.5	<0.02 - <0.22	<0.02 - <0.22	<0.02 - <0.22	<0.02 - <0.22	<0.22 - 1.0
1,4-Dichlorobenzene	WAC 4.0	<0.03 - 0.4	<0.03 - <0.17	<0.03 - <0.17	<0.03 - <0.17	<0.03 - <0.17
cis-1,2-Dichloroethylene	MCL 70	<0.02 - <0.37	<0.02 - <0.37	<0.02 - <0.37	<0.02 - <0.37	<0.02 - <0.37
trans-1,2-Dichloroethylene	MCL 100	<0.03 - <0.33	<0.03 - <0.33	<0.03 - <0.33	<0.03 - <0.33	<0.03 - <0.33
Tetrachloroethylene	WAC 0.8	2.0 - 9.0	1.0 - 9.0	<0.03 - 3.0	<0.03 - 7.0	<0.03 - 3.0
Total organic halides	NA	4.1 - 6.95	2.65 - 12.7	<2.38 - 7.9	<2.38 - 5.95	3.25 - 6.9
Trichloroethylene	WAC 3.0	0.7 - 2.0	0.7 - 2.0	<0.03 - 1.0	0.7 - 3.0	<0.03 - 1.0
1,1,1-Trichloroethane	WAC 0.2	2.0 - 8.0	2.0 - 7.0	2.0 - 6.0	1.0 - 5.0	<0.34 - 4.0
1,1,2-Trichloroethane	MCL 5.0	<0.04 - <0.27	<0.04 - <0.27	<0.04 - <0.27	<0.04 - <0.27	<0.04 - 0.27

(a) WAC = Washington Administrative Code.

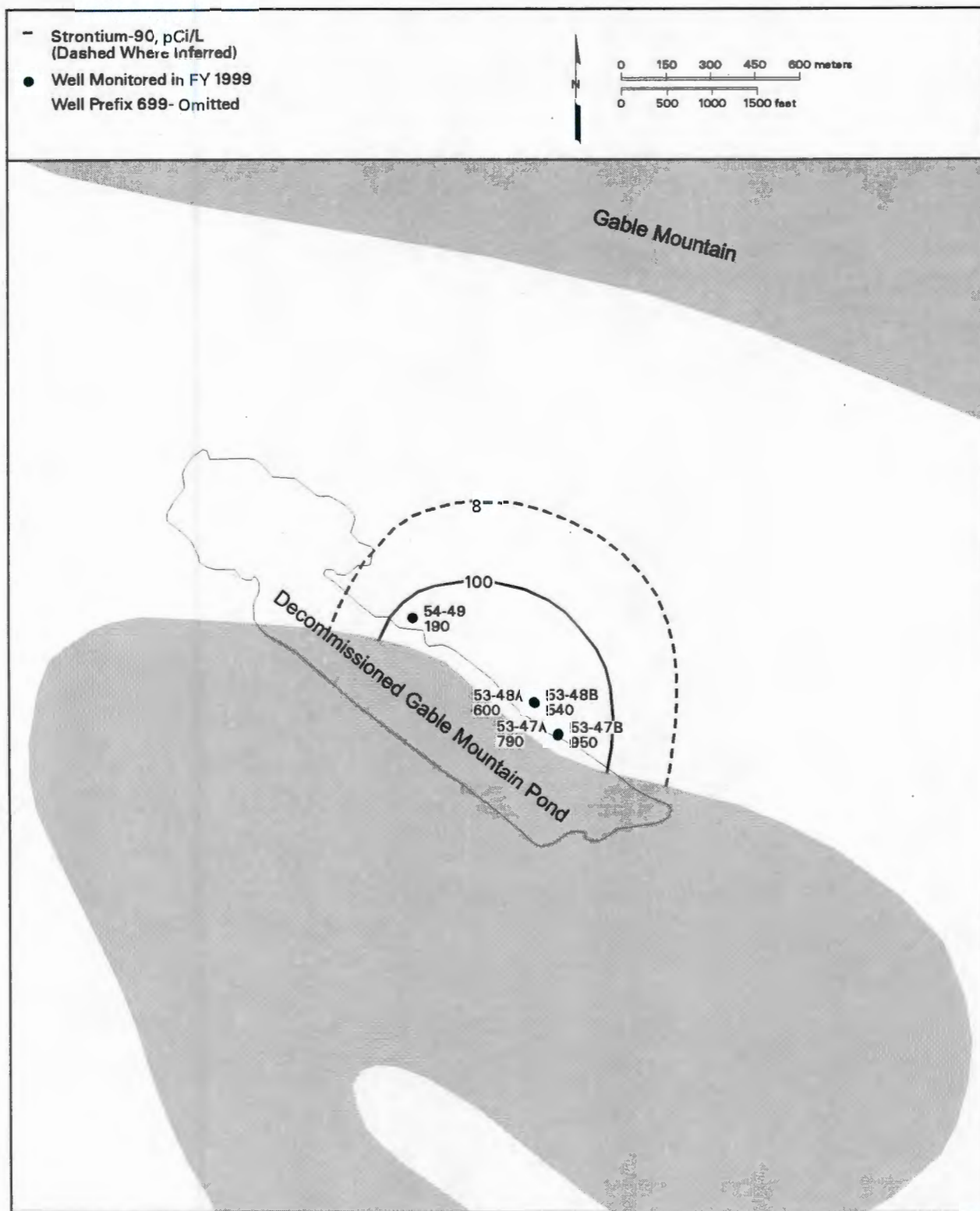
MCL = Maximum contaminant level.

NA = Not applicable.

Values in bold type equal or exceed WAC 173-200-40.

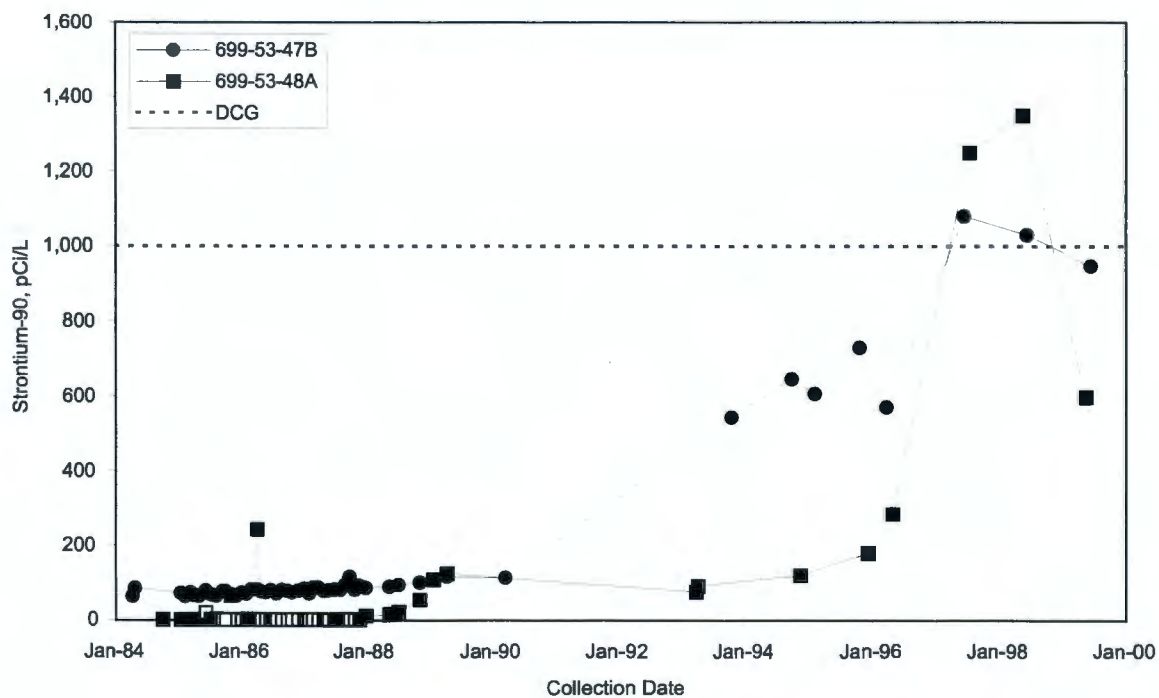
Table 2.11-2. Uranium Isotopic Composition in Well 699-S6-E4A

<u>Well Name</u>	<u>Sample Date</u>	<u>Sample Time</u>	<u>U-234 (µg/L)</u>	<u>U-235 (µg/L)</u>	<u>U-236 (µg/L)</u>	<u>U-238 (µg/L)</u>	<u>Total U (µg/L)</u>
699-S6-E4A	1/25/99	12:27	0.003272	0.516064	0.001344	98.33263	98.853
			<u>U-234 Abundance (µg/L)</u>	<u>U-235 Abundance (µg/L)</u>	<u>U-236 Abundance (µg/L)</u>	<u>U-238 Abundance (µg/L)</u>	
699-S6-E4A			3.37E-05	5.29E-03	1.37E-05	9.95E-01	
Natural abundance			5.50E-05	7.20E-03	0.00E+00	9.93E-01	
Average 200 Area			6.30E-05	7.01E-03	4.44E-05	9.93E-01	



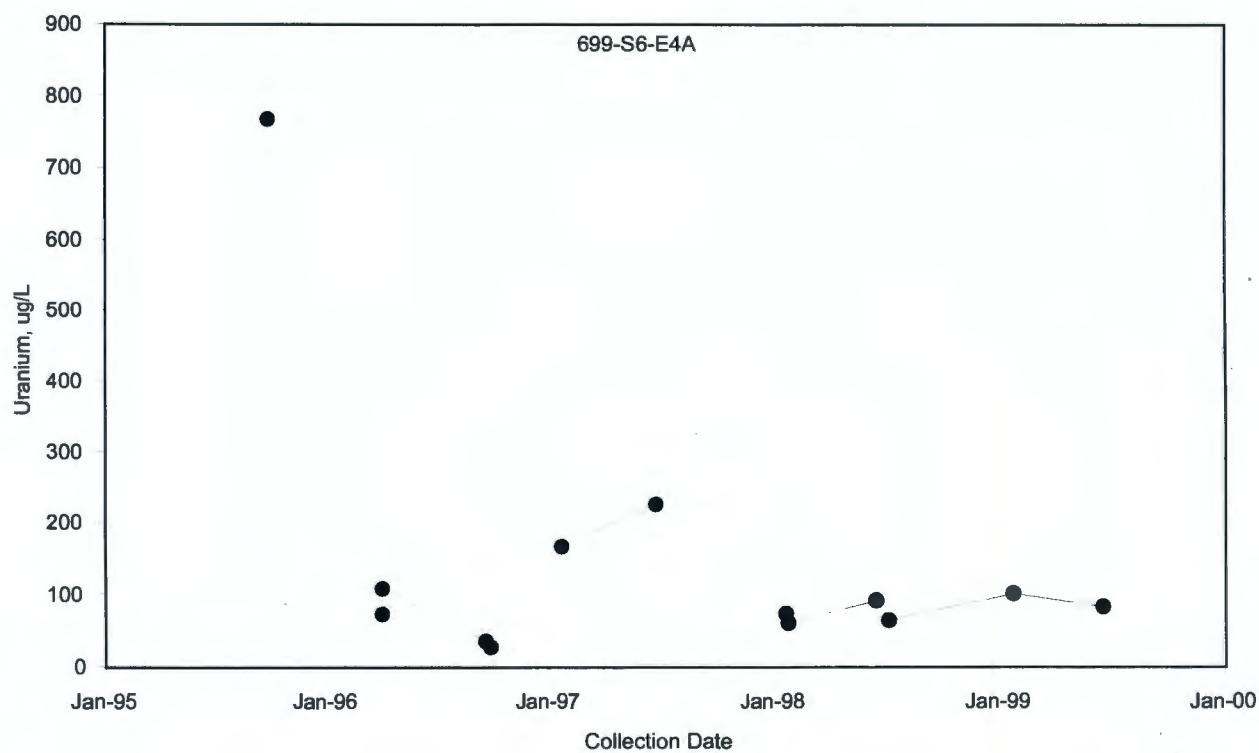
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Figure 2.11-1. Average Strontium-90 Concentrations at Gable Mountain Pond, Top of Unconfined Aquifer



JTR00021

Figure 2.11-2. Strontium-90 in Wells 699-53-47B and 699-53-48A Near Gable Mountain Pond



JTR00022

Figure 2.11-3. Uranium in Well 699-S6-E4A Near 618-10 Burial Ground

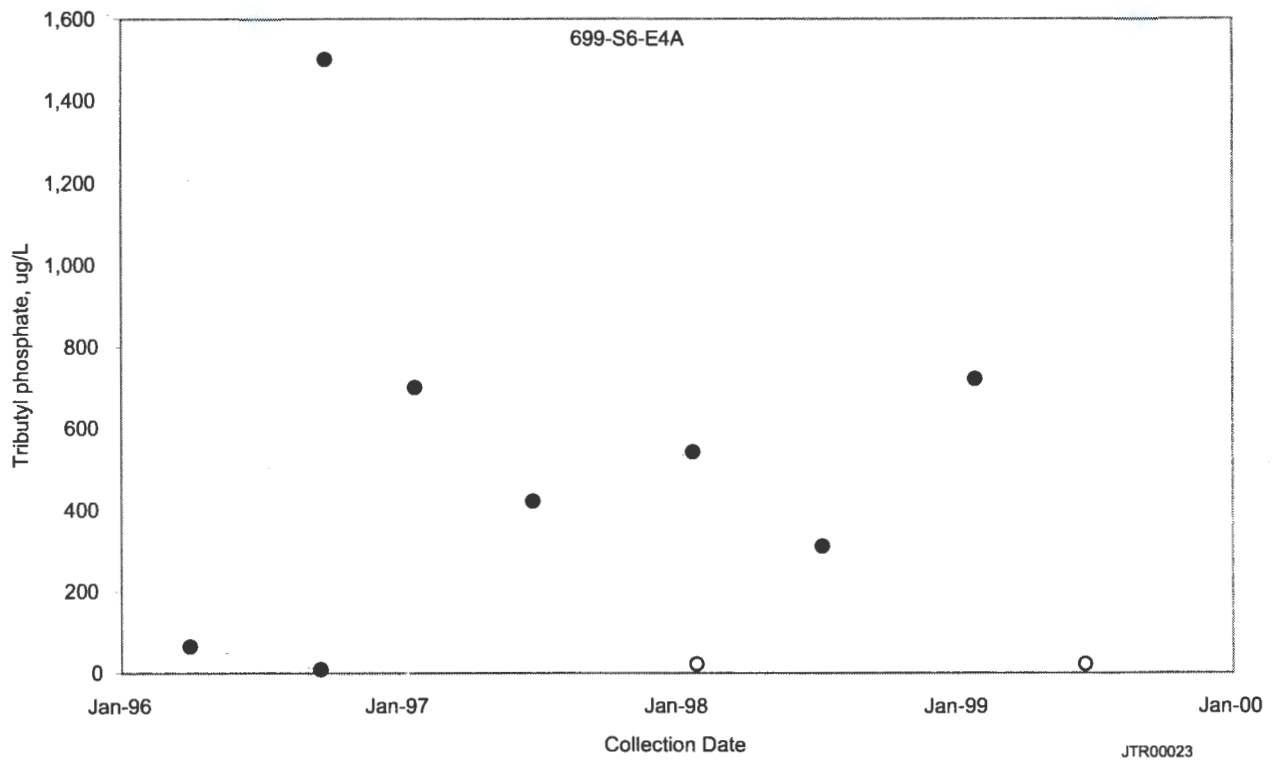


Figure 2.11-4. Tributyl Phosphate in Well 699-S6-E4A Near 618-10 Burial Ground

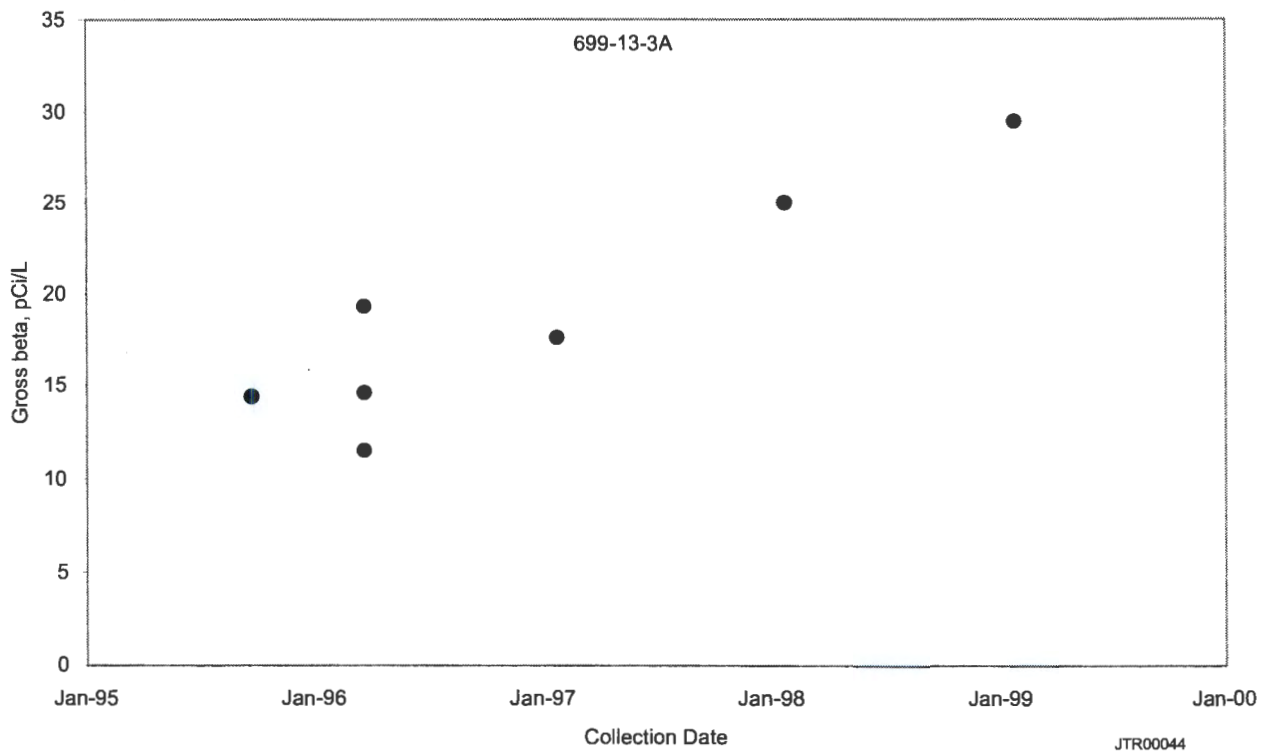
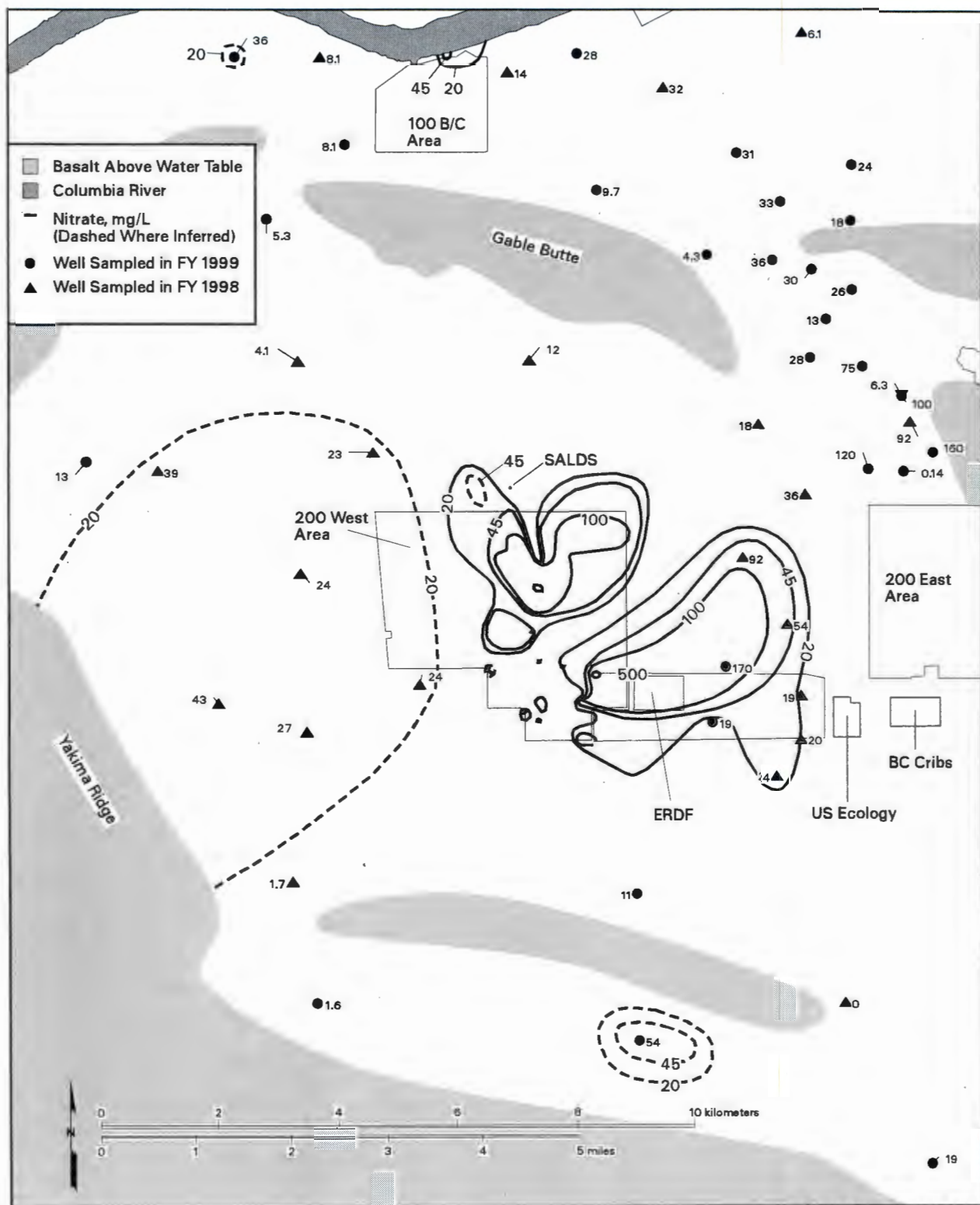


Figure 2.11-5. Gross Beta Concentrations in Well 699-13-3A Near 618-11 Burial Ground



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Figure 2.11-6. Average Nitrate Concentrations in Western 600 Area, Top of Unconfined Aquifer

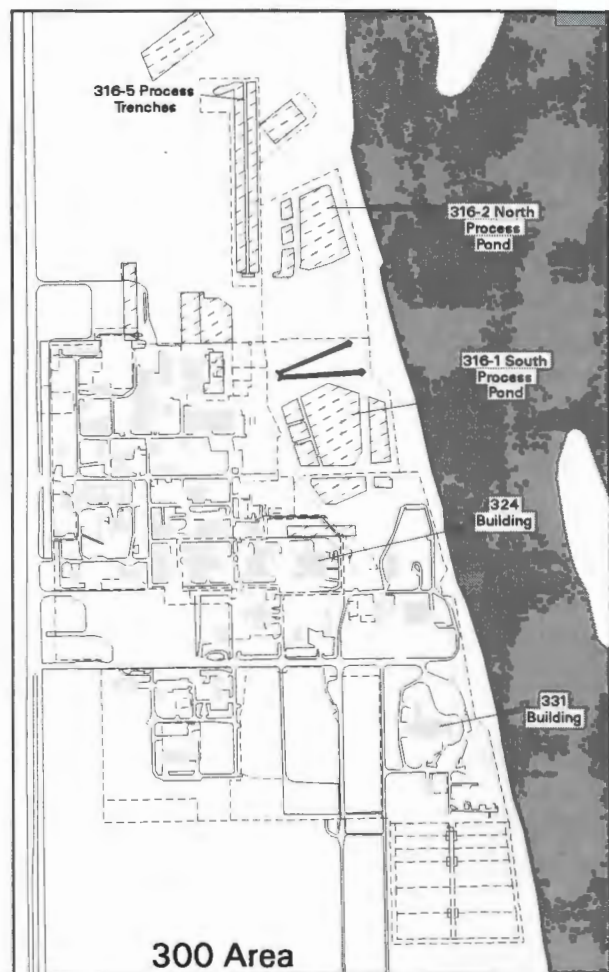
2.12 300 Area

J. W. Lindberg

Uranium is the major contaminant of concern in the 300 Area. Tritium contamination from the 200 East Area impacted the 300 Area at levels less than the interim drinking water standard (see Section 2.13). The 10,000-pCi/L isopleth line trends through the 300 Area and shows little change since fiscal year 1998. 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 1999 include cis-1,2-dichloroethylene, nitrate, strontium-90, tetrachloroethylene, and trichloroethylene.

2.12.1 Groundwater Flow

The primary influence on changes in groundwater elevation in the 300 Area is the fluctuation in Columbia River stage. Changes in river-stage elevation can be correlated to changes in water-level elevations at wells as far as ~360 meters from the river (PNL-8580). During fiscal year 1999, river-stage fluctuations were typical for an average year, and the water-table elevations and corresponding configuration of the water-table map for March 1999 (see Plate 2) were similar to March water-table maps of previous years. This configuration indicates a slight increase in river stage



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Monitoring Objectives in 300 Area

Groundwater monitoring is conducted in the 300 Area:

- ▶ annually to describe the nature and extent of contamination
- ▶ annually to monitor attenuation of contaminants in the groundwater operable unit
- ▶ semiannually to monitor attenuation of contaminants at one RCRA site.

over average. As an example, the March 1999 water-table map appears very similar to the March 31, 1992, water-table map (see Figure G-6 in DOE/RL-93-21, Rev. 0).

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 316-5 process trenches, the flow direction was southward during March 1999 based on the water-table contours. Flow rate there was 0.35

to 105 meters per day (see Table A.2) based on the March 1999 gradient. The southward flow direction is a response to the slight increase in river stage. Average river stage would produce a more southeastward flow direction in the vicinity of the 316-5 process trenches.

2.12.2 Uranium

The uranium distribution in the 300 Area is shown in Figure 2.12-1. The highest uranium concentrations are found in the northern part of the 300 Area, downgradient from the 316-5 process trenches and near the 316-1 process pond. Because the 316-1 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 (20- $\mu\text{g/L}$ proposed drinking water standard) detected in the 300 Area was 322 $\mu\text{g/L}$ in well 399-2-2 in the August 1999 sample. The line of wells from well 399-1-17A through well 399-1-7 to well 399-2-2 has the highest levels of uranium in the 300 Area (and this alignment is along the average groundwater flow direction from the 316-5 process trenches). This alignment suggests that the major source of the uranium contamination is the 316-5 process trenches.

Groundwater in the 300 Area is contaminated with uranium from the process trenches and ponds. Levels have fluctuated since the 1980s, but have declined overall.

Figure 2.12-2 shows the historical trend for uranium in well 399-1-17A, which is the well closest to the inflow portion of the 316-5 process trenches. 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 the process trench discharges ceased in December 1994. In fiscal years 1996 and 1997, the rise continued, though not at the rapid rate

it did in fiscal year 1995. The average uranium levels in fiscal year 1998 were lower than fiscal year 1997, and the levels in fiscal year 1999 were about the same or slightly less than fiscal year 1998.

Presumably, the amount of uranium found in the unconfined aquifer at the process trenches was diluted by the large quantities of process wastewater prior to January 1995. Because wastewater is no longer discharged to the trenches, the increase in uranium reported in groundwater samples indicates that uranium continues to contribute to groundwater contamination by the soil column at the 316-5 process trenches. The lack of dilution by large quantities of process wastewater caused the uranium in the groundwater to continue to rise during fiscal years 1996 and 1997 and remain elevated during fiscal years 1998 and 1999. The total uranium contribution by the soil column at the trenches during fiscal year 1999 may actually be the same, or even lower, than it was prior to January 1995.

Figure 2.12-2 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 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, immediately west of well 399-3-11. However, in recent years, the elevated zone of uranium has moved downgradient (southeast) (see Figure 2.12-1). In fiscal year 1996 the reported concentration of uranium in well 399-3-11 was 130 $\mu\text{g/L}$ (Figure 2.12-3). In fiscal years 1996 and 1997, the reported uranium concentrations in well 399-3-11, decreased from 130 to 32 $\mu\text{g/L}$. At the same time, well 399-4-9, downgradient from well 399-3-11, showed a corresponding increase in uranium concentration over the same years (74 to 130 $\mu\text{g/L}$) (see Figure 2.12-3). In fiscal year 1999, the reported concentration of uranium at well 399-3-11 was 44.4 $\mu\text{g/L}$, while the reported concentration at the downgradient well 399-4-9 continued to rise to 163 $\mu\text{g/L}$. Apparently,

the uranium high near the 324 Building has moved with the groundwater flow to a downgradient position along the Columbia River near well 399-4-9. However, there still appears to be a limited source of uranium near the 324 Building. It is also possible that the uranium near the 324 Building is actually not from the 324 Building but may be a pulse of uranium from farther north (e.g., from the 316-5 process trenches) moving downgradient.

2.12.3 Strontium-90

Strontium-90 (8-pCi/L interim drinking water standard) continues to be detected at well 399-3-11 near the 324 Building. However, the more recently measured concentrations are not as high as those recorded in December 1995 sampling (8.7 pCi/L). Since December 1995, strontium concentration has varied between 3 and 8 pCi/L. During fiscal year 1999, the recorded value was 4.0 pCi/L. Groundwater samples from well 399-3-11 are collected with a bailer and are not filtered. Thus it is possible that much of the strontium-90 is sorbed to sediment in the sample. Although there may have been a release of strontium-90 in the vicinity of the 324 Building, the reported concentration of 8.7 pCi/L in December 1995 was the only result greater than the interim drinking water standard since 1986.

2.12.4 Chlorinated Hydrocarbons

Trichloroethylene was detected at 24 wells in the 300 Area in fiscal year 1999. However, only two had reported concentrations at or above the drinking water standard of 5.0 µg/L. The two wells are 399-1-16B and 399-4-1. Well 399-1-16B is downgradient of the 316-5 process trenches and monitors the lower portion of the unconfined aquifer. The plume downgradient of the 316-5 process trenches is decreasing in concentration as shown in Figure 2.12-4. In fiscal year 1998, the high concentration at well 399-1-16B was 8.0 µg/L. During fiscal year 1999, the concentration of trichloroethylene at well 399-1-16B decreased from 6.0 µg/L in January and February to 4.0 µg/L later in July through September.

Well 399-4-1 is in the southern part of the 300 Area. The source of the trichloroethylene at well 399-4-1 may be the extreme distal portion of the plume from off the Hanford Site to the southwest (Figure 2.12-5 and Section 2.13.4), or more likely, it may be a part of the plume from the 316-5 process trenches. Well 399-4-1 is downgradient of the process trenches because of the south and southwestern component to the groundwater flow direction when the Columbia River stage is high. The plume from the process trenches is the most likely source because the trend of trichloroethylene in well 399-4-1 has been generally decreasing since 1986, a time before the offsite plume approached the 300 Area (Figure 2.12-6). During fiscal year 1999, the reported values of trichloroethylene in well 399-4-1 were 5.0 µg/L in January 1999 and 2.0 µg/L in August 1999.

Trichloroethylene and other chlorinated hydrocarbons are detected in the 300 Area. Levels are declining by natural processes.

A plume of cis-1,2-dichloroethylene was detected at six 300 Area wells, but the reported concentrations exceeded the 70 µg/L drinking water standard in only one well, 399-1-16B. Like trichloroethylene, the source of cis-1,2-dichloroethylene is the 316-5 process trenches. The concentration was at its maximum during fiscal years 1997 and 1998 and decreased slightly during fiscal year 1999 (Figure 2.12-7). During fiscal year 1999, the concentration at well 399-1-16B ranged from 120 to 180 µg/L with the higher reported values at the beginning of the year.

A plume of tetrachloroethylene was detected in the 300 Area during fiscal year 1998. Its source is in the vicinity of the 316-5 process trenches and extends southeast to the Columbia River. The plume continued during fiscal year 1999 (Figure 2.12-8), but the concentration within the plume decreased dramatically (Figure 2.12-9). The maximum reported value at well 399-1-17A, immediately downgradient of the process trenches, was 38 µg/L in fiscal year 1998. The

maximum value at the same well in fiscal year 1999 was 4.0 µg/L. The plume maximum during fiscal year 1999 was 7.0 µg/L at well 399-1-16A, but the yearly average was only 1.8 µg/L.

2.12.5 Nitrate

Nitrate (above background levels, WHC-EP-0595, Table A-1-2) is detected in all wells sampled in the 300 Area (Figure 2.12-10). However, only two of those wells reported nitrate concentrations greater than the 45 mg/L drinking water standards. The wells that reported concentrations greater than the drinking water standard were 399-5-1 and 699-S27-E14 (in the southwestern and southern portions of the 300 Area). The source of the nitrate is probably offsite industry and agriculture (Section 2.13).

2.12.6 316-5 Process Trenches RCRA Parameters

The 316-5 process trenches have been monitored by a *Resource Conservation and Recovery Act of 1976* (RCRA) final status corrective-action network since December 1996. Corrective action is in conjunction with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (see Section 2.12.7). The purpose of groundwater monitoring is to examine the trend of the constituents of concern to determine if they are decreasing in concentration as expected. Eight wells are monitored for uranium and volatile organics (including as a minimum trichloroethylene and cis-1,2-dichloroethylene). During fiscal year 1999, uranium remained above the interim drinking water standard of 20 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. Cis-1,2-dichloroethylene and trichloroethylene were both found to be above the drinking water standard in well 399-1-16B. Tetrachloroethylene was above the 5 µg/L drinking water standard at 7 µg/L in well 399-1-16A in December 1998, but dropped in concentration to below the detection level starting in June 1998. Uranium, as well as cis-1,2-dichloroethylene and trichloroethylene, appear to be decreasing slightly in concentration when their trends are compared over several years. For more information about uranium and the volatile organics, see Sections 2.12.2 and 2.12.4.

2.12.7 300-FF-1 and 300-FF-5 Operable Units

The interim record of decision for the 300-FF-1 and 300-FF-5 Operable Units was approved in July 1996 (ROD 1996b). The selected remedy for the 300-FF-5 Operable Unit is an interim action that involves emplacing security measures to prevent exposures to residual contamination; imposing restriction on the use of the groundwater until such time as health-based criteria are met for uranium, trichloroethylene, and cis-1,2-dichloroethylene; and allowing contaminants in the groundwater to naturally diminish over time.

In fiscal year 1997, remediation of 300-FF-1 Operable Unit started by digging out the contaminated soil at the 316-5 process trenches. By the end of fiscal year 1999, the contaminated soil from the 316-5 process trenches had been completely removed and replaced with clean soil. Also, by the end of fiscal year 1999, the contaminated soil had been completely removed from the 316-2 north process pond and was partially removed at the 316-1 south process pond.

An operation and maintenance plan for the 300-FF-5 Operable Unit was released in September 1996 (DOE/RL-95-73). Its purpose was to complete the tasks necessary to verify the effectiveness of the selected alternative. The groundwater monitoring network includes the eight wells of the RCRA 316-5 process trenches network plus nine other wells in the

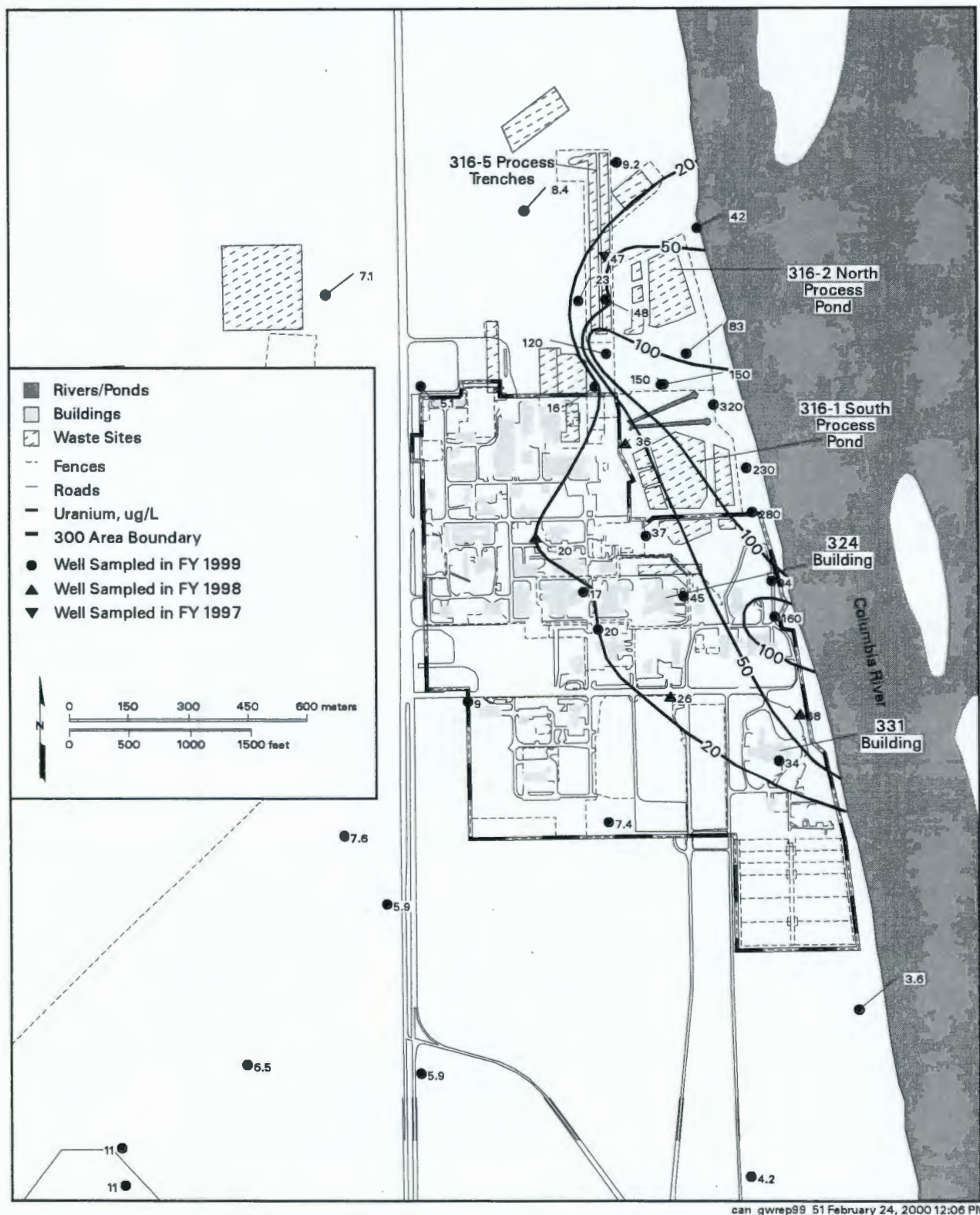
The 316-5 process trenches are a RCRA site monitored under a corrective-action program. The corrective action is deferred to the CERCLA operable units and involves natural attenuation of the contaminants.

300 Area. The constituents of concern are the same as for the RCRA 316-5 process trenches network. During fiscal year 1999, the 300-FF-5 Operable Unit network, like the 316-5 process trenches network, showed that the constituents of concern are still above drinking water standards near the process trenches, but are decreasing with time. For more information, see Sections 2.12.2 and 2.12.4.

2.12.8 Water Quality at Shoreline Monitoring Locations

A seep in the riverbank at the 300 Area is sampled annually in the fall. The most recently available

results are from fall 1998. Specific conductance measured 362 $\mu\text{S}/\text{cm}$. This relatively high value indicates the sample was primarily groundwater, not river water draining back from bank storage. Uranium-234 was detected at 30.9 pCi/L, uranium-235 at 0.57 pCi/L, and uranium-238 at 26.2 pCi/L. Gross alpha and gross beta concentrations were 55.6 and 21 pCi/L, respectively. The sample contained 9,590 pCi/L tritium. These results are consistent with contaminants detected in groundwater in the 300 Area.



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Figure 2.12-1. Average Uranium Concentrations at 300 Area, Top of Unconfined Aquifer

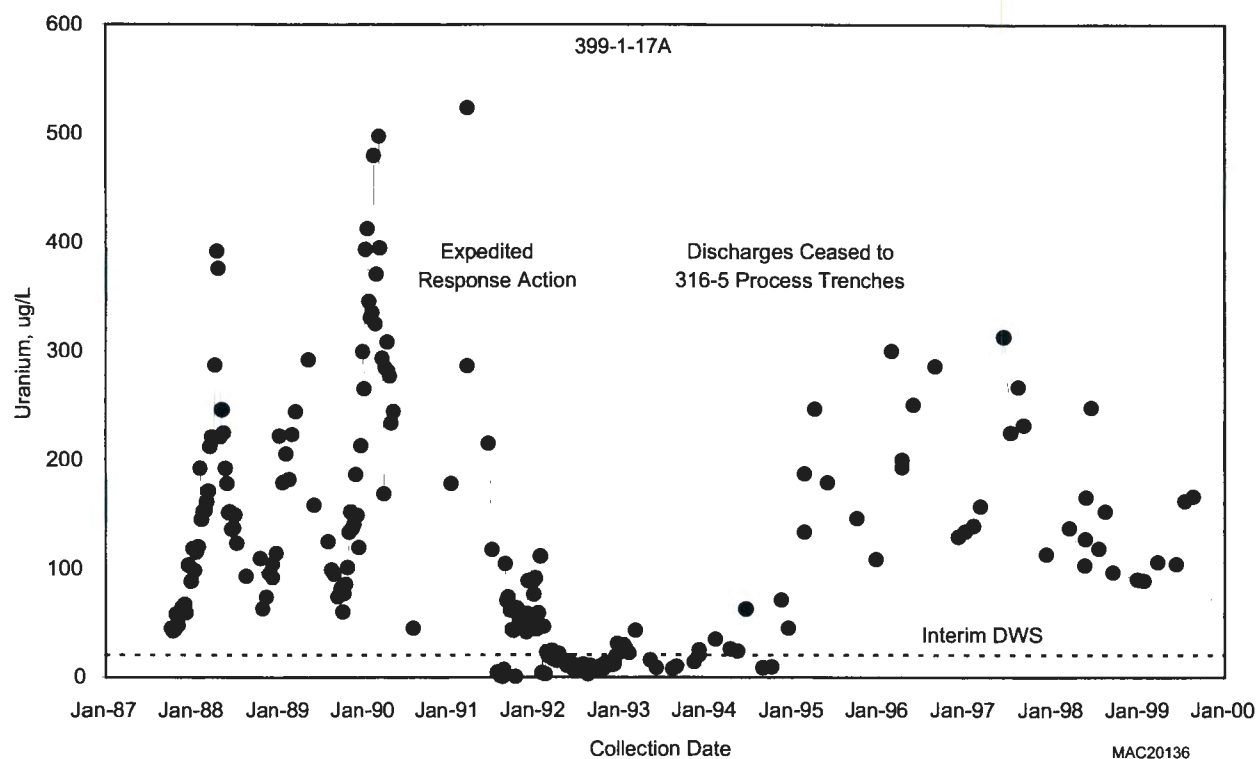


Figure 2.12-2. Uranium in Well 399-1-17A Near 316-5 Process Trenches

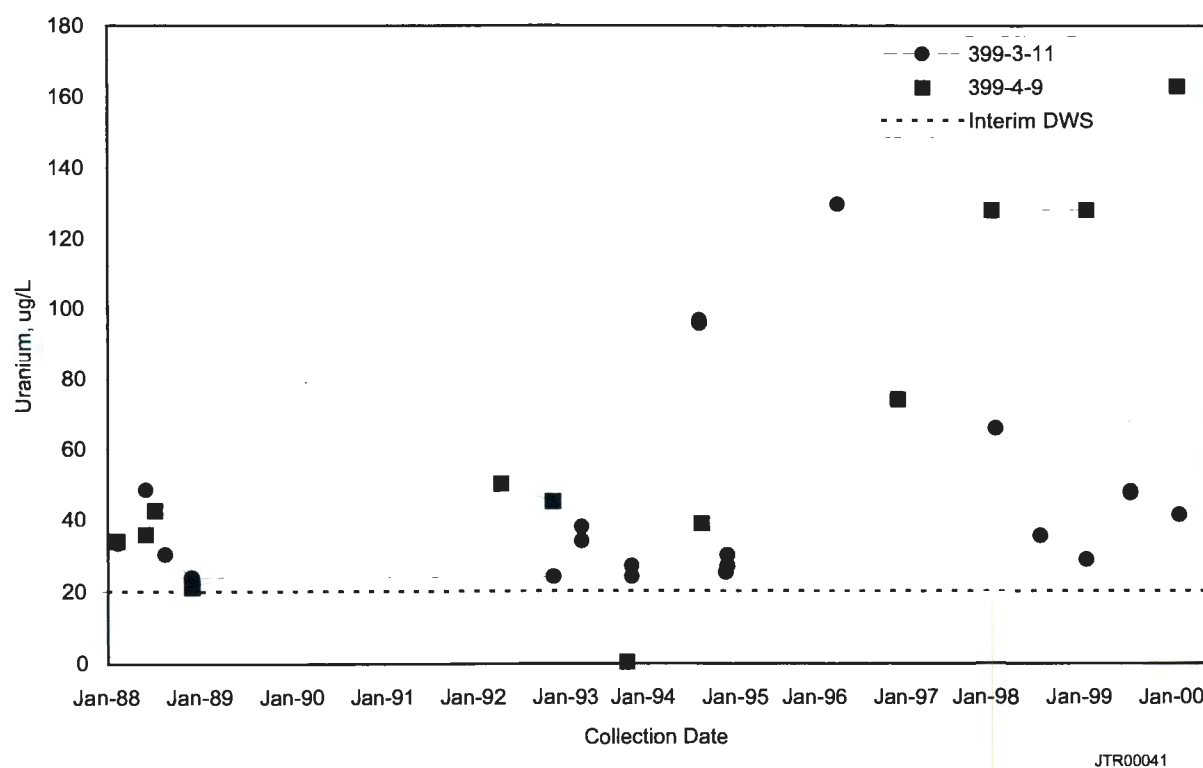


Figure 2.12-3. Uranium in Wells 399-3-11 and 399-4-9 Near 324 Building



2.262

2.263

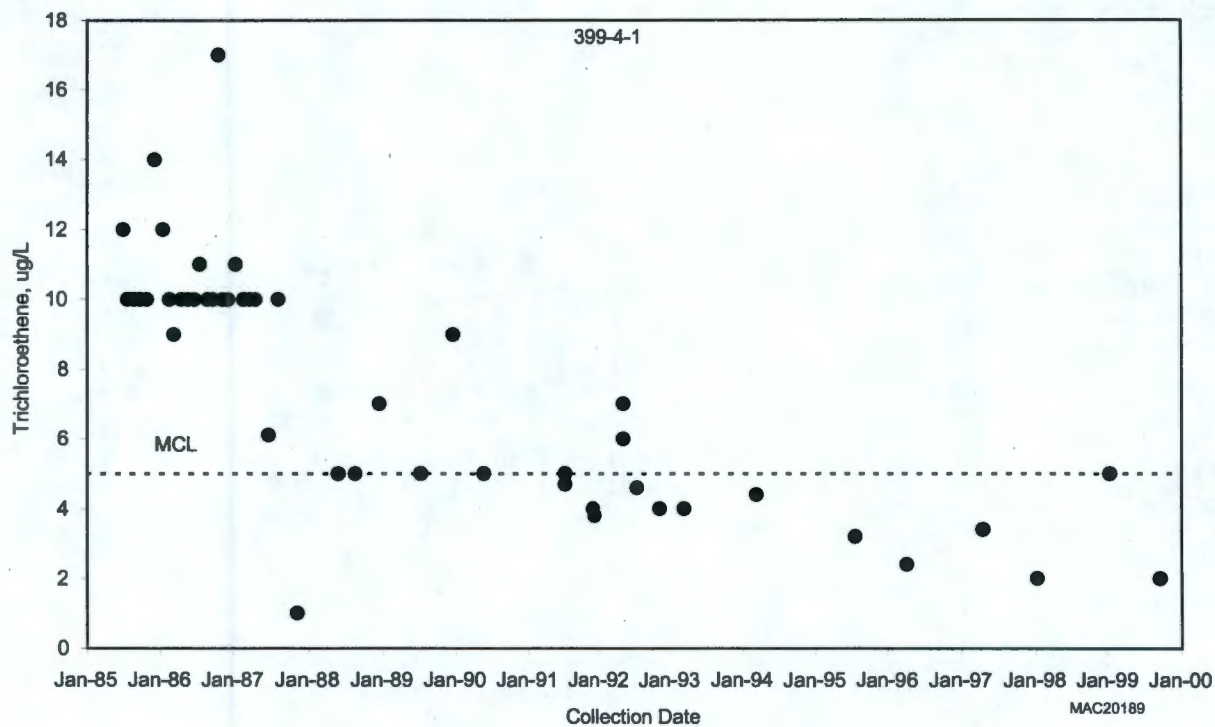


Figure 2.12-6. Trichloroethylene in Well 399-4-1, Southern 300 Area

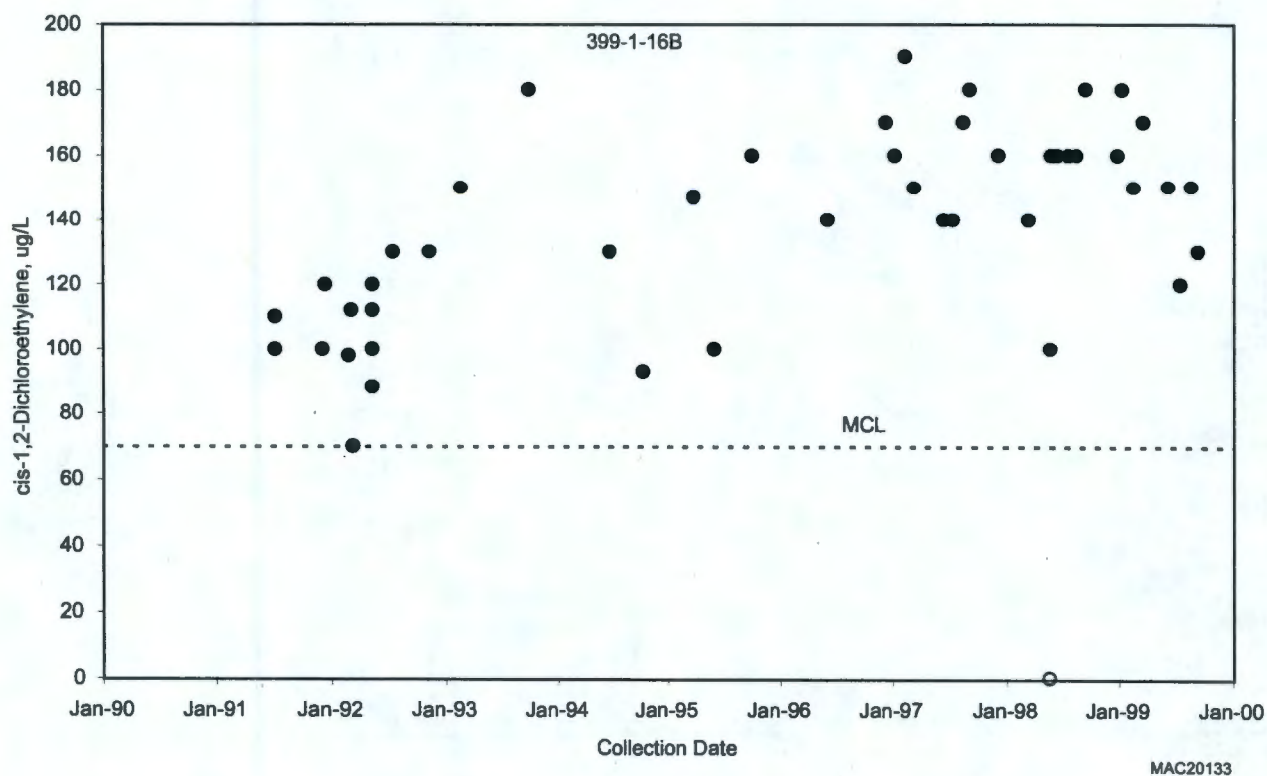
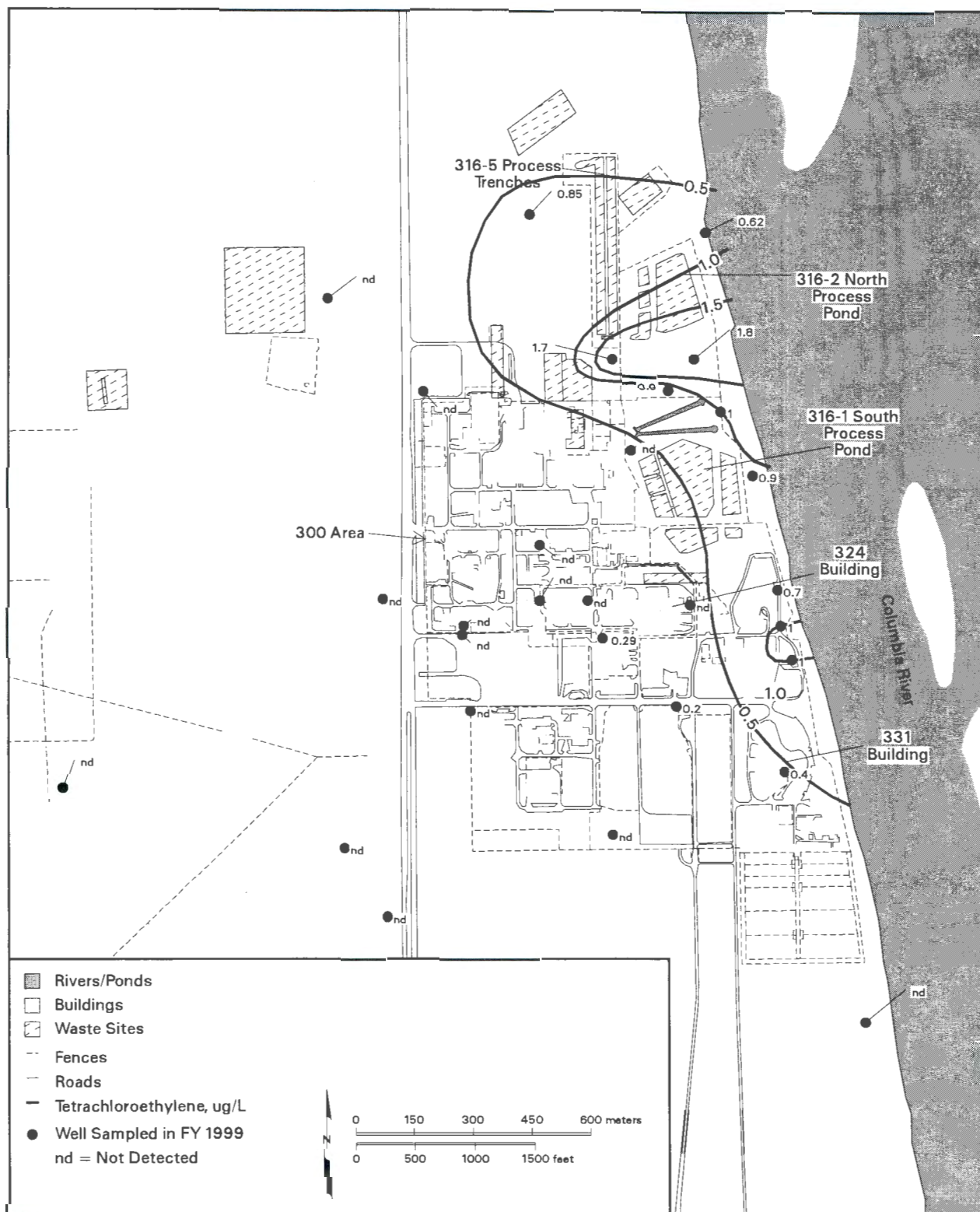


Figure 2.12-7. cis-1,2-Dichloroethylene in Well 399-1-16B Near 316-5 Process Trenches



2.266

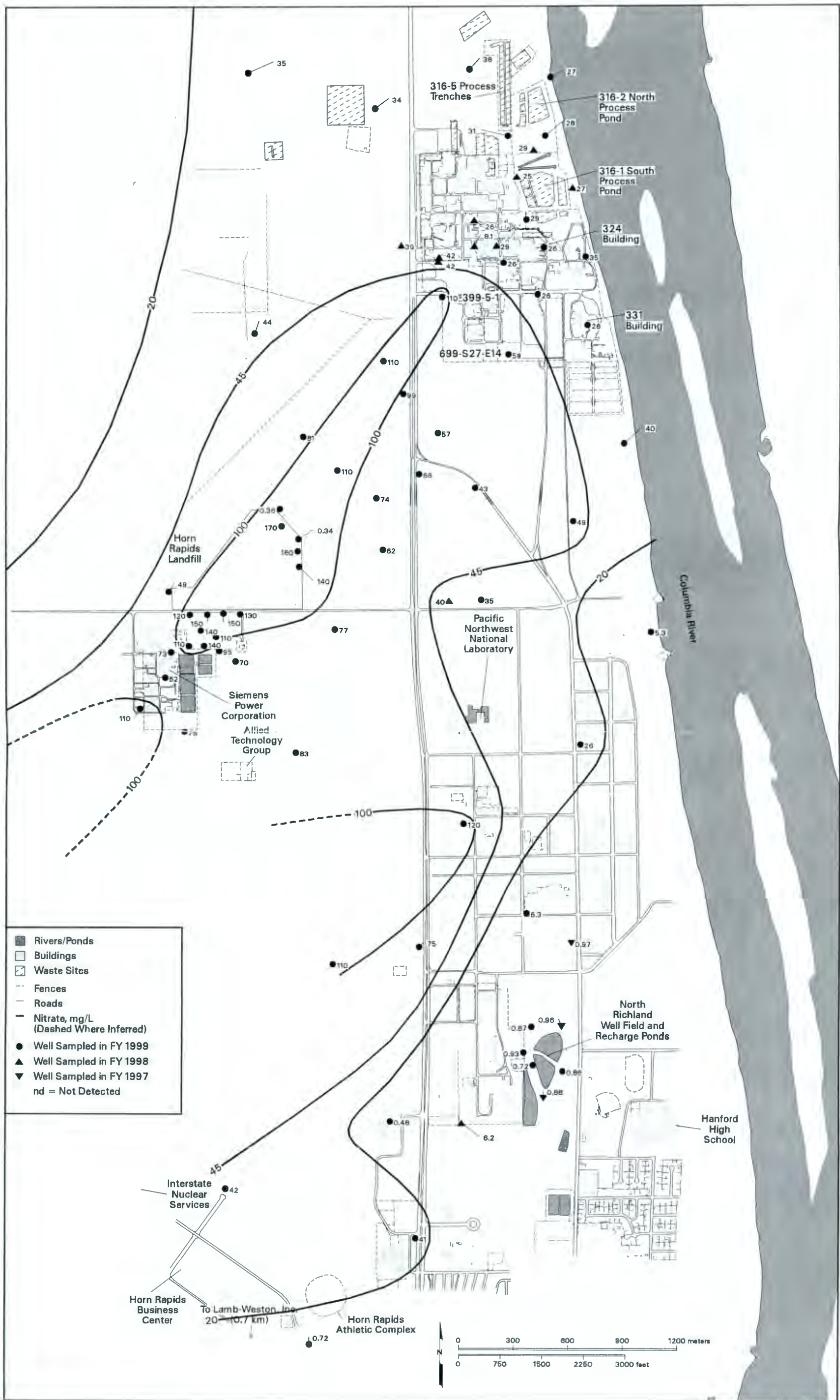


Figure 2.12-10. Nitrate in Wells at the 300 Area and Richland North Area

2.13 Richland North Area

D. R. Newcomer

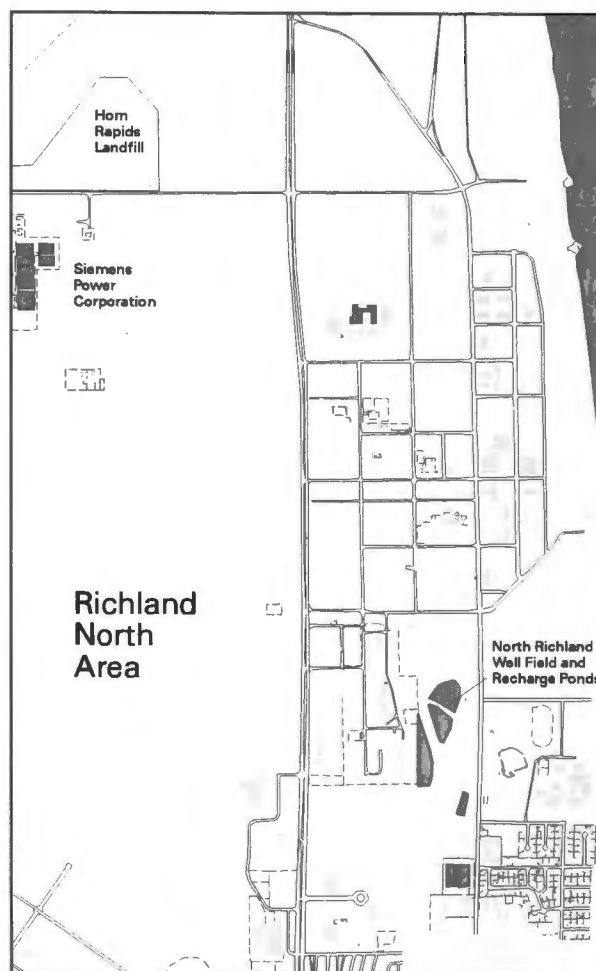
The Richland North Area is located in the southern part of the Hanford Site. The Richland North Area is not formally defined, but includes the former 1100 and 3000 Areas, that part of the 600 Area adjacent to the 300 Area, and parts of nearby Richland between the Yakima and Columbia Rivers. Ownership 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.

2.13.1 Groundwater Flow

Figure 2.13-1 shows the March 1999 water-table elevations (also see Plate 2) and illustrates water-level-elevation trends for selected areas of the Richland North Area. Groundwater in the Richland North Area generally flows eastward from the Yakima River and discharges to the Columbia River. 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.

Recharge from the Yakima River has a regional effect on groundwater flow and is the primary source of groundwater 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.

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 1999. Groundwater levels in much of



the area near the well field generally rose between June 1998 and March 1999. The maximum rise was ~0.5 meter and the effect is illustrated in wells immediately west (699-S40-E14) and north (699-S37-E14) of the well field (see Figure 2.13-1). This rise in the water table is the result of variations in net recharge at the well field and recharge pond system during different times of the year. In June, groundwater is withdrawn for supplying the municipal water-supply system, but in March water is not withdrawn for municipal use.

Irrigation of agricultural fields in the area between the Yakima River and the former 1100 Area has

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.

affected seasonal 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 (see Figure 2.13-1) and more recently by water-level fluctuations in well SPC-GM-2 near Siemens Power Corporation (Figure 2.13-2). Increasing water levels have been observed to the north of irrigation fields along the southern boundary of the Hanford Site (Figure 2.13-3).

2.13.2 Tritium

The southward migration of the tritium plume and the increasing tritium concentrations in the 300 Area continues to raise concern over the potential impact to the city of Richland's North Well Field recharge ponds (Figure 2.13-4). Figure 2.13-4 shows that tritium concentrations decrease from greater than 10,000 pCi/L to less than 100 pCi/L across the 300 Area. The 2,000-pCi/L contour line changed little since fiscal year 1998. South of the 300 Area, the average detectable tritium concentration ranged between 27 and 516 pCi/L (see Plate 3). Several factors limit significant migration 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 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 2). However, modeling efforts have indicated that groundwater flow would still be predominantly west to east without recharge at the north well field recharge ponds. Thus, there is no indication that the tritium plume is migrating southward and might impact the well field.

In late fiscal year 1999, sampling was conducted in the Richland North Area in response to tritium concentrations in groundwater and plant tissue that were higher than trends projected for the area. Richland North Area wells were sampled, and several drive points were installed along the Columbia River shoreline. The results indicated that the tritium trends had stabilized or decreased from the elevated levels at most of the sample locations. Wells showing elevated trends will continue to be sampled in fiscal year 2000. The highest tritium level detected was 516 pCi/L, which is far below the 20,000 pCi/L drinking water standard, in a well west of the north well field recharge ponds.

The area near Richland's North Well Field is monitored closely to detect the possible impact of the tritium plume from the 200 Areas. In fiscal year 1999, tritium levels increased slightly in some monitoring wells. Although levels are far below the drinking water standard, frequent monitoring will continue.

2.13.3 Nitrate

The nitrate distribution in groundwater was shown in Figure 2.12-10. Nitrate contamination that is found in the Richland North Area is likely a result of industrial and agricultural uses off the Hanford Site. In fiscal year 1999, the nitrate plume continued to expand in size, and concentrations continued to increase in a number of wells. The nitrate plume has generally migrated east toward the Columbia River.

Nitrate contamination migrates to the Richland North Area from industrial and agricultural activities off the Hanford Site. Concentrations increased in fiscal year 1999.

Concentrations above the 45-mg/L maximum contaminant level are found both upgradient and downgradient of Siemens Power Corporation. Nitrate data for Siemens Power Corporation wells are reported in EMF-1865, Addenda 15 and 18. The highest nitrate concentrations in the Richland North Area continued to occur northeast (downgradient) of Siemens Power Corporation. The maximum average concentration was ~170 mg/L immediately downgradient of the Horn Rapids Landfill. In fiscal year 1999, nitrate levels increased in wells upgradient of Siemens Power Corporation and are likely a result of agriculture to the west and southwest.

The largest increases in nitrate levels during fiscal year 1999 occurred in an area northwest of the North Richland well field and recharge ponds. These changes are illustrated by the trend plots in Figure 2.13-5. The most likely source of these increased nitrate levels is agriculture 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 2 of water-table map). Nitrate levels in wells at the well field continued to be lower than ambient groundwater as a result of recharge from infiltration of river water at the recharge ponds.

2.13.4 Trichloroethylene

Trichloroethylene contamination occurs on the Hanford Site beneath the Horn Rapids Landfill and off the site in Siemens Power Corporation wells (see Figure 2.12-6). The distribution of trichloroethylene supports the tritium discussion with respect to north-eastward flow around the city of Richland's North Well Field recharge ponds. The plume has an elongated configuration similar to previous years. However, concentrations have decreased in much of the plume area near the Horn Rapids Landfill. In fiscal year 1999, trichloroethylene concentrations ranged from less than detection to 6 µg/L. The highest concentrations were found immediately downgradient of the Horn Rapids Landfill and only two wells (699-S31-E10A and 699-S31-E10C) showed concentrations higher than the 5-µg/L maximum contaminant level. Concentrations were less than this level in the point of compliance wells downgradient of the Horn Rapids Landfill. Trichloroethylene concentrations decreased by more than an order of magnitude in this area since monitoring began in 1990 (Figure 2.13-6). The decreased concentrations in the majority of wells downgradient of the Horn Rapids Landfill suggests that some elements of natural attenuation (e.g., volatilization through passive pumping) may be reducing the plume mass. For a discussion of trichloroethylene in the 300 Area, see Section 2.12.4.

Trichloroethylene concentrations continued to be less than 5 µg/L in all Siemens Power Corporation wells in fiscal year 1999 (EMF-1865, Addenda 15 and 18). The past use of solvent in installing and maintaining process lagoon liners at Siemens Power Corporation is the only potential source of trichloroethylene identified in the Richland North Area (DOE/RL-92-67, Draft B).

Trichloroethylene contamination in the Richland North Area has sources off the Hanford Site. Concentrations are naturally declining.

Vinyl chloride and 1,1-dichloroethylene concentrations, breakdown products of trichloroethylene, continued to be close to or less than their respective minimum detection limits in fiscal year 1999.

2.13.5 Gross Alpha and Uranium

Elevated levels of gross alpha and uranium occur downgradient of Siemens Power Corporation near the Horn Rapids Landfill. Gross alpha levels generally decreased in most of the Siemens Power Corporation wells between fiscal years 1998 and 1999 (EMF-1865, Addenda 15 and 18). Well SPC-GM-8 exhibited the highest gross alpha levels, with an average of 77 pCi/L during fiscal year 1999. Most of the downgradient Siemens Power Corporation wells showed average gross alpha levels that were above the 15-pCi/L maximum contaminant level. Because Siemens Power Corporation manufactures nuclear fuel pellets and assemblies for commercial nuclear power plants, it is probable that the gross alpha levels can be largely attributed to uranium. If gross alpha is attributed to uranium with natural isotopic abundances, then 77 pCi/L gross alpha is equivalent to 111 µg/L uranium, which is above the 20 µg/L proposed maximum contaminant level for uranium. Samples collected from the Siemens Power Corporation wells in fiscal year 1999 were not analyzed for uranium.

Uranium concentrations ranged up to an average of 11.5 µg/L, with the highest concentrations immediately downgradient of the Horn Rapids Landfill in wells 699-S30-E10A, 699-S30-E10B, and 699-S31-E10B. Uranium concentrations have been increasing in wells downgradient of the landfill since approximately 1995. Gross alpha activities, which mimic trends in the uranium concentrations, also increased in these wells since approximately 1995. Gross alpha activities in these wells ranged up to an average of 13.9 pCi/L.

2.13.6 Other Constituents

Ammonia, fluoride, and gross beta are found at low levels in wells near Siemens Power Corporation:

- Ammonia — Concentrations of ammonia in the Siemens Power Corporation wells generally remained steady in fiscal year 1999 (EMF-1865, Addenda 15 and 18). The highest average concentration detected was 12.5 mg/L in well SPC-GM-10. Ammonia is typically absorbed by plants or 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 and is rapidly converted to nitrate by nitrification. The fact that ammonia is found in the groundwater suggests that relatively high concentrations reached the soil column.
- Fluoride — Three downgradient Siemens Power Corporation wells (SPC-GM-5, SPC-GM-8, and SPC-GM-10) had fluoride concentrations above the 4-mg/L maximum contaminant level in fiscal year 1999 (EMF-1865, Addenda 15 and 18). The highest average concentration was 5.0 mg/L in well SPC-GM-10. Average fluoride concentrations in onsite wells for this area were all less than 1 mg/L.
- Gross Beta — Gross beta levels exhibited similar trends to the gross alpha levels in most of the Siemens Power Corporation wells (EMF-1865, Addenda 15 and 18). The highest average gross beta measurement in fiscal year 1999 was 50 pCi/L in well SPC-GM-8. The highest average onsite gross beta measurement in this area was 23.8 pCi/L. Low levels of technetium-99, detected near the Horn Rapids Landfill, may be related to the gross beta measurements.

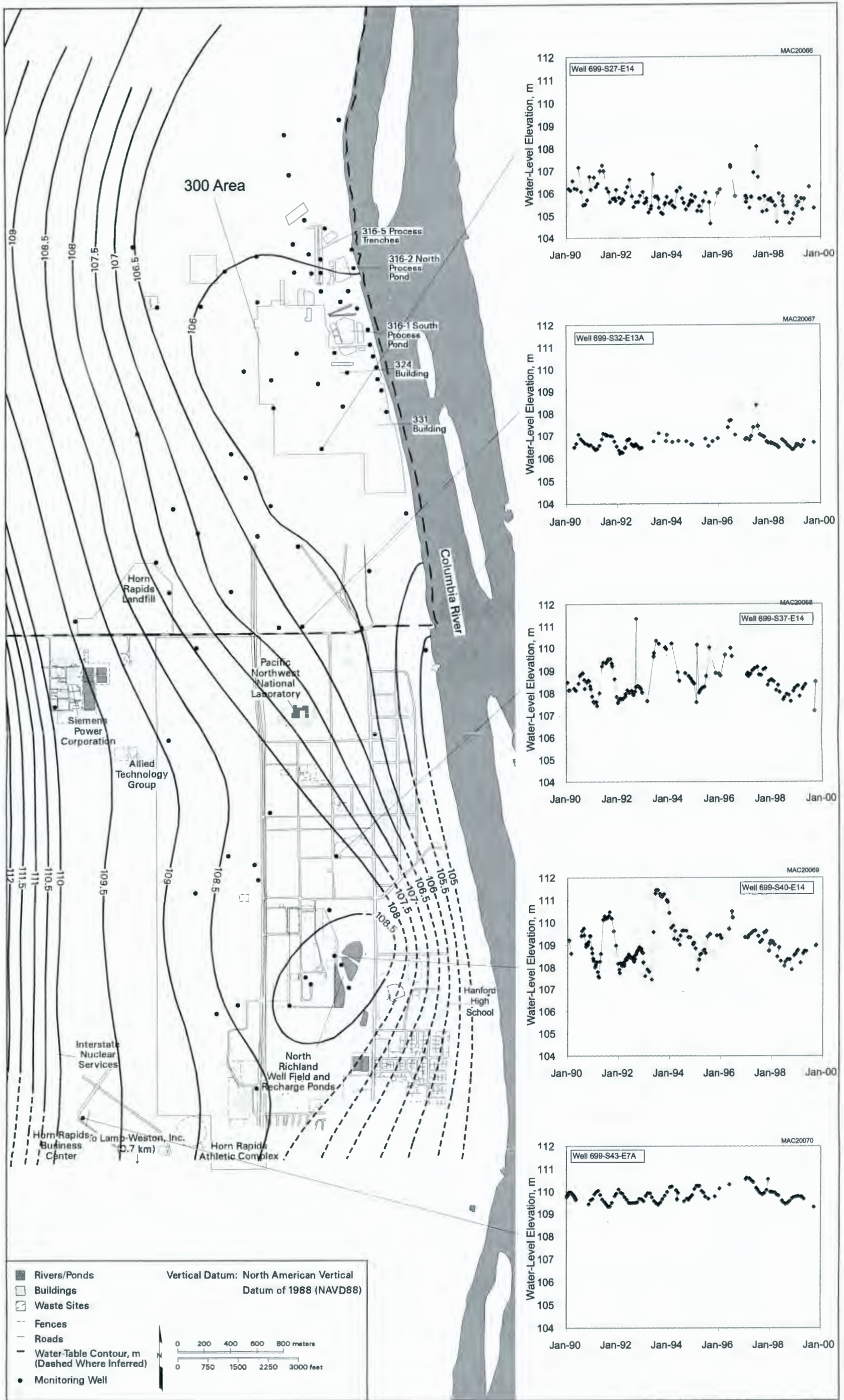


Figure 2.13-1. Water Levels in Wells Monitoring the Richland North Area, March 1999

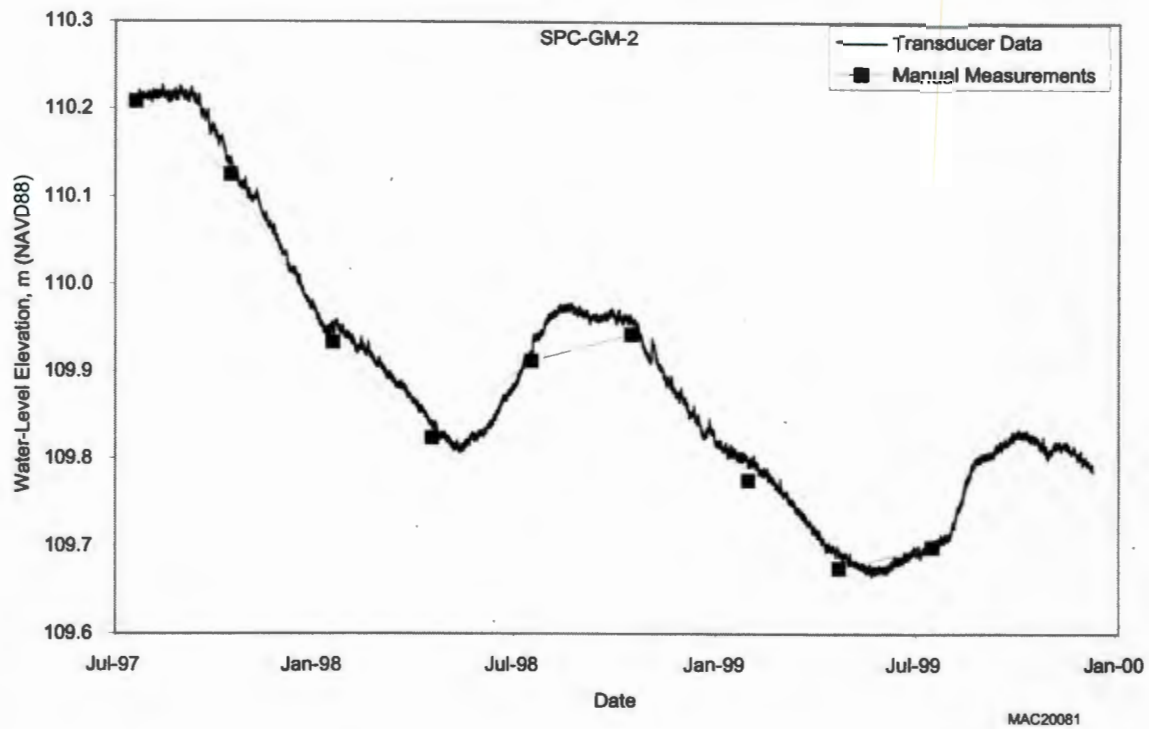


Figure 2.13-2. Water Levels in Well SPC-GM-2 at Siemens Power Corporation

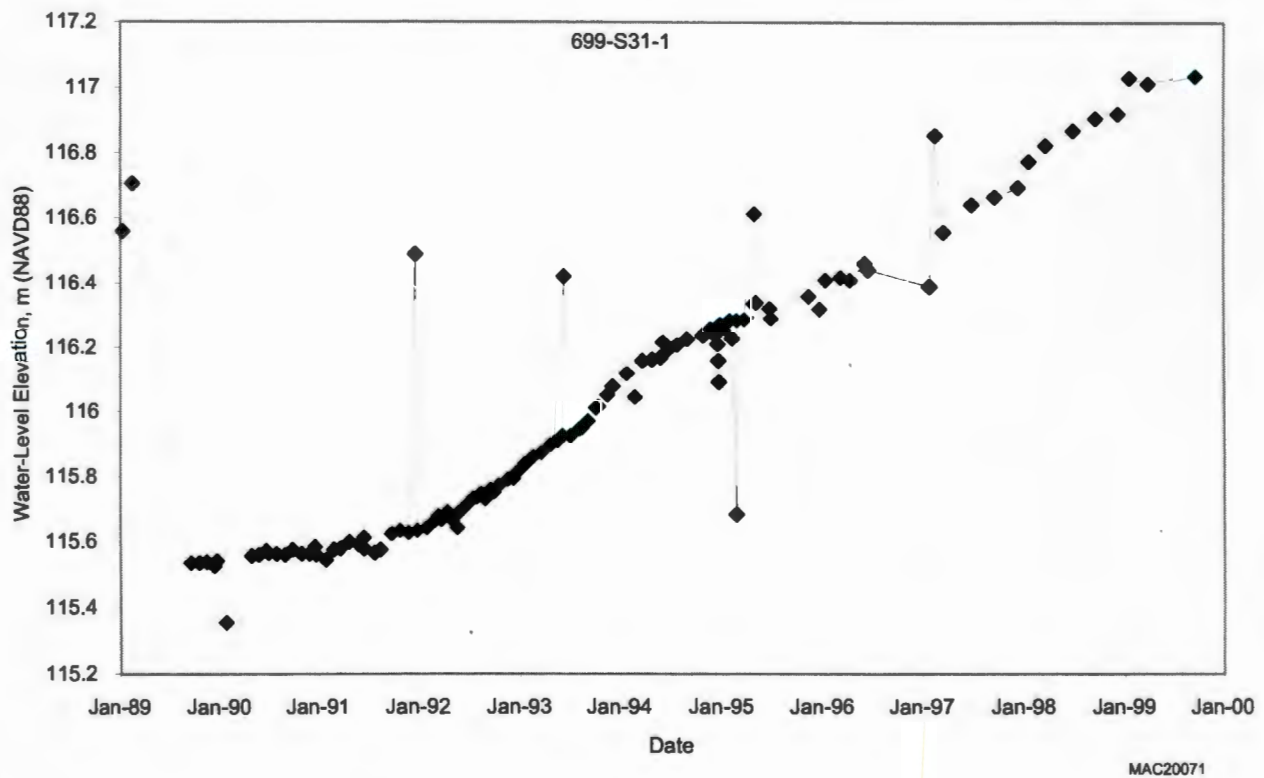


Figure 2.13-3. Water Levels in Well 699-S31-1

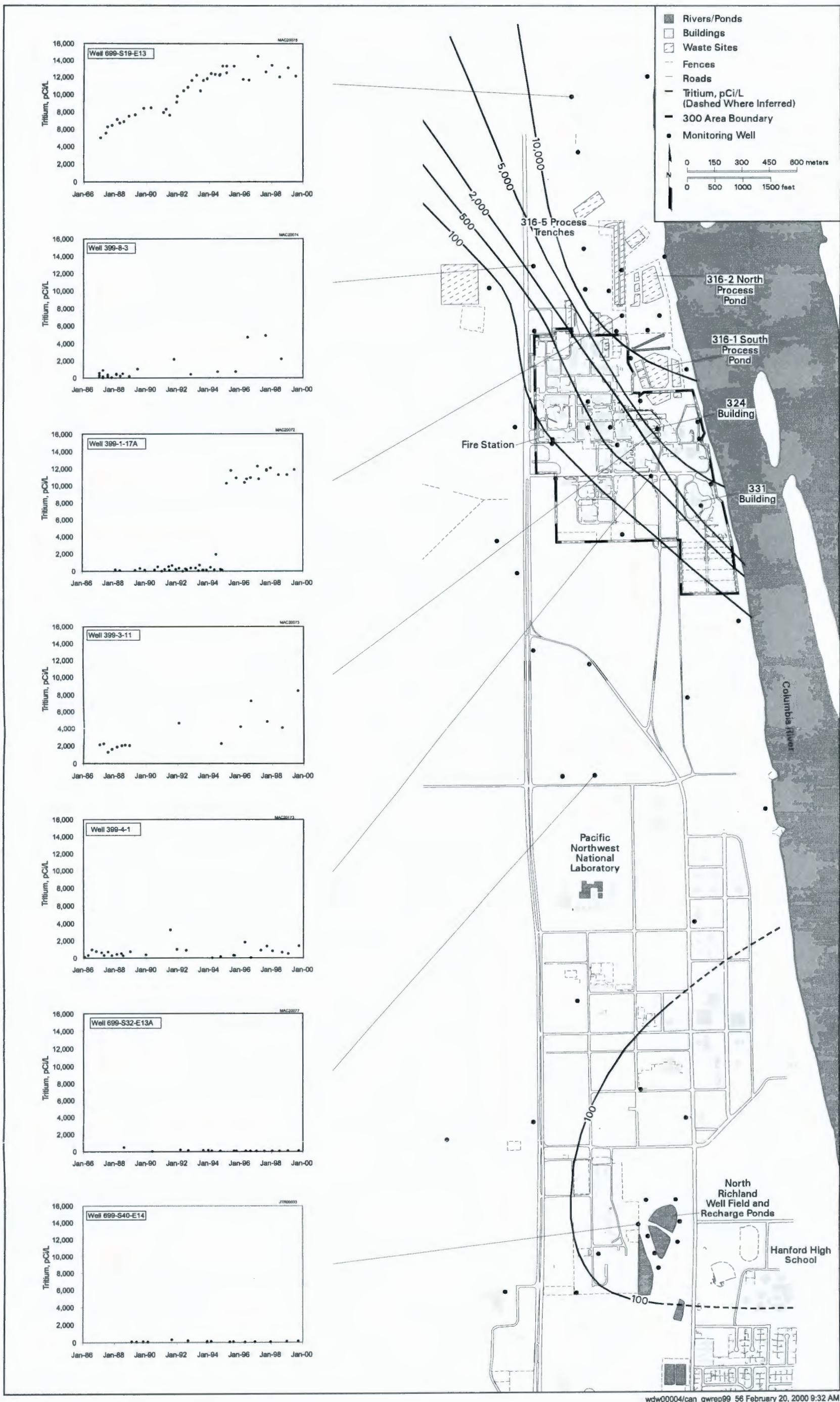
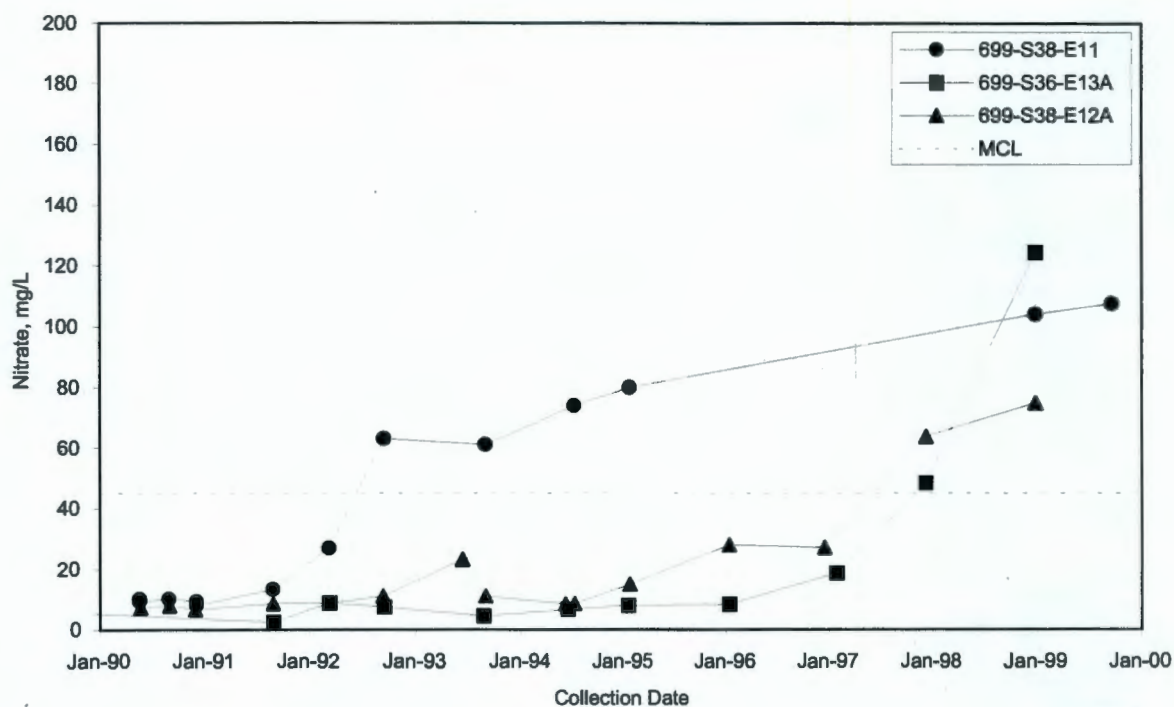
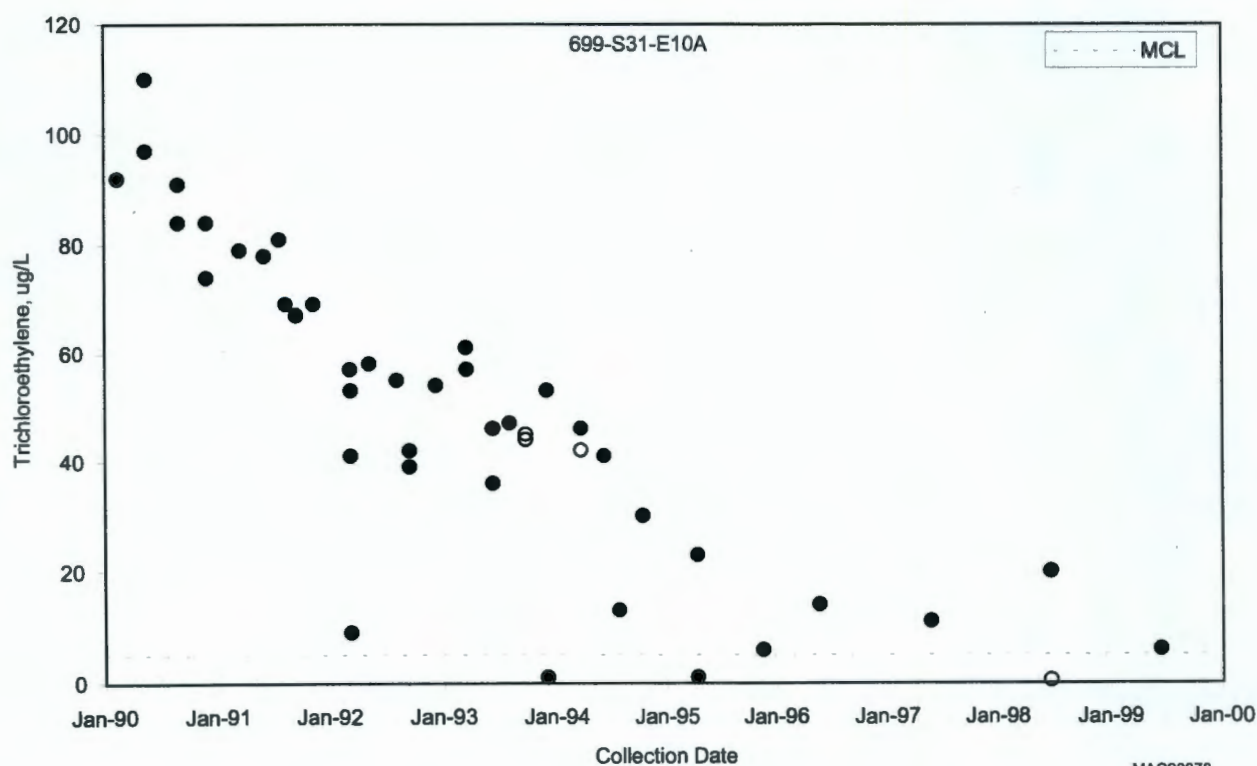


Figure 2.13-4. Tritium Concentrations in Wells at 300 and Richland North Areas, Top of Unconfined Aquifer



MAC20079

Figure 2.13-5. Nitrate in Wells 699-S38-E11, 699-S36-13A, and 699-S38-E12A



MAC20078

Figure 2.13-6. Trichloroethylene in Well 699-S31-E10A

2.14 Upper Basalt-Confined Aquifer

D. B. Barnett, J. P. McDonald

The upper basalt-confined aquifer system, which extends well beyond the limits of the Hanford Site, lies within sedimentary interbeds and hydraulically conductive portions of basalt flows immediately below the Hanford/Ringold aquifer system. Monitoring the upper basalt-confined aquifer system is important because of the potential for contamination to migrate off the Hanford Site. The most recent and comprehensive investigation of the upper basalt-confined aquifer system is presented in PNL-10817, which examines the hydraulic, hydrochemical, and isotopic characteristics of this groundwater system. Approximately 40 wells are located within the upper basalt-confined aquifer system and are used to monitor water levels or water quality (PNNL-13021). Water levels in several of these wells are measured at least annually, but samples for chemical or radiological analyses are taken on a triennial basis. The frequency of sampling was higher in the past, but recent work (PNL-10817) has indicated a relatively low probability that contamination could migrate off the site. Thus, sample frequency has been progressively reduced since 1995.

2.14.1 Groundwater Flow

Groundwater occurs within basalt fractures and joints, interflow contacts, and intercalated sedimentary interbeds within the upper Saddle Mountains Basalt. The thickest and most widespread sedimentary unit in the upper basalt-confined aquifer system is the Rattlesnake Ridge Interbed. Groundwater 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. The groundwater project measures water levels annually in this aquifer system, and these data are used to prepare a potentiometric surface map. Beginning in fiscal year 1999, annual water level measurements are taken during March, instead of June, as in previous years.

Groundwater in the basalt-confined aquifer flows from west to east and discharges to the Columbia River. The water-level map has changed little in the past 7 years.

In 1993, hydraulic head distribution and flow dynamics of the upper basalt-confined aquifer system were evaluated and reported in PNL-8869, which identified the following prominent hydrologic features (Figure 2.14-1):

- a broad recharge mound extending northeastward from Yakima Ridge toward the 200 West Area
- a small recharge mound (now subsiding) immediately east of the 200 East Area in the vicinity of B Pond
- a subsurface hydrogeologic barrier (i.e., an impediment to groundwater flow), believed to be related to faulting, near the mouth of Cold Creek Valley
- a region of low hydraulic head (potential discharge) in the Umtanum Ridge-Gable Mountain structural area
- a region of high hydraulic head to the north and east of the Columbia River associated with artificial recharge attributed to agricultural activities.

Recharge to the upper basalt-confined aquifer system is believed to result from precipitation and surface water infiltration where the basalt and interbeds are exposed at ground surface. Recharge also may occur through the Hanford/Ringold aquifer system, where a downward hydraulic gradient exists between the Ringold Formation confined and upper basalt-confined aquifers. Hydraulic communication with overlying and underlying aquifers is believed to cause the region of low hydraulic head found in the Umtanum Ridge-Gable Mountain structural area (these relationships are given in more detail in PNL-8869). 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 2), and the Ringold Formation confined aquifer (see Figure 2.9-33) 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 (PNL-6313, PNL-8869, PNL-10082, PNNL-11470, PNNL-12067, WHC-EP-0142-3, WHC-EP-0142-4, WHC-EP-0394-3). 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. In other areas of the Hanford Site, the hydraulic gradient is upward from the upper basalt-confined aquifer to the Hanford/Ringold aquifer system.

Figure 2.14-1, constructed by manual contouring, presents a regional approximation of the potentiometric surface for the upper basalt-confined aquifer system based on water-level measurements taken during March 1999. Measurements in the Rattlesnake Ridge Interbed (23 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 (12 wells) were used for general contouring. The monitoring well network used for hydraulic head monitoring is presented in PNNL-13021.

With some exceptions, the major potentiometric map features shown in Figure 2.14-1 are nearly the same as those for 1993 (PNL-8869). The potentiometric map indicates that, south of the Umtanum Ridge-Gable Mountain structural area, groundwater generally flows from west to east across the site toward the Columbia River, which represents a regional discharge area for groundwater flow systems. In the region northeast of Gable Mountain, potentiometric contours, based on scant water-level data, suggest that groundwater flows southwest and discharges primarily to underlying confined aquifer systems in the Umtanum Ridge-Gable Mountain structural area (PNL-8869). This region of

increased hydraulic head is associated with recharge from agricultural activities north and east of the Columbia River and is reinforced by observations from wells completed in deeper, confined aquifer systems. Therefore, the Columbia River does not represent a major discharge area for upper basalt-confined groundwater in the northern portion of the Hanford Site.

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 2.9-33). It is known that the basalt in this area was significantly eroded by late Pleistocene catastrophic flooding (RHO-BWI-LD-5), which facilitates aquifer intercommunication in this area and probably explains the similarity. 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 2). Therefore, it is likely the upper basalt-confined aquifer system discharges to the overlying Hanford/Ringold aquifer system in this region.

Water levels in the central and western portion of the Hanford Site declined over the 9-month period from June 1998 to March 1999, whereas water levels in the eastern portion of the site 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; falling in the range of 0.13 to 0.33 meter over the 9-month period (0.17 to 0.35 meter per year). Water levels near the 200 West Area also continue to show a decline with a range of 0.11 to 0.18 meter (0.15 to 0.24 meter per year). These declines are a 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 center of the groundwater mound associated with B Pond has migrated 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 wells 699-42-40C (located at

B Pond and formerly the approximate center of the groundwater mound) and 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 699-51-36B. This more rapid decline beneath B Pond is related to the apparent shift in the groundwater mound. Comparison of heads between well 699-42-40C and adjacent wells completed in the unconfined aquifer indicate that the vertical head gradient between this aquifer and the upper basalt-confined aquifer system has diminished in recent years and is now virtually nil. 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.

The greatest measured increase in water levels for the upper basalt-confined aquifer system was 1.11 meters in well 199-H4-2, which is near the Columbia River in the 100 H Area. For other wells in the eastern portion of the Hanford Site, the increase in water levels ranged from 0.05 to 0.26 meter over the 9-month period from June 1998 to March 1999. Between March 1991 and March 1993, water levels were measured quarterly in a selected set of upper basalt-confined aquifer system wells (PNL-8869). These data showed a trend of rising water levels for the eastern portion of the Hanford Site, at a rate of 0.2 to 0.4 meter per year. PNL-8869 also demonstrated that river stage fluctuations are most likely superimposed on this trend, at least for wells adjacent to the Columbia River. The rising water levels are attributed to large-scale irrigation activities in areas off the site and east of the Columbia River. The increase in water levels in the eastern portion of the site from June 1998 to March 1999 is consistent with this long-term trend.

2.14.2 Groundwater Quality

The upper basalt-confined aquifer system is affected far less by Hanford Site contamination than the unconfined system. Prior to 1995, several Hanford Site wells in the confined aquifer were sampled annually for radionuclides and hazardous waste constituents. Over

approximately the last 10 years, results of sampling and analyses from these sites indicated that of the wells monitored, there were very few areas of concern that warranted continued annual monitoring. Consequently, the number of wells sampled annually has been progressively reduced since 1995. Most wells have been reduced to a triennial sampling frequency. Figure 2.14-3 shows the locations of wells used for monitoring upper basalt-confined aquifer groundwater chemistry. Only one well, 699-42-E9B, was sampled during fiscal year 1999. Hence, this section will briefly review some of the more prominent historical concerns of groundwater quality in the upper basalt-confined system.

Radionuclides have been detected in the upper basalt-confined aquifer, generally at low levels. Confined-aquifer wells are sampled infrequently because groundwater chemistry does not change rapidly in these wells.

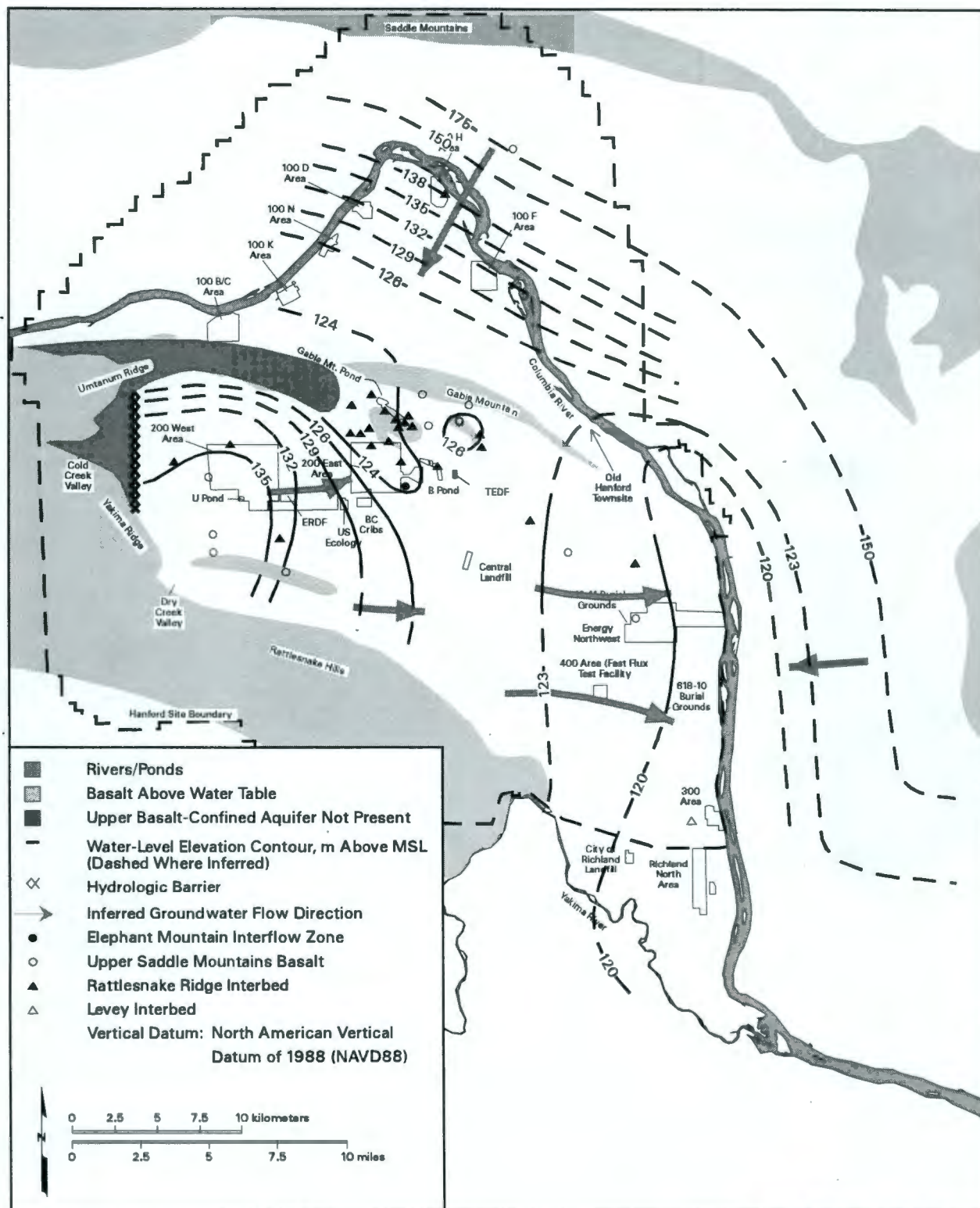
Geochemical studies indicate that the major ionic composition of groundwater in the upper basalt-confined system is dominantly magnesium and calcium bicarbonate in the western portions of the Hanford Site, becoming more sodium bicarbonate dominant in the eastern portions as residence time increases from west to east (WHC-EP-0595; PNNL-10817). Total dissolved solids content is considerably less (mostly less than 250 mg/L) than in the Hanford/Ringold aquifer on the Hanford Site. Tritium activities are naturally low in the upper basalt-confined aquifer (averaging less than 3.2 pCi/L) compared with surface water (e.g., Columbia River) and unconfined aquifer groundwater, except in areas of intercommunication with the Hanford/Ringold aquifer or areas affected by deep drilling operations that used surface water. Well 699-42-40C, near B Pond, is probably located in such an area of intercommunication (RHO-RE-ST-12P), and has produced tritium activities as high as 8,000 pCi/L as recently as 1996. Activities have decreased to ~6,500 pCi/L in subsequent measurements (latest in fiscal year 1998).

Some wells near the northern border of the 200 East Area have historically produced elevated results for radionuclides and nonradiogenic constituents. The most notable of these, well 299-E33-12, has been monitored since the mid 1950s and has produced elevated results for cobalt-60, cyanide, technetium-99, and tritium. The most recent results for these constituents in this well, from August 1998 are: 21.8 pCi/L cobalt-60, 30 µg/L cyanide, 1,810 pCi/L technetium-99, and 630 pCi/L tritium. During the 1950s, this well produced cobalt-60 results as high as 450,000 pCi/L, though the accuracy of these results may be questionable (PNL-10817). The fiscal year 1998 results were generally on trend with declining or unchanging concentrations of all four of these constituents in this well. Slightly elevated levels of nitrate, gross beta, and tritium have occurred in other wells in this general vicinity, but no significant trends have been observed that would warrant more frequent sampling efforts (see PNNL-12086).

Well 699-42-E9B is located on the eastern shore of the Columbia River, just inside the Hanford Site boundary. Since sample collection from this well began in 1991, pH values have risen steadily from ~8.5 in

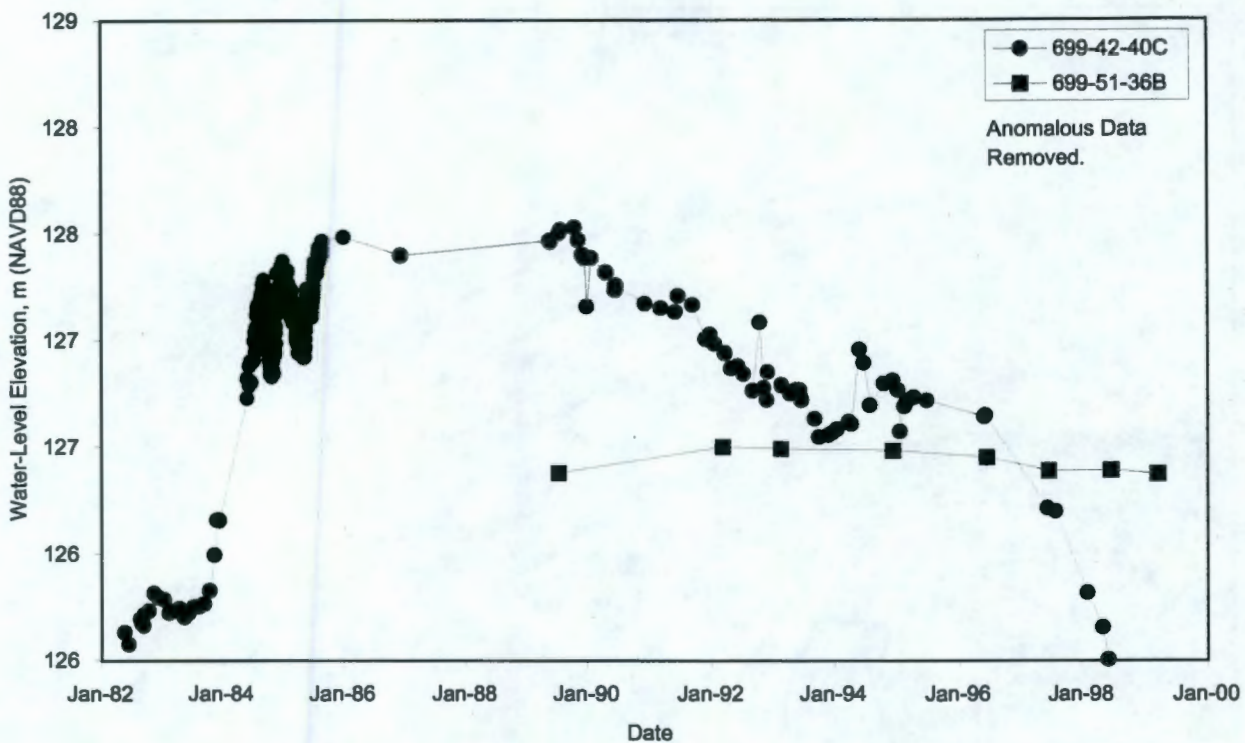
1992 to 9.52 in fiscal year 1999. The reason for this trend is unknown. Tritium concentration declined from 73.1 pCi/L in fiscal year 1998 to 26.9 pCi/L in fiscal year 1999. Cobalt-60 was reported at a maximum of 7.73 pCi/L in 1993, but results of the last 4 years have been below detection. A result of 9.33 pCi/L of cesium-137 was reported in 1993, but since 1996 this radionuclide has been reported below detection (minimum detectable concentration ~0.56 pCi/L in fiscal year 1999). Counting errors are a high percentage of the results for cobalt-60 and cesium-137 in the 1999 samples from well 699-42-E9B.

Because of the prolonged travel times for groundwater, the limited degree of contamination observed in wells, and the hydraulic head distribution in the upper basalt-confined aquifer, there is probably little risk of contamination from this aquifer affecting surface waters or near-surface aquifers. The area where groundwater from the upper basalt-confined aquifer may discharge is essentially limited to the southeast portion of the Hanford Site and along the southern contiguous reaches of the Columbia River where an upward hydraulic potential exists.



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Figure 2.14-1. Potentiometric Map of Upper Basalt-Confining Aquifer System, March 1999



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Figure 2.14-2. Upper Basalt-Confined Aquifer System Hydraulic Head in Wells Near B Pond

2.287